Clouds across the Moon: A comparison of Apollo mission photographs with contemporaneous satellite images

by

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“Methinks, that the Earth would to the people of the Moon appear to have a different face in the several seasons of the year; and to have another appearance in Winter, when there is almost nothing green in a very great part of the Earth, when there are countries all covered in snow, others, all covered with water, others, all obscured with clouds, and that for many weeks together: Another in Spring, when the forests and fields are green, another in Summer, when, whole fields are yellow etc. “

Monsieur Auzout's Speculations of the changes likely to be discoverd in the Earth and Moon by their respective inhabitants. Mr Auzout***,*** Philosophical Transactions, 1665-1666, volume 1.

Acknowledgements & Disclaimer

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List of Abbreviations

AFJ – The Apollo Flight Journal, which details missions before those that landed, and also covers in more detail the flight aspects of other missions. http://history.nasa.gov/afj/

AIA – Apollo Image Atlas. All mission photographs, many available in high resolution. http://www.lpi.usra.edu/resources/apollo/

ALSJ – Apollo Lunar Surface Journal. The essential resource for all things Apollo. http://www.hq.nasa.gov/alsj/frame.html

AOS – Acquisition of signal. The part of the lunar orbit when the orbiting CSM emerges from the radio blackout of the far side of the moon.

APT - Automatic Picture Transmission system. A method of transmitting satellite images between receiving stations.

ATS – Applications Technology Satellite.

CAPCOM – Capsule communications. The Houston based personnel (usually astronauts) who acted as the sole voice link between mission control and the Apollo crew.

CSM (also CM) - Command & Service Module. The portion of the Apollo craft that stayed in lunar orbit. The Command Module (CM) portion is the only part that returned to Earth.

DAPP – Data Acquisition and Processing Program. Polar orbital satellites run by the US military in the 1960s, generally with higher resolution cameras. Also known as DMSP.

DMSP - Defense Meteorological Support Program. See DAPP.

ESSA – Environmental Science Services Administration. Organisation managing environmental research in the USA. Also used as a satellite name (eg ESSA 7).

EVA – Extra-vehicular activity. Any activity outside a spacecraft.

GET – Ground Elapsed Time. Time recorded on the ground since launch. See MET.

ITOS – Improved TIROS Operational System.

LEO – Low Earth Orbit. Usually around 200-400 miles up.

LM – Lunar Module.

LOS – Loss of signal. The part of the lunar orbit where the CSM disappears behind the far side of the moon.

LRV – Lunar Roving Vehicle.

MET – Mission Elapsed Time. Time recorded since launch,

MWL – Mariner's Weather Log. A monthly journal for seafarers that frequently used satellite images in its reports.

MWR – Monthly Weather Review. A useful source of contemporary weather data and satellite images.

NASA – National Aeronautics and Space Administration.

NOAA – National Oceanic and Atmospheric Administration. Successor to ESSA.

SIV-B – The stage of the Saturn V rocket that contained the LM before it docked with the CSM.

TEC – Trans-Earth Coast. The journey from Moon to Earth

TEI – Trans-Earth Injection. The rocket burn (usually carried out on the far side of the moon) that commenced the return to Earth from lunar orbit.

TIROS – Television Infra-Red Observational Satellites.

TLC – Trans-Lunar Coast. The journey from Earth to Moon.

TLI – Trans-Lunar Injection. The rocket burn taking the Apollo craft from Earth orbit towards the Moon.

1. Introduction

The purpose of this document is to demonstrate that any photograph featuring the Earth taken by an Apollo astronaut was taken where and when it is claimed: either *en route* to, walking on the surface of, or returning from, the Moon.

It will use satellite images gathered from a variety of sources and identify weather patterns in them that can also be identified in Apollo photographs. Where possible, the times of those satellite images will be identified. Software such as Stellarium, or the Earthview website, will also be used to show the relative position of observable land masses and the terminator (the dividing line between night and day) on the Earth's surface. All Apollo missions that went to the moon and thus went beyond low Earth orbit (LEO), including the three that did not land: Apollos 8, 10 and 13, will be examined. The images chosen are the best quality available, attempt to provide as complete a coverage of the Earth's surface as possible, and also represent key stages in each mission.

Some missions are better represented than others. Apollo astronauts' main focus was the Moon, and images of the Earth were taken more for the 'wow' factor and novelty value than any attempt at serious scientific record. Possible exceptions to that are the Ultra Violet photographs of the planet taken in later missions, where matching images of Earth were taken as a comparison, and Jack Schmitt (Apollo 17's geologist astronaut) in his effusive and detailed descriptions of the meteorological scene below him.

The number of photographs available for analysis is therefore a result of the whim of the person holding the camera. No apology is made for using many images. If there are photographs from every day of a mission, then they will be examined, because the aim is to demonstrate that for any photograph featuring the Earth it is possible to match that photograph to satellite photographs so that it can be shown beyond any doubt that the Apollo photographs are genuine.

The Earth was also not always in a position to be photographed. Like the Moon from the Earth, the Earth as viewed from the Moon has phases, and a couple of missions took place when the Earth could only be seen as a crescent. The size of this crescent can also change depending on the location of the orbiting Command and Service Module (CSM). On these occasions it is still sometimes possible to determine what weather systems are visible, but a little more detective work is required.

Images will be composited in an image editor. Other than zooming, cropping, altering of levels, and sometimes sharpening (only where appropriate to improve image quality & certainly not to deceive or confuse the reader) to make features clearer, ***absolutely no manipulation*** will be carried out on any image that materially alters their content. This point is worth emphasising again, as some critics of this approach have an immediate knee jerk response that there has been some form of fakery involved.

To repeat: **No content has been added to or removed to any image used here**.

The observable features on both satellite and Apollo images are exactly as they have been given in their source. Any accusation that the images have been altered by the author is false, libellous, and says more about an accuser's unwillingness to listen to reason than the quality of the evidence provided. Any critic of the technique is welcome to take the images provided (they will all be given an internet link)and perform their own analysis. If they arrive at alternative conclusions they are free to argue their case. Good luck.

These images can not, in themselves, prove beyond any doubt that the Apollo missions landed on the moon, but they represent a significant contribution to the body of evidence supporting the historical record. Weather patterns have been identified before in individual Apollo photographs and TV broadcasts, but the analyses presented here are the first to systematically compare all the different contemporaneous sources.

The analyses provided are necessarily repetitive & to some extent formulaic. An Apollo photograph will be selected and a satellite image presented for comparison. Key weather systems will be identified on both. Where possible, images from more than one satellite will be used. Again, where possible, the time of the satellite photograph will be identified. Timelines of the Apollo missions and the journal entries given on the Apollo Flight Journal (AFJ) and Apollo Lunar Surface Journal (ALSJ) websites will be used to support suggestions as to when the Apollo images were taken.

Meteorological data will also be examined, and any other sources of information, such as TV broadcasts, newspaper reports, scientific journals and mission transcripts will be used to add further weight to the arguments presented.

Before going on to analyse the photographs, we will first look at the satellites concerned, then the cameras used by Apollo.

2. Satellite Meteorology

By the late 1960s, the use of satellites to look at the weather was increasingly common, but the technology itself was still in its infancy, and even by the end of the Apollo era there were still many experiments designed to see if the data from satellites were as reliable as those from traditional ground and atmospheric measurements..

Early satellites were launched with a lifespan of just a few months, and the images were examined on their return to Earth. These included the early Soviet Kosmos satellites as well as American efforts.

Advances in communication techniques then allowed signals from an orbiting satellite to be sent back to a receiving station on Earth where they could be translated into photographic images. Although primitive by 2010's standards, the absence of modern circuit board, micro-chips and programming techniques meant that satellite developers crammed a large amount of complex, bulky, interconnected mechanical workings into a relatively small space. Ingenious solutions were arrived at to achieve simple aims, such as using electromagnets that would align with the Earth's magnetic field in order to maintain a satellite's orbital attitude.

There are two basic type of satellite orbit discussed in this work: geostationary and geosynchronous. Geostationary satellites are placed in a position above the Earth that allows them to observe the same features on the ground at all times. Geosynchronous satellites orbit in such a way that they pass over the same place on the ground at the same time each day. They are effectively always following the same path, but the rotation of the earth underneath them means that each time the return to a specific point in their orbit, they are over a different part of the planet.

Images from a number of different types of satellite are examined in this research: ATS, ESSA (and its ITOS and NOAA variations) and NIMBUS.

ATS

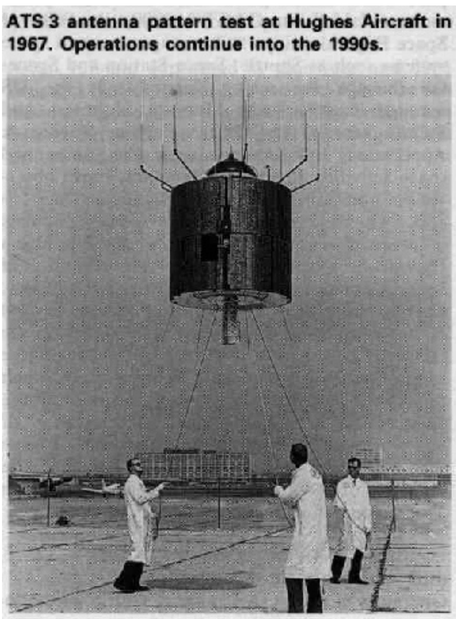

Figure 2.1: The ATS-3 satellite (Source: http://rammb.cira.colostate.edu/dev/hillger/geo-wx.htm)

ATS stands for Application Technology Satellite, and the satellite used in this research is the ATS-3 (sometimes seen written as ATS-III). The following information is a synthesis of that available on a number of websites, listed at the end of this document.

This satellite was launched on 05/11/67[1] and its primary aim was to investigate new ideas in satellite photography, meteorology, and communications technologies. 11 experimental functions in total were on board. It was placed in high earth orbit (HEO) at an altitude of 22300 miles in a position above the equator that allowed observation of the American, African and European continents. Although it was launched by NASA, the experiments it ran involved collaboration with a number of other countries, as well as academic institutions and private companies (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19860066768_1986066768.pdf)

The camera used to image the earth was developed by Dr Vernon Suomi of the University of Wisconsin-Madison, Space Science and Engineering Centre, and is shown in figure 2.2.

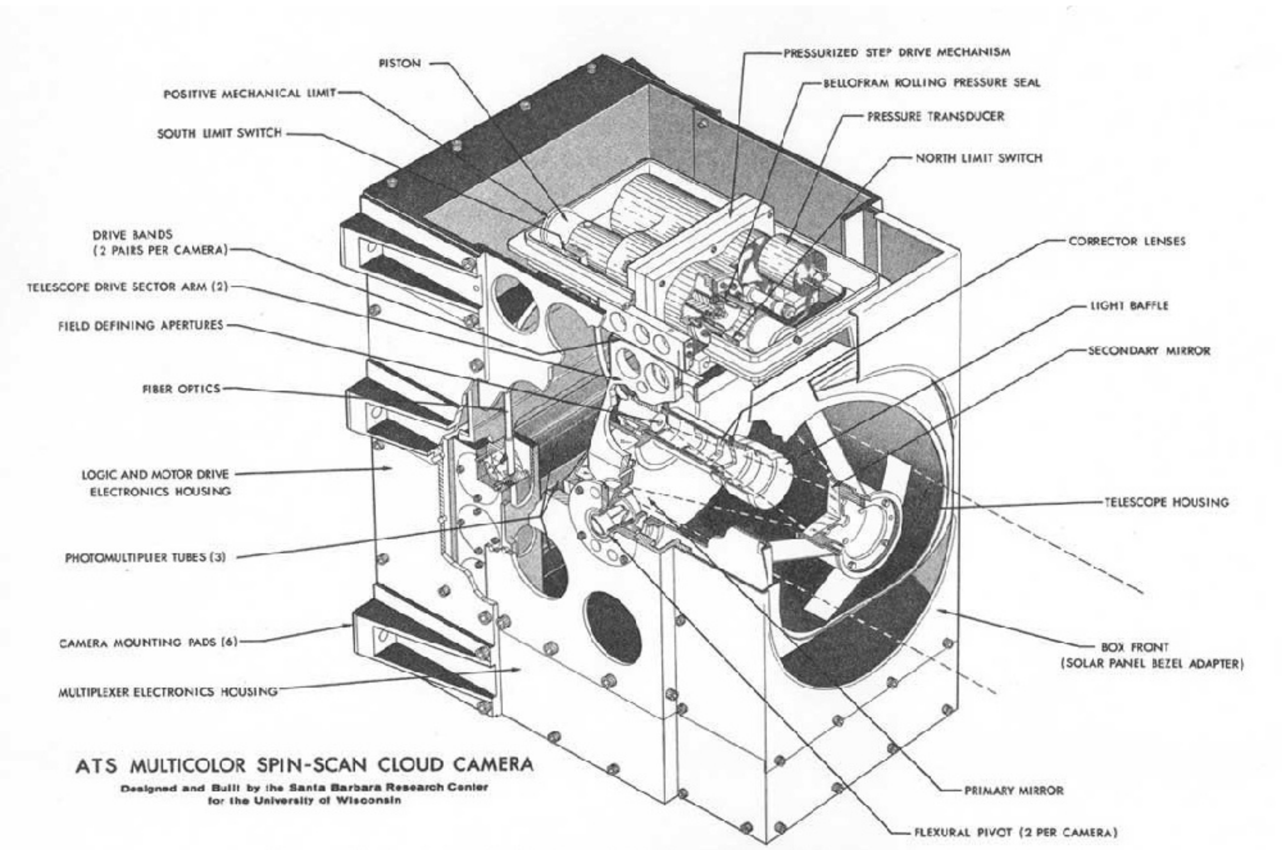

Figure 2.2 – The ATS-3 Multi-colour Spin Scan Cloud Camera system (ATS-3 Image Collection)

While in orbit it span at around 120 rpm, and with each spin it scanned a small line of the Earth's surface, each line representing 3.2 km of latitude. On the next spin it scanned a slightly lower latitude, and over 2400 revolutions it would achieve full coverage. It would take roughly 20 minutes to compose an entire image, after which the camera would reset itself and the process would start again.

The colour image comprised a blue, green and red channel. These three channels worked for just 3 months, after which the red and blue channels ceased to function. Black & white images were still produced until the mid-70s. At the time it revolutionised satellite meteorology. The frequent transmission of images changed high altitude cloud photography from an interesting 'after the fact' image to almost real time imaging, so that meteorologists were able to see weather systems developing and predict more accurately where they were likely to end up. The other experiments on board the satellite allowed cloud movements to be tied in with other observations of other

1 Throughout this work dates will be referred to in the DD/MM/YY format. Times (unless specified) will be GMT.

atmospheric conditions, as well as ground based readings, and investment in satellite technology and meteorology increased significantly.

The satellite became the first to photograph the full Earth from space in high quality colour[2], and this led to the first colour time lapse film of the Earth from space.

Figure 2.3: Earth from space, November 1967 (University of Wisconsin)[34]

Interestingly, the satellite does have a direct link with Apollo.

This NASA page reports that it provided television relay for the live Apollo 11 TV broadcasts to Radio Television Caracas, a Venezualan broadcaster. It is important to note that it served purely as a relay for the TV signal. It took approximately half an hour for the satellites own camera to create a single image and reset itself, it did not have the capacity to broadcast its own images live. It would also not have been possible for Apollo 11 to send a signal direct to the satellite as it would not have been visible. The main TV signal for Apollo 11's moon walk (Extra-Vehicular Activity, or EVA) was received by stations in Australia and transmitted by the communications satellite Intelsat to Houston after which it was relayed to the rest of the world (NASA source , Parkes Observatory).

ATS-3 broadcast its signal to Earth over VHF frequencies, where they were received on VHF antennae of the type shown in Figure 2.4.

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2 the first high quality full Earth black & white images (and the first image of Earth and Moon together) were done by its predecessor, ATS-1. The Russians, however, beat them to it in 1966 Source

3 The image in figure 3 has been incorrectly attributed to Apollo 11 by the British Daily Mail (Daily Mail story), which is an interesting comment on the reliability of the media and the laziness of journalist researchers.

4 It has been argued that the first actual colour full disk photograph was taken earlier by a US DODGE satellite (Source) but the quality is poor

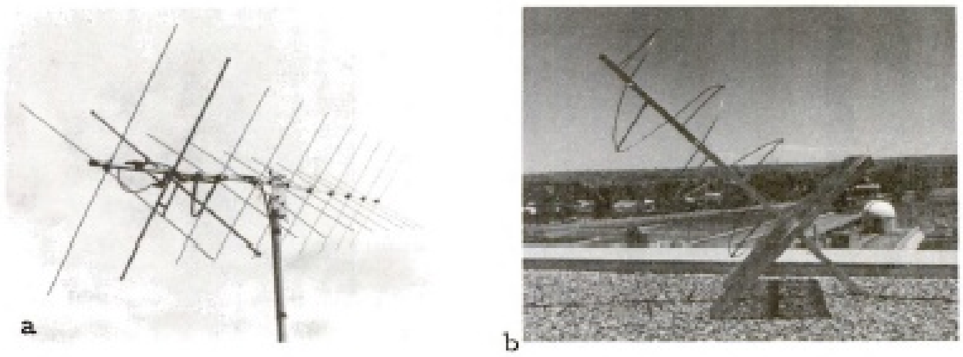

Figure 2.4: VHF antennae used to receive ATS-3 images (Image source)

This document describes early techniques where each strip would be printed, with characters such as '*','/' and ')' in order used to simulate a grey scale, involving a huge amount of paper. Kinescope assemblies (A technique for recording TV images directly on still or moving film) were also used to photograph the TV images.

Information could be recorded on tape and analysed later, but the systems were bulky and slow (figure 2.5).

Figure 2.5: A WINDCO terminal, developed between 1971-1972 (http://www.ssec.wisc.edu/mcidas/software/mcidas25_bams.pdf)

Analogue signals were digitised so that different levels of brightness were assigned numerical values and these values were stored on tape. According to this NASA document, one ATS image could use an entire tape reel when digitised (4 reels for colour). Ultimately, seven track 18 inch reels were used, and these could store 70 images (roughly a day and a half's worth of data). It took an estimated 4 hours between image transmission from the satellite to being visible on a terminal on the ground.

ESSA

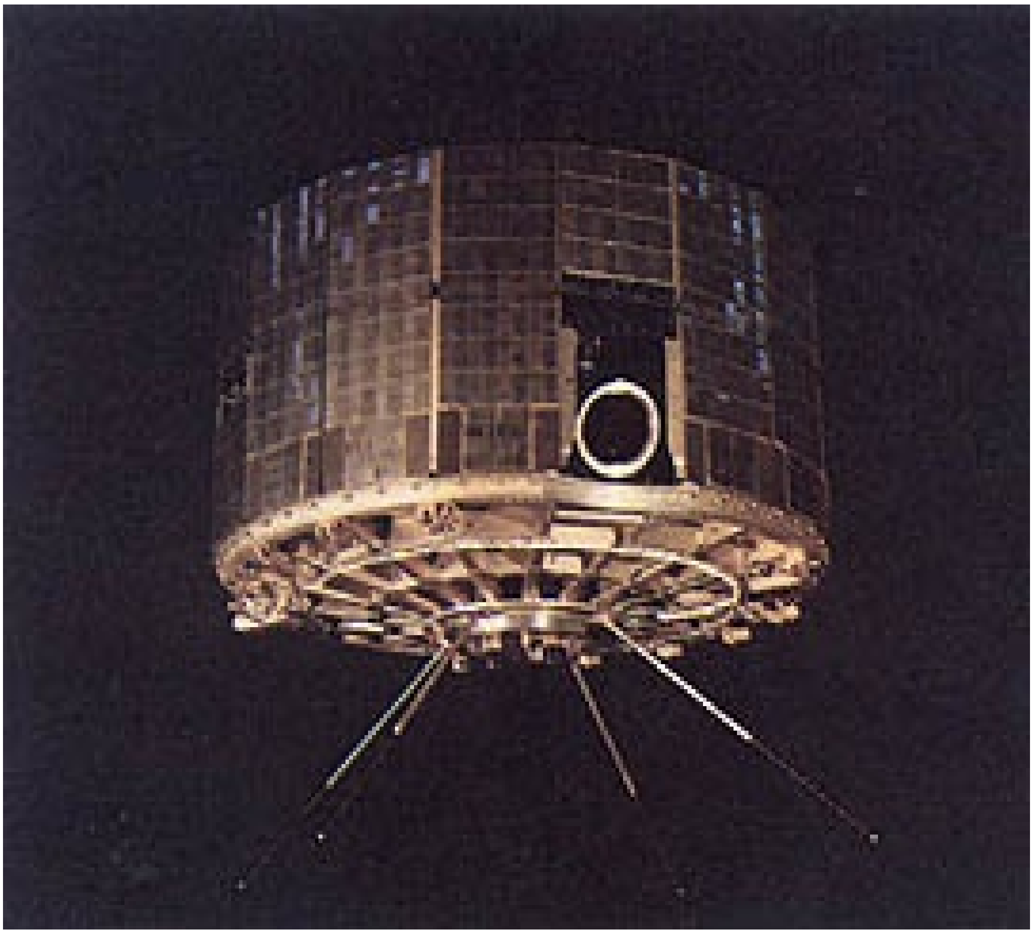

Figure 2.6; An ESSA Satellite (Source)

Environmental Science Services Administration launched a series of 2nd generation TIROS (Television Infrared Observation Satellites) probes through the 1960s. The satellites tended to be much shorter lived (between 1 and 3 years).

These probes were geosynchronous polar orbital satellites operating at a much lower orbital altitude of around 900 miles, taking roughly two hours to complete a single orbit, covering the entire earth's surface in 24 hours. The satellites used on of two types of camera system, both consisting of a camera on opposite sides of the craft, and as it cartwheeled in orbit the camera facing the ground would take an image.

Advanced Vidicon Camera Systems (AVCS) recorded images on tape & transmitted them at pre-determined intervals to ground stations. Automatic Picture Transmission (APT) transmitted analogue signals immediately after acquisition. Photography actually took about 8 seconds, and transmission about 200 seconds (Google Books source). Eventually there were around 300 APT receiving stations located around the world, and the images were therefore immediately available to anyone capable of building a receiver. This article in Radio Science, for example, describes data collected in Peru from the ATS. Amateurs could also collect images. This website for Douai Abbey describes how Benedictine monks at an English Abbey produced satellite images by recording their signals using radio receivers, although it is not clear which satellite they specifically listened to.

The exact coverage of each image would vary depending on the orbital height, but each image covered roughly 400000 square miles, with each line of TV transmission equalling roughly 2 nautical miles. The orbital periods are designed so that the images are recorded in daylight, effectively meaning that photographs are taken during 1 hour of each orbit. One image was taken roughly every 260 seconds ,with an exposure time of around 8 seconds. It was transmitted to earth either automatically or on demand from ground stations. Images were capable of being stored on board on magnetic tape should the satellite be either out of range of a receiver station, or transmitting images whilst taking another.

The images were recorded on photographic film using kinescopes, and also transferred to magnetic tape, with numerical values used to represent different levels of brightness. These tapes were used in “high powered computers” (sic) to be displayed on a cathode ray computer monitor (eg, as shown here). Like APT images, they could be transmitted by fax to other agencies throughout the world.

A diagram showing the orbital paths for ESSA satellites is shown below in figure 2.7. These paths were the same for each ESSA satellite.

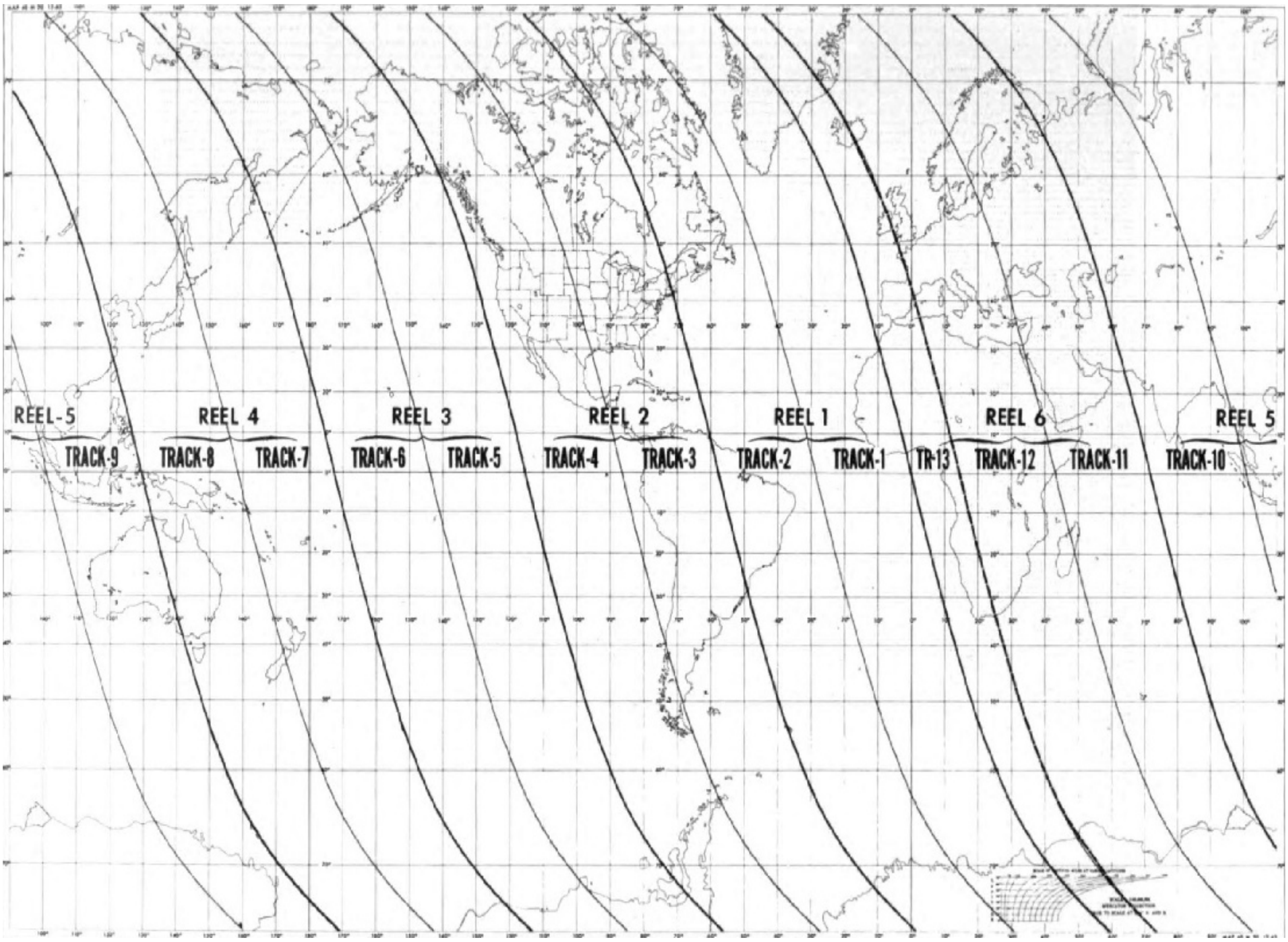

Figure 2.7: ESSA Satellite tracks (this diagram can be seen in most of the ESSA data catalogues, and is the same for each satellite)

NIMBUS

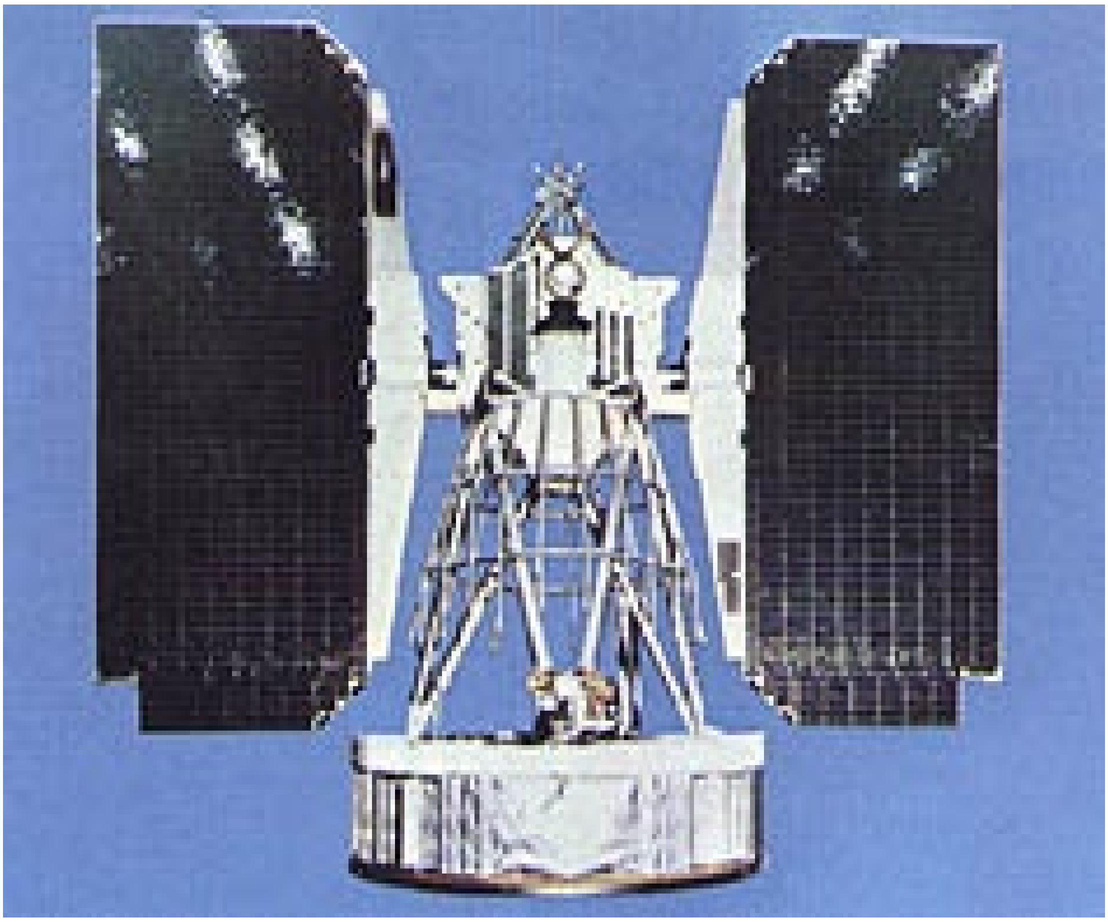

Figure 2.8: A Nimbus Satellite (**Source**)

At the same time as the ESSA program of active meteorological satellites, NIMBUS satellites were being launched as research and development tools to test out new atmospheric sensing techniques, and pioneered the AVCS & ATP techniques used in ESSA satellites. They had a secondary mission of providing useful meteorological data.

Like ESSA, they were polar orbital geosynchronous craft, and over the time of Apollo there were 3 satellites in operation. They orbited slightly lower than ESSA craft at around 700 miles, and orbits were completed in less than two hours. While ESSA used 2 cameras, NIMBUS satellites had 3, one pointing straight down and the other 2 at 35 degree angles at either side, so that despite a low orbital altitude, considerable ground coverage could be achieved (over 800000 square miles per frame). Each line of AVCS imaging equated to roughly 0.6 miles. A complete image took 6 seconds to take and successive images were taken 90 seconds apart (NASA source).

In parallel with the AVCS system, APT was also used. On NIMBUS, the APT images covered roughly 1600000 square miles, with each line of image scan representing roughly 1.5 miles. Each image was stored electrically on a plate and readings from the plate were transmitted to Earth, and the image cycle took just under 4 minutes to complete.

Figure 2.9 illustrates how the NIMBUS satellites were intended to operate in terms of data reception and transmission.

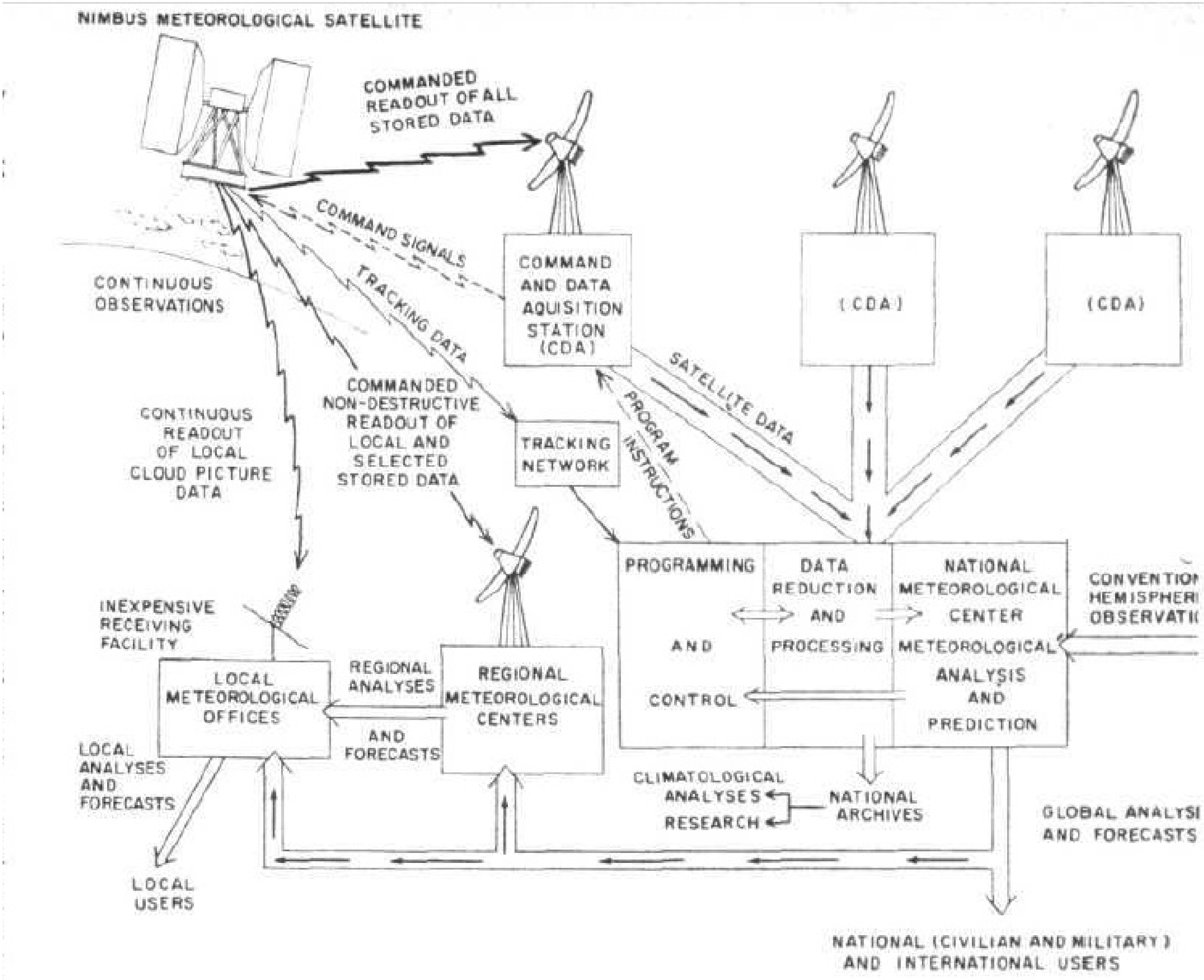

Figure 2.9. Schematic diagram of NIMBUS satellite data transfer (Source)

collection and distribution. As indicated in the diagram, NIMBUS images were available to anyone with a suitable decoder, and the NASA web page here: NASA source reports the uses to which European meteorological agencies put the data.

The VHF signals sent by the satellite were received by the same type of dipolar antennae as ESSA transmissions, and were processed in the same way as ESSA signals.

Figure 2.9 shows a single orbital track's transmission from 24/05/69 (during Apollo 10).10

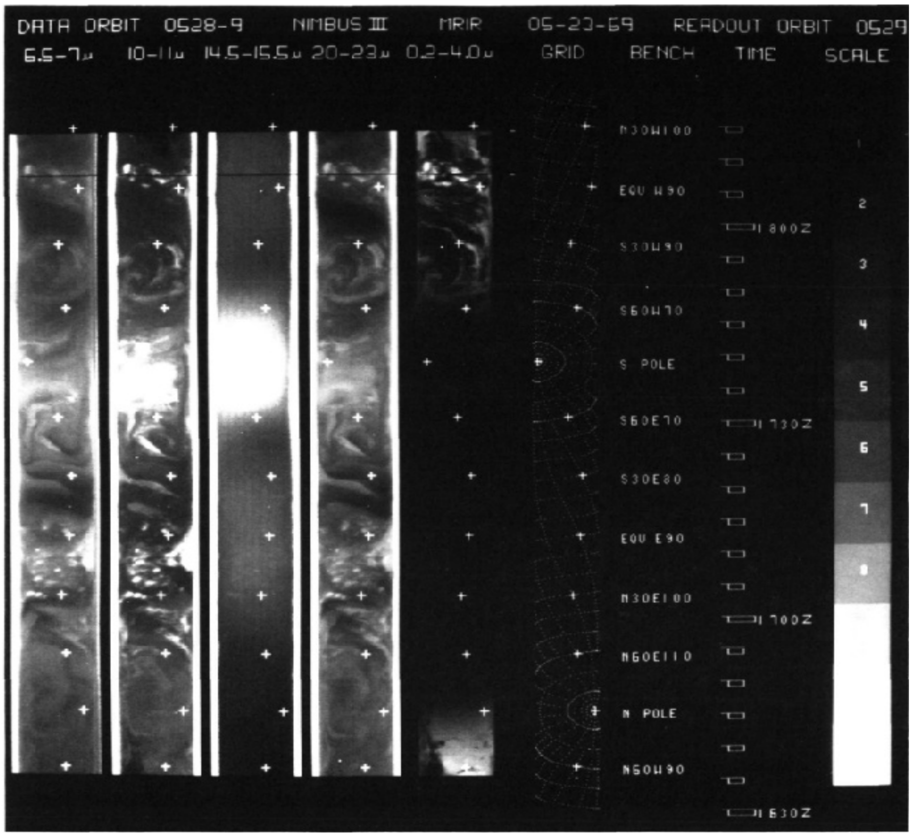

Figure 2.10 – A single orbital pass transmission from NIMBUS 3 (NIMBUS 3 source)

Other Satellites

A number of additional sources of satellite images can be found in largely isolated examples across the internet.

ITOS, or 'Improved TIROS Operational System', was an advancement on the previous ESSA satellites. A series of these new generation TIROS satellites were launched from 1970 onwards, and had various names attached to them as new administrative bodies were formed. The aim was to double the observing power of the satellites in operation by adding more satellites to existing polar orbital patterns.

ITOS-1 was launched in January 1970 and carried 4 improved versions of the camera technology employed by its predecessors capable of both visible and infra-red spectrum data. The satellite was deactivated in June 1971 after technical problems halted some of the on-board experiments in the preceding November, and caused problems with attitude control systems in March 1971. More information can be found here, here and here.

The next launches in the ITOS series were christened NOAA, after the National Oceanic and Atmospheric Administration responsible for them. NOAA-1 (NOAA) was relatively short lived, launching in December 1970 but shutting down in June the following year. The only data catalogue found does not cover any Apollo mission.

The next satellite in the ITOS series was NOAA-2, and for the first time a satellite did not rely on TV imaging for its cloud cover data. NOAA-2 used radiometric imaging, using a combination of thermal and visible radiation measurement to produce an image of the cloud patterns below it. Despite this advancement in measurement technique, the data were still recorded on magnetic tape and transmitted on demand. More information on NOAA-2 can be found here, and links to the scanning equipment here.

There do not appear to be any comprehensive data catalogues for NOAA-2, but occasional examples do show up in journals and other reports.

Perhaps the most interesting satellites available are those specifically operated by the army.

The US military were quick to realise the possibilities of using satellites and rocketry to observe their communist enemies. While early efforts used straightforward 'up and down' rockets, eg those in the 'Corona' programme. to pass cameras over the target territory and return to Earth with films for processing (there was little point in transmitting sensitive images to Earth as they could easily have been intercepted).

It soon became apparent, however, that predicting weather in the Soviet Union (or more likely Vietnam) would be useful, for a number of reasons. Primarily, it made sense, if you were sending a spy plane or a camera up into communist air space, to know whether or not it was cloudy there, and it also made sense to not have to ask someone if the weather over, ooh let's say Moscow, would be cloudy tomorrow at about 09:00 just in case anyone happened to be flying overhead. It also helped to plan attacks or troop movements in those conflict arenas that were active in SE Asia.

At the more extreme end of usefulness, information on likely dispersal patterns for radionucleides, and the availability of long range targets was also likely to be useful. The Cold War is often dismissed as irrelevant in the world of the conspirator, and this is usually a good indicator that they didn't live through the nervy nuclear tensions that were a part of everyday life in the era before the fall of the Berlin wall.

In order to acquire this meteorological information without having to ask anyone, and according to some commentators in order to speed up development where civilian programmes didn't satisfy military needs, the military had a programme of satellite launches of their own.[5] The program went under a variety of names, including the innocuous 'Data Acquisition and Processing Program' (DAPP) , and then later on the Defense Meteorological Satellites Program (DMSP). Some sources also argue that the DAPP programme was a result of frustration with the slow and overly bureaucratic process of satellite design and development within NASA.

While the early Corona images were not fully declassified until the 1990s, the DAPP/DMSP satellite data were declassified in March 1973, and images began cropping up in journals soon after. It is probably no coincidence that this declassification comes shortly after the end of the Vietnam war, which did make use of DAPP weather data.

This early release means the satellite programme is well documented, but the full catalogues do not appear to be readily available online. The satellites themselves were similar in operation to their civilian counterparts, operating a sun-synchronous near polar orbit that took around 101 minutes to complete, at altitudes of around 450 nautical miles and above.

The satellites had a series of developmental stages, and or particular interest to the Apollo missions are the Block 4 & 5 types. At least one Block 4 type was in orbit for Apollos 8-14., and least one block 5 version was also in orbit for Apollo 12 onwards.

Meteorological data were recorded using thermal imaging and visible spectrum cameras, and they

5 It has been suggested that many of the innovations developed for this programme were later adopted in civilian designs, such as magnetic spin stabilisation.

are widely reported as having better image resolutions than, for example, ESSA or NIMBUS, thanks to much better scanning equipment (giving a resolution of up to 0.3 nautical miles per scan line). Block 5 versions replaced vidicon cameras with radiometric systems in the same way that NOAA-1 evolved into NOAA-2.

This NOAA page gives brief details of one of the DAPP satellites, and this excellent history, Cargill Hall, describes the development of the satellites and the military programmes to which they contributed.

A couple of useful journals from ESSA and NOAA give more detail on how the processes worked, as well as give hints about the quality of the images. ESSA World January 1970' and ''NOAA' January 1972 ' have articles on the modern [*sic*] weather forecasting service and the role of the satellite in it. These two magazines have the look and tone of 'in-house' magazines intended for members of the services concerned, and possibly other government and educational agencies. There are adverts and so on for educational material that can be bought from them, so it looks as though they had a wider distribution.

The 'Space Command' article describes how a series of commands are sent to a satellite so that it will turn on a transmitter, transmit its data, and then turn the transmitter back off. It also helps explain the administrative structure. The ATS satellites, for example, are owned by NASA, but the data acquisition process is not carried out by them. Instead it is collected by a data acquisition station and relayed to an operations centre run by NOAA (this would have been managed by ESSA prior to NOAA's creation).

Figure 2.10 shows a member of 'Space Command' checking the quality of a satellite image.

Figure 2.10: Checking satellite image quality on receipt. Source: NOAA

The ESSA World article describes how the satellite images then end up with weather forecasters starting from about 06:00 local time. The strips and mosaics of photographs from the LEO satellites are “less than two hours old” by the time they get to the forecasters, although the ATS images are much newer. The interesting feature about the article is how many people are involved in the process of producing a weather forecast, and how satellite imagery was a relatively small part of that process.

Figure 2.11 shows someone from ESSA looking at a satellite image, and gives a good indication of the size of some of the printouts, and their quality.

Figure 2.11: ESSA staff examine a satellite photograph as part of preparing a weather forecast. Source: ESSA World

Summary

Satellites orbiting the Earth in the 1960s were engaged in data collection for meteorological agencies not just in the USA but worldwide. The operated slightly differently, but in essence they all used cameras that scanned the surface and recorded the image on magnetic tape. Data from these tapes were transmitted, either automatically or on demand), to ground stations using VHF signals. Receiver stations recorded these signals and converted them to TV images, which were photographed using kinescopes. The images could be sent over fax networks, and participating countries could record images directly.

It is also recorded that NASA used satellite imagery to work out forecasts for launch dates, and for the landing areas after re-entry. They also used them to help work out what the astronauts described from their view in space.

The satellite images used in this research all originate from the USA, but other countries were also launching weather satellites, including the UK, China & the then USSR. At the time of writing, images from other space and meteorological agencies are unavailable. It is hoped at some point to incorporate these other sources as further corroboration of Apollo images, as the political situation at the time means that co-operation between the US & USSR in particular was unlikely. Soviet confirmation of US data would be particularly useful.

It has also become evident that many technical journals and academic libraries contain much more information that has been gathered here. The only thing preventing access to these sources is money and proximity. If anyone is well placed in either of those respects they are encouraged to take up the mantle and expand the record further.

3. Apollo Photography

The equipment and methods used to take photographs on the Moon are well documented, particularly on the Apollo Lunar Surface Journal (ALSJ) here ALSJ link 1 and ALSJ link 2 and also on the camera manufacturer's website here

The images themselves are available in a variety of locations, including the following:

Project Apollo Archive
Apollo Image Atlas
ALSJ
Gateway to Astronaut Photography of Earth

and indirectly by searching here: http://www.archive.org/ , a US national archive of various media. Searching by mission photograph number can reveal very high quality TIFF images (around 50Mb each), although their quality is not necessarily any greater than jpeg images a fraction of that size.

The sites listed above generally have a link to high quality versions, although this is not always the case. The Apollo Image Gallery contains the most complete record of all mission photographs, but does not necessarily always have the highest quality image scans.

The cameras used on the lunar surface were the Hasselblad EDC (figure 3.1) fitted with a high quality 80mm Zeiss lens.

figure 3.1; The Hasselblad EDC (Source)

This was a modified version of the EL 500 (figure 3.2) that featured a number of specific features. Instead of loading the film directly into the camera, as would have been the case with standard film cameras of the day, the film was contained in a magazine. The 70mm film used thinner than standard film and as a result up to 40 feet of film (sufficient for up to 200 images) could be packed into each magazine. After taking an image, an electric motor wound on the film.

A Reseau plate, marked with crosses, was built into the camera to check for image distortion and allow for the calculation of angular distances.

The silver body helped to reduce the thermal load on the camera.

The cameras could be hand held or chest mounted, and a special viewfinder allowed the astronaut to use them against their helmet visor without excessive distortion.

All of the cameras used on the lunar surface were left behind, and only the magazines were returned.

A similar camera was used on board the command module and in Apollo 8, the Hasselblad EL (figure 3.2).

Figure 3.2: The Hasselblad EL (Source)

Later missions (eg Apollo 16 link) used cameras that had interchangeable 250mm and 500mm lenses for zooming on on distant objects, and also an adapted Nikon 35mm camera for use on the Command Module.

Other cameras (ie the 16mm Data Acquisition Camera, the close-up cameras used for high quality images of the lunar regolith, and the Scientific Instrument Module cameras that automatically took photographs of the surface from the CM) were available but as they did not photograph Earth they are not discussed here.

After splashdown, the film magazines were transferred to a technician who would inspect them for signs of damage and receive instruction from the astronauts about individual photographs that may be of significance.

The magazines were then couriered to the Manned Spaceflight Centre in Houston, where they were opened in the presence of senior technicians and staff. The films were processed in carefully controlled environments, and in cases where the quality of the film was uncertain, duplicate copies were made before processing.

Each photograph is indexed according to mission, film roll, and then a unique number. Thus image AS11-40-5923 was image number 5923 on roll number 40 from Apollo 11.

As will be discussed later, video footage also featured the Earth. The most documented video footage featuring Earth was made in a number of TV broadcasts from Apollo 11. These broadcasts were made using the Westinghouse Apollo Lunar TV Camera (figure 3.3), which had a range of standard, wide angle and telephoto zoom lenses.

Figure 3.3: The Westinghouse Apollo Lunar Camera Source

The camera could operate at 10 or 0.625 frames per second, and could be operated from the lunar surface or from the CM. At 10 fps, each frame consisted of 320 lines.

A more general discussion of Apollo TV cameras can be found here Apollo TV (NASA) , and on this website TV from the Moon by the author of a book on the subject.

Another source of moving pictures is the Data Acquisition Camera, or DAC.

They were mounted on the Lunar Module, and there was also a slightly different model used on the CM to film eg docking manoeuvres. The DAC was capable of a variety of running speeds, from 1 fps to 24 fps depending on the subject. The entire Apollo 11 moonwalk was filmed using the LM's DAC as a timelapse movie.

Using all these state of the art pieces of equipment, the astronauts were able to obtain high quality still & moving images of their journey to and from the moon, and of the lunar surface, and these images can be compared to satellite photographs obtained completely independently to verify that they were taken where they were claimed to be taken.

4. <u>Comparisons of Apollo & Satellite images</u>

This section will deal with each Apollo mission where the moon was at least orbited (or in the case of Apollo 13, slingshotted around).

For each mission a range of images will be selected representing different stages of the mission and showing different parts of the Earth's surface. Wherever possible, multiple satellite sources will be used. ESSA satellite timings will be derived from the meteorological data catalogues for those satellites. Where individual ESSA, ATS or NIMBUS images are available from contemporary sources, these will used in their entirety. Download managers may be required for some links as they do not always display correctly. As the documents and other material are not hosted by the author, no guarantees can made about their permanent existence.

Where available, synoptic charts will also be used to show that weather systems visible on the satellite photographs were also present on charts.

The most appropriate method of displaying the coincident weather systems has required some thought. A simple method of identifying cloud masses by letter has been employed by others on the internet, but it was felt that this would be potentially confusing. Instead, coloured arrows will be used to identify the same weather patterns. The use of arrows may well appear repetitive and to an extent pointless, but consistency requires their use in each image.

The colours are those available in Open Office, with which this document was written (see figure 4.1 below).

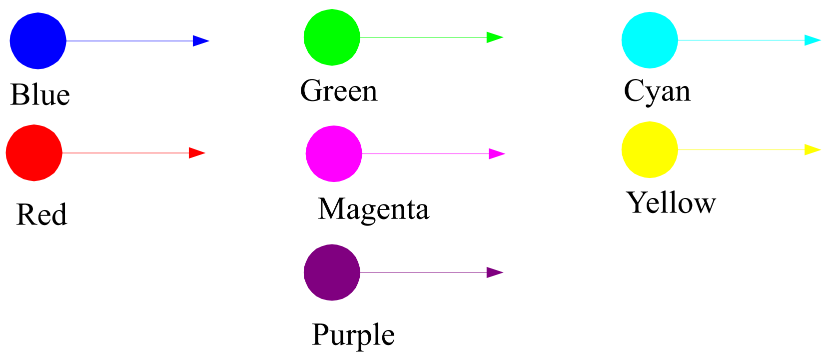

Figure 4.1: Colours used in the text - mainly to clarify cyan, magenta and purple.

The Apollo image will be shown in full, but for the actual analysis only the portion featuring the Earth will be used.

It is worth re-iterating that no material alteration of the photographs has been performed in any way: no weather systems have been changed on any image. All the images are publicly available and sceptical readers are invited to look at these sources themselves to verify their accuracy.

The main aim of each analysis is to identify weather patterns that appear in satellite photographs. A secondary aim is to try and pinpoint a time that the photograph was taken, and this will be primarily done with the track records of the satellites. Additional sources, such as voice transcripts, descriptions given in the various image sources on the internet, contemporary journals and media, and where possible the photographic index from each mission (these can, in some missions, indicate the orbit concerned and the mission elapsed time). The latter will be used sparingly, as it is the evidence within the photographs themselves that is the most important factor here.

4.1 Apollo 8

Apollo 8 is of significance because it was the astronauts on board became the first people to see the far side of the moon, and the first to witness an Earthrise: the apparent rising of the Earth from below the Moon's horizon as the orbiting spacecraft reached *Mare Smythii* in its passage around the Moon. This phenomenon had, of course, already been witnessed by Soviet unmanned probes, but to be captured by human eyes added more significance to the event.

The mission was launched on 21/12/68, reached lunar orbit on 24/12/68, and re-entered the Earth's atmosphere on 27/12/68. During that mission, 865 images were taken on 7 film magazines. The majority of the images were used as source material for preparing future landing sites, but images of Earth are found on magazines 12-16. A number of TV broadcasts were also made, and images will also be examined from those broadcasts. Each image will be given in its original form, then compared with satellite images from the same day. The importance of the original image is mostly to demonstrate how small the Earth is in those images, despite their ability to reveal tremendous amounts of detail.

ESSA 7 images are available in this document: ESSA 7 data catalogue. ATS-3 and ATS-1 images for at least some of the mission can be found in here ATS-III data catalogue. The full transcript of the mission can be found here: NASA link. The mission timeline is here: NASA link. The final section will look at the meteorological data available, to see how the photographic record compares with ground based measurements of the weather at the time.

4.1.1 Apollo 8 Still images

The first magazine containing images of Earth is number 16. This magazine is notable because it contains images from all stages of the mission from initial low earth orbit, separation of the Saturn IV-B stage, lunar orbital images, and then images of the approaching Earth on the voyage home. The first image showing the entire Earth is AS08-16-2593 (figure 4.1.1), and it is compared with satellite images overleaf in figure 4.1.2.

Figure 4.1.1: AS08-16-2593 (Link to high resolution version)

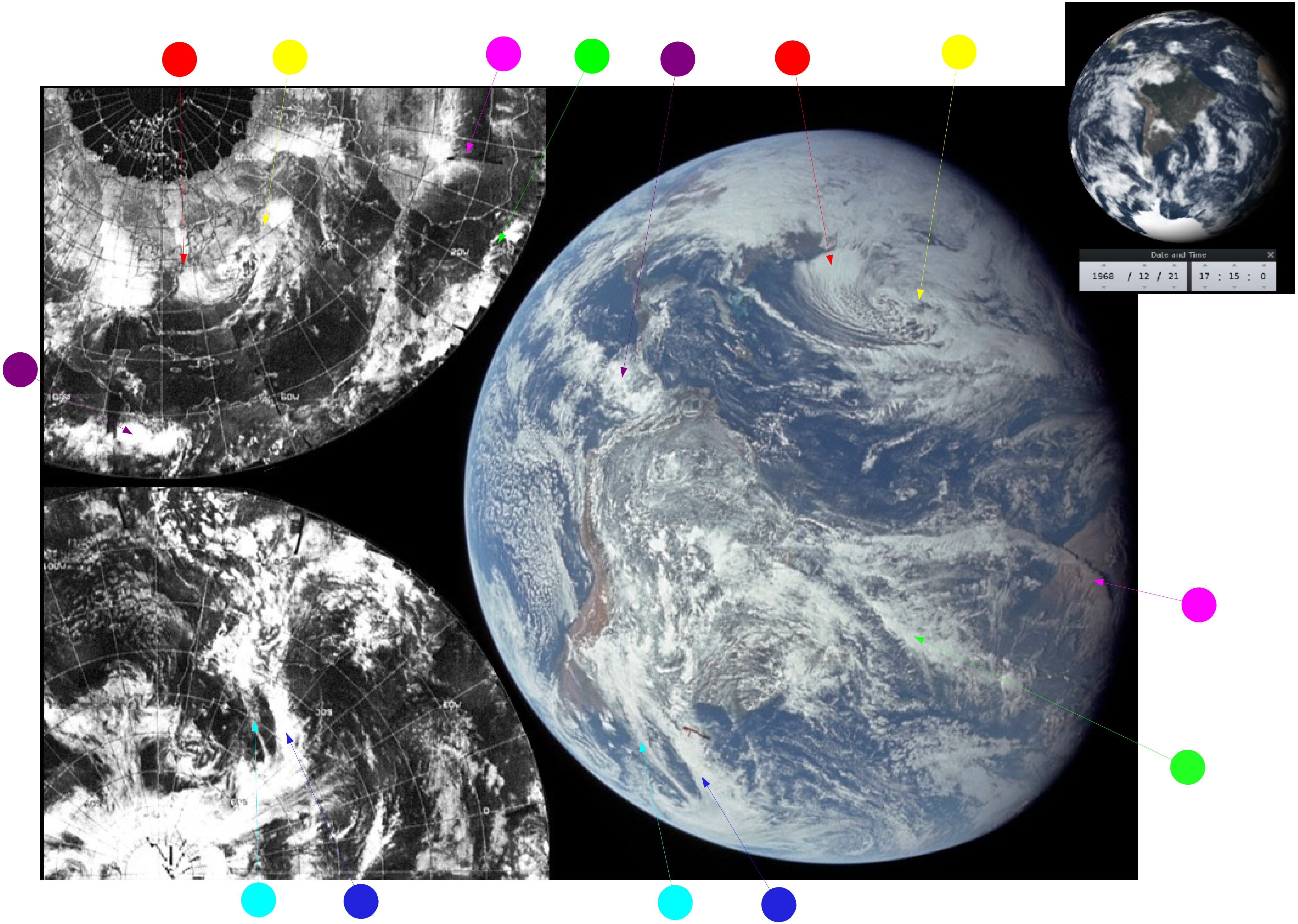

Figure 4.1.2: ESSA-7 satellite image compared with AS08-16-2593 and Stellarium estimate of time at terminator

It is also taken very soon after separation from the Saturn IV-B rocket, as there are photographs of this event before it in the magazine. According to the timeline this occurred at 16:12 on 21/12/68. The most obvious features include the large spiral cloud system in the North Atlantic (yellow arrow), the '<' shaped cloud feature off Brazil (green and magenta arrows), and lines of clouds trending south-east from Argentina (blue and cyan arrows).

It is also worth noting the shadow under the linear cloud mass near the terminator over north Africa (picked out by the green arrow). The direction of that shadow under the clouds is consistent with the sun's direction at sunset.

Stellarium (an astronomical software package used to identify the location of celestial bodies: http://stellarium.org/) can be programmed with times and locations. In this case, using the lunar surface as a view and changing the date to the 21st gives an a time for the Apollo image of around 17:15 , shortly after the initial separation from the SIV-B rocket stage and the trans-lunar injection (TLI) engine burn. It's also worth noting the difference in perspective of the observer. Stellarium's Moon based view is looking 'up' with the southern Hemisphere dominating the view. Apollo's vantage point shows more of the northern hemisphere. At the time the image was taken, the transcript records a crew comment saying that:

"..it's a beautiful view with numerous cloud vortex..I can still see the Cape and isthmus of central America"

ESSA 7 data suggest that South America would have been photographed by the satellite at about 19:09, as this was when track 3 (pass number 1594) of the satellite's daily orbit over it was commenced. The time over the terminator area would be more covered by track number 1, orbit 1592. which commenced at 15:05. At the time of the Apollo image, then, it would be another 2 hours before the satellite would image the area photographed, and there would be a further few hours on top of that before all the visible Earth was covered.

The next in the series of images taken showing any significant change in the scene below them is AS08-16-2595, which is shown below in figure 4.1.3, and analysed overleaf in figure 4.1.4.

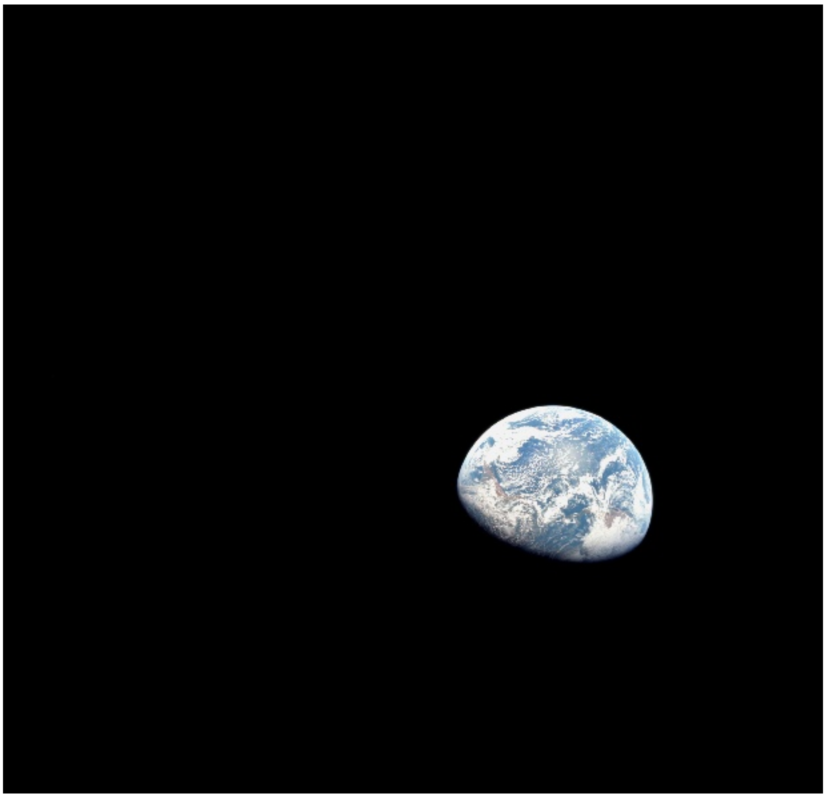

Figure 4.1.3: AS08-16-2595 High quality version here:
http://history.nasa.gov/ap08fj/photos/16-a/hr/as08-16-2595hr.jpg

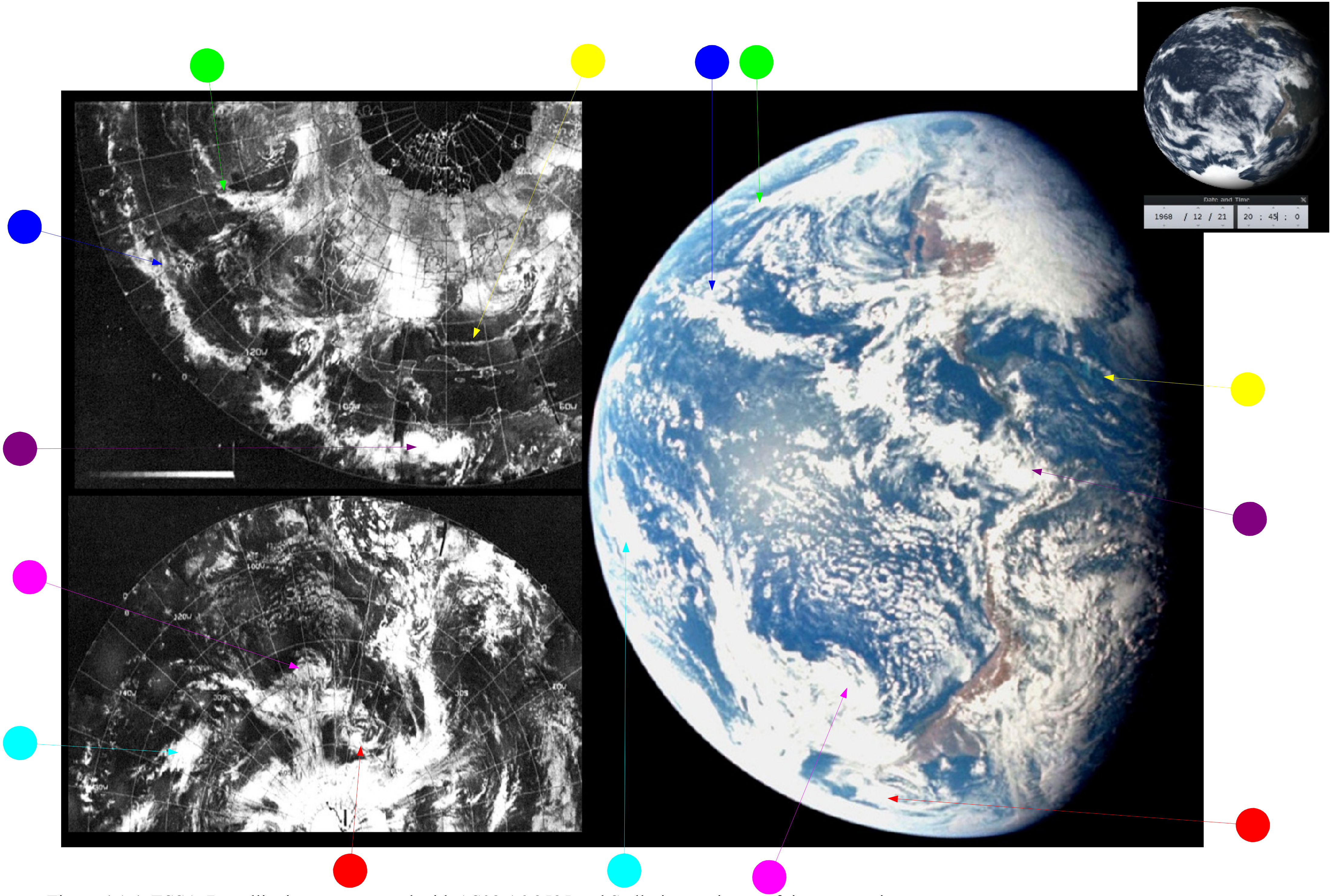

Figure 4.1.4: ESSA-7 satellite image compared with AS08-16-2595 and Stellarium estimate of time at terminator

In this image, the long shadows are cast by the clouds over the Amazon, and the yellow & purple arrows point to the same weather systems as they do in the previous figure, although only the thin tail curling away from the yellow arrow system is still visible.

Much more prominent now are a large spiral system off the north American coast and below Alaska (green arrow), and the scattered clouds over the south Pacific. There is also a prominent plume of cloud heading northwards from Antarctica (magenta arrow), and a small whirl of cloud off south America (red arrow) that are all easily found on the satellite image, along with all the other weather patterns.

The Earth has rotated by a consistent amount between the first two photographs analysed, the shadows lengthen at the terminator, and the weather systems are still visible from the previous image. The bright spot showing the sun's reflection can be seen in this image, and the perspective of the photographer has changed noticeably, with much more of the Antarctic region in view.

Stellarium suggests a terminator time of around 20:45 on the 21st. The ESSA track over the terminator region was commenced at 17:00, as this was when track 2 (pass number 1593) began, as discussed for AS08-16-2593.

A couple of frames later in the magazine we have another view of a still more rotated Earth, and this time it has moved far enough to allow an image from ATS-1 to be included in the analysis. AS08-16-2597 is shown below in figure 4.1.5, and compared with the satellite images over the page in figure 4.1.6.

Figure 4.1.5: AS08-16-2597. High quality source: AFJ

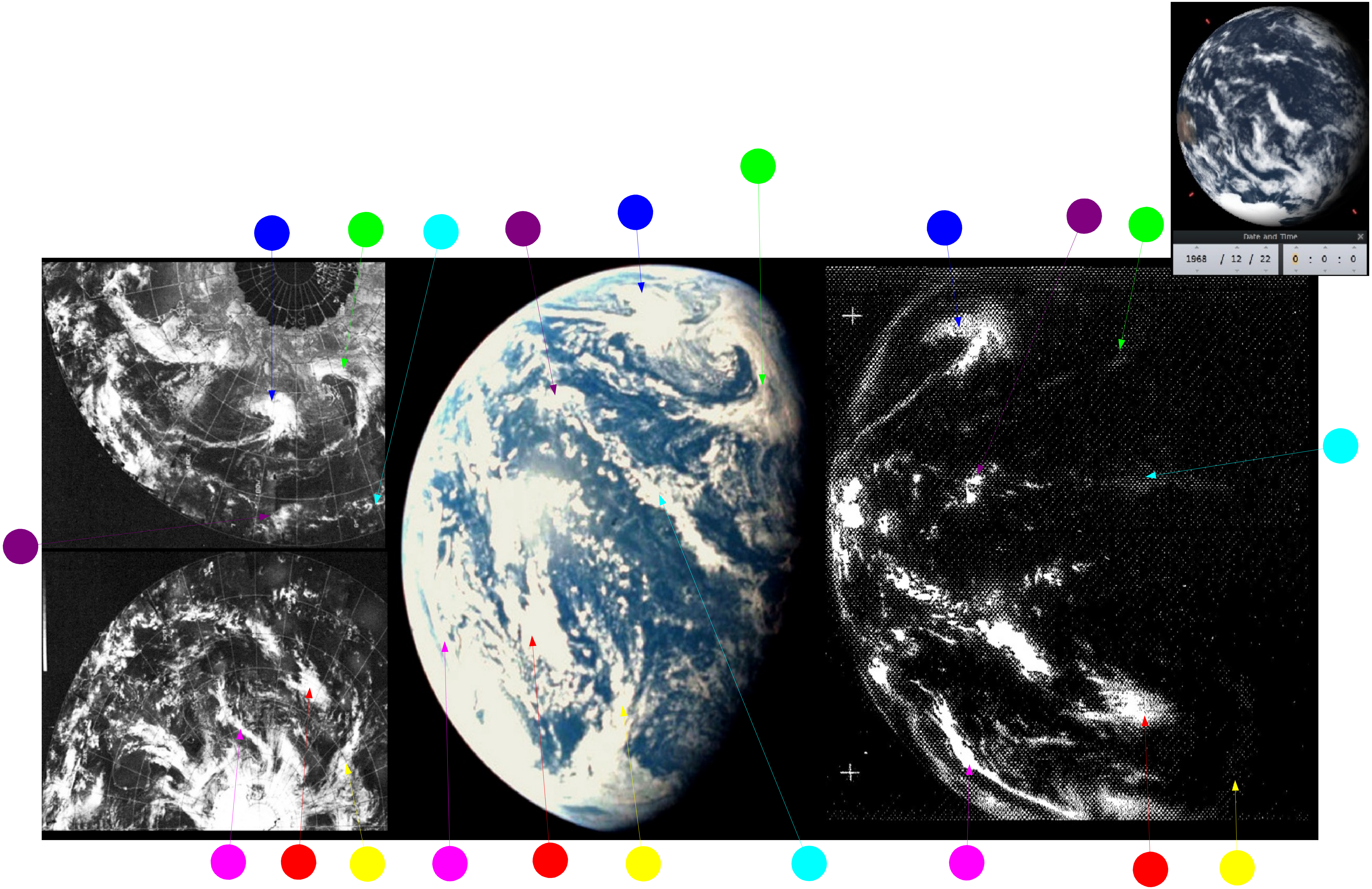

Figure 4.1.6: ESSA 7 (left) and ATS-1 (right) images compared with AS08-16-2597 and Stellarium estimate of time at terminator.

Although there is no land visible in the image, it is possible to mark the position of the terminator with Stellarium by using the previous image analysis as a reference. The weather system highlighted by the green arrow is the same in figure 1.1.6 as in figure 4.1.4, which means that the terminator is just about on the west coast of the USA, which puts the time at around midnight on the 22nd. This corresponds well with the ATS-1 image, which was recorded at 00:54 on the 22nd, and it is evident from it that the eastern half of the image is in, or close to, darkness.

Stellarium also indicates that Australia should be visible on the western limb. This part of the Apollo image is a little washed out, but the magenta arrow points to a band of cloud that should lie off Australia's east coast and that is visible in all 3 images presented here.

The presence of that green-arrowed system is another clue, if one were needed, that this is a picture that is part of a continuous sequence recording the Earth as it rotates, and not some sort of made-up on the spot fiction. As with the other images, and as will become apparent for every other image presented throughout the entirety of this report, the cloud systems on the satellite images match those of the Apollo image. The ESSA path that most represents the terminator line is track number 5, which corresponds to orbit number 1596, which commenced at 22:05 on the 21st.

No specific mention of the actual time of the photograph, but the transcript does have the crew querying what settings they should be using on the camera, and stating at around 01:00 that:

"This PTC attitude isn't the greatest for taking pictures of the Earth"

PTC stands for 'Passive Thermal Control', or the 'barbecue roll' slow rotation that allowed the CSM to balance its temperature in direct sunlight.

A few hours later, we have the next image of Earth showing movement, AS08-16-2599. This is shown below in figure 4.1.7, and analysed in figure 4.1.8.

Figure 4.1.7: AS08-16-2599. High quality source: AFJ

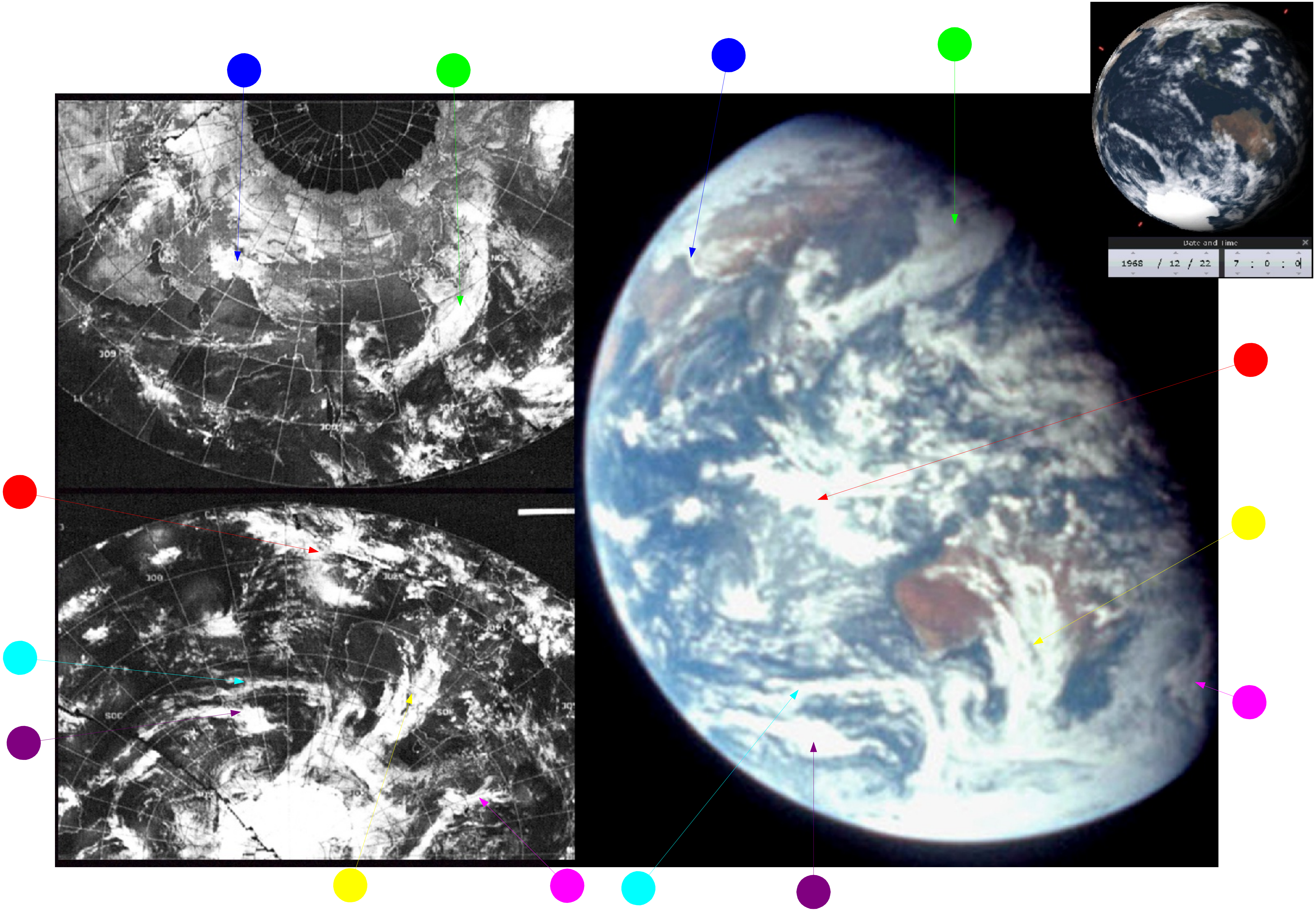

Figure 4.1.8: ESSA-7 image compared with AS08-16-2599 and Stellarium estimate of time at terminator

The rotation of the Earth in this photograph compared with the previous one is such that the ATS image no longer has any features that are visible in it, and the only weather system identified in the previous image that is also identifiable in this one is the one picked out by the magenta arrow.

The system picked out by the blue arrow in figure 4.1.6 can still be seen on the satellite image, just as the green arrow her identifies a weather pattern that was visible on the ESSA part of figure 4.1.6, so it is obviously a continuation of the weather observations on the day.

The plume of cloud extending up from Antarctica (yellow) is very easy to pick out in the Apollo image, as are the 'streams of west trending clouds to the west of it (purple and cyan arrows), the 'Y' shaped pattern near the equator (red arrow), and the Himalayan clouds (blue arrow).

Stellarium shows that the terminator is showing a time of approximately 07:00, and this can be compared with an ESSA time for the orbit nearest the terminator of 02:05 (orbit 1598, track 7).

A couple of images later in the magazine we have another new image of Earth, this time showing Africa as the dominant land mass in view. AS08-16-2601 is shown below in figure 4.1.9, and analysed overleaf in figure 4.1.10.

The ESSA-7 image in that analysis is dated the 22nd, and the dividing line between those orbits that started on the 22nd and finished on the 23rd can be seen to the east of Africa in the southern hemisphere, running up Arabia and across eastern Europe in the northern hemisphere., The majority of the Apollo image is west of that line.

Figure 4.1.9: AS08-16-2601. High quality source: AFJ

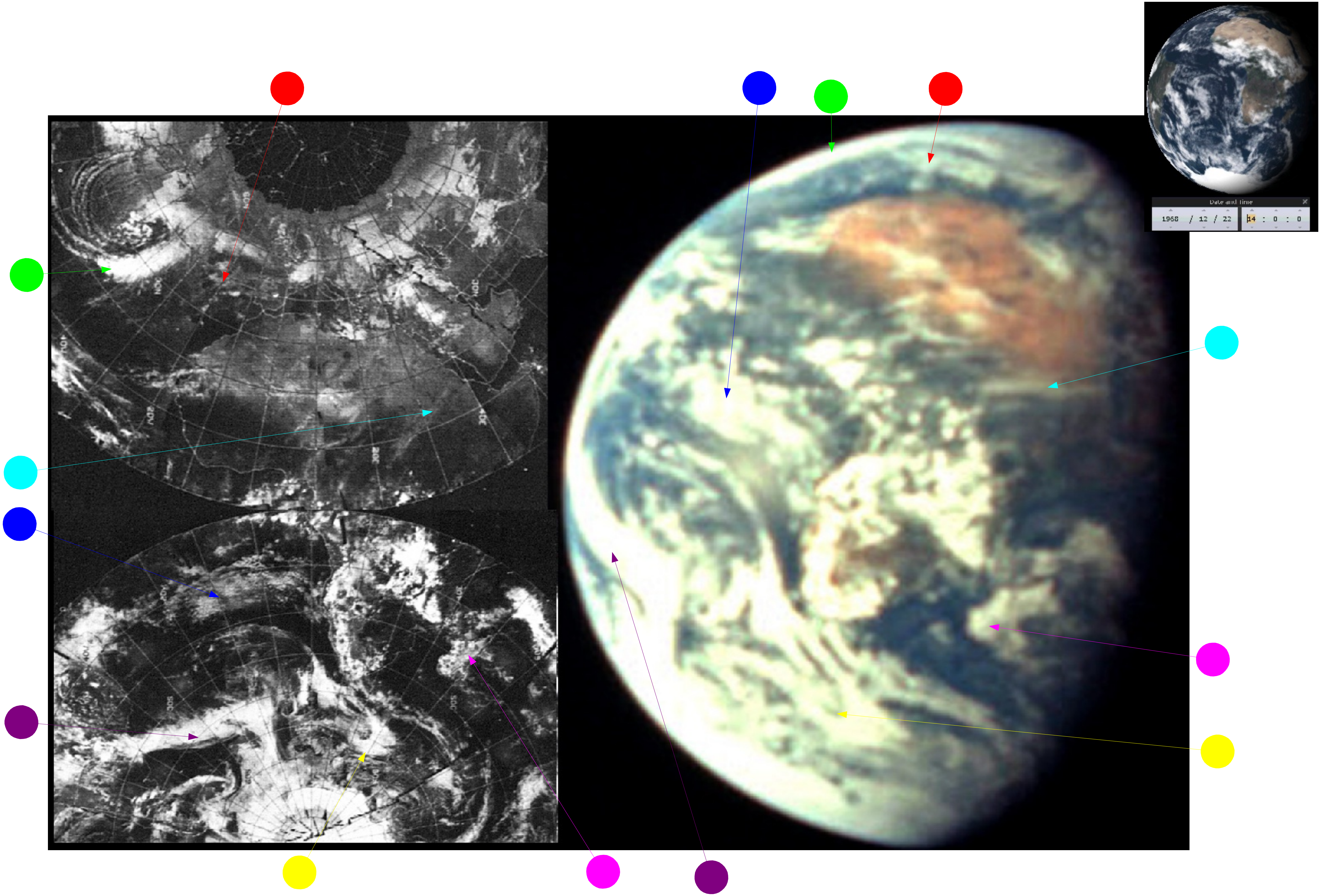

Figure 4.1.10: ESSA-7 image compared with AS08-16-2601 and Stellarium estimate of time at terminator

As usual, the weather patterns on the satellite images correspond exactly with those on the Apollo image, and several of the cloud systems visible in this image will be seen in later ones, not least the spectacular 'dog-leg' frontal mass connecting the Antarctic to south America (purple arrow), and the large frontal mass preceding a series of thin lines of cloud in the north Atlantic (green arrow, although only the main cloud front is visible in this image).

Although the Apollo image is slightly out of focus, it is still possible to pick out the thin clouds over north Africa (eg the cyan arrow), the coastal cloud banks around southern Africa, the typical frontal system off South Africa itself (yellow arrow).

The astronauts themselves describe the view to the ground at exactly the same time as this image was taken:

"This is a mighty nice view we have down there today, A little bit more than a half Earth. Looks like Africa and the Red Sea is visible we're not quite sure as there is quite a bit of cloud cover."

Stellarium suggests a time of around 14:00 on the 22nd for this image. ESSA's nearest track to the terminator is track 11. This is orbit number 1602, which is labelled as the first orbital pass on the image dated the 22nd, and was commenced at 10:05 on the 22nd. The ESSA satellite would barely cover the area around the terminator before the Apollo image was taken, never mind the rest of the photograph.

The next image in the magazine, AS08-6-2602, shows that another few hours have elapsed, and south America dominates the scene. This photograph is shown below in figure 4.1.11, and analysed overleaf in figure 4.1.12

Figure 4.1.11: AS08-16-2602 High quality source: AFJ

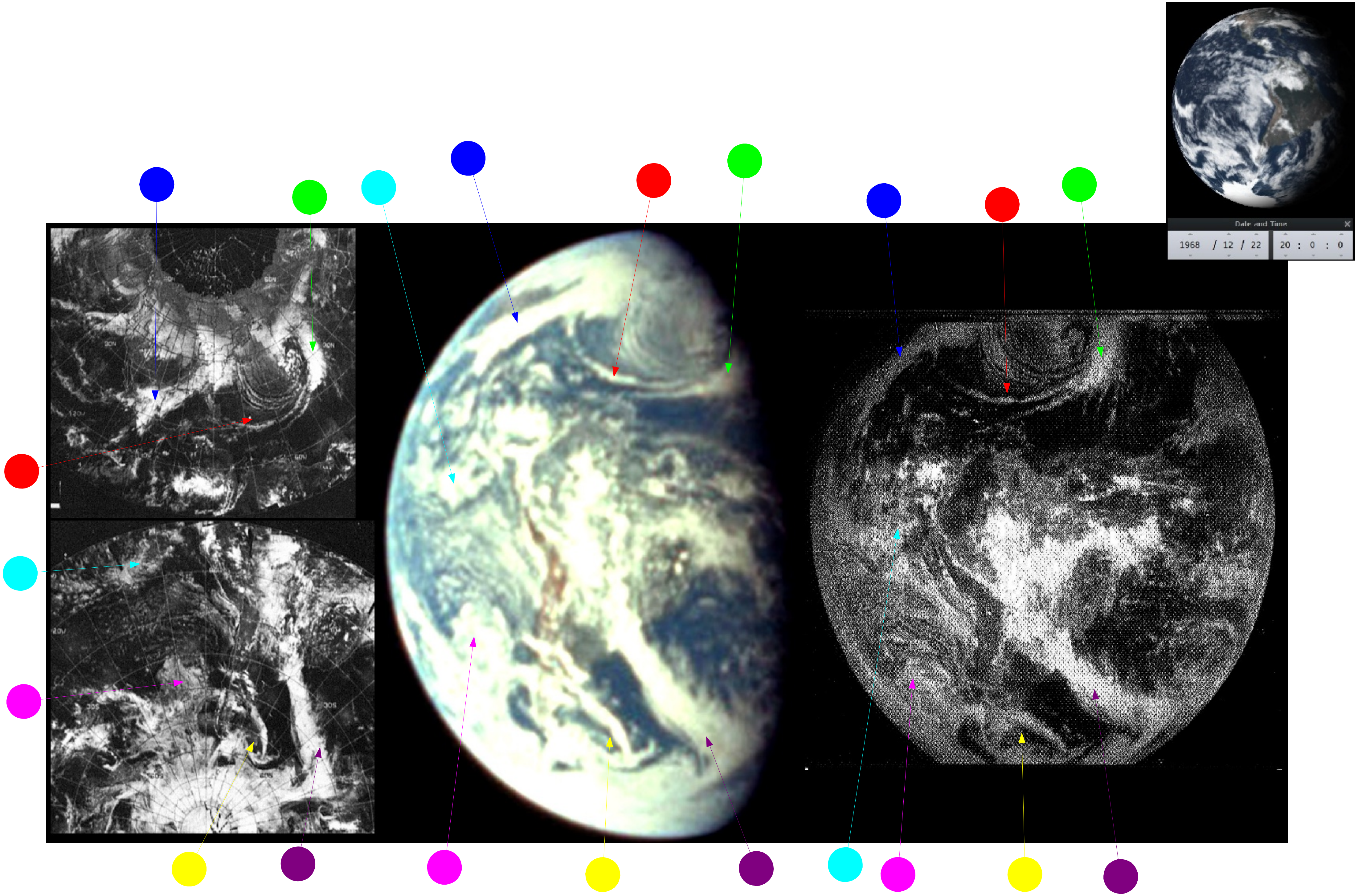

Figure 4.1.12: ESSA-7 (left) and ATS-3 (right) images compared with AS08-16-2602 and Stellarium estimate of time at terminator

The green and purple arrows in figure 4.1.12 point to the same systems shown in figure 4.1.10, and the thin swirls of cloud discussed previously are now clearly in view (red arrow). Similar thin wispy bands of cloud can be seen off the coast of south America (south of the cyan arrow).

For the first time in this section, an ATS-3 image is usable, and this is also showing an excellent match to the Apollo picture. That image was taken at 14:58, and it is evident that the terminator is much further east in that image compared with Apollo's.

ESSA's orbit best matching the terminator is number 1606 (track 2) which commenced at 18:05, just 55 minutes before the Apollo photograph, which Stellarium puts at 19:00.

Ostensibly, the ATS & Apollo images seem (terminator line apart) identical, but there are subtle differences. The clouds over the always dynamic Amazon climate system, for example, are in a different formation to Apollo's, where they are much more similar to the ESSA image taken nearer the time. There are also differences in the way the twin streams of cloud picked out in red are shaped. In ATS-3, they are much more definitely joined to the main bank of cloud (green arrow) and diverge more as they move westward. In the ESSA image,as with Apollo, the northernmost stream has broken away from the main bank of cloud, but there is a wider gap between the streams and they appear more parallel. This is a common theme throughout this research: ostensibly identical systems in fact showing small variations that are entirely consistent with the time differences between the images concerned.

A short while after AS10-08-2602, we have AS10-08-2604. This photograph shows a very similar scene to that of 2602, but much of northern south America has passed beyond the terminator, and more of the Pacific is in view. AS10-08-2604 is shown in figure 4.1.13, and analysed in figure 4.1.14.

Figure 4.1.13: AS08-16-2604. High quality source: AFJ

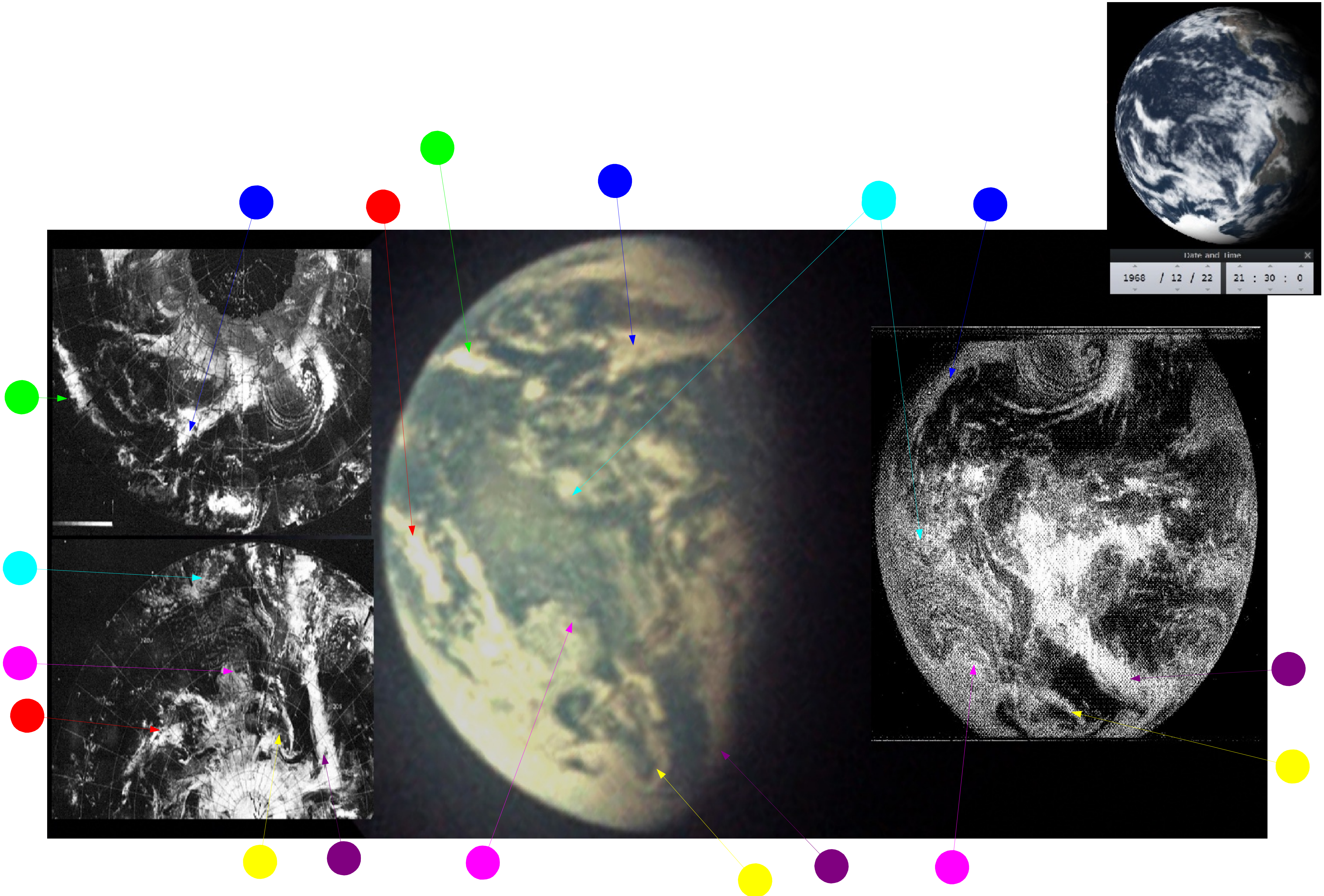

Figure 4.1.14: ESSA-7 (left) and ATS-3 (right) images compared with AS08-16-2604 and Stellarium estimate of time at terminator.

As suggested previously, little has changed in the weather systems already shown, but it does serve to show (again) that the Earth is rotating as the CSM gets further away, and that that rotation brings into view weather systems that were previously hidden. There is no change in the ATS-3 timing, but ESSA's most representative track for the terminator region is number three (orbit 1607), one orbit later than the preceding image, and therefore starting at 20:00.

Stellarium suggests a time for the image of 21:30, just 90 minutes after the previous one, and all of the colours for arrows to identify weather systems in figure 4.1.12 apart from the green and red ones are used again. The reader is also referred back to figure 4.1.4, which showed the same view roughly 24 hours earlier, and where magenta is used to identify the same weather pattern. Those two day's weather patterns are compared below in figure 4.1.15.

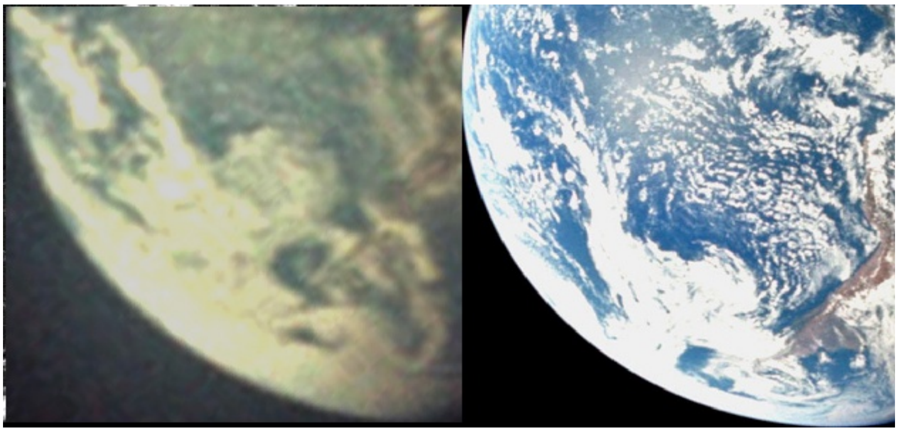

Figure 4.1.15: AS08-16-2595 (right) compared with AS08-16-2604 (left)

The two day's images show what is obviously the same weather system, but that has developed over 24 hours to extend further northwards, while a frontal band to the west moves further eastwards to wards Chile.

After the pair of photographs represented by 2604, the next image if Earth is AS08-01-2606, shown below in figure 4.1.16, and analysed overleaf in figure 4.1.17

Figure 4.1.16: AS08-16-2606. High quality source: AFJ

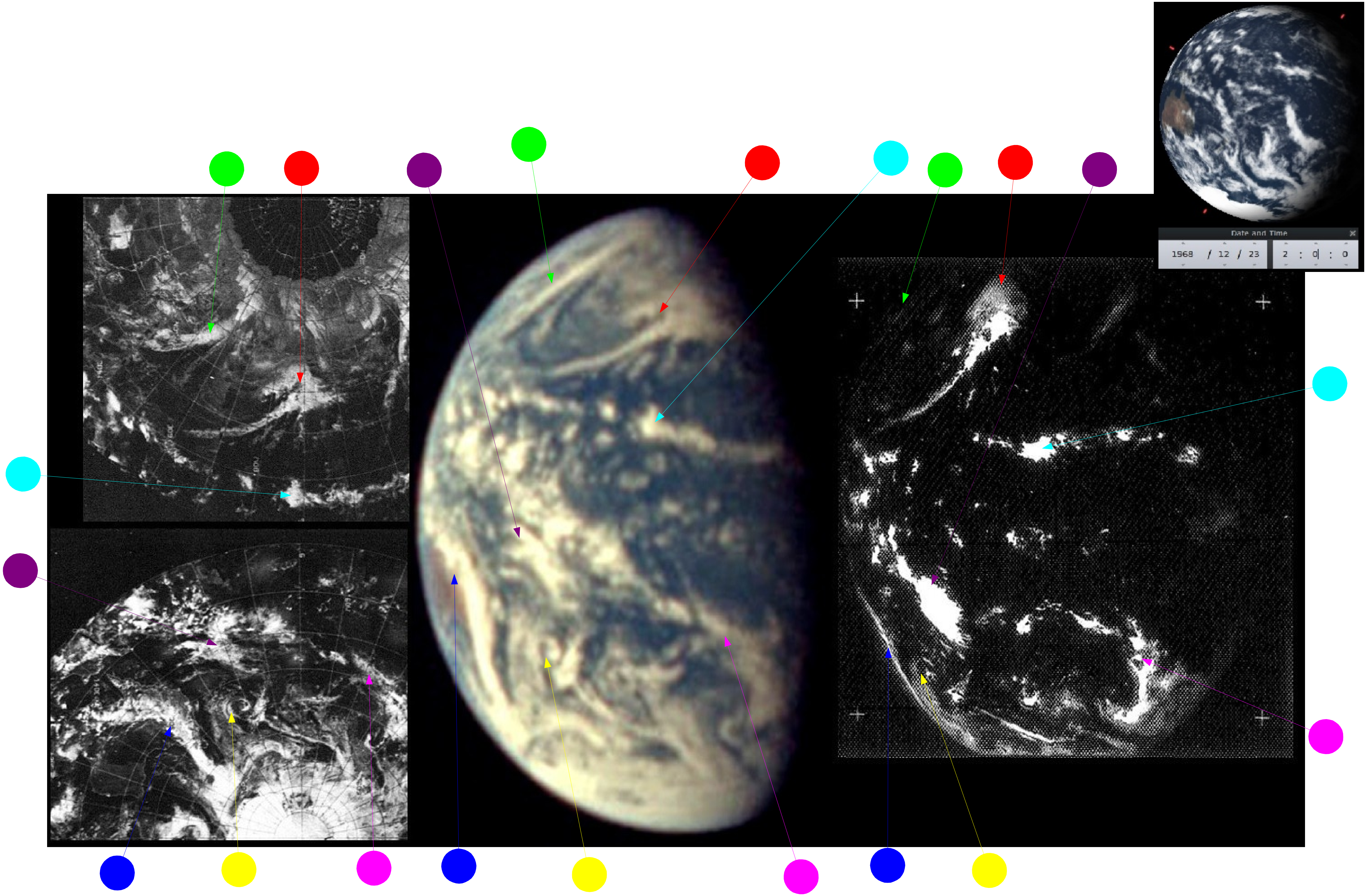

Figure 4.1.17: ESSA-7 (left) and ATS-1 (right) compared with AS08-16-2606 and Stellarium estimate of time at terminator

The Earth has rotated sufficiently to allow ATS-1 to be used as an image source, and for the date (as far as GMT is concerned) to move to the 23rd. ESSA's image date is still the 22nd.

The ATS image was actually taken at 22:43 on the 23rd, over 20 hours after the Stellarium estimate of the image time, and understandably there is a much bigger difference between the Apollo image and ATS-1. However there are, as can be seen from the arrows used, still identifiable weather systems that can be seen on both those images.

Of those systems, the most striking ones are at the northern and southern ends of the planet. In the north there are the two frontal bands (green and red arrows) marking the boundaries of lighter swirls of cloud between them. To the south there are the storms heading north from the Antarctic, including the striking tight curl of cloud marked by the yellow arrow, and the long band of cloud making its way to Australia's east coast.

ESSA is a much better match for the Apollo image, and this is explained by the images being taken much closer in time to it. Orbit number 1609 (track 5) is the closest to the terminator, and commenced at 23:00 on the 22nd.

The next image from magazine 16 is one of the final pair from it before images of the lunar surface are found., which at the very latest puts it at before the 25th of December, and once again south America is the dominant view in the photograph. AS08-16-2608 is shown below in figure 4.1.18, and analysed overleaf in figure 4.1.19.

While the Christmas day 1968 is the very latest that the picture could have been taken, the satellite record places the photo graph very definitely on the 23rd, with Stellarium placing the time at 21:00 on that date. ATS-3's image was taken at 18:16 on the 26rd, while the area area around the terminator line was imaged by ESSA on orbit 1618 (track 2), which commenced at 17:05.

Figure 4.1.18: AS08-16-2608. High quality source: AFJ

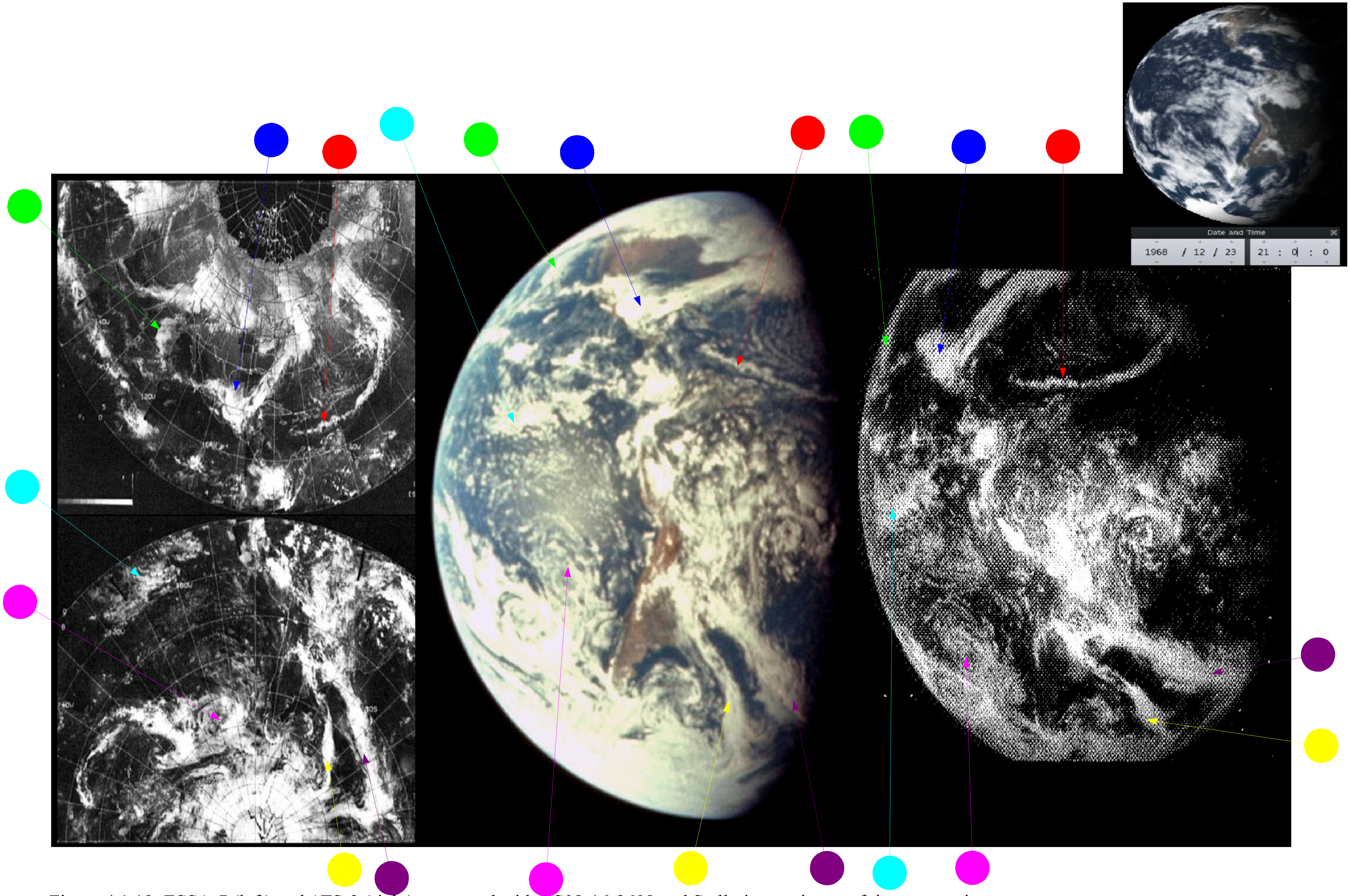

Figure 4.1.19: ESSA-7 (left) and ATS-3 (right) compared with AS08-16-2608 and Stellarium estimate of time at terminator

At 55 hours of mission elapsed time (MET), or about 19:55 on the 23rd, the crew gives confirmation of what is in the photograph by describing the view as seen through the TV cameras in their second transmission to Earth:

"..what you are seeing is the western hemisphere...I can see Baja California and the south-western part of the United States. There is a big long cloud bank going north-east covers a lot of the Gulf of Mexico, and it appears now that the east coast is cloudy. I can see clouds over parts of Mexico, the parts of central America are clear...a long band of - it appears cirrus clouds that extend from the entrance of the Gulf of Mexico going straight out across the Atlantic Ocean right now going from north to south. Southern Hemisphere is almost completely clouded over, and up near the North Pole there is quite a few clouds. South-western Texas and south-western United States is clear. I'd say there are some clouds up in the north-west and over in the north-east portion."

Looking at the Apollo photograph, they are describing accurately what they can see, and have not (as in all cases when discussing the view of Earth on any mission) been prompted in any way. The long cloud heading north-east from the Gulf is indicated by the blue arrow, and the thin cirrus clouds described from the Gulf into the Atlantic are likely to be the ones pointed out by the red arrow (although they actually extend from north to south only if coming from the Atlantic). The maroon arrow points to the same weather system off the coast of Chile identified in previous images, and the purple and yellow ones over south America itself also point to weather systems identified on the previous day by the same colours in figure 4.1.14.

Following this image, the next photographs are of much greater historical significance. As the evidence will show, the following images are not of the first Earthrise to be witnessed by human eyes, but they are the first to be photographed. As it turns out, there are three images of the first Earthrise to be photographed, and they are from three different magazines, 12, 13, and 14. Of these three, the image from magazine 13 is the one chosen as the first, and will be used in comparison with the satellite images. AS08-13-2329 is shown below in figure 4.1.20, and analysed in figure 4.1.21. Figures 4.1.22a and b show AS08-14-2383 and AS08-12-2185 respectively, together with a zoomed and cropped Earth from those images as a comparison with AS08-13-2329.

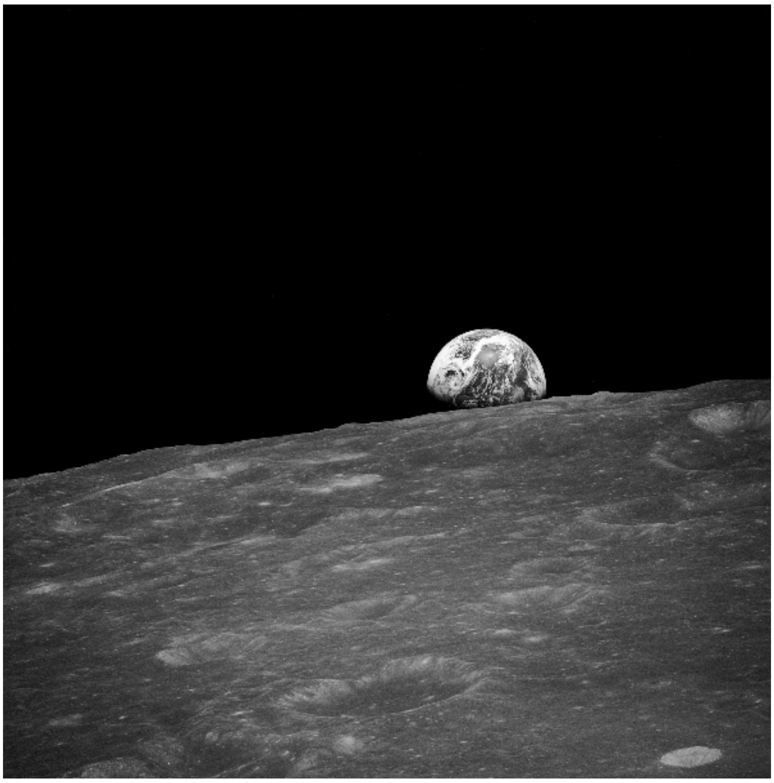

Figure 4.1.20: AS08-13-2329. High quality source: [AFJ]

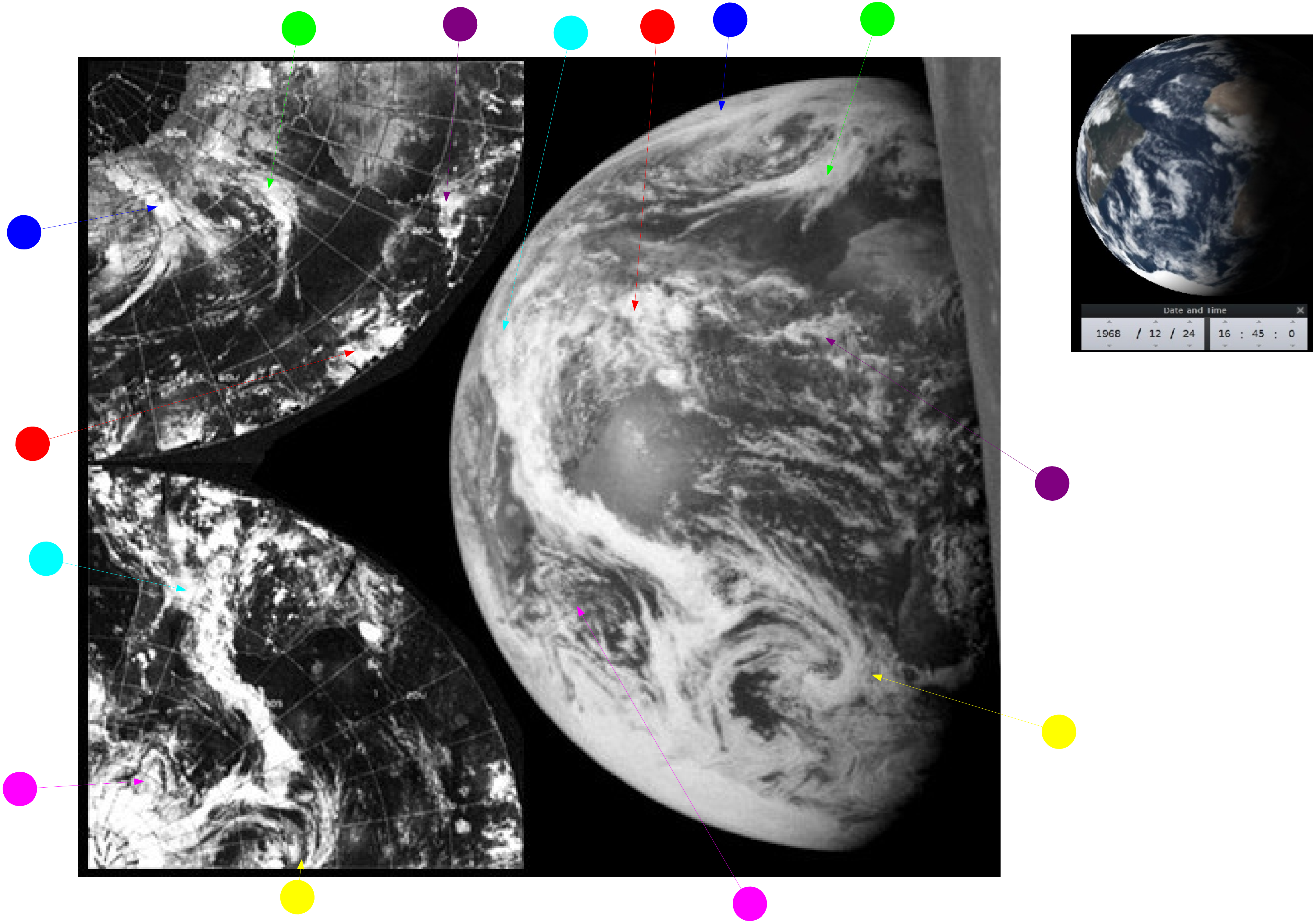

Figure 4.1.21: ESSA-7 image compared with AS08-13-2329 and Stellarium estimate of time at terminator.

a) AS08-14-2383 (High quality source: AFJ

b) AS08-12-2185 (High quality source: AFJ)

Figure 4.1.22: Apollo images of Earth from the same orbital sequence as AS08-13-2329.

That the images all show the same event is obvious – the weather patterns and their distribution in each is identical. The sequence of images presented above is easy enough to determine. Magazine 13's contribution exists in isolation, as all the images around it are of the lunar surface, while magazine 14's image is one of a pair right at the beginning. The fact that it is clearly higher above the lunar surface than 13-2329 obviously places it later in that Earthrise. Examination of the surface in the pictures from 13 and 14 also show that different craters are evident – the photographers are moving over the surface of the Moon, and the twin craters visible in the bottom left of 14-2385 and the larger crater in the bottom right can be seen much closer to the lunar horizon in 13-2329.

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Magazine 12's contribution is also preceded entirely by lunar surface images, and as there is no lunar surface in it is obviously taken later than those from 13 and 14. While there are no lunar surface features visible to act as a comparison, a closer look at the weather system identified by the yellow arrow in figure 4.1.21 shows that it is noticeably closer to the terminator in 12-2185 than in the other two images, suggesting a time lag of around 15 minutes between them.

Determining the time of the image is also simple enough, thanks to the visibility of Africa at the terminator. In order for Africa to be on the terminator, the image must have been taken at around 16:45 GMT on either the 24th or the 25th . As by that time on the 25th Apollo 8 was well on the way back to Earth, the image must have been taken on the 24th, around 76 hours into the mission, and around 7 hours after the Lunar Orbit Insertion (LOI) burn. This should mean that there would be around 3-4 orbits before this first photograph of Earth was taken.

We have the satellite photographs to use as a basis for determining which day the image was taken, and a look at the ESSA image shows the same features as the Apollo image on the mosaic dated the 24th. The previous day's mosaic shows that there are still two bands of clouds running from south America to the Antarctic (previously marked by purple and yellow arrows), while this Apollo omage only shows one. On the following day, this band of cloud has pretty much separated from south America, rather than extending well into it. The configuration of the cloud mass off southern Africa (yellow arrow) is also different on all 3 days, and only matches exactly the one from the 24th.

The terminator on the 24th is best covered by orbit 1629 (track 13), which commenced at 14:00 on the 24th – just a couple of hours before the Apollo image was taken.

We have an additional source for this historic moment in the the mission transcripts. As any conversations concerning Earthrises as they happen are not in the main transcript referred to previously (as this is the technical air to ground, or TEC, transcript), we need to turn to transcripts of the CM voice recordings, which captured the crew's conversations as they passed over the far side after LOS.

A pdf of the document itself is available here: CM transcript, but there is a more readable transcript of the event at the AFJ here: AFJ. Joining the CM and TEC transcripts gives us a complete record of the moment. At 74:40 MET, or 15:31 on the 24th, the crew are engaged in a session of lunar photography of both planned targets and 'targets of opportunity', and the describe in detail which magazines have been used and how many shots have been taken on the three revolutions completed so far. The main significance of this is to set a context for what comes next – the crew didn't suddenly decide to take photos, they were actively photographing the Moon when the Earth came in to view.

At 75:30, or 16:21, the CM starts its 4th orbit, and the lunar module pilot Bill Anders appears to be the person taking surface pictures with magazine 13 (originally labelled 'E'), as he is the one recording the frame numbers and technical details about the photographs. At 75:46 MET, the CM pitches on command and we have the following exchange:

075:47:30: Oh, my God! Look at that picture over there! Here's the Earth coming up. Wow, is that pretty!

075:47:37: Hey, don't take that, it's not scheduled. (Chuckle.)

The AFJ site is more circumspect than the CM transcript, and is not specific as to who actually took the photograph, while the latter has the Anders saying the “don't take that” line and the Borman exclaiming about the view. As Anders was the person in charge of the black & white film prior to this, it perhaps seems reasonable to assume that it was he that took this historic image.

The AJF's author (David Woods) argues that Anders was committed to the photography aspect, and would have been more likely to have been the person making the admonishment about deviating from the schedule.

A few moments later, the crew (at Anders' prompting) scrabble for the colour film in an effort to capture the moment before finally:

075:48:49 Lovell: Well, I got it ri - Oh, that's a beautiful shot.

075:48:54 Lovell: 250 at f/11.

075:49:07 Anders: Okay.

075:49:08 Lovell: Now vary the - vary the exposure a little bit.

075:49:09 Anders: I did. I took two of them.

Anders, then, is definitely the person who took the the colour photographs that launched a thousand environmental movements. While the debate about how took the first image is somewhat esoteric (although to this author's mind the person who took the monochrome would be the person who wanted an even better colour shot, ie Anders!), the main issue as far as this research is concerned is the timing of the images. 75:47 MET is 16:38 GMT on 24/12/68 – just a few minutes short of Stellarium's estimate for an image that matches exactly a satellite mosaic that was taken at the same time. There is no record of when magazine 12's image was taken, although Anders is exhorted to “get another one”.

The next image is AS08-12-2388, shown below in figure 4.1.23, and analysed in figure 4.1.24.

Figure 4.1.23: AS08-12-2188. High quality TIFF image source here: http://www.archive.org/download/as08-12-2188/as08-12-2188.tif

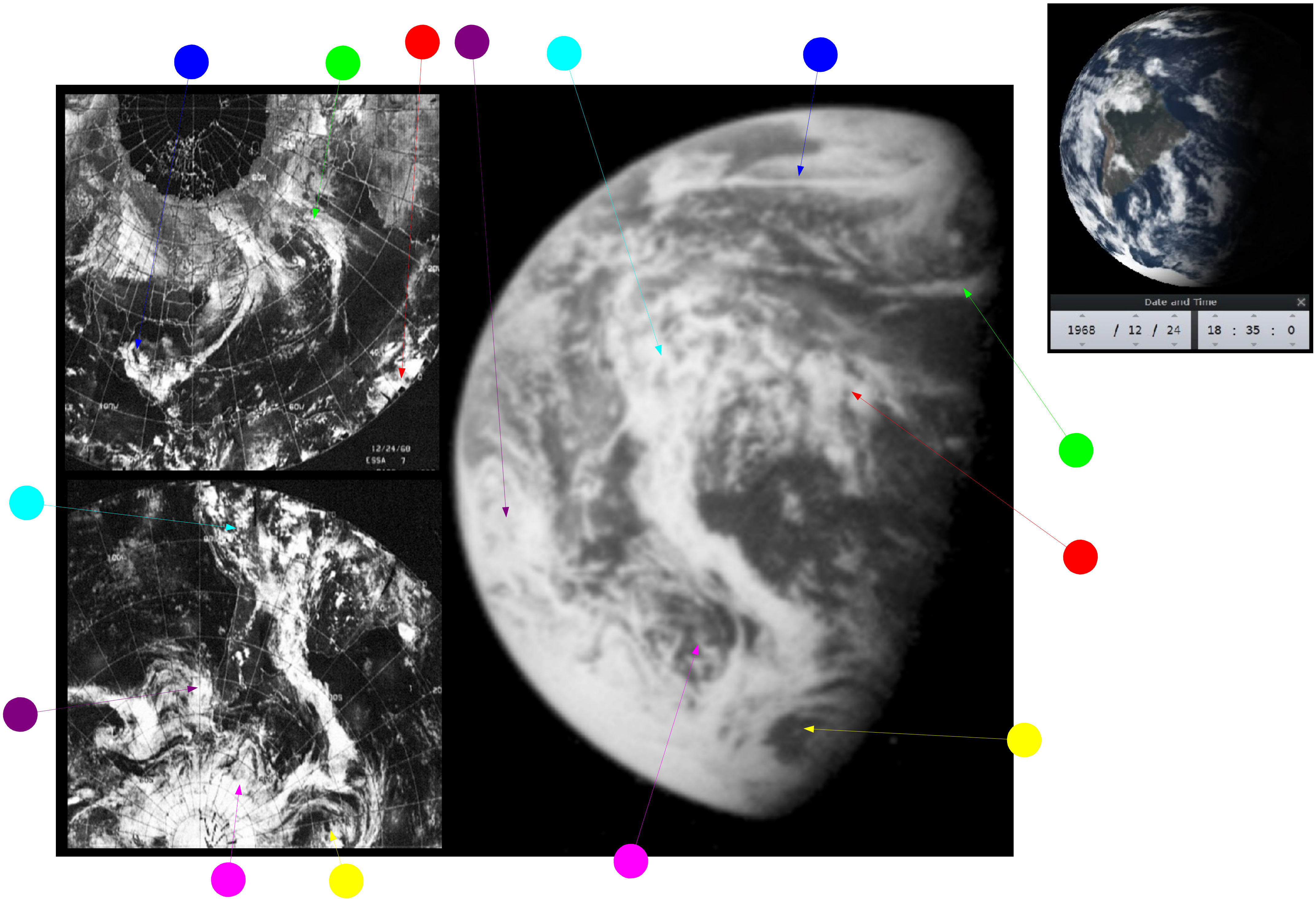


Figure 4.1.24: ESSA-7 image compared with AS08-14-2385 and Stellarium estimate of time at terminator.

As before, the black and white image is matched by a colour image, in this case AS08-14-2385. The original of this image is shown below in figure 4.1.25, together with the zoomed in version of the Earth on it.

Figure 4.1.25: AS08-14-2385 and zoomed Earth from it. High quality source: AFJ

The AJF originally had the magazine 12 image timed as occurring after TEI (Trans-Earth Injection), which is an engine burn that lifts the CSM out of lunar orbit and on a trajectory towards the Earth. This usually occurs at a point on the far side of the Moon, and therefore can still show the lunar surface and an Earthrise.

The TEI burn occurred at 06:10 on the 25th, and we already know that in order for South America to be visible in this way it would need to be around 18:30-19:00, at which point on the 25th the CSM would be well on its way back home and no portion of the Moon would be visible. Combine that with the satellite weather information that confirms that the clouds are all still consistent with the 24th and we can start to be more definite about the time and date.

In terms of the weather systems, it is obvious that they are the same ones as viewed in figure 4.1.21, indeed only one arrow (the purple one) has been moved to new location. The yellow arrow, however, points to a weather system that has largely disappeared beyond the terminator, while the blue arrow shows a band of cloud much more clearly than in the previous image, again showing a perfectly consistent rotation.

We do have a small clue from the CM transcript. Orbit 5 commenced at 77:29 MET, or 18:21 on the 25th. Twenty minutes after this at about the time when the Earth would be rising, we have the following exchange between the crew members:

03 05 43 46 CMP: Bill, ... Do you know I can see the horizon? Can you see the horizon?
03 05 43 59 LMP: Pitch up?
03 05 44 00 CMP: Yes, pitch up to -
03 05 44 20 CDR: Pitch is about 50.

03 05 44 23 CMP Can you pitch up some more?
03 05 45 20 CMP No, that's about right. Let's take pictures of ...

While they aren't specific, they are evidently still taking photographs, and keen to orient the spacecraft to an angle that would allow them to take a photograph of something specific. The contention here is that it is the Earth, now showing above the horizon. The time in days, hours and minutes shown above converts to 77:45 MET, or 18:35 (which is the time used to set Stellarium). Stellarium and the photographs in magazines 12 and 14 show the same configuration of land masses, and the Apollo images show the same weather patterns as the satellite mosaic on the 24th.

The ESSA orbit for the terminator on these two images is best covered by track number 2, or orbit 1631, which commenced at 18:00.

There are no more pictures of Earth in magazine 12, but the next sequence of images in magazine 14 show another Earthrise. They could be mistaken for a continuation of the sequence just examined, but a closer look (and the fact that the first in the sequence is lower on the horizon than the previous one!) shows it is from a separate event.

The only one one of these images where the Earth is completely above the horizon and fully visible is AS08-14-2393, and this is shown below in figure 4.1.26, and analysed overleaf in figure 4.1.27.

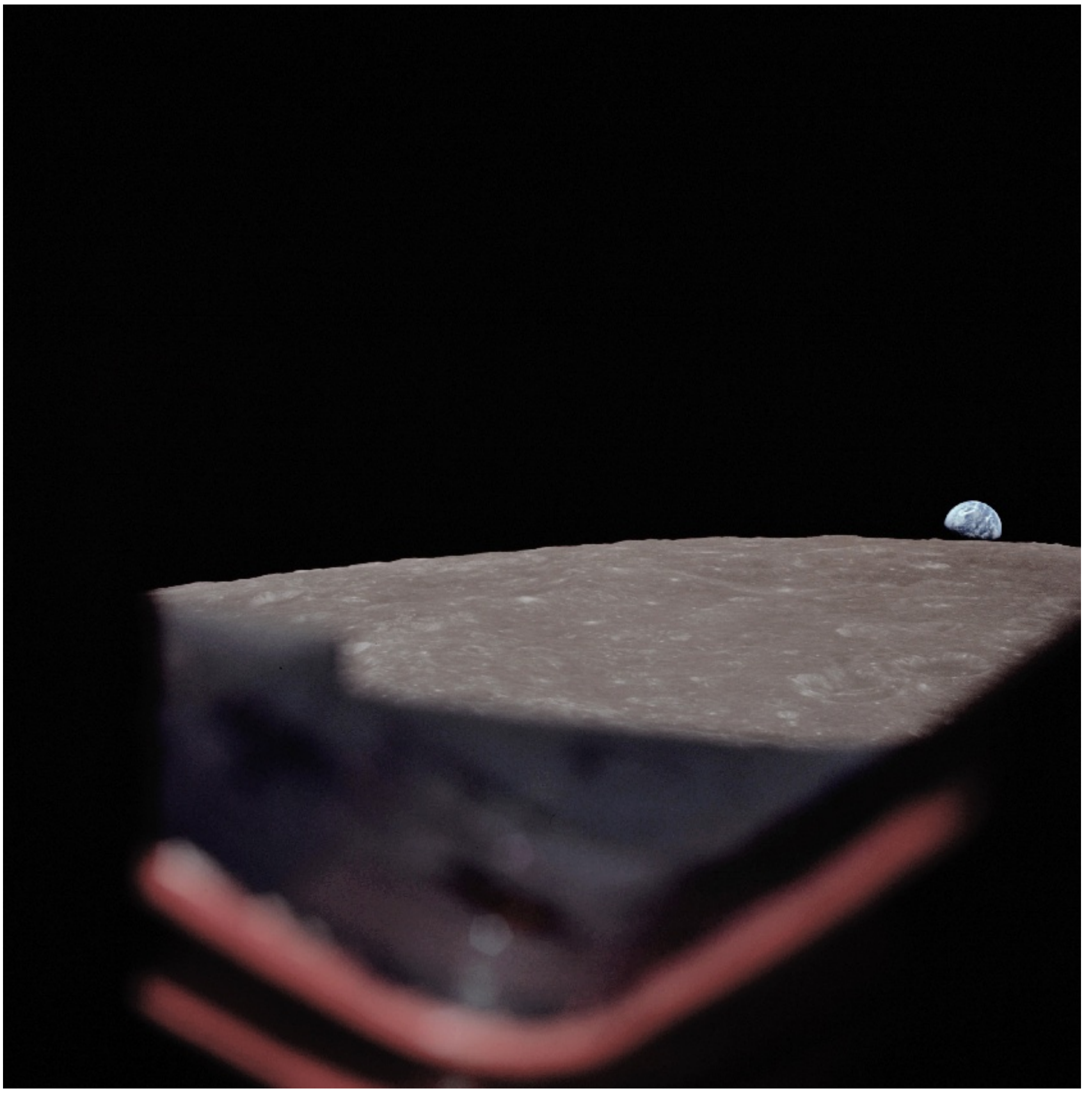


Figure 4.1.26: AS08-14-2393. High quality source here: [AFJ]

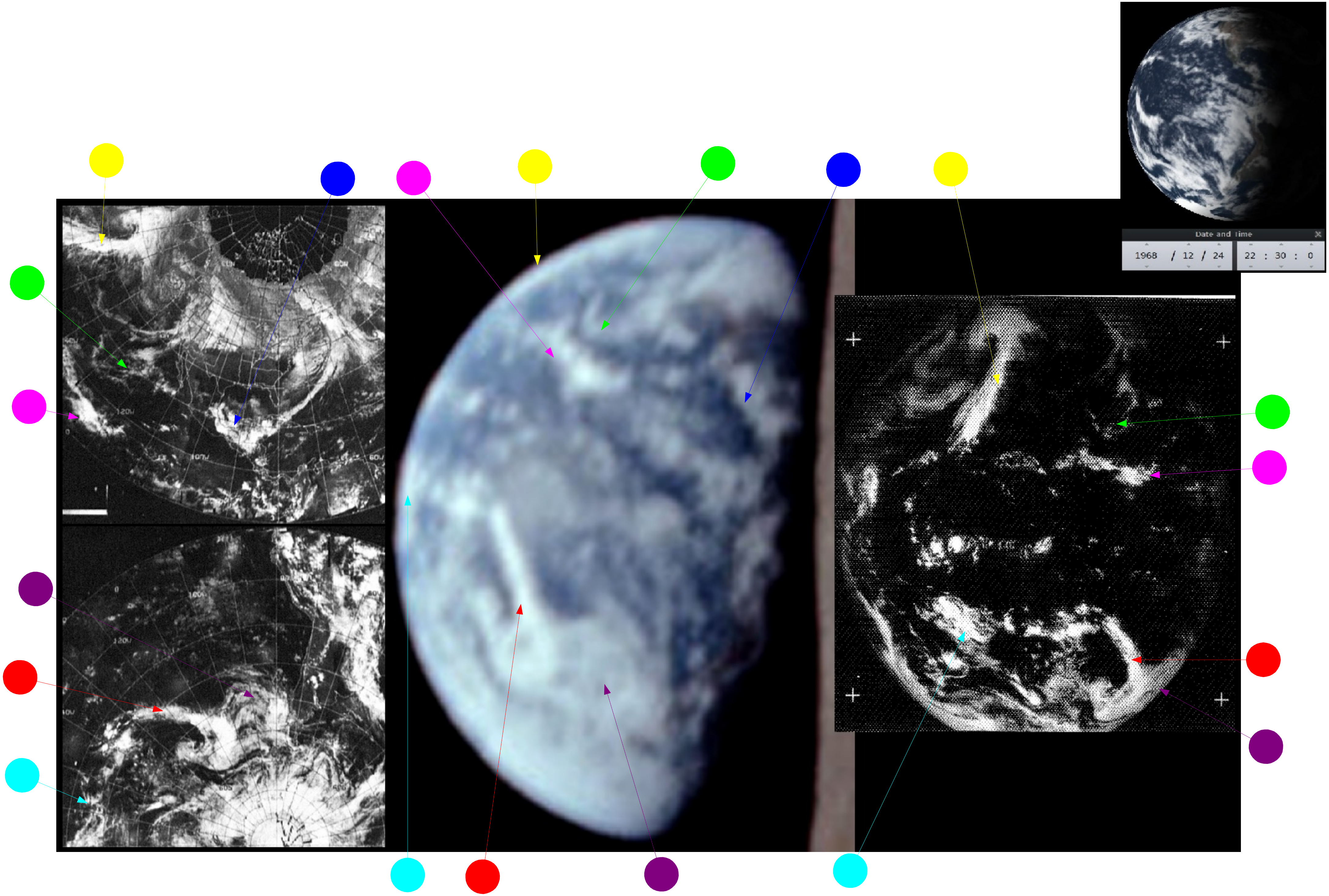


Figure 4.1.27: ESSA-7 (left) and ATS-1 (right) images compared with AS08-14-2393 and Stellarium estimate at terminator

On the face of it this image is very different to the previous ones, but once Chile is glimpsed by the terminator it becomes evident that it is just a continuation of the previous ones, and that a couple more orbits have elapsed, allowing the Earth to rotate a little more. The purple and blue arrows point to the same weather systems as in the preceding analysis, while the remainder indicate those that have come into view as time has elapsed.

As with the previous Earthrise photographs, even if there is no direct reference to a photograph, there is a hint in the crew dialogue, and we know from the mission programme that photographs are still being taken as mission progresses. At 71:43 MET (22:34 GMT), we have the following exchange after the start of orbit 7:

03 09 43 06 CDR: Oh, brother! Look at that!
03 09 43 16 CMP: What was it?
03 09 43 18 CDR Guess.
03 09 43 20 CMP Tsiolkovsky? [a lunar far side crater]
03 09 43 21 CDR No, it's the earth coming up.

Stellarium has been set at 22:30 in figure 4.1.27, and it is again obvious that the land masses visible are a clear match with what can be seen on the Apollo photograph. As the Pacific is now in view, ATS-1 becomes of use, and most of the weather systems visible in the Apollo image are visible in this in one form or another. The time for the ATS image is recorded as 21:55 on the 24th. ESSA's best orbit for the terminator is track 3 (although it is slightly further west than the terminator), or orbit number 1632 which commenced at 19:05.

There are no more images from the 24th, and preparations for TEI mean that no more photographs are taken of Earth until after that burn has taken place. The next image featuring Earth is on magazine 15, and the first image on there, AS08-15-2535 is shown below in figure 4.1.28, and analysed in figure 4.1.29.

Figure 4.1.28: AS08-15-2535. High quality version here: AFJ

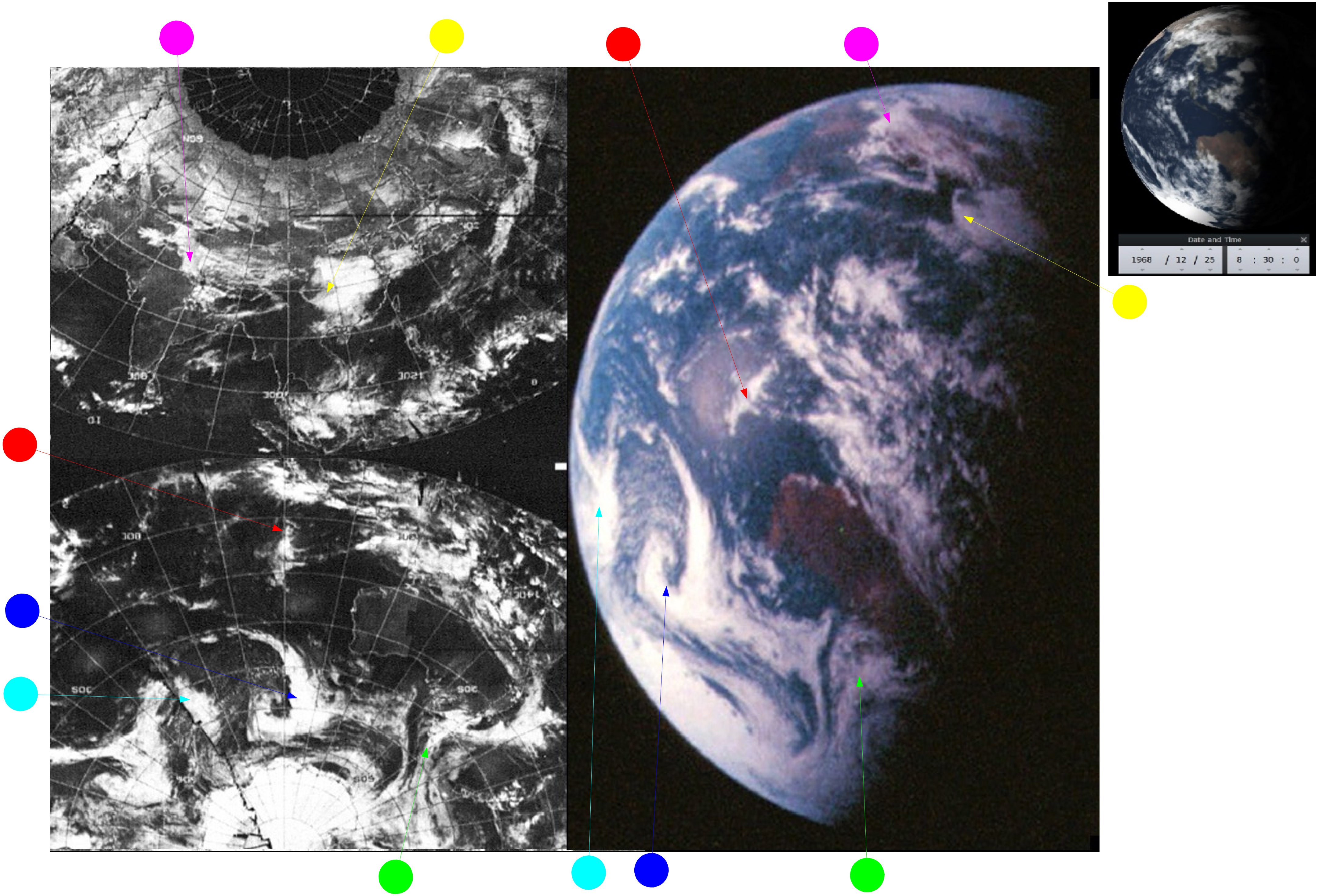


Figure 4.1.29; ESSA-7 image compared with AS08-15-2535 and Stellarium estimate of time at terminator

This view of Australia is repeated several times over the next 48 hours, and the cloud systems in it undergo subtle changes n that time, so it is worth describing what we can see.

The system to the west of Australia is like an inverted bass clef symbol (blue arrow), connected by a west-east trending cloud mass that joins the system from Antarctica. This latter system has a clear and cloudless dividing line separating it from the bass clef system, and a band of cloud runs up from Antarctica parallel with that line (green arrow) before skirting the east coast.. To the north west of Australia the ocean is largely cloud free. Pakistan has a notable '>' shaped cloud mass over it connected to the Himalayan clouds (magenta arrow), and there is a distinct gap between this system and a large cloud mass over SE Asia (yellow arrow).

If the reader cares to return to figure 4.1.8, the plume of cloud extending to Australia from Antarctica is also visible there (yellow arrow),as is a 'bass clef' pattern in what could be seen as an early stage of development, identified by the cyan arrow. If the weather patterns are followed through the satellite images, it becomes evident that what is visible in figure 4.1.29 as a plume actually started out in figure 4.1.8 as a curl of cloud off the west coast, and the cloud systems visible in the images are part of a progression of weather patterns typical for the region.

The position of Australia at the terminator in the photo allows Stellarium to determine a time of 08:30 on the 25th. ESSA's image dated the 24th still applies here, and orbit number 1637 (track 8), which commenced at 05:00 on the 25th.

After this first set of three images in magazine 15, there are a further 4 that were taken some time later. These photographs are represented here by AS08-15-2538, seen below in figure 4.1.30, and analysed overleaf in figure 4.1.31.

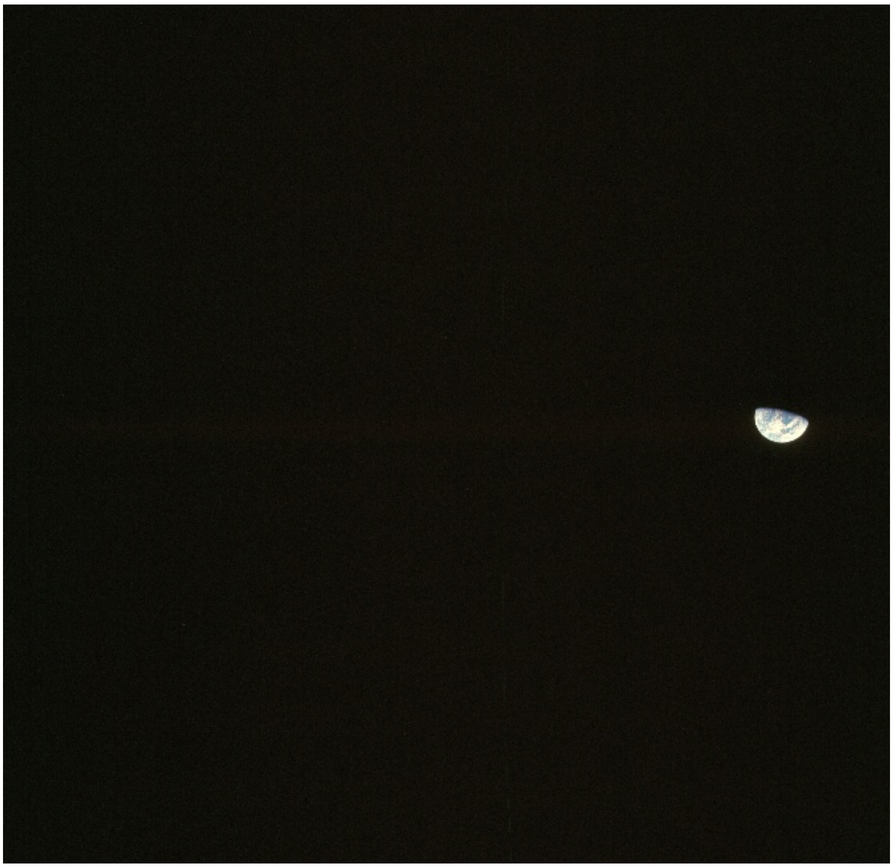


Figure 4.1.30: AS08-15-2542. High quality source here: AFJ

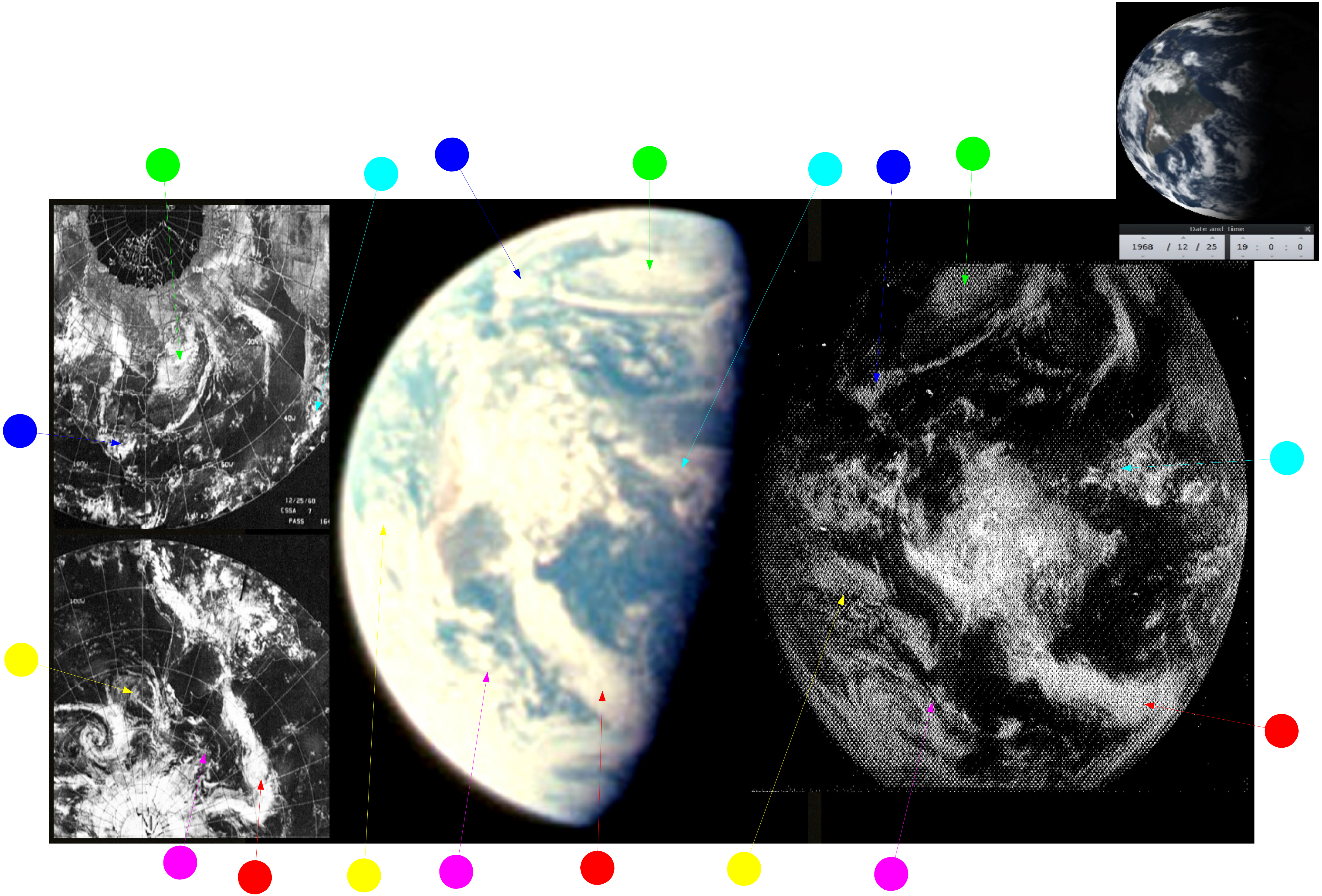


Figure 4.1.31: ESSA-7 (left) and ATS-3 (right) images compared with AS08-15-2538 and Stellarium estimate of time at terminator

The view we have in this image is also one that has been featured before, and the reader is referred back to figures 4.1.2, 4.1.12, 4.1.14 and 4.1.19 for similar views that show the evolution of weather patterns on Earth over several days, and not (as some conspiracy followers claim) some form of painting.

The same broad features seen in previous photographs of south America are still visible, from the long thin band of cloud across the north Atlantic from the Gulf of Mexico (blue arrow) to the large 'dog leg' of cloud extending across from south America towards southern Africa (red arrow). The arrangement of those weather systems is, however unique to the 25th of December 1968.

Stellarium's estimate puts the time of the image at 19:00 on the 25th, and this compares with a time for the ATS-3 image of 14:33 and an ESSA-7 time for the terminator orbit of 16:09 (track 2, orbit 1643).

A little while later there is another pair of photographs, probably taken to coincide with a TV broadcast. While these show only a small rotation, they do allow the use of all 3 satellites in comparing the weather, as for once they are all available.

Figure 4.1.32 shows AS08-15-2542, and figure 4.1.33 shows the satellite comparison.

Figure 4.1.32: AS08-15-2542. High quality source here: AFJ

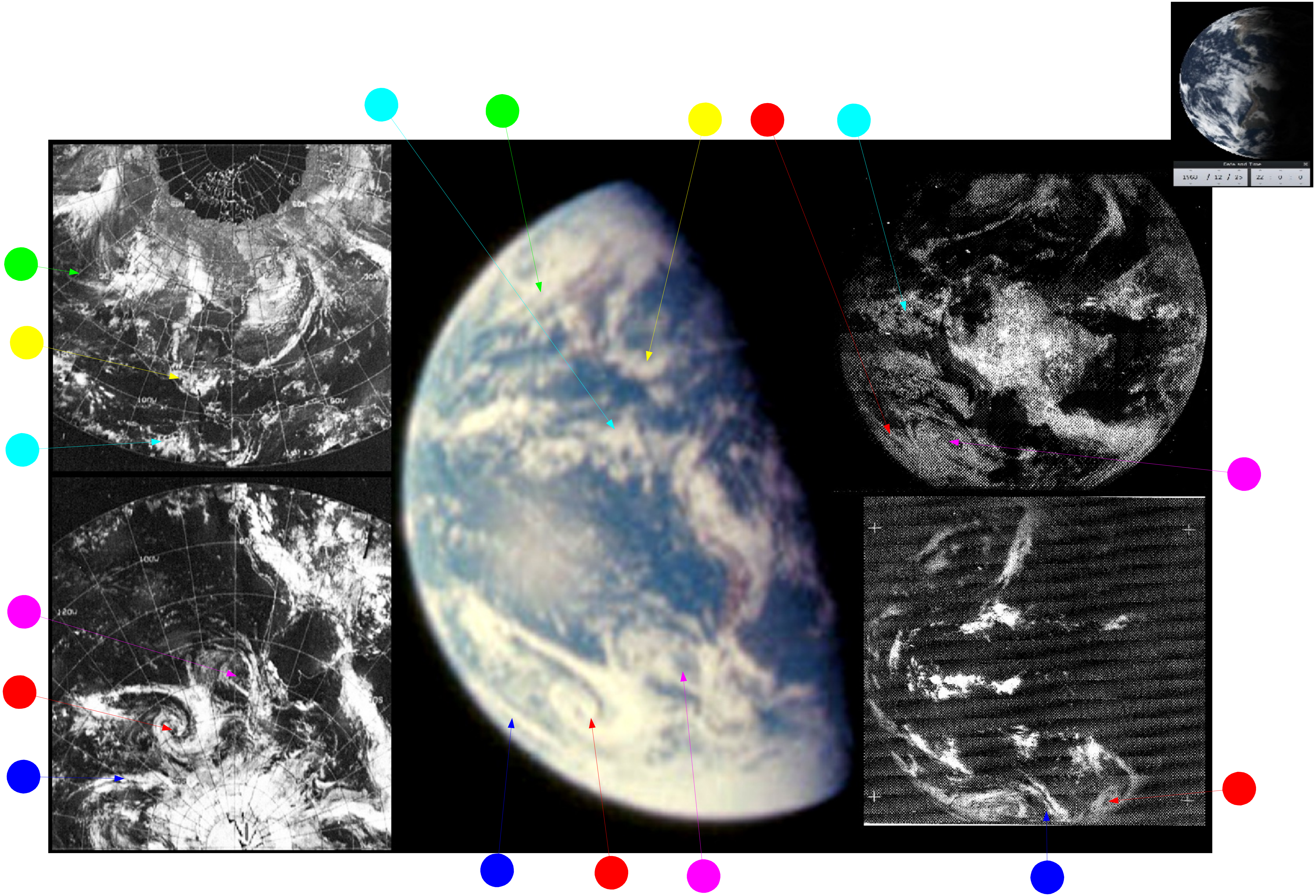


Figure 4.1.33: ESSA-7 (left) ATS-3 (top right) and ATS-1 (bottom right) compared with AS08-15-2542 and Stellarium estimate of time at terminator

In the preceding photograph we have lost sight of most of the weather systems visible in the previous image, but the magenta arrow does pick out the complex cloud patterns off the south American coast that have been a consistent feature throughout photographs of the region. The most striking feature now is a long curl of cloud tightly coiled off southern Chile, a system that is common to all the satellite images in one form or another.

The smaller weather patterns are less striking thanks to the picture being slightly out of focus, but it is still easy to make them out. The clouds over central America stretching down from the USA are very obvious (yellow arrow), and once the ESSA image's green arrowed cloud is noticed, its configuration on the actual image is readily identifiable.

As far as timings are concerned, the terminator cutting across Brazil puts the time at around 19:00 on the 25th. ATS-1's image was taken at 22:41, while ATS-3's image was taken at 14:33 on the 25th. ESSA-7's track 3 best covers the terminator region, and this was carried out by orbit number 1644 at 18:04.

A gap of several hours ensues before any more photographs are taken of Earth in magazine 15, and the next series occur after a few pictures of an increasingly distant Moon (images AS08-15-2543-7 are currently mistakenly labelled in the Apollo Image Atlas as the Earth!). The first high quality image of the sequence is AS08-15-2550 (the preceding two show the same view but are not as zoomed in). This photograph is shown in figure 4.1.34, and analysed overleaf in figure 4.1.35.

Figure 4.1.34: AS08-15-2550. High quality source: AFJ

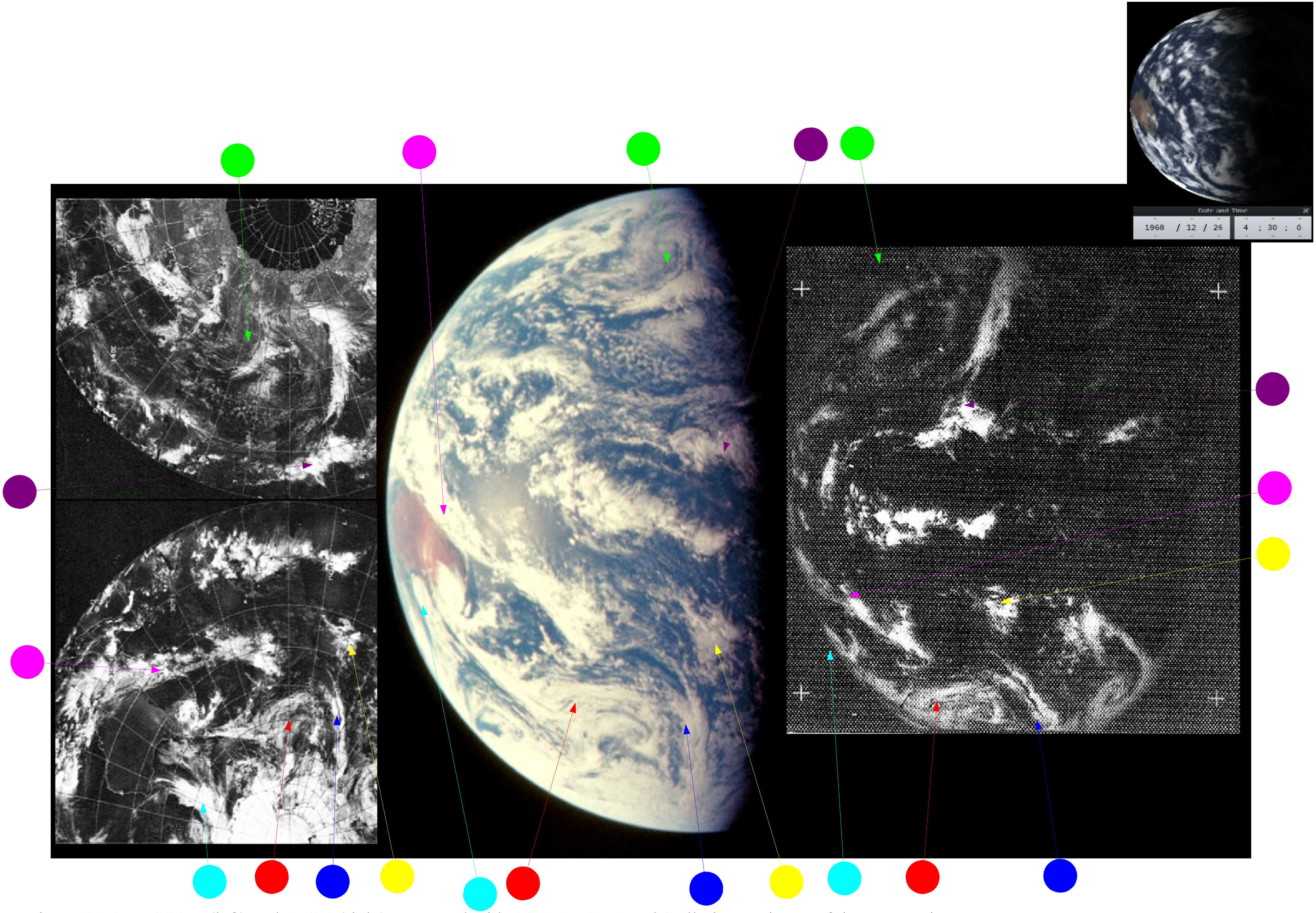


Figure 4.1.35: ESSA-7 (left) and ATS-1 (right) compared with AS08-15-2550 and Stellarium estimate of time at terminator

In this photograph, nearly all of the weather patterns visible in the previous picture have disappeared beyond the terminator, with the exception of the one identified by the blue arrow. In its place are the complex weather patterns dominating the south Pacific around Australia. It is fairly obvious that the long band of cloud to its north (magenta arrow) and those to the east (red arrow) and south (cyan arrow) are present on ESSA's image as they are in Apollo's.

The ATS-1 image also shows the red and magenta arrowed systems clearly, although the fact that it was taken several hours before the Apollo photograph means that there are differences in their configuration. For example the yellow arrow points to a cloud mass that is much more separated from the clouds picked out by the blue arrow in ATS than it is in Apollo.

The green and cyan arrows in the ATS image point to where cloud masses are, but aren't quite as easy to see as they are on the ESSA and Apollo images.

As Stellarium identifies the time as being at around 04:30 on the 26th, the ATS-1's image used is from the 25th (22:41 GMT), as this is nearer in terms of elapsed time between the satellite image and the Apollo one. ESSA's orbit at the terminator is number 1647 (track 6) which was commenced at 00:09 on the 26th.

The next mini-sequence of images in magazine 15 is represented by AS08-15-2554, and Australia is much easier to see in this one. It can be seen below in figure 4.1.36, and analysed overleaf in figure 4.1.37.

Figure 4.1.36: AS08-15-2554. High quality source: AFJ

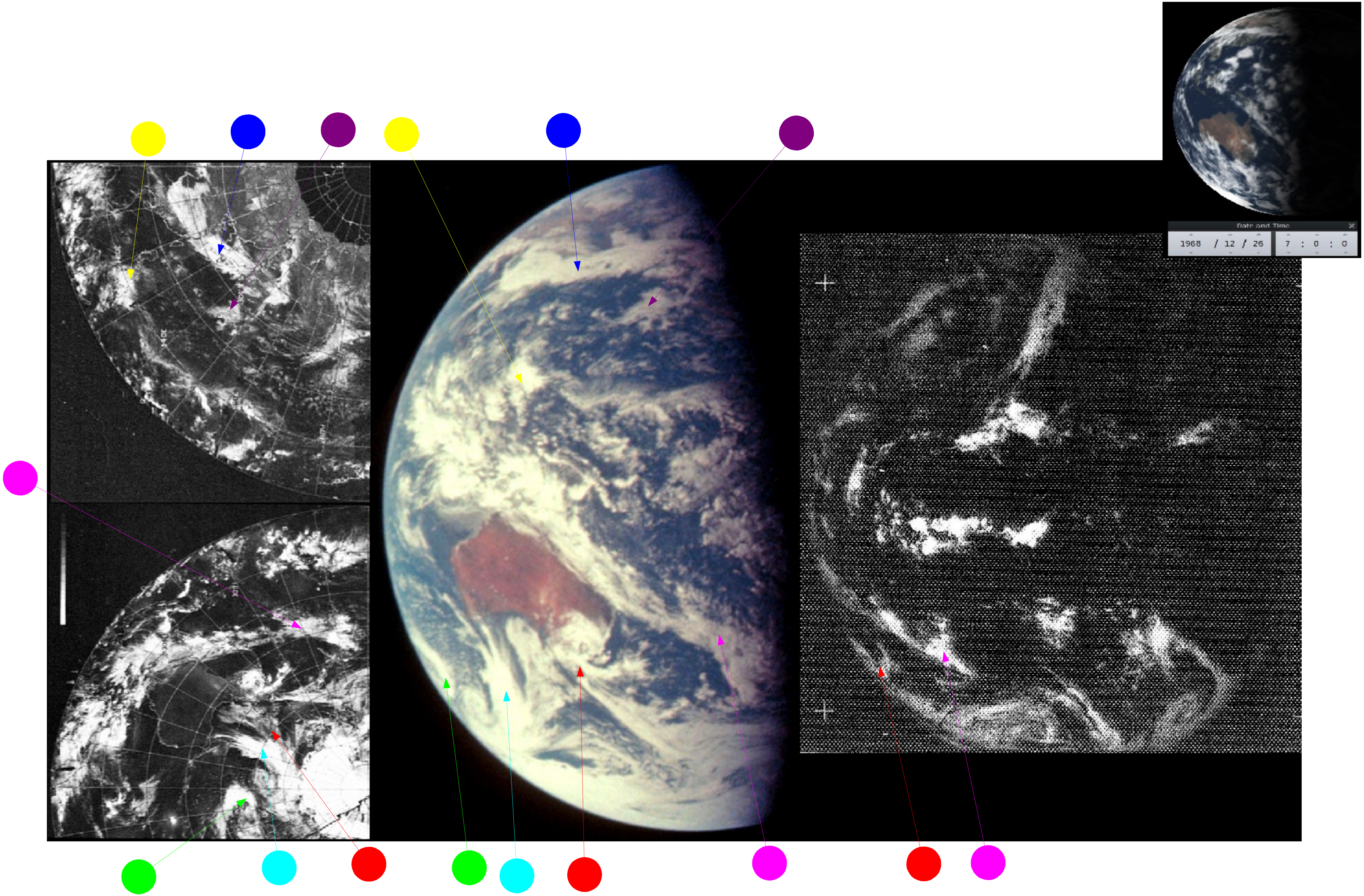


Figure 4.1.37: ESSA-7 (left) and ATS-1 (right) images compared with AS08-15-2554 and Stellarium estimate of time at terminator

Australia has now come into view properly and we can see the development of the weather systems identified in AS08-15-2535. The magenta system in this image is the same one that wrapped itself more closely around the north and eastern coasts 24 hours previously, but has now moved on towards New Zealand leaving the coast clear.

For this image, we can see that the magenta, cyan and red arrows point to systems that are visible on the same ATS-1 image (dated the 25th) as used previously. The blue and purple arrows identify systems that are just visible near the north-western horizon but were not specifically picked out in the previous figure.

The 'plume' system looks very similar, and there is still a hint of the coiled frontal 'bass clef' system to the south and west of the continent. Closer examination of the satellite images shows that in fact the plum has been joined by what was the clef, which has rotated and moved south and east. The system to the west is a new system moving eastwards from off South Africa.

ATS-1's time has already been noted, but the ESSA orbit best matching the terminator is orbit 1648 (track 7), which commenced at 02:05.

A short while later, images are taken showing Australia's east coast passing into darkness, as shown in AS08-15-2562 (figure 4.1.38). Most of the images between the previous photograph and this one consist of poorly framed images of Earth taken at the same time as AS08-15-2554.

Figure 4.1.38: AS08-15-2562. High quality source: AFJ

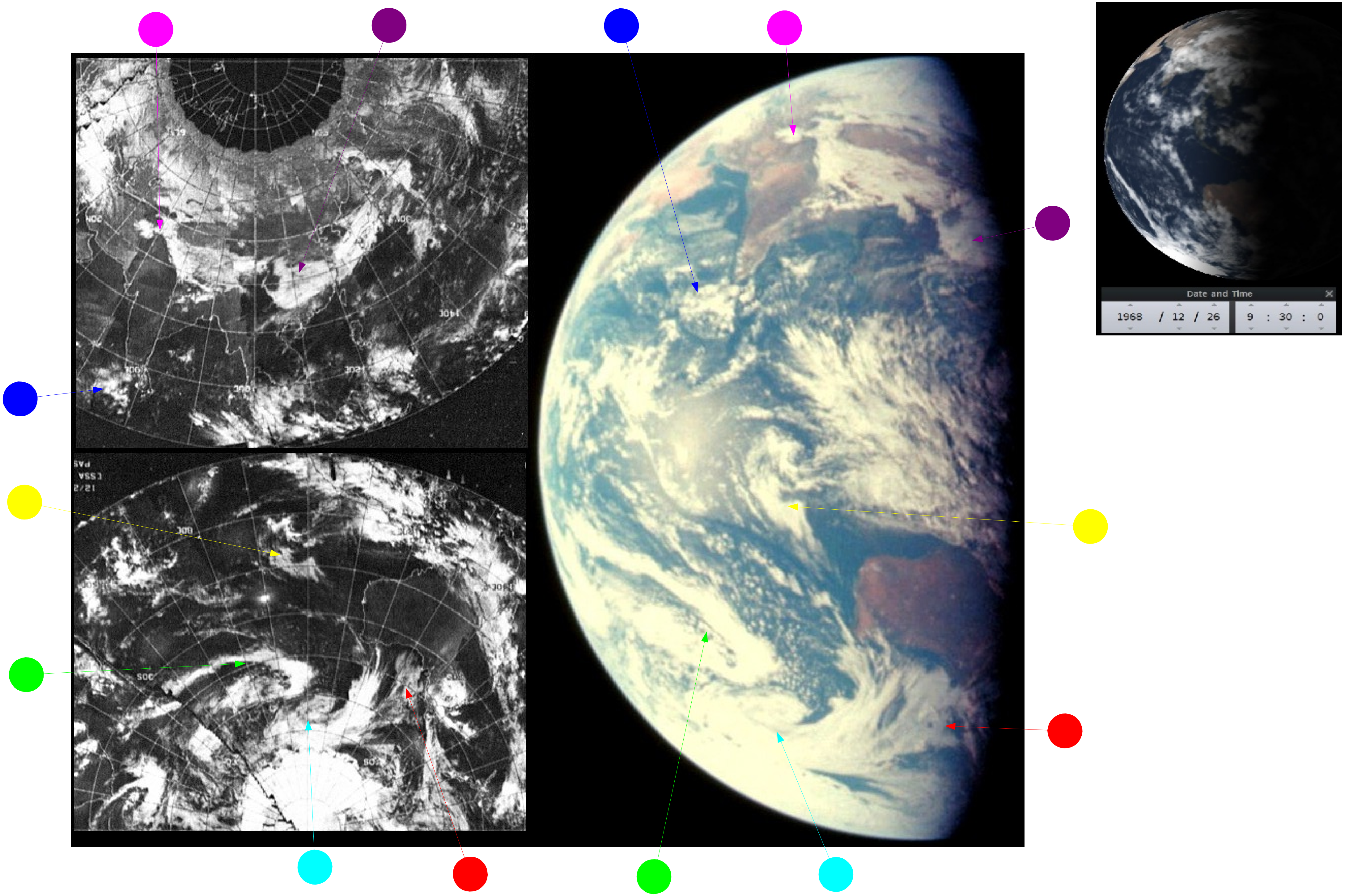


Figure 4.1.39: ESSA-7 image compared with AS08-15-2562 and Stellarium estimate of time at terminator

In this latest instalment, Australia's east coast is now well beyond the terminator, but the new frontal mass off the west coast (green arrow) is easy to make out. The purple arrow points to the long cloud bank identified by a blue arrow in the previous analysis, which joins up to landmasses over the Indian subcontinent and the Himalayas.

It is also easier to see in this image the transformation of the cloud marked by the cyan arrow from an elongated curl off the west coast on the previous day to the more compressed form it has on the 26th.

Although not specifically labelled, it is worth noting the wide band of sub-equatorial cloud north of Australia, is it also appears in the next image showing the continent.

Stellarium puts the terminator at about 09:30 on the 26th ESSA's terminator orbit is number 1649 (track 8), which commenced at 04:00 on the 26th.

The next image in the time sequence is a return to magazine 13. Photograph AS08-13-2369 (figure 4.1.40) is part of a small series of identical shots of Earth that appear after close-ups of the lunar surface and after pictures of a receding Moon, clearly placing it after TEI.

As this photograph shows the exact region where the dividing line between days for ESSA mosaics is placed, ESSA images dated the 25th are used to discuss the areas east of that line, and dated the 26th for areas west of that line.

Figure 4.1.40: AS08-13-2569. High quality source here: AFJ

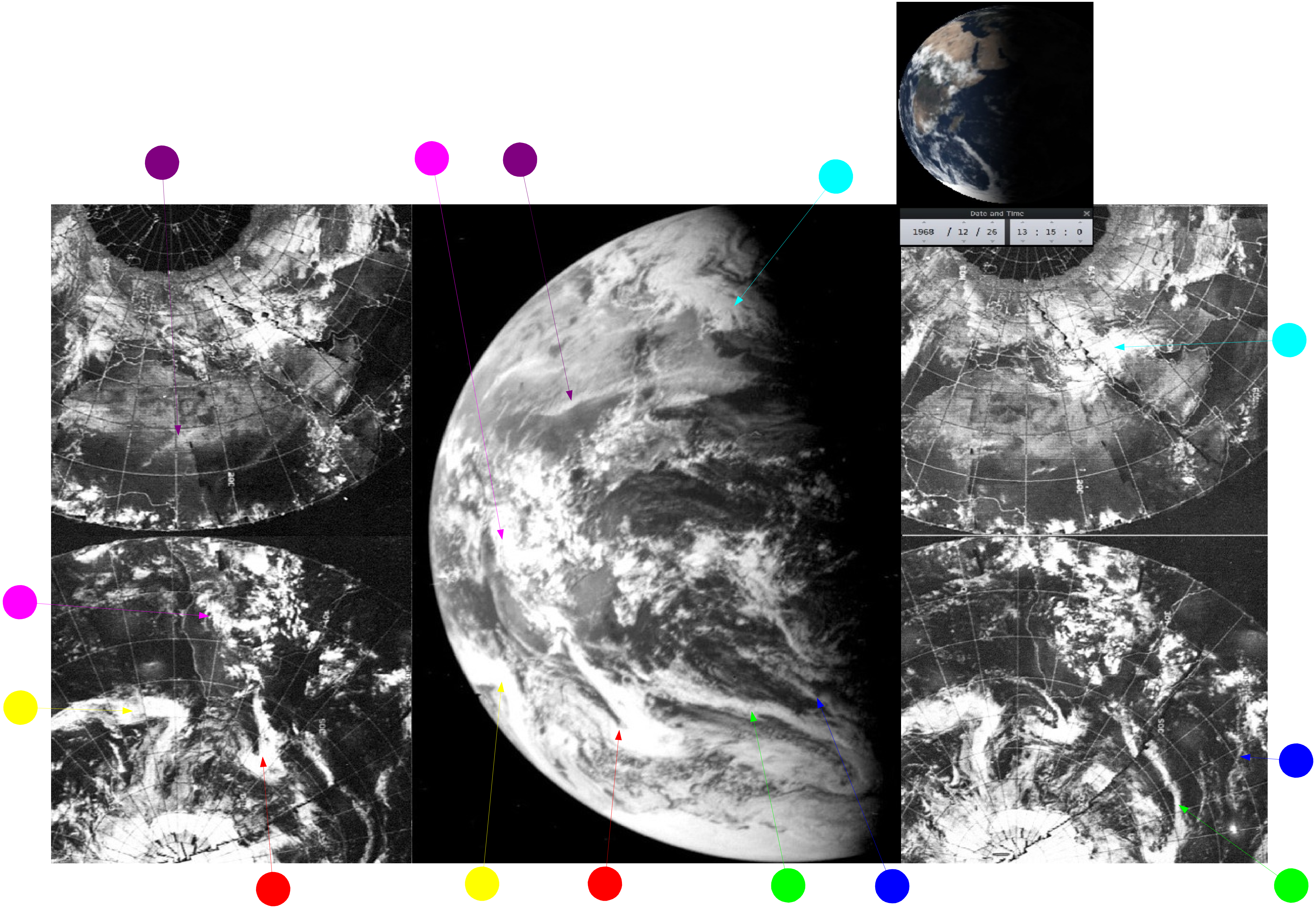


Figure 4.1.41: ESSA-7 images dated 25/12/68 (right) and 26/12/68 (left) compared with AS08-13-2369 and Stellarium estimate of time at terminator

Describing the scene where Africa dominates is always tricky in terms of relating it to ESSA images because of the mosaic dividing line. This image does, however, show clear differences in the weather systems either side of that dividing line hat helps make it simpler.

East of the divide, the green arrow (which is the same weather system identified with that colour in figure 4.1.39) points to clouds that show a definite difference on the image dated the 25th compared with how it looks on the image dated the 26th. Likewise the blue arrow and cyan arrows point to systems east of the divide look very different compared with the west side.

The red arrow points to a front on the western side of the divide, and if this system is compared with the one shown on the ESSA mosaic dated the 25th, he central blob of cloud shown in the latter is missing, and it is also not far enough to the east compared with the image dated the 26th.

The thin line of cloud crossing the Apollo image over the southern Sahara towards Arabia (purple arrow) does not show as clearly on the ESSA mosaic dated the 25th.

The data catalogue for ESSA shows that the images dated the 25th consist of orbits 1640-1652, while the ones dated the 26th are 1652-1664, so the last orbit on the mosaic dated the 25th is the same as the first orbit on the mosaic dated the 26th (the line on the latter is clearly further east).

The time for orbit 1652 is given as 10:05 on 26/12/68, which is roughly 3 hours before the Stellarium suggests the Apollo image was taken.

There is a colour image showing almost the same scene in magazine 15, AS08-15-2563, and this is shown below in figure 4.1.42, along with a zoomed and cropped image of the Earth from that image. Ostensibly this image looks identical to the one from magazine 13, but there zooming in on the terminator does show where the difference lies (figure 4.1.43).

Figure 4.1.42: AS08-15-2563, with a zoomed and cropped Earth from that image. High quality source here: AFJ

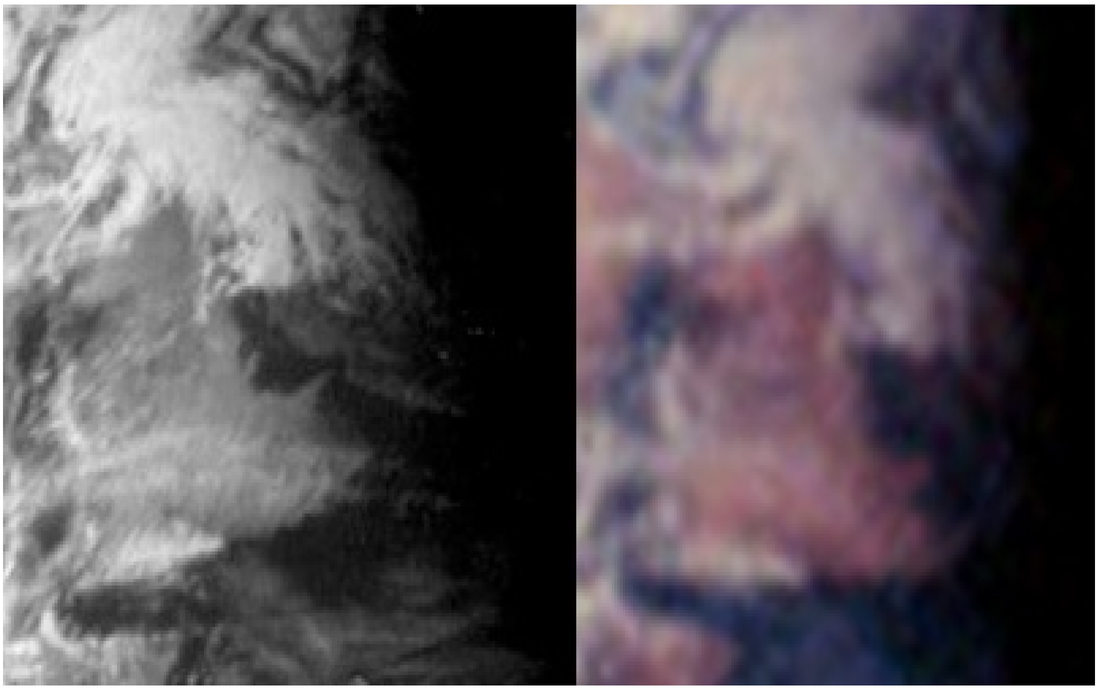


Figure 4.1.43: Arabia as seen in AS08-13-2369 (left) and AS08-15-2563 (right).

The weather systems are very much the same, so it is obviously taken on the same date, but it should be evident that the Arabian landmass is much close to the terminator in the colour image compared with the black and white. The amount of rotation is consistent with a time lapse of about 15 minutes between them.

Several photographs of the same scene were taken in magazine 15, and the next photograph showing a different view in magazine 15 is AS08-15-2574. This is shown below in figure 4.1.44 and analysed overleaf in figure 4.1.45.

Figure 4.1.44: AS08-15-2574. High quality source here: [AFJ]

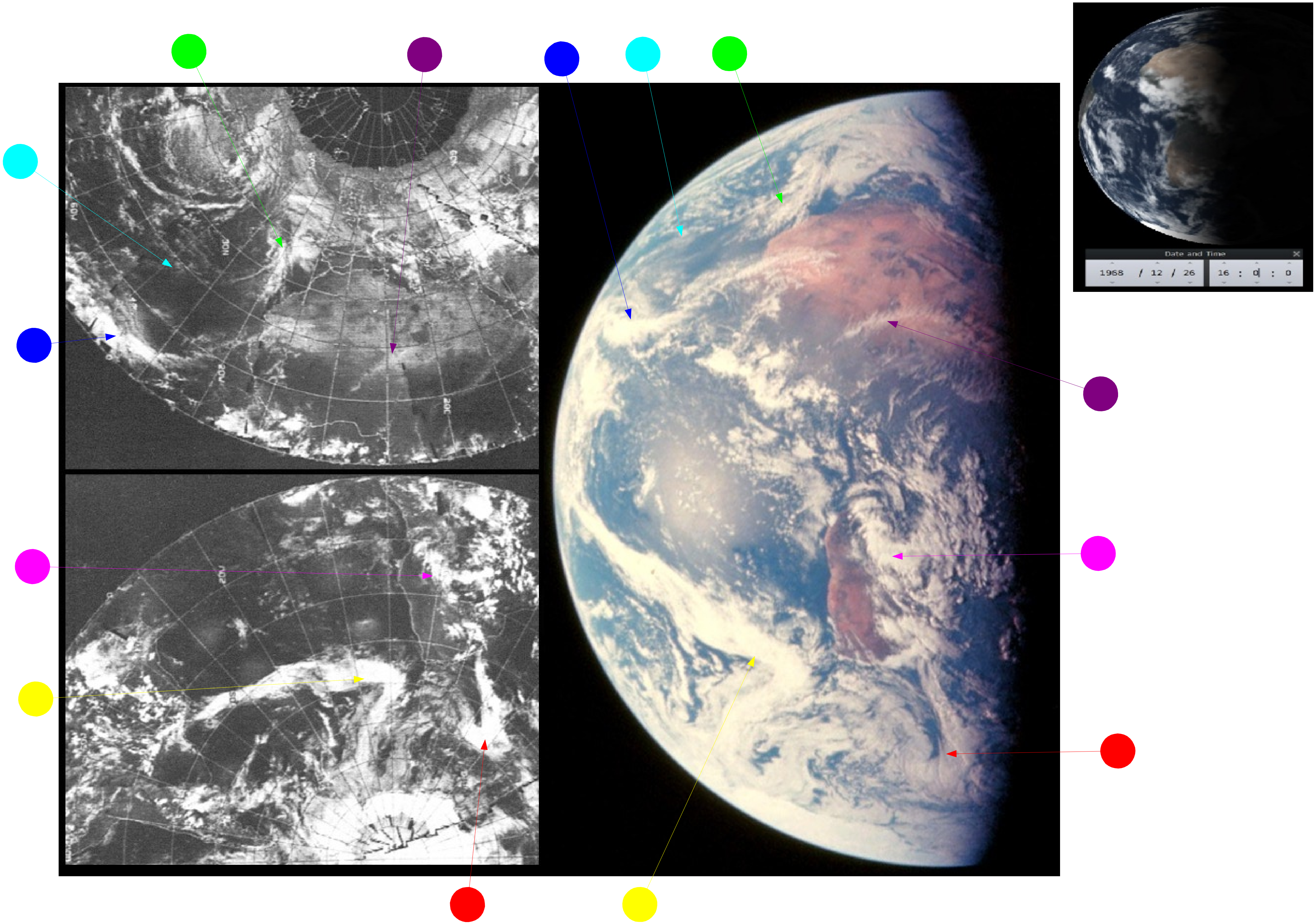


Figure 4.1.45: ESSA-7 image compared with AS08-15-2574 and Stellarium estimate of time at terminator

Despite Africa having moved its relative position by some distance between this photograph and the one used previously, most of the weather systems available for comparison are still visible. The magenta, purple red and yellow arrows all point to the same weather systems identified in figure 4.1.41. The time of the image is put by Stellarium at 16:00, and this time lapse has allowed the front identified by the red arrow to change its position in comparison with figure 4.1.41, and it appears much less solid than before. The ESSA orbit for the terminator here is track 12 (orbit 1653), which commenced at 12:00 on the 26th.

As with the preceding image, a different magazine shows an almost identical view. Magazine 14 has photograph AS08-14-2509, which appears after several photographs of the entire Moon through red and blue filters. This photograph is shown below in figure 4.1.45, together with a zoomed and cropped Earth from it.

Figure 4.1.45: AS08-14-2509 with zoomed and cropped Earth from it. High quality version here: AFJ

Again there is evidence that the two images, although very similar, were not taken at exactly the same time. If the area around the terminator over Libya is zoomed in on, the terminator line seems marginally different, as can be seen in figure 4.1.46.

Of the two, it appears that AS08-14-2609 was taken slightly later than the one from magazine 15. The cloud masses over the Mediterranean to the north are clearly nearer the terminator in magazine 14's contribution, as is the dark spot on the terminator that is Libya#s Haruj volcanic field.

It's also with noting the shadows cast by the long clouds in central Libya between and the Tassilie n Aljer desert area and the Haruj, which are entirely consistent with a sunset time period. Once again we have a situation where two apparently identical photographs are not, purely because the Earth is moving while the astronauts return to it.

Figure 4.1.46: Libya terminator as seen in AS08-15-2574 (left) and AS08-14-2609 (right)

The next image in this time sequence is AS08-15-2576. It is shown below in figure 4.1.47 and analysed overleaf in figure 4.1.48.

Figure 4.1.47: AS08-15-2576. High quality source here: AFJ

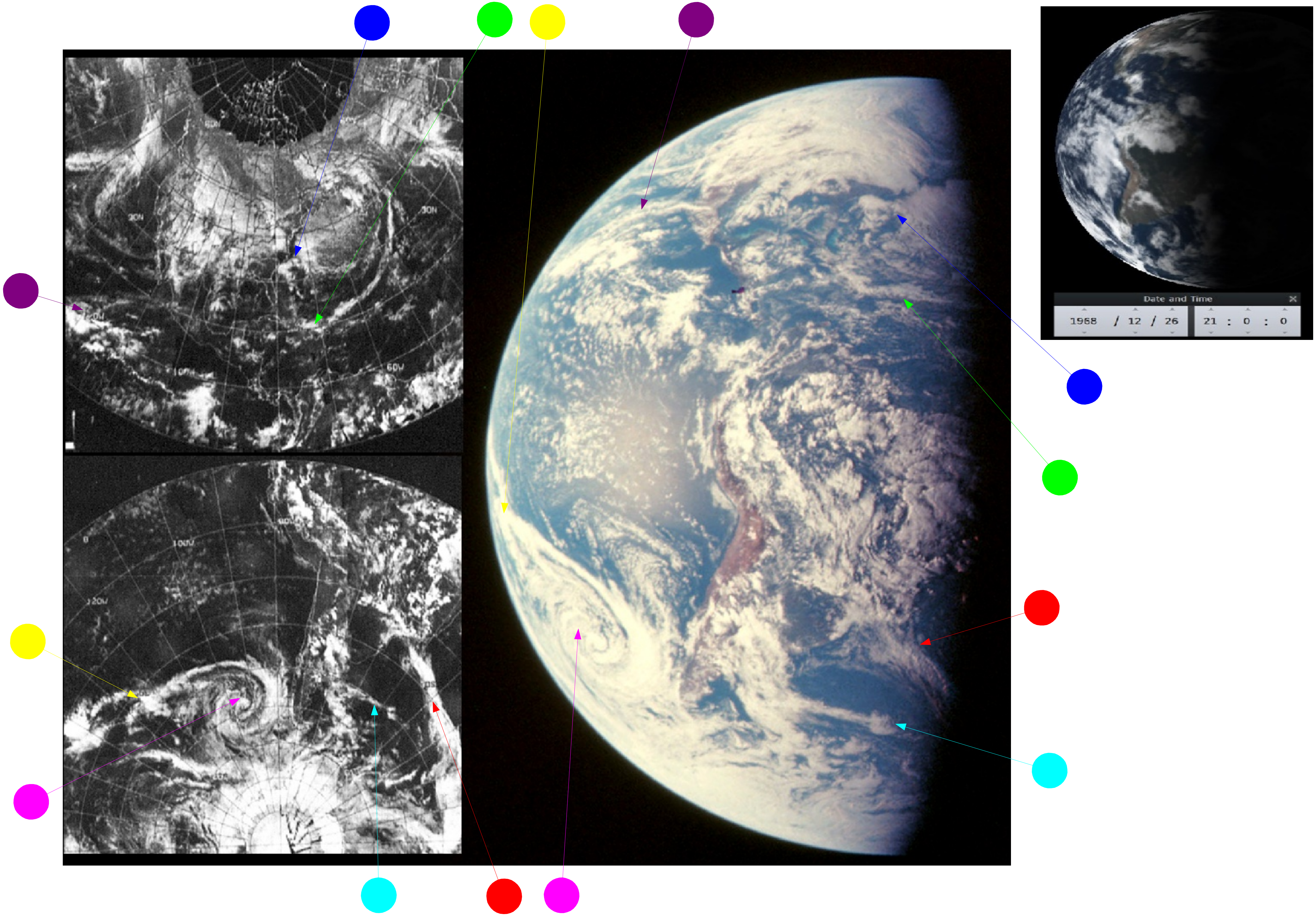


Figure 4.1.48: ESSA-7 image compared with AS08-15-2576 and Stellarium estimate of time at terminator

Figure 4.1.49: AS08-14-2518 with zoomed a&cropped Earth from it. High quality source here: AFJ

Once again we have a duplicate image from magazine 14, AS08-14-2518. This image is shown above in figure 4.1.49, together with a zoomed and cropped Earth from it. On this occasion there is no obvious difference in the relationship of the various land masses and cloud patterns to the terminator, although comparisons are not helped by the out of focus nature of AS08-14-2518.

This view of south America is unique, compared with the same view from other days, and your there are no weather systems in it showing the same configuration as previous ones of south America. The time is now 21:00 in the 26th, and ESSA's orbit for the terminator would have been carried out at 17:05 (track 2, orbit 1656).

We now switch back to magazine 16 for our image sources, as no other magazines contain images after 21:00 on the 26th. The first one under consideration is AS08-16-2619, shown below in figure 4.1.50, and analysed in figure 4.1.51 overleaf.

Figure 4.1.50: AS08-16-2619. High quality source here: AFJ

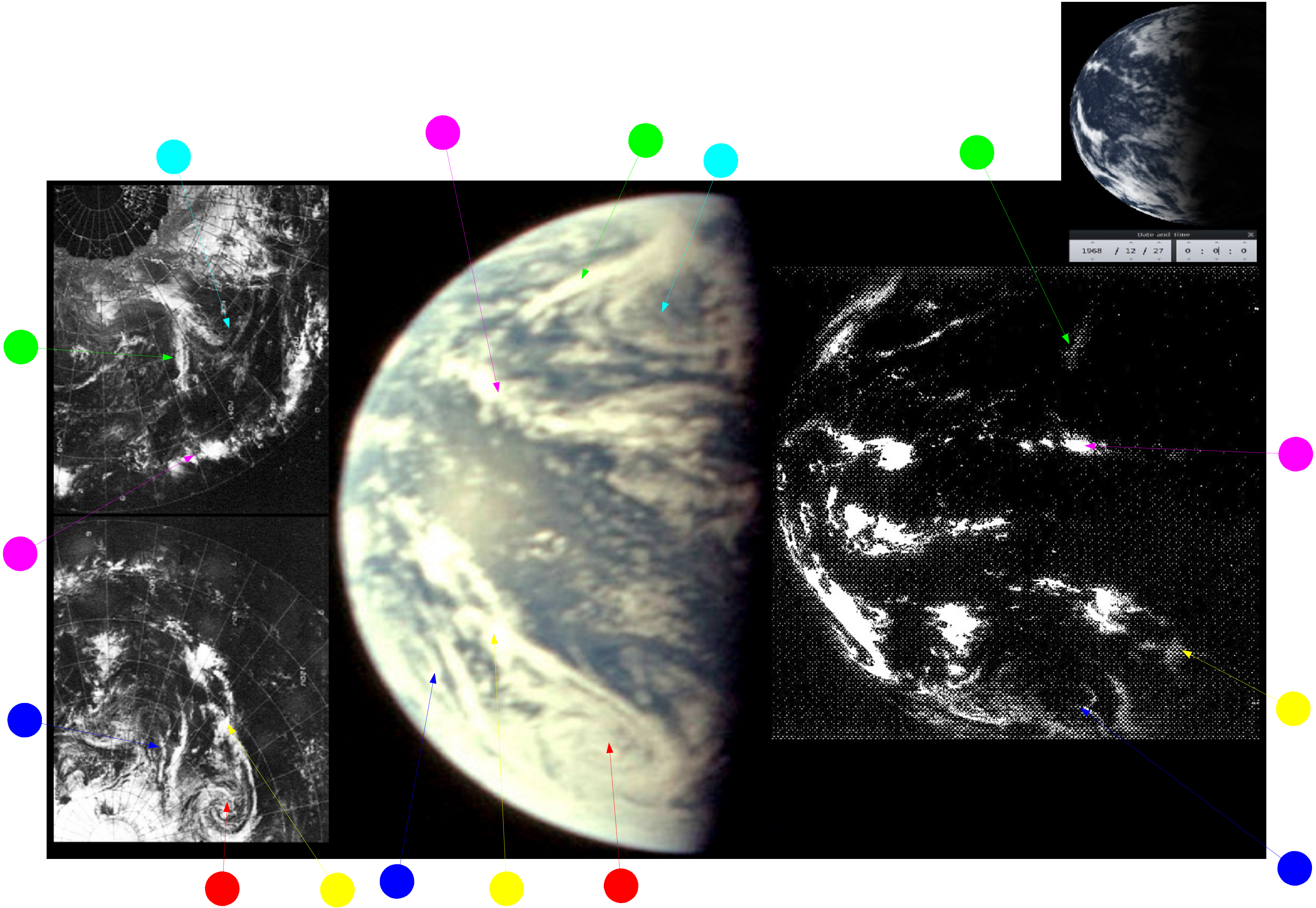


Figure 4.1.51: ESSA-7 (left) and ATS-1 (right) images compared with AS08-16-2619 and Stellarium estimate of time at terminator

The Earth has rotated around to hide all but the very tip of south America in darkness, bringing the large swirl of cloud (red arrow) visible in the previous image towards the terminator. This same swirl of cloud is actually referred to in the mission transcript during a TV broadcast, when at 20:53 GMT the crew describe:

"At the tip of South America, there is a great swirl of clouds down there. It looks like a great storm."

which matches well with the suggested time for the previous image of around 21:00.

Other features visible on the previous image include the feature identified by the yellow arrow, where two streams appear to cross. This can also be seen in figure 4.1.33, where the curl of cloud is also visible, but there is less cloud between the main band cloud in that image.

Stellarium suggests a time for AS08-16-2619 as midnight on the 27th, and the remaining images on the magazine are a regular marking of the mission's progress towards re-entry at 15:27 GMT on that date. ESSA's terminator orbit is number 1658 (track 4), which was commenced at 21:04, while ATS' image was taken at 00:45 on the 27th.

A short while later we have AS08-16-2626, which can be seen in figure 4.1.52 below, and analysed overleaf in figure 4.1.53. There are relatively few differences between this image and AS08-16-2619, but it does at least bring those weather patterns visible in ATS-1 more clearly to the fore.

The blue, yellow and green arrows point to the same weather systems as they do in figure 4.1.51, although for the latter two most of the weather system they are part of are now beyond the terminator.

Figure 4.1.52: AS08-16-2626. High quality source here: AFJ

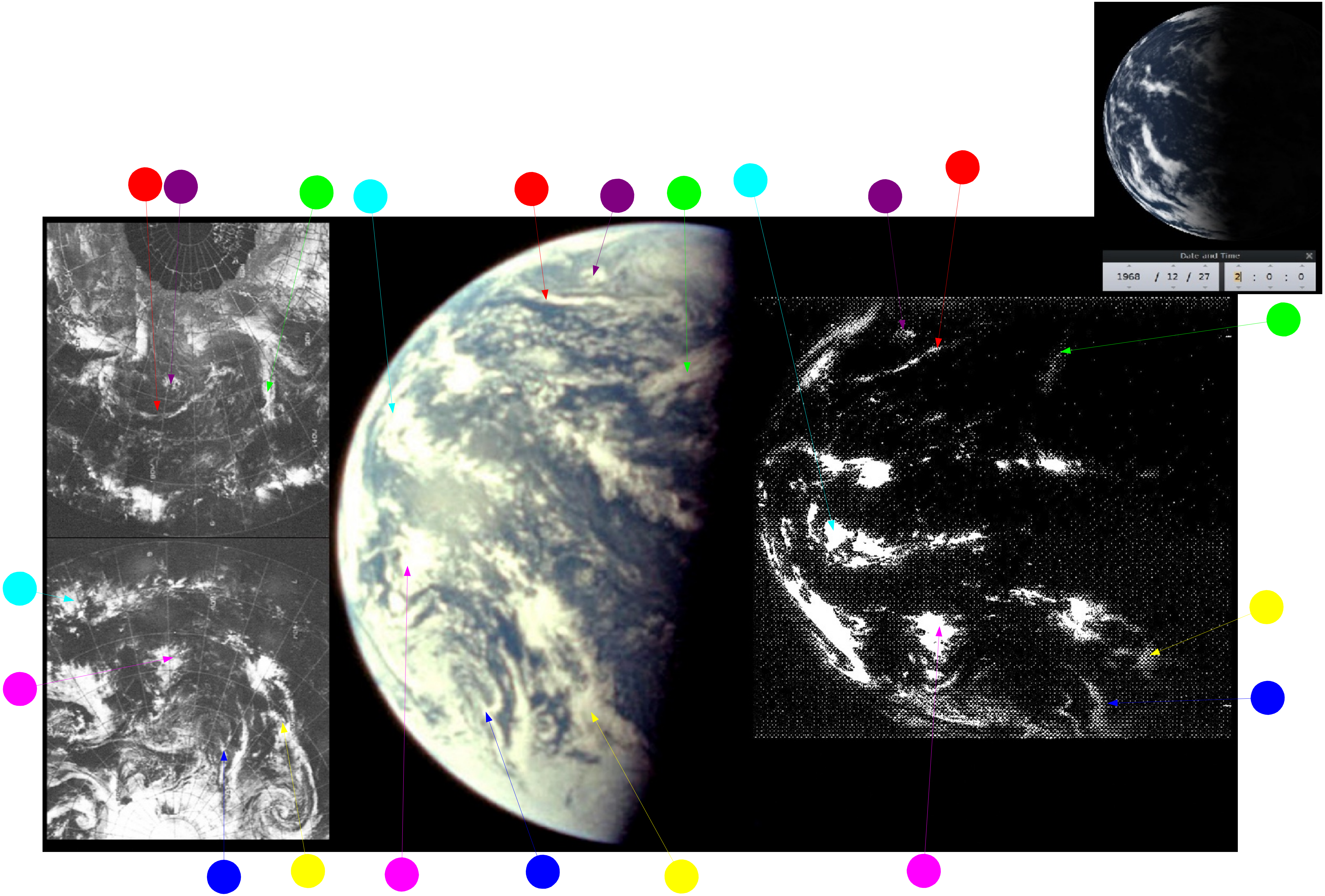


Figure 4.1.53: ESSA-7 (left) and ATS-1 (right) images compared with AS08-16-2626 and Stellarium estimate of time at terminator

ATS-1's time, as before is 00:45, while ESSA's nearest terminator orbit was started at 23:09 (track 5, orbit 1659), which compares well with Stellarium's estimate of 02:00.

The next s showing a different views of Earth (AS08-16-2632 & 2634) show only a small change, and there is little to be gained from analysing them. For the sake of completeness they are shown below in figure 4.1.54, together with the zoomed and cropped Earths from them.

Figure 4.1.54: AS08-16-2632 original and zoomed (far left and left, high quality source here: AFJ) and AS08-26-2634 original and zoomed (right and far right, high quality source here: AFJ)

The next image to be examined in detail is AS08-16-2637, shown below in figure 4.1.55, and analysed overleaf in figure 4.1.56,

Figure 4.1.55: AS08-16-2637. High quality source here: AFJ

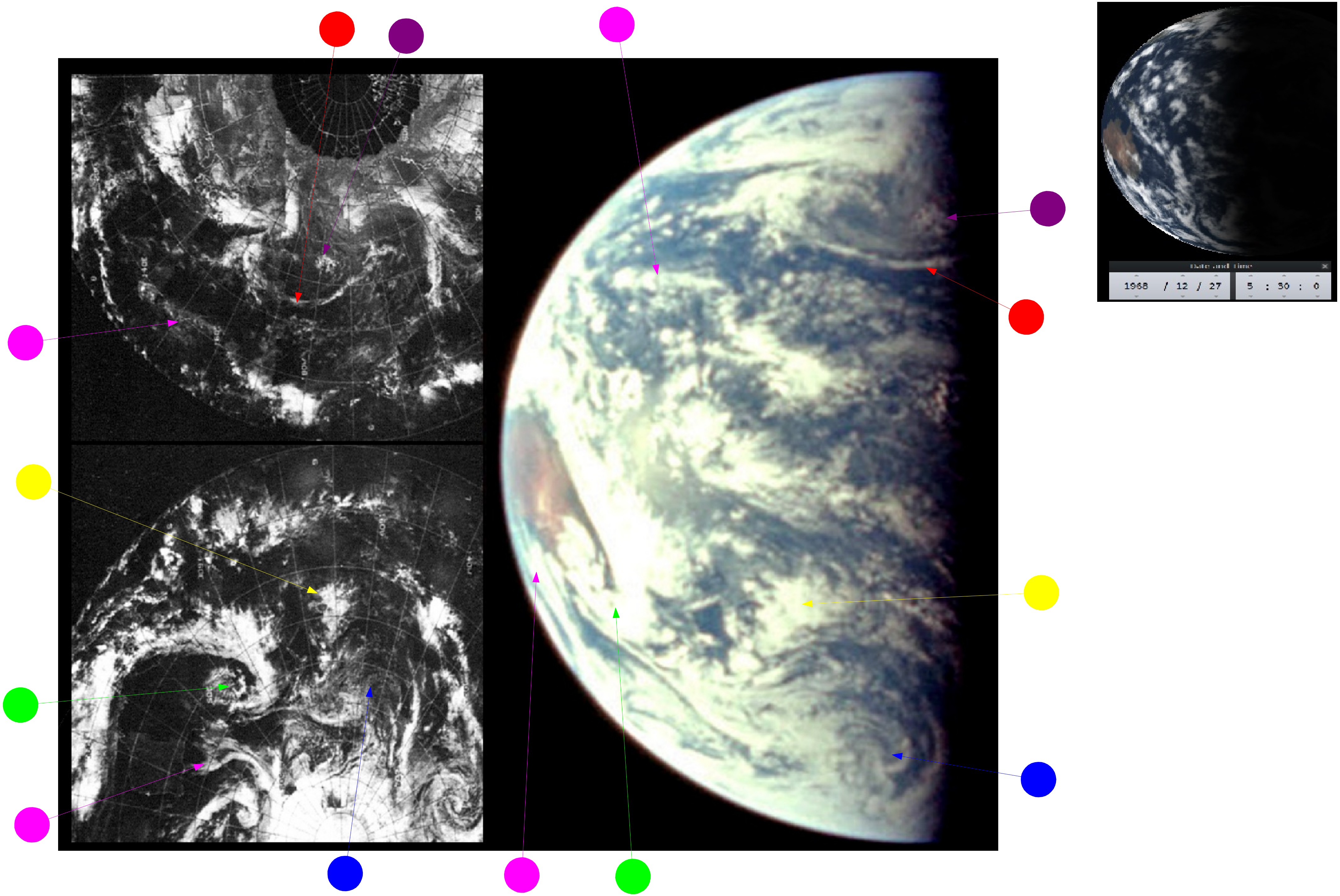


Figure 4.1.56: ESSA-7 image compared with AS08-16-2637 and Stellarium estimate of time at terminator

Stellarium estimates the terminator (based on the position of Australia) at 05:30 on the 27th, and the blue, yellow, red and purple arrows point to weather systems visible on the other images of the Pacific shown previously. The blue arrow in particular points to a swirl of cloud that can be seen progressing from west to east in figure 4.1.54. On the opposite horizon, the magenta and green arrows identify weather patterns that have been a common feature over Australia, but will be discussed in more details when the continent is more squarely in the frame.

ESSA's orbit is somewhere between track 6 and 7 for the terminator line, which is around 01:02 for the earlier of the two (orbit 1660).

The next two sets of images (represented by AS08-16-2647 & 2650) show Australia gradually progressing westwards, and these are shown in figure 4.1.57 to illustrate their connection with the final image that will be analysed, where Australia occupies the same position as other images throughout the mission. AS08-16-2658 is shown in figure 4.1.58, and analysed in figure 4.1.59.

Figure 4.1.57: AS08-16-2647 original and zoomed (far left and left, high quality source here: AFJ) and AS08-26-2650 original and zoomed (right and far right, high quality source here: AFJ)

Figure 4.1.58: AS08-16-2658. High quality source here: AFJ

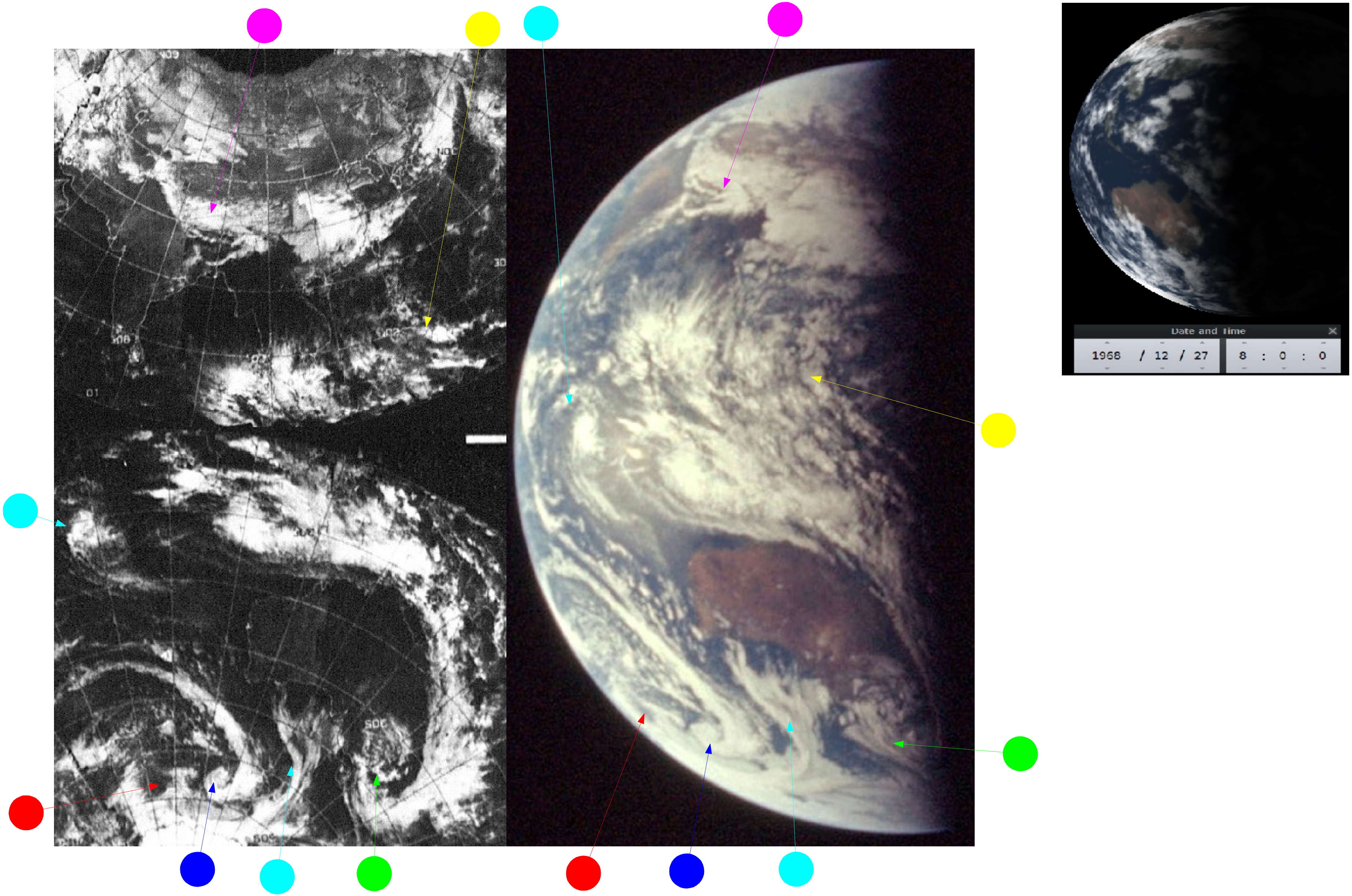


Figure 4.1.59: ESSA-7 image compared with AS08-16-2658 and Stellarium estimate of time at terminator

For what is probably the final photograph taken on the mission, we have the return of a familiar view, and a continuing evolution of the weather systems around Australia. The elongated curl of cloud that was west of Australia has continued it's eastward progression from south Africa and now lies mostly to the south of the continent (blue arrow).

The plume of cloud (cyan arrow) has also moved eastward, and what was two separate plumes is now much more consolidated.

The long, broad band of cloud above Australia (yellow arrow) still extends over the equator and still curls round to the east coast, but has now joined with a small area of cloud that was over the Melbourne area.

In short, all of the images of Australia show a consistent development of weather patterns over time, and in order to assist in the reader's recollection, this development is shown below in figure 4.1.60. This development is matched by the satellite record.

To complete this section covering still images, ESSA's orbit covering the Australia terminator is track 8, orbit number 1662, which was commenced at 05:05. This compared with Stellarium's estimate of the time for the image of around 08:00.

4.1.2 Other media.

As part of their journey, the Apollo 8 crew made a number of short live TV broadcasts to Earth. The most famous of these broadcasts is the Christmas Day broadcast made while rounding the moon, in which the crew took turns to read out a number of verses from Genesis.

Clips from these broadcasts are viewable at the Honeysuckle Creek website here: Honeysuckle creek website

Two clips from the Honeysuckle Creek website are of interest here, as they show images of Earth.

The 2nd TV transmission shown was carried out at 19:53 on December 23rd, and it is possible to capture a screenshot of the Earth from that and compare it with the ESSA 7 and ATS-3 data . The ATS-3 image was taken at 18:16 GMT – just over 90 minutes before the TV broadcast.

Honeysuckle Creek have done their own image showing the orientation of the Earth at that time (figure 4.1.61).

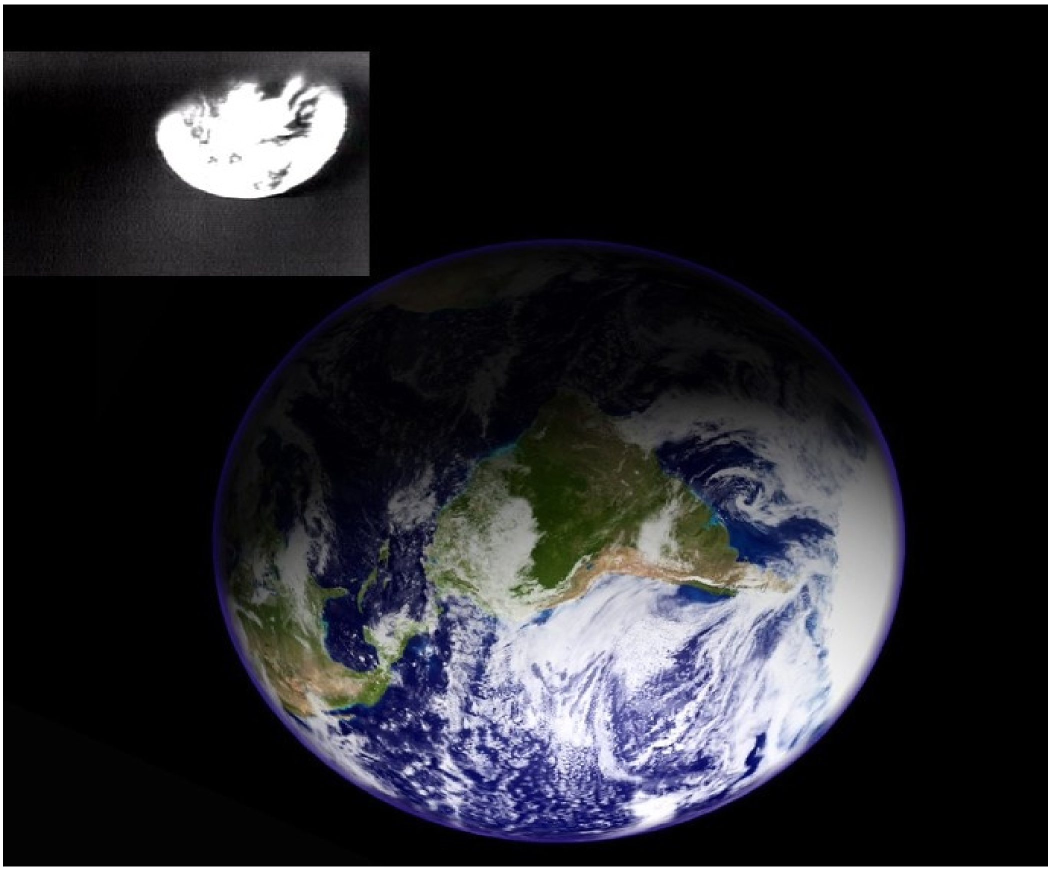


Figure 4.1.61: Honeysuckle Creek interpretation of terminator position during live TV broadcast

The screenshot and associated ESSA images are in figure 4.1.62

The TV image is overexposed, but weather systems in both Hemispheres are identifiable, and are clearly the same as those identified on the still image discussed in figure **4.1.10**.

The broadcast of Earth from space made headline news around the world, but one interesting front page is from the Long Beach Independent of 24/12/68. Figure 4.1.63 shows this front page, with the same weather systems in **4.1.22** identified.

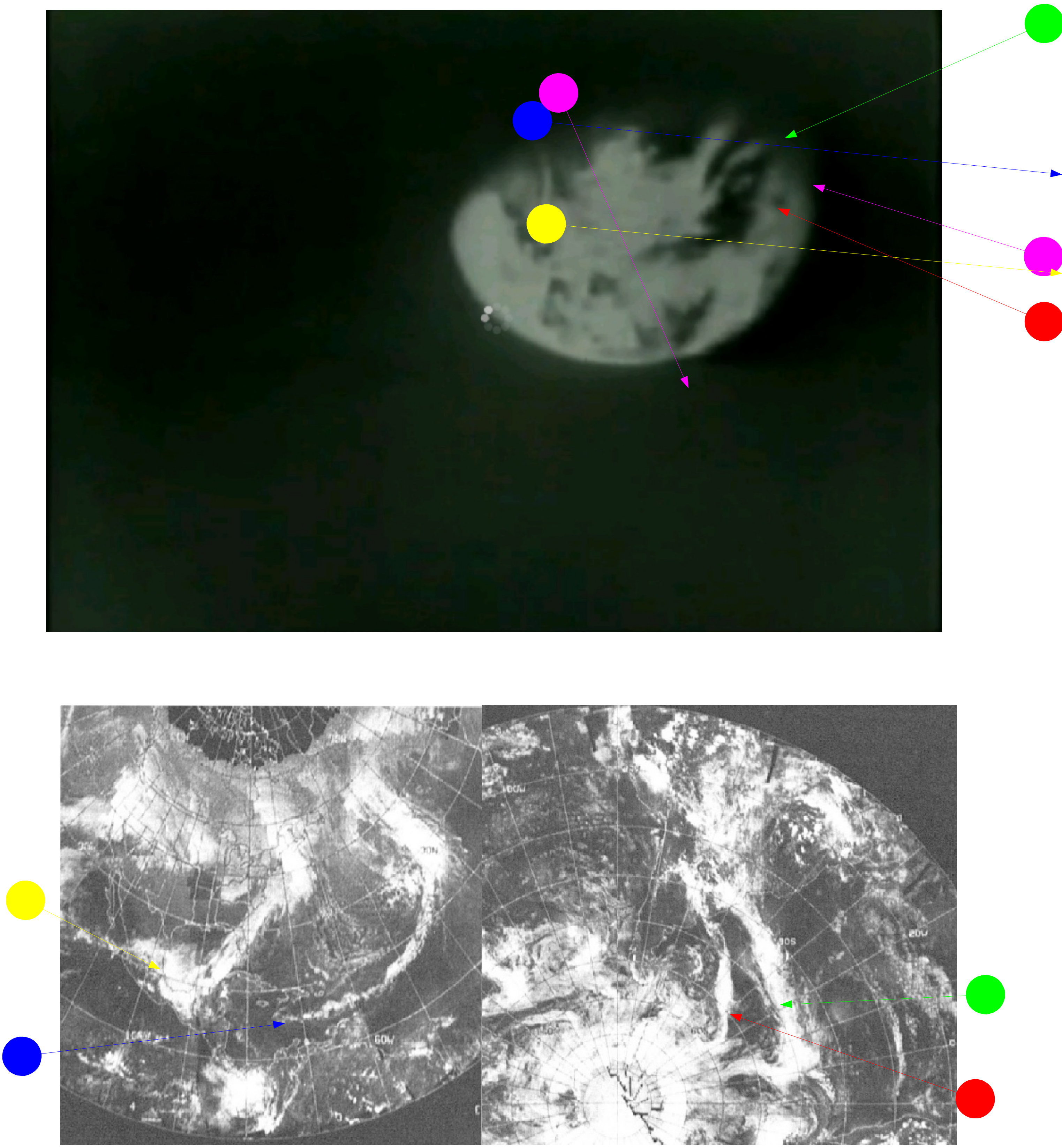


Figure 4.1.62: Live TV screen capture compared with ESSA 7 image from 23/12/68

WATSON BRIBERY COUNT DISMISSED —Story on Page A-3

INDEPENDENT

WEATHER
Increasing cloudiness through Wednesday, otherwise fair. High today about 70, low tonight near 45. Complete weather, Page C-5.

Phone HE 5-1161 — Classified No. HE 2-5959 26 PAGES LONG BEACH, CALIFORNIA, TUESDAY, DECEMBER 24, 1968 VOL. 31, NO. 255 HOME EDITION — 10c

Apollo 8 Reaches the Moon for Orbit

Gets Things Done! **Action Line** DIAL 432-3451

ACTION LINE is your service, solving your problems, getting your answers, cutting red tape and standing up for your rights. To get action, write ACTION LINE, Box 230, Long Beach, Calif. 90801, or dial 432-3451 between 9 a.m. and 1 p.m., or 5 p.m. and 9 p.m., Monday through Friday. Questions to be answered are selected for their general interest and helpfulness.

Cheerful, Courteous, Kind...

Q. I was run over by a car and am confined to a wheelchair for six months. In order to go to the hospital for physical therapy I need to have a ramp made so I can roll my chair down the three steps in front of my house. Can ACTION LINE tell me where to get one inexpensively? I'm on Social Security and can't pay much. C. L., Long Beach.

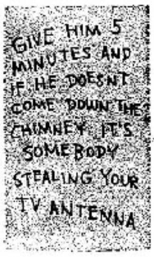
A. ACTION LINE is putting you in touch with a local Boy Scout troop who wrote to us in search of a good deed to do. The troop leader said the boys will be glad to construct a ramp for you. Phil Wiedrick, assistant manager of Long Beach Plywood Co., 1851 Freeman Ave., said he will sell you the necessary materials at wholesale price.

Foster Help

Q. How can I become a foster parent or friend to some child? S. G., Lakewood.

A. There are two main Los Angeles County foster parent plans — Good Neighbor and Homefinders. Under the Good Neighbor program, families give temporary care to neglected or abandoned children. When a child is found by the police or sheriffs after normal working hours, a call is put through to a child welfare worker on duty. The worker contacts a Good Neighbor close to the area where the child is, and the child is taken there by authorities. The child stays in the home for about two weeks while permanent arrangements are made for him. The family is reimbursed for expenses at the rate of $3 per day. Emergency clothing allowances and needed medical attention are arranged for by the County Department of Public Social Services. To become a Good Neighbor, you must be licensed, fingerprinted and found free of tuberculosis. In the Homefinders Program, a child is placed in the home on a more permanent basis — the average stay is a year. The family recieves $78 a month for the child plus a clothing and medical allowance. For further information on the two programs, write them at 501 N. Main St., Los Angeles, Calif. 90012. Locally, you may wish to become involved in Project Friend sponsored by the Long Beach Community Improvement League. You would befriend an underprivileged child and take him to your home and on field trips. The children range in age from 5 to 16. For further information, contact Alfred Reeves, Project Friend Coordinator, 2222 Olive Ave., 427-1820.

GRAFFITI by Leary



Books for Botswana

Q. I have an extensive collection of philosophy books from college. Africa has a number of growing countries. I feel sure there are colleges there which could use my books in their libraries. Can ACTION LINE find such a college for me? I will handle the shipping charges myself. S. H., Lakewood.

A. With the help of the embassies of Uganda and Botswana in Washington, D.C., ACTION LINE found two colleges where your books might be wanted. To make arrangements, write Registrar, Makerere University College, P.O. Box 7162, Kampala, Uganda; or Registrar, University of Botswana, Lesotho and Swaziland, P.O. Roma, Maseru, Lesotho, Southern Africa. English is the main language at both universities. Uganda, a former British protectorate, is in central Africa. The country became a republic on Oct. 9, 1963. Botswana lies in south-central Africa. Also a former British protectorate, it received full independence on Sept. 30, 1966.

Lost Your Balance

Q. The members of our TOPS (Take Off Pounds Sensibly) club worked to earn enough money to buy a new scale for weighing in members. We bought the scale at Metro Scales Co., 4900 E. Compton Blvd., Compton. When it was delivered, the beam was broken. I took it back to the company and was told it would be repaired. They then tried to deliver an old second-hand scale, which I refused to accept. We still don't have our scale, and by this time would just like a refund. N. S., Lakewood.

A. According to Don Goddard, owner of Metro Scales, a new beam was ordered from the factory, but delivery of it was slow. In the meantime he was willing to provide you with the used scale as a loaner, which you refused. As exasperated with your attitude in this situation as you apparently were with his, Goddard says he has sent you a refund check, and hopes the issue is closed. He added that because he has had to watch his own weight, he always has been in sympathy with the work of TOPS, and has sold all TOPS groups the $129 scales for $75.60. "I let the ladies pay on time, don't charge them interest, we always serviced their scales and I often visited their meetings and explained how to use the scales," Goddard said. Unfortunately, he says, his dealings with you were so unpleasant that he will no longer extend these courtesies to the TOPS groups.

Pueblo Heroes Hailed

Fly Home Today; U.S. Will Thank Soviets for Help

SEOUL, Korea (UPI) —The U.S. admiral who supervised the return of the 82 Pueblo crewmen hailed them as heroes today but said they were "all tremendously beat up" from 11 months in Communist captivity.

Rear Adm. Edwin Rosenberg and most of the Pueblo crewmen appeared at a Seoul news conference following thorough medical examinations which found them all healthy enough for the trip home today.

The 82 crewmen took off from Seoul in two Air Force C141 transports at 10 p.m. PST Monday night.

Rosenberg did not allow any of the crewmen to speak, explaining they were "all tremendously beat up." He said they had suffered no apparent psychiatric damage.

* * * *

"FROM what I've seen the last day and a half, I have the utmost admiration for Captain (Cmdr. Lloyd) Bucher and his crew . . . tremendous representatives of America," Rosenberg said. "To me, one of the most remarkable things was their admiration for the United States throughout the ordeal.

"These men are heroes as far as I'm concerned."

Rosenberg said the Pueblo crewmen would arrive in San Diego at 1 p.m. PST.

In Washington, meanwhile, a spokesman said the State Department probably will thank the Soviet Union and many other nations for whatever help they may have given toward arranging release of the crew.

* * *

PRESS Officer Robert J. McCloskey recalled that after the North Koreans seized the intelligence ship last January the U.S. made a worldwide effort to get other governments to work for release of the ship and crew.

The U.S. made repeated approaches to the Soviet government for such assistance, the most recent being within the past two or three weeks.

From across the nation, the Navy brought their families for Christmas Eve reunions at the Miramar Naval Air Station.

Showing the effects of beatings they said were administered during their captivity, the Pueblo crewmen flanked Rosenberg as photographers snapped away at the Seoul news conference.

The news conference came after the crewmen feasted on steaks.

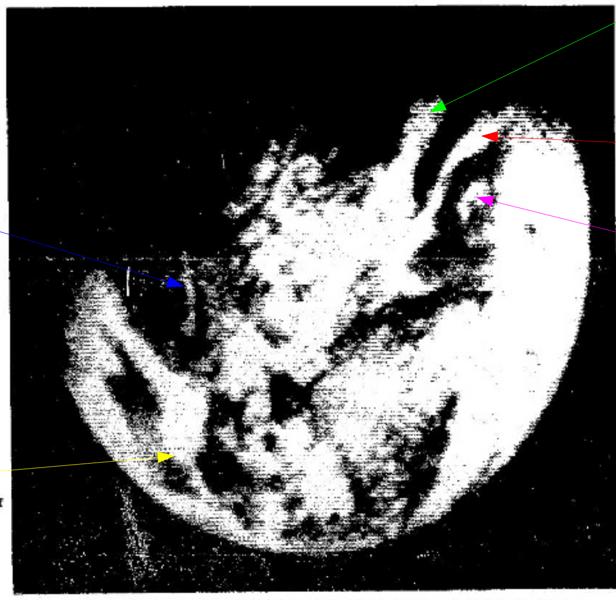
* * * *

ROSENBERG said the men would be allowed a day and a half with their families, followed by two weeks of extensive physical checkups and debrief-

(Continued Page A-5, Col. 1)

TODAY'S CHUCKLE

Mother of modern teenager to friend: "Yes, I always wanted to be the mother of a child with lovely, soft, long blond curls—but I always thought it would be a girl."



APOLLO 8 ASTRONAUTS SHARED THIS VIEW OF PLANET WITH THE EARTHBOUND
Picture of Earth Was Taken From 200,000 Miles in Space as Craft Streaked Toward Moon
—AP Wirephoto

Everything Perfect on Mission

By HOWARD BENEDICT

SPACE CENTER, Houston, Tuesday (AP) — With their target looming incredibly larger, the Apollo 8 explorers bore down on the moon today, ready to blast into a lunar orbit from which they may make a Christmas plea for peace and unity on earth.

The ship, caught in the grasp of lunar gravity, was to slip behind the back side of the moon early today, and 15 minutes later the astronauts were to fire their spaceship engine to inject themselves into an historical orbit.

It was to be a time for the world to hold its breath, because, for more than half an hour, Apollo 8 was to be behind the moon, out of radio contact with the ground. Mission Control in Houston would not know whether the engine firing succeeded until the craft reappeared around the edge of the moon.

Air Force Col. Frank Borman, Navy Capt. James A. Lovell Jr., and Air Force Maj. William A. Anders had the option to cancel the engine firing if they detected anything amiss.

* * *

IN THIS CASE, Apollo 8 would merely swing once around the moon's back side and head back to earth.

The four-minute burst from the engine was intended to slow Apollo 8's speed from about 5,700 to 3,7000 miles per hour and insert the craft into an orbit ranging from 69 to 196 miles from the lunar surface.

About four hours later, after two circuits, a second engine ignition was to circularize the path at the 69-mile altitude.

Borman, Lovell and Anders will gaze down at the wild and wondrous landscape of this heavenly body which has puzzled man for centuries.

During 20 hours in which they were to orbit 10 times, the adventurers were to take hundreds of photographs, determine how well they can navigate by tracking key landmarks on the surface and report visually on what they see.

* *

THEY PLANNED to send television pictures twice to give earthlings a closeup view of their closest neighbor, 230,000 miles away. The shows were scheduled for 4:30 a.m. and 6:31 p.m.

Borman promised before the flight that the crew would make a Christmas

(Continued Page A-4, Col. 1)

Cleaver Forfeits Bail, Wife Appeals to Public for Funds

OAKLAND (AP) — Fugitive Black Panther Eldridge Cleaver forfeited $50,888 bail Monday and his wife made a public appeal for help to raise the money.

Alameda County Superior Court Judge Folger Emerson was scheduled to set trial dates next Monday for Cleaver and five other panthers charged with an Oakland shootout with police April 6.

"Is Mr. Cleaver here?" asked Emerson, when the case of Cleaver, 33, was called.

"No, your honor," replied Charles R. Garry, Cleaver's attorney, who has said he last saw his fugitive client on Nov. 25.

* * * *

"BAIL is forfeited," said Emerson, whose order becomes final June 20, as stipulated by law.

Cleaver's wife, Kathleen, 23, and four others who signed a promissory note guaranteeing the bail held a news conference after Emerson's action.

"The committee has no regrets about Cleaver's actions and we accept our responsibility for the ransom payment and we hope the community at large will help share our financial burden," they said in a statement.

Besides Mrs. Cleaver, others signing the statement were Paul Jacobs, a San Francisco author; Edward Keating, former publisher of Ramparts Magazine; Dr. Philip Shapiro San Francisco psychiatrist, and Godfrey Cambridge, entertainer.

* * * *

MRS. CLEAVER told reporters she had not seen her husband since Nov. 25. She added that she had "put on" a New York reporter when she said she had seen Cleaver Dec. 10.

Mrs. Cleaver said "I told the woman reporter in New York that I gave him $20 million and she didn't know whether to believe it or not."

Cleaver was paroled in 1966. He had served nine years of a 13-year sentence on Los Angeles convictions of assault with intent to commit murder and assault with a deadly weapon.

His parole was revoked after the Oakland shooting and he was ordered to prison. A Solano County judge ordered Cleaver released on grounds he was jailed because of political views.

* * * *

AN APPEALS court overturned the ruling and ordered Cleaver back to prison. Subsequent appeals before the California and U.S. Supreme Courts failed.

Emerson issued a state warrant for Cleaver, since a federal fugitive warrant precluded the necessity for a warrant with greater scope.

A TV Look at Earth and Moon

By HARRY ROSENTHAL

SPACE CENTER, Houston (AP) — The Apollo 8 astronauts, sharing their wondrous journey with a world hardened to fantasy, are set to televise a sight even the most jaded could not ignore: The moon from 70 miles away.

With luck, their camera could capture — behind the pitted foreground of the moon — the gleaming bauble that is Mother Earth, 235,000 miles distant.

The live TV transmissions today are expected to last 15 minutes.

* * * *

AS THEIR ship glided toward its fabled destination Monday, the astronauts sent back an astounding view of earth, wrapped partly in clouds — but with seas and land masses showing through plainly.

"What you are seeing," said astronaut James Lovell acting as a guide, "is the Western Hemisphere. Looking at the top is the North Pole. In the center, just lower to the center is South America, all the way down to Cape Horn.

"I can see Baja Califor-

(Continued Page A-4, Col. 1)

WITHIN MINUTES

Reds Break Own Truce, Hit Bases

SAIGON Tuesday (UPI) — Communist soldiers broke their own Christmas cease-fire minutes after it began today, shelling two South Vietnamese outposts, military spokesmen said.

Within 20 minutes after the 1 a.m. truce the guerrillas unleashed a 40-round mortar salvo into a South Vietnamese military camp 25 miles west of Saigon, but no one was hurt, battlefield reports said.

The Communists declared a 72-hour Christmas truce beginning at 1 a.m. today, with the Allies promising to hold their fire for a 24-hour holiday period beginning at 6 p.m. Christmas Eve.

Spokesmen said the second truce-breaking Red attack came about 4 a.m. — a 30-round mortar barrage into a South Vietnamese camp 80 miles northeast of Saigon. There were no reports of casualties there.

The Communist truce began shortly after U.S. and South Vietnamese troops reported the end of a battle 25 miles southwest of Da Nang in which 158 guerrillas were slain against "light" Allied losses.

With dive bombers, helicopter gunships and artillery, the Allied soldiers tore into the Red buildup threatening Da Nang, 380 miles north of Saigon, in one of the fiercest fights since the Nov. 1 halt in the bombing of North Vietnam.

Air Force B52 bombers preceded the Communist cease-fire with thunderous raids against Red bivouacs 24 to 33 miles north of Saigon in the midst of a buildup threatening the capital, spokesmen said.

6 Children, 2 Adults Die in Watts Fire

Eight persons — six of them children — died in a fire that swept a two-story home in Watts late Monday, and police said an unruly crowd was gathering at the scene.

Firemen said the eight victims were not yet identified, but they believed they were all from the same family.

The fire, which gutted the home at 9800 S. Wilmington Ave., broke out about 10:43 p.m. Cause of the blaze was unknown. Police said the home was in "a fairly average residential district."

INSIDE TODAY'S INDEPENDENT

- BISHOP PIKE banned from pulpit. Page A-2.
- TWO 16-YEAR-OLD girls face bleak Yule after losing $1,415 in phone booth. Page A-3.
- PRESIDENT JOHNSON'S rage against intellectuals; how it began. Page A-8.
- CHURCHES THROUGHOUT Southland hold services tonight celebrating the birth of the Savior. Page B-1.

Figure 4.1.63: Front page of the Long Beach Independent.
http://www.newspaperarchive.com/DailyPerspectiveFullView.aspx?ViewDate=12/24/2007

The second TV broadcast examined here is the 6th TV transmission, which started at 20:36 on the 26th , some 3 hours after the ESSA track was taken. The ESAA image is presented with a screenshot from that broadcast in figure 4.1.6.

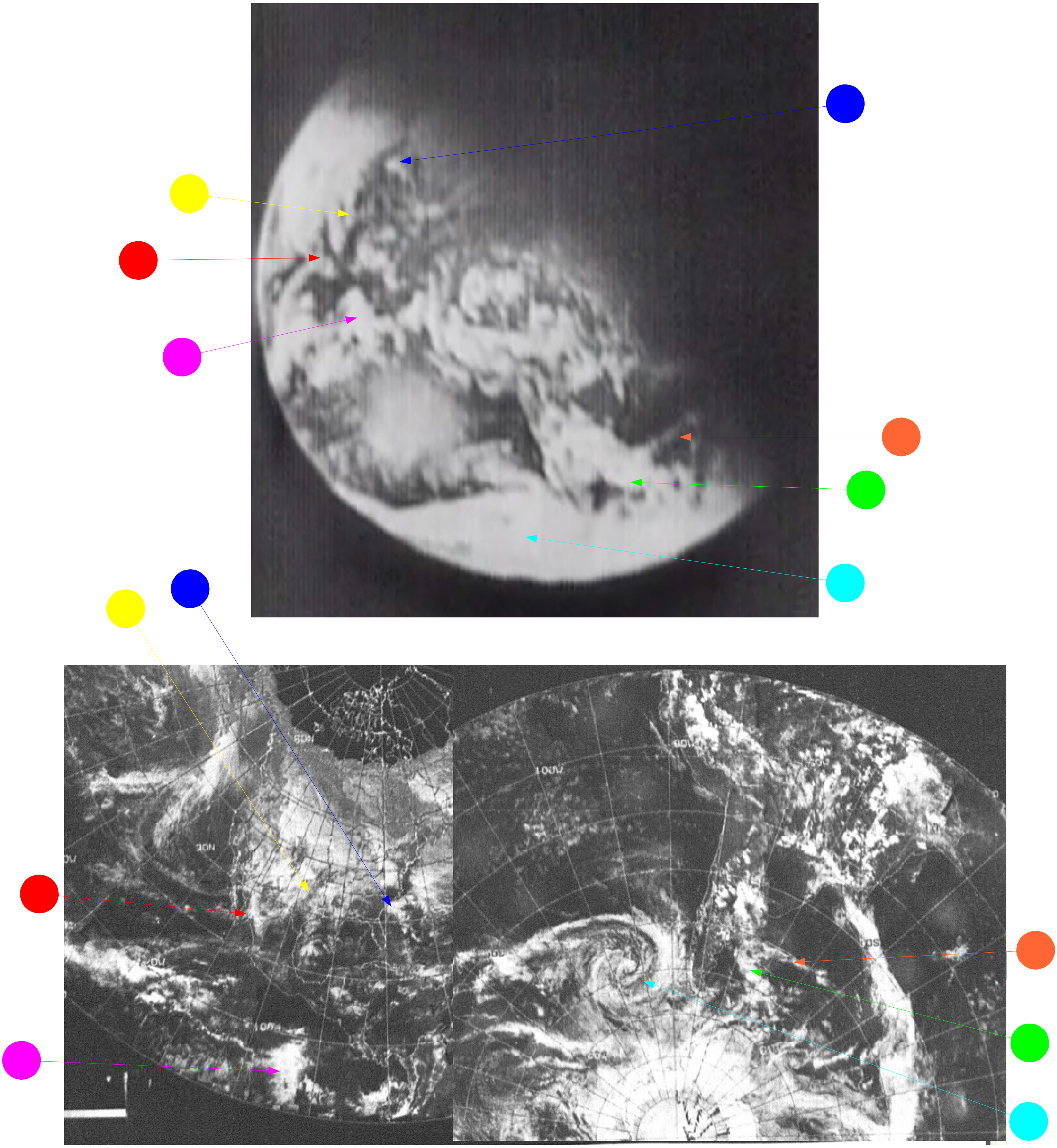


Figure 4.1.66: ESSA-7 image from 26/12/68 compared with TV broadcast from the same date.

The newspaper was published on the 24th, and therefore can only have been taken from the TV broadcast on the 23rd. It could not have been produced from ESSA satellites imagery as the image for the 23rd would not have been completed until the 24th, by which time the newspaper would have been in production. The TV image can only have been broadcast from space on the 23rd. The ATS-3 image could, in theory, have been available, but the polar areas are missing and the angle of view, location of the terminator line, and weather systems visible on the western limb are different.

Another image is also available of the TV broadcast in the form of the image shown below (figure 4.1.64), available from the facebook site Retro Space Images .

Figure 4.1.64: Mission Control during the TV broadcast of 23/12/68

A zoomed and cropped image of the large monitor screen (figure 4.1.65) shows that the image on the screen (and on every monitor visible) is the same as the one on the newspaper front page, which, in turn, is an exact match of the satellite photos from the same date,

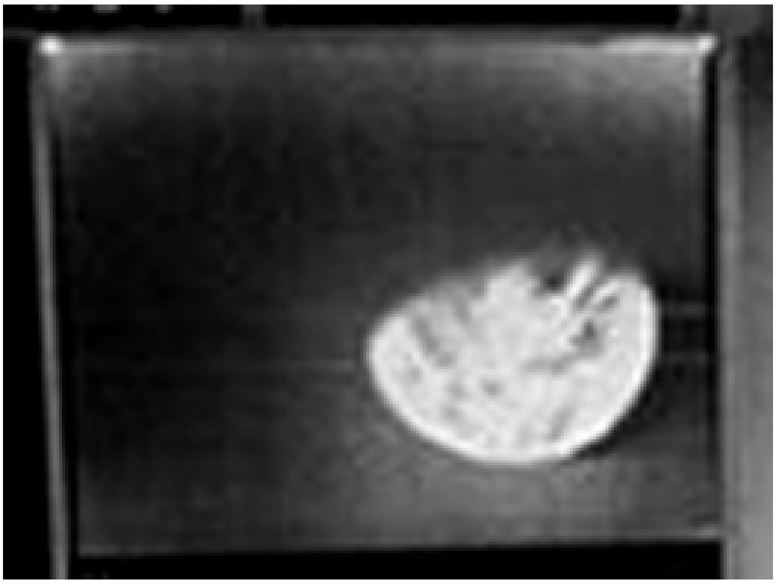


Figure 4.1.65: Zoomed & cropped image from the mission control photograph in figure 4.1.64.

The image is centred on South America, and there is a clearly defined band of cloud along the east coast. The upper left of the image is North America, most of which is obscured by clouds.

The terminator line is just crossing Brazil, and Stellarium confirms that this is exactly where the terminator should be (figure 4.1.67).

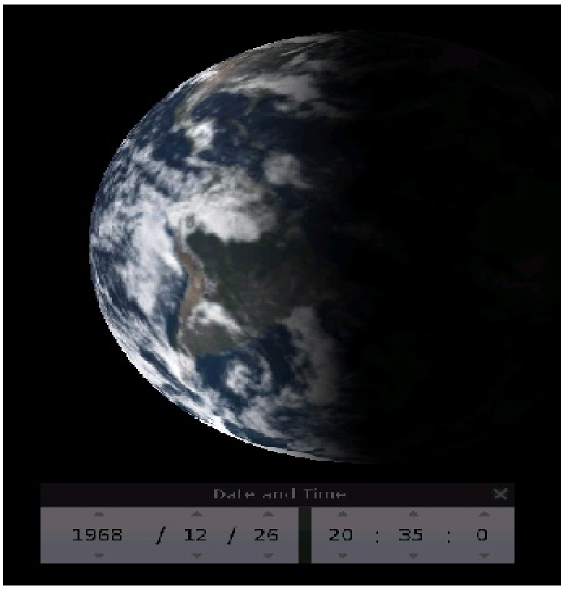


Figure 4.1.67: Stellarium indication of time at terminator

While the TV screenshot is not as sharp as the Apollo photographs, and much of the ESSA clouds are not as clearly visible as those on Earth. it is still possible to discern unique systems that mark it out as having been taken specifically on the 26th, notably a small system, off the coast of New York (identified with the blue marker) that is not there on the 25th.

Interestingly, TV footage exists of mission control during this TV broadcasts (Moon Machines), and the same TV broadcast can be seen on a monitor, with the same clouds – see figure 4.1.68.

Figure 4.1.68: Mission control during Apollo 8's TV broadcast

Another couple of screenshots can be found in a video available on the internet from the launch period. “Apollo 8 – Go for TLI” is available here: archive.org, and contains a couple of sequences taken shortly before TLI. At 02:07 minutes, there is the screenshot shown in the top left corner of figure 4.1.68.

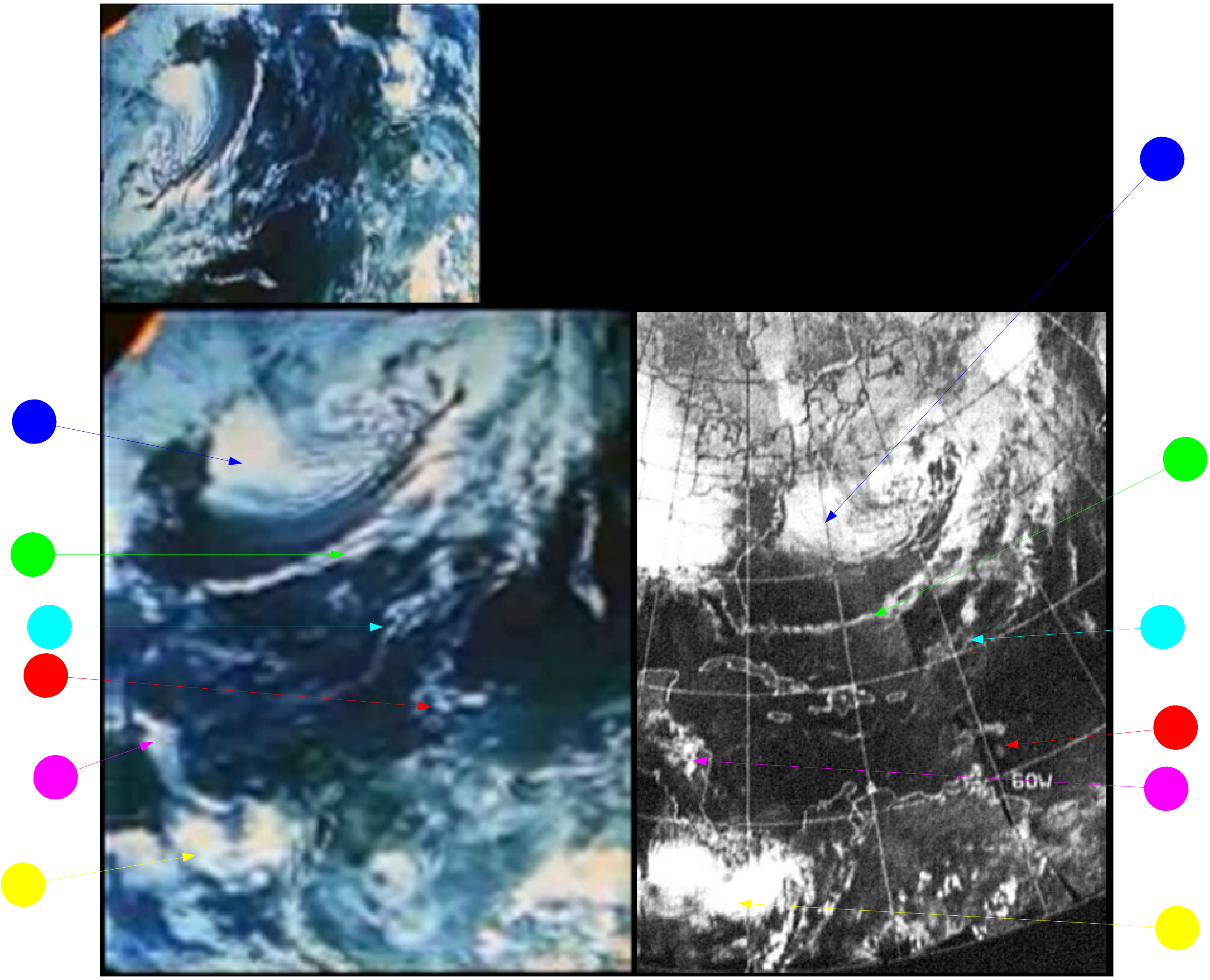


Figure 4.1.69: Apollo 8 screenshot (original top left) flipped, rotated and compared with ESSA mosaic from 21/12/68.

Comparing this with the ESSA mosaic was a relatively straightforward business once it was realised that the film sequence used in the original video was the wrong way round. It's a simple mistake to make when dealing with film to thread it incorrectly, especially when it isn't obvious which way it should go. Once flipped and rotated, the match with the ESSA mosaic is immediate and obvious. More importantly, the Earth orbit insertion at 13:00 on the 21st was several hours before this area was covered by the ESSA satellite. According to the ATS document linked to at the start of this section, only one image was taken by ATS-3 on the 21st, and this was at 18:05. It is not provided in the catalogue. Once again, the visual evidence of from the mission matches the satellite evidence.

4.1.3 Meteorological data.

There are a number of locations that supply general weather data for the Apollo 8 period, but relatively few show good synoptic charts. For this reason we are restricted to looking at what is available, rather than the case with satellite photos where any image of earth can be matched.

The monthly weather review (MWR) from ESSA (the organisation, not the satellite) for December hMWR reveals (as do many newspaper headlines of the time) a very cold period with heavy snowfalls – reaching record levels in some areas.

NOAA has a facility to reproduce the weather maps of any given period here: Daily Weather Maps

Germany kept comprehensive records and these can be found in here NOAA archives here German Data, and there are documents from South Africa that also show synoptic charts with fronts marked on them South African data. The same NOAA site has records from Pakistan here , but frontal systems are not marked

It's important to note that at this point in history, synoptic weather charts were still mostly drawn by hand by interpolating data from weather stations, weather balloons, buoys and ships. Satellite meteorology was still in its infancy, and much research was aimed at reconciling terrestrial and non-terrestrial sources of information. It's also worth pointing out that, while a front (the point where two different air masses meet) will have a cloud mass associated with it (caused by temperature and pressure changes altering the moisture carrying capacity of the air), clouds do not always indicate the presence of a front.

A good starting point for comparing Apollo photos and synoptic charts is the first colour earthrise image examined earlier, AS08-14-2383, and the photograph taken an orbit later, AS08-12-2188, as there are a number of systems that can be seen on the chart and the photographs (see figure 4.1.28). Figure 4.1.29 shows the synoptic charts for the Northern Hemisphere on 24/12/68 as given in the German and South African data.

As already established, this photograph was taken on 24/12/68. Clearly visible are a band of cloud in the North Atlantic, and a large weather system off South Africa.

Image quality for the German synoptic chart is poor, and for this reason the weather fronts marked on the map have been highlighted in red. For orientation purposes, the bottom left of the image shows Central America.

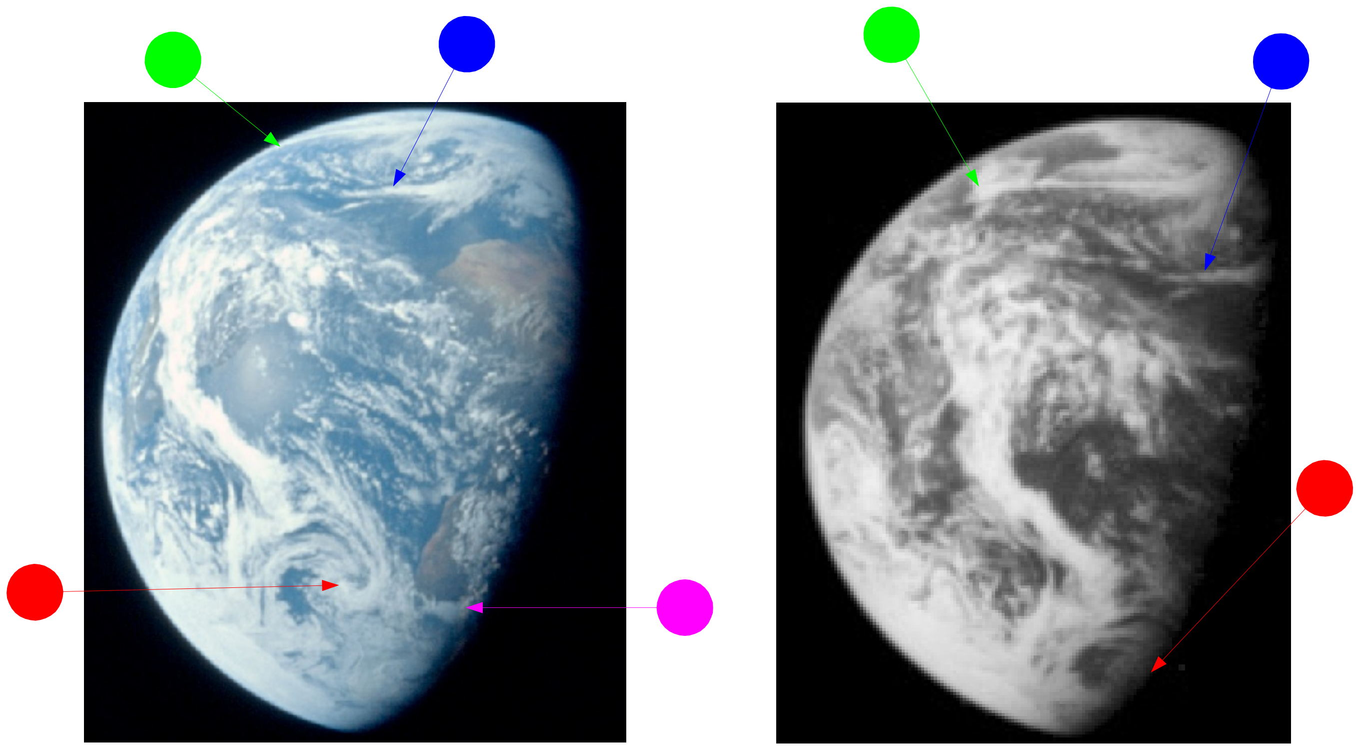


Figure 4.1.70: Earth as seen in AS08-14-2383 and AS08-14-2388 (sources in text)

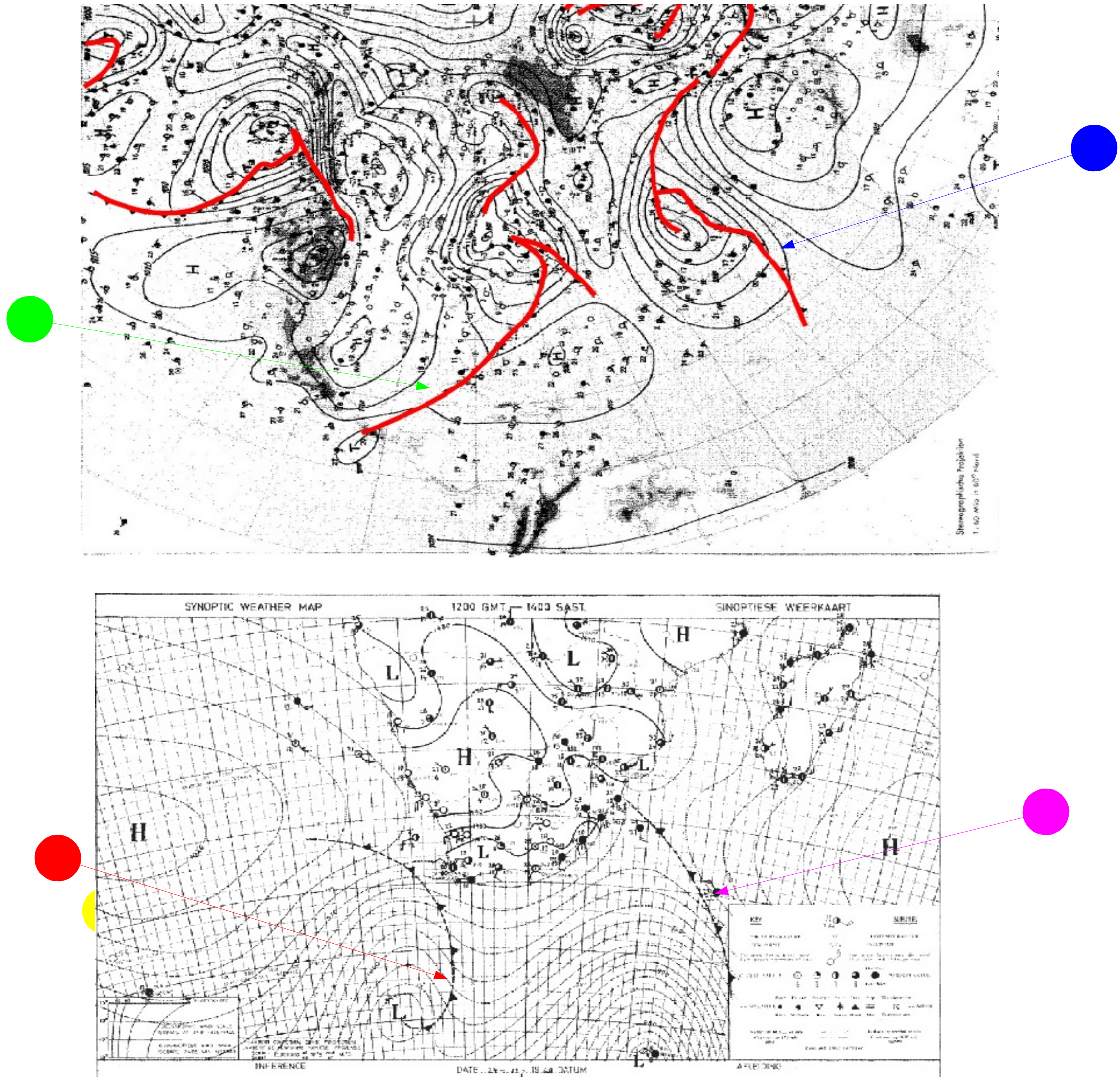


Figure 4.1.71: German & South African Synoptic charts for 24/12/68

The main front visible in the colour Apollo image in the Northern Hemisphere is the one arrows in blue above. The weather front behind it (identified by the green arrow) is the same one visible from on the Long Beach Independent's screenshot of Apollo 8's live TV broadcast. The red arrow points to the swirl of cloud visible off South Africa, and this same front is the one that is still visible in figure 4.1.70**.** A word of explanation is required for the difference in data overland compared with that over the sea. The isobars offshore represent atmospheric pressure related to the amount of mercury raised in a barometer. The lines overland represent geopotential, which takes a given atmospheric pressure and looks at the altitude you would need to be at to reach that pressure. It is a slightly different way of looking at the same information, and is where meteorologists derive the terms 'ridges' and 'troughs' when describing atmospheric conditions.

Two other images will be examined here, both of which have been looked at previously. The first is AS08-16-2595 - [available here](#) . This image was taken on the way to the moon and readers are invited to examine the satellite images in the Appendix if they wish to satisfy themselves that this is the cause. The reason this image has been chosen is that it clearly shows America, and a zoomed and cropped version of it is shown in figure 4.1.72 together with the NOAA weather charts from that day.

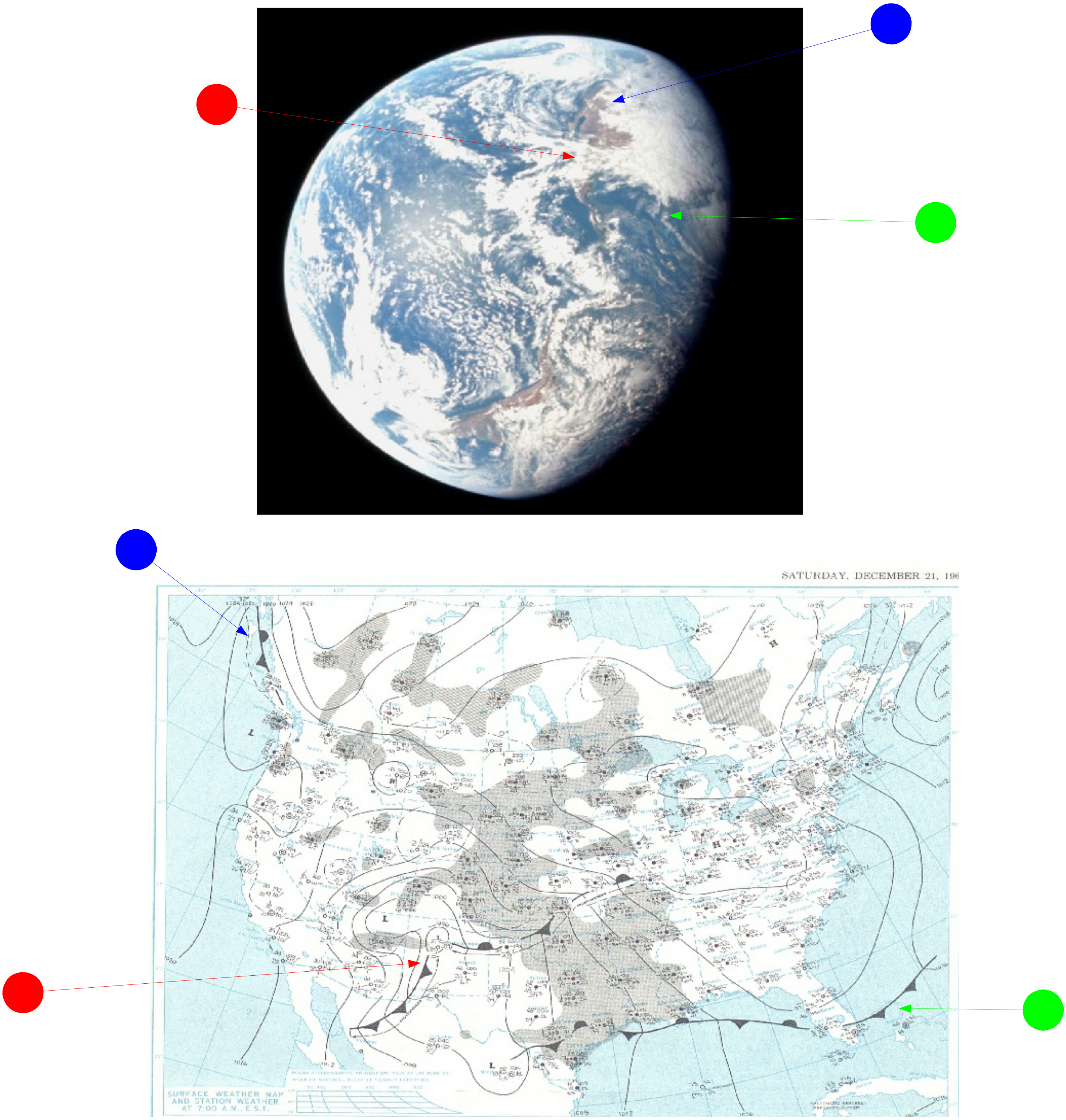


Figure 4.1.72: Earth from AS08-16-2595 and NOAA synoptic chart for 21/12/68

Again, there is good correspondence between the Apollo photograph and ground based meteorological data.

The final image examined is AS08-16-2601, [available here] taken on the 22[rd] of December, and chosen here for the clear image of Southern Africa (see figure 4.1.73).

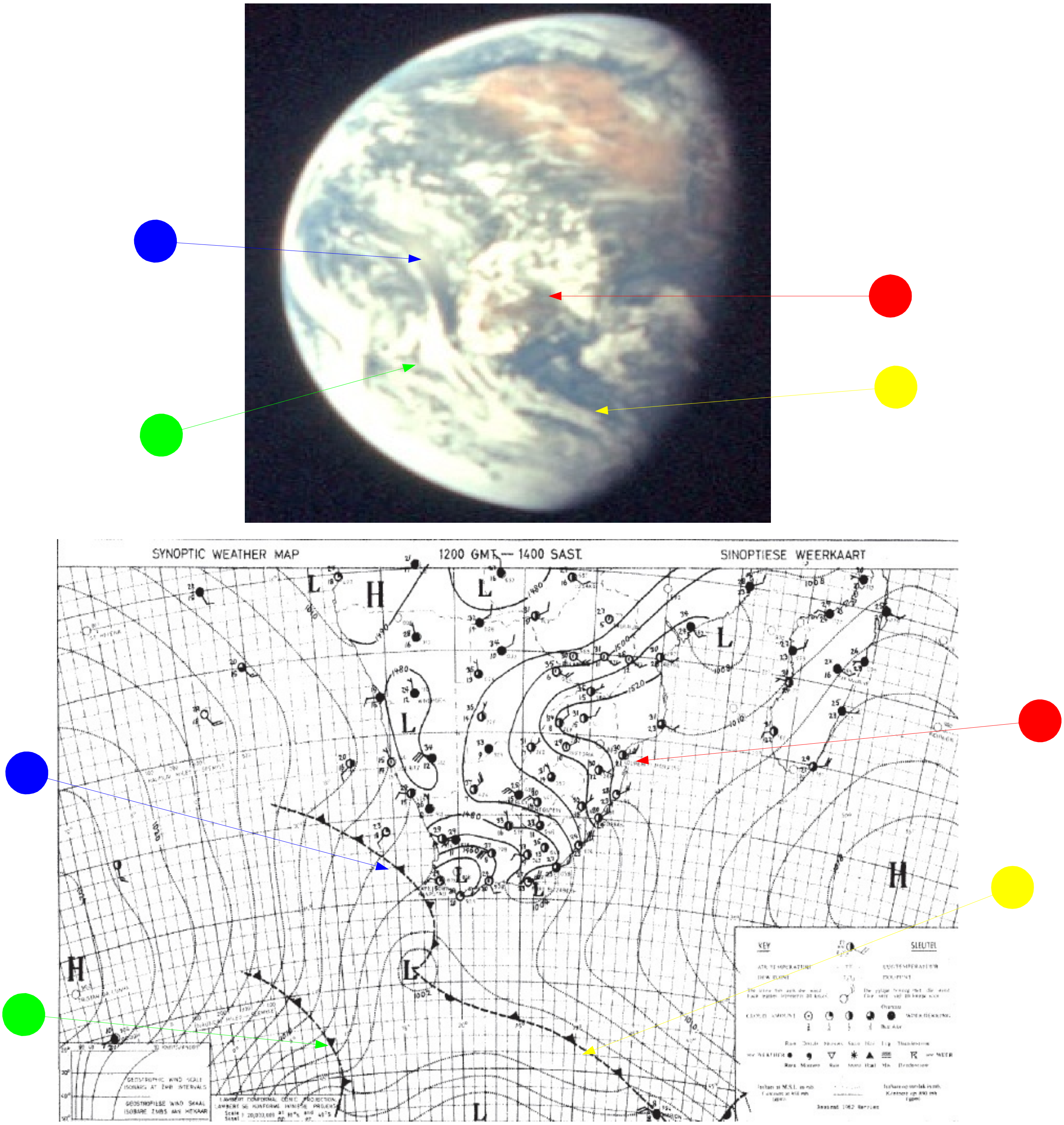


Figure 4.1.73: South African synoptic chart compared with AS08-16-2601.

This time, as well as identifying the fronts, the area arrowed in red identifies a small lobe of high pressure air that is helping keep the skies clear over eastern South Africa.

In conclusion this section demonstrates that three satellites, a couple of TV broadcasts, video footage, synoptic data and a number of still photographs all show a degree of correspondence with each other that makes it difficult to draw any conclusion other than that the Apollo images were taken when & where it is claimed they were taken: on the way to, orbiting around and returning from the Moon.

4.2 Apollo 10

Apollo 10 is an often overlooked footnote in the public memory of the moon landings, but as a full dress rehearsal for the landings proper it deserves every plaudit allowed. Without this mission, Apollo 11 would not have landed.

If Apollo 8 wetted the appetite of the general public for space in general and pictures of the Earth in particular, it seems to have motivated the astronauts even more. As a result, Apollo 10 contains possibly more images of Earth than any other mission, and transmitted colour TV pictures from space for the first time in a number of live broadcasts[1]. Most of the TV footage is of inside the capsule rather than Earth (much to the evident frustration of CBS host Walter Cronkite, who fronted the live coverage of the mission on TV) and of the lunar surface, but there are some shots of Earth..

The mission launched on May 18th 1969 at 16:49 GMT, reached the moon on the 22nd, set off back to Earth on the 24th and landed back on Earth on the 26th. The timeline for the mission can be found here: Apollo 10 timeline .

In total 1463 images were taken over 9 magazines, but most of the Earth images are concentrated on magazines 27, 34 and 45. Few of the images of earth are available automatically in high resolution format. As a result, the Apollo Image Atlas (AIA) was used to browse for images, and the Gateway to Astronaut Photographs of Earth (GAP) search & image request facility was used to obtain higher quality jpgs. The search facility is freely available to anyone.

The images pasted into this document are, where possible, the higher resolution ones.

Three of the rolls containing black & white images feature images of Earth, but high quality versions of these could no be located. They will be dealt with briefly at the end of the next section.

In addition to the photographs, 15 magazines of 16mm films were taken, and these can be viewed at the AFJ DAC video library . These films, taken with the Data Acquisition Camera, show the Earthrise movies as we have come to know them. The TV coverage at the time could not show Earthrise live, as the TV signal could not be transmitted to Earth until after acquisition of signal, ie until the ground based receiving stations were fully visible from the spacecraft as it rounded the far side of the moon. Three satellite sets are available here: ATS-3, ESSA 9 and NIMBUS 3.

The full ATS-3 document (including technical details of its operation) is here: **ATS-3 Document source**, the full ESSA document is available here: **ESSA 9 document source** and the full NIMBUS documents can be found here: **NIMBUS 3 document source 1** and here: **NIMBUS 3 document source 2** . The former shows the relevant orbits joined so that a day's images are presented on a single page, while the latter are the unedited film sets. The whole page images are used here. ESSA and NIMBUS images will be used for each image given as a demonstration that three different satellites on different orbits show the same weather patters as the Apollo images.

Images selected for examination are chosen to be representative of the mission and to show different parts of the Earth's surface featuring the same weather systems. In most cases, only the northern hemisphere of ESSA images are used, as the relatively little of the southern hemisphere is visible in most cases. Screenshots from the videos and TV broadcasts will also be examined.

1 This report http://www.hq.nasa.gov/alsj/AWST690526Art.pdf identifies the docking procedure of the CM & LM as the first ever space TV in colour

4.2.1 Apollo 10 Still Images

Apollo 10, like many missions, took several photographs of Earth as soon as they were safely in Earth orbit, and these can be seen on roll 34 (Magazine M). The first full disk image of Earth is AS10-34-5013 (figure 4.2.1). This image can be seen after an image of the SIV-B after the CM has separated from it. The timeline shows that this separation occurred at 20:45 on May 18th. AS10-34-5013 must therefore have been taken after this time.

Figure 4.2.1: High quality GAP scan of AS10-34-5013. Link to low quality image

Stellarium suggests that this image was taken at around 22:45 (figure 4.2.2), a couple of hours after separation from the SIV-B.

The weather system to the east of the USA has a distinctive shape that should be evident from satellite photographs. The high quality version of the image clearly shows the shadow cast on Baja California by the bank of light cloud to the west. Other cloud systems of note are those north of Alaska with their 'streamers' of cloud extending into the North Pacific from the Arctic.

Figure 4.2.2 shows a zoomed and cropped version of AS10-34-5013 together with the corresponding ESSA 9, ATS 3 and NIMBUS 3 image, and a Stellarium inset showing the estimate of the time at the terminator. The ATS image is in two parts in the data catalogue, and these have been merged in this figure.

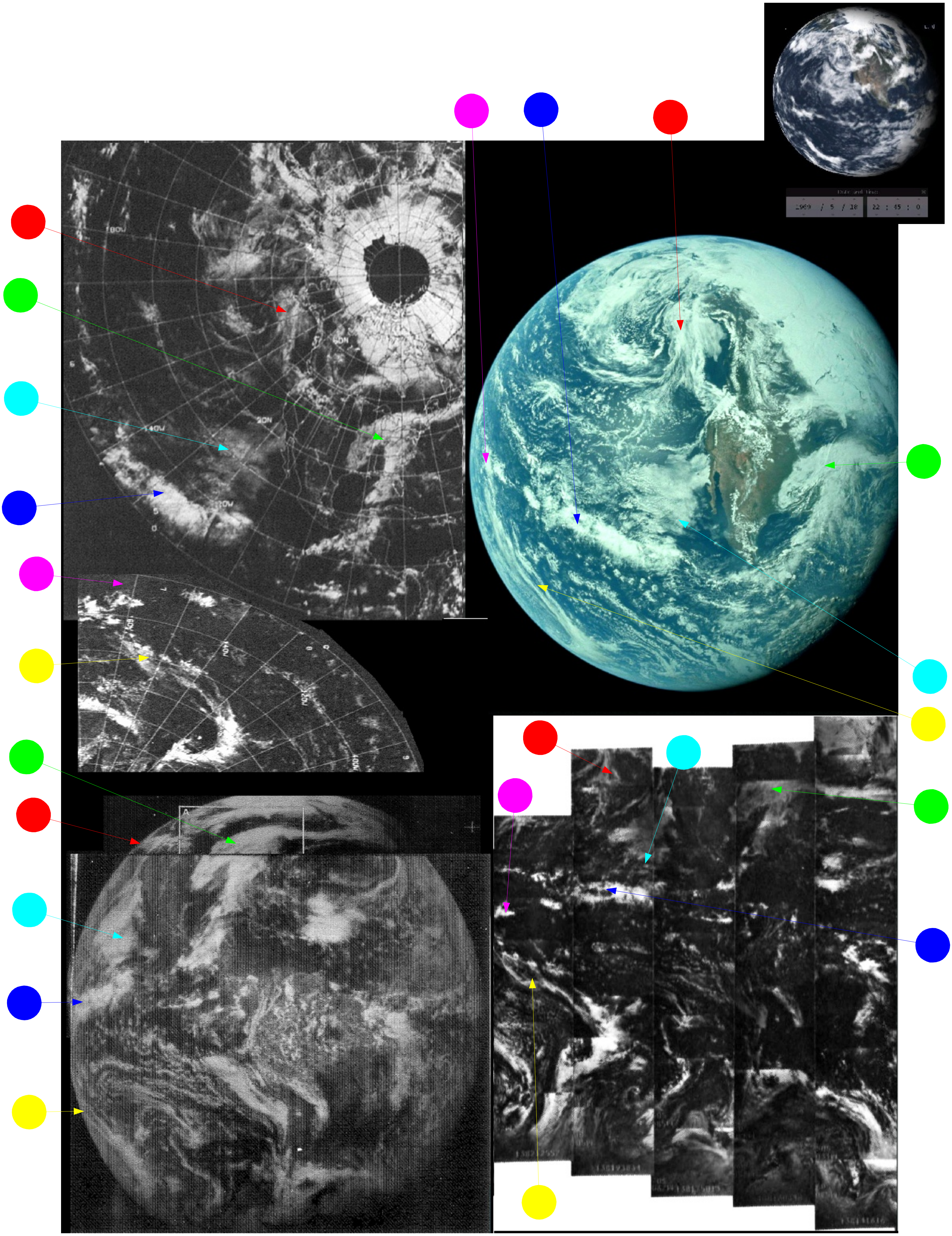


Figure 4.2.2 – ESSA-9 (top left), ATS-3 (bottom left) & NIMBUS 3(bottom right)mosaics from 18/05/69 compared with AS10-34-5013 and Stellarium estimate of time at terminator

The distinctive hammer shaped system off eastern USA is very much evident. What is noticeable about the satellite images is that many of the cloud systems in them are (while still recognisable) less clear than on their Apollo counterparts. This is a consistent feature throughout this three datasets.

The position of the weather systems suggest that the time of the Apollo image and the ESSA track over north America were very close together. North America is covered by track 3-5. The ESSA image dated the 18th of May consists of tracks 1013-1025, putting the ESSA image of North America at roughly between 18:00 and 22:00.

The orbital data for NIMBUS show that the satellite image (orbits 461-464) would have been taken between 16:22 and 21:45 on the 18th, slightly earlier than the ESSA images from the same day. The mapping method used on the photos makes placing some of the weather systems more difficult, but the 'hammer' shaped system off the east coast of the USA is still clearly identifiable, and the weather system identified by the cyan arrow is also very distinctive.

Shortly after AS10-34-5013 was taken, we have AS10-34-5019 (figure 4.2.3), shown here with a Stellarium inset to indicate the time it was taken. The satellite images used are the same, but it is important to demonstrate that the images taken by Apollo are not of a static object, but of a rotating sphere that hides one part of the globe and reveals another as it rotates. ATS-3 is included, although much of the area covered has now passed beyond the terminator.

Figure 4.2.3: High quality GAP scan of AS10-34-5019. Low quality version of the Apollo image available here http://www.lpi.usra.edu/resources/apollo/frame/?AS10-34-5019

AS10-34-5019 already shows that Earth is much smaller than AS10-34-5013 despite being taken very shortly after it. Stellarium shows that it was been taken just after midnight on the 19th of May. The ESSA image suggests that the orbits (tracks 5 to 7) covering the portion of the Earth visible here would have been carried out between 22:08 on the 18th and 02:08 on the 19th, so it is still appropriate to examine the image for the 18th when comparing weather patterns (figure 4.2.4).

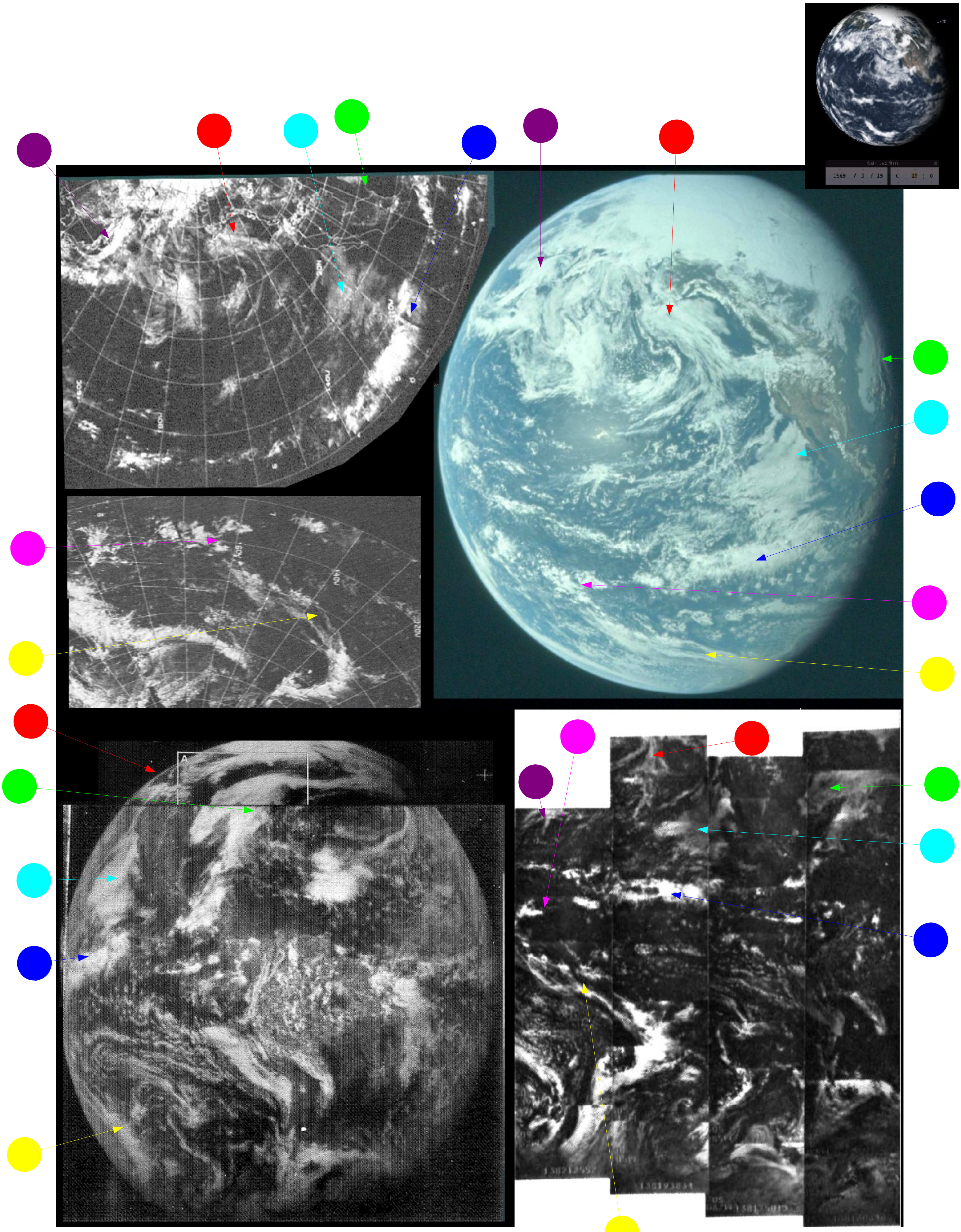


Figure 4.2.4 – ESSA9 Top left upper & lower), ATS-3 (bottom left) & NIMBUS 3 (bottom right) image from 18/05/69 compared with AS10-34-5019 and Stellarium estimate of time at terminator

The overall weather patterns visible in AS10-34-5019 are clearly the same as in AS10-34-5013, but there are subtle differences between them consistent with a dynamic weather system pictured a few hours apart. To illustrate this point more, figure 4.2.5 shows a small section visible in both images.

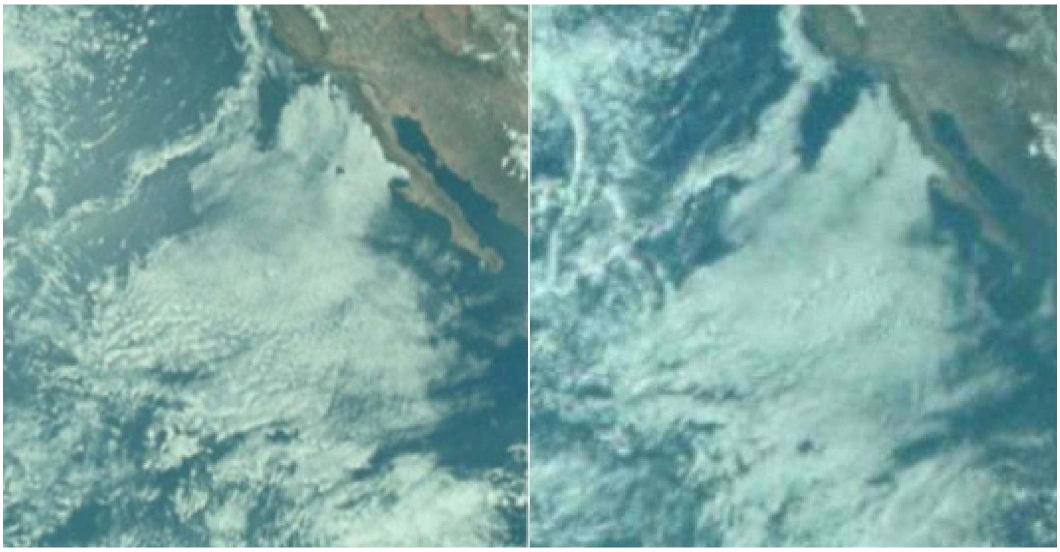


Figure 4.2.5 US & Mexico Pacific coastline from AS10-34-5013 (left) and AS10-34-5019 (right)

The left hand side is from AS10-34-5013, the right hand side AS10-34-5019. The weather patterns are undeniably the same, but it does not take much time to identify the differences between them. Looking at the California coastline, the bank of cloud hugging the coastline south of San Francisco and extending south west into the Pacific is much less developed in 5013.

This bank of cloud then joins offshore with a much larger one between Los Angeles and Geronimo Island lighthouse, and it is very likely that these are large fog banks, as there is a small hole in the cloud in roughly the same position as Guadeloupe The shape and size of the clear area north of Los Angeles is also different in the two photographs. Further to the west, a thin stream of cloud running north-south (top left) is much closer to the US coast in the later photograph, suggesting that this is higher altitude cloud moving more rapidly than the sea level fog bank.

Over the whole of figure 4.2.5, there is not a single cloud that has not in some way altered in a manner consistent with weather system development over time.

Like the ATS image, less of the NIMBUS image is available for use because of the orientation of the Earth and the availability of NIMBUS tracks, but those that are shown do feature weather patterns that match those of AS10-34-5019. ESSA's orbit nearest the terminator is 1017 (track 3), which commenced at 18:07. NIMBUS' equivalent was number 460, which commenced at 14:35.

The next image to be examined is AS10-34-5026. It has been chosen for no particular reason as it is not near any other images in the magazine, but it does show a considerable portion of Africa. As it was taken after AS10-34-5019, but before the images of the lunar surface, it must be before the 21st. The photograph is shown in figure 4.2.6, together with a Stellarium insert indicating the likely time of the photograph.

Based on the terminator position, the estimated time of the Apollo image is 15:00. It is worth pointing out that the view of the Stellarium image is from the lunar surface (Apollo 11, to be precise). Apollo 10 was not yet near the lunar surface, hence the slight difference in the amount of Atlantic Ocean visible from the spacecraft. This difference in perspective will be examined in more detail later.

Figure 4.2.6: High quality GAP scan of AS10-34-5026 . Link to low quality image

Figure 4.2.7a shows the ESSA 9 and NIMBUS 3 satellite images from May 19th, and 4.2.7b shows the ATS-3 version. ATS-3 has only partial coverage here, but has been included for the sake of completeness.

Examination of the satellite photographs taken during the mission show the Apollo image can only have been taken on the 19th. The clouds visible over southern Spain and north Africa (magenta arrows) are much less developed on the 18th, and by the 20th had moved eastwards towards southern France. The very striking north Atlantic system is also poorly developed on the 18th and a completely different shape on the 20th.

The ESSA track data show that the satellite passed over Africa between 10:00 and 15:05 (tracks 11-13 and 1), again tying in nicely with the Apollo image. The ATS images were taken at 17:04 & 17:07 on the 19th.

In the NIMBUS image it is noticeable that the storm over north Africa identified in yellow is not as extensive as it is in either the ESSA 9 or Apollo images. Orbit 471, the path that covers this storm, can be put at 10:16 – several hours before the Apollo image and the path ESSA & the later ATS took over that part of the globe. This greater time difference easily accounts for any differences in cloud formation between the NIMBUS and the ESSA images, and again highlights the fact that the photographs taken from space are showing a dynamic atmosphere.

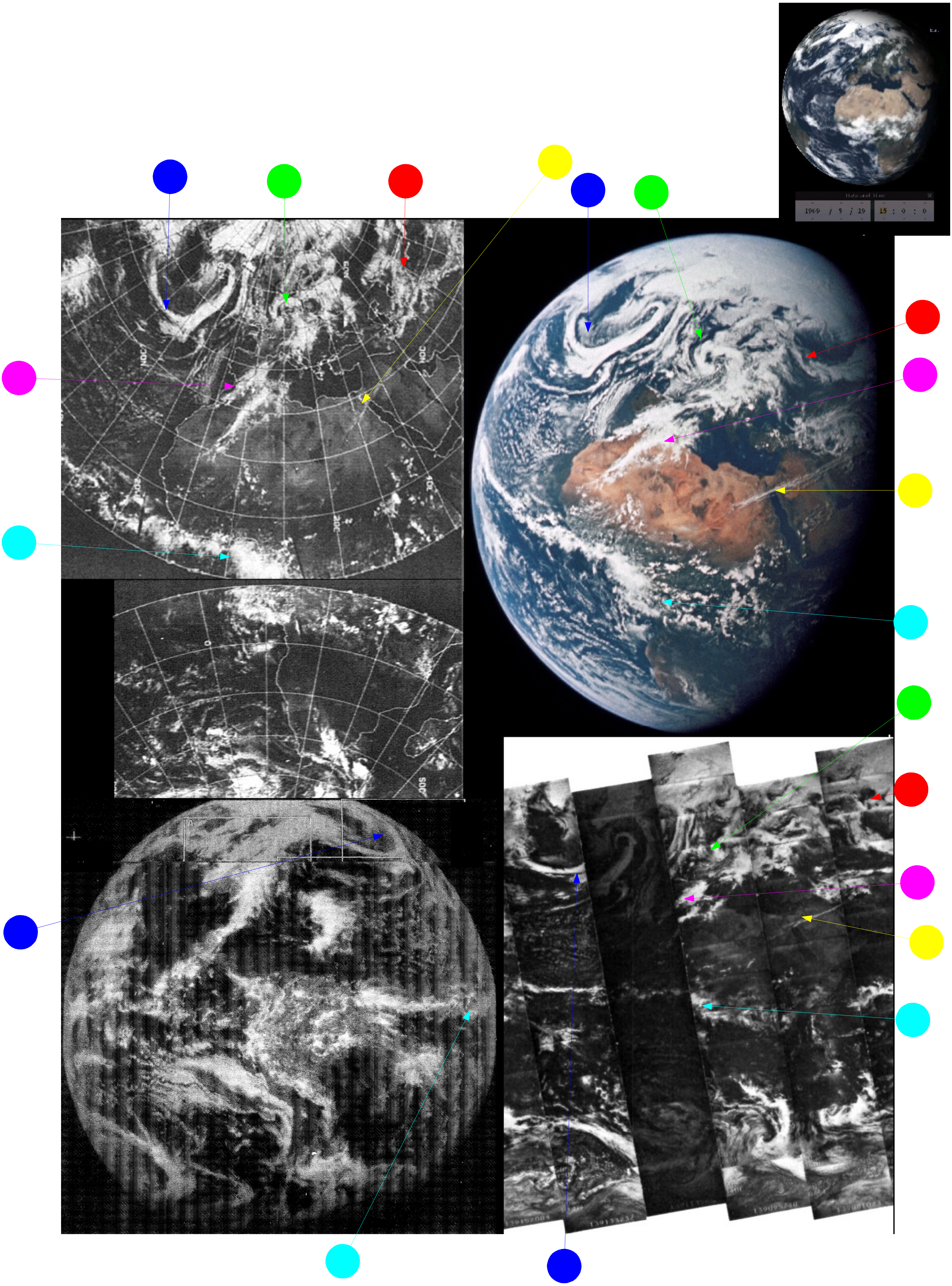


Figure 4.2.7 – ESSA9 (top left upper and lower), ATS-3 (bottom left) & NIMBUS 3 (bottom right) images from 19/05/69 compared with AS10-34-5026 and Stellarium estimate of time at terminator

The next set of images taken by the crew shows north and south America again coming into view. The common denominator between this photograph and the previous one is the large swirl of cloud highlighted by the blue arrow in figure 4,2.7 in the top left of the Earth's disk.

The picture in question is AS10-34-5036, which is shown below in figure 4.2.8.

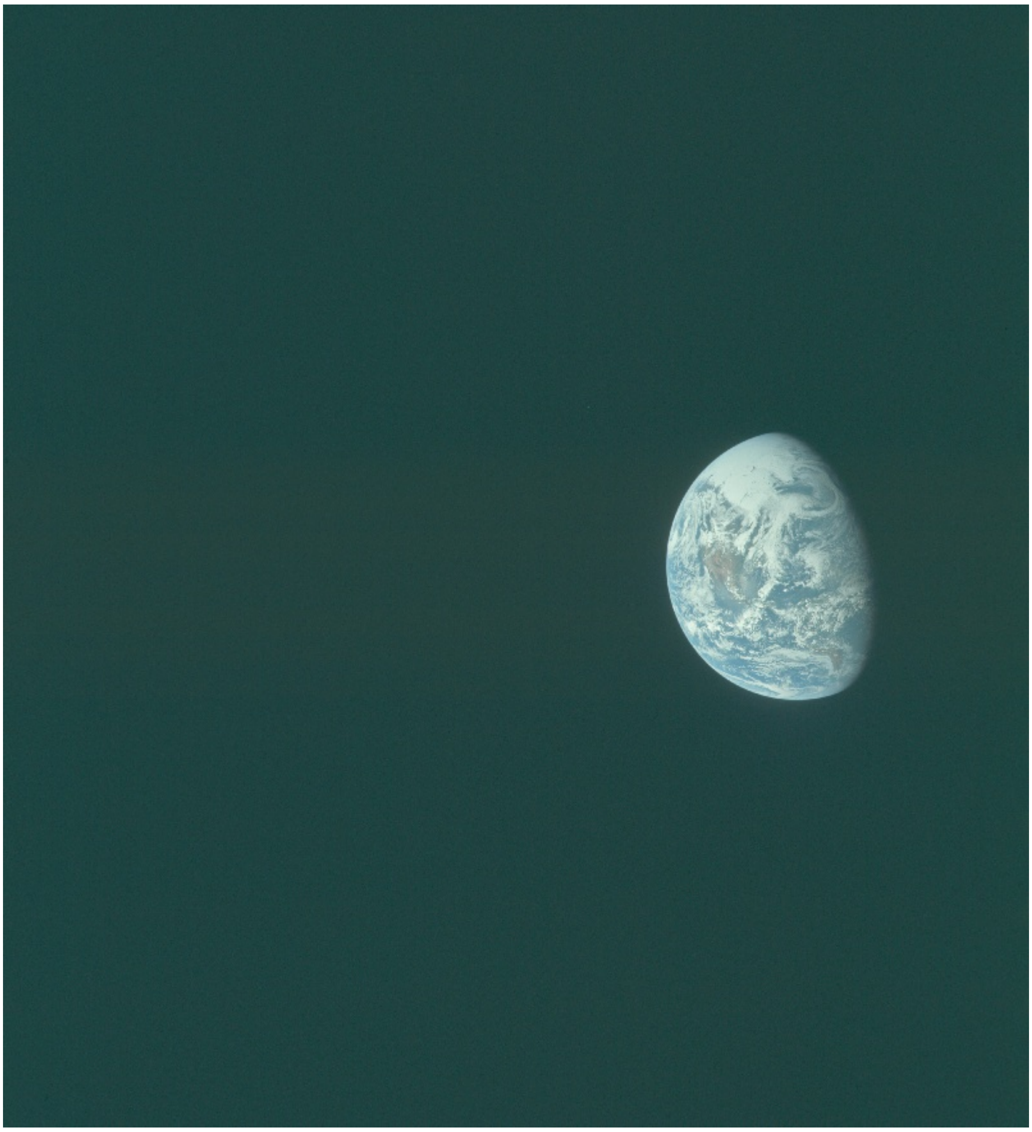


Figure 4.2.8: High quality GAP scan of AS10-34-5036. Low resolution source here: AIA

As before the Earth is visibly smaller, and the scene is dominated by a large polar cloud mass, and the remains of the large 'hammer' shaped formation picked out in figure 4.2.2 by the green arrow. The large swirl is now on the terminator, which Stellarium estimates at around 20:00 on the 19th.

The comparison with ATS, ESSA and NIMBUS data is shown in figure 4.2.9 on the next page.

The blue arrow in figure 4.2.9 points to the same cloud system as the previous analysis, and it should be readily apparent that all three satellite images show the same weather systems as can be observed in the Apollo Earth. We have Stellarium's estimate of 20:00 on the 19th, and this compares favourably with the ATS image time of just after 17:00. The NIMBUS pass that corresponds best with the terminator (number 472) would have started at 13:51 on the 19th. The ESSA pass nearest the terminator would have been track number 2, or orbit 1029, which commenced at 17:01 on the 19th. As before, we have 3 satellites taking pictures on the 19th that match an Apollo image from the same date.

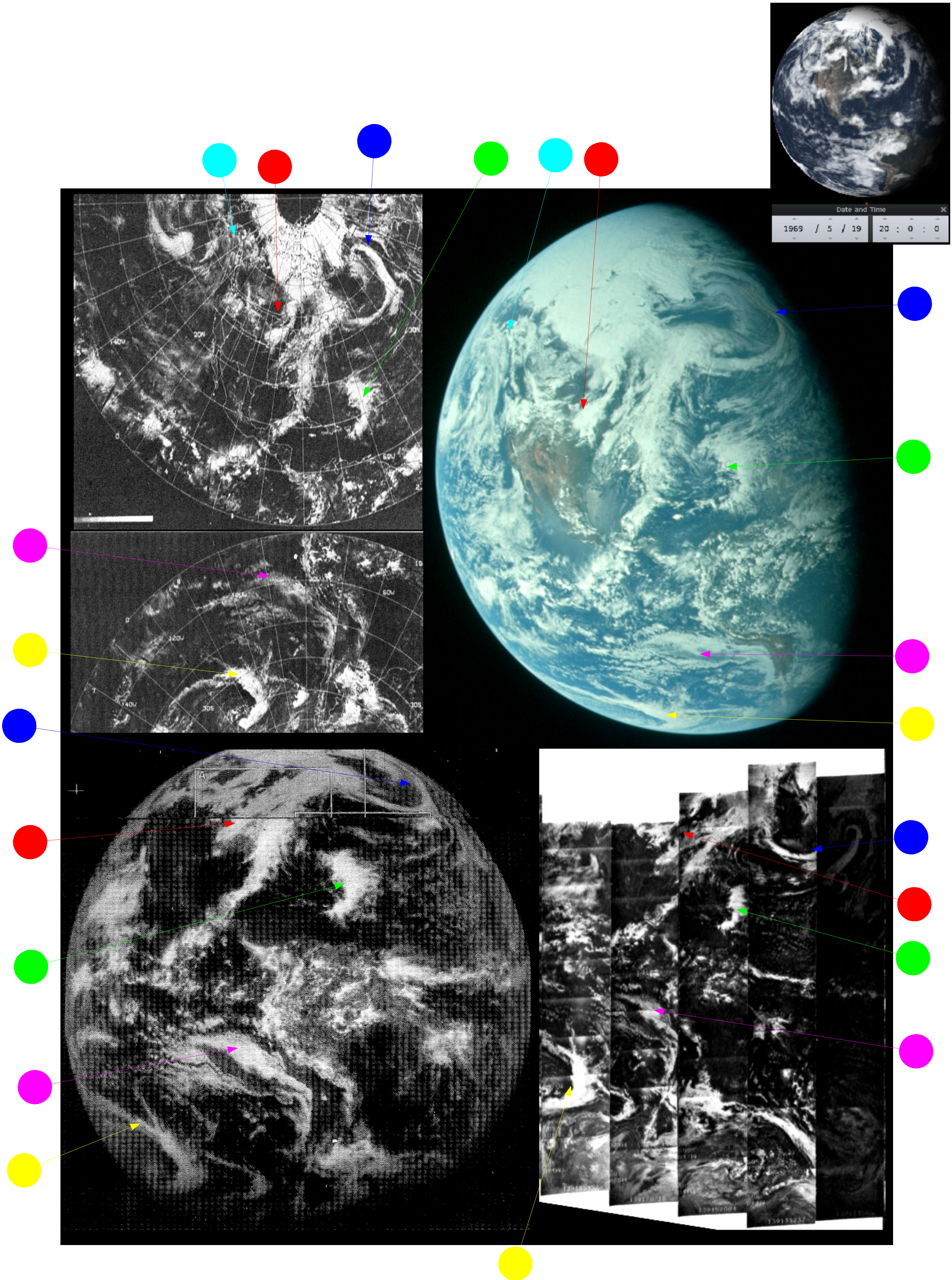


Figure 4.2.9 – ESSA9 (top left upper and lower), ATS-3 (bottom left) & NIMBUS 3 (bottom right) images from 19/05/69 compared with AS10-34-5036 and Stellarium estimate of time at terminator

The next image in magazine 34 (see figure 4.2.10) shows a further degree of rotation of the Earth.

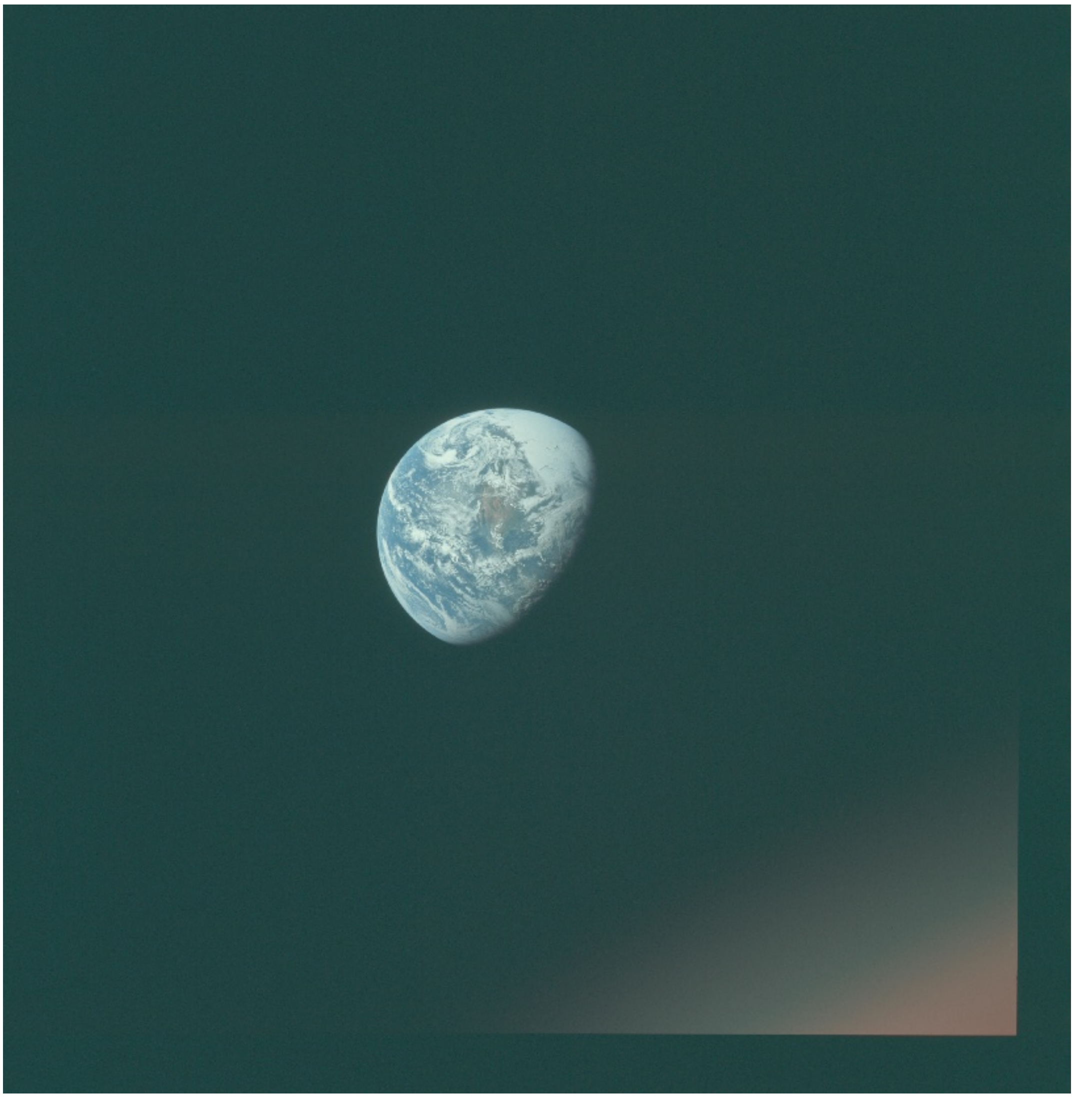


Figure 4.2.10: High quality GAP scan of AS10-34-5037. Low resolution source: AIA

South American has now largely disappeared, but north America is still visible. Some weather systems evident in figure 4.2.8 have no passed beyond the terminator, and there are new ones over the Pacific. The polar cloud mass is still evident, as is the system that runs from the north Atlantic down to central America.

Figure 4.2.11 shows a comparison of the satellite images of these weather patterns and the Apollo image, and the red, cyan, magenta and yellow arrows point to the same weather systems as in figure 4.2.9.

The weather systems are still obviously the same, although there are new systems appearing on the western limb as the Earth rotates, and the large spiral system has now disappeared over the terminator. As the same systems are in view, and they do not look the same on the 20th, they must still be from the 19th, and Stellarium puts the time at around 22:45 on that date. We already know the time of the ATS-3 image, and all that remains is to confirm that the NIMBUS orbit most matching the terminator is pass 474, which commenced at 15:39, while ESSA's most representative track is number 3, or pass 1030, which commenced at 19:06.

The next images of Earth in the sequence taken on the outward bound leg of the mission are actually on two different magazines, but will be skipped over as while they show clear rotation of

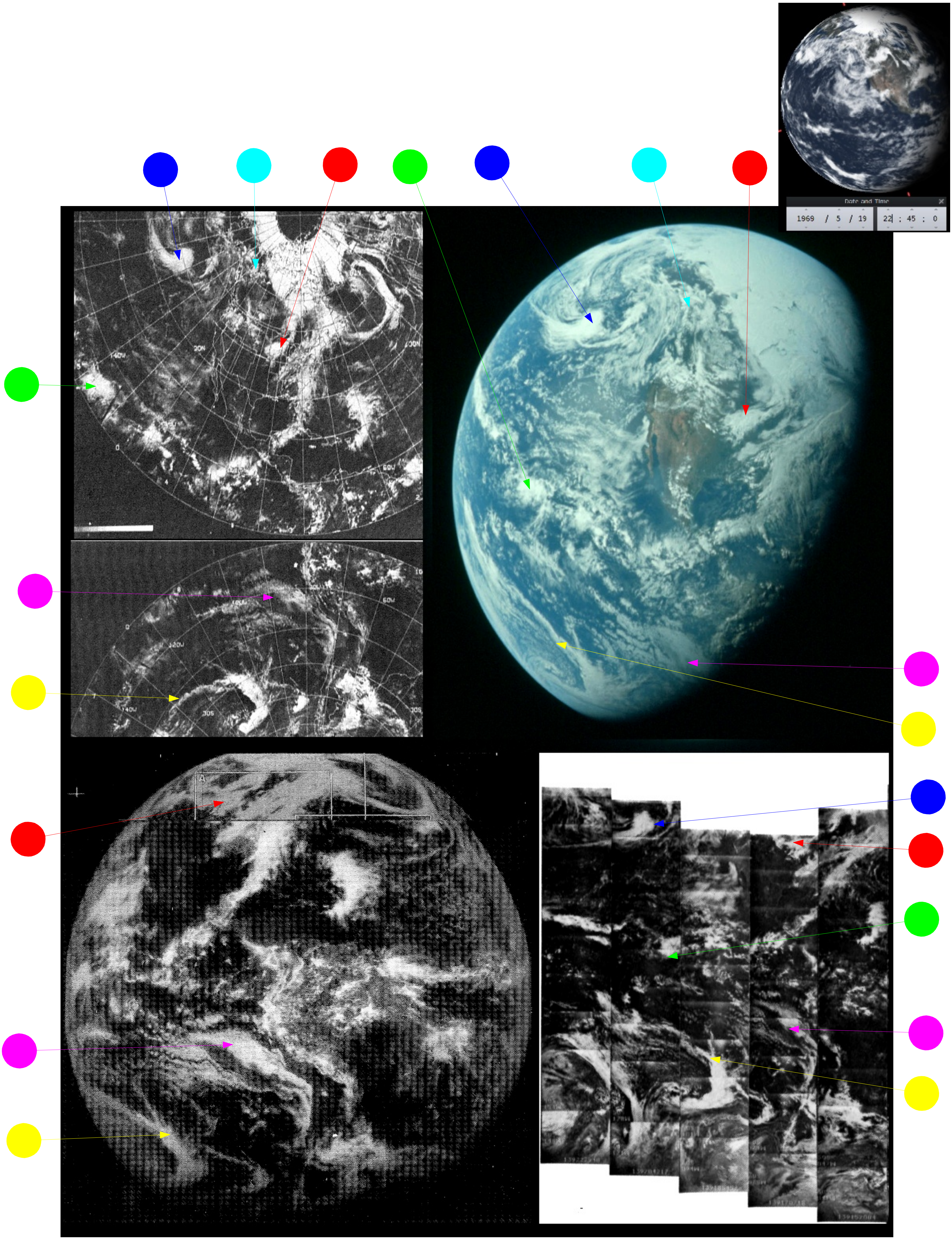


Figure 4.2.11: ESSA 9 (top left upper and lower), ATS-3 (bottom left) & NIMBUS 3 (bottom right) images from 19/05/69 compared with AS10-34-5037 and Stellarium estimate of time at terminator

the Earth, no real difference in weather systems can be seen. Stellarium estimates only about 45 minutes have elapsed since the previous image. The two images, AS10-35-5174 and AS10-34-5041 are shown in figure 4.9.12 so that you can at least see them and decide for yourself.. You can also check the mission transcript (available here: AFJ) where the crew describe the view of north America at 1 day 6 hours , 34 minutes or around 23:30 GMT.

Figure 4.9.12. High quality GAP scans of AS10-34-5041 (left) and AS10-35-5174 (right). Low quality versions here AS10-34-5041 and here AS10-35-5174

A little while later, we have an image from magazine 35 that shows a more significant degree of rotation, and therefore bringing new weather systems into view. Figure 4.9.13 shows AS10-35-5177. Figure 4.9.14 shows the satellite comparison.

Figure 4.9.13: High quality GAP scan of AS10-35-5177. Low quality version here: AIA

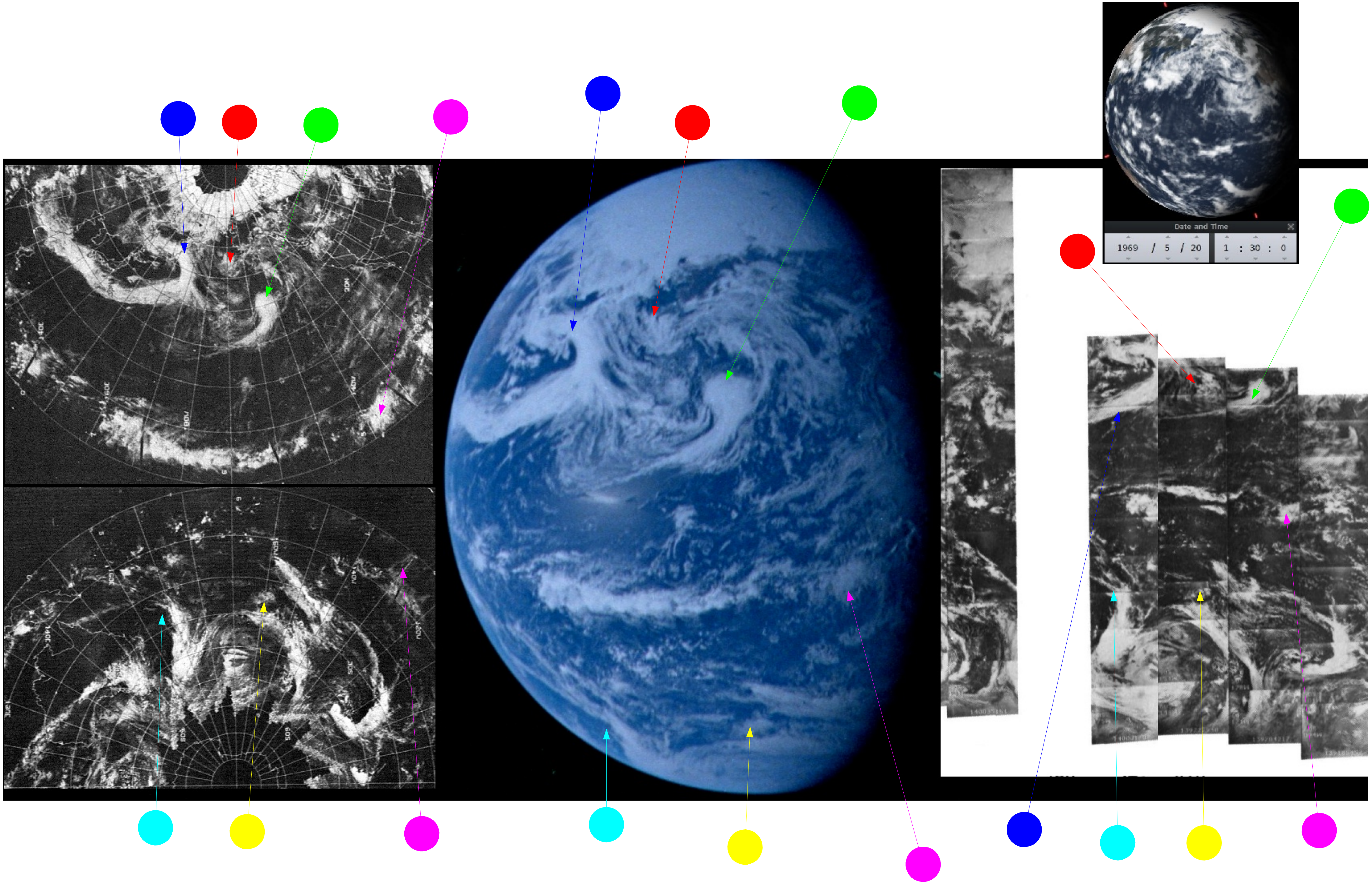


Figure 4.2.14: ESSA 9 (left upper and lower) and NIMBUS 3 (right) images compared with AS10-35-5177 and Stellarium estimate of time at terminator.

Stellarium sets the time at roughly 01:30 for this image, and shows the west coast of north America and Australia just in view. Close examination of the Earth shows that, beneath the thin cloud, the Americas are still there. Australia is more difficult to detect, but the bifurcated thin stream of cloud shown by the cyan arrow is off Australia's east coast at the point where it splits, and what appears to be a small fog bank off Sydney on the satellite photograph is just discernible on the very western edge of the globe.

The Earth, therefore, seems to be where it is supposed to be – a few hours ago the crew were describing north America and now it is only partially visible. Can the satellite timings match up with this suggestion? ATS is not available for this image as it doesn't cover anywhere visible. ESSA's image is still dated the 19th, but is now covering areas that were actually imaged on the 20th, and in this case the orbit that best approximates the line of the terminator is number 1032 (track 5, although in reality the terminator is probably between tracks 4 and 5), which commenced at 23:06.

The NIMBUS image used here is actually a hybrid of two day's passes. The 2 strips of images on the left of the NIMBUS part of figure 4.9.13 are actually from the image dated the 20th, and the remainder are from the image dated the 19th. The track best representing the terminator is number 475, which was commenced at 17:26 on the 19th.

After this image of the Pacific is taken there is a gap in photographs of any kind coinciding with a rest period for the crew. At 1d19h50m the crew are having breakfast and being given a summary of news from home, and they describe the view below:

"..here comes the world, Looking right over Suez cabal, Saudi Arabia, the Mediterranean, Africa, back into the parts of Europe...right now I'm looking at All of Africa, which is almost totally clear with the exception of a few clouds on the western side. I can see across the Straits of Gibraltar, some cloud cover just on the east side of the Straits. I can see Spain which is totally clear, Portugal, almost all of the Mediterranean except the north - north-west corner of the Med, Greece, Crete, Turkey, Italy. They all look clear from here. Saudi Arabia, back up into the Soviet Union, is partially clear in great areas and actually almost back into the parts of China where the terminator is, it's just sort of partly cloudy. There appears to be a big, long, wide swirl out into the Atlantic west of Spain. Generally, it looks like I can see Zanzibar. Generally, it looks like that whole part of Africa and eastward - north-eastward - is pretty clear today"

The time of this conversation translates to 12:50 GMT on the 20th, and there are two photographs taken on separate magazines that correspond with this time both in terms of where the terminator is, and in terms of what is visible below them.

AS10-34-5042 and AS10-35-5181 both show roughly the same scene of a largely clear Earth dominated by a view of Africa.

The image chosen for comparison with the satellite image is AS10-34-5042, and this is shown overleaf In figure 4.2.15a. Figure 4.2.15b shows a close up of the Earth part of the image compared with the same close up of AS10-35-5181, and figure 4.15c shows a further close up of the two images focusing on India.

The extreme close up of India suggests that AS10-35-5181 was probably taken slightly earlier than AS10-34-5042, as the latter shows the two prominent north-south bands of clouds slightly further away from the terminator. It's also worth noting the shadows cast by those two clouds, which is exactly what you would expect to see from clouds at sunset. In other words they are entirely consistent with where the Sun is in the sky back on Earth. The analysis of the chosen photograph is shown in figure 4.2.16.

Figure 4.2.15a) High Quality GAP scan of AS10-34-5042. Low resolution source: AIA

Figure 4.2.15b) AS10-34-5042 (left) compared with zoom of GAP scan of AS10-35-5181 (low resolution source for the latter at: AIA)

Figure 4.2.15c) Close up of AS10-34-5042 (left) and AS10-35-5181 (right).

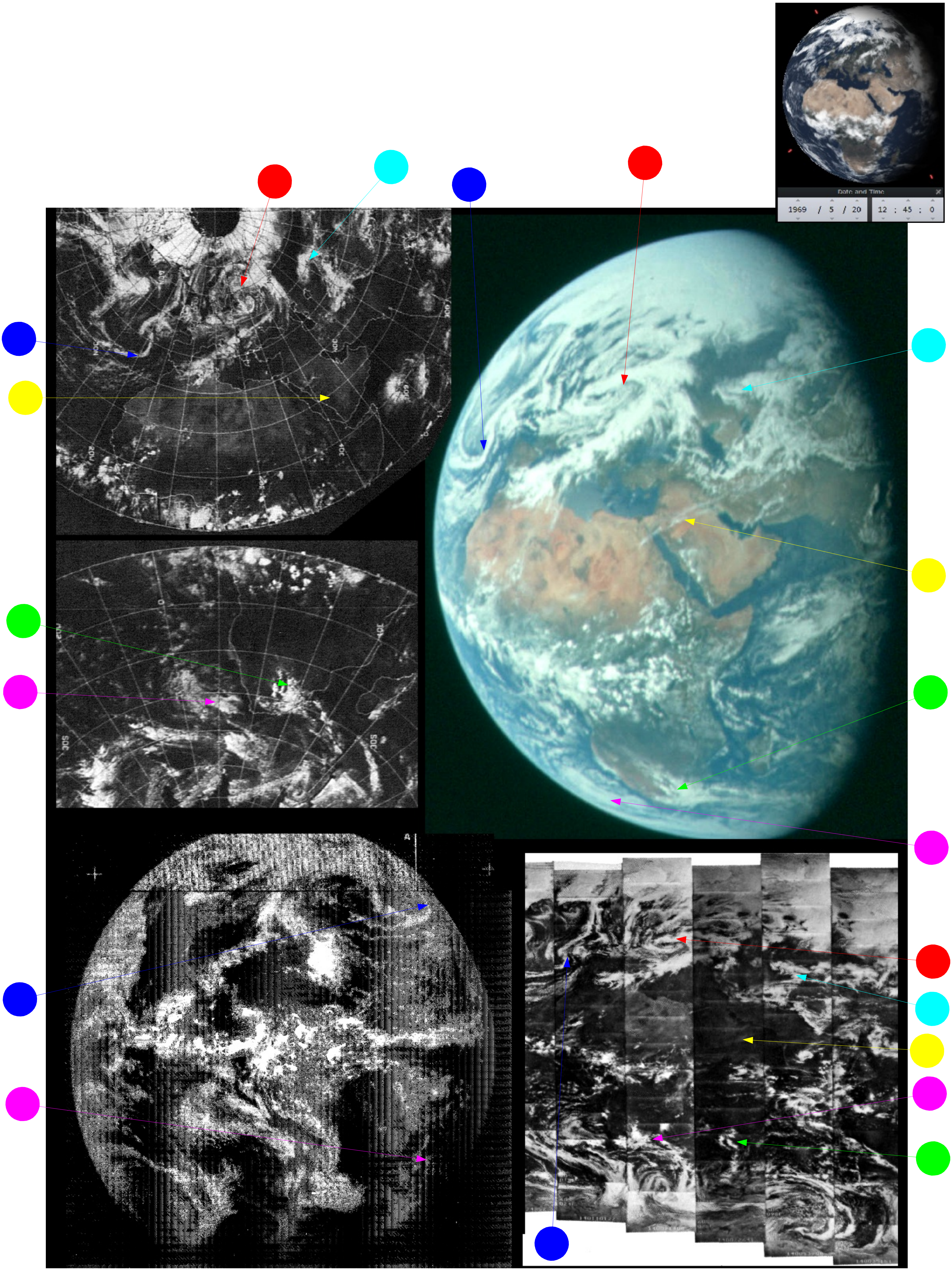


Figure 4.2.16: ESSA 9 (top left upper and lower), ATS-3 (bottom left) and NIMBUS 3 (bottom right) images compared with AS10-34-5042 and Stellarium estimate of time at terminator

The most obvious point to make about the preceding image is that it shows exactly what the astronaut was describing. The ATS image only just shows he very western edge of what they can see, and certainly doesn't show any of Europe or Arabia. At the the photograph was taken it would be several hours before those features would be visible on satellite mosaics. We can determine this by looking at the timings of the satellites concerned.

The ATS image shown here is taken just after 17:00 on the 20th. The ESSA image is complicated by the fact that the terminator line falls roughly along the line delineated by the last orbital pass on the image dated the 19th. The ESSA mosaic states that the last pass on that image is number 1037 (track 10), which commenced at 09:03. Track 11 (orbit 1038) passes along the west coast of India and is the the first image on the image dated the 20th, commencing at 11:08. While this is a good 90 minutes before the Apollo image was taken, the final part of the ESSA image covering what is visible in the Apollo photograph would not be imaged for another 5 hours.

The NIMBUS image is more straightforward, and the line of the terminator was covered by pass number 481 at 04:11 on the 20th, but again the final part of the area visible from Apollo wouldn't be imaged until 13:08 by orbit number 486.

About an hour after the image discussed above, Apollo 10 took another image of Africa (AS10-34-5048, low quality source available here: AIA . Little additional information is revealed by the image other than the obvious rotation of the Earth to hide India in darkness.

The next image to be scrutinised is another case where the same photograph exists on two different magazines. AS10-35-5187 and AS10-34-5049 both show exactly the same scene, and having examined them very closely the only conclusion that can be drawn is that they were both taken at exactly the same time. As for when that time is we have a little help from the mission transcript as well as Stellarium.

Stellarium puts the time at the terminator at around 17:30 GMT, and an hour before that in the transcript the crew describe being able to see the Suez canal. This is clearly not in shot in the Apollo pictures, so they must have been taken after that time. They are able to describe

“...cloud cover down along the coast there, down on the Mediterranean coast. You can see, almost see, I think, Gibraltar...and the Lisbon area over by Portugal seems to be clear. In France, Marseilles is open, and it looks like there's a little cloud cover in northern France. England is under clouds."

and when asked about the islands around Greece and Italy they say that

"..pretty close to the terminator right now...you can see the Nile, the Nile Valley really stands out and, of course, the Sahara desert is very clear. It looks like Lake Chad down there in the middle of the - middle of Africa.”

Again, the middle of Africa and the Nile are not visible in the image, although Greece and Italy are not quite at the terminator a the time they are speaking.

An hour after the Stellarium estimate they discuss the weather situation over north America, thunderstorms over Brazil, and also describe

"Coming out of the North Pole into the central Atlantic are some very weird, picturesque cloud formations, Swirls, not definite low areas, but big large swirls.”

We therefore have some distinctive weather features to look out for in the both the Apollo image, and in the satellite photographs taken on the same day.

The image on magazine 35 is also interesting as it is just a few exposures away from the first real close ups of the Moon, which would imply that it was taken close to LOI.

The image chosen for analysis is AS10-34-5049, mainly because it is slightly clearer than its equivalent on magazine 34. It is shown below in figure 4.2.17.

Figure 4.2.17: High quality GAP scan of AS10-34-5049. Low quality version here: AIA

Figure 4.2.18 show the comparison with the satellite images. ESSA's orbital data puts the time of the satellite passing over the west coast of Africa at 14:09 on the 20th (Track 1, or pass 1040), compared with NIMBUS orbit 485 over the same zone at 11:20. ATS-3 images were taken at 17:06 & 17:21. As with previous images, while the weather systems visible on the different images are obviously and definitely the same (to the point where the use of arrows to point them out seems both superfluous and ridiculous at times), there are subtle differences between them that indicate atmospheric flux over time.

One example is the system arrowed in yellow. In the NIMBUS image, the earliest of the three, this small group of clouds touches the west African coast and trends north-east inland. There is a clear gap in terms of longitude between those clouds and the mass of cloud over southern Spain. A few hours later in the ESSA image, it has moved slightly further inland and there is no longitudinal gap, and by the time of the Apollo image it has moved further inland still and there is an overlap with the clouds over southern Spain

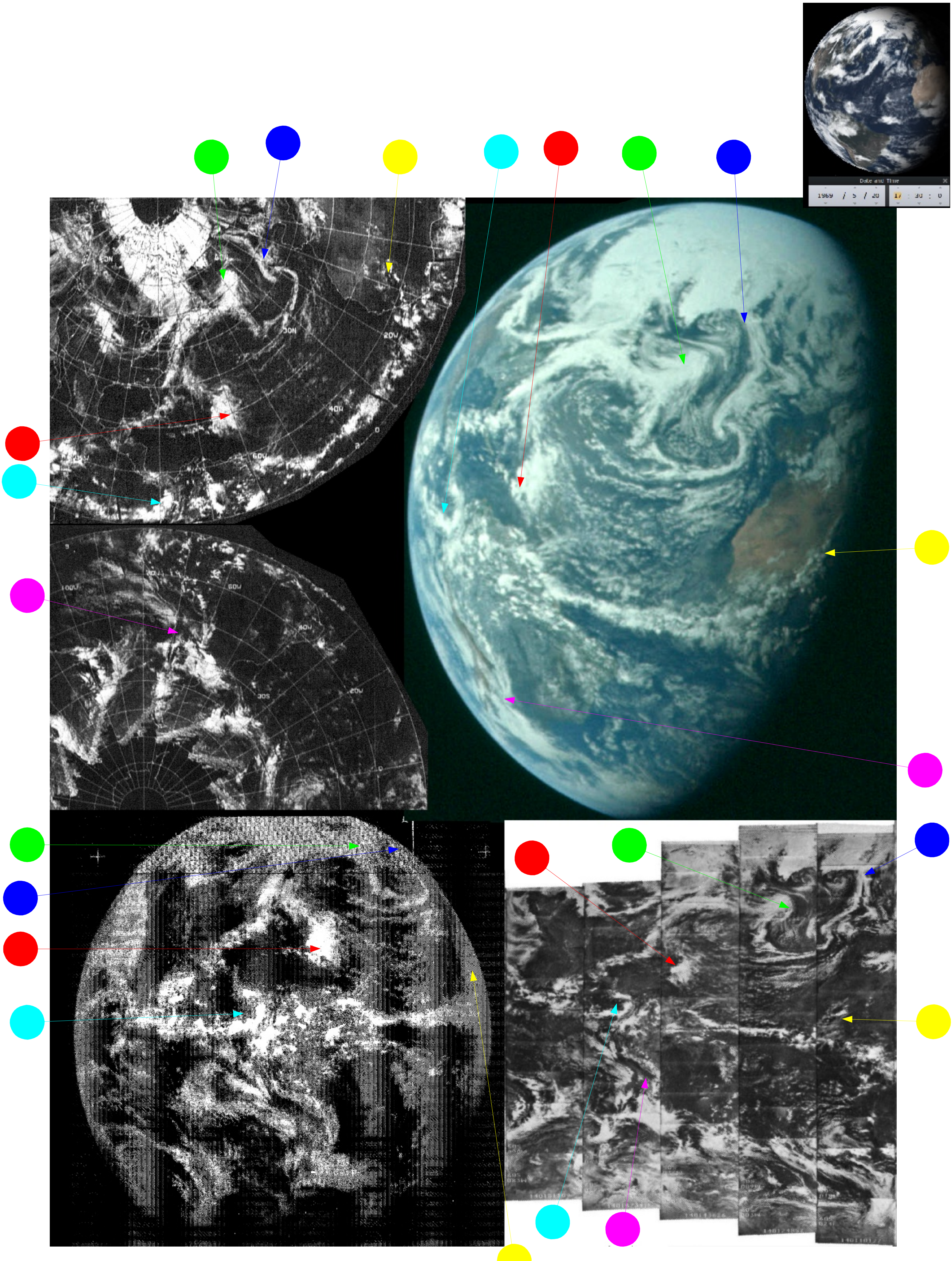


Figure 4.2.18: ESSA 9 (top left upper and lower), ATS-3 (bottom left) and NIMBUS 3 (bottom right) images compared with AS10-34-5049 and Stellarium estimate of time at terminator.

To illustrate this point further, a small section of each image from figure 4.2.9 has been selected so that they can be compared more clearly.

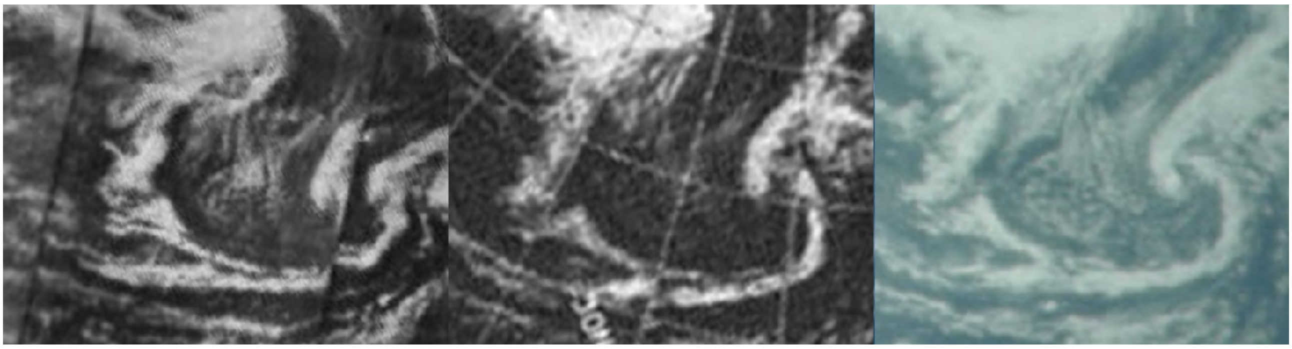


Figure 4.2.19: A section of ESSA 9 (middle) , NIMBUS 3 (left) and AS10-34-5049 on 20/05/69

Allowances need to be made for differences in image projection and quality, but as with other comparisons it is clear that these are the same cloud systems photographed at different times.

The next image of Earth taken is the sequence containing AS10-34-5052, but as in other cases for Apollo 10 it was only taken around 45 minutes after 5049, and reveals nothing new other than (to labour a point) the obvious rotation of the Earth. A low quality version of that image is available here AIA.

The next image where any significant degree of rotation has occurred is in AS10-34-5054. This is shown below in figure 4.2.20, and analysed on the next page in figure 4.2.21.

Figure 4.2.20: High quality GAP scan of AS10-34-5054. Low quality version here: AIA

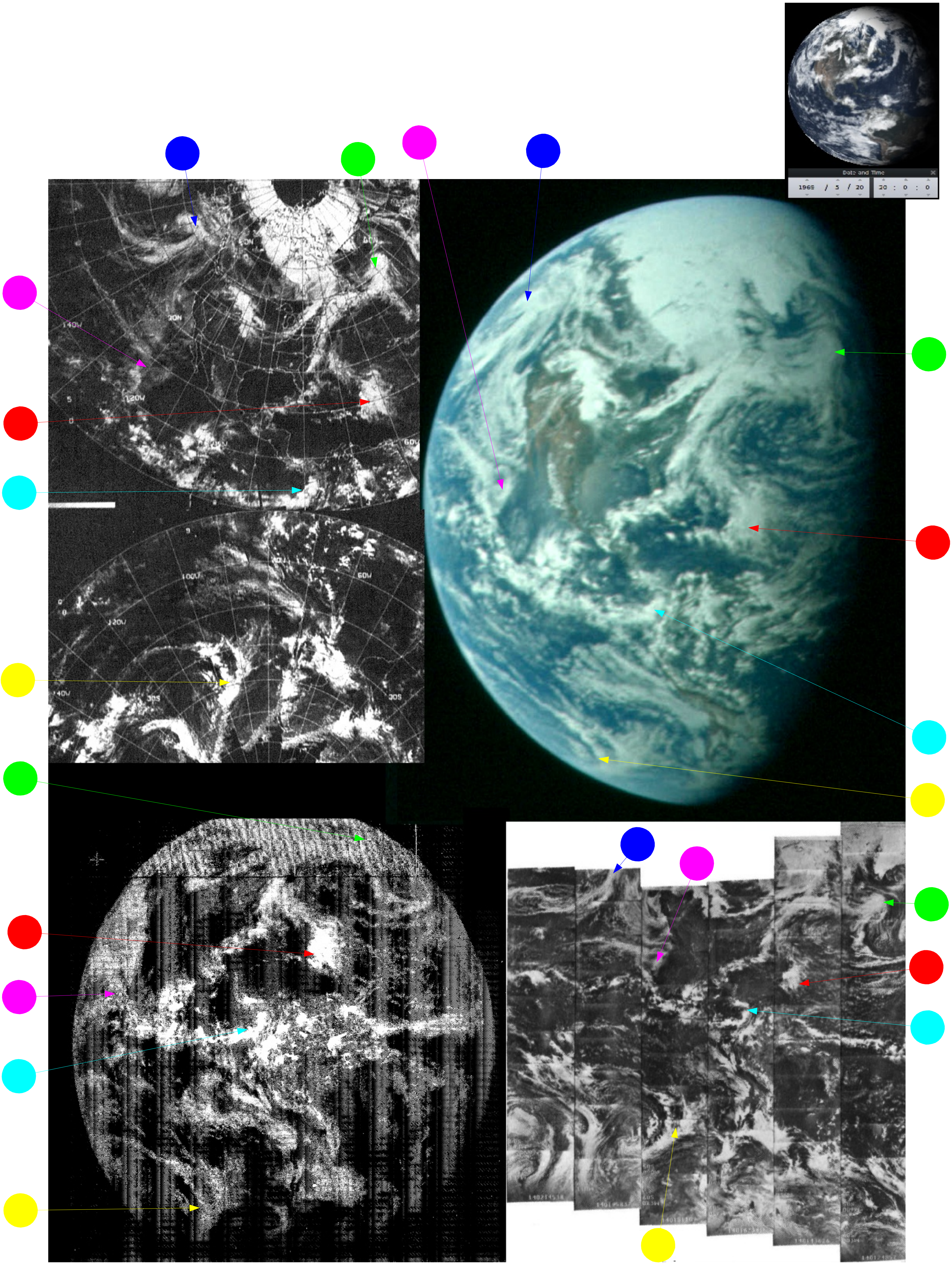


Figure 4.2.21: ESSA-9 (top left upper & lower), ATS-3 (bottom left) and NIMBUS 3 (bottom right) compared with AS10-34-5054. Red, green and cyan arrows are as in figure 4.2.18

No comment is made in the mission transcript (other than the crew saying that they have a fine view of Earth at roughly the right time!), so we are reliant on Stellarium for an exact fix, based on the position of the south American coast on the Apollo image, which gives an estimate of around 20:00 on the 20th, still 24 hours from LOI.

The time of the ATS image has already been stated as just after 17:00 on the 20th, and the rotation of the globe is such that it is now a close match with what can be seen in the Apollo image, with the exception of the system pointed out by the blue arrow, which is just out of shot. The ESSA & NIMBUS mosaics are still a good match and show all the weather systems visible on the Earth.

As far as their timings go, ESSA's most representative orbit at the terminator is track 2, which in this case is orbit 1041, commences at 16:04 on the 20th. NIMBUS' best orbit is pass number 487, which would have commenced at 14:55 on the 20th.

The next useful image in the set of Earth images is AS10-34-5055, but examination of that image (low resolution source available here: AIA) shows it to be only marginally different from AS10-35-5068, so it is this one that will be examiend next, and this is shown below in figure 4.2.22. In between 5055 and 5068 are several photographs of the LM, but it isn't clear what the purpose of these images was. The comparison with the satellite images is done in figure 4.2.23.

Figure 4.2.22: High quality GAP scan of AS10-34-5068. Low quality version here: AIA

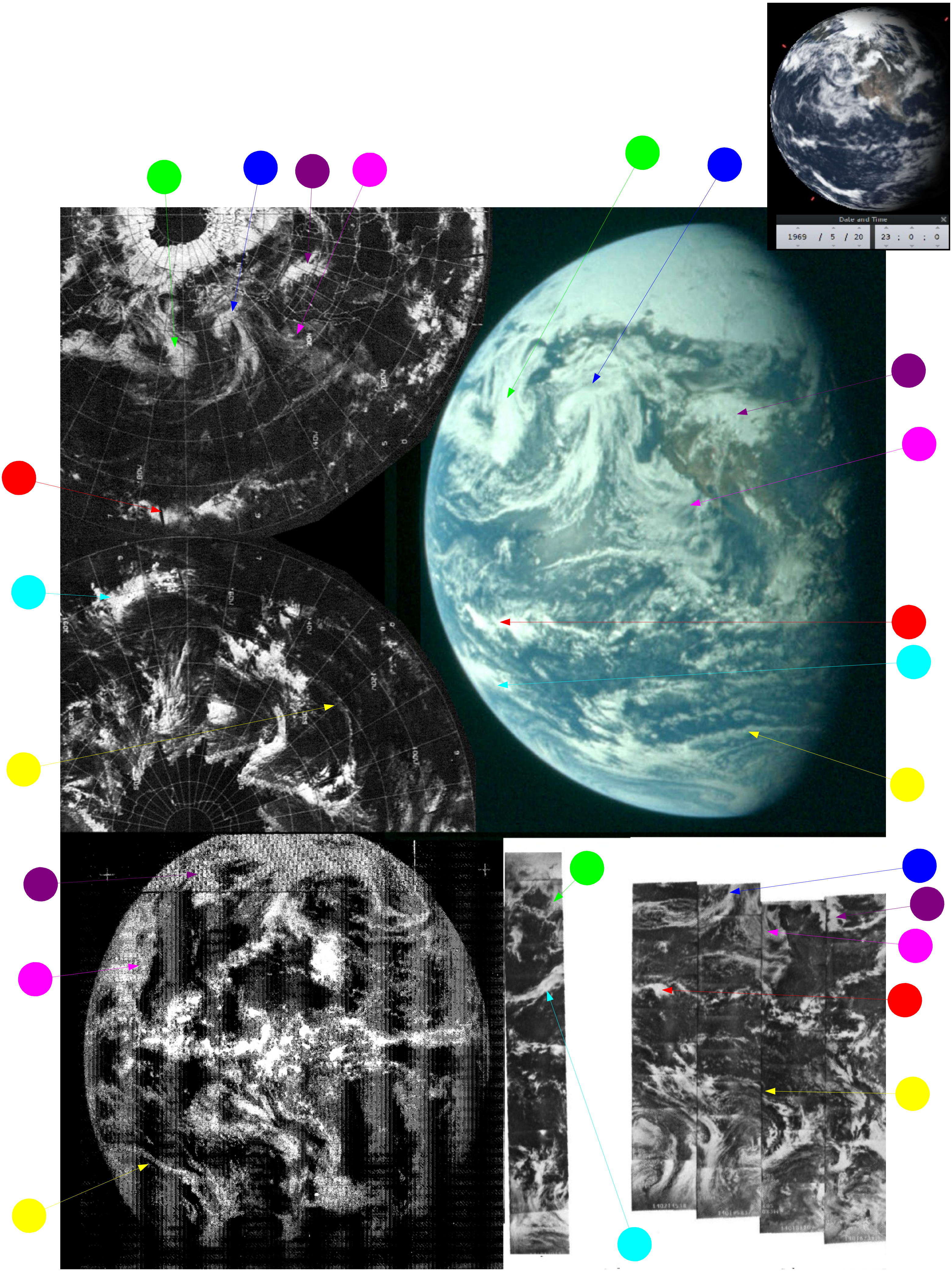


Figure 4.2.23: ESSA 9 (top left upper & lower), ATS-3 (bottom left) and NIMBUS 3 (bottom right) compared with AS10-34-5068. Magenta. Blue and yellow arrows as used in figure 4.2.21

The disappearance of most of south America beyond the terminator puts the time at 22:00, with the satellite images showing weather systems from the 20th. As far as the satellite timings are concerned, ATS is obviously from the same time as before, and nearly all of the land masses visible are now beyond its view.

ESSA's terminator position would have been on track 3 of its circuit, or orbit 1042, commencing at 18:09 on the 20th, but the area over the Pacific wouldn't be imaged for another hour after the photograph (track 6, orbit 1045). NIMBUS' track 489 was commenced at 14:55 on the 20th, and not all of the area in the photograph was imaged on the 20th.

There is also confirmation in the transcript concerning what the astronauts can see, largely thanks to the TV broadcasts they were making. At 53 hours and 6 minutes (53h06m), or 21:55, they describe the

"..storm centre over Alaska. It's finally started to rotate around and has developed into quite a system...most of the US is wide open today and will be in the middle of the Earth as you see it"

That system is the one identified by the green arrow.

At 53h23m (22:12 GMT), there is a more detailed description:

"..the eastern seaboard from the Carolinas on up, just on the seaboard, is going to be covered with clouds and then into the Atlantic...this morning I mentioned there was a long cloud bank from the north eastern part of the United States into Missouri. It looks like now that cloud bank goes from central Indiana up across Lake Erie, north north-eastward into Canada.. Michigan, Lake Superior and the mid-west are very clear except for that cloud and there's some clouds which appear to be over - oh maybe Kansas, Nebraska, I hate to say it, but Oklahoma...the west coast is clear and the south west is all clear."

Capcom confirms that this description matches their weather map. As this is about 45 minutes before the photograph was taken, slightly more of the east coast would be visible than is shown by the photograph.

Capcom have some problems trying to locate landmasses on the TV footage, and the lunar module pilot helps them out with more detail on the view over north America:

"If you follow up - but you might think it is the Gulf of Mexico there - and then go straight north you see a little bit of V in the clouds and there's one going off to the right, and a little thin sliver going to the right...goes from Indiana on through the north-east part of the country; and then the bigger blob that forms the left-hand side of the V is over the north-central United States and then right smack in the centre of the V is Lake Superior and Lake Michigan"

From this description that the cloud mass he is describing is the large mass over the northern US identified by the purple arrow.

At 53h45m (22:45 GMT), shortly before the photograph was taken, the describe at:

"...maybe about 10 o'clock on the globe, you will see a funny cloud pattern that sort of looks like a sea serpent of some sort with his beak pointing to the right. That cloud pattern that Tom was referring to up in the Alaska area"

and they are evidently describing the system pointed out by the blue arrow.

The next photograph in the series showing rotation of the Earth is AS10-34-5070, and is shown below in figure 4.2.4.

Figure 4.2.24: High quality GAP scan of AS10-34-5070. Low quality source here: AIA

The comparative analysis with the satellite images is shown on the next page in figure 4.2.25.

The quality of the image is such even without zooming in it is possible to see that the system identified by the blue and green arrows in the previous analysis are still visible in this one, but the systems shown by the purple and magenta arrows have moved beyond the terminator, and are no longer visible. There is no need to use the ATS image in the analysis, as in there is only the fog banks off the west coast of northern America that is still visible on it.

In terms of when the image was taken, Stellarium suggests a time of around 01:30 on the 21st, at which point the crew were roughly at the point where the Moon & Earth appeared the same size to them, and not far off the point where they passed from the Earth's gravitational sphere of influence and into that of the Moon's.

ESSA's most representative orbit for the terminator is track 5, or pass number 1011, which commenced at 22:00 on the 20th. NIMBUS' pass for the same area is number 490, commenced at 20:17 on the 20th.

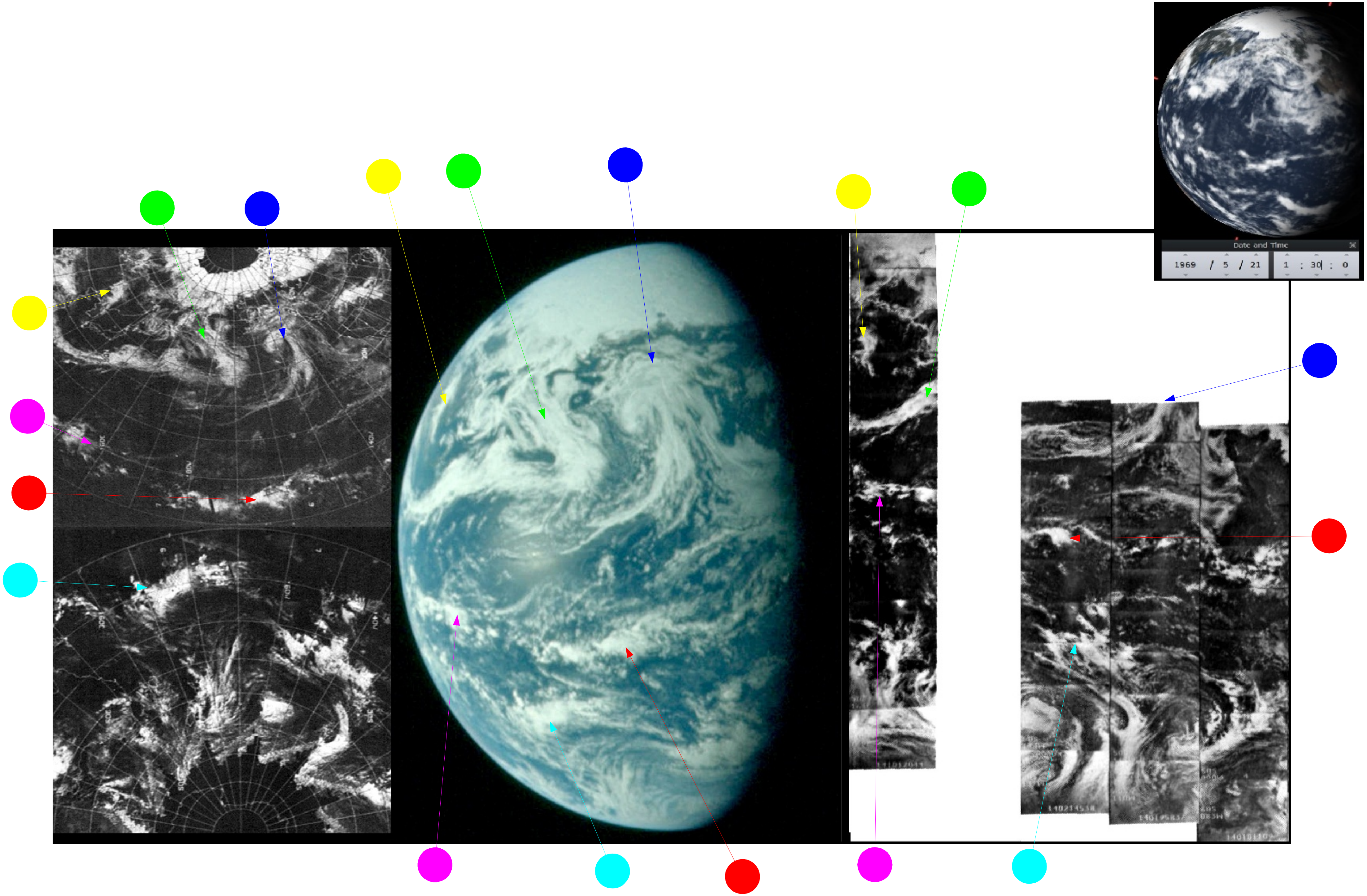


Figure 4.2.24: ESSA 9 (left) and NIMBUS 3 (right) images compared with AS10-34-5070 and Stellarium estimate of time at terminator. Green, blue, red and cyan arrows identify the same cloud systems as 4.2.22

Not long after the preceding image was taken, the crew entered a rest period, and it is some time before any new photographs are taken. The next image of Earth in magazine 34 shows a view of Africa, which obviously means some time has elapsed on the ground. This image is AS10-34-5071, and is almost identical to image AS10-35-5190. For the sake of continuity, 5071 will be used and is shown below in figure 4.2.25. AS10-35-5190 can be viewed as a low quality image here: AIA . 35-5190 is the last image in that magazine before the lunar surface in close-up begins to appear.

Figure 4.2.25: High Quality GAP scan of AS10-34-5071. Low quality version here: AIA

Figure 4.2.26 shows the analysis, and the most obvious weather systems visible are those in the northern hemisphere, particularly the striking spiral off the coast of Africa (red arrow), and the complex frontal system indicated by the blue and green arrows. Neither of these features were evident on the previous day's satellite images, although they are obviously a development of the systems visible in figure 4.2.18 from the previous day.

Stellarium suggests a time at terminator of around 16:15 on the 21st. South America is visible in the Stellarium image, but it is difficult to spot in the Apollo image until it it is spied under a thin layer of cloud. The yellow arrow points to a triangle of cloud that will be more visible in later images.

ESSA would have imaged the terminator area in track 12 of its orbit. As the image dated the 21st starts with the area covered by track 11 onwards, this means that orbit 1051 is relevant pass, commencing at 12:07 on the 21st. NIMBUS' equivalent is orbit 497, commenced at 08:49 on the 21st.

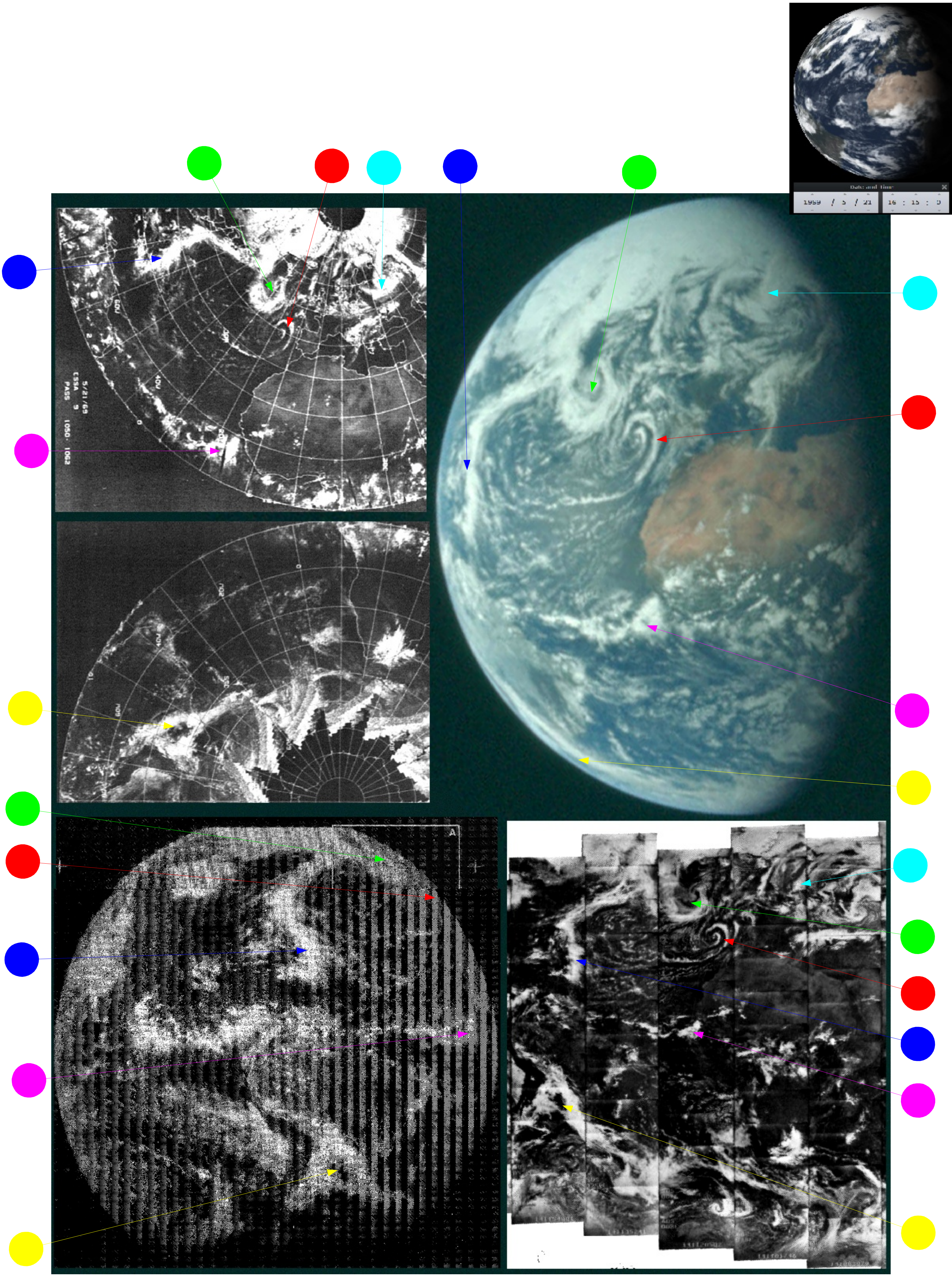


Figure 4.2.26: ESSA 9 (top left upper & lower), ATS-3 (bottom left) & NIMBUS 3 (bottom right) compared with AS10-34-5071 and Stellarium estimate of time at terminator.

One final photograph can be examined before coming to those featuring the Earth with the lunar surface, and this is AS10-34-5072, the last in this magazine before pictures of the lunar surface are featured. This photograph is shown below in figure 4.2.27, and analysed in figure 4.2.28 overleaf.

Figure 4.2.27: High quality GAP scan of AS10-34-5072. Low quality source here: AIA

Stellarium suggests an image time for Apollo of around 19:00. The ESSA orbit for the mid-Atlantic region is number 1053 (track number 1), which was at 15:08. The NIMBUS 3 track for the same area is orbit 500, which was started at 14:11. Again the NIMBUS orbit precedes the other two images. Conversely, the weather systems identified by the blue and green arrows were taken at the roughly same time as the Apollo image. Orbits 501 & 502 by NIMBUS occurred at 15:59 and 17:46, while orbits 1055 & 1056 (tracks 3 & 4) were at 19:08 and 21:03. ATS-3 images were taken at 17:17.

Between taking the image examined in figures 4.2.26 and 4.2.28, there was a brief description of the view from space. At 17:27 GMT on the 21st, the mission commander tells capcom about:

"You can see the south Atlantic ocean there and the orange spot to the right is the North African continent. You can see basically the Sahara desert and, above that, the Mediterranean Sea. The rest of the world is pretty much encased in clouds. The solid cloud cover that's covered the North Pole, and most of Europe, is still with us today...the Sahara desert, the Atlas Mountains, Morocco, Libya we can see from here...The night time – the terminator has cut across the Suez Canal and most of Egypt and is now covering most of South Africa....you can see Brazil, but it is covered mostly with clouds at this time."

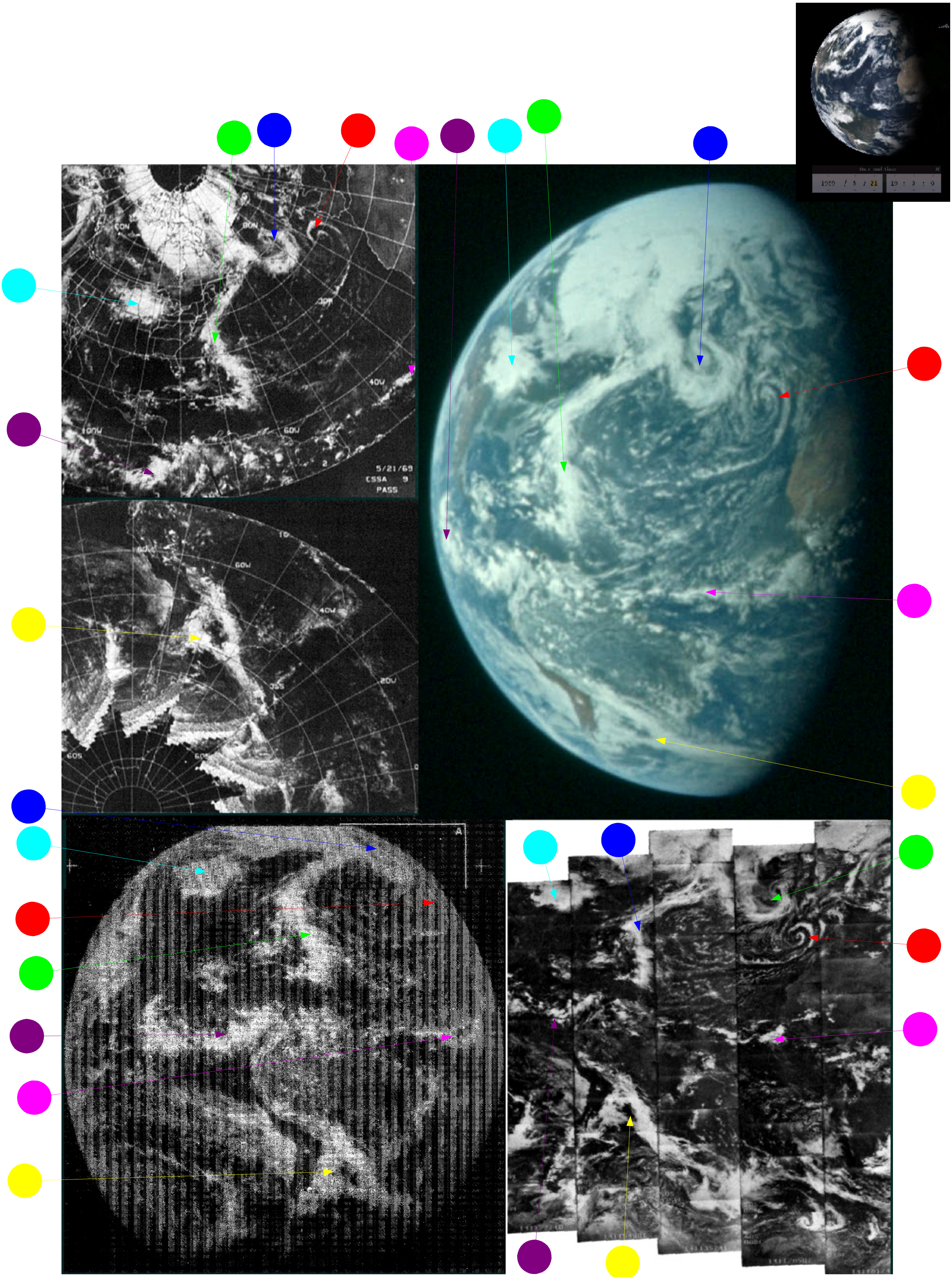


Figure 4.2.28: ESSA 9 (top left upper & lower), ATS-3 (bottom left) and NIMBUS 3 (bottom right) images compared with AS10-34-5072 and Stellarium estimate of time at terminator

Again the description of the scene is accurate, with Egypt now in darkness and Brazil very much under light cloud.

A couple of hours after AS10-34-5072 was taken, the crew performed the LOI manoeuvre, followed 4 hours later by a circularisation manoeuvre that change the orbital path from a much wider ellipse to one where the distance from the orbiting craft to the surface is more constant.

Over the next 24 hours the crew completed a variety of system checks in the LM, before finally undocking the LM from the CSM and the two craft began orbiting separately. The LM ascent and descent stages were separated just as they would be in a landing mission[1]. A serious problem occurred during this latter separation after a switch was placed in an incorrect position. This caused a considerable amount of what NASA describe as 'anomalous motion' that put the mission at great risk of failure.

During this period, no photographs of Earth were taken – mostly because the crew were somewhat pre-occupied with other duties and with photographing the lunar surface. There were TV broadcasts and images taken by the DAC which will be examined in the next section.

Once the ascent stage and the CSM were re-united, the astronauts were able to turn their attention to capturing images of Earth during the numerous Earthrises seen during the rest of the mission.

The next few images will look at a sequence of four photographs taken during Earthrises over the remaining orbits of the 23rd and 24th of May.

The Apollo images are AS10-27-3889, AS10-35-5223, AS10-35-5230 and AS10-35-5239. The images were chosen because they are from 4 series of images taken in separate orbits around the Moon,.as can be seen on the two Apollo Image Atlas pages of those magazines.

http://www.lpi.usra.edu/resources/apollo/catalog/70mm/magazine/?27

http://www.lpi.usra.edu/resources/apollo/catalog/70mm/magazine/?35

The first series of images in magazine 35 appear to have been taken at the same time as the first set of Earthrise images in magazine 27. This can be determined by looking at the distance of weather systems from the terminator. Image AS10-35-5213 (source: AIA) is one example of magazine 35, and this should be compared with AS10-27-3889. These will be given in order of the orbit in which they were taken, an order derived from the Stellarium calculations of the image times, as well as by inference from the order of other photographs in the magazines.

AS10-27-3889 appears just after a sequence of photographs showing the CSM taken from the LM and must therefore have been taken after 19:36 on 22/05/69, as this is when the timeline records that separation. As the TEI burn was started on 24/05/69 at 10:25, all Earthrise images must have been taken before that time.

The Apollo images, with their associated Stellarium insets, are given in figures 4.2.29– 4.2.32. The photographs comparing ESSA & NIMBUS images are given in figures 4.2.33 – 4.2.36. Figure 4.2.20 shows all 4 Earthrises compared with the ATS-3 image.

Analysis of these 4 pictures presents useful evidence in support of the Apollo missions in two ways. Firstly, there is the matching of satellite images to Apollo photographs. The second is the timing of the photographs in relation to the length of time involved in a lunar orbit.

1 While other ascent stages crashed back into the moon, the Apollo 10 ascent stage is still in orbit around the sun..

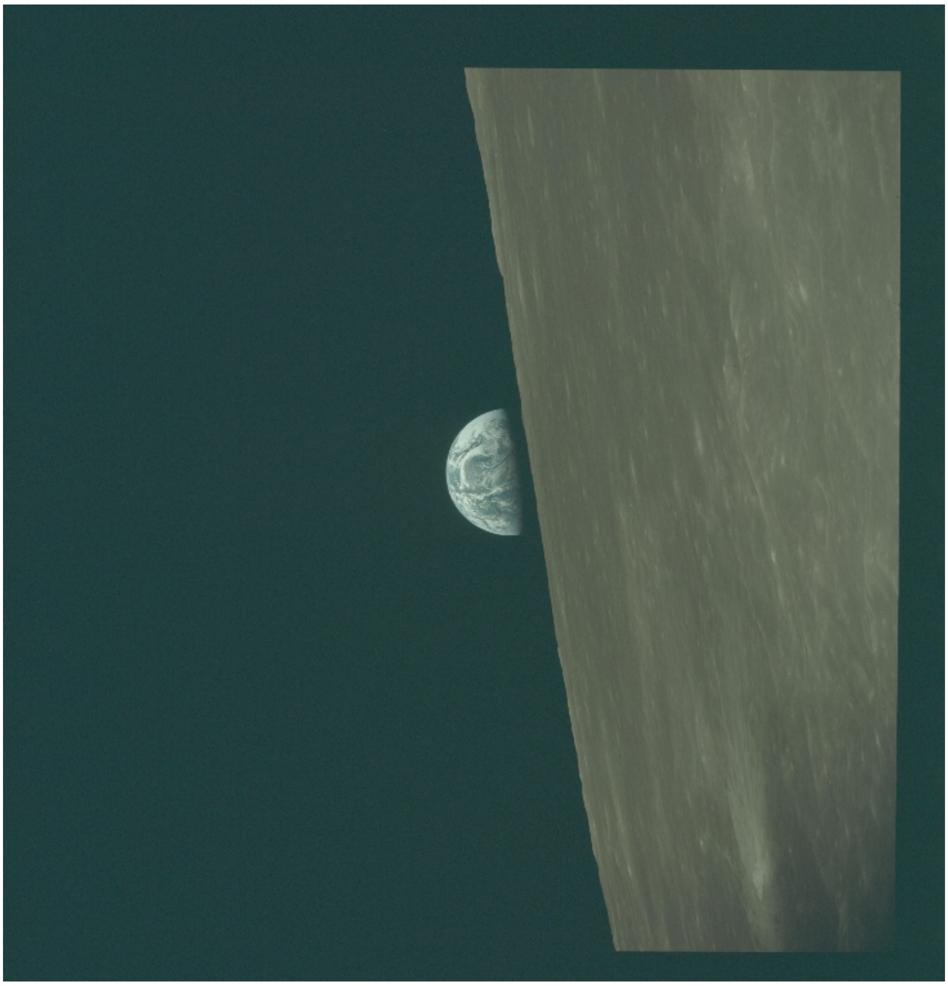


Figure 4.2.29: High quality GAP scan of AS10-27-3889. Link to low quality source: [AIA]

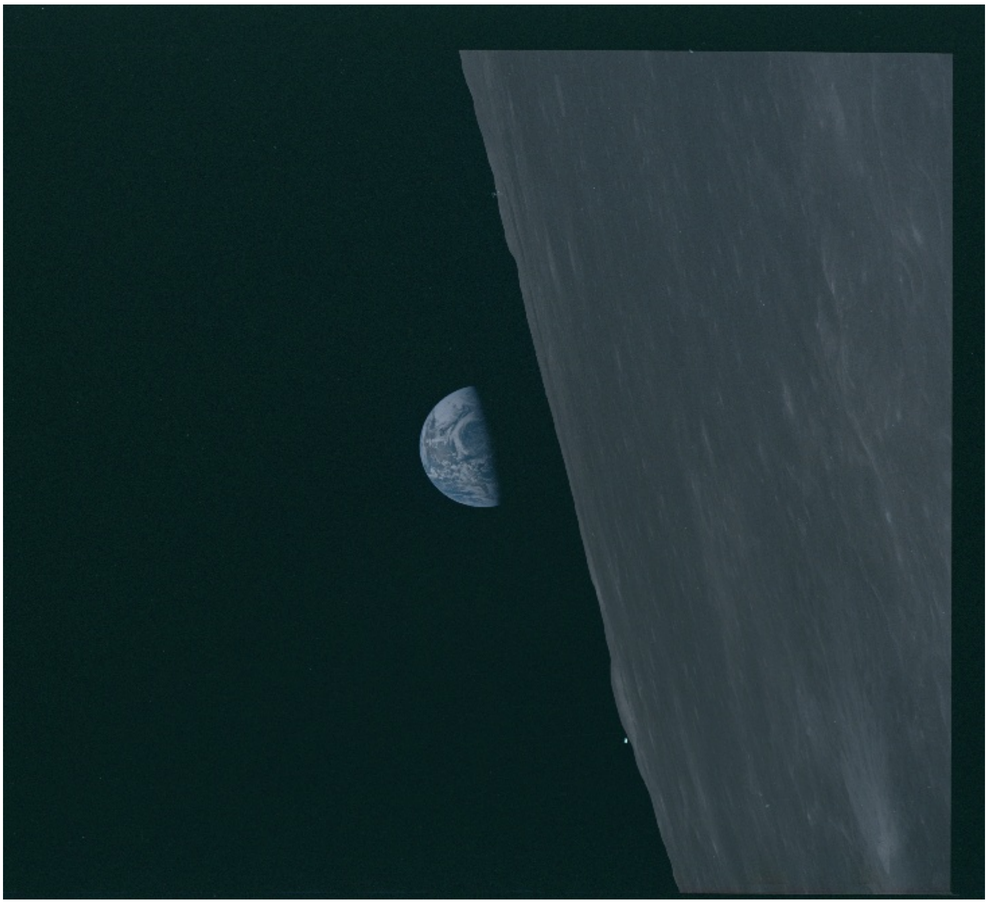


Figure 4.2.30: High quality GAP scan of AS10-35-5223. Link to low quality source: [AIA]

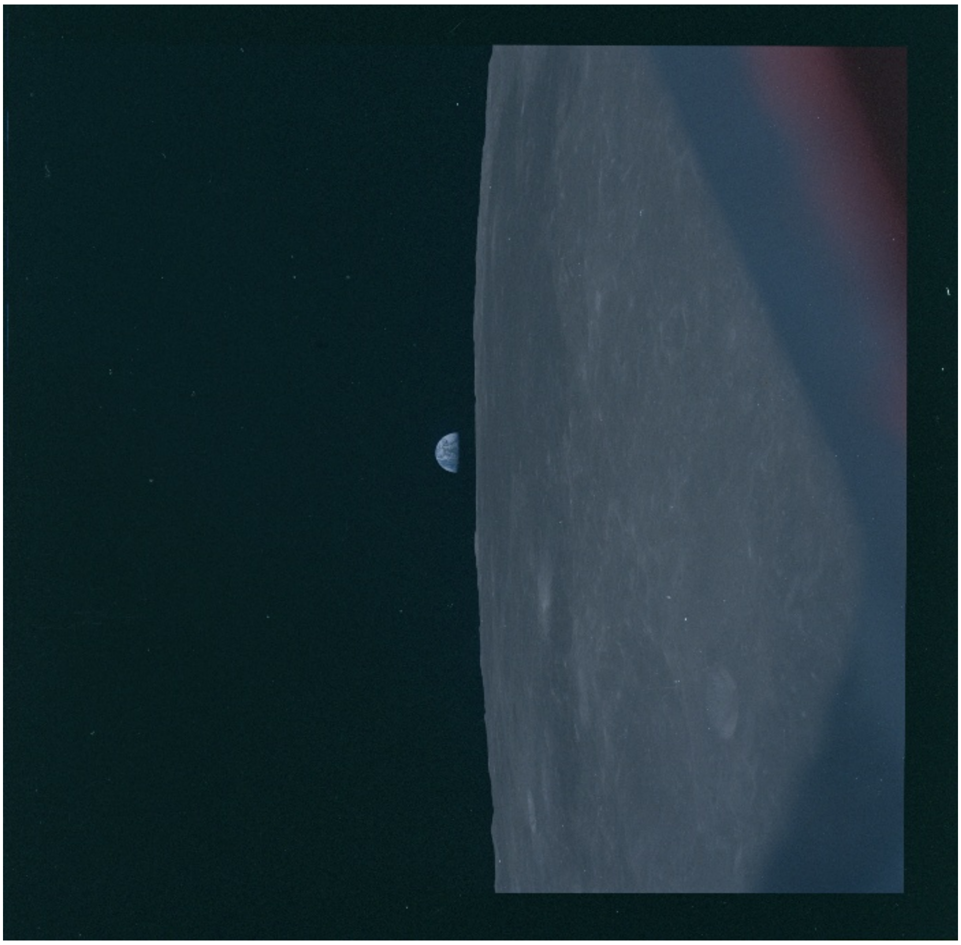


Figure 4.2.31: High quality GAP scan of AS10-35-5230. Link to low quality source: AIA

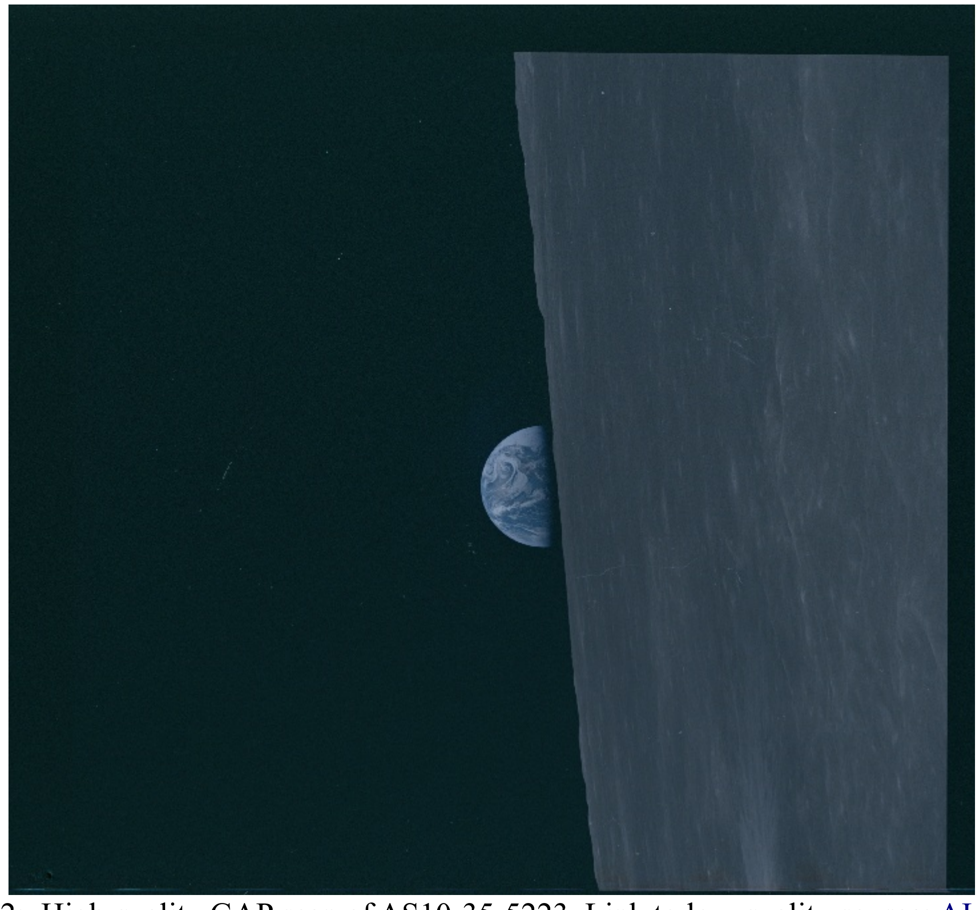


Figure 4.2.32: High quality GAP scan of AS10-35-5223. Link to low quality source: AIA

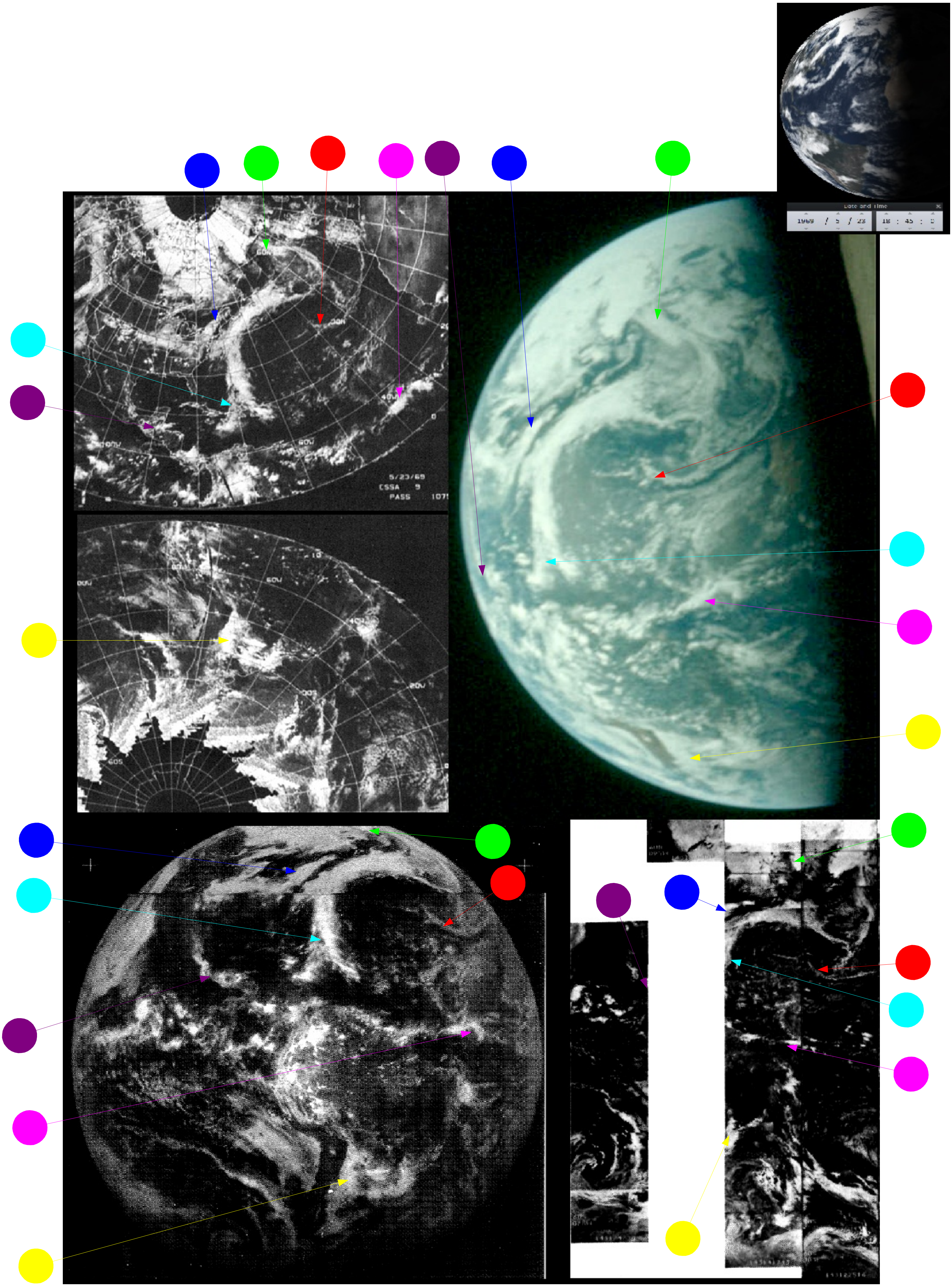


Figure 4.2.33: ESSA 9 (top left upper and lower), ATS-3 (bottom left) & NIMBUS 3 (bottom right) compared with AS10-27-3889 and Stellarium indicator of time at terminator.

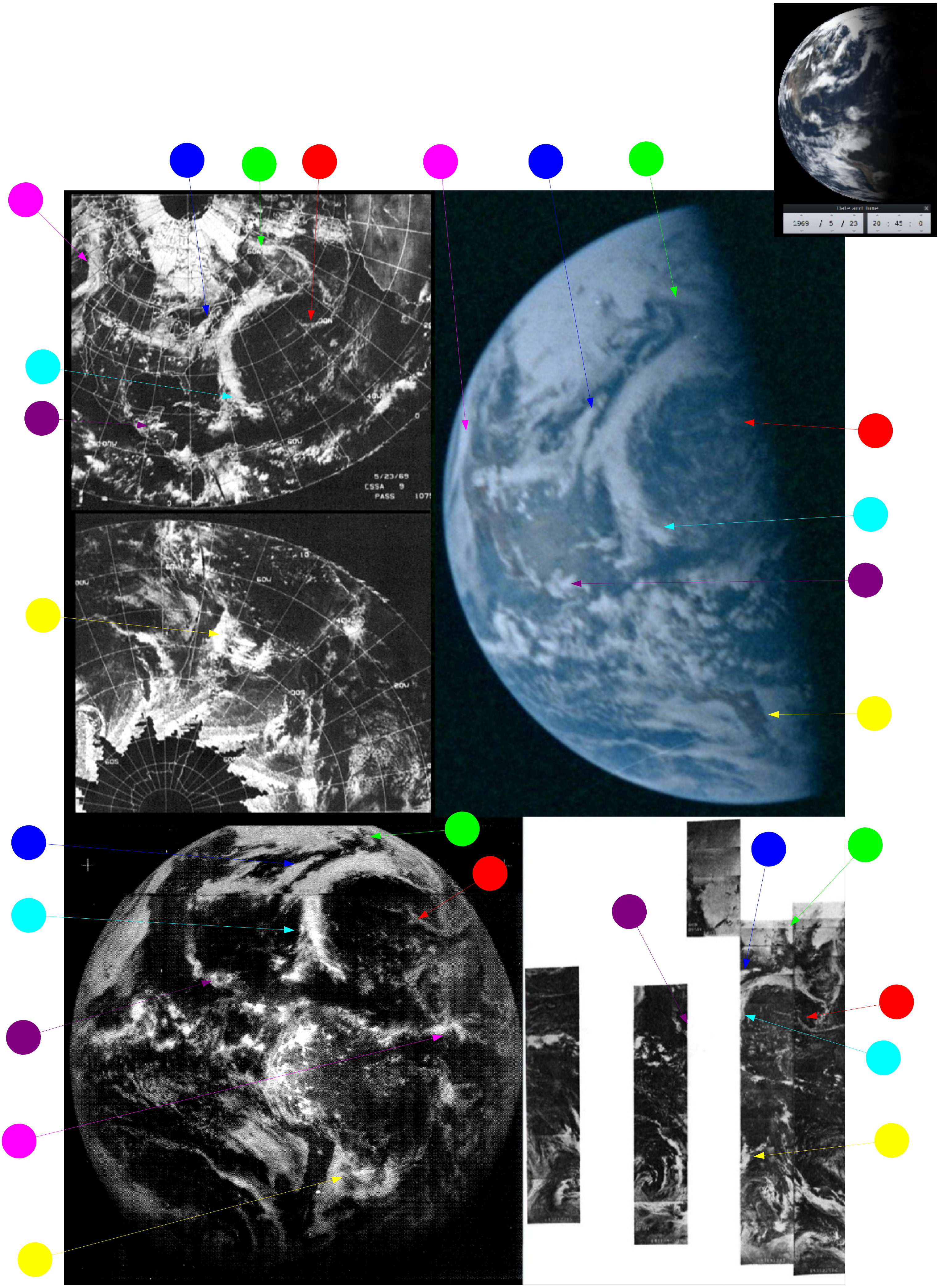


Figure 4.2.34: ESSA 9 (top left upper and lower), ATS-3 (bottom left) & NIMBUS 3 (bottom right) compared with AS10-35-5223 and Stellarium indicator of time at terminator.

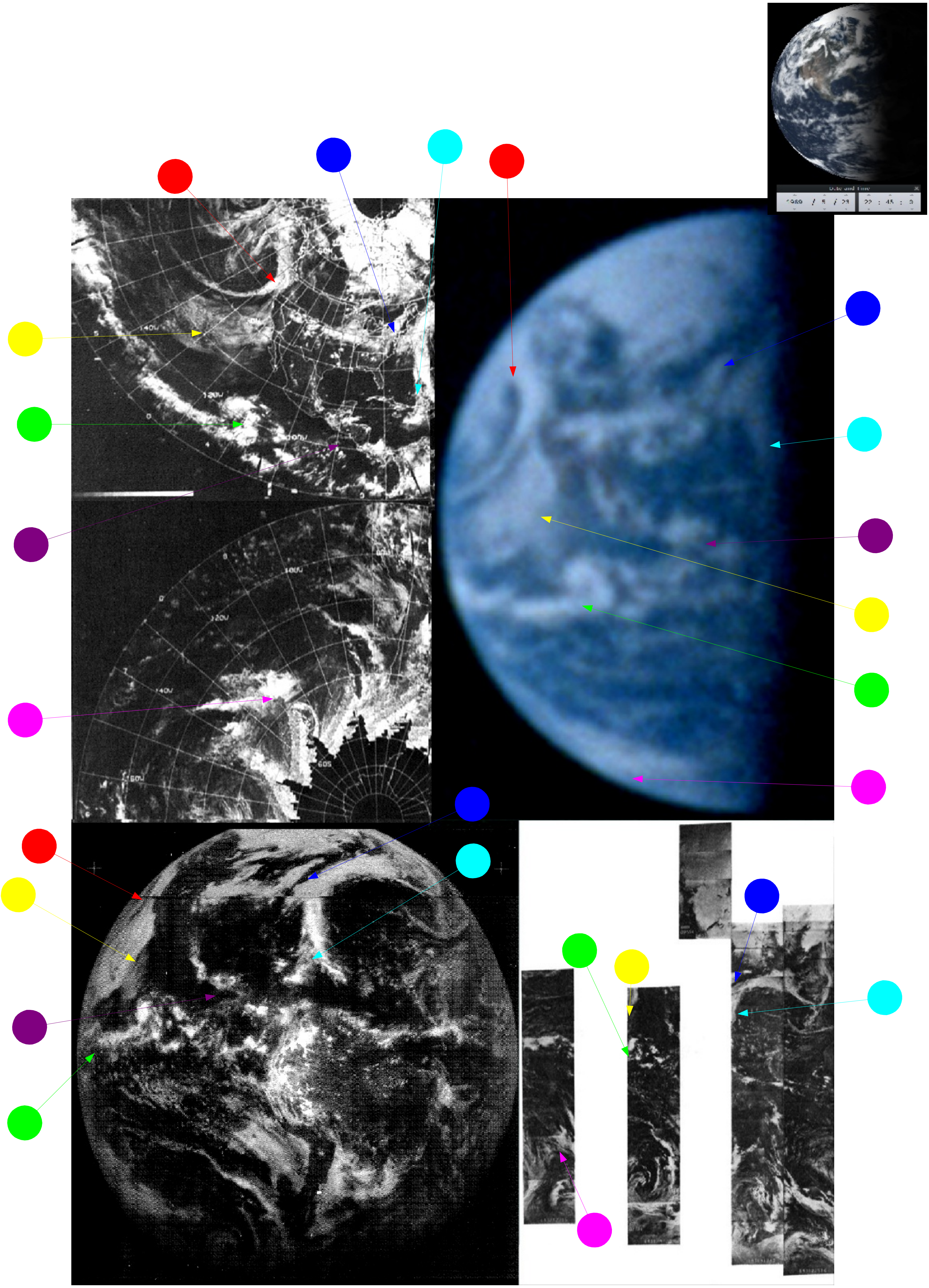


Figure 4.2.35: ESSA 9 (top left upper and lower), ATS-3 (bottom left) & NIMBUS 3 (bottom right) compared with AS10-35-5230 and Stellarium indicator of time at terminator.

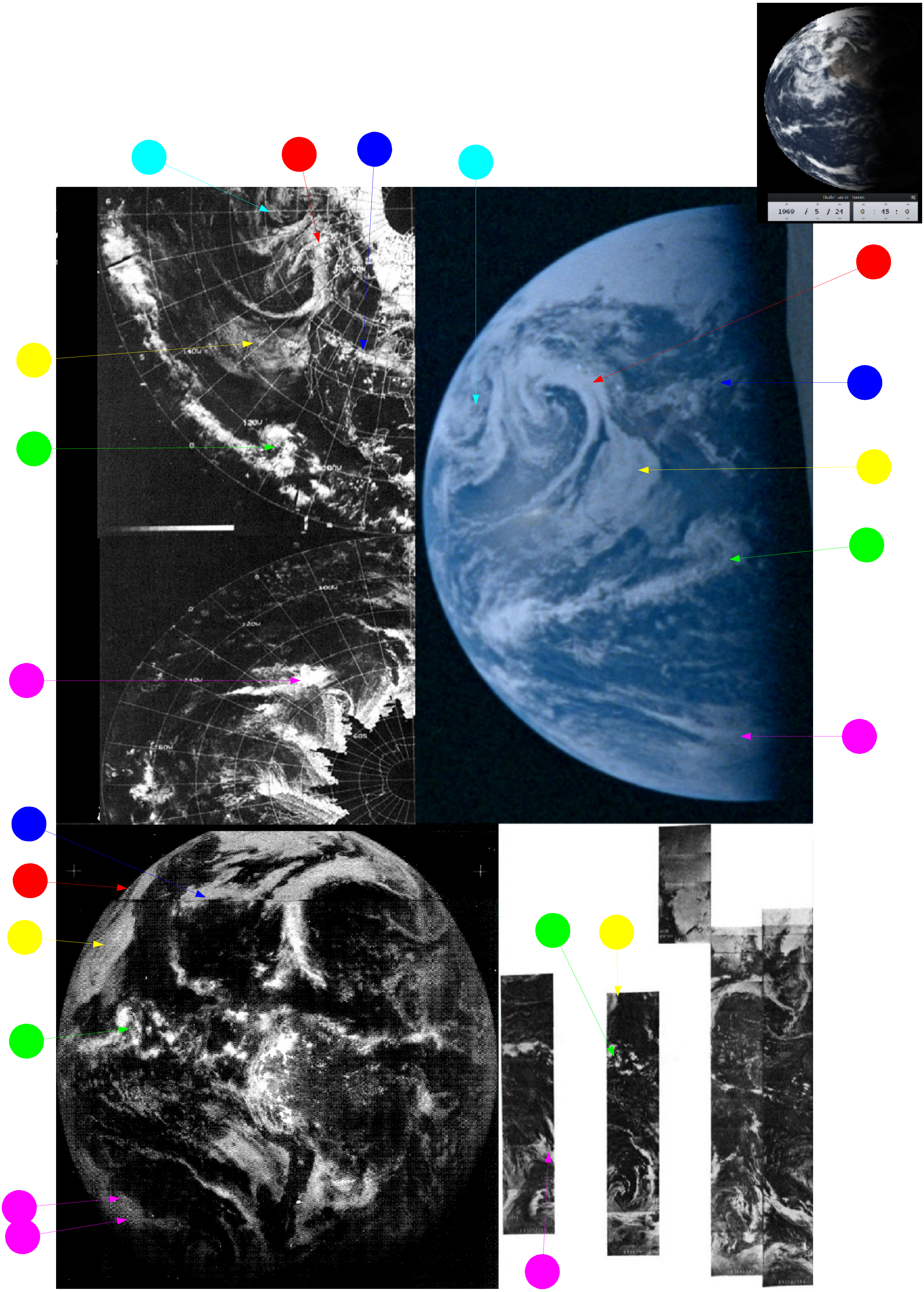


Figure 4.2.36: ESSA 9 (top left upper and lower), ATS-3 (bottom left) & NIMBUS 3 (bottom right) compared with AS10-35-5239 and Stellarium indicator of time at terminator.

The first image in the sequence, AS10-27-3889 (figure 4.2.33), can be timed by Stellarium at around 18:45. The most visible weather system in the photograph the long λ or fishtail shaped pattern stretching from the Caribbean to the mid-north Atlantic, a feature that is only visible in that formation on the 23rd. To the west of this system is a band of cloud running up the east coast of the USA, and extending westwards from this is a band of cloud running across the USA. These systems are identified because they can also be seen in the next image, AS10-35-5223 (figure 4.2.34). Examination of the mission transcript shows that orbit number 24 of the mission's residency around the Moon began at 18:16, and the first voice contact with the crew after AOS was at 18:56, so 18:45 seems a reasonable time to give for the Earthrise photo sequence.

ESSA 9's track covering the terminator in figure 4.2.33 is track 1, or orbit 1078. This would have been started at 16:08. The orbit covering the centre of the daylight part of the Earth (track 3) would have been started at 1900. NIMBUS 3's equivalent orbits are 526 for the terminator, and 529 for the central daylight portions, which equates to 12:44 & 18:06 respectively. ATS-3's image would, as usual have been at just after 17:00 on the 23rd.

In figure 4.2.34, the system described in the previous paragraph has moved eastwards. This movement represents the rotation of the Earth as the Apollo craft orbits the moon, which should take around 2 hours per orbit in a high altitude configuration, as opposed to some difference in the position of the craft above the moon (the craters visible in the whole image are the same). A quick trawl through the transcript reveals that each orbit is recorded as starting 2 hours apart.

Stellarium shows that this image puts the terminator at roughly 20:45 – 2 hours after the first one. This would put the Earthrise as being from the next orbit around the Moon, which is recorded as commencing at 20:14, and with first voice contact after AOS being at 20:55.

ESSA 9's track across USA on the 23rd was orbit 1080, which would put the time for that image at 19:00. NIMBUS 3's equivalent would be orbit 528 (which is actually missing from the dataset), at 16:18.

As the globe has moved, more of the weather system that is visible running westwards across the USA has become more visible, as has a large mass of cloud over the Arctic, and this system is visible in the next image in the sequence, AS10-35-5230 (figure 4.2.35). This photograph, which also shows the window frame of the CSM is of poorer quality as the photographer has not used the zoom lens to the fullest 22:55extent. The larger weather systems are, however, still visible.

The 'fishtailed' system pointed out in the first of the Earthrise images is still visible (just) on the eastern side just behind the terminator, while the clouds running east-west are now in the centre of the image. Two other systems are also brought into view here. The first is the system arrowed in green south of Mexico, and the other is the whirl pattern off the west coast of the USA, arrowed in red.

Stellarium puts this image, based again on the terminator location, as being taken around 22:45 on the 23rd, or an orbit later than the previous image. Orbit 26 in the transcript is recorded as starting at 22:12, with first voice contact after AOS at 22:55. ESSA's orbit would now be track 4 for the part covering middle America, which is orbit 1081 commencing at 21:05.

On the final image of this sequence, AS10-35-5239, the elongated cloud mass arrowed in green on the previous image is now at the terminator line, and the whirl arrowed in red is the most prominent system visible. Stellarium fixes this image at around 00:45, again an orbit later than the previous image. Orbit 27 started at 00:11 on the 24th, and voice contact after AOS was at 00:52

The appropriate image is still that of the 23rd, because the orbits of Apollo 10 are effectively keeping pace with the ESSA & NIMBUS tracks and the satellite images commenced on the 23rd have yet to complete a full day's coverage of the Earth. Because fewer of the NIMBUS tracks are available for this part of the Earth's surface, there are fewer matches, but it is presented for the sake of consistency.

These four images, taken over a period of 6 hours show a clear rotation of the Earth over that time. The weather systems visible on the images come in and out of view in a manner consistent with that rotation. The amount of movement of the globe over those 6 hours matches exactly what would be expected from the Earth in that time. We can demonstrate this with a quick look at where we would expect the terminator to move to over that time. Figure 4.2.37 shows a map of the Earth with 30 degree lines of longitude marked. Marked in red are the lines we would expect the terminator to follow at 2 hours intervals. As there are two hours for each orbit, which equates to 30 degrees of Earth rotation, this makes the task slightly easier.

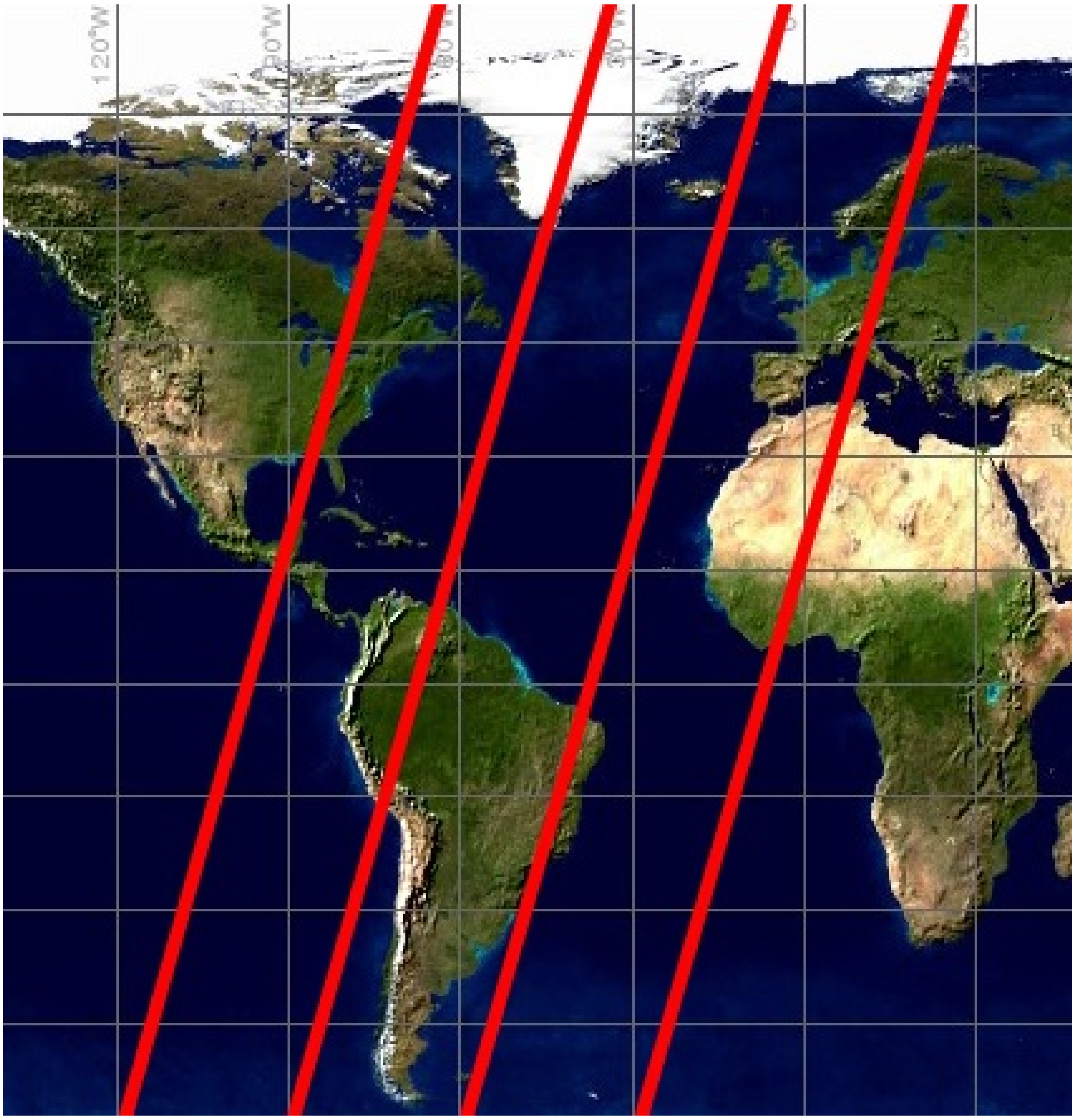


Figure 4.2.37: Terminator lines at 30 degree intervals. The red line on the right marks the terminator line as shown on AS10-27-3889.

It should be pretty obvious from the above that not only do the weather systems on the photographs match exactly the satellite images, but the movement of the Earth in between the Apollo photographs is entirely consistent with what would be expected.

Approximately 9.5 hours after the last Earthrise image in the images examined here, the crew began their TEI burn to launch them on the voyage home. During that voyage the crew took more photographs of the departing Moon and, thankfully for the purposes of this research, the approaching Earth.

One of the first images of the Earth on the way home (and the first of Earth after those of a full disk and obviously shrinking moon, is AS10-35-5258 (figure 4.2.38).

Figure 4.2.38: High quality GAP scan of AS10-35-5258. Low resolution version here: AIA

An experiment with Stellarium would show that at TEI the terminator would have been somewhere over Japan. As the terminator is somewhere over India, it is clearly taken after that. Figure 4.2.39 shows the satellite image comparison with this image. An ATS-3 image is not available here. The terminator line in the image also roughly crosses the boundary where the end of one day's ESSA images starts and the next begin. For that reason the ESSA 9 image used is dated the 24th. Anywhere to the East of the terminator would have been imaged at the end of the image dated the 23rd.

Stellarium's terminator estimates the time for the image at 13:00 on the 24th, which coincides with the end of a TV broadcast and was probably the last thing the photographer did before going to sleep – the next few hours are recorded as a rest period.

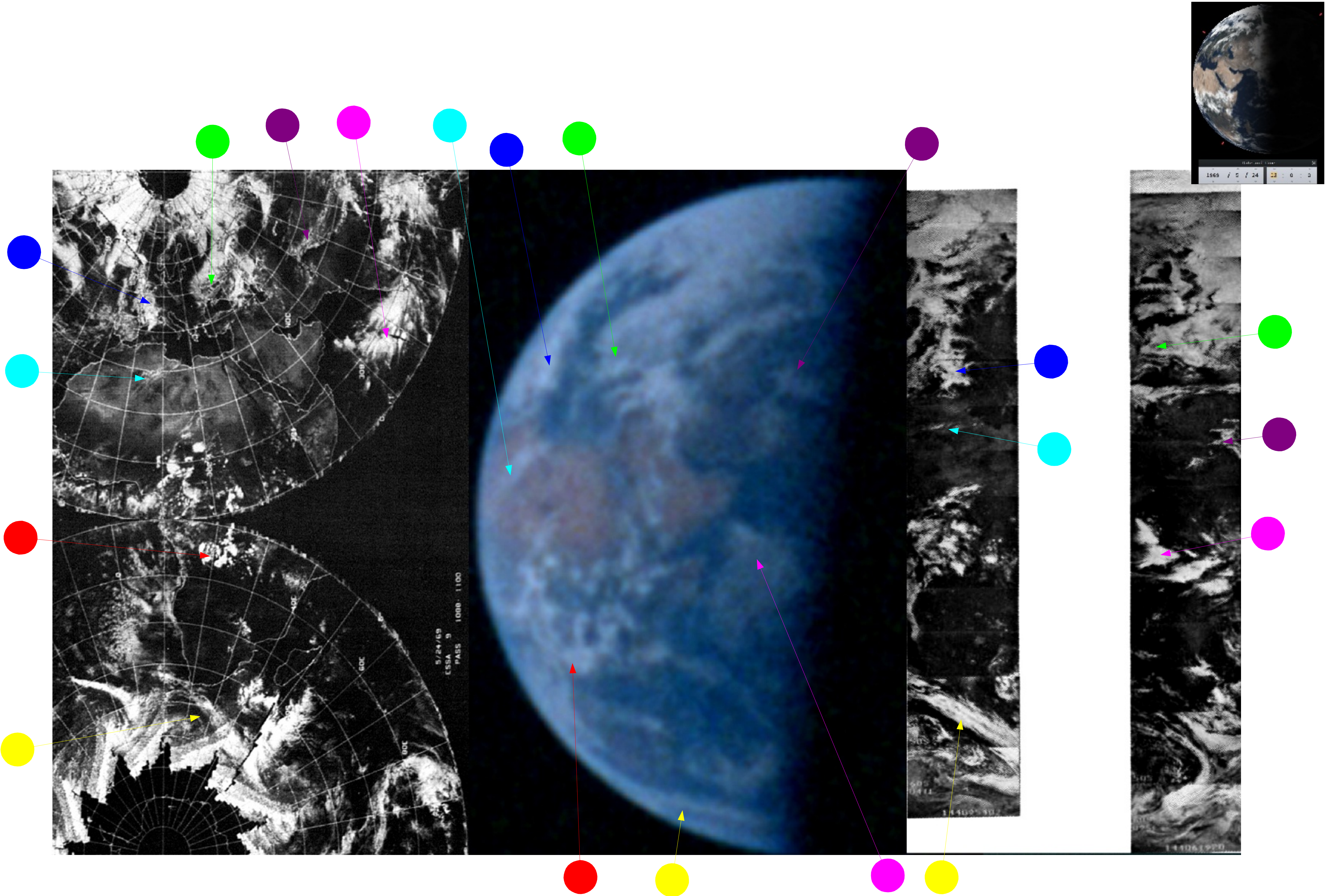


Figure 4.2.39: ESSA 9 (left upper & lower and NIMBUS 3 (right) compared with AS10-35-5258 and Stellarium indicator of time at terminator.

While there are likely to be timing issues in terms of the weather systems picked out in purple and magenta (and possibly green) as a result of their position either side of the ESSA mosaic's dividing line, they are still easily identifiable on the ESSA and Apollo images. The purple arrowed system is one that will be visible in a number of up-coming images, as it represents clouds over the Himalayas

ESSA's image for the 24th started with orbit number 1088 (track 11), which commenced at 11:03 on the 24th. NIMBUS' equivalent pass is number 535, which started at 04:50.

The next image, as will be evident from the position of the terminator, was taken 24 hours after the first of the Earthrise sequences examined above. There are two variants of the same image here, as AS10-27-3952 (also the first image of Earth to be seen after photographs of a retreating Moon in that magazine) is very similar to AS10-35-5262 (amongst others in a short sequence of identical images). By way of variety, the one from magazine 27 will be examined here, and it is shown below in figure 4.2.40. The one from magazine 35 can be found here: AIA . Comparison with satellite images is undertaken in figure 4.2.41.

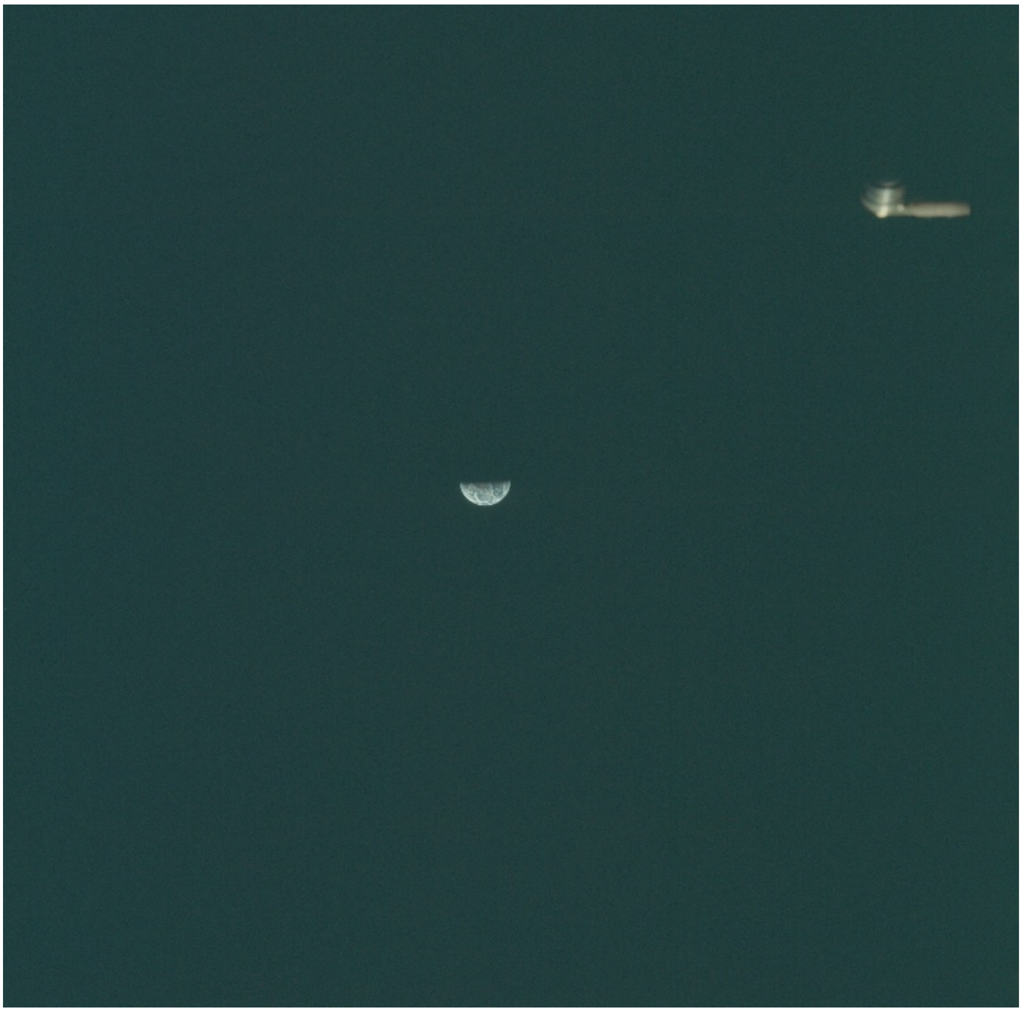


Figure 4.2.40: High quality GAP scan of AS10-27-3952. Low resolution source here: AIA

At first glance the large weather system identified by the green arrow is the same as in the one shown for the 23rd (it is obviously the same cloud mass, but it now has a different shape). Features of the other systems on the satellite photographs mark the Apollo image as having been taken on the 24th, not the 23rd.

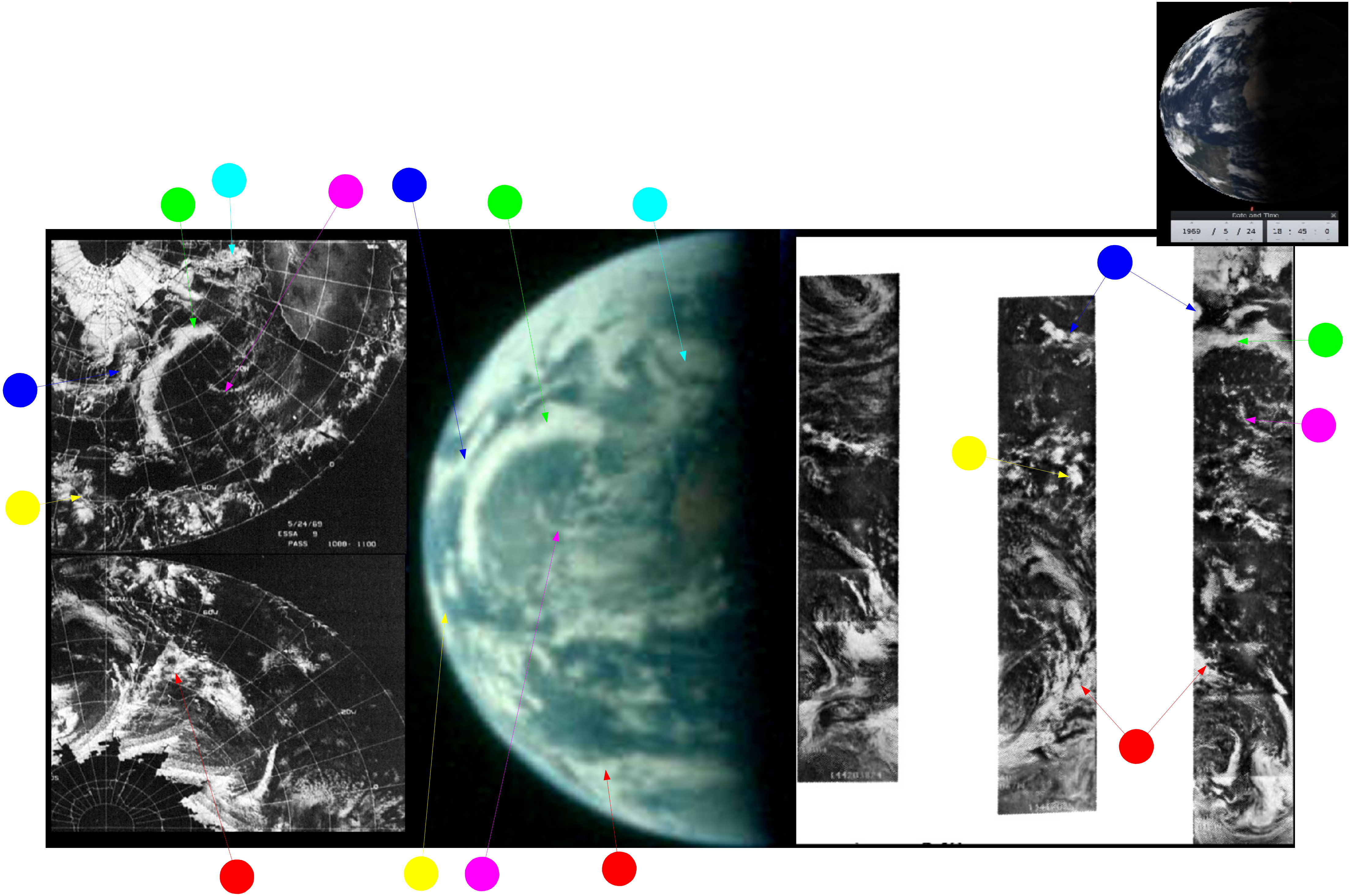


Figure 4.2.41: ESSA 9 (left upper & lower and NIMBUS 3 (right) compared with AS10-27-3952 and Stellarium indicator of time at terminator.

The distinctive fishtail has been lost, and it now extends a further 10 degrees of longitude over towards north Africa than on the day before. The curved cloud mass picked out by the magenta arrow runs more or less along latitude 30 degrees North on the 23rd, and the cloud bank to the east of the one identified by the blue arrow and north of the one marked by the green was not there at all. The red arrow points to a continuation of a system visible in the southern Hemisphere on the previous day on figure 4.2.39 (identified by a yellow arrow).

As with the previous day's image, there is much less available from NIMBUS, but there are still identifiable weather patterns.

As far as timings go, Stellarium suggests a time of 18:45 on the 24th, which would have been shortly before the start of another of their TV transmissions. ESSA's orbit for for the Atlantic on this date is number 1091 (track 2), which started at 16:08. NIMBUS' equivalent (of the ones available) orbit is 540, which started at 13:47. As usual the satellite image timings are consistent with those of the Apollo image.

Having stated that this image is almost identical to one on magazine 35, it is possible to examine the two images together and show that they were not taken at exactly the same time, but perhaps 10 minutes apart. his can be determined by slight differences at the western edge of the Earth in visible cloud masses, and also in the amount of Africa visible by the terminator. Figure 4.2.42 illustrates this, showing an insert of the earlier image on top of the later image, with a line marking the westernmost part of Africa.

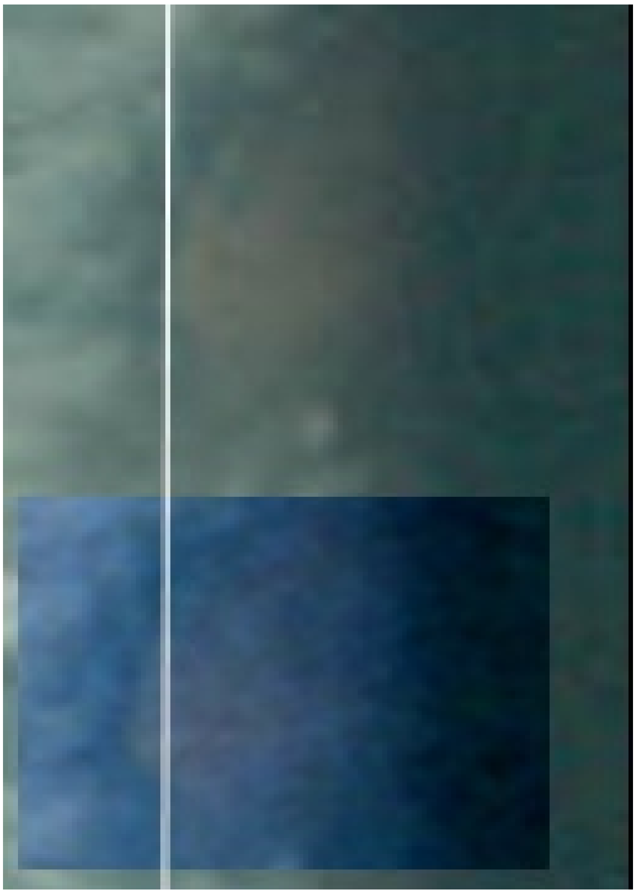


Figure 4.2.42: Comparison of the west African coast by the terminator on AS10-27-3952 and AS10-35-5262 (inset).

There is a very obvious difference between the two images in terms of where the west coast of Africa is. The terminator line has been lined up very carefully, but there is a difference in the position of the coast of about 2.5 degrees. As you would expect a movement of 15 degrees in an hour, this would mean that the two photographs were taken roughly 10 minutes apart.

Later on in the same magazine, after a some photographs of the astronauts inside the CM (in an obviously zero gravity environment) and more shots of a receding moon, is image A10-27-3970 (figure 4.2.43). Apart from its appearance after the astronaut pictures, the image has also been chosen because it features another very obvious weather system visible on the satellite images, again illustrating that the Apollo photographs are of a consistently revolving planet.

The image shows north America, as well as the Pacific ocean. The low cloud off Mexico and southern California visible in AS10-35-5239 (figure 4.2.36) is still in evidence, and the spiral cloud system is a development of the one identified by the red arrow on that image. The satellite images are compared with A10-27-3970 in figure 4.2.44.

Figure 4.2.43: High quality GAP scan of AS10-27-3970. Low quality version here: [AIA]

The most obvious cloud mass is the complex 'S' shaped system stretching from the central Pacific to the Alaska. Another feature of note is the thin band of cloud off the California coast that stretches out into the Pacific. In the south Pacific there is a long band of cloud stretching from the Antarctic towards the the tropics. Both ESSA & NIMBUS images show the 'S' system and the south Pacific arc of cloud, but loss of orbital information along the California coast means only ESSA shows detail there.

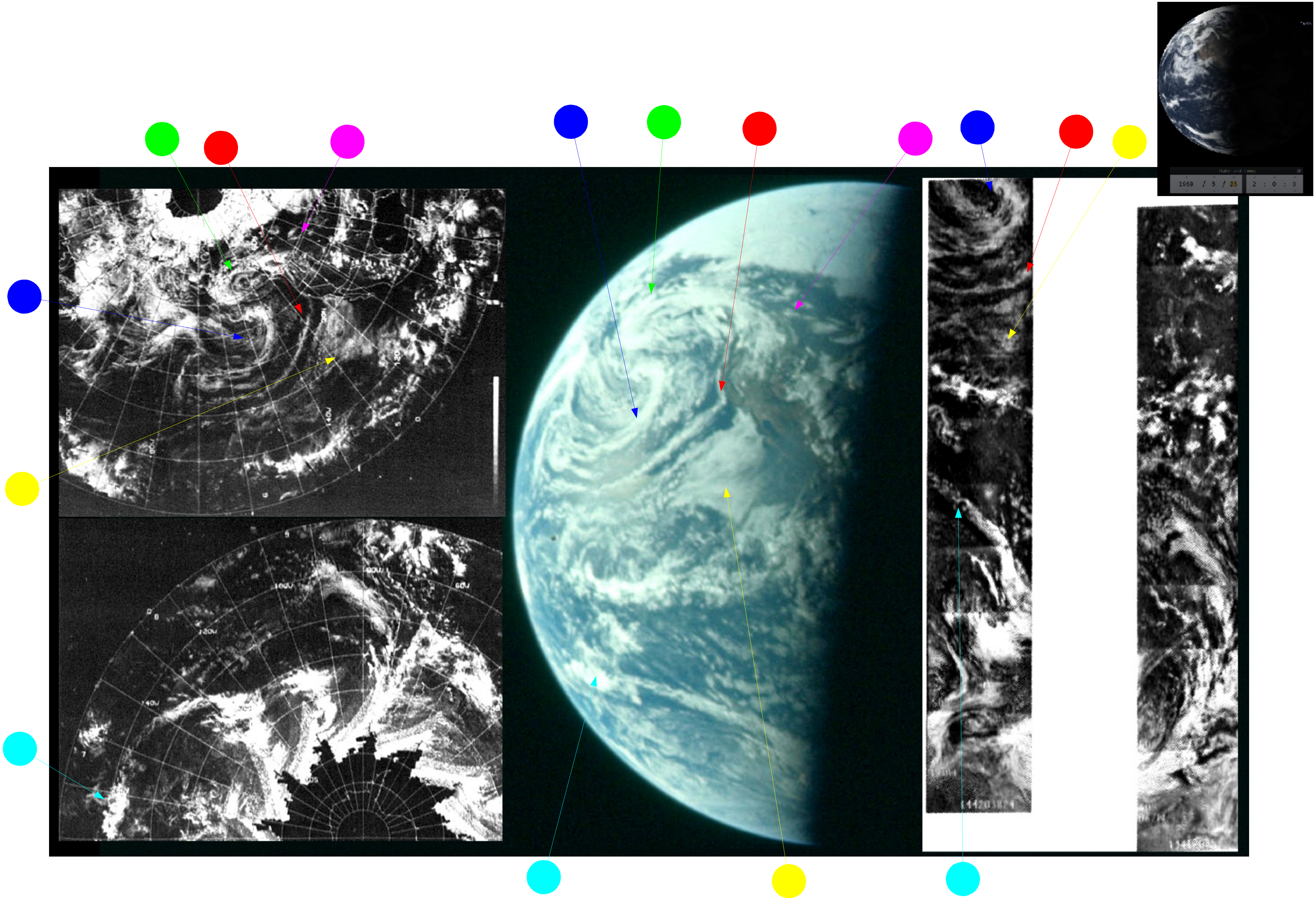


Figure 4.2.43: ESSA 9 (left upper & lower and NIMBUS 3 (right) compared with AS10-27-3970 and Stellarium indicator of time at terminator.

As with previous images, the Stellarium date given is that of the 25th, but the satellite images are those of the 24th. As the Apollo photograph was taken after the previous one examined here, it must therefore be after the 24th. The rotation of the Earth means that the only date possible for this image is the 25th, as by the 26th at this time the shape of the terminator moves to a more curved position.

Can this be confirmed by satellite orbital data? The ESSA orbit for the Pacific part of the image dated the 24th is number 1095 (track 6), started just after midnight on the 25th. As usual NIMBUS' orbit is behind that of ESSA, and orbit 544 from the image dated the 24th was started at 20:57 – 5 hours before the Apollo photograph.

A few images later in the magazine comes AS10-27-3976 (figure 4.2.27). By now, the earth has rotated to bring India towards the terminator and Africa is visible to the west, The Himalayas are picked out by thin cloud, and the larger cloud masses on near the terminator show clear shadows. The Earth is also much larger, providing more evidence that Apollo 10 is much nearer home. Figure 4.2.45 shows the satellite comparison. For reasons which will become clear, 2 different day's ESSA images are used – one (top left) from the 24th, the other (bottom left) from the 25th.

Figure 4.2.44: High quality GAP scan of AS10-27-3976. Low quality version here: AIA

Timing the Apollo photograph AS10-27-3976 is relatively straightforward. It must have been taken after AS10-27-3970, and the rotation of the Earth also means that the former must have been taken after the latter. Stellarium suggests that the actual time of the image was somewhere around 13:30 on the 25th of May. It is trickier to reconcile this timing with the satellite images available, and again this relates to the way that a day's satellite image as given in the NASA catalogues are worked out.

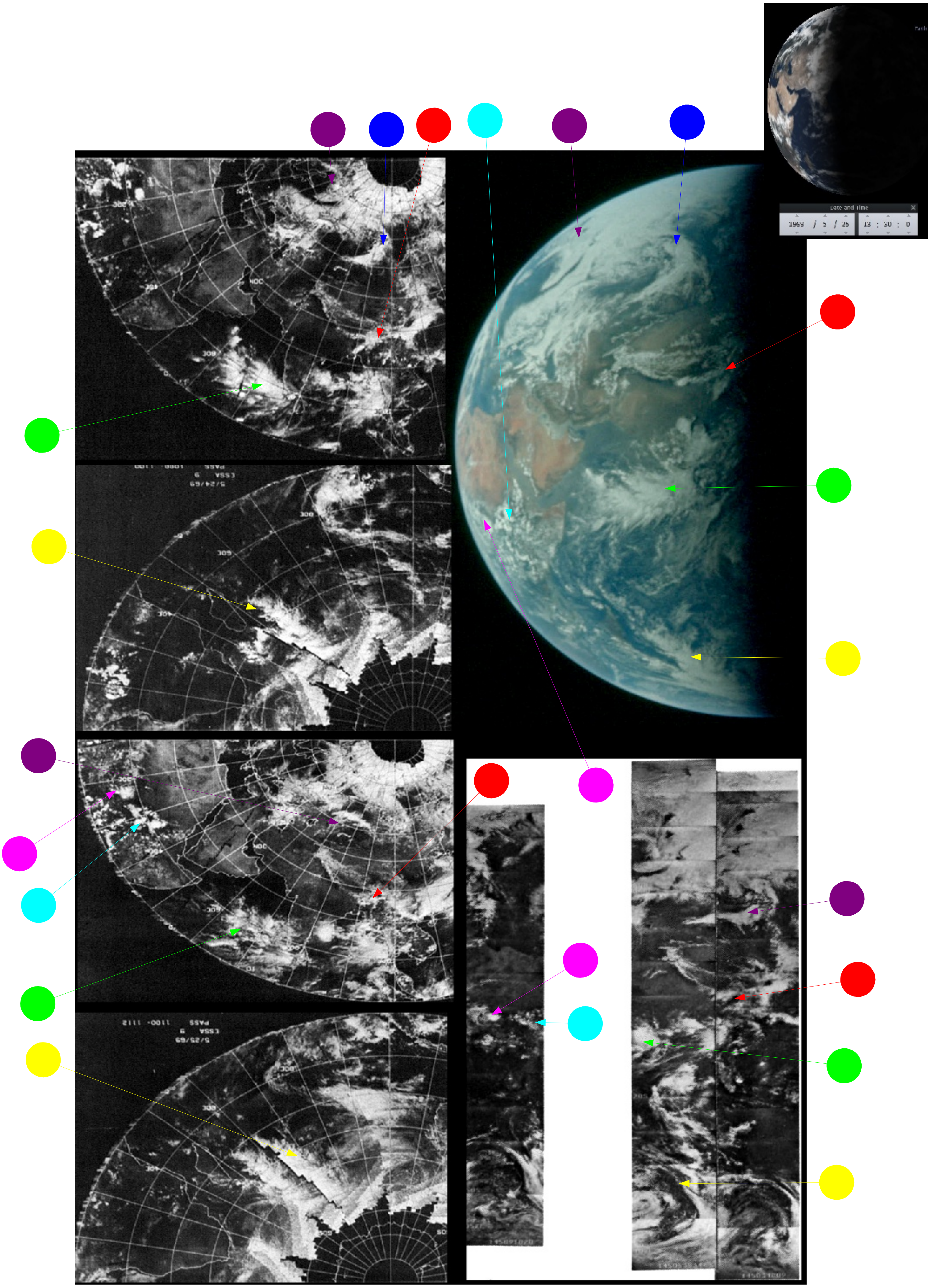


Figure 4.2.45: ESSA 9 dated 24/05/69 (top left upper & lower and 25/05/69 (bottom left upper and lower) & and NIMBUS 3 (bottom right) compared with AS10-27-3976 and Stellarium indicator of time at terminator.

Examination of the satellite photographs used shows that while the cloud formations over India are an excellent match on the ESSA image from 24/05/69, the Africa cloud formations are much better identified on the ESSA image from 25/05/69. The reason for this can be found in the dividing line between the two images used to differentiate the two dates.

While ESSA (& NIMBUS) operate continuously, our need to rationalise the data requires that we separate the information into discrete dates, and in this case the dividing line on the the ESSA image from 24/05/69 is easily visible in the Indian Ocean bisecting a cloud formation. The time of ESSA's India orbit on the 24th (track 10, orbit 1099) east of that dividing line is put at 08:01. The track on the African side of the divide on this image is actually orbit 1088 which was commenced at 11:03 on the 24th. This means that the next ESSA image dated 25/05/69 has it's first pass (track 12, orbit 1101) at 12:01, which is why the cloud formations over the horn of Africa (picked out with cyan and magenta arrows) are a better match on that image than on the previous day's.

The NIMBUS image for the 25th is much easier to work out, as the part of Earth shown in by Apollo is within the confines of a single set of orbits. The India pass, orbit 549, was commenced at 05:54.

In a nutshell: any image of Earth taken at the boundary line in a satellite mosaic is going to be a little confusing, but the appliance of logic will reveal the answer! The answer in this case being that the Apollo photograph was taken on 25/05/69 at around 13:30, just after the crew awoke from their rest period. Not long after taking AS10-27-3976, the crew took AS10-35-5264, a low resolution version of which can be found here: AIA. These two images are, as with other images taken on two different magazines at the same time, ostensibly identical, but close examination reveals they were taken a few moments apart. Figure 4.2.46 compares western Africa as seen on both images.

Figure 4.246: AS10-27-3976 (left) compared with AS10-35-5264 (right).

There is a definite change in the cloud masses visible on the western limb, and in order to show the same amount of Arabia in the crop from magazine 35, that part of the image has had to be wider than that from magazine 27.

A short while later, a less problematic image was taken on magazine 35: AS10-35-5266. This image is shown below in figure 4.2.47, and analysed in figure 4.2.48.

Figure 4.2.47: High quality GAP scan of AS10-35-5266. Low quality source here: AIA

The tricky area of the dividing line between days has now (with the exception of some high latitude eastern parts of the northern hemisphere) passed beyond the terminator, leaving us with an image that is fairly and squarely taken on the 25th.

The weather systems north and west of Europe are particularly distinctive and do not appear in that configuration on other days' satellite records. Furthermore the Stellarium terminator estimate is 16:00, and by that time on the 26th Apollo 10 was on re-entering the atmosphere of the home planet after a successful mission.

The ESSA 9 track covering the the terminator area is number 12, which corresponds to orbit number 1101, which commenced at 12:01. The equivalent NIMBUS pass is number 549, which commenced at 05:54 on the 25th.

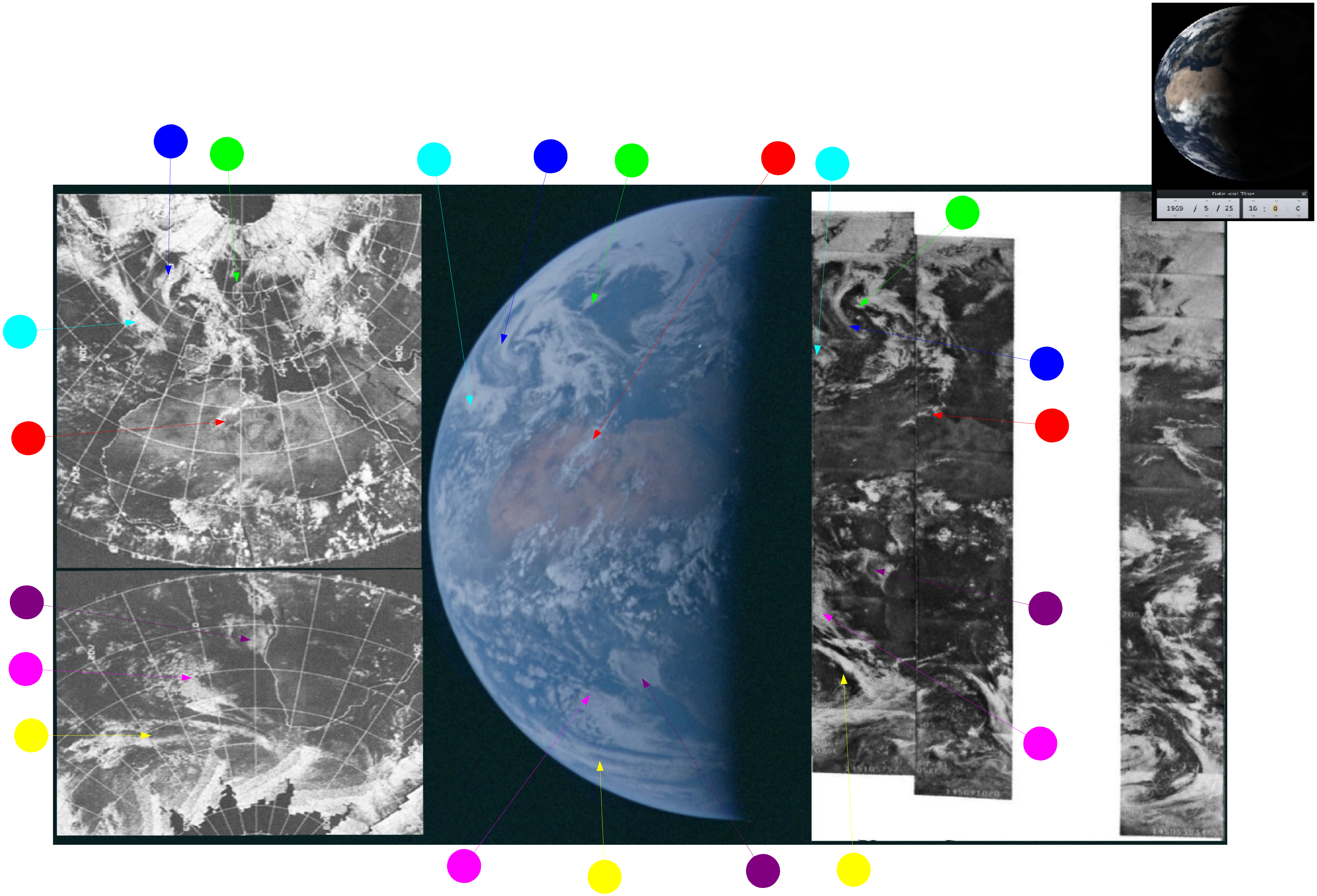


Figure 4.2.48: ESSA 9 (left upper and lower) and NIMBUS 3 (right) images compared with AS10-35-5266 and Stellarium estimate of time at terminator

Later in the day on the 25th the astronauts capture another image of the long band of cloud across the Atlantic featured in several other photograph., AS10-27-3979 (figure 4.2.48). Figure 4.2..49 shows the satellite analysis.

Figure 4.2.48: High quality GAP scan of AS10-27-3979. Low quality version here: AIA

The ESSA orbital pass for the Atlantic (orbit 1104, Track 2) commenced at 17:07 on the 25th. NIMBUS's orbit for the same area is number 554, which commenced at 14:51 on the 25th.

Stellarium suggests a time of around 22:00 on the 25th for the Apollo photograph, shortly before commencing their penultimate TV broadcast. The mission transcript records discussions with ground control before the broadcast feature the Apollo crew describing the coast of Florida, Mexico and south America, exactly as featured in this image. Interestingly they also describe the weather system noted previously over Alaska & the Aleutian islands during that TV broadcast. This area is not quite visible in the photograph, which suggests that it was taken slightly before that discussion took place. Crew comments refer to California appearing on the horizon during the TV broadcast, and they also have to wait for the Goldstone receiving station in California to come into view, which again suggests that this image was taken while waiting for this to happen.

Stellarium's image from 22:00 does not, however, look quite the same as the Apollo image as far as the land masses visible at the western horizon are concerned., and figure 4.2.50 shows that the moon would not have been visible from Anchorage Alaska until 23:50 on the 25th, and the immediate question from a sceptic would e 'why the difference?'. The answer lies in the position of the observer: while the terminator line will be in the same place regardless of the observer's position, the land masses visible at the horizon is very much dependent on the observer's viewpoint.

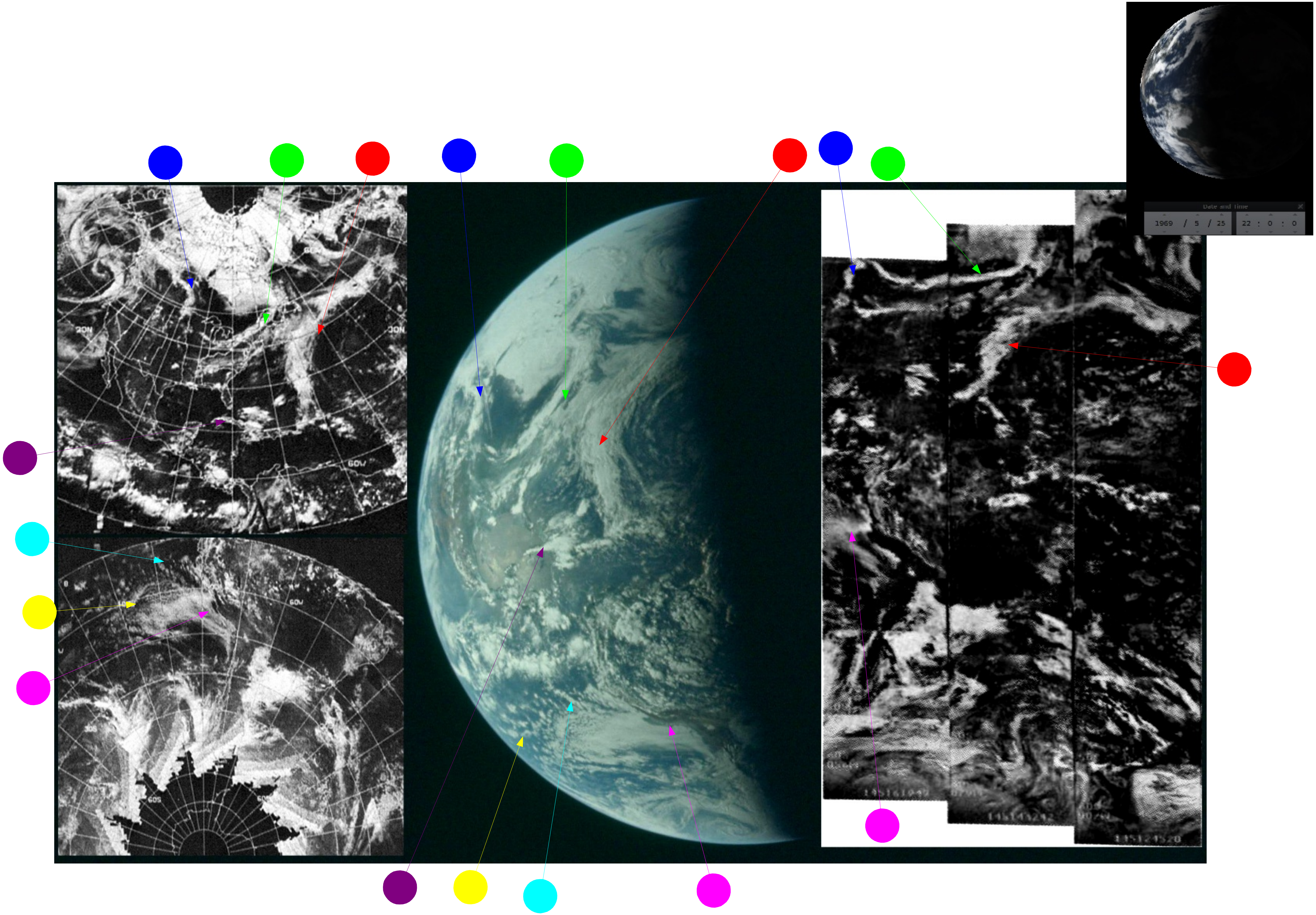


Figure 4.2.49: ESSA 9 (left upper & lower) and NIMBUS 3 (right) compared with AS10-27-3979 and Stellarium estimate of time at terminator

Figure 4.2.50: Moonrise from Anchorage Alaska, 25/05/69 as depicted by Stellarium

While orbiting the moon, the use of a point on it isn't a problem when identifying visible land masses away from the terminator As the spacecraft gets nearer to the Earth, however, there will be a difference that will get more pronounced.

The Apollo 10 mission report (found here) gives trajectory information that helps explain this. The voice transcript gives distance information that puts Apollo 10 about 110000 miles from Earth, and it also gives the time of the TV broadcast at roughly 173.5 hours (7 days 5 and a half hours).

The trajectory images given in figure 4.2.51 taken from that mission report show that it would have been much more difficult to see Alaska from the vantage point of the moon at 173 hours into the mission (the blue line) than from the position of Apollo 10 at the same point (the red line). These may seem like minor points, but in the hotly debated area of Apollo conspiracy theories, where scientifically illiterate, wilfully cynical and mendacious charlatan alike seek to exploit the slightest unexplained facet of an argument to score points it is essential that they are addressed.

In short, Stellarium is using a viewpoint that is growing ever further away and at an increasingly different angle from the vantage point of the photographer.

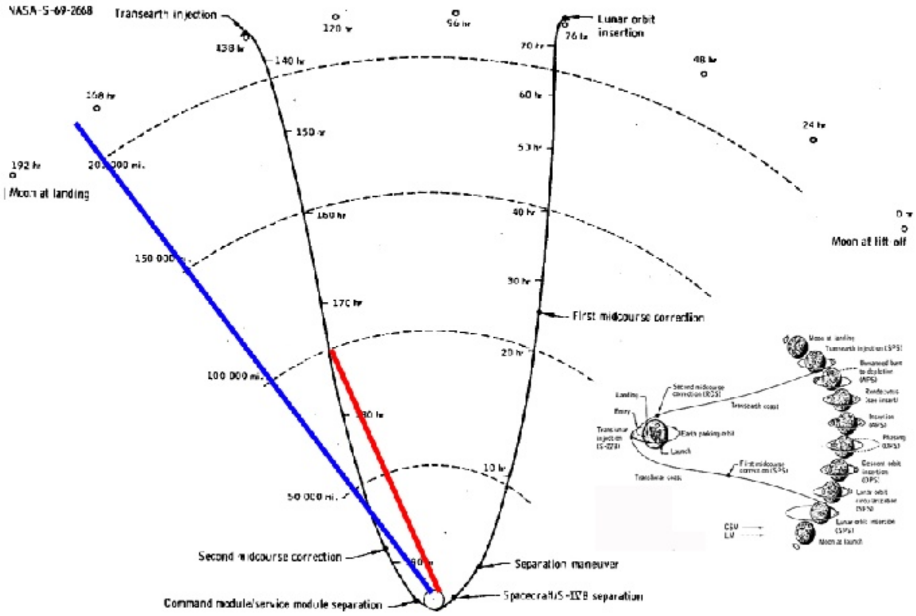


Figure 4.2.51: Suggested lines of sight from the Moon (blue line) and Apollo 10 (red line) at roughly 173 hours into the mission (adapted from NASA sources).

In addition to describing the weather, the crew inform capcom that they are taking photographs of Earth every few hours to provide a record of its appearance. Much of that photography appears to have been done with magazine 27, from which the next image is taken. Figure 4.2.52 shows AS10-27-3981, which is analysed in figure 4.2.53.

Figure 4.2.52: High quality GAP scan of AS10-27-3981. Low quality version here: AIA

The large spiral (blue arrow) system off the west coast of the USA has again changed its appearance, re-consolidating into a more definite single spiral of cloud reminiscent of the shape this system had when observed in lunar orbit. Re-examination of figures 4.2.35 & 36 shows that they are definitely different in appearance, and not a 're-use' of a day's weather in a new photograph. What is also evident from Stellarium is the increasing curvature that would be visible in the terminator's appearance from the Moon's vantage point, something that is not as evident from Apollo as it nears the Earth.

Stellarium puts the time at 00:30 on the 26th. ESSA's 'best fit' orbit would be number 1106 (track 4), which commenced at 21:07. NIMBUS' equivalent would be orbit 555, which commenced at 16:38 on the 25th.

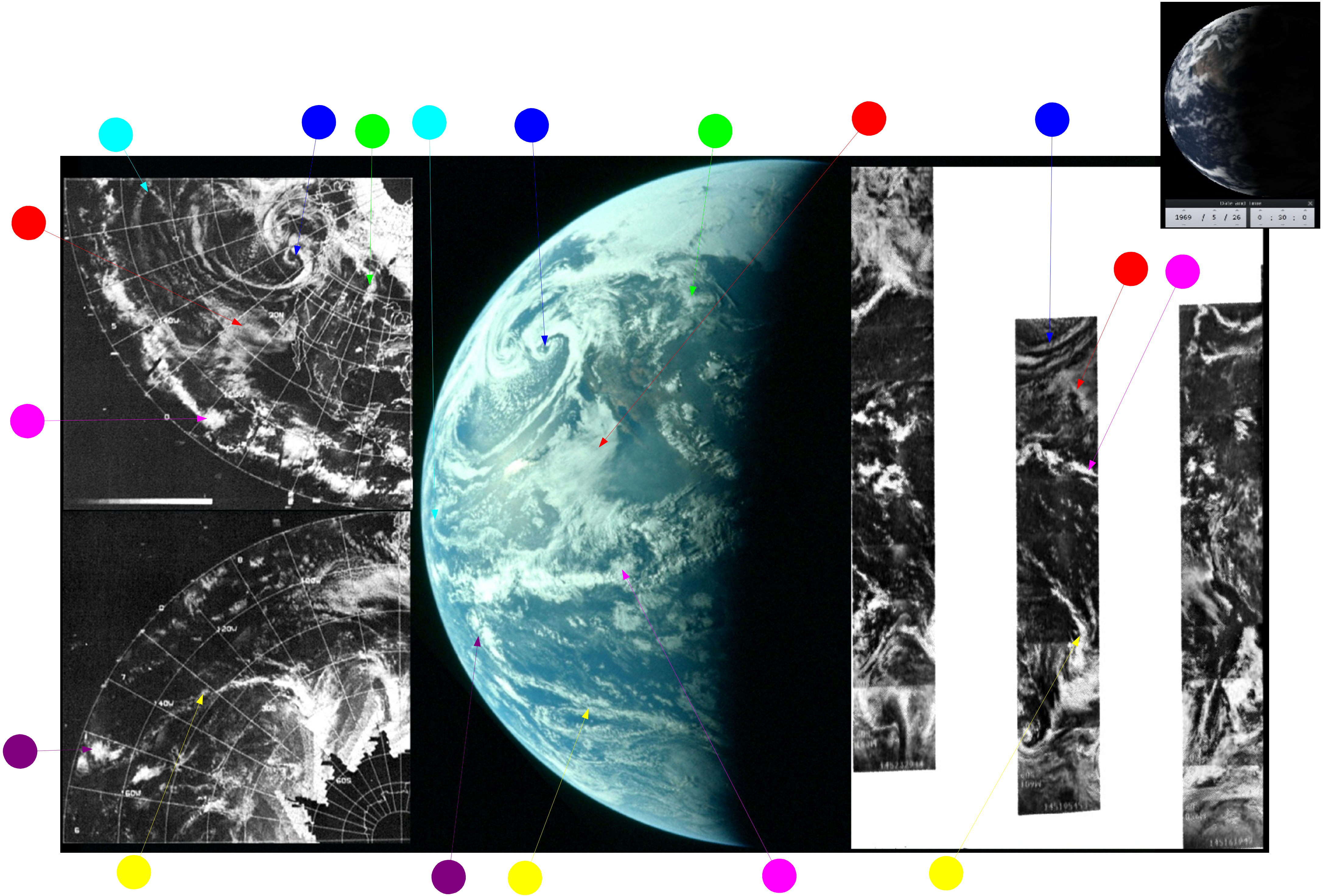


Figure 4.2.53: ESSA 9 (left) and NIMBUS 9 (right) images compared with AS10-27-3981 & Stellarium estimate of time at terminator

The next image in this sequence was taken not long after, but long enough for almost the entire American continent to have vanished beyond the terminator. AS10-27-3984 shows a small amount of rotation and adds little new information to that given in the previous image, but it does allow us to identify weather systems that link in with those found on the final Earth photograph from magazine 27.

AS10-27-3984 is shown below in figure 4.2.54, and analysed overleaf in figure 4.2.55.

Figure 4.2.53: High quality GAP scan of AS10-27-3984. Low resolution source here: [AIA]

The large spiral has moved much closer to the terminator, which now has most of the USA in darkness. Just emerging on the western horizon is another spiral of cloud (marked in green), and this is the system that is visible in the final image on magazine 27.

The blue, red, cyan and purple arrows used in figure 4.2.53 are the same as those in figure 4.2.52. The terminator gives an estimate of around 02:30 on the 26th.

The satellite timings are pretty much one orbit along from the previous image. ESSA's nearest orbital pass covering the terminator is number 2303 (track 5), commencing at 23:07 on the 25th, while NIMBUS' best orbit is 556 (which has no data in the collection used), commencing at 18:26 on the 25th.

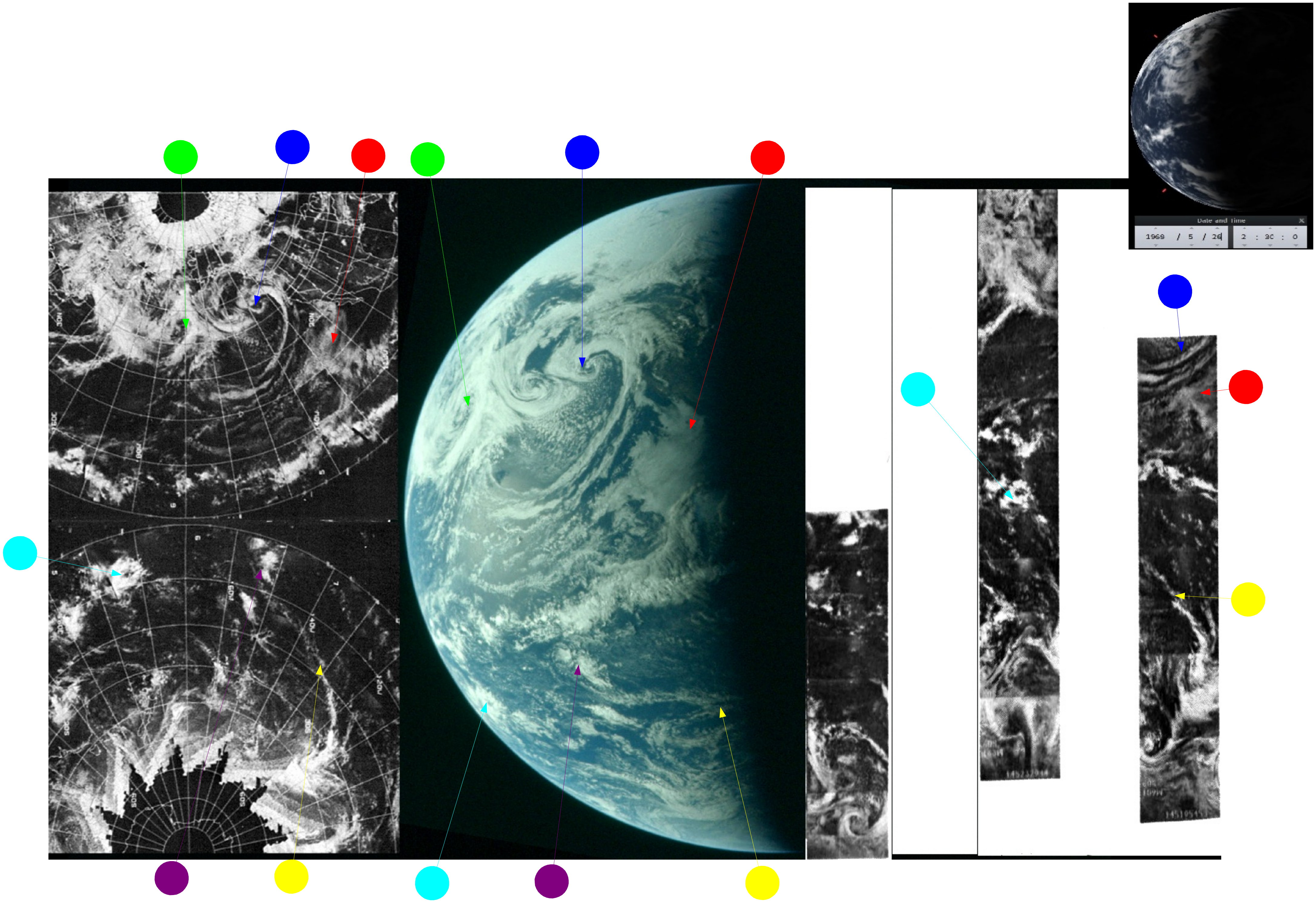


Figure 4.2.54: ESSA 9 (left) and NIMBUS 3 (right) compared with AS10-27-3984 and Stellarium estimate of time at terminator.

The final image in the sequence of regularly spaced Earth photos examined from magazine 27 is one of an identical pair, AS10-27-3986. It is shown below in figure 4.2.55 and analysed on the next page in figure 4.2.56.

Figure 4.2.55: High quality GAP scan of AS10-27-3986. Low quality version here: AIA

There is still a small amount of the large spiral system off western north America (blue arrow) but the main weather system in the northern hemisphere is the green arrowed system to the west of that.

South-west of that system is a twin pronged succession of cloud bands off eastern Asia. Stellarium's time is set at around 04:00, which is derived mainly by the absence of Australia (a small part of the east coast is just visible) and by only Alaska remaining of north America. In 12 hours time, Apollo 10 will re-enter Earth's atmosphere pretty much in the middle of what can be seen in the photograph.

In terms of the satellite images, their coverage of the area over the terminator starts with ESSA at orbit 1108 (track number 6), commencing at 01:08. In fairness, the terminator covered by ESSA is probably somewhere between tracks 5 and 6, just as with the previous figure the terminator was somewhere between tracks 4 and 5. NIMBUS doesn't cover much of the area shown, but the terminator is probably best covered by track 558, commencing at 22:01 on the 25th.

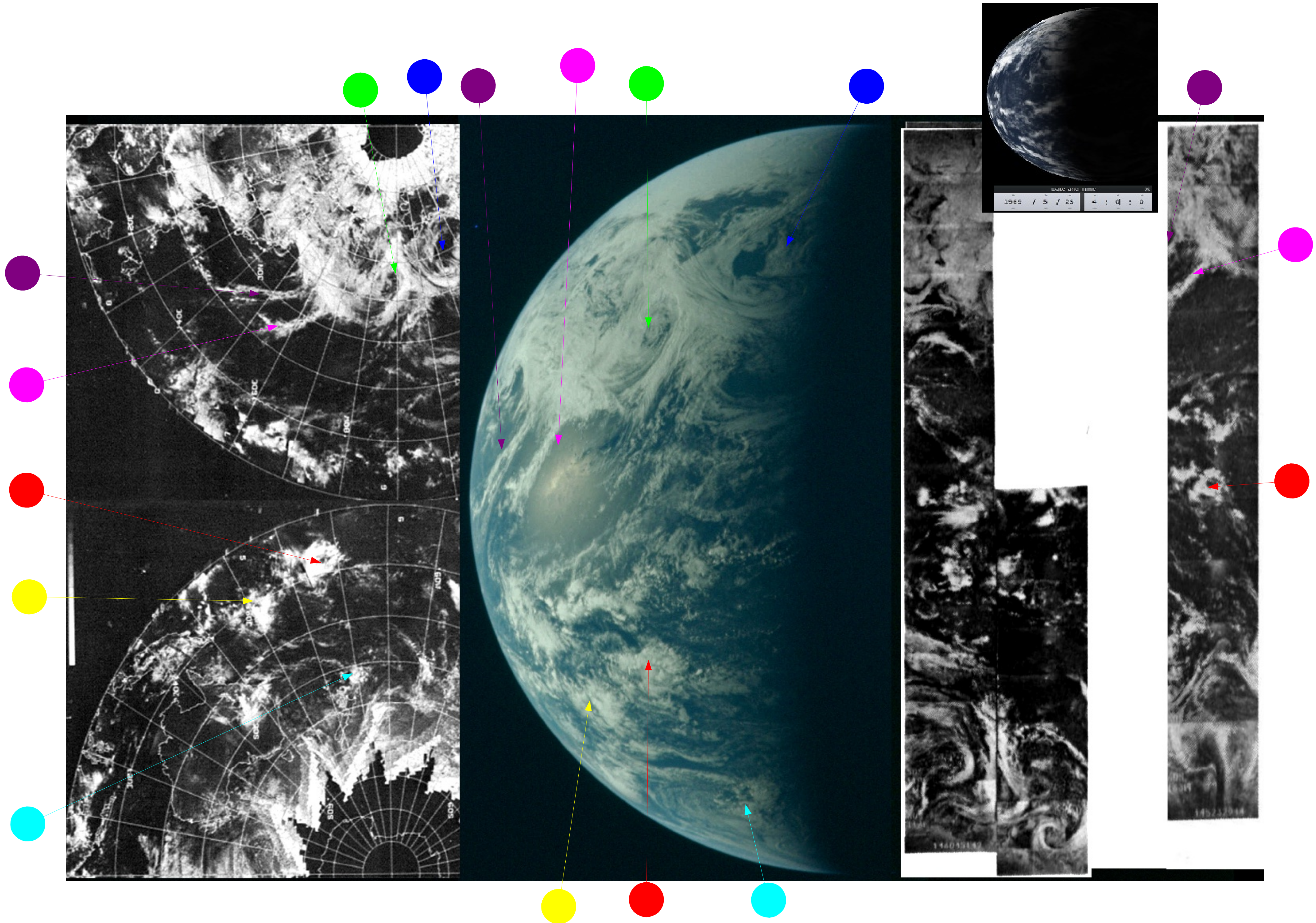


Figure 4.2.56: ESSA 9 (left) and NIMBUS 3 (right) images compared with AS10-27-3986 and Stellarium estimate at tie of terminator

The final photographic image to be analysed, is AS10-35-5280 – part of the last series of Earth photos taken and featuring the Indian sub-continent. It is shown in figure 4.2.57, and analysed in figure 4.2.58.

Figure 4.2.57: High quality GAP scan of AS10-35-5280 Low quality version here: AIA

As with other images featuring this viewpoint, the dividing line between ESSA images makes life slightly difficult when pointing out weather systems. Those over Europe and Africa were taken at the start of the orbital cycle on the 25^{th}, while India and Asia were imaged towards the end of the cycle on the 26^{th}.

Stellarium suggests an image time of around 13:45 on the 26^{th}, just a few hours short of re-entry. Ay five hours before re-entry, the crew are able to describe the scene in a final TV broadcast. They discuss seeing India directly below them, China, and are able to zoom in on Arabia. The cloud caps over the north are the only thing interfering with the TV image.

ESSA's timings for track 10, the best fit orbit for the terminator, show that orbit 1112 (track 10) was started at 09:00 on the 26^{th}. The eastern Africa passes are covered by orbits 1113 onwards, started at 11:05 on the 26th. NIMBUS' orbit 562 covers the Indian portion of the photograph, and was started at 05:10.

As with all the photographs, there is a clear correspondence between the Apollo photographs and the satellite images. Apollo 10's series of Earth photographs show that the astronaut's cameras took photographs of a revolving Earth with evolving weather systems over the course of the mission. The behaviour of the weather systems and Earth in those photographs are entirely consistent with the photographs having been taken in space on the way to, orbiting around, and returning from the moon.

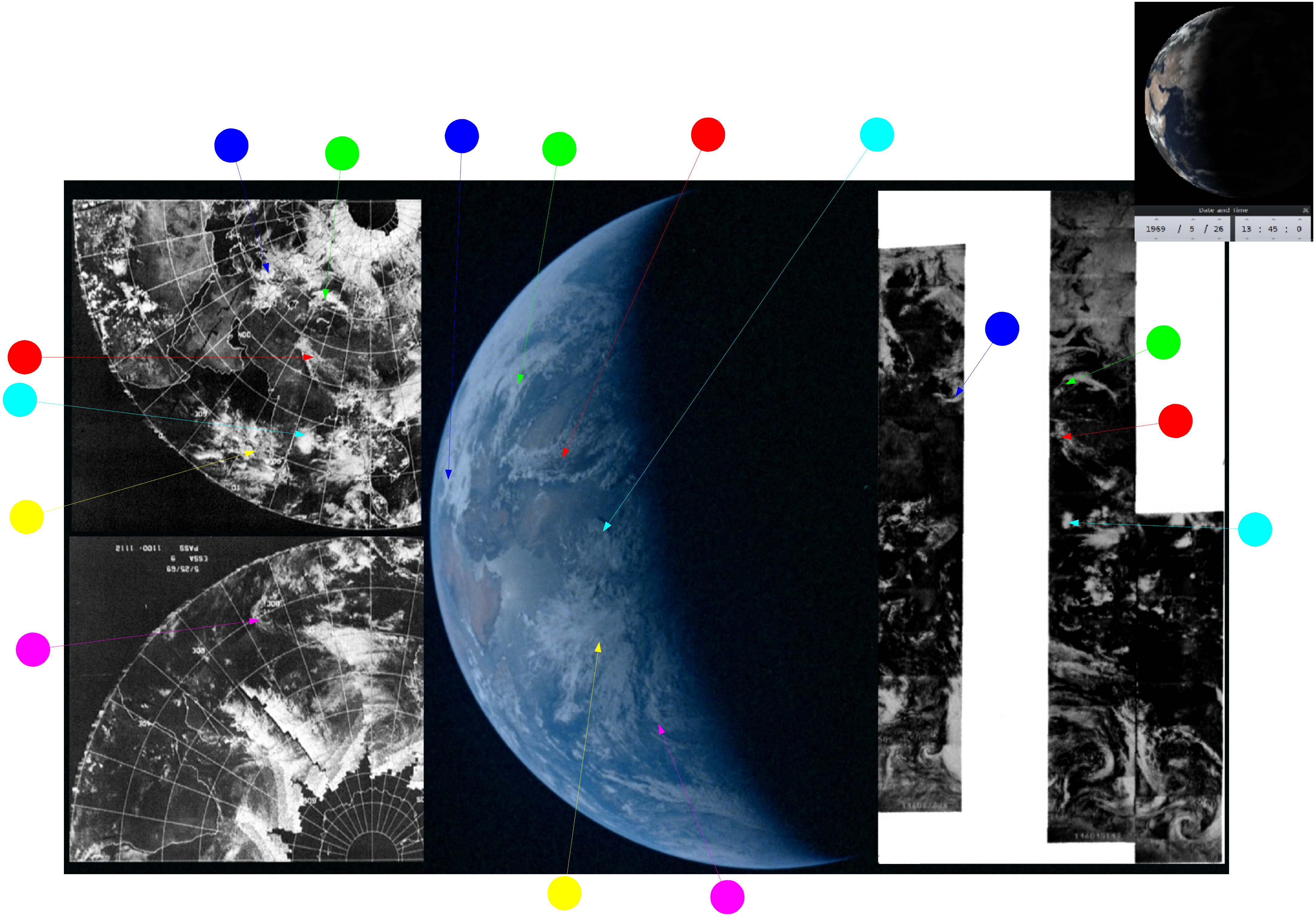


Figure 4.2.58: ESSA 9 (left) and NIMBUS 3 (right) images compared with AS10-35-5280 and Stellarium estimate of time at terminator

4.2.2 Black & White Earthrise Images

In addition to the colour photographs, three magazines of pictures in black & white provided Earthrise images (AS10-29, AS10-30 and AS10-32), but the quality of those images as shown in the AIA leave a lot to be desired. There was a temptation to neglect these images, but it was decided that there may as well be some attempt to examine them, in order that accusations of ignoring inconvenient evidence could not be levied. Any estimates of the time these photographs were taken is necessarily speculative, but other supporting evidence will be used to back up these estimates.

The three Apollo images are shown overleaf in figures 4.2..59a-c, and what analysis that is possible is shown on the subsequent page in figure 4.2.60a-c.

In examining the AIA source images, they were first altered from 72dpi to 300dpi, so that when the Earth images was enlarged details would still be discernible. Following this increase in dpi, levels were adjusted to bring out the detail. Where more than one image existed as part of a sequence, the best quality one was chosen.

As each image is evidently an Earthrise, they must therefore have been taken between LOI at 20:50 on 21/05/69 and TEI at 10:25 on 24/05/69 (although one final Earthrise would have been observed after TEI). All of the magazines featured only the lunar surface and the Earth images, so there are no other identifiable mission milestones with which to narrow down the timings. Magazine 29 shows just one image. Magazine 30 has of 7 images of one Earthrise. Magazine 32 shows 2 images separated by images of the lunar surface, apparently taken during the same Earthrise.

There is some information in the photographic index of the mission, but this does not give any information other than the features taken in these magazines. These features are usually known lunar craters that were planned to be photographed, or they were "T.O." - targets of opportunity. In other words, anything interesting that caught the astronaut's eyes, or 'nice to have' features that were considered desirable but not essential.

There are some clues in the mission transcript, but there is nothing absolutely specific. So, having drawn some arrows on some fairly vague pictures, what other evidence is there to support them being in the right place?

First of all, let's examine figure 4.2.60a. The photographic index (available here: AFJ) records that magazine 29 (originally designated 'P'):

"...contains photographs taken from the LM during the descent approach to landing site 2 (just missing the site)."

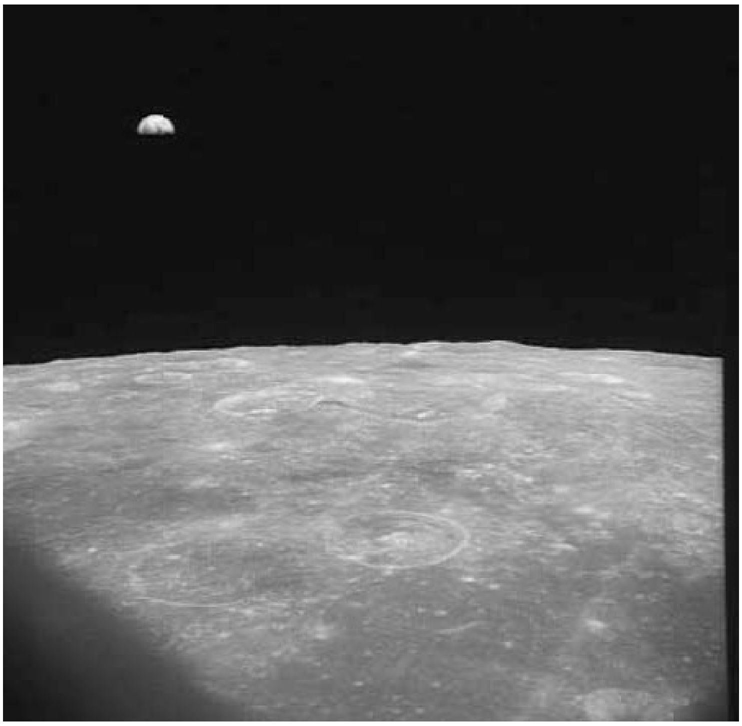
So, any photographs on the magazine were taken from the LM. The crew were only in the LM between 05:00 and 03:31 on the 23rd. Several hours after entering and before leaving the LM, however, the crew would have been busy navigating away from and back to the CSM, so this gives a much narrower window on the 22nd for photography purposes.

The closest approach to the lunar surface is recorded as being at 21:29 on the 22nd, on orbit 13, and around that time in the mission transcript we have this remark from the LM crew:

"we just saw Earthrise and it's got to be magnificent...the only trouble is we're stripping lots of film for him"

'him' being Jack Schmitt, the geologist who finally made it to the Moon on Apollo 17.

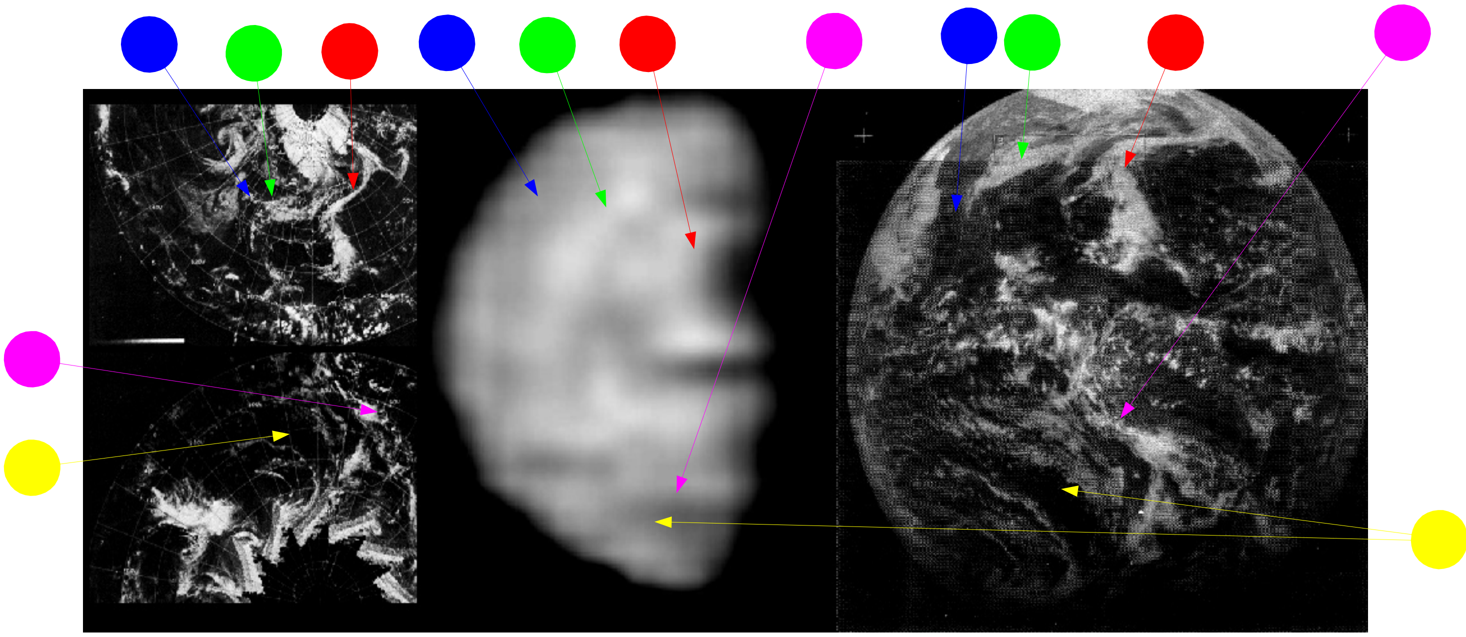
a) AS10-29-4231 AIA Source



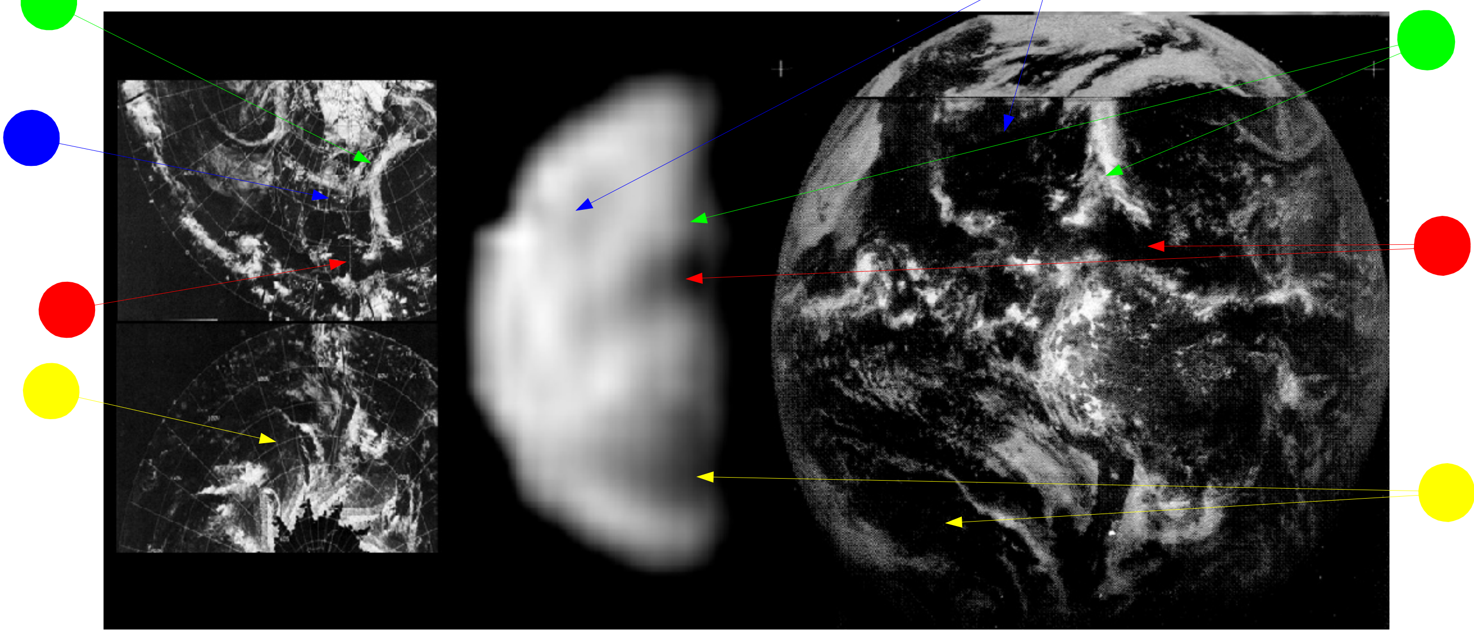
b) AS10-30-4477 AIA source

c) AS10-32-4808 AIA Source

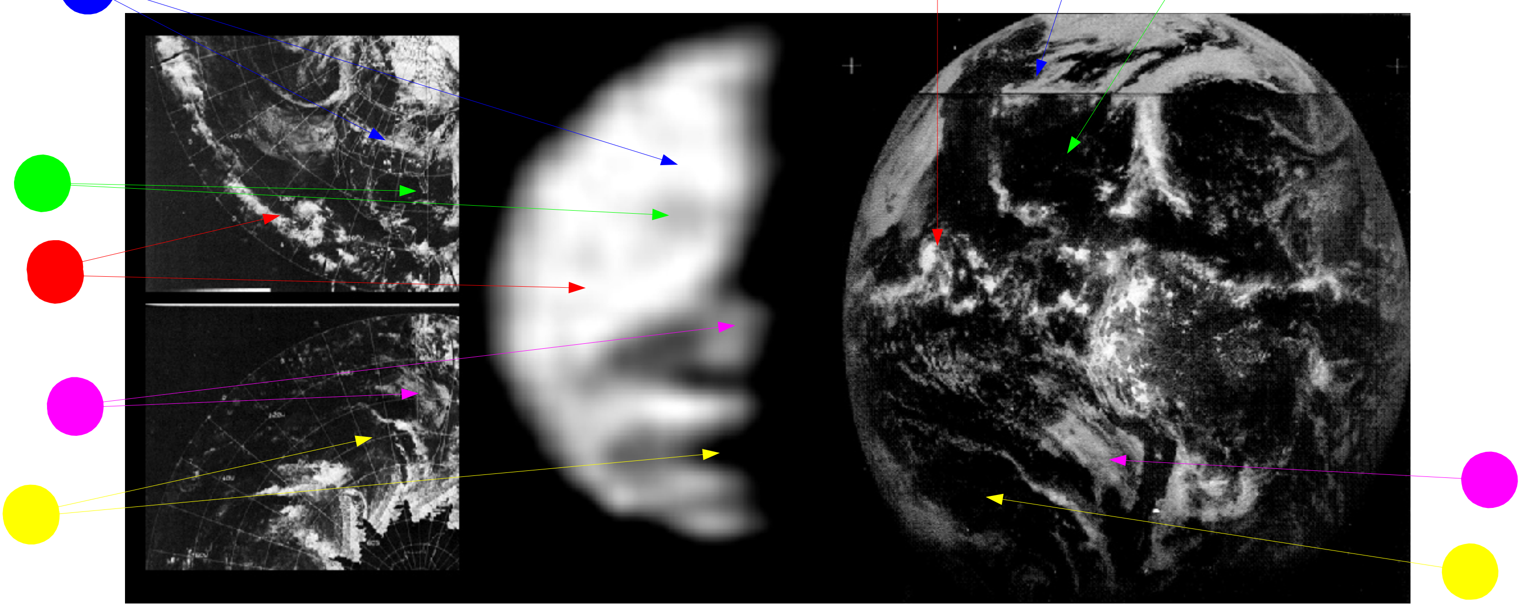
Figure 4.2..59: AS10-29-4321 (top), AS10-30-4477 (middle) and AS10-32-4808 (bottom)



a) AS10-29-4231 compared with ESSA & ATS images from 22/05/69



b) AS10-30-4477 compared with ESSA & ATS images from 23/05/69



c) AS10-32-4808 compared with ESSA and ATS images from 23/05/69

Figure 4.2.60 – AS10-29-4231 (top) AS10-30-4477 (middle) and AS10-32-4808 compared with ESSA & ATS images from 22/05/69 and 23/05/69

A quick look at what would be visible at that point can be see in figure 4.2.61a, showing Stellarium's estimate of the Earth terminator at that time. The Stellarium image would seem to coincide well with the terminator line on the Apollo image and the associated weather patterns around it, particularly the shape of the terminator. The image can be usefully compared with figure 4.2.11b, which shows the Earth in colour a couple of orbits earlier.

The other two images show a terminator line running roughly up the middle of a half phase Earth, which suggests firstly that they were taken later in the orbital phase, and also not too far apart. We can reasonably assume therefore that the images are from the 23rd or 24th of May, but before 10:25 on the 24th.

The suggestion given in figure 4.2.60b is that the image shows dark patches either side of the equator, with the southernmost one being particularly large. It is the contention here that this large area is the south Pacific off the coast of Chile, and the other dark area is the Caribbean. The white patch between these two would be the clouds over the coastal areas of northern south America.

This would give a suggested time of roughly 22 – 23:00 on the 23rd, at which point the crew were carrying out landmark tracking and photography operations. Again referring to the mission transcript, at 123:08 (or about 20:00 on the 23rd), capcom have some jobs for them to do, but given them the option of continuing with photography work if they feel they haven't yet completed it. The crew reply saying that

"..we've shot so much photography we're about out of colour film. We're saving a little bit for the way back. And we still have some black and white to go, and we'll do some of that."

The next orbit (orbit 25), and therefore the next Earthrise came at just before 21:00. There is no reference at the time of AOS for photography, but the crew do discuss the weather systems they can see on Earth over the USA (see the final section for Apollo 10 on Meteorology). The Earthrise for orbit 26 was at around 22::45, which matches well with what figure 4.2.60b suggests. Figure 4.2..61b shows where Stellarium predicts where the terminator would have been at that time.

For figure 4.2.60c, the suggestion is that it was taken not long after the photograph used in 4.2.60b. Indeed the mission transcript shows that after 129 hours the crew were in a rest period.   Prior to that, there are again a number of discussions concerning lunar photography, and the suggestion here is that the time for 4.2.36c is Earthrise during orbit 27, which would have been at around 128 hours, or 00:49 on the 24th.

Figure 4.2.61c shows the suggested terminator line in Stellarium for that time. The large mass of white on the western limb is the fog banks off the west coast of north America merging with north Pacific weather systems, while the strip of cloud in south of the equator shows the equivalent fog bank and cloud systems off Chile. The clouds over Brazil are again easy to make out.

No more still images are to be examined – time to look at other media from the mission.

Figure 4.2.61: Stellarium estimate at time of terminator for figure 4.2.60a (left), 4.2.60b (middle) and 4.2.60c (right)

4.2.3 Other media.

As with Apollo 8, Apollo 10 was well reported in the press and CBS gave the mission large amounts of air time, including the broadcasts from the CSM itself. Most newspapers merely reported the event, or did mock ups of various stages of the mission, but some did present images from the live TV broadcasts on their front pages.

There are reproductions of these front pages available on the internet, but for the most part quality is poor. One relatively decent image can be seen from a local Wisconsin based newspaper, the Post-Crescent, available as a link from this web page at Newspaper Archive and reproduced in figure 4.2.62.

The quality is not perfect, and it is simply described as the western hemisphere in the text, so it is initially difficult to identify where the weather systems are in terms of the satellite images featured so far.

One link that does prove helpful is this one from NASA: NASA archive that is described as a screenshot from the Apollo live TV broadcast. This screenshot, the satellite images, and the Earth screenshot from the TV broadcast is examined in figure 4.2.63.

As with Apollo 8, it is worth remembering that this newspaper front page is from May the 19th, the day after launch, and therefore any photograph of Earth can only have been taken before that day. It is also interesting to note how well the Apollo mission is succeeding in distracting the media from the Vietnam war. The moon missions are often accused of being a deliberate distraction from Vietnam, but while Apollo 10 may have temporarily stolen the headlines, it is clear where the remainder of this paper's focus lies.

Looking at the NASA archive image, it also becomes obvious why it is difficult to place things on the newspaper front page: the Earth is upside down. In all Apollo photographs the terminator is always on the Eastern side when the globe is correctly oriented[1].

ESSA's orbit covering the central part of the daylight image is orbit 1018 (track 4) at 20:02. NIMBUS' orbit is 462, started at 18:10 on the 18th. Those two satellite images show clear correspondence to weather patterns on the TV image that were unique to that day.

One issue that did frustrate the TV networks was the lack of live footage of the Earth. The very first colour TV was not of the home planet, but of a long slow motion docking manoeuvre, which must have been extremely useful for mission control, but less than fascinating to the average TV viewer. The battle between pro and anti-TV camps in the Apollo 10 crew and support teams is well documented, but Walter Cronkite's frustration with the broadcasts is evident at times. Cronkite, and his occasional co-host Arthur C Clarke, were aware of the technical difficulties and did discuss the orientation of the craft relative to the Earth, but they and the watching public wanted to see the home planet, not just hear the astronauts describe the view.

What has emerged is that while many live broadcasts were made by the crew from the CSM, the Earth footage that was required was sometimes recorded and transmitted later in news broadcasts and the mission TV coverage, and this appears to be the case here. Stellarium estimates that the terminator line is at around 23:00 on the 18th of May, falling in between two live broadcasts. If it was the earlier broadcast (finishing at 22:07), more of south America would be visible. If it was the later one (starting just after midnight on the 19th) then there would be no south America coast visible at all.

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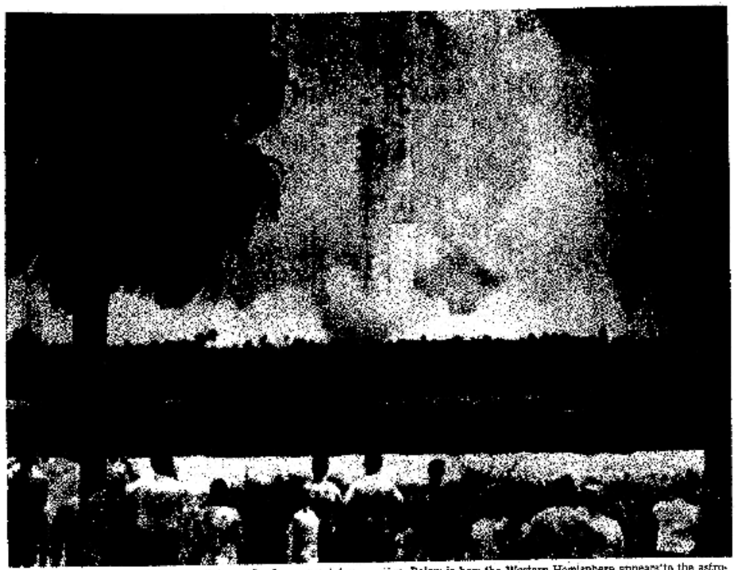
1 In some broadcasts, the inverted picture problem would be solved by turning the camera upside down.

THE POST-CRESCENT

VOL. LXXXII, No. 17 | 36 Pages | APPLETON-NEENAH-MENASHA, WIS., MONDAY, MAY 19, 1969 | ASSOCIATED PRESS WIRE SERVICE | Price Ten Cents



Apollo 10 Is Launched in a mass of flames Sunday as spectators crowd around for a view of the United States' Earth-to-moon mission. Below is how the Western Hemisphere appears to the astronauts from 36,000 miles in space. (AP Wirephotos)

3 Astronauts 'Great'; So Is Apollo Flight

Launch Done With Precision

SPACE CENTER, Houston (AP) — Apollo 10 moved flawlessly toward its moon destination today with only two minor complaints from the crew—dull thuds that interrupted their night's sleep and water chlorine that burned their mouths.

Despite the interruptions caused by periodic bursts from their small rockets the astronauts reported "We had a real great night's sleep."

About two hours after they began their sleep cycle, following Sunday's precise and hitchless launching, the astronauts complained mildly about the noise made by the rockets that slowly rotate the spacecraft. They worried about fuel consumption.

But on awakening after about 10 hours Air Force Col. Thomas P. Stafford reported "All three of us feel great."

Navy Cmdr. Eugene Cernan said the thruster noise sounded "just like a minor pulse, just vibration."

Ahead of Schedule

Stafford and Cernan were awake a half hour ahead of schedule, but Navy Cmdr. John A. Young slept out the distance.

The astronauts began their day by giving a global weather report from their vantage point 107,000 miles above the Earth.

They complained about the chlorine in their water supply and Stafford said: "The water is absolutely horrible. I got a horrible slug of chlorine. My mouth is still burning. John did too. I just want to put that on the record."

Before they retired, the Apollo 10 crew argued mildly with the ground about the necessity for rechlorinating the supply, but lost the argument. Ground controllers, after studying the problem, admitted today they had given the astronauts the wrong procedure for the rechlorination and that apparently a large concentration of the purifier had collected in the bottom of the tank.

The controllers told the astronauts to "open the portable tank inlet and take a bag and draw off a bag full of water—get rid of the chlorine concentration."

Given Horoscopes

"We have your horoscopes for you," said capsule communicator Bruce McCandless. Then he and fellow astronaut Charles Duke began reading them.

"Tom, you have to concentrate mainly on finishing things that are already started," Duke told Stafford, a Virgo. "Line up your plans; take inventory. The pace of the day should be moderate."

Cernan, a Pisces, was told to "make sure your home and workplace are free of hazards. Give thought to your driving and work habits. Do something nice for somebody you care about."

And for Young, a Libra, the message was "Take advantage of a relatively slow day to get a better perspective on your job. Look around, ask some questions and think about the answers from various angles."

Precision Launch

Sunday's launch was accomplished with a precision and nonchalance unimagined when America first ventured into space eight years ago.

The spacecraft's television cameras took Earthlings along as sightseers as they moved smoothly on their pathfinding mission for the landing of the first humans on the moon, scheduled for July.

It went like the script said: the launch of the Saturn 5 rocket, the insertion in orbit, the separation of spacecraft from booster rocket, the spacecraft's somersault, then its return to the booster to pluck out the lunar lander.

A ground controller said it was like a taped replay of Earth bound practice sessions.

"That's all it is, babe," said Cernan.

Until Wednesday, when Apollo 10 nears the moon after hurtling 251,307 miles, its crew has relatively little to do.

The experiments that made this flight look easy were perfected step-by-step, mission-by-mission in America's 19 space trips beginning with Alan B. Shepard's 15 minute, 22 second flight May 5, 1961.

As the bullet shaped ship sped from Earth's grasp, hooked nose-to-nose with the ungainly space taxi that will take Stafford and Cernan close to the moon's surface Wednesday, its crewmen found time to share their exploits with TV viewers on the ground—and to exult over the sights.

Extra Picture

Instead of transmitting only 15 minutes as planned, the color cameras went on four times for a total of 72 minutes.

The Earth, partly swaddled in clouds and glowing brilliant blue and brown against the black velvet of space, prompted Cernan to exclaim:

"You blink your eyes and look

Turn to Page 2, Col. 4

Follow Geneva Rules

Laird Tells Hanoi To Release POWs

WASHINGTON (AP) — Secretary of Defense Melvin R. Laird called upon Hanoi today for prompt release of all American servicemen now held in North Vietnamese prison camps.

Failing this, Laird said the North Vietnamese government should at least provide for humane treatment for the several hundred Americans currently locked up in North Vietnamese camps.

"The North Vietnamese have claimed that they are treating our men humanely," the defense chief said. "I am distressed by the fact that there is clear evidence that this is not the case."

Laird said that by next month more than 200 American servicemen will have been listed either as prisoners of war or as missing in action for more than 3½ years.

"This period of time is longer than any U.S. serviceman was held prisoner during World War II," he stated.

Laird told a news conference the Pentagon "continues to hope for meaningful progress" toward the release of prisoners as part of the Paris peace talks, but he offered no encouragement that this would come about soon.

Laird demanded that North Vietnam at least adhere to provisions of the Geneva convention, which it has signed, which would allow:

—Release of names of prisoners held.

—Immediate release of sick and wounded prisoners.

—Impartial inspections of facilities for prisoners of war.

—Proper treatment of all prisoners, and

—Regular flow of mail.

Lodge Informed

Laird's statement to newsmen was followed by a lengthy briefing by other officials on the prisoner situation. They said the same information had been provided to Ambassador Henry Cabot Lodge, the chief U.S. negotiator in Paris.

Officials said Lodge, as well as the men who preceded him under the Johnson administration, has raised the matter of prisoner release, but the North Vietnamese response "has been very limited thus far."

The Pentagon said the news conference on the prisoner question was called because of considerable interest on the part of the press, but officials acknowledged that it was also a way to get a message across to North Vietnam.

"The other side is aware of what we say," said Frank Sieverts, a State Department representative who helped conduct the prisoner briefing.

Laird urged that Hanoi provide the United States more information about the identities, location and status of U.S. prisoners held in North Vietnam.

Mrs. Eugene Cernan, wife of the Apollo 10 astronaut, appears a bit apprehensive Sunday as she watches the ship launched into space at Cape Kennedy. With her is her daughter Tracey, 6. (AP Wirephoto)

Cool Tonight for White Sox, Foxes

Fox Cities — Partly cloudy tonight and Tuesday, cooler Tuesday. Low tonight near 42, high Tuesday near 68. Wind southwest at 8-14 m.p.h. shifting to north at 8-14 m.p.h. tonight. Precipitation probability 20 per cent tonight and Tuesday.

Appleton — Observations at 9:30 a.m. for the preceding 24 hours: high 57, low 40. Barometer 29.95 and steady. Wind west-southwest at 10 m.p.h. Humidity 77 per cent. Dew point 50. Skies clear. No precipitation.

Sun sets at 8:18 p.m., rises Tuesday at 5:22 a.m. Moon sets at 11:58 p.m.

TODAY'S INDEX

Battle for Mountain

'Gooks Are Still Fighting'

BY JAY SHARBUTT

DONG AP BIA, Vietnam (AP) — The paratroopers came down from the mountain, their shirts dark green with sweat, their weapons gone, their bandages stained brown and red with mud and blood.

Many cursed Lt. Col. Weldon Honeycutt, the hard-nosed battalion commander who sent three companies Sunday to take this 3,000-foot mountain just over a mile east of Laos and overlooking the shell-pocked A Shau Valley.

They failed and they suffered.

"That damn Blackjack won't stop unless he kills every damn one of us," said one of the 40 to 50 101st Airborne Division troopers who was wounded.

Blackjack is Col. Honeycutt's radio code name.

At least 12 died on the hill.

Given Order

Honeycutt, 36, of Columbus, Ga., had been given an order: Take the mountain. It had been steadily pounded since May 10 by artillery, riot gas and more than 70 air strikes. It is believed to contain a North Vietnamese regimental headquarters and a supply cache.

By Sunday, the mountaintop was almost bare. Its heavy jungle cover blasted apart by artillery, rockets, bombs and napalm. But still visible were the bunkers. They looked like evenly spaced shell depressions.

U.S. intelligence said Sunday morning the mountain was held by "two companies, plus." In the afternoon, Honeycutt revised it upwards to two battalions that had infiltrated and reinforced the mountain stronghold Saturday night.

Since May 10 his battalion had suffered heavy casualties assaulting Dong Ap Bia — about 35 killed and some 180 wounded seriously enough to be evacuated.

Shell Lands Short

As of Sunday, the mountain had been ground-assaulted 10 times by the 3rd Battalion, 187th Infantry.

The paratroopers had made it to the top three times, and three times intense enemy fire drove them back.

On the second try, a U.S. artillery shell landed short, wounded a company commander, his first sergeant and a forward artillery observer. The confusion that followed gave the enemy time to regroup and drive the Americans back.

Spec. 4 Anthony Tull, 20, of Nashville, Ind., had made nine of those assaults against Dong Ap Bia, and the dark-haired, slender veteran of eight months in Vietnam was bitter.

"After all those air and artillery strikes, those gooks are still in there fighting. All of us are wondering why they just can't pull back and B52 that hill," he said.

"I've lost a lot of buddies up there. Not many guys can take it much longer."

Why take the hill?

"Well, for one thing, it overlooks a good deal of the A Shau Valley," said Honeycutt. "For another, you pull back and Charlie sure as well will follow you right down and hit you."

More Firepower

Why do the North Vietnamese defend it so strongly?

"I can't say for sure. I wish I could," said the division commander, Maj. Gen. Melvin Zais. He said one option open to him was to back off and "bring in more firepower."

"But you hate to give up the ground you've gained," he added. "You'll have to fight just as hard to retake it. Backing off is one thing that commanders hate to do."

What about a massive B52 strike on Dong Ap Bia?

"Look, those gooks aren't stupid," said one intelligence officer. "They know exactly how much damage an arc light (B52 raid) does, how deep the bombs blow.

10th Assault

"They build their bunkers to withstand that. That's what they've done out there."

And possibly for that reason—to root out the enemy—the men of Honeycutt's battalion were sent up Sunday for their 10th assault against enemy bunkers, claymore mines, rocket-propelled grenades and a hail of bullets.

"Damn it, Cyclone Six, get those men spread out. They're all clustered up. You're get-

Turn to Page 2, Col. 1

P-C Contest Over

The entry deadline for The Post-Crescent's "First American on the Moon" contest was May 1. The P-C's promotion department notes that the flight of Apollo 10 is spurring new interest in the contest, but that new entries are not being accepted.

What They Mean

SPACE CENTER, Houston (AP) — A glossary of terms used by astronauts and their controllers pertinent to Apollo 10's journey into moon orbit:

Charlie Brown — Radio call name for the command module when separate from the lunar landing vehicle.

Cislunar — Adjective referring to space between Earth and moon or between Earth and moon orbit. ("Cis" is Latin for "on this side.")

Equigravisphere—The point at which the gravitational pull of earth and moon are equal.

Escape velocity — The speed an object must reach to overcome a gravitational pull. This is 25,402 miles an hour to overcome the gravity of the Earth and 6,170 miles an hour to overcome lunar gravity.

LEM — Lunar landing craft or lunar module. This acronym once stood for lunar excursion module, but the name has been shortened to lunar module.

LOI — Lunar orbit insertion, or going into moon orbit, planned for Wednesday.

Snoopy — Radio call name for lunar module when separate from command module.

Terminator — Separation line between lighted and dark portions—sunrise or sunset—of a celestial body which is not self-luminous.

Translunar — Toward the moon.

Figure 4.2.62: The Post Crescent headline from May 18th 1969

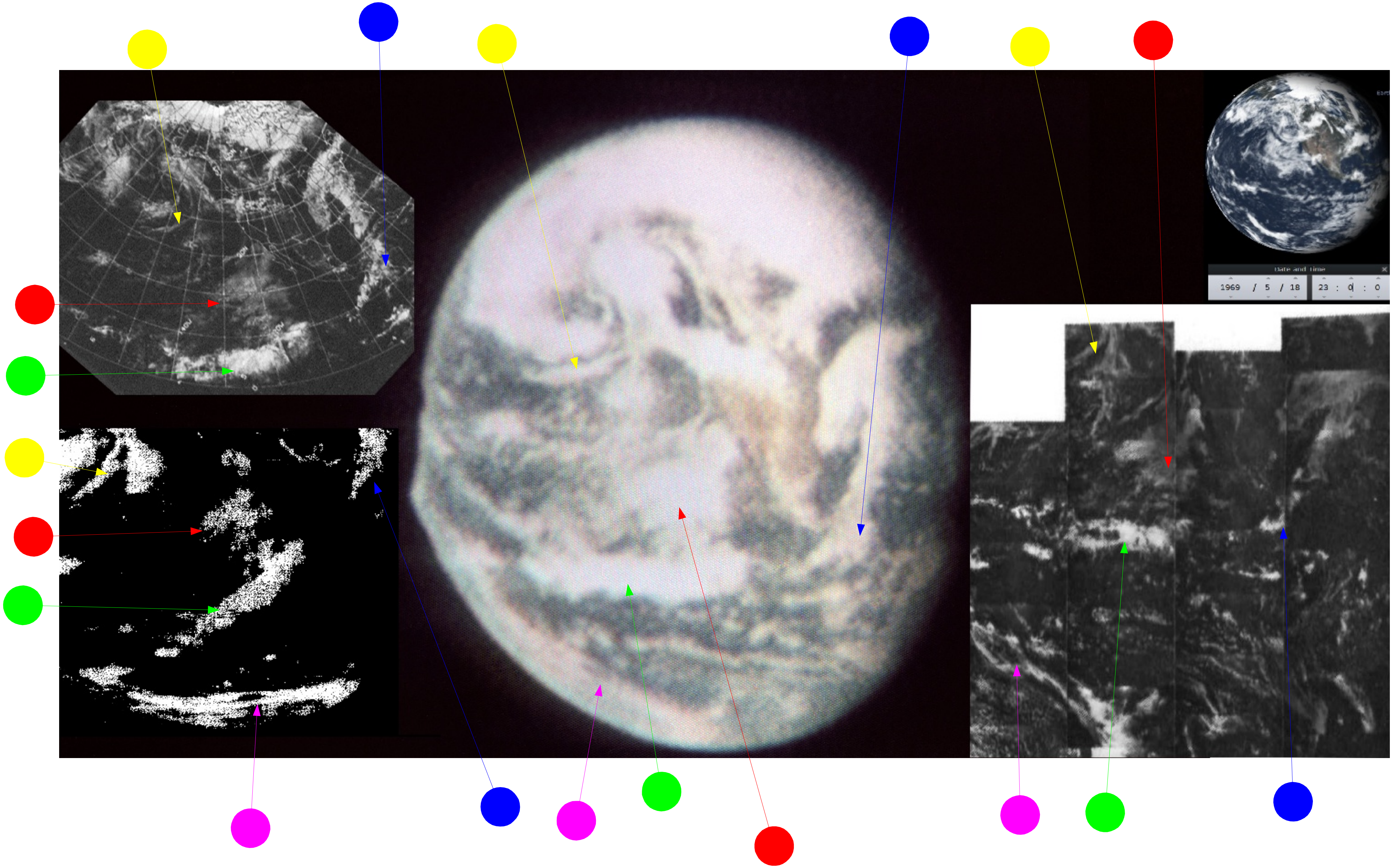


Figure 4.2.63: Comparison of TV broadcast screenshot, Post Herald front page and ESSA & NIMBUS satellite images from May 18th 1969

Figure 4.2.64: Screenshots from TV broadcast, May 19th 1969. Time and distance travelled self evident.

Notwithstanding these issues, the TV image was clearly taken on the 18th. It could not have been taken later as the cloud patterns would have been different and it would not have made it into the newspapers on the 19th.

The day after this image was sent back to Earth, a live broadcast was made that can definitely be pinpointed in time, mainly thanks to CBS helpfully identifying when & where the Earth was filmed (figure 4.2.64 above, youtube source). The time on the left hand image converts to 20:17 on 19/05/69, towards the end of the crew's 5th live TV broadcast. As the screenshot on the right is slightly clearer, this image will be used to compare with ESSA & NIMBUS images (figure 4.2.65).

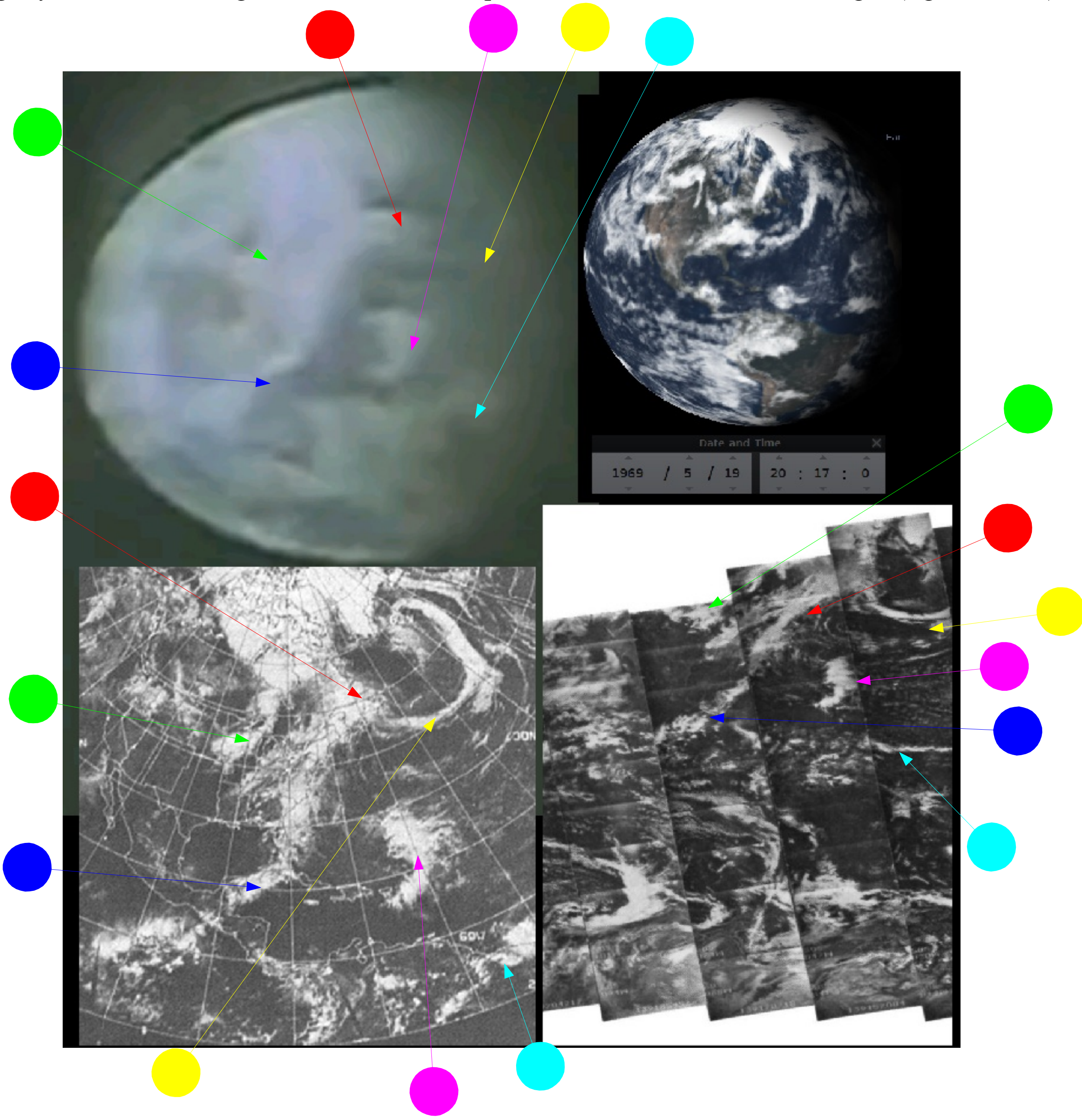


Figure 4.2.65: TV screenshot & ESSA & NIMBUS images from May 19th 1969, with Stellarium inset.

In addition to the arrows pointing out the obvious, the AFJ records the conversations between ground & crew during the live broadcast here AFJ link, in which the crew discuss the land masses visible. Unsurprisingly, they are exactly as depicted here.

A later broadcast (youtube source) that can also be identified with some clarity occurred several days in to the mission. The image (figure 4.2.66 – shown with the relevant satellite images) is from 72 hours and 38 minutes in to the mission, as marked by communications between the astronauts on the AFJ here: AFJ link, where the astronauts again describe features visible on the Earth's surface. As an additional time marker, a couple of hours before ground control relay sports results and other news to the crew, reported on this page AFJ link.

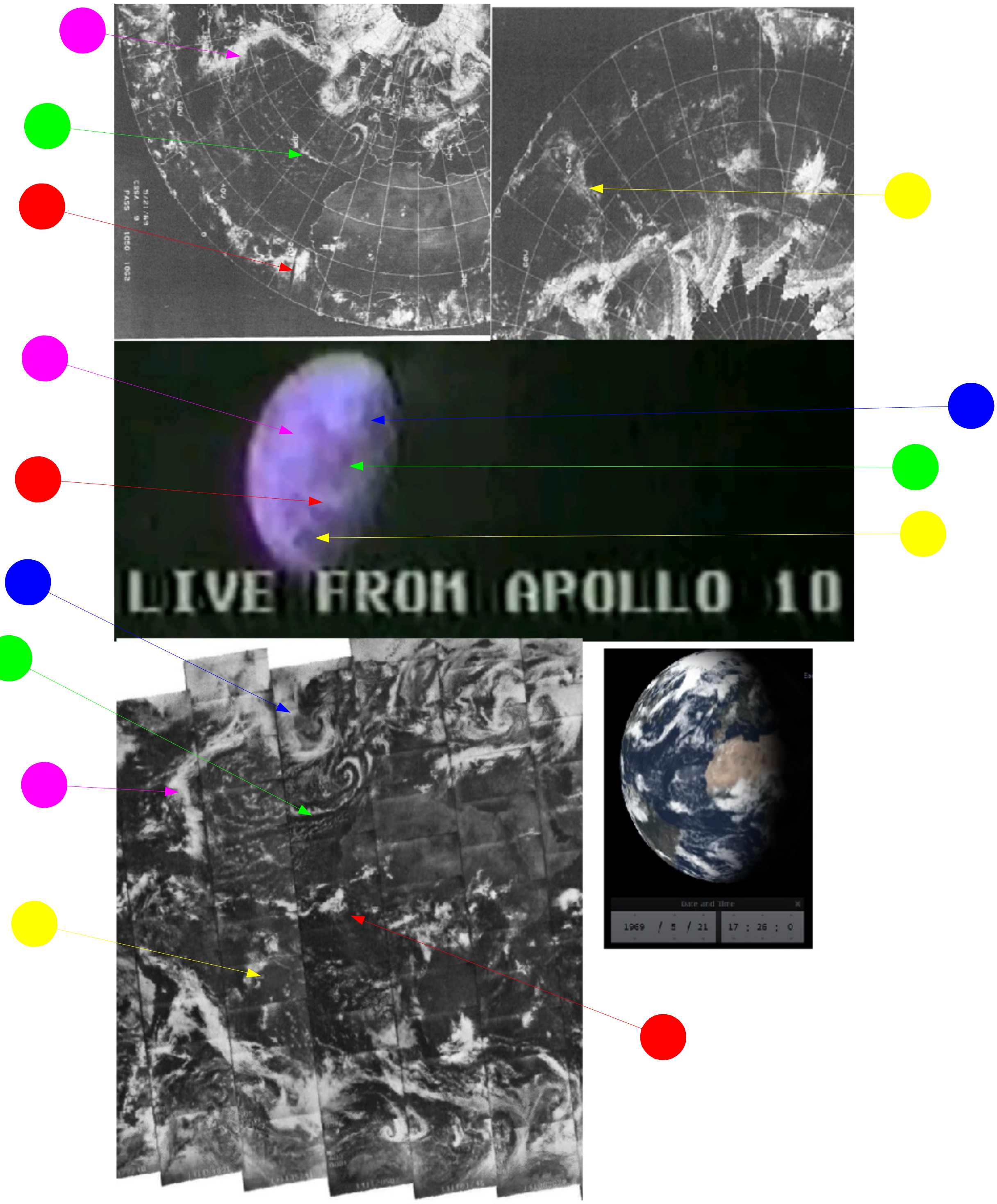


Figure 4.2.66: Cropped screenshot of Apollo 10 live CBS TV broadcast with ESSA & NIMBUS images from 21/05/69, and Stellarium insert showing terminator position at time of broadcast.

Again the satellite evidence, the recorded conversations with the crew, and the inclusion of sports results from the same day all support the premise that the live TV broadcasts cited here were just that, live from space, on the way to the moon.

In addition to the television video, there are also the videos recorded by the DAC as Apollo 10 orbited the moon. For the most part, these images add little to the narrative of this section, as many screenshots taken from the videos are not of the same quality as the still photographs taken at the same time. One exception exists here, however, which is video recorded of an Earthrise on a day that does not have any still photographs featuring Earth: May 22nd.

On magazine h of the DAC films presented on the AFJ page here: AFJ Apollo 10 videos there is an Earthrise sequence. This sequence starts at 4m44s into the clip, but significantly the first glimpse of the Earth is at 4m42s when the camera is moved from focussing on the ground to focussing on the horizon (almost as if the cameraman has suddenly realised what he is missing). This is important because it demonstrates that the Earthrise is part of a long unedited sequence that would not have been possible to recreate in the kind of sound stage that Apollo conspiracy lovers like to imagine was used.

The initial Earthrise component of this magazine ends at 5m29s when the cameraman returns his focus to the ground, but at 6m10s his focus returns to the Earth until 6m20s, when his attention again returns to the ground. In total the video is 7 minutes and 10 seconds of unbroken footage of a single part of a single orbit.

A video screenshot from this Earthrise, together with ESSA & NIMBUS & Stellarium images from 22/05/69 are given below in figure 4.2.67

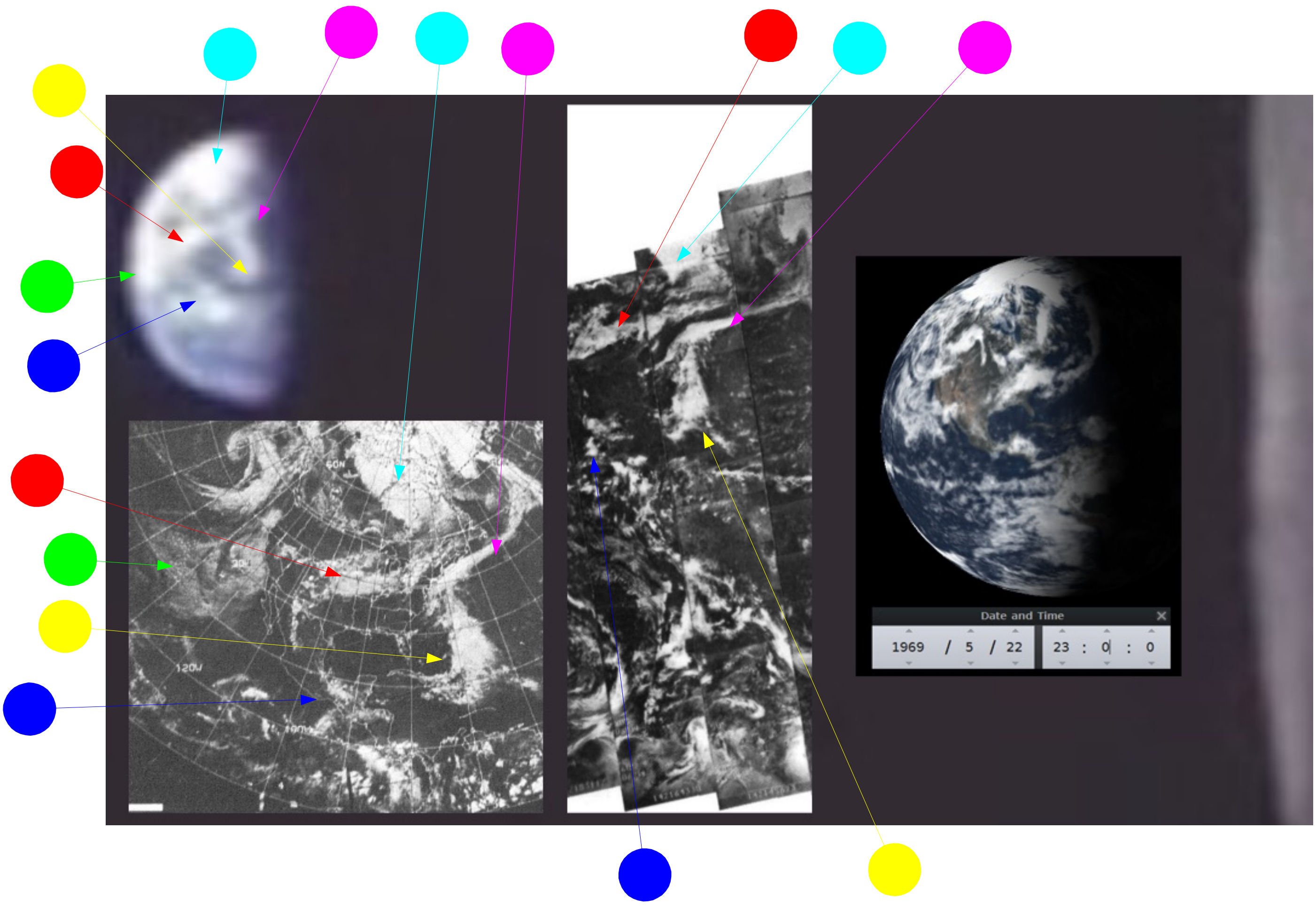


Figure 4.2.67: Screenshot from Magazine H of Apollo 10's DAC footage., combined with ESSA & NIMBUS images from 22/05/69, and Stellarium projection of terminator line.

There are two caveats that must be employed here. Firstly, (as with the TV footage) the quality of the screenshot is not high, and the kind of detail available in the still photographs is absent here. Secondly, the Stellarium projection of the terminator line is based not so much on visible land masses as on the position of the clouds in the satellite images. While this makes this evidence somewhat self-referential, the fact that the large scale weather systems in the DAC image can be related to the satellite images validates its use. Stellarium's terminator has been position based on its proximity to the large cloud mass over the Caribbean. Using this as a marker, the estimated time can be put at roughly 23:00.

It is possible to be a little more precise here. At roughly 23:00 on May 22nd, Apollo 10 was 90 minutes past its closest approach to the lunar surface and would, in another 30 minutes, experience the near catastrophic 'anomalous motion' that caused such alarm. The Apollo 10 mission report (*op. cit.)* states that Apollo 10's craft (now separated & orbiting separately), would experience loss of signal (LOS) as it disappeared behind the Moon at 101 hours and 36 minutes into the mission, or 22:24 GMT. Acquisition of signal (AOS) would be at 102 hours 22 minutes, or 23:12 GMT[2]. As AOS can only occur when the Earth becomes visible to the orbiting craft, the Earthrise image was therefore taken sometime around 23:12, 22/05/69.

There are other video sources available for Apollo 10 with clearer TV images (found late in the preparation of this research). One such example is a documentary film entitled "Apollo 10 – To sort out the unknowns", which is available for download on the archive.org website here. These videos do need to be treated with care, as often images are placed out of context, and it is not uncommon for them to borrow footage from one image and use it in another (Apollo 4's famous separation sequence, for example, makes it into many videos of later missions). Likewise zooming out from, or panning across, still images is often used as a substitute for actual footage. In this video, however, the footage does appear to be genuine moving images,and Earth features several times during it.

For the most part, Earth is shown in sequence through the film, but there is one shot out of context. At 06:55minutes in to the film there is a shot of mission control with an image of Earth in close up on screen that appears after an image of Earth from some distance. The Apollo cameras were good, but not that good. Figure 4.2.68 overleaf shows a screenshot from the film, together with the Earth image cropped and zoomed in and the satellite images that match the clouds.

The fact that there is no horizon visible lends itself to the suggestion that this image was taken not long after launch on the 18th, and it is obviously being broadcast live into mission control, so there should be a record of a TV broadcast (or at least a recording for a TV broadcast) not long after launch. Examination of the satellite images around launch time show the closest available match are indeed ones dated the 18th of May. The coastline of California (at the bottom of the ESSA satellite photograph) allows us to locate where this image was viewing.

Can we find any records in the mission transcript that match up with this? The timelines show that there was a TV broadcast at just after midnight on the 19th – 7 hour and 11 minutes into the mission. After some initial wide shots, the crew begin to zoom in on the Earth, and after describing the general mass of cloud over the northern hemisphere, they discuss some specifics. Capcom mentions the coast of California and Baja California in the 'bottom right' (actually the bottom left by the time the crew zoom in to the screenshot we see), and then asks:

"Roger 10. Up in the vicinity of Alaska, we see a swirl, Does that look like a storm system of low-pressure area to you?"

To which the crew reply:

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2 The times given are for the CSM. The LM times are a few minutes later.

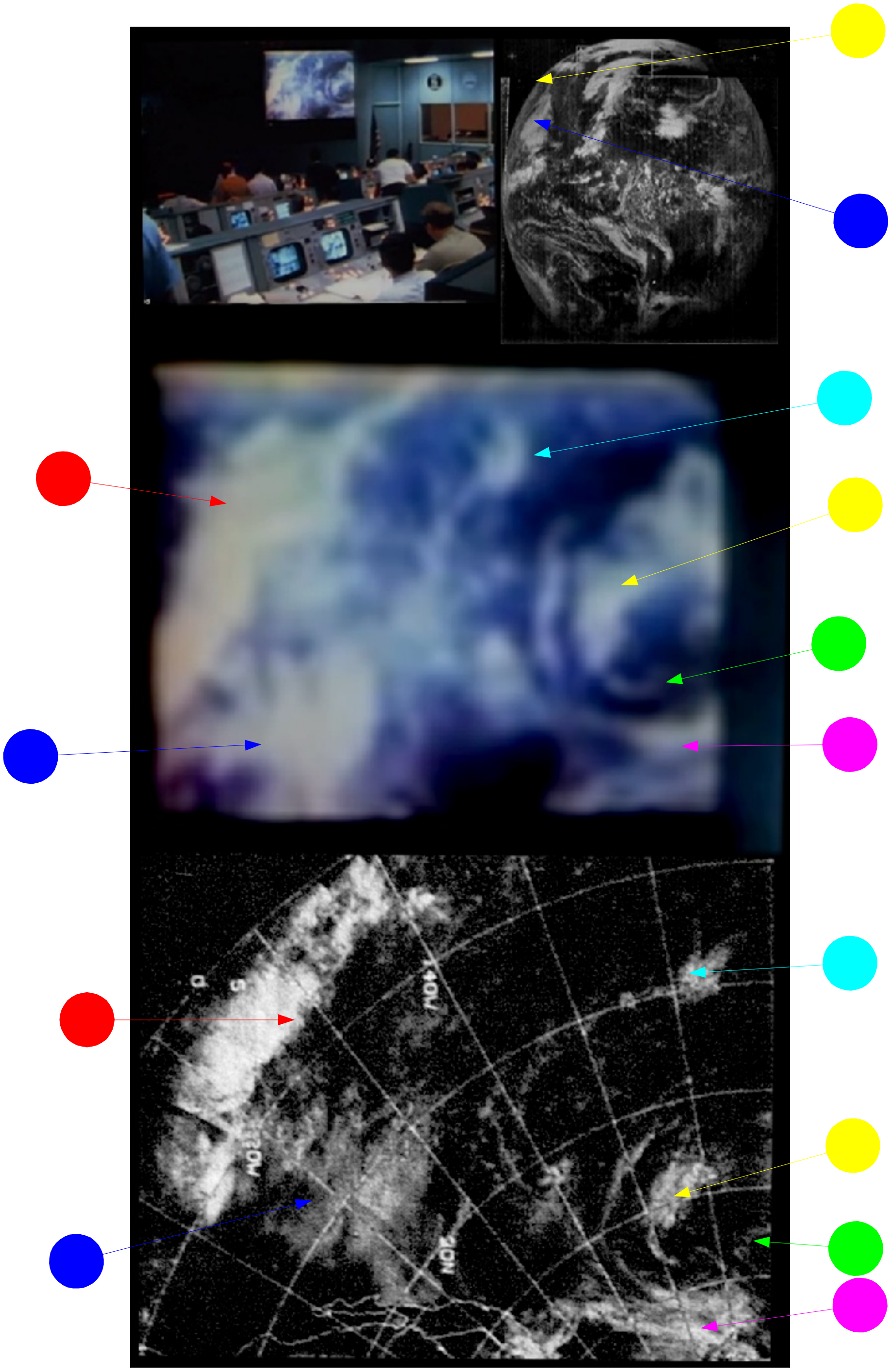


Figure 4.2.68: Apollo TV screenshot compared with ATS-3 (top right) and ESSA 9 (bottom) satellite images dated 18/05/69

"Yes. You've got a swirl out there right on the - off the coast of Alaska."

The annotations should identify the same weather systems in the TV screenshot and satellite images, and it should also be obvious that the weather systems are the same ones as those shown in figure 4.2..63 (the yellow and red arrows are the same, with the yellow arrow being the swirl described by the crew. The ground and Apollo crews both refer to the terminator on the zoomed out picture as showing night falling across the US, which means it is later than the terminator falling some distance off the east coast in figure 4.2.63. The ESSA track covering this part of the Pacific (number 6, orbit 1020) would have commenced at 00:03, and therefore could not have been used to make a fake Earth for the broadcast. ATS-3 did not cover that part of the Pacific.

Earlier in the film, at 05:18, there is a sequence showing the screenshot already discussed in figure 4.2.63, and shortly after that, at 06:10 there is a view of a much smaller Earth (figure 4.2.69).

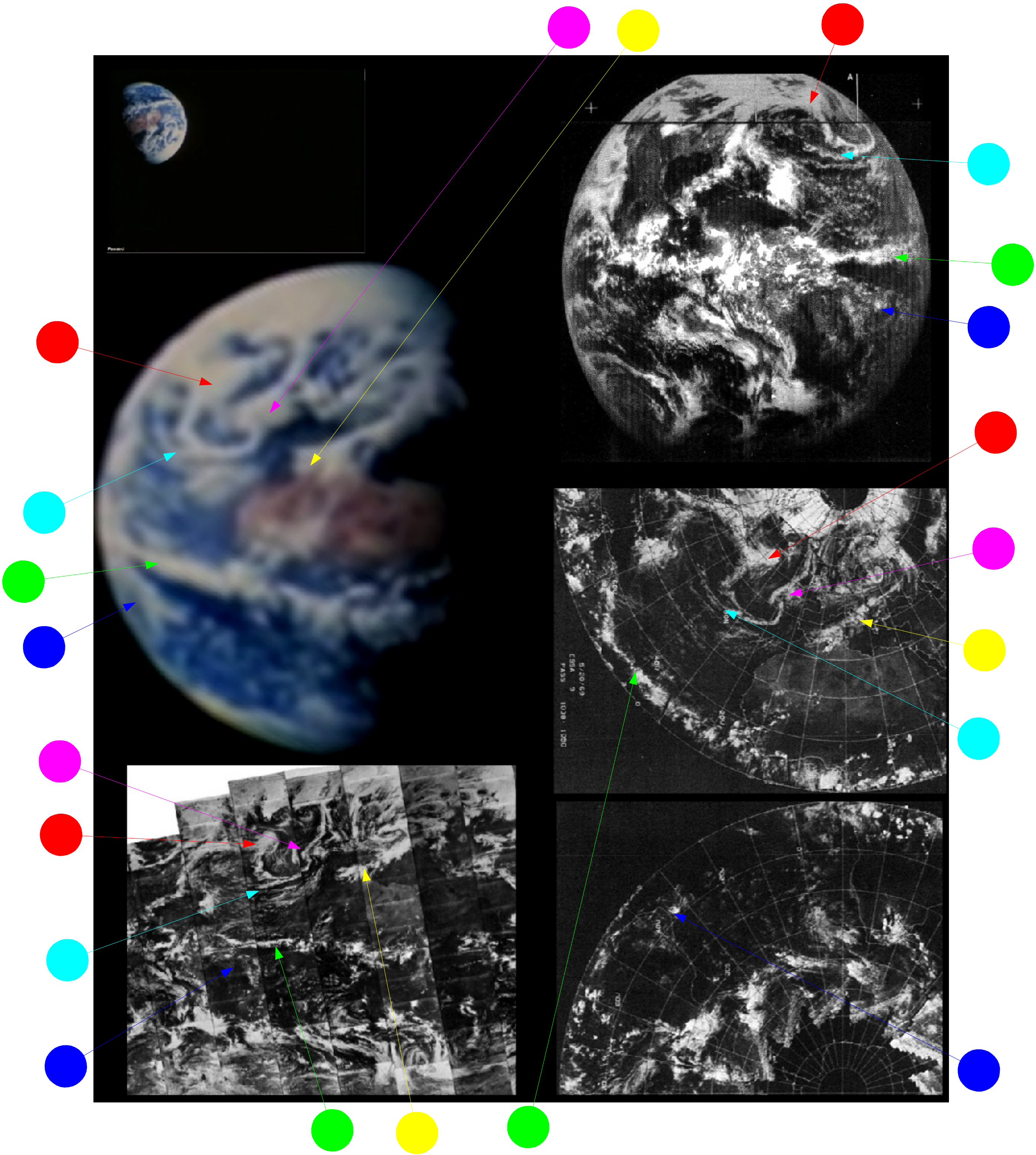


Figure 4.2.69: Screenshot of Apollo TV footage compared with ATS (top right), ESSA (middle and bottom right) and NIMBUS (bottom left) satellite images dated 20/05/69

The terminator line suggests a time of around 16:30. At about this time the crew were sending a signal to the Madrid receiving station for broadcast later. They describe the view of Africa that was visible on their monitor, saying that:

"The Suez Canal appears to be going into darkness"

which is exactly what can be seen on the screenshot, along with the islands off Greece going into darkness, something else they comment on in the transcript.

The next Earth image taken from this film is less easy to pin down. It can be found at 07:20. The width of the visible part of the Earth's disk suggests that it is still early in the mission, but the small size of the disk overall, the out of focus shot, and the visible colours make it difficult to determine which land masses are in view. Figure 4.2.70 shows the suggested analysis for this image.

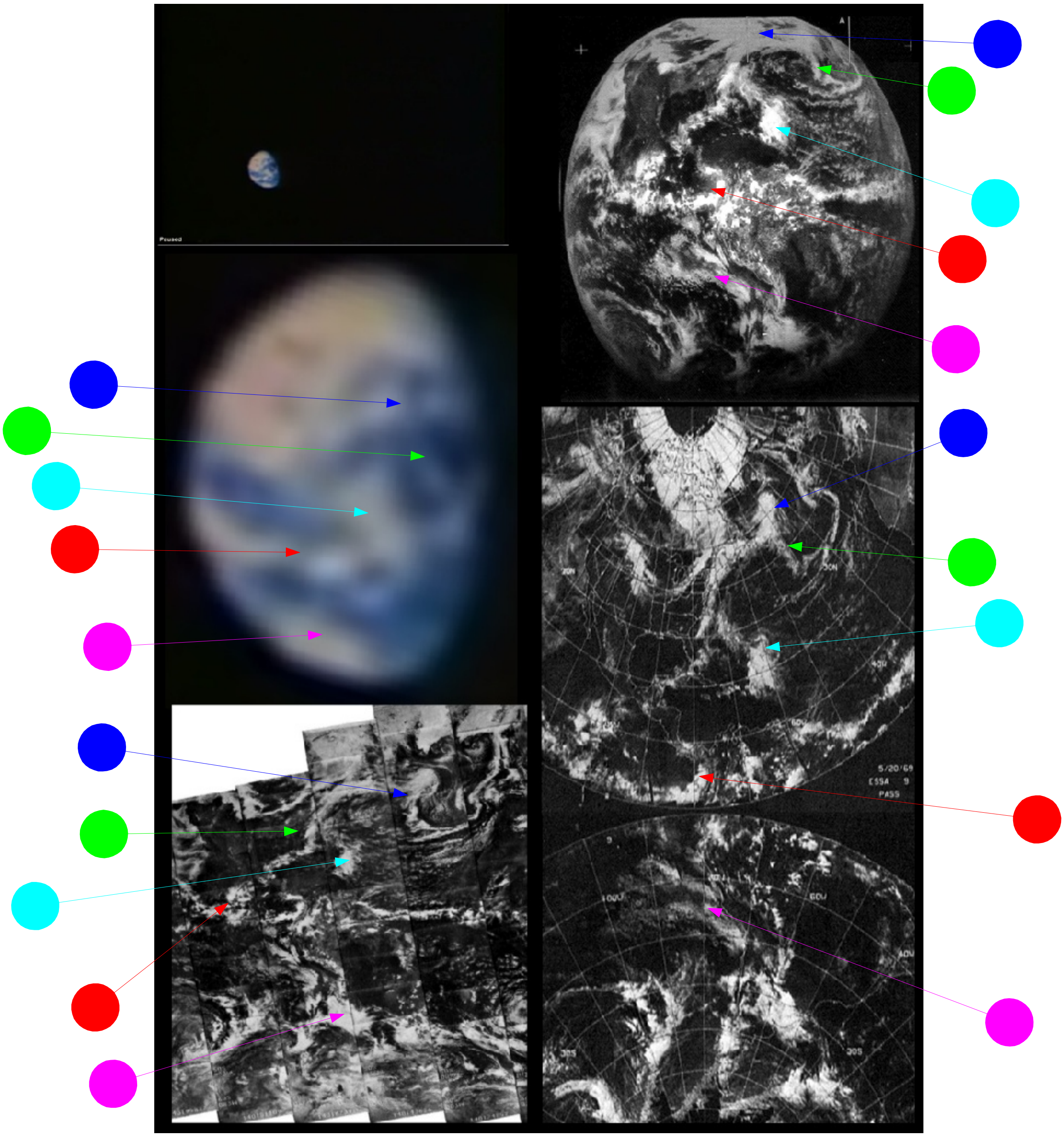


Figure 4.2.70: Apollo 10 screenshot (original shown top left) compared with ATS (top right) ESSA (bottom & middle right) and NIMBUS (bottom left) satellite images from 20/05/69.

A certain amount of interpretation is required here, and alternative versions would be welcomed, but it seems reasonable to suggest a time of broadcast at roughly 17:00. This would coincide with the crew's description of what they can see through the monocular in the transcript – the west coast of Africa, and north and central America. It is difficult to be entirely certain as the clouds in the video are the same colour that would be expected of some land surfaces. The magenta arrow, which is suggested to identify fog banks off western south America, should have south America next to it but it is difficult to see. This does not mean it is not there, and this land mass usually appears very dark thanks to the Amazon rainforest. As with other images elsewhere in this research, it is better to identify and admit areas where there is less certainty rather than pretend they do not exist.

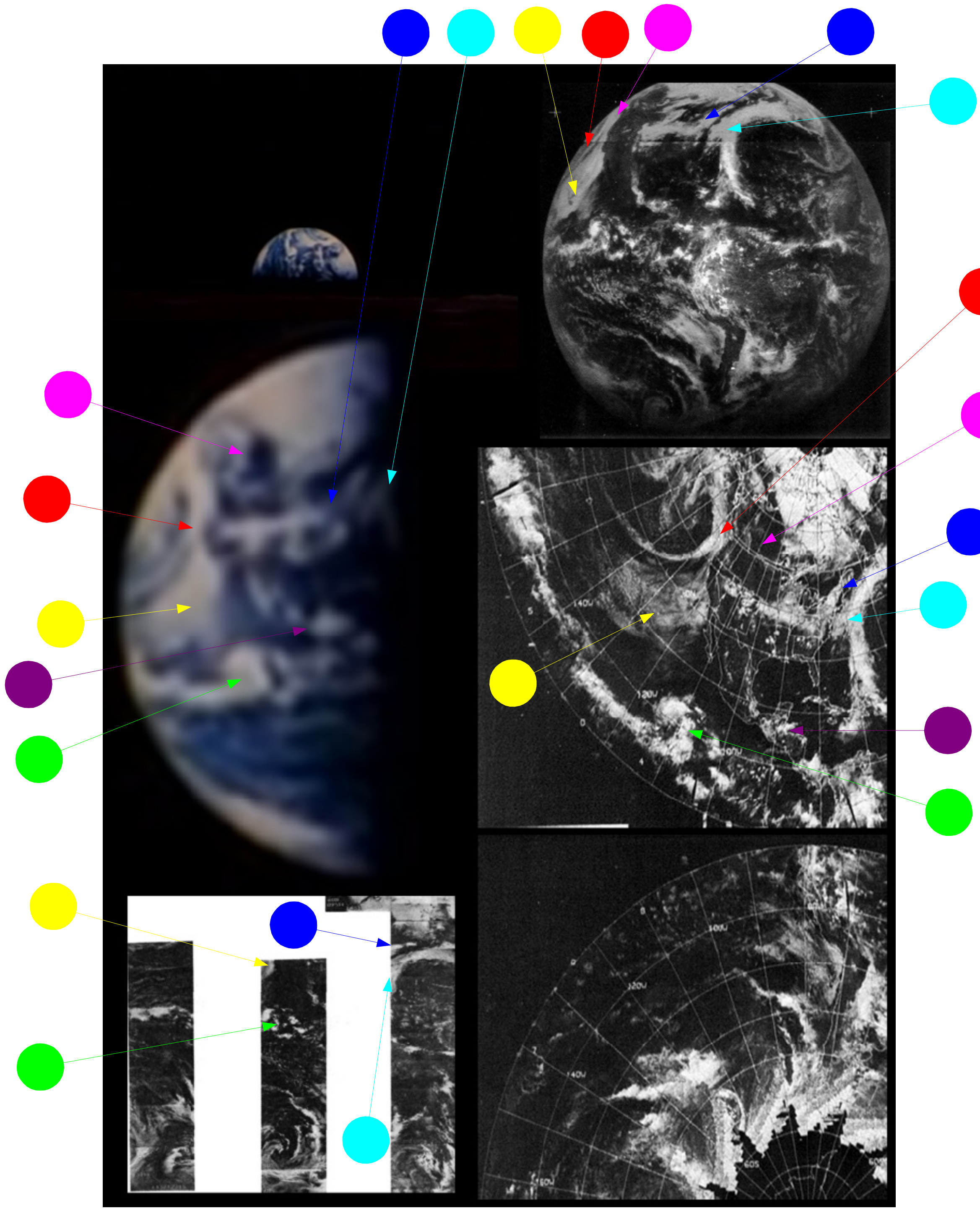


Figure 4.2.71: Apollo 10 screenshot compared with ATS (top right), ESSA (bottom and middle right) and NIMBUS (bottom left) satellite images from 23/05/69. Original screenshot is top left.

The final screenshot from this video is shown in figure 4.2.71 above. It is from an Earthrise video. In comparison with the precious image, there can be no doubt as to which part of the Earth we are looking at. The terminator is running down the east coast of north America, and the cloud band across the USA is very marked, as is the very large swirl of cloud off Alaska.

This screenshot shows the same details as those in figure 4.2.18 for AS10-35-5230, and is obviously taken at the same time – around midnight on the 24th, which is the start date for the two LEO satellites. The coloured arrows are the same as used in that figure, and the reader is referred back to that section for analysis of the timings of the video sequence.

Having dealt with the photographic and video evidence, it is now time to examine other supporting evidence in the form of synoptic charts.

4.2.3 Meteorological Evidence

Having discussed at some length the relationship between Apollo images and satellite evidence, it is again necessary, as with Apollo 8, to quickly confirm that the weather patterns indicated by satellite imagery do actually reflect terrestrial meteorological observations. Some quotes from the mission transcript may already have been referred to.

The same sources are available for Apollo 10 as for Apollo 8, but as few of the photographs available feature southern Africa clearly, the South Africa dataset is of less use. Several day's weather charts will be examined – on the way out, during lunar orbit, and on the return journey. Meteorological data are found in Appendix E, and are from the same sources as referenced for Apollo 8.

Figure 4.2.72 shows a zoomed & cropped versions of AS10-34-5026 and AS10-34-5013 featured earlier in this document, with main weather systems identified. Figure 4.2.73 shows these same weather systems identified on the north Atlantic, South African and north American synoptic charts.

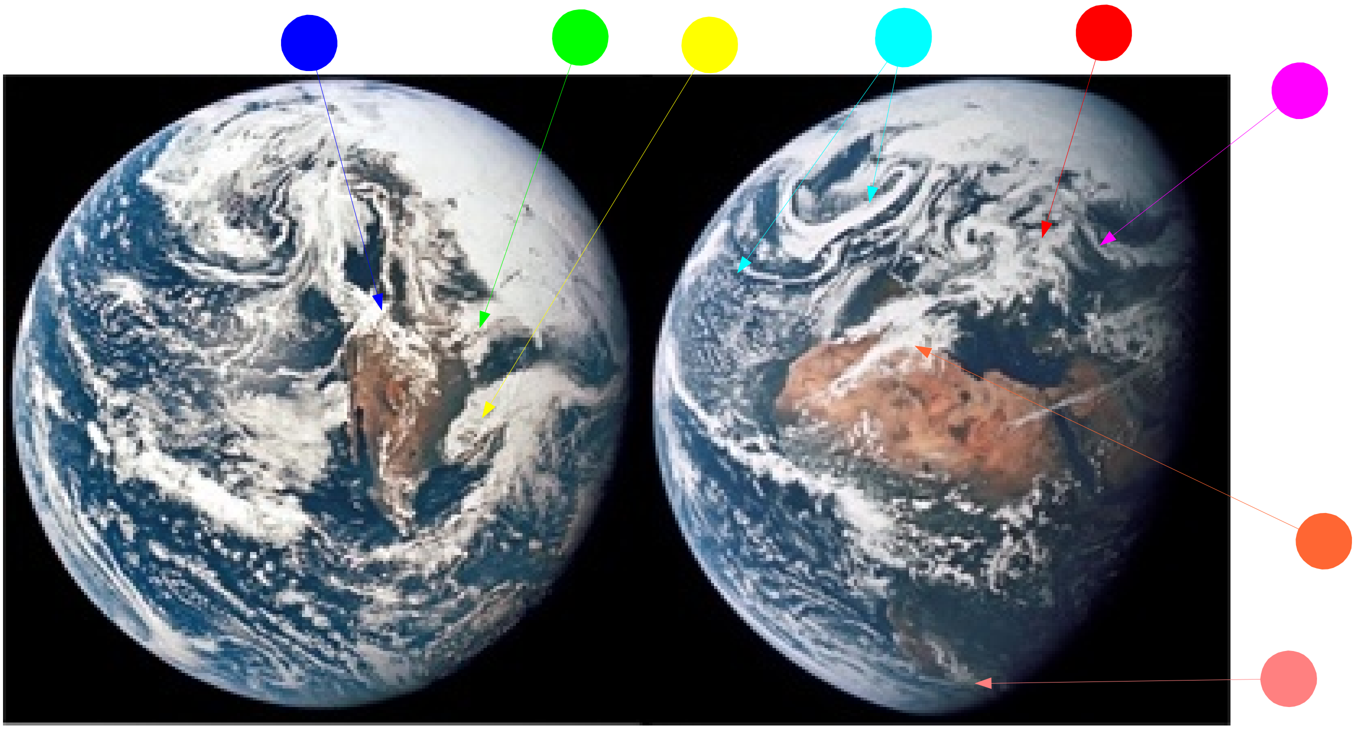


Figure 4.2.72: Earth from AS10-34-5026 and AS10-34-5013[1] on 19/05/69.

As with Apollo 8, no meteorological expertise is claimed here, but the frontal systems, and also the areas of high pressure that tend to produce little or no cloud, marked on the charts have a clear correspondences with those on the Apollo photographs. In common with Apollo 8, the Apollo 10 crew spent some time describing the Earth to mission control, either as part of their regular TV broadcasts or as part of normal communications with the ground. Indeed it is evident in some of the conversations that capcom are looking at weather charts and comparing them with what the astronauts are describing and the TV cameras transmitting.

At around the time AS10-34-5013 was taken, for example, the crew describe over several pages of transcript (around 5 hours in to the mission) the cloud cover over Alaska & Canada and a low pressure system near New England (in all probability the systems identified by the yellow & blue

1 Although dated at 22:45 GMT on the 18th in this analysis, the local time for the US synoptic chart is 7am, on the 19th, or the 03:45 GMT on the 19th. This time difference can reasonably be discounted for this discussion.

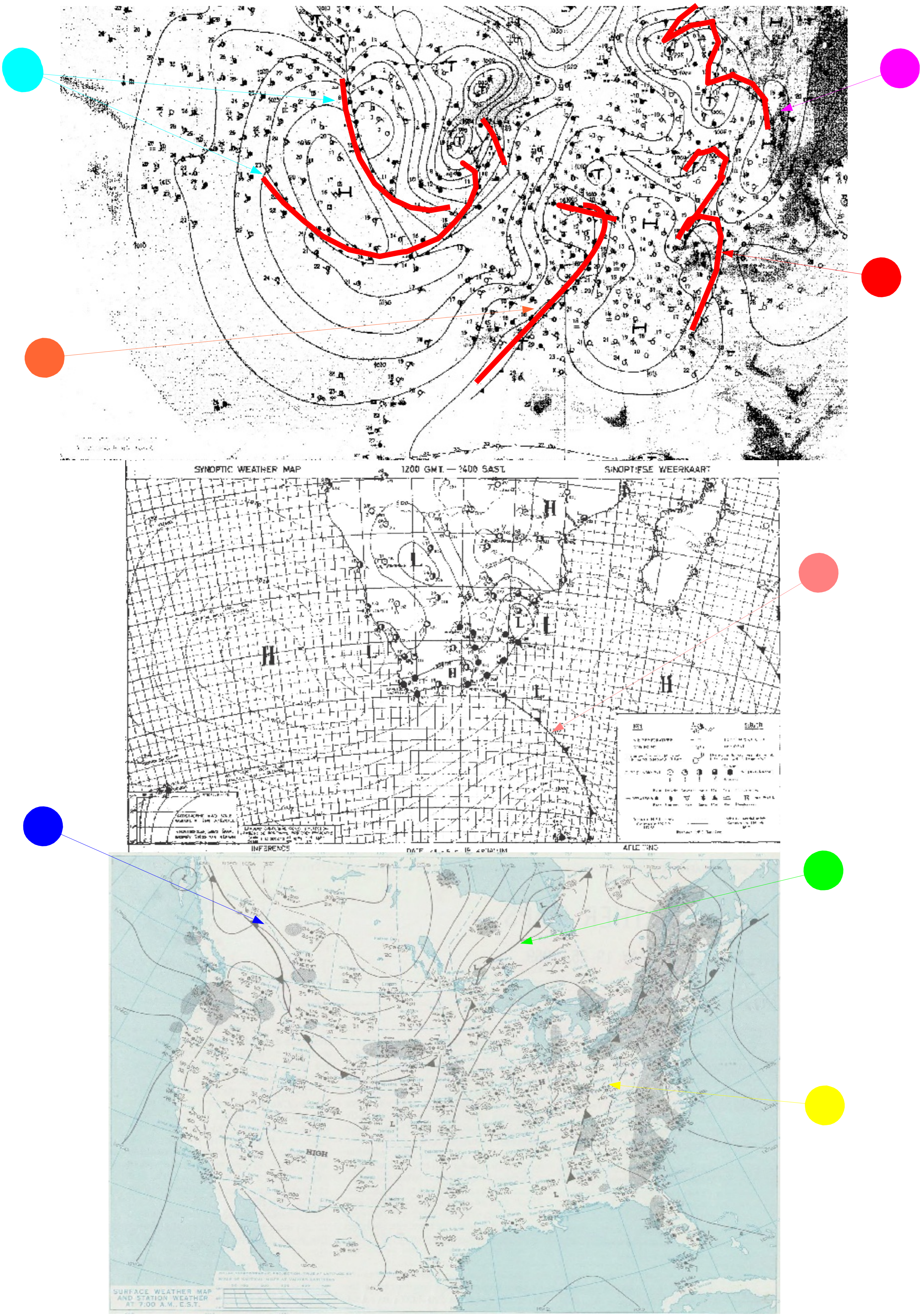


Figure 4.2.73: US, North Atlantic & South African synoptic charts for 19/05/68

arrows respectively in the previous figure) and the associated cloud bank extending towards Florida, as well as the massive cloud cap over most of the Arctic. They even pick out the smog over Los Angeles identified in this analysis, compared with the clear skies over Baja California and Mexico. Hawaii is has “too much cloud coverage” to be picked out The very distinctive weather system off Alaska is picked out by both capcom and crew as a 'big swirl'.

Following some news reports (including sports scores that can only have been done at the time) at 21:50 MET, the crew then begin describing features visible at roughly the time AS10-34-5026 was taken, the describe the patterns over Europe, Africa and parts of Asia, picking out the clear areas over Portugal, western Spain, Italy & Greece compared with the cloudy areas of eastern Spain, Greece & Turkey. They also draw attention to the Arabian peninsula:

“*Arabia appears to be clear. Israel, clear. Jordan, clear. Libya and Egypt are clear* ***except for a cloud strip along the center of the country in Saudi Arabia that runs from $audi Arabia across the Sinai Peninsula and through Egypt****. Africa is clear in the desert to the north and cloudy farther south.”*

The emboldened text is important because that faint line of cloud would not have been identifiable on a synoptic chart. They also talk about

“*a real weird cloud formation ...it's a real peculiar looking cloud swirl. It comes off of what looks like Labrador and goes all the way across the ocean into Europe”*

This one is obviously the system identified by the cyan arrows in figures 4.4.72 & 3 above.

This feature is mentioned again at 1 day 19 hours and 50 minutes as a

“a big long wide cloud swirl out into the Atlantic west of Spain”

after describing the clear conditions over southern Europe and Africa.

Atlantic weather conditions get more exciting for them as they move into 2 days into the mission, and by the time AS10-34-5187 was taken (see figure 4.2.9), and they describe the clouds as follows:

“picturesque cloud formations. Swirls, not definite low areas, but big large swirls.”

Meanwhile, in a description that illustrates image AS10-34-5054 (shown overleaf in figure 4.2.74 with key weather systems identified for comparison with synoptic charts) they very precisely identify the weather system over central and north-eastern USA:

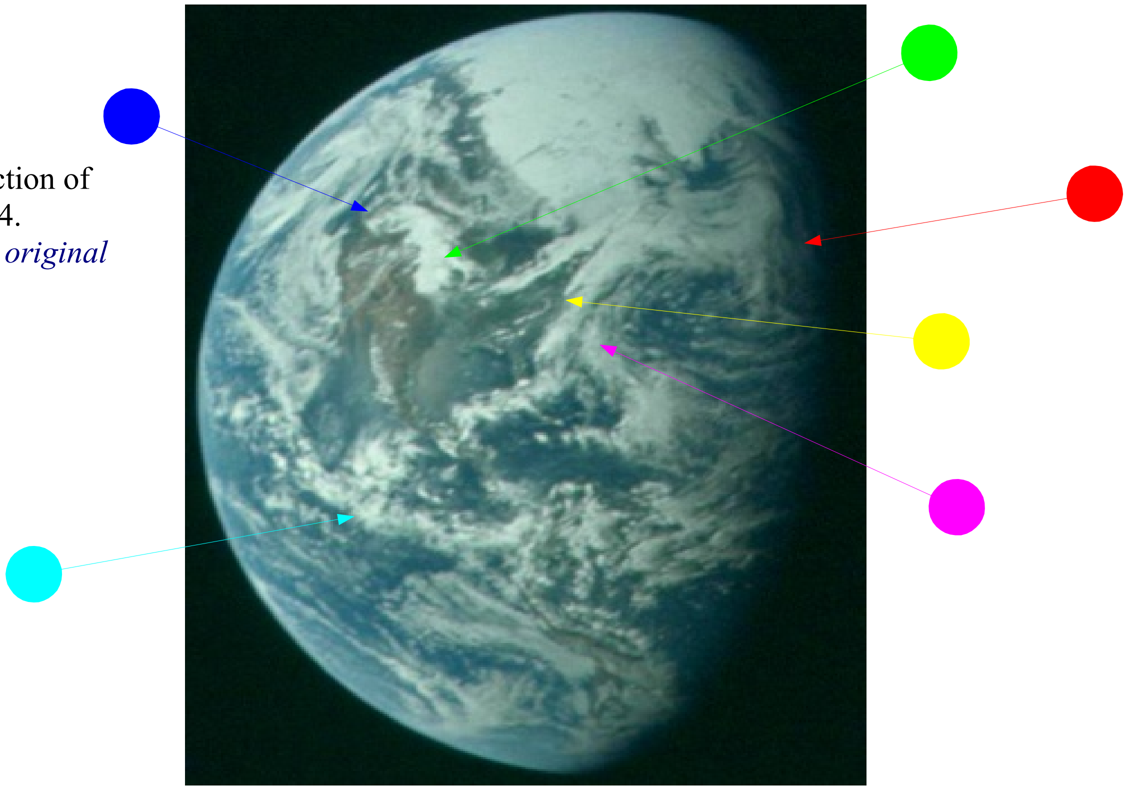
“*..go straight north* [from the Gulf of Mexico] *you see a little bit of V in the clouds and there's one going off to the right and a little thin sliver going to the right is the one I've been mentioning all day that goes from Indiana on through the north-east part of the country; and then that bigger blob that forms the left-hand side of the V is over the north central United States and then right smack in center of the V is Lake Superior and Lake Michigan”*

The magenta & yellow arrows pick out the 'V' they describe. Off Los Angeles the tell capcom:

“you've got some clouds Just off the west coast of California that seem like they come Just short of the coastline.”

Capcom also describe what they can see, identifying the clouds running off the west coast of central

Figure 4.2.74: Section of AS10-34-5054.
Link to low quality original



& north America (cyan arrow) :

"We have one section of clouds that looks like it is almost a circular area – a clear area and then clouds appear to come out of South and Central America - swing out into the Pacific and in the center of that it looks like the clear area which I am saying is the southern part of the United States, from Mexico along the Gulf Coast."

Capcom are also looking at weather charts at this point and comparing them with what they can see on the TV images from Apollo:

"We're looking at a weather map that was Just brought in...The clouds are over Oklahoma and your description is excellent...There's a low pressure up in the very far north turning from the Great Lakes north eastward into -and from - I guess it's up around the - almost to Greenland, it looks like here; and from there, the low pressure weather system with a front comes down into the United States and touches the panhandle of Texas and then goes back on up into Canada again pointing towards Alaska. And there's a band of clouds associated with that on this map."

and also:

"It looks like this cloud system out in the Pacific is associated with another low-pressure system, that's sitting probably north of Hawaii at about 40 degrees latitude. It's located about 150 degrees west, so that's probably what's giving us the cloud pattern up off of Alaska."

The synoptic chart for that day for north America, and the German charts for the northern Hemisphere are given below, and it is clear from these the cloud patterns over north America, south of Alaska, and the complex and picturesque patterns on the Atlantic are all reflected in the synoptic charts of the day (figure 4.2.75).

The orange arrow is the low pressure they pick out south of Alaska, & the red arrows pick out the 'picturesque swirls' in the Atlantic off Spain described earlier. Comparison of the charts from the 19th and 20th of May shows, just as the photographs do, that the weather systems do not exist in isolation but are part of an evolving pattern.

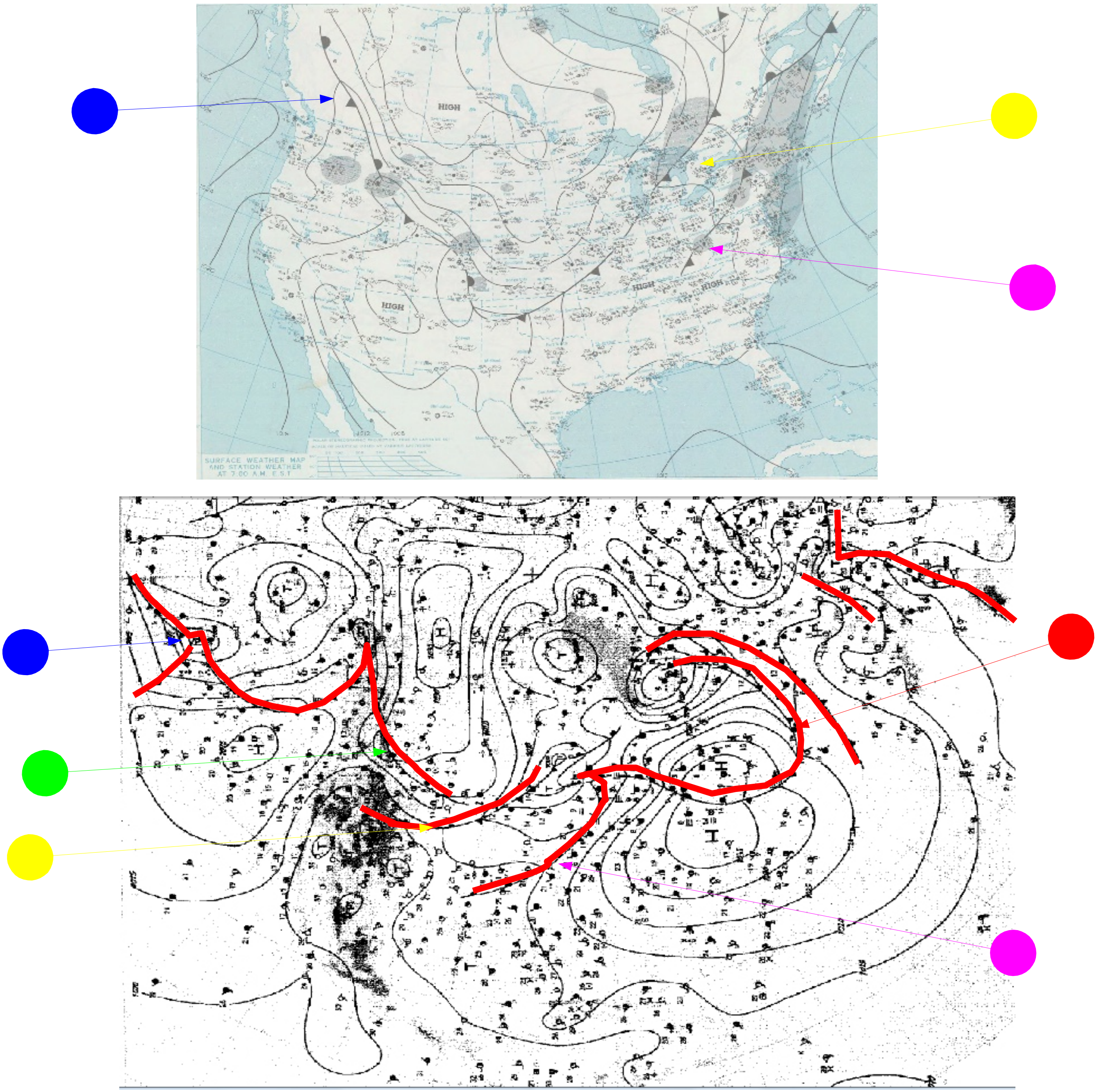


Figure 4.2.75: Annotated US & North Atlantic synoptic charts for 20/05/69

The astronauts do not describe much of the weather systems during their orbit around the moon, pointing out that

“we were kind of busy”

but we can fall back on the photographs taken during orbit and compare those with the available weather maps. Figure 4.2.76 (overleaf) contains all 4 Earthrises shown earlier in this analysis from May 23rd, and the US & north Atlantic synoptic charts and with the main weather systems identified. The main weather systems off the east coast of the USA, the chaotic system off Europe is still evident, as are the large swirls off Alaska.

By the 24th of May, the crew were on the way home and able to resume their regular weather reports., for example:

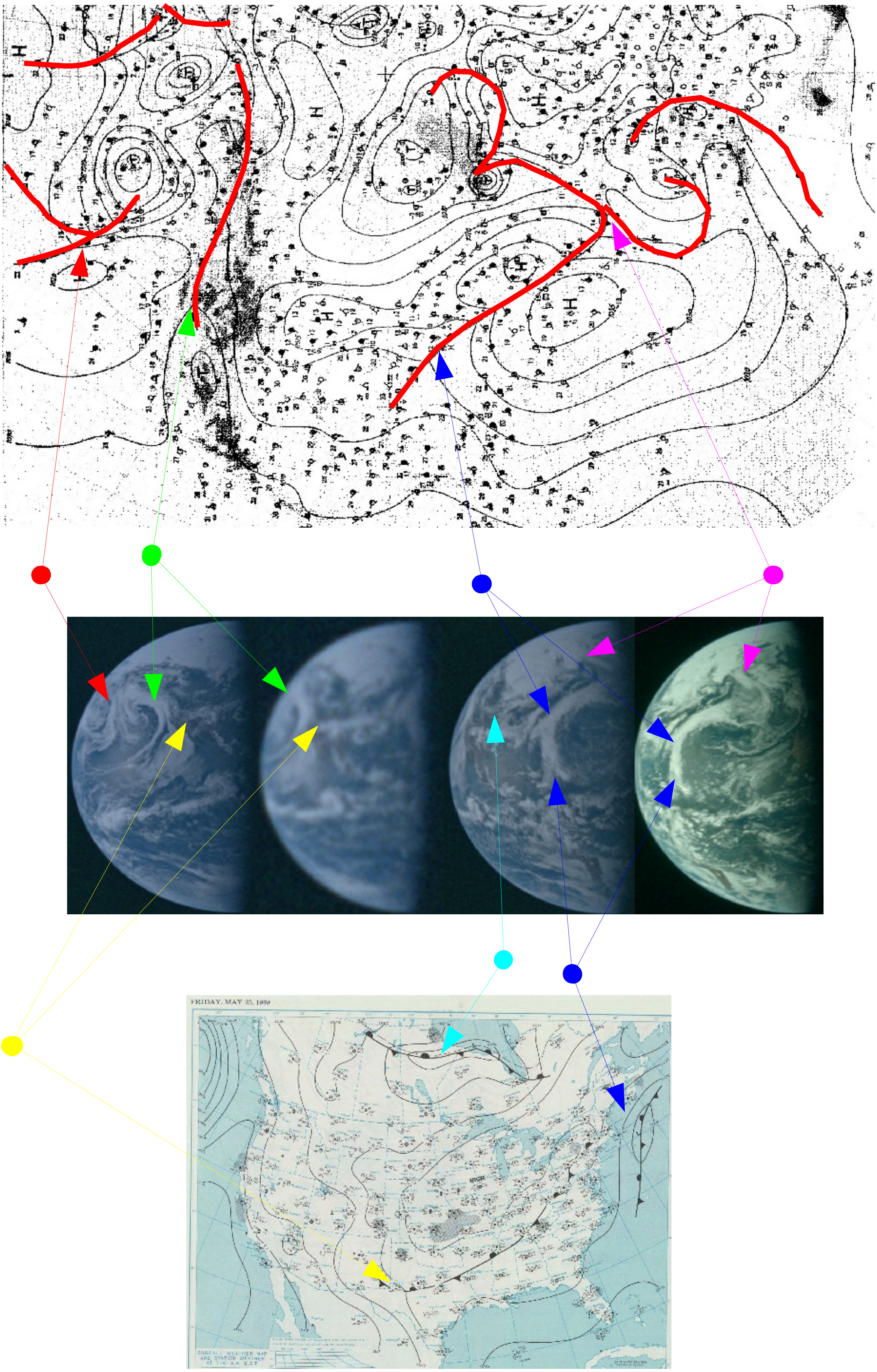


Figure 4.2.76: Annotated amalgamation of (from left to right), AS10-35-5239, AS10-35-5230, AS10-35-5223 and AS10-27-3889, from 23/05/69 compared with US & north Atlantic synoptic charts from the same day..

“You see that big circular weather belt that goes up across the United – up across the east coast of the United States, covers up Florida, and. it appears that some sort of point is in the Gulf of Mexico Between Florida and Texas. It's difficult to make out any landmasses and I doubt that you can see any, hut with the monocular, I can see Cuba, Haiti, and the Indies, end most of South America which is cloud cover. The central United States appears to be open, as well as the western United States...There's a great big - a great big swirl right over the - right over the point south of Florida, goes up through the eastern states. ...and, also, another swirl; it looked like it was up north somewhere, possibly as far north as the Canadian border there, coming down to sort of join them together. Couple of very interesting weather patterns.”

They do describe the former system as covering over Florida, which it does not do in the satellite image, but given that they are still 184000 miles from Earth it is possible that they have misinterpreted what they were seeing. It's also possible that the ESSA image has failed to pick up lighter cloud cover, or that they are actually describing the much larger belt of cloud that arcs over the north Atlantic, a part of which does go close to southern Florida.

These weather patterns are still visible on the 25th, when better coverage of the USA is available in image AS10-27-3979, and again they mention a large system over the north, describing:

“that big low-pressure cloud so very distinctive over the Alaskan area, Aleutian area is very distinctive to us with the naked eye.”

This circular system is clearly visible on AS10-27-3970 (taken in the early hours of the morning of the 25th).

The Earth as seen on those two images are shown in figure 4.2.77 (overleaf), annotated along with the synoptic charts for the north Atlantic and north America. There is no useful angle on South Africa, so this chart will not be used.

Close inspection of north America, the main area that is visible on both images, shows that the weather systems do match up, confirming that they are from the same date.

As with the other synoptic charts, there is no difficulty identifying the same frontal systems on the Apollo images.

In summary: Apollo 10 images taken by the astronauts can be precisely pinpointed in time with the use of satellite images, and the weather systems on those Apollo photographs match with the satellite data. Images produced by TV broadcasts also match, giving further support to the already considerably body of evidence that Apollo 10 went to the moon, orbited around it, rehearsed the landing that would take place by Apollo 11 and returned home.

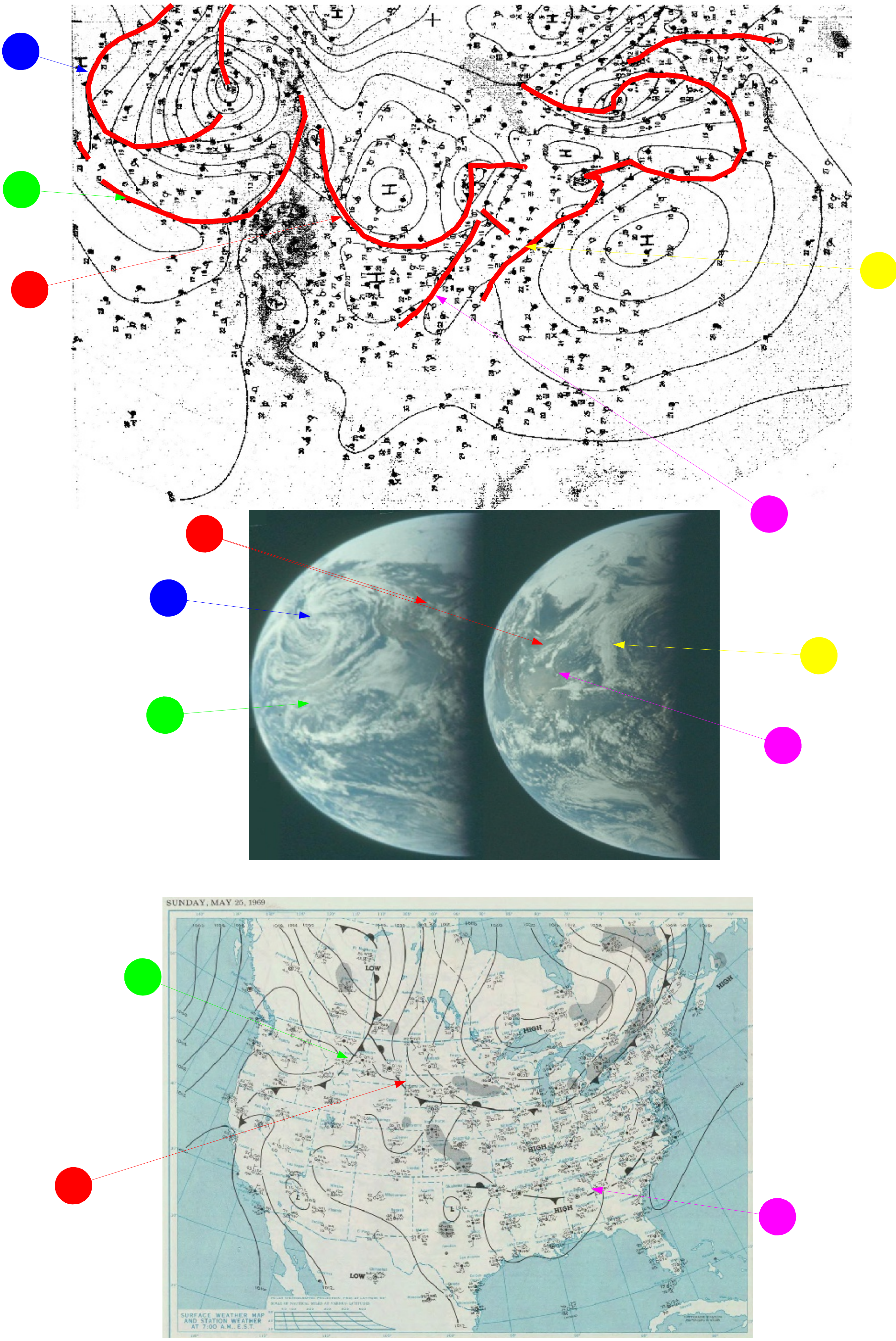


Figure 4.2.77: Annotated amalgamation of (from left to right), AS10-27-3970, AS10-27-3976 from 25/05/69 compared with US & north Atlantic synoptic charts from the same day..

4.3 Apollo 11

After the full dress rehearsal of Apollo 10 came the main event. Given the dramatic images sent by Apollo 10, it could be argued that this mission was less visually impressive. The crew spent most of the time on the lunar surface inside the LM, and did not venture far from it when they did finally emerge. Most of the photographs taken are of the lunar surface either from the ground or from orbit It is, nonetheless, the most historic of the Apollo missions, for obvious reasons.

The mission itself commenced with the launch on July 16th 1969. The crew entered lunar orbit on the 19th, after which the Aldrin & Armstrong entered the LM and departed for the lunar surface on the 20th, landing at 20:17 GMT. The crew set foot on the moon at 02:55 on the 21st, and left it for the safety of the LM at 05:11. The lift off back to the CSM was at 17:54, and the two craft were re-united at 21:35. TEI was at 02:55 on the 22nd, and the crew finally splashed down on the 24th.

During the mission they used 9 magazines to take 1408 images and made 7 TV broadcasts (not including the transmission from the moon itself). Several weather satellites are available from the time of the mission: NIMBUS, ESSA 8 & 9, ATS-1 and ATS-3.

The NIMBUS data can be found here NIMBUS archive. This volume shows visible images from the Image Dissector sensor, and day & night infra red images. The best quality NIMBUS image from any given day will be used (though none of the NIMBUS images are particularly clear). The Australian Bureau of Meteorology kindly supplied a photomontage of 3 NIMBUS frames covering Australia. ESSA data can be found here, hosted by the HATHI trust: ESSA 9 link.

The ATS images have been found in from a variety of sources. A search for ATS-3 images found this one for July 17th hosted on Photobucket July 17th Photobucket source, and a partial image for July 18th can be found in a research document here: July 18th ATS-3. The University of Wisconsin generously sent 2 images from July 20th and 21st, and an ATS-3 image for July 22nd can be found in the Monthly Weather Review Vol 100, No 10 (July 22nd ATS-3). An ATS-1 (and ESSA 8) image for July 22st can be found here: July 22nd ATS-1. A more complete ATS-3 source is available here , but is generally of poorer quality. The other, better quality, ATS images will be used where possible.

An unnamed satellite contributes a further picture for July 21st in a document examining the first 5 years of the environmental satellite programmes here TIROS report . An ESSA 8 image of tropical storm Claudia was uncovered in the Eastern Pacific Hurricane Season report for 1969 here Hurricane season report , as well as good quality images of Hurricane Bernice from July 16th . The Mariner's weather log Vol 13 (Mariners Weather Log) provides a better quality ESSA 9 image of North America from July 22nd . This MSc thesis: BOMEX study provides more examination of ESSA 9 images specifically in the Caribbean from almost all the Apollo mission, and larger scale images from the same study can be found here Measurements from Satellite Platforms Study These documents are mentioned not just as potential sources for discussion but also for the indication they provide that the data from the satellites were not hidden away – they were available for use by anyone who cared to look at them.

The Apollo images used will be the high quality versions found at the Apollo Image Atlas Image Atlas and the Apollo Lunar Surface Journal ALSJ . Some images are not displayed on the ALSJ, but their links can be deduced from those that are. Despite the obvious and understandable focus on the lunar surface, the crew did manage to capture a number of significant images of Earth both on the way to, on the surface of, and back from, the Moon

The importance of this mission, and the variety of satellite sources means this Apollo 11's analysis will be structured slightly differently to that for Apollo 8 & 10.

4.3.1 Mission images

5 hours after lift off, the CSM had undocked from the SIV-B, removed the LM from it and discarded the empty Saturn. Having already taken a few low Earth orbit images before the undocking, the crew now took photographs of the fast receding Earth (having already performed their TLI burn).

The first full disk image of the Earth in these photographs is AS11-36-5330 (AIA), shown below as figure 4.3.1.

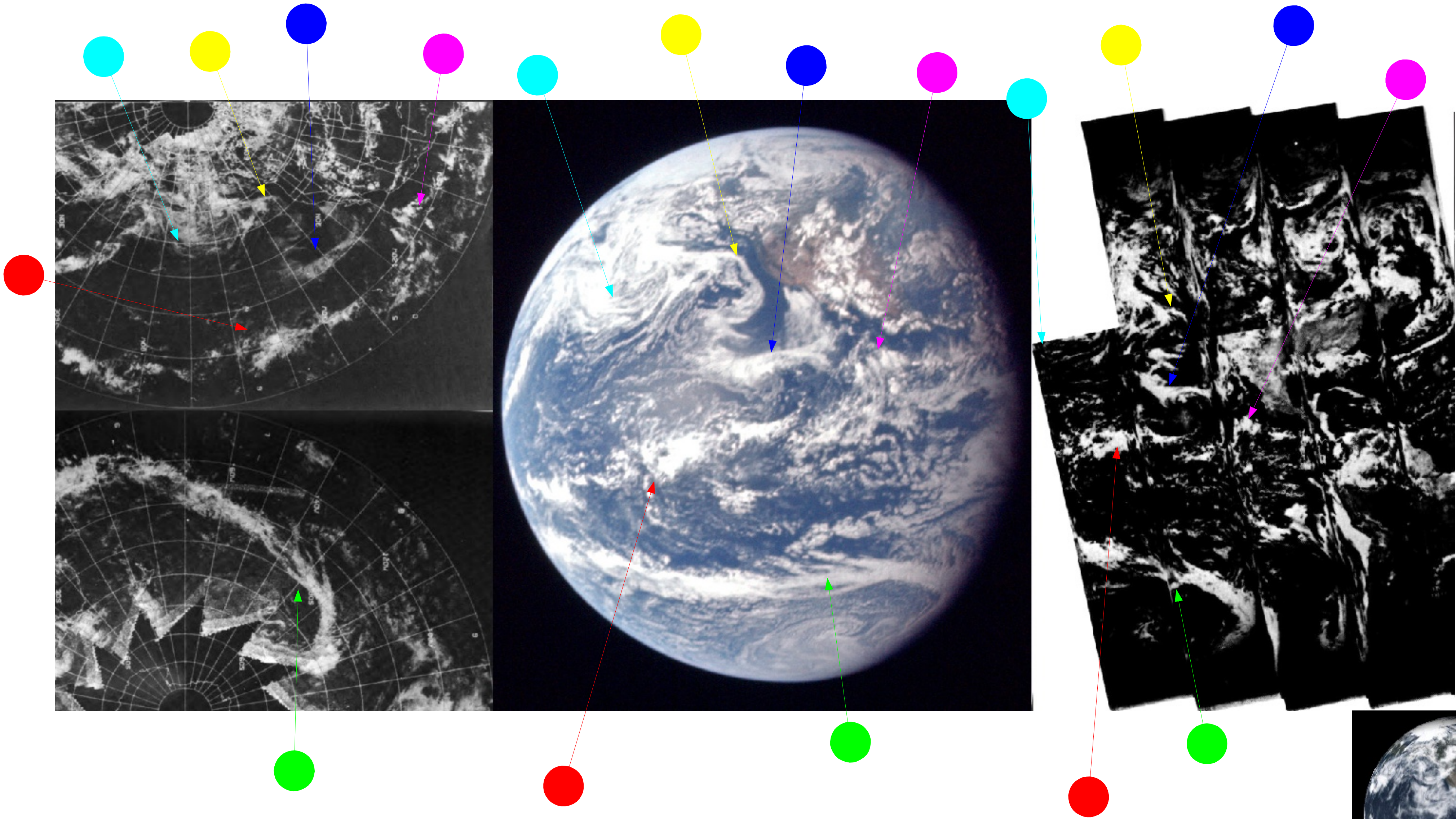
Figure 4.3.1: AS11-36-5330 with Stellarium insert for 23:00 on 16/07/69.

Stellarium suggests a time of 23:00 for this image, just an hour before their first TV recording*, and well on the way to the moon from Earth.

The annotated ESSA & NIMBUS satellite data from the 16th are displayed, along with a zoomed & cropped image of Earth from AS11-36-5330, in figure 4.3.2. The NIMBUS infra-red image has been used as the American landmass is more easily identifiable, and will continue to be the preferred source. The Antarctic is, for obvious reasons, not visible. There are no suitable images matching the ATS-3's position for the 16th.

The ESSA pass data suggest that the orbit covering the west coast of the USA (track 4, orbit 1755) was commenced at 20:07 on the 16th, with the areas west of this covered in the early hours of the 17th. The terminator was covered at 16:07 (track 2, orbit 1753) NIMBUS' orbital data for the west coast suggest that the same west coast orbit image (number 1254) was taken between 19:34 & 20:23 on the 16th.

*The Apollo timeline (source) notes that this broadcast was sent to Goldstone in California and then relayed to Houston at 01:30 on the 17th.



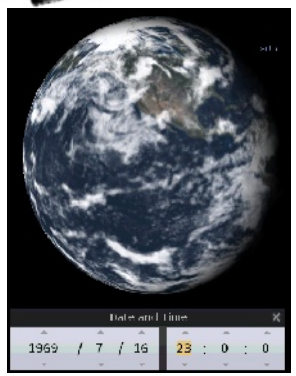


Figure 4.3.2: AS11-36-5330 compared with ESSA 9 & NIMBUS 3 (Infra Red daylight) images and Stellarium estimate of time at terminator

One hour after the Apollo image was taken, the crew began transmitting TV signals to Goldstone in California. The broadcast footage is easily found on Youtube, and this is a screenshot of a camera test from the first broadcast, together with a Stellarium image showing the terminator line. The screenshot has had its resolution increased, the levels altered to provide more contrast and sharpened to improve the level of detail visible.

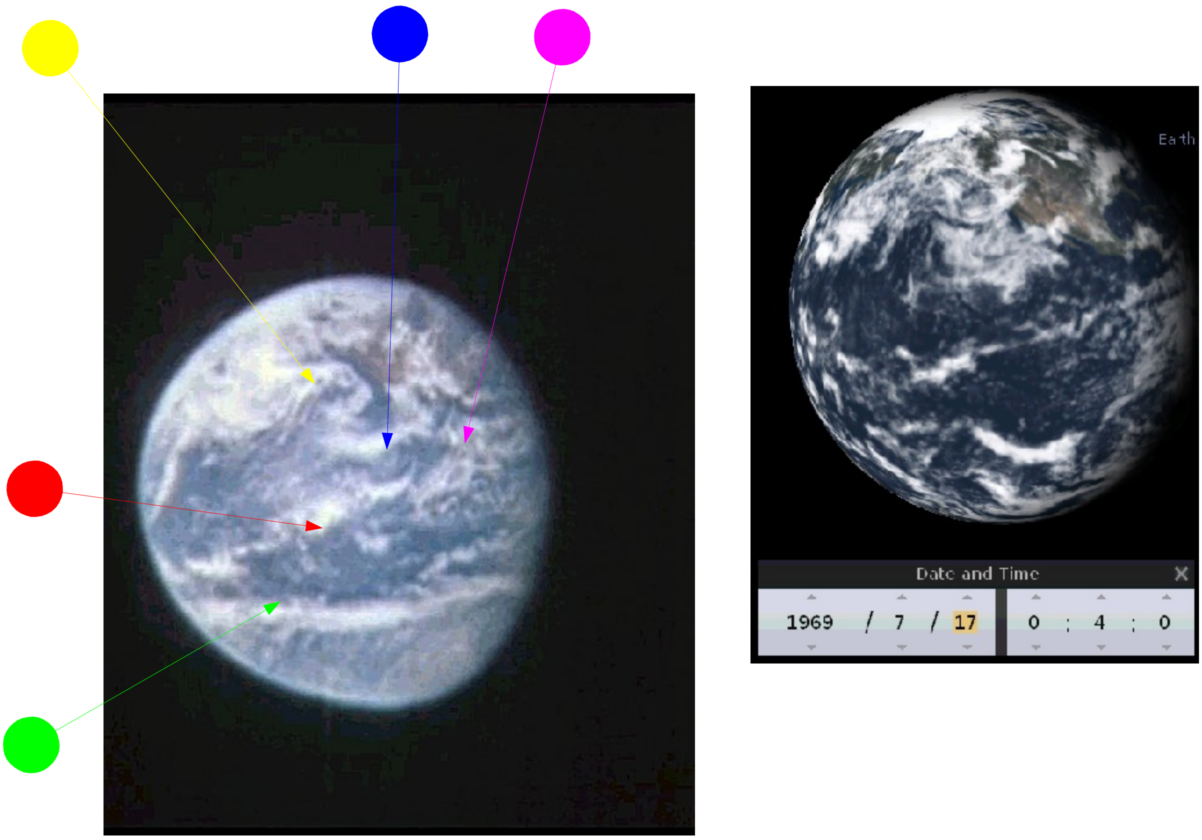


Figure 4.3.3: Apollo 11 TV broadcast with Stellarium time & date. The same colours used in figure 4.3.2 are used here.

The comparison of the TV screenshot and the Apollo still image is important for two reasons. Firstly, the rotation of the Earth is clear in the hour between taking the image and the broadcast, showing that they were taken at the same time.

The second, and by far the most important reason, relates to what is in these two images: Hurricane Bernice.

On July 8th 1969 a tropical depression began forming in the Pacific ocean. This depression strengthened to become a tropical storm, named Bernice, whose strength reached hurricane force on a number of occasions in its lifetime. By July 16th, Bernice was fading fast, and was reclassified again as a tropical depression off the coast of Guatemala.

Bernice's lifespan and development was widely reported in meteorological journals, and is referred to in the Eastern Pacific Hurricane season report, and in the Mariner's log cited earlier. References to Bernice are widely available elsewhere on the internet. This US navy document: Summary of Tropical Cyclones 1969 shows that 35 warnings were issued to shipping, and gives detailed information of the hurricane's track. Figure 4.3.4 shows the storm's development as recorded in the hurricane season report. Figure 4.3.5 clearly identifies Bernice's location on the Apollo image & TV broadcast, indicated by the blue arrow in figures 4.3.2-3.

HURRICANE BERNICE - July 8-16, 1969

The development and decay of an East Pacific Hurricane

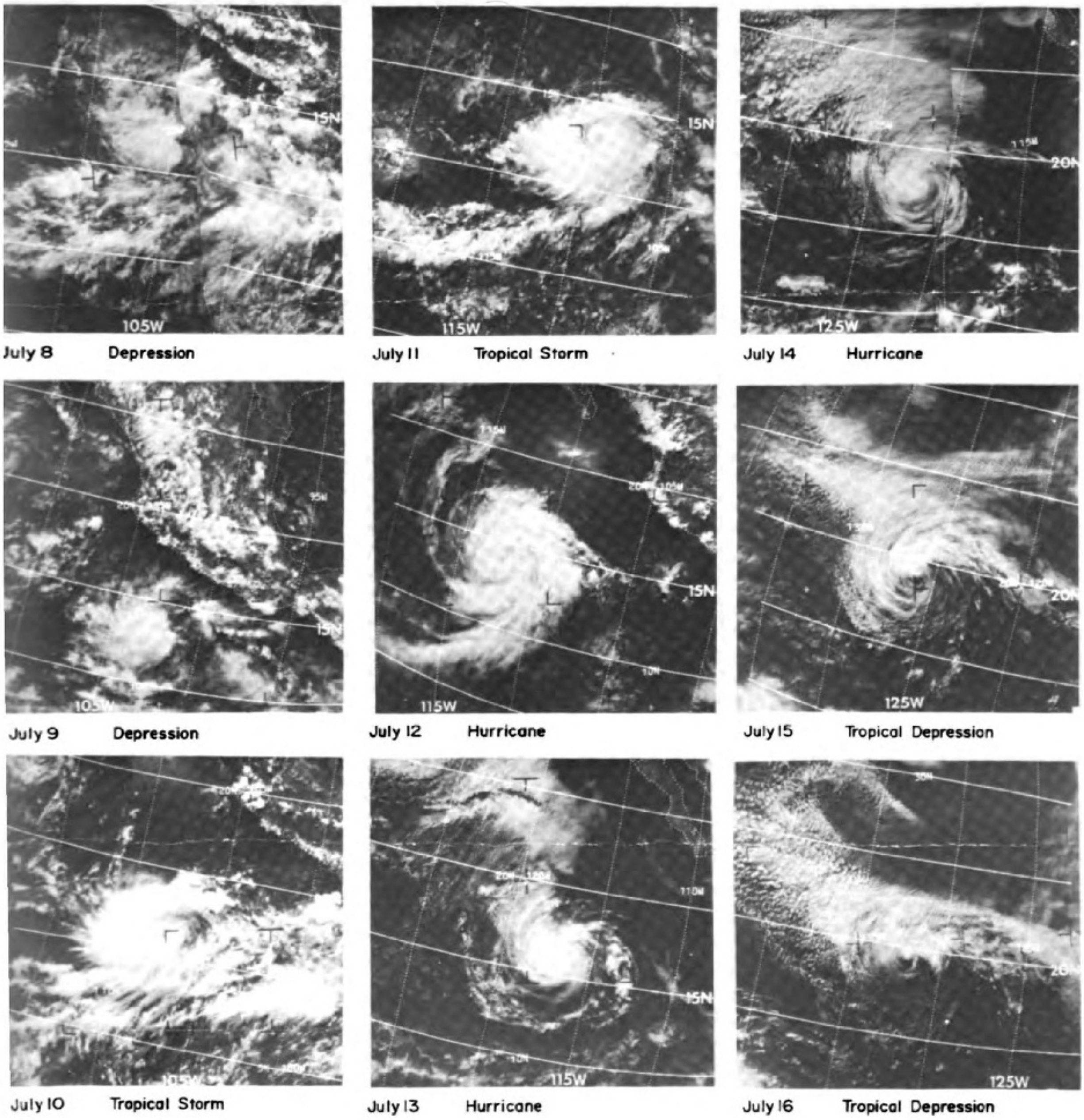


Figure 3. From depression to depression -- the 9-day life of hurricane Bernice portrayed by ESSA 9 satellite photography.

Figure 4.3.4: Mariner's Weather Log 1969 reproduction of ESSA 9 images showing the development of Hurricane Bernice. See text for link.

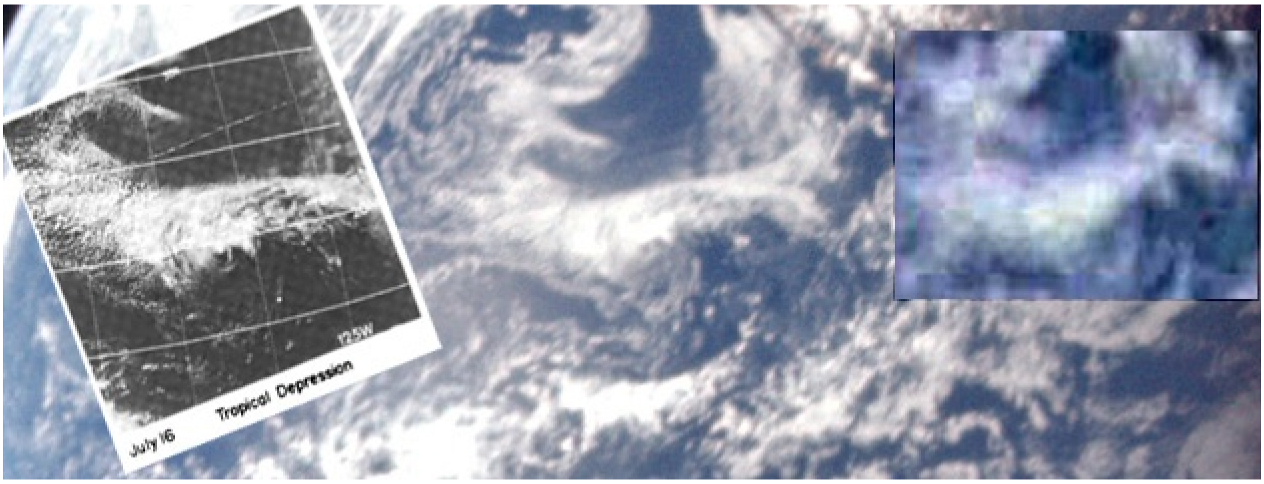


Figure 4.3.5: Close up of Hurricane Bernice from AS11-36-5330, with inset from ESSA 9 (left) and TV broadcast (right). TV screenshot has had the contrast increased to improve detail.

Hurricane Bernice is clearly identifiable on both the Apollo derived images, and suggests that the only place the image & TV footage could have been obtained is from space.

The irony here is that one of the most often quoted pieces of 'evidence' aimed at Apollo 11 (Bart Sibrel's 'A funny thing happened on the way to the moon' - Wikipedia entry) claims two things:

1) The in space footage was filmed in low Earth orbit.
2) The image of Earth used in the TV broadcast was a fake image. An image of Earth obtained from somewhere, but not actually filmed by the Apollo 11 crew.

The first claim is obviously ridiculous, as low Earth orbit images can not show the entire disk. Satellites aiming for full disk coverage go for high Earth orbit at 22000 miles out.

The second claim shoots itself squarely and firmly in the foot by using video clips from the broadcast with Hurricane Bernice visible in them. Not just any footage of Hurricane Bernice, but specifically footage featuring Hurricane Bernice in a configuration that can only have been obtained on July 16th from space. It could not have been obtained anywhere else. Sibrel's own video contains the evidence that proves him completely wrong.

This website: Apollo TV analysis contains a much more thorough analysis of Sibrel's claims than will be covered here, and is the source of the screenshot images, as they are generally of better quality than those available elsewhere.

This first whole disk image is one of a long series of photographs taken of the Pacific, most of which show an identical view to AS11-36-5330. A second batch of seven very similar images captures Bernice as it moves towards the terminator, and a final batch of three photographs show Bernice on the terminator.

A sample from the batch of 7 is shown overleaf in figure 4.3.6 to illustrate the Earth's rotation as Apollo 11 moves away from it, while the final image in the sequence, AS11-36-5351, is shown in full in figure 4.3.7, before it is analysed in figure 4.3.8. It is worth looking closely at the terminator east of Bernice in AS11-36-5343, as the sunset shadows cast by the clouds are quite stunning.

A comparison of the terminator in AS11-36-5351 shows that it is slightly later than the TV screenshot, suggesting a time of around 01:00 on the 17th.

Figure 4.3.6: AS11-36-5343 (left) with Earth zoomed and cropped from it (right). High quality source: AIA

Figure 4.3.7: AS11-36-5351. High quality source here: AIA

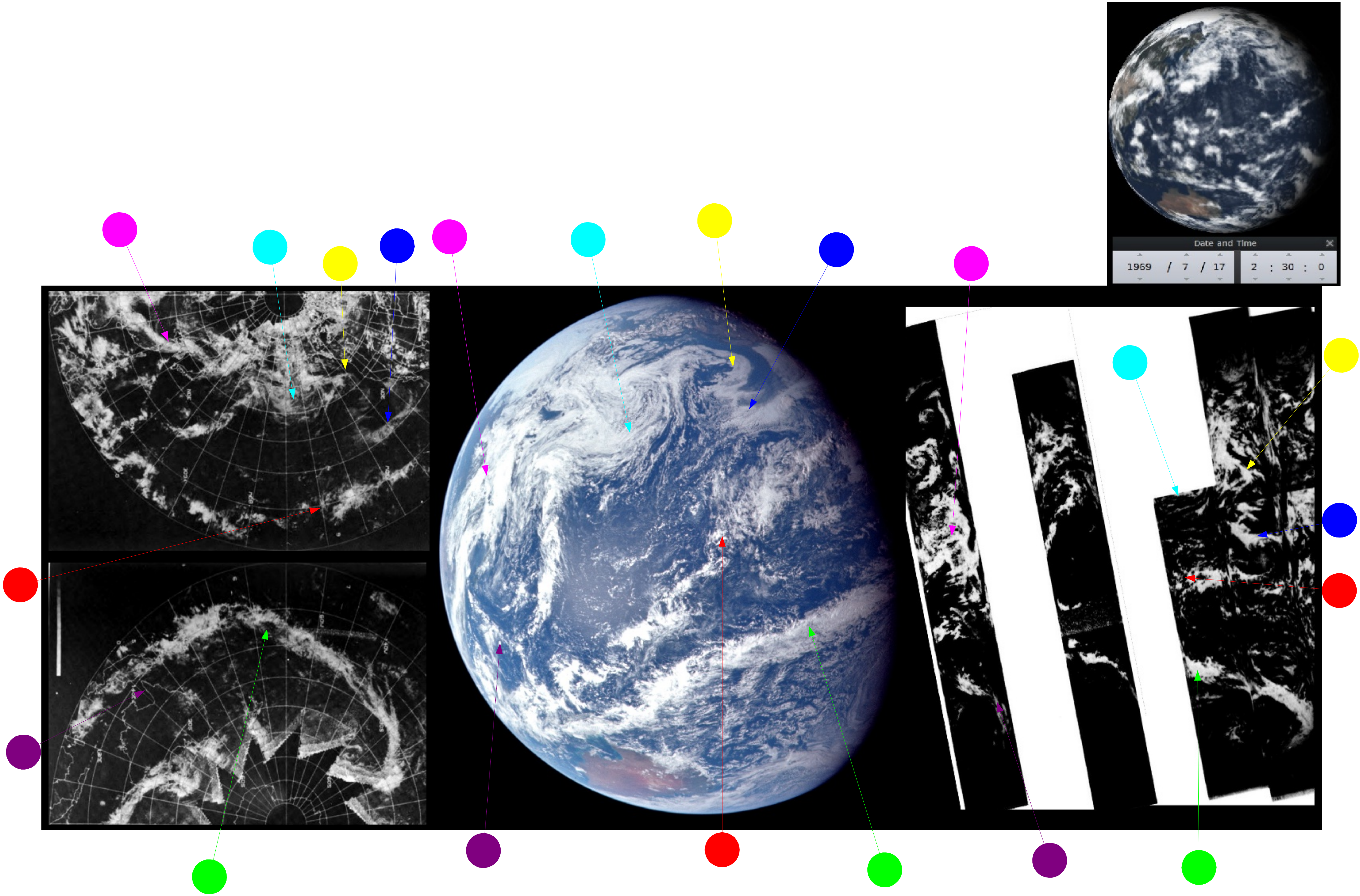


Figure 4.3.8: ESSA-9 (left) and NIMBUS-3 (right) images compared with AS16-36-5351 and Stellarium estimate of time at terminator

As with AS11-36-5343, it is worth zooming in on the clouds around the terminator to see the relief cast by the shadows on the clouds. The central portion of Hurricane Bernice is much more prominent, and the clouds to the south show lengthening shadows entirely consistent with early evening conditions.

Although new weather systems have been brought into view by the Earth's rotation (magenta and purple arrows), and Australia is now clearly visible, the all the other cloud patterns are identified using the same coloured arrows as the previous analysis.

The nearest ESSA track for the terminator region is still on the image dated the 16th, and was commenced at 20:07 (track 4, orbit 1755), compared with Stellarium's estimate of the time at terminator of around 02:30 on the 17th.

NIMBUS' image is actually a composite of the final passes on the infra-red daytime image dated the 16th and the first infra-red daytime ones dated the 17th, with the orbit nearest the terminator being pass 1253, which commenced at 17:46 on the 16th. The final part of the Pacific covered by NIMBUS would not have been covered until 04:30 on the 17th, 2 hours after the Apollo image was taken.

The image after 36-5351 was evidently taken some time later, as we now have Africa clearly in view. AS11-36-5352 is shown below in figure 4.3.9, and analysed on the next page in figure 4.3.10.

Figure 4.3.9: AS11-36-5352. High quality source here: AIA

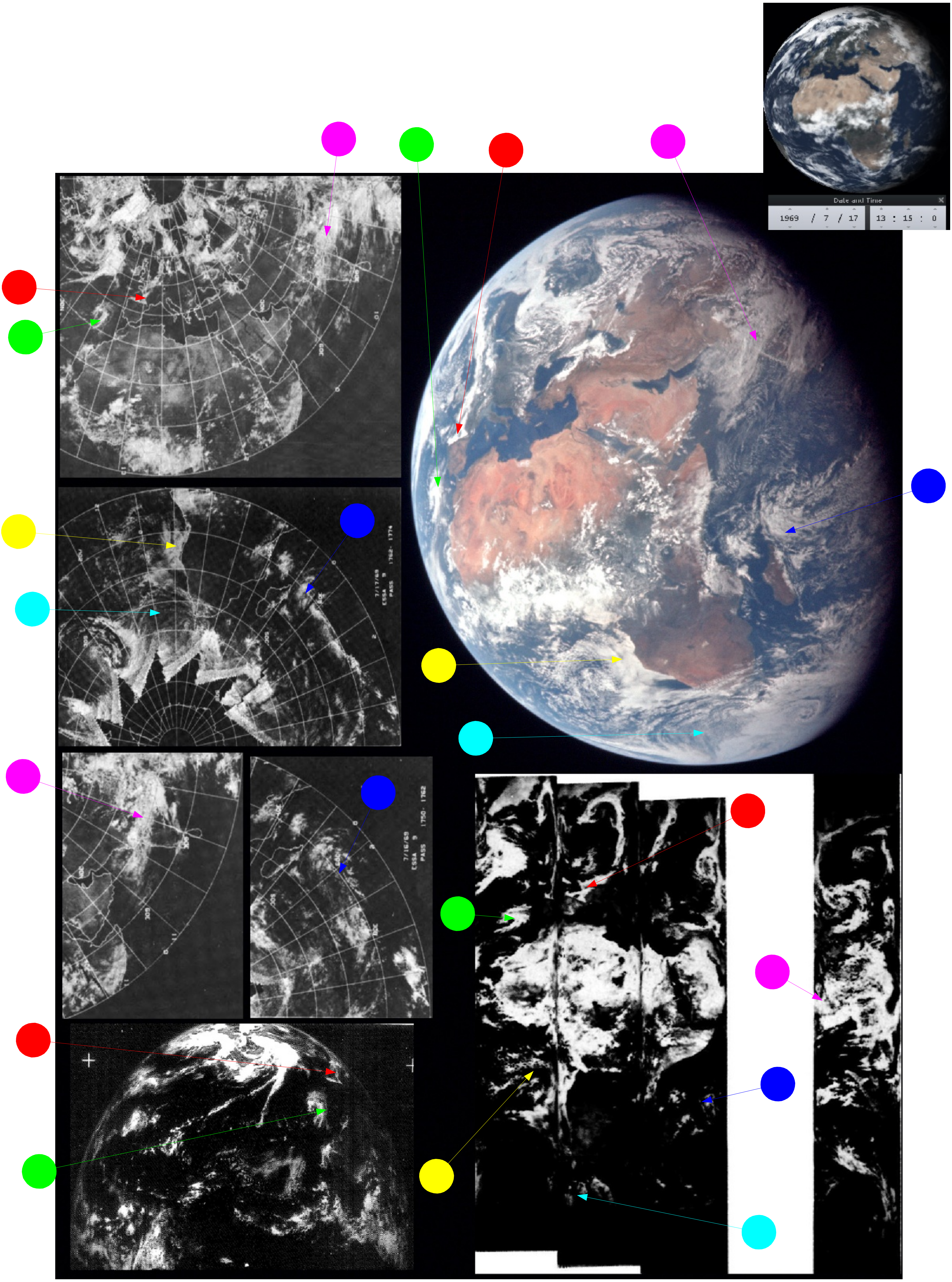


Figure 4.3.10: ESSA-9 images dated 16/07/69 (top left upper & lower) and 17/07/69 (middle left), ATS-3 (bottom left) and NIMBUS 3 images (bottom right) compared with AS16-36-5352 and Stellarium estimate of time at terminator

Figure 4.3.10 is, as always where Africa is in view, complicated by the dividing line between two day's ESSA images. West of a line stretching from around Madagascar up through the Red Sea and Eastern Europe, the ESSA mosaic dated the 17th is the most appropriate and the northern and southern hemisphere mosaics are the upper two in the top left of the figure. East of that line, the most appropriate mosaic is the one dated the 16th, as the tracks from that will have completed on the 17th, and portions of these are shown centre-left on the figure.

Comparison of the weather patterns identified by the magenta and blue arrows shows the difference between the two very nicely. On the Apollo image (which we know must have been taken on the 17th, and which Stellarium puts at 13:15)), the clouds extending eastwards from just north of Madagascar are a wide band of diffuse thin cloud. On the ESSA image dated the 17th, this same band is a more cohesive thin band, compared with the one on the mosaic dated the 16th, which matches that of Apollo. The magenta arrow points to a cloud mass on Apollo's image that extends much further towards Arabia than can be seen in the ESSA image dated the 17th.

On the other side of the line the opposite is true. ESSA's relevant track for the terminator is number 10, or orbit 1761, which on the image dated the 16th was commenced at 08:00 on the 17th. ATS' image is labelled as being taken on at 14:55 on the 17th, while the NIMBUS orbit nearest the terminator (pass 1259) was commenced at 05:24 on the 17th.

Interestingly, at about that time, the mission transcript records capcom telling the crew about the Soviet craft Luna 15, bound for a lunar landing and recorded by Jodrell Bank, but from which signals had been lost.

A short while after the previous image was taken we have an image that allows a greater contribution from the ATS-3 image. AS16-36-5357, which is shown below in figure 4.3.11, and analysed overleaf in figure 4.3.12.

Figure 4.3.11: AS11-36-5357. High quality source here: AIA

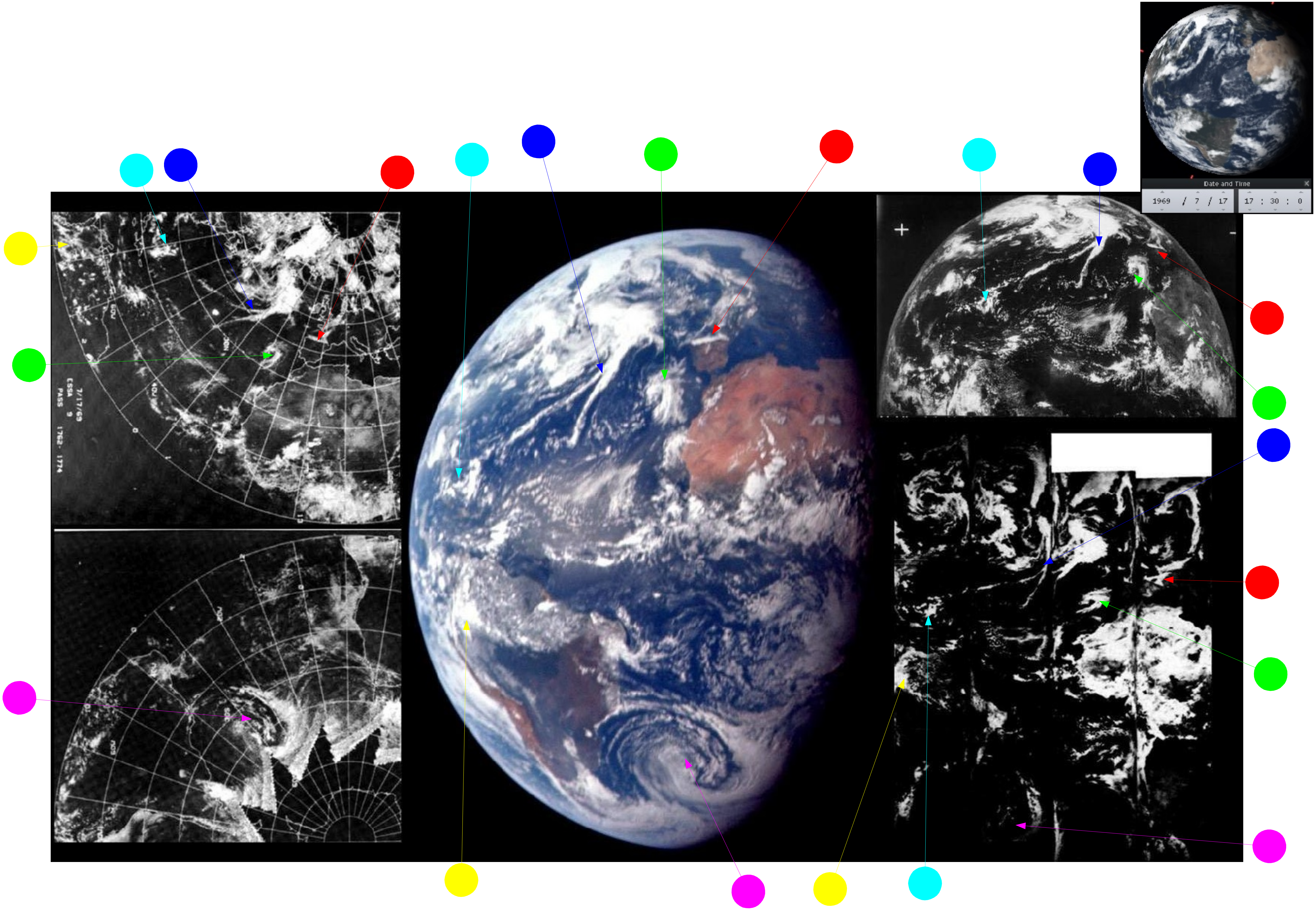


Figure 4.3.12: ESSA-9 (left), ATS-3 (top right) and NIMBUS-3)bottom right) images compared with AS11-36-5357 and Stellarium estimate of time at terminator

The red and green arrows point to the same cloud patterns as shown in figure 4.3.10. The ATS time has already been given as 14:55. The NIMBUS orbit nearest the terminator is number 1261, which commenced at 08:06 on the 17th. ESSA's equivalent orbit is number 1763 (track 12), which commenced at 12:00 on the 17th.

Stellarium's estimate puts the time at 17:30, which is approximately 28 hours into the mission. At 27h18m in the mission transcript, Buzz Aldrin describes:

"an anticyclone going in the southern hemisphere southeast of Brazil, and some - Well, the diameter of it must be over 2000 miles across."

and then tells them

"You all are just beginning to cone over the limb now. I can see parts of Central America, and it looks to be fairly clear there. The islands in the Caribbean are beginning to come in and rather a few streaming lines of clouds. Looks like there is a system up to the - well, off of Greenland that has some large cloud streamers extending back down to the south-west. The east coast of the U.S. is just coming into view now, and it doesn't look too bad that I can see right now."

The magenta arrow is pointing to the storm system of Brazil, and the 'streamers' are on the system identified by the blue arrow. We therefore have an Apollo image showing perfectly the weather systems visible on satellite images, but the astronauts are able to describe the weather conditions to the ground.

The next change of scenery in the picture sequence comes just before some photographs of the LM docking target. AS11-36-5362 is shown below in figure 4.3.13, and analysed overleaf in figure 4.3.14.

Figure 4.3.13L AS11-36-5362. High quality source here: AIA

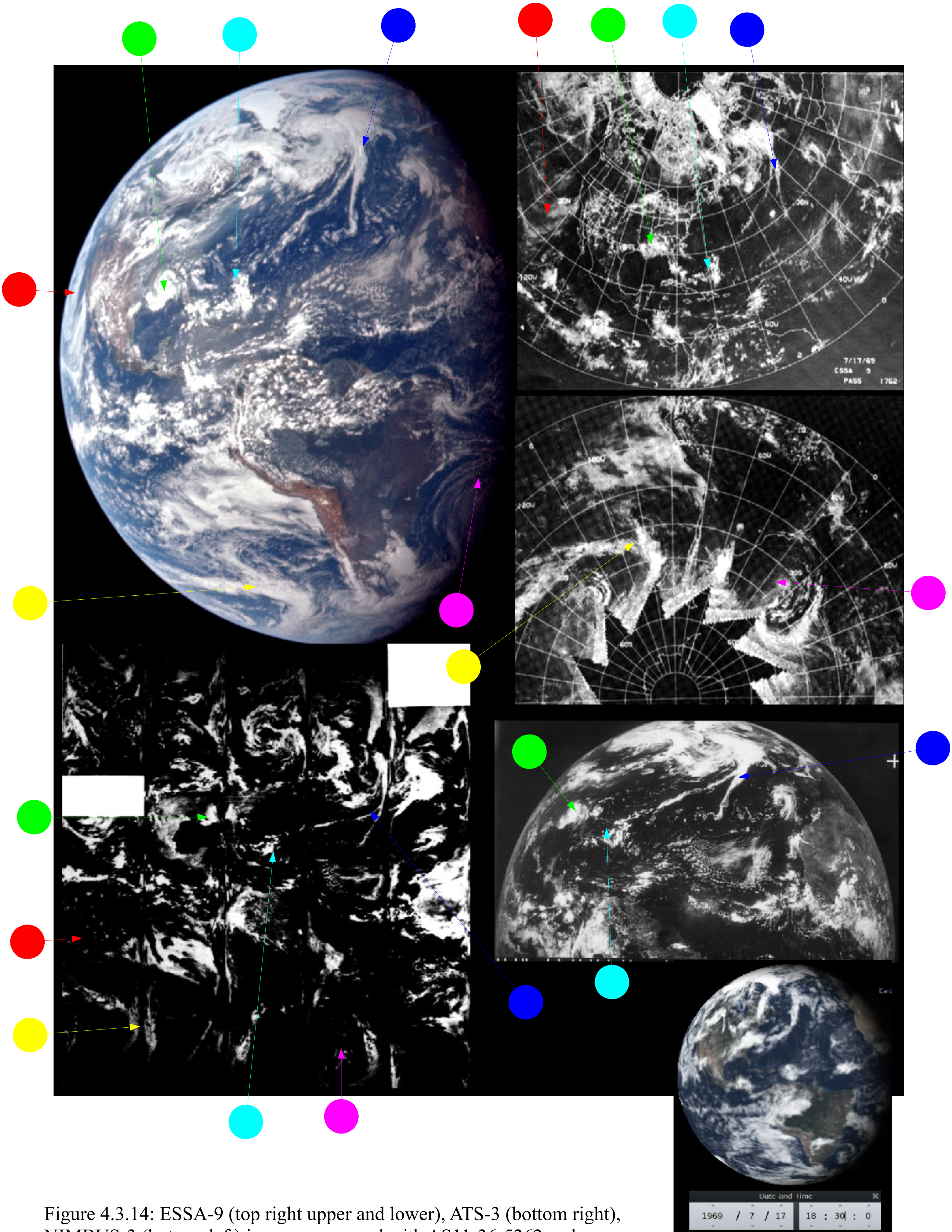


Figure 4.3.14: ESSA-9 (top right upper and lower), ATS-3 (bottom right), NIMBUS-3 (bottom left) images compared with AS11-36-5262 and Stelllarium estimate of time at terminator..

In the preceding figure, the blue, cyan and magenta arrows have been used to identify the same weather systems as shown in figure 4.3.12. The red arrow identifies the remains of Hurricane Bernice, just visible on the western limb.

Now that more of the USA is visible, Buzz again communicates some weather descriptions to the ground, telling capcom:

"we're just looking at you out our window here. Looks like there's a circulation of clouds that just moved east of Houston over the Gulf and Florida area."

and this system has been identified with a green arrow, so once again we have an astronaut accurately describing the view that he could only have had from space

ATS# image time is still the same, but ESSA's terminator orbit as moved on to number 1766 (track 2), and commenced at 17:06. The NIMBUS equivalent was commenced at 13:28 (pass 1264), and both these timings can be compared with the Stellarium estimate of 18:30.

We now enter an interesting phase of the mission, because there are a couple of TV broadcasts made, with (as will we shall see shortly) contemporaneous photographs. The first TV broadcast took place as a camera test at 30:28 MET, or 20:00 GMT on the 17^{th}.

A screenshot from that broadcast is shown below in figure 4.3.15, and analysed overleaf in figure 4.3.16.

Figure 4.3.15: Screenshot from a camera test broadcast. Original source here: Apollo 11 TV Broadcasts

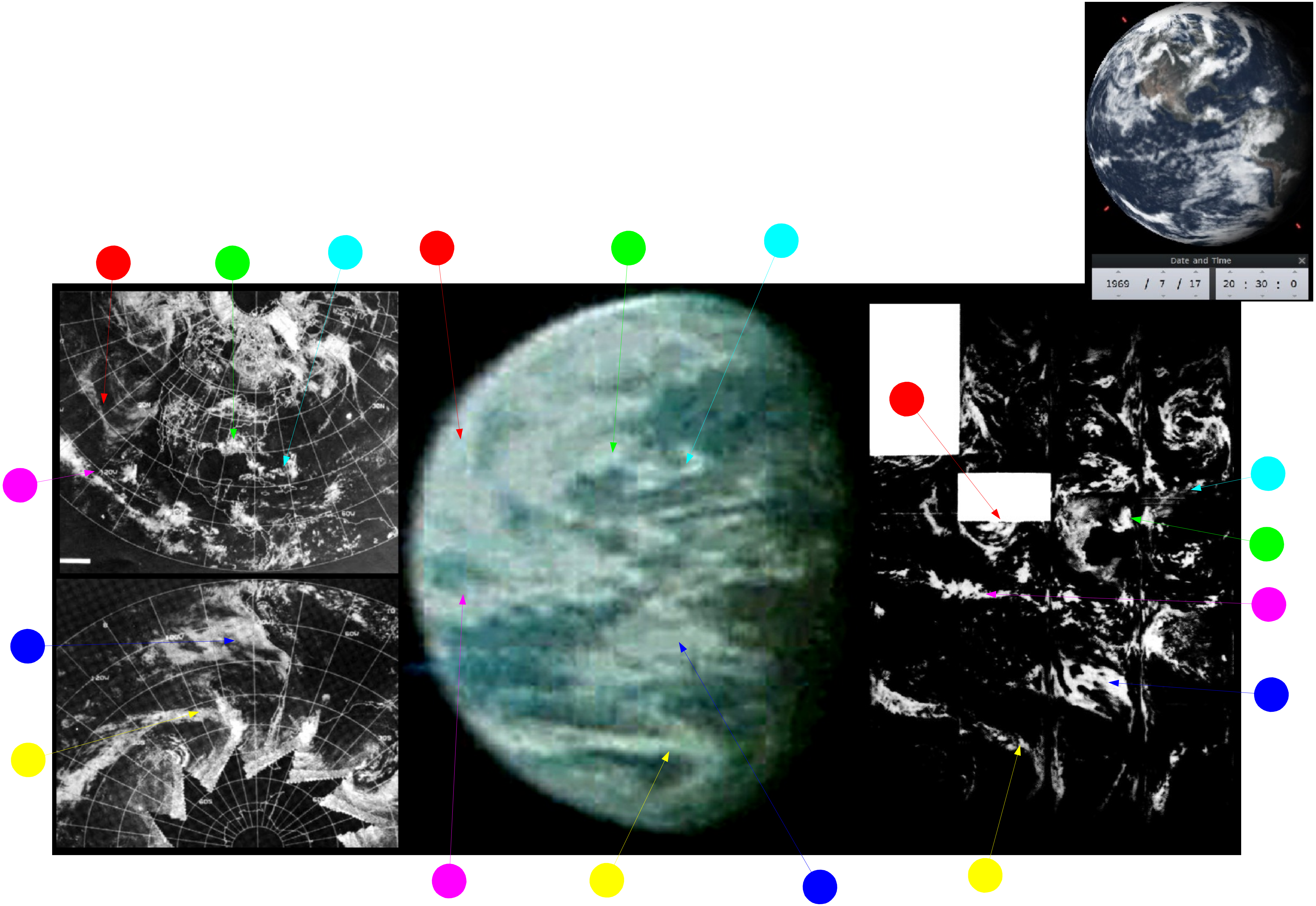


Figure 4.3.16: ESSA-9 (left) and NIMBUS-3 (right) images compared with screenshot of Apollo 11 camera test, and Stellarium estimate of time at terminator

The yellow, green, red and cyan arrows point to the same patterns as shown in figure 4.3.14. The resolution of the image has been increased and the result sharpened to improve clarity.

The camera test seems to have been unscheduled. The Goldstone receiving station in California reported to Houston that they were receiving a signal, who ask the crew about it, to which they reply:

"Roger, we're just testing the equipment up here"

The first images from the transmission are of the CSM intererior, and the crew ask Goldstone to see if they can see any of the readings on the equipment. Half an hour later, they tell them that:

"Goldstone should be getting about the best picture of the Earth we can give them right now"

Which puts the time of an Earth image at about 20:30. The analysis presented on the Apollo 11 TV broadcast site mentioned earlier gives the time as the start of the broadcast, but if that were the case all of South America would be visible.

What should be obvious is that Stellarium's terminator from that time shows that the Earth is in the configuration it should be for that time, and the weather systems visible in this broadcast match exactly what can be seen on the satellite images. The yellow arrow pointing to the long band of cloud is particularly prominent.

The features in the image can be seen in a photograph that was evidently taken at the same time. AS11-36-5366 occurs immediately after images of the LM docking target and is shown below in figure 4.3.17, it is analysed overleaf in figure 4.3.18

Figure 4.3.17: AS11-36-5366. High quality source here: [AIA]

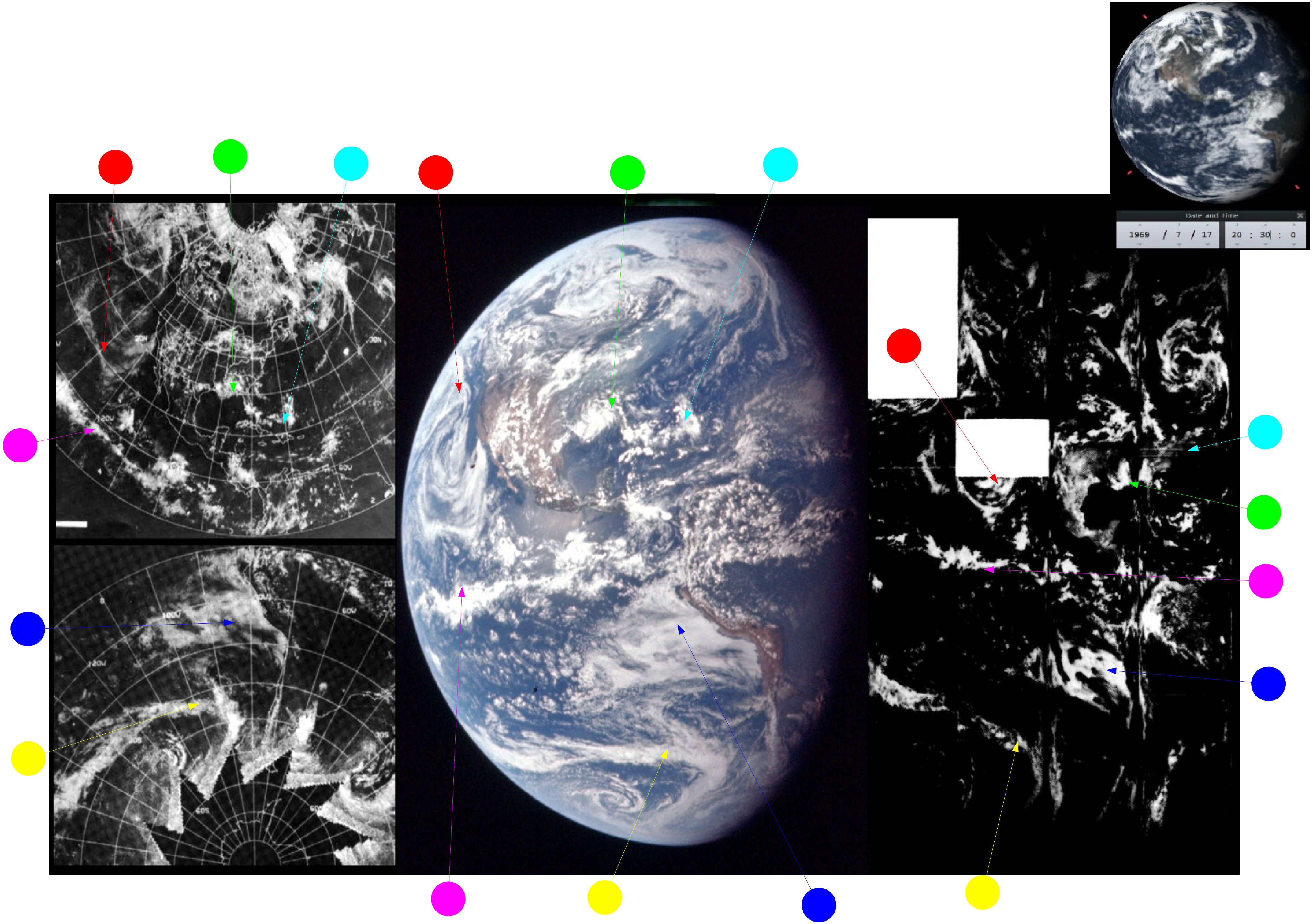


Figure 4.3.18: ESSA-9)left) and NIMBUS-3 (right) images compared with AS11-36-5366 and Stellarium estimate of time at terminator

It should (again!) be obvious that the features in the Apollo photograph are not just a match for the satellite weather patterns but also the TV image. The position of the terminator shows that the two were taken at almost exactly the same time. Although the ATS-3 image has not been included this time, it is still possible to see some weather features that are visible on it

ESSA's terminator orbit this time is nearer to track 3 than track 2 this time, which puts the start of that orbit (number 1767) at 19:01. Likewise the NIMBUS pass is one further along, and the start of pass number 1265, which commenced at 15:15.

The next TV broadcast was a live transmission, and this was started at 33:59 MET (23:31 GMT). There is another image showing a slightly different view before that broadcast, AS11-36-5366, but while much of south America has gone into darkness there is little extra to be gained by analysing it in depth. It is shown below in figure 4.3.19 for completeness. The next point for analysis is the live TV broadcast, a screenshot from which is shown in figure 4.3.20, and analysed overleaf in figure 4.3.21.

Figure 4.3.19: AS11-36-5366 original (left) and zoomed & cropped Earth. Source: AIA

Figure 4.3.20: Screenshot from live TV broadcast. Original Source: Apollo 11 TV broadcast

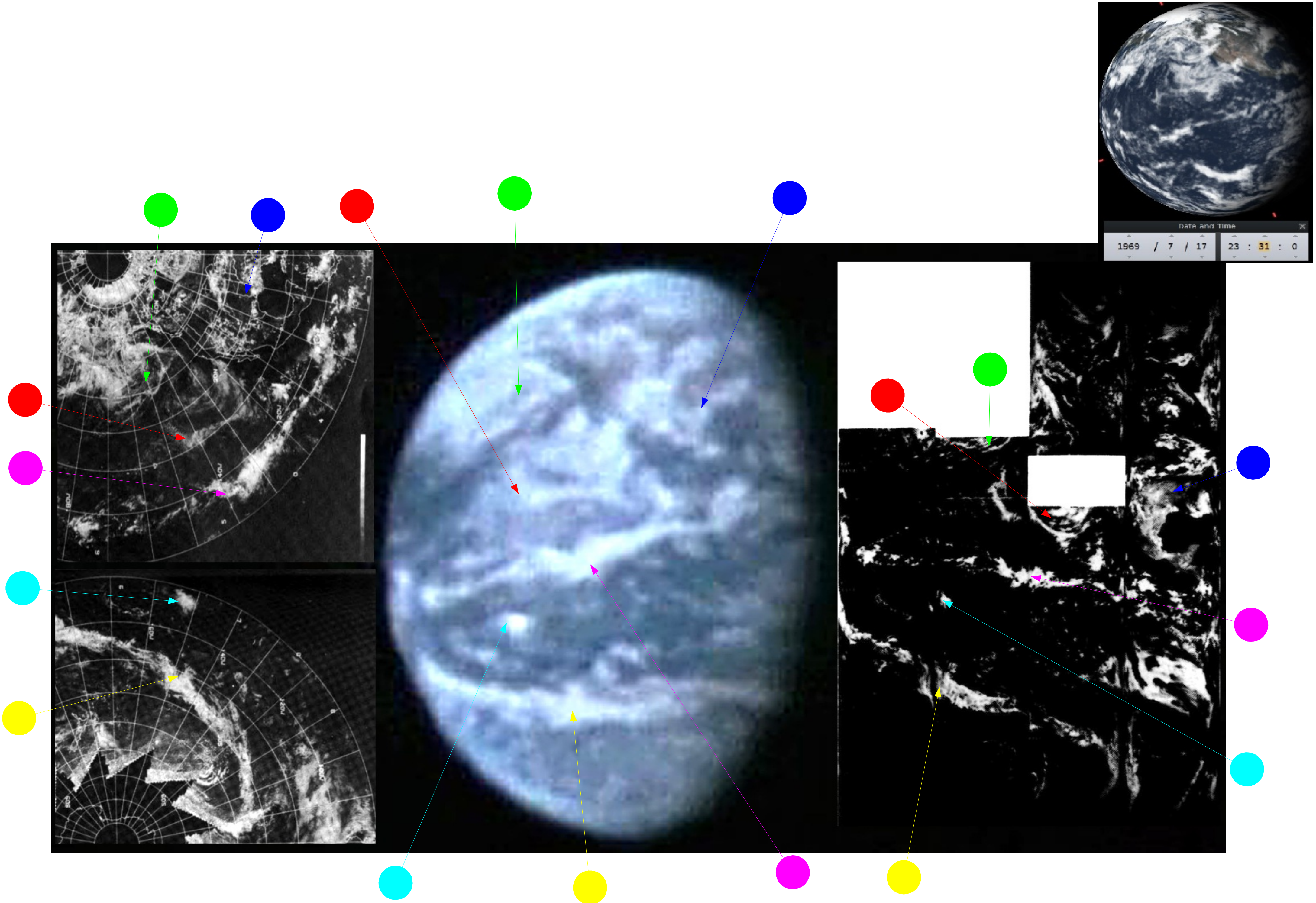


Figure 4.3.21: ESSA-9)left) and NIMBUS-3 (right) images compared with live TV broadcast screenshot and Stellarium depiction of terminator at time of broadcast

We are again faced with an image from Apollo that shows exactly what is visible in satellite images, and this time it is an image that was shown to millions in a live broadcast. This broadcast took place at 23:31, which is where Stellarium's terminator has been set, and this also shows that the view is showing what it should show.

ESSA's nearest terminator pass is that of orbit 1767 (track 3), which commenced at 19:01, while NIMBUS-3's orbit for the terminator region is pass 1265, which commenced at 15:15. We have more confirmations of the time from what the crew describe to the TV audience at the very start of the broadcast:

"You're seeing Earth, as we see it, out our left-hand window, just a little more than a half Earth. We're looking at the eastern Pacific Ocean, and the north half of the top half of the screen, we can see North America, Alaska, United States, Canada, Mexico, and Central America. South America becomes invisible just off beyond the terminator or inside the shadow. We can see the oceans with a definite blue cast, see white bands of major cloud formations across the Earth, and can see coastlines, pick out the western U.S. San Joaquin Valley, the Sierra mountain range, the peninsula of Baja California, and we can see some cloud formations over south-eastern U.S. There's one definite mild storm south-west of Alaska, looks like about 500 to 1000 miles, and another very minor storm showing the south end of the screen near the - or a long ways off of the equator, probably 45 degrees or more south latitude."

As usual, what they describe is what they should be able to see. The storm to the south west of Alaska is identified by the green arrow. The clouds across the south-east USA is identified by the blue arrow, but it is difficult to make out from the screenshot the storm system in the southern hemisphere. This is best viewed by looking at a photograph taken slightly earlier, which shows the storm more clearly. AS11-36-5373 is shown below in figure 4.3.22, and given the same analytical treatment in figure 4.3.23 over the page.

Figure 4.3.22: AS11-36-5373. High quality source: AIA

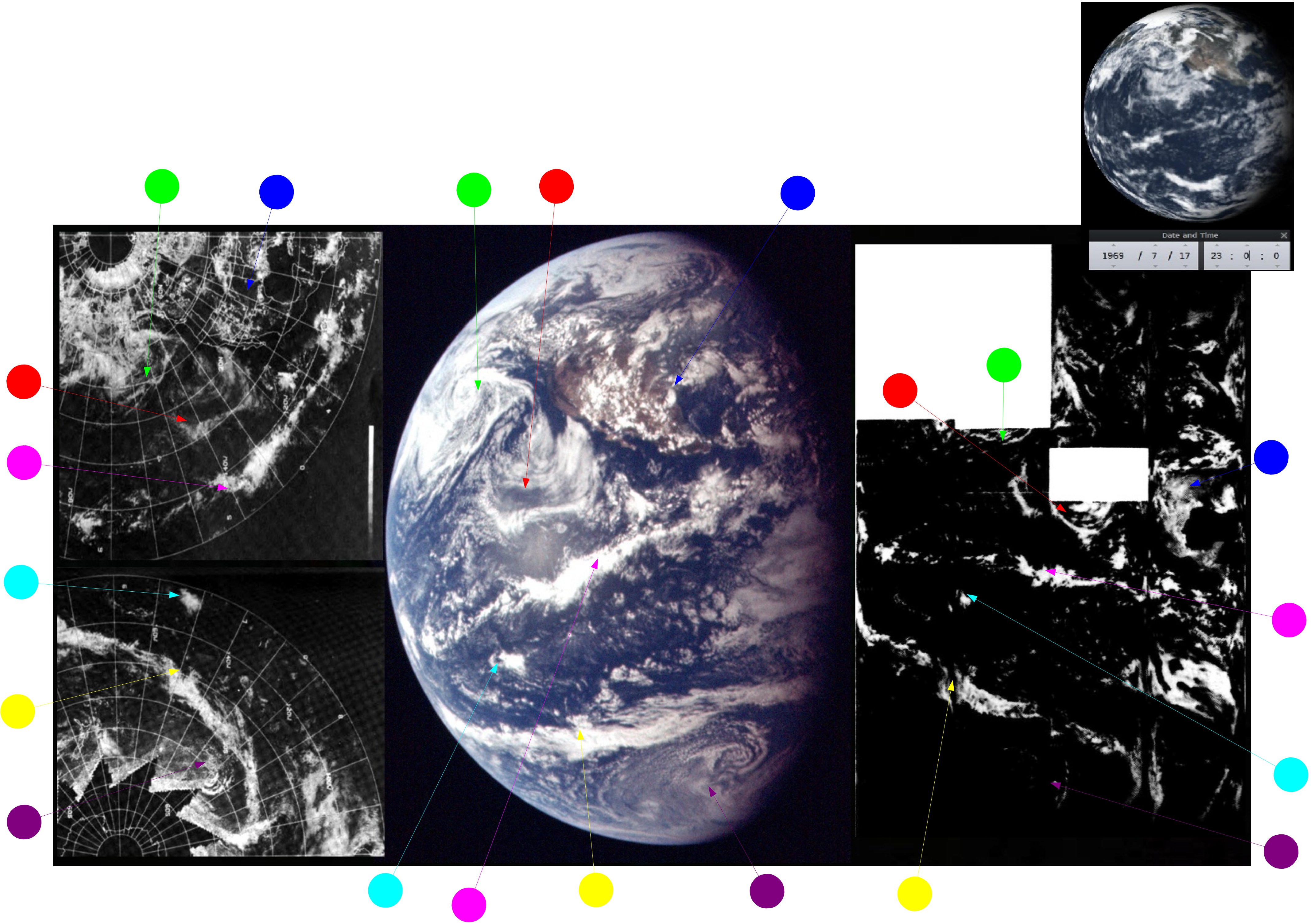


Figure 4.3.23: ESSA-9 (left) and N IMBUS-3 images compared with AS11-36-5373 and Stellarium estimate of time at terminatoor

The position of the terminator is allowing a clearer view of north America than the TV screenshot, which suggests that the time is actually some 30 minutes before the broadcast, but it does allow a clearer view of the storm the astronauts describe to the ground.

Now that we have a clearer view of what he astronauts were looking at, it's possible to tell that the storm in the southern hemisphere to which Buzz refers is identified by the purple arrow. If the reader refers back to the TV screenshot it is possible to just make out where that whorl of cloud is, pretty much on the terminator.

Because of the short difference in time between the TV image and the photograph, the ESSA & NIMBUS orbits are effectively the same for this image as figure 4.3.21.

The next image in the magazine shows the same view but with Florida on the terminator, suggesting at time for the photograph of around midnight on the 18th at the end of the TV broadcast. The whorl in the storm off Chile is still just visible in that photograph, demonstrating that Buzz would definitely have been able to see it in the TV broadcast, and therefore the purple arrow is definitely pointing towards it in figure 4.3.23. The next photograph with any significant degree of Earth rotation is the next image in the sequence, AS11-36-5374. This image is shown below in figure 4.3.24, and analysed overleaf in figure 4.3.25.

Figure 4.3.24: AS11-36-5375. High quality source here: AIA

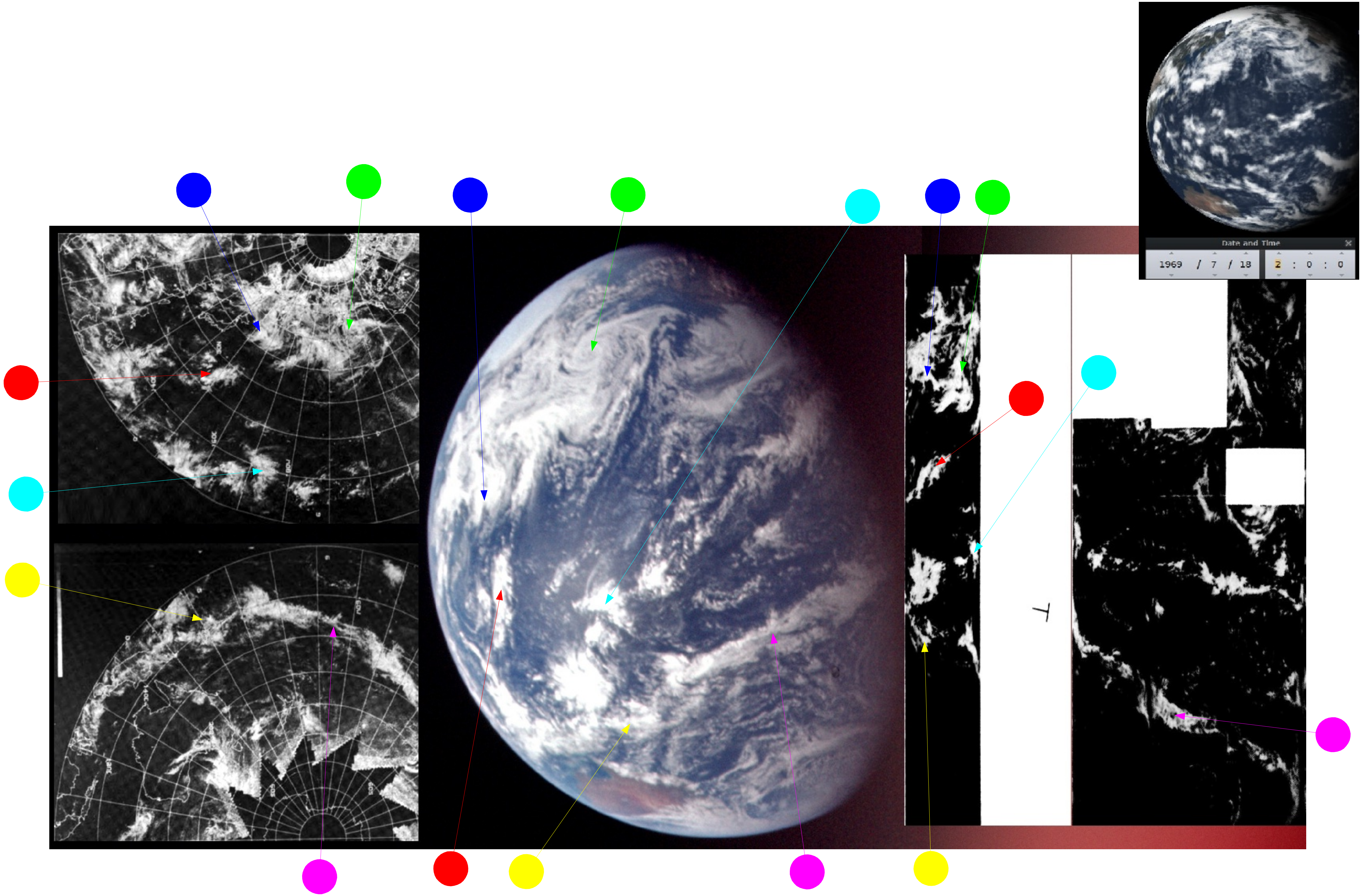


Figure 4.3.25: ESSA-9 (left) and NIMBUS-3 (right) images compared with AS11-36-5375 and Stellarium estimate of time at terminator

Australia has now come into view, and only a thin part of the US west coast is visible, so there has been been longer time lapse between images than has been the case for the previous few photographs. Australia will be seen several more times during the orbital and landing phase of the mission, so it's worth making a mental note of the cloud formations around the coast for future reference.

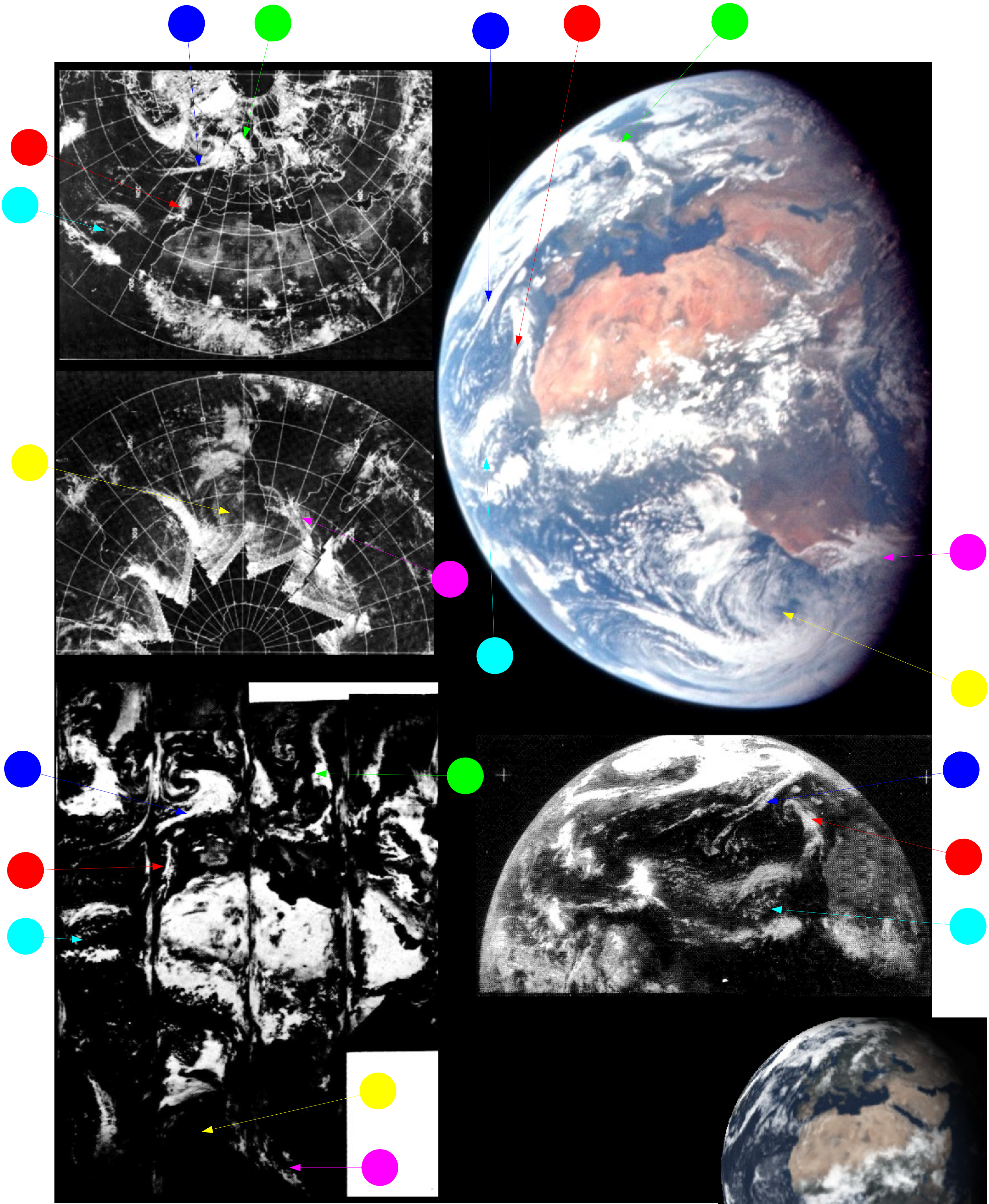
It is still just possible to make out weather systems identified in those pictures, but they have mostly not been marked here. The storm off Chile, for example, is just passing beyond the terminator, but the Alaskan one is more visible and is picked out by the same green colour as in the previous analysis.

As for when this image was taken, Stellarium shows an estimate of around 02:00 on the 18th. ESSA's best fit orbit for the terminator region is number 1769 (track 5) which commenced at 23:02 on the 17th. The NIMBUS image is actually a composite from two days' worth. The westernmost pass included here is actually from the image dated the 18th, and the remainder the 17th. The orbital path covering the terminator is number 1267, which started at 18:50 on the 17th.

The next image in the sequence shows Africa returning into view. This represents a considerable time gap compared with the others, but the mission transcript shows that shortly after image AS11-36-5375 was taken the crew entered a rest period.

AS11-36-5376 is shown below in figure 4.3.26, and analysed overleaf in figure 4.3.27.

Figure 4.3.26: AS11-35-5376. High quality source here: AIA



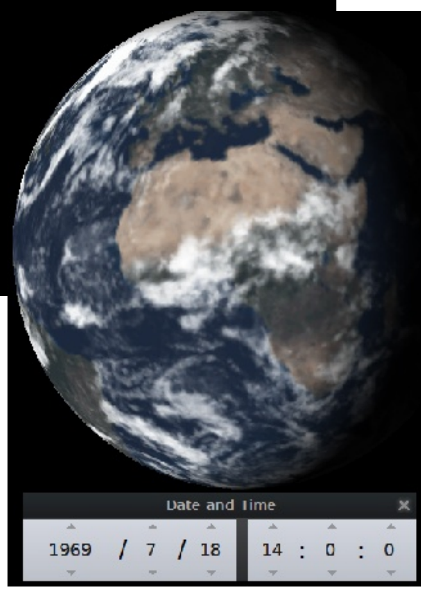


Figure 4.3.27: ESSA-9 (top left upper & lower), NIMBUS-3 (bottom left) and ATS-3 (bottom right) compared with AS11-36-5376 and Stellarium estimate of time at terminator

Stellarium estimates the terminator time as 14:00 on the 18th, which is approximately 48:30 MET . At 48:32 in the transcript, we have the following (edited) quote from Aldrin:

We've got the continent of Africa ... facing toward us right now,... The Mediterranean is completely clear. The Sun looks like it's about to set around Madagascar. The equatorial belt of Africa stands out quite clearly. We're seeing the dark green or a muddy coloured green, compared to the sandier colours in the southern tip of Africa and, of course, the Sahara northern coast of Africa. There's a rather remarkable cloud that appears in the vicinity of the border between Afghanistan and Pakistan. It's just about to go into the sunset now. It is casting quite a large shadow. It's isolated."

The Afghan border cloud is not identified specifically in the preceding figure, as it would not be featured on an ESSA image dated the 18th. If we isolate that area of the globe and compare it with the ESSA image dated the 17th (which would show that storm on it's final orbits on the 18th, we get figure 4.3.28

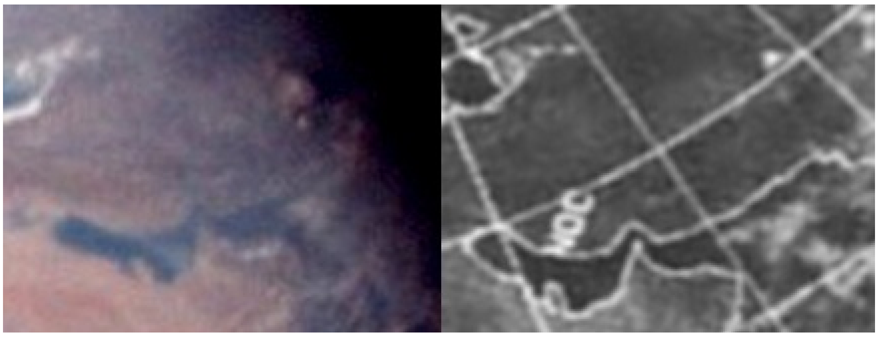
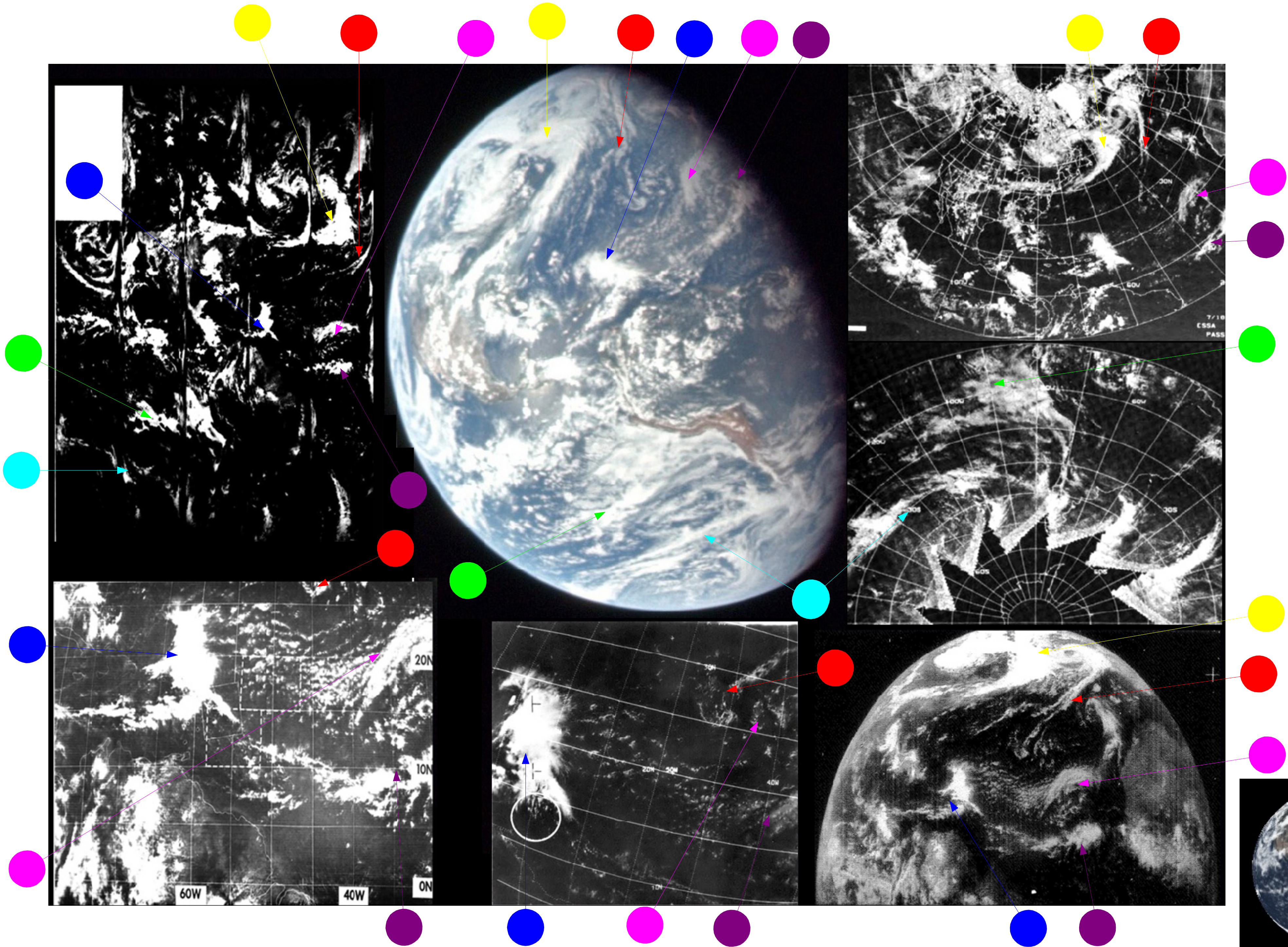


Figure 4.3.28: Section of AS11-36-5376 compared with the same section of the ESSA-9 image from the same time.

It should be evident that there is a cloud in exactly the same place on the ESSA image in isolation. The boundary line of the ESSA image on the 17th is given as track 10 (orbit 1774), although the dividing line appears to be one later (orbit 1775) at the start of the image dated the 18th. The commencement times for these orbits are 09:09 and 11:04 respectively. ATS' time is recorded as 14:55 on the 18th, while NIMBUS' orbit 1273 started at 05:46 on the 18th.

The next image for analysis is AS11-36-5381, shown below in figure 4.3.29 and overleaf in figure 4.3.30.

Figure 4.3.29: AS11-36-5381. High quality source here: [AIA]



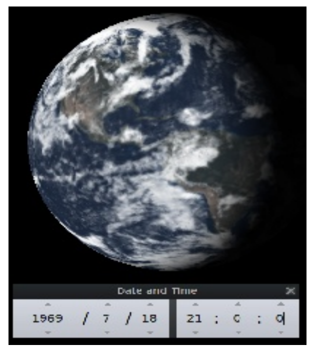


Figure 4.3.30: ESSA-9 mosaic (top right upper & lower), ATS-3 (bottom right), NIMBUS-3 (top left), journal ATS-3 image (bottom left) and BOMEX ESSA-9 image (bottom centre) compared with AS11-36-5381 and Stellarium estimate of time at terminator.

The observant reader will have noticed several more images in figure 4.3.30 than is usual, with the additional images coming from detailed sections of an ATS image from a journal, and an ESSA image from the BOMEX study referenced in the introduction to this section. The cyan arrow in figure 4.3.27 picked out the area between a pair of parallel clouds, which in this figure have been picked out by the magenta and purple arrows, as using both clouds allows more detail to be picked out in the zoomed in ESSA & ATS image.

Stellarium estimates the terminator to be at around 21:00, shortly before Aldrin and Armstrong enter the LM to inspect it, and this Apollo image is the last in magazine 36 before that inspection.

The ATS-3 image's time is given in the journal as having been taken at 14:31, at which time Buzz is describing weather systems over Afghanistan discussed earlier. The Caribbean portion of the ESSA 9 image is reported as being taken at 13:25, but the 'L' after the times in the original document refer to local time, not GMT. The actual satellite pass for the Caribbean (Track 3, number 1779), commenced at 18:04.

The NIMBUS pass over the Caribbean (orbit 1278) commenced at 14:31, which would explain why the weather system picked out by the blue arrows is more similar to the ATS-3 image, compared with the ESSA's later version matching more closely to the Apollo image.

Although the NIMBUS image is again of poor quality, all 3 satellites clearly show the same weather systems as the Apollo image, and these systems are also very obviously part of developing global weather systems.

The first two photographs after the inspection pictures in the LM show that there has been quite a time gap between them, again coinciding with a rest period and preparations for LOI. AS11-36-5402 is shown below in figure 4.3.31, and analysed overleaf in figure 4.3.32.

Figure 4.3.31: AS11-36-5402. High quality source here: AIA

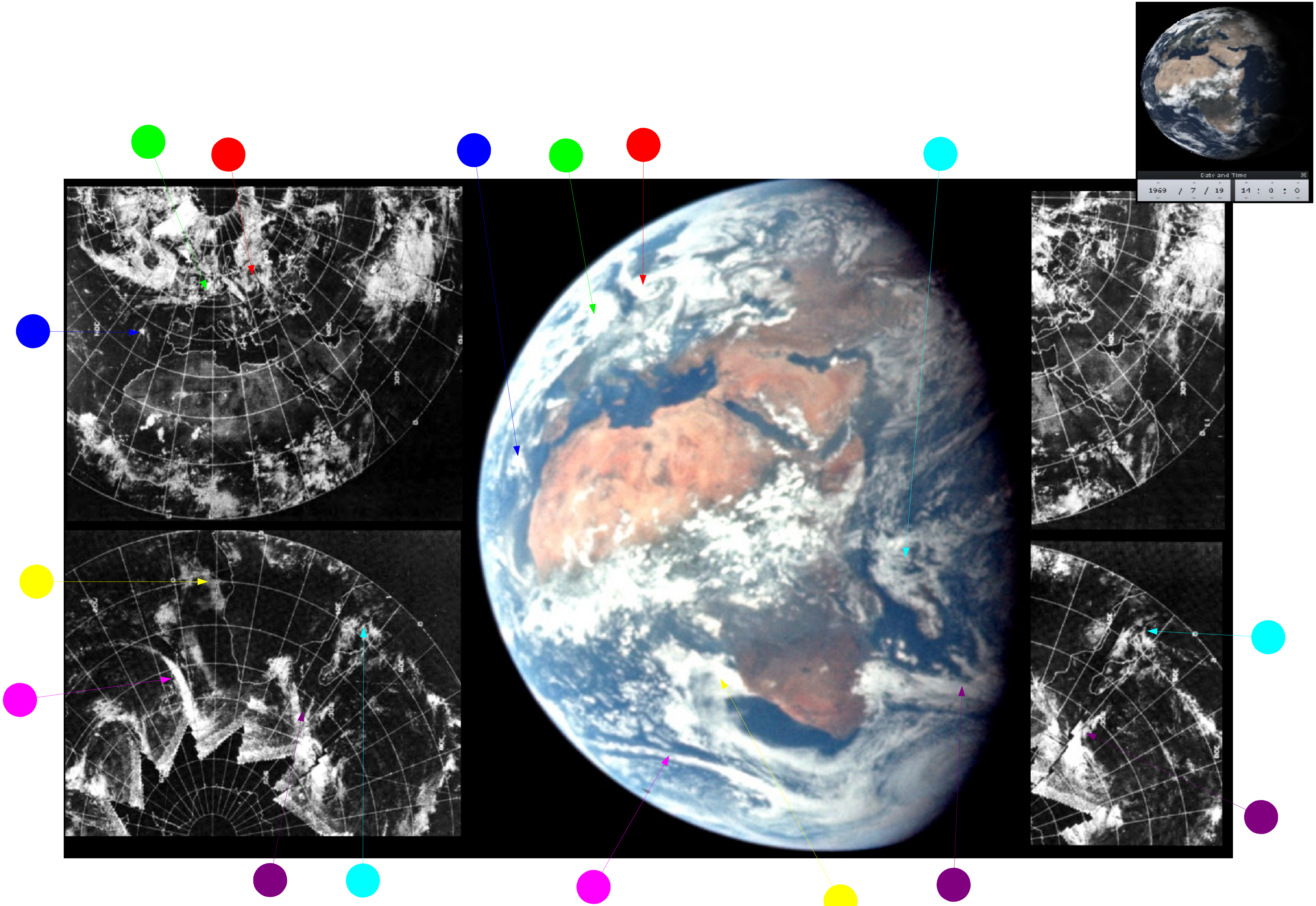


Figure 4.3.32: ESSA-9 image dated 19/0/69 (right) and 18/07/69 (right) compared with AS11-36-5402 and Stellarium estimate of time at terminator

Stellarium puts the terminator here at around 14:00, which would be around 72:30 MET, a few hours after the crew resumed communications after their rest break. The crew are engaged in photographing the solar corona, getting news reports from home (including the progress of the Soviet Luna 15 probe), and preparing for LOI.

As usual with African views there is the split between ESSA's orbital day, running up the East coast of Africa. In this case, there is relatively little difference between the weather patterns either side of that divide, as indicated by the purple and cyan arrows. There is no NIMBUS footage from the 19th, and the only ATS image available shows poor definition of the western hemisphere only, with the African part of the globe in darkness.

The most obvious weather systems are those showing around southern Africa, which don't occur in that formation on any other day. The best fit orbit for the terminator is track 10 (number 1786), the penultimate on the image dated the 18th, which was commenced on the 19th at 08:02.

The next photograph examined is the first to feature the Earth with Apollo equipment in shot, and turns out to be the last one taken before images of the lunar surface appear. After this point we start to get images shown of the Earth from two perspectives: one from the crew bound for the lunar surface, and the other from Collins as he orbits in the CSM.

AS11-36-5404 (shown in figure 4.3.33 and analysed overleaf in figure 4.3.34) occurs after the initial LM inspection, but the LM & CSM are obviously still attached, so it must have been taken (at the very least) before 17:44 on the 20th .

Stellarium suggests that the terminator is at roughly 16:30. If this was 16:30 on the 20th, the crew would have separated into the two craft and be performing system checks, unlikely to be taking photographs, so it seems a reasonable starting point to assume this image was taken on the 19th.

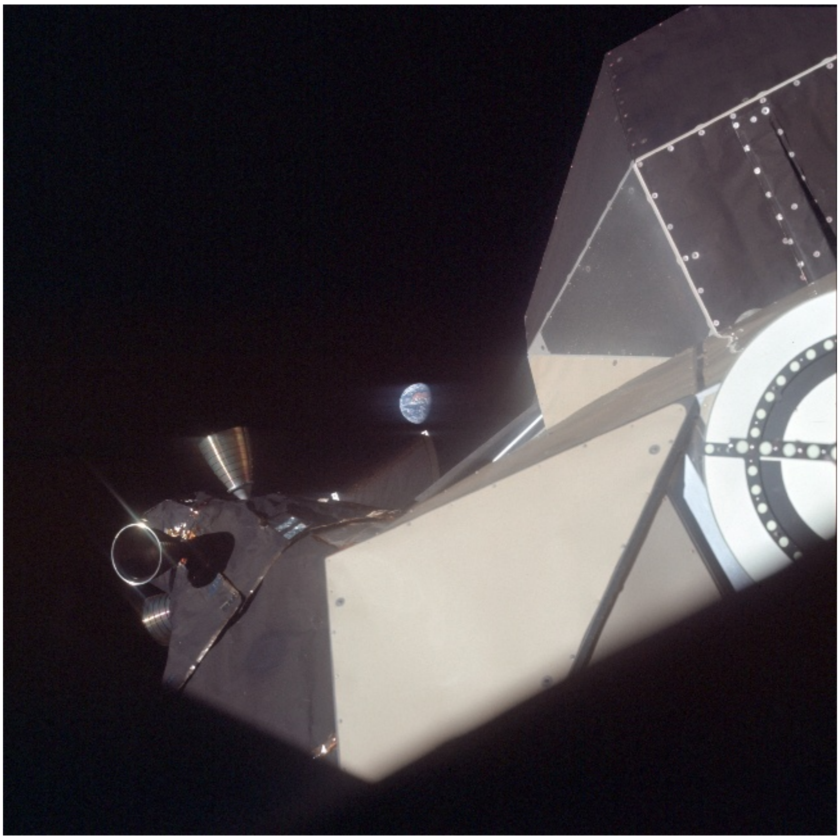


Figure 4.3.33: AS11-36-5404. High quality source here: AIA

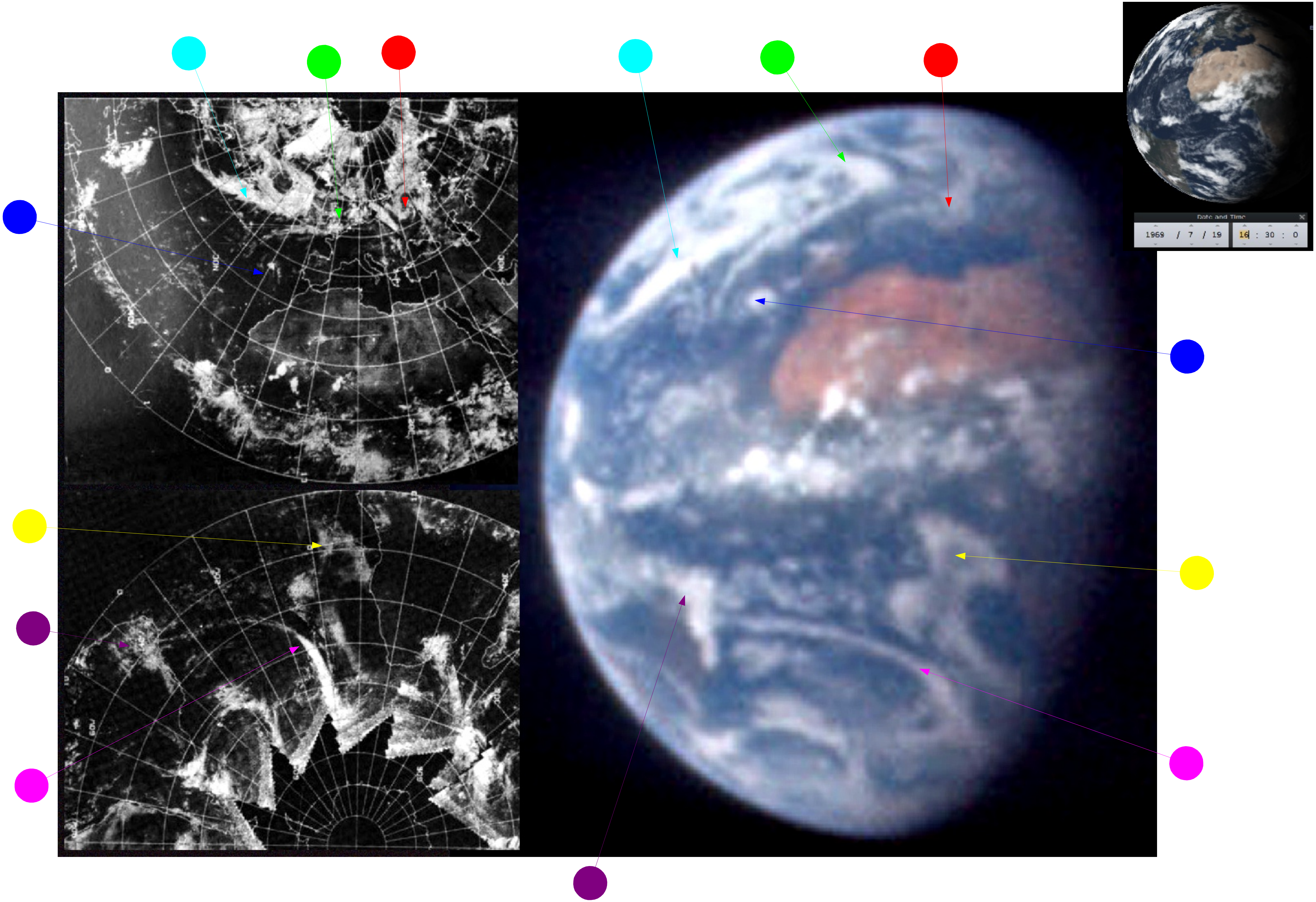


Figure 4.3.34: ESSA-9 image compared with AS11-36-5404 and Stellarium estimate of time at terminator

There are no NIMBUS data available for the 19th of July, so we are reliant on ESSA images alone from that date. The cloud patterns in the north and south Atlantic are distinctive, and easy to pick out on the ESSA images, despite them being fainter. As for timing, the terminator portion of the ESSA image was taken on orbit 1788 (Track 12), which was commenced on July 19th at 12:05, progressing over the Atlantic later that afternoon, coinciding very nicely with the time Stellarium says the Apollo image was taken.

The next series of images examined cover the period of CSM & LM separation, lunar orbit, landing, and then rendezvous of the two craft. Several images exist that allow comparison if different parts of the Earth's surface during those procedures. The first images to be examined are AS11-37-5435 & AS11-40-5845. As will be demonstrated, these were taken at the same time using different cameras. Figure 4.3.35 shows the original photos for 37-5345, figure 4.3.366 shows the original for 40-5845 combined with a zoomed and cropped Earth from it for comparison, and 4.3.37 the analysis of 37-5435, the clearer of the two photographs.

Both magazines are from cameras that made it to the lunar surface, as they both feature the surface in them later on. Magazine 36, from which most of the preceding images were taken, was taken with a camera that remained on the CSM, as can be seen by photographs taken later in the magazine 36 that show parts of the LM after Aldrin & Armstrong had transferred to it.

AS11-37-5435 occurs near the beginning of the magazine, after an image of a curved lunar horizon, suggesting that it is not yet in final orbit. It is also well before an impressive sequence of images of the CSM taking during separation, which puts this image sometime after 17:27 on the 19th, but before 18:11 on the 20th (the time of the separation manoeuvre). The ALSJ records that the image taken 2 pictures later in the magazine was taken at 94 hours and 50 minutes into the mission, or 12:22 on the 20th, which narrows down the window still more. The image shows the west coast of the USA near the terminator, and was evidently taken from behind glass, as there is a clear 'ghost' Earth on reflected on the window.

AS11-40-5845 also occurs at the start of the magazine and is immediately preceded by a very circular lunar horizon. There are no other indicators of the likely time period in which the image could have been taken, other than photographs showing the lunar surface. This narrows down the window to between 17:27 on the 19th and 20:05 on the 20th, the beginning of powered descent towards the surface. This image also features the west Coast of the USA close to the terminator, indicating that it was taken at the same time of day as AS11-37-5435. The sharp black line crossing the Earth's is part of a Reseau mark used to calibrate the images for distance and perspective.

The first thing to note about the Earth's visible in the figures is that they are pretty much identical, and the immediate question must be: why would two photographs be taken at exactly the same time? Stellarium's terminator puts this time at roughly 01:00 on the 20th (confirmation of the date will follow) which would be around 83 hours and 30 minutes into the mission. The ALSJ records a number of conversations between Armstrong, Aldrin & Collins concerning camera equipment that needed to be transferred to the LM. They complain about fogged windows, and then suggest that if they clean the windows they ought to be able to get some nice pictures. At 82:12 Aldrin says:

Alright, then, I think - the way we're sitting, why, we're going to be able to get a picture - of the Earth coming right up there. What do you think about that?

Followed at 82:15 by

Okay. I'll get another good picture of what comes along. Well, hell, I guess we might as well load the other camera and make sure it works, too, huh?

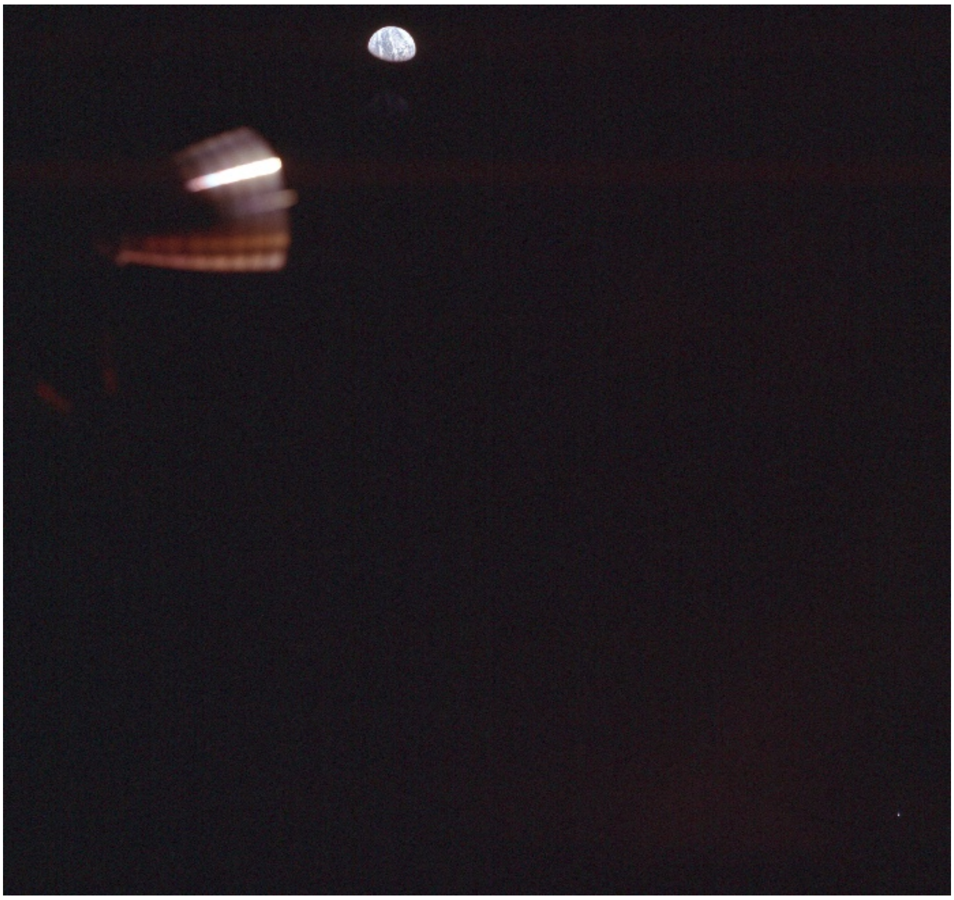


Figure 4.3.35: AS11-37-5435. High quality source here: [AIA]

Figure 4.3.36: AS11-40-5435 and zoomed & cropped Earth from it. High quality source here: [AIA]

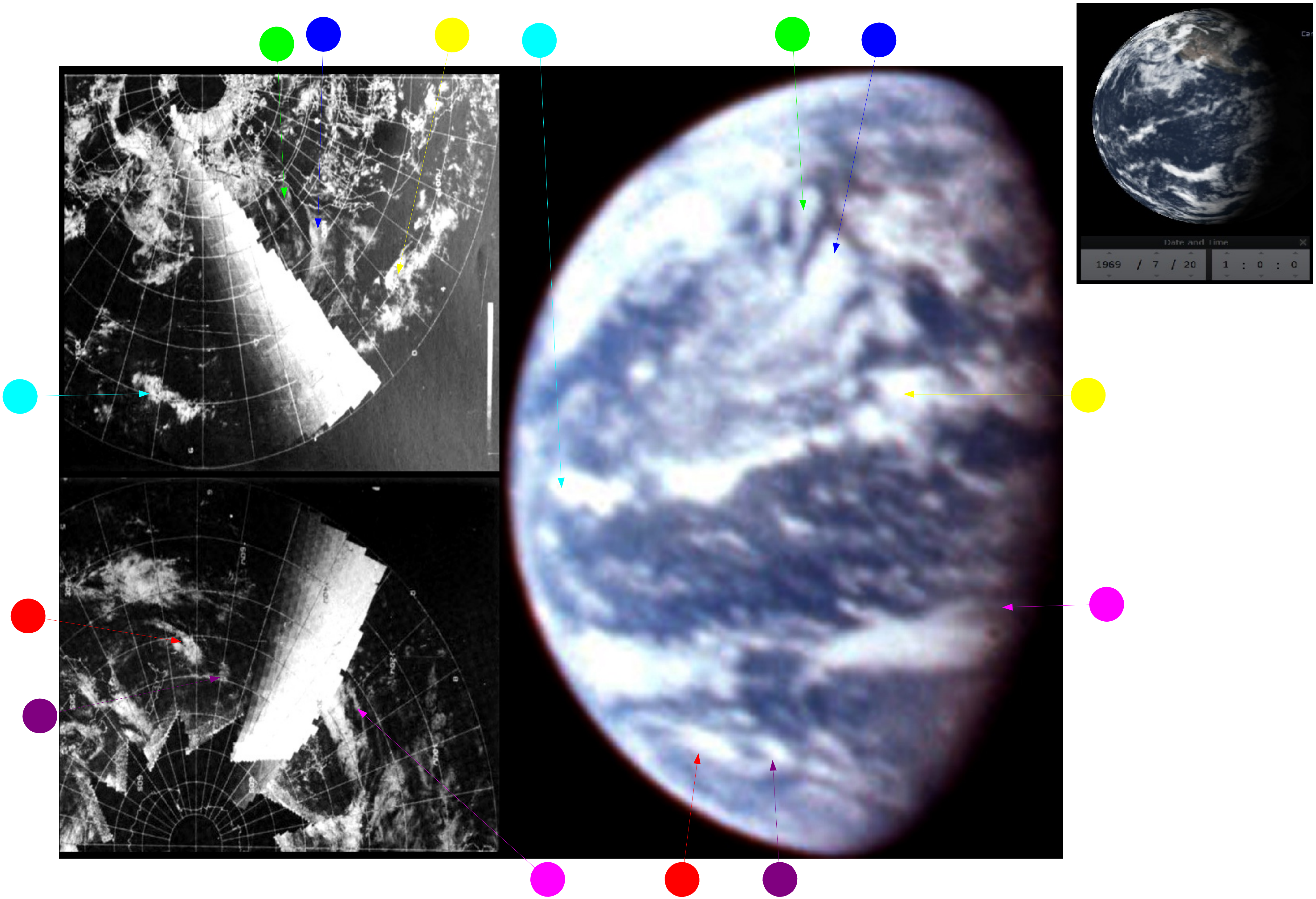


Figure 4.3.37: ESSA-0 image compared with AS11-37-5435 and Stellarium estimate of time at terminator

At 82 hours and 16 minutes Collins says

Well, look, if we load this one - if I put the film on this one, and take a picture or two, well, I'll have to take it back off again; that's the only trouble. I won't have to, but it doesn't stow as neatly. If you don't mind doing - powered descent with the camera in there, I think that's probably alright. Well, wait a minute, I bet I could put this one loaded where the other one goes...

At 82 hours and 32 Aldrin says:

I see the Earth, but it's a lousy picture.

Then 5 minutes later

I got the Earth down by the strut.

An hours later, after Aldrin & Armstrong have transferred to the LM, we get this from Aldrn at 83 hours and 19 minutes:

I'm checking out camera number 4 now.

Then finally:

Roger, Houston. Eagle has checked out both 70-millimetre cameras and both 16-millimetre cameras, and all work fine. Over.

So, it becomes pretty clear from this discussion that the reason for the two identical photographs is that just around 82 - 83 hours into the mission, prior to final transfer to the LM, the crew take a few shots to check that the cameras actually work, and 83 and a quarter hours is around 01:00 on the 20th. It is also clear that the Earth has definitely moved on since figure 4.3.34, and the weather systems visible on the ESSA image from the 19th are clearly present on the Apollo images taken in the early hours of the morning on the 20th.

For ESSA, the relevant pass on the image dated the 19th occurred at around 21:03 (track 4, 1798) – only 4 hours away from the actual time the images were taken. No NIMBUS data exist for the 19th, so none are given for this image.

As for the weather systems, the most obvious features are those of the low cloud off the coasts of north & south America. These cloud banks persist into the following day's satellite images, but their shape has clearly changed over the half a day+ interval between the Apollo images and those taken on the 20th by ESSA. Stellarium and the ALSJ transcripts provide, in this case, a better fix on the timing of the image.

Over the next 12 hours the crew busy themselves preparing the LM, and the next image to be examined is one taken from the CM a few hours into that preparation around the time of a rest period. AS11-44-6550 is one of the clearest sequences of Earthrise images over the mission, and is shown over the page in figure 4.3.38.

The ALSJ reports that this image was probably taken sometime during lunar orbit 12 or 13, which would suggest a time of 98 hours or 100 hours in to the mission, or roughly between 15:00 – 17:00. Immediately following this Earthrise sequence, there are a number of photographs detailing the separation of the CSM from the LM, which we know is timed at 18:11 on the 20th.

Figure 4.3.38: AS11-44-6550. High quality source here: AIA

As time has moved on slightly from the previous analysis, two satellites are once again available and the satellite analysis is given in figure 4.3.39, together with the usual Stellarium terminator screenshot. The NIMBUS data used are visible spectrum, as they provided the best image. ATS-3 does not cover any of the area shown.

In this case, Stellarium suggests that the time of the image would have been somewhere around 04:00 in the morning, seems to be at odds with the ALSJ's interpretation of when the image was taken, and would put it as being taken somewhere after start of orbit 6, after which the crew got some sleep before the next phase of the mission. Had it been taken on orbit 12, it would have shown the Atlantic rather than the Pacific.

Orbit 6 commenced at 86:06 MET, with Earthrise on this orbit at about 86:30 MET, or shortly after 04:00 GMT. At this time in the CM transcript, we have this exchange between Collins (CMP) and Armstrong (CDR):

03 14 24 48 CMP Where the hell is the horizon with the world coming over it? I guess it's behind us, huh?
03 14 24 58 CDR Up there? We should be getting Earthshine – Earthrise features - should be coming up pretty soon.

After which they discuss which films are available, so they are apparently looking for Earthrise with cameras at hand.

Both north and south Pacific have distinctive weather features that should be readily identifiable, notably the large swirl off eastern Australia, the '>' shaped feature over SE Australia itself, & the cedilla shaped cloud off China. All these features are clearly visible on the satellite photographs.

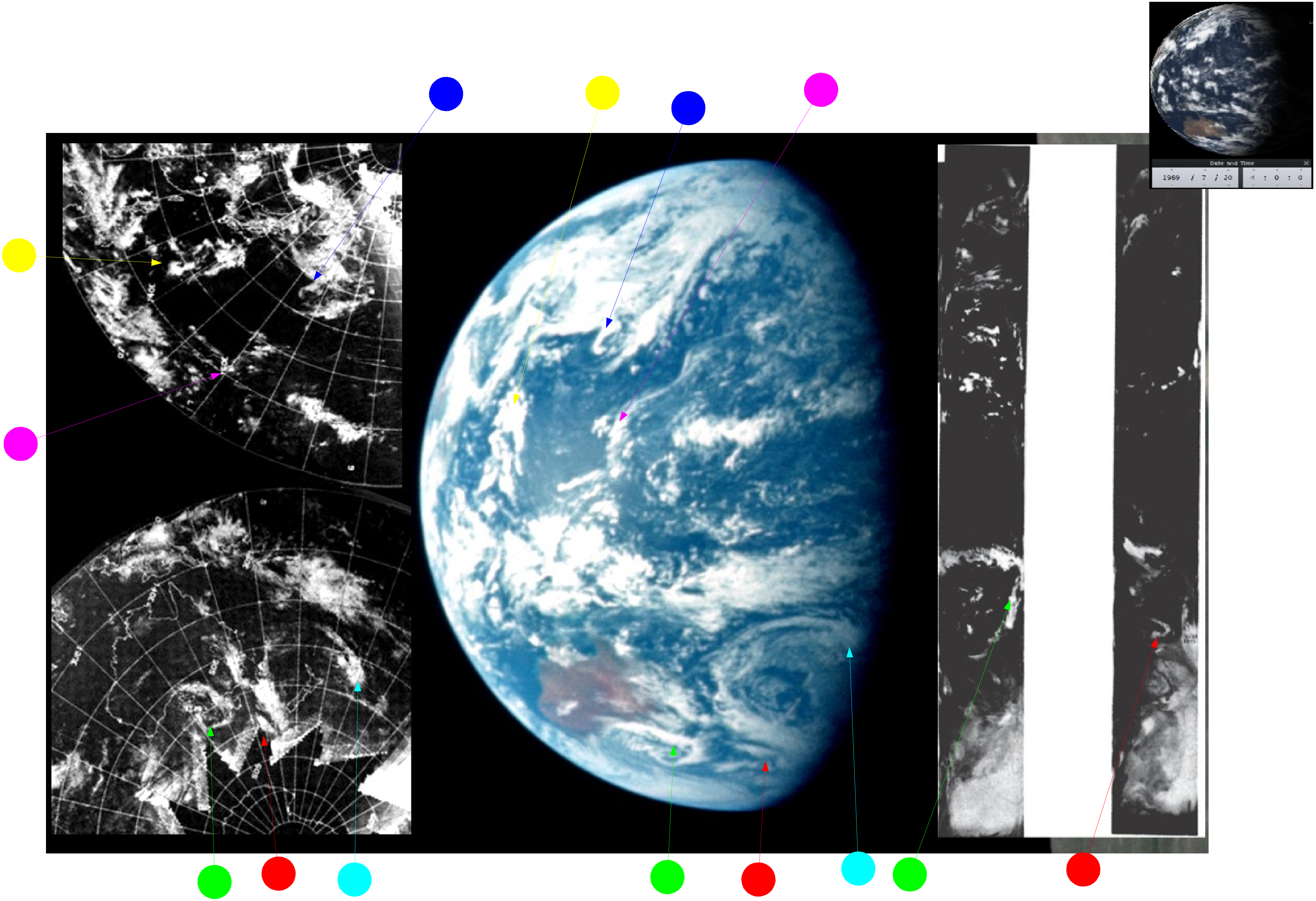


Figure 4.3.39: ESSA-9 (left) and NIMBUS-3 (right) images compared with AS11-44-6550 and Stellarium estimate of time at terminator

As far as placing a time on the satellite images, ESSA's track covering the terminator line on the 20th is actually orbit 1796 on the image dated the 19th. This pass commenced at 03:05 on the 20th, so the satellite passed over Australia not much befpre the time the Apollo crew took their picture. Unsurprisingly, the weather patterns observed by ESSA match exactly those in the Apollo image.

The NIMBUS image is difficult to decipher because there is relatively little of it and what is there is faint. There is, however, a clearer image made available by the Australian Bureau of Meteorology. This image was sent after an initial inquiry as to whether they had any data. This inquiry led to them finding an unscanned collection of old NIMBUS images, requiring them to buy new scanning equipment to archive it. The author would like to apologise to the Australian taxpayer for costing them money.

From the information they sent, the image was from orbit 1297 (which is how the composite image in the previous figure was selected – the continents were difficult to pick out otherwise), and the time for this pass was commenced at 01:22 on the 20th – 4 hours before the Apollo image. This NIMBUS image is shown with a zoomed & cropped part of AS11-44-6550 is shown in figure 4.3.40.

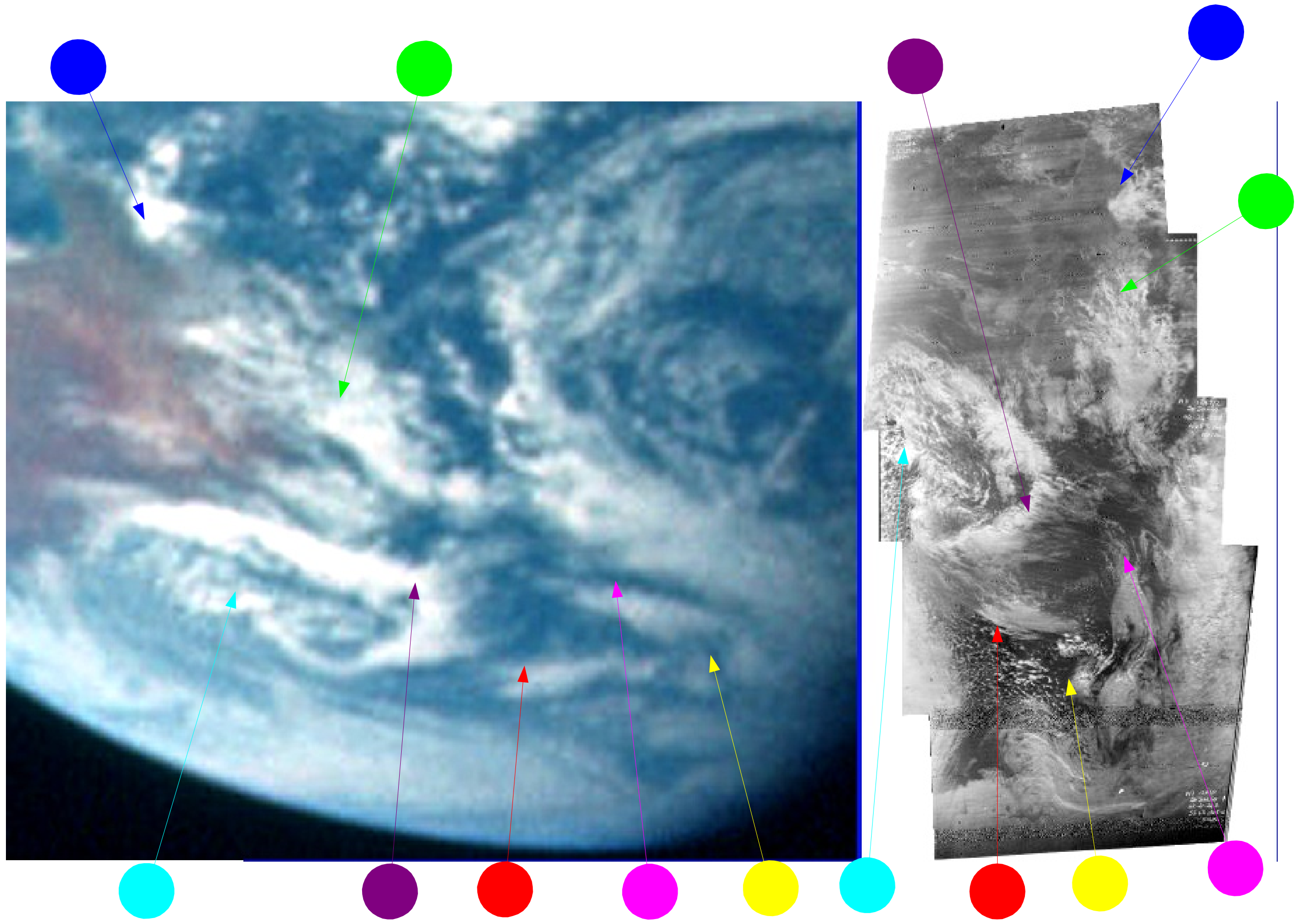


Figure 4.3.40: Parts of NIMBUS orbit 1297 supplied by the Australian Bureau of Meteorology compared with the South Pacific and Australia from AS-11-44-6550.

Even allowing the NIMBUS' flat images and the Earth's curvature, there is a huge amount of correspondence between the two pictures. It is a useful example that the level of detail present in many of the Apollo photographs belies the argument that they are clumsy, hastily produced fakes. The storm over Australia appears in both photographs because both cameras were where they claimed to be: Over Australia, one passing in from a few hundred miles, one from 240000 miles in orbit around the moon.

12 hours later, the crew were in the process of undocking the LM, recorded as being at 110 hours 12 minutes, and image AS11-37-5442 (figure 4.3.41) is part of an Earthrise sequence taken (according to the ALSJ) just after this and featuring parts of the LM in shot. Certainly the photographs immediately after this one shows the CSM taken from the LM.

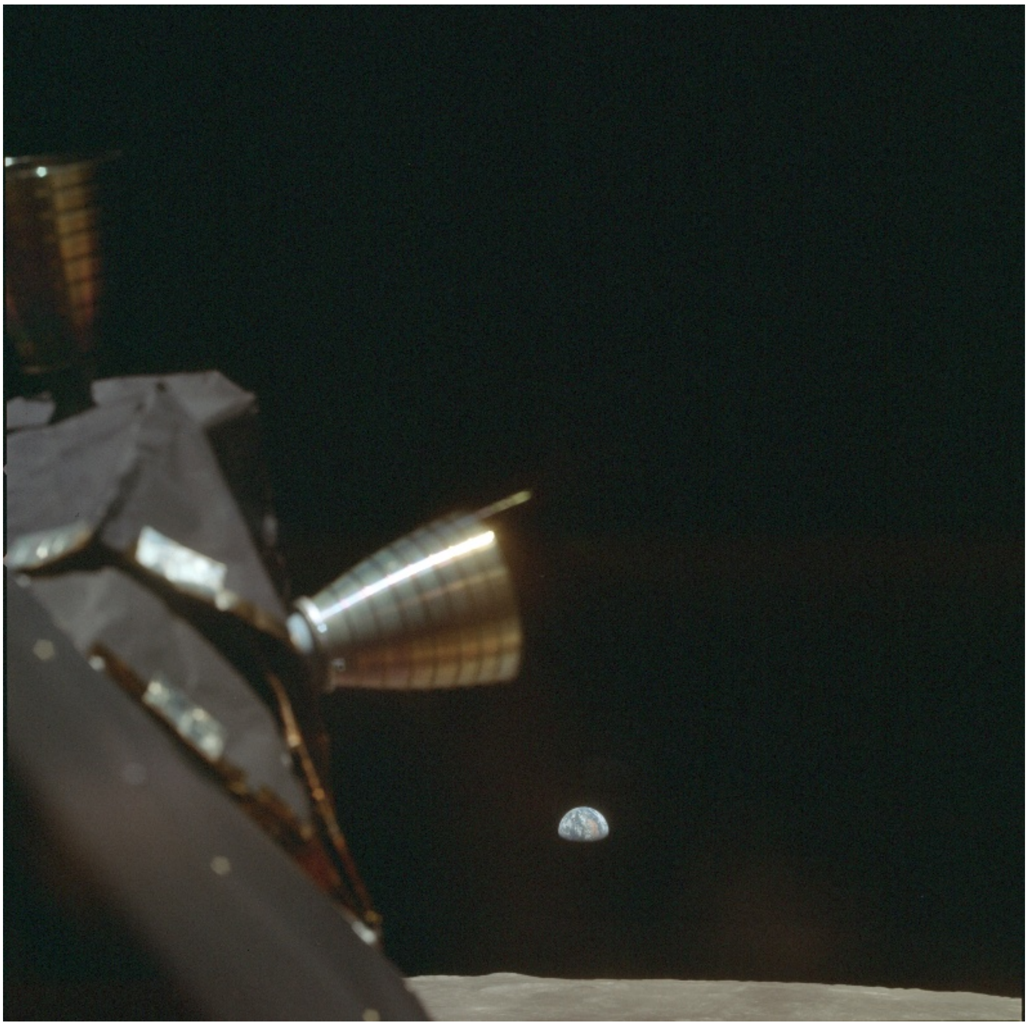


Figure 4.3.41: AS11-37-5442. High quality source here: AIA

The photograph is obviously taken from inside the lunar module, and time has clearly moved on as far as the Earth is concerned as the main landmass visible is Africa. The ALSJ records a photograph taken a few frames before this one (AS11-37-5437) as being taken at 94hrs and 50 minutes into the mission, or 12:22 GMT on the 20th.

All three satellites can be used to compare weather features, and the analysis is given in figure 4.3.42.

In terms of satellite timings, the ATS-3 image is labelled as having been taken at 15:53. The ESSA path over the east African terminator would be track 12, which would be orbit 1801 on the image dated the 20th, commencing at 13:01. The relevant orbit for NIMBUS would be orbit 1302, which commenced at 09:30. The nearest orbit to the time suggested by Stellarium of 16:00 is orbit 12, which had an AOS time of 98:18, or around 15:50 on the 20th.

The satellite comparison again shows that there is excellent correspondence between all 3 satellites' images and the Apollo photograph. The most obvious weather system is that shaped like a bass clef picked out by the blue arrow. The large cloud pattern off Africa shown 24 hours earlier is still visible (magenta arrow) but has changed shape and position.

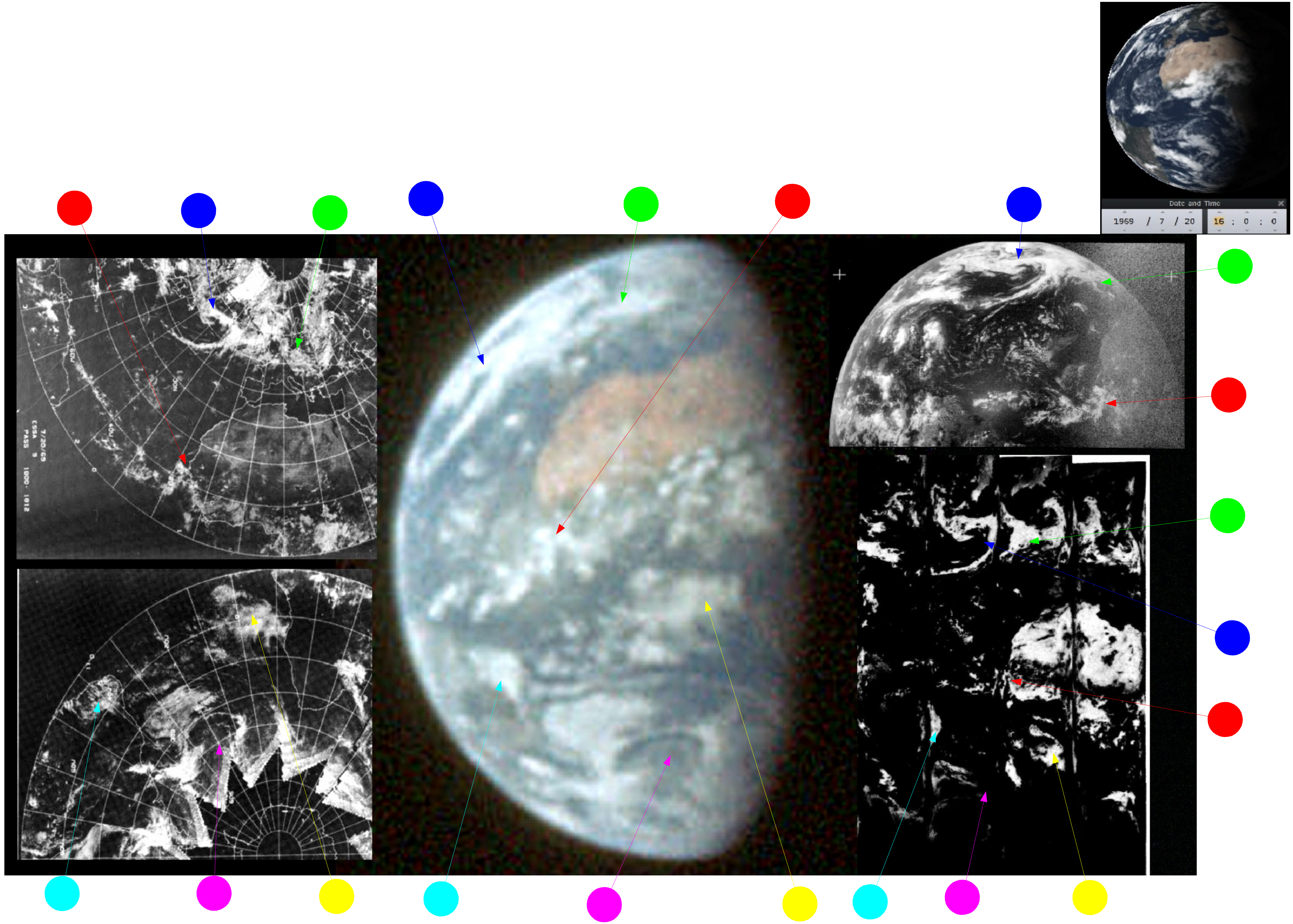


Figure 4.3.42: ESSA-9 (left), ATS-3 (top right) and NMBUS-3 (bottom right) images compared with AS11-37-5442 and Stellarium estimate of time at terminator

It's interesting to note that the blue-arrowed system seems to appear in all 3 satellite images in roughly the same place, and the reason for this is based around the fact that the ESSA & NIMBUS images are composites of several orbits. The NIMBUS orbit passing over the system in question would have started at around 14:30. Likewise ESSA's orbit over it would have been commenced at 15:06 (track 1, orbit 1802). These compare well with the ATS-3's time of 15:53, and are all relatively close to the time Stellarium suggests of 16:00. which means that this image is one of the last taken before the LM & CSM separated.

While Armstrong & Aldrin were in the LM, Collins was left to orbit the moon alone in the CSM, and part of his responsibility during those orbits was to take photographs of the lunar surface (and with any luck identify Tranquility Base.

While orbiting he captured a series of black & white Earthrise images & one of those, AS11-41-6023 (figure 4.3.43) will be examined next. The suggestion of this analysis is that magazine 41 was used after separation of the two craft, and that this image was taken a couple of hours after the LM landed on the surface as part of a long sequence of Earthrise images. Figure 4.3.44 compares all 3 satellite images with a close up of Earth from this photograph.

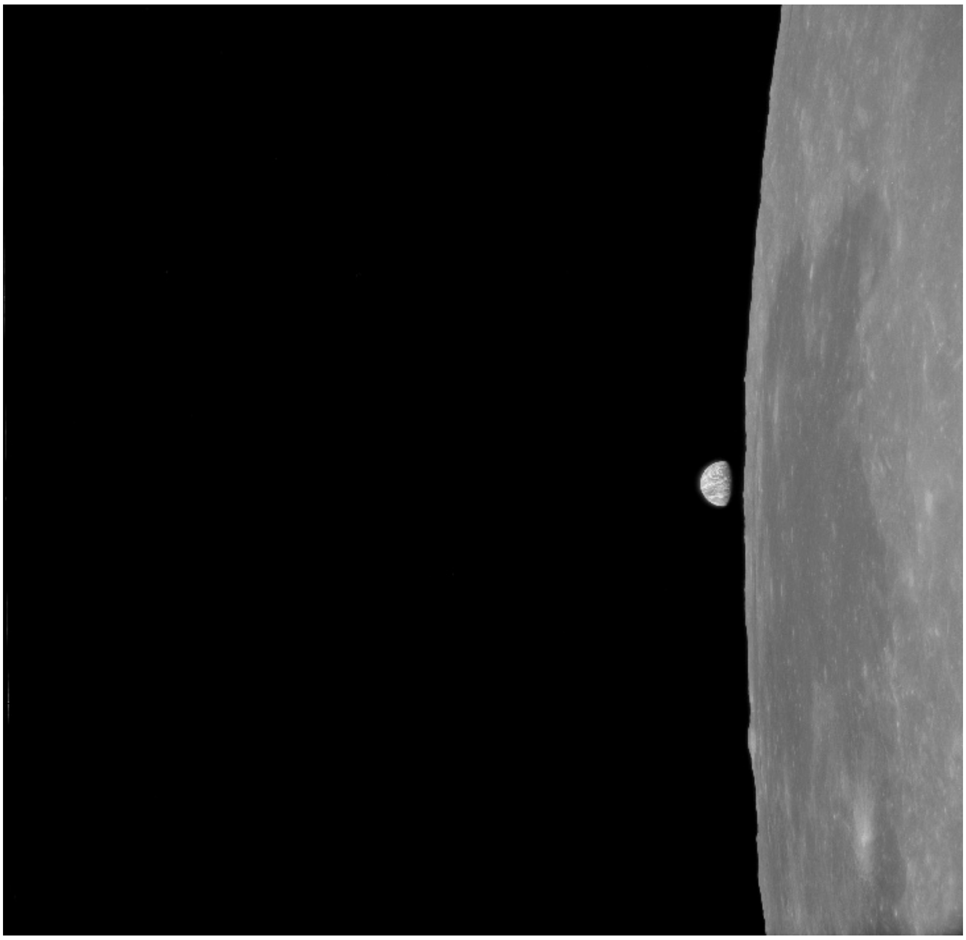


Figure 4.3.43: AS11-41-6023. High quality source: AIA

The ATS-3 image was, as reported earlier, was taken at 15:52, and the by the time of the Apollo photograph Earth has, for the most part, rotated beyond what ATS-3 can see from its geostationary position.

As the cloud masses picked out in red & green on the ATS are still visible in the Apollo image, it is reasonable to assume it that it was also taken on the 20th. ESSA's image on the 20th covering the

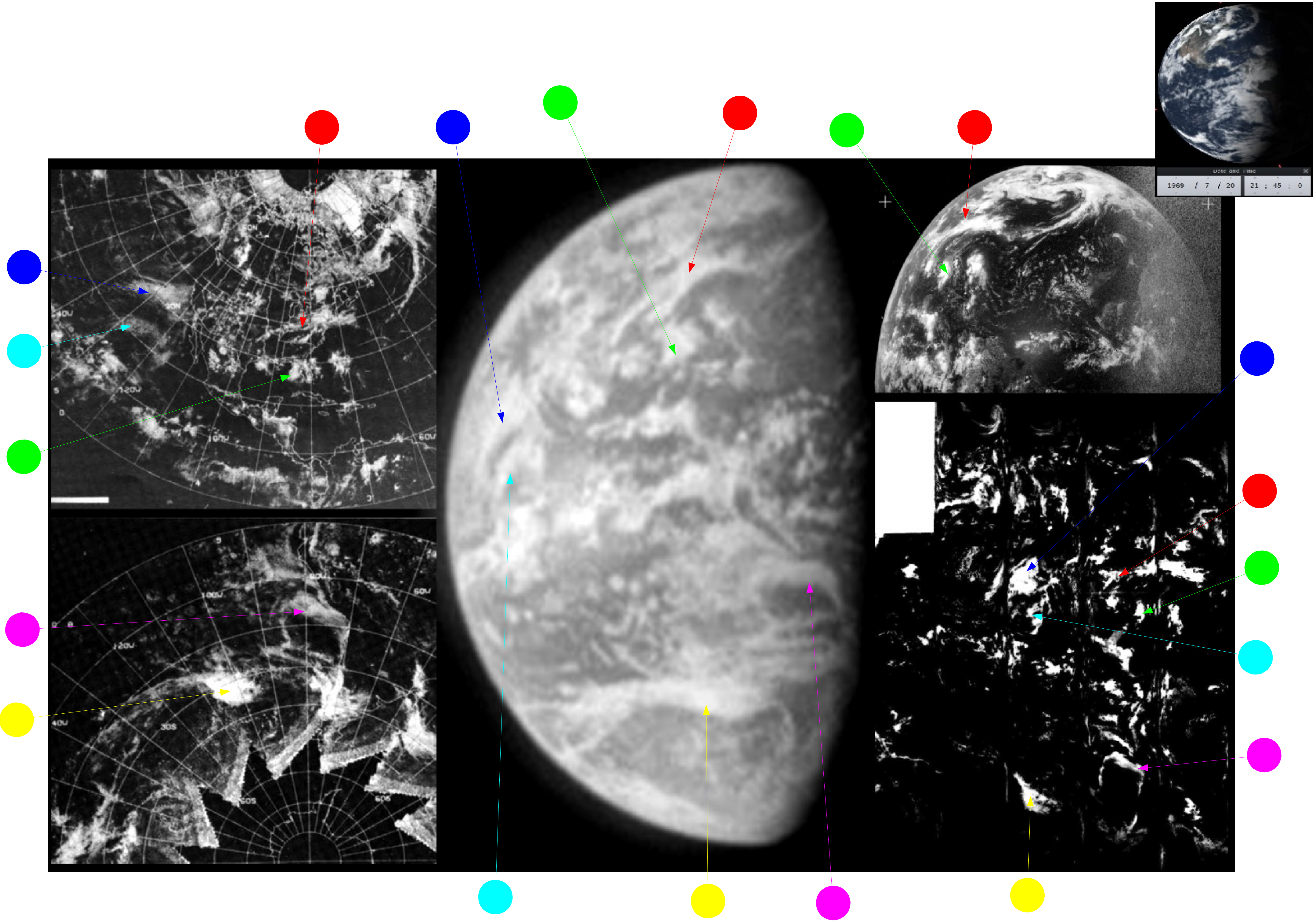


Figure 4.3.44: ESSA-9 (left), ATS-3 (top right) and NIMBUS-3 (bottom right) images compared with AS11-41-6023 and Stellarium depiction of time at terminator

western coasts of south America was commenced at 20:02 (track 4, orbit 1805), while NIMBUS orbit 1306, covering the same coast, was commenced at 16:39.

The Apollo 11 transcripts show that at 103:24 MET signal was lost from the CSM as it disappeared from view, and 41 minutes later at 104:15 (or 21:47) on orbit 15, Mike Collins says (twice):

"Ready to copy"

as he emerged from behind the moon and has acquired a signal from capcom again. Given that an Earthrise photo is taken at AOS, it seems reasonable to suggest that the black & white photograph was taken just before Collins makes his 'ready to copy' radio call. Stellarium's terminator set at 21:45 shows that the Earth in the Apollo image is an exact match for what should be there.

At around the same time as this image was being taken, the decision was made to start the EVA procedure, and a few hours later at 02:56 on the 21st of July, 109 hours and 24 minutes after launch, Neil Armstrong sets foot on the moon.

While Aldrin & Armstrong worked on the lunar surface, Collins continued his orbits around the Moon and captured another Earthrise image on magazine 44 in AS11-44-6604 (figure 4.3.45). This picture occurs immediately after photos of the LM after separation, and later on in the magazine there are images of the LM ascent stage returning, so this image must have been taken before 17:54 on the 21st. The photograph is compared with ESSA & NIMBUS satellite images in figure 4.3.46.

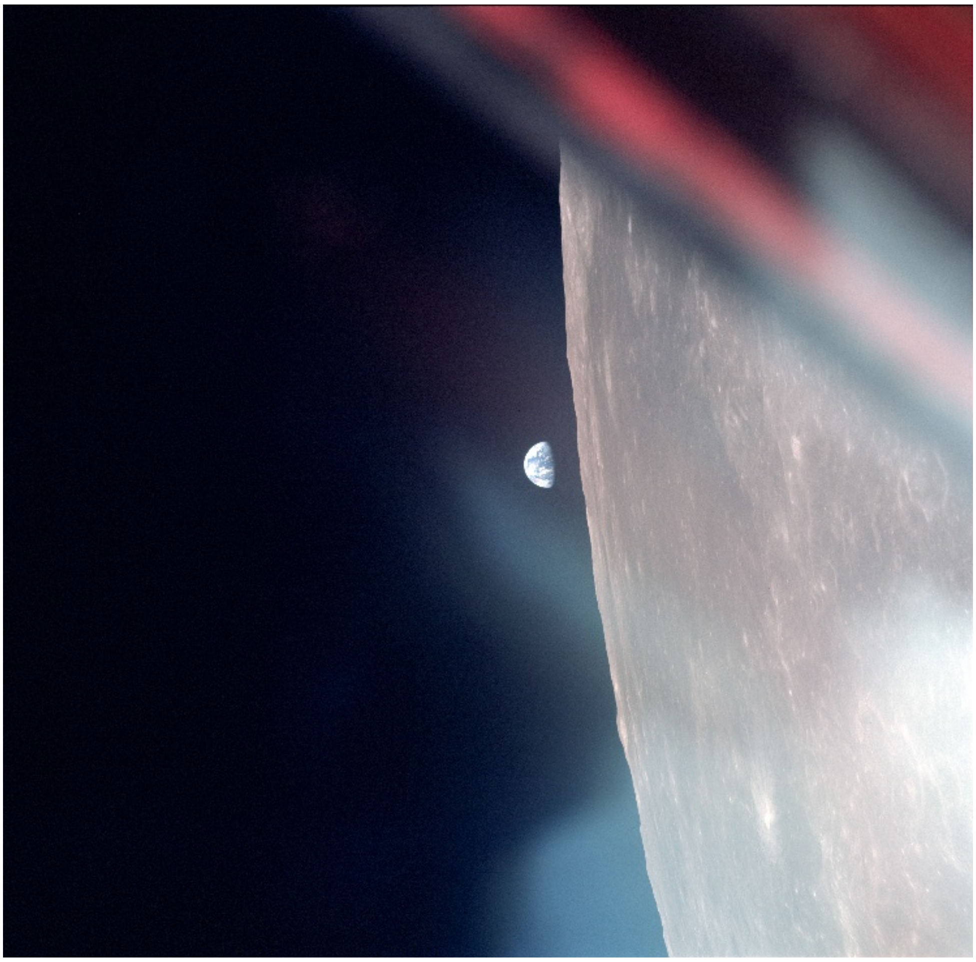


Figure 4.3.45: AS11-44-6604. High resolution version available here:: AIA

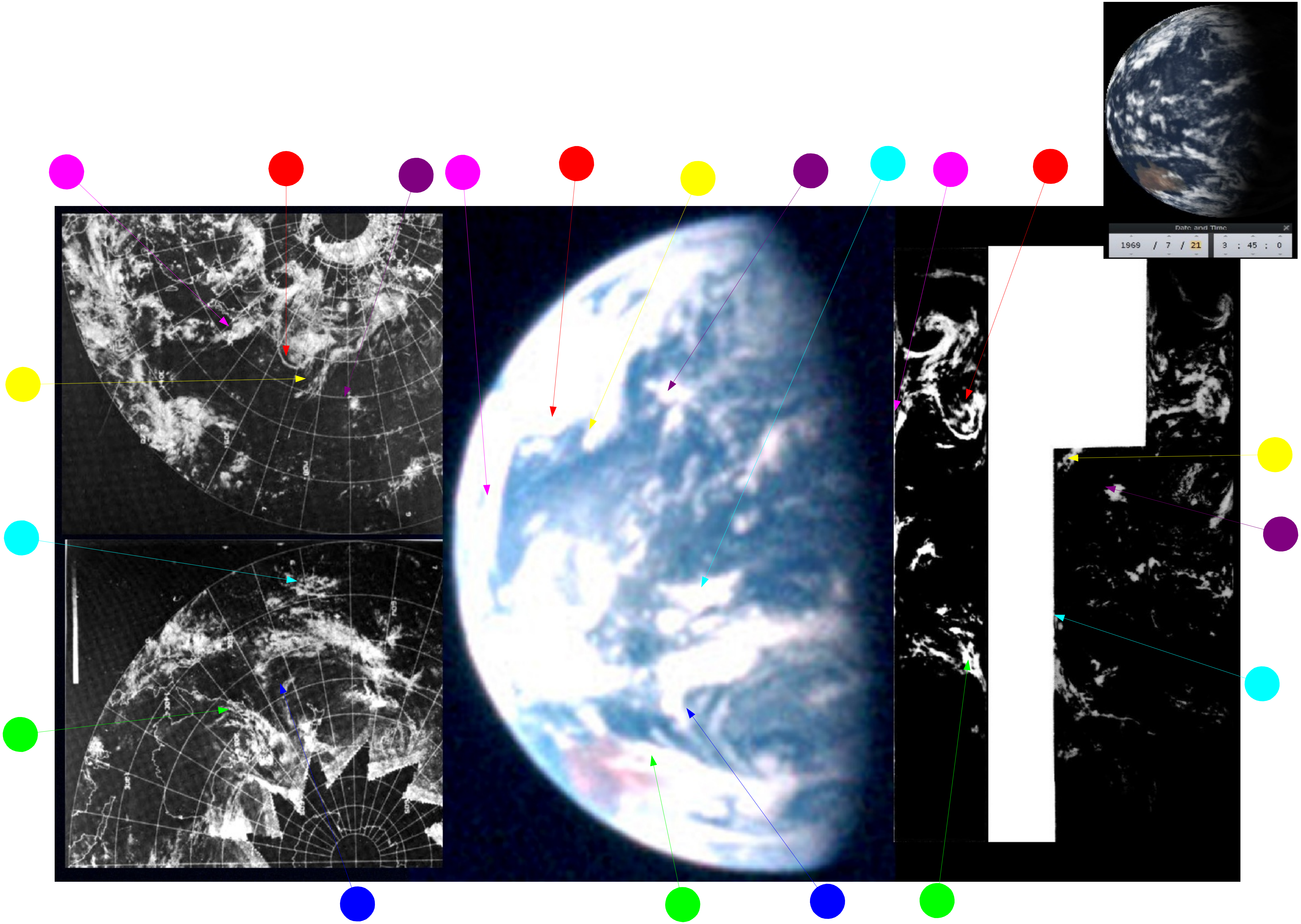


Figure 4.3.46: ESSA-9 (left) & NIMBUS-3 (right) images compared with AS11-44-6604 and Stellarium estimate of time at terminator

According to the mission transcript, at 4 days 14 hours and 7 minutes (or 110 hours 7 minutes or 03:39 GMT) & 20 minutes after the start of orbit 18 capcom contacts the CSM to confirm AOS, which Collins acknowledges some 30 seconds later (it maybe that his message to Houston is not a confirmation of AOS, but querying Houston as to whether he had it.

Stellarium has been set at 03:45 on the 21st, and there is a clear match with the photograph in terms of Australia's position. As with previous photographs where Australasia is featured, the ESSA image featured is not from the 21st but from the 20th, and the NIMBUS image is a composite of strips from the 20th and 21st, The timings will be examined shortly. As the NIMBUS image quality is poor, where it is not possible to identify clearly a comparable cloud pattern it has been omitted.

As far as the weather patterns that are visible are concerned, the system picked out by the green arrow in figure 4.3.39 has moved from a position south of Victoria state to one covering New South Wales coastline. The clouds over Japan and off the coast of east & south east Asia have persisted, but have changed configuration from figure 4.3.39.

For the timings are concerned, ESSA 9's track 8 is the nearest one to pass the east coast of Australia. The ESSA composite dated July 20th shows this track (orbit 1809) as commencing at 04:03 on the 21st. As mentioned previously, the two passes available from NIMBUS covering the area shown in the Apollo image are picked from orbits 1309 and 1310. The former is shown on the composite image dated the 20th, the latter on the composite dated the 21st, these were commenced at 22:02 on the 20th and at 23:50 on the 20th respectively, several hours before the start of the EVA and the Apollo image.

Meanwhile on the surface, Armstrong and Aldrin are collecting samples and installing a variety of scientific equipment. They take many photographs, three of which show the Earth (two of these are the same scene taken twice). The first of these images to be analysed here is AS11-40-5924 (figure 4.3.47), which is done in figure 4.3.48.

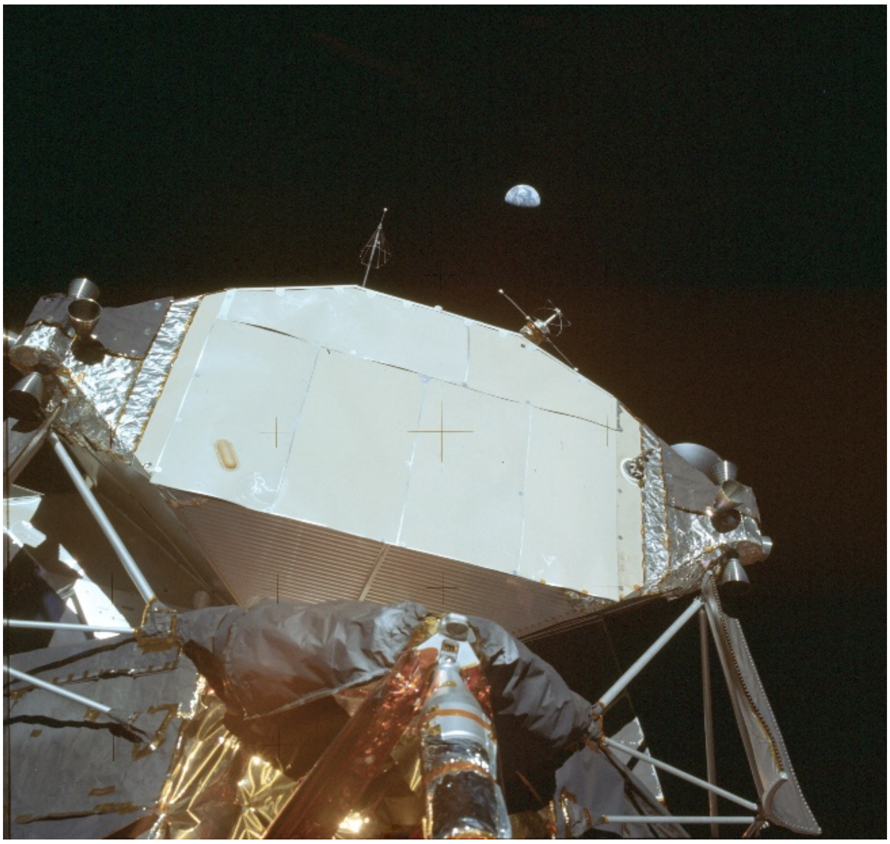


Figure 4.3.47: AS11-40-5924. High resolution source: [AIA](AIA) 50Mb TIFF version here: Archive

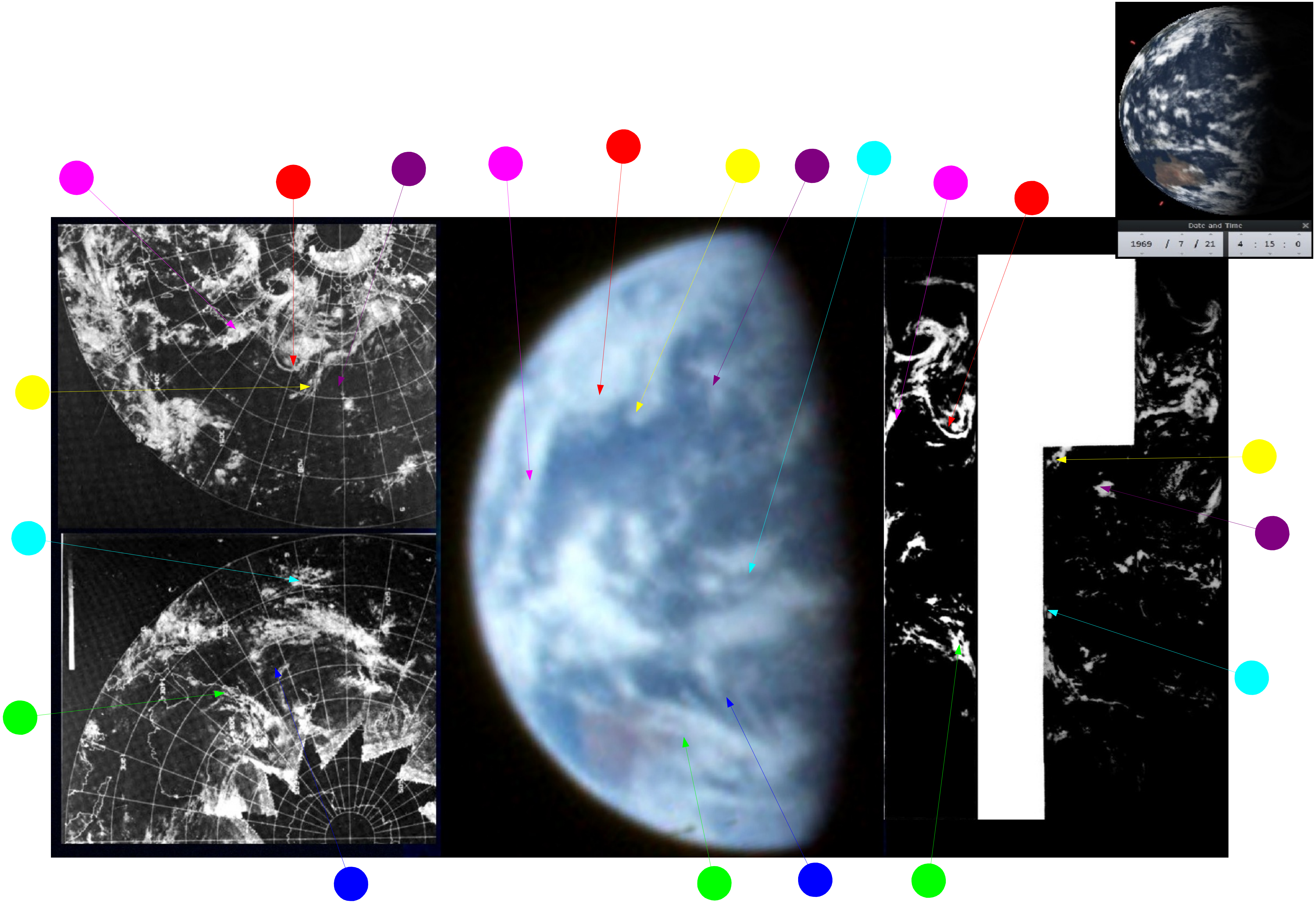
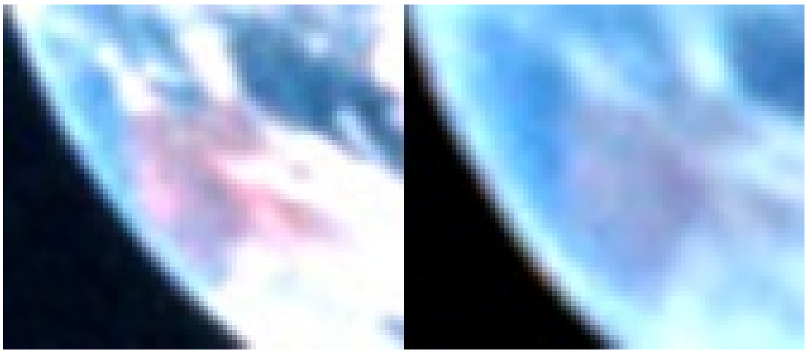


Figure 4.3.48: ESSA-9 (left) and NIMBUS-5 (right) images compared with AS11-40-5924 and Stellarium estimate of time at terminator

The weather patterns in shown in the image taken from the surface are a clear match with the ones taken from the orbiting CSM, although there is more detail observable in the clouds, particularly over Australia, and satellite timings will be the same. The first check to make is whether it is the same view of Earth or not, and figure 4.3.49 compares Australia's position in AS11-44-6604 and AS11-40-5924.

Figure 4.3.49: Comparison of Australia's position in AS11-44-6604 and AS11-40-5924



Australia has evidently moved between the two images, and this movement is consistent with the suggested half an hour time gap between the time of AOS in Collins' orbital image and the Stellarium estimate of time in the ground based picture.

At this point in the mission the timeline and mission transcript shows Aldrin engaged in photographing the LM landing gear, and AS11-40-5924 occurs between a series of images of the LM structure. It seems entirely reasonable that while moving around the base of the LM to capture the effects of the landing on the structure Buzz should look up and see the perfect photographic opportunity.

The next photograph of Earth is AS11-37-5506, which is shown below in figure 4.3.50, and analysed overleaf in figure 4.3.51.

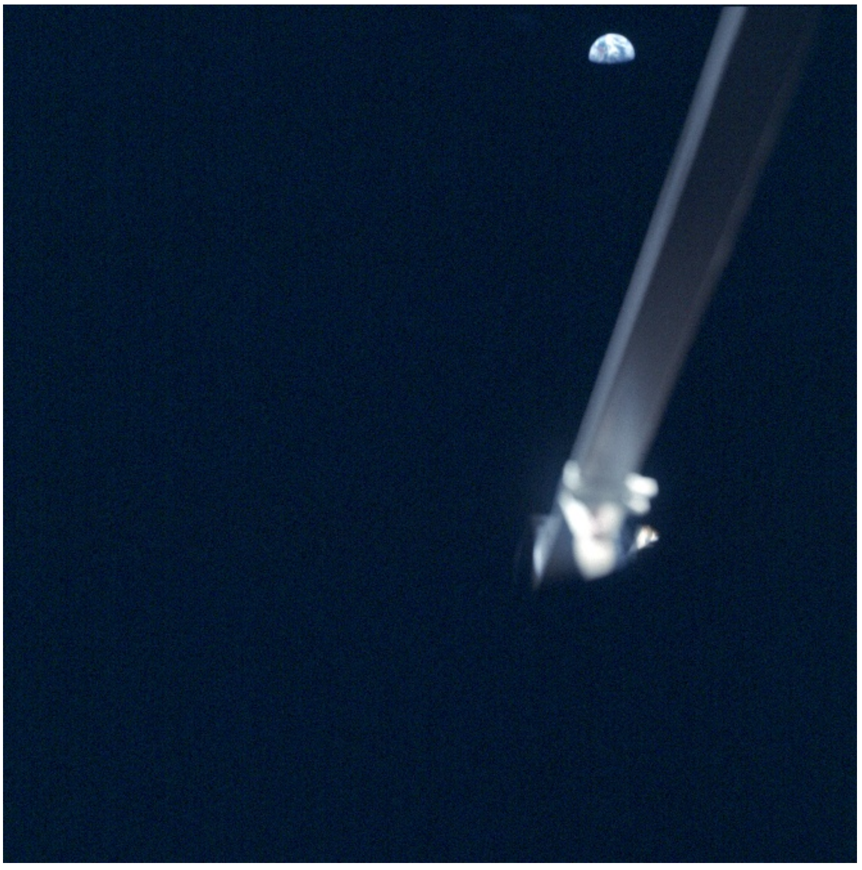
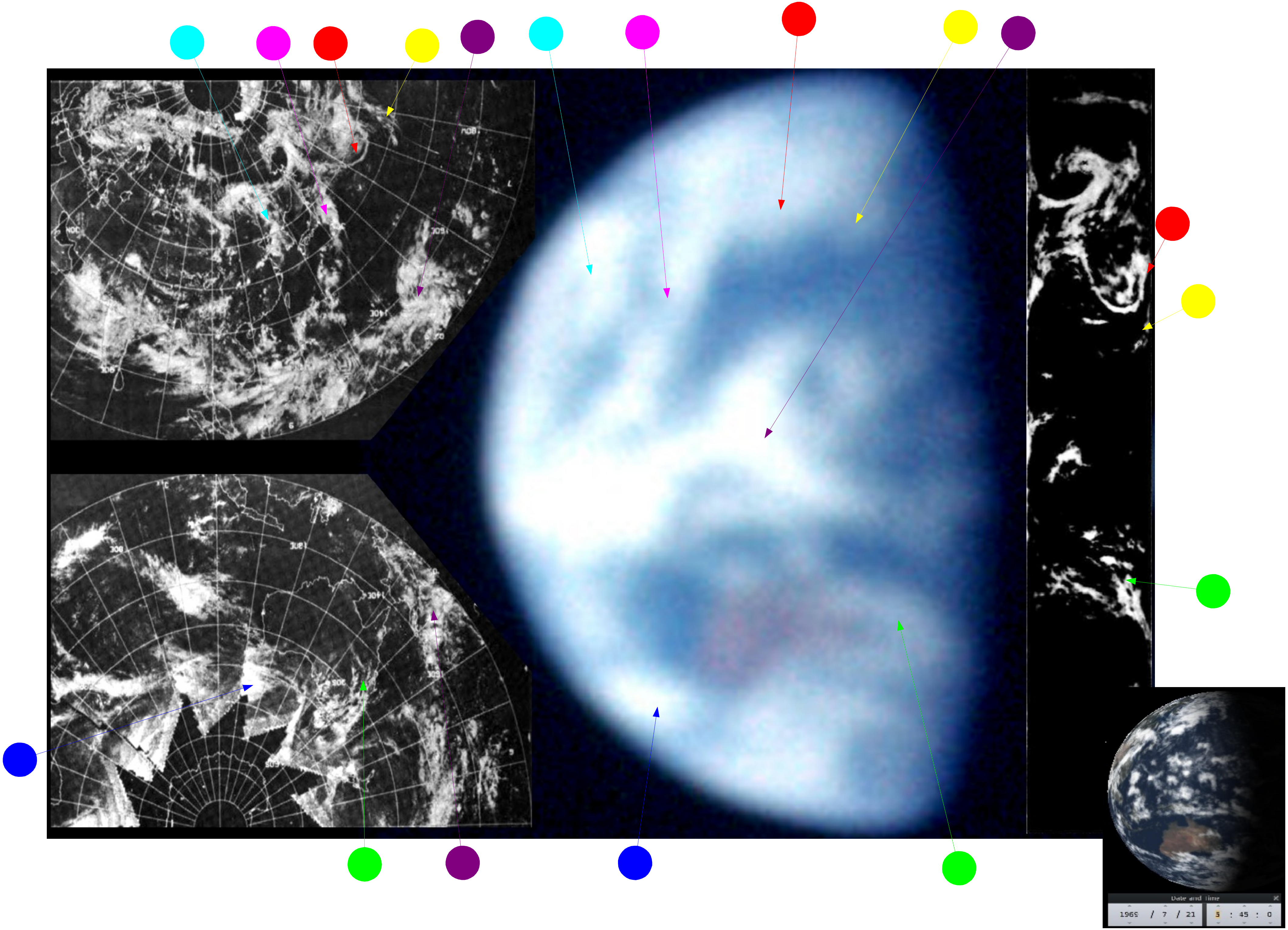


Figure 4.3.51: AS11-37-5506. High quality source here: AIA



Date and Time
1969 / 7 / 21
5 : 45 : 0

This photograph is the only successful attempt of several made to take a picture of the Earth from inside the LM. As the flag and astronaut footprints are visible in the images preceding and following this one, it is reasonable to assume that the crew are back inside the LM after their EVA, so this photograph must have been taken sometime after 05:11, when the LM hatch was closed but before returning to orbit.

Despite the lower quality, brought on both by Armstrong photographing the Earth through the LM window and mis-focussing the camera, it is still possible to identify features common to the ESSA image, and that were also visible in figure 4.3.48, and only the blue and cyan arrows differ

The weather system that started off south over Victoria state before moving east of New South Wales appears to have progressed further eastwards, although it is difficult to tell how far. What is evident is that Australia has moved further eastwards with the Earth's rotation, consistent with being taken 90 minutes later than the previous image, and also fitting in with the timeline of the mission. By 05:45, the time suggested by Stellarium's terminator, the crew had been back inside the LM for around 30 minutes, but 90 minutes later the Hasselblads were jettisoned on the lunar surface to save weight. No more images could have been taken from the LM after that time.

The ESSA orbit at the terminator corresponds to track 8, or orbit 1809, and was commenced at 04:03, so the satellite's orbital progress is matching Earth's rotation as seen from the Moon..

The next usable image of Earth comes from a fantastic sequence of Earthrise images taken as the LM ascended towards the CSM. The Apollo Image Atlas only has poor quality images of most of this event, but the ALSJ has better ones. There is also a large TIF image of AS11-44-6642, available from this site: archive.org. The ALSJ high quality version is shown in figure 4.3.53 and analysed in figure 4.3.54.

Figure 4.3.53: AS11-44-6642. High quality source here: ALSJ

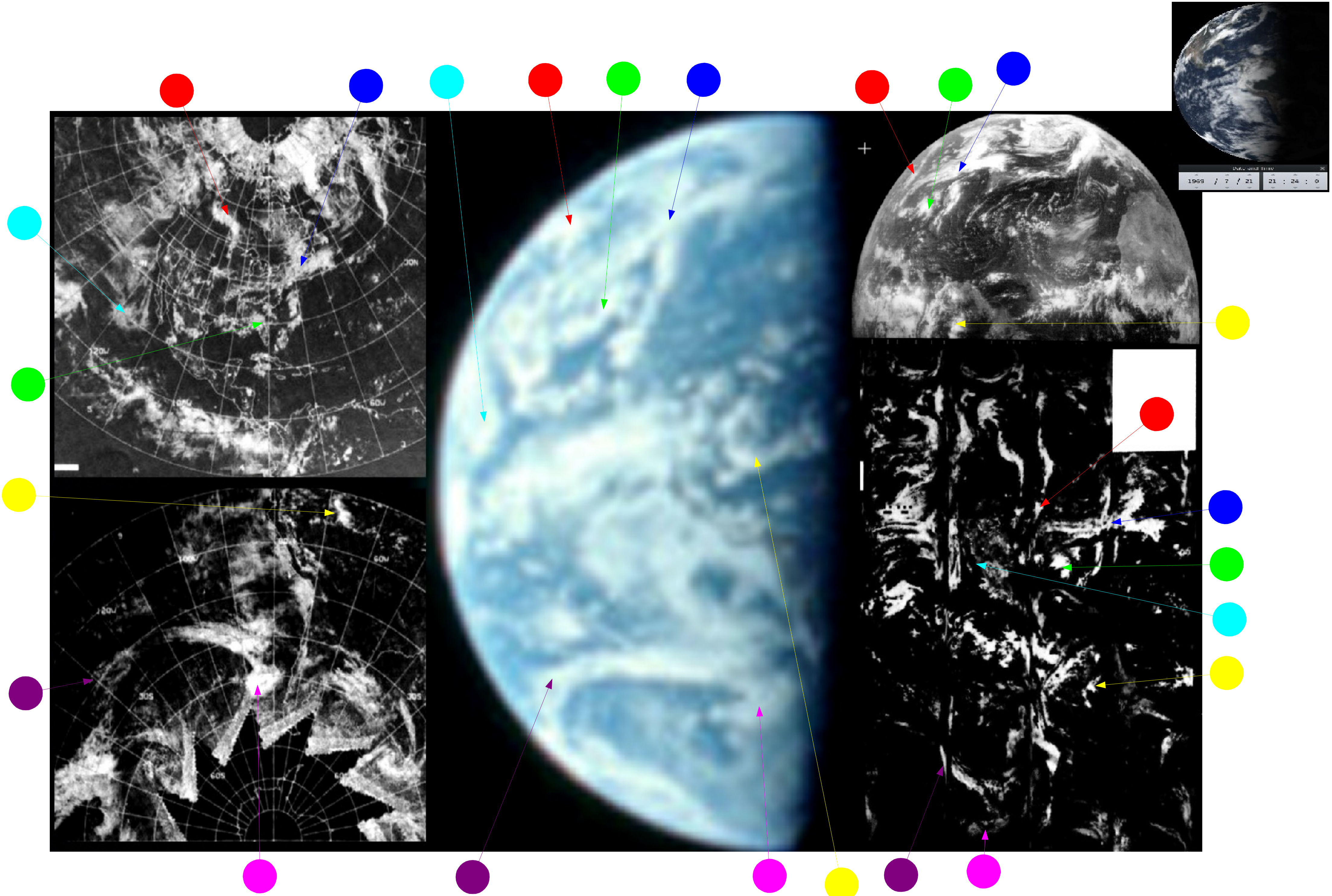


Figure 4.3.54: ESSA-9 (left), ATS03 (top right) and NIMBUS-3 (bottom right) images compared with AS11-6542 and Steallrium depiction of Earth at time of photograph

Dating this photograph within the official chronology is pretty straightforward. The transcript at the ALSJ has this:

> ***127:51:36 Collins (onboard):*** *[Garble] I got the Earth coming up already. It's fantastic!*

and records the photograph as taken immediately afterwards. LM AOS is reported shortly afterwards. The MET equates to 21:24, and this is the time set on the Stellarium view.

As far as satellite timings are concerned, the ATS-3 image is unambiguous, stating clearly that it was taken at 14:11, some 5 hours before the Apollo image. The closest ESSA orbit to the terminator in south America is track 3, orbit 1816, commencing at 18:00 on the image dated the 21st. The NIMBUS orbit for the same area is orbit 1319, which commenced at 15:54.

It is, as usual, obvious that the Apollo image matches the satellite images for the date in question, displaying distinct features not visible in the same configuration on preceding or subsequent days. Particularly obvious are the large 'X' shaped formation over the north Atlantic (marked by theblue arrow in the preceding figure), and the elongated 'C' shape to the south-west of Chile marked by the magenta and purple arrows. Fog banks are also visible off the coast of California and Chile that differ in shape and extent from other days in the mission.

On the subject of Chile, another satellite image is available covering that area for the 21st, as mentioned in the introduction to this section (shown in figure 4.3.55, along with part of AS11-44-6642. The image in question is from a summary report of the 5 years of uninterrupted meteorological observation by satellite. It is unclear which satellite is the source of the image (it could be one of several), but it is certainly much clearer than the ESSA or NIMBUS views used so far. The high degree of correspondence between the lines of latitude, longitude and various points of the storm system on this image and the ESSA image used in the previous analysis suggests this is a higher quality version of the ESSA 9 data . The image is clearly labelled the 21st, and is evidently a photograph of print-outs, as the cut allowing two piece of paper to be overlapped is obvious cutting across the storm and individual lines from the printer ribbon can also be made out.

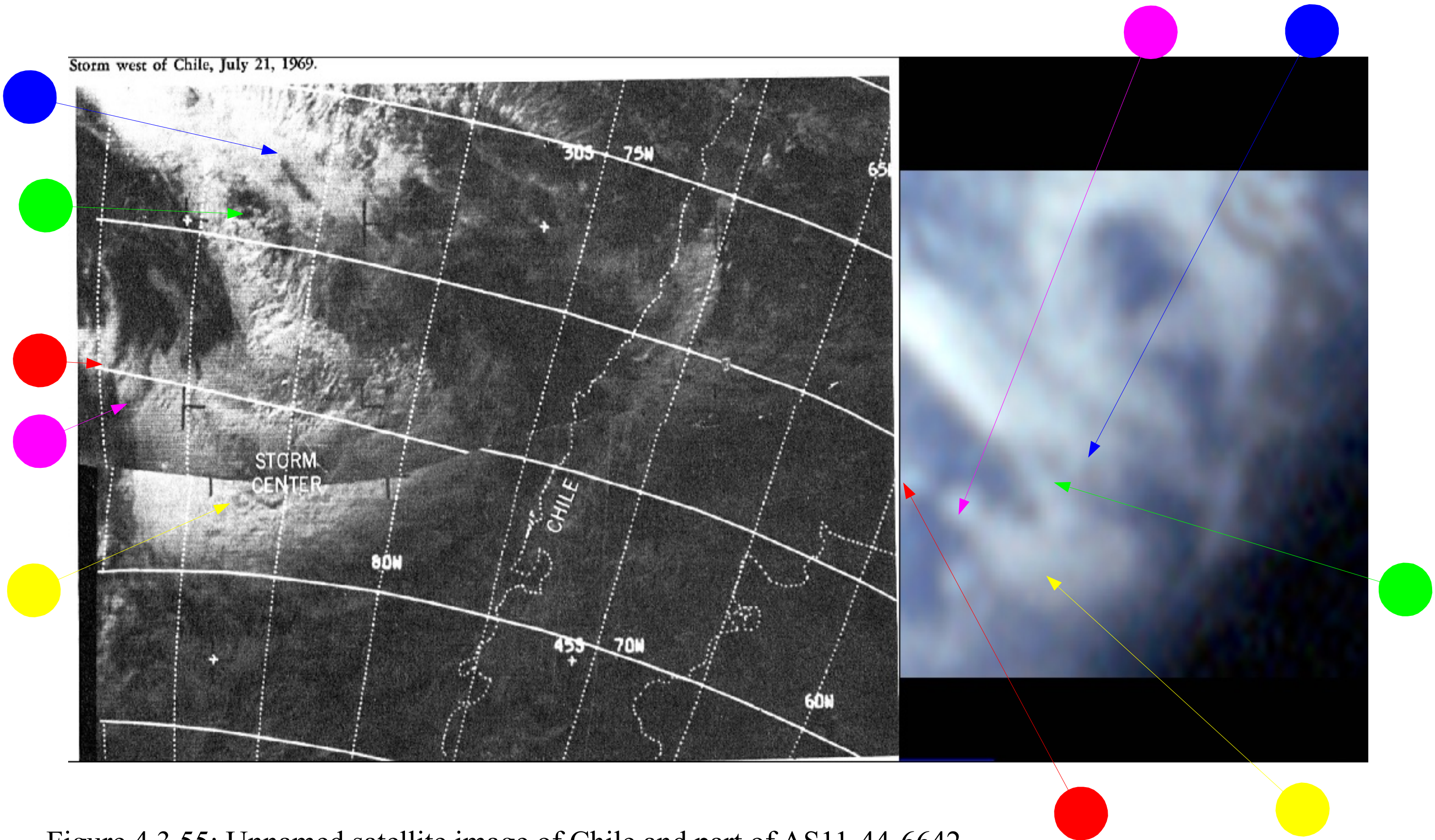


Figure 4.3.55: Unnamed satellite image of Chile and part of AS11-44-6642

Although this adds little to the overall analysis, it is again an illustration that very fine detail can be picked out on the Apollo images with an educated eye, and also that the sources of satellite information were never a secret. This particular image was used to pass on information about a storm in an area that was poorly covered by conventional forecasting, and part of the reason for the report in which the image was printed was to point out the usefulness of satellite data in meteorology, something that was still being evaluated.

While storms were gathering off Chile, the LM ascent module was heading towards the CSM to re-unite the three crew. After their rendez-vous, the re-joined craft continued to orbit the moon until the TEI burn at 04:55 on the 22nd, and during these last orbits a final series of Earthrise images was obtained. The curvature of the Earth in some of the images in this sequence suggests a point

One of the best of these photographs is AS11-44-6651, and a high resolution version is available here: ALSJ . Even without zooming into the image, Australia is visible, and this should already tell readers that it was taken in the early hours of the morning (GMT). As this image occurs after the stationkeeping photograph shown in the previous Apollo image analysed, a date of the 22nd is already a good starting point for the satellite images. It is shown below in figure 4.3.56 and analysed overleaf in figure 4.3.57.

As usual the satellite images tie up exactly with the Apollo image. The storm that started out over Australia's South Eastern corner has moved further eastwards and has been replaced by new weather systems, showing yet again that these are a series of images of a dynamic atmosphere, depicting a continuum of meteorological features and not a faked and static picture.

Figure 4.3.56: AS11-44-6651. High quality source: ALSJ

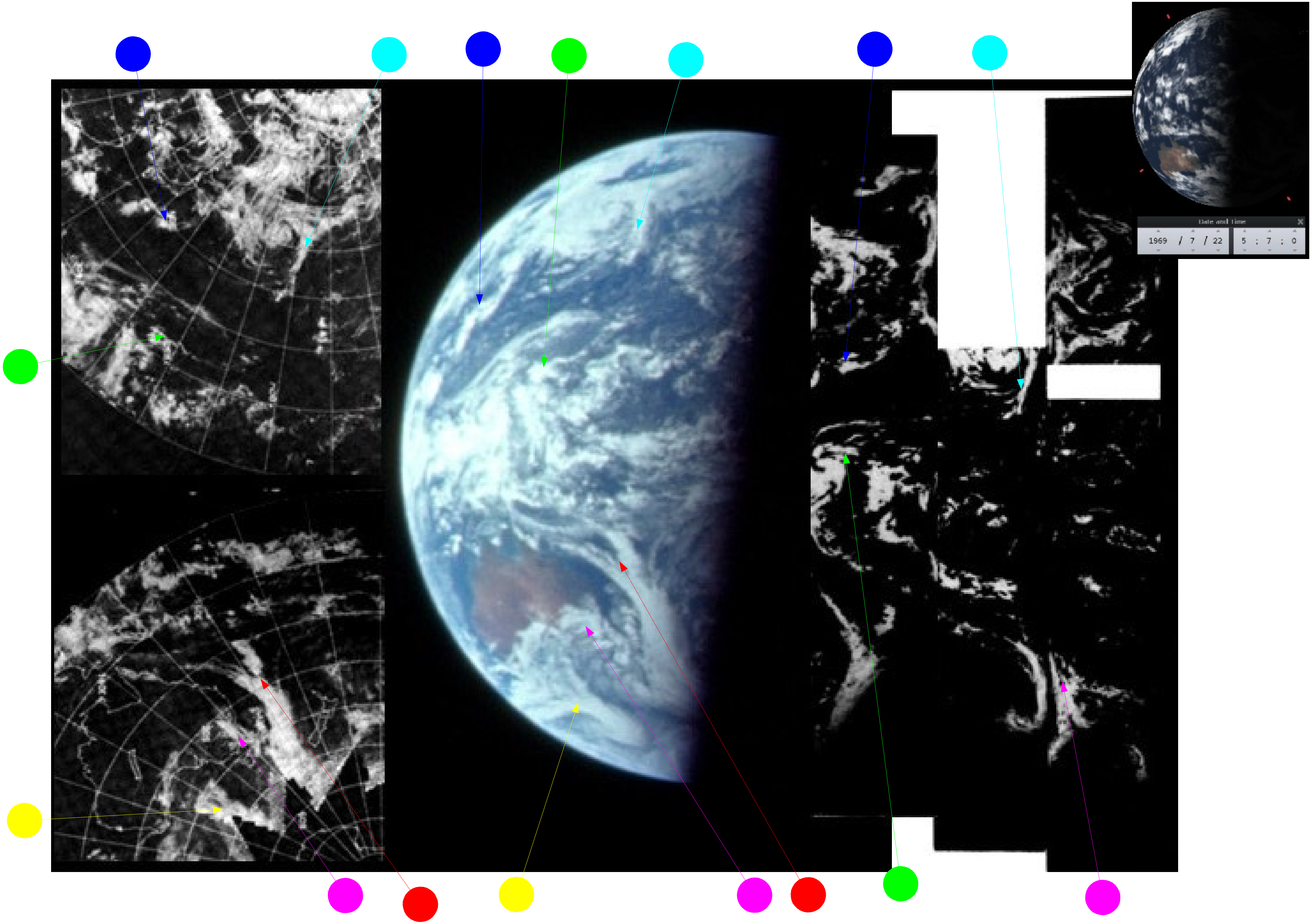


Figure 4.3.57: ESSA-9 (left) and NIMBUS-3 (right) images compared with AS11-44-6651 and Stellarium illustration of Earth at AOS after TEI

As far as timing is concerned, the ESSA pass over the terminator for the image dated the 21st is number 1820 (Track 7), which was started at 01:01 on the 22nd. The NIMBUS orbits used are actually the last two started on the 21st (1322-3) and the first started on the 22nd (1324). The first of these was started at 21:19 on the 21st and the last started at 00:54 on the 22nd .

According to the timeline information and the ALSJ, the TEI burn was performed at 04:55, or 135:23m MET, shortly after what would have been the start of orbit 19. Although before the burn the crew were concerned about the cameras getting in the way (as g forces would be generated by the engines, any free floating equipment is a potential hazard), after it had completed they were very keen to take more photographs, and there are many exchanged discussing what films are available and what should be photographed. We then have this conversation in the CM transcript:

05 15 34 11 CMP Yes, more than two. AOS.
05 15 34 34 LMP Yes, we sure as hell have.
05 15 34 38 CDR Get the burn status.
05 15 34 41 LMP Hey, I hope somebody's getting the picture of the earth coming up.
05 15 34 44 CMP ... Not quite pitched far enough. Well, maybe I can get it out - -
05 15 34 53 CDR I can get around to here.
05 15 34 54 CMP - - your window.
05 15 34 57 CDR Upside down; turn the camera upside down; then it'll look right.

At the time Aldrin was asking whether Earthrise was being photographed, the CM had increased its altitude to over 500 miles, which explains the increased curvature of the lunar surface, and it would seem that the photograph just analysed was the final Earthrise seen after the TEI burn. For this reason Stellarium has been set at the time of AOS, and the match between what should be there and what is there is obvious.

The next image chosen is AS11-38-5684, and is the first one taken on magazine 38 to feature the Earth after a series of images of a departing Moon. It is shown below in figure 4.3.58 and analysed overleaf in figure 4.3.59.

Figure 4.3.58: AS11-38-5684. High quality source: AIA

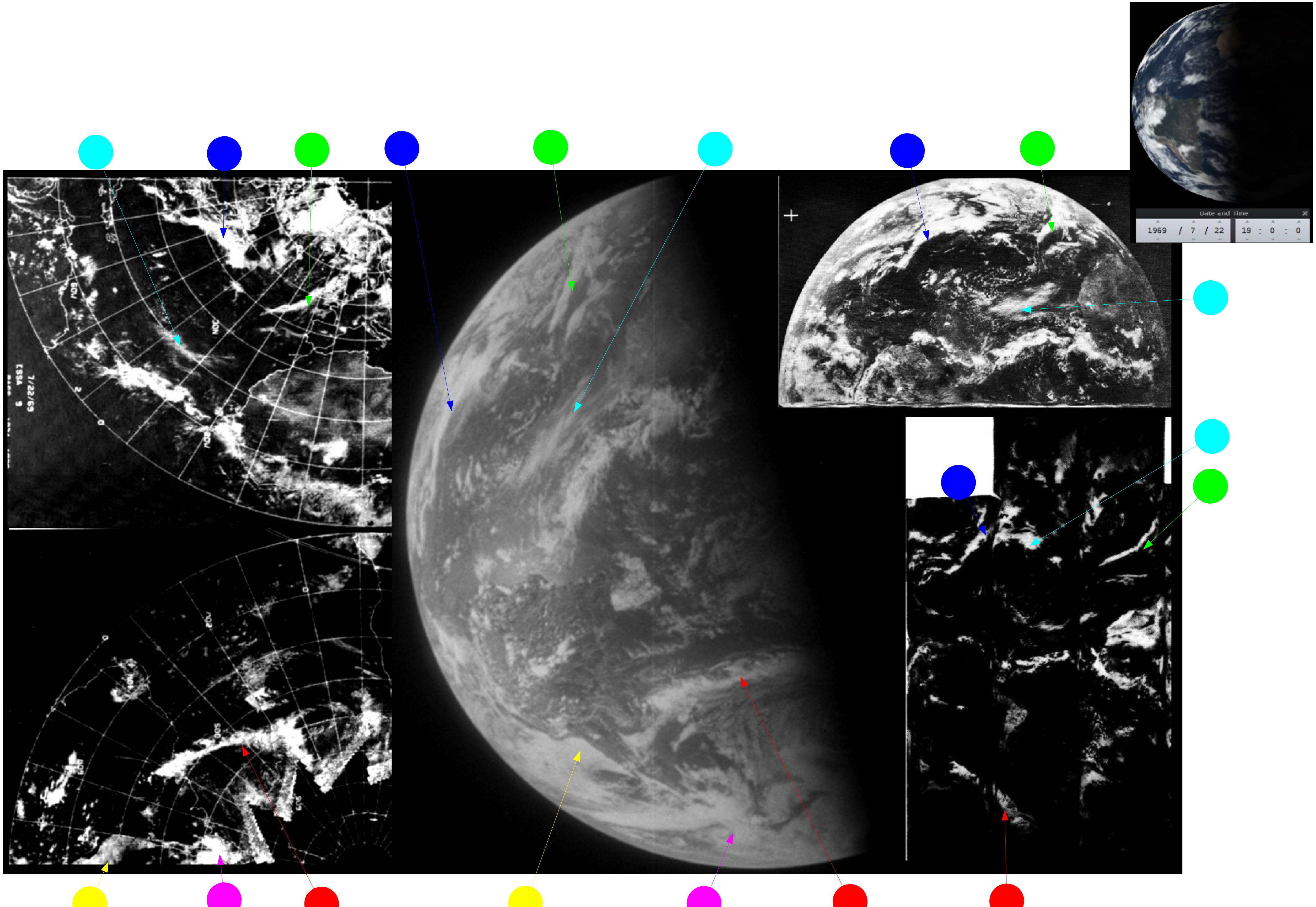


Figure 4.3.59: ESSA-9 (left), ATS-3 (top right) and NIMBUS-3 (bottom right) images compared with AS11-38-5684 and Stellarium estimate of time at terminator

On the now magnified Earth, the storm identified in figure 4.3.54 off southern Chile (magenta arrow) has moved onshore and there are still persistent fog banks off northern Chile (yellow arrow). When the ATS-3 image for the 22nd is compared with that of the 21st, the large 'X' shape of clouds over the western north Atlantic is still discernible (blue arrow), but has changed configuration slightly while progressing eastwards towards Europe. A large circular cloud just inland from the east African coast has moved further inland and changed shape (but is not visible on the Apollo image). The ATS-3 image was used as part of an analysis (referenced at the start of this section) analysing the development of Hurricane Anna later in July. The band of cloud stretching from South America to Africa is part of the inter-tropical convergence zone, and instability in this zone led to the hurricane.

The Stellarium time estimate puts the terminator at roughly 19:00 GMT. As far as satellite timings are concerned, the ATS-3 image is recorded as being taken at 15:18, a few hours before the Stellarium timing. ESSA's orbit over the terminator commenced at 15:08. The NIMBUS orbit over the same area is number 1330, which commenced at 11:38.

There is a very similar colour photograph on magazine 44, AS11-44-6669, shown below in full and with a close-up of Earth from it (figure 4.3.60). A small section of the photograph around the terminator is shown in figure 4.3.61.

Figure 4.3.60: AS11-44-669-69 (left, source: ALSJ) and in close up (right)

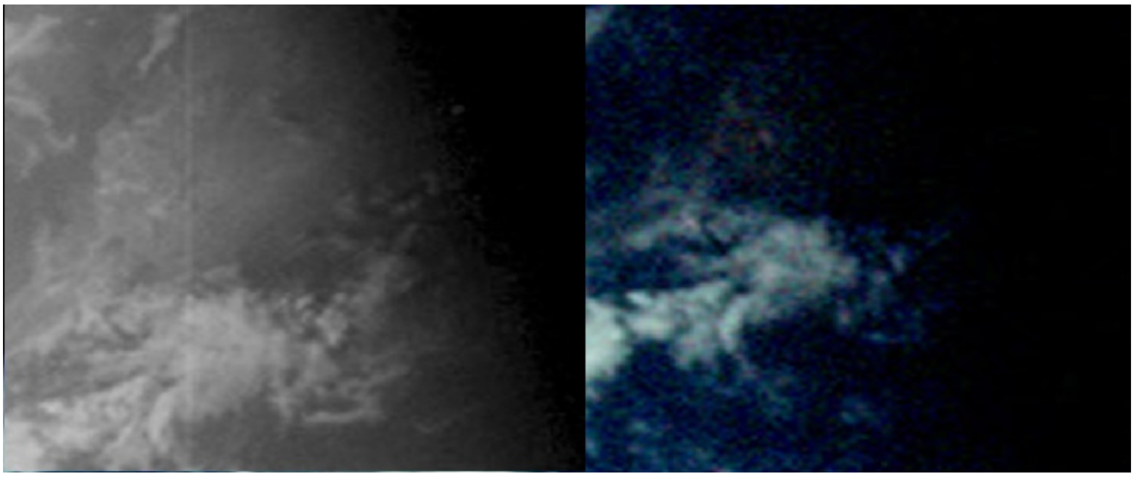


Figure 4.3.61: Section of West Africa around the terminator from AS11-38-5684 (left) and AS11-44-6669 (right)

Although seemingly the same view of Earth as the black and white image from magazine 38, the colour image shows a clear movement along the terminator consistent without about 15-30 minutes' worth of rotation, as much less of Saharan west Africa is now visible in the colour photograph.

The next image from the 22nd is again one that is duplicated in magazines 38 and 44, although on this occasion there is very little difference between the two, and therefore they must have been taken very close together. On this occasion, the colour image (AS11-44-6670) will be used as the one for satellite comparison, and this is shown below in figure 4.3.62. It is analysed overleaf in figure 4.3.64.

Figure 4.3.63 below shows the original and zoomed versions of the black and white photograph AS11-38-5687.

Figure 4.3.62: AS11-44-6670. High quality source: ALSJ

Figure 4.3.63: AS11-38-5687 (left, source: AIA) and zoomed & cropped (right)

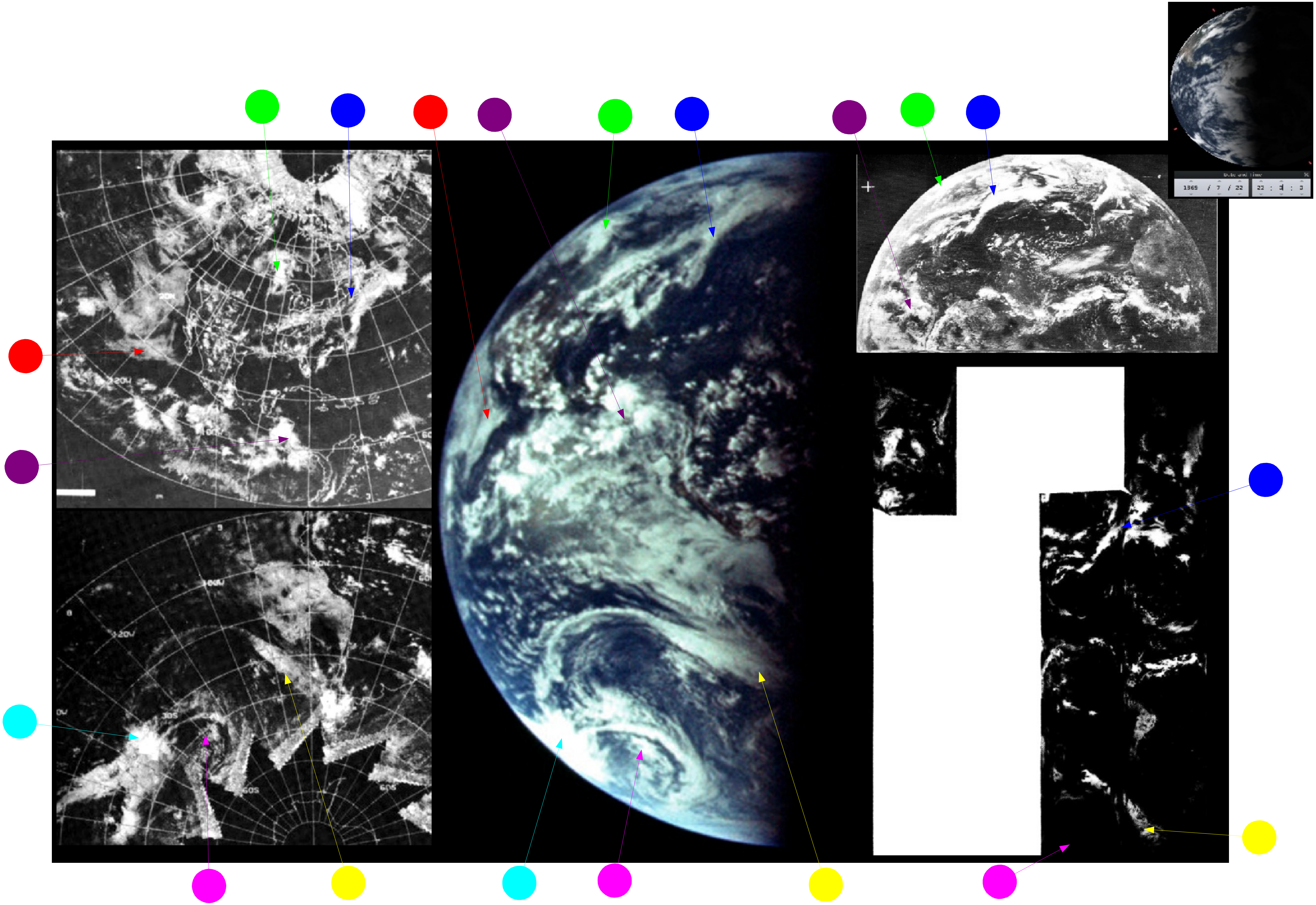


Figure 4.3.64: ESSA-9 (left), ATS-3 (top right) and NIMBUS-3 (bottom right) images compared with AS11-44-6670 and Stellarium estimate of time at terminator

The 'X' shape (blue arrow) is much more visible now, and is evidently not in the same configuration as the 'X' shown on the 21st. The storm systems off south America are coming into view, and these are also in a different configuration to those shown on previous days.

Stellarium estimates a time of around 22:00 for the photographs, and this compares with an estimated start time for ESSA's terminator orbit (track 3, pass number 1829) of 18:09. The NIMBUS track for the terminator is orbit 1332, which commenced at 15:12.

Having suggested that the two photographs were taken at the same time, it's worth double checking that they aren't actually just the same photograph. Figure 4.3.65 shows a comparison of the two images at the terminator region over Chile.

The suggestion here is that the colour image was taken marginally before the black and white image, as the large band of cloud running left to right across the centre of the images appears closer to the terminator in the black and white version, and there are similar differences elsewhere on the photographs.

They could, however, just be reflections of different image quality, but what does emerge is that there are enough subtle differences to show that they are not identical images rendered black and white through some sort of image processing. It is likely that the colour image was taken, and the difference in the two around the terminator represents the time difference involved in setting down one camera, picking up the other, checking the settings and taking the photograph.

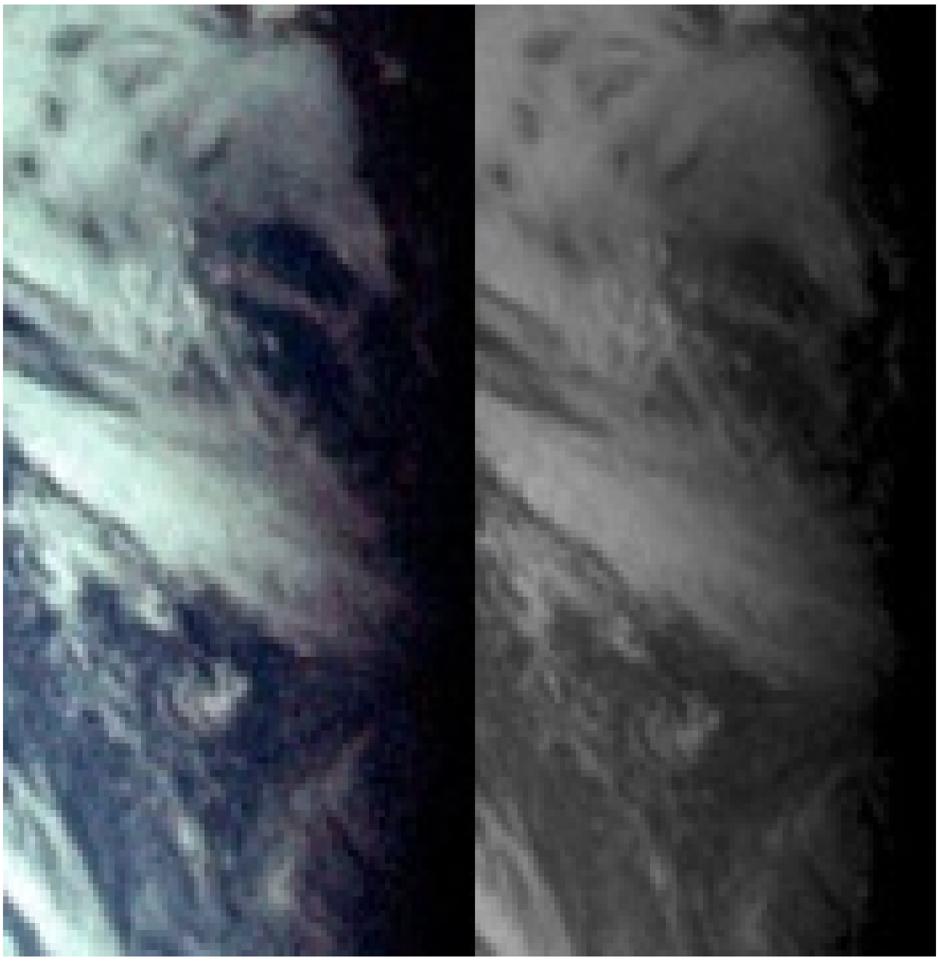


Figure 4.3.65: AS11-44-6670 (left) compared with AS11-38-5687 (right).

July 22nd also presents history with an interesting diversion involving the role of satellite images in the Apollo 11 landing.

In 2004, the Naval Postgraduate School, amongst others, published this article: Saving Apollo 11. It contains an interesting and now declassified story about how naval Captain Willard 'Sam' Houston Jr & Air Force Major Hank Brandli between them managed to divert the Apollo 11 landing site to avoid potential storms that could rip the CM parachutes to shreds, killing the astronauts on impact.. It is full of dramatic language, with tales of secret meetings and information from a covert satellite. This satellite contained (according to Hank Brandli) higher quality images than anywhere else (it is probably one of the DAPP/DMSP satellites described in Chapter 2).

Brandli's own website contains a version of the story here: Brandli link 1, in which it says:

"Brandl was the only person with access to this critical information – NASA's satellites weren't nearly this advanced – and he was forbidden to share what he knew."

In what Brandli claims was a career threatening move, he went to Houston, who then went straight to the top with classified top secret data and convinced Rear Admiral (Donald C.) Davis (the man in charge of the Apollo rescue operation) that Apollo 11 was doomed, who then persuaded NASA to alter the landing area "without proof" to avoid impending disaster. According to the articles, "violent thunderstorms" were found by reconnaissance craft on the 24th (the day of the landing), vindicating the decision and Brandli's meteorological skills. According to 'Saving Apollo 11', Houston was awarded a Navy Commendation Gold Medal for his work

Brandli's website also contains two other versions of the same events: Brandli link 2 Brandli link 3, which are copies of those published elsewhere. It is a dramatic and interesting story, but is it borne out by the evidence?

In October 1969, well before the 1995 declassification of the CORONA mission with which Brandli was involved, ESSA published one of its quarterly publications "ESSA World" (source: NOAA Rescue Archives). In it is an article covering ESSA's support of the Apollo 11 mission, starting with the weather forecasting for the launch period, then describing their monitoring of solar flares, before finally covering weather forecasting for the landing period. An earlier edition of the journal outlines the same role for Apollo 7, and evidently satellite meteorology was a major part of the mission.

The article describes the work of the Spaceflight Meteorology Group's staff at Suitland and Honolulu, whose job was to monitor incoming satellite images covering the target landing area, while other staff in Houston kept NASA informed of developments in the weather. On July 22nd, these meteorologists spotted a change in the weather on the satellite photos, and examination of successive images suggested relatively strong winds, 6 foot waves and the possibility of thunderstorms. The conditions were not too difficult for landing, but turbulence was a concern. To quote one of the meteorologists,

"On the basis of the Spaceflight Meteorology Group's forecasts, the end-of-mission point was shifted"

One of the key military contacts was a "Captain *William* Houston", commander of the Fleet Weather Central at Pearl Harbour, and it seems likely that this is the same Captain *Willard* 'Sam' Houston described in the other articles.

So, we appear to have something of a contradiction in the story. While Houston & Brandli weren't allowed to speak about their weather forecasting role in the Apollo mission, ESSA were freely discussing their own role, and seem more than convinced that they were responsible for re-routing the mission. One of the people involved in that decision was Captain Houston, and far from being *"without proof"*, Houston had access to rather a lot of it. Clearly, Brandli was not the "only person" with access to the information needed to save Apollo from some heavy showers. The article also features a picture of Armstrong & Aldrin with one of the chief meteorologists examining weather data from an earlier mission, so the crew would also be fully aware that this was going on.

ESSA world helpfully includes two satellite images from ATS-1 and ESSA-8 (remember that there were at least 2 other satellites also on patrol over the landing zone at that time), and these are of sufficiently good quality to be compared with an Apollo image. The articles covering Brandli & Houston's efforts also contain an image, with 'Screaming Eagles' (a piece of over dramatic hyperbole used to describe large thunderheads, but also the nickname for the 101st Airborne), and this is below as figure 4.3.66. This image is reproduced from the article cited earlier, but lower quality versions of it occur in many places on the internet.

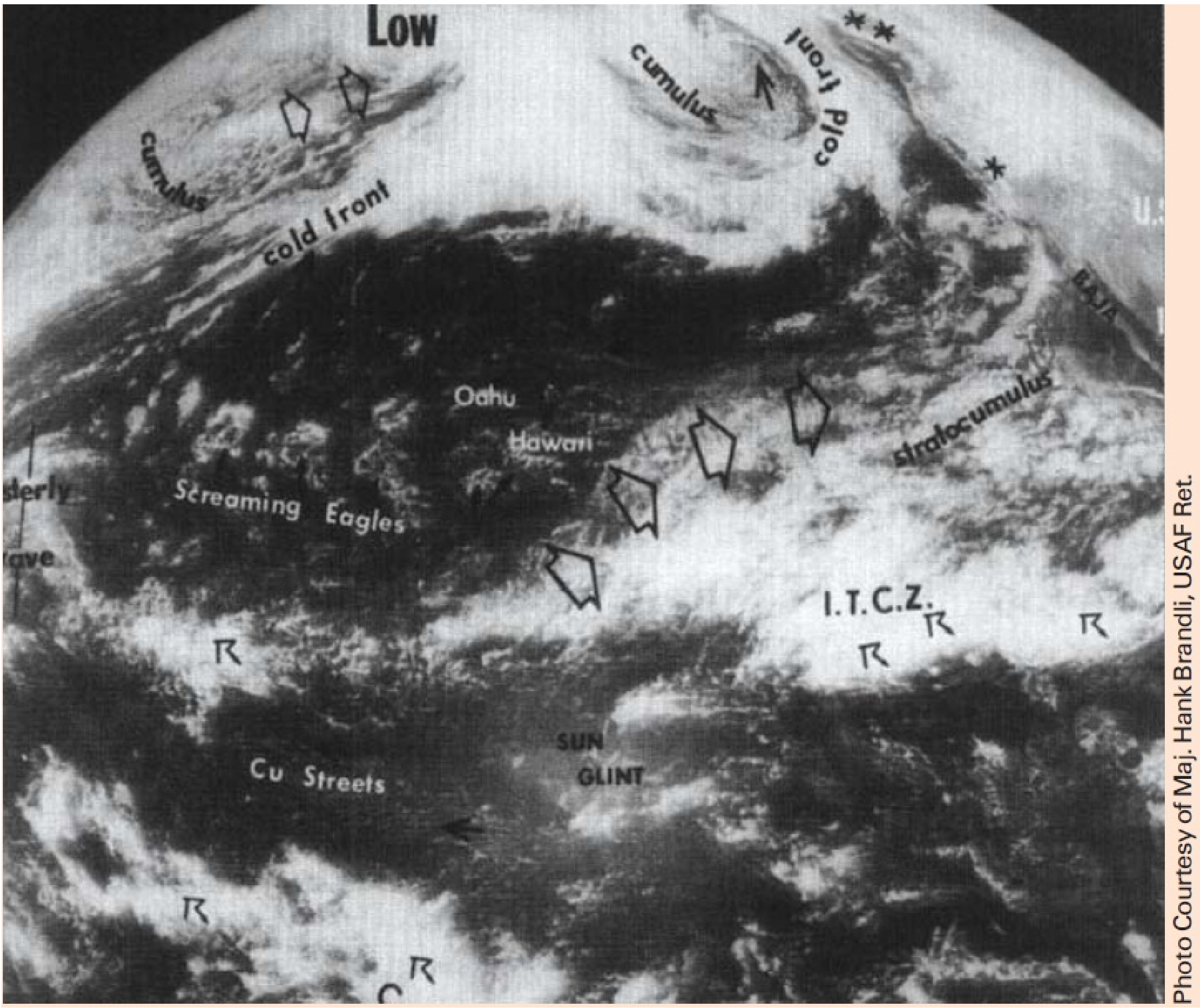


Figure 4.3.66: Photograph cited in this article Saving Apollo 11. No definite date is given, and the photograph may or may not be the one cited by Brandli as being responsible for his actions.

The Apollo image used is a black & white one, AS11-38-5693 and shows much of the area visible in the ATS-1 image. It is shown overleaf in figure 4.3.67, and analysed in figure 4.3.68.

An analysis of Apollo & satellite images are found in figure 4.3.38.

Figure 4.6.67: AS11-38-5693. High quality source: AIA

According to Stellarium, the Apollo image used is actually from the early hours of the 23rd. The ATS-1 image is labelled as being taken on the 22nd at 22:09 GMT. However, the Apollo image from the 23rd is closer in terms of time to this ATS image than one actually taken on the 23nd some 17 hours later. The ESSA-9 part relevant to the image is track 4, orbit 1830, which commenced at 20:04 on the 22rd. It is not clear when the ESSA-8 image was taken, other than on the 22nd. The landing zone is identified by the blue arrow. The NIMBUS-3 terminator track was commenced at 19:18 (orbit 1334).

As an aside, at 156:12 MET into the mission, or about 01:35 on the 23rd, shortly after a TV broadcast, Collins reports that:

> *"Roger. We were watching a few clouds in your area through the monocular along the Texas Gulf Coast this afternoon, and we also noticed there were clouds over Baja California, which is a little bit unusual."*

What is evident is that there were several satellites with the the information that NASA required to judge whether a landing site was safe or not. Reconnaissance flights on the day of the landing itself revealed "considerable showers" in the original landing zone, rather than the "violent thunderstorms" that the article claims they found.

It is entirely possible that Brandli's version of events is true, and he did find evidence of likely problems in the landing zone independently of ESSA in the military's DAPP satellite data, and went hell for leather to Captain Houston to report his findings. There is also a possibility that, to coin a phrase, the two characters here are 'over-egging the pudding', perhaps making their role seem a little more dramatic than it actually was. There are many too areas where the two stories contradict each other. Even the 'Screaming Eagles' image is difficult to reconcile with those taken by ESSA & ATS-1 on any of the days of the mission. There are areas that have broad similarities, but others where there are clear differences.

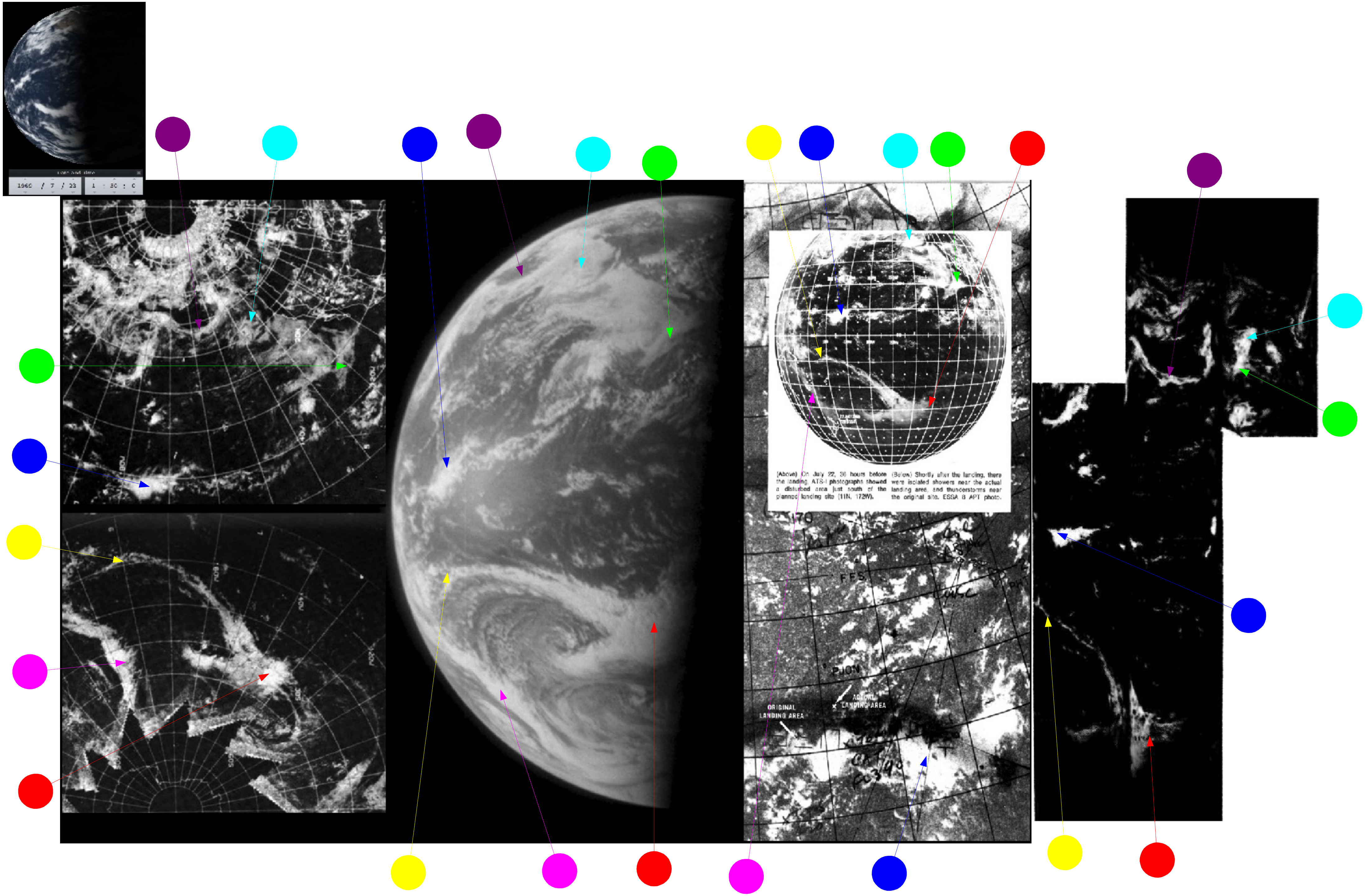


Figure 4.3.68: ESSA-9 (left), ATS-1 (right inset), NIMBUS-3 (far right) and ESSA-8 (right) images compared with AS11-38-5693 and Stellarium estimate of time at terminator

For example where are the cloud and fog banks off Baja California and California that have been a persistent feature over the mission? It is possible that cloud bands picked out by the yellow arrow in the southern Hemisphere and the blue arrow in the north are those either side of the image label "Cu Streets" in figure 4.3.66, but the type of cloud is completely different, and the 'screaming eagles' don't seem to be there at all.

Maybe Brandli's story is correct and ESSA's is just a cover, but it is a cover that has the benefit of using many well publicised 'free to air' satellites and a team of meteorologists actually based with NASA that was published months, rather than decades, after the landings.* It's unlikely that the image used in many articles showing the 'Screaming Eagles' is the one used by Brandli. Even the mosaic ESSA images are of comparable quality, and the zoomed in images from ESSA & NIMBUS used here are extremely clear and detailed. It's more likely that they had access to DMSP images, which were of a higher resolution, and were declassified in 1973, not the '90s.

Another weather system around on the 22nd, one that is mentioned on several occasions in the mission transcripts, is Tropical Storm Claudia. Claudia was a short lived storm that formed off Hawaii on July 21st and was dying away by July 23rd. It was reported in several journals, including the monthly weather review: MWR. It is also mentioned in the Mariner's weather log in September 1969 (MWL). Claudia was hidden by darkness in the photographs from the 21st and 22nd, but should be visible as a remnant on the 23rd in AS11-38-5693.

Figure 4.3.69 shows Claudia as seen from ESSA 8 on the 21st (from the MWR), ESSA-9 (MWL), and in the early hours of the 23rd from Apollo 11 (AS11-38-5693). Capcom kept Apollo 11 up to date about Claudia as a possible problem with the recovery mission, but it was downgraded late on the 23rd to a depression and ceased to be an issue. The Weather log identifies Claudia with an arrow, but this is indistinct on the reproduction and therefore a clearer arrow has been superimposed. Bearing in mind the preceding story concerning NASA's allegedly poor quality images, it is interesting to note the quality of the image published in the MWL.

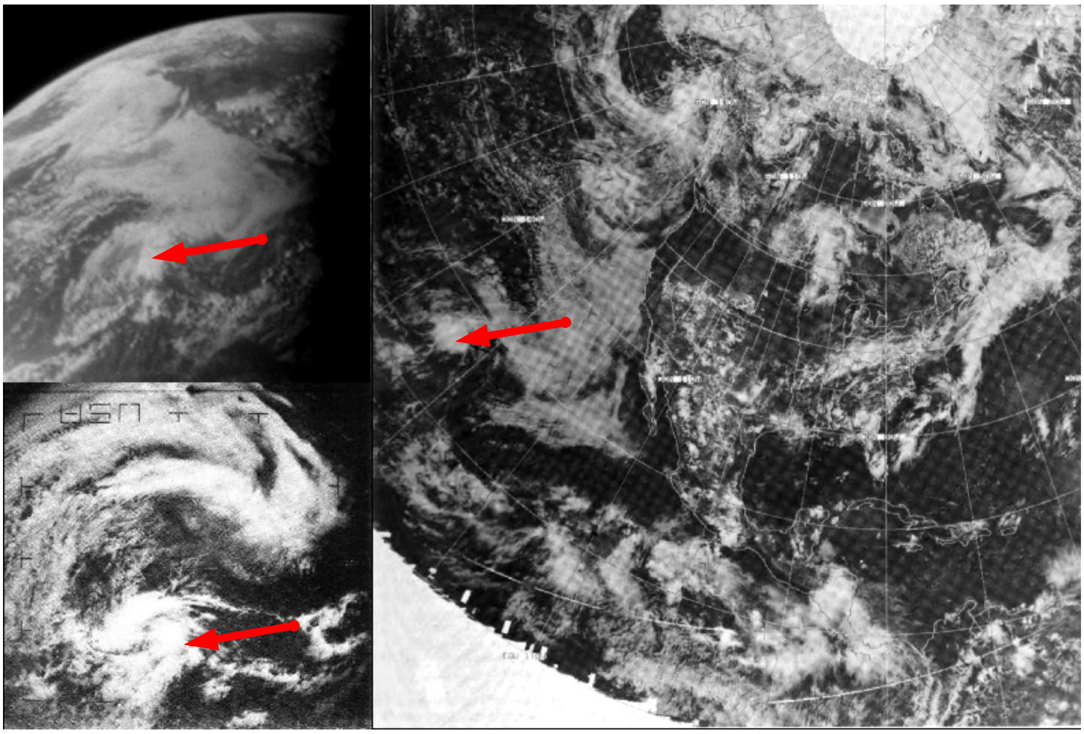


Figure 4.3.69: Tropical storm Claudia on the 21st (bottom left), 22nd (right) and the early hours of the 23rd (top left). Sources identified in the text.

* In fairness, Brandli has also written elsewhere on the Data Acquisition and Processing Program and its results, which used military polar orbital satellites, eg Air Power and MWR and is clearly knowledgeable on the subject.

For the next image we have a return to a view of Australia, this time from Magazine 38.

AS11-38-5697 occurs after a few images of a now very distant Moon, and is shown below in figure 4.3.70. It is analysed overleaf in figure 4.3.71.

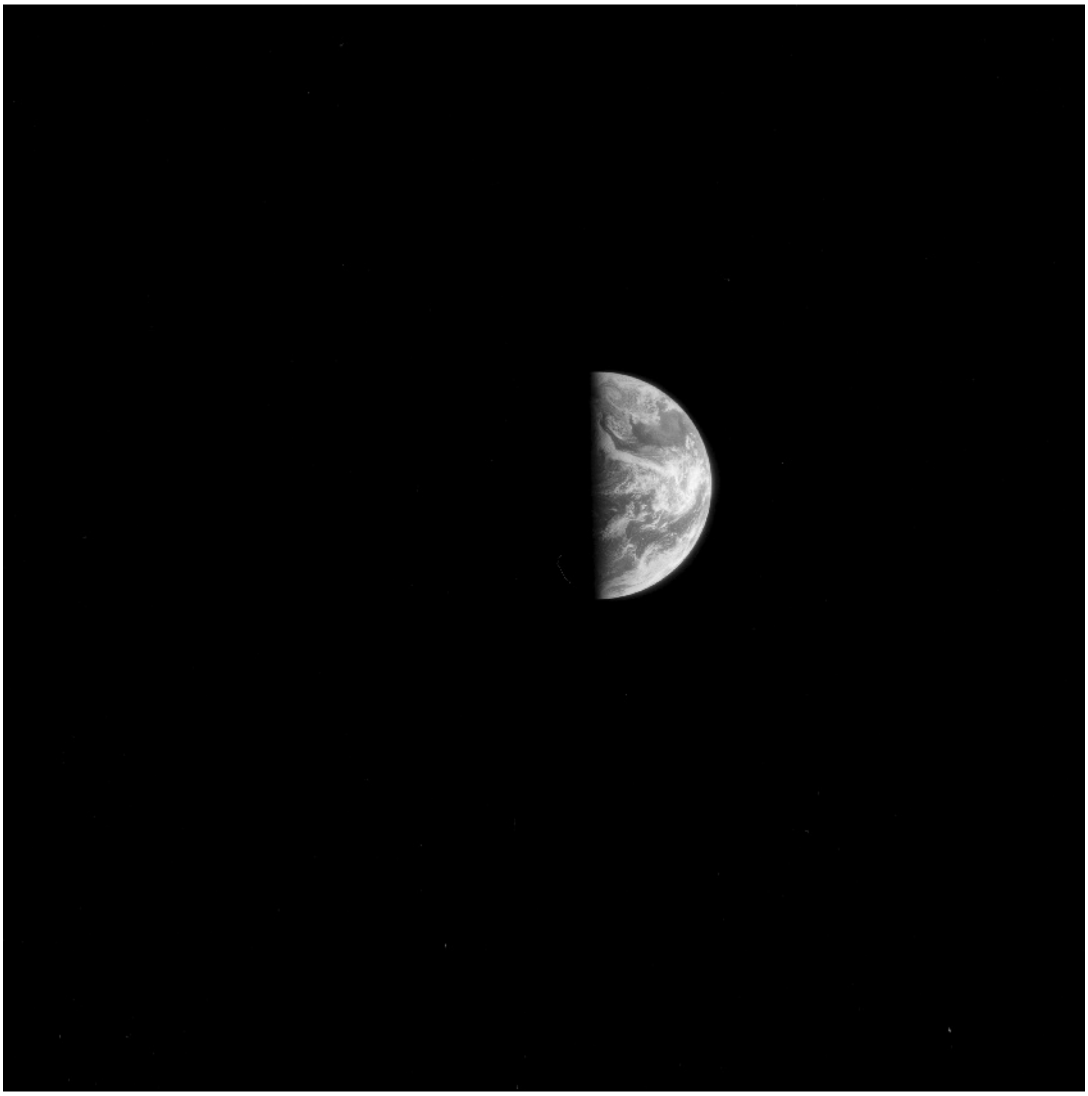


Figure 4.3.70: AS11-38-5697. High quality source: [AIA]

There are some features on this image that can also be found in the previous one,, but they are mostly unidentified to allow for new features to be picked out. The blue arrow in figure 4.3.69 shows the same arrow as the cyan arrow in this one. The purple and yellow arrows in figure 4.3.69 show systems that are still (just) visible in figure 4.3.71. It's interesting to note that the weather systems that were so prominent around Australia on the days around the landing have largely disintegrated and are much less coherent than before.

Stellarium estimates a time for this image as around 05:30 on the 22nd, derived largely from the position of Australia. ESSA's terminator orbit (track 6, pass 1832) commenced at 00:05 on the 23rd. The NIMBUS terminator pass (or at least the first one with any data) is orbit 1338, which commenced at 01:57 on the 23rd.

The next set of images of Earth consist of another pair taken with different cameras, one from magazine 38 and one from the colour magazine 44.

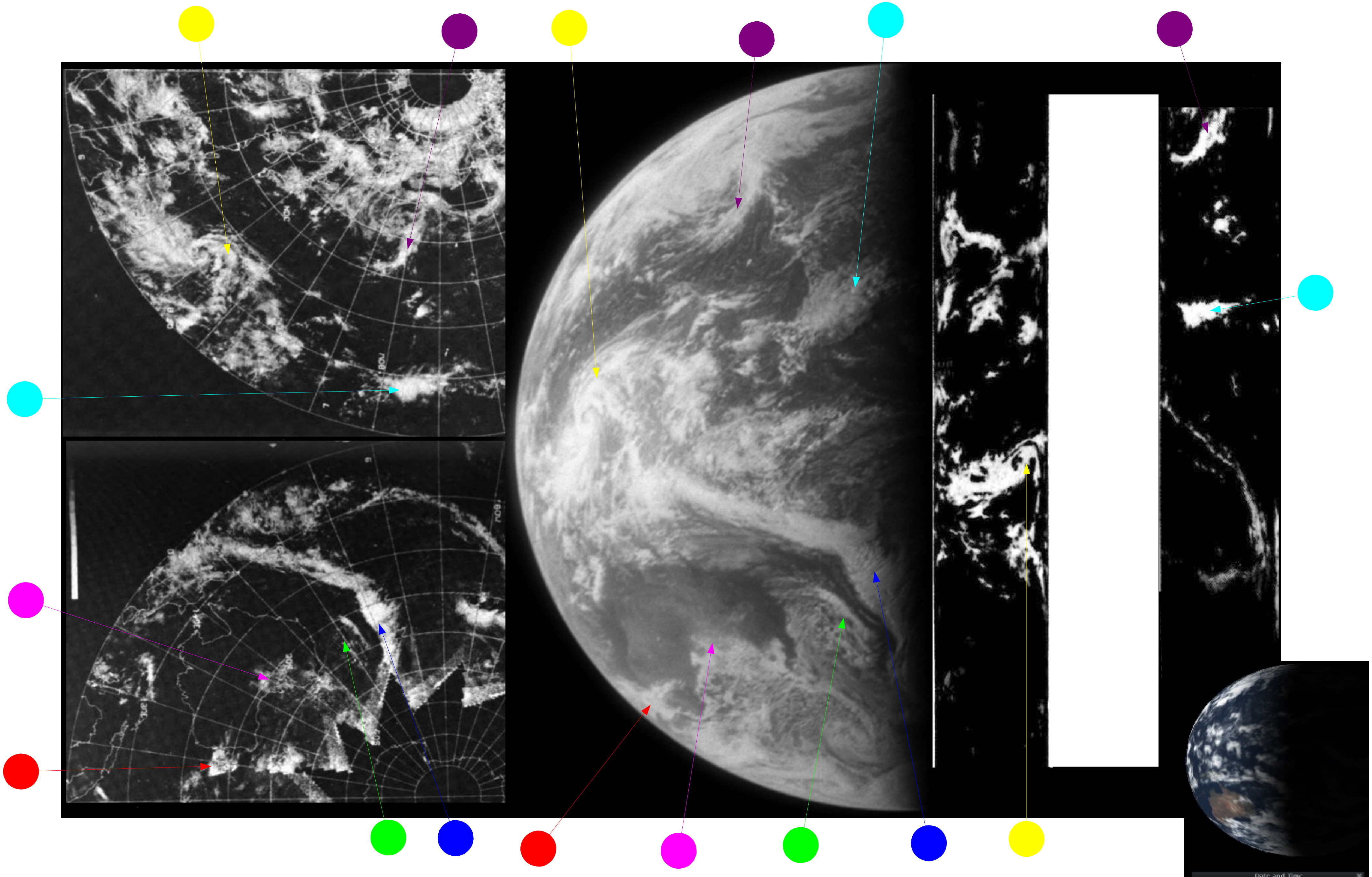


Figure 4.3.71: ESSA-9 (left) and NIMBUS-3 (right) images compared with AS11-38-5697 and Stellarium estimate of time at terminator

By way of variety, the colour image, AS11-44-6672 will be compared with the satellite images It is shown below in figure 4.3.72 and analysed overleaf in figure 4.3.74. AS11-38-5703 is shown below in original form and with the Earth zoomed and cropped as figure 4.3.73.

Figure 4.3.72: AS11-44-6672. High quality source: [ALSJ]

Figure 4.3.73: AS11-38-5703 (left, source: [AIA]) and zoomed & cropped (right)

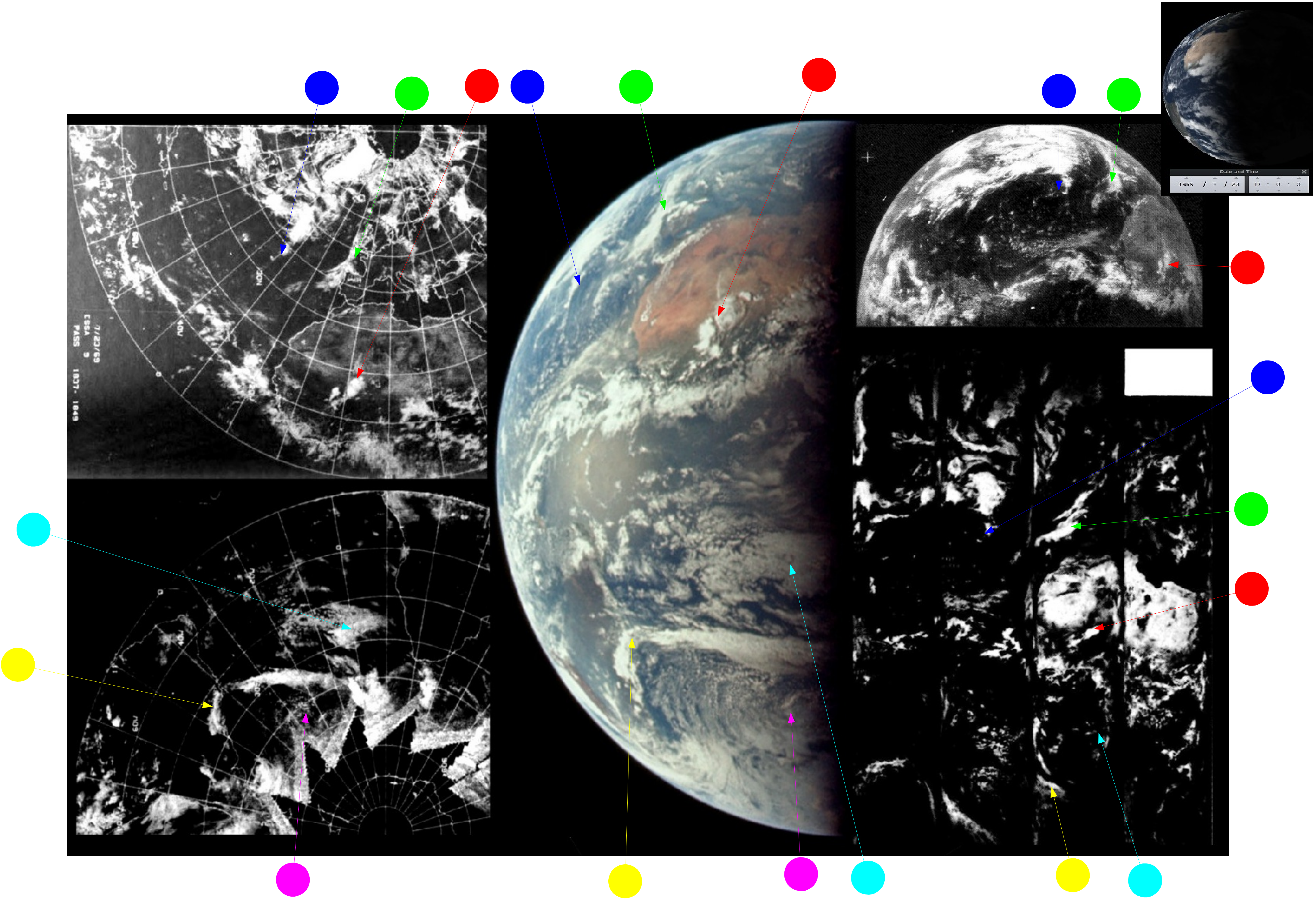


Figure 4.3.74: ESSA-9 (left), ATS-3 (top right) and NIMBUS-3 (bottom left) compared with AS11-44-6672 and Stellarium estimate of time at terminator.

Stellarium estimates a time of this image as around 17:00 on the 23rd, and it is beginning to be more noticeable that the Earth is moving towards a crescent shape as time passes. The colour image hardly differs from the black and white version, although the different angle of the Earth (caused by the PTC roll) suggests that there is a small time gap, it is difficult to pick out anything along the terminator that would indicate how much.

Figure 4.3.75 (right) shows one area that hints at the colour image being taken first, as the seems to be more visible of the cloud trending from the centre to the 4 o'clock position at the terminator, but as before it could easily be a product of image quality.

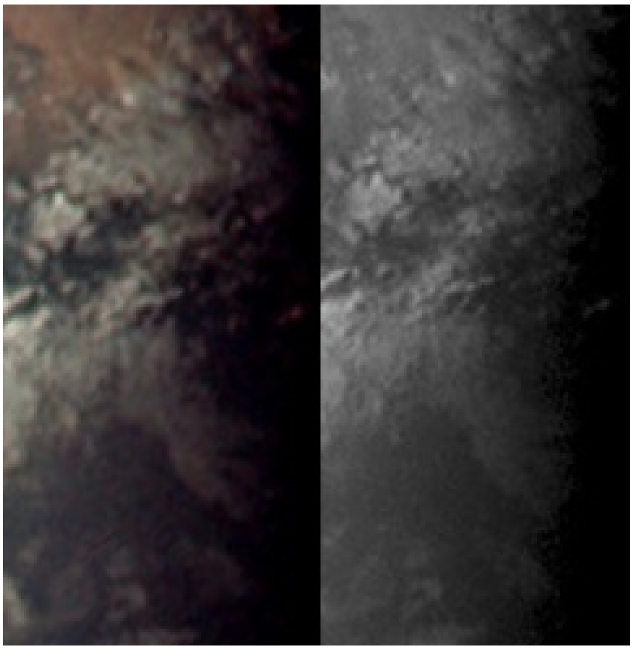


Figure 4.3.75: Comparison of sections of AS11-44-6672 (left) and AS11-38-5703 (right)

The ATS image is timed at 15:17 on the 23rd. ESSA-9's orbital track was commenced at 12:07 on the 23rd (track 12, orbit 1838), and the NIMBUS orbit at 09:07 on the 23rd (pass number 1342).

The next image taken of Earth is AS11-38-5706, which is shown below in figure 4.3.76, and analysed overleaf in figure 4.3.77.

Figure 4.3.76: AS11-38-5706. High quality source: AIA

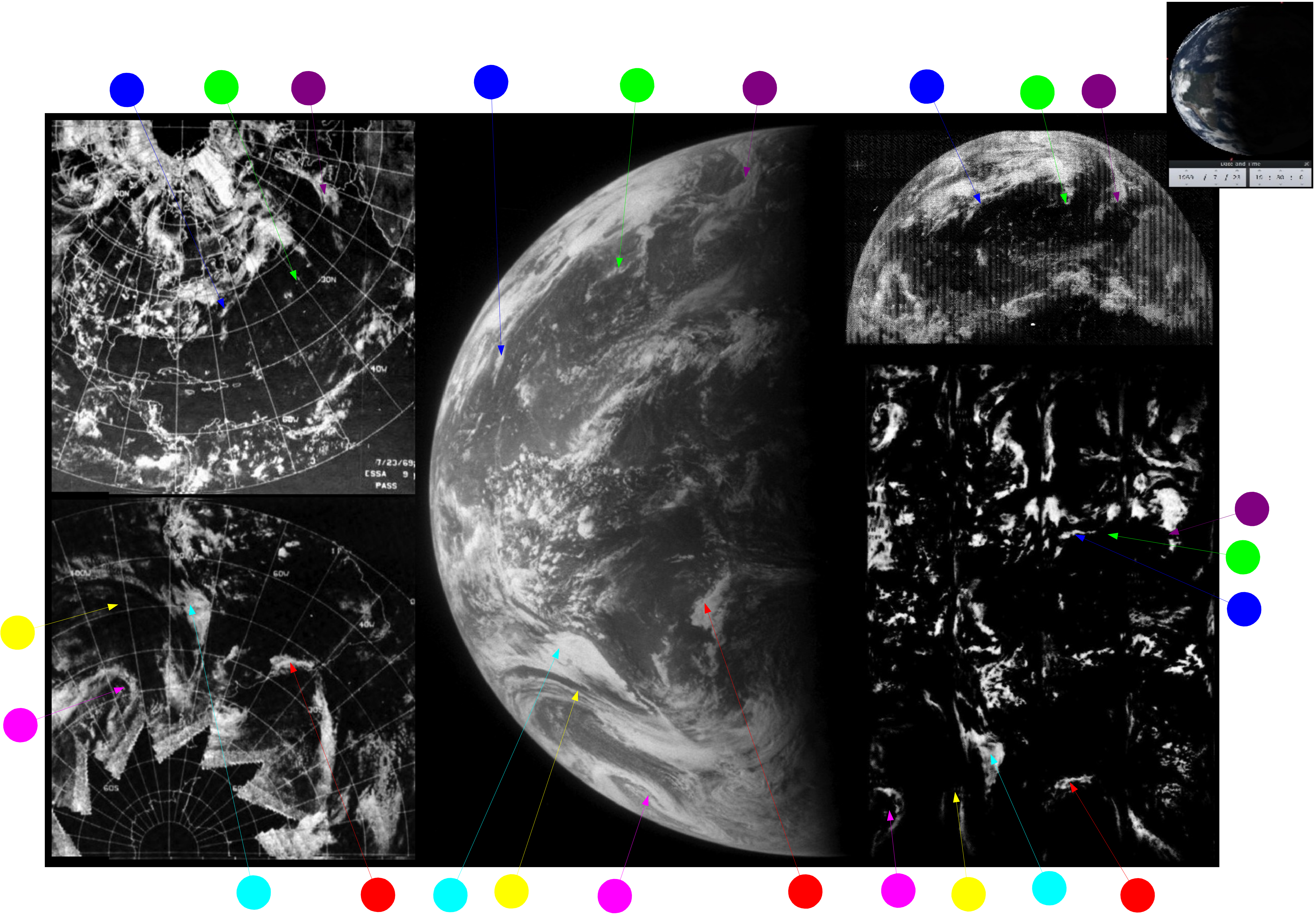


Figure 4.3.77: ESSA-9 (left), ATS-3 (top right) and NIMBUS-3 (bottom right) images compared with AS11-38-5706 and Stellarium estimate of time at terminator

Stellarium puts the Apollo image as being taken at 19:30, and it is interesting to note that the crescent on Stellarium is more pronounced than that of the Apollo view, with Stellarium's lunar viewpoint becoming more divergent from the Apollo one as it nears home.

During their wake-up call from capcom, the crew are informed that:

"The forecast yesterday showed a tropical storm, Claudia, some 500 to 1000 miles east of Hawaii. The - the pictures from Earth satellites taken yesterday afternoon - afternoon showed Claudia dissipating, so this appears to be even less a factor than it was before. Your recovery area is now believed to be just a little ways north of the intertropical convergence zone, which you can probably see when you look out your windows there. Yesterday there was also a report of a tropical storm, Viola, further to the west."

This is, again, confirmation that NASA were using their own satellite images to monitor closely weather conditions likely to affect the landing area, and also that the landing zone had moved. Unfortunately Viola did not (as far as is possible to tell) make it onto any Apollo photographs.

As far as the satellite timings are concerned, ATS-3's recorded time is still 15:17, roughly 5 hours before Stellarium suggests Apollo took its image. ESSA's orbital track over the terminator (track 1) on the 23rd is number 1839, which commenced at 14:02. NIMBUS' equivalent orbit, number 1344, was commenced at 12:41.

A couple of images later, we have AS11-38-5708 for consideration. This is shown below in figure 4.3.78, and analysed overleaf in figure 4.3.79.

Figure 4.3.78: AS11-38-5708. High quality source: AIA

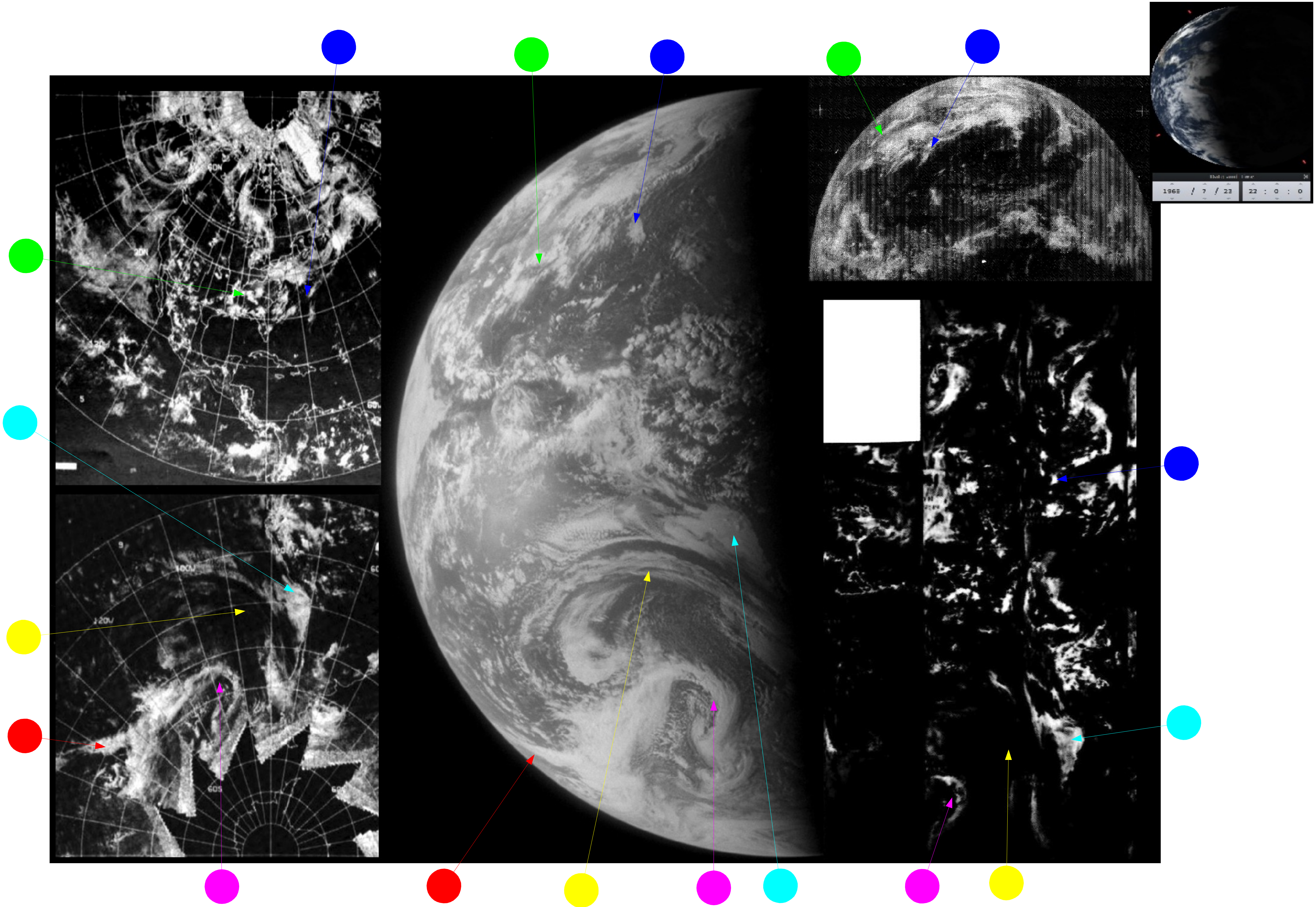


Figure 4.3.79: ESSA-9 (left), ATS-3 (top right) and NIMBUS-3 (bottom right) images compared with AS11-38-5708 and Stellarium estimate of time at terminator

In this photograph, there has been sufficient rotation of the Earth to allow the spectacular weather system off western south America to come more clearly into view, but not sufficient to completely remove some of the cloud patterns visible in the previous analysis to disappear/ The cyan, yellow, magenta and blue arrows all point to features visible in figure 4.3.77

Stellarium puts the time of the photograph as around 22:00,. The time of the ATS image is, as usual unchanged.

ESSA's orbital pass over the terminator is number 1840 (track 2), which commenced at 16:07 on the 23rd. The NIMBUS pass for the same region is 1345, which commenced at 14:28 on the 23rd.

The next image of Earth is a return to the colour magazine, number 44, and shows the scene a few hours later, with the journey home into its final day.

Figure 4.3.80 shows AS11-44-6674, and this image is analysed overleaf in figure 4.3.81.

Figure 4.3.80: AS11-44-6674. High quality source: ALSJ

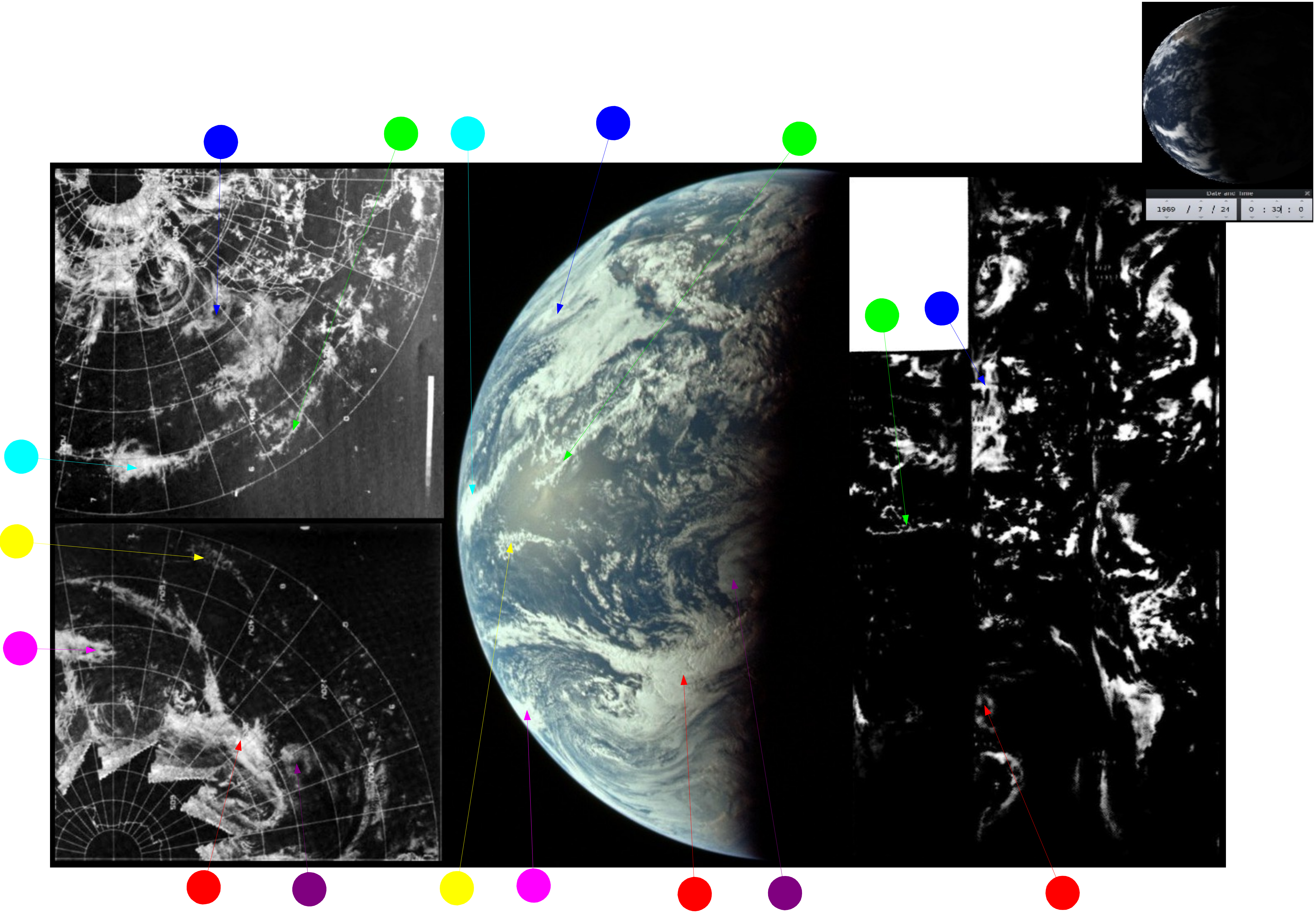


Figure 4.3.81: ESSA-9 (left) and NIMBUS-3 (right) images compared with AS11-44-6674 and Stellarium estimate of time at terminator

In this photograph, all of south America has gone, but much of north America is still visible, and the persistent fog banks off California (blue arrow) dominate the view of the northern hemisphere. The large system in the south identified by the red arrow is also visible in figure 4.3.68, but in a slightly different formation, and slightly further east.

Stellarium puts the terminator, just off the east coast of the USA, at around 01:30 on the 24th, 15 hours before re-entry. ESSA's terminator orbit is track number 3, or orbit 1841, which commenced at 18:02 on the 23rd. Much of the NIMBUS data is either poor or missing for this image, and few features are easily made out. However, the orbital pass over the terminator is still best represented by orbit number 1346, which commenced at 14:28 on the 23rd.

The next image of Earth on magazine 38 shows a very similar scene, and was taken only an hour later (if Stellarium is to be believed) than AS11-44-6674. AS11-38-5712 shown below in figure 4.3.82, and serves merely as a bridge to the next image to be analysed fully, AS11-38-5719 is also shown below in figure 4.3.83, and analysed overleaf in figure 4.3.84.

Figure 4.3.82: AS11-38-5712 (left, source: AIA) and zoomed & cropped (right)

Figure 4.3.83: AS11-38-5719. High quality source here: AIA

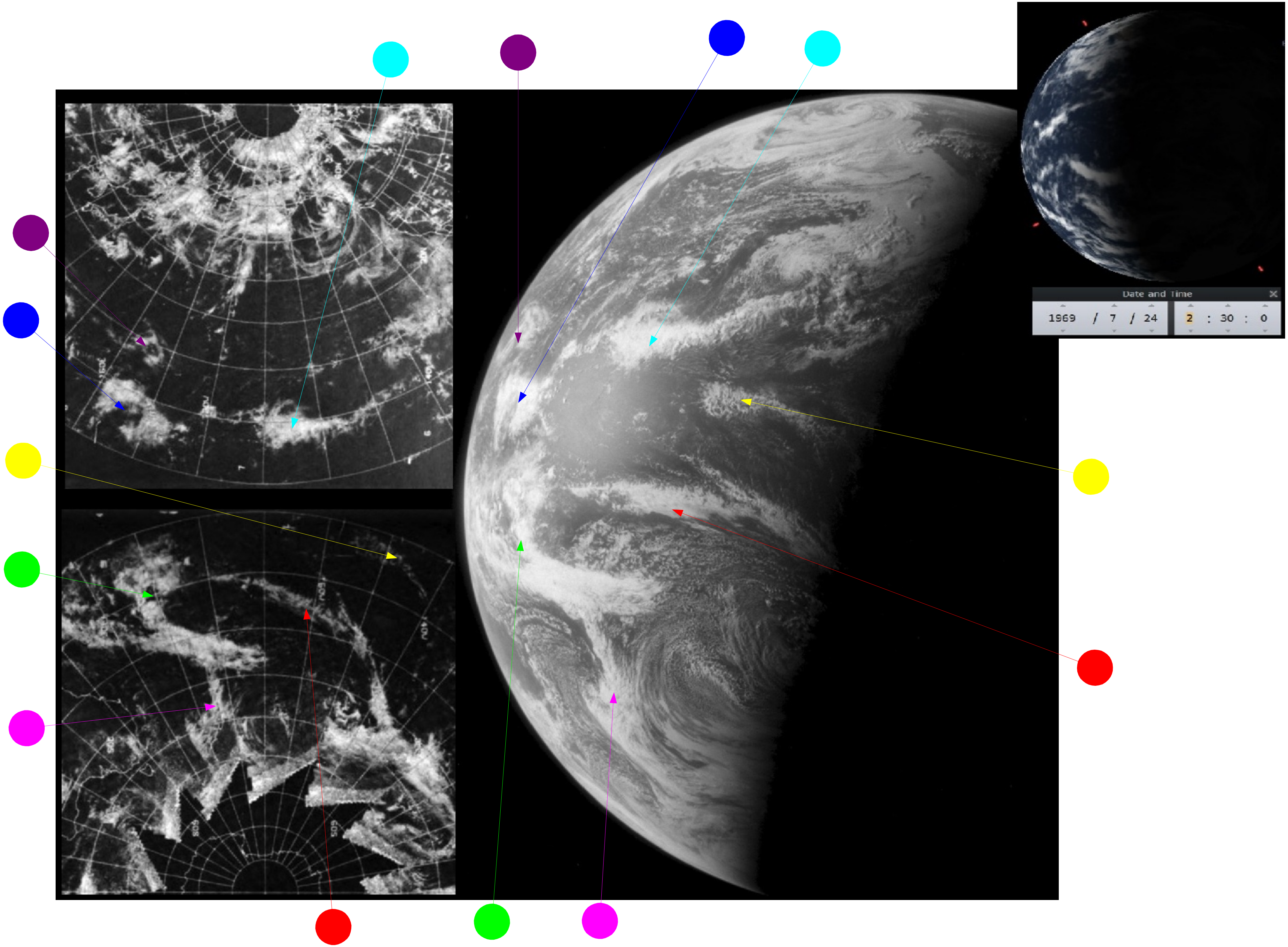


Figure 4.3.84: ESSA-9 image compared with AS11-38-5719 and Stellarium estimate of time at terminator

It should be evident that there are still features visible on this photograph that are also visible on the previous two pictures used from this magazine. The red, yellow and cyan arrows all point to the same cloud features shown in those colours in figure 4.3.82, while the magenta arrow in that figure picks out the eastern end of the band of cloud marked by the green arrow in figure 4.3.84. The banks of fog off the US coast are still visible at the northern end of the terminator line.

No NIMBUS data are available for this part of the image, and so we are left with only ESSA for comparisons.

ESSA's nearest orbit to the terminator is number 1843 (track 5), which commenced at 21:03 on the 23rd.

Stellarium's estimate is that the photograph was taken at 02:30 on the 24th, 14 hours before re-entry

The last images on magazine 38 are all repeat exposures of the image just examined, and we now return to magazine 44 for our final two images of a full Earth. The penultimate image examined is AS11-44-6676, which is shown below in figure 4.3.85, and analysed overleaf in figure 4.3.86.

Figure 4.3.85: AS11-44-6676. High quality source: ALSJ

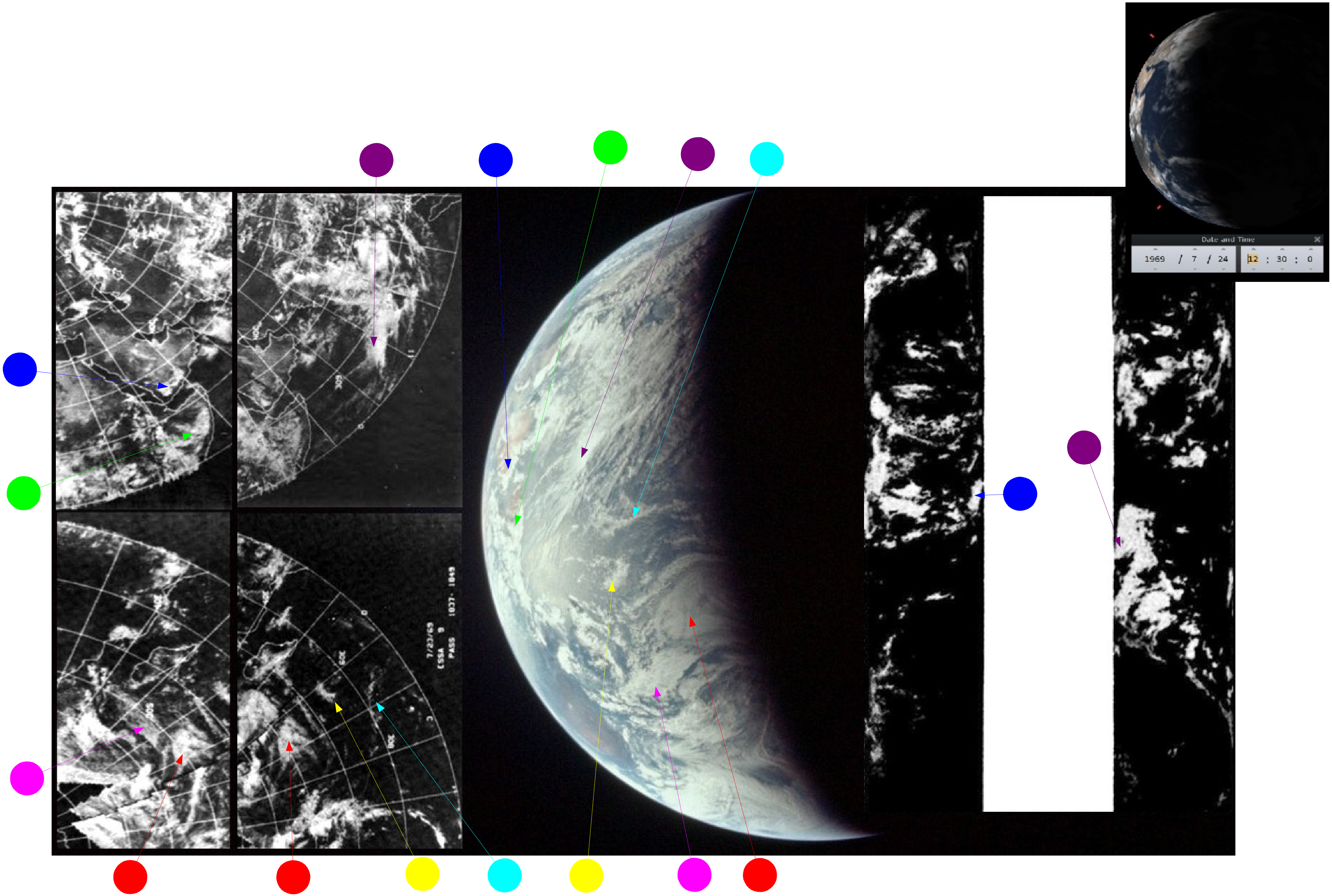


Figure 4.3.86: ESSA-9 dated the 24th (far left) and the 23rd (left), and NIMBUS-3 (right) images compared with AS11-44-6676 and Stellarium estimate of time at terminator

As the Earth becomes increasingly crescented, identifying cloud masses becomes a little trickier. The first task here is to identify the landmasses visible on the western limb, and close inspection reveals that we are looking at the east coast of Africa. The blue and green arrows point to clouds over Somalia and Arabia respectively.

Life is complicated even further by the fact that as the image features Africa, the area visible on the western limb features weather patterns shown on the ESSA image dated the 24th, while those over the Indian ocean are the last featured on the image dated the 23rd. For this reason, sections of both ESSA mosaics are included. The NIMBUS data are poor quality and much of the area visible is either not available or difficult to make out, and for this reason only the blue and purple arrows are used with any confidence.

The cloud masses identified by the blue and green arrows are not visible on the image dated the 23rd, but are shown on the one dated the 24th, which helps date things more precisely. Stellarium estimates that the Apollo image was taken at around 17:30 on the 24th. ESSA's nearest orbit to the terminator is number 1848 (track 10), which commenced at 07:00 on the 24th. NIMBUS' nearest pass is number 1353, which commenced at 04:15.

The final image examined, and the final full disc image of Earth taken, is AS11-44-6689, shown below in figure 4.3.87 and analysed overleaf in figure 4.3.88.

Figure 4.3.87: AS11-44-6689. High quality source: ALSJ

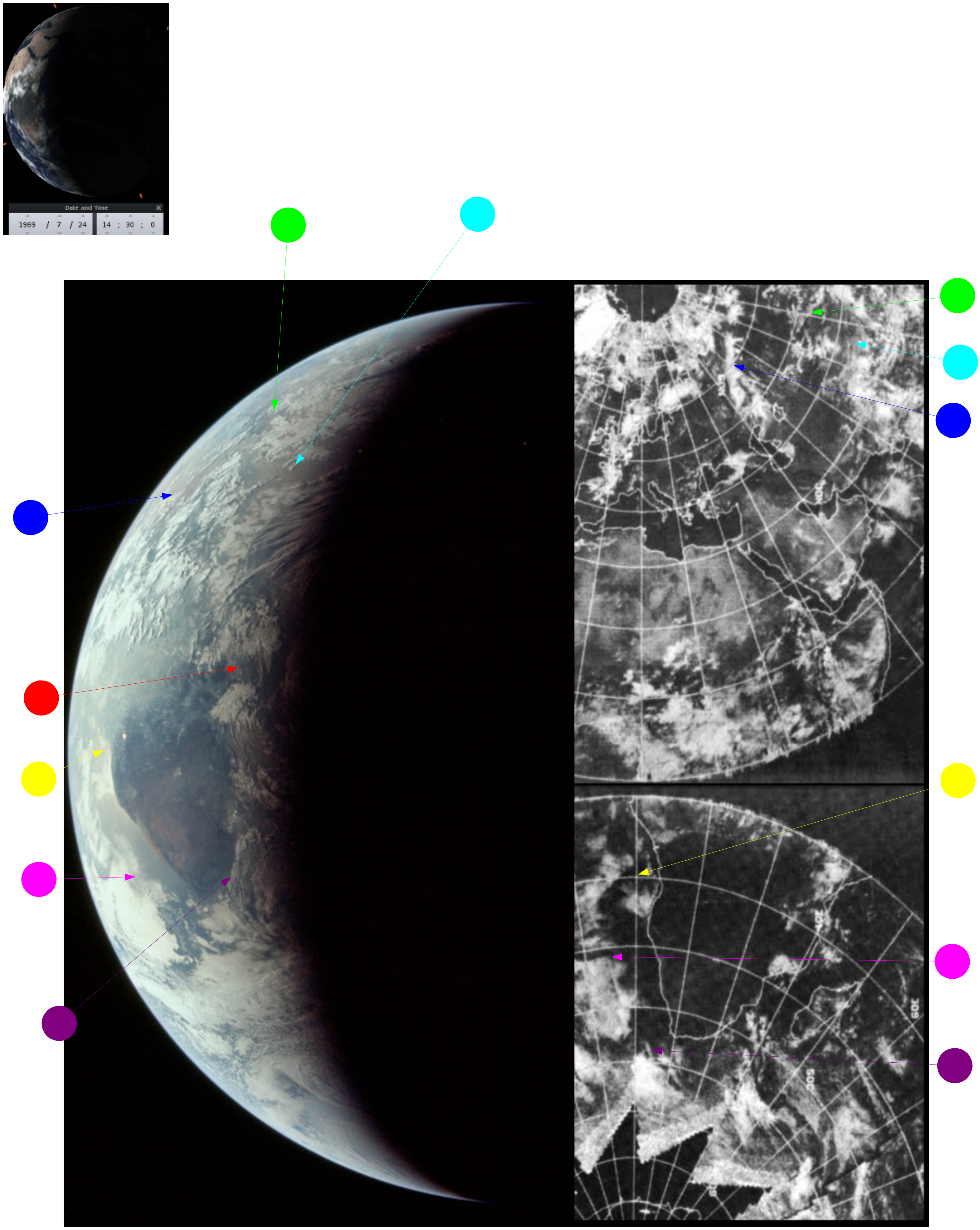


Figure 4.3.88: ESSA-9 (right) compared with AS11-44-6689 and Stellarium estimate of time at terminator.

It should be evident to even the least observant that the preceding figure used only one satellite photograph. NIMBUS' image for the African coast is missing on the 24th, nad the path that is available covering Africa shows very little useful information relevant to the visible part of Africa on the Apollo image. No useful part of ATS-3's view is available. Even with only one satellite, it is still relatively easy to pick out weather patterns on the image that are different to the ones visible on the 23rd's satellite image.

As for dating the image, The most representative track relating to the Apollo image terminator is number 11, which is 1849, and commenced at 09:05, which compares well with the 14:30 time suggested by Stellarium.

Roughly two hours after the Apollo image was taken the CM separated from the SM and the crew began the re-entry procedure. 140 minutes after the image was taken they were in the Pacific, safely away from stormy weather thanks to the satellite images used in this analysis to help prove that they went to the Moon.

So there we have it, the first lunar landing covered from start to finish, with every series of photographs of Earth analysed and compared with satellite photographs to demonstrate that the pictures taken by Apollo 11's cameras could only have been taken where they were claimed to have been taken, including, for the first time, the surface of the moon.

Having compared a variety of satellite images with photographs covering all parts of the Earth's surface during all parts of the mission, there really should be no more need for any meteorological analysis, but there is always a need for thoroughness.

4.3.2 Meteorological sources

Thanks to the fame of the mission, many of the Apollo missions' critics and doubters focus on it in their endless search for the trivial that they believe will help to defend their position. The corollary to this is that much research has been done for Apollo 11 to support it.

Apollo 11's synoptic charts have already been examined in some detail on sites like Apollohoax.net, and at the end of This article on the TV broadcasts . These have tended mostly to focus on the data held as NOAA's weather charts for the USA. This report has deliberately not referred to this other work when writing the following discussion in order not to be influenced by them. The reader is free to make their own interpretations of the data available and use their own methods.

As well as the NOAA data, the same German and South African sources available for Apollo 10 are available here, and these are all from the same source as the Apollo 8 analysis. The Apollo 11 source for German data is here: http://docs.lib.noaa.gov/rescue/cd282_pdf/LSN1163.PDF and the South African data here: http://docs.lib.noaa.gov/rescue/cd126_pdf/LSN0734.PDF. There are also synoptic charts from Pakistan. Other sources are available that contain meteorological data, but these tend to be numerical records rather than charts and aren't useful.

A few days from the mission will be chosen that allow the maximum use of the available charts, starting with an image that was dealt with earlier and two images taken before and after it. AS11-36-5381 was, if we can assume the analysis presented here is correct, taken on July 18th. From the same magazine image 5377 and 5401 (also used earlier) show different parts of the Earth on the same day, which allows us more complete coverage.

Figure 4.3.89 shows these Apollo images in comparison with German and NOAA charts.

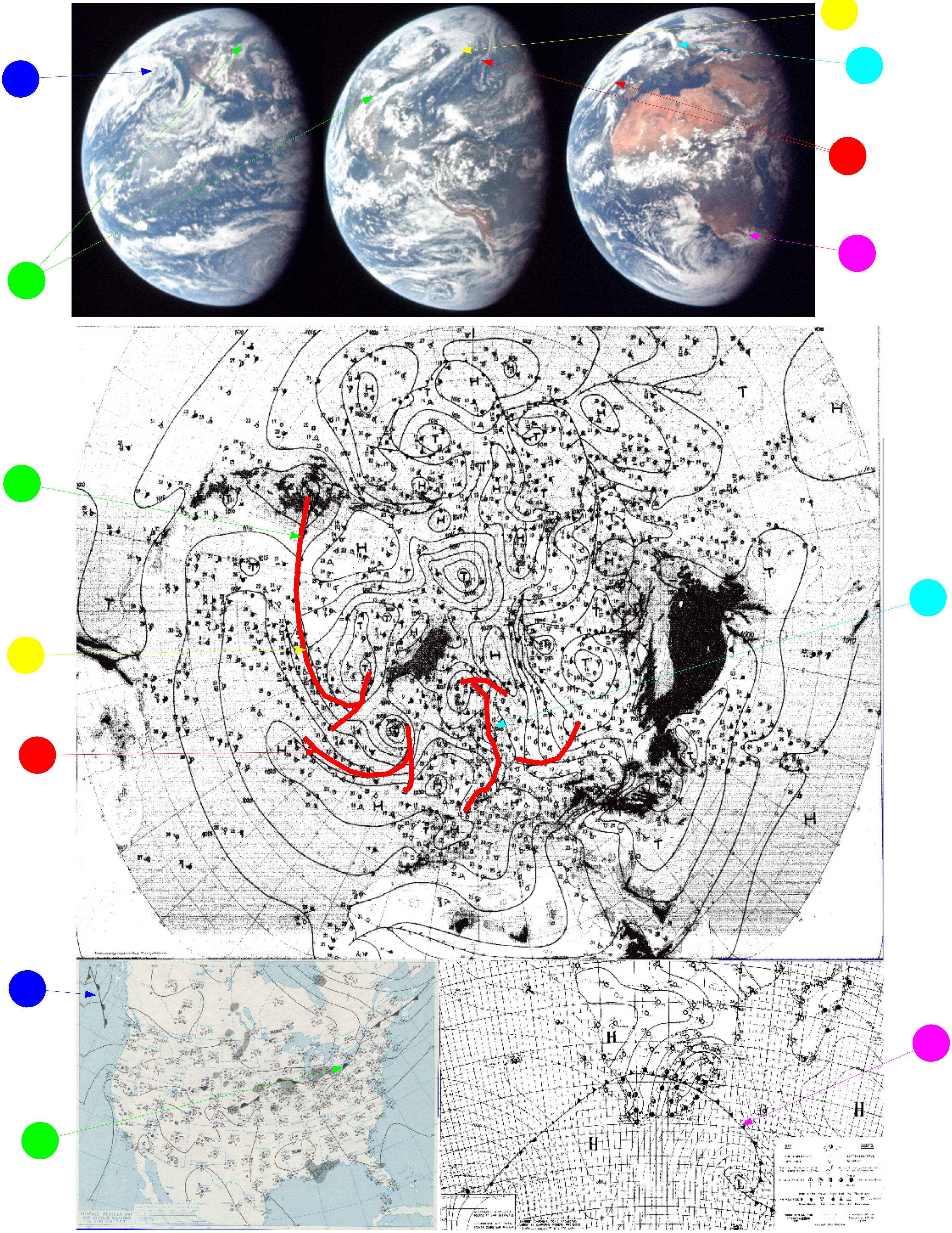


Figure 4.3.89: AS11-36-5377 (top right), 5381 (top middle) & 5401 (top left) compared with German (middle), NOAA (bottom left) and South African (bottom right) synoptic charts.

As with previous sections for Apollo 8 & 10, no claim to in-depth meteorological expertise is made here, but there are obvious comparisons on the charts that match with the systems shown in the Apollo photographs. Also evident are the differences in interpretation that meteorologists from different organisations place on the information with which they are presented.

NOAA, for example, place a cold front off western Canada/USA (blue arrow) that isn't identified on the German synoptic chart. NOAA also place a pattern of broken fronts across the mid west and north-eastern US states leading into the Atlantic, whereas the German data suggest a continuous unbroken front starting more around the northern Rockies area. Some of these differences may be related to differences in scale. The German map covers the entire northern hemisphere, and necessarily has less detail in it thanks to space considerations. NOAA has more details because it covers a smaller spatial extent.

What should be evident is that German & South African meteorologists drew weather charts that match the systems on an Apollo photograph. Sceptics can argue about the independence or otherwise of NOAA staff (it would be interesting to see them say it to their faces), but any arguments suggesting that weather scientists with absolutely no connection to NASA or the Apollo mission were also in collusion begin to stretch the already tortuous conspiracy argument even further into the realm of the ludicrous.

After the 18th there are relatively few Apollo images that provide useful vantage points from which we can compare synoptic charts, as the timing of the mission and the angle of the Earth as viewed from the Moon means that the the usual northern hemisphere land masses are generally unavailable, at least for the period in lunar orbit, and other than South Africa, southern hemisphere data are not available.

For the period covering lunar orbit, we are therefore reliant on just two images, AS11-37-5442 and AS11-41-6023. These images were covered in figures 4.3.41 and 4.3.44 respectively and have been identified as taken on the 20th, the former from the CSM, the latter from the LM.

Not enough of southern Africa is available for a worthwhile comparison with the synoptic chart, as the only front (and therefore the only part of the only part likely to show any significant cloud formations) marked on the chart is in an area in darkness on the Apollo image, and for this reason only the NOAA and German synoptic data will be used.

Figure 4.3.90 shows these two Apollo images compared with the synoptic charts. As indicated, there are relatively few identifiable fronts on the weather charts, but the persistent front across the northern USA stretching into the Atlantic is still identifiable, as are the fronts associated with the depression off northern Europe. The high pressure zone marked over northern Canada is also producing a relative lack of cloud over that region.

While most Apollo 11 images from the vicinity of the moon are of Australia, AS11-44-6642 (examined in figure 4.3.54) does show the Americas and a considerable portion of the North Atlantic. NOAA & German synoptic charts are shown with the Earth from this image in figure 4.3.91.

There is really only one definitely identifiable front on this image, the long one starting out over America (blue arrow) before heading out over the Atlantic (green arrow). The yellow arrow is used to suggest that the cloud mass visible on the Apollo image on the eastern horizon is the same as the front on the German chart, but this can not be absolutely certain thanks to the angle involved.

The final synoptic charts analysed are shown in figure 4.3.92 & 93 and are from July 22nd and 23rd.

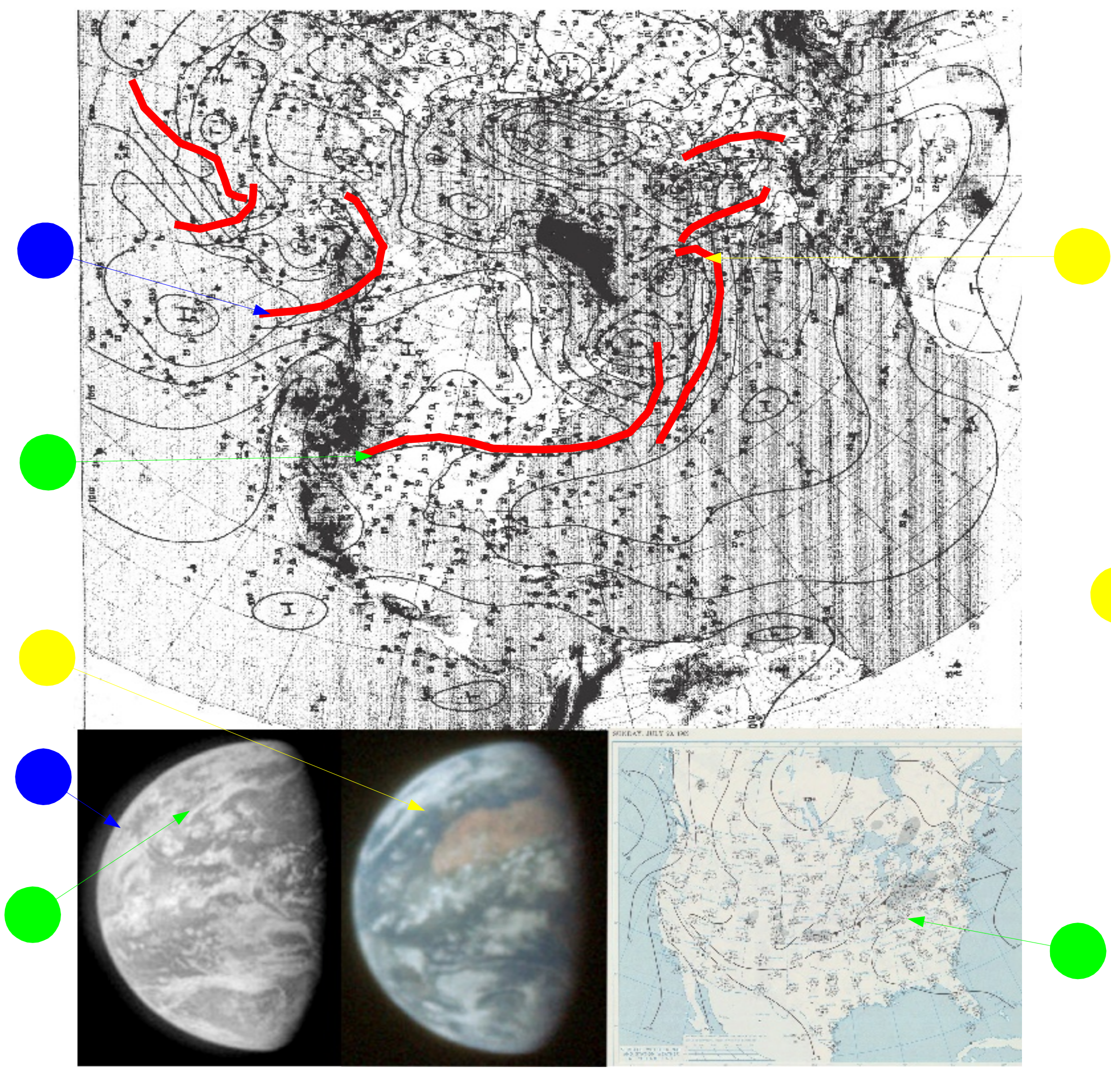


Figure 4.3.90: German (top) and NOAA (bottom right) synoptic charts compared with AS11-37-5442 (bottom left) and AS11-41-6023 (bottom middle).

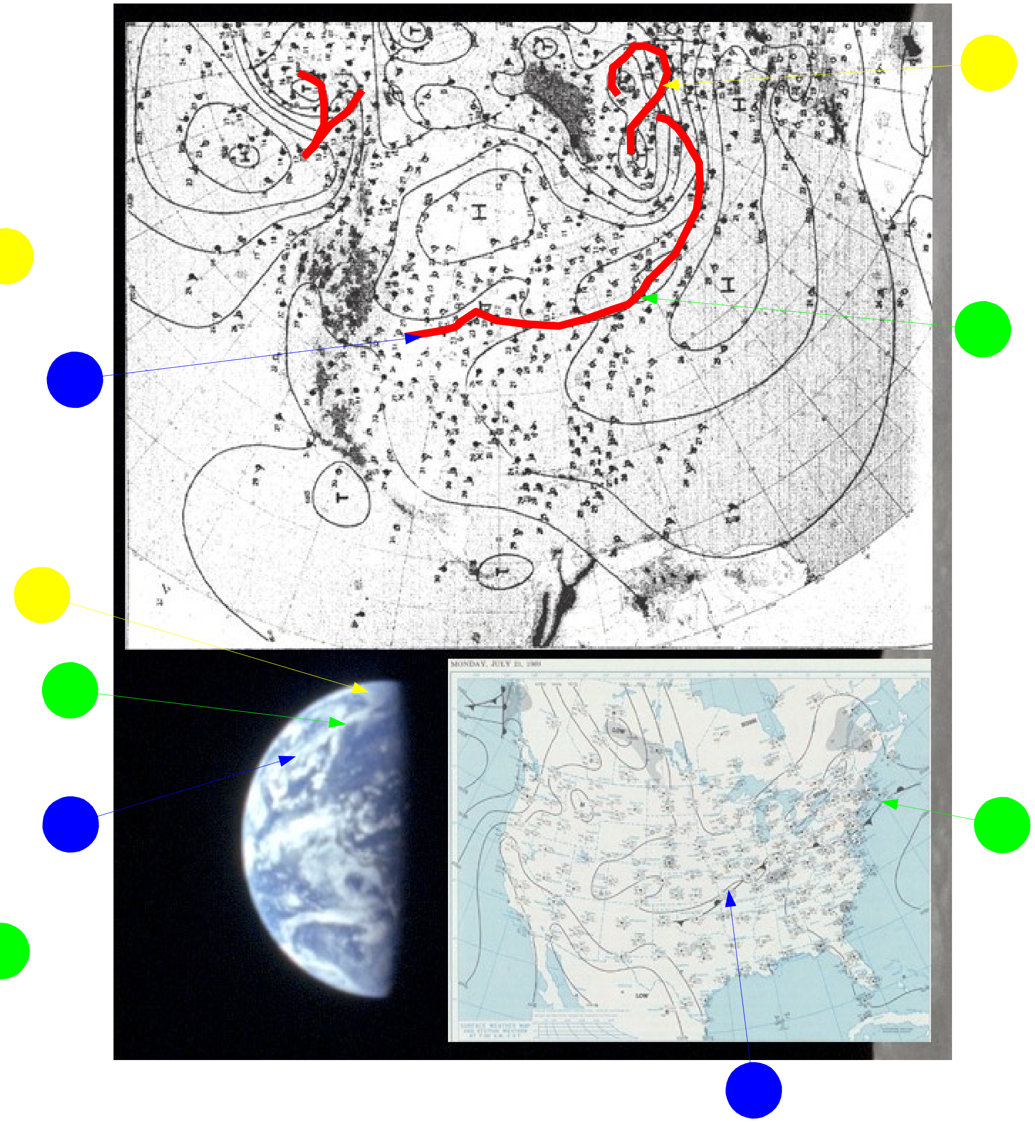


Figure 4.3.91: German (top) and NOAA (bottom right) synoptic charts compared with AS11-44-6642 (bottom left)

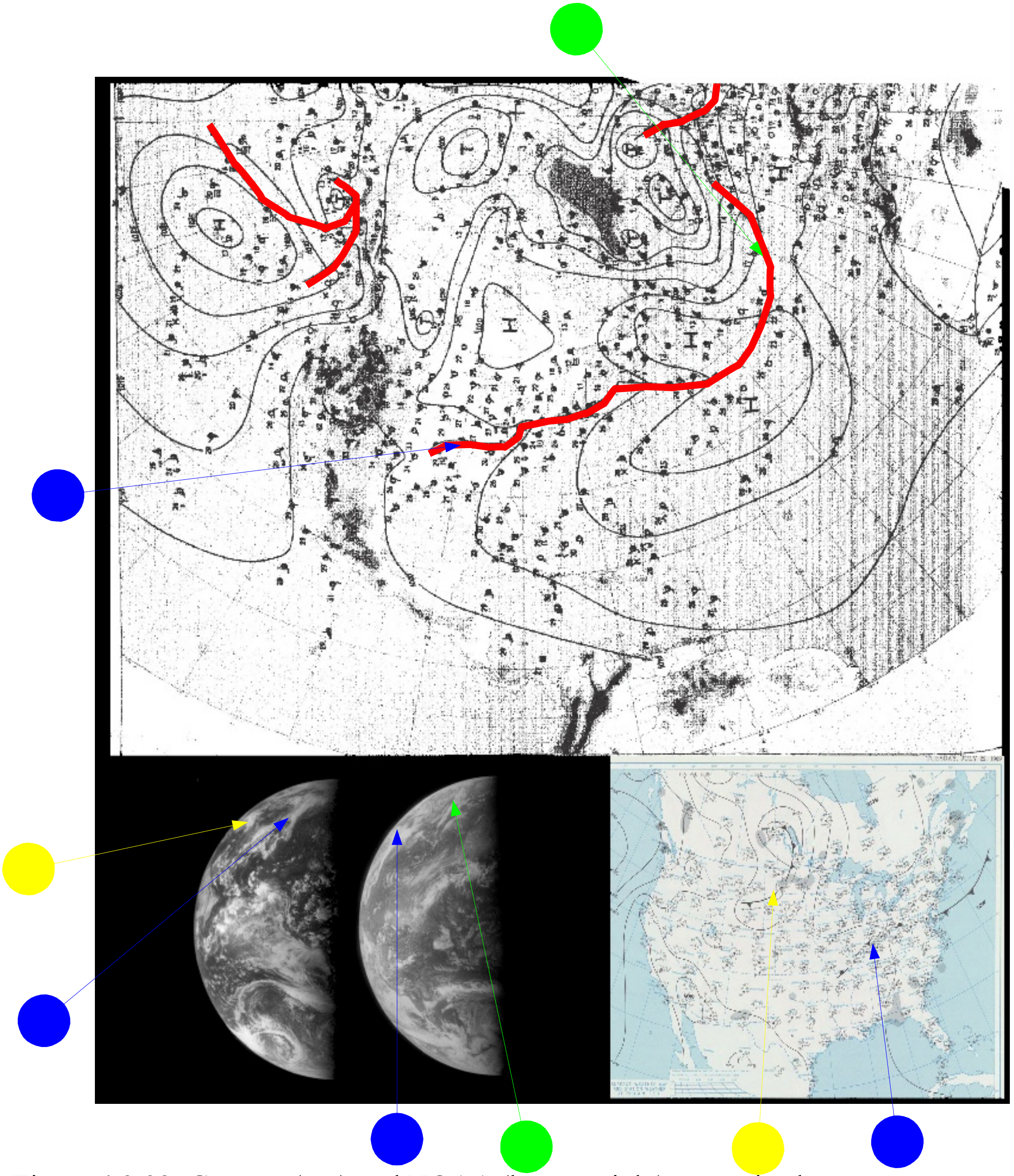


Figure 4.3.92: German (top) and NOAA (bottom right) synoptic charts compared with AS11-38-5687 (bottom left) and AS11-38-5684 (bottom middle).

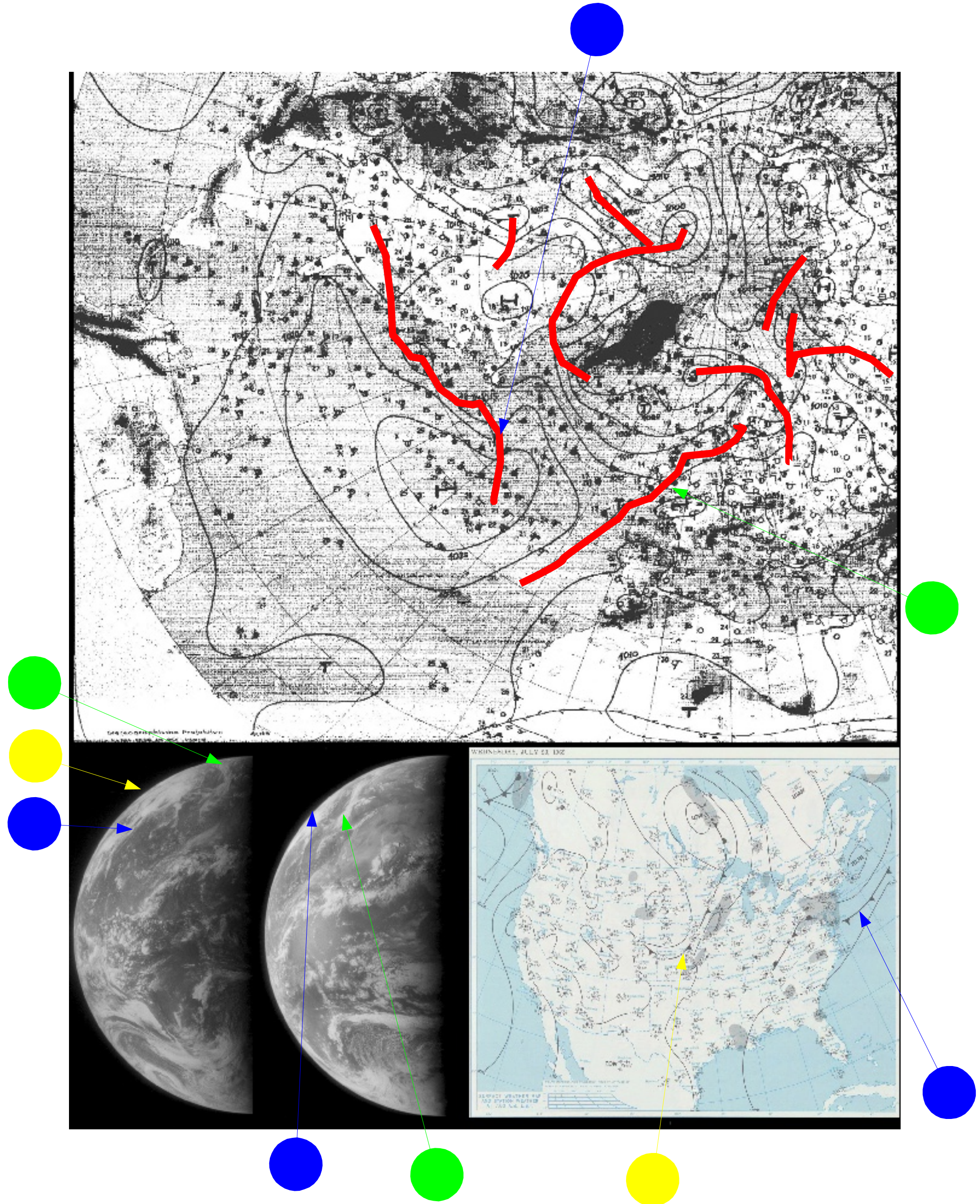


Figure 4.3.93: German (top) and NOAA (bottom right) synoptic charts compared with AS11-38-5707 (bottom left) and AS11-38-5703 (bottom middle).

Figure 4.3.92 shows AS11-38-5684 & AS11-38-5687. The former was examined in figure 4.3.59 and shown to be dated as the 22nd of July, and the latter was taken a few frames later the same day.

The blue and green arrows identify a single weather front (as identified by our German friends) but showing broken cloud along it. This broken cloud is reflection of the nature of the air masses along that front, as hidden under the red line used to mark it more clearly here is a mixture of warm & cold fronts (in other words a change in the nature of the 'leading edge' of the air masses. The German meteorologists have perhaps oversimplified the situation in using one long line.

Figure 4.3.93 features AS11-38-5703 & AS11-38-5707. The former was examined in figure 4.3.74 and identified as being taken on the 23rd, the latter in figure 4.3.77. The long trans-atlantic system has continued to develop and is now no longer shown as an unbroken front, and appears to have split in two as one half heads towards Africa, with attend clouds in tow.

One final image is worth including. Newspapers have long included weather forecasts in their pages, and after contacting http://www.honeysucklecreek.net/ on their website about ARIA support for the Apollo missions, a scan of the synoptic chart from "The Australian" newspaper was very kindly supplied. The image shows fronts marked off south east Australia, fronts which brought snow to the Australian Alps, and heavy rain and wind elsewhere. The map is dated 20/07/69, and is shown in figure 4.3.94 in comparison with views of Australia from that the 20th and 21st of July.

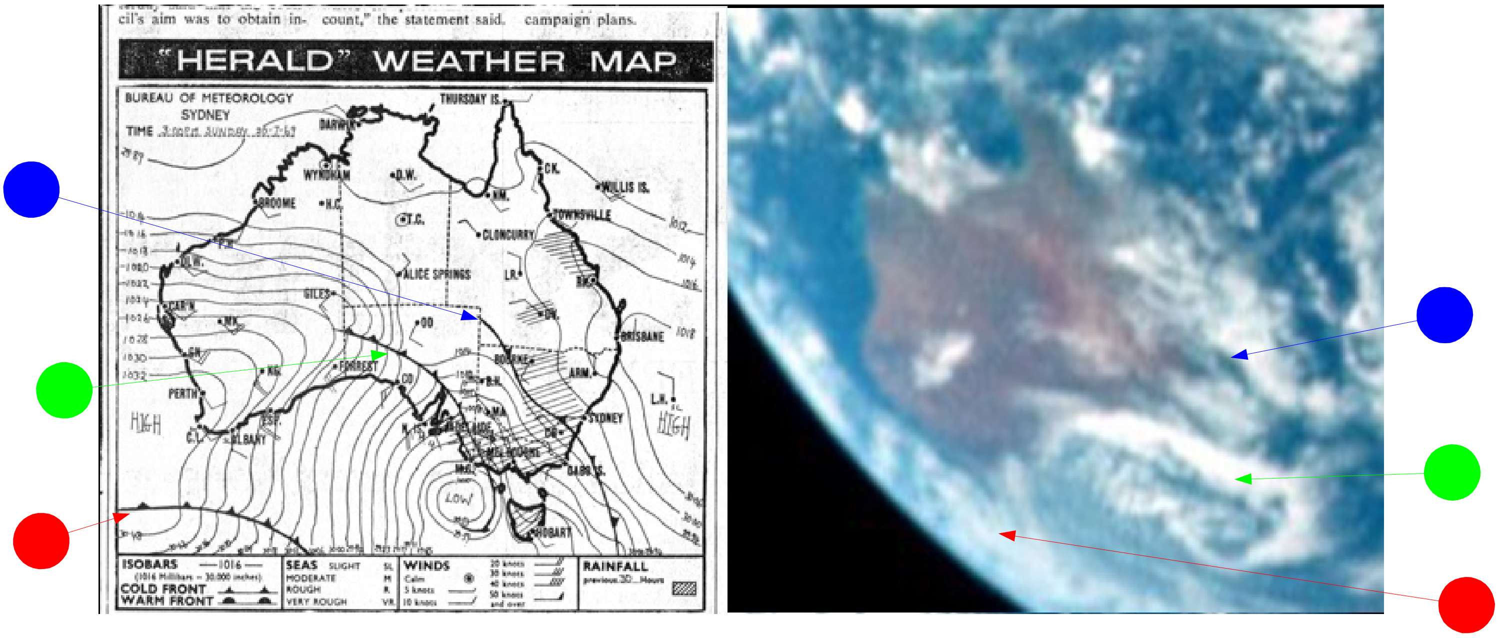


Figure 4.3.94: Sydney Herald chart dated 15:00 20/07/69 (local time) compared with AS11-44-6551 crop of Australia.

The frontal systems marked on the map show clear correspondence with those on the Apollo image. The time given on the newspaper is local, and thus the GMT would be roughly 03:00 on the 20th.

As discussed previously, a professional meteorologist is better qualified to comment on these synoptic charts, but to any observant eye there is no inconsistency between the weather charts produced on the ground and the weather patterns visible in the sky.

Apollo 11 then, finally brought to a close. The most historic flight ever made, documented and analysed from start to finish by the clouds shown in satellite photographs and TV broadcasts and still photographs, with every image consistent with the Earth's rotation and satellite photographs.

4.4 Apollo 12

Despite launching only 5 months after arguably the most historic event in history, Apollo 12 is remarkable for being almost forgotten in the grand scheme of human achievement, and in popular memory it has neither the excitement and hope of Apollo 11 nor the drama of Apollo 13. Politically, Apollo was already being shaved back (missions had actually been cancelled before Apollo 11 had even taken off), and many people began to hold the view that there were more important and pressing problems on the home planet that could use the money being spent on the Apollo programme. After all, we had "been there, done that". We'd made our point, why go again?

It did, however, have the claim to fame of being the first mission to have a pinpoint landing. While Apollo 11 had a landing area within which the crew wanted to set down, the trajectories for Apollo 12 were calculated to put the LM in a very specific spot, something they achieved with sufficient skill and precision to allow them to rendezvous with a much earlier NASA experiment, the Surveyor III craft, which had landed in 1967 in a partially successful mission to sample & photograph lunar soil.

The Saturn V launched at 16:22 on 14/11/69, landing on the moon on 19/11/69th. The crew stayed on the surface for 31.5 hours, re-uniting with the CSM on the 20th, and finally splashing down on the 24th.

Figure 4.4.1: Apollo 12 TV broadcast showing the acting out of mission audio. The video is obviously in a studio and bears no resemblance to the mission photographs.

The mission's main claims to fame are being hit by lightning at launch, and the failure of the colour TV camera, which was burnt out almost as soon as it was set up on the Moon by being pointed directly at the sun. This forced the US TV networks to hire actors on a set to perform the astronaut's roles to the recorded voices of the crew. It's ironic that while many accuse Apollo 11's lunar surface broadcasts of being performed by actors on a set, Apollo 12's actually were (figure 4.4.1: Source).

Live colour broadcasts were resumed after the LM was re-united with the orbiting CSM, and in the docking sequence Pete Conrad (identified by capcom) can be seen moving in the LM window.

They did, however, manage to take still images. During the mission they used 14 magazines of film to take 2119 images, the bulk of which are of the lunar surface (either from orbit or from the ground). Relatively few photographs exist of Earth once out of Earth orbit, and because of the mission's timing, significant numbers of these are of a crescent globe – much less of the surface is visible than in previous Apollo missions.

These photographs are available at the ALSJ & AIA, but for several the images used show an overexposed Earth. Where necessary, images have been obtained from the Gateway to Astronaut Earth Photography (GAPE). Some high quality TIFF images are available at http://archive.org. TV screen captures will be used where available (see figure 4.4.1 for sample source).

As with Apollo 11, 3 satellites are available for comparison with these still images: ATS-3, Nimbus-3, and ESSA-9. ATS-3 images for the period covering Apollo 12 are in this document Source. NIMBUS-3 images can be found here: Source, and ESSA 9 from here: Source.

There are also isolated examples of close-ups from these satellites, which allows better quality. This document contains a close up NIMBUS image of the Sahara desert from November 18th Best of Nimbus, and this one shows a close up of New Zealand, also from November 18th and also from NIMBUS, New Zealand Journal of Marine and Freshwater Research. The Mariners Weather Log from January 1970 (Volume 14, Number 1) contains a more detailed image from ESSA of North America on the 21st of November (Source) showing Hurricane Martha over Panama. As with other missions, all these images have been freely available in one form or another since they were taken, and if possible they will be included in the analysis here.

Now that some sort of context has been established, we can progress to looking at the photographs.

4.4.1 Satellite Imagery

The magazine with the first images taken of Earth is number 50, and the first image approaching a full disk is AS12-50-7331 shown in figure 4.4.2 - the best quality version of which is at the AIA (Source). A comparison with the relevant satellite images is given in figure 4.4.3.

Immediately prior to this, there are several frames showing the SIV-B with the exposed LM visible. The timeline for the mission (source) shows that separation of the CSM from the SIV-B occurred at 19:40, docking with the LM at 19:48 on the 14th. This gives a pretty precise window for when this photograph (and numerous others at various zoom extents before docking). must have been taken

Figure 4.4.2: AS12-50-7331. Source given in text.

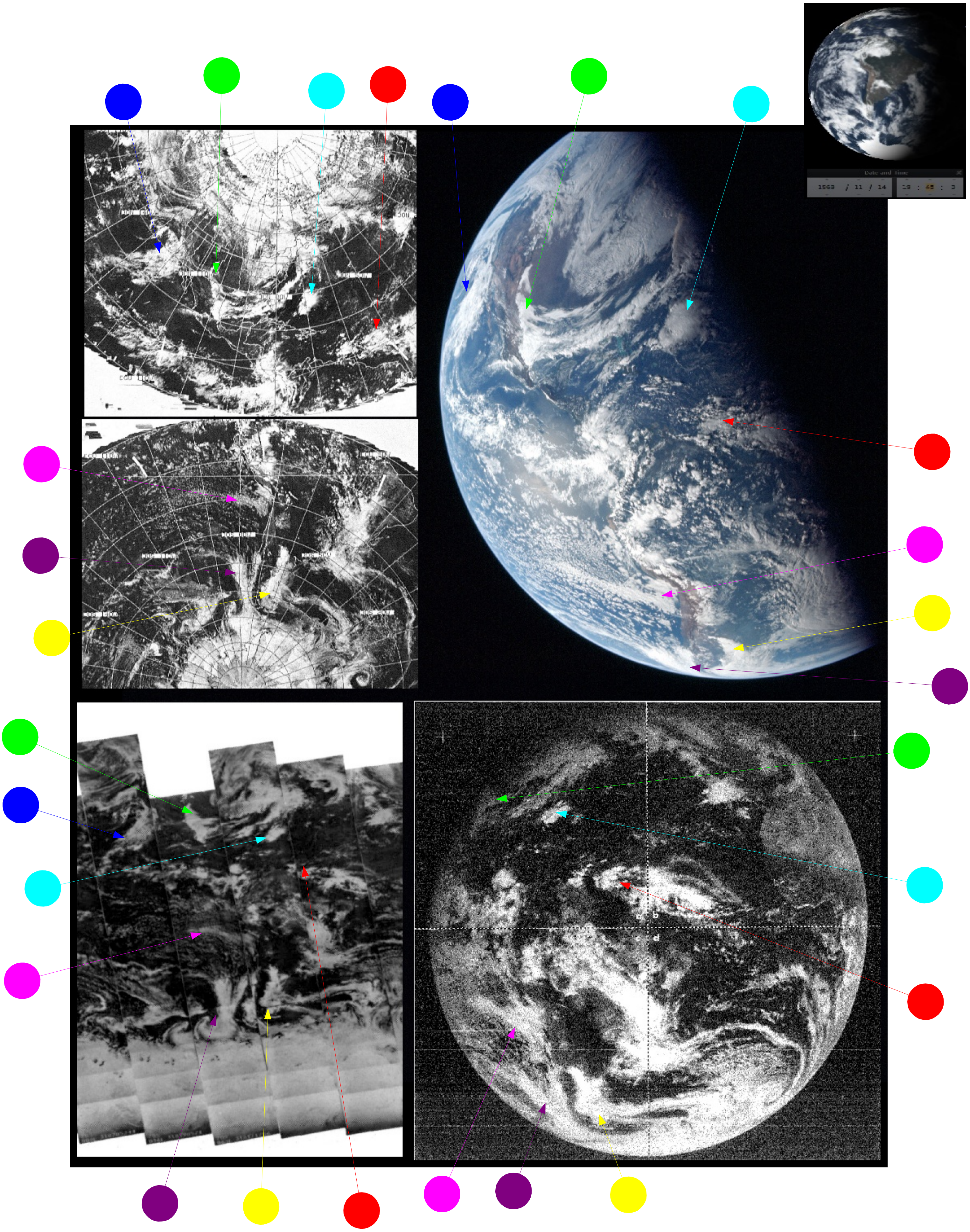


Figure 4.4.3: AS12-50-7331 compared with ESSA-9 (top & middle left), NIMBUS-3 (bottom left) and ATS-3 (bottom right) and Stellarium estimate of time at terminator.

The Apollo image has a number of unique features that are easily visible on the satellite photographs, particularly the large 'tick' shaped feature sweeping from the Mexican coast across the Gulf and up the east coast of the USA. The weather patterns either side of the tip of south America are also very distinctive and easy to spot on the satellite images.

The ATS-3 image provides a useful counter-argument to the suggestion that the colour Apollo photographs were somehow derived from the whole disk images provided by the HEO geostationary satellites. While the Apollo image used shows the Earth taking up a substantial portion of the image, other photographs taken at the same time show a much smaller globe, demonstrating that the Apollo craft was much further out than the ATS satellites. The portion of the Earth shown by Apollo is not matched by the ATS-3 image – it is over a different part of the Earth & at a different angle. ATS-1 was stationed over the Pacific, only a small part of which is seen in the Apollo image.

As far as timings are concerned, the ATS image was taken at 14:25. The NIMBUS orbit closest to the terminator would be number 2873, which was started at 14:14. ESSA's image is more difficult to interpret, as unlike previous missions the orbits that comprise the image dated the 14th are not given. However, the track covering the terminator area would be track 2. For an image dated the 14th this would correspond to orbit 3264, which was commenced at 16:06. As the Stellarium terminator suggests that the time for the image derived from the Apollo timeline is entirely reasonable, these figures suggest, at most, an elapsed time of about 5 hours between the ATS image and the Apollo one. This five hours is sufficient for the cloud system highlighted by the yellow arrow to move from the centre of the tip of south America in the ATS image to nearer the east coast in Apollo. This and many other features show that the overall similarity of the images belies a wealth of subtle differences, demonstrating that while all the images show the same thing, they are not identical replicas.

As in previous missions, the Astronauts communicated their own observations to capcom of the weather conditions on the ground (these are recorded in the technical air to ground transcripts, available here: ALSJ).

At 3:34 MET Dick Gordon says:

"Okay. You should be looking at the Yucatan Peninsula, Mexico; Baja California is in plain sight. It's a pretty nice day down there. In the Gulf, Gulf - The western Gulf of Mexico has a cloud coverage along the coast; looks like it's almost up to Houston. It's south and west of it."

followed a couple of minutes later by

"Hey, Jer, it's a fantastic sight. The Mississippi Valley has a little bit of cloud coverage coming down from Canada, and there's some in the north - north-east part of the country, up in the New England States. Looks like they may be getting some snow over here in the next day or two. Florida is cut in half by that front that went through this morning. The West Coast looks absolutely gorgeous; Baja California is clear, looks like the San Diego/Los Angeles area to the south and west of them is a little cloud coverage covered. I won't say anything about smog."

The smog he doesn't want to talk about is the mass of cloud identified by the blue arrow, and Baja California is indeed clear compared with Los Angeles & San Diego. The green arrow points out the system cutting Florida in half, and the cloud systems descending from Canada into the Mississippi are immediately north of that arrow in the preceding figure, and the snow systems over New England are to the east of that.

While the crew were busy describing the weather to capcom they were also broadcasting on TV. One such broadcast started at 19:45 and continued until 20:50, and there is a copy of this broadcast available on youtube (from the same source as figure 4.4.1). A screenshot from this broadcast is given in figure 4.4.4, together with satellite comparisons. Where possible, the same coloured arrows are used as in figure 4.4.3. While the quality is relatively poor, it's clear that this live broadcast is showing the same features as the satellite images, and also that it could not be a re-transmission of ATS-3's image as there is insufficient coverage of the northern hemisphere by it. The time on the screenshot appears to be mission elapsed time, as was common on ABC broadcasts.

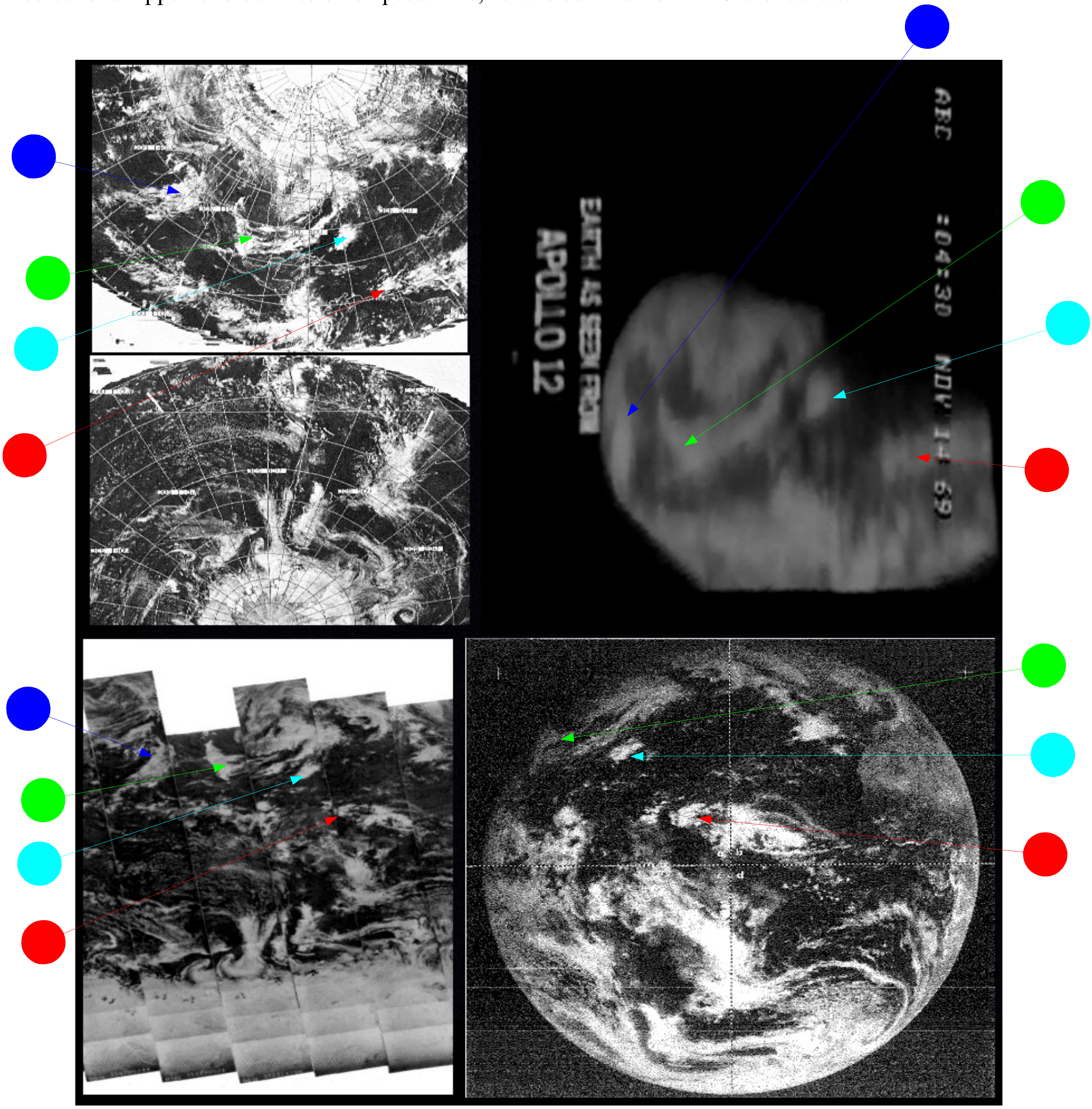


Figure 4.4.4: Screenshot from live TV broadcast compared with ESSA (top left & middle), NIMBUS (bottom left) and ATS (bottom right). Source given in text. Colours as in figure 4.4.3.

The sequence of photographs around docking continues until AS12-50-7353, before which are images of a now empty SIV-B shell, confirming the timing of the earlier image. AS12-50-7354 shows a slightly different view of Earth, and the satellite images should show that this is the same Earth photographed in the previous image, just rotated further around. Figure 4.4.5 shows the Apollo image, and 4.4.6 the satellite comparisons.

Figure 4.4.5: AS12-50-7354. High quality source: AIA

The Stellarium estimate of time based on the terminator line is difficult for this image, as no land masses are visible, but using the assumption that the weather system identified by the blue arrow borders the west coast of the USA, an estimate of 01:00 on the 15th has been derived. The satellite images used are still those of the 14th, as these are the nearest in time to that. The Apollo image is definitely from the early hours of the 15th rather than the early hours of the 16th, as the weather system picked out in blue has changed considerably by then.

The ATS image has been included, but as should be obvious from the preceding page, only one fragment of a weather system shown in the Apollo image is visible in it (identified by the purple coloured arrow). This completely eliminates ATS-3 from any suggestion that it was involved in producing at least this image! The system picked out by the yellow arrow is just visible in figure 4.4.3 slightly to the left of the blue arrow on the Apollo image. This latter system, and the cloud whorl in the southern hemisphere, are obviously visible in the satellite images.

NIMBUS' orbits covering the Pacific area in the image are 2876/2877, and these are shown as starting at 19:53 & 21:34 on the 14th respectively. ESSA's corresponding orbit would be 3267 (track 5), which commenced at 21:01. Again there is a good five hour gap between the satellite and Apollo images. As with the previous example, this time difference means that some of the weather systems have evolved by the time that the Apollo image is taken. The cloud pattern identified by the green arrow, for example, has moved some distance eastwards to a position more directly below that picked out by the blue arrow, and the red arrowed cloud has also moved much closer to the blue arrowed systems. The same weather systems but evolved into a slightly different configuration by the time the Apollo image is taken, and further indication that the Apollo image is not a straight copy of a satellite photograph.

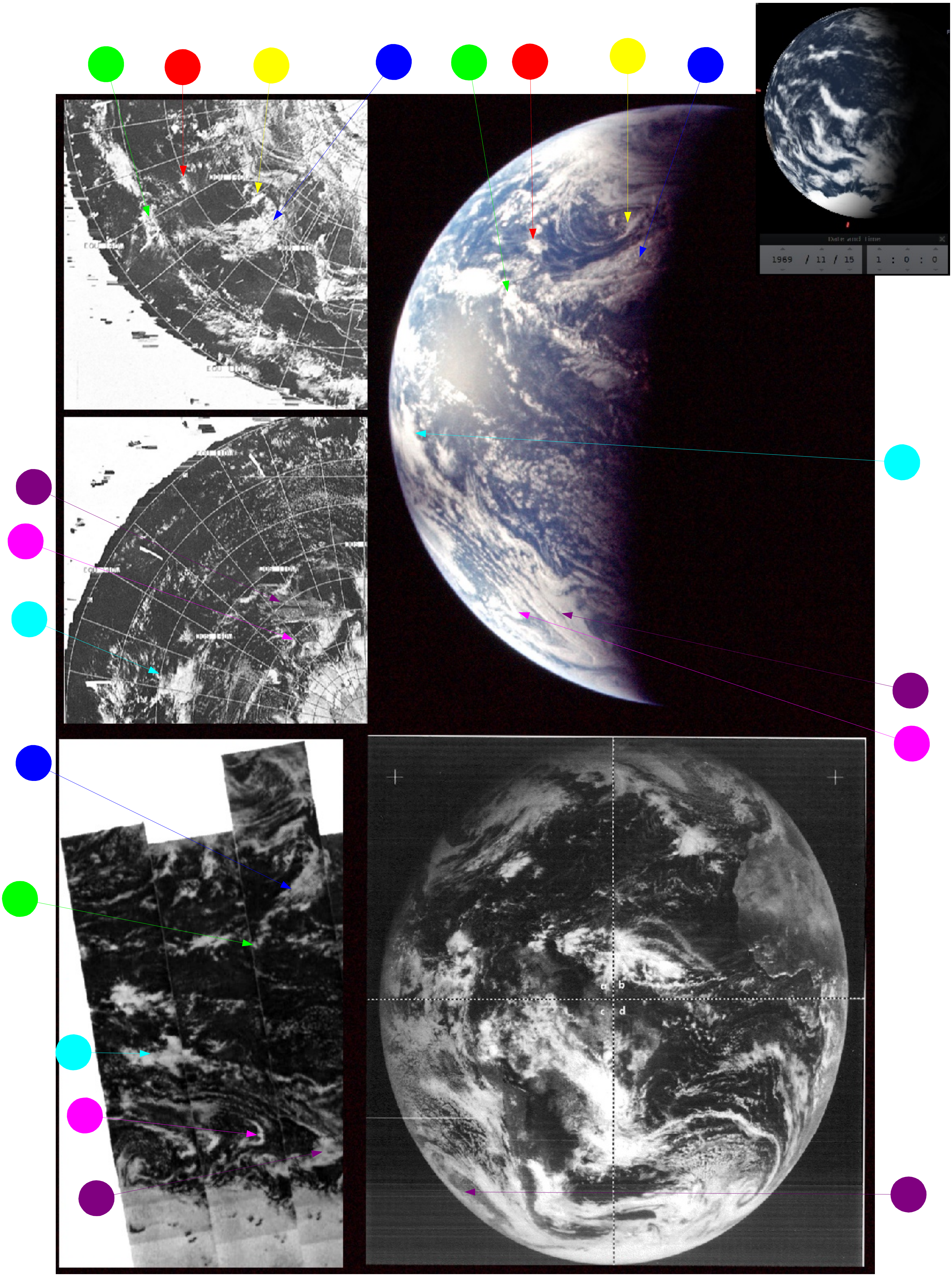


Figure 4.4.6: AS12-50-7354 compared with ESSA (top left), NIMBUS (bottom left) and ATS (bottom right), with Stellarium estimate of time. Blue & purple arrows match those in figure 4.4.2

Again, the crew discuss what they can see on the image, this time Alan Bean says at 08:23 MET (or around 00:45 on the 15th, during inspection of the LM):

"I can't see any landmass at all. All I can see is water with lots of clouds, and I can see sort of a glare point on the Earth. I think that must be the zero phase point to us. Other than that, it's very, very bright. And another interesting thing is, on the dark side, you cannot see where the Earth stops and space begins. It's unlike the Moon at night on in the daytime where you can see it in earthshine. You Just can't see anything."

The glare point is very evident, at about 9 o'clock on the Earth, and the absolute blackness of the night side is also obvious from the Apollo image. The 'zero phase point' is a point that won't change on the surface regardless of perspective because it is the light from the sun, and the sun is not going to change position.

A few frames later in magazine 50, after a couple of partial disk zoomed photographs, there are a few more full disk images, and again time has moved on slightly from the previous image. The first of this sequence is AS12-50-7362 (Source), shown in figure 4.4.7. The main source of interest from this image is that Australia (and many other parts of Australasia) is visible beneath the clouds, and the shadows cast by the clouds. There are several large clouds that show very obvious shadows on the ocean below them, giving a third dimension to the images that the satellite photographs lack. Figure 4.4.8 shows the satellite comparisons.

Figure 4.4.7: AS12-50-7362. High quality source: AIA

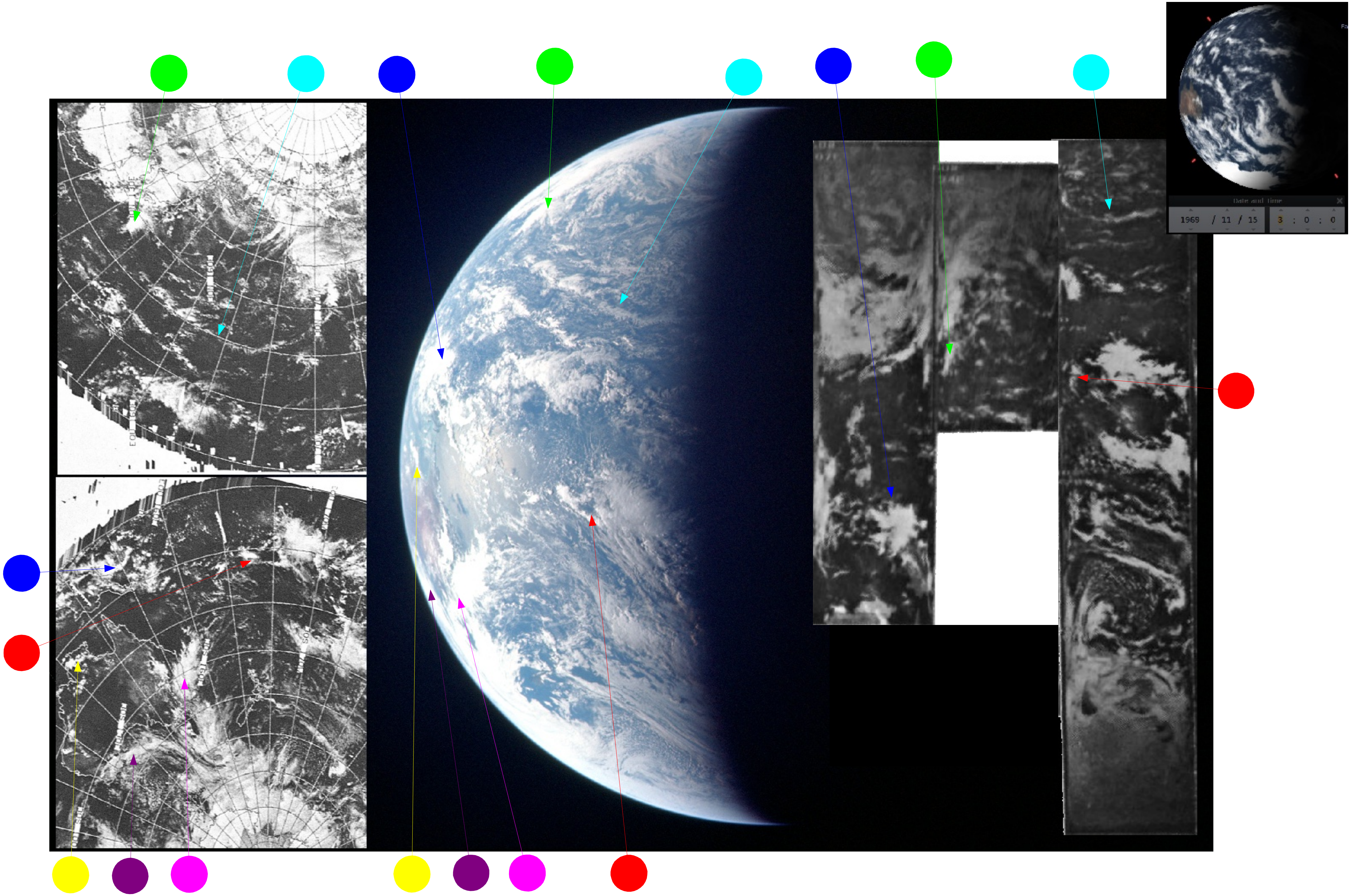


Figure 4.4.8: AS12-50-7362 compared with ESSA-9 & NIMBUS-3 image & Stellarium estimate of time at terminator

Stellarium suggests a time of 03:00 for the picture, and the yellow arrow on the figures point to a system that is only visible on the 15th – on other days that part of Australia is clear. The NIMBUS part of the satellite images consists of orbit 2878-80 of the daylight IR passes, which are given over images labelled the 14th and 15th. Orbit 2878 started at 22:38 on the 14th and 2880 at 02:13 on the 15th. ESSA's most representative orbit for the area covered is number 3268 (track 6) which commenced at 23:07 on the 14th .

On the subject of Australia, the astronauts again discuss what they can see with capcom. At 12:53 MET (or 05:15 on the 15th) the crew give the following message:

Okay, Houston. We've got Australia.... in sight now at the - oh, it's about the 8 o'clock position, with respect to the terminator...There's a lot of clouds out there, Houston. I can see a lot of fairly small clouds, but there is so darn much cloud cover out in the Pacific, except right off the north-east coast of Australia that I really haven't found any islands yet.

The astronauts are obviously describing what can be seen in the Apollo image, but the timings of these transmissions again call into question the Stellarium evidence. A closer look at the Stellarium terminator shows it is convex in relation to the daylight limb – it bulges away from it. The Apollo image shows a concave terminator – it bulges towards the daylight limb. Why the difference?

The answer again lies in the relative position of Apollo 12 in relation to the Earth and the Moon. Apollo 12 is on a course that is pointing at where the moon will be in 4 days time – the 18th, when it will enter lunar orbit. If the perspective of the Apollo 12 landing site is changed to that of the 18th, then it is obvious the the Earth assumes a more crescent profile (figure 4.4.9). Australia's appearance on the western horizon also changes from around 03:00 to more like 05:15, and the timing of the photograph more akin to 06:00 on the 15th.

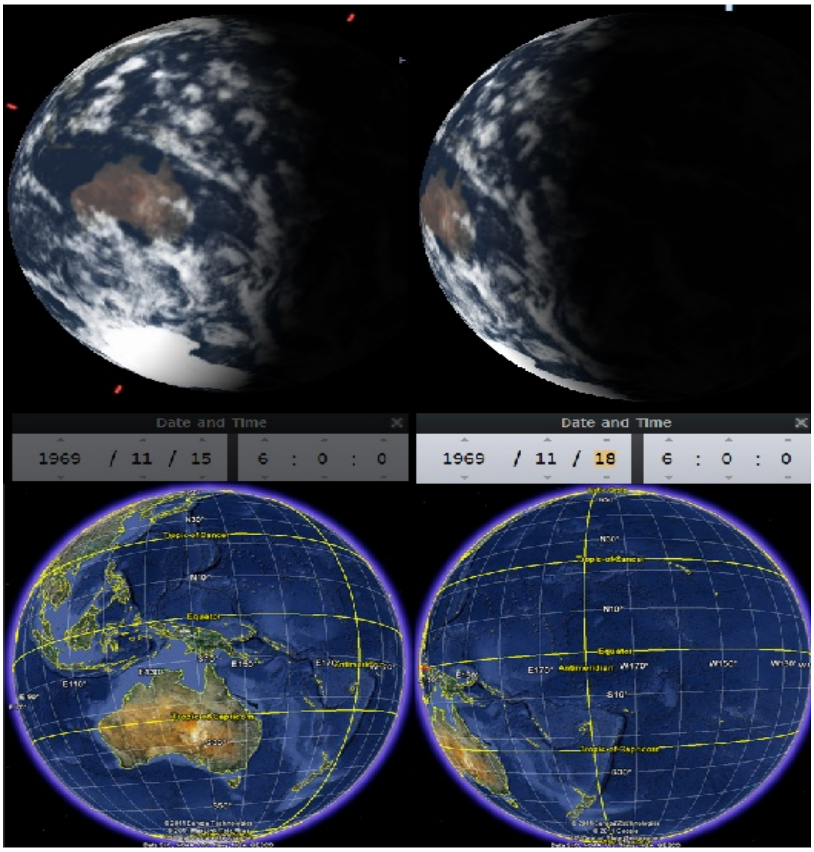


Figure 4.4.9: Views of Earth from the Apollo 12 landing site at 06:00 on 15/11/69 and 18/11/69. Google Earth comparisons indicate the distance to terminator (170 degrees East) from Australia.

What figure 4.4.9 shows is that, while the position of Australia is different in the two views of Earth, the distance to the terminator is the same. The terminator is actually at roughly 170 degrees East, but for ease of interpretation the reader can use the anti-meridian of 180 degrees (the bright yellow line running north to south). If the photograph was actually taken 3 hours earlier, the distance to the terminator would be much greater.

The explanation, therefore, for the difference in the time for Stellarium is not some discrepancy in *when* the photograph was taken, but in Stellarium's assumption of *where* it was taken from. Apollo 12 was pointed in a more or less straight line to where the Moon would be at LOI on the 18th, and therefore using the Moon's location on the 15th to check the timings causes this discrepancy. Stellarium's data are correct, it is the perspective of the view that isn't quite right.

Conspiracy theorists can make of that what they will, but it is an honest interpretation of the facts that don't initially make sense until they are examined properly. This feature is something that is consistent across every mission: Stellarium views at the start and end of missions that differ from the Apollo version, but lunar based images that match exactly.

As the CSM gets nearer the Moon this discrepancy will become less obvious, and the next image is a little closer.

AS12-50-7367 is shown in figure 4.4.10 and is the last image taken before several photographs of a fouled hatch window, and Earth appears much smaller in the viewfinder now. The satellite comparison is shown in figure 4.4.11.

Figure 4.4.10: AS12-50-7367. High quality source: [AIA]

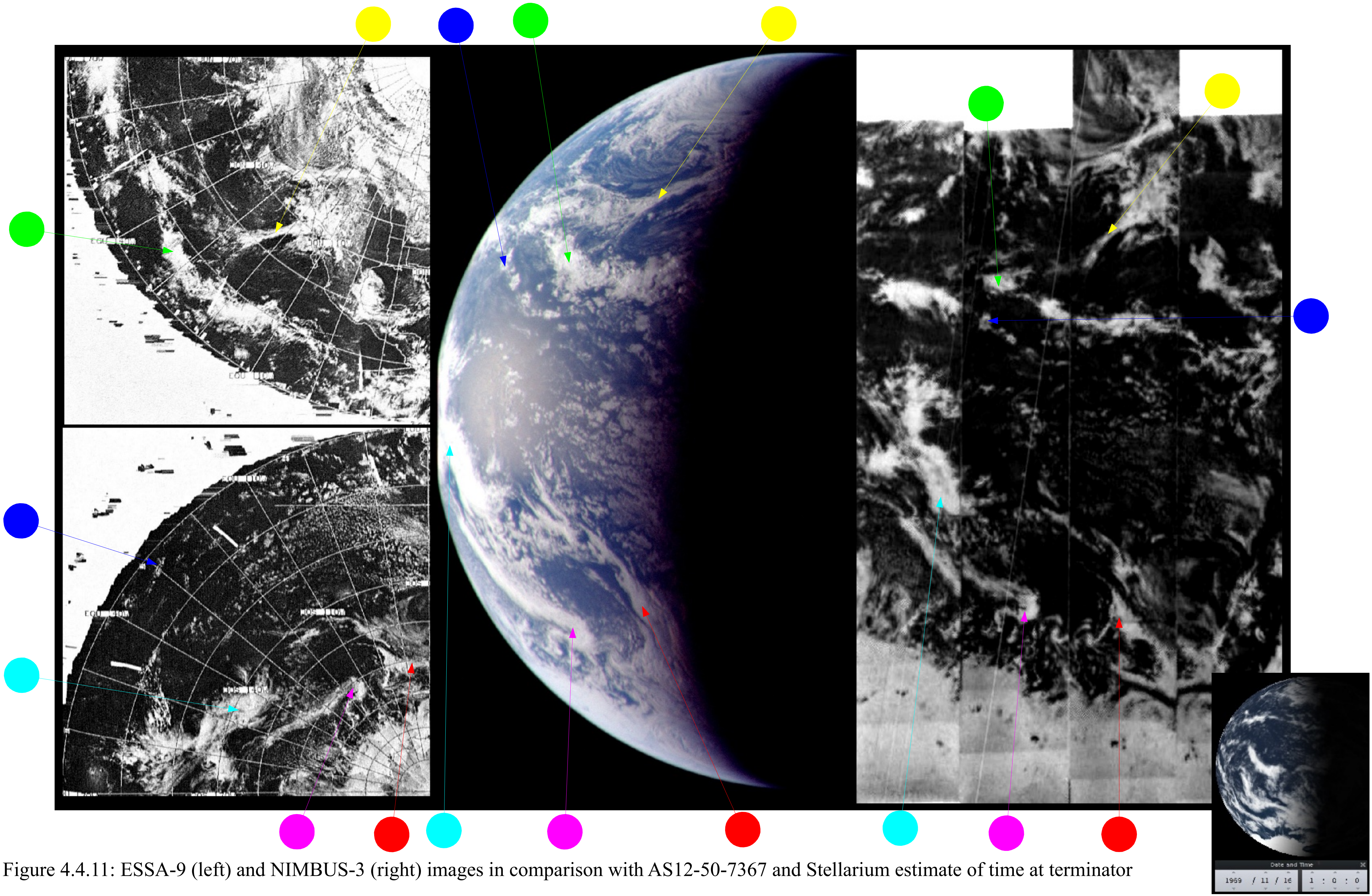


Figure 4.4.11: ESSA-9 (left) and NIMBUS-3 (right) images in comparison with AS12-50-7367 and Stellarium estimate of time at terminator

The photographs of the fouled hatch were taken sometime after 02:15 GMT, as this is the time (according to the mission transcript) that instructions on how best to photograph the windows were supplied by capcom. They were first described to capcom on the previous day, but are gone over in more detail half an hour prior to the photography instructions, so we have latest time of the photographs of around 01:45.

We also have descriptions from the crew of the terminator crossing Florida (although they do describe difficulties in determining land features) at around midnight GMT on the 16th, so we have a time for the photograph already of somewhere between those two. Stellarium has been set at 01:00 on the basis that no land masses are easily visible in the Apollo image.

Assuming a terminator line just off the west coast of north America, this would mean that the best ESSA orbit corresponding to that would be orbit 3280 (track 5), which commenced at 22:00 on the 15th. The equivalent NIMBUS pass is number 2889, which commenced at 18:18 on the 15th.

The next image to be examined is AS12-50-7377 and is shown in figure 4.4.12. It appears after the photographs of a fouled hatch window, which again gives us the starting point for working out when it was taken, and Earth appears much smaller in the viewfinder now. The satellite comparison is shown in figure 4.4.13.

Figure 4.4.12: AS12-50-7377. High quality source: AIA. Horizontal line is a fault on the original scan

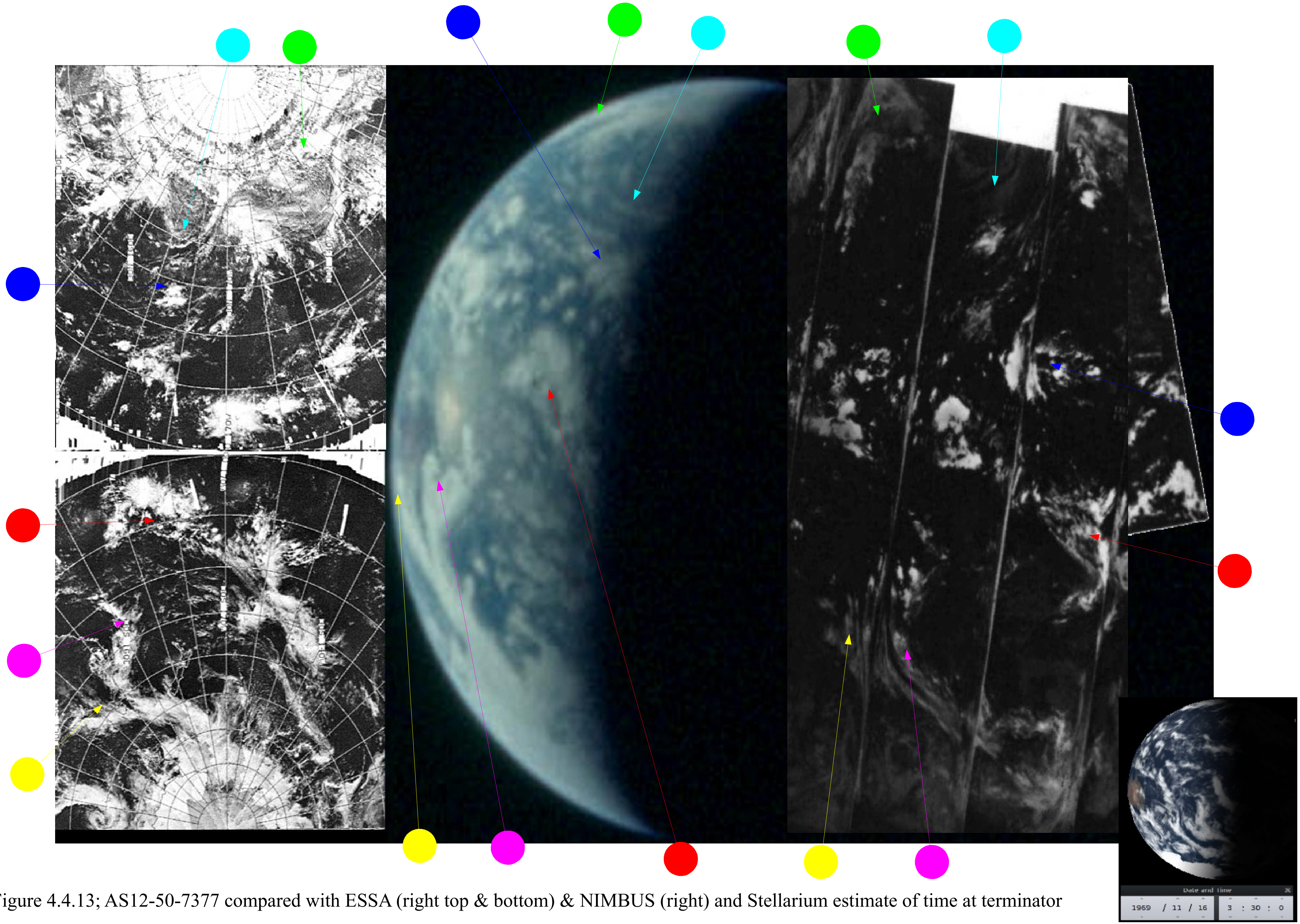


Figure 4.4.13; AS12-50-7377 compared with ESSA (right top & bottom) & NIMBUS (right) and Stellarium estimate of time at terminator

The NIMBUS data in the preceding image is night time infra red, which has the best coverage of that part of the globe on that date. The orbit that best represents the terminator here is number 2896, which commenced at 08:03 GMT on the 16th.

As for ESSA, the Apollo image terminator is mostly covered by track 6, or orbit number 3281. This pass was commenced on the 16th at 00:05 and appears on the image dated the 15th.

These compare favourably with Stellarium's time estimate of 03:30 using the position of Australia as a guide, but as indicated earlier, this figure may be out by a couple of hours because of the difference in perspective between Stellarium and Apollo 12. If a terminator line along the central Pacific is used as a guide (something that seems to be confirmed by the position of the cyan and red arrowed clouds), 05:30 may be a more representative time.

The date of the 16th can be confirmed convincingly by the weather pattern over south-eastern Australia, which does not appear in that configuration on any other date, and is a clear development of the system identified by the purple and magenta arrows in figure 4.4.8.

The next set of Earth photographs is a series of 4 showing the same view, and the first of these, AS12-50-7381, has been selected from this batch for comparison with the satellite images.

It is shown below in figure 4.4.14, and analysed overleaf in figure 4.4.15.

Figure 4.4.14. AS12-50-7381. High quality source here: AIA

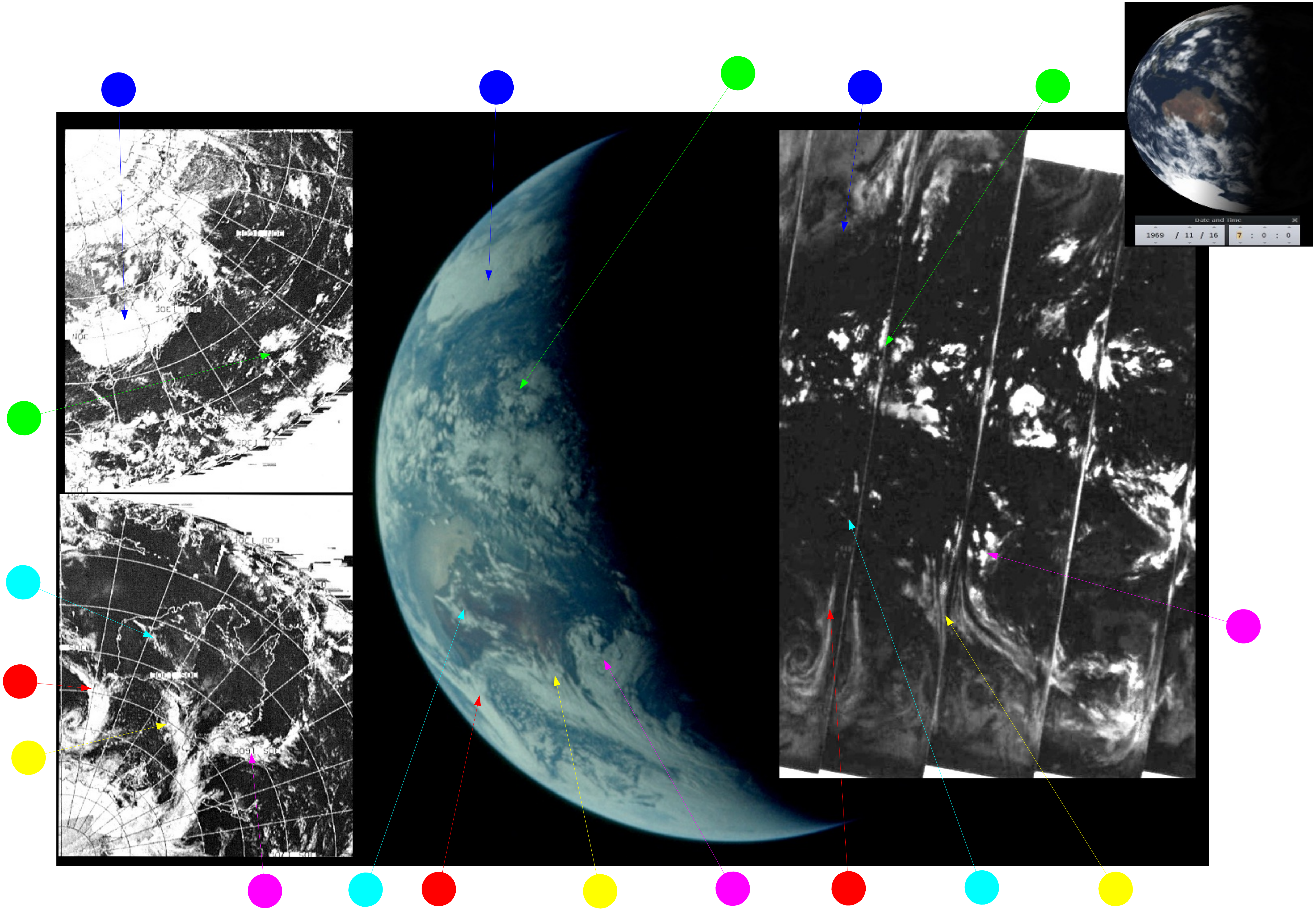


Figure 4.4.15: ESSA-9 (left) and NIMBUS-3 (right) images compared with AS12-50-5381 and Stellarium estimate of time at terminator

The distinctive plume of cloud below Australia (marked by the yellow and magenta arrows) has moved much closer to the terminator than in the previous analysis, which allows a more precise estimate of the time of the image,. Stellarium puts this photograph as being taken at around 07:00 GMT.

As with the previous image, the night time infra-red image has been used for NIMBUS coverage, as this has the best data for the region on that date.. It does mean that, as before, the cloud patterns visible on the NIMBUS mosaic are a reflection of the thermal conditions of the atmosphere, rather than what can actually be seen.

The NIMBUS orbit nearest the terminator is number 2897, which was started at 09:50 on the 16th. ESSA's terminator orbit is number 3283 (track 8) , which commenced at 04:06 on the 16th.

A few images later in magazine 50 there is a short sequence of images that show (on close examination) south America, largely identifiable by the same tell tale fog banks that linger off the west coast of North America. This automatically puts it about 12-14 hour after any image featuring Australia as the focus. Figure 4.4.16 shows AS12-50-7385, and figure 4.4.17 the satellite comparison.

Figure 4.4.16: AS12-50-7385. High quality source: AIA

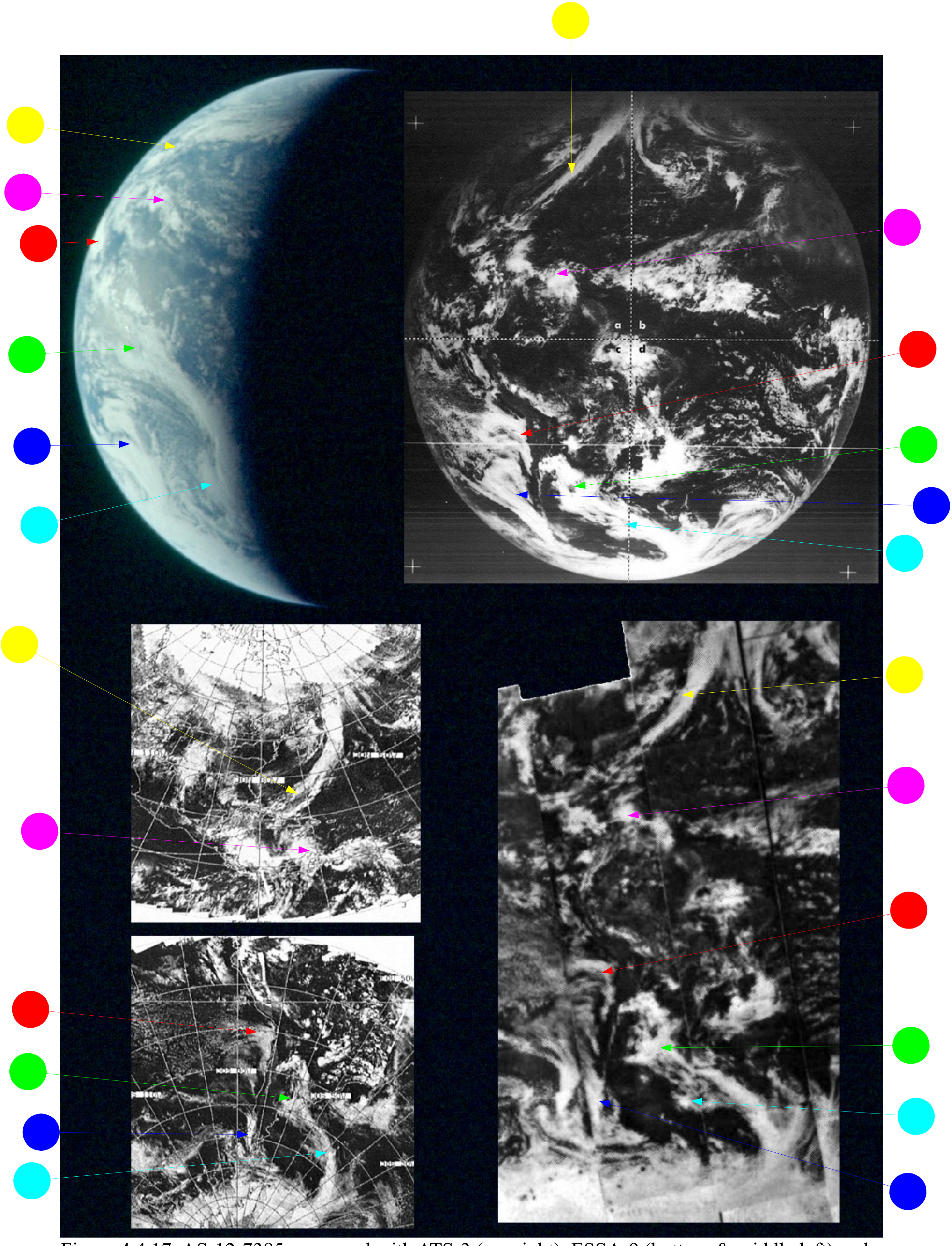


Figure 4.4.17: AS-12-7385 compared with ATS-3 (top right), ESSA-9 (bottom & middle left) and NIMBUS-3 (bottom right), with Stellarium inset.

With the cloud system cutting across south America very obvious on all the satellite images, it is photograph can be much more reliably estimated with Stellarium at around 20:00. That same cloud system is completely different on both the 15th and 17th, so the time and date can very easily be put at the 16th. The crew should, at that point, still have been in a rest period, but evidently someone wasn't asleep.

Also noticeable when comparing the Apollo image and Stellarium terminator lines is that now that Apollo 12 & the Moon are considerably closer together, and the position of the lunar viewpoint nears the point that Apollo 12 is aiming for, the shape of the terminator and the amount of the Earth's disk lit by the sun are much more similar.

The ATS image was taken at 14:44, and the entire globe is very obviously sunlit at that time, and as with other days there is a difference in configuration in the weather systems and in the angle of the satellite's view of the Earth. NIMBUS' daylight visible spectrum view over the east coast of south America would be from orbit 2900, which commenced at 14:03 on the 16th. ESSA's best fit pass for the same area is orbit 3289 (track 2) 16:08. Once again, an Apollo image shows weather patterns that are only visible at a specific time on a specific day.

The next series of Earth photographs occur immediately before two images of a distant lunar far side of the moon as Apollo 12 approaches LOI.

That photograph is shown in figure 4.4.18, and analysed overleaf in figure 4.4.19.

Figure 4.4.18: AS12-50-7388. High quality source: AIA

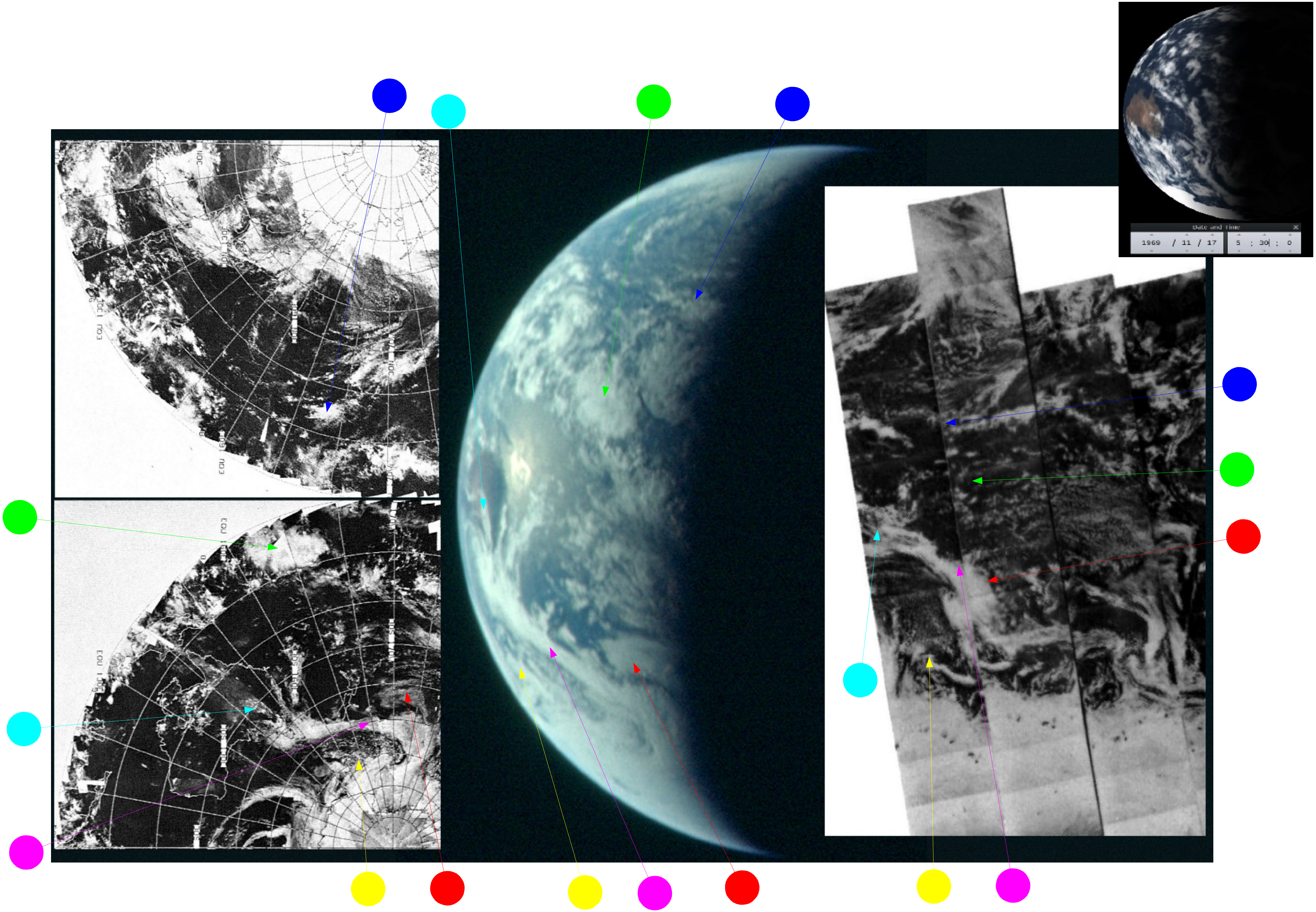


Figure 4.4.19: ESSA-9 (left) and NIMBUS-3 (right) images compared with AS12-50-5788 and Stellarium estimate of time at terminator

Around 24 hours since the last view of Australia and there is again a change in the configuration of the large frontal cloud mass south of Australia that extends up from the Antarctic (magenta arrow). The two distinct branches of the plume have gone, and smaller lobes extend off into the Australian interior than was the case the previous day.

Australia is just visible on the western limb, and this puts the time of the image at around 05:30 on the 17th.

ESSA's orbit nearest the terminator is 3293 (track 6), which commenced at 23:09 on the 16th. Australia itself would not have been imaged completely until 05:05 on the 17th (track 9, orbit 3296). NIMBUS is even further behind, at least for the visible spectrum images, which covered the terminator at 19:25 (pass 2903) on the 16th, putting the NIMBUS satellite some 10 hours behind the Apollo 1. This would help to explain the discrepancies in some areas between the cloud patterns that are easily identifiable on the Apollo and ESSA images, but not the NIMBUS ones (eg the blue and green arrows). Night time infra red images did cover the area nearer the time (around 03:00 on the 17th), but the quality of the image is much poorer, so little would have been gained.

The next few frames show a gradual change in the beneath the CSM (AS12-50-7388 for example shows Australia just appearing on the western horizon) as it rotates from the 16th towards the 17th of November and ever closer to LOI.

In AS12-50-7391 Australia is very obvious, which makes it an obvious candidate for comparison with satellite images . Figure 4.4.20 shows the Apollo image, and 4.4.21 shows the satellite comparison.

Figure 4.4.20: AS12-50-7391. High quality source: AIA

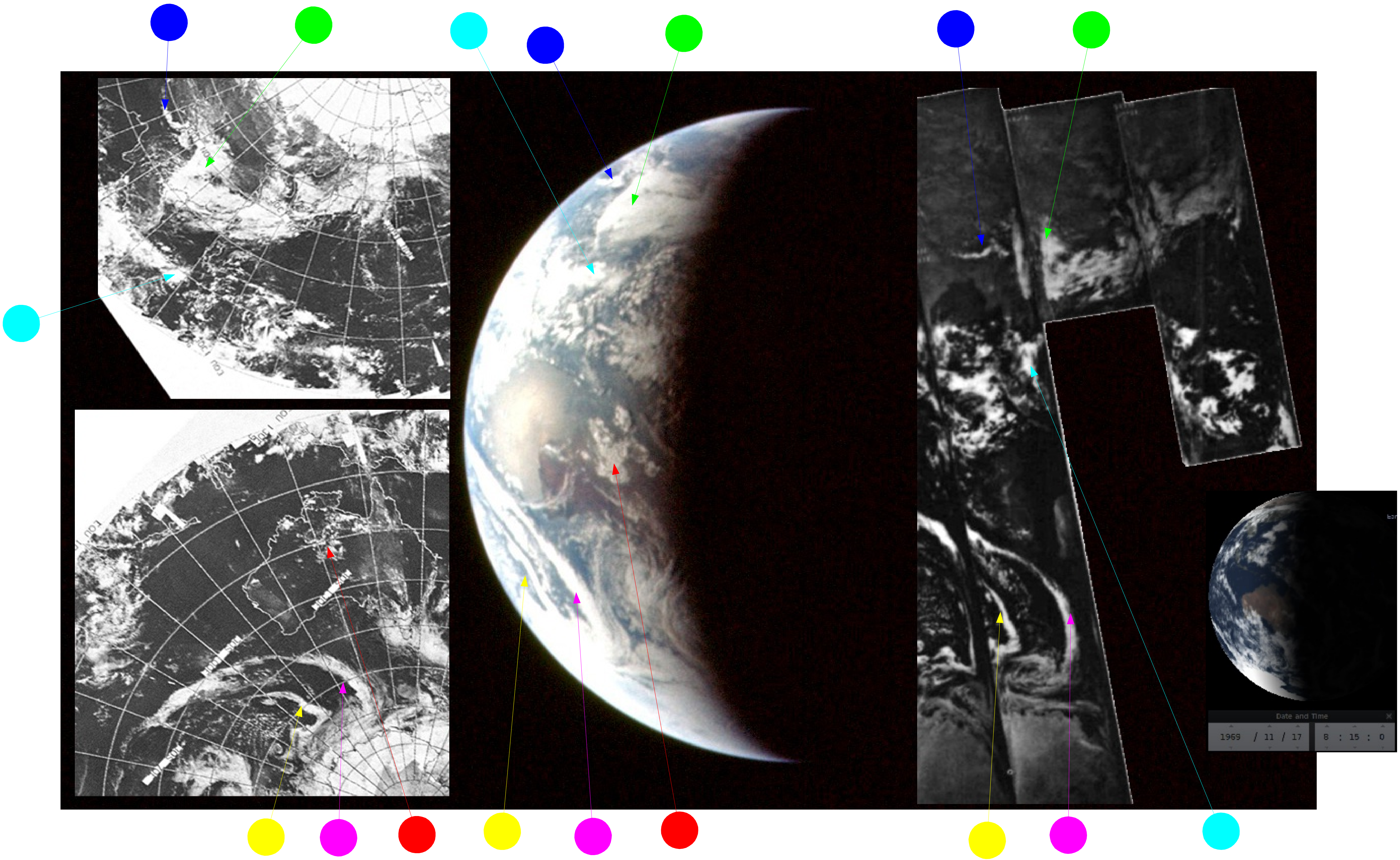


Figure 4.4.21: AS12-50-7391 compared with ESSA-9 (top & bottom left) and NIMBUS-3 (right). Qith Stellarium inset

The position of the terminator on the very edge of eastern Australia puts the time of the Apollo image at around 08:15.

What decides the date of this image is the large pointed weather system off western Australia (picked out by magenta and yellow arrows on the satellite images. ATS-3 does not cover this part of the globe, so we are restricted to NIMBUS & ESSA for our image supply. The system off western Australia does appear on the visible spectrum NIMBUS image, but this does not show the areas north of Australia, and for this reason the daylight infra red image has been used, which does show it.

The NIMBUS pass over Australia is 2907, which commenced at 03:24 on the 17th, giving it a few hours head start on the Apollo image. ESSA's best fit orbit is number 3296 (track 9), which is found on the image dated the 16th, but was actually started on November 17th at 05:05.

It is worth noting that between this and the next sequence of earth images there are two photographs of the Moon. They are noteworthy because they show the Moon in a completely different phase to that visible from Earth. Figure 4.4.22 shows Moon from AS12-50-7389 (Source: AIA). The CSM is approaching the Moon on an intercept course that will place it in an east-west orbit (as viewed from Earth), and hence is looking towards the moon from the west, not face on as in the Stellarium view. Further evidence that the Apollo craft was not looking at the Moon from a terrestrial perspective.

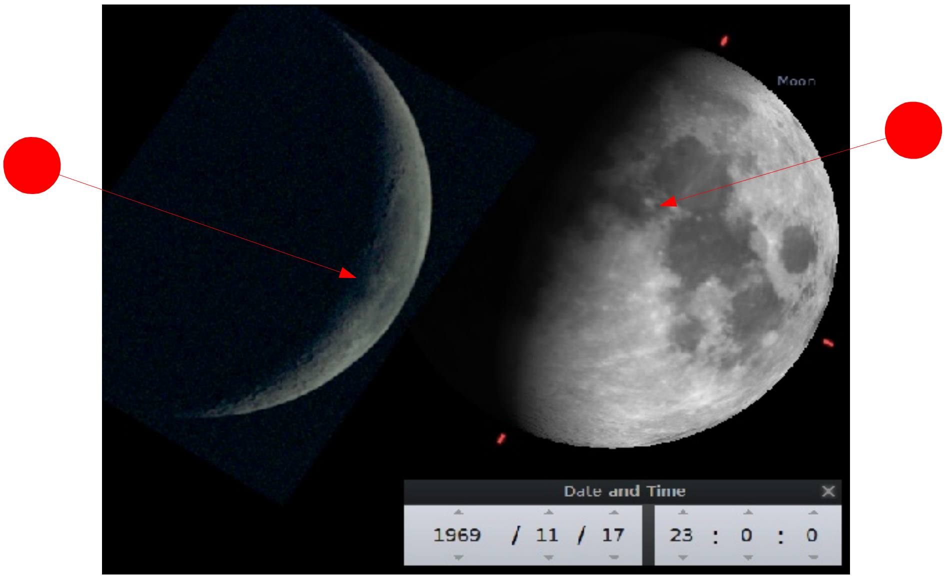


Figure 4.4.22: The Moon as seen from Apollo 12 shown in AS12-50-7389 compared with Stellarium's view from Earth at approximately the same time. The red arrow identifies the same crater, and the Moon has been rotated to the correct position.

The Apollo Image Atlas identifies this image (and the one following it) as showing the 'far side' and before the CSM's first lunar orbit ('Pre-REV 1'). The latter is definitely true, but at least half of the lunar disk would be visible from Earth. The fact that the other half could not is still significant.

Two final images will be examined from magazine 47 as these are the last before LOI, and occur after the images of the moon discussed above. As will be demonstrated, they were taken relatively closely together, and the second one shows the window frame and glass from the Apollo craft.

The images themselves are shown in figure 4.4.23-4, and the satellite comparisons are shown on the following pages as figure 4.4.2 & 4.4.26.

Figure 4.4.23: AS12-50-7394 (Source: [AIA])

Figure 4.4.24: AS12-50-7396 (Source: [AIA])

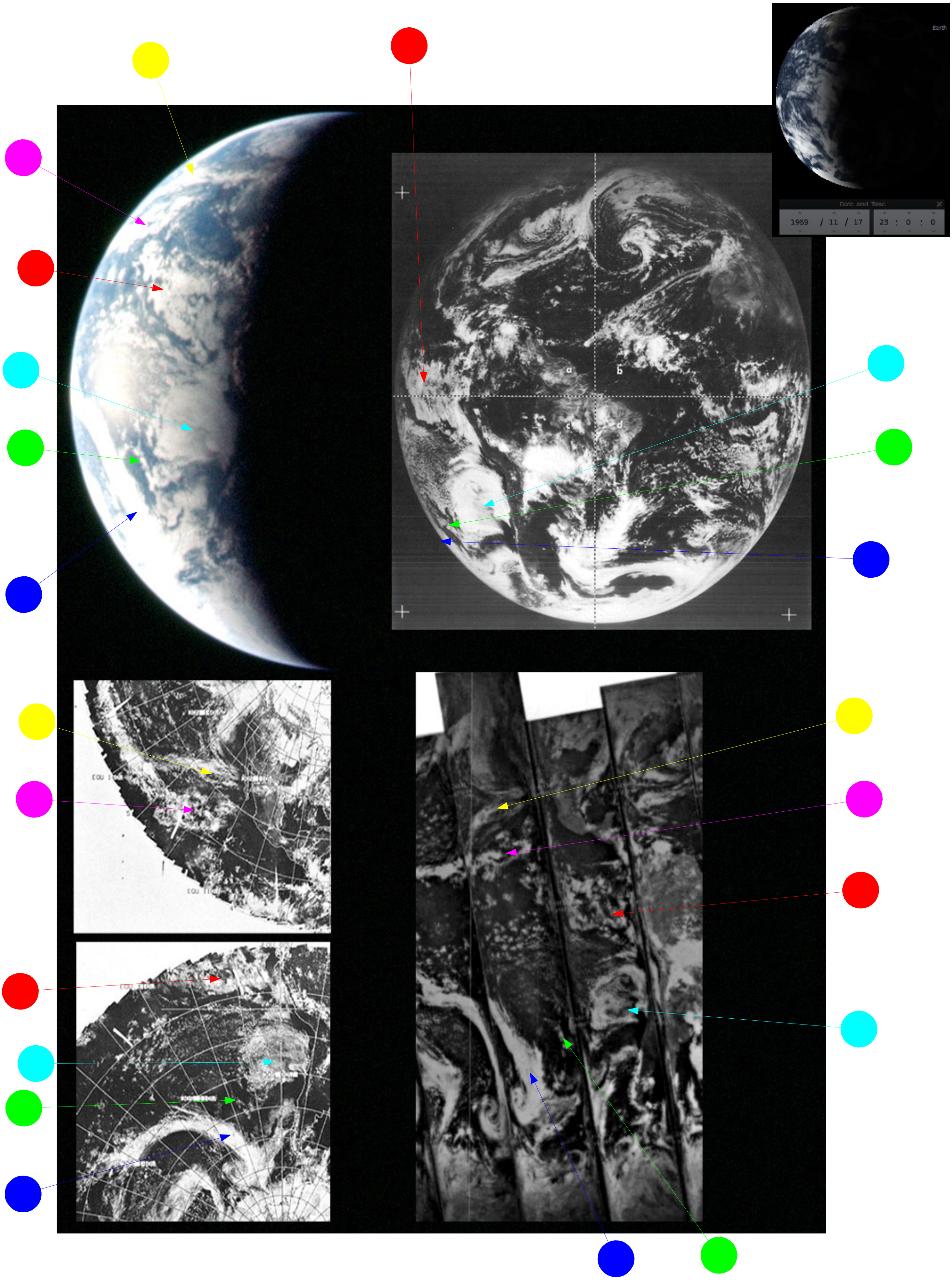


Figure 4.4.25: AS2-50-7394 compared with ATS-3 (top right), ESSA-9 (bottom middle & left) and NIMBUS-3 (bottom right) with Stellarium estimate of time at terminator

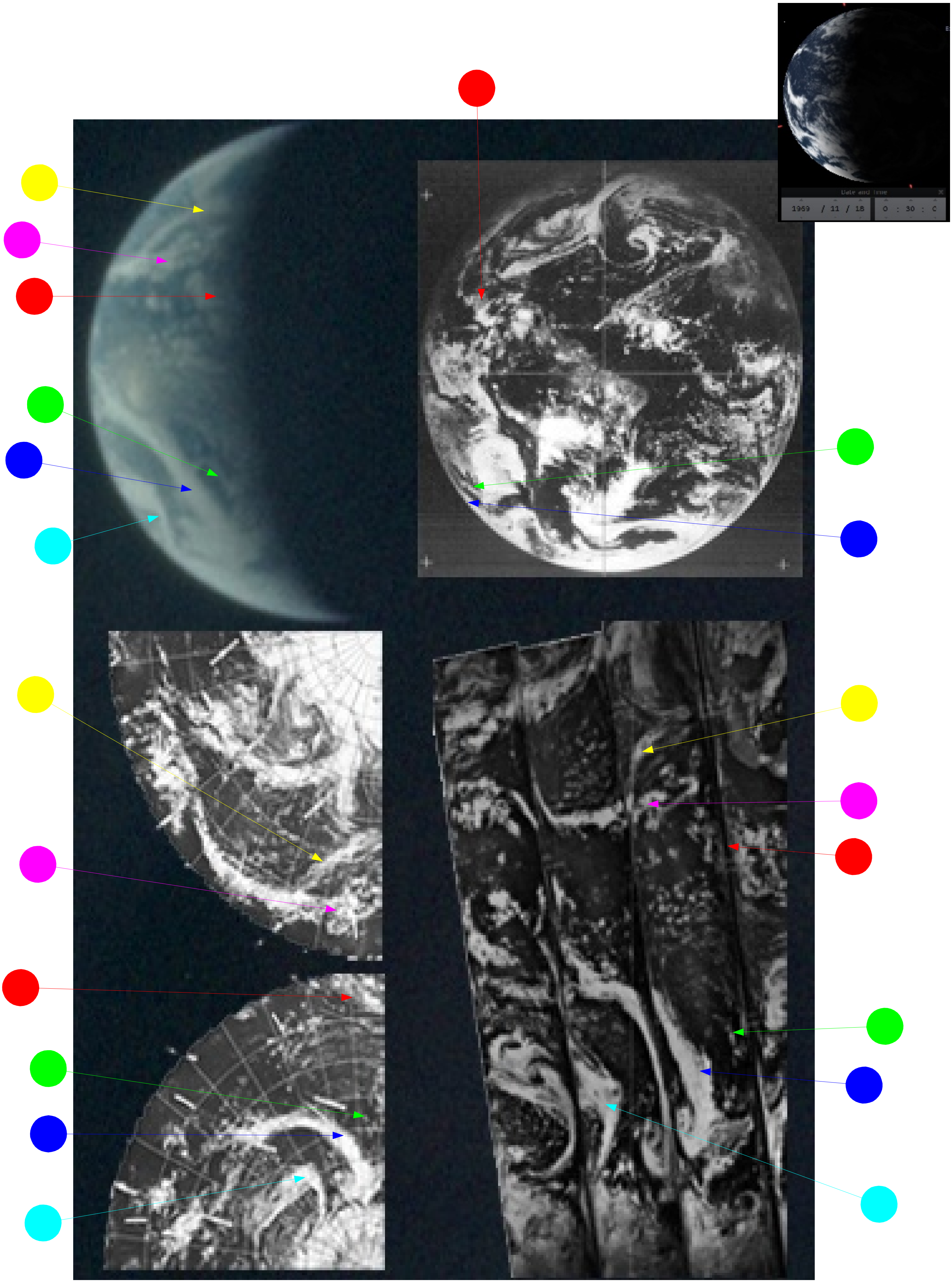


Figure 4.4.26: AS12-50-7396 compared with ATS-3 (top right), ESSA-9 (bottom middle & left) and NIMBUS-3 (bottom right) with Stellarium time estimate. All arrows except cyan as 4.4.25

The images analysed in the preceding two pages were taken relatively close together, as can be determined by nearly all of the identifier arrows being used in both analyses (the cyan one has been used as a link to the next photographs). The first photograph has the west coast of South America just visible, and most of of north America, which allows Stellarium to put the time at around 23:00. It is slightly more difficult to see the coast in the second image, but the cloud patterns picked out by the yellow and magenta arrows show that the terminator is just off the California coast, which would give an estimated time for the image of 00:30 on the 18th of November.

The most obvious features are the large circular cloud off Chile picked out by the cyan arrow (and the attendant flecks of cirrus clouds west of that that are visible once the circular feature disappears in to the night portion of the globe), the long finger of cloud stretching from the Antarctic north-westwards towards the equator (blue arrow), and the bifurcated equatorial cloud mass in the northern hemisphere picked out by yellow & magenta arrows.

As stated previously, the ATS-3 image is timed at 14:43 on the 17th, and as a result only those weather systems off the west coast of South America can be identified with any degree of confidence, but they are nonetheless identifiable. Both the NIMBUS and ESSA images are dated the 17th. The most representative daylight IR passes for NIMBUS are 2915 for figure 4.4.14 and 2916 for figure 4.4.15, which were commenced at 16:54 and 18:41 respectively. ESSA's most representative passes are tracks 4 and 5, passes 3304 & 5, commenced at 20:07 and 22:02 for the two images respectively. The suggested timings for the Apollo images are vindicated by the timings of the satellite photographs.

The remaining images on magazine 50 are close ups of the lunar surface, starting with very rounded lunar horizons and ending with much flatter ones, indicative of a space craft approaching the Moon. LOI for Apollo 12 is recorded as being carried at at 03:47 on the 18th, so it seems that AS12-50-7396 is the last photograph of Earth taken before entering lunar orbit, and the first lunar orbit proper started at 03:53 on the 18th, shortly before LOS.

For the next 24 hours the crew are somewhat busy checking out the LM and preparing for separation of the two craft and initiating the descent to the surface. This separation of the crew and their attendant cameras provides two vantage points for the Earth – one from the CSM & the other from the LM. Magazine 47 has a couple of Earthrise sequences before showing images taken on the lunar surface – one taken before separation from the CSM and one after, while magazine 51 shows one image of a distant Earth before separation, and several photographs of Earth taken on different orbits, including an Earthrise.

Pinning down exact timings of the images in these two magazines involves a certain amount of detective work. After LOI, the LM pilot entered the LM to perform system checks at around 08:50 on the 18th, finally entering with the mission commander at 00:42 on the 19th, where both crewmen remained. The LM & CSM separated at 04:16 on the 19th. Just after the start of magazine 47 are 4 images of an Earthrise. These occur immediately before 2 images of the CSM taken in to the sun, but after two images of the lunar horizon and a distant Tsiolkovsky – a far side crater proving that the image was taken after LOI.

It does not take a great deal of logical leaps to conclude that the 4 Earthrise shots were therefore taken before this time. Also featured in the images are one of the LM's quad thrusters, which suggests that the photographs were taken while in the LM, and it seems reasonable to assume that this was after all the camera equipment and other gear needed for the landing was transferred. A likely time seems around 105 hours and 41 minutes, which would be around AOS on the final orbit before separation.

The 2 photographs immediately following this short Earthrise sequence feature Copernicus, a prominent near side crater almost completely opposite Tsiolkovsky. Copernicus gets an enthusiastic mention by the crew at 106 hours 30 minutes, but prior to this they report that they were unable to find it, which would seem to confirm the suggestion that it the Earthrise was taken on the final orbit before separation, after their sighting of Tsiolkovsky.

This would give a working estimate of around 02:00 on the 19th for the this sequence, and AS12-47-6874 from that set will be examined next.

This image can be found at the AIA (source: AIA), but the high resolution scan has been overexposed and the actual image used has been acquired from the Gateway to Astronaut Photography (GAP). Even the better quality scan from the Gateway is of poor quality, and the Earth is out of focus. Making out anything other than the largest scale features. This complicates matters as these large scale weather systems are broadly similar over the period of lunar orbit, but the additional supporting evidence discussed previously helps to narrow down the relevant portion of the relevant satellite images.

Figure 4.4.27 shows this image, and figure 4.4.28 does what satellite comparison is possible

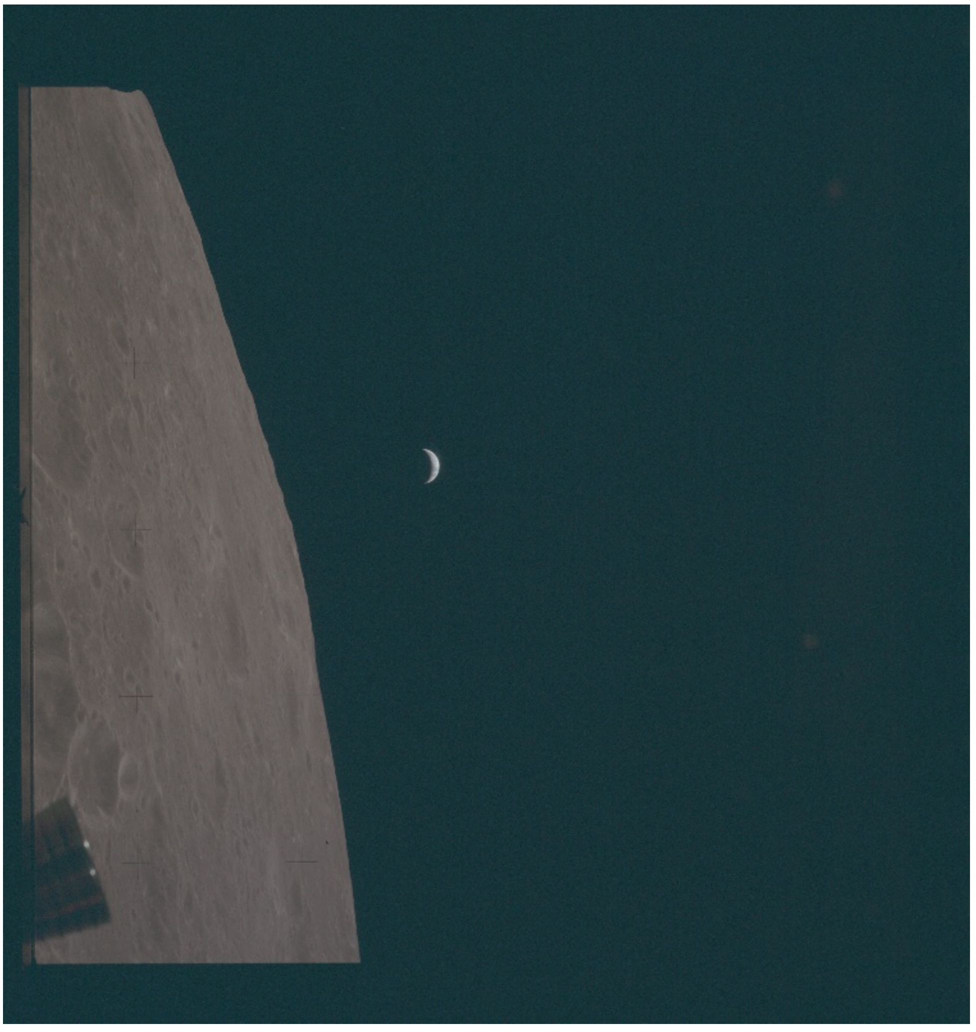


Figure 4.4.27: High quality GAP scan of image AS12-47-6874

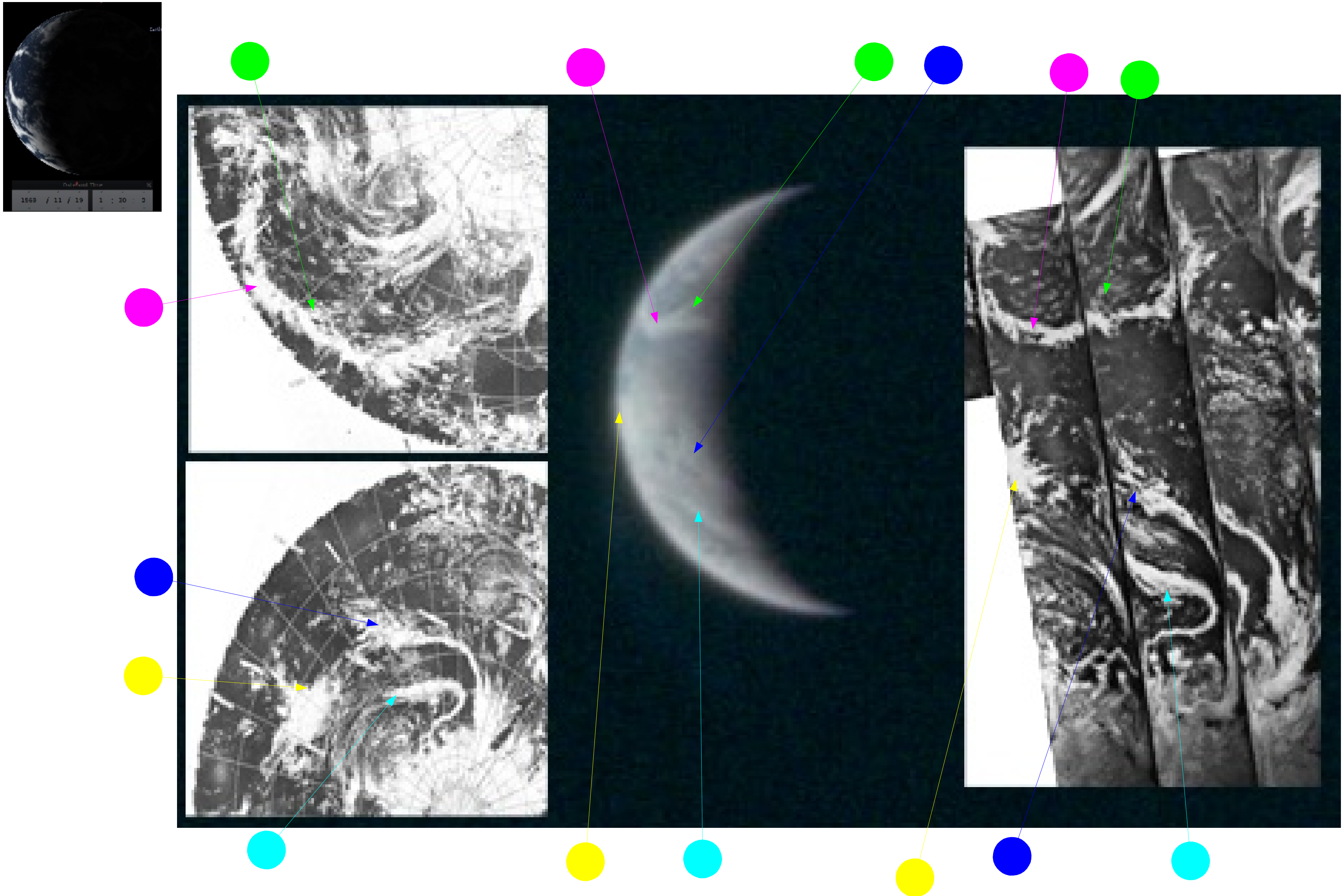


Figure 4.4.28: AS12-47-6874 compared with ESSA-9 (top & bottom left) & NIMBUS-3 (right) with Stellarium estimate of time at terminator. Magenta, cyan & blue arrows are as in figure 4.4.26

Timing this image as there is little in the way of landmass visible to pinpoint the terminator's exact location. The absence of land mass does allow a certain amount orientation in Stellarium. Australia does not appear until 5am, and California disappears at 1am, so the image must fall between these two times. The yellow arrow points to a cloud system that falls on the 170 degree longitude line, and if it is assumed that this is the same one picked out on the Apollo image, them the western horizon is at 170 degrees. If this is the case then the terminator falls roughly along the line picked at 140 degrees longitude in the northern hemisphere, a line which also falls on Alaska. As Stellarium's cloud patterns are fixed and there is a spiral one over Alaska, its estimate of 01:30 seems reasonable, and coincides well with the estimate worked out in the preamble to this image's analysis.

Both of the satellite images chosen are from the 18th, as their orbital passes are closer to this time than they would be in images taken on the 19th. ESSA's best orbit is 3318 (track 6) which commenced at 23:01, & NIMBUS' orbit 2930 on the daylight IR image is the most appropriate one for the Apollo picture, and this commenced at 19:48.

Another film magazine contains an image of Earth before separation but is definitely from lunar orbit: number 51. This roll starts with a large number of 'face on' images of the lunar surface, placing it firmly in lunar orbit. AS12-51-7489 features a very distant shot of Earth, immediately after which comes a sequence of images showing the LM after separation. Image 7489 must therefore have been taken before separation at 04:16 on the 19th, and after LOI at 03:47 on the 18th. As with the previous image, the image is out of focus and blurred, with only large scale systems can be identifiable, but there should be sufficient detail to demonstrate the point. Figure 4.4.29 shows the original image and figure 4.4.30 the satellite comparison.

Figure 4.4.29: AS12-51-7489 (Source: AIA).

They key weather system that allows us to identify both the date and time of the Apollo image is that picked out by the green & cyan arrows off the south-eastern coast of Australia. Although there is an apparent discolouration on the Apollo image that might be taken for the Australian land mass,

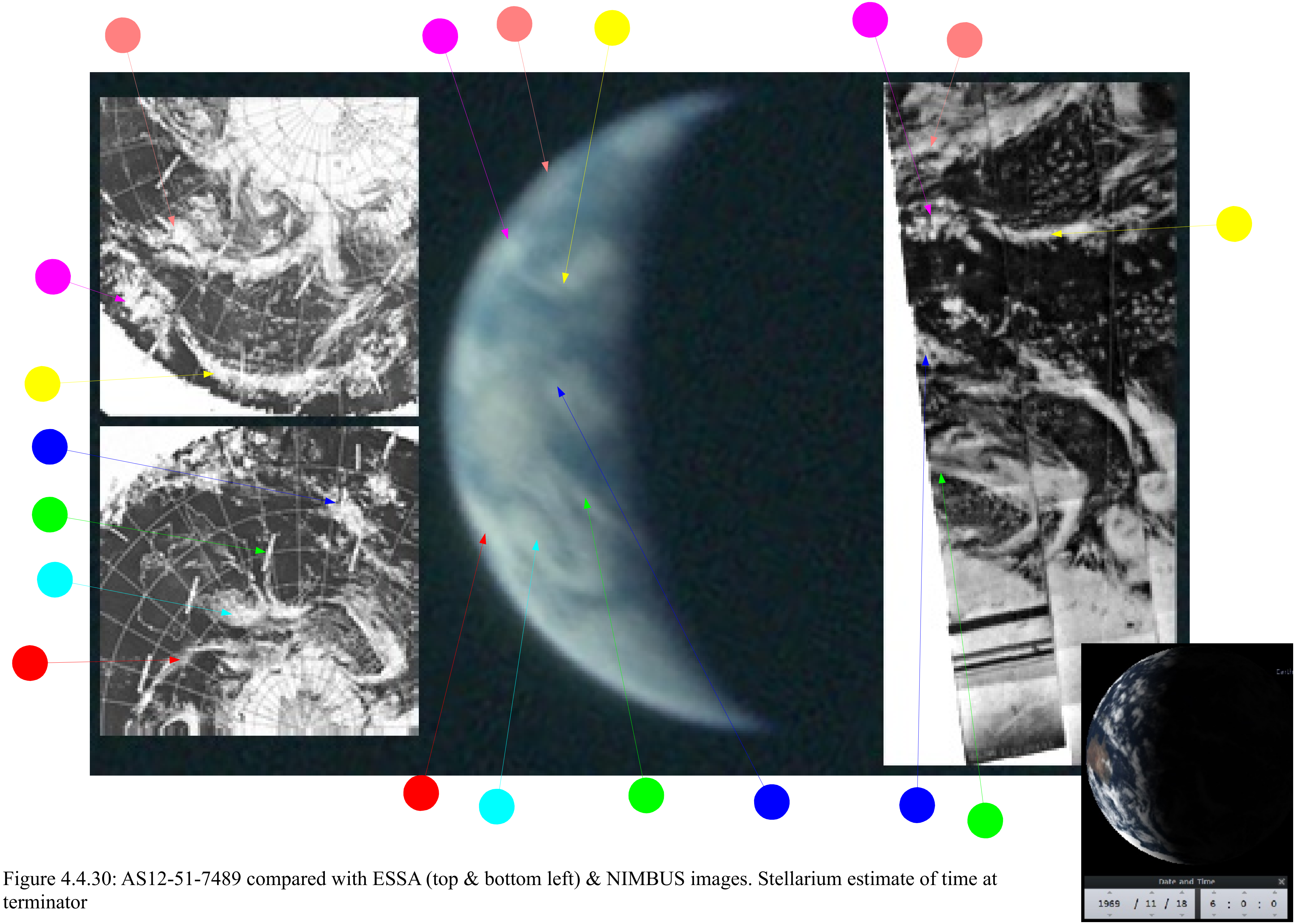


Figure 4.4.30: AS12-51-7489 compared with ESSA (top & bottom left) & NIMBUS images. Stellarium estimate of time at terminator

it is more likely that this is the sub-solar point. This is not to say that Australia isn't underneath it! Once this weather pattern is accepted, the other ones can be more easily identified. What also emerges from this is that the photograph was taken on the 18th, not the 19th. Stellarium puts the time of this (based on Australia's position), at around 06:00. The satellite images used in the comparison are both dated the 17th, as their timings are nearer to this 06:00 position than those dated the 18th.

ESSA's best orbit from this image is orbit 3308 (track 8) which was actually commenced at 04:08 on the 18th, while NIMBUS' best available orbit is 2918 which commenced at 22:16 on the 17th. The orbits covering Australia exactly do not feature clear images, or are absent, hence the much earlier start for this satellite.

A time of 06:00 would put the still joined spacecraft on their second orbit, and the crew do discuss taking photographs during the first two orbits (it also coincided with a TV broadcast). This is supported by the first few images in the magazine, which shows an initially lit lunar surface over *Mare Nectaris* (on the eastern near side), followed by darker frames, then a brightly lit one of *Mare Nubium* in the South East before the darker frames and then the photograph of Earth. This is again strongly suggestive of at least 2 orbits taking place on this magazine before the Earth image, but as Australia would disappear from view very soon, it has to be very early in their series of lunar orbits.

Immediately after separation of the LM from the CSM in magazine 40 is sequence of Earthrise images. As magazine 47 went to the lunar surface, and didn't complete more than one complete revolution as it did so, timing the image is much simpler than the preceding two, It is also helped by the astronauts' chatter in the LM as they discuss the upcoming Earthrise and making sure that they captured it (see the LM voice transcript) at 4d13h43m, or 109:43 hours MET, or around 06:00 on the 19th – 55 minutes before landing.

Figure 4.4.31 shows one of these images, and figure 4.4.32 the satellite comparison.

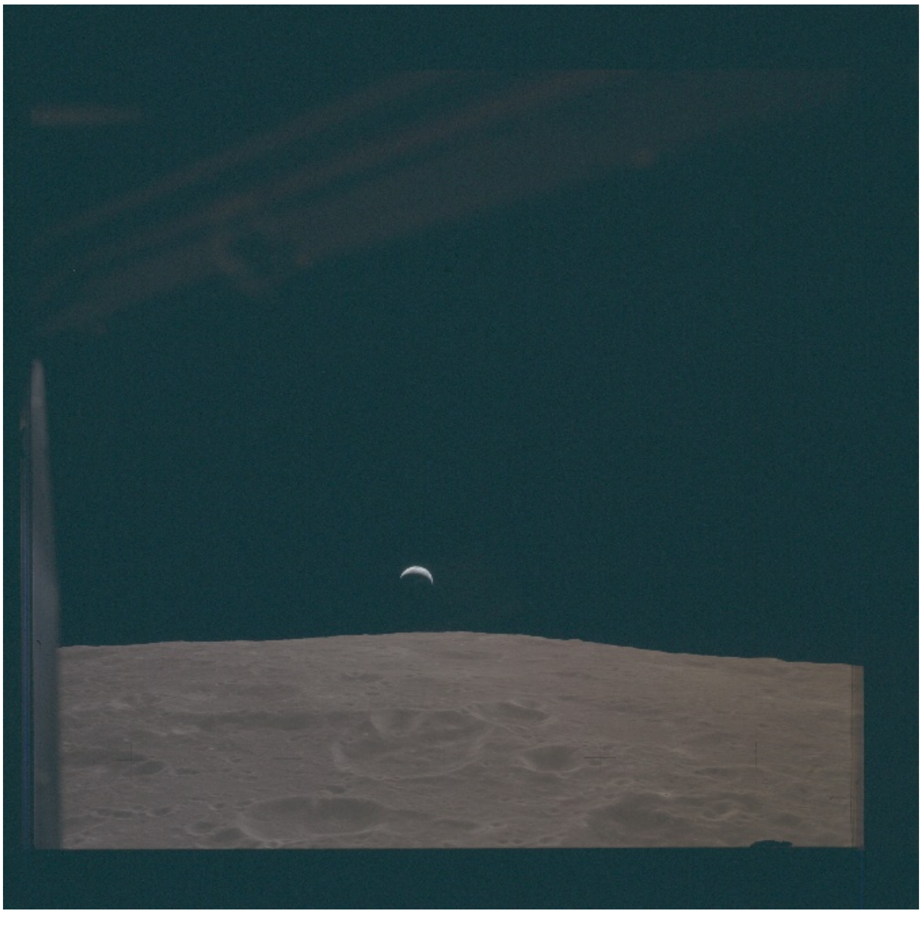
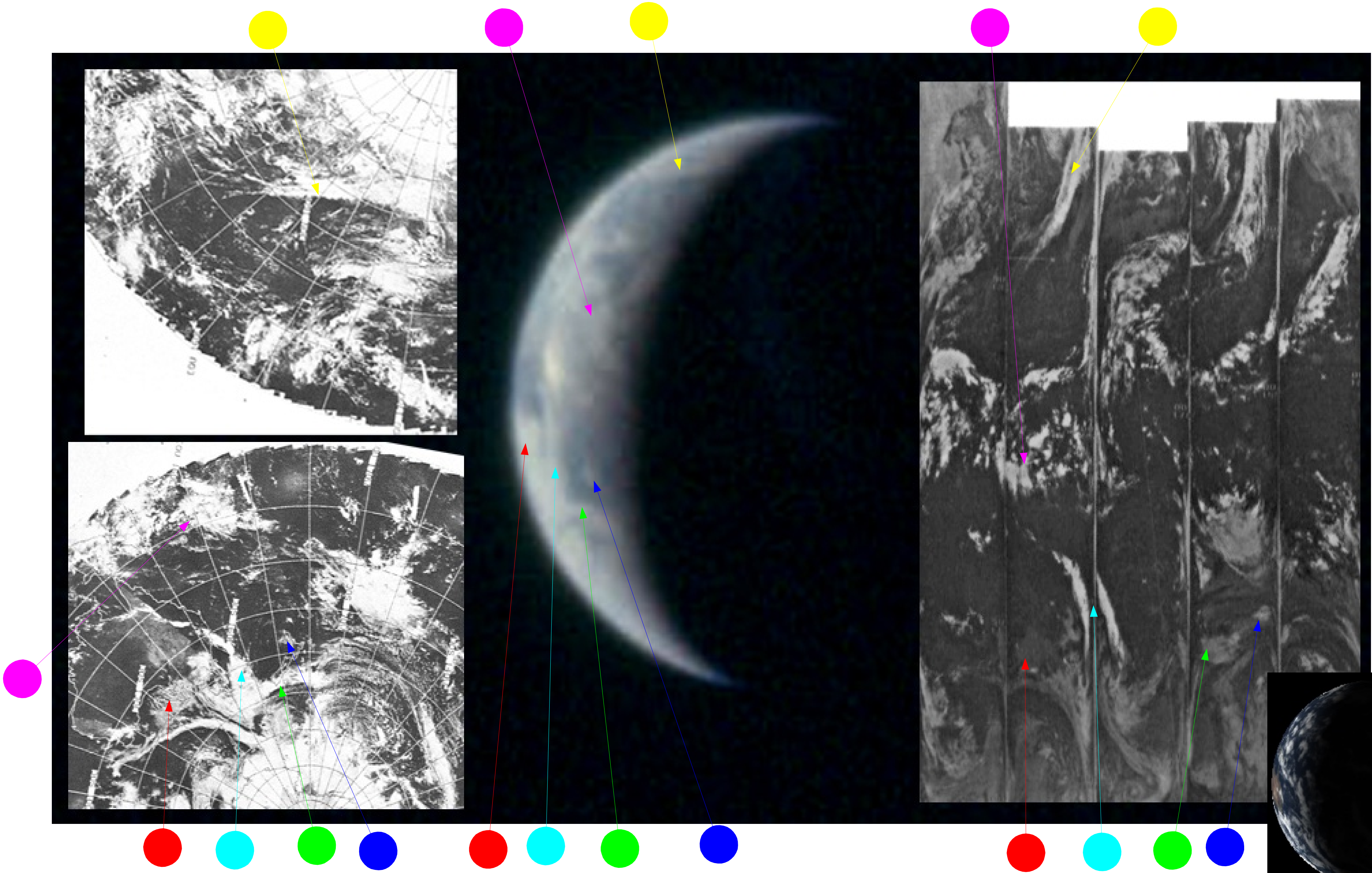


Figure 4.4.32: High quality GAP scan of AS12-47-6894. Poor quality image here http://www.lpi.usra.edu/resources/apollo/images/print/AS12/47/6894.jpg.



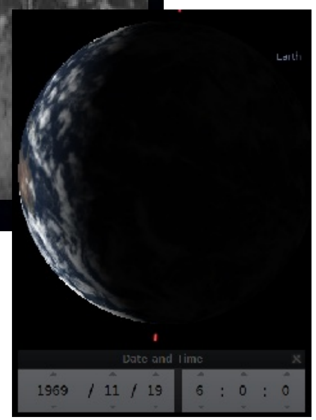


Figure 4.4.32: AS12-47-6894 compared with ESSA (top & bottom left) & Nimbus night time IR (right), with Stellarium estimate of time at terminator.

As with the previous analysis, the key to this one is the weather system off south-eastern Australia, picked out in cyan, green and red arrows. Once these have been identified, the others are relatively straightforward to place, even with the blurred image available. As these clouds are on the western edge of the visible Earth, it becomes relatively easy to position Australia correctly and derive a time from Stellarium that the image was taken. Stellarium confirms very precisely the time suggested by the LM dialogue at 06:00. The satellite images are able to confirm the date as the 19th.

ESSA's best track over this area is again number 8, and orbit 3321 on the image dated the 18th was commenced at 05:07 on the 19th. For once, the NIMBUS night time orbit gives the best visible data (and the day time images are absent!), and pass number 2938 on the 19th was commenced at 11:15 – 5 hours later than the Apollo image but providing a good match.

No more images of Earth from other orbits are available on this magazine, and none were taken by the crew on the lunar surface. By this time it was becoming an increasingly thin crescent and would not have presented much of an object in the sky.

While Bean & Conrad set off for the surface, Gordon continued his orbits, and took a further 3 sequences of Earth images in magazine 51. The first of those occur immediately after the separation images. As separation occurred over crater *Ptolemaeus* in the centre of the near side and the photographs contain no sign of the Moon, it is likely that the Earth image was taken by looking straight back towards home just after separation.

Of the two available, the image chosen is AS12-51-7513 as it is the sharpest. This image is available here: AIA and is shown in figure 4.4.33, figure 4.4.34 shows the satellite comparison.

Figure 4.4.33: AS12-51-7513.

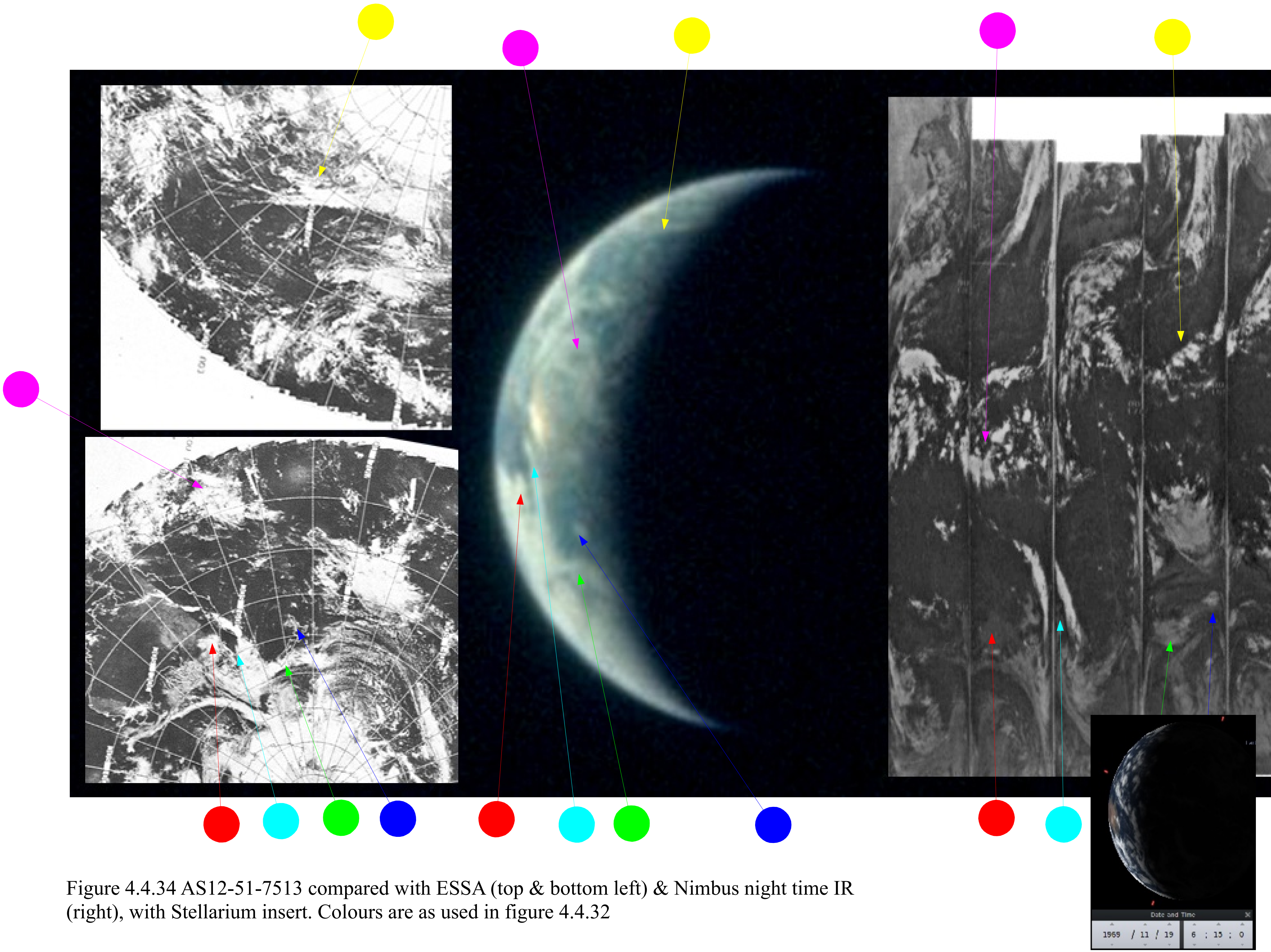


Figure 4.4.34 AS12-51-7513 compared with ESSA (top & bottom left) & Nimbus night time IR (right), with Stellarium insert. Colours are as used in figure 4.4.32

The most obvious point to make about figure 4.4.34 is it's similarity to figure 4.4.32. Indeed the satellite image sections are the same, so the ESSA and NIMBUS timings cited earlier will also be the same for this analysis.

The only significant difference between the two Earths is that in this one the globe has revolved slightly further, exposing more of Australia (see figure 4.4.35), something that proves it is not merely a copy of the Earth seen in the Moon bound photograph. This rotation adds roughly 15 minutes to the time of this image compared with the previous one. The absence of any Moon at all in this photograph also confirms that it was taken some time after the Earthrise greeted so exuberantly by Bean and Conrad.

The relative sharpness of this picture also allows a degree more certainty in identifying the weather patterns on the satellite photographs compared with the Apollo Earth, and has helped to confirm the analysis given in figure 4.4.32.

After separation, the CSM continued to orbit and captured another 2 sequences of images. The first one consists of two photographs of a crescented Earth with no lunar surface visible. This is not an Earthrise sequence, but the CSM has obviously passed around the moon at least once since the preceding image, as there are photographs of the lunar surface in various stages of light and shade, and Mare Nubium on the east followed by far side craters such as Mendelev.

The best quality image is AS12-51-7523 (source: AIA), shown in figure 4.4.35, and analysed in figure 4.4.36.

Figure 4.4.35: AS12-51-7523

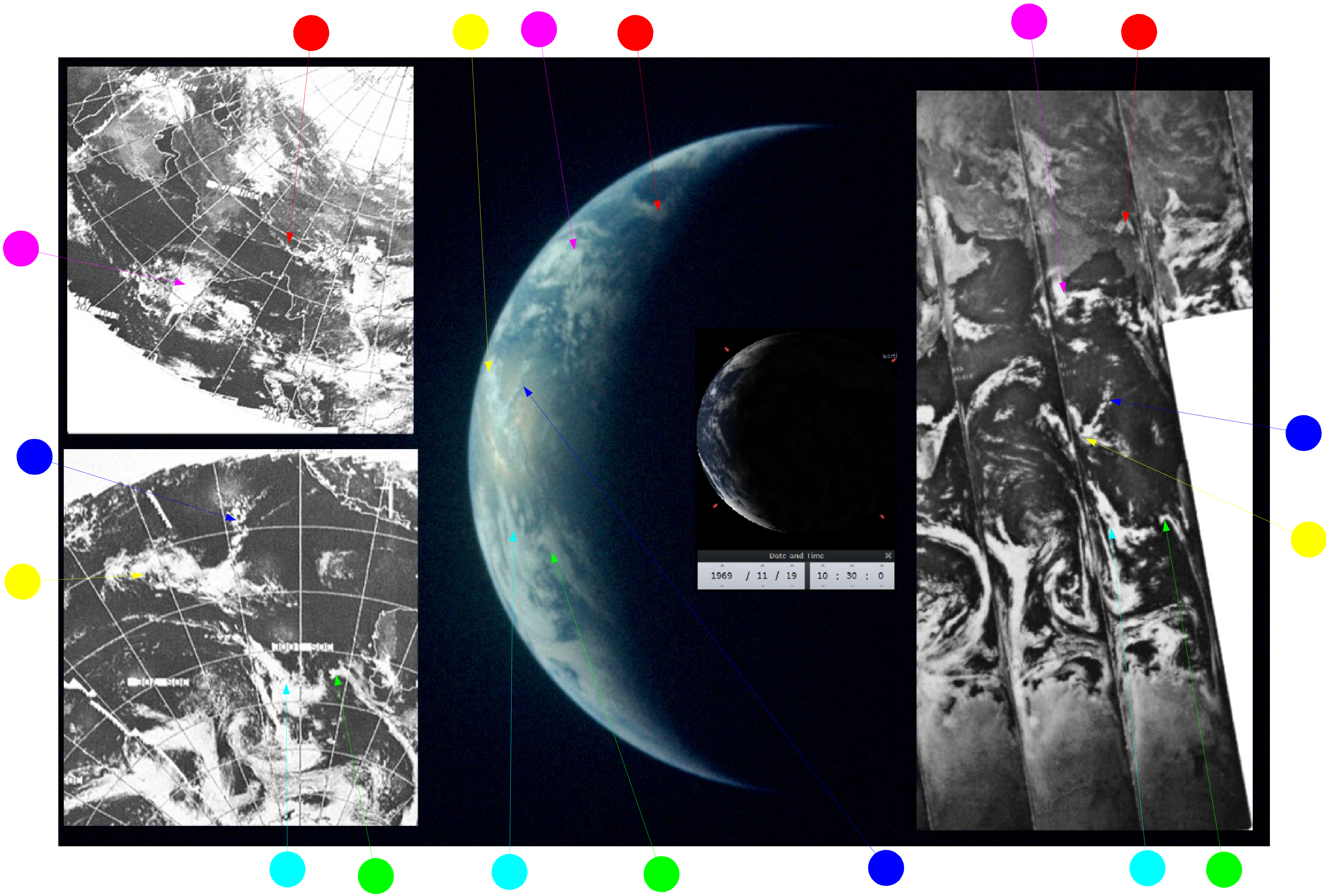


Figure 4.4.36: AS12-51-7523 compared with ESSA-0 (top & bottom left) and NIMBUS-3 (right) with Stellarium estimate of time at terminator

The ESSA image used is again from the 18th, and the most obvious cloud that specifically pins it down to that day's image is the one highlighted by the yellow arrow, and as with previous images once the most obvious cloud is identified the rest fall into place. Track 10 covers most of the image's daylight portion, and this corresponds to pass number 3302, commenced at 07:03 on the 19th. The NIMBUS image is the daylight IR data from the 19th, and pass 2935 covers the coast off western Australia up towards India. This was started at 04:42.

Looking at the top of the Earth's crescent in this image reveals a landmass, and it is this that allows the time at terminator to be picked out. The clouds identified by the red arrow are over that landmass, and which puts the terminator position as at roughly 10:30 – about 3 orbits later than the preceding photograph. As it is not an Earthrise image it could have been taken at any point in the nearside part of the lunar orbit, but there is at least one orbit between the previous image analysed and this one. 10:30 would put the mission elapsed time at just over 114 hours 10 minutes, or 4d18h in. We know that the CSM was over the daylight side at that time, because at 4d18h23m Dick Gordon announces that he has sighted the LM through the sextant.

The final Earth sequence (but not the final Earth image) to be examined was taken immediately after the preceding one. AS12-51-7528 is towards the end of that sequence and is picked for no other reason than it is a high quality image available as a TIFF from Archive.org.

The image is shown in figure 4.4.37, and examined in 4.4.38.

Figure 4.4.37: AS12-51-7528

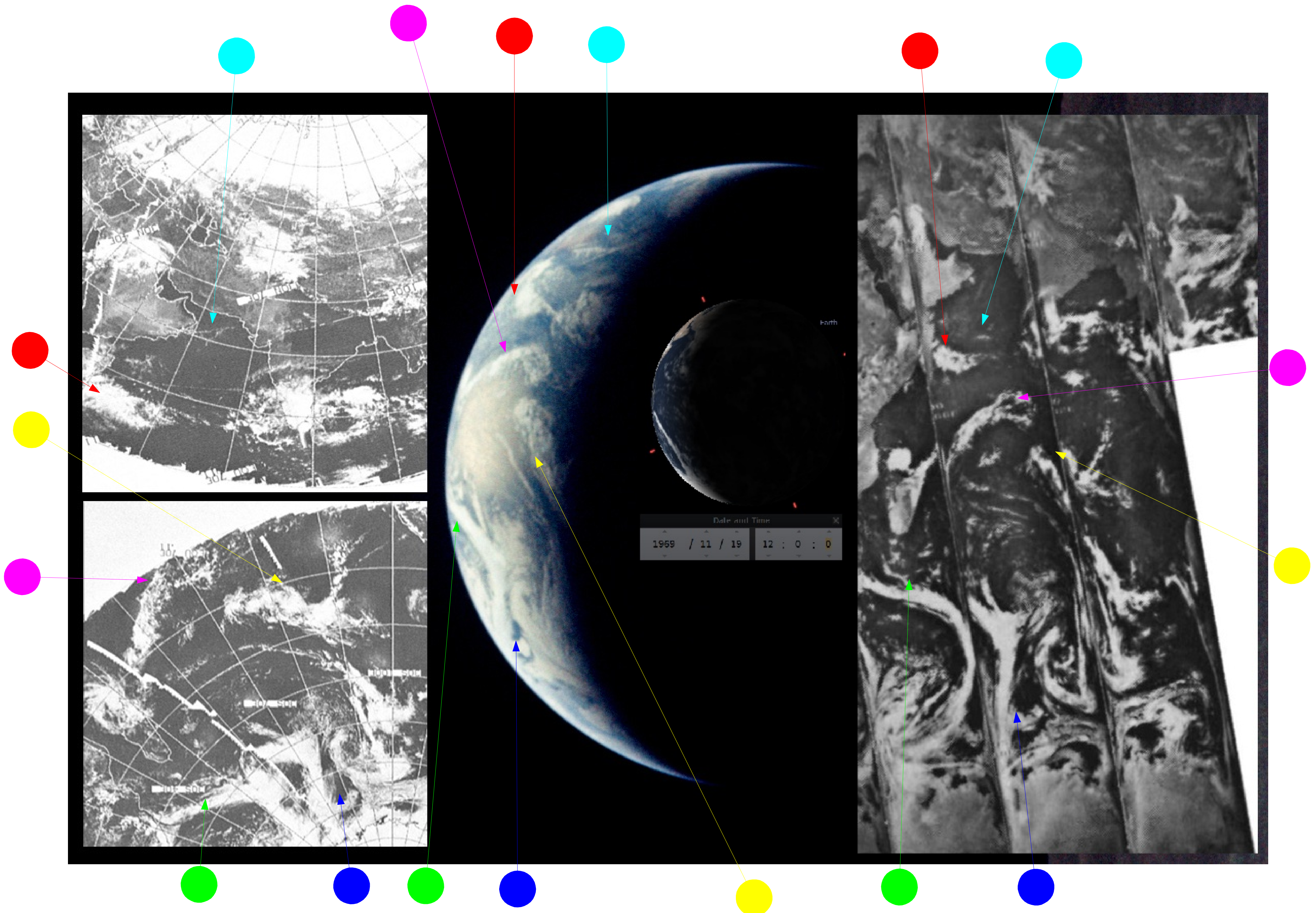


Figure 4.4.38: AS12-51-7528 compared with ESSA-9 (top & bottom left) and NIMBUS-3 (right) and Stellarium inset. Yellow arrow same as figure 4.4.25

There are no intervening pictures of lunar surface to act as a guide for how many orbits have elapsed between AS12-51-7523 and 8, but the clouds identified by the yellow arrow are a clue. It is definitely the same cloud in both images as can be confirmed by the thin strip of cloud running parallel and below it in both photographs. The blob of bright cloud on the very western edge of this band of cloud is highly likely to be a tropical storm over the Comorra islands on the 19th, visible to the north of Madagascar on the NIMBUS image. This allows confirmation that the clouds picked out by the magenta arrow (just visible in AS12-51-7523 on the western edge of the Earth) start at the eastern end overlie Madagascar, which allows a pretty confident identification of where the terminator lies. This gives a Stellarium based estimate of the time of the image as around 12:00 on the 19th. This would put the CSM just one orbit further on than in the previous image.

Consequently, there is not much difference in the satellite image timings for the visible part of the Earth's surface. NIMBUS orbit 2936 is the major part of the daylight IR image used, which commenced at 06:29 on the 19th. ESSA's companion pass is 3323 (track 11). which commenced at 09:08. As usual, two satellites show images from a specific day with specific cloud formations unique to that day, and that match the Apollo image.

The final image examined from Apollo 12 is presented partly as a piece of detective work, and partly to point out a possible error in the Apollo Image Atlas.

AS12-51-7581 (figure 4.4.39) is described by the AIA as “Almost total eclipse of Earth”

Figure 4.4.39: AS12-51-7581 (Source AIA)

Apollo 12 did experience a unique solar eclipse as it passed a point where the Earth completely blocked out the sun. There are, however, a couple of pointers to the fact that this is not a total eclipse. One fact is that by the time of the actual 'eclipse', the 24th, the crew had run out of colour film, and could only shoot the event in black & white. The other major clue is obviously present in the photograph: lens flares. The sun is off to the bottom of the picture (this is even more obvious in subsequent photographs in the magazine but they don't show the Earth crescent as well), so it can't therefore be behind the Earth!

So when was it taken? The image is actually showing the Earth as a crescent continuing to change phase naturally as it has throughout the mission. Figure 4.4.40 shows Stellarium views from the Apollo 12 landing site at noon from the 20th to the 24th of November, illustrating the changing phase from a lunar perspective.

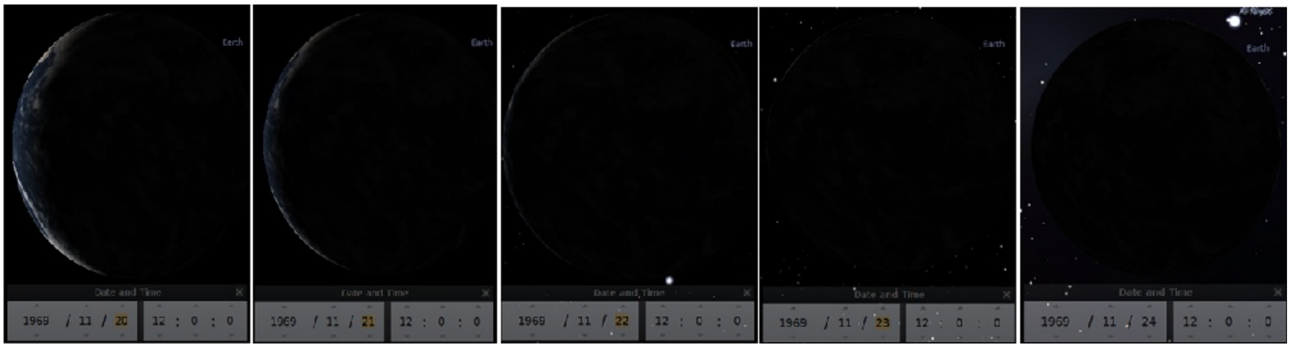


Figure 4.4.40: Stellarium views from Apollo 12's landing site of Earth at noon from 20-24/11-69.

Looking at these crescent views, the perspective most like that in the Apollo image is that of the 21st, probably later than the 12:00. The whereabouts of Apollo 12 by the 21st depends on when it was taken, as early on in the day it was involved in landmark photography while still in orbit, but at 20:51 it performed a TEI burn.

The size of the Earth in the photograph suggests it is much closer to the CSM than the views given in orbital images featuring Earth. The tricky part now is is to identify any weather patterns. We have a very small amount of visible cloud, but at least a 24 hour window within which to search. The ESSA image dated the 21st will cover the globe from around noon on that day to noon the next day, so the clouds we are looking for should be visible on that image somewhere.

The visible cloud system consists of a large but well defined tropical cloud mass, (at that time of year, the centre line through the widest part of the crescent should roughly equate to the latitude 10 degrees south) to the north of which are high altitude cirrus type clouds and to the south an elongated band stretching south-westwards towards the south pole, and west of that a much larger cloud mass. Further north on the western horizon there is a more solid looking body of cloud showing a clear shadow beneath it.

For once, there will be no guarantee that the exact cloud has been found, but figure 4.4.41 shows the most likely candidate. The clouds arrowed in green are on the line of 10 degrees south, there are wispy clouds to the north of them, bands of clouds to the south. These patterns are particularly evident on the NIMBUS daylight IR image, and the cloud's shape is much more similar to the Apollo image. The pictures from the 22nd bear much less similarity to Apollo, and of course after this the Earth's crescent starts to become much too thin.

The exact time at terminator would depend on how much of Australia is assumed to be visible In this case at least some has been assumed, giving a time of around 07:30.

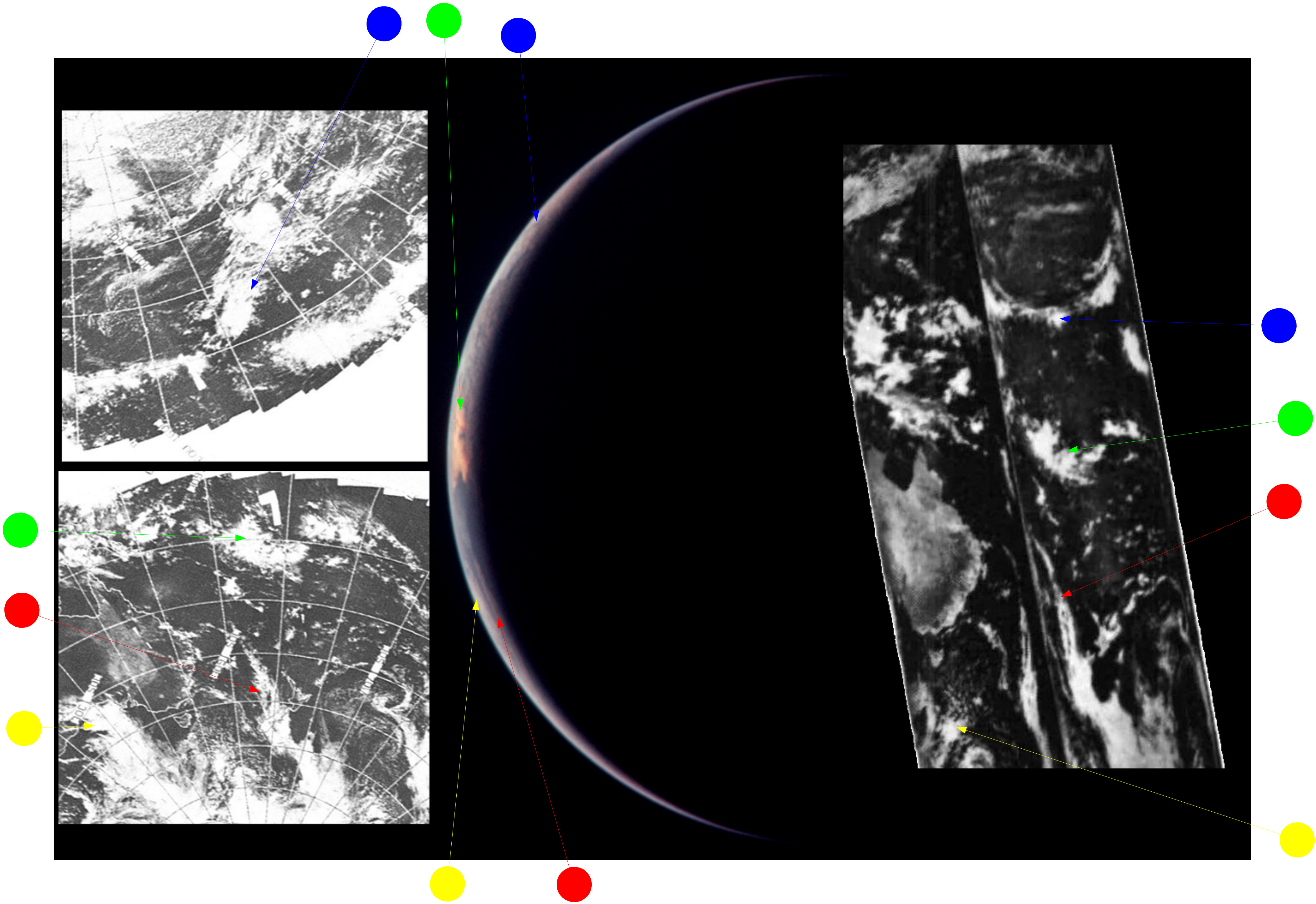


Figure 4.4.41: AS12-51-7581 compared with ESSA (top & bottom left) & NIMBUS (right)

The NIMBUS image pass that covers the terminator line around the main cloud system is number 2959 from the 21st, which was commenced at 23:40 on the 21st, quite a bit later than the Stellarium time would suggest. ESSA's image, although less like the Apollo photograph, would have been started at around 03:04 (pass 3345 from track 8) on the 21st, with the image used having a date of the 20th.

At this time the CSM was still in orbit around the Moon, and the crew taking photographs of the lunar surface, so cameras were to hand, rather than stowed away.

Had this been 24 hours later, assuming that the location is correct, the crew would actually have been asleep, with another 4 hours before they would be woken by capcom to start their day's duties.

As always, the sources of information are there for anyone to repeat this analysis and draw their own conclusions, but aside from last one where this is a possibility of doubt, all of the preceding images have allowed a considerably degree of precision in identifying when a photograph was taken, and more importantly from where: On a Moon bound spacecraft carrying three astronauts.

4.4.2 Meteorological comparisons

For much of this particular mission, the phase of the Earth, the timing of the photographs themselves and the winter season (the Earth's tilt angling the northern hemisphere away from the lunar viewpoint) mean that the German, NOAA & South African data are of less use, at least for the latter part of the mission.

For the early part, however, we have a few days over which to confirm that the satellites were accurately reflecting the situation recorded by terrestrial meteorologists (and are therefore not fabrications), as well as the ground based recordings providing an accurate representation of the reality recorded by Apollo. The sources for the NOAA meteorological data are the same as those given in the preceding sections, and the German data can be found here: http://docs.lib.noaa.gov/rescue/cd277_pdf/LSN1157.PDF .

The Apollo image for the 14th of November (the first one used in this analysis) does feature enough of North America to allow the use of at least the German & NOAA weather charts. Figure 4.4.42 shows the relevant parts of these two charts compared with AS12-50-7354

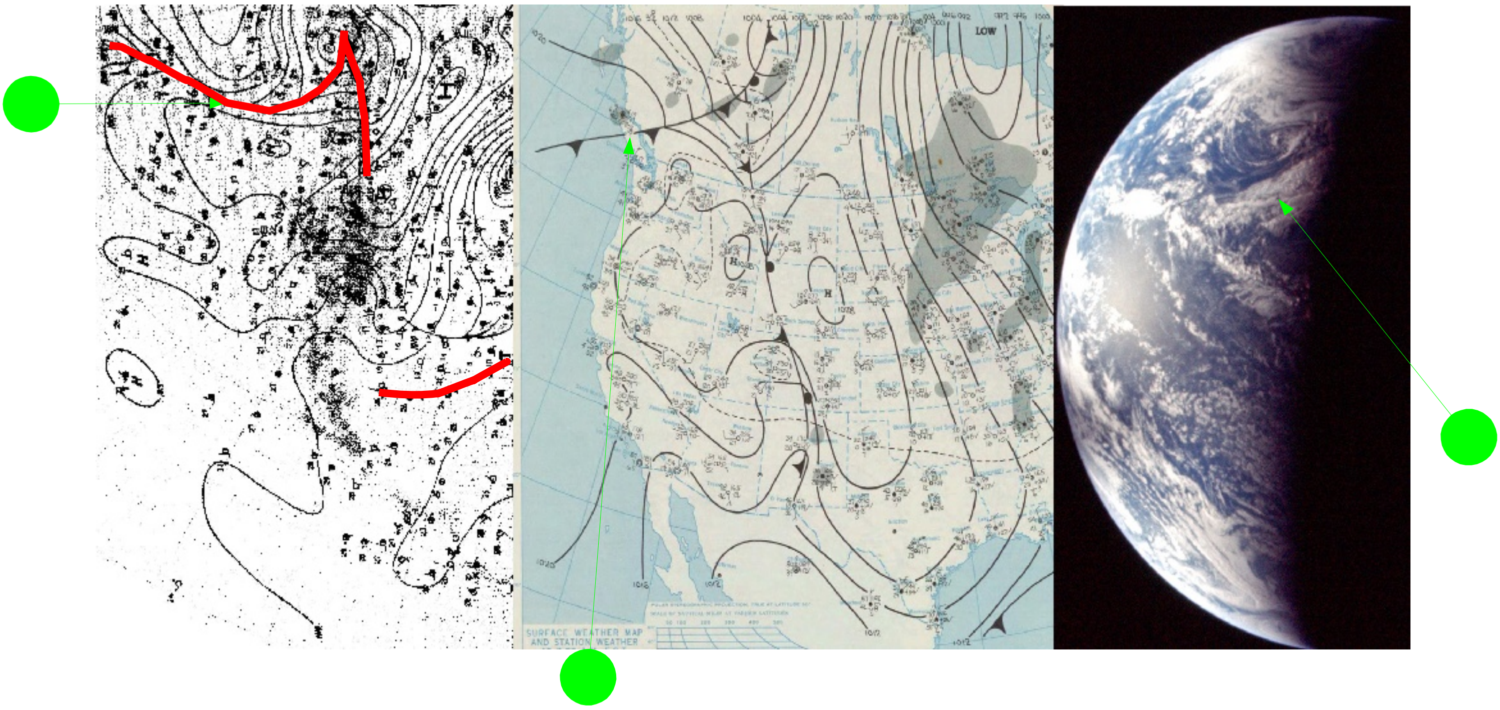


Figure 4.4.42: German (left) & NOAA (middle) weather charts from 14/11/69 compared with AS12-50-7354

The main frontal system picked out here is the one trending roughly west to east over the Pacific before veering to the north-east near the US coast. This front ends in the centre of a low over Canada/Alaska. Other fronts visible on the charts are not visible on the Apollo image. The Apollo image shows that front as a cloud mass in front of it, the cold air of the cold front pushing the warmer, moister air upwards causing the moisture to condense out.

Of the images examined in the previous section, the next one featuring any kind of frontal system that are shown on the weather charts is from November 16th, AS12-50-7385 (figure 4.4.43).

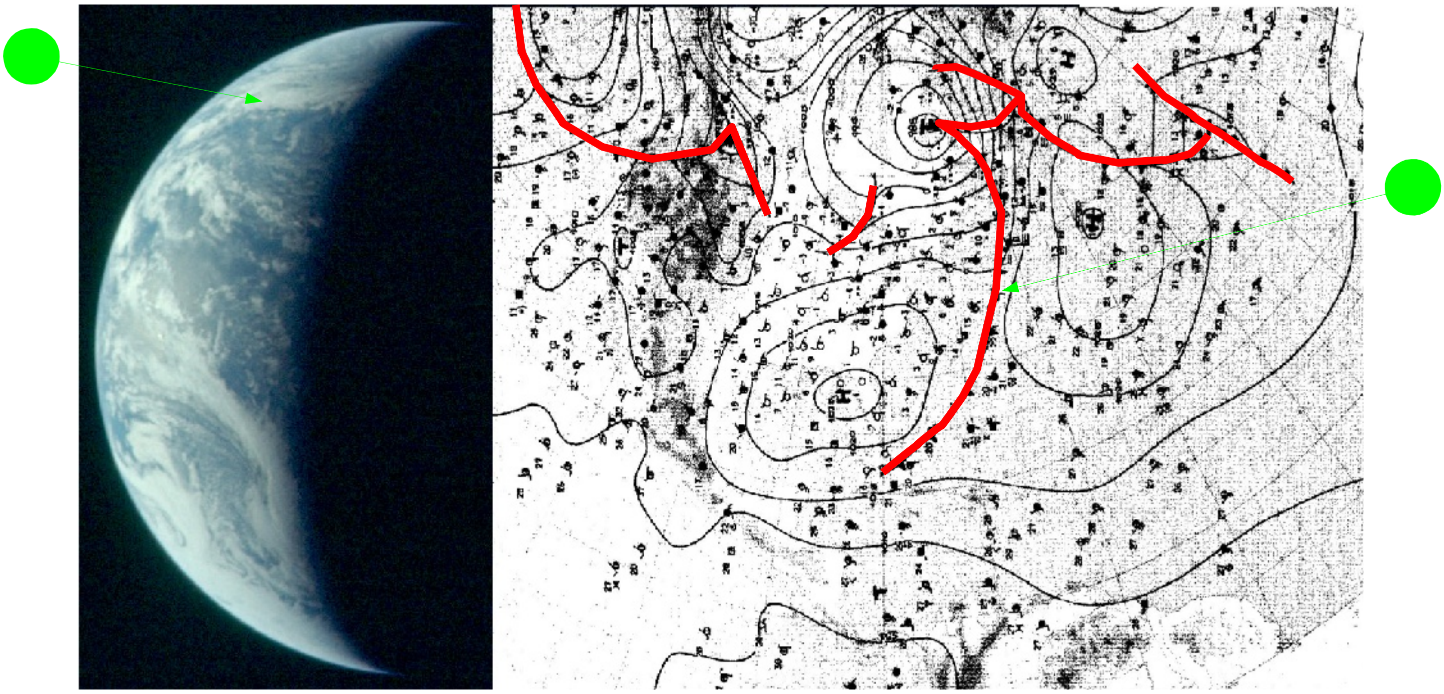


Figure 4.4.43: AS12-50-7385 compared with German meteorological charts from 16/11/69.

The system picked out in green is the the one extending across the Atlantic from the Mexican Gulf towards Europe. The large weather system extending south-eastwards from Brazil does not reach far enough over to Africa to feature on the South African weather charts.

An image from the 17th examined earlier can also be looked in terms of the weather charts available (figure 4.4.44). AS12-50-7394 shows North America, with a band of cloud running west-east across from the Pacific into the southern USA. A large mass of lighter cloud can be observed extending across the north-east of the continent.

As with previous examinations of these meteorological charts from other missions, no absolute guarantee can be given of the accuracy of the author's interpretations, but it doesn't seem unreasonable that the long sweeping frontal system (blue arrow) is the same one in the synoptic charts and the Apollo image. The larger cloud mass over the north-east is bounded, it would seem, by the front indicated by the green arrow.

Apollo 12 then, as with the other missions examined so far, shows a wealth of detail in photographs of Earth that could not have been created in an artist's studio, and accurately portray the weather systems shown on the satellite images for the simple reason that they are photographs of those weather systems, taken from space.

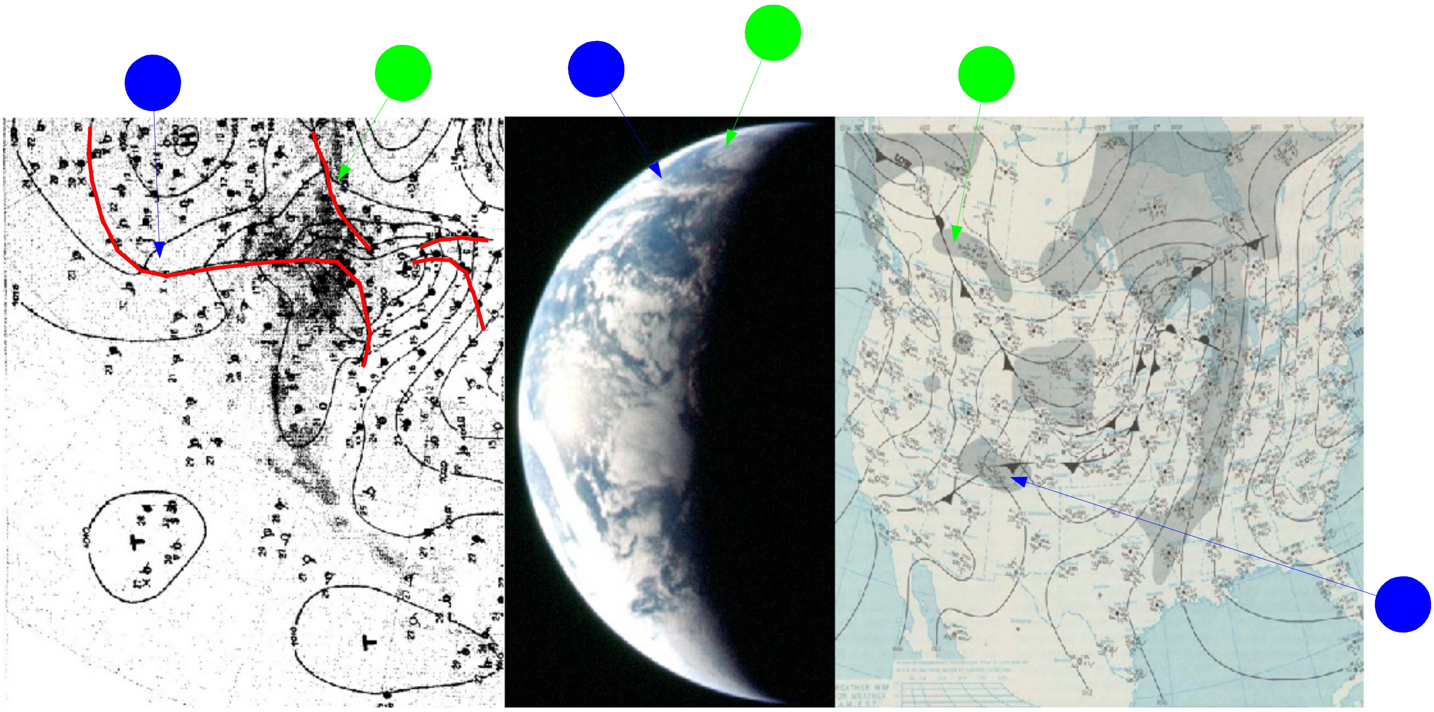


Figure 4.4.44: AS12-50-7394 compared with German (left) & NOAA (right) meteorological charts.

4.5 Apollo 13

While the global populace had tired of the Apollo missions, questioning the value of missions in the face of social problems at home and abroad (Gil Scott Heron's “Whitey's on the Moon” captures the mood of many), NASA still had several missions to run, even if the numbers of them were being ever decreased by budget cuts.

Apollo 13 was launched on April 11th 1970 at 13:13 GMT, intending to land at Fra Mauro on the 13th. As anyone with even a remote grasp of modern history knows this didn't happen. A routine stirring of storage tanks led to a spark that ignited explosive gases, crippling the CSM and causing a substantial proportion of the crew's oxygen supply to evaporate into space. Already well on their way to the Moon, the crew had no option but to carry on towards it and use a gravitational slingshot technique (theoretically understood but never before tried) to propel the craft home after a far side lunar pass.

During the mission, they did manage some Earth photography, especially in the early stage of the mission when a weather photography programme meant an image of Earth was taken every 20 minutes. Later on in the mission, there is a poignancy to the many photographs of home that the crew took and that will be used in this analysis.

Altogether 5 magazines of film were used, exposing 604 images. Many of these are focused on the stricken craft, and of the Moon during their slingshot pass.

The crew did make several TV broadcasts, but such was the decline in interest that the 3rd one, immediately after which came the accident, was recorded instead of transmitted live, and it was shortly after this broadcast that the fateful instruction to stir the tanks was issued. The mission timeline cataloging the events can be found here: NASA source.

Publicly available satellite imagery is in limited supply compared with previous missions. The NIMBUS-3 satellite had reached the end of its useful life as far as visual imagery was concerned and is not available here. The replacement NIMBUS-4 had not yet started full visual recording of its orbital passes (these commenced in full from April 18th). A test image of Scandinavia for the 13th of April can be found in the NIMBUS data catalogue volume 1, but examination of the photographs available from the Apollo mission revealed that no Earth images were taken that day. Given that the crew were somewhat pre-occupied with an exploding spacecraft at the time, this is hardly surprising.

There is also an image available from what appears to be ATS-1 for April 16th showing the Apollo 13 landing site (used to predict likely weather conditions on Apollo 13's return) found in the ESSA publication The first five years of environmental satellites, but while several Apollo photographs were taken on the 16th none of them fell over the area covered by ATS-1.

We are therefore left with the ever reliable ESSA-9 and ATS-3. ATS-3 is not available for all the days of the mission, but is used where possible. ESSA's catalogue can be found here. ATS data are contained in the same volume as those used in the preceding section for Apollo 12.

The Apollo images used are from the Apollo Image Atlas, with the exception of a screenshot from the first TV broadcast. There are a few high quality TIFF images available at http://archive.org (namely AS13-60-8588, AS13-60-8591 and AS13-60-8600). All of the http://archive.org images are incorrectly described as being on the journey home. As will be seen shortly, they were all taken on the way to the Moon.

4.5.1 Satellite comparisons

After launch & TLI, the crew did the usual retrieval of the LM from the SIV-B, and this procedure was recorded as part of a TV transmission 16mm cameras. It's not clear whether this live transmission was purely for NASA's benefit as it covered a fairly dull procedure as far as the viewing public was concerned. This 16mm footage is available here Apollo 13 16mm footage , and at 3h48m in we hear the words “Is that the world there” in response to a comment from capcom about the view of Earth being shown. This timing is derived from the mission transcript (ALSJ).

Although it is not a full Earth view, the presence of images preceding it of the docking manoeuvre means that the craft was no longer in Earth orbit. Figure 4.5.1 shows a screenshot of that footage together with ESSA 9 and ATS-3 views of the Earth on April 11th.

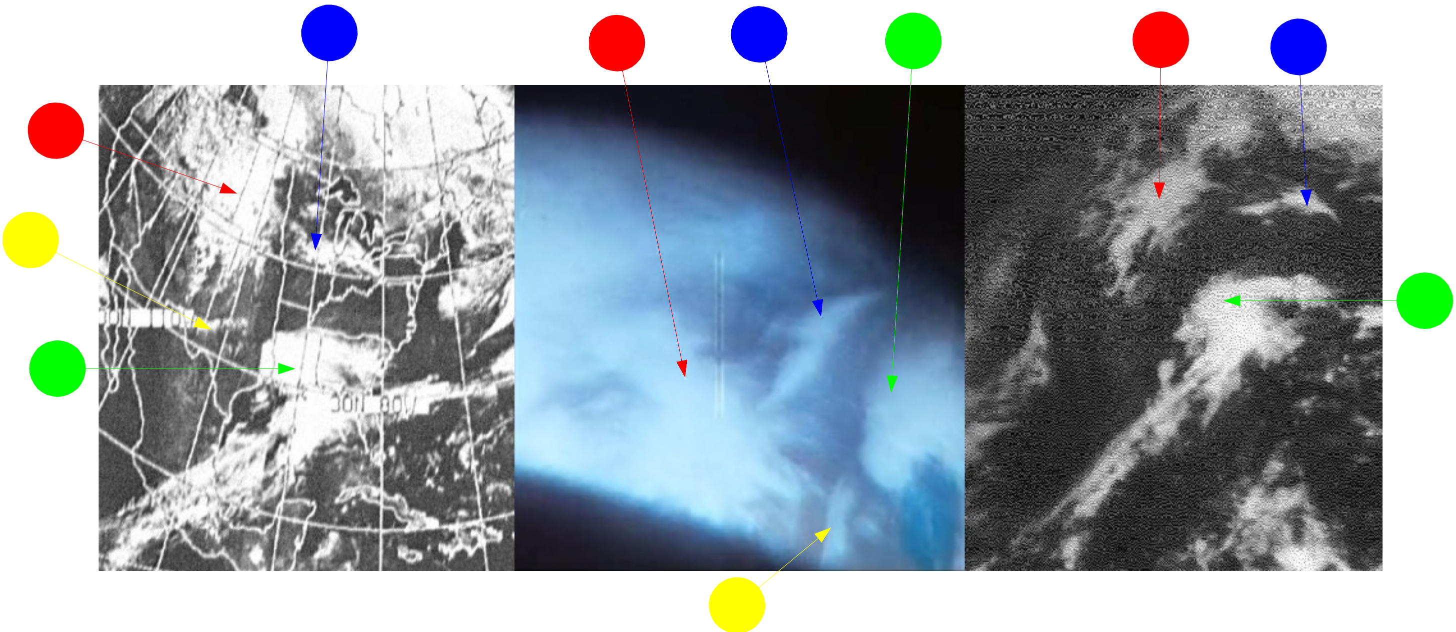
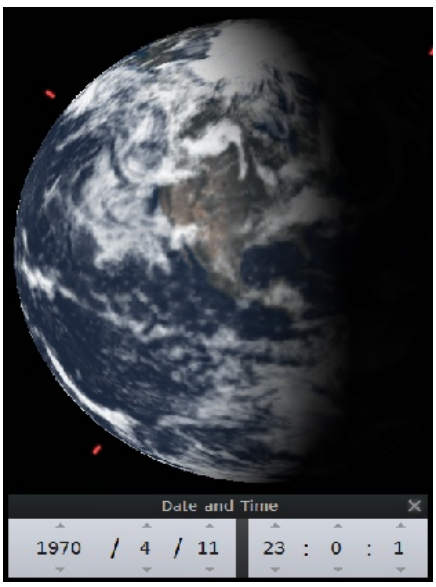


Figure 4.5.1: Screenshot of Apollo 13 16mm footage compared with ESSA-9 (left) and ATS-3 (right). The screenshot has been rotated to give the correct perspective.

It is not immediately apparent from the screenshot shown in the figure above, the darkness in the top right corner of the Earth image is actually the terminator line, something that can be seen more clearly when looking at the footage in its entirety. The time of the quote given in the transcript is 23:01 GMT, and if this is translated into Stellarium from a lunar viewpoint, the terminator line is as shown in figure 4.5.2.



Stellarium suggests a terminator line just off the east coast of northern America. The terminator line in the Apollo screenshot is just to the east of the cloud system identified by the green arrow, and the outline of north America on the ESSA satellite image corresponds exactly with this. The Gulf of Mexico is visible in the bottom right corner of the image, below the green arrowed clouds, and the yellow arrowed cloud is over the Texas/Mexico border.

The ATS image is recorded as taken at 16:23, just over six and a half hours before the Apollo image. ESSA's orbit for that part of north America is track 3, or orbit 5114, which commenced at 18:08. The terminator orbit (5113) was commenced at 16:02

Figure 4.5.2: Stellarium representation of the terminator line at 23:02 GMT on 11/04/70

The satellite images confirm that the 16mm footage shot by Apollo 13 as it left Earth for the Moon does indeed show the clouds it should have seen.

Once safely on the way we begin to see images of the Earth as an entire disk. The first photograph showing the Earth as such is AS13-60-8588.jpg (see figure 4.5.3).

This photograph appears after images of the docking process, and the image immediately preceding it is of the now empty SIV-B floating away into the distance. This means that the picture must have been taken after 23:14, when the LM was finally extracted from the SIV-B.

Figure 4.5.3: AS13-60-8588. Source given in text.

This Apollo image is compared with the ATS and ESSA images from April 11th over the page in figure 4.5.4.

At first glance what should immediately stand out are the weather systems off the coast of north America. These are the same ones visible in figure 4.5.1 (the blue, green and yellow coloured arrows have been used in both). but the position of the terminator line has moved so that it cuts across the cloud system visible in its entirety in the Apollo screenshot. The obvious interpretation is that this photograph was taken slightly later than the 16mm footage.

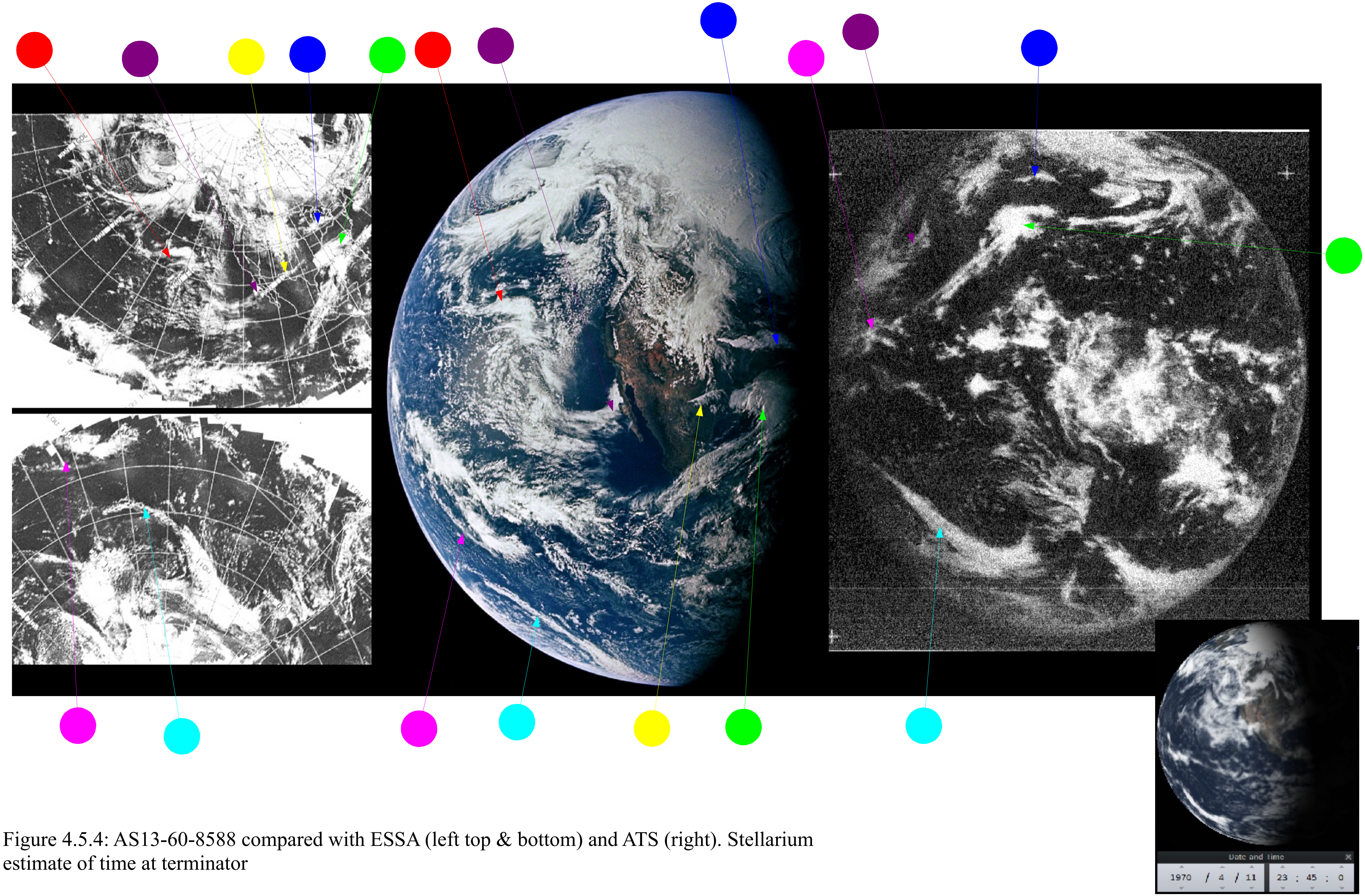


Figure 4.5.4: AS13-60-8588 compared with ESSA (left top & bottom) and ATS (right). Stellarium estimate of time at terminator

The additional rotation of the Earth between the 16mm screenshot and the Apollo image suggests a terminator line consistent with a time of around 23:45. Zooming in close to the Canadian border on the east coast shows that the great lakes are just visible, and Florida would probably be visible if it wasn't covered in cloud.

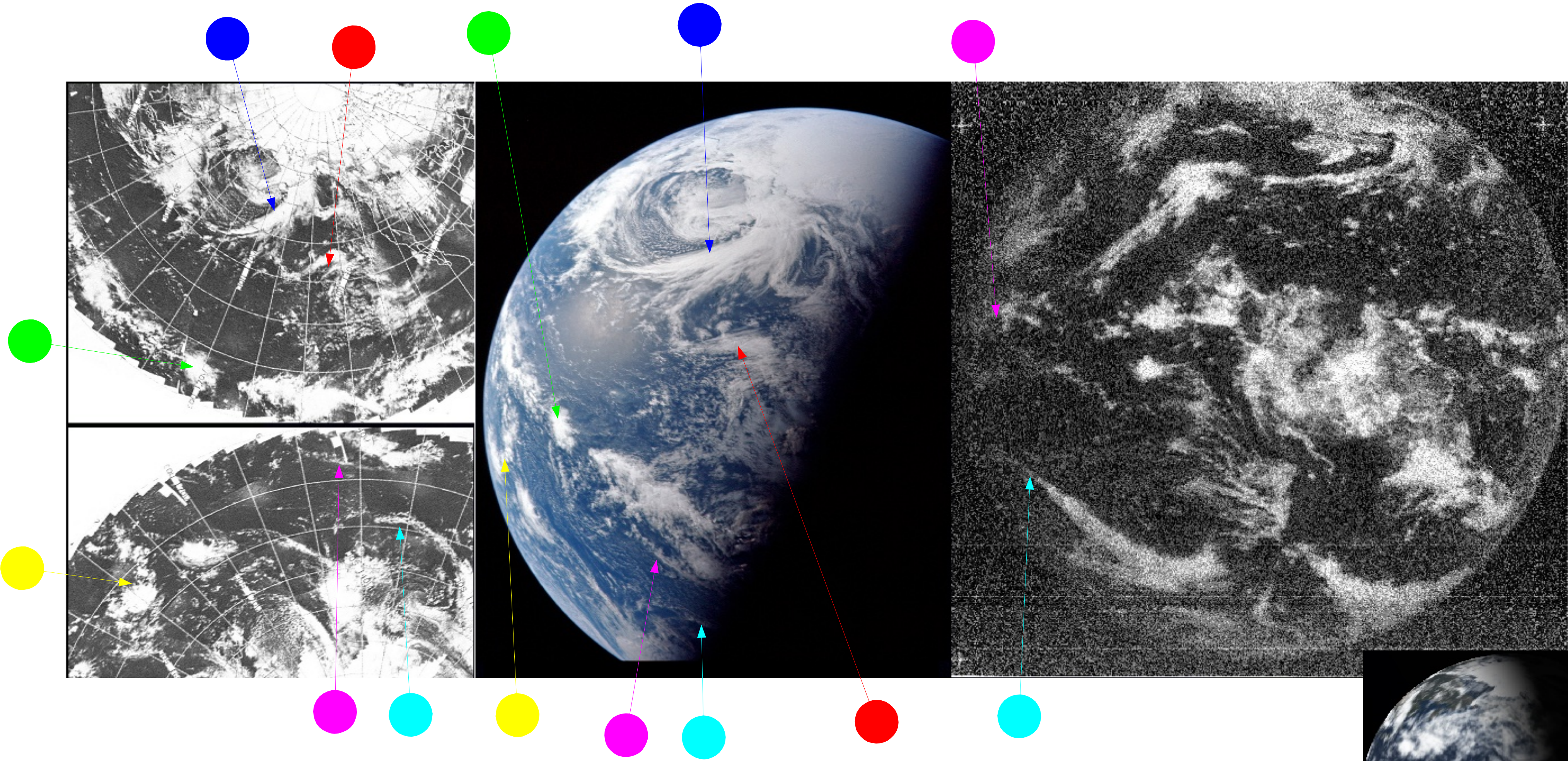
Of the two satellites ESSA has the best coverage here & the timings are the same as the previous image. The streams of cloud off Baja California are just visible in the ATS image, as is the large system peeling off the Antarctic (cyan arrow), but the north Pacific weather pattens over Hawaii (red arrow) are too far around.

A few hours later in the mission comes a period occupied by weather photography. The idea was to photograph the globe at roughly 20 minute intervals. The exact reasons for it are not clear, but the assumption must be that as the exact time of the photograph is known, this can be tied in more precisely to ground based meteorological recordings.

The first image was taken at exactly 02:30:45. The next image of Earth is AS13-60-8590, and this is followed by 10 further ones. In the mission transcript at 11:24 hours in to the mission (06::37 on the 12th), the crew report that they believe they have taken 10 images and will take one more. As AS13-8590 is succeeded by 10 more images, then logically it must be the first in the series, and we can therefore attach a precise time to it.

Figure 4.5.5 shows this image, and figure 4.5.6 the satellite image comparison.

Figure 4.5.5: AS13-60-8590, source AIA



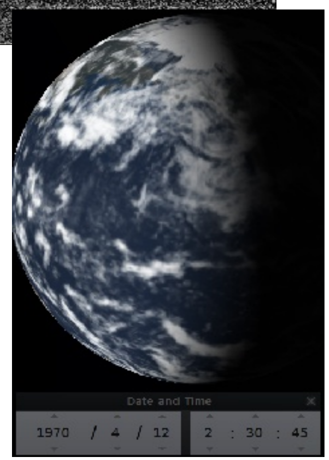


Figure 4.5.6: AS13-60-8590 compared with ESSA (top & bottom left) and ATS (right) satellite images. Stellarium estimate of time at terminator. Cyan, magenta and red arrows are the same as on figure 4.5.4.

The weather system identified by the red arrow is clearly the same as that in figure 4.5.4, and the clouds picked out by the blue arrow, although not identified specifically in the preceding analysis, is very obviously the same one.

Land masses are not readily obvious in either Stellarium or the Apollo image (which in itself is an indicator that the time for both is correct), but for those that wish to zoom in close enough, land is visible through the cloud cover towards the top of the globe, at what would correspond with north-east Asia around Kamchatka and Siberia. The blue arrowed system starts out over Alaska.

We already know the time of the ATS image, and the Earth as far as Apollo is concerned has evidently moved on since it was taken. ESSA's orbit covering the north Pacific best here is track number 6, or pass 5117, commenced at 00:003 on the 12th, so the Apollo image was taken within a few hours of the satellite version.

Given that the next photograph in the sequence (AS13-60-8591) was taken at 02:52, 22 minutes after the preceding one, we have another excellent opportunity to demonstrate that the Earth used in the Apollo images was the real one, rotating at the correct speed, and not a stationary image superimposed on a background. Figure 4.5.7 shows the terminator line near the weather system picked out by the red arrow above in AS13-60-8590 & 8591.

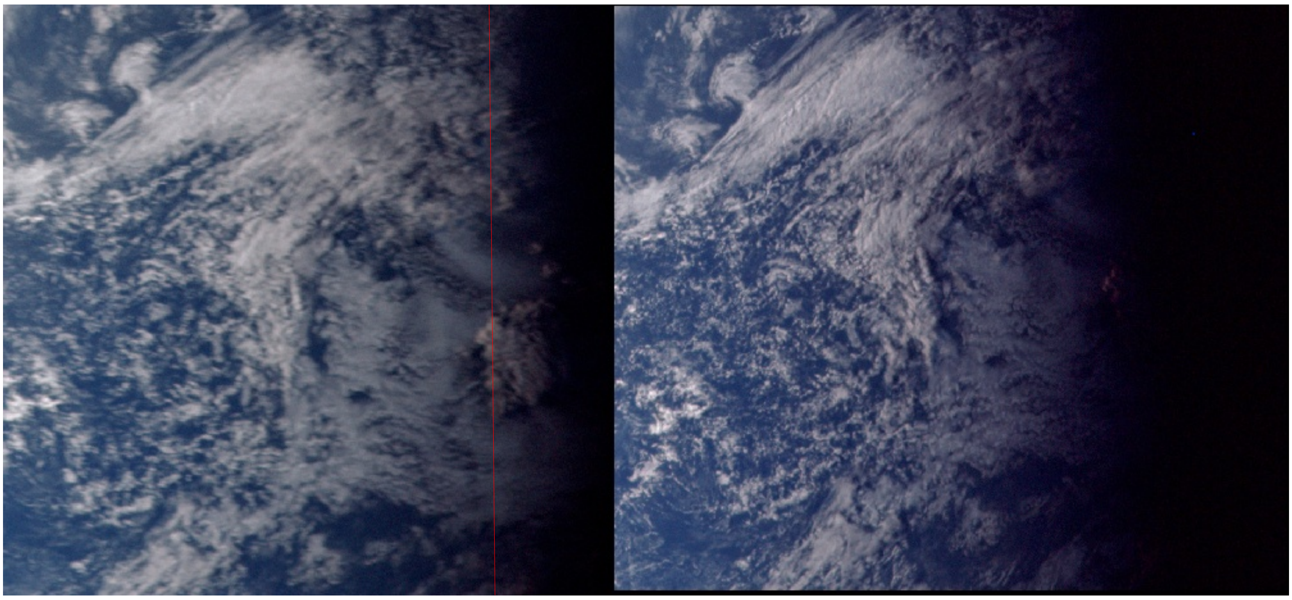


Figure 4.5.7: Detail from AS13-60-8590 (left) and AS13-60-8591 (right). Red line on the left image represents where the terminator is on the right.

It is quite obvious from these two images that the Earth has moved, and moved roughly the sort of distance you would expect it to have moved in around 20 minutes – roughly 5 degrees of longitude, or around 400 km at the latitude of these clouds.

The final image in the sequence of Earth images used here is AS13-60-8600 (figure 4.5.8).

This is the 11th in the series of weather observation photographs, and is pinpointed in the mission transcript as being taken at 06:50:17 on the 12th. As by this time the viewpoint of ATS-3 has long since been passed, only ESSA's images can be used to compare the clouds, and this is carried out in figure 4.5.9.

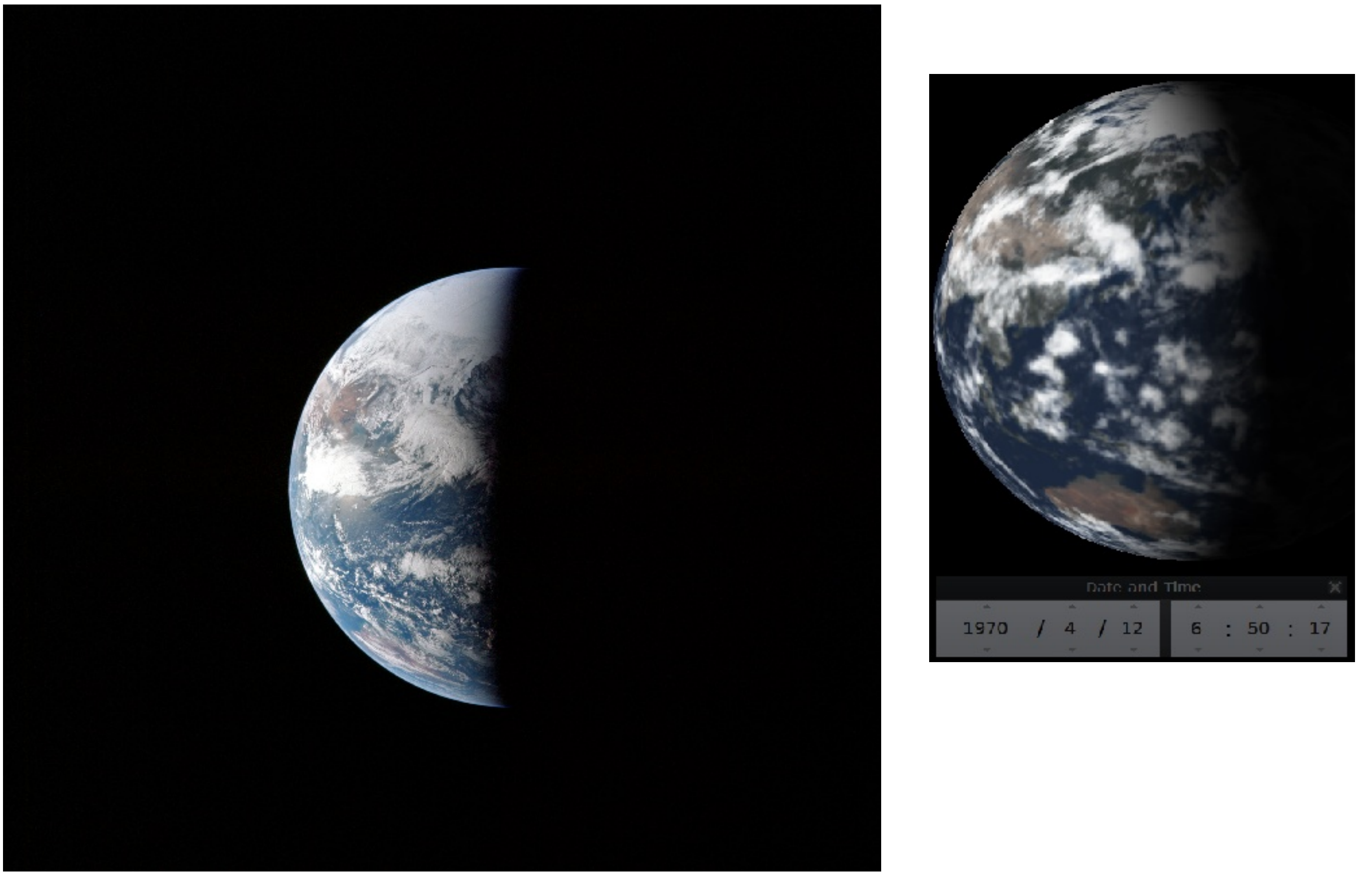


Figure 4.5.8: AS13-60-8600. Source http://www.lpi.usra.edu/resources/apollo/images/print/AS13/60/8600.jpg and Stellarium comparison

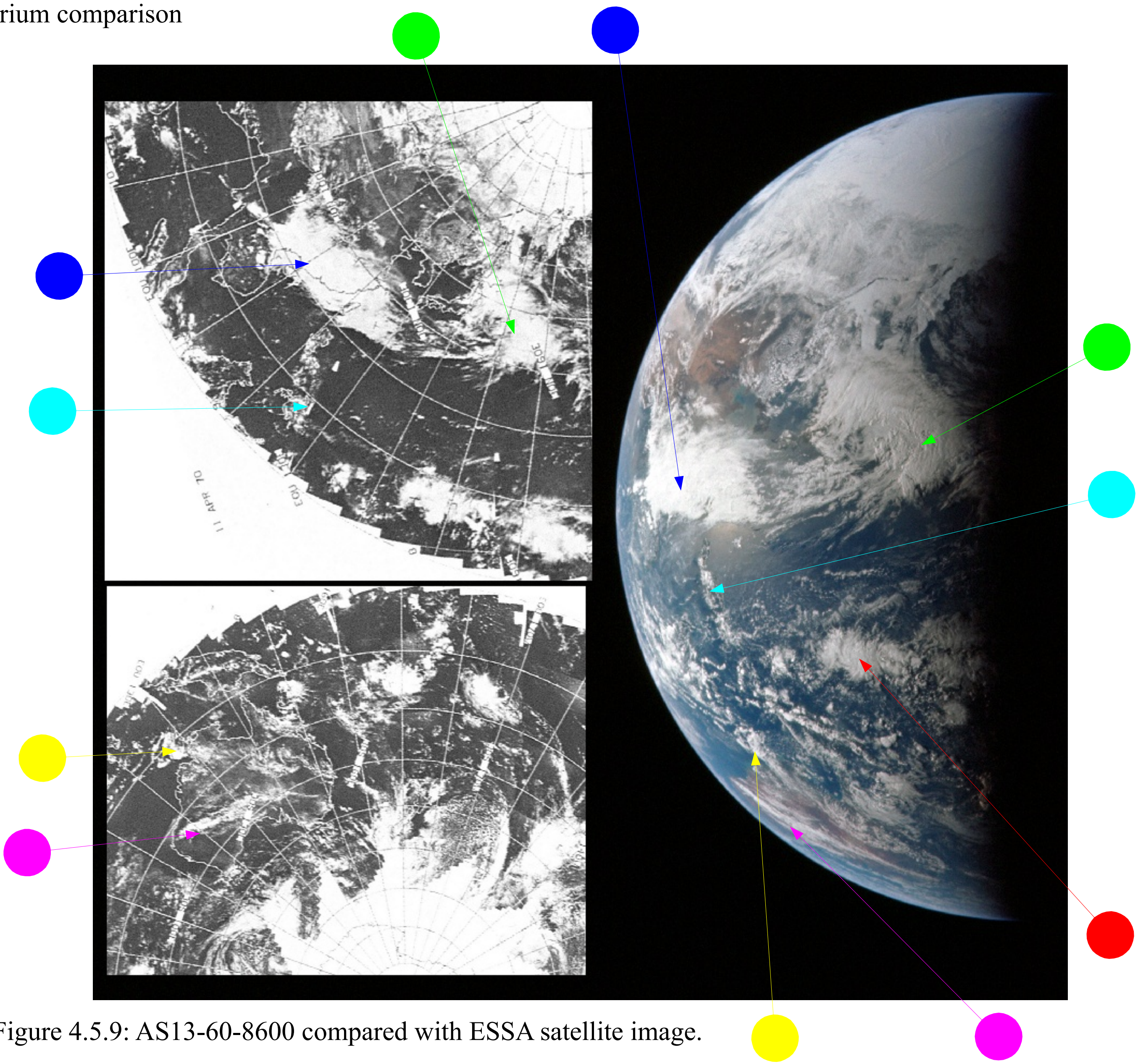


Figure 4.5.9: AS13-60-8600 compared with ESSA satellite image.

Stellarium suggests that by the time of the Apollo image Australia should be fully in view, and indeed it is.

The cloud mass identified by the green arrow is the one to the west of the system picked out in blue in figure 4.5.6, and the red arrowed band of cloud is a continuation of the one picked out in green in figure 4.5.6.

As for whether ESSA's timings can confirm the time given by the Apollo mission and Stellarium, the most relevant track is number 8, which corresponds to pass 5119. commenced at 04:04 on the 12th. Again, ESSA's pass over Australia falls within a couple of hours of the Apollo image.

There is a considerable time lapse between these images ant the next photographs of Earth. The next image in Magazine 60 (AS13-60-8601) is from the 14th, all other images showing it appear after it has passed around the far side of the moon. This particular image will be discussed at the appropriate point in the sequence of images taken on the 14th.

Magazine 61's images featuring Earth all appear after those showing a receding Moon (and are therefore obviously on the way home), Magazine 62 shows a few images at the start of the film with a relatively large crescent Moon, after which there are a few images of a very small crescent Earth, and more are shown towards the end of the magazine after a sequence of far side lunar images. Magazine 59 shows pictures of a relatively large crescent Earth immediately before images taken after the damaged service module was cast adrift. These images of Earth will now be presented in the order that it has been calculated that they were taken.

The first in the sequence is AS13-62-8886, which occurs after the aforementioned set of images of the Moon through the spacecraft window. Figure 4.5.10 shows this image, and 4.5.11 the satellite analysis.

Figure 4.5.10: AS13-62-8886, source http://www.lpi.usra.edu/resources/apollo/images/print/AS13/62/8886.jpg

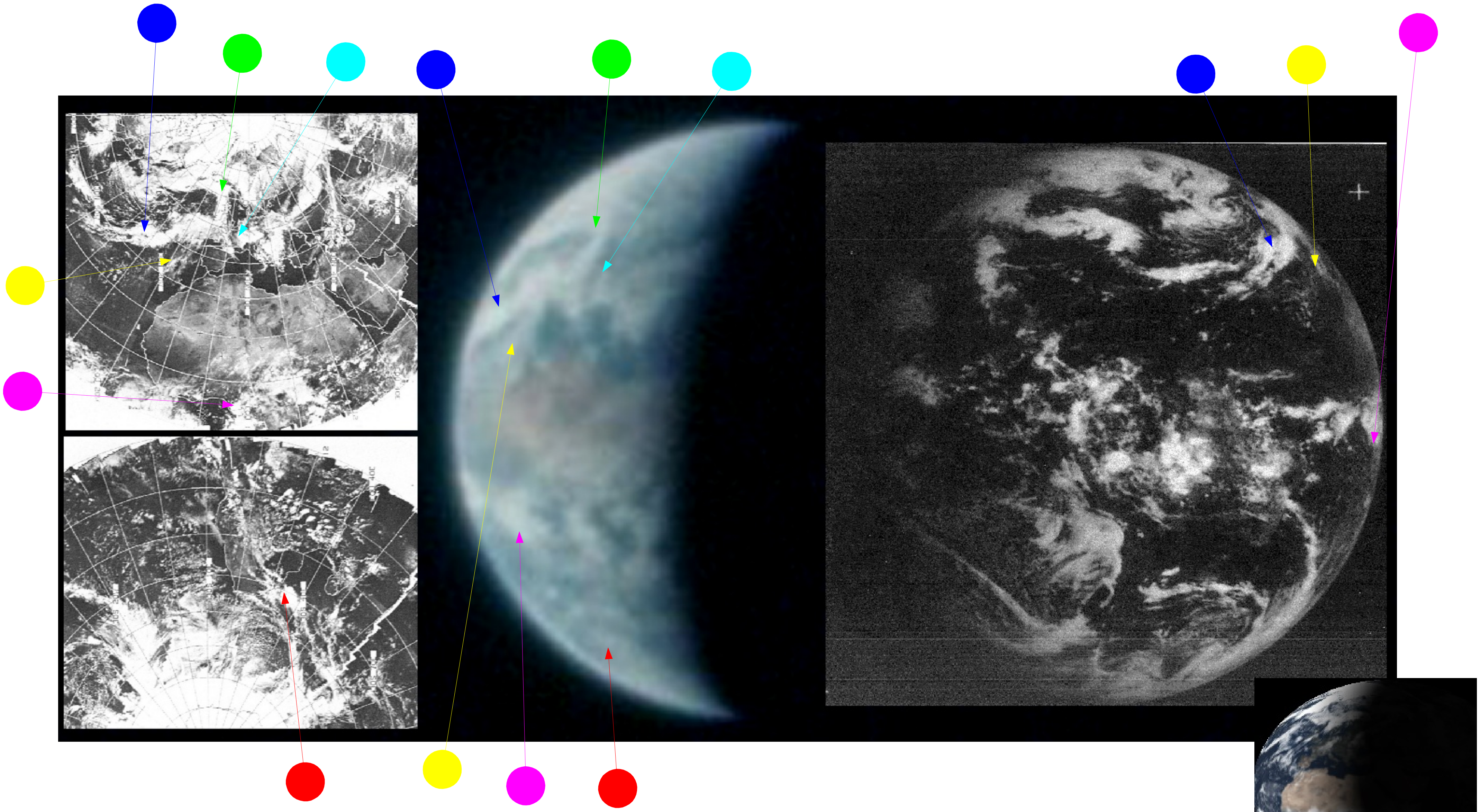


Figure 4.5.11: AS13-62-8886 compared with ESSA (top & bottom left) and ATS (right) satellite images, with Stellarium estimate of time at terminator.

The key to identifying this image as belonging to the 14th of April is the cloud system off western Europe (cyan, green and blue arrows) that extends into the Atlantic to off the west coast of Africa. These clouds patterns do not appear in this formation on other days, and as will become clear, the system pointed out by the blue arrow moves progressively towards Africa over the next couple of days. What will also become clear over the next few images is that the blue arrowed clouds are connected to a weather system that extends over America that is visible in subsequent images.

Returning to this analysis, Stellarium's terminator line through Libya puts the time at around 16:30 on the 14th, just over 13 hours after the crew reported that they had “had a problem”. The ATS image is recorded at 14:01. ESSA's most relevant pass is pass 5148 (track 12), which was started at 12:08. As usual, the reason for the close correspondence between the satellite images and Apollo is that there is relatively little time between them.

The next image in the sequence for the 14th is AS13-60-8601 (figure 4.5.12).

Figure 4.5.12: AS13-60-8601. Source: AIA

Readers may wish to compare it with AS13-62-8901, which shows an almost identical viewpoint but is of inferior quality.

Figure 4.5.13 shows this image compared with the available ESSA and ATS images.

Once 'correctly' oriented, the Florida coastline becomes very obvious, and makes positioning a Stellarium terminator much simpler, placing the time at around 20:45 on the 14th.

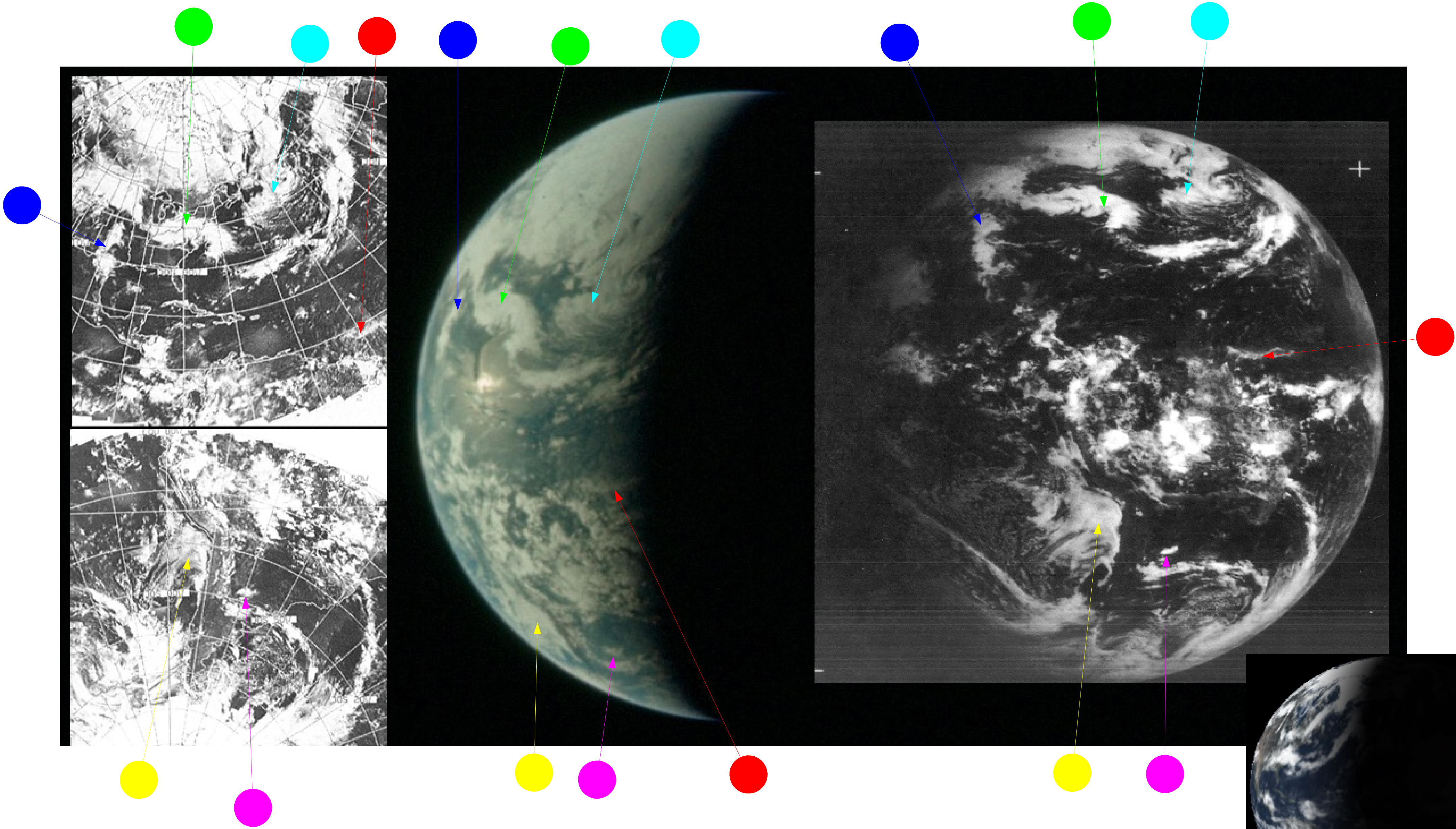


Figure 4.5.13: AS13-60-8601 compared with ESSA (top & bottom left) and ATS (right) satellite images. Stellarium estimate of time at terminator.

At this time in the mission the crew are involved with almost continual dialogue with capcom about the state of the vessel, levels of consumables, and upcoming manoeuvres to orient the craft and position it on a homeward trajectory ahead of a far side lunar pass.

The weather systems picked out by the cyan and green arrows are continuations of weather systems identified in figure 4.5.11 by the blue arrow.

The ESSA orbit for the mid-Atlantic would be pass 5150 (track 1) which was commenced at 15:08.

The next image in this sequence is AS13-60-8716 (figure 4.5.14, source AIA). The photograph occurs after a large number of far side images, and therefore must have been taken after 00:46 on the 15th when they emerged from behind the far side. AS13-61-8826 features a very similar image of Earth (when zoomed in), and this also has far side images preceding it. The ever decreasing lunar disc shown on both these magazines suggests that the image would have been taken well after the TEI burn that occurred at 02:45.

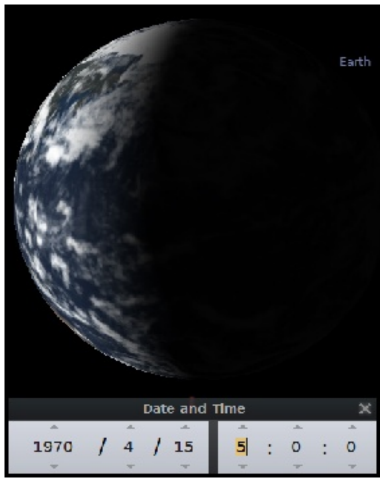


Figure 4.5.14: AS13-60-8916. Source given in text, with Stellarium comparison.

As can be seen in the analysis, the dominant weather system visible is in the Pacific, so only ESSA data are available.

The dominant weather system (blue arrow) on the map is a development of the one identified by the blue arrow in figure 4.5.6, and its centre is still located roughly over Alaska & Kamchatka.

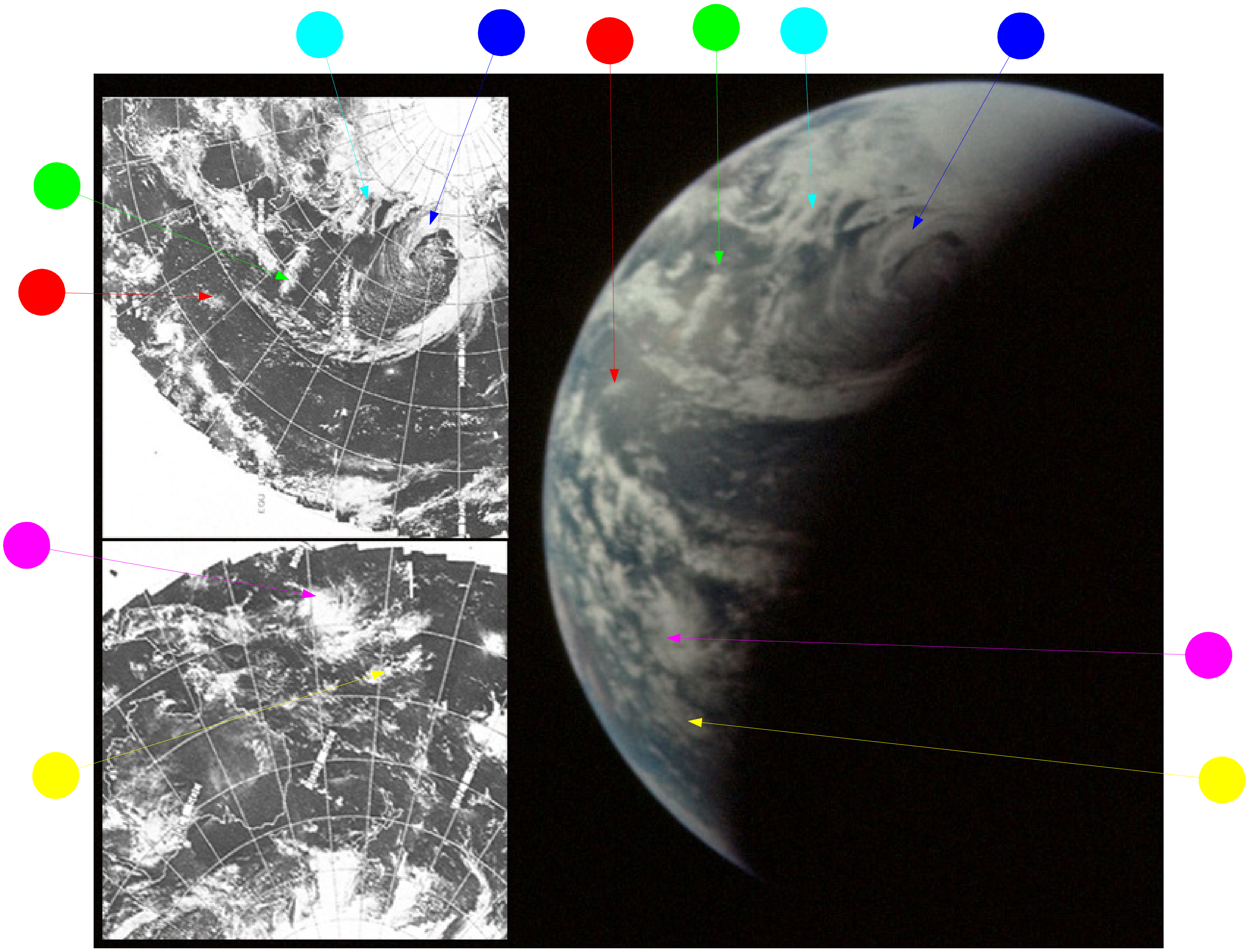


Figure 4.5.15: AS13-60-8916 compared with ESSA satellite images.

Close inspection of the south-west horizon shows that Australia is just visible, and this helps to pinpoint the time as being roughly 05:00 on the 15th. As far as ESSA's timings concerned, the image used is dated the 14th, but the most relevant orbital pass for this part of the globe is orbit 5155 (track 6), which was commenced at 01:04 on the 15th, again just a few hours before the Apollo image was taken.

The next image in the sequence is AS13-61-8864 (source: AIA). This photograph occurs at the end of a sequence of images showing an ever decreasing Moon. Towards the end of the magazine, there are a couple of photographs of the adapted lithium hydroxide cannisters used to scrub the cabin air clean of surplus carbon dioxide. The procedure to adapt these cannisters began at around 90 hours in, or around 13:30 on the 15th, so the images of the Earth must have been taken before then.

Figure 4.5.16 shows the original Apollo image, and figure 4.5.17 the same image compared with satellite photographs.

What the image shows is that weather patterns that were towards the west of the globe gave moved much closer towards the terminator, and systems identified in figure 4.5.15 can also be identified in figure 4.5.17.

Figure 4.5.16: AS13-61-8864 with Stellarium comparison. Source given in text.

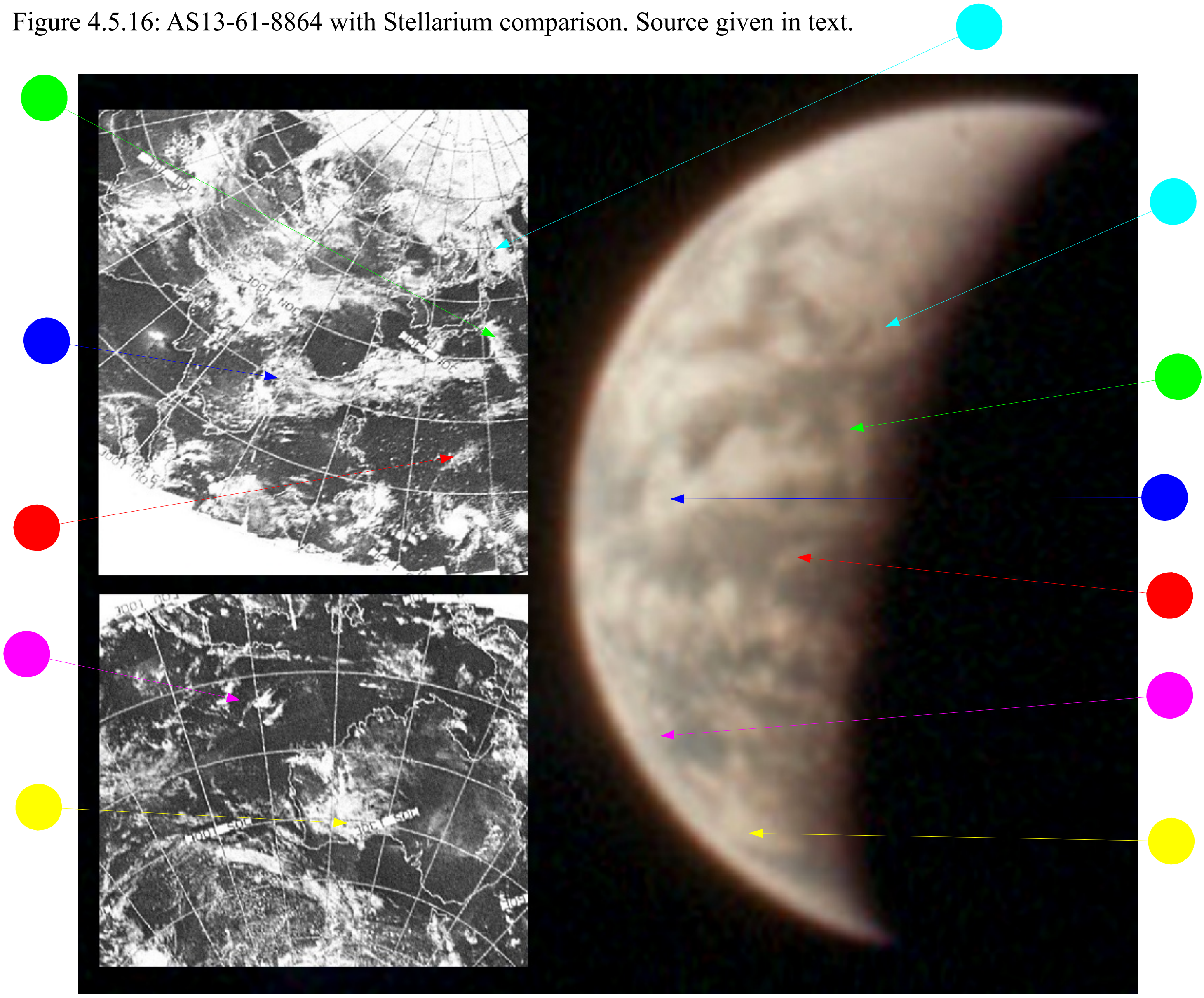


Figure 4.5.17: AS13-61-8864 compared with ESSA satellite images. Cyan, green and red arrows as figure 4.5.15

Australia's position on the terminator allows a relatively precise estimate of the time the image was taken: 08:15. As the satellite photograph is dated the 14th this gives the appropriate orbital pass as number 5158 (track 9), commenced at 07:01 on the 15th.

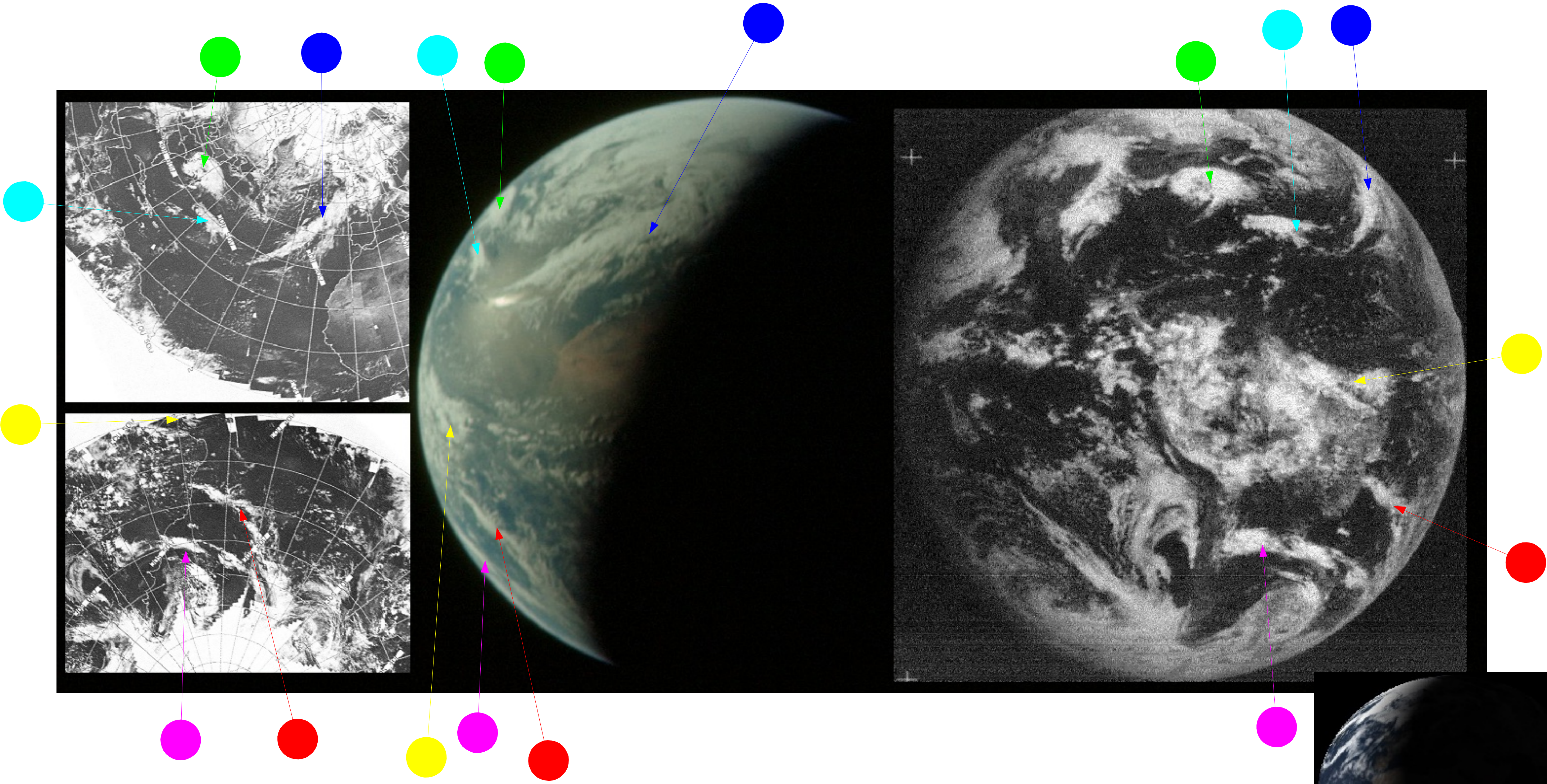
A few hours after the Australis enters darkness, ESSA starts a new collection of orbits that will have the next day's date on them.

The Apollo image to be looked at is AS13-60-8720 (Source: AIA). There are no real clues in the remainder of this magazine as to when it might have been taken, other than it is after images previously examined from this film, so we are reliant in what we can see in it (figure 4.5.18).

Figure 4.5.18: AS13-60-8720. Source given in text.

It doesn't take much zooming in on this image to see that the terminator line crosses north Africa somewhere along the coast of Tunisia/Algeria, which gives a time of the photograph as around 18:00.

The main weather system visible over the Atlantic is the same one observed in figure 4.5.11, but it has changed in the couple of days since it was first photographed, separating itself from the other clouds in the mid-Atlantic and rotating so that the south-western tip is closer to Africa than it was previously. Figure 4.5.19 shows the satellite images as a comparison.



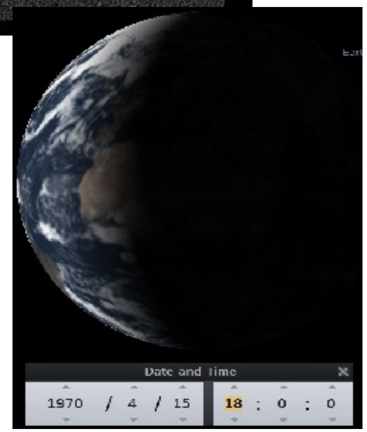


Figure 4.5.19: AS13-60-8720 compared with ESSA (top & bottom left) and ATS (right) satellite images, with Stellarium estimate of time at terminator.

The movement of the Earth has also brought the ATS satellite back into play when confirming the timing of the Apollo image.

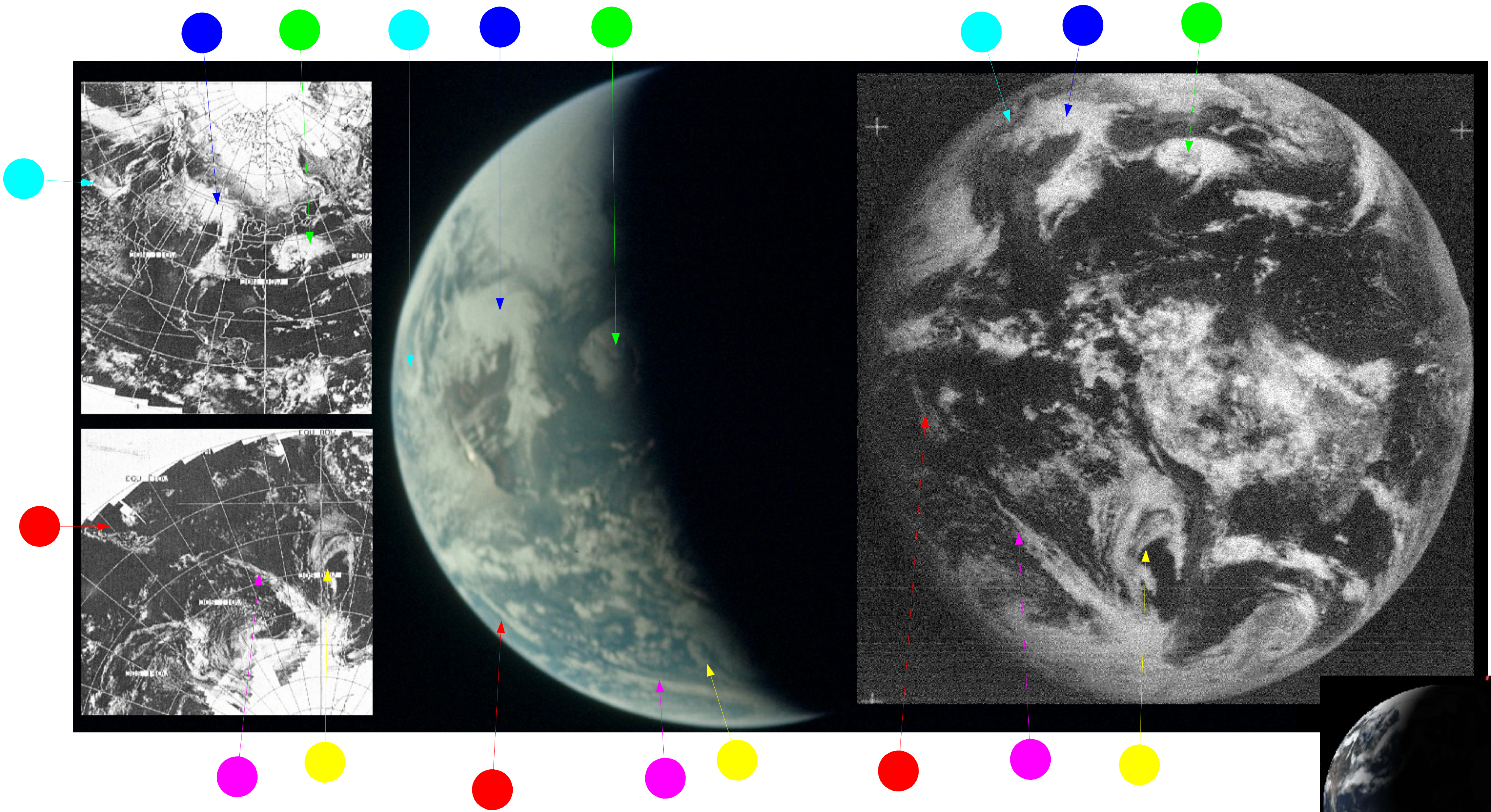
ATS' image is timestamped at 15:59 on the 15th. ESSA's most representative orbit is pass 5161 (track 12), which commenced at 13:06 – not long before the ATS image, and within a few hours of the Apollo photograph.

The next picture to be analysed is the final image in magazine 60: AS13-60-8726. Between the preceding image and this one there are only a few pictures of a now very small Moon. Magazine 62 again has a very similar image in AS13-62-8954 , but there are few clues there as to when precisely this image could have been taken (other than it being after the lithium hydroxide conversion), so we are reliant again on the position of the terminator and satellite analyses.

Figure 4.5.20 below shows the image form magazine 60 (Source: AIA), and figure 4.5.21 overleaf shows the satellite analysis.

Figure 4.5.20: AS13-60-8526 (Source given in text).

At the risk of pointing out the obvious (again), there is a degree of overlap between this image and the previous one. The 'speech bubble' cloud identified by the green arrow in figure 4.5.19 has now been split by the terminator line, and the north American mainland can be made out to the west of it.



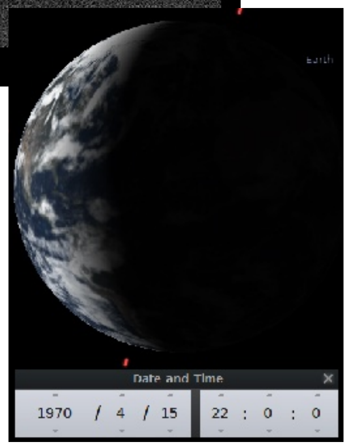


Figure 4.5.21: AS13-60-8526 compared with ESSA (top & bottom left) and ATS (right) satellite images, with Stellarium estimate of time at terminator. Green arrow as in figure 4.5.19.

Using this terminator line Stellarium times this image as roughly 22:30. The ATS image is till the 15th, and the ESSA image is also dated that day. The ESSA pass covering the Atlantic seaboard is track 2, which translates to orbit number 5163, commenced at 16:07. By this time in the journey the CSM and its attendant LM had just passed into the Earth's gravitational sphere of influence and were beginning to accelerate. The crew were also preparing for a mid-course correction burn.

While there are no more images to be used from magazine 60, there were still other magazines being used. Magazine 62 features image AS13-62-8977, which can be seen in figure 4.5.22 (Source: AIA).

Figure 4.5.22: AS13-62-8977. (Source given in text) with Stellarium comparison.

It is always a source of amazement that a figure such as the photograph presented above can contain all the information needed to repel a conspiracist's argument. Ostensibly containing nothing, this photograph, and countless like it, contain sufficient detail of the Earth's weather systems to prove that they were photographed at the same time, or at least within a few hours of, a satellite in orbit much much closer to the subject. Figure 4.5.23 shows the ESSA satellite in comparison with this Apollo photograph.

The terminator is falling across the west coast if the USA, and this allows the time of the photograph to be estimated at 02:30, which must therefore be on the 16th.

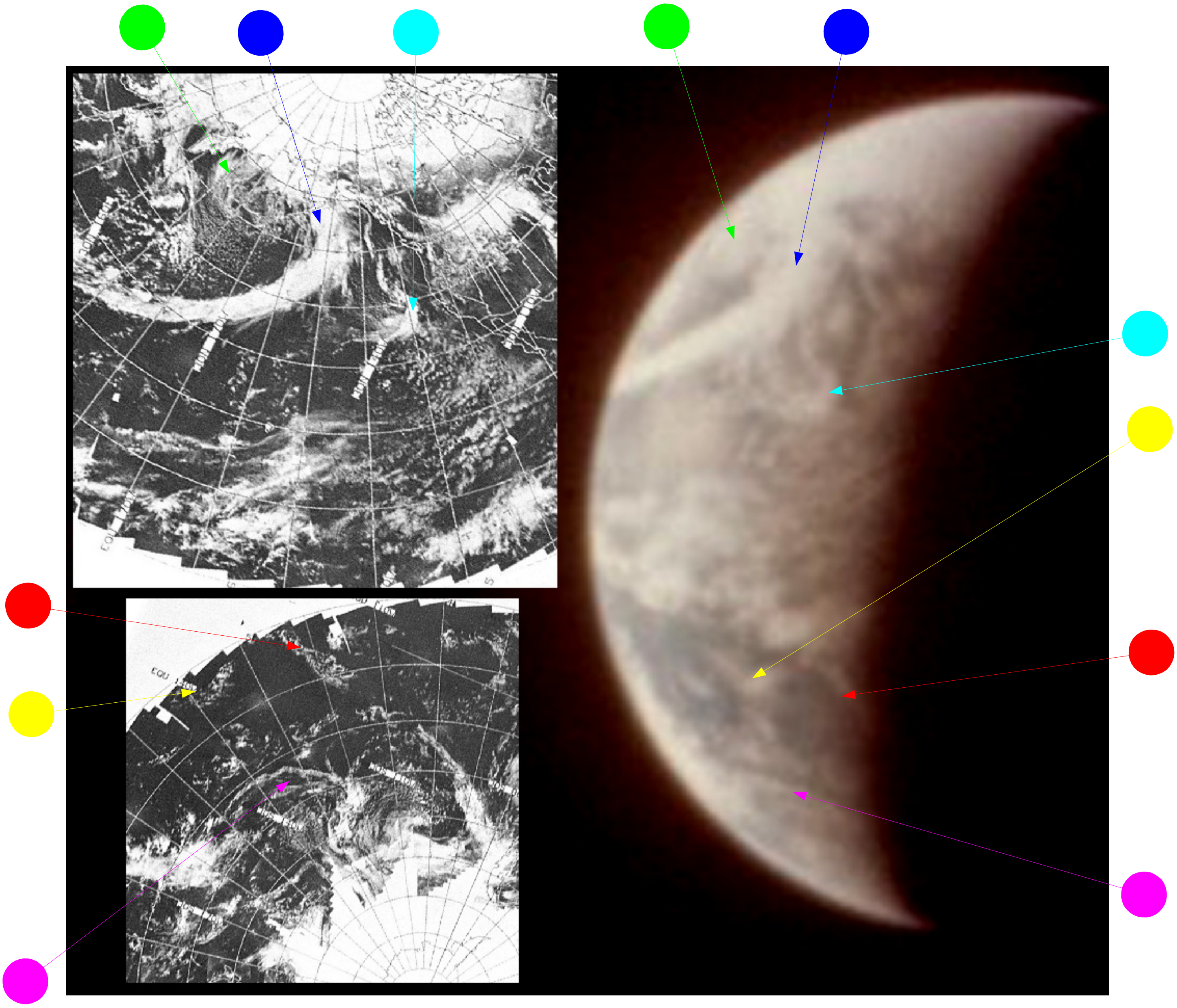


Figure 4.5.23: AS13-62-8977 in comparison with ESSA satellite image.

The main feature on this photograph is obviously the large sweep of cloud that has been a persistent feature over the entire mission, and this has extended from the relatively tight curl centred over Alaska to a much broader sweep. Despite the blurred image, the large swathe of wispy cirrus clouds off Baja California are still very much evident. What is also apparent is that the weather patterns identified by the blue and cyan arrows are noticeably further apart in the ESSA image. Although this may be a product of the angle at which the Earth is being viewed and the distorted perspective of the satellite composite's projection, but it could also be that the weather has moved on between the satellite image's exposure and that of the Apollo photograph.

ESSA's most representative terminator orbit is track 4, which runs along the west coast. This would be pass number 5165, which commenced at 20:07. Examination of the records show pass 5166 is not listed in the data catalogue, and this is either because of some technical problem and data from the surrounding orbits has been used to fill in the gaps (there is a degree of overlap), or it has been missed when generating the list. If the latter is the case, it should have commenced at around 22:00, over 4 hours before the Apollo image was taken. Pass 5167 started just after midnight on the 16th.

The final image that attributable to the ESSA composite from the 15th and its attendant satellite analysis are shown in figures 4.5.24 & 25 respectively overleaf, and involves AS13-62-8993.

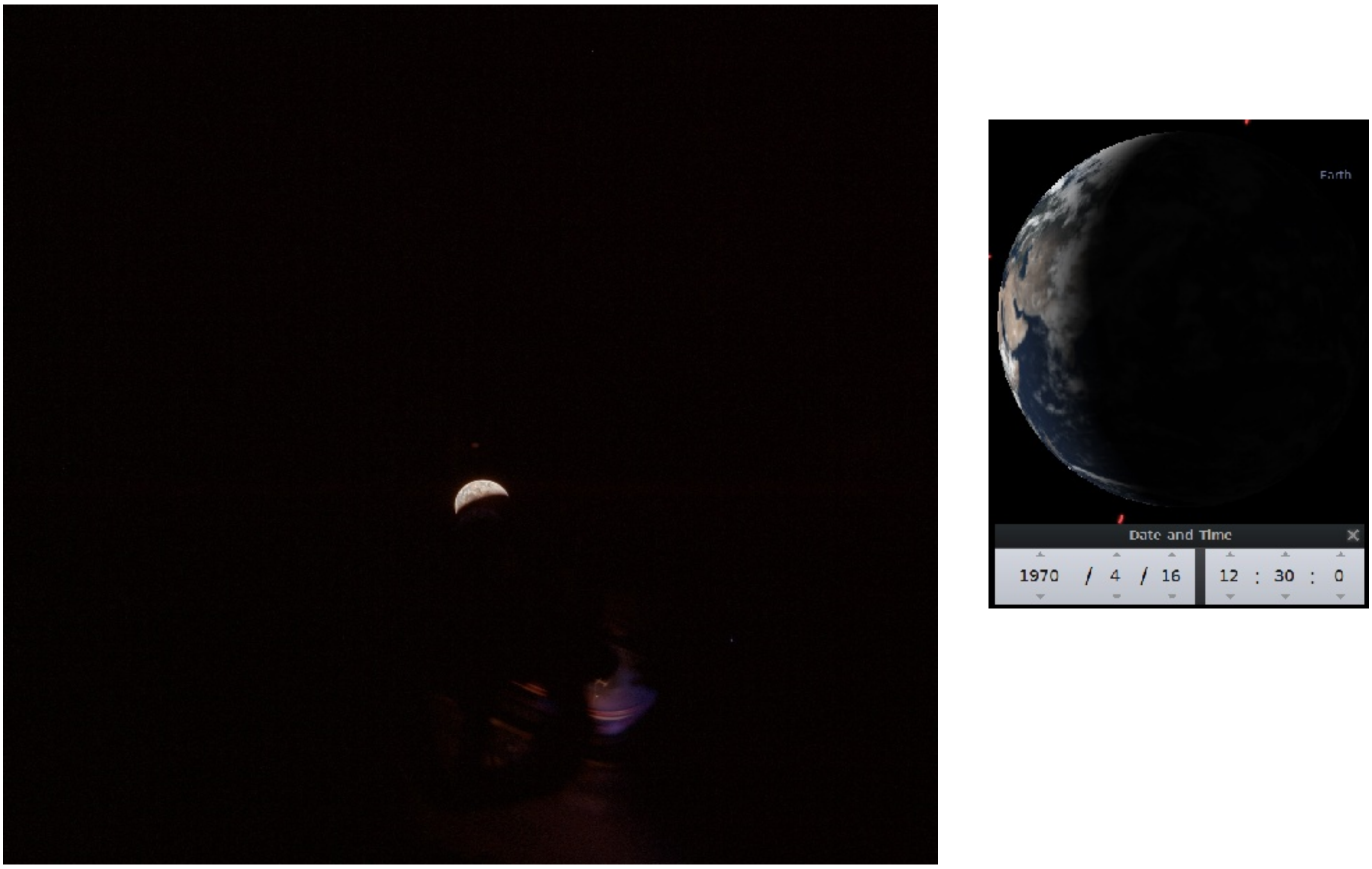


Figure 4.5.24: AS13-62-8993 (http://www.lpi.usra.edu/resources/apollo/images/print/AS13/62/8993.jpg source: with Stellarium comparison.

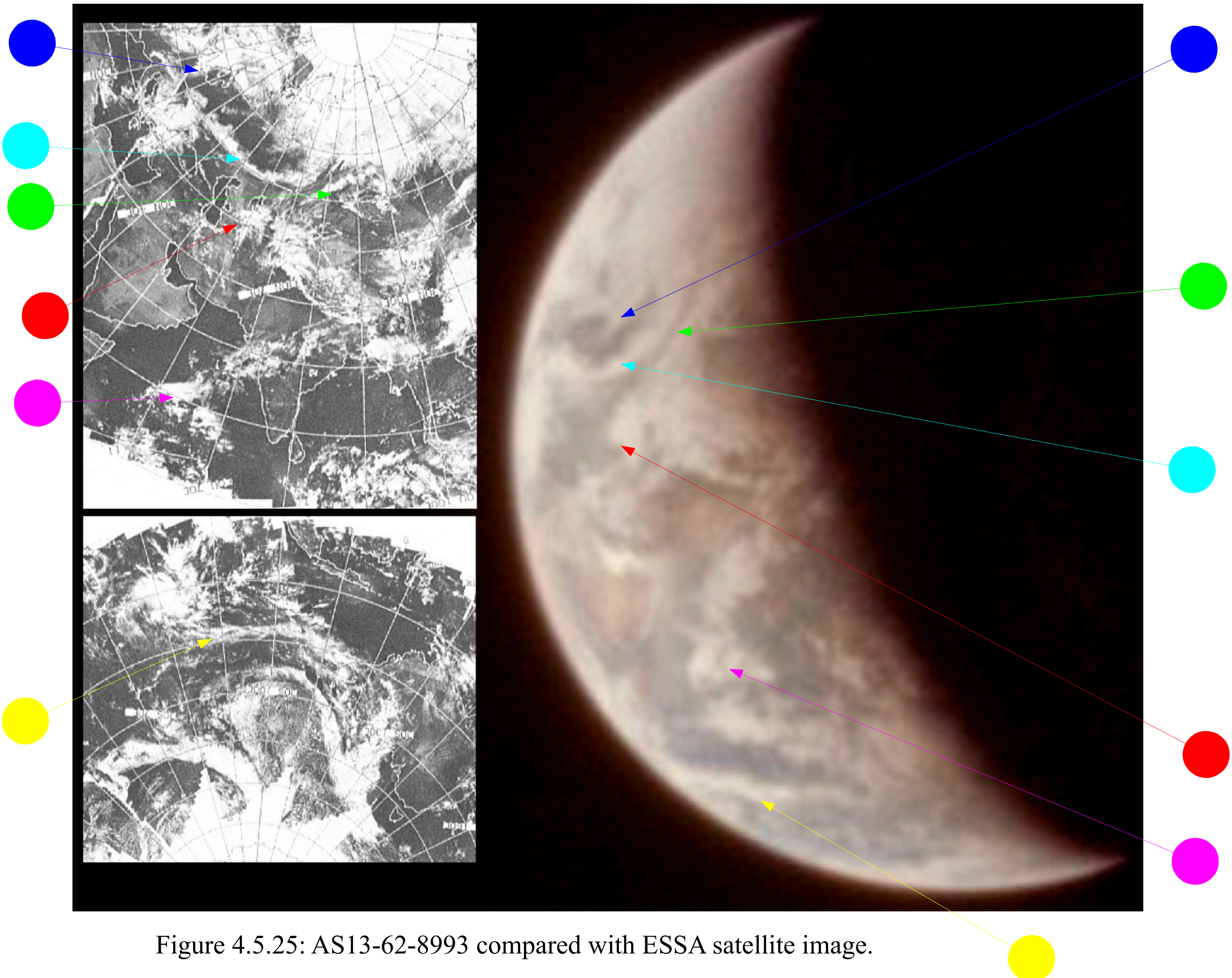


Figure 4.5.25: AS13-62-8993 compared with ESSA satellite image.

The land in the centre of the image is the Indian sub-continent, with Arabia on the western Horizon. The bulk of the visible cloud mass is sweeps over the Himalayas before meeting with another weather system crossing northern India from the Indian Ocean.

The terminator line falls roughly across Bangladesh on the coast, and this gives an estimated time for the image of 12:30 on the 16th.

ESSA's pass over this part of the world is best represented by orbit 5171 (track 10, which intersects the Bangladesh coastline), commencing at 08:09 on the 16th. At this point in the journey, the crew were busy dealing with repeated problems with one of their batteries, and preparing for the final course correction that would put them in the correct alignment for re-entry.

Once ESSA's satellite passes over eastern Africa, it starts a new page, and any images taken by Apollo will therefore be referenced by an ESSA composite labelled the 16th.

The first in the final day's images is AS13-62-9012, (figure 4.5.26).

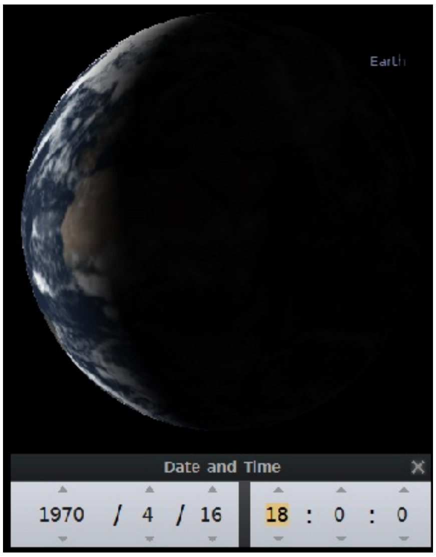


Figure 4.5.26: AS13-62-9012 (source: AIA), with Stellarium comparison.

The image shows another development in the life of the weather system that has lain off the Europe and north Africa over the course of the mission, and the position of the terminator gives an estimated time of the Apollo photograph of around 18:00. The satellite image used is dated the 16th, and the analysis in figure 4.5.27 overleaf demonstrates that this is the appropriate date for it.

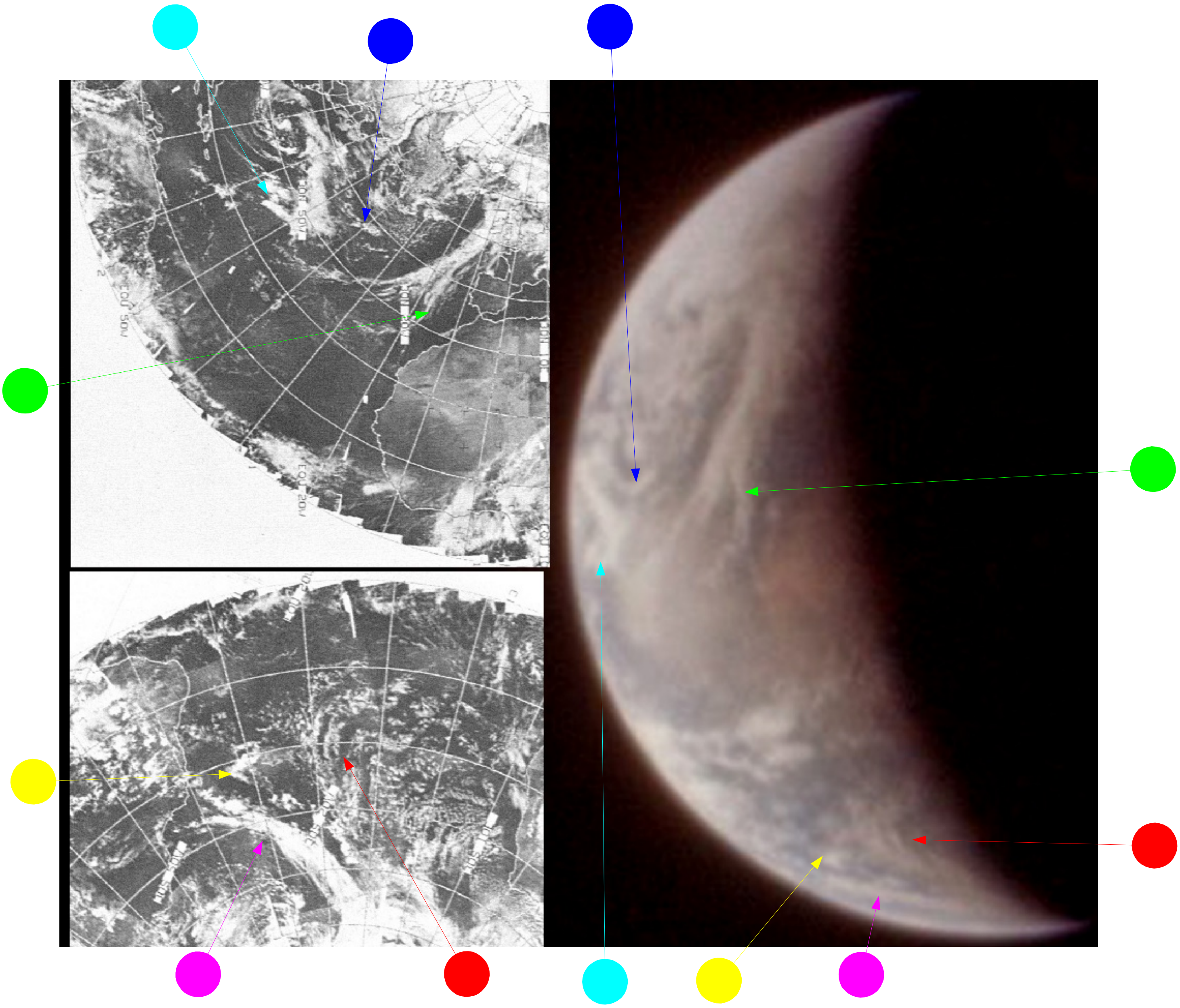


Figure 4.5.27: AS13-62-9012 compared with ESSA satellite images.

The weather front identified by the green arrow is very obviously the same one picked out in numerous previous images, but is also obviously a development of that system and not a reproduction of it. There are, as is often the case, subtle differences between the satellite images and the Apollo photograph that are indicative of a time gap between them.

ESSA's best path covering the photograph is track 13.In this case this would be orbit 5174, commenced at 14:05 on the 16th. The crew are now 24 hours away from a safe landing and are going through the housekeeping and entry procedures that will see them through those final hours.

The final image of Earth in magazine 62 is AS13-62-9038 (source: AIA). On the next page, figure 4.5.28 shows this image as shown in the Apollo Image Atlas, and 4.5.29 shows the analysis of the weather patterns in it.

The terminator line is now runs down through the centre of the north Atlantic, clipping the eastern coast of Brazil. This places the time of the photograph at roughly 20:45, and as the cyan, green and blue arrows point to the same weather systems shown in the previous image, the Apollo image must, therefore, be from the 16th of April.

Figure 4.5.28: AS13-62-9038, compared with Stellarium. Source given in text.

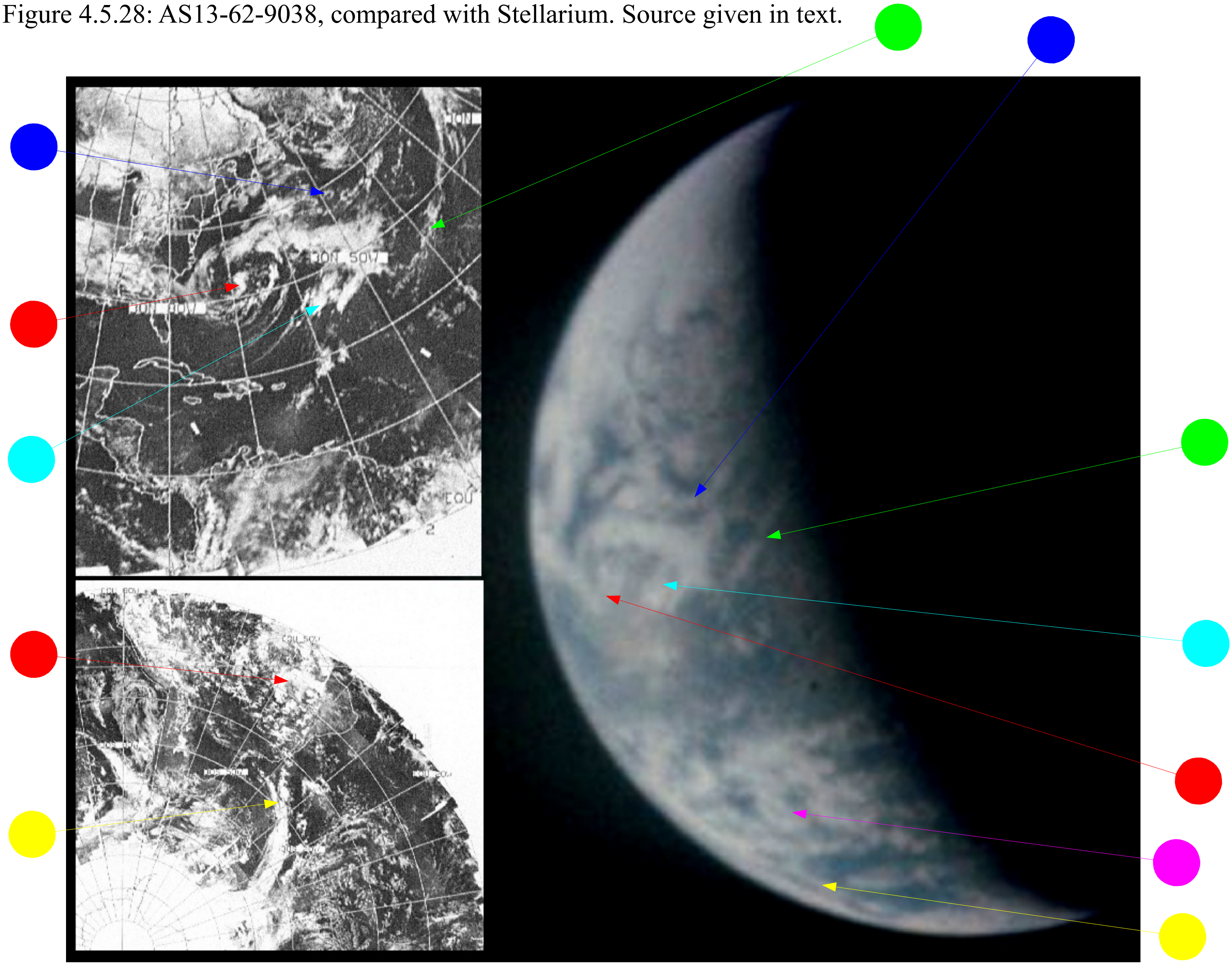


Figure 4.5.29: AS13-62-9038 compared with ESSA satellite images. Blue, green and cyan arrows as in figure 4.5.27.

The ESSA track that covers the central Atlantic around the terminator line is number 2, which means that the most representative orbit is number 5176, which was commenced at 17:05 on the 16th. As usual, the most obvious explanation for the high degree of correspondence between the Apollo & satellite images is that they were taken at roughly the same time, one from space, one from low Earth orbit.

The final image in this sequence is from a so far unused magazine, AS13-59-8492.

It occurs as part of a short sequence of images immediately before photographs of the jettisoning of the damaged service module part of the CSM, which occurred at 13:14 on the 17th. Prior to this are a number of photographs taken from within the CM. The Apollo image is shown in figure 4.5.30, and the satellite analysis in figure 4.5.31.

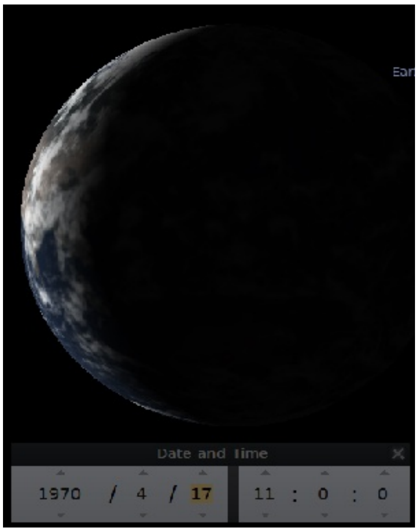


Figure 4.5.30: AS13-59-8492 (source: AIA) compared with Stellarium.

As with the previous analysis, the main land mass visible is that of the Indian sub-continent, and there are a number of similarities between the two photographs. There are, however, subtle differences. The terminator line here crosses the coast of Vietnam, meaning it was taken before the previous one in terms of a single rotation (Stellarium estimates a time of 11:00). The concavity of the terminator line has increased which means that there has been a change in the apparent phase of the Earth, at least in terms of the view from the Apollo 13 craft, the crescent appearing narrower than the preceding day's photograph.

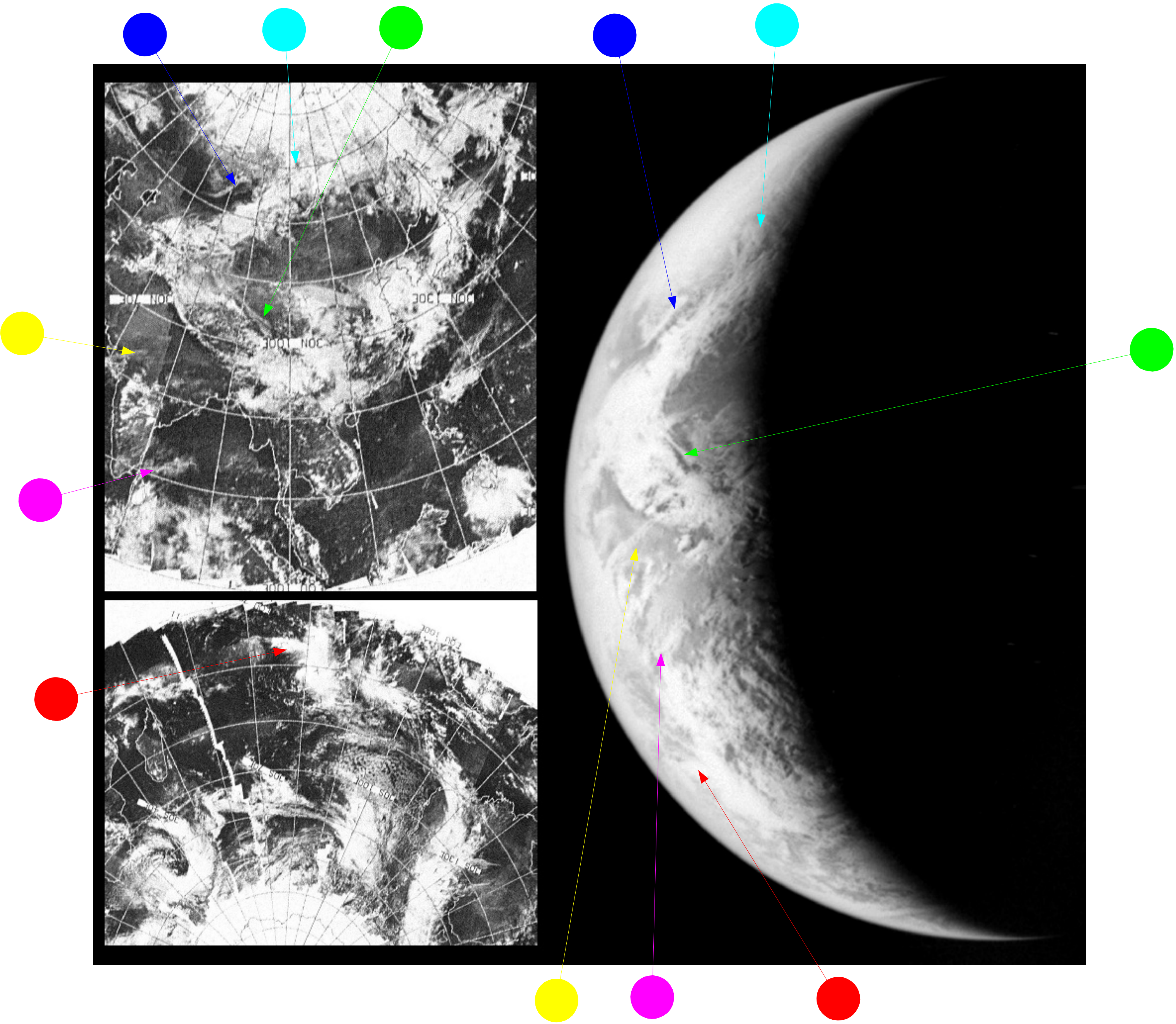


Figure 4.5.31: AS13-59-8492 compared with ESSA satellite images.

There are also clues in the shape of the cloud systems. While there is the same band of cloud covering the Himalayas, the green and blue arrows point to bands of cloud that do not show on the previous day's photographs of the area. The land either side of the broad swathe of Himalayan cloud is considerably clearer than in the photograph taken on the 16th.

ESSA's image, labelled the 16th, still covers this rotation of the Earth, and the most relevant orbital path is number 5184 (track 10), which was commenced at 09:08 on the 17th.

The crew were now only 48000 miles and 7 hours from a safe landing, At 136 hours into the mission (11:15), they ask about settings for black and white film for the upcoming separation from their CM, so the camera was around at this time too. 10 hours earlier, there was a considerable discussion about what cameras were available for photographing the separation manoeuvres, and some concern at the degree of misting on the windows that might interfere with it. This misting is visible on some of the photographs in other magazines.

Apollo 13. Around the moon and home again, with the photographs to prove it.

4.5.2 Meteorological evidence

The same sources used for previous sections are again available here (the reader is referred to those sections if they wish to check them themselves), but as with Apollo 12 the ever diminishing crescent of the Earth and the fact that the majority of photographs show areas not covered by the synoptic charts limits the number of possible comparisons.

April 11th did, at least feature good coverage of North America, which allows us to revisit AS13-60-8588, Figure 4.5.32 shows the NOAA & German synoptic charts for April 11th compared with that NASA image.

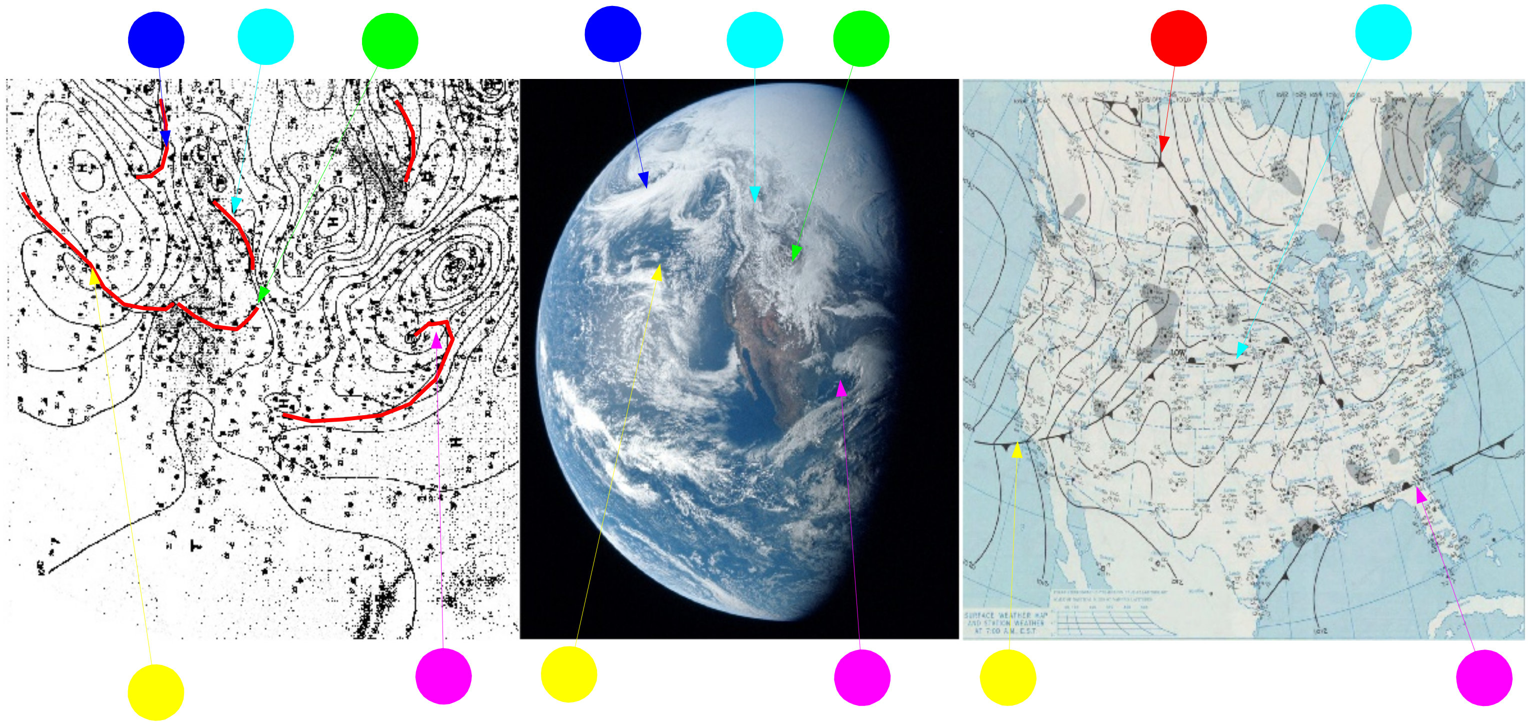


Figure 4.5.32: AS13-60-8588 compared with German (left) & NOAA (right) synoptic charts.

Again, as with preceding sections no claim is made to any great degree of meteorological expertise, and those more expert are welcome to provide their own views as to which fronts correspond to which cloud masses. The front over the gulf seems simple enough to identify, and the German chart even shows the curl of the cloud band off the east coast.

Although less obvious as a band of cloud, the stretch of clear ocean above the front marked in yellow seems to match up. The blue arrow (not shown on the NOAA chart) would appear to correspond with the system off Alaska.

There is, again, no inconsistency in the meteorological charts available and the weather patterns displayed in the Apollo image

The next brief examination of meteorological charts is for April 14th. The two images to be used have already been examined in the previous section and show the Atlantic, with a small portion of the Eastern US seaboard (AS13-60-8601), and the Pacific ocean (AS13-60-8716).

They can be compared with the NOAA and German synoptic charts, and this is done in figure 4.5.33 overleaf.

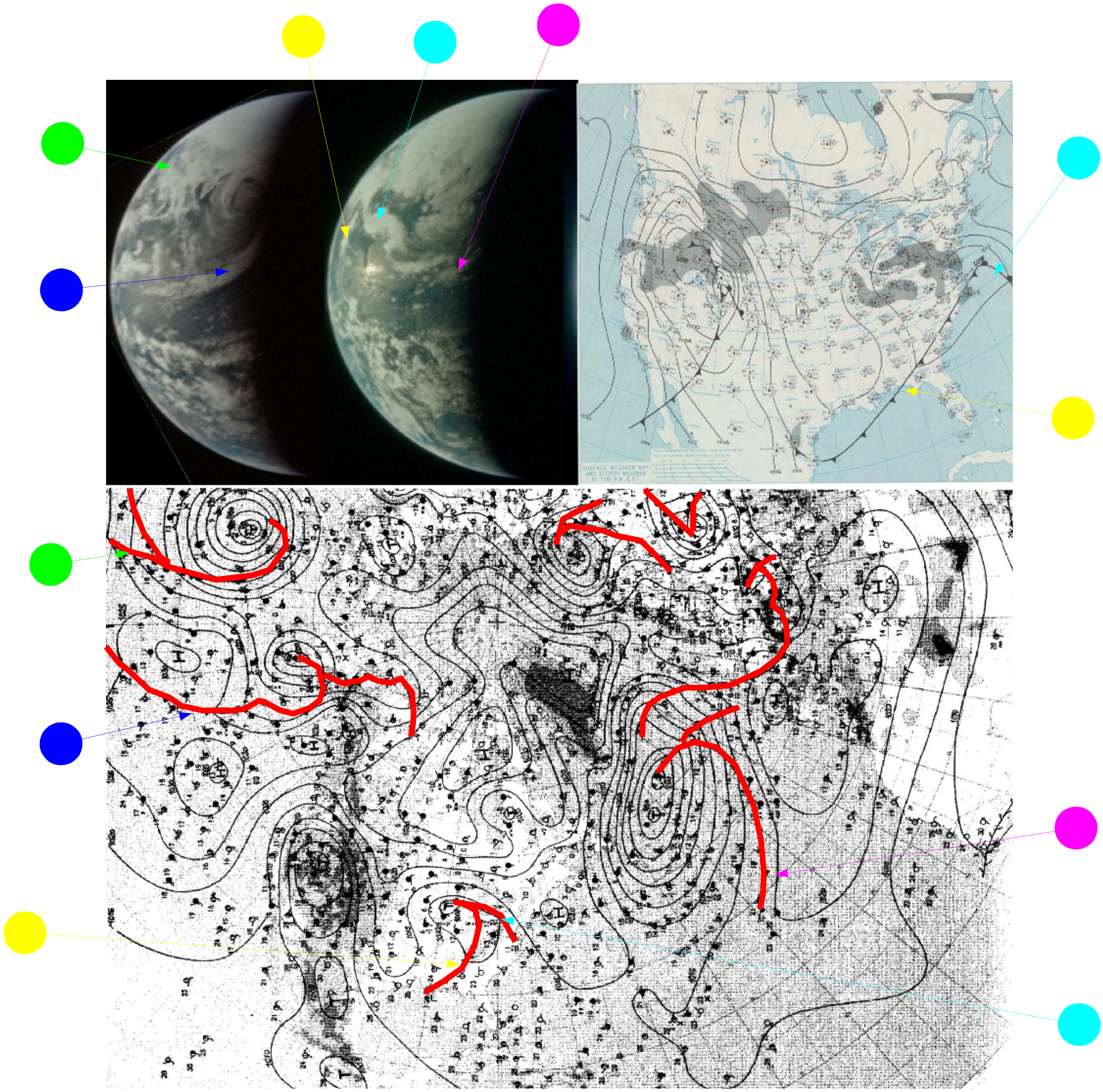


Figure 4.5.33: AS13-60-8716 (top left) and AS13-60-8601 (top middle) compared with German (bottom) and NOAA (top right) synoptic charts. German data is at 00:00 on the 14th, NOAA at 12:00 on the 14th.

It should be noted that there is a difference of opinion as to whether there is a front associated with the depression over the Rockies between the NOAA and German charts, but this area isn't covered by either of the images so it is difficult to suggest which is correct. It is possible that the time difference between them accounts for the difference in interpretation, their being some 12 hour apart.

The other fronts are clearly visible in the photographs, although it should be acknowledged that the cloud pattern off Florida is more difficult to ascribe accurately. It is the contention here that the cyan arrowed front matches that on AS14-60-8601, and the clouds that connect with it across the Atlantic are those from the magenta arrowed front. The author is always open to other explanations.

One final day's synopses will be examined before moving on to study Apollo 14, and that will be the final day for which Apollo images are available: April 16th. AS13-62-9038 and AS13-62-9012 cover the western and eastern Atlantic respectively, and German & NOAA charts should cover both (figure 4.5.34).

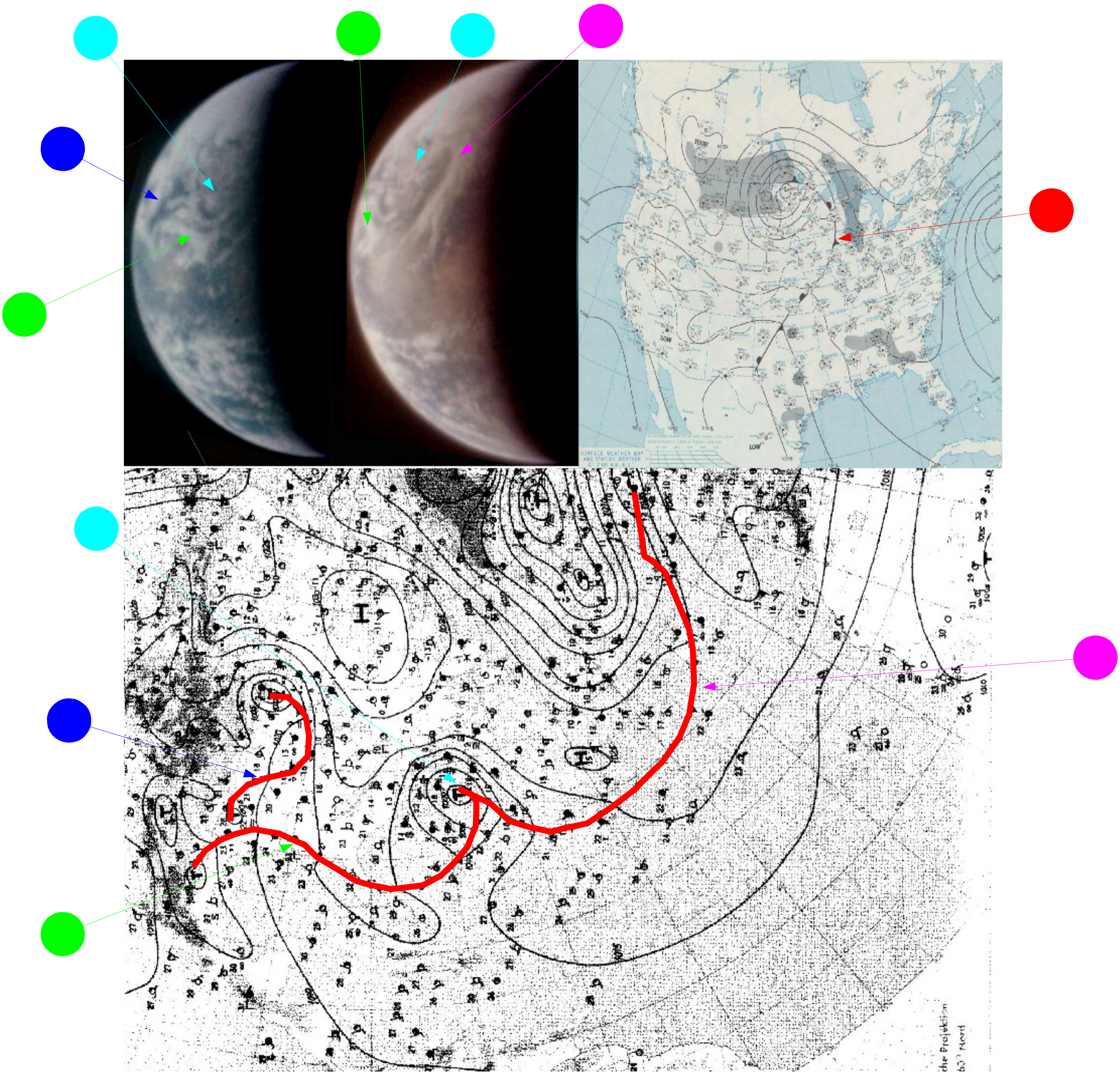


Figure 4.5.34: AS13-62-9038 (top left) and AS13-62-9012 (top middle) compared with NOAA (top right) and German (bottom) synoptic charts for April 16th 1970.

As with previous synoptic examinations, there is no discrepancy between the synoptic data collected on the ground and the Apollo images taken in space.

The most reasonable explanation for this has been made many times: the Apollo images were taken from space, on the days they have always claimed to have been taken.

4.6 Apollo 14

Following Apollo 13's near disaster, it took 9 months for NASA to re-start its remaining lunar missions, and it was not until the end of January 1971 that Apollo rose from the launch pad heading for Fra Mauro (named after a 15th century map of the world), the original destination of Apollo 13 and a replacement of its original destination of the Littrow region of *Mare Serenitas*.

The mission launched on January 31st 1971 at 21:03. It left Earth orbit at 23:37, and was notable for taking several attempts to achieve a successful dock with the LM. It arrived in lunar orbit on February 4th at 07:05, and landing occurred at 09:18 on the 5th. The mission timeline can be found here http://history.nasa.gov/SP-4029/Apollo_14i_Timeline.htm.

Two 4 hour EVAs were undertaken, one on the 5th and one on the 6th, before the LM ascended to rejoin the orbiting CSM on the evening of the 6th. The crew splashed down at 21:05 on the 9th.

During the mission, 1342 images were taken on 15 magazines, but the vast bulk of these were taken on the two EVAs, and also of the Descartes region, which was an area deemed of sufficient interest to help move the landing site from Littrow, the orbital parameters for which would not have allowed Descartes to be observed.

Like Apollo 12 before it, the location of the landing site towards the western limb of the lunar face (as viewed from Earth) means that for there to be a reasonable amount of daylight to be available, the moon would need to be ¾ full, which also means that the Earth needs to be ¼ full by the time the astronauts land, and this limits the number of useful photographs available for this analysis.

In fact, very few images of Earth were taken at all during this mission, and some of those are of very poor quality, possibly a product of a problem with one of the Hasselblads that prevented its use. A number of NASA affiliates were approached to find better quality copies of those currently publicly available, but unfortunately only the same standard of image was made available.

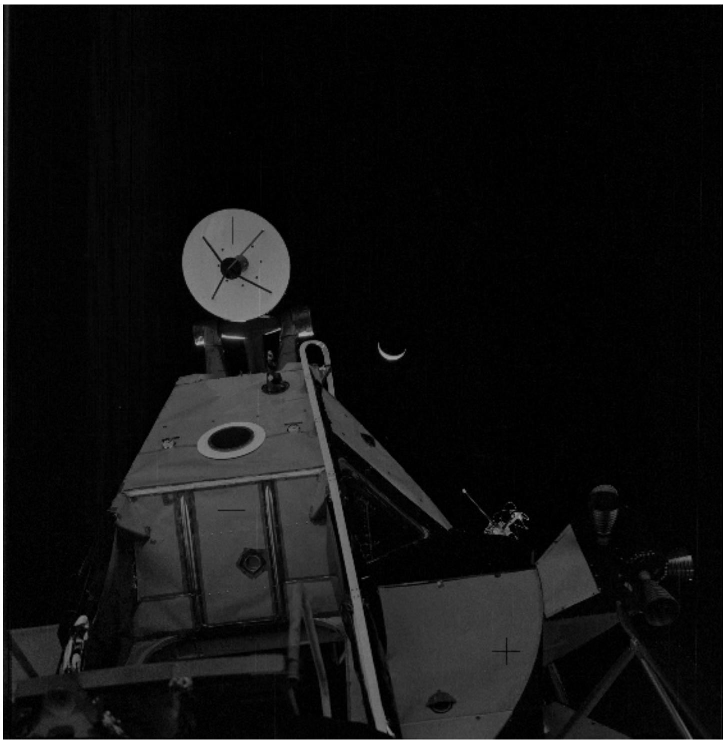


Figure 4.6.1: AS14-64-9189. Apollo Image Atlas

It is a great pity that this image (figure 4.6.1) and the others in its sequence showing the LM Antares on the lunar surface proved unsuitable for analysis here. Even the 44Mb TIFF image held at http://archive.org did not reveal any more detail than lesser copies elsewhere.

It is a shame because apart from the obviously useful juxtaposition of Apollo hardware and the Earth, this series of images from magazine 64 has been shown to show Venus.

The reader is referred to this website for full explanation of this:

http://www.hq.nasa.gov/alsj/a14/a14Venus.html

It is possible, however, to zoom in on one of the images in that sequence (AS14-64-9191: Apollo Image Atlas) and by altering the levels of in the image's histogram and the degree of contrast reveal some degree of detail.

The time of this sequence is given as 12:03 on 06/02/71, so we can use Stellarium to identify what should be visible. Figure 4.6.2 shows a zoomed & cropped version of the image after processing, compared with Stellarium's view of what should be visible.

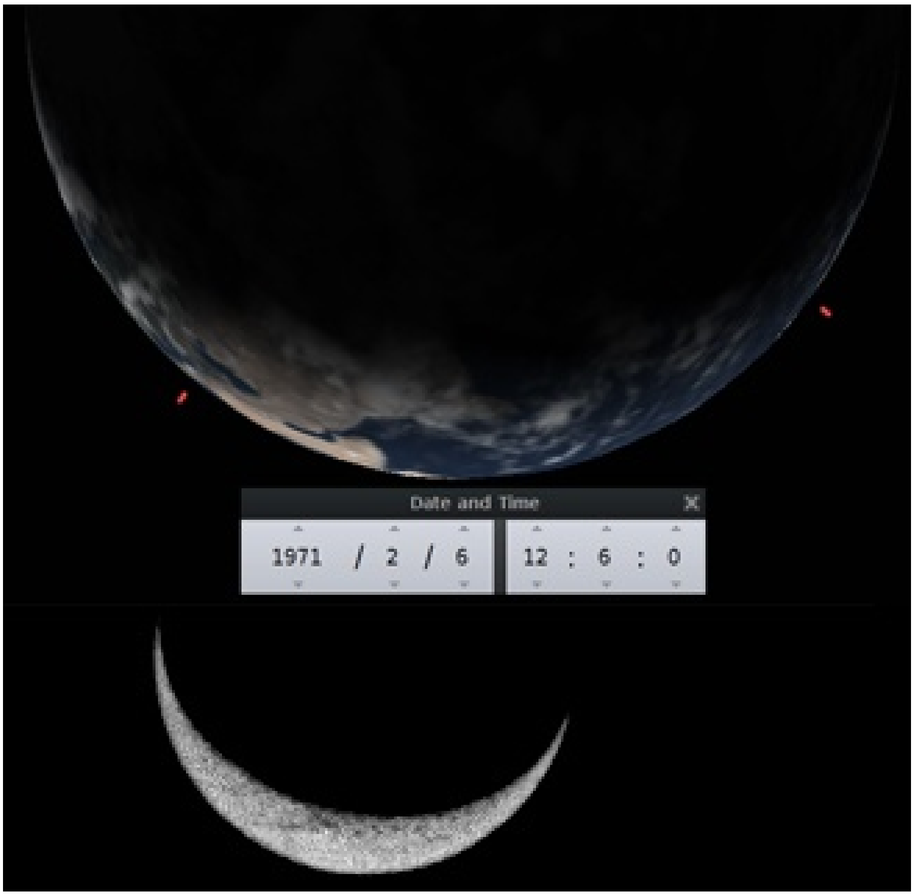


Figure 4.6.2: AS14-64-9191 (source given in text) zoomed to the Earth compared with Stellarium for 12:06 06/02/71

The series of images of which this Apollo one is a part took only a few minutes to complete, so the actual time of this specific image would be around 12:06, as shown in the image. Very little cloud is recorded for this region on that particular day, but while an area of darkness corresponding to roughly where the Indian coast would be can be seen, it would not be wise to claim any degree of certainty as to whether the image is revealing actual detail or just features from image processing. It would certainly not be possible to compare any weather systems on it.

As for what satellite data are available ITOS 1 images are available from here ITOS 1. ITOS 1 was launched on 23/01/70, and occupies the same orbital tracks as ESSA satellites. The introduction to the the ITOS data describes its operation.

NIMBUS 4 had become fully operational by this time, data for which can be found here NIMBUS 4

ATS satellites had, by now, finished their visual imaging programme.

Occasional images from satellites can be found in journals and other publications covering this period. This journal article contains a much clearer ITOS image from the day of Apollo 14's splashdown, as well as a synoptic chart. The Use of Meteorological Satellite Data in Analysis and Forecasting has several images from early February 1971, and a February 4th ITOS image is also available in Satellite activities of NOAA 1971. As with previous sections, these are given more as an indication that the information presented here has always been available, should diligent researchers have cared to look for them, rather than an indication that they will be used.

The Mariner's Weather log also contains an image from the 8th: Weather Log

Another interesting document is Weather support to the Apollo 14 mission from September 1971, which describes the role of weather forecasters during the mission (the launch was delayed thanks to bad weather). It also features synoptic charts and ITOS & NIMBUS images from during the mission.

The mission timeline is available here: NASA . Given the lack of images with clear views of Earth, no synoptic charts will be examined.

4.6.1 Satellite comparisons

Unlike previous missions, no images were taken of Earth until the craft was in (or very close to) lunar orbit. This combines with the fact that those images that are available are of such a narrow Earth crescent and and/or of poor quality that it is very difficult to carry out any meaningful analysis on them.

Those few images that are suitable will be examined, but the results should in most cases be regarded with a degree of caution. More enhancement of the images is required than has been the case so far, but the process will be explained in each case and the reader is free to replicate it. The procedure is rendered even more difficult by the absence of images from the 6th (neither hemisphere) and 7th of February (southern hemisphere only) in the ITOS 1 record, which means that for much of the period when photographs were taken, only the less clear NIMBUS images are available.

In the end, it was determined that only 4 days were covered by identifiable images of Earth, the 5th to the 9th of February. The logic of these deductions is outlined below.

AS14-66-9288 (figure 4.6.3) appears in a magazine that was taken to the lunar surface but is obviously of an Earthrise from orbit, and immediately after photographs taken from the LM showing the CSM. It must therefore have been taken after the 04:50 on the 5th when the two craft separated but before touchdown at 09:18 on the 5th. Shortly after separation at 05:23 the crew flew over the landing site (see the voice transcripts held here: ALSJ), which means the earliest it is likely to be is the start of orbit 13 and AOS at around 06:40. The start of orbit 14 is at roughly 08:00, and this is in all likelihood the last opportunity to image as the next orbit around sees the crew in descent mode and somewhat occupied! During this narrower window Australia comes in to view, and it is off its east coast that weather patterns will be searched.

The image is part of a series of photographs, but is one where image enhancement gave the best results in terms of recognisable features. In order to achieve those recognisable features the image needed some enhancement. Figure 4.6.4 shows the original zoomed and cropped Earth compared with the Earth after levels had been altered, and brightness and contrast values changed and the image sharpened.

Figure 4.6.3: AS14-66-9228. High resolution version available here: ALSJ

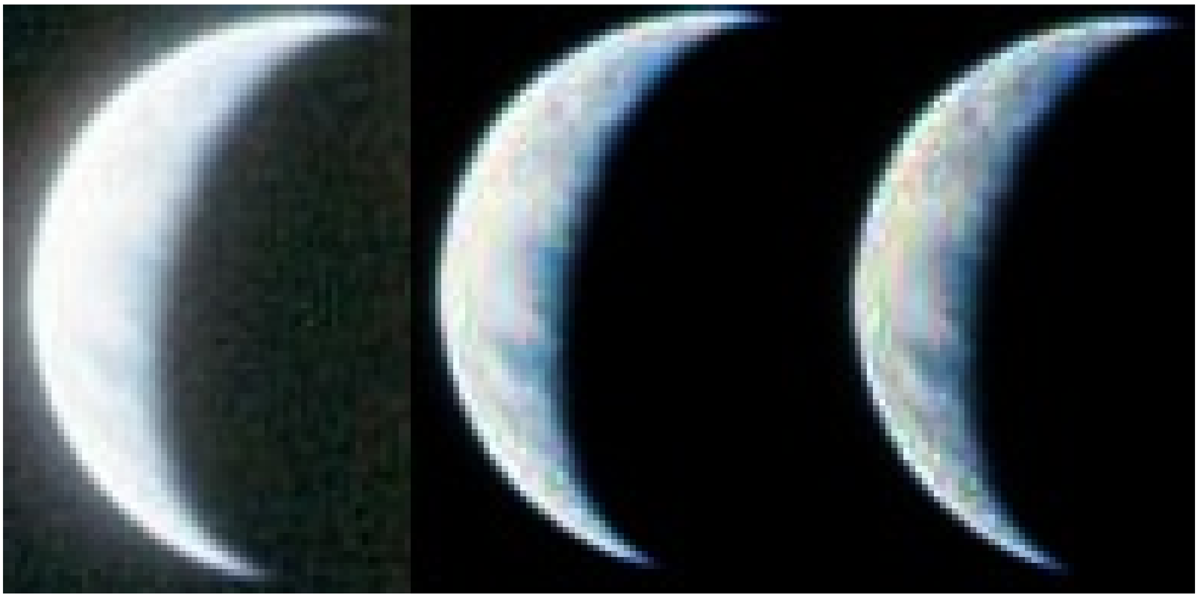


Figure 4.6.4: Original Earth from AS14-66-9228 (left), Earth after level adjustment (centre) and then brightness/contrast adjustment (right). Level adjustment moved dark values from 0 to 68 and grey values from 1 to 0.44. White values were left untouched. Contrast was then increased to 40% and brightness decreased by 60%.

While not the best quality, the levelled and contrasted Earth suggests that there is a body of cloud in the very south of the planet, above which is a thinner band separated from the this mass by a narrow band of sea. North of this relatively thin band is an area of blue, presumably sea, that is narrower at the west than it is at the east. Above this patch of ocean is more cloud, this time narrower at the east than the west. Above the pointed tip of this cloud at the terminator is a lobe of blue ocean, above which is more cloud that extends westwards in an arc to join the cloud below it. We now need to see if these features can be found in an area east of Australia on the 5th of February and this is shown in figure 4.6.5.

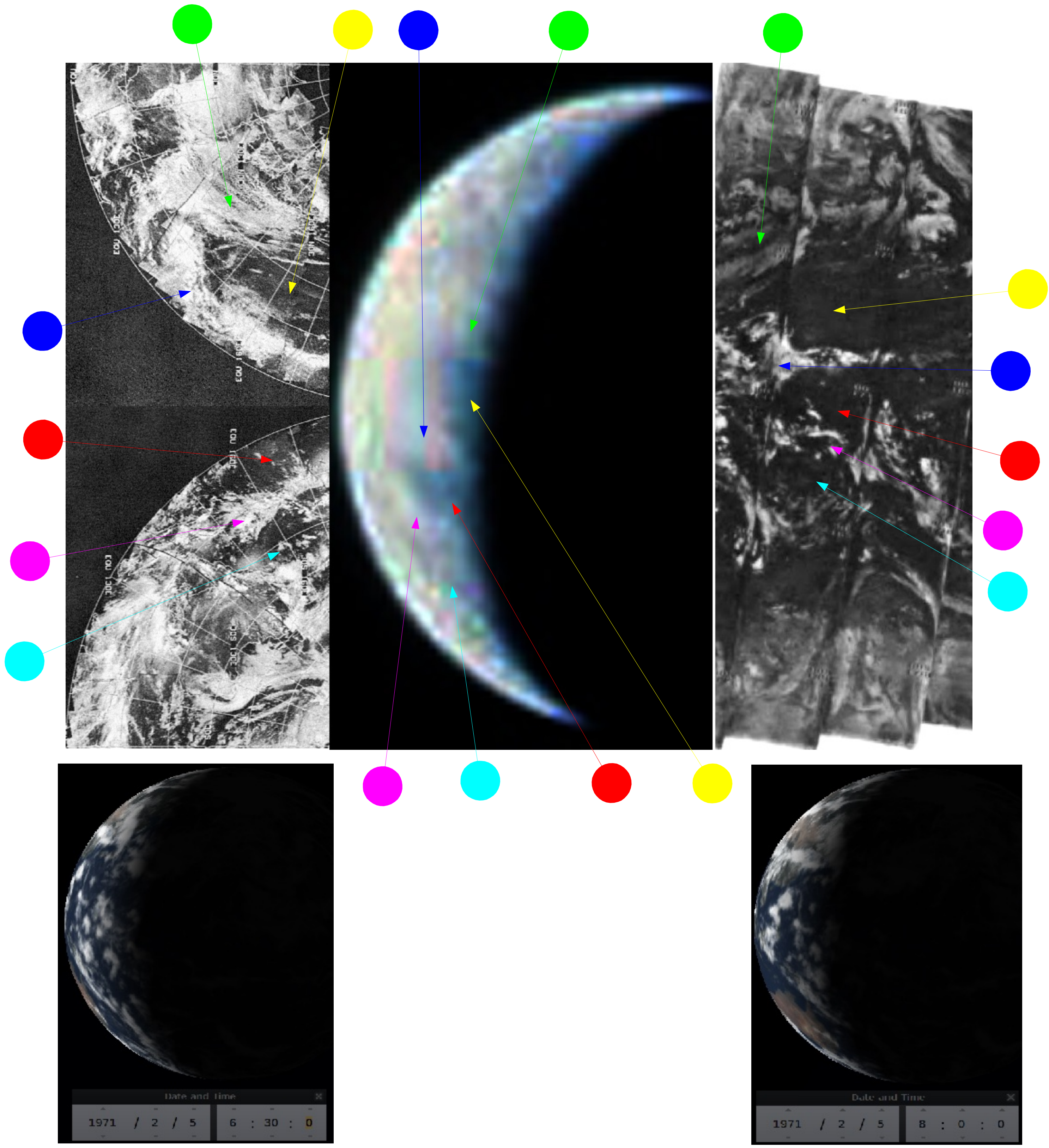


Figure 4.6.5; AS14-66-9228 compared with ITOS (top & bottom left) and NIMBUS (right) night time IR satellite images. Clouds and clear patches are both identified. Stellarium terminators for the suggested likely times are also shown.

As far as confirming timings, the ITOS images follow the same pattern as ESSA and an image dated the 4th will pass over Australia on the 5th. The most appropriate track for the area covered is number 8, which corresponds to orbit 4725, commenced at 04:09. The best coverage of the region by NIMBUS 4 turned out to be the night time IR images, as these were the only ones that covered the area completely (daytime IR and visible spectrum ones give incomplete coverage). On the image dated the 5th, the most relevant pass is number 4071, which was commenced at 11:48. The mission's preliminary scientific report (Source: PSR) confirms that this image was taken 1 orbit before landing, and the Photographic index (ALSJ) states that it was taken on orbit 12, which started at about 08:11 on the 5th. As an aside, Venus is also recorded in the Earthrise sequence: ALSJ.

Despite the caveats mentioned earlier, the images do show broad scale features visible on the satellite images. They may not be as clear as those analysed in previous sections, but the logic used to determine which part of the Earth to look at and the features themselves seem to provide a good match. It is important to re-iterate that nothing has been added to the image of Earth during enhancement. Close examination of the original Earth in the photograph shows the same features, they are just masked by an overexposed image. The reader is, as always, invited to repeat the process undertaken to check that this is the case.

The next image examined is AS14-72-10038 (figure 4.6.6). The image is part of a sequence of photographs of an Earth crescent occurring after a number of images taken looking down at the lunar surface. The photograph must therefore be after entering lunar orbit, and the width of the earth crescent indicates it is some time after the image examined previously.

Figure 4.6.6: AS14-72-10038. Source: AIA

Zooming in on the image reveals much more detail than in the previous image, and therefore only a small altering of levels to bring enhance it is required. The image shows the Americas on the Western limb, and the main weather features are a long band of cloud stretching in from the terminator towards Mexico, which almost a serrated edge. The south western end of this band appears to have another mass of cloud immediately to the north of it. Over north America is a large mass of cloud, and south America shows scattered clouds over Brazil, with a long chain of cloud runs across South America. Cuba is dissected by a thin band of cloud running roughly north-south.

Analysis of this image is made difficult by the absence of high quality images, but the exact date can be narrowed down somewhat by examining the satellite images for other days. As mentioned, the crescent is much thinner than the Earth seen on the 5th, and the 'serrated edge' cloud does not feature an additional mass of cloud to the north of it, so it is clearly not from them. The image from the 8th shows this same cloud has reached the coast of Central America (it actually developed into a substantial in the gulf storm, causing considerable damage to southern US states), ruling that date out.

This leaves either the 6th or the 7th of February as the likely date. The Stellarium terminator just off Florida suggests a time of around 23:00, at which time on the 6th the crew have just jettisoned the LM ascent stage, and the same time on the 7th the crew are long past TEI, have made a mid-course correction and are in the middle of on-board experiments. No mention is made of photographs, and the image could belong to either day. The size of the Earth in the image lends itself to the idea that it was taken post-TEI, but both the AIA and ALSJ describe the photo as being taken in lunar orbit.

Figure 4.6.7 shows a comparison of Stellarium terminator lines with the Earth crescent in the photograph in an attempt to pin down the date more precisely. This seems to pin down the date definitively to the 6th. The photographic index cited earlier seems to contradict this by stating it was taken on orbit 14, which was on the 5th and the preceding analysis shows began with Australia in view. The suggestion here is that the evidence of the photograph, rather than the index, is correct, as a 90 minute orbit beginning over Australia would be completed passing somewhere near India .

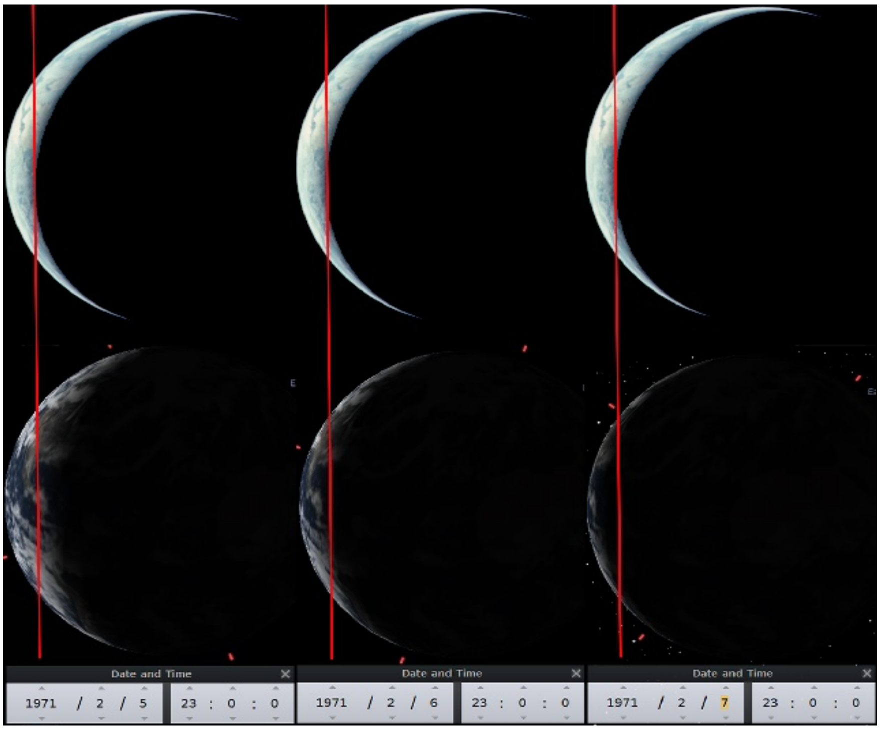


Figure 4.6.7: AS14-72-10038's Earth crescent compared with Stellarium terminator at 23:00 for 05/02/71 (bottom left), 06/02/71 (bottom middle) and 07/02/71 (bottom right).

Having discounted the photographic index evidence and established with a reasonable degree of certainty that the date for this image is the 6th of February, we are left with the problem of a lack of satellite images with which to compare the Apollo photograph. NIMBUS 4 does have an image from the 6th, but only shows a small portion of the gulf in the night time IR image. The visible and daylight IR spectrum images fail to show any portion of the crescent.

We do, however, have images of the southern Hemisphere from the 5th and 7th, and also northern hemisphere images from the 5th and 8th. While not as ideal as in previous missions, it should be possible to demonstrate that the clouds visible on the Apollo image are a good interpolation of what should be there given the weather conditions on days before and after the 6th.

Figure 4.6.8 shows the Earth crescent from AS14-72-10038 compared with southern hemisphere ESSA images from the 5th & 7th, and ESSA northern hemisphere images from the 5th and 8th. The NIMBUS image is from the 6th.

The NIMBUS image does show a band of cloud (blue arrow) extending across the Gulf towards central America. A band of cloud is also visible across where Cuba should be (green arrow). What is noticeable is that the extra cloud mass at the end of this band in the Apollo photograph is not visible in this image, but as it is an IR based image, it may be that this cloud simply hasn't registered with the camera. The northern hemisphere image from the 5th is obviously more similar to the photograph than the one from the 8th, where the storm mentioned earlier has begun to develop in earnest. The ESSA northern hemisphere image from the 5th shows Cuba in its entirety, with band of cloud across it.

Looking over Central America, NIMBUS shows a couple of thin bands of cloud running across it (red arrow), and these seem to correspond to similar just visible strands in the Apollo image. The cloud cover on the 8th in the ESSA image is much more extensive over this region, while the that from the 5th does bear some similarity.

The southern hemisphere in ESSA shows a much less dense cloud pattern in the image form the 7th compared with the 5th, particularly over Brazil. The most visible feature from the Apollo photograph's perspective is the long band of cloud running first along the Andes before cutting across Chile & Argentina heading towards the south Atlantic (purple arrow). A number of shorter bands can be seen in the the Apollo image running parallel with the this larger band (yellow and cyan arrows), and one of these breaks away from running strictly parallel (yellow arrow).

None of these features are seen exactly in the ESSA image. There are definite resemblances between the two and these have been highlighted where a definite comparison can be seen. The 7th is the most similar, but it would be fair to state that the image taken by Apollo 14 shows a continental weather system that falls somewhere between the two states given in the ESSA satellite mosaics.

Despite not having the precise image available for a given day, the presence of images from preceding and following days allows us still to state the Apollo photograph was taken on 06/02/71 at around 23:00, because had it been taken at that time on the other days the craft was in lunar orbit it would have shown different features. For the record, the NIMBUS pass over the Mexican gulf is on the 6th is number 4081, which was commenced at 06:05 – still some time before the Apollo image. ESSA images over that region are track number 3, which are taken commenced between 19:00-20:00.

In addition to this colour image of Earth from lunar orbit, there is a black & white series of an Earthrise that must also have been taken before leaving orbit on the 7th. AS14-71-9845 (figure 4.6.9)

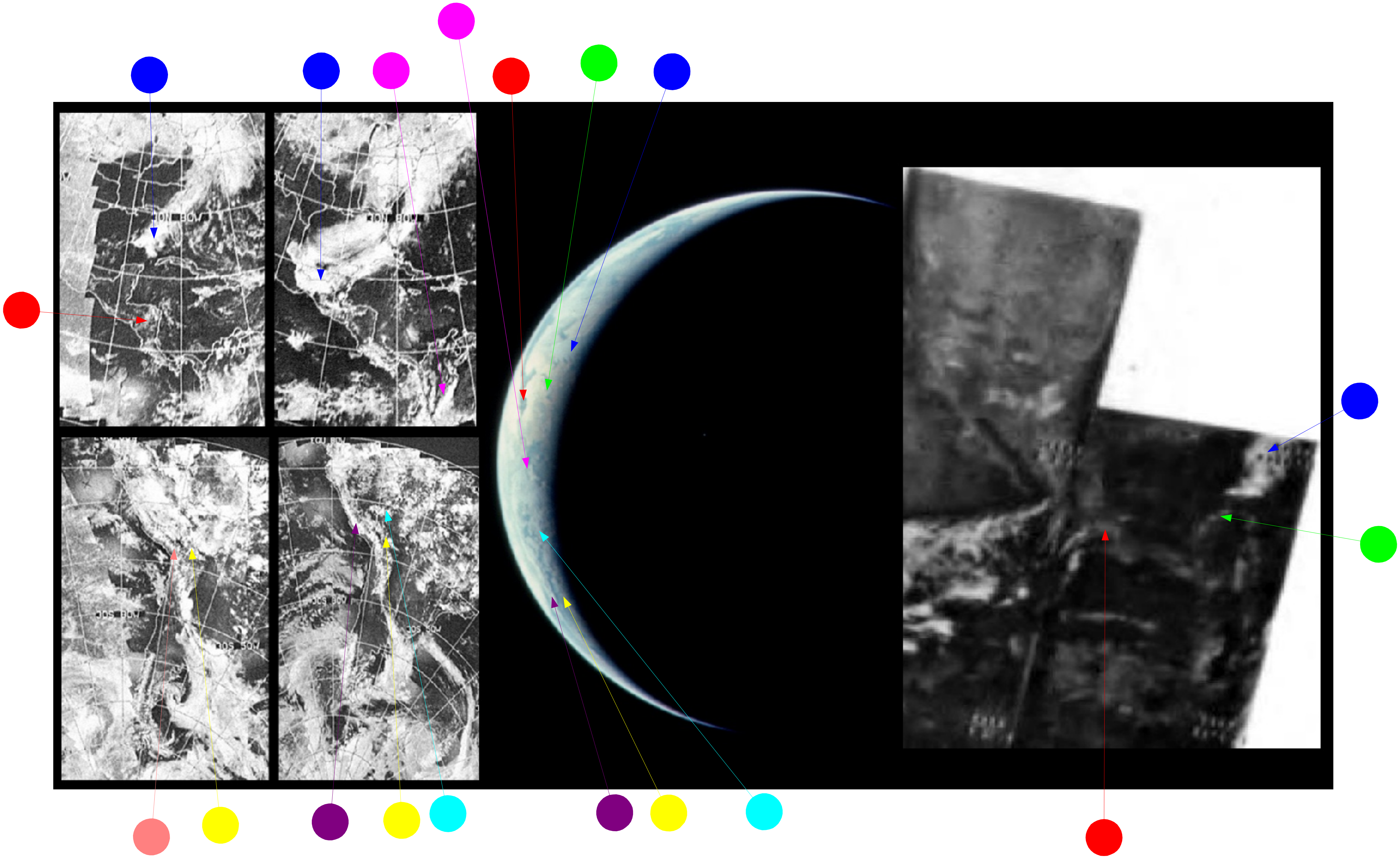


Figure 4.6.8; AS14-72-10038 Earth compared with NIMBUS from the 6th (right), ESSA northern hemisphere from the 5th (top far left) and 8th (top left), and ESSA southern hemisphere from the 5th (bottom far left) and 7th (bottom left) of February 1971.

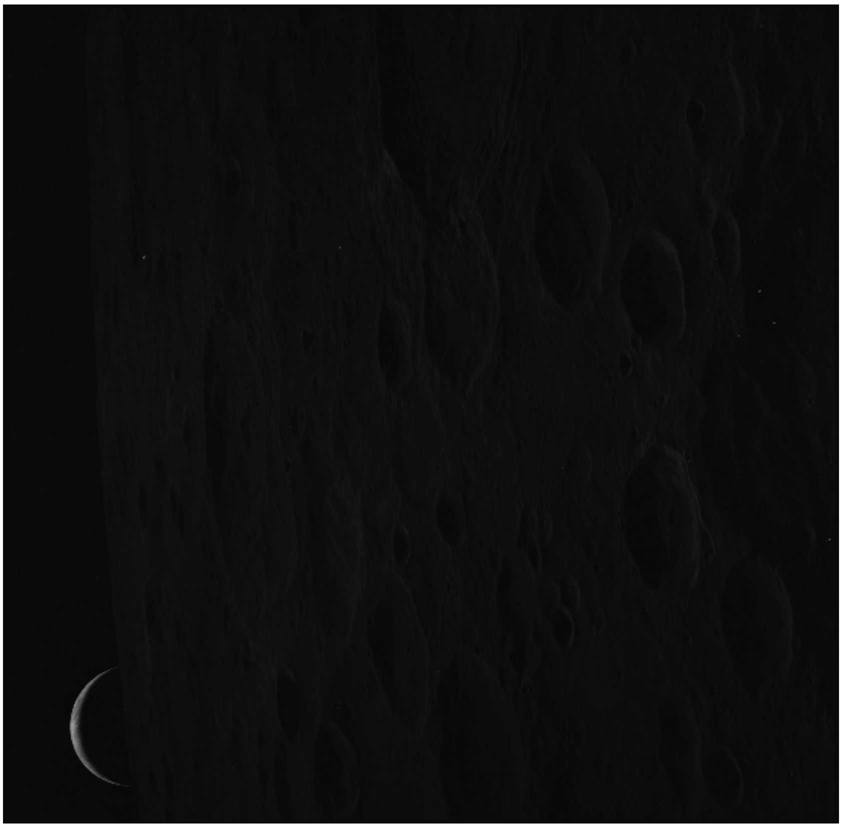


Figure 4.6.9: AS14-71-9847 (Source: AIA)

is the second in a short series of exposures near the start of the magazine. Immediately after them are photos of craters strongly suggestive of increasing orbital altitude, as craters over 200km apart are recorded in the photos after the Earthrise and the lunar horizon becomes increasingly curved.

The width of the crescent in the photograph is roughly the same as that in the previous image, which suggests that it was also taken on the 6th. There are, however, no visible landmass features to allow us to work out where the image is, so we are reliant on weather features as a guide as to where the terminator is falling. The photographic index lists it as taken in trans-Earth coast.

The most obvious feature is the large apostrophe shaped weather system in the northern hemisphere, which should at least be easy to find. The bulk of the tropical region seems to be cloud free, before scattered sub-tropical clouds appear in the southern hemisphere. Some other systems are just visible in the southern temperate region that may be visible in satellite images.

In analysing this image, we need to use the same technique as the previous image and use those days where there data do exist to cover for days where it is absent. It should be obvious from the previous analysis that the photograph must be later than the 5th, and appears to show a crescent consistent with the 6th of February rather than the 7th.

Examination of NIMBUS images from the 6th show that there is are systems resembling those in Apollo photograph in the northern Pacific, as well as the open equatorial oceans and scattered sub-tropical clouds in the southern hemisphere suggested in the Apollo image. The northern Pacific parts of ESSA images from the 5th and 8th are included to ensure complete coverage, and southern hemisphere ESSA images from the 5th and 7th. The NIMBUS image shows the visible spectrum image from the 6th.

Figure 4.6.10 shows the analysis on this basis, with a terminator image from here as a reference.

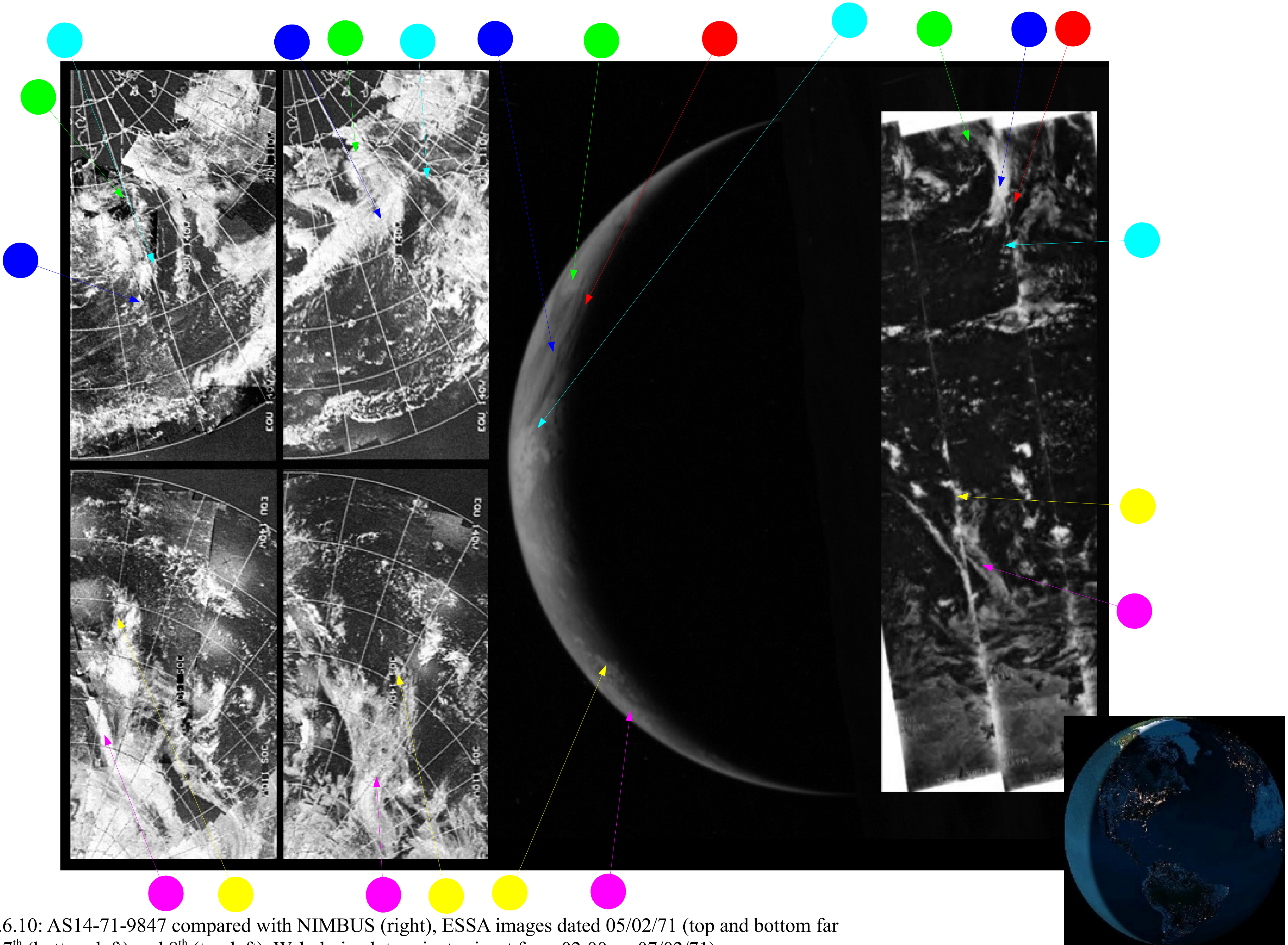


Figure 4.6.10: AS14-71-9847 compared with NIMBUS (right), ESSA images dated 05/02/71 (top and bottom far left), the 7th (bottom left) and 8th (top left). Web derived terminator inset from 02:00 on 07/02/71)

Before discussing the image it is worth pointing out that several sections of the ESSA image from the 5th were over-brightened over significant areas. These areas have been selected and their levels altered to reveal the detail hidden by this excessive brightness. The original, unaltered, images are in the Appendix.

Those readers who have actually been bothering to look at the analyses presented previously will probably have looked at the preceding figure and not quite understood the arrows drawn on the ESSA side of things. Arrows have been drawn, but the weather systems they are pointing at bear only slight resemblances to the Apollo image. The NIMBUS side of the figure is much more obvious – the apostrophe shaped system is very evident in the NIMBUS visible spectrum image, as are the thin band of cloud to the east of it and the scattered clouds to the south of it. This suggests very strongly that we have the date correct for the Apollo image. The track covering this cloud system is number 4090, which was commenced at 20:59 on the 6th.

However, we can see from the Stellarium terminator that the time of the image will have been taken at approximately 02:00, and it seems reasonable to suggest that this would be in the early hours of the 7th. Part of this reasoning is based on the fact if the Apollo image was taken at 02:00, then it should match almost exactly with the ESSA image taken on the 5th, as Alaska would have been imaged at roughly the same time. The remainder of the logic behind dating this image relates to the position of the clouds on the image dated the 5th from ESSA and how they compare with those on the NIMBUS image. To explain this better, figure 4.6.11 shows a close up of the area off the Alaskan coast.

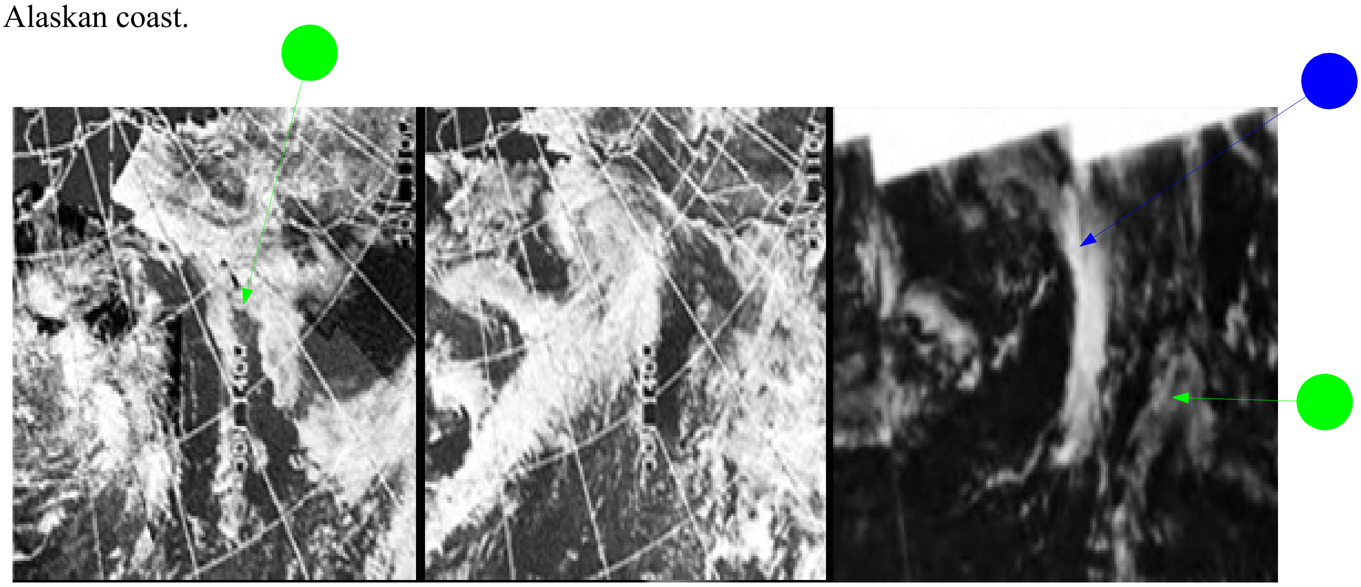


Figure 4.6.11: ESSA image dated 05/02/71 (left) and 08/02/71 (centre) and NIMBUS image dated 06/02/71.

The weather system under discussion is highlighted by the green arrow in the NIMBUS image. The initial temptation was to assume that the cloud pattern on the 140 degrees west longitude line was the same one. However, by going through other images covered by the mission, it was soon established that the edge of the orbital track covering that weather system in the NIMBUS image is also on the 140 longitude line. This effectively means that for the clouds in the ESSA image on that line to be the same ones, the weather systems would effectively be going in reverse – travelling in the opposite direction to the prevailing winds – extremely unlikely.

The clinching observation, however, is the cloud pattern to arrowed in green on the ESSA image from the 5th and the NIMBUS image – they are clearly the same, and this makes much more sense in terms of how weather patterns behave. The NIMBUS image was taken some 18 hours after the

ESSA image on the 5th, which allows plenty of time for the system picked out in blue in figure 4.6.11 to move eastwards to its new position in the NIMBUS mosaic, and for the weather patterns picked out in figure 4.6.10 to move to their new position in the early hours of the 7th.

If we refer to the Apollo mission transcripts and timelines, we can see that (assuming our deductions are correct) at that time the crew had completed their TEI burn (which would have been taken on the far side of the moon as the craft performed one last orbit), and were actually engaged in lunar photography. At 148 hours and 48 minutes (just a couple of minutes after AOS) the mission commander tells capcom that they are

"making like tourists with the cameras right now"

Again, despite missing key elements of the data, logical deduction allows us to make reasonable assertions using the data that are available. We have a photograph taken at Earthrise followed by other images indicating the Moon falling away from the Apollo craft, a crew stating that they are taking photographs, and a weather system photographed at around the same time that doesn't match the same area the day before or two days later.

One final image is available to us for Apollo 14. Shown in figure 4.6.12, AS14-73-10352 (Source: AIA) occurs after a series of images which, if they are zoomed in on, reveal the words "Fluid electrophoresis demonstration" on the CM control panel.

Figure 4.6.12: AS14-76-10352 (source given in text)

This was an in-flight demonstration of a process designed to separate different molecules in a zero gravity environment. At 02:00 on the 8th, the crew discuss with capcom when this should be done. At this point the terminator line would be over Alaska, which like previous images means that we do not have direct ESSA coverage of the northern hemisphere. They then tell capcom that they would like to do that experiment 'after the next P23', which is a navigation procedure involving fixing on stars. The next P23 procedure after this occurs at 03:00.

At 16:00 on the 8th, the crew are asked how they are proceeding with the in-flight demonstrations, and they state that they have finished almost all of them other than some in progress work on metal composites, but more importantly this conversation occurs shortly after waking from a rest period, and the last recorded communication prior to this was at 05:00 (although they report that they were 'not yet ready to go to sleep'. It seems reasonable to assume, therefore, that the photographs of Earth must have been taken after 03:00 and 16:00 on the 8th.

In the photograph itself, once levels are adjusted to remove the over-brightened part, the most obvious feature is a large mass of cloud in the widest part of the crescent. To the north of this is a thin light grey lobe extending towards the terminator, but little detail is discernible in the thinner part of the crescent. South of this feature, it is possible to make out a south-east trending line of thin cloud, as well as another line parallel with this further south still. Towards the thinnest part of the southern crescent is a more substantial looking patch of white. There are also a couple of patches of brown in the thickest part of the crescent, suggestive of land masses

There is mention of Earth dark side photography taking place at 02:47 on the 9th, 18 hours before re-entry. It is not clear how these images were taken, but at that time the terminator would again have been crossing the Alaskan border, and then the Pacific. Given the orientation of the Earth on the 9th, the thickest part of the crescent would be roughly in line with the Mexican border, and there is no large cloud mass in that area that would correspond to the one in the photograph. The crew also report that they aren't able to see any of the Earth's crescent at that point, so we can discount this.

Looking at the land masses that are covered by the timespan available to us, the most likely looking area is around the Asian coast between China and Thailand, which would be on the terminator between 09:30 and 12:00. A terminator here would descend through Indonesia, giving an alternation of land and sea areas suggested in the photograph, and it would also be at the right latitude. Australia would be at the thinnest part of the crescent. As before, however, we have to rely on an ESSA image taken some 14 hours later than the suggested time for the Apollo picture.

Using this as a basis, figure 4.6.12 shows the analysis. There does seem to be a degree of correspondence, but again there can not be absolute certainty in the exact location covered by the Apollo image. For the record the NIMBUS orbit (4112) was commenced at 13:05. ESSA's southern hemisphere image track for the 7th (number 9, pass 4764) would have been commenced at 07:01 on the 8th. The northern hemisphere ESSA image was taken 24 hours later, and will obviously not be a completely accurate picture of conditions for the day before, but will be a development of it.

The preceding analyses represent all that can be examined for Apollo 14. It is conceded that there is an element of doubt over them, such is the poor quality of the images available. If the only source of data available were the satellite and Apollo images, it would have been extremely difficult to derive timings for any of the images based on observed weather systems, but the availability of other sources (notably the mission audio and transcripts) allow some certainty to be gained. The reader is, as always, invited to perform their own analyses from the available data. As the crescented Earth is so thin for most of the mission photographs and the weather systems less than clear, it was decided that a comparison of synoptic charts would serve little purpose, and so the discussion of Apollo 14 ends here.

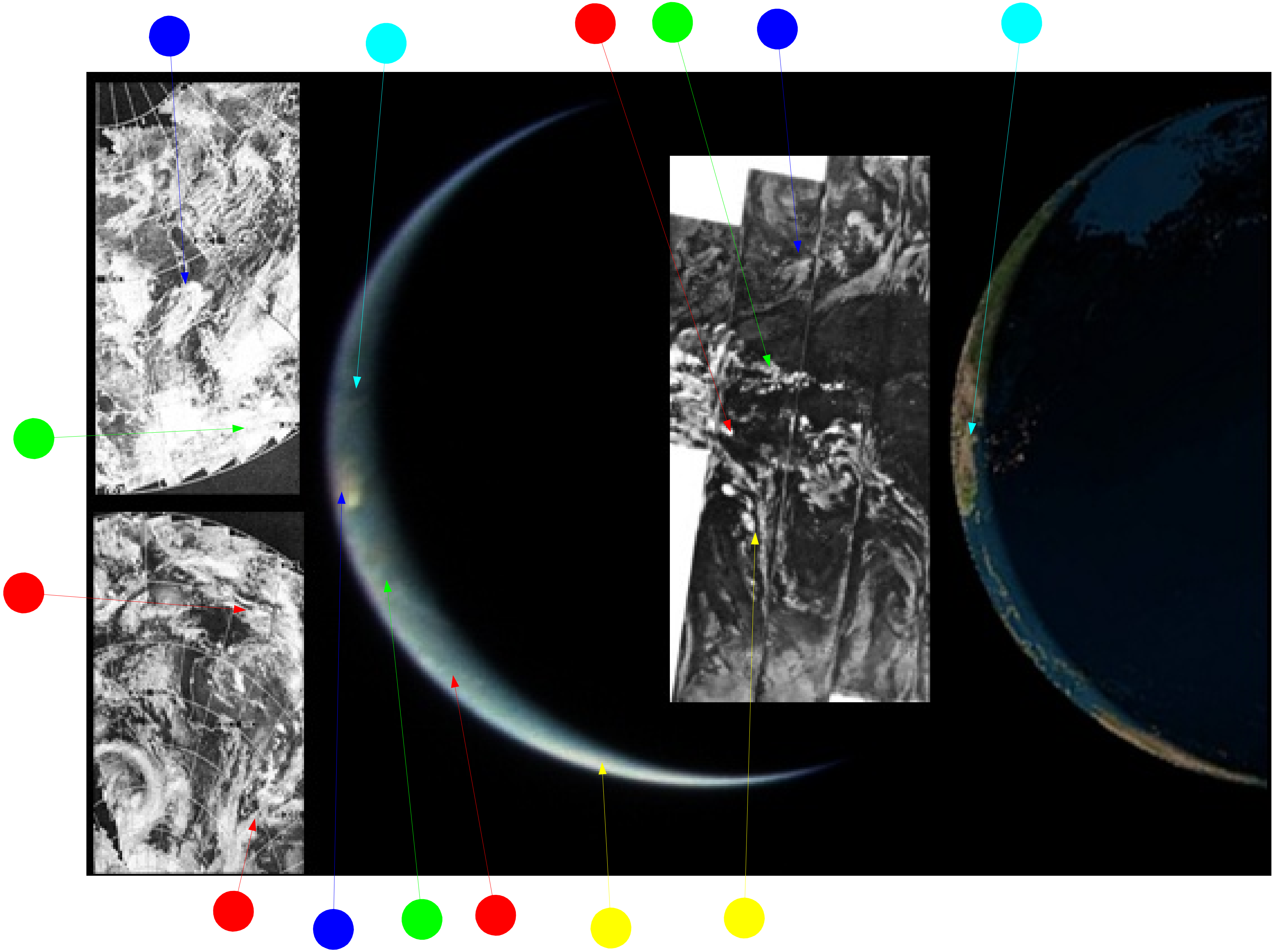


Figure 4.6.12: AS14-76-10352 (centre left) compared with ESSA images from 08/02/71 (top left) and 07/02/71 (bottom left), and NIMBUS night IR image from 08/02/71 (centre right). Earthview image is 08/02/71 09:30. Cyan arrow shows suggested similar land feature.

4.7 Apollo 15

Having re-established the Apollo missions with 14, Apollo 15 took them to new levels of scientific exploration of the Moon, rather than just a technical demonstration that it was possible. It was launched at 13:34 on 26/07/71. It arrived in lunar orbit on the 29th, and landed on the 30th. After 3 EVAs, the surface crew headed back to re-unite with the CSM on the 2nd of August. TEI occurred on the 4th of August, splashing down on the 7th.

Previous missions had been focussed on the need to get back once the surface had been successfully reached, and had resisted suggestions to extend the orbital stay for further study. Apollo 15 changed that by spending additional time in orbit before and after the landing. It featured a number of instruments in the SM's Scientific Instrumentation Module (SIM) to measure the x-ray and gamma ray characteristics of the lunar surface, and deployed a small sub-satellite with its own experimental equipment to measure and map the magnetic and gravitational features of the lunar environment, and to monitor charged particles. Data from the SIM were retrieved by a spacewalk in TEC.

This mission employed an ultra-violet camera, used at set points during the mission, in order to capture images of the Moon and Earth for comparison with similar images of our neighbouring planets. It was not judged a success, and future missions carried additional UV filters.

The crew also had the availability of the LRV (lunar roving vehicle), which greatly extended the exploratory capabilities of the astronauts.

The presence of the LRV dominates the photographic record of the mission. 19 magazines were exposed consisting of 2640 photographs, the majority of which seem to consist of images taken from the LRV, with many photographs showing the small TV camera mounted on the front. The other dominant theme of the photographs is the lunar surface, and most of the orbital magazines are downward photographs of the moon.

While the mission took off with the Earth at ¾ full, the length of their stay in space meant that by the time they left for the return journey the Moon was again a thin crescent, and as a result the best photographs of Earth are from the early phases of the flight. Some good Earthrise images were taken, but unfortunately many are either overexposed or there is so little of the Earth's surface visible that little useful information can be gleaned from them. These images will be referred to, but not examined.

Many of the images available on line at the ALSJ and AIA are of also poor quality low resolution ones, and the bulk of the images used here were requested through the GAP (see previous chapters for links).

The satellite record is also diminished for this mission. ESSA 9 has good coverage: Source. One day of the mission is missing (July 31st), and many days clearly have technical issues, with missing or misplaced images in the overall mosaic. NIMBUS 4 was not routinely sending visual data from its orbits at that time (none, at least, are recorded in the final data catalogue), and the ATS-3 satellite, while still functioning, does not have a data catalogue of images from this period. Contemporary journals feature images from it, but none has yet been found from during the mission. Likewise ESSA 8 is operational but has no available data catalogue, only images from contemporary journals - some of which do coincide with the mission.

Of the journal sources available, the Mariner's Weather Log volume 15 (1971) and the Monthly Weather Report for July 1971 (Source) have again proved useful. The MWR shows images of Hurricane Hilary from ESSA 8 on two separate days within the timespan for the mission (July 26th and 31st), as well as Hurricane Ilsa on the 2nd of August. The MWL shows Hilary on the 1st and an unnamed Atlantic storm on the 5th (Source).

Having identified the available sources for the mission, it is now time to analyse those images of Earth provided by the Apollo 15 astronauts.

4.7.1 Mission photographs.

The first image of Earth (part of a short sequence of Earth photographs) taken during Apollo 15 was taken using magazine 91. It occurs after a sequence of photographs showing the docking sequence of the CSM and LM and a discarded SIV-B, which immediately places those images after 17:52 on the 26th (see here for the mission timeline: NASA source.

AS15-91-12342 (see figure 4.7.1) is focussed on the Atlantic, with south America the dominant land mass visible. There is a curl of cloud stretching from the Gulf to the mid-north Atlantic, and above the thin line of cloud marking the inter-tropical convergence zone is an unusual system that should be obvious on the satellite image. South America is marked by long banks of cloud along its western coast, and a number of bands of cloud run across it. These weather patterns will now be identified in figure 4.7.2.

Figure 4.7.1: AS15-91-12342 from the GAP. Low resolution version available at the AIA

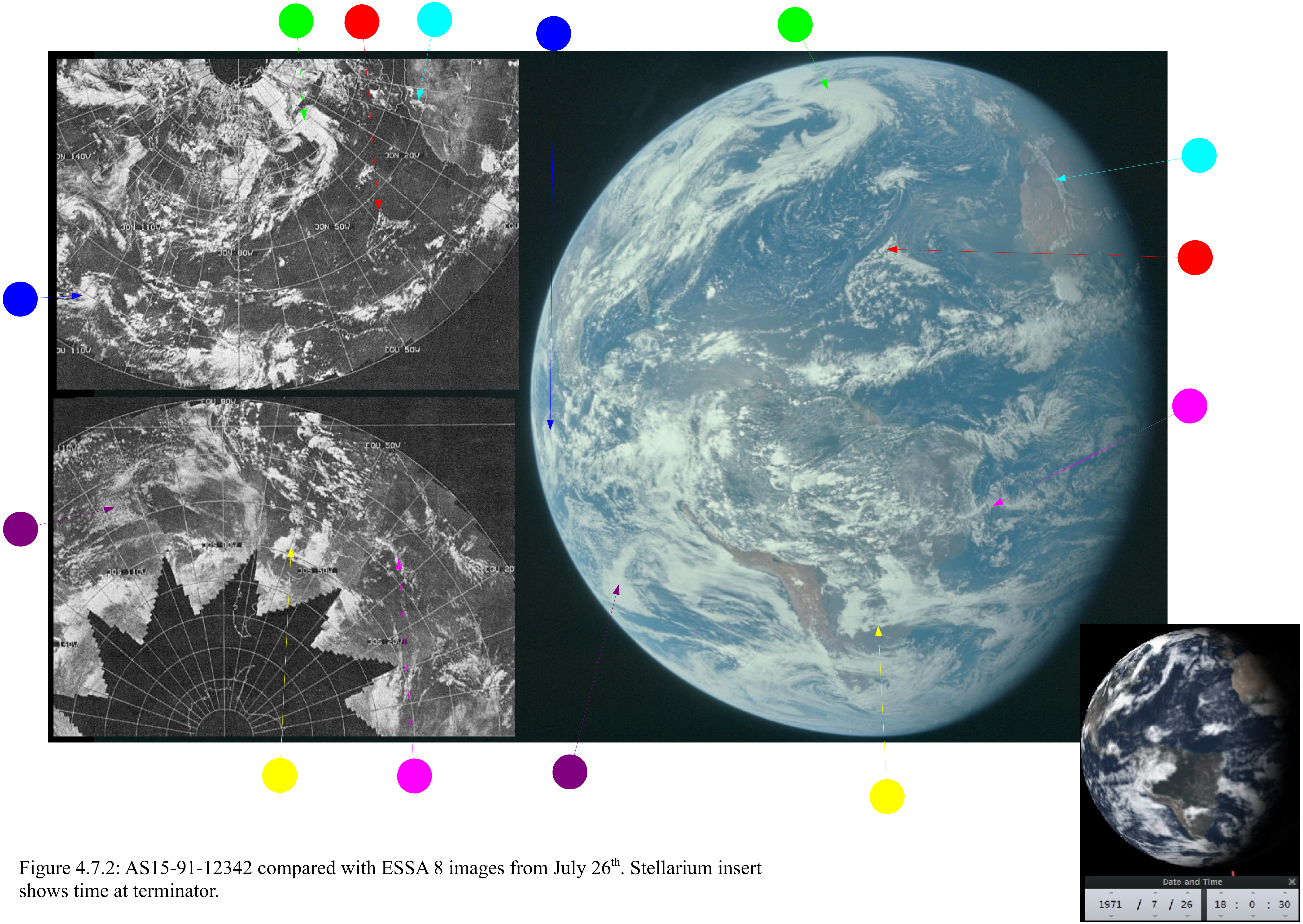


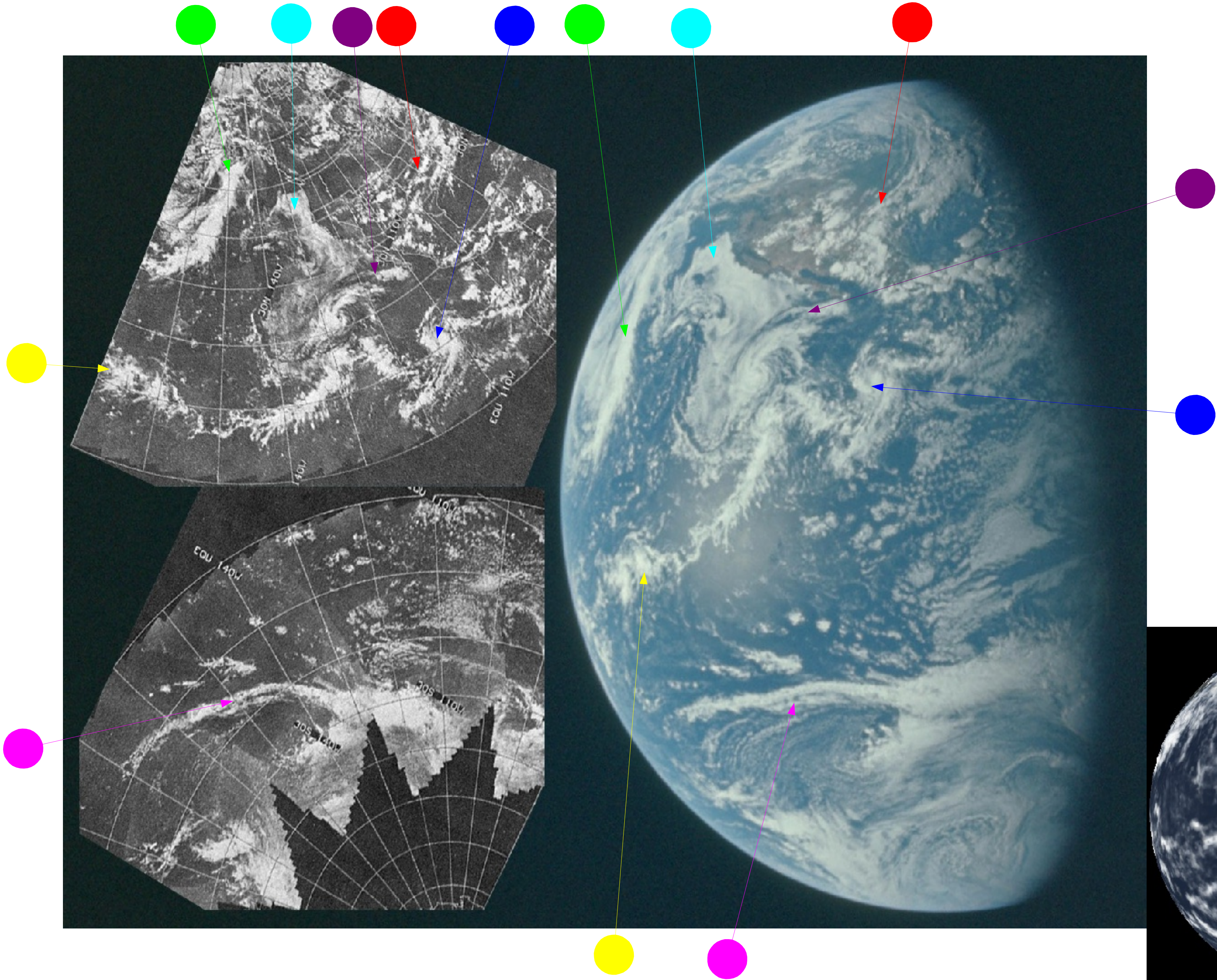
Figure 4.7.2: AS15-91-12342 compared with ESSA 8 images from July 26th. Stellarium insert shows time at terminator.

As is usual with the first Earth images in a mission, there is no difficulty picking out the weather systems shown on the photograph. They are clearly contemporaneous, and as is the way with weather features the patterns visible on the satellite image are different on the following day. The ESSA track covering the centre of the Apollo image would be track number 2, which corresponds to orbit number 996, commenced at 16:01 on the 26th. Again, as has been the case all the way through this exercise, the timing of the satellite image matches that of the Apollo image.

After a duplicate image of AS15-91-12342, another Earth image shows a different surface configuration of clouds. Figure 4.7.3 shows AS15-91-12344.

Figure 4.7.3: AS15-91-12344 from the GAP. Low quality version available here AIA

Once correctly oriented it is easy to see that the only landmass visible is north America, with a prominent bank of low level cloud off the west coast. South of this cloud mass and just north of the equator is a long meandering line of cloud heading towards the western limb. South of the equator is a much more well defined line of cloud extending for the in-darkness south America towards the western limb. This image is compared with ESSA's satellite image in figure 4.7.4.



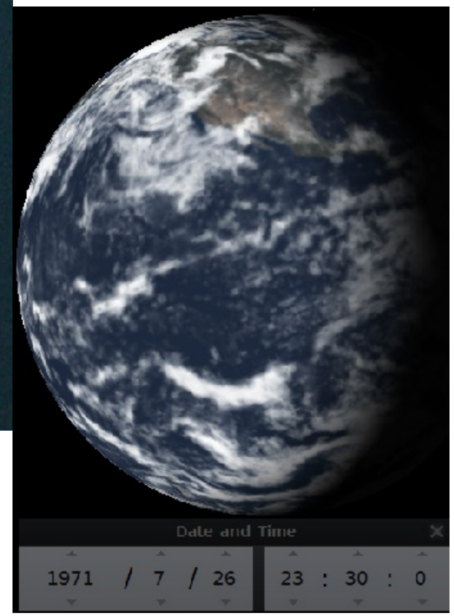


Figure 4.7.4: AS15-91-12344 compared with ESSA 9 image and Stellarium inset. Blue arrow is as in figure 4.7.2

The blue arrowed system in figure 4.7.4 is the same one as identified in figure 4.7.2, and this system will be discussed in more detail momentarily. The system picked out by the cyan arrow is also visible in 4.7.2, west of the system identified by the green arrow in that figure. As for the other systems, it should again be obvious even without the arrows that those visible in the Apollo image are also present on the ESSA mosaic.

The terminator in Stellarium suggests a time for the image of 23:30. ESSA's most representative track covering this part of the Pacific is number 5, which corresponds to orbit 999. This orbit started at 22:07, giving a good correspondence with the Apollo timing.

The significance of the blue arrowed system can be identified in the weather records of the time, and in the documents mentioned in the preamble to this section. The reason it has been singled out here is because it is identifiable as Hurricane Hilary. The ESSA 8 image recorded in the MWR can be matched with the ESSA 9 images in figure 4.7.2 and 4.7.4, as shown in figure 4.7.5

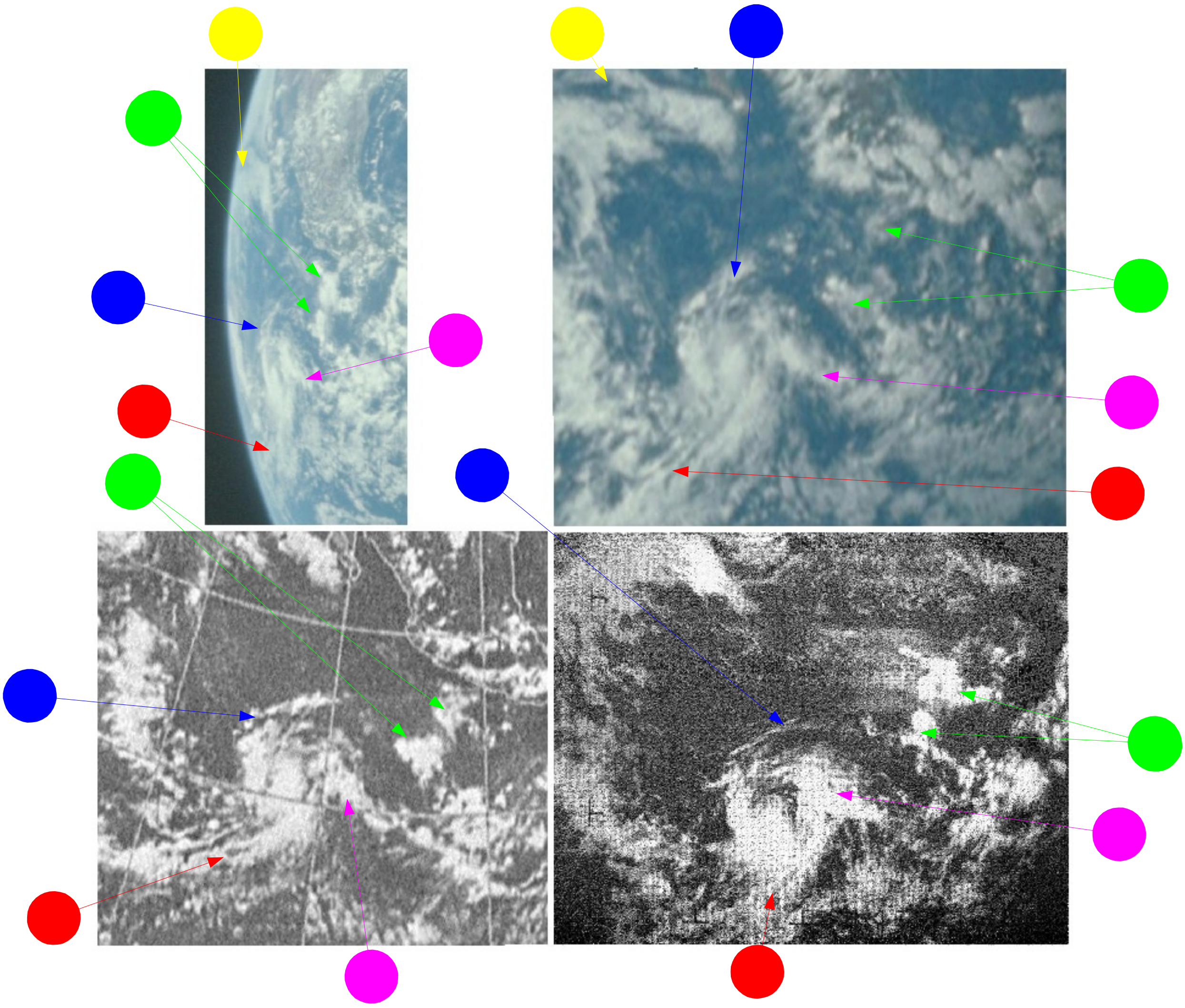


Figure 4.7.5: ESSA 9 (bottom left), ESSA 8 (bottom right), AS15-91-12342 (top left) and AS15-91-12344 (top right) images of Hurricane Hilary, 26/07/71.

Hilary formed on the 26th (or at least the system was officially designated as a tropical storm on the 26th) and lasted just over a week before declining in strength. It succeeded Hurricane Georgette, and overlapped with Hurricane Ilsa, the remnants of the former still being just visible in the above figure, marked by the yellow arrow, and more clearly in figure 4.7.4 (purple arrow). ESSA 8's image of Georgette from July 24th in the MWL on page 332 (Source) is shown in figure 4.7.5.

As with other examples in this research, it is worth noting that while all 4 images show the same features, they are not identical. The cloud immediately to the north of the eye (blue arrow) is thicker in the later Apollo image, and in the ESSA 9 version. The two adjacent small patches of cloud (green arrow) change their overall shape and position in relation to Mexico. Every component of the Hurricane is slightly different in each of the 4 images, showing that each image was taken at a different time and not, as some conspiracists would argue, merely reproductions of the same image.

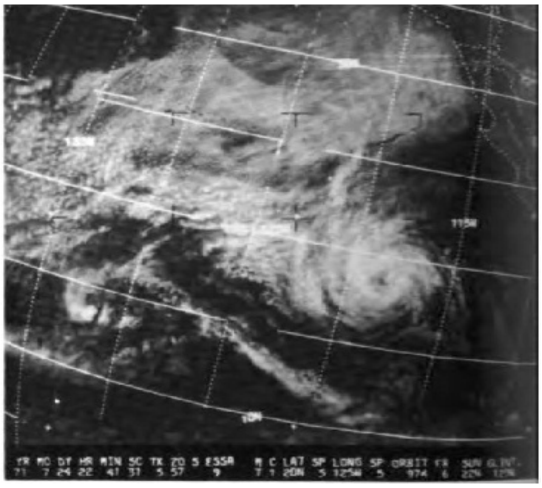


Figure 4.7.5: ESSA 9 image of Hurricane Georgette on 24/07/71. Source given in text.

The next in this short series of receding Earth pictures is AS15-91-12345 (see figure 4.7.6 – low resolution version at AIA).

Figure 4.7.6: GAP high resolution version of AS15-91-12345

Zooming in on this image shows that Australia has just become visible on the western edge, and a number of the weather patterns already identified in figure 4.7.4 are still visible in this one – notably the fog banks off California and the long lines of cloud stretching from east to west either side of the equator. Hurricane Hilary is just the other side of the terminator.

The cloud systems that are still visible are compared with the satellite image in figure 4.7.7.

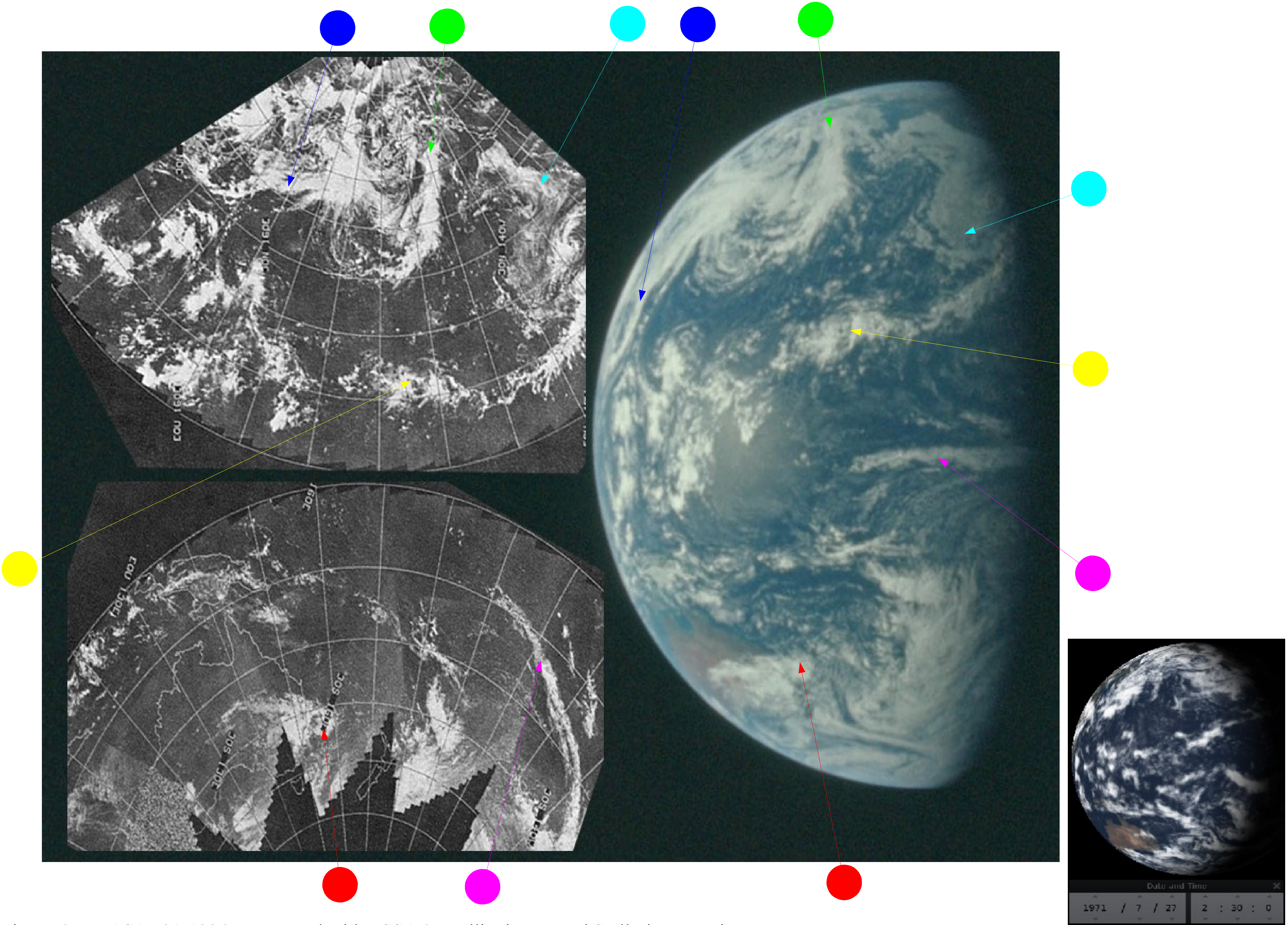


Figure 4.7.7: AS15-91-12345 compared with ESSA 9 satellite image and Stellarium terminator estimate. Green, cyan, magenta and yellow arrows are as figure 4.7.5.

Stellarium's terminator line suggests time for the Apollo image of around 02:30 on the 27th, and the 3 hour time gap between this image and the previous one is amply demonstrated by the appearance of Australia and by differences that are evident in the cloud patterns that are visible in the earlier image. The system identified by the yellow arrow, for example, has clouds that are different to the north and south of it when they are examined closely – see figure 4.7.8.

The most representative ESSA track for the image is orbit number 1000 (track 6) which commenced at 00:02 on the 27th, and as in previous cases is on the image started on the 26th.

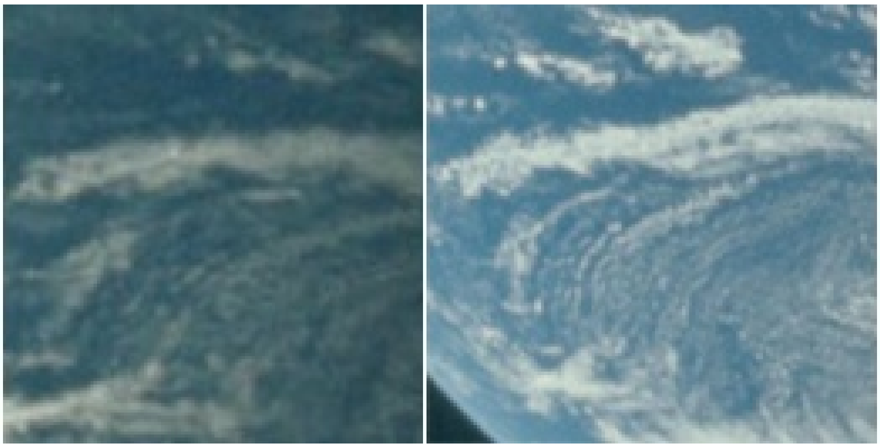


Figure 4.7.8: Zoomed section of AS15-91-12344 and AS15-91-12345 showing the same weather system several hours apart. No two clouds are the same, but the overall features are.

The next image in this sequence of photographs is AS12-91-12347 (see figure 4.7.9, low resolution version available here AIA)

Figure 4.7.9: High resolution GAP copy of AS15-91-12347.

More detail will be given about this image after the satellite analysis overleaf in figure 4.7.10.

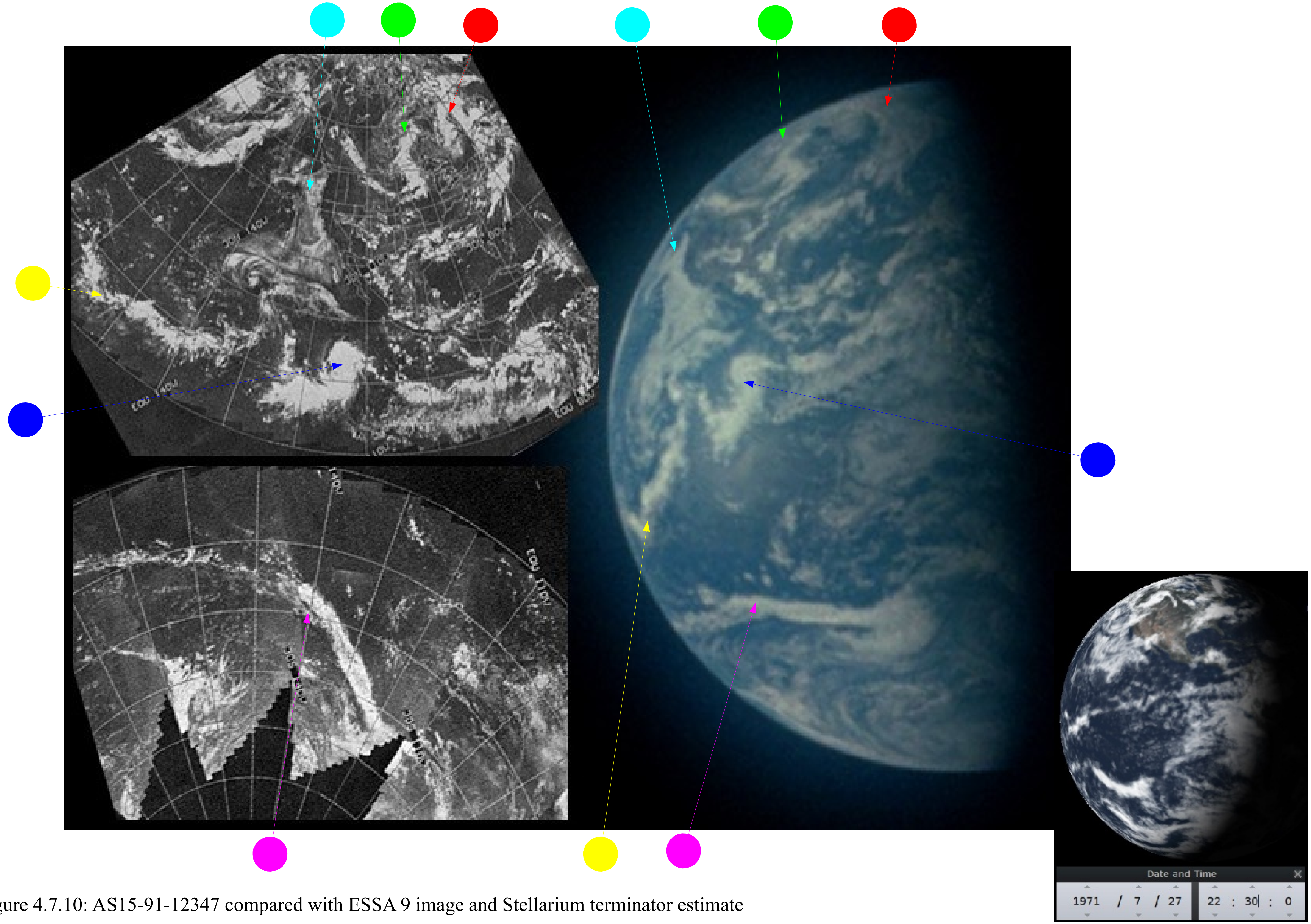


Figure 4.7.10: AS15-91-12347 compared with ESSA 9 image and Stellarium terminator estimate

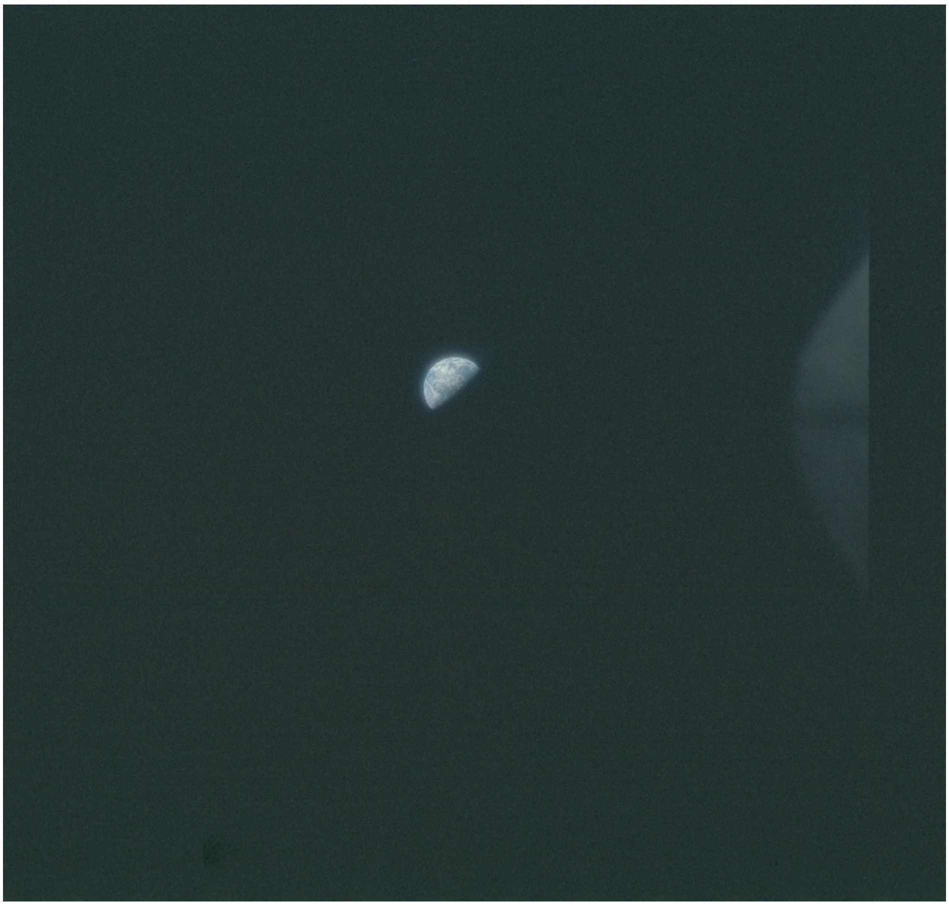
For this latest photograph, north America is back in focus, which means it was taken some time later than the previous photograph. Despite this time gap, some weather features persist from the previous one. Hurricane Hilary is still making progress across the Pacific (blue arrow), and while they have become less coherent systems, the sub-equatorial bands of clouds (magenta and yellow) are still there. Fog also persists along the west coast of north America.

Stellarium estimates that this image was taken at 22:30, and the size of the disk is consistent with the suggested date of the 27th – as are the clouds featured on the ESSA mosaics, which are different in the following day's image. ESSA's best fit orbit for this image is number 1011 (track 4), which commenced at 21:01. As usual, the ESSA image and the Apollo image are taken with a short time of each other, which explains their similarity.

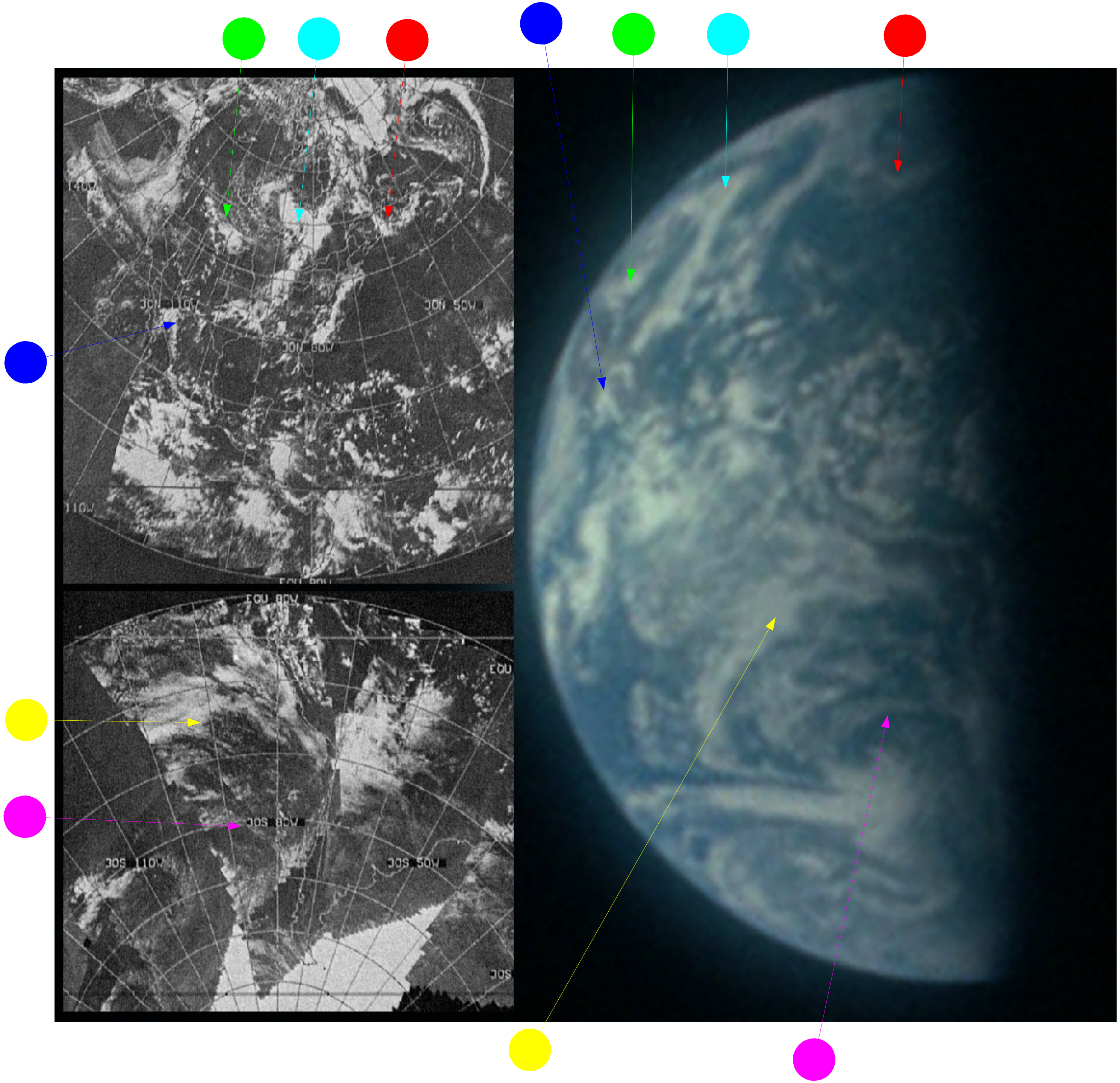
A further confirmation of timing is given by the two photographs immediately after AS15-91-12347 (eg AS15-91-12348). They are labelled simply as 'Spacecraft interior' on the AIA and in the photographic index (source: , but comparison of them with other photographs available on the internet (eg LM interior) clearly identify them as belonging to the lunar module. The LM was inspected at 23:30 on the 27th, and the mission transcript (ALSJ) mentions the camera equipment (the crew were preparing for a TV broadcast). It does seem likely that these two photographs were taken as part of the LM inspection, and this acts both as a later limit for the image 12347 and an earlier limit for the next image, AS15-91-12350.

AS15-91-12350 (see figure 4.7.11. Low resolution version available here: AIA) is the last Earth iamge taken before arriving at the Moon, and indeed the next images in the magazine are looking down at the lunar surface. LOI occurred at 20:05 on the 29th, so we have a timeframe of 48 hours within which this photograph must have been taken.

Figure 4.7.11: High resolution GAP version of AS15-91-12350



Comparison with satellite images is carried out in figure 4.7.12 overleaf.



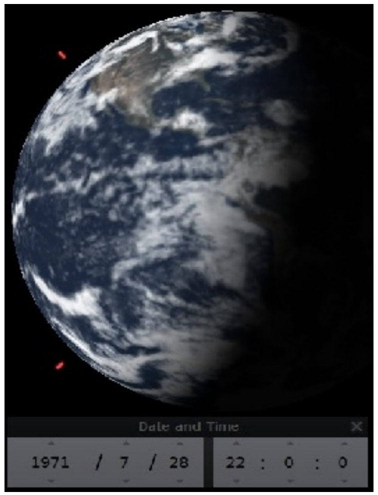


Figure 4.7.12: AS15-91-12350 compared with ESSA 9 image and Stellarium terminator estimate

The weather systems shown in the Apollo image match, as usual, those visible on the satellite image but this is not the only story. Hurricane Hilary is still visible on the Apollo image, and the sub-equatorial cloud in the southern hemisphere is also still present, albeit in an evolved form.

These two features can not, however, be seen on the satellite image as there are large sections where data are absent. This will be discussed momentarily, but first there are some formalities to be attended to: Stellarium puts the terminator line at around 22:00, and the satellite image that most resembles the weather patterns in the Apollo image is from the 28th, so at around the time the Apollo astronauts were taking photographs inside the LM, there is a photograph of Earth. In all probability it is taken from the LM. ESSA's most complete orbit for the Apollo image is number 1023 (track 4) commenced at 20:04. The similarity between ESSA and Apollo's images of Earth is again a product of their being taken at roughly the same time – one from the vantage point of over halfway to the Moon, the other from LEO.

What needs to be addressed now is the issue of the missing data in the image. In doing this, it is worth refreshing our memories as to how these images were collated. The introduction to the data catalogue describes how:

"The digitized cloud maps that appear in this catalog are prepared by a high speed digital computer. In this process the signals comprising the picture taken by the satellite are assigned numerical values to indicate the relative brightness of each element. These data are normalized brightnesses, earth-located and repositioned in a standard map projection. Magnetic tapes are produced for input into a cathode-ray-tube film-display device."

Each individual image is loaded from magnetic tape, recorded from the signal transmitted by the satellite, transposed into its correct position on a globe, and then placed on a kinescope for photographing.

As part of that process:

"In some instances, blank areas and mislocated clouds appear on the digitized cloud maps; these are caused by irregularities in the computer operation and should be disregarded."

And:

"Day to day variations and irregularities which result in improper location or display of the data are apparent in this catalog. At present, inadequate computer facilities prevent any effort to reformat the mosaic on an after-the-fact basis. Some inconsistencies are related to photography and printing problems."

This has obviously happened in the case of the ESSA image used in the preceding analysis. Large chunks of the image over the Pacific are blank, and there are no clouds marked where there should be some. There are also some very sharp boundary lines within south America that suggest missing data, but often such areas represent differences in contrast between parts of the mosaic.

Figure 4.7.13 indicates an area where there are misplaced clouds. There are 3 areas in the region of south America that show the same curl of cloud with a bifurcated ending – two in the south Pacific and one off the Argentinian coast. Evidently something has gone wrong in the process of positioning the images, or the tapes themselves may be corrupt, or the satellite transmission may have been interrupted. Whatever the cause, there should be only one of them. Examining the satellite mosaic does not reveal any real insight as to which is the correct, and there is insufficient coverage by Apollo images to suggest where they might be from.

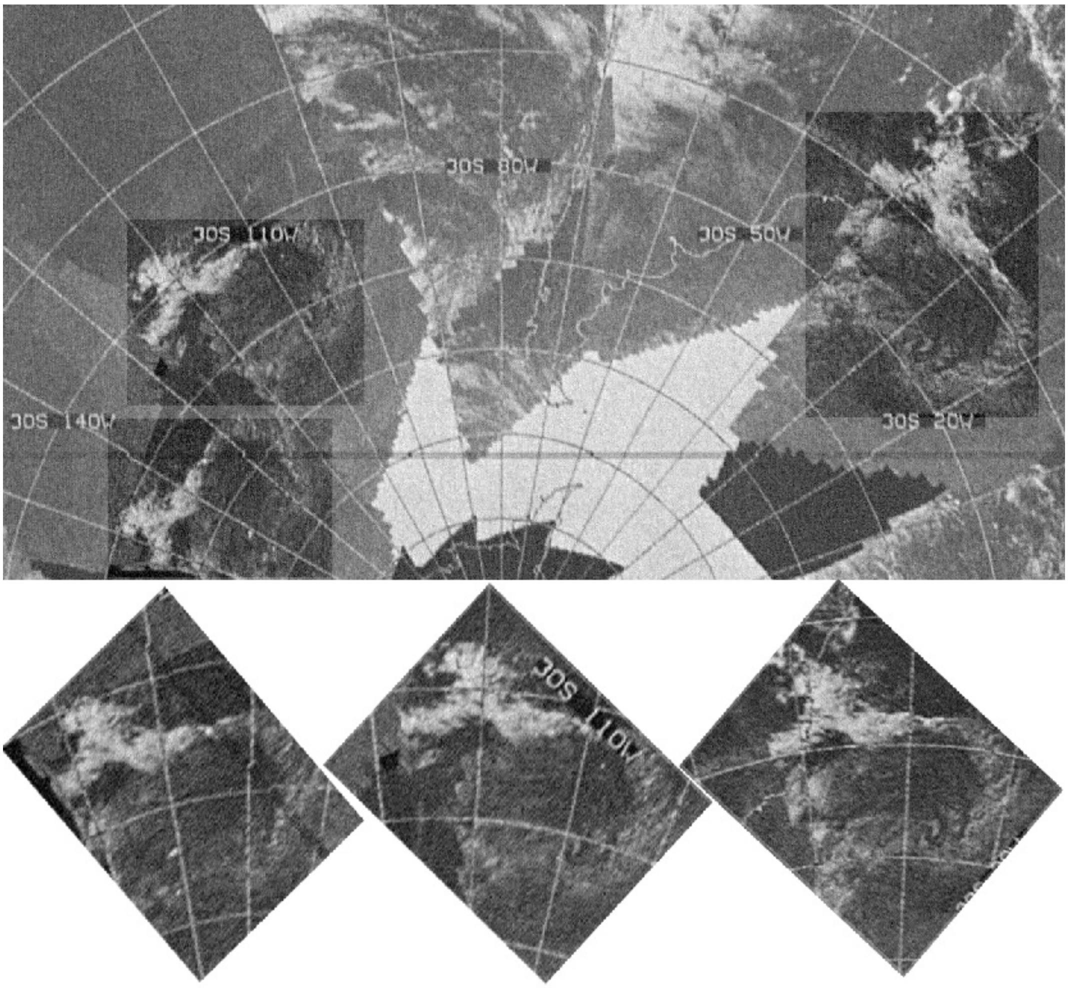


Figure 4.7.13: ESSA 9 image mosaic of South America from 28/07/71. The three darker contrasted areas are apparently the same, and are reproduced below the main image.

Evidence of fakery? Manipulation? Hiding of data? This will no doubt be alleged by conspiracy fans, but the preface to the data catalogue points out that there are some days with problems. Some of these days fall outside Apollo mission days. The easiest thing to have done would be for ESSA to have not released this day's image, rather than use computer technology that didn't exist to try and fake an image. What can be deduced is that the experienced eye can identify issues with data and recognise where problems exist.

The easy path for this document would have been to pretend there was no problem, when clearly there is, but problems with some parts of the data do not invalidate those areas where it is completely transparent that the Apollo image and ESSA match. If anything, it re-enforces the idea that the technology to manipulate these image did not exist at the time they were taken, and that no manipulation has been carried out on them since. It also shows the importance of looking at evidence carefully, and using judgement and deduction to arrive at a conclusion.

The next image to be examined for this mission is from magazine 87. AS15-87-11722 (along with a duplicate image after it) shows a distant Earth between a series of images that show the landing sequence as shot from the LM. Figure 4.7.14 shows this image, and a low resolution version can be found here: AIA.

The first five images in this magazine show a distant CSM, and the timeline shows that undocking of the LM and CSM occurred at 18:13 on the 30th. Following this are several orbital images, including one set showing Hadley Rille, the ultimate landing area.

Figure 4.7.13: High resolution GAP copy of AS15-87-11722.

Immediately following the photographs of Hadley Rille are the two Earth images described. These are then followed by other orbital images (including *Mare Smythii*) before the surface is photographed.

The landing itself occurred at 22:16 on the 30th, so we have a relatively narrow window within which to look for satellite matches.

If only it could be so simple! July 30th is missing from the ESSA data catalogue.

Normally when a day's records are unavailable as a result of some technical issue, a blank page will be inserted stating that there is no record. In this case there is no such page, and there are no orbits missing in the record of passes in the Appendix. The obvious conclusion is that it has been missed out in error. Other pages were checked to see if there was a duplicate July 30th, but none was forthcoming.

What is available, however, are the ESSA mosaics from the 29th and the 31st, which should allow us to interpolate which weather patterns can be seen on the Apollo image.

This is shown in figure 4.7.15.

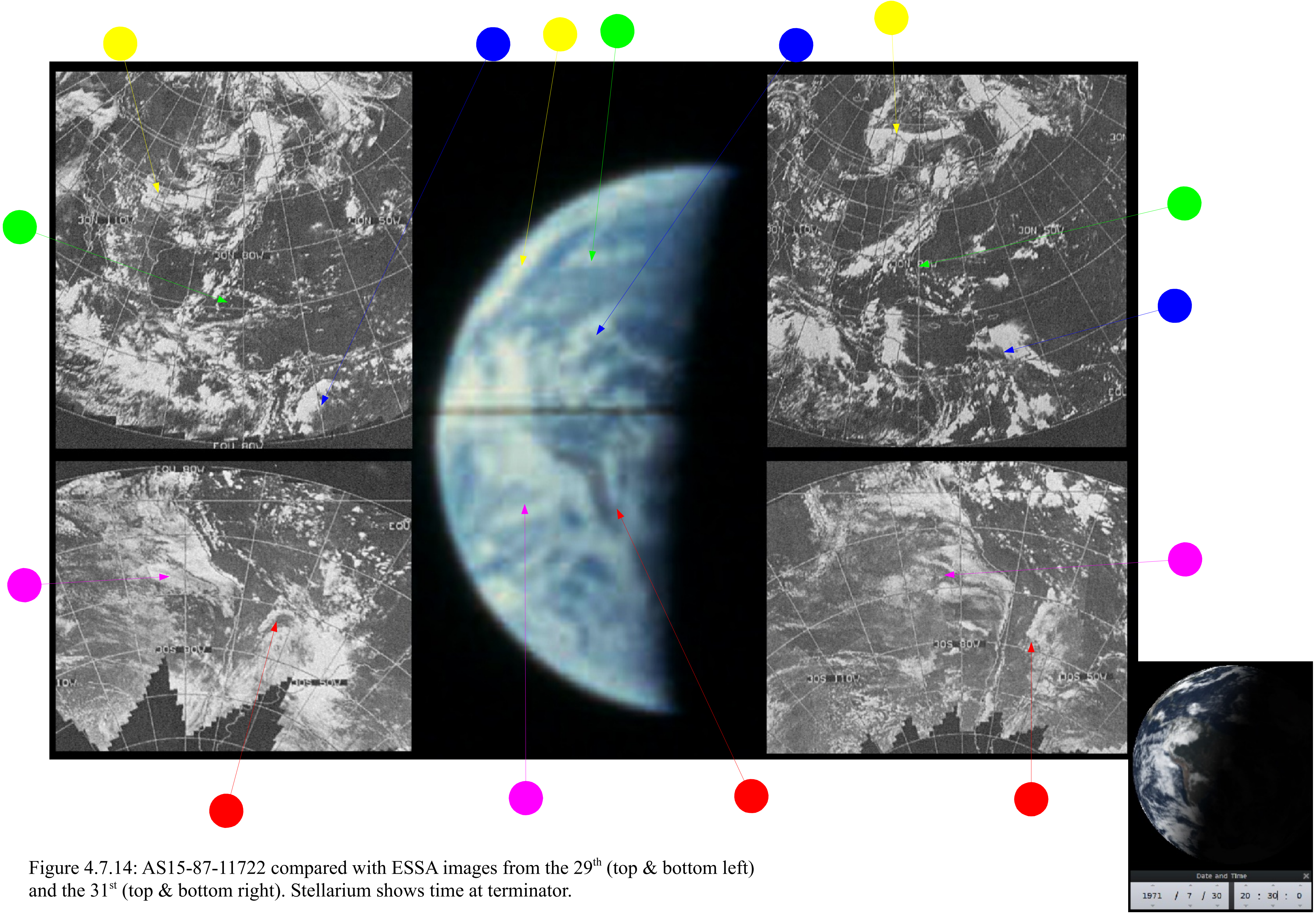


Figure 4.7.14: AS15-87-11722 compared with ESSA images from the 29th (top & bottom left) and the 31st (top & bottom right). Stellarium shows time at terminator.

Two factors are making life difficult with this image comparison. Firstly, the fuzziness of the Apollo image, and its overexposure, means that it is difficult to pick out the weather systems that make out the bulk of the image over central America and off the coast of south America. Secondly, the satellite image itself appears to be under-exposed, so that those weather systems that are visible are not there in their entirety. This is less of an issue when the satellite image is from the same day as the Apollo image, but when we are having to interpret data between two days it can be difficult.

Despite this, there is a good correspondence between the three images, and it does not seem unreasonable to suggest that the Apollo image represents the mid-point between the two ESSA images. As further corroboration, the photographic index records this image as being taken on orbit 13, the mission transcript identifies as starting at 19:20 on the 30th. The image immediately following these two Earth images shows *Mare Ingenii*, a far side feature recorded as in orbit 14, as are the images of *Mare Smythii* immediately before the images taken on the ground. LOS on orbit 14 is almost exactly at 21:00 on the 30th, so the estimate of 20:30 seems like a good one.

Thankfully the next image under the microscope involves a little more reliance on hard evidence rather than deductive logic, and sees a return to magazine 91.

It is clear form looking at this magazine's images that it stayed in orbit with the CSM. AS15-91-12404 is the penultimate image in this magazine and one of two identical Earth photographs. A low resolution version is available here: AIA. A high resolution version is shown in figure 4.7.15 and analysed in figure 4.7.16..

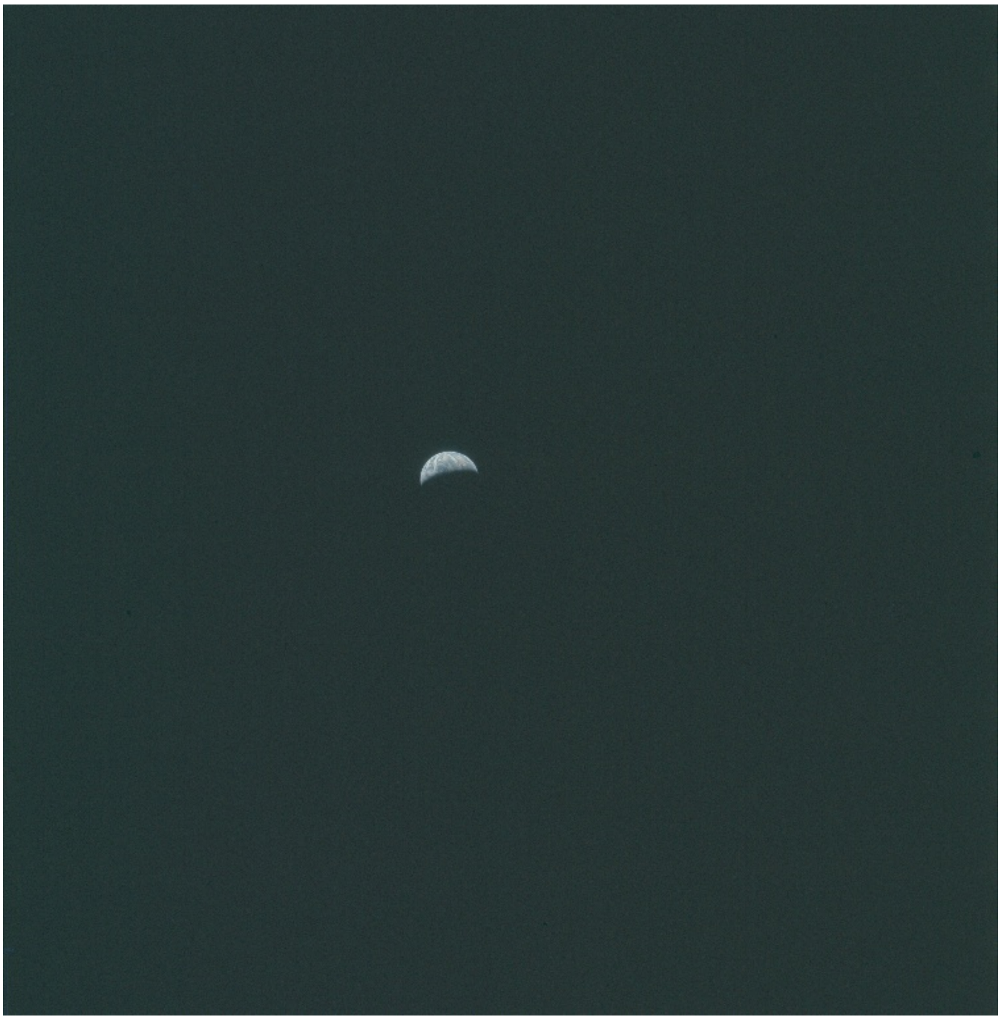


Figure 4.7.15: High resolution GAP version of AS15-91-12404.

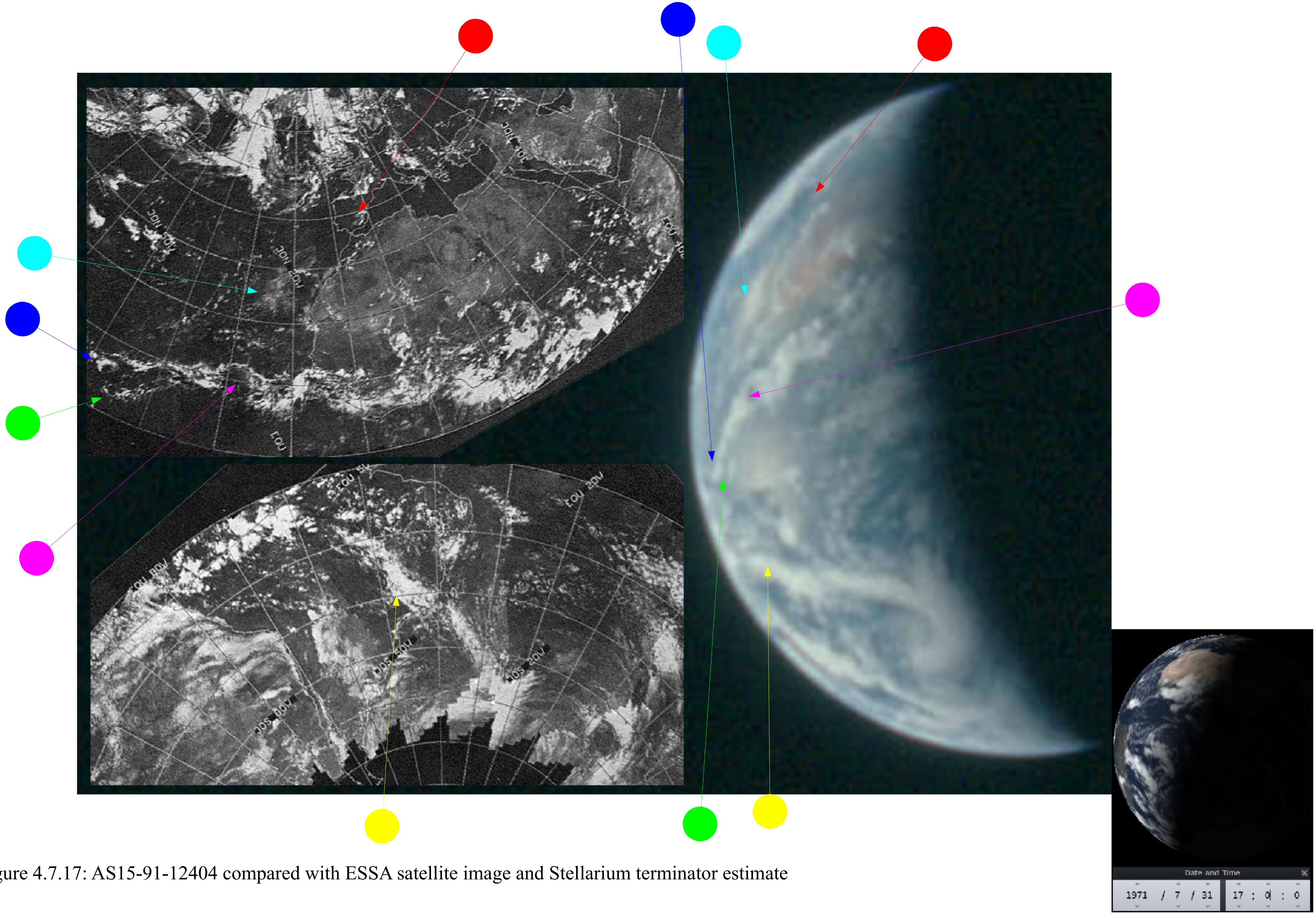


Figure 4.7.17: AS15-91-12404 compared with ESSA satellite image and Stellarium terminator estimate

The dominant land mass shown is Africa, with the Saharan region showing towards the top of the globe. Brazil is visible in the south-western limb as a much darker landmass.

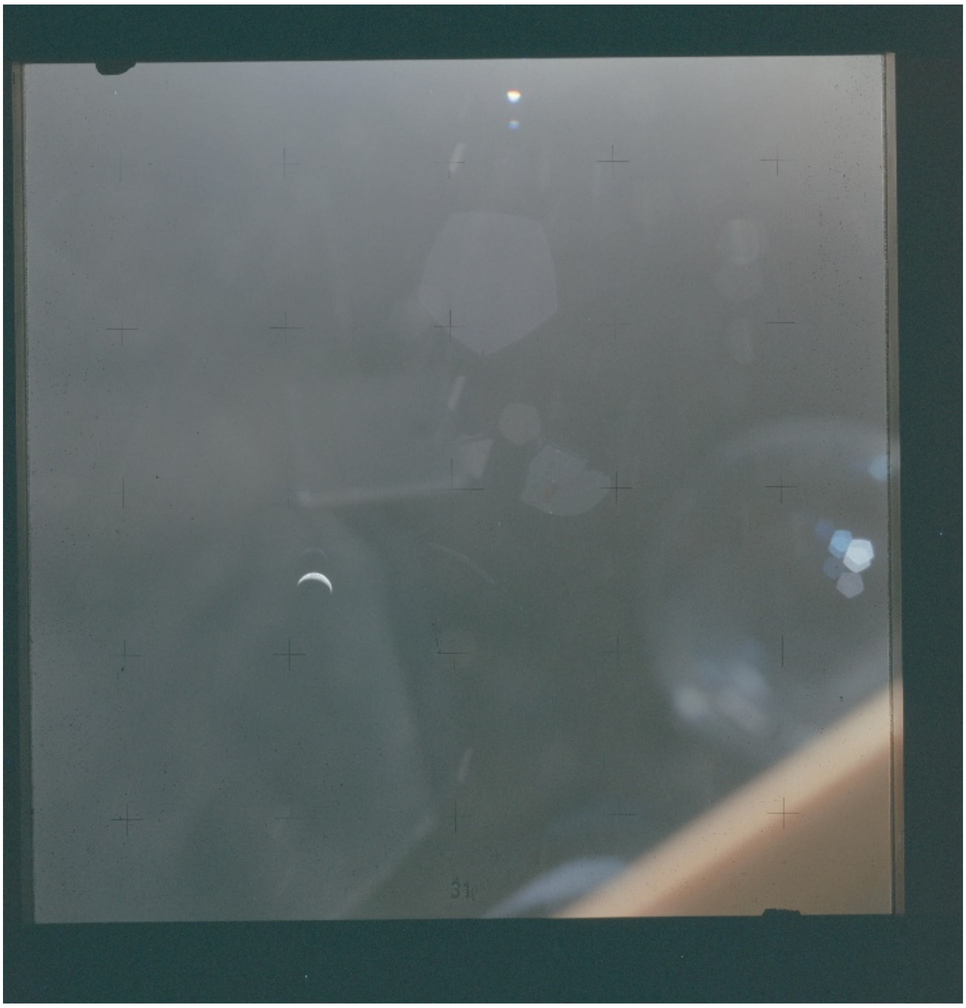
The main areas specifically picking out this Apollo image as being from the 31st are the bands of cloud pointed out by the blue and green arrows. The angle of the Earth photograph makes them less obvious that on the ESSA image, but they are there. The underexposure of the ESSA image also makes the thin band of cloud passing south through Spain into north Africa less obvious, but it is there.

The ESSA mosaic again has data reliability issues, this time off the east cast of Argentina. The mosaic manages to capture the break in cloud on the yellow arrowed system, but where that cloud continues into the south Atlantic and South Africa in the Apollo photograph, it is truncated and mis-shapen in the ESSA version. The images over South Africa also show suggestions of duplication and misplaced mosaic components.

That aside, there is sufficient correspondence with the remainder of the ESSA mosaic to confirm that the Apollo image was taken on the 31st of July at around 17:00. ESSA's own data suggest that the satellite was taking photographs of this area at 17:04 (track 2, orbit 1059).

For the next analysis we visit a new photographic magazine. AS15-88-11976 occurs two thirds of the way through magazine 88. The magazine starts on the lunar surface, but this image occurs immediately after a photograph of the CSM during rendez-vous. We therefore have an earliest possible time for the image of 17:11 on the 2nd of August. The LM & CSM were docked two hours later at 19:10, and it is just visible in the image, looming out of focus on the right with the Earth in the background. We therefore have a 2 hour window within which this image was taken, and we can now see if the satellite and Stellarium evidence supports this. Figure 4.4.17 shows the high resolution version of the image (low resolution available here: AIA) and figure 4.4.18 the satellite comparison.

Figure 4.7.17L High resolution GAP version of AS15-88-11976.



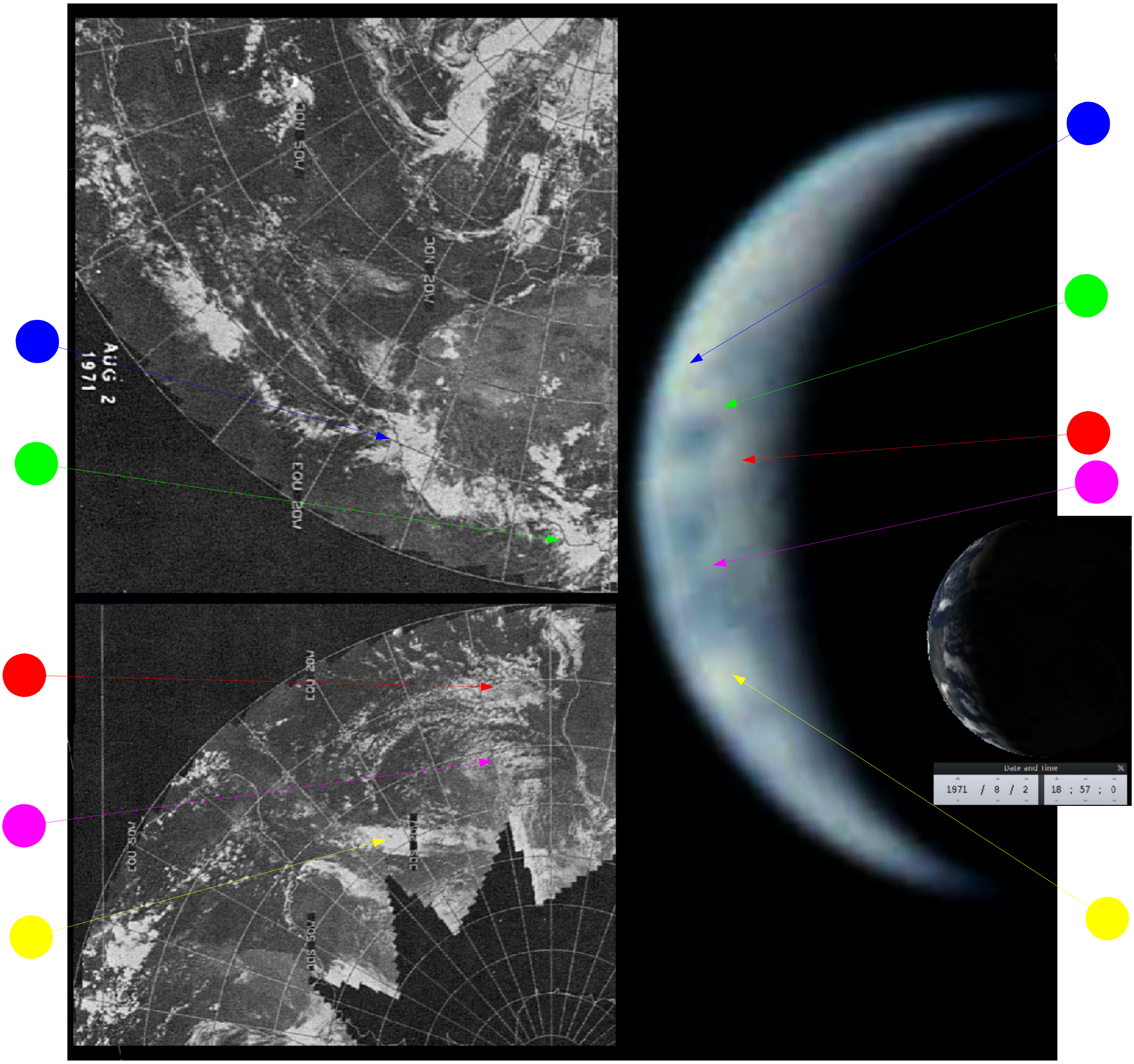


Figure 4.7.18: AS15-88-11976 compared with ESSA 9 image and Stellarium terminator estimate.

The figures given by the timeline for the mission show that the Earth should have been showing the Atlantic, and at least some of Africa. The configuration of the Earth as seen from the Moon also means that the southern Hemisphere is more prominent than the north, placing north Africa at the top of the illuminated crescent. If the levels are adjusted in the image, Africa does become much more visible. This can be seen in figure 4.7.19, where the over-contrasted Apollo image is compared with Google Earth's grid overlay as confirmation that the cloud patterns identified in figure 4.7.18 are in the right place.

The arrows in both sets of figures are identifying clouds bands either side of the equator in the ITCZ, and what appear to be low lying fog banks on Africa's west coast. It should be remembered when looking at the earth in figure 4.7.19 that the enhamcement process effectively moves the terminator, making the crescent narrower.

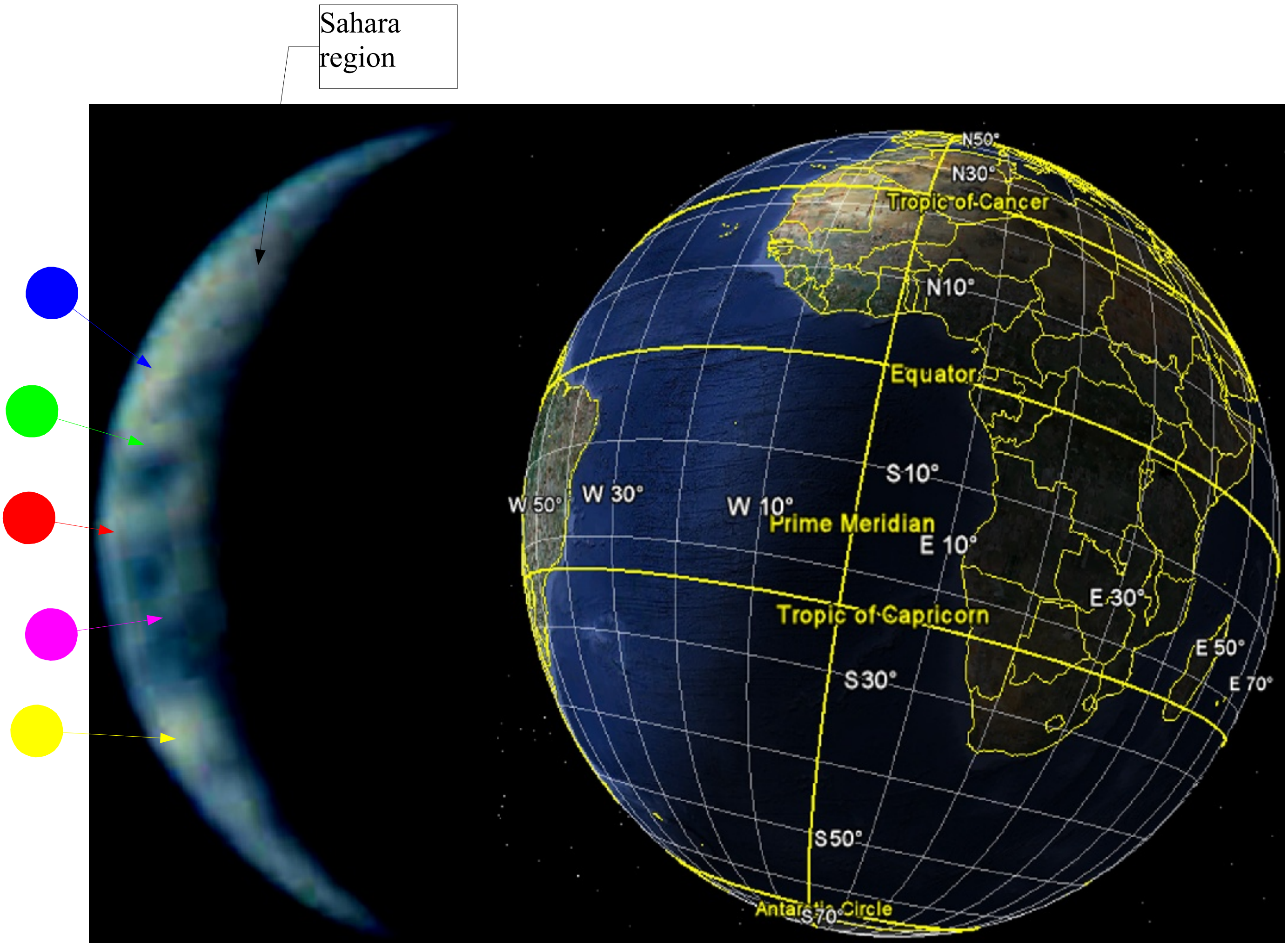


Figure 4.7.19: AS15-88-11976 enhanced by level reduction to remove excess brightness. Google Earth is oriented in the same way to show where latitude lines fall. Arrows used are as in figure 4.7.18.

It is conceded that the view of Earth used here is blurry, but other evidence does corroborate that the features identified in this analysis are correct. Observant readers will have noted that the time on the Stellarium inset shows 18:57. This is the time recorded in the mission transcript for when the LM crew took what they had hoped was an image of the CSM SIM bay. Capcom was keen to have that image before completing the docking manoeuvre.

The ESSA 9 orbit covering this part of the Earth would have been commenced at 15:01 (track 1, orbit 1083), so ESSA's satellite image was taken at around the right time. Stellarium shows where the terminator would be at the time the image is recorded as being taken, and there are cloud shapes in the right place and consistent with the weather patterns visible from ESSA. It would be preferable to have crystal sharp images, but even without them the available data corroborate the version of events that says the Apollo 15 crew met up with each other in lunar orbit on August 2nd just before 19:00 GMT.

With an increasingly crescented Earth matching satellite derived weather patterns with features from mission photographs becomes increasingly difficult. It is further hampered by over-exposure of the Earth when photographed. This is the case with AS15-88-989, the second of two consecutive Earthrise images. It is surrounded by pictures of the lunar surface, and there is another Earthrise sequence later, so it is obviously not yet at TEI, which occurred on the 4th at 21:22.

This image is shown overleaf in figure 4.7.20 (low resolution source here: AIA), and an attempt at satellite comparison presented beneath it in figure 4.7.21.

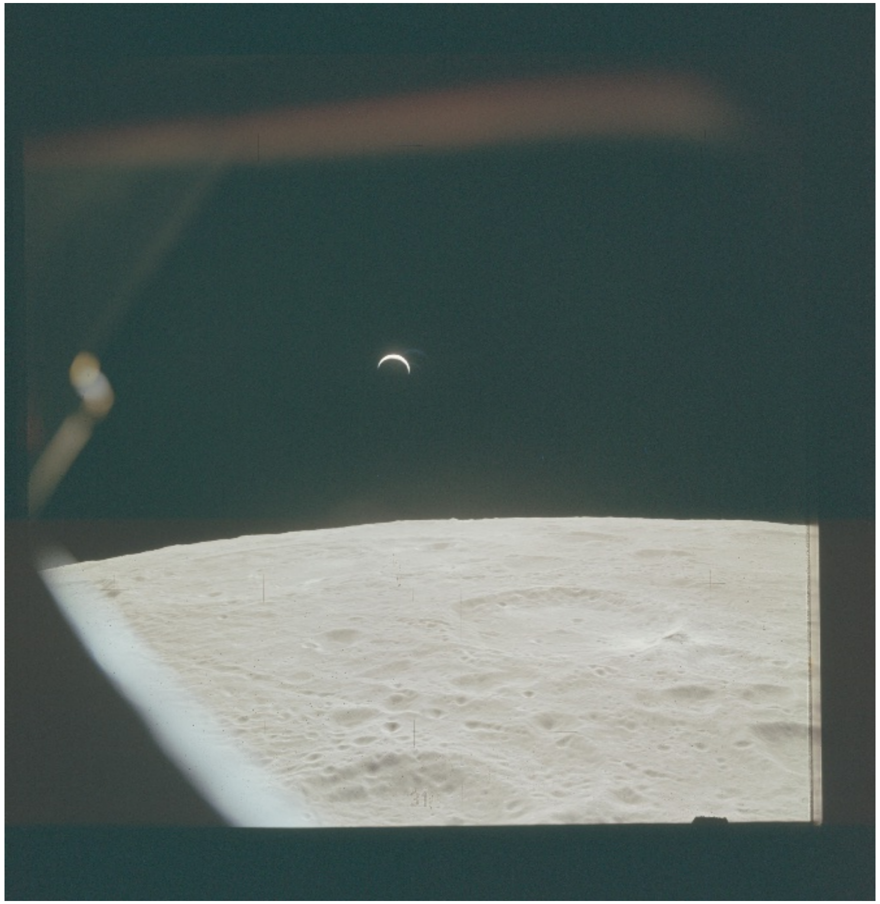


Figure 4.7.20: High resolution GATE version of AS15-88-11989

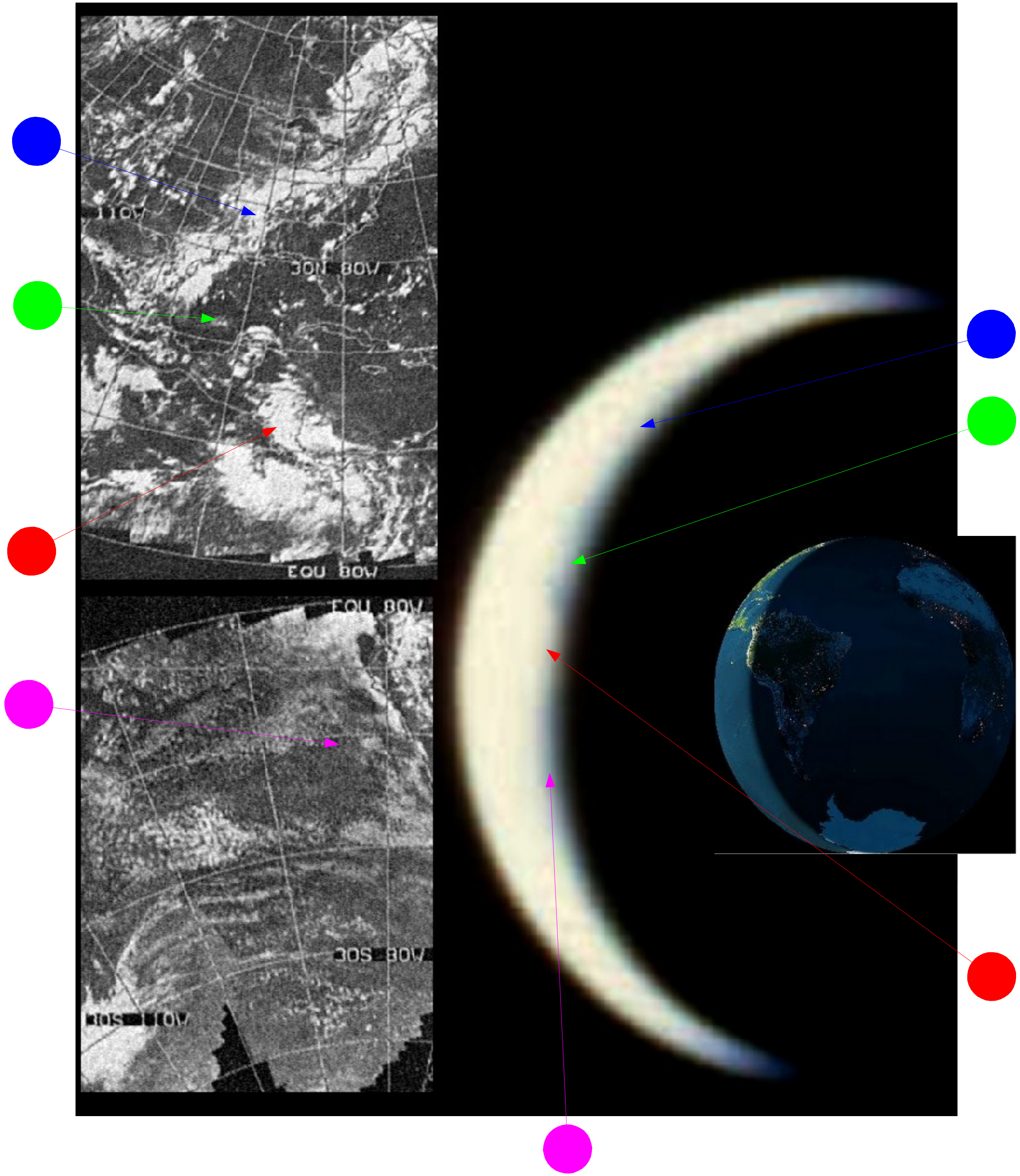


Figure 4.7.21: AS15-88-11989 compared with ESSA 9 satellite image from 03/08/71, with inset of Earthview estimate of terminator line at 23:30 03/08/71

The analysis shown in figure 4.7.21 needs some explaining. Only 4 areas have been identified, and these are less indicators of specific weather systems as variations in light and shade on the Earth. The terminator estimate has been given by the Fourmilab Earthview site (used in previous sections) because it shows land masses more clearly than Stellarium – particularly when the Earth is a thin crescent and less is visible.

The time of the terminator has, in this case, been set at 23:30, because this is the time of AOS on revolution 64. The photo index labels this image as taken in orbits 64-72, but it is only the third in a sequence images with that label, the preceding two being craters on the far side. It seems reasonable to assume that this is the Earthrise from orbit 64 immediately after taking those first two images.

This is not the preferred deductive route for these analyses, as it is effectively deciding in advance what the outcome is and then looking to see if the evidence matches, rather than looking at the evidence, deducing an outcome, and then seeing if the other evidence bears it out. That said, the Apollo image shows an area of bright white north of the equator (blue arrow) in an area that corresponds roughly to the southern USA Gulf states. Below that is a darker area (green arrow) that can be interpreted as ocean over the area corresponding with the Gulf. Below that is a further area of white (red arrow) over central America, and then a darker area (magenta arrow).

These areas seem to correspond well with the pattern of cloud over the southern Gulf states, the Gulf itself, central America, and the Pacific coast of south America. ESSA's satellite pass over this area would have been commenced at 20:02 (track 4, orbit 1098) on the 3rd. Confirmation of this being the 3rd rather than the 2nd or 4th can be deduced from the width of the Earth crescent.

The final Earthrise sequence on magazine 88 suffers from the same problems: overexposed subject and a small area available for image analysis. AS15-88-11999 (low resolution version here: AIA) is not even labelled in the photo index as an Earthrise, such is the glare on the CSM window. This image is shown below in figure 4.7.22, but there is so little detail visible, even after processing, it will not be analysed further other than to suggest that the crescent thickness suggests a time around 12 hours before TEI.

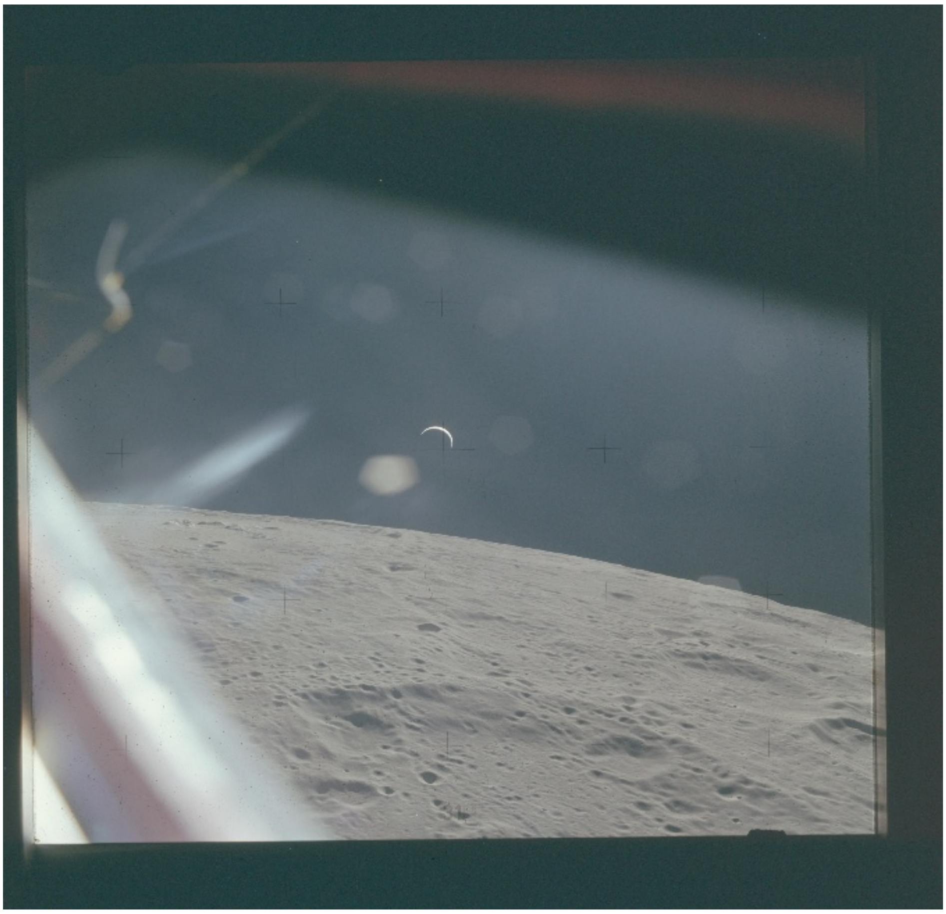


Figure 4.7.22: High resolution GAP version of AS15-88-11999.

Two other colour images of Earth are available in 2 other magazines.

AS15-97-13267 is the first in a single sequence of Earthrise images on a magazine that otherwise consists solely of photographs of the lunar surface. The thin crescent suggests a date of August the 4th, and a considerable amount of time was spent attempting to find the exact cloud matches on that date. The image itself was processed by adding extra contrast to a level reduction, and this has been more useful than the same technique employed on magazine 88 images because the image is less exposed, and is zoomed more closely on the Earth.

The image is shown below in figure 4.7.23, and a low resolution version is available here: AIA.

Figure 4.7.28: High resolution GAP image of AS15-97-13267.

As already mentioned, TEI occurred on at 21:22 on the 4th, which at least provides an upper limit to what should be visible – the tip of Brazil would just be visible at that point. The remainder of the magazine shows at least one orbit after this image, which would bring the time back to roughly 20:00 at the latest. The photographic index shows that it was taken on orbit 70, and figure 4.7.29 shows a satellite comparison on that basis.

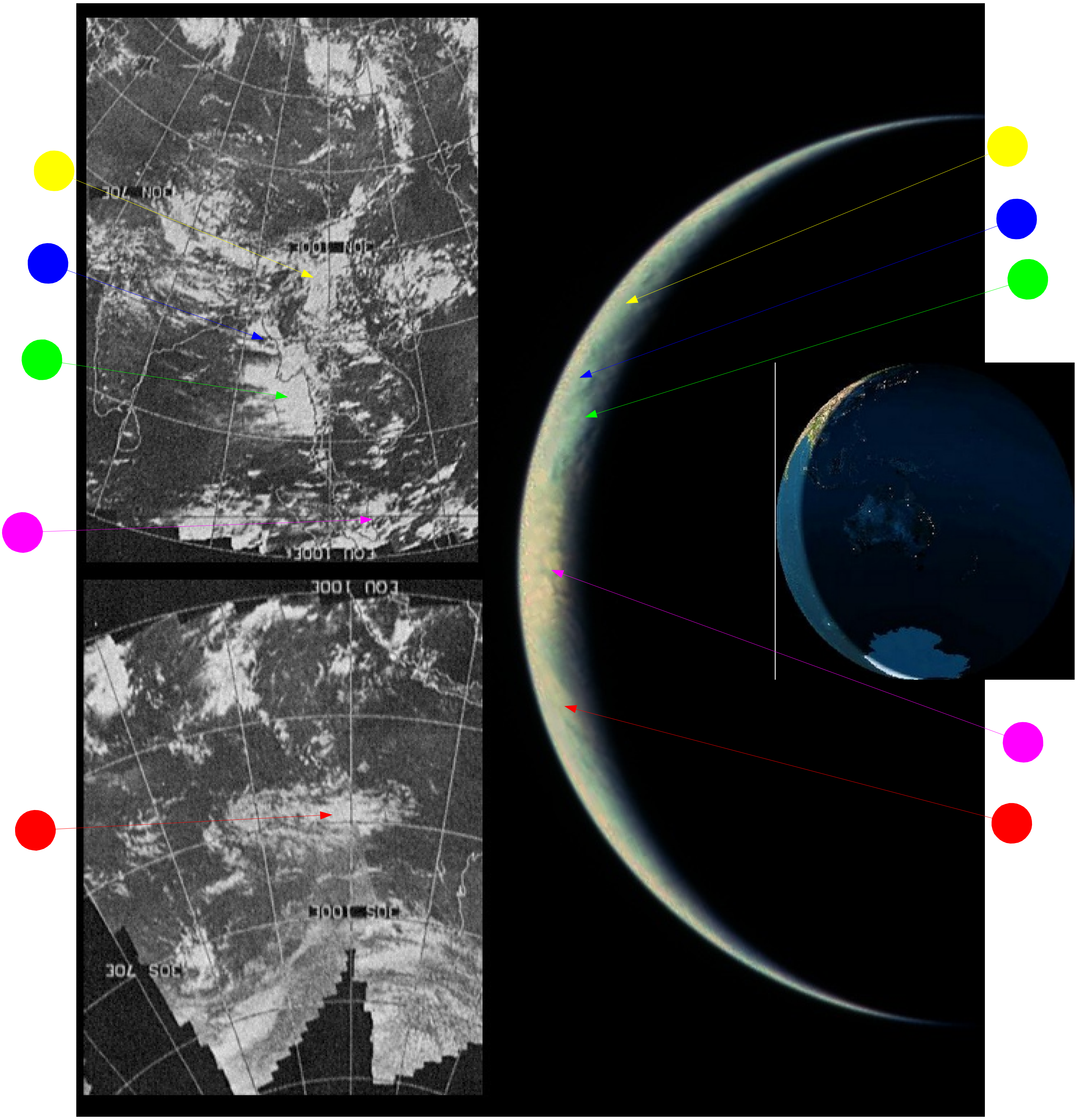


Figure 4.7.29: AS15-97-13267 compared with ESSA 9, and an Earthview terminator set at 12:00 on 04/08/71.

AOS on orbit 70 occurred at 214 hours and 26 minutes in to the mission, or roughly 12 noon on the 4th. This would mean that SE Asia would be just in view. In the widest part of the crescent, the terminator in the above figure (according to Earthview) is roughly following a line along Thailand, and there are definite consistencies in the clouds visible on the satellite mosaic along the terminator and those just discernible on the Apollo image.

ESSA's image for that region would have been commenced at 08:02 (track 10, orbit 1104), with mosaic date being the 3rd.

One final image remains, and again there is only a small amount of Earth visible on it. AS15-93-12639 occurs in the middle of another magazine otherwise devoted entirely to lunar surface photography. The thinness of the crescent and the lunar surface photographs again mark it down as being on the 4th of August, and the photo index suggests that it was taken on orbit 71. AOS on Orbit 71 was at 14:00 on the 14th, and the presence of Humboldt crater is next image suggests that this Earth image probably was taken just after Earthrise. This would put a terminator line along the thickest part of the crescent as eastward of Madagascar.

Figure 4.7.29 shows the GAP version of this image, and a low resolution version is available here: AIA

Figure 4.7.29: High resolution GAP version of AS15-93-12639.

As with other over-exposed crescent Earth images, simple level adjustment is inadequate in revealing much detail, and the analysis carried out on the image (figure 4.7.30) was done after contrast and brightness adjustments were also added.

What becomes clear on the adjusted image is that there is a very obvious dark oval area in the central part of the crescent exactly in the place where Madagascar would be according to the terminator estimation. There is a white mark in this dark area which corresponds well to a cloud shown on the ESSA image, so it would appear that we have a good basis to assume that the photograph shows exactly what it should show.

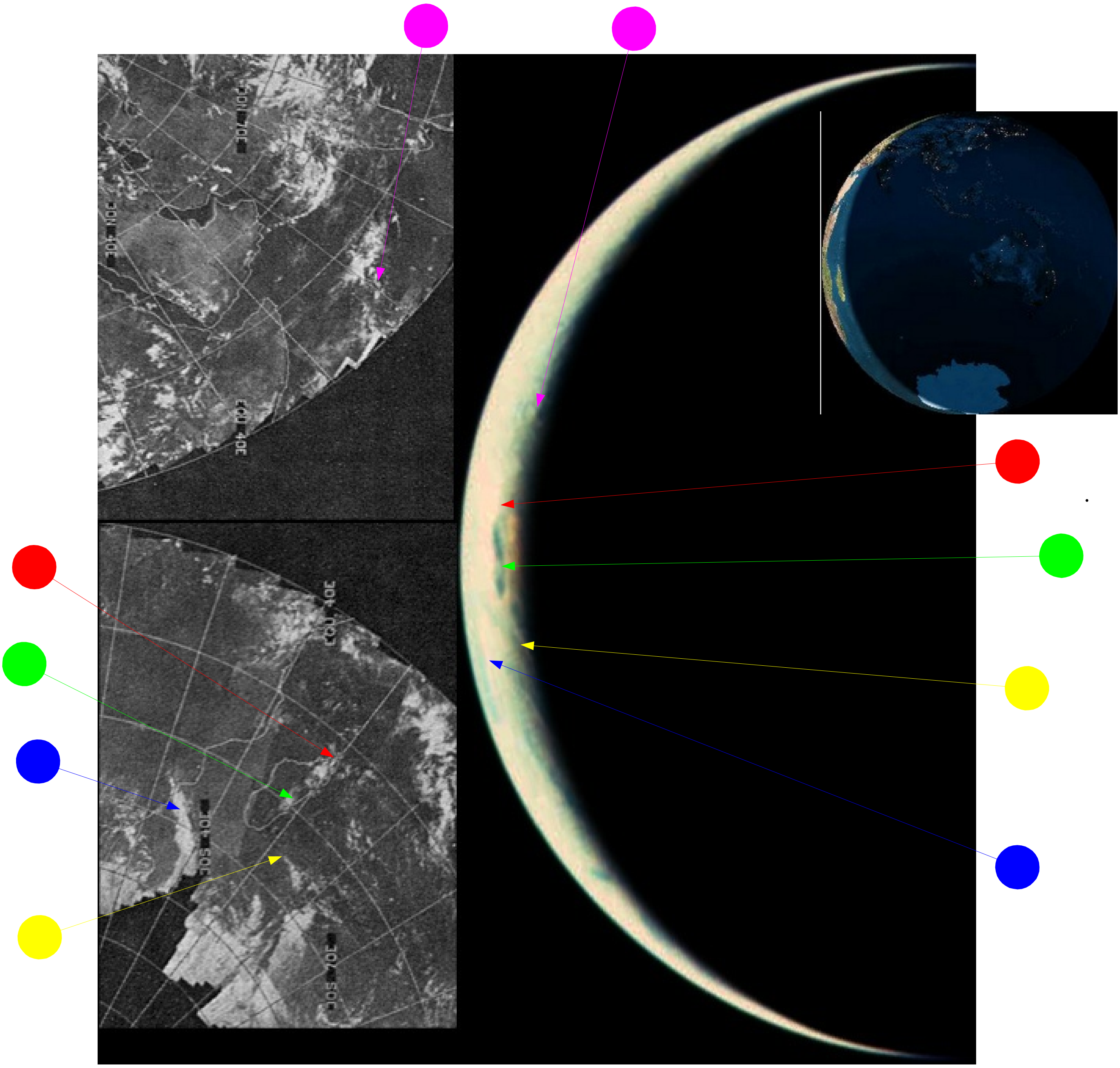


Figure 4.7.30: AS15-93-12639 compared with ESSA 9 image and Earthview terminator estimate for 14:30 on 04/08/71.

Despite the difficulties with the image, there are visible features (not least Madagascar!) that confirm that this photograph was taken at the time it was claimed to have been taken. There are issues with the ESSA mosaic in that this area is often used as the boundary for delimiting between dates, and there is a clear change in contrast down the centre of the southern hemisphere portion of the image. The image chosen above is dated 03/08/11 and the track covering it is assumed to be number 12, which corresponds to orbit 1106, commenced at 11:03 on the 4th.

This image also represents the last available visible spectrum image taken of Earth on this mission. It is not, however, the last set of analyses that will be carried out, as there were several UV spectrum images taken at specific points through the journey.

These UV images will examined next.

4.7.2 Ultra-Violet images taken during Apollo 15

UV photography in Apollo 15's mission was carried out at set times, as shown in figure 4.7.31 – a reproduction of table 5.1 from the Apollo 15 Mission Report (source: ALSJ).

Location of Spacecraft	Subject	Ultraviolet	Color
Earth orbit	Earth limb	8	1
Translunar coast (~ 60 000 n. mi.)	Earth disc	8	1
Translunar coast (~ 60 000 n. mi.)	Moon	8	(a)
Translunar coast (~ 120 000 n. mi.)	Earth disc	8	1
Translunar coast (~ 180 000 n. mi.)	Earth disc	8	1
Lunar orbit	Earth and lunar horizon	8	(a)
Lunar orbit	Earth	8	1
Lunar orbit	Mare areas	[b]10	(a)
Lunar orbit	Terra area	[b]10	(a)
Transearth coast (~ 160 000 n. mi.)	Earth disc	8	1
Transearth coast (~ 120 000 n. mi.)	Earth disc	8	1
Transearth coast (~ 60 000 n. mi.)	Earth disc	8	1
Transearth coast (~ 60 000 n. mi.)	Moon/calibration	8	(a)

[a]No color exposures planned.

[b]Four exposures taken with the 4000- to 6000-angstrom filter.

Figure 4.7.31: Table 5.1 from the mission report showing the UV photography programme.

The first set of Earth images show only a small portion of the globe (and are referred to shortly after lift off in the mission transcript)and therefore will not be examined. It is believed that the colour photographs taken are those discussed in the previous section. Only those images showing Earth will be considered, and only those where there is some level of discernible detail.

The first images looked at were taken 60000 miles form Earth during TLC, and are first discussed in the mission transcript at 9 hours and 30 minutes in to the mission, or 23:00 on the 26th.

Figure 4.7.32 overleaf shows both the original UV image and the satellite comparison with it.

No high quality images were available of the UV photographs.

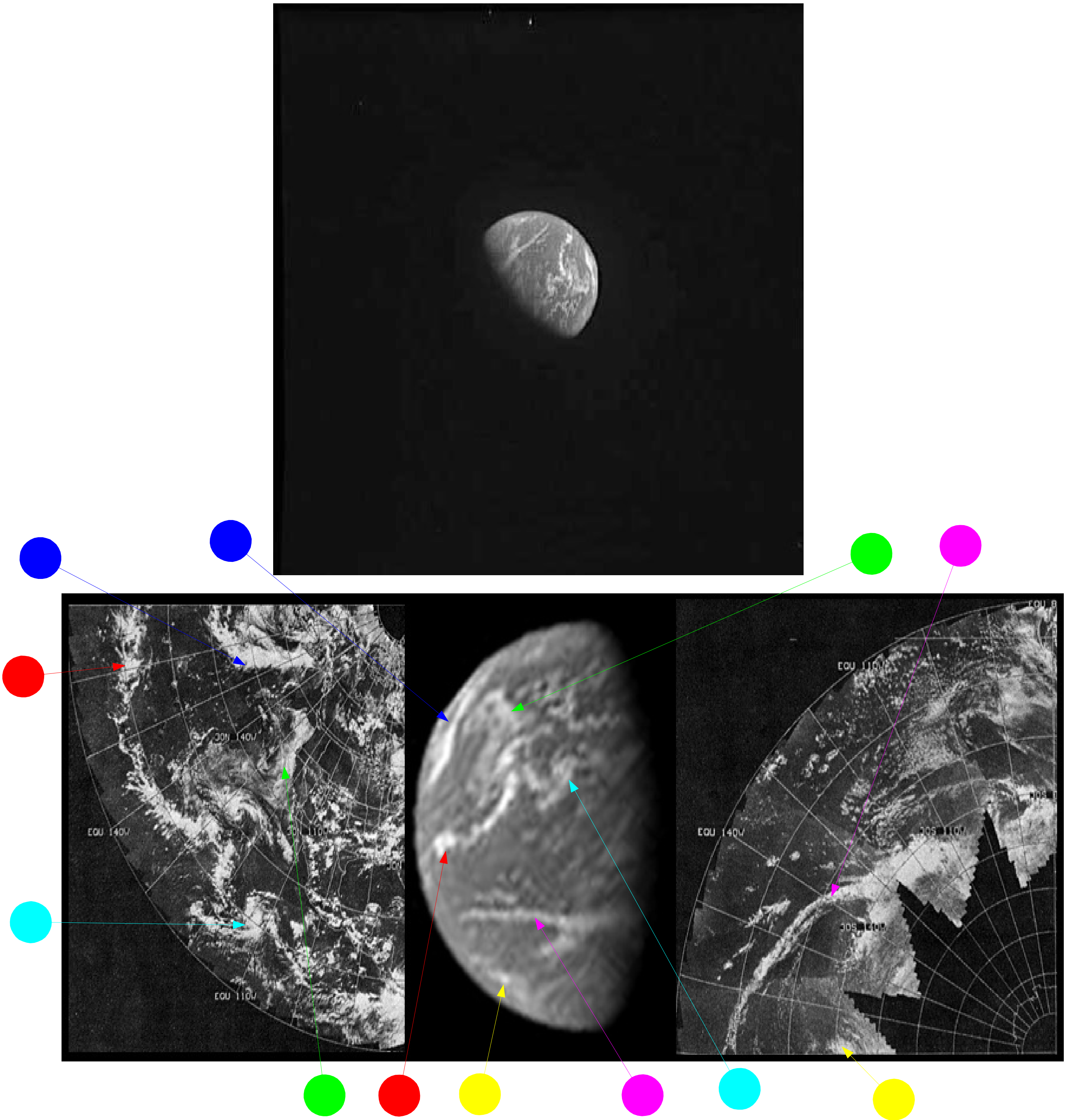


Figure 4.7.31: AS15-99-13413 (source: AIA) compared with ESSA 9 satellite mosaic from 26/07/71

Comparison of the photograph presented above with the image analysed in figure 4.7.4 (AS15-91-12344) suggests that they were taken at the same time – around 11:30 on the 26th, and is the companion colour photograph for this UV series.

The next sequence of UV images featuring Earth took place at 120000 miles and is the 4th in the sequence of UV images taken. The next time UV photography is discussed in the mission transcript is at 31 hours, or 23:00 on the 27th. The best image from that sequence is given in figure 4.7.32, along with a comparison with ESSA mosaics from the 27th.

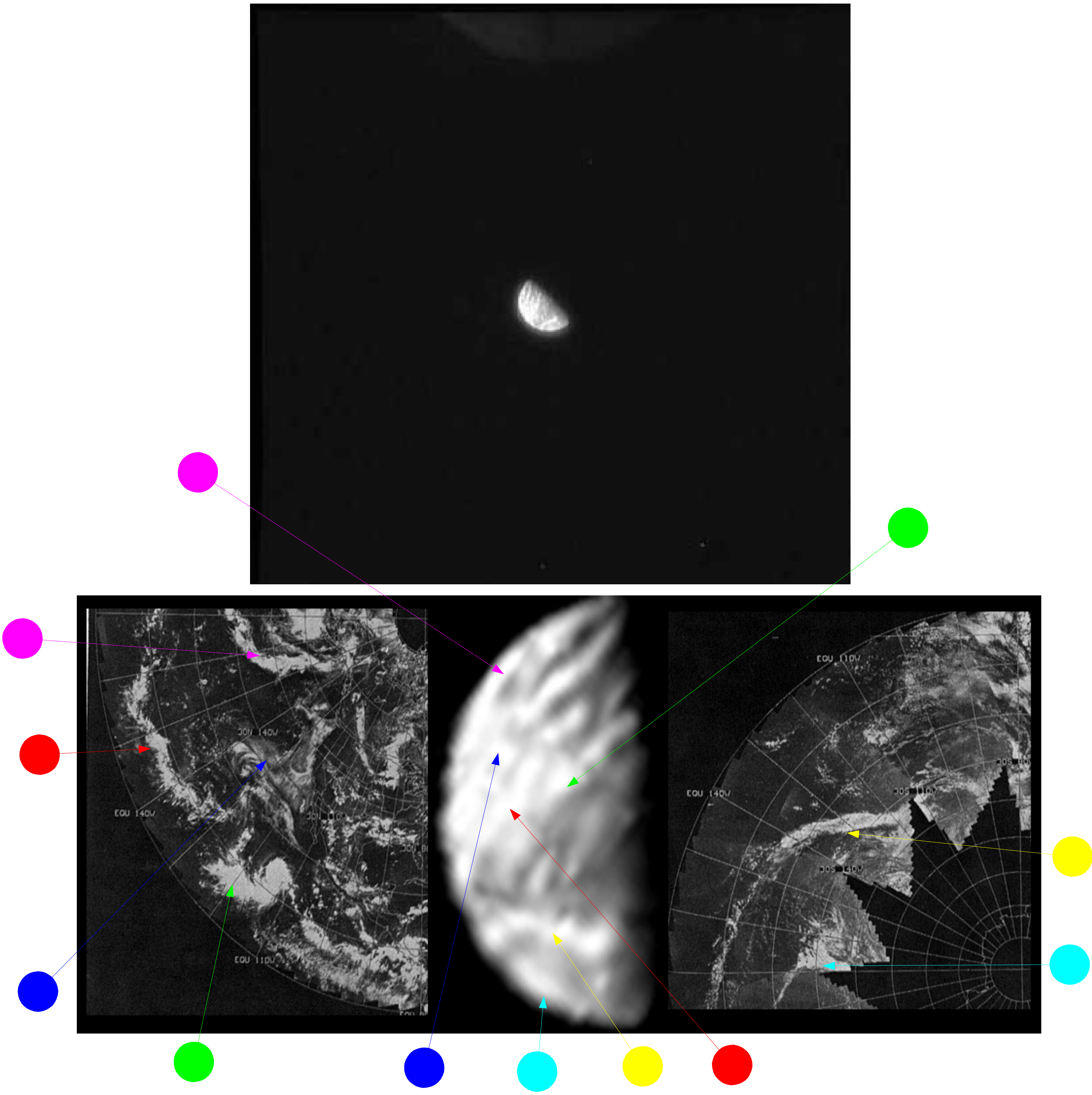


Figure 4.7.31: AS15-99-13431 (source: AIA) compared with ESSA 9 mosaics from 27/07/71.

With the doubling of distance from Earth has come a considerable deterioration in the quality of the UV image. Despite this, however, it is possible to make out the long band of cloud in the southern hemisphere, and once this has been identified it is possible to infer the location of the other major systems identified on the ESSA mosaic.

The companion colour image for this UV sequence was analysed in figure 4.7.10, where the time was identified as 22:30 on the 27th. The Apollo image taken at that time was AS15-91-12347.

The next image sequence was taken at 180000 miles out and the transcript records the crew as saying that they had completed them at 21:30 on the 28th. The best image from that sequence (AS15-99-13439) is shown, together with the relevant ESSA image from that date, in figure 4.7.32.

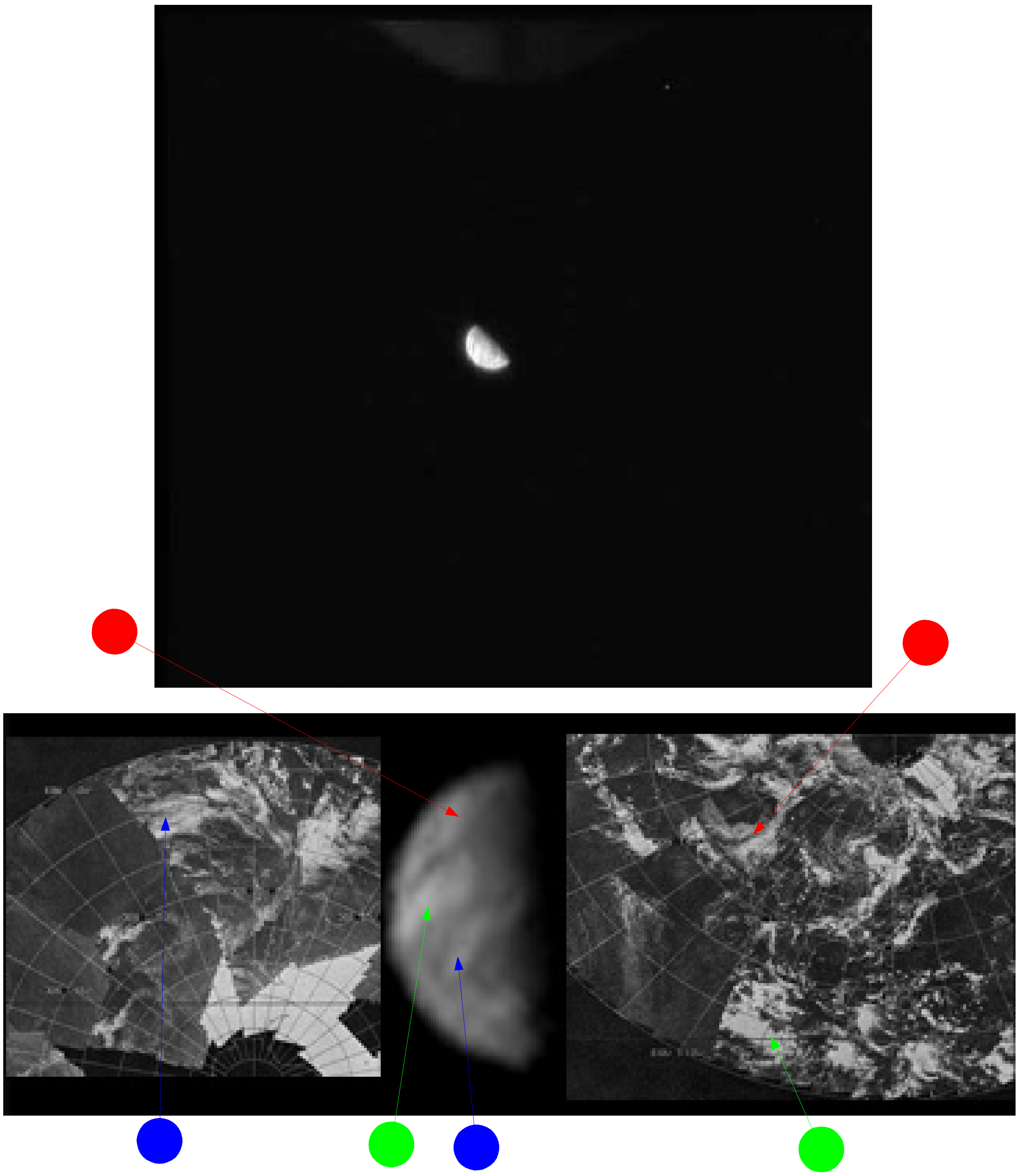


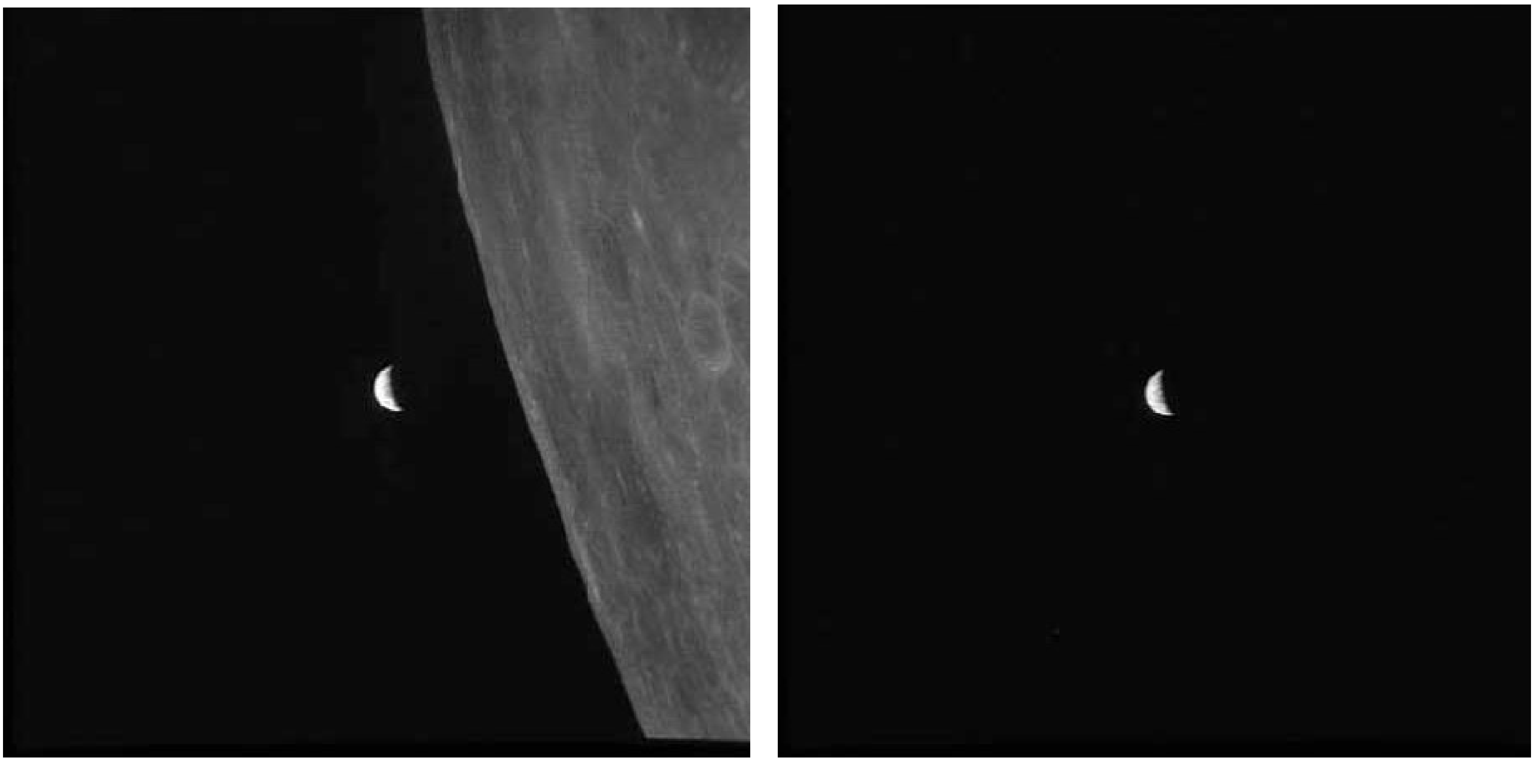
Figure 4.7.32: AS15-99-13439 (source: AIA) compared with ESSA 9 mosaics from 28/07/71.

Observant readers will recall that the 28th was the day when issues regarding ESSA 9 data quality were discussed, in relation to AS15-91-12350 (figure 4.7.12), and so much of what is visible in the UV image is not visible in the ESSA mosaic. It is still just possible to discern the overall shapes of the weather patterns that are present in the mosaic, and to note that the time recorded for the UV photography in this session coincides well with the time derived for AS15-91-12350 of 22:00.

The final image examined in the UV sequence is from in lunar orbit, and as will be evident from it, there is little point in examining the later images of Earth as there is very little detail visible on them.

UV imagery is next mentioned in the mission at being scheduled to start at 123 hours and 50 minutes, or around 17:30 on the 31st of July. Two sets were taken in this sequence. The photo index records this as taking place during orbit 24, which is recorded as starting at 123 hours 54 minutes. As this set of UV photos is of an Earthrise, this seems like a good set of timings.

Figure 4.7.33 shows the best two images from these two sets (sources: AS15-99-13447, AS15-99-13455) combined with the ESSA image from the time of orbit 24 on 31/07/71.



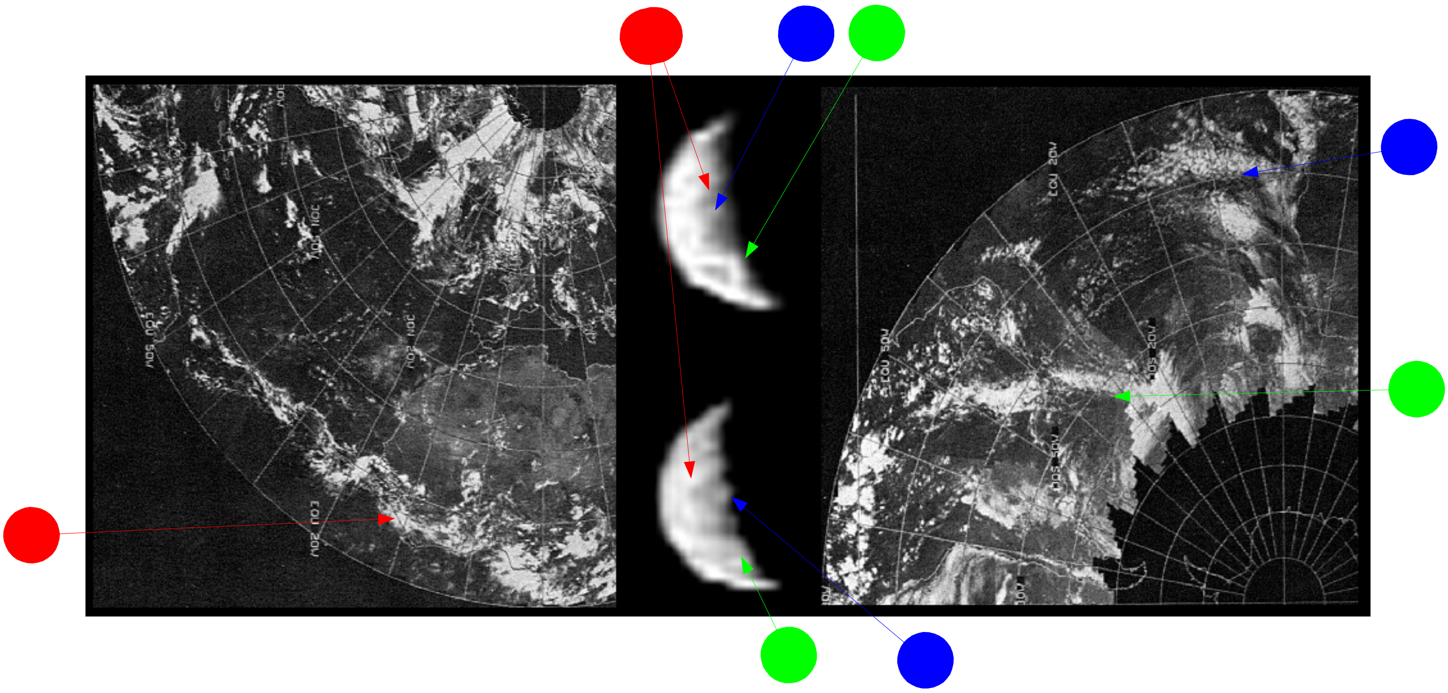


Figure 4.7.32: AS15-99-13447 (top middle) and AS15-99-13455 (bottom middle) compared with ESSA 9 mosaic from 31/07/71. Terminator line is across eastern Africa. See figure 4.7.17 AS15-91-12404 for reference

Again, those readers paying attention will recall that the colour image this analysis refers back to is one where the ESSA data have some quality issues in the south Atlantic region. Notwithstanding this, it is possible to make out the long band of cloud across the south Atlantic in both Earth images. Once this is recognised then, as with the previous images, the other major cloud systems fall into place.

It will no doubt be a bone of contention amongst those who find these analyses difficult to reconcile with their preferred view of the Apollo landings that these small fuzzy images, processed to improve detail and where much is assumed actually provide evidence of any sort. There will be some who will seize upon them as evidence to support their own idea that the analysis this work represents is flawed as a whole. They will neglect to include in their conclusions that the small number of photographs where much has been assumed is far outweighed by the wealth of images where it is blatantly obvious that the satellite representation of Earth's weather matches exactly that in the Apollo image.

It would have been simpler to leave out completely those pictures where things are not clear, or that were difficult to analyse on their own without reference to other supporting data. This is not how understanding of any subject is advanced. Failure to acknowledge that some photographs are not perfect, and brushing over areas where there is a lack of clarity rather than attempting at explanation and logical deduction would have been far worse than opening up this analysis to criticism from people who will view the work selectively and maliciously regardless of what was included.

Having launched that particular diatribe, that concludes the analysis of mission photographs for Apollo 15. There will now be a brief examination of the available meteorological data .

4.7.3 Meteorological data

The preceding sections have already identified several tropical storms and hurricanes that existed during this mission, and these storms were reported in contemporary journals. As with other missions, synoptic charts are available from a few sources, but they are only of any real use for the first half of the mission when there was a sufficient amount of the Earth's surface in view to allow meaningful comparison. The northern hemisphere is also not viewable in many of the Apollo photographs

The usual synoptic chart sources (German, South Africa and NOAA) have been selected again here, as they are consistently available. The relevant pages from these reports are contained in the Appendixes.

The first day of the mission is a good starting point here, as north America is visible, and we have two images taken within a few hours of each other to get good coverage of a considerable amount of the globe.

Figure 4.7.33 overleaf shows the NOAA and German synoptic charts for the 26th in comparison with the two Apollo images from that day: AS15-91-12342 and AS15-91-12344.

The weather system crossing the Atlantic (yellow arrow) is clear on the German synoptic chart, as is thee one over north America.

The purple arrowed system marks the line of disturbed cloud along the ITCZ.

As with other missions, there is good correspondence between the synoptic and photographic data.

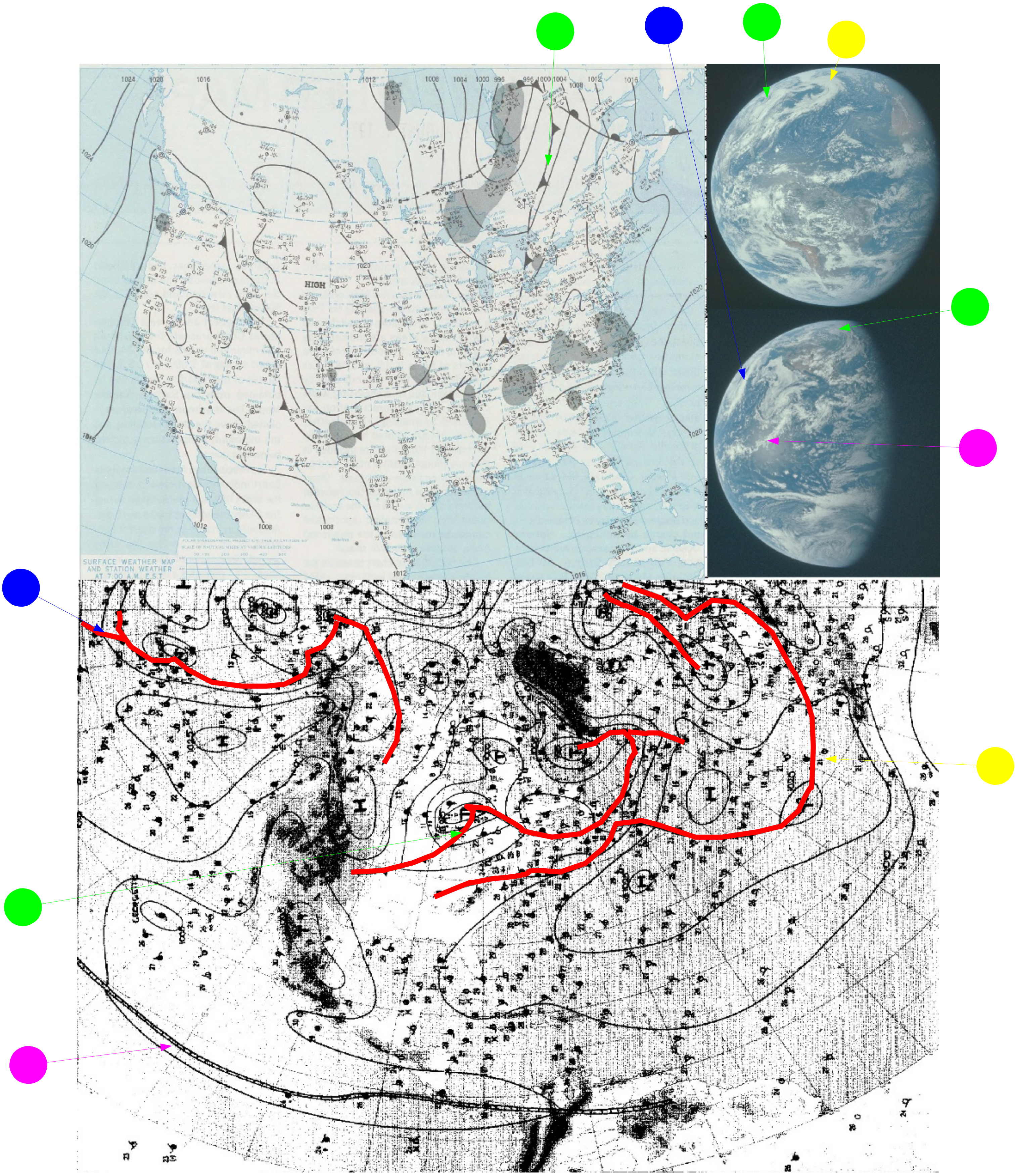


Figure 4.7.33; Synoptic data from NOAA (top left) and Germany (bottom) compared with AS15-91-12342 (top right) and AS15-91-12344 (right, middle)

The next synoptic charts to be examined are from the 28th of July, which was analysed in figure 4.7.12 using AS15-91-12350. The synoptic charts for this date are shown, together with a reproduction of the Apollo image, in figure 4.7.34.

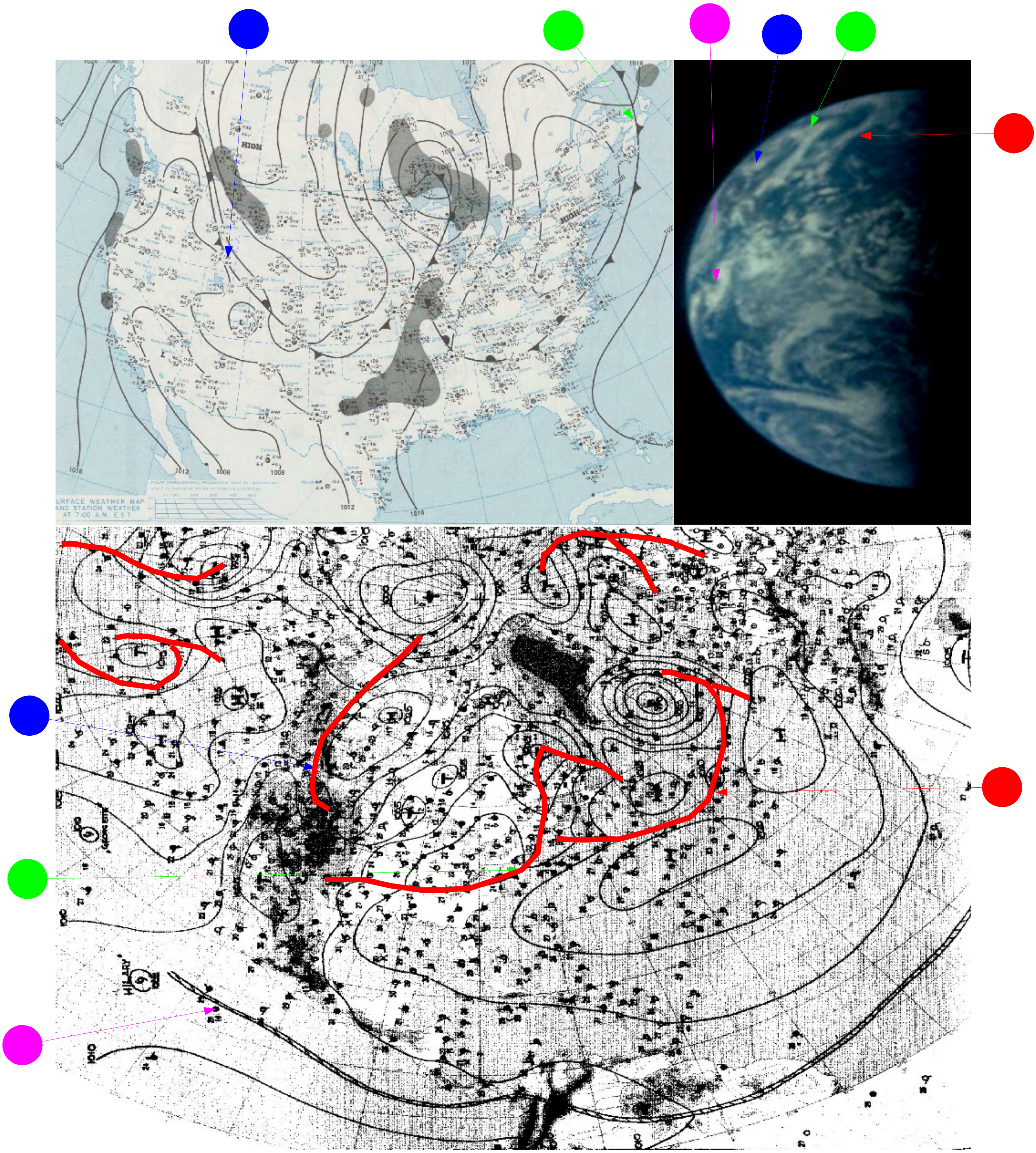


Figure 4.7.34: NOAA (top left) and German (bottom) synoptic chards compared with AS15-91-12350.

The ITCZ is just visible on the Apollo image, but the other main weather systems, themselves a development of the ones seen in the previous image, are still visible and easily identifiable.

The final synoptic image is from the South African data covering July 31st. This allows us to compensate for the tilt of the Earth relative to the lunar based observers. Africa was covered in figure 4.7.17 using Apollo image AS15-91-12404. Figure 4.7.34 shows the resulting analysis.

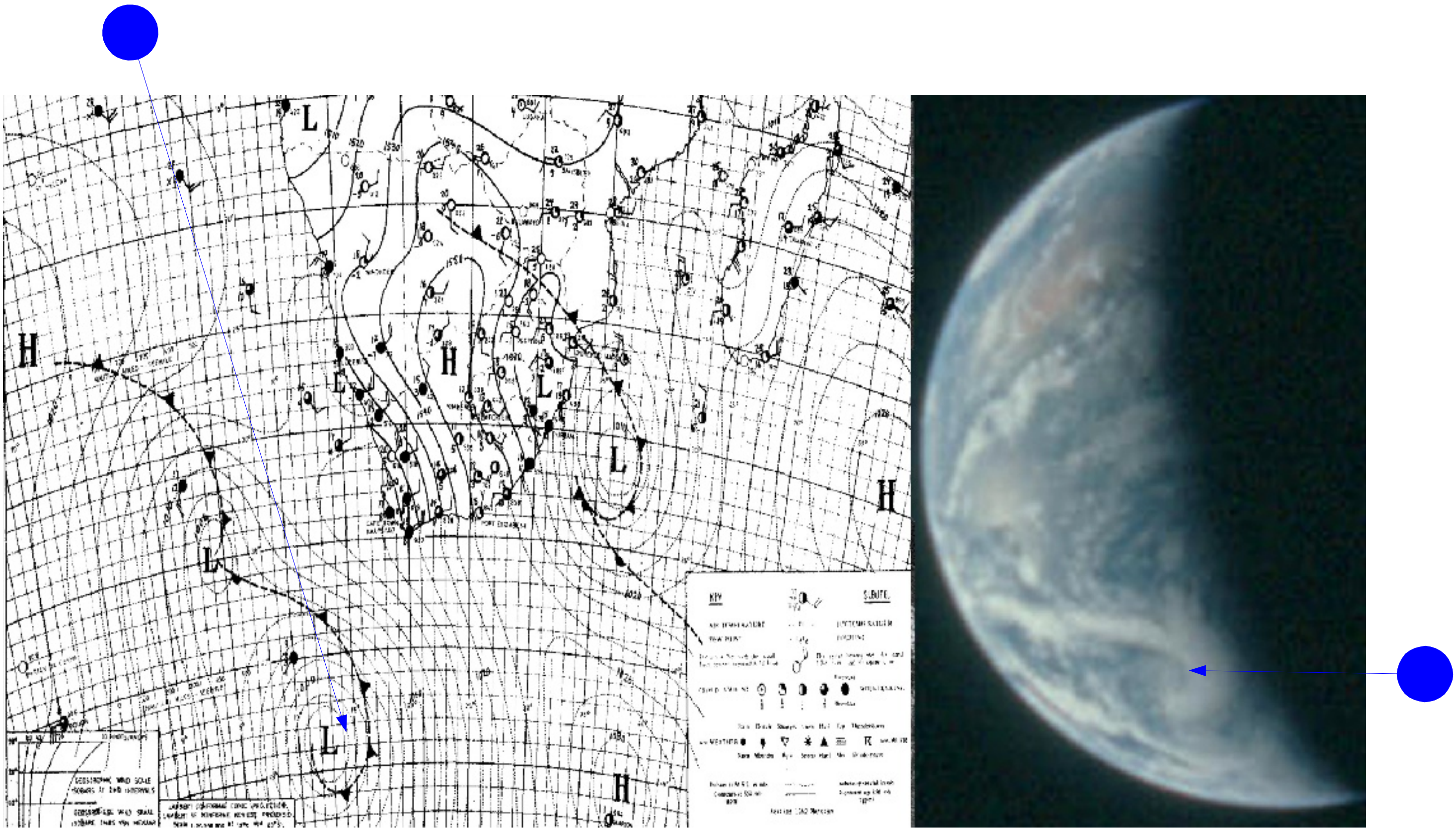


Figure 4.7.34: South African synoptic chart from 31/07/71 compared with AS15-91-12404.

As is obvious from the figure above, there is only one feature visible, and that is the front off the south African coast manifesting itself in the curl of cloud in the Apollo image.

4.7.4 Conclusion

It will come as no surprise to anyone that the photographs of Earth taken by Apollo presented here can be demonstrated to match with satellite derived weather patterns. Most images are easy to place, and it is a relatively simple task to derive a time for the photograph purely from the satellite data and then verify this by using secondary data. In other cases the secondary data assist in identifying the time of the photograph.

The photographic evidence is backed up by meteorological evidence, not least the presence of a hurricane.

It all points to the conclusion that Apollo 15 went to the moon and returned safely, just like the missions before it, and just like the next mission, Apollo 16.

4.8 Apollo 16

Apollo 16 saw another lunar rover head for the moon, this time in an exploration of the lunar highlands. It again involved several EVAs and the use of a CSM SIM bay to record experimental data in orbit while the LM carried its duties on the surface. UV photography was again employed to take images of Earth on the way to the Moon, and also from the lunar surface.

Even before this mission had begun, news reports were full of the next phase of NASA's space programme: the shuttle, and discussions on what to do with redundant launch towers were already under way. The economic cost of Apollo was freely discussed in these news programmes, and the perceived benefits of LEO satellite programmes became much more prominent in the discussions compared with the less immediately useful scientific data.

The flight was intended to launch in March, but technical problems with an explosive separation bolt between the LM and CSM forced a delay. The crew finally lifted off on April 16th 1972 and entered lunar orbit on the 19th. Landing did not occur until the 21st after more technical problems with the CSM engines caused a day's delay. After eventually landing and carrying out 3 EVAs, the surface crew were re-united with the orbiting CSM on the 24th. TEI occurred the next day, and the astronauts finally splashed down on the 27th. On the way back a televised EVA was carried out to retrieve data from the SIM bay, and an unmanned TV broadcast was also made from the lunar surface.

The mission timeline can be found here: http://history.nasa.gov/SP-4029/Apollo_16i_Timeline.htm

As far as mission photographs go, the AIA records that the Hasselblads took 22 magazines if film, with a total of 2808 photographs exposed. An additional magazine comprises the far right UV spectrum long exposure images taken from the surface.

As with Apollo 15 & 14, no high resolution images are stored at the AIA. The Apollo Gateway has been used instead to request the images used here.

In terms of availability of satellite images, only ESSA 9 photographs have a full catalogue online, available here: NOAA. ATS-3 images were still being transmitted, and one can be found here: ATS-3 image in the MWL for April 18th. An ESSA 8 image for launch day can be found here: MWR, in an interesting article about the ARIA (Apollo Range Instrumented Aircraft) that collected meteorological data in support of Apollo missions. ARIA is several times in the early part of the mission in Earth orbit (see the Mission Transcript here: ALSJ), acting as a relay between receiving stations on the ground.

The ESSA image in the article was taken on launch day, but unfortunately the area of the south Pacific shown is not covered by any of the photographs from that day. Understandably, the crew will have been a little busy at TEI and would not have had the time to photograph it.

4.8.1 Satellite data

In a break with the usual format of these sections, the first image to be examined are from a TV broadcast, and will include an Apollo image that does not show the full Earth disc.

At 3 hours and 10 minutes into the mission (21:04 GMT) the crew started a TV transmission to cover the docking of the CSM with the LM.

15 minutes after starting the transmission, the crew have this to say:

"Houston before we turn the TV off...we want to give a picture of the Earth"

Capcom confirm they are receiving the image,

"very nice picture Charlie, we can see south-Western United States, Lower California. Very nice."

and also confirm that it is in colour. A few moments later the Apollo crew describe the view from 7000 miles out:

"...you just can't believe how beautiful it is. See the reds in the desert down there and the southern United States and northern parts of Mexico. And from here, you see the Great Lakes and the State of Florida out there. And it's just absolutely something."

At 21:22 GMT, the TV pictures finished.

These TV images were used a short while later in a NBC news broadcast, available here: Apollo 16 news broadcast.

Amusingly, the TV broadcaster's voice, commenting on the pictures says that

"if my calculations are correct, the North Pole is to the right.. the Earth is tipped on its side"

He's correct about the Earth being viewed sideways on, but has got the location of the North Pole entirely wrong!

Two screencaps from this footage are given in figure 4.8.1. One has been chosen purely because it has the words "Live from Space' on it. The other one is from a couple of seconds later but covers more of the Earth's surface. This is combined with the ESSA 9 mosaic from the 16th, and also AS16-118-18873 (source: AIA). This is not a full disk but is obviously taken at the same time. There are numerous small particles visible in the photograph from the explosive separation of the SIV-B petals to expose the LM, particles referred to by the crew just after starting their TV broadcast:

"We must have a zillion particles along with us"

This image precedes the docking, as photos later in the magazine show the LM still within the SIV-B.

The time is clearly shown on the news broadcast as 5:48* on April 16th. It isn't immediately clear as to which time zone this refers to, NBC had a base in New York, so it doesn't seem unreasonable to assume that the time refers to EDT, or Eastern Daylight Time. It certainly can't be 05:48 am, as this would be before the actual launch, so we are looking at 17:48 EDT. This translates to 21:48 GMT, just 25 minutes after the original broadcast.

The voice in the background of the NBC broadcast of the footage actually sounds like Walter Cronkite, the CBS anchor who fronted all of that network's Apollo coverage, and it is possible that NBC have used CBS footage of the post-TLI phase. At the time, NBC, ABC & CBS news all used the same style of station identifier and date/time stamp.

* *The caption 'Live from Space' is perhaps not quite true for the broadcast shown here, but it may well have been recorded live and transmitted later, as evidenced by Cronkite's comments. Cronkite fronted special coverage of the Apollo missions as well as news broadcasts.*

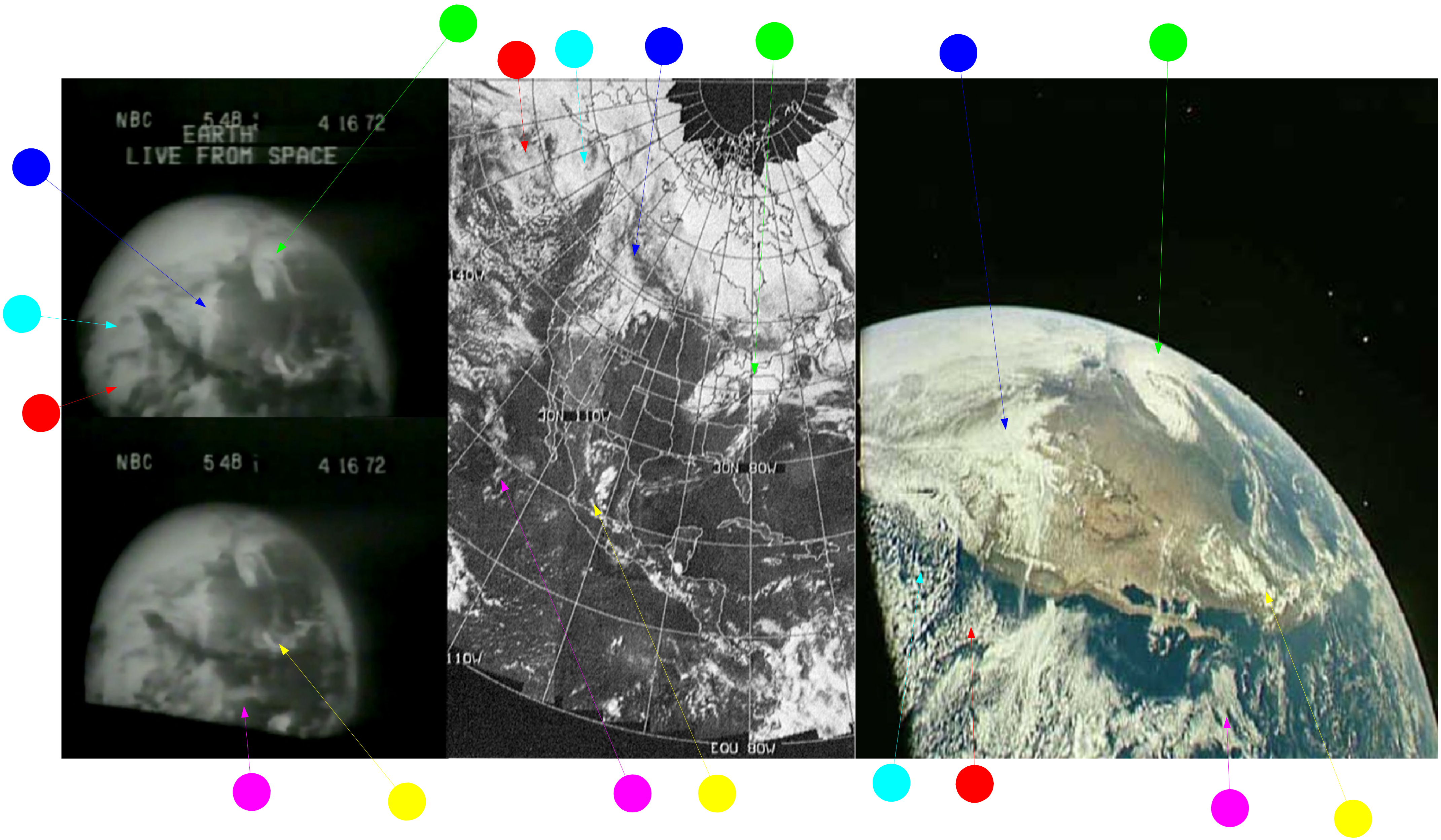


Figure 4.8.1: NBC news screenshots from 17:48 16/04/72 compared with ESSA 9 satellite mosaic and AS16-118-18873

As for what is in the image, the most obvious feature is the large 'speech bubble' shape (green arrow) off the east coast of north America, but all of the other cloud features match perfectly between the TV, Apollo and satellite images. In terms of when the image was taken, we already have a definite match for the video screenshots, and therefore the Apollo image.

The ESSA track covering the east coast of the USA would have been orbit 4308 (track number 3), which started at 20:06. So, at the time of the Apollo images there was actually no satellite mosaic of the region photographed, and ESSA 9 could not, therefore, have been used as the basis for some sort of fake of the Apollo photograph. In order to demonstrate that ESSA 8, or ATS-3 images could have been used (remember both of these sent back black & white images), you would have to have the original source material, which at present are not available. Even ATS-3, which took half an an hour to transmit its images, would have been had to have finished transmitting just as the news footage was obtained, then processed into a whole image, then converted to colour, all inside 25 minutes. Given the technology available this was just not possible.

The first full disk image to be examined from Apollo 16 is AS16-118-1885 (source: AIA)**.

This image occurs after a series of pictures showing the LM thrusters, now docked with the CSM, and the empty SIV-B carcass, which immediately puts the timeframe for the photograph at after 21:53 on the 16th. There is one more image of the SIV-B after this, then a sequence of Earth images showing an ever decreasing disk. The original Apollo Gateway image is shown below in figure 4.8.2, and the analysis overleaf in figure 4.8.3.

Figure 4.8.2: Apollo Gateway image scan of AS16-118-18885.

** *This image was used in the film 'Apollo 13' at 1:48 minutes, as the crippled spacecraft is closing in on Earth.*

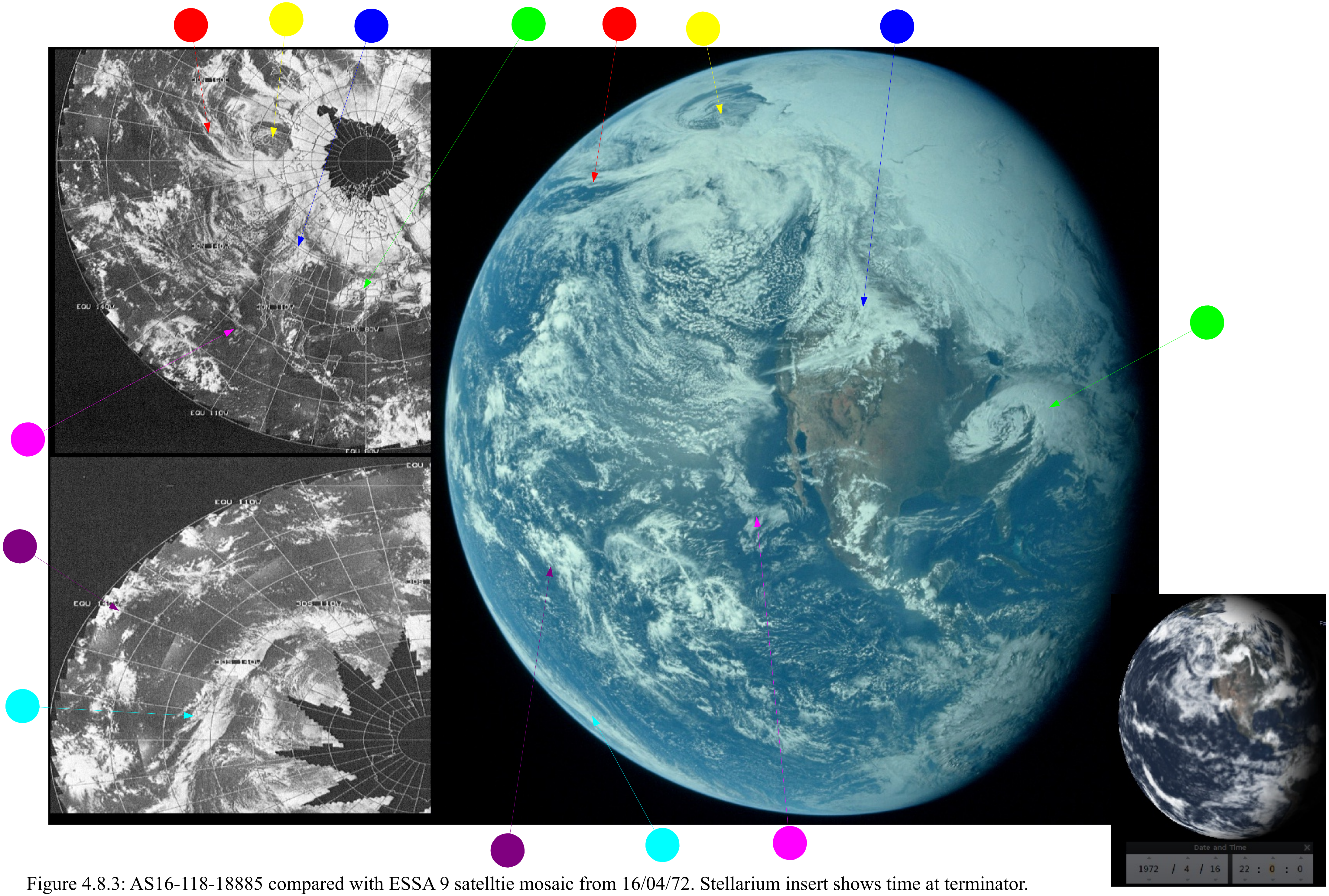


Figure 4.8.3: AS16-118-18885 compared with ESSA 9 satelltie mosaic from 16/04/72. Stellarium insert shows time at terminator.

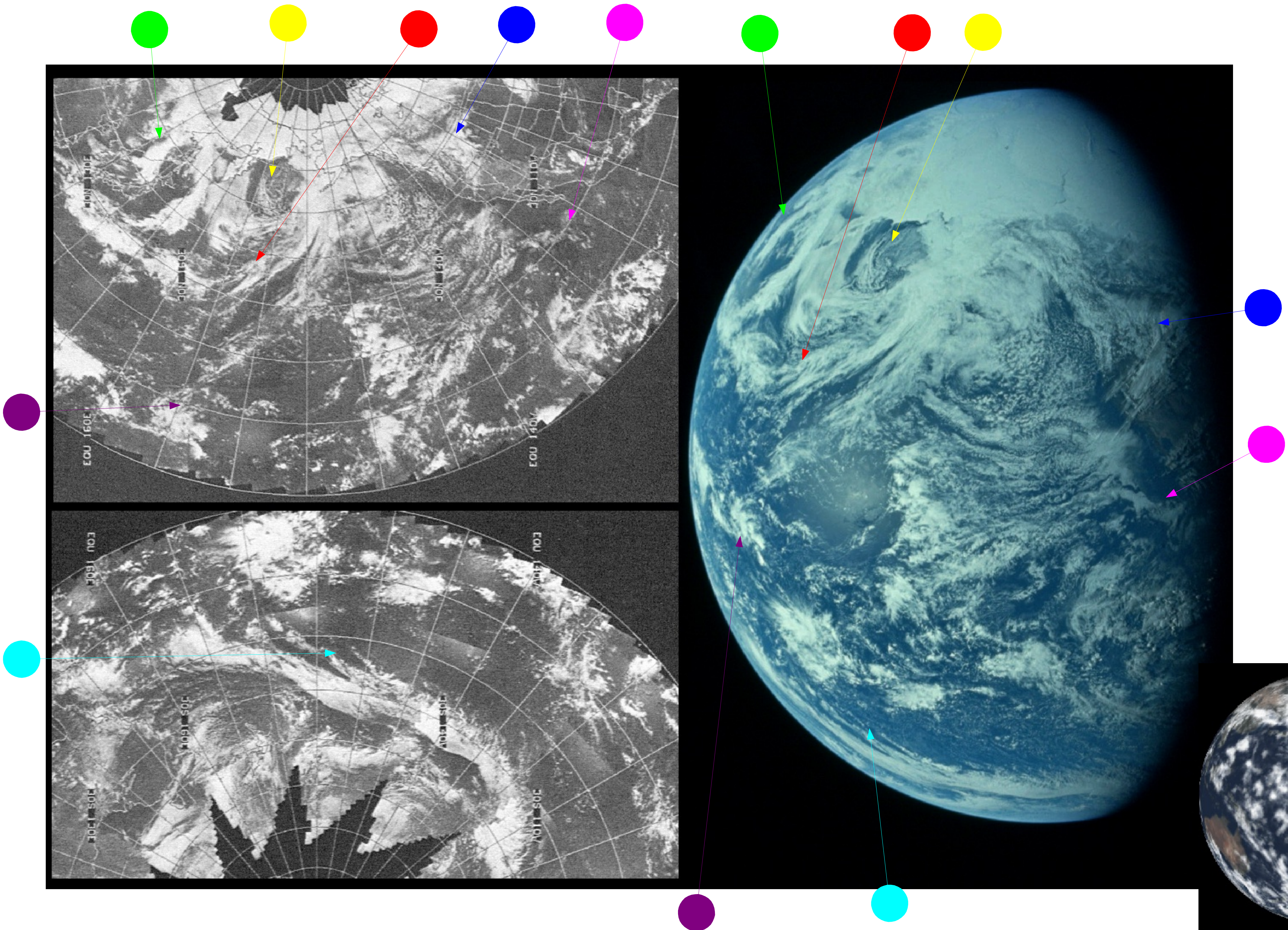
It is unsurprising, given that the image was taken not long after the preceding Apollo photograph analysed, that the same broad weather patterns are visible. Even with the poor quality of the video screenshot, it is still possible to work out that the globe has rotated somewhat, as much more of the Pacific is visible, and the polar cloud mass has moved much further eastwards.

Also coming into view is a large hole in the Arctic cloud (yellow arrow). This feature is interesting because other conspiracy theorists suggest it shows the polar opening to a hollow earth, for example here and here. The tone of some of the articles makes it clear that they don't like using Apollo evidence, because they are forced to admit that the Apollo missions took place! It should be obvious that hole is at neither the magnetic nor geographic pole, and the sea can be seen, not a hole!

The ESSA timings have already been given in the previous image, and the timing of the East coast of the US part of the image would have been around 20:06. The terminator in the image is suggested to be at 22:00, just after the CSM had extracted the LM from the SIV-B.

The next few images of Earth are all from the same sequence of photographs in magazine 118. AS16-118-18887 (source: AIA). This image is shown in figure 4.8.4 below. Comparison with the ESSA mosaic is undertaken on the following page in figure 4.8.5.

Figure 4.8.4: High resolution GAP image of AS16-118-18887.



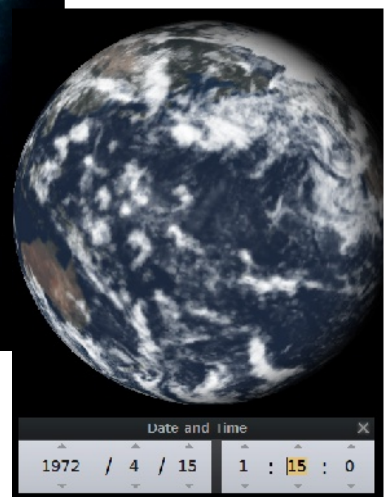


Figure 4.8.5: AS16-118-18887 compared with ESSA 9 mosaic. Stellarium insert shows terminator estimate. Yellow, Blue, Green, Magenta, Red and Cyan arrows are as in figure 4.8.3

The Apollo image shows that the Earth has rotated by some distance since the previous photograph, with more of the Pacific visible, and more than half of the northern USA now in darkness. Australia ia bout to come into view, and the long band of cloud extending from the Arctic towards it is now more prominent, thanks to a change in viewpoint.

The entrance to Earth's hollow interior [*sic*] is also much more in focus, and it should be even more obvious that it is just a gap in the clouds, with other, lower altitude clouds inside it.

The terminator position gives an estimated time of about 01:15 on the 17th of April, as determined by its location through California and Mexico. ESSA's orbits mean that track 4 would be closest to the terminator visible here, which equates to orbit number 4309, which was commenced at 23:01. Note the position of Australia in Stellarium, but absent in the Apollo image, which is again the effect of Stellarium's lunar viewpoint instead of Apollo's TLC position pointing at where the moon will eventually be.

In the next image in the sequence, AS16-118-18858 (source: AIA), figure 4.8.6, the Earth has shrunk considerably, and once the image is zoomed in there is again evidence of a rotating globe, not a static image in repeated use. Australia is now in full view, and south east Asia is visible beneath the clouds. The entrance to inner Earth has now almost disappeared from view completely. Figure 4.8.7 examines the weather patterns visible in ESSA's mosaic in comparison with this image.

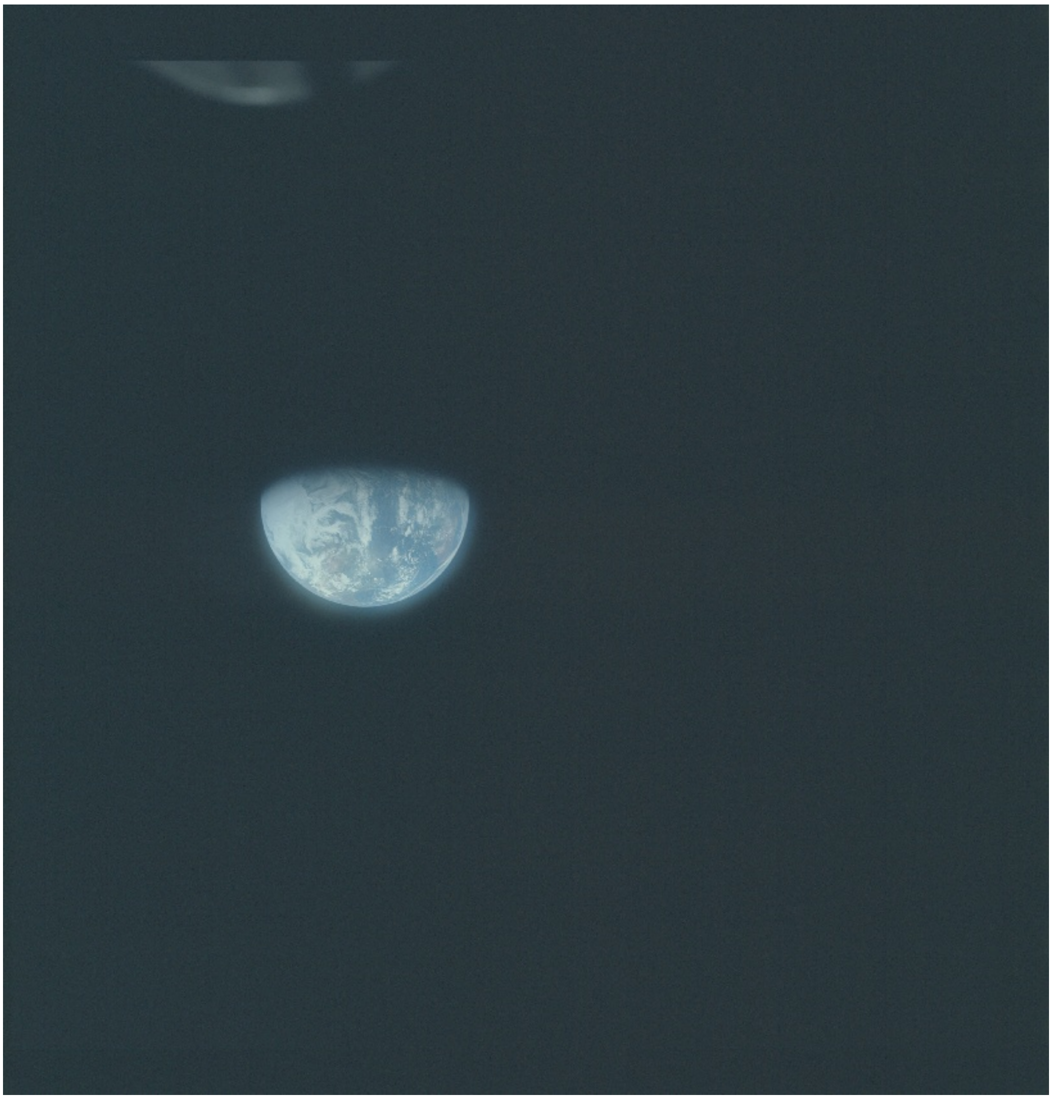


Figure 4.8.7: High resolution GAP scan of AS16-118-18888.

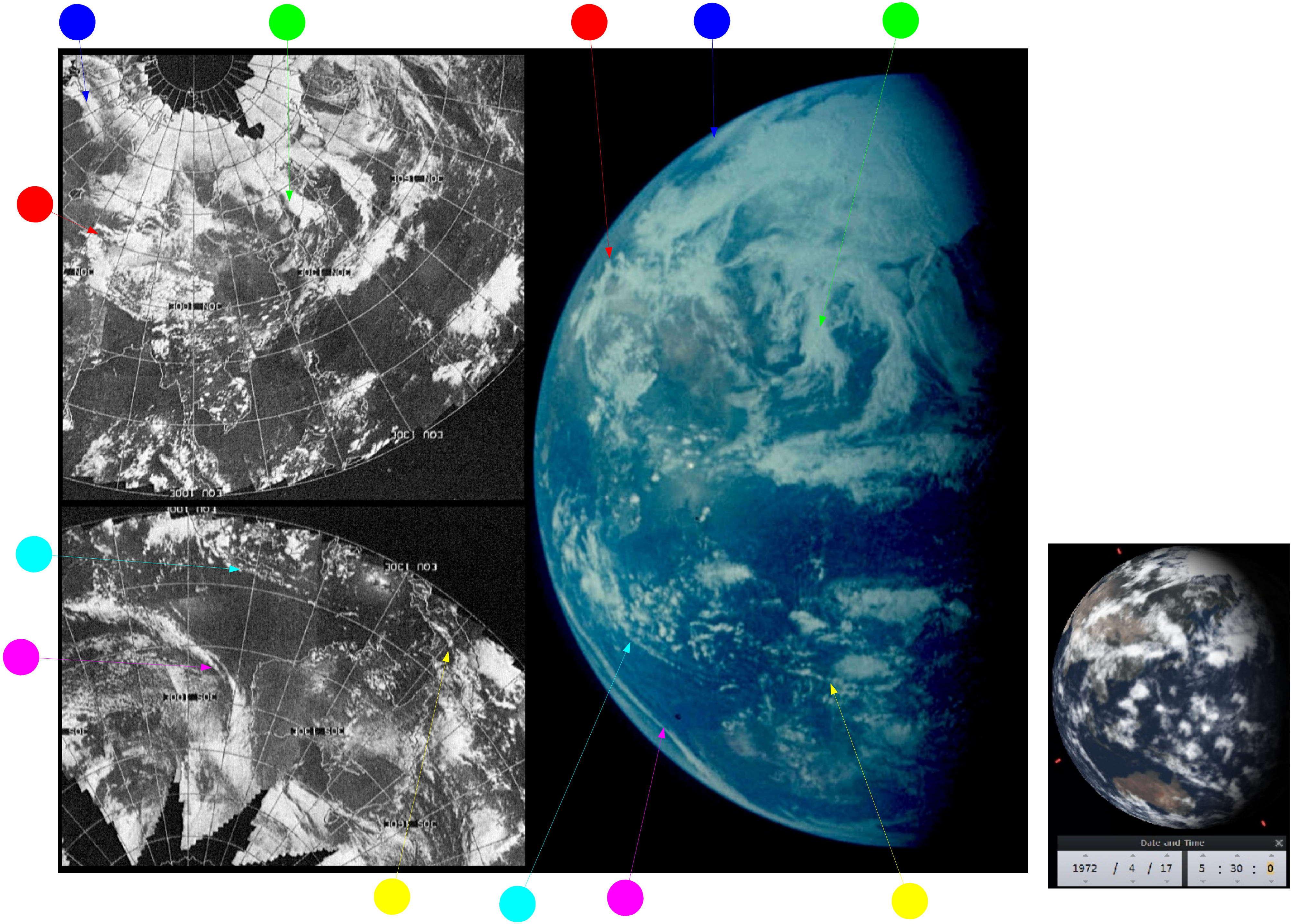


Figure 4.8.7: AS16-118-18888 compared with ESSA 9 mosaic and stellarium inset showing terminator time estimate. Green arrow is as used in figure figure 4.8.5

Having stated that Australia is clearly in view, the casual observer would have trouble identifying its location. Ironically the process used to enhance the clarity of the weather systems on the image has made the continents and some clouds around the terminator less visible, but they are there.

Although only the clouds arrowed in green are specifically pointed out, there are a number of clouds in this image that are visible in the preceding one, notably the band of cloud below the system identified in green, and the band of cloud above the system identified in yellow. Those clouds picked out by the blue, magenta and red arrows have been identified because they are likely to appear in the subsequent image.

The most relevant ESSA track for this image would be around track number 6. This corresponds to orbit number 4311, commenced at 01:02 on the 17th. As has already been established, this is consistent with an image dated the previous day. The position of Australia, and the location of India on the western limb without any suggestion of Arabia in the image points to a time at the terminator of around 05:30 on the 17th. Again, we have to allow for the position of stellarium's observer position and that of the Apollo craft and use the terminator as the reference wherever possible.

As16-118-18889 (source: AIA) sees the Earth smaller still, and is becoming increasingly difficult in the low resolution images at the AIA to spot specific weather patterns without zooming in close. This image is shown below in figure 4.8.8 and analysed in figure 4.8.9.

On the face of it, AS16-118-18888 and 9 seem identical, but in reality they are just taken a short while apart. The change in terminator is only slight, but the time of this second image can be put at around 06:00 on the 17th. This can be demonstrated by a close examination of the system identified in red in figures 4.8.7 and 4.8.9 (see figure 4.8.10).

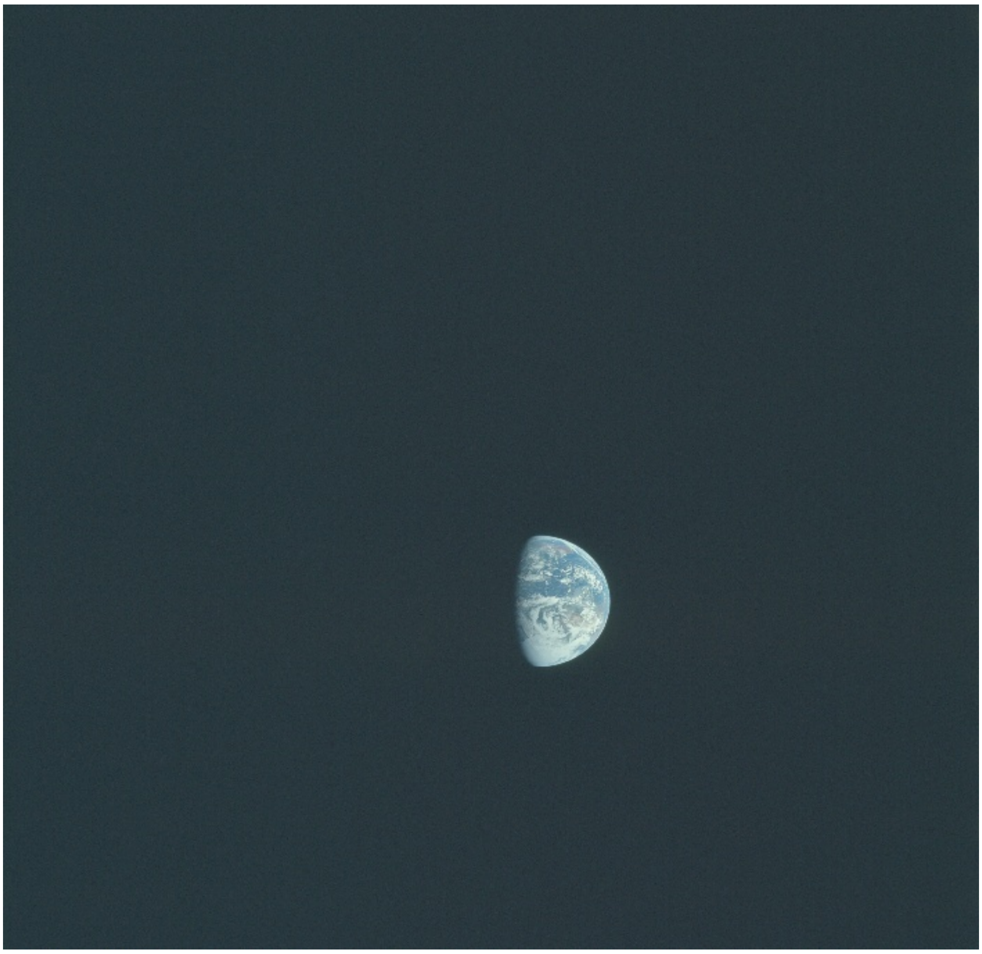


Figure 4.8.8: High resolution GAP scan of AS16-118-18889.

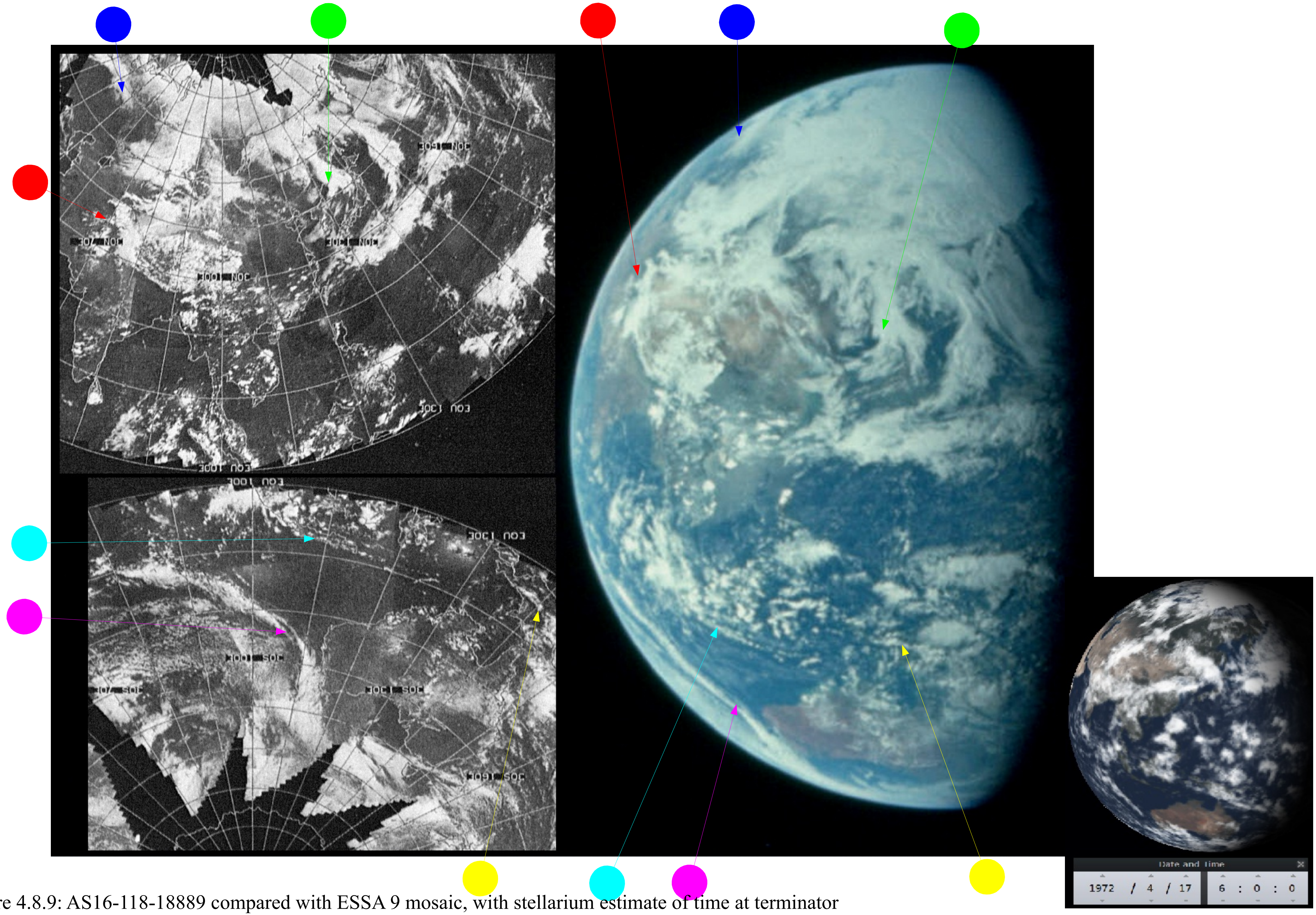


Figure 4.8.9: AS16-118-18889 compared with ESSA 9 mosaic, with stellarium estimate of time at terminator

Figure 4.8.10: AS16-118-18888 (top) compared with AS16-118-18889 (bottom).

The differences are subtle but nonetheless there.

There is a different shoreline configuration in the later as Arabia comes into view, and the system picked out in red is both further in from the western limb and is slightly less elongated.

In fact, there is not a single cloud on the image that is exactly the same, although they are recognisably the same weather patterns.

As with the preceding sections, this provides ample evidence (again) of a rotating, dynamic Earth photographed from space.

The next in the sequence of Apollo images is AS16-118-18890 (source: AIA), which is shown below in figure 4.8.11 and analysed overleaf in figure 4.8.12.

Figure 4.8.11: High resolution GAP image of AS16-118-18890.

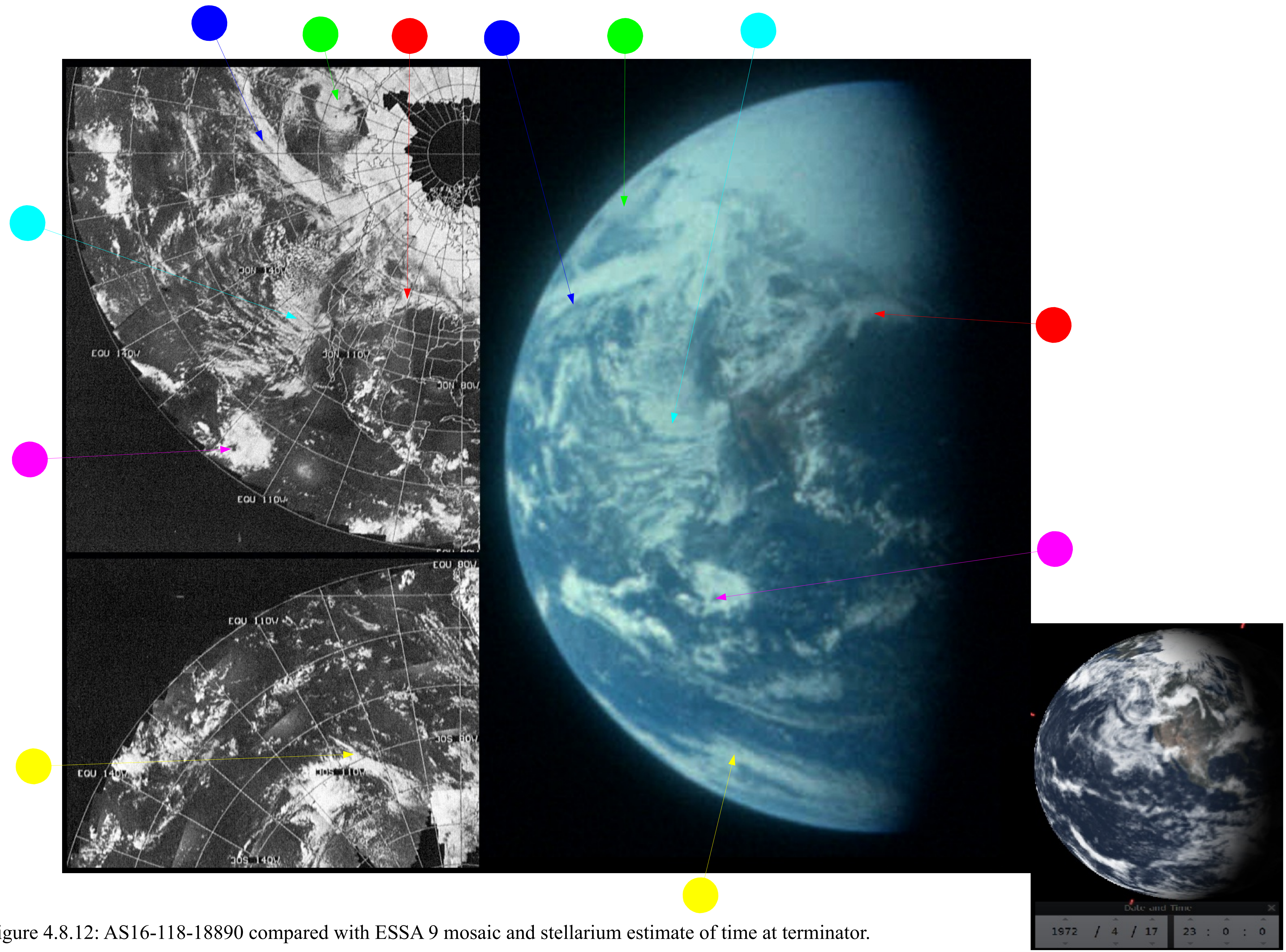


Figure 4.8.12: AS16-118-18890 compared with ESSA 9 mosaic and stellarium estimate of time at terminator.

As north America is now visible on the image, it is obviously a photograph taken much later than the previous one, and the terminator estimate puts the time at around 23:00. The weather patterns are a clear and obvious match for those on the ESSA image dated the 17th. ESSA's most representative orbit for this area is orbit number 4320 (track 3), commenced at 19:09 on the 17th.

The entrance to inner earth (green arrow) has now completely broken up, showing once and for all that it was never anything other than a weather system, and the clouds that made up it's eastern wall has moved onwards to become a clearly defined weather front (blue arrow).

A couple of hours before this photograph was taken at about 20:30 on the 17th, there is a conversation between capcom and Apollo, where the command module pilot says:

"I think one of the most impressive sights...is the cloud formations you can see and polar icecap"

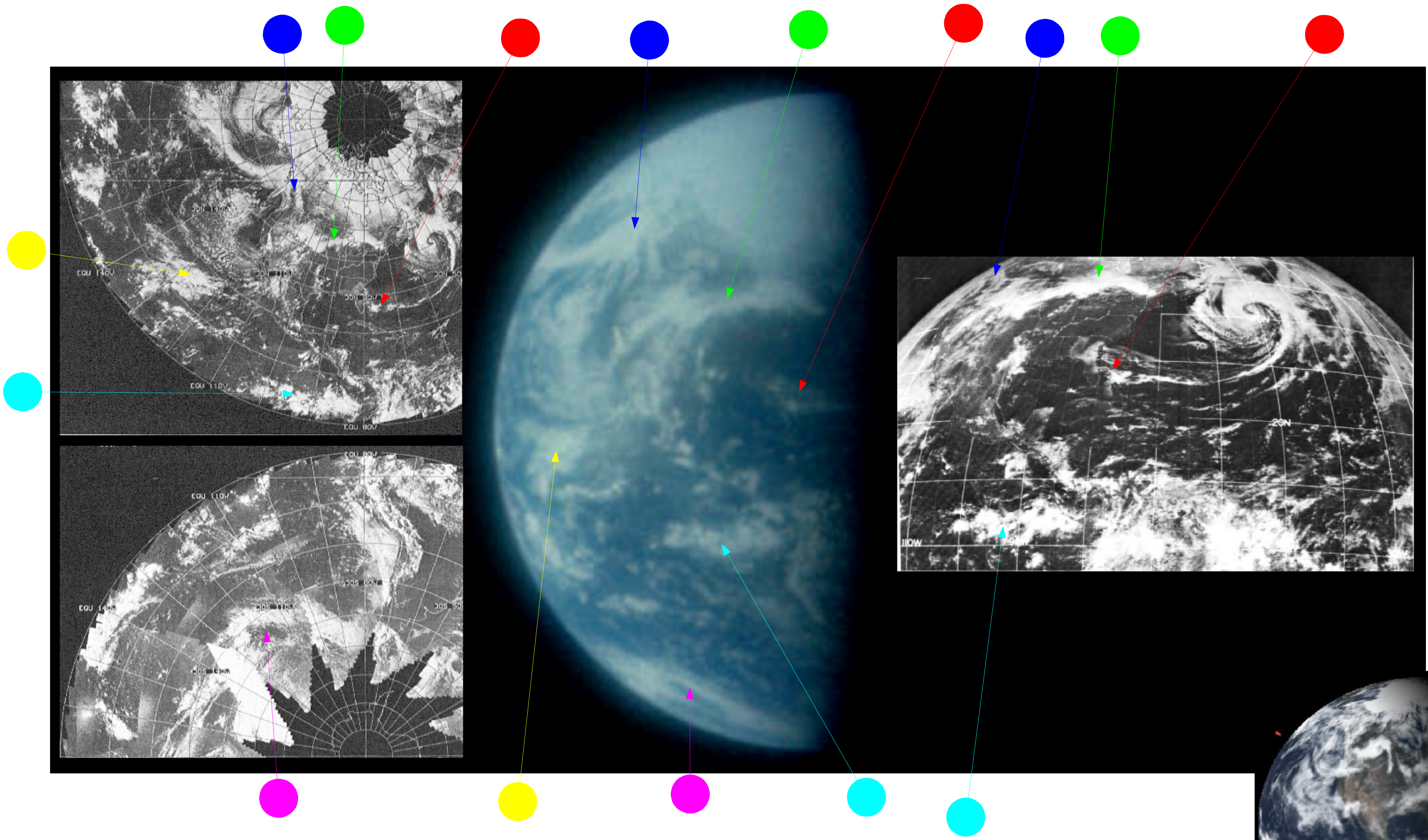
and then the lunar module pilot says that:

“There was that awful big storm up off the coast of Alaska in the Bering Sea, I guess it was yesterday. I can't see that now though.”

The storm to which he refers is the one forming the 'entrance to the hollow Earth' jokingly referred to here. Interestingly, capcom report that their weather charts don't extend that far, as they only cover the landing area for splashdown.

The final image in this sequence on magazine 118 is AS16-118-18891 (source: AIA), seen in figure 4.8.13, and analysed overleaf in figure 4.8.14.

Figure 4.8.13: High resolution GAP scan of AS16-118-18891



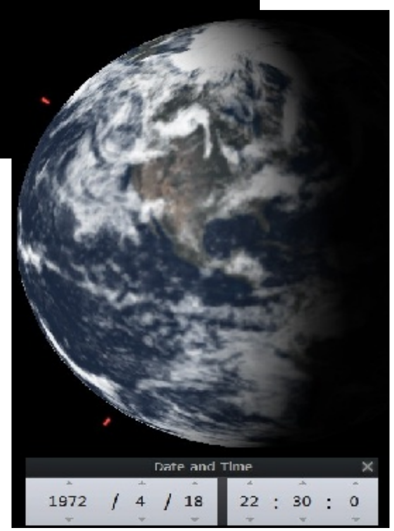


Figure 4.8.14: AS16-118-18891 compared with ESSA mosaic and ATS-3 image, with stellarium insert showing time at terminator

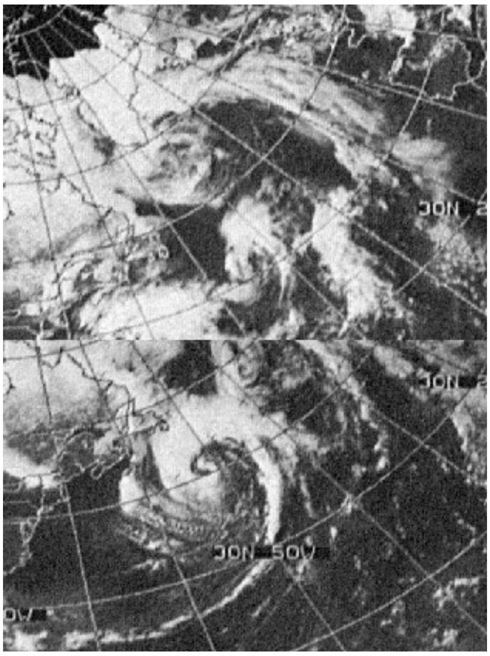


Figure 4.8.15: ESSA 9 mosaics of Atlantic storm on April 17th (top) and 18th (bottom).

This image of Earth is only slightly more rotated than the previous one in the magazine, but the weather patterns are very obviously different and the Earth is much smaller in the image. There are two possible explanations: either NASA got sloppy and forgot to consult their continuity people before using this one, or it is just over 24 hours since the preceding image was taken.

The satellite images act to confirm that the image is actually taken 24 hours later. The ATS-3 image was featured in the MWL as part of their summary of the month's weather, and is part of a discussion of the large storm close to northern Europe. The tail end of this storm is picked out in red on the photographs. The ATS-3 image was taken at 17:05 on the 18th.

On the 17th, this storm can be seen in ESSA images in a different place, and is not as cohesive as in this photograph (see figure 4.8.15)

The ESSA track best matching the terminator area is number 3,which corresponds to orbit number 4333 commenced at 20:08. Stellarium's terminator estimate is 22:30. According to the mission transcript, the crew were preparing for a UV photography session at this time, and capcom confirm them as being over Florida at that time. Everything therefore points to the date being the 18th.

The next image to be examined is AS16-120-19187 (source: AIA), which is shown figure 4.8.16 below and analysed in figure 4.8.17 overleaf.

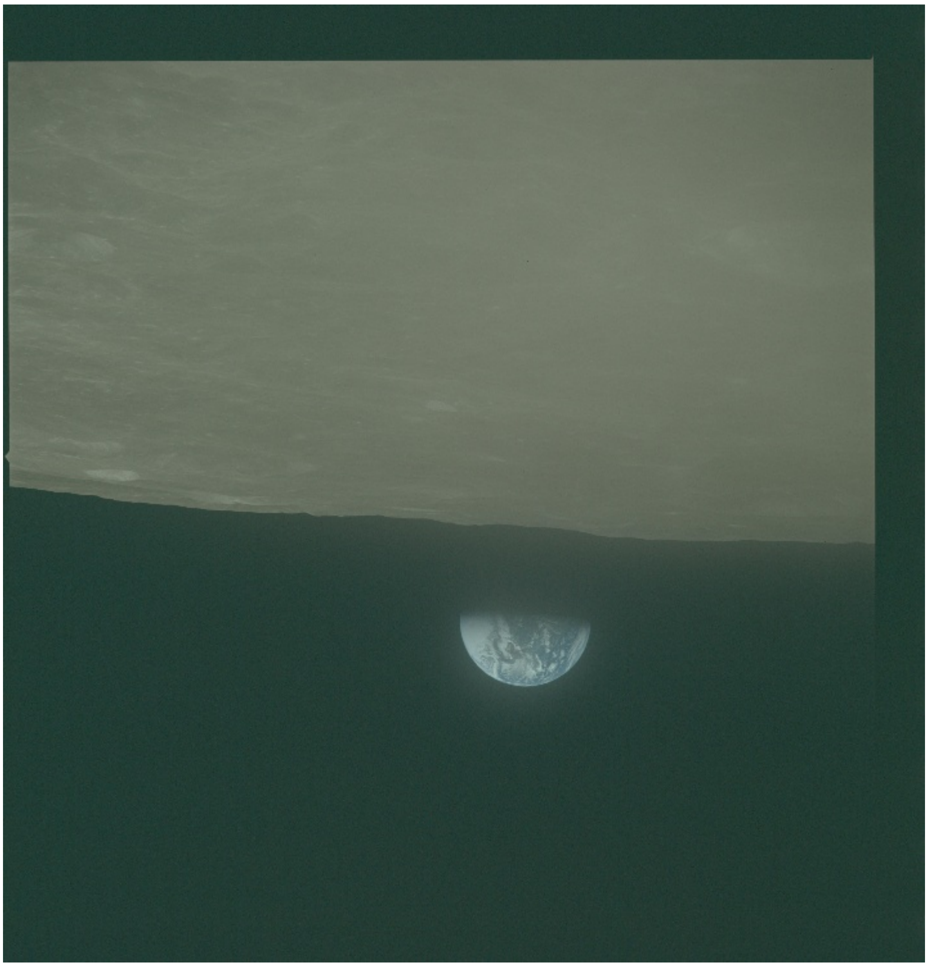
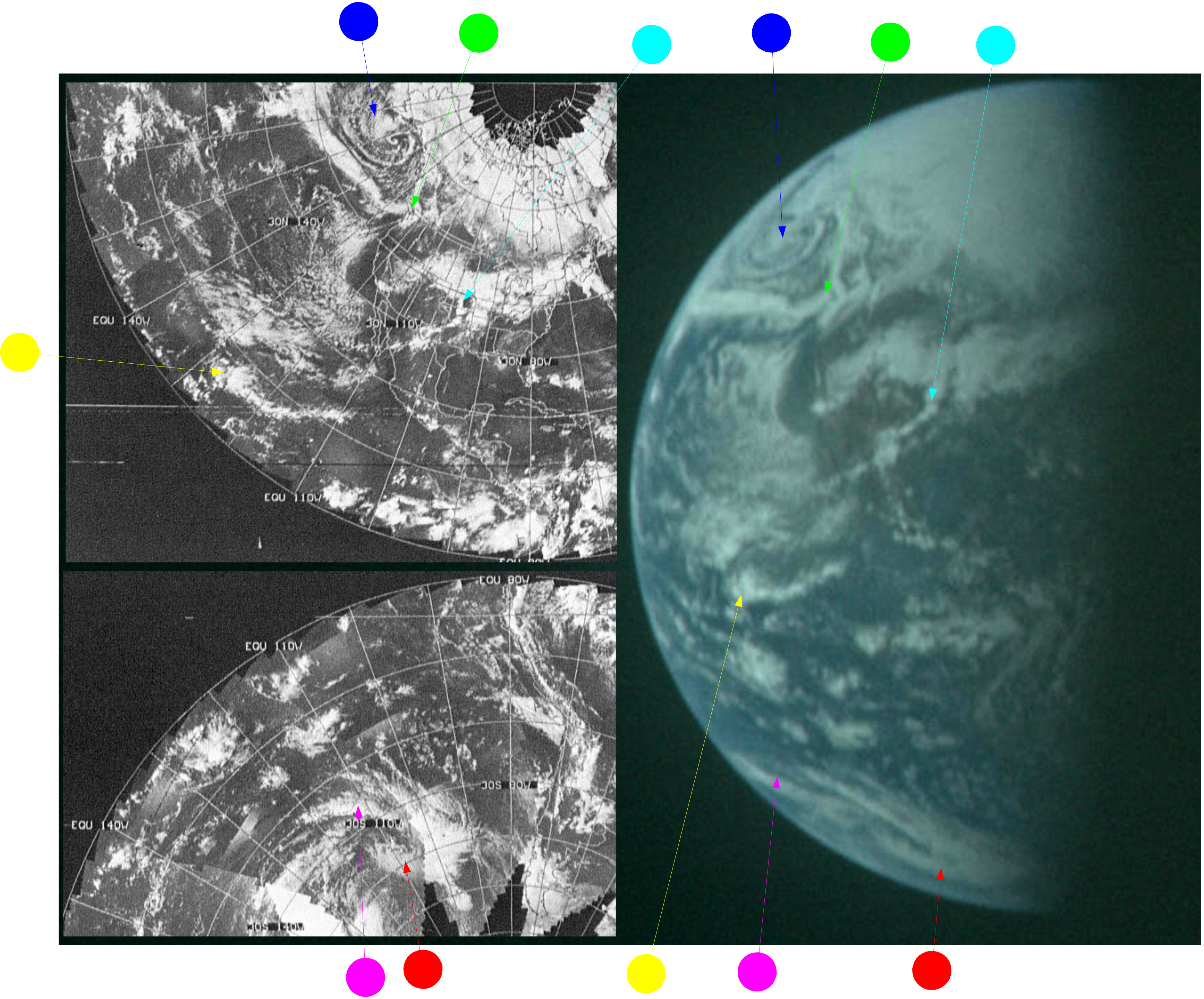


Figure 4.8.16: High resolution GAP scan of AS16-120-19187



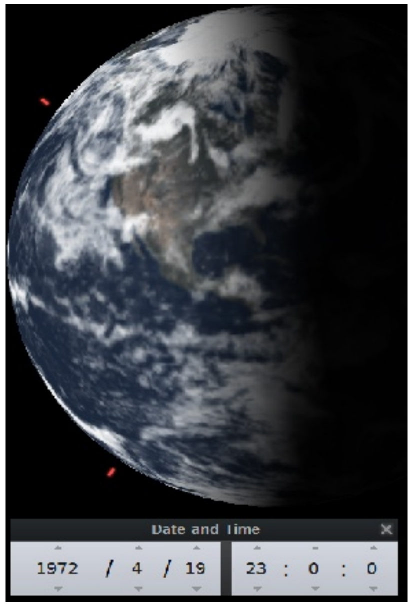


Figure 4.8.17: AS16-120-19187 compared with ESSA mosaic, and stellarium inset showing time at terminator

The Apollo photograph is a lone image of Earth on a magazine otherwise dominated by photographs of the lunar surface. It's appearance as a half illuminated disk immediately points to it being relatively early in the lunar portion of the mission.

Again this image shows north America, and again the weather patterns are considerably different to those featured on the previous day's images. A notable system is the circular 'bullseye' pattern south of Alaska that is very evident on the Apollo and ESSA pictures. The globe is rotated slightly more than in previous ones showing the same broad area, and less of south America is visible. The terminator time here shows 23:00 GMT on the 19th, and this is supported by the ESSA orbit covering north America (track 4) number 4346 commencing at 21:06.

More support for this timing comes from the mission transcript. At the beginning of their second orbit at 77 hours in to the mission (22:54 GMT on the 19th), the crew tell capcom that they have

"just got the 10000th picture of a beautiful Earthrise."

The number 10000 is an exaggeration, but AS16-120-19187 was pretty obviously that image.

The next Apollo picture to be looked at, AS16-113-18289 (source: ALSJ) is one of a series of the most spectacular Apollo images, showing the CSM on the lunar horizon as the Earth rises behind it. It is, therefore, taken from the lunar module after separation from the CSM (the first half a dozen photographs in this magazine are of the CSM immediately after separation) but before the landing. This puts a timeframe for the image of between 18:07 on the 20th, and 02:23 on the 21st.

The image is shown below in figure 4.8.18, and analysed overleaf in figure 4.8.19.

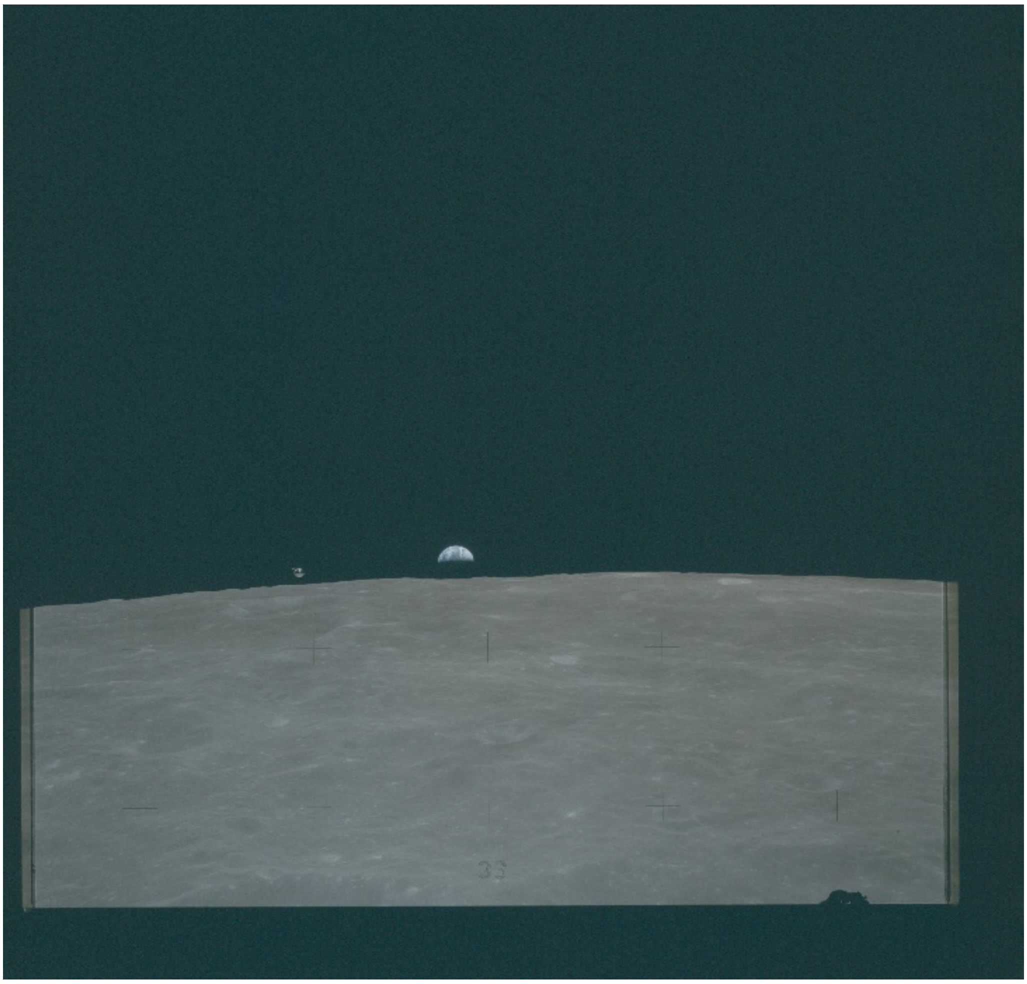


Figure 4.8.18: High resolution GAP scan of AS16-113-18289

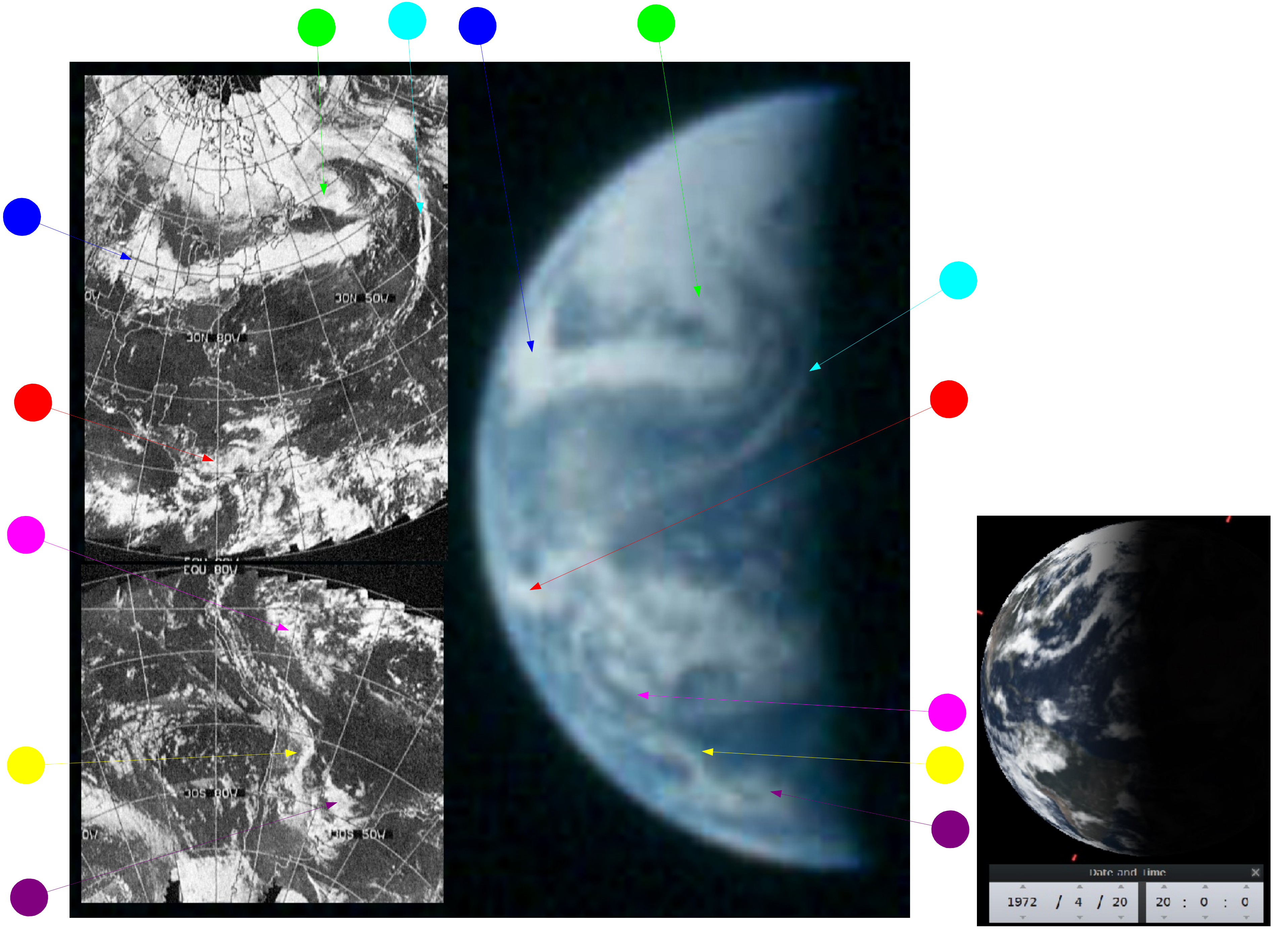


Figure 4.8.19: AS16-113-18289 compared with ESSA mosaic and stellarium inset of terminator estimate

Since the last photograph Earth has moved on again, and once again north America is the focus of the image with a different set of weather patterns, all of which match up with the satellite images taken on the same day, the 20th.

Fixing the time by Stellarium shows a time of roughly 20:00, as the US west coast is not yet visible, but most of south America is. ESSA's orbit for that time would have commenced at 20:00 (track 3, orbit 4358), so there is a perfect reason for a good match.

There is also support for this time estimate from the mission transcript. While it is not specifically mentioned, revolution 13 began at 97 hours and 48 minutes, or 19:42, with radio contact re-established with Houston about 20 minutes later. The photo index for Apollo 16 (source: ALSJ) states that this Earthrise sequence took place on revolution 12, but this is likely to be a difference in interpretation as to when orbit 12 ended and 13 started. Certainly the first image after the Earthrise sequence (of the CSM) is marked as being on orbit 13. It can't have been at the start of orbit 12, as this would have Africa in view, and very little of north America.

Only one more colour image of Earth is available. AS16-122-19564 (source: AIA) is part of a sequence of 4 over-exposed shots of a crescent Earth rising over the lunar horizon. The crescent phase already places it towards the end of the mission, and there are several photographs of the ascent component of the LM earlier on in the magazine. The remaining images in the magazine show an increasingly curved lunar horizon indicative of a post TEI photography session.

Figure 4.8.20 shows a high resolution version of this image, and figure 4.8.21 shows this crescent earth that has had the levels, brightness and contrast adjusted in comparison with the ESSA 9. Earthview has been used to provide a horizon as it shows a clearer view of the landmasses.

Figure 4.8.19: High resolution GAP scan of AS16-122-19564.

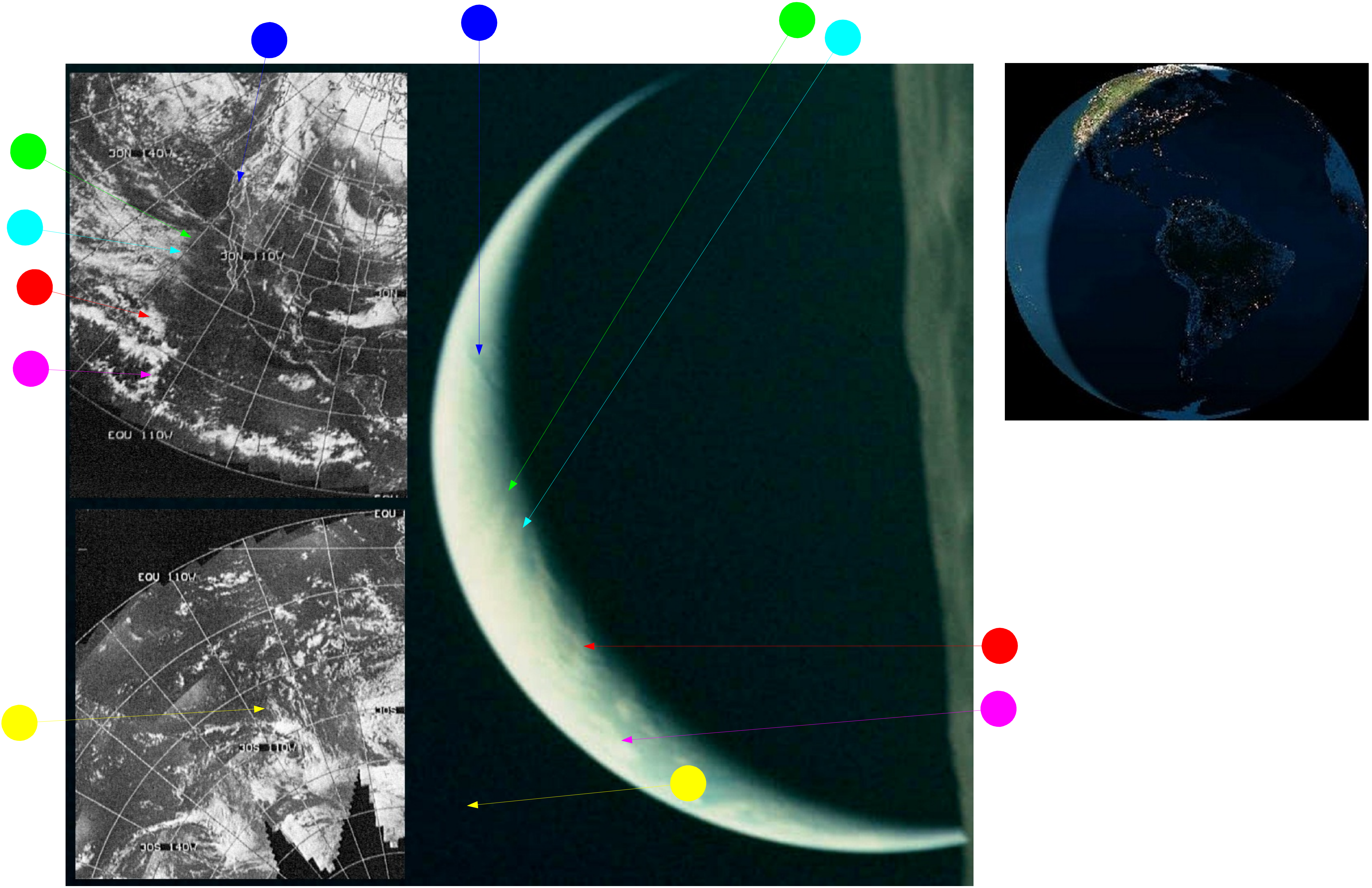


Figure 4.8.20: AS16-122-19564 compared with ESSA 9 mosaic, and an Earthview terminator set at 02:15 on 25/04/72

As with previous missions where the Earth is a thin crescent, it does become more difficult to determine exactly when it was taken, and which weather systems on the ESSA mosaic match those on the Apollo image purely on the basis of the Earth photograph.

In this case there is some documentary evidence in the mission transcript and the photo index. The latter suggests that the image was taken during TEI in the early hours of the 25th (02:15 to be precise) – something the thickness of the crescent would support. The mission transcript records a conversation with capcom at AOS after the TEI burn:

"We got some pictures of Earthrise as we were climbing out"

02:15 has therefore been used as the benchmark for the Earthview image. With this knowledge in hand, it is possible to identify the dark area of the visible crescent as the California coastline (blue arrow). This then allows what cloud systems that are visible to be placed on the ESSA mosaic.

That mosaic's best fit track around the terminator would be number 4, or orbit 4409, commenced at 22:09 on the 24th. As always with thin crescent images, it is difficult to be absolutely certain that the cloud patterns identified on the photograph are the same as those on the ESSA mosaic, but the supporting evidence of the photo index and mission transcript do help.

There are no other images available of Earth in the visible spectrum, but there are some taken in the UV spectrum in TLC.

4.8.2 UV photography in TLC

UV images were taken during TLC and can be found in magazine 131 at the AIA (Source: AIA). There are several series of UV images taken through a number of filters, but only the first three sets show anything like enough detail to give a reasonable interpretation of the cloud systems featured thereon.

The first of these three is AS16-131-2100 (source: AIA), which is seen overleaf together with the weather analysis in figure 4.8.21 and 4.8.22 respectively.

The 'entrance to inner earth' cloud system featured in figures 4.8.3 and 4.8.5 is again visible in this UV image, and the configuration of weather systems suggest it was taken at roughly the same time as the Apollo image used in the latter figure. The position of that system is more akin to that in 4.8.5, so the time must be somewhere around the early hours of April 17th.

The satellite images show the same weather patterns in the UV image as the visible spectrum one, so the conclusion that they were taken at roughly the same time seems entirely reasonable. There are also mentions in the mission transcript. At 6 hours 40 minutes, the crew get a reminder about settings for the UV camera, and at 07:19 hours in they discuss a checklist they will attend to after the photographs. Five minutes later they appear to discuss that checklist.

This would put the time at around 01:15 on the 17th, the same time as that estimated time for figure 4.8.5. This would match up with the stated intention to match UV images with at least one Apollo image for comparative purposes.

The second of the UV sets looked at will use AS16-131-20115 (Source: AIA), see figures 4.8.23 and 4.8.24, and shows the Earth as a much smaller target in the photograph.

Figure 4.8.21: AIA scan of AS16-131-2100.

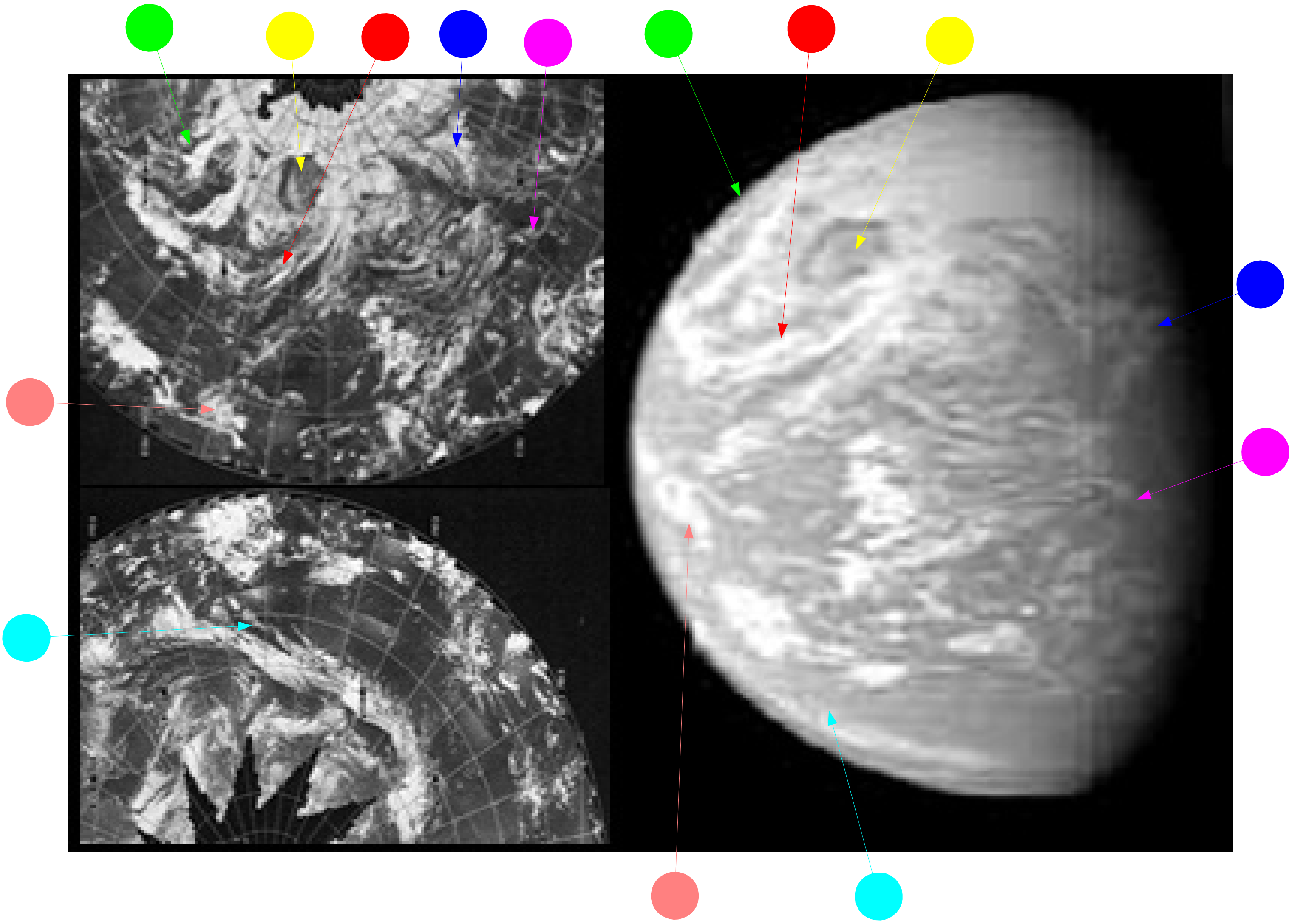
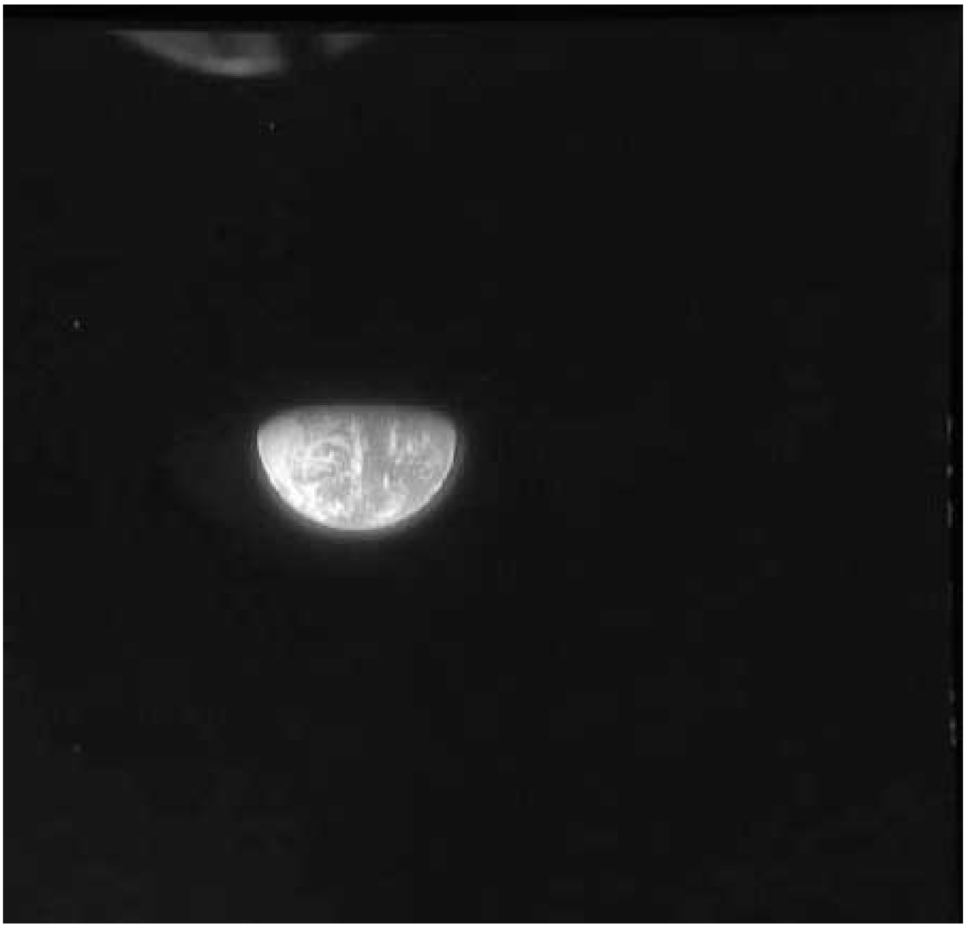


Figure 4.8.22: AS16-131-20100 compared with ESSA 9 image from April 16th. Arrows used match figure 4.8.5

Figure 4.8.23: AIA scan of AS16-131-20115



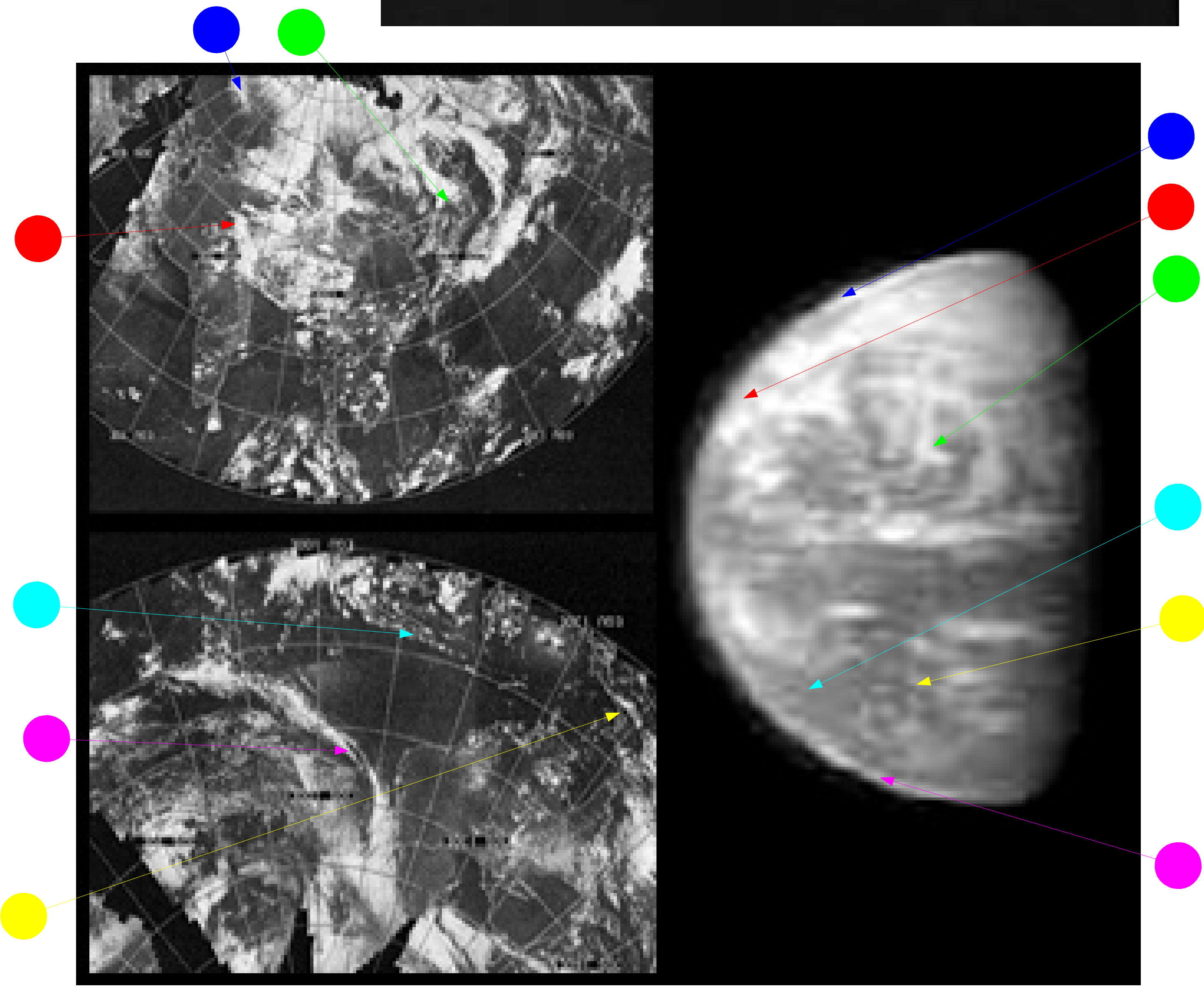


Figure 4.8.24: AS16-131-20115 compared with ESSA 9 mosaic dated April 16th – arrows used match figure 4.8.9.

The observant will already have noticed that this UV image bears a striking resemblance to figures 4.8.7 and 4.8.9, where again there is a colour photograph that can be used in comparison with the UV one. There are again references in the mission transcript at the time this image was taken.

At 11:01 capcom tell the crew that they specifically want UV images taken at the time dictated by the flight programme: 12:20 hours in to the mission, or about 06:15 GMT, and comments made at 12:22 hours suggest that the photography is progress. The position of the terminator close to Australis in figure 4.8.9 suggested a time of around 06:00 on the 17th, so there is again a good correspondence there.

The final UV image worth looking at is the third is AS16-131-20116 (source: AIA) . On the face of it there is very little detail there, but close examination does reveal that weather systems identified in figure 4.8.12.

Figure 4.8.25 shows the original image, and figure 4.8.26 overleaf the weather analysis.

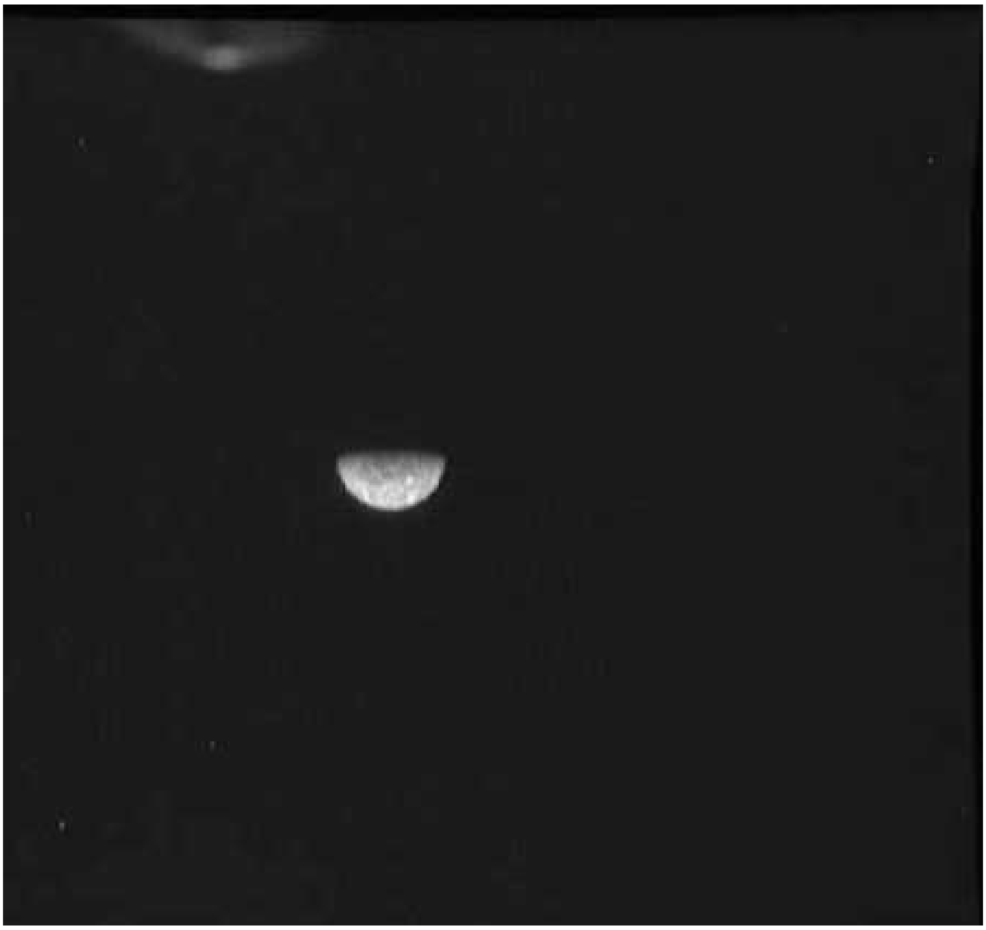


Figure 4.8.25: AIA scan of AS16-131-20116

Once the weather patterns have been pointed out, it becomes obvious that they are the same as picked out in the colour Apollo picture from April 17th. Figure 4.8.12 puts the time at the terminator as about 23:00, and the mission transcript gives just one clue that that is about the same time as this image. At 29 hours 11 minutes the crew state that they are going into the correct attitude for UV photography, and this would equate to 23:05 GMT.

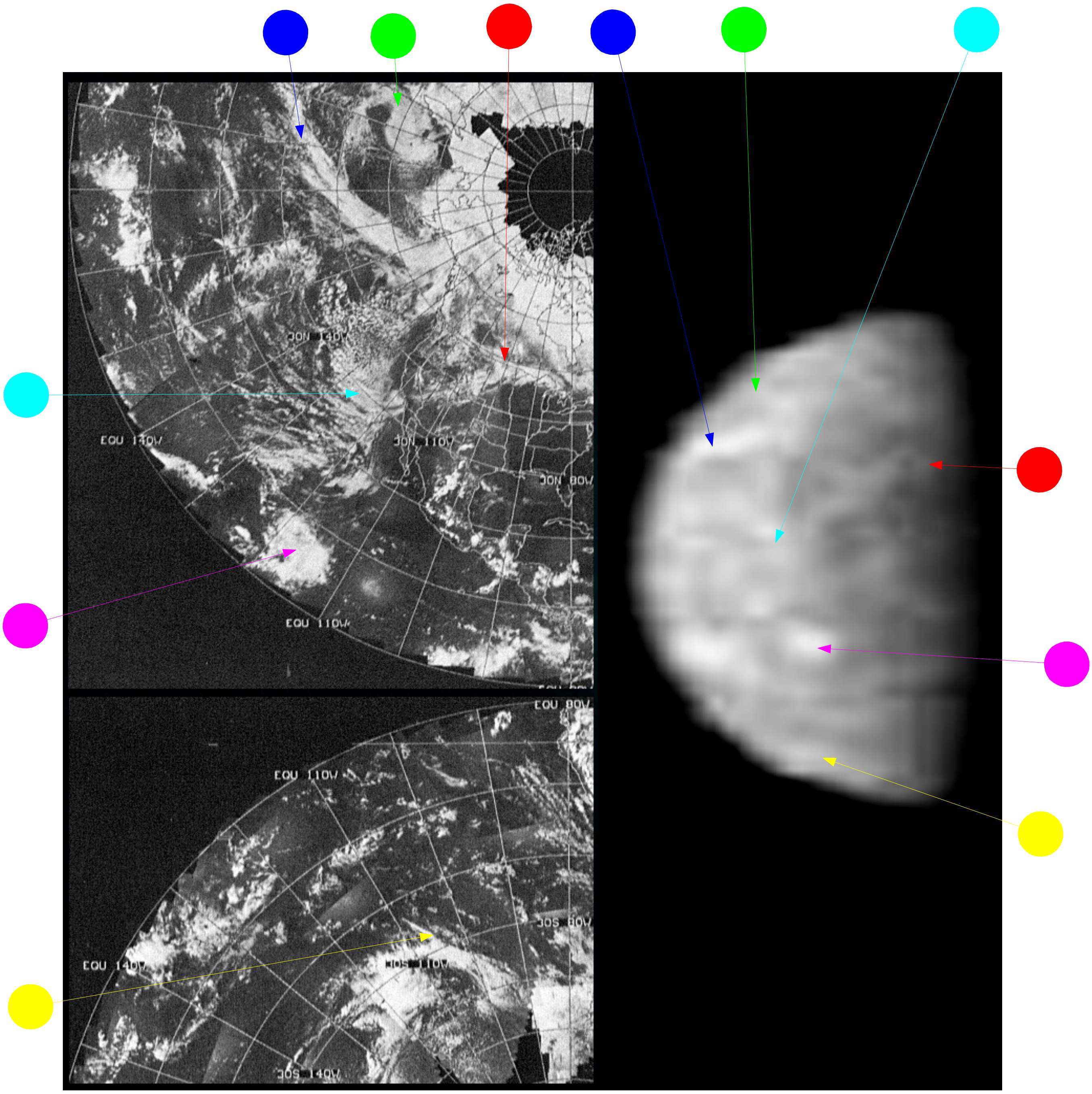


Figure 4.8.26: AS16-131-20116 compared with ESSA mosaic from 17/04/72.

The UV images are therefore consistent with both the colour photographs that were evidently taken at the same time, and with the ESSA satellite images taken on Earth some time later.

The final section will deal with any available synoptic charts and compare those with the Apollo photographs.

4.8.3 Meteorological analyses.

As with previous missions, the main sources of information for synoptic charts is the German and South African data held at NOAA, and the daily charts also held by NOAA. However, none of the Apollo images feature Africa, so only the German and NOAA daily charts can be used. The lack of Earth images available, means that only 5 days are available.

Launch day is the first for which charts are available, and figure 5.8.27 shows the weather charts in conjunction with AS16-118-18885.

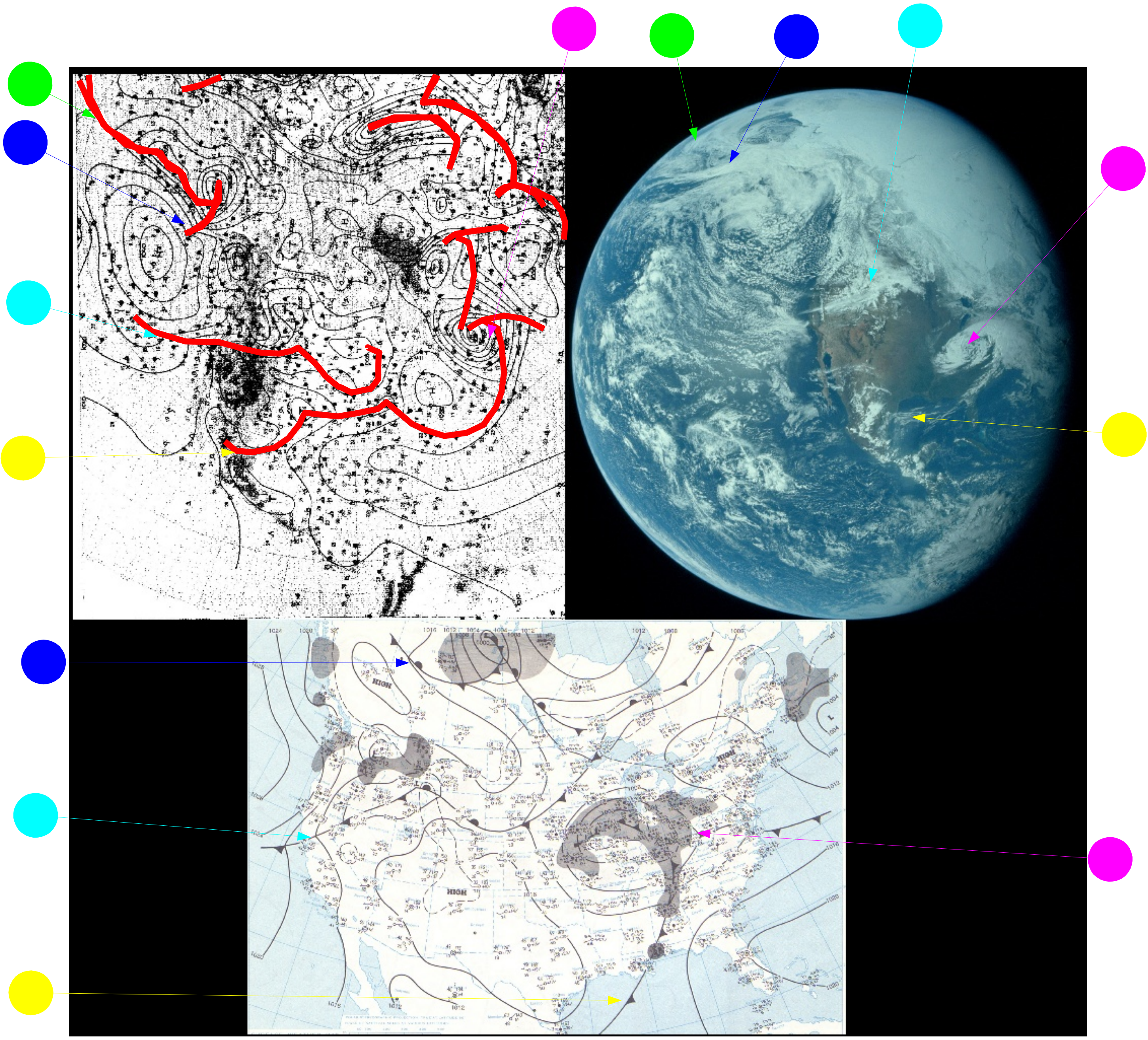


Figure 4.8.27: German (top left) and NOAA (bottom) synoptic charts for April 16 1972 compared with AS16-118-18885

Time differences between the charts, and differences in interpretation of the meteorological data from which the charts are derived account for the differences between them, but the broad patterns are consistent: the complex low towards Alaska, and two broad frontal areas acting as boundaries for the USA, leaving the continent largely clear, other than the complex system towards the east coast.

The second day's charts cover April 17th (see overleaf in figure 4.8.28). In this image, showing much less of the globe overall thanks to the change in relative position of the Apollo craft, compares the synoptic data with AS16-118-18890.

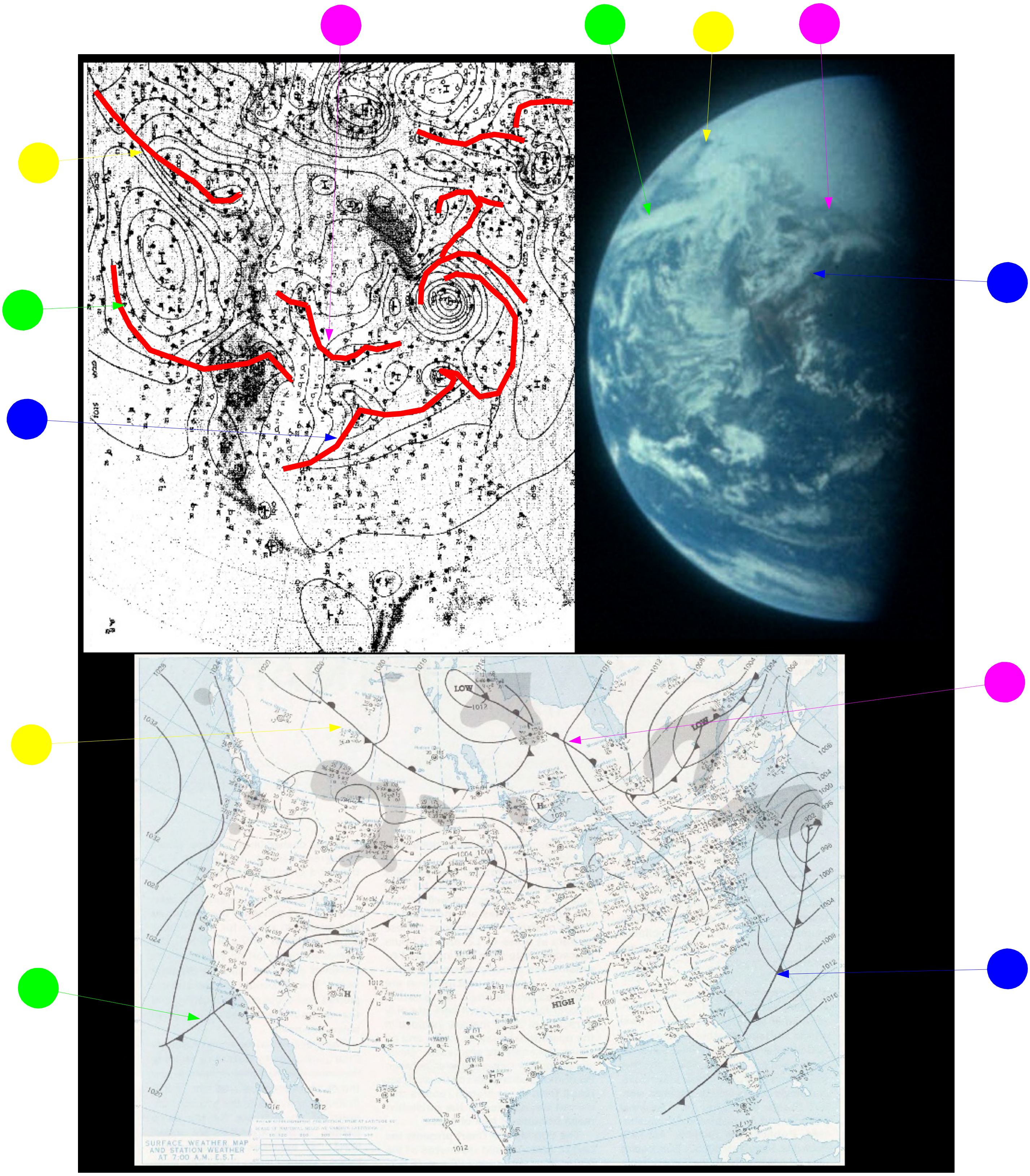


Figure 4.8.28: German (top left) and NOAA (bottom) synoptic charts for April 17 1972 compared with AS16-118-18885.

The frontal systems here are relatively straightforward, although whether the yellow arrowed system on the NOAA charts is just a continuation of the one identified in magenta is one for debate. Either way there is a system in blue across the south east, green starting out in the Pacific, and the magenta one across Canada. All of these also appear on the Apollo image.

The next day's image is covered by AS16-118-18891, and is examined overleaf in figure 4.8.29.

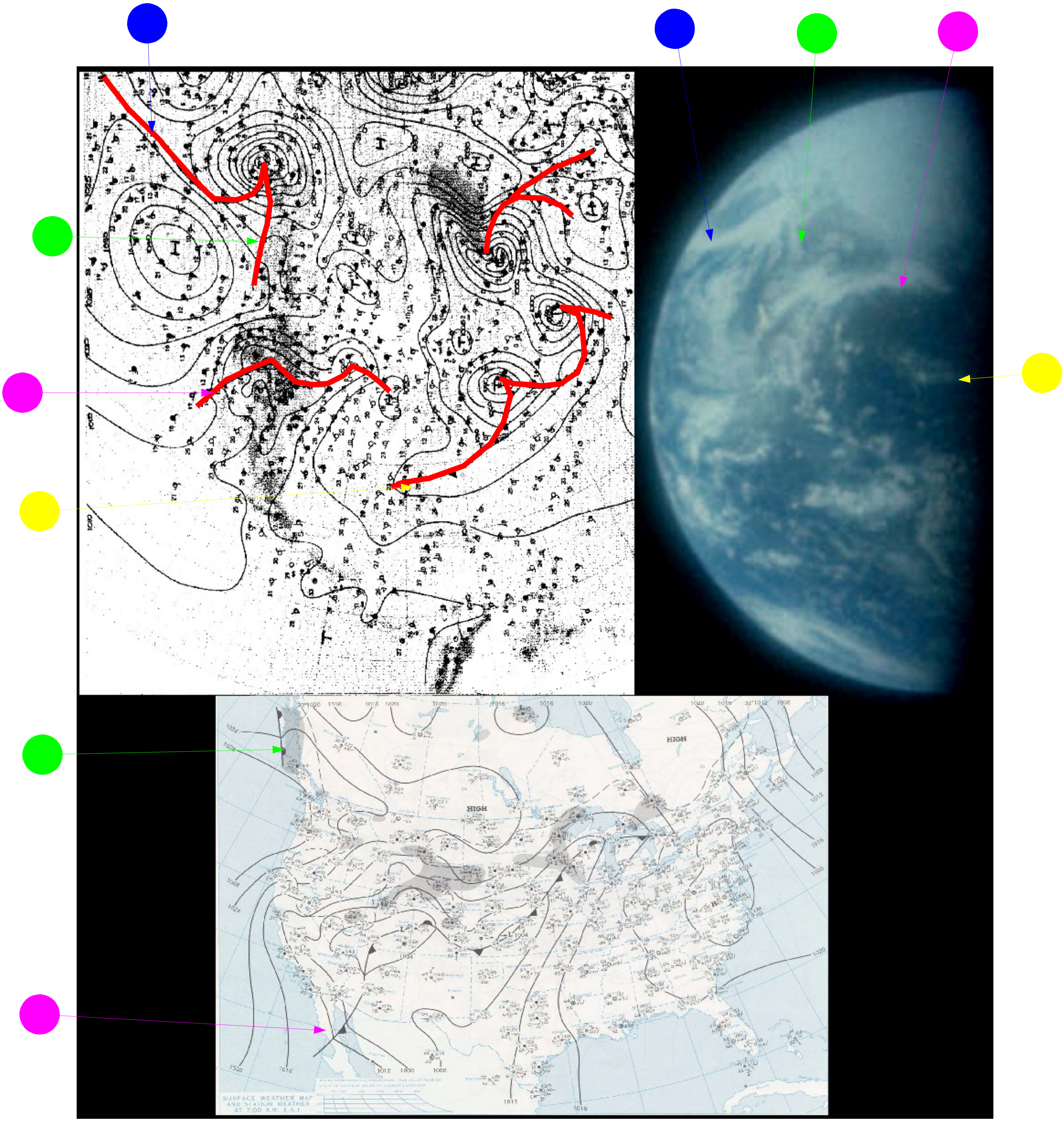


Figure 4.8.29: German (top left) and NOAA (bottom) synoptic charts from April 18 1972 compared with AS16-118-18891

Sadly the main feature of the weather on the 18th, the 'monster' storm featured in the MWL doesn't show on the NOAA chart, but the yellow arrow indicates the tail end of it on the German and Apollo parts of the figure.

The magenta arrowed front is the one crossing the USA in the Apollo image.

The charts from the 19th are compared overleaf in figure 4.8.30 with AS16-120-19187.

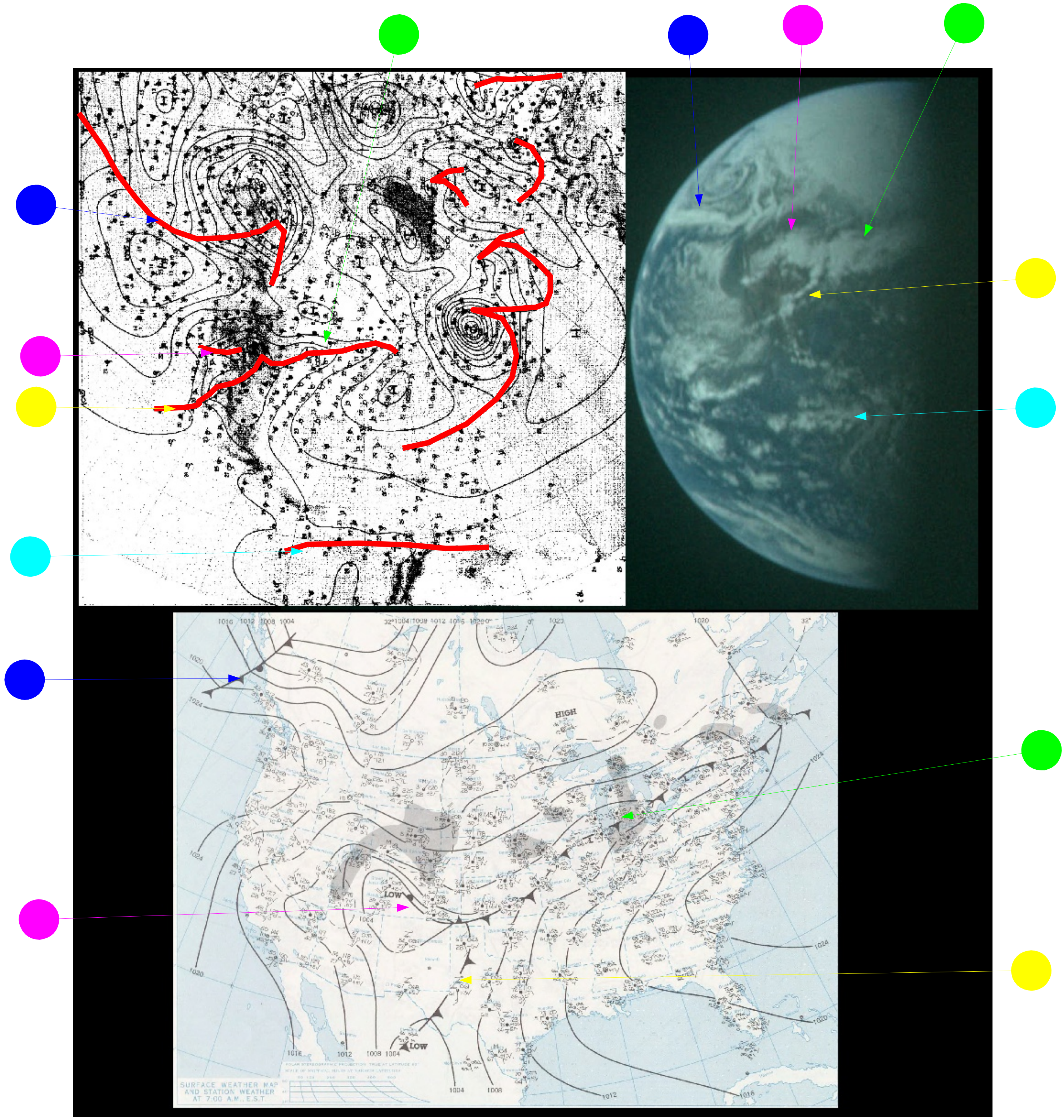


Figure 4.8.30: German (top left) and NOAA (bottom) synoptic charts from April 19 1971 compared with AS16-120-19187. Cyan arrow shows the ITCZ.

The main feature evident here is the front crossing the USA, with an offshoot to the south, that is covered by 3 different coloured arrows, and this is easy to identify on all 3 of the composite parts of the figure above.

The final day's synoptic chart analysis is for April 20th, and uses AS16-113-18269. This is shown in figure 4.8.31 overleaf.

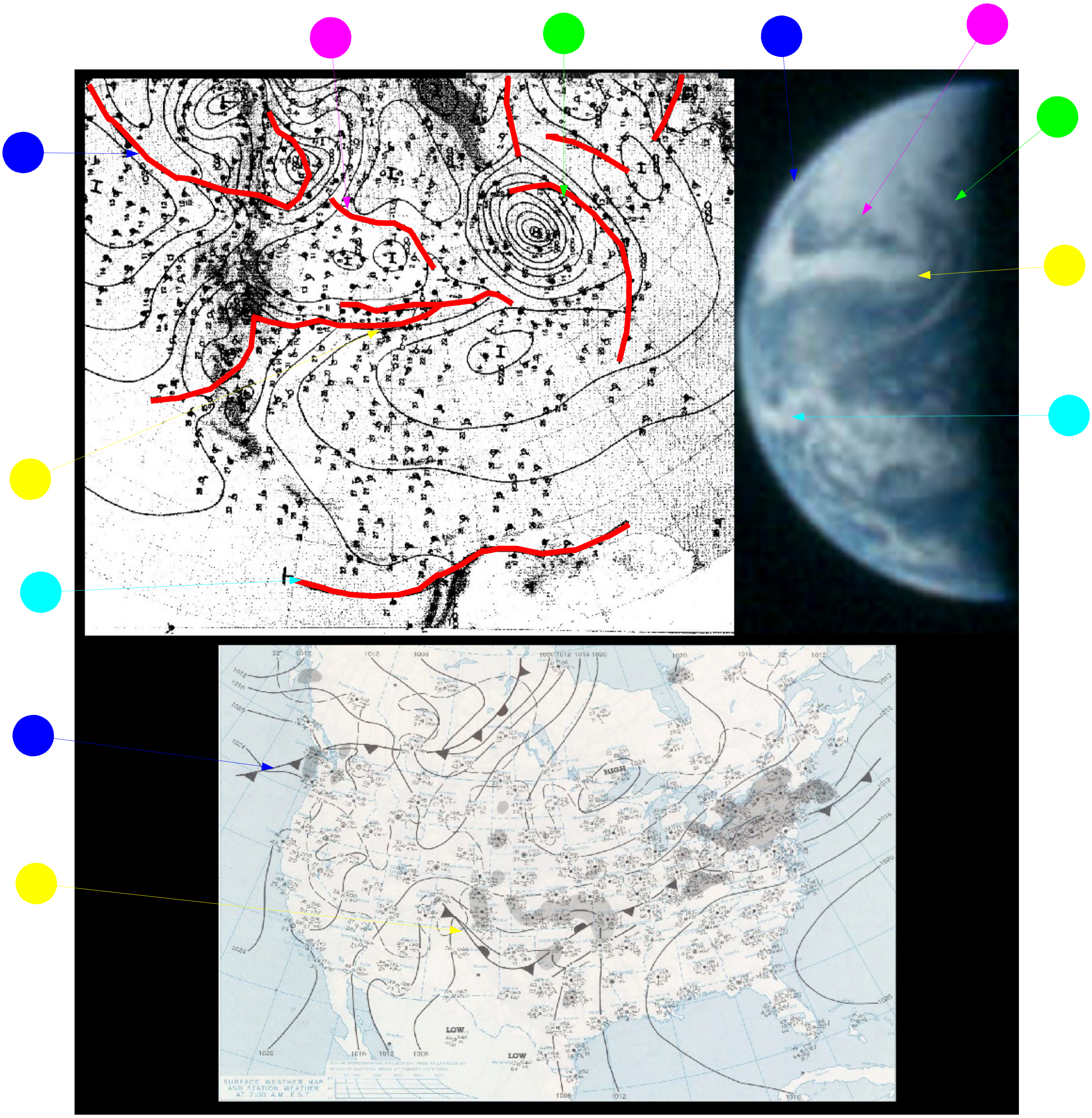


Figure 4.8.31: German (top left) and NOAA (bottom) synoptic charts from April 20 1972 compared with AS16-113-18269. Cyan represents the ITCZ

Again, there may be differences in interpretation between meteorologists, but there is a broad consensus that coincides with the features shown by the Apollo image.

Another mission where the Apollo images, satellite photographs, video screenshots and synoptic charts all tell a consistent story: the photographs were token in space on the way to and back from the Moon.

4.9 Apollo 17

Apollo 17 was launched at 05:33 on 07/12/72, the only night launch of the Apollo series. It performed LOI at 19:47 on the 10th. The last two astronauts to walk on the lunar surface, Gene Cernan (who also took part in Apollo 10's rehearsal mission) and Jack Schmitt (the only scientist to walk on the moon) landed at 19:55 on the 11th. The lunar surface was departed for the final time at 22:55 on the 14th , and the crew finally landed back on Earth on the 19th. The timeline for the mission can be found here: NASA timeline.

During the journey, and the three EVAs of the lunar landing, 23 magazines of film exposed 3584 photographs, the majority of these being sequences on board the LRV used in exploring the surface. The majority of the images are available in high quality at the AIA and/or ALSJ sites, but some have had to be requested from GAP. Archive.org also contains some high resolution scans of the more famous images. Video footage will also be used, and referenced as appropriate.

There is a change in satellite for this mission, with NOAA 2 being the main source of information. The meteorological data catalogue for the mission can be found here hathitrust source. This satellite provides images in the visible and infra-red (IR) spectra. Visible spectrum, images will be preferred, but IR images will be used where necessary and/or appropriate. The data catalogue for this satellite is also interesting in that it does not give timings of orbits. Instead, it gives the time in GMT on longitude lines. The satellite day is still run from around the east coast of Africa onwards , and therefore it is assumed that the weather patterns to the east of this line as far as the west coast of the Americas will be dated the day after the date of the image.

Surprisingly, despite there are very few other sources for satellite data for this mission, despite other countries launching their own missions.

NIMBUS 5 data became available only after the mission finished, and other satellites do not have a comprehensive data catalogue. As usual, however, there are other individual sources that may prove useful, and at least demonstrate (again) that the satellite images were readily available.

Satellite activities of NOAA 1972, for example, contains images from December 7th, 11th and 18th, all covering small areas of the north-east of north America, but none of which would prove of any use. This Journal of Applied Meteorology article has a NIMBUS 5 image of the US east coast down to Florida from December 13th, but again there was no opportunity to use it. NIMBUS 5 was launched on the 11th of December and early images were tests, but the data catalogue for it does not start until the 19th. The MWL provides, as ever, useful images of a tropical storm (Therese) on the 7th, which occupied the north Pacific for the first half of the mission, and also of Tropical Storm Violet on the 13th.

Therese can also be seen on December 6th in a couple of places, notably the MSL and the Annual Typhoon Report, and while these are from before the launch, they are interesting in that they come from the DAPP satellite.

One ESSA image has been found, thanks to an Army veterans' site covering life on Midway Island. The ESSA 8 image is clearly identified as being from December 11th 1972, but no other details are available – the image was sent to the website for posting, and the site owner has no further details about it.

4.9.1 Mission images

The general procedures for any Apollo launch are the same: launch, orbit, TLI, LM extraction. The LM's extraction and docking with the CSM was usually film, and sometimes as part of that filming other shots were recorded. One such shot is given in this recording from Apollo 17: Youtube (this can also be found as a real media file on the Apollo Archive multimedia section). The footage features the camera rolling over the Earth's surface before it goes on to focus on the SIV-B and it's cargo. Separation has only just occurred, as indicated by the numerous small pieces of debris. The timeline suggests that this is part of a TV broadcast.

By taking several screenshots from this footage, it is possible to see, if not a complete disk, at least a full north to south pan. This pan can be seen in figure 4.9.1, together with a satellite image taken on the the same day as the launch.

Before looking at the weather patterns there, it's worth looking at the quality of the images themselves. The lower frame of the Earth image created from the video screenshots is considerably darker than the other three, and this is probably a result of the camera adjusting to the light conditions. Despite the difference, the video as a whole is still a single piece of unedited footage.

The globe is completely lit, which is what would be expected from 09:15 GMT – the separation time for the SIV-B.

The second initial observation is that the NOAA image has evidently suffered some of the image stability issues discussed in preceding sections, particularly off the west African coast. This problem unfortunately obscures an extremely prominent cloud just off South Africa.

The weather system to the east of the system identified by the cyan arrow also looks to have had problems with data interpretation from the satellite image. Lines can be made out running up through southern Africa, and the angle of some of the clouds is not consistent with the overall pattern. Some of the clouds off the eastern South Africa coast, for example, seem to belong to the outer edges of the large sub-Antarctic whorl of cloud. While the cloud identified by the blue arrow has a position consistent with that in the satellite image (ie it extends from the southern Cape to a position south of Madagascar, it is partially obscured by erroneous data from elsewhere.

Despite the quality issues in the satellite image, there are still obvious features that occur in the Apollo video and in the satellite image.

The large whorl of cloud south west of the Cape is very evident, as is the finger of cloud extending from the Antarctic near the coast of South America. The broken clouds across all of southern Africa show the same distribution on both images, as does the small area of localised cloud north of Madagascar.

The time of the Apollo video has already been established at around 09:15, and NOAA's image is recorded as being 06:48 GMT for the east cost of Africa, and 10:48 for the mid-Atlantic.

Next up for analysis is one of the most iconic Apollo images. Actually part of a sequence of Earth photographs, the so called 'Blue Marble' image has been reproduced many times. Students of a certain age undertaking geography studies will remember being asked to identify the various weather system components on the image as part of exam questions.

Apart from the fact that it is of stunning quality, it also shows the Antarctic region in much more detail than is the norm for Apollo photographs, thanks to the trajectory the CSM was given. The

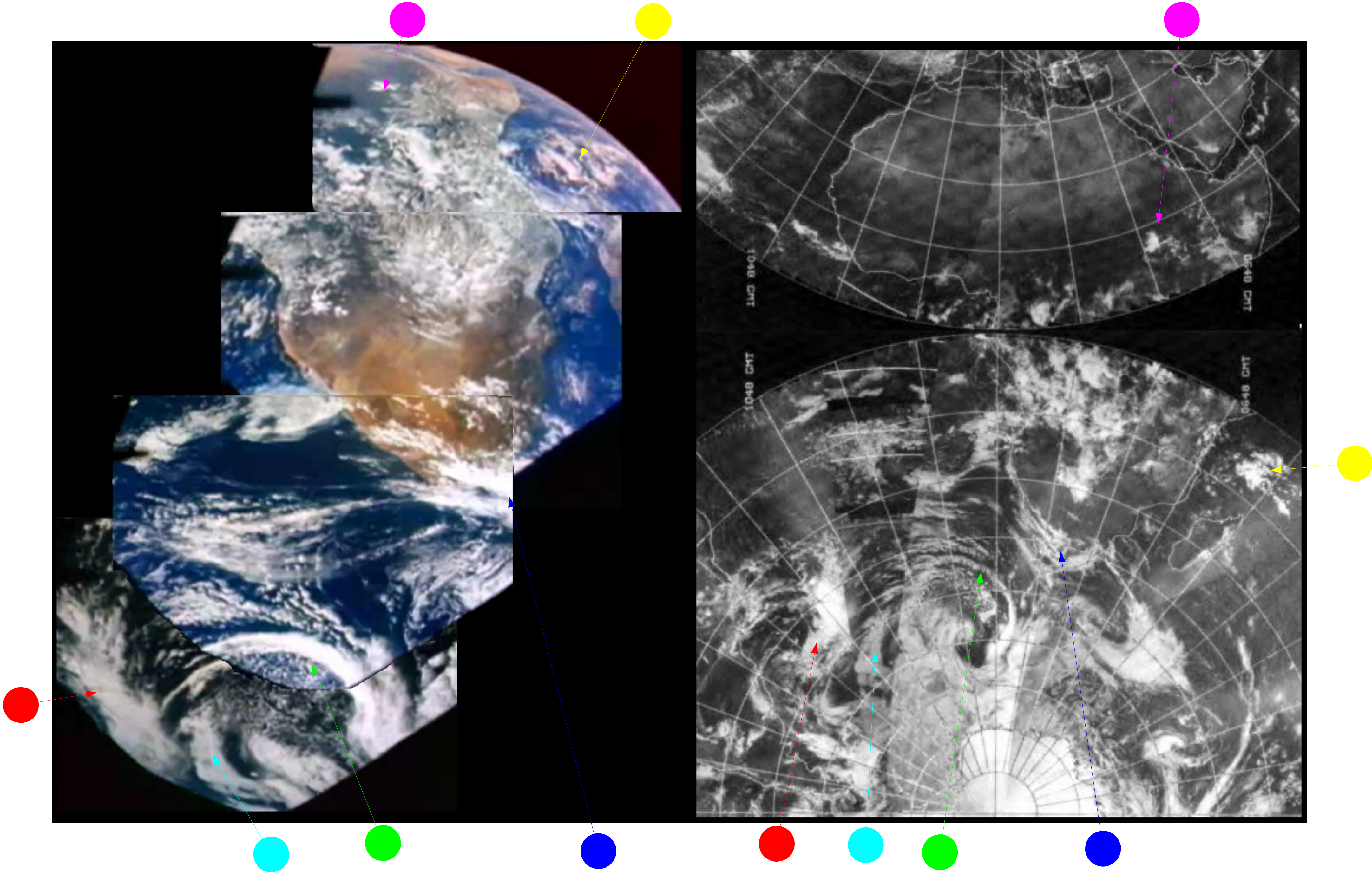


Figure 4.9.1: Screenshots of a TV broadcast from Apollo 17 compared with December 7th NOAA 2 mosaics

Antarctic is also not a region shown in any great detail on any satellite images – at least not those used in this research, thanks to either the orientation of the geostationary satellites or the techniques used in assembling the geosynchronous mosaics.

Of the many versions of the photograph that could have been chosen, the one used here is AS17-148-22725 (figure 4.9.2). This is the first image on that magazine to feature a full disk Earth, and appears after several images showing the LM extraction and docking procedure. The photograph immediately preceding it is of the discarded SIV-B drifting towards its eventual destination of the lunar surface.

Figure 4.9.2: AS17-148-22725 (Source: AIA)

Once correctly oriented, it is very easy to make out the same African continent visible in the video sequence used for figure 4.9.1, and also the same weather systems from that video given a wider context without the limitations imposed by the CSM window frame. Figure 4.9.3 shows the comparison between the Apollo image and the NOAA2 satellite images.

Of the cloud systems picked out, one is worth mentioning in particular as it is often referred to in articles about this image, and that is the compact swirl of cloud over southern India, identified by the cyan arrow. This swirl is in fact a cyclone that started on the 1st of December and lasted until the 8th, causing 80 deaths and considerable damage in the state Tamil Nadu.

The time frame for the NOAA image is obviously still the same, and while there is no terminator visible we can estimate the time based on what is visible. Stellarium's view of the Earth at 10:45 GMT seems reasonable and is consistent with the timeline, as by this time the LM docking procedure was complete and the SIV-B disposed of.

Another comparison possible is of the two Apollo images. The two are taken around 90 minutes apart, and if the viewpoint was from a stationary point above the Earth there would be no change in

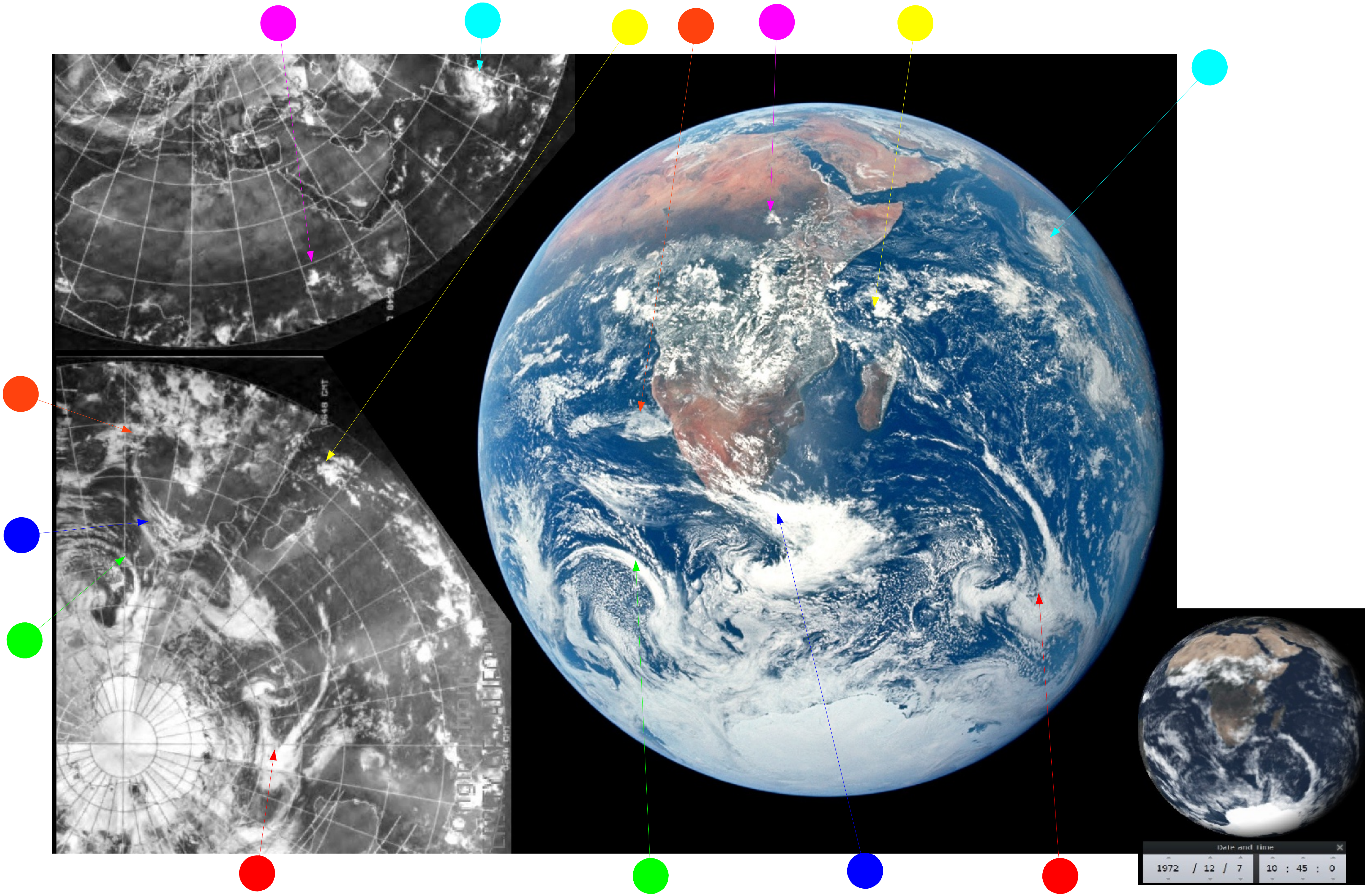


Figure 4.9.3: AS17-148-22725 compared with NOAA2 satellite mosaics from 07/12/72. Blue, green, magenta and yellow arrows are as in figure 4.9.1

the landmass visible. If it was from a geosynchronous orbit, more of the south American continent would be visible as these go against the rotation of the planet. Instead (this is more obvious in the full size stills), we have more of Asia visible in the later still photograph, which indicates a movement both with and faster than the rotation of the Earth as it travels away from it – launches were in fact arranged that way to capitalise on the momentum this rotation gave the Saturn V.

In comparing this Apollo image with NOAA's mosaic the image chosen has been that dated the 7th of December. However, the bulk of the Apollo image shows land and ocean that would actually have been imaged on the mosaic dated the 6th.

With this in mind, figure 4.9.4 above shows a section of southern Africa from the mosaics dated the 6th and 7th compared with the same sections of the post-launch stills.

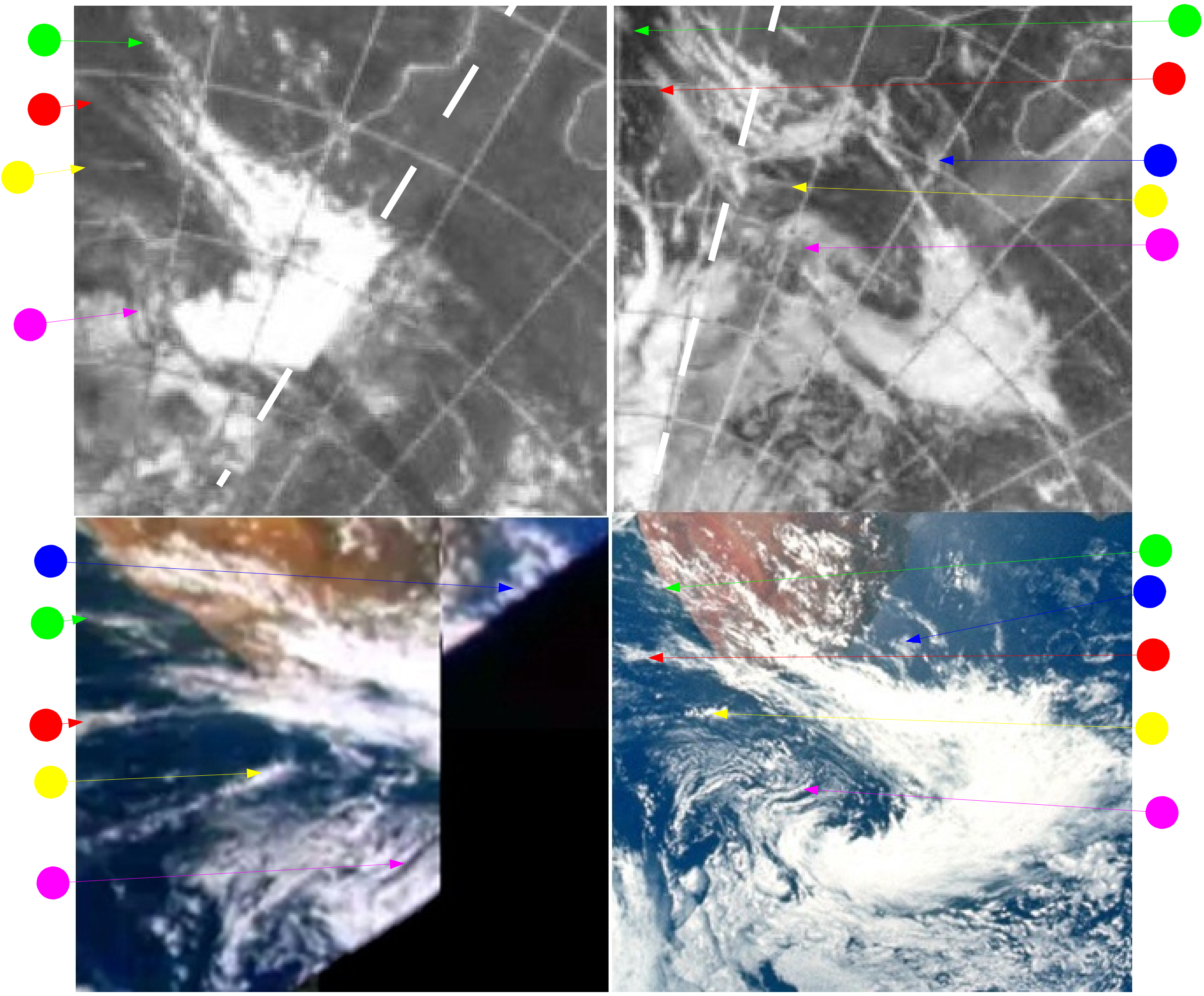


Figure. 4.9.4: NOAA image dated 06/12/72 (top left) and 07/12/72 (top right) compared with video screenshots (bottom left) and a section of AS17-148-22725 (bottom right). White dashed line superimposed by the author to show overlap between days..

As far as the weather systems are concerned, they are clearly the same overall, but as with other examples in other sections, there are subtle differences accounted for by the time gap between them and not accounted for by the slight difference in perspective. The blue arrowed clouds are further east in the later picture, as is the green arrowed one, which has also merged with an onshore cloud mass. The red arrow points to clouds that have also joined another, more easterly, cloud mass later on. The yellow arrowed clouds have apparently moved little but the clouds either side of them have changed their relative positions. The magenta arrows pick out adjacent strips of cloud that have closed the gap between them.

In going over this small area in fine detail then, it is possible to find many differences that demonstrate that they are not simply the same photograph treated. It should also be obvious that they do not match exactly the satellite images. The key point here is the comparison with the clouds as they appear over (and to the west of) South Africa, which are imaged at the start of the satellite's day, and those to the east of South Africa, which were imaged nearly 24 hours later. Despite issues with data quality for the 7th, it should be obvious that the cloud mass over the Cape bears a much better resemblance to the NOAA image from the 7th rather than the 6th.

East of the Cape and it starts to become more difficult. A closer look at the full size image shows that the edge of the large white cloud mass ends more or less on a line of longitude just east of Madagascar, while on the image dated the 7th it ends much further to the east. The blue arrow is relatively easy to place, but the yellow and magenta ones are much trickier to locate precisely. It is suggested here that the dashed lines on the NOAA2 images, drawn to coincide with changes in contrast, are lines that delineate the different day's images.

Does this mean the satellite images aren't genuine? No, they are as good as they can be given the technology of the time they were produced, and anyone who denies that the clouds you can see in them aren't reflected in the Apollo images needs their lenses checking, they clearly are the same. Does this prove that the Apollo images aren't genuine? No, but it does make it more difficult for people to claim that they are simply faked directly from satellite photographs!

Perhaps the best possible confirmations of the weather from space come from the astronauts themselves. The crew (usually Jack Schmitt) give possibly the longest sequence of descriptions of the Earth's appearance of all the missions, with only the occasional interruption from capcom with mission related technical information. The conversation starts at 10:48 GMT:

"You've got a pretty good size storm over the north - I guess it's the northwestern coast of India, where it starts to wrap up and around to the west. It's a - rounded out on the horizon, so I can't make out exactly where it is too well."

This is evidently the tropical storm discussed earlier. A few minutes later at 10:51 GMT, there is this contribution:

"Antarctica is what I would call effectively just a solid white cap down on the - South Pole. There's a definite contact between the continent and the water. But, as Ron said, most of the clouds seem to be very artistic, very picturesque - some in clockwise rotating fashion but appear to be very thin where you can, for the most part, kind of see through those clouds to the blue water below."

"The continent - the continent itself is - is the same colour as the clouds; but, of course, more dense - and striking difference than any of the other white background because you can definitely see that contact with the water and with the clouds over the water."

And again a few moments later:

"We've got a - I guess probably the continent of Africa dominates the world view right now. It's covering the - oh the upper third - upper and western third of the - of the world. We can see the Sinai; we can see up into the Mediterranean; we can see across the Mediterranean, although we

can't make out the countries up there, we can see across into India. I catch a glimpse of Australia out in the far horizon. Got Zanzibar on the southern tip of Africa, the Cape down there just almost directly below us. And, I don't know exactly how big Antarctica is, but I guess we can certainly see more than 50% of it. And - the rest of it is all ocean. The Indian Ocean out into the Pacific Ocean and back into the Atlantic Ocean. And for the most part relatively clear of clouds except in the Antarctica region, and up towards Europe which is - which is on the horizon, across the Mediterranean, it looks like there might be some clouds back up in that way. I probably - probably - well, not probably - I can make out the entire coast of Africa from Mediterranean around to the west, coming back to the south back where it takes its big dip to the east, back around the cape, back around the Suez Canal, almost perfectly."

"And there's one batch of clouds in northern Africa, just a small batch, it looks like it may be up near the - well, no, it's not near the mouth of the Nile; it's quite a bit west of that, as a matter of fact, I can see the mouth of the Nile; I can see it running straight down towards us as it parallels the Suez and then sort of fades out into the central darker brown of darker green portions of Africa."

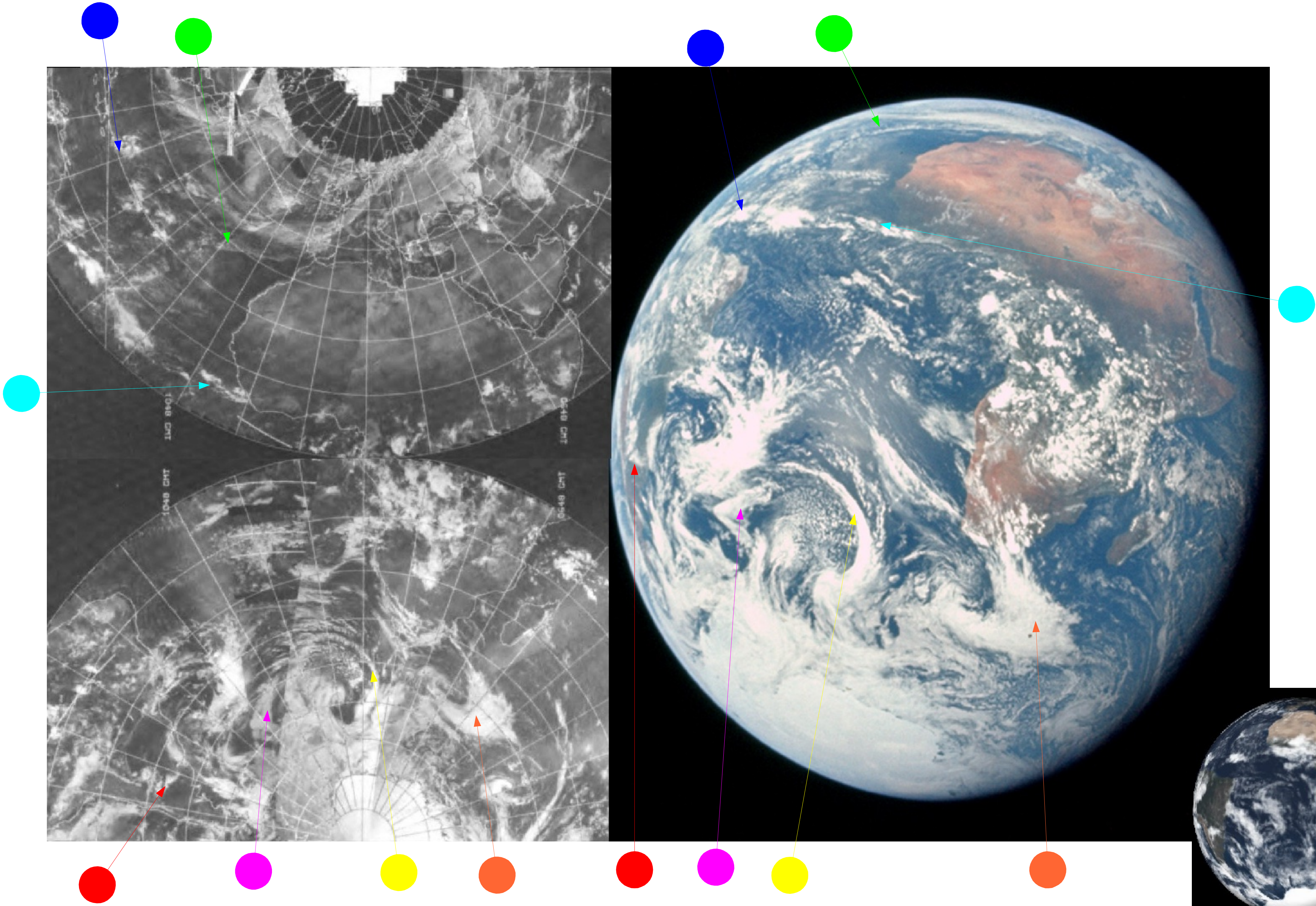
At 11:02 Schmitt takes over the commentary:

"it must be an awful clear day for the so-called convergence zone across Africa...most of Africa is clear. Only some - probably are broken and scattered clouds - cumulus in the east central portion that are running along the line of north/south lines. Looks like a major circulation system off the southern tip of Africa...plus one [east] of that, 20 or 30 degrees of longitude...and southwest of the tip of South Africa at the Cape Good Hope, there looks to be an incipient circulation system developing about half way between the coast of Antarctica and Africa."

There are another couple of pages of this, including confirmation they had been taking photographs of the view, and it should be evident that they are describing what is in the photograph, and that there is no way they would have known this other than seeing if for themselves, as the satellite evidence would be unavailable for several hours yet.

The next image is again part of the long sequence of photographs of a receding Earth. AS17-148-22736 can be seen below in figure 4.9.5, and the satellite analysis on the next page in figure 4.9.6.

Figure 4.9.5: AS17-148-22736
Source: http://www.lpi.usra.edu/resources/apollo/images/print/AS17/148/22736.jpg



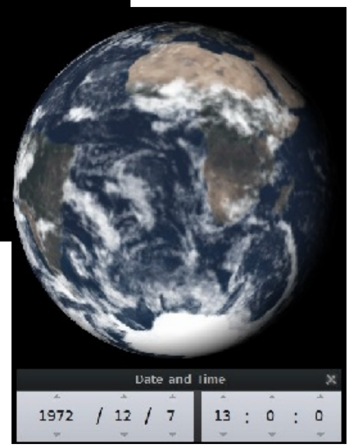


Figure 4.9.6: AS17-148-22736 compared with NOAA2 satellite mosaic dated 07/12/72 with stellarium inset of time at terminator

On the face of it the Apollo image is little different to the previous figure analysed, but there are some interesting points to be made. Firstly, the weather system discussed in much detail in preceding pages (identified by the orange arrow) has moved further eastward and is much more in line with the location given on the satellite image than the earlier Apollo photograph.

Secondly, the Earth is now less than a full disk – night is just beginning to fall across Arabia, and the estimate from Stellarium for the terminator is about 13:00.

The large reduction in the amount of Earth visible in such a relatively short time is explained by the third item of significance. During the conversation describing the Earth's weather systems described earlier, capcom relay a piece of information about the crew's trajectory, saying at 10:59 GMT:

"...shortly you're going to start heading backwards on the Earth here and head back across the Atlantic. That ought to be some sort of a first. You cross the Atlantic twice, going from west to east, and the, now you're going to cross it going from east to west"

So, having started with a path that sped them with the Earth's rotation they now start moving (in relative terms given they are now 20000 miles out) against the rotation.

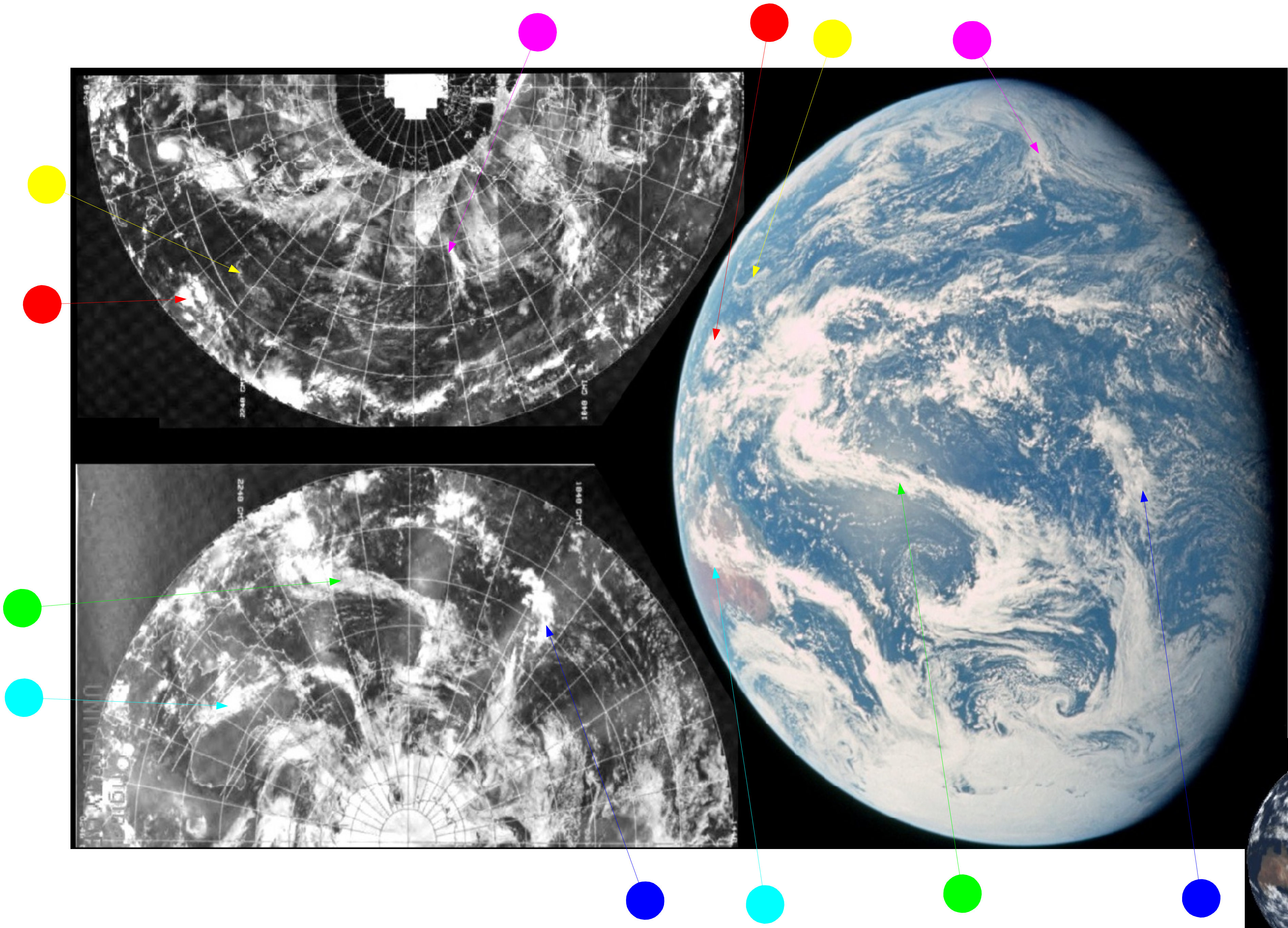
We already know that the ESSA time over Africa would be early morning on the 7th, and the timing of the Apollo photograph is confirmed by the Schmitt at 7h57m in to the mission (around 13:30) while confirming numbers on the camera magazines, stating that:

"...I just took another set of Earth pictures"

We therefore have another example of photographs that are consistent not only with the weather patterns described by the crew, consistent with satellite images taken at the same time, and also that show a consistency with the mission flight path.

The next photograph in the sequence is taken some time after this one, as it shows the Pacific and Australia. Figure 4.9.7 shows the Apollo photograph, and figure 4.9.8 the satellite analysis.

Figure 4.97: AS17-148-22737
Source: http://www.lpi.usra.edu/resources/apollo/images/print/AS17/148/22737.jpg



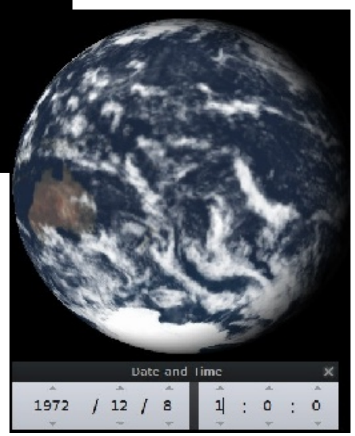


Figure 4.9.8: AS17-148-22737 compared with NOAA 2 satellite mosaic dated 07/12/72 and Stellarium estimate of terminator time

The visible portion of the globe has shrunk again since the previous image as time passes and the Earth's orientation relative to Apollo 17 changes – certainly Stellarium's visible disk showing Earth as seen from the moon is much larger. The time markings on the satellite suggest a time around the terminator of around 10:40 GMT on the 7th, with Australia being overpassed about 12 hours later. Stellarium's suggested time (based on the absence of land masses other than Australia and the clouds by the terminator) is somewhere around 01:00 on the 8th – roughly 19.5 hours since launch.

The appearance of Australia in the frame is useful in terms of confirming that suggested time of. While no mention is made directly of photography, there is discussion of the Earth's appearance some time before and after midnight (as an Earth scientist, Schmitt was particularly keen to describe what he could see, earning him the description "human weather satellite" from capcom).

At just short of 19 hours (00:30) capcom tell the crew that:

"...we'll be having a communications handover to Honeysuckle in about a minute and a half"

with Schmitt responding:

"That's great. Next time I look at Earth I'll see what's happening in Australia."

As communication is by line of sight and Goldstone in California was just about to disappear, Honeysuckle in Australia becomes the next link in the communications chain as it comes into view. Australia is visible in the image, whereas the coast of the USA is not, which suggests a time for the image after that statement. More helpfully for this analysis, he does at 20 hours (01:30 GMT)

"I took two 5-50-millimetre pictures."

Schmitt then gives a lengthy description of what he can see:

"...It looks like there's a very well developed front coming out of the north-western portion of Antarctic ice shelf....That front looks like it starts and develops as a small - it - it actually seems to start with an anticyclone development off the coast of Antarctica. Moves up across New Zealand. Looks like the South Island primarily, a little bit of the North Island is still visible and into the eastern coast of Australia..."

"...that front is going off across to the coast of Australia north of Sidney and largely a little south of Brisbane and - and swings across the whole of Australia and seems to come - near as I can tell, go by into the Indian ocean about - well, where the Great Sandy Desert intersects the north-western coast of Australia....That front does cross. Probably Brisbane is probably cloudy. it does cross that area, and - however, there is a bank of clouds that runs off of it down the coastline. So Sidney is either cloudy or has some pretty nice clouds off - off shore. And the remnants of the front as it dissipates in the hinterland of Australia dies out at about the Great Sandy Desert, and there is not a good indication that it crosses into the Ind - Indian Ocean. ...it looks more and more like the cyclone circulation developing right over the top of New Zealand, the South Island, I think...anticyclone circulation is centred on the ice shelf. "

"Now the north of Antarctica... there is a large cyclone circulation pattern that has its southern extremity right on the edge of the ice shelf. And that - that is east by 20 or 30 degrees of longitude of the front that I was just discussing....Between New Zealand and Australia, the front I was discussing previously has some fairly strong transverse cloud patterns......but the bulk of Australia is very clear, all the south and the north. It's just one line of clouds that crosses the centre section."

As before, he describes the scene uncannily accurately, almost as if he was actually looking at it!

At 02:20 GMT, Schmitt says:

"I've been trying to spot tropical storm Teresa [sic]*, which is is - a couple of days ago was in the Philippines. But I can't - I don't think I quite have that visible to me right now."*

The Philippines are only just visible on this image, and Schmitt also refers earlier to the Hawaiian Islands weather, which is further support that he is looking at a scene where Australia has only just become visible.

Tropical storm Therese began life on 30/11/72 and lasted until December 12th, but causing damage to the Philippines an Vietnam on the 3rd and 9th respectively and the introduction to this section provides links to the images of it. This storm becomes more interesting in light of the next couple of images analysed.

A short while after Schmitt's long range weather report, another couple of photographs are taken. AS17-148-22739 is shown below in figure 4.9.9 , and analysed over the page in figure 4.9.10.

Figure 4.9.9: AS17-148-22739. Source:
http://www.lpi.usra.edu/resources/apollo/images/print/AS17/148/22739.jpg

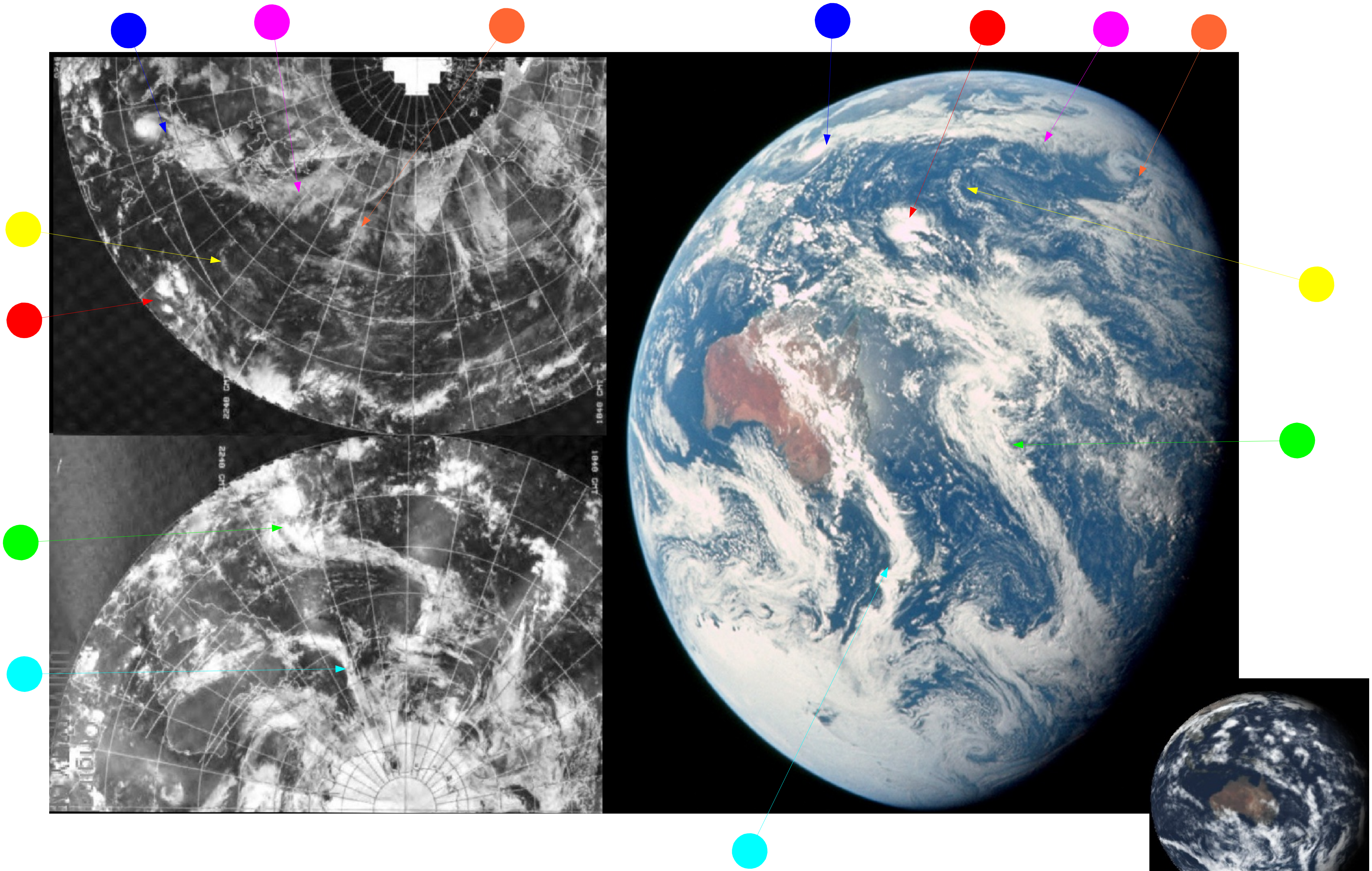


Figure 4.9.10: AS17-148-22739 compared with NOAA2 satellite mosaic from 07/12/72 and stellarium estimate of terminator time. Cyan, green, yellow and red arrows are as in 4.9.8

As with the preceding image, the first question to settle for figure 4.9.10 is the time at terminator. The Stellarium estimate is given as 04:00, but the Earth as seen from the Moon is obviously still almost full, compared with the three quarters full as seen from Apollo's vantage point. This, combined with a Pacific view, makes defining the line of the terminator much more difficult. How then was the estimate derived?

At the risk of again employing circular logic, the satellite photograph comes in useful here, and it can be seen from that the terminator line cuts along the westernmost edge of the band of cloud identified by the green arrow. The furthest edge of this cloud falls along the 170 degrees West line of longitude (making Hawaii all but invisible to the crew), and by using a combination of Google Earth and the Earthview website, it's possible to determine that the terminator line would follow a line from 30 degrees East of New Zealand (visible at the point of the cyan arrow) up towards the Bering Straits. Australia is slightly over 20 degrees west of New Zealand, and this distance of around 50 degrees gives a time at the terminator of roughly 04:00

To complete the time analysis the time at the terminator on the NOAA image is given as 19:40 GMT.

Having established a rough time for the image, we can now take a look at what is in the image, and what Jack Schmitt has to say about it! Perhaps thee most impressive feature is the procession of angular fronts proceeding across the sub-Antarctic oceans, features that are easily spotted on the satellite mosaics, and we will see Schmitt's description of them shortly. His first observations about the state of the weather for this picture occur at 22:26 MET (roughly 04:00 GMT):

"...we're starting to be able to see the coast of Asia. The Philippines are wide open today. And the - that tropical storm Theresa [sic] *that I mentioned that I thought I could see - indeed, I'm sure that's what that little concentrated mass of clouds was north of New Guinea. And, I suspect, that the folks in Guam may be in for some heavy weather...oh and Bob, I got another pair of pictures...about 10 minutes ago."*

This is a fairly good clue that the AS17-148-22739 (and it's companion in the magazine) was taken at roughly 04:15 on the 8th. Examination of the Apollo photograph does indeed show that East and SE Asia are just beginning to be visible. Guam is located north of the area of cloud arrowed in red. New Guinea (now called Papua New Guinea) is just north of Australia and south of Guam. From this description it looks as though he suspects that the red arrowed cloud mass is Therese – but is he correct?

Fortunately for us, we have a few satellite photographs available, as described in the introduction to this section, namely the original NOAA2 pass and also a DAPP satellite image.They are not from the exact date of the Apollo image used here. We can, however, use them to identify where Therese is. Figure 4.9.11 shows the north-west corner of AS17-148-22739 compared with the DAPP and NOAA images from the 6th and 7h respectively.

As with any time-series images of weather phenomena, there is no exact match here, rather an indication of the storm's progressive development as it moves westwards towards land and an overall indication of the weather system's make-up.

The spiral arms of the storm are nicely picked out by all three images, and the long band of cloud trending north-eastwards from it is also well defined. The gap between Therese and the other north/north-east trending system further to the west is visible in the NOAA image, and the southern tip of that secondary band is just included in the DAPP image.

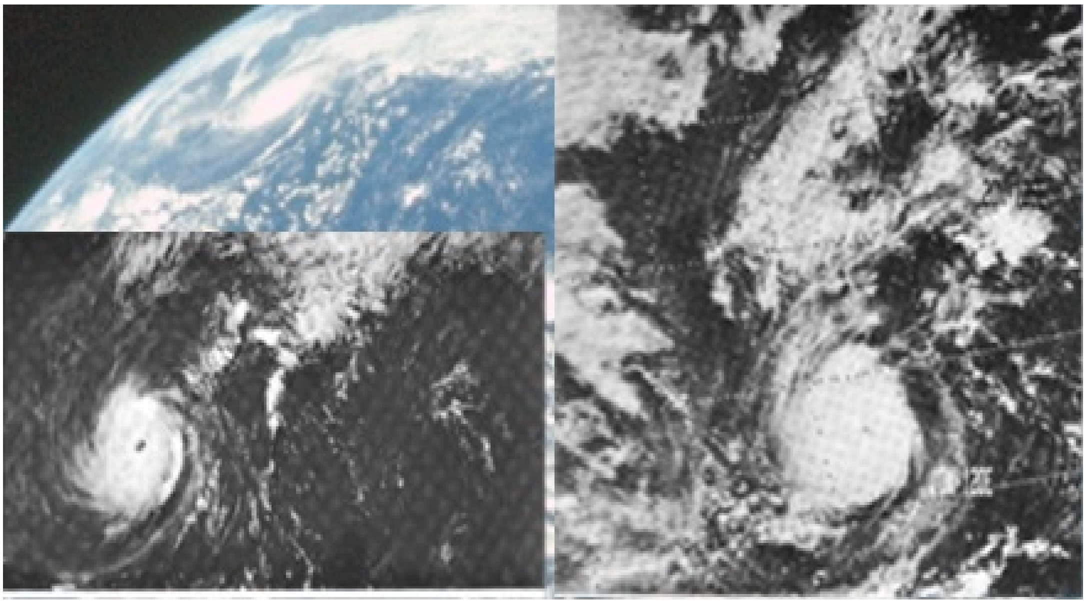


Figure 4.9.11: AS17-148-22739 compared with DAPP from 06/12/72 (left) and NOAA from 07/12/72 (right) images.

It is a pity that there are no publicly available photographs from the 8th of December that would tie in more precisely with the Apollo image, but (like the Tamil Nadu cyclone) it is present in the image where it should be.

Cynics will argue that Schmitt (and presumably NASA and ESSA) knew about the storm, and would know that it should be in the photographs. They will probably also argue that Schmitt's apparent inability to see Therese was a pretence, instead of the reality that he was observing the Earth through distant optics. The mission transcript does indicate exactly what information capcom had to hand, and this will be dealt with shortly.

We can at least attempt to clarify the exact date of the NOAA-2 image. The original source gives it as December 7th, which is the date of the satellite mosaic originally used to look at the Apollo source picture. Does this mean that the NOAA-2 image is one taken actually on the 7th (and would therefore appear on the mosaic dated the 6th) or part of the dataset starting the 7th, and therefore actually imaged on the 8th? Figure 4.9.12 compares the NOAA mosaic versions dated the 6th and 7th with the NOAA image from the MWL dated the 6th.

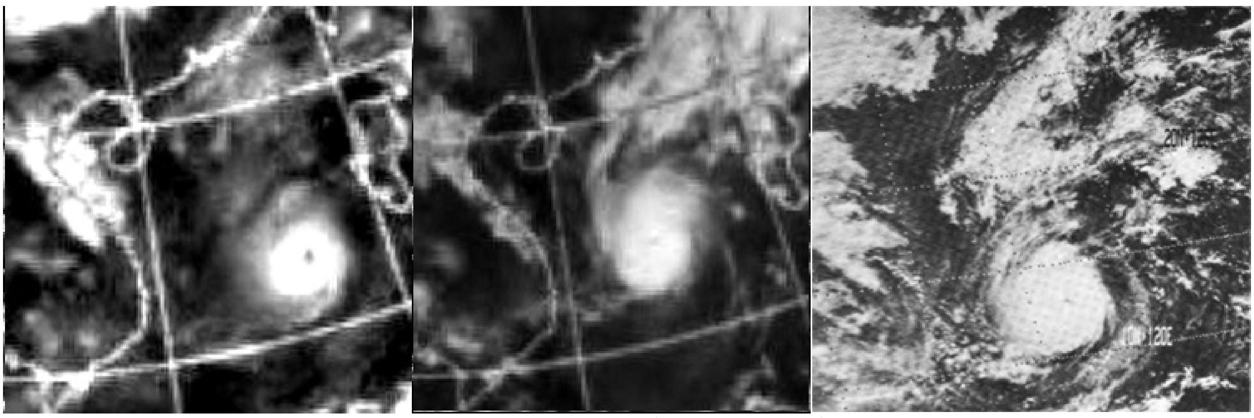


Figure 4.9.12: NOAA2 mosaic segment dated the 6th (left) and 7th (right) compared with NOAA2 image dated the 7th (right)in the MWL (source given in the introduction to this section).

Figure 4.9.12 illustrates 2 things. Firstly, that the NOAA-2 image published in the MWL is dated the 7th correctly, and can be identified in the mosaic dated the 6th. The cloud mass over the Vietnam coast and the ones adjoining Therese at sea are a better match in the left hand mosaic section compared with the right, and the long thin cloud over the Vietnam coast on the centre image matches Apollo's more closely. Secondly, the degradation in image quality when compiling the mosaic is very evident. The original source image used in the MWL is much clearer and has far more detail.

We will return to Jack's hunt for Therese shortly, but first he has other descriptions of what he can see for capcom. At 22:35 MET he gives a lengthy description of Australasia's weather:

"...I was talking about the circulation patterns around Antarctica. We were looking then at the Indian Ocean, actually, South Atlantic in the Indian Ocean region. And you see the same pattern at about the same latitude, say 60 degrees south, where all the linear cloud patterns which presumable are - reflect the various cold fronts have - are arcuate with their convex sides, or more actually, almost pointed sides are all lined up in a west-to-east direction around that latitude. It's quite a spectacular appearing circulation pattern. And the little wave that I mentioned on New Zealand seems to be beginning to form another arrow or another convex point on that front that's fitting right into the same circulation pattern..that would make four of those major convex fronts that I can see from this view crossing - south of Australia up into the South Pacific."

The fronts he describes are those that appear south and then east of Australia in the photograph, with the green arrow identifying the largest of them.

Having briefly gone over Australia and the Antarctic Ocean, he then returns to the search for Therese. In order to help those less familiar with the region, figure 4.9.13 shows an annotated Google Maps page, with the main places mentioned identified.

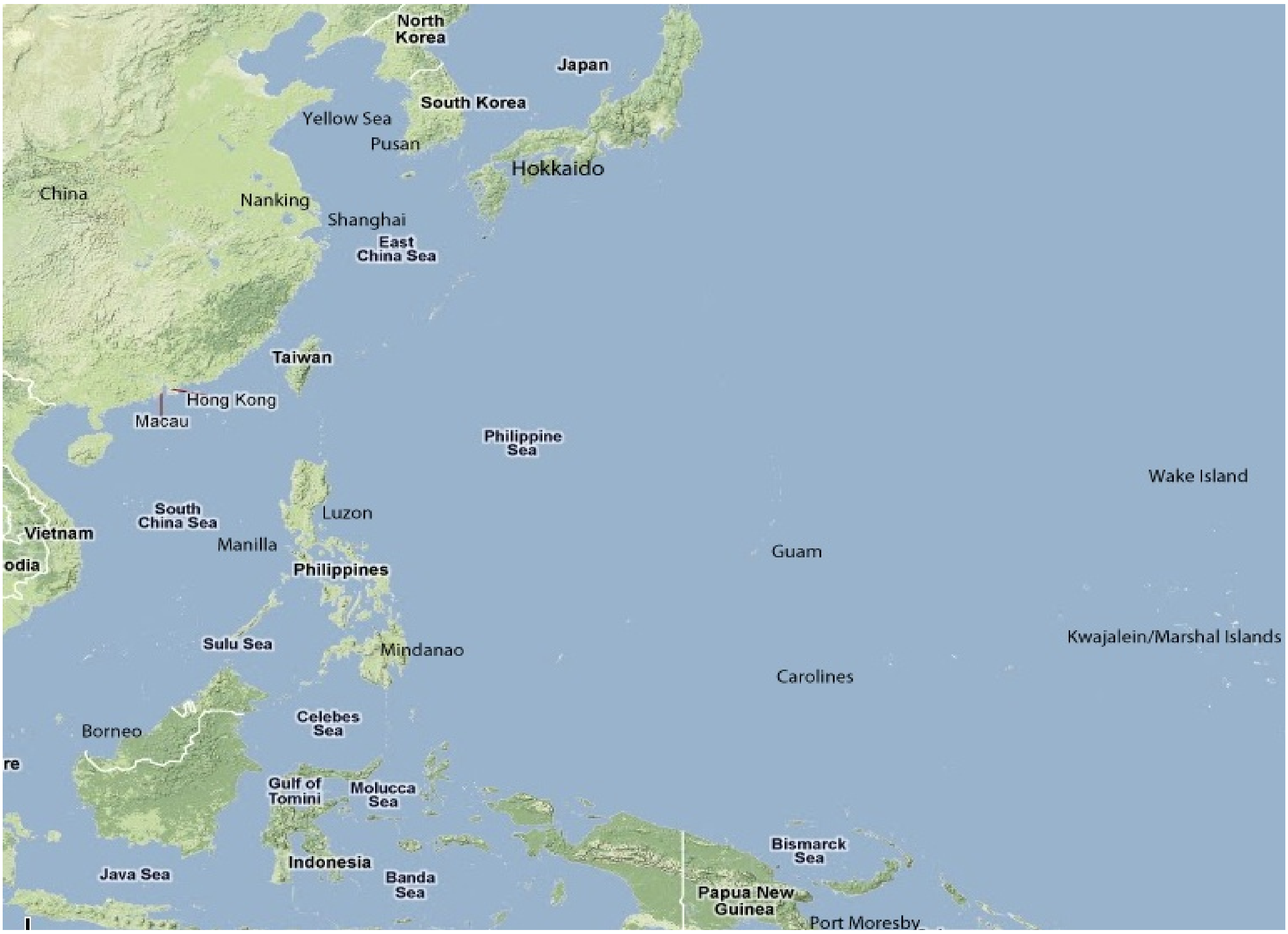


Figure 4.9.13: Google Maps page showing the Asian Pacific region, with additional annotations identifying locations mentioned in the Apollo 17 mission transcript.

He starts the discussion with:

"On that tropical storm that was Theresa...I'm not sure it may be a little south of Guam. Guam may be in trouble with that one."

So, while we know exactly where Therese is at this point, Schmitt is still unsure, and is picking out what to him would appear as the largest and most obvious tropical disturbance, rather than Therese's actual location at the end of a longer band of cloud. Capcom, meanwhile, have their own maps and are trying to locate Therese as well, and they respond with:

"It looks like it's just a bit to the west of Manila there - about 5 or 6 degrees, no more that about. it looks like it's about 5 degrees west of Manila and 5 degrees south."

To which Jack replies:

"...I don't like to argue with you but I think our analysis chart is a little more up to date ...That area you mentioned...is very clear and the centre of the - what appears to be the storm I'm speaking of, would be about 142 longitude and maybe 8 degrees north latitude...which would put it south of Guam"

We then have the following exchange between capcom and Schmitt, which reveals interesting information about the weather data held by ground crews supporting the mission:

Capcom: *"Okay yes, you're over in the area between Guam and the Carolines, then."*

Schmitt: "*Yes, you're probably looking at a - oh, I don't know - maybe a what - a 12 hours old prog, or something."*

Capcom: *"Yes, that's the one I had for launch date...We'll get a satellite photo and bring it in here in a bit"*

Schmitt: *"Okay, well, it's - it's - moved quite a bit now and I guess it's the same storm; still seems to be very well organised but quite concentrated and small."*

Capcom: *"Okay we'll get in a new prog and compare your estimate there"*

Schmitt: *"OK, I think that's pretty good - those 142 and 8 degrees would be pretty good centre of that storm. I've got some pretty good coor - I can see Mindanao, and I can see the - let's see - just a second, what is that on Australia?...Yes of course, that's Port Moresby. I can see that point there, and between those two - I can pin down that one probably with a couple of degrees"*

Capcom: "*OK. We'll get a satellite photo and bring it in here in just a bit.*

It appears from this exchange, then, that capcom are predominantly using synoptic charts for their information, and are looking at relatively old data compared with Schmitt's view. As the main concerns for the weather are mainly with launch day and re-entry – and even then only for the Florida and splashdown locations, this is unsurprising. It would be up to other agencies like ESSA to monitor any emergent trends on a wider regional level, who would update NASA as required.

Schmitt's fascination with the weather is something that was evidently not anticipated by capcom (and to a certain extent seems to bemuse them somewhat, particularly as his lengthy dialogues do get in the way of essential technical transmissions governing spacecraft maintenance and mission details. Jack's amateur meteorologist status (which he does briefly mention by way of explaining an errors he may be making) is revealed by his assumption that Therese has shifted several thousand miles over a relatively short period!

Briefly mentioning the front over New Zealand (cyan arrow in figure 4.9.10), he then returns to SE Asia:

"...Borneo is very clear today; and, as is the Philippines. And as I mentioned, there's a - looks like a very strong system that stretches from, oh, let's the south coast of - or southeast coast of Vietnam up - up between and across Tai - between the Philippines and Taiwan and across Taiwan. And right along, and I can't tell I think, just off - just south of Japan...The strongest storm centre that I can see on that is - is way north, and probably - Hokkaido is - has a fair amount of weather from the storm system. There seems to be a tropical depression just north of Borneo, a very strong circulation system north of Borneo and, I guess, just south of - of Vietnam.,,that's not what's left of Sally is it?"

He has now managed focus in on the correct area for Therese, which is lurking at the end of that storm front over Japan. Tropical Storm Sally was a small event that had pretty much died out by the time Apollo 17 launched, and the tropical depression he describes is actually Therese! Capcom can't identify that depression on their current chart (probably because Jack has confused them by mis-identifying storm systems!) and are still awaiting their more up to date chart. Schmitt goes on to describe clear skies over Korea and cloud cover over Japan before returning to the the area around Therese:

"...As I recall, they had a tropical storm called Sally that went into - ... a few days ago, and so I suspect this new one that seems - that I think I see between Borneo and Vietnam maybe something else; a new depression or I maybe - be fooled by it.... Mainland China, Bob, was the last pass here. I can't see the Ear - see the Earth now, but Mainland China looked like it was clear as far as I could see. There might be a front quite a ways inland...but Korea, Yellow Sea, and the regions of China south of there - Shanghai, Nanking and those places are - looks as if they are quite clear....It looks like some residual cloudiness would be affecting the Pusan region of Korea. And, also, that's residual after the frontal passage. And it looks like maybe Shanghai, after all, may have some storms associated with it, but it's really hard to pick out exactly 0 the exact coast line of Asia, but I - there are some clouds in the Yellow Sea behind the front. Looks like they might be possibly some high cirrus is all."

It's worth pointing out that the above conversation took place over 45 minutes after the Apollo photograph under discussion took place, so that while initially the coast of China would have been difficult to make out clearly, it would have moved into view by the time Jack made the comments above. He is, however, managing to pick out areas and their weather conditions accurately, even if the storm that is Theresa is still confusing him!

By now it is 23h17m MET and capcom ask Schmittt about the storm around Guam, to which he responds:

"I see there is this cloud concentration between New Guinea and Guam. The more I look at it the less well developed it appears to me compared to some of the other circulation patters. it could be just a residual depression from Teresa [sic] *that has moved out into that area. it is an isolated, a relatively isolated cloud pattern, fairly small, but apparently fairly dense. But has - does not have a strong cyclonic pattern to it. Nothing at all like the pattern that now exists above Borneo and seems to be moving towards Luzon."*

He has therefore managed to identify that the circulation pattern we would expect for a cyclonic storm is absent in the clouds near Guam, but is still sticking to his guns that it is a leftover from the (still active) Therese, despite the very obvious cyclonic pattern he can actually see on the storm that is Therese!

Twenty minutes later, he gets asked about Wake Island, prompted by requests from the ARIA support team based there, to which he responds:

"...around Wake, or in the vicinity of the Kwajaleins and north of Wake, about all you have is a lot of cloudiness although - and in a generally - over wide part of that Pacific, I'm talking about 15 or 20 degrees of longitude and latitude, there's a - roughly a clock - a clockwise circulation pattern. But the clouds do not look very dense or concentrated in any one area. And at leading off to the south-east from that general cloud mass, they're cyclonic - anticyclonic cloud mass is a - is one of the old fronts - or at least one of the old linear cloud patterns that extends down into the south Pacific....I wouldn't expect [winds] to be anything - anything what might be down - associated with the remnants of the tropical depression Theresa. Now that Theresa - what's left of it, if I'm correct in - in picking out there, probably is - is moving in that direction, although it looks weak enough. But right now I don't think it would be any big problem. And it may, in fact, go south of there."

The general cloudiness is obvious on the Apollo photograph, although the circulation pattern of the cloud would appear to be more perceived than actual, as it is difficult to pick out with any certainty any rotational evidence other than a slightly arced band on the eastern side of the cloudy area he is describing. The old front moving south-east is picked out by the green arrow in figure 4.9.10.

Capcom then deliver a bombshell to Schmitt:

"..The prog I got in my hand for 3 hour old weather has Theresa located just about in the Manilla area. Did you concur with that, or do you think it passed the - the Philippines."

The 'prog' they refer to indicates that they still don't have an up to date satellite image, and instead are relying on synoptic charts. Jack then responds with:

"Well, I don't - Manila's clear. The only thing approaching near Manila is - is this other storm center that is north of Borneo. And to the east of Manila, it's clear all the way over to this little cloud mass that I was guess might be Theresa."

Schmitt is displaying a classic symptom of confirmation bias, which is ironic because it is something of which conspiracy theorists are routinely guilty: he has made a judgement based on incomplete information, and despite all evidence to the contrary suggesting he is wrong, he is sticking with his original story! He believes Therese to be a spent force, so the obviously active storm he can see can't be Therese! His final comment on the subject for the day is that:

"...that circulation pattern or tropical depression possibly that I saw earlier north of Borneo is now even more strongly developed at the tail end of the front that stretches up towards Japan. And it - ot really looks like a humdinger from here. Beautiful circulation patters and very concentrated. And it is now east of Vietnam, and again between Vietnam and - and the island of Luzon."

Following this statement, and with a few technical and housekeeping matters, the crew (who have all taken sleeping tablets) have a rest period and Jack's weather forecast service ends for the night, but not before he takes another pair of photographs. He confirms this before the final weather observation cited above, saying at 24:00 MET (05:30 GMT):

"I'll probably take two more pictures before we go to sleep"

After the rest period, Schmitt confirms that he did take two photographs before retiring, and one of those, AS17-148-22742, is shown below in figure 4.9.14.

Figure 4.9.14: AS17-148-22742. Source: AIA

Australia has moved around under the CSM while Jack has been delivering his synoptic sermons and is pretty much directly below them. New Zealand is now equidistant between Australia and the terminator, and this allows a quick determination of the time to be not long after Schmitt said he would take the photograph. The added rotation of the Earth allows a much better view of Theresa, and we can confirm that it is where capcom think it is, and not where Jack thinks it is, and also that the image mosaic dated the 7th is correct for Therese, and not the one dated the 6th. This can be seen in figure 4.9.15. The full satellite analysis for this image is given overleaf in figure 4.9.16.

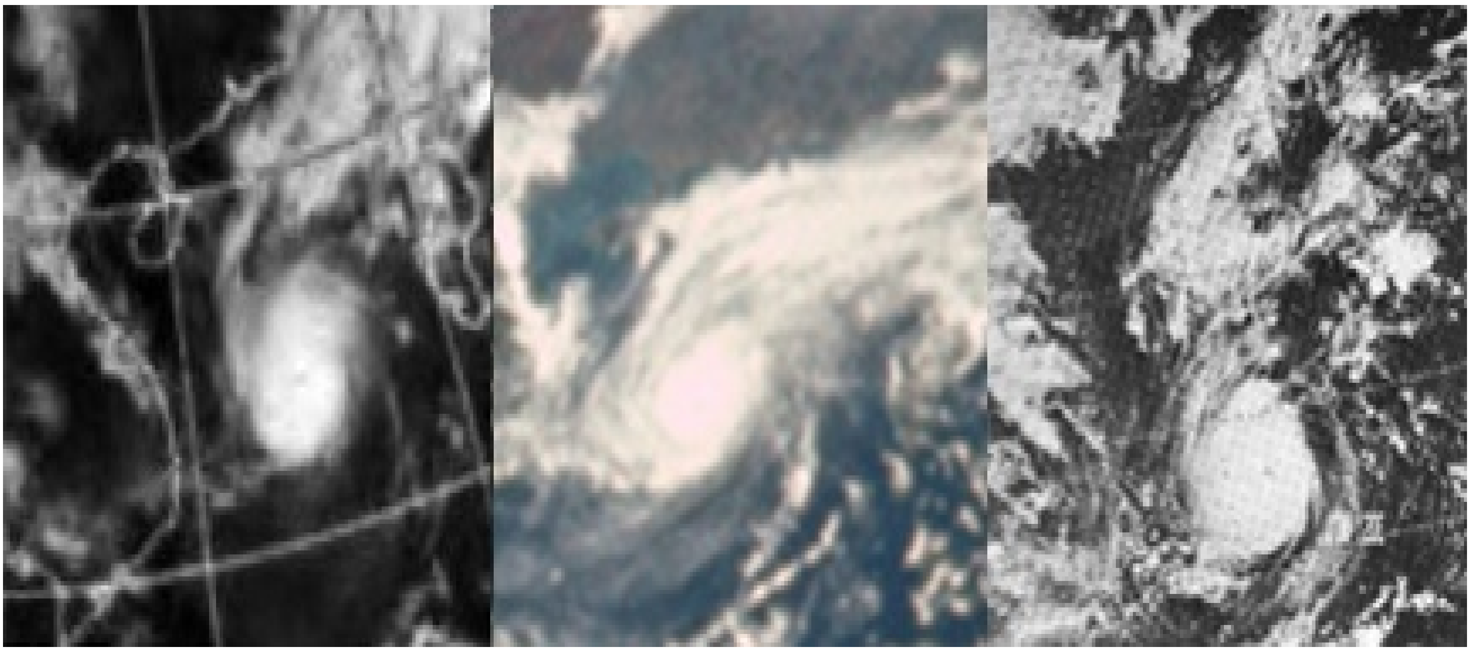
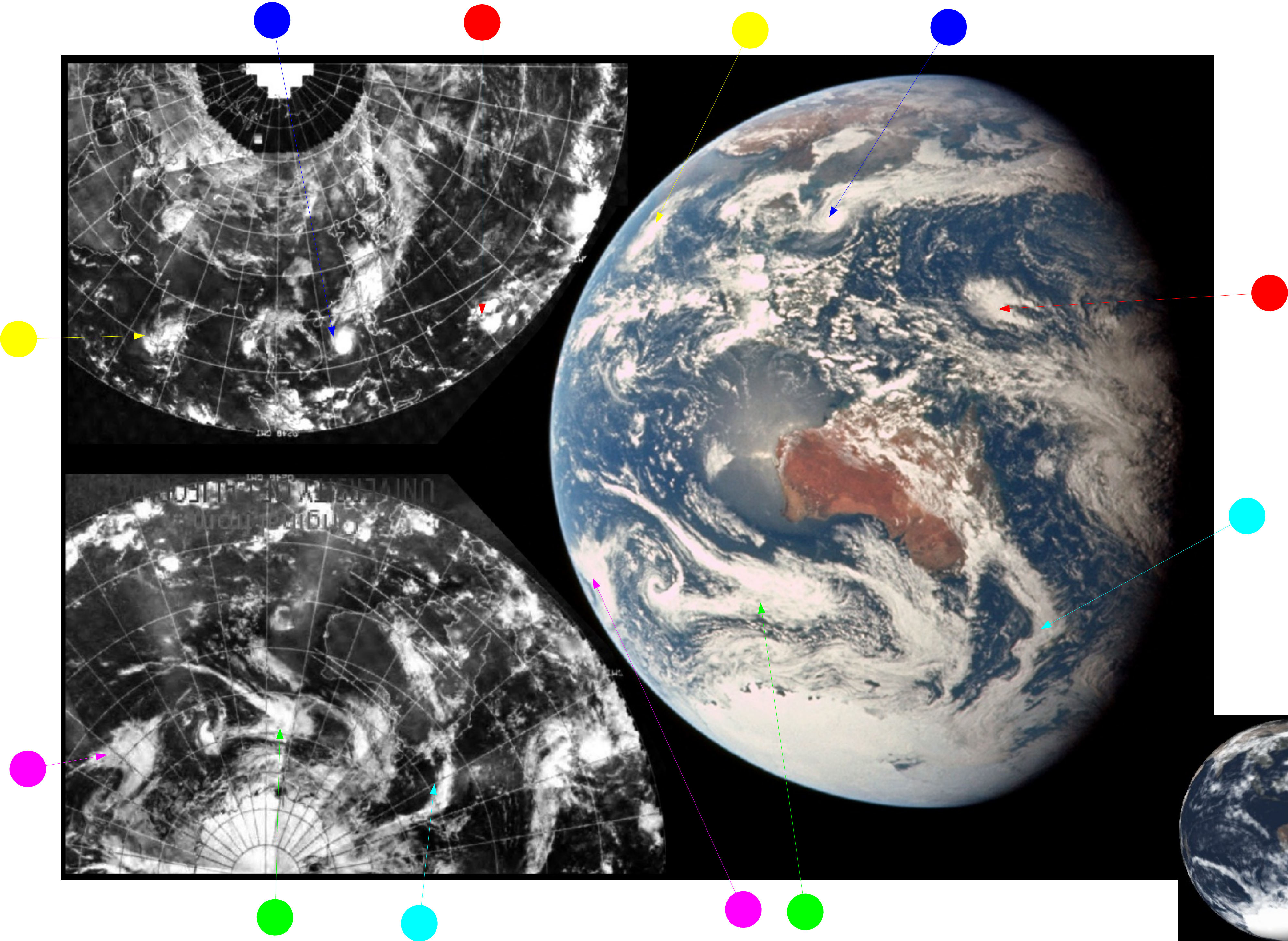


Figure 4.9.15: Tropical storm Therese as seen on the NOAA mosaic dated the 7th (left), AS17-148-22742 (centre) and NOAA image dated the 6th (right). The coastline superimposed on the NOAA mosaic can be seen easily on the Apollo image.



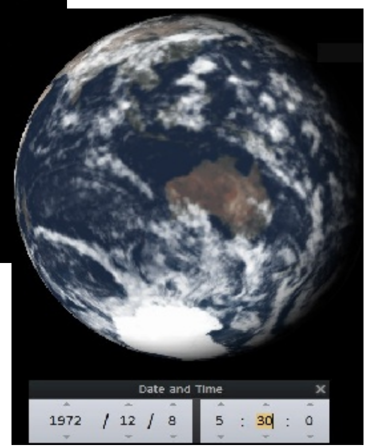


Figure 4.9.16: AS17-148-22742 compared with NOAA2 satellite mosaic and Stellarium terminator estimate. Red cyan and blue arrows are as in figure 4.9.10. Blue arrow points to Tropical Storm Therese.

There is little to add to this image, given that we have already had a lengthy description of it from Jack already. It is worth mentioning the obvious rotation of the Earth over time that is entirely consistent with the narrative recorded in the mission transcript.

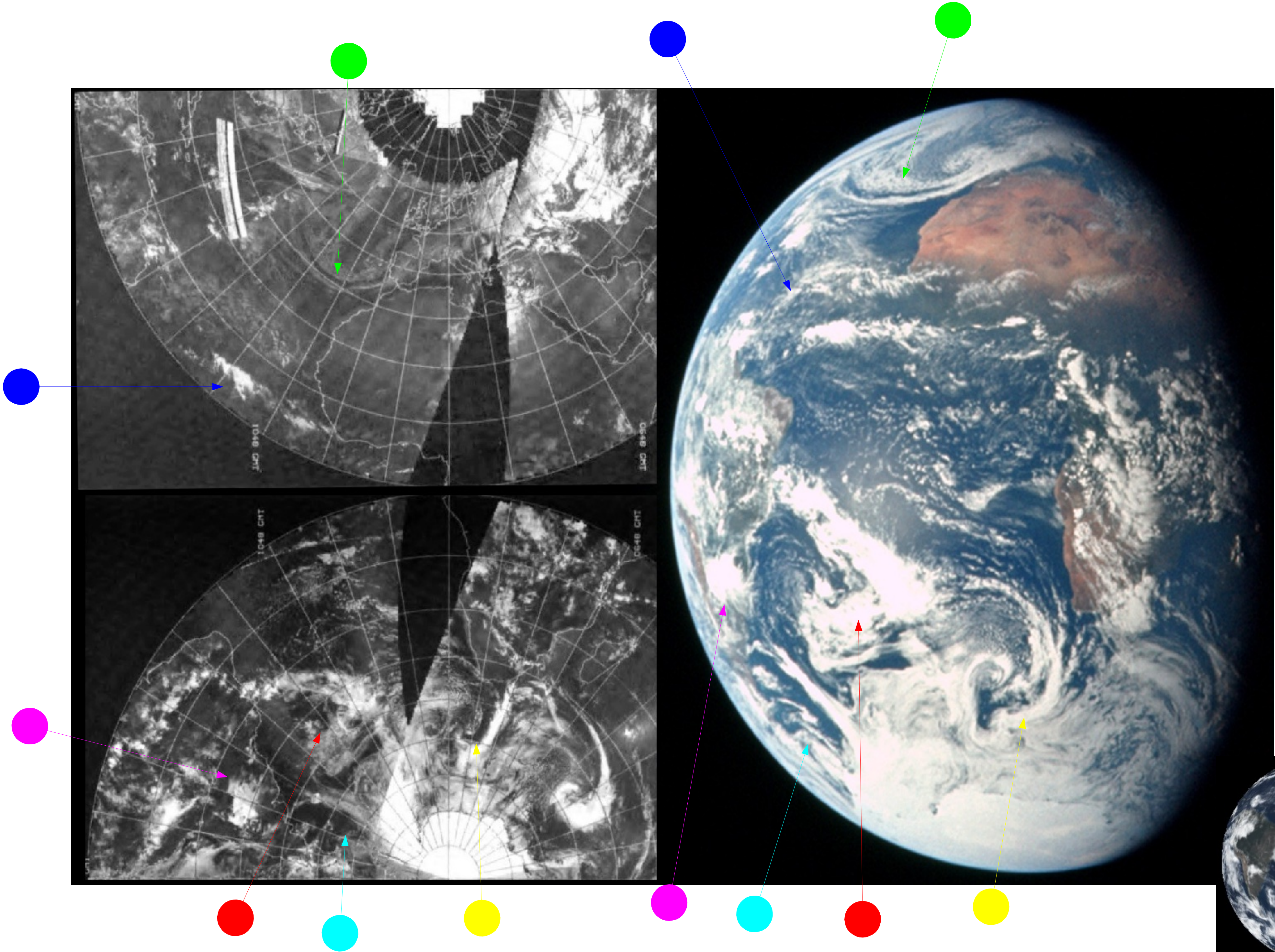
Later in this mission day, Schmitt asks capcom if they had managed to find any more information on the storm he had picked out by the Philippines. Capcom confirm that the storm is, in fact, Therese, after which Jack asks about the storm he had thought was Therese over in the Guam area. Capcom tell him that they have no detailed charts of the Guam area. It is likely that the more detailed charts over the Philippines and Vietnam are a consequence of the still ongoing military operations in that area.

As well as confirming that he had taken a pair of photographs before going to sleep, Schmitt also advises capcom that he has taken another couple at 33h30 MET, or about 15:00 GMT. One of those photographs, AS17-148-22743, is shown in figure 4.9.17, and the satellite analysis is shown on the next page in figure 4.9.18.

Figure 4.9.17: AS17-148-22743. Source: AIA

The first observation that can be made here is that, with increasing distance from Earth (the crew are now over halfway to the Moon), the shape of the visible Earth is becoming much more similar to the view from the Moon as given by Stellarium's terminator estimate. It is also very obvious that Stellarium's predicted terminator line for Jack's stated time for this image of 15:00 is exactly right.

The satellite image suffers the usual problem when viewing Africa of featuring a portion of the



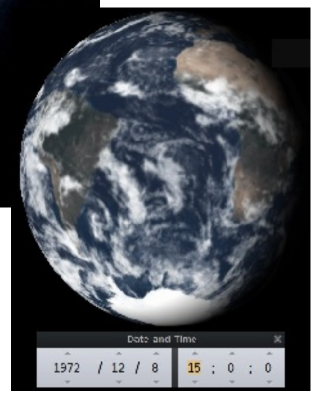


Figure 4.9.18: AS17-148-22743 compared with NOAA2 satellite mosaic, and Stellarium estimate of terminator time.

image that was actually scanned the following day. The yellow arrowed cloud pattern is one that is further East on the satellite image compared with the Apollo version for that reason. The time at the terminator on the NOAA mosaic is difficult to determine because of that, but an estimate of around 08:00 GMT on the 8th would fit in with the time markings shown on the lines of longitude.

In this mission, if there is a photograph of Earth, our resident meteorologist has observations to make about it, and this image is no exception. At 33:45 MET (or 15:15 on 08/12/72). he observes the following:

"...Africa looks in pretty good shape. There is a - except for an area probably around Zambia and Rhodesia [Zimbabwe] *in the tropical convergence zone there, where it looks pretty cloudy and probably quite rainy. There's a strong circulation pattern, and presumably a storm off - just off the coast of north-west Africa. Very spectacular spiral formation of clouds in a cyclone development. it looks like there are probably two fairly week Southern Hemisphere cyclones in the South Atlantic, One, south-west of Cape of Good Hope, and other about due west of the Falkland Islands, maybe a little bit north of that. South America looks to be in quite good shape weatherwise, except possibly Uruguay and maybe northern Argentina which appear to have a - at least some fairly thick clouds there, although no strong circulation currents associated with this."*

His most obviously accurate description is of the 'spectacular spiral' in the north Atlantic (green arrow), which is visible very faintly in the NOAA mosaic but is still clearly there. There is indeed cloud cover over what is now Zimbabwe and Zambia just to the north of it. The yellow and cyan arrows pick out the fronts off the Cape and Falklands respectively. The thick cloud over Argentina is identified by the magenta arrow.

Schmitt has much more to say about the next image he took. He begins his narrative at 38h19 MET (c. 19:45), but the key moment for this research is his statement at 38:33 (c. 20:00):

"about 15 minutes ago I took two more Hasselblad shots of the Earth...and also, Houston, frame number – let's see, that's 16 or 17 - were taken of the Earth about 15 minutes ago too. And that's magazine Sierra Sierra."

We therefore have an photographs taken at about 19:45 on magazine 148, and also on Sierra Sierra, magazine number 162, a colour roll of 35mm film in a Nikon Camera.

The image chosen to examine from magazine 148 is AS17-148-22745, and this is shown in overleaf in figure 4.9.19. AS17-162-24047 from the Nikon 35mm film is shown below it in figure 4.9.20.

The satellite analysis of the Hasselblad image is given in figure 4.9.21, and this is briefly repeated without the NOAA mosaic in 4.9.22. The Nikon image is not of good quality and the usual procedures of level and brightness/contrast adjustment did not much more than confirm they show the same features. The focus therefore has been on the better quality image. Figure 4.9.23 shows an annotated map of the visible landmasses that Jack then goes on to discuss at length.

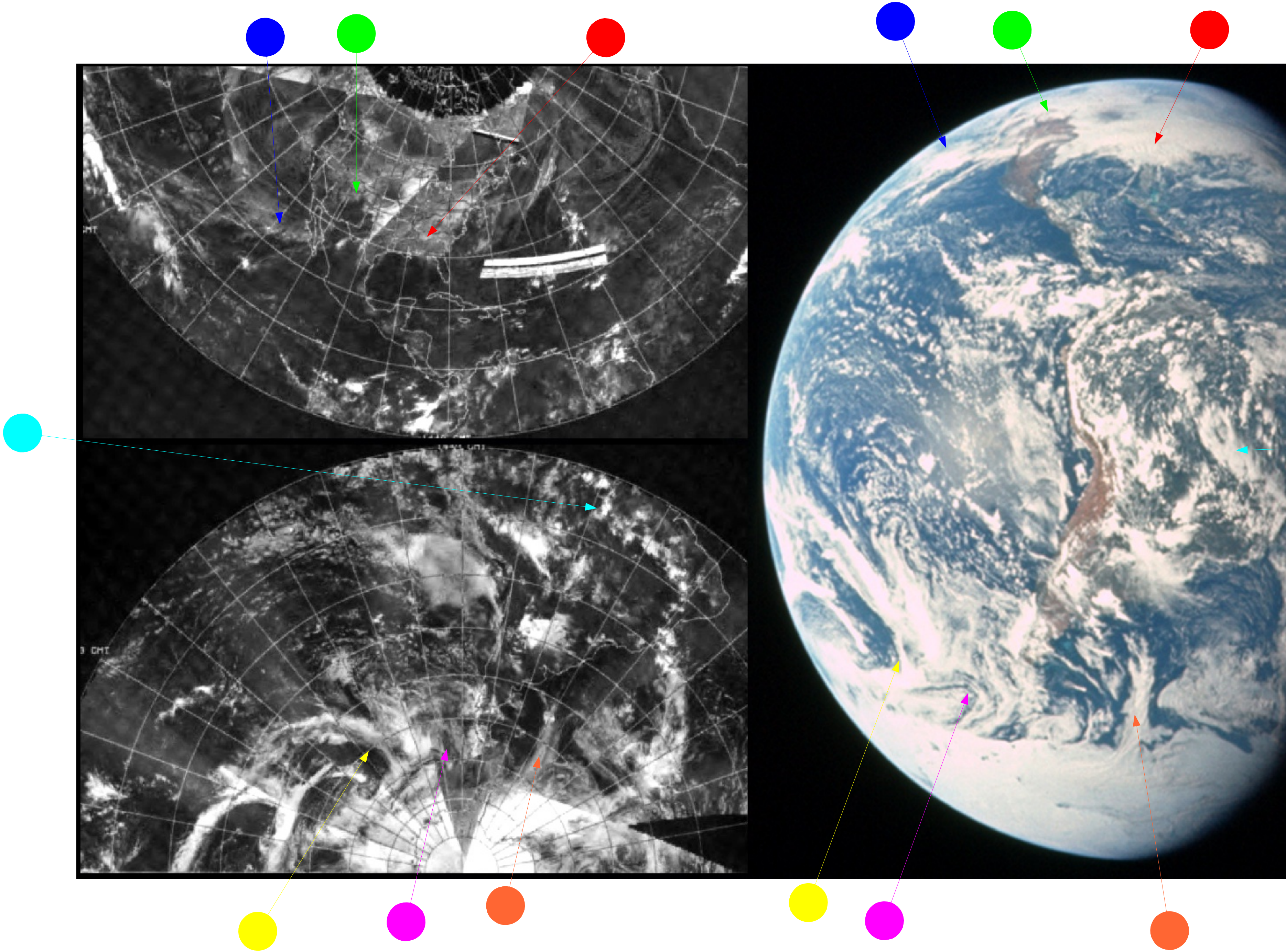
As far as dating the image is concerned, the Stellarium estimate is again a perfect match for when Schmitt states he took the photographs, and both photographs show the same features, with the Hasselblad's superior zoom lens giving the better detail than the Nikon.

In terms of what can be seen, we may as well let Jack do the talking again. His opening statement at 19:45 GMT is:

"...it looks like there is a fairly strong mass of polar air moving from the southwest up towards

Figure 4.9.19: AS17-148-22745. Source AIA

Figure 4.9.20: AS17-162-24047. Source: AIA



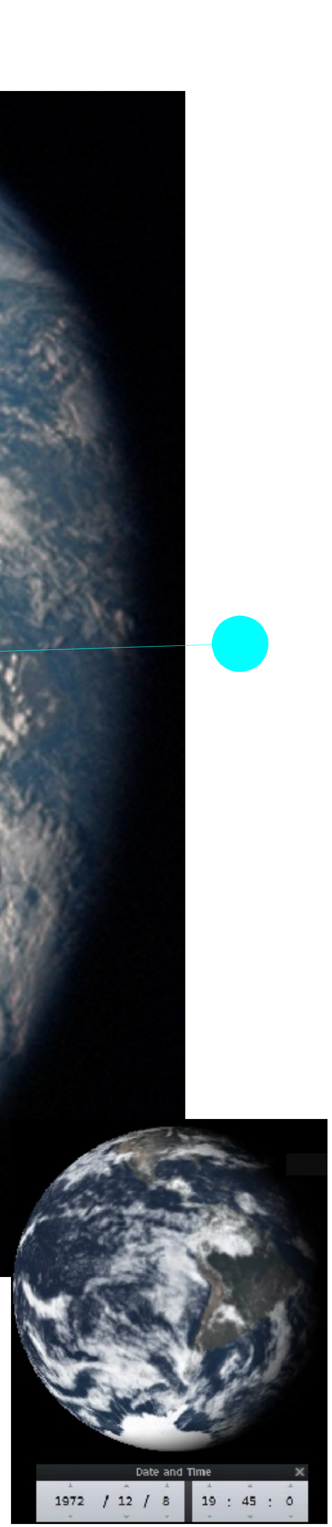


Figure 4.9.21: AS17-148-22745 compared with NOAA2 satellite mosaic and Stellarium estimate of time at terminator

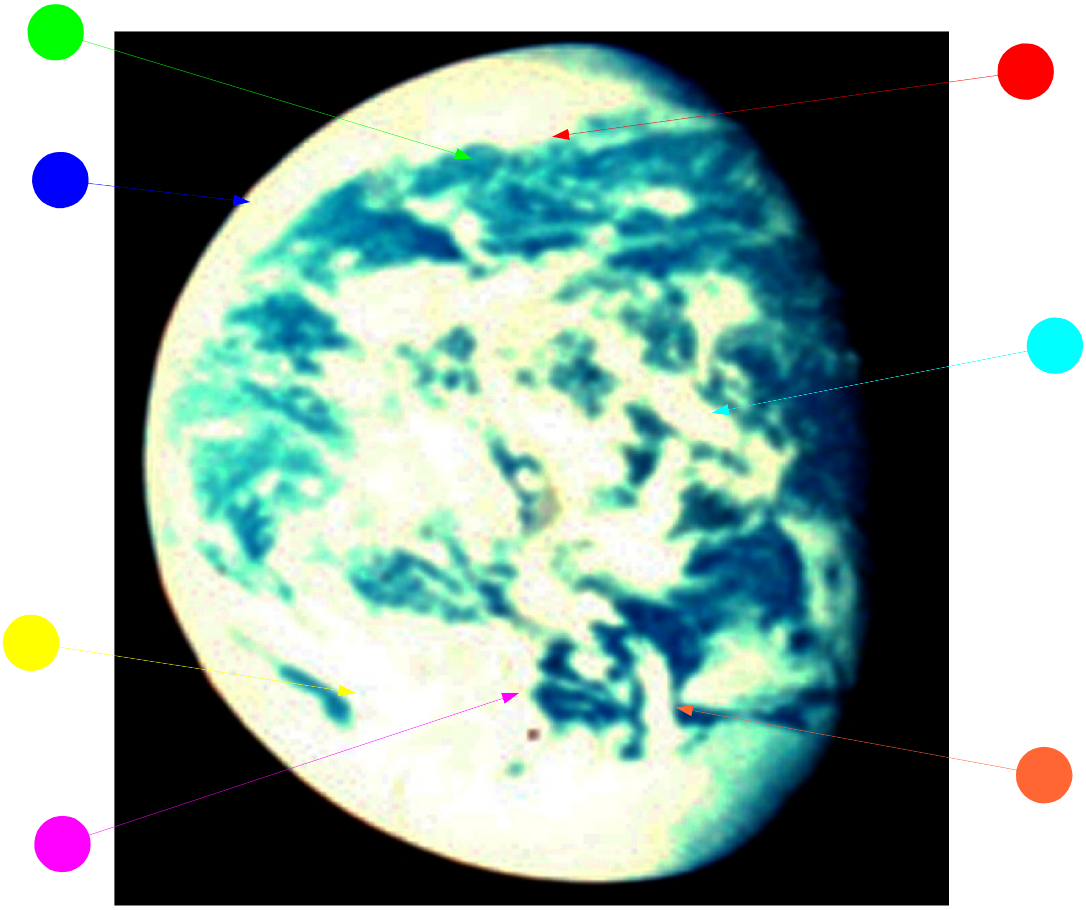


Figure 4.9.22: AS17-162-24047 with weather patterns identified in figure 4.9.21 identified. This image has had brightness and contrast levels adjusted and the degree of blue enhanced.

Figure 4.9.23: Outline map of the Americas with annotations showing places referred to by the mission transcript.

Tierra del Fuego. it's mixed with some cloudiness that extends from that area all the way down to the Antarctic ice shelf. But it looks like some pretty good movement patterns from the south-west, north-north-east. No strong weather waves or cyclone development on that yet, although one may be picking up halfway between Tierra del Fuego and the coast of Antarctica, the - where the front, or at least the cloud masses, curve from the east-west direction to an almost due south direction. Most of South America looks like pretty good weather. There is cloudiness on the Andean Ridge and also in the Amazon Basin , stretching from the eastern coast of South America on up about, oh, 2/3 of the way towards Central America. It doesn't look like frontal weather there. It's probably tropical convergence weather. Now there is this - still this small, moderately developed cyclone pattern that's hanging pretty much over Buenos Aires now, I think. Uruguay and Buenos Aires."

The developing cyclonic system, and the frontal clouds associated with it are picked out by the magenta arrow. The cyan arrow identifies the clouds running from the east coast to central America. The clouds over Buenos Aires aren't given an arrow, but they are visible south of the system pointed out by the cyan arrow.

Schmitt then moves on to the northern hemisphere:

"...Except for scattered clouds, Central America and Mexico, for the most part, are clear - as is most of the Caribbean islands. Cuba and he others are - all look like they've pretty good weather. There's a little clouds off - cloud pattern off to the east of those islands, but it doesn't look like any major weather in that area. The eastern half of the Midwest of the United States is completely cloud covered right now. There - however, the - extending from Mexico to Sonora and up into Arizona and New Mexico, and possibly as far north as Colorado, is a clear band. But there is more cloudiness to the north of that. The Pacific regions west of - The West Coast of the United States is cloudy at least west of Southern California. I cannot see Baja, so that cloudiness extends down south of - into Baja California. I see no strong new frontal patterns, although I'm looking right across the limb at the Earth now. There may be one that would be lying maybe across northern California and - and into Colorado, with a little clear area ahead of it, possibly in Kansas. But them into this, a solid bank of clouds that stretches from Brownsville, at least, clear up to - well, along the Gulf Coast and on out past Nova Scotia, I'm sure. Florida is clear. Florida - the peninsular portion of Florida is - it looks very clear..."

His assessment of the central Americas is completely accurate, and despite the fact that the US is 'out on a limb', he makes a good job of that too. The bank of cloud stretching to Nova Scotia is identified by the red arrow, and the clear area in the centre of the USA is obvious without an arrow to find it. It is bounded to the north by a cloud mass shown by the green arrow.

Capcom are able to confirm his observations on their synoptic charts and also on a satellite image, although they are not up to date. The satellite image is probably an ATS-3 one, as capcom state that it covers the same areas that Schmitt is describing. Schmitt is also informed that his broadcasts are being listened to with great interest by

"weathermen and a lot of other people around here"

At 38h49 MET, or around 20:15 GMT, Schmitt goes back to the southern hemisphere to describe the scene there:

"..there's an axis that runs from, say, the outer portion of the Ross Ice sheet along the - and just off the coast of Antarctica, then bends up so that it would pass just to the east of Tierra del Fuego and - and then continues on that heading so that it would intersect the far east coast of South America, if it continued. Now along that axis, the - what appear to be multiple frontal patterns or at least

frontal cloud bands, bend very sharply and change from a heading that roughly parallels the axis around the one that is roughly north-south. And some of the front - frontal direction changes that I gave you earlier, down in that area, are - also bend around that axis...and there just, oh, there are probably a dozen, if you tried to pull them out, cloud bands between the Ross Sea and Tierra del Fuego that bend around the same axis"

"...the whole coastline of Chile is, or all of Chile practically, is clear, Beautifully exposed to us here, particularly the Atacama desert...and the coast of Peru is also clear with clouds following the Andes ridge, probably the - certainly the coast side of the Andean ridge. Lima ought to be enjoying a very nice day today. The - Ecuador, however, looks like it might have a little more cloudy weather, although it doesn't look like any major storm activity."

The Ross Sea can be found south of New Zealand, and the 'axis' he is describing is really the edge of a bank of cloud running along a rough line of latitude starting from there and ending at the northward trending cloud arrowed in orange. The cloud bands and fronts to which he refers appear to almost 'peel off' this long axial bank of cloud, then double back on themselves. His description is complex, but it does match what is there. This accuracy also extends to the absence of weather patterns over Chile and Peru (although admittedly a lack of clouds over Atacama is no great surprise).

There follows quite a gap between the previous image and the next one, largely thanks to the Schmitt, the lunar module pilot, being heavily involved in checking out the LM systems. The next image of Earth we come across is still in magazine 148, and is AS17-148-22747. This image is shown in figure 4.9.24, and the satellite analysis in figure 4.9.25.

Figure 4.9.24: AS17-148-22747. Source: http://www.lpi.usra.edu/resources/apollo/images/print/AS17/148/22747.jpg

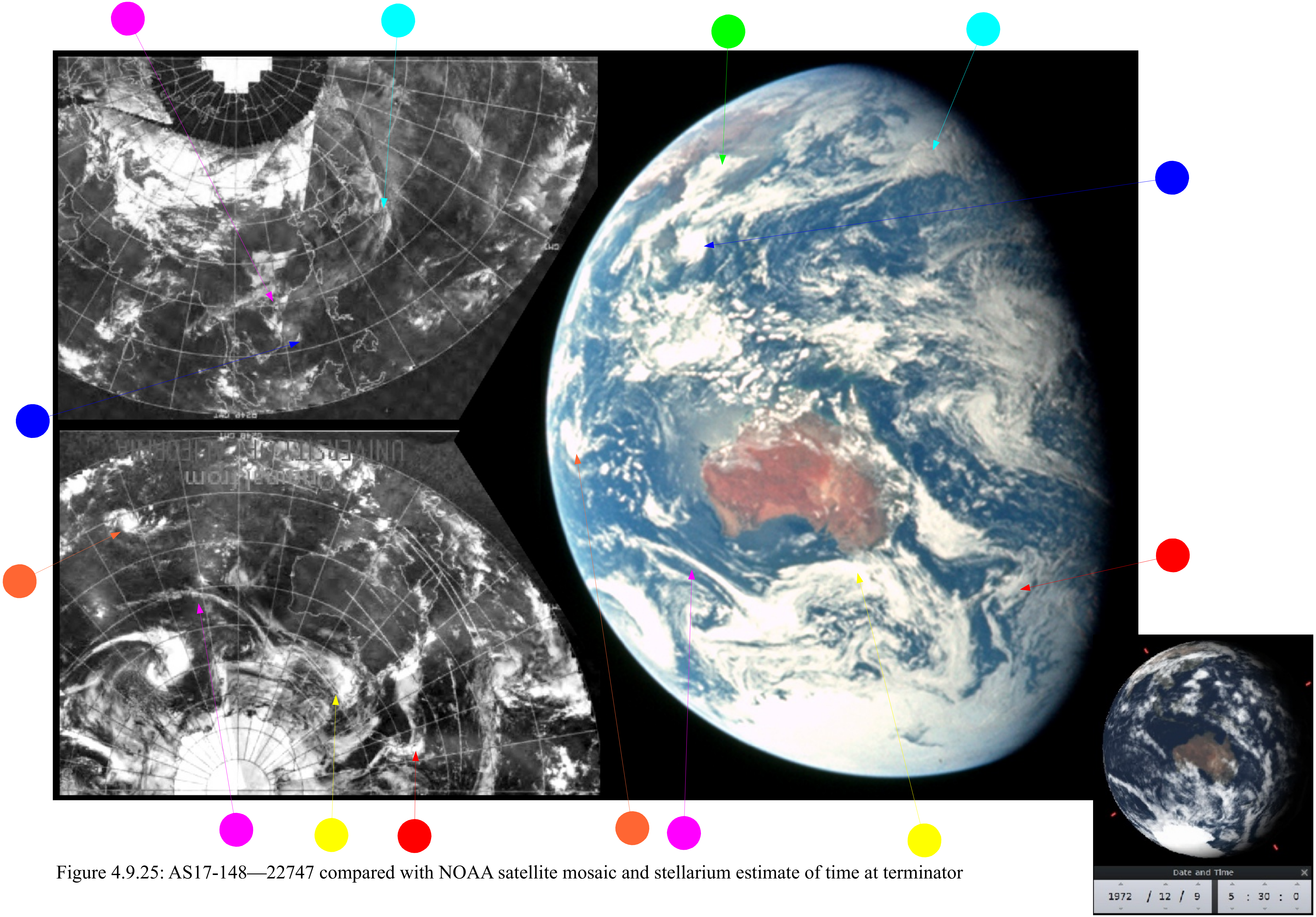


Figure 4.9.25: AS17-148—22747 compared with NOAA satellite mosaic and stellarium estimate of time at terminator

Such has been Jack Schmitt's influence on this part of the narrative of Apollo 17 that it mention of the actual satellite photographs that are the point of this research has been almost put to one side. To redress the balance slightly, the satellite image used here, dated the 8th but showing cloud formations on the 9th of December, are a clear match with what Jack sees and describes from Apollo 17. The northern hemisphere mosaic has issues with data quality, and some of the features are difficult to identify clearly – particularly in the eastern part of the picture. There is a clear line on the mosaic inland of China's east coast where the clouds are much better defined.

It is still, however, possible to pick out the patterns. Therese (about we will here from Jack later) is just visible, highlighted in blue and heading for landfall in Vietnam. Southern hemisphere systems are much better defined, and the clouds off Australia and over New Zealand are very easy to identify. The time markings suggest a rough time at the terminator on the NOAA mosaic of around 22:00.

Systems easy to identify in an image taken from a few hundred miles up are still easy to identify from over 150000 miles away, with the benefit of good monocular viewing equipment (anyone with a telescope will have a similar level of detail available to them of the much smaller Moon from much further away!). After the hiatus of testing the LM systems, Jack is able to return to his meteorological observations.

We start his synopsis some time before the photograph was taken, at 44:17 MET (c. 01:45 GMT), discussing the weather patterns over New Zealand (red arrow):

"...looks like a little - cyclonic circulation we had over New Zealand is still there. It's - looks like the front it was associated with is broken up a little bit; however, that pattern is - seems to be hugging the New Zealand area, and - but not - has not intensified. If - if not - it may have even weakened a little bit since yesterday. It's hard to be sure exactly. The front does not look as strong, and it still seems to be hanging just stabilised and with all of Australia clear now and the western edge of that front being just offshore south of Brisbane. The - there is - east of New Guinea - in the vicinity of the Solomon Islands, it looks like a fairly moderate-sized cyclone developing at the western edge of the - of a front that was somewhat farther north and west than the one over New Zealand. North that - Wake//Kwajalein region that was of interest yesterday to the ARIA people - still seems to be in general overcast conditions, but the clouds do not look very heavy or impacted at all."

The emerging cyclone he describes is the one identified with the orange arrow, and the front south of Brisbane in yellow.

Not to be outdone, mission commander Gene Cernan joins in at 44:35 MET with his own interpretation of what he can see:

"...that big storm that Jack was referring to - that has moved off to the - well to the east of Australia. Very definite counter-clockwise rotation and then it stretches to the south or what even be the south-east. And then just rolls right - we...a big frontal pattern and then rolls right into another – another clockwise - clockwise rotating low down there near Antarctica. It gives me the impression of a parrot's comb when he's got his feather's ruffled. And it, in turn, has another low trailing it, arcing and then flowing into another - another low that is very near the continent down there in Antarctica. They form a chain, as I just described forming - coming from - well, possible south-east of Antarctica...South of Australia, you get a hint of a very large cloud mass, from there all the way down to Antarctica."

Cernan is trying to describe the front that rolls up from Antarctica towards New Zealand, heads westward towards Tasmania before merging with a thin front off Perth. Closer examination of the

Apollo image does show other systems with similar patterns below that large front, and the cloud mass is indeed fairly solid below that towards the ice sheets.

Capcom respond by referring to their ATS satellite image:

"...You might be interested; we've got an ATS map in here from this morning. Just - you're just about on - We can see the flow patterns in the Antarctic just about at 120 degrees west, which is a little closer to South America than what you're calling, I guess. But we do - we do see that activity down there."

Evidently the ATS images are available to them, but equally evidently the images they have are not as up to date as the Apollo descriptions. Cernan has a final contribution here:

"...and there is a very large cloudy air mass between Australia and Antarctica. It has a tendency to want to start a rotation, and can see a hint of that; it's not too strong right now. We're seeing about 3/4 of the Earth, I guess. Judging from our clocks and what we can see, it looks like the Sun is setting out over the west coast."

A couple of hours later, Schmitt resumes the commentary and describes the New Zealand front in more detail at 46h36m MET:

"...It looks like it's merging with some more weather to the south-east. I suspect it's stormy there, but I still - It's not a terribly well developed storm, although it seems to be broadening in its extent. Australia is completely free of any significant weather and almost completely free - free of clouds. The - there appears to be a front - although right now it does not look too intense - approaching from the south-west. And it looks like it's about 5 degrees of longitude south of the south-western tip of Australia. The typhoon Cirrus - or Therese, I guess it is - appears to be just about the same position it was yesterday. And that is north of Borneo and between Vietnam and the Philippines."

After capcom acknowledges that this matches their synoptic charts, he continues:

"...I need to make a correction. It looks as if that storm area that was in New Zealand yesterday has moved up across the two islands and is now sitting north-west. it's getting a little hard to identify the smaller islands in the Pacific, but - pretty sure I've got it in the right place now looking at the map. And it is north-west of New Zealand. and it looks like New Zealand is probably having reasonably good weather today, although I suspect it rained last night."

This time, capcom tell him they don't have up to date coverage of the area he's describing, so it's likely the previous agreement is for his identification of Therese (blue arrow).

Schmitt's appraisal of Australia's conditions are spot on. He identifies the thin front to the south-west (magenta arrow), and correctly notes that New Zealand is also out from under the clouds. Jack continues:

"...the front that's south of Australia now - I presume front - just looking at a fairly well-developed, although narrow, cloud line, is about 5 - about 10 degrees south of Perth right now, south-west of Perth and runs on a north-west - south-east line - over a point about 10 or 15 degrees south-west of Tasmania. And then it intersects a curved front that runs from there up to - to Tasmania, and then back around down south of New Zealand about 10 degrees.....we're starting to get...just off Luzon on the north-east trend...seen is a shadow line of fairly thick high clouds overlying some thick lower clouds behind the front."

His greater detail on the thin front shows we have correctly picked out what he was describing earlier, and the Tasmanian front we have identified using a yellow arrow is also very obvious. All of these antipodean systems are evident on the NOAA mosaic..

He then moves back to SE Asia, and the north-east trending cloud from the Philippines is identified here by a cyan arrow. Schmitt continues his description of Asian weather:

“...generally, South China looks clear. I haven't had a real good look at it yet, it's out on the limb. I's clearly, however, overcast over Korea and Manchuria. It does not appear to be frontal weather, though. The dominant front in the north-western Pacific stretches on a north-west line from just off Luzon on up as far as I can see to the terminator. And it seems to be an extremely strong front with what I would guess is heavy air-mass weather all along with it. And up to the east-north-east of Japan, there's an excellent example of a shadow line from some fairly thick high clouds on solid overcast of lower clouds.”

The main front he is describing there is the one picked out by the cyan arrow, and rather than “north-west” being the compass bearing, he means “north to west”, as this line of cloud does go from the Philippines area to the terminator. The 'shadow line' he refers to is close to the terminator, pretty much on the point of the cyan arrow, where the smooth lower level cloud to the left of the arrow point contrasts with the higher altitude 'lumpier' cloud mass to the right of it.

Capcom again tell Schmitt that they don't have all of the area he describes on their charts, but that what they do have matches what he's telling them. Schmitt then goes back to Australia and predicts heavy weather for South Australia in a few day's time. He then tells capcom at 47:43 (c. 05:15 GMT) that:

"I'm going to take two more pictures before I go to sleep.”

Followed at 48:00 MET (05:30):

“I got those pictures...that typhoon off - north of Borneo - looks like it's right off the coast of - the east coast of Vietnam now ,And it's about as tightly organised and solid as anything I can remember seeing in photographs. It looks as if, from yesterday, it's moved quite a bit to the west.”

So we have a pretty accurate time for the image under discussion of 05:30 GMT, and an examination of the Stellarium inset included in the previous figure shows that the distance between the terminator and Australia matches exactly what it should be, as does (allowing for the relative viewpoints of Stellarium and Apollo 17) the distribution of Asian land masses on the western limb.

The photographs to which he is referring are general pictures of hurricanes and tropical storms, not this specific one, although we do know that photographs of a nicely formed spiral Therese with a defined eye were around before launch. Therese has indeed moved west, and is due to make landfall in Vietnam in the very near future. Capcom's weather charts also show a tightly formed storm, and predict that landfall will be in another 6 hours time. Jack is even able to describe Therese as being roughly the size of South Vietnam, which is a reasonable estimate of its diameter.

Next up in magazine 148 is AS17-148-22749. This must have been taken some time after the previous image, as it now shows west Africa and south America, so the Earth has rotated some distance during the 'overnight' rest period.

The image itself is shown overleaf in figure 4.9.26, and the satellite analysis on the page after that in figure 4.9.27.

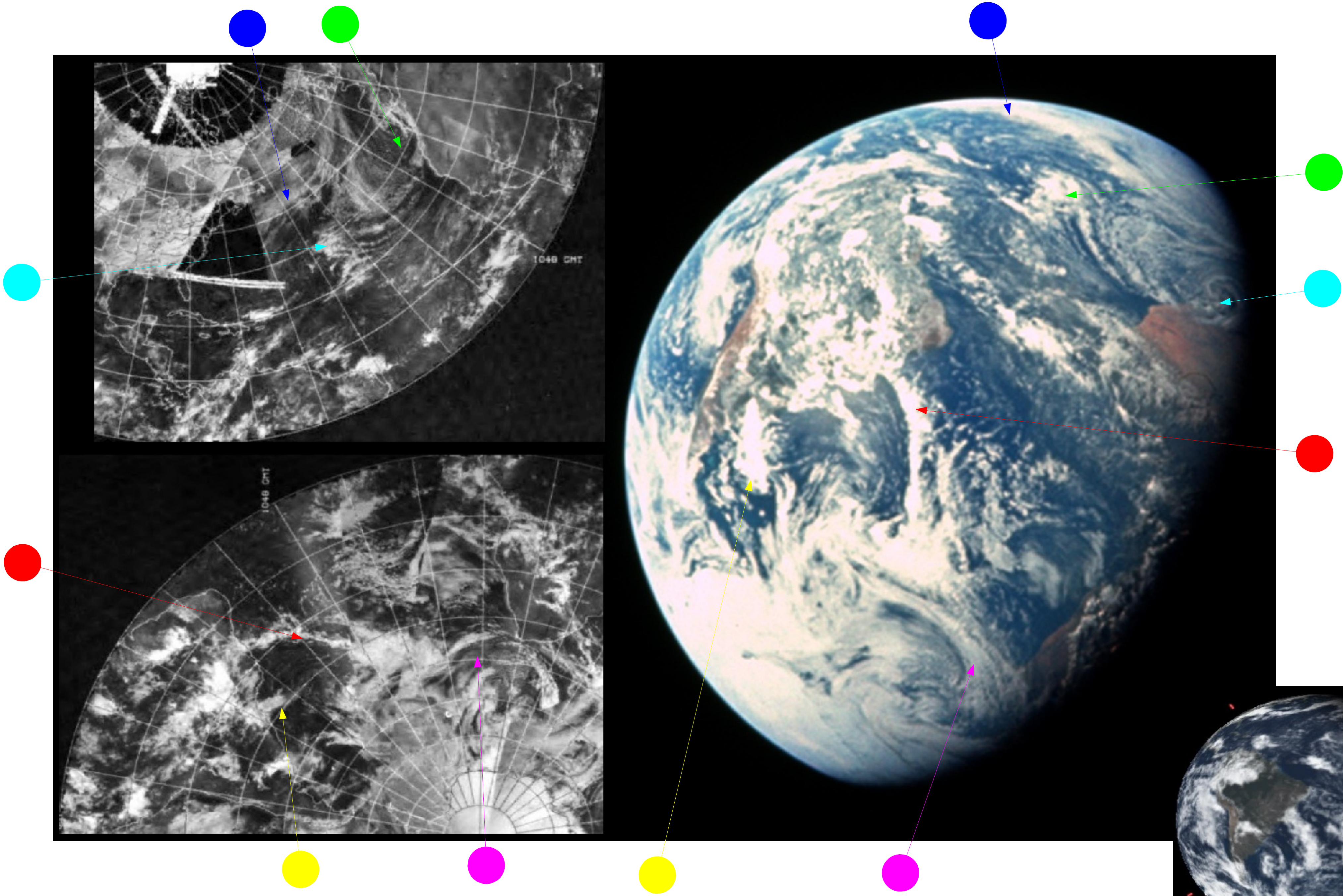
Figure 4.9.26: AS17-148-22749. Source: [AIA]

The terminator on the image runs almost through the prime meridian, at least in the northern Hemisphere, suggesting a time of around 17:00 GMT, and the time indicators along the edge of the NOAA mosaic suggest a time of noon on the 9th at that location.

The mosaic again suffers from very poor image quality, with lighter clouds difficult to make out, and a large data 'hole' in the north Atlantic off the coast of north America. Sub-tropical clouds southern hemisphere weather systems have fewer issues of this type.

As far as the weather systems themselves are concerned, we again have Jack's observations, found at 58h39m MET in the transcript:

"...That...fairly big storm - that was off the coast of north-west Africa yesterday, has moved inland and presumably is giving those people up there some weather. Might even be getting some snow up in the Atlas mountains. It's still fairly well organised and inland a few hundred miles - or the edge of it is inland a few hundred miles. The people at the Cape of Good Hope ought to be seeing some clouds that are forerunners of a large circulation system that's south - south-west of them - that, although large, it seems to have most of its heavy clouds to the south-east of the centre. And they may not be get any major weather out of this one. But they'll probably have cloudiness for a few days. the storm that was over Buenos Aires yesterday has apparently moved out to sea and is now west - or east-south-east of that area. Otherwise the - except for those three storm areas, the South Atlantic looks relatively calm."



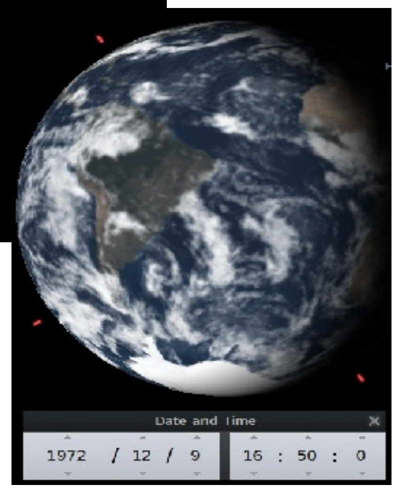


Figure 4.9.27: AS17-148-22749 compared with NOAA satellite mosaic and Stellarium estimate of time at terminator.

Schmitt's description of the large and spectacular frontal system that used to be in the north Atlantic is again accurate, and it is interesting to note that while his description (and the observable reality of the photograph) find the leading edge of that storm (indicated by the green arrow) inland on north Africa, it is still on the shore 5 hours or so earlier in the NOAA mosaic. The tight central spiral of cloud is also not visible on the NOAA image, but it is possible that NOAA's sensors and/or the mosaic compilation process have not used the required level of detail to see what are obviously thin clouds.

The large system he identifies off the Cape of Good Hope is picked out by the magenta arrow.

The other system picked out by Jack is the one that was over Buenos Aires, which is picked out here by the yellow arrow. In the Apollo image this storm has moved almost completely out to sea, as Jack describes, but in the NOAA mosaic it is still half over the Argentinian capital.

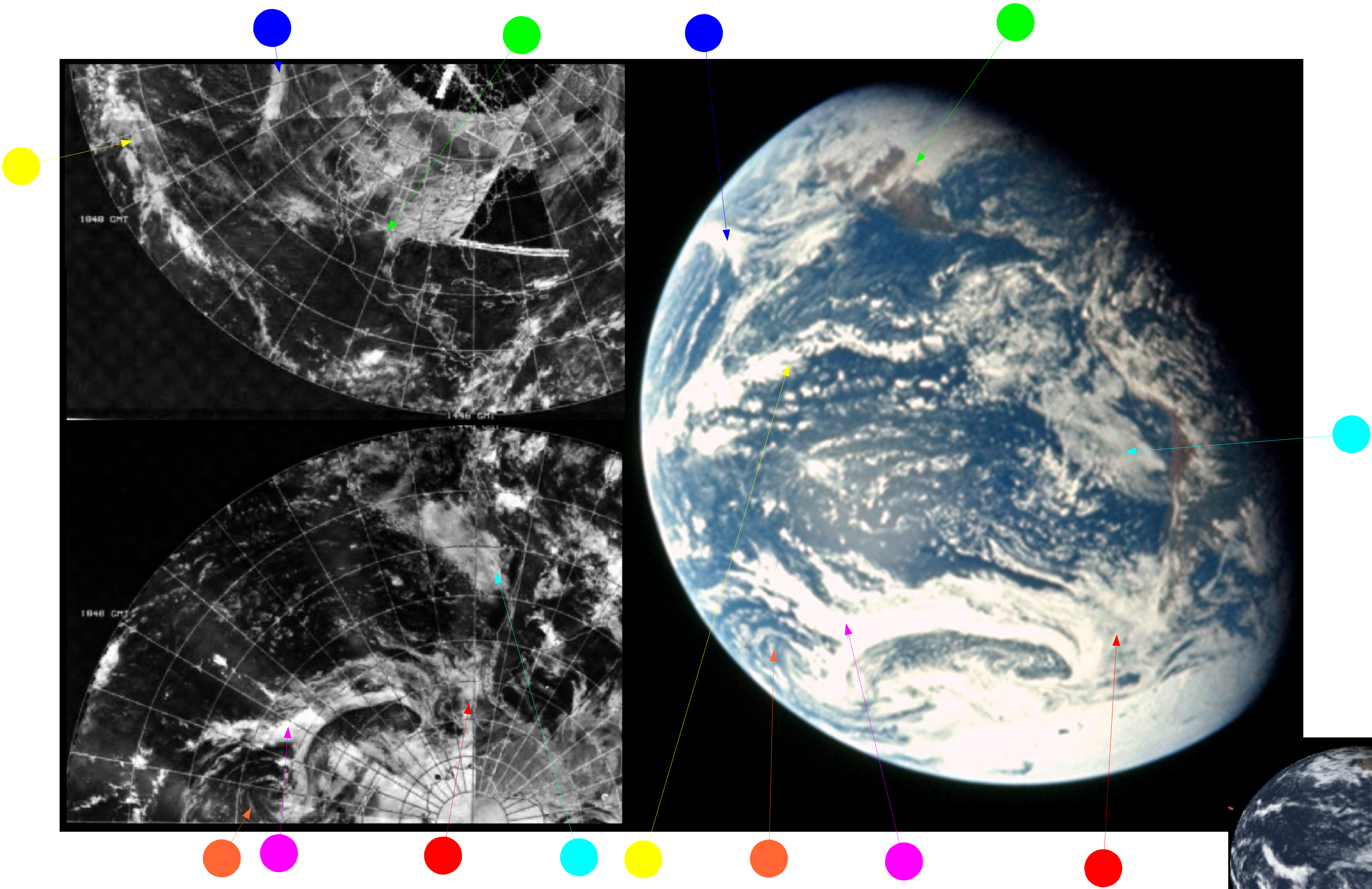
A few moments later, at 59:20 MET-, or 16:50 GMT, Schmitt tells us that:

"I took three pictures of the Earth. I thought I might have moved one of them"

The image used in this particular analysis is indeed one of three, rather than the pairs of images Schmitt has been taking to date. The time he specifies there confirms the earlier rough estimate of about 17:00 for the time at terminator, and 16:50 was used to derive the Stellarium image, which shows a perfect match in terms of what land masses can be seen.

The next images in magazine 148 show the the CSM as viewed from the LM, as Cernan and Schmitt carry out some telemetry checking from the LM. Following this sequence of pictures, the next one of Earth is AS17-148-22758. This is shown in in figure 4.9.28, and analysed in figure 4.9.29. As will be seen, Nikon image was taken at the same time (AS17-162-24071), and this is shown in figure 4.9.30, with the same arrows used to analyse it in figure 4.9.31.

Figure 4.9.28: AS17-148-22758. Source: http://www.lpi.usra.edu/resources/apollo/images/print/AS17/148/22758.jpg



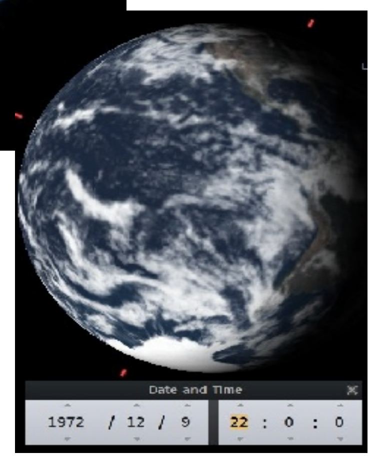


Figure 4.9.29: AS17-148-22758 compared with NOAA satellite mosaic from 09/12/72 and Stellarium estimate of time at terminator

Figure 4.9.30: AS17-162-24071. Source: AIA

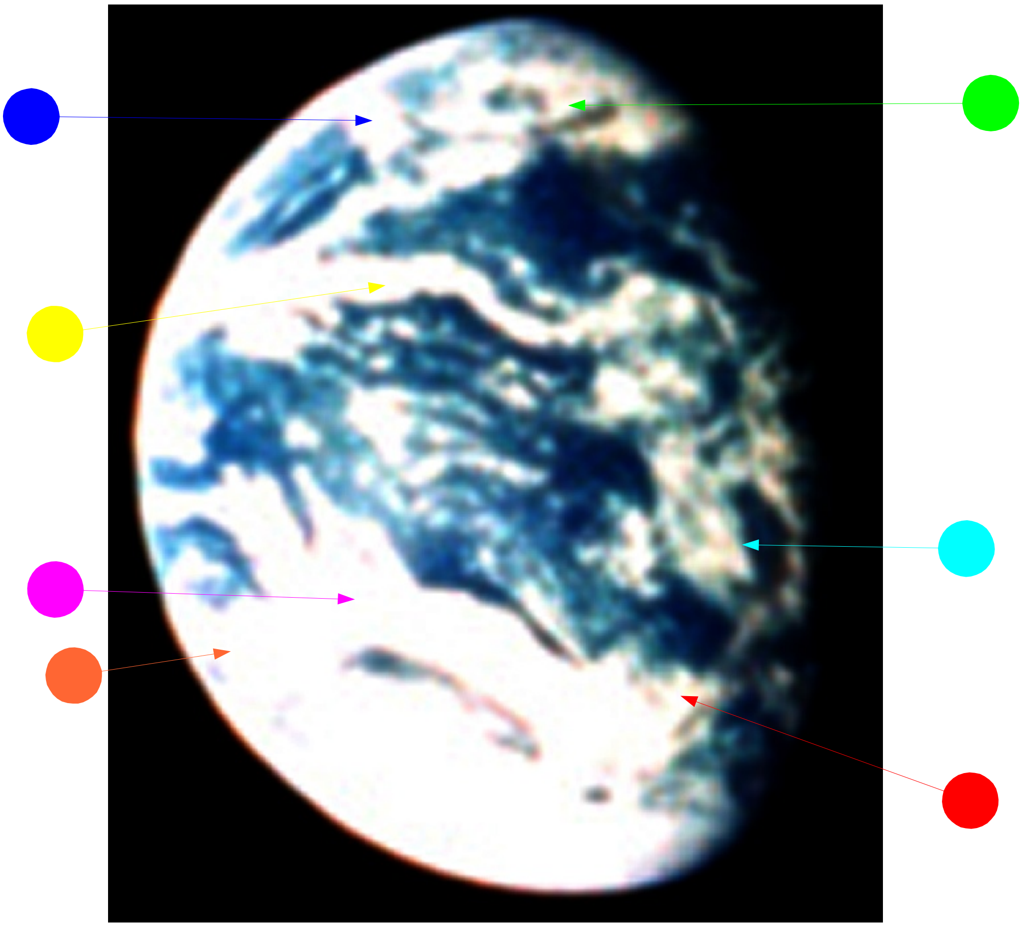


Figure 4.9.31: AS17-162-24071 analysed using the same colour coded arrows as in figure 4.9.29.

Before seeing what Cernan and Schmitt have to say about their view of Earth when these were taken, NOAA should be given a quick examination. The image used is from the 9th of December, and for once the quality of the cloud representations is roughly equal between the hemispheres, although there is a substantial gap off the east coast of North America. For this photograph this gap is of no consequence as it is that part of the Earth is no longer visible.. The two most obvious features are the large loop of cloud from the Antarctic up towards Australia, and the '<' shaped twin bands of clouds stemming from the western Pacific towards California and south America. The terminator line just on from the US east coast would have been scanned by NOAA at roughly 15:00 GMT.

As for Apollo's image shows us, it is Cernan who takes up the narrative at 62:52 MET (roughly 20:30 GMT):

"It looks like Houston might be right on the fringes of either being clear or clearer. The entire Gulf is pretty nice. Florida looks pretty clear, and Mexico looks pretty clear. There's a but air mass of clouds that looks like it picks up somewhere around the coast at Houston, heads on up north, and then covers most of the mid-west and the east - from about the middle of Mississippi, Alabama and Georgia on north. It's clear enough now to even see the coral reefs down off of Florida. And it looks like west Texas is probably also pretty clear, at least in a run from east to west. We can see Baja, and on up the coast of California up north."

His description is, as expected, an accurate one. The cloud mass covering Houston and northwards is picked out by the green arrow, and his assessment of the clear areas matches what we can see. Schmitt then takes over the narrative, effectively repeating Gene's description, before commenting on the southern Hemisphere:

"One of the more unusual features is developed - as I see - developed in the south-east Pacific just north of the Ross Sea and that is a very striking mushroom pattern on a very large scale. It has north/south clouds streaming streamers from the Ross Sea. And when it gets up about the latitude of Tierra del Fuego, but quite a bit west of that land, it branches out to the east and west in a large mushroom pattern. And it looks like the top of that mushroom may be a curved cold front that's pushing its way up into the south-east Pacific. It currently - the eastern edge of that front is probably 10 degrees longitude from Tierra del Fuego, and it looks like that land in southern Chile is picking up high clouds, probably associated with that front's movement. I'll get some shots of that next time around. That's a spectacular pattern."

The mushroom pattern is the system identified by the magenta arrow, and again the description is very accurate, right down to the 'streamers' that head northwards from roughly where the magenta arrow head is., and the high clouds mentioned next to Tierra del Fuego are marked by the red arrow.

After a brief discussion on whether he can see any changes in the Ross Sea, capcom given another mention of their use of satellite images, saying at 64:21 MET:

"I'm looking at a satellite picture here, which I guess is about 12 hours old though. But over to the east of Australia, maybe abut a continent width east of Australia, there is really striking long frontal system - striking because it's so long and so straight, sort of west-north-west, trending west north-west and east south-east trending. Can you see that?

Capcom's description matches what Jack & Gene have already described, but his ATS image must lack the detail of their monocular view of a colour Earth.

At this point Gene takes over again, and discusses the various sub-Antarctic systems he can see:

"Now Jack and I may be talking about two different frontal systems or patterns, but the one I think you might be referring to is the one I referred to yesterday as a ruffled parrot's beak. Actually two of them tied together, one starting up probably south-east of Australia and - and then heading down with a long arcing frontal system to another clockwise rotational parrot's - parrot's comb, I should say, down around - near the tip of South America, between it and Antarctica. There is one strong tributary front heading up to the north-north-west from the western side of this big, arcing, frontal mass. I'm not sure, I can't quite see Australia coming up over the - over the horizon yet."

Gene is right in thinking that this is the same weather system he described earlier, and all three of them are describing the same system, but Jack's "mushroom" analogy is the better description of it. Capcom tells Gene that his ATS image doesn't go as far south or west as far as he is describing, after which Gene continues to describe the same system:

"There is some tremendous - western side of that curve front is a tremendous clockwise rotational airmass. It must cover hundreds of square miles. The one down near - near the continent of Antarctica, down there, near the tip of South America, seemed to be squashed slightly as if there is possibly some - some squashing or effect coming off - off the South Pole near Antarctica. I think, if I turn around and look at it the way Jack was looking at it, it's a cap of a mushroom. Only instead of simply curving in underneath the cap, it has clockwise rotations on both sides as it curves under."

In this passage Cernan first describes the system marked by the orange arrow – where there are several circles of cloud at one end of the 'mushroom'. The other system he mentions is at the eastern end, just below the clouds marked by the red arrow.

Confirmation of the timing of the Apollo photograph comes from Schmitt at 64:28 MET, when he says that:

"I just took two pictures of the Earth"

and after another brief exchange about what capcom's ATS image covers goes on to give his description:

"...that mushroom pattern we've been talking about, on either edge - either end of the cap - and the mushroom points north - is a major cyclone circulation system. And also taking - moving, in one case - or trending, in one case, to the north-west and the other to the north-east, there are some linear cloud patterns. Gives it a very symmetrical and a striking appearance."

A few moments later, Jack confirms that he has taken some more photos of Earth with the Nikon:

"just took a series of the Earth with the 35-mm using the polarising filter"

So we have both Gene Cernan and Jack Schmitt describing weather patterns, many of which are not available on capcom's ATS images, showing an Earth that matches exactly what should be visible according to Stellarium. The weather systems they see and describe are matched by NOAA's satellite mosaic.

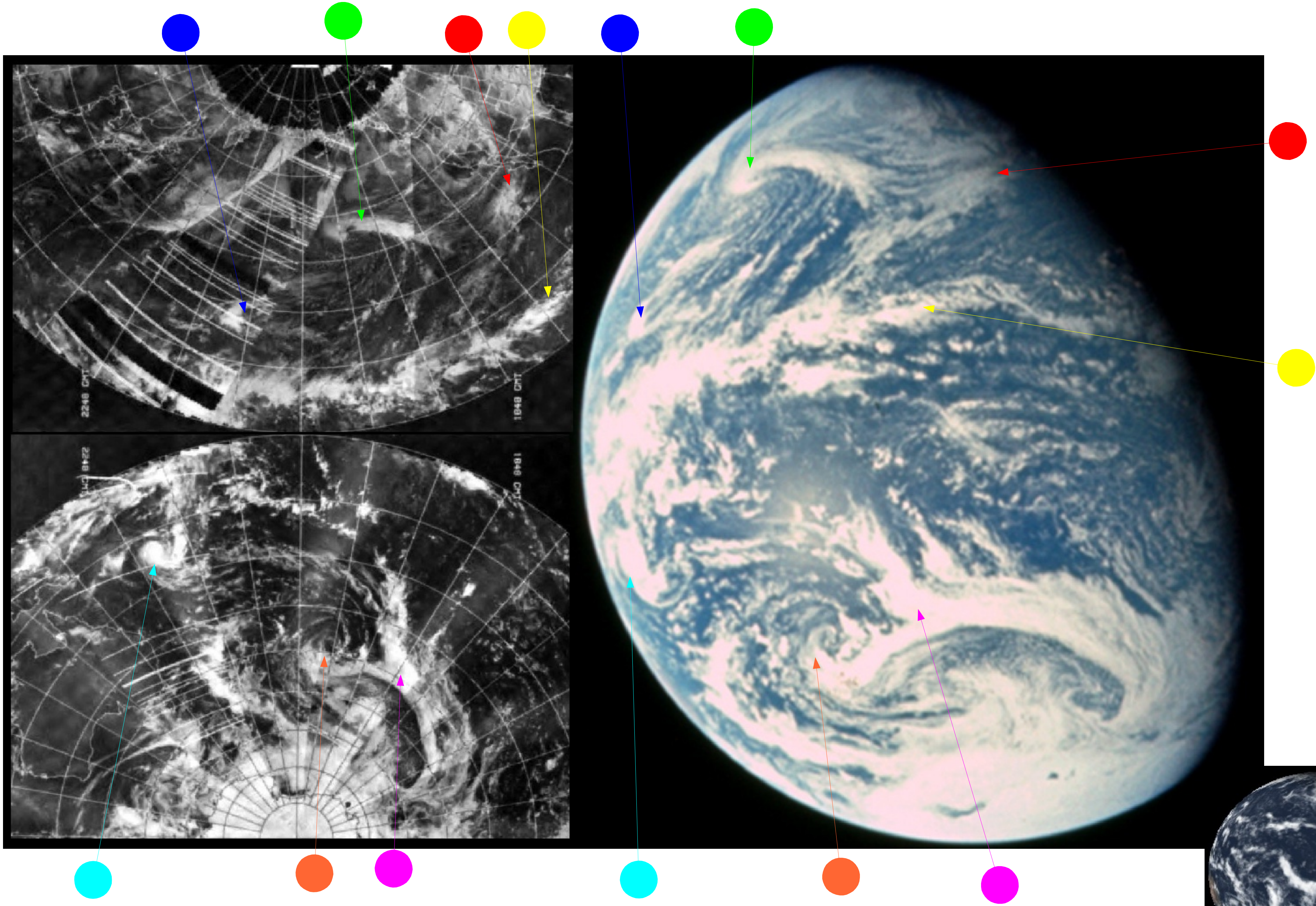
The timings given for the remaining images in the mission are open to some confusion, as there was an update to the mission clocks during TLC. Updates to the clock were done where, for example, a launch delay introduced a a lag between the planned time of events for the mission (eg ultra-violet photography, EVAs) and the actual time thanks to the delay. The aim of changing the clock was so that the time shown on the mission clocks (usually referred to as GET, or Ground Elapsed Time in the transcripts, but what this research has called MET) was synchronised with the events programmed into the flight plan. It is analogous to the change in the clocks for daylight saving time.

Technical problems during the countdown sequence for Apollo 17 introduced a substantial delay to the flight plan, and as a result at 65 hours GET 2 hours and 40 minutes were added to the mission clocks. This event is referred to in both the timeline and the mission transcripts referred to here, but there is no apparent alteration to the actual times recorded. It is assumed that times referred to by capcom and the crew are the adjusted times, while the times recorded in the documents themselves are the unaltered original elapsed times. Certainly when photographs are recorded as being taken, the recorded times match those derived from Stellarium, rather than the time 160 minutes later. The analogy here is that, for example, the astronauts are using daylight saving time, but all the documents continue to record GMT.

Having accounted for any likely discrepancies in what the various mission personnel may say and when they are recorded as saying it, we can move on to discussing the next image in the sequence.

That image is again from magazine 148, and again there is much narrative description of the view they have as the image is taken by Cernan and Schmitt. The photograph in question is AS17-148-22760. This can be seen below in figure 4.9.32, and analysed overleaf in figure 4.9.33.

Figure 4.9.32: AS17-148-22760. Source: AIA



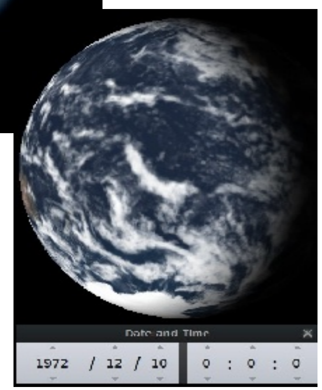


Figure 4.9.33: AS17-148-22760 compared with NOAA satellite mosaic and Stellarium estimate of time at terminator

The absence of South America but the persistence of the 'mushroom cloud' shows that this image was taken not long after the previous one, and therefore the NOAA mosaic is still the one dated the 9th of December. The similarities between the Apollo photograph and the NOAA mosaics are still obvious, and the reader should, as usual, have no problem identifying any particular cloud from Apollo in the NOAA image. The time markers on the mosaic suggest that the area around the terminator was scanned at around 17:00 GMT on the 9th.

As far as the crew's observations are concerned, they begin at 65:24 MET (or c. 22:55 GMT) while Jack is using the polarising and colour filters available with the Nikon camera, when he makes the following observation:

"..there's a very strong band of clouds, shaped sort of like a narrow fir tree, with a base about 20 degrees of longitude west of Baja California, that extends up to, I believe, into the vicinity of Hawaii. And the top terminates in a very strong northern cyclone pattern."

The 'fir tree' analogy describes the cloud formation identified here by the green arrow, and is perhaps easier to understand if the globe is viewed from the same angle as astronauts were seeing it. The strong cyclonic pattern he describes is where the green arrow head is.

Capcom are able to find (after first misunderstanding Jack's description of the location) on the satellite image they have available, and also on their synoptic charts. The term actually used is *"from one of our satellites"*, which is an indication that other satellite images may be available in addition to the ATS ones.

Jack gives us more details on this cloud formation at 66:56 MET (c. 00:30 GMT on the 10th)

"... that line of clouds I called a fir-tree pattern that swings up towards Hawaii - Hawaii, if you will - has - also has a mushroom pattern on the top. it has the appearance is if two major air masses - one going from west to east and other from east to west - have converged along that line, and the joint movement of air at the interface being south to north. And up in the area of Hawaii, I think it tends to mushroom so that the pattern then goes back to flow from west to east on the east side and from east to west on the west side....in a little while, we'll probably get a pretty good look at a - what looks like a very concentrated intense storm that, I think is just east - east ..."

The use of the word 'up' needs again to be taken in the context of the upside-down view the astronauts have at the time, but the description is again detailed and accurate. Unfortunately the description is interrupted by the need to go over details for the up coming LOI manoeuvres, so we won't know which storm he was about to describe, but it's possible that it is the one marked by the cyan arrow, which is east of Australia.

Schmitt doesn't mention at the time when he took the picture of the scene he is describing, but he does mention it sometime later. He was describing the view just after completing an experiment designed to explore what was believed to be the influence of cosmic rays on the crew – the widely reported phenomenon of 'light flashes' seen on the retinas while they had eyes closed or blindfolded ready for sleep. He says, at 68:44 MET (c. 02:15 GMT):

"I took another picture of the Earth and forgot to give you the GET on it. That was about 15 minutes before the end of the [light flash] *experiment."*

The light flash experiment ended at 00:12 GMT, which supports the Stellarium estimate of midnight for the time of the image.

The next image of Earth in magazine 148 is one of a pair showing Australia taking more centre stage. Image AS1-148-22762 is shown below in figure 4.9.34, and analysed on the following page in figure 4.9.35.

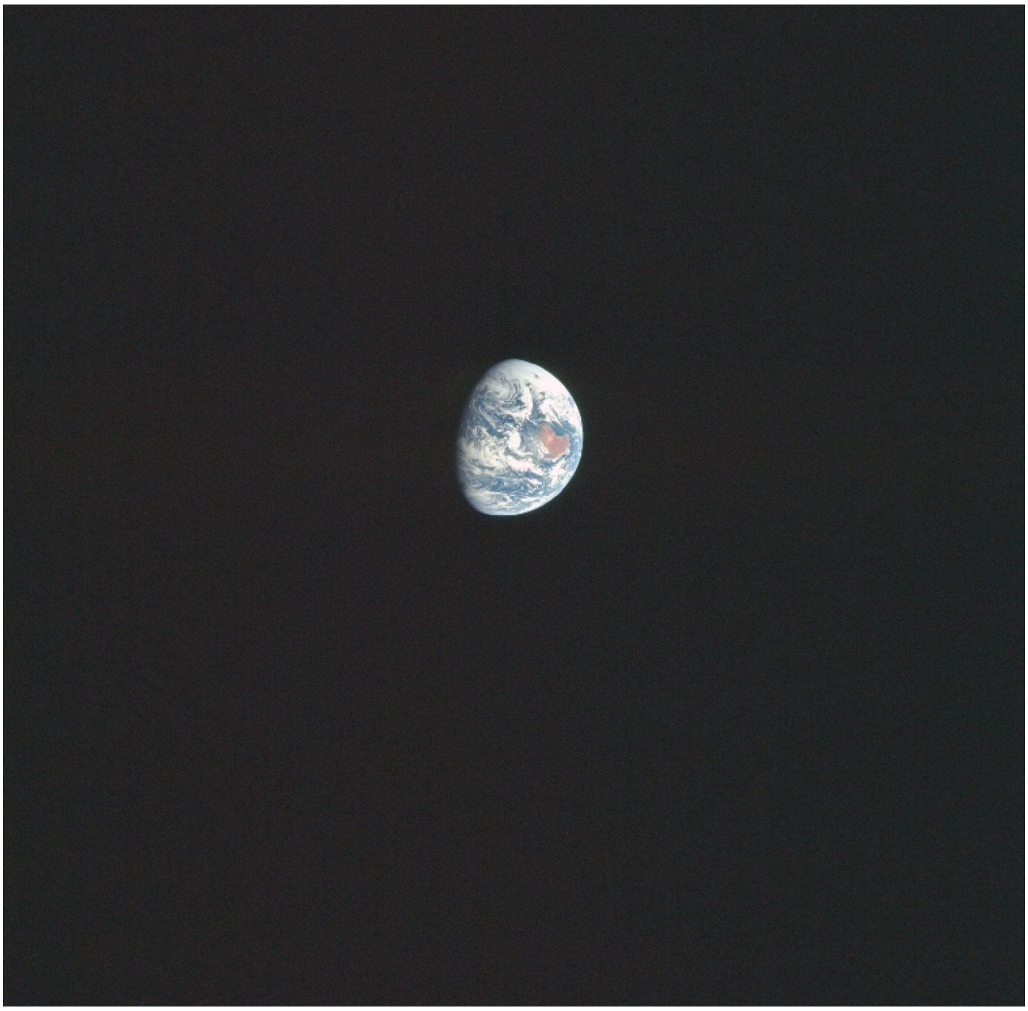


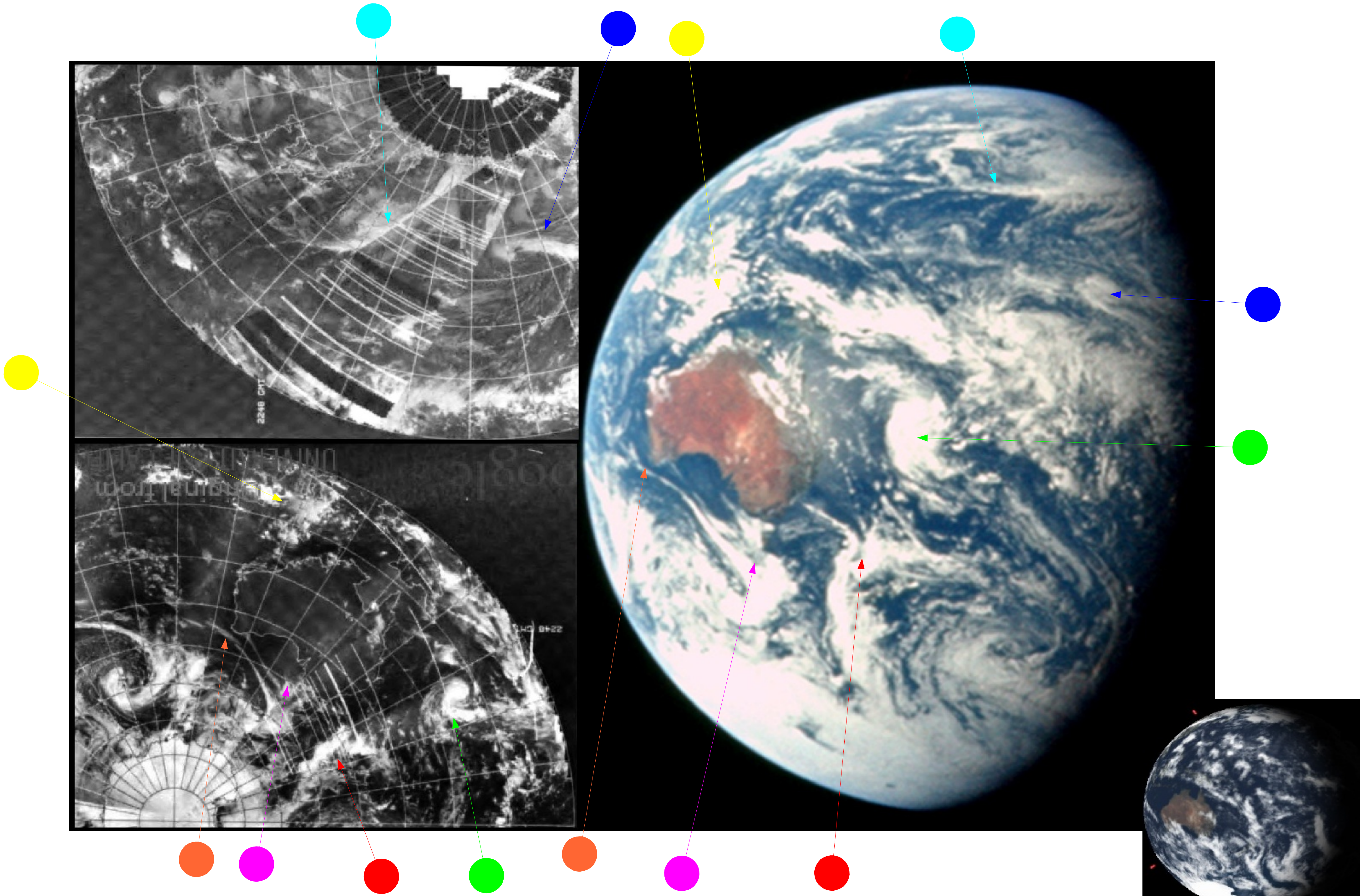
Figure 4..9.34: AS17-148-22762. Source: AIA

The NOAA image from that the 9th does have quality issues for a large part of the Pacific and Australasia, but the underlying cloud pattern is still visible. A rough guideline for the time the terminator region was scanned would by 21:00 on the 9th. The cloud patterns visible can be found easily on both NOAA mosaic and Apollo image, and some features (notably the clouds identified in figure 4.9.33 by the blue arrow). The storm system shown by the cyan arrow in figure 4.9.33 is identified by a green arrow in figure 4.9.35, and the front shown by the red arrow in figure 4.9.35 appears to the east of the system identified by the orange arrow in figure 4.9.33. An estimate of 03:30 has been given as the time of the Apollo image.

There is therefore, as usual, an obvious continuity between the images.

The crew's description of the view begins some time before the suggested time of the photograph, with Schmitt beginning his narrative at 67h31m MET (c. 01:00 GMT):

"...The coast of Australia is starting to come into view. Still looks pretty clear. We'll give you more that later, probably. That cyclone I talked about yesterday in the vicinity, I believe of the Solomon Islands, looks even better organised than yesterday. It's really tightening up. Starting to look very



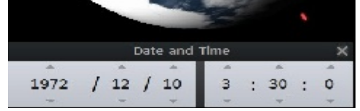


Figure 4.9.35: AS17-148-22762 compared with NOAA2 mosaic and Stellarium estimate of time at terminator
Blue arrow as in figure 4.9.33

bright and dense right in the core, not too dissimilar from Therese. Although it has a little broader extent in the south-east quadrant.

The Solomon Islands are in the region of the large cloud mass identified by the green arrow, and after capcom state their difficulties finding it, he confirms that it is the system he began to describe before he was so rudely interrupted to be the tedious business of organising going into orbit around the Moon.

Although the photograph analysed shows Australia very obviously in view, Stellarium users can easily confirm that it would be appearing on the western limb at around 01:00 GMT.

Capcom are then able to find the storm:

"I've got a pretty disorganised area to the east of New Guinea. It's probably right over the Solomons. looks pretty disorganised on our satellite photo - from, let's see, i guess that was this morning sometime."

As usual, the ground personnel have access to satellite images, but they are relatively out of date.

At 67:49 MET (c.01:20 GMT) MET, after capcom asks if New Guinea is in for bad weather, Schmitt resumes his description:

"No, not really. New Guinea is at the western edge of a cloud zone that is part of that inter-tropical convergence zone that starts at New Guinea and swings east north-east in an arc for about half the visible Pacific, and then that arc crosses back down over the equator and heads generally towards Central America, I suspect, although that's beyond the terminator. The storm I'm talking about is clearly south and separate from that inter-tropical convergence cloud - pattern...it's getting very tightly wound in the - the clockwise sense, and - and is - is just where there was a less well-organised pattern yesterday. Although maybe it's moved northward a little bit....just one last thing on that line of clouds that stretches up towards Hawaii. They're very - they look very thick and dense based on the structure you can see as that - as the terminator approaches them. They cast a pretty strong shadow to the west."

He correctly picks out the location of Papua New Guinea and the ITCZ cloud under which it is hiding. The Solomon Islands weather is below that cloud, and the storm itself is probably Tropical cyclone Diana, described in this link: Australia Severe Weather. The storm track shown in the link suggests it was around from the 6th and persisted throughout most of the mission. Unfortunately no other information seems to be available about this storm.

The line of clouds he mentions running towards Hawaii is likely to be the one identified by the cyan arrow, and again capcom confirms that they are visible on a satellite photograph.

At 68:48 MET (c. 02:20 GMT), after more discussion on the Ross ice sheet changes and the sub-solar point and the precise location of Hawaii, Jack returns to the antipodes:

"...that weak front that I talked about south of Australia yesterday has moved north, but it looks considerably weaker than it did yesterday even. Just a very thin line of clouds - very thin line of clouds that is touching the - the tip of Australia, south of Perth."

This particular one is the system identified by the magenta arrow in figure 4.9.25, and it has evidently got much thinner since that photograph was taken, although it is not quite touching land just yet.

Capcom again point out the shortcomings of the data they have available to them in response to this:

"...I can't tie up with you in that one, Jack, because my prog doesn't go down that far; it only stays up in the landing area. And my satellite photo doesn't go down that far south either."

Thus confirming earlier suggestions that the ground personnel would have information relevant to their part in the mission, rather than global data ready to cover any point the Apollo crew may wish to discuss. Capcom's role was not to prompt the crew to describe what they could already see on the ground, it was to have information about the launch and re-entry. They were also not in a position to confirm every observation Apollo 17 made.

Jack's response to this is:

"OK, well it looked stronger yesterday, and it might have developed. Now there is a larger disturbance at the south-eastern end of that front, still south of Tasmania..."

and he is therefore describing the much larger cloud formations shown by the magenta arrow in the current image.

He then returns, at 68:53 MET, to tropical cyclone Diana:

"...that disturbance over the So - Solomon Islands is an awfully tightly wound little storm system. And right now, I finally have see New Zealand for the first time in a couple of days for sure. And the South Island's got some, probably high cirrus over it. North Island looks pretty clear."

New Zealand is nestling in the arc of cloud shown by (and just to the east of) the red arrow,. It requires some zooming in to see that, and this is something Jack is able to do using the sextant, which he describes as a fine instrument, and better than the binoculars he has also been using.

Much of the discussion after this point refers to local weather conditions and sea state around Hawaii, but he does return to wider issues with:

"...that major front we talked about last night as being east and south of Japan has progressed even farther and is, oh, maybe 20 degrees longitude - about 20 degrees longitude from the Hawaiian islands."

It's not immediately obvious which front he is referring to, but in the vantage point of the image Japan is on the north northern part of the horizon, while Hawaii is in darkness over to the east. This makes it likely that he is descrbing the cyan arrowed band of relatively thin cloud stretching horizontally (as portrayed in the preceding figure) across the northern quarter of the photograph.

Capcom confirm that this is shown on the satellite photograph and charts, before Jack briefly describes the clear sky over Australia.

At 69:21 MET, Jack makes an interesting comment:

"...I hope you're going to save all those charts you're gathering together as we talk about it on this outbound leg. Be interesting to compare them, and the pictures we take sometime in January."

Capcom confirm that the 'weather people' are very keen to do just that, and it would be really interesting to know if this meeting and its results are recorded anywhere.

As a brief aside, Schmitt does give some insight into his meteorological interest in an oral history interview that many astronauts gave many years after the missions, available on this website: Oral History .

He describes his fascination with the changing views of Earth as it receded, and then he is asked how he it arose that he took on the role of meteorologist for the mission. He describes his childhood interest in the subject before going on to say:

"as I approached the launch, I started talking with the Air Force meteorologist at the air base that supported the launches down in Florida {Patrick Air Force Base}...They got interested in this, and so just as I suited up, one of my friends with that group brought in the latest satellite pictures that covered the Earth, that gave me the whole southern hemisphere of the Earth. So I had those in my pocket as we went out to the launch pad.

I had planned, and we had talked about it, that in my spare time on the three and a half days to the Moon I would try to build on those, what those satellites pictures showed, primitive as they were, and try to experiment with how well could I forecast the weather, because the Earth in what we called a lunar reference trajectory, we would see the Earth turn every twenty-four hours beneath us. So you could see what the weather pattern was, try to predict the trend for the next day, and then see how well you did the next day.

Of course, we were getting farther and farther away and the Earth was changing from full to about two-thirds. But we had a 10-power binocular on board, so you could look out the window and see it. So all of that several inches of transcript was me exercising that little experiment, because there really wasn't much else to do, except try to get a little exercise and eat and check out systems. But it certainly was not a full day's work any one day.

Interestingly enough, somebody just recently has contacted me and they want to put together a journal of that particular phase of the mission, which is not in the [ALSJ]... So I think we're going to see a Web-based version of that transcript. I can't believe it's going to be of any great interest to anybody, but we'll see."

Well, Jack, it certainly has been of very great interest! It's useful to know that he did have some satellite photographs with him – he evidently had something to work with from the start, but it's also informative that he says quite clearly that those images were primitive. It's also useful to know that he only had images of the southern hemisphere, which of course is the only part he would be able to see at the outset of the mission.

Returning now to the Apollo 17 mission; as with the previous image, Jack doesn't record immediately when he took the image we have just discussed, but after a rest period the following day at 79:44 MET (c. 13:20 GMT) he says that:

"I just completed two pictures of the earth about 5 minutes ago. And there's one I did not report late yesterday about 72:30."

We need to remember here that this time is actually 2 hours and 40 minutes later than the actual time of the photograph, so this would convert to an MET (as used here) of 69:50, or around 03:30 GMT, the time used by Stellarium.

This quote also provides a useful reference point for the next image to examine in magazine 148, AS17-148-22763 (see figure 4.9.36).

Figure 4.9.36: AS17-148-22763. Source: *AIA*

As this image features the whole of Africa, and therefore the dividing line for the start and end of new satellite mosaics, there will be the same issues of interpretation as previous images of Africa.

The analysis of that image, containing the NOAA mosaic, can be seen over the page in figure 4.9.37.

It's fairly easy to tell where the join is between the start and nd of the mosaic started on the 10th, and the estimated time that NOAA would have scanned the terminator is around 07:00 on the 10th.

We may as well see what Jack has to say about the view, seeing as we know he will have done. He starts at 78:59 MET with this:

"...we got a pretty spectacular view of - of Africa today. We can see the Sinai, can see the Red Sea, the Sea of Aden, and for the first time I think we can not only see the Mediterranean, but we an see the - most of the Southern European countries, Turkey and Greece and up into Italy and some of those places, can't quite see Spain because you're just about on the horizon. And for the most part, it looks like the weather throughout the Mediterranean and Northern Africa looks pretty good."

So far so accurate, there is indeed more of Europe on display than in previous views of this type, certainly in comparison with the classic 'Blue Marble' image, although his inability to see Spain may be more influenced by the cloud over it than its position on the horizon.

It's after this initial comment that he records taking his two pictures of Earth, and these are the last two on this magazine before the landing, and only one more image of Earth is recorded on it during TEC.

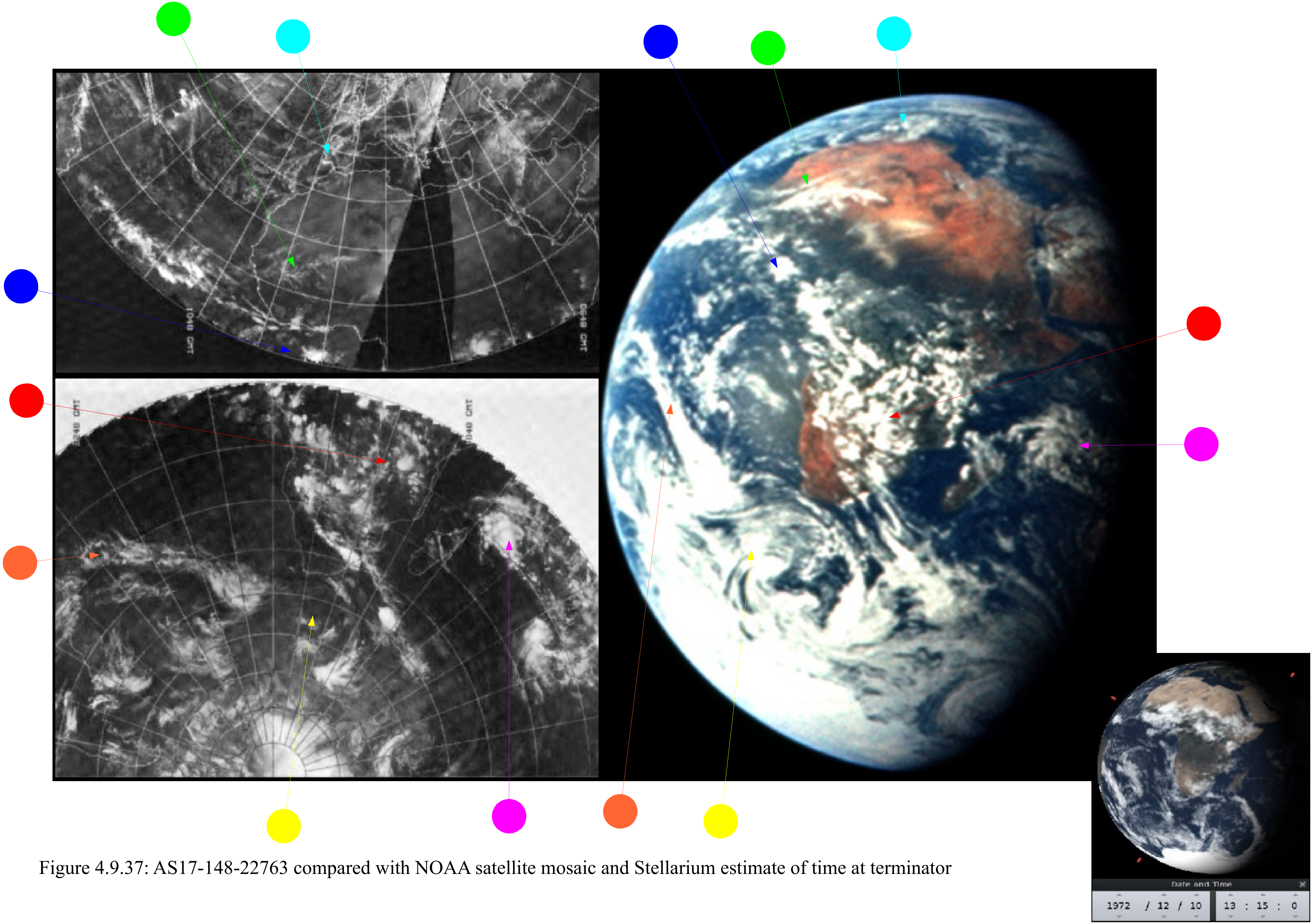


Figure 4.9.37: AS17-148-22763 compared with NOAA satellite mosaic and Stellarium estimate of time at terminator

As far as the rest of the weather conditions are concerned, he continues at 79:56 MET with:

"...That storm I talked about yesterday that was in North Africa, looks like it has left the area and has moved in - maybe, of it's there at all, it's just over the - Iberian Peninsula. And maybe Gibraltar and that area is getting a little activity today...the storm I guessed yesterday - I thought might be moving into the Cape of Good Hope looks like it's dissipating and also staying south of that area. The whole of Africa is essentially clear, except in the southern part of the inter-tropical convergence area where there's scattered patches of - of fairly dense clouds. They're probably getting scattered rain showers this morning. Some of those extend farther down south than I've - than we've seen them - down into South Africa. There's a - On one of the earlier revs, although now it's at the terminator, it looked like there was a depression developing about 30 degrees longitude east of Madagascar in the middle of the Indian Ocean. A little bit north-east of Madagascar, there's also a new area of clouds developed that looks like it's getting organised into a cyclone pattern."

The initial description is correct, and the storm over north Africa has gone, but it may have moved north as there are just visible circular bands of cloud on the horizon and on the satellite image, picked out by the cyan arrow over the Iberian peninsula (he has now realised he can see Spain).

Storm south of the Cape (yellow arrow) that started to the south-west has now moved to south of it and is not as prominent as it was before, and this is also reflected in the NOAA mosaic. The red arrow, rather than picking out a specific cloud or storm, is pointing to the general area of the ITCZ clouds in the southern half of Africa.

The depression he describes north-east of Madagascar is shown by the magenta arrow, and a quick examination of the same system identified on the NOAA mosaic shows that it has consolidated by the time that area is imaged at the end of the 10th. The front to the east of Madagascar is just on the terminator and has not been identified here, but it is visible on the NOAA mosaic which does include areas beyond the terminator line.

An hour later, Jack has more to say, this time about the southern Africa and the South Atlantic:

"...it looks like the cloudiness and possibly the showers associated with the inter-tropical convergence over Africa are moving as far south as Johannesburg right now. It's quite a distinct change from even an - an hour or so ago - a couple of hours ago. They're down in an area where, presumably, they're not normally found if vegetation indications are any criteria. And also, in the Atlantic - South Atlantic near Goa Island, there seems to be a possible storm developing as part of what was probably now a fairly weak front."

and 15 minutes later still:

"That weak front I mentioned in the South Atlantic stretches from the apparent storm centre around Goa Island...up to the coast of South America from Brazil, where it reaches its maximum eastward extent."

The words 'Goa Island' have been taken directly from the transcript, but Jack clearly means 'Gough Island', which is in the South Atlantic (not Goa Island off Mozambique) – he does say that he is unsure of its pronunciation. It is, at least, in the correct place as the starting point for the large band of cloud marked by the orange arrow.

90 minutes after this last observation, magazine NN, ore number 148, is stowed away for the time being, and we will move onto other magazines, at least until the journey home.

The next image viewed is from magazine 149. This magazine evidently stayed on board the CSM during the mission as it contains pictures of a returning LM. The photograph in question is AS17-149-22779, the clearest of a series of 3 identical images of Earth at the start of the magazine. No high quality version of the image could be found online, and so the one used was obtained from the GAP.

The image itself is shown below in figure 4.9.38.

Figure 4.9.38: GAP scan of AS17-149-22779. Low quality source: *AIA*

The analysis of this image is shown overleaf in figure 4.9.39.

The first point to make about the satellite comparison is that southern hemisphere data for the mosaic in the visible spectrum are missing. In order to compensate for this, the mosaics for the IR spectrum are included. By and large, these show the same cloud patterns as the visible one, but it should be remembered that colder clouds will not show as well as warmer ones, and warm air masses will also be included in the image. IR scans are done during the dark parts of the NOAA orbit, and therefore have different time values to the daytime visible spectrum passes.

It will also be fairly obvious that the Apollo image is not of the best quality, and has been affected by camera shake.

The terminator position is estimated as being at around 19:00 using Stellarium, and the time at terminator on the NOAA mosaics is roughly 23:00 on the IR spectrum and 11:00 for the visible.

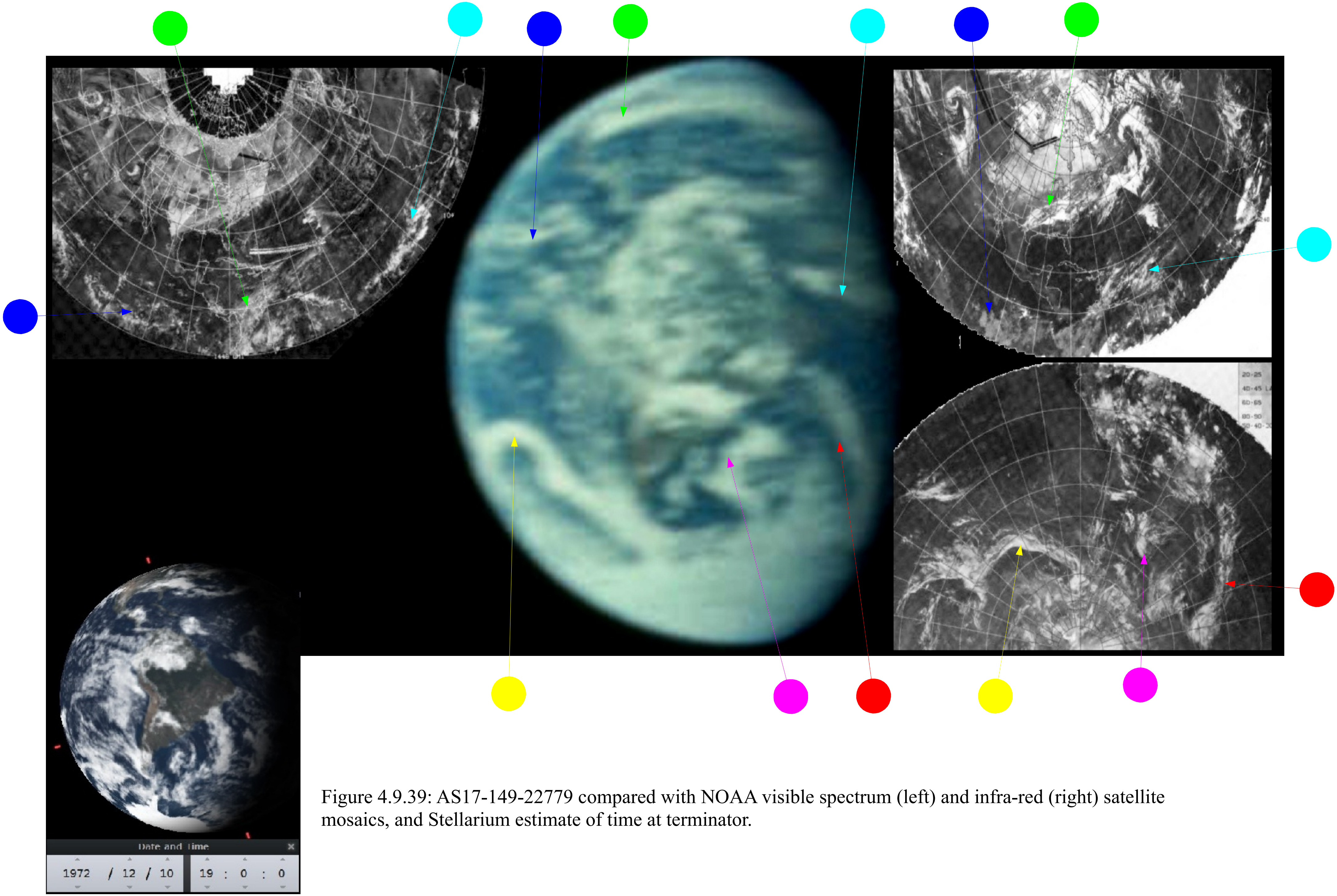


Figure 4.9.39: AS17-149-22779 compared with NOAA visible spectrum (left) and infra-red (right) satellite mosaics, and Stellarium estimate of time at terminator.

For once, the time of the Apollo image isn't recorded directly, but despite the mission entering one of its most intense periods of activity (LOI), Schmitt still finds time to give a casual observation:

"..and just to round out things as we pitch back into LOI attitude, lo and behold from over the top of the LM came the Earth...we can - we can see we're right over South America and, of course, we can see up the Gulf Coast. Ant it looks like Houston is covered in clouds, but poetically enough, we can see the Cape, at least we can see Florida."

He makes this observation at 85:40 MET, or just after 19:00 GMT.

Although the image quality is not the best, it is still evident that south America is central to the image, and the Gulf coast is clear below the prominent front picked out by the blue arrow. This cloud band for this front is visible north of the Gulf coast in both the the IR and visible spectra.

The other weather systems on the Apollo image are also relatively easy to pick out, particularly the long band heading north west from the tip of south America that eventually loops back downwards, seemingly towards the Antarctic (yellow arrow). On the opposite side of south America there is another well defined band heading from Brazil south-eastwards, and this is likely to be the same front identified by Jack in the previous image analysis.

The northern hemisphere's feature picked out by the blue arrow is a twin pringed thin band of cloud that is likely to appear in a subsequent image, hence its being identified in this one.

The next image for examination is from magazine 151. AS17-151-23173 (figure 4.9.40) appears after several images of the lunar surface, the curvature of which suggests it is at, or not long after LOI. Analysis of this image can be seen in figure 4.9.41.

Figure 4.9.40: AS17-151-23173. Source:
http://www.lpi.usra.edu/resources/apollo/images/print/AS17/151/23173.jpg

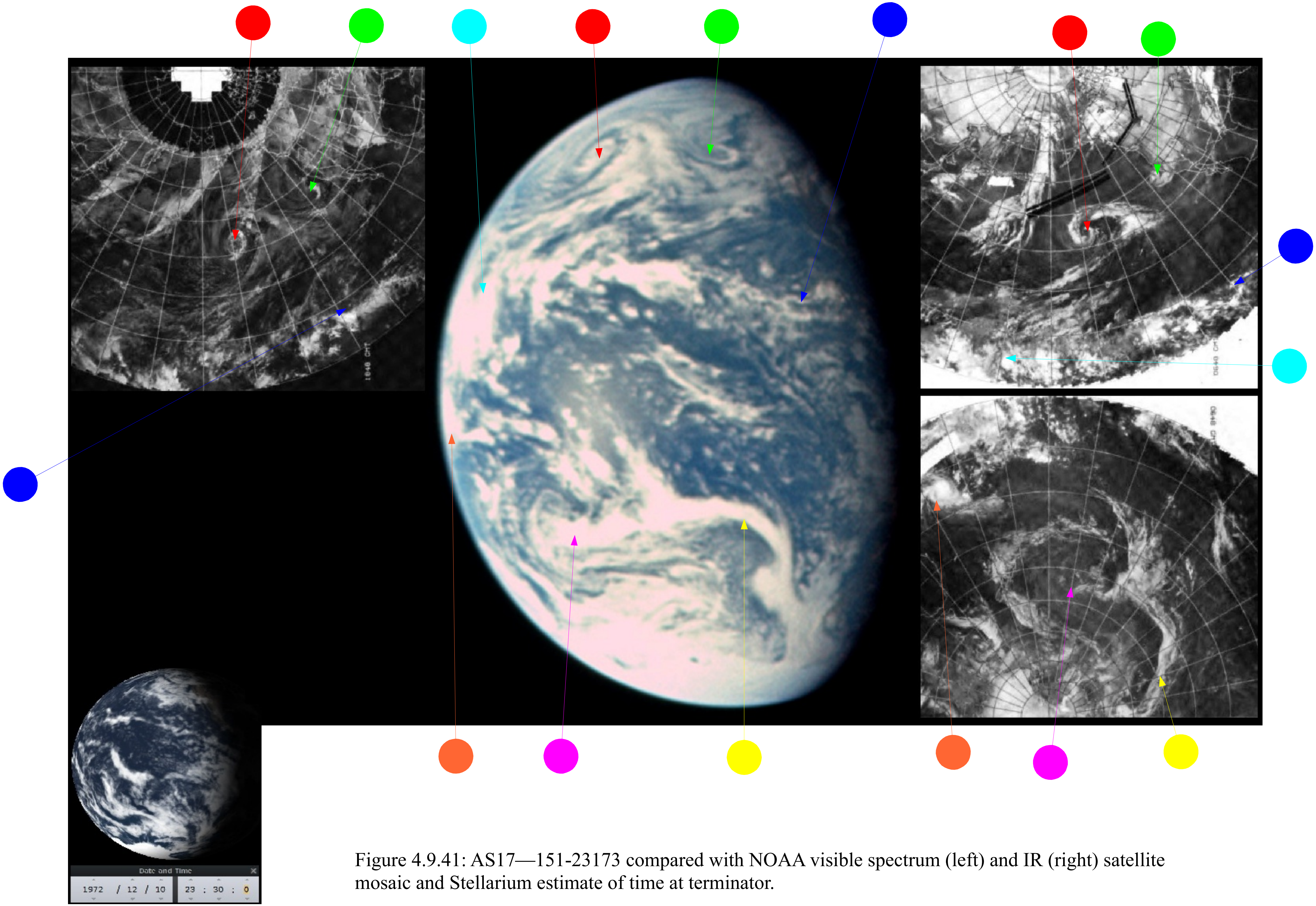


Figure 4.9.41: AS17—151-23173 compared with NOAA visible spectrum (left) and IR (right) satellite mosaic and Stellarium estimate of time at terminator.

Before discussing anything else about this photograph, it is worth drawing attention to what it is. We have become accustomed to seeing Earthrise images from Apollo, but this one is the start of a sequence of Earth*set* pictures, ie it is looking back at the Earth as it disappears behind the Earth. The next few images in that sequence show an Earth sinking below the lunar horizon, increasingly obscured by mountains and crater rims.

As far as timing the image is concerned, zooming closely in on the photograph shows that the west coast of north America is still just visible, which would give a time, as shown by Stellarium, of around 23:30. The date is identified by the the weather patterns visible on the NOAA mosaic, which is dated the 10th and shows patterns not visible on those formations on other days.

As before, the IR mosaics have been included thanks to a lack of southern hemisphere data for the 10th. The pass covering the area of the terminator would have been around 18:00 on the 9th, on the visible image, and 06:00 on the 10th for the IR. IR images will always be dated the same day here.

We also have Jack Schmitt, who helpfully asks capcom to:

"...log us a picture of the Earth at 92:40 on mag Oscar Oscar"

Magazine Oscar Oscar is number 151, and 92:40, thanks to the time adjustment, is 90:00 MET, or 23:30 GMT.

Schmitt also says that:

"You've got a lot healthy weather out there in the Pacific today. Looks like most of those things we talked about yesterday, up in the Hawaii region and also in the south, have intensified"

This time of the image is also recorded as

"...about 3 minutes until LOS"

putting the craft in just the right place for a few follow-on photographs of the Earth setting.

The most obvious feature that can be made out on both the mosaics and the Apollo image is the large spiral of cloud towards the top of the Earth, shown by the red arrow. It is Gene Cernan who, on the next lunar orbit at 91:37 MET (c. 01:00 GMT on the 11th) gives us some more detail on it:

"...there is really one heck of a big low-pressure area developing somewhere off the coast of California, Washington, or Canada, out in the Pacific north-west part of the country...we were watching it earlier today, but I tell you, now, it's really dragged in some other clouds with it. it must cover an enormous distance and it's got some real spectacular circulation."

after an interruption from capcom, during which he confirms he is using binoculars to see this, he continues, saying that he has lost sight of the continent now, and describing a:

"...tremendous trailing front. Roughly north north-west, south south-east, and it looks like it may just sweep up the western coast. It's hard to tell how far off the actual centre rotation or even a front is. I just remember from earlier this morning, when I could see landmasses, that it appeared to me to be off the Pacific north-west out in the ocean."

This large cloud mass is also visible on an ESSA 8 picture, obtained from a Midway Island veteran website described in the introduction to this section. The ESSA image (which has been converted from it's original sepia to a slightly clearer monochrome) is shown, together with the relevant part of AS17-151-23173, in figure 4.9.42.

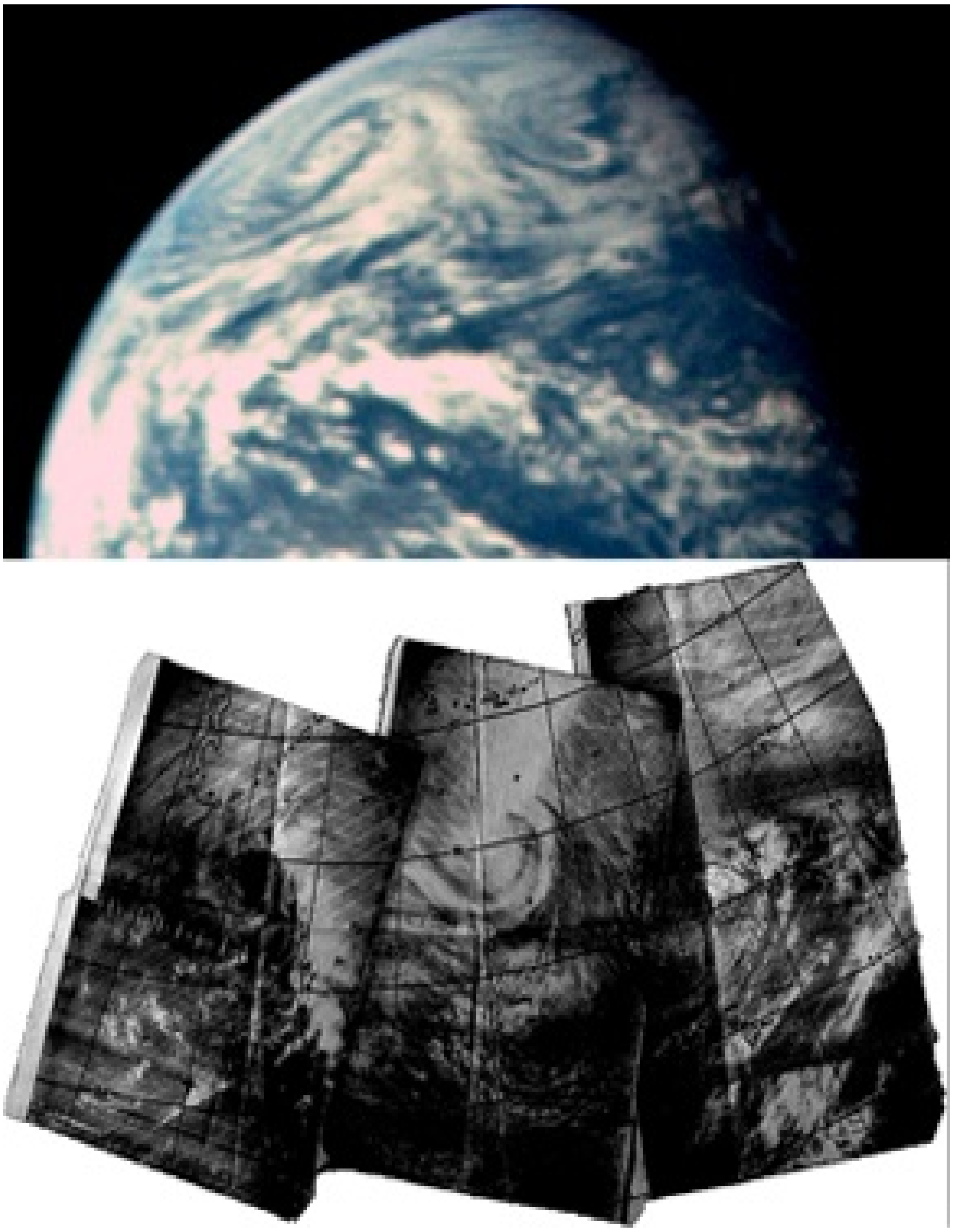


Figure 4.9.42: Part of AS17-151-23173, compared with ESSA 8 mosaic from 11/12/72. Source given in text.

Both the cyclonic cloud mass and the trailing front are very obvious, dominating the north Pacific.

An interesting feature of the ESSA image is that it there appear to be the marks of a spiral bound notebook across at least one section of it (the left hand part of the triptych, halfway down the page). It looks very much like a printout (possibly from a fax machine) that has been manually compiled and then photographed.

In the interests of continuity, there are other weather systems shown on the Apollo image that are a follow-on from the previous photograph under scrutiny, and that are also obvious on the NOAA mosaic.

The yellow arrow shows the long looping system visible in the rather shaky image from magazine

149, and it should be evident that this loop encloses what remains of the 'mushroom' formation described in such detail earlier. The formations at the eastern end of that cloud band have not changed as much as the weather it encloses to the south of it.

Tropical storm Diana is just about coming into view, and is identified by the orange arrow on the western limb. The IR image gives a much sharper view of this emergent storm than is shown by Apollo.

The next photograph to be analysed is also from magazine 151, and is part of a short series taken from the CSM, showing the LM, the lunar horizon, and the Earth hanging just above it. The orientation of the home planet shows that it is an Earthrise image.

The LM is still obviously attached here, and there is a later sequence of photographs showing it after separation, which tells us that it must have been taken before 17:20 GMT on the 11th, but :obviously after 23:30 on the 10th, the previous Earth images in the magazine.

A time of 17:20 would put the terminator over Africa, and close inspection of this image shows that it still features that spiral storm described so vividly by Cernan. It must, therefore, be taken shortly after the previous image, probably at AOS on orbit 3 at 90h54, or around 00:30 on the 11th, half an hour before Cernan gives us his description of the large storm.

AS17-151-23188 is shown below in figure 4.9.43, and analysed on the next page in figure 4.9.44.

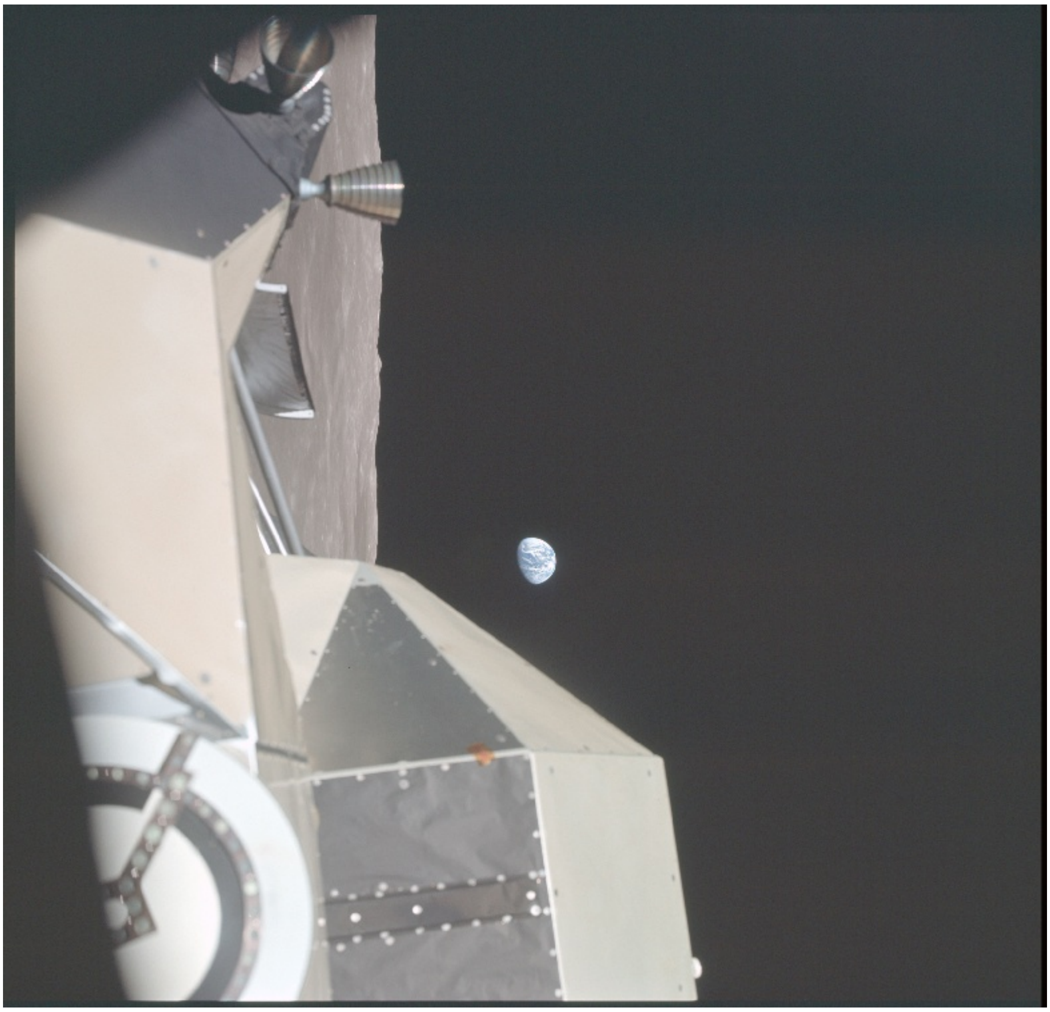


Figure 4.9.43: AS17-151-23188. Source: AIA

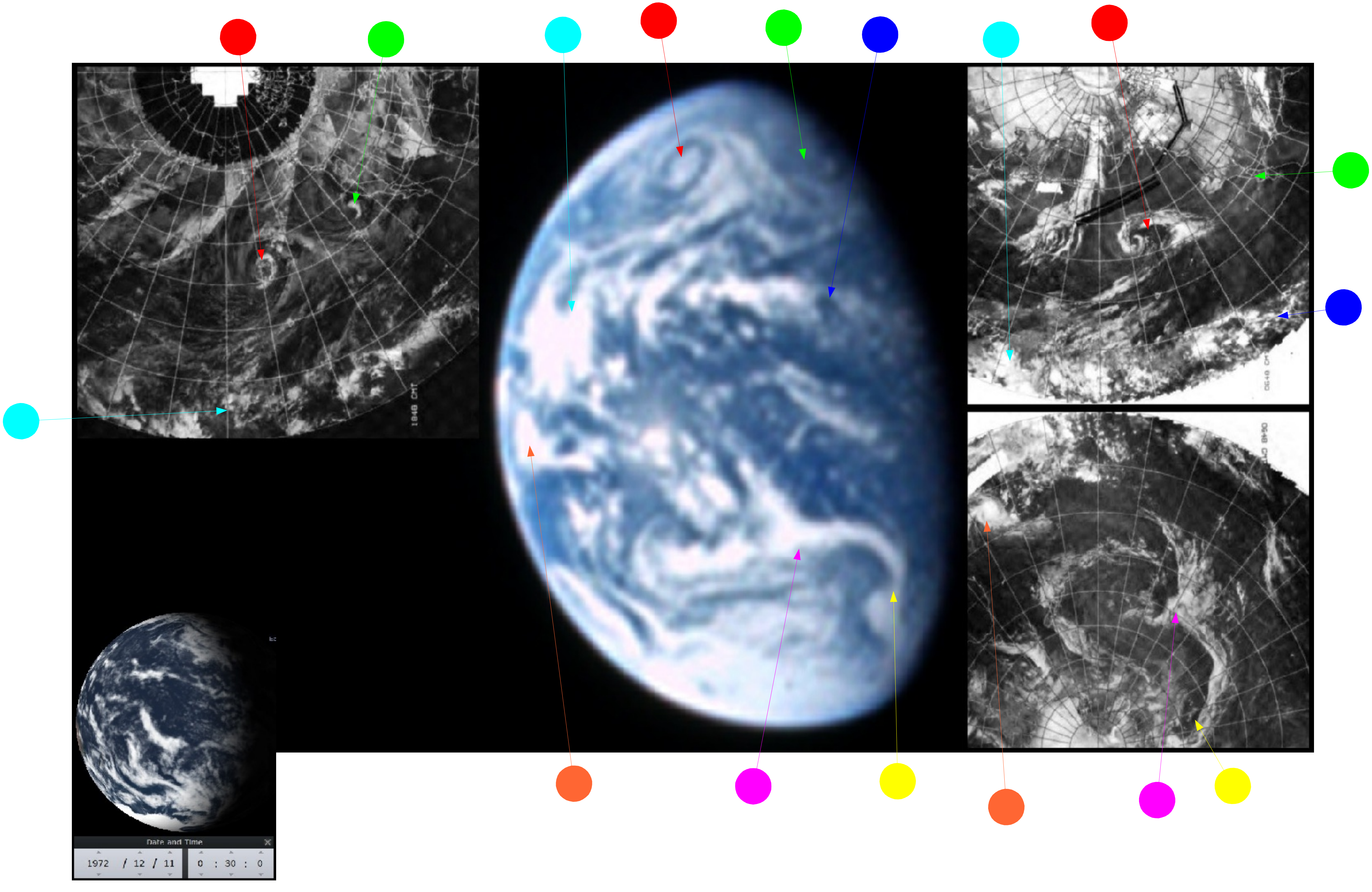


Figure 4.9.44: AS17-151-23188 compared with NOAA visible spectrum (left) and IR (right) mosaics and Stellarium estimate of time at terminator.

In terms of the weather systems we can see, there is little to add from the previous image.

What is obvious is that the Earth has rotated some distance since then in a manner consistent with roughly an hour's worth of rotation. The crew had, during this orbit, gone from the higher LOI orbit to the lower descent orbit for LM separation, and thus the orbits were still relatively long.

As Cernan observed, the west coast of the US has now disappeared, and Australia is just coming into view on the western limb, which matches the time on Stellarium of 00:30 for the 11th.

NOAA's mosaics are the same ones used before, and the area will have been passed at a correspondingly later time.

There now follows quite a hiatus in terms of Earth photography for this mission. The crew's next objectives are to transfer to the LM, separate, descend and land.

The next image of Earth, at least in a time-based series, that we can use for analysis turns out to be in magazine 134. This magazine went to the lunar surface, and starts with the first EVA after the extraction of the LRV and the erection of the flag. This latter event is recorded as being at 01:13 on December 12th 1972.

The first image showing Earth on this magazine is after flag deployment, which gives us a start marker for the event, and is part of a short series of pictures showing astronauts in close up with the flag. Two of those images feature the flag, and the 2nd one of these, AS17-134-20387 is used here. This image is shown below in figure 4.9.45, and analysed over the page in figure 4.9.46.

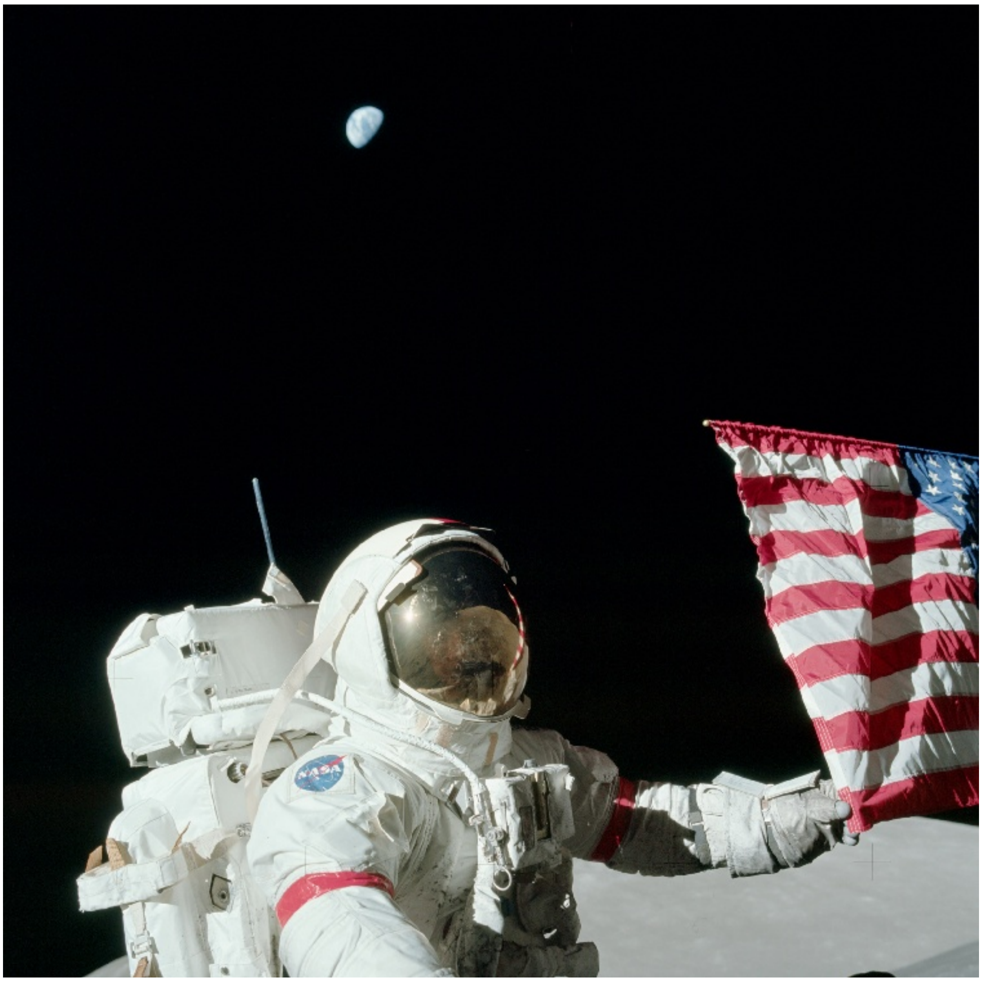


Figure 4.9.45: AS17-134-20387. Low resolution source: [ALSJ]

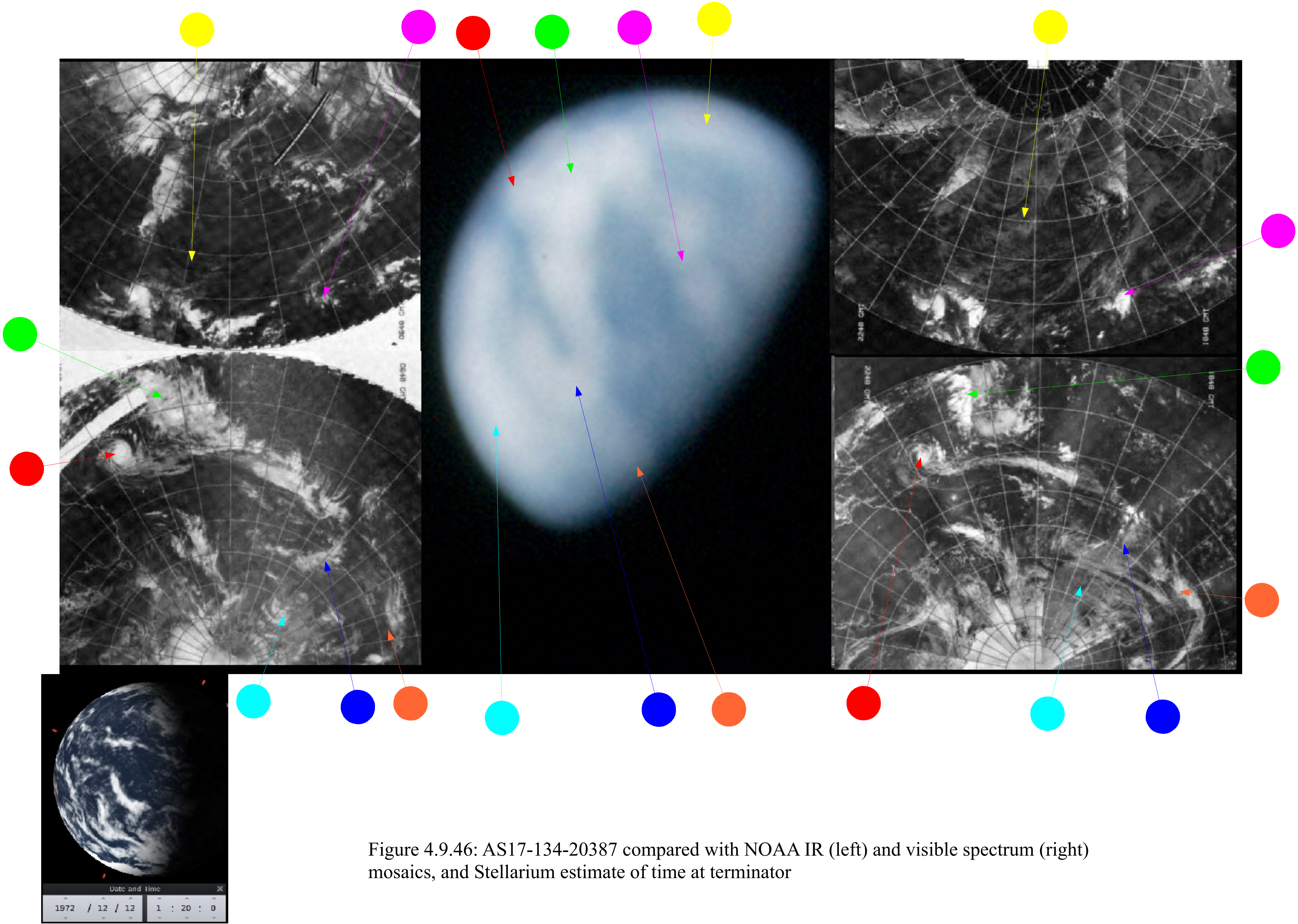


Figure 4.9.46: AS17-134-20387 compared with NOAA IR (left) and visible spectrum (right) mosaics, and Stellarium estimate of time at terminator

Both NOAA mosaics from the 11th have been included here (the IR one actually dated the 11th), as the IR one has a better definition of some northern hemisphere features. The passes over the terminator line are given as roughly 20:00 on the 10th and 08:00 GMT on the 11th for the visible and infra-red respectively.

Recording the time of the image requires a little deductive work, as the image is not clear. The main cloud feature dominating the image is the one starting at the equator in the west (green arrow), heads roughly eastwards before looping back on itself in a kind of letter mirrored 'C' formation (blue arrow). The terminator falls some way east of this inverted C.

The location of the blue arrow on the NOAA mosaics suggests that the terminator is perhaps another 20 degrees of longitude to the east. The western end of this long band of cloud meets up with tropical storm Diana (red arrow), now east of Australia. Close examination of the image shows that blue sea is just visible beyond Diana, which suggests that Australia is only just coming into view. This would suggest a time for the photograph of around 01:00 – 01:30 GMT.

The ALSJ gives a specific time for this image as 118h26m, which is almost 04:00 GMT. If this were the case, then Australia would be clearly visible. The timeline that has been used so far, however, says that at 04:00 Cernan and Schmitt would have just completed installing the lunar seismic experiment equipment at the ALSEP, not at the flag. The most obvious answer is that the ALSJ is using the GET, which is 2 hours 40 ahead of the timeline and transcripts. If this time difference is removed from the ALSJ time, we get a time of 01:20 GMT, putting the astronauts exactly where the photograph says they should be (at the flag) and the Earth's features exactly as they should be.

The next image comes from a different magazine, number 137, which was taken n EVA 2. AS17-137-20910 is one of several photographs taken showing the Earth above a large boulder (named, with no sense of grandeur whatsoever, 'Boulder 2'). The photographs were taken at the equally unspectacularly named Station 2. Several other images from around station 2 also feature the Earth taken at the same time. The image itself is shown below in figure 4.9.47, and is analysed overleaf in figure 4.9.48.

Figure 4.9.47: AS17-137-20910. Source: http://www.hq.nasa.gov/alsj/a17/AS17-137-20910HR.jpg

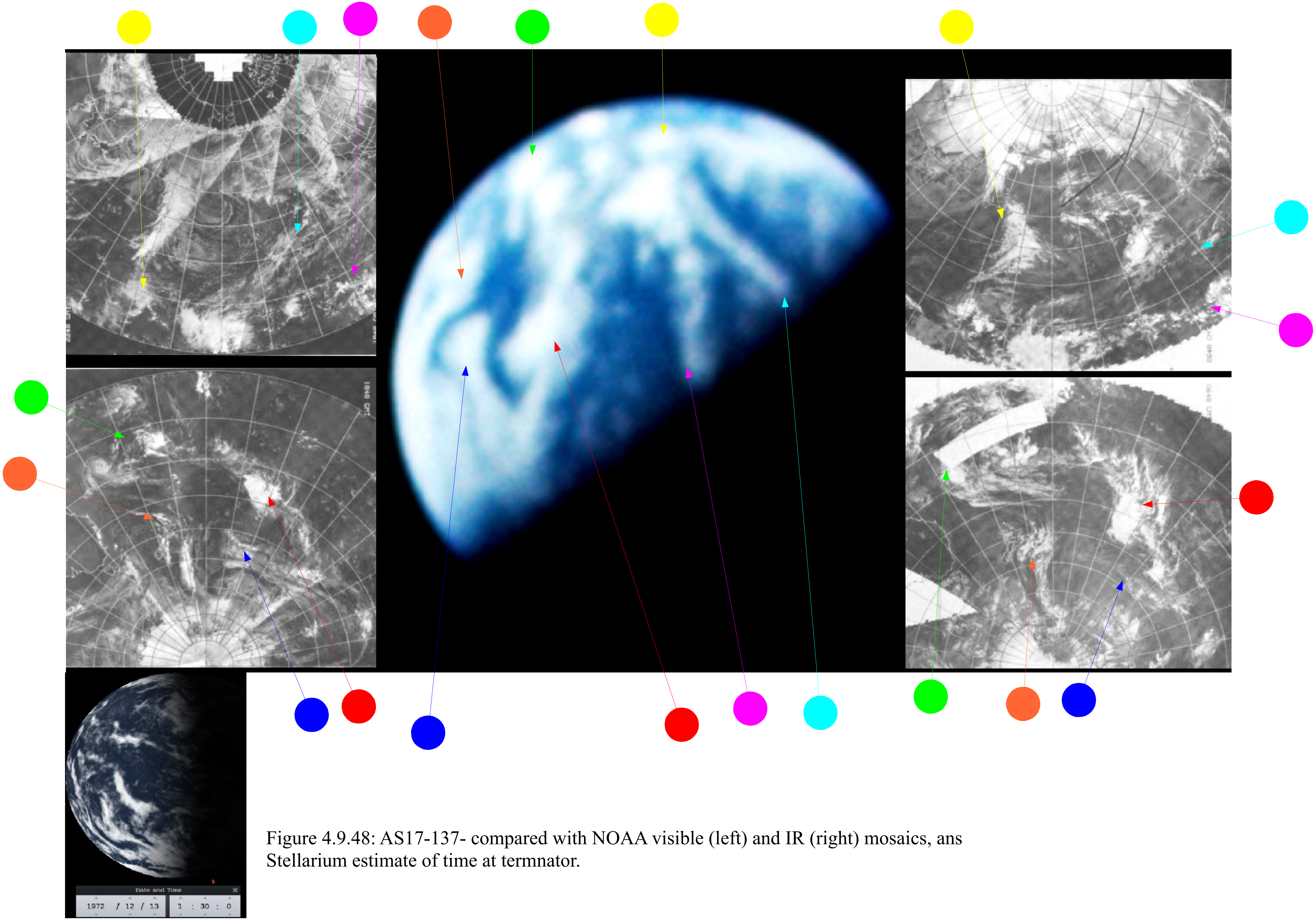


Figure 4.9.48: AS17-137- compared with NOAA visible (left) and IR (right) mosaics, ans Stellarium estimate of time at termnator.

As with the previous image, there is some detective work to do in the absence of obviously visible land mass (something that automatically points towards a view of the South Pacific in the early hours GMT). The size of the visible disk is narrower than in the previous photograph, which means that it must be later in the mission.

The key areas on the photograph to pinpoint where the terminator is falling are the two lines in the northern tropical area (cyan and magenta), and the orange arrowed lobe of cloud near the western horizon. In the case of the former, following the line of longitude north would put see that line crossing half way through Alaska. The latter clouds are a good 15 degrees east of Australia, which would therefore not be visible. Using Stellarium, we can achieve a configuration of the Earth where Australia is not visible and Alaska just crossed by the terminator as roughly 01:30 GMT. The NOAA times for visible and infra red passes over this area would be approximately 19:00 (on the 12th) and 07:00 (on the 13th) respectively.

At 01:35 on the 13th, we find from the timeline that Cernan and Schmitt are indeed at Station 2 on EVA 2, and they leave it 65 minutes later. A photograph of a damaged LRV fender's repair was taken just before that departure (AS17-137-20979), as recorded by the ALSJ, several frames after the photograph used here.

Something else that should be visible in the image is Tropical Storm Violet. Violet developed over the Marshall Islands, a small group of islands just north of the equator and just west of the 180 degree longitude line.

The storm began as Therese died away, but was most active between the 12th and 15th of the month. On the 13th, the MWL (reference given in the introduction to this section) shows a more detailed NOAA image of Violet, with lines of longitude and latitude clearly marked., and this is shown below in figure 4.9.49.

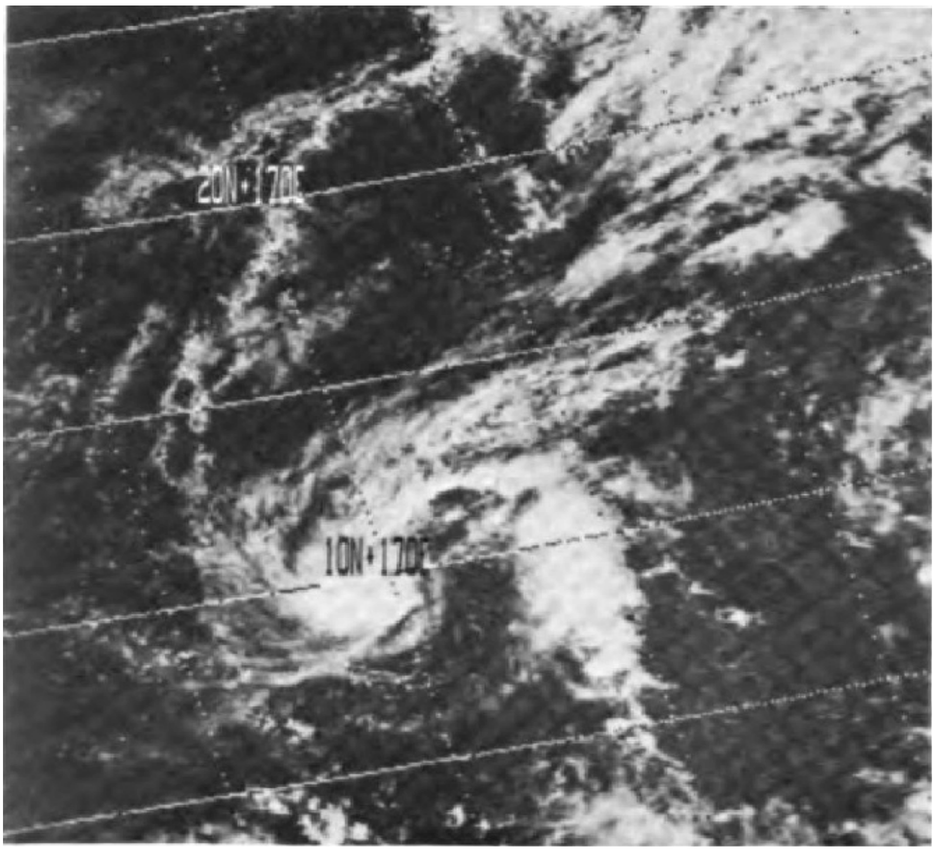


Figure 4.9.49: Tropical storm violet from the Mariner's Weather Log. Source given in text.

The first thing to note on the MWL image are the latitude and longitude markings, which puts the storm as being at 10 degrees north and 170 degrees east on the 13th of December. If figure 4.9.48 is examined, particularly the NOAA mosaic, then there is indeed a storm there with a similar, but less detailed, configuration as is shown in figure 4.9.49.

This storm (identified by the yellow arrow) also has the same overall shape (a sort of extra-wide '9'), although the lower level of detail masks this in the mosaic. That storm is to the east knot of white cloud that marks the join between the twin bands of cloud marked by the cyan and magenta arrows.

If the corresponding point is searched for on the Apollo image, the same storm pattern can be found, as can the bank of less well defined cloud to the north-east of it shown in figure 4.9.49. This gives us another tropical storm visible at a specific point in time and space on NOAA and Apollo images.

Additional evidence for the time comes from TV signals sent back to Earth from station 2. The ALSJ has video links to some of this TV cover, and one of them, found here: ALSJ, contains a picture of Earth. A screenshot of from that video is shown below in figure 4.9.50, together with a zoomed in version of it and the NOAA visible spectrum mosaic from 4.9.48.

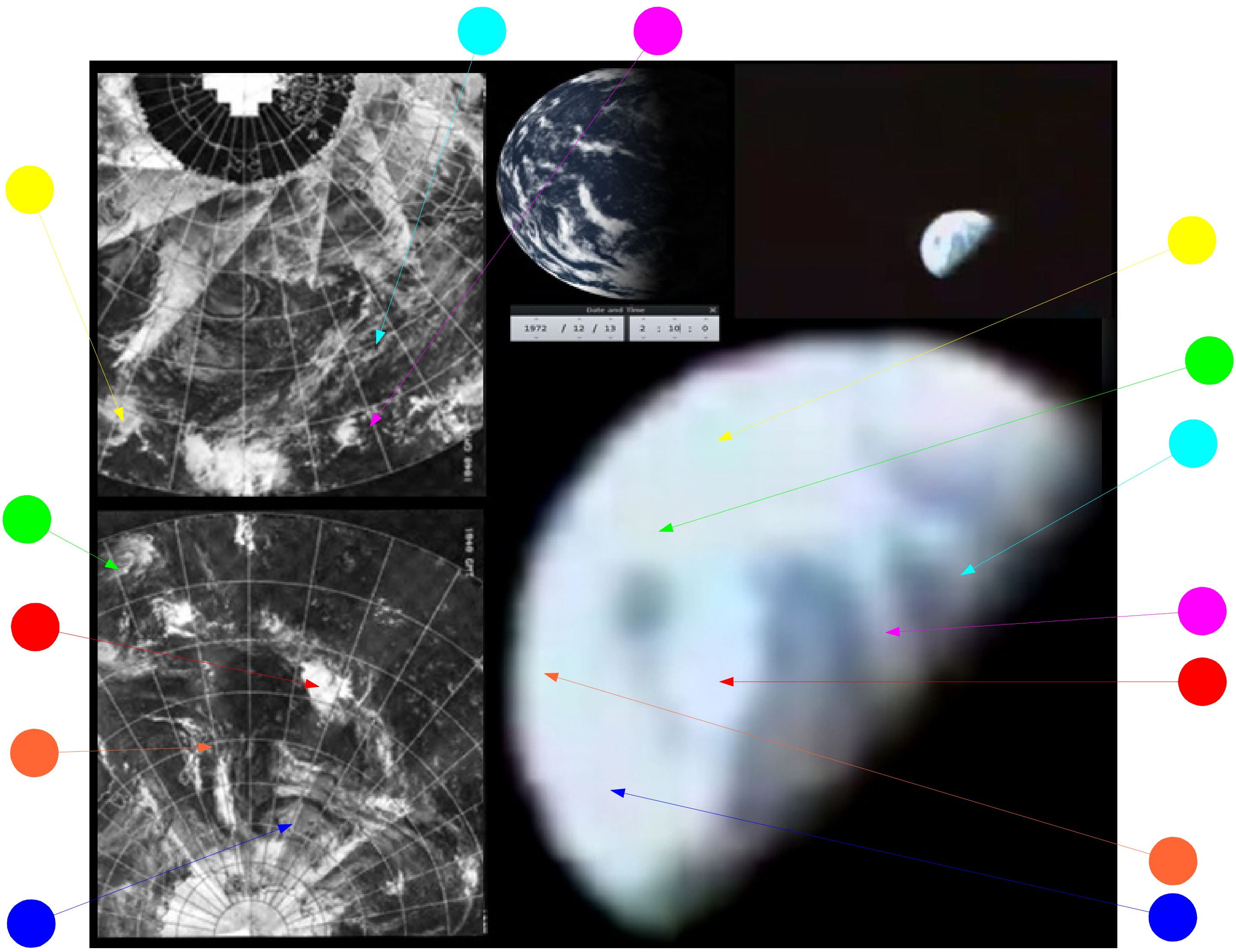


Figure 4.9.50: Video screenshot from EVA-2 TV broadcast (top right, source given in text), zoomed in (main image) and compared with NOAA mosaic (left) and Stellarium terminator estimate (top, middle). Arrows are the same colours as used in figure 4.9.48.

The screenshot shows the same scene as was shown in figure 4.9.48, and the text of the broadcast confirms its timing. At 140:37 MET (roughly 02:10) capcom tell the astronauts:

"..17, if you want to take a minute, you might want to look up in the sky and notice that our camera is taking a beautiful picture of mother Earth...isn't that a beautiful picture of the Pacific there? Ed finally found it"

If the video is watched from the start, the camera operator does take a while to find the image, and the words spoken there coincide with the Earth appearing in shot. The similarity between the video screenshot and the astronaut photographs is undeniable, as is the resemblance to the satellite mosaics. There is a suggestion that the cloud bands marked by the cyan and magenta arrows in this screenshot are slightly shorter than in figure 4.9.48, which would be consistent with the still image being taken earlier in the EVA, but this could also be a product of the poorer quality.

Returning now to magazine 134, from image AS17-134-20461 to AS17-134-20473 there are several photographs featuring, variously, the LM, an astronaut, the flag and the LRV and the Earth. One of these, AS17-134-24071 is one of the better quality ones in terms of the view of Earth it provides, and this is the next image for examination here. It was chosen partly because of that image quality, and also because it is often cited by conspiracy lovers as an obvious fake, given the "unbelievable" juxtaposition of astronaut and Earth in the same photograph. It must, because of this appearance together, be the result of chicanery. It is shown below in figure 4.9.51, and analysed in figure 4.9.52.

The Apollo image is recorded as being from the end of EVA 3. The EVA itself ended at 168h07m MET, or 05:40 GMT on the 14th. The image is recorded by the ALSJ (after subtracting the extra 160 minutes) as 166h53m MET, or about 04:25 GMT on the 14th – just over an hour short of the mission being a week old.

Figure 4.9.51: AS17-134-20471. Source: ALSJ

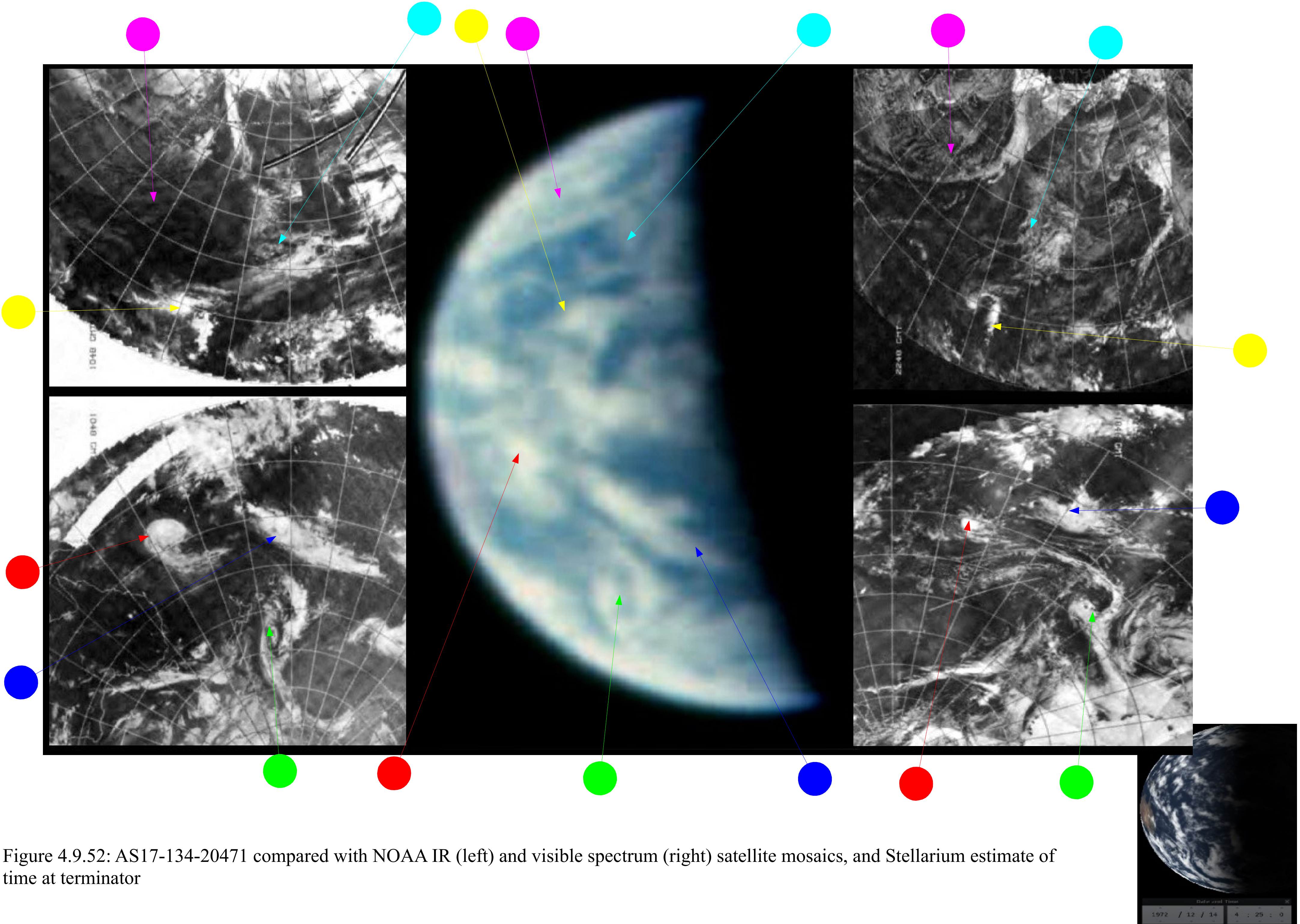


Figure 4.9.52: AS17-134-20471 compared with NOAA IR (left) and visible spectrum (right) satellite mosaics, and Stellarium estimate of time at terminator

Setting Stellarium at this time shows that Australia should just be visible on the western limb of the Earth, and that is exactly what we can see. The slightly less than half full Earth also matches what should be visible, according to Stellarium.

Again, the analysis includes both the IR and visible spectrum images, and these, again show perfect correspondence with what is visible in the Apollo image, despite issues with the data near the southern hemisphere terminator region with the visible spectrum mosaic (the grid overlay is offset by some distance, and there appear to be errors in the data over to the terminator area (over the cloud mass picked out in blue).

Between them, the IR and visible spectrum mosaics provide an exact match. The times their orbital pass over the terminator area would have been made are roughly 07:00 on the 14th and 19:00 on the 13th respectively. The storm identified by the blue arrow is a particularly good match, as is the multi-pronged storm identified by the green arrow. The large cyclonic storm in the northern hemisphere is much less visible in the IR spectrum and is probably much colder winter air. Tropical storm Violet is still evident, marked by the yellow arrow.

Only one image remains from the surface, and it was not taken by anyone on the surface. While Cernan and Schmitt were in the LM awaiting the time to lift off and rejoin the CSM for the journey home, the LRV camera, positioned a safe distance away, remotely scanned the horizon and, eventually, the distant Earth. A screenshot of that video, which can be found here: ALSJ and it is analysed over the page in figure 4.9.53.

This video clip is recorded by the as commencing at 170h40m in the ALSJ, but as they are recording GET time 160 minuted ahead, this can be reduced to 168h, or 05:34 on the 14th. At exactly this time in the transcript (and in the video!), capcom tell the crew:

"And as you guys say farewell to the Moon, we're looking up to the Earth down here"

Shortly after this, Gene Cernan utters the final words as the last man to have his feet on the Moon, stepping back inside the LM for the last time.

As this is only an hour after the previous still image used, the features visible should, image quality permitting, still be broadly visible.

The arrows used in figure 4.9.53 match those used in 4.9.52, with the exception that where it isn't clear where an arrow should go, it has been omitted.

Can we be sure that it is an appropriate match? We are relying here on the words spoken on the video matching those of the transcript, which gives a time, and then using that time to see what clouds should be visible, and drawing arrows to what we assume are the same clouds. The argument here is that this is a reasonable use of the evidence to support the argument, but it is somewhat circular.

We do have, however, a large mass of cloud in the northern hemisphere (magenta arrow) next to a large band of clear ocean that ends with a band of equatorial cloud (yellow arrow). In the southern hemisphere at the roughly 4 o'clock position there is a distinct and thinner band of cloud corresponding to the blue arrow, and below that is (if it is examined closely) the multi-pronged cloud mass heading north from the Antarctic.

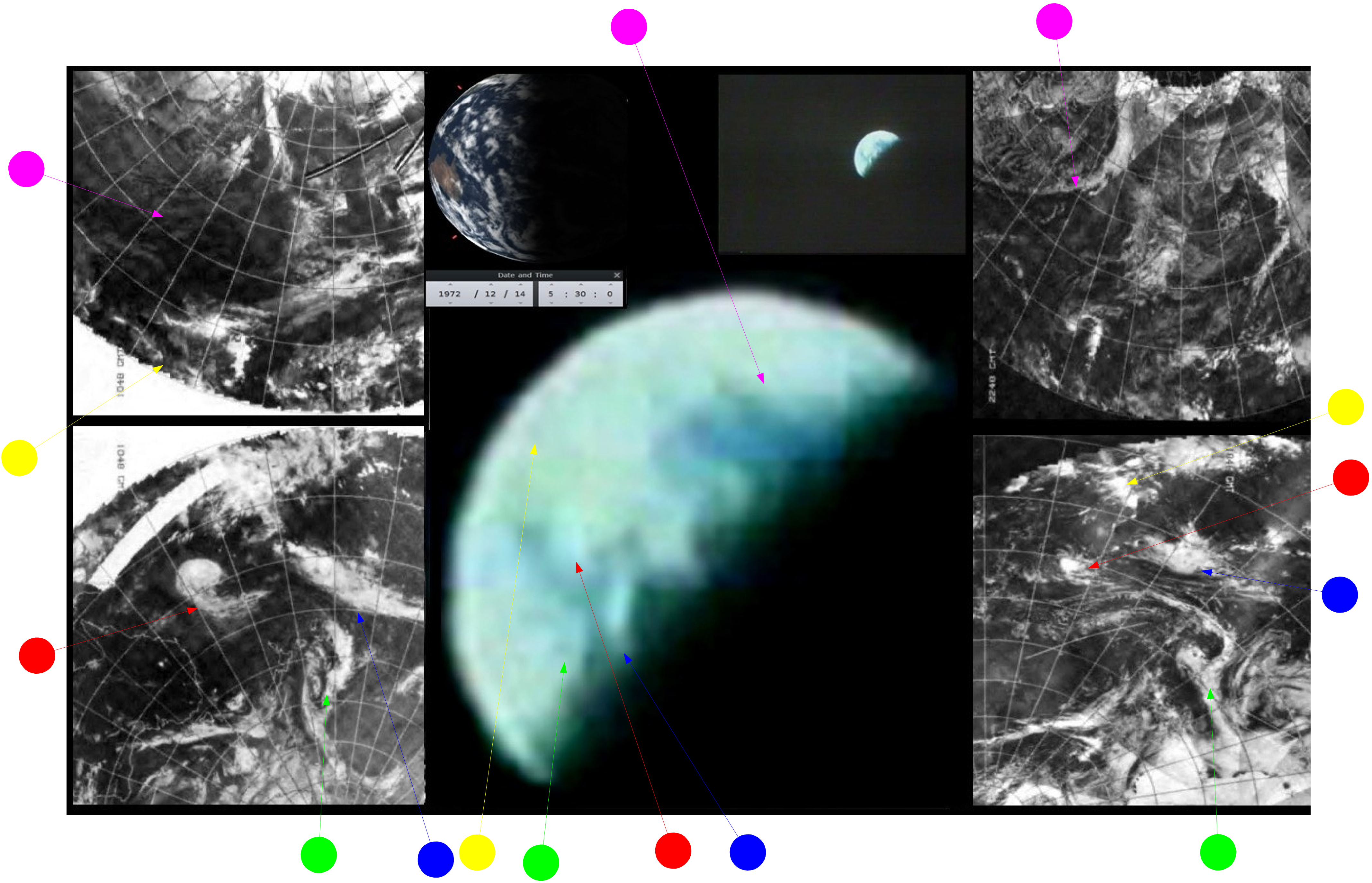


Figure 4.9.53: Screenshot of Apollo 17 LRV footage (top right) zoomed and cropped (main image) compared with NOAA 2 IR (left(and visible spectrum (right) mosaics and Stellarium estimate of terminator at time of broadcast.

This multi-pronged cloud mass can be examined in more detail my cropping and zooming into it, and then altering levels to bring out any detail. This is shown below in figure 4.9.54.

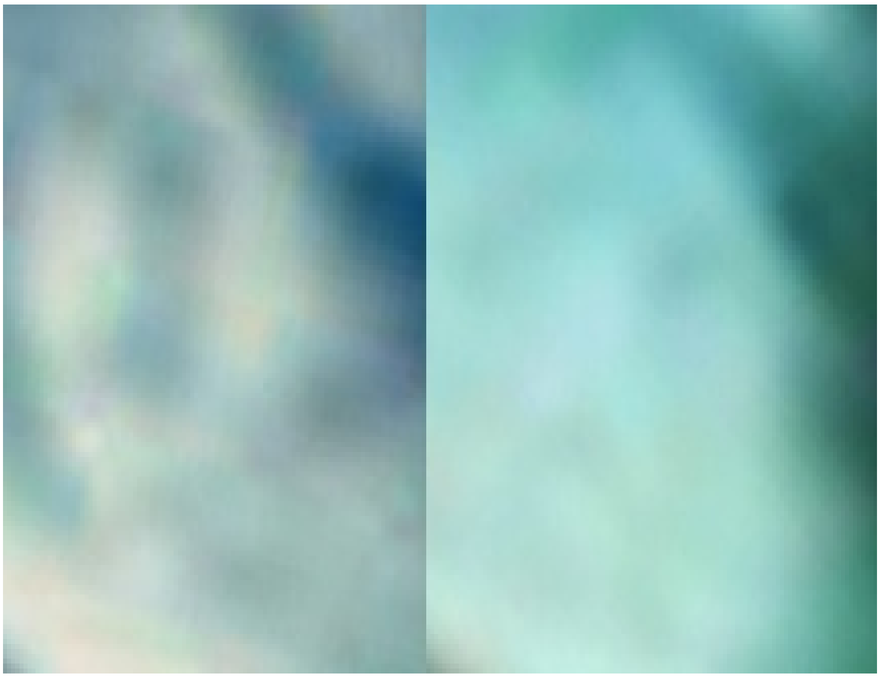


Figure 4.9.54: Close up of AS17-134-20471 (left) video screenshot compared video screenshot close up (right). Both images rotated so that terminator is vertical.

Although the image on the right from the video is much brighter, swamping detail in the dark areas, it is still possible to make out the gap between the multi-pronged cloud and the thinner band above it in the top right the picture. It's also possible to match other gaps in the cloud in each picture. Arrows have been deliberately left off to avoid confusing the image.

Are we, however, victims of our own prejudice?

In the initial stages of preparing this section, a video was found (since removed by the youtube user) showing this same segment of LRV footage combined with the the later footage of the ascent module firing and returning to orbit. With no audio to confirm the timing, it was assumed that the footage showing Earth was done much later. This mistake was compounded by the 160 minute time addition in the ALSJ to effectively infer that the Earth should be showing features visible some 14 hours later. Equipment visible outside the LM was assumed to be that dumped by the astronauts (2 sets of equipment disposals were carried out during preparations for launch to reduce weight), when in fact they were part of experimental equipment.

This led erroneously to the assumption that what was visible in the image was a view of north and south America. On other words, a conclusion was made, and the available evidence was made to fit that conclusion. On closer examination, it was found that while there were broad generalisations that could be made that seemed to provide a good fit, the details, such as those compared in figure 4.9.54, did not stand up to close scrutiny.

Three important lessons can be learned here. Firstly, there is always a danger of making evidence fit the theory, and this is just as unwise for people who don't adhere to conspiracy theories as it is to those who will dismiss this work out of hand.

Secondly: check the data. Check it again. Don't rush to publish until it's right!

Finally: Don't be afraid to admit your errors. There is, to quote the song, always someone somewhere with a big nose who knows. Somebody will remember them and use it as evidence against all your other explanations. In the mind of a conspiracy theorist, one easy mistake will always outweigh 99 perfectly correct answers.

Having finally left the surface of the moon, the re-united crew orbit the Moon for a day before heading home. During that day, they get an Earthrise image, taken using magazine 152. This magazine starts with that Earthrise sequence which covers images AS17-152-23271 to 23277, and the last one in that sequence is used to compare with satellite images.

AS17-152-23277 is shown below in figure 4.9.55, and analysed overleaf in figure 4.9.56.

Figure 4.9.55: AS17-152-23275. High resolution source: [Archive.org]

The crescent Earth is an early indicator that some time has passed since the last photographed examined here. The timeline tells us that the LM & CSM were re-united at 01:10 on the 15th, and that TEI was carried out at 23:35 on the 16th, so the last possible Earthrise would be shortly after that. We also have a couple of clues from the Photo Index, and the mission transcript.

At the risk of carrying out exactly the sort of pre-judgement warned against only a few paragraphs ago, the Photo Index tells us that this image was taken on orbit number 66. At AOS on this orbit, which occurred at 04:10, Cernan says:

"We've been taking [Earth's] picture just as we came up"

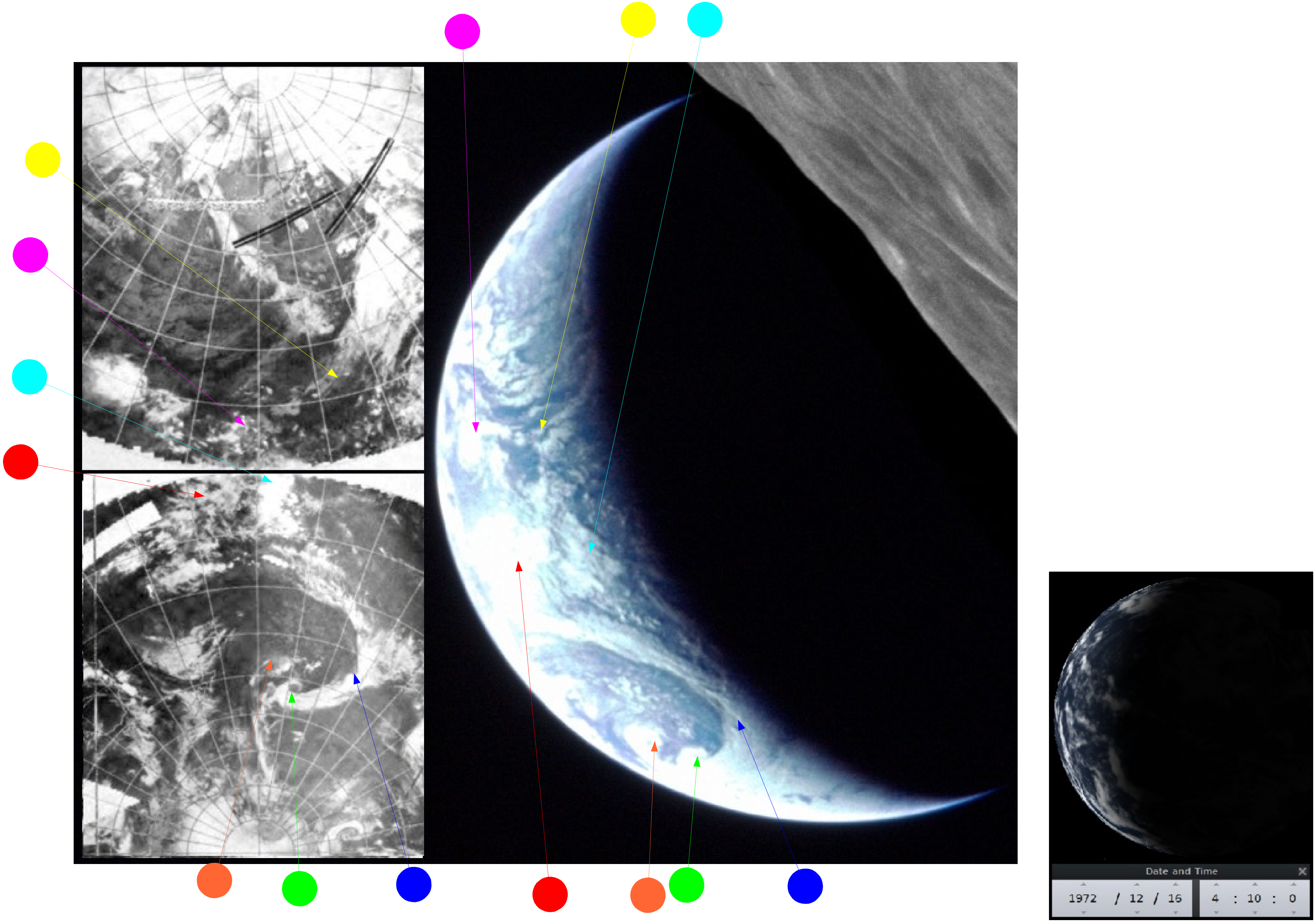


Figure 4.9.56; AS17-152-23275 compared with NOAA IR mosaic from 16/12/72 and Stellarium estimate of terminator using mission transcript data

Can we therefore find weather patterns on the crescent Earth that we would expect to find at that time and date?

Before going on to answer this question, it is first necessary to point out that only the IR spectrum image was available covering this time. No data were available for the 15h in the visible spectrum, which is the mosaic that would have been required to cover the early hours of the 16th. The time of the orbital pass at the terminator would be around 06:00 on the 16th.

The most obvious feature to be seen is the large arc of cloud just on the terminator, and this can easily be made out on the IR mosaic. Once this is correctly picked out, all other weather features are easy to match up, and the we therefore have an an Apollo photograph taken 2 hours before even the very first part of the infra red mosaic was taken that matches exactly with it.

After the Earthrise sequence in magazine 152, there is an Earthset, comprising AS17-152-23278 to 23282. The first in this sequence will be used here.

In addition to photographs from magazine 152, we also have a contribution from 139, this time in black and white. Magazine 139 was taken to the lunar surface, and the first half of the photographs on it are those from an EVA. AS17-139-21300 and 2301 also show an Earthset, and these are also shown as being from orbit 71 in the Photo Index. As the 2nd of these shows an Earth almost totally hidden behind the lunar horizon, 20300 will be used.

Again, we can use the Photo Index and mission transcript to act as a guide as to what part of the Earth's surface is appropriate to start looking, and we find that the photos are recorded as being taken on orbit 71.

The mission transcript has this to say towards the end of orbit 71,

“...we're going to get your picture as you set this time."

LOS on orbit 71 is recorded as 225:45 MET, or 15:25 on the 16th.

Both these images are shown overleaf in figure 4.9.57 a and b, and they are analysed together in figure 4.9.58.

If the colour version of the image is examined carefully, it is possibly to make out the coast of South Africa, and the fog shrouding that coast is marked by the red arrow. Land continues north of that fog almost all the way up the image, so we can be confident that our prediction for what should be visible is correct, and the images do show Africa.

As far as the NOAA images are concerned, the visible spectrum image (now available again) has the usual problem of half of Africa being commenced at the start of the day in question, and the other half 24 hours later. The IR spectrum however has no such problems. The times for these mosaics at the terminator are roughly 19:00 GMT for the IR image, and 07:00 for the visible spectrum. For the visible spectrum, most of Africa was started on the 16th, but the terminator area would actually have been imaged on the 17th.

The Stellarium image confirms that Africa should be visible at the time of the photographs, but were they both taken at the same time? Neither image shows the moon, so there is no reference point that we can use to say “this one was taken before that one”.

Figure 4.9.57a: GAP scan of AS17-152-23278. Low quality source: AIA

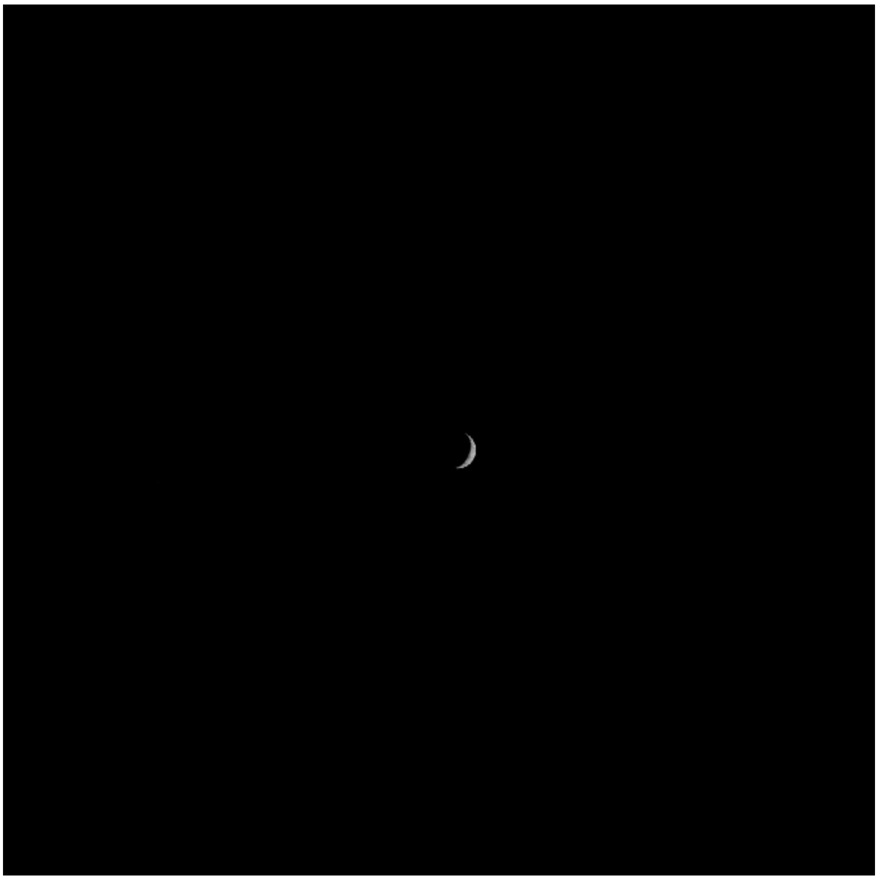
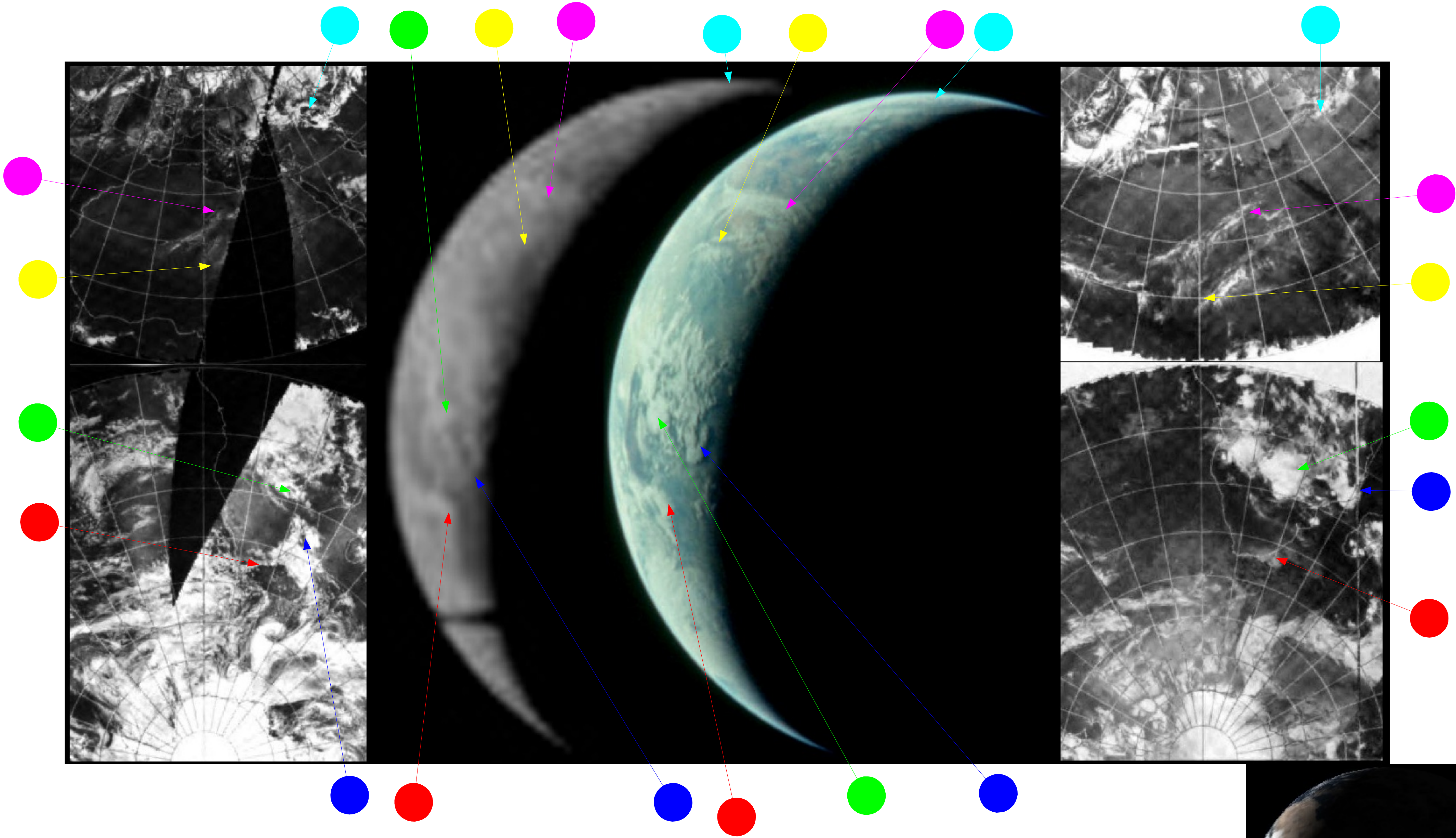


Figure 4.9.57b: AS17-139-21300 Source: ALSJ



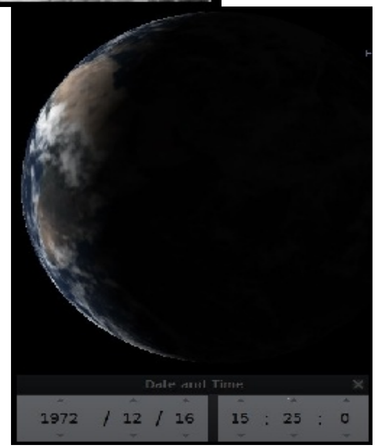


Figure 4.9.58: AS17-139-21300 (centre left) and AS17-152-23278 (centre right) compared with NOAA visible spectrum (left) and IR (right) mosaics, with Stellarium indication of terminator position at time image recorded

We can also conclude that the clouds shown in the central part of the image are the same ITCZ clouds, and the long strips of cloud in the top half of the image are over the Sahara in the mosaics.

If the 'V' shaped cloud picked out by the blue arrow is looked at more closely, it appears that the colour version shows it to be further from the terminator than the black and white one. This is matched by other surface and atmospheric features on both images, for example the long band of cloud shown by the magenta arrow ends shortly before the terminator in the colour image, but is coincident with it in the black and white. Likewise the distance between the coastal fog (red arrow) and the terminator is much less in the black and white compared with the colour. This would suggest that colour image was taken first. It also demonstrates that the Earth is moving as time passes, and not some static representation of Earth.

For the next image in the story we return to magazine 148, which was used in orbit to take photographs of the lunar surface, but features one final image of a crescent Earth. This photograph, AS17-148-22773, is shown below in figure 4.9.59, and analysed overleaf in figure 4.9.60.

As the visible area of the Earth diminishes, we are again reliant on other sources of information to work out when the image was taken. The Photo Index states that it was taken on orbit 73, which started at 228:00 MET, or just after 17:30 on the 16th., and ended at 229:45 MET, or about 19:15 GMT.

The photograph immediately preceding this one was also taken on orbit 73 of a crater called *Sulpicius Gallus*, and the one after it is of *Mare Smythii* on orbit 74.

Figure 4.9.59: AS17-148-22773. Source: AIA

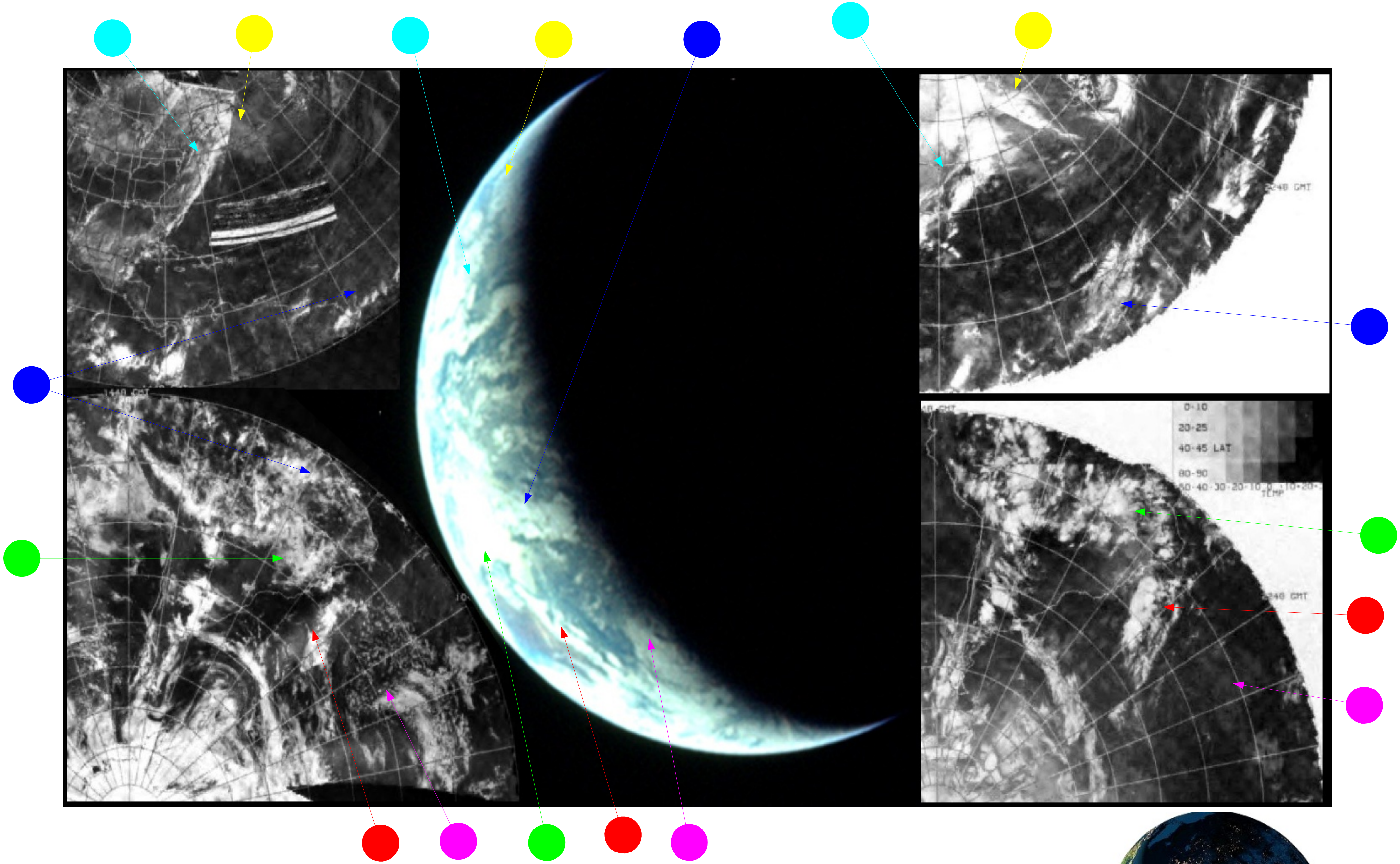


Figure 4.9.60: AS17-148-22773 compared with NOAA visible (left) and IR (right) mosaics, and Earthview depiction of terminator at 19:00 GMT 16/12/1972.

The *Sulpicius Gallus* area is in the south west of the *Mare Serenitatis* area. This area is fairly close to the centre line of the Moon as we view it, and we can reasonably assume that it would be crossed halfway between the AOS and LOS parts of the orbit. The mission transcript records that they are passing to the west of *Sulpicius Gallus* at 229:04m MET, or about 18:40 GMT. We therefore have a suggested time of between 18:40 and LOS at 19:15.

As Stellarium isn't clear, Earthview has been used to show the midpoint between those two times, 19:00. Close examination of this shows that the northernmost part of the crescent is actually the very top of Canada, with Greenland just east of that on the dark side of the terminator. Most of Brazil and northern Argentina can be seen, but not much else of south America. Brazil is at the widest part of the crescent. Africa is just obscured by darkness, having just crossed the terminator.

The southern Hemisphere is relatively simple to sort out, as once it is realised that Brazil is much higher on the crescent that you would expect (sunlight, it being winter, is illuminating the Antarctic). Locating he northern hemisphere's clouds rely on recognising two things: firstly the location of Greenland, which is visible here but is not given any data on the NOAA mosaics (mapping square images causes issues on spheres at the poles because of the amount if overlap and distortion required), and secondly the position of the large data gap north of Haiti & the Dominican Republic The one band of cloud that was impossible to place on the image was the lobe extending from the Gulf region towards northern Europe, and the only conclusion (assuming that all other assumptions made are correct) is that it is sitting squarely under that data gap.

It doesn't appear on the NOAA IR mosaic, however, the IR mosaic would have imaged the terminator area at around 02:00 GMT, and the visible spectrum at 14:00. 17 hours is more than adequate time for a weather system to have migrated. Convenient? Conspiracy lovers will no doubt seize upon it as an example of inconsistency in the data that invalidates the whole exercise. Alternatively, it's just a gap in the data.

During TEC, Ron Evans, the command module pilot, carried out an EVA to retrieve equipment from the CSM SIM bay. During that EVA, several photographs were taken that show the Earth, including the one below in figure 4.9.61, analysed overleaf in figure 4.9.62, AS17-152-.23395.

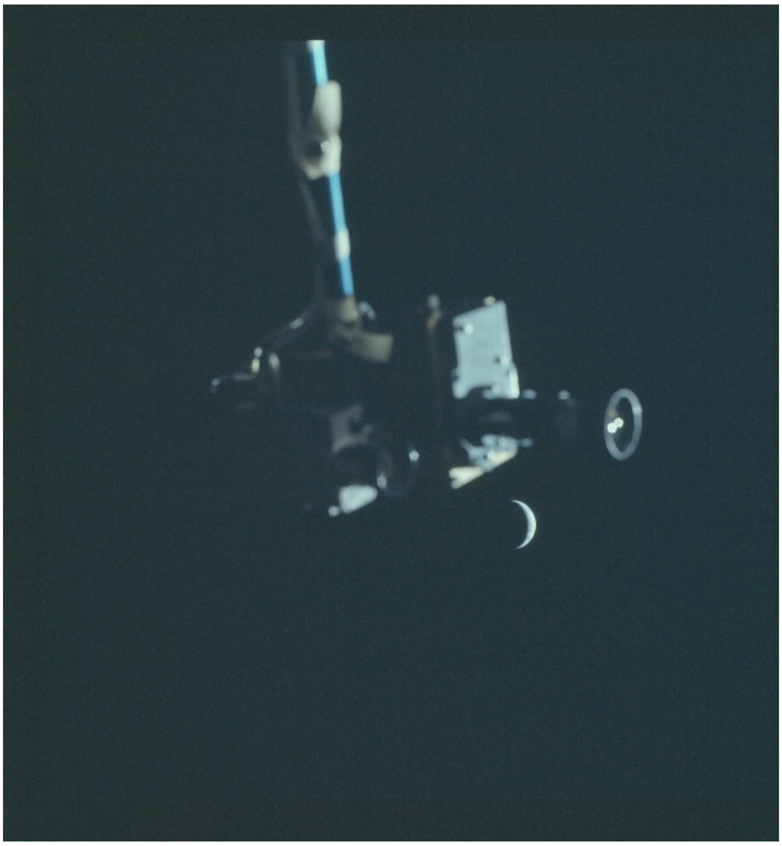


Figure 4.9.61: GAP scan of AS17-152-23395. Low resolution source:
http://www.lpi.usra.edu/resources/apollo/images/browse/AS17/152/23395.jpg

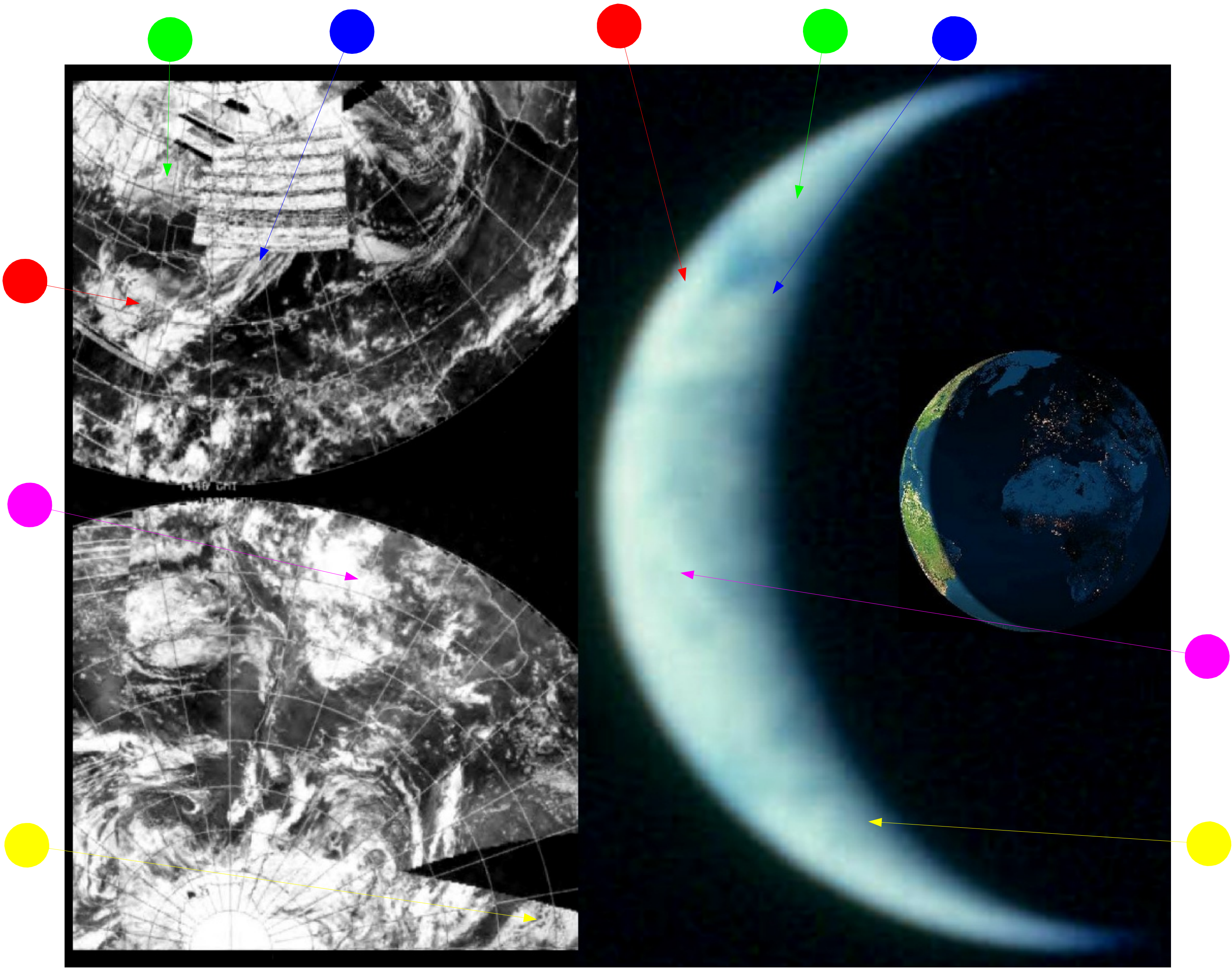


Figure 4.9.62: AS17-152-23395 compared with NOAA mosaic and Earthview estimate of terminator at 21:00 17/12/72.

The NOAA mosaic would have imaged the area around the terminator at around 13:30 GMT.

The EVA commenced at about 20:30 on the 17th, ending just over an hour later. Evans makes several references to the crescent Earth and mentions wanting to take photographs of it, but doesn't mark specifically when photographs were taken Although the photograph used (featuring one of the cameras that recorded the event) appears relatively early in the EVA sequence, a mid-point time of 21:00 has been used for the Earthview terminator estimate, which again has again been used to identify the distribution of landmasses in an increasingly thin crescent.

The most obvious weather pattern, and one that can definitely be identified, is the large 'tick' shaped mass in the northern hemisphere, partially obscured in the NOAA mosaic by data errors. This band, the cloud mass to the north of it, and the gap between them, are easy to pick out. The Amazonian cloud masses and south Atlantic weather bands are also simple to locate once the correct orientation of the land masses at the time of the EVA is determined.

A few photographs taken during the EVA show Evans with the Earth in the background. Unfortunately these are all, by and large, showing a very small and out of focus Earth and there is very little detail to seen in them. In the interests of completeness (bit little hope of conclusiveness), the image with the best view of Earth, AS17-152-23401 is shown over the page in figure 4.9.63, and compared with the same NOAA mosaics as in figure 4.9.64.

Figure 4.9.63: GAP scan of AS17-152-23401. Low resolution source: AIA

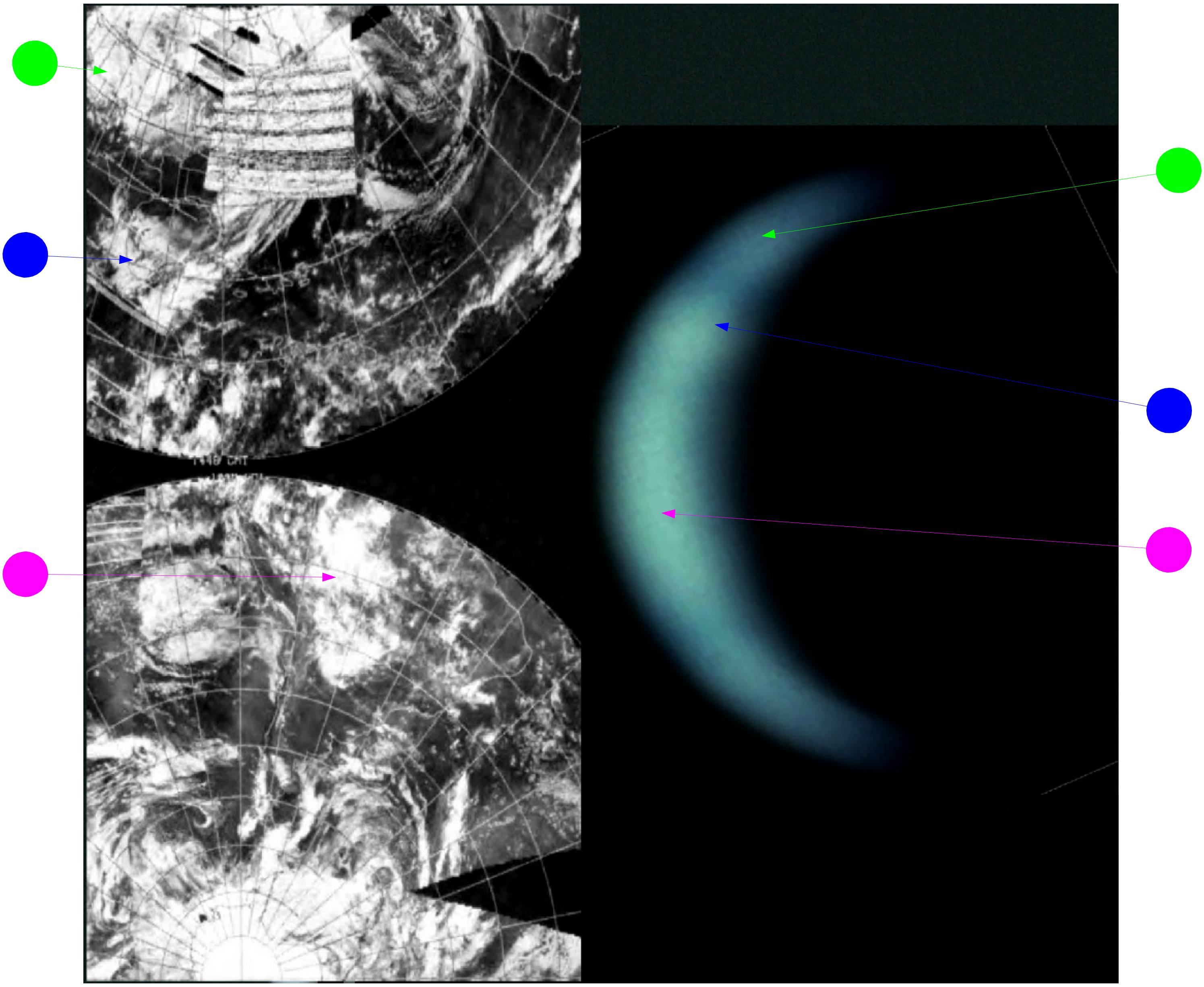


Figure 4.9.64: AS17-152-23401 compared with NOAA mosaic and Earthview estimate of terminator at 21:00 17/12/72.

The view of Earth presented in figure 4.9.64 is so blurred there is little point in doing anything more than identify areas of light and shade. We know roughly when the image was taken, we know roughly what should be there but it would be unwise to state definitively what is there.

What has been picked out is the high latitude cloud mass (green arrow) to the north of the 'tick' shaped band (blue arrow), and there is a suggestion of darker blue between those two masses. The location of the Amazonian clouds is pointed out (magenta arrow), and again there is a suggestion of a gap between that and the blue arrowed cloud to the north that may well be the Caribbean Sea. Whether these are reasonable conclusions to draw is left to the reader to decide.

At the end of this magazine come the final pictures of Earth. There are half a dozen of them, seemingly in sets of 4 and 2, and they follow a number of photographs of the moon. Close inspection suggests that the first 4 were taken about an hour before the last 2, and this will hopefully be demonstrated by the following.

The first of two images, one from each set, is shown below and is AS17-152-23415 (figure 4.9.65). It is analysed over leaf in figure 4.9.66.

Figure 4.9.65: GAP scan of AS17-152-23415. Low resolution source: [AIA]

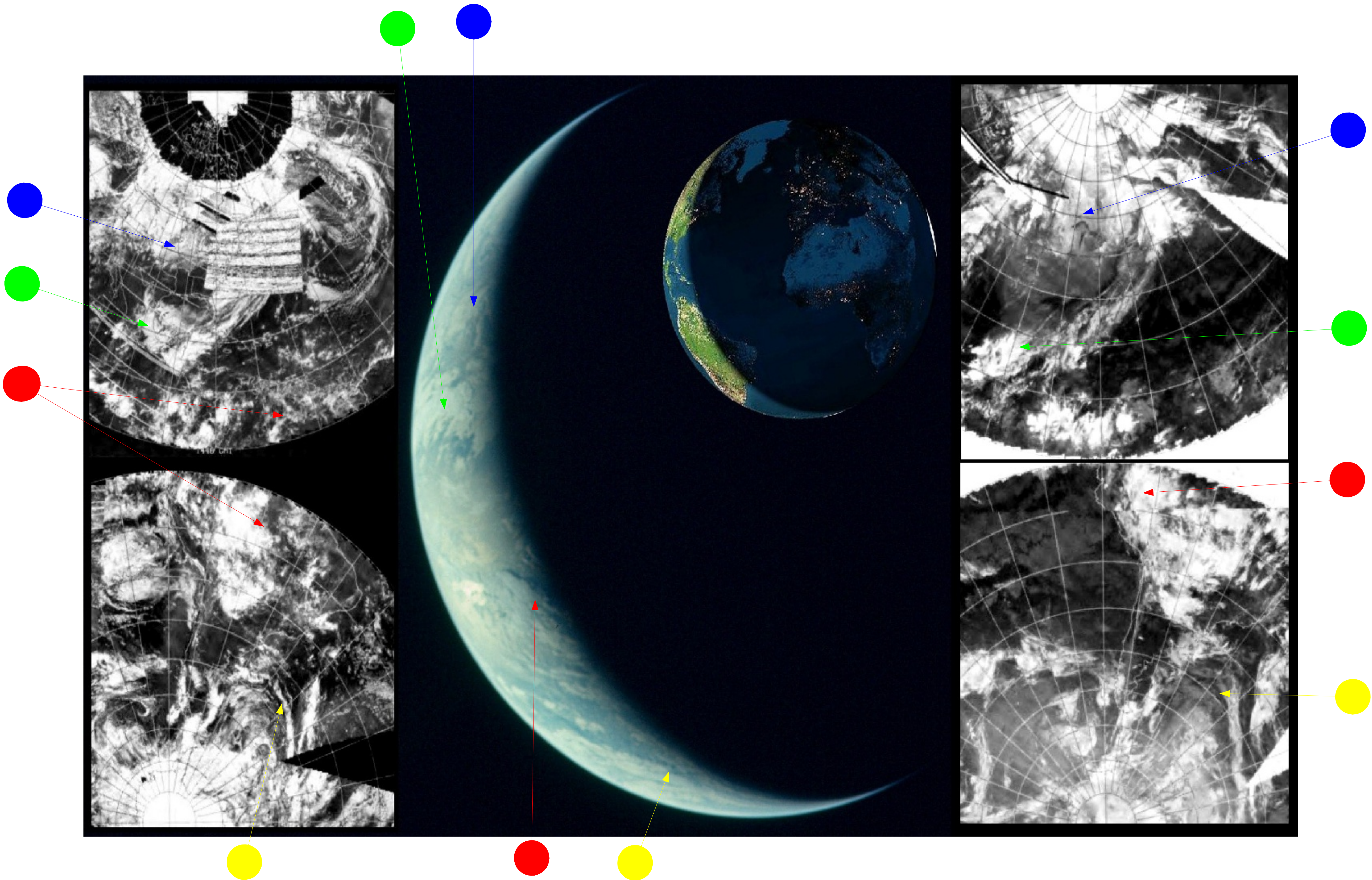


Figure 4.9.66: AS17-152-23415 compared with NOAA visible (left) and IR (right) mosaics and Earthview depicting the terminator at 22:00 on 17/12/72

They key to identifying when this picture was taken lies not so much in the cloud patterns as in what can be seen on the surface. The Earthview depiction shows what should be visible at 22:00 on the 17th. If the photograph was taken on the 18th, the crescent would be much thinner.

Zooming in close to just north of the thickest part of the crescent reveals, faint but still detectable, the thin lines of the central American coast, and from there the bulge of south America becomes clear. Having identified those landmarks, placing the clouds becomes relatively straightforward.

The westward end of the 'tick' shaped cloud discussed previously is positioned over the Gulf and central America, and the clouds of northern Amazonia are also visible The glare on the western horizon shows the subsolar point is over ocean and not land.

As with the previous images taken around the EVA, NOAA would have imaged the terminator region on this image at around 13:00 on the 17th. The IR mosaic equivalent was imaged at around 01:00, and is therefore nearer to the time of the image than the visible spectrum one

The second image is AS17-152-23420, which is shown below in figure 4.9.67 and analysed overleaf in figure 4.9.68.

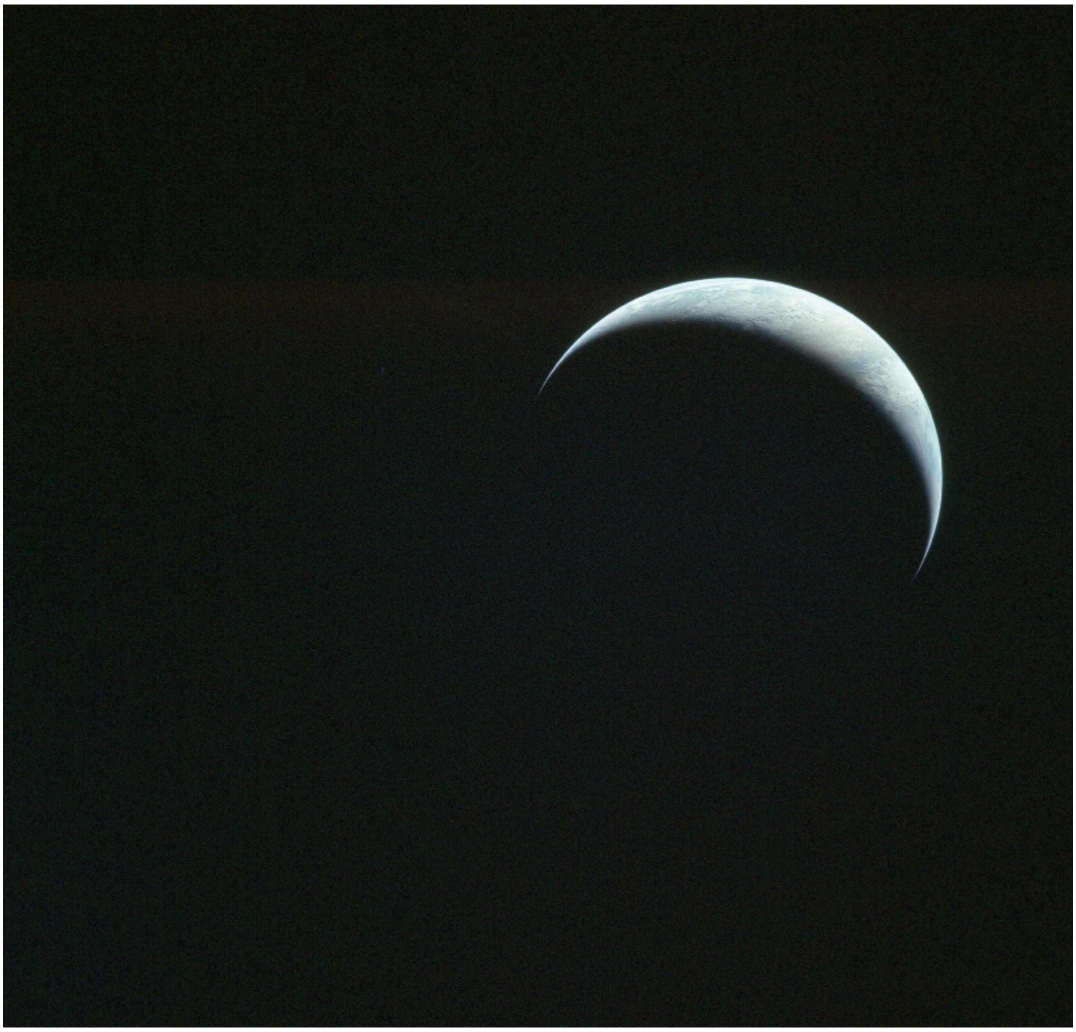


Figure 4.9.67: AS17-152-23420. High resolution source: [Archive,org]

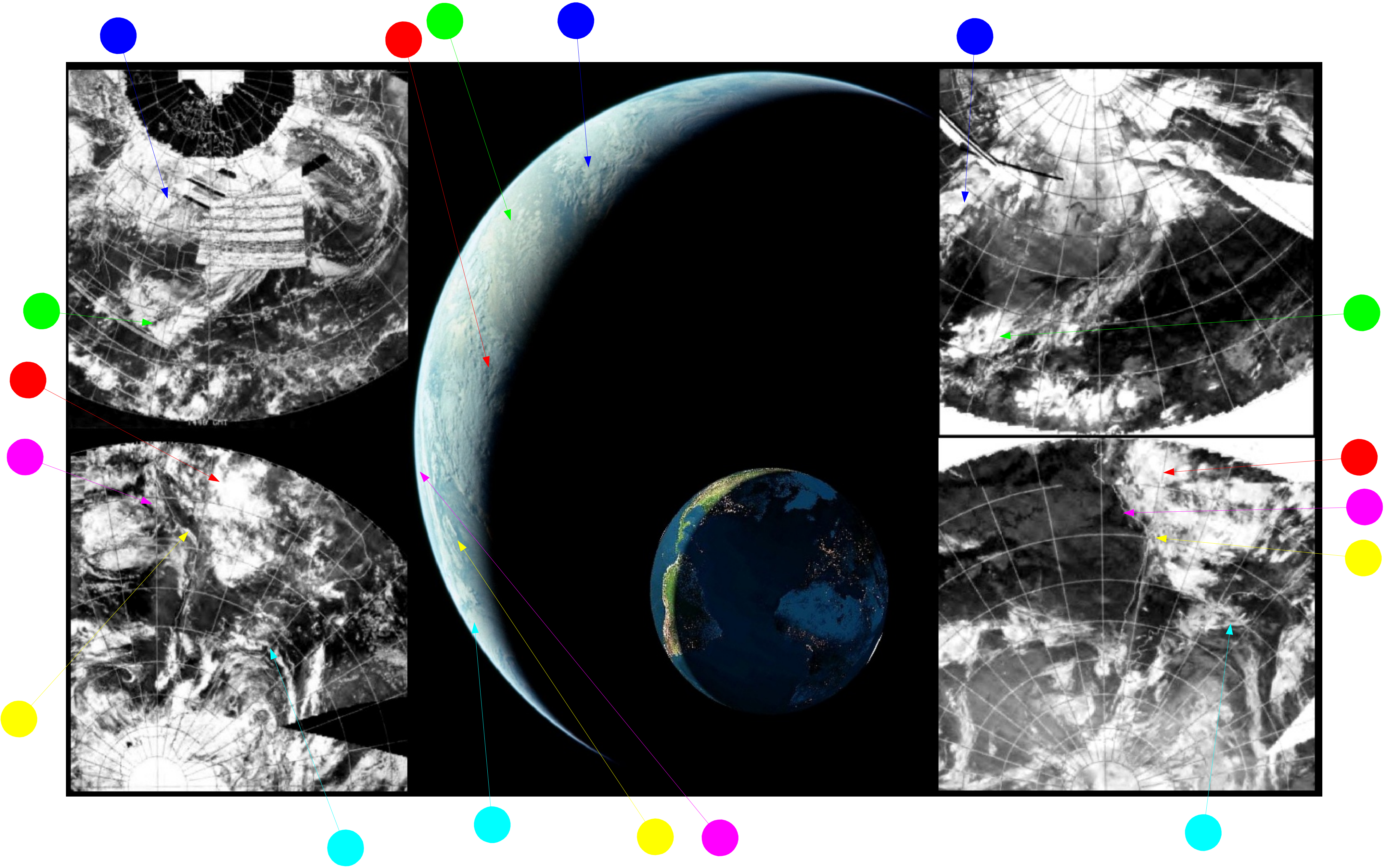


Figure 4.9.68: AS17-152-23420 compared with NOAA visible (left) and IR (right) mosaics and Eaerthview depiction of terminator at 23:00 17/12/72.

As before, the thickest part of the Earth's crescent shows the coast of central America, but in this instance it has rotated further round and much more of it is visible in the photograph. An estimated time lapse of around an hour has been used, and this does seem to correspond with the change in the amount of central America visible in the two Apollo images.

In broad terms the weather systems are still the same, but they do not necessarily appear in the obvious place, thanks to the orientation of the Earth and its rotation.

As before we have the large cloud mass over the USA (blue arrow), and the long 'tick' shape (green arrow) ends in the gulf near the central American coast. The red arrow picks out the cloud over northern Amazonia.

The magenta arrow picks out what appears to be coastal fog, which would explain why it does not appear on the IR image, either because it was ephemeral in nature or because the cool air mass that would produce this fog is less visible to IR cameras. The yellow arrow is really only there to pick out features within those coastal fog banks. The cyan arrow points to the curve of the top end of a cyclonic south Atlantic system.

The times for the NOAA mosaics would be an hour further on than those for the previous image, assuming that the time gap between the Apollo images is correct.

No more images of Earth exist for Apollo 17, and the next stop for the crew is the final re-entry procedure for a returning CM, and the end of the Apollo programme.

The end of this part of this research will be after selected parts of the available synoptic data are examined.

4.9.2 Synoptic data

Disappointingly, given the many and beautiful pictures taken of the weather during their voyage, there are relatively few opportunities to compare with the synoptic charts of the day..This is thanks to a combination of most of the images being from the southern hemisphere, and also a large gap in the German data that has proved so useful so far.

The daily weather charts are available for north America, but for the most part there are few opportunities to use them. Mexico charts are available for the mission periods, but they add little to the information given by the north American ones (as will be seen shortly). There are many pictures of Africa, and so the South African data are useful, but it is a shame that more of the continent is covered.

There may be other data sources out there, but they have not been uncovered during the writing of this report.

A final problem is the fact that most of the images are taken during the outward journey, and cover only a few days. The period on the moon and the return have many fewer images and those that do exist are, obviously, of a much narrower Earth crescent..

The first image compares the African part of the 'blue marble' image with the South African weather chart from 7/12/72. This can be seen in figure 4.9.69 overleaf.

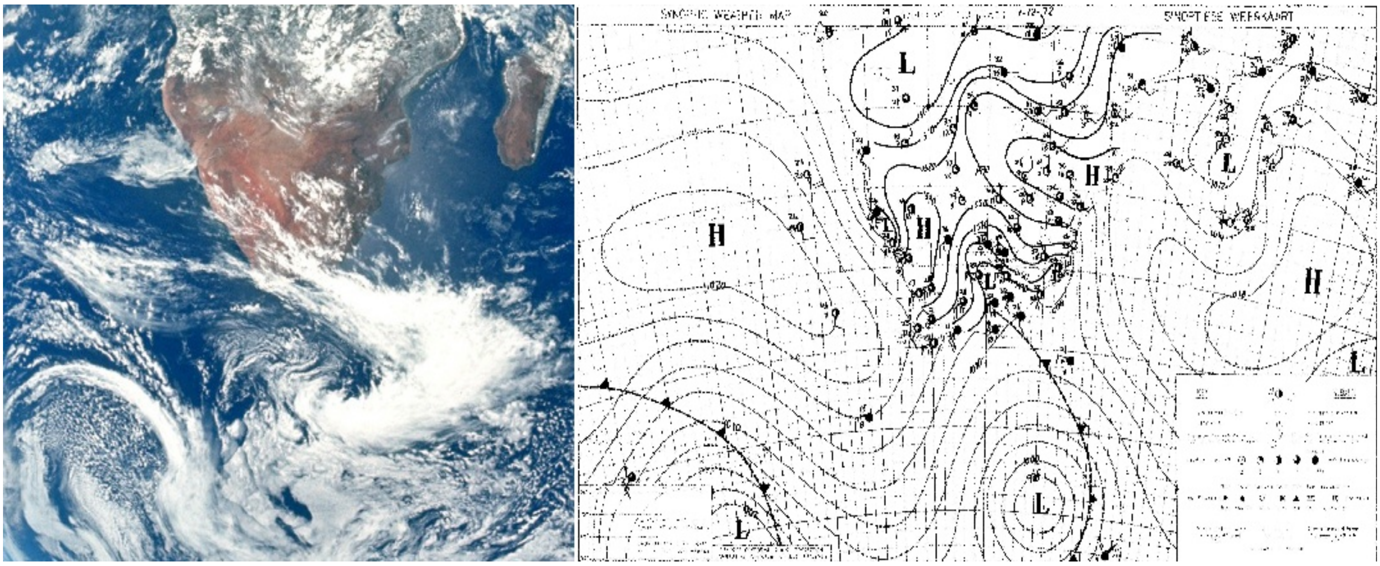


Figure 4.9.69: AS17-148-22725 compared with South African synoptic chart from 7/12/72

The two fronts marked on the synoptic chart are so obvious there is no need for arrows, and it is interesting to note the high pressure zones south of Madagascar and west of South Africa are largely cloudless, in short, the Apollo image shows exactly what it should.

On the 8th of December, two images were taken that cover Africa and the Americas, and therefore we can introduce the chart from North America as well as Africa. Figure 4.9.70 below shows a section of AS17-148-22743 compared with the South African synopsis from 8/12/72.

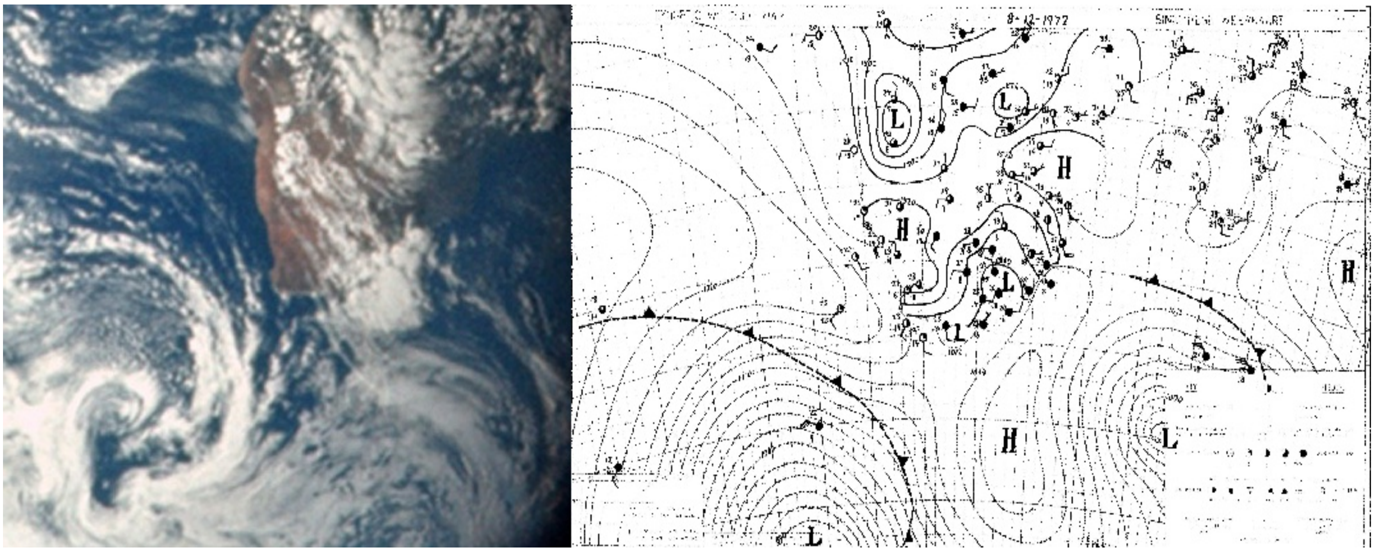


Figure 4.9.69: AS17-148-22743 compared with South African synoptic chart from 8/12/72

The progression of the weather fronts across South Africa over 24 hours is self evident in both the Apollo image and the synoptic chart, and the two fronts marked on the synopsis are again obvious. The high pressure zone between the two fronts is not clear of cloud, but the cloud is broken. Highs to the north of both fronts are much clearer.

The situation in north America is shown over the page in figure 4.9.70.

The red lines on the Mexican chart are used to emphasise thin lines that appear to be those of fronts. It is unclear what the dashed lines are meant to imply on the drawings.

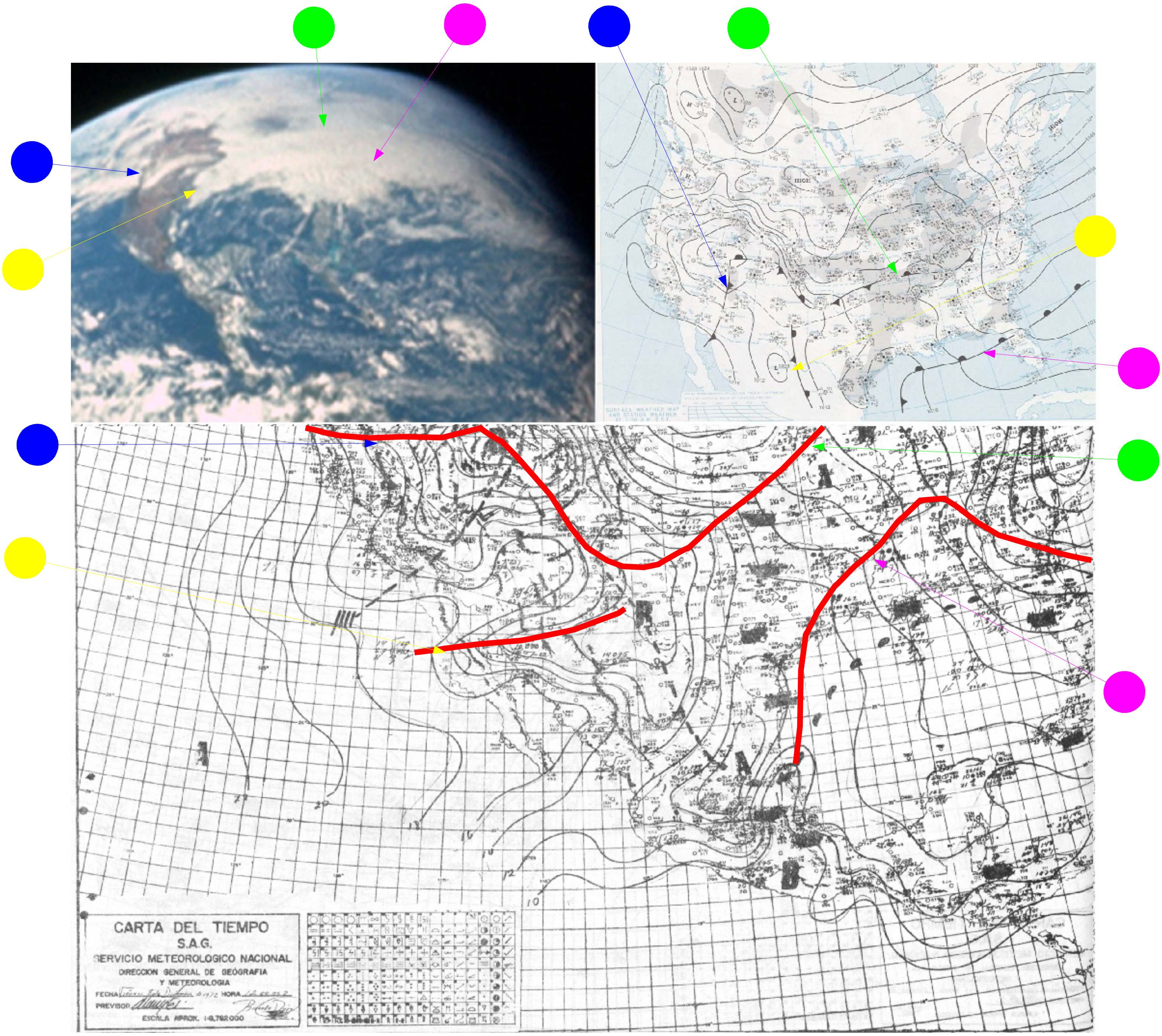


Figure 4.9.70: AS17-148-22745 compared with NOAA (top right) and Mexican (bottom) synoptic charts from 08/12/72.

The main point to make about the north American image is the good degree of correspondence between the hand drawn Mexican chart and the more modern looking chart from the NOAA, despite the many obvious amendments of the former. While they are not identical, there are broad similarities.

The meandering front across the continent (blue to green) is well marked, and zooming in closer to the image makes it possible to differentiate between the leading and trailing edges of the large bank of cloud that marks the border between that front and the one to the south (red arrow). The line marked in yellow seems to match the orientation of the cloud seen in the Apollo photograph, even if it does not quite match the orientation of the NOAA front drawn several hours earlier.

A similar exercise can be undertaken for the following day. AS17-148-22749 and 22758 show most of |Africa and north America respectively. The South African comparison is shown overleaf in figure 4.9.71. North America's data are shown in figure 4.9.72.

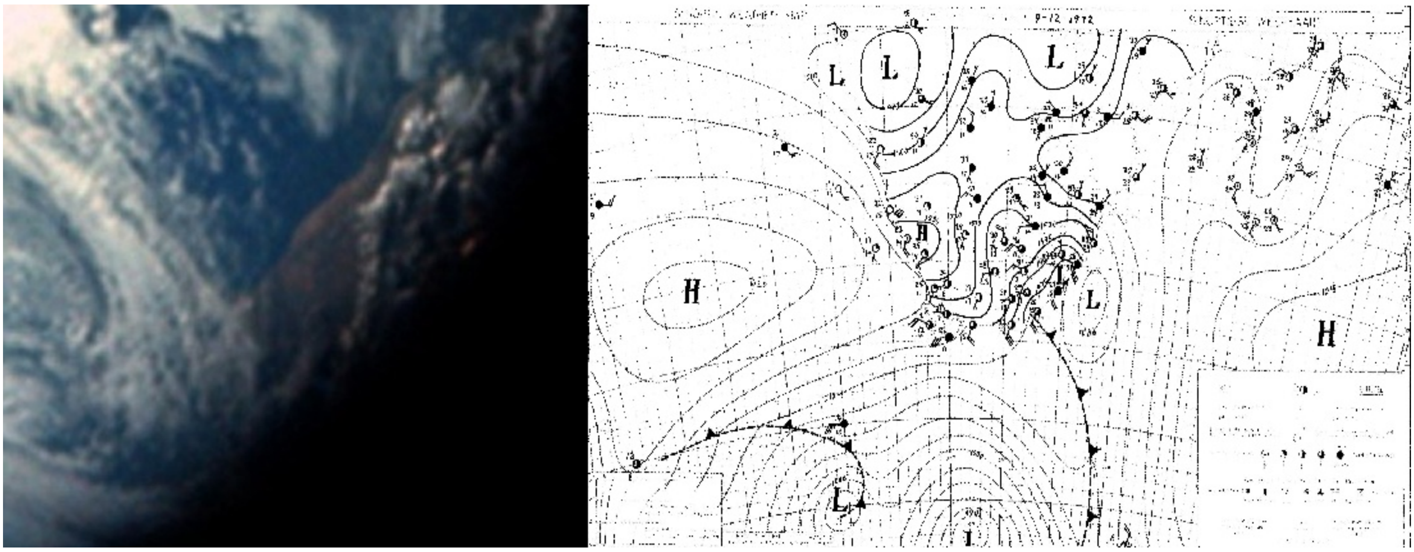


Figure 4.9.71: AS17-148-22749 compared with South African synoptic chart from 9/12/72

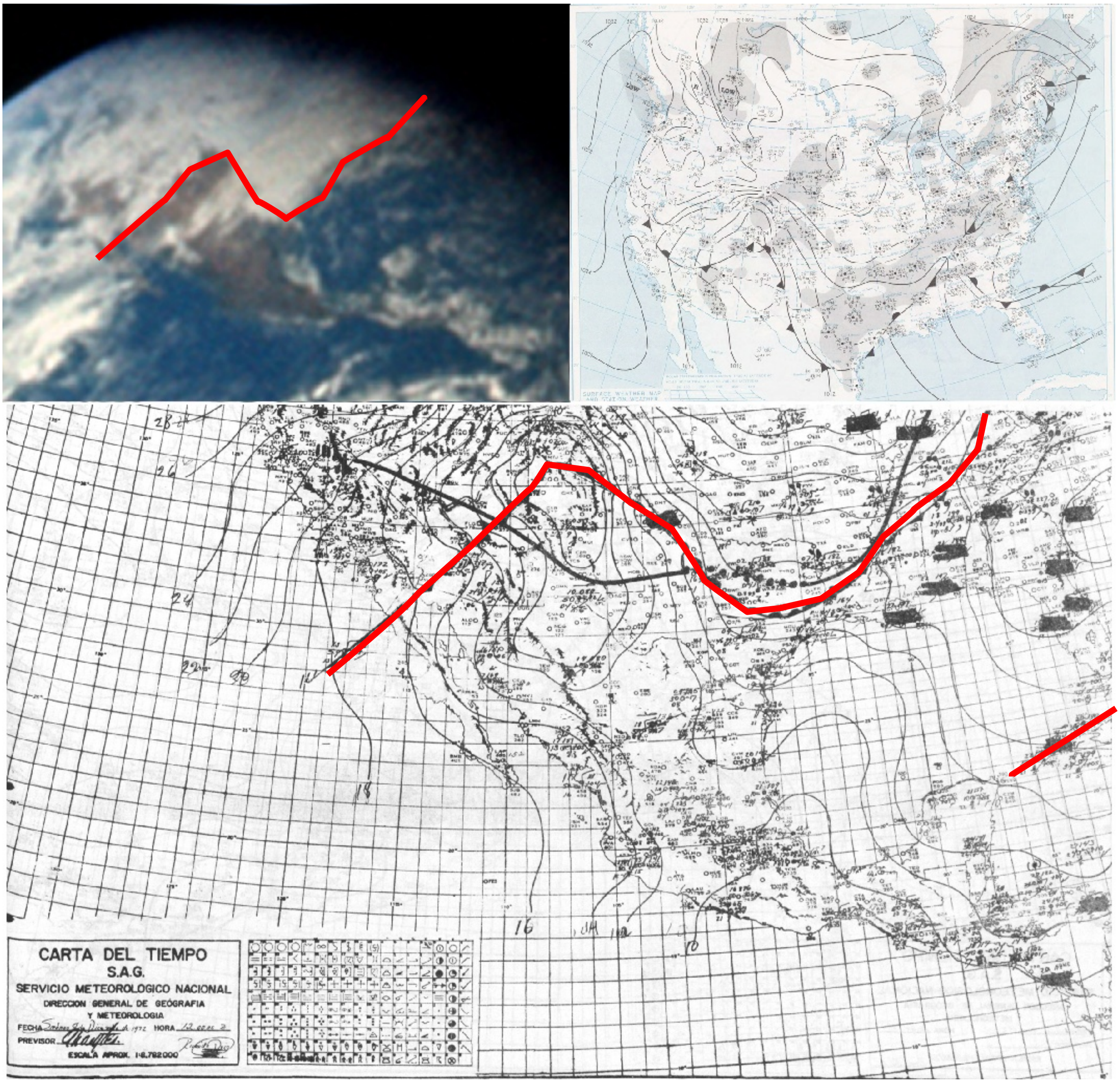


Figure 4.9.72: AS17-148-22758 compared with NOAA (top right)and Mexico (bottom) synoptic charts for 09/12/72.

Again from South Africa we see a development of the frontal systems from the south-west, and there is also the fact the cloud mass in the Apollo image is oriented east-west as is the frontal system, in the front, showing again that the two correspond well.

The NOAA and Mexican data also see good correspondence with the Apollo image. The long sinuous front shown on the NOAA image is matched by that on the Mexican one (although the markings on the latter were difficult to see and have been emphasised in red here. Florida is just out of view on the Apollo image, and thus it was not possible to place the front there reliably.

The 10th of December sees another good image of South Africa in AS17-148-22763, and this is shown below in figure 4.9.73.

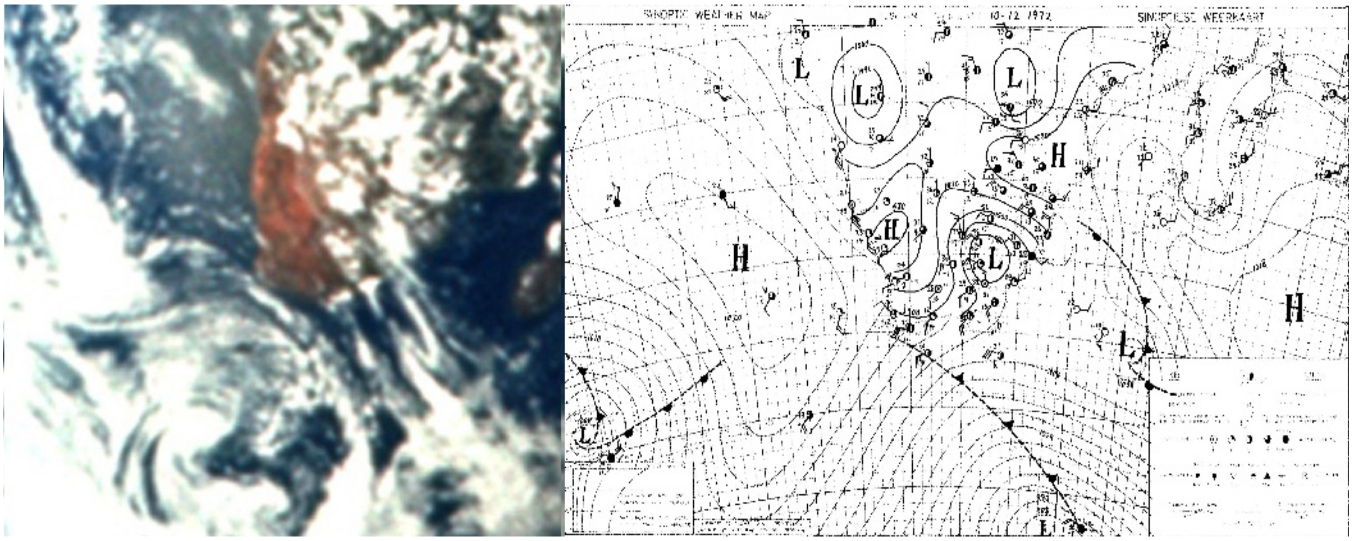


Figure 4.9.73: AS17-148-22763 compared with South African synopsis from 10/12/72.

The three fronts on the chart can easily be found on the Apollo image, right down to the right-angled bend in the system to the west.

There is also a blurred view of north America available on the 10th in AS17-149-22779 (figure 4.9.74). The Mexican chart showed no front, but does show the same undulating front boundary area along the Mexican border. It has been omitted as much for space reasons as for the fact that it doesn't show as much detail as the NOAA chart. What is visible on the Apollo image is that long front across Mexico and the Gulf, showing a band of cloud along the cold front to the north of it.

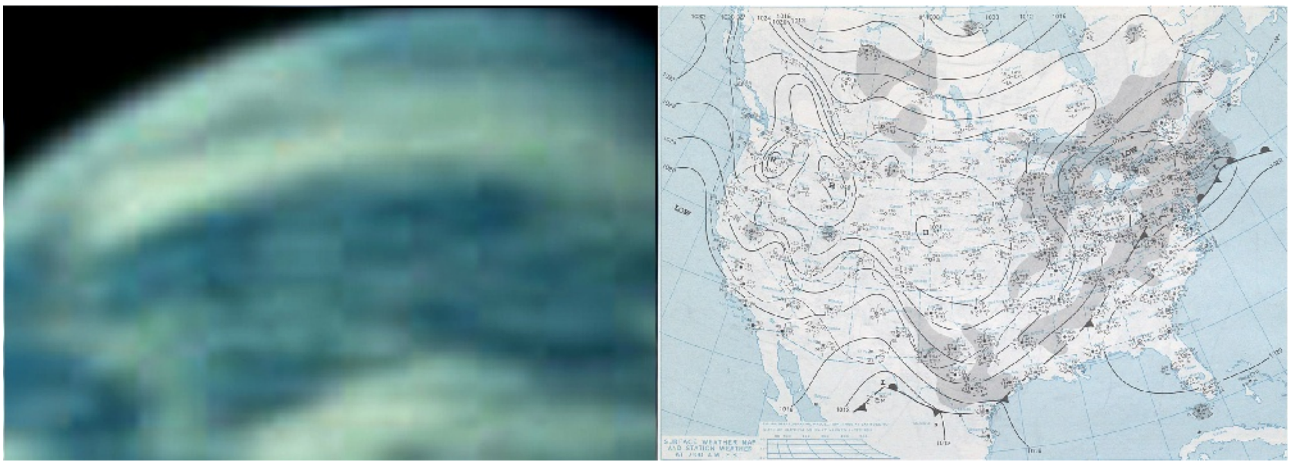


Figure 4.9.74: AS17-149-22779 compared with NOAA synoptic chart from 10/12/72.

Africa has one final bow to make in AS17-152-23278, which was taken on the 16th. Figure 4.9.75 shows South Africa with it's attendant frontal system visible in both the Apollo image and the synoptic chart.

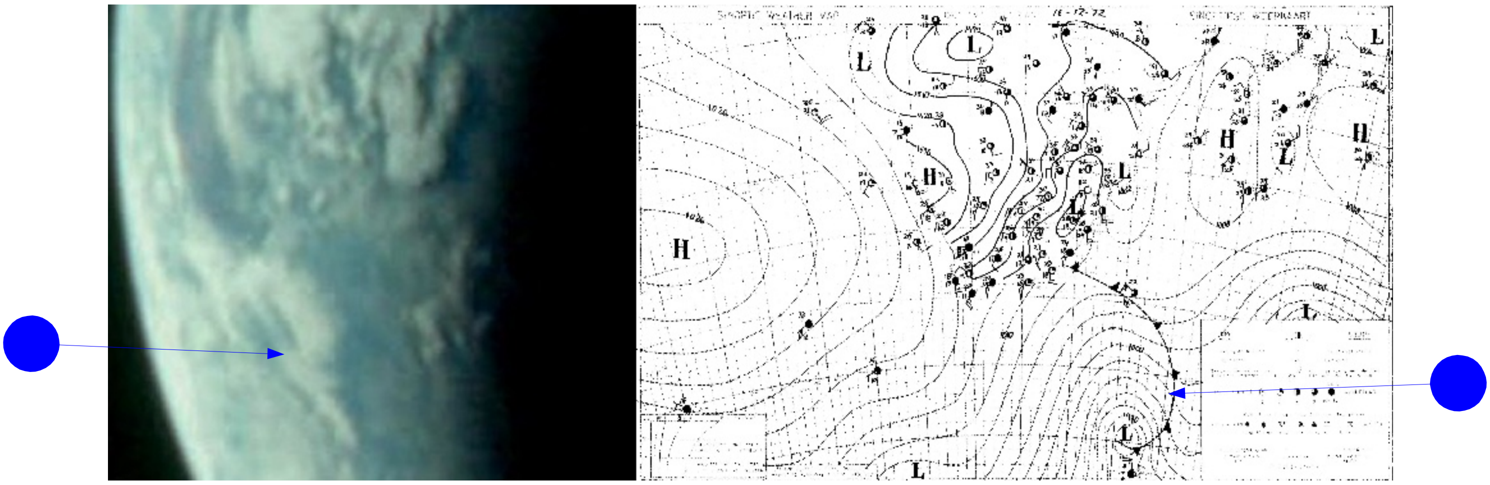


Figure 4.9.75: AS17-152-23278 compared with South African synoptic chart from 16/12/72

The curl of the band of cloud off South Africa is, as with the other images, self-evident on both the synoptic chart and the Apollo image.

Although, from the 16th, German data become available, the angle of the Earth and the size of the crescent visible means that little is added to the debate by including them, and as a result this section of this research will come to a close.

Nine missions sent around the Moon and back, all shown to have weather patterns in the photographs they took that conform with the synoptic data taken in several countries, and with satellite images from a number of different satellites in images that were available to anyone who cared to look at them.

The contention here is that the data presented represent substantial supporting evidence in favour of the Apollo missions that show a consistent narrative from start to finish of the Apollo programme.

The following section will examine if that contention is reasonable by scrutinising the likely criticisms of the research from those who will refuse to believe it.

5: Discussion & Conclusion

Section 4 has gone over, in painstaking and occasionally painful detail, the photographs and videos taken of Earth by the 9 moon bound Apollo missions and compared them with the satellite images of Earth taken by geostationary and low earth orbit satellites. The process of writing it has been as immensely repetitive and tedious as no doubt it has been to read it. Points have been laboured, minutiae have been microscopically examined, arrows have been used to point out the blatantly obvious lest someone claim that they could not see the obvious.

What have we learned? That the satellite record contains a wealth of corroborating evidence to support the claim that 9 Apollo missions went to the moon, 6 of which landed. As stated at the start, they are not the be all and end all of proof but, taken in conjunction with the wealth of other evidence, they are a hefty nail in the conspiracy theory coffin.

If you believe in the Apollo landings and have enjoyed this work, thanks for sticking with it. Feel free to quote it wherever you like, as long as you reference it when you do.

If you did not believe in the landings, or were equivocal about them, and this evidence has helped persuade you that they did in fact happen, then I am pleased that it has been of some use.

If you have waded through the arguments and still disbelieve in the truth of the Apollo missions, then there is no hope for you. I am only glad I was able to keep you out of contact with normal people for as long as you were sat reading it, and that the town centre shop windows were unlicked for at least a short while.

This work will not be without its critics, and I am sure there will be attempts to disprove it, or to claim it is another establishment lie. There will be those whose response to this entire discussion will be “There are no stars in the photographs and Von Braun was a Nazi” as if that is all the evidence they need.

I will now take the opportunity to fend off the most likely claims.

1. You are a NASA shill

Listen very carefully, I will say this only once: I have no affiliation with NASA, or any of its subsidiaries or affiliates. I have never had any affiliation with NASA or any of its subsidiaries or affiliates. I am not even American. I have never been approached by anyone, ever, to post or write on their behalf. I have not been paid, ever, by anyone to post or write on their behalf. I have never been supplied with information to post by a third party unless I have asked for it as part of this research. I have not been paid, ever, to post on the internet, unless you count the time I updated Facebook at work when I should have been doing something else.

I have contacted various branches of NASA during this research, some of which has been useful, but for the most part they have either ignored my requests for information or were unable to help.

Occasionally information has been supplied and I have used it, but I have never taken instruction on how to use it. Any accusation that I am simply a mouthpiece for NASA is a lie, and besides that, anyone who dismisses cast iron evidence purely on the basis that it is from NASA is an idiot. The research either works or it doesn't. The source of the information is irrelevant.

3. 2. You admit to doctoring the photographs

Now this I will spend a little time explaining, after I have made this clear (again):

I have never added to, or taken away from, any of the photographs used in this research. Ever. I have not manipulated any image in order to misrepresent its contents. Ever.

I am happy to state (and have said so in the text) that I have used some basic techniques to enhance images in order to make what is there clearer. This is entirely different from doctoring or faking.

I will now demonstrate those techniques so that readers can try it for themselves using a free image editing software package: GIMP, available for download here: http://www.gimp.org/ .

The main technique used is adjusting the 'levels' in an image. Any image can contain the balance of light and shade you want, but it can also contain light and shade that you don't want. Image editing software like GIMP contains a simple tool that allows you to remove unwanted brightness and dark areas. If you have ever had a photograph that looks very 'washed out', for example on a hazy summer day, you will find the following useful in removing that haze and revealing the image behind it.

As a worked example, I opened the high resolution GAP scan of AS16-118-18885 (used in section 4.8) and navigated to the 'Levels' menu ('Tools','Colour Tools', 'Levels').

In figure 5.1 below, the tool is on the left and has already been applied by moving the two triangle markers in from the outer edges, and the effect on the selected part of the image should be obvious.

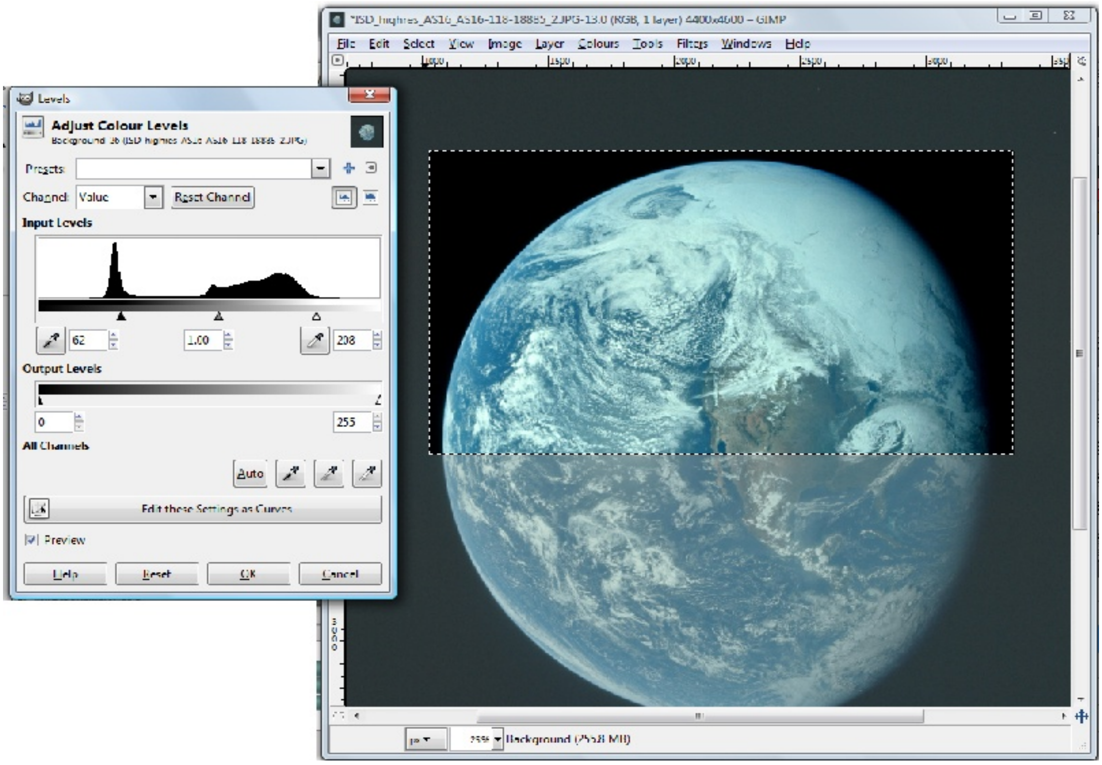


Figure 5.1 – Level editing tool in GIMP

Next, I decided to add a little sharpening to the 'entrance to inner Earth'. The sharpening tool can be found in the 'Filters', 'Enhance' menu, and I have the chosen 'Unsharp Mask' tool. The operation of the tool can be seen in figure 5.2, and figure 5.3 shows the end result on a selection of the image. It's an easy one to overdo (as in this example) but can be useful in bringing out detail in blurred images. When it has been used in this research, I have identified it.

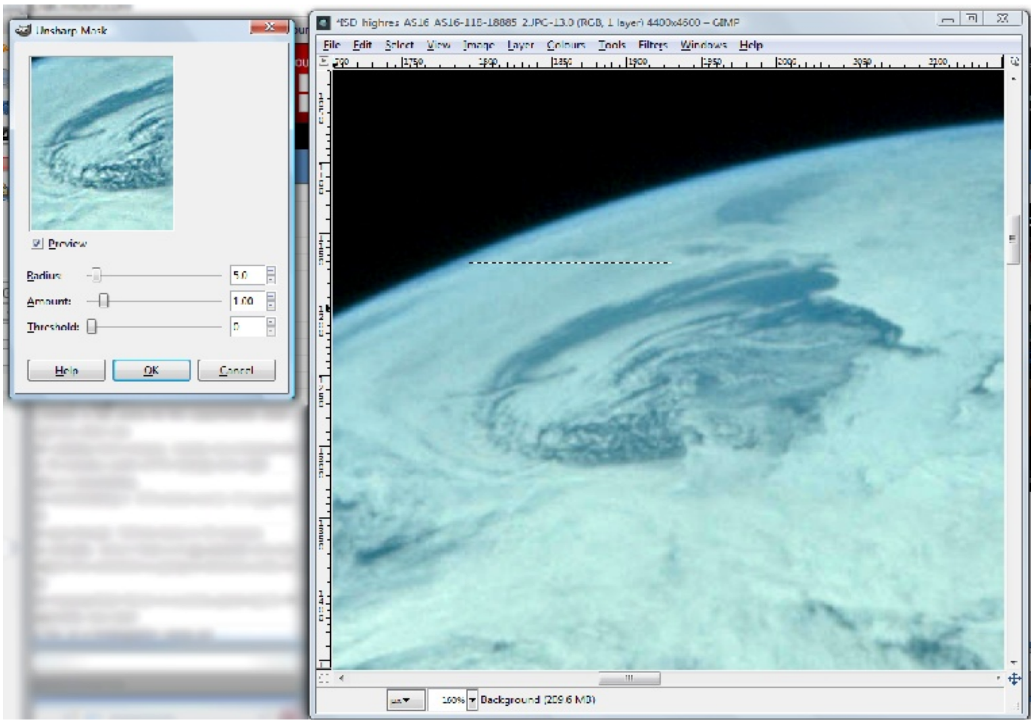


Figure 5.2: The Unsharp mask tool. Adjusting the 3 sliders alters the level of sharpening.

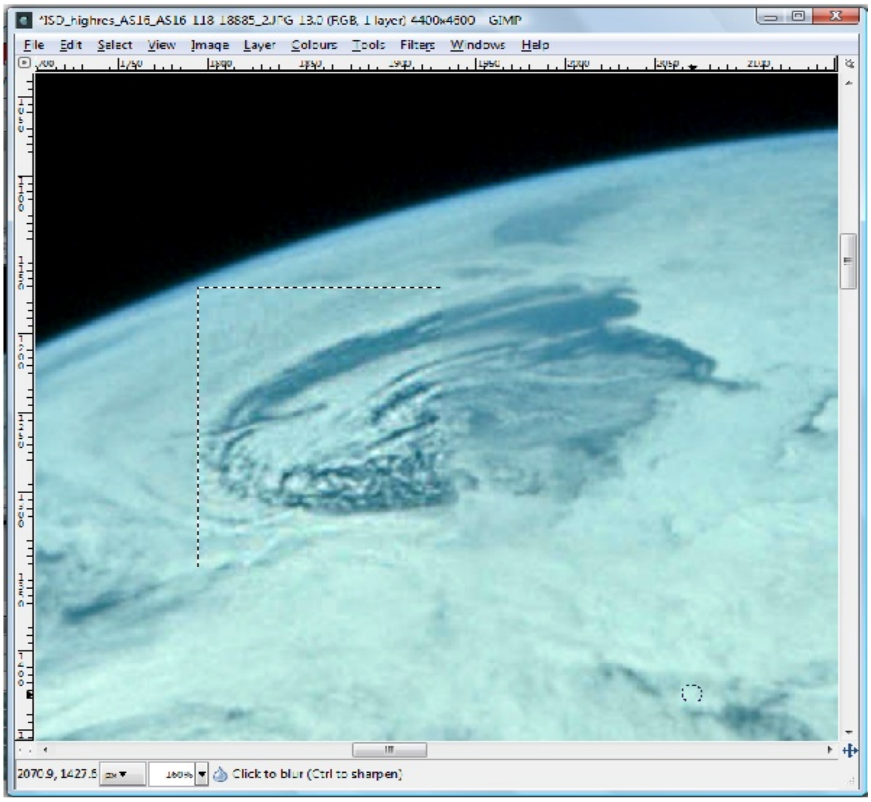


Figure 5.3: After applying 'Unsharp Mask'

Now that it's been level adjusted and sharpened, let's have a quick look at contrast and brightness ('Colours', 'Contrast – Brightness' menu) in figure 5.4:

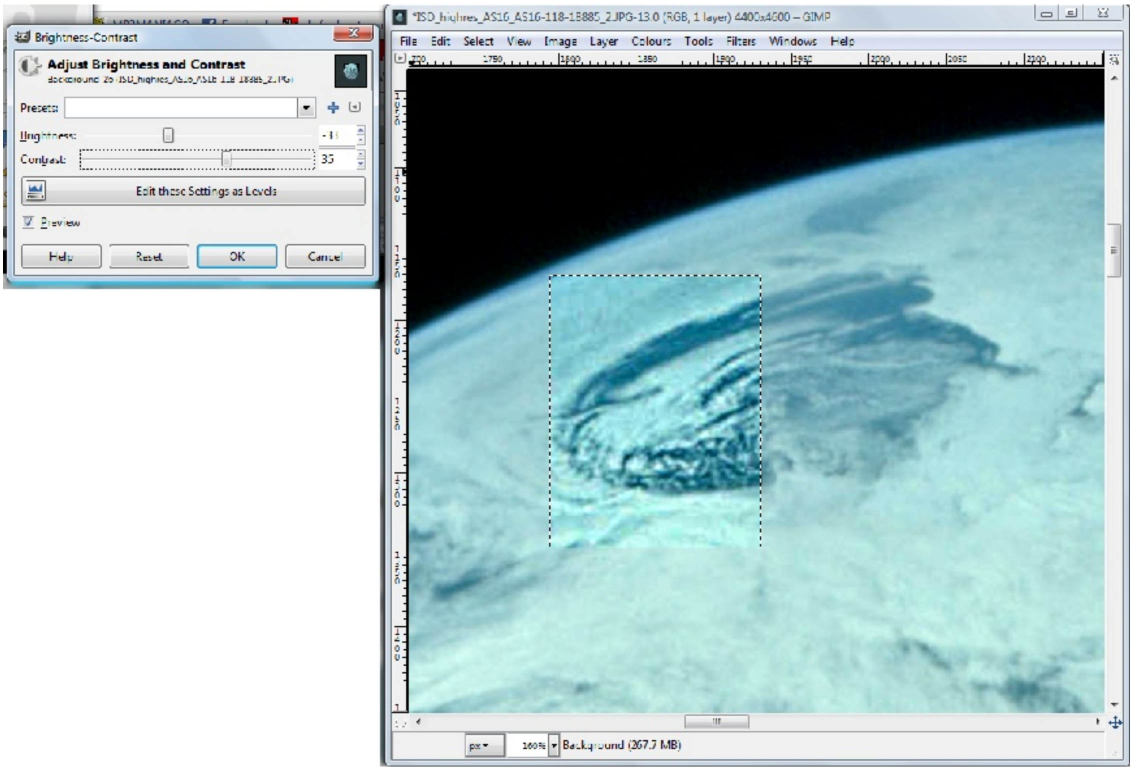


Figure 5.4: The contrast/brightness tool, showing the impact on a selected area.

Figure 5.5 shows the end product of level adjustment, sharpening and contrast/brightness adjustment. It has been overdone for the purposes of this illustration, but it should be evident what the overall impact of this enhancement process is, and that nothing has been added or removed as a result. This particular image did not need anything other than level adjustment, but it can make the difference between important details being hidden or revealed in poor quality photographs.

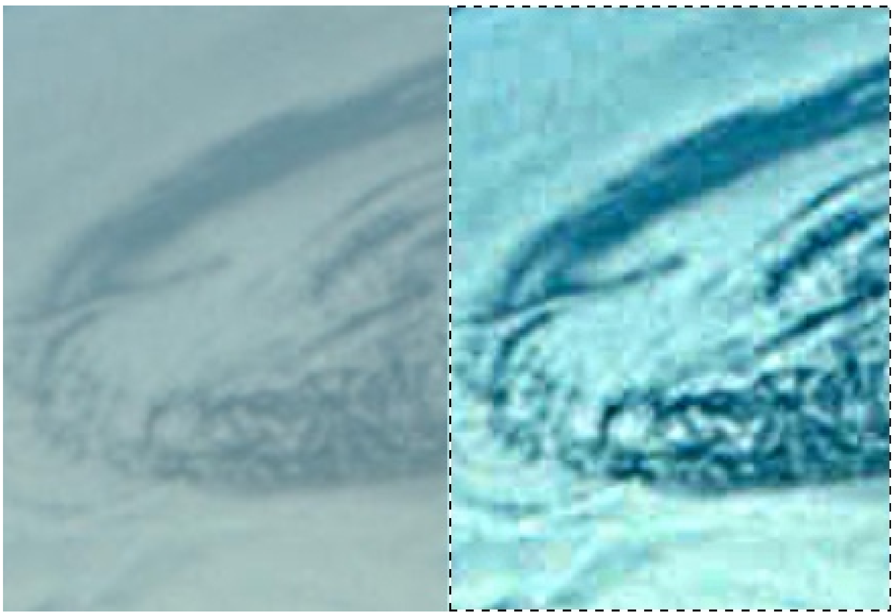


Figure 5.5: The original section of the GAP image with no alterations (left) and the finished product (right).

4. **They did it all in Photoshop**

Well, I just did, so surely NASA must have, right?

It is a common mistake amongst many conspiracy theory lovers to assume that what they see around them on a daily basis has always been available. Films show levels of special effects where the clearly impossible happens in front of the viewer's eyes, and image manipulation tools like Photoshop are used to change images or manufacture them completely almost routinely. It is difficult for them to conceive that these are recent developments, and that there was a world that had to cope with non-digital methods of recording and storing information, where camera films had to be developed in darkrooms, and photographers had no idea what images they were taking until some time after they had taken them.

Ironically, it is often claimed that the computers in Mission Control were incapable of managing simple navigational computations, but at the same time capable of altering Apollo images. Pictures of the computers used to process the satellite images have already been shown in Chapter 2, but it is perhaps worth going over the state of the art in terms of computer graphics at the time of Apollo to see whether the claim that digital manipulation is reasonable, or whether simple airbrushing could have been up to the job.

In 1968, the year of the first Apollo circumlunar mission, the first mass marketed PC was launched by Hewlett Packard, the HP 9100A. You can see what it looked like in figure 5.6.

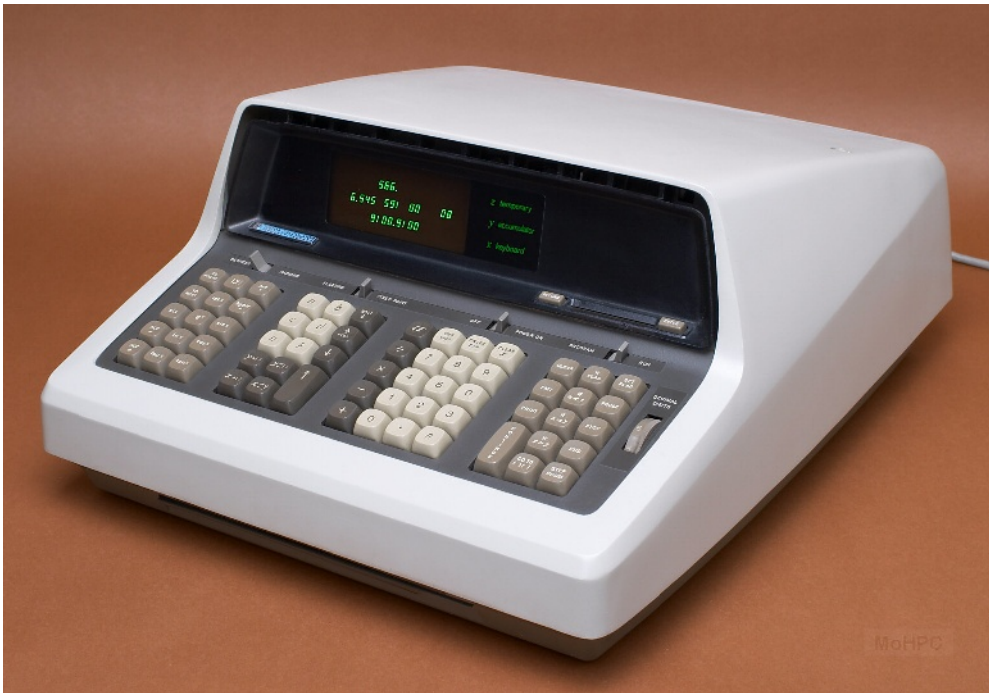


Figure 5.6: The HP 9100A. Source: HP Museum

The HP museum states that his little beauty helped Dr Van Allen, the man after whom the Van Allen belts are named (and whose evidence is often misused and misquoted by conspiracy lovers to 'prove' the landings never occurred), to calculate the use of Jupiter's gravity to slingshot a space probe towards Saturn. It is obviously capable of significant calculations in terms or orbital mechanics, but it has no graphics capability other than an LED alphanumeric display.

There were more powerful mainframe computers. These were large central computers, the equivalent of a modern server, that could be interrogated directly or by satellite terminals. The terminals themselves would have little functionality other than as a communications device to the mainframe.

Figure 5.7 shows an example of an IBM mainframe that would have been around in the late 1960s:

Figure 5.7: The IBM System/360 Model 30. Source: IBM

Have a careful look at the picture Where is the monitor? Where is the graphics capability? Here is IBM's top of the range personal computer 9 years after the end of the Apollo mission:

Figure 5.8: The IBM Personal Computer 1981. Source: IBM

The ESSA World journal cited in chapter 2 also has images of the kinds of computer technology available to those receiving the satellite data.

Figure 5.9 shows banks of computers and tapes that were used to process meteorological data (not just satellite data, while figure 5.10 shows the kind of graphics capability available to ESSA meteorologists. In this case it is being used do show isobars on a map, along with the various overlays that could be used in the process.

Figure 5.9: Computer equipment at ESSA. Source: [ESSA World]

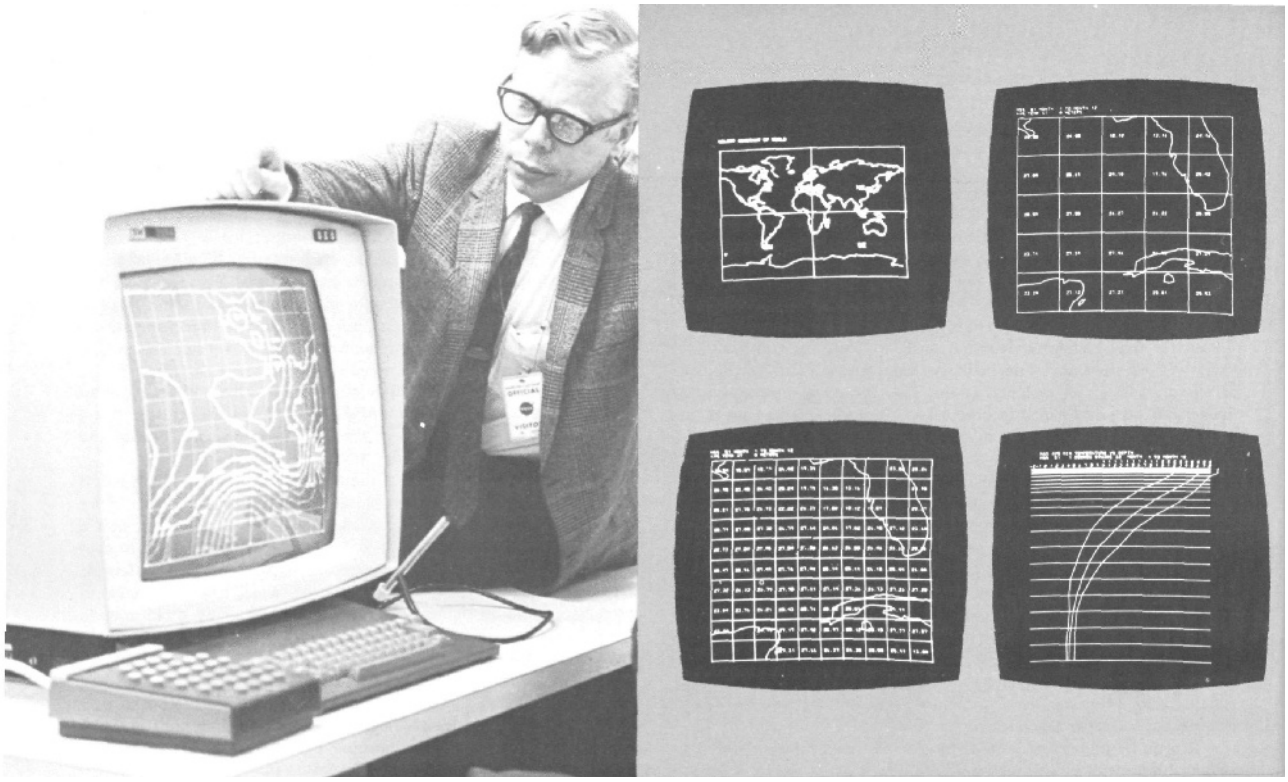


Figure 5.10: Computer terminal used to produce weather charts. Source: [ESSA World]

So, the computers shown above had no graphics capability, but does that mean there were no computer graphics at all? Or digital images?

The first digital image is widely reported as being the one shown in figure 5.11.

This image is a scan of a photograph and was achieved in 1957 by Russell Kirsch. This news must fill the heart of every sceptic with joy, but let's take a look at it.

Anyone imagining that we suddenly have the capability of high resolution digital images, and therefore the ability to manipulate them, is surely going to be disappointed. Granted there are another 11 years until the first Apollo photograph of the Moon is taken, but we still need in that time to achieve colour display and graphics software.

The sharp-eyed amongst you will have noticed that the image is black and white, not colour. Colour television was indeed around at the time of Apollo, but there wasn't any computer hardware capable of rendering colour. Colour rendering did not actually appear until 1977 with the introduction of the Apple II. The first dedicated graphics cards did not appear until the 1980s, and the first edition of

Figure 5.11: The first digital image. Source: PetaPixel

Photoshop appeared in 1990. In a nutshell, because the history of graphic computing is beyond the scope of this study, the techniques of computer manipulation of graphic images were in their infancy during Apollo. Neither the hardware nor software existed that would allow the photographs taken by Apollo astronauts to be manipulated by a computer in order to incorporate satellite images.

What they conspirators expect us to believe is that photographs were taken on the ground. Those photographs then had added to them images taken by black and white satellites that were converted to colour, rendered in a 3D realistic form, given the correct orientation in space and then reproduced for public release with no seams or joins or errors or inconsistencies. I am reluctant to use the word impossible, as it's not a scientific term, but that is what the task would have been: impossible. Impossible to do in a photograph and certainly impossible to do in a live TV broadcast.

Yes, NASA had access to higher quality satellite images than were available here, and Jack Schmitt even managed to take one to space with him, but black and white images in 2D projection are not realistic 3D colour images with shadows and shading and perspective thanks to the curvature of the Earth. In theory, it could have been possible to transmit images to an Apollo craft, assuming they had the kind of equipment we have already seen that is needed to reproduce a satellite image, but why do this? If they are on the way to the Moon they can see the weather and there is no need to send them the images.

In short, no, it could not have been done using a computer.

Could other techniques have been used, such as airbrushing? Airbrushing is a skilled technique where fine mists of paint are applied with a jet of air to a surface. Fine detail can be achieved by a skilled practitioner, but the obstacles for such a scenario are the same. Assuming for just one second that the Apollo images were done in a studio or in LEO, the Earths rendered in the Apollo photographs could not have been done at the same time as the photographs were taken as they would not have had the satellite images available to them.

They would have to have been done after they had the satellite images to work with. For the higher resolution LEO satellites, it could take 12 hours just to acquire the images needed for a full disk Earth image These would then have to be reproduced by an artist who not only knew how to airbrush well, but understood meteorology well enough to know how the weather patterns would progress. They would then have to faithfully reproduce these weather patterns in photograph after photograph, all the while adjusting the photograph for the correct amount of Earth rotation.

Impossible? Again, I am reluctant to use the word but to all intents and purposes it is. The task would have been too much even for a team of skilled airbrushers, who would have to be relied on to keep quiet about their fakery.

By far the simpler solution is that the photographs taken by Apollo were taken by the astronauts on their way to the Moon, on the surface of the Moon, and on the way back,

You'd also have to recognise that if they were faking them, they are equal opportunity fakers. The Soviets also returned images from of Earth from around the Moon from their many probes. The better quality images of returned by the Zond probes are shown on a number of websites, for example http://www.mentallandscape.com/C_CatalogMoon.htm

Figure 5.12 shows one of the images from Zond 5. Encyclopaedia Astronautica states that Zond 5 was launched on 14/09/68, entered a lunar orbit on 18/09/68 and splashed down in the Indian Ocean on 21/09/68. The ESSA data for this period can be found here: TIROS anniversary site and the Zond 5 image can be found here: Mental Landscape.

For once, you can make up your own mind, Does the ESSA mosaic show the same weather patterns as the Zond 5 image? The mosaic used is from the 21st of September, and the location of Arabia suggests a time of around 12:00 GMT for the image – 4 hours before re-entry and splashdown.

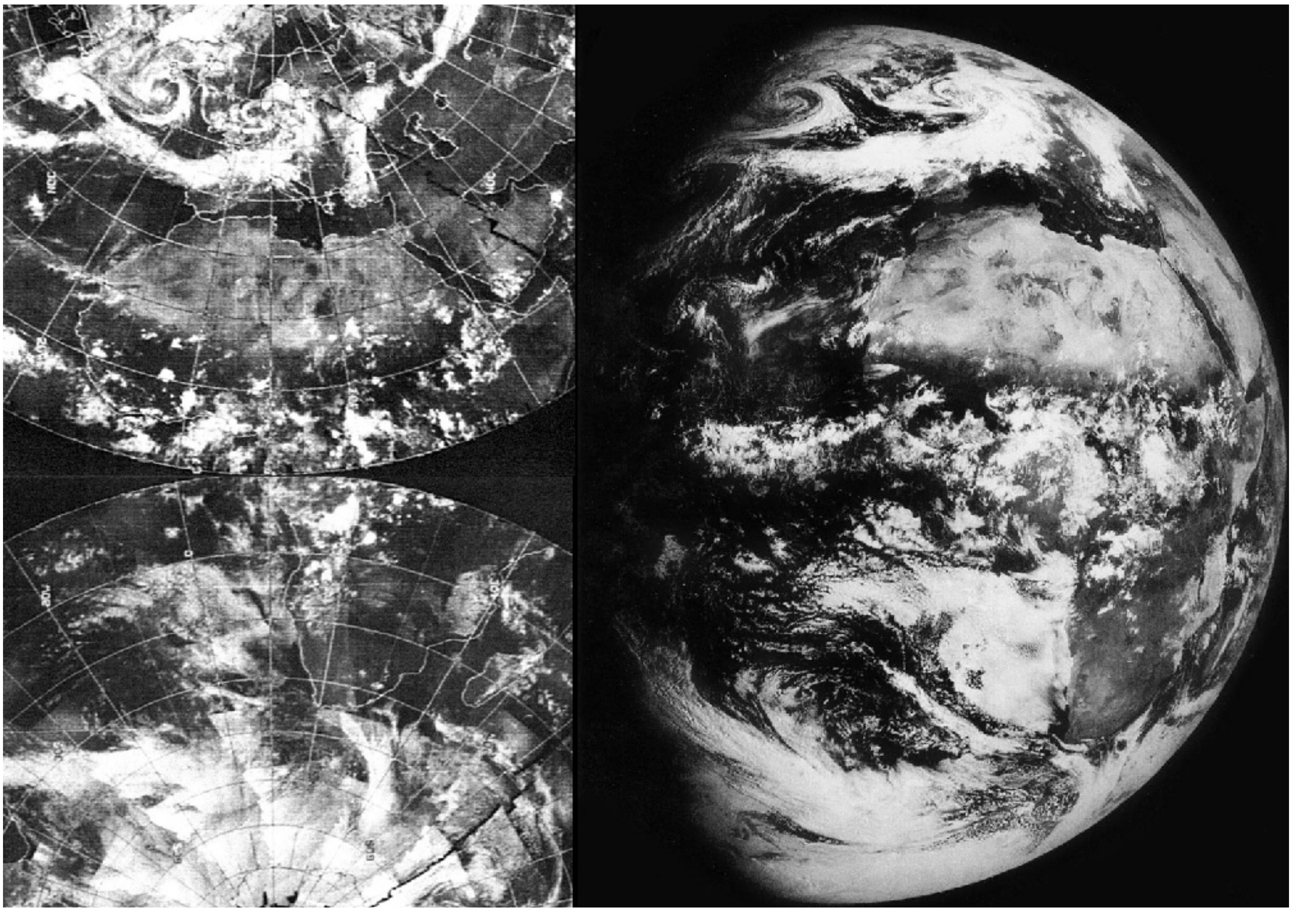


Figure 5.12: Zond 5 photograph of Earth compared with ESSA mosaic from 21/09/68

A similar study can be made of Zond 7, which shows spectacular colour images of Earth as seen rising above the lunar horizon. Zond 7, according to this page: NASA, was launched on 08/08/69, and managed several photography sessions of Earth. A close up of the Earthrise photo is shown in figure 5.13, compared with an ESSA mosaic from 10/08/69. The ESSA mosaic is found here Hathi trust, and the ZOND 7 image is from here: Mental Landscape.

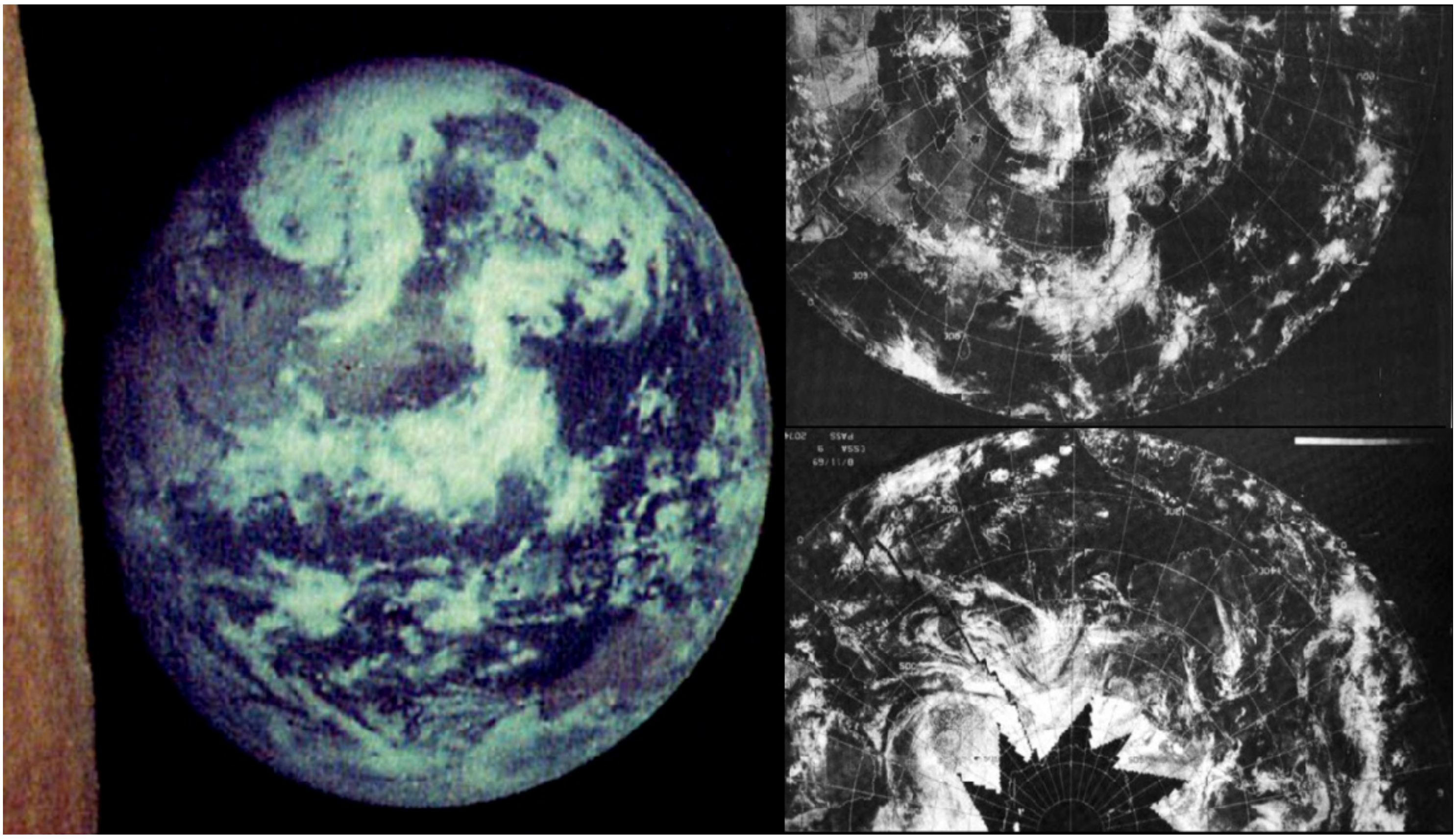


Figure 5.13: Zond 7 image compared with ESSA mosaic dated 10/08/69.

As with the NASA images, the ESSA mosaic is dated the 10th, but this part of the world would have been imaged on the 11th. As before, you can answer the question for yourself: does the Soviet image match the data supplied by their superpower rival? It's a shame that the craft did not wait a little longer to take its images, as lurking off to the west in the Caribbean is Hurricane Camille, which caused considerable damage in August 1969.

One final image from the Zond program can be found from Zond 8. This photograph (source: Mental Landscape) is usually referred to as an Earthrise, but a quick check of what it shows (and which can be confirmed by Stellarium) proves that it is actually an Earthset.

The probe was launched on October 20th 1970, and orbited the Moon on the 24th. A close look at the images from that probe show that Australia can be seen in the image, which means that any showing it as an Earthrise are actually upside down.

As it features Australia, this means that the ESSA mosaic needs to be dated the 23rd in order to show it. The ESSA data catalogue can be found here (source: TIROS anniversary) and a comparison of the relevant part of the mosaic with a close up of the Zond 8 image can be seen in figure 5.14.

Again, you be the judge: do the weather patterns match or not?

It should be pretty obvious that in all the Zond images the satellite mosaics are a match.

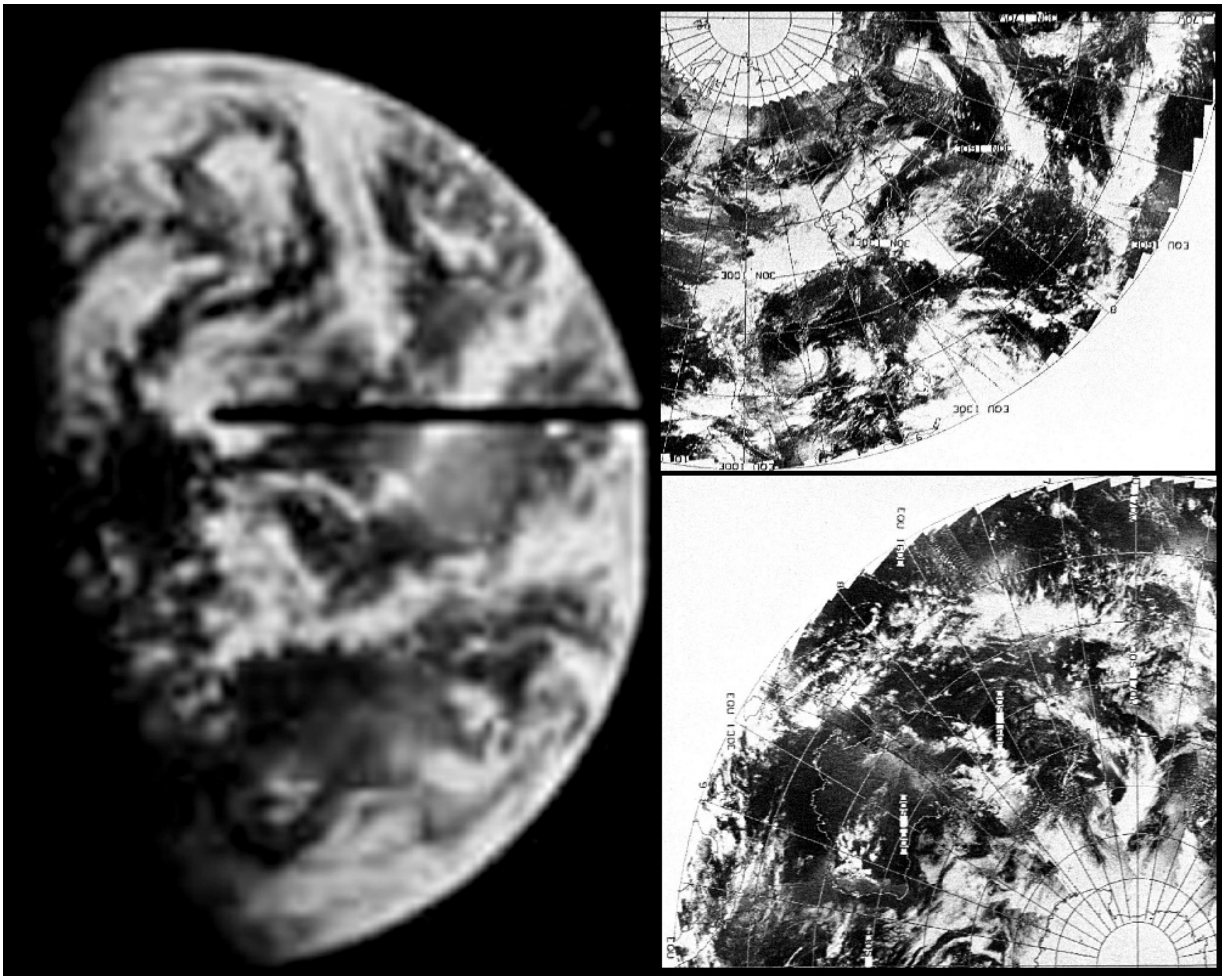


Figure 5.14: Zond 8 image compared with ESSA mosaic dated 23/10/70.

There is one final point: I genuinely do not believe it has ever occurred to anyone at NASA, or ESSA, or NOAA, or whoever has the data at their hands at the moment, that the weather data they had held the key to so much supporting evidence for the Apollo missions.

Aside from the fact that no-one there believes extra evidence is necessary, I don't think it occurred to anyone that the photographic record from Apollo and the meteorological evidence from the satellites could be married in this way. If the conspiracy believers are right, they would have gone to all that trouble just on the off chance that someone would check, and it has taken 40 years for someone to start doing that

5. **NASA owns the satellites, they have all the opportunity to fake the images**

It is another feature of those who believe that the moon landings were faked that NASA is some omnipotent organisation that both controls and dictates all of the scientific information worldwide on any facet of the space programme by anyone, ever. They are unable to grasp the idea that once the satellites were launched, they were no longer the responsibility of NASA but of the organisation that paid for them. It is like assuming Ford are still entirely responsible for everything that I do in my car.

Granted it is difficult to deny the interlinked nature of the various organisations involved. ESSA, NOAA, JPL, NASA are all involved in building and launching satellites and operating them afterwards, but while many hoax believers will raise a big “A-HAA!” at this, it is not in itself proof of anything.

The other factor to bear in mind here is that the satellite images were 'free to air' broadcasts. Anyone could download them providing they had the equipment. The images were used in many journals and research programmes, and no-one has every questioned them. They were used in conjunction with weather charts and no-one has ever questioned these.

Suggesting that the satellite images themselves were faked is clutching at straws.

6. **The military own NASA**

Again, there undeniable links as NASA launched them, but military had their own satellite programme. The Apollo 11 'rescue' story is indicative of parallel development, not cooperation. If the histories presented in chapter 2 are anything to go by, the military were in fact frustrated at NASA's lack of speedy progress in the field and went their own way.

Of course the conspiracy theorists will argue that “they would say that, wouldn't they?”, but even with a proven link between the military, NASA and the Apollo programmes, this does not invalidate the evidence presented here.

The military were obviously involved in the Apollo programme even if their role was only to pick up the newly returned astronauts and provide support through ARIA, but the question there is “so what?”. Does military involvement mean that Hurricane Bernice didn't exist? Or Tropical Storm Therese? Or any other of the hurricanes and cyclones visible from space in the Apollo images showing storms where they should be on the dates the should be there and in the correct configuration?

The weather is not a military secret, and neither were any of the weather satellites that provided the information about the weather..

7. **Your evidence is self-supporting and therefore suspect**

There are two strands to this. The first being that the evidence is pretty much all from NASA and its affiliates, and the second being that where it isn't immediately obvious what weather systems are visible,a supporting argument has been constructed around other evidence, possibly introducing biassed interpretation.

As far as the first point is concerned, it's an unfortunate fact that the vast majority of the evidence concerning the Apollo missions comes from NASA, and many sources have been referenced from them (eg the mission transcripts, photo indices). The satellite evidence also has a link with NASA, as previously discussed. In an ideal world there would be other sources of information, but it is a fact of life that at the time of the missions the two major players were either NASA or their Soviet rivals. The former of these two has been very free with all its information, the latter less so.

I have no doubt that somewhere there are satellite photographs produced by other countries such as India, China and the USSR that would absolutely verify the weather patterns in the Apollo images. They might even be completely different, which would prove the argument against once and for all as well. Unfortunately I do not have the time, contacts or resources to find them. The door is open for anyone who cares to have a go to find that evidence and either blow my theory out of the water or prove it absolutely.

The second point was at least partially covered during the section on Apollo 17, but is worth further examination.

Wherever possible the approach I have taken throughout this research has been to take an Apollo photograph, find a matching weather pattern, and then try and see what other evidence supports the suggestion that they were taken at the same time. Stellarium, the mission transcripts, the photograph indices, and any other sources I could find are all used to back up the suggestion that the Apollo image was taken at a particular time.

What needs to be avoided is making a decision based on incomplete evidence, then trying to make all the other evidence fit (and ignoring the inconvenient evidence that says you are wrong. There have been a number of occasions where I have had to completely re-think when a photograph was taken because what looked right on the screen couldn't possibly be right because the evidence of other sources said otherwise.

As far as I can tell everything included in this research is correct, and is consistent with all the sources of evidence available. It is not correct because I have forced it to be so. If you believe there are errors or inconsistencies, you have all the information you need to repeat the exercise yourself. Knock yourself out.

8. There are no stars in the photographs

There's no hope for you is there? This document isn't about that issue, you need to go elsewhere for it. In the mean time, go outside and take some photographs of stars, see how you get on.

Summary and Conclusion

We went to the Moon.

It's that simple.

In addition to all the photographic and hours of video evidence, the soil samples that could not have been made on Earth, the scientific data transmitted from Moon to Earth by equipment that could only be installed by people, the radio tracking of the spacecraft, we now have weather satellites that show that the clouds in Apollo photographs match those taken by satellites to which anyone with the right equipment had access.

There really is only one question to answer: Do the satellite photographs and Apollo images match? The inescapable answer is that they do, and the only conclusion that makes any sense is that the Apollo photographs were taken where it has always been claimed they were taken: on the way to, on the surface of, or on the way back from the Moon.