Operations Plan

For the

GOES-R Proving Ground Aviation Weather Experiment

Conducted at the

Alaska Aviation Weather Unit

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Table of Contents

1 Introduction

1.1 Plan Purpose and Scope

The Aviation Weather Experiment provides the GOES-R Proving Ground (PG) with a pre-operational environment in which to deploy and demonstrate algorithms associated with its next generation GOES-R geostationary satellite system. These products are to include both aviation related GOES-R baseline products and operational readiness trials of products transitioning from Risk Reduction, but with the main focus on demonstrating the official GOES-R Baseline and Option-2 products. The availability of GOES-R products will demonstrate, pre-launch, a portion of the full observing capability of the GOES-R system, subject to the constraints of existing high latitude data sources to emulate the satellite sensors. The Aviation Weather Experiment includes participation from the Alaska Aviation Weather Unit (AAWU), the Aviation Weather Center (AWC), and the NWS Regional Headquarters. This Operations Plan covers the activities at the AAWU only. There is a separate Operations Plan for the activities at AWC and the NWS Regional Headquarters.

1.2 Overview

The Aviation Weather Proving Ground will focus on providing GOES-R aviation related products to the AAWU in Anchorage, AK. The AAWU will receive early exposure to GOES-R PG products during the 2010 Experiment running from October 2010 to February 2011. Pre-operational demonstrations of these GOES-R PG data will provide the aviation forecasters the opportunity to critique and improve the products relatively early in their development.

2 Goals of Proving Ground Project

The Aviation Experiment will focus on demonstrating the GOES-R products selected for this year's aviation related activities including cloud phase, volcanic ash, SO2 detection, and low cloud and fog. This strategy has the best chance of maximizing the Operations-to-Research feedback that is one of the PG goals. An important aspect of the interactions is to build relationships between each key product development team and the forecasters within the aviation community. Thus, the forecasters at the AAWU will participate in the experimental activities and discussions (in particular regarding satellite-based products) and provide feedback to improve integration of GOES-R PG effort in these test bed activities for future years.

3 GOES-R product(s) to be demonstrated

There are five GOES-R products from the Advanced Baseline Imager (ABI) identified to be demonstrated during the Aviation Weather Experiment at the AAWU: (1) Volcanic Ash: Detection and Height, (2) Cloud Phase, (3) Low Cloud and fog, and (4) SO2 Detection. These products are listed in Table 1 and described further in the following subsections.

Table 1. Products to be demonstrated during Experiment

Demonstrated Product	Category
Volcanic Ash: Detection and Height	Baseline
Cloud Phase	Baseline
Low Cloud and Fog	Option 2
SO_2 Detection	Option 2
Category Definitions:	

Demonstrated Product	Category
Baseline Products - GOES-R products that are funded for operational implementation as part of the ground segment base contract. **Option 2 Products** - New capability made possible by ABI as option in the ground segment contract. **GIMPAP** - The GOES Improved Measurement and Product Assurance Plan provides for new or improved products utilizing the current GOES imager and sounder	

3.1 Volcanic Ash

The GOES-R volcanic ash algorithm utilizes infrared channels (7.3, 8.5, 11, 12, and 13.3 μm) to identify potential volcanic ash clouds (when the ash is the highest cloud layer) and to retrieve the ash cloud height, mass loading, and effective particle radius. These parameters are important for both nowcasting and forecasting purposes. The ash cloud height is needed to determine if ash is at cruising altitudes and to initialize the plume height in dispersion models. The GOES-R ash cloud height retrieval accounts for transmission of radiation through the ash cloud from below (e.g. the ash clouds are allowed to be semi-transparent to infrared radiation), so it produces high quality results even when applied to optically thin ash clouds. Validation efforts indicate that the GOES-R ash height retrieval can determine the ash cloud top height with an accuracy (bias) of -1.35 km and a precision of 1.61 km, for tropospheric clouds.

Ash concentration data are needed to determine if jet engine tolerances are exceeded (should accurate thresholds be made available by engine manufacturers). If a 1 km ash cloud thickness is assumed, the ash mass loading (ton/km^2) is numerically equivalent to ash concentration in mg/m^3. Ash loading data can also be used to initialize models. Comparisons to spaceborne lidar indicate that the GOES-R ash mass loading has an accuracy (bias) of 0.42 ton/km^2 and a precision of 1.17 ton/km^2, subject to certain microphysical assumptions.

The ash effective particle radius is not an official GOES-R requirement, but it is automatically produced in the process of retrieving the ash height and mass loading. The ash effective particle radius can be used to determine if the ash cloud is dominated by small or large particles, which is important for predicting the atmospheric residence time (small particle remain suspended longer than large particles, all else being equal). This information can also be used to initialize models. Since it is not an official GOES-R product, the ash effective particle radius information will be retained in the quality flag output.

The GOES-R volcanic ash algorithm can be applied to data from the Moderate Resolution Imaging Spectroradiometer (MODIS), which is in a low-earth orbit, and, as such, provides coverage of Alaska. Example GOES-R volcanic ash products are shown in the figure below for an Alaskan eruption (Kasatochi).

Finally, it is important to point out that while the GOES-R volcanic ash products meet all of the accuracy and latency specifications, the ash detection component of the GOES-R algorithm is not designed to be used in an automated ash alert system (the GOES-R requirements did NOT include an automated alert capability). In recognition of this shortcoming, a GOES-R automated alert capability will be developed in the coming months. This capability will be a more advanced version of the automated alert capability developed for the Advanced Very High Resolution Radiometer (AVHRR). The GOES-R automated alert system will hopefully be available for testing under the GOES-R Proving Ground in 2011 or 2012.

Questions concerning the GOES-R volcanic ash products can be sent to:
Mike.Pavolonis@noaa.gov

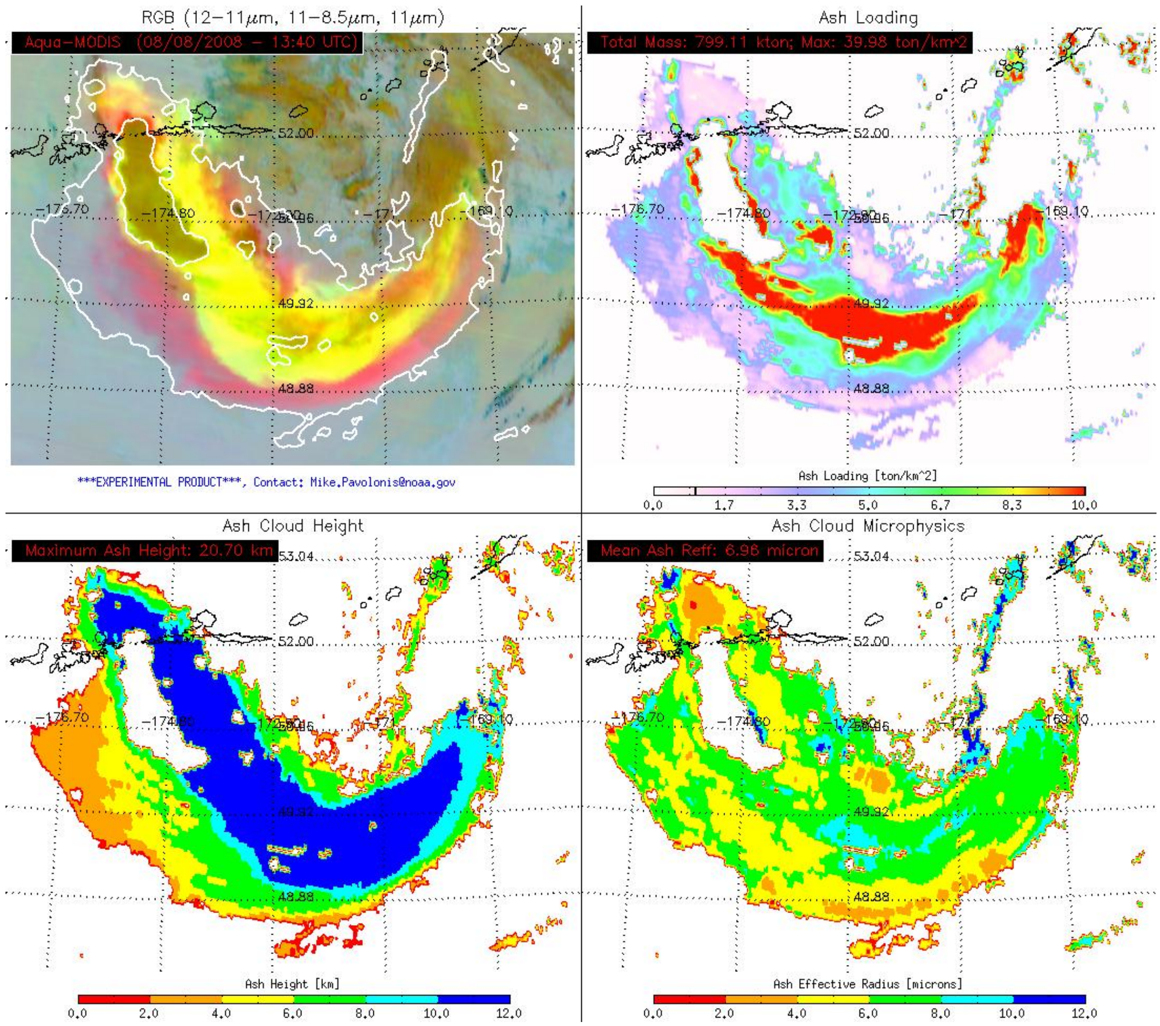

Figure 1: Example GOES-R volcanic ash products generated using *Aqua* MODIS data from August 8, 2008 at 13:40 UTC. The ash cloud present in this scene is from an eruption of Kasatochi, located in the Aleutian Islands of Alaska. A false color image (top left panel), the ash mass loading product (top right panel), the ash height product (bottom left panel), and the ash effective radius product (bottom right panel) are shown. The ash detection results are displayed as white contours on the false color image.

3.2 Cloud Phase

The GOES-R cloud top phase algorithm utilizes infrared channels (7.3, 8.5, 11, and 12 μm) to determine the thermodynamic phase of the highest cloud layer. Since the algorithm utilizes only infrared channels, the performance is spectrally independent of solar zenith angle. The cloud phase categories are: liquid water, supercooled liquid water, mixed phase, and ice. It is important to note that the cloud phase classification applies to the portion of the cloud that contributes to the measured radiances (hence the name cloud top phase). For optically thick clouds, the infrared measurements are only sensitive to the top-most portion of the cloud. For example, deep convective clouds will be classified as ice clouds since the upper-most portion of those clouds are glaciated. The "liquid water" category includes clouds that are composed entirely of liquid water at temperatures above the melting point of water (0^oC). Supercooled liquid water clouds are composed entirely of liquid water at temperatures below the melting point of water. Mixed phase clouds likely contain both liquid water and ice in the cloud layer that contributes to the measured radiances. Ice phase clouds are composed entirely of ice (in the cloud layer sensed by the radiometer).

The GOES-R cloud top phase algorithm is required to determine the cloud top phase with a classification error no larger than 20%. Our validation analysis indicates that the classification error is around 10%.

Potential applications of the cloud top phase product are (but not necessarily limited to):

1. Assessing aircraft icing potential
2. Assessing freezing rain/drizzle potential
3. Diagnosing cloud top glaciation in growing cumulus clouds
4. Diagnosing cirrus cloud cover, including cirrus which overlap lower cloud layers

Further, the GOES-R Cloud Type product provides more detailed cloud phase information, including multi-layered cloud detection and information on ice cloud opacity. The GOES-R Cloud Type product is generated within the cloud top phase algorithm module. Example GOES-R cloud top phase and cloud type products over Alaska are shown in the figure below.

Finally, while the GOES-R cloud top phase algorithm will be most accurate when applied to the ABI, it can be generated using the current GOES imager, MODIS, Spinning Enhanced Visible and Infrared Imager (SEVIRI), or Multi-functional Transport Satellite (MTSAT).

Questions concerning the GOES-R cloud top phase product can be sent to: Mike.Pavolonis@noaa.gov

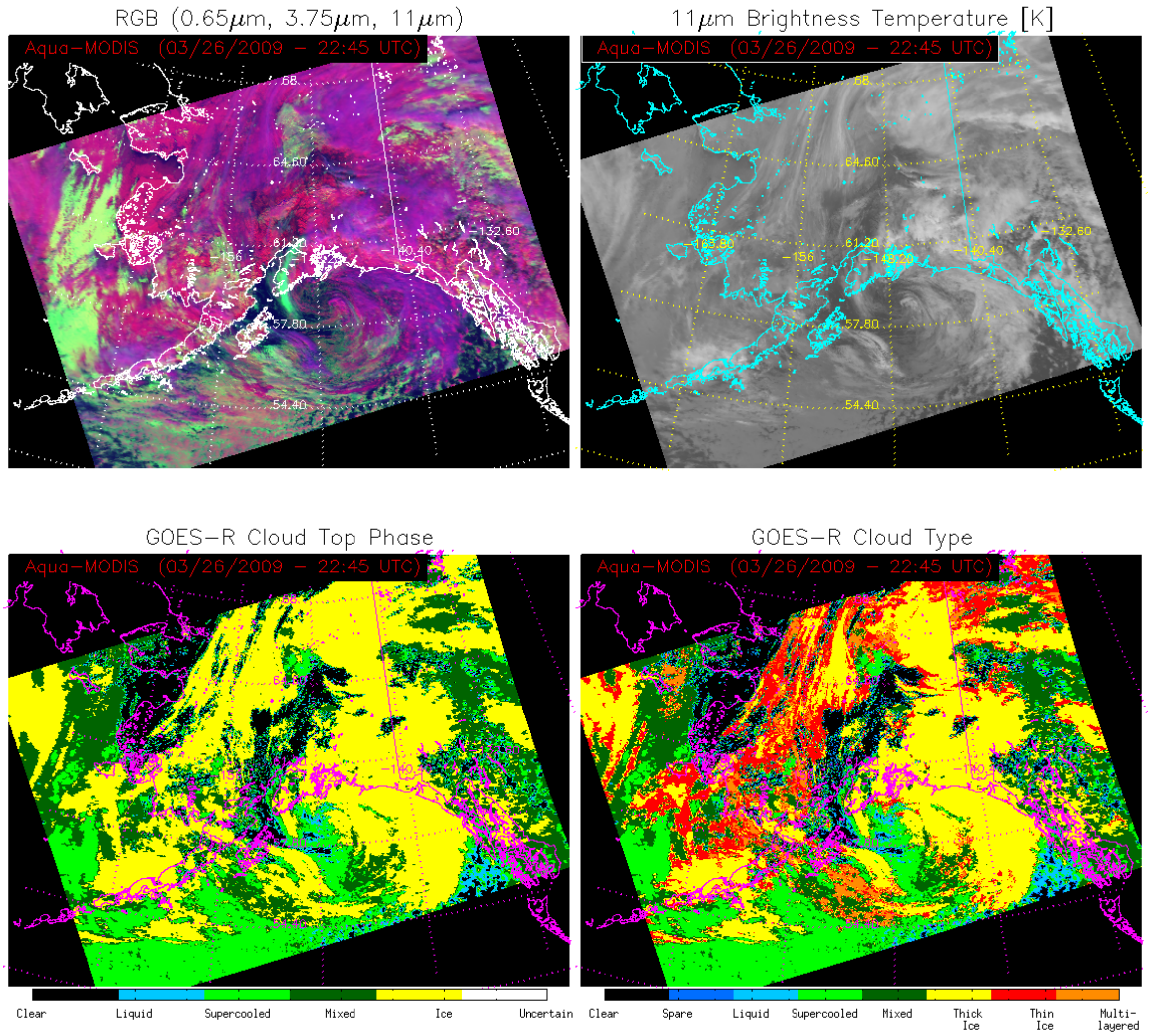

Figure 2: Example GOES-R cloud top phase and cloud type products generated using *Aqua* MODIS data from March 26, 2009 at 22:40 UTC. A false color image (top left panel), an IR image (top right panel), the GOES-R cloud phase product (bottom left panel), and the GOES-R cloud type product (bottom right panel) are shown.

3.3 Low Cloud and Fog

The GOES-R fog/low cloud detection product is designed to quantitatively identify clouds that produce Instrument Flight Rules (IFR) or Low Instrument Flight Rules (LIFR) conditions (ceiling < 1000 ft (305 m)). The aviation flight rule categories are defined in the table below. The GOES-R fog detection is expressed as a probability. At night, the algorithm utilizes the 3.9 and 11 μm channels to assign a fog probability. Fog probability during the day is determined using the 0.65, 3.9, and 11 μm channels. The fog probability is based on textual and spectral information, as well as the difference between the cloud radiative temperature and surface temperature. An example of the GOES-R fog product is shown in the figure below.

Table 2: Aviation flight rules

Flight Rule	**Ceiling**

Visual Flight Rules (VFR)	> 3000 ft (914 m)
Marginal Visual Flight Rules (MVFR)	1000 ft (305 m) – 3000 ft (914 m)
Instrument Flight Rules (IFR)	500 ft (152 m) – 1000 ft (305 m)
Low Instrument Flight Rules (LIFR)	< 500 ft (152 m)

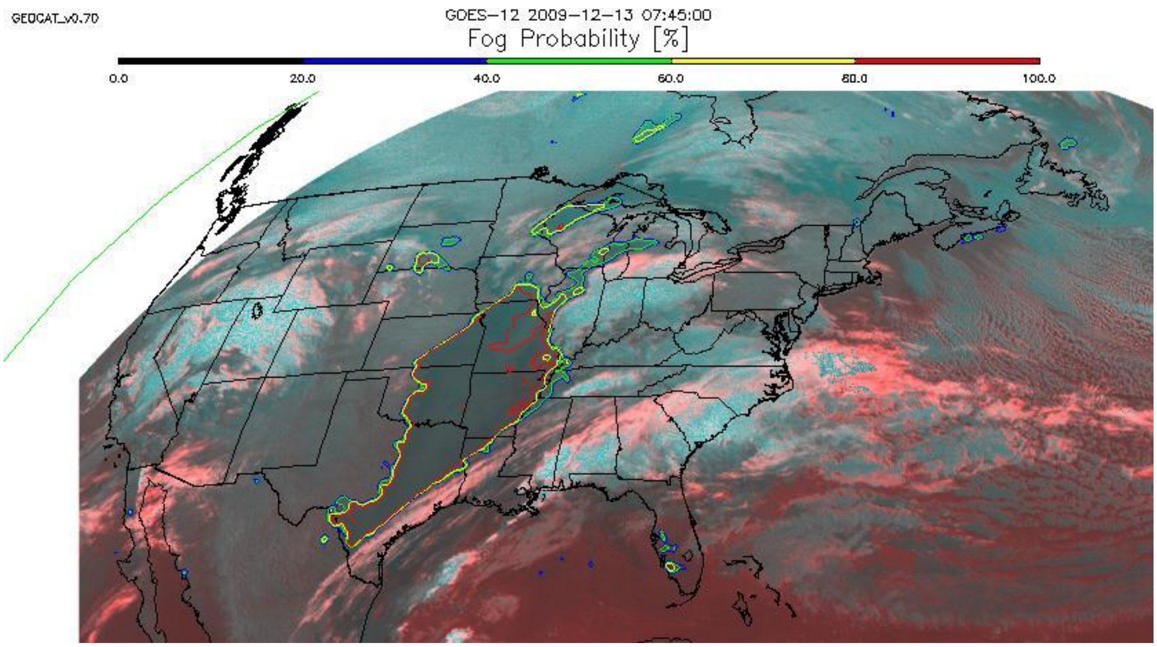

Figure 3: An example of the GOES-R fog detection product generated using GOES-12 on December 13, 2009 at 07:45 UTC. The satellite derived fog probability is denoted by the color contours overlaid on the false color image.

There are a few important caveats that users need to be aware of. Fog cannot be detected if there are higher cloud layers overlapping the fog layer. The GOES-R fog/low cloud product specifications reflect this fundamental limitation of passive remote sensing. Secondly, passive satellite measurements do not provide direct information on cloud base or ceiling, so the properties of the cloud layer actually sensed by the radiometer must be used to indirectly infer information on cloud base. Since the properties of the cloud base are not directly measured, variations in cloud base due to local boundary layer effects (e.g. local moisture sources/sinks and local turbulent mixing processes) generally will not be captured. As such, not every surface observation underneath a GOES-R detected low cloud will necessarily indicate a ceiling of 1000 ft or lower, but those surface observations that do not indicate LIFR or IFR will generally indicate Marginal Visual Flight Rules (MVFR) conditions. In other words, the GOES-R fog/low cloud algorithm will rarely identify Visual Flight Rules (VFR) conditions, which is desirable.

The GOES-R fog/low cloud detection algorithm is required to achieve a skill score (probability of detection – probability of false alarm) of 0.70. Validation efforts indicate that we are on track to meet this specification.

Finally, while the GOES-R fog product requires output from the cloud mask and cloud top phase algorithms, which will be most accurate when applied to the ABI or a comparable sensor, it can be generated using the current GOES imager, MODIS, SEVIRI, or MTSAT.

Questions concerning the GOES-R fog/low cloud product can be sent to: Mike.Pavolonis@noaa.gov

3.4 SO_2 Detection

Identifying SO_2 clouds is important, since SO_2, when combined with water, is corrosive and harmful to breath, and, as such, is a potential aviation hazard. Further, when injected into the stratosphere, SO_2 is converted to sulfate droplets, which reflect incoming sunlight back to space, impacting climate.

The GOES-R SO_2 detection product utilizes infrared measurements (6.2, 7.3, 8.5, 11, and 12 μm) to identify pixels that contain 10 or more Dobson Units (DU) of Sulfur Dioxide (SO_2), when the SO_2 cloud is the highest cloud layer. The SO2 detection algorithm utilizes a unique blend of spectral and spatial information to detect SO_2. SO_2 loadings less than 10 DU are difficult to detect using the Advanced Baseline Imager (ABI), since the ABI cannot resolve individual SO_2 absorption lines. Validation efforts indicate that the SO_2 detection algorithm meets the GOES-R accuracy specification (70% correct detection). More specifically, the probability of detection is ~70% and the probability of false alarm is ~0%. The low false alarm rate makes this product ideal for use in an automated volcanic cloud alert system. In addition, while not required, the SO_2 loading is also estimated using a simple regression relationship. Since the SO_2 loading is not a required product, the loading information will be stored in the quality flags.

The GOES-R SO_2 algorithm can be applied to data from the Moderate Resolution Imaging Spectroradiometer (MODIS), which is in a low-earth orbit, and, as such, provides coverage of Alaska. Example GOES-R SO_2 products are shown in the figure below for an Alaskan eruption (Kasatochi).

Questions concerning the GOES-R SO_2 product can be sent to: Mike.Pavolonis@noaa.gov

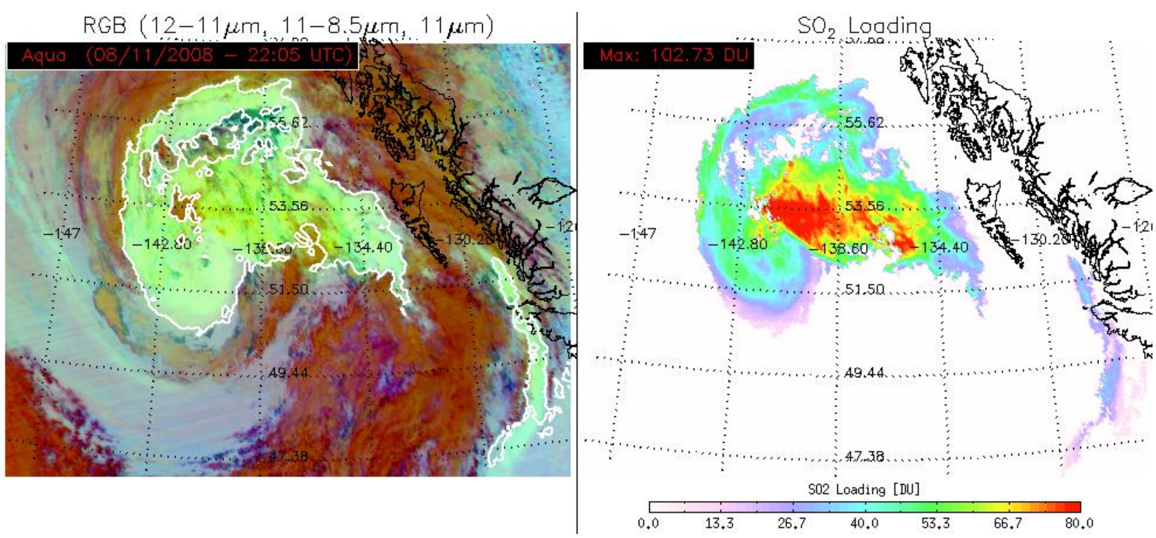

Figure 4: Example GOES-R SO_2 products generated using *Aqua* MODIS data from August 11, 2008 at 22:05 UTC. The SO_2 cloud present in this scene is from an eruption of Kasatochi, located in the Aleutian Islands of Alaska. A false color image (left panel) and the estimated SO_2 loading (right panel) are shown. The SO_2 detection results are displayed as white contours on the false color image.

4 Proving Ground Participants

The Proving Ground participants are broken into two categories, Providers and Consumers. Providers are those organizations that develop and deliver the demonstration product(s) and training materials to the consuming organization. The Consumers are those who work with the providers to integrate the product(s) for demonstration into an operational setting for forecaster interaction. For the Aviation Weather Experiment there are three providers, the Cooperative Institute for Meteorological Satellite Studies (CIMSS), NASA Langley, the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), and NASA's Short-term Prediction Research and Transition Center (SPoRT).

4.1 CIMSS

CIMSS will be providing the four products demonstrated in the Aviation Weather Experiment and they are described below.

4.1.1 Volcanic Ash: Detection and Height

For the AAWU, the volcanic ash products will initially be generated at CIMSS using MODIS proxy and ftp push/pull to the Geographic Information Network of Alaska (GINA)/UAF. GINA/UAF will in turn, distribute the products to the AAWU.

4.1.2 Cloud Phase

The Cloud Type product will be generated using MODIS data captured and processed at CIMSS. Cloud Phase information can be extracted from the Cloud Type product. The product will be generated in netCDF and IC4D formats and pushed to UAF-GINA UAF-GINA will distribute the product to the NWS for evaluation.

4.1.3 Low Cloud and Fog

For the AAWU, the fog/low cloud product will initially be generated at CIMSS using MODIS proxy and ftp push/pull to the GINA/UAF. GINA/UAF will in turn distribute the product to the AAWU for evaluation.

4.1.4 SO_2 Detection

The SO_2 product will be generated using MODIS data at at CIMSS then ftp push/pull to GINA/UAF and then distributed to the AAWU for evaluation. The SO_2 product will be made available in an AWIPS compatible format.

4.2 Alaska Aviation Weather Unit

Alaska has its own Aviation Weather Unit with responsibility for both commercial and general aviation forecasts and products. The AAWU is a consumer and will evaluate these products relevant to aviation applications. The lead at the Office will be the SOO who will work directly with the GINA Liaison.

5 Responsibilities and Coordination

5.1 Project Authorization

- Steve Goodman – GOES-R Chief Scientist and PG Program Manager
- Gary Hufford – Regional Scientist, NWS Alaska
- Tony Hall - AAUW

5.2 Project Management

- Bonnie Reed – NWS/OST
- Dick Reynolds – GOES-R
- Gary Hufford – Regional Scientist, NWS Alaska

5.3 Product Evaluation

- Select forecasters at AAWU

5.4 Project Training

5.4.1 General Sources

GOES-R training is developed and provided by a number of different partners across the weather enterprise. NOAA, collaboratively through NESDIS and the NWS, partners with the Cooperative Program for Operational Meteorology, Education and Training (COMET), Virtual Institute for Satellite Integration Training (VISIT), and Short-term Prediction Research and Transition Center (SPoRT) to develop and deliver training on the new features, operations, and capabilities of the GOES-R satellite. Training for the Aviation Weather PG Experiment will be developed and provided through e-learning training modules, seminars, weather event simulations, and special case studies.

5.4.2 Product Training References

5.4.2.1 Volcanic Ash: Detection and Height

A product description along with examples and caveats will be made available at the beginning of the experiment (in presentation form) by Mike Pavolonis.

5.4.2.2 Cloud Phase

A product description along with examples and caveats will be made available at the beginning of the experiment (in presentation form) by Mike Pavolonis. In-person training may also be conducted at the beginning of the experiment in Anchorage.

5.4.2.3 Low Cloud/Fog

A product description along with examples and caveats will be made available at the beginning of the experiment (in presentation form) by Mike Pavolonis.

5.4.2.4 SO2 Detection

A product description along with examples and caveats will be made available at the beginning of the experiment (in presentation form) by Mike Pavolonis.

6 Project Schedule

There are many activities that lead up to the successful execution of the Experiment such as identifying participants, coordinating schedules, delivering and integrating algorithms, and developing training materials. These specific activities are identified in the chart below.

(1) Begin: June 2010
   a. Identify products (June 2010)
   b. Identify AWG Leads (June 2010)
   c. Establish an Operations Plan - roles and responsibilities and expectations (August 1)
   d. AAWU receive and integrate GOES-R algorithms (mid-October start)
   e. Produce demonstration products (October 29)
   f. Capture and provide Forecaster and user feedback (Nov 2010 – Aug 2011)

(2) End: August 29, 2011

Below is a table describing the timeline of the integration of products into the AAWU.

Table 2. AAWU Timeline of product integration

Proving Ground Product	Acquisition into Testbed due date	Evaluation Campaign dates
Volcanic Ash: Detection and Height	Oct. 2010	Oct. 2010-Aug.2011
SO_2 Detection	Oct. 2010	Oct. 2010-Aug.2011
Cloud Phase	Nov. 2010	Nov.2010-Aug -2011
Low Cloud and Fog	Oct. 2010	Nov.2010-Aug. 2011

7 Milestones and Deliverables

7.1 Products from Providers

Products to be demonstrated within this year's Aviation Weather Experiment should be delivered to the AAWU according to the schedule in Section 6 to insure product dataflow and display work correctly within the forecast programs.

7.2 Training materials from providers

Each product delivered to the GOES-R PG Experiment will be accompanied by related training material. Forecasters and scientists participating in the Experiment may not be familiar with the products; therefore, it is important that they receive training in order to properly evaluate product performance during real-time forecasting exercises. Training may include an in-person briefing and/or a descriptive write-up explaining how the product works and its uses, including example images. It is expected that the product developer or the producer provide the training material.

7.3 Mid-term evaluation report

A mid-term evaluation report shall be provided to the project authorization team roughly halfway through the experiment timeframe. This report shall detail the current status and progress of the GOES-R PG Experiment activities and suggest changes if needed.

7.4 Final report

A final report detailing the GOES-R PG Experiment activities during the entirety of the experiment shall be provided to the GOES-R Program Office in March 2011 from the AAWU. The report will discuss how each product was demonstrated within the AAWU. The report will also present feedback provided by participants within the experiment as well as suggestions for improvements upon the GOES-R PG Experiment activities for years to come.

8 Related activities and methods for collaboration

8.1 GOES-R Risk Reduction Products and Decision Aids

At this time there is no plan to demonstrate GOES-Risk Reduction products or Decision Aids during this Experiment.

9 Summary

This year's GOES-R Aviation Weather PG Experiment will support the PG effort to demonstrate the defined GOES-R products within an operational framework through real time access. Feedback gathered from these activities will aid in successful product training for not only forecasters but for the many users of GOES-R products.

10 References