CERES NOAA-20 VIIRS Edition1B SSF Cloud Properties

This section briefly discusses the cloud products included in the **SSF** data set version **NOAA-20 VIIRS Edition1B (Ed1B)** and is meant to supplement the detailed Suomi NPP Ed1A data quality summary by documenting several algorithm changes that were introduced for Ed1B and to briefly quantify their impacts. The NOAA-20 VIIRS Ed1B cloud algorithm was developed specifically for the purpose of improving consistency between cloud properties derived from VIIRS with those derived from MODIS using the Edition4A (Ed4A) cloud algorithms, a level of agreement that in some respects is not being met with VIIRS Edition1A and 2A (Ed1A and Ed2A). In this way, the Ed1B cloud properties derived from NOAA-20 are meant to serve as a temporary 'continuity' version that would enable a more seamless record of CERES Earth radiation budget data products when the transition from the use of Ed4A MODIS cloud properties must occur due to the inevitable drift of the MODIS satellites out of their nominal orbits. The transition is expected to occur prior to the release of Edition5 (Ed5), which is the long-term continuity solution that is still in development, and will allow CERES to continue to extend its data product record until the time that the planned Ed5 record becomes available. In order to accomplish this, some algorithm changes, including bug fixes, that were implemented to improve cloud property accuracies in Suomi NPP Ed1A and Ed2A relative to MODIS Ed4A had to be removed or reversed for NOAA-20 Ed1B. A new VIIRS+CrIS Data Fusion Level-2 product (Baum et. al., 2019) is also ingested to help facilitate improved continuity. This product provides VIIRS pixel-level radiances that are constructed for the spectral response functions of the MODIS bands 27 (6.7 µm, WV) and 33 (13.3 µm, CO2) channels that are missing from the VIIRS sensor but used in the Terra and Aqua MODIS Edition4A cloud retrievals. Based on comparisons between the MODIS Ed4A cloud properties and those from Suomi NPP VIIRS Ed1A, the VIIRS Ed1A algorithm was updated for Ed1B with the following changes in order to address:

1. **Non-polar nighttime cloud fraction differences**
   - Modified the nighttime cloud mask to increase clouds over tropical ocean and reduce clouds over non-polar land areas.
2. **Polar daytime and nighttime cloud fraction differences**
   - Ingested the CrIS/VIIRS fusion data product that provides a WV and CO2 channel for VIIRS .
   - Tuned the polar cloud mask algorithm to improve consistency with Ed4A and utilize the CO_2/WV bands when available.
3. **Cloud optical property differences in polar regions**
   - Replaced the improved VIIRS 1.24 µm and 3.7 µm cloud reflectance models and parameterizations with those developed much earlier for Edition4A.

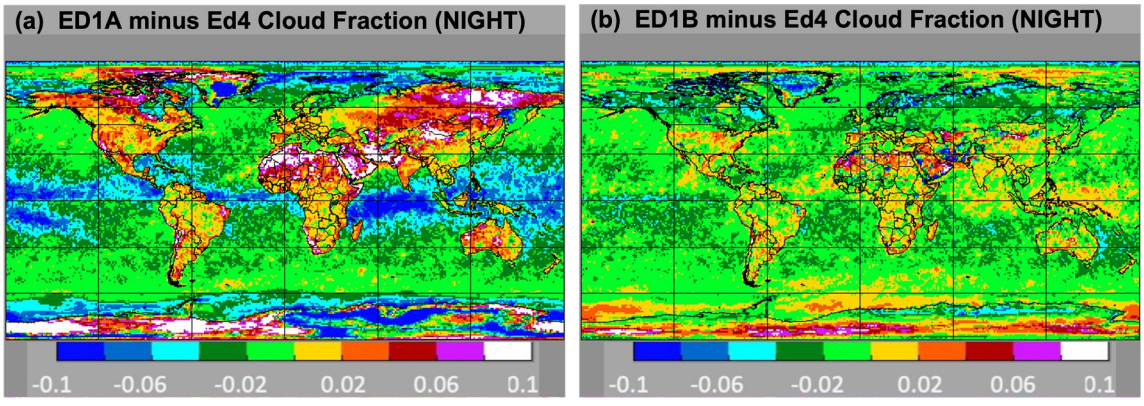

Figure 1. 2018 annual mean nighttime cloud fraction differences from Ed4A for (a) Ed1A and (b) Ed1B.

Figure 1a shows the 2018 mean nighttime total cloud fraction differences between Suomi NPP VIIRS Ed1A and Aqua MODIS Ed4A which are substantial over most land areas and the tropical oceans, and even exceed +/- 10% over some areas. In contrast, the Ed1B differences shown in Figure 1b are markedly reduced owing to the algorithm changes highlighted above. Figure 2 further illustrates the improved level of agreement with Aqua-MODIS Ed4A for Ed1B compared to Ed1A over non-polar (60N-60S) land (Figure 2a) and

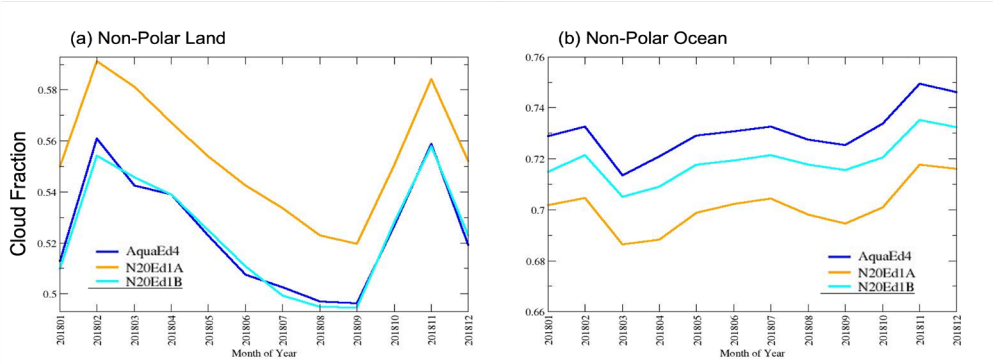

Figure 2. Time series of 2018 monthly mean nighttime cloud fractions for non-polar regions derived from the Aqua-MODIS Ed4 and the VIIRS Ed1a and Ed2B cloud algorithms over (a) land and (b) ocean.

ocean (Figure 2b) in the time series of monthly mean cloud fractions derived for 2018. While all three algorithms track changes in the monthly mean cloudiness in a similar way, the magnitude of the MODIS and VIIRS cloud fractions are in better agreement for the Ed1B algorithm compared to that from Ed1A. Over land, the agreement between Ed1B and Ed4A is excellent while over ocean a bias of about -1% remains in the cloud fraction differences. This represents about a 66% relative level of improvement over the Ed1A cloud fraction differences over ocean. The Ed1A nighttime cloud fractions also differ substantially from those in Ed4A over the high latitudes, particularly over the land regions as shown in Figure 3a and Figure 3c for the Arctic and Antarctic polar regions, respectively. These difference are attributed primarily to MODIS and VIIRS 3.7 µm channel sensitivity differences to very cold scenes and due to the lack of a WV and CO_2 channel on VIIRS which are used in the Ed4A polar cloud mask. With the addition of the fusion data, modifications

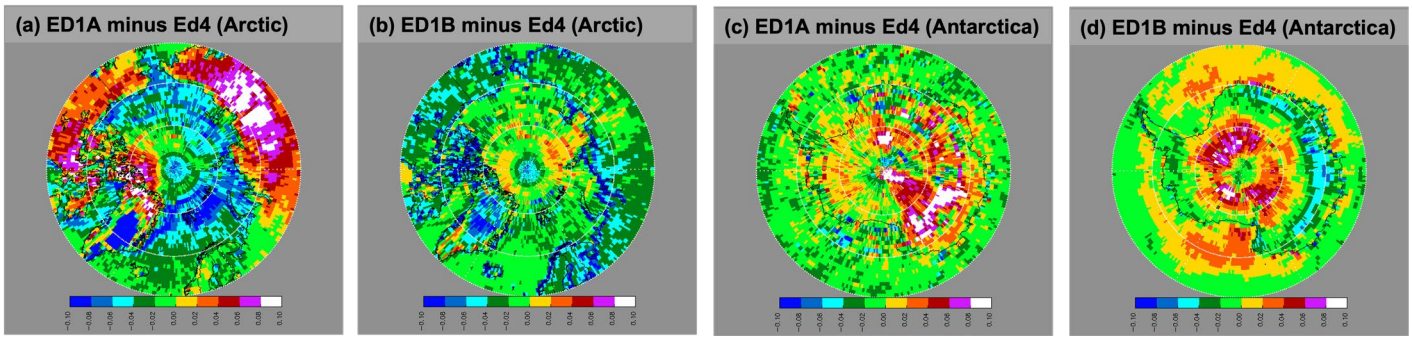

Figure 3. 2018 annual mean nighttime cloud fraction differences from Ed4 for (a) Ed1A over the Arctic, (b) Ed1B over the Arctic, (c) Ed1A over the Antarctic, (d) Ed1B over the Antarctic

to utilize the fusion WV and CO_2 channels in the cloud mask, and some additional tuning, the Ed1B cloud mask produces more consistent annual mean cloud fractions with MODIS (Figure 3b and Figure 3d), particularly over Siberia, Canada and Alaska. The differences over Antarctica and Greenland are only marginally improved owing to the unresolved 3.7 µm problem, and the level of agreement over the sea-ice areas of the southern ocean are slightly worse in Ed1B than Ed1A with respect to Ed4A. In general, the daytime cloud fractions are relatively consistent between Ed1A, Ed1B and Ed4A as shown in Figure 4a which depicts the monthly mean time series for 2018 over land and ocean regions. The nighttime time series shown in Figure 4b and Figure 4c over land and ocean, respectively, again show the improved level of agreement between MODIS Ed4A and VIIRS Ed1B compared to that found with VIIRS Ed1A, including months (Jan and Feb) that the fusion data were unavailable. Figure 5 and Figure 6 illustrate the impact of replacing the VIIRS 1.24 um and 3.7 um cloud reflectance models and parameterizations with the Ed4A models for use over snow and ice covered surfaces in Ed1B. The Ed4A models developed with an adding doubling technique have a known interpolation bug that can lead to spuriously high values of cloud optical depth (COD) for ice clouds under some conditions. This Ed4A bug was fixed and the daytime cloud models were updated for VIIRS Ed1A and Ed2A based on discrete ordinate radiative transfer calculations to improve accuracies but this led to some notable differences in polar ice COD compared to Ed4A. Figure 5a and Figure 5c show the regional monthly mean ice COD differences (Ed1A minus Ed4A) for 2018 over the north and south polar regions, respectively. The linear averaged mean COD

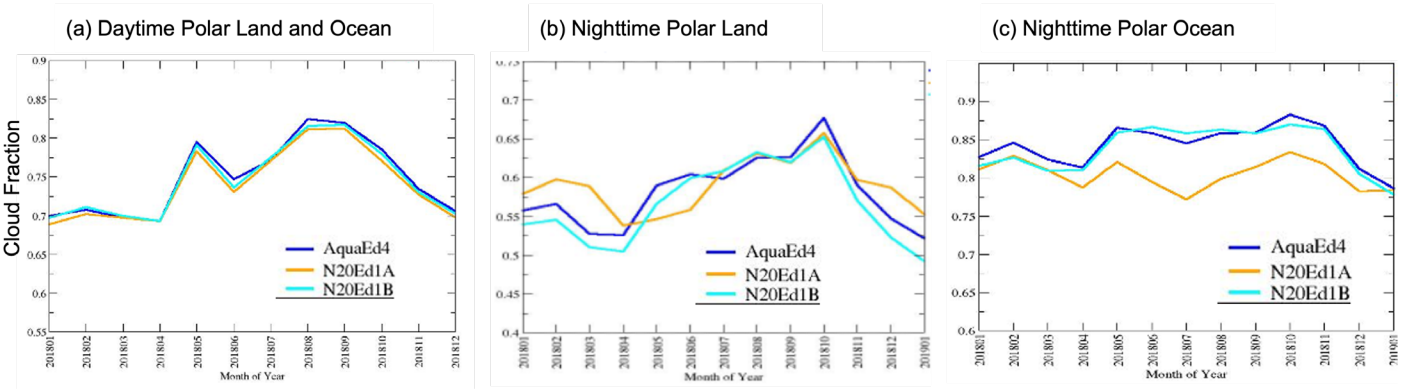

Figure 4. Time series of 2018 monthly mean nighttime cloud fractions for (a) daytime polar land and ocean, (b) nighttime polar land and (c) nighttime polar ocean derived from the Aqua-MODIS Ed4 and the VIIRS Ed1a and Ed2B cloud algorithms.

differences are less than -5 in many areas. In order to improve the level of agreement between the Ed1B daytime polar ice COD estimates and those produced in Ed4A, the older Ed4A models and the code with the interpolation bug were incorporated into the Ed1B algorithm. The impacts of these changes are shown in Figure 5b and Figure 5d. Figure 6a shows the time series of the monthly mean polar ice COD. While the overall agreement with Ed4A seems to be much improved on average for Ed1B compared to Ed1A as evident in Figure 6a, some large regional differences remain as shown in Figure 5b and Figure 5d which appear to be somewhat correlated with the remaining regional cloud fraction difference patterns shown in Figure 3, particularly over the south polar region shown in Figure 3d. Finally, the results shown in Figure 6b indicate that for daytime polar water clouds, the changes in the cloud reflectance models for Ed1B had little impact overall so that some significant disagreements between the Ed1B and Aqua-MODIS Ed4A water cloud COD also remain over polar regions.

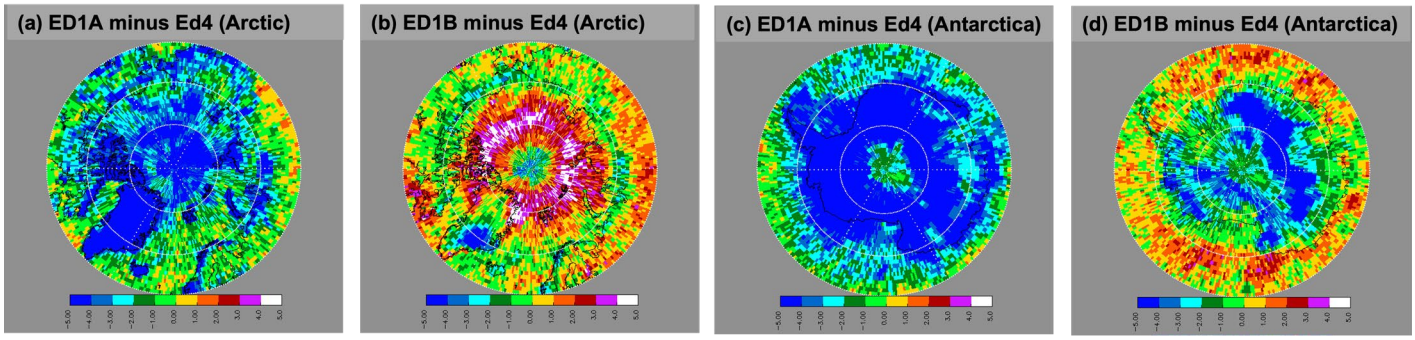

Figure 6. 2018 annual mean daytime cloud optical depth differences from Ed4A for (a) Ed1A over the Arctic, (b) Ed1B over the Arctic, (c) Ed1A over the Antarctic, (d) Ed1B over the Antarctic

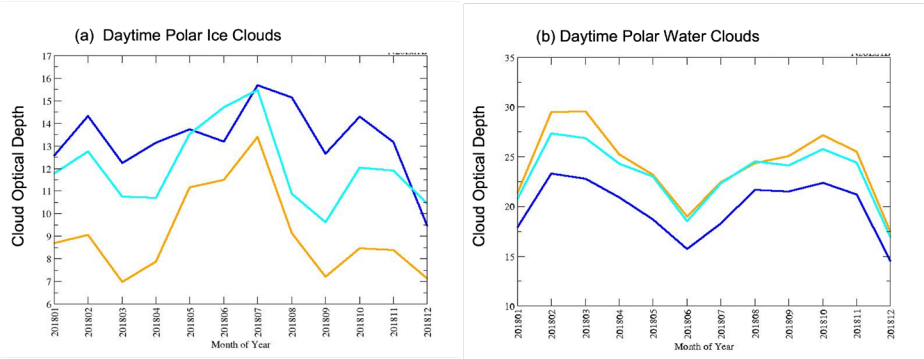

Figure 5. Time series of 2018 monthly mean nighttime cloud optical depths (linear average) for non-polar regions derived from the Aqua-MODIS Ed4 and the VIIRS Ed1a and Ed2B cloud algorithms for(a) ice clouds and (b) water clouds.