NOAA ROSES Semi-Annual Report

Reporting Period: March 2021 – August 2021 (2nd report)

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Project Title: Development and implementation of a new set of enhanced GOES-R ABI snow cover products

Executive Summary

The project focuses on the development of an enhanced snow retrieval algorithm and a corresponding new set of advanced snow products for GOES-R ABI. The new set of snow products includes the binary and the fractional snow cover maps as well as the estimated snow depth. The final goal of the work consists in operational implementation of the developed algorithms at NESDIS Office of Satellite and Product Operations (OSPO). This document reports the work progress in the second half of the first year of the project implementation. During this time period we extensively modified and adapted the VIIRS Enterprise binary and fractional snow cover mapping technique to ABI data. The first version of the new ABI snow retrieval code has been thoroughly tested and delivered NESDIS operations. The framework for routine processing of the data from other geostationary satellites (SEVIRI MSG and AHI Himawari) has been created. Application of the ABI snow identification and mapping technique to SEVIRI and AHI data has yielded promising results but revealed the need for additional tuning of the ABI algorithm for use with these sensors.

Progress toward FY21 Milestones and Relevant Findings

1. Adaptation of the VIIRS Enterprise binary and fractional snow cover algorithms to ABI

Difference in the spectral response functions of matching VIIRS and ABI bands and, more importantly, a considerable difference in the observation geometry of the two instruments required a special adaptation of the existing VIIRS Enterprise snow algorithms for use with ABI data. Adaptation included minor changes to threshold values in the snow identification algorithm and implementation of a whole new set of reflectance anisotropy models in the snow fraction retrieval algorithm. The Enterprise snow fraction retrieval algorithm uses a linear unmixing technique which involves the observed reflectance in one (visible) bad and two endmembers representing the model TOA reflectance of a completely snow-covered and completely snow-free land surface. Both the snow-free land and the snow cover reflectance are strongly dependent on the viewing-illumination geometry of observations. Accurate characterization and parameterization of the angular anisotropy of both endmembers is required for accurate estimates of the snow cover fraction.

For the ABI algorithm we followed a physical approach in characterizing the TOA reflectance of the snow-free land and of the snow cover. It incorporated in situ-observed reflectance anisotropy factors for snow cover and vegetated land surface (NASA PARABOLA measurements) and subsequent simulations of the top of the atmosphere (TOA) reflectance using SBDART radiative transfer model. The TOA simulated reflectance of snow-covered and snow-free land surface are presented in the form of looks-up tables. This approach is completely different from the one used in the VIIRS data processing system where the TOA mean anisotropic reflectance for snow and snow-free land surface was predicted from the statistics of observed TOA reflectance and was parameterized using simple geometric kernel functions.

The physical approach implemented in the ABI retrieval system provides more adequate and accurate characterization of the land surface and snow reflectance angular anisotropy and therefore allows for more reliable and robust snow fraction retrievals. The model TOA reflectance of the snow-free land surface and of snow cover in the ABI snow retrieval system presented in Figure 1 illustrates a complex angular structure of reflectance which is hard to properly approximate with a set of empirical functions.

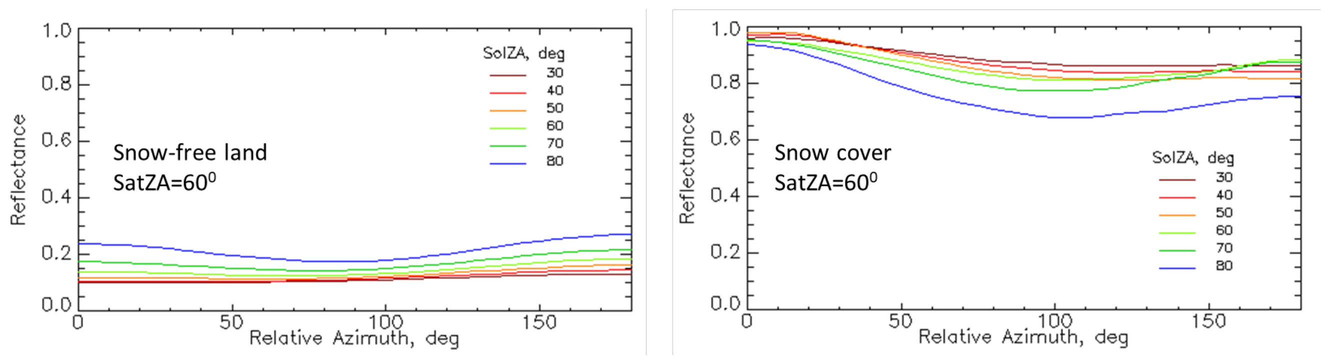

Figure 1. Predicted visible reflectance of snow-free land surface (left) and of snow cover (right) incorporated in the ABI snow fraction retrieval algorithm. Modelled reflectance values are presented for observations at 60^0 satellite zenith angle. Zero relative angle value corresponds to the forward scatter observation geometry.

2. Evaluation of ABI snow products derived with the Enterprise algorithm

The Enterprise snow fraction algorithm adapted to ABI data have been used to generate ABI maps of the fractional snow cover. Similar to VIIRS, ABI snow fraction is derived only for scenes flagged by the snow identification as “snow-covered”. Adjustment of the Enterprise snow identification algorithm to ABI data was performed during the first half-a-year reporting period and was addressed in the previous progress report. Qualitative analysis of the ABI snow fraction maps revealed their good agreement to similar maps produced with observations from polar orbiting satellites both with respect to the snow cover distribution and to the estimated values of the snow fraction. This can be seen in particular from Figure 2 which shows matched snow fraction maps derived from GOES-16, GOES-17 and METOP AVHRR on the same day in December 2020.

Quantitative comparison of the ABI snow fraction with matched retrievals from AVHRR has revealed the bias between the two estimates ranging mostly within -0.1 to 0.1 and the root-mean-square difference (RMSD) ranging within 0.15-0.25. This magnitude of difference agrees well to theoretical estimates of the accuracy of snow fraction estimates with the proposed unmixing technique ranging within 0.20-0.25. As an example, Figure 3 presents scatterplots and histograms of the matched of ABI GOES-16 and AVHRR snow fraction over the CONUS region. The comparison results in this particular case demonstrate the bias within -0.06 to 0.13 and the RMSD within 0.16-0.21

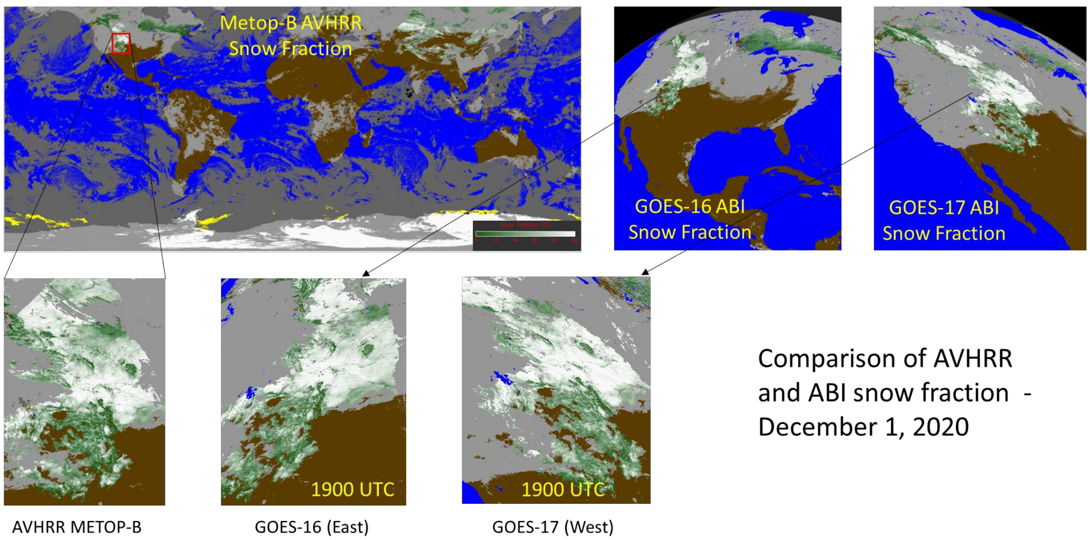

Figure 2. Snow fraction maps derived from ABI (GOES-16 and -17) and METOP AVHRR with the Enterprise algorithm on 12/01/2020.

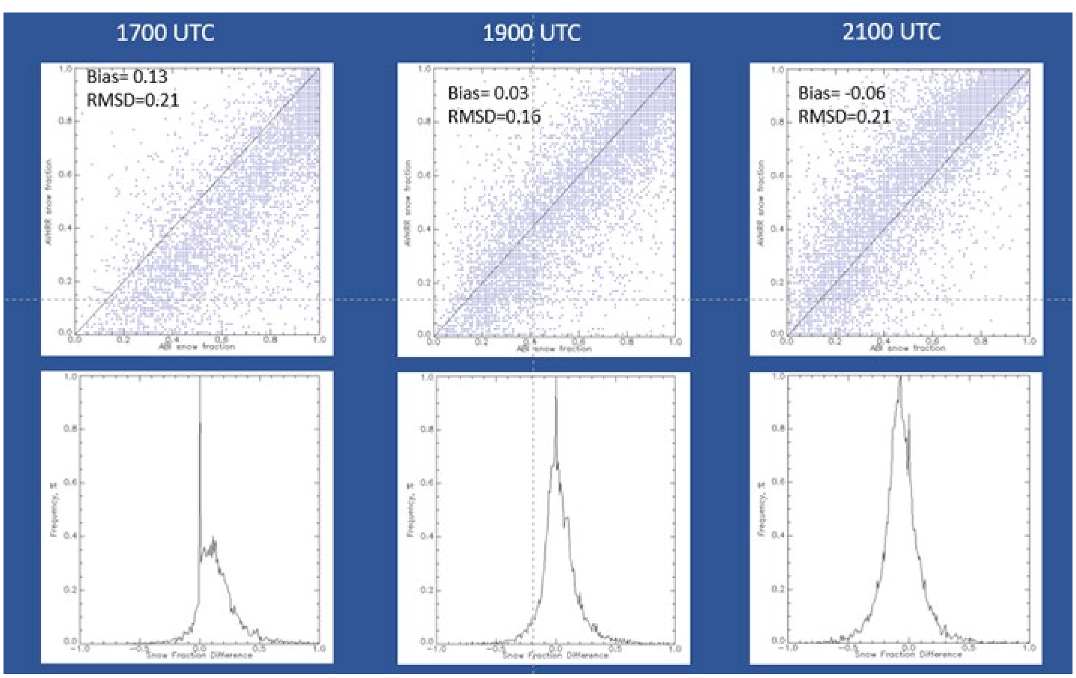

Figure 3 Scatterplots of matched snow fraction estimates from METOP AVHRR and ABI GOES-16 on Dec 19, 2020. Scatterplots are presented for ABI observations at 1700, 1900 and 2100 UTC.

3. Delivery of the ABI snow algorithm to operations

The first version of the ABI snow retrieval system has been developed and delivered to NESDIS/STAR ASSISTT team for further implementation at NESDIS Office of Satellite and Product Operations (OSPO). The snow retrieval algorithms incorporated in the delivered system are Enterprise algorithm adjusted and adopted for geostationary satellite data. Scripts and codes comprising the new system have been revised for compliance with the requirements of NESDIS Satellite Product and Services Review Board (SPSRB). This version of the system includes the two “standard” image-based snow products, the binary snow cover map and the snow fraction. Both maps along with associated quality flags and other support information will be provided to the users as a single NetCDF file.

4. Implementation of the new ABI snow algorithms with other geostationary satellite data

Scripts and codes have been developed to routinely process SEVIRI data from both MSG satellites (MSG1 over Europe at 0^0E longitude and MSG4 over Indian Ocean at 41^0E longitude) and from the AHI sensor onboard Himawari satellite (140^0E longitude). Binary snow maps and maps of the snow fraction for these sensors have been derived with the GOES-R ABI algorithm. Because of the lack of a standard cloud cover product for SEVIRI and AHI, we have developed a simple cloud mask which uses SEVIRI observations in the visible, near-IR, shortwave IR and thermal infrared band. Figure 4 present an example of the full disk binary snow and fraction snow cover products derived from Himawari AHI data. At this time all snow products derived from geostationary satellite data are strictly image-based with no image compositing is involved.

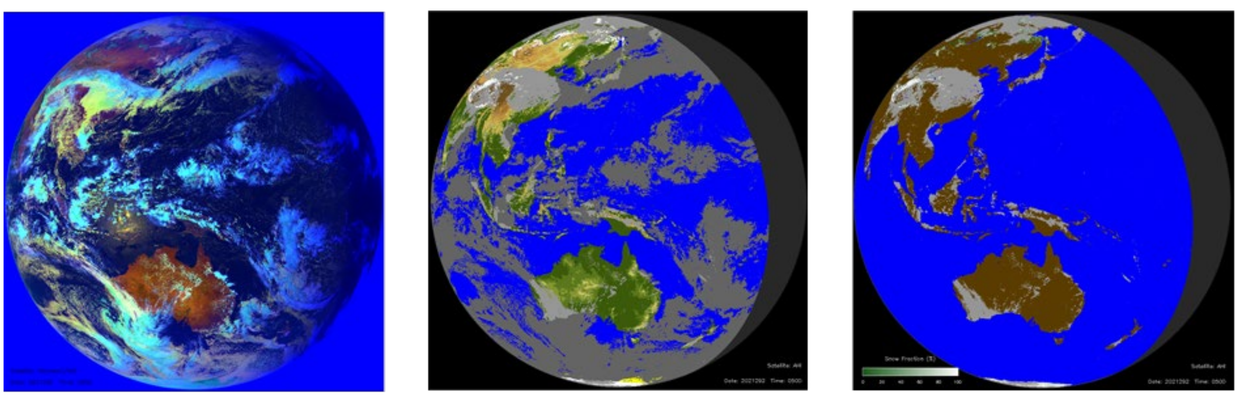

Figure 4. Example of Himawari AHI full disk RGB image (left) along with corresponding derived binary snow map (center) and the map of snow fraction (right). In the binary snow map clouds are shown in gray and snow is white. Background colors represent surface elevation. In the map of snow fraction clouds are shown in gray whereas the snow fraction is shown as shades of green.

Because of a small amount of seasonal snow cover over mid-latitude Europe and Asia at the time of the algorithm development (summer-early fall 2021) evaluation of the new MSG-based and Himawari-based snow products was only qualitative and was confined mostly to alpine areas. Our analysis has demonstrated a good consistency of snow retrievals over time in the course of the day and their consistency between different satellite sensor (see Figure 5 for particular examples). This is indicative of a robust performance of the snow retrieval algorithm under changing viewing/illumination geometry of observations. Qualitative comparison with polar-orbiting satellite data revealed a small underestimation of the snow extent mapped in the

AHI product which apparently requires an additional tuning of snow identification threshold values in the Enterprise algorithm for this particular sensor. Further Testing and Quantitative validation of the snow products derived from all non-ABI geostationary satellite sensor will continue with the seasonal advance of the snow cover in Europe and Asia during the 2021-2021 winter season.

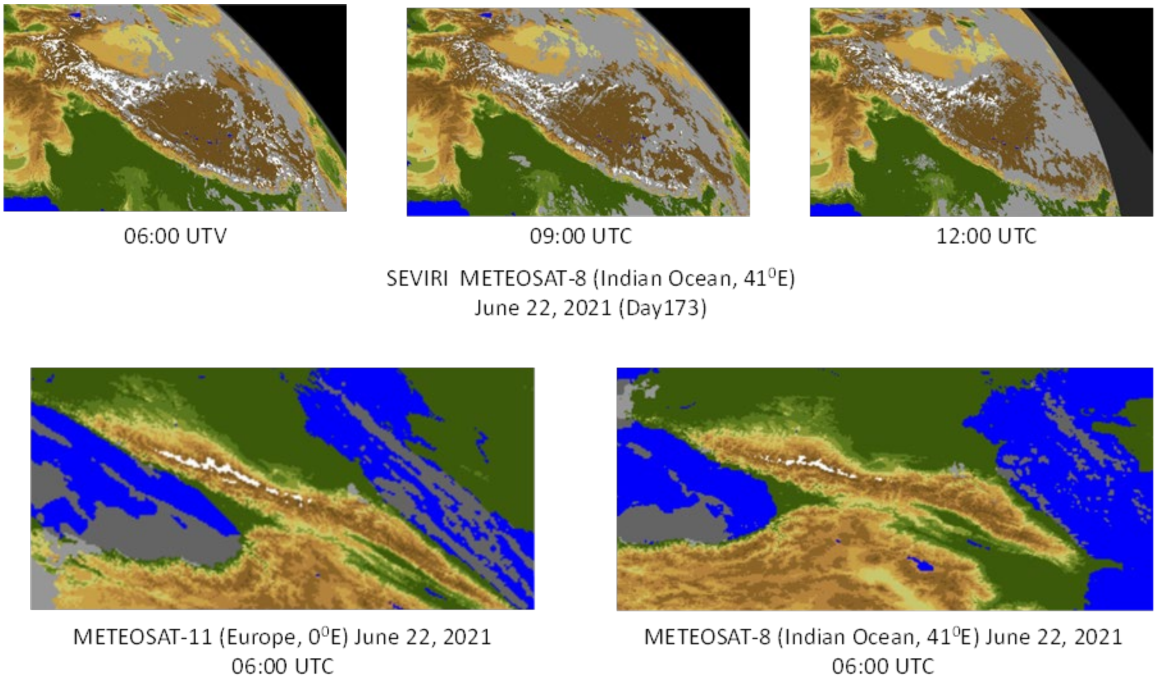

Figure 5. Upper panel: Identified snow cover in Tibet in MSG-1 (METEOSAT-8) SEVIRI images on June 22, 2021 at different times of the day. Lower panel: Snow cover identified in Caucasus in MSG-4 (METEOSAT-11) and MSG-1(METEOSAT-8) images on June 22, 2021 at 06:00 UTC. In the snow map clouds are shown in gray and snow is white. Background colors represent surface elevation.

Plans for Next Reporting Period

- Thorough testing and validation of the ABI binary and fractional snow products during the 2021-202 winter season.
- Evaluation of snow products derived with SEVIRI and AHI data using the ABI retrieval algorithm
- Development of the ABI daily composited snow product. Testing various data compositing techniques.
- Conducting experiments to combine ABI snow retrievals with satellite passive microwave observations to provide spatially continuous snow cover characterization