NOAA ROSES Semi-Annual Report

Reporting Period: September 2021 – March 2022 (3rd report)

PI: Peter Romanov (NOAA-CESSRST, City University of New York)

Co-PI(s): Aaron Letterly (University of Wisconsin, Madison), Jeffrey Key, NOAA/NESDIS/STAR, Madison, WI, Yinghui Liu, NOAA/NESDIS/STAR, Madison, WI

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 first half of the second year of the project implementation. During this time period we have started routine off-line generation of a new set of ABI snow products derived with the Enterprise binary and fractional snow cover mapping technique adapted to ABI data. The retrieval results are being tested and evaluated. The algorithms and the software to derive a new set of ABI snow products has been delivered to the STAR ASSISTT team and is now ready for operational implementation at NESDIS/OSPO. The framework for routine processing of the data from other geostationary satellites (SEVIRI MSG and AHI Himawari) has been created and is being tested. Daily snow products which combined multiple ABI instantaneous snow products derived during the day have been created. It has been determined that daily cloud-clear compositing of ABI snow products provides a 10-20% increase of the product effective area coverage as compared to instantaneous snow products. Potentials for generating ABI snow cover products at full, 0.5 km. spatial resolution has been tested. Testing of the ABI snow retrieval algorithms with other geostationary satellite data (MSG/SEVIRI, Himawari/AHI) continues.

Progress toward FY22 Milestones and Relevant Findings

1. ABI Snow Products at improved spatial resolution (2 km to 0.5 km)

Software has been developed and is being tested to derive ABI snow products at an improved spatial resolution of 0.5 km. This presents a 4 times enhancement in the spatial resolution from the current 2 km snow maps. The software relies on the full, 0.5 km, resolution observations in the visible band (band 2). Observations in the shortwave infrared (band 5) at 1 km resolution and in the infrared (band 13) at 2 km resolution used by ABI snow algorithms are resampled by replication to match the resolution of the visible band. Higher spatial resolution allows for a much more detailed characterization of the snow cover fraction (see Figure 1). As seen from Figure 1, at 0.5 km spatial resolution over mid-latitudes the level of detail in the snow fraction distribution in the ABI product is close to the corresponding VIIRS snow fraction retrievals gridded to 1 km.

Improved spatial resolution is particularly beneficial for snow cover mapping and monitoring in alpine areas (see Figure 2 focusing on Patagonia Ice fields in South America). Although, in this case misinterpretation of mixed land/snow scenes as clouds by the cloud mask hampers accurate delineation of the edge of the snow cover.

Once testing is complete, higher resolution ABI snow cover products will be proposed for implementation into operations.

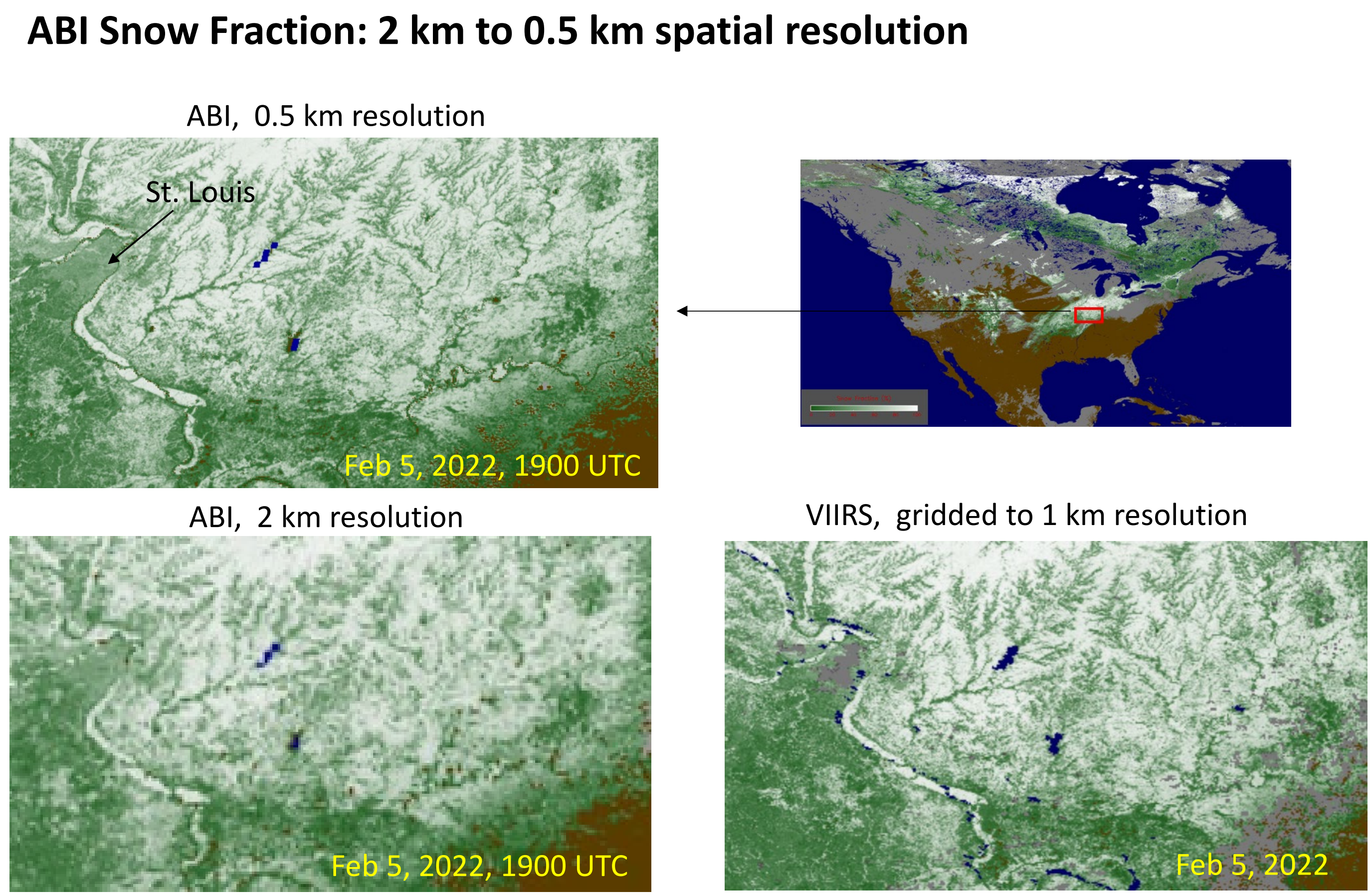


Figure 1. Fragment of an ABI-based snow fraction map at 2 km spatial resolution (lower left) and an improved, 0.5 km, resolution (upper left). Corresponding snow fraction map derived from VIIRS data is shown in the lower right.

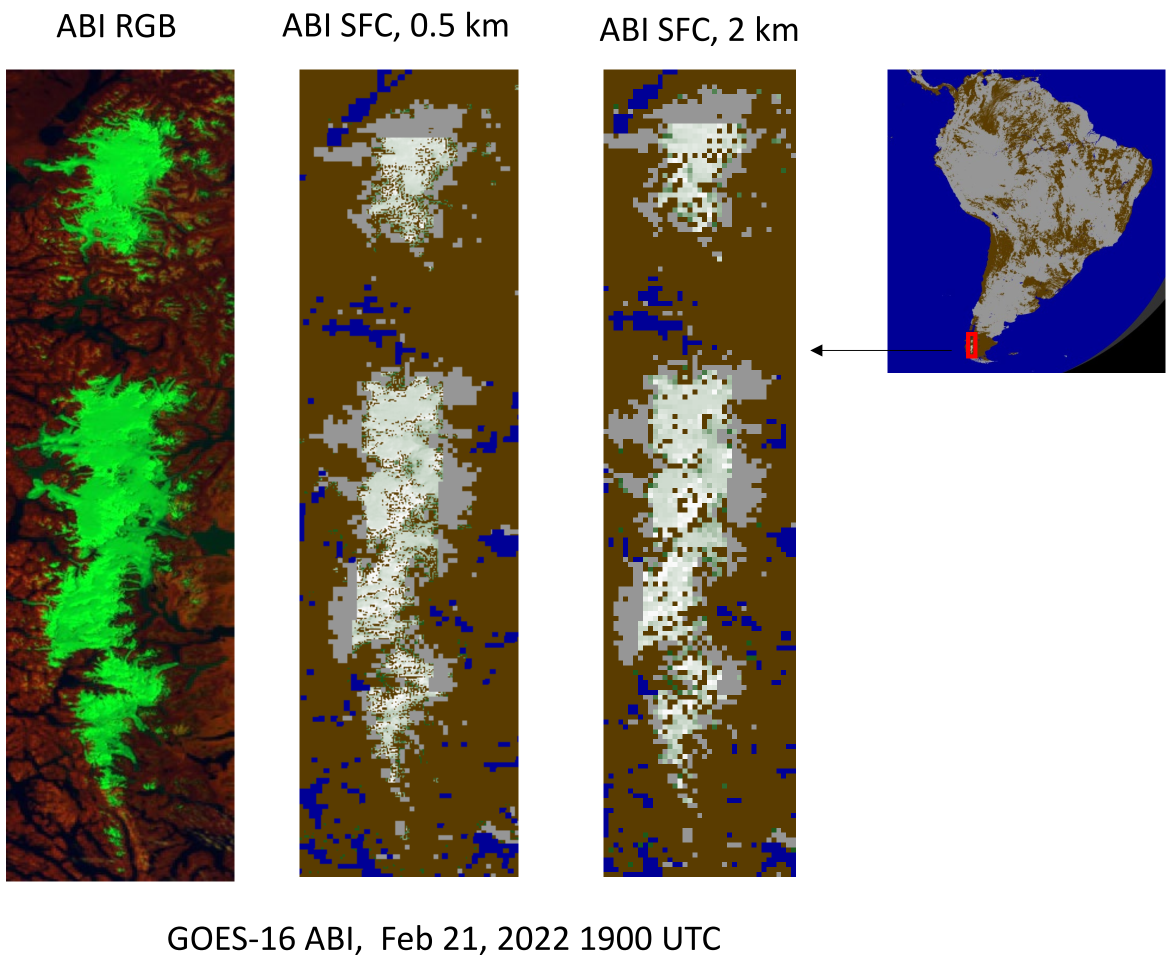


Figure 2. GOES-16 ABI mapped snow cover fraction over Patagonian Ice Fields at 0.5 and 2 km spatial resolution. ABI false color RGB image is on the left.

2. ABI daily composited snow products have been developed and are being tested

A new algorithm and corresponding software have been developed to generate daily composited snow cover products from ABI sensor data. The algorithm uses instantaneous snow fraction images derived from ABI data. Clear sky snow fraction retrievals obtained during the day within each grid cell are retained and the estimated snow cover fraction is averaged. Because of the cloud movement this procedure reduces cloud contamination and improves the effective area coverage of the daily composited product as compared to individual instantaneous images.

The compositing algorithm has been applied to GOES-16 and GOES-17 ABI data acquired in January and February 2022. Test runs have shown that compositing of hourly snow products during the day provided about 10-20% reduction of the cloud-obscured area in the daily product as compared to instantaneous images. An example of the daily composited snow cover product derived from GOES-16 ABI is shown in Figure 3.

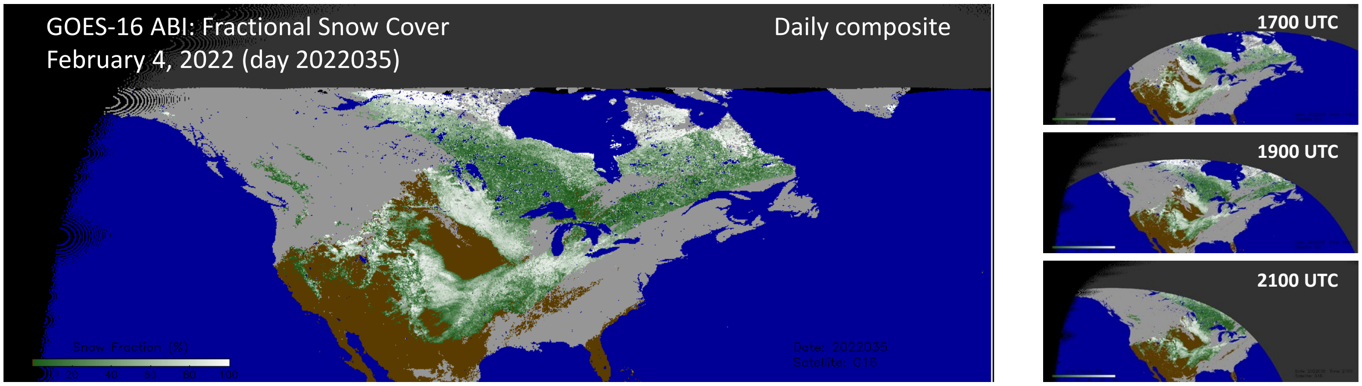


Figure 3 Left: Example of ABI daily composited snow fraction product. Right: Several instantaneous snow products incorporated in the daily snow fraction map. All products are presented on a regular latitude-longitude projection.

The list of new snow products proposed for future implementation has been complemented with the map of the snow cover temperature. The product helps to quickly and efficiently identify and delineate areas of melting snow. At this time the snow temperature product uses ABI brightness temperature value in band 13 (10.35 µm) as an estimate of the surface temperature. Algorithms providing a more accurate estimate of the surface temperature are being evaluated. Figure 4 presents an example of the daily snow fraction product generated from GOES-17 (West) ABI data on February 6, 2022 and a corresponding snow temperature product. The map clearly shows active snow melting in the band of snow cover which developed due to a strong snow storm in the beginning of February 2022.

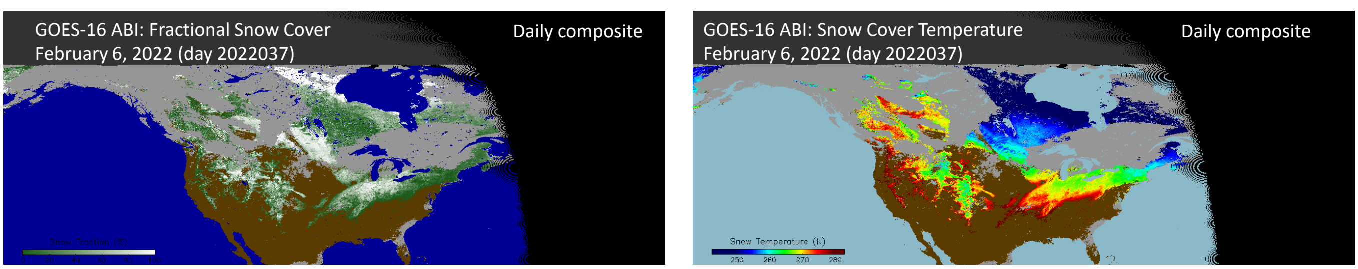


Figure 4 Daily snow fraction map (left) and corresponding daily snow temperature map generated from GOES-17 (West) ABI observations on February 6, 2022. Red and dark areas in the snow temperature map indicate melting snow.

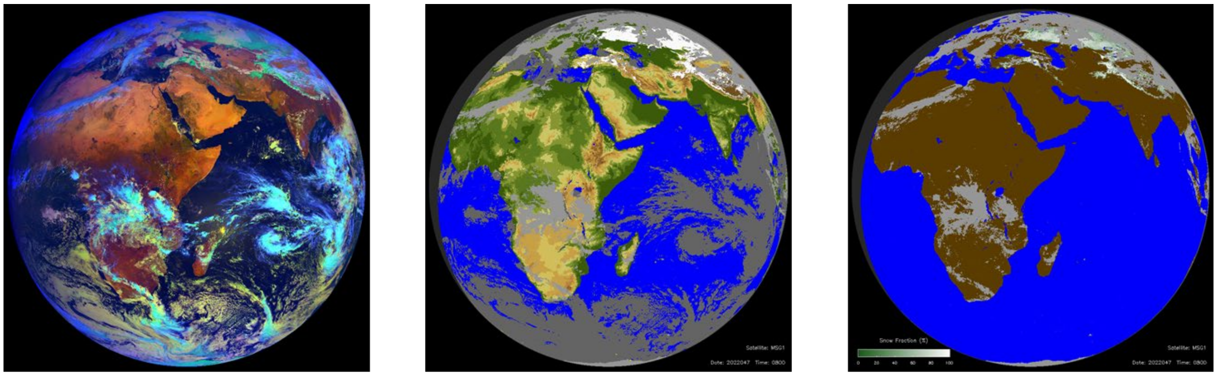
3. Delivery of the ABI snow algorithm to operations

The first version of the ABI snow retrieval system developed within this project has been prepared for operational implementation NESDIS Office of Satellite and Product Operations (OSPO). A number of adjustments have been made to the code and to the output product to comply with the requirements of NESDIS Satellite Product and Services Review Board (SPSRB). The output product in NetCDF format includes the binary snow cover map and the snow fraction along with quality flags and quality information. The Algorithm Theoretical Basis Document (ATBD) for the new ABI snow cover product is being developed.

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.

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.



RGB Image Snow Map Snow Cover Fraction

SEVIRI MSG-1 (METEOSAT-8) Indian Ocean, 41^{0}E
February 15, 2022, 08:00 UTC

Figure 4. Example of MSG SEVIRI 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.

Plans for Next Reporting Period

- Thorough evaluation of the ABI binary and fractional snow product performance during the 2021-2022 winter season.
- Establish routine generation of snow products derived from SEVIRI and AHI
- Validation of ABI daily composited snow product.
- Conducting experiments to combine ABI snow retrievals with satellite passive microwave observations to provide spatially continuous snow cover characterization