A NEW BLENDED SNOW PRODUCT USING VISIBLE, MICROWAVE AND SCATTEROMETER SATELLITE DATA

James Foster[1] (presenting author), Dorothy Hall[1] and John Eylander[2]
1 NASA/GSFC, Hydrospheric and Biospheric Sciences Laboratory, Greenbelt, MD, USA
2 HQ AF Weather Agency,106 Peacekeeper Dr., Suite 2N3, Offutt AFB, NE, USA

PHONE: 301-614-5769; FAX 301-614-5808
EMAIL; JAMES.L.FOSTER@NASA.GOV

ABSTRACT

For this blended product, snow cover extent, snow water equivalent (SWE) and snowmelt are mapped and measured globally on a daily or near-daily basis, initially at a resolution of 25 km, utilizing Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Microwave Scanning Radiometer for NASA's Earth Observing System (AMSR-E) passive microwave data and QuikSCAT scatterometer data. A snow algorithm referred to as the Air Force, NASA Snow Algorithm (ANSA) has been developed, and is still being fine tuned, to derive the above stated snow parameters. The algorithm results have thus far been evaluated in the lower Great Lakes area of North America, in Colorado (Cold Lands Project Experiment sites) in portions of Finland, and eastern Turkey.
Key Words: Snow; microwave, MODIS, scatterometer

INTRODUCTION

The ability to characterize snow storage more accurately at the drainage basin scale is crucial for improved water resource management. Snow-water equivalent (SWE), snow extent, and melt onset are important parameters for climate modeling and for the initialization of forecasts at daily and seasonal time scales. Snowmelt data are needed in hydrological models to improve flood control and irrigation management. In addition, knowledge of snowpack ripening is essential for natural-hazard applications such as flood prediction. Furthermore, data on snow depth and snowmelt are useful for assessing trafficability for military tactical operations.

A new, blended global snow product that utilizes Earth Observation System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Microwave Scanning Radiometer for EOS (AMSR-E) and QuikSCAT (QSCAT) scatterometer data has been developed jointly by the USAF and NASA [6,7]. Figure 1 shows an example of this blended product. The initial blended-snow product includes snow cover extent, fractional snow cover, SWE, onset of snowmelt, and will include, in the near future, identification of actively melting snow cover at a 25-km resolution. These products have been evaluated using in situ data from the lower Great Lakes region of the U.S., from the Cold Lands Processes Experiment (CLPX) in Colorado, and from snow course data in Finland and in Turkey [19,2,5,1].

PRODUCT DEVELOPMENT

MODIS data have been used since early 2000 to produce validated, daily, global snow maps in an automated environment (http://modis-snow-ice.gsfc.nasa.gov). These maps, available at a variety of spatial resolutions – 500 m, 0.05° and 0.25° – provide snow extent, fractional-snow cover (FSC) and snow albedo [9,15,18,17,10] in both a sinusoidal projection and a latitude/longitude grid known as the climate-modeling grid (CMG). Validation activities for snow extent and FSC have been conducted by the data-product developers and also by other investigators [10].

Passive microwave-derived methods to estimate regional to global snow depth or SWE use frequent and wide-swath-coverage observations from sensors on board several different satellites. There is a heritage of nearly 30 years of global-daily observations from such instruments [3,4,21]. From November 1978 to the present, the SMMR instrument on the Nimbus-7 satellite and the SSM/I on the Defense Meteorological Satellite Program (DMSP) series of satellites have acquired passive microwave data that can be used to estimate SWE. The SMMR instrument failed in 1987, the year the first SSM/I sensor was placed in orbit. The AMSR-E sensor, launched in 2002 on board the Aqua satellite, is the most recent addition to the passive microwave suite of instruments. AMSR-E snow products [12,13] are archived and distributed through the National Snow and Ice Data Center, and are available in the Equal Area SSM/I Earth Grid (EASE-grid) projection (at a 25 km x 25 km pixel scale).

The sensitivity of spaceborne scatterometer data to snow parameters has been gaining more attention in recent years (e.g., [16,14,11]). Nghiem and Tsai [16] indicate the potential of the scatterometer (QSCAT) data for applications to remote sensing of snow at the global scale by showing that Ku-band (14 GHz) backscatter is sensitive to snow properties. Moreover, the diurnal backscatter change method was developed to detect and map snowmelt areas using QSCAT data [16]. See Figure 2.

The confidence for mapping snow cover extent is greater with the MODIS product than with the microwave product when cloud-free MODIS observations are available. Therefore, the MODIS product is used as the default for detecting snow cover. The passive microwave product is used as the default only in those areas where MODIS data are not obtainable due to the presence of clouds and darkness. Though the AMSR-E product is especially useful in detecting snow through clouds, passive microwave data often misses snow in those regions where the snow cover is thin, along the margins of the continental snowline, and on the lee side of the Rocky Mountains, for instance. In these regions, the MODIS product can reliably map shallow snow cover under cloud-free conditions. The AMSR-E snow product is used in association with the difference between ascending and descending satellite passes (Diurnal Amplitude Variations, DAV) to detect the onset of melt. For more details on the above see [8].

Our blended-snow product will be fully automated and thus amenable to the production of future climate-data records (CDRs) or Earth Science Data Records (ESDRs), following necessary re-processing.
Though snow-cover extent and snow albedo are currently available from various sensors including the MODIS (see [10]), and SWE is available from AMSR-E [12], snowpack ripening is currently unavailable as a product. Nonetheless, QuikSCAT scatterometer data are highly suited to this task [16]. There are several advantages in using active and passive microwave observations together for snow monitoring. 1) The resolution is similar (~20-25km); 2) the incidence angle is constant (QuikSCAT: 46º for H and 54º for V channel, SSM/I/AMSR-E: ~53º); 3) both sensors have a wide swath (QuikSCAT 1800 km, e.g. SSM/I 1400 km) and sun-synchronous polar orbits allowing excellent global coverage and frequent polar coverage.

This blended-snow product will begin with the first combined MODIS/AMSR-E data from the Aqua satellite (June of 2002) and continue through the present. Note that QuikSCAT data are available from June 1999 to present. By fusing products we will complement their capabilities and aid in reducing the limitations and errors inherent in each separate product.

CONCLUSIONS

Our blended-snow product is an example of data fusion, with minimal modeling in order to yield improved snow products, which include snow-cover extent, SWE, fractional snow cover, onset of snowmelt, and areas of snow cover that are actively melting. These maps are currently presented daily and globally at 25-km resolution. MODIS data allows us to view the snow covered surface at a high resolution (greater than 5 km); whereas AMSR-E data enables us to estimate the snow water equivalent. Using AMSR-E and QSCAT data, we have the capability of delineating areas of dry snow (AMSR-E, 37 GHz), incipient melt using AMSR-E (19 GHz horizontal channel), and active-melt areas using QSCAT.

The ANSA blended product has been evaluated thus far using data from the lower Great Lakes region, from the CLPX site in Colorado, from Finland and from Turkey. We will continue to validate the snow products by using data from well maintained and reliable meteorological stations such as those found in Canada and selected World Meteorological Organization sites.

REFERENCES

[1]Akyurek, Z, D.K. Hall, G.A. Riggs and A. Sensoy, submitted: Evaluating the utility of the ANSA Blended Snow Cover Product in the Mountains of Eastern Turkey, *International Journal of Remote Sensing.*

[2]Casey, K.A., Kim, E., Hallikainen, M.T., Foster, J.L., Hall, D.K. and Riggs, G.A., in press, Validation of the AFWA-NASA blended snow-cover product in Finland, 2006 – 2007. In *Proceedings of the 65th Eastern Snow Conference,* Fairlee, Vt., 28 – 30 May 2008.

[3]Chang, A.T.C., Gloersen, P., Schmugge, T., Wilheit, T., and Zwally, J., 1976, Microwave emission from snow and glacier ice. *Journal of Glaciology,* 16: 23-39.

[4]Chang, A.T.C., Foster, J.L. and Hall, D.K., 1987, Nimbus-7 derived global snow cover parameters. *Annals of Glaciology*, 9:39-44.

[5]Finnish Meteorological Institute. 2008, 'Finland's Climate.' http://www.fmi.fi/weather/climate.html

[6]Foster, J., Hall, D., Eylander, J., Riggs, G., Nghiem, S., Tedesco, M., Kim, E., and Choudhury, B., 2008a, A new blended global snow product using visible, microwave and scatterometry satellite data. In *Proceedings of the 88th Annual Meeting of the A.M.S., New Orleans, Louisiana*, January, 2008.

[7]Foster, J., Nghiem, S., Tedesco, M., Riggs, G., Hall, D., and Eylander, J., 2008b, A global snowmelt product visible, passive microwave and scatterometry satellite data. In *Proceedings of the XXI Congress of the ISPRSE, Beijing, China*, July, 2008.

[8]Foster, J. L., Hall, D. K. J. Eylander, G. Riggs. S. Nghiem, M. Tedesco, E. Kim, P. Montesano, R. Kelly, K. Casey, and B. Choudhury, A blended, global snow product using visible, microwave, and scatterometer satellite data. *International Journal of Remote Sensing* (in press).

[9]Hall, D.K, Riggs, G.A., Salomonson, V.V., DiGirolamo, N.E. and Bayr, K.J., 2002, MODIS snow-cover products. *Remote Sensing of Environment* 83:181-194.

[10]Hall, D.K. and Riggs, G.A., 2007, Accuracy assessment of the MODIS snow-cover products. Hydrological Processes, 21:1534-1547.

[11]Hallikainen M., Halme, P., Lahtinen, P. and Pulliainen, J., 2004, Retrieval of snow characteristics from spaceborne scatterometer data, In *Proc. of IEEE Geoscience and Remote Sensing Symposium, IGARSS 2004, Anchorage, Alaska, USA*, Conference CD.

[12]Kelly R.E.J., Chang, A.T.C., Tsang, L., and Foster, J.L., 2003, A prototype AMSR-E global snow area and snow depth algorithm. *IEEE Trans. Geosci. Remote Sens*., EO-1 Special Issue, 41 (2):230-242.

[13]Kelly, R.E.J., in press, The AMSR-E Snow Depth Algorithm: Description and Initial Results. *Journal of the Remote Sensing Society of Japan*. (in press).

[14]Kimball, J.S., McDonald, K.C., Keyser, A.R., Frolking, S. and Running, S.W., 2001, Application of NASA Scatterometer (NSCAT) for determining the daily frozen and nonfrozen landscape of Alaska. *Remote Sensing of Environment*, 75:113-126.

[15]Klein, A.G. and Stroeve, J., 2002, Development and validation of a snow albelo algorithm for the MODIS instrument. Annals of Glaciology 34: 45-52.

[16]Nghiem, S.V., and Tsai, W.Y., 2001, Global snow cover monitoring with spaceborne Ku-band scatterometer. *IEEE Transactions on Geoscience and Remote Sensing*, 39, 2118-2134.

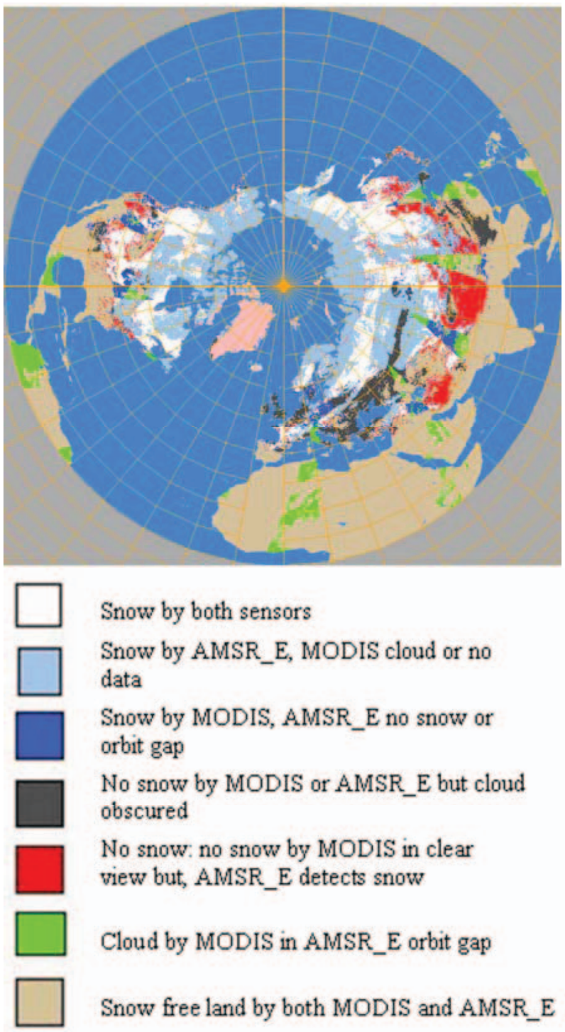
[17]Riggs, R.A., Hall, D.K. and Salomonson, V.V., 2006, *MODIS Snow Products User Guide,* available online at http://modis-snow-ice.gsfc.nasa.gov/sugkc2.html.

[18]Salomonson, V.V. and Appel, I., 2004, Estimating the fractional snow covering using the normalized difference snow index. *Remote Sensing of Environment*, 89:351-360.

[19]Tedesco, M., Kim, E.J., Gasiewski, A. and Stankov, B., 2005, Analysis of multi-scale radiometric data collected during the Cold Land Processes Experiment -1 (CLPX-1), *Geophysical Research Letters*, 32, L18501.

[20]Tedesco, M., 2007, Snowmelt detection over the Greenland ice sheet from SSM/I brightness temperature daily variations, *Geophysical Research Letters*., 34, L02504,doi:10.1029/2006GL028466.

[21]Walker, A.E. and B. Goodison, B., 2000, Challenges in determining snow water equivalent over Canada using microwave radiometry, *Proceedings of IGARSS 2000, Honolulu, HI*, 24-28 July 2000.



Aggregation of blending visible and microwave data at 25 km spatial resolution in Lambert Azimuthal polar projection

Figure 1: ANSA Blended Snow Map for January 26, 2007

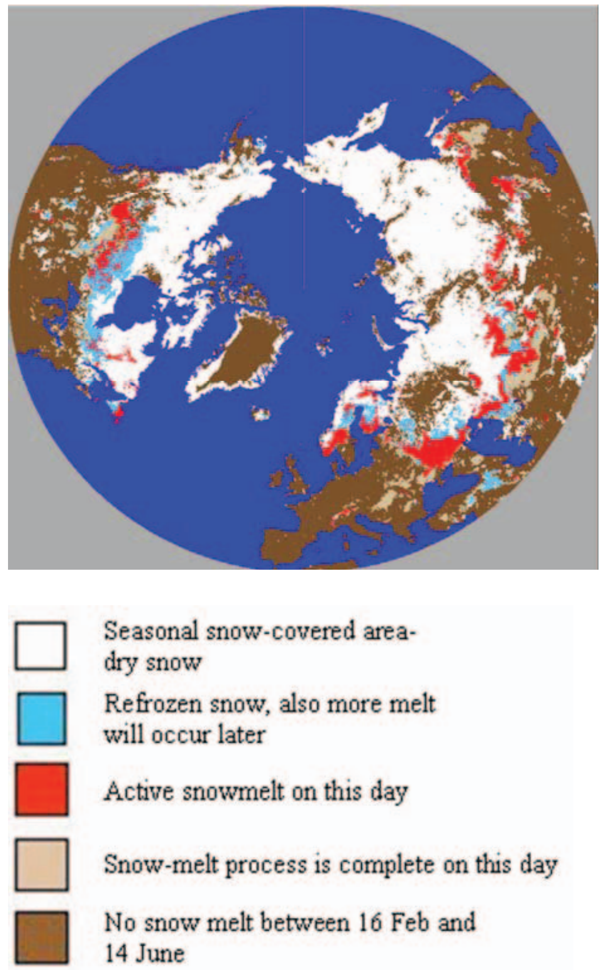


Figure 2: QuikSCAT Snowmelt Product for March 26, 2003 (After S. Nghiem/JPL.)