

MODIS Semi-Annual Report
Snow and Ice Project
Reporting Period: January - June 2002
Submitted by: Dorothy K. Hall/974 (7/19/02)

Abstract

During this reporting period, we have continued to validate the snow products, begun validation on the sea ice products, completed a MODIS/snow animation with the Scientific Visualization Studio, made many presentations, presented and submitted papers and made progress on algorithm deliveries for Collection 4. In addition, we have continued to enhance and update our Web site.

Algorithm and Coding Work

MOD10C1 - Daily Snow CMG

We are continuing to work with the DAO so that they can utilize the snow products. We developed two alternate versions of the daily CMG code for Matt Rodell/974. One version was the same as the regular daily CMG, except that the full range 0-100 percent snow was reported (rather than 40-100). The 2nd version was a change in the resolution - to 1/8th degree grid (rather than 5km, or 1/20th degree). New ancillary data (lat/lon tile lookup tables, and land/sea mask file) were created for this version.

The daily CMG MOD10C1 code was delivered in April.

Modifications to the operational daily CMG code were made. This included re-creation of the tile lat/lon index tables used for binning the 500m data into the 5km CMG grid. The new grid values were made using the center of the 500m datapoint, rather than the top/left corner. Other modifications involved changes/additions to metadata.

The new version of the daily CMG was delivered in May.

Since then, an additional improvement has been made: The handling of the transition zone between night and no data (near the poles) was modified to reduce false night classifications. This will be included in the next delivery.

MOD10C2 - 8-Day Snow CMG

Processing of MOD10C2 output continued - ie, production of images and extracted datasets for analysis and posting on the MODIS snow website.

Worked on a special request for monthly-averaged CMG fractional snowcover for the period November 2001-February 2002. An IDL procedure was developed to read the appropriate 8-day CMG output for each month, and produce a composite that closely represented the monthly average.

MOD10C2 was delivered and implemented in April. Similar to the MOD10C1, a new version was delivered in May. This version included the change to the tile lat/lon calculation, and changes/additions to metadata.

Since then, an additional improvement has been made: The handling of the transition zone between night and no data (near the poles) was modified to reduce false night classifications. This will be included in the next delivery.

MOD10A1

Worked on modifying the MOD10A1 snow code to include calculation of an albedo product. The algorithm for this would be based on code developed by Andrew Klein/Texas A&M. Some progress was made on this, and some preliminary tests were run to produce fake (test) albedo data (ie, entire algorithm has not been implemented).

MOD29A2 - 8-day Seaice

Work on this new product has begun. A developmental version of the code has been written, and tests are currently being run.

MODIS/snow Web site

Updates to the snow project website were made as needed, and we have included the MODland minimum requirements. <http://modis-snow-ice.gsfc.nasa.gov/intro.html>

Education/Outreach activities

A MODIS snow product animation has been completed with the Scientific Visualization Studio (SVS) at Goddard. These animations are available through the SVS <http://svs-f.gsfc.nasa.gov/~cindy/SnowCover> and will be shown on high-definition T.V.

Fractional snow cover

Several fractional snow cover (FSC) algorithms are in the process of being explored. A promising FSC algorithm that is based on the NDSI has been developed by Appel and Salomonson (2002) (see paper reference, below) and is being tested in various parts of the country. This work was presented at the Eastern Snow Conference 2002 and IGARSS 2002.

Snow Albedo

A snow albedo algorithm has been developed for the Moderate Resolution Imaging Spectroradiometer (MODIS) by Andrew Klein/Texas A&M. The algorithm will complement existing MODIS products by providing albedo measurements for areas mapped as snow on a global daily basis by MODIS. Currently, the algorithm's primary input is the MOD09 daily surface reflectance product. The snow albedo algorithm provides an albedo estimate for the 'best' MODIS observation of snow-covered pixels each day. The MOD09 surface reflectances are adjusted to account for the bi-directional reflectance of snow using a discrete ordinates radiative transfer (DISORT) model are used to correct for anisotropic scattering effects over non-forested surfaces. A narrow-to-broadband conversion scheme is then used to create an integrated broadband albedo. Coding has begun at GSFC. Dr. Klein plans to spend a week here in August 2002 to help with the albedo coding.

Snow Map Accuracy Investigations

We compared the 8-day composite CMG MODIS-derived global maps from November 1, 2001, through March 21, 2002, and daily CMG maps from February 26 – March 5, 2002, with National Oceanic and Atmospheric Administration (NOAA) Interactive Multisensor Snow and Ice Mapping System (IMS) 25-km resolution maps for North America. For the Norwegian study area, national snow maps, based on synoptic measurements as well as visual interpretation of AVHRR images, published by the Det Norske Meteorologiske Institutt (Norwegian Meteorological Institute) (MI) maps, as well as Landsat ETM+ images were compared with the MODIS maps. The MODIS-derived maps agreed over most areas with the IMS or MI maps, however, there are important areas of disagreement between the maps, especially when the 8-day composite maps were used. It is concluded that MODIS daily CMG maps should be studied for validation purposes rather than the 8-day composite maps, despite the limitations imposed by cloud obscuration when using the daily maps. A paper on this topic was prepared for the Eastern Snow Conference: <http://modis-snow-ice.gsfc.nasa.gov/publications.html>. Other work, that also compared the MODIS data with passive-MW-derived snow maps was presented at the PIERS'02 conference: http://modis-snow-ice.gsfc.nasa.gov/pap_piers02.pdf.

Cloud-mask Issues

Due to the overly conservative nature of the cloud mask developed by the University of Wisconsin, we have been working with selected spectral tests provided by the MODIS cloud mask and have developed a more liberal cloud mask. The more liberal mask does a better job of distinguishing clouds from snow, at least during the Northern Hemisphere winter, than does the conservative mask.

Snow and clouds often have similar spectral reflectance features across the spectrum and may have similar temperatures making discrimination difficult. The MODIS cloud mask algorithm employs many cloud spectral tests to determine if a pixel is cloud or clear; a cloud mask summary flag as well as all the cloud spectral tests applied are stored in the product. The production version of the MODIS snow algorithm uses the cloud mask summary flag to discriminate snow from cloud. The cloud conservative nature of the cloud mask algorithm generally results in more cloud obscuration than necessary, relevant to snow identification, which has impacted the ability to map snow extent. Analysis of the cloud mask algorithm techniques, processing paths and cloud tests, has led to improved usage of cloud spectral test data for masking clouds in the snow algorithm. Described are refinements in the use of cloud tests from the cloud mask product that minimize cloud obscuration of snow cover, maximize snow identification and constrain confusion between snow and clouds, leading to an improved mapping of snow cover extent. A paper on this topic has been prepared by Riggs et al., for the *Proceedings of the 59th Eastern Snow Conference* (see publications below).

Sea Ice Map Accuracy Investigations

Substantial progress has taken place in the analysis of the accuracy of the MOD29 sea ice extent and ice-surface temperature (IST) products. Sea ice maps have been compared in both the Arctic Ocean and the Southern Ocean with natural-color MODIS images. Other than the fact that the cloud mask is overly conservative in some cases, the agreement is excellent. Preliminary analysis shows that the IST values are close to expected temperatures. The following people have been consulted: Dr. Jeff Key/NOAA (developer of the IST algorithm) and Dr. Shusun Li/Univ. of AK (MODIS sea ice validation scientist). Ground truth along with aircraft overflights will be performed in connection with Dr. Don Cavalieri/971 next winter.

Problems

At least half of the detectors comprising band 6 on the Aqua MODIS are not functional. Therefore we will have to develop an entirely new snow and sea ice algorithm for the Aqua MODIS. This is a major problem because we need for the products on the Terra and Aqua satellites to be completely compatible.

Peer-Reviewed Papers (in preparation, submitted, accepted and in press) since 2000:

Hall, D.K., G.A. Riggs, K.A. Casey, J.R. Key and D. Cavalieri, in preparation, "The MODIS Sea Ice Cover and Ice Surface Temperature Products."

Hall, D.K., G.A. Riggs, V.V. Salomonson, N.E. DiGirolamo and K.J. Bayr, in press: "MODIS Snow-Cover Products," *Remote Sensing of Environment*.

Hall, D.K., R.E.J. Kelly, G.A. Riggs, A.T.C. Chang and J.L. Foster, in press: "Assessment of the Relative Accuracy of Hemispheric-Scale Snow-Cover Maps," *Annals of Glaciology*.

Kaufman, Y.J., R.G. Kleidman, D.K. Hall, J.S. Barton and V.J. Martins, "Remote sensing of subpixel snow cover using 0.66 and 2.1 μm channels, submitted to Geophysical Research Letters (accepted for publication).

Hall, D.K., G.A. Riggs, V.V. Salomonson and G.R. Scharfen, 2001: Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS) Snow-Cover Maps, Proceedings of the IAHS Hydrology 2000 Conference, 2-8 April 2000, Santa Fe, NM, pp. 55-60.

Tait, A.B., J.S. Barton and D.K. Hall, 2001: A prototype MODIS-SSM/I Snow Mapping Method, Proceedings of the IAHS Hydrology 2000 Conference, 2-8 April 2000, Santa Fe, NM, pp. 139-141, 2001.

Tait, A.B., J. S. Barton, D.K. Hall, 2001: A prototype MODIS/SSM/I snow-mapping algorithm, International Journal of Remote Sensing, 22(17):3275-3284.

Hall, D.K., J.L. Foster, V.V. Salomonson, A.G. Klein and J.Y.L. Chien, 2001: "Development of a Technique to Assess Snow-Cover Mapping Errors from Space," IEEE Transactions on Geoscience and Remote Sensing, 39(2):432-438.

Hall, D.K., A.B. Tait, J.L. Foster, A.T.C. Chang and M. Allen, 2000: "Intercomparison of satellite-derived snow-cover maps," Annals of Glaciology, 31:369-376.

Tait, A.B., D.K. Hall, J.L. Foster, A.T.C. Chang and R.L. Armstrong, 2000: "Utilizing multiple datasets for snow cover mapping," Remote Sensing of Environment, 72:111-126.

Riggs, G., D.K. Hall and S.A. Ackerman, 1999: "Sea ice extent and classification with the Moderate Resolution Imaging Spectroradiometer Airborne Simulator (MAS)," Remote Sensing of Environment, 68(2):152-163.

Polissar, A.V. P.K. Hopke, P. Paatero, Y.J. Kaufman, D.K. Hall, B.A. Bodhaine, E.G. Dutton and J.M. Harris, 1999: "The aerosol at Barrow, Alaska: long-term trends and source locations, Atmospheric Environment," 33:2441-2458.

Winther, J.G. and D.K. Hall, 1999: "Satellite-derived snow coverage related to hydropower production in Norway - present and future," International Journal of Remote Sensing," 20(15&16):2991-3008.

Proceedings Papers and selected Abstracts since 2000:

Hall, D.K., G.A. Riggs and V.V. Salomonson: Mapping Global Snow Cover using Moderate Resolution Imaging Spectroradiometer (MODIS) data, *Glaciological Data Report*, NSIDC special report (submitted March 2002).

Hall, D.K., R. Solberg and G.A. Riggs: Validation of satellite snow cover maps in North America and Norway, *Proceedings of the 59th Eastern Snow Conference*, 5-7 June, 2002, Stowe, VT.

Riggs, G.A. and D.K. Hall: Reduction of cloud obscuration in the MODIS snow data product, *Proceedings of the 59th Eastern Snow Conference*, 5-7 June, 2002, Stowe, VT.

Appel, I.L. and V.V. Salomonson, Estimate of fractional snow cover using MODIS data, IGRSS'02, 24-28 June 2002, Toronto, Canada.

Hall, D.K. and J.L. Foster, in press: Snow, *Our Changing Planet – A View from Space*, Cambridge University Press..

Hall, D.K., R.E.J. Kelly, A.T.C. Chang, J.L. Foster and J.Y.L. Chien, "Analysis of Relative Errors in Snow Maps in North America, Winter 2001-02," (abstract only) , presented at Progress in Electromagnetics Research Symposium 2002 (PIERS 2002), Cambridge, MA, 1 July 2002.

D.K. Hall, V.V. Salomonson, G.A. Riggs and Janet Y.L. Chien, "Snow-Cover Variability in North America in the 2000-2001 Winter as Determined from MODIS Snow Products," *Proceedings of IGARSS'01*, 9 – 13 July 2001, Sydney, Australia, 2001.

R.E.J. Kelly, A.T.C. Chang, J.L. Foster and D.K. Hall, "Snow cover observations in north-east Asia using multi-sensor satellite imagery," *Proceedings of IGARSS'01*, 9 – 13 July 2001, Sydney, Australia, 2001.

Riggs, G.A., D. K. Hall, J. R. Key, in press: "Initial Evaluation of MODIS Sea Ice Observations," *Proceedings of the 58th Eastern Snow Conference*, 14-18 May 2001, Ottawa, Canada.

Hall, D.K., G.A. Riggs and V.V. Salomonson, in press: "Analysis of a Time Series of Snow-Cover Maps of North America Derived from the Moderate Resolution Imaging Spectroradiometer Instrument," *Proceedings of the 58th Eastern Snow Conference*, 14-18 May 2001, Ottawa, Canada (Abstract only).

Barton, J.S., D.K. Hall and G.A. Riggs, 2001: "Fractional snow cover from the MODIS snow-mapping algorithm," *Proceedings of the 57th Annual Eastern Snow Conference*, 17-19 May 2000, Syracuse, NY.

Klein, A.G., D.K. Hall and A. Nolin, in press: "Development of a prototype snow albedo algorithm for MODIS," *Proceedings of the 57th Annual Eastern Snow Conference*, 17-19 May 2000, Syracuse, NY.

Hall, D.K., A.B. Tait, J.L. Foster, A.T.C. Chang and M. Allen, 2000: "Comparison of snow-cover maps from multiple data sets," *Proceedings of the 56th Annual Eastern Snow Conference*, 2-4 June 1999, Fredericton, N.B., Canada, pp. 71-74.

Klein, A.G. and D.K. Hall, 2000: "Snow albedo determination using the NASA MODIS instrument," *Proceedings of the 56th Annual Eastern Snow Conference*, 2-4 June 1999, Fredericton, N.B., Canada, pp. 77-85.

Hall, D.K., G.A. Riggs, V.V. Salomonson and G.R. Scharfen, 2000: "Early results from the Moderate Resolution Imaging Spectroradiometer (MODIS) global snow and ice cover products," *Proceedings of IGARSS'00*, 23-28 July 2000, Honolulu, HI, pp. 1763-1765.

Justice, C. and 20 others (including D. Hall), 2000: "Preliminary land surface products from the NASA Moderate Resolution Imaging Spectroradiometer (MODIS)," *Proceedings of IGARSS'00*, 23-28 July 2000, Honolulu, HI, pp. 1157-1162.

Scharfen, G.R., Hall, D.K., S.J.S. Khalsa, J.D. Wolfe, M.C. Marquis, G.A. Riggs and B. McLean, 2000: "Accessing the MODIS snow and ice products at the NSIDC DAAC," *Proceedings of IGARSS'00*, 23-28 July 2000, Honolulu, HI, pp. 2059-2061.

MODIS-related presentations during the reporting period:

Hall, D.K., "Moderate Resolution Imaging Spectroradiometer (MODIS) snow and sea ice research," to MIT/Goddard short course on remote sensing of the Earth's environment from Terra, GSFC, 16 January 2002.

Hall, D.K., "Arctic studies," JASON Project in conjunction with The National Geographic Society, Washington, D.C., 8 February 2002.

Hall, D.K., "MODIS Land Products," to a group of science teachers, GSFC Visitor's Center, 27 March, 2002.

Hall, D.K., "Remote sensing of snow and ice," at the *Remote Sensing of the Hydrosphere Workshop* for teachers, GSFC Visitor's Center, 3 May 2002.

Riggs, G.A., "Development of a more liberal cloud mask for the MODIS snow products," Eastern Snow Conference, Stowe, VT, 6 June 2002.

Hall, D.K., "Status, availability and ordering of MODIS snow-cover products," to a group of undergraduate students in the Department of Meteorology, University of Maryland, College Park, MD, 18 June 2002.

Appel, I.L., "Estimate of fractional snow cover using MODIS data," IGARSS'02, Toronto, Canada, June 2002.

Hall, D.K., "Analysis of relative errors of snow maps of the Northern Hemisphere, winter 2001-02," PIERS Symposium, 1 July 2002, Cambridge, MA.