

MODIS Semi-Annual Report
Snow and Ice Project
Reporting Period: July - December 2001
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Introduction

During this reporting period, we began to provide 8-day composite CMG global snow products on a regular basis, downloadable from our Web site. We also began obtaining near-real-time data from the University of Wisconsin SSEC and producing snow maps on the day of data acquisition. We have hosted an advisory-group meeting and received their final report. We have given presentations both to scientific and more general audiences. We have submitted abstracts for future meetings, and completed and published peer-reviewed papers. We have continued to improve and validate the snow algorithms and Web site. We have completed the snow albedo code, and it is now ready to be modified for ingestion into MODAPS.

Ad-Hoc Advisory Group Meeting, October 31, 2001

A meeting of the MODIS snow and ice project advisory group was held at Goddard on October 31, 2001. Presentations were made by the snow and ice group members and the advisory group provided feedback and preliminary recommendations. Their final report (available on request) was submitted in early December, and the group is currently studying and implementing their suggestions .

Algorithm and Coding Work

MOD10_L2

We continued the investigation and analyses of false snow detection in the MOD10_L2 snow products, and investigating ways to alleviate false snow detection. Testing and analyses led to implementation of a land thermal mask in the snow algorithm that greatly improved accuracy of snow mapping by eliminating false snow detection. Delivered MOD_PR10 SCF Version 3.2.0, that included the land thermal mask, to SDST. Continued investigation into what cloud spectral tests in the MODIS cloud mask product (MOD35_L2) are most appropriate for cloud detection in the snow algorithm. Objective is to make better use the cloud spectral test data to create a reasonably good cloud mask for the purpose of snow mapping. Investigation focused on processing paths, ancillary data and cloud spectral tests applied within the cloud mask algorithm to determine circumstances where cloud and snow confusion exists and how it might be alleviated.

A special demonstration MODIS direct broadcast snow algorithm and data product was prototyped. MODIS direct broadcast data processed at the U. Wisconsin SSEC facility was the input data source. This MODIS direct broadcast special demonstration snow cover algorithm was implemented as an IDL procedure. Several test runs were made of snowfall events in late 2001 using this special demonstration snow algorithm. Imagery and data from those test runs were used in presentations and for investigation of snow and cloud confusion.

MOD10A1

Revised the algorithm to handle as input the new reduced volume L2G products. A new L2G algorithm was implemented to reduce volume and processing load in the MODAPS. Investigation of the new reduced volume algorithm revealed that changes in MOD10A1 were required. Revised code was delivered to SDST on 12-07-01.

MOD10A2

A version of MOD10A2 with Aqua compatibility was delivered to SDST on 07-20-01. Discovered that several past revisions of the algorithm had not been promoted past baselined stage by the project. Wrote and submitted a change request for MOD10A2 in CYP processing to the Science Team Leader so that the latest version of the algorithm would be run in MODAPS.

MOD10C1

Commenced modification of the original MOD10C1 algorithm from 1/4° spatial resolution to 1/20° spatial resolution. Extensive use was made of the MOD10C2 algorithm code to integrate the modifications. A working version of the 5km daily CMG was completed.

MOD10C2

Several improvements were made in the eight-day snow climate modeling grid (CMG) algorithm and data product. The 1 km landcover dataset developed by DeFries (from University of Maryland), was acquired and rebinned to generate the 5km resolution percent land dataset used in the MOD10C2 algorithm. The GTOP030 global data files, from which the DeFries data was derived, was also acquired and used to add Hawaii to the 5km total land mask. Modified code to set Antarctica to 100% snow, and to set transition zone between night and fill/no data to night. Incorporated new ECS MCF into MOD10C2 algorithm processing.

When new MOD10A2 inputs, generated with the newest version of MOD10_L2 in MODAPS, became available, MOD10C2 was run without a restricted snow threshold so that the snow mapping accuracy could be analyzed. Analyses revealed that the snow threshold could be reduced to 40% and an accurate snow map would result. That was a marked improvement over the previous 80% threshold. The code was revised for the new snow threshold and delivered to the project on 11-28-01.

Time series of the MOD10C2 products were generated at the SCF as data became available from MODAPS. This was done until MODAPS began routine production of MOD10C2 in mid-December 2001. The MOD10C2 products, browse images and full resolution products, were posted on the MODIS snow website and made downloadable in HDF-EOS format or in flat file format.

MOD29A1

Revised the algorithm to handle the new reduced volume L2G products as input. A new L2G algorithm was implemented to reduce volume and processing load in the MODAPS. Investigation of the new reduced volume algorithm revealed that changes in MOD29A1 were required. Analyzed and solved problems in MOD29A1 that arose with the L2G center tiles of the polar projection, sometimes having more than the maximum specified number of observations in them. Two revisions of the algorithm code were delivered to the project.

Snow product web pages

MOD10C2 products were added to the website for downloading as flat-binary and HDF files.

Updates to the snow project website were made as needed. Minor corrections were made to the website as needed. Installed all security patches, banners, and service/port restrictions in order to launch system. Successive website re-launches were completed. Publication webpages were added and existing publication webpages were improved to include interactive access to publication figures, tables, and references. In total, 4 publication webpages were added or improved.

Education activities

Education site focusing on the new educational video “Observations of Snow Cover from the Ground and Space,” was developed and launched <http://snowcover.gsfc.nasa.gov> .

A snow/EOS video focusing on MODIS and Landsat data of global snow cover was completed with Code 588 and is now ready for distribution.

A MODIS snow product animation has been started with the Scientific Visualization Studio at Goddard.

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.

The algorithm has undergone initial validation through comparisons with broadband albedo measurements made at the NOAA SURFRAD site in Fort Peck, Montana. *In situ* SURFRAD albedo measurements have compared to daily MODIS snow albedo retrievals for the period from November 21 to 26, 2000 using five different five narrow-to-broadband albedo conversion schemes.

Generally, the prototype MODIS algorithm produces reasonable broadband albedo estimates. Maximum daily differences between the five MODIS broadband albedo retrievals and *in situ albedo* is 15 percent. Daily differences between the 'best' MODIS broadband estimate and the measured SURFRAD albedo range from 1 to 8 percent. However, no single conversion scheme consistently provides the closest albedo estimate. As with the other MODIS snow products, correct cloud masking remains problematic.

The comparisons at the Fort Peck site are continuing. The time series of MODIS snow albedo estimates is being extended to allow comparisons over a larger range of solar zenith angles and snow conditions. Further validation is planned for Greenland and other North American sites where broadband albedo measurements are routinely made. Further validation and algorithm development using data from North American and Greenland is ongoing.

Snow Map Accuracy Investigations

Numerous comparisons with NOAA operational data sets have been accomplished. These results have been presented at scientific meetings during this reporting period, and accepted for publication (see list of presentations and publications). The pre-publication versions of the papers cited below are available on request. While MODIS compares favorably with the operational products, the MODIS maps show more snow cover than do the operational maps. This is partly because MODIS maps all snow cover present (during an 8-day compositing period), and the other maps do not, but also partly because of problems with our algorithm that we have not yet worked out. Analysis continues and will focus on North America and Scandinavia for the 2001-02 N.H. winter.

Problems

The group has continued to be plagued with workstation problems. The workstation, Icecap, which hosts our website has been hacked into and the website is frequently down

MODIS-related presentations during the reporting period:

1. Hall, D.K., "Snow and Ice and Global Climate Change," and presentation of the EOS snow video entitled, "Observations of Snow Cover from the Ground and Space," Anne Arundel County Earth Science Teacher Academy, GSFC, Greenbelt, MD, 16 July 2001.
2. Hall, D.K., "An Update on the MODIS Snow and Ice Project at Goddard," Ad-Hoc meeting of the MODIS Snow and Ice Advisory Group, Greenbelt, MD, 31 October 2001.
3. Riggs, G.A., "An Update on the MODIS Sea Ice Algorithm," Ad-Hoc meeting of the MODIS Snow and Ice Advisory Group, Greenbelt, MD, 31 October 2001.
4. Casey, K.A., "The MODIS Snow and Ice Project Web site," Ad-Hoc meeting of the MODIS Snow and Ice Advisory Group, Greenbelt, MD, 31 October 2001.
5. J.S. Barton, "Thermal mask enhancement to the MODIS snow algorithm," Ad-Hoc meeting of the MODIS Snow and Ice Advisory Group, Greenbelt, MD, 31 October 2001.

6. A.G. Klein, "Daily MODIS Snow Albedo algorithm," Ad-Hoc meeting of the MODIS Snow and Ice Advisory Group, Greenbelt, MD, 31 October 2001.
7. G.L. Liston, "Potential for GCM modeling using MODIS snow products," Ad-Hoc meeting of the MODIS Snow and Ice Advisory Group, Greenbelt, MD, 31 October 2001.
8. Hall, D.K., "MODIS snow cover products: status and future prospects," NOAA/NESDIS seminar, Camp Springs, MD, 15 November 2001 (invited).
9. Hall, D.K., "MODIS Snow-Cover Products," AGU fall meeting, San Francisco, CA, 11 December 2001.
10. Hall, D.K., "Recent changes to the MODIS snow and ice algorithms," MODIS Team meeting, Baltimore, MD, 17 December 2001.

The following is a list of the peer-reviewed and the proceedings papers that have been written since 1999:

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

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 and V.J. Martins, "Remote sensing of subpixel snow cover using 0.66 and 2.1 μm channels, submitted to Geophysical Research Letters (submitted January 2001 – in review process).

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 1999:

D.K. Hall, R.E.J. Kelly, A.T.C. Chang and J.L. Foster, "Determination of errors in visible/near-infrared and passive-microwave-derived snow maps in different land-cover types," invited paper for PIERS'02, 1-5 July 2002 (abstract submitted).

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.

Ackerman, S.A., C.C. Moeller, W.P. Menzel, J. Spinhirne, D. Hall, J. Wang, H. Revercombe, R.A. Kuteson, E. Eloranta, A. Nolin and M. King, 1999: "**WINCE**: A **WIN**ter **C**loud **E**xperiment," Proceedings of the American Meteorological Society Conference.

Hall, D.K., S. Li, A. Nolin and J.C. Shi: 1999: "Pre-launch validation activities for the MODIS snow and sea ice algorithms," Earth Observer, 11(4):31-35.

Klein, A.G., D.K. Hall and K. Seidel, 1999: "Algorithm intercomparison for accuracy assessment of the MODIS snow-mapping algorithm," Proceedings of the Eastern Snow Conference, 2-3 June 1998, Jackson, NH, pp.37-45.