

**MODIS Semi-Annual Report**  
**Snow and Ice Project**  
**Reporting Period: July - December 2002**  
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**Abstract**

During this reporting period, we have continued to validate the snow and sea ice products, completed an outreach CD project dedicated to the snow and ice products, participated in a MODIS CD outreach product, presented and submitted papers and completed algorithm deliveries for Collection 4. In addition, we have continued to enhance and update our Web site. We have also worked with modelers to try to incorporate the global snow and ice products into regional and global models.

**Algorithm and Coding Work**

MOD10A1

Effects of the new L2G algorithm with the reduced volume technique were investigated. In addition, the order of the first input pointer selection, by time order from earliest to latest acquisition time, was determined for the daily snow product. The new L2G algorithm affected the MOD10A1 product by decreasing the quality of the product. Analysis was done and the effect was determined. A new scoring algorithm was implemented to select the most favorable observation of the day based on time of acquisition and location of observation in a swath; this was integrated into the MOD10A1 daily snow mapping algorithm. The new scoring algorithm enhanced the quality of the daily snow map. A revised version of the MOD10A1 algorithm was delivered to the project on 31 October. Analysis of products from the Collection 4 test runs revealed that there was a bug in the new scoring algorithm. That version of MOD10A1 was withdrawn from Collection 4 until the bug is corrected and the snow albedo product is integrated into the algorithm.

Significant progress was made in development and integration of the snow albedo algorithm and data product into the MOD10A1 product code. This is a collaborative effort with Dr. Andrew Klein (Texas A&M University). The following features were integrated into the snow albedo algorithm;

- Reading and calibration of reflectance channels 1, 2, 3, 4, 5, 6, 7 from the MOD09 albedo product
- BiDirectional Reflectance Function (BRDF)
- Reading and used of surface slope and aspect data
- Reading and usage of the MOD12Q1 surface vegetation data, International Geosphere Biosphere Programme (IGBP) classes
- Snow albedo calculations, narrow to broadband conversions are specific for snow

- Conversion to 1km snow albedo product based on the 500m snow input map

Miscellaneous:

Changed to sinusoidal projection in the MOD10A1 product. For ECS Collection 4 the sinusoidal projection will be the standard MODLAND projection.

Evaluated MOD10A1 products from the reprocessing stream of the ECS Collection 4 processing.

#### MOD10A2

Changed to sinusoidal projection in the MOD10A2 product. Evaluated MOD10A2 products from the MODAPS Collection 4 processing test runs to determine the quality of the data product. This version was declared ready for Collection 4 processing.

#### MOD10C1

Modified the algorithm so that the transition zone between night data and no-data zones near the poles is distinctly shown. Revised and applied a snow impossible mask, at 0.05 degree resolution, to prevent mapping of snow in regions of the world where occurrence of snow is a climatological impossibility. The snow impossible mask was generated as an ancillary input (HDF file) to the snow algorithm. The transition across the day/night terminator was implemented in the snow map. Antarctica was masked as completely snow-covered.

Developed a simple IDL procedure to make browse images of the MOD10C1 snow map. The browse images are colorized thematic snow maps. That procedure was given to NSIDC to support their development of browse capability at the DAAC.

Miscellaneous:

Delivered a version of MOD10C1 V4.0.0 to SDST for the ECS Collection 4 processing.

Evaluated MOD10C1 products from the MODAPS Collection 4 processing test runs to determine the quality of the data product. This version was declared ready for Collection 4 processing.

Evaluated MOD10C1 products from the reprocessing stream of the ECS Collection 4 processing.

#### MOD10\_L2

Performance of the estimated surface temperature screen in the algorithm was analyzed and evaluated. The surface temperature screen was adjusted to a higher setting to allow for improved mapping of snow in mixed pixel conditions primarily in the transition seasons.

A minor change was made in the liberal cloud mask that resulted in fewer low confidence cloud pixels being mapped as cloud and improved the ability to map snow.

A revised version of the MOD10\_L2 algorithm for ESC Collection 4 production was delivered to the project.

Evaluated MOD10\_L2 products from the MODAPS Collection 4 processing test runs to determine the quality of the data product. This version was declared ready for Collection 4 processing.

Evaluated MOD10\_L2 products from the reprocessing stream of the ECS Collection 4 processing.

A prototype MODIS snow algorithm using reflectance data from the MOD09GHK reflectance product was developed. The prototype has a limited capability for applying only the basic grouped criteria tests for snow. These criteria tests are the same as used in MOD10\_L2. Limited comparative analysis of snow maps generated from this prototype to the normal MODIS snow maps in MOD10\_L2 was done.

A prototype for a MODIS monthly snow climatology map/product from the MOD10C1 data products was developed. Several techniques for deriving monthly snow climatology were tested in the algorithm. Prototype products were made using 30 days of MOD10C1 (daily) CMG data for March/April 2002 as input to the prototype algorithm. The various outputs were analyzed with objective of determining which algorithm method could best represent monthly snow cover.

#### MOD10C2

Modified the algorithm so that the transition zone between night data and no-data zones near the poles is distinctly shown. Revised and applied a snow impossible mask, at 0.05 degree resolution, to prevent mapping of snow in regions of the world where occurrence of snow is a climatological impossibility. Generated the snow impossible mask as an ancillary input (HDF file) to the snow algorithm. Improved the transition across the day/night terminator in the snow map. Antarctica was masked as completely snow-covered.

Miscellaneous:

Delivered a version of MOD10C2 V4.0.0 to SDST for the ECS Collection 4 processing.

Evaluated MOD10C2 products from the MODAPS Collection 4 processing test runs to determine the quality of the data product. This version was declared ready for Collection 4 processing.

Evaluated MOD10C2 products from the reprocessing stream of the ECS Collection 4 processing.

#### MOD29

Evaluated MOD29 products from the MODAPS Collection 4 processing test runs to determine the quality of the data product. This version was declared ready for Collection 4 processing.

Evaluated MOD29 products from the reprocessing stream of the ECS Collection 4 processing.

Progressed with sea ice surface temperature (IST) validation efforts. Comparative analysis between MODIS and Landsat TM imagery or data was conducted. Nine cases of diverse sea ice conditions were selected from the data searches done and corresponding Landsat TM scenes were acquired and used in comparative analysis. Graphics of comparative results, including a color bar of ice surface temperature were generated.

Validation efforts included usage of NOAA tide station meteorological data, and Japanese buoy meteorological data. Comparative mathematical analysis comparing four sets of MOD29 data and NOAA tide station data at Prudhoe Bay, AK was done and results reported.

#### MOD29P1

Investigated effects of the new L2G algorithm with the reduced volume technique and order of first input pointer selection, by time order from earliest to latest acquisition time, on the daily sea ice product. The new L2G algorithm affected the MOD29P1 product by dramatically decreasing the quality of the product. Analysis was done and the affect was determined. In response a new scoring algorithm to select the most favorable observation of the day based on time of acquisition and location of observation in a swath was integrated into the MOD29P1 daily sea ice algorithm. The new scoring algorithm enhanced the quality of the daily sea ice extent and sea ice surface temperature maps.

Miscellaneous:

Delivered MOD29P1 V4.0.0 for Collection 4 processing to SDST.

Evaluated MOD29P1 products from the MODAPS Collection 4 processing test runs to determine the quality of the data product. This version was declared ready for Collection 4 processing.

#### MOD29C1

Developed a MODIS sea ice daily CMG product prototype. A spatial resolution of 4.2 km was chosen for the products as that resolution nests well in the EASE-Grid. Input to this algorithm is the MOD29P1D products. Both hemispheres (north and south) grids are contained in the products and data arrays of sea ice extent and ice surface temperature are generated for both grids. Only daytime data was used in the algorithm. Data products from test runs of the algorithms were evaluated.

#### **Fractional Snow Algorithm**

Demonstrated the great accuracy of the fractional snow cover algorithm based on the NDSI snow detection technique at regional and global scales of 500m and 5km spatial resolution, respectively. Modification of georegistration technique between MODIS data and validation data, dramatically improved the accuracy of fractional snow cover retrieval. The standard error of snow fraction calculation is on the order of 0.1 for 500 m

cells. The standard error of calculated snow fraction is on the order of 0.1 for the CMG scale. The accuracy of the snow fraction regression with NDSI by far exceeds the quality of other assessed methods.

Analyses of snow fraction calculations for Colorado revealed systematic picture of seasonal changes in snow fraction at 500 m resolution. Results confirmed that use of NDSI technique for fractional snow retrieval is very promising and could be globally applicable.

### **MODIS/snow Web site**

“What’s New?” updates to the MODIS snow and sea ice website were posted as needed to alert users to problems discovered in the products and to alert users to when the problems were corrected.

The revised snow user guide was posted on the website in November 2002.

New imagery was added to the website image gallery. Various interesting images of snow and sea ice were posted including, snow maps generated from SSEC direct broadcast data, daily and eight-day CMG snow maps, and SVS MODIS snow cover animation for winter 2001-2002.

Website content was brought up to MODIS Land PI minimum website content specifications.

Validation status of products was added to each product page. Validation status includes information on; MODIS snow and sea ice data product validation activities, definitions, publications, and related links. Hyperlinked validation status and validation definition web pages to data product pages.

Links to MODIS land validation efforts, product availability information, and data product quality assessment information were added.

Fixed a webserv data transfer bug that caused communication errors with external computers.

- Installed counter software.

- Updated several data product web pages to allow for more user-friendly design.

- Checked out all links on the website and updated outdated links.

- Discovered major errors with new web browsers, and the website display.

- Analyzed the cause of errors, and quickly worked to resolve the display problems.

### **Collaborative Activities**

Collaborative study with Lamont-Doherty Earth Observatory continued in order to evaluate the performance of the fractional snow cover algorithm over the Kuparuk River basin in Alaska. The study demonstrated the accuracy of the fractional snow cover algorithm and revealed an accurate systematic picture of seasonal changes in snow fraction at 500 m resolution as characterized by smooth snow depletion curves.

### **Education/Outreach activities**

An outreach CD on MODIS snow and ice products was prepared in conjunction with the NSIDC DAAC. The primary purpose of this CD was to hand it out at the Boston Outreach Workshop.

Assembled and processed a few MODIS images of sea ice in response to a request from the Discovery Channel for particular MODIS sea ice imagery.

### **Problems**

At least half of the band 6 detectors 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. Preliminary work has begun attempting to use ratioing techniques to utilize the remaining good band 6 detectors in conjunction with the Terra detectors.

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

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

Appel, I. and V. Salomonson, in preparation, "Estimating Fractional Snow Cover from MODIS Using the Normalized Difference Snow Index (NDSI)."

Hall, D.K., G.A. Riggs, V.V. Salomonson, N.E. DiGirolamo and K.J. Bayr, 2002: "MODIS Snow-Cover Products," *Remote Sensing of Environment*, 83:181-194.

Hall, D.K., R.E.J. Kelly, G.A. Riggs, A.T.C. Chang and J.L. Foster, 2002: "Assessment of the Relative Accuracy of Hemispheric-Scale Snow-Cover Maps," *Annals of Glaciology*, 34:24-30.

Kaufman, Y.J., R.G. Kleidman, D.K. Hall, J.S. Barton and V.J. Martins, 2002: "Remote sensing of subpixel snow cover using 0.66 and 2.1  $\mu$ m channels," *Geophysical Research Letters*, 28(16).

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.

### **Proceedings Papers and selected Abstracts since 2000:**

Hall, D.K., G.A. Riggs, G. Scharfen and M. Kaminski, in preparation, "MODIS Snow-Cover Products for Climate Modeling," for *Proceedings of SnowWatch 2002*.

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 59<sup>th</sup> 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 59<sup>th</sup> 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 58<sup>th</sup> Eastern Snow Conference*, 14-18 May 2001, Ottawa, Canada.

Hall, D.K., G.A. Riggs and V.V. Salomonson, 2001: "Analysis of a Time Series of Snow-Cover Maps of North America Derived from the Moderate Resolution Imaging Spectroradiometer Instrument," *Proceedings of the 58<sup>th</sup> 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 57<sup>th</sup> Annual Eastern Snow Conference*, 17-19 May 2000, Syracuse, NY.

Klein, A.G., D.K. Hall and A. Nolin, 2000: "Development of a prototype snow albedo algorithm for MODIS," *Proceedings of the 57<sup>th</sup> 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 56<sup>th</sup> 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:**

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

2. Hall, D.K., "Progress and validation of the MODIS snow and sea ice maps," MODIS Team meeting, 24 July 2002, Greenbelt, MD.
3. Hall, D.K., "Problems and progress in ordering MODIS products," MODIS Team meeting, 24 July 2002, Greenbelt, MD.
4. Hall, D.K., "Remote sensing of snow and ice and global change," a lecture in a graduate seminar, Geography 652 at the University of Delaware, Newark, DE, 10 September 2002.
5. Hall, D.K., "Use of MODIS snow and ice products in general circulation models," ECHAM-5 Parameterization meeting, 16-17 September 2002, Hamburg, Germany.
6. Riggs, G.A., "Recent Enhancements to the MODIS Snow Maps" a poster presented at the GSFC Posters and Tea gathering, 17 September 2002.
7. Hall, D.K., "Global snow mapping," a lecture in a graduate seminar, Geography 652 at the University of Delaware, Newark, DE, 1 October 2002.
8. Hall, D.K., "Remote sensing of snow and ice and global change," University of Delaware Geology Seminar Series, 1 October 2002 (invited).
9. Hall, D.K., "MODIS snow and ice products," George Mason University class, Vienna, VA, 17 October 2002 (invited).
10. Hall, D.K., "An introduction to using the suite of MODIS snow and ice products," MODIS Outreach Workshop, Boston, MA, 21 October 2002.
11. Riggs, G.A., "MODIS Snow and Sea Ice Algorithms & Products" MODIS Land Surface Radiance Variables and Snow and Ice Outreach Workshop, held at Boston University, 21 October 2002.
12. Hall, D.K., "Use of MODIS monthly snow-cover maps for GCM modeling," SnowWatch meeting, Silver Spring, MD, 31 October – 1 November 2002.
13. Hall, D.K., "The use of satellite data for analysis of global change in the Arctic," Department of Geography, University of Delaware seminar series, Newark, DE, 8 November, 2002 (invited).
14. Hall, D.K., "Integration of MODIS snow and ice maps into models," IWG, Ellicott City, MD, 18 November 2002 (invited).
15. Appel, I., "Estimating Sub-Pixel Snow Fraction in MODIS 500 m Pixels Using Normalized Difference Snow Index (NDSI) authored by I. Appel and V. Salomonson was presented at the AGU Fall Meeting, December 2002.

