

MODIS Semi-Annual Report
Snow and Ice Project
Reporting Period: July - December 2000
Submitted by: Dorothy K. Hall/974 (1/17/01)

Note: There is a new format for this report. Peer-reviewed and proceedings papers submitted, in press or published in the last five years are shown at the end. This obviates the need to attempt to figure out if a paper should be included in this or a previous (or future) reporting period.

Introduction

Much progress has occurred in this reporting period. A new website was launched, the snow products were released to the public, code improvements were done, results from field work were analyzed, more field work was conducted, the fractional snow-cover algorithm was tested, modeling work was initiated, and several talks were presented and an abstract was submitted and accepted. Papers have also been published.

Algorithm Code Deliveries

Version 2.1.0 of the MODIS daily snow CMG algorithm (MOD_PR10C) and data product (MOD10C1) was developed, tested, documented and delivered to the project. Quality assurance (QA) data content was improved and revisions were made to comply with new metadata and PGE processing requirements.

Version 2.1.1 of the MODIS daily snow CMG algorithm (MOD_PR10C) and data product (MOD10C1) that incorporated improvements recommended from the ClimRAMS study was developed, coded, tested and delivered to the project.

Version 2.4.1 of the MODIS level 2-snow algorithm (MOD_PR10) and data product (MOD10_L2) was developed, tested, documented and delivered to the project. Major improvements were made to handle MODIS “dead” detector data and improve data content. Revisions were also made to comply with new metadata and PGE processing requirements. A patched version fixing some bugs in the code was delivered later.

Version 2.4.1.1 of the MODIS level-2 snow algorithm (MOD_PR10) and data product (MOD10_L2) making the algorithm capable of running with MODIS Aqua or Terra data was developed and delivered.

Patched version of the MODIS level-3 daily sea ice algorithm (MOD29A1) fixing various ECS metadata items was delivered.

Field Work

Analysis of the March 6, 2000 field work from Keene, NH, in conjunction with the NASA ER-2 overflight was accomplished. Results show approximately a 73% agreement between the MODIS snow map and the NOHRSC snow map of the area. The agreement was excellent except in south-central New York where the MODIS-derived and NOHRSC snow map did not agree well; the NOHRSC map showed a full snow cover while the MODIS map showed patchy snow. The MODIS snow map agreed better with the meteorological station data, but analysis showed that it may underestimate some snow as compared to the NESDIS snow maps. The NESDIS snow map and the Seawifs visible data show partial snow cover. Preliminary results were reported in Hall et al., 2000 (IGARSS'01 proceedings).

Field work has been conducted in December 2000 by Dr. Klaus Bayr and students at Keene State University in conjunction with a Landsat and MODIS overflight. Further field work is planned near Keene, NH, in conjunction with all of the Landsat overflights in January and February 2001. Field work is also planned in conjunction with NESDIS personnel in January and February 2001 in the Catskill and Adirondack Mountains of New York.

Fractional Snow Cover

Two fractional snow cover (FSC) algorithms are under consideration. Results of one developed by our group are given in a paper published and presented at the Eastern Snow Conference 2000 (Barton et al., in press – see publication list). The other was developed by Yoram Kaufman and Rich Kleidman of code 913. Those results were presented by R. Kleidman at the fall AGU meeting. Papers and abstracts are available on request.

Modeling Work

There has been an attempt to incorporate MODIS snow cover data into two models. One is the DAO model and the other is the CLIMAP model. Discussions have been held with Paul Houser and Matt Rodell regarding the DAO model, and with Glen Liston of Colorado State University regarding the CLIMAP model.

A time series of special MODIS snow climate modeling grid (CMG) products was generated from regular MODIS snow CMG products to support a collaborative investigation of the use of MODIS snow data product in the climate version of the Regional Atmospheric Modeling System (ClimRAMS). Recommendations for improvements to the MODIS CMG snow product that were made in the study were used to improve the next version of the product. Included cloud coverage as a data array in the snow CMG product as a result of that study.

For both modeling efforts, our collaborators need at least one month of MODIS CMG snow maps from our group. We are developing those data sets now.

MODIS Snow Website

The MODIS snow project website was totally redesigned, tested, debugged, and launched. Organization and content of the site were greatly improved and much more imagery of MODIS snow data products was included on the site. A revised snow users' guide in HTML and PDF formats was posted. A page detailing "current status", based on staff's analyses of the MODIS snow products was integrated. Notice of the redesigned website was sent to the Goddard Intranet coordinator; the snow project website appeared on GSFC intranet website as "a COOL redesigned website" highlight. Minor corrections were made to site as needed and increased functionality was added. Successive website relaunches were completed.

Snow Map Accuracy Investigations

Extensive investigation into the accuracy and error of snow cover mapped by the MODIS snow algorithms and products was carried out. Analyses of special cases, e.g. storm events, snow and cloud confusion instances, and for consistency over spatial domains and temporal periods were carried out. Locations from all around the world were included in analyses. Search and order from NSIDC, GESDAAC, MEBDOS were done to support analyses. Default setting of the science quality flag was investigated and assigned for the snow products. Investigation of changes in the new version of the MODIS cloud mask, an input to the level 2-snow algorithm, was done. Vicarious validation of the MODIS snow products by comparisons to NOAA operational snow products was done. Monitored snow cover conditions in North America to support analysis of MODIS snow data products.

Public Release of Snow Products

Public release of the MODIS snow products (MOD10_L2, MOD10A1 and MOD10A2) was made on 13 September 2000. Prepared documentation for public release of MODIS snow products. Interacted with NSIDC to exchange information related to release of products.

Sea Ice Algorithm Development

Analyses of the MODIS sea ice algorithm and data products were done. Accuracy and detection of ice features, e.g. extent, floes and leads, and of the estimated ice surface temperature (IST) were carried out. North and South Polar regions were investigated. Integrated new sets of IST coefficients base on geographic location and surface temperature into the algorithm, and made the code Terra and Aqua capable. Searched for and ordered input data sets for testing of the revisions from NSIDC, GESDAAC and MEBDOS.

MODIS Image Data

Several Interactive Data Language (IDL) procedures to support analysis of data, mapping of data and generation of images were revised or developed in the course of analysis of the MODIS snow and sea ice data products. Installed EDC DAAC MODIS Reprojection Tool onto local computer to support analysis and image generation.

MODIS and related presentations during the reporting period:

Hall, D.K., “Early results from the Moderate Resolution Imaging Spectroradiometer (MODIS) snow and ice products, IGARSS’00, 26 July 2000, Honolulu, HI.

Hall, D.K., “Preliminary results from the MODIS snow and ice products,” a seminar at NOAA/NESDIS, Suitland, MD, 13 September 2000 (Invited).

Hall, D.K., “Update on MODIS snow and ice products processing and validation issues,” Polar Oceans DAAC Advisory Group (PODAG) meeting, Suitland, MD, 27 September 2000.

Riggs, G.A., “MODIS snow product metadata,” Polar Oceans DAAC Advisory Group (PODAG) meeting, Suitland, MD, 27 September 2000.

Hall, D.K., “Remote sensing of snow and ice and global change,” Department of Civil Engineering/University of Maryland, College Park, College Park, MD, 23 October 2000 (Invited).

Hall, D.K., “History of remote sensing of snow and ice, with emphasis on the EOS era” Department of Geography/University of Maryland, College Park, College Park, MD, 26 October 2000 (Invited).

Hall, D.K., “Remote sensing of snow and ice and global change,” Department of Earth Sciences/Syracuse University, Syracuse, NY, 2 November 2000 (Invited).

Riggs, G.A., “Update on MODIS snow products,” AGU, 19 December 2000, San Francisco, CA. [**Appendix A**]

The following is a list of the peer-reviewed and the proceedings papers that have been written since 1996:

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

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).

Tait, A.B., D.K. Hall, etc. **must locate title**, International Journal of Remote Sensing, accepted for publication, May 2000.

Hall, D.K., J.L. Foster, V.V. Salomonson, A.G. Klein and J.Y.L. Chien, "Development of a Technique to Assess Snow-Cover Mapping Accuracy from Space," IEEE Transactions on Geoscience and Remote Sensing, in press.

Hall, D.K., G.A. Riggs, V.V. Salomonson and G.R. Scharfen, 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, in press.

Tait, A.B., J.S. Barton and D.K. Hall, A Prototype MODIS-SSM/I Snow Mapping Method, Proceedings of the IAHS Hydrology 2000 Conference, 2-8 April 2000, Santa Fe, NM, in press.

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

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

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

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

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

Klein, A.G., D.K. Hall and G.A. Riggs, "Improving Snow-cover mapping

in forests through the use of a canopy reflectance model,” Hydrological Processes, 12(10-11):1723-1744, 1998.

Hall, D.K., J.L. Foster, A.T.C. Chang, C.S. Benson and J.Y.L. Chien, “Determination of snow-covered area in different land covers in central Alaska from aircraft data,” April 1995, Ann. Glaciol., 26.,149-155 1998.

Justice,C.O., E.Vermote,J.R.G. Townshend, R.Defries, D.P. Roy,D.K. Hall,V.V. Salomonson, J.L Privette, G. Riggs, A. Strahler, W. Lucht, R.B. Myheni, Y. Knyazikhin, S.W. Running, R.R. Nemani,Z.Wan, A.R. Huete, W. Vanleeywen, R.E. Wolfe, L. Giglio, J.P. Muller, P.Lewis and M.Barnsley, “The moderate resolution imaging spectroradiometer (MODIS): Land Remote Sensing for Global Change Research,” IEEE Trans. Geosci. Remote Sens., 36(4):1228-1249, 1998.

Hall, D.K. J.L.Foster, D.L. Verbyla, A.G. Klein and C.S. Benson, “Assessment of snow cover mapping accuracy in a variety of vegetation cover densities in central Alaska,” Remote Sensing of Environment, 66:129-137, 1998.

Chang, A.T.C., D.K. Hall and J.L. Foster, “Multiangle observations of directional reflectance of snow fields,” Chinese Journal of Remote Sensing, 1(suppl.), 1-17, 1997.

Riggs, G.A., D.K. Hall, R.E. Feind, and R. Welch, A comparative look at two algorithms for mapping snow cover from Earth Observing System instruments, Proc. 53rd Ann. Eastern Snow Conference, 1-3 May, 1996.

Proceedings Papers:

Klein, A.G. and D.K. Hall, “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, in press.

Hall, D.K., G.A. Riggs, V.V. Salomonson and G.R. Scharfen, “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, 2000.

Justice, C. and 20 others (including D. Hall), “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, 2000.

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

Barton, J.S., D.K. Hall and G.A. Riggs, “Fractional snow cover from the

MODIS snow-mapping algorithm,” Proceedings of the 57th Annual Eastern Snow Conference, 17-19 May 2000, Syracuse, NY, in press.

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

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, “**WINCE: A WINTER** Cloud Experiment,” Proceedings of the American Meteorological Society Conference, 1999.

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

Hall, D.K., A.B. Tait, J.L. Foster, A.T.C. Chang and M. Allen, “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, 1999.

Klein, A.G., D.K. Hall and G.A. Riggs, Global snow cover monitoring using MODIS, Proc. International Symposium on Remote Sensing of Environment, 8-12 June 1998, Tromso, Norway, pp. 363-366, 1998.

Klein, A.G., D.K. Hall and K. Seidel, “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, 1999.

Winther, J-G. and D.K. Hall, Satellite-derived snow coverage related to hydropower production in Norway - present and future, Proc. 27th International Symposium on Remote Sensing of the Environment, 8-12 June 1998, Tromso, Norway, 1998, pp. 371-374, 1999.

Hall, D.K., J.L. Foster, V.V. Salomonson, A.G. Klein and J.Y.L. Chien, Error analysis for global snow-cover mapping in the Earth Observing System Era, Proc. IGARSS’98, 6-10 July 1998, Seattle, WA, 1998, pp. 1524-1526, 1998.

Tait, A., D. Hall, J. Foster and A. Chang, 1998: High Frequency passive microwave radiometry over a snow-covered surface in Alaska, Proc. IGARSS ‘98, 6-10 July 1998, Seattle, WA, pp. 1518-1520, 1998.

Liston, G.E., R.A. Pilke, Sr., D.K. Hall and E.M. Greene, 1998: Assimilating observed snow-distribution products in a regional Climate Model, GCIP Mississippi River Climate Conference, 8-12 June 1998, St. Louis, Missouri, p.55, 1998.

Klein, A.G., D.K. Hall, and G.A. Riggs, Improving the MODIS global snow-mapping algorithm, Proc. IGARSS ‘97, 619-621, Singapore, 1997.

Scharfen, G.R., D.K. Hall, G.A. Riggs, MODIS snow and ice products from the NSIDC DAAC, Proc. SPIE meeting, 27 July-1 August 1997, San Diego, CA, 143-147, 1997.

Hall, D.K., J.L. Foster, A.T.C. Chang, D.J. Cavalieri, J.R. Wang, and C.S. Benson, "Analysis of melting snow cover in Alaska using aircraft microwave data (April 1995)," Proc. of IGARSS '96, May 26-30, 1996, Lincoln, NE, 2246-2248, 1996.

Riggs, G., D.K. Hall, and V.V. Salomonson, "Recent progress in development of the MODIS snow cover algorithm and product," Proc. IGARSS '96 Symposium, May 26-30, 1996, Lincoln, NE, 139-141, 1996.

Riggs, G.A., D.K. Hall, R.E. Feind, and R. Welch, A comparative look at two algorithms for mapping snow cover from Earth Observing System instruments, Proceedings 53rd Annual Eastern Snow Conference, 1-3 May, 1996.

Abstracts Accepted

Hall, D.K., G.A. Riggs, A.T.C. Chang, J.L. Foster and R.E.J. Kelly, "Assessment of the relative accuracy of Earth Observing System snow-cover maps," accepted for oral presentation at the IGS Fourth Symposium on Remote Sensing in Glaciology, 4-8 June 2001.

Appendix A

Abstract of oral presentation given at the AGU Fall 2000 Meeting, 15-19 December 2000, San Francisco, CA:

The First Ten Months of MODIS Snow Cover Observations

G. Riggs and D. Hall

The MODIS instrument on-board the NASA EOS Terra spacecraft has been collecting data since it was switched to science mode on 25 February 2000, after a successful 18 December 1999 launch. MODIS snow data products produced since that date have been investigated and analyzed for accuracy and in-accuracy of snow cover mapping. The sequence of snow products from the level 2 swath, 500 m spatial resolution, to the level 3 daily global climate modeling grid (CMG) snow cover product at a quarter degree resolution have been analyzed. Preliminary investigation has revealed that the MODIS snow maps are mapping snow in approximately the same locations as snow mapped using operations snow maps. Quantitative analyses of specific regions of interest (i.e., the northeastern U.S. and the North Slope of Alaska) are ongoing. Use of the daily snow CMG product in a regional atmospheric model showed significant improvements in the output. Many initial situations of confusion between clouds and snow and resulting

errors have been resolved. Analysis continues, especially with respect to the evaluation of accuracy of the algorithms, and in regard to false snow detection.