MODIS Project Final Report
Snow and Ice Project
Reporting Period: ending December 14, 2003
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Summary

Both snow and sea ice products have been developed for this project. These are discussed in detail in various publications listed in this report and most publications are downloadable from the MODIS snow and ice project Web site publications page: http://modis-snow-ice.gsfc.nasa.gov/publications.html. The products are also described in the user guides and the ATBD available from the project Web site: http://modis-snow-ice.gsfc.nasa.gov. Validation of most of these products has been undertaken and is discussed in the various publications and addressed briefly in this report. Many products are validated to stage 2 and others are still in the process of being validated. A section on "lessons learned" is also provided herein.

I. Introduction

This final report is intentionally brief because the many results from this project are detailed in the published literature which is available on request. Therefore, we provide only a listing of the products, a section on product validation and accuracy, a section on "lessons learned," and a listing of the publications from 1995 to the present. All of the other information is available by referring to the semi-annual reports, and through the project Web site: http://modis-snow-ice.gsfc.nasa.gov.

Throughout the duration of the project, the user community has been involved. In 1995 a workshop was held at GSFC wherein users provided feedback about the developing products. An advisory group was also set up which met twice more, the last time in 2001, to provide continued feedback on the snow and ice products. In addition, the snow and ice team has been responsive to comments and problems identified by the National Snow and Ice Data Center (NSIDC) DAAC and users.

II. Snow and ice products

Tables 1 &2 below show the snow and sea ice data products that have been developed for this project. Some of the products are in the process of being made available to the public through NSIDC. Algorithms for other products are still being coded at GSFC.

Table 1. MODIS snow data products.

Long Name	Earth Science Data Type (ESDT)	Spatial Resolution
MODIS/Terra Snow Cover 5-Min L2 Swath 500m*	MOD10_L2	500-m resolution, swath of MODIS data
MODIS/Terra Snow Cover Daily L3 Global 500m SIN Grid (includes daily snow albedo)	MOD10A1	500-m resolution, projected, gridded tile data
MODIS/Terra Snow Cover 8-Day L3 Global 500m SIN Grid	MOD10A2	500-m resolution, projected, gridded tile data
MODIS/Terra Snow Cover Daily L3 Global 0.05Deg CMG	MOD10C1	0.05° resolution, lat/lon climate modeling grid
MODIS/Terra Snow Cover 8-Day L3 Global 0.05Deg CMG	MOD10C2	0.05° resolution, lat/lon climate modeling grid
MODIS/Terra Snow Cover monthly L3 Global 0.05Deg CMG**	MOD10CM	0.05° resolution, lat/lon climate modeling grid
MODIS/Aqua Snow Cover 5-Min L2 Swath 500m*	MYD10_L2	500-m resolution, swath of MODIS data
MODIS/Aqua Snow Cover Daily L3 Global 500m SIN Grid (includes daily snow albedo)	MYD10A1	500-m resolution, projected, gridded tile data
MODIS/Aqua Snow Cover 8-Day L3 Global 500m SIN Grid	MYD10A2	500-m resolution, projected, gridded tile data
MODIS/Aqua Snow Cover Daily L3 Global 0.05Deg CMG	MYD10C1	0.05° resolution, lat/lon climate modeling grid
MODIS/Aqua Snow Cover 8-Day L3 Global 0.05Deg CMG	MYD10C2	0.05° resolution, lat/lon climate modeling grid
MODIS/Aqua Snow Cover monthly L3 Global 0.05Deg CMG **	MYD10CM	0.05° resolution, lat/lon climate modeling grid

*A FSC enhancement at 500-m resolution will be available in 2004.
**Future enhancement.

Table 2. MODIS sea ice data products.

Long Name	Earth Science Data Type (ESDT)	Spatial Resolution
MODIS/Terra Sea Ice Extent 5-Min L2 Swath 1km	MOD29	1-km resolution, swath of MODIS data
MODIS/Terra Sea Ice Extent Daily L3 Global EASE-Grid Day	MOD29P1D	1-km resolution, projected, gridded tile data
MODIS/Terra Sea Ice Extent Daily L3 Global EASE-Grid Night	MOD29P1N	1-km resolution, projected, gridded tile data
MODIS/Terra Sea Ice Extent and Ice Surface Temperature Daily L3 Global 4km EASE-Grid Day *	MOD29E1D	4-km resolution, global, gridded
MODIS/Terra Ice Surface Temperature Daily L3 Global 4km EASE-Grid Night *	MOD29E1N	4-km resolution, global, gridded

MODIS/Terra Sea Ice Extent and Ice Surface Temperature 8-Day L3 Global EASE-Grid Day *	MOD29E2D	4-km resolution, global, gridded
MODIS/Terra Ice Surface Temperature 8-Day L3 Global EASE-Grid Night*	MOD29E2N	4-km resolution, global, gridded
MODIS/Terra Sea Ice Extent and Ice Surface Temperature Monthly L3Global 4km EASE-Grid Day*	MOD29EMD	4-km resolution, global, gridded
MODIS/Terra Ice Surface Temperature Monthly L3Global 4km EASE-Grid Night *	MOD29EMN	4-km resolution, global, gridded
MODIS/Aqua Sea Ice Extent 5-Min L2 Swath 1km	MYD29	1-km resolution, swath of MODIS data
MODIS/Aqua Sea Ice Extent Daily L3 Global EASE-Grid Day*	MYD29P1D	1-km resolution, projected, gridded tile data
MODIS/Aqua Sea Ice Extent Daily L3 Global EASE-Grid Night*	MYD29P1N	1-km resolution, projected, gridded tile data
MODIS/Aqua Sea Ice Extent and Ice Surface Temperature Daily L3 Global 4km EASE-Grid Day*	MYD29E1D	4-km resolution, global, gridded
MODIS/Aqua Ice Surface Temperature Daily L3 Global 4km EASE-Grid Night *	MYD29E1N	4-km resolution, global, gridded
MODIS/Aqua Sea Ice Extent and Ice Surface Temperature 8-Day L3 Global EASE-Grid Day *	MYD29E2D	4-km resolution, global, gridded
MODIS/Aqua Ice Surface Temperature 8-Day L3 Global EASE-Grid Night*	MYD29E2N	4-km resolution, global, gridded
MODIS/Aqua Sea Ice Monthly Global EASE-Grid *	MYD29EMD	4-km resolution, global, gridded

*Future enhancement or product (to be implemented in 2004).

III. Validation and Accuracy

1. Validation of data products

There is a mix of beta, provisional and validated stage 1 and 2 products. The validation status of the products is provided on the snow and ice project Web site and also on the MODLand Web site: http://landdb1.nascom.nasa.gov/cgi-bin/QA_WWW/terraPage.cgi and http://landdb1.nascom.nasa.gov/cgi-bin/QA_WWW/aquaPage.cgi.

Terra MODIS products that are validated to stage 2 are the MOD10_L2 and MOD10A1 and MOD10A2 binary and fractional-snow-cover products, the MOD10C1 and MOD10C2 products, and the MOD29 sea ice extent and ice-surface temperature daytime products. Peer-reviewed publications are available on the validation activities related to these products.

Also for the Terra MODIS, the snow albedo part of the MOD10A1 product is a relatively new product and is in the beta stage. The monthly snow products, recently developed but not yet available to the public, are also beta. The nighttime sea ice extent and IST products are provisional.

Aqua MODIS snow and ice products are provisional because the switch to band 7 from band 6 (due to the Aqua band 6 non-functional detectors) has forced the snow and ice project personnel to develop a new algorithm to map snow and sea ice. Further testing of the resulting products must be accomplished before the validity of the Aqua MODIS snow and ice products can be fully assessed.

2. Accuracy of data products

Snow products. Validation at stage 2 has been accomplished for the MODIS 500-m resolution snow maps (MOD10). Accuracy is lowest in forested areas and highest in land-cover classes that contain low (or no) vegetation (Table 3).

Table 3. Errors for 500-m resolution snow maps in 7 land-cover classes when snow cover is continuous and when skies are clear. (Errors may vary in different areas within land-cover types.)

Forest	<10%
Mixed agriculture & forest	<5%
Barren/sparsely vegetated	<2%
Tundra	<2%
Grassland/shrubland	<2%
Wetland	<2%
Snow & ice	<2%

Accuracy Relative to Other Snow Maps. Accuracy of the MODIS 500-resolution snow maps (MOD10_L2 and MOD10A1) has been discussed in the following papers: Hall et al. (2002a), Bitner et al. (2002), Klein and Barnett (2003), Mauer et al. (2003), Simic et al. (submitted).

The accuracy of the 0.05º (~5-km resolution at the Equator) resolution climate-modeling grid (CMG) snow maps (MOD10C1 and MOD10C2) has been studied by several authors: Hall et al. (2002a) & Hall et al. (2002b); Bussieres et al. (2002), Bitner et al. (2002).

Pre-Launch Accuracy Assessment Statement. *A*s determined using prototype MODIS data, the annual average estimated pre-launch error of the Northern Hemisphere snow-cover maps was estimated to be ~ 8% in the absence of cloud cover. Pre-launch accuracy assessment is described in Hall et al. 2001. Field studies demonstrated that under cloud-free conditions when snow cover is complete, snow-mapping errors are small (<1%) in all land covers studied except forests where errors are often greater and more variable. Thus the accuracy of Northern Hemisphere snow-cover maps is largely

determined by percent of forest cover north of the snowline. From the 17-class International Geosphere-Biosphere Program (IGBP) land-cover maps of North America and Eurasia, the Northern Hemisphere was classified into seven land-cover classes and water. Estimated snow-mapping errors in each of the land-cover classes are extrapolated to the entire Northern Hemisphere for areas north of the average continental snowline for each month. The resulting average monthly errors varied from about 5 – 10%, with the larger errors occurring during the months when snow covers the boreal forest in the Northern Hemisphere (Table 4 and Figure 1).

Table 4. Estimated pre-launch snow mapping errors in cloud-free areas according to land-cover class (from Hall et al. 2001).

Forest	15%
Mixed agriculture & forest	10%
Barren/sparsely vegetated	5%
Tundra	5%
Grassland/shrubland	5%
Wetland	5%
Snow & ice	5%

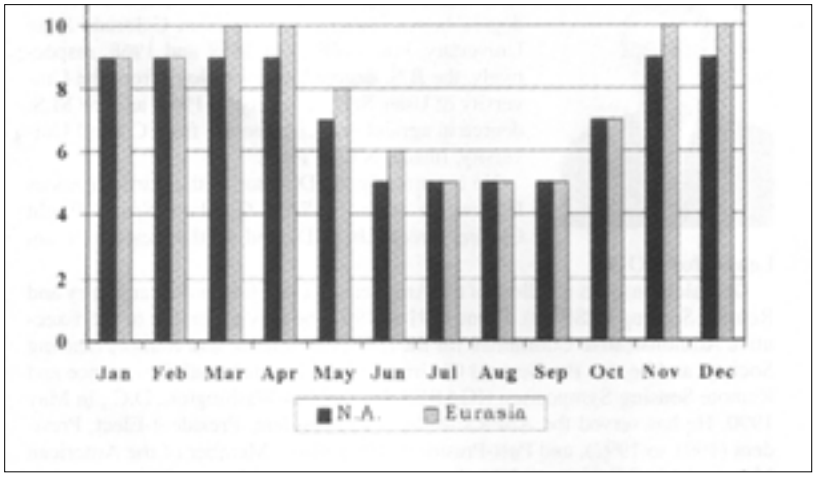

Figure 1. Estimated, pre-launch errors (in %) by month for snow mapping using EOS/MODIS data for the Northern Hemisphere (from Hall et al. 2001).

References for snow product accuracy section

Bitner D, Carroll T, Cline D and Romanov P (2002) An assessment of the differences between three satellite snow cover mapping techniques. *Hydrological Processes* 16:3723-3733.

Bussières, N., D. De Sève and A. Walker, 2002: Evaluation of MODIS snow-cover products over Canadian regions, *Proceedings of IGARSS'02*, dates, Toronto, Canada, pp. 2302-2304.

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

Hall, D.K., R.J.E. Kelly, G.A. Riggs, A.T.C. Chang and J.L. Foster, 2002b: "Assessment of the relative accuracy of hemispheric-scale snow-cover maps," *Annals of Glaciology*, 34:24-30.

Maurer, E.P., J.D. Rhoads, R.O. Dubayah and D.P. Lettenmaier, 2003: "Evaluation of the snow-covered area data product from MODIS," *Hydrological Processes,* 17:59-71.

Simic A., R. Fernandes, R. Brown, P. Romanov and W. Park, submitted: "Validation of VEGETATION, MODIS, and GOES+SSM/I snow cover products over Canada based on surface snow depth observations," *Hydrological Processes.*

Sea ice products. Validation at stage 2 has been accomplished for the MODIS 1-km resolution daytime sea ice maps of ice extent and ice-surface temperature (IST) (MOD29) (Hall et al. in press). RMS errors with the MODIS products under clear skies are shown to be 1.2 – 1.3K under clear skies during the "cold months," or when there is no surficial melt on the sea ice.

Validation activities during the "cold period" (when meltwater is generally not present) in the Northern Hemisphere defined here as October through May, have been undertaken to assess the accuracy of the 1-km resolution MODIS IST algorithm and product. In the Arctic Ocean near-surface air-temperatures from the Prudhoe Bay tide station, and from drifting buoys from the North Pole Environmental Observatory (NPEO) buoy program were compared with MODIS-derived ISTs. When additional cloud screening is performed to eliminate MODIS pixels thought to be contaminated by fog, results improved, with a subset of the larger data set showing a bias of – 0.9K and an RMS error of 1.6K. The negative bias means that the satellite retrieval is less than the air temperature. Uncertainties would be reduced in the Arctic Ocean data set if the skin temperature of the sea ice were reported instead of the near-surface air temperatures. Results from the South Pole station in Antarctica show that under clear skies as determined using lidar measurements, the MODIS ISTs are very close to those of the near-surface air temperatures with a bias of -1.2K and an RMS error of 1.7K. It is not possible to get an accurate IST from MODIS in the presence of even very thin clouds or fog, and this is the main limitation of the MODIS sea ice product. These results may be found in Hall et al. (in press).

Pre-Launch Accuracy Assessment Statement. Though pre-launch estimates specific to the MODIS products were not calculated, the Advanced Very High Resolution Radiometer (AVHRR) RMS error for IST was shown to be 0.3 – 3.0K (Key et al. 1997) under clear skies. The AVHRR product is a heritage product to the MODIS IST product.

References for sea ice product accuracy section

Hall, D.K., J.R. Key, K.A. Casey, G.A. Riggs and D.J. Cavalieri, in press: "Sea Ice Surface Temperature Product from the Moderate Resolution Imaging Spectroradiometer (MODIS)," *IEEE Transactions on Geoscience and Remote Sensing.*

J. Key, J. Collins, C. Fowler, and R. Stone, 1997: "High-latitude surface temperature estimates from thermal satellite data," *Remote Sensing Environment*, 61:302-309.

IV. Lessons learned

1. Submitted by D.K. Hall/974:

- Data products should not have been provided to users as HDF files; flat-binary files should have been provided in addition to the HDF files. HDF is not a common file format and nearly all users prefer to use flat-binary files. The HDF files must first be converted to flat-binary by users and this is not a straightforward procedure. I think that the use of HDF files caused a delay in community acceptance of the MODIS products.

- The EOS Data Gateway (EDG) was very user "unfriendly" at first. It is much better now and actually works quite well. However the learning curve was steep at first and caused many users to be disenchanted with ordering MODIS data. Also, for the uninitiated, the entire architecture of the system is complex and the nomenclature etc., is not intuitive in many cases. Though I can't say what should have been done instead, I think that these early problems delayed community acceptance of the MODIS products.

- Band 6 on the Aqua MODIS should have been fixed before launch. The problem with the Aqua band 6 detectors was known before launch and there was time to fix the detectors without delaying the launch. Band 7 is not a perfect substitute for band 6 and some of the snow and ice algorithms derived from the Aqua MODIS may never be as good as those derived from the Terra MODIS due to the problem with the band 6 detectors on Aqua.

- Cloud masking specific to ice/snow especially during the nighttime, should have been developed. Though there are many cloud-mask spectral tests that are available to select from the MODIS cloud-mask product, it has been a very time-intensive activity to identify the suitable spectral tests. Additionally, using the IR bands to measure nighttime ice-surface temperature over sea ice is greatly hampered by the lack of a good nighttime cloud mask. This is a very difficult problem and may not have been

able to have been solved using the MODIS bands, but a thorough assessment of a nighttime cloud mask by the cloud-mask developers over sea ice would have been good.

2. Submitted by G.A. Riggs/SSAI:

- Design the science software (algorithm) with the science elements separated from the metadata elements whenever practical. That design allows for revision of either science elements or metadata independently of one another.

- Thoroughly document the algorithm code and have metadata and data matrixes to track data flow through a sequence of data products. That allows for assessing impacts from revised input products on data products.

- Monitoring products for consistently and investigating anomalies required more action than originally planned. Anomalies occurred with greater frequency and variety in products in regions, situations and times than were originally anticipated. The original plan for monitoring products turned out to be inadequate. A monitoring plan with a great deal of flexibility for investigating data product anomalies was needed.

- The SCF website continued to grow beyond expectations during the project. Size of the site, content posted, data products made available on it exceed expectations. Several redesigns had to be done and new NASA website policies and guidelines have to be incorporated. More resources than anticipated were needed for the website. Website was a valuable path of direct contact with users of the data products.

V. Publications since 1995

In addition to the peer-reviewed and non-peer-reviewed publications listed below, numerous abstracts, posters and oral presentation were presented at national, international and EOS meetings. These are listed in each semi-annual report which are available through the MODIS project and are therefore not repeated here. All publications shown below are downloadable from the project Web site and/or are available upon request.

In Press or Submitted

Hall, D.K., J.Key, K.A. Casey, G.A. Riggs and D. Cavalieri, in press: "Sea ice surface temperature product from the Moderate Resolution Imaging Spectroradiometer (MODIS)," *IEEE Transactions on Geoscience and Remote Sensing*.

Hall, D.K., R.E.J. Kelly, J.L. Foster and A.T.C. Chang, in press: "Hydrological application of remote sensing: surface states - snow," chapter in: Encyclopedia of Hydrologic Sciences (Malcolm Anderson, editor).

Hall, D.K., G.A. Riggs and V.V. Salomonson, "MODIS Snow and Sea Ice Products," in press, chapter in: Earth Science Satellite Remote Sensing - Volume I: Science and Instruments, J. Qu (ed.), Springer-Verlag Press.

Déry, S.J., V.V. Salomonson, M. Stieglitz, D.K. Hall and I. Appel, submitted: "Validation of snow areal depletion curves inferred from MODIS and their application to land surface modeling in Alaska," *Hydrological Processes*.

Riggs, G.A. and D. K. Hall, in press: "Reduction of Cloud Obscuration in the MODIS Snow Data Product," *Presented at the 59th Eastern Snow Conference*, 5-7 June 2002, Stowe, VT.

2004

Salomonson, V.V. and I. Appel, 2004: "Estimating the fractional snow covering using the normalized difference snow index," *Remote Sensing of Environment*, 89(3):351-360.

2003

Hall, D.K., V.V. Salomonson, G.A. Riggs and A.G. Klein, 2003: "Snow and ice products from the Moderate Resolution Imaging Spectroradiometer," *Proceedings of the ASPRS meeting*, 5-9 May 2003, Anchorage, AK.

2002

Appel, I.L. and V.V. Salomonson, 2002: "Estimate of fractional snow cover using MODIS data," *Proceedings of IGARSS 2002*, Toronto, Canada.

Hall, D.K., G.A. Riggs, V.V. Salomonson, N. DiGiromamo 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*, V.34:24-30.

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

Klein, A.G. and J. Stroeve, 2002: "Development and validation of a snow albedo algorithm for the MODIS instrument," *Annals of Glaciology*, 34:45-52.

Kaufman, Y.J., R.G. Kleidman, D.K. Hall, J.V. Martins, J.S. Barton, 2002: "Remote sensing of subpixel snow cover using 0.66 and 2.1 channels," *Geophysical Research Letters*, 29.16:28-1 - 28-4.

2001

Barton, J.S., D.K. Hall, and G.A. Riggs, 2001: "Thermal and geometric thresholds in the mapping of snow with MODIS." (not published, but available on the MODIS snow and ice Web site)

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.

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).

Tait, A.B., J.S. Barton, and D.K. Hall, 2001: "A prototype MODIS-SSM/I Snow Mapping Algorithm," *International Journal of Remote Sensing*, 22(17):3275-3284.

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.

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Barton, J.S., D.K. Hall and G.A. Riggs, 2000: "Remote sensing of fractional snow cover using Moderate Resolution Imaging Spectroradiometer (MODIS) data," *Proceedings of the 57th Eastern Snow Conference*, 18-19 May 2000, Syracuse, NY, pp.171-181.

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.

Klein, A.G., D.K. Hall and A.W. Nolin, 2000: "Development of a Prototype Snow Albedo Algorithm for the NASA MODIS Instrument," *Proceedings of the 57th Eastern Snow Conference*, 18-19 May 2000, Syracuse, NY, pp. 143-157.

Riggs, G.A. and D.K. Hall, 2000: "Early Analysis of the EOS MODIS Snow Cover Data Products," *Proceedings of the 57th Eastern Snow Conference*, 18-19 May 2000, (Extended Abstract).

Scharfen, G.R., D.K. Hall, 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 IGARRS '00*, 23-28 July 2000, Honolulu, HI, pp. 2059-2061.

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Hall, D.K., A.B. Tait, J.L. Foster, A.T.C. Chang and M. Allen, 1999: "Comparison of snow cover maps from multiple data sets," *Proceedings of the 56th Eastern Snow Conference,* 3-5 June 1999, Fredericton, N.B., Canada, pp 71-74.

Klein, A.G. and D.K. Hall, 1999: "Snow albedo determination using the NASA MODIS instrument," *Proceedings of the 56th Eastern Snow Conference,* 3-5 June 1999, Fredericton, N.B., Canada, pp. 77-85.

Polissar, A.V., P.K. Hopke, P. Paatero, Y.J. Kaufman, D.K. Hall, B.A. Bodhaine and E.G. Dutton, 1999: "Long-term trends and seasonal variations of aerosol concentration at Barrow, Alaska," *Atmospheric Environment,* 33:2441-2458.

Riggs, G.A., D.K. Hall, S.A. Ackerman, 1999: "Sea Ice Extent and Classification Mapping with the Moderate Resolution Imaging Spectroradiometer Airborne Simulator," *Remote Sensing of Environment,* 68:152-163.

Tait, A.B., D.K. Hall, J.L. Foster, A.T.C. Chang and A.G. Klein 1999: "Detection of snow cover using Millimeter Imaging Radiometer (MIR) data," *Remote Sensing of Environment,* 68:53-60.

Tait, A.B., K.K. Hall, J.L. Foster and A.T.C. Chang, 1999: "High frequency passive microwave radiometry over a snow-covered surface in Alaska," *Photogrammetric Engineering and Remote Sensing,* 65(b):689-695.

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.

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Hall, D.K., J.L. Foster, A.T.C. Chang, C.S. Benson and J.Y.L. Chien, 1998: "Determination of snow-covered area in different land covers in central Alaska from aircraft data - April 1995," *Annals of Glaciology,* v. 26, pp. 149-155.

Hall, D.K., J.L. Foster, D.L. Verbyla, A.G. Klein and C.S. Benson, 1998: "Assessment of snow-cover mapping accuracy in a variety of vegetation-cover densities in central Alaska," *Remote Sensing of Environment,* 66(2): 129-137.

Hall, D.K., J.L. Foster, V.V. Salomonson, A.G. Klein and J.Y.L. Chien, 1998: "Error analysis for global snow-cover mapping in the Earth Observing System (EOS) era," *Proceedings of IGARSS '98,* 6-10 July 1998, Seattle, WA, USA, pp. 1524-1526.

Klein, A.G., D.K. Hall, and G. Riggs, 1998: "Improving snow-cover mapping in forests through the use of a canopy reflectance model," *Hydrological Processes,* 12:1723-1744.

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.

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. Myneni, Y. Knyazikhin, S.W. Running, R.R. Nemani, Z. Wan, A.R. Huete, W. van Leeuwen, R.E. Wolfe, L. Giglio, J.P. Muller, P. Lewis and M. Barnsley, 1998: "The Moderate Resolution Imaging Spectroradiometer (MODIS): Land Remote Sensing for Global Research," *IEEE Transactions on Geoscience and Remote Sensing,* 36(4) 1228-1249.

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

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

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

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Hall, D.K. (editor), 1995: *Proceedings of the First MODIS Snow and Ice Workshop,* 13-14 September 1995, Greenbelt, MD, NASA Conference Publication 3317, 128 p.

Hall, D.K., G.A. Riggs, V.V. Salomonson, 1995: "Development of methods for mapping global snow cover using Moderate Resolution Imaging Spectroradiometer (MODIS) data," *Remote Sensing of Environment,* 54:127-140.

Salomonson, V.V., D.K. Hall and J.Y.L. Chien, 1995: "Use of passive microwave and optical data for large-scale snow-cover mapping," *Proceedings of the Second Topical Symposium on Combined Optical-Microwave Earth and Atmosphere Sensing,* 3-6 April 1995, Atlanta, Georgia.