MODIS Semi-Annual Report
Snow and Ice Project
Reporting Period: January - July 1999
Submitted by: Dorothy K. Hall/974

**Papers and abstracts:**

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

2. Hall, D.K., A.B. Tait, J.L. Foster, A.T.C. Chang and M. Allen, "Comparison of snow-cover maps from multiple satellite data sets," Eastern Snow Conference, in press.

3. Klein, A.G. and D.K. Hall, "Snow albedo determination using the NASA MODIS instrument," Eastern Snow Conference, in press.

4. Tait, A.B., D.K. Hall, J.L. Foster and R. Armstrong, Tait, A.B., Hall, D.K., Foster, J.L., and Armstrong, R.L. Utilizing multiple datasets for snow cover mapping," submitted to Remote Sensing of Environment.

5. 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, submitted.

6. Hall, D.K., G.A. Riggs, V.V. Salomonson and G.R. Scharfen, "Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS) global snow and ice cover maps," abstract submitted to the *Hydrology 2000* conference to be held in April 2000.

**Presentations:**

Hall, D.K., "Comparison of snow-cover maps from multiple satellite data sets," Eastern Snow Conference, Fredericton, N.B., Canada, 3 June 1999 (poster presentation)

Riggs, G.A., "What's in the MODIS snow data products"? Eastern Snow Conference, Fredericton, N.B., Canada, 3 June 1999 (poster presentation)

Klein, A.G., "Snow albedo determination using the NASA MODIS instrument," Eastern Snow Conference, Fredericton, N.B., Canada, 3 June 1999 (oral presentation)

Tait, A.B., Tait, A.B., Hall, D.K., Foster, J.L., and Armstrong, R.L. (submitted) Utilizing multiple datasets for snow cover mapping, AGU meeting, Boston, MA, 4 June 1999 (poster presentation).

**Algorithm work (G. Riggs/RDC)**

We participated in the Terra end-to-end system test (TESS); snow and sea ice data products were received from the NSIDC DAAC and quality assurance inspections were made of those data products.

Quality assurance (QA) procedures and investigations were applied to numerous MODIS snow and sea ice products produced in the MODAPS week in the life (WILT), N-day and X-day production tests. Exercised the MEBDOS system and the LDOPE database and tools for evaluation of QA data and setting of science quality flags in products. Fixes to the snow and sea ice algorithm codes were made based on results of applying QA procedures and investigations to data products from the above MODAPS production tests.

The MODIS level 2 snow (MOD_PR10) and sea ice (MOD_PR29) algorithms were revised to read a new format of MOD02, the MODIS L1B data product, and delivered to the project.

The MODIS daily snow climate modeling grid (CMG) algorithm (MOD_PR10C1) version 2.0.0 was tested with daily snow product (MOD10A1) inputs. The MOD10A1 product was analyzed; errors discovered in analysis were corrected, improvements were made in the code, and an ancillary land mask for the CMG was created and used to improve data analysis. Metadata was revised to conform to ECS requirements. Algorithm code was delivered to the project on 23 April 1999.

The eight-day snow algorithm (MOD_PR10A2) was revised to run with 2-8 days of daily snow product MOD10A1 as input for any defined eight-day period with the input data in any chronological order. Minor changes in the metadata were also made. MOD_PR10A2 version 2.1.0 was delivered on 15 March 1999.

New decision logic for determining daily snow cover in the daily snow algorithm (MOD_PR10A1) was developed, evaluated and integrated into the algorithm to make version 2.1.0.

Procedures and software tools for analysis and QA of the snow and sea ice data products were improved and new ones developed as a result of investigating MODIS snow and sea ice products produced in MODAPS test runs.

The MODIS snow algorithm, with sensor specific modifications for NOAA AVHRR-3 data, was applied to two time series of AVHRR-3 data covering the Eastern USA and Alaska. Algorithm code and analysis software tools were written for this application. Results were analyzed, vicarious validation applied, and visuals of the snow maps were created (Riggs and Jon Barton/GSC).

**Determination of errors in satellite-snow-cover mapping (D. Hall)**

Efforts are ongoing to determine errors of satellite-derived snow-cover maps. EOS Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Microwave Scanning Radiometer-E (AMSR-E) snow-cover products will be produced. For this study we compare snow maps covering the same study area acquired from different sensors using different snow-mapping algorithms.

Four locations are studied: 1) southern Saskatchewan; 2) a part of New England (New Hampshire, Vermont and Massachusetts) and eastern New York; 3) central Idaho and western Montana; and 4) parts of North and South Dakota. Snow maps were produced using a prototype MODIS snow-mapping algorithm used on Landsat Thematic Mapper (TM) scenes of each study area at 30-m and when the TM data were degraded to 1-km resolution. National Operational Hydrologic Remote Sensing Center (NOHRSC) 1-km resolution snow maps were also used, as were snow maps derived from ½° x ½° resolution Special Sensor Microwave Imager (SSM/I) data. A land-cover map derived from the International Geosphere-Biosphere Program (IGBP) land-cover map of North America was also registered to the scenes.

The TM, NOHRSC and SSM/I snow maps, and land-cover maps were compared digitally. In most cases, TM-derived maps show less snow cover than the NOHRSC and SSM/I maps because areas of incomplete snow cover in forests (e.g., tree canopies, branches and trunks) are seen in the TM data, but not in the coarser-resolution maps. The snow maps generally agree with respect to the spatial variability of the snow cover. The 30-m resolution TM data provide the most accurate snow maps, and are thus used as the baseline for comparison with the other maps.

Comparisons show that the percent change in amount of snow cover relative to the 30-m resolution TM maps is lowest using the TM 1-km resolution maps, ranging from 0 to 40%. The highest percent change (>100%) is found in the New England study area, probably due to the presence of patchy snow cover. A scene with patchy snow cover is more difficult to map accurately than is a scene with a well-defined snowline such as is found on the North and South Dakota scene where the percent change ranged from 0 to 40%. There are also some important differences in the amount of snow mapped using the two different SSM/I algorithms because they utilize different channels.

**Comparison of visible and passive-microwave snow-cover data sets (A. Tait/USRA)**

Work has been completed on the comparison and combination of satellite-derived snow-cover products from visible and passive microwave sensors (AVHRR/GOES and SSM/I). The results showed that combining datasets can produce an improved snow-cover product. The main problem area is forested land, where both optical and microwave sensors have difficulty discerning snow. This problem is specifically addressed in the

MODIS snow-cover algorithm. This work has been undertaken to provide a template for a MODIS-SSMI snow-cover product, and eventually a MODIS-AMSR product.

Currently, work is ongoing on projecting the MODIS snow cover test data onto a polar projection that is compatable with the NSIDC Equal Area Scalable Earth (EASE)-Grid. We have successfully done this for the level 2 test swath data over the Great Lakes and Hudson Bay. This projection will be used for hemispheric analyses of snow cover and sea ice and will be used when the MODIS and SSMI data are combined.

**Snow-cover GCM work (G. Liston/Colorado State University)**

The snow-evolution routines in ClimRAMS were modified to perform the energey balance partitioning of Liston (1995) to account for subgrud snow-vegetation patchiness.

The snow-classification scheme of Sturm et al. (1995) was also implemented in ClimRAMS so that the model is capable of handling regional-scale spatial variations in snow density, albedo and grain size.

Using National Operational Hydrologic Remote Sensing Center (NOHRSC) snow-distribution data, I developed proxy MODIS-SNOMAP data sets. These were cast on a 1-km (for the 500-m data) grid, and a 25-km grid (for the 1/4-degree data), and correspond to a winter period representative of central U.S. climatological snow conditions.

For the period coincident with that chosen for th Task 3 data sets, acquired the National Centers for Environmental Prediction (NCEP) reanalysis data required to run ClimRAMS. Also accessed the SST, topography, soils, and vegetation-related data sets required to perform the climate model simulations. Performed all required model setup procedures for the simulation and domain of interest, and cast all required model input data sets on the model grid.

In preparation of the climate model simulations, I cast the MODIS-SNOMAP proxy snow-cover data sets from Task 3 into three forms that correspond to the climate model grid defined by the efforts of Task 4. These three forms are: 1) each atmospheric model grid cell is either snow covered or snow free, 2) each atmosphric model grid cell is assigned a fractional snow-covered area, and 3) each atmospheric model grid cell is assigned the observed spatial snow-cover distribution.

**Snow albedo algorithm development (A. Klein/Texas A&M University)**

For MODIS, I am hoping the surface reflectance product gives some indication of the state of the atmosphere so we can properly select a proper BRDF model since they differ

a lot based on the ratio of direct to diffuse illumination.  I will use, as a first pass, the confidence level of the cloud mask to select, but will also look into what meterological data exists for WINCE.

We are are working on:
1) developing (improved) data sets for NY, Madison, Wisconson, and soon California,
2) correcting the input images with 6s,
3) improving the performance in complex terrain