MODIS Semi-Annual Report
Snow and Ice Project
Reporting Period: January - June 1996
Submitted by: Dorothy K. Hall/974

SUMMARY

During this reporting period, work has focused on preparation for and delivery of software to the SDST. Version 1 specifications for MODIS snow data products were submitted to the SDST. Research continued on the passive microwave data set collected from the April 1995 flights in Alaska. An EOS educational video was completed and distributed. Collaborative work with Doug Machoney from Alan Strahler's MODIS project, and Ron Welch from the ASTER team continued. The EOS Land Workshop/Review was attended and the MODIS snow algorithm was reviewed by a peer-review committee. A sea ice surface temperature algorithm is under development. Plans for a joint field mission to New Hampshire and Vermont in February 1997 are being formulated collaboratively with Alan Strahler's MODIS group. Work has begun on updating the snow and ice ATBD. Additionally, 6 papers were prepared for 2 scientific meetings (IGARSS and the Eastern Snow Conference), and a paper has been submitted to the special issue on BOREAS results for JGR. A total of 8 poster or oral MODIS snow presentations were made.

SOFTWARE DELIVERY

Drafting version 1 (Vi) data product specifications for all product levels of the MODIS snow and ice algorithms was a major algorithm development activity. V1 specifications for the MODIS snow data products (MODl0, MOD10A1, MODl0G, MOD33) and sea ice products (MOD29, MOD29A1, MOD29G, MOD42) were submitted to the MODIS SDST. Product specifications included ECS and MODLAND mandatory metadata and product-specific metadata. Summary statistics such as area of snow cover in km^2, were defined as product-specific metadata. Iterative revisions of V1 specifications were made to keep them current with revisions made in project requirements and toolkits.

A formal delivery of V1 code for MODl0 (Process MOD_PR10) was made to SDST configuration management. That delivery began an iterative interaction process with MODIS STIG for integration of code into the MODLAND data products processing flow. Revisions to code and specifications have been made as the ECS and SDST revise the toolkits and requirements for code and products.

Error and exception handling capabilities in the code were increased to make the code more robust and able to handle situations that maybe anticipated to occur in the input data sets and operational processing environment. Structure of code was also revised to enhance efficiency and reduce memory requirements where possible. Responses to SDST inquires regarding software standards, product metadata, and product specifications were generated throughout the course of software development and delivery.

Code writing and delivery was done by George Riggs/RDC and Hugh Powell/GSC.

SNOMAP ALGORITHM DEVELOPMENT

Work is continuing on improving the SNOMAP algorithm. A summer JOVE Fellow, Dr. Alexandra Moore, a geologist from Hartwick College in New York, has been working with TM data and the SNOMAP algorithm to undertake quantitative comparisons of the results of SNOMAP with results from a well-validated scene of the Sierra Nevada mountains. Though this has been done previously, the current work represents an attempt to utilize the sub-pixel snow classes in the Sierra Nevada scene, classified by Walter Rosenthal/UCSB, to enhance our algorithm with the idea that we may be able to classify a total of three categories of pixels: 10-30 percent, 30-60 percent and 60-100 percent snow covered. The availability of some sub-pixel snow information would provide additional information that will be useful to many people, as discussed at the First MODIS Snow and Ice Workshop.

A comparative study of snow and ice classification techniques employed in the MODIS snow cover and ice extent algorithms with the techniques employed by Ron Welch, SDSMT for classification of snow, ice and clouds in Landsat TM data of polar regions was undertaken. A suite of C programs for preprocessing data was written and procedures for comparative analysis were formed. An integrated version of the MODIS snow cover and ice extent algorithms was written specifically for this comparative study. A land/water mask was manually generated for the TM images used in the comparison. The objective of comparative study is to identify strengths and weaknesses of the MODIS algorithms and validate the techniques used. Over 20 TM scenes have been included in the study. preliminary results and next analysis steps have been discussed among the collaborators. The study continues to progress. A jointly-authored paper was prepared for the Eastern Snow Conference (see Appendix I).

Collaboration with Dr. Doug Machoney of Boston University from Dr. Alan Strahler’s MODIS project was begun. Machoney is running a neural net classification on one of our Glacier National Park TM scenes (14 March 1991). When this is completed, we will compare our results from SNOMAP with his results as part of our efforts to validate our algorithm.

Summary of spatial degradation of snow maps of the Sierra Nevada TM scene of 10 May 1992

The snow maps generated by the MODIS SNOMAP algorithm and the SCA technique of Rosenthal were degraded to 500 m resolution to get a visual impression of how they might appear at the 500 m resolution of MODIS.

The degradation technique used was simple resampling by nearest neighbor of the snow maps from 30 to 500 m resolution. IDL was utilized to do the degradation using the CONGRID function. The 30-m data (an array of 6967 pixels by 5965 lines) was degraded by a factor of 17 (500/30 = 16,6666) creating an array of 410 pixels by 351 lines. There is no interpolation of numeric values, original SCA classes are preserved. Degraded snow maps are essentially reduced copies of the originals. Areal extent and proportions of snow cover remain constant between the original 30-m resolution snow maps and the spatially degraded 500-m snow maps. This technique does not degrade the original signal sensed by the TM, thus does not answer the question of how the algorithms will perform on 500-m data that would be "blurred," that is contain a signal from a larger surface area. To study that, degradation of the original TM data would be required, and a sensor response function would need to be included. It maybe possible to "blur" the original data using a cubic convolution technique followed by application of the two snow mapping algorithms. At this point that would be very difficult to do for the SCA technique because the code is not operational here. It is more doable for SNOMAP.

Degradation Results

SCA Class	Full scene 30 m			Degraded scene 500 m		
	Pixel count	area (km2)	% of scene	Pixel count	area (km2)	% of scene
96	1087368	864	2.62	3672	918	2.55
84	1058108	756	2.55	3732	933	2.59
72	919800	648	2.21	3276	819	2.78
60	392887	540	0.95	1299	324.8	0.90
50	468958	450	1.13	1524	381	1.06
38	829887	342	2.00	2943	735.8	2.05
22	895902	198	2.16	3125	781.3	2.17
09	821239	81	1.98	2799	699.8	1.94
Totals		3879	15.60		5592.7	15.54

SNOMAP class	Full scene 30 m			Degraded scene 500 m		
	Pixel count	area (km2)	% of scene	Pixel count	area (km2)	% of scene
Snow	3557031	3201.3	8.5	11379	2844.8	7.9
Not snow						

Note: the numbers in the above tables need to be verified. The area numbers seem to be inconsistent.

Generally the proportions of snow cover are consistent between the 30 m results and the 500 m degradation result. Essentially the results are a proportional resampling from 30 m to 500 m.

Major difference between the SCA and SNOMAP is the amount of snow cover in the scene. SCA identifies approximately 15% of the scene as snow covered. SNOMAP identifies approximately 8% of the scene as snow covered. That shows that SNOMAP is more restrictive in mapping snow cover than is the SCA algorithm. The next step is to identify the SCA fractional snow cover classes that correspond, to SNOMAP. Since the SCA algorithm is applied only after non-snow pixels are masked from analysis it is important to determine the agreement and disagreement between the binary snow masks of SNOMAP and SCA.

SEA ICE SURFACE TEMPERATURE ALGORITHM DEVELOPMENT

An ice surface temperature (IST) algorithm that shows much promise for a MODIS application is that of Key and Haefliger (1992). It is a split-window technique using AVHRR bands 4 and 5. The equation used is:

$$IST = a + bT_4 + cT_5 + d[(T_4 - T_5) \sec \theta]$$

where T_i are the satellite-measured brightness temperatures in the AVHRR thermal channels 3 and 4, and the coefficients are obtained from least squares regression of modeled temperatures to satellite-derived temperatures, and θ is dependent on the degrees from nadir.

This algorithm can only be used when the sky is clear, as any cloud can introduce serious errors. The Arctic atmosphere is assumed to be mostly dry, except in the summer when water vapor is present. Therefore, an atmospheric-correction program like LOWTRAN-7 must be run in conjunction with this algorithm.

We have been working with Jeff Key/Boston University in the early stages of developing this algorithm. He is a member of the ad-hoc committee on MODIS snow and ice products (see below) thus ensuring continued collaboration on the sea ice surface temperature algorithm.

AD-HOC COMMITTEE ON MODIS SNOW AND ICE PRODUCTS

An ad-hoc committee on MODIS snow and ice products has been set up. The committee consists of 6 members: Steve Ackerman/University of Wisconsin, Roger Barry, NSIDC/University of Colorado, Tom Carroll, NOHRSC/NOAA, Jeff Key, Boston University, Bruce Ramsay, NESDIS/NOAA and Dave Robinson, Rutgers University. The first meeting of the ad-hoc committee will be held at Goddard sometime in the fall of 1996.

Formation of an ad hoc committe on MODIS snow and ice products was deemed necessary because there are no other snow/ice investigators on the MODIS team. Therefore we have sought outside advice in order to ensure that we are developing products that will be useful. Thus we held the workshop in September of 1995. We will probably hold a second workshop following the launch of MODIS in 1998 or 1999 when we have some real MODIS data. Until then we plan to have an annual one-day meeting of the ad-hoc committee (in the fall of 1996 and 1997) as well as a meeting at the second workshop, and perhaps beyond that.

APRIL 1995 ALASKA MISSION

Work is ongoing in analysis of the Millimeter-wave Imaging Radiometer (MIR) data collected during April 1995 over snow and sea ice in and near Alaska. MIR data at 89-, 150- and 220 GHz show patterns that are related to snowmelt in central Alaska, and snow conditions and vegetation patterns in central and northern Alaska. The data clearly show that one cannot interpret passive-microwave data and infer snow depth in Alaska or elsewhere unless the vegetation is taken into account. A paper for the IGARSS '96 symposium was prepared on this topic (see Appendix II).

Additionally, MIR data from the Alaska '95 mission has begun to be analyzed for the sea ice portions of the mission. Preliminary results show that the radiometric brightness temperature over ice-free ocean increases with frequency, but over sea ice, brightness temperature increases with frequency sometimes, but not always. Perhaps when snow is present on the sea ice, surface scattering causes lower brightness temperatures at higher frequencies. A paper for the IGARSS '96 symposium was prepared on this topic (see Appendix III).

EDUCATIONAL VIDEO

An EOS educational video entitled, "Glacier Bay, Alaska, from the Ground, Air and Space," was completed. This 13-minute long, narrated video was done as a collaborative effort between Goddard's Scientific Visualization Studio (SVS) and the Hydrological Sciences Branch/Code 974. The video is being shown widely, including on Montgomery County and Howard County School Systems Cable T.V. A web page is also under construction by Code 930. Copies of the video are available from D. Hall/974.

ANALYSIS OF FEBRUARY 1992 ASAS DATA OF GLACIER NATIONAL PARK, MONTANA

Analysis of data from the February 1992 ASAS mission to Glacier National Park, Montana is nearing completion. Work was essentially stopped on this data set in 1993 when development of the snow-mapping algorithm was in the early stages and it was necessary to devote full time efforts to developing that algorithm. With the newer programs now available to analyze the ASAS data (available from Jim Irons/923), analysis of the ASAS data is more efficient and accurate, and analysis has resumed. Analysis of snow in a meadow, snow in a mixed forest and wind-blown ice over a lake is underway. The reflectance at nadir, 30,60 and 75° are being calculated. Results will be written up during the summer for a journal publication.

MISCELLANEOUS

The Validation Plan for the snow and ice project was written and incorporated into the MODIS Land Group Validation Plan.

The first tape of the MODIS Airborne Simulator (MAS) data from the April 1995 Alaska mission was received.

PAPERS, CONFERENCES, POSTERS AND PRESENTATIONS

Papers

The following papers were published in the IGARSS '96 Symposium Proceedings, 27-31 May 1996, Lincoln, NE:

Hall, D. K., J.L. Foster, A.T.C. Chang, D.J. Cavalieri and J.R. Wang, "Analysis of snow cover in Alaska using aircraft microwave data (April 1995)."

Cavalieri, D.J., D.K. Hall and J.R. Wang, "Comparison of aircraft and DMSP SSM/I passive microwave measurements over the Bering Sea in April 1995."

Riggs, G. A., D.K. Hall and V.V. Salomonson, "Recent progress in development of the moderate resolution imaging spectroradiometer snow cover algorithm and product."

The following papers were prepared for the Eastern Snow Conference Proceedings held 1-3 May 1996 in Williamsburg, VA:

Riggs, G. A., D.K. Hall and R. Welch, "A comparative look at two algorithms for snow from Earth Observation System instruments." Appendix IV

Chang, A. T. C., J.L. Foster and D.K. Hall, "Effects of forest on the snow parameters derived from microwave measurements during the BOREAS winter field campaign."

The following paper was submitted to the special issue of <u>JGR</u> on BOREAS results:

Hall, D.K., J.L. Foster, A.T.C. Chang, K.S. Brown and G.A. Riggs, "Mapping snow cover through forests during the BOREAS winter experiment (February 1994)."

Posters

Riggs, G. A., "A comparative look at two algorithms for mapping snow cover from EOS instruments," Eastern Snow Conference, 2 May 1996.

Riggs, G. A., "Recent progress in development of the MODIS snow cover algorithm and product," IGARSS '96,27 May 1996.

Riggs, G. A., "Recent progress in development of the MODIS snow cover algorithm and product," Code 930 Afternoon Tea, 26 June 1996.

Presentations ***(the following MODIS-related presentations were made):***

Hall, D. K., “Measurements of snow cover in Alaska during a field and aircraft mission (April 1995),” Eastern Snow Conference, 2 May 1996, Williamsburg, VA.

Hall, D. K., “MODIS snow products,” a peer review held at the EOS Land Products Workshop and Review, 16 May 1996, Greenbelt, MD.

Hall, D. K., “Analysis of snow cover in Alaska using aircraft microwave data ,“ IGARSS ’96,31 May 1996, Lincoln, NE.

Hall, D. K., “Analysis of snow and ice cover using satellite data, Part I,” GSFC/UMD Teacher Ambassador Program, 26 June 1996, Greenbelt, MD.

Hall, D. K., “Analysis of snow and ice cover using satellite data, Part II,” GSFC/UMD Teacher Ambassador Program, 27 June 1996, Greenbelt, MD.