National Snow and Ice Data Center

World Data Center for Glaciology, Boulder

Data Management | Cryospheric Science

Annual Report 2001

25 years of snow & ice data and research

http://nsidc.org/

NSIDC staff in 2001

NSIDC's Earth Observing System Data and Information System staff

Audience attending the panel discussion at NSIDC's 25th Anniversary in October 2001

NSIDC staff in the late 1980s

NSIDC staff visiting the National Ice Core Laboratory in Lakewood, Colorado

A casual moment at one of NSIDC's annual Science Retreats

NSIDC's User Services staff members in 1997

Members of the Environmental Working Group team in 1999

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INTRODUCTION

"NSIDC/WDC makes fundamental contributions to cryospheric science and excels in managing data and disseminating information in order to advance understanding of the Earth system."

The National Snow and Ice Data Center (NSIDC) and World Data Center for Glaciology (WDC), Boulder, is part of the University of Colorado Cooperative Institute for Research in Environmental Sciences (CIRES), and is affiliated with the NOAA National Geophysical Data Center (NGDC) through a cooperative agreement. NSIDC serves as one of eight Distributed Active Archive Centers funded by NASA to archive and distribute data from NASA's past and current satellites and field measurement programs. NSIDC also provides support for National Science Foundation programs through the Arctic System Science Data Coordination Center, the Antarctic Glaciological Data Center, and the U.S. Antarctic Data Coordination Center.

The WDC marked 25 years of operation at the University of Colorado in October 2001. Events marking this anniversary are noted below. The scope of the Center's activities has greatly expanded over this time, particularly in the last decade. New activities for frozen ground and a snow science and field campaign (Cold Land Processes) are reported in this overview of the year's activities.

R.G. Barry
Director
NSIDC/WDC for
Glaciology, Boulder
February 2002

HIGHLIGHTS

NSIDC Celebrates 25 Years

This year marked the 25th anniversary of the National Snow and Ice Data Center, and we celebrated the anniversary with special events in October and December. In October NSIDC hosted a special talk on the NASA Cold Land Processes (CLP) initiative by Don Cline, CLP Principal Investigator, and a reception featuring a poster exhibit. A brief history by NSIDC Director Roger Barry was followed by a panel discussion on "Cryosphere in the Balance: NSIDC's Role for the Next Quarter Century," moderated by Mark Anderson, University of Nebraska, Lincoln. Panelists included Ted Habermann, NOAA National Geophysical Data Center; Judith Curry, University of Colorado; Don Cline, NOAA National Weather Service; and Konrad Steffen, CIRES Associate Director for Cryospheric and Polar Processes. Special guest Gregory Withee, Assistant Administrator of NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), remarked on the long and productive partnership between NOAA/NESDIS and NSIDC. Jerry Peterson, Interim Vice Chancellor for Research, and Susan Avery, Director of CIRES, commented on the scientific importance of NSIDC's work.

NSIDC continued its anniversary celebration at the Fall 2001 American Geophysical Union (AGU) conference, December 10-14, 2001, with a special session on *Monitoring an Evolving Cryosphere: The 25th Anniversary of NSIDC,* chaired by NSIDC scientists Anne Nolin and Ted Scambos. Over 70 oral and poster presentations were given, encompassing ice, snow, permafrost, and NSIDC's role in providing, processing, and archiving data. NSIDC also co-hosted an Icebreaker Reception with the Arctic Research Consortium of the U.S., the Arctic Institute of North America, and the new Snow, Ice, and Permafrost section of AGU.

NSIDC had its origin in 1976, when the WDC for Glaciology-A transferred from the U.S. Geological Survey in Tacoma, Washington, to NOAA, to be operated jointly by NOAA and the University of Colorado under the direction of Roger Barry. In 1982, the NOAA Environmental Data and Information Service designated the National Snow and Ice Data Center as a coexistent institution with the World Data Center-A for Glaciology.

PSQ and GISMO Tools Improve Satellite Data Product Delivery

The Graphical Interface for Subsetting, Mapping, and Ordering (GISMO) and the Polar Spatial Query (PSQ) applications greatly increase the efficiency with which large satellite data sets are delivered to users. GISMO allows users to more easily search for and order Polar Pathfinder data sets (AVHRR, SMMR, SSM/I, and TOVS), and to subset their order spatially, temporally, and/or by parameter. As a result, requests of Pathfinder products have increased (to 494 requests from 66 unique users in the last year). Because users can now subset data, the volume delivered was only 2.27 percent of what it would have been had users received complete data sets (127 gigabytes versus 1.7 terabytes).

PSQ allows users to order swath data in a variety of grids, for a product that is best suited to their purposes. Both applications were developed by Ross Swick and Vince Troisi. For more information, see *DAAC Engineering and Development Activities.*

Climate Warming and the Break-up of Antarctic Ice Shelves

NASA-funded work by Ted Scambos and colleagues has shown that warmer summers are responsible for the recent extensive disintegration of some Antarctic ice shelves. Using satellite data, Scambos documented the destruction of the Larsen ice shelves, which took place in just 10 years (Figure 1). Meltwater from ponds, the result of increasingly warm summer temperatures, flows into cracks in the ice and freezes. The freezing water acts as a wedge, driving the crack to the bottom of the shelf and hastening the shelf's destruction. The work was reported in the Journal of Glaciology (Scambos et al., 2000), and has received significant press coverage.

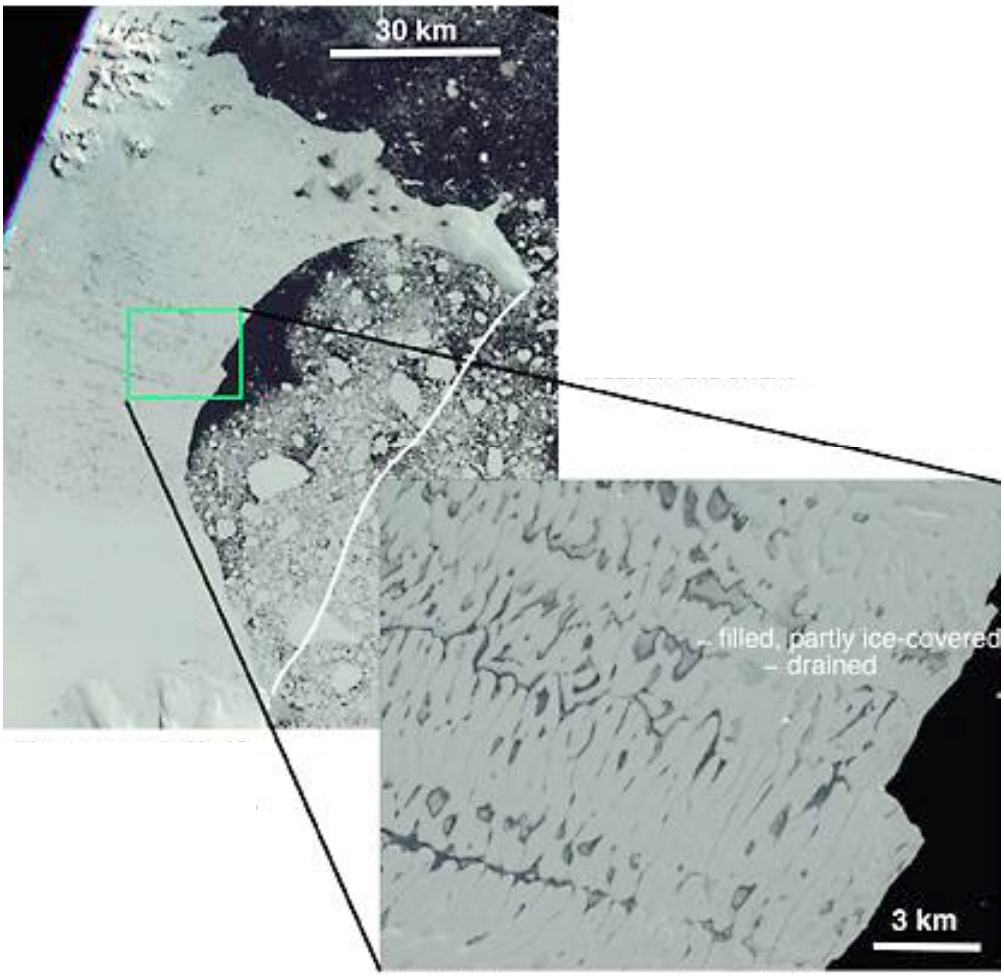

Figure 1. The Larsen 'B' ice shelf in a 21 February 2000 Landsat image. Larsen 'B' has been retreating rapidly, associated with extensive melt ponding during summer. The approximate extent in March 1995 is indicated by the white line in the upper left image. The inset shows meltponds that fill low areas on the shelf caused by slight variations in ice thickness along flowstripes.

Data Sets

The *Environmental Working Group Arctic Atlases on CD-ROM* continued to be the most often requested product in 2001. *Into the Arctic*, an educational product on CD-ROM, was also popular. *MODIS Leve1 2 and Level 3 Snow Cover* products, in their first full year of availability, generated significant interest. The following data sets were released or significantly updated in 2001.

From the Antarctic Glaciological Data Center (AGDC)

- Airborne Laser Altimetry of the Southern Ross Embayment in West Antarctica
- Antarctic Ten-Meter Temperature Data
- Central West Antarctic Glaciochemistry from Ice Cores
- Firn Air Isotope Measurements from Siple Dome and South Pole
- Multi-year, Daily Averaged Temperature Composites for Inland West Antarctica

From the Arctic System Science (ARCSS) Data Coordination Center

- Chemical and Isotropic Tracers from the Arctic Ocean
- Happy Valley Permanent Vegetation Plots
- Large Area Estimates of Carbon Fluxes of Arctic Landscape
- Meteorological and Hydrographic Data, Kuparuk River Watershed, 1985-1999
- Physical and Chemical Properties from Selected Expeditions in the Arctic Ocean
- R-ArcticNet: A Regional Hydrographic Data Network for the Pan-Arctic Regio
- Russian Historical Soil Temperature Data
- SCICEX Hydrographic Data, 1997 and 1998
- SHEBA Reconnaissance Imagery
- Soil Temperatures and Snow Depth Measurements for Barrow, Alaska
- Variations in Circumpolar Frozen Ground Conditions and Modeled Future Conditions
- Vegetation and Site Characterization, 1998-99 ATLAS Grid Transect, Northern Alaska

From the Distributed Active Archive Center (DAAC)

- Greenland 5 km DEM, Ice Thickness, and Bedrock Elevation Grids
- IPAB Antarctic Drifting Buoy Data
- Program for Arctic Regional Climate Assessment (PARCA) Data
- Snow Melt Onset Over Arctic Sea Ice from SMMR and SSM/I Brightness Temperatures
- AVHRR Polar Pathfinder Twice-daily 1.25 km EASE-Grid Composites
- AVHRR Polar Pathfinder Twice-Daily 5 km EASE-Grid Composites
- Ancillary SSM/I Data: Ice Extent and Covered Area, Ice Persistence, and Missing Ocean Pixels
- MODIS/Terra Snow Cover Daily L3 Global 500m ISIN Grid V001
- MODIS/Terra Snow Cover 8-Day L3 Global 500m ISIN Grid V001
- MODIS/Terra Snow Cover 5-Min L2 Swath 500m V001

- MODIS/Terra Snow Cover Daily L3 Global 500m ISIN Grid V003
- MODIS/Terra Snow Cover 8-Day L3 Global 500m ISIN Grid V003
- MODIS/Terra Snow Cover 5-Min L2 Swath 500m V003
- MODIS/Terra Sea Ice Extent L2 Swath 1km V001
- MODIS/Terra Sea Ice Extent L2 Swath 1km V003
- MODIS/Terra Sea Ice Extent Daily L3 Global 1km EASE-Grid Day V001
- MODIS/Terra Sea Ice Extent Daily L3 Global 1km EASE-Grid Night V001
- MODIS/Terra Sea Ice Extent Daily L3 Global 1km EASE-Grid Day V003
- MODIS/Terra Sea Ice Extent Daily L3 Global 1km EASE-Grid Night V003

From NOAA @ NSIDC

- AWI Moored ULS Data, Weddell Sea (1990-1998)
- Environmental Working Group Joint U.S.-Russian Arctic Sea Ice Atlas
- Global Lake and River Ice Phenology Database
- World Glacier Inventory

NSIDC's New Web Site and Web Content

NSIDC released a redesigned Web site that features improved navigation, an automated and searchable data catalog, automated user forms, and additional educational content. The redesigned site addresses the wide variety of our users and thereby allows us to more efficiently direct education and general public users to appropriate informational content, while maintaining a solid data focus for the research community. The site, which also clearly represents our organizational structure, includes new and improved data catalogs for each funded program within NSIDC. Additionally, the site now includes a research component, a revamped news section, a larger cryospheric gallery, and organizational information about the Data Center.

For data users, we released four significant new Web sites in 2001. A Data Help Center (http://nsidc.org/data/help/) provides users with information on data set tools, data formats and media, finding data, and more. An “AVHRR data at NSIDC” (http://nsidc.org/data/avhrr/) site describes the variety of Advanced Very High Resolution Radiometer (AVHRR) data products we maintain and distribute. A Hierarchical Data Format - Earth Observing System (HDF-EOS) site (http://nsidc.org/data/hdfeos/) orients users to the HDF-EOS data format. Finally, a popular new site called "Sea Ice Products at NSIDC" (http://nsidc.org/data/seaice/) summarizes the characteristics of various sea ice data sets derived from passive microwave sensors and other sources. It helps users quickly understand their similarities and differences, and provides links to other sea ice resources and tools for passive microwave data. Internally, NSIDC this year developed a Web publishing system that includes automated publishing tools and outlines our Web standards and guidelines.

THE DISTRIBUTED ACTIVE ARCHIVE CENTER (DAAC)

The NSIDC DAAC serves communities identified by the NASA Earth Science Enterprise Strategic Plan[1], by providing easy and reliable access to Earth Observing System (EOS) satellite data, ancillary *in situ* measurements, baseline data, model results, and relevant algorithms relating to cryospheric and polar processes. Current activities and existing practices at the NSIDC DAAC will evolve, permitting a smooth implementation of future levels of service being formulated by NASA through the Strategic Evolution of the Earth Science Enterprise Data Systems process.

The NSIDC DAAC receives regular guidance from the Polar DAAC User Working Group (PoDAG). At an April, 2001, meeting in Boulder, PoDAG recommended that NSIDC

- Provide information or tools to facilitate access and use of Moderate Resolution Imaging Spectroradiometer (MODIS) data sets.
- Review the gaps in the topics spanned by the DAAC in response to the National Research Council report on NASA Polar Geophysical Data Sets.

The NSIDC DAAC is addressing these recommendations through the activities reported below, in particular through MODIS, Radarsat Antarctic Mapping Project (RAMP), and MODIS Swath to Grid Toolbox (MS2GT) activities. Ron Weaver is DAAC Manager, Vince Troisi is Deputy DAAC Manager and Senior Systems Engineer, and Roger Barry is Senior DAAC Scientist.

[1] "Exploring our Home Planet" Earth Science Enterprise Strategic Plan, January 2001, http://www.earth.nasa.gov/visions/stratplan/ More detail may be found in the ESE Research Strategy Document at http://www.earth.nasa.gov/visions/researchstrat/Research_Strategy.htm.

DAAC Data and Information Activities

Polar Pathfinder Data Sets. The NOAA/NASA Pathfinder Program was initiated in 1993 to facilitate the application of currently archived satellite data for global change research. NSIDC's involvement has been to

- Archive and format Advanced Very High Resolution Radiometer (AVHRR) data from the NOAA polar orbiters for crysopheric research.
- Ingest, archive and distribute TIROS Operational Vertical Sounder (TOVS) products generated by other elements of the Polar Pathfinder program.
- Ingest and archive Special Sensor Microwave/Imager (SSM/I) derived products for both sea ice and snow cover, and to
- Ingest and archive radar altimetry data sets.

A new Web site (http://nsidc.org/data/avhrr/) describes AVHRR Polar Pathfinder data as well as other AVHRR products. The NSIDC DAAC user working group, PoDAG, has recommended that the DAAC continue acquisition of 1-km and 4-km AVHRR data for both polar regions until at least 18 months after the start of MODIS data acquisition; until approximately July 2002. The DAAC will continue acquisition of SSM/I data until the completion of the SSM/I missions.

In addition to the data assembly and distribution work described above, NSIDC developed access tools for HDF-formatted Pathfinder data. This small prototyping project was funded by the NASA Earth Science Technology Office (ESTO) through a grant to Ron Weaver and Siri Jodha Singh Khalsa. The first goal of the *Polar Pathfinder HDF-EOS Pilot Project* was to evaluate the suitability of HDF-EOS, the standard data format that NASA chose for its EOS missions, for data that have been gridded in a polar coordinate system. This was accomplished by converting samples of the Polar Pathfinder data sets into HDF-EOS, and then exercising the geolocation-based functions in the HDF-EOS library. This was important to do for polar gridded data sets, because their coordinate systems do not align with constant latitude and longitude lines, thereby making spatial selection via the commonly-used "bounding boxes" problematic. The second project goal was to demonstrate to the polar research community the advantages of HDF-EOS for storage, access, analysis, and display of multi-sensor polar gridded data. We created a tool that allows researchers to access, geolocate, visualize, and subset data that originate from different sources and have different spatial resolutions but which are placed on a common polar grid.

Cold Land Processes. The Cold Land Processes (CLP) field experiments in Colorado are taking place over the winter of 2001/2002 and will continue into 2003. A CLP Experiment planning meeting was hosted by NSIDC 7-9 November 2001. The CLP, sponsored by the NASA Land Surface Hydrology Program, offers a unique opportunity for the science community to link field measurements of snow cover morphology to remote sensing. It should advance our understanding of snow observations by passive and active microwave, as well as visible and infrared sensors. Participation in the CLP is a tremendous opportunity for the NSIDC DAAC to partner with a primary user

constituency on a highly relevant scientific experiment. The DAAC is providing data management services for field data collected during the CLP experiments, and may take on additional roles in the future.

Radarsat Antarctic Mapping Project (RAMP). In collaboration with the Ohio State University, the Alaska Synthetic Aperture Radar (SAR) Facility (ASF), the Jet Propulsion Laboratory, and Vexcel Corporation, NSIDC DAAC is participating in a program to map Antarctica using data from the SAR on the Canadian Radarsat satellite. The mapping mission is now complete. NSIDC DAAC's main function is to provide access to high-quality Digital Elevation Map (DEM) products, and to provide long-term archival, and assistance in the distribution of the high-level SAR-mosaic products. The Byrd Polar Research Center at Ohio State University, in Columbus, Ohio, is the leading organization for this project. During 2001, the DAAC completed an assessment of user requirements for data formats and delivery methods. The project team completed documentation about the platform, sensor, data set, and scope of the project. In collaboration with ASF, NSIDC developed an online order form for accepting requests for the 25-m resolution data. Further details about RAMP can be found at http://nsidc.org/daac/ramp/.

Moderate Resolution Imaging Spectroradiometer (MODIS) Products. MODIS, now operating on the NASA EOS Terra satellite, is an optical, 36-spectral-band instrument that provides daily coverage of the polar regions at spatial resolutions of 250, 500, and 1,000 m. NSIDC archives and distributes MODIS snow and sea ice products, and helps guide the development of products by participating in the MODIS Snow and Ice Products Ad Hoc Advisory Group. This group recommends future directions to the MODIS Snow and Ice Science Computing Facility based on input by the scientific research community. The NSIDC DAAC continued its outreach to the user community at the Fall 2001 American Geophysical Union meeting, where a new data flyer on MODIS products was distributed, a survey of eighteen potential MODIS users was conducted, and posters on MODIS were presented.

NSIDC receives MODIS data from the NASA Goddard Space Flight Center (GSFC) in Greenbelt, MD. During 2001, efficiency of the MODIS data product generation system at GSFC improved to the point that production and archive of products lag receipt of the data at the Terra ground system by only one week. At NSIDC, improved reliability of the EOSDIS Core System (ECS) ingest and distribution subsystems has led to an increase in the volume of data archived and distributed. The monthly volume of MODIS data archived at NSIDC has reached 1.4 terabytes, while the volume of data distributed by the ECS has reached a peak of almost 70 gigabytes in late 2001 (Figure 2).

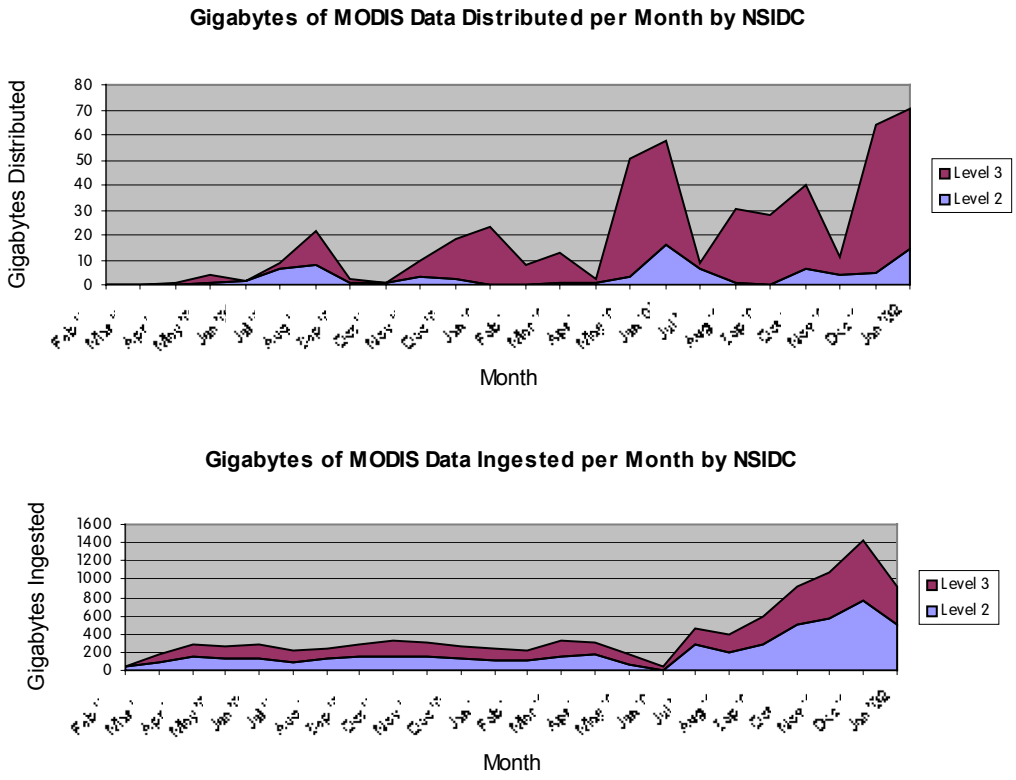

Figure 2. MODIS data volume ingested and distributed by month, February 2000 through January 2002.

NSIDC expects to begin receiving the 8-day Climate Modeler's Grid products and making these data available to the research community in early 2002. For more information, see "MODIS Data at NSIDC" (http://nsidc.org/data/modis/).

Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E). AMSR-E is one of the instruments scheduled to launch in 2002 on the EOS PM (Aqua) platform. AMSR-E, a passive microwave radiometer, operates in six frequencies (both vertical and horizontal polarizations) and has a sampling interval of 10 km. Measurements derived from the AMSR-E observations include cloud properties, radiative energy flux, precipitation, land surface wetness, sea surface temperatures, sea ice, snow cover, and sea surface wind fields. NSIDC will archive and distribute all 21 AMSR-E data products. Details about the mission, science algorithms, and products are available at http://nsidc.org/daac/amsr/.

During 2001, in preparation for AMSR-E data operations, the NSIDC DAAC

- Modified and tested the AMSR-E L1A interface at NSIDC. The interface generates the metadata for the L1A products transmitted to NSIDC from the Jet Propulsion Laboratory PL Physical Oceanography DAAC.
- Completed draft data catalog entries using the Global Change Master Directory (GCMD) Directory Interchange Format (DIF) standard.

- Reviewed and verified the contents of the L2B Data Algorithm Package generated by the AMSR-E SCF. This package contains the processing software and ancillary information required to generate the L2B product.

ICESat/GLAS**.** Geoscience Laser Altimetry System (GLAS) is the sole instrument that will fly on the Ice, Cloud, and Land Elevation Satellite (ICESat). The projected launch of ICESat is in late 2002. The GLAS instrument will provide accurate, high-resolution elevation data that will contribute to our understanding of ice-sheet mass balance in the polar regions. NSIDC will be archiving and distributing 16 products, including Levels 1A, 1B, and 2 laser altimetry and atmospheric lidar data. The initial data stream will be around 20 Gigabytes per day. Details about the mission, science algorithms, and product are available at http://nsidc.org/daac/glas/.

During 2001, in preparation for GLAS data operations, the NSIDC DAAC

- Completed draft catalog entries using the GCMD DIF standard and circulated these to the ICESat SCF and ICESat Scientific Investigator-led Processing System (SIPS) for review.
- Completed a draft of the guide documentation for the altimetry data sets and circulated it to the ICESat SCF and ICESat SIPS for review.
- Successfully ingested and archived test granules of 14 data types that NSIDC expects to receive operationally from the ICESat SIPS.

In addition to the above activities, NSIDC routinely distributes data to users. New data sets in the DAAC catalogue this year are listed in the "Highlights" section.

DAAC Engineering and Development Activities

NSIDC DAAC EOSDIS Core System (ECS). NSIDC participated in a series of Mission Operations Science Systems (MOSS) exercises to verify and validate ECS readiness to support the Aqua mission. Preparation for the MOSS tests included upgrades to the hardware and software components of the ECS. Earth Science Data Type (ESDT) descriptors for the MODIS/Aqua, AMSR-E/Aqua, and GLAS/ICESat data collections were installed in order to ingest the Aqua data products into the ECS test environment. NSIDC's ECS engineering and data operations staff completed installation of the configurations required to support each of the MOSS exercises.

Product Distribution System. The Product Distribution System (PDS) is a new subsystem that was integrated into the ECS to support distribution on media. Media types supported by the PDS include 8mm tape cartridges, CD-R, and DVD.

Information Technology Security. NSIDC is developing plans with the ECS contractor to install a firewall for all of the IT resources on the NSIDC ECS networks. In 2001, the NSIDC DAAC completed three IT security documents required by the NASA Office of the Inspector General. These were a risk management plan, an IT security plan, and a site contingency plan. NSIDC will review the documents annually. An IT security audit of the NSIDC DAAC was conducted by the ESDIS Project Office in October. NSIDC

received an excellent score with a vulnerability rating of 0.06 (a rating of 0.25 is acceptable). The vulnerability index is a ratio of the number of high vulnerabilities to the total number of IT systems. The auditors complimented NSIDC on their IT security monitoring procedures and stated that NSIDC is setting a good example for other DAACs to follow.

Polar Spatial Query: Orbit Search and Gridding (PSQ). PSQ version 1.2, the first operational version, is a Java-based Web application that allows users to search satellite orbit and scene data sets by collection, parameter (channel), date, and region of interest. It is used for SSM/I and AVHRR data sets. PSQ is unique in that it uses a backtrack orbit search algorithm and satellite orbit parameters to locate data meeting search criteria, rather than searching a data-base of orbit and scene coordinates. This technique gives more accurate search results. Additionally, requested data from different channels of instruments are gridded to a common user-selected grid and projection, covering the user's region of interest, prior to delivery. NSIDC requires users to register to access the application (see the PSQ site http://nsidc.org/data/psq/ for more information). **Graphical Interface for Subsetting, Mapping and Ordering (GISMO)**. GISMO version 2.2 allows users to search and subset gridded Polar Pathfinder data sets. By giving users the ability to order only the spatial and temporal subset that they want, we have significantly reduced the level of effort required to fill requests, saved on media costs, and improved user satisfaction. Further information can be found at http://nsidc.org/data/gismo/.

MODIS Swath to Grid Toolbox (MS2GT). The MS2GT is a set of software tools that can be used to read HDF-EOS files containing MODIS swath data, and produce flat binary files containing gridded data in a variety of map projections. Multiple input files corresponding to successively acquired 5-minute MODIS "scenes" can be processed together to produce a seamless output grid. MS2GT was developed at NSIDC in cooperation with Liam Gumley at the University of Wisconsin. Input data to the MS2GT includes MODIS Level 1B files, MODIS Level 2B snow cover files, or MODIS Level 2B sea ice files, and the respective MODIS geolocation files. If desired, the MODIS Level 1B radiance data can be converted from raw counts to radiances or to surface reflectances; similarly thermal channel data can be converted to surface temperature data. Latitude and longitude coordinates are converted to appropriate row and column numbers of the desired grid. The row and column files are interpolated to the resolution of the input data. Finally, the interpolated row and column files, together with the input data files, are run through a forward navigation algorithm to produce a gridded flat binary file.

THE ARCSS DATA COORDINATION CENTER

The Arctic System Science (ARCSS) Data Coordination Center (ADCC) continues to provide users with new data sets, and has worked to make our Web site (http://arcss.colorado.edu) more user friendly. For example, the ADCC Web site can now be searched by the name of the investigator, the name of the project, and by subject (i.e., by the measured parameter). At some later date it will also be searchable by keyword. Other significant accomplishments are

- The addition of Geographical Information System (GIS) maps to numerous data sets; making it easier for users to determine if the data set reflects information in a desired area of the Arctic. The use of GIS with our data sets permits an interactive map search for specific data subsets.
- Development of a new Data Submission Form. This on-line form will ensure that all the required metadata will be captured early in the data submission cycle.
- Release of the *Physical and Chemical Properties from Selected Expeditions in the Arctic Ocean* (http://arcss.colorado.edu/data/arcss077.html), unofficially referred to as the Western Oceans data Set (WODS). This is a collection of data derived from a number of Arctic cruises.
- Completion of a backlog of Directory Interchange Format (DIF) metadata forms. These have been contributed to the Global Change Master Directory
- Production of a CD-ROM titled *R-ArcticNet: A Regional Hydrographic Data Network for the Pan-Arctic Region.* It may be ordered free of charge through the Web site (http://arcss.colorado.edu/data/arcss062.html).

Several new data sets are available from our Web site. These are listed in the "Highlights" section.

THE US ANTARCTIC DATA COORDINATION CENTER and US ANTARCTIC GLACIOLOGICAL DATA CENTER

U.S. Antarctic Data Coordination Center (USADCC)

Since 1996, the National Science Foundation (NSF) has funded the USADCC at NSIDC to facilitate development of U.S. data set descriptions for inclusion in the Antarctic Master Directory (AMD), a node of the International Directory Network/Global Change Master Directory (GCMD). The AMD contains data set descriptions (metadata) for multidisciplinary Antarctic scientific data collected by approximately fourteen countries, under the auspices of the Scientific Committee on Antarctic Research and the Council of Managers of the National Antarctic Programs. This year, we worked closely with the GCMD to implement a set of data entry and search-and-order tools for the AMD, and to develop a notification procedure for contributing scientists and NSF program managers. We also worked with the relevant NSF program managers to educate NSF-funded scientists about the importance of this program, investigator responsibilities, and the utility of the AMD for conducting research. The USADCC web site (http://nsidc.org/usadcc/) provides information to contributing scientists and users of the AMD, including access to tools, tutorials, and NSF data policies. Greg Scharfen leads ADCC activities at NSIDC.

Antarctic Glaciological Data Center (AGDC)

NSIDC operates the AGDC as a data management program for the NSF's Antarctic Glaciology Program. The AGDC provides online access to more than 25 data sets (most of these were added this year) including 10-m temperature, ice velocity, basal topography, and various ice core-derived geophysical records. Each data set is presented in a standard format, consistent with other NSIDC data sets, that includes documentation, data samples, citation information and access to the data. The AGDC website (http://nsidc.org/agdc/) also provides access to data submission tools, related NSF data policies, and information about Antarctic research programs and investigators. Greg Scharfen leads AGDC activities at NSIDC.

THE FROZEN GROUND DATA CENTER

Permafrost and seasonally frozen ground regions occupy about 24 percent and 60 percent, respectively, of the exposed land surface in the Northern Hemisphere. Frozen ground data and information are critical for fundamental process understanding, environmental change detection, impact assessment, model validation, and engineering applications. However, much of this information remains widely dispersed and unavailable to the science and engineering community, and some data are in danger of being lost permanently. The International Permafrost Association (IPA) has developed a strategy for data and information management (see the section on International Activities). The WDC for Glaciology, Boulder, and NSIDC played an active role in implementing this strategy by developing and distributing the first Circumpolar Active-Layer Permafrost System (CAPS) CD-ROM, including the Global Geocryological Database (GGD), as a NOAA@NSIDC data set. Now, with the financial support and collaboration of the International Arctic Research Center (IARC), University of Alaska, Fairbanks, and with funding from NSF we have begun to expand the CAPS data holdings, update the GGD, and improve frozen ground data availability through a new "Frozen Ground Data Center" (http://nsidc.org/frozenground/). Work is underway to reformat several existing data sets and create value-added products such as gridded fields for model validation and analysis. We are also acquiring and distributing key data sets from IPA programs and elsewhere. Mark Parsons and Tingjun Zhang are leading this activity at NSIDC.

NOAA @ NSIDC AND THE WORLD DATA CENTER FOR GLACIOLOGY, BOULDER

The NOAA project at NSIDC ("NOAA@NSIDC") operates in cooperation with the NOAA National Geophysical Data Center (NGDC) to extend the NOAA National Data Center's catalogue of cryospheric data and information products. We manage about 60 NOAA data sets, with an emphasis on *in situ* data, data rescue, and data sets from operational communities. We also help develop educational pages, and contribute to larger projects of relevance to NOAA. In 2001, the NOAA team at NSIDC

- Improved the web interface, search utility, and database for the *World Glacier Inventory* data set. This data set is the most comprehensive source of online glacier data available.
- Released *AWI Moored ULS Data, Weddell Sea (1990-1998).* These data, contributed by the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany, are the first upward looking sonar (ULS) data from Antarctica to be made publicly available. Ice thickness can be inferred from ULS measurements.
- Released the *Environmental Working Group Joint U.S.-Russian Arctic Sea Ice Atlas.* This product joins the extremely popular Arctic Ocean and Arctic Meteorology and Climate atlases released earlier. We worked with the product authors on documentation and developed an Errata and EWG project pages (http://nsidc.org/data/ewg/) to assist users. The atlases were used in a course on Polar Oceanography and Meteorology at the United States Naval Academy.
- Released the on-line *Arctic Climatology and Meteorology Primer* (http://nsidc.org/arcticmet/). This educational site is a collection of information about the factors that determine arctic weather and climate, based on an EWG atlas that was developed at NSIDC with NOAA funding.
- Updated the *Global Lake and River Ice Phenology Database*, a data set of freeze-up and breakup dates that provides evidence of an increasingly lengthy melt season in the Northern Hemisphere.
- Added data from eight cruises to the *Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics* data set, which now holds data from 18 U.S. and Royal Navy cruises. These data are the most comprehensive unclassified source of ice thickness information from submarines.

These and other NOAA data products at NSIDC are also available through the NOAA/National Virtual Data System (NVDS) and NOAAServer.

The World Data Center (WDC) for Glaciology, Boulder, (http://nsidc.org/wdc/) is home for many of NSIDC's international activities (see "International Collaboration" section), and has its own data catalog. With funding from the NSF and in collaboration with the International Arctic Research Center (IARC) in Fairbanks, AK, the WDC is developing a new Frozen Ground Data Center (http://nsidc.org/frozenground/). This year, with NGDC,

we proposed new data acquisition activities for historical data sets from Russia and China, and for glacier photograph digitization. NOAA also contributes support to the Library (see " Information Center/Library" section).

A new "NOAA@NSIDC" Web site (http://nsidc.org/noaa/) describes our relation to NOAA and provides a catalogue of NSIDC's NOAA data. NOAA@NSIDC activities are supported primarily by NOAA's National Environmental Satellite, Data and Information Service. Florence Fetterer is NSIDC's NOAA Liaison and project lead.

THE INFORMATION CENTER/LIBRARY

The Information Center/Library at NSIDC/WDC serves as a resource to cryospheric information, both for researchers at NSIDC and the University of Colorado, Boulder, as well as for the general public. The Library acquires and catalogs both published and unpublished analog materials on snow, ice, and permafrost, as well as digital data such as CD-ROMs and Web resources. Library staff filled over 600 information requests during 2001, relating to glaciers, ice thickness, snow crystal formation, permafrost, climate change, ice and snow terminology, and a variety of other issues. The Library is funded by the NOAA@NSIDC project and by the NASA-supported DAAC.

The Library houses over 45,000 monographs, serials, journal articles, reprints, videos, and CD-ROMs. In 2001, 1246 new items were added. We currently receive over 75 serials and periodicals relating to the cryosphere and to remote sensing of ice and snow. All of the Library's holdings have been cataloged and can be searched during business hours on our in-house library system. The catalog is also available as part of the Arctic and Antarctic Regions Database put out on CD-ROM and the Web by the National Information Services Corporation (NISC).

In 2001, we received several new analog data sets, including aerial photographs and other materials related to satellite passive microwave SSM/I sea ice data, and ice charts from the Navy/NOAA/Coast Guard National Ice Center. These materials are currently being processed and will be included in our data catalog in 2002. One of our most important analog data sets is the Historical Glacier Photograph Collection. The Library has partnered with the NOAA's National Geophysical Data Center to have a subset of these photographs digitized under the NOAA Climate Database Modernization Program. A Web site will be developed in 2002 to provide online access to the digital photographs.

USER SERVICES and STATISTICS

The User Services staff of five provides responses to user inquiries on behalf of the NSIDC DAAC, the ARCSS Data Coordination Center, the U.S. Antarctic Data Coordination Center, the WDC for Glaciology, Boulder, and NOAA@NSIDC. Michelle Holm leads NSIDC's User Services group. A diverse range of users are served; examples of inquiries received include students requesting information for school projects and reports, media and textbook publishers requesting photographs and interviews, and science researchers requiring information about data holdings, processing, formats, and data processing algorithms.

User Services contributes to data product design and enhancement through representation on NSIDC product development teams, and participation in data center outreach activities (such as staffing the NSIDC exhibit booth and presenting posters at scientific conferences, and writing articles for the quarterly newsletter, *NSIDC Notes*). At the Fall 2001 AGU Meeting, User Services staff presented two posters describing data products, and prepared and staffed the NSIDC exhibit booth. The AGU booth drew approximately 100 new requests for data or information, with a large percentage of contacts being new to the organization. User Services also participated in the EOSDIS DAAC Alliance exhibit booth at three conferences in 2001.

The number of new requests handled by User Services grew by 9% in FY2001, increasing for the 5th straight year (Figure 3). The increase is attributed to continued high interest in old and new products, including Greenland Summit Ice Cores; Into the Arctic: Information and Educational Activities for Studying Climate; R-ArcticNet: A Regional Hydrographic Data Network for the Pan-Arctic Region; MODIS Snow and Sea Ice products; Environmental Working Group (EWG) Sea Ice Atlas; EWG Arctic Meteorology and Climate Atlas; and the Polar Pathfinder products. (Note that the number of requests is not related to the number of NSIDC data users. Most users browse and download data using NSIDC's online catalog. These users are not tracked by User Services). The breakdown of users by type has been consistent over the last four years (Figure 4). The largest category is Research and Education, which includes universities, NASA, and NOAA.

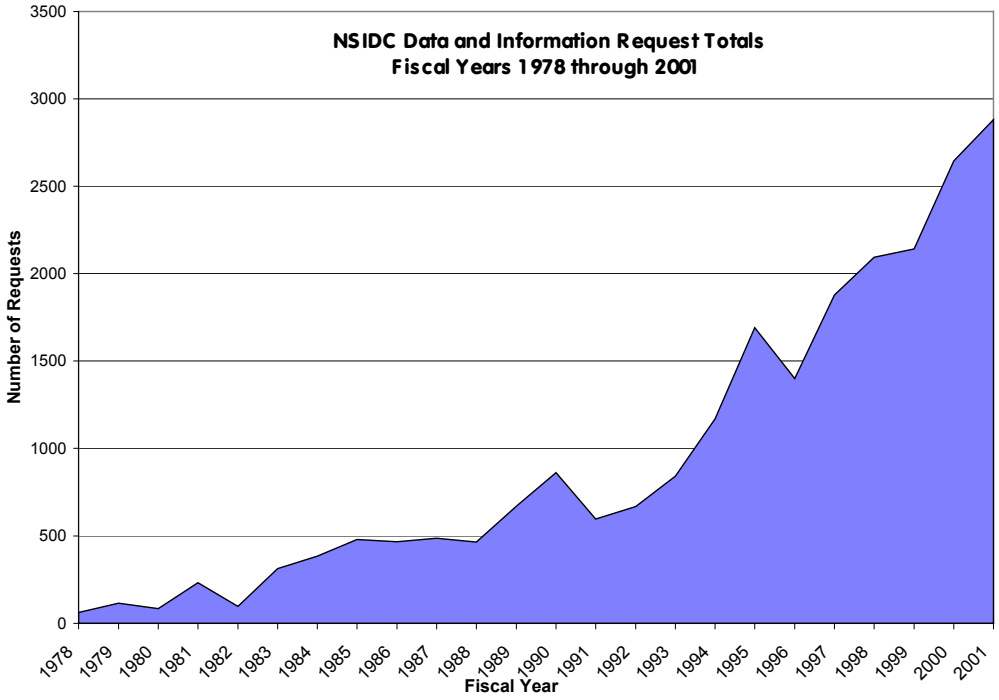

Figure 3. Number of new information requests received by User Services during each fiscal year for 1978 through 2001.

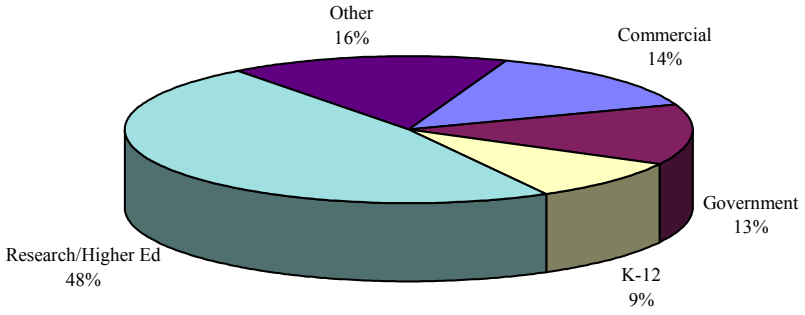

Figure 4. Requests by user category, FY 1997-2001

NSIDC also categorizes the types of transactions, or exchanges of data or information to users in support of their requests. Six percent of transactions result in a referral to another organization, 10% result in library services, 38% result in providing the user with information about our products and services, 38% result in the delivery of a data product, and 6% of transactions result in NSIDC providing support for one of our data products.

OUTREACH and EDUCATION

Through a variety of outreach activities and through operation of the Library, NSIDC works to educate the general public about the importance of the cryosphere. The NSIDC Outreach Committee developed a new logo and tag line this year, both of which now appear on our publications. The logo, which replaces the NSIDC "snowflake," features a stylized polar grid symbolizing our polar scope and recalling our satellite data sets. The tag line, "Supporting cryospheric research since 1976," reflects our continuing commitment to provide data sets and resources to further research on the cryosphere.

Community Involvement

Several NSIDC members contributed to the community by participating in outreach activities to schools and at earth science fairs and science bowls during 2001. Mark Serreze served as a judge at the science fair held at Martin Park Elementary School, and Julienne Stroeve was a science fair judge for Community Montessori. Ted Scambos made visits to several schools to discuss his research in Antarctica, including a talk for kindergarten and first grade classes of Louisville Elementary School, and a lecture to a group of science-oriented high school students selected by the Boulder Valley School District in which he discussed ice shelf breakups and global warming. Julienne Stroeve was an expert witness for "mock Senate" hearing on climate change for a CU class. Betsy Sheffield and Feng Ling participated in the National Ocean Science Bowl in February. This event was hosted by CIRES and was the regional competition for Colorado and Wyoming. Betsy Sheffield also attended the Education Workshop for Scientists, Engineers, and Education and Public Outreach Professionals, hosted in May by the University of Colorado's Space Science Institute. The workshop focused on science education using inquiry centered, hands-on instruction, and scientist-education partnerships.

In May, NSIDC participated in the annual Institute for Arctic and Antarctic Research (INSTAAR) Open House for middle school children. Michelle Holm, User Services, and Teresa Mullins, Outreach Coordinator, presented information on climate change and the study of cryospheric processes. The presentations were prepared with the help of Tracy Thrasher Hybl, Betsy Sheffield, and Cindy Brekke. Approximately 150 eighth graders from Southern Hills Middle School participated in the half-day event, which aims to encourage involvement in the sciences.

Michon Scott volunteered her expertise to develop a Web feature for the Rocky Mountain Public Broadcasting Service's New Frontier site on science and technology in Colorado. The "Cool Careers" section (http://www.rmpbs.org/learn/frontier/career/career.html) features an interview with NSIDC's Anne Nolin, in which Anne describes her work on mapping the Martian polar ice caps. "Ice on Mars" (http://www.rmpbs.org/learn/frontier/explore/mars/explore.html) includes fascinating images from NASA's Mars Global Surveyor mission.

The DAAC Yearbook and Earth Observatory

NSIDC published the 2000/2001 DAAC Alliance Yearbook, which highlights research uses of Earth observing data from NASA's Earth Science Enterprise. The Yearbook was distributed from NSIDC's exhibitor booth at the AGU Fall Meeting in December 2001. NSIDC also maintained and updated the DAAC Alliance Web site (http://nasadaacs.eos.nasa.gov/) and contributed regularly to NASA's Earth Observatory Web site. NASA presented several members of the NSIDC Communications team with a Public Service Group Achievement Award for their help in providing "timely information about current Earth science activities, data, and images on the Earth Observatory Web page."

A New On-line Arctic Meteorology Primer

The "Arctic Climatology and Meteorology Primer" (http:///nsidc.org/arcticmet/) is a collection of interesting and informative meteorology and climate facts with particular emphasis on arctic phenomena. It includes general information about arctic weather, the factors that determine weather and climate, and some of the weather patterns observed in the Arctic. Brief sections also explore the Arctic's role in the global climate system and concerns about climate change. The Primer also includes a glossary of meteorological terms in both English and Russian, and a gallery of photographs illustrating historical data collection activities on Russian drifting ice stations. The Primer is based on material from the Environmental Working Group's Arctic Meterology and Climate Atlas on CD-ROM; a product that combines data for research and information for the general public in one package. It joins other educational theme pages including "State of the Cryosphere" and the award-winning "All About Glaciers," and was developed by NOAA@NSIDC with the assistance of other NSIDC project team members.

NSIDC Wins Web and CD-ROM Awards

The Rocky Mountain Chapter of the Society for Technical Communication presented NSIDC with an Award of Merit for the Arctic Climatology Project: Arctic Meteorology and Climate Atlas on CD-ROM, while our "All About Glaciers" site won a "Best of Denver 2001" award from Denver's Westword newspaper. Westword readers named the site "Best Web Site for Slow Modems" and Westword editors said this site "contains everything anyone would ever want to know about glaciers."

INTERNATIONAL COLLABORATION

The WCRP Climate and Cryosphere (CliC) Project

The cryosphere is an integral part of the global climate system with important linkages and feedbacks generated through its influence on surface energy and moisture fluxes, precipitation, hydrology, and atmospheric and oceanic circulation. The cryosphere is a key component of climate model response to global change, and serves as an important indicator of change in the climate system. However, many aspects of the cryosphere have not been fully covered within the World Climate Research Program (WCRP). There are notable gaps in present studies of cryospheric elements and in appropriate treatment of cryospheric processes in climate models.

NSIDC/WDC for Glaciology, Boulder, is taking a leadership role in shaping a new WCRP project on Climate and the Cryosphere (CliC) through the involvement of its Director, Roger Barry, as Co-Vice Chair of the CliC Science Steering Group. The WCRP Joint Scientific Committee (JSC) approved the establishment of CliC in March, 2000. The Science and Coordination Plan describes research and coordination initiatives required to integrate fully studies of the impact and response of the cryosphere, and the use of cryospheric indicators for climate change detection, within the WCRP. The plan draws on a meeting on Cryospheric Processes and Climate in Cambridge, UK, (February 1997) and meetings of the CliC Task Group in Utrecht, Germany (July 1998) and in Grenoble, Austria (August 1999).

The CLIC Science Plan addresses:

- Interactions between the atmosphere, snow and land
- Interactions between land ice and sea level
- Interactions between sea ice, oceans, and the atmosphere, and
- Cryospheric interactions with the atmosphere and the ocean on a global scale, and
- Cryospheric indicators of climate variability and change.

The scientific strategy for a CliC program is similar in each of the areas of interaction: a combination of measurement, observation, monitoring and analysis, field process studies, and modeling over a range of time and space scales. A CliC modeling strategy must address improved model parameterization of the direct interactions between all components of the cryosphere, the atmosphere, and the ocean. This is required at scales from the regional to global, and with a hierarchy of models. It is also essential to provide the improved data sets needed for validation of models and parameterization schemes via *in situ* and remote sensing observations. CliC data requirements will necessitate the continuation of many Arctic Climate System data activities and their expansion to Antarctic and other cryospheric data needs.

The CliC Scientific Steering Group is writing an Implementation Plan that is complementary to other initiatives and draws on expertise of other organizations; in particular other WCRP and World Meteorological Organization projects. The

Implementation Plan will be available for comment early in 2002 through the International ACSYS/CliC Project Office (http://clic.npolar.no). Discussions are underway in the United States concerning the possibility of developing a national program for CliC analogous to that for the WCRP Climate and Variability (CLIVAR) project.

Global Land Ice Measurements from Space (GLIMS)

GLIMS is an international project to survey the majority of the world's glaciers with the accuracy and precision needed to assess recent changes and determine trends in glacial environments. This will be accomplished by comprehensive periodic satellite measurements, coordinated distribution of screened image data, analysis of images at worldwide Regional Centers, validation of analyses, and a publicly accessible database (http://www.glims.org/). The primary data source will be the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument aboard the EOS Terra spacecraft, and Landsat ETM (Enhanced Thematic Mapper Plus), currently in operation. Approximately 1,400 ASTER images suitable for GLIMS analysis (with the necessary gain settings and minimal cloud cover) have been acquired as of early 2002. GLIMS is a collaborative effort with the USGS, NASA, other U.S. agencies, and a group of internationally distributed glaciologists at Regional Centers of expertise. NASA is funding NSIDC to develop the information management system for GLIMS. We will ingest GLIMS-analyzed glacier data from Regional Centers and provide online data access. Design of the GLIMS database is nearly complete. It will include measurements (over time) of glacier length, area, boundaries, topography, surface velocity vectors, and snowline elevation, derived primarily from remote sensing data. Interface tests with the Regional Centers have begun and we expect to implement user interfaces and begin populating the database during the next two years. Greg Scharfen is Principal Investigator on the NSIDC GLIMS grant.

International Ice Charting Working Group and the Global Digital Sea Ice Data Bank

The International Ice Charting Working Group (IICWG) was formed in 1999 by the U.S. Navy/NOAA/Coast Guard National Ice Center and other centers to promote cooperation on all matters concerning sea ice and icebergs. NSIDC hosts the IICWG Web site (http://nsidc.org/noaa/iicwg/) and participates as part of the Data, Information, and Customer Support standing committee. At IICWG's meeting in Tromsø, Norway, 13-16 November, Florence Fetterer led discussions on archive formats for charts from ice services participating in the Global Digital Sea Ice Data Bank (http://www.aari.nw.ru/gdsidb/gdsidb_2.html). The group endorsed a GIS export format called shapefile format, and will recommend this open format to the World Meteorological Organization's Joint Commission on Marine Meteorology for adoption by the GDSIDB. Shapefile format preserves more of the information content of ice charts and is easier for centers to produce and for researchers to use than existing archive format. The Data Bank of sea ice chart information resides at NSIDC and at the Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia.

International Permafrost Association (IPA) Standing Committee on Data, Information, and Communications (SCDIC)

The objectives of the SCDIC are to initiate and implement IPA strategies for data, archiving, information product development, and communication within and beyond the permafrost community. In addition to the co-chairs Roger Barry (USA) and Mike Clark (UK), members include Julia Branson (UK), Margo Burgess (Canada), Daniel Vonder Muehll (Switzerland), Hanne Christiansen (Denmark), representatives from China, Russia and several Working Groups, and Jerry Brown (USA) as liaison for the IPA Executive Committee and the Global Terrestrial Network for Permafrost (GTN-P).

To continue the IPA strategy for data and information management as part of the Global Geocryological Database (GGD), the SCDIC is working with NSIDC and the International Arctic Research Center (IARC), University of Alaska, to revise and update the 1998 CAPS CD-ROM and expand the GGD (see the section on the Frozen Ground Data Center). Tingjun Zhang and Mark Parsons are leading the work at NSIDC. Provisional plans include development of a Web site with a new search engine for data access. Current status, plans and requirements for GGD-CAPS II activities were presented at the IPA meetings in Russia, Rome, Copenhagen, and Mongolia. Since 1998, IPA projects have developed large amounts of information for inclusion in the GDD. These include results from the GTN-P, the Arctic Coastal Dynamics project; the Cryosol database and maps; and the results from the task forces on permafrost creep and mountain permafrost modeling and mapping. Other candidate data sets and products include: selected Chinese permafrost maps and borehole data; time series of Russian soil temperatures from climate stations; data from Russian International Association for the promotion of co-operation with scientists from the New Independent States of the former Soviet Union (INTAS), projects on ground ice and tundra; the Japanese GEWEX Asian Monsoon Experiment (GAME)-Tibet and GAME-Siberia projects; the Canadian climate cryopshere programs; the United States Arctic System Science (ARCSS) projects; revisions to the English-Russian permafrost glossary; an updated bibliography on frozen ground; experimental data from the Caen, France ice-segregation bedrock experiment; and a catalog of frozen ground models.

While on sabbatical visit to Russia, SCDIC Co-chair Roger Barry attended the annual Earth Cryology and Council meetings in Pushchino and the 2nd Russian Conference on Cryology at Moscow State University, where he presented reports on the role of snow and ice in the climate system, the GGD, and the distribution of frozen ground in the northern hemisphere.

RESEARCH

Richard Armstrong

Hemispheric-scale comparison and evaluation of passive microwave snow algorithms. Passive microwave satellite remote sensing can greatly enhance large-scale snow measurements based on visible satellite data alone, because of the ability to acquire data through most clouds or during darkness. In addition, passive microwave data can give a measure of snow depth or water equivalent. This study provides preliminary results from the comparison and evaluation of several different passive microwave algorithms. These algorithms include examples of both mid- and high-frequency channel, vertical and horizontal polarization, and polarization difference approaches. In our comparisons we utilize large, comprehensive validation data sets that can be expected to provide a full range of snow/climate conditions, rather than limited data that may only represent a "snapshot" in time and space. Evaluation of snow extent derived from passive microwave data is undertaken through comparison with the NOAA Northern Hemisphere snow charts that are based on visible-band satellite data. Results clearly indicate those time periods and geographic regions where the two techniques agree and where they tend to consistently disagree. Validation of snow water equivalent derived from passive microwave data is undertaken using measurements from snow course transects in the former Soviet Union. Preliminary results indicate a general tendency for nearly all of the algorithms to underestimate snow water equivalent. Future work will include validation data sets from the United States and Canada as well as data obtained from the NASA Cold Land Processes Experiment, which is being undertaken in Colorado during 2002 and 2003. *(R. Armstrong, P.I. Funded by NASA)*

Recent Northern Hemisphere Snow Extent: A Comparison of Data Derived from Visible and Microwave Satellite Sensors. During the past four decades much important information on Northern Hemisphere snow extent has been provided by the NOAA weekly snow extent charts derived from visible-band satellite imagery. Passive microwave satellite remote sensing can enhance these large-scale snow measurements that are based on visible satellite data alone, because passive microwave sensors have the ability to acquire data through most clouds or during darkness. In addition, passive microwave data can potentially provide an index of snow depth or water equivalent. We compare the fluctuation of Northern Hemisphere snow cover over the past twenty years using these two satellite remote sensing techniques. Results show comparable inter-annual variability with similar long-term hemispheric-scale trends showing decreases in snow extent of approximately 0.2 percent per year. The passive microwave snow algorithm applied in this study indicates less snow-covered area than the visible data during fall and early winter when the snow is shallow. New algorithms designed to reduce this apparent error are currently being developed and tested. *(R. Armstrong, P.I. Funded by NASA)*

Validation of AMSR-E Snow Products. Passive microwave signatures of seasonal snow cover are clearly characterized by the strong dielectric contrast between snow-covered and snow-free ground, by decreasing emissivity (dry snow) with increasing microwave frequency (negative spectral gradient) and by decreasing emissivity with increasing snow mass. Because of this clear capability, a microwave snow cover algorithm is under development by the EOS AMSR-E Science Team. Our validation study will supplement and enhance the validation activities currently planned by the Science Team for the AMSR-E snow water equivalent products. We will evaluate algorithm skill on a wide range of scales. Local or grid scale studies will be accomplished through direct participation in the NASA Cold Land Processes Experiment. Larger river basin scale validation will be facilitated through participation in an ongoing NASA and NSF funded program that involves an integrated near-real-time monitoring and analysis of the major components of the pan-Arctic hydrologic cycle. Output from the AMSR-E snow algorithm will be compared with river discharge data compiled by this project, as well as with modeled values of distributed winter precipitation. For validation at the hemispheric scale, we will evaluate the snow algorithms by comparison with the EOS MODIS daily global snow extent, as well as with the NOAA IMS daily Northern Hemisphere snow extent maps. For snow extent and water equivalent, we will use data from the United States (NOAA/NWS, NOHRSC, and USDA) as well as station data obtained through our ongoing collaboration with the All-Russia Research Institute of Hydrometeorological Information, Obninsk, Russia; the Satellite Meteorology Institute, Beijing, China; the Cold and Arid Regions Environmental and Engineering Research Institute, Lanzhou, China; and the Canadian IDS team CRYSYS. *(R. Armstrong, P.I. Funded by NASA)*

Advancing Glaciological Applications of Remote Sensing with EO-1
(See entry under Zhang)

Collaborative Research: A Hydrological Observing System for the Pan-Arctic Landmass (See entry under Serreze)

Andy Barrett

NASA Southwest Regional Earth Science Applications Center. The objective of our contribution to this project is to develop methods that integrate remotely sensed information of snow covered area and snow water equivalent into hydrologic modeling and analysis tools (see Barrett et al., 2001). The accuracy of snow covered area maps generated by the USGS Precipitation Runoff Modeling System (PRMS), a distributed hydrologic model, has been assessed using gridded snow covered area and snow water equivalent maps produced by the National Operational Hydrologic Remote Sensing Center (NOHRSC), part of the NOAA National Weather Service. Algorithms are being developed to integrate NOHRSC snow maps into PRMS. Integration procedures are being tested for two headwater basins of the Gunnison River, a tributary of the Upper Colorado River. Figure 5 illustrates satellite and model products. The work is being done in collaboration with G. Leavesley and L. Hay, U.S. Geological Survey; R. Bales,

University of Arizona; and R. Davis, U.S. Army Corps of Engineers. *(A. Nolin, P.I., M. Clark, Co-I, A. Barrett, Co-I. Funded by NASA)*

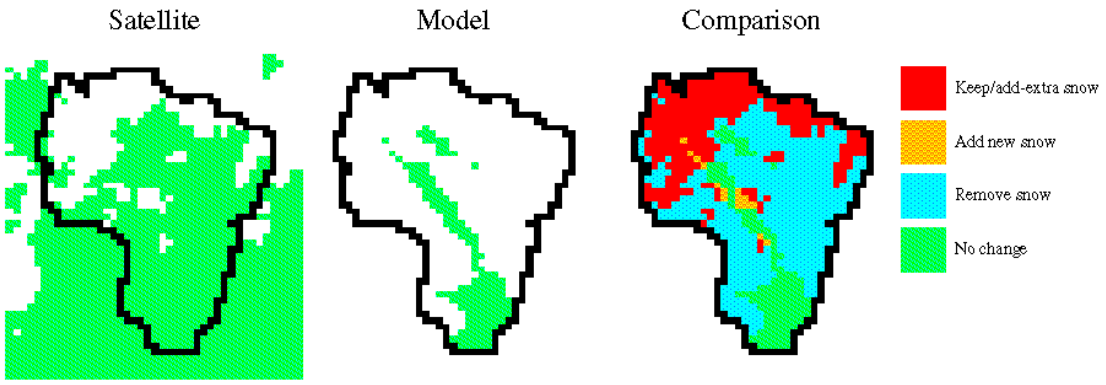

Figure 5. The spatial distributions of snow cover (white) estimated from NOHRSC snow cover maps (left) and simulated by PRMS (middle), and the strategy for updating model simulations of snow-covered cells (right) for the East River Basin, southwestern Colorado, for 2 June 1997.

Roger Barry

Frozen Ground Studies. These studies revised an assessment of the actual area of the northern hemisphere exposed land surface underlain by permafrost, and the ground ice volume. Previous calculations followed earlier practice in not taking account of the fractional coverage of permafrost in zones mapped as continuous, discontinuous, sporadic, and isolated. The revised area is estimated to be 12.2-17.0 million km^2 (12.8-17.8 % of the exposed land). The ground ice volume is 10.8 -35.5 thousand km^3, or 2.7 to 88 cm of sea level equivalent. *(T. Zhang, P.I., R. G. Barry, Co-I. Funded by NSF)*

Snow Cover and Soil Temperature. In conjunction with CIRES Visiting Fellow Dr. Sergei Sokratov, a study was made of the effects of seasonal snow cover on soil freezing and energy balance, based on soil temperature data for 1993-98 at Barrow, Alaska, collected by K.M. Hinkel. When combined with data on snow depth, these temperature observations allowed us to distinguish several stages in the intra-seasonal variation of snow cover effect on the temperature regime and energy balance of the underlying soil. Each stage corresponds to specific snow cover thermo-insulation effects, in terms of the effect of snow depth on energy balance at the soil surface. Results show there is a direct snow depth effect on soil temperature only in two stages of the winter season: after the thawed active layer temperatures fall below 273 degrees Kelvin and heat losses occur from the entire soil layer measured (stage II), and during equalization of heat fluxes from the surface and at depth, with the fluxes gradually diminishing to zero (stage III). The results are in press in the Journal of Geophysical Research (Sokratov and Barry, 2002).

Collaborative Research: A Hydrological Observing System for the Pan-Arctic Landmass (See entry under Serreze)

Collaborative Research: Hydro-Climatology of the Major Eurasian Arctic Drainages (See entry under Serreze)

Florence Fetterer

Sea Ice Surface Characteristics from High-Resolution Reconnaissance Imagery. Every arctic summer, snow on sea ice melts and forms ponds. These ponds may cover up to 50percent of the sea ice surface. Because they are darker than sea ice, they lower the albedo of sea ice considerably. Their spatial distribution and development over time is of interest to those parameterizing the evolution of albedo in climate models, but few data on melt pond development exist. In this project, high-resolution (1 m) satellite imagery is being used to produce 10 km x 10 km surface type maps (images in which pixels are classed as ice, pond, or open water), accompanying tables of pond statistics for cloud-free 500 m x 500 m cells, and files of pond sizes for ponds in each individual cell (Figure 6). Supervised maximum likelihood classification done using GIS software isolates individual ponds. Pond statistics (percent of area covered by ponds, number of ponds, size of ponds) are written for each 500-m cell. Resulting files are hand edited to remove cloud-contaminated or otherwise "bad" cells. Approximately 1100 images have been acquired for four locations over the summers of 1999, 2000, and 2001. Images from 2000 have been selected for further analysis, and that analysis is underway. The project will result in a data set of melt pond surface type maps and statistics from 1999, 2000, and 2001 at four Arctic Ocean locations. Data will be available through the ARCSS Data Coordination Center at NSIDC. This work is being done in partnership with the REx (Rapid Exploitation) National Civil Applications Program Laboratory at the United States Geological Survey Rocky Mountain Mapping Center, Lakewood, CO. *(F. Fetterer, P.I. Funded by NSF Arctic Systems Science)*

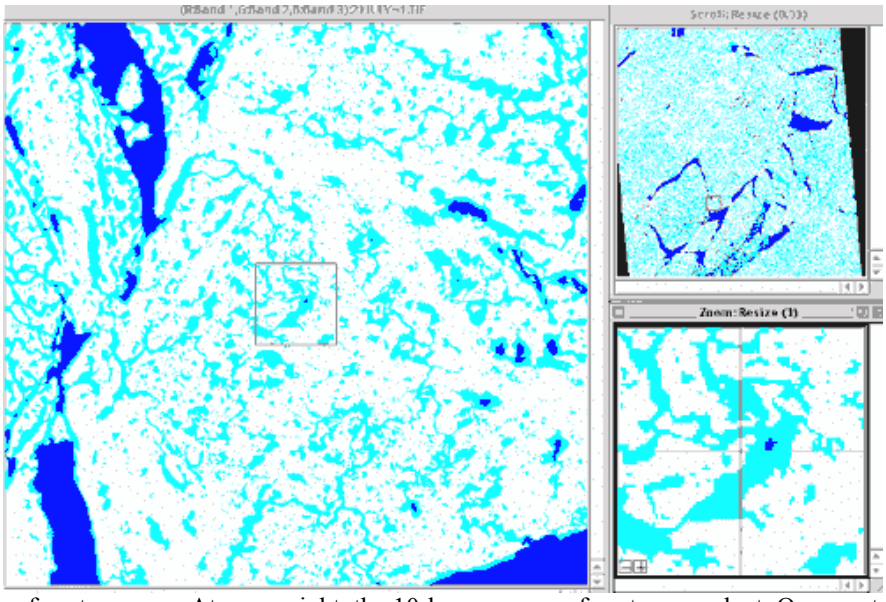

Figure 6. A surface type map. At upper right, the 10-km-square surface type product. Open water is blue, ice is white, and ponds are cyan. The image at left shows a higher level of detail, while the image at lower right shows the 1-m pixel size.

Feng Ling

The Role of Shallow Tundra Lakes in Arctic Land-Atmosphere Interactions and Feedbacks. Thaw lakes are one of the dominating landscape features in the Alaskan Arctic. The extent of their role in climatic and hydrologic systems has not fully been quantitatively analyzed. This study assesses numerically the long-term impacts of shallow thaw lakes on the thermal regime of permafrost. Using a two-dimensional, physically based, finite element model of heat transfer with phase change under a cylindrical coordinate system, we investigated the influence of shallow thaw lakes on the thermal regime of permafrost and talik formation. We also studied the thermal consequences to permafrost and talik after drainage of thaw lakes and the effects of changes in mean permafrost surface temperature on the thermal regime of ground under drained thaw lakes. The simulated results indicate that thaw lakes are a significant heat source to permafrost. For a lake with a long-term lake bottom temperature greater than 0.0°C, a talik forms under the lake. The maximum talik thickness (distance from lake bottom to permafrost surface) ranges from 27 m, 43 m, 61 m, to 77 m with long-term lake bottom temperatures of 1.0°C, 2.0°C, 3.0°C, and 4.0°C, respectively, after 4000 years of a shallow thaw lake over permafrost. For a lake with a long-term mean annual temperature less than 0.0°C, no talik forms under the lake; however, permafrost temperature increases significantly. Changes in lake bottom temperature, which are a product of changes in air temperature, snow thickness and properties, lake ice thickness, and lake water depth, have a significant influence on permafrost thermal regime, talik thickness, and talik formation rate under thaw lakes. The change in lake water depth, however, has very limited impact on the thermal regime of permafrost if the mean lake bottom temperature does not change. The potential long-term response of permafrost thermal regime and talik freeze-up after lake drainage are also investigated. The simulated results indicate that talik of 27 m, 43 m, and 61 m in thickness under a thaw lake could freeze up in 95, 246, and 355 years, respectively, after drainage of a thaw lake. Changes in mean annual permafrost surface temperature would have significant impact on the time of talik freeze-up. We concluded that talik freeze-up and permafrost aggradation are very fast processes under the drained lakes in northern Alaska. *(T. Zhang, P.I.; F. Ling Co-I. Funded by the International Arctic Research Center/Cooperative Institute for Arctic Research, Univ. of Alaska, Fairbanks)*

Jim Maslanik

Development and Summary of Arctic Basin-Scale to Local-Scale Gridded Data Products in Support of Modeling Investigations During the SHEBA Period. The objective of this work is to develop gridded data sets and statistical summaries of Arctic climatic conditions to support modeling and process studies underway as part of the NSF Surface Heat Budget of the Arctic Ocean (Phase 3) effort. Thus far, a variety of primarily satellite-derived data sets have been prepared and studied, with most data sets to date made available via a Web site. See http://just-ice/SHEBA/sheba.html for data and progress reports. See Arbetter et al., 2001, and Drobot et al., 2001, for more information. *(J Maslanik, P.I.; C. Fowler, A. Lynch, T. Arbetter, J. Key; Co-Is. Funded by NSF)*

Sea Ice Variability in the Beaufort and Chukchi Seas: Processes and Prediction. The main objectives of this study are: a) to improve our understanding of, and ability to

predict, seasonal variations in sea ice conditions in the Alaskan North Slope region; b) to determine whether recent variations in ice cover appear related more to long-term climate trends or to short-lived, natural variations in climate; and c) to provide information on extreme ice events and forcings for local planning and hazards assessment. Activities during Year 1 have involved assembly of data sets, calculation of ice conditions from ice charts and satellite data, and statistical analyses of relationships between ice conditions and atmospheric pressure patterns, winds, and air temperature. A principal task was the updating and extension of "sea ice severity" indices that had been developed by previous researchers. In particular, we consider the index set comprising the Barnett Severity Index (BSI) developed in 1980. A second area of investigation underway is the estimation of local and regional correlations between atmospheric circulation and melt onset in the North Slope area. Work to date has included development of a statistical model to predict ice severity with an approximately six-month lead time. See http://just-ice/PROJECTS/BEAUFORT/Beaufort_mainb.html for details. *(J. Maslanik, P.I.; S. Drobot, C. Fowler; Co-Is. Funded by NSF.)*

Improving the Simulation of Sea Ice Lead Conditions and Turbulent Fluxes Using RGPS Products and Merged RADARSAT, AVHRR, and MODIS Data. This project's objectives include: a) derivation of detailed lead conditions for modeling test cases using RADARSAT, aircraft, and other satellite data sets acquired during the SHEBA period and from Earth Observing System (EOS) products; b) use of these data to evaluate the differences in fluxes and ice growth for leads estimated using a new lead model versus estimates obtained using standard bulk formulae; c) application of the SAR data and SAR-based products to test and refine the parameterizations and assumptions inherent to the new lead model; and d) identification of correlations and relationships between local lead conditions critical for the lead model and larger-scale ice and atmospheric conditions. To date, work has focused on merging sets of RADARSAT, AVHRR, and MODIS images of lead complexes, analyses of time series of lead development in the different sensor types, processing of airborne passive microwave image sets from SHEBA, and testing of data fusion methods. See http://just-ice/PROJECTS/FUSION/FUSION_maina.html for details. *(J. Maslanik, P.I.; M. Tschudi, A. Alam, Co-I's. Funded by NSF.)*

Validation of AMSR-E Polar Ocean Products Using a Combination of Modeling and Field Observations. This work contributes to the validation of EOS Advanced Microwave Scanning Radiometer polar products. See http://paos.colorado.edu/~curryja/aerosonde/fprojects-cg.html for details. *(J. Maslanik, P.I.; J. Stroeve, M. Sturm, T. Markus, J. Heinrichs; Co-I's. Funded by NASA.)*

Evaluation and Error Assessment of Operational Passive Microwave Sea Ice Algorithms (see entry under Stroeve)

Other Projects:

- Applications of Aerosondes to Long-Term Measurements of the Atmosphere and Sea Ice Surface in the Arctic Ocean (see http://paos.colorado.edu/~curryja/aerosonde/fprojects-cg.html)

- Integrated Assessment of the Impacts of Climate Variability on the Alaskan North Slope Coastal Region (see http://www.colorado.edu/Research/HARC/).

Anne Nolin

Validation Studies and Sensitivity Analyses for Retrievals of Snow Albedo for EOS AM-1 Instruments. Recent progress has been made towards the retrieval of snow albedo from MISR data. Using *in situ* data from five different automatic weather stations (AWS) from the Greenland ice sheet, ground-based measurements of surface albedo were compared with snow albedo retrieved from the MISR data. A total of 29 clear-sky images were used for this intercomparison. Two techniques were used to derive the surface albedo: one based on the spectral information from the MISR instrument at nadir following the method of Stroeve et al. (1997), and one based on a statistical relationship derived between the red channel reflectance at all viewing angles and the *in situ* albedo. In general, the surface albedo from the two different methods using the MISR instrument shows good agreement with the *in situ* data (within about 5 percent). In addition, both methods yield similar results; at this point it is not possible to say which method is better. Further validation with more MISR clear-sky imagery is needed to make any conclusive statements. The angular information of the MISR data does, however, appear capable of capturing the general variability and magnitude of the surface albedo. The advantage of developing such a statistical model is the relative ease in which such a model can be implemented. In other validation work, a field experiment was held during February-March 2001 in Steamboat Springs, Colorado. A number of unique data sets were obtained including data from the AirMISR instrument and concurrent ground-based data from a unique, angular-viewing radiometer called PARABOLA. Results from the atmospherically corrected AirMISR image and the concurrent PARABOLA data show excellent agreement (Figure 7). This is the first such comparison of multi-angular airborne and ground-based data over snow. *(A. Nolin, P.I., J. Stroeve, Co-I. Funded by NASA.*)

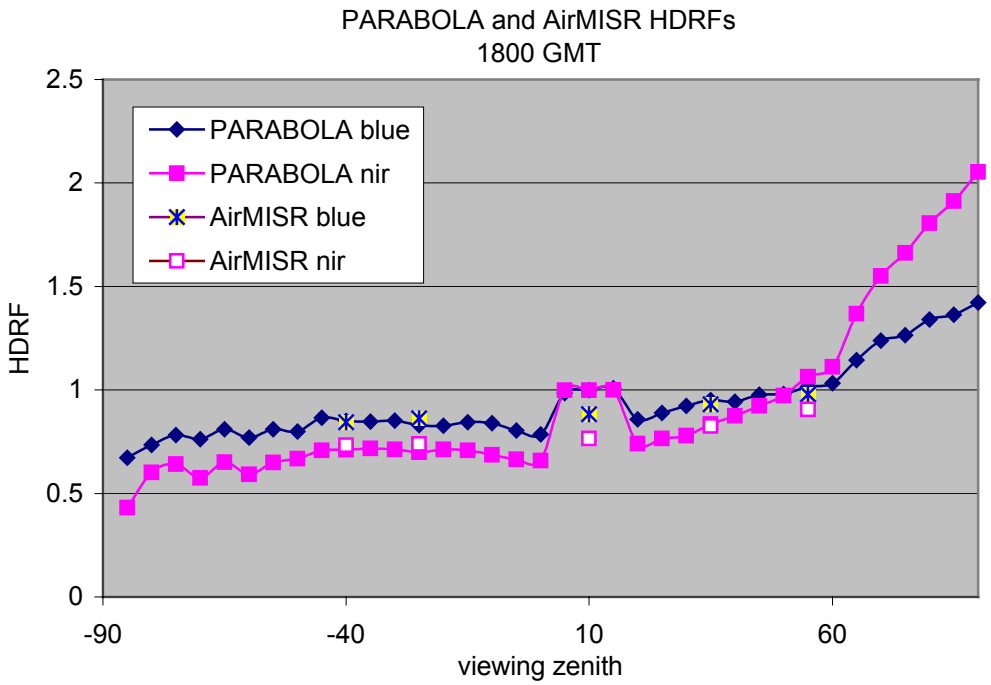

Figure 7. Hemispherical-directional reflectance factor (HDRF) values measured by PARABOLA and AirMISR. In the near-infrared channel, snow is more forward scattering than in the blue channel, causing the higher peak reflectance at oblique viewing angles. The "bump" in the middle is the reflectance off of the Spectralon reference panel.

Multispectral Mapping of the Martian Polar Ice Caps. During the third year of this project we have focused on mapping ice and frost on craters and edge regions of the North Polar Cap using data from the Mars Orbiter Camera (MOC) and Mars Orbiter Laser Altimeter (MOLA). We see clear indications of differences in ice and frost areas on the craters, with frost-covered residual ice in the crater centers and thin frosts on the crater rims (Figure 8). In the cap edge region, compositional differences appear to be related to the proximity to dark dust regions, implying a single ice type with varying dust concentrations. Multi-temporal observations of changes in the composition of Martian crater ices and cap edge ices will provide an improved understanding of the cycling of CO2 in the Martian atmosphere. (*A. Nolin, P.I., W. Farrand, Co-I. Funded by NASA*)

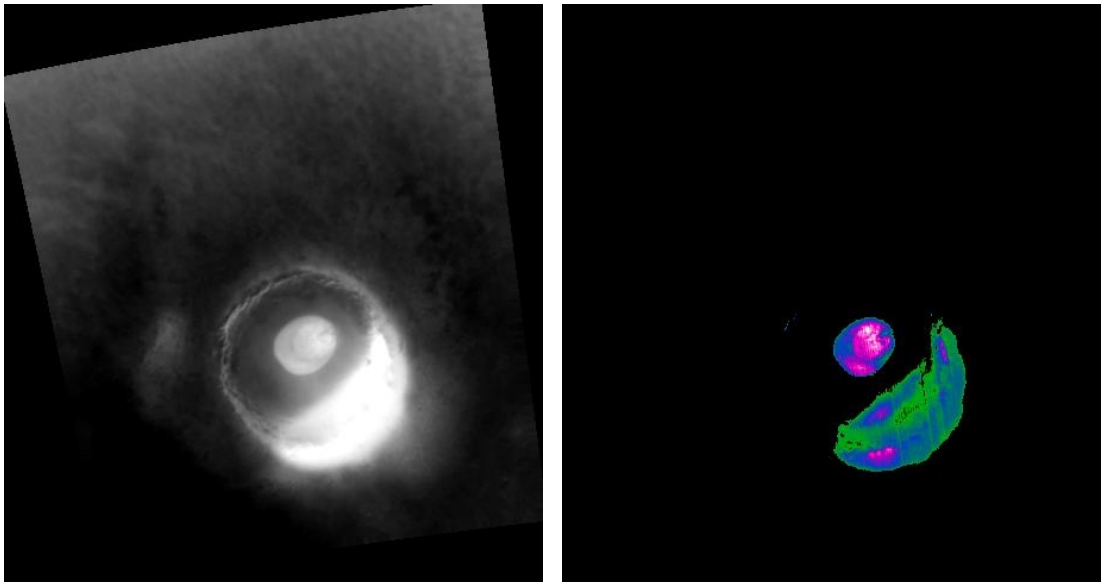

Figure 8. MOC red channel image of an icy crater on the high northern plains of Mars (left). The linear spectral unmixing image (right) indicates that the ice at the center of the crater is frost-covered residual ice (in pink). The green and blue areas show thin frost-covered portions of the crater, particularly along shaded portion of the crater rim.

Local, Regional, and Remote Effects of Northern Hemisphere Snow Cover on Western U.S. Climate and Water Resources. In work with Sue Marshall (University of North Carolina, Charlotte) and Robert Oglesby (NASA-Marshall SFC), we performed several climate model experiments aimed at understanding the predictability of snow cover based on a specified initial state. These results indicate a moderate level of skill in predicting surface air temperature and snow water equivalent at sub-seasonal time scales. Albedo-temperature feedbacks responsible for this predictability are most pronounced for late winter and spring snow cover anomalies. An extension of this work for Eurasia is now underway. Martyn Clark and Fiona Lo have analyzed the relationship between spring snow mass in the mountain areas of the western U.S. and summer monsoonal precipitation in the southwestern U.S. We have confirmed an inverse relationship exists between snow-monsoon precipitation using snow water equivalent and July-August precipitation station data for the period 1948-1997. Graduate student Eileen McKim has investigated the intraseasonal variability of the North American Monsoon System (NAMS) that shows alternating periods of widespread, heavy thunderstorm activity (bursts) and drier periods (breaks). Wavelet analysis of precipitation data indicate characteristic 10-20 day and 30-50 day periodicities in monsoon precipitation, similar to that seen in the Eurasian monsoon (Figure 9). Continued efforts are focusing on understanding the synoptic controls for the observed periodicities in the NAMS. (*A. Nolin, P.I., M. Clark, M. Serreze, M. Hoerling, S. Marshall, Co-I's. Funded by NSF*)

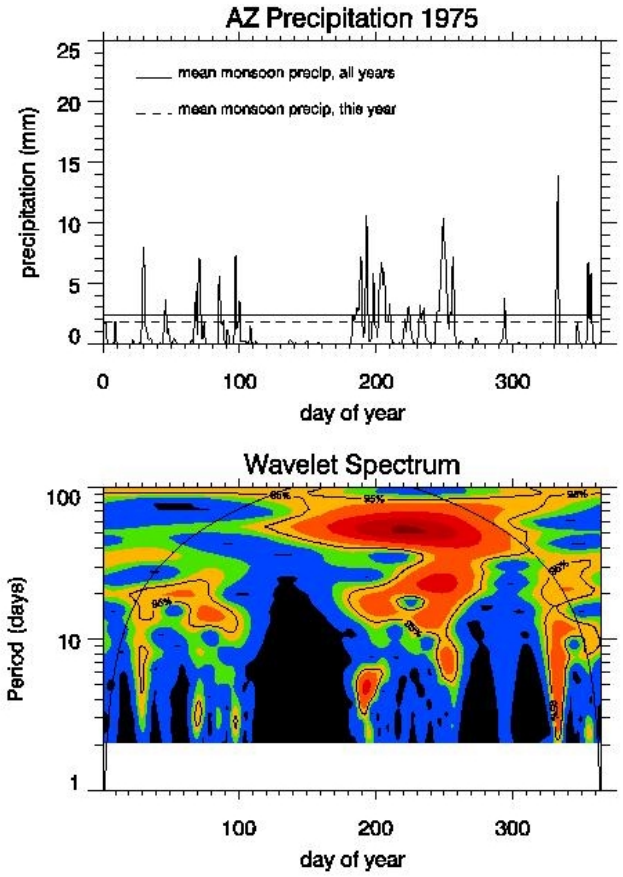

Figure 9. Arizona precipitation data for 1975 (upper plot) and the wavelet spectral analysis (lower plot) showing statistically significant periodicities at 10-20 days and 30-50 days.

Advancing Glaciological Applications of Remote Sensing with EO-1 (See entry under Scambos)

NASA Southwest Regional Earth Science Applications Center (See entry under Barrett)

Collaborative Research: A Hydrological Observing System for the Pan-Arctic Landmass (See entry under Serreze)

Advancing Glaciological Applications of Remote Sensing with EO-1. (See entry under Scambos)

Christoph Oelke

ArcticRIMS project: Regional Integrated Hydrological Monitoring System for the Pan-Arctic Land Mass. In this contribution to the Arctic-RIMS (Rapid Integrating Monitoring System) project, a finite-element one-dimensional heat-transfer model is applied to simulate soil freeze/thaw processes for the Arctic drainage area. Reanalyzed

NOAA National Center for Environmental Prediction (NCEP) surface temperature with a topography correction and SSM/I-derived snow thickness are the main forcing parameters. Soil bulk density and composition (sand, gravel, silt, and clay) are from the Soil Data System of the International Geosphere Biosphere Project, and an annual snow density cycle for different snow classes is taken from a Cryosphere System in Canada (CRYSYS) data set. Active layer depth (ALD) and frozen ground depth (FGD) are calculated for the period September 1998 through December 2000 on the 25 km NSIDC EASE-Grid with a daily time step. Figure10 shows the maximum ALD calculated for the thawing season of 2000. Results are compared to measurements of maximum active layer depth at Circumpolar Active Layer Monitoring Network (CALM) field sites located in continuous permafrost areas.

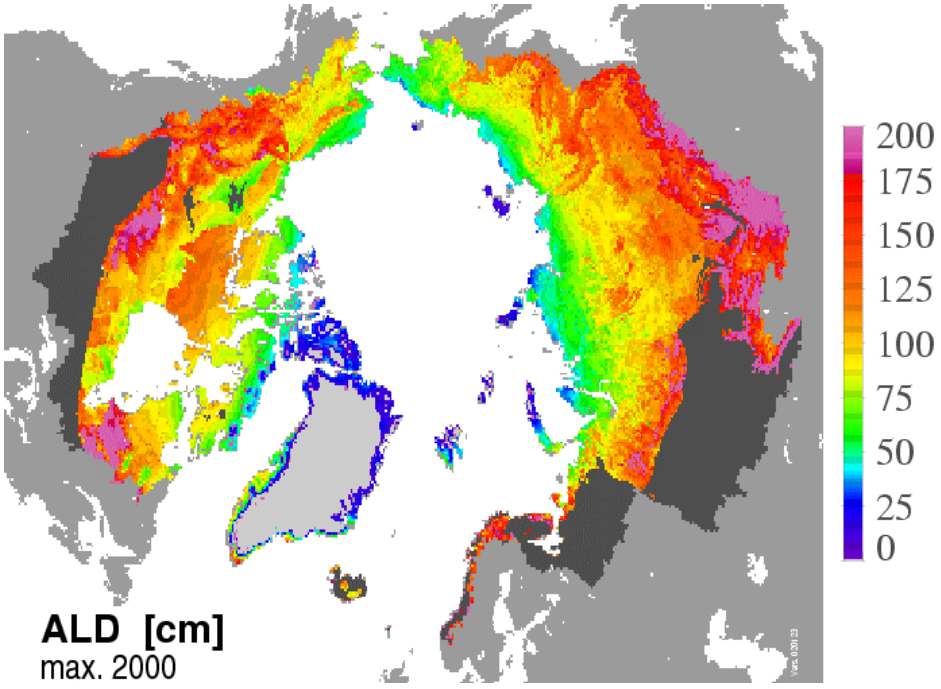

Figure 10. Maximum active layer depth in centimeters for 2000, based on a finite-element heat-transfer model.

Ted Scambos

History and Evolution of the Siple Coast Ice Stream System as Recorded by Former Shear Margin Scars The last thousand years have seen remarkable changes in ice flow from a large portion of the West Antarctic Ice Sheet – the portion that drains into the Ross Ice Shelf. These changes are revealed by remnant flow-related features identified in satellite images. A program of remote sensing analysis and field mapping of ice flow and internal layering has been funded by a NSF grant to the University of Colorado and University of Washington. Initial field work and post-field analysis have revealed several former flow margins and have refined the timing of shutdown of the formerly active flows. GPS topographic measurements and ice motion surveys indicate the vertical scale of the remnant flow features and their residual ice flow speeds. The end result will be a better picture of the recent history of the West Antarctic Ice Sheet and, from that, a better

idea of its near-term evolution in the future. *(T. Scambos, P.I., C. Raymond and H. Conway, Co-Is. Funded by NSF-OPP)*

Ice Shelves and Landfast Ice on the Antarctic Perimeter: Characteristics and the Effects of Climate Change Determined by Remote Sensing. In the past few years I and my colleagues (Mark Fahnestock of University of Maryland and Christina Hulbe of Portland State University) have been conducting a study of the recent history of the Larsen 'A,' Larsen 'B,' and Wilkins Ice Shelves. These ice shelves have been retreating rapidly as a result of climatic warming in the Antarctic Peninsula. We have proposed a detailed model for ice shelf breakup based on the effect of summer melt ponds on crevasse propagation within the shelf. We made extensive use of NSIDC's archive of satellite images of the ice shelves in both tracking the shelf breakup history and determining the root causes of disintegration. Melting to the point of ponding on the surface appears to be an important precursor to ice shelf breakups. With the advent of ponding, any crack formed on the surface fills to the brim with meltwater. Modeling of shelf behavior and of ice crack propagation shows that, if brim-full, crevasses as shallow as 5 to 15 meters will rapidly propagate through the shelf, weakening it and eventually leading to breakup. Another requirement is that the shelf regions with the ponding have relatively low compressive stresses acting on the ice – otherwise, the initial cracks do not form. The implication is that any shelf area with the appropriate stress regime that reaches a mean January temperature of ~0C is susceptible to rapid disintegration. This places several important ice shelves, such as the Larsen 'C,' Fimbul, and Ross, much closer to their climatic stability limit than was earlier estimated. Further, some of these shelves lie in front of major glacier systems draining the Antarctic and act as a 'braking system' for them. If these larger areas should undergo a warming of 2 to 4 degrees C, (as has occurred in the Antarctic Peninsula over the last 50 years), the ice shelves may rapidly retreat, causing an increase in outflow of ice from Antarctica and an increase in the rate of sea level rise. This project is now making extensive use of MODIS imagery to monitor ice shelves for extent, evidence of surface ponding, and surface temperature mapping. *(T. Scambos, P.I., C. Hulbe, Co-I. Funded by NASA-ESE)*

Characterizing the Siple Coast Ice Stream System using Satellite Images, Improved Topography, and Integrated Aerogeophysical Measurements. Photoclinometry is applied to the refinement of Digital Elevation Models (DEMs) over ice sheets in a new approach that uses existing low-resolution DEM information to calibrate the imagery and generate a higher-resolution elevation model. Both techniques are now described in several recent papers submitted by Ted Scambos in collaboration with Geir Kvaran (a geography graduate student), Mark Fahnestock, and Terry Haran. Over the last year, the technique was used to generate the most accurate DEM of Greenland to date, adding considerable detail at ~1km horizontal scale and ~1.5 meter vertical accuracy to the best current DEM, provided by KMS of Denmark. New details revealed in the topography include sub-ice drainage features, possible sub-ice volcanic edifices, and a better representation of the undulations on the flanks of the ice sheet. We plan to use this DEM to investigate the effect of topography on mean annual surface temperature, and to attempt to map the bedrock features of Greenland by inverting the surface topography

and flow characteristics for bedrock structure. *(T. Scambos, P.I., D. Morse, Co-I. Funded by NASA-ESE)*

Advancing Glaciological Applications of Remote Sensing with EO-1. A group of scientists at NSIDC have been evaluating the effectiveness of a suite of new sensors flying on the EO-1 satellite for mapping snow grain size, snow albedo, and ice sheet morphology. The sensor suite, conceived as possible instruments for a 'next generation' Landsat satellite, includes a high-spatial-resolution, high signal-to-noise sensor, Advanced Land Imager (ALI), and a hyperspectral sensor with 220 channels spanning the visible and near infrared spectrum, Hyperion. With Hyperion, we have investigated the potential of measuring albedo by first determining grain size of the surface snow, which is determined by evaluating the area of an absorption feature in the near-infrared portion of the spectrum that is highly correlated with mean grain size. From this, we use radiative transfer model results to infer the entire reflectance spectrum of the surface snow (which also varies with grain size) and then calculate broad-band albedo. This method has the potential to provide more accurate albedo measurements because it avoids a number of problems surrounding the direct measurement of albedo related to viewing geometry and atmospheric effects. With ALI, we use the high signal-to-noise of the sensor, (i.e., its sensitivity to surface slope over smooth surfaces) to evaluate ice surface morphology and ice flow. Morphologically, we are mapping flow-related striping that is present on many of the ice shelves surrounding Antarctica. Using shape-from-shading, we determine a quantitative surface elevation profile across the flow stripes and track their evolution from upstream (where they are formed) to downstream on the shelf. From this work, we hope to gain insight into ice shelf stresses from the work. Ice flow is also mapped using ALI by mapping the distortion of groups of surface features that are formed in ice shear zones. Pairs of these images separated by a few months are compared, and a computer algorithm is used to track flow in unprecedented detail. *(T. Scambos, A. Nolin, J. Stroeve, P.I.s. Funded by NASA ESE)*

Mark Serreze

Collaborative Research: A Hydrological Observing System for the Pan-Arctic Landmass. This effort addresses monitoring and historical analysis of components of the pan-Arctic terrestrial water budget. The project contains both a NSF and a NASA component. The NSF component is a collaborative effort between the University of Colorado (CU), the University of New Hampshire (UNH), (lead institution) and the Ohio State University (OSU). The NASA component includes collaboration between CU, UNH, OSU and the Jet Propulsion Laboratory, with CU being the lead institution. The project, known as Arctic-RIMS (Rapid Integrating Monitoring System), synthesizes station precipitation, observed river discharge, satellite data streams, hydrologic and thermal modeling, and output from the National Centers for Environmental Prediction - National Center for Atmospheric Research (NCEP-NCAR) reanalyses. At time lags of approximately one month, updated fields of precipitation, surface air temperature, moisture flux convergence, active layer thickness, snow water equivalent and near-surface freeze-thaw status are assembled. Precipitation and temperature represent inputs into a Permafrost/Water Balance Model (P/WBM). The P/WBM outputs fields of evapo-transpiration, soil moisture, shallow groundwater storage and runoff, and simulated river

discharge. The output fields represent variables for which direct observations are scanty. The simulated river discharge provides estimates of freshwater input to the Arctic ocean from the un-gauged portions of the Arctic drainage. In turn, comparisons between simulated discharge and observed values provide estimates of water budget closure. All Arctic-RIMS spatial fields are being assembled at 25x25 km equal-area grids over a domain covering the entire terrestrial Arctic drainage. Using P/WBM in conjunction with surface records, thermal models, atmospheric reanalysis, and available satellite information, budget variables are being compiled back to 1960 to provide a historical baseline. Arctic-RIMS data will be posted on a web site maintained by University of New Hampshire. Long-term archives will also be available from the NSF/ARCSS Data Coordination Center. *(M. Serreze, P.I., R. Armstrong, R. Barry, Co-I's. Funded by NSF)*

Collaborative Research: Hydro-Climatology of the Major Eurasian Arctic Drainages. This project addresses the large-scale hydro-climatology of the terrestrial Arctic drainage system, with a focus on the primary Eurasian watersheds (the Ob, Lena, and Yenisey). It is a collaborative effort between the University of Colorado (lead institution) and the Ohio State University. Station data are used to compile monthly gridded time series of gauge-corrected precipitation (P). Gridded time series of precipitation minus evapotranspiration (P-ET) are calculated from the moisture flux convergence using data from the National Centers for Environmental Prediction - National Center for Atmospheric Research (NCEP-NCAR) reanalysis. Estimates of ET are obtained as a residual. Runoff is obtained from available discharge records. Studies have included analysis of the mean seasonal cycles, variability and trends in P, P-ET and runoff, and their linkages with the atmospheric circulation. As examples of notable findings, variability in P and P-ET over the Ob exhibit strong links with the Urals trough. Water year time series of runoff and P-ET are strongly correlated in the Lena only, reflecting extensive permafrost. Cold-season runoff has increased in the Yenisey and Lena. The mechanisms for these changes in the Yenisey are not entirely clear. While they fundamentally relate to higher air temperatures, increased winter precipitation, and strong summer drying, we speculate possible links with changes in active layer thickness and thawing permafrost. *(M. Serreze, P.I., M. Clark, R. Barry, Co-I, with D. Bromwich, P.I., Byrd Polar Research Center, Ohio State University. Funded by NSF)*

Julienne Stroeve

Assessment of Greenland Outlet Glacier Variability. This project examines the variability in the surface albedo from the AVHRR Polar Pathfinder (APP) Project at four outlet glaciers in Greenland: Kangerdlugssuaq, Storstrommen, Petermann, and Jakobshavn. Progress to date includes extracting surface albedo from the APP data set and cloud filtering all the images to obtain clear-sky surface albedo estimates. Monthly means and deviations of the means have been computed. For example, the figure below shows a time-series of the deviation from the mean surface albedo during July at the Kangerdlugssuaq glacier in southeast Greenland derived from the 5-km APP data. Negative numbers refer to anomalously low surface albedos and, hence, warmer temperatures. This glacier has witnessed thinning rates of as much as 10 meters per year in recent years. The albedo record at Kangerdlugssuaq shows large interannual variability, with low surface albedo occurring in 1988, 1991, and 1995. Similarly, the

surface temperature record from AVHRR shows anomalously high temperatures during the same years. Thus, some of the thinning at this glacier could be a result of increases in ablation rates resulting from warmer temperatures that subsequently lowered the surface albedo and resulted in more ablation during the summer months. Further work will focus on assessing the albedo variability at each glacier and how examining the albedo changes correspond to mass balance changes at each glacier. *(J. Stroeve, P.I. Funded by NASA)*

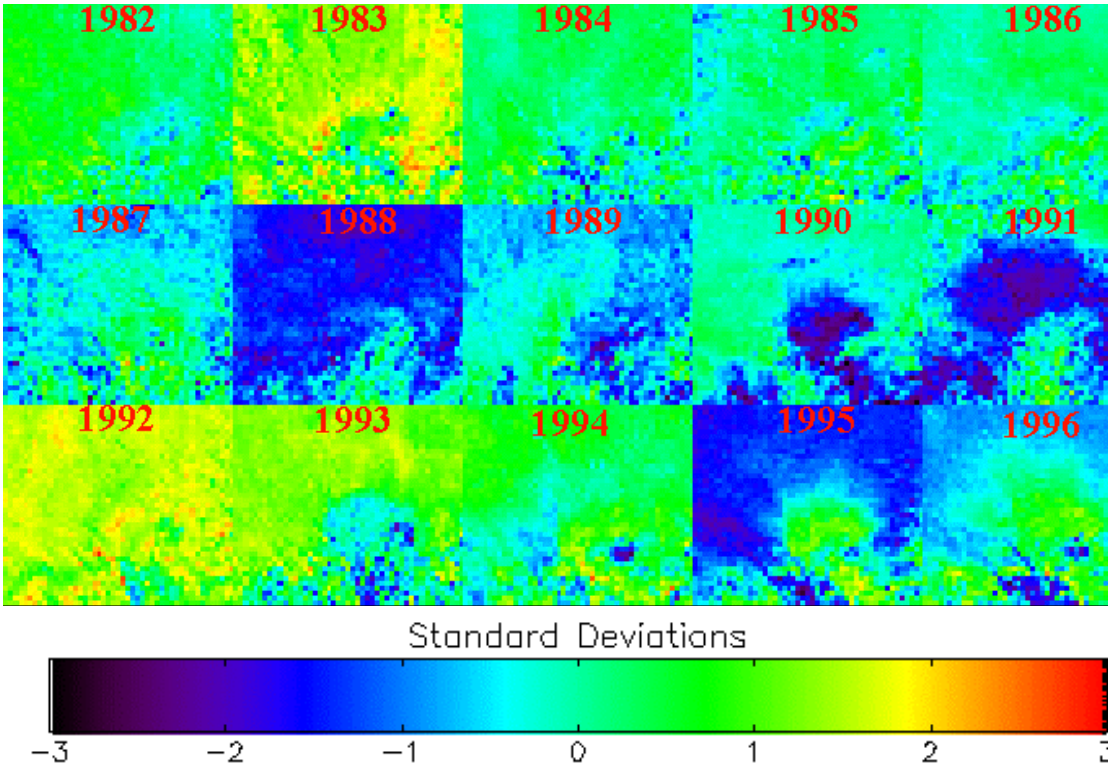

Figure 11. Deviations from the mean albedo during July from 1982 to 1996 near the Kangerdlugssuaq glacier. Negative numbers refer to anomalously low surface albedo and, hence, warmer temperatures, whereas the reverse is true for positive numbers.

Validation Studies and Sensitivity Analyses for Retrieval of Snow Albedo from EOS AM-1 Instruments. This project involves retrieving the surface albedo from the MODIS and MISR instruments. Comparisons between MODIS and MISR-derived surface albedo and *in situ* measurements in Greenland continue. A narrow-to-broadband conversion is being developed and tested for both MODIS and MISR, allowing for intercomparison of broadband albedo retrievals between the two instruments. This relationship is complicated by the fact that the conversion from narrowband to broadband albedo depends not only on surface conditions, but also on atmospheric conditions. Another complication is that the narrowband albedos are highly intercorrelated, with the consequence that a narrow-to-broadband albedo equation may perform badly when implemented on data independent of the training sample. Results from comparing MODIS-derived surface albedo with *in situ* measured surface albedo at the ETH/CU (69.5^{o}N, 49.5^{o}W, elev. 1150m) and the Summit (72.5^{o}N, 38.5^{o}W, elev. 3220m) stations in Greenland show that MODIS-derived surface albedo are accurate as long as the viewing angles are not too oblique. Two different broadband albedo from MODIS data

are derived: one using a linear combination of channels 1 and 2 (similar to AVHRR) and one using a linear combination of channels 3-5. Both these models give similar results. Discrepancies at very oblique viewing angles may be a result of problems in the angular model accurately accounting for the variation of the HDRF with sensor zenith angle. More MODIS data are needed for further intercomparisons to fully assess the accuracy of the MODIS albedo retrievals. Similar comparisons were made using the nadir MISR data to derive the broadband albedo. Agreement between the MISR-derived and *in situ* measurements was found (within 5%). Future work will focus on validating the angular model used in this study, further validation of narrow-to-broadband conversions, and processing more MODIS and MISR data for intercomparisons. *(A. Nolin, P.I., J. Stroeve, Co-I. Funded by NASA)*

Evaluation and Error Assessment of Operational Passive Microwave Sea Ice Algorithms. The purpose of this project is to quantify the sensitivity of satellite-derived sea ice concentrations to changes in ice physical properties, atmospheric conditions, and instrument-related factors. Three commonly used algorithms, two of which are used to produce sea ice data sets distributed by NSIDC, were evaluated using model sensitivity tests. For thin bare ice, ice density, air pocket size, ice thickness (up to about 0.1 m), and salinity of the ice are the most important determinants of passive microwave signature. For thicker ice with snow cover, free-water content of the snow, air pocket size, snow density, snow thickness, and snow grain size are important. All algorithms are sensitive to ice thickness up to about 2 cm. For thicker ice, the Bootstrap algorithm performs better than the NASA Team algorithms. For sea ice with snow cover, oscillations in the NASA Team algorithm sea ice concentrations occur as a result of the oscillations in the H-polarized brightness temperatures. This channel exhibits greater sensitivity to small-scale variations in snow depth, although both polarizations show an overall decrease in brightness temperature with increasing snow depth. Saturation with snow depth occurs at about 15 cm at 85 GHz. In general, the NASA Team algorithm shows stronger sensitivity to small-scale changes in surface conditions than the Bootstrap sea ice algorithm. This sensitivity is decreased with the use of the Enhanced NASA Team algorithm. Ice concentrations show less sensitivity to variations in atmospheric conditions, such as cloud type. Since both cloud liquid water content and precipitable water vapor effects are most pronounced at 85 GHz, reduced sensitivity is expected. Only the NASA Team algorithm shows some dependence on the cloud type. The enhanced NASA Team algorithm improves upon the original NASA Team algorithm by providing weather-corrected sea ice concentrations by using a forward atmospheric radiative transfer model. *(J. Stroeve, P.I., J. Maslanik, T. Marcus, Co-I's. Funded by NASA)*

Advancing Glaciological Applications of Remote Sensing with EO-1
(see entry under Scambos)

Validation of AMSR-E Polar Ocean Products Using a Combination of Modeling and Field Observations (see entry under Maslanik)

Tingjun Zhang

Stochastic Variability of Seasonal Freezing and Thawing at Local, Regional, and Hemispheric Scales under Modern and Predicted Climate. Through this international collaboration, we received soil temperature data from Russia for about 100 meteorological stations. We also collected data sets including air temperature, precipitation, snow cover, soil type, vegetation, and soil moisture to support the related project of Prof. Fritz Nelson (University of Delware). Preliminary analyses of the historical near-surface soil temperature measurements from 250 stations in the former Soviet Union indicate that mean annual soil temperature at 40 cm depth has increased by about 0.9^{o}C from 1930 to 1990. The increase is more pronounced from 1970 to 1990. Further analyses show that the increase is largest, during winter months (DJF) about 1.8^{o}C over the period of the record; followed by spring (MAM), about 1.0^{o}C. Corresponding changes in summer (JJA) and autumn (SON) are slightly less than 0.4^{o}C. On an annual basis, changes in soil temperature followed the pattern of changes in air temperature with some modification due to precipitation. In winter months, changes in soil temperature correlated positively with changes in air temperature and winter precipitation (presumably snowfall). Variations in snow cover thickness affect soil temperature due to snow insulation effects. In summer, changes in soil temperature are probably mainly controlled by precipitation (presumably rainfall), since air temperature exhibits little variability. There is an anti-correlation between soil temperature and summer precipitation (rainfall). This is because of the so-called soil moisture feedback mechanism, assuming that an increase in rainfall will increase the near-surface soil moisture. Although soil temperature increased about 1.0^{o}C during spring months over the period of record, there are no clear relationships between soil temperature, air temperature, and precipitation. Other factors, such as the timing of snowmelt and near-surface soil moisture, may play roles in affecting soil temperature. Further analyses are needed to understand fully the response of soil temperature to changes in climate variables. (*T. Zhang, P.I., R. Barry, Co-I. Funded by NSF)*

Investigation of the Seasonal Freeze/Thaw Cycles of Soils in the GCIP Region. In this study, the timing, duration, and extent of surface soil freeze/thaw cycle were investigated using passive microwave satellite remote sensing data combined with ground-based measurements and numerical modeling in the Northern Hemisphere. Three different algorithms were validated against ground-based measurements from more than 20 stations throughout the contiguous United States over two years. Different cut-off brightness temperatures were used for different land surface type and vegetation. Results indicate that frozen soil algorithms can predict the near-surface soil freeze/thaw cycle with accuracy of 90% or better. Generally, the onset of surface soil freezing starts in September or October at high latitude/altitude regions, and in December or even January over middle latitude lowlands. The last day of surface soil freezing ranges from February or March in middle latitude regions to May or June at high latitude/altitude regions. These results show that the duration of surface soil freezing varies from a few weeks to several months. The number of days that surface soil actually experiences freeze/thaw cycles varies from a few days to more than five months. Surface soil experiences freezing

before snow covers the surface. However, the frozen soil may disappear quickly after a steady snow cover is established over the freezing surface, especially in the middle latitudes. For the period from 1988 through 2000, more than 50% of the land surface in the Northern Hemisphere was either snow-covered or experienced freeze/thaw cycles. (*T. Zhang, P.I., R. Armstrong, Co-I. Funded by NOAA)*

Application of Satellite SAR Imagery in Mapping the Active Layer of Arctic Permafrost. This project intends to map the arctic and subarctic active layer using Interferometric Synthetic Aperture Radar (INSAR) data. Information on surface albedo and the timing of snowmelt is required. For this purpose, spatial and temporal variations of surface albedo were investigated using both ground-based tower measurements and satellite remote sensing data of the North Slope of Alaska. We use ground-based measurements of incident and reflected solar radiation at several stations along the Dalton Highway over the period 1985 to 1998 to determine in situ surface albedo. AVHRR-derived surface albedo is obtained from AVHRR Polar Pathfinder products using a modified cloud mask. AVHRR-derived surface albedo agrees closely with *in situ* measurements. Results from this study indicate that surface albedo varies from greater than 0.9 for snow-covered land surface under overcast conditions to less than 0.1 for wet tundra land surface. Five distinct periods are discerned, based on seasonal variations of surface albedo: winter stationary period, spring snowmelt period, post-snowmelt, summer stationary, and autumn freeze-up period. Spatially, we divide the North Slope into three zones: mountain, foothills, and coastal zones. This study suggests that the heat island effect in the vicinity of Barrow is very minimal. Progressive earlier snow cover disappearance at the Barrow National Weather Service station may be an indication of regional spring warming. This study also suggests that snow surface albedo in land surface models should be treated differently for snow at high latitudes as compared with snow in middle latitudes, especially during winter months. (*T. Zhang, P.I. Funded by NASA)*

Hydrologic Response of Siberian Major Rivers to Climate Change and Variations. Long-term temperature, precipitation, and river streamflow records have been analyzed to examine the hydrologic regime of large Siberian rivers (Lena, Yenesei, and Ob Rivers) and their response to climate change and variation. This study found significant changes in hydrologic characteristics over Siberia. The Ob River winter runoff has increased by 30 to 40 percent, and the summer runoff has risen in July by 10 percent. There is a clear tendency, particularly during the 1980s and 1990s, toward peak streamflow of the Ob River in July, August, and September. This shift of the Ob River's maximum monthly discharge toward late summer may be a response of the river system to intensified summer rainfall over western Siberia. Yenesei River summer runoff has decreased by 20 to 30 percent and winter discharge has increased by 35 to 110 percent. Lena River snowmelt starts early due to strong warming in spring season, resulting in an increase of discharge in May and a decrease of runoff in June. Mid-summer runoff has not changed significantly for the Lena River, but the winter runoff has increased by 25 to 80 percent mainly due to changes in river ice and permafrost conditions. The changes identified in this study are very likely the consequence of recent climate warming over the Siberian regions and are closely related to change in permafrost. Warming in Siberia results in

higher permafrost temperatures and a deeper active layer. The thicker active layer increases groundwater storage and results in a greater contribution of subsurface water to the river systems and greater winter season runoff. Future research will focus on identifying the changes in hydrologic regimes in different sub-basins of the watersheds, and on examining the inter-annual variation of monthly discharge/river ice and their responses to climate and atmospheric circulation. Development of a coupled regional climatic-hydrologic model is also necessary to better understand and quantify the complex land-atmosphere interaction and feedback. *(D. Yang, P.I., T. Zhang, Co-I. Funded by the Cooperative Institute for Arctic Research, UAF)*

The Role of Shallow Tundra Lakes in Arctic Land-Atmosphere Interactions and Feedbacks (See entry under Ling)

PUBLICATIONS and PRESENTATIONS

NSIDC employees are indicated by bold type.

Publications

Allison, I., **R. Barry**, B. Goodison. (eds). 2001. Climate and Cryosphere (CliC) Project. Science and Co-ordination Plan, Version 1. WCRP-114, WMO/TD No. 1053. World Climate Research Programme, Geneva, 75 pp.

Armstrong, R. and **M. Brodzik**, 2001, Recent Northern Hemisphere snow extent: a comparison of data derived from visible and microwave satellite sensors. *Geophysical Research Letters, Vol. 28, No.19*. pp. 3673-3676.

Armstrong, R. and **M. Brodzik**, 2001. Validation of passive microwave snow algorithms, remote sensing and hydrology 2000. *IAHS Pub. No. 267*, Eds. M. Owe, K. Brubaker, J. Ritchie and A. Rango. pp. 87-92.

Barrett, A., G. Leavesley, R. Viger, **A. Nolin, M. Clark**. 2001. A comparison of satellite-derived and modelled snow-covered area for a mountain drainage basin. In M. Owe, K, Brubaker, J. Ritchie and A. Rango. Remote Sensing and Hydrology 2000. *IAHS Publ. No. 267*, 569-573.

Barry, R. 2001. Snow cover, in A. S. Goudie (ed in chief) Encyclopedia of Global Change, Vol 2, Oxford University Press, pp. 380-82.

Barry, R. 2001. The cryosphere. Mountain climates. in T. Munn, (ed-in chief), Encyclopedia of Global Environmental Change, Vol. 1, The Earth System: physical and chemical dimensions of global environmental change (Volume Editors: M C MacCracken and J S Perry), J Wiley and Sons, Chichester, UK, pp. 330-31; and 540-41.

Barry, R. 2001. Dynamic and Synoptic Climatology, Ch. 5 in A. Orme (ed) "The Physical Geography of North America," Oxford University Press, pp. 98-111.

Barry, R. and A. Carleton. 2001. "Synoptic and Dynamic Climatology," Routledge, London, 620 pp.

Barry, R. and T. Zhang. 2001. Distribution of frozen ground in the Northern Hemisphere. In Materialy. Vtoroi Konferentsii Geokriologov Rossii, Tom 3: (Proceedings of the 2nd Russian Conference on Geocryology, Vol. 3). Regional and Historical Geocryology. Moscow University Press, pp. 285-86

Brown, J., W. Haeberli, **R. Barry**, and F. Nelson. 2001. The proposed international permafrost monitoring network and service. In R. Paepe and V. Melnikov, (eds). "Permafrost Response on Economic Development, Environmental Security and Natural Resources," *Kluwer Academic*, pp. 601-606.

Hall-McKim, E., **A. Nolin, F. Lo, M. Serreze, M. Clark**, 2001. Frequency analysis of intraseasonal variations in the North American Monsoon System. *13th Symposium on Global Change and Climate Variations, 82nd Annual Meeting of the AMS*, Orlando Florida, No. 14.2.

Key, J., X. Wang, **J. Stroeve, C. Fowler**, 2001. Estimating the cloudy sky albedo of sea ice and snow from space. *Journal of Geophysical Research-Atmospheres*, 106 (D12), 12,489-12,497.

Lazzara, M., K. Jezek, **T. Scambos**, D. MacAyeal, C. van der Veen, 1999. On the recent calving of icebergs from the Ross Ice Shelf. *Polar Geography 23(3)*, 201-212. (Out in 2001).

Marshall, S., R. Oglesby and **A. Nolin**, 2001. Effect of western U.S. snow cover on climate. *Annals. Glaciol*, 32, 82-86.

Nolin, A., and A. Frei, 2001. Remote Sensing of Snow and Snow Albedo Characterization for Climate Simulations. In Beniston, M. and M. M. Verstraete (Eds.), Remote Sensing and Climate Simulations: Synergies and Limitations, Advances in Global Change Research, *Kluwer Academic Publishers*, Dordrecht and Boston, pp. 159-180.

Nolin, A., J. Stroeve, T. Scambos, F. Fetterer, 2001. Cryospheric applications of MISR data. Proceedings of the International Geoscience and Remote Sensing Symposium '01, Sydney, Australia, issued on CD-ROM.

Nolin, A., A. Frei, and S. Pitter, 2001. Assessment of modeled snow cover from general circulation models. Proceedings of the Annual Meeting of the Association of American Geographers, issued on CD-ROM.

Nolin, A., A. Frei, and S. Pitter, 2001. Assessment of modeled snow cover from general circulation models. Proceedings of the American Meteorological Association, 12th Symposium on Global Change and Climate Variations, 128-129.

Pitter, S. and **A. Nolin**, 2001. Improving western United States snow water equivalent estimates from passive microwave sensors. 16th Conference on Hydrology, 82nd Annual Meeting of the AMS, Orlando Florida, No. 3.1.

Scambos, T., 2001. Book Review: The West Antarctic Ice Sheet, Behavior and Environment. *Antarctic Science* 13(2) 221-223.

Scambos, T., C. Hulbe, M. Fahnestock, and **J. Bohlander**. 2001. The link between climate warming and break-up of ice shelves in the Antarctic Peninsula. *Journal of Glaciology*, vol. 46, no. 154, pp. 516-530

Serreze, M., M. Clark, A. Etringer and D. Bromwich, 2001: Variability and trends in the hydro-climatology of the major Eurasian Arctic drainages, in Extended Abstracts, Second Wadati Conference on Global Change and the Polar Climate, March 7-9 2001, Tsukuba Science City, Japan, pp. 83-86.

Serreze, M., A. Lynch and **M. Clark**, 2001: The Arctic frontal zone as seen in the NCEP/NCAR Reanalysis, *Journal of Climate*, 14, 1550-1567.

Sokratov, S., V.Golubev, and **R. Barry**. 2001. The influence of climate variations on the thermoinsulation effect of snow cover and on the temperature regime in the underlying soil. (in Russian). *Kriosfera Zemli*, 5(2): 83-91.

Stocker, T., G. Clarke, and 9 Lead Authors (eds); 56 Contributing Authors incl. **R. Barry**. 2001. Physical Climate Processes and Feedback, Ch. 7. In J.T. Houghton and 7 others (eds) "Climate Change 2001. The Scientific Basis," Cambridge University Press, pp. 417-470.

Stroeve, J., T. Markus and **J. Maslanik**, 2001. Sensitivity analysis of operational passive microwave sea-ice algorithms, Proceedings of the International Geoscience and Remote Sensing Symposium, Sydney, Australia. pp. 1798-1799.

Stroeve, J. 2001. Assessment of Greenland albedo variability from the AVHRR Polar Pathfinder Data set, *Journal of Geophysical Research-Atmospheres,* 106(D24), 33,989-34,005.

Stroeve, J., J. Box, C. Fowler**, T. Haran**, and J. Key, 2001. Intercomparison Between *in situ* and AVHRR Polar Pathfinder-derived Surface Albedo over Greenland. *Remote Sensing of the Environment*, 75/3,360-374.

Zhang, T. and R. Armstrong, 2001. Soil freeze/thaw cycles over snow-free land detected by passive microwave remote sensing. *Geophysical Research Letters*, 28(5): 763-766.

Zhang, T., 2001. Book review: Geocryology in China by Y. Zhou et al. Permafrost and Periglacial Processes, 12, 315-322.

Zhang, T., 2001. Book review: Geocryology in China by Y. Zhou et al. Arctic, Antarctic, and Alpine Research, 33(2), 244-247.

Zhang, T., R. Barry, and W. Haeberli, 2001. Numerical simulations of the influence of the seasonal snow cover on the occurrence of permafrost at high latitudes. *Norsk Geografisk Tidsskrift (Norwegian Journal of Geography)*, 55(4): 261-266.

Zhang, T., R. Barry, D. Gilichinsky, S. Bykhovets, V. Sorokovikov, and J. Ye, 2001. An amplified signal of climatic change in soil temperature during the last century at Irkutsk, Russia, *Climatic Change*, 49: 41-76.

Zhang, T., K. Stamnes, and S. Bowling, 2001. Impact of the atmospheric thickness on the atmospheric downwelling longwave radiation and snowmelt under clear-sky conditions in the Arctic and Subarctic. *Journal of Climate*, 14(5): 920-939.

Presentations

Barry, R. and T. Zhang, 2001. Distribution of frozen ground in the Northern Hemisphere, International Permafrost Conference, Moscow State University, June, 2001.

Barry, R., 2001. The WCRP Cryosphere and Climate (CliC) Project -- a new opportunity for Hydroclimatology. Association of American Geographers, 97th Annual Meeting, New York, NY, March, 2001.

Barry, R., 2001. Mountain cryospheric studies and the WCRP CliC Project International Association of Hydrological Sciences, 6th Scientific Assembly on Water for a Thirsty Planet in Maastricht, Netherlands, July, 2001.

Barry, R., 2001. Climate Change and Cryospheric Reponses in the Mountains: a Review. World Mountain Symposium. Interlaken, Switzerland, Oct. 2001.

Drobot, S., **J. Maslanik**, and **C. Fowler**, 2001. Spatial and temporal variations in monthly averaged cloud cover based on AVHRR Polar Pathfinder data. *Proceedings of the AMS 6th conference on Polar Meteorology and Oceanography,* San Diego, CA, 14-18 May.

Khalsa, S., 2001. Facilitating Access to EOS Data at the NSIDC DAAC. *NASA Earth Science Technology Conference*, College Park, MD, 28-30 August.

Ling, F., and T. Zhang, 2001. Numerical Simulation of Thermal Regime of permafrost and Talik Formation under Shallow Thaw Lakes in the Arctic and Sub-Arctic. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-14 December.

Lo, F., M. Clark, 2001. The Influence of Snow Mass in Modulating the North American Monsoon Precipition. *American Meteorological Society, 12th Symposium on Global Change and Climate Variations*, Albuquerque, NM, 14- 19 January.

Marquis, M., 2001. Distribution of GLAS Data by NSIDC. *GLAS Science Team Meeting*, Scripps Institute, La Jolla, CA, 14-15 Feb.

Marquis, M., 2001. Management of AMSR-E and GLAS Data by NSIDC. *Polar DAAC Advisory Group (PoDAG) Meeting*, Boulder, CO, 25-26 April.

Marquis, M., 2001. Management of AMSR-E Data by NSIDC. *AMSR-E Science Team Meeting*, CU, Boulder, CO, 22-23 March.

Oelke, C., T. Zhang, M. Serreze, and R. Armstrong, 2001. Regional-scale modeling of soil seasonal freeze/thaw over the Arctic drainage basin, *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-14 December.

Parsons, M., 2001. Data Management for the Cold Land Processes Experiment. *Cold Land Processes Workshop*, Boulder, CO. 7-9 November.

Raup, B., G. Scharfen, S. Khalsa, A. Kaeaeb, 2001. The Design of the GLIMS (Global Land Ice Measurements from Space) Glacier Database. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-14 December.

Scharfen, G., S. Khalsa, 2001. Evaluation of the Year 2000 Arctic Ice Pack Using MODIS. *6th Conference on Polar Meteorology and Oceanography*, San Diego, CA, 14-18 May.

Stroeve, J., J. Maslanik, T. Markus, 2001. AMSR Validation Plans. *AMSR Validation Meeting,* NASA Goddard Space Flight Center, Greenbelt, MD, 3 August.

Weaver, R., 2001. NSIDC DAAC readiness status. *EOS IWG AQUA Working Group, IWG,* San Antonio, TX, 30 October.

Zhang, T., 2001 (invited), The role of frozen ground in climate system, Climatic Research Division, Chinese Meteorological Administration, Beijing, China, 19 September.

Zhang, T., 2001. Response of seasonally frozen ground to climatic change, Beijing University, Beijing, China, 6 September.

Zhang, T., 2001. Potential impact of seasonal freeze/thaw cycle of soils in climate system, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China, 12 September.

Zhang, T., R. Armstrong, and J. Smith, 2001. Investigation of near-surface soil freeze/thaw cycles in the GCIP regions, 2001 NOAA/NOAA GAPP PI Meeting, Washington, D.C., April 28 - May 3.

Zhang, T. and R. Barry, 2001, Numerical Simulations on the Influence of the Seasonal Snow Cover on the Occurrence of Permafrost, the 1st European Permafrost Conference, Rome, 26-30 March.

Zhang, T. and R. Barry, 2001. Distribution of frozen ground in the Northern Hemisphere, International Permafrost Symposium, Mongolia, 2-6 September.

Zhang, T. and R. Barry, and J. Brown, 2001. Global Geocryological Database (GGD): A continuing task of the international permafrost community, International Permafrost Conference, Pushchino, June.

Zhang, T. and R. Barry, and J. Brown, 2001. Global Geocryological Database (GGD): A continuing task for the international permafrost community, the 1st European Permafrost Conference, Rome, Italy, 26-30 March 26-30.

Zhang, T., T. Schambos, T. Haren, and S. Li, 2001. Spatial and temporal variations of surface albedo and snowmelt on the North Slope of Alaska, presented at the 2001 NASA/NOAA GAPP PI Meeting, Washington, D.C., April 28 - May 3.

Posters

Armstrong, R. L., M. J. Brodzik, M. Dyurgerov, **J. A. Maslanik, M. C. Serreze, J. Stroeve, T. Zhang,** 2001. The State of the Cryosphere - Response to Global Warming. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-14 December.

Bauer, R. J., Bohlander, J. A., Raup, B. H., and Scambos, T. A., 2001. Monitoring changes in the Antarctic ice sheet: the VELMAP and THERMAP projects at the National Snow and Ice Data Center. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-14 December.

Fetterer, F. and V. Radionov, 2001. An Arctic Meteorology and Climate Atlas on CD-ROM. *Proceedings of the AMS 6th conference on Polar Meteorology and Oceanography* San Diego, CA, 14-18 May.

Khalsa, S.J.S., and R. Weaver, 2001. Polar HDF-EOS Data Imaging and Subsetting Tool. *American Geophysical Union Spring Meeting*, Boston, MA, May 29-June 2.

Khalsa, S.J.S., G. Scharfen, R. Weaver, B. McLean, T. Haran, 2001. Early Assessment of the MODIS Snow Products and their Availability from the NSIDC DAAC. *NASA/EOS Investigators' Working Group (IWG) Meeting*, Ft. Lauderdale, Florida, Jan. 30 - Feb. 1.

Khalsa, S.J.S., G. Scharfen, B. McLean, 2001. Evaluation of MODIS Snow and Sea Ice Products at the NSIDC DAAC. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-15 December.

Lutz, B. and **M. Marquis**, 2001. An End-to-End Description of the Data Flow of AMSR-E and GLAS Data Products: Product Generation through Product Delivery to Users. *American Geophysical Union Conference*, San Francisco, CA, 10-15 December.

Machado, A.E., B. McLean, G. Scharfen, M.M. Holm, 2001. EOS Snow and Ice Products at NSIDC DAAC. *American Geophysical Union Spring Meeting*, Boston, MA, May 29-June 2.

Machado, A.E., G. Scharfen, R.G. Barry, S.J.S. Khalsa, B. Raup, R. Swick, V.J. Troisi, I.P. Wang. Global Land Ice Measurements from Space (GLIMS) and the GLIMS Information Management System at NSIDC. *American Geophysical Union Conference*, San Francisco, CA, 10-15 December.

Marquis, M., K. Barbieri, A. Brenner, D. Hancock, **T. Haran**, S. Palm, **V. Troisi**, **J. Wolfe**, H. Zwally, 2001. Geoscience Laser Altimeter System (GLAS) Data Products from NASA's Ice, Cloud, and Land Elevation Satellite (ICESat) Mission. *American Geophysical Union Conference*, San Francisco, CA, 10-15 December.

Marquis, M., D. Conway, **V. Troisi**, **R. Armstrong**, **J. Stroeve**, **J. Maslanik**, **Y. Axford, J. Wolfe**, 2001. Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) from NASA's Aqua Mission. *American Geophysical Union Conference*, San Francisco, CA, 10-15 December.

McLean, B., G. Scharfen, S.J.S. Khalsa, J. Wolfe, 2001. Accessing and Utilizing the MODIS Snow and Ice Products at the NSIDC DAAC for Cryospheric Research. *American Geophysical Union Fall Meeting*, San Francisco, CA, December 10-15.

Nolin, A. and A. Frei. 2001. Model Parameterizations of Snow Albedo. Annual meeting of the American Association of Geographers.

Nolin, A., B. Raup, T. Scambos, and J. Stroeve. 2001. Mapping Snow Grain Size and Albedo on the Greenland Ice Sheet Using an Imaging Spectrometer. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-15 December.

Parsons, M., T. Zhang, R.G. Barry, J. Brown, 2001. The Frozen Ground Data Center at NSIDC. *American Geophysical Union Conference*, San Francisco, CA, 10-15 December.

Parsons, M., 2001. Data Management at the National Snow and Ice Data Center. *NSIDC's 25th Anniversary*, Boulder, CO, 25 October.

Raup, B. et. al., 2001. GLIMS database: scientific considerations in the design of a global glacier data archive. *Fourth International Symposium on Remote Sensing in Glaciology*, College Park, MD, 4-8 June.

Scambos, T., and T. Haran, 2001. Antarctic photoclinometry using AVHRR and MODIS. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-14 December.

Stroeve, J., and A. Nolin, 2001. Comparison of Snow Albedo from MISR, MODIS and AVHRR with ground-based observations on the Greenland Ice Sheet. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-15 December.

Stroeve, J., T. Markus, **J. Maslanik**, 2001. Sensitivity Analysis of Operational Passive Microwave Sea-Ice Algorithms. *International Geoscience and Remote Sensing Symposium*, Sydney, Australia, 9-13 July.

Weaver, R., R. Barry, G. Scharfen, R. Dichtl, F. Fetterer, 2001. NSIDC at the Millenium. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-15 December.

Wolfe, J., Fowler, C., Scambos, T., 2001. Monitoring long-term regional changes in the Arctic and Antarctic with AVHRR 5-km Polar Pathfinder data. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-14 December.

Wolfe, J., T. Scambos, T. Haran, 2001. Monitoring long-term regional changes in the Arctic and Antarctic using AVHRR 5 km Polar Pathfinder data. *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-15 December.

Zhang, T., R. Armstrong, Chien-Lu Ping, and Toshio Koike, 2001. Seasonal Freeze/Thaw Cycle of Soils on the Qinghai-Xizang (Tibetan) Plateau, China, presented on the Symposium on Remote Sensing of Cryosphere, International Glaciological Society, University of Maryland, College Park, April.

Zhang, T., R. Barry, **R. Armstrong**, 2001. Distribution of frozen ground in the Northern Hemisphere, *American Geophysical Union Fall Meeting*, San Francisco, CA, 10-14 December.

APPENDIX

Funding

NSIDC's annual budget is about 7 million dollars. Approximately 82 percent of NSIDC's support from NASA, primarily for operation of the DAAC, with about 5 percent from NOAA for NOAA data set management and operation of the WDC, about 11 percent from NSF for Arctic and Antarctic data management activities and research, and the remainder from other sources. Funding for NSIDC confers an annual benefit to the University of Colorado of about 2 million dollars. In addition to contracts and grants for data management work, NSIDC researchers were supported by 25 grants in 2001.

Staff

NSIDC grew to 63 persons (excluding visiting scientists, students, and graduate students) in 57 full-time positions at the end of 2001. Raytheon staff, who are primarily responsible for installation, testing, and maintenance of the NSIDC DAAC EOSDIS Core System, number six employees. On-site subcontractors for Raytheon are Siri Jodha Singh Khalsa (with L-3 Communications) and Doug Fowler (with AverStar, Inc.)

New employees

Name	*Start Date*	*Title*
Christoph Oelke	January 1, 2001	Research Scientist II
Elizabeth Sheffield	January 1, 2001	User Services Representative
John Maurer	March 1, 2001	Operations Technician
Jennifer Bohlander	March 1, 2001	Scientific Programmer
Paul Zaffino	March 12, 2001	Web Server Administrator
Jim Miller	May 14, 2001	Research Assistant
Donna Scott	June 11, 2001	User Services Representative
Yarrow Axford	July 16, 2001	Science/Technical Writer
Mike Hartman	July 23, 2001	ARCSS Data Coordinator
Mike Stowe	August 1, 2001	IT Security Coordinator
Ruth Duerr	September 1, 2001	Operations Supervisor
Andy Etringer	September 1, 2001	Research Assistant
Lisa Ballagh	September 17, 2001	Operations Technician
Mike Wygant	September 17, 2001	Operations Technician
Jeff Groth	September 24, 2001	Systems Administrator
Daryl Kohlerschmidt	October 1, 2001	Administrative Assistant II
Matt Savoie	December 1, 2001	Scientific Programmer

Promotions

Name	*Effective Date*	*Title*
Melinda Marquis	July 1, 2001	EOS Data Management Team Leader
Brad McLean	July 1, 2001	User Services Distribution & ECS Coordinator
Tingjun Zhang	July 1, 2001	Research Scientist III
Michelle Holm	July 1, 2001	Associate Scientist III

Departures

Name	*Departure Date*	*Title*
Marianne Primett	January 18, 2001	Sr. Operations Technician
Allan Frei	January 28, 2001	Research Scientist
Jing Ping Ye	January 31,2001	Scientific Programmer
Ann Bessenbacher	May 4, 2001	Data Operations Supervisor
Diana Starr	May 4, 2001	User Services Representative
Tracy Thrasher Hybl	June 7, 2001	User Services Representative
Carol Pedigo	June 20, 2001	Administrative Assistant
Nick Suszczyk	July 13, 2001	Systems Administrator
Robin Welsh	October 31, 2001	Science/Technical Writer
Tom Elliot	December 7, 2001	Computer Operator
Annette Varani	December 14, 2001	DAAC Outreach Coordinator

Raytheon additions

Michael Gehmeyr	January 22, 2001	Sr. Software Engineer
Todd Edmands	October 1, 2001	Security Administrator

Raytheon departures

Michael Primett	January 18, 2001	Sr. Software Engineer

CPP Division Seminars

Mark Helmlinger, Validation Field Engineer for the Multiangle Imaging SpectroRadiometer (MISR) project. "MISR and the EOS SAFARI-2000 Experiment," 23 February 2001.

Jeremy Mennis, Geography Faculty. "A Spatio-Temporal GIS Database for Monitoring Alpine Glacier Change," 21 September 2001.

Anton Seimon, Graduate Student, Geography. "Climatic Change and Ecological Consequences in the Peruvian Andes," 16 November 2001.

Committee Representation

AATSR LST Validation Team Member – *J. Stroeve*
AMS Committee of Polar Meteorology and Oceanography – *J. Stroeve*
AMSR-E Sea Ice Team Member – *J. Maslanik*, *J. Stroeve*
ASF User Working Group Meeting, Seattle, April, 2001 – *T. Scambos*
Chairman, ICSI Snow and Climate Working Group – *R. Armstrong*
Co-Chair, Standing Committee for Data, Information and Communications, International Permafrost Association – *R. Barry*
GLAS Science Team Meeting, Greenbelt, MD, November 2001 – *T. Scambos*
International Commission on Snow and Ice (ICSI), representative to International Association of Hydrological Sciences (IAHS) – *R. Armstrong*
International Ice Charting Working Group Standing Committee on Data, Information, and Customer Support – *F. Fetterer*
International Satellite Land Surface Climatology Project (ISLSC) Science Panel – *R. Armstrong*
Joint US-Canadian Ice Center Working Group's Standing Committee on Research,
Remote Sensing and Modeling – *F. Fetterer*
McMurdo Area User's Committee, Denver, May 2001 – *T. Scambos*
NASA AMSR-E Science Team – *R. Armstrong*
NASA EOS Data Gateway (EDG) Guide Authors Group – *J. Wolfe*
Program for Arctic Regional Climate Assessment (PARCA) – *J. Stroeve*
RAMP Antarctic Mapping Advisory Group, Boulder, May 2001 – *T. Scambos*
Remote Sensing Working Group, GEWEX Asian Monsoon Experiment (GAME) – *R. Armstrong*
Terrestrial Observation Panel for Climate (TOPC) member – *R. Barry*
WCRP-ACSYS/CliC Data and Information Management Panel – *R. Armstrong*
World Climate Research Programme. Co-Vice Chair, Scientific Steering Group(SSG) for the Arctic Climate System/Cryosphere and Climate(CliC) project – *R. Barry*
World Meteorological Organization, Joint IOC/WMO Technical Commission for Oceanography and Marine Meteorology. Co-Chair, Steering Group for the Global Digital Sea Ice Data Bank (GDSIDB) – *R. Barry*

Meetings Attended

ACSYS/CliC SSG 2nd Session Halifax, NS, 15-19 October 2001, Attended as co-Vice Chair of the SSG. – *R. Barry*

American Geophysical Union, Fall Meeting, San Francisco, CA, 10-14 December 2001. – *R. Barry, F. Fetterer, M. Hartman, A. Machado, B. McLean, T. Mullins, L. Naranjo, A. Nolin, M. Parsons, T. Scambos, J. Stroeve, J. Wolfe, R. Weaver*

American Geophysical Union Spring Meeting, Boston, MA, 29 May – 2 June 2001. – *A. Machado*

American Library Association Meeting, San Francisco, CA, June 2001 – *T. Mullins*

American Society for Photogrammetry and Remote Sensing Conference, St. Louis, MO 23 – 27 April 2001. – *B. Sheffield*

AMS Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 6-8 May 2001. – *F. Fetterer*

AMSR-E Science Team Meeting. Boulder, CO, 9 November 2001. – *M. Marquis, J. Stroeve, and others*

AQUA Operational Readiness Review and Monthly Status Reviews – *R. Weaver*

Arctic Research Consortium of the U.S., Arctic GIS Workshop, Seattle, WA, 22-24 January 2001. - *N. Auerbach and R. Dichtl*

Association of American Geographers 97th Annual Meeting, New York, NY, 2 March 2001. – *R. Barry*

Briefing: U.S. agency representatives on the CliC Science Plan, Washington, DC, 2 February 2001. – *R. Barry*

Canadian Climate Action Fund project on Arctic Islands climate data rescue workshop, University of Edmonton, BC, Canada, 9-11 February 2001. – *R. Barry*

Cold Land Processes Experiment Planning Meeting, Winter Park, CO, 24-25 June 2001. – *R. Weaver, J. Stroeve*

Cold Land Processes Experiment Workshop, Boulder, CO, 7-9 November 2001. – *B. McLean, M. Parsons*

Cultural Heritage Collaboration in the Digital Age, Denver, CO, June 2001. – *T. Mullins*

DAAC Managers Quarterly Meeting, Huntsville AL, 26 February – 2 March 2001. – *R. Weaver, V. Troisi*

ECHO Client Developers Workshop. Landover, MD, 22-23 August 2001. – *R. Swick*

ECHO Data Provider Workshop. Landover, MD, 11-12 June 2001. – *R. Swick*

EOSDIS Data Gateway Workshop, Greenbelt, MD, 13-14 June 2001. – *B. McLean*

Gaining Knowledge from Environmental Data - A Workshop on the Data Information-Knowledge Continuum, sponsored by U.S. Global Change research Program, hosted by USGS, Ft. Collins, CO, 1-3 May 2001. – *F. Fetterer*

GIS in the Rockies, "Convergence of Information & Geography for Everyone," Sponsored by American Congress of Surveying and Mapping, American Society for Photogrammetry and Remote Sensing, Geospatial Information and Technology Association, Professional Land Surveyors of Colorado, and Urban and Regional Information Systems Association, Denver, CO, 18-20 September 2001. - *N. Auerbach*

GLAS Science Team Meeting, San Diego, CA, 14-15 February 2001. – *R. Swick, T. Haran, M. Marquis*

GLAS Science Team Meeting, Greenbelt, MD, 31 May – 1 June 2001. – *M. Marquis*

IGARSS (International Geoscience and Remote Sensing Symposium), Sydney, Australia, 9-13 July 2001. – *L. Schmidt, J. Stroeve, T. Scambos, J. Stroeve, A. Nolin*

Imaging and Geospatial Information Society (ASPRS), St. Louis, MO, 25-26 April 2001. – *R. Swick*

International Conference, Conservation and Transformation of Matter and Energy in the Earth Cryosphere, Russian Academy of Science, Consolidated Scientific Council on Earth Cryology, Pushchino, Russia, 1 June 2001. – *R. Barry*

International Geosphere Biosphere Program Meeting, Amsterdam, The Netherlands 10-14 July 2001. – *M. Holm*

International Glaciological Society, 4th International Symposium on Remote Sensing in Glaciology, College Park, MD, 4-8 June 2001. – *A. Machado, T. Scambos, M. Marquis, M. Brodzik, R. Armstrong*

International Glaciological Society Meeting, Ice Core Symposium, Kangerlusuaq, Greenland, August 2001. – *T. Scambos*

International Glaciological Society Meeting, Remote Sensing and Glaciology Symposium, College Park, MD, May 2001. – *T. Scambos*

Midwest Glaciology Meeting, DeKalb, IL, April 2001. – *T. Scambos*

MODIS Science Team Meeting, Columbia, MD, 24-26 January 2001. – *B. McLean*

NASA Cold Land Processes Experiment planning meeting, Boulder, CO, 7-8 November 2001. – *R. Barry, M. Parsons, J. Stroeve*

NASA EOS Investigators Working Group, San Antonio TX, 29 October – 1 Nov 2001. – *R. Weaver*

NASA HQ briefing by the National Research Council report on Polar Data Sets, 23-24 May 2001. – *R. Weaver*

NASA HQ NEWDiss planning meeting, 27 March – 2 April. – *R. Weaver*

NASA HQ review of the proposed EMD contract for ECS followon, 2-3 April and 15-17 Aug 2001. – *R. Weaver*

National Ocean Partnership Program Virtual Ocean Data Hub Project Workshop, Reagan Building, Washington, D.C., 25-27 April 2001. – *F. Fetterer*

NOAA Planning Meeting for Study of Environmental Change in the Arctic (SEARCH): Chair, Panel Session, University of Washington, Seattle, 28-29 November 2001. – *R. Barry*

Polar DAAC Advisory Group Meeting, Boulder, CO, 25-26 April 2001. – *M. Holm, J. Stroeve, R. Weaver, and others*

Polar Research Board, National Research Council, (briefing on CliC) Washington, DC, 23 March 2001. – *R. Barry*

QA Working Group Meeting, NCAR, Boulder, CO, 27-28 March 2001 – *M. Marquis*

Second Russian Conference on Geocryology, Moscow State University, 6-8 June 2001. – *R. Barry*

SEARCH Workshop on Large-scale Atmosphere/Cryosphere Observations, University of Washington, Seattle, WA, 27-29 November 2001. – *F. Fetterer*

SHEBA Phase 3 Investigators Meeting, Boulder, CO, 11-13 July 2001. – *F. Fetterer*

Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment, concurrent with the 8th International URSI Microwave Specialist Symposium on Microwave Remote Sensing of the Earth, Oceans, Ice, and Atmosphere Boulder, CO, 5-9 November 2001 –*R. Armstrong, M. Brodzik, J. Stroeve*

Third Annual International Ice Charting Working Group (IICWG) Meeting, Norwegian Meteorological Institute, Tromsø Meteorological Office, Reykjavik, Iceland, 14-16 November 2001. – *F. Fetterer*

Third International Workshop on Multiangular Measurements and Models (IWMMM-3), Steamboat Grand Resort Hotel and Conference Center, Steamboat Springs, CO, 10-12 June 2001. – *J. Stroeve Co-organizer*

Twenty-First Annual ESRI International User Conference, "Geography Creating Communities," San Diego, CA, 9-13 July 2001. - *N. Auerbach*

User Services Working Group Meeting, Huntsville, AL, 8-10 May 2001. – *D. Starr, B. Sheffield*

West Antarctic Ice Sheet Science Meeting, Sterling VA, September 2001. – *T. Scambos*

Workshop on High-mountain Regions. International Association of Hydrological Sciences, 6th Scientific Assembly on Water for a Thirsty Planet in Maastricht, Netherlands, 19 July, 2001. – *R. Barry*

World Mountain Symposium, Interlaken, Switzerland, 1 October 2001. – *R. Barry*

The NSIDC 2001 Annual Report was compiled and edited by F. Fetterer, with assistance from L. Cheshire, D. Kohlerschmidt, L. Schmidt, J. Wolfe, and L. Yohe. Many staff members contributed to the report.