National Snow and Ice Data Center
World Data Center for Glaciology, Boulder
Biennial Report, 2002 - 2003

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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, and supports the International Arctic Research Center (IARC), University of Alaska Fairbanks through the Frozen Ground Data Center.

During the period of this report, the Advanced Microwave Scanning Radiometer sensor on the NASA Aqua satellite began sending data, and the ICESat Geoscience Laser Altimeter System was launched. These new sensors promise snow and ice products with improved accuracy and higher resolution, which will advance our understanding of the cryosphere and its role in the climate system. NSIDC contributed to the International Conference on Permafrost in 2003 with the *Circumpolar Active-Layer Permafrost System Version 2.0* (CAPS 2) CD. These and other programs are reported in this overview of NSIDC activities for 2002-2003.

R.G. Barry
Director
NSIDC/WDC for
Glaciology, Boulder
July 2004

Highlights

NSIDC Data Sets Published in 2002 and 2003

More than 100 new data sets were made available through NSIDC's online catalog in 2002 and 2003, ranging from small data sets collected by individual investigators under National Science Foundation supported research, to historical glacier photographs, and to exciting new Moderate Resolution Imaging Spectroradiometer satellite data products. Taken together, these data sets represent the spirit of cooperation that the cryospheric research community shares - through the support of our funding agencies and the generosity of investigators who contribute data, NSIDC is able to multiply the value of these data for scientific inquiry by making them available to all.

For data set details, see the sections on NSIDC's main agency supported programs: the NSF-funded Antarctic Glaciological Data Center (AGDC) and Arctic System Science Data Coordination Center (ADCC), the NASA Distributed Active Archive Center (DAAC), the Frozen Ground Data Center, and NOAA at NSIDC.

Record Minimum Arctic Sea Ice Extent

In September 2002, arctic sea ice extent reached a new record low, four percent lower than any previous September since satellite monitoring began in 1978, and 14 percent lower than the long-term (1978-2000) mean. In 2003, ice extent retreated almost as far (Figure 1). The summer ice minimum was outside one standard deviation for two years in a row, an unprecedented occurrence over the period of the satellite data record. NSIDC researchers monitored the developing summer minimum each year using the Sea Ice Index (http://nsidc.org/data/seaice_index/), a web site that relies on ice concentration estimates from the Near Real-Time DMSP SSM/I Daily Polar Gridded Sea Ice Concentrations processing stream (NRTSI). NRTSI gives up-to-date assessments of sea ice cover from satellite observations of microwaves emitted from the surface (http://nsidc.org/data/nsidc-0081.html). Visible-light images from the Moderate Resolution Imaging Spectroradiometer (MODIS) aided confirmation of the microwave results.

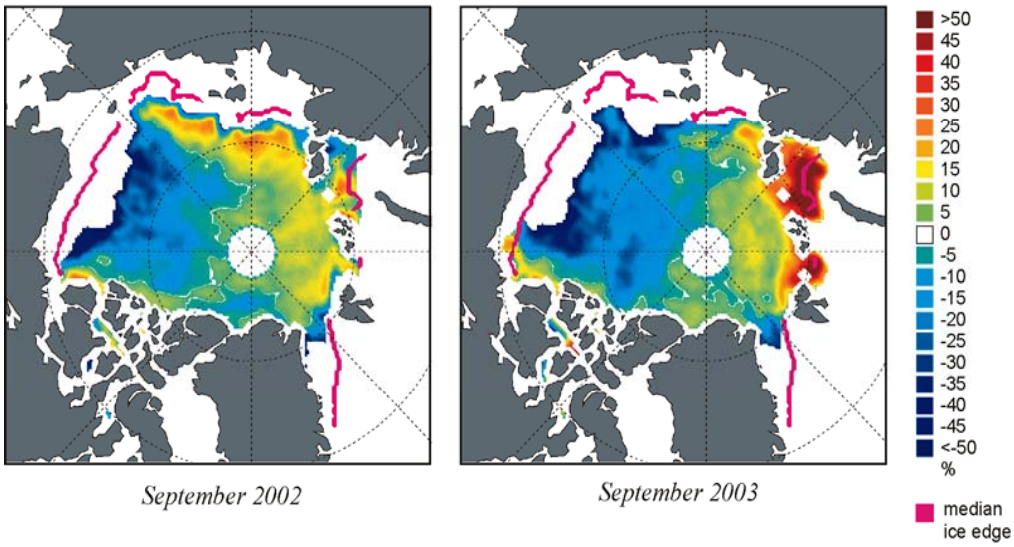

Figure 1: Sea ice extent (all colored areas) and anomalies in ice concentration (see color bar) for September of 2002 and 2003. The solid line shows the median ice extent over the period 1988-2001.

The 2002 and 2003 summer extent values are the most recent evidence of a downward trend in arctic sea ice in the decades since satellite monitoring began. NSIDC researchers attributed the 2002 minimum extent to unusually warm temperatures during the summer over much of the Arctic Ocean, combined with stormy conditions that helped break up the ice. Conditions in 2003 were broadly similar. The research, published in *Geophysical Research Letters*, Serreze *et al.,* 2003, garnered extensive media attention. NSIDC developed Web content to support the story (see http://nsidc.org/news/press/ 20021207_seaice.html and http://nsidc.org/seaice/news.html).

Antarctic Megadunes Project

Scientists gathered in a rarely visited part of the Antarctic Plateau in November 2002 to study an area of large surface snow dunes called "megadunes." The research is a collaboration among five scientists at five different institutions, funded by NSF.

Megadunes are a feature unique to Antarctica. Although the exact formation mechanism is yet to be determined, it appears that persistent katabatic winds arrange the snow in a wave pattern, similar to that seen in clouds near mountain ridges. Because of low snow accumulation in the dune troughs, snow remains near the surface for many decades, perhaps centuries, and is modified by repeated warming and cooling over the years. This results in chemical and physical modifications to the snow that may affect the original climate information preserved in the snow when it first fell. The science team is seeking to understand how the snow is modified, to aid in interpreting other ice cores in Antarctica that may have drilled through an old megadune field.

Fieldwork included drilling an ice core, and gathering ground penetrating radar (GPR), Global Positioning System (GPS), and automated weather station data. The team sought to understand the megadune structure at depth, the surface topography, snow structure, and air chemistry. Ted Scambos led NSIDC's team, with support from Safety Officer Rob Bauer, and scientific programmer Terry Haran. A group from the Scripps Institution of Oceanography and Princeton University, collected an ice core and air samples. The megadunes project also uses remote sensing data, such as visible and near-infrared (IR) satellite images (from MODIS and Landsat 7), Synthetic Aperture Radar, and passive microwave emissions.

The NSIDC megadunes web site (http://nsidc.org/antarctica/megadunes/dunes.html) provides information about the Antarctic Plateau as well as biographies of scientists and students. During the field season it is continuously updated with information about the megadunes research.

Frozen Ground Data Center Online, Circumpolar Active-Layer Permafrost System CD Published

The Frozen Ground Data Center (FGDC), a collaborative effort between NSIDC and the International Arctic Research Center, Fairbanks, Alaska, greatly increased access to data about permafrost and frozen ground. The FGDC acts as a central node of the International Permafrost Association's Global Geocryological Data (GGD) system, an internationally distributed system linking investigators and data centers around the world. In 2002, the FGDC published online the complete GGD metadata collection and over 50 complete data sets previously unavailable over the Web.

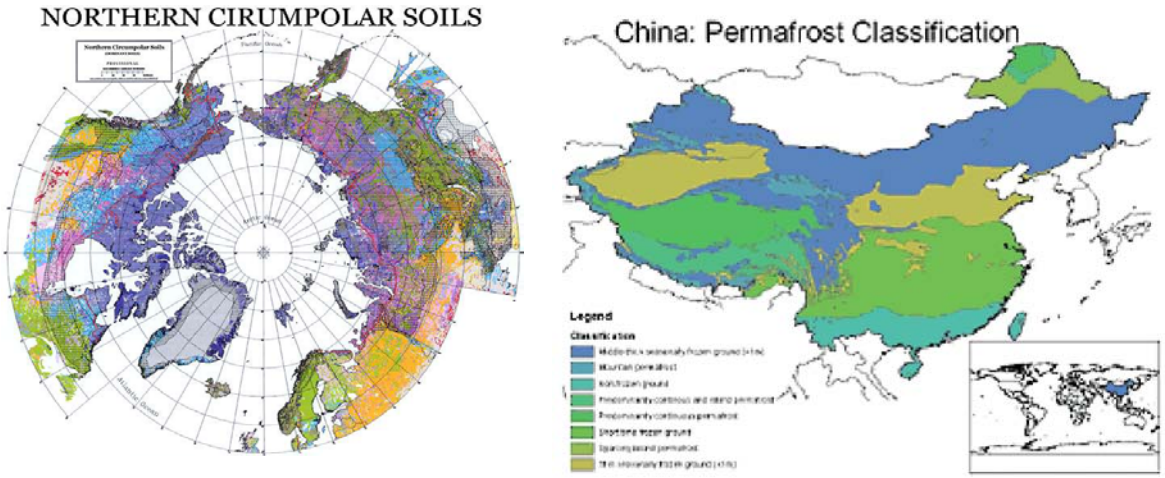

Figure 2: Map of Northern Circumpolar Soils (left) and Map of Geocryological Regions and Classifications in China (right).

The FGDC continues to expand GGD data holdings, with a particular emphasis on permafrost and related maps. New data sets include the Northern Circumpolar Soils Map, Maps of Geocryological Regions and Classifications in China (Figure 2), and detailed maps of permafrost and soils from Russia. See http://nsidc.org/fgdc/index.html for more information and the most current data. In 2003, the FGDC published the *Circumpolar Active-Layer Permafrost System Version 2.0 (CAPS 2)* CD set (http://nsidc.org/data/g01175.html). The CAPS 2 compendium of data and metadata serves as a snapshot of frozen ground and related data holdings available as of spring 2003.

Cold Land Processes Field Experiment

The Cold Land Processes Experiment (CLPX) was conducted in the mountains and high rangelands of northern Colorado and southern Wyoming during the winter and spring of 2002 and 2003. CLPX consisted of intensive ground- based snow measurements in concert with satellite and airborne remote sensing measurements at a variety of spatial scales (Figure 3). NSIDC scientists were actively involved in the design and implementation of the experiment. NSIDC data managers participated in the ground data collection, provided on-site data processing and quality control, and developed a set of data grids to facilitate data analysis. See http://nsidc.org/data/clpx/index.html for more information and to access the data. NASA named CLPX as one of its top Earth science accomplishments for 2003.

Figure 3: Former NSIDC employee, Kate Daniels, takes a snow density sample at the bottom of a deep snow pit near Rabbit Ears Pass, Colorado (left). Hyperspectral image of the Walton Creek Intensive Study Area in the Rabbit Ears Meso-cell Study Area, acquired March 31, 2003, by the NASA/JPL Airborne Visible Infrared Imaging Spectrometer (AVIRIS). The image shows an area of 1 km^2 and has a spatial resolution of ~ 2 m. The snow cover and grain size were generated with the Multiple Endmember Snow Covered Area and Grain-size model. This and other such images will be used for validating snow cover retrievals from the microwave data collected during the CLPX, and in forward modeling the passive microwave emission from snow-covered forested terrain.

Glacier Photograph Database and Digitization Project

In December 2002, in partnership with NOAA's National Geophysical Data Center, NSIDC released the Online Glacier Photograph Database. This database (http://nsidc.org/data/g00472.html) now includes nearly 3000 digitized historical glacier photographs and their accompanying metadata. The images are part of the NSIDC archive of the American Geographical Society's collection of historical glacier photographs, dating from the 1880s to 1975, and include both aerial and terrestrial photos.

Figure 4: Historical glacier photographs in danger of deterioration and selected for scanning.

Over long periods of time, glacier extents fluctuate in response to climate changes. Historic glacier photos can be used to determine changes in glacier terminus location, and can be used to estimate changes in mass balance. To obtain a complete picture of climate change as recorded by glacier fluctuations, information from many glaciers must be used. The glacier photograph collections at NSIDC are the only source of this information for many glaciers, and therefore constitute an important resource for the scientific community. Images in the database are retrievable by glacier name, photographer name, date, state, geographic coordinates, and subject keywords. Glaciers from Colorado, Wyoming, Montana, Washington, and Alaska are represented. In expanding the collection, NSIDC hopes to pair present-day photographs with the historical photos to provide visual evidence of glacier fluctuations, and to add additional images of glaciers outside the United States. Funding to digitize the photographs was provided by NOAA's Climate Database Modernization Program (CDMP).

The Distributed Active Archive Center (DAAC)

The NSIDC DAAC serves scientists, educational communities, and the general public by providing cryospheric land, and ocean data and information. The primary goal is to provide easy and reliable access to Earth Observing System (EOS) satellite data, ancillary *in situ* measurements, and relevant baseline data, model results, and relevant algorithms relating to cryospheric and polar processes. The NSIDC DAAC is an integral part of the multiagency-funded efforts at NSIDC to provide snow and ice data and information management services. The DAAC handles products from the following instruments:

- Moderate Resolution Imaging Spectroradiometer (MODIS)
- Advanced Microwave Scanning Radiometer-EOS (AMSR-E)
- Geoscience Laser Altimeter System (GLAS)
- Special Sensor Microwave/Imager (SSM/I) and the follow-on Special Sensor Microwave Imager/Sounder (SSMI/S)
- National Oceanic and Atmospheric Administration (NOAA) Advanced Very High-Resolution Radiometer (AVHRR)
- Radarsat Antarctic Mapping Mission (RAMP) mosaic data

Ron Weaver is the DAAC Manager, Vince Troisi is the Deputy DAAC Manager and Senior Systems Engineer, and Roger Barry is the Senior DAAC Scientist.

External Data Coordination Efforts

Ron Weaver, NSIDC's DAAC program manager, became the DAAC Alliance Chairman in 2002 for a one-year term. The DAAC Alliance is an informal organization that coordinates activities between the NASA DAACs. The group holds quarterly management-level meetings and bi-weekly telecons. In August 2003, a workshop was held at the Consortium for International Earth Science Information Networks (CIESIN) to coordinate data access and distribution techniques. DAAC Senior Engineer Vince Troisi and NSIDC Operations Manager Ruth Duerr participated in two workshops devoted to the development of a working approach for the Strategy for Evolution of ESE Data Systems (SEEDS).

NSIDC Participated in the Earth Science Information Partner (ESIP) Federation Committee of the Whole, and special interest group meetings. Several staff members participated in Federation meetings during 2002 and 2003. Vince Troisi serves as the official NSIDC DAAC representative to the Federation, and as a Board Member to the Earth Science Foundation, the non-profit governing organization of the ESIP Federation.

Science Data Operations and User Outreach

Moderate Resolution Imaging Spectroradiometer (MODIS) Products

MODIS is an optical, 36-spectral-band instrument aboard the NASA Earth Observing System (EOS) Terra and Aqua satellites that provides daily global coverage 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 through close interaction with the development team. The NSIDC DAAC continued its outreach to MODIS the user community through numerous avenues. A user workshop was held in October 2002, and at the Fall 2002 American Geophysical Union

(AGU) meeting, NSIDC distributed a new data flyer on MODIS products, conducted a survey of 18 potential MODIS users, and presented posters on MODIS. NSIDC participated in a general MODIS workshop at the International Geoscience and Remote Sensing Symposium (IGARSS) in July 2003, and presented a poster at the Fall 2003 AGU meeting. The DAAC also created a new brochure and a CD-ROM data sampler.

In 2002, MODIS/Terra data quality was elevated to a status of "validated stage 2," a significant improvement for science users. Two climate modeling grid products (daily and 8-day) were released for public use, and NSIDC developed a web-based interface to access daily Climate Modeling Grid (CMG) browse products. In 2003, MODIS/Terra products were reprocessed, resulting in a consistent time series of data, beginning in February 2000. In September 2003, snow albedo measurements were added to the daily gridded snow cover product, and a new daily polar-gridded sea ice product containing sea ice extent and ice surface temperature was added to the processing stream.

In February 2003, the MODIS/Aqua Level-2 snow and sea ice products were released to the public upon completion of algorithm changes that use MODIS Band 7 in lieu of the nonfunctional Band 6. Reprocessing of all products was planned to begin January 2004, enabling release of the full suite of MODIS/Aqua products.

NSIDC receives MODIS data from the MODIS Data Processing Facility at the NASA Goddard Space Flight Center (GSFC) in Greenbelt, MD. During 2002 and 2003, the facility's efficiency improved so much that products were created and archived only a few days after they received data from the Terra and Aqua ground systems. In 2003, NSIDC added a capability for users to browse reduced-resolution images of data prior to order, as well as to subset and regrid data prior to delivery.

For more information, see "MODIS Data at NSIDC" (http://nsidc.org/data/modis/).

GLAS Data from ICESat

The Geoscience Laser Altimeter System (GLAS) is the sole instrument on the Ice, Cloud, and land Elevation Satellite (ICESat), launched in January 2003. The GLAS instrument provides high-resolution elevation data that will improve understanding of ice-sheet mass balance in the polar regions. NSIDC archives and distributes 15 products, including Level-1A, -1B, and -2 laser altimetry and atmospheric lidar data. The initial data stream was approximately 20 Gigabytes per day. Details about the mission, science algorithms, and products are available at http://nsidc.org/daac/glas/.

During 2002, in preparation for GLAS data operations, the NSIDC DAAC completed metadata and catalog entries for data products using the Global Change Master Directory (GCMD) Directory Interchange Format (DIF), completed documentation for the altimetry data sets, and successfully ingested and archived test granules of 14 data types that NSIDC expects to receive operationally from the ICESat Science Investigator-led Processing System (I-SIPS).

In 2003, NSIDC continued testing ingest, distribution, and science quality of improved versions of data products, and revised guide documents and DIFs as the data products matured. NSIDC staff members began using remote Science Computing Facility (rSCF) visualization/analysis software and subscriptions for areas of particular interest, e.g., Greenland, Antarctica, and Colorado. On 31 October 2003, NSIDC released the first GLAS data to the public: 8-day samples of all standard data products (from 12-20 March 2003). After extensive testing, NSIDC recommended that that the data producers (I-SIPS/SCF) make specific improvements to software for reading these products.

AMSR-E data from AQUA

The Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) is a mission instrument launched on NASA's Aqua Satellite on 4 May 2002. The Aqua mission provides data for multidisciplinary studies of the Earth with a special emphasis on oceans. NSIDC has been archiving the Level-0 data since the Aqua launch and will continue to do so for the life of the mission. NSIDC will archive and distribute all 16 standard data products, including Level-1A, -2A, -2B and -3 data. Details about the mission, science algorithms, and products are available at http://nsidc.org/daac/amsr/.

During 2002, in preparation for AMSR-E data operations, the NSIDC DAAC ingested initial Level-1A granules and higher-level products from the NASA Jet Propulsion Laboratory (JPL) Physical Oceanography DAAC (PO.DAAC) and from the AMSR-E Science Investigator-led Processing System (SIPS), respectively, while NASA's Japanese partner, the Japanese Aerospace Exploration Agency (JAXA), worked to calibrate the instrument. NSIDC completed testing of the AMSR-E Level-1A interface with the PO.DAAC. The interface generates metadata necessary for ingest of Level-1A data products from the PO.DAAC into the EOSDIS Core System (ECS).

NSIDC completed data metadata and catalog entries using the GCMD DIF in 2002 and reviewed and verified the contents of the Level-2A Data Algorithm Package (DAP) generated by the AMSR-E SIPS/SCF. This package contains the processing software and ancillary information required to generate the Level-2A product. NSIDC reviewed and verified the contents of the Level-1A DAP generated by JAXA.

In 2003, NSIDC continued testing improved versions of data products (testing ingest, distribution and the science quality of the products). The AMSR-E team revised guide documents and DIFs as the data products matured, and extensively tested and made operational the HDF-EOS Web-based (HEW) subsetter, so that it correctly subsets all AMSR-E products (Level-2A, -2B and -3, expcet for Level-2B land, which is in point format and thus not a substrate for the HEW subsetter).

In June and September 2003, NSIDC began ingesting and distributing Level-1A and –2A AMSR-E data, respectively.

AMSR-E Validation Data Management

NSIDC is supporting the AMSR-E validation activities by hosting a web site portal to all AMSR-E validation experiments, including soil moisture, rainfall, and cryospheric validation campaigns. NSIDC provides documentation (user guides) as well as metadata (GCMD DIFS) for AMSR-E validation experiments and collaborates with the AMSR-E SIPS to provide scientists in the field (Arctic and Antarctic ship and flight campaigns) with quick, easy access to subsetted and reformatted data for their experiments. For more information, see http://nsidc.org/data/amsr_validation/.

During 2003, NSIDC published 13 Soil Moisture Experiment (SMEX) data sets and a rainfall data set, and received metadata on many additional SMEX, rainfall, and cryospheric data sets.

Non-EOS Passive Microwave Data Products and EASE-Grid Products

NSIDC supports and distributes a significant amount of satellite passive microwave data, much of which is continually updated. NSIDC continues to ingest, manage, and distribute passive microwave data from the SSM/I instrument on Defense Meteorological Satellite Program (DMSP) satellites, and also archives and distributes sea ice and snow cover products produced at NSIDC and at NASA GSFC.

NSIDC polar stereographic standard sea ice products were updated routinely through 2002, including "Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I Passive Microwave Data" product (Volume 5 on CD-ROM), and the "Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I" product (available via ftp). Accompanying ancillary products of ice area and extent, monthly climatologies, and Geographic Information Systems (GIS) files were also updated, and the ancillary products web page was updated with a map interface to allow point-and-click selection of regional statistics (http://nsidc.org/data/smmr_ssmi_ancillary/area_extent.html).

NSIDC reprocessed Nimbus-5 Electrically Scanning Microwave Radiometer (ESMR) sea ice concentrations, gridded data to a polar stereographic projection, and addressed several quality control issues. These data are planned for release in 2004.

NSIDC also began an assessment survey of polar stereographic product usage.

Several minor changes were implemented in the Near Real-Time SSM/I EASE-Grid Daily Global Ice Concentration and Snow Extent (NISE) product. NISE production time was moved to earlier in the day to be more compatible with MODIS production, and quality control procedures were strengthened and documented by the Operations Group. A new Land-Ocean-Coast-Ice (LOCI) mask was implemented, correcting some deficiencies over the antarctic ice shelves. Finally, a new resampling procedure for brightness temperatures was implemented for snow determination.

EASE-Grid regular processing and CD-ROM production continued for all three EASE-Grid projections. The processing kept up with ingest from Remote Sensing Systems in Santa Rosa, CA.

NSIDC distributed a new EASE-Grid interpolated sea ice motion product, which consists of daily, weekly, and monthly fields of ice motions derived from SSM/I, AVHRR, and buoy observations.

DAAC Alliance Annual

As a member of NASA's DAAC Alliance, the NSIDC DAAC published the 8th and 9th editions of the DAAC Alliance Annual, a multidisciplinary publication that highlights applications and research uses of satellite data from NASA's Earth Science Enterprise. The 8th edition, titled *Supporting Earth Observing Science 2002*, highlighted research on volcanic domes, African ecosystems, the breakup of the Larsen B Ice Shelf in Antarctica, the spread of viruses and dangerous organisms, and improving meteorological forecasts.

The 9th edition, titled *Supporting Earth Observing Science 2003*, covered research on oceanography, seismology, land processes, cryospheric processes, and human influences on native habitats. For the first time, the 2003 edition also included a special center section featuring full-color data images designed to enhance the readers' understanding of the feature articles.

NSIDC distributed copies of both editions from its exhibitor booth at the 2002 and 2003 AGU Fall Meetings, respectively, and at the 2003 joint session of AGU, the European Geosciences Society (EGS), and the European Union of Geosciences (EUG) held in Nice, France. At the 2003 AGU Fall Meeting, DAAC Alliance Annual Editor Laurie Schmidt presented a poster session on the 9th edition of the Annual in a session related to education and outreach. The presentation, titled "NASA's DAAC Alliance Annual and Electronic Publishing: Communicating Research Uses of Earth-Observing Data to a Broad Audience," included an overview of the DAAC Alliance Annual project and covered various techniques for overcoming challenges associated with explaining scientific concepts to lay audiences.

Articles from the DAAC Alliance Annual are also available electronically on the DAAC Alliance web site (http://nasadaacs.eos.nasa.gov/).

DAAC Alliance Web Site

NSIDC staff maintains the DAAC Alliance web site (http://nasadaacs.eos.nasa.gov/), which is the official presence for the DAACs and points users to all individual DAACs. NSIDC updated the site to ensure accessibility (Section 508 compliance) in 2002. In 2003, the User Services Working Group outlined its vision for long-term site goals, and the project lead for the DAAC Alliance Electronic Publishing Project worked with the group to refine implementation plans. Discussions in outreach meetings in May and October led to a new design for the DAAC Alliance home page. This new design also reflects "NASA Affinity" rules communicated by the agency to promote a consistent look and feel across NASA Web sites. The DAAC Alliance Electronic Publishing Project also included web site design and programming to publish all of the 2003 DAAC Alliance Annual stories on NASA's Earth Observatory web site.

New DAAC data sets in FY02 and FY03

- **AMSR-E/Aqua L1A Raw Observation Counts:** Each half-orbit data granule consists of observation counts, antenna temperature coefficients, offsets for calculating antenna temperatures, calibration temperature counts, land/ocean flags, time, latitude, longitude, and navigation fields in HDF format. For more information, see http://nsidc.org/data/amsrel1a.html.
- **AMSR-E/Aqua L2A Global Swath Spatially-Resampled Brightness Temperatures (Tb):** Improves on past microwave radiometers by providing spatial resolution double that of SMMR and SSM/I. Data are resampled to be spatially consistent and therefore are available at various resolutions that correspond to the footprint sizes of the observations. For more information, see http://nsidc.org/data/ae_l2a.html.
- **AMSR-E Validation Data:** In 2003, data sets were released for the Soil Moisture Experiment 2002 (SMEX02) conducted in Iowa, USA, as well as daily and monthly rainfall data from the Next Generation Radar (NEXRAD) site in Eureka, California. For more information about the program and available data sets, see http://nsidc.org/data/amsr_validation.
- **AVHRR Polar Pathfinder Twice-Daily 25 km EASE-Grid Composites:** See http://nsidc.org/data/nsidc-0094.html. For general information on all AVHRR data see http://nsidc.org/data/avhrr/index.html.
- **ICESat/GLAS Data:** Preliminary versions of all products were released to the public on 31 October 2003. For more information, see http://nsidc.org/daac/icesat/.
- **MODIS daily and eight-day snow cover products in the Climate Modeling Grid:** These products consist of 3600-pixel by 7200-pixel global arrays of snow cover at 0.05° resolution. Production began in March 2002. See http://nsidc.org/data/modis/data.html.
- **MODIS/Aqua L2 snow cover and sea ice products:** These products consist of five-minute swaths. Production began in May 2002 with public release in February 2003. See http://nsidc.org/data/modis/data.html.
- **MODIS daily snow albedo:** These data arrays are produced as part of the daily gridded snow cover product. Production began in September 2003. See http://nsidc.org/data/modis/data.html.
- **MODIS daily sea ice in EASE-Grid:** This product consists of sea ice extent and ice surface temperature data arrays for the Northern and Southern Hemispheres, produced in

day mode. Production began in September 2003. See http://nsidc.org/data/modis/data.html.

- **Radarsat Antarctic Mapping Project (RAMP) Mosaic and DEM:** Image tiles cover the entire continent at 25 m resolution, and single mosaic images cover the continent at resolutions ranging from 125 m to 1 km. See http://nsidc.org/data/nsidc-0103.html . **Version 2 of the DEM** improves upon the original version by incorporating new topographic data, error corrections, extended coverage, and other modifications. See http://nsidc.org/data/nsidc-0082.html.
- **Snow Melt Onset Over Arctic Sea Ice from SMMR and SSM/I Brightness Temperatures:** Data cover the years 1979 through 1998, in a polar stereographic grid at 25 km resolution. See http://nsidc.org/data/nsidc-0105.html.
- **Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 2:** This significant update extends snow charts back from 1971 to 1966, and forward from 1995 to 2001, and includes an extensive reanalysis of the original time series that NSIDC used from 1971 to 1995. NSIDC also made significant improvements to ice climatology, replacing a static annual climatology with monthly climatologies derived from SMMR and SSM/I data from 1978 to 1999. See http://nsidc.org/data/nsidc-0046.html.
- **Historical Arctic and Antarctic Surface Observational Data:** This product consists of meteorological data from 105 Arctic and 138 Antarctic weather stations, extracted from the National Climatic Data Center (NCDC)'s Integrated Surface Hourly (ISH) database.

Updates to DAAC Products

- **Near Real-Time SSM/I EASE-Grid Daily Global Ice Concentration and Snow Extent:** On 20 March 2002, NSIDC revised the snow algorithm to provide corrected wet and dry snow extent, particularly over such regions as the high-elevation deserts of Central Asia. See http://nsidc.org/data/nise1.html.
- **Sea Ice Time Series:** Data from the NASA Team algorithm are current through December 2002. See http://nsidc.org/data/nsidc-0051.html. Data from the Bootstrap algorithm are current through September 2001. See http://nsidc.org/data/nsidc-0079.html.
- **CD-ROM production is current for SSM/I Pathfinder Daily EASE-Grid Brightness Temperatures** for all projections. See http://nsidc.org/data/nsidc-0032.html. CD-ROM production for SMMR Pathfinder Daily EASE-Grid Brightness Temperatures is nearly complete for the Global and Northern Hemisphere projections. See http://nsidc.org/data/nsidc-0071.html.

Web Site Updates

The following web pages were updated in 2002 and 2003:

- **Cryosphere (http://nsidc.org/cryosphere/):** This section of our web site is intended for the general public.
- **State of the Cryosphere (http://nsidc.org/sotc/):** "Ice Shelves-Rapid response to climate change" highlighted the collapse of the Larsen B Ice Shelf (also covered in more detail on our Ice Sheets and Ice Shelves site).
- **All About Snow (http://nsidc.org/snow/):** Developed a collection of snow data sites.

- **Q&A about the Cryosphere (http://nsidc.org/cryosphere/questions/):** Answers to common questions from the public.

The following new web pages were created in 2002 and 2003:

- **MODIS Image Gallery (http://nsidc.org/data/modis/gallery/)**: This site provides several representative MODIS snow and sea ice images with explanatory text.
- **MODIS Climate Modeling Grid browse products (http://nsidc.org/data/modis/cmg_browse/index.html)**: These reduced-resolution images of global daily CMG products provide an easy way for users to monitor changes in global snow cover.

Mission Coordination

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, the NSIDC DAAC is providing access to high-quality Digital Elevation Model (DEM) products for Antarctica, as well as long-term archival and assistance in the distribution of the high-level SAR-mosaic products. Work in 2002 followed on 2001's accomplishments, including an assessment of user requirements for data formats and delivery methods, and documentation about the platform, sensor, data sets, 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 are available at http://nsidc.org/daac/ramp/.

Cold Lands Field Experiment (CLPX) Support

The NSIDC DAAC, through the AMSR-E Validation activity, supported the CLPX field experiments in 2002 and 2003 with computer support for data reduction, storage, and distribution of field measurements, and with remote sensing data. A separate grant provided direct support for field data collection staff. This field effort is somewhat unique in that NSIDC, as the data center for CLPX, has been involved in data collection, planning, and execution from the onset of the Cold Lands Experiment. See the CLPX descriptions elsewhere in this report.

Systems Engineering and Systems Development

NSIDC DAAC EOSDIS Core System (ECS)

NSIDC DAAC collaborated with the MODIS Science Computing Facility (SCF) and Raytheon development staff in an effort to tune the NSIDC ECS system so that it could ingest the data flow coming from the MODIS Data Production System (MODAPS), successfully raising the level of ingest throughput from about 13 granules per minute to almost 30 granules per minute. This rate is sufficient to ingest the current data flow. Enhancements to the ECS that improved efficiencies in the system over the past two years include the following:

- **Hardware, operating system (OS), and commercial off-the-shelf (COTS) consolidations and upgrades**. Many of the information technology systems that had reached end-of-life or no longer supported efficient system functionality were upgraded or were replaced by the ECS Maintenance and Development (EMD) contractor. Increasing the number of drives in the StorageTek® PowderHorn® tape library from 5 to 10 increased ingest, throughput, and distribution capacity. Replacement of the Rimage® system used to generate CD-ROM and DVD for distribution enabled the DAAC to use less costly media. Routers and network

switches were updated as needed or dictated. OS upgrades enabled the DAAC to stay in sync with the user communities and help maintain security standards. COTS upgrades, such as Sybase®, resolved some problems related to the stability of the ECS but also aided in increased functionality and better system performance.

- **Custom code installation and system enhancements**. Enhancements to the ECS ingest, archive, and distribution processes enabled the DAAC to keep current with the problem resolution and the development cycle. These system enhancements increased ECS ingest rates from approximately 10 granules per minute to approximately 32 granules per minute.
- **Data Pool.** Data Pool is a short-term data cache that provides FTP access to AMSR-E and MODIS products. A simple search interface helps users quickly locate data of interest. If the user knows the location of the required data, they are able to access the data directly on the FTP site. Users can view metadata and browse data directly in their web browser.

  The Data Pool concept was proposed by the Science Working Group on Data (SWGD). This group viewed the lack of adequate data distribution solutions by the DAACs as the most critical problem the EOS faces.

  Data Pool uses a large disk cache at each DAAC to replicate EOS data in easily accessible storage for a limited period of time, allowing users to quickly retrieve current data. The contents of the cache are tuned to the needs of the user community. The goal is to increase the distribution capacity of the ECS by significantly reducing the need to access a tape archive. In addition, user access to these data is faster and easier.

EOS Clearing House (ECHO)

NSIDC DAAC staff continues to participate in the development of the NASA Earth Science Enterprise ECHO, a centralized repository of metadata describing Earth Science data and services. Data providers will use ECHO to publish information about their data holdings and related services. Data users will use ECHO to locate data and services of interest. DAAC staff members are engaged in the following ECHO-related activities:

- Testing the data provider interface between the NSIDC ECS and ECHO to ensure that ECHO can ingest metadata related to NSIDC data holdings accurately and in a timely manner. The Bulk Metadata Generation Tool (BMGT) is used to test the interface. BMGT extracts metadata information held in the ECS databases and converts the information to XML. The extracted metadata are sent to the ECHO server to update the ECHO inventories consistent with the DAAC inventories.
- Providing support to the ECHO developers by adding the backtrack orbit search algorithm as a search option for orbital-swath data.
- Developing a client/server application (GISMO-E) that interfaces to ECHO.

HDF-EOS Web-Based (HEW) Subsetter

NSIDC DAAC staff installed the HEW subsetting service developed at the University of Alabama, Huntsville, as an extension to the ECS. The HEW subsets HDF-EOS formatted files. Users of the EOS Data Gateway (EDG) can specify subsets based on spatial and temporal ranges and specific parameters to deliver. NSIDC is working with the developers of the HEW, the EDG, and the ECS, to allow users to specify spatial subsets using row and column ranges, and latitude and longitude ranges.

Graphical Interface for Subsetting, Mapping, and Ordering (GISMO) and GISMO-EOS (GISMO-E)

New versions of GISMO and GISMO-E were released in 2002. These search and order interfaces for NSIDC DAAC data cater to the specific needs of the polar research community. In particular, they allow users to conduct spatial searches using coverage maps in projections suitable for polar studies (for example, Polar Azimuthal and Polar Stereographic projections).

Search 'N Order Web Interface (SNOWI)

The NSIDC Search 'N Order Web Interface (SNOWI) allows users to search and order data archived in the NASA ECS at the NSIDC, Goddard Earth Sciences (GES), Land Processes (LP), and Atmospheric Sciences Data Center (ASDC) DAACs. SNOWI is designed as an alternative to the EDG search and order interface. The application is easier to navigate than the EDG, requiring fewer screens to complete a search and/or order. The web-based interface is geared toward the user who is familiar with the data and who does not need ancillary information associated with data products such as granule maps or thumbnails. SNOWI is used not only by researchers, but also by NSIDC User Services staff to assist users who experience problems with their orders. SNOWI is capable of querying non-ECS DAAC holdings, but is not currently configured to do so. A version of SNOWI is being developed to work with ECHO.

Metadata Database

NSIDC developed a schema for an enterprise-wide metadata database: a single repository of information about current and future NSIDC products and services that will lead to efficiencies in managing the Center's metadata. Historically, individual projects maintained metadata using a variety of technologies. Most of the metadata did not reside in a database, but were found in a variety of documents such as GCMD DIFs and guide documents. Many individuals maintained information about NSIDC products and services, and information resources often became inconsistent. In addition, metadata standards are in a state of flux, with new requirements and capabilities for metadata arising frequently.

The goal for initial instantiation of the metadata database is to provide a repository of information that will be used by scientific writers at NSIDC for the purpose of publishing catalog pages served from the NSIDC web site. The metadata database schema is built on the NASA-funded Version 0 Information Management System (IMS) database model. The Metadata Database and Writer's Interface to the database will help maintain consistent metadata, reduce the overall work required to write a DIF or to generate other information resources using a different format, and to enforce NSIDC standards for metadata content.

The Metadata Database and Writer's Interface was rolled out in the first quarter of 2003. Metadata about over 200 data sets was loaded into the database from DIFs and other metadata formats. The catalog pages for the NSIDC web site are generated from the database, and are automatically updated whenver a change is made. The catalog search page now retrieves information from the database which allows users to search for data sets using a larger set of search criteria than before. Late in 2003 NSIDC began working on adding preservation and archive information to the Metadata Database schema and assessing the feasibility of supporting other national and international metadata standards.

The Arctic System Science (ARCSS) Data Coordination Center (ADCC)

Since 1991, the NSF has continuously funded the ADCC at the NSIDC. The purpose of the ADCC is to present ARCSS-related research data on the ADCC web site at (http://arcss.colorado.edu), to prepare metadata for submission to the Global Change Master Directory, and to provide long-term storage of data within its archive. A user-friendly web site provides tools to permit a search for data by the name of the Principal Investigator (PI), the project title, the measured parameter, or keywords (http://nsidc.org/data/search.html). A Metadata Submission Form is a part of the data submission protocol and is the starting point for all PIs who wish to submit data sets to ADCC. Rudolph Dichtl is the manager and PI of the ADCC project.

Significant accomplishments during 2002-2003 are:

- Publication of 43 data sets on the ADCC web site (see below).
- Improvement of Geographical Information System (GIS)-based data display.
- Registration as a new National Spatial Data Infrastructure (NSDI) clearinghouse. For users interested in digital geospatial data, the NSDI node provides broader exposure to data sets managed and archived by the ADCC and other arctic climate data centers. The NSDI node provides search interoperability among different servers of geospatial metadata through the ANSI Z39.50 search and retrieve protocol.
- Presentations on the significance of metadata to many of the ARCSS project groups.
- Poster presentations on metadata and the ADCC at several national and international conferences.
- Addition of an off-site, long-term data archive facility
- Acquisition and ingest of Surface Heat Budget of the Arctic Ocean (SHEBA) Phase II data, and posting of all 120 data sets (see http://arcss.colorado.edu/arcss/sheba/sheba_table.html).
- Transfer of the Arctic Transitions in the Land-Atmosphere System International Tundra Experiment (ATLAS/ITEX) data sets. Western Arctic Shelf-Basin Interactions (SBI) data sets will be transferred in 2004.

New Data Sets

Titles are listed with contributing investigators.

- Soil properties of carbon-flux monitoring sites in northwestern Alaska. Ping, C.L., and G. Michaelson.
- Automated weather station data for Greenland ice core locations. Stearns, C.
- Borehole temperatures from the North Slope of Alaska, 1977-2001. Osterkamp, T.
- Soil temperatures for Happy Valley and Barrow, Alaska. Hinkel, K.
- Soil temperatures, Toolik Lake, Alaska, 1995 and 1996. Oberbauer, S.
- Canopy foliage area index, Toolik Lake, Alaska, 1995 and 1996. Oberbauer, S.

- Sedimentary dentrification rates from the Bering, Chukchi, and Beaufort Seas. Devol, A., L. Codispoti, and J. Christensen.
- SCICEX dissolved barium data, 1995-1997. Falkner, K., C. Guay, and T. Wagner.
- Soil descriptions and soil chemistry for LAII/ATLAS winter carbon flux sites, Alaska, 1992 and 1998-2000. C.L. Ping, V. Romanovsky, G. Michaelson, and W. Lynn.
- Physical and chemical properties from selected expeditions in the Arctic Ocean. Swift, J. compiler.
- 1999 Canadian transect for the Circumpolar Arctic Vegetation Map. Gonzalez, G., W. Gould, and M. Reynolds.
- N-factor values and air and ground surface temperatures, Kuparuk River Basin, Alaska. Klene, A., F. Nelson, and N. Shiklomanov.
- North Pole Environmental Observatory aerial CTD survey. Morison, J., Steele, M., and K. Falkner.
- Controls on carbon flux in moist acidic versus non-acidic tundra, Arctic LTER Data. Hobbie, S., and L. Gough.
- Monitoring and manipulation of tundra response to climate change, Arctic LTER, Toolik Lake, Alaska. Shaver, G., E. Rastetter.
- Eurasian river historical nutrient and sediment flux data. Holmes, R., and B. Peterson.
- Radiation measurements from the USCGC Polar Sea, 1994. Lubin, D.
- Seawater chemistry from the North Pole Environmental Observatory. Falkner, K.
- Model output from MBL-GEM III for a typical tussock-tundra hill slope, 1921-2100. Hobbie, J., E. Rastetter, B. Kwiatkowski, and S. Le Dizes.
- Model output from MBL-GEM III for typical tussock tundra in the Kuparuk River basin, Alaska, 1921-2100. Hobbie, J., E. Rastetter, B. Kwiatkowski, and S. Le Dizes.
- Alaska North Slope 100 m Digital Elevation Model (DEM). Manley, W.
- Point Barrow, Alaska and Vicinity Bathymetry. Lestak, L., W. Manley, J. Maslanik.
- Heterotrophic Bacteria and Protists in the Upper Water Column of the Central Arctic Ocean. Sherr, E., Sherr, B., Fessenden, L., Gosselin, M., Thibault, D., and P. Wheeler.
- Western Arctic Mooring CTD and ADCP Data, 1992-1995. Weingartner, T.
- Distribution of Zooplankton in the Northeast Water Polynya Project, Summer 1992 and 1993. Smith, W., P. Lane, S. Smith, and C. Ashjian.
- Modeled Carbon Responses of Tundra Ecosystems to Historical and Projected Climate. McGuire, A.
- Preliminary Investigation of Paleoenvironment, Processes, and Carbon Stocks of Drained Thaw-Lake Basins, Arctic Coastal Plain, Alaska. Eisner, W.
- Thaw Depth and Vegetation Radiance Measurements, Happy Valley, AK, 1994. Oechel, W., A. Hope, D. Stow, and J. Fleming.
- Hydrographic Parameters from Fram Strait and Denmark Strait, 1998. Falkner, K.
- Methane Flux Measurements, Happy Valley, AK, 1994. Oechel, W., J. Verfaillie, and G. Vourlitis.

- Data Correlating the Shallow GISP2 Dust Profile with the Wolf Sunspot Number Series. Ram, M.
- Growing Season Energy and CO2 Fluxes over a Larch Forest Tundra Ecosystem in Siberia. Randerson, J.
- Benthos and Water Column Process Influences, Northeast Water Polynya Project, 1992. Ambrose, W. and P. Renaud.
- Glacial Geology Map of the Toolik Lake and Upper Kuparuk River Region, Alaska. Walker, D., T. Hamilton, A. Balser, and J. Anderson.
- Toolik Snowfence Experiment: 1994-2002 Active Layer Depth. Walker, M.
- Meteorological, Radiation, Soil, and Snow Data from Alaska Sites, 1998-2002. Hinzman, L., D. Kane, and D. Goering.
- East Siberian Air, Ground Temperature, and Snow Depth Measurements, 1882-1994. Romanovsky, V., editor.
- Alaskan Air, Ground, Snow, and Soil Temperatures, 1998-2001. Romanovsky, V., editor.
- Climate and Flux Data from Alaska Sites, 1998-2000. Beringer, J., F. Chapin III, C. Copass.
- Elevated Soil Temperature and Water Table Manipulation Data from Barrow, Alaska, 1999-2001. Oechel, W.
- Air and Soil Temperatures from Sites in Alaska 1995-2001. Welker, J., and J. Fahnestock.
- Climate Data from Barrow and Atqasuk, Alaska, 1995-2001. Webber, P., and R. Hollister.
- Snow Depth Yearly Measurements at Toolik Station 1995-2001. Oberbauer, S.

U.S. Antarctic Data Coordination Center (USADCC)

The NSF has funded the U.S. Antarctic Data Coordination Center (USADCC) at NSIDC since 1996 to facilitate the development of U.S. data set descriptions for inclusion in the Antarctic Master Directory (AMD), a node of the GCMD. The AMD contains metadata for multidisciplinary Antarctic scientific data collected by approximately 14 countries, under the auspices of the Scientific Committee on Antarctic Research (SCAR) and the Council of Managers of the National Antarctic Programs (COMNAP). Internal to the United States, the USADCC provides a national focal point for this activity, by assisting scientists with metadata directory tools, formats, and requirements, and by providing assistance to researchers with a host of related data management issues. Internationally, the USADCC represents the United States in the continuing international collaborative effort to develop, implement, and maintain the AMD.

During 2002-2003, the USADCC worked directly with NSF-funded Antarctic PIs, the GCMD, and NSF Antarctic Program Managers to increase U.S. data set description content in the AMD by more than 150 percent in 2002 and more than 30 percent in 2003. United States-contributed metadata records in the AMD now number more than 688, (up from 519 in February 2003). Searches of the AMD average several hundred per month, and retrievals of information from those searches average between 100 and 200 per month. 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 (PI) and Robert Bauer (Co-I) lead the USADCC activities at NSIDC.

Antarctic Glaciological Data Center (AGDC)

The NSF's Office of Polar Programs (OPP) funds the Antarctic Glaciological Data Center (AGDC) at NSIDC to archive and distribute antarctic glaciological and cryospheric system data obtained by the U.S. Antarctic Program. AGDC provides two types of data sets: PI data sets that hold data acquired by specific grants, and Compiled Products data, offering collections of important glaciological parameters. Compiled data archived at AGDC include ice velocity, firn temperature, shallow ice core measurements, geochemical composition of ice cores, snow pit data, and satellite images of ice shelves.

The AGDC now contains data contributed by about 50 PIs, spanning a broad variety of glaciological topics. Recent additions (eight data sets from six PIs) include tephra descriptions, Vostok gas isotope data, and ice motion data. Further, 19 Western Antarctic Ice Sheet Initiative ice cores (WAISCORES) data sets have been transferred and incorporated into the AGDC. The AGDC has four additional data sets under development. Users can access data and documentation, citation information, locator maps, derived images, and references at http://nsidc.org/agdc/. Ted Scambos (Co-I), Robert Bauer (Co-I) and Greg Scharfen (PI) lead the AGDC activities at NSIDC.

New Data Sets

- Snow and firn temperature and permeability measurements from Siple Dome, Antarctica. Albert, M.
- Ice velocity from Ice Stream C, West Antarctica. S. Anandakrishnan.
- Antarctic ice sheet velocity data. Bindschadler, R, P. Price, I. Whillans, and C. Van Der Veen.
- Antarctic ice sheet velocity data. Bindschadler, R., P. Vornberger, D. Blankenship, T. Scambos and R. Jacobel.
- Methane data from Taylor Dome ice core. Brook, E.
- Interplanetary dust helium isotope data from Vostok ice core. Brook, E.
- South Pole snow pit 1988 and 1989. Mayewski, P., and S. Whitlow.
- Dominion Range snow pit and ice core data 1984 and 1985. Mayewski, P., and S. Whitlow.
- Newall Glacier snow pit and ice core, 1987 to 1989. Mayewski, P., and S. Whitlow.
- Dronning Maud Land, Antarctica, ice core data, 1991 and 1992. Mayewski, P., and S. Whitlow.
- Central West Antarctic glaciochemistry from ice cores. Reusch, D.
- Firn air isotope and temperature measurements from Siple Dome and South Pole. Severinghaus, J., A. Grachev, and M. Battle.
- Decadal-length composite inland West Antarctic temperature records. Shuman, C., and C. Stearns.
- Taylor Dome ice core beryllium-10 data. Steig, E., and J. White.
- Taylor Dome ice core 20-cm resolution oxygen isotope data. Steig, E., and J. White.
- Taylor Dome ice core 1-m/0.5-m resolution oxygen isotope data. Steig, E., and J. White.
- Taylor Dome ice core deuterium isotope data. Steig, E., and J. White.
- Taylor Dome ice core 0.5-m resolution deuterium isotope data. Steig, E., and J. White.

The Frozen Ground Data Center

Data and information on frozen ground collected over many decades and in the future are critical for fundamental process understanding, environmental change detection and impact assessment, model validation, and engineering applications in regions of seasonal frost and permafrost. However, many of these data sets and information remain widely dispersed and relatively unavailable to the national and international science and engineering communities, and some data are in danger of being lost permanently.

The Frozen Ground Data Center (FGDC) (http://nsidc.org/fgdc), a collaborative effort between the World Data Center (WDC) for Glaciology, Boulder and the International Arctic Research Center (IARC), continues to work internationally to collect and distribute data and information for permafrost and seasonally frozen ground regions. The FGDC has worked closely with the International Permafrost Association (IPA) to help it meet its strategy for data and information management laid out by the IPA's Standing Committee on Data, Information, and Communication (SCDIC). Mark Parsons and Tingjun Zhang lead FGDC activities at NSIDC.

The FGDC has improved access to existing data and has augmented data holdings. The Center has a large collection of data and information for permafrost and seasonally frozen ground regions from *in situ* measurements and provides access to data and metadata for all the major IPA programs (http://nsidc.org/data/fgdc). The FGDC also has developed a collection of regional and hemispheric maps of permafrost, soil classifications, and related parameters. The FGDC is now exploring new areas of frozen ground data, including data from models and satellite remote sensing.

In July 2003, the FGDC published the *Circumpolar ActiveLlayer Permafrost System Version 2.0* (CAPS2) CD set (http://nsidc.org/data/g01175.html). Publication and distribution of CAPS2 marks a milestone for the FGDC and the IPA. CAPS2 is a compendium of GGD data and metadata currently available in the FGDC and around the world. It serves as a snapshot of frozen ground and related data holdings available as of spring 2003, and enables access to these data for users lacking ready Internet access or high-speed connections.

The FGDC also publishes an online, searchable Permafrost and Frozen Ground Bibliography at http://nsidc.org/fgdc/biblio/.

Other highlights of data released in 2002 and 2003 include:

- **The Circum-Arctic Map of Permafrost and Ground Ice:** Depicts the distribution and properties of permafrost and ground ice in the Northern Hemisphere.
- **Modeled Daily Thaw Depth and Frozen Ground Depth:** Modeled daily thaw depth and freezing depth for the Arctic terrestrial drainage basin.
- **Chinese Geocryological Regions and Classifications:** A digital version of "The Map of Geocryological Regionalization and Classification in China" from *Geocryology in China* by Y. Zhou, D. Guo, G. Qiu, G. Cheng, and S. Li.
- **Maps of Russian Permafrost and Ground Ice:** Includes map coverages of permafrost extent, permafrost temperature, the permafrost boundary, and ground ice thickness for all of Russia.
- **Russian Historical Soil Temperatures:** A collection of monthly and annual average soil temperatures measured at Russian hydrometeorological stations from the 1880s through 1990. Data were recovered from many sources and compiled by staff at the University of Colorado, USA, and the Russian Academy of Sciences in Puschino, Russia.

- **Maps of Russian Soil Characteristics:** Map coverages of various soil characteristics for all of Russia, including soil classifications and detailed soil characteristics. In addition, the data set includes two databases (.dbf files) of detailed soil characteristics from 234 measured soil profiles.
- **Northern Circumpolar Soils:** A circumpolar map of dominant soil characteristics covering the United States, Canada, Greenland, Iceland, northern Europe, Russia, Mongolia, and Kazakhstan.
- **Arctic Soil Freeze/Thaw Status from SSM/I:** Near-surface (< 5 cm) soil freeze/thaw status on snow-free and snow-covered land surfaces over the arctic terrestrial drainage basin. Data from August 1998 through December 2000 are projected onto a 25 km x 25 km NSIDC Northern Hemisphere EASE-Grid.
- **Modeled Daily Thaw Depth and Frozen Ground Depth:** Modeled daily thaw depth and freezing depth for the Arctic terrestrial drainage basin, with data from September 1998 through December 2000. A finite-difference model for one-dimensional heat conduction with phase change calculates daily thaw and freezing depths, based on data of snow water equivalent, soil temperature, soil dry-bulk density, and soil water content.

NOAA at NSIDC and the World Data Center for Glaciology, Boulder

The NOAA project at NSIDC ("NOAA@NSIDC") operates in cooperation with the NOAA NGDC to extend the NOAA National Data Center's catalog of cryospheric data and information products. NSIDC manages about 65 NOAA data sets, with an emphasis on *in situ* data, data rescue, and data sets from operational communities. NSIDC also helps develop educational pages, and contributes to larger projects of relevance to NOAA. In 2002 and 2003, the NOAA team at NSIDC:

- Released *Airborne Surface Profiling of Alaskan Glaciers*. These data, contributed by researchers at the University of Alaska, Fairbanks, are part of a data set that documents recent changes in Alaskan glaciers (see Arendt et al., 2002. Rapid Wastage of Alaska Glaciers and their Contribution to Rising Sea Level. Science, 297:382-386).
- Released *Norwegian North Polar Expedition 1893-1896: Oceanographic Data* Measurements from the North Polar Basin and the Barents Sea, collected by F. Nansen and crew on the *Fram*, and digitized at NSIDC to increase accessibility of these historical data.
- Released *Reconstructed North American Snow Extent, 1900-1993.* The contributing investigator combined satellite and early twentieth century station observations for a spatially comprehensive and long time series of snow extent.
- Released *Reconstructed North American, Eurasian, and Northern Hemisphere Snow Cover Extent, 1915-1997*. Using snow depth and climate data from the United States, Canada, China, and the former Soviet Union, the investigator generated a monthly snow-cover index to characterize snow extent, depth, and water equivalent.
- Released the *Sea Ice Index.* This web site shows trends and anomalies in arctic and antarctic sea ice, with explanatory text. It is helpful for researchers seeking to characterize the response of sea ice to climate, and to users with general questions about ice conditions. A poster on this product was given at the Fall AGU meeting, at which a press conference covered the record low ice extent that occurred in September 2002. A Sea Ice Index graphic was used in the NOAA National Climatic Data Center's Climate of 2002 Preliminary Annual Review.
- Released the *Glacier Photograph Collection* digital subset. Photographs of almost 3000 glaciers in Colorado, Wyoming, Montana, California, Alaska, and parts of Canada were scanned and made available online through a web-searchable interface, through a joint NGDC/NSIDC project funded by NOAA's Climate Database Modernization Project. The photos are part of a larger collection of historical photographs dating from the 1880s to 1975. Librarian T. Mullins presented a poster on the project at the Fall Meeting of AGU in 2002.
- Released *Meteorological Data from the Russian Arctic, 1961-2000,* Monthly mean station observations include 2-meter air temperature, sea level pressure, total and low cloud amount, precipitation, and relative humidity. Data are available in ASCII text format via FTP.
- Added data from two cruises to the *Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics* data set. These data are the most comprehensive unclassified source of ice thickness information from submarines.
- Significantly revised documentation for the following data sets*: Russian River Ice Thickness and Duration; IABP Drifting Buoy, Pressure, Temperature, Position, Interpolated Ice Velocity; World Glacier Inventory; Former Soviet Union Hydrological Snow Surveys, 1966-*

1996; Environmental Working Group Joint U.S.-Russian Atlas of the Arctic Ocean and Joint U.S.-Russian Arctic Sea Ice Atlas (added online "User Notes").

- Updated *International Ice Patrol Iceberg Sightings Database* and *Great Lakes Surface Ice Reports from U.S. Coast Guard* data sets, in cooperation with the International Ice Patrol and NOAA National Weather Service respectively.
- Archived digital ice chart data from 1997 through 2001, in cooperation with the U.S. National Ice Center.

These and other NOAA data products at NSIDC are available through NOAA National Data Center data servers, as well as from NSIDC.

The NOAA team also maintained a web site for the International Ice Charting Working Group, and developed a web site for the WMO Global Digital Sea Ice Data Bank at NSIDC. NSIDC's participation in these groups helps preserve ice chart data for use by researchers, and encourages its conversion from paper or graphical form to digital form.

Major progress was made on reviewing and updating the archive status of all NOAA@NSIDC data sets, in cooperation with NGDC's Mai Edwards. This work will be completed in 2004.

The World Data Center (WDC) for Glaciology, Boulder, is home for many of our international activities (see "International Activities" section), and has its own data catalog. Most WDC activities are supported by and overlap those of the NOAA@NSIDC team. An exception is the Frozen Ground Data Center, which is being developed with funding from NSF and in collaboration with the International Arctic Research Center (IARC) in Fairbanks, Alasca (see FGDC).

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. In 2002 and 2003, the NOAA team included Alejandro Machado for programmer and User Services support, Lisa Ballagh for operations support, and Lyne Yohe for technical writer support (with Keri Webster taking over in September 2002). Ken Knowles helped develop the Sea Ice Index, and Teresa Mullins led the Glacier Photograph Collection project, with NGDC's Mai Edwards.

Cold Land Processes Field Experiment (CLPX)

The NASA Cold Land Processes Field Experiment (CLPX) has been designed to advance understanding of the terrestrial cryosphere. Quantitative understanding of cold land processes over large areas will require advancements in 1) understanding how cold land processes extend from local to larger scales, 2) representation of cold land processes in land-surface models, and 3) a breakthrough in large-scale observation of hydrologic properties, including snow characteristics, soil moisture, the extent of frozen soils, and the transition between frozen and thawed soil conditions. Synergistic advancement on these fronts requires the following four major science questions to be addressed together:

1. How do the extent and evolution of snow and frozen landscapes affect fluxes, storage, and transformations of water, energy, and carbon?
2. At what scales does spatial variability of key state variables in the terrestrial cryosphere (including snow characteristics, soil moisture, the extent of frozen soils, and the transition between frozen and thawed conditions) control fluxes and transformations of water, energy, and carbon, and can remote sensing resolve this variability at these scales
3. What are the rates of change of the dominant cold land processes, and can remote sensing resolve these with sufficient accuracy to diagnose and improve land surface models?
4. How do the various uncertainties associated with remote sensing observations and models of cold land processes constrain/affect data assimilation and the ability to improve prediction?

Scientists, including NSIDC researchers, have developed a comprehensive field experiment to address these questions. The experiment used a set of nested study areas to permit a detailed examination of cold land processes, modeling, and measurement over a wide range of physiographic conditions and spatial scales. Within this framework, intensive ground, airborne, and spaceborne observations were collected, and land surface model data sets generated, to produce a comprehensive data collection.

NSIDC was a close partner in field experiments that took place in Colorado during the winter and spring of 2002 and 2003. NSIDC data management personnel participated in the field studies to collect data and provide on-site data processing and quality control. This greatly reduced data uncertainties and collection errors and improved data quality as much as 20%. NSIDC staff also generated custom subsets and grids of MODIS, AMSR, and SSM/I snow cover products for the CLPX Large Regional Study Area. Field data from the 2002 field campaign is available to the public. Other data from the experiment is available to CLPX science team members and will be released to the broader public after a one-year embargo. NSIDC plans to acquire and publish all of the data by fall 2004. For more information see http://nsidc.org/data/clpx/index.html.

The NSIDC Information Center/Library

The NSIDC Information Center/Library serves as a resource for cryospheric information, both for researchers at NSIDC and the University of Colorado, Boulder, and for the general public. The Library acquires and catalogs both published and unpublished analog materials on snow, ice, and permafrost, and digital data such as CD-ROMs and web resources. In addition to information requests addressed by the NSIDC User Services team, library staff filled over 450 information requests during 2002, and 424 information requests during 2003. The Library is funded by the NOAA@NSIDC project and by the NASA-supported DAAC.

The Library houses over 48,000 monographs, serials, journal articles, reprints, videos, and CD-ROMs. In 2002, 1,039 new items were added; 707 new items were added in 2003. The Library currently receives 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, published on the Web and on CD-ROM by the National Information Services Corporation (NISC). In 2003 a system of movable shelves was installed in the Library to increase the available shelf space for the monograph and book collections.

In addition to the Library, the Information Center also houses numerous analog data sets relating to the cryosphere. One of the largest of these data sets, the Glacier Photograph Collection, is being digitized as part of the NOAA Climate Database Modernization Project (see *Glacier Photograph Database and Digitization Project* highlight). During 2003, 2,000 additional photographs were digitized and placed online in a searchable database, which can be found at http://nsidc.org/data/glacier_photo/photo_query.html.

User Services and Statistics

Six User Services staff members responded to user inquiries at NSIDC, including Inquiries about the Antarctic Glaciological Data Center, ARCSS Data Coordination Center, Frozen Ground Data Center, NOAA at NSIDC, NSIDC DAAC, U.S. Antarctic Data Coordination Center, and the WDC for Glaciology, Boulder. 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 participates 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 2002 and 2003 Fall AGU Meetings, NSIDC staff presented posters describing data products, tools, and services, and prepared and staffed the NSIDC exhibit booth. The AGU booth drew approximately 65 new requests for data or information in 2002, and 94 in 2003, with about two thirds of the contacts being new to the organization. User Services also participated in the EOSDIS DAAC Alliance exhibit booth in support of one conference in fiscal year 2002.

The largest category of users is the Research and Education category, which includes universities, NASA, and NOAA (Figure 5). The number of new requests handled by User Services grew by 13% in FY 2002, and 23% in FY 2003, increasing for the 7th straight year (Figure 6). The increase is attributed to continued interest in existing products as well as growing interest in the EOS AMSR-E and MODIS data sets, which accounted for almost 30% of requests received by NSIDC in FY 2003. The majority of NSIDC data sets are available directly online and do not require users to be in contact with the organization unless they have questions or need support. These users are not reflected in the request statistics of Figure 6. NSIDC distributed a total of 6,372 gigabytes of data during FY03, with over 67% of distribution by volume represented by EOS data. Almost 30% of the data distributed by volume were on media, and 70% were via FTP.

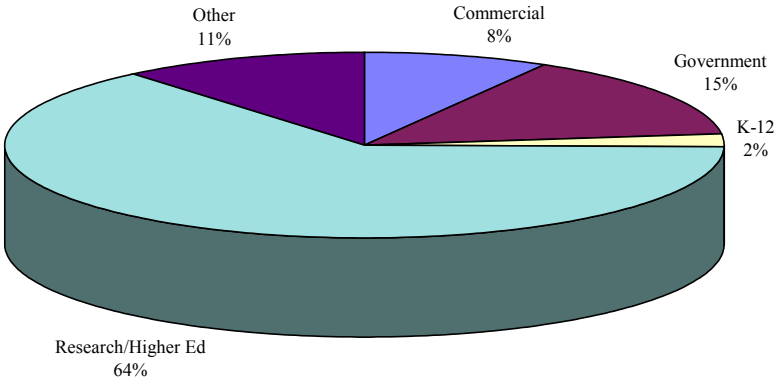

Figure 5: NSIDC Percentage of Requests by User Type

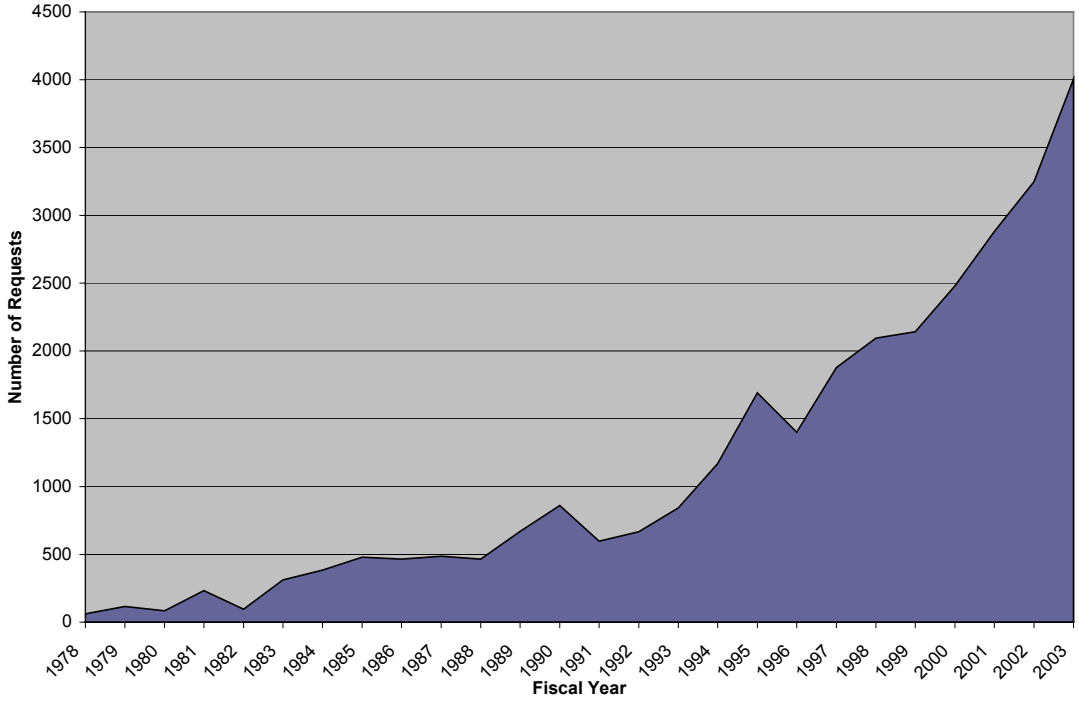

Figure 6: NSIDC Data and Information Request Totals, FY 1978-2003

Outreach and Education

NSIDC participated in the Fall Meeting of the American Geophysical Union (AGU) in 2002 and, in 2003, with its new booth and backdrop design. The 2003 meeting set a new attendance record, and NSIDC brought in nearly 100 new users at the event. In addition, NSIDC also had a booth at the joint session of the European Geosciences Society (EGS), European Union of Geoscientists (EUG) and AGU in Nice, France, in April of 2003. This event allowed NSIDC to reach approximately 50 new users, and increased the organization's recognition among the international community.

At these conferences and elsewhere, NSIDC scientists participated in press briefings that garnered widespread media interest. In 2002, NSIDC presented findings about record low sea ice in the Arctic at a press briefing during the Fall Meeting of AGU. This topic continued to be of interest in 2003, and was picked up by numerous news organizations after a NASA *Earth Science Update*. At the 2002 Fall AGU Meeting, Outreach Coordinator Marijke Unger presented a poster titled "Communicating Complex Concepts: A Guide for Scientists," which described the challenges and opportunities inherent in making scientific research accessible to the public.

In 2002-2003 NSIDC published and distributed eight quarterly newsletters, *NSIDC Notes*, to over 500 subscribers. Many NSIDC staff members – from scientists to technical writers to User Services representatives – contribute to the articles in *Notes*. Marijke Unger is the editor of the newsletter.

In NSIDC's continuing efforts to serve the user community and the public, the organization undertook the task of redesigning its outreach and data center collateral (print and electronic materials supporting NSIDC's mission, and intended for a broad audience). This task was the next step in solidifying NSIDC's identity after developing the current NSIDC logo in 2001.

Identity, brand recognition, and a cohesive message are important factors in shaping the communications, experiences, and influences an organization has with the public. Strong brand and identity design brings coherence and continuity to the information being presented, making it more accessible, and better conveying the voice and mission of the Center. Furthermore, it makes the organization more recognizable to its potential audiences. By redesigning, and in some cases creating, NSIDC's outreach material on and off the Web, the new collateral serves to engage new and existing users, while achieving NSIDC's overall mission of supporting cryospheric research. Examples of collateral that were redesigned or created include a Center-wide brochure, Program brochures and product fliers, redesigned CD covers and corresponding CD interfaces, the re-branding of theme sites and Center-specific sections of the NSIDC web site, the creation of NSIDC templates for PowerPoint presentations and posters, and a new backdrop design for the tradeshow booth that carries over to the accompanying tradeshow

materials. Nancy Geiger Wooten, Graphic and Web Designer at NSIDC, led this effort to its successful completion.

The new look for the print and digital materials not only provides a consistent face to the valuable information presented to the user, but it also provides an opportunity for NSIDC to stand out and set itself apart from other sources of scientific data. It has proven effective in facilitating user access to data, and users have responded favorably to the redesigned web site and printed materials. User requests in 2003 have increased compared to 2002.

In the realm of educational outreach, NSIDC hosted the cryospheric session of the INSTAAR Open House, bringing over 80 local high school students to the Center for a “quiz show” format competition featuring information related to cryospheric science and exploration. NSIDC Director Roger Barry co-organized a Conference for the International Year of the Mountains sponsored by CIRES and held at the University of Colorado, Boulder, in Novemeber of 2002. Barry opened the meeting with a talk on "The Global Significance of Mountains" and speakers addressed climate variability in the western United States, changes in mountain glaciers, alpine biodiversity, geologic hazards, and high altitude medicine, as well as mountain cultures, mountain climbing, and film making.

During the course of 2002-2003, a number of Outreach and User Services staff participated in a Space Science Institute workshop on educational outreach, with support from CIRES, and NSIDC staff also participated in science fairs, science bowls, and workshops for teachers. NSIDC also regularly contributes materials to CIRES outreach efforts, including a workshop for earth science teachers held in conjunction with the 2003 Fall AGU Meeting, where over 150 of NSIDC’s educational *Into the Arctic* CDs were distributed.

International Collaboration

The WCRP Climate and Cryosphere (CliC) Project

The cryosphere is an integral part of the global climate system with important links 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.

NSIDC/WDC for Glaciology, Boulder, continues to play a major role in the World Climate Research Program (WCRP) project on Climate and the Cryosphere (CliC), established in March 2000, through the involvement of Roger Barry, as Co-Vice Chair of the CliC Science Steering Group, Richard Armstrong as a member of the Data Management and Information Panel, and Mark Serreze as Chair of the Ad Hoc Panel on Products for Polar Reanalysis. The Science and Coordination Plan and the CliC Implementation Strategy are available at: http://clic.npolar.no.

The CliC Scientific Steering Group held its third session in Beijing in November 2002, and its 4th session in St Petersburg after the Final ACSYS Science Conference in November 2003, under the new chairmanship of Dr. Barry Goodison, Canada.

Discussions are continuing in the United States concerning the establishment of a science committee to coordinate national activities relevant to 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 17,000 L1A and 7,000 L1B ASTER images suitable for GLIMS analysis (with the necessary gain settings and minimal cloud cover) have been acquired as of early 2003. 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 (Greg Scharfen PI). NSIDC will ingest GLIMS analyzed glacier data from Regional Centers and provide online data access.

The database design, data transfer specification, and ingest module are complete. The database design reflects extensive input from the glaciological community, and includes over twenty tables storing such information as glacier name, glacier geometry, surface velocity, snowline elevation, descriptive characteristics compatible with the World Glacier Inventory, names of analysts and their institutions, and pointers to source data. Simple user interfaces for data submission and search and order have been created. NSIDC is working closely with several of the Regional Centers to facilitate the analysis of imagery attributes and their ingest, archive, and distribution. NSIDC is collaborating with the USGS on the development and testing of the GLIMSview image analysis software, and will also incorporate historical data from Central Asia, China, and Alaska, which will permit comparison of current and past conditions.

The GLIMS project benefited from an 8-month visit of Fulbright Scholar Tatiana Khromova Institute of Geography, RAS Moscow, during 2002-2003 through her GIS expertise in glacier data analysis.

The GLIMS project at NSIDC will continue with new funding from NASA (NASA CAN 02-OES-01 and NRA 03-OES-02: Richard Armstrong, PI) beginning in mid-2004. Related GLIMS efforts at the USGS also have continuing funding.

Workshop on Global Glacier Recession

NSIDC Director Roger Barry convened an NSF-sponsored workshop on "Mapping Global Glacier Recession" in Boulder, 16-18 March 2003. The meeting brought together experts from 11 countries to consider improved and faster methods to map mountain glaciers and ice caps in light of the recent acceleration in their recession. In addition to invited papers and contributed posters, three working groups addressed the status of the Global Terrestrial Network for Glaciers (GTN-G) within GCOS/GTOS, the World Glacier Inventory/World Glacier Monitoring Service, and methods of glacier mapping with new technologies. The workshop noted that the previously estimated number of glaciers worldwide and their calculated ice volume are undoubtedly too low, due to the omission of ice bodies around the Greenland and antarctic ice sheets. Most mountain areas show evidence of accelerated glacier wastage over the last two to three decades. Recommended procedures to increase the availability of digital data on glacier extent were proposed. A report on the Workshop highlights will appear in ICE nos. 32-33, and Glaciological Data Report Number 32 (GD-32) on the workshop proceedings was published late in 2003. GD-32 can be found at http://nsidc.org/pubs/gd/index.html.

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. The Global Digital Sea Ice Data Bank (GDSIDB) is a World Meteorological Organization project designed to preserve ice chart data from operational centers. The Data Bank of sea ice chart information resides at NSIDC and at the Arctic and Antarctic Research Institute, St. Petersburg, Russia. At the ninth session of the Steering Group for the GDSIDB, hosted by the Argentine Naval Hydrographic Service in Buenos Aires, October 2002, the Steering Group accepted recommendations for a new vector format for digital ice charts that was developed by the IICWG Ad Hoc Format team, coordinated by NSIDC's F. Fetterer.

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

The SCDIC initiates and implements IPA strategies for data, archiving, information product development, and communication within and beyond the permafrost community. To continue the IPA strategy for data and information management as part of the Global Geocryological Database (GGD), the SCDIC worked 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. Tingjun Zhang and Mark Parsons are leading the work at NSIDC as part of Frozen Ground Data Center (FGDC) activities. The FGDC has collected data from the GTN-P, the Arctic Coastal

Dynamics project; the Cryosol database and maps, and from task forces on permafrost creep and mountain permafrost modeling and mapping. Data products include selected Chinese permafrost maps and borehole data, a time series of Russian soil temperatures from hydrometeorological stations, data from the 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 Global Energy and Water Cycle Experiment (GEWEX) Asian Monsoon Experiment (GAME)-Tibet and GAME-Siberia projects, the Canadian climate cryosphere programs, the United States Arctic System Science (ARCSS) projects, revisions to the English-Russian permafrost glossary, and an updated bibliography on frozen ground. An informal working group meeting to discuss CAPS2 contents was held at NSIDC on 13-14 February 2003. CAPS2 comprises three CDs that were distributed to attendees at the 8th International Conference on Permafrost in Zurich in July 2003.

Long-Term Archive Committee Activities

NSIDC's Long-Term Archive Committee, led by Ruth Duerr, is engaged in developing policies and procedures to ensure proper stewardship of data entrusted to NSIDC. The committee

- Recommended adoption of the OAIS Reference Model, as well as the "Global Change Science Requirements for Long Term Archiving", 1999, as NSIDC archive standards.
- Finalized an NSIDC Data Management Policies document that defines minimum requirements for data management by NSIDC programs and projects, defines NSIDC standards for metadata and data formats, and defines standard levels of service.
- Developed a standards-based preservation metadata model to be implemented as part of NSIDC's metadata database.
- Developed Center-wide procedures for archiving new data sets that ensure data recovery and address data set versions.

Research

Richard Armstrong

Standard global snow cover products derived from satellite remote sensing: Long-term climatologies from historical data sets and near real-time products from current and future EOS data sets. The NOAA/NASA Pathfinder Program was initially designed to ensure that certain key remote sensing data sets of particular significance to global change research were scientifically validated, consistently processed, and made readily available to the research community at minimal cost. Through this program, NSIDC (R. Armstrong PI) has developed the SMMR and SSM/I Level 3 (EASE-Grid format) Pathfinder data sets for the period 1978 to 2004. We are currently building on these accomplishments in two distinct ways. First, we are developing a standard global snow cover product derived from historical visible and passive microwave data and future EOS data. The historical product will be in the form of a monthly climatology of snow extent and snow water equivalent for the period 1978 to 2004. Second, we are combining the specific advantages of passive microwave (AMSR-E) and optical data (MODIS) to provide an integrated near real-time global gridded snow cover product during the EOS era. Prototype snow cover maps from AMSR-E compare well with maps derived from SSM/I. Our current EASE-Grid blended product incorporates MODIS data from the Climate Modelers Grid (CMG) at approximately 5 km (0.05 deg.) with microwave-derived SWE at 25 km, resulting in a blended product that includes percent snow cover in the larger grid cell whenever the microwave SWE signal is absent. We've developed tools that describe the relationships between the percent area covered by snow as indicated by the MODIS data and the threshold for the appearance of snow as indicated by the passive microwave data. Both MODIS and AMSR-E data have enhanced spatial resolution compared to the earlier sensor systems, and analysis describing how this increased spatial resolution results in more accurate snow cover maps is being undertaken. *(R. Armstrong, P.I., Funded by NASA)*

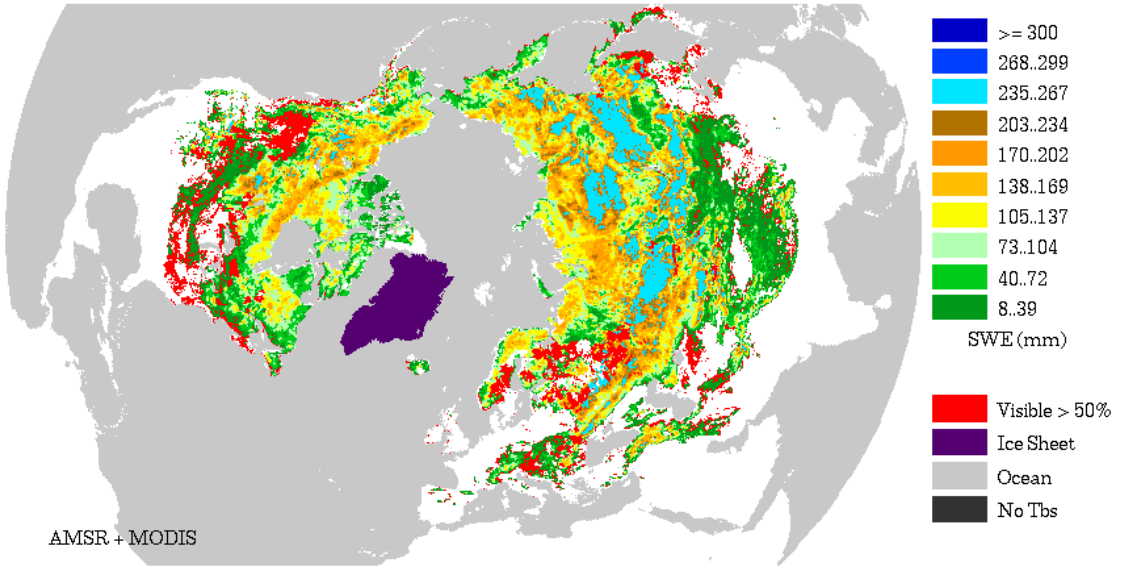

Figure 7: Example of AMSR-E SWE product combined with MODIS snow extent for 1-8 January 2003. MODIS is shown in red for those locations where AMSR-E fails to detect snow and MODIS indicated snow cover over at least 50% of the 625 km^2 EASE-Grid pixel.

Validation of AMSR-E snow products. This validation study supplements and enhances the validation activities currently planned by the Science Team for the AMSR-E snow products. In order to include a wide range of spatial scales, we have evaluated algorithm performance at the local or grid scale, the river-basin scale, and the regional to hemispheric scale. Local or grid scale studies use data from the NASA Cold Land Processes Experiment (CLPX) undertaken during mid-February and late March of 2002 and 2003 in northwestern Colorado. Larger river basin scale validation is based on participation in an ongoing NASA- and NSF-funded program that involves integrated near real-time monitoring and analysis of the major components of the pan-Arctic hydrologic cycle. For comparison and validation at the continental to hemispheric scale, we are evaluating the snow algorithms by comparison with the EOS MODIS daily global snow extent and the NOAA Interactive Multisensor Snow and Ice Mapping System (IMS) daily Northern Hemisphere snow extent maps, as well as with an NSIDC research data set that integrates snow depth and snow water equivalent from the Natural Resources Conservations Service's SNOTEL network and NOAA's COOP station network. To support further calibration/validation of AMSR-E brightness temperatures, we are providing comparisons with SSM/I data over stable targets. While others on the Science Team will work with ocean and atmosphere targets, we will work with land surface targets, which exhibit spatial homogeneity and stability with respect to emissivity (e.g., desert, jungle, ice sheets). *(R. Armstrong, P.I., Funded by NASA)*

Lead on development of the NSIDC Web product "State of the Cryosphere" This web site is directed towards a broad audience of scientific and general users, and provides a current and succinct overview of the response of various components of the cryosphere to climate change. The site focuses on seasonal snow cover, sea ice, mountain glaciers, ice sheets, permafrost, and sea level, and their response to global warming. During 2003 we updated the sea ice and snow cover time series, added a section on ice shelves, and reviewed and edited the entire site. *(Funded through NSIDC NASA DAAC)*

NASA Cold Land Processes Experiment (CLPX). As one of the five CLPX PIs, Armstrong participated in the 2003 field experiment and in all meetings pertaining to the compilation and initial analysis of data from the 2002 and 2003 field experiments, in addition to monitoring ingest, QC, archival, and distribution of CLPX data at NSIDC. Armstrong operated the University of Tokyo Ground-Based Microwave Radiometer (GBMR-7) (AMSR Simulator) at the Fraser, Colorado, site in close collaboration with Professor Toshio Koike, University of Tokyo, four graduate students, and two technicians. The analysis of data from the GBMR-7 is underway and the data are being compared to brightness temperatures derived from the radiation transfer model MEMLS (Microwave Emission Model for a Layered Snowpack), *(R. Armstrong, Co.I., Funded by NASA)*.

Andy Barrett

CIRES/NOAA Western Water Assessment – South Platte regional assessment tool. The Western Water Assessment (WWA) is part of the NOAA Regional Integrated Scientific Assessment (RISA) Program. The South Platte Regional Assessment Tool (SPRAT) was developed by a group of climatologists, hydrologists, limnologists, economists, and water policy specialists at the University of Colorado, with the help of Hydrosphere Consulting, Boulder, to assess the impact of historical climate variability on the current water resources allocation system in the South Platte River Basin. Our contribution to this project was to develop a set of homogeneous, serially continuous simulations of runoff for the period 1918 to 2002 for 25 basins in the headwaters of the Colorado and South Platte rivers, using historical climate records and a set of climate scenarios that simulated warmer drier conditions within the region. Ensembles of runoff were produced for each basin to account for uncertainty in the model and temperature and

precipitation inputs. The spread of ensemble runoff provides a measure of the expected range of runoff, given our knowledge of the hydrological systems and the assumptions about this system that are built into the model. Runoff from the 25 basins provides input to a water allocation model that computes the optimal distribution of available resources between prescribed municipal, industrial, and agricultural water demands. Currently, SPRAT is being validated for the 2002 drought. (*A. Barrett. Funded by NOAA*)

Mass balance and hydrology of a small Front Range glacier. Changes in the mass of glaciers and snow patches can provide information about how the regional water balance changes with climate. Arapaho Glacier is one of 14 small glaciers located on the east side of the Continental Divide in the Colorado Front Range. There are also hundreds of semi-permanent snow patches in this region. We measured snow accumulation and summer balance at Arapaho Glacier every two to three weeks between May and October 2003. We use estimates of mass balance for 2003 in conjunction with historical records of mass balance, photographs, and remotely sensed images to document changes in the mass balance, area, and melt water runoff from Arapaho Glacier over previous decades. These changes are interpreted in terms of sensitivity of Front Range glaciers to climate change. Measurements of mass balance at Arapaho Glacier will continue in 2004, and we intend to extend the study to other Front Range glaciers. This work is being done in collaboration with Mark Dyurgerov and Tad Pfeffer of INSTAAR. The work is also related to the Global Land Ice Measurements from Space (GLIMS) project. (*Andrew Barrett, Thomas Painter, and Bruce Raup).*

Roger Barry

Distribution and temporal characteristics of seasonally frozen ground in the Northern Hemisphere. This study used climate and remote sensing data to investigate the distribution of seasonally frozen ground in the Northern Hemisphere. We estimated the southern boundary of seasonally frozen ground (frozen for two weeks or more) using the 0^{o}C mean monthly air temperature as a threshold. Using this estimate together with data from passive microwave remote sensing and numerical models, we found that the number of days that near-surface soils experience a freeze/thaw cycle varies from more than six months in high-latitude and high-altitude regions, to less than two weeks in middle and low latitudes. During the course of a year, approximately 40 percent of the Northern Hemisphere experiences freeze/thaw cycles. The average maximum extent of seasonally frozen ground is between 55 and 60×10^6 km^2, or 58-63 percent of the exposed land surface in the Northern Hemisphere. The annual maximum extent of seasonally frozen ground decreased by about 15-20 percent over the past several decades, mainly due to an increase in winter air temperatures and a reduction of snow cover extent. (*T. Zhang, P.I., Roger G. Barry, Co-P.I. Funded by NSF.)*

Collaborative Research: Stochastic variability of seasonal ground freeze-thaw at local, regional and hemispheric scales under modern and predicted climate (see entry under T. Zhang).

Collaborative Research: A regional integrated monitoring system for the hydrology of the Pan-Arctic Landmass (see entry under M. Serreze).

Glacier recession in central Asia. This project assessed changes in glacier extent in mountain regions of Russia during the second half of the twentieth century, and was conducted in collaboration with Tatiana Khromova, Institute of Geography, Russian Academy of Sciences (RAS), Moscow, while a Fulbright Visiting Scholar at NSIDC in 2002-2003. We compared historical survey maps of glaciers in the Ak-Shirak Range, Tien Shan, using GIS techniques with 2001 Advanced Spaceborne Thermal Emmission and Reflection Radiometer (ASTER) imagery. Ice area decreased by more than 20 percent after 1977, compared with minor reductions over the previous 34 years. Records from a nearby mountain weather station show significant summer

warming and annual precipitation decreases after 1977. The results are presented in Geophysical Research Letters (Khromova, Dyurgerov, and Barry, 2003) and research proposals to extend the work have been funded by NASA under the GLIMS project (see entry under G. Scharfen).

Florence Fetterer

Sea Ice Index. This interactive web site and data product (http://nsidc.org/data/seaice_index/) was developed with K. Knowles to address a need for a readily accessible, easy-to-use source of information on sea ice concentration trends and anomalies. The Sea Ice Index was designed to answer the following types of questions, graphically and at a glance: "Has the concentration of sea ice in the Beaufort Sea become less in recent years?" and "Is the ice edge position in the Weddell Sea this austral summer about where it usually is?" We used the NSIDC Near Real-Time DMSP SSM/I Daily Polar Gridded Sea Ice Concentrations processing stream to generate monthly mean, trend, and anomaly images, so that users can monitor monthly mean ice conditions as they evolve. Text on interpreting the trends and anomalies discusses the variability of sea ice and the applicability of statistical methods for trend detection, with a bibliography for further reading. Archived images can be displayed in tabular form with a Web Image Spreadsheet Tool. While in development, the product alerted NSIDC investigators to the 2002 Record Minimum Arctic Sea Ice Extent (Serreze et al., A record minimum arctic sea ice extent and area in 2002, GRL, 2003) *(F.Fetterer, PI. Funded by NOAA/NESDIS/NGDC)*

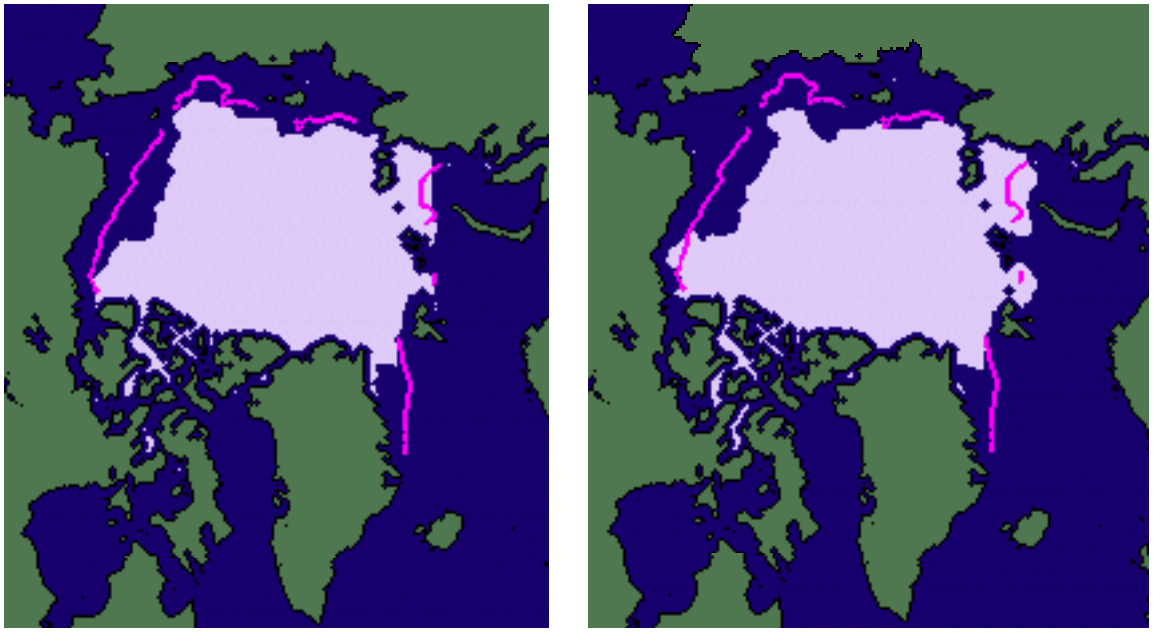

Figure 8: Sea ice extent in September 2002 (left) and September 2003 (right) from the Sea Ice Index. The web site gives trends, anomalies, and means for extent and concentration.

Oliver Frauenfeld

Changes in freeze-thaw cycle and permafrost dynamics, and their hydrological implications over the Russian Arctic. Seasonal freezing and thawing processes in cold regions play a major role in ecosystem diversity, productivity, and the arctic hydrological system. Long-term changes in seasonal freeze and thaw depths are also important indicators of climate change. Only sparse historical measurements of seasonal freeze and thaw depths are available for permafrost and seasonally frozen ground regions. Using mean monthly soil temperature data for 1930–1990 for 242 stations located throughout Russia, we derive active layer and seasonal freeze depth based on

soil temperature data measurements. A comprehensive evaluation of interdecadal trends in these new data for Russia indicates that, in permafrost regions, active layer depths have been steadily increasing. In the period 1956–1990, the active layer exhibited a statistically significant deepening, by approximately 20 cm. The changes in the seasonally frozen ground areas are even greater—the depth of the freezing layer decreased 34 cm between 1956 and 1990. Changes in active layer thickness are most strongly related to snow depth, while freeze depth is influenced most strongly by air temperature. Air temperature and snow depth have been changing less in the seasonally frozen ground regions of Russia compared to permafrost regions, although observed changes in freeze depth are greater than changes in active layer depth for 1930–1990. This indicates that the seasonally frozen ground regions of the Russian high latitudes are more susceptible to climate change than the Russian permafrost. However, as temperatures have been rising over recent decades, especially in the high-latitude continental regions, both permafrost and seasonally frozen ground regions are being impacted. *(T. Zhang, P.I., R. Barry, Co-I., Funded by NSF).*

Climate change trends in Northern Hemisphere atmospheric circulation. The circumpolar vortex is a useful measure of atmospheric circulation because it captures multiple aspects of mid- and high-latitude circulation variability and incorporates long-wave circulation trends, such as changes in standing waves, and regional circulation features such as strengthening or weakening of troughs and ridges. In addition, the vortex implicitly incorporates all non-tropical atmospheric teleconnection patterns such as the Pacific/North America pattern, the North Atlantic Oscillation, the Arctic Oscillation, etc. We developed a circumpolar vortex climatology for 1949–2000 at multiple pressure levels within, and both north and south of, the primary Northern Hemisphere baroclinic zone. From the beginning of the record until 1970, the vortex exhibited a statistically significant expansion, but the vortex has been contracting significantly since then at all examined levels. These observed trends are strongest in the lower latitudes and weakest in the higher latitudes; the trends are also stronger in the upper troposphere than in the lower troposphere. These hemispheric changes were driven primarily by expansion/contraction over Eurasia and North America. Contraction of the circumpolar vortex at every level of the atmosphere implies that the atmosphere has been warming at depth since 1970. Comparisons with satellite temperatures indicate that the size and position of the vortex is coupled strongly to atmospheric temperature, and is therefore a good indicator of climate change. *(Funded through various sources).*

Northern Hemisphere atmospheric circulation variability and the Pacific Ocean. The relationship of the Pacific Ocean to the climate of the Pacific/North America region, the Northern Hemisphere, and the entire globe have been investigated for many decades. However, significant uncertainty still exists about complex ocean-atmosphere interactions. We used multivariate statistical approaches to determine the major patterns of Pacific Ocean-Northern Hemisphere circumpolar vortex variability. The dominant association is an interdecadal pattern that likely represents the true multidecadal signal in the climate of the Pacific Ocean-atmosphere system. Sea-surface temperature variability of this climate pattern is linked with upstream circulation variability over Eurasia, suggesting the importance of the Eurasian landmass in driving hemispheric climate. The second pattern of ocean-atmosphere interaction is indicative of El Niño-like variability. However, the associated vortex patterns occur independently of El Niño. Subsequent patterns of ocean-atmosphere interaction depict local air-sea feedbacks that are not reconcilable with known patterns of ocean or atmosphere variability. Nonetheless, these local interactions between the Pacific Ocean and Northern Hemisphere circulation are again largely independent of El Niño, further suggesting that El Niño plays a smaller role in the global climate system than is generally believed. *(Funded through various sources).*

Feng Ling

A numerical model for surface energy balance and thermal regime of the active layer and permafrost containing unfrozen water. Predicting the direction and consequences of global changes in cold regions requires accurate simulation of the thermal regime of the active layer and permafrost. This study used a one-dimensional heat transfer model, based on the surface energy balance approach, to estimate surface energy balance components and the thermal regime of soil. We used the surface energy balance approach to estimate the upper boundary temperature conditions for thermal conduction calculations and to calculate surface heat fluxes. The influence of unfrozen water on the thermal properties of soils was accounted for in the heat transfer model. We included the effect of snow in the model by extending the heat conduction solution into the snow layer and computing the surface heat balance and the snow surface temperature. The model was driven by meteorological data collected at Barrow, Alaska, and was validated against observed ground temperatures at Barrow. The results show good agreement between the simulated and the measured soil temperatures at depths of 0.01, 0.29, 0.50, and 1.0 m. When snow cover was present, snow surface temperatures were colder than ground surface temperatures and air temperatures, with mean temperatures of -5.36^{o}C and -1.55^{o}C, respectively. We conclude that the model presented in this study can be used to accurately calculate surface energy balance components and ground temperatures, and to simulate the impact of seasonal snow cover on the thermal regime of the active layer and permafrost containing unfrozen water. Snow density, which determines the snow thermal conductivity, volumetric heat capacity, and albedo in this model, can strongly affect the performance of this model. (*Tingjun Zhang, P.I., Feng Ling, Co-I. Funded by IARC/NSF*.)

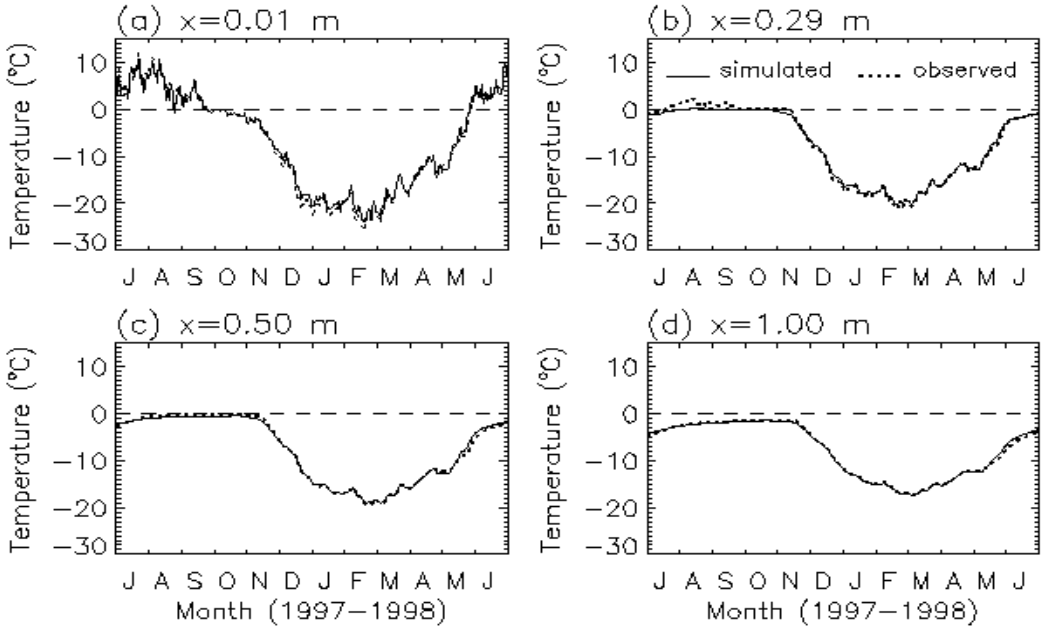

Figure 9: A comparison between simulated and measured ground temperatures at depths of (a) 0.01 m; (b) 0.29 m; (c) 0.50 m; and (d) 1.0 m for the period of July 1997 to June 1998.

Impact of changes in snowpack appearance and disappearance dates on surface energy balance in the Alaskan Arctic. The onset date of seasonal snow cover in the Alaskan Arctic varies from late September to early October, while the disappearance date ranges from late May through middle June. Variations in snowpack onset and disappearance dates can strongly affect energy exchange between the atmosphere and the surface due to changes in surface conditions. In

this study, we used a one-dimensional heat transfer model with phase change (based on a surface energy balance approach) to quantify the impact of variations in snowpack onset and disappearance dates on the surface energy balance. The model was validated against meteorological data and ground temperatures collected at Barrow, Alaska, and driven with observed mean daily air temperature, dew point temperature, snow cover depth, incident solar radiation, wind speed, and atmospheric pressure collected at Barrow, Alaska, from 1995 to 1998. A series of simulation cases was conducted by varying the snowpack onset date by 10 days in autumn in 1997 and the disappearance date by 10 days in spring in 1998. The preliminary results indicate that the surface (snow surface when seasonal snow cover was present and ground surface when seasonal snow cover was absent) temperature, net solar radiation, net longwave radiation, sensible heat flux, latent heat flux, and conductive heat flux are all sensitive to variations in snowpack onset and disappearance dates. (*Tingjun Zhang, P.I., Feng Ling, Co-I. Funded by IARC/NSF)*

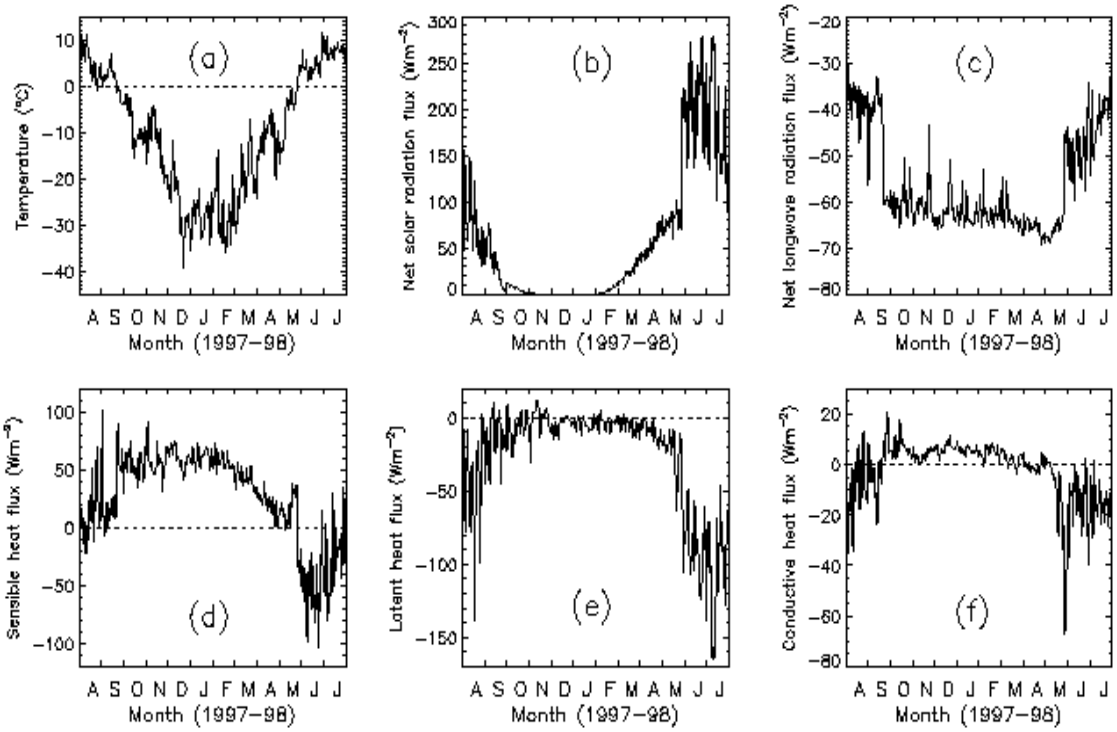

Figure 10: Simulated time series of (a) surface temperature; (b) net solar radiation; (c) net longwave radiation; (d) sensible heat flux; (e) latent heat flux; and (f) conductive heat flux using mean daily meteorological values. Energy fluxes toward the surface are defined to be positive.

Jim Maslanik

Areas of research during the past two years included further investigation of factors affecting regional sea ice severity in the western Arctic, assessment of environmental change and future climate change-related effects on the western Alaskan North Slope, analysis of remotely sensed sea surface temperatures in the marginal sea ice zone, development and testing of small unpiloted aerial vehicles for polar research, and and participation in a sea ice comparison and cultural exchange project between Barrow, Alaska and Clyde River, Nunavut. In support of the AMSR-E ice product validation effort, an in situ snow and ice measurement campaign was planned and carried out for the shore-fast ice near Barrow, Alaska and at an ice camp in the central Beaufort Sea. This effort included collection of a wealth of snow and ice data, in conjunction with coordinated overflights of the NASA P-3. Other research efforts underway included: (a)

investigations of methods to retrieve sea-ice meltpond fraction; (b) analyses of trends and patterns in sea surface temperature near and within the marginal sea ice zone; (c) continuing operations of the Aerosonde unmanned aerial vehicles (UAVs) from Barrow, Alaska for marine and atmospheric research; (d) investigations of remote sensing and modeling approaches to improve the calculation of turbulent fluxes from sea ice leads; (e) ongoing assessment of shoreline change and effects of severe storms on Alaskan North Slope communities, and (e) participation as a member of the NASA NPP science team to assess suitability of NPOESS environmental data records as climate data records. Funding for the above work is provided by NASA and NSF.

Walt Meier

Investigation of the assimilation of ice motion data in sea ice models. This project combines observed ice motion fields with sea ice models to understand the model's sensitivity to the observations and to improve model fields. The results to date indicate the observed ice motions improve the model motion fields. However, the model ice thickness and extent is sensitive to the changes imposed on the model dynamics by the observations. This leads to enhanced ridging and divergence in the ice cover and to excessive melt during summer. The sensitivity of the model to the motions is affected by the choice of atmospheric forcing fields and small changes in fields such as surface temperature can have a substantial effect in how the model responds to the observed ice motions. Results have been presented at a variety of conferences and workshops and manuscripts are under preparation (*T. Arbetter, CIRES, PI; W. Meier, co-PI. Funded by NASA, NAG5-10556)*

Improved multiyear sea ice concentrations from SSM/I using neural net methods. We computed new estimates of multiyear sea ice fraction from SSM/I data by using neural net methods with Okean passive and active microwave products as training data. The new estimates are more realistic than those from standard ice concentration algorithms. The estimates show considerable interannual variability in multiyear ice cover. Meier spent a week in Moscow, Russia, consulting with scientists at the Russian Academy of Sciences, led by Gennady Belchansky, along with David Douglas of the USGS and Bob Stone of NOAA/CIRES. (*Funded by NATO)*.

Improved sea ice analyses and forecasts by assimilation of sea ice motion into a newly developed sea ice model. Advances in observed ice motion products, and new modeling approaches, have the potential to greatly increase the benefits of data assimilation. Assimilation of passive microwave SSM/I 85-GHz ice motion data substantially reduces motion RMS errors and improves correlation with buoys. Ice motion derived from new datasets, such as AMSR-E, could yield twice the spatial resolution (5 km vs. 12.5 km) of current SSM/I products and provide daily coverage of the entire Arctic and Antarctic. AVHRR (and potentially MODIS) visible and IR imagery, with even higher spatial resolution (0.5 km), can supplement passive microwave data in clear-sky regions. (*Submitted to National Ice Center*).

Evaluation of SSM/I sea ice concentration fields using AVHRR imagery. In this study, we evaluated four SSM/I ice concentration algorithms for the eastern Arctic peripheral seas during summer and winter, through comparisons with AVHRR visible and infrared imagery. Differences in biases of the algorithms were statistically significant, with the NASA Team 2 algorithm having the lowest bias. The Bootstrap algorithm has the lowest error standard deviation. However, the error standard deviations of the algorithms were not statistically different from each other, indicating that the uncertainty of ice concentration estimates are primarily limited by spatial resolution, not by choice of algorithm. (*Funded by U.S. Naval Meteorological and Oceanographic Command*).

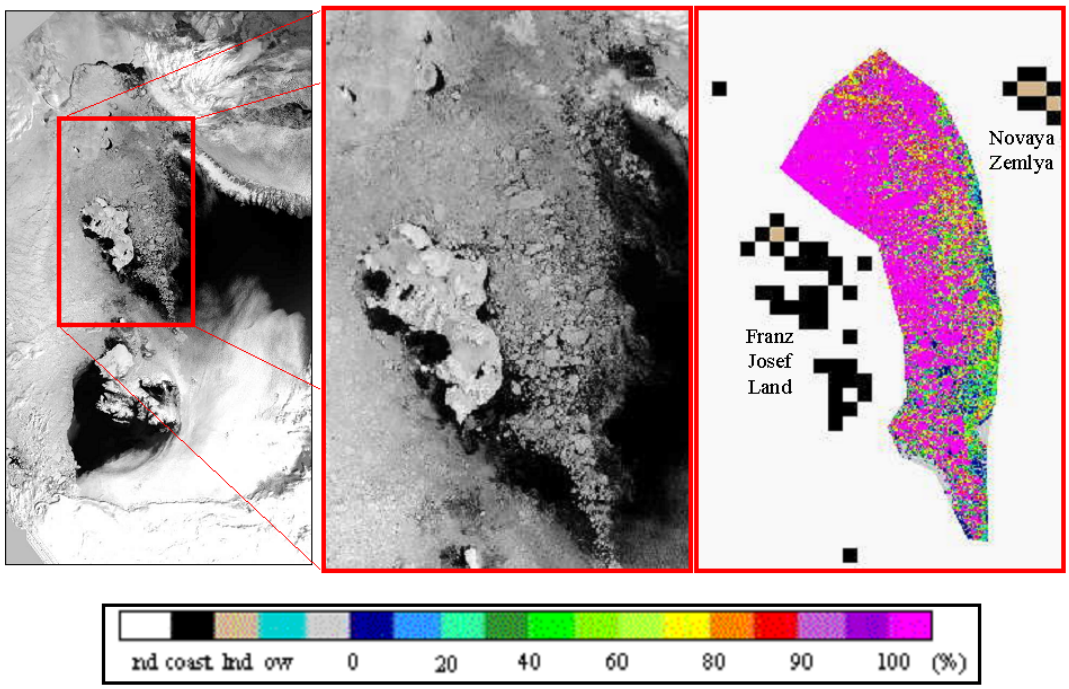

Figure 11: AVHRR channel 2 reflectance (left) gridded at 2.5 km resolution, a zoom of the area (middle), and ice concentration derived using a mixing algorithm (right). The region is the northern Barents Sea; north is to the left in the images. The color bar indicates ice concentration ranges in 5% or 10% intervals and flag values for 'no data' (nd), 'coast', 'land' (lnd), and 'open water' (ow)

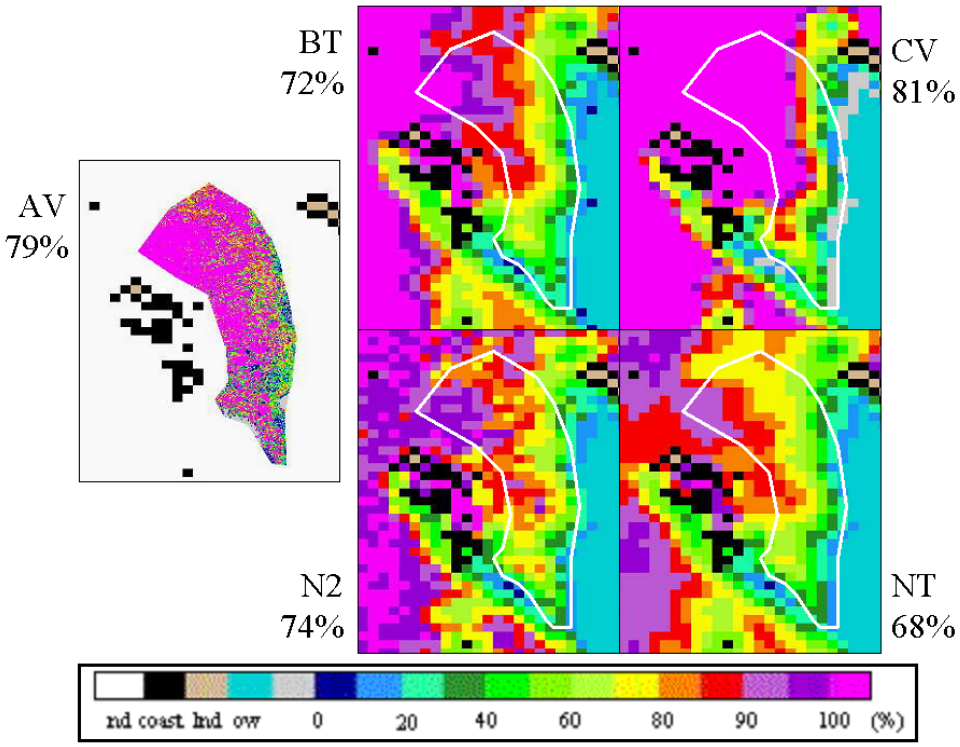

Figure 12: AVHRR ice concentration (AV) and ice concentration derived from four common SSM/I algorithms: Bootstrap (BT), NASA Team (NT), NASA Team 2 (N2), and Cal/Val (CV). Color scale is same as for Figure 6. Percentages are concentration levels for each field. The white outlined regions in the SSM/I concentrations delineate the region covered by AVHRR.

Christoph Oelke

Arctic soil temperature and active layer modeling: We completed a pilot study for soil thermal modeling of the arctic terrestrial drainage area covering the 28-month time period from September 1998 through December 2000 (*Oelke et al., 2003*). We used temperature forcing from topography-corrected NCEP reanalysis data, and snow forcing from SSM/I satellite data. Derived parameters are daily thaw depth and frozen-ground depth, active layer depth, maximum annual frozen ground depth, and the lengths of annual freezing and thawing seasons. A comparison of modeled thaw depth and measured thaw depth at more than 60 Circumpolar Active Layer Monitoring (CALM) field sites shows quite good agreement. This project was expanded to cover the 22-year period 1980-2001, using the same model setup for the Arctic drainage. Improvements are a 50-year spin up for model initialization necessary for studying climatological trends in soil temperature, active layer, and frozen-ground depth, and freezing and thawing periods (*Oelke and Zhang, 2004*). The model is also used to output these parameters for regional studies of circum-Arctic sea basins, and for the major river basins.

Figure 13 shows depth cross sections of soil temperatures (a) and soil temperature trends (b) of four regions within the Arctic drainage basin (*Oelke and Zhang, 2004*). Air temperature and insulating snow depth are the main forcing parameters determining soil temperatures in this model. Positive trends occur for air temperature and soil temperatures in permafrost regions at all depths, while snow depth experiences a slightly negative, but insignificant, trend. Results point to the strongest warming in continuous permafrost regions (Figure 14). The warming since 1994 is about three times greater that the warming for the whole time series (*Oelke et al., 2004*).

In a related project, we are modeling the conterminous United States soil thermal regime at 2.5 km resolution for 1979-2000. Input data are station observations of surface air temperature and snow depth measurements. Soil characteristics, including bulk density and composition of fine or coarse-grained material, are from the CryoSoil data set

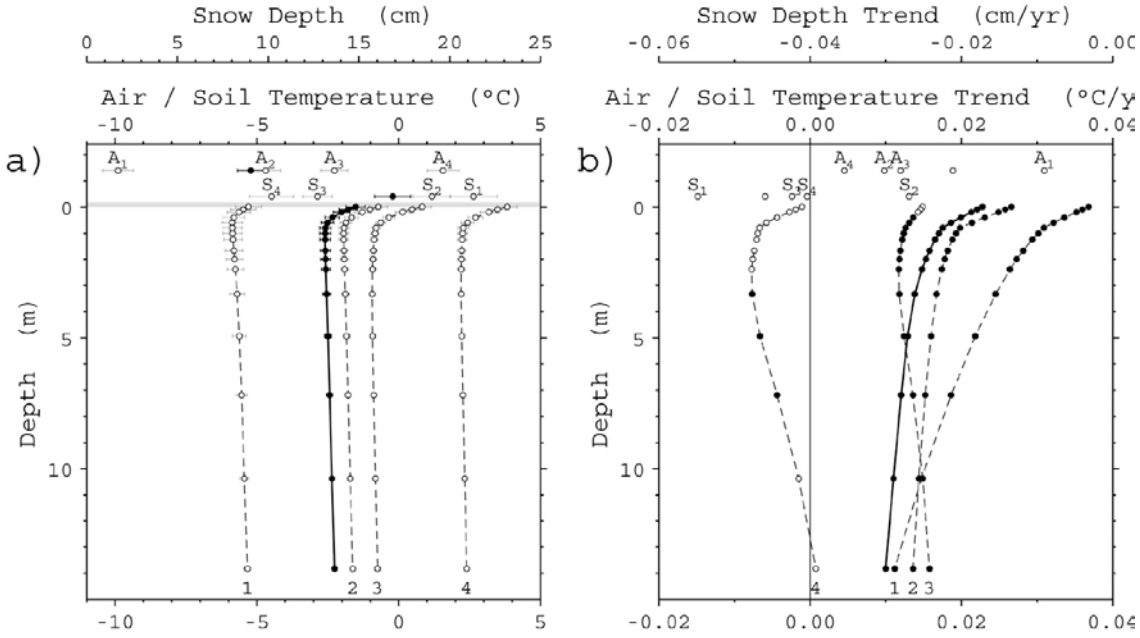

Figure 13: Average annual soil temperature (a) from the surface to 14 m depth for the entire Arctic drainage (thick solid line) and for the four regions continuous (1), discontinuous (2), and isolated permafrost (3), and for seasonally frozen ground (4). Also shown are average air temperatures A_i for the same regions and average snow heights S_i, including their standard deviations. The basin-wide average snow thickness is shown in light gray. A depth cross-section of trends for the time period 1980-2001 is presented in (b), together with the trends in surface air temperature and snow depth. Filled circles indicate trends significant at the 95% confidence level.

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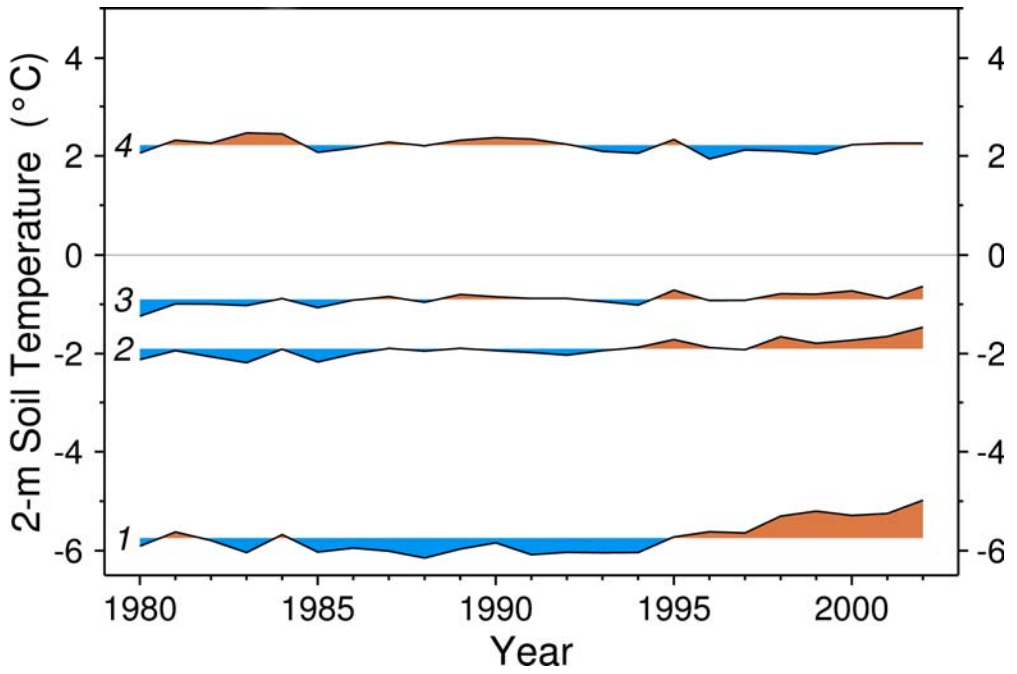


Figure 14: Time series of modeled annual 2-m soil temperatures for the four permafrost and seasonally frozen ground regions. The color shading refers to the average of the entire period.

Tom Painter

NASA REASoN Multi-resolution Snow Products for the Hydrologic Sciences. For three decades, satellite remote sensing instruments operating at visible, near-infrared, and microwave wavelengths have measured snow properties. In all snow products, and in remote sensing in general, there is a tradeoff between spatial resolution and swath width (and thus frequency of observations). Because most hydrologic applications require regular, frequent measurements, the instruments that provide the bulk of the data used have been AVHRR and MODIS in the optical part of the spectrum, with spatial resolutions of 1.1 km and 500 m at nadir, and the passive microwave sensors, with spatial resolutions of tens of kilometers. Because snow-covered area usually varies at a spatial scale finer than that of the resolution of the remote sensing instrument, this subpixel heterogeneity introduces artifacts into the measurements. The sensors usually measure radiation reflected or emitted from a mixture of snow, rock, soil, and vegetation. Under NASA's Research, Education and Applications Solution Network (REASoN),we are developing a new set of products – snow-covered area, albedo, and snow water equivalence – that fuse optical (MODIS, AVHRR) and microwave data (SSMR, SSM/I, AMSR-E) and that incorporate spatial heterogeneity into the analysis. We plan to use a technology suite we call the Earth System Science Server (ES3), to manage the creation, maintenance, updating, and dissemination of these data products. The technology is based on the Microsoft® TerraServer and runs on clusters of small computers. This infrastructure is flexible and is robust enough to support public access. This work is being done in collaboration with J. Dozier (P.I., UCSB), R. Bales (Co-I., UC-Merced), J. Frew (Co-I., UCSB), A. Nolin (Collaborator, OSU) and J. Shi (Co-I., UCSB). *(NSIDC Painter, Co-Investigator, Funded by NASA)*

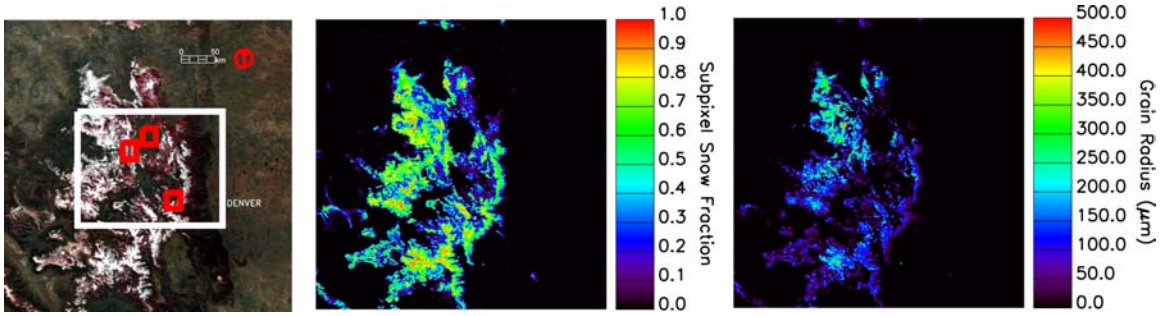


Figure 15: MODIS subpixel snow fraction and subpixel snow grain size from the MODIS Snow Covered Area and Grain Size (MODSCAG) model that forms the core of the optical analysis for the REASoN Snow Hydrology project. The left image is a color-infrared MODIS image of 500 m surface reflectance bands (29 March 2002) covering the NASA Cold Land Processes Experiment Large-Scale Study Area, Small-Scale Study Area (white border), and the Meso-cell Study Areas (red borders). The middle image is the subpixel snow fraction and the right image is the subpixel snow grain size for the study area as inferred from MODSCAG.

Ted Scambos

Ice shelves and icebergs in Antarctica. In the past two years, Scambos and colleagues (M. Fahnestock, University of Maryland; C. Hulbe, Portland State University; and D. MacAyeal of University of Chicago) completed two new studies of the processes leading to the rapid disintegration of the Larsen and Wilkins ice shelves, and refined a model for ice shelf breakup based on the effect of melt ponds and crevasse propagation within the shelf. We used NSIDC's archive of satellite images of ice shelves to tracking ice shelf breakup history and to determine the root causes of disintegration. Melting, to the point of ponding, on the surface appears to be an important precursor to ice shelf breakups in the Larsen Ice Shelf. With the advent of ponding, any crack on the surface of the shelf fills with meltwater. Modeling shelf behavior and ice crack propagation shows that, if full of water, crevasses as shallow as 5 to 15 m will rapidly propagate through the shelf, weakening it and eventually leading to shelf breakup. The implication is that any shelf area that reaches a mean January temperature of ~0°C is susceptible to rapid disintegration. We developed a new method for monitoring and evaluating Antarctic ice shelves for susceptibility to break up using remote sensing data. The thermal limit of 0°C places several important ice shelves, such as the Fimbul and the Ross shelves, much closer to their climatic limit than was earlier estimated. These shelves lie in front of large glacier systems draining the Antarctic, and act to retard ice flow from the continent. If these larger shelves should undergo a warming of 2 to 4°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. Direct proof of the retarding effect of ice shelves, and the response of feeder glaciers to shelf removal, was observed in a series of Landsat images of the Larsen B shelf spanning the period before, during, and after the March 2002 breakup event. Glaciers draining to the removed section of the shelf accelerated two to five times faster immediately following the breakup, and glacier speeds up to 15 times higher than pre-retreat (pre-1995) rates were observed in late 2002. Acceleration rates were already high prior to March 2002, probably because of the earlier reduction of shelf area in the preceding seven years. Glaciers south of the area of shelf loss, with little shelf retreat, showed no acceleration, or speed change, after the 2002 event. *(Funded by NSF-OPP and NASA; T. Haran and J. Bohlander assisted)*

Snow megadunes in the east Antarctic Plateau. This study mapped broad, stripe-like accumulation features over large regions of the Antarctic continent using radar and MODIS images.Tthese features had been reported sporadically over the years, but the new maps revealed their full extent and potential importance. We undertook a field program of radar layer mapping, snow and firn sampling, and snow stratigraphy mapping in November/December of 2002 and

2003. Results confirm many of the observations made by remote sensing: megadunes occur in regions of near-constant windflow, where accumulation is very low and vapor phase migration of snow is high. The dunes represent a centuries-old pattern in which wind flow and snow surface have evolved into a sympathetic structure of migrating accumulation and ablation stripes. The primary importance of the dune features is in the effect they may have on snow chemistry; because they are so widespread (covering a California-sized area of the East Antarctic) it is likely that some ice recovered in deep ice cores was previously firn in a megadune field. The effect on isotopes and chemistry of the snow appears to be profound in early chemistry data. Two field seasons have now been conducted, gathering extensive GPS and radar data. *(Funded by NSF-OPP; R. Bauer and T. Haran assisted)*

History of ice flow in West Antarctica. A grant funded in April 2000 continues to support field and image analysis of former ice flow features in the Siple Coast region of West Antarctica. This area is among the most dynamic region of any ice sheet, and its complex history is not yet fully understood. Using satellite images to guide field traverses, we spent two field seasons traversing several 'scar' features in the ice with ice profiling radar, and establishing a network of GPS-located poles. GPS data for ice motion and topography across several of the scars is now processed, and radar profiles are available. The overall objective is to create a timeline of the flow changes in this section of the Antarctic over the last 1,000 years. This will provide a guide to possible future changes in the Antarctic ice sheet. *(Funded by NSF-OPP)*

Photoclinometry. 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. The technique was used to generate the most accurate DEM of Greenland to date, adding considerable detail at ~2 km horizontal scale and ~1.5 m vertical accuracy to the best previous DEM. 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 continue to map areas of interest in both Greenland and Antarctica, and use the resulting maps in investigations of accumulation and temperature variations. In the coming year, we plan to use laser altimetry and MODIS images to further refine the technique. Mapping of the highest latitudes of the Antarctic ice sheet (near the pole) and of regions of upcoming scientific activity, such as deep ice coring sites, is also planned. *(Funded by NASA; T. Haran assisted)*.

Sea ice mapping using AVHRR and MISR. We participated in studies aboard the R/V *Aurora Australis* in Antarctic waters near the Australian Casey Station to validate the AVHRR ice surface temperature algorithm. Additionally, NSIDC provided the ship's research crew with supporting data from a number of satellite sensors in support of this cruise. The results of the study confirmed that the AVHRR ice surface temperature algorithm used in the AVHRR Polar Pathfinder is accurate, though noisy at the ~±1°C level (Figure 11). It further confirmed that the effect of winter surface inversions in the polar regions can be extremely high (up to 10°C over the lowest 10 meters of atmosphere, and the majority of that in the lowest meter). *(Funded by NASA; T. Haran assisted)*.

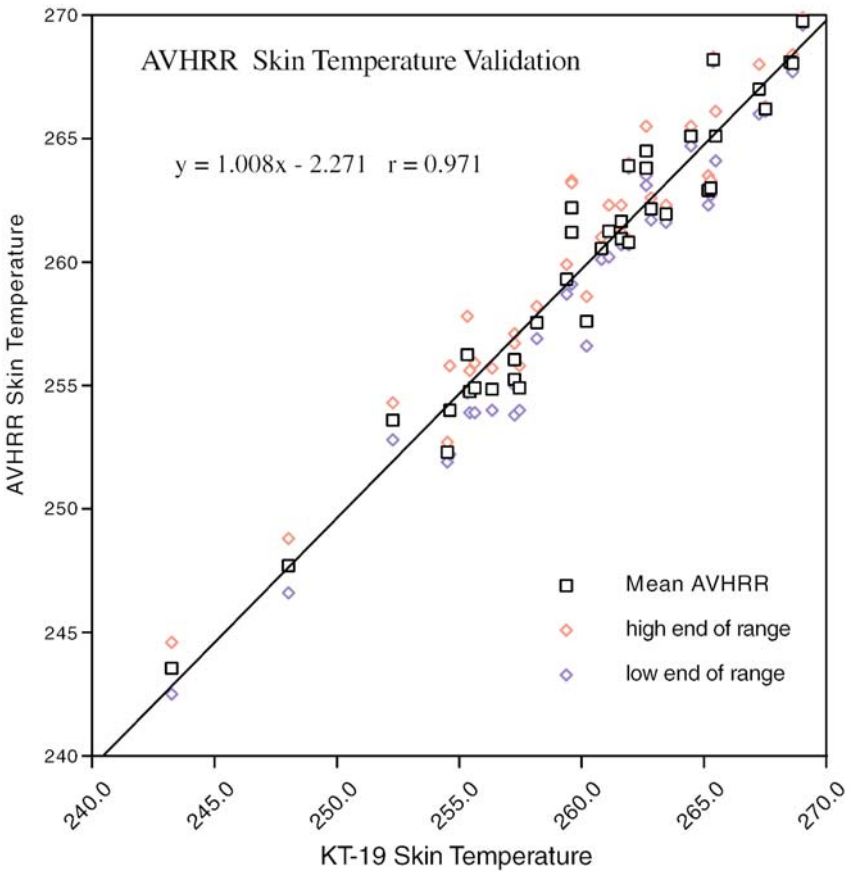


Figure 16: Satellite-derived skin temperature versus in situ skin temperature for sea ice near Cape Poinsett, Antarctica, collected between 25 September and 21 October 2003. AVHRR skin temperature was determined from ship-received NOAA polar orbiter data from NOAA-12, -15 and –16. The data were processed using the AVHRR Polar Pathfinder algorithms and calibrations. In situ skin temperature was collected using a rail-mounted thermal radiometer calibrated on fresh ice water. Each point is the mean of several near-ship AVHRR thermal channel pixels in a single scene selected to eliminate subpixel surface type mixing.

Mark Serreze

Understanding and tracking Arctic change. Satellite remote sensing has provided systematic monitoring of the Arctic's sea ice cover since 1979. These data show that sea ice extent has declined by about three percent per decade, with larger changes in summer. In tracking these changes, it became apparent that the year 2002 would be quite unusual. During summer, the sea ice pulled back dramatically from the coasts of Alaska and Eurasia, and there seemed to be very little ice in the East Greenland Sea. By the end of September, we had determined that 2002 set a new record minimum in ice extent (Serreze et al., 2003a). Ice extent did not recover the following year; September of 2003 nearly set another new record (See Figure 1). Sea ice retreat is just part of a system-wide change in the Arctic. There have been pronounced shifts in the atmospheric circulation, most evident in winter, but also in summer. The ice minima in 2002 and 2003 can be linked in part to unusually stormy summer conditions, which caused the pack ice to diverge and rapidly melt. The downward trend in sea ice is attended by, and in part driven by, rises in surface air temperature. This warming encompasses both the ocean and land (warming of Arctic soils and permafrost). Winter precipitation also seems to be on the rise, and river discharge to the Arctic Ocean is increasing. While research over the past year was wide ranging, our guiding framework was questions such as: “What is causing these changes and how unusual are they with respect natural variability in the Arctic System? How can we best track them? How do they fit within the

larger context of global climate change?" Studies of sea ice (Serreze et al., 2003c), hydrologic and atmospheric variability (Serreze et al., 2003a; Serreze et al, 2003b; Serreze and Etringer, 2003), and permafrost active layer depth (Oelke et al., 2003) employed a variety of tools, including atmospheric reanalysis (a form of numerical weather prediction), remote sensing, regional climate models, thermal models, and surface observations. Our efforts also focused on building better research tools, such as Arctic-RIMS (Regional Integrated Monitoring System, http://rims.unh.edu/tour.shtml). Arctic-RIMS, a collaborative effort with several institutions, combines data synthesis, modeling, and visualization software in a harmonized system to monitor hydrologic variability and change over the pan-Arctic terrestrial region. A related effort seeks to increase our understanding of Arctic terrestrial processes using a suite of land surface models. A key part of this project, conducted in conjunction with Arctic-RIMS, involves assembling the best-possible model forcing fields of temperature, precipitation, radiation, winds, and other variables. A new effort was initiated to extend the RIMS concept to the Arctic Ocean, addressing aspects of sea ice cover and ocean circulation. Output from the "next-generation" ERA-40 reanalysis, an effort of the European Centre for Medium-Range Weather Forecasts, became available in 2003, and we began to evaluate this output and incorporate it into Arctic-RIMS and the land surface modeling study. Another devlopment on the horizon is the development of a reanalysis system tailored specifically to the Arctic region - the Arctic System Reanalysis (ASR). With so much interest in the Arctic region, it is useful to step back and synthesize our knowledge of how the Arctic system works. One contribution to this synthesis was a review article, published as part of the "Encyclopedia of Atmospheric Sciences" (Serreze et al., 2003). A new textbook co-authored with Roger Barry, *The Arctic Climate System,* neared completion in 2003, and is scheduled for publication in 2004.

Research Grants and Contracts:

NSF OPP-9910315: "Collaborative Research: A Hydrological Observing System for the Pan-Arctic Landmass"

NASA NAG5-9568: "A Regional, Integrated Monitoring System for the Hydrology of the Pan-Arctic Landmass"

NASA (not yet assigned): "Assessment of Recent Hydrologic Change over the Arctic Terrestrial Drainage"

NSF OPP-0229769: "Collaborative Research: A Land Surface Model Hind-Cast for the Terrestrial Arctic Drainage System"

NSF OPP-0229651: "Collaborative Research: An Integrated Assessment of the Arctic Freshwater System: Analysis of Retrospective and Contemporary Conditions"

NSF OPP-0138018, "Characterization of Atmospheric Moisture Transport and the Freshwater Budget of the Arctic with an Improved Regional Model"

NSF, OPP-0240948, "Characteristics of Cyclone Development and Decay in the Arctic"

NOAA, Transfer under CIRES-NOAA Cooperative Agreement "Initiation of Arctic Reanalysis Activity"

Julienne Stroeve

Greenland glacier albedo variability. This study examined the albedo variability in four outlet glaciers to help separate the relative contributions of surface melting versus ice dynamics to the recent mass balance changes. Analysis of AVHRR Polar Pathfinder albedo shows that at the Petermann and Jakobshavn glaciers, there has been a negative trend in albedo at the glacier terminus from 1981 to 2000, whereas the Strostrommen and Kangerdlussuaq glaciers show

slightly positive trends in albedo. These findings are consistent with recent observations of melt extent from passive microwave data which show more melt on the western side of Greenland and slightly less on the eastern side. Significance of albedo trends will depend on where and when the albedo changes occur. Since the majority of surface melt occurs in the shallow sloping western margin of the ice sheet where the shortwave radiation dominates the energy balance in summer (e.g., Jakobshavn region) this region will be more sensitive to changes in albedo than in regions where this is not the case. Near the Jakobshavn glacier, even larger changes in albedo have been observed, with decreases of as much as 20 percent per decade. Using a simple energy balance model to derive melt rates, a 20 percent/decade decrease in albedo will result in 29 percent more melt at 500 m and 189 percent more melt at 1000 m. Current estimates in changes of albedo near the Jakobshavn glacier reveal decreases of 20 percent/decade at 300 m, 10 percent/decade at 500 m, and 5 percent/decade at 1000 m. We used data from MODIS and MISR to extend the time-series to 2002 and to observe the anomalous melt during that year. Figure 17 shows the monthly mean climatology of surface albedo derived from AVHRR and compared with albedo from 2002 MODIS and MISR imagery for the Jakobshavn glacier. This work is being done in collaboration with A. Nolin (Oregon State University) and A. Ahlstrom (Denmark Technical Institute). *(J. Stroeve. Funded by NASA)*

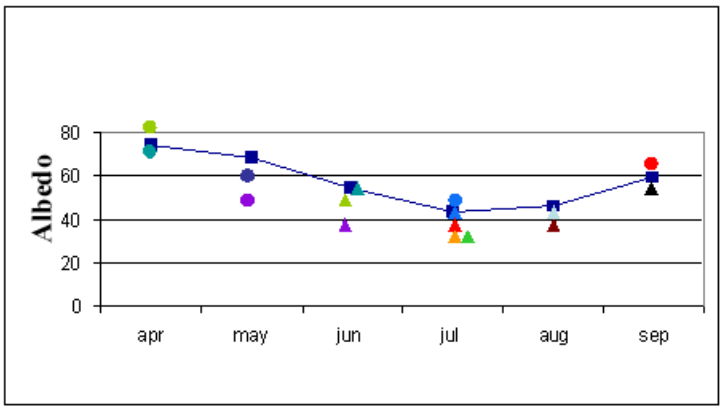


Figure 17: AVHRR-derived climatology of monthly albedo for the Jakobshavn glacier, Greenland, with MISR (circles) and MODIS (triangles) albedo from 2002.

Collaborative research: EO-1 hyperspectral applications: snow grain size and albedo (with Anne Nolin). Snow grain size is highly variable over large regions of the East Antarctic Plateau due to multi-year thermal cycling of near-surface firn (low accumulation, large annual temperature range). We use the high spectral resolution EO-1 Hyperion instrument to resolve and map grain-size variations, and subsequently determine the albedo for ice sheets, which is an important component of surface energy balance. Snow grain size is determined using the 0.97 – 1.06 μm spectral range. The method we use to retrieve the snow grain size and the subsequent surface albedo produces an albedo that is accurate to within ±2percent.

Collaborative research: Snow albedo from MISR and MODIS (with Anne Nolin). Accurate estimation of snow albedo is essential for monitoring the state of the cryosphere. The high albedo of snow-covered surfaces allows little energy to be absorbed by the snowpack. However, as snow ages and/or begins to melt, the albedo decreases and more energy is absorbed by the snowpack. This study retrieves snow albedo using the MISR and MODIS instruments and validates the methods using in-situ data from the Greenland ice sheet. Two different methods are used to compute the albedo. The first method uses spectral information from MISR and MODIS. The second method uses angular information from MISR to develop a statistical relationship between in-situ albedo and the red channel reflectance at all nine MISR viewing angles. Good agreement with in-situ measurements is found using either method, although problems with instrument calibration, snow BRDF models, and narrow-to-broadband albedo relationships can cause the albedo error to still be large with the first method. With a few exceptions, the satellite-derived surface albedo is within about 6 percent of that measured at the stations.

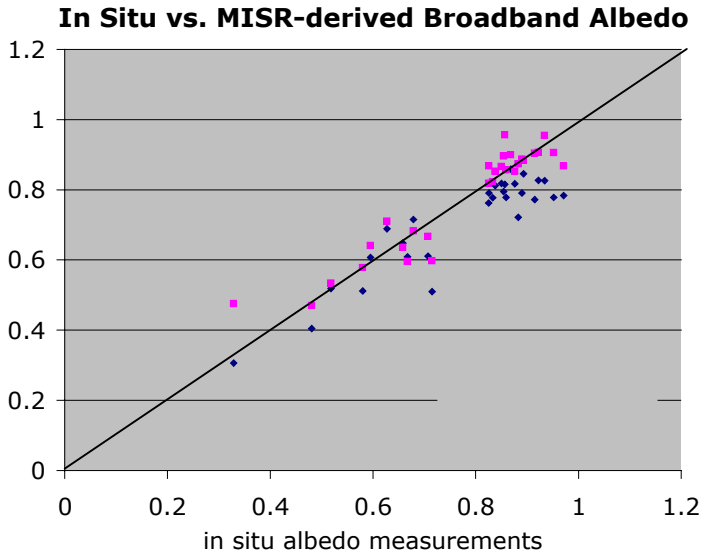


Figure 18: Comparison of MISR-derived and in-situ measured snow albedo in Greenland. The pink squares are the MISR albedo derived using the angular model whereas the blue triangles are the MISR.

Accuracy assessment of the MODIS 16-day snow albedo product. This study makes use of the newly reprocessed Version 4 MOD43 products. This version of the data set includes new shortwave and near infrared (NIR) narrow-to-broadband (NTB) conversion factors for "pure" snow pixels. To access how well the improved algorithm works over pure snow pixels, we examined intercomparisons between the MODIS 16-day albedo product and in situ measured albedo from 16 automatic weather (AWS) stations over the Greenland ice sheet from 2000 to 2003. Figure 19 shows a comparison between the MODIS-derived and ground-based albedo at the 16 AWS locations. Comparisons are shown for the MODIS black sky (BSA) and white sky (WSA) albedo. They can be combined with the appropriate optical depth information to derive the "true" albedo. The mean difference in albedo between the BSA and in situ measurement is 0.019; between the WSA and in situ albedo it is 0.024. This work is being done in collaboration with J. Box, The Ohio State University; F. Gao, Boston University; Shunlin Liang, University of Maryland; C. Schaaf, Boston University; and A. Nolin (Oregon State University). *(J. Stroeve. Funded by NASA).*

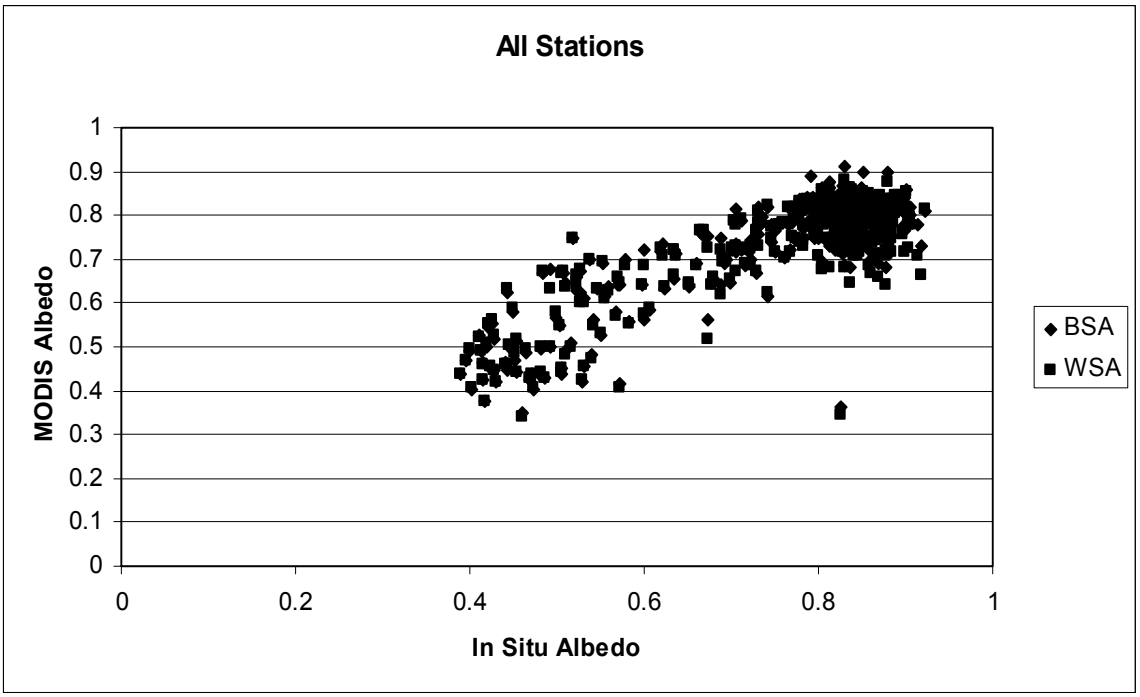


Figure 19: Comparison between MODIS and in situ albedo from 16 AWS locations in Greenland using data from 2000-2003. Triangles represent the BSA, squares the WSA. Open symbols are labeled as "poor" quality by the MODIS algorithm.

Validation of AMSR Sea Ice Products. In March 2003, J. Stroeve participated in a field validation campaign on the sea ice near Barrow, AK. The campaign goals were to produce an extensive data set of sea ice and snow properties to validate the AMSR sea ice products. Field, airborne, and satellite data will be compared in order to validate and improve existing algorithms for sea ice retrieval from AMSR. Additionally, the sea ice and snow data are to be used to investigate the nature of snow and ice heterogeneity. Using the surface data collected, J. Stroeve at NSIDC and T. Markus at NASA GSFC are currently using the data to model the AMSR brightness temperatures. After that work is completed, we will make comparisons with the airborne AMSR data and access how variability in surface conditions effect the sea ice retrieval algorithms. This work is being done in collaboration with J. Maslanik (University of Colorado), M. Sturm and D. Perovich (CRREL), J. Heinrichs (Ft. Wayne State College), T. Markus and D. Cavalieri (NASA GSFC). *(J. Stroeve-co-PI, Funded by NASA).*

Tingjun Zhang

Stochastic variability of seasonal freeze-thaw at local, regional, and hemispheric scales under modern and predicted climate. Soil temperature is a combined product of energy and mass exchange between the atmosphere and the land surface. Soil temperature change is a sensitive climate indicator and integrator, and plays an important role in the physical, biological, and microbiological processes occurring in soil. This study analyzed soil temperature (measured at more than 250 stations in Russia), air temperature, and precipitation data for signs of climatic change between 1930 and 1990. Over this 51-year period, mean annual soil temperature (at 40 cm depth) increased 0.9 to 1.0^{o}C. The increase was more pronounced between 1970 and 1990. Mean annual air temperature decreased slightly (about 0.5^{o}C) from 1930 to the late 1960s, and then increased more than 1.0^{o}C from 1970 to 1990. Changes in air temperature alone cannot explain the changes in soil temperature. Observed increases in soil temperature during the winter months are related to increases in both air temperature and precipitation (mostly as snowfall). Variations in snow cover thickness have an overall positive impact on soil temperature due to snow's

insulating effect, and the timing of snowmelt and soil moisture may also be important. This study indicates that changes in soil temperature in Russia are probably controlled by changes in air temperature, with some modification by precipitation. *T. Zhang, P.I., R. Barry, Co-I Funded by NSF.*

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, which requires information on surface albedo and the timing of snow melt. We investigated spatial and temporal variations of surface albedo on the North Slope of Alaska, using ground-based measurements of incident and reflected solar radiation at several stations along the Dalton Highway between 1985 and 1998 to determine in-situ surface albedo, and AVHRR Polar Pathfinder products (with a modified cloud mask). AVHRR-derived surface albedo agrees closely with the 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. The study discerned five distinct temporal periods based on seasonal variations of surface albedo: winter stationary, spring snowmelt, post-snowmelt, summer stationary, and autumn freeze-up periods. Spatially, we divided the North Slope into three zones based on patterns of seasonal variation in surface albedo: a *Mountain Zone* along the ranges and slopes of the Brooks Range with elevations above 1000 m, a *Foothills Zone* along the foothills of the Brooks Range with elevations from 300 m to 1000 m, and a *Coastal Zone* along the Arctic coastal plain, with elevations lower than 300 m. This study suggests that snow surface albedo in land surface models should be treated differently for snow at high latitudes than for snow in middle latitudes, especially during winter months. *(T. Zhang, P.I., Funded by NASA).*

Investigation of the seasonal freeze/thaw cycle of soils in the GAPP regions. freeze/thaw cycles of soils at local, regional, and global scales. investigation of the spatial and temporal variations of the seasonally frozen ground in the USA. In order to evaluate the impact of cold season/cold region processes on surface and subsurface hydrology, on regional and global climate, on carbon exchange between the atmosphere and the land, and on the entire terrestrial ecosystem, we need a good understanding of the near-surface freeze/thaw cycle of soils. We developed a frozen soil algorithm to investigate seasonal and inter-annual variations of the near-surface soil freeze/thaw cycle over snow-free and snow-covered land areas. The frozen soil algorithm consists of two parts: (i) over snow-free land areas, we used a passive microwave satellite remote sensing algorithm to detect the near-surface soil freeze/thaw cycle, (ii) over snow-covered land areas, we used a one-dimensional numerical heat transfer model with phase change to detect soil freeze/thaw status under snow cover. This combined frozen soil algorithm was used to investigate the timing, duration and number of days, and daily area extent of near-surface frozen soils over the contiguous United States from 1978 through 2003. The frozen soil algorithm has a 76 percent accuracy in detecting frozen soil, and an 83 percent accuracy in correctly classifying both frozen and unfrozen soils, with an error of about 17 percent. Further algorithm validation is needed to improve the accuracy of the near-surface soil freeze/thaw cycle detection and to estimate the thickness of the seasonally frozen ground. The frozen soil algorithm is also useful for investigating net ecosystem exchange of carbon dioxide, and extrapolating results from small local scales to large spatial scales. Timing of the thaw onset of seasonally frozen ground may be one of the key factors controlling the spring-time initiation of net carbon uptake by plants. ArcticRIMS Project: Regional Integrated Hydrological Monitoring System for the Pan-Arctic Land Mass (see entry under Serreze). **(***T. Zhang, P. I., Richard L. Armstrong, Co-P. I., funded by NOAA, and NASA. T. Zhang, P.I. R. L. Armstrong, Co-P.I., Funded by NOAA. T. Zhang, P.I., C. Oelke, R. L. Armstrong, and M. Clark, Co-I's, funded by DOE NIGEC).*

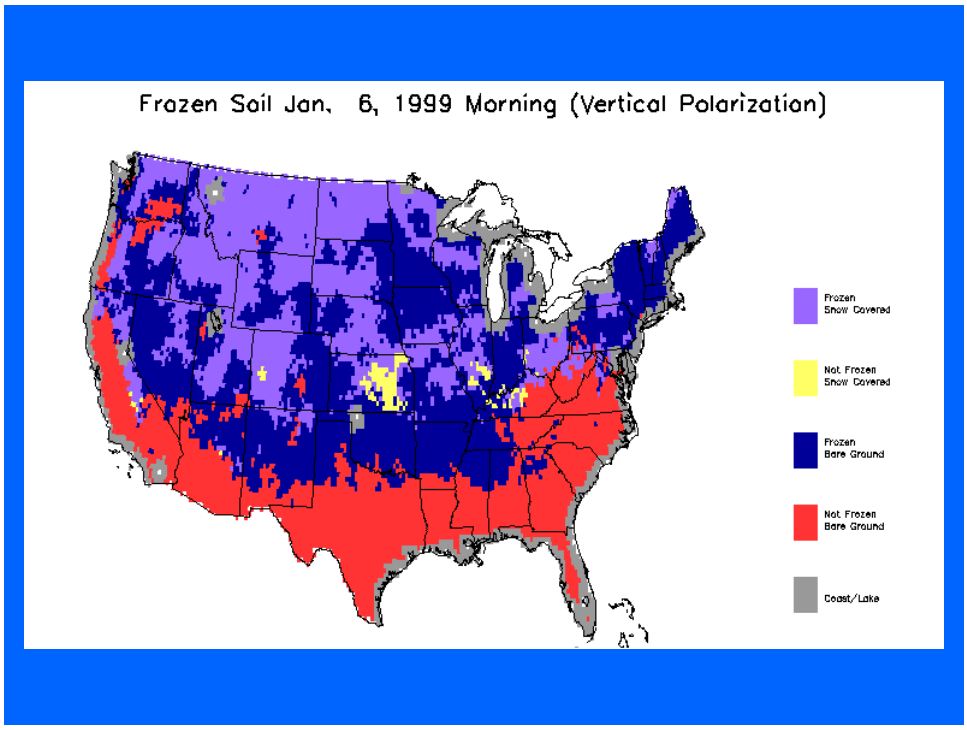
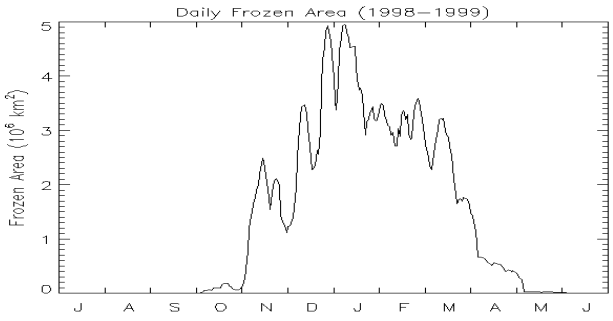


Figure 20: Areal extent of seasonally frozen ground and snow cover on 6 January 1999 in the contiguous United States. Near-surface soil freeze/thaw status is detected using the NSIDC Frozen Soil Algorithm, which includes passive microwave satellite remote sensing and one-dimensional numerical heat transfer modeling (see Zhang et al., 2003, for details).

Daily total area of frozen soil in the contiguous United States during the winter of 1998-1999.



Daily percentage of frozen soil of total land area in the contiguous United States during the winter of 1998-1999.

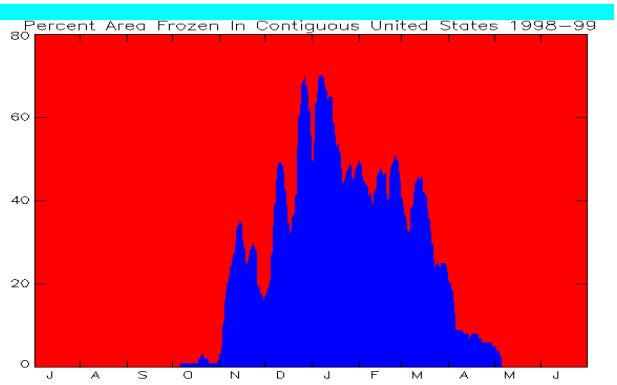


Figure 21: Seasonal variation of daily frozen soil area extent for the winter of 1998/1999 over the contiguous United States. Up to 70% of the land area in the contiguous United States experiences soil freezing and thawing.

Changes in freeze/thaw and permafrost dynamics and their hydrological implication over the Russian Arctic Drainage Basin. Permafrost degradation and hydrologic response in the Russian Arctic Drainage Basin. Hydrologic response of siberian rivers to climate change. In these studies, we hypothesize that changes in the active layer and in permafrost dynamics play a key role in the recent changes in the Arctic hydrological regime. We investigated this hypothesis by studying (i) permafrost and ground ice distribution; (ii) changes in permafrost temperature, active layer thickness, and length of thaw season over the past few decades, and (iii) their impact on the hydrologic cycle over the major Siberian river basins. We studied inter-decadal variations of active layer thickness over the Ob, the Yenisey, and the Lena river basins during the 20th century, using historical soil temperature data, annual air temperature thawing indices, and numerical modeling. Based on ground-based measurements, mean annual soil temperature (at 40 cm depth) increased about 0.8 to 1.5°C in the Ob, the Yenisey, and the Lena river basins between 1930 and 1990, with the most pronounced increases occurring between the mid 1960s and 1990. This increase in \ near-surface soil temperature can lead to degradation of permafrost and thickening of the active layer. Active layer thickness in the Lena River basin increased more than 30 cm from 1956 through 1990. The thawing index increased substantially over all three river basins from the 1950s to the 1990s, implying that an increase in active layer thickness is a widespread phenomenon over the Russian Arctic drainage basin during the past few decades. The length of thaw season has also increased in the Russian Arctic. Increase in the length of thaw season and thickening of the active layer delay the freeze-up date of the active layer. Late freeze-up date of the active layer partly explains a substantial increase in runoff in the Russian Arctic drainage basin during winter months. (*T. Zhang, P.I., R. Barry, Co-P.I., funded by NSF. T. Zhang, P. I., funded by CIFAR/NOAA and IARC. T. Zhang, P. I., Funded by CIFAR/NOAA).*

Soil temperature increase at each river basin (1969-1990):

Ob: **1.2°C**

Yenisey: **0.8°C**

Lena: **1.5°C**

Increase in soil temperature basin-wide leads to thickening the active layer and thawing of permafrost.

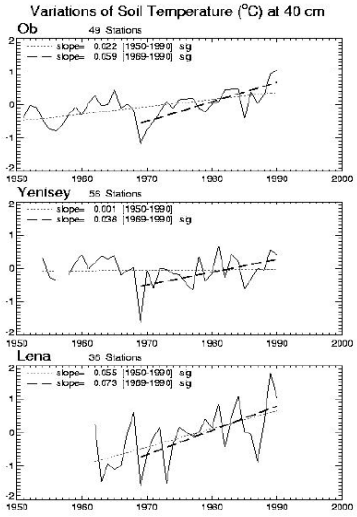


Figure 22: Changes in soil temperature at 40 cm depth from the Ob, the Yenisey, and the Lena river basins over the Russian Arctic drainage basin.

Other research grants and contracts:

The role of shallow tundra lakes in Arctic land-atmosphere interactions and feedbacks. *(T. Zhang, P.I., Feng Ling, Co-P.I. see entry under Feng Ling. Funded by IARC/CIFAR).*

Investigation of the spatial and temporal variations of the seasonally frozen ground in the contiguous United States. *(T. Zhang, P.I., C. Oelke, R. Armstrong, M. Clark, and Feng Ling, Co-P.I.s, see entry under Feng Ling Funded by DOE NIGEC).*

Permafrost Database Center at the International Arctic Research Center. *(T. Zhang, P.I., R. G. Barry, Co-P.I. see entry under The Frozen Ground Data Center. Funded by IARC)*

A Regional, Integrated Monitoring System for the Hydrology of the pan-Arctic land mass. *(T. Zhang, Co-P.I., M. Serreze, P.I. see entry under Serreze. Funded by NASA).*

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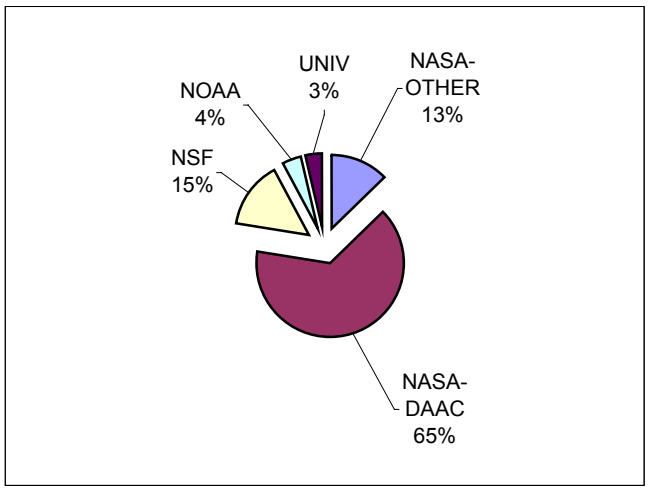
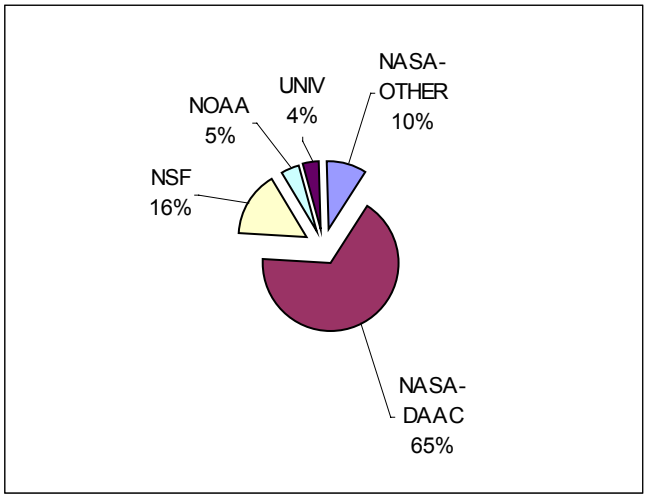
Financial Support

NSIDC's annual budget is about 7.8 million dollars, with funding from national agencies as shown in the figures below. In 2002, about 24% of funding was for research, with the remainder for data management. In 2003, about 21% was for research. Funding for NSIDC confers an annual benefit to the University of Colorado of about 2.5 million dollars. Apart from data management work, nine NSIDC researchers were Principal Investigators on 36 research grants in 2002 and 39 research grants in 2003. Data management grants numbered six in both 2002 and 2003.

YEAR ENDING JUNE 2002



YEAR ENDING JUNE 2003



NSIDC Visitors

Dr. Marina Leibman of the Earth Cryosphere Institute, Russian Academy of Sciences, Moscow, visited NSIDC from February to April 2003. As a member of the International Permafrost Association's Standing Committee on Data Information and Communication, she prepared data for the CAPS2 CD, concentrating on the Circumpolar Active Layer Monitoring System.

CIRES Visiting Fellow Ann Henderson-Sellers and Kendal McGuffie visited NSIDC from July to December 2003. While working on a third edition of their climate modeling book *Land Surfaces and Isotopes*, Drs. Henderson-Sellers and McGuffie undertook novel investigations of isotopes as sensitive tracers of land-atmosphere exchanges. Dr. McGuffie is an associate professor in the Department of Applied Physics, University of Technology, Sydney. Dr. Henderson-Sellers is the Director for Environment at the Australian Nuclear Science and Technology Organisation.

CIRES Visiting Fellow Ute Christina Herzfeld visited NSIDC from November 2002 to July 2004. Using *in situ* and satellite data, Dr. Herzfeld investigated ice-surface features as indicators of glaciologic and climatic processes. Her research objectives included comparing data from new satellite sensors and field observations of surface roughness, characterizing dynamically and climatically induced features and their changes, understanding and monitoring ablation processes in the Greenland ice sheet, producing thematic maps from satellite data, and investigate the relationship of gravity and topography for Greenland and Antarctica. Dr. Herzfeld recently completed her book *An Atlas of Antarctica—Topographic Maps from Geostatistical Analysis of Satellite Radar Altimeter Data*. Before her appointment she was a professor and head of the Geomathematics Division at the Universitaet Trier, Germany.

Svetlana Tchoudinova visited NSIDC from October 2003 to August 2004 on an NSF-NATO Postdoctoral Fellowship. Her research focuses on the effects of 20th-century climate change on the temperature regime of Russia's permanently and seasonally frozen soils. Dr. Tchoudinova is a research scientist with the Laboratory of Soil Cryology, Institute of Physico-Chemical and Biological Problems in Soil Science, Russian Academy of Sciences, Pushchino.

Tatiana (Tanya) Khromova visited NSIDC from January to September 2002 as a Fullbright Visiting Scholar. Her research focused on GIS data related to glaciers, snow, and ice. A contributing author to *World Atlas of Snow and Ice Resources*, Dr. Khromova is a research scientist at the Institute of Geography, Russian Academy of Sciences, Moscow.

CPP Talks

Jason Box	3/1/02	Greenland ice sheet climatology with emphasis on results from a network of automated climate stations
Ted Haberman	3/15/02	Relational database management systems and geographical information systems (GIS)
Heinz Wanner	4/12/02	North Atlantic – European climate 1500-2000 AD Reconstruction and diagnosis of state variables, modes and extremes
Etienne Berthier	4/29/02	Did the Mertz glacier show a change in its velocity during the last decade?
Ute Herzfeld	5/24/02	Geostatistical Classification and Applications in Remote Sensing
Shari Fox	9/6/02	Studies of Inuit Knowledge of Environmental and Climate Change in the eastern and central Canadian Arctic
Tanya Khromova	9/13/02	Mapping glacier change in central Asia using Russian survey results and ASTER images
Thomas Painter	10/11/02	Subpixel snowcover characterization with optical hyperspectral and multispectral remotely sensed data
Ted Scambos	11/4/02	Climate induced ice shelf disintegration in Antarctica
Richard Fortier	1/17/03	Impacts of climate warming on permafrost in Northern Quebec, Canada: human and engineering challenges to the Inuit community of Salluit
Alex Hall	1/24/03	The role of surface albedo feedback in climate variability and climate change.
Purevjav Gomboluudev	1/31/03	Studies on Climate Change in Mongolia
Marina Leibman	2/21/03	Arctic Coastal Processes Connected with Massive Ground Ice
Carmen de Jong	2/28/03	Snow depletion modelling in the High Atlas Mountains of Morocco
Robert E. Davis	9/5/03	Army Research on Snow and Ice: CRREL's Legacy and Major Accomplishments, 1950 to Present
Connie Woodhouse	9/19/03	Snowpack Reconstructions from Tree Rings for the Central Rocky Mountains
Walt Meier	10/3/03	SSM/I Sea Ice Concentrations in the eastern Arctic MIZ: A comparison of four algorithms with AVHRR imagery
Ann Henderson-Sellers	10/24/03	Land Surfaces and Isotopes
David Schimel	10/31/03	Carbon sequestration in the mountains of the Western United States
Kendal McGuffie	11/7/03	Modelling Isotopes
Rudy Dichtl	11/21/03	Who is Oetzi? A.k.a. the Iceman!
Todd Arbetter	12/5/03	Using Data Assimilation to Improve Sea Ice Models: Issues and Applications

Index of Figures

The NSIDC 2002-2003 Biennial Report was compiled and edited by H. M. Unger, F. Fetterer, and D. Kohlerschmidt, with additional editorial assistance from K. Webster and E. Yohe, and design work by N. Geiger Wooten. Many staff members contributed to the contents of this report.