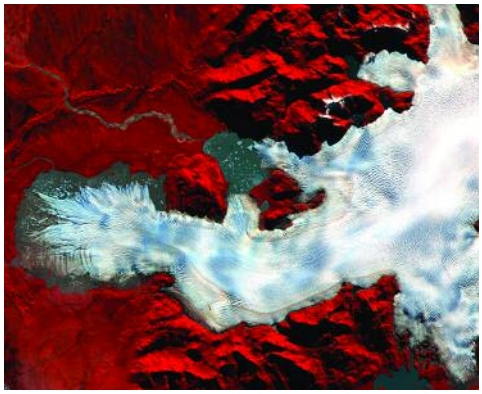
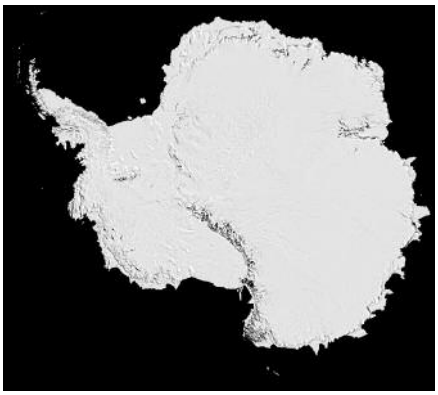
# National Snow and Ice Data Center

## World Data Center for Glaciology, Boulder

*supporting cryospheric research since 1976*

SUPPORTING CRYOSPHERIC RESEARCH SINCE 1976

# Annual Report 2004

# National Snow and Ice Data Center
# World Data Center for Glaciology, Boulder
# Annual Report 2004

## Cover images

### Left:
Snow and ice recede from the western side of southern Greenland in this true-color Aqua MODIS image of Greenland from August 7, 2004. As summer settles over the Northern Hemisphere, increased temperatures bring a brief growing season to even remote landscapes. But despite the warmer conditions, Greenland's ice sheet continues to dominate the interior of the huge island. (Image courtesy of NASA's MODIS Land Rapid Response Team.)

### Center:
This ASTER image was acquired on 2 May 2000 over the North Patagonia Ice Sheet and covers an area of 36 by 30 kilometers. The false color composite displays vegetation in red. A semi-circular terminal moraine indicates that the glacier was once more extensive than at present. (Image courtesy of NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.)

### Right:
A composite satellite photograph of Antarctica in orthographic projection. (Image courtesy of NASA)

# Table of Contents


Introduction....1
Highlights....3
The Distributed Active Archive Center (DAAC)....5
- The year in summary....5
- External data coordination efforts....5
- Science data operations and user outreach....6
  - GLAS data from ICESat....6
  - AMSR-E data from Aqua....8
  - AMSR-E validation data management....8
  - Non-EOS passive microwave data products and EASE-Grid products....9
  - DAAC Alliance Annual....9
  - DAAC Alliance Web site....10
  - Web site updates....10
- Systems engineering and systems development....10

The Arctic System Science (ARCSS) Data Coordination Center (ADCC)....12
U.S. Antarctic Data Coordination Center (USADCC)....13
Antarctic Glaciological Data Center (AGDC)....14
The Frozen Ground Data Center....15
Global Land Ice Measurements from Space (GLIMS)....16
NOAA at NSIDC and the World Data Center for Glaciology, Boulder....17
Research....19
- Todd Arbetter....19
- Richard Armstrong....20
- Andrew Barrett....22
- Roger Barry....23
- Florence Fetterer....23
- Oliver Frauenfeld....24
- Jim Maslanik....26
- Walt Meier....26
- Tom Painter....27
- Ted Scambos....29
- Mark Serreze....31
- Andrew Slater....32
- Julienne Stroeve....32
- Tingjun Zhang....34

International Collaboration....37
- WCRP Climate and Cryosphere Project (CliC)....37
- Cold Land Processes Field Experiment (CLPX)....37
- Terrestrial Observation Panel for Climate (TOPC)....37
- International Commission on Snow and Ice (ICSI)....38
- Global Digital Sea Ice Data Bank (GDSIDB)....38
- Global Climate Observing System (GCOS)....38

Science Communications and Outreach....39
The NSIDC Information Center/Library....41
NSIDC visitors....42
CPP talks....43
Financial support....44
Products and tools released in 2004....45
Publications and presentations....51
- Journal articles....51
- Book chapters....52
- Conference presentations....53
- Conference proceedings....58
- Other publications....59

# National Snow and Ice Data Center
# World Data Center for Glaciology, Boulder
# Annual Report 2004

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 National Oceanic and Atmospheric Administration (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 (NSF) 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 (FGDC).

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.

During the period of this report, NSIDC began distributing data from the Advanced Microwave Scanning Radiometer (AMSR) sensor on the NASA Aqua satellite and from the ICESat Geoscience Laser Altimeter System (GLAS). 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 also released a multimedia interactive CD-ROM, *When the Weather is Uggianaqtuq: Inuit Observations of Environmental Change*, in which Inuit from two communities in Nunavut, Canada, share their observations and perspectives on recent environmental changes. These and other activities are included in this report for 2004.

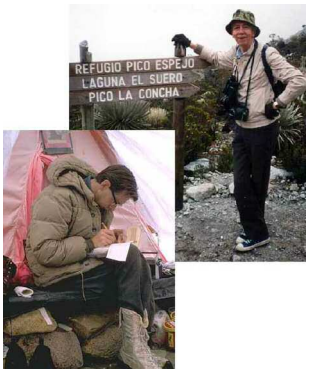
R.G. Barry
Director
NSIDC/World Data Center for Glaciology, Boulder
August 2005

# Highlights

## New data products

NSIDC made more than 50 new data sets available through the online catalog in 2004, ranging from small data sets collected by individual investigators, to historical glacier photographs, to exciting new AMSR and ICESat/GLAS 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.

## Roger Barry named distinguished professor




Roger Barry, director of the NSIDC for the past 27 years, was designated Distinguished Professor by the University of Colorado Board of Regents in March 2004. Bestowed on members of the university faculty "who have distinguished themselves as exemplary teachers, scholars and public servants and who are individuals having extraordinary international importance and recognition," the designation honors his research in climates of arctic and alpine environments as well as his contributions to NSIDC. NSIDC sponsored a symposium, "A Chronicle of Distinction: From the Arctic to the Andes," from 8 to 10 August 2004. The symposium highlighted Dr. Barry's extensive accomplishments and contributions to the science of climatology, as well as his teaching and mentoring. Refer to the research section of this report for more details about Dr. Barry's research activities.

## Mark Serreze and Roger Barry completed textbook, *The Arctic Climate System*

*The Arctic Climate System* starts with an outline of early arctic exploration and the growth of modern research. Using an integrated systems approach, subsequent chapters examine the Arctic's heat budget, the atmospheric circulation, the surface energy budget, the hydrologic cycle and interactions between the atmosphere, ocean and sea ice cover. The book then examines recent directions in numerical modeling and the characteristics of past arctic climates. This sets the stage for a discussion of recent climate variability and change, and projected future states of the arctic climate system. The book is scheduled for publication in September 2005 by Cambridge University Press.

## Global Land Ice Measurements from Space (GLIMS)

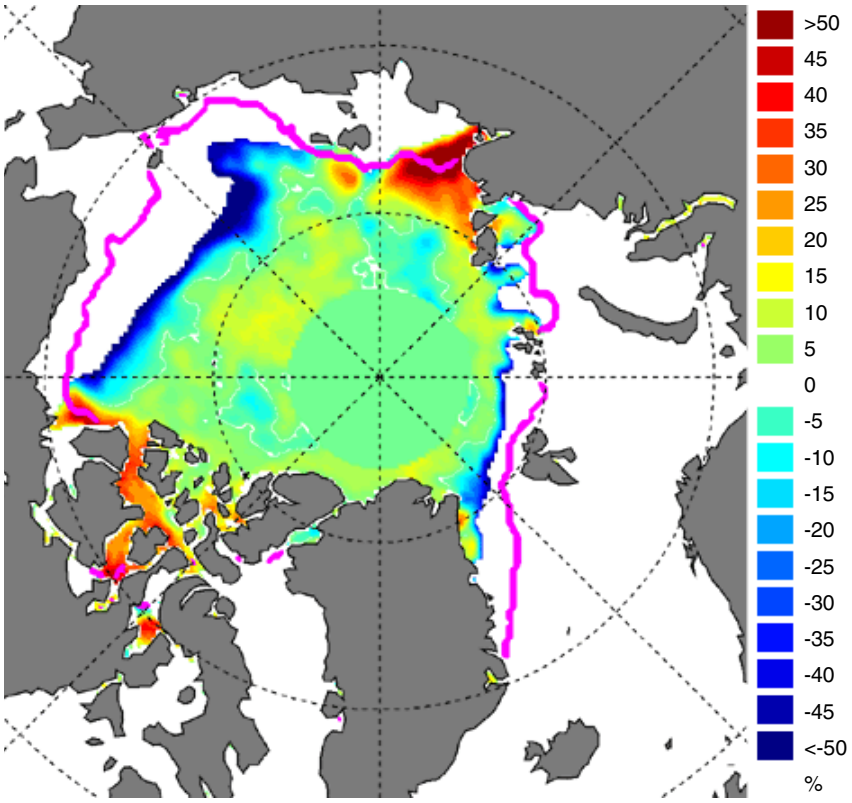
The GLIMS project is creating a glacier inventory containing information about the current extent and rates of change of all the world's glacial resources. GLIMS is a collaborative effort between NASA, the United States Geological Survey (USGS) and more than sixty institutions worldwide. Each institution oversees the creation and analysis of data for a particular region appropriate to their expertise. The project is building a geospatial and temporal database of glacier data composed of glacier outlines and various scalar attributes, derived from satellite imagery, primarily ASTER and Landsat. NSIDC has implemented a Web-based interface to the GLIMS Glacier Database, which enables exploration of the data using interactive maps. Visit http://nsidc.org/data/glims/ for more information.

## Megadunes of East Antarctica

A year of field work, data processing, and interpretation culminated in a 2004 AGU Fall Meeting Special Session on Antarctic Megadunes, during which several new results regarding these unique ice plateau wind features were announced. The NSIDC/University of Colorado investigators (Ted Scambos, Terry Haran, and Rob Bauer) focused on automatic weather stations (AWS) and ground-penetrating-radar (GPR) studies. Two AWS locations at the megadunes, one on a windward face and one leeward, include a sensitive snow thermal profiler that broadcasts snow temperatures at several depths for the entire annual cycle. This data showed that typical cooling trends during fall and winter were modified by airflow through the dune firn. GPR results revealed the deep (to 80 meters) structure of the dunes, and showed an interesting sedimentary pattern. Dunes accrete into the wind, and one dune crest slowly advances over the back of a previous dune, burying it. Snow between the crests may lie within a few inches of the surface for up to two centuries, and during that time it is highly modified, both structurally and chemically, by the intense winter-summer temperature cycling. These layers of highly modified snow were imaged by the GPR, and were observed at the same depths by a shallow ice core at the site, confirming the GPR observations. The team is planning a summary paper on the extent, properties, and formation of snow megadunes for late 2005.

## Another low year for Arctic minimum sea ice concentration

For a third consecutive year, the Arctic has seen near-record low sea ice extent in September 2004. This replicates similar patterns seen in 2002 and 2003. There were hints that this might occur as early as May, when anomalously low conditions were first observed. As these conditions persisted throughout summer of 2004, the statistical likelihood of an extreme year increased. The failure of the sea ice pack to recover supports the hypothesis of a thinner ice pack that is more sensitive to surface air temperature anomalies. For current sea ice information and sources, please see http://nsidc.org/data/seaice_index/.




Sea ice conditions for September 2004, derived from the Sea Ice Index. Ice concentration anomaly images (the difference in estimated concentration from the mean) and the 1979-2000 median September ice edge (indicated by the pink line) are combined. The ice edge is well north of its median position off the coasts of Alaska and Siberia, and there is a striking lack of sea ice off the east coast of Greenland, a feature noted for the first time in 2002. Anomalies are not calculated north of the circle centered over the pole (shown as light green) where satellites prior to 1988 provided no coverage.

# 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 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-Earth Observing System (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.

## The year in summary

The NSIDC DAAC sustained and expanded operational data processing from EOS satellites in 2004. The EOS Core System (ECS) has kept up with the integrated data flows from Terra, Aqua, and ICESat, and we are pleased with the ECS functionality and stability. Our data distribution has increased, with total distribution between .5 and 1.5 terabytes (TB) per month, with a single month maximum of 3 TB.

We are encouraged with science community interest in the MODIS snow and ice products and expect greater interest in the Advanced Microwave Scanning Radiometer-EOS (AMSR-E) data when these data are released to the science community.

We started evaluation of a Massive Array of Idle Disks (MAID) device late in 2004. We are an early adopter of the COPAN MAID device. Acquisition will be completed in 2005. We chose the MAID to replace our V0 tape storage archive that is near the end of its operational life. Our V0 Redundant Array of Independent Disks (RAID) capacity was also expanded by another terabyte.

NSIDC provided extensive support to the first Workshop on EOS Snow and Ice Products held 16 to 17 November 2004 in Landover, MD. Marilyn Kaminski served as co-convenor, along with Dorothy Hall of NASA/Goddard Space Flight Center (GSFC), and gave a presentation on data access and tools available at NSIDC. Melinda Marquis participated on the organizing committee. Richard Armstrong, Walt Meier, and Tom Painter gave panel presentations; numerous other staff presented posters, gave demonstrations, and participated in discussions. This extremely well-received workshop included details on usage of MODIS, AMSR-E, and GLAS instruments, and provided an excellent opportunity for user interaction and discussion of current issues involving EOS data use.

## External data coordination efforts

Several DAAC staff have participated in planning efforts for the International Polar Year (IPY) in 2007 to 2009. Our efforts have included attending the Polar Research Board meeting in October 2004, presenting talks and posters at the 2004 AGU Fall Meeting, and contributing to NSIDC's expressions of interest for IPY Data Management and grey literature rescue.

The NSIDC DAAC senior scientist participated in the successful effort to establish an International Association for the Cryospheric Sciences (IACS), under the International Union of Geodesy and Geophysics (IUGG) umbrella. The DAAC scientist chaired the committee that wrote the Association's white paper proposal. Formal approval of IACS is anticipated at the 2007 General Assembly of the IUGG in Perugia, Italy.

NSIDC strives to serve as a cryospheric focal point for NASA's Earth Science Enterprise.

The DAAC Scientist served as a reviewer of the Arctic Climate Impact Assessment (ACIA) report (in press, to be published in 2005) and Executive Summary (released in November 2004).

The DAAC manager and DAAC engineer continue to participate in the DAAC Alliance. The DAAC Alliance is an informal organization that coordinates activities between the NASA DAACs. The

group holds quarterly management-level meetings and biweekly teleconferences. NSIDC User Services Office (USO) lead also became the User Services Working Group (USWG) co-chair in October 2004. She will continue in this position through October 2006.

NSIDC participated in the Earth Science Information Partner (ESIP) Federation Committee of the Whole and related special interest group meetings. Several staff members participated in Federation meetings during 2004. Vince Troisi served 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. Several DAAC staff also participated in the Earth System Data Science Working Group meetings. This organization provides data system planning and coordination in lieu of the disbanded Strategy for Evolution of ESE Data Systems (SEEDS).

# Science data operations and user outreach

## Moderate Resolution Imaging Spectro-radiometer (MODIS) Products

MODIS, an optical instrument with 36 spectral bands, is carried aboard the NASA EOS Terra and Aqua satellites providing daily global coverage at spatial resolutions of 250, 500, and 1,000 meters. 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 the MODIS user community through numerous avenues in 2004. NSIDC staff presented MODIS posters at the Fall International Geoscience and Remote Sensing Symposium (IGARSS) and at the 2004 AGU Fall Meeting. In addition, NSIDC presented a poster combining MODIS, AMSR-E, and GLAS at the AGU Spring Meeting. An updated brochure describing the latest product and tool suites was distributed at numerous conferences and science meetings.

We are encouraged by science community interest in the MODIS snow and ice products.

In 2004, MODIS/Aqua products were reprocessed into Collection 4, resulting in a consistent time series of data beginning in July 2002. This collection uses algorithms very close to those used in Terra Collection 4, providing users the means to easily correlate data from the two platforms. NSIDC modified its Web-based interface for accessing browse images of the daily snow climate modeling grid product to include Aqua as well as Terra, and configured the HEW and HEG tools to allow manipulation of Aqua data products. In February 2004, all MODIS/Aqua snow and sea ice products, except the daily nighttime sea ice extent product, were released to the public. These products continue to have a provisional data quality status due to the ongoing issues caused by the algorithms' use of Band 7 instead of Band 6. In 2004 the MODIS/Terra Collection 3 "golden month," a temporal subset of the data intended to be kept indefinitely to facilitate correlation of data between collections, was established and made publicly available. The remainder of Terra Collection 3 was deleted.

NSIDC receives MODIS data from the MODIS Data Processing Facility at the NASA GSFC in Greenbelt, MD. During 2004, the processing and ingest functionality continued to operate with such efficiency that NSIDC frequently archived and distributed data within a few days of capture. In conjunction, increased use of subscriptions for automated distribution has resulted in a greatly enhanced ability for users to receive MODIS data in close to near-real time. For more information, see 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, Level-1B, and Level-2 laser altimetry and atmospheric lidar data. The initial data stream was approximately 20 Gigabytes (GB) per day. However, problems with the instrument that lead to fewer laser shots have been ameliorated by running the lasers intermittently, rather than continuously. So far there have been three campaigns each year, each of them lasting about 33 days. Details about the mission, science algorithms, and products are available at http://nsidc.org/daac/glas/.

During 2004, NSIDC made the following GLAS data releases available.

7 April 2004: Release-13 altimetry data for GLA01, and Release-14 altimetry data for GLA05, GLA06, and GLA12 through 15 for a 33-day cycle from 15 October 2003 to 18 November 2003.

7 June 2004: Release-17 atmospheric data (GLA02, GLA07 through 09) for for a 33-day cycle from 15 October 2003 to 18 November 2003.

24 September 2004: Release-18 data for all 15 ICESat products for 30 September to 18 November 2003.

Snow and ice recede from the western side of southern Greenland in this true-color Aqua MODIS image of from 7 August 2004. As summer settles over the Northern Hemisphere, increased temperatures bring a brief growing season to even remote landscapes. But despite the warmer conditions, Greenland's ice sheet continues to dominate the interior of the huge island. (Image courtesy of NASA's MODIS Land Rapid Response Team.)

October 2004: Release-18 data for GLA01 through 09 and GLA12 through 15 from 20 February through 19 March 2003.

For each new data release, we install and test new Earth Science Data Types (ESDTs), and test sample products for ingest, search and order via EOS Data Gateway (EDG).

We revise our documentation (http://nsidc.org/data/icesat/data.html) as the products mature and as users request more details on certain subjects. Updated materials include guide documents, DIFs, and Web pages. We maintain extensive documentation on the many releases of the GLAS data at http://nsidc.org/data/icesat/data.html #release_schedule and http://nsidc.org/data/icesat/detailed_disclaimer.html.

NSIDC collaborates with the GLAS Science Computing Facility (SCF) and the ICESat Science Investigator-Led Processing System (ISIPS) to provide a variety of readers and visualizations tools for users to work with ICESat data. See http://nsidc.org/data/icesat/tools.html for an overview of tools.

We also distribute Fortran 90 and Interactive Data Language (IDL) readers, developed by the SCF.

We distribute the NSIDC GLAS Altimetery Tool, an IDL reader developed in-house to extract elevation and geoid data from GLAS altimetry products (GLA06 and GLA12 through 15). This tool outputs latitude, longitude, elevation, and geoid in ASCII columns. We also distribute an IDL visualizer tool, developed by the SCF, and an IDL ellipsoid conversion tool, developed by NSIDC. Additionally, we provide users with the 8-day and 91-day orbit files, so that users can view the geodetic latitude and longitude location of the ICESat reference orbit ground tracks. A Fortran program (read_orbit.f90) and an IDL program (plot_orbit.pro) are also available to ingest these data files. NSIDC developed a means to provide subsetting to GLAS users, and released

this functionality in the fall of 2004. We received such a high volume of subsetting requests in the first few weeks that we had to discontinue the service and re-engineer our process. We expect subsetting to become available in 2005.

## 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, Level-2A, Level-2B and Level-3 data. Details about the mission, science algorithms, and products are available at http://nsidc.org/daac/amsr/.

The Aqua mission provides data for multi-disciplinary studies of the Earth with a special emphasis on oceans.

In March 2004, NSIDC began receiving and distributing to the public the daily and weekly Level-2B and Level-3 higher level products from Science Investigator-led Processing System at the University of Alabama in Huntsville (SIPS-UAH). In April 2004, NSIDC began receiving and distributing to the public the monthly Level-3 products from SIPS-UAH. In May 2004, NSIDC began distributing improved versions of eight Level-2B and Level-3 products. In October 2004, the SIPS completed the first historical processing of the AMSR-E data for June 2002 (the beginning of the mission) through February 2004. In November 2004, because of the loss of the 89 GHz A-horn, algorithm changes to the Level-2A product were made.

We revise our documentation (http://nsidc.org/data/amsre/index.html) as the products mature and as users request more details on certain subjects. Updated materials include guide documents, DIFs, and Web pages. We maintain extensive documentation on the many versions of the various AMSR-E data products at http://nsidc.org/data/amsre/versions.html.

We distribute tools for working with the AMSR-E data at http://nsidc.org/data/amsre/tools.html. NSIDC developed the AMSR-E Swath to Grid Toolkit (AS2GT), which subsets and grids Level-1B and Level-2A AMSR-E swath data. We also provide Fortran readers for Level-2B data, which were developed by the rain product algorithm developers. NSIDC points users to a Web site about HDF-EOS to answer common questions about HDF-EOS and to provide simple methods for working with the HDF-EOS format. Tools are provided to convert from HDF-EOS to binary, and to dump HDF metadata into ASCII text. NSIDC also provides land masks for the sea ice products.

Further, NSIDC has tested and distributed many of the AMSR-E Delivered Algorithm Packages, which contain the product code and necessary inputs to produce the products.

**Updates to AMSR Data Products**

- 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): This update 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 management

NSIDC supports 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, in the form of Global Change Master Directory (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/.

NSIDC published eighteen and archived sixteen AMSR-E validation data sets in 2004 primarily for the soil moisture campaigns. NSIDC also participated in the Soil Moisture Experiment 2004/North American Monsoon Experiment (SMEX04/NAME) in Tombstone, AZ.

**Cold Lands Field Experiment (CLPX) Support**

In 2004, NSIDC made available almost all of the data from the 2002 and 2003 field campaigns. A total of 37 data sets, with accompanying documentation and metadata, are currently available.

# Non-EOS passive microwave data products and EASE-Grid products

**Polar Stereographic Products**
NSIDC routinely updates polar stereographic standard sea ice products. In 2004, Goddard sea ice time series products were updated through 2003 for both NASA Team and Bootstrap algorithms. Accompanying ancillary products of ice area/extent, monthly climatologies, and Geographical Information Systems (GIS) files were also updated. The distribution method of the NASA Team product was changed from CD-ROM to FTP. The complete archive of both products is available online at http://nsidc.org/data/nsidc-0079.html for Bootstrap and http://nsidc.org/data/nsidc-0051.html for NASA Team.

TIROS Operational Vertical Sounder (TOVS) updates for the daily northern hemisphere product were received, quality checked, and distributed. A new daily southern hemisphere TOVS product was also distributed. Daily TOVS products are now available for both hemispheres from 1979 through 2001. Monthly product updates are planned in the future. The data are available online at http://nsidc.org/data/nsidc-0027.html.

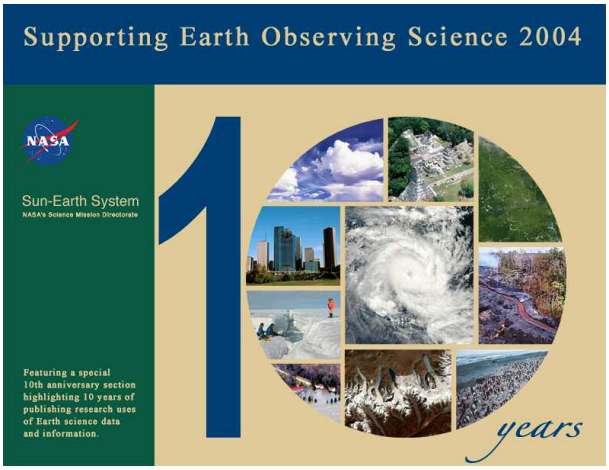
Reprocessed Electrically Scanning Microwave Radiometer (ESMR) sea ice concentrations were distributed. This product is gridded to the polar stereographic projection and has been quality checked. Bad data are noted and daily fields of extent with a 0 percent concentration and a 15 percent concentration threshold were produced. Also, monthly averages were computed for each month with enough good data. Finally, a monthly climatology was produced from the ESMR record, which extends from 11 December 1972 to 11 May 1977. The archive is available online at http://nsidc.org/data/nsidc-0009.html.

A merged time series of total sea ice extent for the ESMR-SMMR-SSMI/I record was acquired. This is a daily and monthly total extent for the Northern and Southern Hemisphere from 1973 through 2002, providing the longest consistent passive microwave time series of sea ice extent. The data are available at http://nsidc.org/data/smmr_ssmi_ancillary/area_extent.html.

**NISE Products**
Several minor changes were implemented in the Near real-time Ice and Snow Extent (NISE) product. A configuration management plan for NISE software was put into operation. This was a trailblazing effort in the data center and a challenging one as NISE employs different libaries, algorithms and processing steps. NSIDC created a revised daily image of NISE snow cover over the continental US, as well as an 11-day animation. The animation was used at the NSIDC booth for the 2004 AGU Fall Meeting. The National Polar-orbiting Operational Environmental Satellite System (NPOESS) intends to use NISE data as an ancillary product in their operational data production system. NSIDC conducted a review of failures in NISE production and provided it to the NPOESS development team. Operational procedures and software have been developed to reduce failures during product generation and distribution.

**EASE-Grid**
Regular processing and CD-ROM production continued for the products on all three Equal-Area Scalable Earth Grid (EASE-Grid) projections. The processing kept up with ingest from Remote Sensing Systems.

**DAAC Alliance Annual**
As a member of NASA's DAAC Alliance, the NSIDC DAAC published the 10th Anniversary edition of the DAAC Alliance Annual, a multidisciplinary publication that highlights applications and research uses of data from NASA's Earth Observing System satellites. This special edition of the DAAC Annual highlights the progress of NASA's Earth-Sun System science programs by contrasting imagery taken from NASA's previous satellites with recent imagery from the Earth Observing System. It also includes information about user trends, as well as an index of all articles published in DAAC Annuals from 1994 to 2004.




In addition to the special 10th Anniversary section, the 2004 Annual included a collection of feature articles that highlighted research on glaciers and ice shelves, volcanoes, biology and ecosystems, atmospheric processes, and urban landscapes.

Articles from the 2004 DAAC Alliance Annual are also available electronically on the DAAC Alliance Web site at http://nasadaacs.eos.nasa.gov/.

**DAAC Alliance Web Site**
In 2004, the Cross-DAAC Web site, known to the public as the "Earth-Sun System Division Data and Services" site, underwent a major overhaul. This overhaul put the site in compliance with new OneNASA design guidelines. The site also maintained compliance with other NASA specifications and Section 508 guidelines achieved in prior designs. The site also added enhanced search capabilities using features from the Global Change Master directory to focus on DAAC data sets. See http://nasadaacs.eos.nasa.gov/ for more information.

**Web Site Updates**
The following Web pages were updated in 2004:

- The Cryosphere (http://nsidc.org/cryosphere/), the section of our Web site intended for the general public
- State of the Cryosphere (http://nsidc.org/sotc/), highlighting the collapse of the Larsen B Ice Shelf, which is also covered in more detail on our Ice Sheets and Ice Shelves Web 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/), revised and added answers to common questions from the public.
- MODIS Climate Modeling Grid browse products (http://nsidc.org/data/modis/cmg_browse/index.html), added reduced-resolution images of global daily CMG products to provide an easy way for users to monitor changes in global snow cover (includes the Aqua daily CMG product in addition to the Terra product).

## Systems engineering and systems development

**NSIDC DAAC EOSDIS Core System (ECS)**
The ECS is operational. In addition to nominal ingest archive and distribution functions, several important sustaining engineering tasks related to improving the efficiency of the ECS were completed during 2004.

- Phase one of the Sun Server consolidation plan was completed in 2004. The consolidation included replacing servers deemed end-of-life by the vendor with current technology and combining services into a fewer number of servers, thereby reducing the total cost of ownership.
- The ECS ingest, archive, and distribution processes were enhanced, enabling the DAAC to keep current with the problem resolution and the development cycle.
- Release 7 of the ECS was installed, requiring numerous configuration changes, including:
  - Integration of multiple Apache and Tomcat servers into a single instance to provide Data Pool processing services in both operational and test modes
  - Configuration of Order Manager Subsystem to take responsibility for most orders including staging data from ECS archive into the Data Pool for FTP pull and FTP push order, as well as submitting physical media orders to the PDS
  - Data Pool changes that enable compression on Data Pool inserts and improve log processing to enhance EDGRS reporting
  - End-to-end Checksum, providing ingest, storage, verification, and distribution of checksums associated with science granules
  - A service to transfer HDF-EOS to GeoTiff (HEG) in order to provide data in a usable format for GIS applications.

We established a team of technical staff supporting the ECS architecture to develop a process for reviewing requirements, developing, and maintaining DAAC-Unique Extensions (DUEs) to the ECS. DUEs are tools that provide additional system and metrics reporting capabilities not available in the custom code delivered in ECS releases.

**EOS Clearing House (ECHO)**
NSIDC DAAC staff continue 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:

- Routinely submitting metadata in XML of all NSIDC ECS data holdings to ECHO using the Bulk Metadata Generation Tool (BMGT) and the BulkURL Tool
- Conducting reconciliation of the inventory-level metadata transmitted and inserted into the ECHO databases against the inventory-level holdings in the NSIDC ECS databases
- Developing plans for transmitting browse products associated with science granules to ECHO.
- Providing support to the ECHO developers by adding the backtrack orbit search algorithm as a search option for orbital swath data.
- Developing client/server applications, such as WISRD and the Search 'N Order Web Interface (SNOWI-E) that interface to ECHO.

**HDF-EOS Web-Based (HEW) Subsetter**
NSIDC DAAC staff continue to operate the HEW subsetting service developed at the University of Alabama in 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 as well as latitude and longitude ranges. A Sun Microsystems V880 server was installed to provide the processing environment for subset requests as a replacement for a Sun Microsystems E450. The E450 server was declared end-of-life by Sun Microsystems Incorporated.

**PerlDesk Help Desk System**
PerlDesk is a Web-based application that provides a management framework for help desk and e-mail communications. NSIDC staff obtained a copy of the freeware package and customized the interfaces and databases to provide a communication vehicle for submitting and tracking requests for services that are provided by our data operations staff.

Recently, NSIDC User Services staff reviewed the capabilities of PerlDesk in order to assess the feasibility of using the PerlDesk architecture as a replacement to a heritage e-mail communications system. A prototype help desk and communications tracking application has been developed for evaluation by NSIDC User Services staff, and a final version is planned for deployment in early 2005.

**Migration of non-ECS managed archives to Massive Array of Idle Disks (MAID) Architecture**
During 2004, NSIDC entered into an early adopter program with COPAN Systems. COPAN provides a secondary storage solution based on Massive Array of Idle Disks (MAID) technology. The basic architecture uses a large number of disk drives that provide high capacity, high volumetric density, and spins each of the drives only when necessary. COPAN uses proprietary disk and power management functions to monitor the health of both disks and data. The current personality of the COPAN Revolution 200t is that of a virtual tape library.

NSIDC procured the entry level 200t subsystem comprised of two shelves; each shelf currently has the raw data capacity of 28 terabytes consisting of 250 gigabyte Serial ATA (SATA) disk drives. The 200t has the capacity of holding up to eight shelves per rack. The 200t is controlled by a linux server and the Virtual Tape Library (VTL) is emulated using the FalconStor product.

The 200t was installed in August 2004. A Sun Microsystems V240 server provides network access to the 200t. The AMASS file system management software from ADIC provides the archive management environment.

NSIDC staff discovered poor performance during our early tests of the archive configuration described above. NSIDC, COPAN, and ADIC staff are investigating the source of this problem. NSIDC expects to begin data migration from the DLT tape library to the COPAN Revolution 200t MAID storage subsystem in the first quarter of calendar year 2005.

**Plans for the Transition SGI and Sun Microsystem Servers to Intel-based Linux Servers**
NSIDC is in the process of replacing some of the Silicon Grahics, Incorporated (SGI) and Sun Microsystem servers to Intel-based Linux servers. Phase one of the transition includes migrating e-mail, calendar manager, FTP, and Web services to linux servers. This transition is expected to be completed summer of 2005. Phase two of the transition includes porting science data production environments from an SGI/IRIX server to Intel/Linux environment.

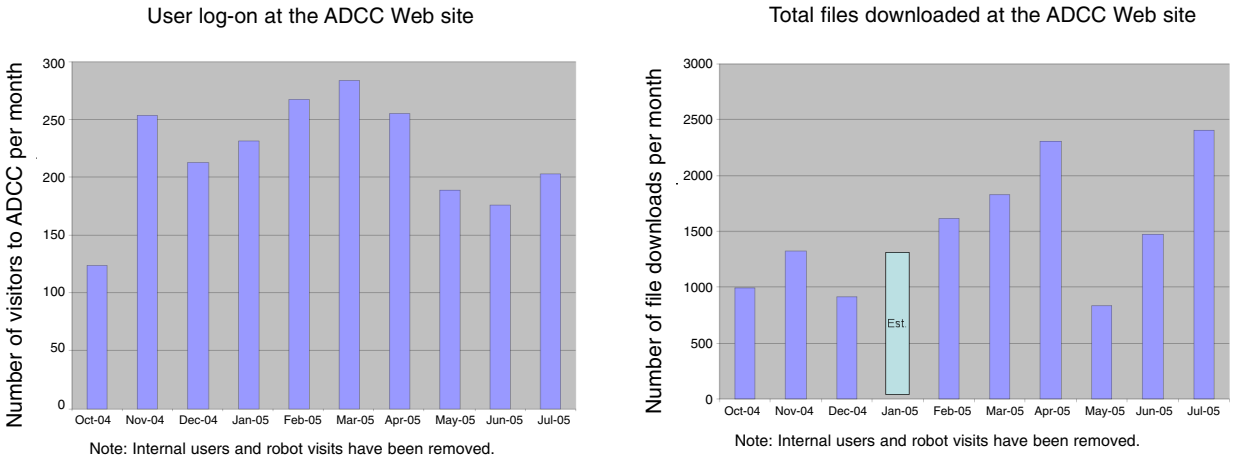
# The Arctic System Science (ARCSS) Data Coordination Center (ADCC)

The Arctic System Science (ARCSS) Data Coordination Center (ADCC) at NSIDC is the permanent data archive for all components of the ARCSS Program. Since 1991, the NSF has continuously funded the ADCC at NSIDC. During 2004, the ADCC operated on reduced supplemental budget and experienced a loss of technical writing support.

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 data search using the name of the Principal Investigator (PI), the project title, the measured parameter, or keywords. A Metadata Submission Form is a part of the data submission protocol and is the starting point for all PIs who wish to submit their data sets to the ADCC. Chris McNeave is the data coordinator and Jane Beitler is the technical writer, in addition to several other staff members who work on this project part time as required. Rudolph Dichtl is the ADCC manager and PI and Dr. Roger Barry is Co-PI. They both lead the ADCC activities at NSIDC.

2004 accomplishments include the following:

- Published 6 new data sets on the ADCC Web site
- Included data from 182 PIs and Co-PIs on the ADCC Web site
- Updated the ADCC Address Book to include contact information for more than 575 PIs and Co-PIs
- Received NSF award of two years funding from 01 December 2004 to 30 November 2006
- Coordinated directly with NSF/ARCSS funded PIs to assist in the acquisition, preparation, and publication of data sets
- Received and processed 13 Metadata Submission Forms




User statistics for the ADCC Web site.

# U.S. Antarctic Data Coordination Center (USADCC)

The National Science Foundation (NSF) funds the U.S. Antarctic Data Coordination Center (USADCC) at NSIDC to facilitate the development of U.S. data set descriptions (metadata) for inclusion in the Antarctic Master Directory (AMD). The AMD is an internationally-based electronic data directory that is a significant part of the International Directory Network (IDN) Global Change Master Directory (GCMD). The AMD contains data set descriptions for multidisciplinary Antarctic scientific data collected by approximately 19 countries, under the auspices of the Scientific Committee on Antarctic Research (SCAR) and the Council of Managers of National Antarctic Programs (COMNAP). 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 2004 to 2005, the USADCC worked directly with NSF-funded Principal Investigators, GCMD staff and NSF Antarctic Program Managers to increase U.S. data set description content in the AMD. United States-contributed metadata records in the AMD now number 767 (up from 688 in 2003). Searches of the AMD average several hundred per month, and retrievals of information from those searches are approaching 450 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 Rob Bauer (Co-I) lead the USADCC activities at NSIDC.

The Antarctic Treaty calls on parties to exchange and make freely available scientific observations and results from Antarctica. NSF and the USADCC have been leaders in the establishment of the international framework for this activity.

Significant achievements include the following:

- There are now more than 3000 entries in the AMD (compared to 1326 in July 2001, 2116 in July 2002, 2544 in April 2003, 2966 in June 2004, and 3094 in March 2005)
- The number of countries adding metadata has increased from 9 in 2002 to 19 in 2005
- The number of AMD users has grown from 100 per month in January 2003 to 450 per month in March 2005
- An increasing number of countries have set up national portals with the AMD (from 2 in 2002 to 15 now)

# 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.

A composite satellite photograph of Antarctica in orthographic projection. (Image courtesy of NASA)

The AGDC now contains data contributed by more than 90 PIs, spanning a broad variety of glaciological topics. Recent additions include data from the U.S. International Trans-Antarctic Science Expedition (U.S. ITASE):

- *Ice Thickness and Internal Layer Depth along the 2001 and 2002 US-ITASE Traverses*
- *U.S. International Trans-Antarctic Scientific Expedition (U.S. ITASE): GPR Profiles and Accumulation Mapping*
- *U.S. International Trans-Antarctic Science Expedition 400 MHz Subsurface Radar Profiles*

Users can access data and documentation, citation information, locator maps, derived images, and references at http://nsidc.org/agdc/. Ted Scambos (PI), and Rob Bauer (Co-I) lead the AGDC activities at NSIDC.

# The Frozen Ground Data Center (FGDC)

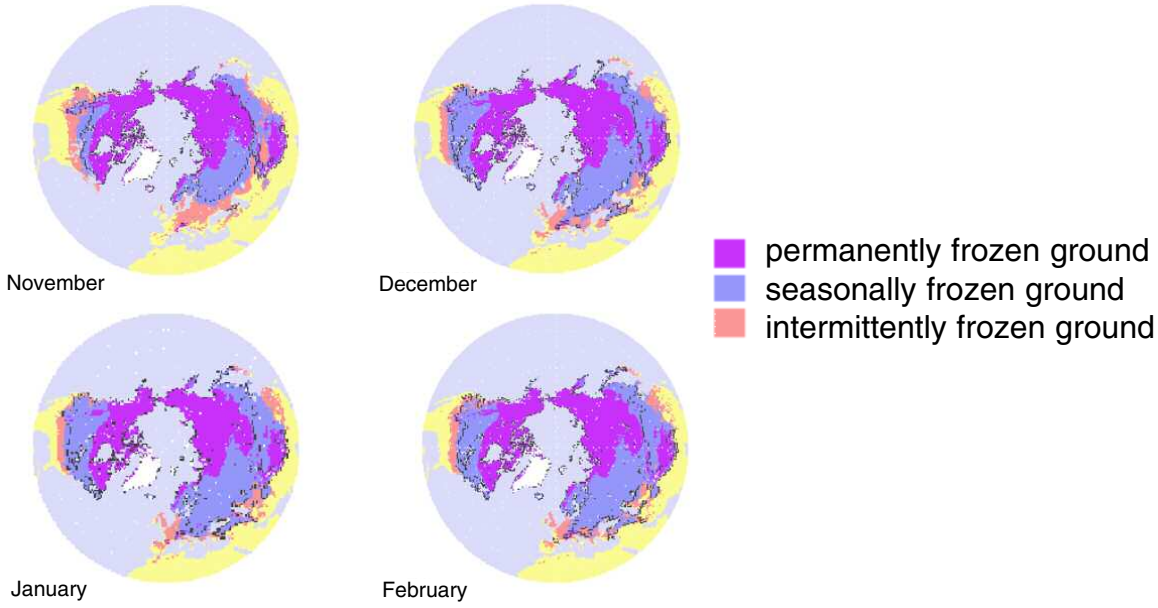
Data and information on frozen ground are critical for understanding fundamental processes and detecting environmental change. Frozen ground data is also useful for impact assessment, model validation, and engineering applications in regions of seasonal frost and permafrost. However, much of this information and many of these data sets remain widely dispersed and unavailable to the international science and engineering communities. Some data are in danger of being lost permanently.

The Frozen Ground Data Center (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 on permafrost and seasonally frozen ground. FGDC worked closely with the International Permafrost Association (IPA) to help meet its goals for data and information management laid out by the IPA's Standing Committee on Data, Information, and Communication. Mark Parsons and Tingjun Zhang lead FGDC activities at NSIDC.

In 2004, FGDC has improved access to existing data and augmented its data holdings. The Center provided access to data and metadata for all the major IPA programs (http://nsidc.org/data/fgdc). FGDC has also developed a collection of regional and hemispheric maps of permafrost, soil classifications, and related parameters. The Center is now exploring new sources of frozen ground data, including data from models and satellite remote sensing.

In 2004, FGDC focused on developing new data products, including the *Distribution of Seasonally and Perennially Frozen Ground in the Northern Hemisphere* product and the *Weekly Extent of Near-Surface Frozen Soil in the Northern Hemisphere, Derived from Microwave Satellite Remote Sensing Data* product.

The FGDC plans to play a major role in the upcoming International Polar Year (IPY) 2007 to 2009 by coordinating data management for the 20 to 30 permafrost-related projects planned as part of IPY. We also anticipate developing the third version of the Circumpolar Active-layer Permafrost System (CAPS) for the 2008 International Conference on Permafrost. See http://nsidc.org/fgdc for more information.

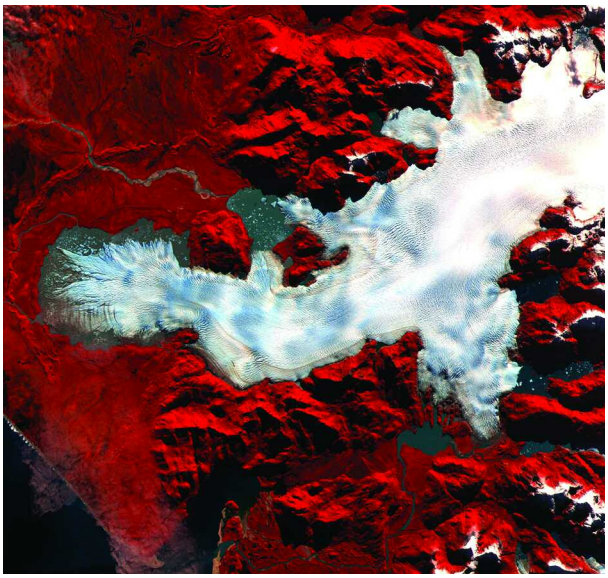



Distribution of permafrost, average area extent of seasonal frozen ground (1950-1996) for November, December, January, and February in the Northern Hemisphere. These historical data show that the total area of monthly frozen soil extent has decreased about 15 to 20 percent over the past few decades.

# Global Land Ice Measurements from Space (GLIMS)

## Developing a comprehensive inventory of the world's glaciers

GLIMS is an international project with the goal of surveying a majority of the world's estimated 160,000 glaciers. GLIMS uses data collected primarily by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument aboard the Terra satellite and the LandSat Enhanced Thematic Mapper Plus (ETM+).



This ASTER image was acquired on 2 May 2000 over the North Patagonia Ice Sheet and covers an area of 36 by 30 kilometers. The false color composite displays vegetation in red. A semi-circular terminal moraine indicates that the glacier was once more extensive than at present. (Image courtesy of NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.)

Glaciers are unique in their ability to provide clear visual indicators of climate change and thus compiling a globally complete database of glaciers is an important task. The GLIMS project is currently creating a glacier inventory containing information regarding the current extent and the rates of change of all the world's glacial resources to obtain a better understanding of past, present and future changes in glaciers and the relationships to local and global climatic fluctuations as well as sea level change.

GLIMS is a collaborative effort with NASA, USGS, and more than sixty institutions worldwide. Each institution (called an RC, or Regional Center) oversees the creation and analysis of data for a particular region appropriate to their expertise. Each RC is provided an application called GLIMSView, a specifically designed, cross-platform digitizing tool developed to view different forms of satellite imagery, digitize glacier outlines, attach GLIMS-specific attributes, and prepare data to be imported into the GLIMS database. NSIDC is working directly with the USGS in Flagstaff on the development of GLIMSView.

The NSIDC GLIMS project is building a geospatial and temporal database of glacier data composed of glacier outlines and various scalar attributes. These data are being derived from satellite imagery, primarily ASTER and Landsat, while historic data (maps and photographs) are used to document changes from earlier periods. Each "snapshot" of a glacier is from a specific time and the database is designed to store multiple snapshots representative of different times. NSIDC has implemented a Web-based interface to the GLIMS Glacier Database, which enables exploration of the data using interactive maps. The Web server is an Open Geospatial Consortium (OGC) compliant Web Map Server (WMS) and Web Feature Server (WFS). This means that other Web sites can display glacier layers from our site over the Internet, or retrieve glacier features in vector format. All components of the system are implemented using Open Source tools: PostgreSQL (the object-relational database), PostGIS (geospatial extensions to the database), MapServer (WMS and WFS), and several supporting components such as Proj.4 (a geographic projection library). These tools are robust and provide a flexible and powerful framework for Web mapping applications. The system allows users to select a spatial subset and then download the results of the query, both the vector data and the scalar attributes, to their own computer in a choice of several formats, including ESRI Shapefiles, MapInfo Tables, and Geography Markup Language (GML).

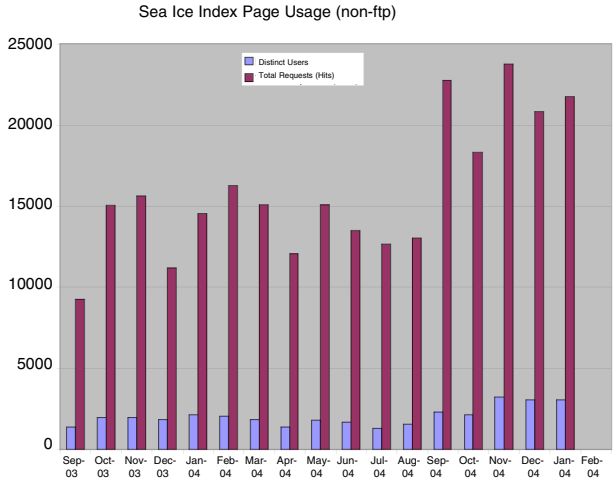
The GLIMS project at NSIDC is led by Richard L. Armstrong and Roger G. Barry, with assistance from fellow NSIDC staffmembers Christopher W. Helm, Siri Jodha Singh Khalsa, and Bruce Raup, and with help from Mark Dyurgerov of the Institute for Arctic and Alpine Research (INSTAAR).

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

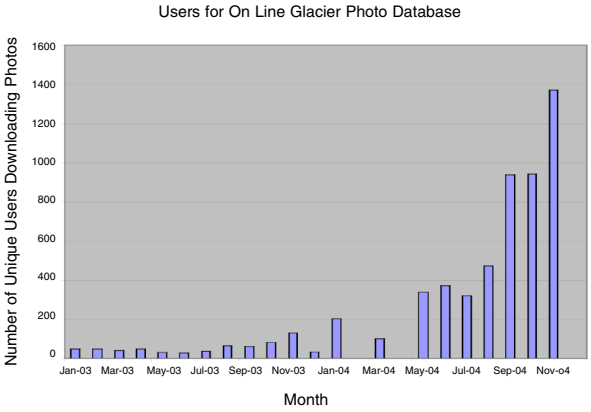
The National Oceanic and Atmospheric Administration (NOAA) project at NSIDC operates in cooperation with the NOAA National Geophysical Data Center (NGDC) to extend the NOAA National Data Center's catalog of cryospheric data and information products. The NOAA project manages about 65 data sets, with an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

In 2004, NOAA at NSIDC released several data sets, including the *IMS Daily Northern Hemisphere Snow and Ice Analysis at 4 KM and 24 KM Resolution* and the *Snow Data Assimilation System (SNODAS) Data Products at NSIDC.* NOAA at NSIDC also extended the *Sea Ice Index* by 10 years, and in conjunction with the NSIDC library, expanded the *Glacier Photograph Collection*. NOAA at NSIDC staff members also significantly revised documentation, made corrections to data, or added data to several data sets.

The NOAA team also maintained Web sites for the International Ice Charting Working Group (IICWG) and the WMO Global Digital Sea Ice Data Bank at NSIDC, and developed a Web page on Moored Upward Looking Sonar Data for the World Climate Research Programme's Arctic Climate System Study/Climate and Cryosphere (ACSYS/CliC) programs. NOAA's participation in these groups helps preserve ice chart data for use by researchers and encourages the contribution of data to NSIDC's public archive. The IICWG Ad Hoc Format Working Group's efforts have lead to a new archive format, described in *SIGRID-3: A Vector Archive Format for Sea Ice Charts* (a JCOMM Technical Report Series No. 23, 2004, WMO/TD-No. 1214). See http://nsidc.org/noaa/gdsidb/formats.html for more information.




Figures from the Sea Ice Index have been used in numerous research papers and press articles, and were included as a visual aid during a congressional hearing on climate change (see the 16 November 2004 item at http://nsidc.org/news/archives/#2004/). The Web site receives more than 20,000 hits per month. About six percent of users visiting the site come from educational or government servers, while about 65 percent of users come from commercial or other domestic servers.




More than 1300 glacier photos are online, and in 2004, an additional 2000 were scanned. Prior to the scanning project, only a handful of users saw the delicate prints each year. Now, usage has grown to more than 1000 users each month.

NOAA at 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 2004, the NOAA team included Alejandro Machado (programmer and User Services support) and Lisa Ballagh (operations support). Keri Webster provided technical writer support, and Jonathan Kovarik joined the team in September for operations.

The Sea Ice Index was developed with NSIDC lead programmer Ken Knowles. The Glacier Photograph project is being carried out in partnership with NSIDC librarian and analog data archivist Allaina Howard and database administrator I-Pin Wang.

# Research

Researchers at NSIDC investigate the dynamics of Antarctic ice shelves, arctic regions, new techniques for the remote sensing of snow and freeze/thaw cycle of soils, the role of snow in hydrologic modeling, links between changes in sea ice extent and weather patterns, large-scale shifts in polar climate, river and lake ice, and the distribution and characteristics of seasonally and permanently frozen ground.

In-house scientific expertise helps NSIDC improve the quality of research data sets and respond quickly to inquiries on snow and ice topics from the general public. Scientists pursue their work as part of the Cooperative Institute for Research in Environmental Sciences (CIRES) Cryospheric and Polar Processes Division at the University of Colorado, Boulder. A number of agencies, including NASA, NSF, NOAA, CIRES, the Naval Research Laboratory, and the International Arctic Research Center (IARC) fund research through the peer review proposal process.

Guests from NSIDC, the National Center for Atmospheric Research, the Institute for Arctic and Alpine Research, NOAA/CIRES Forecast Systems Laboratory, and Colorado State University with staff of the Institute of Plateau Meteorology, China Meteorological Administration, Chengdu.

NSIDC researchers present their findings in peer-reviewed journal articles and at conferences and meetings around the world. They collaborate with colleagues worldwide to study cryospheric processes and manage data, and participate in a variety of national and international organizations.

# Todd Arbetter

## Arctic Albedo and its Relationship to Sea Ice Conditions

The purpose of this project is to make use of in situ and satellite observations of Arctic sea ice albedo to foster a better understanding of the role of albedo in the life cycle of Arctic sea ice. The focus of this sub-project is to incorporate these observations into basin-scale sea-ice and regional climate models, and determine what improvements can be made in surface albedo parameterization. Observations indicate that the surface albedo can vary greatly on small scales, but large-scale modeling currently requires a bulk value which is applicable to a large area of hundreds of square kilometers, all of which may be represented by one grid cell. The goal of the project will be to improve these grid- and sub-gridscale parameterizations. Part of the modeling effort will focus on improving the parameterization of surface melt. (Funded by NASA grant NNG04GJ81G)

## Data Assimilation of Ice Motion in Sea Ice Models

This project made use of observations of sea ice motions from drift buoys and satellites to enhance and improve the solution of sea ice drift in basin-scale sea ice models. The models contain complex parameterizations of internal sea ice physics and, governed by a momentum balance, predict ice motion using external forcing such as National Centers for Environmental Prediction (NCEP) or European Centre for Medium-Range Weather Forecasts (ECWMF) atmospheric analyses. However, these solutions are hampered by the quality and/or resolution of the atmospheric forcing, and often do not compare favorably with observations. Here, using optimal interpolation techniques, observations of ice drift are blended with the model's initial predictions, yielding an improved solution. The assimilated solution compares more favorably with the observations, but due to the nature of the assimilation, the new solution is in violation of some of the key physical assumptions of the dynamic ice model. Hence, these are mixed results, but careful application and cautious interpretation of the modeled/assimilated ice motion can lead to improvements in the model's physics and a better overall solution. Todd Arbetter is the PI and Walt N. Meier is Co-PI. (Funded by NASA grant NAG5-10556)

# Richard Armstrong

## Monthly EASE-Grid Snow Water Equivalent Climatology

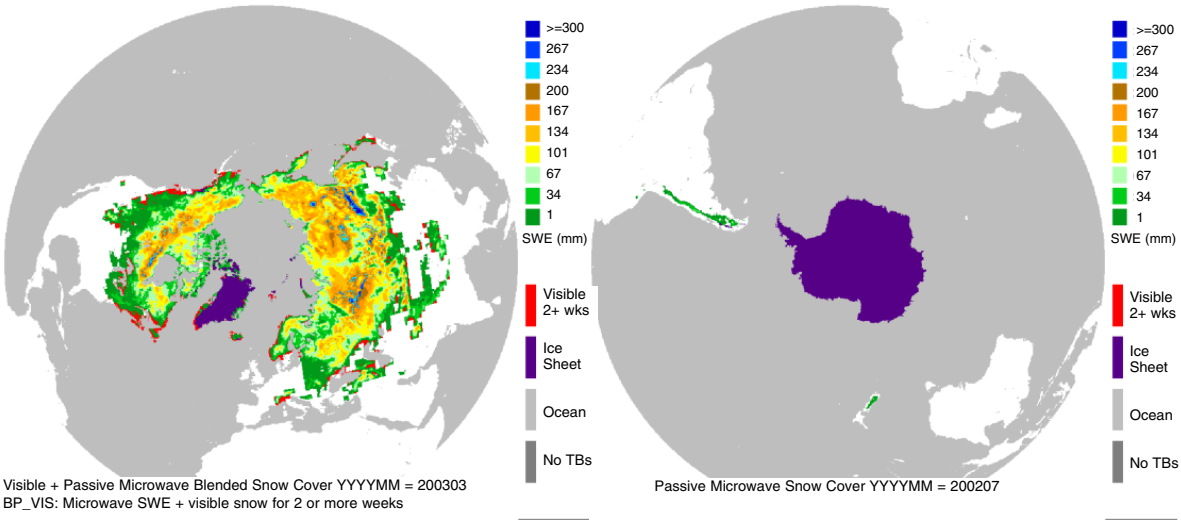
During 2004, the Global Monthly EASE-Grid Snow Water Equivalent Climatology data set was completed and distributed. This data set comprises monthly satellite-derived snow water equivalent (SWE) climatologies from November 1978 through June 2003. Global data are gridded to the Northern and Southern 25 kilometer Equal-Area Scalable Earth Grids (EASE-Grids). This new data set is the first available global product to merge snow water equivalent derived from SMMR and SSM/I passive microwave sensors with snow extent derived from weekly NOAA (optical sensor) snow maps. It is the only product to include Southern Hemisphere passive microwave-derived snow water equivalent. The data are in flat binary format, with Portable Network Graphics (.png) browse images included. Animations of the monthly data are available for users with JavaScript-enabled browsers at http://nsidc.org/data/docs/daac/nsidc0271_ease_grid_swe_climatology/browse/viewer.html. (Funded by NASA)

## AMSR-E Sensor Calibration

EASE-Grid SSM/I TB time series were routinely processed, archived, and distributed. In the context of work reported on here, the SSM/I data serve as redundancy for the AMSR-E TBs and contribute to the validation and cross-calibration of AMSR-E TBs and snow products. One of the primary efforts of this project is to develop and implement an optimal procedure to merge the AMSR-E TBs with the legacy or precursor SMMR and SSM/I data. In order to accomplish this it is first necessary to identify ground targets with suitable temporal and spatial brightness temperature stability.

Onboard satellite instrument calibration systems allow ground-based processing to derive brightness temperatures of the Earth. However, a variety of post-launch artifacts, such as uncorrected attitude errors, instrument misalignment, thermal gradients, and component degradation, create a need for fine-tuning of the calibration in the data production system. The challenge of post-launch tuning is finding suitable targets. Reference targets should be homogenous over a large enough surface to resist nonlinear averaging and antenna pattern effects, while remaining stable and well-known in their brightness temperature characteristics. Calm ocean scenes have been used to cross-calibrate the SSM/I, TMI and AMSR-E sensors at the cold end (80 to 150 Kelvin) of the typical Earth-view brightness temperature range. However, even with excellent cold end calibration, such that ocean geophysical products are accurate, the warmer temperature calibration may be inaccurate, causing errors in the geophysical retrievals over land. Some previous studies have investigated suitable targets at the mid-range (~200 Kelvin) and warm end (250 to

Global Monthly EASE-Grid Snow Water Equivalent Climatology




Northern (left) and Southern (right) Hemisphere average snow water equivalent (millimeters) from passive microwave with additional area in red indicated as snow for two or more weeks of the month in the NOAA weekly snow maps (optical). The left image is from March 2003, and the right image is from July 2002.

300 Kelvin) of the Earth's emission range. The optimal locations and dimensions of such targets have not been studied adequately from a satellite sensor viewpoint.

In this current study, using AMSR-E EASE-Gridded TBs, specific ice sheet locations are investigated for the mid-range, and tropical forest locations for the warm end. We have developed a systematic method to evaluate the spatial and temporal variability of brightness temperatures over these land targets. Targets with minimal variability will be selected as optimal sites for long-term spaceborne radiometer system calibration monitoring over land. The preliminary results were reported at the AGU Fall Meeting. (Funded by NASA)

## Merging of Precursor and EOS Data Sets: Resampling of AMSR-E Swath TBs to EASE-Grid

For temporal investigations including the production of CDRs, original satellite swath data must be resampled to a fixed Earth grid in such a way that brightness temperature histories refer to specific areas on the ground that are stationary in time and common to all channels of the sensor. Because the passive microwave data are inherently of low spatial resolution, the resampling scheme should minimize loss of spatial information. Resampling to an effective common spatial resolution implies resampling all data to the lowest spatial resolution of any channel. For the SSM/I, this corresponds to the 40 by 70 kilometer spatial resolution (-3dB footprint) of the 19 GHz channels. AMSR-E offers many improvements over the SSM/I. In addition to more frequencies and higher spatial resolution at the equivalent SSM/I frequencies, the 6.9 GHz channel, the channel having the lowest spatial resolution (50 kilometers), is oversampled by a factor of five. This significant oversampling offers possibilities of synthesizing more ideal footprints with reduced elongation and deconvolving antenna temperatures for limited improvements in spatial resolution.

We have completed test versions of the software and ancillary data needed to implement the Backus-Gilbert resampling for the AMSR-E data. We defined and tested the five and 10 kilometer versions of the EASE-Grid. We modified our AMSR-E processing system to handle the latest format changes to the Level-2A data. The requirements for the operational processing system are complete and we built "scaffold" software to do timing tests for various approaches to implementing the resampling. We have chosen a method and completed the software design for the production system. The resampling of AMSR-E swath TBs to EASE-Grid will be completed during the coming year. (Funded by NASA)

## Generating New Products within EOS: Continued Work on MODIS/AMSR Blend

We continue to develop an optimal procedure to blend the EOS MODIS and AMSR-E snow products. Work on this blended product involves building a turnkey software system, whereby we "blend" global SWE derived from passive microwave with snow extent derived from the MODIS CMG product. Given an 8-day MODIS product file, with one command we currently produce a blended product using Pathfinder SSM/I data, up to and including our most recent "near real-time" (within the last 24 hours) SSM/I data. With slightly more manual intervention, we can create the blended product using the standard AMSR-E daily snow product.

This development includes generating gridded AMSR-E TBs from the standard Level-2A TB product, and modifying our current software that produces SWE from SSM/I or SMMR data to also accept AMSR-E gridded TBs as input. With some operator intervention (retrieving and staging Level-2A TB files for the desired time period), we can produce Northern Hemisphere gridded AMSR-E TBs. The SSM/I SWE algorithm software is being modified to accept AMSR-E TBs as input. During year two we will customize the software to adjust for AMSR's slightly different frequencies. (Funded by NASA)

## State of the Cryosphere Web Site

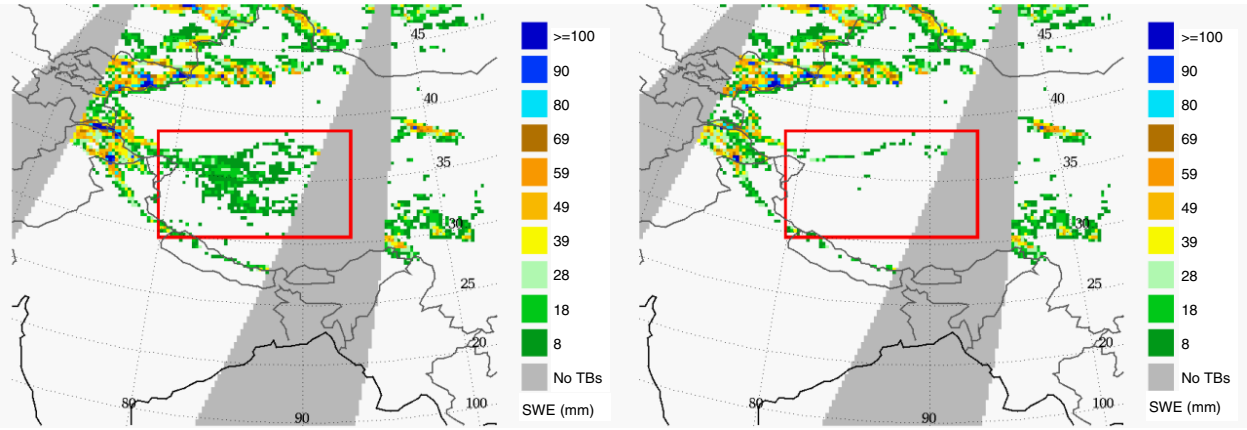
Armstrong leads the development and maintenance of this NSIDC Web product. This Web site, http://www.nsidc.org/sotc/, is directed towards a broad audience of scientific and general users, and provides a current and succinct overview of how various components of the cryosphere respond to climate change. The site focuses on seasonal snow cover, sea ice, mountain glaciers, ice sheets, ice shelves, permafrost, and sea level, and their response to global warming. During 2004 we updated the sea ice, snow cover, mountain glacier and sea level time series and reviewed, edited, and updated the entire site. In addition, the home page was totally redesigned. This work was directed by Michon Scott. In recent years *Science* magazine has published two reviews supporting and encouraging the use of this Web site. (Funded by NSIDC NASA DAAC)

## Snow Cover Validation Case Study: Tibet Plateau:

Previous studies have shown that the Tibetan Plateau is one the areas of largest disagreement between optical and microwave satellite snow products. At this point it is not entirely clear which remote sensing data set is correct, due to the fact that only a very limited amount of surface station data have been available to support objective validation. For the purposes of this study we have treated the optical (MODIS) data as "truth," or at

least closer to "truth" than results coming from our current microwave algorithm which appears to overestimate snow cover. We are aware that the optical sensors may in fact undermeasure the snow cover over the Plateau due to uncertainties resulting from cloud cover. Therefore, we are currently acquiring new surface snow observations over this region through a collaborative study with the Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI) in Lanzhou, China. In addition, we are receiving feedback on our prototype daily SSM/I Tibetan Plateau snow maps from CAREERI and the Remote Sensing Center of the Tibetan Meteorological Bureau in Lhasa, Tibet.

The apparent overestimation of snow cover by the passive microwave data may be partially explained by the effect on the microwave algorithms of an enhanced spectral gradient resulting from decreased atmospheric absorption in this region of extremely high elevation. Most current microwave snow algorithms are based on the assumption that the atmosphere is essentially transparent at frequencies around 18 and 36 GHz. However, recent work by Wang and Manning (2003) demonstrates that the atmosphere should be considered when validating microwave satellite retrieval algorithms based on surface and low-elevation aircraft measurements. In the case of the Tibet Plateau, the reduced atmosphere between the orbiting sensor and the ground surface at the mean elevation of 4,000 meters would significantly affect the spectral gradient at 18 and 36 GHz. We have applied the corrected temperature gradient, provided by our colleague Dr. James Wang, to pixels on the Plateau resulting in a microwave-retrieved snow extent that agrees more closely with that of the optical sensor. (Funded by NASA)



Result of atmospheric correction, 29 November 2003. SWE over Tibet derived from uncorrected AMSR-E (left) and corrected AMSR-E (right).

# Andy Barrett

## CIRES/NOAA Western Water Assessment: Use of Climate Data in a Water Resources Assessment Tool

The Western Water Assessment (WWA) is part of the NOAA Regional Integrated Scientific Assessment (RISA) program. The project described here is one component of the WWA. It addresses how climate data can be used in models to assess the impact of climate variability on water resources. A fundamental problem in assessing of the affects of climate variability on water resources and water supply systems is obtaining long-term records of natural river flows. Flow records in many basins are too short to examine long-term variability. Often, river flows are affected by abstractions or are controlled by reservoir storage and releases. Some basins may be ungauged. Precipitation runoff models driven by historical climate records can be used to simulate natural river flow. However, these models cannot be calibrated for ungauged basins. Furthermore, impact assessments should include some measure of uncertainty.

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, and by Hydrosphere Consulting in Boulder, Colorado, to assess the impact of historical climate variability on the current water resources allocation system in the South Platte River Basin. Monthly river flows are the primary input to SPRAT. A monthly water balance model was developed to generate an ensemble of homogeneous, serially continuous natural river flows for

the period 1870 to 2002 for 25 basins in the Upper Colorado and South Platte River Basins. Historical time-series of gridded precipitation and temperature from the University of Oregon PRISM database are used as inputs to the water balance model. To solve the ungauged basin problem, multiple regional parameter sets were developed by conditioning the water balance model for basins with long-term river flow records using a Monte-Carlo procedure to sample the parameter space. This approach generated nearly 400 possible parameter sets for the water balance model, reflecting the uncertainty of river flows as a result of model parameterization. These 400 parameter sets were then used to generate ensembles of river flow for the SPRAT basins. In a gauged basin, the range and temporal variability of time-series of river flows simulated by models using regional parameter sets were comparable to flows simulated by models that used parameter sets conditioned using observed flows for that basin. This modeling approach provides one method for generating river flows for ungauged basins using historical climate data and also provides a method for detecting future climate scenarios. (Funded by NOAA)

# Roger Barry

Barry spent April through June 2004 on sabbatical leave at the Laboratoire de Glaciologie et Geophysique de l'Environnment (LGGE) of the Centre National de la Recherche Scientifique (CNRS) in Grenoble, France. He studied the interactions of glaciers and climate and global glacier recession. A paper on this work, "The status of research on glaciers and global glacier recession: a review," has been accepted by *Progress in Physical Geography* and is scheduled for publication in early 2006. He also prepared material for his presentation "Perspectives on a century of climate science" at the August 2004 symposium held in his honor, "A Chronicle of Distinction: From the Arctic to the Andes." The symposium at the University of Colorado recognized his appointment as a Distinguished Professor in March 2004.

Roger Barry and Mark Serreze, completed a new textbook, *The Arctic Climate System,* to be published by Cambridge University Press in 2005. Roger also co-authored six research papers on cryospheric topics.

Roger was PI on an NSF Post-Doctoral Fellowship grant supporting Dr. Svetlana Tchoudinova and he sponsored Dr. Igor Zotikov as a visiting Fulbright Fellow (see "NSIDC Visitors" section).

# Florence Fetterer

## Observations for SEARCH: Data Integration for Arctic Reanalysis and Change Detection

"Unaami," the changes in the Arctic that are the subject of the Study of Environmental Arctic Change (SEARCH) program, became apparent to researchers in the context of long-term and pan-Arctic observations. The first phase of our work assessed what data are relevant to SEARCH reanalysis and change detection activities, and, where possible, facilitated access to the data. Our major accomplishments were to research sources and characteristics of precipitation datasets, culminating in the publication of two new precipitation data sets. These are particularly important for the Arctic reanalysis.

Beginning in 2004, the NOAA at NASA team developed the *Cryospheric Climate Indicators* Web site (http://nsidc.org/noaa/search/indicators/). These are a suite of data records presented in a way to highlight temporal and spatial changes by showing time series, trends, anomalies, and basic statistics, along with interpretative text that can be understood by the general public. In 2004 the soil temperature indicator was developed with time series and temperature profiles from locations in Alaska and Russia. We began testing an algorithm that determines yearly melt onset day (north of tree line) from passive microwave. MODIS and AVHRR Pathfinder data sets were acquired and testing began on a Normalized Difference Vegetation Index (NDVI), or "greenness," indicator site. The Sea Ice Index, upon which the Indicator concept is modeled, was extended by 10 years,

resulting in trends with greater significance. Progress was presented in a poster presentation at the American Meteorological Society's 8th Conference on Polar Meteorology and Oceanography in January 2005. The SEARCH team consists of Florence Fetterer (lead), Ken Knowles (sea ice index), Mark Parsons (soil temperature), Bruce Raup (melt onset and precipitation) and Matt Savoie (NDVI and melt onset).

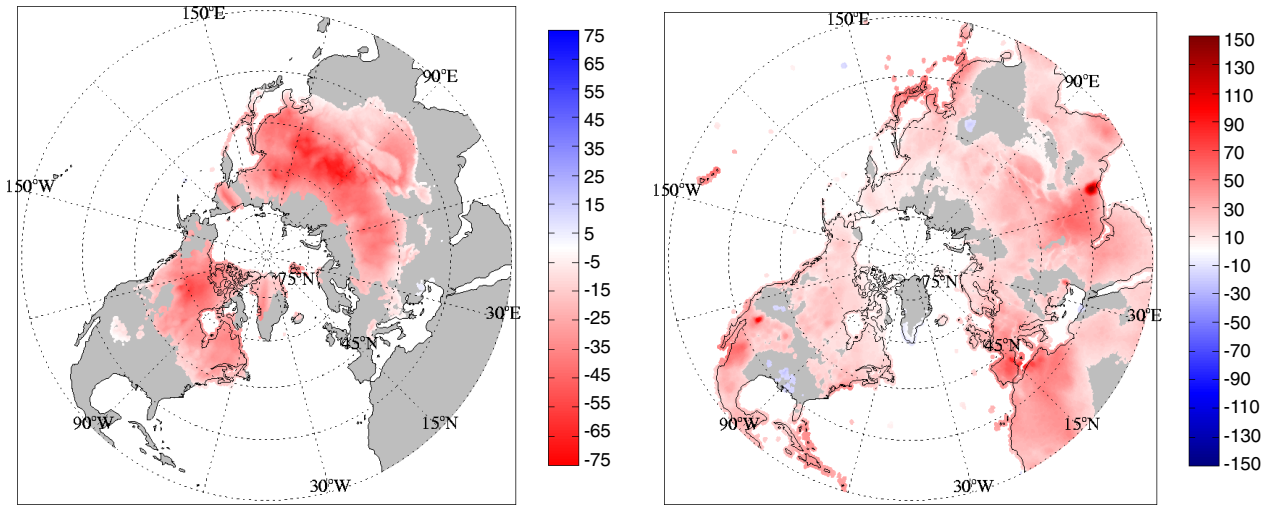
# Oliver Frauenfeld

## Changes in Freeze-Thaw Cycle and Permafrost Dynamics, and their Hydrological Implications over the Russian Arctic

Only sparse historical measurements of freeze-thaw status, such as seasonal freeze and thaw depths, are available for permafrost and seasonally frozen ground regions. However, soil temperatures can be used to derive these variables. Soil temperature variations in high latitude regions provide important indications of short and long-term climate variability. Continued data rescue resulted in the addition of 47 new stations with soil temperature records through 1990, as well as updates through 2000 for 63 of the stations in the existing database. Active layer and seasonal freeze depths are derived from mean monthly soil temperature data for 1930 to 1990 for 242 stations of these locations throughout Russia.

A comprehensive evaluation of interdecadal trends in these new data indicates that, in permafrost regions, active layer depths have been steadily increasing, with even greater changes observed in the seasonally frozen ground areas. Changes in active layer thickness are most strongly related to snow depth, while freeze depth is influenced most strongly by measures of air temperature. In general, 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, especially in the high latitude continental regions, both permafrost and seasonally frozen ground regions are being greatly impacted.

An additional focus of this research project has been the creation of high-resolution gridded (25 kilometer NSIDC EASE-Grid) freezing and thawing indices for the Northern Hemisphere. The freezing (thawing) index is the cumulative number of degree-days below (above) 0°C. These variables are useful in the prediction and mapping of frozen ground distribution, and active layer and freeze depth estimation. Trends indicate significant changes in high-latitude areas. Tingjun Zhang is the PI and Roger Barry is a Co-Investigator. (Funded by NSF)

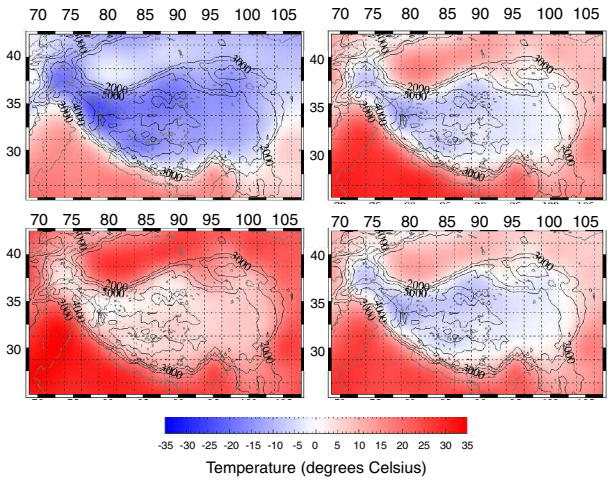



Statistically significant 1901 to 2001 trends (degree Celsius days per decade) in freezing (left) and thawing (right) index for the Northern Hemisphere north of 15 degrees north.

## Land-Surface Processes on the Tibetan Plateau

The Tibetan Plateau, approximately the size of Texas, is the highest (averaging >4000 meters above sea level) and largest plateau on Earth. Surrounded by Earth's highest mountains, it represents some of the most complex terrain of the globe. During summer, the plateau represents an anomalous mid-tropospheric heat source. It therefore plays a key role in the generation of the Asian monsoon which drives the climate of the Asian continent, thereby impacting more than half of the world's population. Consequently, the Tibetan Plateau exerts a strong influence on global climate and may be a harbinger of climate change: high altitude areas have reportedly warmed more, and perhaps sooner than other similar-latitude regions. The plateau in particular is argued to have warmed significantly in recent decades, which has been attributed to increases in greenhouse gas concentrations.

However, an equally important anthropogenic component to climate change may be land cover and land use changes. These local-regional surface effects related to agriculture and urbanization potentially outweigh greenhouse gas forcing. In fact, we have demonstrated that plateau-averaged station records, biased toward low-lying populated regions, show a warming trend of 0.16 degrees Celsius per decade over the last 50 plus years. However, information from a largely independent data source free of surface contamination indicates no trend. We therefore hypothesize that land use and land cover changes, not greenhouse gas loading, could largely account for the reported warming on the Tibetan Plateau. Land cover changes have been widespread in this part of the world, and we are currently evaluating our hypothesis. (Funded by NSF, the Institute of Plateau Meteorology at Chengdu, China Meteorological Administration, and NOAA)




Temperature climatology based on ERA-40 2-meter temperatures for the Tibetan Plateau: (top left) winter, (top right) spring, (bottom left) summer, and (bottom right) autumn.

## Northern Hemisphere Atmospheric Circulation Variability and the Pacific Ocean

A new, distinctly interdecadal signal in the climate of the Pacific Ocean has been uncovered by examining the coupled behavior of sea-surface temperature (SST) variability and the atmospheric circulation of the Northern Hemisphere. This interdecadal signal exhibits a highly statistically significant component of interdecadal variability, yet contains virtually none of the interannual (El Niño scale) variability common to other Pacific climate patterns. The interdecadal Pacific signal (IPS) therefore represents the only empirically derived, distinctly interdecadal signal of Pacific Ocean SST variability, which likely also characterizes the true interdecadal behavior of the Pacific Ocean-atmosphere system. After removal of the IPS, the residual variability of the Pacific's leading SST pattern is highly correlated with El Niño anomalies. This indicates that by simply including an atmospheric component, the Northern Hemisphere circumpolar vortex, we have decomposed the leading mode of Pacific SST variability into its interdecadal and interannual patterns. While the IPS is unrelated to interannual El Niño variability, it still seems closely linked to the tropical Pacific. Isolation of this interdecadal signal in the Pacific Ocean–atmosphere system has potentially important and widespread implications to climate forecasting and climate impact assessment because prior abrupt changes in Pacific SSTs have been related to anomalies in a variety of physical and biotic parameters throughout the Northern Hemisphere, and because of the persistence of these changes over several decades. (Funded by various sources)

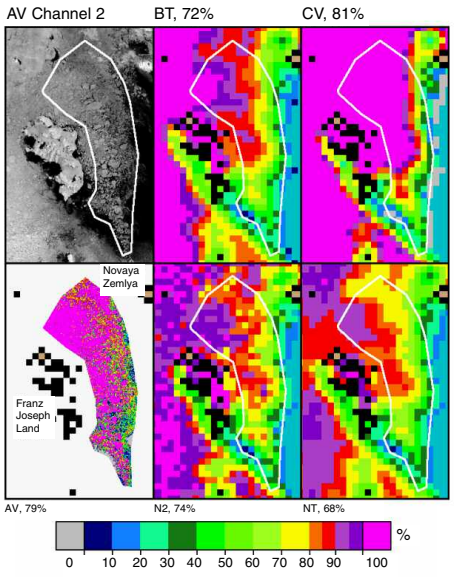
# Jim Maslanik

Areas of research during the past two years included investigating 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, investigations of changes in ice age and other ice characteristics using Lagrangian drift-track analyses, and participation in evaluation of NPOESS Preparatory Project cryospheric products as a member of the NASA NPOESS Preperatory Project (NPP) Science Team. 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) ongoing assessment of shoreline change and effects of severe storms on Alaskan North Slope communities, and (e) development of a laser profiling system for use on UAVs. (Funded by NASA and NSF)

# Walt Meier

## Evaluation of SSM/I Sea Ice Concentration Fields Using AVHRR Imagery

Four SSM/I ice concentration algorithms are evaluated in the eastern Arctic peripheral seas during summer and winter through comparisons with AVHRR visible and infrared imagery (Meier, 2005). 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 choice of algorithm. (Funded by U.S. Naval Meteorological and Oceanographic Command and NASA through the University Corporation for Atmospheric Research (UCAR) Visiting Scientist Program)




Sea ice concentration comparison for different passive microwave algorithms. Clockwise from upper left: (1) AVHRR Channel 2 reflectance, (2) Bootstrap (BT) concentration, (3) Cal/Val (CV) concentration, (4) NASA Team (NT) concentration, (5) NASA Team 2 (N2) concentration, (6) concentration derived from AVHRR Channel 2 imagery.

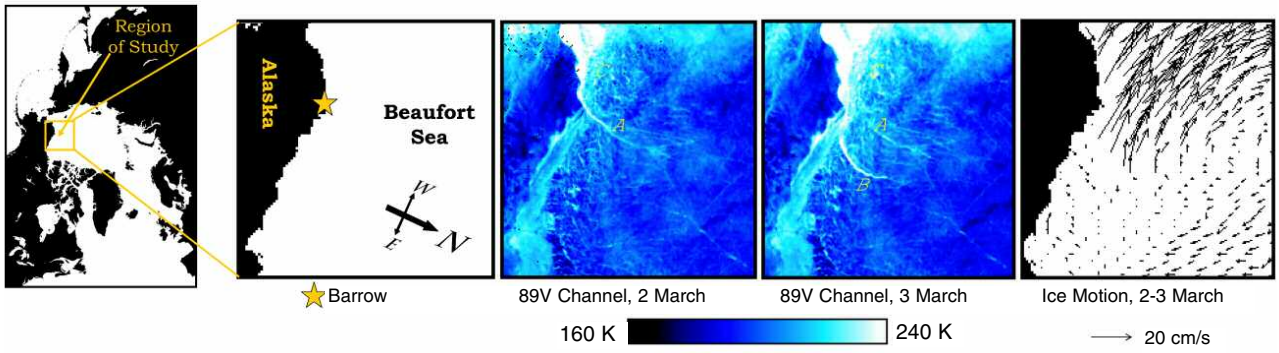
## Kalman Filter Techniques for the Assimilation of Ice Concentration Data into an Ice Prediction Model

A Kalman filter method has been developed to assimilate observed sea ice concentrations from passive microwave imagery into a simple sea ice model. The model physics include free drift dynamics and a simple heat transfer model. Even with a simple model, the Kalman filter produces improved skill scores of ice forecasts over a 30-day period. The model development is ongoing and improved thermodynamics as well as a more sophisticated dynamics treatment is planned. This project is a collaboration with UCAR Visiting Scientist Mingrui Dai and M. Van Woert of NSF. (Funded by NASA through the UCAR Visiting Scientist Program)

## Improved Sea Ice Analyses and Forecasts via Assimilation of Sea Ice Motions 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 motions substantially reduces motion root mean square (RMS) errors and improves correlation with buoys. The research to date shows that ice motions derived from the AMSR-E datasets have much lower errors than the SSM/I products and still provide daily coverage of the entire Arctic and Antarctic. The high

resolution 6.25 kilometer AMSR-E products can track the openings of relatively large leads. The lower resolution AMSR-E channels (36.5 GHz, 12.5 kilometer) have much lower errors than the SSM/I channels with a comparable spatial resolution (85.5 GHz, 12.5 kilometer). Walt Meier is the PI. (Funded by the Naval Research Laboratory grant N00173-04-P-6210)




AMSR-E tracking of a large lead. Images from left to right: (1) map of Arctic region, (2) zoomed area of imagery in the Beaufort Sea, (3) AMSR-E 89V Tb for 2 March 2004, (4) AMSR-E 89V Tb for 3 March 2004, (5) sea ice motion derived from 2 to 3 March AMSR-E imagery. The image from 2 March shows a lead (A) off the coast near Barrow. A larger lead (B) opens up between 2 to 3 March, which is indicated by the divergence seen in the ice motion field.

# Tom Painter

## Multi-resolution Snow Products for the Hydrologic Sciences

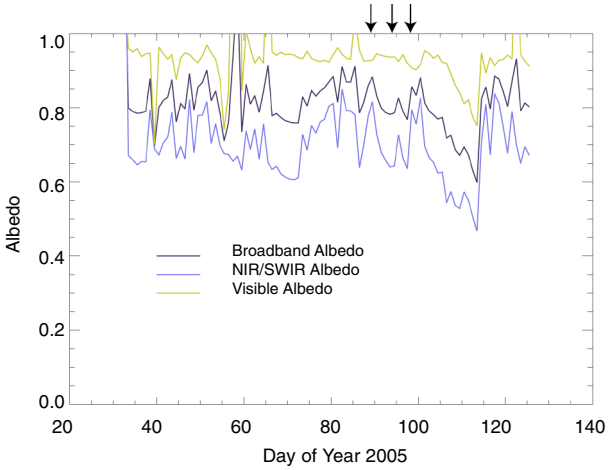
This NASA Research, Education and Applications Solution Network (REASoN) Cooperative Agreement Notice (CAN) project combines high resolution, state of the art snow cover and snow water equivalence (SWE) mapping with metadata and lineage tracking for the advancement of hydrologic sciences. Spatial snow hydrologic modeling requires inputs of distributed snow cover, snow albedo, and SWE. We deliver daily fractional snow cover and snow albedo to hydrologic clients for their respective study basins. We compute fractional snow cover and the albedo of the fractional snow cover from MODIS surface reflectance data (MOD09, MYD09) using the spectral mixture model MODIS Snow Covered Area and Grain size (MODSCAG). The model is inherently parallelizable computationally and is implemented on a 30-node Linux cluster at the University of California, Santa Barbara. We presently process MODIS data for two grids in the western United States; the Sierra Nevada of California and the Upper Rio Grande of Colorado and New Mexico. We also have delivered on-request products to researchers studying Tibet and others studying the Nepal Himalaya.

Collaboration has begun between Co-Investigator Painter and NSIDC's Richard Armstrong and Mary Jo Brodzik to improve estimates of snow water equivalence. Thomas H. Painter is a Co-Investigator. (Funded UCSB Sub-Contract KK4133)

## Radiative Effects of Desert Dust Deposits in Alpine Snow

In this work, we investigate the radiative effects of absorbing dust deposits to alpine snow surfaces in the San Juan Mountains of Colorado. Until this work, these effects remain unstudied despite frequent and extensive red dust deposition in the snowfields of the mountains of Colorado. We hypothesize that dust entrained from the Colorado Plateau is frequently deposited in snow fields of the San Juan Mountains of Colorado given the deep red coloring of the dust (likely rich in hematite), the known frequency of dust emission events from the Colorado Plateau, and the proximity of the dust source. Dust layers decrease the snow albedo and, our observations indicate, dramatically accelerate regional melt when the overlying snow layers melt to expose the dirty layers.

This project was funded in September 2004 in collaboration with the Center for Snow and Avalanche Studies (CSAS) in Silverton, CO. Our initial efforts were directed at purchase and deployment of the instrumentation for complete energy balance and more detailed radiation measurements. We purchased a CIMEL sunphotometer to measure aerosol optical properties during dust deposition events and non-deposition periods. The study is being car-



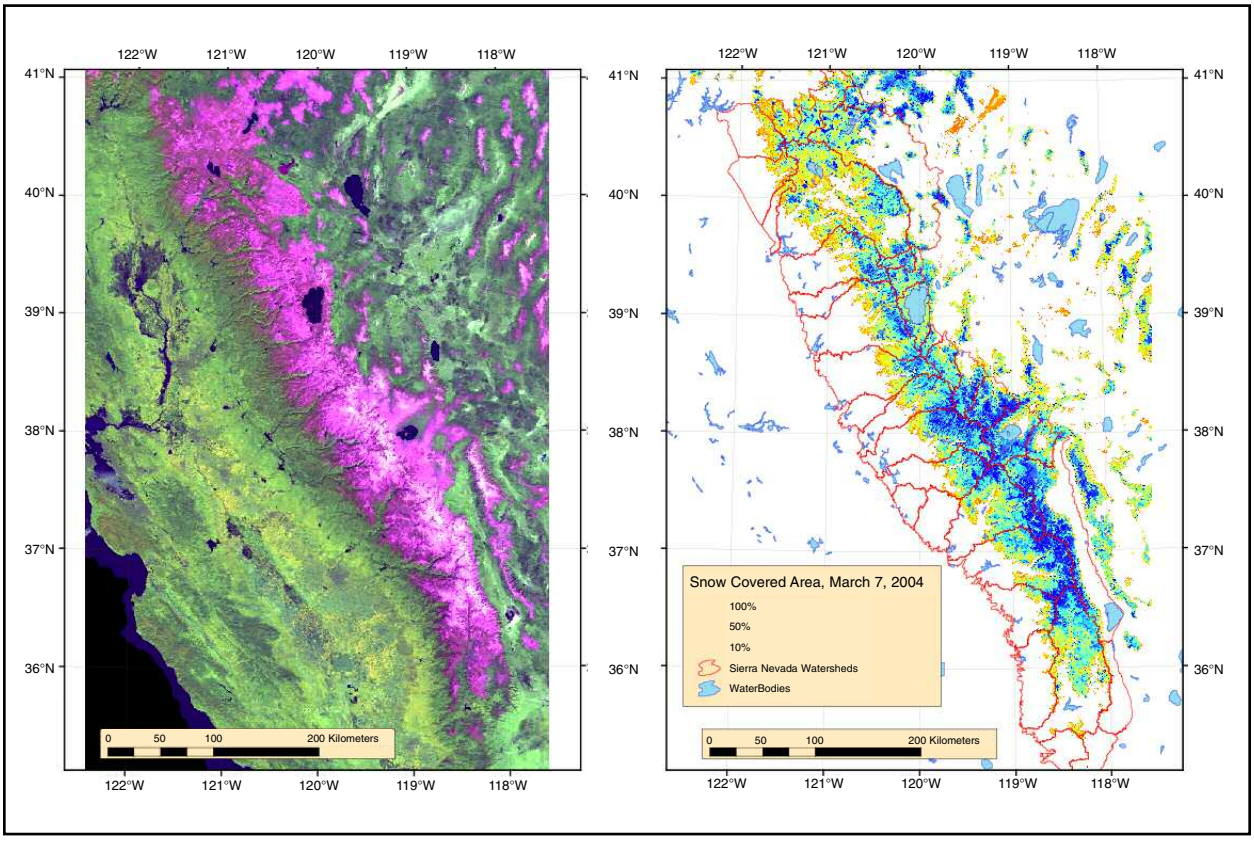

Broadband, visible, and NIR snow albedo at the alpine study energy balance site in Senator Beck basin, Colorado, winter/spring 2005. Arrows indicate dates of significant dust deposition from dust plumes entrained from exposed soils on the Colorado Plateau of Utah, Colorado, and Arizona. Immediately after these deposition events, snow albedo in the three wavelength ranges dropped dramatically with the visible albedo responsive to dust concentration, the NIR snow albedo responsive to snow grain size increases, and broadband snow albedo the composite of the visible and NIR snow albedos.

ried out in the Senator Beck Basin which spans subalpine to alpine in elevations from 3341 to 4118 meters above sea level. By early January, 2005, the alpine and subalpine energy balance towers were fully implemented and operational by the CSAS.

Painter took delivery of the CIMEL sunphotometer in February, 2005, and forwarded the instrument to NASA Goddard for retrofitting that allows incorporation of the unit into the NASA AErosol RObotic NETwork (AERONET). The placement of this sunphotometer in the Senator Beck Basin is the highest in the global AERONET. In April, 2005, Painter presented preliminary results at the Annual Meeting of the Association of American Geographers in Denver, CO. Thomas H. Painter is the PI and Chris Landry is Co-Investigator. (Funded by NSF grant ATM0432327)

## Radiative Effects of Desert Dust Deposits in Alpine Snow: Hydrologic Aspects

In November 2004, the NSF Hydrological Sciences Program funded our supplemental request associated with the radiation project ATM 0432327 for one year. This project is a collaboration between NSIDC and the Center for Snow and Avalanche Studies under Chris Landry.




MODIS fractional snow cover mapping with the MODIS Snow Covered Area and Grain size (MODSCAG) spectral mixture model for data collected 7 March 2004 over the Sierra Nevada. Color composite (left) of MODIS Surface Reflectance data (MOD09) for the Snow REASoN Sierra grid RED (0.555 μ), GREEN (1.64 μ), BLUE (0.469 μ). Fractional snow covered area (right) from MODSCAG retrieval.

The reduced snow albedo associated with dust deposition will increase snowmelt rates at the snow surface. We hypothesize that increased surface snowmelt modifies the runoff hydrograph of the Senator Beck Basin to an earlier rising limb and a greater peak discharge. The initial work on this project involved purchase and deployment of snow temperature detectors, soil moisture meters, and soil heat flux instrumentation. Because funding came after snowfall commenced, not all of the instrumentation was deployed. Remaining instrumentation will be deployed as soon as snow cover completely melts.

We also began developing snow albedo modules for a basin scale hydrologic model based on the Precipitation-Runoff Modeling System (PRMS). These modules are being trained on data from the Tokopah basin in Sequoia National Park in California, and then data from the Senator Beck Basin. During April through June 2005, we conducted field campaigns in the Senator Beck Basin to measure the spatial distribution of snow water equivalence (SWE) at 100 meter resolution. A summary survey will be performed in July 2005.

We have deployed pressure transducers to sample stream stage at the sub-basins to determine the spatial distribution of runoff and its timing. Andrew P. Barrett will present preliminary results at the 2005 AGU Fall Meeting. We have also been collaborating with Jeffrey Deems, a NASA graduate fellow. Thomas H. Painter is the PI and Andrew P. Barrett is Co-Investigator. (Funded by NSF grant ATM0432327)

# Ted Scambos

## Glacier Acceleration after Ice Shelf Collapse in the Antarctic Peninsula

A series of glaciers flowing into the Larsen B ice shelf embayment were mapped for velocity and thickness changes using Landsat 7 and Ice, Cloud,and land Elevation Satellite (ICESat) data in the period before, during, and after the Larsen B ice shelf collapse. The maps revealed that glacier changes (acceleration and thinning) followed the shelf collapse. Flow increased by up to a factor of six, and thickness changes of tens of meters were observed within one year of the collapse. Adjacent glaciers flowing into remaining parts of the ice shelf showed no significant change over the period. The work is a major contribution to climate change research: since ice shelves are known to respond rapidly to air and ocean temperature changes, the confirmation that their removal leads to large changes in mass flux of grounded ice means that a real threat of rising sea level exists from other, larger, shelf-glacier systems. Jennifer Bohlander assisted in this effort. (Funded by NASA grant NAG5-11308 and NSF grants OPP-9814550 and OPP-0338134)

## Snow Megadunes in the East Antarctic Plateau.

Broad, stripe-like accumulation features, termed 'megadunes' by early Landsat researchers, were mapped over large regions of the Antarctic using new radar and MODIS images; the new maps revealed the full extent and potential importance of the dunes. Two field seasons of in situ geophysical measurements were undertaken in November through December of 2002 and in January 2004. Results confirm many of the observations made by remote sensing: megadunes occur in regions of near-constant windflow, where accumulation and mean temperature are very low. Radar profiling shows a windward-advancing structure, with broad areas of near-zero accumulation between dune crests. The interdune areas are exposed for up to two centuries without burial. This results in extreme firn metamorphism due to repeated annual thermal cycling. 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 Plateau) it is likely that some ice recovered in deep ice cores was previously firn in a megadune field. Rob Bauer and Terry Haran assisted in this project. Ted Scambos is the PI. (Funded by NSF grant OPP-0122570)

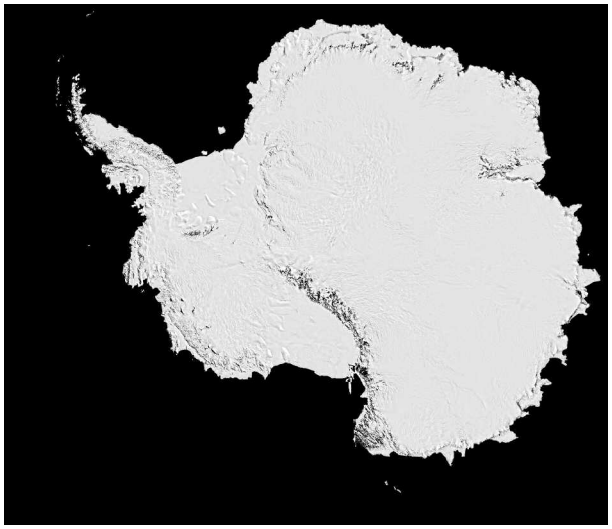
## A New MODIS Mosaic of Antarctica (MOA)

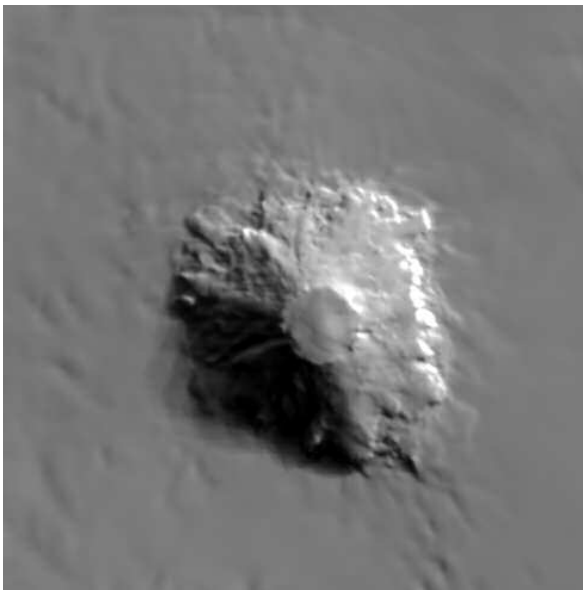
A new image map at 125 meter resolution, covering the entire continent and surrounding islands, was compiled by assembling 256 MODIS band 1 (red) and band 2 (near-infrared) images. The image provides an unprecedented, seamless, and detailed view of the ice sheet surface, and contains excellent detail of subtle ice structures indicative of bedrock structure or glacial flow. The mosaic will be provided as a new product from NSIDC in 2005. A glaciological analysis of the surface structures combining the MOA mosaic, radar images, and elevation data is planned for later in 2005. Terry Haran

and Jennifer Bohlander assisted with this effort. (Funded by NASA grant NNG04GM10G)

## 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. Rob Bauer, Jennifer Bohlander, Amy Casey, and Betsy Sheffield assisted with this project. Ted Scambos is the PI, and Roger Barry, Greg Scharfen, and Robert Bauer are Co-PIs. (Funded by NSF grant OPP-0338134)





The upper left image shows the MODIS mosaic of Antarctica, composed of 256 images that provide a seamless view of the ice sheet surface. Detailed images on the right include Mount Takahe in West Antarctica (upper right), and Steers Head on the Ross Ice Shelf (lower right).

# Mark Serreze

## Synthesis of the Arctic System

Despite the wealth of research in arctic climate science, we still have an incomplete view of how the Arctic functions as an integrated system. In recognition, the year 2004 saw the Arctic System Science (ARCSS) program of the National Science Foundation (NSF) in the midst of a major restructuring centered around the goal of synthesis. As a member of the ARCSS Science Steering Committee, I was heavily involved with trying to answer a central question: How can we break the barriers imposed by discipline-oriented research to achieve the synthesis framework needed to better understand the Arctic as an integrated system? While a full answer is not yet at hand, it is clear that part of the process involves stepping back and placing the vast amount of arctic data already collected into a more holistic framework. Scientists must increasingly reach out beyond their own disciplines and digest information from the wider research community. While no single research project, or even groups of projects, can attain a full synthesis, all efforts must contribute to painting the larger canvas of arctic system science. My own research over the past year, funded by NSF, NASA and NOAA, was guided by synthesis and integration, with the hope that the whole of the research will be greater than the sum of its parts.

The arctic freshwater cycle continued to be a dominant theme in my research. The hydrologic cycle is a wonderful integrator. Understanding the hydrologic cycle requires that we understand the intimate connections between the Arctic's atmosphere, land, and ocean as part of the global system. Assessments of the contemporary hydrologic cycle (based on observations and land surface models) were complemented by studies of its potential future states in a greenhouse-warmed world, which drew on results from coupled global climate models. Progress was made in understanding the complex synoptic-scale processes in the northern North Atlantic, in particular, the effects of the Greenland Ice Sheet and surrounding region on cyclone activity.

How do these studies fit into the synthesis framework? As a result of the strong cyclone activity in this area, the northern North Atlantic is the primary gateway for the transport of heat and moisture into the Arctic. The Arctic as we see it today is strongly determined by the nature of these transports. One of our most important tools for synthesis, especially for linking variability in the atmospheric circulation and the hydrologic cycle is output from atmospheric reanalyses, provided by the European Center for Medium Range Forecasts.

Arctic change also continued as a dominant theme. The key question is: Based on synthesis of observational records, paleoclimate information, model results and theory, to what extent are observed changes in the Arctic system, such as rising air temperatures, the shrinking sea ice cover, increasing river discharge and permafrost warming due to natural variability versus the impacts of greenhouse gas loading of the atmosphere? The answer seems to be that while natural variability has and will always be large in the Arctic, greenhouse gas loading is now becoming an important player.

Understanding the hydrologic cycle requires that we understand the intimate connections between the Arctic's atmosphere, land, and ocean as part of the global system.

Grants supporting this research include

- Collaborative Research: A Hydrological Observing System for the Pan-Arctic Landmass (funded by NSF OPP-9910315).
- A Regional, Integrated Monitoring System for the Hydrology of the Pan-Arctic Landmass (funded by NASA NAG5-9568).
- Assessment of Recent Hydrologic Change over the Arctic Terrestrial Drainage (funded by NASA NNG04GJ39G).
- Collaborative Research: A Land Surface Model Hind-Cast for the Terrestrial Arctic Drainage System (funded by NSF OPP-0229769).
- An Integrated Assessment of the Arctic Freshwater System: Analysis of Retrospective and Contemporary Conditions (funded by NSF OPP-0229651).
- Characterization of Atmospheric Moisture Transport and the Freshwater Budget of the Arctic with an Improved Regional Model (funded by NSF OPP-0138018).
- Characteristics of Cyclone Development and Decay in the Arctic (funded by NSF OPP-0240948).

In 2004 I also completed the draft of a textbook, co-authored with R.G. Barry, entitled *The Arctic Climate System*. This book is slated for publication by Cambridge University press in September 2005. The core feature of this book is synthesis – drawing together the vast amount of information we already have about the Arctic into a coherent picture. The book would never have been completed without the assistance of many individuals at NSIDC.

# Andrew Slater

## Improving Operational Streamflow Forecasts in the Colorado River Basin

The aims of the study are to improve both the accuracy and probabilistic information content of streamflow forecasts in the Colorado River basin. Objectives of the project are to develop and evaluate methods to assimilate measurements of snow water equivalent into the National Weather Service River Forecast System as well as to develop and evaluate methods to produce forecast inputs on time scales of days through to seasons.

Progress thus far includes the creation of a system for stochastic generation of model forcing data over a wide domain in complex terrain. This synthesized data maintains both temporal and spatial correlation amongst the variables and has been fully verified for its probabilistic skill. With our ability to generate ensembles of model forcing and produce cross-validated error estimates of other quantities, such as snow water equivalent, we have applied an ensemble Kalman filter assimilation scheme to optimally combine the information of our models and observations, resulting in a prediction that is superior to either of the individual components.

Current direction of the work is to apply the probabilistic framework to satellite derived snow quantities and assimilate them into hydrologic and land surface models. Satellites provide the most expansive view of snow cover, but can often prove to be unreliable in both extent and quantity of snow; hence the research challenge. Martyn P. Clark is the PI and Andrew G. Slater is Co-PI. (Funded by NOAA)

# Julienne Stroeve

## Satellite Studies of Arctic Climate Connections between Sea Ice, the Greenland Ice Sheet, the Adjacent Land and Atmospheric Cloud Properties

Specific objectives of the project are to

- Document the seasonal and inter-annual variations in snow, ice sheet and sea ice conditions over a 27-year time period (1978-2005) and compare respective variabilities
- Determine the degree to which these variations correlate (including lagged correlations) with observed trends in air temperature, winds, cloud properties, atmospheric indices such as the AO and NAO, and the surface energy budget
- Test the utility of multivariate analysis of cryos--pheric variables as a more effective means of detecting climatic change in regions where field observations are scarce
- Quantify relationships between snow and ice melt and thermodynamic variables.

In the process of meeting these objectives, we will produce spatial statistics and estimates summarizing dates of melt onset, dates of freeze-up, melt duration, dates of first snow cover and snow-free conditions, and duration of continuous snow cover.

We will also assess significance of multivariate trends in terms of large-scale climatic forcings versus localized, weakly correlated weather conditions. In addition, we will intercalibrate between the various passive microwave (SMMR, SSM/I and AMSR-E) and the optical and thermal sensors (AVHRR and MODIS) using the EOS era sensors as the baseline. These objectives will also help us summarize statistics and trends for a suite of cryospheric variables and related atmospheric conditions.

**1) Role of Melt in the Recent Arctic Summer Minima**

During 2004, Stroeve submitted a paper to *Climate Dynamics* summarizing the role of melt in the recent ice losses by investigating the links between the timing of snow melt onset over sea ice in the Arctic and the following September ice extent. Approximately 66 percent of the sea ice extent variability is explained by the timing of the melt onset, with earlier melt onset resulting in less ice at the end of summer and vice versa. It is interesting to note that the correlation between melt onset and the following September ice extent is generally slightly lower during years with low September ice cover than during years with anomalously high September ice cover, suggesting that ice dynamics also plays an important role in the loss of ice during extreme minima ice years. A marked difference exists in the regional distribution of the timing of melt onset during the last three years, compared with other previous low ice years, showing wide-

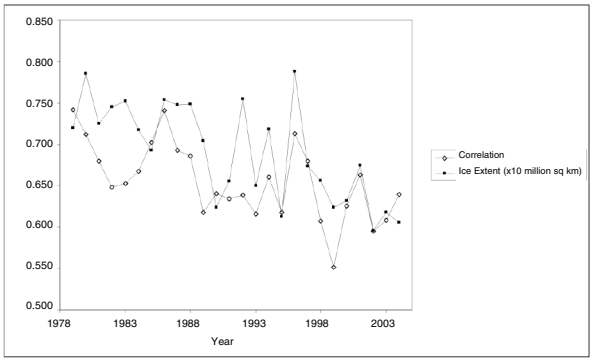
spread earlier melt in the western Arctic, particularly during the record low ice year of 2002.

**2) Intercomparison between MODIS and AVHRR Polar Pathfinder albedo over Greenland**

In order to extend our time series from AVHRR into the MODIS era, it is necessary to perform intercomparisons between the albedo derived from the AVHRR Polar Pathfinder (APP) data set and that from the MODIS instrument. Unfortunately, due to the lack of funds for validation and calibration of the MODIS daily snow albedo algorithm, this algorithm has been discontinued. Therefore, this part of our project has focused on comparing the APP albedo with a MODIS albedo derived using the direct-estimation algorithm, as well as obtaining the operational daily MODIS snow albedo algorithm so that we can look at albedo over Greenland and compare it with in situ observations and access the accuracy of the algorithm.

Specific progress:

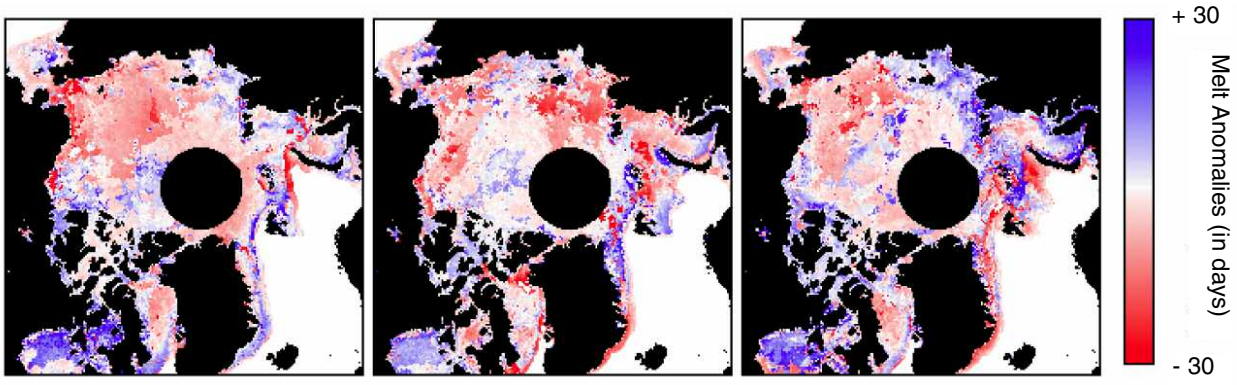
- We extracted Greenland subsets of 5 kilometer APP data corresponding to a set of MODIS albedo images.
- We subsetted 600-by-600 five-kilometer APP data to a 465-by-435 five-kilometer EASE-Grid region corresponding to the 1860-by-1740 1.25 kilometer EASE-Grid region that the MODIS data are in.
- We resampled the 1.25 kilometer MODIS data to the 465-by-435 five-kilometer EASE-Grid region. Flickering between corresponding pairs of images indicates that there are geolocation problems with the five kilometer APP data that need to be investigated further. We applied a single set of x and y shifts to each APP image, and then the images were reshifted as necessary (only one image needed reshifting).
- We created 22 scatter plots of MODIS versus AVHRR albedo, which indicate that the APP albedo is biased high compared with the albedo derived from MODIS using the direct estimation algorithm.




September ice extent and the correlation between melt onset and September ice extent. The extent has been scaled by 107 to plot both parameters on the same scale.

- We reordered and regridded all 22 MODIS 2000 test images over Greenland, including several scenes that were missing from the original images, and produced time-series and scatter plots
- We ordered, downloaded, and stitched together four MOD10A1, MYD10A1, MCD43B3, and MOD43B3 tiles containing 2004 albedo information over Greenland. The albedo was extracted from these images corresponding to a set of 20 Automated Weather Service (AWS) locations. We also generated time series and scatterplots correlating the MODIS data with a set of AWS albedo observations at three AWS sites that we have data for in 2004. Unfortunately, the quality of the in situ data during 2004 is suspect. Therefore, the code to generate the MODIS daily snow albedo product was obtained so that years prior to 2004 can be processed and compared with the in situ data.

(Funded by NASA grant NNG04G051G)




Melt onset anomalies (in days) during 2002, 2003, and 2004. Red (negative) values indicate earlier melt than normal; blue (positive) values indicate later than normal melt onset.

# Tingjun Zhang

## Freezing-Thawing Cycle of Soils at Local, Regional, and Global Scales

Understanding cold season atmosphere-hydrosphere interactions and their feedbacks in Earth's weather and climate system is essential for assessing variations in the regional and global energy and water cycles. This is a critical and integral component of the Global Energy and Water Cycle Experiment (GEWEX) program. Important components of the terrestrial hydrology are soil water freezing and thawing processes. The long-term average maximum area extent of the seasonally frozen ground, including the active layer over permafrost, is approximately 48.12 by 106 square kilometers or 50.5 percent of the land mass in the Northern Hemisphere. Seasonal freezing and thawing processes of soils have a great impact on the thermal and hydrologic characteristics of the soils, which have a significant impact on the surface energy and water balance, and hence on weather and climate systems, and surface and subsurface hydrologic processes such as river runoff and soil moisture. However, the study of seasonally frozen ground has received little attention.

In this study, we will give a brief review of studies of seasonally frozen ground over the past decades. We will estimate annual and interannual variation of distribution of seasonal frozen ground using the annual freezing and thawing index of air temperature. Preliminary results indicate that area extent of seasonally frozen ground has decreased about 15 to 20 percent during the past few decades. Based on annual freezing index, we will estimate the potential maximum freezing depth at each grid pixel and areal extent of seasonally frozen ground. Over the permafrost regions, active layer thickness will be estimated using simplified Stefan solution. We will further investigate interannual/interdecadal variability of areal extent of seasonally frozen ground in the Northern Hemisphere. The annual freezing index of air temperature will be calculated based on daily ERA-40 reanalysis data. Over the contiguous United States, the annual freezing index will also be calculated based on gridded daily air temperature using ground-based measurements. Comparison of the results from two data sets will be conducted to evaluate the accuracy of the ERA-40 reanalysis data over the contiguous United States and its applicability in the Northern Hemisphere.

We investigated the spatial and temporal variability of active layer thickness from 1950 through 2000 over the permafrost regions north of 50 degrees north. Active layer thickness was estimated by a simplified Stefan solution using the "edaphic factor" and the annual thawing index of air temperature. The edaphic factor was determined using ground-based active layer thickness from 31 stations from 1950s through 1990 in the Russian Arctic, 103 CALM stations since the early 1990s, and six stations over the Tibetan Plateau from 1996 through 2002. Edaphic factor data from ground-based measurements are used to validate and calibrate the calculated values of the edaphic factor from model outputs. The validated and calibrated values are used to estimate active layer thickness over the study area with resolution of about 0.5 degrees latitude by 0.5 degrees longitude. The annual thawing indexes were calculated from gridded monthly mean air temperature. Compared to annual thawing indexes obtained using daily air temperature, annual thawing index errors obtained from mean monthly air temperature are relatively small in the Arctic and Subarctic. Further study will be carried out to estimate active layer thickness over the entire arctic region. Tingjun Zhang is PI, and Richard Armstrong is Co-PI. (Funded by NASA)

## Investigation of the Spatial and Temporal Variations of the Seasonally Frozen Ground in the Continguous United States

A combined frozen soil algorithm was developed and validated to detect the near-surface soil freeze/thaw cycle over snow-free and snow-covered land areas in the contiguous United States. The combined frozen soil algorithm consists of two parts: (1) a passive microwave remote sensing algorithm was used to detect the near-surface soil freeze/thaw cycle over snow-free land areas, and (2) a one-dimensional numerical heat transfer model with phase change was used to detect soil freeze/thaw status over snow-covered land areas.

Using the Defense Meteorological Satellite Program's Special Sensor Microwave Imager (SSM/I) data, the passive microwave algorithm uses a negative spectral gradient between 19 GHz and 37 GHz, vertically polarized brightness temperatures, and a cut-off brightness temperature at 37 GHz with vertical polarization (TB(37V)). SSM/I data and soil temperature data from 26 stations over the contiguous United States from two year period, 1 July 1997 through 30 June 1999, were used to calibrate the algorithm (year 1), to validate the algorithm (year 2), and to demonstrate freeze/thaw classification (both years). A cut-off brightness temperature of 258.2 Kelvin was obtained based on a linear correlation ($r^2=0.84$) between the soil temperature at five centimeter depth and the TB(37V). The combined frozen soil algorithm provides the accuracy for frozen soil detection of about 76 percent and the accuracy for

the correct classification of both frozen and unfrozen soils of approximately 83 percent with a percent error of about 17 percent.

For the first time, the 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 study area.

The primary results indicate that near-surface soil freezing started in the northern Great Plains and along the Rocky Mountains in October and November, gradually expanded into northern states as the winter progressed, and finally retreated back in the spring. The maximum area extent of seasonally frozen ground during the winter of 1997/1998 was about 4.4 by 106 square kilometers or 63 percent of the total land area of the contiguous United States, while during the winter of 1998-1999, the maximum area extent was about 5.2 by 106 square kilometers or 74 percent of the total study area. The maximum area extent over the two winters occurred in late December and early January.

Area extent of seasonal snow cover was substantially less than that of seasonally frozen ground. The maximum extent of snow cover was about 2.8 by 106 square kilometers or 40 percent of the total land area of the contiguous United States during the winter of 1997/98, and 2.5 by 106 square kilometers, or about 35 percent of the total study area during the winter of 1998/99. The maximum area extent of snow cover occurred in March during these two winters.

During the early winter, the area of frozen soil over snow-free ground dominated the total frozen soil area. As winter progressed and snow cover area expanded, frozen soil under snow cover dominated the total frozen soil area. Due to the insulating effect of snow, frozen soil under snow cover may be thawed by the end of winter. Area extent of unfrozen ground under seasonal snow cover was relatively small, the maximum extent by the end of winter was about 0.34 by 106 square kilometers, accounting for about 7 percent of the maximum frozen area or less than 5 percent of the study area.

The duration of soil freeze ranged from less than one month in the south to more than nine months in the Rocky Mountains. The actual number of days of soil freezing varied from a few weeks to several months. The number of the near-surface soil freeze/thaw cycles varied from one to more than 11 during the winters of 1997/98 and 1998/99, while the average length of frozen period varied from less than 20 days to more than 220 days. Frequency of freeze/thaw cycles changed significantly, varying from one to more than 10 per winter season. The length of the freeze/thaw cycle also varied from less than 20 days to a few months. Both the maximum and integrated frozen area from 1987 through 2000 changed significantly, with an interannual variation by more than 20 percent.

One important parameter – daily soil freezing depth of seasonally frozen ground – has not been included in this study. In principle, the combined frozen soil algorithm is capable of predicting daily soil freezing depth. In addition to air temperature and snow cover, there are many other factors that influence soil freezing depth, such as ground surface temperature, soil type, structure, density, soil moisture content, and deep geothermal heat fluxes.

To detect soil freezing depth, the combined frozen soil algorithm requires inputs of all of these parameters, especially soil moisture content which changes significantly with time and has a great impact on soil thermal properties. Soil moisture also has a substantial influence on the amount of latent heat of fusion due to phase change when soil water freezes. The lack of these data sets at regional scales limits the capability of the combined frozen soil algorithm to detect soil freezing depth.

Understanding cold season atmosphere-hydrosphere interactions and their feedbacks in Earth's weather and climate system is essential for assessing variations in the regional and global energy and water cycles.

When these data sets are available in the future, especially soil moisture content within the top meter of soils, soil freezing depth can be detected with confidence. Further validation is needed to improve the accuracy of frozen ground detection and to estimate thickness of the seasonally frozen ground using the combined frozen soil algorithm. Extensive field measurements, especially ground-based radiometer brightness temperature measurements, are needed to further calibrate and validate the combined frozen soil algorithm. These works certainly need more effort and additional funding. Tingjun Zhang is PI, and Richard Armstrong, Christoper Oelke, and Martyn Clark are Co-PIs. (Funded by the Department of Energy's National Institute for Global Environmental Change)

## Changes in Freeze-Thaw Cycle and Permafrost Dynamics and their Hydrological Implications over the Russian Arctic Drainage Basin

Changes in active layer thickness (ALT) over northern high-latitude permafrost regions have important impacts on the surface energy balance, hydrologic cycle, carbon exchange between the atmosphere and the land surface, plant growth, and ecosystems as a whole. This study examines the 20th century variations of ALT for the Ob, Yenisey,

and Lena River basins. ALT is estimated from historical soil temperature measurements from 17 stations (1956 to 1990, Lena basin only), and from annual thawing index based on both surface air temperature data (1901 to 2002) and numerical modeling (1980 to 2002). The latter two provide spatial fields. Based on the thawing index, the long-term average (1961 to 1990) ALT is about 1.87 meters in the Ob, 1.67 in the Yenisey, and 1.69 meters in the Lena basin. Over the past several decades, ALT over the three basins shows positive trends, but with different magnitudes. Based on the 17 stations, ALT increased about 0.32 meters between 1956 and 1990 in the Lena. To the extent that results based on the soil temperatures represent ground truth, ALT obtained from both the thawing index and numerical modeling is underestimated. It is widely believed that ALT will increase with global warming. However, this hypothesis needs further refinement since ALT responds primarily to summer air temperature while observed warming has occurred mainly in winter and spring. It is also shown that ALT exhibits complex and inconsistent responses to variations in snow cover. For more information, please see Oliver Frauenfeld's research. Tingjun Zhang is PI, and Roger G. Barry and Oliver W. Frauenfeld are Co-PIs. (Funded by NSF)

## Permafrost Modeling and Data Assembly

The primary prerequisites for the success of Climate of the Arctic: Modeling and Processes (CAMP) and impact assessments, such as the Arctic Climate Impact Assessment (ACIA), are understanding the distribution and characteristics of permafrost and the seasonal freezing and thawing processes of the near-surface soil; quantifying seasonal and interannual variations in timing, duration, area extent, and thickness of soil seasonal freezing and thawing; and potential response of permafrost to climate change. Such knowledge is essential for the accurate prediction of future changes in climate and the global environment. The overall objective of the International Arctic Research Center (IARC) Permafrost Data Assembly project is to provide frozen ground data and information for the IARC modeling effort and ACIA. Specifically, researchers are involved in (1) identifying and collecting potential permafrost- related data and information from national and international organizations, institutions, and individuals; (2) conducting complete quality control and documentation for all data sets from different sources; and (3) compiling and reformatting data sets as required for the modeling process studies and the international community at large.

During the past year, both data collection and compilation have been conducted. We continue to collect data from various sources. In addition, we have digitized permafrost maps from China and Mongolia and the digitized version of the maps are available from the NSIDC Frozen Ground Data Center (http://nsidc.org/fgdc). Based on data we acquired in the early stage of this project, we are doing the compilation on the following three products: (1) gridded soil temperature over Russia; (2) climatologies and time series of active layer thickness over permafrost and seasonally frozen ground depth over nonpermafrost regions in the northern hemisphere; (3) climatologies and time series of seasonal snow cover in the region north of 50 degrees north. These products will be available in the very near future. Tingjun Zhang is PI, and Roger G. Barry is Co-PI. (Funded by the IARC/NSF)

# International Collaboration

## The WCRP Climate and Cryosphere Project

The crysophere 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). Roger Barry serves as co-vice chair of the CliC Science Steering Group, Richard Armstrong is a member of the Data Management and Information Panel, and Mark Serreze serves as chair of the Ad Hoc Panel on Products for Polar Reanalysis. The Science Coordination Plan and the CliC Implementation Strategy are available at http://clic.npolar.no.

The CliC Scientific Steering Group held its fourth session in Hobart, Australia, 25 to 29 October 2004. The first CliC Conference, held in Beijing, 11 to 15 April, 2005, attracted some 250 participants. The Scientific Program is available at http://www.clic2005.org/programme.php. Attendees at both meetings spent considerable time preparing the Implementation Strategy Document for release to the community on the CliC Web site at http://clic.npolar/no in July.

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.

## Cold Land Processes Field Experiment (CLPX)

In 2004, almost all data from the 2002 and 2003 field campaigns of the NASA Cold Land Processes Experiment (CLPX) were made available to the public. These data include ground, airborne, and satellite observations of snow properties in northern Colorado and southern Wyoming. A total of 37 data sets, with accompanying documentation and metadata, are currently available.

The NASA Cold Land Processes Experiment is a multisensor, multiscale field program of nested study areas in Colorado and Wyoming. CLPX was designed to develop new remote sensing methods for measuring snowpack properties such as snow water equivalent, grain size, and snow extent. The experiment uses ground observations and airborne and spaceborne remote sensing data, along with land surface models, to improve forecasts of springtime water supplies, snowmelt, runoff, and regional weather and climate trends.

International science and data management programs promote free exchange of data and accelerate research aimed at understanding the role of the cryosphere in the Earth system.

The first two CLPX field campaigns were conducted in February and March of 2002 and 2003. These campaigns covered two seasons: mid-winter (when conditions are generally frozen and dry), and early spring (a transitional period when both frozen and thawed and dry and wet conditions are widespread). The study areas ranged from low-relief (flat topography) unforested areas with shallow snow cover to high-relief (complex topography) densely forested areas with deep snow cover. They varied in size from thousands of square kilometers down to one square kilometer intensive study areas and a one hectare local-scale observation area. Researchers and field assistants from NSIDC took part in both CLPX campaigns. NSIDC also serves as the data manager and the data archive for most of the CLPX data. NSIDC data managers were in the field with researchers, transcribing and documenting data and identifying data collection issues that could be resolved in the field. A future CLPX campaign is planned for 2006 in Alaska.

## Terrestrial Observation Panel for Climate (TOPC)

TOPC was established to develop a balanced and integrated system of in situ and satellite observations of the terrestrial ecosystem. Sponsored by the Global Climate Observing System (GCOS) and the Global Terrestrial Observing System (GTOS), TOPC provides climate-related observations.

Roger Barry attended the TOPC meeting in Ispra, Italy, in April 2004 and provided input on cryospheric observations to the GCOS Implementation Plan for the United Nations Framework Convention on Climate Change Conference of the Parties IX.

## International Commission on Snow and Ice (ICSI)

Roger Barry served as chair of an ad hoc task force established by ICSI to develop a proposal to the International Union of Geodesy and Geophysics (IUGG) for ICSI to become an independent Association of Cryospheric Sciences. Following a presentation to the IUGG Executive Committee in September 2004, the Committee approved, as a first step, the establishment of an IUGG Commission for the Cryospheric Sciences (CCS) through 2007.

## Global Digital Sea Ice Data Bank (GDSIDB)

The objective of the GDSIDB project is to preserve ice chart data for use by researchers, and to encourage its conversion from paper or graphical form to digital form. NSIDC, along with the Arctic and Antarctic Research Institute (AARI) in Russia, serves as an archive location for sea ice charts.

Roger Barry served as co-chair for the GDSIDB Steering Group. He attended and co-chaired the GDSIDB tenth session, and attended the second session of the Joint World Meteorological Organization (WMO)/Intergovernmental Oceanographic Commission (IOC) Technical Commission for Oceanography and Marine Meteorology (JCOMM) Expert Team on Sea Ice (ETSI) meetings in Hamburg, Germany. Florence Fetterer also attended the ETSI meetings.

## Global Climate Observing System (GCOS)

NSIDC's WDC contributed to the Global Climate Observing System (GCOS) report, *Analysis of Data Exchange Problems in Global Atmospheric and Hydrological Networks*, published in 2005 by the World Meteorological Organization (GCOS-96, WMO/TD No. 1255).

# Science Communications and Outreach

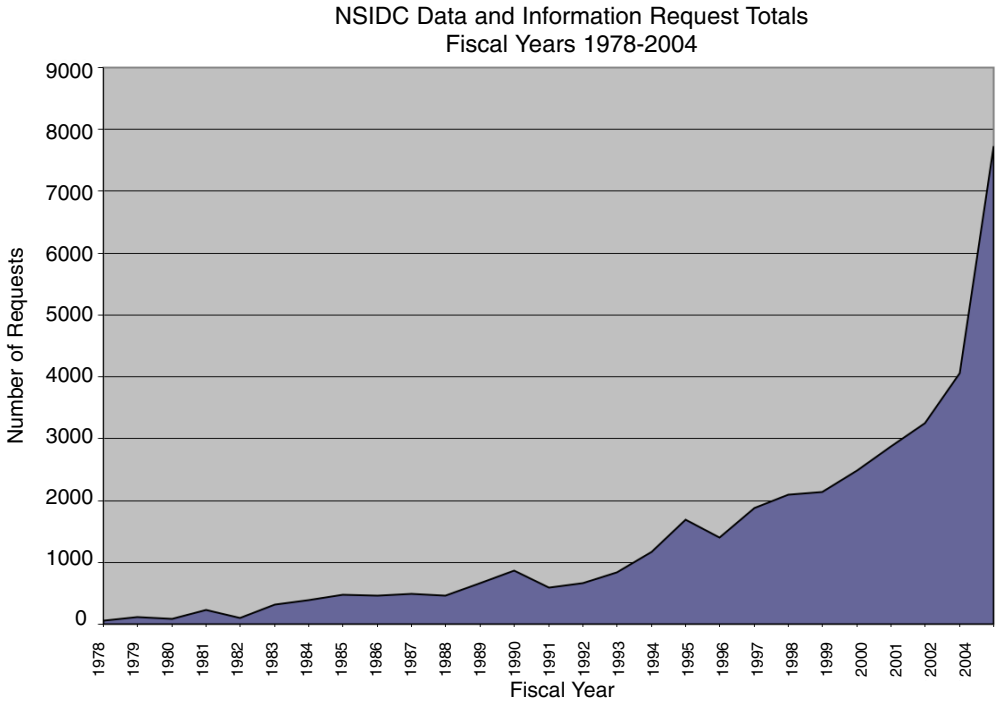
NSIDC approaches data management with the needs of our worldwide users in mind. We apply several methods to ensure ease of data discovery, understandability of data and their limitations, and efficiency and usability of tools to access and obtain data. The Science Communications Group at NSIDC is part of this data management philosophy. This group of user experts, outreach specialists, technical and science writers, and Web and graphics designers serves our user community and the public by providing needed information about our data sets, our research, and the cryosphere in general. Applying their joint user intelligence, communication strategies, and standards, the group helps make information accessible and usable to many audiences, including seasoned cryospheric researchers, graduate students and new researchers, secondary school students, the general public, the press, policymakers, and stakeholders.

## Documentation, Metadata, and User Intelligence

Technical writers and User Services specialists represent user needs when new data are being developed for release. User Services staff have developed expertise on data usage and user requests, and contribute to data product design and enhancement through representation on NSIDC product development teams, resulting in products that are easier to locate, access, understand, and request. Technical writers create metadata and documentation for data users that make it possible to locate data by geography, variable, or other research interest. Technical documentation helps preserve the context for the research as well providing as the facts, limits, and uncertainties of data production and processing, so that data have more durability by remaining comprehensible and able to be used accurately in subsequent research. Web specialists, graphics designers, and human factors specialists create interfaces to data and information that reduce user time and frustration. With their product teams, writers and designers help create and implement special-topics Web pages, such as the "Sea Ice Index," designed to help researchers interested in sea ice data understand the strengths and limitations of the myriad and overlapping sea ice data products that are available.

Once data are published, five User Services staff members respond to scientific and public inquiries at NSIDC. We hear from science researchers with questions about data holdings, processing, formats, and data processing algorithms; students needing information for school projects and reports; media and textbook publishers requesting photographs and interviews.

User Services researches and provides timely and accurate responses to these divergent audiences, while minimizing disruption to researchers and data contributors. User Services also provides a valuable "feedback loop" into the data management process. By advising product teams on inquiries, questions, needs, and data applications, teams can build this intelligence into future data



releases as well as continuously improve the quality and usefulness of information provided about the data.

## Data Dissemination and Outreach

Our foremost communication focus is on our scientific data user community. This community is eager to know of data and data research that may support their work. Data are constantly extended, new algorithms provide increased accuracy, new instruments create new data sets, and new measurement theories result in new data.

In addition to announcing data developments on our Web site, in 2004 NSIDC published and distributed four quarterly newsletters, NSIDC Notes, to more than 1400 subscribers. Many NSIDC staff members – from scientists to technical writers to User Services representatives – contribute to the articles in Notes.

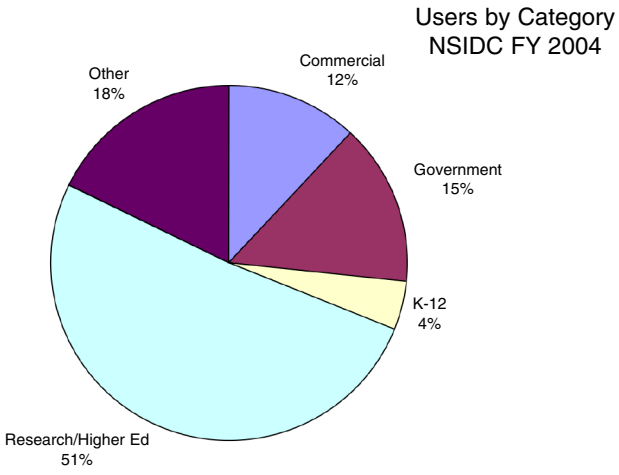
The Science Communications Group also provides outreach support at meetings and conferences. Most notably, at the 2004 Fall AGU Meeting, NSIDC researchers had a significant presence with more than 25 posters, seven oral sessions, and three press conferences. Communications Group staff assisted NSIDC presenters in preparing for their press conferences, oral sessions, and posters, and themselves presented four posters describing data products, tools, and services. Outreach staff themselves presented at two oral sessions: Jane Beitler presented a talk, "Influencing the Future: Special Considerations for IPY Education and Outreach;" and Marijke Unger spoke on "Finding a Common Language: How To Communicate Climate Change Science to Non-Scientists." The team also managed logistics for the NSIDC exhibit booth and provided booth staffing to answer questions and introduce potential users to NSIDC data. The AGU booth drew approximately 67 requests for data or information, with about two thirds of the contacts being new to NSIDC data. Our outreach coordinator and our DAAC manager also participated in the OneNASA exhibit booth at AGU.

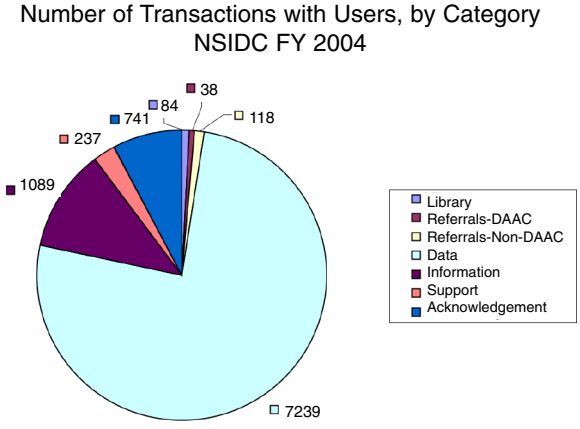
In addition to supporting communications to our research audience, we also support our own researchers in talking to the press and policymakers about their work. In 2004 we helped coordinate ten press releases about crysopheric research at NSIDC, and coordinated numerous press inquiries and referrals. Significant stories in 2004 included continued Arctic sea ice decline, and evidence of rapid Antarctic glacier acceleration following ice shelf breakup. We also developed more than 60 active news links to important coverage of cryospheric science, to help press report accurately on these events and topics.

Researchers access our data, tools, and services over the Internet, and the public accesses our Web site heavily as well. In 2004, our site had more than 840,000 visitors, who collectively viewed more than five million Web pages. A significant number of page accesses, nearly 725,000, could be identified as international users. NSIDC also fields numerous questions from K-12 teachers and students about glaciers, snow, and other cryospheric topics. Our "All About Snow" and "All About Glaciers" Web sites are highly rated for accessibility and accuracy of information, and received more than 2.7 million page hits in 2004. More locally, NSIDC hosted the cryospheric session of the INSTAAR Open House, bringing more than 80 local high school students to the Center for a "quiz show" format competition featuring information related to cryospheric science and exploration.

## 2004 Accomplishments

NSIDC measures data usage trends by counting both volume of data distributed, and also data and support requests to User Services. Requests to User Services for data and information increased for the 8th straight year in FY 2004, growing by 8 percent. Strong user interest in existing products as well as growing interest in the EOS AMSR-E and MODIS data sets (66 percent of all requests) account for this increasing product demand.



# The NSIDC Information Center/Library

NSIDC librarians Gloria Hicks and Allaina Howard.

The NSIDC/WDC Library/Information Center supports the NSIDC mission to "make fundamental contributions to cryospheric science and will excel in managing data and disseminating information in order to advance understanding of the Earth system" by serving as a resource for cryospheric information and providing research materials and reference services both for researchers at NSIDC and the University of Colorado, Boulder, as well as for the general public.

The Library acquires and catalogs both published and unpublished analog materials on snow cover, land and sea ice, cold climates, and permafrost, as well as digital data such as CD-ROMs and Web resources. It contains more than 44,000 monographs, serials, journal articles, reprints, videos, maps, atlases, and CD-ROMs. We currently receive more than 100 periodicals and newsletters relating to the cryosphere and to remote sensing of ice and snow. The Center's collection also includes many hard-to-locate international journals dating back well into the mid-20th century, as well as many foreign language materials. The Library is funded by the NOAA at NSIDC project and by the NASA DAAC.

In 2004, staff turnover resulted in an opportunity to hire two new professional librarians, Gloria Hicks and Allaina Howard, one with archival training. A period of assessment laid the foundations for new collaborations and major improvements to be undertaken in 2005. The new librarians completed a review of library procedures and reduced a large backlog of checking materials in and cataloging. In addition, the archivist began a review of historic analog holdings, and identified needs for improving storage and preservation of fragile items. From these activities, the librarians identified a number of initiatives to make materials more accessible and useful to patrons.

During the last quarter of the year, library staff processed more than 500 periodical issues, books, and other items, added 273 new items to the catalog, and began the processes needed for future funding, budgets, and growth. Library personnel shipped the first batch of 200 historically valuable Dehn ice charts for digitization, and set up the procedures for future shipments. Also, during the last three months of the year, the staff opened up channels of communication with other similar institutions and libraries in the region. In search of special funding for future projects, the NSIDC Information Center began work on several grant applications in collaboration with the Information Center at the Institute for Arctic and Alpine Research (INSTAAR).

The Center's collection includes many hard-to-locate international journals dating back well into the mid-20th century, as well as many foreign language materials.

# NSIDC Visitors

15 October 2003 - 28 August 2004
**Svetlana Tchoudinova** (Institute of Physicochemical and Biological Problems in Soil Science)
NSF Postdoctoral Research Fellowship
Dr. Tchoudinova Svetlana investigated the effect of climatic change during the 20th century on the temperature regime of permanently and seasonally frozen soils of Russia. During the past six years, with support from the NSF OPP, we have worked with our Russian colleagues on collecting and digitizing ground-based soil temperature measurements from more than 250 stations throughout the former Soviet Union. All data products from the NSF-funded projects have been transferred to NSIDC. Our current NSF project will further expand stations from 250 to more than 400, with data time series to be updated to 2000.

15 January 2004 - 15 October 2004
**Igor Zotikov** (Glaciologist and Chief Scientist at the Institute of Geography of Russian Academy of Sciences)
Dr. Zotikov visited NSIDC on a Fullbright fellowship. His project aimed at eliminating unsolved questions of glaciological, geophysical, hydrological, biological, planetological origins of Lake Vostok using resources and data from American and Russian libraries and 30 years of research.

27 December 2003 - 8 March 2004
**Stephan Gruber** (Physical Geography, University of Zurich)
Dr. Gruber worked with Tingjun Zhang on a permafrost distribution model for the project "Mountain permafrost modelling - synthesizing European and American experience."

5 January 2004 - 23 January 2004
**Martin Miles** (Research Scientist, Bjerknes Centre for Climate Research, Bergen Norway)
Dr. Miles visited NSIDC to support his research interests in arctic sea ice and arctic climate change.

March 2004
**Francisca Bown** (Laboratorio de Glaciologia, Universidad de Chile)
Dr. Brown visited as a representative of the GLIMS Chilean Regional Center (RC) and the Centro de Estudios Cientificos. She worked on getting at least one GLIMS data set from the Chilean RC into the GLIMS database, offered hands-on experience with 'GLIMSView' and worked on clearing remaining obstacles to transfer GLIMS data from the RC to NSIDC.

15 February 2004 - 19 March 2005
**Tatiana Khromova** (Russian Academy of Science, Moscow)
Dr. Khromova worked closely with NSIDC GLIMS personnel and entered glacier outlines derived from ASTER images for 547 glaciers in the Pamir region and 471 in the Caucasus region. She also participated in the testing of the Web-based data submissions interface and co-authored a manuscript.

17 June 2004 - 7 August 2004
**Gao Feng** and **Che Tao** (Cold and Arid Regions Environment and Engineering Research Institute)
Drs. Feng and Tao visited NSIDC from Lanzhou in north central China, funded through the NOAA ESDIM program. They are both from the Cold and Arid Regions Environment and Engineering Research Institute (CAREERI) which is also the location of the World Data Center for Glaciology - Lanzhou. They are providing NSIDC with the most recent updates of the Chinese snow depth, air, and soil temperature data plus a limited amount of snow depth data for Tibet during the 1999 through 2003 winter seasons, which will contribute to our efforts to validate AMSR-E snow products. They will assist personnel at NSIDC in understanding the format and content of these data sets, the measurement techniques used to obtain the original measurements, and the associated quality control undertaken. They will also assist NSIDC in the validation and enhancement of the passive microwave snow and frozen ground algorithms in order to ultimately provide accurate near real-time snow and frozen ground products for the Tibet Plateau region. They will also help us ingest the latest version of the Chinese glacier inventory.

27 April 2004 - 12 May 2004
**Frank Rau** (Department of Physical Geography, University of Freiburg, Germany)
Dr. Rau's research interests include climate changes on the Antarctic Peninsula and the related modifications of the glacial systems in this region. He worked on entering least one GLIMS dataset from his RC into the GLIMS database, and worked on clearing remaining obstacles to operational transfer of GLIMS data from his RC to NSIDC.

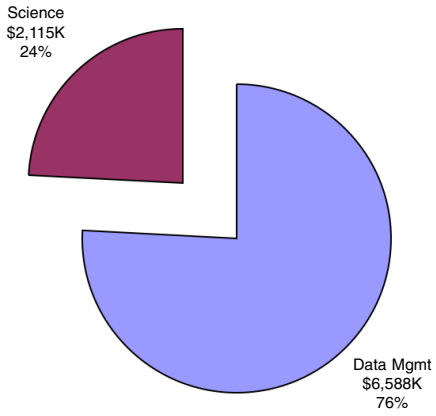
# CPP Talks

| | |
|---|---|
| 9 January 2004 | **Michael Alexander** (NOAA Climate Diagnostics Center)<br>"The atmospheric response to realistic arctic sea ice anomalies" |
| 23 January 2004 | **Mark Serreze** (NSIDC/CIRES)<br>"Arctic perspectives on the climate change debate" |
| 6 February 2004 | **Stephan Gruber** (Glaciology and Geomorphodynamics Group, Department of Geography, University of Zurich)<br>"The distribution and evolution of alpine ground temperatures" |
| 27 February 2004 | **Siri Jodha Singh Khalsa** (NSIDC)<br>"Extraction of glacier information from satellite imagery: issues and methodologies" |
| 5 March 2004 | **Betsy Weatherhead** (CIRES)<br>"Designing systems for detecting trends" |
| 19 March 2004 | **Richard Armstrong** (NSIDC/CIRES)<br>"Passive microwave remote sensing of snow" |
| 2 April 2004 | **Tyler Erickson** (Institute of Arctic and Alpine Research)<br>"Working with spatially correlated measurements in the modeling of environmental properties" |
| 16 April 2004 | **Bruce Raup** (NSIDC/CIRES)<br>"Automating the extraction of glacier information from satellite imagery" |
| 23 April 2004 | **Bruce Molnia** (USGS)<br>"Alaskan glaciers" |
| 7 May 2004 | **Frank Rau** (Institut fur Physische Geographie, Freiburg, Germany)<br>"An inventory of glaciers on the antarctic peninsula for the GLIMS database" |
| 3 September 2004 | **Georg Kaser** (University of Innsbruck, Germany)<br>"Studies of tropical glaciers" |
| 17 September 2004 | **Charles Knight** (NCAR Mesoscale and Microscale Meteorology Division)<br>"Ice cube spikes" |
| 1 October 2004 | **Meredith Betterton** (University of Colorado Department of Applied Mathematics)<br>"Theory of structure formation of penitentes, suncups, and dirt cones" |
| 8 October 2004 | **Gregory V. Jones** (Southern Oregon University Geography Department)<br>"Climate change and global wine quality" |
| 19 October 2004 | **Bruce Jakosky** (Laboratory for Atmospheric and Space Physics)<br>"Ground ice, liquid water, and the potential habitability of Mars" |
| 12 November 2004 | **Noah Molotch** (CIRES/CSES)<br>"The representation of snow surface albedo in distributed snowmelt models: a comparison of ground-based and remotely sensed approaches" |
| 19 November 2004 | **Jessica Lundquist** (CIRES)<br>"Synchronous snowmelt and the spring equinox" |
| 3 December 2004 | **Kalle Kronholm** (Montana State University Department of Earth Sciences)<br>"Snow cover spatial heterogeneity at the slope scale: measurement methods, results and implications for snow avalanche release" |

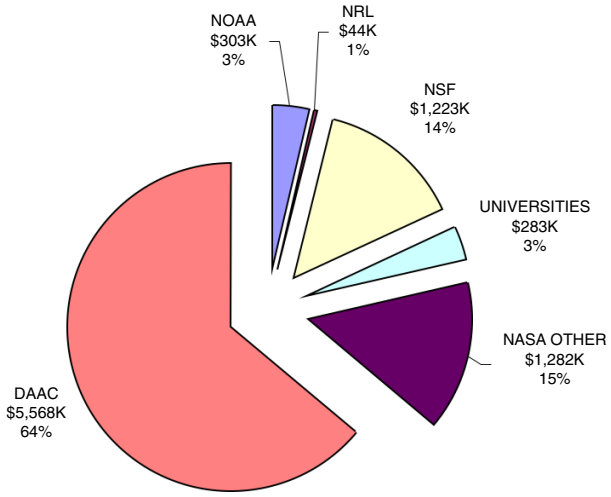
# Financial Support

NSIDC's annual budget from July 2004 through June 2005 was 8.7 million dollars, with funding from national agencies such as NASA, NOAA, and NSF, as well as from the Naval Research Laboratory (NRL) and various universities.

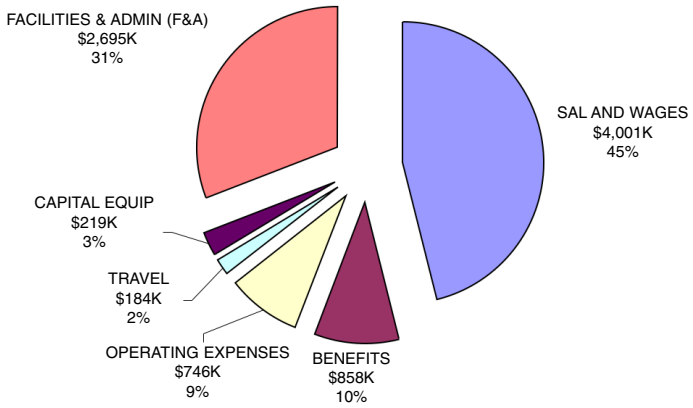
Year Ending June 2005
Comparison of Scientific Research v. Data Management
Total Dollars - $8,703K




Year Ending June 2005
Actual Expenses by Sponsor
Total Dollars - $8,703K




Year Ending June 2005
Actual Expenses by Category
Total Dollars - $8,703K



# Products Released in 2004

NSIDC released more than 100 data products in 2004, ranging from small data sets collected by individual investigators under NSF-supported research to Earth Observing System satellite data products. NSIDC also released a number of tools to help users work with AMSR-E and ICESat/GLAS data. All NSIDC data may be accessed through a user-friendly Web site that permits a search for data by the name of the scientist, the project title, the measured parameter, or keyword (http://nsidc.org/data/ ).

## Data Sets

*Airborne Cloud Radar (ACR) Reflectivity, Wakasa Bay, Japan*
http://nsidc.org/data/nsidc-0212.html

*AMMR Air and Brightness Temperature Data, Wakasa Bay*
http://nsidc.org/data/nsidc-0194.html

*AMSR-E/Aqua Daily L3 6.25 km 89 GHz Brightness Temperature (Tb) Polar Grids*
http://nsidc.org/data/ae_si6.html

*AMSR-E/Aqua Daily L3 12.5 km Tb, Sea Ice Conc., & Snow Depth Polar Grids*
http://nsidc.org/data/ae_si12.html

*AMSR-E/Aqua Daily L3 25 km Tb, Sea Ice Temperature, & Sea Ice Conc. Polar Grids*
http://nsidc.org/data/ae_si25.html

*AMSR-E/Aqua Daily L3 Global Ascending/Descending .25x.25 deg Ocean Grids*
http://nsidc.org/data/ae_dyocn.html

*AMSR-E/Aqua Daily L3 Global Snow Water Equivalent EASE-Grids*
http://nsidc.org/data/ae_dysno.html

*AMSR-E/Aqua Daily L3 Surface Soil Moisture, Interpretive Parms, & QC EASE-Grids*
http://nsidc.org/data/ae_land3.html

*AMSR-E/Aqua L2B Global Swath Ocean Products derived from Wentz Algorithm*
http://nsidc.org/data/ae_ocean.html

*AMSR-E/Aqua L2B Global Swath Rain Rate/Type GSFC Profiling Algorithm*
http://nsidc.org/data/ae_rain.html

*AMSR-E/Aqua L2B Surface Soil Moisture, Ancillary Parms, & QC EASE-Grids*
http://nsidc.org/data/ae_land.html

*AMSR-E/Aqua L3 Global Snow Water Equivalent EASE-Grids*
http://nsidc.org/data/ae_5dsno.html

*AMSR-E/Aqua Monthly L3 5x5 deg Rainfall Accumulations*
http://nsidc.org/data/ae_rngd.html

*AMSR-E/Aqua Monthly L3 Global Ascending/Descending .25x.25 deg Ocean Grids*
http://nsidc.org/data/ae_moocn.html

*AMSR-E/Aqua Monthly L3 Global Snow Water Equivalent EASE-Grids*
http://nsidc.org/data/ae_mosno.html

*AMSR-E/Aqua Weekly L3 Global Ascending/Descending .25x.25 deg Ocean Grids*
http://nsidc.org/data/ae_wkocn.html

*AMSR-E Brightness Temperatures*
http://nsidc.org/data/docs/daac/ae_si6_6km_tbs.gd.html

*AMSR-E Global Ocean Products, Daily*
http://nsidc.org/data/docs/daac/ae_ocean_products.gd.html

*AMSR-E Global Ocean Products, Monthly*
http://nsidc.org/data/docs/daac/ae_ocean_products.gd.html

*AMSR-E Global Ocean Products, Weekly*
http://nsidc.org/data/docs/daac/ae_ocean_products.gd.html

*AMSR-E Global Rain Rate*
http://nsidc.org/data/docs/daac/ae_rain_l2b.gd.html

*AMSR-E Global Rain Rate, Monthly*
http://nsidc.org/data/docs/daac/ae_rain_l2b.gd.html

*AMSR-E Sea Ice Concentration, Sea Ice Temperature, and Brightness Temperatures*
http://nsidc.org/data/docs/daac/ae_si25_25km_tb_and_sea_ice.gd.html

*AMSR-E Sea Ice Concentration, Snow Depth, and Brightness Temperatures*
http://nsidc.org/data/docs/daac/ae_si12_12km_tb_sea_ice_and_snow.gd.html

*AMSR-E Snow Water Equivalent, Daily*
http://nsidc.org/data/docs/daac/ae_swe_ease-grids.gd.html

*AMSR-E Snow Water Equivalent, Five Days*
http://nsidc.org/data/docs/daac/ae_swe_ease-grids.gd.html

*AMSR-E Snow Water Equivalent, Monthly*
http://nsidc.org/data/docs/daac/ae_swe_ease-grids.gd.html

*AMSR-E Surface Soil Moisture*
http://nsidc.org/data/docs/daac/ae_land_l2b_soil_moisture.gd.html

*AMSR-E Surface Soil Moisture, Daily*
http://nsidc.org/data/docs/daac/ae_land3_l3_soil_moisture.gd.html

*Antarctic Aerogeophysics Data*
http://nsidc.org/data/nsidc-0240.html

*Arctic Ocean Section Porewater Chemistry Data, 1994*
http://nsidc.org/data/arcss029.html

*Baltic Sea Experiment (BALTEX) Ground-Based Radar Polar Volume Data*
http://nsidc.org/data/nsidc-0209.html

*Barrow Area Information Database (BAID) Geospatial Data Sets, Barrow, AK, USA*
http://nsidc.org/data/arcss400.html

*Biogenic Sulfur in the Siple Dome Ice Core*
http://nsidc.org/data/nsidc-0201.html

*CLPX Airborne: Gamma Snow and Soil Moisture Surveys*
http://nsidc.org/data/nsidc-0158.html

*CLPX-Airborne: Multiband Polarimetric Scanning Radiometer (PSR) Imagery*
http://nsidc.org/data/nsidc-0155.html

*CLPX-Ground: Ground-Based Frequency Modulated Continuous Wave (FMCW) Radar*
http://nsidc.org/data/nsidc-0164.html

*CLPX-Ground: Ground-Based Infrared Images of the LSOS Site*
http://nsidc.org/data/nsidc-0161.html

*CLPX-Ground: ISA Main Meteorological Data*
http://nsidc.org/data/nsidc-0172.html

*CLPX-Ground: ISA Soil Moisture Measurements*
http://nsidc.org/data/nsidc-0178.html

*CLPX-Ground: University of Michigan Ground-Based Microwave Radiometer*
http://nsidc.org/data/nsidc-0167.html

*CLPX-Model: Local Analysis and Prediction System: 4-D Atmospheric Analyses*
http://nsidc.org/data/nsidc-0179.html

*CLPX-Satellite: Multi-angle Imaging Spectroradiometer (MISR) Products*
http://nsidc.org/data/nsidc-0150.html

*CLPX-Satellite: Radarsat Synthetic Aperture Radar Imagery*
http://nsidc.org/data/nsidc-0146.html

*Daily Precipitation Sums at Coastal and Island Russian Arctic Stations, 1940-1990*
http://nsidc.org/data/g02164.html

*Double Rain Gauge Network, Iowa*
http://nsidc.org/data/nsidc-0210.html

*Elevation Change of the Southern Greenland Ice Sheet from 1978-88*
http://nsidc.org/data/nsidc-0223.html

*GISP2 Stable Isotopes (Deuterium, Deuterium Excess, and Oxygen)*
http://nsidc.org/data/arcss137.html

*GLAS/ICESat Antarctic and Greenland Ice Sheet Altimetry Data*
http://nsidc.org/data/gla12.html

*GLAS/ICESat Global Aerosol Vertical Structure Data*
http://nsidc.org/data/gla10.html

*GLAS/ICESat Global Altimetry Data*
http://nsidc.org/data/gla01.html

*GLAS/ICESat Global Atmosphere Data*
http://nsidc.org/data/gla02.html

*GLAS/ICESat Global Backscatter Data*
http://nsidc.org/data/gla07.html

*GLAS/ICESat Global Cloud Heights for Multi-layer Clouds*
http://nsidc.org/data/gla09.html

*GLAS/ICESat Global Elevation Data*
http://nsidc.org/data/gla06.html

*GLAS/ICESat Global Engineering Data*
http://nsidc.org/data/gla03.html

*GLAS/ICESat Global Land Surface Altimetry Data*
http://nsidc.org/data/gla14.html

*GLAS/ICESat Global Laser Pointing Data*
http://nsidc.org/data/gla04.html

*GLAS/ICESat Global Planetary Boundary Layer and Elevated Aerosol Layer Heights*
http://nsidc.org/data/gla08.html

*GLAS/ICESat Global Thin Cloud-Aerosol Optical Depths Data*
http://nsidc.org/data/gla11.html

*GLAS/ICESat Global Waveform-based Range Corrections Data*
http://nsidc.org/data/gla05.html

*GLAS/ICESat Ocean Altimetry Data*
http://nsidc.org/data/gla15.html

*GLAS/ICESat Sea Ice Altimetry Data*
http://nsidc.org/data/gla13.html

*Ground Temperatures from Deep Boreholes in the Ob River Valley, Russia (VK-1615 and ZS-124/124a)*
http://nsidc.org/data/ggd646.html

*Historical Arctic and Antarctic Surface Observational Data*
http://nsidc.org/data/nsidc-0190.html

*IMS Daily Northern Hemisphere Snow and Ice Analysis at 4KM and 24 KM Resolution*
http://nsidc.org/data/g02156.html

*J-CAD Drifting Buoy Data, Arctic Ocean, 2000-2002*
http://nsidc.org/data/arcss126.html

*Meltpond2000 Polarimetric Scanning Radiometer Sea Ice Brightness Temperatures*
http://nsidc.org/data/nsidc-0208.html

*Meteorological Data from the Russian Arctic, 1961-2000*
http://nsidc.org/data/g02141.html

*Meteorology and soil temperatures, Hot Weather Creek, Ellesmere Island, NWT, Canada*
http://nsidc.org/data/ggd220.html

*Millimeter-wave Imaging Radiometer Brightness Temperatures, Wakasa Bay, Japan*
http://nsidc.org/data/nsidc-0193.html

*MODIS/Aqua Sea Ice Extent 5-Min L2 Swath 1km*
http://nsidc.org/data/myd29.html

*MODIS/Aqua Sea Ice Extent Daily L3 Global 1km EASE-Grid Day*
http://nsidc.org/data/myd29p1d.html

*MODIS/Aqua Sea Ice Extent and IST Daily L3 Global 4km EASE-Grid Day*
http://nsidc.org/data/myd29e1d.html

*MODIS/Aqua Snow Cover 5-Min L2 Swath 500m*
http://nsidc.org/data/myd10_l2.html

*MODIS/Aqua Snow Cover 8-Day L3 Global 0.05Deg CMG*
http://nsidc.org/data/myd10c2.html

*MODIS/Aqua Snow Cover 8-Day L3 Global 500m Grid*
http://nsidc.org/data/myd10a2.html

*MODIS/Aqua Snow Cover Daily L3 Global 0.05Deg CMG*
http://nsidc.org/data/myd10c1.html

*MODIS/Aqua Snow Cover Daily L3 Global 500m Grid*
http://nsidc.org/data/myd10a1.html

*Morphometric Characteristics of Ice and Snow in the Arctic Basin: Aircraft Landing Observations from the Former Soviet Union, 1928-1989*
http://nsidc.org/data/g02140.html

*Radiocarbon Dates and Pollen Data, Peterson Erosional Remnant, Arctic Coastal Plain, Alaska*
http://nsidc.org/data/arcss136.html

*Seawater Chemistry from the North Pole Environmental Observatory*
http://nsidc.org/data/arcss095.html

*Siple Dome Core Date from Measurement of the d18O of Paleoatmospheric O2*
http://nsidc.org/data/nsidc-0123.html

*SMEX02 Airborne Synthetic Aperture Radar (AIRSAR) Data, Iowa*
http://nsidc.org/data/nsidc-0206.html

*SMEX02 Aircraft Polarimetric Scanning Radiometer (PSR) Data*
http://nsidc.org/data/nsidc-0205.html

*SMEX02 AMSR-E Level 3 Daily Gridded Brightness Temperatures, Iowa*
http://nsidc.org/data/nsidc-0196.html

*SMEX02 Ancillary Data, Iowa*
http://nsidc.org/data/nsidc-0204.html

*SMEX02 Balloon-borne Radiosonde Data, Iowa*
http://nsidc.org/data/nsidc-0231.html

*SMEX02 CODIAC Soil Climate Analysis Network (SCAN) Data, Iowa*
http://nsidc.org/data/nsidc-0238.html

*SMEX02 European Remote Sensing Satellite (ERS-2) AMI Data, Iowa*
http://nsidc.org/data/nsidc-0198.html

*SMEX02 QuikSCAT/SeaWinds Backscatter Data, Iowa*
http://nsidc.org/data/nsidc-0233.html

*SMEX02 Rain Gauge Network, Walnut Creek, Iowa*
http://nsidc.org/data/nsidc-0236.html

*SMEX02 Soil Moisture Atmosphere Coupling Experiment (SMACEX), Iowa*
http://nsidc.org/data/nsidc-0232.html

*Snow Data Assimilation System (SNODAS) Data Products at NSIDC*
http://nsidc.org/data/g02158.html

*Southern Hemisphere Ice Limits, 1973-1978*
http://nsidc.org/data/g02129.html

*Sulfate-Based Volcanic Record from South Pole Ice Core*
http://nsidc.org/data/nsidc-0215.html

*Vertical Boundary Layer Profiles for Ozone and Meteorological Parameters at Summit, Greenland, 2000*
http://nsidc.org/data/arcss100.html

*West Siberian Lowland Peatland GIS Data Collection*
http://nsidc.org/data/arcss131.html

*When the Weather is Uggianaqtuq: Inuit Observations of Environmental Change*
http://nsidc.org/data/arcss122.html

## UPDATED DATA SETS

*Airborne Surface Profiling of Alaskan Glaciers*
http://nsidc.org/data/g01378.html

*Borehole Temperatures from the North Slope of Alaska, 1977-2002*
http://nsidc.org/data/arcss034.html

*CLPX-Ground: ISA Snow Pit Measurements*
http://nsidc.org/data/nsidc-0176.html

*CLPX-Ground: Sub-Canopy Energetics at the Local Scale Observation Site (LSOS)*
http://nsidc.org/data/nsidc-0170.html

*Former Soviet Union Hydrological Snow Surveys, 1966-1996*
http://nsidc.org/data/g01170.html

*Nimbus-5 ESMR Polar Gridded Sea Ice Concentrations*
http://nsidc.org/data/nsidc-0009.html

*Reprocessed ESMR Data*
http://nsidc.org/data/nsidc-0009.html

*Sea Ice Index*
http://nsidc.org/data/seaice_index/

*Seawater Chemistry from the North Pole Environmental Observatory*
http://nsidc.org/data/arcss095.html

*Soil Temperatures for Happy Valley and Barrow, Alaska, USA*
http://nsidc.org/data/docs/arcss/arcss038/

## NEW TOOLS RELEASED

AS2GT: AMSR-E Swath-to-Grid Toolkit
http://nsidc.org/data/tools/pmsdt/as2gt.html

Tools for working with ICESat/GLAS Data
http://nsidc.org/data/icesat/tools.html

# Publications

## Journal articles


**Arbetter, T.E.**, A.H. Lynch, and D.A. Bailey. 2004. Relationship between synoptic forcing and polynya formation in the Cosmonaut Sea: 1. Polynya climatology. *Journal of Geophysical Research - Oceans* 109: doi:10.1029/2003JC001837.

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Bishop, M., **R.G. Barry**, and 15 others. 2004. Global Land Ice Measurements from Space (GLIMS): Remote sensing and GIS investigations of the Earth's cryosphere. *Geocarto International* 19: 57-84.

Dozier, J., and **T.H. Painter**. 2004. Multispectral and hyperspectral remote sensing of alpine snow properties. *Annual Review of Earth and Planetary Sciences* 32: 465-494.

**Frauenfeld, O.W., T. Zhang, R.G. Barry**, and D. Gilichinsky. 2004. Interdecadal changes in seasonal freeze and thaw depths in Russia. *Journal of Geophysical Research* 109: doi:10.1029/2003JD004245.

**Frauenfeld, O.W.**, **T. Zhang**, and **M.C. Serreze**. 2004. Climate change and variability using European Center for Medium-Range Weather Forecasts reanalysis (ERA-40) temperatures on the Tibetan Plateau. *Journal of Geophysical Research* 110: doi:10.1029/2004JD005230.

**Khalsa, S.J.S.**, M. Dyurgerov, T. Khromova, **B. Raup**, and **R.G. Barry**. 2004. Space-based mapping of glacier changes using ASTER and GIS tools. *IEEE Transactions on Geoscience and Remote Sensing* 42(10): 2177-83.

Ling, F., and **T. Zhang**. 2004. A surface energy balance approach based on finite difference model for thermal regime of permafrost containing unfrozen water. *Cold Regions Science and Technology* 38(1): 1-15.

**Meier, W.N., M. Marquis, M. Kaminski**, and **R. Weaver**. 2004. NASA EOS sensors demonstrate potential for multiparameter studies of Arctic sea ice. *Eos, Transactions of the American Geophysical Union* 85(46): 481, 488-489.

Michaels, P.J., P.C. Knappenberger, **O.W. Frauenfeld**, and R.E. Davis. 2004. Trends in precipitation on the wettest days of the year across the contiguous USA. *International Journal of Climatology* 24: 1873-1882, doi:10.1002/joc.1102.

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Oelke, C., **T. Zhang,** and **M.C. Serreze.** 2004. Modeling evidence for recent warming of the Arctic soil thermal regime. *Geophysical Research Letters* 31: doi:10.1029/2003GL019300.

Okin, G., and **T.H. Painter**. 2004. Effect of grain size on spectral reflectance of sandy desert surfaces. *Remote Sensing of the Environment* 89(3): 272-280.

**Painter, T.H.,** and J. Dozier. 2004. The effect of anisotropic reflectance on imaging spectroscopy of snow parameters. *Remote Sensing of the Environment* 89(4): 409-422.

**Painter, T.H.,** and J. Dozier. 2004. Measurements of the hemispherical-directional reflectance of snow at fine spectral and angular resolution. *Journal of Geophysical Research - Atmospheres* 109(D18): doi:D18115,10.1029/2003JD004458.

**Parsons, M.A**., **M.J. Brodzik**, and N.J. Rutter. 2004. Data management for the Cold Land Processes Experiment: improving hydrological science. *Hydrological Processes* 18: 3637-3653.

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**Tsukernik, M**., T.N. Chase, **M.C. Serreze, R.G. Barry**, R. Pielke Sr., B. Herman, and X. Zeng. 2004. On the regulation of minimum mid-tropospheric temperatures in the Arctic. *Geophysical Research Letters* 31: doi:10.1029/2003GL018831.

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Ye, H., D. Yang, **T. Zhang**, X. Zhang, S. Ladochy, and M. Ellison. 2004. The impact of climatic conditions on seasonal river discharges in Siberia. *Journal of Hydrometeorology* 5: 286-295.

**Zhang, T., R.G. Barry**, and **R.L. Armstrong**. 2004. Application of satellite remote sensing techniques to frozen ground studies. *Polar Geography* 28(3): 163-196.

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**Barry, R.G**. 2004. Climate: research programs. In *Encyclopedia of the Arctic, Volume 1*. Ed. M. Nuttall, 379-384. New York: Routledge.

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# Conference presentations

**Arbetter, T**. 2004. A 20-year simulation of Arctic sea ice 1979-1998 using assimilated sea ice motion. Presented at the American Geophysical Union Joint Assembly, Montreal, Canada.

**Arbetter, T.E**. 2004. Using data assimilation to improve sea ice models: issues and applications. Presented at the Environment Canada Workshop on Data Assimilation in Sea Ice Models, Montreal, Canada.

**Arbetter, T.E.**, and **W.N. Meier**. 2004. Assimilation of observed ice motions in sea ice models. Presented at the American Geophysical Union Spring Meeting, Montreal, Canada.

**Arbetter, T.E.**, and **W.N. Meier**. 2004. On the use of raw and gridded ice motion vectors in an optimally-interpolated data assimilation sea ice model. Presented at the American Geophysical Union Joint Assembly, Montreal, Canada.

**Armstrong, R.L.**, **M.J. Brodzik**, and **M. Savoie**. 2004. Enhanced snow cover mapping using optical and passive microwave satellite data. Presented at the IGARSS 2004 Conference, Anchorage, AK.

**Armstrong, R.L.**, **M.J. Brodzik**, **M. Savoie**, and **K. Knowles**. 2004. AMSR-E snow products validation. Presented at the Joint AMSR Science Team Meeting, Ft. Collins, CO.

Bales, R., J. Dozier, N. Molotch, **T. Painter**, and R. Rice. 2004. Mountain hydrology of the semi-arid western U.S.: research needs, opportunities, and challenges. Presented at the American Geophysical Union Fall Meeting, San Francisco, California.

**Ballagh, L.**, **F. Fetterer**, and **A. Barrett**. 2004. NOAA @ NSIDC snow products. Poster presented at the NOAA Snowfall Network Observations Workshop (SNOW), Kansas City, MO.

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**Barry, R.G.**, B.E. Goodison, I. Allison, C. Dick, and V. Ryabinin. 2004. The role of the cryosphere in climate: the new WCRP CliC project. Presented at the 30th Congress of the International Geographical Union, Glasgow, United Kingdom.

**Bauer, R.**, **T. Scambos**, and **T. Haran**. 2004. GPS and GPR profiles of snow megadunes in East Antarctica. Poster presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

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**Duerr, R**. 2004. Challenges of a small archive. Presented at the THIC Meeting, Boulder, CO.

**Duerr, R**. 2004. HDF and HDF-EOS: implications for long-term archiving and data access. Presented at the HDF and HDF-EOS Workshop VIII, Aurora, CO.

**Duerr, R**., **M.A. Parsons**, and **R. Weaver**. 2004. The International Polar Year: making data and information available for the long-term. Poster presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

**Fetterer, F**., **R. Armstrong**, **M.J. Brodzik**, **W. Meier**, and **J. Stroeve**. 2004. Climate data records for sea ice and snow cover. Presented at the 4th International Symposium on the Tibetan Plateau, Lhasa, China.

**Fetterer, F**., **R.G. Barry**, and **C. Judy**. 2004. Overview of the U.S. National Snow and Ice Data Center and WDC for Glaciology, Boulder. Presented at the Workshop on Land-Atmosphere Interaction on the Tibetan Plateau, Chengdu, China.

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**Haran, T**. 2004. Demonstration of end-user tools for subsetting, analysis, and visualization of EOS snow and ice data products. Presented at the Workshop on EOS Snow and Ice Products, Landover, MD.

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**Khalsa, S.J.S**. 2004. Assessment of AMSR-E retrievals of soil moisture over the Tibetan Plateau. Presented at the 4th International Symposium on the Tibetan Plateau, Lhasa, China.

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**Marquis, M**. 2004. ICESat/GLAS status at NSIDC. Presented at the GLAS Science Team Meeting, Boulder, CO.

**Marquis, M**. 2004. ICESat/GLAS status at NSIDC. Presented at the GLAS Science Team Meeting, Landover, MD.

**Marquis, M**. 2004. ICESat/GLAS status and User Statistics. Presented at the GLAS Science Team Meeting, La Jolla, CA.

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**Marquis, M**. 2004. Status of AMSR-E and ICESat/GLAS at NSIDC. Presented at the Polar DAAC Advisory Group Meeting, Boulder, CO.

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**Marquis, M**., M. Smith, and **W.N. Meier**. 2004. Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) data products and browse images. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

**Marquis, M**., M. Smith, and **W. Meier**. 2004. Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) snow and sea ice data products and browse images. Poster presented at the Workshop on NASA Earth Observing System (EOS) Snow and Ice Products, Lanham, MD.

**Maurer, J.**, **M. Marquis**, and **M. Savoie**. 2004. Tools for working with the Geoscience Laser Altimeter System (GLAS) data products from the Ice, Cloud, and land Elevation Satellite (ICESat) mission. Poster presented at the American Geophysical Union Fall Meeting, San Francisco, California.

**Maurer, J.**, **M. Marquis**, and **M. Savoie**. 2004. Tools for working with the Geoscience Laser Altimeter System (GLAS) data products from the Ice, Cloud, and land Elevation Satellite (ICESat) mission. Poster presented at the Workshop on NASA Earth Observing System (EOS) Snow and Ice Products, Lanham, MD.

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**Painter, T.H**., R. Bales. 2004. Enhanced snow cover products from MODIS for the hydrologic sciences. American Geophysical Union Fall Meeting, San Francisco, CA.

**Parsons, M.A**., and **R. Duerr**. 2004. Designating user communities for scientific data: challenges and solutions. Presented at the 19th International CODATA Conference--The Information Society: New Horizons for Science, Berlin, Germany.

**Parsons, M.A.**, **R. Duerr**, **R. Weaver**, and **R.G. Barry**. 2004. Data management considerations for the International Polar Year. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

**Raup, B**., **S.J.S. Khalsa**, **R. Armstrong**, F. Cawkwell, C. Georges, G. Hamilton, W. Sneed Jr., and R. Wheate. 2004. GLIMS round-robin comparative image analysis experiment. Presented at the GLIMS Workshop, Oslo, Norway.

**Scambos, T**. 2004. A shattered shelf-image: ice shelf retreat and collapse in the Antarctic Peninsula. Presented at the Meeting on Antarctic Peninsula Climate Varibility: History, Causes, and Impacts, Cambridge, United Kingdom.

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**Scharfen, G.**, and **R. Bauer**. 2004. The Antarctic Master Directory: a fundamental data management element for the International Polar Year 2007-2008. Poster presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

**Serreze, M.C**. 2004. Arctic perspectives on the climate change debate. Presented at the University of Colorado, Boulder, CO.

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**Serreze, M.C**. 2004. Sea ice, storms and moisture flux: everything is changing. Presented at the 4th Arctic/Subarctic Ocean Fluxes ISSG Meeting, Vigo, Spain.

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**Sheffield, E**. 2004. A day in the life of NSIDC User Services. Presented at the User Services Working Group meeting, New York, NY.

**Slater, A.G**. 2004. Data assimilation for land surface models. Presented at the Workshop on Spatially Distributed Modeling and Remote Sensing of Permafrost, Fairbanks, AK.

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**Troisi, V.J**. 2004. Evolvable technical infrastructure. Presented at the NASA Earth Science Data Systems Working Group Meeting: Technology Infusion, Greenbelt, MD.

**Troisi, V.J**. 2004. MAID: A massive array of idle disks. Presented at the DAAC Alliance Meeting, New York.

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**Zhang, T**., **R.G. Barry**, and **R.L. Armstrong**. 2004. Application of satellite remote sensing on frozen ground. Presented at the Permafrost Modeling Workshop, Fairbanks, AK.

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**Zhang, T**., and C. Oelke. 2004. Modeling study of the active layer and permafrost in the Arctic drainage basin. Presented at the Permafrost Modeling Workshop, Fairbanks, AK.

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**Duerr, R**., **M. Parsons**, **M. Marquis**, **R. Dichtl**, and T. Mullins. 2004. Challenges in long-term data stewardship. 21st IEEE Conference on Mass Storage Systems and Technologies, NASA/CP-2004-212750, 47-67.

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## Other

Kendal McGuffie and Ann Henderson-Sellers acknowledged NSIDC in their book, *A Climate Modelling Primer, 3rd Edition*, published in March 2005 by John Wiley & Sons.

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