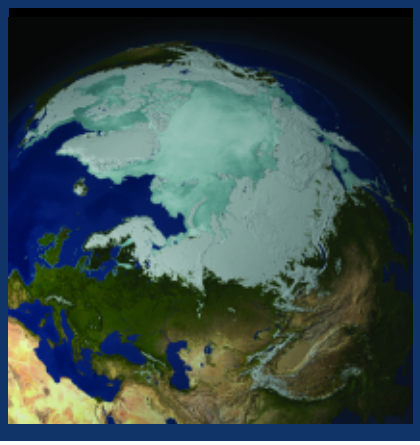
National Snow and Ice Data Center

World Data Center for Glaciology, Boulder



Annual Report 2005

Supporting Cryospheric Research Since 1976

National Snow and Ice Data Center
World Data Center for Glaciology, Boulder
Annual Report 2005

Cover image captions (clockwise from upper left)

NSIDC staff members Rob Bauer, Terry Haran, Ted Scambos, Atsuhiro Muto, and Ken Knowles assembled a weather tower in preparation for iceberg investigations in Antarctica. Although the mission didn't take place until early 2006, the team spent several months during 2005 designing instruments and monitoring iceberg positions around Antarctica.

Roger Barry and Genrikh Alexeev next to the Russian icebreaker, the *Kapitan Dranitsyn*, in September 2005.

This global image highlights the Arctic region on 23 April 2003 with AMSR-E Sea Ice Brightness Temperature shown in light blue and MODIS Daily Snow Cover shown in white. The DAAC-held AMSR-E and MODIS data products are distributed by NSIDC. Image is from the DVD, *A Tour of the Cryosphere, Earth's Frozen Assets*. (Courtesy NASA/Goddard Space Flight Center Scientific Visualization Studio)

Melt pond on multiyear ice floe, October 2004. (Courtesy T. Arbetter)

Table of Contents

National Snow and Ice Data Center
World Data Center for Glaciology, Boulder
Annual Report 2005

Scientists around the world are studying the cryosphere, deciphering frozen clues that reveal how the Earth's cold regions impacted past climate, and how changes in these regions may affect present and future climate. The National Snow and Ice Data Center (NSIDC) plays an active role in this research by archiving and distributing an extensive catalog of free, high-quality data products to researchers, education communities, and the commercial sector worldwide. To promote a greater understanding of the cryosphere, NSIDC scientists and staff also provide information to educators and the general public, collaborate with international organizations, publish findings, and communicate research progress and data improvements in conference presentations worldwide.

NSIDC supports National Science Foundation (NSF) programs, providing cryospheric data management 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) at University of Alaska Fairbanks through the Frozen Ground Data Center.

NSIDC also collaborates with other research and data management communities. NSIDC and the co-located World Data Center for Glaciology (WDC), Boulder, are part of the University of Colorado Cooperative Institute for Research in Environmental Sciences (CIRES), and are affiliated with the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center (NGDC) through a cooperative agreement. In addition, 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.

During 2005, NSIDC staff and scientists published a textbook on Arctic climate; monitored the continuing Arctic sea ice decline; released a high-resolution, cloud-free satellite map of Antarctica, expanded an online glacier photograph database; and began planning data collection and management efforts for the upcoming International Polar Year (IPY). These and many other contributions to cryospheric research and data management are included in this report.

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

NSIDC/WDC will make fundamental contributions to cryospheric science and will excel in managing data and disseminating information in order to advance understanding of the Earth system.

Highlights

NSIDC Monitored Arctic Sea Ice Decline

NSIDC and NASA scientists continued to track a stunning reduction in Arctic sea ice at the end of the northern summer, as well as a decline the end of the northern winter. The persistence of near-record low extents lead the group to conclude that Arctic sea ice is likely on an accelerating, long-term decline. Scientists used NASA Distributed Active Archive Center (DAAC) satellite data from the Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Scanning Radiometer–EOS (AMSR-E), Geoscience Laser Altimeter System (GLAS), and Special Sensor Microwave/Imager (SSM/I). For more information, see the NSIDC press release (http://nsidc.org/news/press/20050928_trendscontinue.html).

NSIDC and A Tour of the Cryosphere, Earth s Frozen Assets

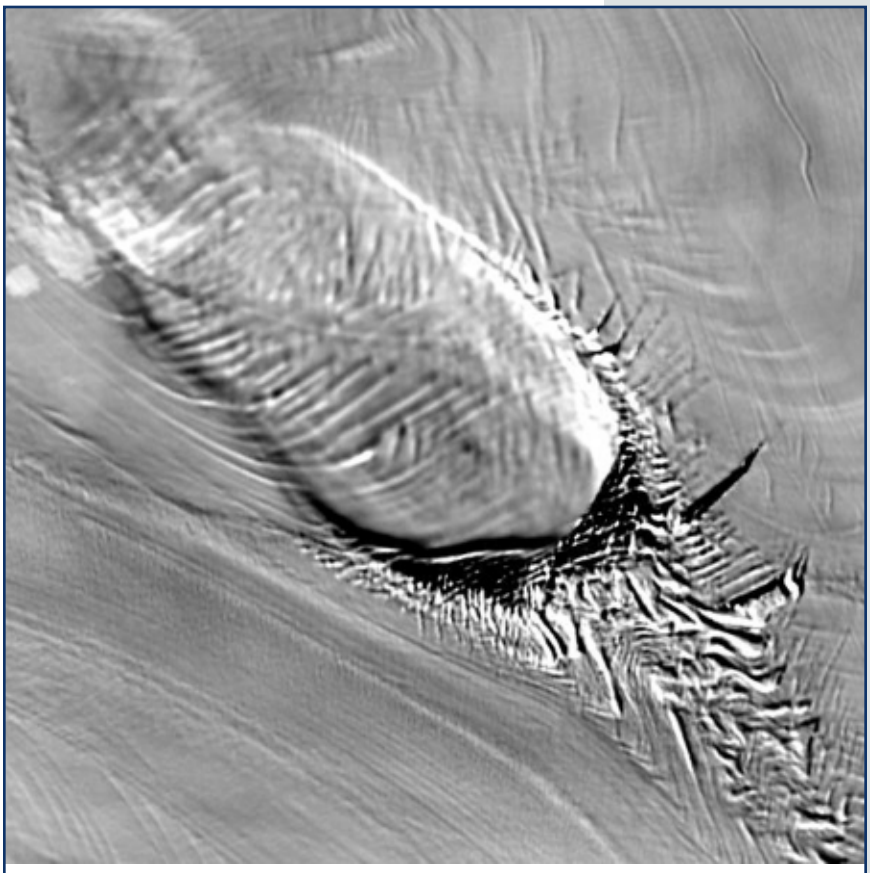
NSIDC contributed to the NASA educational DVD, A Tour of the Cryosphere, Earth's Frozen Assets, released in December 2005. This eight-minute feature animation takes the viewer on a tour of the cryosphere as it exists around the world. From shrinking Arctic sea ice, to retreating glaciers and collapsing Antarctic ice shelves, this unique global view of cryospheric research features state-of-the-art Earth's observing satellite data animations. Walt Meier, Ron Weaver, Mary Jo Brodzik, and Richard Armstrong provided imagery and served as science advisors. For more information, visit NASA's Life on Earth Web site (http://www.nasa.gov/vision/earth/environment/cryosphere.html).

NSIDC Scientists Published Arctic Textbook

Mark Serreze, Senior Scientist, and Roger Barry, NSIDC Director, announced the publication of their textbook, *The Arctic Climate System*. *The Arctic Climate System* provides a comprehensive and accessible overview of Arctic exploration, research, physical characteristics, and climatic features. Details about the book may be found at the Cambridge University Press Web site (http://www.cambridge.org/0521814189).

NSIDC Released New Image Mosaic of Antarctica

NSIDC released a new, high-resolution image mosaic of the Antarctic continent and surrounding islands. The map, called the MODIS Mosaic of Antarctica (MOA), is the best representation to date of the Antarctic continent surface. NSIDC manually cleared clouds, sensor noise, and striping from 260 images. The resulting mosaic has very few artifacts. All land and ice areas (and islands greater than a few hundred meters across) south of 60 degrees south are included in the mosaic. MOA is available through FTP distribution upon request, and geolocated subscenes are available from an interactive Web site (http://nsidc.org/data/moa/).



The new mosaic provides close-ups of features such as Steershead Ice Rise on the Ross Ice Shelf, Antarctica.

NSIDC Data Contributed to Study on Alaskan Shrubs and Changing Climate

Researchers have found that higher Arctic temperatures are causing vegetation changes on Alaska's North Slope. The study, "Changing snow and shrub conditions affect albedo with global implications," was published in the first issue of *Journal of Geophysical Research - Biogeosciences*, Volume 110. NSIDC houses two of the data sets used in this study: Snow and Vegetation Measurements from Selected Sites Near Council, Alaska, USA, 2000-2002; and A Half-Century of Change in Arctic Alaskan Shrubs: A Photographic-Based Assessment. The authors also acknowledged NSIDC scientist Drew Slater's help with fieldwork during this study.

Muir Glacier, photographed in 1941 by William O. Field (top), and in 2004 by Bruce F. Molnia (bottom). This photograph pair is taken from NSIDC's *Online Glacier Photograph Database*.

Online Glacier Photograph Database Tripled in Size

The *Online Glacier Photograph Database*, featured in the 22 July 2005 issue of *Science,* is housed at NSIDC. When the collection could only be seen in person, fewer than a dozen people each year accessed the collection; now, more than 12,000 online viewers visit the collection each year. In July 2005, NSIDC added 2,000 photographs to the database, tripling the size of the online collection and bringing the total number of online prints to 2,914 images. For more information, see the *Online Glacier Photograph Database* (http://nsidc.org/data/g00472.html).

NSIDC Contributed to Permafrost Model Analysis, Shows Extreme Thaw

NCAR and NSIDC scientists conducted an analysis of model results that suggests that global warming may decimate the top three meters or more of perennially frozen ground across the Northern Hemisphere, potentially altering ecosystems as well as damaging buildings and roads across Canada, Alaska, and Russia. The study was the first to examine the state of permafrost in a global model that includes interactions among the atmosphere, ocean, land, and sea-ice, as well as a soil model that depicts freezing and thawing. The results were published in *Geophysical Research Letters*, volume 32, number 24.

NSIDC Testing Google Base

NSIDC began working with Google to test Google Base, a free extension of Google's existing content collection efforts. Google Base is similar to a database, allowing content owners to describe and assign attributes to the information they submit. Google uses this metadata to better target search results to what users need. NSIDC has already submitted metadata for a number of data sets to Google Base and plans to monitor the resulting traffic.

NSIDC Hosted Visiting Scientists

During 2005, visiting scientists Tatiana Khromova and Mingrui Dai conducted cryospheric research at NSIDC. Khromova helped create the Global Land Ice Measurements from Space (GLIMS) database from ASTER images, topographic maps, and other historical glacier observations to estimate glacier area changes in the Tien Shan Mountains in central Asia and in the Caucasus Mountains of Russia. Dai analyzed remotely-sensed and in situ sea ice data to help assimilate the data into sea ice models.

Data Management at NSIDC

NSIDC manages scientific data on behalf of our research communities, in turn supporting the quality, efficiency, and innovativeness of the research that depends on these data. NSIDC distributes hundreds of data sets, and continuously adds new data sets, extends temporal coverage of existing data sets, and publishes new data algorithms and versions using refined processing methods that represent the most current scientific methodologies for retrieving parameters from remote sensing data.

We strive to disseminate scientific data that is accessible, discoverable, understandable, reliable, and stable. Much more than physically housing and distributing data, we add value to the data we manage by enhancing its usefulness, promoting its discovery and use, developing algorithms that retrieve additional parameters from data, and developing tools that facilitate working with data. Experience, in-depth knowledge, and the professional diversity of our staff have resulted in a cost-effective, responsive, and flexible data management discipline at NSIDC.

Data centers

NSIDC includes several data centers, each focusing on a particular objective as defined by the sponsoring agency. These data centers allow NSIDC personnel to develop strong connections to data providers and to maintain expertise in their methods and topics, whether satellite or ground observations, Arctic or Antarctic, or specialized fields such as frozen ground research. In 2005, NSIDC contained seven data centers, whose highlights are featured in the following section of this report.

Data Center	Focus
The Arctic System Science (ARCSS) Data Coordination Center (ADCC)	NSF-funded Arctic System Science Program data
U.S. Antarctic Data Coordination Center (USADCC)	U.S.-funded Antarctic scientific data
Antarctic Glaciological Data Center (AGDC)	Antarctic glaciological and cryospheric system data collected by the U.S. Antarctic Program
The Frozen Ground Data Center (FGDC)	Data related to permafrost and seasonally frozen ground
Global Land Ice Measurements from Space (GLIMS)	Inventory of critical information about the extent and rates of change of the world's estimated 160,000 glaciers
NASA Distributed Active Archive Center (NSIDC DAAC)	Snow and ice data from NASA's past and current Earth science research satellites and field measurement programs
NOAA at NSIDC and the World Data Center for Glaciology, Boulder (WDC)	Snow and ice in situ data, data rescue, and data sets from operational communities such as the U.S. Navy

Product teams

Product teams at NSIDC focus on ingesting and processing data, assuring data quality, and publishing new data sets for access by researchers. Using well-defined processes, cross-functional teams of data operations specialists, scientists, scientific programmers, user support experts, technical writers, and Web designers manage quality control, documentation, accessibility, and scientific and technical aspects, such as adjustments to data processing. Data operations staff provide feedback to scientists and developers about problems observed during processing, which leads to improvement in the quality of the product. Product teams provide suggestions on organization of the data, which improves accessibility and ease of use.

NSIDC scientists and scientific programmers

Scientists at NSIDC serve on product teams, collaborate on special research topics such as sea ice measurement or frozen ground studies, perform research with the data, and create new data sets in response to research questions. Because they understand the research questions in these fields, and how researchers want to use data, their contributions ensure that NSIDC data, documentation, discovery, and access meet the needs of the research community. NSIDC researchers specialize in numerous topics in snow, glaciers, sea ice, frozen ground, ice shelves, polar oceanography, and polar meteorology. Several researchers specialize in remote sensing methods for specific parameters.

Metadata and catalog

For each data set, NSIDC generates metadata records. Metadata, which is data about the data, provides documentary and descriptive information about each data set. These metadata, in turn, enable data discovery, support understandability and stability of data, and support its long-term preservation and access. NSIDC staff maintain knowledge of evolving metadata standards, including FGDC and ISO standards. Metadata is increasingly used on the World Wide Web to share information about data holdings and enable discovery through multiple search portals. NSIDC provides metadata to the NASA Global Change Master Directory (GCMD) on an ongoing basis to enable discovery of our data, and has engaged in discussions with other search portals to enhance the dissemination and value of our data.

Data discovery

NSIDC offers multiple data search, access, and distribution capabilities, based on the demands of particular data sets and projects. Satellite remote-sensing data, for example, require sophisticated search, subsetting, and ordering tools, while in situ data sets may be easily searched by science parameter and downloaded through FTP. Programming staff at NSIDC work continuously with NSIDC scientists and User Services to develop search mechanisms that more closely match the needs of data users. Data Operations specialists and User Services staff work one-on-one with users who have unique issues with access to data, to help them get data as efficiently as possible (for example, users who need long time-series data and have no easy way to identify the thousands of granules they want).

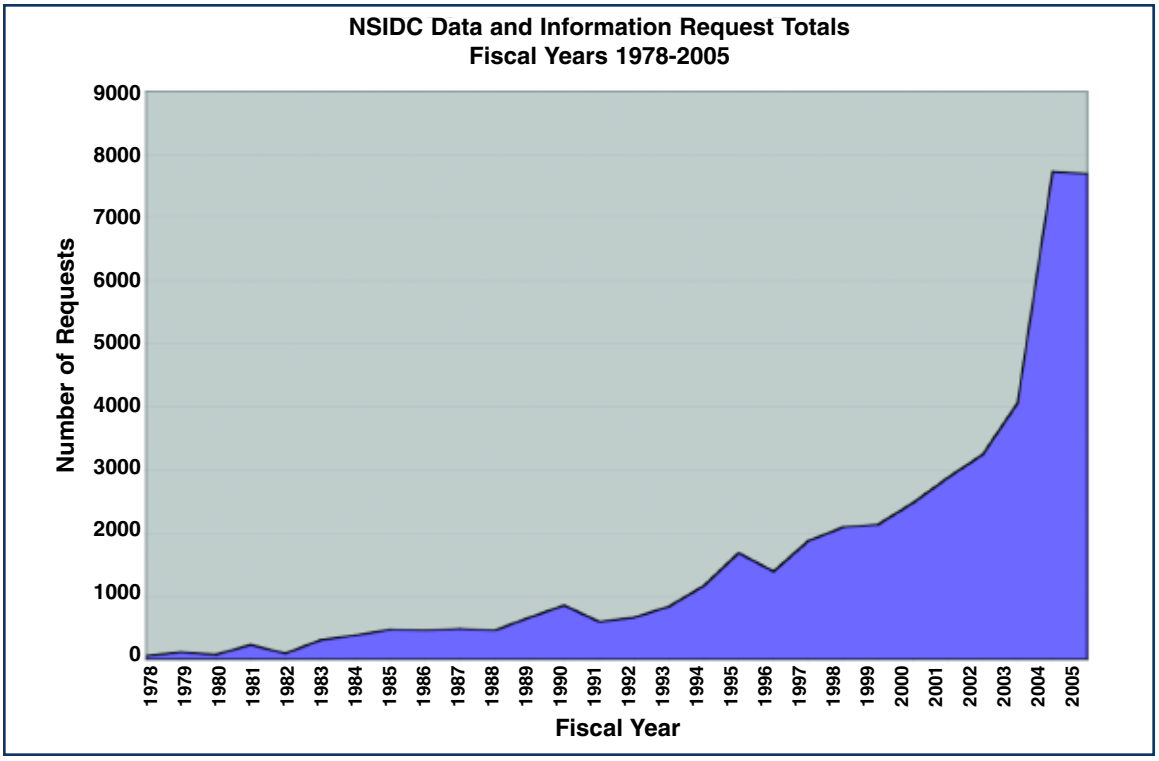
Data quality

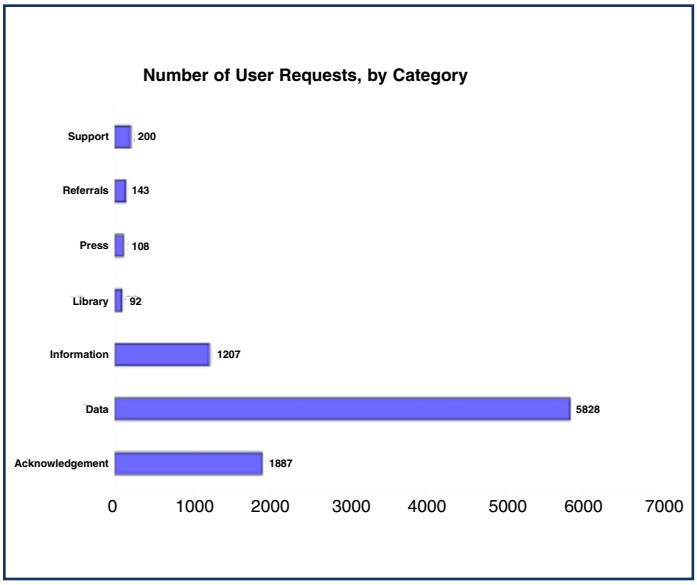
NSIDC product teams strive to ensure that data are of the highest possible quality for scientific research. Data quality activities may range from statistical checks of data integrity and completeness, to researching and assimilating techniques for development of data sets, design, analysis, software development, production, user interface, scientific interpretation, and data delivery. Operations team members monitor data production to detect processing errors quickly. We maintain close ties with external and internal developers to expedite problem identification and resolution, and identify “beta testers” who get early access to the data to provide additional feedback on technical issues about the data.

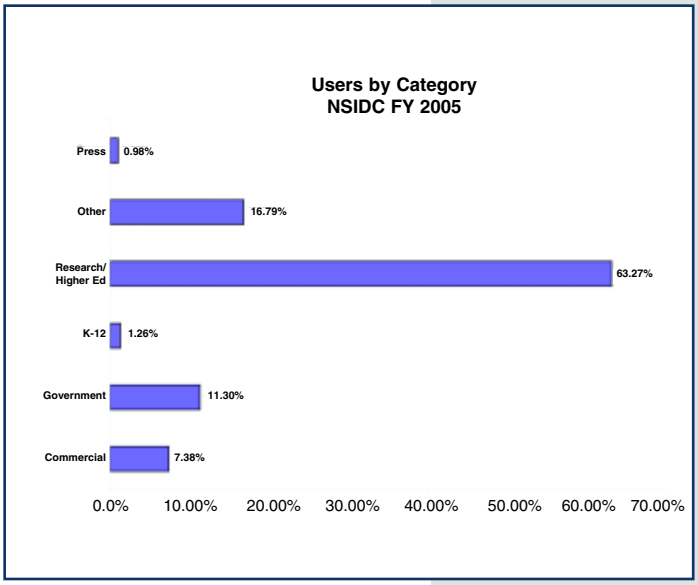
User services

NSIDC's User Services Office (USO) is staffed by specialists who maintain scientific and technical knowledge about the data we distribute. These specialists are also expert in user needs, and represent those needs on product teams, helping to ensure data and documentation usability. They are the first point of contact for all user inquiries; they provide prompt responses to requests, solve problems, and research user questions about data. USO also helps educate data users on our holdings through e-mail broadcasts, development of cryospheric parameter brochures, and our quarterly data newsletter, *NSIDC Notes*.

To ensure prompt response and resolution, USO tracks user requests. During 2005, USO responded to 7,692 user inquires. The following charts depict historical growth in user requests, breakdown by type of request, and by type of user:







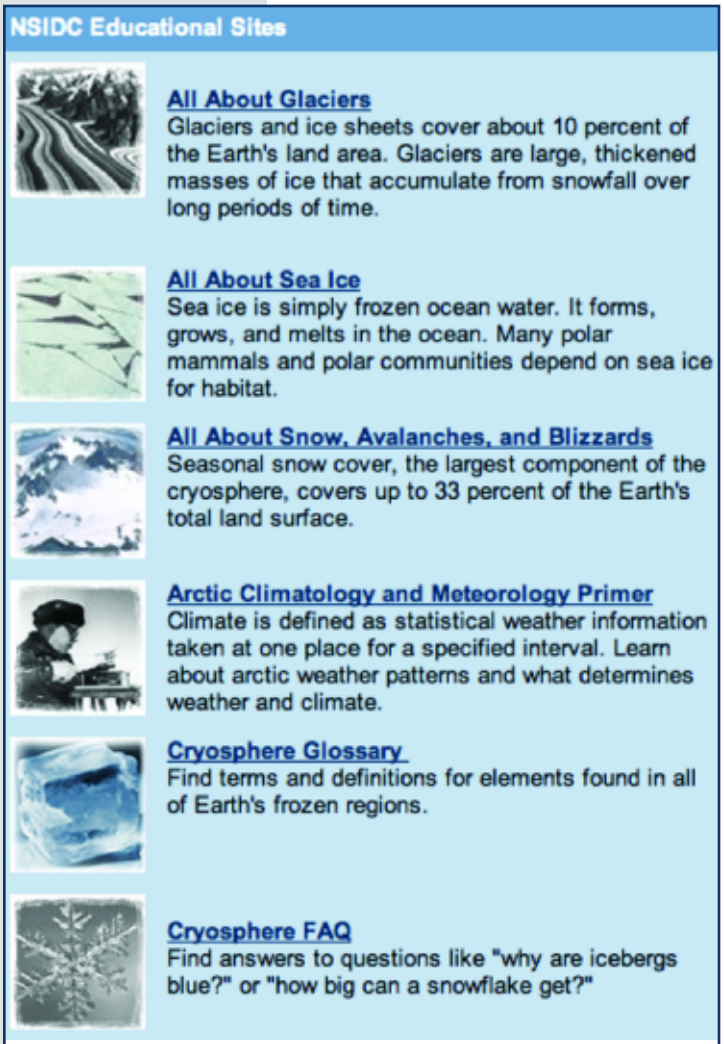
Information Center

NSIDC data include a unique, specialized research collection focusing on the cryosphere. This collection is open to researchers who visit NSIDC, and includes published and unpublished analog materials on snow cover, land and sea ice, cold climates, and frozen ground, 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. Our analog data archives include rare field notebooks, photographs, and other research materials.

During 2005, library and archives staff hosted visitors from around the world; added more than 200 items to the collection; responded to reference requests from researchers and the public; repaired and protected older and historical holdings; developed and implemented new catalog software; and coordinated the digitization of rare materials, such as the Dehn Ice Chart collection and the Glacier Photograph collection.

NSIDC on the Web

NSIDC's primary interface to the world is through our Web site (http://nsidc.org). Users may obtain general information about data offerings, search the data catalog, use our search and ordering tools, obtain data, and obtain data set documentation. Our site also provides general information about the cryosphere and research developments to the public, press, educators, and students. During 2005, our site received nearly 30 million page requests from more than one million distinct users. Many of these visitors were seeking general information about the cryosphere, such as about glaciers, snow, or ice. See "Outreach" below for more information about the Web content we host for these visitors.



Main contents of *The Cryosphere* section of the NSIDC Web site.

Scientific data users can obtain information on all of our data holdings using our Web site, and many products can be downloaded directly from the Web using FTP. Users can also search for and create distribution requests for larger data sets, in particular remote-sensing data and data subsets.

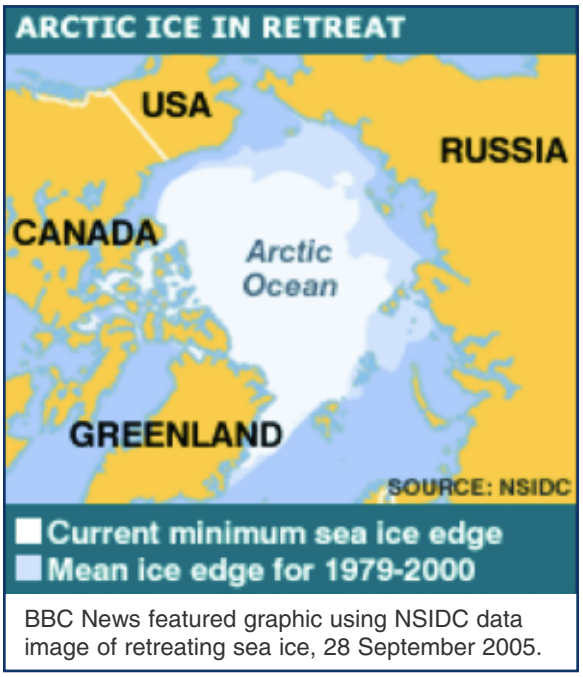
NSIDC staff and product teams include technology experts, user interface design specialists, and professional designers and writers who focus on making interactions with our site efficient, intuitive, and productive. During 2005, we enhanced several content areas to improve content and ease of use. We also completed a usability study that examined the structure of our site, with the goal of implementing improved navigation and search capabilities during 2007.

Outreach

NSIDC scientists and writers research, create, and maintain *The Cryosphere* (http://nsidc.org/cryosphere/), containing educational materials about snow, ice, glaciers, sea ice, Arctic meteorology, and other cryospheric topics of interest to K-12 students and the public. This reference work is extremely popular, receiving nearly 3.5 million visits during 2005.

Other outreach events in 2005 included a major scientific press release regarding the unprecedented decline of Arctic sea ice at the end of summer 2005. Researchers believe this melt to be a strong indicator of a globally warming climate. This research was picked up by major news media around the world. NSIDC's outreach coordinator responded to inquiries from more than 147 media representatives; coordinated scientist television interviews with CNN and local channel KBO; coordinated on-site visits from Discovery Canada, BBC News, and BBC/Discovery Channel for filming; providing data images; coordinated numerous telephone interviews; and disseminated scientific facts in response to journalist inquiries.

Another major outreach project at NSIDC, on behalf of the NASA DAACs, was the eleventh annual publication of *NASA: Supporting Earth System Science 2005*. This fifty-two page print publication and accompanying Web site describes research applications of NASA remote sensing data, in feature story format and including color data images. The complete publication is available online, and stories are republished on the DAAC-sponsored site, "NASA Earth System Science Data and Services" (http://nasadaacs.eos.nasa.gov/), which NSIDC develops and maintains on behalf of the DAACs to promote interest in DAAC data products. NSIDC publications staff research and write ten to twelve articles each year. This publication continues to be a popular educational piece for NASA audiences and also generates interest among potential data users.



BBC News featured graphic using NSIDC data image of retreating sea ice, 28 September 2005.

The cover of *NASA: Supporting Earth System Science 2005*.

The Distributed Active Archive Center (DAAC)

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

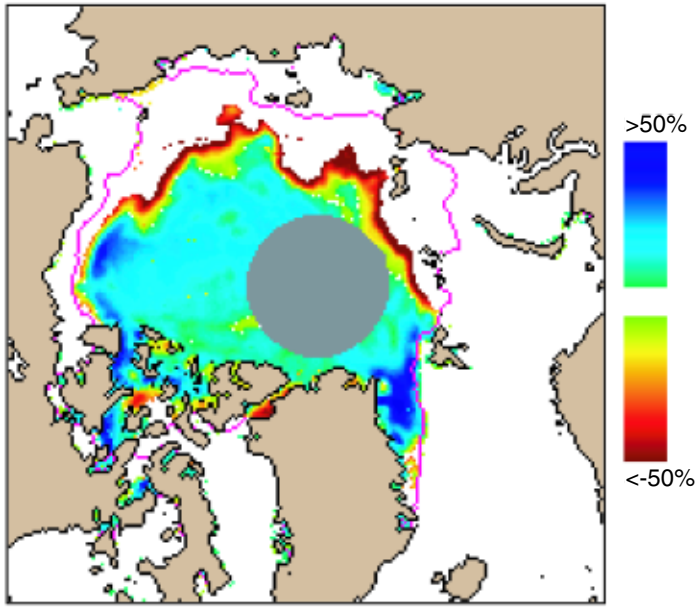
- Moderate Resolution Imaging Spectroradiometer (MODIS)
- Advanced Microwave Scanning Radiometer–EOS (AMSR-E)
- Geoscience Laser Altimeter System (GLAS)
- Special Sensor Microwave/Imager (SSM/I) and the follow-on Special Sensor Microwave Imager/Sounder (SSMI/S)
- National Oceanic and Atmospheric Administration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

Ron Weaver is the DAAC manager, Vince Troisi is the deputy DAAC manager and senior systems engineer, and Roger Barry is the senior DAAC scientist.

The Year in Summary

All data product sets from MODIS on Aqua and Terra, AMSR-E on Aqua and GLAS on ICESat continue to be ingested, archived, and distributed. Operations during the year were routine. Data distribution increased from about 654 megabytes (MB) per month at the beginning of 2005 to 3,225 MB per month in December 2005. This increase in distribution is encouraging and indicates wider use of all types of products and data sets. By the end of 2005, the size of DAAC data holdings was 75 terabytes (TB) and 4.7 million data granules.

5-Day Mean: September 2005 Minimum Concentration Anomaly



September 2005 broke the record for low summer sea ice extent, the measure of area containing at least 15 percent ice. The ice extent is shown by the edge of the colored region. The long-term average minimum extent contour (1979 to 2000) is in magenta. The grey circle indicates the area where the satellite does not take data. Data are from DAAC-held passive microwave products.

In 2005 we decommissioned our DLT tape archive after all the data were transferred to the Massive Array of Idle Disks (MAID) device. We are an "early adopter" of the COPAN MAID. We chose the MAID to replace our V0 tape storage archive, which was at the end of its operational life. We also expanded our V0 Redundant Array of Independent Disks (RAID) capacity.

External Data Coordination Efforts

DAAC staff members began planning for the International Polar Year (2007-2008), presenting talks and posters at the 2005 American Geophysical Union (AGU) Fall Meeting, and contributing to NSIDC's expressions of interest for IPY Data Management and grey literature rescue.

Roger Barry participated in the successful effort to create the International Association for the Cryosphere Sciences (IACS), under the International Union of Geodesy and Geophysics (IUGG) umbrella. The DAAC scientist

chaired the committee, which wrote the Cryosphere Association white paper proposal. The first formal meeting will be at the IUGG meeting in Perugia, Italy, in July 2007.

Ron Weaver and Vince Troisi continued participation 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 bi-weekly teleconferences. The NSIDC User Services Office (USO) lead also became the User Services Working Group (USWG) co-chair in October 2004. She will continue to fill this role through October 2006.

Science Data Operations

Moderate Resolution Imaging Spectroradiometer (MODIS) Products

(http://nsidc.org/data/modis/)

MODIS is an optical, 36-spectral-band instrument aboard the NASA Earth Observing System (EOS) Terra and Aqua satellites that provides daily global coverage at spatial resolutions of 250, 500, and 1,000 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 2005.

GLAS Data from ICESat

(http://nsidc.org/daac/glas/)

The Geoscience Laser Altimeter System (GLAS) is the sole instrument on the Ice, Cloud, and land Elevation Satellite (ICESat), launched in January 2003. The GLAS instrument provides high-resolution elevation data that will improve understanding of ice sheet mass balance in the Polar Regions. NSIDC archives and distributes 15 products, including Level-1A, -1B, and -2 laser altimetry and atmospheric LIDAR data. The initial data stream was approximately 20 gigabytes (GB) per day. However, problems with the instrument have been ameliorated by not running the lasers continuously, but intermittently instead. So far, there have been three campaigns each year, most of them lasting about 33 days each. Details about the mission, science algorithms, and products are available at the NSIDC GLAS Web site.

AMSR-E data from AQUA

(http://nsidc.org/daac/amsr/)

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

AMSR-E Validation Data Management

(http://nsidc.org/data/amsr_validation/)

NSIDC is supporting the AMSR-E product validation activities by hosting a Web site portal to all AMSR-E validation experiments, including soil moisture, rainfall, and cryospheric validation campaigns. NSIDC provides documentation (user guides) as well as metadata (GCMD DIFS) for AMSR-E validation experiments and collaborates with the AMSR-E Science Investigator-Led Processing Systems (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.

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

Polar Stereographic Products

Bootstrap Sea Ice Concentrations
(http://nsidc.org/data/nsidc-0079.html)

NASA Team Sea Ice Concentrations
(http://nsidc.org/data/nsidc-0051.html)

The NSIDC polar stereographic standard sea ice products were routinely updated, and Goddard sea ice time series products were updated through 2005 for both NASA Team and Bootstrap data sets. Accompanying ancillary products of ice area/extent, monthly climatologies, and 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 also available online.

DMSP SSM/I Daily Polar Gridded Brightness Temperatures
(http://nsidc.org/data/nsidc-0001.html)

Reprocessing of this product began in 2005. An error was discovered in the fields due to software used for data before 2000. The error resulted in some scan lines with erroneous data not being flagged with bad data. The reprocessing continued into 2006, with the expectation that it will be complete in mid-2006.

DMSP SSM/I Daily and Monthly Polar Gridded Sea Ice Concentrations
(http://nsidc.org/data/nsidc-0002.html)

Routine processing of these products continued, and kept up with ingest from Remote Sensing Systems.

NISE Products
(http://nsidc.org/data/nise1.html)

We implemented several minor changes in the NISE product, and we initiated a new configuration management plan for NISE software. This was a trailblazing, challenging effort for the data center, because NISE employs different libraries, algorithms, and processing steps. In addition, we created a revised daily image of NISE snow cover over the continental U.S., as well as a running 11-day animation. The animation was used at the NSIDC booth at the 2005 AGU Fall Meeting. The National Polar-orbiting Operational Environmental Satellite System (NPOESS) intends to use NISE 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 generation and distribution of this product.

EASE-Grid products

Regular processing 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. CD-ROM production was discontinued and replaced with online FTP access to the complete SSM/I time series of all three Equal-Area Scalable Earth Grid (EASE-Grid) projections. FTP files are now available to users immediately upon production, with no delays for CD-ROM production.

Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 3
(http://nsidc.org/data/nsidc-0046.html)

We updated this product to incorporate the following improvements:

1) Extension of time series from 2001 to 2005
2) Use of new, improved Goddard Time Series and NRTSI-G data (more suitable for long-term trend analysis than earlier releases)
3) Improved land-ocean-permanent ice mask, derived from BU-MODIS land cover data
4) Includes online data set browse animations, available in JavaScript-enabled browsers

Global Monthly EASE-Grid Snow Water Equivalent Climatology
(http://nsidc.org/data/nsidc0271.html)
This product is the first global Snow Water Equivalent (SWE) climatology derived from the historical record (1978-2005) of satellite passive microwave data, enhanced with additional snow cover frequency information derived from NOAA weekly snow charts. Produced in the 25-kilometer Equal-Area Scaleable Earth Grid (EASEGrid), the new product is unique in blending information from both kinds of sensors on a global scale for the period when both types of sensor data are available. Periodic updates are planned, and will be made available on NSIDC's FTP site as new data from both sources become available. Data are free and available through anonymous FTP, and users with JavaScript-enabled browsers can view the entire data set online with the SWE Browser (http://nsidc.org/data/docs/daac/nsidc0271_ease_grid_swe_climatology/browse/viewer.html).

Outreach and Collaboration

All About Sea Ice Web site
(http://nsidc.org/seaice/)
NSIDC debuted this site as an information source about sea ice, including physical processes, its importance in climate, and data examples.

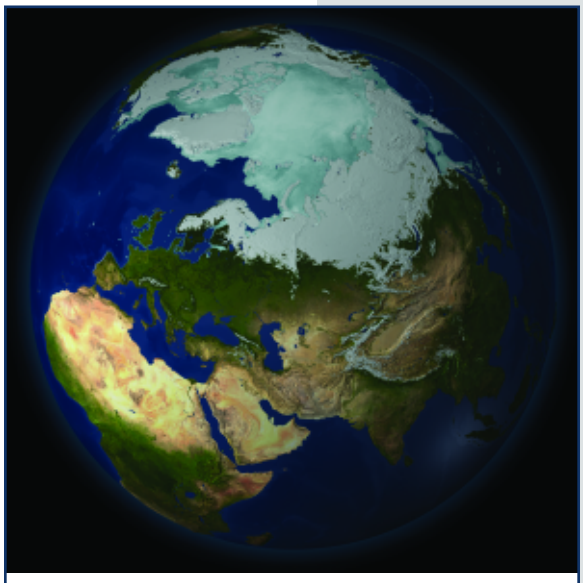
Scatterometry Web site
(http://nsidc.org/daac/scatterometry/)
To better serve data users, NSIDC implemented this site, which includes information and links to order data through the NASA Scatterometer Climate Record Pathfinder (SCP).

2005 Arctic sea ice extent press release
(http://nsidc.org/seaice_index/)
NSIDC participated in a joint press release with NASA Goddard on the record low September 2005 Arctic sea ice extent. NSIDC used the polar stereographic products and the Sea Ice Index to produce the accompanying images.

NASA DVD, *A Tour of the Cryosphere, Earth's Frozen Assets*
(http://www.nasa.gov/vision/earth/environment/cryosphere.html)
NSIDC contributed polar stereographic sea ice data, along with other data and imagery, to the DVD, *A Tour of the Cryosphere, Earth's Frozen Assets*, which was created by the NASA Scientific Visualization Studio. The DVD was released at the 2005 AGU Fall Meeting.

Maud Rise Nonlinear Equation of State Study (MAUDNess) expedition
NSIDC provided near real-time support for the NSF-funded MAUDNess expedition, a cruise in the Weddell Sea during July through September 2005, led by chief scientist Dr. Miles McPhee. NSIDC provided operational sea ice motions from AMSR-E imagery.

DAAC Alliance Annual
(http://nasadaacs.eos.nasa.gov/).
As a member of NASA's DAAC Alliance, the NSIDC DAAC published the 11th edition of the DAAC Alliance Annual, *NASA: Supporting Earth System Science 2005*, a multidisciplinary publication that highlights applications and research uses of data from NASA's Earth Observing System satellites. Articles from the 2005 DAAC Alliance Annual are also available electronically on the DAAC Alliance Web site.



This global image highlights the Arctic region on 23 April 2003 with AMSR-E Sea Ice Brightness Temperature shown in light blue and MODIS Daily Snow Cover shown in white. The DAAC-held AMSR-E and MODIS data products are distributed by NSIDC. Image is from the DVD, *A Tour of the Cryosphere, Earth's Frozen Assets*. (Courtesy NASA/Goddard Space Flight Center Scientific Visualization Studio)

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, NSF has continuously funded ADCC at NSIDC. During 2005, ADCC operated once again on a reduced supplemental budget. The purpose of ADCC is to present and archive ARCSS related research data on the ADCC Web site, to prepare metadata for submission to the Global Change Master Directory, and to provide long-term storage of data within its archive. The Web site allows users to search using the name of the Principal Investigator (PI), the project title, the measured parameter, geographical location, or keywords. An online 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 ADCC. Chris McNeave is the data coordinator and Lindsay Husted is the technical writer, in addition to several other staff members who work on this project as required. Rudolph Dichtl is the ADCC manager and PI and Dr. Roger Barry is Co-PI. They both lead ADCC activities at NSIDC. During 2005 ADCC received and processed 16 Metadata Submission Forms, each indicating a submission of a new ARCSS data set for publication.

Featured Data Products

IFSAR Imagery and Related GIS Data for Barrow, Alaska, USA
(http://nsidc.org/data/barrow/)
This suite of products contains Interferometric Synthetic Aperture Radar (IFSAR) imagery and terrain models, and related Geographic Information Systems (GIS) layers to support multidisciplinary research of environmental changes in the Barrow, Alaska, area. Two versions of the data are available. High resolution data on five DVDs are available to NSF-funded investigators. Reduced resolution data are available to the general public and are distributed by FTP or on one CD-ROM.

Svalbard Fjord Conductivity, Temperature, Depth Data, 2001-2004
(http://nsidc.org/data/arcss150.html)
This product includes vertical ocean profiles of temperature, salinity and backscatter beneath ice cover in Svalbard Fjord, Norway.

For more information, visit the ADCC Web site (http://nsidc.org/arcss/)

Summer Surface Hydrographic Measurements in the Laptev Sea 1980-2000
(http://nsidc.org/data/arcss099.html)
This ADCC data set consists of surface hydrographic data, including temperature and salinity, from the Laptev Sea.

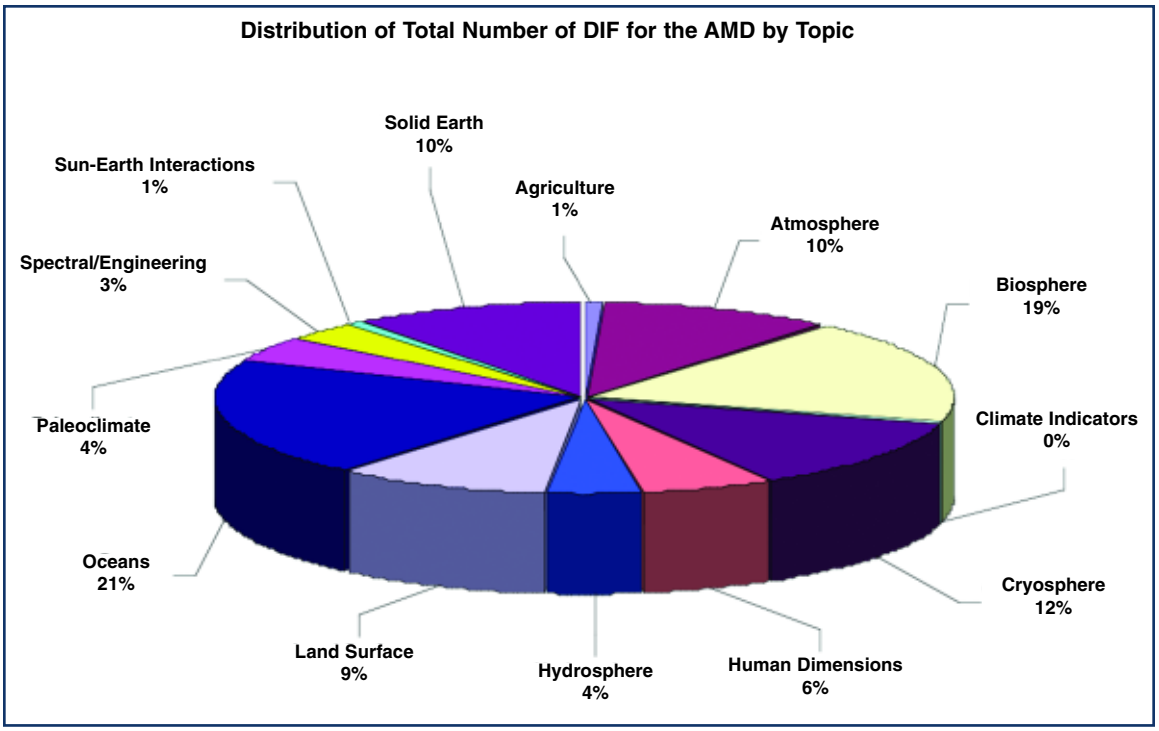
A Half-Century of Change in Arctic Alaskan Shrubs: A Photographic-Based Assessment
(http://nsidc.org/data/arcss130.html)
This ADCC data set provides snapshots of vegetation cover change in northern Alaska using pairs of aerial photographs taken fifty years apart.

Radiocarbon Dates and Pollen Data, Peterson Erosional Remnant, Arctic Coastal Plain, Alaska
(http://nsidc.org/data/arcss136.html)
This data set consists of pollen data and radiocarbon (14C) dates resulting from microscopic analysis and mass spectrometry of soil cores taken from the Peterson Erosional Remnant, located on the Arctic Coastal Plain near Barrow, Alaska.

U.S. Antarctic Data Coordination Center (USADCC)

Since 1996, NSF has funded the U.S. Antarctic Data Coordination Center (USADCC) at the National Snow and Ice Data Center (NSIDC) to facilitate the development of U.S. data set descriptions for inclusion in the Antarctic Master Directory (AMD), a node of the Global Change Master Directory (GCMD). The AMD contains metadata for multidisciplinary Antarctic scientific data collected by 23 countries, under the auspices of the Scientific Committee on Antarctic Research (SCAR) and the Council of Managers of the National Antarctic Programs (COMNAP). Internal to the United States, 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, USADCC represents the United States in the continuing international collaborative effort to develop, implement, and maintain the AMD. United States-contributed metadata records in the AMD now number more than 930, as of July 2006 (up from 836 in September 2005). AMD use represents a considerable fraction of total GCMD usage. The USADCC Web site provides information to contributing scientists and users of the AMD, including access to tools, tutorials, and NSF data policies. Rob Bauer, Greg Scharfen, and Clark Judy lead the USADCC activities at NSIDC.



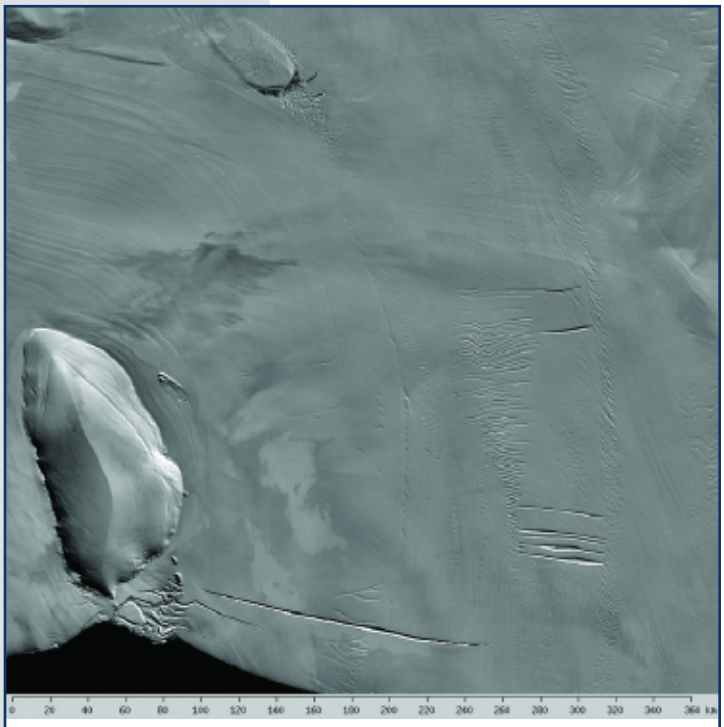
For more information, visit the USADCC Web site (http://nsidc.org/usadcc/)

Antarctic Glaciological Data Center (AGDC)

Antarctic Data Management

NSIDC operates two Antarctic data management projects for the National Science Foundation Office of Polar Programs (NSF OPP): the Antarctic Glaciological Data Center (AGDC) and the U.S. Antarctic Data Coordination Center (USADCC). The archives provide long-term access to Antarctic data sets so that past and present findings are available for comparison with future data in change-detection studies. By facilitating broad data access, the centers promote interdisciplinary scientific research.

AGDC archives and distributes Antarctic glaciological and cryospheric system data collected by the U.S. Antarctic Program. Furthermore, AGDC provides data management for the U.S. Antarctic Glaciological Program and related cryospheric science investigations. AGDC archives and distributes physical and geochemical data, such as ice core chemistry measurements, ice surface elevations, ice thicknesses, bedrock topography, snow accumulation records, firn temperatures, ice velocity measurements from remote sensing imagery, and other various forms of field survey data. Ted Scambos (PI), and Rob Bauer (Co-Investigator) lead the AGDC activities at NSIDC.



The Mosaic of Antarctica (MOA) map server lets users choose the magnification level for any image. This image illustrates ice movement on the Ross Ice Shelf, showing flow lines and crevasses, in addition to topographic features, like Steershead Ice Rise in the upper left corner. Images are based on MODIS data.

Antarctic Data Discovery

AGDC archives and distributes physical and geochemical data, such as ice core chemistry measurements, ice surface elevations, ice thicknesses, bedrock topography, snow accumulation records, firn temperatures, ice velocity measurements from remote sensing imagery, and other various forms of field survey data. Data are available through the AGDC Web site.

AGDC is pursuing new approaches to data representation, data discovery, and data distribution through the use of interactive geospatial search tools. The center offers geospatial presentations of data sets using maps and image data of the Antarctic. Image data such as the surface morphology and snow grain size derived from Moderate Resolution Imaging Spectroradiometer (MODIS) images are being migrated into the Mosaic of Antarctica (MOA) data product, which utilizes interactive map server technology. Both AGDC and USADCC are contributing data set locations from the USADCC's metadata files, image time-series data from the AGDC's Images of Antarctic Ice Shelves, project point data from the AGDC's Web archive, and velocity vector locations from Antarctic outlet glaciers to Web-based search and discovery applications—Google Earth, for example.

Educational Resources

NSIDC is a source of scientific information for educators, students, researchers, scientists, decision makers, and journalists interested in learning or teaching about the cold regions of our planet. AGDC conducts outreach efforts and maintains educational Web sites where users can learn about the expeditions of our in-house scientist and find research updates for the latest information on what scientists are learning. For more information, visit the Icetrek Web site (http://nsidc.org/icetrek) and the NSIDC Megadunes Web site (http://nsidc.org/antarctica/megadunes/).

Featured Data Products

MODIS Mosaic of Antarctica (MOA) Image Map

(http://nsidc.org/data/nsidc-0280.html)

Staff from the National Snow and Ice Data Center (NSIDC) and the University of New Hampshire have assembled a digital image map and a snow-grain-size image of the Antarctic continent and surrounding islands. The Moderate Resolution Imaging Spectroradiometer (MODIS) Mosaic of Antarctica (MOA) image map is a composite of 260 orbit swaths acquired between 20 November 2003 and 29 February 2004. MOA provides a cloud-free view of the ice sheet, ice shelves, and land surfaces. Image data are available through FTP at two spatial grid scales, 750 meters and 125 meters, and through a Web-based map server that can create manually-selected JPEG images.

AWS Data: Characteristics of Snow Megadunes and Their Potential Effect on Ice Core Interpretation

(http://nsidc.org/data/nsidc-0283.html)

One of a series Antarctic Megadunes data sets collected by NSIDC investigators, this AGDC data set contains automated weather station (AWS) data from two sites on the East Antarctic Plateau where the researchers conducted field research. The stations collected snow/firn temperature, air temperature, air pressure, and wind data from 16 January 2004 to 17 November 2004.

Firn Air Inert Gas and Oxygen Observations from Siple Dome, 1996, and the South Pole, 2001

(http://nsidc.org/data/nsidc-0290.html)

This data set includes gas ratios in polar firn air: O_2/N_2, $^{15}N/^{14}N$, $^{40}Ar/N_2$, $^{40}Ar/^{36}Ar$, $^{40}Ar/^{38}Ar$, $^{84}Kr/^{36}Ar$, $^{132}Xe/^{36}Ar$, and $^{22}Ne/^{36}Ar$. Investigators sampled air from the permeable snow pack (firn) layer at two sites: Siple Dome, Antarctica in 1996 and at the South Pole in 2001. They observed and modeled the processes of gravitational settling, thermal fractionation, and preferential exclusion of small gas molecules from closed air bubbles. By measuring these gas ratios in the ancient air preserved in bubbles trapped in ice, researchers can determine past atmospheric composition and local temperature changes along with the relative timing and magnitude of such events.

Subglacial Topography: Airborne Geophysical Survey of the Amundsen Sea Embayment, Antarctica

(http://nsidc.org/data/nsidc-0292.html)

This data set includes five kilometer gridded data from the Airborne Geophysical Survey of the Amundsen Sea Embayment, Antarctica (AGASEA) conducted during the 2004 to 2005 austral summer. Investigators derived maps of the ice sheet surface and subglacial topography, which cover the entire catchments of both the Thwaites Glacier and the Pine Islands Glacier, from airborne survey systems mounted on a Twin Otter aircraft.

For more information, visit the AGDC Web site (http://nsidc.org/agdc/).

Frozen Ground Data Center (FGDC)

Permafrost and seasonally frozen ground regions occupy approximately 24 percent and 60 percent, respectively, of the exposed land surface in the Northern Hemisphere. The actual area underlain by permafrost is approximately 12 to 18 percent of the exposed land area. Frozen ground data and information are critical for fundamental process understanding, environmental change detection, impact assessment, model validation, and engineering applications.

FGDC collaborates with the International Permafrost Association (IPA) to manage, develop, and distribute frozen ground data products. The most popular product continues to be the Circum-Arctic Map of Permafrost and Ground-Ice Conditions followed by the Northern Circumpolar Soils Map, both IPA products. During the period from September 2005 to August 2006, a total of 2,014 distinct users ordered 18.4 GB of data through FTP during that period. In addition, 39 users contacted the User Services Office directly for assistance, usually to order the CAPS2 CDs.

Planning for a CAPS 3.0 CD Rom is under discussion. Since the production of CAPS 2.0 in 2003, there has been essentially no support for the management of the new data, and no support for interconnection between FGDC and the many Global Geocryological Database (GGD) products held elsewhere. It is likely that more of these data will be lost by the time the Ninth International Conference on Permafrost is held in 2008. A collective decision has been made to delay production until funding and initial data sets from International Polar Year (IPY) projects are available. Plans are to issue the CD in early 2010.

Featured Data Products

Geocryology and Geocryological Zonation of Mongolia
(http://www.nsidc.org/data/ggd648.html)
The map of Geocryology and Geocryological Zonation of Mongolia was derived from the National Atlas of Mongolia. The data set depicts the distribution and general properties of permafrost and seasonally frozen ground and locations of specific cryogenic phenomena in Mongolia. Originally released in 1990, the data were digitized in 2005.

The Arctic Soil Freeze/Thaw Status from SMMR and SSM/I, Version 2
(http://nsidc.org/data/ggd641.html)
This product contains near-surface (<five centimeter) soil freeze/thaw status on snow-free and snow-covered land surfaces over the Arctic terrestrial drainage basin. Data are in the 25-kilometer resolution EASE-Grid format.

For more information, visit the FGDC Web site (http://nsidc.org/fgdc/).

The Northern Hemisphere EASE-Grid Annual Freezing and Thawing Indices, 1901-2002
(http://nsidc.org/data/ggd649.html)
This data set contains annual freezing and thawing indices based on the monthly mean air temperature for each year from 1901 to 2002.

The Northern Hemisphere Seasonal and Intermittent Frozen Ground Areas 1901-200
(http://nsidc.org/data/ggd650.html)
This product contains monthly values of the total exposed land area of seasonally frozen ground and annual values for intermittently frozen ground in the Northern Hemisphere.

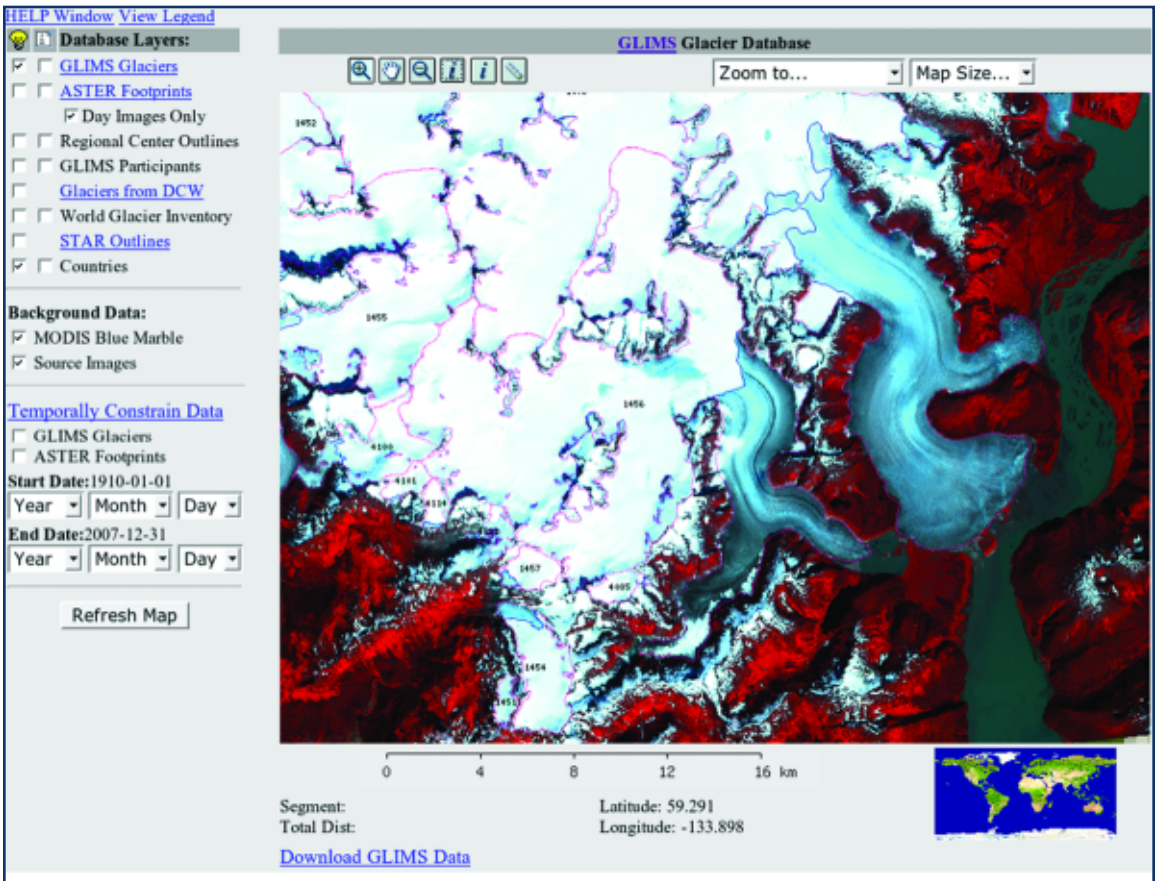
Global Land Ice Measurements from Space (GLIMS)

GLIMS Data Products at NSIDC

The GLIMS project is creating an inventory of the majority of the world's estimated 160,000 glaciers and mapping their extent and rate of change. This work is being undertaken in direct collaboration with the World Glacier Monitoring Service (WGMS) in Zurich, Switzerland, and is considered to be a logical extension of the WGMS World Glacier Inventory (WGI). GLIMS is an international project with participation from more than 60 institutions in 28 nations worldwide. Each institution (called a Regional Center, or RC) oversees the creation and analysis of data for a particular region appropriate to their expertise. These data are submitted to the GLIMS database at NSIDC. This Web site provides an overview of the GLIMS Glacier Database and describes the GLIMS Web Mapping Service (WMS) as well as providing links to the GLIMS WMS, the data submissions page, data analysis, related research, and the main GLIMS project home page. The NSIDC GLIMS project is funded through research grants from NASA.

Database

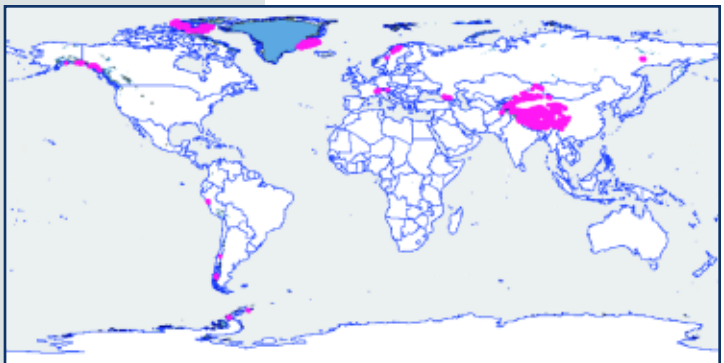
The NSIDC GLIMS project has created a geospatial and temporal database composed of glacier outlines and various scalar attributes. These data are derived from high resolution optical satellite imagery, primarily the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument aboard the NASA EOS Terra satellite and the LandSat Enhanced Thematic Mapper Plus (ETM+), while historic data (maps and photographs) are also 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 imple-



This screenshot of the GLIMS MapServer shows database layers and options for temporally constraining data.

mented a Web-based interface to the GLIMS glacier database that enables exploration of the data through interactive maps. The GLIMS Glacier Database currently contains outlines for more than 53,000 glaciers including high-resolution imagery for some areas as well as information about GLIMS participants and institutions.

The database also includes metadata for more than 100,000 ASTER images acquired over glacierized terrain. The ASTER footprints can be spatially viewed, temporally constrained, and queried in order to help users quickly find ASTER imagery of interest. Statistics on the number and quality of ASTER scenes, grouped by RC, have been generated. This information is crucial to understanding where suitable images currently exist and for determining what regions require an increased priority in ASTER acquisition scheduling.



This base map shows the world's glaciers in blue, and shows GLIMS glacier outlines in red.

MapServer

(http://glims.colorado.edu/glacierdata/)

The GLIMS MapServer Web site allows users to view and query several thematic layers, including glacier outlines, ASTER footprints, GLIMS Regional Center locations, and the World Glacier Inventory. Query results can be downloaded into a number of GIS-compatible formats, including ESRI Shapefiles, MapInfo tables, Generic Mapping Tools (GMT), and Geographic Mark-up Language (GML). The Web site allows users to perform a variety of functions on the data including attribute querying, selecting, and exporting the glacial data through the use of a visual selection map or a form-based selection process (text search interface). The data are stored in a spatially enabled database (PostGIS), which has sophisticated functions for spatial data analysis and query. The MapServer application provides data from the GLIMS Glacier Database to other Open Geospatial Consortium (OGC)-compliant services through OGC-standard protocols, thereby increasing the utility of this glacier data set.

The GLIMS glacier database represents a fundamental baseline study that will enable scientists to quantify the areal extent of existing glaciers in order to accurately assess the magnitude of glacier change that is occurring worldwide.

Featured Data Product

Glacier Mass Balance and Regime Measurements and Analysis, 1945-2003

(http://nsidc.org/data/g10002.html)

This GLIMS data set was updated in 2005 to include annual mass balances, ablation, accumulation, and equilibrium-line altitude of mountain and sub-polar glaciers outside the two major ice sheets.

For more information, visit the GLIMS Web site (http://nsidc.org/glims/).

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

The NOAA program at NSIDC operates in cooperation with the NOAA National Geophysical Data Center (NGDC) to produce data sets relevant to polar and climate research. We manage about 65 data sets, with an emphasis on in situ data, data rescue, and data sets from operational communities. We also help develop educational pages.

2005 Accomplishments

- NOAA@NSIDC tracked sea ice with the Sea Ice Index (http://nsidc.org/data/seaice_index/). Arctic sea ice reached a new record low in September. The Sea Ice Index, a Web site that allows users to visualize ice trends and anomalies on a month-to-month basis, received almost 40,000 hits from about 5,500 distinct users in September. 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. For more information, see the press release "Sea Ice Decline Intensifies" (http://nsidc.org/news/press/20050928_trendscontinue.html).
- We collaborated with international sea ice charting groups, and maintained Web sites for the International Ice Charting Working Group (IICWG) and the WMO Global Digital Sea Ice Data Bank.
- We continued to improve data sets as resources allowed. For instance, we corrected errors and overhauled the documentation of the World Glacier Inventory. For more information, visit the product Web site (http://nsidc.org/data/g01130.html).

New and Updated Data Products

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

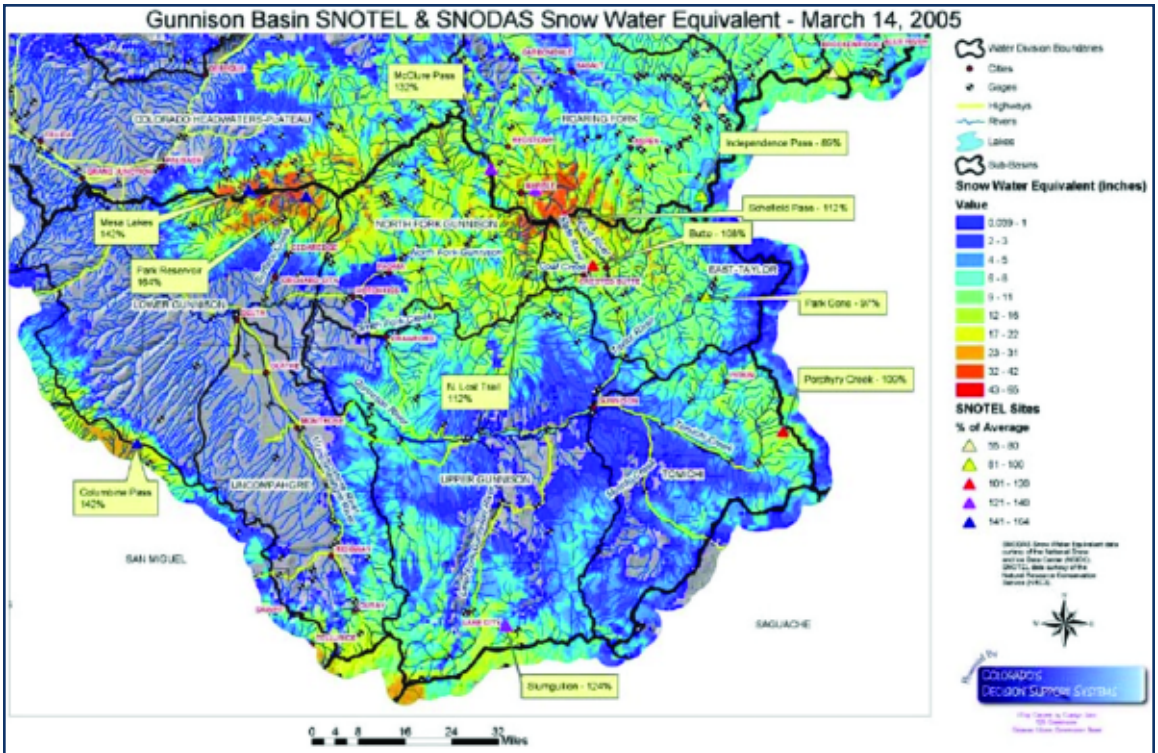
In cooperation with the NOAA National Weather Service (NWS) National Operational Hydrologic Remote Sensing Center (NOHRSC), NSIDC is providing archive, access, and user support for selected SNODAS fields. SNODAS is a modeling and data assimilation system that provides estimates of snow cover and associated variables. The product is unique in terms of its utility for hydrological modeling.

Snowpack runoff provides about 80 percent of Colorado's reservoir storage, and can cause spring flooding. Agencies responsible for managing water resources and flooding risks need to know snowpack characteristics:

- How much snow water equivalent (SWE) does the snowpack contain?
- What is its spatial and elevation distribution?
- What is its evolution with time during the water year?

In Colorado, the Bureau of Reclamation and Colorado Water Conservation Board are intensively assessing SNODAS for hydrological forecasting purposes, because its fields offer advantages over maps from Snow Telemetry (SNOTEL) site data. For more information, visit the Snow Data Assimilation System Colorado Data Plots Web site (http://www.usbr.gov/pmts/rivers/awards/SNODAS/SNODAS_CO_hist.html).

The NOHRSC products available from NSIDC are daily gridded data sets for the continental U.S. at one kilometer spatial resolution. In 2005, we added subsetting options through an NSIDC Graphical Interface for Subsetting, Mapping, and Ordering (GISMO) interface, and a Frequently Asked Questions page that includes help for users who wish to import SNODAS fields into GIS environments.



SNODAS fields can be imported into GIS, as illustrated in this view of SWE in Colorado's Gunnison Basin. (Courtesy Joe Busto, Colorado Water Conservation Board)

NSIDC's agreements with NOAA's SNODAS and IMS snow product data providers stipulate that NSIDC will focus on meeting the needs of research users of retrospective data, rather than those of operational customers or others in need of near-real-time data.

AWI Moored ULS Data, Greenland Sea and Fram Strait, 1991-2002
(http://nsidc.org/data/g02139.html)
Upward Looking Sonar data provided measurements of sea ice draft that can be used to estimate ice thickness. These data were made available in partnership with the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany, as a contribution to the World Climate Research Programme's Arctic Climate System Study/Climate and Cryosphere (ACSYS/CliC) Project.

The Dehn Collection of Arctic Sea Ice Charts, 1953-1986
(http://nsidc.org/data/g01111.html)
The charts, covering the years 1953 to 1986, were put online as a result of a NOAA Climate Database Modernization Project-supported effort to scan approximately 7,000 paper ice charts of Alaska, the western Canadian Arctic and Bering Sea. The collection is uniquely valuable because it predates satellite ice observations, and may shed light on recent summertime retreat of the ice edge north of Alaska. This is a joint project with the NSIDC Library.

IMS Daily Northern Hemisphere Snow and Ice Analysis at 4 km and 24 km Resolution
(http://nsidc.org/data/g02156.html)
The NOAA Interactive Multisensor Snow and Ice Mapping System (IMS) allows analysts from the Office of Satellite Data Processing and Distribution (OSDPD), Satellite Services Division (SSD), Satellite Analysis Branch (SAB), to produce a daily snow and ice analysis at 4 kilometer and 24 kilometer resolution. In cooperation with OSDPD, NSIDC archives and distributes IMS products and image browse files. In response to requests from users for geospatially referenced

products, 4 kilometer data was made available in GeoTIFF format. Manual analysis of satellite imagery produces the most accurate snow cover product available on a hemisphere-wide scale. NSIDC's cryospheric research user community benefits from access to the gridded version of this product, while OSDPD continues to serve its operational users. The IMS products join NWS National Operational Hydrologic Remote Sensing Center products as NOAA operational snow products permanently archived at the NSIDC/World Data Center for Glaciology, Boulder.

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)

Beginning in 1937 and ending in 1993, the High-Latitude Airborne Expeditions program SEVER collected snow and sea ice data for the Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia. A selection of data from these and other expeditions is now available. These data are a unique contribution to Arctic science. Snow measurements were made in the spring and therefore represent annual snow accumulation prior to significant summer melt. Assessments of area, thickness, and the spatial distribution of snow contribute information useful for evaluating Arctic freshwater balance. Sea ice thickness data are valuable additions to the limited and more recent record provided by upward-looking sonar.

Online Glacier Photograph Database Digital Subset

(http://nsidc.org/data/g00472.html)

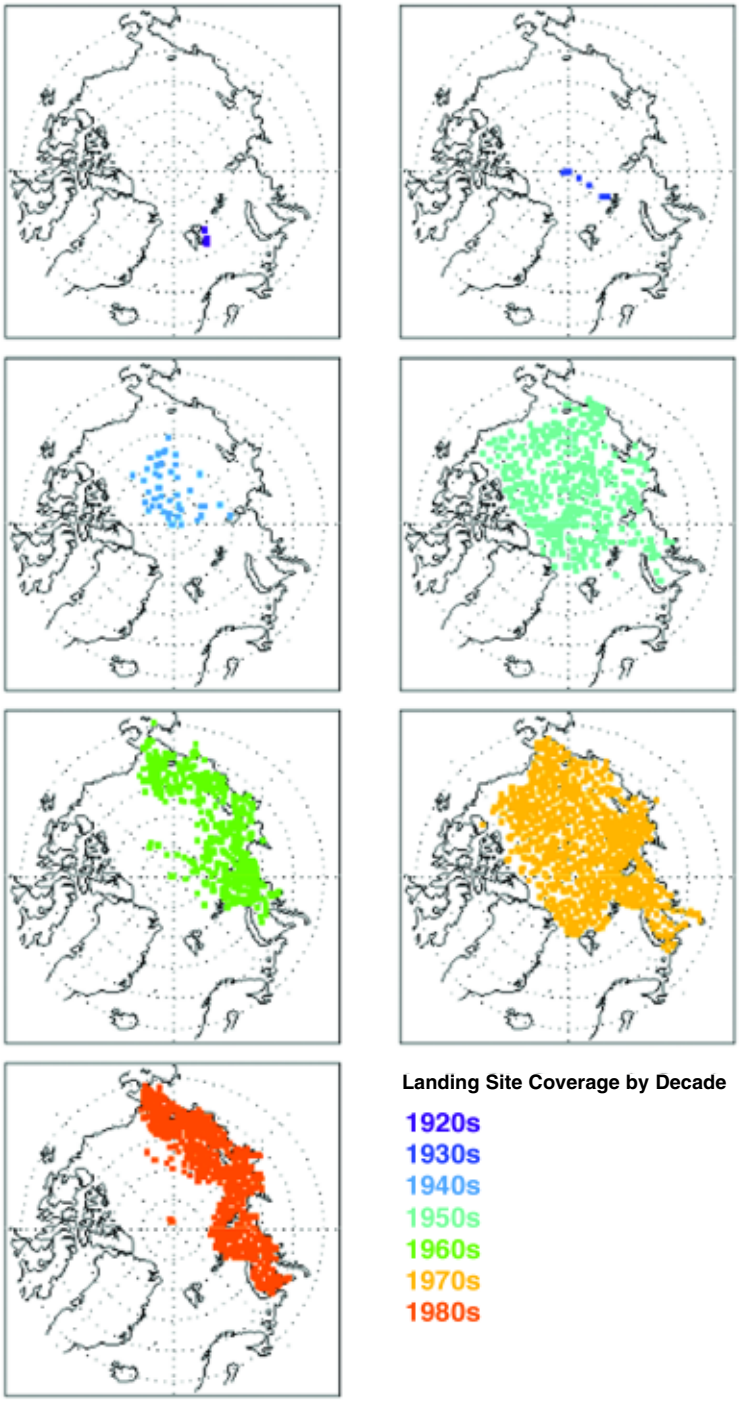
Photographs dating from the 1880s selected from NSIDC's large collection of historical glacier photos are being scanned through a joint NGDC/NSIDC project funded by NOAA's Climate Database Modernization Program. In 2005, we expanded the Glacier Photograph Collection by about 2,000 images, bringing the total available online to about 3,000. Prior to the scanning project only a handful of users saw the delicate prints each year. Now, usage has grown to more than 2,000 users each month. The photographic record of glacier fluctuations can be used to study climate change. This is a joint project with the NSIDC Library. The collection can also be accessed through the World Glacier Map Viewer Web site (http://map.ngdc.noaa.gov/website/nsidc/glacier/viewer.htm) at NGDC.

McBride Glacier, Alaska, photographed in 1950 by W. O. Field.

About NOAA@NSIDC

NOAA@NSIDC activities are supported primarily by NOAA's National Environmental Satellite, Data and Information Service, National Geophysical Data Center. In 2005, the NOAA team included Florence Fetterer (NOAA liaison and program manager), Lisa Ballagh (project manager) and Jonathan Kovarik (operations).

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



Maps showing the position of each landing site by decade for the data product, *Morphometric Characteristics of Ice and Snow in the Arctic Basin: Aircraft Landing Observations from the Former Soviet Union, 1928-1989*.

For more information, visit the NOAA@NSIDC Web site (http://nsidc.org/noaa/).

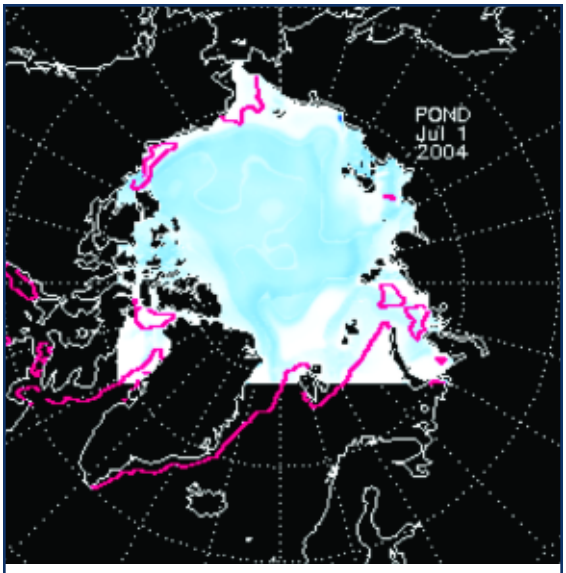
Research

Scientists from around the world use data housed at NSIDC to support their research. Some of these scientists work here at NSIDC, providing both context and input concerning our data management activities. Through their research, our scientists help further understanding of the many changes that our planet is undergoing. NSIDC scientists are widely published in peer-reviewed scientific journals. This year, their expertise reached a wide audience through outlets such as *Scientific American*, *The New York Times*, *The Washington Post*, CNN, and the British Broadcasting Corporation (BBC).

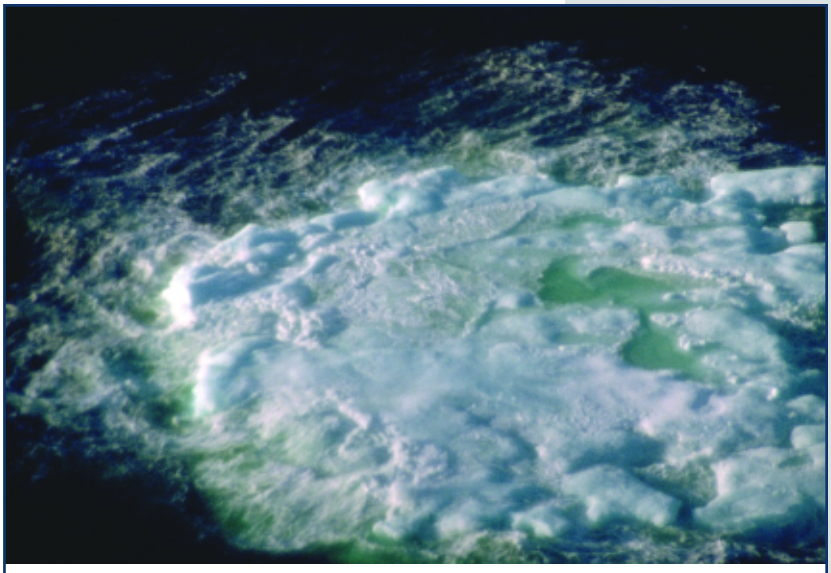
Scientists pursue their work as part of the CIRES Cryospheric and Polar Process Division, University of Colorado, Boulder. National agencies fund research through the peer review proposal process.

Todd Arbetter

Characterization of Arctic Albedo and Its Relationship to Sea Ice Conditions: a Collaborative Study Between NCAR, University of Colorado, and US Army CRREL
The purpose of this project is to make use of in situ and satellite observations of 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 gridscale and sub-gridscale parameterizations. Part of the modeling effort will focus on improving the parameterization of surface melt. Mark Tschudi is the PI, and J. A. Maslanik, J. W. Weatherly, C. W. Fowler, D. K. Perovich, and T. E. Arbetter are Co-PIs. (Funded by NASA grant NNG04GJ81G)



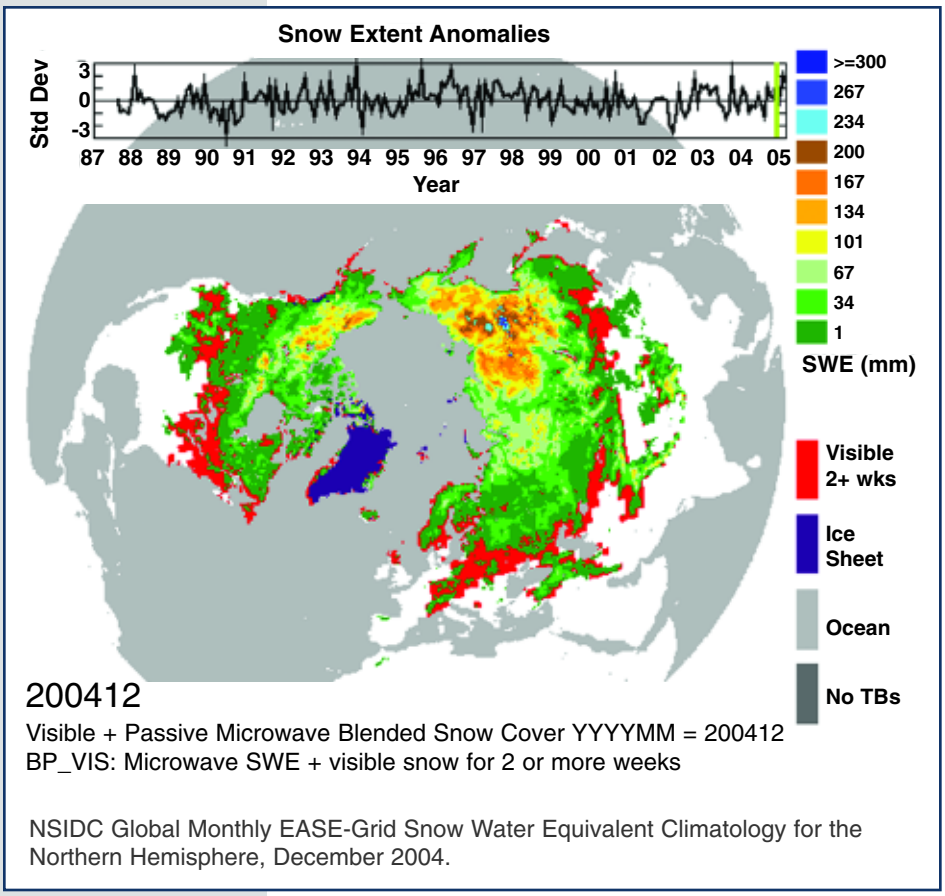
Simulated fraction of pond-covered ice area, 1 July 2004.



Melt pond on multiyear ice floe, October 2004 (Courtesy T. Arbetter).

Richard Armstrong

Standard Global Snow Products Derived from Satellite Remote Sensing
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. For more information, see the product Web site (http://nsidc.org/data/nsidc-0271.html) as well as the NSIDC Global Monthly Climatology Browse Web page (http://nsidc.org/data/docs/daac/nsidc0271_ease_grid_swe_climatology/browse/viewer.html).
(Funded by NASA NAG5-9412)



NSIDC Global Monthly EASE-Grid Snow Water Equivalent Climatology for the Northern Hemisphere, December 2004.

Validation of AMSR-E 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 allowed 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, created a need for fine-tuning of the calibration in the data production system.

The challenge of post-launch tuning was 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. Other investigators have used calm ocean scenes to cross-calibrate the SSM/I, TRMM Microwave Imager (TMI), and AMSR-E sensors at the cold end (80 to 150 degrees 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 (about 200 degrees Kelvin) and warm end (250 to 300 degrees Kelvin) of the Earth's emission range. The optimal locations and dimensions of such targets have not been studied adequately from a satel-

lite sensor viewpoint. Our study investigates specific ice sheet locations for the mid-range, and tropical forest locations for the warm end, using AMSR-E EASE-Grid TBs. The investigators 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.
(Funded by NASA NAG5-11107)

Validation of Snow Products over the Tibet Plateau
Previous studies have shown that the Tibetan Plateau is one of 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, the optical (MODIS) data are treated as "truth," or at least closer to "truth" than results coming from the investigator's current microwave algorithm, which appears to overestimate snow cover. However, 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 receive feedback on 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. When the corrected temperature gradients are applied to pixels on the Plateau, the result is a microwave-retrieved snow extent that agrees more closely with that of the optical sensor.

Detection of Change in Glacier Systems (GLIMS)
The GLIMS (Global Land Ice Measurements from Space) project is creating an inventory of the majority of the world's estimated 160,000 glaciers, mapping their extent and rate of change. GLIMS is an international project with participation from more than 60 institutions in 28 nations worldwide. Each institution (called a Regional Center, or RC) oversees the creation and analysis of data for a particular region appropriate to their expertise. These data are submitted to the GLIMS database at NSIDC. The NSIDC GLIMS Web site (http://nsidc.org/glims/) provides an overview of the GLIMS Glacier Database and describes the GLIMS Web Mapping Service (WMS), providing links to the GLIMS WMS, the data submissions page, data analysis, related research, and the main GLIMS project home page. For more information, see GLIMS under the Programs section of this report.
(Funded by NASA)

Development of an Internally Consistent, Multi-Sensor, Multi-Platform Long-Term Series of Global Snow Cover Using Heritage and EOS-Era Data
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 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 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.

Investigators have

- Completed test versions of the software and ancillary data needed to implement the Backus-Gilbert resampling for the AMSR-E data
- Defined and tested the 5- and 10-kilometer versions of the EASE-Grid
- Modified NSIDC's AMSR-E processing system to handle the latest format changes to the Level-2A data by building "scaffold" software to do timing tests for various approaches to implementing the resampling
- Chosen a method and completed the software design for the production system.

The resampling of AMSR-E swath TBs to EASE-Grid is currently being undertaken using a basic inverse distance method but we will implement the new method based on the actual antenna pattern during the coming year.

Within this project, work continued on 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 the investigators "blend" global SWE derived from passive microwave with snow extent derived from the MODIS CMG product. Given an 8-day MODIS product file, one command currently produces a blended product using Pathfinder SSM/I data, up to and including the most recent "near real-time" (within the last 24 hours) SSM/I data. With slightly more manual intervention, investigators 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 the 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), investigators can produce Northern Hemisphere gridded AMSR-E TBs. The SSM/I SWE algorithm software is being modified to accept AMSR-E TBs as input.
(Funded by NASA NNG03GN38G)

State of the Cryosphere Web Site
Armstrong leads the development and maintenance of this NSIDC Web product. The State of the Cryosphere Web site 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 2005 the sea ice, snow cover, mountain glacier and sea level time series were updated and the entire site was reviewed, edited, and updated. In addition, the home page was totally redesigned. In recent years, Science magazine has published two reviews supporting and encouraging the use of this Web site (http://nsidc.org/sotc/).

Andy Barrett

Integrated Analysis of the Freshwater Cycle in the Arctic Terrestrial, Cryospheric, Atmospheric, and Oceanic Systems
The primary goal of this research is to explore the final link in the progressive integration of Arctic freshwater cycling research from local to pan-Arctic to global scales. The emphasis is on the influence of changes in the Arctic freshwater cycle on the global thermohaline circulation (THC). The study uses available global coupled model simulations from the Community Climate System Model, Version 3 (CCSM3). The study is a collaboration between M. Serreze, the PI, and M. Holland.
(Funded by NASA NNG04GH04G)

Assessment of recent hydrologic change over the Arctic terrestrial drainage system
This project is guided by the question, "To what extent are observed changes in river discharge to the Arctic Ocean associated with climate variability and change versus the more direct human influences on hydrology, such as land cover change, water diversions, and impoundments?" It involves and assesses variability in net precipitation, evapotranspiration, active layer and permafrost, vegetation, glaciers, snowpack, river impoundments, and wetland/natural lake area and volume. The study is a collaboration between the University of Colorado, C. Birket (University of Maryland), D. Bromwich (Ohio State University), J. Kimball (University of Montana), R. Lammers and C. Vorosmarty (University of New Hampshire), and K. McDonald (Jet Propulsion Laboratory). Mark Serreze is the PI.
(Funded by NASA NNG04GJ39G)

Collaborative Research: A Heat Budget Analysis of the Arctic Climate System
The goal of this project is to better understand Arctic climate variability and change by integrating the large-scale heat budget. We are evaluating components of the Arctic heat budget using information from atmospheric reanalyses, satellite data, hydrographic data, and land surface models. Mark Serreze is the PI.
(Funded by NSF ARC-1531040)

Hydrologic Impacts of Dust on Snow
This study evaluates how dust on snow impacts the timing and magnitude of runoff from mountain drainage basins in southwest Colorado. Dust deposited on mountain snowpacks decreases snow albedo (the fraction of solar radiation reflected from the snow surface) and increases snow melt rates. Natural deposition of dust on snow at two sites in the San Juan Mountains in southwestern Colorado caused snow to disappear from study plots up to 20 days earlier. This work will expand our study from these study plots to examine the impacts of dust on snowmelt and runoff at the basin scale. The approach is a model-based study. We combine remote sensing-derived maps of snow-covered area, snow albedo, and dust concentration with field observations of snow depth and density and distributed modeling of micrometeorology and basin hydrology to simulate snowmelt and runoff under dust and dust-free conditions. This work is a collaboration between Thomas Painter and Chris Landry of the Center for Snow and Avalanche Studies in Silverton, Colorado.
(Funded by the NOAA-CIRES Western Water Assessment and NSF ATM-0432327)

Roger Barry

NSIDC Director Roger G. Barry is a University of Colorado Distinguished Professor and CIRES Fellow in the geography department. In Fall 2005, Barry and NSIDC senior scientist Mark Serreze completed a new textbook, *The Arctic Climate System*, published by Cambridge University Press. The book won the Atmospheric Science Librarians International Choice Award

for the best book of 2005 in the fields of meteorology/climatology/atmospheric sciences. During the summer of 2005, Barry served on the WDC Panel Review Team for China's World Data Centers. As a team member, he visited the WDCs for Oceanography, Tianjin; Meteorology, Beijing; Renewable Resources and Environment, Beijing; Glaciology and Cryopedology, Lanzhou; and the proposed WDC for Mountains and Plateaus, Lanzhou.

In addition to teaching and research, Barry is responsible for the scientific activities and for the data management centers within NSIDC. He serves as senior DAAC scientist for NSIDC, and is the PI for the NOAA Cooperative Agreement Task II (Operation of the WDC for Glaciology, Boulder) grant. Barry also supports a range of research efforts as a Co-Investigator, as well as serving as Principal Investigator on the following grants.

Twentieth Century Sea Ice Conditions in the Eurasian Arctic from a Comprehensive Reconstitution and Synthesis of Russian Data Sources with Modern Satellite Data
The primary objective of this work is to fill specific gaps in the sea ice data record by extending the record back and forward in time. A secondary objective is to analyze the acquired data in order to provide summary statistics, and to assess the evidence for climate change in the Russian Arctic from the 1930s to 2000. By obtaining a 70-year record, results from shorter intervals used by modelers can be placed in the context of historical means, variability, and trends. Acquiring multidecadal records is critical for understanding links between the Arctic Oscillation (AO) and polar climate. The 1930s to 1940s saw significant high-latitude warming and therefore it is important to document accompanying changes in ice conditions for comparison with those of summers since 1990. Historical Eurasian Arctic ice charts (1933 to 1949 and 1997 to 2003) and ice index data (1924 to 1933) will be used after digitization, quality assurance, documentation and creation of the database in gridded format. In 2005, data were acquired in cooperation with the Arctic and Antarctic Research Institute (AARI) in St. Petersburg, Russia. Data analysis will begin in 2006. Roger Barry is PI, and Florence Fetterer and Vasily Smolyanisky are Co-Investigators.
(Funded by NASA NNG04GH03G)

An Integrated Investigation of Coupled Human and Sea Ice Systems: A Comparison of Changing Environments and Their Uses in the North American Arctic
Inuit and Inupiat hunters in the North American Arctic rely on sea ice for travel and hunting for much of the year. Their use of the ice requires detailed knowledge of ice conditions for both safety and success in hunting, their main livelihood. The sea ice environment in the Arctic is changing, however. Studies of sea ice characteristics from scientific and indigenous knowledge perspectives have found major changes in the extent and thickness of the Arctic ice pack as well as local and regional changes in certain characteristics like the thickness, stability, and dates of formation of the shorefast ice used by hunters. As a result, Inuit and Inupiat communities are making changes to their day-to-day and long-term livelihood strategies and are dealing with traditional knowledge and skills that are, at times, no longer applicable. At the same time, scientists struggle to understand the interactions of the forces influencing sea ice changes and variations of change at multiple scales. How can these two groups inform each other and benefit from collaboration on this topic of mutual concern? This project will investigate the dynamics of the coupled systems of Inuit and Inupiat hunters and shorefast or drifting sea ice in the context of environmental change. A multidisciplinary team of investigators will collaborate with the communities of Barrow, Alaska, and Clyde River, Nunavut, to carry out this investigation. Roger Barry is the PI, and James Maslanik and Shari Gearheard are Co-PIs.
(Funded by NSF OPP-0308493)

Data management for a community-based monitoring network: A pilot project
This Small Grants for Exploratory Research (SGER) project will develop a general, community-sensitive method of data transfer, integration, and archiving for qualitative and quantitative infor-

mation collected as part of an envisioned Arctic community monitoring network. This project will develop a database in a standardized format utilizing best practices, digitize the primary data, produce the metadata that can be utilized by researchers, and develop a format that will be accessible to scientists, indigenous, and education communities. Roger Barry is the PI and Mark Parsons is Co-PI.
(Funded by NSF ARC-0533480)

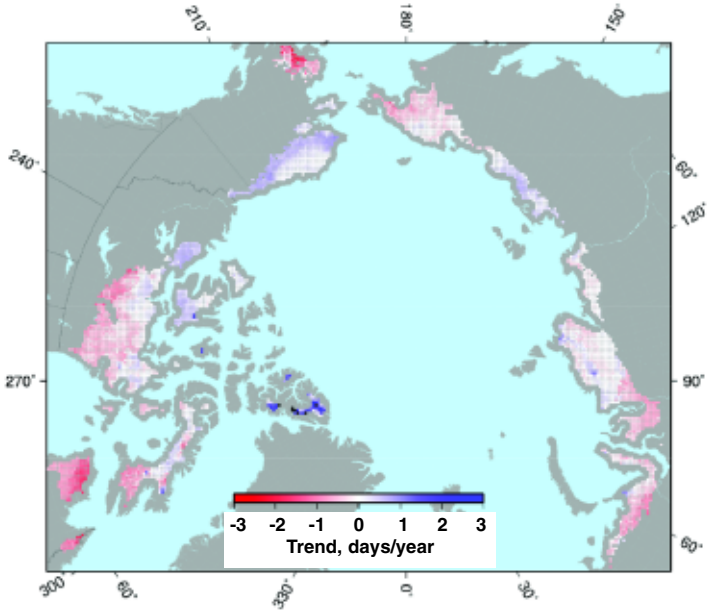
Florence Fetterer

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

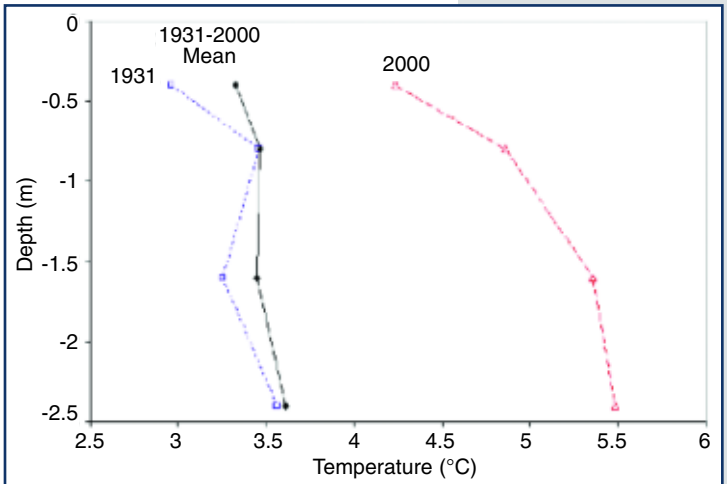
"Unaami," the changes in the Arctic that are the subject of the Study of Environmental Arctic Change (SEARCH) program, became apparent to researchers in the context of long-term and pan-Arctic observations. The first phase of our work assessed what data are relevant to SEARCH reanalysis and change detection activities, and, where possible, facilitated access to the data. Our major accomplishments were to research sources and characteristics of precipitation data sets, culminating in the publication of two new precipitation data sets. These are particularly important for the Arctic reanalysis. Beginning in 2004, we moved on to the development of "cryospheric climate 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 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.

We presented progress in a poster presentation (Raup, et al.) at the January 2005 American Meteorological Society (AMS) meeting. Work in 2005 focused on validating the melt onset indicator algorithm, completing the greenness indicator, and planning for the continuing update of all indicator time series. 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). For more information, visit the SEARCH Web site (http://nsidc.org/noaa/search/indicators/).



Trends in melt onset day (MOD) from an early version of the MOD algorithm, using SSM/I data (1988 to 2000). Blue represents later melt onset and red represents earlier onset. Algorithm validation is underway.



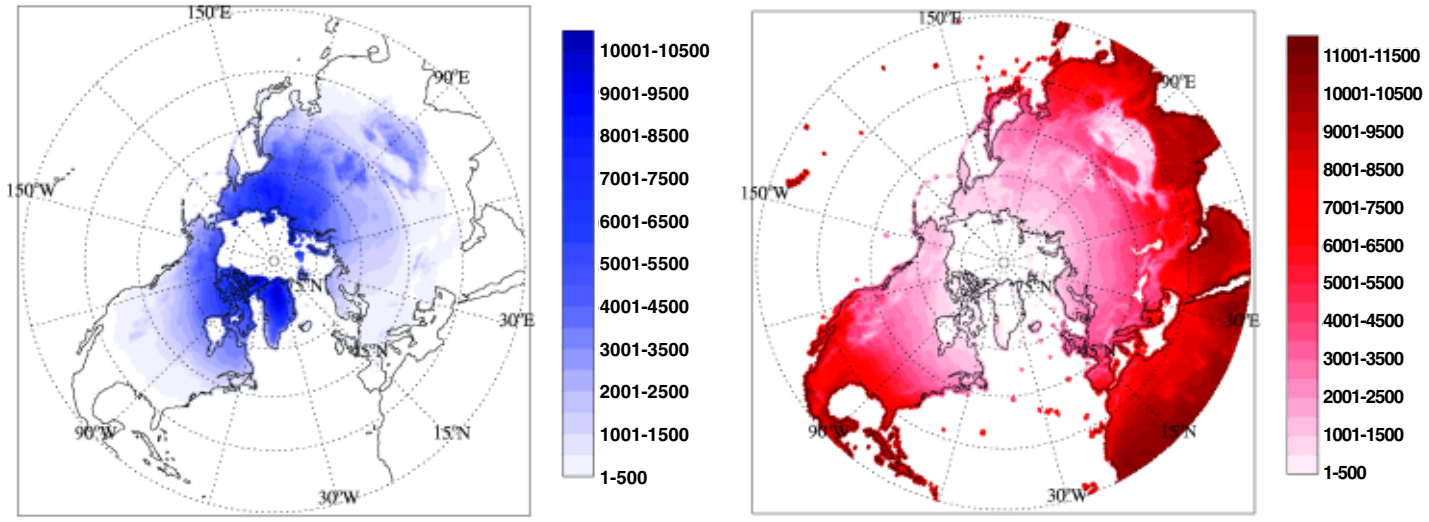
This graph illustrates soil temperature profiles from the Irkutsk Basin near the Angara River, Russia, in a region of isolated (<10 percent) permafrost. (From the Soil Temperature Indicator Web site, http://nsidc.org/noaa/search/indicators/soil_ru.html)

Oliver Frauenfeld

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

2005 saw the conclusion of our data rescue under this present effort, updating our database of Russian observing stations with monthly soil temperature measurements at 13 depths, ranging from close to the surface to a depth of 3.2 meters. These data are also now available through the year 2000, and the total database includes more than 400 sites. Future projects will focus on obtaining additional data, and the continued analyses and investigation of this data set.

This research resulted in the creation of a temporally and spatially continuous long-term 25 by 25 kilometer gridded Northern Hemisphere freezing/thawing index product. Variability in the ground thermal regime in high-latitude cold regions has important ramifications for surface and subsurface hydrology, carbon exchange, the surface energy and moisture balance, and ecosystem diversity and productivity. However, assessing these variations, particularly in light of reported widespread atmospheric and terrestrial changes over recent decades, remains a challenge due to the sparse observing networks in high latitudes. The annual freezing/thawing (F/T) index can be used to predict and map permafrost and seasonally frozen ground distribution, active layer and seasonal freeze depths, and has important engineering applications, thereby providing important information on climate variability in cold regions. The freezing/thawing index is generally defined based on daily observations, which are not readily available for many high-latitude locations. However, we established the reliability of using monthly temperature observations, which are readily available from a variety of sources. Based on a comprehensive evaluation, we selected the University of East Anglia's Climatic Research Unit (CRU) temperature product, available for 1901 to 2002, which enabled us to produce and analyze a 25 by 25 kilometer gridded Northern Hemisphere freezing/thawing index product. Long-term climatologies of the freezing/thawing index delineate the cold regions of the Northern Hemisphere, as well as areas of seasonally frozen ground and permafrost. Objective trend analysis indicates that in recent decades, no significant changes have occurred in Russian permafrost regions; however, seasonally frozen ground areas are experiencing significant warming trends. Over North America, Canadian and Alaskan permafrost regions are experiencing a decrease in freezing index during the cold season, while coastal areas and eastern Canada are seeing significant increase in warm season thawing index. Tingjun Zhang is PI, and Roger Barry is Co-Investigator.
(Funded by NSF)



Long-term climatology of the 1901 to 2001 freezing index (left), and the 1901 to 2002 thawing index (right) in °C-days for the Northern Hemisphere north of 15 degrees North.

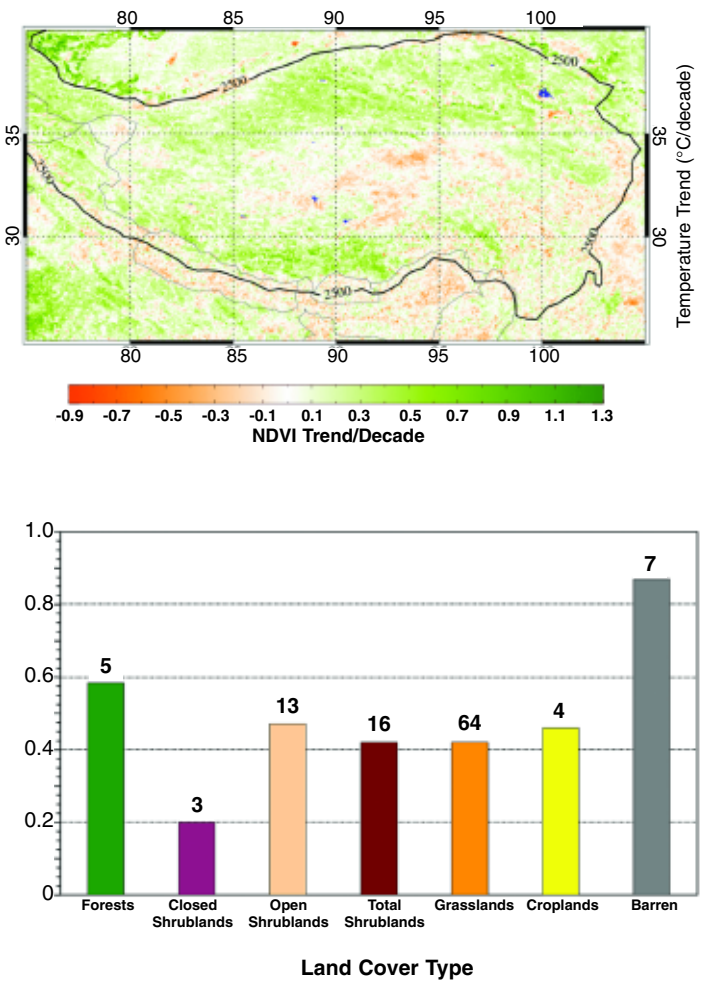
The Contribution of Land-Surface Processes to Climate Change on the Tibetan Plateau

The Tibetan Plateau (TP), with an average elevation of more than 4,000 meters and approximately the size of Texas, is a semi-arid environment occupied by montane grasslands and shrublands. More than 62 percent of this temperature and moisture limited plateau is used for agriculture. Since the early-late 1950s, and accelerated since the 1980s, significant urban expansion and changes in agricultural and industrial practices have shaped this part of the world, resulting in a substantially altered landscape. Because of the plateau's role in the Asian Monsoon system, the water resources of most of the Asian continent and therefore the livelihoods of more than 3.7 billion people, the extensive changes to the land surface in this part of the world are arguably of heightened importance to local-global resources and the climate system.

In this study, we use long-term in situ temperature observations for 161 locations, ERA-40 temperatures, a MODIS land cover classification, and Normalized Difference Vegetation Index (NDVI) data. These data are used to quantify the degree to which land-atmosphere interactions play a major role in driving climate change on the TP. As socioeconomic changes have caused a net reduction in vegetation, this has resulted in significantly reduced soil moisture, which feeds back to further decrease vegetation, but also increase sensible (versus latent) heat fluxes, and hence increase temperatures.

Our previous work had also demonstrated that reported warming on the TP seems to be confined to low-lying populated regions, but is absent in temperature data free of surface biases. Indeed, we observe statistically significant vegetation decreases over the last 20 years in the central and eastern TP. Based on this geographic distribution of vegetation changes as well as the land cover type classification, we also observe different temperature trends based on disturbed versus undisturbed regions. The seasonality of these changes plays an important role; however, vegetation changes alone do not account for observed temperature increases. Surface temperature trends are likely also affected by the reported general warming of the atmosphere in recent decades. A further complicating factor on the TP is the presence of discontinuous permafrost in certain regions, and we hypothesize that the distribution of permafrost also factors into the complex changes in vegetation, soil moisture, heat fluxes, and surface temperatures. Oliver Frauenfeld is PI, and Tingjun Zhang is Co-Investigator.

(Funded by a CIRES Innovative Research Grant)



The top image shows twice-monthly 1-kilometer NDVI trends for 1981 to 2003 in standard deviation units; the bottom graph shows the 1981 to 2003 temperature trends in °C/decade by land cover type based on in situ station observations.

Walt Meier

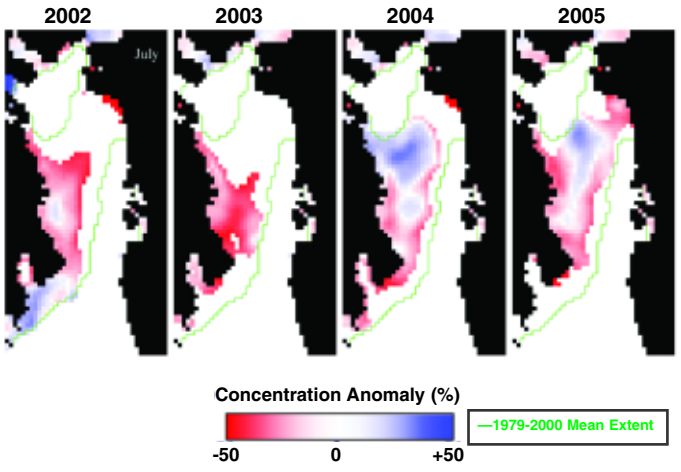
Kalman Filter Techniques for the Assimilation of Ice Concentration Data into an Ice Prediction Model

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 we plan to improve thermodynamics and develop a more sophisticated dynamics treatment. This project is a collaboration with UCAR visiting scientist Mingrui Dai and M. Van Woert (NSF).

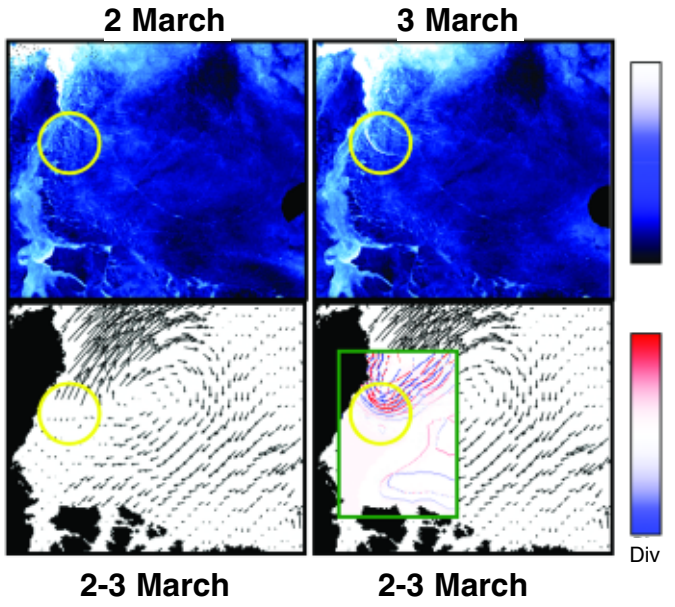
(Funded by NASA through the UCAR Visiting Scientist Program)

Bridging Perspectives from Remote Sensing and Inuit Communities on Changing Sea Ice Cover in the Baffin Bay Region

Passive microwave imagery indicates a decreasing trend in Arctic summer sea ice extent since 1979. The past four summers, 2002 through 2005, have exhibited particularly reduced extent and have reinforced the downward trend. Even the winter periods have now shown decreasing trends. At the local level, Arctic residents are noticing changes in sea ice, as well. In particular, indigenous elders and hunters report changes such as earlier breakup, later freeze-up, and thinner ice. The changing conditions have profound implications for Arctic-wide climate, but there is also regional variability in the extent trends. These can have important ramifications for wildlife and indigenous communities in the affected regions. This study unites observations from remote sensing with observations and knowledge of Inuit who live in the Baffin Bay region. Weaving the complimentary perspectives of science and Inuit knowledge, we investigate the processes driving changes in Baffin Bay sea ice extent and discuss the present and potential effects of changing sea ice on local activities. This project was completed in collaboration with Julienne Stroeve and S. Gearheard (Harvard University).



Sea ice concentration and extent anomaly charts for Baffin Bay during July 2002 to 2005. There is much less ice overall, and where ice remains, it is generally at a lower concentration level. The anomalies extend from the onset of melt in March through freeze-up in October. Melt onset is occurring earlier and freeze-up later. These changes are having a significant impact on Inuit livelihood.



AMSR-E horizontally polarized 89 GHz brightness temperatures for 2 March and 3 March (top row) and sea ice motion for 2 to 3 March (bottom row). The region of lead formation is circled, and shows light-colored, linear features. High-resolution deformation estimates for the lead region are overlaid on the motion field on the right.

Potential Improved Sea Ice Analyses and Forecasts via Assimilation of Sea Ice Motions
AMSR-E has more than double the spatial resolution of previous passive microwave remote sensing instruments. This allows it to obtain much more precise sea ice motion estimates and have the potential to greatly increase operational ice analyses and forecasts. The data will also improve understanding of sea ice model dynamics by estimating relatively small-scale motions at daily and sub-daily timescales. The spatial resolution is high enough that it may even be able to obtain reasonable estimates of ice deformation on daily timescales. Walt Meier is PI.
(Funded by the Naval Research Laboratory grant N00173-04-P-6210)

Tom Painter

Multi-Resolution Snow Products for the Hydrological Sciences
The project is developing a new set of products—snow-covered area, albedo, and snow-water equivalence—that fuse optical and microwave data and that incorporate spatial heterogeneity into the analysis. The core of the project is the MODIS Snow Covered Area and Grain size (MODSCAG) model for daily fractional snow cover, fractional snow grain size, and fractional snow albedo for client-specific hydrologic regions. This project is currently in research mode but we intend operational use of the model in the future NASA EOS distribution. For more information, visit the Multi-Resolution Snow Products for the Hydrological Sciences Web page (http://nsidc.org/research/multires_snowproducts/). Jeff Dozier is PI, and Thomas H. Painter, James Frew, and J. C. Shi are Co-Investigators.
(Funded by NASA NNG04GC52A/NASA Research, Education, and Applications Solutions Network)

Radiative Effects of Desert Dust Deposits in Alpine Snow
In this study, we investigate the radiative effects of absorbing dust deposits to alpine snow surfaces in the San Juan Mountains of Colorado. Prior to this research, these effects had not been studied, despite frequent and extensive red dust deposition in the snowfields of the Colorado mountains. 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 is a collaboration with the Center for Snow and Avalanche Studies (CSAS) in Silverton, Colorado. The study is being carried out in the Senator Beck Basin, which spans subalpine to alpine in elevations from 3,341 to 4,118 meters above sea level. Thomas H. Painter is PI and Chris Landry is Co-Investigator.
(Funded by NSF grant ATM0432327)

Radiative Effects of Desert Dust Deposits in Alpine Snow: Hydrologic Aspects
The reduced snow albedo associated with dust deposition will increase snowmelt rates at the snow surface and in turn modifies the basin distribution of snowmelt. We hypothesize that this enhanced surface snowmelt modifies the runoff hydrograph of the Senator Beck Basin to an earlier rising limb and a greater peak discharge. During April through June, we conduct field campaigns in the Senator Beck Basin to measure the spatial distribution of snow water equivalence (SWE) on a 100-meter grid and work with scientists at the University of California, Santa Barbara, on snow cover remote sensing products for this region. The above data drive a spatially distributed snowmelt model that allows us to modify the radiative and snowmelt forcings of dust in snow and assess the impact of dust on the timing and magnitude of snowmelt runoff. Thomas H. Painter is PI and Andrew P. Barrett is Co-Investigator.
(Funded by the NOAA Western Water Assessment)

Realization of snow/vegetation interactions with contact spectroscopy
We use field spectroscopy combined with contact illumination to make spatially continuous (both vertical and horizontal) observations of snow grain size in a sub-alpine mixed conifer forest. Using a contact probe coupled with a field spectrometer, we can infer the spatial distribution of snow grain size stratigraphy and with this innovative measurement approach, we can address the following questions:

- How does snow grain size change with proximity to vegetation?
- How does the control of vegetation on grain size change through the snow accumulation and snowmelt seasons?
- Do the feedbacks between vegetation and snowpack metamorphism change as a function of vegetation density?

Noah Molotch is PI and Thomas H. Painter is Co-Investigator.
(Funded by the CIRES Innovative Research Program)

Highly resolved wavelength dependencies of aerosol optical properties in the shortwave spectrum
Our objective is to measure the wavelength dependence of aerosol optical properties at high spectral resolution across the solar spectrum. Quantification of these properties is necessary for modeling the impact of aerosols on climate, but direct, high spectral resolution measurements of these properties have never been made. These measurements require instrumentation that can determine the angular distribution of sky radiance at high angular resolution (< 0.1 degree) in certain angular domains with the capabilities of a field spectroradiometer. We propose here to modify an existing field-portable, hyperspectral goniometer system and its angular sampling protocols to produce the first data set of this kind. Allison McComiskey is PI, and Thomas H. Painter and Paul Ricchiazzi are Co-Investigators.
(Funded by CIRES Innovative Research Program)

Ted Scambos

Snow Megadunes
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 PI.
(Funded by NSF OPP-0125570)

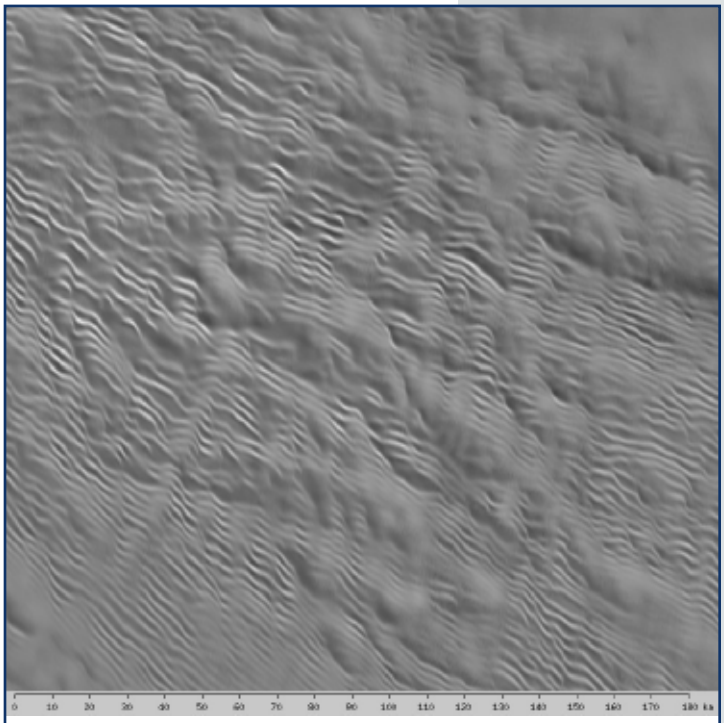
Improved Ice Sheet DEMs Using MODIS and GLAS
The detailed surface elevation of the ice sheets is an important component of any model of ice sheet dynamics, air flow, temperature, or accumulation. Past research has pioneered the use of AVHRR and MODIS images, combined with other elevation data, to provide new, high-resolution elevation maps through photoclinometry (shape-from-shading). We are currently investigating several possible approaches using MODIS imagery and ICESat elevation

profiles. A preliminary product of this work was the generation of the MODIS Mosaic of Antarctica (MOA) and a related MODIS Mosaic of Greenland (MOG).
(Funded by NASA NNG04GM10G)

An International Workshop on the Ice and Climate System of the Antarctic Peninsula
This grant supported a two-day international workshop on the ice and climate system of the Antarctic Peninsula held on May 15-16, 2006. During the meeting, a group of approximately 55 participants discussed recent research results and possible logistical cooperation for future research during the International Polar Year (IPY). The National Snow and Ice Data Center at the University of Colorado hosted the meeting. The meeting format included a series of invited keynote talks, contributed talks, and a poster session.
(Funded by NSF OPP-0550099)

Detecting Ice Sheet Changes via Optical Image Differencing
This grant supports an investigation into the possible insights that may be provided by careful subtraction of satellite images that were similarly illuminated and processed. Recent work has indicated that the approach is useful for detecting elevation uplift or lowering due to sub-glacial lake filling and draining. The image shows promise as a confirmation tool for ICESat-measured elevation changes, by indicating the exact extent of the elevation change detected by ICESat's laser profiles.
(Funded by NASA NNG06GA60G)

Building the VELMAP Database for Antarctic Outlet Glaciers
This grant supports research staff at NSIDC, and partially supports a post-doctoral researcher (Dr. Ian Howat) in mapping and analysis of ice flow and flow speed changes for several major Antarctic glaciers.
(Funded by NASA NNG05GO82G)



MODIS Mosaic of Antarctica (MOA) image of snow megadunes in the East Antarctic Plateau.

"At Risk" Ice Shelves and Outlet Glaciers
The Antarctic Peninsula and other regions of frequent melting in the Antarctic represent regions where very rapid changes may occur as climate warms on the Antarctic perimeter. The grant supports remote sensing work combining MODIS image monitoring of ice edge changes and melt pond formation, with ICESat changes in elevation, Landsat and ASTER ice flow mapping, and radar backscatter changes as the firn evolves due to increased melt percolation. At present, research efforts have focussed on Crane Glacier, a major glacier draining into the now-disintegrated area of the Larsen B ice shelf. Two papers are in preparation, one on ice flow speed changes (with C. Hulbe), and another on ice elevation changes (with C. Shuman).
(Funded by NASA NNGO6GA69G)

Investigating Iceberg Evolution During Drift and Break-Up: A Proxy for Climate-Related Changes in Antarctic Ice Shelves
This award supports a small grant for exploratory research to study the processes that contribute to the melting and break-up of tabular polar icebergs as they drift north. This work will enable the participation of a group of U.S. scientists in this international project, which is collaborative

with the Instituto Antartico Argentino. The field team will place weather instruments, firn sensors, and a video camera on the iceberg to measure the processes that affect it as it drifts north. In contrast to icebergs in other sectors of Antarctica, icebergs in the northwestern Weddell Sea drift northward along relatively predictable paths, and reach climate and ocean conditions that lead to break-up within a few years. The timing of this study is critical due to the anticipated presence of iceberg A43A, which broke off the Ronne Ice Shelf in February 2000 and which is expected to be accessible from Marambio Station in early 2006.

It has recently been recognized that the end stages of break-up of these icebergs can imitate the rapid disintegrations due to melt ponding and surface fracturing observed for the Larsen A and Larsen B ice shelves. However, in some cases, basal melting may play a significant role in shelf break-up. Resolving the processes (surface ponding/fracturing versus basal melt) and observing other processes of iceberg drift and break-up in situ are of high scientific interest. An understanding of the mechanisms that lead to the disintegration of icebergs as they drift north may enable scientists to use icebergs as proxies for understanding the processes that could cause ice shelves to disintegrate in a warming climate. A broader impact would thus be an ability to predict ice shelf disintegration in a warming world. Glacier mass balance and ice shelf stability are of critical importance to sea level change, which also has broader societal relevance.
(Funded by NSF ANT-0540915)

NSIDC staff members Rob Bauer, Terry Haran, Ted Scambos, Atsuhiro Muto, and Ken Knowles assembled a weather tower in preparation for iceberg investigations in Antarctica. Although the mission didn't take place until early 2006, the team spent several months during 2005 designing instruments and monitoring iceberg positions around Antarctica.

The Antarctic Glaciological Data Center: Continued Data Collection and Management for Antarctic Glaciology
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 PI, and Roger Barry, Greg Scharfen, and Robert Bauer are Co-PIs.
(Funded by NSF OPP-0338134)

Mark Serreze

Characterization of Atmospheric Moisture Transport and the Freshwater Budget of the Arctic with an Improved Regional Model
This effort seeks to understand relationships between atmospheric moisture transport into the Arctic and the Arctic hydrologic budget, making use of output from a regional climate model and atmospheric reanalysis. Studies are being coordinated with the grant, "Characteristics of Cyclone Development in the Arctic and their Hydrologic Impacts."
(Funded by NSF OPP-138018)

Characteristics of Cyclone Development in the Arctic and their Hydrologic Impacts
Simulations using the polar optimized version of the Mesoscale Model 5 (Polar MM5) are focusing on moisture transports into the Arctic via the north Atlantic "gateway," between Greenland and Scandinavia. Impacts of Greenland's orography on moisture transports are being examined in sensitivity tests through case studies and longer one-month integrations. These studies compare results from control simulations to simulations where the topography of Greenland is removed. Additional studies are addressing the sensitivity of synoptic development and moisture transports to altered sea ice distributions.
(Funded by NSF OPP-0240948)

Collaborative Research: A Land Surface Model Hindcast
This project uses different land surface models to examine patterns, variability, and trends in land surface energy exchanges and surface state variables across the pan-Arctic landmass. We are using five land surface models, CHASM, Noah, CLM, VIC, ECMWF, which represent a wide range of model physics, particularly with respect to high-latitude processes. Initial runs forced each model with surface meteorology derived from the ERA-40 reanalysis. Further studies will employ ensemble approaches, where the five models are forced by a suite of different forcing (for example, replacing ERA-40 precipitation with gridded fields based on surface observations). This approach offers great potential for enlightenment regarding large-scale hydrology in this poorly observed region. Results reveal up to a 30 percent difference in annual partitioning of precipitation between evaporation and runoff within major Arctic watersheds such as the Lena. Capturing the correct baseflow of the large rivers is a consistent problem. Compared to station data, all models produce similar errors in snow water equivalent; yet they differ widely in their snow regimes in terms of snowfall quantity, estimated snow depths and most importantly, sublimation rates. Additionally, model albedo is consistently higher than observations in the presence of snow. This project is a collaboration between the University of Colorado (M. C. Serreze and A. G. Slater) and the University of Washington (D. Lettenmaier).
(Funded by NSF OPP-0229769)

Characteristics of Cyclone Development in the Arctic and their Hydrologic Impacts
This project seeks to better understand aspects of cyclone development on the Arctic and links between regional development processes and Arctic hydrology. Use is being made of output from atmospheric reanalyses and a regional climate model. The primary focus area is the northern North Atlantic. The dominant feature of the mean sea level circulation in this region during winter is the Icelandic Low (IL) and an associated pressure trough extending far into the Arctic. The region encompassing the IL and this trough can be broadly thought of as representing the terminus of the North Atlantic cyclone track. It is one of the most synoptically active and variable areas of the planet, especially during winter. The region is particularly important in representing a primary gateway for the transport of heat and moisture into the Arctic. The IL and surrounding region modulate the Arctic's freshwater budget, especially through impacts on net precipitation over the Arctic Ocean and the export of sea ice and low salinity waters out of the Arctic and into the North Atlantic via Fram Strait, between northern Greenland and Svalbard. This flux is the principal mechanism by which freshwater inputs to the Arctic Ocean from river runoff, Bering Strait inflow, and net precipitation over the Arctic Ocean are balanced. The flux is closely linked to the SLP gradient in the vicinity of the strait, which varies with the strength and location of the IL and high-latitude pressure trough. Impacts of Greenland's orography are prominent in the synoptic complexity of the region. Typical synoptic situations include splitting, or "bifurcation" of cyclones at the southern tip of Greenland, orographic cyclogenesis in the lee of Greenland, at the location of the mean IL, and deepening of pre-existing systems near the IL.
(Funded by NSF OPP-0240948)

Collaborative Research: Integrated Analyses of the Arctic Freshwater Cycle and its Influence on Global Climate and **Integrated Analysis of the Freshwater Cycle in the Arctic Terrestrial, Cryospheric, Atmospheric, and Oceanic Systems**
These two projects are strongly related to each other. The primary goal is to explore the progressive integration of the impacts and processes of the Arctic freshwater cycle on local, pan-Arctic and global sales. The study is focusing on analyses of the physical processes, as represented by global-scale models, in the Arctic water cycle. Particular areas of interest include projected future changes in Arctic precipitation and Arctic influences in the thermohaline circulation. Extensive use is being made of output from Version 3 of the Community Climate System Model (CCSM3). Both projects represent collaboration between University of Colorado and NCAR (M. Holland).
(Funded by NSF OPP-0242125 and NASA NNG04GH04G, respectively)

Assessment of Recent Hydrologic Change over the Arctic Terrestrial Drainage System and **Collaborate Research: An Integrated Assessment of the Arctic Freshwater System: Analysis of Retrospective and Contemporary Conditions**
These two projects, which leverage each other, address the further development and applications of the Arctic Rapid Integrating Monitoring System (Arctic-RIMS), for analysis of variability and change in the Arctic freshwater system. Arctic-RIMS synthesizes station precipitation, river discharge, satellite data, hydrologic and thermal modeling, and output from atmospheric reanalysis. Precipitation and temperature represent inputs into a Permafrost/Water Balance Model, which outputs a suite of fields. The RIMS Web site, maintained by the University of New Hampshire (http://rims.unh.edu/), contains background material, a tutorial for site navigation, and visualization and analysis tools. Arctic-RIMS represents a long-standing collaboration between NSF and NASA. The project involves coordination between the University of Colorado, the University of New Hampshire (C. Vorosmarty), the Ohio State University (D. Bromwich), the Jet Propulsion Laboratory (K. McDonald), the University of Montana (J. Kimball), the University of Maryland (C. Birkett), and the University of Washington (M. Steele).
(Funded by NASA NNG04GJ39G and NSF OPP-0229651, respectively)

Collaborative Research: Synthesis of Modes of Ocean-Ice-Atmosphere Covariability in the Arctic System from Multivariate Century-Scale Observations
The objective is to perform an integrated statistical analysis of long climate data sets for the Arctic and subpolar North Atlantic. These include meteorological and oceanographic measurements, sea ice observations and climate indices, such as the phase of different atmospheric teleconnection patterns. These are being used to better understand organized spatial patterns of variability and covariability in the ocean-ice atmosphere system. Efforts at the University of Colorado have been focusing on understanding variability in the summer atmospheric circulation of the central Arctic Ocean and its link with sea ice conditions. This is a collaborative effort between NOAA (J. Overland), the Environmental Systems Analysis Research Center (M. Miles, Boulder, Colorado) and the University of Colorado.
(Funded by NSF ARC-0531302)

Collaborative Research: A Heat Budget Analysis of the Arctic Climate System
The goal is to better understand Arctic climate variability and change from the integrating and simplifying viewpoint of the large-scale heat budget. The change in the energy content of the Arctic atmosphere depends of the sum of horizontal energy transfers into the region through the atmospheric circulation, the net radiation budget at the top of the atmosphere, and the net surface heat flux. The latter represents energy transfers between the atmosphere and the underlying ice/ocean column. In turn, the heat budget of the underlying ice-ocean column depends on the net surface heat flux and heat transfers into/out of the column via ocean currents and the transport of sea ice. Studies of the Arctic heat budget are making use of information from atmospheric reanalyses, satellite data, hydrographic data, and land surface models. This project is a collaboration between the University of Colorado and the University of Washington, Seattle (M. Steele).
(Funded by NSF ARC-1531040)

Andrew Slater

Improving operational streamflow forecasting in the Colorado River Basin
This ongoing effort focuses on the assessing and accounting for uncertainty with hydrologic modeling with a view to improving operational capabilities. The Colorado River Basin is a snow-dominated watershed and provides a useful testbed for these endeavors. Our research addresses the main areas of uncertainty within hydrologic forecasting: inputs, parameters, model structure, and initial conditions.

To address input uncertainty, we developed a method for generating high-resolution ensemble inputs for the hydrologic model. The method, which is based on locally-weighted regression, was used for precipitation generation in regions with complex terrain. We preserved both the temporal and spatial correlation structures of the ensemble variables by using correlated random field in the stochastic sampling strategy. Probabilistic verification techniques showed that our resulting ensembles were statistically reliable and provided good discrimination in terms of having probabilities that differ significantly between cases when specific events occur and when they do not. Our method is flexible and can be extended to other model input fields.

We can reduce the uncertainty of initial conditions through data assimilation. Building on our ensemble generation work, we applied an Ensemble Kalman Filter (EnKF) data assimilation system to the problem updating snow water equivalent (SWE) in the National Weather Service River Forecast System (NWSRFS) module, SNOW-17. The uncertainties of the model and assimilated data were both derived directly from observed data through cross validation. SWE improvements were most evident during the early accumulation and later melt periods of the snow season. Accounting for the temporal correlation in SWE values further improved results.

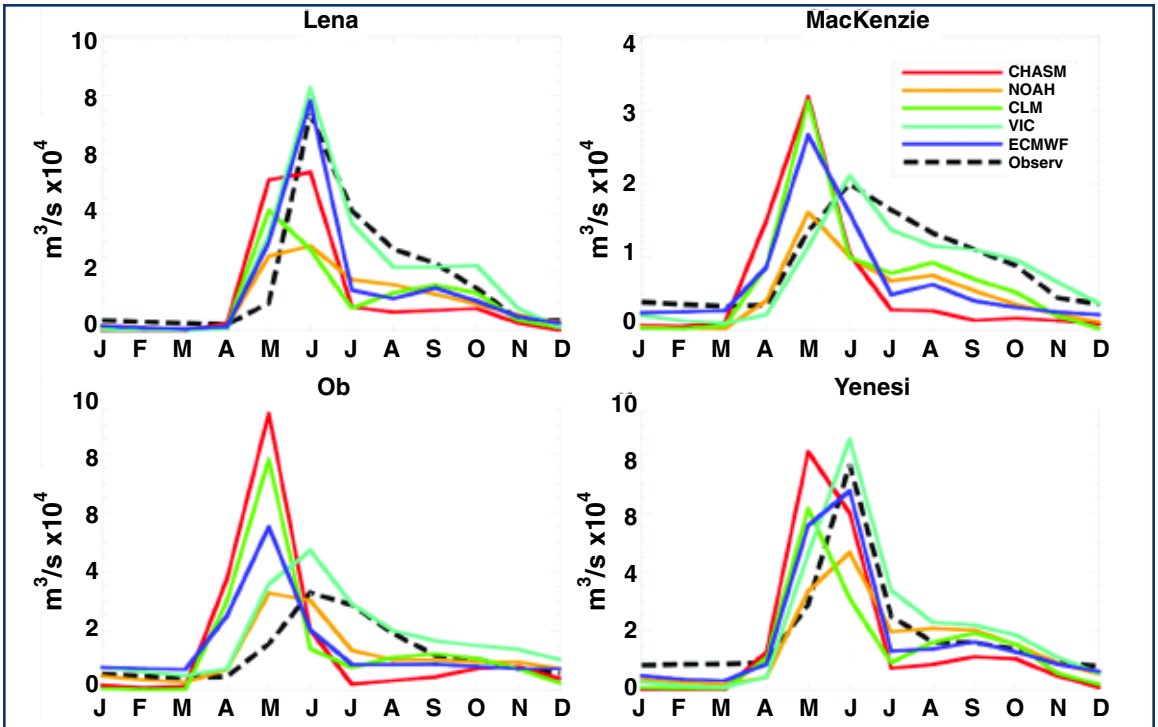
Within the limits of available information, our assimilation results were consistently superior to either the model or interpolated observations.

Recognizing that estimates of snow covered area (SCA) are more readily available than SWE, we proposed a method for assimilating this quantity into models. The effectiveness of SCA assimilation is limited in regions where significant amounts of snow melt occur before bare ground is exposed. For regions with ephemeral snow it could prove a useful strategy, but overall the result points to dual SWE-SCA assimilation as perhaps being most effective.

Structural uncertainty describes uncertainty inherent in a model due to its underlying philosophy and construction, but we were able to disentangle the complex interplay of parameter and structural uncertainty. Within this framework, parameters maintained the same meaning across all models, thus allowing for identification of parameters important to each structure. Different parameters were more clearly identifiable in different models, and parameter sets with the lowest error could vary markedly between different model structures. However, most model parameters examined in the study were poorly identifiable. Poorly identifiable parameters mean that equally accurate streamflow simulations can be obtained in a number of different ways.
(Funded by NOAA-OHD)

Pan-Arctic Land Surface Modeling
Observations clearly indicate that the climate is changing. Observations already suggest that the terrestrial Arctic is experiencing the largest change of any world region in terms of temperature, and modeling studies and current trends suggest that this change will continue.

In collaboration with the National Center for Atmospheric Research (NCAR), we investigated the future state of permafrost in the near-surface soil layers. These upper layers are important due to their potential impact upon hydrology, ecology, and trace gas emissions. Results from the high-resolution (T85) version of the Community Climate System Model (version 3; CCSM3) agree quite well with current estimates of continuous permafrost extent, providing a mean value



Seasonal hydrographs of the four major Arctic catchments. Note that baseflow is difficult to capture, particularly in the MacKenzie and Yenesi basins.

of 10.6 million square kilometers for the period from 1980 to 1999. A century later in time (2080 to 2099), the model projects more than an 80 percent reduction in continuous permafrost in the upper 3.5 meters of the ground under the current emissions scenario. Additional experiments show that there is still "heat in the pipeline," meaning that if greenhouse gas levels remain at current levels, we would still see a 10 to 15 percent reduction in the extent of continuous near-surface permafrost. Perhaps the most concerning result was the rapid thaw of very large regions over a period of only 40 years.

Under the projected climate change scenario, freshwater discharge into the ocean will increase by 28 percent, 15 percent of which can be attributed to melting ground ice. The seasonal hydrograph for the period 2080 to 2099 shows higher baseflow and higher springtime runoff, though summer runoff remains similar to present day estimates. The current simulations do not account for the consequences of increased carbon and methane fluxes from Arctic soils; this is an area of ongoing research and is perhaps the area of largest uncertainty for future Arctic climate.

In additional, related studies, we compared the performance of five land surface models (CHASM, Noah, CLM, VIC, ECMWF), in the simulation of hydrological processes across the terrestrial Arctic drainage system for the period 1980-2001. The models represent a wide range of physics, particularly with respect to high-latitude processes and are forced with surface meteorology derived from the ERA-40 reanalysis. Our objective is to assess the ability of the models to capture various aspects of Pan-Arctic hydrology as well as identify those features that contain the largest uncertainty. Compared to station data, all models produce similar errors in snow water equivalent; yet they differ widely in their snow regimes in terms of snowfall quantity, estimated snow depths and most importantly, sublimation rates. Additionally, model albedo is consistently higher than observations in the presence of snow. No single model was the best or worst performing when compared to a range of observations. (Funded by NSF)

Julienne Stroeve

Diagnosing the Declining Arctic Ice Cover
The objective of this proposal is to answer the question "Why is the Arctic sea ice cover declining?" In order to answer that question, the interannual variability in atmospheric heat budgets and surface heat fluxes over the Arctic Ocean will be evaluated and ice-ocean model simulations will be performed to test the sensitivity of sea ice to atmospheric forcings. Additionally, observational data (i.e. from satellite data) will be analyzed to help better understand the recent changes. (Funded by NASA NNG06GB26G)

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 cryospheric 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.
(Funded by NASA grant NNG04G051G)

Investigations of Sea Ice State using Multisensor Data, Time History, and Lagrangian Tracking
Investigations of Arctic sea ice are performed using as many variables as possible from satellite observations together with information on how the sea ice evolved over time by tracking individual ice parcels. Main components of this work include:

- Assemble gridded database at the University of Colorado for use in time series analysis (consisting of 40 or so parameters including satellite data, NCEP/NCAR reanalyses, etc,. for the entire Arctic and some Antarctic coverage
- Generation of additional data sets (backscatter, enhanced resolution AMSR-E, etc.) to be added to the University of Colorado database
- Development of SAR forward modeling capabilities, as applied to SHEBA data
- Extension of forward modeling to include passive microwave modeling and visible/thermal modeling
- Analysis of brightness temperature variations related to snow cover
- Investigation of thermal/albedo factors related to "survivability" of ice during summer melt.

(Funded by NASA NNG04GP50G)

Tingjun Zhang

Freezing and Thawing Cycles of Soils at Local, Regional, and Global Scales
The goal of this project is to improve our understanding of the near-surface soil thermal regime and seasonal freezing/thawing processes of soils, and their interactions and feedbacks to changes in hydrologic and climatic systems at local, regional, and global scales. More specifically, the project will (i) further improve and validate passive microwave frozen soil algorithms and numerical models to detect surface soil freeze/thaw status, (ii) investigate seasonal and interannual variations of seasonally frozen ground, (iii) examine the snow-frozen ground-monsoon hypothesis over the GAPP (GEWEX American Prediction Project) study area associated with the North American monsoon system, and (iv) generate a frozen ground data set as part of a contribution to the NASA/NOAA Land Data Assimilation Systems and to the GEWEX CEOP program.

In 2005, we developed a combined frozen soil algorithm, which we 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. For snow-free land areas, we used a passive microwave remote sensing algorithm to detect the near-surface soil freeze/thaw cycle over snow-free land areas, and for snow-covered land areas, we used a one-dimensional numerical heat-transfer model with phase change to detect soil freeze/thaw status under snow cover. We applied the validated frozen soil algorithm to investigate near-surface soil freeze/thaw status over the contiguous United States from 1978 through 2003 and the Northern Hemisphere as a whole. The long-term average maximum area extent of seasonally frozen ground, including the active layer over permafrost, is approximately 50.5 percent of the land-mass in the Northern Hemisphere. Preliminary results indicate that the extent of seasonally frozen ground has decreased about 15 to 20 percent during the past few decades.

This study also examined the 20th-century variations of active layer thickness (ALT) for the Ob, Yenisey, and Lena River basins over the Russian Arctic. ALT is estimated from historical soil

temperature measurements from 17 stations (1956 to 1990, Lena basin only), an annual thawing index based on 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 (1961 to 1990) average ALT is about 1.87 meters in the Ob, 1.67 meters 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 has complex and inconsistent responses to variations in snow cover. Tingjun Zhang is PI, and Richard Armstrong is Co-Investigator.
(Funded by NASA)

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

The overall objectives of this project are to

- Improve our understanding of the seasonal freezing and thawing processes of soils and their interactions with hydrologic and climatic systems at local and regional scales.
- Provide information such as the timing, duration, thickness, and areal extent of the seasonal freeze/thaw cycle of soils for the period from 1978-present in the United States for studies of plant growth, carbon exchange, ecosystem, surface hydrology, and soil moisture, and for model improvement and validation.

Based on data from 1978 to 2003, the onset date of autumn soil freeze starts in October along the Rocky Mountains and North Dakota, then gradually expands into the western U.S. and southern regions. The maximum extent of soil freeze is reached in January. Approximately 80 percent of the contiguous United States landmass experiences freezes in winter. Overall, the trend indicates a later onset date of autumn soil freeze, especially in the eastern part of the United States. The delay can be up to three weeks in some parts of the study area, a very significant change. Further validation of these results is needed, ideally using ground-based measurements.

The climatology of the last date of near-surface soil freeze starts in January in the south, and occurs later in the north. In the majority of western and northern states, the last date of soil freeze is in April, but occurs in May along the Rocky Mountain regions. The last date of soil freeze occurs later in the central Plains and eastern states, while in the western states, especially along the Rocky Mountains, the last date of surface soil freeze occurs earlier than the long-term average.

The duration of the surface soil freeze is defined as the time period from the onset date of autumn soil freeze to the last date of spring soil freeze. Overall, the average duration varies from less than a month in the south to more than eight months in some Rocky Mountain regions. Along the Rocky Mountains, duration lasts about five to six months. Over the central Plains and in the eastern part of the United States, the duration is usually three to four months, while in the northern and western states, the duration can be four to five months. For most of the country, except in the Rocky Mountain region, the duration of surface soil freeze has become longer. This is mainly due to the delay of spring thaw.

The frequency of surface soil freeze is defined as the number of days of soil freeze divided by the total number of days in a year. In the Rocky Mountain region, more than 50 percent of the time, near-surface soil is frozen. Although surface soil freeze can last as long as eight months, the frequency is just above 50 percent. This means there are days where the surface soil may not in be frozen, but is in between freeze/thaw cycles. Over most of the country, surface soil is

frozen for about 20 to 40 percent of the year. In southern States, the frequency decreases accordingly. Interestingly, the frequency along the Rocky Mountains is decreasing while the rest of the country is increasing. Further study is needed to validate the discoveries in this study. Potential implication changes in frequency of soil freeze can be extremely significant in surface hydrology and carbon exchange studies. Tingjun Zhang is PI, and Richard Armstrong, Christoph Oelke, and Martyn Clark are Co-PIs.
(Funded by the DOE National Institute for Global Environmental Change)

Hydrological Response to Changes in Active Layer and Permafrost Conditions in the Russian Arctic
Recent studies indicate that runoff over the Siberian Arctic drainage basins has increased substantially over the past several decades. The source of water causing the runoff increase is unknown. In this study, we hypothesize that changes in the active layer and permafrost dynamics play a role in the recent changes in the Arctic hydrological regime. We document several elements, including permafrost and ground ice distribution; changes in permafrost temperature, active layer thickness, and length of thaw season over the past few decades; and their impact on the hydrologic cycle over three Siberian river basins (the Ob, Yenisey, and Lena).

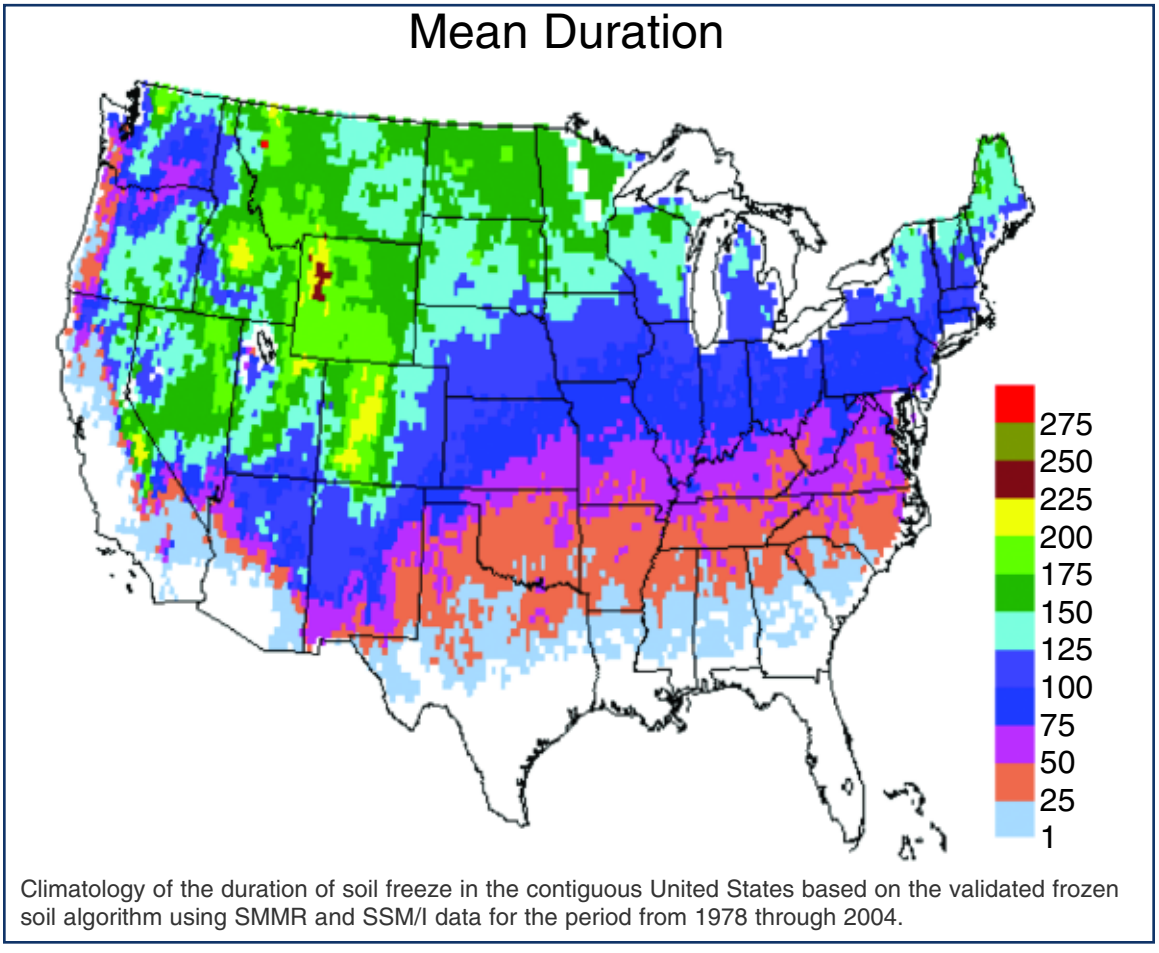
Permafrost underlies approximately 4 to 10 percent of the total area of the Ob basin, 36 to 55 percent in the Yenisey basin, and 78 to 93 percent in the Lena basin. Consequently, total volume of the excess ground ice varies from approximately 302 to 854 cubic kilometers in the Ob, 1,699 to 2,462 cubic kilometers in the Yenisey, and 3,523 to 4,227 cubic kilometers in the Lena basin. According to ground-based measurements, mean annual soil temperature at the 40-centimeter depth has increased about 1.3 degrees Celsius in the Ob, 0.8 degrees Celsius in the Yenisey, and 1.6 degrees Celsius in the Lena river basin for the period from 1930 through 1990. The increase is more pronounced from the mid 1960s to 1990. An increase in the near-surface soil temperature leads to lateral thawing of permafrost and thickening of the active layer. Long-term soil temperature measurements indicate that permafrost has been degrading during the past several decades. Active layer thickness has increased about 30 centimeters from the mid 1950s to 1990s over the Lena river basin. Thawing index has increased substantially over all three river basins from the 1950s to 1990s, implying that the increase in active layer thickness is a widespread phenomenon over the Russian Arctic drainage basin during the past few decades.

Changes in active layer thickness of 15 centimeters produce a runoff equivalent of about 0.9 to 2.4 millimeters in the Ob, about 7.8 to 11.3 millimeters in the Yenisey, and about 15.3 to 19.4 millimeters in the Lena. An anti-correlation of changes in active layer thickness and runoff may exist due to possibly high evaporation and storage in the thickened active layer. There might be a time lag between changes in active layer thickness and runoff. Late freeze-up of the active layer may also contribute to the increase in the winter runoff. Overall, changes in permafrost conditions in the Ob basin have a minimum impact on runoff. Lateral thawing of permafrost and thickening of the active layer may account for the significant increase in runoff over the Yenisey river basin. Melting of the excess ground ice through thickening of the active layer might be one of the major sources of runoff in the Lena river basin. Further work will include better understanding of the rate of lateral thawing and spatial permafrost distribution of discontinuous, sporadic, and isolated permafrost. Tingjun Zhang is PI, and Roger G. Barry is Co-Investigator.
(Funded by NSF)

Permafrost Models Intercomparison Project
Quantitative estimates of the environmental and socioeconomic impacts of changing climate in the northern regions require robust permafrost projections. These estimates are also critically dependent on the availability of models and the forcing data that are needed for predictive calculations. In this project, we examined four high-resolution hemispheric-scale gridded sets of monthly temperature and precipitation that have been constructed using different interpolation routines and reanalysis of data from a large number of weather stations. Four data sets differ in

mean annual air temperatures averaged over the 15-year period by one to two degrees Celsius and in degree-days of thawing by more 200 degree Celsius days from observations at more than one half of the 156 stations in Russian permafrost regions. A permafrost model forced with the gridded climatic data sets was used to calculate the maximum depth of seasonal thawing (active layer thickness) over permafrost, which we compared with the observations. We developed a comprehensive procedure for the evaluation of the permafrost model, which is based on the statistical ensemble approach and accounts for the natural small-scale variability of active layer thickness. At any given site, the model is forced with prescribed climatic data and run repeatedly with combinations of the varying snow, vegetation, and soil parameters to generate the statistics of calculated results, and the results are compared with the observation statistics.

Our evaluations, using data from selected Russian permafrost monitoring sites, indicated good correspondence between the calculated and observed active layer thickness in both the mean values and the standard deviations. To estimate the effect of uncertainties in forcing climatic data on permafrost projections, we compared the broadscale characteristics of the frozen ground calculated using four different data sets. We analyzed the zonal mean air and ground temperatures, active layer thickness, and the area occupied by the near-surface permafrost in the Eurasian latitudinal zone to the north of 45 degrees North. Results were noticeably different and largely consistent with the differences in the zonal mean air temperatures. The 0.5 to 1.0 degree Celsius difference in the zonal mean air temperature between the data sets led to a 10 to 20 percent range of uncertainty in the estimates of the zonal near-surface permafrost area, which is comparable to the changes projected for the following several decades. Our ultimate conclusion is that more observations and theoretical studies are needed to improve the characterization of the baseline climatic conditions and to narrow the range of uncertainties in model-based permafrost projections.
Tingjun Zhang is PI and Roger G. Barry is Co-Investigator.
(Funded by NSF)



Climatology of the duration of soil freeze in the contiguous United States based on the validated frozen soil algorithm using SMMR and SSM/I data for the period from 1978 through 2004.

International Collaboration

International Polar Year
The International Polar Year (IPY, 2007-2009) will be a concentrated effort to increase understanding of the polar regions and their interaction with global climate and societies. NSIDC has been working to raise the profile of data management within the International Polar Year and is seeking to take a leading role in the effort. NSIDC scientists will conduct research with national and international planners, and data managers at NSIDC will work to make data collected during IPY available to researchers during IPY and beyond.

Planning for the data management challenges IPY represents picked up momentum at NSIDC in 2005. NSIDC Director Roger Barry and Mark Parsons met with the Director of the International Programme Office, David Carlson, several times, and Mark Parsons (along with Taco de Bruin of the Netherlands) was selected as the Co-Chair of the IPY Data Policy & Management Subcommittee. Mark presented a talk, "Data management for the International Polar Year," at the Joint Committee for Antarctic Data Management in Buenos Aires in September 2005 and at the IPY Discussion Forum in Copenhagen in November 2005. Here in Colorado, NSIDC supported "Poles Together," a workshop sponsored by NOAA and CIRES to plan coordinated IPY outreach and education.

The Joint Committee also approved a large, international, collaborative effort led by Parsons to host an IPY Data and Information Service (IPYDIS). The IPYDIS is a federation of data centers and institutions committed to preserving and providing access to the data legacy of IPY. NSIDC has been seeking funding for the IPYDIS and related efforts. One small planning award and one prototyping award led by Parsons and Roger Barry will begin in 2006. Through the efforts of Mark and others, NSIDC and the WDC for Glaciology, Boulder, is taking on a leadership role for IPY data management.

World Data Centers
The World Data Center system was established as part of the International Geophysical Year (1957-1958), The WDC for Glaciology, Boulder, is collocated with NSIDC and includes the Library and an extensive collection of analog material such as photographs of glaciers. In response to a World Data Center recertification process taking place in 2005, the WDC documented that we 1) Have significant holdings; 2) Provide data on a nondiscriminatory basis, without restriction, for no more than the cost of reproduction; 3) Maintain a Web-accessible directory of holdings that adhere to national or international standards; and 4) Provide a means for users to find and download data online.

During the summer of 2005, Roger Barry and Tingjun Zhang served on the WDC Panel Review Team for China's World Data Centers. As a team member, he visited the WDCs for Oceanography, Tianjin; Meteorology, Beijing; Renewable Resources and Environment, Beijing; Glaciology and Cryopedology, Lanzhou; and the proposed WDC for Mountains and Plateaus, Lanzhou.

International Union of Geodesy and Geophysics
The International Union of Geodesy and Geophysics (IUGG) works to promote cooperation in research and to keep data and information openly available for the benefit of society. Senior scientist Richard Armstrong is a member of the IUGG/CCS (Commission for Cryospheric Sciences) Working Group on Snow Classification, which is engaged in updating the 1990 International Commission on Snow and Ice (ICSI) snow classification system. Richard is also a member of the IUGG/CCS Panel to review the World Glacier Monitoring Service.

Global Digital Sea Ice Data Bank

The Global Digital Sea Ice Data Bank (GDSIDB), with "branches" located at the Arctic and Arctic Research Institute, St. Petersburg, Russia, and at NSIDC, stores archives of ice charts from operational centers. It is guided by an Expert Team on Sea Ice (Roger Barry is a member) under the World Meteorological Organization (WMO) Joint Commission on Marine Meteorology (JCOMM). The GDSIDB works on improving digital archive formats, and collaborates with the International Ice Charting Working Group (IICWG). Florence Fetterer leads these projects and maintains the IICWG home page. The 2005 IICWG meeting focused on interoperable formats for electronic charts. Issues worked out in this international, operational forum have parallels in international scientific data management. In 2005, Florence joined the Global Climate Observing System Sea Surface Temperature and Sea Ice Working Group, where ice charts are seen as a valuable resource for improving the representation of sea ice in modeling and reanalysis.

International Research

Roger Barry and Graduate Student Maria Tsukernik also assisted in a summer school course on board a Russian icebreaker. The course, arranged by the International Arctic Research Center (IARC) at the University of Alaska, took place on board the *Kapitan Dranitsyn*, 6 to 27 September 2005. Dr. Barry gave talks on Arctic exploration, climate, ice-climate interactions and feedback, and optical remote sensing. Light ice conditions in the Laptev Sea kept the scientific party from establishing more than one ice camp.

Roger Barry and Genrikh Alexeev next to the Russian icebreaker, the *Kapitan Dranitsyn*, in September 2005.

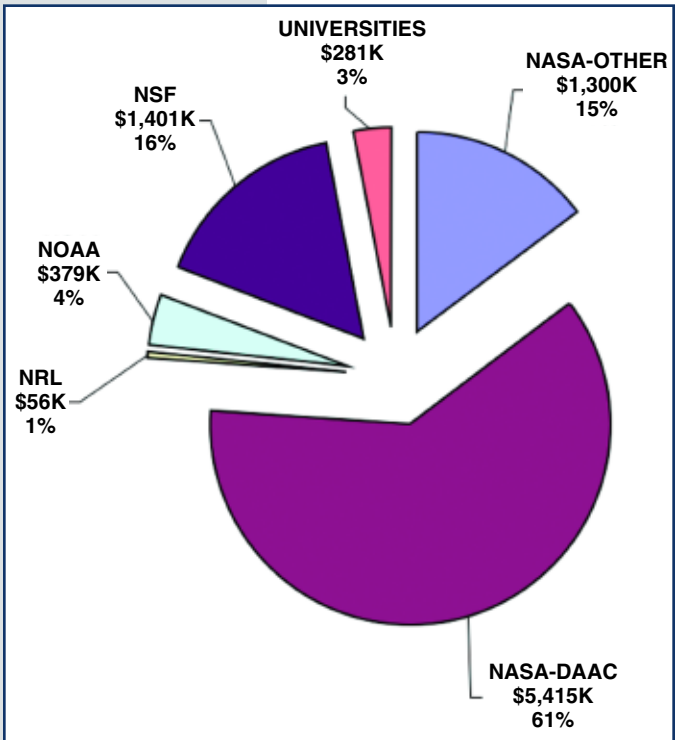
Researchers extended a global reach with especially strong activities in central Asia. Tom Painter is involved in snow pack monitoring in Pakistan, developing innovative tools to monitor snow cover for climate studies, hydrologic research, and catastrophic events such as the severe snowfall in the Hindu Kush during February and March 2005. Richard Armstrong is working with the Meteorological Bureau of Tibet to develop a memorandum of understanding to allow official collaboration in research on the causes of extreme weather on the Tibet plateau, optimal snow mapping and land cover/land use change. Tingjun Zhang is coordinating data exchange and research in Lanzhou, China, with the Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI).

The permafrost community enjoys strong international organization. In 2005, Oliver Frauenfeld and Lisa Ballagh became the U.S. National Coordinators of the Permafrost Young Researchers Network. PYRN is an education and outreach effort for IPY and beyond, with about 200 members in 22 countries.

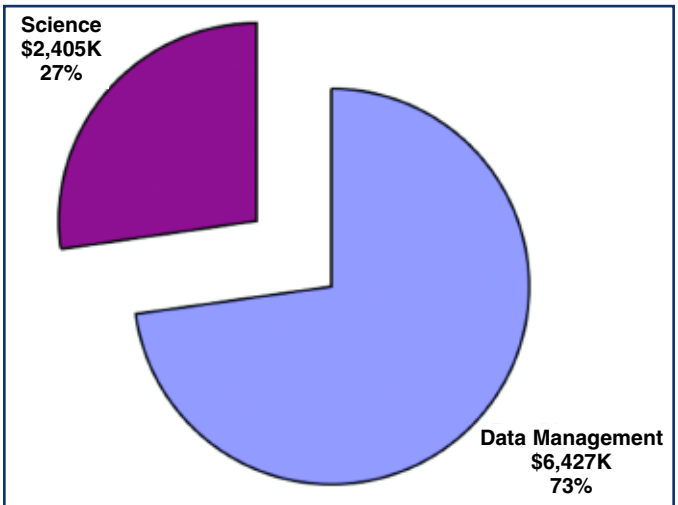
See the Research section for more information on the international activities of NSIDC's scientists.

Financial Support

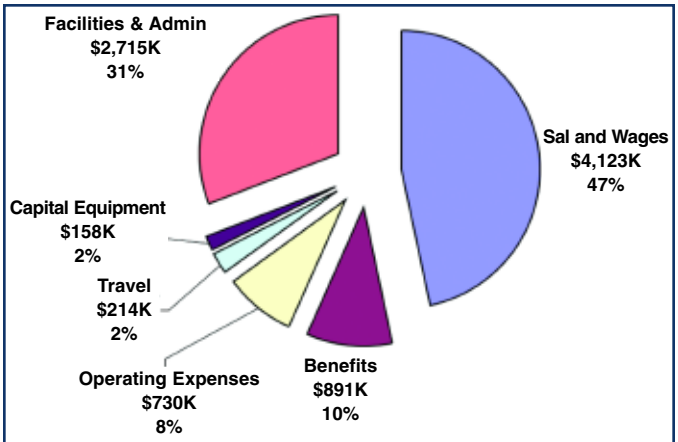
NSIDC's annual budget from July 2005 through June 2006 was 8.8 million dollars, with funding from national agencies such as NASA, NOAA, and NSF, as well as from the Naval Research Laboratory (NRL) and various universities.



NSIDC fiscal year 2006 total expenditures by funding source.



Fiscal year 2006 comparison of scientific research versus data management.



Fiscal year 2006 actual expenses by category.

Publications and Presentations

Journals

Albert, M., C. Shuman, Z. Courville, R. Bauer, M. Fahnestock, and T. Scambos. 2005. Extreme firn metamorphism: Impact of decades of vapor transport on near-surface firn at a low-accumulation glazed site on the East Antarctic plateau. *Annals of Glaciology* 39: 73-78.

Brown, I., and T. Scambos. 2005. Satellite monitoring of blue ice extent near Byrd Glacier, Antarctica. *Annals of Glaciology* 39: 223-230.

Catania, G., H. Conway, C. Raymond, and T. Scambos. 2005. Evidence for floatation or near floatation in the mouth of Kamb Ice Stream, West Antarctica, prior to stagnation. *Journal of Geophysical Research* 111, doi:10/1029/2005JF000355.

Chang, A. T. C., R. E. J. Kelly, E. G. Josberger, R. L. Armstrong, J. L. Foster, and N. M. Mognard. 2005. Analysis of ground-measured and passive-microwave-derived snow depth variations in midwinter across the northern Great Plains. *Journal of Hydrometeorology* 6(1): 20-33.

Chapin III, F. S., M. Sturm, M. C. Serreze, J. P. McFadden et al. 2005. Role of land-surface changes in Arctic summer warming. *Science* 310: 657-660.

Diner, D., B. Braswell, R. Davies, N. Gobron, J. Hu, Y. Jin, R. Kahn, Y. Knyazikhin, N. Loeb, J. P. Muller, A. Nolin, B. Pinty, C. Schaaf, G. Seiz, and J. Stroeve. 2005. The value of multiangle measurements for retrieving structurally and radiatively consistent properties of clouds, aerosols, and surfaces. *Remote Sensing of the Environment* 97(4): 495-518.

Frauenfeld, O. W., R. E. Davis, and M. E. Mann. 2005. A distinctly interdecadal signal of Pacific Ocean-atmosphere interaction. *Journal of Climate* 18(11): 1709-1718.

Fetterer, F., and I. Smolyar. 2005. On the creation of environmental data sets for the Arctic region. *Arctic Research of the United States* 19: 77-90.

Frauenfeld, O. W., T. Zhang, and M. C. Serreze. 2005. Climate change and variability using European Centre for Medium Range Weather Forecasts Reanalysis (ERA-40) temperatures on the Tibetan Plateau. *Journal of Geophysical Research* 110, doi:10.1029/2004JD005230.

Hulbe, C., R. Johnston, I. Joughin, and T. Scambos. 2005. Marine ice modification of fringing ice shelf flow. *Arctic, Antarctic, and Alpine Research* 37(3): 323-330.

Kargel, J. et al. (B. Raup, contributing author). 2005. Multispectral imaging contributions to Global Land Ice Measurements from Space. *Remote Sensing of Environment* 99(1-2): 187-219, doi:10.1016/j.rse.2005.07.004.

Lawrence D. M., and A. G. Slater. 2005. A projection of severe near-surface permafrost degradation during the 21st century. *Geophysical Research Letters* 32, doi:10.1029/2005GL025080.

Liang, S., J. Stroeve, and J. Box. 2005. MODIS-derived Greenland ice sheet albedo: The improved direct estimation algorithm. *Journal of Geophysical Research* 110, doi:10.1029/2004JD005493.

Ling, F., and T. Zhang. 2005. Modeling the effect of variations in snowpack-disappearance date on surface-energy balance on the Alaskan North Slope. *Arctic, Antarctic, and Alpine Research* 37: 483-489.

Ling, F., and T. Zhang. 2005. Sensitivity of ground thermal regime and surface energy fluxes to tundra snow density in northern Alaska. *Cold Regions Science and Technology* 44: 121-130.

Meier, W. N. 2005. Comparison of passive microwave ice concentration algorithm retrievals with AVHRR imagery in the Arctic peripheral seas. *IEEE Transactions on Geoscience and Remote Sensing* 43: 1324-1337.

Meier, W., J. Stroeve, F. Fetterer, and K. Knowles. 2005. Reductions in Arctic sea ice cover no longer limited to summer. *Eos, Transactions of the American Geophysical Union* 86(36): 326, doi:10.1029/2005EO360003.

Overpeck, J., J. A. Francis, D. K. Perovich, M. C. Serreze et al. 2005. Arctic system on trajectory to new, seasonally ice-free state. *Eos, Transactions of the American Geophysical Union* 86: 309-316.

Parsons, M. A., and R. Duerr. 2005. Designating user communities for scientific data: Challenges and solutions. *Data Science Journal* 4: 31-38.

Raup, B., T. Scambos, and T. Haran. 2005. Mapping and topography of streaklines on an Antarctic ice shelf using Advanced Land Imager (ALI). *IEEE Transactions of Geoscience and Remote Sensing* 43(4): 736-742.

Scambos, T., and C. Novak. 2005. On the current location of the Byrd "Snow Cruiser" and other artifacts from Little America I, II, III, and Framheim. *Polar Geography* 29(4): 237-252.

Scambos, T., O. Sergienko, A. Sargent, D. MacAyeal, and J. Fastook. 2005. ICESat profiles of tabular iceberg margins and iceberg break-up at low latitudes. *Geophysical Research Letters* 23, doi:10.1029/2005GL023802.

Serreze, M. C., A. Barrett, and F. Lo. 2005. Northern high latitude precipitation as depicted by atmospheric reanalyses and satellite retrievals. *Monthly Weather Review* 133: 3407-3430.

Srivastava, A. N., N. C. Oza, and J. C. Stroeve. 2005. Virtual sensors: Using data mining techniques to efficiently estimate remote sensing spectra. *IEEE Transactions on Geosciences and Remote Sensing* 43(3), doi:10.1109/TGRS.2004.842406.

Stroeve, J. C., J. Box, F. Gao, S. Liang, A. Nolin, and C. Schaaf. 2005. Accuracy assessment of the MODIS 16-albedo product for snow: Comparison with Greenland in situ measurements. *Remote Sensing of the Environment* 94(1): 46-60.

Stroeve, J. C., M. C. Serreze, F. Fetterer, T. Arbetter, W. Meier, J. Maslanik, and K. Knowles. 2005. Tracking the Arctic's shrinking ice cover: Another extreme September minimum in 2004. *Geophysical Research Letters* 32, doi:10.1029/2004GL021810.

Zhang, T. 2005. Historical overview of permafrost studies in China. *Physical Geography* 26: 279-298.

Zhang, T. 2005. Influence of the seasonal snow cover on the ground thermal regime: An overview. *Reviews of Geophysics* 43:1-23.

Zhang, T., O. W. Frauenfeld, M. C. Serreze, A. J. Etringer, C. Oelke, J. L. McCreight, R. G. Barry, D. Gilichinsky, D. Yang, H. Ye, L. Feng, and S. Chudinova. 2005. Spatial and temporal variability in active layer thickness over the Russian Arctic Drainage Basin. *Journal of Geophysical Research* 110, doi:10.1029/2004JD005642.

Books

Serreze, M. C., and R. G. Barry. 2005. *The Arctic climate system*. Cambridge, England: Cambridge University Press.

Book Chapters

Barry, R. G. 2005. Alpine climate change and cryospheric responses: An introduction. In *Climate and hydrology in mountain areas*. Eds. Carmen de Jong, David Collins, and Roberto Ranzi, 1-4. London: John Wiley and Sons, Ltd.

Barry, R. G. 2005. Synoptic climatology. In *Encyclopedia of world climatology*. Ed. J. E. Oliver, 700-704. Dordrecht, the Netherlands: Springer.

Duerr, R. 2005. Royal society. In *Encyclopedia of science, technology, and ethics*. Ed. Carl Mitcham. MacMillan Reference USA.

Duguay, C. R., T. Zhang, D. W. Leverington, and V. E. Romanovsky. 2005. Satellite remote sensing of permafrost and seasonally frozen ground. In *Remote sensing in northern hydrology*. Eds. C. R. Duguay and A. Pietroniro, 91-118. Washington, D. C.: American Geophysical Union.

de Jong, C., D. N. Collins, R. Ranzi, R. G. Barry, G. Leavesley, and B. Bachhi. 2005. Introduction: Climate and hydrology of mountain areas. In *Climate and hydrology of mountain areas*. Eds. C. de Jong, D. N. Collins, and R. Ranzi, xix-xxi. London: John Wiley and Sons, Ltd.

Koerner, C., M. Ohsawa et al. (R. Barry, contributing author). 2005. Chapter 24: Mountain systems. In *Ecosystems and human well-being, current state and trends, Volume 1, millennium ecosystem assessment*. Eds. R. Hassan, R. Scholes, and N. Ash, 681-716. Washington, D. C.: Island Press.

Stroeve, J. C., D. Long, J. C. Comiso, T. A. Scambos, and C. A. Shuman. 2005. Estimation of glaciers and sea ice extent and their properties. In *Encyclopedia of hydrological sciences, volume 2*. Ed. Malcom G. Anderson, 831-852. London: John Wiley and Sons, Ltd.

Conference Presentations

Armstrong, R., M. J. Brodzik, and M. A. Parsons. 2005. Graphical representation of snow pit data from CLPX. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Armstrong, R., M. J. Brodzik, M. H. Savoie, K. W. Knowles, and R. G. Barry. 2005. Snow cover mapping at the continental and global scale using combined optical and passive microwave satellite data. Presented at the CliC First Science Conference, Beijing, China.

Ballagh, L., D. Dye, A. Howard, and F. Fetterer. 2005. Climate records of snow, glaciers, and sea ice. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Barrett, A. P., T. H. Painter, and C. Landry. 2005. Impact of desert dust on meltrates and runoff from mountain snowpacks. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Barry, R. G. 2005. Impacts of climate and cryospheric change. Presented at the CliC First Science Conference, Beijing, China.

Barry, R. G., B. E. Goodison, I. Allison, C. Dick, and V. Ryabinin. 2005. The WCRP Climate and Cryosphere Project (CliC): Status and plans. Presented at the Annual Conference of the Association of American Geographers, Denver, CO.

Barry, R. G., and M. C. Serreze. 2005. Climatic processes affecting Arctic coastal environments: A review. Presented at the Sixth Conference on Coastal Atmospheric and Oceanic Prediction and Processes.

Barry, R. G., T. Zhang, O. W. Frauenfeld, M. C. Serreze, A. J. Etringer, C. Oelke, J. McCreight, D. Gilichinsky, D. Yang, H. Ye, F. Ling, and S. Chudinova. 2005. Spatial and temporal variability in active layer thickness over the Russian Arctic Drainage Basin. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Bauer, R., T. Scambos, G. Scharfen, and C. Judy. 2005. National Snow and Ice Data Center: Antarctic data management support. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Beitler, J. 2005. When instant gratification isn't soon enough: Getting attention in a short-attention-span world. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Brodzik, M. J., R. L. Armstrong, K. Knowles, and M. H. Savioe. 2005. The effect of sensor differences in deriving long-term trends from satellite passive microwave snow extent and snow water equivalent. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Cassidy, M. P., and T. H. Painter. 2005. Hyperspectral analysis of dust concentration, snow grain size, and broadband albedo of alpine snowcover. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Catania, G. A., T. Scambos, H. Conway, and C. Raymond. 2005. Century-scale ice stream variability and stability: A case study of the Kamb Ice Stream, West Antarctica. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Clark, M. P., and A. G. Slater. 2005. One-dimensional compared to three-dimensional snow data assimilation. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Clark, M. P., and A. Slater. 2005. Probabilistic quantitative precipitation estimation in complex terrain. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Dozier, J., T. H. Painter, and J. E. Frew. 2005. Characteristics of snow cover in the Sierra Nevada from MODIS and Landsat. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Duerr, R., M. A. Parsons, and J. Beitler. 2005. Distributed data management for the long term. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Fahnestock, M. A., C. Shuman, T. Scambos, M. Albert, T. Haran, Z. Courville, and R. Bauer. 2005. Mapping Antarctic megadunes and other accumulation-related features on the East Antarctic Plateau. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Finnis, J., M. C. Serreze, M. M. Holland, and C. J. John. 2005. Influence of climate change on extratropical cyclones and resulting effects on Arctic hydrology. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Frauenfeld, O. W., and H. Jin. 2005. Permafrost and seasonally frozen ground in a changing climate II. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Frauenfeld, O. W., T. Zhang, R. G. Barry, and D. Gilichinsky. 2005. Observed changes and drivers of permafrost temperatures in Northeastern Siberia. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Fricker, H. A., T. Scambos, and E. Domack. 2005. Antarctic ice shelves and ice sheet evolution: Recent advances from modeling and field investigations II. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Fricker, H. A., T. Scambos, and E. Domack. 2005. Antarctic ice shelves and ice sheet evolution: recent advances from modeling and field investigations III. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Hicks, G. J., A. L. Howard, and S. Sommer. 2005. Library collaboration aids global research. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Howat, I. M., S. Tulaczyk, I. Joughin, S. O'Neel., and T. Scambos. 2005. Mechanical feedbacks in the calving glacier retreat, thinning, and acceleration. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Khalsa, S. S., B. H. Raup, and M. Dyurgerov. 2005. How well do observations on bench mark glaciers represent a glacier system? Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Khromova, T., G. Nosenko, R. Armstrong, B. Raup, S. S. Khalsa, and R. Barry. 2005. First results of GLIMS database population for former Soviet Union glacier regions. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Kindig, D. N., M. Tsukernik, and M. C. Serreze. 2005. Modeling characteristics of winter cyclone activity in the northern North Atlantic. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Knowles, K., and R. Swick. 2005. Spatial search of orbital swath data. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Lawrence, D. M., and A. G. Slater. 2005. Permafrost and climate change: Here today, gone tomorrow. A coupled climate model projection for the 20th and 21st centuries. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Lettenmaier, D. P., T. J. Bohn, A. G. Slater, J. McCreight, and M. C. Serreze. 2005. Multi-model estimates of Arctic land surface conditions. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Mahowald, N., D. Muhs, S. Levis, M. Yoshioka, P. Rasch, C. Zender, G. Okin, and T. Painter. 2005. Deposition changes in the past and the future. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Maslanik, J., U. C. Herzfeld, M. Sturm, and D. J. Cavalieri. 2005. On the role of spatial sea-ice roughness in understanding sea-ice properties, processes, and their changes. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

McCreight, J., T. Zhang, O. W. Frauenfeld, A. J. Etringer, R. G. Barry, and D. Gilichinsky. 2005. Means and trends of seasonally frozen ground thickness in the Northern Hemisphere. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

McBride, K., T. Painter, and C. Landry. 2005. A synoptic climatology of desert dust deposition to the alpine snowpack in the San Juan Mountains, Colorado, U. S. A. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Meier, W. N. 2005. Potential of AMSR-E derived sea ice motions for assimilation into sea ice models. Presented at the American Meteorological Society 8th Conference on Polar Oceanography and Meteorology, San Diego, CA.

Meier, W. N., F. Fetterer, J. Stroeve, D. Cavalieri, C. Parkinson, J. Comiso, and R. Weaver. 2005. Towards a satellite-based sea ice climate data record. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Muto, A., T. A. Scambos, and J. Bohlander. 2005. Antarctic firn temperature measurements from 1949-1970: Potential for climate trend determination via re-measurement. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Neff, J. C., L. Farmer, T. H. Painter, C. Landry, and R. Reynolds. 2005. Effects of desert dust on nutrient cycling in the San Juan Mountains, Colorado. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Noonan, G. J., E. C. Weatherhead, S. Gearheard, and R. Barry. 2005. Arctic weather change: Linking indigenous (Inuit) observations with the surface temperature record. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Painter, T. H., A. P. Barrett, C. Landry, and J. C. Neff. 2005. Radiative effects of desert dust deposits to alpine snow. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Painter, T. H., and K. A. Hibbard. 2005. Integrative Earth sciences: Biogeochemical and water cycles I. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Parsons, M. A., R. Duerr, and J. Beitler. 2005. Data management, a utility for science. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Pharris, K. 2005. Web site usability: First, ignore the science. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Renfrow (Collins) S., W. Meier, J. Wolfe, D. Scott, A. Leon, and R. Weaver. 2005. What about sea ice? People, animals, and climate change in the polar regions: An online resource for the International Polar Year and beyond. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Scambos, T., O. Sergienko, A. Sargent, D. MacAyeal, J. Fastook, and D. Long. 2005. Tabular iceberg evolution and break-up at low latitude: Imitating ice shelves. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Scharfen, G., R. Bauer, and C. Judy. 2005. Supporting access to Antarctic scientific data—Antarctic Master Directory content and usage continues to increase. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Serreze, M. C. 2005. A new look at the Arctic freshwater cycle: The charge of the budgeteers. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Serreze, M. C. 2005. Seasonal and regional aspects of northern high latitude cyclone activity. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Shiklomanov, N. I., O. A. Anisimov, and T. Zhang. 2005. Spatial assessment of performance of hemispheric permafrost models using a multiscale, hierarchival approach to model validation: Results for north-central Alaska. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Slater, A. G., T. Bohn, J. L. McCreight, M. C. Serreze, D. P. Lettenmaier, X. Wang, and J. Key. 2005. Freshwater input to the Arctic: Uncertainty in model forcing vs. model structure. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Stern, H., F. Fetterer, and C. Fowler. 2005. A new look at the Northern Hemisphere sea ice concentration. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Swick, R., and K. Knowles. 2005. Spatial tools for a round planet. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Tschudi, M. A., J. A. Maslanik, and D. K. Perovich. 2005. Evolution of melt pond cover in the Beaufort/Chukchi Sea region during summer 2004. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

True, S. A., B. Collins, R. J. Birk, N. Labelle-Hamer, W. N. Meier, and R. L. Weaver. 2005. Multidisciplinary global modeling: The really big picture posters. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Tsukernik, M., M. Serreze, and D. Kindig. 2005. Winter cyclone activity in the northern North Atlantic: Observational analysis. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Ullman, R. E., and S. S. Khalsa. 2005. Community approaches to data sharing posters. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Yang, D., Y. Zhao, D. Robinson, R. Armstrong, and H. Ye. 2005. Streamflow response to seasonal snowcover change over the large northern rivers. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Zhang, T., O. W. Frauenfeld, R. G. Barry, A. J. Etringer, J. McCreight, and D. Gilichinsky. 2005. Response to changes in active layer and permafrost conditions to hydrological cycle in the Russian Arctic. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Zhang, T., S. Gruber, and F. Nelson. 2005. Permafrost and seasonally frozen ground in a changing climate IV Posters. Presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Other Publications

Maslanik, J. A. 2005. Review and summary of Arctic Ocean surface conditions. *State of the Arctic conference report*. U.S. Army Cold Regions Research and Engineering Laboratory, 7 pp.

Naranjo, L. 2005. Matter in motion: Earth's changing gravity. In *NASA: Supporting Earth System Science 2005*. Boulder, Colorado: University of Colorado.

Naranjo, L. 2005. A rainforest divided. In *NASA: Supporting Earth System Science 2005*. Boulder, Colorado: University of Colorado.

Naranjo, L. 2005. SPoRTscast. In *NASA: Supporting Earth System Science*. 2005. Boulder, Colorado: University of Colorado.

Renfrow, S. 2005. Arctic melt accelerating. *WWF Arctic Bulletin, World Wide Fund for Nature International* 4.05: 14.

Scott, M. 2005. Mosaic of Antarctica. NASA Earth Observatory. http://earthobservatory.nasa.gov/Study/MOA/.

Scott, M. 2005. Out of the crevasse field. NASA Earth Observatory. http://earthobservatory.nasa.gov/Study/Crevasse/crevasse.html.

For more information about NSIDC, please contact

User Services
National Snow and Ice Data Center
449 UCB, University of Colorado
Boulder, CO 80309

phone: +1 303.492.6199
fax: +1 303.492.2468
e-mail: nsidc@nsidc.org

http://nsidc.org