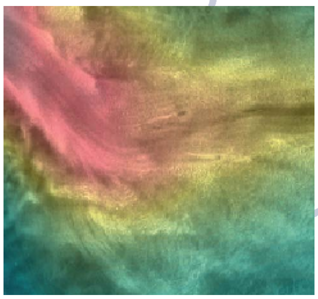

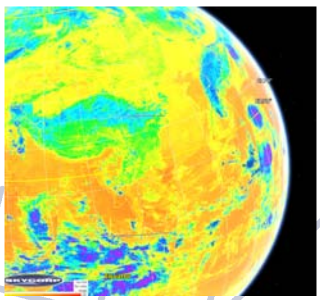

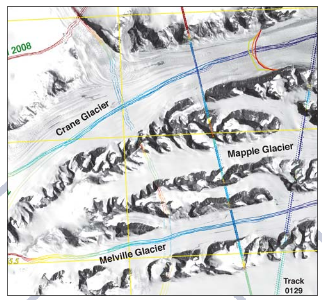

NSIDC

National Snow and Ice Data Center

University of Colorado at Boulder

National Snow and Ice Data Center

Annual Report 2010

Supporting Cryospheric Research Since 1976

National Snow and Ice Data Center Annual Report 2010

National Snow and Ice Data Center
University of Colorado at Boulder

http://nsidc.org/annualreport/

Cover image captions

Top

A huge area of the Larsen Ice Shelf, pictured here, collapsed unexpectedly in 2002. This collapse was only one of the dramatic changes observed on the Antarctic Peninsula in recent years. The new Mosaic of Antarctica will allow researchers to discover other changes in the ice sheet that have occurred since 2004, and better understand the dynamics of the frozen continent. Image courtesy Ted Scambos, NSIDC

Middle (left to right)

In April 2009, a strong dust storm brought unprecedented levels of dust to the Rocky Mountains. This photo was taken in the mountains near Aspen, Colorado, on April 3, 2009. Credit: Jeff Deems, NSIDC

This aerial photograph looks down the iceberg-choked fjord that leads up to the calving front of Jakobshavn Isbrae, 43 kilometers (27 miles) away at the head of the fjord. Between 2000 and 2010, Jakobshavn dumped 260 gigatons of ice into the ocean. Photo courtesy Ian Joughin, University of Washington

Bottom (left to right)

This map of Jakobshavn shows how much the glacier's surface dropped between 2000 and 2010. The background image shows the glacier surface as it looks in radar images in the winter of 2005. Red and yellow indicate the very large ice losses in the trunk of the glacier, and ending at the summer 2009 ice edge, which is well behind where the ice edge was in the winter of 2005. Bright areas at lower right are surface crevasses formed in the fast-flowing part of the glacier. Image courtesy Ben Smith, University of Washington

On September 23, 1966, Nimbus II acquired the temperature data shown in this image of Asia, overlaid on Google Earth. The warm waters of the Persian Gulf are clearly seen in contrast with the cold temperatures of the Himalayas. Blues and greens indicate cooler temperatures, and yellows and reds indicate warmer temperatures.

This Landsat image of Crane Glacier on the Antarctic Peninsula is overlain with ICESat and Airborne Topopgraphic Mapper (ATM) tracks. ATM is a lidar sensor that is now part of the IceBridge mission. Over time, ICESat and ATM measurements, together with visible imagery, can detect thinning of the ice and accelerated flow of ice into the ocean. Large glaciers such as Crane have the potential to contribute significantly to sea level rise.

Supporting Cryospheric Research Since 1976

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Director's Overview of 2010

Our Mission

The mission of the National Snow and Ice Data Center (NSIDC) is to improve our understanding of the Earth's frozen realms. This includes our planet's floating sea ice cover, lake ice, glaciers, ice sheets, snow cover and frozen ground, collectively known as the cryosphere. NSIDC advances its mission through:

- Managing, distributing and stewarding cryospheric and re lated climate data collected from Earth orbiting satellites, aircraft missions and surface observations.
- Conducting research addressing all major elements of the cryosphere; over the past decade, this research has increas ingly focused on understanding how and why the cryosphere is changing and the implications of these changes;
- Conducting informatics research aimed at finding better ways to discover, integrate and distill the vast and growing volume of cryospheric and climate data;
- Educating the public about the cryosphere, the changes that are being observed, and their implications

The National Snow and Ice Data Center is part of the Cooperative Institute for Research in Environmental Sciences, at the University of Colorado Boulder.

CIRES

Colorado
University of Colorado at Boulder ™

Background

NSIDC traces its roots to 1976 when Roger G. Barry took over the Directorship of the transferred World Data Center-A for Glaciology, to archive analog data and information from the 1957–1958 International Geophysical Year. NSIDC got its name in 1982 from the National Oceanic and Atmospheric Association (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) as a result of funding to serve as a national information and referral center for polar research. Dr. Roger G. Barry was the director of NSIDC from its inception until spring of 2009, at which time the torch was passed to Dr. Mark C. Serreze.

Today, NSIDC makes hundreds of scientific data sets accessible to researchers around the world, ranging from small text files to terabytes of remote sensing data from the National Aeronautics and Space Administration (NASA) Earth Observing System satellite program and other sources. Our data managers, technical writers and scientific programmers operate in teams to create or publish data sets, working closely with data providers and users to understand their needs and to offer documentation, tools, and formats that support scientific research. NSIDC also works to ensure that data and metadata (data describing the data) are continually preserved and will be accessible for the longer term, so that researchers can study climate change over long periods. Together, these practices ensure the physical and scientific integrity of the data we manage and disseminate. We manage data under sponsorship from NASA, the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF).

Major areas of research at NSIDC include

- Studies of processes driving the observed downward trend in Arctic sea ice extent over the period of modern satellite observations (1979 onwards);
- The environmental impacts of this sea ice loss both within and beyond the Arctic;
- The behavior of the Greenland and Antarctic ice sheets, Himalayan glaciers and their contributions to sea level rise;

- Links between snowfall, temperature and streamflow; and
- The implications of changes in earth's permafrost.

This research, funded primarily by NASA and NSF, is performed in collaboration with researchers all over the world, and includes participation by both graduate and undergraduate students at the University of Colorado.

Informatics is a relatively new but quickly growing branch of study at NSIDC. It includes

- Research into alternative database structures to enable investigators to more efficiently search through vast data volumes to answer science questions;
- Development of data casting services to making NSIDC data more visible to more researchers;
- Investigating new directions in data stewardship involving the University library system; and
- Enhancing data discovery through semantic interoperability.

A major strength of NSIDC is synergy between its environmental and informatics research and data management. Our in-house scientists consult in creating data products, answer questions from data users, and in some cases produce new data sets distributed by NSIDC.

NSIDC's education and outreach efforts are wide ranging. NSIDC scientists are in high demand by the media to lend their expertise on environmental issues involving cryospheric change. Arctic Sea ice News and Analysis (http://nsidc.org/arcticseaicenews/), the most popular web page at NSIDC, provides daily updates of Arctic sea ice extent along with scientific analysis of evolving conditions that that is both accurate but accessible to a wide audience. NSIDC's new Icelights section (http://nsidc.org/icelights/) provides detailed information on ice and climate topics to complement Sea Ice News and Analysis. The NSIDC Education Center (http://nsidc.org/cryosphere/) provides a range of information about Earth's snow and ice, from comprehensive "All About" sections to quick facts on popular snow and ice topics.

Highlights of 2010

In 2010, NSIDC initiated a new "Monthly Highlights" section (http://nsidc.org/monthlyhighlights/), outlining how we are addressing challenges in data management, investigating current questions in the cryosphere, and developing innovative ways to add value for our data and information users.

Tracking a runaway glacier

In 2001, Jakobshavn Glacier on the west coast of Greenland was already the fastest-moving glacier on Earth; like the majority of glaciers around the world, Jakobshavn was displaying the effects of climate warming. Since then it has continued to accelerate, and by 2010 it was moving at a pace of fifteen kilometers per year, twice as fast as before. In fact, preliminary research by Ohio State University glaciologist Ian Howat shows that in the last ten years Jakobshavn Glacier alone has dumped 260 gigatons of ice into the ocean, enough to add one millimeter to sea level rise. Jakobshavn is not the only runaway glacier in Greenland—and together, faster moving glaciers are draining ice from the Greenland Ice Sheet into the ocean, adding to sea level rise.

Birds-eye view

The weight of glacial ice normally causes its icy mass to inch towards the glacier's low end, shedding ice in a natural cycle, but in recent decades the pace has picked up. Behind Greenland's glaciers lies a massive ice sheet, amd this ice too can become ocean-bound when glaciers accelerate. Ben Smith, a glaciologist at the University of Washington, is keeping an eye on Jakobshavn and other fast-moving glaciers in Greenland with remote sensing data from satellites and airplanes. Those data now include data products from the NASA IceBridge mission, an airborne data-gathering project aimed at bridging the data gap between two Ice, Cloud, and land Elevation Satellite (ICESat) missions. The first ICESat mission ended in 2010, and ICESat-2 will launch in 2015. Smith said, "The ice sheet is not going to stop doing interesting things between the two ICESat missions. Having a picture of how glaciers have changed during that time will be really important."

This aerial photograph looks down the iceberg-choked fjord that leads up to the calving front of Jakobshavn Isbrae, 43 kilometers (27 miles) away at the head of the fjord. Between 2000 and 2010, Jakobshavn dumped 260 gigatons of ice into the ocean.
Photo courtesy Ian Joughin, University of Washington

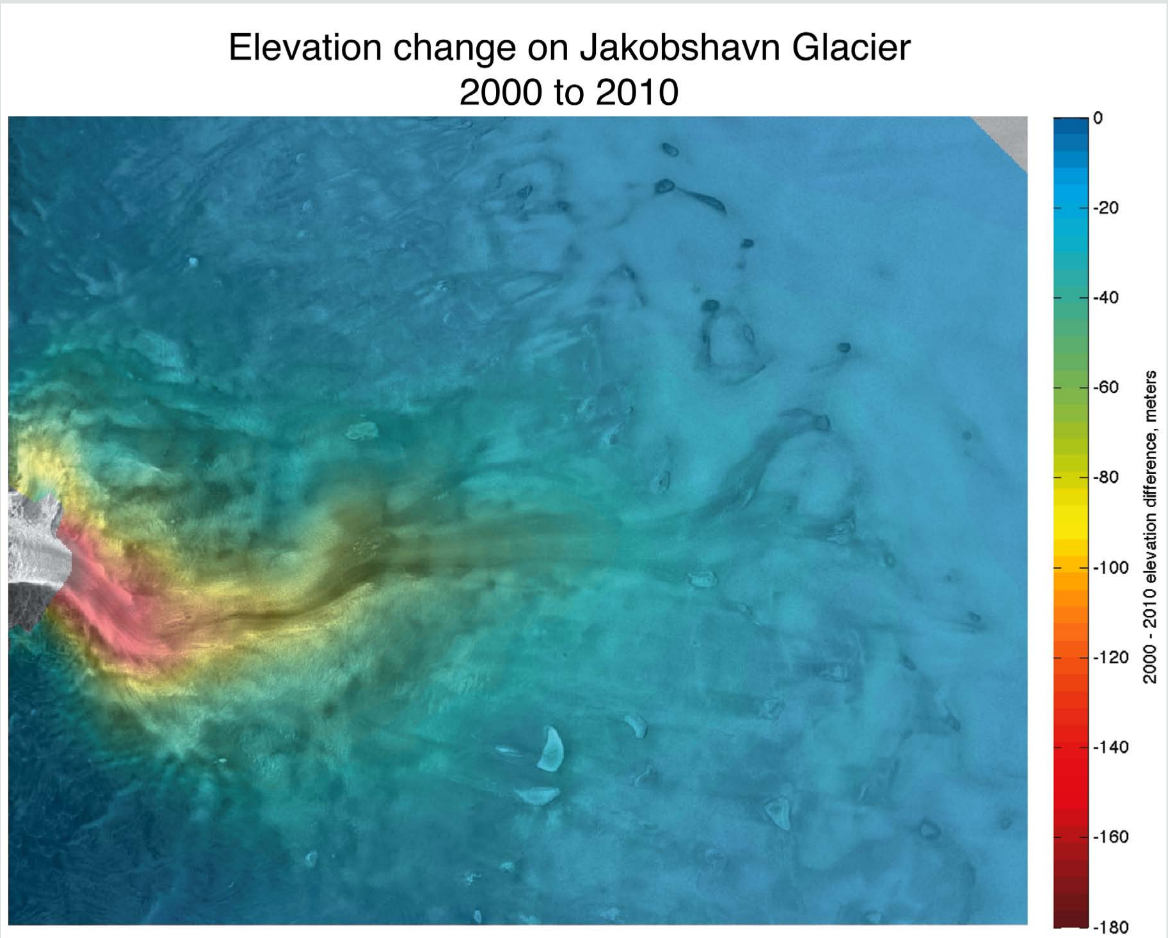
IceBridge prevents a data gap

Although the IceBridge mission just started a little over a year ago, data are already online at NSIDC for researchers worldwide. The data sets include elevation profiles from the Airborne Topographic Mapper (ATM), similar to the elevation data provided by ICESat, and ice-penetrating radar data which shows the topography of the land beneath the ice sheet. Smith and his colleagues are combining these two data products with elevation data from ICESat and ATM data from pre-IceBridge missions, which NSIDC also distributes.

Smith's preliminary studies with these data show that while Jakobshavn continues to dump ice into the ocean, two other fast-moving glaciers, Kangerdlugssuaq and Helheim on Greenland's east coast, are no longer losing as much ice as they were in 2003 or 2004. While the surface of both glaciers continues to move at about the same speed, the amount of ice flowing into the ocean has slowed as the glaciers thinned.

It turns out that glacier flow varies with factors like the topography of land under them and the thickness of the glacier. "This is good news in the short term," Smith said, especially for low-lying coastal dwellers most at risk from sea level rise, because ice may not be flowing into the ocean through these glaciers as fast as data collected in 2004 and 2005 indicated. But he added, "It's hard to say what will happen as the ice fronts retreat further up the fjord."

So as Greenland's glaciers continue to flow, Smith and other Arctic glaciologists will be watching, using all the data available to better understand how, why, and how fast the Greenland Ice Sheet is changing.



This map of Jakobshavn shows how much the glacier's surface dropped between 2000 and 2010. The background image shows the glacier surface as it looks in radar images in the winter of 2005. Red and yellow indicate the very large ice losses in the trunk of the glacier, and ending at the summer 2009 ice edge, which is well behind where the ice edge was in the winter of 2005. Bright areas at lower right are surface crevasses formed in the fast-flowing part of the glacier.
Image courtesy Ben Smith, University of Washington

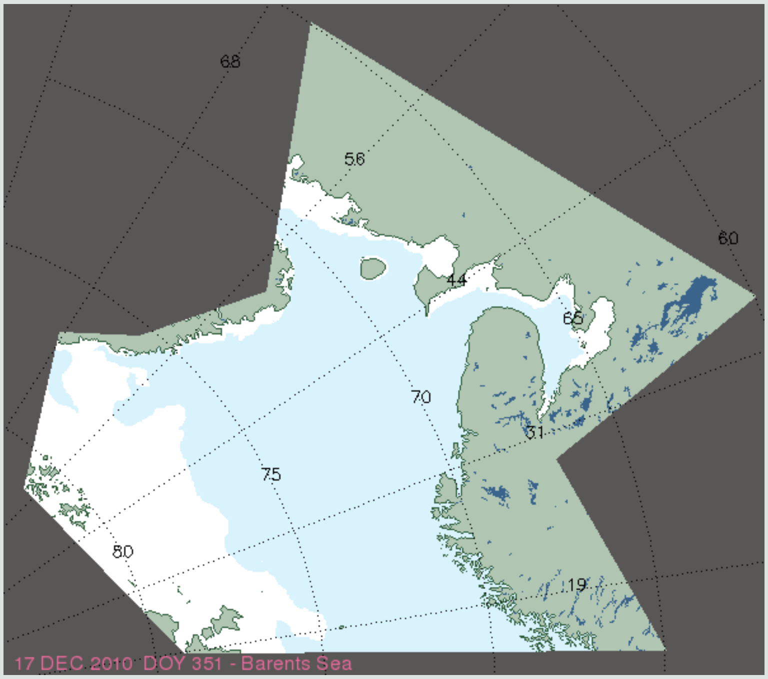
On the leading edge of sea ice

Stringing around the Arctic for tens of thousands of miles, the edges of the sea ice pack are a maker of seasons and ecosystems. As seasons and climate and local weather change, so does the position of the ice edge. Until now, the satellite view of sea ice extent for climate studies has been too panoramic for studying the ice edge, and ice charts for navigation have been too close-up. But a new marriage of these data promises to provide that just-right view.

The cold locker

Butterfly sightings may signal spring in mid-latitudes, but in the Arctic, it is the sight of open water along the coasts, as sea ice begins to recede. Travel over the ice ceases, and travel over the water may, at some peril, begin. The ice edge teems with phytoplankton, anchoring a longer food chain: fish, and the seals that eat them, and the polar bears that eat seals. The ice locks to the shore in winter, allowing man and beast to travel quickly over the smooth, solid ice pack.

Local weather and longer-term changes in climate can move that edge and its dependents. Can fauna and humans adapt? What if polar bears need to swim farther to reach the ice edge? What if the hunting season for humans ends earlier, because the ice has opened more quickly? Will shorter shipping routes over the Arctic create new economies, and alter political balances? These are only some of the questions that call for better data on sea ice edges.



A particular strength of MASIE when compared with the Sea Ice Index daily product is that MASIE maps ice along coasts much more reliably. This is because the NIC IMS product upon which MASIE is based does not suffer from the "land contamination" that is deleterious to passive microwave products, and has a much higher resolution. This regional MASIE image from Dec 17, 2010, is illustrative. MASIE provides a more accurate estimate of sea ice edge position than other sea ice data sources distributed by NSIDC.

Where is the Arctic ice NOW?

To give the best available Arctic-wide answer to the question,"Where is Arctic sea ice NOW?" NSIDC worked with the U.S. National Ice Center to create MASIE (may-zee), the Multisensor Analyzed Sea Ice Extent project.

MASIE lets you view and download several kinds of data about sea ice edge:

- Northern Hemisphere-wide sea ice coverage for yesterday and the last four weeks
- Sea ice coverage by region
- A file of sea ice extent, in square kilometers, for the entire Northern Hemisphere and by region for the last four weeks, updated daily
- Convenient formats: georeferenced image (GeoTIFF), compressed image (PNG), GIS-ready (shapefile), and Google Earth (KMZ)

MASIE is similar to NSIDC's Sea Ice Index (SII) product: it is easy to use and gives a graphical view of ice extent in various formats. However, the SII uses only low-resolution satellite passive microwave data. As a result, the monthly average product is a consistently processed 30+ year record, good for climate studies, but the daily product can be off by tens or hundreds of kilometers in tracking any specific ice edge.

In contrast, MASIE relies more on visible imagery than on passive microwave data. MASIE takes advantage of important features of the daily 4-kilometer sea ice component of the National Ice Center (NIC) Interactive Multisensor Snow and Ice Mapping System (IMS) product: visible and radar imagery, passive microwave data, NIC weekly analysis products and other data that are combined via intensive daily manual analysis at the NIC.

MASIE processes the data to provide an accessible, rolling view of ice edge position. MASIE and the Sea Ice Index fill a need for immediate information over several temporal scales. A FAQ explains when to use MASIE and when to use the SII, and directs users to operational sources if needed. As of December 2010, MASIE launches with Northern Hemisphere data, but soon the team plans to release data for the Southern Hemisphere as well.

MASIE was developed with support from NIC and the Naval Oceanographic Office, and is hosted by the NOAA at NSIDC project. We are seeking funding for its long-term maintenance.

Dust on snow drains a precious resource

NSIDC researchers are exploring an unexpected risk to the U.S. Rocky Mountain snowpack and Western water supplies: a coating of desert dust. Their ongoing project suggests that desert dust landing on mountain snow may reduce water supplies for cities, agriculture, and industry far downstream.

Dark questions

Large dust storms in spring can blow from distant plains and deserts, settling as a pinkish or brown coating over the white snow high in the mountains, where cold temperatures normally keeps the snowpack stable and slow to melt. The Rocky Mountain region has become dustier since the 1800s, as human settlement and activity kicked up more dust, and recent periods of drought across the West brought even more dust to the Rockies' snowy heights.

In April 2009, a strong dust storm brought unprecedented levels of dust to the Rocky Mountains. This photo was taken in the mountains near Aspen, Colorado, on April 3, 2009. Credit: Jeff Deems, NSIDC

NSIDC scientist Tom Painter saw firsthand from his treks in the mountains that dust-covered snow seemed to melt faster. As a cryospheric scientist, he knew the importance of snow's bright, highly reflective properties in slowing its melt. Could he show that a dusty coating defeated snow's usually high albedo and sped up melt? In 2003, Painter and PhD student Jeff Deems set up observations to find out: They teamed with other Colorado researchers to collect measurements of dust-covered snow, hiking far into the high country in winter to collect samples.

This small study demonstrated this to be the case: dust-covered snow, which is darker in color that clean snow, absorbs more of the sun's energy and melts faster. The simple finding that dust affects snowmelt raised many questions: Would dustier conditions affect vegetation in alpine regions? Would earlier snowmelt affect the flow of rivers, which provide water to the Western United States? And how would climate change affect the amount of dust falling on snow?

A dustier outlook

Deems has since graduated and now works at NSIDC and at the Western Water Assessment (WWA), and Painter is now at the NASA Jet Propulsion Laboratory in California, but they continue to work together on dust. In September 2010, they published a study estimating the effects of dusty conditions on snow cover in the Upper Colorado River basin, using a hydrology model of the Colorado River basin. The study showed that dust on snow robs the Colorado River of about five percent of its water each year.

Now Deems and Painter are leading a broader NASA and WWA study to more thoroughly explore the connections between dust, snow, and water. With combined field observations, satellite data, and computer models, the researchers will study how dust gets blow up from the desert, travels through the atmosphere, lands on snow, and how that dust impacts snowmelt and river flow. By exploring the related systems, the researchers hope to better understand how climate change and different land management outcomes could affect the availability of water from snow. And although the study focuses on the Western U. S., the models for snowmelt and river flow could apply to mountain regions worldwide.

NSIDC researcher Jeff Deems points out dust layers in snow during field work in 2009. As the snow melts in the spring, the layers of dust get exposed on the snow surface, speeding melt. Credit: Jeff Deems, NSIDC

Mosaic of Antarctica: Mapping a changing continent

How do you map a continent that has no permanent residents, is 99% covered in ice, and dark half the year? Antarctica's remote location and harsh conditions make it extremely difficult to map its thousands of miles of jagged coastline, its remote mountain ranges, and its vast ice sheet. In the Antarctic summer of 2003 to 2004, NSIDC scientists helped solve that problem. They combined more than 260 satellite images to capture the surface and topography of the continent, producing a map called the Mosaic of Antarctica (MOA). But because some areas of Antarctica have been displaying rapid change, the team hopes that an update of the MOA satellite imagery and comparison of the maps will help reveal the secrets of the Antarctic Ice Sheet.

A map of difference

When it came out in 2006, MOA was the most detailed map of Antarctica ever released. The value of satellite imagery in mapping remote Antarctica had been recognized for decades, but the MOA team was able to solve challenges caused by clouds, blowing snow, and shadows by stacking a number of images for each location, carefully selecting images with clear skies, and matching light conditions in each one. MOA, compiled from images from the NASA Moderate Resolution Imaging Spectroradiometer (MODIS), allowed researchers to see subtle topography in the ice sheet surface, trace the Antarctic coastline, and locate with precision the grounding zone, the location where ice moves from land into the water.

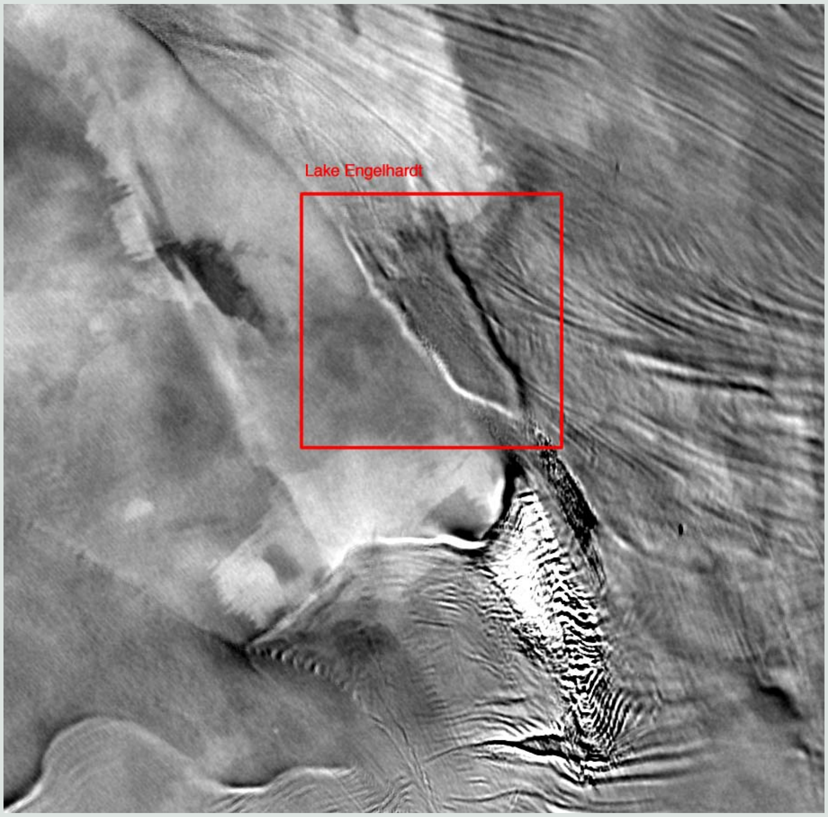
A huge area of the Larsen Ice Shelf, pictured here, collapsed unexpectedly in 2002. This collapse was only one of the dramatic changes observed on the Antarctic Peninsula in recent years. MOA 2009 will allow researchers to discover other changes in the ice sheet that have occurred since 2004, and better understand the dynamics of the frozen continent.
Image courtesy Ted Scambos, NSIDC

But while the Antarctic Ice Sheet is frozen, it is anything but unchanging. Icebergs calve away, ice shelves collapse into the ocean, glaciers advance and retreat, new fractures and wind-carved dunes appear, and gigantic ice streams wind slowly through frozen peaks and valleys, moving tons of ice from the continent interior towards the coast. So NSIDC researchers decided to update the mosaic based on new data. They carefully selected images from the austral summer of 2008 to 2009 to match the date, time, and light conditions used in MOA 2004, and created a new version of MOA (MOA 2009). This updated map can be compared to MOA 2004 to see changes, large and small, in the ice surface.

Using the two maps, researchers can now make detailed comparisons of the surface of Antarctica, by comparing the surface of Antarctica in 2009 to the surface in 2004. This method allows them to potentially identify changes in topography and better understand the dynamics of the massive ice sheet. Already, the NSIDC MOA team has used the new product to identify changes in the ice. Using the two maps, they were able to visually confirm changes in Antarctic ice shelf extent since 2004.

NSIDC researchers also used a technique called a difference map, essentially subtracting one image from the other, to identify the draining of Lake Engelhardt, a subglacial lake that lies deep beneath the Antarctic Ice Sheet. Sometime between the creation of the two maps, the buried lake drained, and the ice above it sank by nine meters. The two maps also confirm the retreat of several ice shelves along the Antarctic Peninsula, and could help researchers identify other changes in the Antarctic coastline.

MOA 2009 is scheduled for release in early 2011.



Subtracting MOA 2004 from MOA 2009 creates a difference map that researchers can use to identify changes in the Antarctic Ice Sheet. In the difference map above, the deep depression indicates an area that sunk by nine meters between 2004 and 2009. The difference suggests that a subglacial lake drained during the interval between the two MOAs.
Image courtesy NSIDC

Embedded Arctic researcher joins worlds of knowledge

Most climate researchers venture into the field once in a while, studying glaciers in Antarctica for a month or digging snow pits in the Colorado mountains for a few weeks. But one NSIDC researcher never leaves the field—Shari Gearheard lives year-round in the Inuit community of Kangiqtugaapik (Clyde River), Nunavut, Canada, where she works with native Inuit to link their traditional knowledge of the environment with climate science. NSIDC Monthly Highlights interviewed Gearheard about her life and work in the far North.

What are your research areas?

I study how science and Inuit knowledge can work together to understand the changing Arctic environment, and work on ways to combine the knowledge of scientists and Inuit to benefit local communities and help Inuit and scientists reach their goals. I am also interested in the Inuktitut language and how the language helps to communicate and explain knowledge, especially concepts of the environment.

NSIDC Researcher Shari Gearheard (right) and hunter Lasalie Joanasie keep an eye on a nearby polar bear during a recent trip on Arctic sea ice. Gearheard lives full time in Kangiqtugaapik (Clyde River), Nunavut, Canada, where she studies the intersection between Inuit knowledge and western science.
Credit: Image courtesy Edward Wingate

What is it like to live and work in the Arctic?

Clyde, the community where I live, sits on the northeast coast of Baffin Island. The landscape ranges from low rolling tundra to dramatic mountains and fjords. In fact, some of the highest, uninterrupted vertical cliffs in the world are just a short snow machine ride away in Sam Ford Fjord.

People here rely on a subsistence economy and "country food." Inuit in Clyde eat seals, narwhal, Arctic char, caribou, polar bear, geese, eggs, and some traditional plants. The weather is literally arctic. Temperatures range from about negative 35 degrees Celsius [-31 degrees Fahrenheit] in the winter, though it can get much colder, to 8 degrees Celsius [46 degrees Fahrenheit] in the summer, though it can be much warmer. We have 24-hour light and 24-hour dark for several months of the year.

I love living in Clyde because of the people. I have good friends here and I learn so much every day. I am grateful to the people who work on projects with me and also help me with other aspects of living and learning here. For example I have learned how to sew clothing (especially warm parkas) and I have become a passionate dog teamer. All of my knowledge and skills around dogs are because people have been willing to share that with me. I can't put into words how grateful and fortunate I am for living in this place.

How is working in Canada's far north different than working at the NSIDC offices in Boulder, Colorado?

Working here is much different than at NSIDC. I have a small office in my house, but most of the time my work takes me into the kitchens of local hunters and Elders who partner with me on all my projects. We also work on the sea ice much of the time, travelling by snow machine and dog team. In the summer, we travel by boat and ATV. I never stop moving for long, and having the opportunity to work so much outside is really incredible, I am learning so many new skills all the time.

I'm very fortunate that NSIDC supports having a researcher in the field like this. To me being here is more than "living in the field." This is my life. I have a home here, my husband, dogs, and friends are here. Living here and being part of the community helps my research, because I am able to observe and experience life and the environment all year and over many years. I am more easily able to continue to learn and practice the language, and I am learning skills that I would never learn anywhere else, like dog teaming, hunting, and how to travel the land and ice. Living here also ensures that I can design projects that come from local ideas, and cooperate with local individuals and organizations. I'm able to contribute something to the community every day and be part of the ongoing sharing and learning that happens here.

What's one thing you want people to know about your work or the people you work with?

I want people to know that there are many ways to know the world. Science and indigenous knowledge are complementary sources of information, knowledge, and evidence that can be brought together to help us to understand many environmental patterns, processes, and changes. If you know anyone who has worked outside for most of their life (a farmer, fisherman, forester, ski patrol, hunter, gardener) you know how much these people can know about the world around them. Research, more and more, is learning from and including indigenous knowledge and citizen science. I think this is a very good thing.

What are you currently researching?

I have three major projects going on at the moment:

The ELOKA project provides data management and user support to facilitate the collection, preservation, exchange, and use of local observations and knowledge of the Arctic. [http://eloka-arctic.org/]

The Silalirijiit project, or "Linking Inuit Knowledge and Local-Scale Environmental Modeling to Evaluate the Impacts of Changing Weather on Human Activities at Clyde River, Nunavut," links Inuit observations of the environate the Impacts of Changing Weather on Human Activities at Clyde River, Nunavut," links Inuit observations of the environment to quantitative climate models.

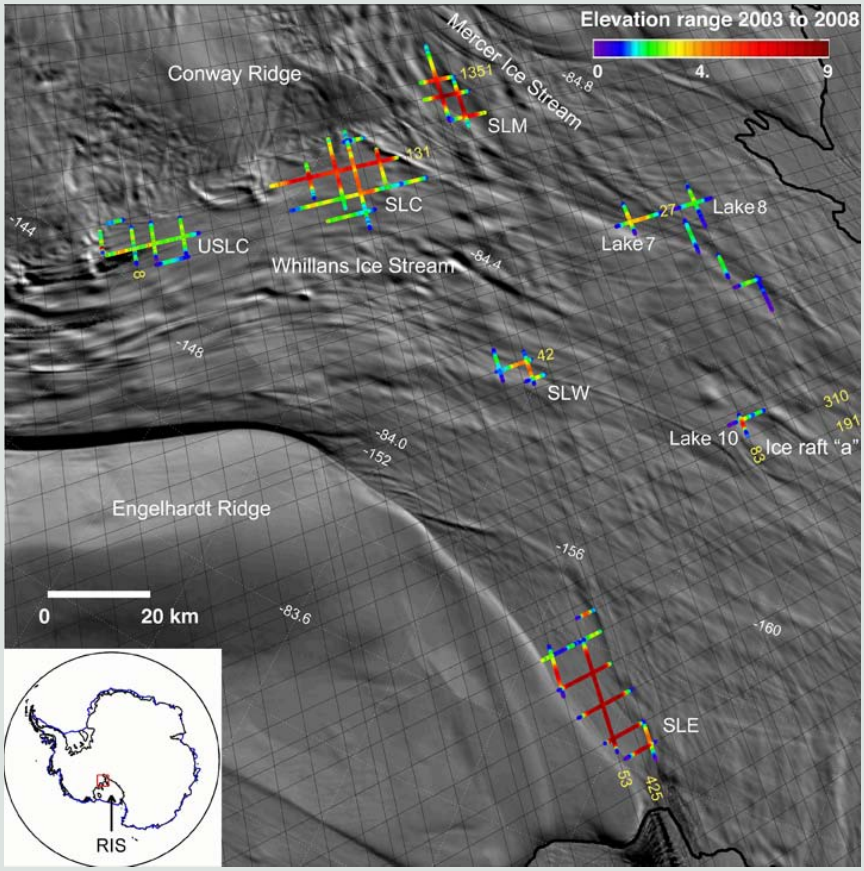
The Arnait (Women) Project, or "Inuit women and subsistence: Social and Environmental Change," focuses on women's changing roles in two communities in Nunavut (Clyde River and Qikiqtarjuaq). Many research projects have looked at harvesting and economies in Inuit communities, but they almost always focus on men and on hunting. We are interested in what women's roles and concerns are in terms of mixed economies in the two communities, how women share resources and knowledge, how these have changed over time, and what practical resources women need today to have a healthy life.

A satellite signs off; science data live on

Circling Earth, a landmark Earth observing mission turns a now-dark eye over the Arctic and Antarctic regions. Soon, engineers will nudge it out of orbit, to burn up in Earth's lower atmosphere. NASA's Ice, Cloud, and Land Elevation Satellite (ICESat) was already several years beyond its life expectancy when it made its last scans of Earth's surface in October 2009. But scientists have not yet unlocked all the secrets of ICESat data, captured during this time of rapid changes in the cryosphere. They continue to pore over ICESat data to learn more about these unprecedented events and, possibly, what the future may hold for Earth's frozen regions.

Thick and thin

ICESat was launched to sense ice, clouds, and land, as its name suggests—but its most compelling observations were of snow and ice. Just a few degrees of temperature change in the sensitive polar regions have begun to alter cryospheric processes that were stable for thousands of years: glaciers recede; ancient, massive ice sheets and ice shelves exhibit rapid summer melt and lose mass; once-thick sea ice cover succumbs to summer warmth, becoming thin and rotten.



In this image, ICESat elevation tracks show changes over time in ice sheet elevation, over lakes hidden a half mile beneath the Antarctic ice sheet. Reds and yellows indicate greater changes in elevation, marking the flow of liquid water from basin to basin, deep under the ice.
Image courtesy Fricker and Scambos, 2009, Jour. Glaciology.

These changes raise many essential questions. How much icy mass is being lost? How might global sea levels be altered as ice moves from land to ocean? While other satellite instruments have for decades measured the extent or outlines of glaciers, ice sheets, and sea ice, they lacked the third dimension for mass estimates: thickness.

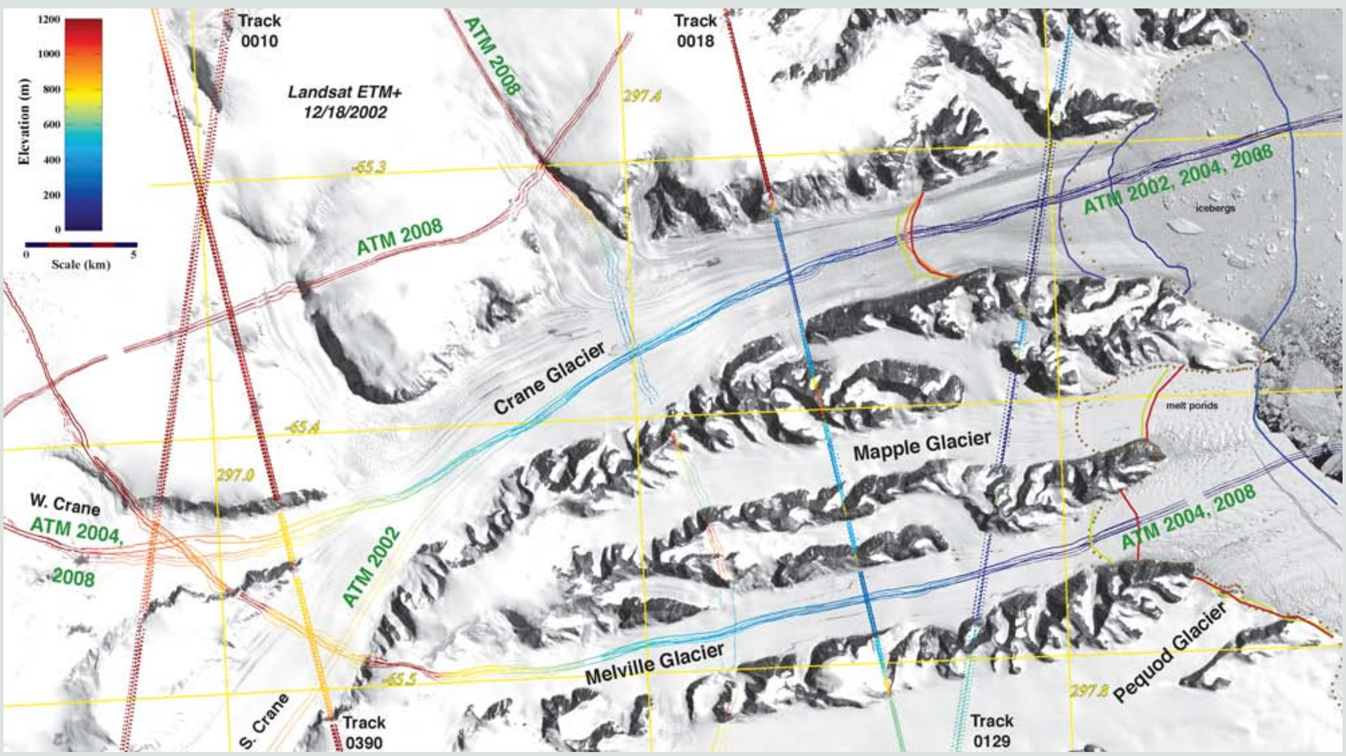
The Geoscience Laser Altimeter System (GLAS) instrument on board ICESat used lidar to measure surface elevation, data that can then be used to calculate thickness and total mass, and over time to observe volume change. Beginning in 2003, scientists could study and monitor the wasting of Greenland's ice sheet, or of Antarctic Peninsula ice shelves and glaciers, in three dimensions. ICESat data continue to answer questions and stimulate new research: do ice shelves help hold back glaciers? Is melt water lubricating the base of Greenland's ice sheet? Is the older, thicker Arctic sea ice that is the mainstay of the ice cover disappearing? GLAS data have also helped uncover surprising features and dynamics, such as a series of lakes thousands of feet beneath the West Antarctic ice sheet, flowing from basin to basin and draining the water at the base of the ice streams.

An active archive

ICESat/GLAS offered the first chance for a year-round look at snow and ice elevations in these remote lands that are dark and dangerous and severely cold during long winters, forbidding on site research. To seize the opportunity for as long as possible, the GLAS science team devised measurement campaigns to make best use of three onboard lasers and to stretch their lifespans. These 33-day campaigns covered each year's most crucial times and events, such as maximum ice and snow extent in late winter, the beginning of melt season in spring, and the end of melt season and sea ice minimum in October. Originally planned for a three-year lifespan, the GLAS instrument collected almost seven years of data.

Scientists and data managers expect ICESat's record to be of vital scientific importance for decades to come, and an irreplaceable record of climate during a period of rapid change. Working with the GLAS science team, NSIDC continues its data management mission by maintaining the GLAS data archive and continually serving data and information to researchers. The science team recently improved its data algorithms, improving data quality, and is re-processing the entire time series of data. Before the end of 2010, a new version of data, Release 33, will be archived at NSIDC and will be available to scientists and researchers.

Meanwhile, NASA is preparing for a new ICESat II laser altimeter, scheduled for launch in 2015. In the interim, NASA's Operation IceBridge mission, initiated in 2009, is collecting airborne remote sensing measurements of coastal Greenland, coastal Antarctica, the Antarctic Peninsula, interior Antarctica, the southeast Alaskan glaciers, and Antarctic and Arctic sea ice. These data are also accessible through NSIDC.



In this image, ICESat elevation tracks show changes over time in ice sheet elevation, over lakes hidden a half mile beneath the Antarctic ice sheet. Reds and yellows indicate greater changes in elevation, marking the flow of liquid water from basin to basin, deep under the ice.
Image courtesy Fricker and Scambos, 2009, Jour. Glaciology.

A commons at the poles

In 2008, thousands of the world's polar researchers wrapped up a two-year, simultaneous research collaboration called the International Polar Year (IPY), and turned their thoughts to the future. Climate change is showing up fast and strong in polar regions, especially in the Arctic, where flora and fauna, and human ways of life, are beginning to change. During the IPY, researchers collected an irreplaceable record of the polar regions at this time in history, studying climate patterns that no longer behave as they have for hundreds or thousands of years.

But where will these data be fifty years from now? Will they be available and accesible for future scientists and other users? Sadly, experience from prior Polar Years in the 1880s, 1930s, and 1950s taught scientists that they must answer these questions before, during, and immediately after data are collected; much of the data from those IPYs were lost. If data are to remain intact for future researchers to study and reuse, something must be done now.

A space for polar data

A single giant, central archive was not practical for these data, held in over sixty nations. Instead, IPY organizers and data managers dreamed of a collaborative, virtual space, where scientific data and information could be shared ethically and with minimal constraints. Inspired by the Antarctic Treaty of 1959 that established the Antarctic as a global commons to generate greater scientific understanding, they conceived of the Polar Information Commons (PIC). The PIC would serve as an open, virtual repository for vital scientific data and information.

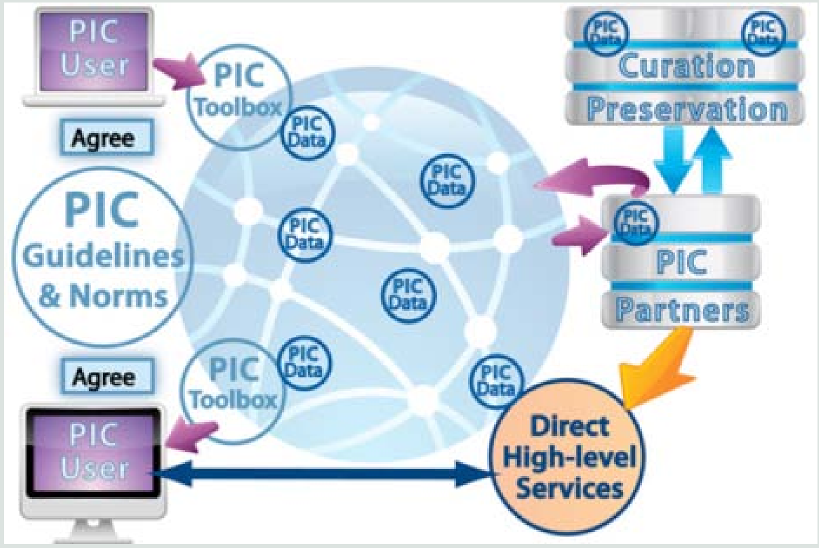
NSIDC data manager Mark Parsons (top, right) explains the Polar Information Commons to a group at the IPY Oslo Science Conference.
Image courtesy Taco de Bruin

This community-based approach would foster data preservation and sharing, which in turn would support innovation and improved scientific understanding. Ultimately, IPY organizers hope it will encourage participation in research, education, planning, and management in the polar regions. Open access to data helps researchers understand and predict rapid polar change, and supports wise resource management and international cooperation on resource and geopolitical issues.

Norms, ethics, practices, and tools

Good scientific practice dictates a set of norms on data use, such as appropriate attribution, accurate description of the data, and community efforts to assure their quality. But how to implement this vision? The larger community lacked practical and technical means to enable, reinforce, and reward the right behaviors. Part of the solution was to build a suite of tools and services that make it easy for scientists to do the right thing.

At the IPY Oslo Science Conference in June 2010, the international IPY Programme Office announced the launch of the Polar Information Commons to the community of polar researchers who had gathered to share science results from IPY. The launch was supported by NSIDC's Libre, a project devoted to liberating science data from its traditional constraints of publication, location, and findability. Leveraging open-source technology and data management standards, Libre helps make it easy for scientists to make their data discoverable and usable by the whole world.



A schematic of the Polar Information Commons concept shows how data can be distributed over many locations, yet be findable and sharable.
Image courtesy IPY Programme Office

For example, one Libre tool lets researchers easily create a graphical badge indicating that their data are part of the Commons, and describing any conditions for sharing. Other Libre tools will include a simple tool to help others find your data, either via the Web or by depositing metadata in the PIC Cloud, an organized, virtual storage space built by Australian researchers for all types of polar data.

Long known for its expertise as a centralized data repository, NSIDC is helping show the polar world how a collaborative, distributed data management scheme can be effective in stewarding scientific data for the long term. Visit the Libre Web site and the Polar Information Commons Web site for more information.

Submarine data emerges from the Arctic depths

Lurking beneath the thick Arctic Ocean ice, a U.S. Navy submarine probed the dark waters. The sub hugged the ocean floor, seeking passage through ridges of ice (called keels) hanging from the underside of the ice cover. Walls of ice appeared unexpectedly, threatening to box in the submerged craft and its crew. As navigators finessed the sub with white knuckles through this uncharted undersea maze, other crew used upward-looking sonar to measure the thickness of the ice sheet overhead.

These submarine crews used their nerve and skills in a unique cooperation between the U.S. Navy and scientists. From 1995 to 1999, Navy submarines made an annual cruise under the ice to collect research data on ice and ocean conditions. Until recently, some of the data from these submarine missions, called SCICEX (Science Ice Exercise) had no home, and were scattered among several institutions. NSIDC is leading the efforts with other data centers to create a SCICEX data archive, ensuring their preservation and access for continued research.

A unique view from below

Remote and inhospitable, the Arctic Ocean had long resisted a comprehensive analysis. But when weather and ice canopy limit work from ice camps and air reconnaissance, submarines can operate. So SCICEX data constitute one of the best mappings of the ice canopy in the central Arctic Basin, collecting an extraordinary volume of ice draft measurements, and orders of magnitude more depth soundings of the Arctic Basin than ever before.

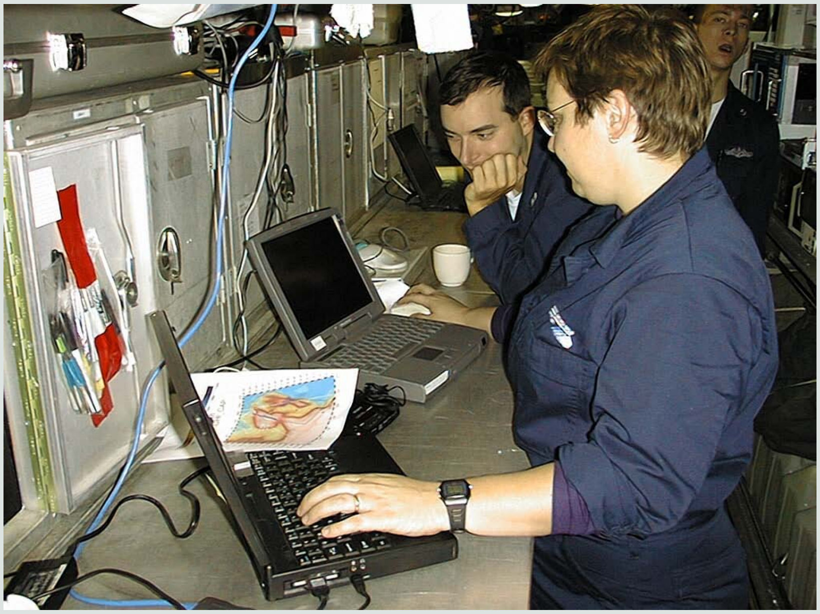
SCICEX observations have helped scientists form and validate hypotheses about the oceans and climate. Perennial ice in the Arctic Ocean influences both Earth's surface heat balance and the thermohaline circulation of its oceans: both the Atlantic and Pacific Oceans have their northern boundaries there. During the 1990s, SCICEX scientists were some of the first to notice marked changes, such as thinning of the present-day Arctic sea ice and changes in Arctic Ocean water temperature.

The bow of the U.S. Navy submarine USS Hawkbill rises out of the Arctic sea ice cover, during the 1999 SCICEX expedition.
Image courtesy University of Alaska Fairbanks Institute of Marine Science

Data management in retrospect

SCICEX data never had a management scheme defined, so NSIDC is working to organize these data that are currently spread out over many different desk drawers, so to speak, of the original research teams. NSIDC's goal is to ensure that the different SCICEX data types, including upward looking sonar (ULS) ice draft measurements, bathymetry, and ocean nutrient and chemistry data, can be discovered and cross-referenced among the various disciplines and data centers that will ultimately house them.

NSIDC currently archives and distributes the ULS data, and is in the process of receiving the bathymetry data, working with the National Geophysical Data Center (NGDC) for archive. NSIDC will also work with the National Oceanic Data Center (NODC), who will ingest and archive the nutrient and chemistry data, and with the Lamont-Doherty Earth Observatory (LDEO) on pathways for securely archiving future submarine data. These data continue to hold vital information for researchers in climate, cryosphere, and marine sciences—but only if they can be found and used.



Scientists work in the lab onboard the USS Hawkbill during the 1999 SCICEX expedition. Image courtesy University of Alaska Fairbanks Institute of Marine Science

NSIDC Scientists get a closer look at accelerating glaciers

NSIDC Scientist Ted Scambos had been stuck in a tent on Flask Glacier in Antarctica for nine days when the skies finally broke. A helicopter had dropped off Scambos, along with Martin Truffer and Erin Pettit of the University of Alaska Fairbanks, and then went back to base aboard the research vessel Nathaniel B. Palmer for a second run. But fog rolled in, and the pilots could not risk a second landing. So Scambos, Truffer, and Pettit hunkered down to wait out the bad weather. They now had less than a month to complete their mission and so far, they had not even set up one of the weather and GPS stations they had planned on; had they traveled seven thousand miles to Antarctica in vain?

For nine long, boring days the scientists waited in their small tent—unable to go anywhere and without their research gear—but finally, the helicopter returned with the rest of the team and the supplies they needed to set up a GPS unit and a super weather station known as an AMIGOS station. After a year of planning, a month of weather delays, and nine days of tense waiting on the ice, the expedition was finally on. They could begin to set up the AMIGOS station to take data that will help researchers understand the effect of rapidly changing climate on vulnerable ice shelves in Antarctica.

Understanding the Larsen Ice Shelf system

Scambos and NSIDC researchers Terry Haran and Rob Bauer, and Australian electronics consultant Ronald Ross as well as Truffer and Pettit, were in Antarctica to explore the causes and effects of ice shelf breakup. In March 2002, a huge portion of the Larsen B Ice Shelf disintegrated in just a few days. Immediately afterward, glaciers in the affected area began to accelerate. Within a few years, they were moving six to ten times faster, and thinning at an astounding rate (up to 500 feet in 6 years). A small portion of the Larsen Ice Shelf remains, but in recent years it, too, has started to melt, thin, and crack apart.

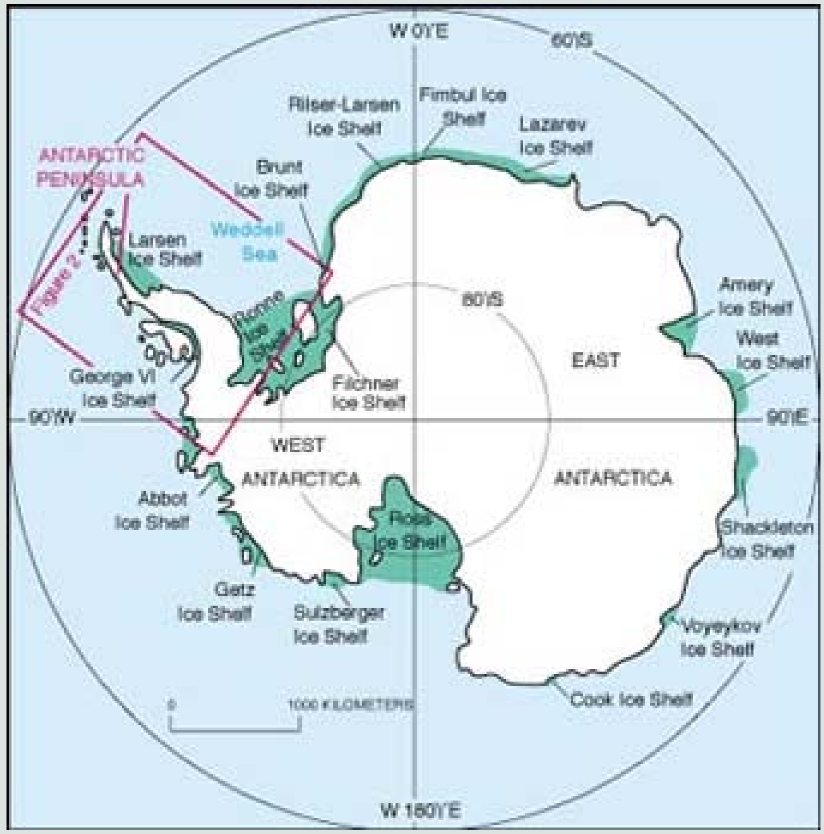
So from December 2009 to March 2010, scientists from several disciplines traveled to the Antarctic Peninsula aboard the Palmer, on the NSF-sponsored Larsen Ice Shelf System, Antarctica (LARISSA) expedition. The ship was a base for groups of scientists ranging from biologists to glaciologists to carry out various measurements on the Larsen Ice Shelf.

Scambos' team, the glaciology group, aimed to set up instruments on the glaciers that feed into the remaining portion of the Larsen ice shelf. The AMIGOS stations record weather conditions, GPS location, photographs, and other data, and send them back to the researchers via satellite.

Ronald Ross, Ted Scambos, and Terry Haran pose in front of the AMIGOS station on Flask Glacier in Antarctica, which flows into the changing Larsen Ice Shelf region. The data from AMIGOS stations may help scientists understand how ice shelf breakup affects glaciers.
Image courtesy Ted Scambos, NSIDC.

Fieldwork in the worst conditions

Conducting research in Antarctica always carries a risk of weather delays and other problems. The LARISSA expedition this winter was hampered by stormy weather and thicker than usual sea ice. The heavy sea ice prevented the Palmer from reaching its planned destination on the east side of the Antarctic Peninsula, and fog and storms delayed helicopter flights to the planned AMIGOS sites. Scambos and his team were stuck in tents more than once when fog rolled in and trapped them in the field. Towards the end of the mission, the team relocated from the research ship to Rothera, the British research station, to complete the rest of their goals.



This map shows the location of the Larsen Ice Shelf, on the eastern side of the Antarctic Peninsula. The peninsula is one of the fastest-warming regions on Earth.
Image courtesy United States Geological Survey (USGS)

Despite the bad weather, heavy sea ice, and other delays, the NSIDC team set up three AMIGOS stations, two GPS stations built by UNAVCO, and two seismic stations at key sites on glaciers that flow into the Larsen Ice Shelf. The stations are already sending back data, which will help the researchers understand the dynamics of these glaciers. Scambos hopes that the stations will continue to operate for two to three years. And if, during that time, the last of the Larsen Ice Shelf breaks apart, the researchers will have one-of-a-kind data that will help them figure out how other glaciers in the region will respond to similar events.

Science and traditional knowledge intersect in the Arctic

"I believe it is time for the harpoon and the computer to work together" — Peter Kattuk, Sanikiluaq, Nunavut

Climate change has come so quickly to the Arctic that Inuit residents describe their environment as "an old friend acting strangely." Climate researchers have begun to seek out Arctic residents and indigenous people because their local and traditional knowledge of the environment is extremely valuable in studying Arctic climate change. NSIDC scientist Shari Gearheard, a resident of Clyde River in Nunavut, Canada, helps foster these partnerships through the Exchange for Local Observations and Knowledge of the Arctic (ELOKA). Members of the NSIDC-based ELOKA team collaborate with communities across the Arctic to help document and preserve local knowledge and make this information easily available.

The Exchange for Local Observations and Knowledge of the Arctic (ELOKA) facilitates efforts to record and preserve local and traditional knowledge. Here, members of the international Siku-Inuit-Hila (Sea Ice-People-Weather) project are photographed on the sea ice near Qaanaaq, Greenland. (Photograph courtesy Andy Mahoney)

Recording and sharing traditional knowledge

Many Arctic communities have begun collecting environmental data and gathering traditional knowledge. But it can be difficult to successfully preserve and manage that information and make it available to interested groups, such as Arctic residents, researchers, teachers, students, and decision makers. To help communities overcome this challenge, ELOKA provides a network and data management system that supports traditional knowledge and community-based research that will help

- capture extremely precious data that may otherwise be misplaced or lost when elders pass away
- generate awareness of studies being conducting with various communities to avoid repetitive research and maximize financial resources
- provide a data management system that encourages community-based research.

ELOKA currently manages data for projects conducted by several indigenous communities in the Hudson Bay region, Baffin Island, and Greenland. Not only are local residents observing and reporting changes in their environment, they are also sharing wisdom gleaned from generations of living in an Arctic environment, providing valuable references for scientists and researchers.

Tracking traditional observations of sea ice

Sanikiluaq is one of the southernmost Inuit communities in Nunavut, Canada, located on the Belcher Islands in Hudson Bay. Hunters draw on traditional knowledge of climate to find animals and navigate around the islands. However, sea ice conditions in Hudson Bay have recently become unstable and less predictable.

To document these changes, the Municipality of Sanikiluaq partnered with the Government of Nunavut and Nunavut Tunngavik to form a Nunavut Hudson Bay Inter-Agency Working Group, also known as Nunavuummi Tasiujarjuamiuguqatigiit Katutjiqatigiingit, or NTK. Furthering Sanikiluaq's environmental work, the community collaborated with ELOKA on the Sanikiluaq Sea Ice Project. Three Sanikiluaq hunters were interviewed and provided their observations of local sea ice conditions. ELOKA will archive and distribute the resulting information and has created a Web site to share the videos and maps that record changing conditions around the islands.

Investigating the narwhal tusk

Martin Nweeia, from the Harvard School of Dental Medicine, initiated the Narwhal Tusk Research project as an interdisciplinary and cross-cultural investigation to explore the secrets of traditional knowledge from Inuit communities in Nunavut and northwestern Greenland. This collaborative approach, combining scientific research and Inuit knowledge, reveals that there is much more to the narwhal tusk than scientists imagined. ELOKA is collaborating with Nweeia to provide Web access to the interviews and data he gathered during his research.

Continued partnerships

In addition to partnering with a growing number of communities, ELOKA team members also collaborate with similar pan-Arctic research initiatives and organizations to raise more awareness about the need for local and traditional data management. Examples include Inuit Tapiriit Kanatami (ITK), the national Inuit organization in Canada; the Russian Association of Indigenous Peoples of the North (RAIPON); and the LTK component of the Sustained Arctic Observing Network (SAON), an initiative of the Arctic Council. By providing data management and user support among Arctic communities worldwide, ELOKA will help preserve generations of local and traditional knowledge and ensure access to this irreplaceable information for generations to come.

Lucassie Takatak is a full-time hunter for Sanikiluaq, an Inuit community located on the Belcher Islands in Hudson Bay. He was one of three hunters interviewed for the Sanikiluaq Sea Ice Project. Here, he communicates through translator Dinah Kavik while indicating his sea ice observations on a map. (Photograph courtesy Miriam Fleming/Sanikiluaq Sea Ice Project)

Martin Nweeia and his fellow researchers scan a narwhal to learn more about its anatomy and unique tusk. (Photograph courtesy Joseph Meehan)

NASA mission bridges satellite gap; NSIDC bridges data access

Ice at the ends of the Earth

In the Arctic and Antarctic, ice is not what it used to be. There, vast expanses, bitter cold, and months of darkness can thwart ground studies of changing ice shelves, glaciers, and ice sheets, so researchers depend on remote sensing to capture data on the rapid and unprecedented change in these remote regions. Scientists seeking to understand changes in the mass balance of polar ice, and its potential to contribute to global sea level change, have turned to NSIDC for access to data from the Geoscience Laser Altimeter System (GLAS), on board NASA's ICESat (Ice, Cloud, and Land Elevation Satellite).

But soon, they will be turning to NSIDC for data on polar ice from a new source: NASA's IceBridge mission. IceBridge addresses the gap between ICESat-I, expected to conclude operations in early 2010, and the next satellite, ICESat-II, planned for launch until 2015. To keep these essential climate data continuous, NASA moved to fill the data gap with aircraft-borne sensors, and selected NSIDC as the bridge between the mission's data and the researchers who depend on it.

A web of flight tracks and observations

Begun in 2009, Operation IceBridge is a six-year campaign of annual flights over the poles, covering coastal Greenland and Antarctica, the Antarctic Peninsula and interior, glaciers in southeast Alaska, and Antarctic and Arctic sea ice. The IceBridge aircraft carry an array of instruments to study conditions and change in these regions.

The IceBridge sensors can map ice surface topography, bedrock topography beneath the ice sheets, and grounding line position. Other instruments measure ice and snow thickness, sea ice distribution, and sea ice freeboard. Data from laser altimeters and radar sounders are paired with gravimeter, magnetometer, mapping camera, and other data to provide dynamic, high-value, repeat measurements of rapidly-changing areas of land and sea ice.

This view from a NASA DC-8 aircraft flying over the Antarctic Peninsula gives a glimpse of the ice sheet and the glaciers that Operation IceBridge is observing with an array of onboard remote sensing instruments. The mission ensures a continuous set of observations that may help scientists understand changing ice mass for Earth's ice sheets, glaciers, and sea ice. (Photograph courtesy Michael Studinger/NASA)

Data coming soon to your fingertips

NSIDC is managing the active archive of both GLAS and IceBridge data, providing needed data access and supporting services to researchers studying the changing polar cryosphere. NSIDC's goal is to simplify data access and usage from this many-faceted mission. NSIDC has begun corralling these data from the various mission groups and creating data access points. Ultimately, NSIDC will be the central access point for all IceBridge data, and will further process and organize these data into products that can be used with much less data manipulation and programming than the raw data from the IceBridge mission.

Instruments on board an IceBridge aircraft also record its flight tracks, shown here over the Antarctic Peninsula. NSIDC will make these flight tracks available to researchers along with the instrument data, to show flight coverage patterns and other important aspects of the campaign. (Courtesy NASA)

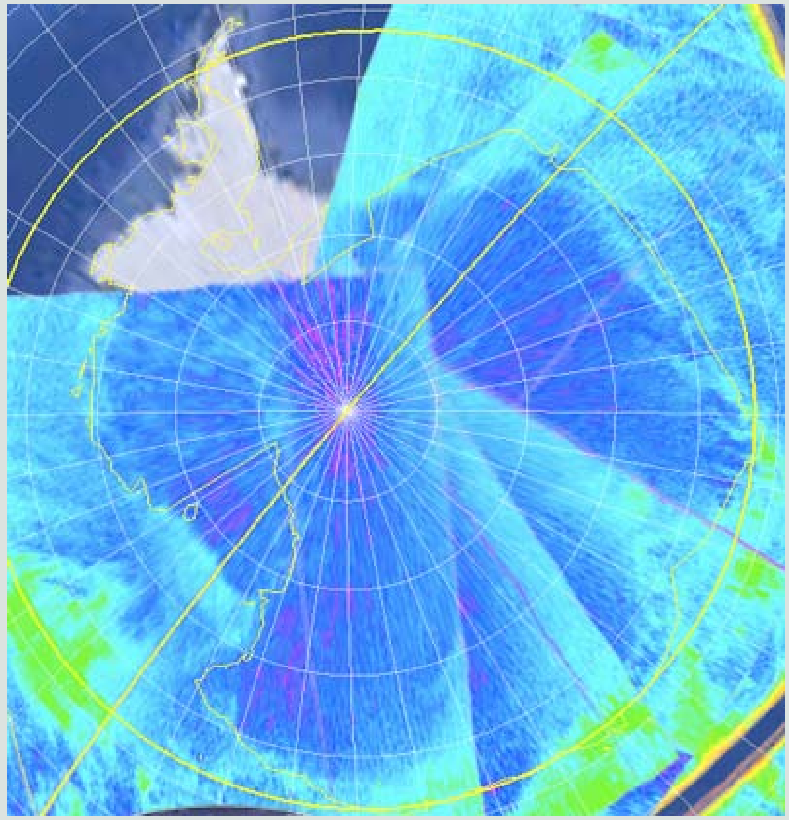
Techno-archaeology rescues climate data from early satellites

NSIDC and NASA data scientists proved the use of 21st-century techniques to revive data from 1960s satellites.

Archived, but not forgotten

Scientists today who study polar sea ice conditions rely on satellite records reaching back to 1979. But soon, data scientists hope to extend the look back by another decade or more. Researchers at NSIDC and NASA have shown that the oldest Earth observing satellite data can be made to yield new information, adding significantly to the view of Earth's climate history.

When NASA launched the first Nimbus satellite in the 1960s, they also launched an era of Earth observations from space. While the early Nimbus satellites provided meteorological and other observations, methods did not yet exist to detect features such as the margins of the sea ice cover in the Arctic and Antarctic. Even if they had, the limits of computer processing in those days would have made quantitative analysis unfeasible.



Forty-three years after the Nimbus II satellite collected these data, a team from NSIDC and NASA recovered a global image from September 23, 1966. In this view over Antarctica, overlaid on Google Earth, the Ross Ice Shelf appears clearly at left.

These early satellite data still reside in NASA archives on archaic, two-inch tape media. When NSIDC scientist Walt Meier and project manager Dave Gallaher learned that NASA researchers had retrieved 1960s images of Earth from the Lunar Orbiter, they wondered if early NASA satellite data could also yield information about sea ice conditions before 1979. They saw a disappearing window of opportunity to recover these data. Only one tape drive remained in the world that could read the Ampex two-inch media. Plus, the original Nimbus researchers were now in their late 70s and 80s, and contact with them would be critical to answering some of the necessary instrumentation questions.

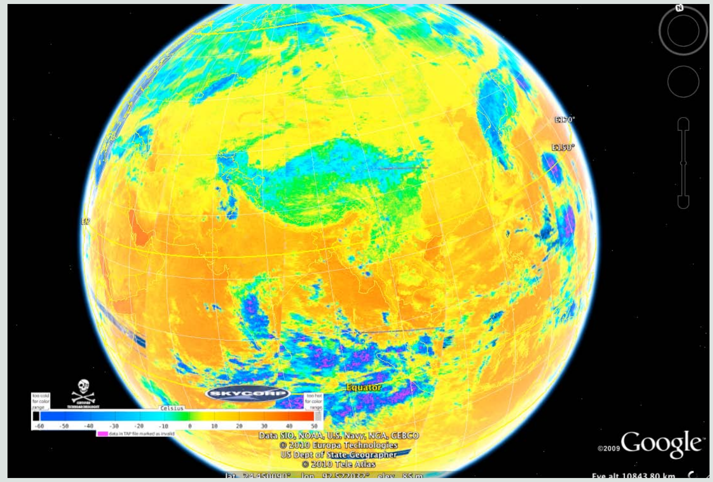
Reprocessing could make new 1960s-era global data available to the entire Earth science community. The techniques could also bring the quality of archaic data from other Earth-observing satellites up to contemporary standards, reinvigorating the data sets for current applications.

Modern data science meets historic data

The Nimbus satellites carried a High Resolution Infrared Radiometer (HRIR), with a resolution of 8 kilometers, a medium-resolution infrared radiometer (MRIR), and an Advanced Vidcon Camera System (AVCS). Although Nimbus collected data for only short periods, Meier suspected that these early Nimbus satellites likely captured the annual Arctic sea ice minimum, occurring each September.

Starting with the methods developed for the Lunar Orbiter Image Recovery Project (LOIRP) at NASA Ames Research Park, a team at NSIDC worked with Dennis Wingo at LOIRP to search NASA archives for the original Nimbus tapes containing raw images and calibrations. Their first goal was to read and reprocess the data at a higher resolution, removing errors resulting from the limits of the original processing.

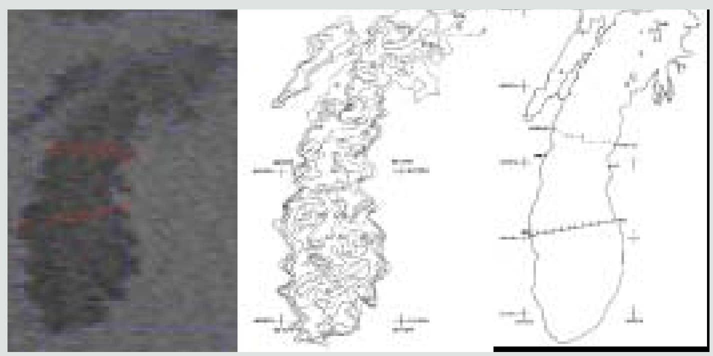
These tasks proved more challenging than expected, due to truncated data, missing algorithms, and other issues. But the result was a global image of the Arctic from Nimbus II, captured on September 23, 1966, in higher resolution than ever seen before from this type of data. This date falls around the time that Arctic sea ice would have reached its end-of-season minimum extent. The image demonstrates the possibility of re-processing the entire available time series, supporting new scientific study of past conditions on Earth.



On September 23, 1966, Nimbus II acquired the temperature data shown in this image of Asia, overlaid on Google Earth. The warm waters of the Persian Gulf are clearly seen in contrast with the cold temperatures of the Himalayas. Blues and greens indicate cooler temperatures, and yellows and reds indicate warmer temperatures.

Unlocking the hoard

This proof-of-concept research was supported by an Innovative Research Program seed grant from the Cooperative Institute for Research in Environmental Science (CIRES) at the University of Colorado at Boulder, the home of NSIDC.The team now plans to apply for further research funding to expand the study. More work is needed to reprocess 2,600 half-orbit records, develop a de-jitter algorithm, and then complete a painstaking process of image comparison to separate clouds from ice.



At left, an image of Lake Michigan from the HRIR sensor on the Nimbus II satellite, acquired October 6, 1966, is shown alongside temperature plots, at right, derived from the data. The "jitter" caused by missing waypoints in the satellite data is readily apparent in the plots. (Images courtesy V. E. Noble and J. C. Wilkerson)

Processing of more data could allow Meier and other scientists to determine sea ice extent during the Nimbus I through III campaigns (1964, 1966, and 1969). The team also hopes to extend their methods to later instruments, and characterize both minimum Arctic and maximum Antarctic sea ice extent for 1964 to 1978. If successful, the sea ice climatologies would gain up to fourteen years of data—an increase of 50 percent over their temporal span today.

NSIDC Grants and Contracts

In 2010, NSIDC had 44 active contracts and grants, with a total value (over the anticipated lifetime of each award) of $58,590,300. Approximately 61% of NSIDC's funding is from a renewable NASA contract for operation of the Snow and Ice Distributed Active Archive Center (DAAC). Remaining funding is in the form of grants from NASA, NSF and NOAA. NSIDC had 12 active data management grants in 2010 and 31 active research grants. Current major data management projects and programs follow below:

Distributed Active Archive Center (NASA): The NSIDC DAAC is one of NASA's Earth Observing System Data and Information System (EOSDIS) data centers. The NASA data centers process, archive, document, and distribute data from NASA's past and current Earth Observing System (EOS) satellites and field measurement programs. Each data center serves one or more specific Earth science disciplines and provides its user community with data products, data information, user services, and tools unique to its particular science. Each data center is also guided by a User Working Group in identifying and generating these needed data products. The NASA data centers serve as the operational data management and user services arm of EOSDIS, performing such tasks as data ingest and storage, filling user orders, answering inquiries, monitoring user comments, and providing referrals to other data centers. (http://nsidc.org/daac/index.html)

Antarctic Glaciological Data Center (NSF): The AGDC archives and distributes Antarctic glaciological and cryospheric system data collected by the U.S. Antarctic Program. It contains data sets collected by individual investigators and products assembled from many different PI data sets, published literature, and other sources. The catalog provides useful compilations of important geophysical parameters, such as accumulation rate or ice velocity (http://nsidc.org/agdc/)

Exchange for Local Observations and Knowledge of the Arctic (NSF): ELOKA facilitates the collection, preservation, exchange, and use of local observations and knowledge of the Arctic. ELOKA provides data management and user support, and fosters collaboration between resident Arctic experts and visiting researchers. By working together, Arctic residents and researchers can make significant contributions to understanding the Arctic and recent changes. (http://eloka-arctic.org/)

Operation Icebridge (NASA): NASA's Operation IceBridge, initiated in 2009, collects airborne remote sensing measurements to bridge the gap between NASA's Ice, Cloud and Land Elevation Satellite (ICESat) mission and the upcoming ICESat-2 mission. IceBridge mission observations and measurements include coastal Greenland, coastal Antarctica, the Antarctic Peninsula, interior Antarctica, the southeast Alaskan glaciers, and Antarctic and Arctic sea ice. The IceBridge mission combines multiple instruments to map ice surface topography, bedrock topography beneath the ice sheets, grounding line position, ice and snow thickness, and sea ice distribution and freeboard. Data from laser altimeters and radar sounders are paired with gravitometer, magnetometer, mapping camera, and other data to provide dynamic, high-value, repeat measurements of rapidly-changing portions of land and sea ice (http://nsidc.org/data/icebridge/index.html).

NOAA@NSIDC: The National Oceanic and Atmospheric Administration team at NSIDC manages, archives, and publishes data sets with an emphasis on in situ data, data sets from operational communities such as the U.S. Navy, and digitizing old and sometimes forgotten but valuable analog data. We also help develop educational pages, contribute to larger center-wide projects, and support the Roger G. Barry Resource Office for Cryospheric Studies (ROCS) at NSIDC (http://nsidc.org/noaa/).

Roger G. Barry Resource Office for Cryospheric Studies: ROCS is an information resource for people studying Earth's frozen regions, the history of science, or past climate related to the Earth's frozen regions. As ROCS has evolved, it has expanded its mission to include responding to questions from the public, teachers, students, and researchers. Its holdings include thousands of maps, photographs, prints, and expedition journals. One of the newer and growing collections is comprised of materials from indigenous communities of the Arctic area including local and traditional knowledge records. These materials are being gathered as part of an ongoing collaboration with these communities. ROCS holds more than 44,000 cryospheric-related monographs, serials, journal articles, reprints, videos, maps, atlases, and CD-ROMs and receives over 50 periodicals and newsletters (http://nsidc.org/rocs/index.html).

New Funding Awarded in 2010

International Network of Arctic Knowledge (Interop, PI M. Parsons): Interop is an NSF funded effort to enhance the interoperability of sea ice data to establish a network of practitioners working to enhance semantic interoperability of all Arctic data. It is a collaborative project between NSIDC and the Rensselaer Polytechnic Institute (RPI) Tetherless World Constellation project. It will build on the work initiated under the International Polar Year (IPY) and create a community of practice working to improve interoperability within the Polar Information Commons (PIC), the Sustained Arctic Observing Network (SAON), and broader global systems. The initial focus is on the scientific understanding of sea ice, by developing a sea ice ontology. Interop will work initially from a scientific perspective, but over time, will explore incorporating the knowledge and perspectives of Arctic residents. Interop will hence collaborate closely with the ELOKA project (http://nsidc.org/ssiii).

Updating IT infrastructure: Reducing Energy Consumption and Enhancing Data Flow to Researchers (Green Data Center, PI M. Serreze): This NSF effort funds an energy-efficient, carbon footprint reduction upgrade to NSIDCs research computing facility. The project includes: 1) Installation of a replacement cooling system featuring external air and evaporative cooling systems; 2) Consolidation of IT facilities in a single server room; 3) Virtualization of servers and arrangement of systems in hot/cold aisle rack configuration; 4) Installation of rooftop solar panels; 5) A battery array, connected to the solar system, to provide uninterrupted power and eliminate the need for a backup generator; 6) Upgrading internet connectivity to 1 Gb/s. The new cooling system, roof top solar array and improved connectivity will reduce the computer center's carbon footprint and support NSF's cyberinfrastructure goals of facilitating the flow of information to earth science researchers.

Icelights (NSF): IceLights represents an augmentation to the NSIDC Arctic Sea Ice News and Analysis (ASINA) website. The goal is to explain in more detail some of the issues that ASINA mentions at an easily understandable level. It addresses topical "questions of the moment" that arise, as well as discussing more general Arctic sea ice issues to help readers understand important scientific questions raised in ASINA.

Publications

Journals

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