2013 Annual Report

National Snow and Ice Data Center

Advancing Knowledge of Earth's Frozen Regions

Cover: Upper Melville Glacier, northern Antarctic Peninsula, looking southward. Lenticular clouds drape the upper Peninsula ice plateau areas. Larissa project, April, 2013.

Credit: T. Scambos, NSIDC

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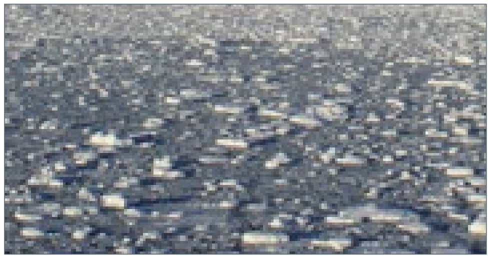


Director's Overview

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 related climate data collected from Earth orbiting satellites, aircraft missions and surface observations
- Facilitating the collection, preservation, exchange, and use of local observations and knowledge of the Arctic
- Conducting research addressing all major elements of the cryosphere; this research has increasingly 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

> NSIDC is finding more efficient ways of conducting its work, including capitalizing on synergies between different projects and embracing a more flexible and responsive team-oriented approach to software development.

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

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 long term, so that researchers can study polar climates 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:

- Processes driving the observed downward trend in Arctic sea ice extent and the environmental and societal consequences of this 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
- Forecasting stream flow in the American west
- Changes in earth's permafrost and their implications
- Alternative database structures to enable investigators to more efficiently search through vast data volumes to answer science questions
- Data casting services to making NSIDC data more visible to more researchers
- New directions in data stewardship
- Enhancing data discovery through semantic interoperability

A continued 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 is both accurate but accessible to a wide audience. Icelights (http://nsidc.org/icelights) provides detailed information on ice and climate topics to complement Sea Ice News and Analysis. About the Cryosphere (http://nsidc.org/cryosphere) provides a range of information about Earth's snow and ice, from comprehensive sections to quick facts on popular snow and ice topics. Greenland Ice Sheet Today (http://nsidc.org/greenland-today) focuses on assessing summer surface melt over the ice sheet. Images are updated daily, and we post analysis periodically as conditions warrant. We recently released Satellite Observations of Arctic Change (http://nsidc.org/soac) to expose NASA Satellite data in the form of maps that illustrate changes today taking place over time.

2013 Highlights

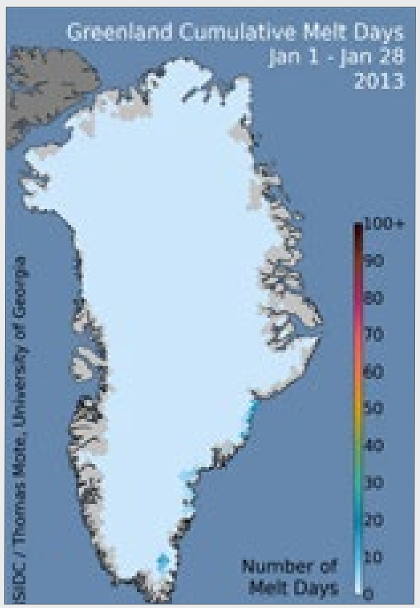
NSIDC Monthly Highlights (http://nsidc.org/monthlyhighlights) which follows illustrates the breadth of work at the Center, including how we are addressing challenges in data management, research on the cryosphere and the changes that are taking place, and how we are developing innovative ways to add value for our data and information users.

However, words and pictures are ineffective in conveying the pride, spirit of teamwork and willingness to adapt to change that characterize the employees of NSIDC. In response to an increasingly challenging funding environment, NSIDC strives to find more efficient ways of operating, including capitalizing on synergies between different projects, embracing a flexible and responsive team oriented approach to promote better coordination and communication between the different functional groups of the center. NSIDC is always learning, and is constantly trying to improve itself to better serve the global community.

We are transitioning the content and timing of our annual report. This annual report contains publications and projects from calendar year 2013 and financials for fiscal year 2014. Our next report will be solely based on fiscal year 2015 and will be on line during the early autumn of 2015.

Monthly Highlights

Greenland Ice Sheet Today



Greenland Ice Sheet Today features data-based melt images of the ice sheet, updated daily with a one-day lag.

Credit: NSIDC, Thomas Mote, University of Georgia

Greenland is home to the largest ice sheet outside of Antarctica, and scientists are discovering that its ice is not immune to temperatures that continue to rise across the Arctic. While scientists do not expect a rapid or sudden thawing, a recent burst of surface melt revealed just how vulnerable Greenland's ice may be.

During the summer of 2012, nearly 97 percent of the ice sheet's surface melted, the most extreme melt extent scientists had seen in three decades of satellite records. This stood in contrast to the 40 to 50 percent surface melt that typically occurs during the summer. Although scientists were able to blame the extreme melt on an unusually warm mass of air that parked over Greenland for several weeks, this event occurred as the Arctic sea ice extent was declining to what would become a record low later in the year. Consequently, scientists are paying closer attention to the Greenland Ice Sheet and its potential for melting and contributing to even small amounts of sea level rise.

Watching the ice

The extreme summer melt of 2012 caught many by surprise, and prompted NSIDC to develop a new Web site to help track Greenland's ice. This site, Greenland Ice Sheet Today, features daily melt images and images showing cumulative melt days on the ice sheet. Both images are updated daily, with a one-day lag. A daily graph will chart the current melt percentage against the average melt observed in the satellite record.

NSIDC partnered with two experts to help develop the site: Dr. Thomas Mote of University of Georgia and Dr. Marco Tedesco of the City University of New York. They both provide expertise on the Greenland Ice Sheet, and Dr. Mote will supply imagery derived from NSIDC's passive microwave brightness temperature data.

NSIDC will post regular updates describing conditions in Greenland and provide analysis placing

Opposite: Wind-eroded crevasses on the Scar Inlet ice shelf, northern Antarctic Peninsula. Dark areas are wind-blown dirt from adjacent mountains. Larissa project, April, 2013. Credit: T. Scambos, NSIDC

A large stream of meltwater, about 5 to 10 meters wide, emerges from an upstream supraglacial lake in the Greenlandic ice. This photograph was taken during the summer of 2012, when a record 97 percent of the ice sheet surface experienced melting.

Credit: M. Tedesco/CCNY

them in the larger historical context, as well as in the context of Arctic-wide conditions.

Ice in the balance

All across the Arctic, warming oceans and declining sea ice are leaving tidewater glaciers vulnerable to melting, and making many of Greenland's outlet glaciers more likely to retreat. And further inland, higher air temperatures may be thawing interior ice more rapidly. Greenland's ice has begun to feature more melt ponds, rivers, and other melt water features that drain increasing amounts of water from the ice sheet.

Melting on the Greenland Ice Sheet continue to mirror changes happening in the larger Arctic environment. "If you look at years where we've had minimum sea ice extent, like 2007 and 2012 for example, those are often years in which we've seen extensive melting over Greenland," Mote said. "There are certainly similarities between what we're seeing in Greenland and what we're seeing in other parts of the Arctic."

While the changes in Greenland may not yet be as dramatic as those in other regions, scientists are concerned that more melting on the ice sheet could pump massive amounts of freshwater into the oceans. In addition to raising sea levels, a large influx of water could reduce salinity in parts of the ocean and potentially alter ocean currents.

The images and analysis featured in Greenland Ice Sheet Today provide a new way to monitor conditions in and around Greenland. The site complements NSIDC's Arctic Sea News and Analysis Web site and will help pinpoint changes and emerging patterns around the Arctic in near-real time. Mote said, "I think we're still trying to get a sense of just how inter-related these different cryospheric measures are across the Arctic." Greenland Ice Sheet Today will be another tool to help users see how changes across the Northern Hemisphere may be influencing Greenland's ice.

Although the Greenland Ice sheet undergoes seasonal melting each summer, surface melt during July 2012 reached record levels. Runoff from the ice sheet flooded the Watson River and swept away parts of a bridge in the town of Kangerlussuaq. The left image is from May 31, 2012, prior to the melt. The right image is from July 25, 2012, after the record surface melt.

Credit: NASA Earth Observatory image created by Jesse Allen and Robert Simmon, using Advanced Land Imager data from the NASA EO-1 team.

Austin Post Glacier Photographs

"I have often claimed this collection to be more valuable than the moon rocks—after all, we can go back to the moon for more rocks, but we can not go back to take pictures of glaciers 30 years ago."

—Robert Krimmel, U.S. Geological Survey

From above, glaciers look like rivers of ice. Like rivers, but much more slowly, they flow downhill, are replenished by precipitation, and diminished by melting. On balance, they ought to stay about the same, but glaciers are sensitive to changes in climate. Telltales of larger climate changes, they shrink in a warming climate or grow in a cooling climate.

Only fairly recently have satellites been used to monitor glaciers on a global scale by tracking changes in area, length, elevation, and velocity. Before satellites and still today, scientists with cameras documented the state of a glacier so that they could study whether it is growing or shrinking, advancing or retreating.

A massive problem

Photographing glaciers on foot by hiking to the terminus with a camera could only capture a small number of glaciers, because it is time consuming. With the world's glaciers uncounted (NSIDC's World Glacier Inventory contains records of 130,000 glaciers, but scientists think there are many more), Alaska alone may have as many as 50,000 glaciers, but only about 500 of them are named. So before space-based remote sensing became prevalent, glaciologists used aerial photography to study glaciers in their remote, hostile environments.

This aerial photograph of Douglas Glacier, Washington State, USA was taken by Austin Post on September 27, 1960. Access the full-resolution photograph via the NSIDC Glacier Photograph Collection.

Credit: A. Post, NSIDC Glacier Photograph Collection

Some visionary glaciologists with airplanes and cameras captured important records of glaciers, starting in the 1930s. As part of a United States Geological Survey (USGS) program for more than 35 years, photographer and glaciologist Austin Post (1922-2012) sometimes lugged his large-format camera weighing more than 60 pounds up mountain trails to photograph glaciers. But more often, he flew in small aircraft over mountain wildernesses, wrangling several cameras as he shot through cutouts in the aircraft floor and sides. Post, who started as a support technician on glacier projects, was passionately interested in glaciers and eventually earned the title of research scientist, despite lacking a college degree. He became an expert observer of glaciers as well as highly skilled in capturing them from vertical and oblique angles. As pioneering glaciologist William O. Field noted, "Not only does

Austin know glaciers and appreciate what features should be photographed, and how and to what detail, but also he is a good observer."

Starting in the 1960s Post photographed glaciers in Alaska, Canada, Greenland, and the western U.S., leaving an irreplaceable legacy of documentation regarding glaciers and changes in Earth's climate.

Captured and on display

The USGS collected these aerial photographs over the years, but at first they were inaccessible to most researchers. Starting in 1978, NSIDC (then called the World Data Center for Glaciology-A) helped create metadata describing the photographs, and created a database of the metadata, as well as copies of the photographs on microfilm. In 2008, these images began to be digitized under the National Oceanic and Atmospheric Administration (NOAA) Climate Database Modernization Project, and added to the NSIDC Glacier Photograph Collection online. NSIDC is currently creating metadata for the digitized images and adding them to the online collection as time and funding permit. Today more than 14,000 images are online, including over 6,400 photographs by Post. Researchers and the public can search for and download images using NSIDC's Web site. Work continues to make the entire collection accessible online. NSIDC has more than 100,000 Austin Post glacier photographs in its archives, as well as many other photographs waiting to be added.

The Austin Post photographs and the NSIDC Glacier Photograph Collection were developed with the support of USGS and NOAA. Today, however, these resources are in need of ongoing stewardship of the physical materials, as well as resources to continue their digitization and metadata to enable online discovery and access. As climate records, their value continues indefinitely as a record of past climate and are used by researchers to compare glaciers then and now, and by educators and communicators to help everyday people see how most of the world's glaciers are changing. We may not be able to stop many glaciers from disappearing, but we can work to keep these valuable observational records intact and accessible for future research.

Austin Post remained fascinated with glaciers and glacier photography to the end of his life.

Credit: B. Molnia, USGS

This aerial photograph of Nisqually Glacier, Washington State, USA was taken by Austin Post on September 21, 1960. Access the full-resolution photograph via the NSIDC Glacier Photograph Collection.

Credit: A. Post, NSIDC Glacier Photograph Collection

Glimpses of sea ice past

National Snow and Ice Data Center acquires dozens of canisters of 35-millimeter film that contain images of the 1964 Arctic sea ice minimum and the Antarctic maximum. The images were collected by the Nimbus 1 satellite, which circled the globe from August 28, 1964 to September 23, 1964.

Credit: NSIDC

Recently, the National Snow and Ice Data Center acquired stacks of 49-year-old film rolls from a National Climate Data Center storage facility in North Carolina. "There were fifty cardboard boxes. Each contained ten rusty, dusty canisters, each containing 500 feet of 35-millimeter negative film," said NSIDC technical services manager Dave Gallaher. "We really wanted these."

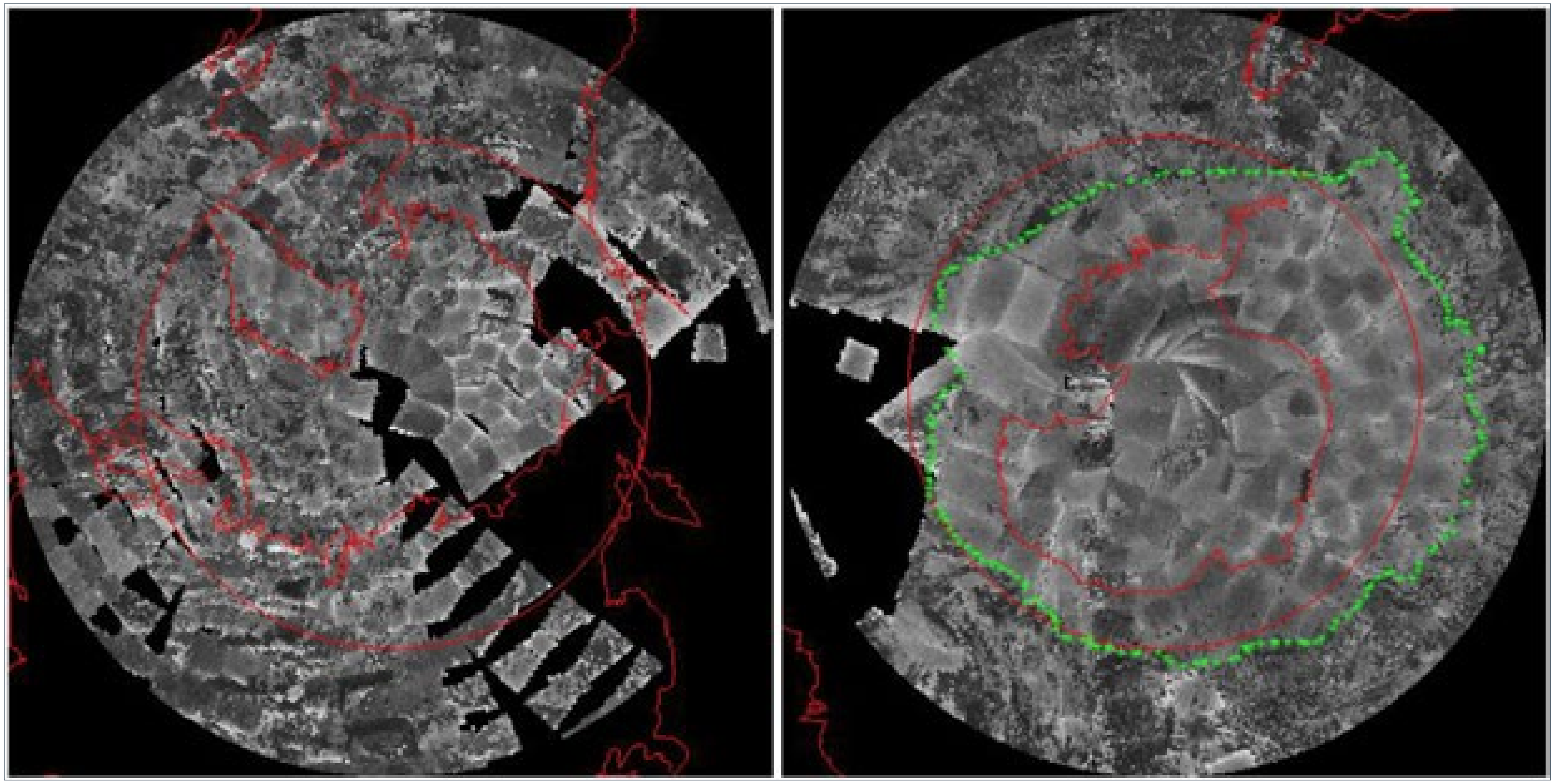
NSIDC scientist Walt Meier, who studies the yearly waxing and waning of sea ice in the Arctic, said the old film from one of the first U.S. Earth-observing missions, the NASA Nimbus 1 satellite, could give scientists a deeper look back at climate. It happened that the dusty boxes of old film were dated August to September 1964. "This film contains basically the earliest satellite data we have of Arctic and Antarctic sea ice extent," Meier said. But making those canisters of film talk would be no easy task.

Right place, right time

Scientists pay close attention to the ice in September, when it shrinks to its minimum extent. Arctic sea ice has long been recognized as a sensitive climate indicator, and has undergone a dramatic decline over the past thirty years. They currently depend on a satellite record that begins in 1979.

Nimbus 1 was a test of weather satellite technology, including a video camera, so scientists could improve weather forecasts. Data specialist Garrett Campbell at NSIDC, "There were no fancy satellite sensors in 1964," he said. "Scientists strapped a video camera to the Nimbus 1 satellite, sent it into orbit, and hoped for the best."

As it circled the globe in August and September, Nimbus 1 transmitted still shots of the Earth to a television monitor,



The National Snow and Ice Data Center scanned close to 40,000 images from Nimbus 1 satellite data to produce the earliest satellite images of Arctic and Antarctic satellite extent. The left image is a composite of the Arctic and the right image is a composite of the Antarctic.

Credit: NSIDC

which researchers photographed. After using the stills for weather forecasting research, scientists archived them in a secure storage facility.

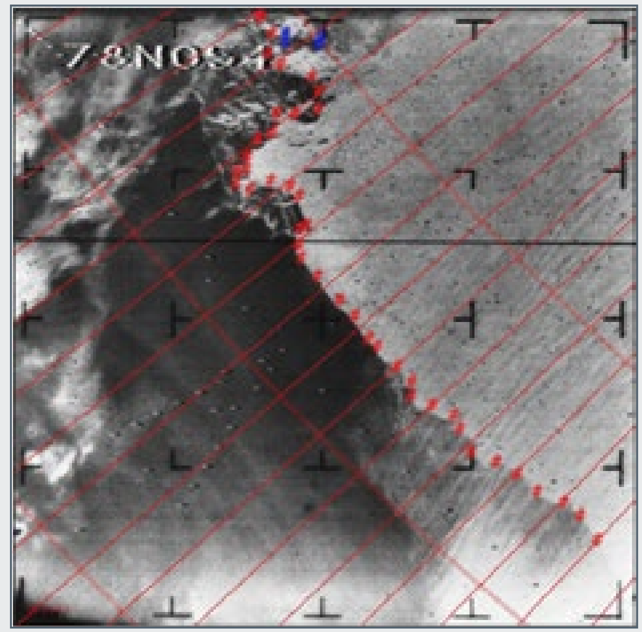
In 2009, Gallaher stumbled on a NASA conference poster about the recovery of the film, and realized that it would have captured images of the Arctic sea ice minimum and the Antarctic maximum in 1964. Satellite records of Arctic sea ice extent only went as far back as 1978. There were other observations before 1978, like ice charts from naval ships, radiometer records, and other satellite imagery. None of these gave scientists a full view of the Northern Hemisphere. But the old film would. So Gallaher teamed with Meier and the Lunar Orbiter Image Recovery Project (LOIRP) at NASA Ames Research Park to try to recover any information the old films might contain.

Arctic and Antarctic sea ice, 1964

Campbell, who spent the past two years examining shots from the film rolls, said the images would have been too overwhelming for researchers to process in the 1960s. “We didn’t have the computing power to handle all those images at that time,” Campbell said. “In 1964, researchers would have had to develop every single frame as a photograph and lay it out on the floor of a large room.” To get a good view of this composite of thousands of photographs, one would have to be standing a few floors above the photograph-covered floor, ideally on a very tall ladder.

But with today’s technology, Campbell simply worked with two undergraduate students to scan close to 40,000 frames, made sure the images had the right latitude and longitude, and stitched the photos together in his computer. With those images, Campbell produced the first satellite maps of the sea ice edge in 1964 and an estimate of September sea ice extent for both the Arctic and the Antarctic. According to the data, September Antarctic sea ice extent measured about 19.7 million square kilometers. “That’s higher than any year observed from 1972 to 2012,” Meier said.

Figuring out the sea ice extent for the Arctic was more challenging. It was harder for the team to distinguish the ice edge along the coasts from snow or glacier-covered islands in the Canadian Archipelago. Also, there were not many images of Alaska and eastern Siberia to work from, so Campbell relied on old Russian and Alaskan ice charts. His analysis yielded a September 1964 Arctic sea ice extent of 6.90 million square kilometers. “The 1964 estimate is reasonably consistent with 1979 to 2000 conditions,” Meier said. “It suggests that September extent in the Arctic may have been generally stable through the 1960s and the early 1970s.”



A single frame image of the Arctic ice edge north of Russia near Franz Josef Land (centered at 78 degrees North and 54 degrees East) on September 4, 1964, after processing by the National Snow and Ice Data Center. The estimated boundary between the ice and ocean is marked by red hash tags; openings, or leads, within the ice are marked by blue hash tags.

Credit: NSIDC

NSIDC will be making these images, as well as high-resolution infrared data from the Nimbus 1 satellite, available to researchers beginning May 2013. The team has also acquired satellite imagery from Nimbus 2 and 3, and other satellites operating in the late 1960s and early 1970s. The result, hopefully, is a longer record of sea ice that Meier said would “put the dramatic decline of Arctic summer sea ice extent in a longer-term context” and prove useful to other scientists studying today’s changing climate.

All About Arctic Climatology and Meteorology

This aurora appeared over the city of Iqaluit in Canada's Nunavut Territory. High-altitude oxygen, about 200 kilometers (124 miles) up, produces rare, all-red auroras, while lower-altitude oxygen, about 60 kilometers (37 miles) up, is the source of the most common auroral color, a bright yellow-green. Blue light comes from ionized nitrogen molecules. The nitrogens also create purplish-red and red colors in the aurora.

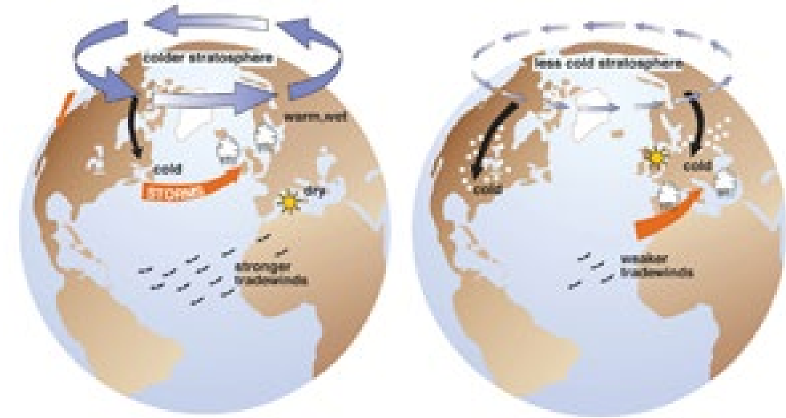
Credit: ascappatura, Flickr

The Arctic is often referred to as the Earth's icebox, helping cool the globe's ocean currents and shaping the jet stream. Similarly, warming in the Arctic influences conditions elsewhere on the planet. This means what happens in the Arctic doesn't stay in the Arctic. NSIDC's educational Web site, All About Arctic Climatology and Meteorology, helps explain how the region plays a role in weather and climate across the Northern Hemisphere.

Ripples from the Arctic

In the Arctic, the usual meteorological conditions factor into the region's weather: wind, humidity, temperature, clouds, precipitation, air pressure, and more. But the Arctic's unique geography and high latitude also foster longer-term weather patterns, which recur regularly, even yearly. All About Climatology and Meteorology describes and illustrates these patterns, including cyclones and polar lows. One major pattern that scientists are always tracking is the Arctic Oscillation. Different phases of this oscillation carry consequences across the Northern Hemisphere, either causing warm and dry winters or blasting unusually cold and wet weather across Europe, China, and parts of the United States.

Readers can also learn about interesting and unique local phenomena caused by the Arctic's icy surfaces and special atmospheric conditions, including ice blink, fog bows, and of course, the famous Aurora Borealis. Early polar navigators sometimes relied on these optical illusions to determine whether open water or sea ice lay ahead. At other times these illusions deceived explorers into turning back, sailing away from mirages that made open water look like towering mountains.



The left side of this illustration shows effects of the positive phase of the Arctic Oscillation, while the right side shows the effects of the negative phase of the Arctic Oscillation. Both phases influence weather patterns further south in Europe, China, and the United States.

Credit: J. Wallace, University of Washington

New updates to a popular site

All About Arctic Climatology and Meteorology is one of NSIDC's most popular sites, consistently ranking among our top ten pages. The content was originally derived from a CD released in 2000, the Primer for Newcomers to the North, part of the Environmental Working Group's Arctic Atlases. NSIDC recently updated the site with new information, additional photographs and images, and sections about climate change, exploration, and Arctic peoples.

To read more, visit the updated and expanded All About Arctic Climatology and Meteorology site. Learn how the Arctic keeps its cool, and how changes in the Arctic produce far-reaching effects around the globe. Read about how the Arctic was discovered and explored, how people now survive life in the Arctic, and how scientists conduct research in such an icy and inhospitable region. In addition, the site also includes a gallery of new and historic photographs of the Arctic.

Visit All About Arctic Climatology and Meteorology in About the Cryosphere, or go to the Web site directly at http://nsidc.org/cryosphere/arctic-meteorology/index.html.

Ways of seeing, ways of knowing

The Arctic is changing, shifting animal and plant life cycles to adapt to thinning ice and shorter winter seasons. To understand how small, regional processes are behaving, scientists are turning to the Arctic's long-time residents.

"Scientists are increasingly aware that Indigenous people have a deep and broad understanding of our changing environment and landscape," said Peter Pulsifer, lead for the Exchange for Local Observations and Knowledge of the Arctic (ELOKA) program at NSIDC. Technology offers new avenues for recording observations that have for generations been passed down through the oral tradition. But where does all this documented knowledge go? How can it be maintained to guarantee its preservation for future generations? And who has access to it? To answer some of these questions, ELOKA with its partners has developed several digital atlases, due to launch during the summer months of 2013.

From left: Lasalie Joanasie, Ken Qillaq, and Teema Qillaq install a sea ice monitoring station near Clyde River, Nunavut in the Siku-Inuit-Hila Project.

Credit: S. Gearheard/NSIDC

The Yup'ik Environmental Knowledge Project

Yup'ik elders recognize the power of names. "One who speared another" and "Place where one takes something out" are not just places, but gateways to stories. And within each one Yup'ik values unravel. That is why in partnership with the Calista Elders Council (CEC), ELOKA has developed the Yup'ik Environmental Knowledge Project website and online atlas. As a major research organization, the CEC has worked for ten years with elders from Bering Sea coastal communities to document Yup'ik place names.

Young Nenets boy Anton Taleev on a reindeer sledge in Nenets Autonomous Okrug, Northwest Russia.

Credit: B. Forbes

Elder John Phillip of Kongiganak says, "Today people travel at fast speeds using snow machines. Many fail to recognize places they pass and lose their way. Elders instruct that continual observation is still important and can be a matter of life and death." With insight into Yup'ik culture, values, and languages, the website provides Yup'ik and English translation text, photos, audio, and video files to be associated with more than 3,000 identified place names in the online atlas.

The Atlas of Community-Based Monitoring in a Changing Arctic

Changes that are not good for the reindeer are not good for the Nenet people. With dramatic shifts in their landscape, these nomadic reindeer herders struggle to maintain a thousand-year-old tradition on the Yamal Peninsula in Northwest Siberia. Staying too long in one place can be a matter of life or death. Rivers are surging in early winter, instead of freezing and providing safe passage. Ancient permafrost thaws and drains away lakes. Gnat fly populations increase while mosquitoes decrease. Longer autumns lead to delayed springs. The Nenet people continue monitoring such changes, as well as their own social shifts.

They are not alone. Many Arctic Indigenous communities are learning to apply observation and monitoring practices in new and collaborative ways. The Atlas of Community-Based Monitoring in a Changing Arctic (http://www.arcticcbm.org) is mapping both traditional knowledge and scientific approaches to monitor community concerns, including sea ice, snow cover, weather, biodiversity, and water quality. The Atlas serves as an important resource for local and sometimes regional or national decision-making. The project is a partnership between Inuit Circumpolar Council Canada (lead), Brown University, Inuit Quajisarvingat: The Inuit Knowledge Center, and ELOKA.

The PHENARC Project

With prolonged autumns and delayed winters, migratory birds arrive at the "wrong" times. The first bloom is a significant marker for researchers studying the shifts in plant and animal cycles, but for the communities that live through these changes, it is a matter of survival. Susan Crate at George Mason University (GMU) involves communities in northeastern Siberia and in the Labrador/Nunatsiavut areas in studying links between Arctic phenology and climate change.

In northeastern Siberia, changes in snow cover affect the Viliui Sakha, who depend on their horse and cattle breeding practices. Here snow remains on the ground about a month longer than usual, delaying spring, shortening the growing season, ruining the berry season, and sometimes starving horse and cattle populations on thinning pastures. A thousand years ago, Viking would-be settlers named the Labrador/Nunatsiavut region "Markland," or forest-land, a sub-arctic forest too brutal from some. Still the determined integrated, developing a culture of diverse traditions. Today, 30 percent of Labradoreans are Aboriginal people, once drawn here by the abundance of whales. Shifts in sea ice cover impact all these communities and their relationship to the area's rich fishing industry.

For both regions, the PHENARC atlases will allow community members to delineate routes and record points of interest with the ability to attach observations, stories, pictures/videos, and other materials to each path and point. The first atlas to be developed will involve the community of Makkovik in Nunatsiavut, where school children, Elders, and a local museum will take part in populating the atlas.

"Helping to develop tools like the atlases enables broad sharing of knowledge, now and in the future," said Pulsifer. "Such information will help all of us deal with the local, regional and global effects of a rapidly changing Arctic."

A new way to find Arctic data

Icy water in the fjord of the Kangerdlugssuaq Glacier in eastern Greenland, as seen from NASA's P-3B aircraft during an Operation IceBridge flight. Diverse data on the Arctic, including IceBridge data, can be discovered through the Arctic Data Explorer.

Credit: J. Beck, NASA

When David Bailey, a climate modeler from the National Center for Atmospheric Research (NCAR), needs scientific data, he does one of two things: search for them using Google or write to the researcher who might have them. "I can't even imagine the days before Google and e-mail," he said. "You would hope to find some reference to the data in published literature, and that the authors point to where the data are available." But this is seldom the case. Researchers also try their luck at major scientific conferences where they just might meet other researchers who have the data they need.

Although usually effective, these data search methods can be time consuming. Researchers may go through hundreds of Web sites to find the data they need or run into dead ends when they write to other scientists for data. Lynn Yarmey, a data curator at the National Snow and Ice Data Center (NSIDC), said this is especially true when scientists look for data in another discipline. "They might be talking about the same data but will have different names for it," she said. For example, what plant ecologists call photosynthesis is gross primary production to climate modelers. "If one community calls it something different than what others call it, then how would they know where to look?" Yarmey said.

Diverse data

Through the Advanced Cooperative Arctic Data and Information Service (ACADIS) project, NSIDC, in collaboration with NCAR, has put together a data search tool that will make data search easier for scientists who study the Arctic. The Arctic Data Explorer crosses disciplines and offers Arctic data on sea ice, biology, permafrost, meteorology, chemistry, demography, marine ecology, anthropology, oceanography, hydrography, biodiversity, and terrestrial ecology.

A search for the term "polar bear" for example, gets results that include biological data like blood, muscle and breath analyses, behavioral data like location and movement, and local traditional knowledge of the animals in relation to changing sea ice conditions. A search for the term "fish" brings up data collected by groups as diverse as Arctic communities, research expeditions, and the oil industry. "There are so many pieces that all need to come together to answer these really big questions about climate change and the Arctic. We have to take a much broader view of science," Yarmey said.

Minimizing clicks

The Arctic Data Explorer brings diverse data together by storing metadata from top Arctic data centers, including NSIDC, the ACADIS Gateway, the Earth Observing Laboratory/Computing, Data and Software Facility, the National Oceanographic Data Center, and the Norwegian Meteorological institute. "The Arctic Data Explorer searches through the metadata and connects the researcher with the data they are interested in, no matter which organization has that data set," Yarmey said. "It really reduces the time and clicks that it takes for someone to get to the data."

NSIDC produced the Arctic Data Explorer as part of its work with ACADIS, which is reaching out to Arctic researchers to add their data to its growing collection. Bailey, who serves on the ACADIS Data Advisory Committee, said "We need to make it easy for observational scientists to put their data in the collection, and to make a search engine that will make end users want to keep coming back. It's a huge challenge to make it useful at both ends."

Yarmey dreams that some day the process of contributing and finding data will be efficient and painless. "We can take some of the work out of sharing and finding data by building solid systems, automating metadata collection, and interconnecting data management systems. Then researchers can get the data they need quickly, and get back to doing research," she said.

For more information, see the Arctic Data Explorer at http://nsidc.org/acadis/search or contact support@aoncadis.org.

A seal hunter prepares to jump back on his the sled in Qanaaq, Greenland. ACADIS data includes local traditional knowledge shared by Arctic residents and indigenous people.

Credit: A. Mahoney,NSIDC

Hacking the cryosphere

In 2012, NSIDC faced a challenge: how to unleash the creative potential of software development in the service of science. Scientists and informatics researchers needed better tools, while NSIDC software developers wanted to stretch their coding skills and work with data in innovative ways. "We had this brilliant staff of researchers, an enormous amount of data, and tech-savvy software developers," Erik Jasiak, head of NSIDC software development, said, "but the three weren't coming together on new ideas."

Earth's cryospheric features, like Crane Glacier in Antarctica, can be vast, remote, and often shrouded in polar darkness. Technology is increasing important to assembling a picture of how the cryosphere is changing.

Credit: T. Scambos, NSIDC

Nobody was speaking the same language. "It was a war of abbreviations," Jasiak said. "The researchers didn't understand new technologies, and the developers didn't feel they had permission to push the envelope. They all had the data, though," he said. As well, the tight confines of scientific funding may afford little space for exploration of new technologies. How could developers find the chance to show researchers what those technologies could do?

Space for creativity

Jasiak gained agreement from NSIDC stakeholders to try a practice common with software industry leaders: software "hack" sessions, aka hackathons. Developers periodically get a small amount of free time to code and demonstrate a new technology. The concept is simple: give the developers a high-level goal and a little room to explore, and trust in their instincts.

NSIDC hackathon time is relatively small by industry standards, just one to two days each quarter per developer. Expectations are straightforward: participation is voluntary, the work must relate to NSIDC objectives, and a developer must always report back their results. They must either demonstrate a new technology relevant to science or informatics at NSIDC, or, just as valuable, discuss their learning experience on what technologies were problematic.

Early hackathons revealed some of the gaps that needed to be bridged. In one of the first hackathons, developer Hannah Wilcox demonstrated overlaying NSIDC sea ice data sets in new mapping technologies. Scientists and analysts were impressed with the display, and what could be done with the format, but immediately began questioning the pixel colorations. "I kept having to tell people, 'This is not a done deal,'" Wilcox said. "'It's not even correct yet; it just shows up.'" But the conversation about new technologies and research was beginning.

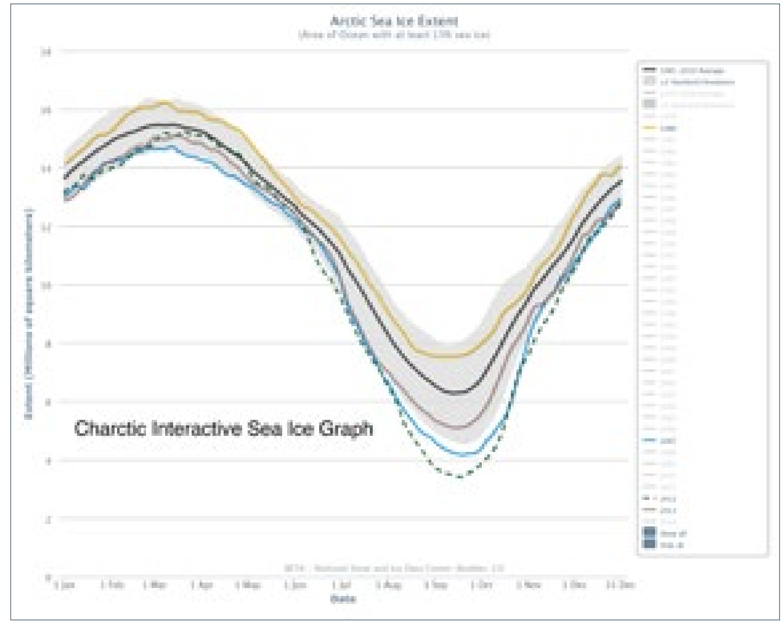
Building collaboration

One year in, NSIDC hackathons are a growing success. One of the first projects teamed a relative newcomer to NSIDC, Kevin Beam,

NSIDC software developers work through a programming problem in their team room.

Credit: A. Veale/NSIDC

with an expert developer, Matt Savoie. Together, they produced an early version of an interactive Arctic sea ice extent chart (now live on the NSIDC Web site as Charctic) in two days. "Matt knew the sea ice data, and had this idea for a Google finance chart for sea ice, and I knew the Ruby on Rails and JavaScript-fu [libraries] to make that work," said Beam. "It was kind of perfect because we had the data, and Matt knew what he wanted it to look like. We just combined the knowledge and tools."



A hackathon session at NSIDC showed scientists that this interactive Arctic sea ice chart was worth developing. It is now featured in NSIDC Arctic Sea ice News & Analysis as Charctic.

Charctic was an immediate hit with the NSIDC Arctic Sea Ice News and Analysis (ASINA) product team. "My first impression was 'Wow, this is so useful,'" said Walt Meier, a former NSIDC scientist (now with the NASA Goddard Cryospheric Sciences Lab). "We had always gotten comments from users asking to see specific years or other parts of the year than what we were showing at the time," Meier said. Now instead of scientists having to manually make the relevant plots, users can make their own plots. "It's addicting to play around with, even for someone as familiar with the data as I am," Meier said. "The flexibility is amazing. It's great be able to hone in on a specific time of year, look at the specific data values, even pull up images of a given day's sea ice."

The hackathon program continues to generate a storehouse of new ideas, tools, and libraries to help scientists with their data. Just as in scientific research, even failed experiments can produce useful knowledge. For example, a few ideas turned out be too cumbersome to set up during a hackathon session, and are now noted as having potential ramp-up issues—invaluable knowledge as researchers put together proposals. The conversations between researchers and developers about what is possible, and what is useful, improve every time.

Changes all around

The next five years will bring exciting additions to the National Snow and Ice Data Center's (NSIDC) holdings: new scientific data types, new technologies, and even new kinds of users with different expectations. NASA recently renewed a contract with NSIDC to operate and manage the Earth Observing System Data and Information System Snow and Ice Distributed Active Archive Center (DAAC), which offers over 250 cryospheric data products, primarily from Earth observation satellites. NSIDC has managed the data center since 1993, and the new contract keeps the DAAC in NSIDC until May 2014 with optional one-year extension all the way to 2018.

Despite NSIDC's long history in operating the DAAC, NSIDC's NASA DAAC manager Ron Weaver expects a lot of changes in the DAAC in those five years. "The year 2018 will look very different from this year," he said.

For instance, NSIDC will have added data from the NASA Ice, Cloud, and Land Elevation Satellite (ICESat-2) to its holdings. ICESat-2 launches in 2016 and will measure ice sheet mass balance, cloud and aerosol heights, as well as land topography and vegetation characteristics. NSIDC will have also started distributing data from the Soil Moisture Active Passive (SMAP)

NSIDC will archive and distribute the new ICESat-2 data stream, expected in 2016, which will measure ice sheet mass balance, cloud and aerosol heights, as well as land topography and vegetation characteristics.

Credit: Satellite image courtesy of Orbital Earth image illustrating AMSR-E sea ice courtesy of the NASA Scientific Visualization Studio

An artist's rendition of the Soil Moisture Active Passive (SMAP) satellite is superimposed over a satellite view of Earth. NSIDC will distribute snow cover, frozen ground, and permafrost data from the SMAP mission.

Credit: NASA

mission, a synergy between active radar and passive microwave for snow cover, frozen ground, permafrost. "That's a massive amount of data that is coming," Weaver said. "By 2018, we'll be over a petabyte of data or very close. But we'll be able to handle that with more powerful computers."

The coming years will also bring the challenge of making the data accessible to a growing community of users who favor mobile devices. "The times, they are a-changing," said Weaver. "Our data users are experts in cryospheric research, other scientists, and graduate and undergraduate students. But think about who the undergraduate is going to be in 2018. It's going to be today's ninth grader who is extremely comfortable with mobile devices."

According to trends, today's mobile computing platforms, such as tablets and phones, will become faster and more stable, and in a few years time could rival PCs and laptops as the computing workhorse of choice. If these are what NSIDC data users are using, "then we want to stay relevant to our users' needs," Weaver said.

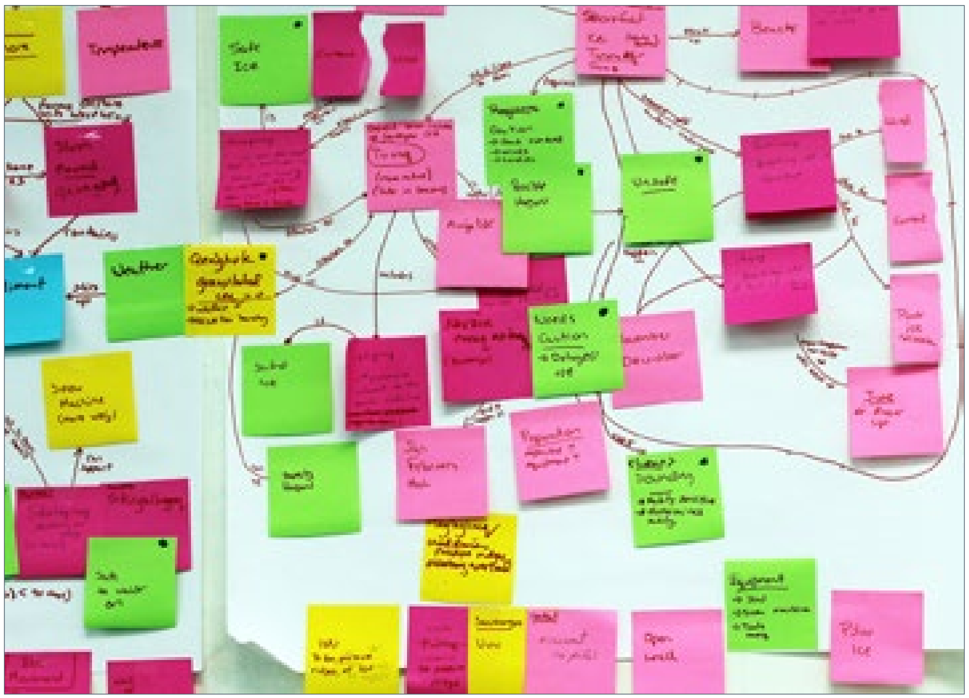
A growing number of non-expert users, like journalists, educators, students and policymakers, have also been using NSIDC data, and the trend will probably continue. Weaver attributes this to the growing interest in the cryosphere and the changes it has undergone over the past several years. NSIDC has adapted to this demand by presenting some data in a format that is more accessible to this audience. The Charctic interactive sea ice graph for example, plots Arctic sea ice extent time series from 1979 to the present with a few clicks of the mouse.

"These rapidly changing directions are going to be a challenge for us," Weaver said. "But we have a really good, flexible team and we've put systems in place. We are up to this challenge and we'll stay relevant, stay flexible, and yet do cost effective data management."

Former NSIDC scientist Walt Meier (now with the NASA Goddard Cryospheric Sciences Lab) sets up an albedo experiment for Boulder middle school students while NSIDC's NASA DAAC manager Ron Weaver looks on. NSIDC anticipates adapting to the data needs of future cryospheric scientists who might favor more mobile means of computing.

Credit: N. Vizcarra, NSIDC

In search of a common language



Simple technologies like flip charts, markers and "sticky notes" are used to quickly record Indigenous sea ice terms and concepts in the form of a concept map. Concept maps are then used in further discussion and possibly the development of a computer-based knowledge model.

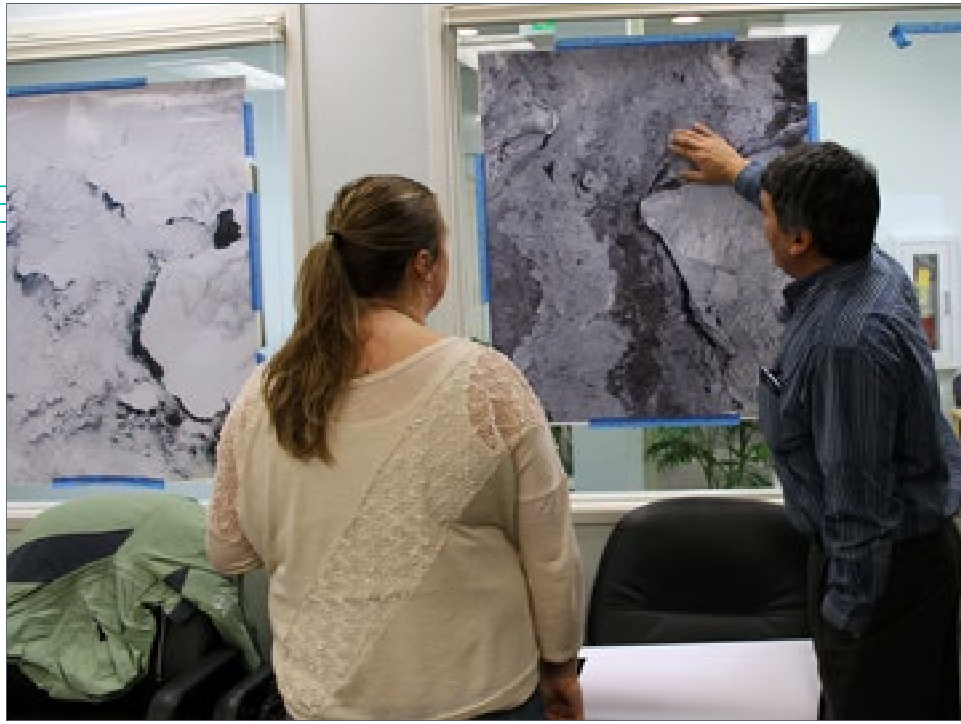
Credit: P. Pulsifer, NSIDC

What's the use of data that is difficult to retrieve? The Semantic Sea Ice Interoperability Initiative (SSIII), a project at NSIDC, tries to tackle the challenge of organizing data within language systems. "Semantics is a big thing in web technologies and it's how you can get computers to understand the concepts beneath words," said Ruth Duerr, NSIDC's informatics team lead. "It puts the smarts in your ability to build tools for users," she said. A smart enough tool knows to search for various forms of precipitation when asked to find rainfall data. It has made the link between rainfall and precipitation. This is basic semantics.

On naming

SSIII wants to bring semantic technology to the Arctic data community. Using nomenclature from the World Meteorological Organization, the team garnered a set of sea-ice terms. "It's turned out to be very interesting," said Duerr. "People may not necessarily realize that the terms they're using are not as logically organized as they thought. We kept running into small issues."

Finding data gets complicated when disparate groups use their own terminologies. "They may use the same word for



Lewis Brower, Sea Ice expert from Barrow, Alaska, shares his knowledge with Rebecca Legatt from the National Weather Service's Anchorage Ice Desk. Combining knowledge, expertise, and data can greatly enhance the understanding of sea ice.

Credit: P. Pulsifer, NSIDC

different things or use different words for the same things," Duerr said. Let's deconstruct sea ice. Is it simply defined as frozen seawater? Not for the floating chunks of freshwater ice calved from the Greenland ice sheet. They may float in the sea, but they are freshwater. And when is there no sea ice? Remote sensing scientists say that it is when less than 15 percent of the surface is covered in ice, because remote sensing microwave satellites can no longer see it. That, however, is not a definition that works well with mariners because that 15 percent may still cause serious damage to boats and ships.

After collecting the essential nomenclature, the team needed to turn it into series of ontologies. The term ontology has its roots in a branch of philosophy that deals with the nature of reality or metaphysics. For informational science, ontology refers to an explicit (machine-readable) and formal representation of concepts and their relationship. Ontologies attempt to circumvent the ambiguity and vagueness of natural language. Structures must, therefore, be well defined. Though quite abstract, the basic premise is to group concepts within a domain to establish fixed, controlled vocabularies of rich and complex knowledge about things, groups of things and the relations between things. It attempts to make implicit knowledge explicit.

On the backs of napkins

Creating a set of ontologies in the same language is challenging enough, but what about working with multiple languages? "It's one thing to say we want doctors from different hospitals sharing information," said Peter Pulsifer, a lead for the Exchange for Local Observations and Knowledge of the Arctic (ELOKA), "but it's another thing to say we want doctors to share information with theologians, for example." ELOKA deals with Indigenous knowledge of sea ice. How does a historically oral tradition translate to written language, let alone an information system environment? "We don't know if this is an appropriate method with Indigenous knowledge and terminology," said Pulsifer. "So what we're trying to do here is learn."

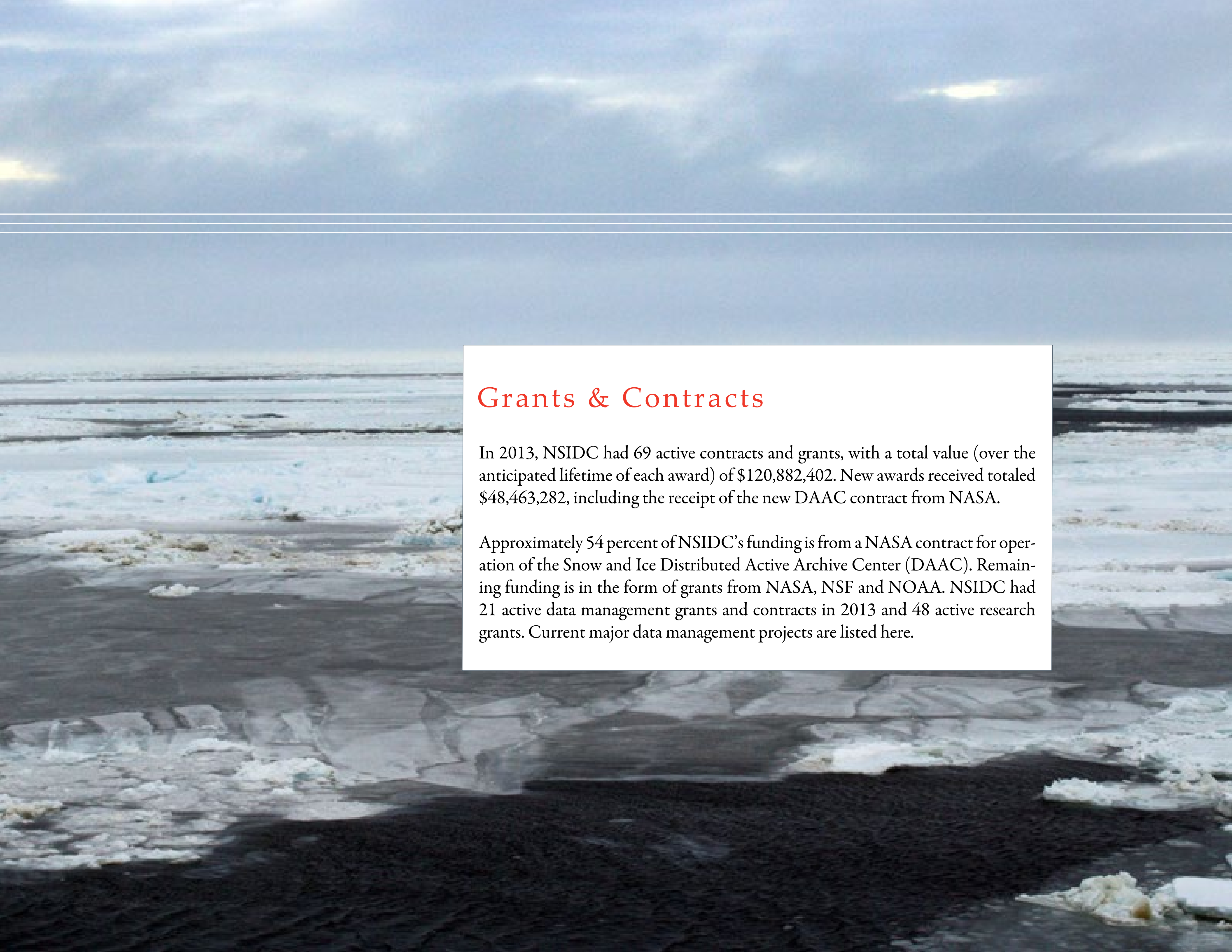
To make the appropriate links between scientific and operational vernacular, Pulsifer is using methods such as concept mapping or diagramming to visually organize Indigenous terms and concepts. "Concept maps are great for human beings," said Pulsifer. "They provide a fast recognition of patterns. But computer based systems can't handle the graphic component." Concept maps need to be transformed into statements or assertions with a reasoning end, meaning implementing logic to establish links and relationships between ideas. For instance, if an assertion is made that a particular sea ice phenomenon melts at -3 degrees Celsius, it can then be inferred that if the temperature is recorded at -1 degree Celsius, sea ice in this area is likely melting.

Practical applications

Concept maps can get tricky as they cross many disciplines. And trying to share data across communities that already aren't working together complicates semantics, to say the least. "We're not at a place where we can say SSIII and semantic approaches are a panacea, where all the issues can be resolved," said Pulsifer. "As you get deeper into multidisciplinary questions and environments, it becomes even more challenging."

An outcome to SSIII's research has been the development of hands-on teaching tools. Using Barrow, Alaska as a case study on sea ice safety, two products—a poster and website—resulted, showcasing how well various domains can be linked. Designed as a flow chart, the poster offers scientists and graduate students, who have little to no experience with sea ice safety, a visual aid in making decisions regarding sea ice concerns. The website is a visual representation of a concept map that includes photographs, audio, and will eventually include video of sea ice and weather phenomenon.

Pulsifer added, "We're looking at this research from a holistic perspective. It's not simply a technical act with a best route or effective method for any particular community but one that needs a larger perspective as well."



Grants & Contracts

In 2013, NSIDC had 69 active contracts and grants, with a total value (over the anticipated lifetime of each award) of $120,882,402. New awards received totaled $48,463,282, including the receipt of the new DAAC contract from NASA.

Approximately 54 percent of NSIDC's funding is from a 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 21 active data management grants and contracts in 2013 and 48 active research grants. Current major data management projects are listed here.

NSIDC Major Grants & Contracts

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)

Advanced Cooperative Arctic Data and Information Service (ACADIS, PI M. Serreze and J. Moore, UCAR)

ACADIS is designed to manage the diverse data needs of the Arctic research community supported by the NSF Office of Polar Programs (OPP) Division of Arctic Sciences (ARC). ACADIS is a collaborative effort between the National Snow and Ice Data Center (NSIDC), the University Corporation for Atmospheric Research (UCAR), and the National Center for Atmospheric Research (NCAR). It represents an expansion of the Cooperative Arctic Data and Information System (CADIS) system originally developed by NCAR, NSIDC and UCAR, which provided data management support and archival services for the Arctic Observing Network (AON) for nearly four years. ACADIS, by contrast, is serving needs of the broader Arctic NSF-funded community, including, but not limited, to projects funded by OPP under AON, Arctic System Sciences (ARCSS), Arctic Natural Sciences (ANS) and the Arctic Social Sciences Program (ASSP).

ACADIS is designed to allow scientists an easier path to archive, access, integrate and work with data spanning multiple disciplines. ACADIS is providing data ingest and access services to scientists, decision-makers and other Arctic stakeholders, as well as archival services to ensure data accessibility through the coming years and decades.

Opposite: Early autumn sea ice in the northwestern Weddell Sea near the Antarctic Peninsula, looking southeast. Larissa project, April, 2013. Credit: T. Scambos, NSIDC

NSIDC is focused on improving the discoverability, accessibility, and usability of NSF data in conjunction with broader Arctic data holdings from other agencies and countries. NSIDC also works with UCAR/NCAR on data stewardship, integration and (as is necessary), customized services, and activities for a broad user community. For each potential value-added product or activity, NSIDC scopes the level of effort required and meets the need based on recommendations by the ACADIS Data Advisory Committee (ADAC) and NSF management.

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).

Collaborative Research: ELOKA Phase III

Toward Sustainable Data Management Support for Community Based Observation Contributing to the Arctic Observing Network (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 Archives and Resource Center (ARC) at NSIDC (http://nsidc.org/noaa).

Early autumn sea ice in the northwestern Weddel Sea near the Antarctic Peninsula, looking southeast. Larrisa project, April, 2013.

Credit: T. Scambos, NSIDC

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Opposite: Wind-driven grease ice and an iceberg in the northwestern Weddell Sea near the Antarctic Peninsula. Larissa project, April, 2013. Credit: T. Scambos, NSIDC

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