NEWSLETTER OF THE NATIONAL ICE CORE LABORATORY — SCIENCE MANAGEMENT OFFICE

Vol. 6 Issue 2 • FALL 2011

Getting to the Bottom

NICL Team Processes Deepest Ice from WAIS Divide Project

By Peter Rejcek, Antarctic Sun Editor
Courtesy: *The Antarctic Sun*, U.S. Antarctic Program

National Ice Core Lab intern Mick Sternberg measures the final section of ice core from the WAIS Divide project. This summer a team of interns and scientists processed the bottom cores of ice drilled from West Antarctica. The ice will be shipped to labs across the country to analyze. Photo Credit: Peter Rejcek

MICK STERNBERG had literally made the same measurement a thousand times before. But this meter-long ice core was perhaps just a little more special. He double-checked his numbers on the final length, stood back, and rechecked again.

"No reason to rush through this," he said under his breath, which steamed out in the freezing temperatures of the National Ice Core Laboratory's processing room.

After all, this last section of ice, drilled from near the bottom of the West Antarctic Ice Sheet (WAIS) at a depth of about 3,331 meters, had been waiting around for a while. Probably somewhere in the neighborhood of 55,000 to 60,000 years.

Sternberg, an intern at the National Ice Core Lab (NICL), gave a nod and the cylinder of ice moved down the ice-core processing line shortly after 3 p.m. on Aug. 16. It would be trimmed, scanned, sliced and diced to be sent out with tons more ice to laboratories around the United States for various analyses.

— *continued on page 3*

In-Depth

In-Depth is published semi-annually by the **National Ice Core Laboratory - Science Management Office (NICL-SMO)**.

We are interested in project stories and news from the ice coring community. Please contact us if you are interested in submitting a story or news item to *In-Depth*.

***In-Depth* Newsletter**
Mark Twickler (MST), Director
Joe Souney (JMS), Production/Editing

nicl.smo@unh.edu
(603) 862-1991
http://nicl-smo.unh.edu

University of New Hampshire
Institute for the Study of Earth, Oceans, and Space
Durham, New Hampshire 03824

Masthead photos courtesy of Lonnie Thompson and Michael Morrison.

Message from the Director

2011, what a remarkable year for U.S ice coring. WAIS Divide reached a milestone at 3,331 meters depth, creating the deepest ice core ever drilled by the U.S. and the second deepest ice core ever drilled by any group. In East Antarctica, two projects collected old ice from "blue ice" areas at Allan Hills and Taylor Glacier. And in West Antarctica, a traverse collected ice cores to evaluate recent changes in accumulation.

In the Arctic, shallow ice cores were collected along the Arctic Circle traverse and along the Thule-Summit traverse. And in Alaska, hand coring was done on the McCall Glacier.

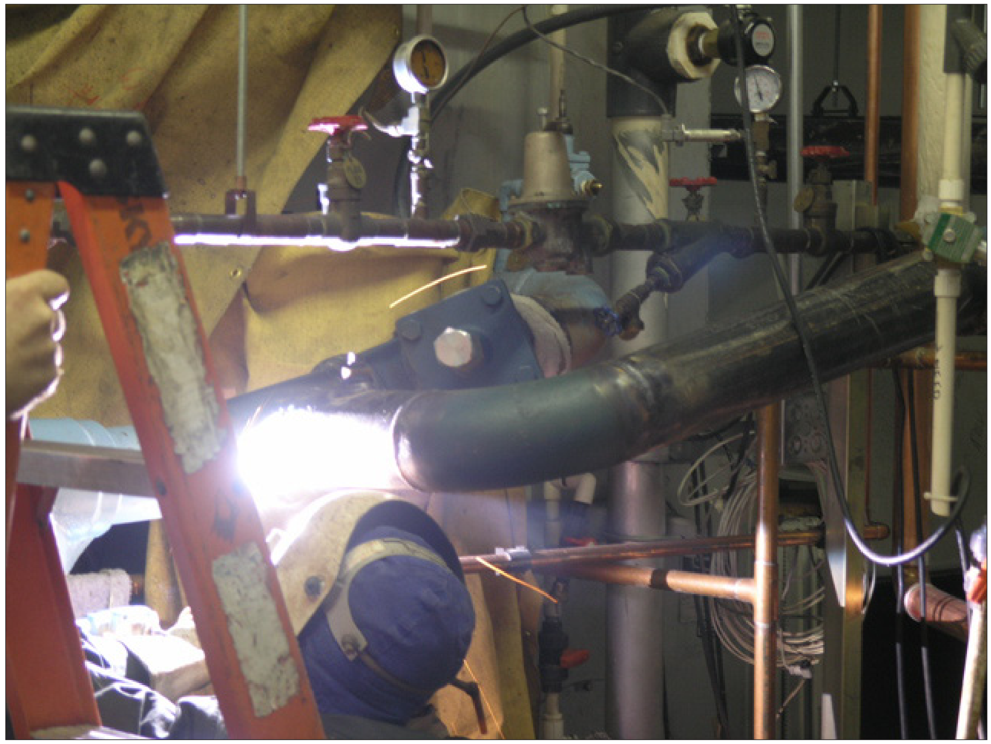
NICL had a very busy schedule this past year. Ten weeks were spent during the summer processing the WAIS Divide core; a record of 1400 meters processed in a single CPL. The cores collected during the West Antarctic traverse were also processed at NICL. Probably one of the most important accomplishments at NICL was the replacement of an aging evaporative condenser unit, along with installation of a redundant backup unit, which did not exist before. Let us hope 2012 brings us as much success as did 2011.

-MST ■

NICL Update

Evaporative Condenser Unit

By Betty Adrian, Acting Technical Director, National Ice Core Laboratory



A contractor welds the liquid return line that allows the NICL freezer to be cooled by either one of the two new evaporative condenser units. Photo: Geoff Hargreaves

ON 20 OCTOBER 2011 the NICL refrigeration system was officially cooled using the new backup evaporative condenser unit (ECU-2). Once it was determined ECU-2 worked well, the process of removing the original (circa 1993) ECU began. The NICL refrigeration system ran on ECU-2 for several weeks while the primary cooling tower, ECU-1, was replaced. November 3, 2011 was a very big day in NICL history. ECU-1 was brought online and, for the first time in NICL's history, the NICL refrigeration system had two new functioning evaporative condensers! Because the passivation process was not yet completed on ECU-2, the system was switched back to operate on ECU-2.

On November 28 it was determined that the passivation for ECU-2 was still not complete; the consensus among the key parties was that the chemical passivation process should continue for another two weeks. On December 12 the passivation of ECU-2 will be complete and we will bring ECU-1 on-line as the primary cooling tower. From then on, ECU-1 will run most of the time; ECU-2 will be exercised on regular basis to ensure all is working well. If there is a problem with ECU-1, ECU-2 can be brought on-line with minimal effort. The switch from ECU-1 to ECU-2 can occur in 30-45 minutes once the refrigeration contractor is on site.

By December 31, 2011 the NICL refrigeration system will be operating with redundant evaporative condensers. Thanks to all who were a part of this process. The NICL could not have completed this major accomplishment had it not been for the National Science Foundation funding, input, insight, and encouragement.

■

CH2M HILL Wins Arctic Contract

CH2M HILL Polar Services Awarded NSF Arctic Research Support and Logistics Contract

ON 28 SEPTEMBER 2011, NSF awarded CH2M HILL Constructors, Inc., of Englewood, Colorado the Arctic Research Support and Logistics Contract to provide research support and logistics services for NSF-sponsored research in the Arctic. Since 1999, CH2M HILL has teamed with subcontractors Polar Field Services and SRI International to form CH2M HILL Polar Services (CPS). A new partner, Ukpeagvik Iñupiat Corporation's UMIAQ, will join the CPS team for the contract period beginning in October 2011.

CPS will deliver pre-proposal fieldwork estimates, risk assessments, logistics and operational plans, transportation, communications, safety training, telemedicine, engineering, design and construction, maintenance, field camp operations, and personnel to groups working in the Arctic.

UMIAQ is a subsidiary of the Ukpeagvik Iñupiat Corporation (UIC), the Barrow village corporation established under the Alaska Native Claims Settlement Act (ANCSA) of 1971. UMIAQ will provide local support to researchers working in Barrow, Alaska and surrounding communities, including operation of UIC-owned facilities and the Barrow Environmental Observatory. UMIAQ understands the politics, culture, land use, regulations, and engineering and design conditions in arctic and subarctic Alaska and provides local knowledge and expertise.

For further information about CPS, please go to: http://www.polar.ch2m.com/ or contact Mike McKibben, CPS Program Manager, at mike.mckibben@ch2m.com.

For more information about the NSF arctic research program, visit http://www.nsf.gov/div/index.jsp?div=ARC.

Getting to the Bottom

— continued from cover

"It's really cool to be here at the end of this," said Ed Brook, one of the principal investigators on the WAIS Divide project whose lab at Oregon State University is one of several analyzing the trapped gases in the ice core, particularly those associated with the greenhouse effect, like carbon dioxide and methane.

"I'm pretty confident that the data are going to be as good as we said they would be, just looking at the ice and its quality, and as good as the processing has been," he added.

The cores had been extracted from a high, snowy spot in West Antarctica where ice begins to flow in different directions, akin to the Continental Divide in the United States. The location would help guarantee a simple stratigraphy, with thick layers that represent individual snowfall years that went deep into the ice sheet. Researchers believed they would be able to construct a climate record from the ice so good that they could count the individual years for at least 40 millennia.

"The quality of the ice is better than we expected. The age of the ice is younger than we expected, but for most of what we're doing, that's a good thing, because it gives

— continued on page 4

Upcoming Meetings

March 2012
2012 Ice Core Working Group Meeting, Denver, CO
www.nicl-smo.unh.edu

7-9 March 2012
42nd Annual International Arctic Workshop, Winter Park, CO
http://instaar.colorado.edu/meetings/AW2012/

22-27 April 2012
EGU General Assembly 2012, Vienna, Austria
www.egu.eu/meetings/meeting-overview.html

22-27 April 2012
IPY 2012 Conference "From Knowledge to Action", Montreal, Quebec
www.ipy2012montreal.ca

24-29 June 2012
International Symposium on Glaciers and Ice Sheets in a Warming Climate, Univ. of Alaska Fairbanks, AK
http://glaciers.gi.alaska.edu/events/igs2012

16-19 July 2012
Global and Regional Climate Signals from Ice Cores, 2012 SCAR Open Science Conference, Portland, OR
http://scar2012.geol.pdx.edu

11-12 September 2012
2012 WAIS Divide Ice Core Science Meeting, Scripps Seaside Forum, La Jolla, CA
http://waisdivide.unh.edu/meetings/

1-5 October 2012
IPICS 2012 Open Science Conference, Giens, France
www.ipics2012.org/

Ice Core Working Group

Karl Kreutz, Chair
University of Maine

Murat Aydin
University of California-Irvine
Gases

Ian Baker
Dartmouth College
Physical Properties

Ryan Bay
University of California-Berkeley
Borehole Logging

Brent Christner
Louisiana State University
Biology

Tom Neumann
NASA
Surface Glaciology

Erin Pettit
University of Alaska-Fairbanks
Ice Flow Dynamics

Mark Skidmore
Montana State University
Biogeochemistry

Eric Steig
University of Washington
Isotopes

Kendrick Taylor
Desert Research Institute
At Large

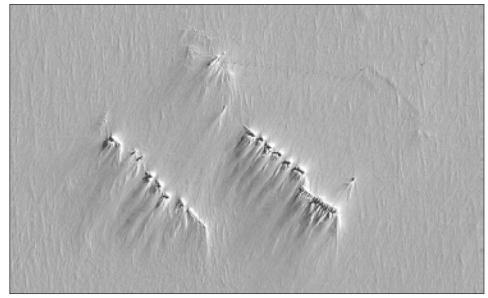
In 1986, the National Academy of Sciences recommended developing an Ice Core Working Group of representatives from institutions prominent in ice coring activities. Administered by the NICL-SMO, ICWG is organized around scientific disciplines, rather than institutions. Members are elected to a three year term, with the committee chair typically serving three years.

Getting to the Bottom

— continued from page 3

us a higher time resolution for our record," explained Kendrick Taylor, chief scientist of the WAIS Divide project, who was at NICL a few weeks earlier.

The project reached its target depth in West Antarctica on Jan. 28 after five years of drilling, representing the deepest core ever drilled by the U.S. ice-coring community. [See related article: Deep core complete.] Researchers had expected to recover ice as old as 100,000 years, but preliminary indications from the ice-core processing line (CPL) at NICL are that it is maybe 60,000 years old at the bottom.



Satellite view of the WAIS Divide field camp on Oct. 7, 2010, as acquired by the DigitalGlobe constellation of high-resolution satellites. Photo Credit: Polar Geospatial Center

"We're trading off the amount of time covered by the record for a record with more detail. To some extent, it's disappointing that we're not going to get the last interglacial period," Brook said, referring to a warmer time more than 100,000 years ago between ice ages, though it was unlikely the record would have gone back that far in time. The present time, called the Holocene, is also an interglacial period.

The WAIS Divide project drill is housed under a metal arch. Photo Credit: Jay Johnson

"Instead, we're going to get a lot more information about younger times. It's actually a good fit for what's needed to understand Antarctic climate. It's going to be a more unique record than if it was longer," he said.

Ice cores packed and ready for shipment from the field camp by the 109th New York Air National Guard to McMurdo Station. Each pallet holds 128 ice cores. Photo Credit: Mark Twickler

Constraining CO2

Topping the science goals is the reconstruction of carbon dioxide concentrations in the atmosphere over the timeline represented by the WAIS Divide core at a resolution never before achieved.

CO2 is one of the primary greenhouse gases that most researchers believe is causing the planet to warm and the climate to change. They are particularly interested in determining whether natural increases and decreases in CO2 in the past preceded or followed temperature changes. That would help scientists better understand the relationship between temperature and CO2 today.

Other ice cores have shown that CO2 lags temperature, but there is uncertainty about the timing because the age of the ice is different from the age of the trapped gases, sometimes on

— continued on page 5

Getting to the Bottom

— *continued from page 4*

Logan Mitchell, from Oregon State University, saws a section of an ice core destined for gas measurements. The WAIS Divide researchers are particularly interested in measuring past concentrations of greenhouse gases like carbon dioxide and methane in the atmosphere. Photo Credit: Peter Rejcek

the scale of centuries or millennia. The WAIS Divide core should be able to constrain much of that uncertainty because the annual layering offers such a highly detailed view of the past.

"I feel very confident saying this is really the best place on the planet to figure how greenhouse gases influence the climate on the timescale of the last 50,000 years or so," said Taylor, a research professor at the Desert Research Institute in Nevada.

Processing ice

But first, all of the ice has to pass through NICL, a facility managed by the U.S. Geological Survey and funded by the National Science Foundation (NSF), which also supported the WAIS Divide project.

NICL staff and scientists (many of them students) from the labs collaborating on the WAIS Divide project spent most of the summer processing more than 1,300 meters of ice. A team processed a similar amount of ice from WAIS Divide last year as well. [See related article: On the line.]

The Antarctic ice had been flown from the field camp in West Antarctica by military cargo plane to McMurdo Station, and then shipped to Port Hueneme, Calif. It was eventually trucked to Lakewood, Colo., where the NICL ice core warehouse and facility are located on the sprawling Denver Federal Center campus.

The CPL seems more like lumberyard than laboratory. Technicians and scientists operate various saws to carve out sections of ice for different sorts of analyses. For example, long sticks of ice will be melted for different chemical measurements covering 70 percent of the elements in the periodic table.

The chemistry can reveal information about past conditions such as sea ice extent, the amount of dust in the atmosphere and even seasonal changes, which reveals clues to the environmental conditions of the time.

Results are still months, if not years, away for some of the project's biggest science goals, according to Taylor.

"The ice that we're cutting today won't be sampled by labs for a year, two years. We have so much ice right now," said Taylor.

Drilling deeper

And there's still more ice to come.

Researchers plan to return to West Antarctica in 2011-12 to extract up to 100 more meters of cores. They will stop 50 meters away from the bottom of the ice where they expect there is a thin layer of meltwater on top of rock. The 50 meters of ice they leave behind will prevent contamination of the pristine water.

However, ice that deep starts to do strange things. In the last couple of hundred meters, the team started to detect irregular flow patterns in the ice, which make the record a bit fuzzy.

"At some point as you approach the bed, every ice core will start to show disruption in the stratigraphy. It can't be helped, because the drag is so significant at the bed, whether it's frozen to the bed or not," explained Joan Fitzpatrick, a scientist at the USGS who works on the physical properties of the core, down to individual ice grains.

A few weeks before the final core was processed, the CPL team noticed some irregular flow in sections of the core as it passed below 3,000 meters, including dramatic slopes in visible ash layers, likely from ancient volcanic eruptions.

To further investigate the severity of the irregularities, Fitzpatrick cut thin sections of the core to analyze the individual grains to see if their orientations have changed. The illumination system she uses makes the thin sections look like colorful kaleidoscope images.

— *continued on page 6*

Getting to the Bottom

— *continued from page 5*

The WAIS Divide ice core boxes occupy this entire side of the aisle in the NICL freezer. Photo Credit: Peter Rejcek

USGS scientist Joan Fitzpatrick looks at a thin section of ice core, analyzing the pattern of individual ice crystals. Photo Credit: Peter Rejcek

An ash layer at about 2,822 meters shows some streaking patterns. Photo Credit: Peter Neff

An ice core sample melts under vacuum to release the ancient air bubbles for isotopic analysis at a lab. Photo Credit: Anais Orsi

If the grains are in a different orientation, Fitzpatrick said, then "you know you have some significant stratigraphic disruption going on and all bets are off."

However, more recent discussions among the team following the CPL and after examining the evidence has encouraged the researchers that going deeper would be worthwhile.

Replicating data

A new type of instrument called a replicate coring drill is being created by the engineers at the Ice Drilling Design and Operations (IDDO) group at the University of Wisconsin-Madison. The smaller drill will fit into the original borehole and core into the side, retrieving additional ice for analysis from layers of particular interest.

Researchers are especially keen to examine abrupt climate changes in the past, especially the transition from the last ice age to the current warm period. The gas measurements by Brook and others often require large volumes of ice, so additional samples at different depths will be very useful.

"We are collecting quite a bit more gas samples than previous ice core projects, and the reason for that is that we've learned there's a lot of information to be obtained from gases at this high resolution," Brook said.

The gas record is so important, particularly the CO_2 data, that the team cutting ice for those measurements purposefully avoids sections of the core that show high dust concentrations. Dust in the core can interact with acids in the ice and release CO_2 in situ, skewing the data. That's why cores from Greenland, which is surrounded by land in the Northern Hemisphere, aren't as a reliable source for past carbon dioxide concentrations in the atmosphere.

That's another reason for the high hopes surrounding the WAIS Divide ice core.

"We are going to get a record of greenhouse gases that extends back 40,000 years, with the highest possible time resolution. The record will be used to test and improve the computer models that are used to determine the extent that human activity is influencing climate. It is great to be part of this team," Taylor said.

For a complete list of all NSF-funded projects related to WAIS Divide, see the WAIS Divide webpage of funded projects.

The Antarctic Sun
"News about the USAP, the Ice, and the People"

Replicate Ice Coring System

By Joe Souney, Ice Drilling Program Office, U.S. Ice Drilling Program

What is replicate coring?

Replicate coring is the act of deviating out of an existing borehole to collect additional ice samples from depth intervals of particular interest.

Why is replicate coring important?

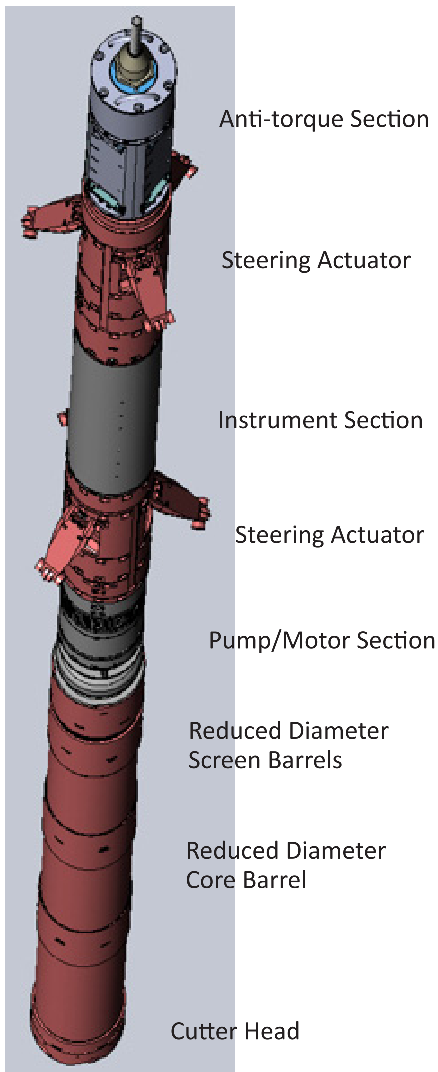
Replication of results is fundamental to science, and the ability to obtain additional ice samples from "intervals of scientific interest" will aid in the replication and verification of key results from ice core science. In addition, within a given ice core, scientific demand for ice samples is very unevenly distributed, with the ice core archive being completely depleted in depth intervals of high scientific interest. Replicate coring allows scientists to obtain additional ice samples from intervals of high scientific interest without needing to re-locate the drill to bore another hole.

How does it work?

The Replicate Ice Coring System collects additional ice at depths of interest by deploying into an existing borehole and then deviating from it. The drill uses two steering actuator sections to tilt itself in the parent borehole by applying sidewards force against the borehole wall. The sidewards force causes the drill to preferentially "cut" into the "up hill" side of the borehole wall with a broaching head. The process of preferentially broaching the "up hill" side of the borehole wall is repeated until a separate borehole is created. The broaching head is then replaced with a coring head, the actuators tilt and guide the drill into the replicate borehole, and additional ice samples are collected via traditional ice coring.

When will it be available for use by the community?

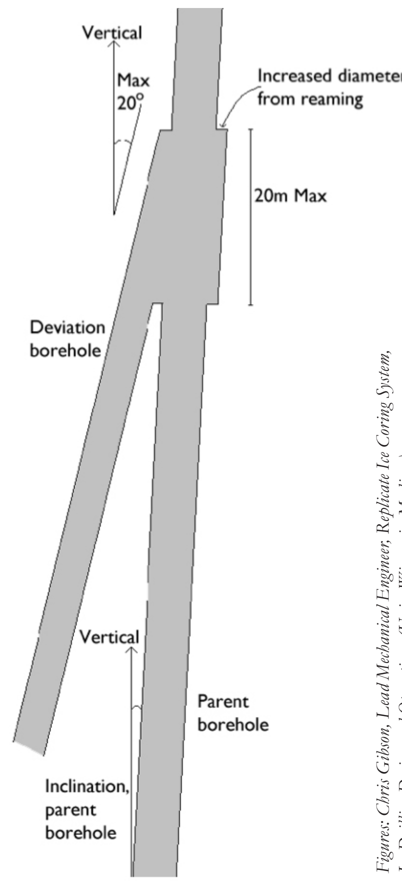
The Replicate Ice Coring System will be field-tested at the West Antarctic Ice Sheet (WAIS) Divide deep ice coring site in Antarctica in January 2012. Production drilling with the system is planned for the 2012-2013 Antarctic field season at WAIS Divide.



What level of field logistics are needed to use the equipment?

The Replicate Ice Coring System is designed to be used with the Deep Ice Sheet Coring (DISC) Drill and thus requires substantial logistics and infrastructure support. However, the design and engineering behind the system is such that it can be scaled down for use with smaller, more agile drilling systems as well.

For more information about the Replicate Ice Coring System, as well as other ice drilling equipment available to the U.S. ice science community, visit:
http://icedrill.org/equipment/index.shtml



Figures: Chris Gibson, Lead Mechanical Engineer, Replicate Ice Coring System, Ice Drilling Design and Operations (Univ. Wisconsin-Madison)

The U.S. Ice Drilling Program maintains and operates existing ice drilling equipment and develops new systems with two principal foci:

1. to provide high quality ice cores, and
2. to produce boreholes that provide access to the interior and beds of ice sheets and glaciers for such purposes as embedding instruments, collecting gas samples, setting seismic charges, studying subglacial processes, and studying subglacial geology.

www.icedrill.org

U.S. Ice Drilling Program
Ice Drilling Program Office | Ice Drilling Design and Operations

NICL Use and Ice Core Access

The U.S. National Ice Core Laboratory (NICL) houses approximately 17,000 meters of ice cores recovered from Greenland and Antarctica that are available for study. Investigators funded by the National Science Foundation (NSF) may access the facility's resources. However, investigators must contact the NICL-Science Management Office (NICL-SMO) Scientific Coordinator, Mark Twickler, before submitting a proposal to NSF and must include details of expected usage of the NICL facility in the proposal.

You must contact the NICL-SMO Scientific Coordinator at least three weeks before you submit your proposal if you:

(a) plan on requesting samples from an ice core stored at NICL; and/or

(b) plan on collecting a new ice core and would like to store it (even just temporarily) at NICL; and/or

(c) would like to use the NICL facility for a core processing line or for other labwork.

The NICL-SMO will coordinate your request and, if approved, provide a letter of support, which must be included as Supplemental Information with your NSF proposal.

Please visit the following web site for more information:
http://nicl-smo.unh.edu/nicl/access.shtml

National Science Foundation Projects Related to Ice Cores or Ice Core Data

The table below shows projects related to ice core research that have been funded by the National Science Foundation (NSF) since the last issue of *In-Depth* was published. To learn more about any of the projects listed below, go to the NSF Award Search page (http://www.nsf.gov/awardsearch/) and type in the NSF Award Number. If you have a newly-funded NSF project that was omitted from this listing, please let us know and we will add it to the next issue of *In-Depth*.

Title of the Funded Project	Investigator	Award Number
Collaborative Research: Ice Core Studies Reconstructing Greenland Climate During the Eemian and Beyond	Aciego, Sarah Bender, Michael Brook, Ed	1107369 1107343 1107744
Collaborative Research: P2C2--ICE age Chemistry And Proxies (ICECAP) Phase 2	Alexander, Becky Mickley, Loretta	1103163 1102880
Collaborative Research: P2C2--Synchronizing the North American Varve Chronology and the Greenland Ice Core Record Using Meteoric 10Be Flux	Balco, Gregory Bierman, Paul Ridge, John Rood, Dylan	1103037 1103381 1103399 1103532
Collaborative Research: Response of the Northwest Greenland cryosphere to Holocene climate change	Axford, Yarrow Birkel, Sean Osterberg, Erich	1108306 1107421 1107411
FESD Type 1: Sun to Ice--Impacts on Earth of Extreme Solar Events	Spence, Harlan	1135432
Investigating links between atmospheric chemistry and climate using oxygen isotope measurements of sulfate and nitrate from Greenland ice cores	Alexander, Becky	1106317
Roosevelt Island Climate Evolution Project (RICE): US Deep Ice Core Glaciochemistry Contribution (2011- 2014)	Mayewski, Paul	1042883
The Chemistry and Sources of Carbon Monoxide in Present and Past Atmospheres	Mak, John	1136302

This material is based upon work supported by the National Science Foundation under Award Number ANT-0635515. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.