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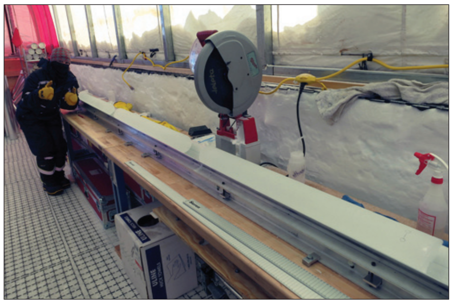
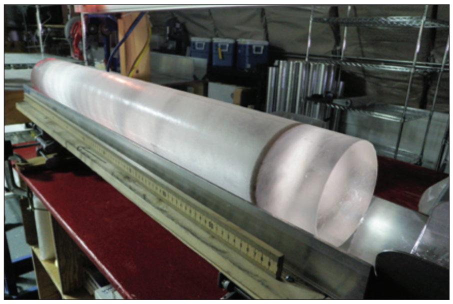
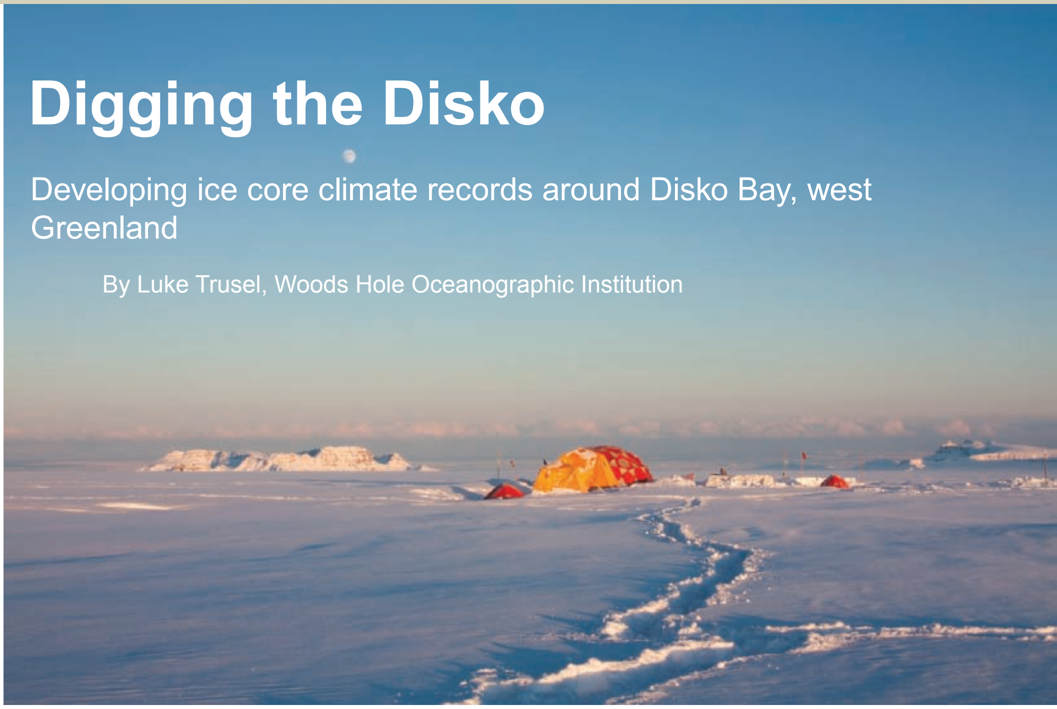




Digging the Disko

Developing ice core climate records around Disko Bay, west Greenland

By Luke Trusel, Woods Hole Oceanographic Institution



Field site on the Disko Island ice cap of west Greenland. Below the clouds in the distance, a sea-ice and ice berg covered Disko Bay can be seen. Reconstructing the past variability of this marine ice coverage is a central goal researchers from this WHOI-led project seek to address. –Credit: Luke Trusel

GREENLAND IS MELTING. Over recent decades, this melt has accelerated and so have contributions from the Greenland Ice Sheet to global sea level. These mass losses are linked to warming both in the atmosphere and ocean. *But just what are the connections between the ice sheet, the ocean, and the atmosphere; how have these evolved over time and space; and what happened before we had detailed satellite observations of changes across this region of the Arctic?* These are all central questions our team of researchers from Woods Hole Oceanographic Institution (WHOI), Clark University, Wheaton College (MA), and the University of Washington is actively seeking to constrain.

To begin to address these questions, fieldwork was just completed in Spring 2015 at several coastal locations in central west Greenland. To specifically focus on coastal climate and oceanic links to the Greenland Ice Sheet, three field sites were strategically identified: ice caps on Disko Island and Nuussuaq Peninsula (both located just west of the Greenland Ice Sheet), and a third location inland of these sites on the Greenland Ice Sheet proper. Drilling of firn and ice cores was undertaken by a team led by Sarah Das (Associate Scientist, WHOI), who was accompanied by myself, Luke Trusel (Postdoctoral Scholar, WHOI), as well as Matt Osman (Ph.D. Student, MIT-WHOI Joint Program) and expert driller, Mike Waszkiewicz (Ice Drilling Design and Operations; IDDO).

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Digging the Disko

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The 2015 field team next to their drilling tent atop an ice cap on Nuussuaq Peninsula. Left to right: Mike Waszkiewicz, Sarah Das, Matt Osman, and Luke Trusel. –Credit: Inge Fast

Firn and ice cores with target depths of around 100 meters were collected from all three sites, each of which presented unique logistical challenges. The inherently unpredictable weather of the remote field sites was a primary constraint on our fieldwork, and access to the sites was also governed by the suitability and availability of aircraft and helicopters. For instance, the small and highly crevassed Nuussuaq Peninsula ice cap site was only accessible by helicopter, whereas the inland distance of the ice sheet site required Twin Otter (a reliable ski-equipped aircraft) flights of about an hour and a half for field put in and pull out. Getting the weather to align with flight and fieldwork plans is a constant challenge working in these environments! After establishing field camps at each site, our team used IDDO's Eclipse Drill and recovered cores in about 1 meter sections. The use of a drilling tent proved to be extremely valuable, as we were able to drill in weather conditions otherwise unsuitable, therefore enabling the completion of all fieldwork roughly according to plan – not a small task!

After successful drilling at each site, the collected ice cores were then flown from the ice to the town of Kangerlussuaq, where they were kept cold in a freezer container. From Kangerlussuaq they are being promptly shipped to the National Ice Core Laboratory (NICL) for a core processing line (CPL) to commence in mid-June 2015. During the NICL CPL, we will create a digital archive of the ice cores using a digital line scanning system, record electrical conductivity profiles, and finally subsection the cores into discrete samples via precision sawing. From here, the samples will be shipped to the project's host institutions for further glaciochemical analyses.

After the fieldwork and NICL CPL, our team's science objectives begin in earnest. At the heart of these objectives is the critical and increasingly recognized influence of conditions at oceanic margins of ice sheets in governing ice sheet processes and overall health. Indeed, these marine impacts include effects on glacier advance and retreat, ice flow velocities, accumulation rates, and melt rates both at the ice sheet-ocean interface and across the ice sheet surface. Many of these processes are well documented today owing to satellite observations and climate models that can be driven by datasets incorporating observations. As we move back in time prior to the modern satellite era (that begins ~1978), however, this understanding is more poorly constrained. This increased uncertainty surrounds both our understanding of the state of the ice sheets and the surrounding oceans, and also the interactions between these important components of the cryosphere and climate systems.

Drilling ice cores such as those collected by our WHOI-led team can help address these uncertainties. To this end, researchers in this project will analyze the chemistry of the ice cores to determine ice dating (using parameters that vary seasonally, such as stable isotopes; as well as those varying more sporadically, such as known volcanic events). These analyses will allow us to reconstruct accumulation rate histories and develop additional proxies of past climate. As the ice cores were all obtained from locations of relatively high snow accumulation rates, proxy records with high temporal resolution (seasonally- to annually-resolved) will result, and these 100+ meter records are anticipated to span at least the last couple of centuries, including notably into the end of the Little Ice Age.

Of particular focus will be the analysis of isotopic and glaciochemical species that can be correlated with sea ice and sea surface temperature (SST) variability. For example methane sulfonic acid (or MSA) concentrations in ice result from a chain of events spanning back to photosynthesis via primary production at the nearby ocean surface. This primary productivity is in turn linked to the presence or absence of sea ice, and thus by measuring MSA in ice cores, regionally or locally specific proxies of past sea ice variability can be developed. Similarly, sea salts (e.g. Na and Cl) are concentrated on

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Cold and SPICE-y

By Mindy Nicewonger, University of California Irvine

Mindy Nicewonger at the core processing station inside the drill tent at South Pole. The drill recovers ice cores approximately 2-meters in length. The 2-meter long sections of core are then cut into 1-meter long sections so that they fit into the standard-sized insulated shipping container boxes used by the US ice-coring community to transport ice cores. A dry-cut circular saw is used to make the cuts. –Credit: Murat Aydin

THINKING BACK TO THE DAILY LIFE AT SOUTH POLE sometimes feels like a dream. However, the hundreds of pictures I took and the 500+ meters of ice core sitting in the archive freezer at the National Ice Core Laboratory prove that it really happened. For three months, I lived and worked at the South Pole as part of the science team for the new South Pole Ice (SPICE) Core.

A collaborative effort of the University of California Irvine (Murat Aydin), the University of Washington (Eric Steig), and the University of New Hampshire (Mark Twicker and Joe Souney) – with assistance from NASA GSFC (Tom Neumann) – the SPICE Core will reach a depth of 1,500 meters and provide a history of atmospheric trace gases, stable isotopes, aerosols, and other climate records for the past 40,000 years. The SPICE Core will be the first deep ice core drilled at the South Pole and will span the last interglacial period and allow for further investigation into the abrupt climate changes that have occurred in the past (see Peter Rejcek's *Going deep* story on page 8 for more information).

When the ten of us comprising the SPICE Core team arrived at the South Pole in mid-November 2014, the SPICE Core drill camp was just a dot on a map and an area where several cargo boxes had been deposited. Within about three weeks, the drill trench had been excavated, the drill tent constructed and the new intermediate depth drill was in place ready to drill into the ice sheet. Specially designed by the Ice Drilling Design and Operations (IDDO) group at the University of Wisconsin-Madison, the intermediate depth drill can recover a two-meter long, 98-mm diameter, ice core during a single drill run. On December 8th, a little less than a month after arriving at the South Pole, the 10-person SPICE Core team celebrated the first run of the drill and a successful recovery of the first two meters of the SPICE Core. For the remainder of the field season, drilling took place 20 hours a day and 6 days a week. The season goal of 700 meters was surpassed and drilling finished for the 2014-2015 season at a depth of 736 meters.

Daily life at the South Pole was much different than my typical life in Southern California. The warmest day during the field season occurred around late December when ambient temperatures peaked around -25°C. Fortunately, the drill tent had an insulating effect and kept the drill trench near -20°C for most of the season. Some days, weather systems would move in and we'd experience winds up to 20 knots and wind chills in the -50°C range. In addition to the cold, the South Pole packs another punch: 10,000 feet elevation. Although the physical elevation of the Pole is closer to 9,000 feet, the thin atmosphere at the Pole leads to a physiological elevation that is higher. Simple daily activities at the drill site such as packing ice core boxes or climbing stairs were quite an exertion.

The harsh climate at Pole was also hard on the drill. The bitterly cold ice (-50°C) tore up the cutter heads which required replacement by the skilled machinists at the station on what seemed like a weekly

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Cold and SPICE-y

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Mindy Nicewonger standing next to insulated shipping container (ISC) boxes filled with 1-meter long sections of ice cores. Each ISC box contains five 1-meter long sections of ice core. The ice cores are 98 mm (3.86 inches) in diameter. –Credit: Murat Aydin

basis. The dry air also was not very kind to electronics and circuit boards. Can you say static electricity? In the end, the first season of the SPICE Core drilling was a remarkable feat. To start from scratch and surpass the season goal despite a few setbacks took a great deal of effort from all involved.

Roughly 550 meters of the upper portion of the SPICE Core were shipped back to the National Ice Core Laboratory (NICL) in Denver, Colorado for processing. Annual layer counting and electrical conductivity measurements of peaks in acidity corresponding with volcanic events will aid in developing a reliable chronology. Although drilling of the ice core will likely conclude during the 2015-2016 season, the analysis and interpretation of the SPICE Core will continue on for many years.

One of the main motivations for drilling the SPICE Core was to acquire an ice core that is suitable for trace gas research – the research we conduct at the Saltzman/Aydin Research Group at UC Irvine. The goal of our research is to use trace gases found in ice core air bubbles as tracers for biogeochemical cycles. The trace gases we extract from ice core bubbles are typically in concentrations of parts per trillion (one part gas per one trillion parts air). Gases such as carbonyl sulfide (OCS) and ethane (C_2H_6) have relatively simple pre-industrial atmospheric budgets. Therefore, an ice core record of these gases can inform us about the variability in the sources or sinks of these gases in the past. Ultimately, these gases aid in developing proxy records for various natural processes, such as primary productivity

Mindy Nicewonger saws a section of an ice core that will be analyzed for its ancient trapped gases, such as carbonyl sulfide and ethane, during a core processing line at NICL. –Credit: Mindy Nicewonger

or biomass burning. The SPICE Core is a very cold site with mean annual temperatures of -50°C. This temperature is very similar to the temperature of the ice down to 1,500 meters. The cold temperature of the SPICE Core makes it an exceptional site for the preservation of trace gases in the ice core air bubbles.

This research is supported by the National Science Foundation Graduate Fellowship Program (DGE-1321846) and Division of Polar Programs (awards 1142517, 1443470). Further information about the SPICE Core project is available on the web at http://spicecore.org and in Peter Rejcek's 'Going deep' story on page 8 of this newsletter.

Upcoming Meetings

26th Union of Geodesy and Geophysics (IUGG) General Assembly
22 June - 2 July 2015
Prague, Czech Republic
http://www.iugg2015prague.com/

SCAR: XII International Symposium on Antarctic Earth Sciences
13-17 July 2015
Goa, India
http://www.isaes2015goa.in/

2015 PIRE/ICEICS Workshop
9-11 September 2015
Saint-Martin d'Heres, France
http://iceics.science.oregonstate.edu/content/events

WAIS Workshop
16-19 September 2015
Loveland, Colorado, USA
http://www.waisworkshop.org/

WAIS Divide Ice Core & South Pole Ice Core Science Meetings
22-23 September 2015
La Jolla, California, USA
http://waisdivide.unh.edu/meetings/index.shtml

2015 AGU Fall Meeting
14-18 December 2015
San Francisco, California, USA
http://fallmeeting.agu.org/2015/

IPICS 2nd Open Science Conference
7-11 March 2016
Hobart, Australia
http://www.ipics2016.org/

Digging the Disko

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An Air Greenland helicopter lifting a load ice core boxes on Nuussuaq Peninsula. Assisting the operation on the ground is IDDO driller and fearless sling-loader, Mike Waszkiewicz. –Credit: Luke Trusel

the surface of newly formed sea ice, and sea salt aerosols can thus be linked to periods of sea ice formation. To fully understand the ice core chemical records at each site, our group will examine the variability of the ice core-derived variables back in time in unison with satellite-observed sea ice and SST dynamics. After establishing the nature of these relationships over space and time, important records of past sea surface variability that predate the satellite era will be developed using only the novel ice core records. This will allow us to uniquely situate the detailed satellite record of recent Disko Bay and Davis Strait sea surface changes into a longer-term context.

An additional detailed record of past climate to be developed will be derived from the analysis of refrozen melt layers in the cores. The amount of melting each summer at the ice sheet surface is linked quite simply to the relative warmth of each summer: warmer summers produce more melt, colder summers produce little or no melt. At the coastal west Greenland sites of this project (all located within the glacier percolation zone) surface melt drains into the near-surface firn and then refreezes. By analyzing the amount of refrozen melt archived in the ice core using instruments such as the NICL imaging system, we can reconstruct a history of melt back in time. Combined with existing datasets and the glaciochemically-derived sea surface variability records, the melt history will provide important insights into the coupling between the ice sheet, the ocean surface, and the climate system over the last several hundred years. Furthermore, the dramatic acceleration of melt observed with satellites over the last several decades will be framed within a centennial-scale perspective.

This research is supported by the National Science Foundation Arctic System Science Program (awards 1205196, 1205008, 1205018, and 1205062). Further information about the project, fieldwork, and ongoing research can be found on the group's blog at Milton Academy (http://www.miltonacademy.info/science/).

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NSF Press Release 15-048

Antarctic ice core reveals how sudden climate changes in North Atlantic moved south

Analysis indicates that northern temperature changes led corresponding southern patterns by 200 years

An ice core from the West Antarctic Ice Sheet Divide project. The dark band is a layer of volcanic ash that settled on the ice sheet approximately 21,000 years ago. –Credit: Heidi Roop, NSF

April 29, 2015

A NEW, HIGHLY DETAILED ICE CORE retrieved by researchers with the National Science Foundation (NSF)-funded West Antarctic Ice Sheet (WAIS) Divide project reveals a consistent pattern of climate changes that started in the Arctic and spread across the globe to the Antarctic during planet Earth's last glacial period, tens of thousands of years ago.

Representing more than 68,000 years of climate history, data extracted from the core--a cylinder of ice that represents a cross-section of the ice sheet--is helping scientists understand past, rapid climate fluctuations between warm and cool periods that are known as Dansgaard-Oeschger events.

Published today in the journal *Nature*, the new research illustrates how sudden climate changes that began in the North Atlantic around Greenland circulated southward, appearing in the Antarctic approximately 200 years later. Further, the new findings show how ocean currents were largely responsible for redistributing the heat between the Northern and Southern hemispheres in a process called the bipolar seesaw.

The ice containing the data is known as the WAIS Divide ice core. The cylinders that make up this core contain uniquely detailed information on past environmental conditions such as the atmospheric concentration of greenhouse gases, surface air temperature, wind patterns, and the average temperature of the ocean.

"Our findings show how ocean currents can transmit climate changes that start in the Arctic across the globe all the way to the Antarctic," said Kendrick Taylor of the Desert Research Institute (DRI) in Nevada and chief scientist for the WAIS Divide project, who in addition to leading the project spent five seasons in Antarctica collecting the core and helped determine the age of the ice.

"Knowing how ocean currents influenced past climates will help us predict how the current human-caused variations in climate could propagate across our planet," he added.

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Antarctic ice core reveals how sudden climate changes in North Atlantic moved south

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The WAIS Divide Project is a major ice-coring and climate investigation, encompassing numerous collaborative awards to investigators at many institutions nationwide, supported by the Division of Polar Programs in NSF's Geosciences Directorate. The Division manages the U.S. Antarctic Program, through which it coordinates all U.S. scientific research on the southernmost continent and in the surrounding oceans, and provides the logistical support that makes the research possible.

A team of researchers based at the DRI and led by Joe McConnell, used their unique ice-core analytical system to measure impurities associated with sea salts and desert dust in more than two kilometers (1.6 miles) of the WAIS Divide ice core in support of this research.

Many of the methane measurements used in this study were measured by Oregon State University researchers also working in DRI's ice-core laboratory in Reno. The past temperatures were determined by measuring the isotopes of the melted ice at the University of Washington.

The Dansgaard-Oeschger events reference the name given to warm periods in Greenland that lasted a few thousand years. The transition into and out of these warm periods occurred in less than 20 years, much faster than anything experienced in the last 10,000 years. Temperature changes in Antarctica followed an opposite pattern, with Antarctica cooling when Greenland was warm, and vice versa.

"These past climate changes are different from what is happening today," said the study's lead author Christo Buizert, a postdoctoral researcher at Oregon State University.

"The abrupt climate changes during the ice age were regional in scope and caused by large-scale changes in ocean circulation. The changes in temperature and precipitation that are occurring now are global and primarily caused by increasing levels of carbon dioxide in the Earth's atmosphere."

However, Buizert explained, these new observations can be used to test and improve the global climate models that are used to predict future warming.

The research team, consisting of 28 science and engineering groups from around the United States, considered sites all over Antarctica before selecting the WAIS Divide site with the best combination of thick ice--3,405 meters (11,200 feet), simple ice flow and the optimal amount of annual snowfall: roughly ~40 centimeters (1.5 feet).

Previously drilled ice core records from Greenland had provided the detailed history of Arctic temperature change. The new WAIS Divide core data provides the Antarctic record required to make a detailed comparison.

The 12.2-centimeter (4.8-inch) diameter cylinders of ice that make up the 3405-meter (11,200 foot) long ice core were recovered at a field camp in the center of West Antarctica, 1040 kilometers (650 miles) from the geographic South Pole.

Researchers determined the relative timing of past, sudden climate changes between the Arctic and Antarctic using variations in the atmospheric concentration of methane, water isotopes, and sea salt concentrations in the Greenland and Antarctic ice cores.

An engineering team from the University of Wisconsin-Madison designed the ice coring drill and recovered the ice core. DRI, along with the University of New Hampshire, coordinated the science, drilling and logistics activities. The National Ice Core Laboratory in Colorado led the sampling and archiving of the ice core.
-NSF-

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Related Websites
This series of NSf-produced videos provides a look at the history of the West Antarctic Ice Sheet, the life a scientist leads while on the ice, and the results from the data obtained by scientists studying the WAIS Divide.: https://www.youtube.com/playlist?list=PL0ujJTaPsv3cYFqpPc-eF4NMwHIIZLs-1

Going deep

Drilling project to retrieve longest ice core ever from South Pole

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

Lead driller Tanner Kuhl guides the Intermediate Depth Drill into position to start ice-coring operations. –Credit: Murat Aydin

THE SOUTH POLE IS A VERY COLD PLACE, with an average annual temperature of around minus 50 degrees Celsius. It's become a premiere location for a variety of atmospheric and astrophysical experiments thanks to its cold, clean, stable atmosphere.

Even the ice is especially cold at the bottom of the world – and that's also a good thing for a team of researchers interested in extracting the first deep ice core at the South Pole.

"Ice cores are a great way to look into the past," said T.J. Fudge, a postdoctoral researcher at the University of Washington who was the on-site science lead for the last few weeks of drilling operations during the 2014-15 summer season.

Working in two shifts around-the-clock – and in a large unheated tent at an ambient temperature of about minus 25C – the group reached a depth of 736 meters below the surface on Saturday, Jan. 24, before shutting down operations until next year. That's almost halfway to the goal of 1,500 meters – a depth estimated to cover about 40,000 years of climate history.

The National Science Foundation's Division of Polar Programs is funding the project, called SPICE, for South Pole Ice Core.

An ice core is something of a time capsule. Akin to tree rings, which develop annual layers that record different environmental conditions during the year they grew, ice cores also capture clues about Earth's past climate.

In the case of ice cores, however, the timeline is vertical, with the years and centuries rolling back into the past with depth. Scientists can analyze bubbles of various gases trapped in the ice to get a sample of the ancient atmosphere. Dust and chemicals found in the ice can also provide details about past climate.

SPICE is targeting a timeline 40,000 years back into the past as part of an initiative called International Partnerships in Ice Core Sciences (IPICS), which seeks to create a network of ice cores over similar timescales spread across both Antarctica and Greenland.

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A close-up of an ice core still in the drill barrel. –Credit: Peter Rejcek

The target of 40,000 years represents the transition from the last ice age, known as a glacial, to the present warm period called an interglacial. A series of abrupt climate changes also occurred during that time.

"We want to be able to predict how the climate is going to change in the future," Fudge said. "One of the ways we can understand how our climate system works better is to look back in the past at these abrupt changes."

The very cold ice at the South Pole is particularly useful for capturing miniscule traces of rare gases in the atmosphere. Carbon dioxide, the most heavily studied gas due to its influence on climate, is measured in parts per million. Some of the gases researchers are interested in studying to understand past climate from the SPICE core are measured in parts per trillion.

The SPICE Core field camp is located only a couple of kilometers from the South Pole Station. –Credit: Peter Rejcek

"The very cold temperatures preserve a lot of trace gases," Fudge said.

The SPICE project follows on the heels of a nearly decade-long effort to recover an ice core from the West Antarctic Ice Sheet (WAIS) on the divide where the ice flows in different directions, sort of like the Continental Divide in the United States.

WAIS Divide project scientists and drillers extracted 3,405 meters of ice, the longest ever recovered by a U.S.-based project. Analysis of the ice is still ongoing, focusing on carbon dioxide and its role in abrupt climate change events.

The SPICE project is a much smaller operation, with two years scheduled for drilling the core itself. Located a couple of kilometers from Amundsen-Scott South Pole Station, the site was excavated and trenched to accommodate the drilling system, core processing and storage beginning in November before operations could commence.

The Ice Drill and Design Operations (IDDO) group at the University of Wisconsin-Madison designed and built the drilling system, called the Intermediate Depth Drill. Based on a Danish drill called the Hans-Taunsen drill, the Intermediate Depth Drill was purpose-built for coring 1,500 meters of ice, according to Tanner Kuhl, lead driller for SPICE and a mechanical engineer at IDDO.

"Logistically, this drill is easier to get to the field. It's substantially smaller than the DISC drill system," said Kuhl, referring to the ice-core drilling system at WAIS Divide that required a large, metal arch building to house all the equipment and instruments.

The drill returns to the surface after retrieving an ice core. –Credit: Peter Rejcek

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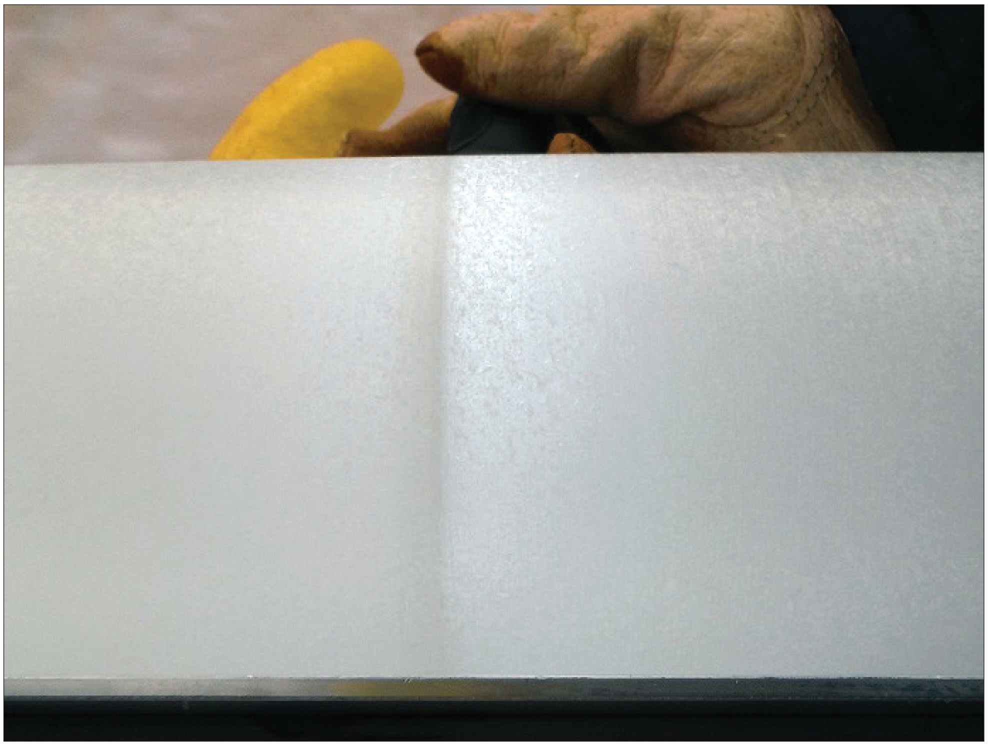

The first visible volcanic ash layer in the SPICE ice core. –Credit: Mindy Nicewonger

The DISC (Deep Ice Sheet Coring) drill is capable of pulling out 3 ½ meters of ice at a time from depths up to 4,000 meters, with a diameter of 122 millimeters. The Intermediate Depth Drill can core two meters at a time with a smaller diameter of 98 millimeters. It was first tested last year in Greenland, recovering about 285 meters of ice in about two weeks of drilling.

The team is finding that the colder ice at the South Pole is also harder and slower to drill through than warmer locations, Kuhl noted. The drill head cutters are quicker to dull or even break, he said.

"Cutting of the ice is an extremely slow process to get good core quality, which is primarily what we're after," he added. It takes between 15 and 20 minutes to cut one two-meter-long core at a rate of about two millimeters per second.

The cold ice, of course, also makes it physically hard to handle for the drillers and scientists.

Mindy Nicewonger, a doctoral student at the University of California, Irvine, handles each core only minutes after emerging from the borehole. Her job involves inspecting and measuring each core before it's packaged for shipment back to the United States, a 14,000-kilomter-plus-long journey that involves planes, ships and refrigerated trucks.

A tractor moves two boxes of ice cores to be loaded onto an LC-130 for transport to McMurdo Station. –Credit: Peter Rejcek

She notes any cracks or other imperfections during each inspection that might affect later analyses. A break that freezes, for example, might trap modern air, confusing measurements of the ancient atmospheric record.

"If you have a lot of breaks, then you're actually losing the gas inside the core," she explained.

Sometimes interesting features show up in the ice as well, such as a visible ash layer found at 306 meters that had been seen in previous, shallower cores in the 1980s. The ash comes from a volcanic event dated to 3,200 years ago in the South Sandwich Islands off the Antarctic Peninsula.

Nicewonger is particularly invested in good core quality, as part of her research focuses on the analysis of trace gases from SPICE. Her work can tease out details about biomass burning – large wildfires in the tropics, for example – and how that changed naturally through time.

Reaching the end of the first season's goal of 700 meters is only the beginning for her work and others.

"We work long hours. It's really exciting," she said. "I know this core is going to provide some awesome science for people like myself and other young students and scientists across the world."

NSF-funded research in this article: Murat Aydin, University of California-Irvine, Award No. 1142517. Eric Steig, University of Washington, Award No. 1141839. Mark Twickler and Joe Souney, University of New Hampshire, Award No. 1142646.

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
Carbonyl Sulfide, Methyl Chloride, and Methyl Bromide Measurements in the New Intermediate-depth South Pole Ice Core	Aydin, Murat	1443470
Collaborative Research: Record of the Triple-oxygen Isotope and Hydrogen Isotope Composition of Ice from an Ice Core at South Pole	Steig, Eric White, Jim	1443105 1443328
Collaborative Research: South Pole Ice Core Chronology and Climate Records using Chemical and Microparticle Measurements	Osterberg, Erich Cole-Dai, Jihong Kreutz, Karl	1443336 1443663 1443397
Collaborative Research: Using Stable Isotopes to Constrain the Atmospheric Carbon Monoxide Budget over the Last 20,000 Years	Mak, John Petrenko, Vasilli	1443482 1443267
Controls on Variations in Atmospheric Carbon Dioxide and Nitrous Oxide During the Last 10,000 years	Brook, Ed	1443550
Geophysical Reconnaissance to Expand Ice Core Hydroclimate Reconstructions in the Northeast Pacific	Kreutz, Karl	1502783
Using Electrical Conductance Measurements to Develop the South Pole Ice Core Chronology	Waddington, Edwin	1443232

The U.S. National Ice Core Laboratory (NICL) is a facility for storing, curating, and studying meteoric ice cores recovered from the glaciated regions of the world. It provides scientists with the capability to conduct examinations and measurements on ice cores, and it preserves the integrity of these ice cores in a long-term repository for current and future investigations. NICL is funded by the National Science Foundation Division of Polar Programs and operated by the U.S. Geological Survey. Scientific management is provided by the University of New Hampshire.

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**
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Masthead photos courtesy of Lonnie Thompson and Michael Morrison