Collaborative Research: Climate, Ice Dynamics and Biology Using a Deep Ice Core from the West Antarctic Ice Sheet Ice Divide (I-477)
PI: Ken Taylor (Desert Research Institute) NSF-OPP supported
PI: Mark Twickler (University of New Hampshire) NSF-OPP supported

Collaborative Research: Replicate Coring at WAIS Divide to Obtain Additional Samples at Events of High Scientific Interest (I-476)
PI: Jeff Severinghaus (Scripps Institution of Oceanography) NSF-OPP supported
PI: Jihong Cole-Dai (South Dakota State University) NSF-OPP supported
PI: Ed Brook (Oregon State University) NSF-OPP supported

Field Team:
Don Voigt[1,6], Jeff Severinghaus[2,7], John Fegyveresi[1], Logan Mitchell[3], Gifford Wong[4] and Jakob Schwander[5]

[1] *Penn State University*
[2] *Scripps Institution of Oceanography*
[3] *Oregon State University*
[4] *Dartmouth College*
[5] *University of Bern, Switzerland*
[6] *2011-12 WAIS Divide Chief Scientist and SCO Representative*
[7] *WAIS Divide Borehole Deepening and Replicate Coring Chief Scientist*

Field Season Summary:
The put-in crew, led by Camp Manager Dean Einerson, made it to WAIS Divide (WSD) on 5-Nov after a 6 day (since 10/31) delay due to bad weather and equipment issues.

On 22-Nov, Don Voigt (I-477), Krissy Dahnert, Josh Goetz, Mike Jayred, and Elizabeth Morton (T-350) arrived at WSD. Inspection of the Arch revealed that the core processing side sustained very little, if any, damage or heaving during the winter. The drilling side, however, sustained considerable heaving of floor panels between the core transfer truss and the slot entry hatch. This is the same area that sustained substantial heaving last season. At the start of the 2010-11 season, a measurement from the side of the Arch to center-line at the slot entry hatch showed 11" of elevation increase. This season, the same measurement showed 19" total rise in elevation.

Phase 1: Borehole Logging
The borehole logging crew of V. Miller (I-161), Gary Clow (Chief Scientist for Borehole Logging), Frank Urban (I-168), Ed Waddington, Sridhar Anandakrishnan and Dan Kliskiewicz (I-162) arrived to WSD on 29-Nov, and Ryan Bay on 3-Dec with the lowering of the temperature probe. The initial round of logging, which was directed towards measuring the thickness of ice remaining in the borehole, consisted of two complete (I-122) and Leo Peters (I-161) arrived on 01-Dec. After installation of the logging winch, erection of the logging Weatherhaven, and testing of the borehole logging tools, borehole logging commenced temperature logs, two complete roundtrip optical logs, a sonic log to 2000 meters at which point communication to the tool was lost, and a seismic log with a sequence of seismic shots at 3000 m, 2500 m, and 2000m. A second round of logging was conducted consisting of temperature logging, sonic logging to 2000 m, and one additional seismic experiment at 2000 m.

Phase 2: Borehole Deepening
On 23-Dec, Jeff Severinghaus (Chief Scientist for Borehole Deepening), Jakob Schwander (I-476), Gifford Wong, Logan Mitchell (I-477) and John Fegyveresi (I-477 and I-168) arrived to WSD. Borehole deepening began on 26-Dec. Pressure logging (Severinghaus) was conducted and

completed successfully, allowing better fluid compensation of the borehole for stewardship purposes. Acoustic logging (Schwander) was also conducted in hopes of further defining the depth to the bed and hence the thickness of ice remaining. However, no further information on the depth of the bed was obtained by the acoustic logging. At 9:16AM on 31-Dec-2011, the final core was collected from the bottom of the borehole at the driller's (cable) depth of 3405 meters. This leaves ~50 m of ice under the bottom of the hole to act as a barrier between the basal water system and the drilling fluid.

As part of the borehole deepening activity, samples were collected from the bottommost cores for fugitive gases within minutes of the core being brought to the surface (Severinghaus).

The newly drilled ice was flown to MCM via an LC-130 cold-deck on 13-Jan (WSD off-deck at 0030 on 13-Jan, arriving to McMurdo at 0350).

Phase 3: Borehole Logging of Deepened Borehole
All three tools (temperature, optical and sonic) were used to log the additional ~75 meters of the main borehole and the logging was finished on Wednesday, 4-Jan.

Phase 4: Replicate Coring
Replicate coring methods were tested. The equipment operated as designed, but was not able to cut into the borehole wall enough to make a deviation. As expected with any new equipment and procedure, there were many technical issues to work through.

Supplementary Science: Quantifying the Spatial Variability of Chemical Deposition at the WAIS Divide Site
Gifford Wong, with assistance from Logan Mitchell and John Fegyveresi, extracted nine 5 m-long firn cores at WAIS Divide for the purpose of quantifying the local spatial variability of chemical concentrations in the snow and firn. The firn cores were collected along a 2000-m NE transect centered along 79.45022 S, 111.80365 W. In addition, a 1.5 m-deep snowpit (79.44931 S, 111.79823 W) was sampled for the purpose of isolating and identifying volcanic ash particles from the June 4, 2011 Puyehue-Cordón Caulle eruption in Chile (40°35'25" S latitude). The snowpit was sampled for density, major ions, water isotopes, particulates, trace elements, and microbial loading. Snowfall from specific storm events during the field season was also collected, and a 3-sided backlit snowpit excavated. For the backlit snowpit, detailed photographs of the walls were taken, the physical stratigraphy between adjacent walls was noted, and samples were collected for density based on grain size and stratigraphy. Samples were stored in a total of 6 ISC boxes, placed in a normal (not SAFECORE) freezer-milvan, and loaded onto the re-supply vessel for transport to Port Hueneme.

Other
There were no major injuries or stuck drills.

Elizabeth Morton and Michael Jayred tested the Eclipse drill this season. The resultant borehole is WDC12A and it is 121.5 meters deep. The position of WDC12A is 79^{o} 27.86' S, 112^{o} 06.69' W. The hole is cased for the top two meters, and the casing extends to 2 meters above the current snow surface. An additional 1.5 meters of casing is stored in the Arch for extension in the future.

Acknowledgements:
There was great support from RPSC, particularly the camp staff. Despite a particularly stormy season and heavy drifts, camp was maintained in outstanding condition throughout the season

due to the exceptional camp management skills of Dean Einerson. The staff from all of the organizations (RPSC, IDDO, and science) worked and played exceptionally well together.

***Fig 1**. Logan Mitchell, John Fegyveresi, Don Voigt, and Gifford Wong celebrate finishing the WAIS Divide borehole at 3,405 meters depth. Photo: Logan Mitchell.*

***Fig 2.** Jeff Severinghaus (Chief Scientist for Borehole Deepening and Replicate Coring), Krissy Dahnert (Lead Driller), and Don Voigt (WAIS Divide 2011-12 Chief Scientist) celebrate reaching 3,405 meters depth. Photo: Logan Mitchell.*

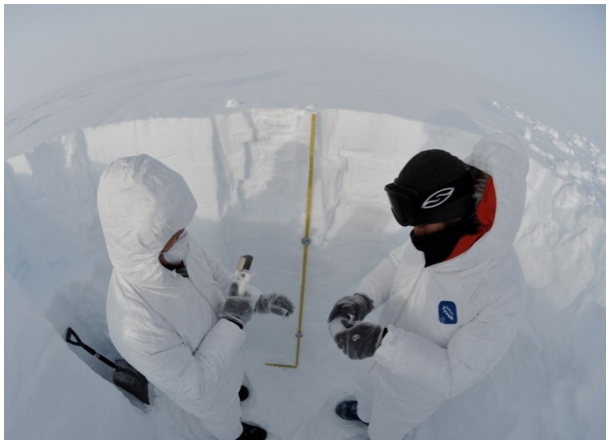


***Fig 3**. Gifford Wong and John Fegyveresi sample a snowpit for density, major ions, water isotopes, particulates, trace elements, and microbial loading. Photo: Logan Mitchell.*

Physical Properties of the WAIS Divide Deep Core (I-168-M)
PI: Richard Alley (Pennsylvania State University) NSF-OPP supported
PI: Kurt Cuffey (Univ. of California – Berkeley) NSF-OPP supported

Field Team: John Fegyveresi
Gary Clow[1], Frank Urban[1], Elizabeth Morton[2], and John Fegyveresi[3]
[1] *U.S. Geological Survey*
[2] *Ice Drilling Design and Operations*
[3] *Penn State University*

Season Objectives:
1. Our primary objective was to obtain a relatively undisturbed temperature profile through the West Antarctic Ice Sheet at WAIS Divide in support of a number of studies, including borehole paleothermometry, heat flow, and ice dynamics. The measurements are expected to provide a better understanding of the temperature history experienced by each section of the WAIS-D ice core.

2. To monitor the physical properties of the final 50-100 meters of the WDC06A core, document any obvious changes or deformation, record additional site information from observing snow pits and photographing surface evolution, deploy various temperature monitors, mount and configure net radiometer on the AWS, drill and document shallow firn cores, and record insolation data using small pyranometers.

Field Season Overview:
1. Temperature Logging
We made two complete logging runs of the WAIS-D borehole with the USGS high-precision temperature system at the very onset of the field season (before any other instruments were lowered into the hole). Although these two logs contain some thermal disturbance caused by the drilling of the hole, this disturbance should have been relatively small as the borehole had been sitting idle for about 10 months prior to these measurements. Considerable effort was made to calibrate the depth-measuring system of the USGS 4-km logging winch under WAIS-D environmental conditions; this winch utilizes a 4.72-mm diameter counter-wound steel logging cable. At the onset of the 2011-12 field season, we measured the total borehole depth to be 3328 m. The temperature at the bottom of the hole was -8.756°C.

The borehole was then deepened 74 m yielding a new total borehole depth of 3402 m according to the logging winch depth system. About 48 hours after completion of the drilling, we measured temperatures in the 3178-3402 m depth range. The temperature at the bottom of the hole was found to be -6.05°C at that time. Multi-hour temperature experiments were conducted at 2265, 2770, and 3275 m to determine the nature and extent of borehole fluid convection in the lower half of the borehole (where the temperature gradient is positive).

Analysis of the temperature profiles obtained during 2011-12 is expected to yield the magnitude of the Wisconsin-to-Holocene temperature change, the vertical (downward) velocity of the ice below 2000 m, and the heat flow into the base of the ice sheet at WAIS Divide.

2. Physical Properties of Ice Core and Near-Surface Snow and Firn
John Fegyveresi deployed to Antarctica on schedule. While in McMurdo, John was able to prepare various science equipment for monitoring temperature and insolation data at WAIS Divide. A Kipp-Zonen CNR2 net-radiometer sensor was hand carried to be installed on the U. of Wisconsin AWS (Kominko-Slade). Following a week of weather delays, he arrived at WAIS Divide

on December 23rd. For the following 8 days, the main WDC06A borehole was drilled and deepened by ~75 meters and John was responsible for logging these cores on work shift one. Following this work, and with the help of Logan Mitchell and Gifford Wong, John was able to dig and sample a 2-meter backlit snowpit (three-walled). This pit was also extensively photographed in order to capture the stratigraphy and various crust features. In addition to this pit, John set up several temperature sensors around the camp at various depths in the surface and covered with various solar shields. This was done in order to capture an accurate account of near-surface summer firn temperatures at WAIS Divide. John also installed a custom-made insolation monitoring station that consisted of two hand built short-wave pyranometers. This was left recording for the entire season so that the data could be combined with those from the on-site automatic weather station in order to conduct a proper net energy balance survey for WAIS Divide. Lastly, John observed and documented various surface crusting, glazing, cracking, and frosting events over the 1 month long season. After primary ice-core drilling began on Dec 25th, John also monitored and documented any obvious changes in physical properties in the ice cores or if any deformation was observed. Lastly, John was able to document the physical properties of nine shallow firn cores drilled at the site.

Season Note: John Fegyveresi deployed on December 12th as a member of the I-477 ice-core science tech group. Work that was done related to I-168 was done as a second priority to this project and was accomplished during non-working hours and drill down-time.

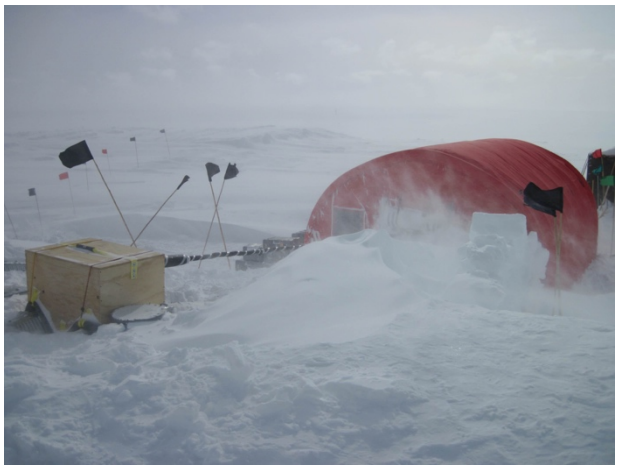


Fig. 1: Logging shelter located adjacent to the drilling arch. The logging cable exits the shelter, passes over a sheave wheel (inside a protective box), before dropping into the arch. With the shelter, logging operations were able to continue unimpeded through the poor weather that was prevalent during the 2011-12 field season.

Fig. 2: Group photo of the 2011-12 borehole loggers. Shown, left to right, are: Dan Kluskiewicz (U. Washington), Jeff Severinghaus (Scripps Inst. Oceanography), Ed Waddington (U. Washington), Don Voigt (Penn State), Ryan Bay (UC-Berkeley), Gary Clow (USGS), Sridhar Anandakrishnan (Penn State), Leo Peters (Penn State), and Elizabeth Morton (IDDO).

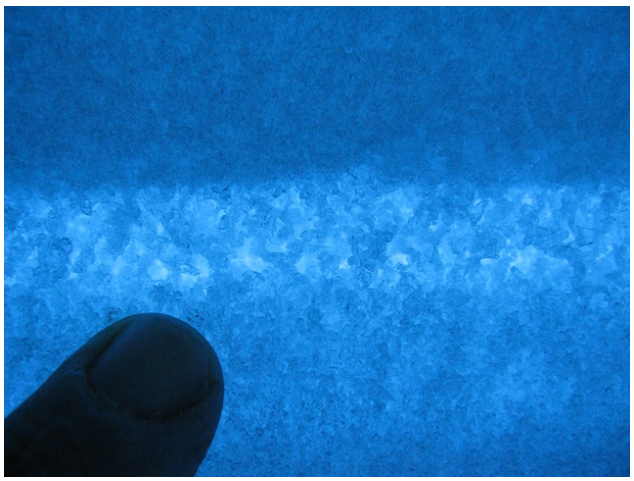


Fig. 3: Significant hoar layer in snowpit wall. Photo: John Fegyveresi

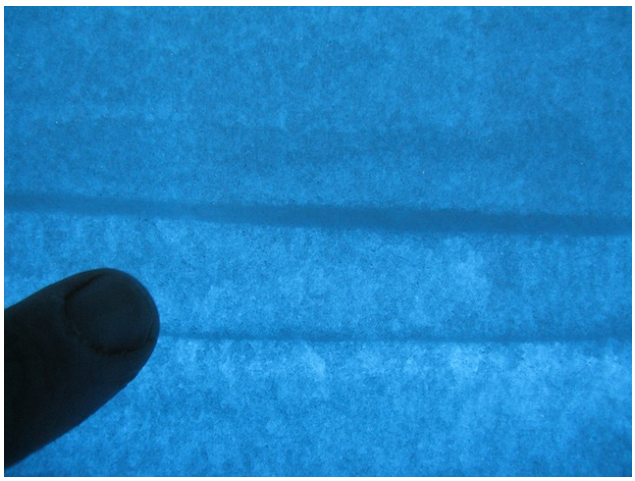


Fig. 4: Large crust in snowpit wall. Photo: John Fegyveresi

Fig. 5: Possible melt layer documented in shallow firn core. Photo: John Fegyveresi

Climatology, Meteorology, and Microbial Metabolism in Ice with Dust Loggers and Fluorimetry (I-122)
PI: P. Buford Price (University of California - Berkeley) NSF-OPP supported

Field Team:

Ryan Bay	Gary Clow
Elizabeth Morton	Frank Urban

Field Season Overview:
We made a total of three optical logs at WAIS Divide with the laser dust logger, taking approximately 10-12 hours for each round trip profile of the 3400 m borehole. The logger provides a high-resolution measurement of particulate stratigraphy for reconstructing detailed paleoclimate records. In bubbly ice the logger signal responds to absorption by thin volcanic ash layers; in clear ice the back-scattering signal is a tracer for both ash and continental mineral dust.

We made two logging runs before hole deepening, on December 6 and again on December 8. We detected hundreds of ash layers and image quality was comparable to logs made in hot-water boreholes. After the drill team completed coring to the final depth, we made a third roundtrip log of the bottom ~300 meters on January 2. We were able to date the borehole back to ~62 thousand years, through comparison with dust logs taken at South Pole and Dome C. The borehole fluid was remarkably transparent prior to hole deepening, which provided superb conditions for imaging dust and volcanic horizons with millimeter depth resolution. The deepening operation likely increased turbidity of the borehole fluid and image quality in the third log was notably degraded.

Support from the science team, drillers and camp staff was excellent.

Fig 1. *IDDO driller Elizabeth Morton assists with borehole logging operations. Photo: Kristina Dahnert*

Acoustic Wave Velocities and Ice Petrofabric at WAIS Divide

PIs: Ed Waddington (University of Washington) and Sridhar Anandakrishnan (Penn State University) NSF-OPP supported

Field Team:

Ed Waddington[1], Dan Kluskiewicz[1], Sridhar Anandakrishnan[2]

1. University of Washington
2. Penn State University

Season Objectives:

Our goal was to measure the speeds of elastic p-waves and s- waves with decimeter-scale vertical resolution in ice throughout the 3.4-km depth of the WAIS-Divide core-hole. These wave speeds are a proxy for the crystal orientation fabric and the associated mechanical properties of ice that control ice flow rates in that vicinity.

Field Season Overview:

We made our first measurements on December 8th, using a sonic logging instrument (see Figure 1) that measures wave travel times between two pressure sensors that are separated 3 meters. We were able to record p-wave and s-wave speeds in 5 cm increments from the top of the borehole to approximately 2000 m, at which point the tool stopped, possibly because borehole drilling fluid entered the tool and possibly because some internal electronic connectors separated due to tool motion and vibration.

We replaced o-rings in the tool at all accessible connections, and secured loose electronic connectors. We also discovered a bulge in the piezo-electric crystal that emits the sound waves. The tool continued to send and receive signals despite this damage; however the consequent signal asymmetry probably degraded our waveform data.

Our subsequent logging runs were more successful. We ultimately recorded four downward logs (i.e. logged while tool was descending in the hole) and three upward logs, with two logs reaching within a few meters of the bottom of the borehole at 3405 meters. Preliminary analysis indicates relatively abrupt acoustic velocity changes in the bottom 400 m of the borehole, indicating changes in the vertical clustering of ice-crystal c-axes there. The experience that we gained should lead to more robust sonic-logging experiments in the future.

Acknowledgements:

Ken Taylor (DRI), provided the sonic tool, and Erin Pettit (UAF) provided the MATRIX logging system. Before and during the field season, Erin Pettit and Alessio Gusmeroli (UAF), and John Stowell (Mt. Sopris Instruments), provided troubleshooting advice. Gary Clow and Elizabeth Morton operated the USGS deep winch, and Ryan Bay (UC Berkeley) provided extensive electronics-related advice and assistance. The project is supported by ANT-0944199.

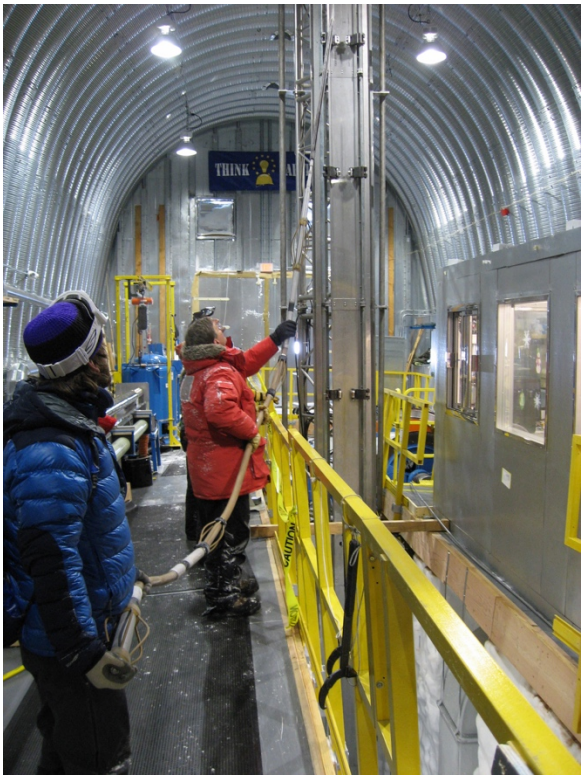


Figure 1. *The five-meter-long sonic-logging tool is about to be lowered into the drill slot. In the foreground, Dan is holding the transmitter section. The flexible tan hose-like sections separate the transmitter and the receivers, and prevent propagation of sound waves directly through the tool itself.*

Ice Drilling Design and Operations (IDDO) Activities at WAIS Divide 2011-2012 (T-350)
NSF-OPP supported
PI: Charles Bentley (University of Wisconsin-Madison)

Field Team:
The IDDO field crew consisted of nine drillers lead by Jay Johnson, IDDO Drill Operations Engineer and Kristina Dahnert, IDDO Field Support Manager. The field crew and the dates of their stays at WAIS Divide are shown in the following table.

Name	Date In	Date Out
Steffen Bo Hansen	January 10	January 23
Kristina Dahnert	November 22	January 9
Chris Gibson	January 3	January 31
Josh Goetz	November 22	January 31
Mike Jayred	November 22	January 31
Jay Johnson	January 3	January 31
Nicolai Mortensen	January 9	January 31
Elizabeth Morton	November 22	January 31
Paul Sendelbach	December 8	January 9
Chuck Zander	December 16	January 31

Season Overview:
- Weather only delayed camp opening by six days. This is a decreased delay from previous seasons.
- Poor weather for entirety of season, with storms every 3-4 days bringing blowing snow and low visibility.
- Despite storms, temperatures were warm and WAIS Divide went above freezing, to 34°F, for 30 minutes one day.
- Thanks to excellent winter berm building the previous season, camp structures were quickly erected and heavy equipment fully operational in no time.
- Technically, no lost days due to weather
- Elizabeth, Jayred, Josh and Krissy arrived in camp prior to Arch excavation to assist with Arch assessment and tilting of the tower
    - Don Voigt, the SCO Representative, also arrived with first drill crew to begin preparations for borehole logging
- Drill Arch sustained additional damage over winter
    - Overall structure damage less than 2010 winter
    - Severe heaving of floor near slot entrance
        - From side wall of Arch to centerline was 11" of rise as measured in November 2010
        - Side wall to centerline now measured a 19" rise in November 2011
    - Additional rippling effect in floor down the length of the Arch
    - Both crane rails were shimmed as planned
        - Completed by RPSC Science Construction crew, supervised by Mike Jayred
        - Rails/floor not made 'level' as leveling everything would create serious clearance issues with the cranes and other equipment in the building

    - Difficulty leveling other equipment
        - Core transfer trusses
            - Removed and cut back window on bulkhead wall
            - Removed all truss shims and 'started from scratch' this season
            - Removed floor panel to use jig transit
        - Optical table
- Cargo Movement
    - DNF issue in McMurdo
        - Drill computer rack found outside; outside between 1-13 days
        - Function of winch and sonde computers tested prior to shipping to WAIS
        - New procedures developed in McMurdo for DNF cargo
    - Large Replicate crate mistakenly marked as DNF
    - All cargo arrived at WAIS quickly
    - New WAIS Divide Cargo Coordinator, Rafael Pizano
    - The Pengo cable tensioner, P05 cable spooler and the old 3400m cable will remain at WAIS through the end of the project
- Heavy Equipment Support
    - Continued issues with the CAT 953 track loader and the CAT D4 dozer; one or the other was down for most of the season
        - Have discussed the need for onsite spare parts with RPSC
    - Pisten Bully critical to Arch snow removal
    - PM schedule not completed during previous seasons; new lines ordered for hydraulic line failure, but necessary o-rings not procured
- Generators
    - The power system was reliable and had only a few unscheduled outages
    - The fan hub on one of the 225kw generators failed violently on January 7th
        - Several repair parts were required; this unit was down for the remainder of the season

IDDO Goals for the Season:

- Assist with borehole logging
    - Install rooftop and slot-spanning sheaves
- Remove old 3400m cable from DISC Drill winch
- Spool on new 4200m cable
- Terminate fiber optics
- Deepen the main borehole to ~50m above the bed at the Chief Scientists direction
    - Produce high quality ice core
    - Adjust drilling procedures and techniques to drill and deliver warm ice, if encountered
- Test Replicate Coring capability

Borehole Logging:

- Elizabeth Morton served as a winch operator with Gary Clow and Frank Urban
- First round of logging completed between 12/3/11-12/21/11
- Second round of logging completed between 1/1/12-1/4/12
- Five logging tools deployed
    - Optical dust logger
    - Sonic 'snake' logger
    - Seismic tool
    - Temperature logger
    - Sonic pinger

Early Season Activities:

- Cable Unspooling
  - Unspooled 3400m cable off of the winch drum using the P05 cable spooler
- Cable Spooling
  - Spooled on new 4200m cable using the Pengo cable tensioner
  - Difficult to get enough pick height with the blue crane when lifting the cable spool due to the floor heaving in the middle of the Arch
  - New cable was much cleaner than the old cable
- Cable Termination
  - Terminated both ends of the fiber optic cable over a period of 5 days
    - Very acceptable levels of dB loss, 13.5 - 15.0 dB, across all fibers
  - Tested new cable spooling and terminating manual written prior to the season
    - Manuals will now be released as controlled documents
    - Took many photos to enhance documentation
    - Took photos and wrote a short procedure for testing dB loss across the cable

Drilling:

- Starting depth: 3331.538m
- Ending depth: 3405.077m
- Total meters drilled: 73.539
- Total days at WAIS: 73
- 18 days for crew arrival, Arch work, slot work, logging set up
  - 2 days for unspooling
  - 2 days for spooling
  - 5 days for cable termination
  - 7 days for drill startup and other Arch prep o 2 days of borehole reaming/1 shift operation o 6 days of 2 shift operation
  - Borehole deepened per original schedule
  - No lost time!
  - 20 days for replicate drill set up and testing o 2 days for packing
- Tripping speeds
  - Descended at up to 1.0 m/s with the pump running
  - Ascended at up to 2.0 m/s
- Cutter Speed
  - 80rpm continues to be the sweet spot
- Penetration rates
  - Varied with ice conditions
  - Between 2.5-5.7 mm/s
- Borehole fluid
  - Density was maintained at .920 @ -31°C throughout the season
  - Fluid was mixed to .935 @ -31°C to compensate for 141B loss
  - 4,391L (1,160 gal) of drilling fluid were used
    - 3,140L (830 gal) of Isopar K
    - 1,251L (330 gal) of 141b
  - Total fluid loss for the season was 91%
    - Loss for 2010-11 was 43%
    - Loss for 2009-10 was 25%
    - Loss for 2008-09 was 37%
    - Loss for 2007-08 was 35%

    - Note: The loss rate is higher than past seasons because of replicate drill testing. Also, the volume of the deviation created is not known and therefore was not accounted for in volume added to the borehole. It is therefore reflected as increased fluid loss.
- Weight on Bit
    - Did not work for borehole deepening due to a wiring error
    - WOB worked well after re-wiring
- Instrument section
    - No problems (DISC section)
- Motor sections
    - A few small intermittent leaks still persist in the compensator piston and where the housing sections meet
    - Broken hall sensor wire in the compensator on section Z
        - Repair was made without disassembling the motor section
- The pumps worked well
- The small winch motor would not stop when commanded to at times
    - New problem this season
    - The E-stop had to be used
- One of the 24v DC power supplies in the winch cabinet failed
- The power switch on the Glassman broke; repair made on site
    - Spare Glassman in McMurdo shipped to WAIS
- WAIS Divide Main Borehole completed on December 31, 2011 at a final driller's depth of 3405.077 meters!

Replicate Coring Drill:

- Instrument sections
    - Updated inclinometer with improved accuracy
    - Initially had problems with the I^2C power bus not coming up properly
        - A timing delay was added in to solve the problem
    - Fitted with a programming cable that permits changes to be made to the software without removing the instrument section it from the drill
    - Assembly issue with loose cooling clamp on motor driver
    - No instrument section failures
    - Both sections were fluid tight
- Two deviating heads used
    - Broaching head tried but did not achieve penetration into side wall
        - Drill flexure is speculated to be the main reason
    - Milling head used in a variety of configurations
        - New face shoe for cutter head designed and machined onsite
- Actuator sections
    - Wiring on strain gauges was easily damaged making them unusable
        - Were found to not be needed and will most likely be removed for next season
    - The failsafe mechanisms were found to trip at a lower force in the borehole than on the surface.
    - The hall sensors were not reading reliably due to electrical noise from the interconnect cables
        - Made the skew table unusable
    - Rollers were made in the field for the lower actuator arms
        - Two gear motors locked up and had to be replaced
    - Cause of failure is not known at this time

    - There were oil leaks on all actuator sections around the ball screw shafts
- Screen and core barrels
    - Centering pads on the screens had to be turned down so the screens would fit into the barrel
    - The inner sleeve of the core barrel had a poor fit which required modifications in the field to resolve
- Replicate Drill Testing
    - Verification that the sonde will find desired orientation
        - Repeatable within ±15° after infield calibration of the six actuator channels
    - Verified the sonde can find the uphill side of the borehole
    - 25-30 screens full of chips were recovered
    - Could not create a ledge
    - The milling process was cutting ice, but not at the rate we were expecting it to
        - Lack of stiffness in the drill seemed to prevent full intended side force from being applied to the cutter head
    - Three major issues identified
        - Axial stick-slip
        - System rigidity
        - Cutter geometry

Lessons Learned:

- Overall System
    - Stick slip of the drill made it difficult to achieve stable cutting
    - Using the milling method, we were able to fill the screens
    - The drill deflects more than originally anticipated
    - The side push cutting method was not possible because the upper sonde is a smaller diameter than the barrels
    - Complete system testing needs to be done at IDDO to better understand the dynamics of the system
- Control system/electronics
    - Significant time was initially spent troubleshooting problems with the instrument section
    - The system can reliably find the high side of the hole
    - Auto azimuth works well
    - The external programing cable on the instrument section was very useful
    - Hall sensor count drift makes the lever position uncertain and the skew table unusable
    - The system jumps out of auto operation on its own
- Actuators
    - The fail safe mechanisms trip at a lower force in the hole than on the surface
    - Oil leaks need to be addressed
    - Two gear motors failed
    - The strain gauges were never fully operational due to wiring and connector issues
    - A more reliable method of monitoring arm position is needed
- Core and Screen barrels
    - The threaded barrel connections work OK as long as the threads are kept very clean
    - The screens didn't initially fit into the screen barrel
    - Several modifications had to be made to the core barrels to make them usable
    - More barrel length options would be useful
- Cutter heads

    - The modular head arbor worked well
    - We were unable to get the broaching head to cut. We suspect bending of the drill was the main reason.
    - The milling cutters cut well radially, but the geometry could be better optimized
    - Larger diameter cutters may be needed to compensate for drill deflection
    - The cutters for the coring head had negative clearance on the OD and had to be modified to make them usable
- Surface operations
    - The pivoting handles on the barrel wrenches made them unsafe to use
    - Stiffer handles are needed on the barrel wrenches
    - The barrel turning fixture should be modified to work with a 1m core barrel
    - The screen table could use some refining to work better with different barrel combinations

Borehole Camera:

- New for 2011-2012 season
- New fiber optic transceivers had to be ordered and shipped directly to WAIS
- Centering blocks added to camera housing
- Two camera runs were done

Drill Cable Vacuum:

- A cable vacuum for removing drilling fluid from the winch cable as it comes out of the hole was installed
    - Based on the one used by the Danes at NEEM
    - Was effective at reducing the amount of drilling fluid carried up to the crown sheave and winch

Steffen Bo Hansen Visit:

- Steffen Bo Hansen, from the Centre for Ice and Climate (CIC) in Copenhagen, Denmark, visited WAIS Divide as a drill observer for two weeks in January
    - His experience as a drill engineer provided good insight into issues experienced during Replicate Coring testing
    - Was able to assist with trouble-shooting and driller training on the Badger-Eclipse Drill training

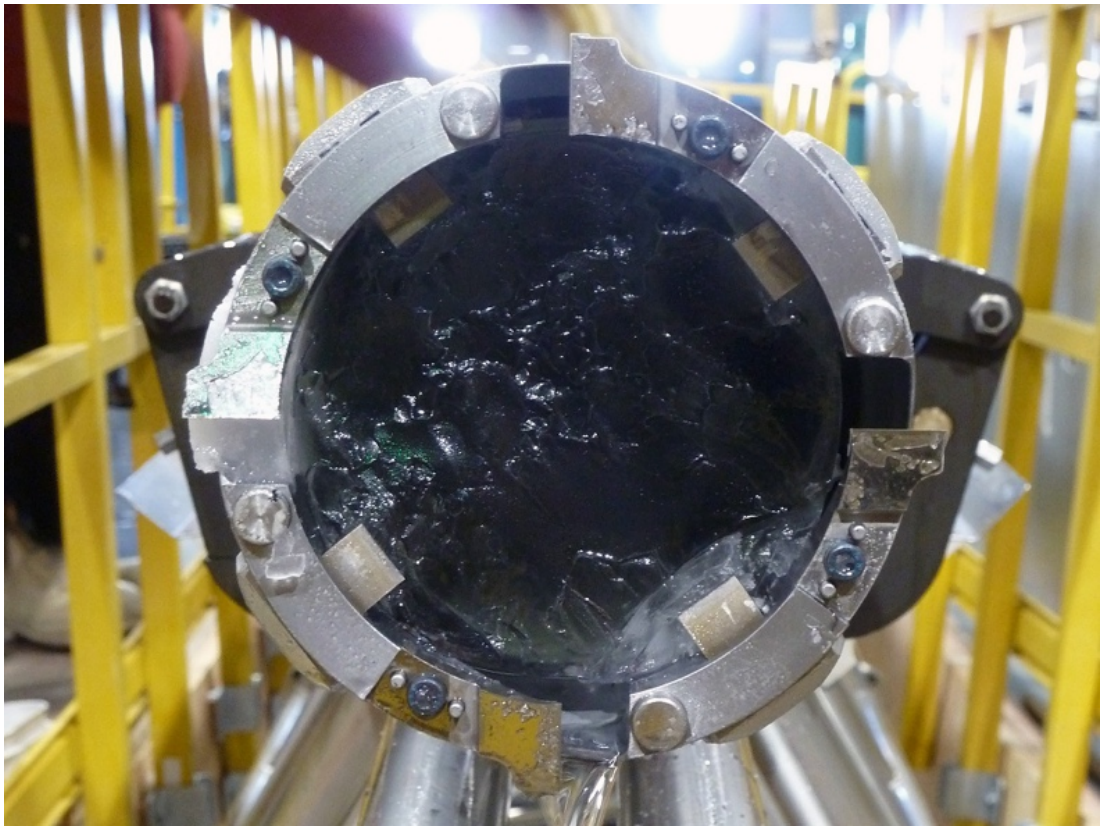
Safety:

- Safety Equipment & Inspections
    - DISC Drill is well-equipped with PPE
    - Equipment usage demonstrated with entire crew
    - Startup, daily and weekly safety checks performed
- Safety Planning
    - Camp managers and medics took a VERY active role in Arch safety Emergency planning
    - Extensive planning and scenario-based meetings for first responder personnel in camp (both RPSC and science)
- Air Monitoring
    - Ventilation system worked well again this season
    - Approximately 1-2 air monitor alarms per drill run
    - Alarmed mainly during ascent tripping
    - O_2 sensor still will not hold calibration
    - Handheld oxygen monitor used for slot entry

    - NICL monitor maintained by Don Voigt/SCO
- No reportable injuries the entire season
- A very safe season overall!

End of Season:

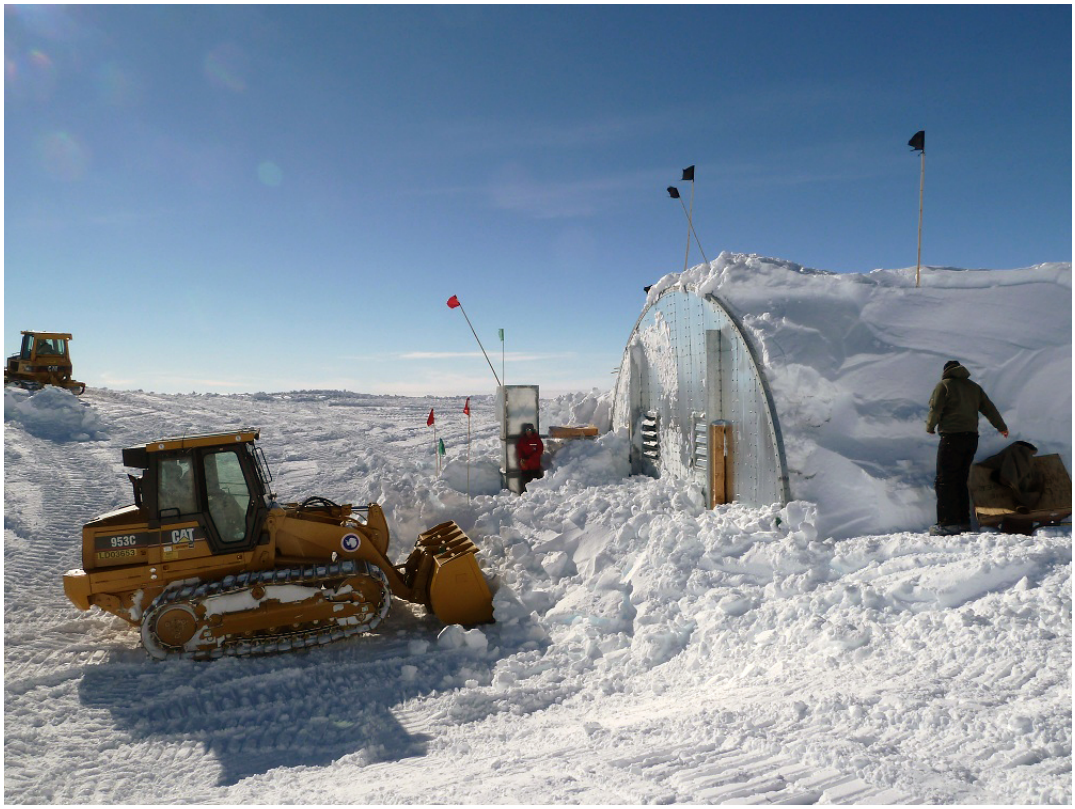
- Removed DNF items for McMurdo storage
- Winch cabinet returning to Madison via vessel for repairs
- Large 150hp winch motor also returning for repair
    - Suspect bearings
- Outdoor equipment, including MECC, moved to winter berms
- Cargo returning to MSN:
    - All sonde sections
    - Replicate barrel sections
    - Computer rack
    - Electrical hardware and tools



Final core of the WAIS Divide deep borehole. Photo: Kristina Slawny.

Unspooling of the old 3400-meter-long drill cable from the DISC Drill's winch drum. Photo: Kristina Slawny


Spooling on the new 4200-meter-long drill cable. Photo: Kristina Slawny



Digging out the doors to the drilling and core handling arch at the beginning of the field season. Photo: Kristina Slawny