WAIS Divide Ice Core Project
2005/2006 End of Season Field Reports

Investigation of Climate, Ice Dynamics and Biology using a Deep Ice Core from the West Antarctic Ice Sheet Ice Divide
NSF-OPP supported
PI: Ken Taylor (Desert Research Institute)

Field Team:

Scientists	Drillers (ICDS)
Ken Taylor (DRI)	Lou Albershard
Mark Twickler (UNH)	Bella Bergeron

05/06 Field Season Objectives:
1) Sample a snow pit at the main drill site before the area was effected by construction activities.
2) Collect a 130 meter ice core with assistance of ICDS prior to beginning of arch construction.

Season Overview:
We arrived at McMurdo on 4 November. WAIS Divide put-was scheduled for 24 October, but was delayed until 14 November due to poor weather and issues associated with landing LC-130s at a new location. Due to the difficulties associated with the LC-130s, a twin otter was used to transport Ken and Mark to the camp on November 20. We sampled a 3 m snow pit for chemistry and isotopes (5 cm sampling interval), density and stratigraphy. The sample pit was then converted to a 2 meter backlit pit (Fig. 1). Ken and Mark departed WAIS Divide on 21 November.

After the completion of the ICDS drilling for Sowers et al, Lou, Beth and Jay Kyne collected a 130 meter ice core next to the arch facility. While ideally this would have been collected prior to arch construction we are grateful to the ICDS crew for drilling, logging, packaging, and shipping the core. ICDS departed WAIS Divide on 12 January.

Acknowledgements:
Extreme gratitude to all those involved in the WAIS Divide activities this year especially, Matthew Kippenhan's planning management, Dave Zastrow's camp management, Andy Young's science support, Billy Texter's construction management, and multitudes of others too numerous to list. This project would not be possible without the dedication and continual support of Julie Palais and Brian Stone, our sincere thanks to them.

Fig. 1: A 2 meter backlit snowpit at WAIS Divide. Bright sections on right are 50cm intervals. The snowpit is at the exact location where the deep ice core will be drilled. The snowpit was sampled for chemistry, isotopes, density, and stratigraphy to 3 meters (after sampling the pit was then converted to a 2 meter backlit pit). The snowpit had to be done before construction of the arch facility, which will house the drill, could start at the site.

Detection of Crystal Orientation Fabrics in the Divide Region Using Polarimetric Radar Methods (I-163M)

NSF-OPP supported

PI: Charlie Raymond and Kenichi Matsuoka (University of Washington)

Field Team:

Kenichi Matsuoka
Joe MacGregor
Donovan Power
Ryan Eastman
Peter Braddock

Season Overview:

To detect the alignment of crystals in ice (ice fabrics), polarimetric radar measurements were conducted using two radar systems near the divide region (Fig. 1). As ice deforms, ice fabrics are produced, which, in turn, influence further deformation. Consequently, measurements of fabric variations can help reveal the deformation history of the ice and indicate how the ice will deform in the future. The polarimetric radar measurement is the most feasible way to determine horizontal variations of ice fabrics.

60-MHz and 179-MHz radar systems were housed in a Faraday cage on a Komotek sled and towed by a skidoo (Fig. 2). At nineteen sites shown in Figure 1, the azimuth of the sled was changed by 15^{o} intervals. Radar data were collected for each azimuth so that we can see how the radio-echo intensity varies with the polarization. We did radar profiling connecting all of these sites. It allows us to date the ice using radar-detected isochronous layers and the future WAIS divide ice core. In addition, we installed a five-marker strain grid, several kilometers wide, at each of the nineteen locations and surveyed the markers using precise GPS. Re-occupation of these markers in the 06/07 season will give present-day strain rates, which will be used as a reference to evaluate the past strain rates inferred from ice fabrics detected by the radar.

The project conducted two traverses; first one was from December 20 to December 30 and the second one was from January 13 to 27. Most of GPS measurements were done during the first traverse, while the radar measurements were done only during the second traverse. In addition to these traverses, 41 of 99 markers installed by Howard Conway in 2002 near the ice coring site were re-occupied on day trips from the divide camp, giving supplemental information of ice movement and surface mass balance over three years. The field team was consisted of Kenichi Matsuoka, Joe MacGregor, Donovan Power, Ryan Eastman, and Peter Braddock. More information about the project including the view of fresh eyes of first-comer students (web journal with photos) can be found at http://www.ess.washington.edu/matsuoka/wais/wais.html

Acknowledgements:

The radar system was loaned by Dr. Shuji Fujita at National Institute of Polar Research, Tokyo, as a part of collaborative research. Special thanks go to Camp Staff led by Dave Zastrow, science construction staff led by Jay Ranson, Andy Young, Julie Palais, and Howard Conway. This project is supported by NSF OPP-0440847.

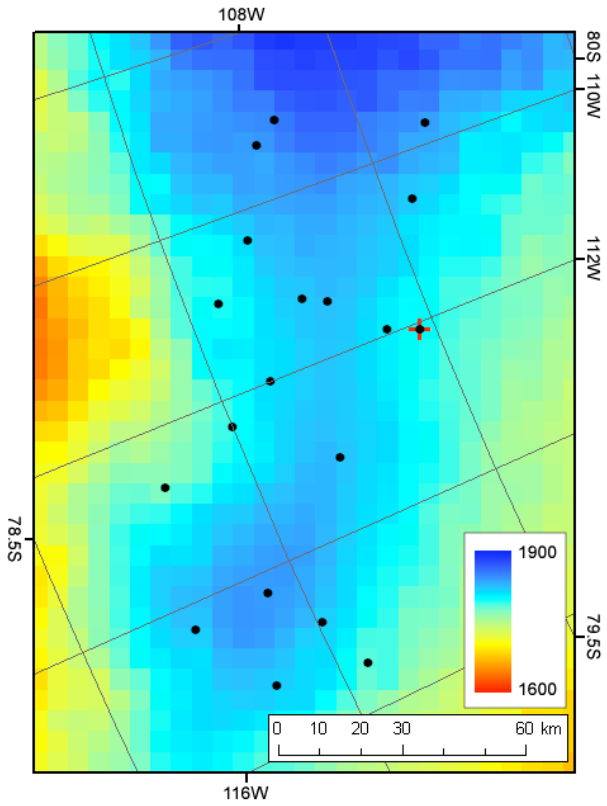

Fig 1: Location of polarimetric-measurement sites (closed circles). Radar profiling was done to connect all of these sites. The WAIS Divide coring site is shown with the red plus. Background color indicates ice sheet surface elevation (m).

Fig. 2: Dual-frequency radar system on a 16-foot-long Komotek sled. The gray Faraday cage houses the radar system. The front black part hosts an operator during the polarimetric measurements. Bigger 8-element Yagi antennas are for 179 MHz, while smaller 3-element Yagi antennas are for 60 MHz. Transmitting and receiving antennas were installed at each side parallel to the sled axis so that the polarization-plane azimuth is consistent with that of the sled axis. As the shape of the antenna structure suggests Frankenstein, the sled was named Frankensled.

Gases in firn air and shallow ice at the proposed WAIS Divide drilling site (I-177)
NSF-OPP supported
PI's: Todd Sowers (PSU; lead), Mark Battle (Bowdoin College), Ed Brook (OSU), Eric Saltzman (UCI), Jeff Severinghaus (Scripps), Jim White (Univ. of Colorado)

Field Team:

Scientists	Drillers (ICDS)
Todd Sowers (PSU)	Jay Kyne
Mark Battle (Bowdoin)	Bella Bergeron
Mark Dreier (INSTAAR)	Lou Albershard
Murat Aydin (UC Irvine)	Terry Geake
	Mike Wasinoski

05/06 Field Season Objectives:
1) Drill one core to 300m to recover ice for reconstructing atmospheric records covering the last 1000 years.
2) Sample two holes for firn air composition down to the firn/ice transition region.

Season Overview:
The bulk of our party and cargo arrived on site on 16-17 December 2005. The drill camp was set up ~1km from the main drill dome along the boundary of the clean air sector. The camp consisted of two Arctic Oven tents, two drills (4" and Eclipse) and numerous generators. The 4" drill was set up and tested on 18 December by drilling a 32 m core. On 19 December 2005, the 300 m core was initiated. The core was measured for density, logged, boxed and stored in a cave near the main camp until retro to McMurdo. This core was completed to 299.4m on 5 Janurary, 2006. Core quality was excellent above 150m, very good to 240m, and good/fair between 240 and 300m. The majority of the ice was retrograded to MCM on 29 December 2005 with digital temperature loggers embedded to monitor ice temperature throughout the trip back to the National Ice Core Laboratory (NICL).

On 21 December, we set up the Eclipse drill to begin firn air sampling. These cores were also logged and retrograded along with the 300m core. We drilled two holes ~15m apart and sampled firn air between the surface and the firn/ice transition region (72-74m). All totaled we sampled 23 depths from the two holes and filled a total of 158 flasks. The firn air work was completed on 1 January 2006. Firn air samples will be returned on the cargo ship in March at which time analyses will commence.

Plans are currently being formulated to process the cores at NICL during the summer of 2006.

Acknowledgements:
Special thanks go out to the Camp Staff lead by Dave Zastrow. It was as close to a Club Med experience as one can expect in the field. The ICDS drill crew was especially efficient in generating top quality core and listening to the scientists when core quality began to head south. Special thanks go to Geoff Hargreaves and Mark Twickler who designed and fabricated a core processing system that made core handling in the field a dream.

ITR/SI+AP: A Mobile Sensor Web for Polar Ice Sheet Measurements (I-188-M)
NSF-OPP and NASA supported
PI's: Sivaprasad Gogineni (lead), Arvin Agah, Christopher Allen, David Braaten, Costas Tsatsoulis, Victor Frost, and Glenn Prescott (University of Kansas), Ken Jezek (Ohio State University) and C. Lingle (University of Alaska, Fairbanks)

High Resolution Ice Thickness and Plane Wave Mapping of Near-Surface Layers (I-346-M)
NSF-OPP supported
PI's: Pannirselvam Kanagaratnam (lead) and David Braaten (University of Kansas)

Field Team:

Eric L. Akers (KU)	Pannirselvam Kanagaratnam (KU)
Torry L. Akins (KU)	Claude M. Laird (KU)
David A. Braaten (KU)	Jerome E. Mitchell (ECSU)
Allan J. Delaney (CRREL)	Abdul Jabbar Mohammed (KU)
Prasad Gogineni (KU)	Joel C. Plummer (KU)
Jennifer F. Holvoet (KU)	Richard S. Stansbury (KU)

05/06 Field Season Objectives:
1) Map deep snow layers and basal topography with a SAR (Synthetic Aperture Radar)/radar depth sounder with a vertical resolution of 5 m or better to characterize internal layering in deep ice and obtain ice thickness.
2) Map near-surface annual layers with an accumulation radar system to a depth of about 150 m with 10-cm vertical resolution to characterize spatial variability and longer-term accumulation rates.
3) Map near-surface snow and ice layers to a depth of about 10 m with about 3-cm vertical resolution using a plane wave radar system to characterize spatial variability and recent accumulation rates.

Season Overview:
In an effort to characterize the history of the ice sheet in the vicinity of the planned West Antarctic Ice Sheet (WAIS) deep ice core and the WAIS Divide, to detail past glacial deformation from the deep internal layering, and to determine basal conditions (whether the bed is wet or frozen), a set of radars were deployed to map an 9-km x 25-km area. The radars deployed include: (1) a wideband, SAR/radar depth sounder that generates a linearly-swept FM chirp in the 120- to 300-MHz band for measuring ice thickness with fine resolution (< 1 m vertical) and mapping deep internal layers and basal topography; (2) an ultra - wideband accumulation radar that operates at frequencies from 0.5 to 2.0 GHz for mapping near–surface firn and ice layers with fine resolution of about 10 cm from the surface to about 100 m depth, and (3) a wideband plane wave radar operating over a frequency range of 12 – 18 GHz to detect near-surface internal firn layers with 3-cm resolution from the surface to a depth of about 10 m.

An advance group of five researchers (Akers, Akins, Kanagaratnam, Laird, and Mohammed) and cargo arrived on site on December 19, 2005, after considerable delays, due mostly to poor weather at WAIS and the backlog of flights that resulted. Telephone and internet connections were established, first via ground antennas and Iridium satellite, followed by setup of our differential GPS system for accurate logging of antenna positions. Starting December 20, 2005, three radar sleds were assembled, one for the plane wave radar and two for the SAR/radar depth sounder— one for the transmitter array and the other for the receiver antenna array. The radars were then assembled and tested, starting with a series of calibration procedures. The SAR was first deployed on December 24, 2005, and tested in bistatic mode along a straight line, stopping every 200 m, on a precisely marked 4-km flagged route set up previously using the GPS system. Unfortunately, due to the higher ice loss and/or weaker bedrock scattering in this region, SAR operation was not possible, and some adjustments to the radar were required. Because of this, the radar was operated in a narrowband mode to optimize antenna and transmit amplifier performance as well as to increase the pulse-width limited bedrock echo return power. The

resulting 20-MHz bandwidth limited the vertical resolution to about 5 m. The in-situ modifications were successful and allowed mapping of the deep internal layers and bedrock topography. On December 28, the plane-wave radar was tested around the deep core site and was found to be working well.

The rest of our team arrived on December 29, allowing us to work in three groups. One group focused on the plane-wave radar operation and accompanying snow pit studies, a second group ran the modified SAR/depth sounder and accumulation radars and a third group monitored our data downloads, GPS and communications systems and worked on outreach activities from our base in the science hut. The plane-wave radar/snow pit studies were conducted between December 30, 2005, and January 8, 2006. Four snow pits were excavated to a 2-m depth at different sites in the vicinity of WAIS field camp, including at one of the shallow core sites drilled by Sowers' group. Visual stratigraphy was recorded in the 4 pits, a series of fixed-volume firn samples were collected and temperature measurements were made at regular intervals down the pit walls. The firn samples were weighed to determine density vs. depth profiles. The plane wave radar system, pulled by a Skidoo, mapped around all four pit sites so that the density measurements can be used to improve the accuracy of the layer depths provided by the radar. The mapping by the depth sounder and accumulation radars was done from December 31, 2005 – January 7, 2006. These systems were housed in a PistenBully, with the transmitter and receiver sleds pulled behind, and driven along 9 parallel lines spaced 1 km apart in an 8-km x 30-km rectangular grid. The grid was centered on the future site of the deep ice core near one end and overlapped the WAIS Divide near the other. On January 8, the two radars were used to map a 2-km x 2-km fine mesh grid centered on the deep core drill site. Grid lines were spaced every 200 m. Work was completed on January 9, 2006, when the accumulation radar was used to map near-surface snow and ice layers along two lines (20 km each) spaced roughly 200 m apart out across the WAIS Divide to an ice core drill site on the 2000/2001 ITASE traverse and back.

Acknowledgements:
We wish to thank all the WAIS field camp staff, and especially Camp Manager Dave Zastrow and Mechanic Dave Anderson, for their phenomenal support. They were always willing to help out, even on Sundays and holidays. Thanks also go to Keith DePew and the Science Cargo staff, to Andy Young.

Ice Coring and Drilling Services (ICDS) at WAIS Divide Camp 2005/2006
NSF-OPP supported

Field Team:

Beth (Bella) Bergeron
Louise (Lou) Albershardt
Mike Waszkiewics
Terry Gacke
Jay Kyne

Season Overview:

Five ICDS drillers and three science personnel flew into WAIS Divide Camp on Friday, 16 December, 2005. The ICDS crew included: Beth (Bella) Bergeron, Louise (Lou) Albershardt, Mike Waszkiewics, Terry Gacke, and Jay Kyne. The science personnel were Todd Sowers, Murat Aydin and Mark Dreier. Mark Battle joined this crew about one week later. This putin was about three weeks after the first two ICDS drillers were originally scheduled to arrive, but did not due to flight delays during early camp putin.

The original schedule was that two ICDS drillers-Bella and Lou-were to put in with Ken Taylor and Mark Twickler and were to take a series of cores (30m, 100m) at or near the yet undisturbed site where the deep core would be taken. The timing was to place them there before the construction began of the steel structure that would house the deep drill the following season. According to this plan, Bella and Lou, after satisfying Ken's requirements, would also take core for Mary Albert (CRREL) and also provide her with a series of reamed 30m holes for her experimentation. In addition, before the arrival of the other three ICDS drillers and the Sowers group, they had hoped to prepare the site for the Sowers work.

As it turned out: Seeing the coring opportunity escaping them, Ken Taylor and Mark Twickler put in to WAIS Divide by Twin Otter aircraft and sampled a three-meter snowpit at the deep drilling site before the snow was disturbed by the construction crew. Plans were then made with Bella and Lou for ICDS to take the core at a later date, as then yet to be determined because of the limited number of higher priority flights that had made it there. In the end, Bella and Lou were delayed to being put in with the rest of the ICDS crew. Upon arrival, the 5 ICDS crew immediately began to help with the set up of the Sowers/Battle camp, which was about one kilometer from camp. Within two days from the ICDS crew putin, 30 meters of core had been taken with the 4-inch drill for Mary Albert, and the drill had been moved and again set up to begin the 300m core for Todd Sowers. At that point, the team of ICDS drillers and science personnel split into two shifts and began the transition to drilling night and day. The Eclipse drill was set up nearby to make two firn-air sampling holes for Mark Battle. The Eclipse drilling and air pumping were done nearly without any disruption to the progress of the 300m hole. The date of completion for the Sowers and Battle requirements was 31 December. In all, these tasks were accomplished with very few problems and very satisfactory results, especially with the 300m hole, given the brittle nature of the ice at a relatively shallow depth. ICDS had two experimental designs, to both of which can be attributed significantly improved core quality. Before their departure, the science group helped ICDS set up for core processing of the final ICDS task, which was a single core of 130m for Ken Taylor at the pit site. By this time, the steel drilling structure had been erected and was receiving the finishing details only a few feet away from the pit/core location. Three ICDS personnel-Lou, Bella and Jay-remained at WAIS Divide to drill and process the Taylor core and oversee its shipping. The departure of the last of the ICDS crew and the final ice shipment was on 12 January. No core was left at the WAIS Divide camp for winter storage.

-Jay Kyne, ICDS Drill Engineer, 8 February 2006.