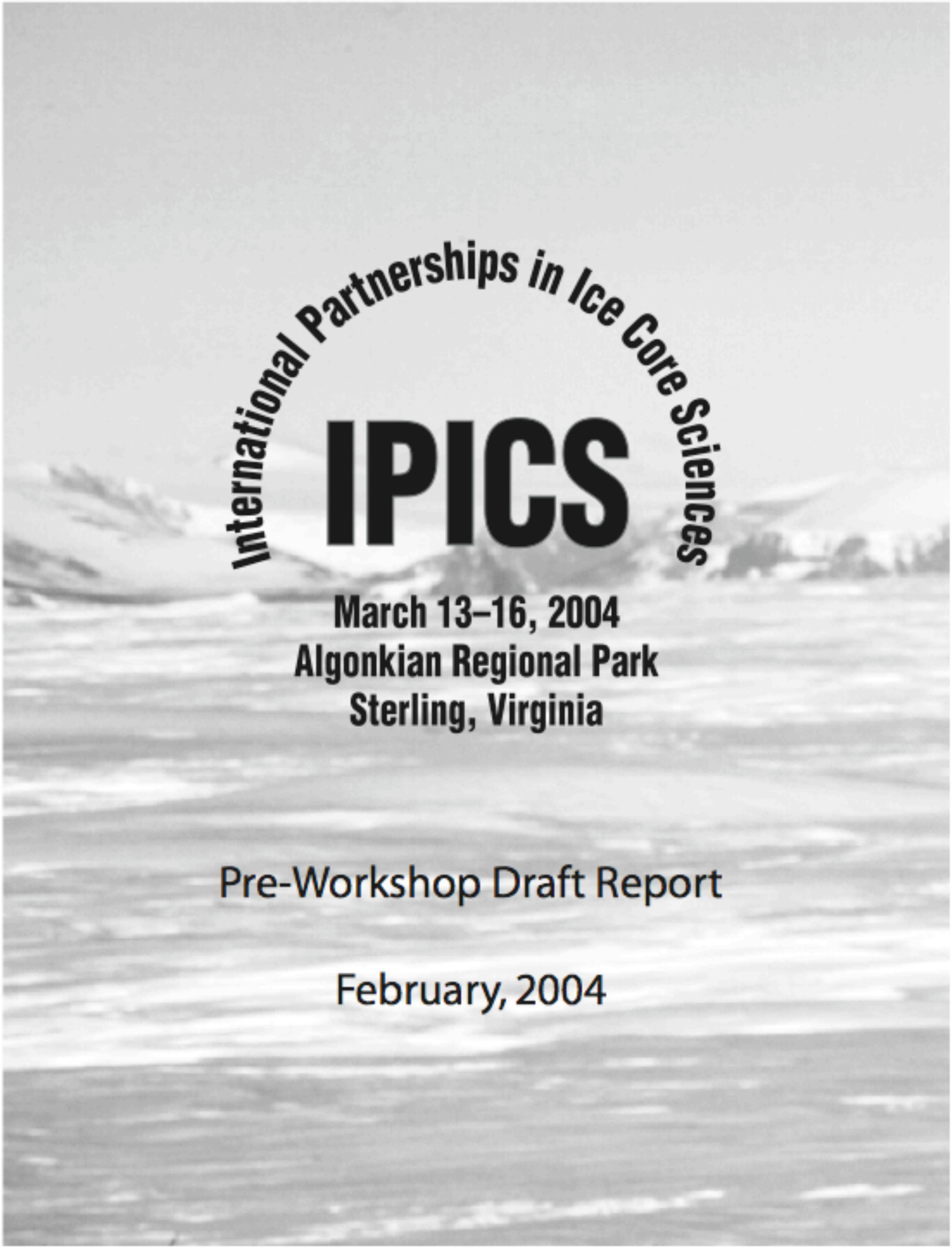

International Partnerships in Ice Core Sciences

IPICS

March 13–16, 2004
Algonkian Regional Park
Sterling, Virginia

Pre-Workshop Draft Report

February, 2004

This document was produced for the International Partnerships in Ice Core Sciences Workshop being held at Algonkian Regional Park in Sterling, Virginia on March 13-16, 2004. The reports are to provide background information for the participants at the workshop. This information may be modified and included into the final workshop report.

February, 2004

Revised April, 2004

This report was compiled by the National Ice Core laboratory – Science Management Office (NICL-SMO) at the University of New Hampshire. We would like to thank the contributing authors to this document and look forward to working with them on the final workshop report.

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Table of Contents

National Reports

Name of Country: ***Australia***

Name and title of person completing report: Vin Morgan (leader of ice-core palaeoclimate group in Glaciology Program of Australian Antarctic Division)

Names of ice core drilling and analysis projects that have been active in the last 5 years:

Law Dome Summit South (DSS) Deep Drilling. Drilling completed in 1993, analysis of core ongoing.

Intermediate depth coring on Law Dome 1999/2000. Small project to recover core from ~80 – 130 m depth to fill a gap in the DSS record.

East Antarctic and Circum-Antarctic climate History from ITASE ice coring in Eastern Wilkes Land. Field work over 2003/04 aims at retrieving two, ~150m deep cores from two sites ~50km apart in coastal Eastern Wilkes Land.

There is ongoing analysis of a number of intermediate and shallow depth cores from Law Dome and Wilhelm II land.

Other drilling/coring such as AMISOR (Amery Ice Shelf/Ocean Research)

Please briefly describe what drilling expertise this nation has:

Thermal drilling (CRREL thermal drill): Amery Ice Shelf 1968, 315m; on Law Dome: 1969, SGA 320m, SGD 385m; 1974 BHF 348m; 1977, BHD 475m, BHQ 419m; 1982 BHC1 305m, BHC2 350m; 1997 DSS97 270m

Large diameter (200 mm) thermal coring at DE08 (240m) and,DSS (82m) on Law Dome.

Deep electromechanical drilling (Australian "ISTUK" type drill on Law Dome: 1991 -1993 to 1200m

Intermediate depth electromechanical drilling (Icefield Eclipse drill): 270m on Law Dome, Wilhelm II Land.

Various shallow drills and corers: PICO, SIPRE

Hot water drilling and coring. Access holes through the Amery Ice Shelf (~380m) in 2000/01, 2001/02 and 2003/04. Cores obtained at selected depths.

Firn air collection from shallow boreholes (Eclipse and French electromechanical drills, CSIRO-AR firn-air sampler).

Please list the ice core analysis laboratories and their specialties for this nation.

Glaciology Program of Australian Antarctic Division at the Antarctic Climate and Ecosystems CRC: Measurements: Stable isotopes ($\delta^{18}O$), trace ions, peroxide concentration, microparticles, crystal fabrics. Research: climate change, interaction between climate and ice sheets, ice dynamics.

CSIRO Atmospheric Research, Aspendale. Measurement: ice core and firn air composition, concentrations and isotopes of all major greenhouse gases, ozone depleting compounds and other trace gases. Research: atmospheric composition changes, modeling of air enclosure (age characteristics, diffusion effects), trace gas budgets, causes of change.

Department of Applied Physics, Curtin University of Technology, Perth. Measurements: trace metals (Pb, Sr etc) concentrations and isotope ratios. Research: relations between trace metals and climate, sources of atmospheric dust.

Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights: Measurements: ^{7}Be, ^{10}Be, ^{14}C, Research: Air and ice dating, trace gas budgets, snow accumulation rates, aerosol transport and deposition, methane sources.

Future plans:

Intermediate depth core recovery (one or more of the following):

E. Wilkes Land (2003/04), Wilhelm II Land (2005+?), Mill Is/Mikhaylov Is (2005+?) Enderby Land/Mawson Coast (2005+?). Notes: The E. Wilkes Land work is currently (at the time of writing) under way. It is likely that the drilling at the other sites will go ahead as it supports key scientific aims that require high-resolution coastal records (see Scientific Issues at the end of this document).

Further deep coring at Law Dome (after 2006). Notes: The high accumulation Law Dome site gives rise to records with sub-seasonal resolution in the upper part of the core and leads to a relatively small ice-age/air-age difference even in the Transition and the Glacial. Resolution of the existing core however is limited by the poor core quality – much of the deep ice is badly fractured. Future plans include drilling down to ~900m with a rapid access (non-coring) drill and then using a coring drill (possibly thermal) to try to recover good quality core from 900m to the bottom, representing the early Holocene, the Transition and last glacial to ~90.000 BP).

Deep coring on the East Antarctic ice sheet inland of Law Dome (after 2005). Notes: this project depends on the scientific outcomes of the EPICA, DML and Dome F. About 500 km inland of Law Dome on the flank of the ice sheet downstream from Dome C the ice thickness is >4000m. It could be possible to get a very long record from this site.

Intermediate ice core drilling and firn air sampling, lead agency CSIRO-AR (2005+).

Retrieval of large ice core amounts for radiocarbon determination of causes of past methane changes (2004/5), on Law Dome, lead agency ANSTO.

Australian researchers interest in listed projects:

Longest ice core record: high interest

Eemian ice: moderate interest

Antarctic inland array: moderate interest

Antarctic coastal arrays: very high interest (similar work underway)

Arctic arrays: low interest

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities. The principal agency operating ice coring activities is Australian Antarctic Division (AAD). AAD operates Antarctic Stations and provides logistics for field programs. AAD scientists and scientists from other agencies carry out projects that have been approved by an assessment committee. Information on Antarctic Division, science carried out by Antarctic Division, the Australian Antarctic Science Strategic Plan, Technical support that can be provided and research applications can be found at:

http://www.aad.gov.au/default.asp?casid=58

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years.

Vin Morgan	vin.morgan@utas.edu.au	Ice core/climate research
Tas van Ommen	tas.van.ommen@utas.edu.au	Ice core/climate research
Mark Curran	mark.curran@utas.edu.au	Ice core chemistry/climate
Barbara Smith	barbara.smith@utas.edu.au	Ice core dust/trace chemistry
David Etheridge	David.Etheridge@csiro.au	Ice core and firn air, isotopes
Ian Allison	ian.allison@aad.gov.au	Sea ice/Ice shelf/ocean interaction
Mike Craven	M.Craven@utas.edu.au	Sea ice/Ice shelf/ocean interaction
Neal Young	neal.young@utas.edu.au	Remote sensing
Kevin Rosman	K.Rosman@curtin.edu.au	Trace heavy metals
Andrew Smith	ams@ansto.gov.au	Cosmogenic isotopes
Cathy Trudinger	cathy.trudinger@csiro.au	Trace gas changes and their causes
Ian Goodwin	ian.goodwin@newcastle.edu.au	Chemical/isotopic tracers of atmos circulation
Ian Simmonds	simmonds@unimelb.edu.au	Interpretation of water isotopes
Cecelia MacFarling	Cecelia.Macfarling@csiro.au	Ice core gas concentrations

Appendix 1.

SCIENTIFIC ISSUES

Replication and validation of sea-ice/MSA proxy and extension to other sites

High-resolution calibration of links between ice chemistry and meteorology

Methodologies for synthesizing paleodata: the problem of combining heterogeneous multi-parameter, multi-core data-sets to extract new proxies

Application of proxy data to model validation (eg PMIP)

Spatial variability of Antarctic climate (ITASE)

Determination of leads and lags in climate responses/forcings through major climate events: deglacial, 8.2ky. Also, phasing of these events in NH and SH.

Characterization of Southern Ocean and Antarctic climate variability through the Holocene: persistence properties of phenomena such as ENSO, AAO, ACW

Characterization of some ecosystem variability through available proxies (MSA and other biogenic sulphur, methyl halides)

Determination of linkages and sensitivities to climate forcing factors

LGM deep-ocean water masses in response to decreased overturning

Causes of changes in atmospheric composition: natural, anthropogenic, climatic, feedbacks.

Explore the use of intermediate-complexity models (collaboratively) to capture time-dependent behavior of Southern Ocean climate and carbon cycle on LGM- Holocene time scales (e.g. can we understand the Holocene CO2 trend, the controls on CO2 during deglacial (iron fertilisation, sea ice, ocean ventilation)?)

What evidence is there of clathrate CH4 emissions (ocean, permafrost) during past rapid changes (14CH4)?

Aerosols (natural, Holocene, glacial, volcanic, anthropogenic).

Improve the S.H. climate record of the past few millennia-water isotopes, gas isotopes, borehole temperature inversions.

Appendix 2
AAD ice cores

Name of Country: **Canada**

Name and title of person completing report: David A Fisher, chief

Glaciology Group, Geological Survey of Canada

601 Booth St

Ottawa Ontario K1A 0E8

Names of ice core drilling and analysis projects that have been active in the last 5 years:
Geological Survey of Canada : Devon Ice Cap, Mt Logan, POW

University of Alberta, Edmonton, Geography Dept , Martin Sharp, POW

University of Alberta, Calgary, Shawn Marshal, POW

University of Ottawa, David Fisher and Ian Clarke, Devon Ice Cap

*POW= Prince of Wales ice cap, Ellesmere Island

Please briefly describe what drilling expertise this nation has. The Group presently at the Geological Survey of Canada has done virtually all of Canada's ice coring and analysis to date, but the universities are now partnering up and starting their own programmes along and in conjunction with the GSC. The GSC has two medium depth tipping tower drills (Hild and Simon) . These drills are close copies of the Danish tipping tower shallow drill and like them have achieved depths down to about 350 m in both dry and partially wet holes. The drill fluid of choice is a type of lamp oil . A third drill a close copy of the Rufli-Rand drill and was 'inherited' from G Holdsworth, we have used down to 177m .

Please list the ice core analysis laboratories and their specialties in this nation. At GSC the lab can do major ion chemistry with a Dionex system, and PE AA, both with auto samplers. There is a multi-sizer Coulter counter for particulates and an ECM rig . There are cold rooms for storage , rough sample prep and one certified class 10 freezer room for preping ultra clean samples. Stable isotope work has been traditionally done by the University of Copenhagen who are always considered as project collaborators .

At the University of Ottawa , Ian Clarke has good mass spec facilities for stable isotopes of water at the 50 samples per day rate and for gas analysis for O18/O16 and total CO2 for ice cores.

At the University of Alberta in Edmonton Martin Sharp's group has 2 ion chromatographs for major ions + & - . On order for a central geo-science lab facility is an ICPMS and a mass spect for stable isotopes. These would be shared instruments.

At the University of Calgary , Shawn Marshall and Ann-Lise Norman can do stable isotopes of water and sulfur isotopes in snow and ice samples.

If there is a written plan for future ice core projects please provide the citation for the plan and explain how a copy of it can be obtained. Recently we put together a futures ice coring wish list of sites. This table is attached and includes all our input here in Canada. David Fisher was the lead contact person in this polling.
Please provide a description of ice coring activities your nation has a strong interest in approaching as part of an international effort.
The name of the project POW = Prince of Wales ice cap project, Ellesmere Island_

The goal is to drill two 300 m holes for climate history with focus on sea-ice sensitive variables. The history of sea ice over the last 2000 years is the main goal. As part of the project would be the inter-comparison of this record with all existing ice core records that could possibly contain a sea ice signature.

A Holocene melt layer record, a sulfur isotope and trace metal history would also be major goals of this work. It is a good site in Canada because the accumulation rate is very high (0.5 m/a) for the Eastern Arctic and the annuals are likely countable back many millenia. The annual temperature is in a good range ~25 C and there are some melt layers every year presently. The depth sought is about 300m. We have still to do the detailed site survey and selection, we only have the approximate site picked.

An indication of the level of interest in the project by the science community and funding agencies

Virtually all the ice core players in Canada are 'on' this project and it in the funding mill presently. The main funding agency approached is CFCAS (Canadian Foundation for Climate and Atmospheric Sciences). The GSC , University of Alberta, and University of Ottawa are all involved with the proposal. There are about 10 research scientists involved and about 6 students in various places. The drilling would be done by the GSC group and the analysis tasks and student opportunities shared out equally. The other funding sources are NSERC and the CRYSYS projects, mainly for student support. The GSC also supports it sown people through salary and O&M on the labs it runs.

The CFCAS funders wanted us to re-submit our proposal to cover just the immediate field aspects of the project which means we will have to tap into other sources for student and lab infrastructure support. Otherwise they were very positive. We expect to get the money to do the drilling in 2005. In the mean time we have much pit data already in hand and plan to do the final site selection this coming field season.

Degree of readiness for participation in the project

We expect the main drilling year to be 2005 and subsequent 3-4 years for analysis and write up. PhD students should have at least 4 years after the drilling to do their work.

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities. Please comment on how these agencies and the science community interact.

NSERC (= NSF) a merit based awards systems for university research. Since ice coring has had small constituency in the past in Canada's universities , NSERC is not "used" to awarding the relatively large amounts to university groups that want to do ice coring. There is no equivalent of a "Polar Office" in NSERC, which is odd considering what a large amount of Arctic Canada has. NSERC interacts with PCSP the logistics organ but does not coordinate with it, see below.

PCSP Polar Continental Shelf Project)= VECO+NSF . PCSP provides infrastructure for most polar research in Canada, accommodation, fixed and helicopter flying hours, gear, communications etc. Canadian (and many non) researchers could not really operate without their help. PCSP has their own application process that is loosely connected with the universities funding system. PCSP is presently part of GSC and until quite recently has been suffering funding cuts. Last year seems to have marked a turn-around and the hopefully Arctic research in Canada will be getting more.

Various "foundations" , like the present CFCAS (Canadian Foundation for Climate and Atmospheric Sciences). This money comes from the federal government for focused science support and depends of the fashionable problems of the day and the amount of money the government has in its 'surplus'; a moveable but presently very rich feast for the universities, who needed an infusion .

CCAF Canadian Climate Action Fund, awarded by the Federal government on "call" basis towards targeted science goals with the theme of climate change, science, adaptation, mitigation. The actual science part of this money tends to be about 10% of its total, but is good for start ups and smaller projects. Of limited value for "new" science that involves field work. The CCAF office is run out of the Canadian Federal Government 's Natural Resources Department, (of which GSC is a part).

CRYSYS , an over-arcing research coordination organization that does a good work in bringing together the cryo-sciences in Canada and connects with US and other non-Canadian like minded organizations. Run here by Environment Canada through Barry Goodison and Ross Brown. In addition to running workshops ,conferences and coordinating activities, they provide some top-up and analysis funding for researchers in universities, using what funds they have available.

NEI Northern Environments Initiative A relatively new source that we are just now exploring for data handling , outreach and student support .

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years.

GSC, NRCan, Glaciology D Fisher, R Koerner, C Zdanowicz, J Bourgeois, M Demuth, J Zheng. Produce and measure cores from Arctic and Mt Logan, Yukon.

University of Alberta, Edmonton, Geography Dept. Martin Sharp, Melissa Lafrenier, measure shallow cores they obtain from Ellesmere Island, POW.

University of Calgary, Calgary, Geography & Geomatics, Shawn Marshall, Vivian Wasiuta , Dept Physics and Astronomy Roy Krouse, Ann-Lise Norman, Berhard Meyer. Obtain and measure cores from POW, Ellesmere Island.

University of Ottawa, Geology, Ian Clarke, Raphaelle Cardyn. Uses GSC cores from Arctic and Logan.

University of Victoria, Earth & Ocean Science . Hinrich Schaefer Methane analysis, isotopes. Uses GSC cores from Arctic and Logan.

UBC Oceanography, Curtis Suttle, viruses. Uses GSC cores from Arctic.

Tentative List of Suggested Places to Drill that GSC and Canadian Universities have an interest in supporting along with colleagues from USA, Japan and Europe

Site, Approx field Years, Interested Contributors(tentative), Major Aspects of Interest

Canadian Eastern Arctic

Mt Oxford. NW Ellesmere Island, 2004-05, U Mass ,coordinating Institution, U Alberta, U Alaska, U Copenhagen, NIPR, GSC, drill, U of Ottawa, U Washington, BAS/SPRI, Arctic Ocean influence and open water history

Prince of Wales Ice Cap (POW), 2004-06, U Alberta, co-lead institution, GSC, co-lead, drill, NIPR, U Ottawa, , U Copenhagen, BAS/SPRI, Very High resolution site to get history of open water (North Water)

Smaller Ice Caps around NW Passage & Hellís Gate, 2004-06, U Alberta, GSC, drill, NIPR, U Alaska y, BAS/SPRI, U Copenhagen, U Ottawa, Get transects and history of Open water in the NW Passage & Hells Gate

Grant Ice Cap, Northern Ellesmere, 2005-06, GSC , drill, U Alberta, U Copenhagen, BAS/SPRI, Arctic Ocean effect, furthest North Ice Cap

Barnes Ice Cap Baffin Island, 2006-07, GSC, lead, U Copenhagen, drill, U Alberta, U Ottawa, NIPR , drillers, Only remaining actual Laurentide Ice Sheet ice.

Agassiz Ice Cap, Ellesmere Island, 2005-2007, GSC, lead drill, NIPR, drill, U Alberta, A very well understood site with outstanding stratigraphic record, melt layer record defined for all Holocene

Axel Heiberg Island, Muller Ice Cap, ?, GSC, NIPR, U Alaska, U Alberta, U Copenhagen, U Ottawa, BAS/SPRI, Un-drilled ice cap ,with promising geometry in promising middle ground between E and W Arctic .

Canadian Western Mountain Sites

Peyto/Wapta Ice Field, Canadian Rocky Mountains, 2005-06. GSC, drill, lead, U Alberta, U Copenhagen, U Ottawa, NIPR, UBC, Accumulation history in head water area of major rivers pollution studies in same

Snow Dome/Columbia Ice Fields, Canadian Rocky Mountains, 2007-08, U Alberta, U Copenhagen, U Ottawa, NIPR, UBC, GSC , drill, Accumulation history in head water area of major rivers pollution studies in same

Lucania Icefield, St Elias Mountains, 2004-05, UBC , lead, NIPR, GSC, U Alberta, U Ottawa, Accumulation history in head water area of major rivers pollution studies in same

Edziza Ice Field N coast BC, ? , GSC , lead, others ?, Accumulation history in head water area of major rivers pollution studies in same

Re-visit King Col Mt Logan, 2003-04, NIPR, lead ,drill, GSC, Complete King Col to bedrock for full Holocene

Antarctic Sites

James Ross Island Ice Cap, Weddell Sea, ? , GSC, NIPR, BAS/SPRI, Separate ice cap near Larson Ice Shelf, with possible Holocene record of the shelf

Name of Country: **China** (Mountain Glaciers)

Name and title of person completing report: Tandong Yao, Professor, Director, Institute for Tibetan Plateau Research, Chinese Academy of Sciences

Names of ice core drilling and analysis projects that have been active in the last 5 years: There are five ice cores collected from the Tibetan Plateau and surrounding regions: Dasuopu ice core (N28^{0}23’, E85^{0}44’, 7200m a.s.l.) from the Xixiabangma Mountain, Puruogangri ice core from the Qiangtang (N33^{0}55’, E89^{0}7’, 6000m a.s.l.), Malan ice core from Kekexili (N35^{0}50’, E90^{0}40’, 5680m a.s.l.), Qomolamgma ice core from the Qomolamgma , Mutztag Ata (N38^{0}17’, E75^{0}04, 7020m a.s.l.’).

Please briefly describe what drilling expertise this nation has: Mr. Zhu Guocai

Please list the ice core analysis laboratories and their specialties in this nation: Laboratory of Ice Core and Cold Regions Environment cooperatively running by the Institute for Tibetan Plateau Research and Cold and Arid Regions Environment and Engineering Research Institute, Chinese Academy of Sciences.

The name of the project: Ice Core Environmental Records in Tibetan Plateau.

An indication of the level of interest in the project by the science community and funding agencies: the science community includes Tandong Yao, Lonnie G Thompson, Nakawo Masayoshi, Shichang Kang, Lide Tian, Ninglian Wang and Shugui Hou; the funding agencies include National Natural Science Foundation of China, Chinese Academy of Sciences, Ministry of Science and Technology, China, National Science Foundation, the USA, JST, Japan.

In what year would this nation be able to make a substantial field effort to initiate the project? The field work for the project will be starting in 2004.

Name of Country: **China** (Polar/Antarctica)

Name and title of person completing report: Yuansheng Li, Head of Department of Polar Glaciology, Polar Research Institute of China. E-mail: yshli@sh163e.sta.net.cn

Names of ice core drilling and analysis projects that have been active in the last 5 years:
1000 year climate records on the East Antarctic Plateau. The following shallow ice cores have been obtained at the selected points on the East Antarctic Plateau and Amery Ice Shelf:

79 00 S and 77 00 E, a 102m ice core (1999), about 1200 years climate record.
76 32 S and 77 01 E, a 82m ice core (1999), about 800 years.
70 50 S and 77 04 E, a 102m ice core (2002).

Mass balance observation on the traverse from Zhongshan Station to Dome A
Processes on Amery Ice Shelf and its interaction with the ocean: One 295m shelf ice core was obtained in 2002/2003 season at 69 26 S and 71 26 E. There are three parts of the continuous ice core: 33m firn core, 245m land ice and 20m marine ice.

Please briefly describe what drilling expertise this nation has: Mechanic shallow ice core drilling systems designed in China and Japan.

Please list the ice core analysis laboratories and their specialties in this nation:
Ice core laboratory of Polar Research Institute of China, focusing on the polar ice core research.
Ice core laboratory of Institute of Glaciology, Chinese Academy of Sciences; mountain ice core and polar ice core research.

The name of the project:
Chinese "ITASE" project from Zhongshan Station to Dome A, 1998-2008.
200m ice core drilling at the summit of Dome A, 2004/2005 is being planned.
A deep ice core drilling program at the summit of Dome A is under planning for 2007-2012..

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities:
Polar Research Institute of China, Dr. Zhanhai Zhang, Director, email: zhangzhanhai@263.net.cn
Chinese Antarctic and Arctic Administration, Mr. Weijia Qin, Project Manager, email: qinweijia@263.net.cn
China National Meteorology Agency, Dr. Dahe Qin, Director-General. E-mail: qdh@rasy.cma.gov.cn
Chinese Sciences Funding Committee, contactor is Mr. Hui Wang, Chief Project Manager.

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years. (Names and email addresses are requested. If possible, please provide a few key words describing the investigator's expertise.)

Dr. Yuansheng Li, involved in 1000 year climate records on East Antarctic Plateau, an ice coring project on Amery Ice shelf, and an ice core drilling project at the summit of Dome A,. Research speciality: geochemistry of snow and ice core, email: yshli@sh163e.sta.net.cn
Dr. Bo Sun, Research speciality: ice radar investigation, email: sunbo@public3.sta.net.cn
Dr. Jiawen Ren, Research speciality: glaciology, email: jwren@ns.lzb.ac.cn
Dr. Cunde Xiao, Research speciality: glaciology, email: cdxiao@cams.cma.gov.cn
Dr. Ming Yan, Research speciality: isotope geochemistry, email: mingyan6@sh163e.sta.net.cn

Name of Country: **Denmark**

Name and title of person completing report: Dorthe Dahl-Jensen

Names of ice core drilling and analysis projects that have been active in the last 5 years:

NorthGRIP and EPICA Deep Drilling Projects

NorthGRIP Shallow ice cores (six 100-150 m ice cores)

Stable Isotopes on the NorthGRIP Ice Core

Stable Isotopes on the DomeC and DML Ice Cores

Dust and Impurities on the NorthGRIP and EPICA Ice Cores

Crystal Orientation and C-axis studies on the NorthGRIP Ice Core

ECM on the NorthGRIP Ice Core

Dating of the NorthGRIP Ice Core

Temperature measurements and calculations on the NorthGRIP and EPICA boreholes

Please briefly describe what drilling expertise this nation has.

The Glaciology Group at Niels Bohr Institute has expertise in deep drilling, intermediate drilling, shallow drilling, drilling in warm ice and borehole logging

GEUS has experience in hot water drilling

Please list the ice core analysis laboratories and their specialties in this nation.

Glaciology Group, Niels Bohr Institute (stable isotopes, CC and laser detection of dust, Ion and Cation Chromotography, ECM, Ice Physics (Automatic c-axis instrument, deformation tests), Coutinuous dust, NO3 and conductivity measurements, Volcanic Thephra Studies)

There is no written plan for future ice core projects. Please refer to the IPICS report on a new North Greenland Eemian Project.

North Greenland Eemian Project (pls refer to IPICS report on this project)

An indication of the level of interest in the project by the science community and funding agencies

The level of interest is very high and we expect several international partners

Degree of readiness for participation in the project

In what year would this nation be able to make a substantial field effort to initiate the project? 2007

Pls refer to the IPICS NorthGRIP report and the IPICS North Greenland Eemian report

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities.

Danish Natural Research Center, Ole Fejerskov (Director), of@dg.dk Call for proposals every second year.

Denmarks Natural Science Foundation, John Renner Hansen (Chairman), renner@nbi.dk Call for proposals every half year

Adoption of a program as strategic research area Decided by the Danish goverment

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years.

Henrik B. Clausen, hbc@gfy.ku.dk (stratigraphic dating, volcanic horizons)
Sigfus J. Johnsen, sigfus@gfy.ku.dk (isotopes, ice core drilling, modeling, tephra)
Claus U. Hammer, cuh@gfy.ku.dk (stratigraphic analysis of ice cores, impurities)
Jørgen Peder Steffensen, jps@gfy.ku.dk (ice core curator, chemistry, stratigraphic dating)
Christine Hvidberg, ch@gfy.ku.dk (ice flow modeling, ice sheets on Mars)
Anders Svensson, as@gfy.ku.dk (stratigraphic data, ice physics, cfa)
Katrine K. Andersen, kka@gfy.ku.dk (stratigraphic dating, statistic analysis, modeling)
Eske Willerslev, ewillerslev@zi.ku.dk (DNA in ancient ice)
Anders J. Hansen AJHansen@zi.ku.dk (DNA in ancient ice)
Peter Ditlevsen, pditlev@gfy.ku.dk (statistic analysis of ice core records)
Dorthe Dahl-Jensen, ddj@gfy.ku.dk (modeling)

Name of Country: **Europe** (European nations under the umbrella of EPICA and related projects).

Name and title of person completing report: Eric Wolff

Names of ice core drilling and analysis projects that have been active in the last 5 years:

European Project for Ice Coring in Antarctica: EPICA Dome C and EPICA DML

NorthGRIP (NGRIP)

Related projects carried out by subsets of these consortia include Berkner Island and Talos Dome

Please briefly describe what drilling expertise this nation has.

European expertise resides mainly within several different laboratories with a particular heritage in deep drilling in Copenhagen, Grenoble, Bern, and more recently Bremerhaven. ENEA (Italy) has provided electronics modules and other support for the EPICA DC drill. Shallow drilling expertise exists in several other laboratories. See individual national and drilling forms for more details.

Please list the ice core analysis laboratories and their specialties in this nation.

Numerous laboratories in at least 10 European nations carry out the whole range of analyses. Within EPICA, there are consortia for isotopes and beryllium (chaired by Jean Jouzel), gases (chaired by Jerome Chappellaz), chemistry (chaired by Eric Wolff), dust (chaired by Jean-Robert Petit), physical properties (chaired by Sepp Kipfstuhl), ice dynamics (chaired by Philippe Huybrechts), atmospheric/modeling (chaired by Michiel van den Broeke). Both EPICA and NGRIP have scientific steering committees that organize access to samples, publication policies and other organizational aspects.

Please provide a description of ice coring activities your nation has a strong interest in approaching as part of an international effort.

The next task of European ice coring is to complete the two existing holes at Dome C and DML. A bid for funds from the European Union (3 years from late 2004) is in progress, and we expect it to be successful. Beyond this, we anticipate that the European collaboration will remain intact under a similar umbrella, and will want to pursue further major collaborative projects in Antarctica or Greenland. Shallower cores (such as Berkner or Talos Dome) will involve just some of the existing partners, while further deep drilling will likely involve most or all existing partners, and could involve external collaborators. No single project has been adopted within the "EPICA plus" community at this point, but there is clearly considerable interest in the coastal array, in the longest possible record, and in Eemian ice from Greenland.

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities.

Funding will likely continue to be by a pooling of commitments (cash and logistic facilities) from different national funding agencies, combined with European Union input where appropriate. For EU, scientists develop proposals in response to calls for proposals in specific areas of work. National agencies have a mix of models. Several of the funders are also logistic agencies with substantial infrastructure in Antarctica (several nations) or Greenland (Denmark). The GRIP and EPICA projects were run under the aegis of the European Science Foundation, but this is not a funding agency for this work, rather a facilitator of collaborative projects.

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years.

See individual national and project reports.

Name of Country: **France**

Name and title of person completing report: Dominique Raynaud, Research director at CNRS

Names of ice core drilling and analysis projects that have been active in the last 5 years:

Participation at the EPICA project with emphasis on the DC drilling

Participation at the NGRIP project

Participation at the Berkner drilling project

Participation at the Vostok drilling project

France is providing analysis for all these projects (ice isotopes, gases, dust, chemistry, Beryllium 10, physical properties,…..), as well as for the Australian project on Law Dome

Please briefly describe what drilling expertise this nation has.

Hot water drilling: down to 300m depth, French Alps, 1980-1985.

Thermal drilling: dry hole, down to 905m, Antarctica, 1978.

Thermal drilling: liquid filled hole, down to 800m, Antarctica, 1987-1989.

Electro mechanical drilling: dry hole, down to 300m, Antarctica, Greenland, continuously.

Electro mechanical drilling: liquid filled hole, down to 3200m, Antarctica , Greenland, since 1990.

Hole logging: temperature, pressure, diameter, inclination, orientation.

Please list the ice core analysis laboratories and their specialties in this nation.

LGGE (Grenoble): gas, dust, physical properties, chemistry

LSCE (Saclay): ice and gas isotopes

CSNSM (Orsay): 10 Be

Please provide a description of ice coring activities your nation has a strong interest in approaching as part of an international effort.

The name of the project

See the 2 formats Vk 200, small lakes and DC replay

An indication of the level of interest in the project by the science community and funding agencies

The projects are of large interest in the paleoclimatic community and by French funding agencies (IPEV and CNRS) and European Commission

Degree of readiness for participation in the project

See the suggested international projects

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities.

IPEV, Gerard Jugie, director

INSU/CNRS, Sylvie Joussaume, director

European Commission, Hans Brehlen, contact person

There are about 50 scientists involved in this country. Here are 4 contact scientists:

Jean Jouzel and Valerie Masson-Delmotte at LSCE
Dominique Raynaud and Jerome Chappellaz at LGGE

Name of Country: **Iceland**

Name and title of person completing report: Thorsteinn Thorsteinsson

Names of ice core drilling and analysis projects that have been active in the last 5 years:

1. 100 m core drilling on the summit of Hofsjökull ice cap (1790 m a.s.l.), August 2001, using a shallow drill built at the Alfred Wegener Institute in Germany.
2. 115 m core drilling on the ice shelf covering the Grímsvötn subglacial lake, Vatnajökull, June 2002, using the same drill modified for use in temperate ice.

Please briefly describe what drilling expertise this nation has.

Construction of first specially built drill for operation in temperate ice and drilling of a 415 m core on Bárdarbunga, Vatnajökull ice cap, in 1972. There was no continuation of these activities and the drill was discarded.

Experience with shallow drilling in temperate ice gained in above mentioned projects on Hofsjökull and in Grímsvötn, using the AWI drill.

Participation of scientists and technicians in the deep coring projects in Greenland (GRIP, NGRIP) and Antarctica (EPICA)

Please list the ice core analysis laboratories and their specialties in this nation.

- No laboratories specialized on ice core research – studies done mainly at the laboratories of the Alfred Wegener Institute in Bremerhaven, Germany.

- A mass spectrometer at the Science Institute, Univ. of Iceland, has been used for measurements of D/H and $^{18}O/^{16}O$ isotope ratios on samples from Greenland cores.

- The chemical composition of volcanic ash grains in Greenland ice cores has been analysed at the Nordic Volcanologic Institute in Reykjavík.

Written plan for future ice core projects? : A new drill designed for use in temperate ice is being built in Iceland. Project plans set out in applications pending with the Icelandic Centre for Research call for a 200 m coring on Bárdarbunga (2000 m.a.s.l.), Western Vatnajökull, in 2005. This would be followed up by a 300 m coring on the summit of Hofsjökull 2 years later.

The name of the project: The person submitting this report and his Icelandic collaborators have already submitted an application to the Icelandic Centre for Research, outlining an ice coring project in 2005. This will be carried out within the framework of two closely intertwined projects (one Icelandic-led, the other US-led) that will study recent decadal climate variations in Iceland, the geochemistry of subglacial volcanic products and microbial life in subglacial lakes. Ice core drilling and thermal drilling efforts will be central to these projects.

Project names:

Evolving glacial, subglacial and glaciovolcanic environments in Iceland.

Microbial ecology of Icelandic subglacial lakes as analogs to past and present habitats in the Solar System.

An indication of the level of interest in the project by the science community and funding agencies

Project 1 above: Several Icelandic scientists at 3 institutes involved. PI: Thorsteinn Thorsteinsson. Application submitted to Icelandic Centre for Research November 2003.

Project 2 above: Involves 2 US laboratories and Icelandic collaborators. PI. Eric Gaidos, Dept. of Geology & Geophysics, University of Hawaii. Application submitted to NASA Astrobiology program, August 2003. Continuation of a NSF-funded program 2001-2003: Coupled cycles of carbon and nitrogen in an ice-covered volcanic caldera lake. (NSF "Biocomplexity in the Environment" Program). The commitment of funding agencies will be known in February 2004.

Degree of readiness for participation in the project:

If funded, the above mentioned projects will be carried out in the years 2004-2006. Fieldwork plans have already been laid out in detail, drawing on many years of experience.

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities. Funding for ice core studies and related glaciological research in Iceland has been provided by:

The Icelandic Centre for Research (formerly Icelandic Research Council)

The National Power Company, which utilizes glacial rivers for hydropower production.

The Public Road Authority, which must deal with repeated *jökulhlaup* flooding of roads and bridges.

The US National Geographic Society (Committee for Research and Exploration) provided startup funds for ice core drilling projects in 2001 and 2002.

Although not a member of the European Union, Iceland takes part in the EU´s scientific framework programs. Possibilities for funding of ice coring programs from the 6th Framework Programme are being investigated.

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years. (Names and email addresses are requested. If possible, please provide a few key words describing the investigator's expertise.)

Thorsteinn Thorsteinsson (National Energy Authority and University of Iceland): Leader of recent ice core drillings in Iceland, participant in NGRIP deep drilling in Greenland and involvement in EPICA project in Antarctica. thor@os.is
Oddur Sigurdsson (National Energy Authority): Geologist/glaciologist, expert in glacier variations in Iceland, leader of mass balance studies on Hofsjökull 1987-2003. osig@os.is
Tómas Jóhannesson (Icelandic Meteorological Office): Geophysicist/glaciologist, expert in ice dynamics and modeling of the response of glaciers and ice caps to climate change. tj@vedur.is
Gudrún Larsen (Department of Geology, University of Iceland). Geologist, expert in tephrochronology. E-mail: glare@raunvis.hi.is
Árný Sveinbjörnsdóttir (Science Institute, University of Iceland). Geologist, expert in isotope analysis of ice core samples, runs mass spectrometer analysis at SI. arny@raunvis.hi.is
Karl Grönvold (Nordic Volcanologic Institute, Reykjavík). Geologist, expert in geochemical analysis of volcanic ash particles in ice cores.

Name of Country: **ITALY**

Name and title of person completing report: Prof. Valter Maggi – Environmental Sciences Dept. – Univeristy of Milano Bicocca, Piazza della Scienza 1, 20126 Milano Italy

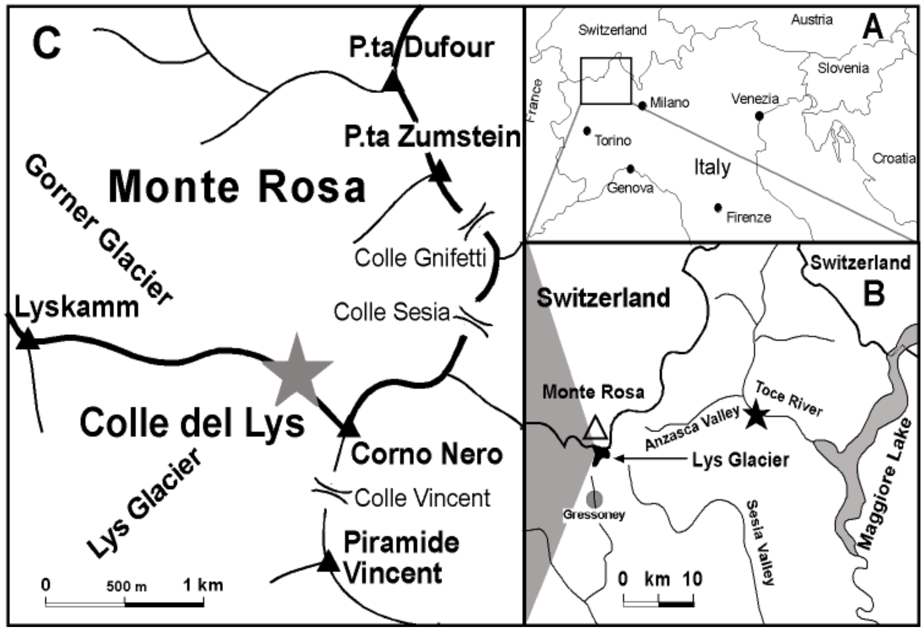
Names of ice core drilling and analysis projects that have been active in the last 5 years:

Ice core on the Italian Alps: Ice core in the Colle del Lys, Monte Rosa area (Italy),

LYS00/1, LYS00/2: Surficial firn cores (11 and 24 m depth), drilled in June 2000.

LYS03: Ice core drilled in the july 2003, 106 m depth, Preliminary bottom age 1929 (+/- 5 years) dated using 3H peak (1963). Accumulation rate 1.32 m w.e.

See figure on next page



Ice core in Antarctica:

ITASE – Different ice core from Talos Dome to DC and from D85 to Talus Dome (East Antarctica)

EPICA – Participant on the Dome C and Dronning Maud Land ice core (see the specific reports).

Please briefly describe what drilling expertise this nation has. The expertise start with the Alpine ice core projects, using a shallow system (around 100 m) in the 1994 on the Braithorn (Iyalian-Switzerland border). Ice core drilling on Colle Gnifetti (1995), and Colle del Lys (1996, 2000, 2003) both on the Monte Rosa Group (Italian Alps). In the same periods start the collaboration inside the EPICA project, with the Danmark, France, Switzerland, Italian Drilling Consortium. The Italian part was mainly related to the electronic control of the drilling and the surface to drilling system communications (see the IPICS EPICA report). The drilling expertise for the surficial ice coring (until 100 m depth) were used also during the Italian ITASE Traverses from Northern Victoria Land, Dome C and Adelie Land (see the IPICS ITASE report).

Please list the ice core analysis laboratories and their specialties in this nation.

University of Milano Bicocca – Ice core drilling, Dust, Chemistry (Organics and pesticides), Glacier modelling, ice cores management, Ice core storage.

ENEA Brasimone (Bologna) – Ice core drilling and drilling system development

University of Florence – Chemistry, IC and CFA

University of Venice – Chemistry, heavy metals

University of Trieste – Stable Isotope, oxygen, hydrogen, tritium

ENEA Casaccia (Rome) – Volcanic Tephra, IC chemistry, Antarctic Logistic

CNR Pisa (National Science Foundation) – Bore hole logging

The name of the project

The Colle del Lys area, because the high accumulation rate (more than 1.3 m w.e.), represent one of the few site on the Alps where is possible found cold conditions. Because inside of one of the most industrialized areas of the word, and close to some large cities (Milano and Torino, Italy) and important agricultural region (Po Plain, Italy), the Monte Rosa, and the Colle del Lys, represent one of the best archives of the human atmospheric impact.

Until now no large project was defined for the future.

Because the Talos Dome ice core project and the next 50th ITASE ttraveses, most of the energies was re-direct to the Antarctica (especially for the next 5 years). The Colle del Lys can be used only for some testing in the instrumentation, mainly for the surficial ice core drilling.

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities.

Normally the main sources for the national activities are the Italian Antarctic Project (PNRA) and the European Union (EU), with some opportunities in small financial facilities from some Italian agencies (i.e. local administrations).

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years.

University of Milano Bicocca – Ice core drilling, Dust, Chemistry (Organics and pesticides), Glacier modelling, ice cores management, Ice core storage; main investigators: Valter Maggi – valter.magi@unimib.it and Marco Vighi (Organic chemistry) – marco.vighi@unimib.it.

ENEA Brasimone (Bologna) – Ice core drilling and drilling system development: Fabrizio Frascati - frascati@brasimone.enea.it

University of Florence – Chemistry, IC and CFA: Roberto Udisti – udisti@unifi.it

University of Venice – Chemistry, heavy metals: Carlo Barbante – barbante@unive.it

University of Trieste – Stable Isotope, oxygen, hydrogen, tritium: Barbara Stenni - stenni@univ.trieste.it

ENEA Casaccia (Rome) – Volcanic Tephra, IC chemistry, Antarctic Logistic: Massimo Frezzotti – frezzotti@casaccia.enea.it

CNR Pisa (National Science Foundation) – Bore hole logging: Aristide Rossi – rossi@iig.cnr.it

Main References

Maggi, V., C. Smiraglia, A. Novo, P. Casati, B. Delmonte, P. Johnston, and G. Rossi, Ice core drilling on Colle del Lys (Monte Rosa, Italian Alps): Climate and environmental signals, *Bollettino Geofisico*, *XXIII* (3-4), 57-66, 2000.

Smiraglia, C., V. Maggi, A. Novo, G. Rossi, and P. Johnston, Preliminary results of two ice core drillings on Monte Rosa (Colle Gnifetti and Colle del Lys), Italian Alps, *Geografia Fisica Dinamica Quaternaria*, *23*, 165-172, 2000.

Villa, S., V. Maggi, C. Negrelli, A. Finizio, E. Bolzacchini, and M. Vighi, Historical profile of polychlorinated biphenyls (PCBs) in an alpine glacier, *Fresenius Environmenatl Bulletin*, *10* (9), 701-705, 2001.

Villa, S., E. Bolzacchini, C. Negrelli, A. Finizio, and V. Maggi, Analisys of organic micropollutants in the Stelvio glacier, *Ingegneria Ambientale*, *XXX* (9), 2001.

Largiuni, O., R. Udisti, S. Becagli, R. Traversi, V. Maggi, E. Bolzacchini, P. Casati, C. Uglietti, and S. Borghi, Formaldehyde record from Lys glacier firn core, Monte Rosa massif (Italy), *Atmospheric Environment*, *37* (27), 3849-3860, 2003.

Villa, S., M. Vighi, V. Maggi, A. Finizio, and E. Bolzacchini, Historical trends of organochlorine pesticides in an Alpine glacier, *Journal of Atmospheric Chemistry*, *46* (3), 295-311, 2003.

Name of Country: **Japan**

Name and title of person completing report: Yoshiyuki Fujii

Names of ice core drilling and analysis projects that have been active in the last 5 years:

Study on deep ice core from Dome Fuji, Antarctica

Phase 1: Basic analysis

Phase 2: High time-resolution analysis

2) Second deep ice coring project at Dome Fuji, Antarctica

3) Study on Japanese ITASE shallow cores

Study on Arctic shallow ice cores from Svalbard, Mt. Logan, Greenland, Kamchatka, and Mt. Wrangell, Alaska.

Ice core drilling project at McCall Glacier, Alaska.

Study on high mountain ice cores from Altai Mts and Qilian Mt.

Drilling expertise this nation has.

Deep ice coring: Deep ice core drilling was carried out to a depth of 2503 m at Dome Fuji, Antarctica in 1995-1996 with a JARE-type mechanical drill. Second deep ice coring project at Dome Fuji aiming to drill to the bedrock started 2003/2004 using the improved drill.

Intermediate depth coring: A 700 m deep ice coring was carried out at Mizuho Station, Antarctica in 1983-1984.

Shallow ice coring: First shallow ice coring was done to a depth of 70 m at Mizuho Station, Antarctica in 1971 with a primitive mechanical drill. Shallow drill has been improved and has been used at Antarctica, Greenland, Svalbard, Patagonia, Himalaya, Kunlun, Altai, Kamchatka, western Siberia, Mt. Logan and Alaska.

Ice core analysis laboratories and their specialties in this nation.

National Institute of Polar Research, Tokyo: Chemistry, oxygen and hydrogen isotopes, microparticles, tephra and electric properties.

Institute of Low Temperature Science, Hokkaido University: Physical properties such as clathrate hydrate, Raman spectral N2/O2 ratio, bulk density by X-ray transmission, and total air content.

Nagaoka University of Technology: Ice fabrics, and laser scattering tomography.

Center for Atmospheric and Ocean Studies, Tohoku university: Atmospheric compositions such as CO2, CH4 and N2O, and the isotopic ratios of 13C and 15N.

Kitami Institute of Technology: Mechanical properties and total gas content.

Yamagata University: Dust component.

Shinshu University: Chemistry.

Tokyo Institute of Technology: Hydrogen isotope and d-excess and microorganisms.

Nagoya University: Organic chemistry, pollen and oxygen isotope.

Highest priority project: Second deep ice coring project at Dome Fuji, Antarctica

Number of investigators: about 60 investigators.

Funding agency: National Institute of Polar Research, Tokyo for ice coring and analysis

Institute of Low Temperature Science, Hokkaido University, Sapporo and others for ice core analyses.

Commitments: Collaboration for drilling and core analyses.

Degree of readiness for participation in the project: The ice coring started in 2003/2004 after five-year preparation of improvement of drill, transportation of fuel and building new drilling site.

List of the names of agencies and the contact persons that might fund future ice coring activities.

National Institute of Polar Research, Tokyo Contact person: Yoshiyuki Fujii, Professor.

The science community proposes an ice coring plan as a part of program of the Japanese Antarctic Research Expedition to the Science Committee on Meteorology and Glaciology.

Japanese Society for Promotion of Science (JASP)

General research funds for science.

The science community can propose their research plan to the JSPS.

List of the investigators

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Name of Country: **Russia**

Name and title of person completing report:

Vladimir Lipenkov, Dr., Leading researcher at the AARI, St. Petersburg, PI for national project entitled “Deep ice coring, paleoclimate research and subglacial Lake Vostok exploration in Antarctica”.

Names of ice core drilling and analysis projects that have been active in the last 5 years:

VOSTOK. The drilling of 5G hole has been performed in collaboration with French and US scientists. The drilling stopped in 1998 at 3623 mbs, 130 m above Lake Vostok, the ice core analyses are in progress.

Deep ice coring on Academy of Science ice cap, archipelago Severnaya Zemlya (Russian-German project implemented in 1999-2001, the drilling reached bedrock at 724 mbs, the ice core analyses are in progress.

Please briefly describe what drilling expertise this nation has.

For the past 25 years deep ice coring has been performed in East Antarctica at Vostok Station (3G, 4G, and 5G holes, the deepest 5G hole reaches 3623 mbs), Dome B (780 m), Komsomolskaya (870 m), at 73 km from Mirny (750 m), and at 105 km from Mirny (720 m); the shallow drilling down to 150 m has been done along the route Mirny-Vostok at 60 km , 140 km, 200 km, 240 km, 340 km and 400 km from Mirny. A number of holes down to the bedrock (400-724 m) have been drilled in ice caps of archipelago Severnaya Zemlya. Both thermal and electromechanical drills of different designs and capacity have been employed to drill these holes. The drill units used in these projects were designed and built at St. Petersburg Mining Institute, and also at the AARI.

Please list the ice core analysis laboratories and their specialties in this nation.

Arctic and Antarctic Research Institute (AARI Roshydromet), St. Petersburg – physical properties of ice, water isotopes (in collaboration with Center of Isotopic Research of All-Russian Geological Research Institute);

Laboratory of Microbiology and Biogeochemistry of Water Reservoirs, Institute of microbiology (IM RAS), Moscow – microbiology of polar ice cores;

Division of Molecular and Radiation Biophysics, Petersburg Nuclear Physics Institute (PNPI RAS), Gatchina – molecular biology of polar ice cores;

All-Russia Research Institute for Geology and Mineral Resources of the World Ocean (VNIIOkeangeologia) – bedrock microparticles in ice cores;

Kazan State University (KSU), Kazan – mathematical modeling of physical processes in polar ice, data interpreation;

If there is a written plan for future ice core projects please provide the citation for the plan and explain how a copy of it can be obtained. Also, please provide four copies of the document.

The ice core projects in Russia are implemented in the frame of the long-term Federal Targeted Program “World Ocean”, subprogram “Antarctica”, project 4 “Deep ice coring, paleoclimate research and subglacial Lake Vostok exploration in Antarctica”. The tentative plans for this program covers the period from present to 2012 (available only in Russian at http://www.aari.nw.ru/projects/Antarctic/default_en.asp). In particular, project 4 is aimed at paleoclimate research through deep and shallow ice coring, and exploring subglacial Lake Vostok by means of remote (radio-echo and seismic) surveys, as well as sampling and studying the accreted ice, lake water and bottom sediments. The document describing the program contains overarching scientific objectives rather than implementation plans for which it provides general guidance. Annual plans are being elaborated based on actually available funding and current scientific priorities as indicated by events and progress. For 2004/05 and 05/06 field seasons, the continuation of coring of accretion (Lake Vostok) ice in hole 5G down to 3680-3700 m has been put forward as the first priority.

Please provide a description of ice coring activities your nation has a strong interest in approaching as part of an international effort.

See description of the suggested international project of deep ice coring in a site located about 200 km north from Vostok Station in the melting area of subglacial Lake Vostok.

An indication of the level of interest in the project by the science community and funding agencies

The project is part of proposal for IPY-associated Russian activity in Antarctica. The decision on funding (from Russian side) will be taken by the Federal Service of Hydrometeorology and Environmental Monitoring of Russia (Roshydromet), the national agency distributing the state funds for polar research, by the end of 2004. The decision to initiate and fund the deep drilling in the northern part of Lake Vostok will strongly depend on the level of interest in this project shown by other nations.

In what year would this nation be able to make a substantial field effort to initiate the project?

The beginning of deep drilling in the northern part of Lake Vostok is currently scheduled for 2006-2007 field season.

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years. (Names and email addresses are requested. If possible, please provide a few key words describing the investigator’s expertise.).

Sabit S. ABYZOV	abyzov@inmi.host.ru	microbiology
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Sergey A. SOKRATOV	socratov@geol.msu.ru	physical properties, water isotopes
Nikolay I. VASILIEV	vasilev_n@mail.ru	drilling technology, borehole geophysics

Name of Country: **Switzerland**

Name and title of person completing report: T. Stocker, J. Schwander, M. Schwikowski

Names of ice core drilling and analysis projects that have been active in the last 5 years:

Greenland Ice Coring Project (GRIP): ongoing analysis

European Project for Ice Coring in Antarctica (EPICA Dome C) : Drilling, onsite and lab. analysis

European Project for Ice Coring in Antarctica (EPICA DML) : Drilling, onsite and lab. analysis

North Greenland Ice Coring Project (NGRIP): Drilling, onsite and lab. analysis

Paleoclimate of the Central Andes

Reconstruction of air pollution levels and climate in the Altai region of Central Eurasia from high-altitude glacier ice core records

Paleo climate from Andean ice cores and lake sediments

Varves, Ice cores, and Tree rings – Archives with annual resolution (VITA)

P*lease briefly describe what drilling expertise this nation has.*

Shallow and intermediate depth drilling in dry holes.

Manufacturing of precision drill heads.

Expertise in retrieval of ice cores from high-mountain glaciers, above the range of helicopter operation.

Please list the ice core analysis laboratories and their specialties in this nation.

Climate and Environmental Physics, Physics Institute, University of Bern: Greenhouse gas mixing ratios (GC and IR absorption spectroscopy), Continuous flow analysis (Ca, Na, NH4, HCHO, H2O2, N03, conductivity, [dust, SO4: in cooperation with DK, IT]), ECM, mass-spectrometric analysis of isotopes of water, and elemental and isotopic ratios and air, low level radioactive measurements, firn air extraction..

Swiss Federal Institute for Environmental Science and Technologie , CH-8600 Dübendorf: 10Be and 36Cl with AMS (In collaboration with Heidelberg)

Laboratory of radio and environmental chemistry, Paul Scherrer Institut: Analyses of major ions, trace elements, radioisotopes

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities.

Swiss National Science Foundation

Swiss Office of Education and Research

Swiss Office of Energy

European Commission

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years.

B. Stauffer (Greehouse gases, logistics)
T. Stocker (Climate modelling)
J. Schwander (Firn gases, drilling, chronology, logistics)
M. Leuenberger (Isotopes)
T. Blunier (Greenhause gases, synchronisation, Isotopes)
H. Gäggeler (Alpine drilling, major ions, trace elements, radioactive isotopes)
M. Schwikowski (Alpine drilling, major ions, trace elements, radioactive isotopes)
J. Beer (10Be, 36Cl, solar activity)

Name of Country: **United Kingdom (UK)**

Name and title of person completing report: Dr. Eric Wolff

Names of ice core drilling and analysis projects that have been active in the last 5 years:

European Project for Ice Coring in Antarctica (EPICA) – with 9 other European countries, Dome C and DML.

Berkner Island drilling project.

Shallow ice cores in Antarctic Peninsula and Weddell Sea region.

Participation in Lomonosovfonna (Svalbard) drilling (R. Mulvaney).

Please briefly describe what drilling expertise this nation has. Participation in EPICA has given some knowledge of deep drilling systems, and we are now users of the new 1000 m French drill being used at Berkner. However our own BAS drill is a lightweight system capable of perhaps 200 m depth (see Mulvaney et al. Mem. NIPR Special Issue 56, 82-90 (2002) for details). There is additionally considerable expertise in hot water drilling within BAS (used so far to penetrate ice shelves).

Please list the ice core analysis laboratories and their specialties in this nation. Main ice core laboratory is British Antarctic Survey (BAS). This has logistics capacity, drilling expertise (as above), and particular strength in ice core chemistry (ion chromatography and CFA), electrical properties of ice (original developer of DEP), SEM studies of ice, links between ice cores and atmospheric chemistry. Deuterium and oxygen isotope analyses are carried out for BAS through a collaboration with the NERC Isotope Geosciences Laboratory (NIGL). BAS has taken part in firn air collections, but does not have its own gas analysis facilities.

Other players in UK:

University College London: Mechanical properties of ice cores

University of East Anglia: Gas analyses (particularly halogenated gases and other minor trace gases)

University of Bristol: temperate ice studies, ice physics.

A number of other groups have undertaken shallow core drillings at sites in the Arctic and elsewhere.

Written plan for future ice core projects? No public document exists. A bid for funding for 2005-2010 is currently active. This would envisage: completion of EPICA and Berkner Island projects, a bedrock ice core at James Ross Island (Antarctic Peninsula) with international partners: this core should offer at least the full Holocene; estimated timeframe would be 2006-2008. possible initial reconnaissance of potential sites in the south of the Antarctic Peninsula

Particular interests include:

Longest ice core record. BAS is already highly involved in EPICA Dome C, and has strong science interest in even longer records. Funding agency would be BAS, as well as EU. Unlikely to be available for substantial effort before around 2010.

Coastal array: Berkner Island and planned James Ross Island core would contribute to such an array, both offering at least the full Holocene.

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities.

BAS itself has two sources of funds. BAS is mainly funded through the UK government agency, Natural Environment Research Council (NERC). BAS scientists submit proposals for internal competition with projects in other areas of science within an overall Antarctic funding envelope. EU funding may also be available for international projects, but these must be targeted on particular interests of the EU call.

Other UK universities can seek funding through responsive mode grant calls from NERC.

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years.

Dr Eric Wolff (ewwo@bas.ac.uk): palaeoclimate of the late Quaternary, atmospheric chemistry, air/snow interactions, ice chemistry, ice physics
Dr Robert Mulvaney (rmu@bas.ac.uk): palaeoclimate of the late Quaternary, ice chemistry, ice microchemistry, firn air, drilling
Dr. Piers Barnes (now in Australia, piers.barnes@unsw.edu.au), ice physics, electrical studies.
Dr Trevor McCormack (trmc@bas.ac.uk): ice chemistry, CFA
Dr Genevieve Littot (gcl@bas.ac.uk): ice chemistry
Dr Andrew Rankin (amra@bas.ac.uk): air/snow transfer, sea salt in ice
Dr David Peel (dape@bas.ac.uk): ice core chemistry and climate
Dr Heidy Mader (h.m.mader@bristol.ac.uk): ice physics
Dr. Jemma Wadham (J.L.Wadham@bristol.ac.uk): chemistry of temperate ice
Dr Peter Sammonds (p.sammonds@ucl.ac.uk): mechanical properties of ice
Dr Dimitri Grigoriev (d.grigoriev@ucl.ac.uk): mechanical properties of ice
Dr Bill Sturges (W.Sturges@uea.ac.uk): Trace gases in firn and ice
Dr Aloys Bory (abory@bas.ac.uk): Dust in ice cores.

Name of Country: **United States of America**
Name and title of person completing report: Mark Twickler, Director, National Ice Core Laboratory Science Management Office
Names of ice core drilling and analysis projects that have been active in the last 5 years:

A New Mt. Logan Ice Core Record - Change in Climate and Chemistry of the Atmosphere for the North Pacific
A Science Management Office for the U. S. Component of the International Trans Antarctic Expedition (US ITASE SMO) A Collaborative Pgrm of Research from S. Pole to N. Victoria Land
A Sulfate-based Volcanic Record from South Pole Ice Cores
A Tropical Perspective on 20th Century Climate Change from Ice Core Histories and Glacier Area and Volume Measurement from the Quelccaya and Coropuna Ice Caps in the Southern Andes
Acquisition and Development of Two ICP Instruments: Continuous Ice Core Elemental Analyses and Other Environmental Applications
An Investigation of Impurities in Greenland Ice Cores
An Ion-Chromatography Based Continuous Flow Analyzer for Soluble Chemical Species in Ice Cores
Collaborative Research: Anisotropic Flow, Depth-Age Relationships and Stratigraphic Disturbances in Polar Ice Sheets
Applications of an Automated C-Axis Analyzer
Argon and nitrogen isotope measurements in the Vostok ice core as aconstraint on phasing of CO2 and temperature changes
Bacteria in Glaciers: A Mechanism for Bacterial Speciation in an Extremely Cold Environment
Borehole Fingerprinting: Vertical Strain, Firn Compaction, and Firn Depth-Age Scales
Carbon Cycle Variations during the Last Glacial Period Based on Atmospheric Delta 14C
CO2 and Delta 13CO2 in Antarctic Ice Cores
Collaborative Research: A 700-Year Tephrochronology of the Law Dome Ice Core, East Antarctica
Collaborative Research: A Glaciochemical Record of Natural and Anthropengic Environmental Change in the Northwestern North American Arctic
Collaborative Research: Characteristics of Snow Megadunes and their Potential Effects on Ice Core Interpretation
Collaborative Research: Deposition of the HFC Degradation Product Trifluoroacetate in Antarctic Snow and Ice
Collaborative Research: Determining Methane Sources During the Last Deglaciation with Large-Volume Air Samples from Pakitsoq, West Greenland
Collaborative Research: Developing and Testing Radiation-Transfer Models for Snow-Pack Photochemistry during the ALERT2000 Field Campaign
Collaborative Research: Digital Optical Imaging of Ice Cores for Curation and Scientific Applications
Collaborative Research: Dynamics and Climatic Response of the Taylor Glacier Ssystem
Collaborative Research: Fabric and Texture Characteristics of Micro-Physical Processes in Ice
Collaborative Research: Past and Present Climatic Controls on the Stable Isotope Composition of Precipitation at Low Latitude Proxy Sites
Collaborative Research: Refining a 500-kry Climate Record From the Moulton Blue Ice Field in West Antarctica
Collaborative Research: Remote Observations of Ice Sheet Surface Temperature: Toward Multi-Proxy Reconstruction of Antarctic Climate Variability
Collaborative Research: Sonic Logging of GISP2, GRIP and NGRIP Boreholes
Collaborative Research: Trapped gas composition and the chronology of the Vostok ice core
Collaborative Research: Western Divide West Antarctic Ice Cores (WAISCORES) Site Selection
Constructing the first D/H record of atmospheric methane covering the last two centuries.
Continuation of Physical Properties of the Siple Dome Deep Ice Core
Continuous High Resolution Ice-Core Chemistry using ICP-MS at Siple Dome
Cosmogenic Radionuclides in the Siple Dome Ice Core
Developing Dry Extraction of Ice Core Gases and Application to Millennial-Scale Variability in Atmospheric CO2
Development of High-Resolution, Multi-Century Records of Trace Element Deposition in West-Central Greenland Using ICP-MS
Diffusion in Crystalline Ice Measured Using Laser Resonant Desorption Techniques
Dry Valleys Late Holocene Climate Variability
Electrical and Optical Measurements on the Siple Dome Ice Core
Extraction and Analysis of Halocarbons and Other Trace Gases in Greenland Ice Cores
Generating an Isotopic Record of Atmospheric Methane and Nitrous Oxide Over the Last Century from South Pole Firn Air
Glacial-Interglacial Variations in d17O of O2 in Ice Cores: Implications for Interactions Between Climate and the Biosphere
Glaciology of Blue Ice Areas in Antarctica
Greenland Ice Sheet Accumulation Variability
High Resolution Records of Atmospheric Methane in Ice Cores and Implications for Late Quaternary Climate Change
High-Resolution Reconstruction of the South Asian Monsoon from the Puruogangri Ice Cores (Tibet)
How Thick Is the Convective Zone: A Study of Firn Air in the Megadunes Near Vostok, Antarctica
Ice Core Reconstruction of North Pacific Climate Variability and Environmental History from the Bona-Churchill Ice Field, Alaska
Ice Core Records of Atmospheric Carbon Monoxide
Ice Coring and Drilling Services
Investigation of Photochemical Transformation within Snow and Their Effect on Snow and Atmospheric Composition
Investigation of the Glacial History of the Siple Coast Using Radar-Detected Internal Layers and the Ice Core from Siple Dome
Laboratory Studies of Photochemistry in Antarctic Snow and Ice
Mass Balance and Accumulation Rate Along US ITASE Routes
Measurement and Interpretation of d13C of Atmospheric Methane from the Law Dome Ice Cores
Methyl chloride and methyl bromide in Antarctic ice cores
Modelling Climate, Solar and Geomagnetic Related Variations in the Deposition of Ice Core Beryllium-10 Isotopes
Operation and Maintenance of the U.S. National Ice Core Laboratory
Oxidation, Photooxidation and Photodecomposition of Dicarbonylic and Ketocarboxylic Ice Core Dopants
Paleoclimate from Mount Everest Ice Cores
Physical and Structural Properties of the Siple Dome Core
Preparation for a Deep Ice Coring Project in West Antarctica
Relating West Antarctic Ice Cores to Climate with Artificial Neural Networks
Revision of the Greenland Ice Sheet Program 2 (GISP2) Depth-Age Scale

Science Coordination Office for Summit, Greenland Environmental Observatory
Science Management of the National Ice Core Laboratory
Seasonal Differences in Air-Snow Chemical Relationships at Summit, Greenland
Separating Net Accumulation into Precipitation and Sublimation in Firn
Stable Isotope Studies at West Antarctic ITASE Sites
Temperature Variability of the Last 1000 years in East Antarctica
Testing the 'Clathrate Gun Hypothesis' with Atmospheric Methane from the Greenland Ice Sheet Project Two (GISP II) Ice Core
The Physical Properties of the US ITASE Ice Cores
U.S.-France Cooperative Research: Nitrogen and Sulfur Cycles in Antarctica Inferred from Concentration and Isotopic Measurements
US ITASE Glaciochemistry
Workshop for International Partnerships in Ice Core Sciences; March 13-16, 2004; Sterling, VA
Workshop on Interdisciplinary Polar Research Based on Fast Ice-Sheet Drilling - FASTDRILL; Santa Cruz, CA, October, 2002

Please briefly describe what drilling expertise this nation has.

Ice Core Drilling Service (ICDS) at the University of Wisconsin provides ice core drill services to the U.S community. See US Drill Report

Please list the ice core analysis laboratories and their specialties in this nation.

Bowling Green State University	Biology
Cold Regions Research and Engineering Lab	Physical Properties
Dartmouth University	Physical Properties
Jet Propulsion Lab - NASA	Biology
Lawrence Livermore National Lab	Isotopes
Lamont-Doherty Earth Observatory	Particles/Geochemistry/Biology
Montana State University	Biology
New Mexico Technology	Volcanics
Ohio State University	Particles/Geochemistry/Isotopes
Ohio University	Physical Properties
Penn State University	Physical Properties/Gases
Princeton University	Gases
South Dakota State University	Geochemistry
State University of New York - Buffalo	Particles
University of California - Berkley	Physical Properties/Biology/Biology/Isotopes
University of California - Irvine	Gases/Geochemistry
University of California - San Diego	Gases/Geochemistry
University of Colorado	Isotopes
University of Idaho	Geochemistry
University of Maine	Isotopes/Geochemistry/Volcanics/Particles
University of Nevada - Desert Research Institute	Geochemistry
University of New Hampshire	Geochemistry
University of Texas - Austin	Site Selection/Geophysics
University of Washington	Site Selection/Geophysics/Isotopes
US Geological Survey	Physical Properties/Geochemistry

If there is a written plan for future ice core projects please provide the citation for the plan and explain how a copy of it can be obtained. http://nicl-smo.unh.edu/documents/pdf/USICS2003.pdf

Please list the name(s) of agencies and a contact person(s) that might fund future ice coring activities.

National Science Foundation: Julie Palais, Jane Dionne, Neil Swanberg, David Verado

Please list investigators in this nation who have been involved in ice coring projects in the last 5 years.

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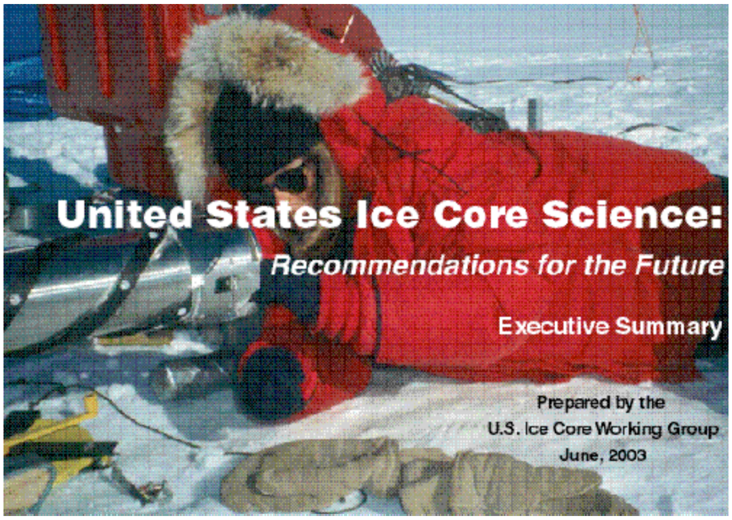

Executive Summary

Polar ice sheets and tropical ice caps are remarkable archives of climate and environmental change, preserving records of global, local, and regional significance on time scales of months to hundreds of thousands of years. Collecting and analyzing ice core records is a specialized science, requiring deep drilling operations in extreme conditions, careful sample handling, and painstaking data collection over literally miles of ice. Ice core data are influential in a wide variety of disciplines, underpin much of global change research, and continually provide observations that both inform and challenge our understanding of the global Earth system.

The U.S. scientific community has played an important role in ice core research since the first ice coring activities in the IGY. U.S. investigators contributed to the first deep ice cores collected in the late 1960s and participated in subsequent international projects, including the tripartite Russian, French, and U.S. collaboration on the Vostok ice core in East Antarctica and collaborative efforts of the GISP and GISP2 projects.

In 1986, the Polar Research Board of the National Academy of Sciences convened an ad hoc committee to examine U.S. efforts in ice coring. The committee report, "Recommendations for a U.S. Ice Coring Program", recommended a new program of U.S. ice coring. Subsequent projects initiated by U.S. investigators included the GISP2 project in Greenland, probably one of the most influential research projects of modern polar research, deep ice cores at Taylor Dome and Siple Dome in Antarctica, and the U.S. contributions to ITASE (International Trans Antarctic Scientific Expedition) and PARCA (Program for Arctic Regional Climate Assessment) in Greenland.

The scientific payoff from ice coring is significant. Rapid ice accumulation rates and the pristine nature of the ice matrix provide records of past environmental changes available from no other medium. Ice cores record the history of human impacts on greenhouse gases and other aspects of atmospheric chemistry, other atmospheric pollutants, and global temperatures. Ice cores also look further back to times prior to human impacts, providing highly detailed records of climate variations, atmospheric chemistry, and global change over time scales of up to 500,000 years or longer. Studies on both of these time scales provide fundamental data about how the Earth system works and with which to view human impacts. Studies of ice cores also make significant contributions to understanding the dynamics and history of polar ice sheets, including the response of ice sheets to climate change and impacts on sea level. Ice is an archive for trace constituents of all types, including micrometeorites, terrestrial dust, and a wide variety of biogenic compounds. And, polar ice also harbors unique in situ microbial communities, studies of which have just begun.

The future of ice coring science promises a significant increase in the amount of information we can extract from ice core records. Advances in analytical instrumentation for trace elements, isotopes, and biological compounds, in situ borehole logging, new drilling techniques, and a variety of other technical advances will contribute to a much more complete interpretation of ice core results. New disciplines-for example, the Life in Extreme Environments (LExEn) community-joining the traditional ice core science community will add to the tremendous payoff from ice coring. New records from critical locations can significantly increase our understanding of key aspects of climate and environmental change on all time scales.

The Ice Core Working Group, a committee of U.S. scientists that makes recommendations about U.S. ice coring projects and assists in administrating the National Ice Core Laboratory, met in March of 2002 at the National Science Foundation to discuss the progress of U.S. ice coring programs and future plans. This meeting considered scientific achievements as well as funding, logistical, and administrative issues related to U.S. ice coring programs.

The meeting and subsequent discussions led to the following recommendations for future U.S. ice coring activities.

1. Reinvigorate U.S. ice coring with a long-term integrated plan for future drilling projects to answer fundamental scientific questions. A draft science plan outlined in this document includes:

a. A deep ice core in West Antarctica (the inland WAIS core) for high-resolution Antarctic climate studies.

b. A deep ice core in north Greenland to recover an intact section of the last interglacial period to examine the stability of the Greenland Ice Sheet in warm climates and the dynamics and termination of interglacial climate.

c. An array of intermediate depth ice cores in both hemispheres to capture climate variability and modes in both hemispheres.

d. Deep ice cores in Antarctica to extend the ice core paleoclimate record to at least one million years.

e. A spatial array of records that penetrate the last glacial maximum to examine Earth system history response to large changes in forcing.

2. Rebuild and maintain U.S. capability to collect shallow, intermediate, and deep ice cores in both hemispheres.

a. Design and construction of a new deep ice coring drill.

b. Design and construction of a new generation of drilling technology that is easy to deploy for shallow, intermediate, and deep drilling.

3. Support development of improvements in ice core analysis and scientific expertise.

a. Enhancement of analytical techniques for trace elements and particles.

b. Development of techniques for trace biogenic gases, and stable isotopic composition of trace biogenic gases.

c. Development of techniques for small samples for all measurements.

d. Development of rapid analytical techniques for high-resolution records of greenhouse gases, stable isotopes, greenhouse gas concentrations, and elemental and isotopic composition of major atmospheric gases.

e. Development and improvement of borehole logging techniques for dust and a variety of other components.

f. Development of reliable sample handling and laboratory techniques to characterize biological material (living and dead) in polar ice.

g. Development of improved techniques for physical analysis of ice cores for paleoclimatic and ice-flow studies.

4. Upgrade polar logistics support.

a. Upgrade logistics support to alleviate current delays in ice-coring projects in Antarctica by increasing aircraft support and over-ice transport.

b. Maintain Air National Guard and other logistics support in Greenland.

5. Maintain, and expand the National Ice Core Laboratory facility.

a. Support short-term expansion of storage capacity by implementing denser racking.

b. Support long-term expansion of NICL freezer space and upgrade of mechanical equipment.

6. Support engineering developments in drilling, logging, and remote sensing that enhance ice core results.

7. Develop and support a stable cadre of drillers, core handlers, and engineers involved in ice coring, including evaluation and improvement of the current relationship between NSF, the scientific community, and the ice coring contractor, with the goal of improving the efficiency of contracted services and developing technology more rapidly.

8. Develop and implement a stable funding strategy for ice coring that maintains continuity of U.S. expertise in acquisition and interpretation of ice core records. This strategy needs to go beyond single campaign style projects to create a longer term commitment to ice coring, analogous to the long term commitment that supports ocean drilling and research ship operations. The ice coring scientific community should initiate this process by creating a long term science plan, then enter into discussions with funding agencies about how to implement this plan. An initial science plan is presented in the full report.

To access the complete report, “U.S. Ice Core Science: Recommendations for the Future”, visit the web site: http://nicl-smo.unh.edu/documents/index.html

Current Projects

Project Name: **ITASE drilling in Eastern Wilkes Land**

Major science objectives:

1. To drill and retrieve 2 firn/ice cores which span the last 200-300 years on the western and eastern flanks of a major ice divide in eastern Wilkes Land.

2. To survey the ice sheet surrounding the drilling sites and between the borehole drilling sites using Ground Penetrating Radar to investigate the spatial variability in snow accumulation layers and physical firn/ice characteristics.

3. To develop a 200-300 year paleoclimate and paleoenvironmental history, including: annual records of snow accumulation, and subannual proxy records of climate; surface temperature; maritime cyclone incursions into Wilkes Land; fluctuations in the katabatic wind field; and, midtropospheric ridging over the Southern Ocean and Wilkes Land

Characteristics of the drill site(s):

Site 1: inland of Porpoise Bay.

GD17 S 67° 51', E 127° 02', elevation 1520 m

Site 2: GD18 S 68° 43', E 122° 17', elevation 2000 m

Characteristics of the core:

Greatest age to which annual layers are preserved: not known at present

Age of oldest ice that is in stratigraphic order: not known at present

Countries and Institutions participating: University of Newcastle, Australia; Australian Antarctic Division

Funding Agencies: University of Newcastle, Australia; Australian Antarctic Division

Schedule (i.e., start and end dates, milestones): 2003/04 summer season program. At the time of writing this the drilling camp is being set up at GD17.

Name of drill system: Drilling uses the Icefield "Eclipse"drill.

Drilling fluid: none

Primary contact person(s): Ian Goodwin ian.goodwin@newcastle.edu.au

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Barbara Smith Barbara.smith@utas.edu.au

Additional background information

During the period from 1975 to 1986 the Australian National Antarctic Research Expeditions (ANARE) conducted glaciological research in Wilkes Land, East Antarctica by oversnow vehicular traverses. In 1980, 1981, 1982 and 1985 these traverses were conducted in eastern Wilkes Land along the 69° S latitude parallel between longitudes 112°E and 131°E, at an elevation range of 1600 to 2300 m (Figure 1). Figure 1 showing the location of existing and proposed (*) drill sites in eastern Wilkes Land, together with the surface wind field vectors. The Wilkes Land region lies entirely within the strong katabatic wind zone where erosional surface winds from east-south-east (ESE) to south-south-east (SSE) drain cold air from the ice sheets interior down-slope to the coast. Snow precipitation accompanied by an E-ESE wind occurs during synoptic-scale maritime cyclonic incursions over the Wilkes Land katabatic slope, at least to the 2000 m elevation. A suite of shallow ice cores were drilled by the CI and his colleagues on the 1985 ANARE Eastern Wilkes Land Traverse. The deeper cores (30 m depth), spanning the period 1930-1985 were drilled at 150 km intervals along the route. Core analysis resulted in the interpretation of annual snow accumulation time series, together with some additional proxy climate data, such as surface temperatures and snow chemistry time series. These are published in Goodwin (1990, 1991, 1995) and Morgan et al. (1991). In the last 2 years, collaborative (with the LGGE in France) laboratory analysis of sub seasonal snow chemistry has been completed for one of the cores collected in 1985 at the GD09 site. The time series and climate history interpretations are described in Goodwin et al. (submitted).

The time series for DSS, GD03, GD06 and GD15 display a pronounced regional increase in accumulation of ~20% since the early 1960s. Morgan et al. (1991) and Goodwin (1991) suggested that the accumulation rate variability in Wilkes Land was related to regional air temperature fluctuations (based on oxygen-isotope temperature transfer functions), and to an increase in cyclonic activity. All the time series display variability with an ~ 10-15 year oscillation particularly since the early 1940s to 1960s. Accumulation rate minima are observed during the 1940s and 1960s in all time series except that for GD09. In contrast, an accumulation rate maximum occurs in the GD09 time series during the early 1960s. This period of maximum accumulation rate is highly anti correlated to the minimum in accumulation rates at GD03 and GD06. This pattern may be explained by the cyclone trajectories into Wilkes Land, downstream tropospheric ridging and their effects on the surface wind field and snow redistribution.

Upper-level atmospheric ridging is a key feature in the circum-polar circulation and the periodic amplification of the ridge is related to the occurrence of a stationary topographic Rossby wave number 3, which possibly reinforces hemispheric atmospheric blocking over the Australia-New Zealand region to the north east of Wilkes Land (Bromwich et al., 1993). The blocking action significantly influences the advection of warmer and relatively moist, lower latitude air, into the East Antarctic interior to the east of Wilkes Land up to at least 2500 m to 3000m elevation. Cullather et al. (1998) established that the strength of the ridging over Wilkes Land influenced the circumpolar storm tracks, resulting in cyclones being steered into Wilkes Land. From field experience, these cyclone incursions are observed to the west of GD09, particularly in the vicinity of GD06. Murphy and Simmonds (1993) and Bromwich et al. (1993) have established that tropospheric ridging has a significant influence on the surface windfield. Katabatic winds were found to intensify in response to stronger than average surface temperature inversions produced by an enhanced high surface pressure and at the 500 hPa level over the East Antarctic interior. These high pressure anomalies over East Antarctica are associated with a blocking anticyclone to the south east of New Zealand (170 to 180°E), and approaching low pressure systems in the circumpolar trough at 100-120°E. Strong wind events are the product of enhanced katabatic wind flow down slope together with strong geostrophic wind flow across the Wilkes land slopes (Murphy and Simmonds, 1993).

Goodwin et al. (submitted) established from the annual sea salt and nitrate concentration time series, that anomalously high accumulation rate and nitrate concentrations at GD09, are the product of the accumulation of blown snow, increased surface wind speed and/or wind pumping efficiency, rather than synoptic precipitation. Satellite scatterometer data have been used to determine surface wind trajectories (Young, pers. comm., 2002) and indicate that GD09 is located in area of windfield convergence at the boundary of a regional maxima in katabatic outflow drainage from the interior. Hence, the GD09 region experiences the deposition of blown snow as the boundary layer is saturated with entrained snow. The nitrate time series is a proxy for the strength of the surface windfield. Goodwin et al. (submitted) have shown that the GD09 annual mean nitrate concentration has a strong statistical relationship with winter (June, July and August) meridional MSLP indices (Macquarie Is-Scott Base, and Kerguelen Is-Casey MSLP) which describe the oscillations in the Southern Annular Mode of climate variability (SAM) (Thompson and Solomon, 2002). See Figure 2 for the comparison of MSLP and ice core nitrate fluctuations. High nitrate concentration (>55 ppb) at GD09 is associated with a synoptic pattern of ridging and a weakened surface pressure gradient in the circumpolar trough, combined with a strengthened surface pressure gradient over East Antarctica. Low nitrate concentration occurs at GD09 under the contrary conditions where a strong pressure gradient exists over the circumpolar trough as described by the MSLP difference of 6 to 18 hPa between Macquarie Island and Scott Base. The decreasing trend in annual mean nitrate concentration in the GD09 core after 1964 suggests a reduced incidence of mid-latitude atmospheric ridging into Wilkes Land during winter. This is in agreement with the observed deepening of the circumpolar trough since the mid 1960s (Allan and Haylock,1993) and the trend towards the high index phase of the SAM (Thompson and Solomon, 2002) . The conclusion drawn from these studies is that atmospheric ridging into Wilkes Land is an important determinant of the temporal accumulation pattern in Wilkes Land. Hence, the measurement of snow chemical time series at strategically located sites dominated by maritime cyclonic precipitation or katabatic snow redistribution in Wilkes Land has the potential to resolve the history of cyclolosis (sea-salt concentration), and the zonality of the circumpolar trough (nitrate concentration). Hence, the proposed development of 200-300 year long proxy climate times series in this study have the potential to provide significant data relating to interannual and decadal changes in the longwave circulation in the circumpolar trough and mid latitudes. The Wilkes Land time series when combined with the high-resolution time series from Law Dome (DSS ice core) will be fundamental input data for climatologists using Global Circulation Models to study the evolution of the SAM, ENSO and the Antarctic Circumpolar Wave under natural and anthropogenic forcings. The development of 200-300 year time-series of the decadal changes in the circum-Antarctic longwave circulation are of high relevance to understanding Southern Australian climate, particularly, precipitation variability. In addition, ice temperature logging of the boreholes will produce a unique data set from which the variability of ice sheet surface temperatures in Wilkes Land can be calculated.

On a continental scale the proposed study will form a significant Australian contribution to the International Trans Antarctic Scientific Expedition (ITASE) (Mayewski and Goodwin, 1997). ITASE is a multinational program of ice coring and surface studies to provide a proxy climate data base covering the last 200-300 years. Thirteen nations have been contributing to ITASE since 1997. Australia is responsible for contributions to ITASE from the Kemp Land to Terre Adelie sector of East Antarctica. The earlier ANARE work in Wilkes land was a precursor to the modern ITASE program. For more information on ITASE refer to http://www.ume.maine.edu/itase.

Logan Consortium ICE2000

This Logan project is in the analysis and interpretation phase, with most of the field work having been completed in the interval 2000-2002. Automatic weather stations are still on site and downloaded and pit work is still undertaken .

The main groups involved are :

PRCOL (Prospector-Russell Col): GSC (Canada) : Summit core drilling and coordinating consortium. University of Maine : chemical analysis of Summit core. University of Copenhagen is doing O18 for Summit samples and University of Washington is doing Deuterium. University of Ottawa is doing Summit core gases.

Eclipse Icefield: University of New Hampshire

King Col:NIPR (Japan)

Project Name: Logan Consortium ICE2000 Mt Logan suite of ice cores. This was(is) a multigroup international project involving people from Canada, Japan , USA and Denmark . There were three cores drilled and handled by three groups from Canada US and Japan.

Major science objectives: The main goal of this project was to obtain one or more ice cores from near the top of Mt Logan , Yukon (lat 60 30' N long 140 35 W elevation 5340 m) and some secondary cores from lower elevations near Mt Logan(at 4300 and 3000 masl) . The Logan site is high and cold (-28.9 C) enough to preserve undisturbed continuous stratigraphy over the last 100000 years. The core will be sampled for of O-18, major ion chemistry, pollen ,trace metals and biological organisms. Gas extraction is also planned. The scientific value of the Logan site lies in its uniqueness in the Pacific NW and the continuity and length of its record. The time series from the Logan site can address questions about the history of NW Pacific air moisture flux, temperature and impurity loading and can look for the effects of recent human induced changes . Having two other near Logan-sites at very different elevations is a major advantage as taken together the 3 cores are above , below and almost at the planetary boundary layer and thus they have very different source areas. The Logan , and many eastern Arctic ice core derived paleo-climate records can be used to examine the out of phase relation the Pacific NW has with the Eastern Arctic and place the present Alaska/Yukon extreme warming in context.

Characteristics of the drill site(s): PRCOL (Prospector-Russell Col) Lat. 60 35.7’ N, Long. 140 30.0’ W; elevation 5340 masl ; depth 190 m ; accum rate ~0.60 m/yr (Ice) . At flat centre of Col , zero surface slope, near zero horizontal velocity. Temperature , mean –29.5 C highest –4 , lowest –50 C. Core length, to bed rock 190m. Pit work also done, AWS in place, 2 yrs of data.

King Col Lat. 60 35.4’ N, Long. 140 36.2’ W, elevation 4150 masl. Accum rate ~ 1.0 m/yr (ice). Temperature mean –20, highest +3 , lowest –37 C. Near top of local dome at head of King Trench on the side of Mt Logan. Ice Depth ~230m. Core length 220m .Pits also done. One yr of AWS.

Eclipse (Dome) Icefield. Lat. 60.51 N Long 139.47 W, elevation 3017 masl. Accum rate ~ 1.4 m/year (ice. Temperature mean ~ -5 , highest +10 lowest -25 C . At the centre of an separate but joined ice field . Ice depth ~380 m . Core lengths , 130, 345 , 40 & 20 m, AWS in place, 1 yr of data.

Characteristics of the core:

Greatest age to which annual layers are preserved:

PRCOL ~ 1500 BP in O18 and deeper for chemistry.

King Col ~ 2000 BP,

Eclipse ~2500 BP

Age of oldest ice that is in stratigraphic order.

PRCOL ~35 ka,

King Col . ~ 300 years ,(lowest core taken)

Eclipse ~ 2.3 ka , (lowest core taken)

Countries and Institutions participating:

The three core sites were managed by their lead groups, which were:

PRCOL- GSC Canada, On analyses side is U Maine and U Copenhagen.

King Col NIPR , Japan

Eclipse UNH , U New Hampshire & U Maine.

Funding Agencies:

PRCOL : For field 65 % IARC , 20 % NIPR, 15 % GSC.

On the analysis side 35% NSF, 35 % NRCan (Canadian Fed gov) 35 % U Copenhagen (in kind).

King Col 100 % NIPR

Eclipse 100 % NSF.

Schedule (i.e., start and end dates, milestones):

PRCOL start caching 2000 ,2001 camps set up at 3 sites , 140m drilled at summit, 2002 drilling complete camps pulled out , cores taken out and stired in Ottawa. Cores split for chemistry and trucked to U Maine. Analysis (chem) underway. O18 sampling and ECM completed by GSC/Copenhagen.

King Col, drilling started 2002, completed in 2002. Cores out and shipped to Japan, NIPR. Analysis underway.

Eclipse , drilling started 2002 , complted in 2002, cores out and trucked to UNH.

The three groups used common flying assets, core storage, fuel dump and communications. They timed their programmes to optimize each others presence. This proved essential to the overall success of all the coring and core transport. Personel were also shared in part.

Name of drill system:

PRCOL ; drill is called “clean-Simon” , and is essentially a copy of the Danish tipping tower drill. It has a stainless steel and interchangeable titanum barrel/cutter head versions, the latter for ‘ultra clean coring. Core diameter 83 mm, typical core length 1 m . Has fluid capabilty , nit used here.

King Col . Japanese shallow drill.

Eclipse , drill called “Eclipse” drill, and is manufactured by Icefield Instruments, (Whitehorse, Yukon). “Eclipse” is a copy of “clean-Simon”, which is a copy of the Danish drill and has barrels that are interchangeable with Simon’s. In fact the UNH group borrowed Simon’s titanium barrels for getting some very ‘clean’ cores’ from Eclipse.

Drilling fluid:

PRCOL (“clean-Simon”) Lamp Oil , D60 . Note all holes were drilled “dry”.

Primary contact person(s):

Overall Mt Logan Consortium lead , David Fisher

PRCOL , stable isotopes, ECM and overall, David A Fisher, GSC fisher@ nrcan.gc.ca:

chemistry analysis : Paul Mayewski and Karl Kreutz, UMaine.

Gerry Holdsworth , AINA.

King Col, Kumiko Goto-Azuma, NIPR

Eclipse , Cameron Wake, UNH

Web Site: PRCOL http://thrust_2.tripod.com/glaciology/one.html and http://members.tripod.com/thrust_2/glaciology/logan.html

Eclipse http://www.ccrc.sr.unh.edu/~cpw/

King Col NB PI for King Col ; Kumiko Goto-Azuma is presently in month 2 of her 16 month tour of duty in Antarctica and a bit tied up . The King Col site etc are covered in the PRCOL site also.

Project Name: **NGRIP**

Major science objectives: The objective is to drill a deep ice core penetrating the Greenland Ice Sheet at (75.10N, 42.32W). The science objectives are to date and produce high resolution climatic records from the glacial period and to recover ice older than 105.000 years reaching back into the previous interglacial period, the Eemian in order to recover a northern atlantic record of this climatic period. The annual layers at the NGRIP site are all over 1 cm due to basal melting at the site and a major scientific goal is to identify and count the layers to produce a well documented time scale for the Greenland ice cores. Programs for measuring stable isotopes, ECM, DEP, ice rheology properties, continuous chemical parameters, dust, gas, Be, and more are ongoing and the core will be central in comparing the north and south ice cores. Bedrock was reached at a depth of 3085m during the 2003 field season and basal water entered the bottom 45 m of the borehole. Final science objectives are to recover the frozen column of refrozen basal water and log the borehole.

Characteristics of the drill site(s):

Location: 75.10N, 42.32 W

Ice Thickness: 3085 m

Accumulation rate: 0.196 m ice equ. per year

Mean Annual temperature: -31 deg C

Ice Dynamics: NGRIP is located on a NNW trending ice ridge

Characteristics of the core: The annual layers are expected to be preserved though the whole ice core with an age at the bottom of 123.000 years.

Countries and Institutions participating:

Denmark: Niels Bohr Institute, University of Copenhagen

Denmark: Zoological Institute, University of Copenhagen

Denmark: GEUS

Denmark: Kort og matrikelstyrelsen

USA: Lamont Earth Observatory, Columbia University

USA: Center for Geochronological Research, INSTAAR, University of Colorado

USA: USGS, Boulder

USA: Physics Department, University of California, Berkley

USA: Radar Systems and Remote Sensing Laboratory, University of Kansas

France: Laboratoire de Glaciologie et Géophysique de l'Environment, Domaine Universitaire

France: Laboratoire de Modélisation du Climat et de l'Environment

Japan: National Institute of Polar Research

Japan: Center for Atmospheric and Oceanic Studies, Tohoku University

Sweden: Naturgeografiske Institutionen, Stockholm's University

Sweden; Uppsala University

Germany: Alfred-Wegener-Institut für Polar- und Meeresforschung

Germany: Institut fur Umweltphysic, University of Heidelberg

Switzerland: Physikalisches Institut der Universität Bern

Switzerland: EAWAG-ETH Zurich

Begium: Dept. des Sciences de la Terre et de l'Environnement, Université Libre de Bruxelles

Iceland: National Energy Authority

Iceland: Science Institute, University of Iceland

Funding Agencies: Institutes and Science Foundations from the nations mentioned above, Villum Kann-Rasmussen Fonden, Carlsberg Fonden

NGRIP formal acknowledgements: The NorthGRIP Project is directed and organized by the Department of Geophysics at the Niels Bohr Institute for Astronomy, Physics and Geophysics, University of Copenhagen. It is being supported by Funding Agencies in Denmark (SNF), Belgium (FNRS-CFB), France (IFRTP and INSU/CNRS), Germany (AWI), Iceland (RannIs), Japan (MEXT), Sweden (SPRS), Switzerland (SNF) and the United States of America (NSF).

Schedule (i.e., start and end dates, milestones):

1996: Establishment of NGRIP camp, shallow drilling, casing, establishment of deep drill

1997: Drill stuck at 1371 m. The drill was not recovered and this core is referred to as the NGRIP1 ice core

1998: Shallow drilling, casing and establishment of deep drill for the NGRIP2 ice core

2000: Drill stuck and recovered at a depth of 2930 m

2001. Drill stuck and recovered 4 times

2003: Bedrock reached at a depth of 3085 m

Name of drill system: NGRIP/EPICA deep drill (IPICS Technical Reports, DK), Hans Tausen drill (IPICS Technical Reports, DK)

Drilling fluid: A D60/Forane 141b and a D60/Solkane 123 mixture

Primary contact person(s):

Dorthe Dahl-Jensen, chairman of the NGRIP Steering Committee, Logistic chairman

Sigfus Johnsen, Chief Driller

Science team: J.P.Steffensen, D. Dahl-Jensen, S. Johnsen, J. Jouzel, Chappalez, H. Miller, S. Kipstuhl, H. Fisher, V. Masson,A. E. Sveinbjornsdottir, T. Thorsteinnson, Watanabe, Fujtii, J. White, M. Hansson,

Web Site: www.glaciology.nbi.ku.dk/ngrip

The NorthGRIP deep drilling program

Introduction The NorthGRIP deep drilling program in Greenland is an international program involving Denmark, Germany, Japan, Belgium, Sweden, Iceland, USA, France and Switzerland. The main goal is to obtain an undisturbed, high resolution record of the ice from the Glacial and Eemian climatic periods (11.5-130 ka BP). The drill site at 75.10N, 42.32W with a surface elevation 2921 m above sea level was selected based on radio echo sounding profiles and geophysical models (Dahl-Jensen, Gundestrup et al. 1997). Ice thickness is 3085 m at the drill site, which is located 325 km down stream of the NNW-trending ice ridge from the top point of the Greenland Ice Sheet where the European Drill Site GRIP is located. Drilling started at NorthGRIP during the summer 1996 and 17 July 2003 bedrock was reached and basal water entered the lowest 45 m of the borehole.

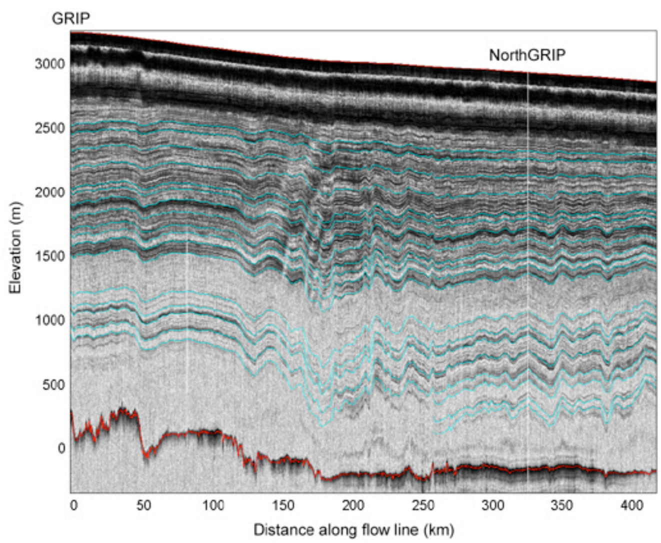

Figure 1
Radio echo sounding image of the flow line from GRIP (0 km) to NorthGRIP (325 km). Internal layers can be traced between the sites allowing the time scales of the two deep ice cores to be connected. The age of the oldest layer that can be traced between the sites is 52 ka BP. Image from P. Gogineni, U. of Kansas

Background The two deep ice cores, GRIP and GISP2, were drilled in central Greenland in the years 1989 to 1993 by European and American teams. The GRIP ice core was drilled on the top point of the Ice Sheet (72.59N, 37.64W) while the GISPII core was drilled 28 km to the west of the GRIP site (72.59N, 38.46W). The stable oxygen isotope records from the two ice cores show exellent agreement and give very detailed records of the Last Glacial period (11-115 ka BP) found at the depths 1625m to 2780 m and 1678m to 2750 m respectively. At depths greater than 2760 m at GRIP and 2750 m at GISPII, the stable oxygen isotope records differ significantly. Careful study of the two ice cores has revealed that these deeper layers are inclined up to 20o and discontinuous layering as well as small scale folds are observed. It is concluded that the records have been disturbed in the lower 10% due to deformation and/or folding probably due to flow over bedrock with undulations of the order of 300 m. Using information from the central Greenland ice cores, the NorthGRIP ice core was selected based on the following criteria:

-the site should be on the ice ridge in order to minimize disturbance by flow. -the bedrock should be flat.

-the accumulation rate should be low so that the Eemian ice is as far from bedrock as possible, but not so low to allow basal melting now or in the past.

Based on measurements of the accumulation rates in North Greenland and 500 km radio echo sounding profiles reaching from the GRIP and GISPII drill sites in central Greenland along the ice the NorthGRIP drill site was chosen 316 km NNW of the GRIP site.

The NorthGRIP deep drilling site The drill site is located on the NNW-trending ice ridge at (75.10N, 42.32W). The annual accumulation rate is measured to be 0.195 m ice equivelent /yr and the mean annual temperature is -32 deg C. The surface elevation is 2921m above sea level and the ice thickness is 3085m. A strain net, established in 1997 and remeasured in 1998, 1999 and 2001, shows the horizontal surface velocity at NorthGRIP is 1.33 (±0.02) m/yr along the NNW ice ridge.The horizontal strain rate in the flow direction is -0.4 (±0.6)10^{-5} yr^{-1} while the horizontal strain rate perpendicular to the ridge and the flow direction is 7.1 (± 0.6) 10^{-5} yr^{-1}. The horizontal velocity along the ridge is constant in the region around NorthGRIP and it can also be observed that the surface slope along the ice ridge is also constant. The bedrock is very flat along the ridge with undulations less than 50m. The radio echo image shown on figure 1 shows well resolved internal layers that are believed to be isochrones. The internal layers can be followed back to the GRIP drill site where they are dated. The deepest layer that can be traced at a depth of 2340 m at NorthGRIP and 2420m at GRIP is dated to 52 ka BP. The deep internal layers have undulations with amplitudes of up to 200m, which cannot be explained by bedrock undulations or accumulation changes along the ridge. Dahl-Jensen and others (A.of G, 37 in press) suggested that the undulations are caused by changes in the geothermal heat flux along the profile.

The NorthGRIP deep drilling program Deep drilling started during the summer 1996. The main structure of the camp is a wooden dome that contains a generator, kitchen, dinning facilities, communication center, desks for computers and a few beds. The drill is installed in a 6 m deep roofed snow trench that connects to the science trenches and the storage area for the ice cores. Weatherports on the surface are used as sleeping quarters for the 20-35 participants. A 110 m hole was drilled with a shallow drill and the upper 100 m of the hole was cased to prevent loss of for drill liquid in the firn. The European deep drill was installed and a drill depth of 300m was reached. The 11 m long European electromechanical retrieves core sections with a diameter of 98 mm that are up to 3.55 m long. During the 1997 season the ice from 700m to1200m was brittle due to the pressure of the airbubbles in the ice. Keeping the ice as cold as possible on the surface, leaving it for at least 1 week in the core storage and handling it carefully in the science trench has resulted in a complete but broken ice core and all measurements have been made continuously through the brittle zone. The drill got stuck at a depth of 1310m at a borehole temperature of -32.4 deg C. It was not possible to pull the drill free or to release it with glycol probably due to the cold temperatures at the position where the drill was stuck. The 1310 m long ice core drilled in the years 1996 to 1997 is referred to as the NGRIP1 ice core. In the field Electrical Conductivity Measurements (ECM), Dielectrical Properities (DEP) and studies of the air bubbles and clatherates have been performed. Samples have been cut for detailed measurements of ion chromotography, gases, physical properties, stable oxygen and deuterium isotopes. The 1998 season was used to build a new drill trench and prepare for a new deep

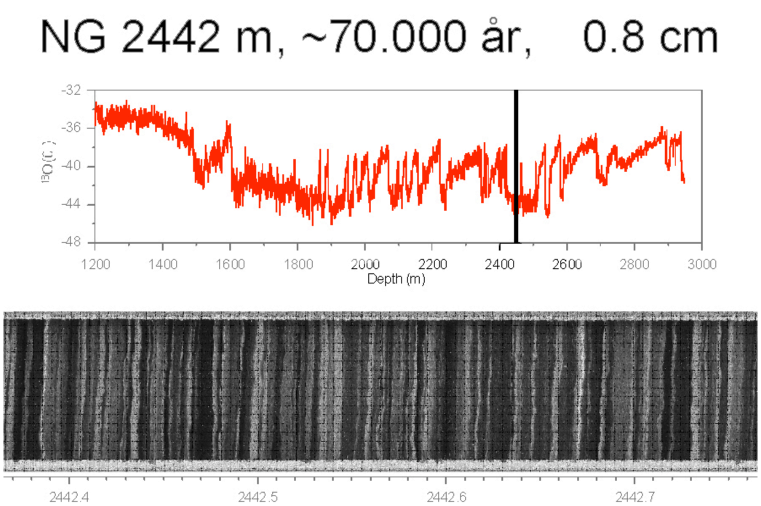

Figure 2
Optical line scan section from 2443 m depth on the NorthGRIP ice core. Layers are still detectable with a layer thickness of 0.8 cm. (data from A. Svensson)

drilling with a cased hole down to 110 m. In 1999 the NGRIP2 ice core was drilled to 1750m. Only DEP was measured in the core down to 1280m and the rest of the ice was stored on site for the year 2000 season. In year 2000 a science team of 15 scientists worked with the NGRIP2 ice from 1280m down to the depth of 2930 m reached during this season. During this season 30-50 m of ice was processed in the science trench each day. ECM and DEP was measured in the field and in addition, a newly developed line scan instrument was used to scan and record visable stratigraphy on a cleaned thick slab of the ice core. Several soluble chemical components as well as the insoluble dust were measured continuously on the ice with a resolution of 1-2 cm. The insoluble components for each 55 cm section were also collected on tephra filters for further analysis. Samples where taken for gas studies as well as for discrete ion chromotographic studies, luminecence measurements, for studies of the physical properties of ice and for the stable oxygen and deuterium isotopes measurements. The drill because stuck at a depth of 2930m where the borehole temperature is -7.2 deg C. Pellets of frozen glycol were dumped in the borehole so the glycol would pass the major and cold part of the borehole before reaching the bottom where the high temperatures would allow the glycol to melt and act with the ice. After one week the drill became free, but the rest of the season was spent bailing the glycol/ice/water mixture up from the borehole. The year 2001 season was used to drill 70m of ice from 2930m to 3001m. The temperature of the ice here is between -7 deg C and -5 deg C which is very close to the pressure melting point of -2.4 deg C. The heat released from drilling allows ice to form on the cutters and it was very difficult to drill with the electromechanical drill. A short version of the deep drill, referred to as the 'Hans Tausen' drill was used in order to improve the performance but the average core length was only been 0.30m this season. The drill was stuck and freed four times during the season using 2-3 kg of frozen pellets of glycol each time. 30 July it was decided to stop the drilling for this season. DEP and ECM has been measured and samples have been cut for stable oxygen isotope and helium 3 measurements. In 2003 drilling was resumed using the 'Hans Tausen' drill and small amounts of ethonal. The average core length increased to 1.1 m, close to full size cores using the 'Hans Tausen' drill and the core quality was good. After 84m of drilling bedrock was reached 17 July 2003. The liquid level in the borehole was kept 180 m above surface in order to have a lower

Figure 3
Refrozen subglacial water hanging under the drill. The water is reddish even though this picture plats it as yellow. The refrozen water has frozen as the drill was pulled up and is contaminated by the drill liquid.

pressure in the borehole liquid than the surrounding ice and the subglacial water system. As the drill reached bedrock 8 kg of pink subglacial water was recovered on and in the drill. The subglacial water entered the lowest 45 m of the borehole. The borehole was left so the subglacial water could freeze undisturbed and it is our hope to drill these 45 m of refrozen subglacial water in 2004.

Discussion

The climate record from NorthGRIP (stable oxygen isotope measurements) contains ice back to 123.000 years BP. The annual layer thickness is still of the order of 1 cm in the 123.000 year old ice. No abrupt climate changes are observed in the Eemian part of the record. The NorthGRIP core contains 30 m of from the transition from warm Eemian climate to cold glacial ice and we hope to be able to resolve the single annual layers through this period.

The NorthGRIP ice core contains the most detailed record of the glacial period and the termination of the Eemian period. Continiuos measurements of soluble and insoluble impurities and optical line scan are very promising for producing a dated climate record produced by counting the layers. An example is shown on the figure below. Together with the EPICA ice cores we have very unique records for studies of the evolution of the climate system during the last 123.000 years.

As an (unexpected) add on to the NorthGRIP program we have recovered subglacial water. The water is very red and contains a large amount of gas. Pilot studies have been made on the refrozen subglacial water so we know the O18-value is 34o/oo, a typical Eemian value, the reddish impurities consist of very fine grained material and DNA can be recovered from the ice but the materiale is too contaminated to be conclusive.

We have great expectations for the 45m long frozen column of subglacial water to be recovered in 2004. The material is less contaminated and contains water and material from an ecosystem that has been sealed from the surface in several million years.

Project Name: **VOSTOK**

Major science objectives:

Complete the ice core data acquisition and the interpretation of the climatic record over several climatic cycles.

Study of the properties of the accretion (Lake Vostok) ice and its microbiological content.

Drilling the next 50 meters of the accretion ice to obtain new data on Lake Vostok water composition.

Characteristics of the drill site(s): Vostok Station is located at 78°28' S, 106°48' on the ice-flow line, which starts at Ridge B and passes over the southern part of Lake Vostok. Ice-sheet thickness is 3750 m; surface ice velocity is 2-3 m yr^{-1}; mean accumulation rate is 2.0 g cm^{-2} yr^{-1}; mean annual temperature is –55.5 °C.

Characteristics of the core: The diameter of the ice core is 10 cm

Countries and Institutions participating: The ice core down to 3623 m has been obtained in the frame of Russia-France-US project. The ice core analyses and interpretation is performed mainly by institutions and laboratories from these three nations. Recently some other nations (Japan, Korea) have been contributing to different measurements.

The planed deepening of the hole at Vostok (by 50 m) is currently a Russian initiative.

Funding Agencies: In Russia, the Antarctic field operations are performed and funded through the Russian Antarctic Expedition; the ice core analyses and data interpretation are carried out and funded through the long-term Federal Targeted Program "World Ocean", Subprogram 9 "Antarctica", Project 4 "Investigations of Lake Vostok, deep ice drilling, ice core study and paleoclimate research".

In France, the funding agencies are IPEV (French Polar Institute), and CNRS. In USA, the funding agency is NSF.

Schedule (i.e., start and end dates, milestones): The next 50 meters are planned to be drilled in the 04-05 season.

Name of drill system: Electromechanical drill KEMS-132 designed and built in St. Petersburg Mining Institute.

Drilling fluid: The mixture of kerosene and halogenated solvent (Forane 141b) used as a densifier.

Primary contact person(s): V. Lipenkov, D. Raynaud, E. Brook

Web Site:

European Project for Ice Coring in Antarctica (EPICA) Dome C

Major science objectives: The aim of EPICA Dome C is to produce the longest ice core record to date of climate and forcing factors, and at a resolution not previously available over much of the record. (This project is closely linked to EPICA-DML, which aims to produce a shorter, but higher-resolution record facing the Atlantic).

Characteristics of the drill site(s):

Dome C - 75°06'S, 123°21'E, 3233 m asl

Ice thickness: 3309 ± 22 m

Accumulation rate: 25 kg m^{-2} yr^{-1}

Mean annual temperature: -54.5°C

Dome site

Characteristics of the core:

Annual layers not countable

>800 kyr, probably 900 kyr available.

Countries and Institutions participating:

Numerous institutions in 10 European countries: Belgium (Free University of Brussels), Denmark (University of Copenhagen), France (LGGE (Grenoble), LSCE (Saclay), IPEV (Brest), and other associates), Germany (AWI Bremerhaven and other associates), Italy (ENEA-PNRA, Universities of Milan, Florence, Venice, Trieste and others), Netherlands (IMAU Utrecht), Norway (Norwegian Polar Institute), Sweden (University of Stockholm), Switzerland (University of Bern and other associates), UK (British Antarctic Survey and other associates)

Funding Agencies: European Union, and national funding agencies in all 10 countries. Organised under auspices of European Science Foundation, which is not however a funding agency.

Schedule: Started drilling first time in 1996. 3200 m depth reached in 2003, aiming for bedrock in next year or so.

Name of drill system: EPICA drill

Drilling fluid: D30 + HCFC 141b

Primary contact person(s):

Chair of Steering Committee: Heinz Miller

Chair of science sub-group: Eric Wolff

Chair of drilling sub-group: Jakob Schwander

Chief Driller Dome C: Laurent Augustin

Web Site: http://www.esf.org/esf_article.php?language=0&article=85&domain=3&activity=1

Project Name: **Berkner Island drilling project**

Major science objectives: The project will produce a bedrock core from this separate ice dome embedded in the Ronne-Filchner Ice Shelf. The aim is to produce a high resolution climate record spanning the past 35 kyrs, focussed on a regional picture of change within the Weddell Sea sector of Antarctica, a critical region to the transport of energy via the Atlantic deep water currents. The record from Berkner Island is crucial to understanding the phasing of climate change between the South Atlantic and the Antarctic and Arctic regions during the transition from the Last Glacial Maximum (LGM) to the Holocene. It will also provide a high resolution record of the Holocene in this sector of the continent. An additional goal will be to determine whether Berkner Island was over-ridden by inland ice at any point during the period covered by the core.

Characteristics of the drill site(s):

Berkner Island South Dome, Thyssenhöhe, 79°34'S, 45°47'W, 890 m asl.

Thickness: 950 m

Accumulation rate: 130 kg m^{-2} yr^{-1}

Mean annual temperature: -26°C (estimated bed temperature -12°C)

Dome site

Characteristics of the core:

Expect annual layers certainly throughout Holocene, probably throughout

Expect >30 kyr in stratigraphic order

Countries and Institutions participating: UK (BAS), France (LGGE, IPEV, others), Germany (U. Heidelberg), Netherlands (IMAU)

Funding Agencies: British Antarctic Survey (BAS, UK), IPEV (France).

Schedule (i.e., start and end dates, milestones): Drilled to 84 m, casing emplaced in 2002/03. Drilled to 526.57 m in 2003/04. Further drilling ongoing with aim of reaching bed in 2004/05.

Name of drill system: French 1000 m drill.

Drilling fluid: D60 with densifier HCFC141b.

Primary contact person(s): Dr Robert Mulvaney (rmu@bas.ac.uk)

Web Site: No specific Berkner page at present, but general context of programme can be seen at

http://www.antarctica.ac.uk/BAS_Science/Programmes/SAGES/index.html

Project Name: **Ice core drilling on the Hofsjökull ice cap**

Major science objectives: An ice coring project was carried out at 1800 m elevation on Hofsjökull, a temperate ice cap in Central Iceland, in August 2001. A shallow drill was used to retrieve a 100 m long ice core at the summit of the ice cap in 9 days. The water table in the ice cap was encountered at 35 m depth, but it was possible to continue drilling below the water level in spite of numerous difficulties.

The ice core was processed at the Alfred Wegener Institute in Bremerhaven, Germany. Results indicate that one of the major aims of this pilot project, accurate identification of annual layers in the ice core by continuous measurements of wind-blown dust of local origin, has been successfully achieved. 33 annual layers have been identified and the average net balance of the drilling site in the period 1968-2001 is found to be 3.3 m ice/year. Tephra layers from the 1980 and 1991 eruptions in Hekla helped constrain the dating.

Results indicate a good match between precipitation variations on Hofsjökull and at the nearby meteorological station Hveravellir, and there are indications that $\delta^{18}O$ variations due to seasonal and decadal temperature changes are not completely obliterated by summer melting. Soluble impurity content is dominated by the marine aerosol, but washout of major ions occurs in summer. DEP conductivity is correlated with ion concentration. Bubble-free meltlayers comprise about 15% of the core and the crystal size increases rapidly downward.

Characteristics of the drill site(s):

Location: Summit of Hofsjökull (1790 m a.s.l.), a 900 km^2 ice cap in Central Iceland

Ice thickness: 300 m at drilling site, which is situated above the eastern rim of a subglacial volcanic caldera. The maximum thickness of the ice cap is 750 m, within the caldera.

Accumulation rate: 3.3 m ice equivalent/year (average 1987-2002). Very little summer melting.

Mean annual temperature: - 5 °C

Ice dynamics: Dome summit, located above a subglacial caldera rim.

Characteristics of the core:

Greatest age to which annual layers are preserved: 33 years (1968 AD)

Age of oldest ice that is in stratigraphic order. Same

Countries and Institutions participating:

Hydrological Service, National Energy Authority, Iceland; Icelandic Meteorological Office; Science Institute, University of Iceland; Alfred Wegener Institute, Bremerhaven, Germany

Funding Agencies: Icelandic Research Council; US National Geographic Society (Committee for Research and Exploration); Alfred Wegener Institute

Schedule (i.e., start and end dates, milestones): Core drilled in 2001.

Name of drill system: Shallow drill of Alfred Wegener Institute, Germany

Drilling fluid: Water (temperate ice cap, water table at 35 m depth).

Contact person: Thorsteinn Thorsteinsson (thor@os.is)

Web Site: www.os.is/~thor

References:

Thorsteinsson et al. (2002). Ice core drilling on the Hofsjökull ice cap. *Jökull*, 51, 25-41.

Thorsteinsson et al. (2002). Ice core drilling on the Hofsjökull ice cap for measuring mass balance. Research report to National Geographic Society (Committee for Research and Exploration).

Project Name: **Ice core drilling on the Grímsvötn ice shelf**

Major science objectives: The purpose of the Grímsvötn core drilling project in 2002 was to:

Test an improved system for ice-core recovery in a water-filled borehole.

Test methods for ice-core processing in the field and perform continuous measurements of the dust concentration in the core on site.

Obtain a record of dust and tephra deposition on the ice shelf, covering a period of 50-100 years. Since the dust and tephra is released into the subglacial lake as the ice shelf is melted from below, such a record can provide important new information on the input of particulates into the lake.

Compare the dust record with an existing 50-year record of winter accumulation from the Grímsvötn ice shelf, and study if the core record can be correlated with climatic parameters.

Study the general stratigraphy of the ice core and obtain information on the rate of ice-crystal growth within the ice shelf.

Characteristics of the drill site(s):

Location: Ice shelf covering the Grímsvötn subglacial lake, 1350 m a.s.l. during drilling (elevation variable due to periodic emptying out of lake)

Ice thickness: 280 m at drilling site.

Accumulation rate: ~2.8 m ice equivalent/year. Considerable summer melting and in some years the entire winter accumulation melts away in summer.

Mean annual temperature: - 3 °C

Ice dynamics: Central part of 25 km^2 ice shelf. Ice flows into depression mainly from the northeast (velocity ~20 m/yr). Catchment area ~160 km^2.

Characteristics of the core:

Greatest age to which annual layers are preserved: ~65 years (1937 AD)

Age of oldest ice that is in stratigraphic order. Same

Countries and Institutions participating: Hydrological Service, National Energy Authority, Iceland; Icelandic Meteorological Office; Science Institute, University of Iceland; Alfred Wegener Institute, Bremerhaven, Germany; Glaciology Department, University of Copenhagen, Denmark; Geology Department, University of Tromsoe, Norway

Funding Agencies: Icelandic Research Council; US National Geographic Society (Committee for Research and Exploration)

Schedule (i.e., start and end dates, milestones): Core drilled in 2002

Name of drill system: Modified shallow drill of Alfred Wegener Institute, Germany

Drilling fluid: Water (temperate ice cap, water table at 17 m depth).

Contact person: Thorsteinn Thorsteinsson (thor@os.is)

Web Site: www.os.is/~thor

References:

Research Report to National Geographic Society, Committee for Research and Exploration.

Abstract of presentation at Third International Conference on Mars Polar Science and Exploration, Alberta, Canada, Oct. 2003.

Project Name **Second deep ice coring project at Dome Fuji, Antarctica**

Major science objectives: The purpose of the project is to carry out ice coring to the bottom of 3,030 m in depth at Dome Fuji, Dronning Maud Land, and to perform detailed study on climate and environment changes in global scale for a period of more than 800,000 years in the past including the emergence of 100 k-year glacial cycles in Quaternary period and the Brunhes-Matuyama magnetic reversal.

Characteristics of the drill site: Very top of the Dronning Maud Land, east Antarctic ice sheet at the altitude of 3,810 m. No horizontal ice flow is considered at least to the depth of 2,500 m by the ice fabric study and no layer disturbances are expected even at the depth deeper than 2,500 m judging from precise radio-echo sounding.

Characteristics of the core: Age of the bottom ice at 3,030 m below the surface is expected to be older than 800,000 years.

Countries and Institutions participating: Japan: National Institute of Polar Research, Institute of Low Temperature Science of the Hokkaido University and other many institutions. China: Polar Research Institute of China (planned)

Funding Agency: National Institute of Polar Research

Schedule:

2002/2003 summer Construction of new drilling site

2003 winter Preparation of drilling site and drilling system

2003/2004 summer Final test of improved drill and start coring

Coring depth: 362.31 m

2004/2005 summer Continuation of the ice coring

2005/2006 summer End of the ice coring

2006/2007 summer Extra season

Name of drill system: Improved JARE-deep ice core drill

Drilling fluid: Butyl acetate

Primary contact person: Yoshiyuki Fujii, National Institute of Polar Research

Web Site: http://domefuji.at.infoseek.co.jp/japan/index-j.html (Japanese edition)

Project Name: **Ice core drilling project at McCall Glacier, Alaska**

Major science objectives: The purpose of the project is 1) to reconstruct high time resolution records of climate and environment change from the various parts of the Arctic region, 2) to know the relation to global climate change as well as the Arctic climate mode such as Arctic Oscillation (AO) and North Atlantic Oscillation (NAO), and 3) to clarify the role of the Arctic on global change. The research objective of the project is to obtain ice at the McCall glacier, Brooks Range (2400m), where various kinds of glaciological research have been done since IGY year and long-term data are accumulated but no ice core sampling to reconstruct pale-environment has not been accomplished.

Characteristics of the drill site: It is planned to make a drilling at the flat accumulation basin with less summer melt water effect. The ice thickness is measured as 150 m. The altitude is about 2500 m.

Characteristics of the core: As annual accumulation rate is estimated to be about 1 m in thickness, the whole depth core is expected to cover past 200 years.

Countries and Institutions participating: Japan: Kitami Institute of Technology, National Institute of Polar Research, Tokyo Institute of Technology US: University of Alaska Fairbanks. Belgium: Vrije Universiteit Brussel.

Funding Agency: Japan: National Institute of Polar Research

Schedule:

2003 summer	Reconnaissance research
2004 spring/summer	Ice coring to the bottom at the accumulation area

Name of drill system: JARE-shallow mechanical drill

Drilling fluid: Not used.

Primary contact persons: Japan: Prof. Shuhei Takahashi, Kitami Institute of Technology

US: Dr. Matt Nolan, Institute of Northern Engineering, University of Alaska Fairbanks

Web Site: No

Project Name: **Ice core drilling project at Mt. Wrangell, Alaska**

Major science objectives: The purpose of the project is to reconstruct flux of ion transported as Aeolian dust from China in the past several hundred years to confirm shortage of iron in the bio-geochemical cycle in the northern Pacific Ocean.

Characteristics of the drill site: It is planned to make a drilling at center of the flat snow buried volcanic crater of Mt. Wrangell with the ice thickness of about 1,000 m. The altitude is about 4,100 m.

Characteristics of the core: As annual accumulation rate is estimated to be 1 to 1.5 m in depth, the 300 m deep core is expected to cover past 300 to 500 years.

Countries and Institutions participating: Japan: Institute of Low Temperature Science, Hokkaido University, and Research Institute for Humanity and Nature US: Geophysical Institute, University of Alaska Fairbanks. Russia: Institute of Volcanology, Russian Academy of Sciences.

Funding Agency: Institute of Low Temperature Science and Research Institute for Humanity and Nature

Schedule (i.e., start and end dates, milestones):

2003 summer	Reconnaissance research. Ice coring to 50 m depth.
2004 spring/summer	Ice coring to 300 m depth
2005 spring/summer	Borehole measurement

Name of drill system: Shallow mechanical drill with titanium cutters and barrel

Drilling fluid: Not used.

Primary contact persons: Japan: Prof. Takayuki Shiraiwa, Institute of Low Temperature Science, Hokkaido University
US: Prof. C.S. Benson, Geophysical Institute, University of Alaska Fairbanks

Web Site: No

Project Name: **Ice core drilling project in east Tian-Shan Mts., China**

Major science objectives: The purpose of the project is to reconstruct mass balance and dust events in the past to evaluate aridification in the central China.

Characteristics of the core: Whole depth ice coring is planned at the top of ice cap in east Tian-Shan Mts. As annual accumulation rate is estimated to be 0.5 m in depth, the 60 m deep core is expected to cover past 100 to 200 years.

Countries and Institutions participating: Japan: Research Institute for Humanity and Nature, and Nagoya University China: Hunan Normal University

Funding Agency: Research Institute for Humanity and Nature

Schedule (i.e., start and end dates, milestones):

2003 summer Reconnaissance research.

2004 summer Reconnaissance research for better access.

2005 spring/summer Ice coring.

Name of drill system: Shallow mechanical drill.

Drilling fluid: Not used.

Primary contact persons: Japan: Prof. Masayoshi Nakawo, Research Institute for Humanity and Nature China: Prof. Hang Hunan Normal University

Web Site: No

Project Name: **Swiss Participation in Talus Dome Project (Antarctica).** Project description see Italian Reports

Major science objectives: Greenhouse gases, CFA

Characteristics of the drill site(s):

Countries and Institutions participating:

F*unding Agencies:*

Schedule (i.e., start and end dates, milestones):

2004/5 Put in, Camp, Casing

2005/6 Start deep drilling

Name of drill system:

Drilling fluid:

Primary contact person(s): T. Stocker, Climate and Environmental Physics, University of Bern

Project Name: **Varves, Ice cores, and Tree rings – Archives with annual resolution (VITA)**

Major science objectives: The project VITA aims to compare proxy climate records from trees, lakes, peat bogs and glaciers within a small region of Switzerland. A suitable site for the extraction of the VITA ice core archive (a 300-500 year annually resolved record) was thought to be the Fiescherhorn glacier, Berner Oberland. VITA is a subprogram of the Swiss National Centre of Competence in Research on Climate (NCCR Climate).

Characteristics of the drill site(s): Fiescherhorn glacier, 46°33´N, 8°4´E, 3900 m asl, thickness: 150 m, accumulation rate: 1.8 m water equivalent, flank flow

Characteristics of the core:

Age of the oldest ice: about 400 years

Countries and Institutions participating: Switzerland: Paul Scherrer Institut, University of Bern, Laboratory of Hydraulics, Hydrology and Glaciology/ETH Zurich

Funding Agencies: Swiss National Science Foundation

Schedule (i.e., start and end dates, milestones): Start: March 2002, end: April 2005

Name of drill system: FELICS

Drilling fluid: None

Primary contact person(s): Margit Schwikowski

Project Name: **Paleo climate from Andean ice cores and lake sediments**

Major science objectives: The major objective of the project is the reconstruction of climatic variations on annual, interannual and decadal time scales of the last millennium from ice cores and varved lake sediments in a region in South America influenced by extratropical Westerlies (~35° to ~28°S). In this region a significant negative correlation between SOI and the amount of winter precipitation is well documented. Thus, paleoclimatic archives with annual resolution are expected to reveal information about ENSO in the past. A novel aspect is that in this region a large number of small pro-glacial lakes is located next to glaciers allowing for direct comparison of climate signals in two different types of archives for the same window of time.

Characteristics of the drill site(s): Drilling planned for February 2004 on La Ollada glacier on Mercedario, 31°58'S, 70°07'W, 6100 m a.s.l., Argentina, thickness about 130 m, flank flow

Characteristics of the core: Not yet known

Countries and Institutions participating: Switzerland: Paul Scherrer Institut, University of Bern, Laboratory of Hydraulics, Hydrology and Glaciology/ETH Zurich, Chile: Centro de Estudios Cientificos, Valdivia

Funding Agencies: Swiss National Science Foundation

Schedule: Start: 1 May 2003, end: 30 April 2006, core drilling in February 2004

Name of drill system: FELICS

Drilling fluid: None

Primary contact person(s): Margit Schwikowski

Project Name: **Past climate changes derived from a high-altitude ice core in Patagonia**

Major science objectives: This is a project for retrieving and analyzing one deep (100-150 m) high-mountain ice-core from the Southern Patagonia Icefield, Chile. The drilling site will be selected by glaciological and geophysical methods. Because of the severe weather conditions, special logistics including high-altitude mountaineering techniques and helicopters are required. Chemical and physical analyses of the ice core will allow for the reconstruction over several centuries of a series of paleoenvironmental and climatic proxy data unique for Patagonia. The recovery of deep ice cores from Patagonia is an urgent task because of the rapid retreat and melting of the valuable glacier archives.

Characteristics of the drill site(s): Cordón Mariano Moreno (3,300m), ice cap

Characteristics of the core: Not yet known

Countries and Institutions participating: Switzerland: Paul Scherrer Institut, Chile: Centro de Estudios Cientificos, Valdivia, Universidad de Chile, Santiago

Funding Agencies: National Geographic Society, FONDECYT (Chilean National Science Foundation)

Schedule Start: February 2004, Drilling in September 2004 or later, End: December 2007

Name of drill system: FELICS

Drilling fluid: None

Primary contact person(s): Gino Casassa, Margit Schwikowski

Project Name **Siple Dome, Antarctica**
This is the first core in the WAISCORES program.

Major science objectives: Investigate the climate and ice dynamics of West Antarctica during the last 100,000 years.

Characteristics of the drill site(s):

Location: 81.65°S 148.81°W, 621 m A.S.L.

Thickness: 1004 m

Accumulation rate: 13 cm/yr

Mean annual temperature: -24.5° C

Ice dynamics: Dome flow

Characteristics of the core:

Greatest age to which annual layers are preserved: 8,600 years

Age of oldest ice that is in stratigraphic order: 97,000 years

Countries and Institutions participating: multiple universities and national labs from the U.S.A.

Funding Agencies: Glaciology program, National Science Foundation

Schedule: Drilling was completed in January 1999

Name of drill system: US 5.2 inch system

Drilling fluid: Butyl Acetate

Primary contact person: Ken Taylor, email: Kendrick@dri.edu

Web Site: waiscores.dri.edu

Additional Information:

Peer Reviewed Publications Related to the Siple Dome Ice Core Project

Ahn J., Wahlen M., Deck B., Brook E., Mayewski P.A., Taylor K.C., and White J.W., A record of atmospheric CO_2 during the last 40,000 years from the Siple Dome, Antarctica ice core. In review for JGR.

Alley, R.B., J. Marotzke, W.D. Nordhaus, J.T. Overpeck, D.M. Peteet, R.A. Pielke, Jr., R.T. Pierrehumbert, P.B. Rhines, T.F. Stocker, L.D. Talley and J.M. Wallace. Abrupt climate change. Science 299, 2005-2010 (2003).

Bay R.C., P. B. Price, G. D. Clow, and A. J. Gow. Climate logging with a new rapid optical technique at Siple Dome; Geophysical Research Letters 28, 4635-4638 (2001).

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Elsberg, D.H., W.D. Harrison, M.A. Zumberge, J.L. Morack, E.C. Pettit, E.D. Waddington, and E. Husmann. Depth- and time-dependent vertical strain rates at Siple Dome, Antarctica. In review for Journal of Glaciology.

Hawley, R.L., E.D. Waddington, R.B. Alley and K.C. Taylor. Annual layers in polar firn detected by borehole optical stratigraphy. Geophysical Research Letters 30(15), 1788, doi:10.1029/2003GL017675, 2003. http://www.agu.org/pubs/crossref/2003/2003GL017675.shtml

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Nereson, N.A., E.D. Waddington, C.F. Raymond and H.P. Jacobson. 1996. Predicted age-depth scales for Siple Dome and inland WAIS ice cores in West Antarctica. Geophysical Research Letters 23(22), 3163-3166.

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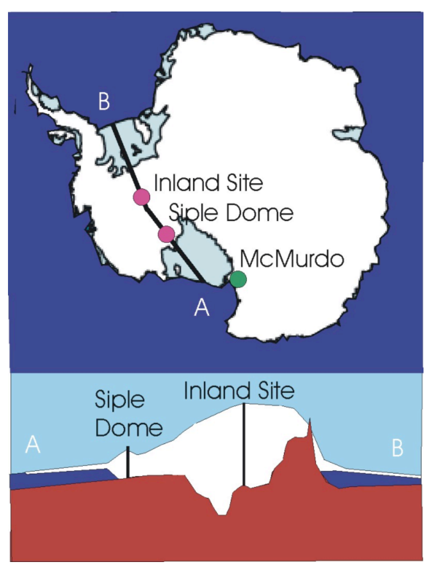
Project Name **WAIS Divide Core**
This is the second core in the WAISCORES program (tentative).
Major science objectives: Investigate the climate, ice dynamics and biology of West Antarctica during the last 100,000 years.
Characteristics of the drill site(s):
Location: ~111.5° W 79.5°S, elevation: 1800 m
Thickness: ~3300 m
Accumulation rate: ~ -30 cm/yr
Mean annual temperature:~ -30° C
Ice dynamics: Divide or near divide flow
Characteristics of the core:
Greatest age to which annual layers are expected: ~40,000 years
Age of oldest ice that is in stratigraphic order: ~100,000 years
Countries and Institutions participating: multiple universities and national labs from the U.S.A.
Funding Agencies: National Science Foundation, mostly the Glaciology program
Schedule: Construction of the drill and site selection activates are underway.
Drilling test in Greenland: June 2005
Site preparation: November 2005 (pending approval of funding)
Deep drilling: November 2006 + several more field seasons (pending approval of funding
Name of drill system: A new ice coring system is being built by Ice Core Drilling Services at the University of Wisconsin.
Drilling fluid: not yet determined
Primary contact person: Ken Taylor, email: Kendrick@dri.edu
Web Site: The science plan is at http://www.waiscores.dri.edu/Waisfinal.pdf
Additional Information:
NSF has funded the site selection effort and the design and testing of the drill. A proposal to recover the core, and proposals for the science to be done on the core, will be submitted in June 2003.
Some of the specific topics that will be address are listed below.
•What are the characteristics of natural climate change during the last 100,000 years?
•Is recent climate change abnormal?
•What is the influence of solar activity on climate?
•How did the Southern Hemisphere respond to the well-documented abrupt climate changes in the Northern Hemisphere? •What was the relationship between climate and atmospheric carbon dioxide during pre-industrial times?
•What biological activity occurs at the contact between the bottom of the ice sheet ice and the bed?
•What biological activity occurs within the ice sheet?
•What does a continuous collection of biological material spanning the last 100,000 years tell us about ecological and evolutionary process?
•How is the West Antarctic Ice sheet changing and what is the influence of this change on sea level?



WAIS Divide Location Map

Project Name **USITASE**

Submitted by the Members of the United States Contribution to the International Trans Antarctic Scientific Expedition (US ITASE) Paul Mayewski (Chief Scientist)

Introduction

Antarctica is encircled by the world's most biologically productive oceans, is the largest reservoir of fresh water on the planet, is a major site for the production of the cold deep water that drives global ocean circulation, is a significant influence (through albedo effects) on Earth's energy budget, and is a crucial driving component for Southern Hemisphere atmospheric circulation. Antarctica thus plays a pivotal role in the coupling of critical components in Earth's complex climate system. Yet despite its importance, Antarctica is the most poorly documented continent, in a climate sense, over the instrumental era of climate monitoring. Fortunately, it has the potential, through ice core sampling, glacier geophysics, and atmospheric chemistry programs, to be the best understood over multi-decadal to centennial and longer time scales. The International Antarctic Scientific Expedition (ITASE) is a nineteen-nation strong, multidisciplinary research program endorsed by the Scientific Committee on Antarctic Research (SCAR) and the International Geosphere Biosphere Program (IGBP) (Mayewski and Goodwin, 1997). It is designed to reconstruct the recent climate history of Antarctica through ice coring and related observations along a network of extensive intra-continental traverses (Figure 1).

West Antarctica and Phase One of US ITASE

The first four years of the United States contribution to ITASE (1999-2003) have focused on a series of traverses extending over West Antarctica (Figure 1). West Antarctica is of particular importance because this region is strongly linked with climate variability at lower latitudes and therefore offers an opportunity for understanding regional to global scale climate variability. In particular, the El Niño-Southern Oscillation (ENSO) phenomenon in the tropical and the subtropical Pacific Ocean is known to impact West Antarctica from the Ross Sea to the Weddell Sea as part of the Pacific-South American (PSA) teleconnection pattern. The "ENSO teleconnection" exhibits substantial seasonal to decadal scale variability.

The suite of sub-annually resolved climate records retrieved by US ITASE will allow climate variability over West Antarctica to be established on inter-annual through centennial timescales. In combination with deep ice cores – some already completed, others to be drilled in the near future – US ITASE will also contribute to the understanding of climate on millennial time scales. Information about climate variability in the middle and high latitudes of the Southern Hemisphere is obtained, through calibrations developed between US ITASE ice core records and direct atmospheric observations collected over the last 45 years. A primary goal of the calibration work is to document variation in the ENSO teleconnection and to better understand the relationship between global scale variability and regional Antarctic climate. This will establish a record of natural fluctuations of ENSO frequency and amplitude prior to the beginning of anthropogenic influence on climate, and will help in determining whether the frequency of El Niños changed in the late 20th century relative to earlier periods. This is a question of great importance because climate models indicate El Niño frequency may be enhanced due to global warming. Another important goal is to better understand the Antarctic Oscillation (AAO) (also known as the Southern Annular mode or the high latitude mode). It is the dominant atmospheric teleconnection pattern in West Antarctica after ENSO, and may be the most important for the rest of the continent. Recent changes in the AAO have been related to anthropogenic ozone destruction (Thompson and Solomon, 2002), but the existing record is too short to establish whether those changes are unprecedented. ITASE research will contribute important data to resolving this question.

US ITASE also contributes to our knowledge of current and future projected changes in sea level by improving understanding of ice sheet mass balance. The US ITASE logistics platform provides a base for the collection of field mass balance measurements for large portions of West Antarctica, an area which currently accounts for the greatest uncertainty in global estimates of ice sheet contributions to sea level change. US ITASE is examining two of the major West Antarctic ice drainages (Ross Sea catchment and Amundsen Sea catchment) where existing studies indicate contrasting styles of behavior (Shepherd and others, 1998; Joughin and Tulaczyk, 2002).

US ITASE Program Description

US ITASE has developed a suite of field experiments and observations utilizing an over snow traverse platform (Figure 2) that has now covered >5000 km (Figure 3) with studies at a variety of spatial scales extending from the subglacial bedrock (>3000 m), through the surface of the ice sheet, to >20 km into the atmosphere (Figure 4). For each of several stations, spaced approximately 100-200+ km apart (Figure 3), we have obtained high-resolution isotopic, geochemical, and physical measurements from numerous ice core and snowpit profiles ranging in depth from 15-115m (typical sites 60-70m). At each site, global positioning system (GPS) measurements of differential vertical velocity are gathered to study mass balance variations. Calculated rates of ice sheet thickness change from the GPS work are used for interpreting the ice core records of snow accumulation, and as ground-truthing for surface elevation histories derived from NASA's ICESat laser altimetry mission.

In addition to the ice core and GPS measurements, we have obtained high resolution radar records of the entire firn structure to reveal the spatial variation in annual layering and to interpolate accumulation rates between coring sites. This radar work is unprecedented in its combination of high resolution (<35 cm) and depth (>100 m). At each site, detailed snow stratigraphy measurements are also made, including annual layering, grain growth, permeability and microstructure profiles which are important for understanding the influence of vertical and horizontal mass transport on the geochemical species used in the climate reconstruction. This is complimented by measurements, both in the snow and in situ in the atmosphere, of reactive chemical species (eg., formaldehyde, hydrogen peroxide), that may be only partly preserved in the ice, yet are critical to our understanding of global atmospheric chemistry. Finally deep radar soundings are used to correlate surface and bottom topography, to assess basal melting, and to aid in the selection of specific sites for future deep coring projects.

Results

Although the final field season for the first phase of US ITASE has just been completed and there remains much data processing and laboratory work to do, initial results from US ITASE are impressive. A few examples are given below:

Shallow radar Variable accumulation rates and ice movement can deform stratigraphy and thus affect the vertical density distribution of annual layers. However, field measurements show that slow variation of amplitude in these parameters (eg., Figure 3) along the US ITASE traverse routes allow single ice cores to be representative well beyond local scales.

Internal stratigraphy in both shallow and deep (discussed below) radio echo sounding records represent isochronal events. This has been validated by sub-annual scale dating of ice cores penetrating these layers, providing therefore a record of depositional and ice flow history along the traverse.

Horizons detected by shallow, short-pulse radar transmitting near 400 MHz are particularly continuous along or near ice divides, are continuous within 2 m of the surface, get stronger into the firn, and still persist beneath the firn, although they weaken with greater depth (Arcone, 2002). Away from ice divides, they may plunge up to 35 meters yet maintain their amplitude. For this latter reason, and since they are continuous where density is highly variable (nearsurface), and where there should be no density contrasts (beneath the firn), they do not appear to be responses solely to density contrasts, as is the current paradigm for firn. Comparisons between radar horizons and ice core chemical series are in progress.

Deep radar

The bedrock topography and geothermal flux beneath West Antarctica strongly influence ice flow and the overall stability of the ice sheet. Continuous ground-based low frequency radar (eg., Figure 3) characterizes bedrock topography, internal ice stratigraphy, and provides the potential to determine regions of cold and warm based ice. Ice thickness measurements (up to 3200 m depth) contribute to ice flow models that characterize the dynamics in ice core sites.

As with the shallow radar, internal ice reflectors represent isochronal regions, but due to the longer wavelength, are probably longer duration events. Internal ice stratigraphy is mapped along the traverse route with layers as deep as 2200m.

Ice coring

US ITASE utilizes spatially distributed (Figures 3 and 4), multi-parameter ice core measurements to develop climate proxy records (Figure 5). A depth-age scale for each core is produced using the multi-parameter procedure developed for the Greenland Ice Sheet Project 2 (Meese et al, 1997). Parameters containing an annual signal include: visible stratigraphy, major ions, oxygen isotopes, and hydrogen peroxide. The accuracy of the dating within each core and between cores is determined using sulfate peaks from known volcanic eruptions. The presence of several major events in all of the U.S. ITASE ice cores allows precise calibration of annual layer counting between cores (eg., Meese and Gow, 2002).

Temperature dependence of crystal growth rates investigated thus far is consistent with previous measurements across Antarctica and Greenland. However, there is a large gap between –30^{o}C to –50^{o}C in previous studies that we will be able to address with US ITASE data. Snow and firn physical characteristics show large site-to-site variations both on the surface and with depth (Leeman and Albert, 2002). A feedback exists between air-snow vapor transport processes and the physical properties of snow that can induce large site-to-site differences in metamorphism (Albert, 2002). Variations in permeability and microstructure can cause differences in the dynamics of the air-snow transport processes between sites for reversible chemical species. Sites where the air-snow exchange is dominated by ventilation will likely show much greater postdepositional change in reactive species concentrations, while sites where interstitial transport is dominated by diffusion will show better preservation of chemical records. In addition, changes in climate at a given site could make the snow and firn more or less likely to retain the climate signal for reversible species As illustrated in Figure 5, stable isotopes are poorly preserved in the highly permeable firn from a site visited in 1999-2000, but are well preserved elsewhere.

Ice core parameters (eg., methane sulfonate, stable isotopes) and ice sheet surface climate are very closely linked to large-scale atmospheric circulation patterns such as ENSO (Meyerson et al., in press) and the AAO (Schneider and Steig, 2002). Reconstruction of these patterns prior to the instrumental record, which would not be possible with a single ice core, will be achievable with the multi-site, multi-proxy records gathered by US ITASE, As Figure 6a illustrates, data from the ice sheet surface alone (in this case, temperature data derived from satellites) provides sufficient information to reconstruct the ENSO teleconnection pattern over West Antarctica. We have not yet compiled data from all ice cores, but the results are extremely promising, as illustrated by the confirmation with new US ITASE data of the original finding of Kreutz et al. (2000) at Siple Dome, that low pressure anomalies – which may also be related to ENSO forcing – can be detected with ice core sodium concentration data, because advection of sea salt to the ice sheet is enhanced when the Amundsen Sea Low is strong. Using relationships such as these, US ITASE surface climate reconstructions for West Antarctica will ultimately allow for largescale reconstructions of Southern Hemisphere climate variability for sub-annual to multi-decadal and low frequency modes of the climate system, extending far beyond the available instrumental record.

Mass balance

The calculation of local rates of change relies on accurate long term accumulation rate averages derived from ice core stratigraphy. In addition, the interpretation of satellite altimeter derived surface elevation changes in terms of ice equivalent thickness changes requires that temporal variability in accumulation rate be known. Snow accumulation is a standard parameter derived from ice core records. For ice core sites not located on flow divide,s accumulation rate patterns are convolved with ice flow effects due to ice motion through an undulating topography. Local accumulation rates can exhibit variability because of this effect. At each of the US ITASE core sites (eg., Figure 3), we have measured local topography, ice flow, and accumulation rate for the distance up-flow corresponding to the length of the record.

Surface glaciology results from US ITASE sites where data are complete indicate that the interior portion of the ice sheet is close to steady state and is not currently contributing to changes in global sea level. Lower elevations of the Ross Sea drainage, show net thinning of about 10 cm/yr. Repeat GPS occupations of sites in the Amundsen Sea drainage are used by US ITASE to confirm the presence of rapid thinning in this region of WAIS as implied from repeat satellite radar altimetry (Shepherd and others, 1998).

Atmospheric chemistry

Contributions to the understanding of polar atmospheric chemistry and its reconstruction over the past centuries through ice cores include: the characterization of summer boundary layer levels of hydrogen peroxide, organic peroxides, formaldehyde, acetaldehyde and acetone in air above the snow pack and in the interstitial pore space in the firn. Data will be used to estimate the HO_x radical budget with photo-stationary state models.

US ITASE has undertaken the first quantitative measurements of higher organic peroxides over West Antarctica and demonstrated that they consist exclusively of methylhydroperoxide. Trifluoroacetate (a product of atmospheric degradation of HFCs and HCFCs) is also measured in snow pits to develop a better understanding of the processes that control deposition of trifluoroacetate in polar snow because there is concern that this highly stable, man-made molecule will accumulate in the hydrosphere.

Results from US ITASE atmospheric studies will further elucidate the impact of the upper snow pack on levels of atmospheric trace gases in the boundary layer. Measurements of hydrogen peroxide and formaldehyde in air, snow pits, and ice cores are used to validate existing physical atmosphere-snow transfer models and to develop a spatial picture of preservation of these species in snow and firn, Initial results from U.S. ITASE cores demonstrate that the seasonal signal of hydrogen peroxide is preserved at sites where the accumulation rate is sufficiently high and the mean annual temperature sufficiently low.

Conclusions

US ITASE offers the ground-based opportunities of traditional style traverse travel coupled with the modern technology of GPS, crevasse detecting radar, satellite communications and multidisciplinary research. By operating as an over snow traverse US ITASE offers scientists the opportunity to experience the dynamic range of the Antarctic environment. US ITASE also offers an important interactive venue for research (currently eleven integrated science projects – Table 1) similar to that afforded by oceanographic research vessels and large polar field camps, without the cost of the former or the lack of mobility of the latter. Most importantly, the combination of disciplines represented by US ITASE provides a unique, multi-dimensional (x, y, z and time) view of the ice sheet and its history. In its current four year cycle, US ITASE has sampled the environment of West Antarctica over spatial scales of >5000 km, depths of >3000 m, heights in the atmosphere of >20 km, and time periods of several hundred years (sub-annual scale) to hundreds of thousands of years (millennial scale).

Continued US ITASE research, future proposed US ITASE traverses (Figure 1), and collaboration with our international ITASE colleagues, will, in the next several years, provide unprecedented knowledge of past Antarctic climate and ice sheet variability and improve prediction capability.

Acknowledgements

US ITASE is funded by a series of grants from the Office of Polar Programs, National Science Foundation. Logistics support is coordinated through Raytheon Polar Services. Air support is provided by the 109th New York Air National Air Guard. Field science activities are coordinated through the Institute for Quaternary and Climate Studies at the University of Maine (www.ume.maine.edu/USITASE/). US ITASE outreach is conducted by the Museum of Science (Boston) (www.secretsoftheice.org) in cooperation with the University of Maine.

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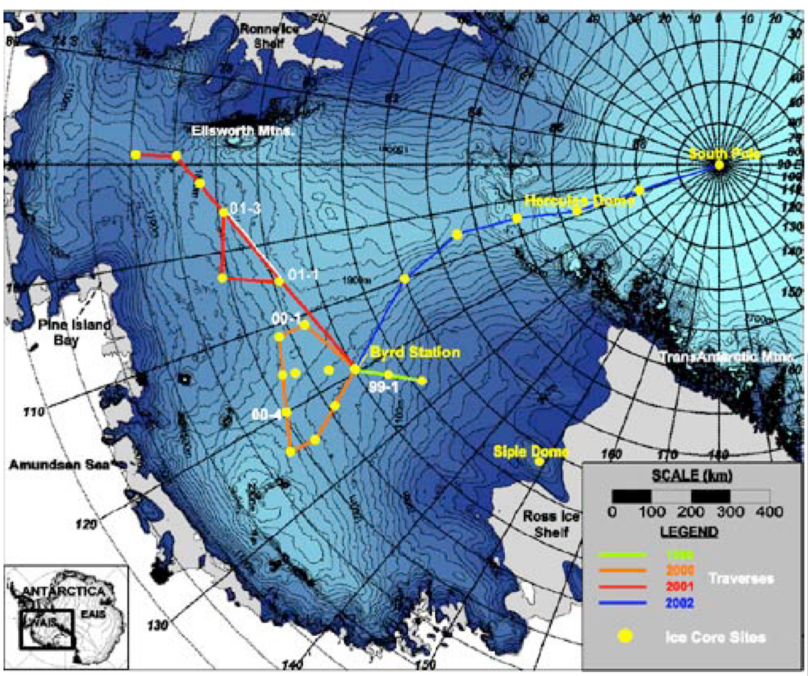

Figure 1 (left) - ITASE traverse routes – completed (solid), proposed (dashed).

Figure 3 – US ITASE traverse routes, WAIS topography and core sites. Data from sites 99-1, 00- 1, 00-4, 01-1, and 01-3 are presented in Figures 4 and 5 12

Figure 2 – US ITASE traverse tractors and sleds. Crevasse detection equipment mounted on lead tractor. Sleds contain berthing, kitchen, fuel drums, scientific equipment, and ice cores.

Table 1 - US ITASE PROJECTS

Research Team Members	Institution	Projects
Mary Albert, Ursula Leeman	CRREL	Snow and firn microstructure
Steve Arcone	CRREL	High resolution radar profiling
Roger Bales, Markus Frey	U Arizona	Hydrogen peroxide and formaldehyde
Joe McConnell	(DRI)	
David Bromwich	OSU	Meteorology
Gordon Hamilton, Blue Spikes	U Maine	Mass balance and satellite image analysis
Ian Whillans	(OSU)	
Bob Jacobel , Brian Welch	St. Olaf	Deep radar
Paul Mayewski, Dan Dixon	U Maine	Glaciochemistry and calibration with instrumental records
Susan Kaspari		
Paul Mayewski	U Maine	Science management
Joe McConnell	DRI	Tri-fluoroacetate
Deb Meese, Tony Gow	CRREL	Stratigraphy and grain growth
Eric Steig, David Schneider	U Washington	Stable isotopes and satellite observations of surface temperature
James White	(U Colorado)	
Chris Shuman	(NASA)	

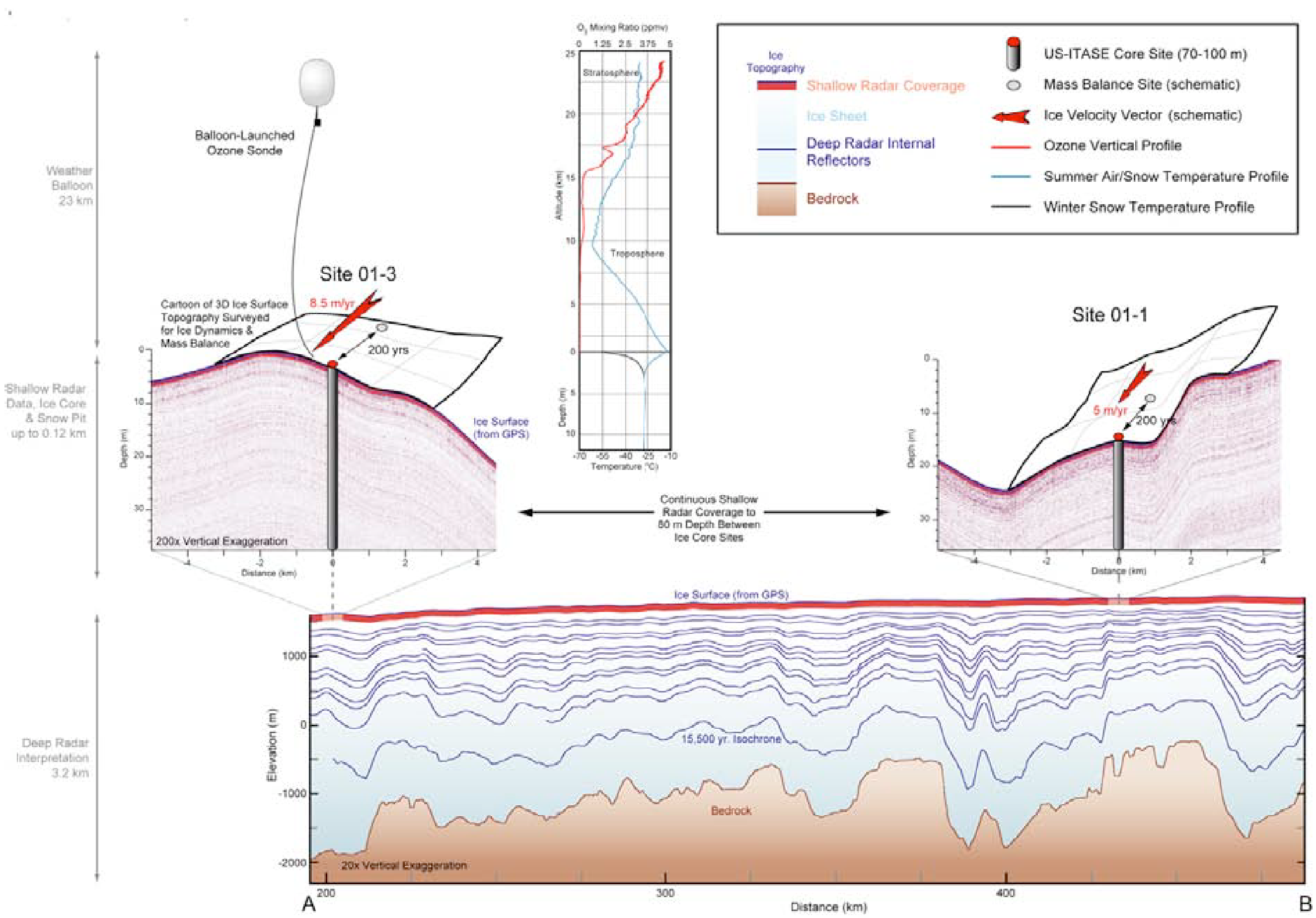

Figure 4: Multi-dimensional approach to the multi-discipline US-ITASE objectives. Studies at a variety of spatial scales extend from the subglacial bedrock surface to over 20 km into the atmosphere. Ice core sites along each traverse route yield 200+ year annually dated climate records. Ice core

site selection is determined by field interpretation of shallow radar data. Numerous measurements are made at each core site to provide context for the ice core climate records. These measurements include: high resolution surface topography maps; snow pit measurements of density, chemistry, and temperature; and meteorological data. Ice mass balance and horizontal velocity studies located 200 years upstream provide past ice flow history for the ice cores. Shallow and deep-penetrating radio echo sounding data tie the ice cores together and provide large-scale context for US-ITASE cores and future deep ice core climate records. Internal stratigraphy in both radio echo sounding records represent isochronal events and a record of depositional and ice flow history along the traverse. The radar data and interpretation, ozone sonde data, and ice topography along the radar profiles shown here are actual examples from the 2001 US-ITASE season. Ice topography, mass balance sites, and ice velocity vectors are shown in schematic to represent results obtained once repeat analyses are completed. See Figure 3 (01-1 and 01-3) for locations of the datasets presented in this figure.

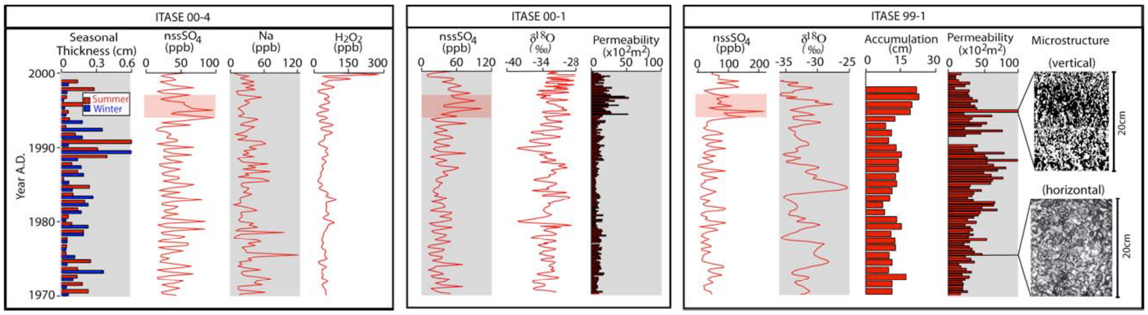

Figure 5 – High-resolution US ITASE ice core records are analyzed for a variety of parameters including: major ion chemistry (Na+, NH4 +, K+, Mg2+, Ca2+, Cl-, NO3 -, SO4 2-), stable isotopes, reversibly deposited species (H2O2, HCHO) and physical properties. Annual layers are determined through high resolution sampling (minimum 10 samples per year to significantly greater sampling) and identification of seasonality in a variety of parameters (eg., Na, non seasalt (nss) SO4, seasonal thickness, and where not post-depositionally altered stable isotopes and H2O2). Annual layer dating is calibrated using known volcanic events identified by SO4 spikes traced from site to site. Volcanic eruptions in mid 1990's are picked up in all three locations as highlighted in the figure. Changes in accumulation rate are derived from measurements of density (not shown) and annual layer thickness. Changes in other climate parameters such as temperature and sea level pressure are developed from calibration between instrumental and ice core records of stable isotopes and major ions, respectively (eg., Figure 6). Measurements of permeability and microstructure are used to assess post-depositional changes in the firn and snow and their effects on reversibly deposited chemical species. Significant site to site variations exist in permeability and microstructure. The data shown come from the upper sections of ice cores collected during the 99-00 and 00-01 field season. See Figure 3 for locations of the datasets (99-1, 00-1, 00-4) presented in this figure.

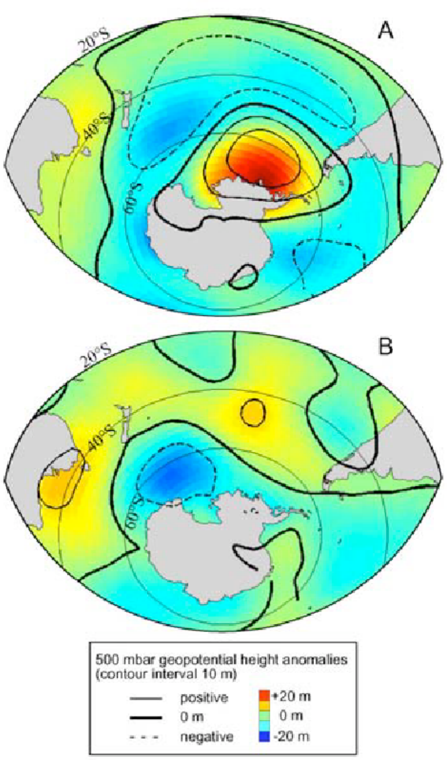

Figure 6 – Covariance of atmospheric circulation with time series from the Antarctic ice sheet surface and from global climate indices. A) Contours show covariance of annual 500 mbar geopotential height (NCEP/NCAR reanalyses) with the Southern Oscillation Index (sign reversed to illustrate the typical pressure anomaly pattern characteristic of an El Niño year). Colors show covariance with the 2nd principal component (time variation of the spatial pattern) of ice sheet surface temperature derived from passive microwave satellite observations (Schneider and Steig, 2002). B) Contours and colors show covariance of springtime 500 mbar geopotential height with sodium concentrations in ITASE core 2000-01 (central West Antarctica) after Kreutz et al. (2000).

Non-Polar Ice Coring

Name and title of person completing report: Dr. Vladimir Aizen

Names of ice core drilling and analysis projects that have been active in the last 5 years:

The mid- low- latitudes, high altitudes ice-core paleo-climatic and environmental change program (supported by US DOE since 1995 till present time and by NSF in 2000)

Please briefly describe what drilling expertise this Program has.

A PICO, 10 cm diameter fiberglass hand auger to recover 20-30 m shallow snow/firn cores (south-eastern Tibet, elevations 6100-6300 m a.s.l.; central Tien Shan, 6100, 5200 m a.s.l.; Altai, 4115 m a.s.l.)

The Mini-Felix backpack, 8 cm diameter solar-powered electromechanical auger to recover 15-20 m shallow snow/firn cores (south-eastern Tibet, elevation 6100 m a.s.l.; Altai, 4150 m a.s.l.)

An ECLIPSE, 8.2 cm diameter solar-powered electromechanical auger (designed and built by Icefield Instruments) was used on the Inilchek Glacier (Central Tien Shan at elevation 5150-5200 m a.s.l.). Two 160 m cores have been recovered in summer 2000.

The Geo Techs Co. (Japan), 10 cm diameter electromechanical auger powered by solar battery or electric generator was used on Belukha snow/firn plateau in Siberian Altai. Two 175 m surface to bottom ice-cores were recovered at 4115 m elevation in summer 2003.

Please list the ice core analysis laboratories and their specialties in this team.

The ice-core freezer, ice-core processing and geochemistry laboratories of the Climate Change Research Center at the University of New Hampshire (major ions, trace elements analysis)

Stable isotope laboratory at the University of Maine (^{18}O, ^{2}H analysis)

Geochemistry laboratory at Marine Biology Department, the University of California Santa Barbara (major ions analysis)

The Paul Scherer Technological Institute Accelerator Mass Spectrometer (PSI/ETH AMS facilities) (^{36}Cl, ^{129}I, ^{127}Ce analysis)

Ice-core freezer storage, ice-core 1000 level dedicated cold laboratory for ice core processing and stratigraphic research and stable isotopes and geochemistry laboratories at the University of Idaho (^{18}O, ^{2}H, major ions, trace elements and heavy metals analysis)

The Tokyo National Polar Research Institute and the Nagaoka Institute of Snow and Ice freezers, cold processing and isotope-geochemistry laboratories (^{18}O, ^{2}H and major ions analysis).

The Isotope-geochemistry Laboratory at the Institute of Inorganic Chemistry, Siberian Branch of the Russian Academy of Sciences (heavy metals analysis).

1. Deep ice-core paleo-climatic and environmental research in Pamir (Central Asia). A collaborative international project proposal to the US NSF and the European Scientific Agency. The proposing start time is in 2005 and finish in 2009. This project proposal is in process of development. See Proposed Projects

2. Paleo-climatic and environmental reconstructions through two 175 m surface to bottom ice-cores recovered in Siberian Altai in 2003. A collaborative international project runs from 2001. The University of Idaho, USA; the Kyoto Institute for Humanity and Nature, Japan; the Tomsk State University, Russia. Currently this project is seeking an additional financial support for two years ice-core processing, samples analysis, data interpretation and publications (2004/2006) See Proposed Projects

3. Long-term dynamics of the southern Asian monsoons and regime of the south-eastern Tibetan glaciers. Ongoing collaborative international project runs from 2002 through 2003 with US DOE and the National Geographic support. The University of Idaho and the Lanzhou Cold and Arid Regions Environmental Engineering Institute the Chinese Academy of Sciences. The deep ice-coring expedition will start at the autumn of 2004 supported by US DOE. Currently this project is seeking an additional financial support for one year meteorological monitoring at the drill sites, the GPS satellite grounded (ASTER, IKONOS) glacier's surface and terminus measurements, and two more years for ice-core processing, samples analysis, data interpretation and publications (2005/2007) See Proposed Projects

4. Paleoclimate and glaciological reconstructions in Central Asia through two 160 m ice cores recovered in Tien Shan. Outgoing collaborative international project runs from 1998 supported through 2000 by US DOE and NSF. University of Idaho, University of Maine, University of New Hampshire, the INEEL, USGS, Paul Scherer Technological Institute, Switzerland. Currently this project is seeking one year additional financial support to finish ice-core analysis, data interpretation and publications.

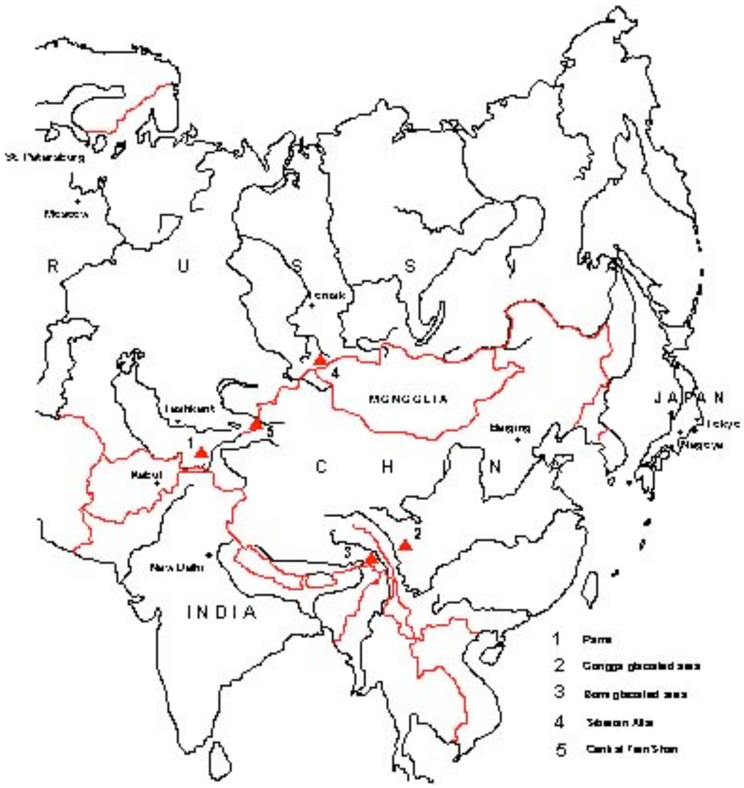

Fig. 1. Map of Asia and located drilling sites described in this report (also referred to in other Aizen projects)

Project Name: **Inilchek Glacier, Tien Shan Mountains, Kyrgyzstan**

Major science objectives: The overall goal of this project is to investigate the natural and anthropogenic processes responsible for observed climate and environmental changes in the Tien Shan Mountains over the past 200 years through the development of high-resolution (seasonal) multivariate glaciochemical records. The research is based on the successful recovery of two 165 m ice cores during July-August 2000 from the accumulation zone of the Inilchek Glacier. The ice cores are currently being processed using established ultra-clean techniques and analyzed for stable isotopes, major ions, trace elements and metals, Pb isotopes, and radiogenic isotopes. Gridded meteorological data combined with regional meteorological station data will be used to calibrate the relationships between ice core data and atmospheric dynamics. Detailed analysis of this data will provide the basis to address the following scientific questions:

Has the North Atlantic Oscillation (NAO) influenced interannual to decadal-scale climate variability in Tien Shan over the past 200 years?

To what extent has the desiccation of the Aral Sea and related land use changes over the past 45 years affected dust deposition and glacier mass balance in the Tien Shan?

What are the primary sources of anthropogenic emissions and how have they changed over the past 200 years?

Characteristics of the drill site(s): Lat: 42º 12.5N Long: 80 º 12.2' E Elev: 5100 m Ice Thickness: 285 – 300 m

Accumulation rate: 1.5 m water equivalent per year (last 40 years)

Mean annual temperature: -17.4ºC at 30 m in borehole; -11.2ºC at 165 m in borehole

Flat snow/firn accumulation area at the glacier circus (8x3 km) at elevation 5200-5250 m. Measurement of surface elevation and velocity, using detailed GPS measurements at the beginning and end of the field season indicated a relatively slow moving body of ice equal 0.1 m. No snow melt or sufficient snow redistribution.

Valley glacier (we only drilled to 55-60% of total depth; no apparent folds in core stratigraphy

Characteristics of the core:

Greatest age to which annual layers are preserved: 200 years?

Age of oldest ice that is in stratigraphic order: 200 years?

Countries and Institutions participating:

USA: University of New Hampshire, University of Maine, Columbia University (Lamont-Doherty Earth Observatory), University of Idaho – Moscow, US Geological Survey, Idaho Falls

Switzerland: ETH Zürich

Funding Agencies: NSF and DOE

Schedule (i.e., start and end dates, milestones): Drilling started and completed in summer of 2000. Cores stored in freezer at UNH. Cores currently being processed for chemical analysis

Name of drill system: ECLIPSE ice core auger build by Icefield Instruments with "Natasha" drill sonde

Drilling fluid: None

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Web Site(s): http://www.ccrc.sr.unh.edu/~cpw/AsiaRes/AsiaRes.html

http://www.webpages.uidaho.edu/~aizen/

Publications:

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Kreutz, K.J., V.B. Aizen, L.D. Cecil, and C.P. Wake (2001) Oxygen isotopic and soluble ionic composition of precipitation recorded in a shallow firn core, Inilchek glacier, central Tien Shan. *Journal of Glaciology* 47, 548-554.

Gerasimoff, M and C.P. Wake (2001) A Reason for Resin. *J. Glaciol.,* 47, 153.

Project Name: **Bona-Churchill Col, Alaska** (Ohio State University)

Major science objectives: Our scientific objectives for the Bona-Churchill cores include:

(1) Assess whether the warming of the last 30 years that appears to be amplified at high elevations in the tropics and subtropics extends to northwestern North America;

(2) Assess the character of the most recent 'step' change in the dynamics of the Pacific Basin climate regime that occurred in 1976-77 and explore whether similar abrupt transitions have occurred in the past and if so, determine when and of what magnitude were the changes;

(3) Explore whether the recently identified multi-decadal ENSO-like mid-latitude climate variability has its roots in the tropical Pacific;

(4) Determine the bottom age of the ice on Bona-Churchill col; and

(5) Determine whether Mt. Churchill is indeed the source of the White River Ash.

Characteristics of the drill site(s): This project was designed to retrieve and analyze ice cores from the col situated between Mt. Bona and Mt. Churchill (61o 24' N, 141o 42' W; 4420 m asl) in Wrangell-St Elias Mountains of southeastern Alaska.

Web Site: http://www-bprc.mps.ohio-state.edu/Icecore/Alaska.html

Project Name: **Coropuna in sw Peru** (Ohio State University)

Major science objectives: The Coropuna ice cap located southwest of Quelccaya in the Western Andean Cordillera (15° 32'S; 72° 39' W). The Coropuna cores will be analyzed for oxygen and hydrogen isotopic ratios, insoluble dust and major anions and cations.

Characteristics of the core: Three cores were collected on Coropuna:

Core 1 was drilled to bedrock (34.26 m) on the summit (elevation: ~6450 masl)

Core 2 was drilled to bedrock (34.25 m) on the summit (elevation: ~6450 masl)

Core 3 was drilled to bedrock (146.28 m) in the central crater (elevation: ~6410 masl

Cores 1 and 2 are shallow as they were drilled on the crater rim (6450 masl) while Core 3 was drilled in the crater

Web Site: http://www-bprc.mps.ohio-state.edu/Icecore/Coropuna2003.html

Project Name: **redrilling of Quelccaya** (Ohio State University)

Major science objectives: In July 2003 the OSU team returned to the Quelccaya ice cap in the southern Andes of Peru to drill a new set of ice cores to bedrock. The newly collected cores will allow the dating of the cores by counting visible dust layers to be complemented by the seasonal variations in insoluble dust, $\delta^{18}O$, and soluble chemical species (major anions and cations).

Characteristics of the core: Three cores were collected on Quelccaya:

Core 1 was drilled to bedrock (168.68 meters) on the Summit Dome (elevation: 5670 m asl)

Core 2 was drilled to 29.74 meters on the North Dome

Core 3 was drilled to bedrock (128.57 meters) on the North Dome

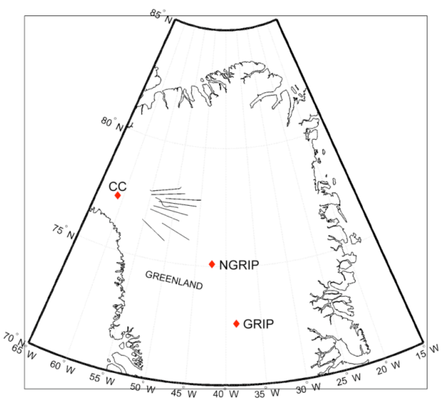
Web Site: http://www-bprc.mps.ohio-state.edu/Icecore/Quelccaya2003.html

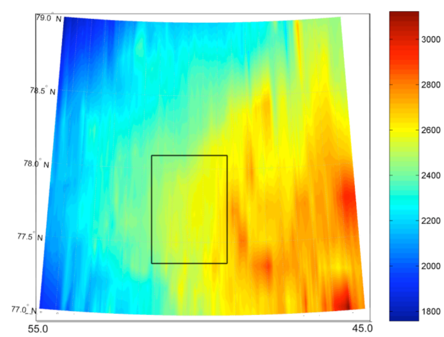
Proposed Projects

Eemian Greenland ice

Major science objectives: The major objective of drilling an Eemain Greenland Ice Core is to obtain a climatic record on the onset of the Eemian period from the Northern Hemisphere. This is a climatic period has not been obtained from other Greenland Ice Cores because the ice stratigraphy has been disrupted in the Central Greenland Ice Cores, the ice has melted at the base at NorthGRIP and this climatic period was too compressed at CampCentury and Dye3. The process of understanding the climate dynamics on the scale of interstadials and interglacials including the north south teleconnections is a research field that we expect to give major results in the coming years with the high resolved records from the NorthGRIP and EPICA ice cores. This makes the need to have a full Northern Hemisphere Eemian record very urgent. In addition it is believed to be a site where the stable isotope curve will contain a clear interglacial climate signal because the source region for the precipitation is not influences by the Icelandic Low Pressure System.

Previous work: The RSL-group at University of Kansas has produced a remarkable amount of Radio Echo Sounding profiles over the Greenland Ice Sheet (http://tornado.rsl.ukans.edu/Greenlanddata.htm) and these are very helpful in selecting a good site.





The left figure shows the area under investigation for a coming drill site. The lines shown are the available Radio Echo Sounding Profiles. Based on the profiles the ice thickness in the area is mapped on the right plot and a smaller area is marked with a solid black line. This is the area in which we believe is the best to drill a new ice core.

Desirable characteristics of the drill site(s): The desired location is a site with low surface velocity so the site should be on an ice divide or an ice ridge. The thickness should be more than 1500m to avoid finding the ice from the Eemian period in the brittle zone. The bedrock should be smooth to avoid disturbed layers near the bed. The accumulation rate should be as low as possible but there should be no basal melting at the site or upstream from the site in the region where the basal ice at the drill site might be affected by the melt. At the selected area shown above the accumulation rate is 0.30 – 0.40 cm water equiv. per year and the mean annual temperature is -30 deg C.

Desirable timescale of the core(s): The time scale should reach more than 135.000 year back in time to cover the Eemain period.

Schedule: A good start would be in 2007, the International Polar Year. We expect the project to take 3 years.

Contact person(s): Dorthe Dahl-Jensen

Web Site: None yet

Coastal Arrays of Ice Cores, CAIC

Major science objectives: An international project of coring coastal sites along the large ice sheets (Antarctica and Greenland) is proposed. Coastal ice cores are different from deep inland cores in a number of important ways that make them both complimentary to inland cores and valuable paleo-environmental archives in their own right. First, the more low lying coastal sites are thought to be more sensitive to local ocean conditions, such as sea ice extents, deep water upwelling, and ocean productivity, and local climate drivers (such as ENSO) to name a few. Measurements such as MSA, sodium and chlorine concentrations and deuterium excess are all thought to be sensitive to local oceanic conditions. New, trace chemical analyses may also be available in the future to focus on specific types of oceanic production. Second, coastal sites on higher domes (e.g. Law Dome, Siple Dome and Renland) have much of the same characteristics as those described before, but can "see" further out into the ocean, allowing quasi-independent records of Pacific, Atlantic and Indian Ocean conditions, for example, in Antarctica. Third, coastal domes are often restricted in their geometry by their location, thus they cannot become significantly higher or lower. This makes them valuable calibrators of deep inland cores, in whose paleoclimatic records elevation changes are potentially convolved. They can also tell us when the larger ice sheets have overrun their coastal positions, as well as when ice domes were free from the larger ice sheets. Fourth, coastal cores have a wide range of accumulation rates, from extremely high (Law Dome) to relatively low, depending on local meteorology. High accumulation rate cores have proven to be valuable, temporally detailed, archives of paleo-environments, with high-resolution gas records and sub-annually resolved climate records. Lower accumulation rate cores, such as Siple Dome, contain paleo-environmental records of 100,000 years or more. Finally, coastal domes are generally shallower than inland ice sites, meaning that ice coring proceeds rapidly, often in one season, and many sites, or an array, can be contemplated within the same logistics funds and constraints that are used in a single deep ice site. Arrays of ice cores are particularly attractive, given the significant regional differences that have emerged in ice cores that are relatively close (e.g. Siple Dome, Taylor Dome and Byrd, or NorthGRIP-Summit cores).

Examples of Previous work:

*Renland*_The Renland ice cap is located in the bottom of the Scoresbysund fjord in Eastern Greenland. The present mean annual temperature is -18 °C, accumulation rate 48 cm ice/year and elevation 2340 m a.s.l. Estimated ice thickness at the drill site from ice radar measurements is 321 +- 5 m. A deep core was drilled in 1988 very close to the local summit [Johnsen et al. 1992]. Of the 324 meters drilled only the deepest 18 meters contain the last glacial period and a part of Eem. The core was drilled with the Danish dry Shallow Drill producing some fractures in the core, and the coring did not quite reach bottom.

There is an amazingly precise presentation of all the Dansgaard-Oeschger events in the core, but the d18O amplitudes are only half the ones normally found in Greenland and less saw tooth like.

The isotope record displays a strong climatic optimum in the Holocene part of the core.

The deepest part of the core, from the isotopically warm (3 ‰ more positive than at present) Eem period contains a few meter thick layers of melt pointing to several degree warmer Eem summer temperatures than at present.

In spite of the fractured core the chemistry and dust profiles are of good quality [Hansson, 1994]. But gas measurements on the core are problematic. A new core from summit reaching bottom would be a cheap and scientifically most rewarding project. The ice cap is accessible by helicopter or Twin Otter from the nearby Constable Point airport.

Hans Tausen A 350 m core was drilled in 1995 using the NGRIP/EPICA prototype drill, the HT drill, in wet mode. The core was of perfect quality. The lower half of the core was all refrozen with no glacial ice present.

This points to total disintegration of the ice cap in the climatic optimum [Hammer et al., 2001].

Law Dome (taken from Vin Morgan's web site) Law Dome is a medium size, (200 km dia., 1390 m high) ice dome situated at the edge of the main East Antarctic ice sheet. Precipitation on Law Dome is mainly due to easterly winds from the low-pressure systems centered on 65 degrees S, which move around Antarctica. These result in exceptionally large amounts of precipitation on the eastern side while the western side experiences relatively low precipitation with net accumulation reaching zero in some areas. The high accumulation, low temperatures and the lack of strong winds in the summit area cause records from cores drilled there to have exceptionally fine resolution and high dating accuracy due to the easily resolvable annual accumulation layers.

Recent findings from Law Dome include: The relatively high annual accumulation and the low incidence of strong winds allow annual layers of snow to be consolidated so that measurements all show clear annual cycles back 8-10 thousand years. Example: a there has been a 20% decline in Sea Ice Extent since about 1950 based on MSA analyses (Curran et al Science 2003)

Data from the preliminary analysis of the core confirms that Law Dome existed as an independent ice sheet even at the Glacial Maximum and that only relatively minor changes occurred as sea level rose in response to the melting of the Northern Hemisphere ice sheets.

The time scale covered by the DSS core gives exceptionally good resolution of the emergence of the earth's climate from the LGM to the present climatic regime. Example: The ACR leads the Bolling warming in Greenland (Morgan et al, Science, 2002)

Atmospheric chemistry is well recorded in cores from near the Law Dome summit because the high accumulation gives good age resolution of both the ice and the trapped air and temperatures are sufficiently low to preclude summer melting which affects air composition. Examples: high resolution CO_2, CH_4, halocarbon and other gas records that blend into the modern records (Etheridge et al 1996, 1998 Francey et al, 1999, Trudinger at al, 2002, all JGR)

Siple Dome This ice dome at the base of the ice streams in West Antarctica has yielded a number of records that serve to illustrate the utility of coastal cores.

Siple Dome has been a dome for 100,000 years, implying that the ice streams are also at least that old and that WAIS has not overrun Siple Dome in that time.

Siple Dome has several records that correlate well with ENSO, including chemistry (Kreutz et al), accumulation (Bromwich et al), and stable isotopes (Schilla et al).

Siple Dome has a very different Holocene climate record than Taylor Dome on the other side of the Ross Ice Shelf, implying that regional climatic differences have evolved over that time, in turn implying that climate processes in this part of the world have evolved over that time.

Siple Dome has an abrupt climate change not seen in other cores.

Siple Dome has a period of apparent “no accumulation” not seen in other cores.

Siple Dome has a fundamentally different deuterium excess record, than that seen at Vostok, implying that different regions of Antarctica get their moisture from distinctly different oceanic regions. Coastal cores should help to amplify those differences.

Desirable characteristics of the drill site(s): A core on the dome or divide is best, but to test some hypotheses, flank cores may be desirable as well. An example of this is the origin of the abrupt climate change in the Siple Dome core. Also, shallow coring in support of deep (i.e. 1000m) cores is desirable to constrain spatial and temporal gradients in the region.

Two types of coastal cores are envisioned. One type has the highest snow accumulation available in a region to maximize the temporal resolution, and provide annual to near annual dating of the recent (Holocene +) part of the record. The second type has moderate accumulation to yield maximum age. Regardless, we envision that cores should be drillable in one field season.

Schedule (i.e., start and end dates, milestones): We envision a program of acquiring coastal ice cores that could begin in the IPY and continue for 10 to 20 years. Periodic evaluation of the program would include numbers of publications from the various projects, impact, and utility for improving the interpretation of deep ice cores.

Contact person(s): Jim White

Web Site: none

Potential sites

Antarctica

Roosevelt Island (Ross Ice Shelf area)

Others??

Greenland

Ingelfield Land :A small local ice cap north of Thule. Almost no info. available.

Disco Island: Some interesting small ice caps.

Sukkertoppen: A small ice cap south of Sondre Stromfjord.

Milne Land: A small local ice cap, south of Renland in Scoresbysund.

Scoresbysund Massive: Small ice caps in the mountains south of Scoresbysund.

Others??

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An Ice Coring Program for non-Polar Regions

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Summary of present work: Ice cores from mid- and low-latitude glaciers contain records of past climate and environmental changes on millennial to decadal time scales. Such information may be seen as more relevant to the history of human development than that retrieved from polar regions. This is illustrated by the fact that the vast majority of the Earth's population lives in the mid- and low-latitudes. In addition, one-half of the Earth's surface area lies in the tropical climate zone between 30°N and 30°S, supporting about 70 percent of the global population. Thus, temporal and spatial variations in the occurrence and intensity of coupled ocean-atmosphere phenomena such as El Niño-Southern Oscillation (ENSO) and the monsoon system, which are most strongly expressed in the tropics and the subtropics, are of world-wide importance. One example of the dependence of human civilization on climate comes from Andean ice cores, which provide evidence that significant droughts coincided with the decline of major South American civilizations.

Non-polar ice cores have now been obtained from all continents except Oceania, including even Africa (see Figure 1, and "Earth Paleoenvironments: Records preserved in mid- and low-latitude glaciers"). These ice cores have been recovered exclusively by small teams representing primarily one or two institutions, and with a modest amount of funding as compared to polar ice-coring projects. Consequently, only a handful of the great number of possible analysis that could have been done on the ice have actually been completed on these cores.

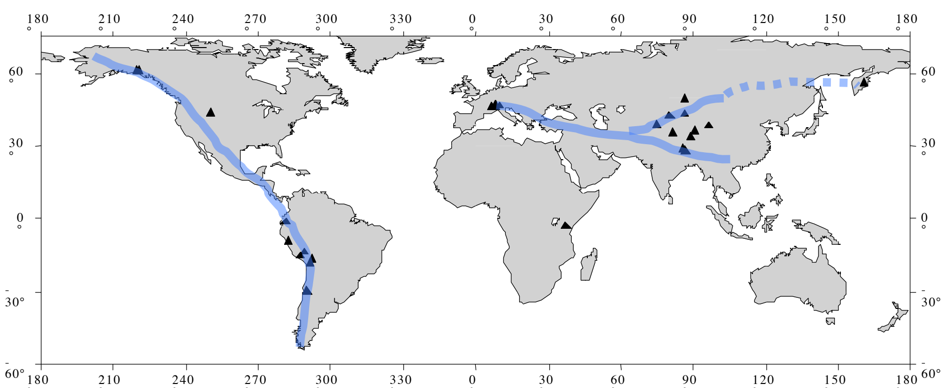

Figure 1: Locations of mid- and low-latitude ice core sites (triangles) along with suggested North-South Transect and West-East Alpide-Asiatic Transect (see below).

Recommendations for future work: In order to document the regional scale variability in both the tropics and temperate regions, associated with the larger global change, it is important that we continue to develop an array of well-dated, high-resolution, continuous, multivariate ice core records from mid- and low-latitude glaciers. The particular focus will be on climatic variations of the last 2000 years, which have witnessed the most extreme conditions of the entire Holocene. Fundamental issues to be addressed include low-frequency climate variations related to ENSO and other large-scale climate systems as the Pacific-North America (PNA) and NAO circulation modes, as well as the variability of the South Asian Monsoon system and its geographical expression. Further topics are related to the main pathways of the global water cycle, i.e. how far the influence of the Mediterranean extends toward the East, the "spill-over" of monsoonal moisture sources across the Himalayas and, last but not least, the influence of continentality, which is much more pronounced on the Eurasian continent than over the Americas.

Another important aspect is to extend our understanding of anthropogenic perturbations upon the composition of the atmosphere, in particular the concentration history of those aerosol particles with significant climate-forcing potential e.g.

sulfate, mineral dust, and carbonaceous particles (including black carbon and organic matter). Because aerosol lifetimes are typically only several days, the global distribution is very inhomogeneous, thus requiring data from many locations.

Two major transects for retrieval of mid- and low-latitude ice cores are therefore proposed (see Figure 1):

North-South Transect through the Americas (Rocky Mountains, Andes), in accordance with the Pole-Equator-Pole 1 initiative (PEP1, IGPB-PAGES)

West-East Alpide-Asiatic Transect (European Alps, Elbrus, Demawend, Hindukush/Pamir, Tien Shan, Altai, Himalayan mountain ranges, Kamchatka)

A certain number of high-quality ice core records along the two transects are already available (see Figure 1). However, to fill in the gaps, a program for ice core drilling along these two transects is needed and could proceed in the following way. A systematic reconnaissance based on short 10-15 m firn cores throughout the transects would be performed to establish the geophysical characteristics of all possible ice coring sites. In parallel, a deep coring effort would begin once a clear consensus on a site or region was established. Proxy information to be retrieved would include temperature, precipitation, moisture source, and aerosol content of the atmosphere (mineral dust, anthropogenic sulfate, carbonaceous particles from fossil fuels and biomass burning).

Technical requirements (organization, drilling, training of personnel, analyses)

a) Organization of non-polar ice core community: More international meetings are clearly needed to organize and coordinate the non-polar ice core community. To date, the tradition has been for several groups to work independently, with collaboration only on a bilateral or trilateral basis. However, to implement the proposed transects, coordination with regard to new sites and regions would be essential. In particular, the sharing of field logistics (personnel and equipment) and laboratory facilities within a program of international cooperation would likely promote a more efficient means of data collection, which additionally may be attractive to funding agencies.

The integration of scientist from the countries, where the mid- and low-latitude glaciers are located (e.g. in South America and in Central Asia) is important for coordination with local climatic studies.

b) Drilling technology: Due to the remoteness and high altitude of most non-polar glaciers, drilling equipment must be custom-designed to meet narrow specifications. Particularly for glaciers located above 5500 m, i.e. above the range of helicopter operation, a lightweight and modular drill design is required to allow for transportation by either porters or pack animals. The drill must be easy and fast to assemble and operate under extreme conditions, in order to limit the exposure of scientists to dangerous high-altitude environments. Because ice conditions vary from “warm” ice (just below freezing point), to “cold” ice, a multi-faceted drilling technology is favorable for retrieving the best possible core quality. Only one system has been designed so far that can quickly be switched from dry hole electro-mechanical drilling (used to 180 meters) over to a thermal-alcohol electric drill for deeper ice (ICPRG at OSU), and still be transported by porters. The other drilling device used above 5500 m, the Fast Electromechanical Lightweight Ice Coring System (FELICS, Ginot et al., 2002) is for dry hole drilling, only. For the proposed larger program to retrieve more mid- and low-latitude ice cores, a concentrated effort would therefore be needed to share such an advanced drilling technology.

c) Training of personnel: A crucial point is the training of researchers to work under extreme high-altitude conditions, which remains risky even if all possible safety measures are taken. Worldwide only few groups are able to successfully operate on glaciers above 5500 m, which requires sound mountaineering skills in addition to the normal demands of ice core drilling.

d) Handling and analysis protocols: For the drilling, handling, transportation, and storage of the ice cores as well as for the analysis, protocols have to be established on the basis of present experience. Ice core recovery should be accompanied by standard site surveys, including surface and bedrock topography, surface velocity and accumulation measurements as well as operation of automatic weather stations.

e) Modeling: More coordination of modeling/calibration is needed, including additional processes-based studies in several key regions; i.e., networks of meteorological/precipitation data collection. Sharing of resources makes this easier.

f) Ice core repository: A coordinated international effort to establish a repository for ice cores from mid- and low-latitude glaciers would be needed to safeguard these valuable archives.

Glacier retreat and need for action: As almost all glaciers in mid- and low-latitude regions are disappearing rapidly, these glacier archives of our past climate and environmental history are at risk. The archived paleoclimatic information, unattainable elsewhere, might be forever lost. The retrieval of a number of mid- and low-latitude ice cores from carefully selected sites is therefore now an urgent task.

Along this line, it is essential to improve and develop methods for extracting useful information from those glaciers partially affected by meltwater percolation. As has been demonstrated by previous studies, the seasonal variations in stable isotope profiles may still be preserved in such cores through the formation of impermeable ice layers at the end of each summer, even in poly-thermal and temperate glaciers. Also, the ice layers themselves have successfully been used as a summer-temperature proxy. Temperate glaciers containing ice thousands of years old exist throughout the high-precipitation regions of the Canadian and Chilean west coasts, as well as in New Zealand, Scandinavia, and elsewhere.

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Sub-glacial sampling

Major science objectives: Sampling the water in sub-glacial lakes and setting observatory for in situ measurements. The project aims to investigate the biological and chemical content of the lakes as well as their physical properties. This implies the development of clean sampling technologies preserving the lake environment, and possibly using low energy consumption. An appropriate drilling method would be to adapt the fast drilling technology (coiled tube) to the Antarctic environment (cold and clean). Test holes could be used for geophysics.

Desirable characteristics of the drill site(s): Small lakes in DC area, as well as Concordia lake (50 km diameter) would be of high interest (presence of a station and existence of a deep drilling).

Schedule (i.e., start and end dates, milestones): In the coming ten years

Contact person(s): Petit, Raynaud

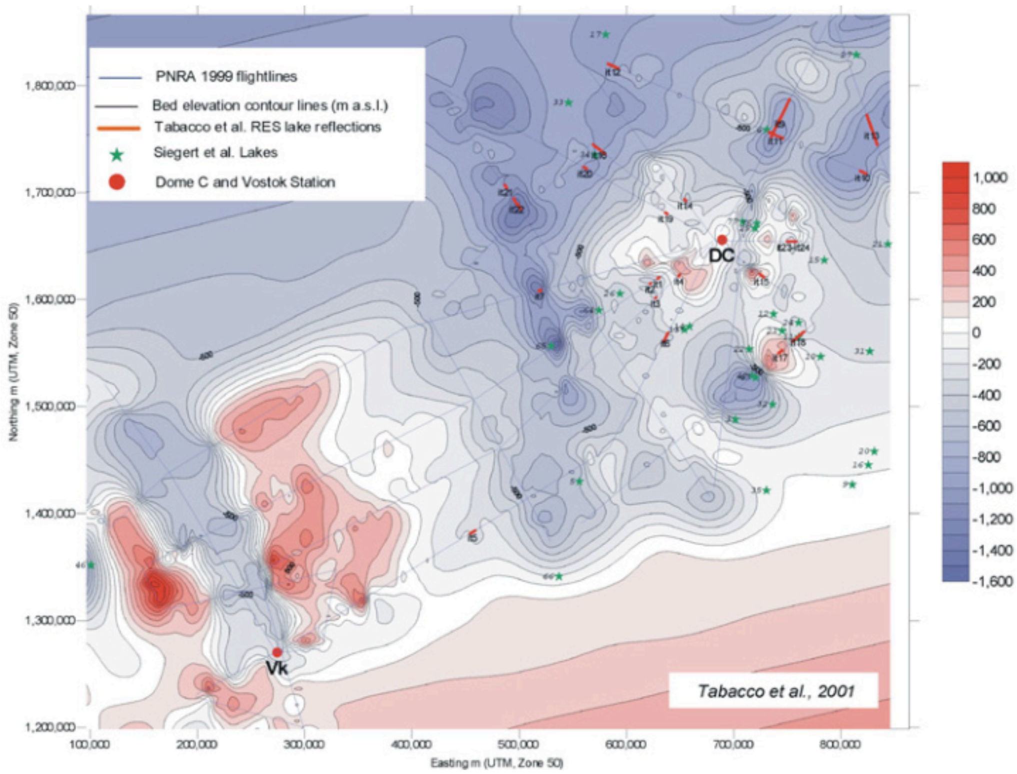

Fig: Subglacial map for the Vostok and Dome C area with the place where water and possibility for lakes is detected from Radio echo soundings. From Tabacco et al, 2001.

Vostok 200

Major science objectives: The idea is to drill in a site located about 200kms north from Vostok station on the melting area of the lake. The ice thickness is about 4.1 kms and the accumulation rate is 30-40mm/yr (2 times higher than at Vostok).

The drilling has not to penetrate into the lake. At this site the melting rate is evaluated to be 10mm/yr and the climatic sequence should cover 800,000 years (Salamatin et al, 2003). The time resolution should be higher than at EPICA DC and Vostok. Apart from the climatic interest, drilling at this site will offer the opportunity to get new information on lake Vostok: constraining energy balance, renewal time of the water, and chemical and biological supply.

Previous work: Vostok and Epica ice cores. Vostok Mirny glaciological traverses traverses. Intensive radio echo soundings for Lake Vostok. SCAR Salegos reports , (Kennecutt 2001 and http://salegos-scar.montana.edu)

Desirable characteristics of the drill site(s): (see above)

Desirable timescale of the core(s): 800,000 years

Schedule (i.e., start and end dates, milestones): Could be started in the next 5 years.

Contact person(s): V. Lipenkov, D. Raynaud

Area of interest:

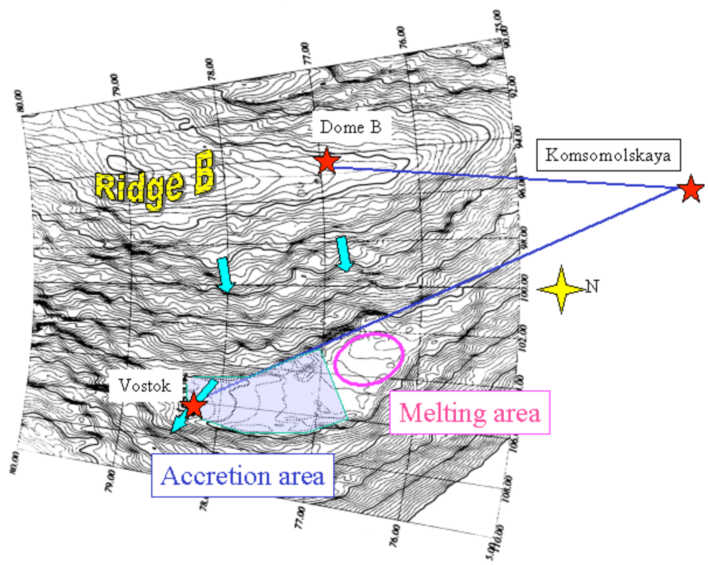

Fig1 : Surface topography of Vostok and Ridge B area (from Rémy et al, 2000). Dome B, Komsomolskaya, Vostok are drilling sites, linked by traverse routes. The arrows (azimuth ~90° East) indicate the ice flow according to the mean slope (from Siegert et al, 2001). The ice velocity is increasing from 0m/a for Ridge B to 1.5 m/a at the boundary of lake Vostok (Siegert and Kwok, 2000).

At Vostok, the mean ice velocity is ~3m/a (Bell et al, 2002) but the azimuth of the flow line is ~130° East, likely because a local effect. Over the lake, the shaded area corresponds to location (up to 165 km) where accretion ice was detected (from Bell et al, 2002). Melting area is represented by the circle at 240 km distance from Vostok and could be the location for the deep drilling project. *From Jouzel et al, 2003 ; Petit et a , 2003.*

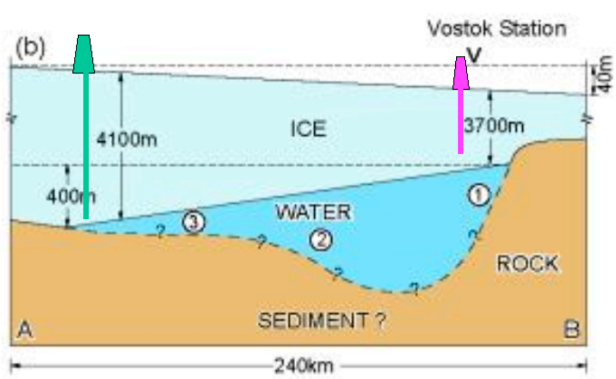

Fig 2: Cross section of lake Vostok (modified from Siegert et al, 2001). The project aims to get an ice core record in the Northern part of Lake Vostok. (left on fig).

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Dome C

Major science objectives: The experience of GRIP/GISP2 indicates how important can be to have several deep drillings in the same area to document the spatial variability and avoid climatic misinterpretation due to artifacts linked , for instance, with special ice flow behaviour. The EPICA DC ice already available provide a unique climatic ice record in terms of length (800 kyr). We propose to drill a new deep hole in the DC area. The best location has still to be defined, taking into account the bedrock map and ice modeling simulations constrained by the results of the EPICA DC core.

Previous work: Radar mapping

Desirable characteristics of the drill site(s): To the best extent possible, please describe the desired location, thickness, accumulation rate, mean annual temperature, and ice dynamics (dome, divide or flank flow).

Desirable timescale of the core(s): 800 ka.

Schedule (i.e., start and end dates, milestones): In the coming ten years

Contact person(s): Jouzel, Raynaud, Petit

Talos Dome Ice Core Project (TALDICE)

Italian-French-Swiss-German glaciological national communities have presented, to their respective national funding programmes, a proposal concerning a new intermediate drilling at Talos Dome in Antarctica. A drilling at Talos Dome could greatly improve our knowledge about the response of near-coastal sites to climate changes and Holocene history of accumulation rates in the Ross Sea region. It will provide detailed Holocene records of temperature, accumulation rates, trace-gas changes and aerosol variations with regard to other Antarctic sites. As such, it would be a significant contribution to a future network of drillings, focussing on Antarctic spatial distribution of key-tracers (complementing studies at EPICA DML, Berkner Island, inland US cores, etc.). In addition, Talos Dome would strongly contribute to the understanding of the last glacial-interglacial transition when different climatic features and trends are observed between West-East Antarctica (Byrd, Vostok, EPICA-Dome C, Dome Fuji, Law Dome) and two near-coastal sites in the Ross Sea sector (Taylor and Siple Dome). Lastly it would provide a perspective for future variability of accumulation and dynamic changes in this sensitive area.

As part of the ITASE project, two traverse surveys were carried out in the Talos Dome area. Six shallow snow-firn cores up to 89 m deep, were drilled in the TD area. Within a radius of 20 km from summit, 300 km of snow radar (200 MHz frequency) and 450 km of GPS surveys were performed in order to link core sites and to obtain detailed information on the spatial variability of snow accumulation and summit topography. Airborne radar surveys (60 MHz frequency) were conducted in the Talos Dome area to provide ice thickness and bedrock topography. A surface strain network consisted of a total of 9 stakes geometrically located at a distance of 8 km from the centre of the topographic dome was established in 1996 and measured using GPS. In order to determine accurately the growth or shrinkage of the dome, a submergence velocity system was installed and measured using GPS at the TDC core, with markers anchored in the firn at depth of 54 m. A stake farm (40 poles) was installed and re-measured, and an Automatic Weather Station was installed in order to characterise climatic conditions and the spatial-temporal variability of snow precipitation on local and seasonal scales.

Core temperature (-41 °C), snow accumulation (80 mm we yr^{-1}) and isotopic-chemical snow composition demonstrate that a very interesting climatic signal is incorporated into the firn at Talos Dome, which represents the junction of three different environments (East Antarctica-Ross Sea Sector, northern Victoria Land, and Wilkes Land-Southern Ocean). The close-off depth is 66 m, and the ice (in the 1996 core) dates to 1460 AD, with □□ages of about 535 years. Preliminary RES (Radio echo sounding) analysis shows that Talos Dome summit is situated above a sloped bedrock about 400 m in elevation, covered by about 1900 m of ice. There is a relatively flat bedrock 5-6 km in the distance along the SE ice divide, where the bedrock is about 750 m in elevation and covered by 1550 m of ice. The ice temperature at the. bedrock is expected to be around –20 °C; basal melting has most likely never occurred. Analysis of the velocity field and surface topography shows that the surface flow centre is nearly co-located with the dome summit. Snow radar and GPS surveys show that the internal layering is continuous and horizontal up to 15 km from the summit.

In order to calculate a preliminary age vs. depth profile for Talos Dome, a simple one-dimensional steady-state model was formulated. This model predicts that the ice 100 meters above the bedrock may cover more than one glacial/interglacial period (160-240 kyr).

This drilling is planned to be initiated in 2004-05 and performed on 2005-07.

Talos Dome drains into the blue ice field of the Outback Nunataks, 40 km apart. This blue ice field contains not only ice from Talos Dome, but also numerous tephra layers from the Mount Melbourne Volcanic Province. Stratigraphic and microscopic features of many englacial tephra layers suggest that they were entrapped into the ice with negligible reworking and mixing, and therefore represent isochronous time planes. They dip from near-horizontal to near-vertical, depending on the geometry of the local surface ice flow. By studying the chemical signatures of the tephra layers, it will be possible to establish reliable stratigraphic correlations between blue ice fields and the deep ice core at Talos Dome. Old ice is known to potentially outcrop at the surface of blue ice areas, where it is possible to collect large volumes of ice for detailed analysis of the trace elemental and gas isotopic composition.

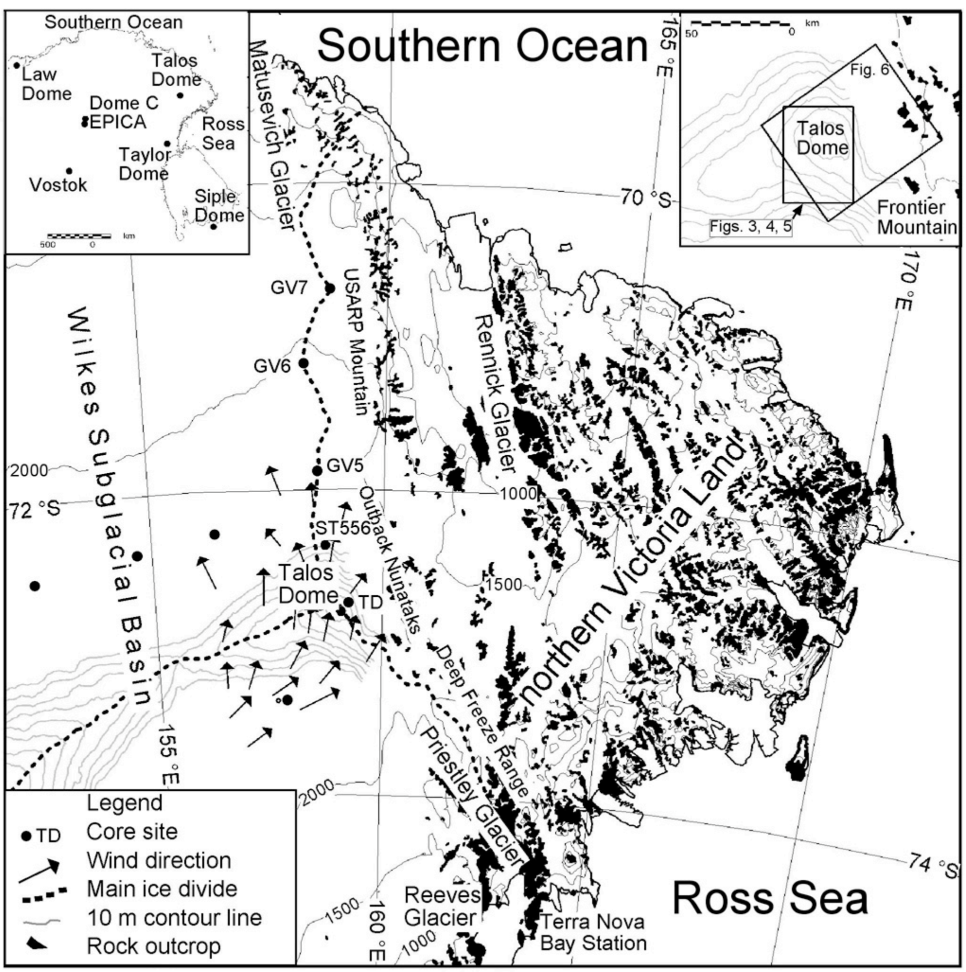

Figure 1. Schematic map of Talos Dome drainage, contour every 500 m, contour every 10 m in Talos Dome area (Frezzotti and others, 2004).

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Deep ice-core paleo-climatic and environmental research in Pamir (Central Asia)

Proposes on collaborative international project: University of Idaho, USA; Bavarian Academy of Sciences, Germany; Nagoya University, Japan; Tajik National Academy of Sciences, Tajikistan.

The proposed project focuses on the Pamir snow/firn plateau 6100 m elevation (Fig. 1 pg 39) at the Central Pamir mountains. The Pamir Mountains are locating on the north-western periphery of the highlands that define the Central Asia Great Mountain System (CAGMS). The location of the Pamir on the north-western margin of the CAGMS provides a unique opportunity to develop ice-core records relating to major circulation systems, the moisture advection dynamics from the Atlantic/Mediterranean basin and the Indian monsoons. As the Pamir represents a significant montane barrier to northern and western air masses moving in CAGMS, it plays an important role in determining the climatic processes in Central Asia, similar to that of the Himalayas and Karakoram to the south and south west. Moreover, the existence of long-term (over 100 years) meteorological records over Pamir allows calibrating ice-core climatic and environmental records for further interpretation and pale-climatic reconstructions. Meteorological and hydrological data are available from over 800 stations in the Pamir.

The major objectives:

estimate the climatic variability at the north-western periphery of CAGMS during last hundreds to thousands of years;

estimate contribution of different sources of moisture to the Pamir glaciers snow accumulation and coupling the large scale atmosphere dynamic with glacier's ice records time-series;

analyze an anthropogenic and natural impact on fresh water systems in the Central Asian closed drainage basin recovering snow and glacier's ice records on radionuclides and chemical elements accumulated during the industrial and pre-industrial period;

determine long-term changes in the carbon emission to the atmosphere from the Former USSR agriculture and industry, and recent oil fires at the Middle East.

Previous work: No any ice-core records have been recovered in Pamir.

The characteristics of the drill site: The Pamir snow/firn plateau (38°23' N, 73°08'E) located at 6100 m a.s.l. at footstep of the highest central Pamir Peak of Somoni (7495 m). The large (5x2 km) flat snow/firn accumulation area.

Desirable timescale of the proposed ice cores: The deep surface to bottom ice cores from Pamir snow/firn plateau may reach up to 250 m. The ice cores may recover climatic and environmental records for the last 5 000-10 000 years.

Schedule (i.e., start and end dates, milestones): Four years: the August 2005 is a desirable project start date.

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An indication of the level of interest in the project by the science community and funding agencies Approximately 20 scientists from USA, Germany, Switzerland, Japan, U.K., France and Central Asia are interested for collaboration in this project. The NSF Paleoclimate and Earth Science History Programs and the NOAA Paleoclimate Program can be potential agencies for support from the USA side.

Degree of readiness for participation in the project: This proposal is in development and opens for discussions.

Paleo-climatic and environmental reconstructions through two 175 m surface to bottom ice-cores recovered in Siberian Altai

Collaborative international project supporting by US DOE and the Japanese Ministry of Science and Education since 2001 (University of Idaho, USA; Kyoto Institute Humanity and Nature, Japan; Tomsk State University, Russia)

Altai Mountains are located at the center of Asian continent and define the northern periphery of Central Asia Great Mountain System and the southern periphery of Asian Arctic basin. Altai Mountains are storing glaciers' ice records on moisture advection from the Atlantic and Pacific Oceans, and from the Aral-Caspian closed drainage basin to the Arctic Ocean. Moreover, the ice-cores recovered from Altai glaciers are appropriative for studying air pollution dynamics eastward from the major Former USSR air pollutants in Ural, Kazakhstan and Siberian boreal forest fire activity. During the last century Altai Mountains became extremely contaminated region by heavy metallurgy, nuclear and rocket facilities. Among the Altai glaciers the West Belukha high elevated snow/firn plateau is only appropriate spot where accumulated snow is not affected by avalanches or melts water percolation preserving proxy climatic/environmental records (Fig. 1, pg 39).

The major objectives: The overall goal of the research is to develop high-resolution paleoclimatic records covering the last 2 000 – 5 000 years, which will be calibrated with meteorological data from the robust station network including several high elevation stations in the Altai.

estimate the contribution of precipitation to snow accumulation from external and internal moisture sources and coupling the large scale atmosphere dynamic with glacier's ice records time-series;

analyze an anthropogenic and natural impact on fresh water systems in the Asian Arctic basin recovering snow and glacier's ice records on radionuclides and chemical elements accumulated during the industrial and pre- industrial period;

determine long-term changes in the black carbon emission to the atmosphere caused by Siberian forest fire activity.

Previous work: During two summer filed seasons of 2001 and 2002, hundreds of snow samples from 2 to 7 m snow pits, one 21 m firn-ice core were collected at 4109 - 4115 m elevations of the Belukha Plateau. One year meteorological and snow accumulation measurements were recorded by automatic weather station (2002/2003). Detailed ice thickness measurements by lightweight mono-pulse radar system revealed the glacier depth reached 170 - 180 m.

In summer 2003 two 175 m each surface to bottom ice-cores were recovered for further paleo-climatic and environmental analysis and interpretations.

Precipitation and snow samples, firn and ice cores were transported in water and frozen to the Nagaoka Snow and Ice Institute and to the University of Idaho for stable isotope, major ions, heavy metals, radionuclide, trace elements, black carbon and microbiological analyses.

The partial results of this research has been reported at several National and International Meetings and submitted to the Journal of Glaciology and Journal of Geophysical Research for publication (see more information on the web: (http://www.webpages.uidaho.edu/~aizen/)

Well preserved seasonal $\delta^{18}O$ and $\delta^{2}H$ signals were revealed in the snow-firn records. The preliminary analysis revealed extremely high concentration of H_3COO^- and $C_2O_4^{2-}$ in snow/ice samples indicating the Siberia forest fire biogenic activity. An abnormal high concentration of Pb, Zn and Cu is the result of emission from the Eastern Kazakhstan mining and metallurgic industry. The Atlantic, Pacific Oceans and internal central Asian basins are three distinct sources of moisture in the Altai Mountains determined through $\delta^{2}H$ □□and $\delta^{18}O$ time series.

The characteristics of the drill site: The West Belukha snow/firn plateau at the Siberian Altai (49°48' N, 86°32'E) located at 4130 m a.s.l. The annual average accumulation rate is 600 mm in water equivalent at the center of large (3x2 km) flat snow/firn plateau. The three years GPS/geodesic grounded measurements (accuracy ± 0.1 cm) over the accumulation sticks revealed only 0.1 m a year horizontal surface velocity at the drilling site, where 175 m ice depth measured by radar.

Desirable timescale of the cores: The 175 m surface to bottom core allows reconstructing up to 5 000 ±100 years of climatic and environmental records.

Schedule (i.e., start and end dates, milestones): Two years: June-July 2004 is the proposed start date for ice-core processing, samples analysis, interpretation and the results publications.

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http://www.chikyu.ac.jp/takeuchi/

An indication of the level of interest in the project by the science community and funding agencies

Approximately 20 scientists from USA, Russia, Japan, Switzerland, Belgium and China are interested for collaboration in this project. In addition to the US DOE commitment to support this project during next two years, the NASA (Carbon Cycle Program), the NSF (Arctic Program and Earth Science History Programs) and the NOAA (Paleoclimatic Program) can be potential agencies for support.

Degree of readiness for participation in the project The field effort has been done but we still need two years financial support for the USA team for the costs of ice-core analysis and the results interpretation.

Long-term dynamics of the southern Asian monsoons and regime of the south-eastern Tibetan glaciers

Collaborative international project supporting by US DOE, the Chinese Academy of Sciences and the National Geographic (University of Idaho, USA; Lanzhou Cold and Arid Region Engineering Environmental Institute, China)

The major scientific objectives: are combining the development of detailed paleo-climatic/environmental records with the collection and analysis of modern observational data

We propose, to develop well dated, high resolution, multi-parameter paleo-climatic records of the Indo-Chinese monsoon, the Tibetan High, and the westerly jet stream over the past hundreds years through the chemical and physical analysis of several surface to bottom ice-cores recovered from high elevated firn/ice plateau (over 6000 m a.s.l.) at Bomi and Gongga Shan glaciated area (a border between the Indo-China monsoon equatorial zone and the subtropical monsoon region (**Fig. 1**).

With snow and ice-core, hydrological and meteorological data we are collecting we will investigate and simulate the mechanism of moisture transfer, that sustain glaciers, thereby allowing an estimation and prediction of the intensity, timing, extent and distribution of precipitation and water resources in the head of Yanszi, Mekong and Brahmaputra rivers. The complimentary data sets will be interpreted together to obtain a comprehensive understanding the hydrologic and climatic system and to forecast the climatic and environmental changes at the World most populated region.

Previous work: One glacio-climatological expedition has been accomplished on the Gongga glacier in 1990 (supported by Russian Academy of Sciences) and two expeditions at Bomi glacierized area in 2002 and 2003 (supported by the US Department of Energy and the National Geographic). No one glaciological research has been done in this part of Tibet before these expeditions. Several shallow (14-20 m) firn-ice cores and 2-4 m snow pits recovered at 6000-6200 m elevation range of the large snow/firn fields illuminated an excellent annual isotope-geochemistry records during the previous 10 years of snow accumulation. Measurements taken with a lightweight mono-pulse radar system indicated that ice depths range from 200 to 270 m in the center of the snow/firn fields. Visual stratigraphy on the firn cores and in snow pits indicate several small ice lenses (<1 cm) but there was no indication of substantial summer melting. One year meteorological records at Gongga Shan and two years at the Bomi glaciated areas were collected with three automatic weather stations. A preliminary GPS satellite grounded survey on the glacier's area distribution has been accomplished at Bomi area. The results of this research were presented on the National and International Meetings and published in several peer review papers (http://www.webpages.uidaho.edu/~aizen/).

Well-preserved annual isotopic variations were revealed in the snow-firn records. Mean and absolute (maximum and minimum) values are slightly lower than from Altai core, although moisture source transport distance is less. While mean values (-16‰) for both the Tibet and Tien Shan sites are similar.

Extremely low values of anions compared to other sites are associated with the greatest amount of precipitation, close location of moisture sources and farthest removed from terrestrial dust inputs. Elevated Cl^- levels among other anions caused by proximity to marine moisture. Low sulfates and nitrates concentrations point on minimal effects from anthropogenic impact.

Characteristics of the drill sites: The possible drill sites at Gongga Shan and Bomi glaciated areas (Gongga and Zuoqiupu Glaciers) located at the center of large flat snow/firn plateau (approximately 3 x 5 km size each) that located on the water divides, which is possible to reach during two walking days from the base camps at 3900 m and 4800 m respectively. In our previous expeditions we used local porters to carry equipment and expositional stuff up to the drilling sites. The annual air temperature at elevation of 5800 m, measured by automatic weather stations, was -9C and ice temperature was -12C at the depth of 23 m at 6200 m a.s.l. The average annual accumulation rate is 800 mm according to snow pits and shallow firn cores. The surface velocity measured by GPS on the Zuoqiupu snow firn plateau is 0.1 m a year.

Desirable timescale of the core(s): Approximately 2 000 year records in 250 m depth surface to bottom ice-core.

Schedule (i.e., start and end dates, milestones): Start date of deep ice-coring expedition is September 15, 2004 and finish date is October 30, 2004. For the laboratory analysis and analytical research we suppose to request two additional years.

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An indication of the level of interest in the project by the science community and funding agencies

Approximately 20 scientists from the USA, China, Japan, India, U.K., Germany, France, and Switzerland are interested for collaboration in this project. In an addition to the US DOE and the Chinese Academy of Sciences, which have commitment partly support this project during one more year, the NSF (Earth Science History Programs), the NOAA (Paleoclimatic Program) and APN (Asian Pacific Network) can be potential agencies for additional support.

Degree of readiness for participation in the project: The project is open for collaboration upon receiving an additional financial support for the field and analytical research.

Drilling the North Cap of Mars.

The natural evolution of our science on earth is to go off earth. The reasons and methods carry over. Who has the expertise ? Our community. JPL and the space science people would welcome more terrestrial interest. Students are attracted like bees to honey. There is a technology close to ready. When ready it would robotically do most of the things that we do with ice cores and also 'drill' them. Once developed, the technology could be used on earth to multiply the number of vertical profiles that we could obtain; more holes and analysis for a given buck.

There are already many terrestrial glaciologists and groups that have an interest in planetary ice bodies. For example the Danes under Dorth Dahl-Jenssen have set up a Planetary Centre that marries the Terrestrial and Space science communities very well. There are other examples of terrestrials who have 'strayed' into the planetary field eg. Jay Zwally, Gary Clow, Ralf Greve, John Nye, Ed Waddington, Christine Schott and myself to mention but a few.

Major science objectives: The North Cap of Mars is about 85% water ice and about 15% wind blown dust. It has accumulation areas and ablation (sublimation) areas, to which are a added ~ +.1 and ~ -.3 mm/a. There are visible layers in the ablation scarps right down to the ~2m resolution of present images and there is no reason to think even annual layers might not be preserved.

The North Cap of Mars contains a temporal stratigraphy up to 100,000,000 years long and includes not only the history of Mars Climate but also the history of the solar system's climate. Solar variability and cosmic ray flux changes both would effect Earth's and Mars climate simultaneously.

Previous work: There have been two thorough proposals put forward to 'drill' the North Cap. In the early 90's Dave Paige's "Mars Polar Pathfinder" was to use a type of Philberth probe to sample down a few 100 meters and again in 2003 more or less the same mission ,"Cryoscout" was put forward as one of the 20 scout mission candidates; this time put forward by by Frank Carsey, JPL. Both missions received very high scientific merit appraisals but lost out to essentially the same mission (South Polar Lander 99 and presently the Phoenix lander), that would put a lander beside the cap and dig in the frozen soils. This was largely because the ice cap technology (probe) was not mature enough. The probe today is in a much better state of maturity and improving .

The technology for a lander to measure the stable isotopes, micro-stratigraphy, chemistry, dust and possible life traces already exists in flight ready format and was part of the Cryoscout proposal.

Previous work that directly contributes to the science objectives. The North Cap of Mars is presently the best topo-mapped ice cap in the solar system , Thanks to the laser altimeter (MOLA) on board the wildly successful MGS (Mars Global Surveyer). There is little hard data on accumulation rates or ablation rates, and the ages of the ablation scarp layers are not really known, but one usually assumes the major dark dust layers equate to the major climate cycle caused by the 13 degree obliquity cycle that has a period of ~ 120,000 years.

At the peak of summer there is a precipitable water vapor 'dome' over the North Cap of 80 microns of water , which goes to zero in the fall. The ice cap is one of its own main sources of moisture ; a boot-strap operation.

The are measures of [D/H] ratios from earth based observations that suggest that there is an annual cycle . These ratos also suggest that the ice cap ice is very old.

There is a funded mission , "Phoenix", that is to put a lander beside the North Cap in late 2007. It will examine the ground ice, water vapor fluxes, met and stable isotopes of the vapor and ice as well as use a robot chemistry lab on the recovered icy soil samples. Since the soil water and dust are probable co-recipiants of water and dust along with the ice cap, what comes from this mission will be useful for interpreting the Ice Cap environment. JPL and the University of Arizona are the lead groups. There are a number of Canadian Terrestrial scienctists on this project , myself included and the Canadians are responsible for the met-package.

Desirable characteristics of the drill site(s): The best site for 'drilling' is that suggested by the Cryoscout . It is the middle of the ridge that joins the two main domes of the North Cap. It is large , white and flat with very gentle surface micro-relief. There are reasons to believe the region has a 'high' accumulation rate and hence a good (for Mars) resolution. The ice is about 2.5 km thick , but even reaching 100m would be a success as it would penetrate more than about 1,000,000 years of accumulation.

As the melt probe has a vertical resolution limited (by the method) to a few mm , one would also want to do a 1m augered hole at the site and examine and sample the hole with micron resolution to pick up seasonals and identify historically observed glbal dust storms. This would help with establishing the time scale for the deeper record.

Desirable timescale of the core(s): The accumulation rates are not known but a likely in the few x 0.10 mm range, so a 100 m hole would cover about 1,000,000 years. The high resolution augered hole with its 1 micron resolution and ID-ed dust events would help set the time scale then possible counting of annuals down to the first obliquity cycle dust maximum would corroborate the this time scale.

Schedule (i.e., start and end dates, milestones): There are presently no funded missions on the books to do this drilling ,, but the have been two credible attempts and I think the next shot will be sucessful. In the mean time testing of the probe and its science payload here on earth would help insure this. The Phoenix which is beside the North Cap is funded and will launch in 2007.

The full cycle from proposal building through competition to launch and landing seems to take about 6-7 years.

Contact person(s): Frank Carsey, Mike Hecht , JPL David Fisher , GSC

Web Site: just “google” cryoscout jpl and lots of sites come up.

Drill Technology

Australia

Name of drills: **AMISOR drill**

Name of person making report: Vin Morgan

What projects has this drill been used on: Various drillings on (through) the Amery Ice Shelf.

Who built the drill: The drill was built in the Australian Antarctic Division workshops.

What is the design history of the drill: The drill was designed in Antarctic Division laboratories following information provided by Keith Echelmyer (Geophysical Institute Alaska), Keith Nichols (BAS) and Josef (Sepp) Luthiger (VAW, ETHZ, Switzerland. Australian personnel involved in the design were: Mike Craven, Alan Elcheikh, Andrew Fleming and Russell Brand

Maximum depth it has been used to recover core: ??

Core diameter: ??

Length of core collected on each trip down hole: ~1m

What is the typical travel speed up and down the hole: ??

What drill fluids have been used with it: Water (naturally)

What improvements would you like to make to this drill: ??

What technologies are unique to this drill: ??

References:

Craven, M., A. Elcheikh, R. Brand and N. Jones 2002. Hot Water Drilling on the Amery Ice Shelf – The AMISOR Project. In; Ice Drilling Technology 2000. *Memoirs of National Institute of Polar Research. Special Issue*. 56. 217-225

Name of drill: **Australian ISTUK**

Name of person making report: Vin Morgan

What projects has this drill been used on: The DSS (Dome Summit South) drilling on Law Dome, East Antarctica between 1990 and 1993

Who built the drill: The drill was built in the Australian Antarctic Division workshop, Kingston Tasmania. Involved in the design of the drill and control systems were: Andrew Fleming, Egon Wehrle, George Musil, Vin Morgan

What is the design history of the drill: The drill is a modification of the Danish ISTUK drill. It uses the same piston suction principal for chip removal and collection and the basic dimensions are the same but the electronics, motor and piston actuation system are quite different.

Maximum depth it has been used to recover core: 1200m

Core diameter: 100mm

Length of core collected on each trip down hole: Average is about 2m

What is the typical travel speed up and down the hole: 1-2 m/s.

What drill fluids have been used with it: Kerosene with perchlorethylene as a densifier

What improvements would you like to make to this drill: The main problem with the drill is the extruded aluminium chip channels. The idea behind these was to avoid the possibility of leaks that can occur where roof shaped channels are brazed to the core barrel. The slow suction system that collects chips in the ISTUK design is very susceptible to any leakage that reduces suction. The Al channels were certainly leakproof themselves but there were problems sealing the top and bottom junctions. The main problem however was that the low strength of the Al meant that if there is a blockage at the drill head the suction would collapse the Al channels. If the drill was to be reused the aluminium chip channels need to be replaced with stronger steel ones.

What technologies are unique to this drill: The drill was powered by a brushless DC motor that ran immersed in the borehole fluid. This eliminated the necessity for a high pressure rotating seal in the electronics chamber. The motor and driver were highly satisfactory. No problems were experienced and the good speed control and monitoring of load through the electronic controller assisted drilling.

Additional information about the drill and the DSS operation can be found in:

Morgan, V., Wehrle, E., Fleming, A., Richardson, M., Elcheikh, A. and Brand, R. (1994) Technical aspects of deep ice drilling on Law Dome. In: Proceedings of The Fourth International Workshop on Ice Drilling Technology. Ed Okitsugu Watanabe. Tokyo. April 20-23, 1993. pp 78-86.

Name of drill: **Australian Thermal Drills**

Introduction Australian Antarctic Division used first used a CRREL thermal drill to obtain core through to the frozen-on basal ice on the Amery Ice Shelf in 1968. The drilling system later went through extensive modification and was used at a number of sites on Law Dome. There are two CRREL type drills that take a 120mm diameter core and another core barrel and melt-tank assembly that takes 200mm cores.

Name of drills: Horace, Maria and Errol. (I (VM) was not involved in the naming of these drills)

Name of person making report: Vin Morgan

What projects has this drill been used on: Various drillings on the Amery Ice Shelf and Law Dome between 1968 and 2000 (see Australian drilling summary sheet)

Who built the drill: The drills (current versions) were built in the Australian Antarctic Division workshops.

What is the design history of the drill: Modifications were made to CRREL drills; core and melt-tank barrels were extended, a copper melt head was made with a cast-in heating element and electronics were incorporated to monitor vacuum and head temperature.

Maximum depth it has been used to recover core: 475m

Core diameter: 120mm and 200mm

Length of core collected on each trip down hole: Average is about 2m

What is the typical travel speed up and down the hole: 1-2 m/s.

What drill fluids have been used with it: None

What improvements would you like to make to this drill:

The CRREL type drills are now old and unreliable. The large diameter drill (Errol) is in reasonable condition but a new electrics and vacuum pump module is required.

What technologies are unique to this drill: None

References:

Bird, I. G. 1976. Thermal Ice Drilling Australian Developments and Experience. In: Ice Core Drilling; ed John Splettstoesser. Proceedings of a symposium, University of Nebraska, Lincoln, 28-30 August 1974.

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Canada

Name of drill: **ECLIPSE**

Name of person making report: Erik Blake

What projects has this drill be used on: There are 4 drill systems in use. High-altitude drilling in Tibet, Nepal, Kazakhstan, Yukon. US-ITASE. Australian Antarctic Division drilling near Casey.

Who built the drill: Icefield Instruments Inc.

What is the design history of the drill: Drill sonde based closely on Danish intermediate-depth tipping tower drill. Drill sonde direct heritage: Geological Survey of Canada's HILDA and SIMON drills, as well as drawings provided by the National Research Council of Canada. Modifications to drive system and rifling of non-rotating outer barrel. Winch design is unique, designed to greatly reduce transport weight. Winch incorporates level winder. Complete redesign of control system.

Later sondes have offset anti-torque springs to improve anti-torque performance.

Maximum depth it has been used to recover core: 346m at Eclipse Ice Field, Yukon

Core diameter: 82mm, design for 101mm.

Length of core collected on each trip down hole: 100cm

What is the typical travel speed up and down the hole: 80cm/s

What drill fluids have been used with it: None, although close cousin HILDA/SIMON drill has been used in de-aromatized kerosene (ISOPAR).

What improvements would you like to make to this drill: Improvements in core quality, particularly in brittle ice.

What technologies are unique to this drill: Ultra-clean modification uses titanium and HDPE core sleeves to reduce surface contamination of core (see David Fisher report).

Name of drill: **"Clean-Simon"**

Name of person making report: David A Fisher

What projects has this drill be used on: Drilled, Agassiz ice cap (Ellesmere Island), Penny Ice Cap (Baffin Island), Drilled Devon Ice Cap, Drilled Mt Logan . In total drilled about 2km of core, since 1993.

Who built the drill: Geological Survey of Canada, Instrument Development Workshop; master mechinist, Romeo Forconi.

What is the design history of the drill:

(For example, is it a minor modification of a previous design, if so what was changed.)

Based closely on Danish tipping tower drill. Danes provided what plans they had and talked our machinists through the undocumented spots by phone. The liquid capability also follows the Danish modifications to their shallow drill. The "ultra-clean" version of the Simon system was developed by GSC and Icefield Instruments Inc (Whitehorse) and includes titanium barrels, cutting head and pre-cleaned plastic inserts that go into the inner barrel for each core , which are then shipped in the plastic cylinder they were drilled into. The titanium barrels etc fit onto the stainless steel motor gear section of Simon with no modification.

Maximum depth it has been used to recover core: Max drilled on Penny Ice Cap was 347 m .

Core diameter: 83 mm

Length of core collected on each trip down hole: nominal 1 m , but varies from 0 to 2 m.

What is the typical travel speed up and down the hole: 1 m/sec down and up.

What drill fluids have been used with it: lamp oil D60 .

What improvements would you like to make to this drill: For some odd reason the titanium version of the drill refuses to go deeper than about 65m, even with weigths added. It would be nice to figure out and fix this . Also needs a cable winder, like its Eclipse cousin.

What technologies are unique to this drill. The clean aspects of "clean-Simon" are unique . Icefield Instruments Inc . is now prepared to make and sell the clean up-grade to its Eclipse drill which is identical to Simon.

Denmark

Name of drill: **Danish Shallow drill**, [*Gundestrup et al*., 1989; *Johnsen et al*., 1980].

Name of person making report: Sigfus Johnsen and Steffen Hansen

What projects has this drill been used on? GISP1, Renland, GRIP, Hans Tausen, NorthGRIP, EPICA DML

Who built the drill? Department of Glacilogy, University of Copenhagen.

What is the design history of the drill? Designed in 1975, tested at Dye 3 in 1976 and modified to final form in 1977.

The basic design concept has later been adopted in several shallow-, intermediate-

and deep drill constructions, and a commercial copy of the shallow drill is now

available from Eric Blake in Canada.

Maximum depth it has been used to recover core: 350 m.

Core diameter: 7.8 cm

Length of core collected on each trip down hole: 1 m. Max drilling speed: 100 m in 16 hours. Total length of core drilled exceeds 3500 m.

What is the typical travel speed up and down the hole? 1 m/s

What drill fluids have been used with it? Used with D60 in 1993 in preparation for building the HT and NGRIP liquid drills.

What improvements would you like to make to this drill? Moveable top wheel and a detachable winch motor (already applied in the Swiss version of the drill.)

What technologies are unique to this drill?

3 cutter drill head with changeable shoes for control of pitch.

Tilting tower and integrated winch providing fast handling.

Anti torque section with three forth order shaped spring blades [*Reeh*, 1984], built in hammer and sliding contacts along with a rotation detector.

Name of reamer: **Danish reamer system,** [*Johnsen et al.*, 1994]
Name of person making report: Sigfus Johnsen and Steffen Hansen

What projects has this reamer been used on? GISP1, GRIP, NorthGRIP, EPICA Dome-C, EPICA DML, Berkner Island.

Who built the reamer? Department of Glaciology, University of Copenhagen.

What is the design history of the reamer? Designed and built in 1978, modified with larger diameters up to 25.5 cm in 1989. Uses same motor section as for shallow drill and a modified shallow drill anti torque section.

Maximum depth it has been used and speed of operation: 120 m. Typical time to ream from 10.4 cm to 25 cm in 4 steps and with 1 shift is 4 days.

Reamer diameters: 13.5 cm, 18.3 cm, 22.2 cm and 25.5 cm.

Length of runs on each trip down hole: 2 m to 4 m of ice equivalent depending on reamer.

What is the typical travel speed up and down the hole? 1 m/s using the winch for the Danish shallow drill.

What improvements would you like to make to this reamer system? Slightly different chips collection tube design allowing larger tolerances for the tube diameters.

What technologies are unique to this reamer? Cutter design ensures almost 100% chips recovery. The reamer system takes advantage of already existing drilling equipment.

Name of drill: **ISTUK**, [Gundestrup et al., 1994; Gundestrup et al., 1984; Johnsen et al., 1994]
Name of person making report: S Sigfus Johnsen and Steffen Hansen

What projects has this drill been used on? GISP1 (1979-1981) and GRIP (1990-1992).

Who built the drill? Department of Glaciology University of Copenhagen. Drill head was manufactured in the University of Bern.

What is the design history of the drill?
Basic design made from 1977 to 1978, test made in 1978 at Dye-3 and in early 1979 at CRELL. The original design was finalized in 1979. Prior to the GRIP 1989 season several improvements were made on the ISTUK drill system.

Maximum depth it has been used to recover core: 3028 m at GRIP and 2039 m at Dye-3.

Core diameter: 97 mm.

Length of core collected on each trip down hole: 2.4 m.

What is the typical travel speed up and down the hole? 1 m/s.

What drill fluids have been used with it? 1) DFA/Jet A1 with PCE, 2) D60 lamp oil with Freon.

What improvements would you like to make to this drill? Update electronics and remove batteries.

What technologies are unique to this drill?
A single tube system with 3 piston pumps providing 1.5 l/min throughput for each pump. The cuttings were sucked through 3 outside channels placed between the cutters and the corresponding suction chamber. Furthermore, this design allowed fast traveling speed of the drill in the hole.

The drill was partly run by rechargeable batteries in order to reduce cable size. The tightness of all seals was monitored by pressure gauges. Communication between drill and console was performed by the use of a modem, and 30 drill parameters including cutter load could be displayed on the console screen. The shallow drill tilting tower concept was adopted for the ISTUK deep drill in order to greatly facilitate handling of the drill at surface.

Name of drill: **Hans Tausen drill**, a prototype drill for the NorthGRIP/EPICA deep drill.
Name of person making report: Sigfus Johnsen and Steffen Hansen

What projects has this drill been used on? The Nordic Hans Tausen drilling project, the NorthGRIP drilling project (to drill an access hole and for recovering the warm bottom ice) and the EPICA DML drilling project.

Who built the drill? Tubes and inner parts were manufactured by different companies in Grenoble, France. Drawings for the drill parts built in Grenoble were made in LGGE. Drill heads and cutters were made by the University of Bern; electronic section, anti torque section and the double action pump were made in Copenhagen.

What is the design history of the drill? The drill design was based on the experience of the Copenhagen group with the Danish Shallow Drill and the ISTUK drill. The basic design concepts of the Icelandic shallow drill and the JARE deep drill were furthermore adopted. Initial tests in a liquid filled hole of these concepts were made with a modified version of the Danish Shallow Drill in 1993. The test was quite successful in terms of core quality and chips recovery. The HT drill also shows excellent performance in a dry hole using narrow cutters and a booster to compact the cuttings.

The wet version was originally equipped with a Suzuki booster, but was later replaced by a double action pump acting together with half height (2 mm) flights on the core barrel allowing clearance to the outer barrel.

In 2003 the drill was modified for warm ice drilling. A 2 l plastic hose, filled with 40% ethanol water solution, was clamped on to the hollow shaft for each run. A pointed screw was fixed to the chips chamber in order to rip open the plastic hose when drilling was started. This prevented the water produced by drilling to refreeze and made warm ice drilling with good quality core possible to bedrock at NorthGRIP.

Maximum depth it has been used to recover core: 350 m at Hans Tausen and 3085 m at NorthGRIP..

Core diameter: 98 mm.

Length of core collected on each trip down hole: 1.6 m

What is the typical travel speed up and down the hole? More than 1 m/s.

What drill fluids have been used with it? D60 and a D60/Forane 141b mixture.

What improvements would you like to make to this drill? A lightweight intermediate winch.

What technologies are unique to this drill? Internal bypass valves that allow liquid to flow through the drill during descent to ensure fast travel speed. Drill works both in dry and liquid filled holes. A hollow driving shaft that acts as a filter for the wet chips.

Name of drill: **NGRIP/EPICA drill**

[*Gundestrup et al*., 1996], [*Gundestrup and Johnsen*, 2002].

Name of person making report: Sigfus Johnsen and Steffen Hansen

What projects has this drill been used on? NorthGRIP and EPICA DML deep drilling projects.

Who built the drill? Tubes and inner parts were manufactured by different companies in Grenoble, France. Drawings for the drill parts built in Grenoble were made in LGGE. Drill heads and cutters were made both by the University of Bern and in Copenhagen; electronic section, anti torque section and the double action pump were designed and made in Copenhagen.

What is the design history of the drill? The NGRIP/EPICA drill is a longer version of the Hans Tausen drill. To ensure efficient chips recovery this longer version needed a pump, which required flights of reduced height as described in the HT drill section. The pump was designed so it could physically replace the booster. The ISTUK type electronics with batteries has been replaced with a more conventional design based on efficient DC/DC converters.

Maximum depth it has been used to recover core: 2930 m.

Core diameter: 98 mm.

Length of core collected on each trip down hole: 3 to 3.5 m.

What is the typical travel speed up and down the hole? 1.3 m/s

What drill fluids have been used with it? A D60/Forane 141b and a D60/Sukane 123 mixture [*Gundestrup*, 1989; *Talalay and Gundestrup*, 2002a; *Talalay and Gundestrup*, 2002b].

What improvements would you like to make to this drill? Optimize the core barrel length /chips chamber length ratio.

What technologies are unique to this drill?

A double acting pump that also acts as a bypass valve. The core barrel can be released from the drill down hole in case of difficulties with core brakes. The coupling allows the entire drill to be used as a hammer in order to free a stuck core barrel.

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France

Name of drill: **Shallow drill: Pourchet.**

Name of person making report: Laurent Augustin.

What projects has this drill be used on: Itase traverse.

Who built the drill: LGGE Grenoble France.

What is the design history of the drill:

Maximum depth it has been used to recover core: 30m.

Core diameter: 70mm.

Length of core collected on each trip down hole: 0.50m.

What is the typical travel speed up and down the hole: 0.20m/s.

What drill fluids have been used with it: No fluid.

What improvements would you like to make to this drill: None.

What technologies are unique to this drill:

Fixed tower and integrated winch.

Motor supplied from surface. No batteries.

This drill is set on a sledge to be pulled by a skidoo.

Name of drill: **EPICA long version.**

Name of person making report: Laurent Augustin.

What projects has this drill be used on: EPICA, Dome Concordia.

Who built the drill: European consortium:

Denmark, UCPH, Kopenhagen (anti torque section and double action pump, winch).

France, CNRS, LGGE, Grenoble (drawings, valves, tubes, pressure section, winch motor control).

Italy, ENEA, Brasimone (electronic section).

Switzerland, University of Bern (drill head, cutters shoes, tilting tower).

What is the design history of the drill: Basic design from JARE deep drill and the Danish shallow drill head. First planed to be used with an endless screw to suck the chips, an Epica pump (double action pump) was designed to replace physically the endless screw to improve fluid circulation and chips recovery.

Maximum depth it has been used to recover core: 3200m.

Core diameter: 98mm.

Length of core collected on each trip down hole: 2.5m < length < 3m.

What is the typical travel speed up and down the hole: 1.5m/s

What drill fluids have been used with it: D30 and Forane 141B foam.

What improvements would you like to make to this drill: Improve the pump capacity.

What technologies are unique to this drill.

Technology fully compatible with the EPICA short version drill.

Two versions: liquid filled hole and dry hole.

Can be handle by 2 persons only.

Tiling tower for easy handling.

Anti torque section with 3 spring blades.

Bypass valves to allow a great travel speed for descent.

Specific electronic, embedded for drilling parameters.

3 cutters, drill head with changeable shoes for pitch control.

Original pump design: double action pump.

Name of drill: **Carotelem 145 reamer system.**

Name of person making report: Laurent Augustin.

What projects has this drill be used on: Water well, Dome Concordia station, Antarctica (2003-2004).

Who built the drill: LGGE, Grenoble, France.

What is the design history of the drill:

Maximum depth it has been used to recover core: 120 m.

Reamer diameter: maximum diameter 255mm.

Length of runs on each trip down hole: 2m to 4m depending of depth.

What is the typical travel speed up and down the hole: 0.25m/s.

What drill fluids have been used with it: No fluid.

What improvements would you like to make to this reamer system:

What technologies are unique to this reamer.

Using the base of Carotelem 145 drill.

Collecting chips while reaming.

Name of drill: **EPICA short version.**

Name of person making report: Laurent Augustin.

What projects has this drill be used on:

Hans Tausen, Greenland.

EPICA, dome Concordia, Antarctica.

Who built the drill: European consortium:

Denmark, UCPH, Kopenhagen.

France, CNRS, LGGE, Grenoble.

Switzerland, University of Bern.

What is the design history of the drill: Called also Hans Tausen drill which was the prototype version of the EPICA drill. Basic design from JARE deep drill and the Danish shallow drill head.

Maximum depth it has been used to recover core: 350m.

Core diameter: 98mm.

Length of core collected on each trip down hole: 1m < Length < 1.5 m.

What is the typical travel speed up and down the hole: 0.8 m/s.

What drill fluids have been used with it: D30 and Forane 141B foam.

What improvements would you like to make to this drill: Improve the pump capacity.

What technologies are unique to this drill.

Technology fully compatible with the EPICA long version drill.

Two versions liquid filled hole and dry hole.

Tiling tower for easy handling.

Anti torque section with 3 spring blades.

Bypass valves to allow a great travel speed for descent.

3 cutters, drill head with changeable shoes for pitch control.

Can be equipped with the double action pump from the EPICA long drill version.

Name of drill: **1000m drill.**

Name of person making report: Laurent Augustin.

What projects has this drill be used on: Berkner Island, Antarctica (2003-2004).

Who built the drill:

France, IPEV, CNRS, LGGE, Grenoble.

United Kingdom, BAS, Cambridge.

What is the design history of the drill:

Maximum depth it has been used to recover core: Design for 1000m depth.

Core diameter: 98mm.

Length of core collected on each trip down hole: 2m.

What is the typical travel speed up and down the hole: 0.7m/s

What drill fluids have been used with it: D60 and Forane 141B foam.

What improvements would you like to make to this drill: Under test season 2003-2004.

What technologies are unique to this drill.

Equipment designed for Twin Otter transportation.

Drill based on the design of the EPICA drill.

Motor supplied from surface. No batteries.

Drill to be used without any embedded electronic.

Name of drill: **Carotelem 145.**

Name of person making report: Laurent Augustin.

What projects has this drill be used on:

French Alps: Mont Blanc.

Vostok, gaz sampling, Antarctica, shallow core BH3 to BH8.

Caroline, Adélie Land, Antarctica.

Law Dome, gaz sampling, Antarctica.

Eurocore, gaz sampling, Greenland.

Firetrac, gaz sampling, Dome Concordia, Antarctica.

Epica, pilot hole, Dome Concordia, Antarctica (1999-2000).

Who built the drill: LGGE, Grenoble, France.

What is the design history of the drill:

No major changes since 1980.

Maximum depth it has been used to recover core: 240m.

Core diameter: 98mm.

Length of core collected on each trip down hole: 0.50m.

What is the typical travel speed up and down the hole: 0.25m/s.

What drill fluids have been used with it: No fluid.

What improvements would you like to make to this drill: Pretty old and heavy equipment.

What technologies are unique to this drill.

Tilting tower and integrated winch.

3 phases motor supplied from surface. No batteries.

Drill head with 3 round cutters.

Anti torque section with 3 spring blades.

Name of drill: **Thermal 4000m.**

Name of person making report: Laurent Augustin.

What projects has this drill be used on:

D47, Adélie Land, Antarctica (1987-1989).

2004, this equipment is not complete: tower, winch and cable are missing.

Who built the drill: LGGE, Grenoble, France.

What is the design history of the drill: After the dome C experience in 1978 of the thermal dry hole down to 905m, was decided to design a thermal liquid filled hole.

Maximum depth it has been used to recover core: 871m.

Core diameter: 122 mm.

Length of core collected on each trip down hole: 8m.

What is the typical travel speed up and down the hole: 0.25m/s.

What drill fluids have been used with it: D30 and CFC 11.

What improvements would you like to make to this drill: The design need to be changed in order to retrieve the core in horizontal position instead of vertical position.

What technologies are unique to this drill.

3 phases drill head 7 kw, nude electric wire.

Carbon Kevlar fiber glass tube.

Electronic for telemetering and remote control system by multiplexing frequency.

Germany

Name of drill: **NGRIP/EPICA deep drill**

Name of person making report: Frank Wilhelms

What projects has this drill be used on: EPICA-DC, EPICA-DML, NGRIP

Who built the drill: EPICA consortium

What is the design history of the drill: The drill was newly designed for EPICA/NGRIP. For the NGRIP and EPICA-DML drilling first the old battery buffered ISTUK electronics was used, which is now replaced by a new German-Danish development based on DC/DC Converters. The winch performance has been improved by the use of a new motor controller thus permitting slow and constant cable feed.

Maximum depth it has been used to recover core: 2560 m at DML and 3080 m at NGRIP

Core diameter: 98 mm

Length of core collected on each trip down hole: around 3 m

What is the typical travel speed up and down the hole: 1.3 m/s up and 1.1 m/s down the hole

What drill fluids have been used with it: D60, D40, D30 with HCFC-141b

What improvements would you like to make to this drill:

1.) New section with motor driven Anti-torque to better control the penetration of the drill. Thus the shoes under the cutters could become obsolete and the pitch could be controlled during the run. This would improve the performance in warm ice significantly. Eventually it could also increase the lowering speed of the drill.

2.) New section with independently powered sucking pump. This would improve the chip recovery and could permit higher drilling speed, as it limits the present performance of the drill.

3.) Overwork the core catcher geometry, as in warm ice the core breaks get pretty high, due to plastic deformation of the ice and wedging of ice towards the bore hole walls.

Italy

Name of drill: **IDRA "Italian Drilling system for Antarctica"**

Name of person making report: Fabrizio Frascati – ENEA Brasimone (Italy)

What projects has this drill be used on: The TALDICE (Talos Dome Ice Core Project) project, to drill the peripheral dome 300 km NW of Station Zucchelli at Terra Nova Bay Italian (northern Victoria Land, Antarctica), and to improve the EPICA drilling system in collaboration with France, Switzerland and Denmark.

Who built the drill: The IDRA system were build up in the ENEA Brasimone Research Center (Bologna Italy), Department of Experimental Engineering in collaboration with LGGE (Grenoble, France).

What is the design history of the drill: IDRA would be an evolution of EPICA system, the development is related mainly to the necessity of develop an airborne drill system with an improvement of chips evacuation and chips chamber storage.

The first target is develop the EPICA drill in an airborne system by Twin Otter (or similar), and for this reason is in study the possibility to use composite materials for build up the winch, without reduce the cable characteristics.

In EPICA drill, the mechanical pump system is not enough efficient, especially related with very "high temperatures" (temperature around –3°C). This reduced efficiency can be related with the strong power adsorption from the pump (10% to 15% of the power available). The idea is use two separate electrical engine, one for the drilling rotation and the second for the chips pumping, but both manage with the same driving system. The drawings (see the figure) show the two possible solutions for the pump system, one with two electric pumps, and one with a mixed "electric-mechanic" systems (in any case the drilling rotation and pump engine are separate).

The cable will be of 4000 m, with adequate winch, in steel with 6 electrical wires, and the maximum resistance around 5 tons. We are in evaluation to include one more wire (the seventh) in optic fiber to increase both the speed and the performance of the drilling system-surface communications.

Maximum depth it has been used to recover core: Not yet used

Core diameter: The core will be 10 cm of diameter, also for use in the old EPICA bore-holes. In any case the external diameter will be 127 mm, because can be used in old bore-holes.

Length of core collected on each trip down hole: The length could be the 3500 mm of the old EPICA systems. The length in any case can be related to the performance of the pump system. In any case more than 3000 mm. An increase of the length need more power for the winch operations.

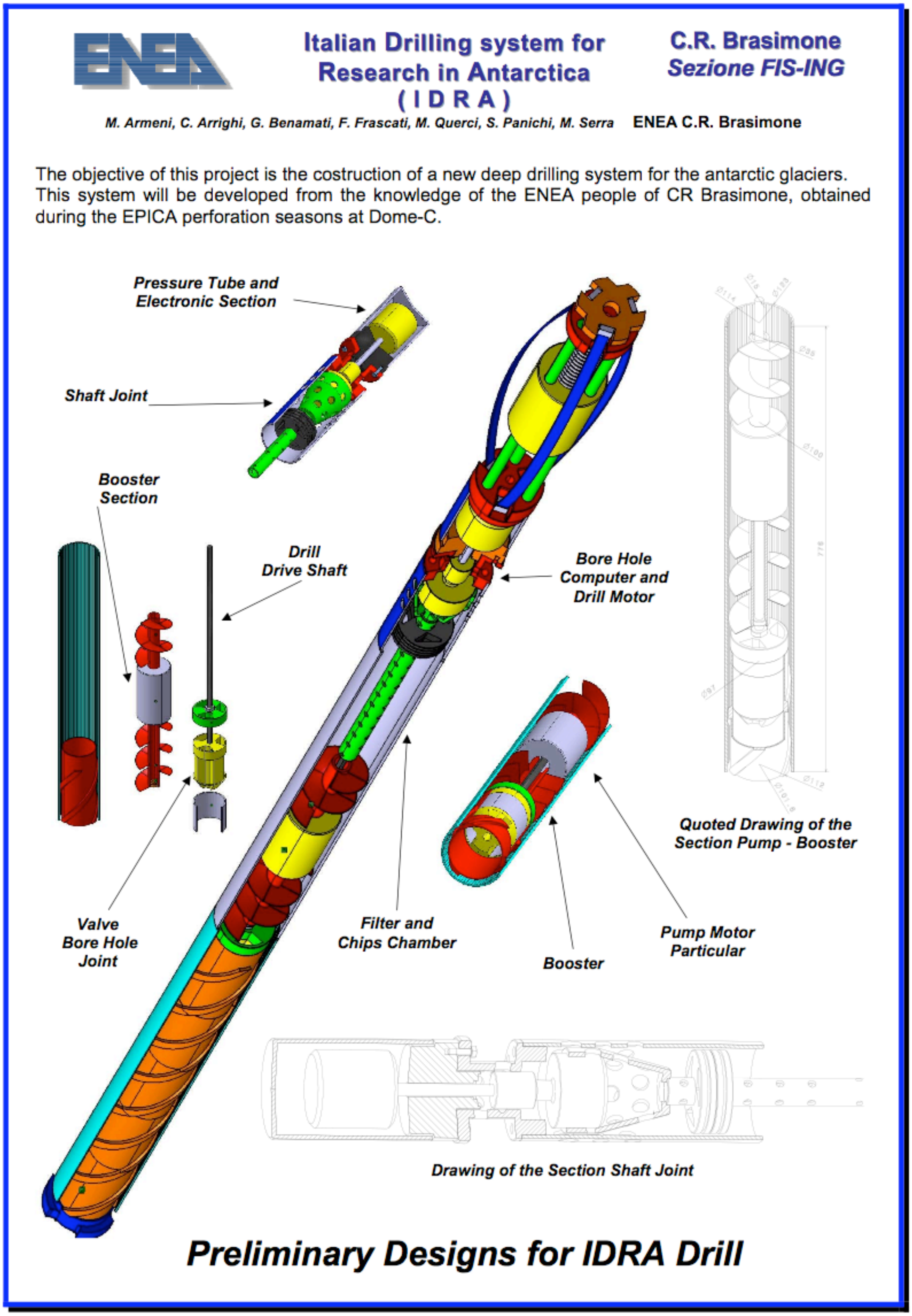
What is the typical travel speed up and down the hole: The speed is strictly related to the hydrodynamics of the entire drilling system, not yet tested. The project target is 600-800 mm/sec during descending and 1200-1500 mm/sec during the recovery operations.

What drill fluids have been used with it: The drill was developed for use with:

FORANE 141 B (1,1 DICHLORO -1- FLUOROETANE) JET A-1 FUEL

What improvements would you like to make to this drill: The modularity, due mainly to the possibility to share some parts (i.e. electronics) with other drilling operations (i.e. TALDICE and EPICA) and the possibility to transport all the drilling system by Twin Otter.

What technologies are unique to this drill. The pump is a commercial instrument, easy to find on the market. Some problems arise for the rotation speed regulations, from 1500 to 3000 rpm, and some vibrations during the pumping operations. Moreover the “coaxial” system to share pumps rotation and drilling rotations can be well studied, but could became a good solution for the drilling operations (see the figure).



Japan

Name of drill: **JARE deep ice core drill**

Name of person making report: Yoshiyuki Fujii

What projects has this drill be used on: Second deep ice coring project at Dome Fuji, Antarctica

Who built the drill: GeoTech Co., Nagoya

What is the design history of the drill:

1988 Start of development of deep ice core drill. Production of prototype drills A and B.

1989 Test of prototype drill in the Antarctica. Production of prototype drill C.

1990 Test of prototype drill in the Antarctica.

1991 Test of prototype drill in Greenland.

1992 Test of prototype drill in Greenland and Hokkaido using artificial ice tower.

1993 Test of prototype drill in Hokkaido using artificial ice tower.

1994 Test of deep ice core drill in Hokkaido using artificial ice tower. Completion of drilling system.

Major specifications: Electro-mechanical drill with DC brushless motor of 600 W. Barrel spiral chip transportation. Maximum core length: 2.2 m. Total length: 8.5 m.

1995 Start of deep ice coring at Dome Fuji, Antarctica. Drilling to 612 m depth.

1996 End of deep ice coring at 2503 m depth. Drill was stuck at 2332 m depth.

2000 Start of modification of the drill for the second deep coring at Dome Fuji. Test of chip transportation.

2001 Test of chip transportation.

2002 Test of the improved deep ice core drill in Hokkaido using artificial ice tower. Completion of new drilling system.

Major modifications: DC brush motor of 500 W. Maximum core length: 3.8 m. Total length: 12.3 m. Perforated chip chamber. Anti-chip-effluence valve.

Maximum depth it has been used to recover core: 2503 m.

Core diameter: 94 mm.

Length of core collected on each trip down hole: 3.85 m.

What is the typical travel speed up and down the hole: 80-90 cm /sec

What drill fluids have been used with it: Butyl acetate

What improvements would you like to make to this drill: No at present.

What technologies are unique to this drill: Very simple mechanism.

Russia

Name of drill: **KEMS-112 and KEMS-132** – Russian abbreviation of "Core electromechanical drill", numbers 112 and 132 mean the outer diameters of drill head;

Name of person making report: P.G.Talalay (St. Petersburg State Mining Institute)

What projects has this drill be used on:

Drilling at Vostok Station (East Antarctica): 2 holes

Drilling on Vavilov ice cap (October Revolution Island, Severnaya Zemlya archipelago, Russian Arctic): 3 holes

Drilling on Akademiya Nauk ice cap (Komsomolets Island, Severnaya Zemlya archipelago, Russian Arctic): 1 hole

Who built the drill: Leningrad Mining Institute (since 1991 St Petersburg State Mining Institute)

What is the design history of the drill: CRREL electromechanical drill[1,2] was chosen as prototype of KEMS drill. The designing of KEMS drill was going on step by step: designing and stand experiments from unit to unit, drilling of the experimental shallow holes, drilling of the deep hole. KEMS drill is able to drill ice and subglacial rocks as well.

Maximum depth it has been used to recover core:

3623 m (Vostok Station, 43 RAE, 1998) – the deepest hole in glaciers

Core diameter:

KEMS-112: 85, 87 or 89 mm

KEMS-132: 106 or 107 mm

Length of core collected on each trip down hole: 2.0-2.5 m

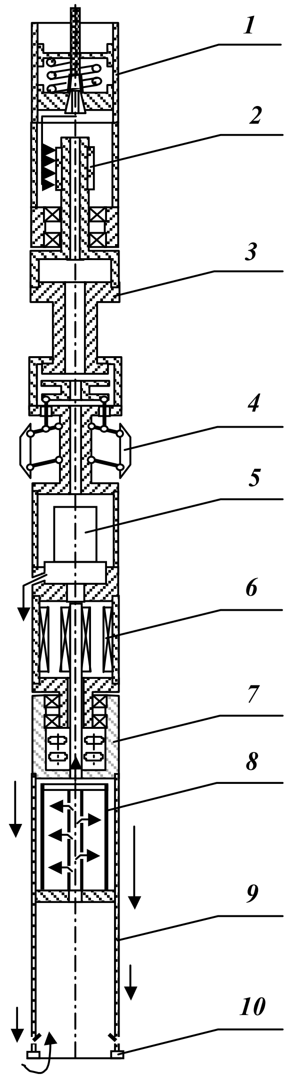
What is the typical travel speed up and down the hole: 1 m/s

What drill fluids have been used with it: aircraft fuel TS-1 mixing with densifer (CFC 11, HCFC 141 b)

What improvements would you like to make to this drill: decreasing of hydraulic resistances in the circulation system; developing of the control system

What technologies are unique to this drill:

The core barrel section consists from the single tube. The design of the drill provides for using of two motors: one of them for driving of the core barrel and another one for driving of the pump. The independent drive of the pump provides continuous circulation of hole fluid not only during drilling but also at the time of other technological operations (bore-hole filtering, for example). The design of the drill is protected by Patent certificate of USSR # 1472613 (1986).



1 – cable termination; 2 – current collector, 3 – hammer, 4 – antitorque device, 5 – pump, 6 – motor, 7 – gear reducer, 8 – chip chamber, 9 – core barrel, 10 – drill head

[1,2] **Ueda H.T., Garfield D.E.** 1968: Drilling through the Greenland ice sheet. *USA CRREL Spec. Rep.* 126. 15 p.

Ueda H.T., Garfield D.E. 1969: Core drilling through the Antarctic ice sheet. *USA CRREL Tech. Rep.* 231. 17 p.

Name of drill: **TBZS-152 (TBZS-152M) and TBZS-132** – Russian abbreviation of “Thermal drill for fluid-filled holes”, numbers 152 and 132 mean the outer diameters of drill head; after the modernization the name of the TBZS-152 drill was added by letter “M”.

Name of person making report: P.G.Talalay (St. Petersburg State Mining Institute)

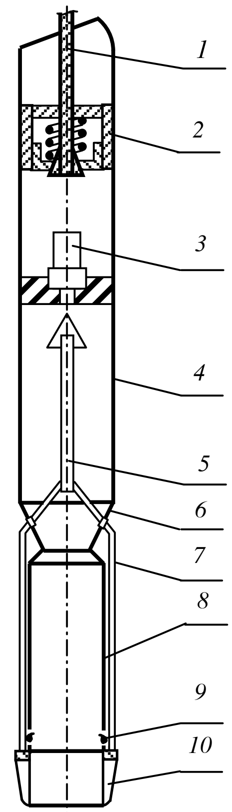
What projects has this drill be used on:

Drilling at Vostok Station (East Antarctica): 3 holes

Drilling on Vavilov ice cap (October Revolution Island, Severnaya Zemlya archipelago, Russian Arctic): 9 holes

Who built the drill: Leningrad Mining Institute (since 1991 St Petersburg State Mining Institute)

What is the design history of the drill: In general, the design of TBZS-152 drill is close to CRREL thermal drill (for fluid-filled holes)[1] but simpler. The drill head 10 (see Figure) has the ring form made from copper or aluminum with two tube electrical heating elements inside. The melted water is picked up by the hydrophobic fluid and lifted through water sucking tubes 7 into the tank 4 where due the rapid decreasing of the flow speed the water is separated from the drilling fluid.



1 – cable, 2 – cable termination, 3 – pump, 4 – water tank, 5 – central water sucking tube, 6 – connector, 7 – water sucking tubes, 8 – core barrel, 9 – core catcher, 10 – thermal head

Maximum depth it has been used to recover core: 2775.3 m (Vostok Station, 37 RAE, 1992) – the deepest hole drilled by thermal drills

Core diameter:

TBZS-152: 106-110 mm (inner diameter of drill head: 114 mm)

TBZS-132: 87-91 mm (inner diameter of drill head: 95 mm)

Length of core collected on each trip down hole: 2.8-3.2 m

What is the typical travel speed up and down the hole: 0.5 m/s

What drill fluids have been used with it: aircraft fuel TS-1 mixing with densifer (CFC 11, HCFC 141 b)

What improvements would you like to make to this drill: installation of dawn-hole sensors of temperature, inclination, rate of flow, filling of water tank, etc.

What technologies are unique to this drill:

The thermal head containing the sealing-in tube electrical heating elements is able to operate at high fluid pressure. The smoothly regulated DC motor of the pump controls the rate of fluid flow in order to ensure the complete separation of drilling fluid from water in water tank.

[1] **Ueda H.T., Garfield D.E.** 1968: Drilling through the Greenland ice sheet. *USA CRREL Spec. Rep.* 126. 15 p.

Name of drill: **TELGA-14 (TELGA-14M)** – Russian abbreviation of "Electrothermal drill constructed by Leningrad Mining Institute and Arctic and Antarctic Research Institute", number 14 means that the drill was constructed for using during 14th Soviet Antarctic Expedition; after the modernization the name of the drill was added by letter "M".

Name of person making report: P.G.Talalay (St. Petersburg State Mining Institute)

What projects has this drill be used on:

Drilling at Vostok Station (East Antarctica): 7 holes

Drilling along the traverse Myrnyi – Vostok Station (East Antarctica): 17 holes

Who built the drill: Leningrad Mining Institute (since 1991 St Petersburg State Mining Institute) together with Arctic and Antarctic Research Institute

What is the design history of the drill: In general, the design of TELGA-14 drill is close to CRREL thermal drill (for dry holes)[2] but simpler. The drill head 10 (see Figure) has the ring form, and the heating element was made from the nichrome wire isolated by ceramic beads. The melted water is picked up by the airflow like airlift pumping.

Maximum depths it has been used to recover core: 952.4 m (Vostok Station, 17 SAE, 1972) – the deepest dry hole in glaciers;

740 m (105 km from Mirnyi, 33 SAE, 1988)

Core diameter: 125-128 mm (inner diameter of drill head: 130 mm)

Length of core collected on each trip down hole: 2.3-2.5 m

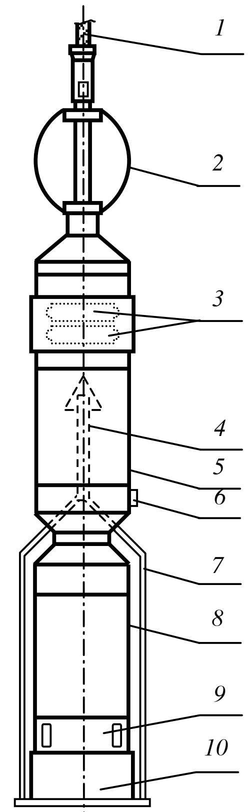
What is the typical travel speed up and down the hole: 1.2 m/s

What drill fluids have been used with it: dry hole

What improvements would you like to make to this drill: installation of dawn-hole sensors of temperature, inclination, rate of vacuum cleaner, filling of water tank, etc.

What technologies are unique to this drill:

The main advantage of TELGA-14 drill is the circulation system providing the fast and complete sucking of the melted water from the bottom, in particular, sizes, quantity and location of special holes at the lower end of water sucking tubes. This technology ensures the recovering of the core (for example, in firn zones) non-soaked by water. The design of the drill is protected by Patent certificate of USSR # 399600 (1972).



1 – cable, 2 – centralizer, 3 – vacuum pump,
4 – central water sucking tube, 5 – water tank, 6 – valve, 7 – water sucking tubes, 8 – core barrel, 9 – core catcher, 10 – thermal head

[2] **Ueda H.T., Garfield D.E.** 1968: Drilling through the Greenland ice sheet. *USA CRREL Spec. Rep*. 126. 15 p.

Name of drill: **TBS-112VCh** (Russian abbreviation of "Thermal drill with high frequency supply", number 112 means the outer diameter of drill head)

Name of person making report: P.G.Talalay (St. Petersburg State Mining Institute)

What projects has this drill be used on: Drilling at Vostok Station (East Antarctica) – 1 hole

Who built the drill: Leningrad Mining Institute (since 1991 St Petersburg State Mining Institute)

What is the design history of the drill: In order to reduce the electrical losses at first specialists of Glaciological Laboratory (CNRS, Grenoble, France) proposed the using of voltage transformer[3]. The other step was to use the frequency transformer as it was provided in TBS-112VCh drill.

Maximum depth it has been used to recover core:

2201.7 m (Vostok Station, 30 SAE, 1985) - the deepest hole in glaciers from 1985 until 1988

Core diameter: 90 mm

Length of core collected on each trip down hole: 1.5-1.7 m

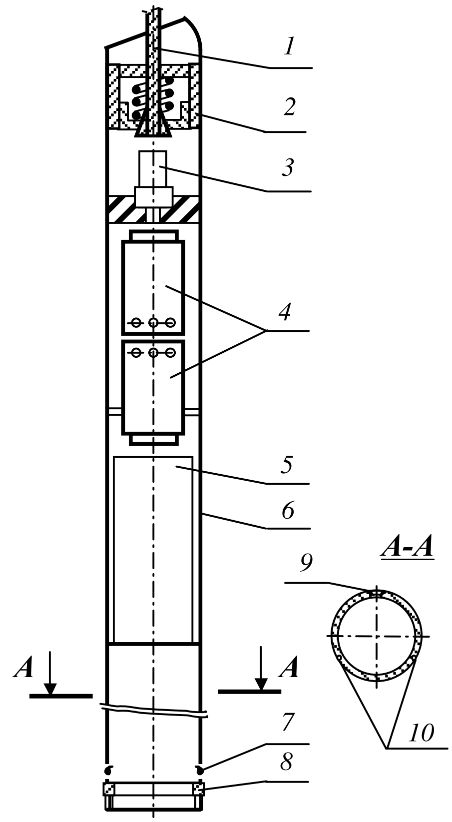
What is the typical travel speed up and down the hole:

0.5-0.6 m/s

What drill fluids have been used with it: aircraft fuel TS-1 mixing with densifer (CFC 11)

What improvements would you like to make to this drill: installation of dawn-hole sensors of temperature, inclination, rate of flow, filling of water tank, etc.;

developing of the drill head design in order to increase its "life-time".



1 – cable, 2 – cable termination, 3 – pump, 4 – frequency transformers, 5 – removable water tank, 6 – core barrel, 7 – core catcher, 8 – thermal head, 9 – electrical lines, 10 – water sucking tubes

What technologies are unique to this drill: The power supply has the following scheme: the surface power supply – increasing frequency transformer (2500-4000 Hz) – cable – down-hole reducing frequency transformer – electrical consumers in the drill. The water tank isn't heated. The melted water is collected in tank and freezes inside. At the surface the tank is removed and replaced by the empty one. The core barrel was made from a thick-walled tube, and water sucking tubes and electrical lines were "hidden" in the wall. The design of the drill head is protected by Patent certificate of USSR # 1263845 (1984).

[3] Gillet F., Donnou D., Ricou G. 1976: A new electrothermal drill for coring in ice. Ice-Core Drilling: Proc. of the Symp., Univ. of Nebraska, Lincoln, USA, 28-30 Aug. 1974. Lincoln, Univ. of Nebraska Press, 19-27.

Switzerland

Name of drill: **Swiss UNIBE 4-inch drill**

Name of person making report: Jakob Schwander, Henry Rufli

What projects has this drill be used on: Dye-3 (1986, 1988), Eurocore (1989)

Who built the drill: Henry Rufli

What is the design history of the drill: Design based on 3-inch drill (first version 1973). Later improvements: motordrive (constant speed), drill head with integrated pre-cutters for improve core quality.

Maximum depth it has been used to recover core: 304.8 m

Core diameter: 105 mm

Length of core collected on each trip down hole: 1 m

What is the typical travel speed up and down the hole: up: 1 m/s; down: 1.2 m/s

What drill fluids have been used with it: dry

What improvements would you like to make to this drill: Use less sticky core barrels, Improve anti-torque (similar to 3-inch version)

What technologies are unique to this drill: retractable anti-torque

References:

Schwander, J., and H. Rufli, Electromechanical drilling in dry holes to medium depths, in *Ice Core Drilling, Proceedings of the third international workshop on ice drilling technology*, pp. 32-37, Grenoble 10-14 Oct. 1988, 1989.

Schwander, J., and H. Rufli, Electromechanical drilling of a 300-m core in a dry hole at Summit, Greenland, in *Memoirs of National Institute of Polar Research. Ice drilling technology. Proc. of the Fourth Internl. Workshop on Ice Drilling Technology, Tokyo, April 20-23, 1993*, pp. 93-98, Tokyo, 1994.

Name of drill: **Swiss UNIBE 3-inch drill**

Name of person making report: Jakob Schwander, Henry Rufli

What projects has this drill be used on: Vernagtferner (AT),Camp-3 (1978) (GL), Colle Gnifetti (CH), Mont Blanc (FR), Dobsina (SK)....

Who built the drill: Henry Rufli

What is the design history of the drill: First version in 1974 (50 m light weight drill)

Improvements: core barrel, motordrive (constant speed), Antitorque with 5 skates only 0.3 m long, drill head with integrated pre-cutters for improve core quality.

Maximum depth it has been used to recover core: 120 m

Core diameter: 76 mm

Length of core collected on each trip down hole: 0.8 m

What is the typical travel speed up and down the hole: 1.2 m/s

What drill fluids have been used with it: dry, can be used in 1 m of hole liquid.

What improvements would you like to make to this drill: Winch with exchangeable cable drum,

What technologies are unique to this drill: 2 versions of tiltable tower base (one for a 1.3 m trench, and one for surface operation without trench)

Reference:

Rufli, H., B. Stauffer, and H. Oeschger, Lightweight 50-meter core drill for firn and ice, in *Ice-core drilling*, edited by J.F. Splettstoesser, pp. 139-153, University of Nebraska Press, Lincoln, Nebraska, 1976.

Schwander, J., and H. Rufli, Electromechanical drilling in dry holes to medium depths, in *Ice Core Drilling, Proceedings of the third international workshop on ice drilling technology*, pp. 32-37, Grenoble 10-14 Oct. 1988, 1989.

Name of drill: **Swiss 2-inch drill**

Name of person making report: Jakob Schwander, Henry Rufli

What projects has this drill be used on: various Alpine cores.

Who built the drill: Henry Rufli (design) hardware: FS Inventor AG (www.icedrill.ch), Felix and Dieter Stampfli, Muri 18, CH-3132, Switzerland

What is the design history of the drill:

Maximum depth it has been used to recover core: 25 m

Core diameter: 51 mm

Length of core collected on each trip down hole: 0.4 m

What is the typical travel speed up and down the hole: hand operated

What drill fluids have been used with it: dry

What improvements would you like to make to this drill: Improve reliability

What technologies are unique to this drill: Only 18 kg total weight, battery drive, generator or solar panel recharge (one charge for 15 m firn core)

Name of drill: **FELICS (<u>F</u>ast <u>E</u>lectromechanical <u>L</u>ightweight Ice <u>C</u>oring <u>S</u>ystem)**

Name of person making report: Margit Schwikowski, Paul Scherrer Institut

What projects has this drill be used on: Drilling of ice cores from high-alpine glaciers in the Alps, the Andes, the Altai

Who built the drill: FS Inventor AG (www.icedrill.ch), Felix and Dieter Stampfli, Muri 18, CH-3132, Switzerland, in close collaboration with our group at Paul Scherrer Institut

What is the design history of the drill: This drill has especially been designed for drilling at high elevations (outside helicopter reach)

Maximum depth it has been used to recover core: 150 m

Core diameter: 8. 2 cm

Length of core collected on each trip down hole: Maximum 90 cm

What is the typical travel speed up and down the hole: About 0.5 m/sec

What drill fluids have been used with it: None

What improvements would you like to make to this drill: We would like to add a thermal drilling head.

What technologies are unique to this drill. Especially lightweight, modular design (weight of the heaviest piece: 30 kg), solar powered, no outer barrel, no tilting table, one-piece cutting ring, easy and fast to assemble even under the extreme conditions of high-altitude, installation in a protective tent, exists in a smaller version for shallow (15 m) hand drilling

Reference:

Ginot, P., F. Stampfli, D. Stampfli, M. Schwikowski, H.W. Gäggeler, FELICS, a new ice core drilling system for high-altitude glaciers. Proc. of the workshop “Ice Drilling Technology 2000”, Memoirs of National Institute of Polar Research, Special Issue, **56**, 38-48 (2002).

United Kingdom

Name of drill: **BAS drill**

Name of person making report: Robert Mulvaney

What projects has this drill be used on: Berkner Island shallow core (152 metres), DML shallow cores, identical *IMAU drill also used at several other Antarctic and Arctic sites.*

Who built the drill: Last Engineering based on designs by BAS; winch by MacArtney A/S

What is the design history of the drill: Many features based on AWI medium depth drill, which in turn is based on earlier designs.

Maximum depth it has been used to recover core: 160 metres

Core diameter: 106 mm

Length of core collected on each trip down hole: Typically 90 cm

What is the typical travel speed up and down the hole: 13.8 metres/minute

What drill fluids have been used with it: None (dry holes only)

What improvements would you like to make to this drill:

What technologies are unique to this drill. Very low weight for transport in Twin Otter aircraft: 340 kg including drill, winch, cable, tower and generator.

United States

Name of drill: **PICO 4 Inch Electromechanical Drill**

Name of person making report: Charles Bentley/Don Lebar

What projects has this drill be used on: Many shallow coring (<300 meters) projects

Who built the drill: PICO Nebraska and Alaska

What is the design history of the drill: This drill is a cable suspended and motorized version of the hand auger with an attachment to ream - up to 12 inch diameter. There is also an electrothermal coring head for use in warm ice. In 2000 ICDS added instrumentation to measure inclination, weight on cutters, and depth.

(For example, is it a minor modification of a previous design, if so what was changed.)

Maximum depth it has been used to recover core: 312 meters, 1974 Barnes Ice Cap, Canada, 309 meters, 1992, Guliya, Tibet

Core diameter: 4 inch

Length of core collected on each trip down hole: nominal one meter

What is the typical travel speed up and down the hole: 1.5 meters/sec

What drill fluids have been used with it: None

What improvements would you like to make to this drill: Replace with a lighter model, reduce the kerf

What technologies are unique to this drill. Easy to transport, can be taken apart, has been carried to 25,000 feet. First solar powered in 1983. The electrothermal coring head is slow but will go to any depth

Name of drill: **Caltech 7cm Hot Water Ice Corer and Caltech 10cm Hot Water Ice Corer**

Name of person making report: Charles Bentley/Don Lebar

What projects has this drill be used on: Barclay Kamb and Hermann Englehardt – Ice Stream B, C, D, and Siple Dome

Who built the drill: California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, California

What is the design history of the drill: New design in 1992, first hot water coring drill supported by NSF

Maximum depth it has been used to recover core: 1,200 meters, capable of going deeper, limited by current capabilities of the Caltech Hot Water Drill

Core diameter: 7cm or 10cm

Length of core collected on each trip down hole: nominal 2m with 7cm and 4m with 10cm

What is the typical travel speed up and down the hole: 10 meters/minute

What drill fluids have been used with it: Only water

What improvements would you like to make to this drill: Make the 10cm drill section longer to increase core length, reducing the number of trips down hole. Improve capability of drilling in debris laden ice. Increase depth by upgrading the Caltech Hot Water Drill.

What technologies are unique to this drill. Fast production of ice core below the firn. Able to obtain ice core without using petroleum/chemical based drilling fluids. Mobility of hot water system allows sampling several different sites in a single season.

Name of drill: **PICO Hand Augers**

Name of person making report: Charles Bentley/Don Lebar

What projects has this drill be used on: Many shallow coring (<50 meters) projects

Who built the drill: PICO Nebraska

What is the design history of the drill: The "Prairie Dog" modification includes a stationary outer barrel to facilitate chip transport in solid ice. The optional "Sidewinder" addition consists of an electric motor to drive the auger and retrieve the drill string. It is used particularly with the Prairie Dog to handle the extra weight of the outer barrel and anti-torque system. Electric power can be provided by solar cells or a small generator.

Maximum depth it has been used to recover core: 46 meters

Core diameter: 3 or 4 inch

Length of core collected on each trip down hole: .5 meter or one meter

What is the typical travel speed up and down the hole: As fast as you can pull

What drill fluids have been used with it: None

What improvements would you like to make to this drill: Replace with a lighter model, reduce the kerf

What technologies are unique to this drill. Easy to transport

Name of drill: **Hand-Held Short Coring Drill**

Name of person making report: Charles Bentley/Don Lebar

What projects has this drill be used on: Ed Brook – Western edge of the Greenland Ice Sheet (Pakitsoq)

Who built the drill: ICDS/PSL University of Wisconsin-Madison

What is the design history of the drill: New design, to replace chain saws for collecting surface ice samples. This is a motor driven, hand held drill that quickly collects (about 60 seconds per sample) a short (<50 cm) 1.6 inch core in solid ice (horizontally or vertically).

Maximum depth it has been used to recover core: 50 cm – this drill is designed for surface sampling only.

Core diameter: 1.6 inch

Length of core collected on each trip down hole: nominal 10 to 20 cm

What is the typical travel speed up and down the hole: Surface use only

What drill fluids have been used with it: None

What improvements would you like to make to this drill: Reduce barrel wobble by improving the bayonet mount and improve the cutters.

What technologies are unique to this drill. Designed for fast retrieval of short surface ice cores. Easy to transport, driven by a hand held drill, entire system fits into a single Hardigg box (power supply not included - could be powered by solar panels).

Name of drill: **Glacier Data 2 inch solar drill**

Name of person making report: Mark Wumkes

What projects has this drill be used on: ITASE

Who built the drill: Glacier Data, 750 Spudwood Road, Fairbanks, Alaska 99712

What is the design history of the drill: The drill is a combination of features found on several other drills. The tipping tower is similar to the Danish shallow drill and the Eclipse drill produced by Icefield Instruments.

The inner core barrel is similar to the Stampfli/Rufli drill produced in Switzerland.

The cutters use similar geometry to that used on the GISP and Siple Dome drill.

Maximum depth it has been used to recover core: 42 meters

Core diameter: 2 inch (5 cm)

Length of core collected on each trip down hole: 1 meter

What is the typical travel speed up and down the hole: 20 meters/min

What drill fluids have been used with it: None. It is a shallow dry drill.

What improvements would you like to make to this drill: I have a wet version designed but not yet built.

What technologies are unique to this drill: The drill uses a DC Brushless motor driven by a solid-state servo amplifier. It uses a 220-watt solar P.V. array for power so there is no need for a gas or diesel driven generator for a cleaner work environment. The winch is hand cranked which minimizes power requirements. The drill is very lightweight. The drill sonde weighs 68 pounds (31 kg) and the entire system weighs 200 pounds (90 kg) not counting the solar array. It easily fits into a Twin Otter aircraft.

Name of drill: **Intermediate depth ice core drilling system: 500 and 1000 m depth capabilities, dry hole electro-mechanical (EMD) and ethanol thermal electric drill (ETED)**

Name of person making report: Victor Zagorodnov

What projects has this drill been used on:

Franz Jozef Land (Eurasian Arctic), Greenland (PARKA) 2 field operations, Sajama (Bolivia) , Kimanjaro (Africa) , Puruogangri Cap (Tibet), Bona-Churchill Col, Alaska; Quelccaya and Coropuna (Peru) Total: 820 m with ETED; 1815 with EMD

Who built the drill: Victor Zagorodnov and OSU

What is the design history of the drill: Concept of chip separate storage from Y.Suzuki, design ^ Victor

Maximum depth it has been used to recover core: 214 m EMD, 468 ETED

Core diameter: 102 mm

Length of core collected on each trip down hole: 1050 mm EMD, 2100 mm ETED

What is the typical travel speed up and down the hole: 0.68/1.2 m/s EMD; 0.5/0.68 ETED

What drill fluids have been used with it: ethanol water solution?

What improvements would you like to make to this drill: EMD: shorter, lighter, better core quality and performance bellow 150 m.

What technologies are unique to this drill?

EMD:

Fast operation: average ice core production rate in 150 m borehole is 7 m/h

Drill operates at air temperature above the melting point in sunny days.

Operates in ice at temperatures close to the melting point, - water drip into the borehole.

Lightest, Shortest

New type of cutters

New type of antitorque - 0.12 m length, 10 mm radial space.

ETED:

Safe for operators

Low environmental impact

Low borehole fuel requirements roughly 1/3 of the borehole volume

5 times less thermo-elastic stress compare with old thermal drills resulted in less fractures.

Exchangeable, of the shelf heating element

Low power (compare to others) 2 m/h ice core production rate at 3.15 kW in 468 m depth.

Shortest, Lightest