# Addendum to February, 2004 IPICS – Pre-Workshop Report



## National Reports

*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:* **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: **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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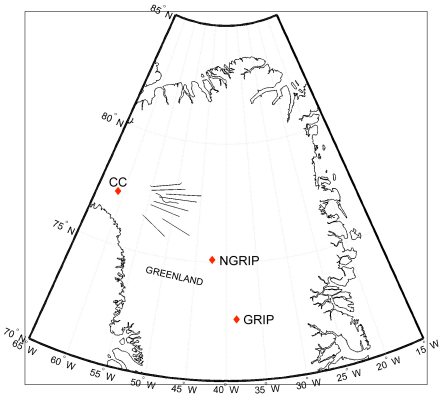
| Nikolay I. VASILIEV | vasilev_n@mail.ru | drilling technology, borehole geophysics |

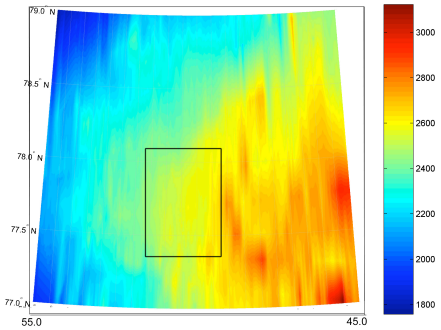
## Proposed Projects

### 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??

*References (work in progress)*


Etheridge, D. M., L. P. Steele, R. L. Langenfelds, R. J. Francey, J.-M. Barnola, V. I. Morgan, Natural and anthropogenic changes in atmospheric CO2 over the last 1000 years from air in Antarctic ice and firn, J. Geophys. Res., 101(D2), 4115-4128, 1996.

Etheridge, D. M., L. P. Steele, R. J. Francey, R. L. Langenfelds, Atmospheric methane between 1000 A.D. and present: Evidence of anthropogenic emissions and climatic variability, J. Geophys. Res., 103(D13), 15979-15994, 1998.

Francey, R. J., M. R. Manning, C. E. Allison, S. A. Coram, D. M. Etheridge, R. L. Langenfelds, D. C. Lowe, L. P. Steele, A history of &dgr;13C in atmospheric CH4 from the Cape Grim Air Archive and Antarctic firn air, J. Geophys. Res., 104(D19), 23631-23644, 1999.

Hansson, M.E., The Renland ice core. A Northern Hemisphere record of aerosol composition over 120,000 years, Tellus, 46B, 390-418, 1994.

Hammer, C.U., S.J. Johnsen, H.B. Clausen, D. Dahl-Jensen, N. Gundestrup, and J.P. Steffensen, The Paleoclimatic Record from a 345m long Ice Core from the Hans Tausen Iskappe, Meddelelser om Grønland, Geoscience, 39, 87-95, 2001.

Johnsen, S.J., H.B. Clausen, W. Dansgaard, N.S. Gundestrup, M. Hansson, P. Jonsson, J.P. Steffensen, and A.E. Sveinbjörnsdottir, A "deep" ice core from East Greenland, Meddelelser om Grønland, Geoscience, 29, 1-22, 1992.

Trudinger, C. M., I. G. Enting, D. M. Etheridge, R. J. Francey, V. A. Levchenko, L. P. Steele, D. Raynaud, L. Arnaud, Modeling air movement and bubble trapping in firn, J. Geophys. Res., 102(D6), 6747-6764, 1997.

Trudinger C. M., D. M. Etheridge, P. J. Rayner, I. G. Enting, G. A. Sturrock, and R. L. Langenfelds, Reconstructing atmospheric histories from measurements of air composition in firn, J. Geophys. Res., 107 (D24), 4780, 2002.

Turrock G. A., D. M. Etheridge, C. M. Trudinger, P. J. Fraser, and A. M. Smith, Atmospheric histories of halocarbons from analysis of Antarctic firn air: Major Montreal Protocol species, J. Geophys. Res., 107 (D24), 4765, 2002.

**An Ice Coring Program for non-Polar Regions**

Margit Schwikowski Paul Scherrer Institute, CH-5232 Villigen, Switzerland, e-mail: margit.schwikowski@psi.ch

*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.

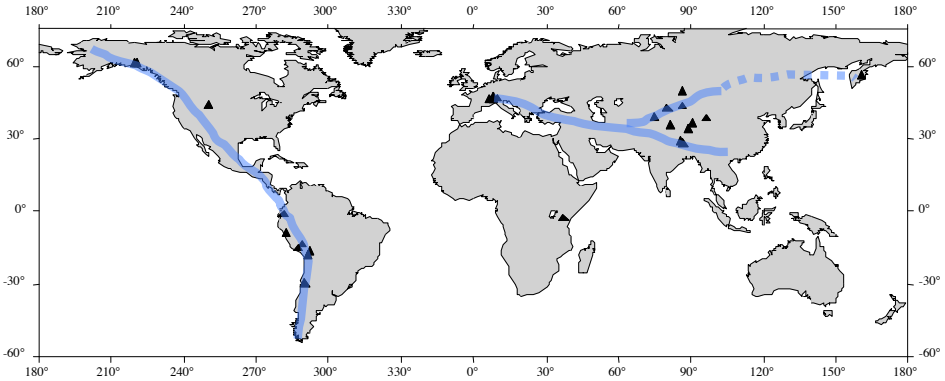



Figure 1: Locations of mid- and low-latitude ice core sites (triangles) along with suggested North-South Transect and West-East Alpide-Asiatic Transect (see below).

*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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## Drill Technology

**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.