To: Ice Core Community
Fr: Mark Twickler - NICL-SMO
Re: Meeting Reviews
Date: April 5, 2002

Greetings,

This message contains a review of the March 20th meeting held at Arlington, VA (also as a Word attachment). To begin with we would like to extend our sincere thanks and gratitude to all those who attended the meetings. We know that you all have very busy schedules and your time at the meetings was very appreciated and valuable. A special thanks goes out to the invited speakers, our European colleagues, NSF and USGS managers for all of their contributions to the meetings and are hopeful they can participate in the development of the Workshop Report. Reviews of the March 21 and 22 ICWG meetings will be coming out shortly.

March 20th Meeting: "Future of US Ice Core Sciences"
The meeting was in the National Science Boardroom and attendance exceeded more than seventy at times. The Board Room provided an excellent venue for the meeting and special thanks to Julie Palais for reserving the room and the NSF technical staff provided excellent support. The meeting consisted of a series of invited talks in the morning. The talks were limited to 15 minutes and the speakers did a excellent job in keeping to the allotted time. The purpose of these talks were to highlight the recent results from the ice cores and identify questions that still remain. The afternoon was spent discussing these questions and where to go, what we needed, and how international collaborations could help answer the questions raised.

Below are short highlights of the invited talks and discussion sessions. Apologizes to the speakers for condensing their well prepared and informative talks to a short paragraph. These topics will be greatly expanded in the workshop report. Discussions on some of these topics continued on march 21st and those comments are incorporated here. As always, additional input from anyone is appreciated.

Ed Brook, Chair of ICWG : Review of the 1986 National Academy of Sciences "Recommendations for a U.S. Ice Coring Program".
The majority of the recommendations made in 1986 have been meet but the long term stability of ice coring is presently not clearly defined. One of the recommendations was the development of a deep drill for the US community, this was completed and the drill was used for GISP2, Taylor and Siple Dome projects. The drill has not been recovering quality core in the recent projects. We need to revisit priorities and develop new recommendations. This is the purpose of this meeting.

Invited talks - First session
Michael Bender: Greenhouse gases
Greenhouse gases increase from glacial to interglacial cycles. Increases in greenhouse gases are related to temperature increases in the ice cores. Isotopic analysis of gas elements give new views on biospheric activity, carbon cycles, sources of gases, rapid temperature changes, inter-

linking of ice cores timescales, solar insolation on the ice sheet. These relationships can only be defined using ice core analysis.

Jim White: Abrupt Climate Change
Ice cores have shown climate changes on time scales challenging to human beings. The climate system has thresholds and when these are crossed climate can change abruptly. Abruptly means temperatures have change 15 degrees Centigrade in 50 years, a human lifetime. Climate records from ices cores also show changes 6C in a decade. Accumulation in Greenland doubled in less than 2 years. Ice cores are the key archive for studying abrupt climate change.

Kurt Cuffey: Ice Sheets, Climate and Sea Level
Ice cores have provided insights on the mass balance of ice sheets, stability of the West Antarctic ice sheet and provide data for ice flow models. All new cores can provide ice flow history, bedrock exposure history, geothermal flux and climate forcings, all of which are imperative for ice dynamics. Major questions ice cores can help answer: What happened to the ice sheets during the last interglacial? Where is the longest record available to understand Pleistocene glaciation?

Wallace Broecker: Bi-Polar Seesaw
The triggering of climate changes are probably the result of reorganization of ocean circulation but some say it is triggered from the tropics. Need to establish geographical signature of major climate events to better understand the system. The Heinrich events were not climate driven but caused climate changes. Understanding of the solar influence on climate is needed. Need to understand the phasing between the poles and ice cores can answer these questions.

Discussion period: Led by Jeff Severinghaus
Challenges:
Where is the fulcrum for the seesaw phasing between the north and south?

If the Antarctic Oscillation is the cause, coring the Antarctic Peninsula should answer this questions. Some research points to the tropics as being the fulcrum. Ice cores should be able address this questions.

Need to continue the initiated effort undertaken to synchronize the ice and marine records.

Abrupt climate change is not just temperature: What about the hydrological changes?

Atmospheric circulation changes cause precipitation patterns to change.

Stable isotopes of water not only record temperature but also show changes in precipitation.

Modeling of dust input to Greenland during glacial periods supports the expanded size of source regions.

What can we find by doing high resolution of CO2 concentrations?

Taylor Dome record of CO2 and C13 from the gas shows massive decrease in terrestrial biomass carbon from 8kyr to present.

Concentrated effort needed on all isotopic gas studies, not only CO2.

Need to understand the relationship between greenhouse gases and temperature.

What caused the flattening out of the CO2 increase in the late 40's-early-50's? Not related to emissions, suggested to be a biospheric response

What is the solar role in climate?

The amplitude of cosmic ray changes reconstructed from Berylium10 is the same as those for Carbon14.

These also agree very well to sunspots since 1600AD.

Solar activity more important than changes in visible and UV light changes.

Ice cores are unique in the way that they provide the most direct information about changes in atmospheric properties.

Invited talks - Second Session

Scott Rogers - Biological

Ice is a very good matrix for the preservation of DNA, which may have a half-life of a million years. Ice cores have produced "living fossils". Because microbes can survive in glaciers they are eventually released into the environment through meltwater. Future research holds a wide range of possibilities but contamination issues need to be addressed throughout the process of glacier formation, collection and processing. To learn more about Biological ice core aspects read the "Life in Ancient Ice Workshop Report" at:
http://salegos-scar.montana.edu/docs/Workshops.htm#June 2001

Buford Price - Future Directions

1986 NAS Document focused on paleoclimate, this will continue but what else can be done? The Antarctic sub glacial lakes have grand potential as does the biological aspects of ice coring. The South Pole region has what appears to be a frozen lake at the bed. This would be a location to test a sterile drill prior to using in liquid lake. Down hole sensors and a fast access drill could be used as tools to survey the ice sheet.

Richard Alley - Societal Relevance of Ice Cores

Climate change affects humans and humans affect climate. Linkages between greenhouse gases and temperature are real. Even small changes in climate have affected human civilizations. We have only one chance at climate forecast and we can't afford to get it wrong. The need for ice cores and other paleo records are needed to understand how climate changes. Every new ice core has produced interesting results and the biological community is just scratching the surface. We need a recommitment to ice coring science along with a high resolution record from the Southern Hemisphere.

Discussions - Led by Michael Mann and Thomas Stocker

Challenges:

What is the natural variability of the climate forcings?

The use of isotopic gas measurements can help answer.

Need to understand the dynamics of deglaciation and changes in the climate system.

How do we fill in holes in the temperature/circulation reconstruction records?

Ice cores, since they can be annually dated, are vital for global temperature and circulation reconstruction.

Currently southern hemisphere is lacking data: ITASE should be able to fill these gaps.

What location, studies and kinds of ice cores can help expand the biological community?

Environmental microbiology at low temperatures very important.

Defining microbiology communities in the ice sheets-"Life in extreme environments"

Track virus epidemics over long timescales.

Although ice cores are not long enough for evolutionary biology changes in RNA do occur over available time scales.

Typically about 2kg is needed for some biological analysis prior to the cleaning process.

Might be possible to add a tracer material to the drill fluid to check for penetration into the core.

Emerging Scientific Questions and New Programs.

Several speakers gave short discussion of coring projects. After the presentations there was a discussion periods. Parts of discussions that were most relevant to a specific project are below the short description of the projects. Some were either related to multiple projects or new ideas. These are included at the end of this section. Discussions were led by Ken Taylor

USITASE:

USITASE is currently operating and has traveled ~4000km over the West Antarctic ice sheet collecting radar profiles, ice cores, mass balance measurements, atmospheric profiles and other parameters. This coming field season USITASE will travel from Byrd to the South Pole. A proposal is being submitted to continue the traverse from the South Pole towards Northern Victoria Land. To learn more about the USITASE program visit the project website at:. http://www.ume.maine.edu/USITASE

ITASE provides good regional records.

Paradigm shifts in modern climate: Need to understand these

Antarctic ozone hole

Sea ice changes - albedo changes

ENSO previously thought to be tropical but now has been shown to have global signature

Antarctic Subglacial Lakes

Numerous lakes are under the Antarctic ice sheet. The scientific drive to explore these lakes is very high. One of the major challenges is how to penetrate the lake with out introducing contamination. Downhole logging tools could detect life in the ice above the lake surface and the lake itself. A probe could penetrate the ice to the lake boundary, dropped to the bottom to collect sediments and water samples along with taking in situ measurements and be retrieved back to the hole, refreeze the bottom of the hole and back surface. The retrieved water and sediment samples would need to be pressurized to lake pressures to get undisturbed samples. To learn more about the Antarctic Subglacial Lakes visit:
http://salegos-scar.montana.edu/

Sub-glacial lake exploration taking ice core collecting into planning.

Paleoclimate and biological priorities are not always the same. Need to work on areas of similar interest.

Sediment record from lake Vostok probably contains a paleoclimate record but not currently enough information to base scientific questions.

Search for Ancient Ice

Although not yet determined exactly where, it is expected that ice more than a million years old exist in East Antarctica. This ice when recovered could reveal major contributions to global change. One of the outstanding questions in paleoclimate research is the changes in the glacial cycle of ~100kyr to ~40kyr about 600kyr ago. Analysis of a core of this age could greatly expand our concept of biogeochemical processes and climate change over the past million years.

Old ice could give new insights to glacial cycle periodicities.
Locations could be defined by modeling but access drill would be important to confirm.
This ice might be available from the Dome C or Dome F coring projects.

Greenland Core

An ice core from North Central Greenland is the only place in the northern hemisphere that were an ice core record from the last interglacial can be found. This was the goal of the NGRIP project but due to unknown geothermal flux from the bedrock below the goal was not achieved. This record could answer questions on the stability of climate and the history of the Greenland ice sheet during the last interglacial. It should also provide a record of the penultimate/last interglacial transition. This record would allow us to compare the Holocene with the stability, timing and magnitude of the last interglacial. Part of the record would overlap with the NGRIP and allow for additional samples from specific depths that have been depleted from the GISP2 ice core archive.

Possibilities of Greenland Cores:

North Central Greenland core depth ~2500 meters. Could be possible to work as international project both scientifically and instructional in use of European drill.

Island just North of Thule: Logistical ease with vicinity of Thule Air Base, Twin Otter supportable. 1000m depth. Would give good record of Western weather systems.

Renland Ice Cap: Northeast Greenland. Previous core holds glacial ice. This core was not drilled on divide due to drill depth capability. Would give good record of Eastern weather systems.

Access road: Just outside of Kangerlussuaq a road is built onto the ice sheet. Glacial age ice exposed on the surface. Opportunity to get large quantities of glacial age ice.

Northern Greenland core should provide good solar record.

Areas of basal melting could provide glacial age samples with more than a centimeter yearly thickness.

Human Influence on Southern Biology and Climate

What is the human influence on the Antarctic environment? The recent warming on the Peninsula, cooling in the interior, collapsing of ice shelf, depletion of fisheries, etc: Are these changes human induced or natural? This program would collect a spatial array of ice cores that are annually resolved to 2000 years. Although some records are currently available the need for a greater spatial coverage is needed. Coastal sites are important and this is envisioned to be a international program with a interdisciplinary effort to understand the records. Start in the Antarctic and expand to the north.

2000 year records would probably have interest from European community since many countries have that technology and wouldn't require international funding to recover cores.

Ice cores are very important to fill spatial gaps of temperature reconstruction over the past several millenniums.

WAISCores

The recently completed Siple Dome project was part of the WAISCores project. The record from here has shown new rapid climate shifts in the past 5000 years. A core from Inland WAIS is needed to address a series of scientific questions. Although the relationship between CO2 and temperature has been shown to exist we still don't know the lead/lag relationship between these variables. Only a high resolution core from Antarctica can answer this questions. The detailed CO2 record would also give important information on the Carbon cycle. A high resolution Holocene record would allow for better understanding of the solar influence on climate and oscillations seen in other records. Present Antarctic cores do not have high enough resolution to record the rapid climate changes seen in the Greenland cores. Inland WAIS would provide this record . A biological aspect is incorporated into the science plan which also includes looking at how biology may effect the ice core record. Questions on the stability of the West Antarctic ice sheet can be addressed with the ice core. Site work has been done and is continuing. Logistically the location is a fair distance from McMurdo but the WAISCores plan has been planned since 1988 and has been the highest priority supported by the ICWG for years. It is recognized by SCAR and PAGES. To learn more about the WAISCores project visit the website at: http://www.maxey.dri.edu/WRC/waiscores/

From the European view the Inland WAIS core is the most important record needed.

Need record of abrupt climate change in Antarctica

Other Discussions

Two distinct biological conditions:

Microbiological community - ecosystem of organisms there because they want to be.

"Meteoric Organisms ": organisms and biological material fall from atmosphere and get trapped in ice.

Most meteoric organism probably don't come from the Antarctic region

Meteoric organism/material probably be easier to find in the Arctic region

Biological ice core research in it's infancy much like the paleoclimate community was 30 years ago. Need to give them the opportunity to develop technology with correct samples to learn what can be accomplished.

Is the life in ice grain boundaries? Work is currently investigating this question.

There are hints that microbiology could affect some gas concentrations. More work needed.

Ice cores can provide information on the biospheric ecosystem, not just what is incorporated in the ice matrix.

Records spanning 12,000 years important to consider to understand the glacial/interglacial transition (i.e., isolated domes)

Technical and Analytical Capabilities - Led by Jim White
The US ice core community has moved out of it's infancy in ice coring and becoming more mature. One of the major hurdles is deep drilling capability. What are some of the things we learned about deep drilling capability:
- Larger diameter core may not be as important
- Core quality is very important
- Logistical cost must be taken into account
- Scientist need to be more involved in the drilling process

What are some of our drill requirements:
- Efficient deployment
- Recovery of core in any ice condition (i.e. warm/cold ice)
- Recovery of bedrock core
- 100% core recovery
- Highest quality of core feasible
- Logistically and financially feasible
- Drilling fluids compatible with all studies
- Samples free of biological contamination
- Ability to recover additional samples at specific depths

Are these feasible?
- Accomplish as many requirement as financially feasible
- Design team approach including scientist and engineers
- Open community meetings to assure what we build will be usable for current and future users
- Design team responsibility

Additional ice core drills/sampling
- Shallow drilling needs to recover quality cores
- Deep drill compatibility with intermediate drill
- Large volume sampling at specific depths (melting ice, recovering water and air)
- Downhole sampling tools

New Drill Technology:
Access Drill - The access drill is proposed to provide rapid drilling access to great depths on an ice sheet. Some of the properties, uses and characteristics include:
- Deep core site selection
- Add rock coring capability
- Recovery of cores at specific depths
- Use of different drill fluids
- Drill could be steerable
- 1000m/day penetration rate predicted
- Allow for rapid down hole temperature logging
- Components to build drill exist

Analytical Capabilities - Currently the US community have good analytical capabilities but some updates could be used.

New Opportunities:

- Biological wide open
- Adapt existing mass spec technology to recover better gas isotope records
- Ultra trace gasses at the ppt levels with gas chromatography
- Visual tools - direct imagining of cores
- ICPMS - smaller sample needs-wider selection of measurements
- Need to address continual storage capabilities of ice core archive.
- Sampling strategies of cores, are we as efficient as possible.
- Continuous sampling techniques
- Improved analytical improvements will be around for next deep core.
- Need more 3 dimensional modeling of air/snow exchange

Continuity of required personnel:

Need to address the ability of keeping experienced drilling, scientific and technical personnel available to the community. This also pertains to the ability to attract top students into the field. One way to address this is to not allow hiatus between drilling programs with detailed, long term drill projects that are flexible enough to be able to be modified buy budget and logistical constraints.

Logistical Concerns

What is the scalability of the deep core drill? Ideally it would be able to be used as a deep drill or intermediate drill

Supportability of the drill as a package: What kind of field camp would be required to support the drill? This would be taken into account in the designing of the drill and a smaller field infrastructure is expected. Some of the reduction in field support could be brought using alternative energy sources.

International Perspectives: Led by Eric Wollf and Dorthe Dahl Jensen

Current European Drilling:

EPICA: (European Program for Ice Cores in Antarctica)

2 cores: Dome C and Dronning Maud Land

- Dome C update:
  - Current depth - 2864m -11C at depth
  - Thickness - 3264m predicted to be within a degree of the melting point
  - Science "trench" on surface due to -55C mean temperature
  - 14 scientist, 8 drillers
  - Camp supplied and built using overland tractor traverse
  - Personnel transported by Twin Otters from Terra Nova
  - 10cm core
  - Continuous flow analysis, electrical and physical properties on site
  - Dating from electrical records:
    - 2864m 530,000 years
  - Modeled dating
    - 3064m 750,000 years

Dronning Maud Land
  Camp constructed
  Drilling to depth 400 m
  No processing on site
  Processing to be done at Bremerhaven
Berkner Island
  British project
  One year behind due to no ship arrival at Halley this year
Other non-European
  Dome F - Japanese plan to restart core to bedrock
  Dome A - Chinese planning core
  West Antarctica - Core needed

Greenland
  NGRIP
    Present depth - 3001m
    Thickness - 3080m
    International project - US included
    Continuous flow analysis on site
      Same as Dome C instrument, 1 cm resolution.
    Line scanning of core stratigraphy
    Very warm ice at present depth. Many drill sticking and getting unstuck.
    1 cm layer thickness at present depth
    Should provide record of 120,000 years

Currently Europeans do not have a clear long term plans in place for coring.

US ice coring from European perspective:
  US community suprisingly quite in past few years. Is the reason because of technical or logistical problems?
  Frustrations of US scientist felt overseas.
Need to explore the possibilities of joint projects in the future. Bridges needed between the European Union, NSF and NASA funding agencies.
  Different approaches between drilling and scientist
    European scientist are responsible for the drilling and logistics. People who do the work are the ones interested in the data

Discussions:
Analysis of cores in field or back in country?
  Advantages (some)
    Close connection to drilling process and can address problems immediately
    Less distractions to be more productive
    Data available more quickly
  Disadvantages (some)
    Possible lack of interest of senior scientist spending long tie in field
    Many new techniques can not be used in field setting

Logistical cost very high

Does the 10 cm core provide enough sample for investigators?
Mostly not a problem with the exception of studies who require large quantities of ice.
Agreements on core allocation made before drilling is started.
New techniques are requiring less sample volume.

How to collaborate?
Data synthesis - ITASE, Global modeling
Drilling and core sharing
Last major collaboration DYE3
Establish consortiums of disciplines
Establish core allocations at beginning of process defined by time periods, specific scientific questions, sharing of sample mass.