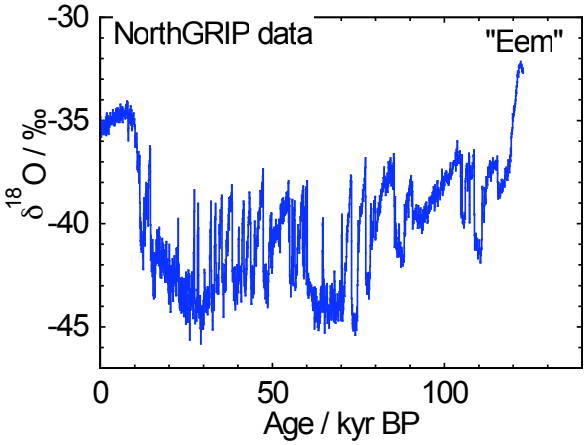
White paper

The last interglacial and beyond: A northwest Greenland deep ice core drilling project

Introduction

Starting with the initial projects in the 1960s (Camp Century and Byrd), deep ice cores have come to be regarded as a crucial pillar of knowledge about late Quaternary palaeoclimate. The current state of the art is represented in Greenland by the three detailed records of GRIP and GISP2 (at Summit) and of NGRIP (NorthGRIP). These are supplemented by the earlier records from Dye 3 and Camp Century, and by the more compressed but valuable Greenland coastal cores (such as Renland). The most compelling message from the Greenland cores has been that of the very abrupt, millennial-scale, climatic flips of the last glacial period, known as Dansgaard-Oeschger events. Understanding the cause of these events, and their implications for future change, has become one of the hottest topics in climate studies, with significant policy implications.



Despite their great significance, the existing Greenland cores are deficient in one important respect. The last interglacial (also known as the Eemian) has proved to be a tantalising target: Eemian ice is present but highly garbled in the Summit cores, incomplete due to basal melting in the NGRIP core, and too compressed to use in the Camp Century and Dye 3 cores.

The scientific issues

The last interglacial period is critical for understanding climate change, because it offers a period of warmth like our present one, in which there was unequivocally only natural forcing. It also appears to have been warmer than the present, and therefore allows us to see what happens in a climate like the one we are approaching. Models suggest that the Greenland ice sheet will waste away under warmer conditions; the last interglacial provides a test of whether this actually happened. The period preceding it will likely yield further examples of rapid climate change, allowing us better to understand the rules by which they work. While climate records covering this period exist in other archives, only from a Greenland ice core can we add crucial high-resolution information about rapid climate change, and about what was occurring in the North Atlantic. If the site is in North Greenland we believe the ice core will provide isotopic information on the climate variations during the last 10,000 years that are easier to interpret than those already obtained. This will allow us to relate the scenarios expected from global warming to the climate varations experienced naturally in interglacials. We will be able to:

- Chart the full course of an interglacial from termination to inception at very high resolution in numerous parameters, including greenhouse gases

- Confirm whether Greenland was indeed significantly warmer than at present
- Determine whether any rapid climate changes occurred in such a warmer climate
- Make an improved assessment of the state of the Greenland ice sheet under such a warmer climate
- Show whether Dansgaard-Oeschger events occurred in a previous glacial period
- Determine a detailed climate record from our present interglacial period
- Relate climate variations from the present and the last interglacial period to the predicted scenarios under global warming

The challenge

Answering these questions requires that we meet a single challenge:

- Obtain a reliable high-resolution northern hemisphere ice core record of the onset of the Eemian period and if possible even the previous glacial period
  which implies
- Obtaining an undisturbed Greenland ice core record of climate covering at least 140,000 years

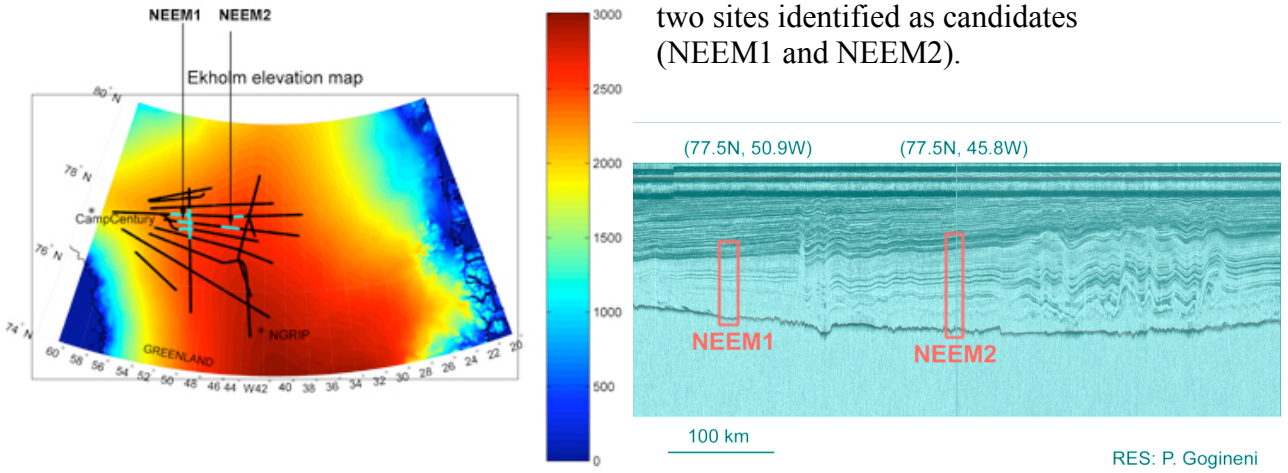
Meeting the challenge

We will need

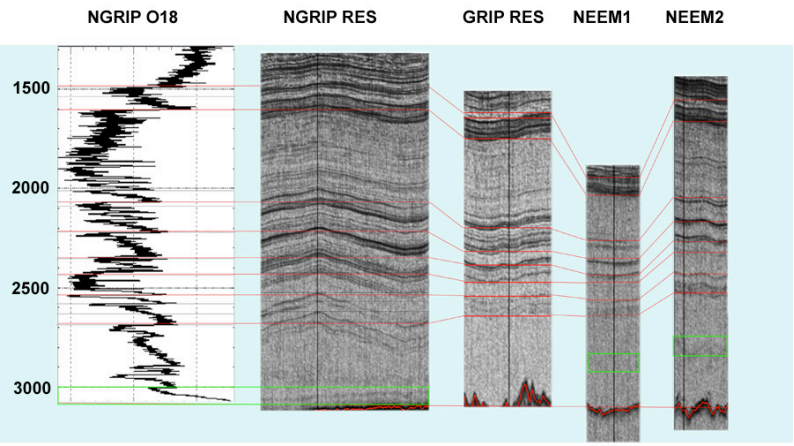
- To identify a suitable site, at which we can be confident that the full Eemian period is present and has not been subject to flow disturbance
- To find a location where the source region for precipitation is unchanged during climate variations.
- To assemble an international team capable of supplying the logistics, and the drilling and scientific capacity to drill, analyse and interpret the core
- To drill and analyse the core

Choosing the site:

The team at University of Copenhagen that led previous Greenland drillings has deduced that the most likely candidate area for achieving old ice is in northwest Greenland. The RSL-group at University of Kansas has produced a remarkable amount of Radio Echo Sounding (RES) profiles over the Greenland Ice Sheet and these are very helpful in selecting a good site. (http://tornado.rsl.ukans.edu/Greenlanddata.htm). The map of surface elevation (Bamber et al., 2001) shows the radio echo sounding lines in this area, and the location of two sites identified as candidates (NEEM1 and NEEM2).



We know the age of internal layers seen in the radio echo profiles at GRIP and NorthGRIP. We can follow these across the Greenland ice sheet to the candidate sites. The deepest tracable internal layer is dated to 82000 years before present. At NEEM1 the ice thickness is 2542 m, accumulation rate is 0.23 m ice/yr, and we can estimate the Eemian thickness is 80 m with annual layers 7 mm thick, At NEEM2 the ice thickness is 2756 m, accumulation is 0.17 m ice/yr, the Eemian thickness is 100 m with annual layers 8 mm thick. The bedrock at NEEM2 is not as smooth as at NEEM1 and there is a folding 'shadow' at the predicted location of the NEEM2 Eemian indicating a risk of folding layers here. NEEM1 is therefore already identified as a preferred deep drilling site with suitable characteristics.



The international team

The International Partnership in Ice Core Science (IPICS) has selected the deep Greenland drilling as a target for the Polar Year (http://nicl-smo.unh.edu/IPICS/IPICS.html). The core plays a central role in the IPY cluster project "The Greenland Ice Sheet – Stability, History and Evolution" which was invited to be one of the lead proposals for IPY. The size of the logistic, technological and scientific effort required has led to a realisation that ice coring efforts must be multi-institute, and often multinational, from the three-nation Dye-3 drilling to the 10-nation efforts of EPICA. We propose to build on the successful NorthGRIP team, and several nations have already expressed interest in joining the new project.

Drilling and analysing the core

Technically, this drilling is possible: the NEEM1 site is shallower than previous Greenland cores, but we expect ice near to the pressure melting point at the base. It will therefore challenge the drilling groups to improve techniques for drilling in warm ice; at climatically important depths it would also be desirable to use sideways drilling to obtain extra ice. The location should be accessible from Kangerlussuaq, which has already served as the coordinating centre for previous projects. The ice core community has the analytical and intellectual capacity to carry out the project.

The next steps and schedule

The second meeting of International Partnerships in Ice Core sciences in Brussels in October 2005 discussed the implementation of this project. The International Polar Year (IPY, 2007-08) provides a realistic target for drilling this core to bedrock.

International Partnerships in Ice Core Sciences (IPICS) is a group of scientists, engineers and logistics experts from the leading laboratories and national operators carrying out ice core science. At the first IPICS meeting, in Washington, DC in 2004, participants identified several high priority international scientific projects to be undertaken over the next decade or more. At the second IPICS meeting, in Brussels, Belgium, in October 2005, these projects were further defined, and routes to implementation were discussed. The 2005 meeting also placed IPICS on a more formal footing. It now has an international steering committee including representatives of 18 nations, planning groups are being formed around each of the scientific projects, and an additional international group of drillers and engineers has been organized. IPICS has been officially approved as an IPY project by the International IPY Committee.

The current document is one of four describing the science proposals; a fifth looks at some of the technical challenges and drilling needs for implementing the IPICS plans. The five documents are entitled:

1. The oldest ice core: A 1.5 million year record of climate and greenhouse gases from Antarctica.

2. The last interglacial and beyond: A northwest Greenland deep ice core drilling project.

3. The IPICS 40,000 year network: a bipolar record of climate forcing and response.

4. The IPICS 2k Array: a network of ice core climate and climate forcing records for the last two millennia

5. Ice core drilling technical challenges

For more information about IPICS or any of these projects please contact the IPICS co-chairs:

Edward Brook
Department of Geosciences
Oregon State University
Corvallis, OR 97330
USA
brooke@geo.oregonstate.edu

Eric Wolff
British Antarctic Survey
High Cross, Madingley Road
Cambridge CB3 0ET
United Kingdom
ewwo@bas.ac.uk

Drafting committee for this document:

Dorthe Dahl-Jensen, University of Copenhagen, Denmark
Edward Brook, Oregon State University, USA
Yoshiyuki Fujii, National Institute of Polar Research, Japan
Jean Jouzel, IPSL/LSCE, France
Vladimir Lipenkov, Arctic and Antarctic Research Institute, Russia
Jeff Severinghaus, Scripps Institute of Oceanography, USA
James White, University of Colorado, USA
Eric Wolff, British Antarctic Survey, UK