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 very important respect. The last interglacial 115.000 to 130.000 years before present (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, the Eemian, 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 by 5 deg C in Greenland, and therefore allows us to see what happens in a climate like the one we are approaching. In particular, models suggest that the Greenland ice sheet will waste away under warmer conditions; the last interglacial may provide 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 Antarctica and in marine and terrestrial sediments, 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. A new ice core will also contain high resolution climatic information on our present interglacial period. If the site is selected 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 interpretate than those already obtained. This wil enhance our knowledge on present climate variations and allow us to relate the global warming scenario to these interglacial climate varations.

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 from a Northern record
- 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 of the climate variations of our present interglacial period
- Relate climate variations from the present and the last interglacial period to the predicted global warming scenarios

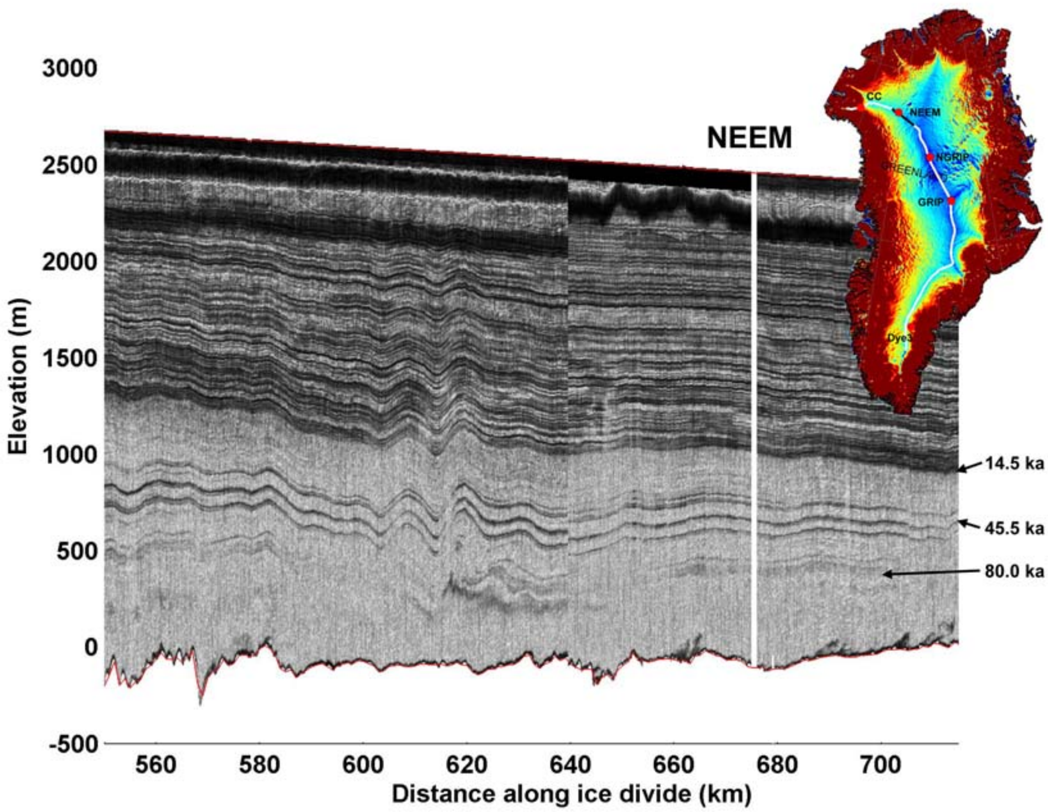

Figure 1. *The Radio Echo profile along the flow line leading to the NEEM drill site. The location of the line is shown on the Greenland map of surface slopes as the part of the ice ridge flow line colored black.*

The challenge

Answering these questions requires that we meet a single challenge:

- To 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
- Find a location where the precipitation from the atmospheric driven circulation is unchanged during climate variations.

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 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 at (77.5N, 50.9W) where the ice thickness is 2542m and the annual precipitation is 0.23 m of ice equivalent. 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. (Figure1). 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 traceable internal layer is dated to 80.000 years before present. At NEEM we have used inverse models to date the deeper ice and we estimate that ice from the Eemian period is found at the depth 2265m to 2345m. With a 80m thickness of the Eemian period the annual layers are expected to be of the order of 7mm.

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 and is chaired by Dorthe Dahl-Jensen. At present 14 nations are interested in participating in the Greenland deep drilling project NEEM (Belgium, Canada, China, Denmark, France, Germany, Iceland, Japan, Netherlands, S. Korea, Sweden, Switzerland, U.K. and U.S.). Of these 6 have obtained national IPY funds for the logistics of the project (Denmark, U.S., Netherlands, Canada, Belgium and France). Detailed information on the national funding and the budget for the NEEM project is attached as Appendix 1. At the moment the logistics of the project is funded with 81% of the needed 44.4 mill dk kr. The first Steering Committee meeting for NEEM will be held in Copenhagen March 2007, 29-30th with representatives from all 14 nations. At this meeting the funding expectations from the remaining nations will be discussed followed by a discussion of the science plan and the planning of the field seasons.

Drilling and analysing the core

The ice core to be drilled is 2542m deep and we expect the ice to be close to it’s pressure melting point at the base. The deep drill used for the NGRIP ice core drilling will be further developed for the new project. As a new and environmentally friendly drilling fluid will be used for the first time for a deep ice core drilling the drill needs to be changed so it can function in the rather viscous drill fluid. New drilling challenges also include improved techniques to drill in the warm basal ice and to explore the possibility of providing additional ice core material at climatic interesting locations by side wards drilling. Analyses of the core will be partly performed in the field and partly in the national laboratories of the participating nations. A broad scope of measurements will be performed on the ice core including newly developed techniques for high resolution in situ measurements of the impurities in the ice, stable isotopes, electrical properties, cosmogenic isotopes, concentrations of greenhouse gasses and the isotopes of the gasses, ice properties, biological material in the ice and dust concentrations. High emphasis will be on the use of methods that use as small ice samples as possible in order to measure in high resolution and to preserve 40% of the ice core for future new analysis. At the Steering Committee meeting we expect to form Science Consortiums for the various studies on the ice and a program will be formed in which the distribution of science will match the logistical input to the project for the nations.

NEEM project outline

A very short outline of the logistical components of the 5 years are listed below.

2007:
Borehole logging at NGRIP.
Traverse from NGRIP to NEEM with AWI traverse train along ice divide.
Radar sounding, shallow ice coring and GPS strain net survey during the traverse.
At NEEM, setting up garage, skiway and radar grid mapping.
Transporting heavy equipment from NGRIP to NEEM.
A team of 10 will participate (5DK, 2 US, 1FR, 1G, 1IS)
Flight missions SAAM'ed : xx June, xx June to NGRIP and xx July to NEEM
Containers by ship to Kangerlussuaq with camp construction material for 2008 season

2008:
Construction of ice drilling camp which includes main building, weatherports, workshops, drilling trench and science trench.
Drilling pilot hole to 100 m, hole casing, setting up deep drill infrastructure and drilling to 400m depth.
Ice core logging and limited processing.
Containers by ship to Kangerlussuaq with camp construction material and equipment for late 2008 season

2009:
Full time deep drilling and full processing to 1600 m depth.

2010:
Full time deep drilling and full processing to warm ice (2450m) or bedrock (2560m).

2011:
Finish deep drilling. Borehole logging. Sampling of basal material.
Additional shallow ice coring and limited processing.
Last associated programs.
Dismantling of camp and pull out.