White paper

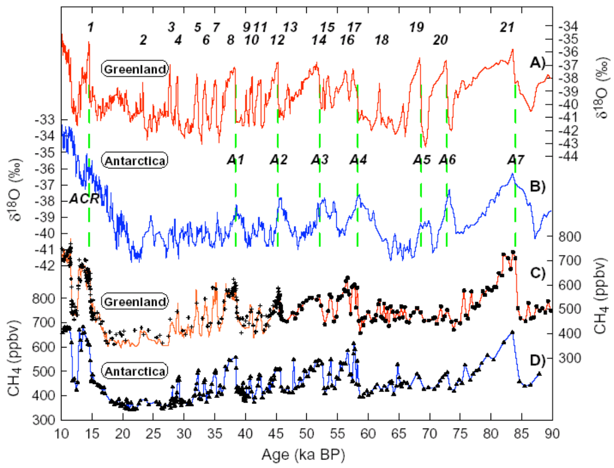
The IPICS 40,000 year network: a bipolar record of climate forcing and response

Introduction

Records of past climate are critical tools for ensuring that the relevant processes are represented in climate models: the same models used to predict future climate. Recent paleoclimate reconstructions clearly document that the Earth's climate is an intricate interplay of oceanic, atmospheric, biogeochemical, and cryospheric processes. However, the reasons for changes in greenhouse gas concentrations and aerosol loads, sea-level and ice masses as well as their coupling to atmospheric and ocean circulation are still not sufficiently understood. Previous ice core records from central Greenland and East Antarctica defined the overall features of glacial and interglacial periods and transitions between them, and the characteristics of rapid climate change during the last ice age, at a few individual sites. However, the progression of deglaciation, the spatial evolution of climate change, and the processes responsible for those changes cannot be diagnosed from single locations. A network of temporally synchronized, high-resolution ice cores from both polar regions, documenting in greater spatial and temporal detail parameters that play a pivotal role in climate evolution, such as storm activity, marine biospheric productivity, sea ice and ice sheet extent is the key to diagnosing climate change mechanisms.

The scientific issues

The last 40,000 years include the transition from the last glacial into the present warm interglacial and a sequence of abrupt swings in climate as recorded in Greenland ice cores and other climate archives. The glacial-interglacial transition is the best- documented global response to very large-scale changes in climate boundary conditions, and the earlier abrupt changes are the best examples of this enigmatic process. Understanding and simulating these changes are critical challenges for our ability to model the earth system. To do so we need to understand their spatial and temporal evolution better. Existing data show that the transition and the abrupt changes are characterized by different patterns of long-term warming in the north and south, and related changes in greenhouse gas concentrations, accumulation and ice sheet extent. However, we do not yet fully understand the mechanism linking the climate of the two hemispheres, or the patterns of the regional response in the two polar regions. In particular, we need to:

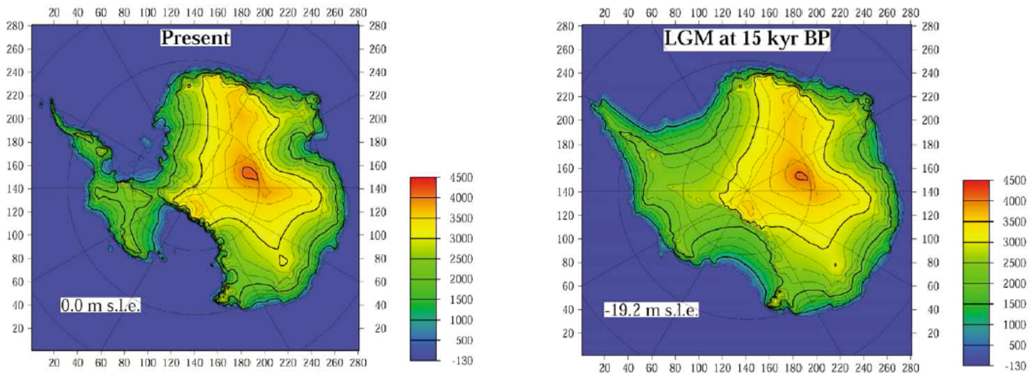


A comparison of climate records from Antarctica and Greenland covering the last 90,000 years. The last 40,000 years is the best documented time period of both abrupt shifts in climate in both hemispheres, and the large change from glacial to interglacial conditions. From: Blunier and Brook, 2001, Science, 291, 109-112.

- Determine spatial patterns in environmental parameters that relate to the ocean surface conditions (e.g., sea ice and marine biological productivity).
- Construct the sequence of events (including forcings and responses) through the last glacial-interglacial transition across different geographic areas of both polar regions at the highest resolution possible.

- Synchronize the new records using high-resolution measurements of CH_4, CO_2, and dust, as well as isotopic compositions of air components.
- Quantify and understand the spatial and temporal evolution of rapid climate changes in both polar regions related to changing thermohaline circulation, an objective of utmost relevance for a future world subject to increased anthropogenic warming.
- Identify climate modes and teleconnection patterns under different climate boundary conditions (orbital forcing, greenhouse gas concentration, land ice masses) by using coupled atmosphere-sea ice-ocean models, possibly in conjunction with regional models.

In addition, we need to understand the response of the ice sheets to climate change. Ice sheet models differ in predictions of the extent and thickness of the major ice sheets at the LGM and their contribution to global sea level during the deglaciation. With the expansion of the ice sheets during the glacial period, some modern coastal ice domes may have merged with the inland ice. Ice cores from these locations can provide basic information (snow accumulation, temperature, altitude, ice sheet extent) reflecting changes in the mass balance of ice caps and ice sheets, which ultimately control long-term sea level evolution, and provide validation data of glacial land ice extent in coupled climate models. To achieve these goals we need to reconstruct accumulation changes at inland and coastal sites subject to different climate evolution and moisture transport, identify changes in ice volume and local ice sheet altitude and, where possible, look for evidence of over-riding of local domes.



Modelled extent of the Antarctic ice sheet for glacial and present conditions. From: Huybrechts, 2002, Quat. Sci. Rev., 203-231

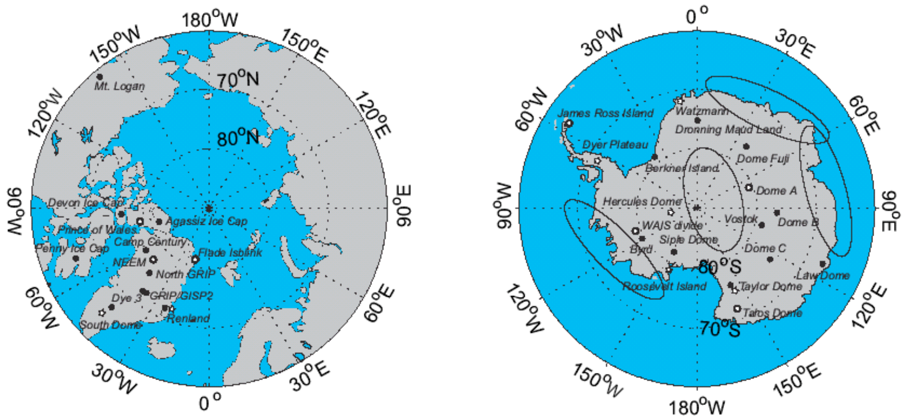
The challenge

In order to view both the last glacial-interglacial transition, and the abrupt climate changes before, we need to complete a network of ice core records, covering each major sector of both polar regions, and extending over at least the last 40,000 years. Although some of the potential records might extend 100 kyrs or more, practical limitations confine most of them to a shorter period. The 40,000 year target is important, as it includes one of the major Antarctic warming events related to abrupt climate change in the northern hemisphere.

Existing work and plans

Many of the cores that would be needed for this network have already been drilled, or are planned in the near future. In particular:

- In central East Antarctica several cores already exist
- In central West Antarctica, US investigators plan to drill a deep core in inland West Antarctica during 2006-2010
- Around the coast cores spanning the appropriate period are already available from Taylor Dome, Siple Dome, Law Dome and Berkner Island. An Italian led project will drill at Talos Dome drilling during 2005-2008. Additional planned drilling projects at James Ross Island (UK) and the Neumayer hinterland (Germany) are expected to reach the relevant period



Map of both polar regions indicating drill sites of existing (dots), ongoing or approved (open circles) and potential future (stars) ice cores covering the last deglaciation and beyond. Areas of other potential drill sites but lacking any spatial coverage so far are circled.

- Inland Greenland is served by a south-north span of cores from Dye 3, Summit and North GRIP. The Renland core also spans the period, although new cores from Renland and other coastal ice caps are crucial to get more information on local climate variations around the Greenland ice sheet.
- A number of cores in the Canadian Arctic Islands (Agassiz Ice Cap, Devon Ice Cap, Penny Ice Cap, Prince of Wales Ice Field) and in Alaska (Mt. Logan) may span at least part of the required period.

Meeting the challenge

The international ice core community needs

- To complete drilling and analysis of all planned cores.
- To identify the gaps in the spatial network of ice core sites and assess whether further suitable sites exist.
- To implement plans for drilling "gap" sites.
- To synthesize data from all the sites with the goal to produce a comprehensive picture of the spatial and temporal pattern of major climate change over the last ~40,000 years

The international dimension

Very large ice coring projects have a long tradition of international co-operation. However, many of the planned and as-yet missing sites are less ambitious in terms of depth and location, and can be drilled by relatively small teams. Probably many of these will be carried out by efficient groupings of 2-3 nations. However, planning and completing the network, as well as integrating its results, will require the inclusion of all leading ice core nations.

The next steps and schedule

A site selection team will be established to identify the missing sites, to document their importance for the network and to coordinate the transfer of knowledge between individual projects. A science plan will be developed to ensure that comparable data sets will be available for all drill sites and to coordinate efforts for process related studies in parallel to the deep ice core drilling. We will also be able to identify possible leaders for each component of the network in cases where there is not yet a concrete plan. The International Polar Year (IPY) is already marked as an important point for two of the largest sites that have to be done: WAIS Divide and Talos Dome. We envisage further cores to complete the network being completed over the following decade.

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

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