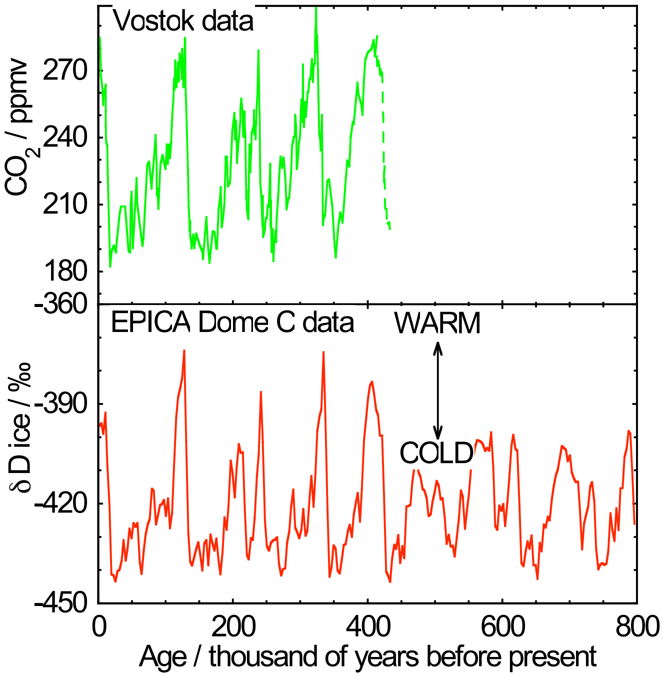
White paper

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

Introduction

Climate scientists have an obligation to provide realistic assessments of how climate will change in the future. Doing so requires accurate models of how the Earth's climate system works and responds to changes. This in turn requires that we understand all the processes that can occur, and how they interact. This knowledge comes only from studying the past. Ice-core studies in particular have already revolutionized our view of the Earth system, documenting the recent rise of greenhouse gas concentrations beyond historical norms, the existence of abrupt climate changes, and the tight coupling in the past of climate and greenhouse-gas concentrations.

In deep Antarctic ice cores, we can observe that we are currently living in a relatively mild "interglacial" phase within a series of warm/cold oscillations occurring every 100,000 years. These cycles must arise from a strong amplification of weak changes in energy inputs. And we can see that these small changes in input also cause major changes in the partitioning of carbon dioxide and other greenhouse gases between the atmosphere and other reservoirs. However, we still lack understanding of why these processes occur; this means that we still lack crucial knowledge about the natural regulation of carbon dioxide, and about the amplifications that make the climate system so sensitive. Both these factors are important as we try to predict the future.



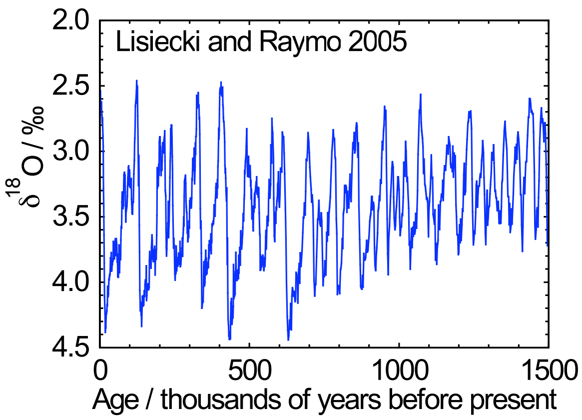
EPICA ice core data for the last 800,000 years

The scientific issues

Our oldest ice core now extends over 800,000 years into the past. However, from marine sediments, we know that just before this time the pattern of climate variability was different, with cycles of only 40,000 year length. If we are to understand the state our climate is in now, we need to understand what caused the length of the cycles to change. Studying the interactions of climate and biogeochemistry in this earlier period will allow us to:

- Understand the natural variability that has led us to our current climate
- Assess the likely course our climate would take in the next few centuries to millennia in the absence of human interference
- See numerous examples of the natural relationship between greenhouse gases and climate, allowing us to deduce the underlying rules

- Test the hypothesis that the change from 40,000 to 100,000 year cycles was caused by a lowering of atmospheric carbon dioxide concentrations
- Better understand the timescales and processes that control exchange of carbon dioxide (including excess CO_2 from human activities) between reservoirs



Marine isotopic data show the change in dominant frequency

Many of these questions can only be addressed by a deep ice core, because only ice cores can provide an accurate measure of past greenhouse gases, and with climate clearly documented in the same core. New dating methods mean that it should be possible to tie such a record well to other climate records and external forcings, thus adding new value to existing studies of this time period.

The challenge

In order to confront the issues outlined above, we have a simple goal:

- to obtain from Antarctica a reliable ice core record of climate and biogeochemistry extending through several of the 40,000 year cycles and up to the present

which in practice means that we need to obtain

- a replicated Antarctic ice core record extending at least 1.2 million and preferably 1.5 million years, into the past.

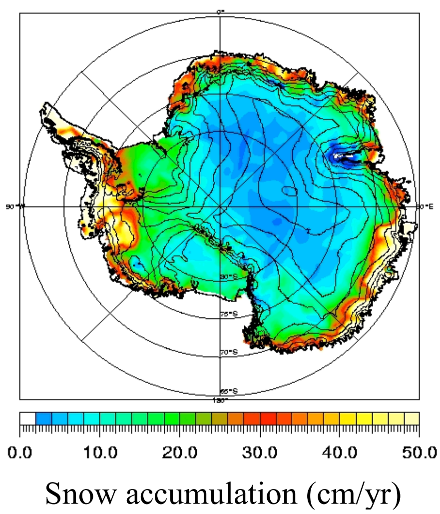
Meeting the challenge

We will need

- To carry out detailed survey and modeling work to identify sites where we can expect to find the oldest ice
- To assemble an international team capable of supplying the logistic effort, drilling expertise and intellectual knowledge to obtain the core and the scientific returns from it
- To drill and analyse preferably two cores at different sites in order to fully validate the records obtained

Identifying the site(s)

Undoubtedly, ice older than 800,000 years does exist in the Antarctic ice sheet. Candidate sites are likely to have a high ice thickness, a low snow accumulation rate, and low ice velocity. In practice, this implies a site in the relatively little-surveyed interior of East Antarctica. Suitable sites will also have a rather flat bedrock, and recent experience suggests that a slight melting at the base could be favourable for getting undisturbed sequences near the bed.



One characteristic of target sites will be a low snow accumulation rate

To identify such sites, an iterative process of modeling and survey is required. The survey should include at least measurements of:

- Ice thickness, elevation, velocity, surface and basal topography
- Snow accumulation rate

- Temperature, including estimates of basal temperature
- Internal radar layers, allowing us to follow deep layers of known age from existing drill sites
- Present-day measurements of meteorology and atmospheric chemistry

A combination of airborne and ground-based survey, combined with shallow coring traverses, satellite remote sensing data and modeling is required in the sparsely-sampled areas of East Antarctica. Some such surveys are already planned for the International Polar Year (2007-2008). IPICS would assess the results of this work in order to recommend one or more target drilling sites.

The international dimension

Ice coring has been an intensely international business: two of the most successful projects of recent times have involved nine nations (NorthGRIP, Greenland) and ten nations (European Project for Ice Coring in Antarctica) respectively, while almost all the large projects have included an international dimension. The current project, certain to be set in logistically remote sites, is a challenge that can only be met through an international initiative. All the major ice coring nations have expressed interest in the project; we need next to set up a task committee drawn from these nations to plot the detailed requirements and to share out the tasks.

Drilling and analyzing the core

Beyond the logistics of working at such remote sites, this project does not throw up any technical challenges we have not already met in earlier drillings. A new drill fluid will need to be found to meet the scientific, technical and legislative requirements, and improved drilling techniques will allow better core recovery. The ice core community currently has the analytical and intellectual capacity to carry out such a project.

Although retrieval of a single core would be a fine achievement, there are important reasons for drilling two cores:

- Replication is the only way to ensure that the results have not been affected by flow disturbance or other artifacts
- Despite our survey work, there is a risk that local variability near the bed could deny us very old ice in a single core; drilling two cores doubles the probability of finding the very oldest ice

The next steps and schedule

International Partnerships in Ice Core Sciences had its second meeting in Brussels in October 2005 and confirmed its wish to develop this project. The International Polar Year (IPY, 2007-08) offers the best opportunity to carry out the survey of large swathes of East Antarctica that is required. It should therefore be possible to pinpoint the best drilling sites by 2010, and to start drilling in the following years.

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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