TAS van OMMEN

Lightweight ice core drilling rigs, such as this, can be deployed by aircraft and allow short, remote field programmes to retrieve cores to several hundred metres depth.

Solving an ice age mystery with a million year old ice core

International moves are afoot to drill an ice core in Antarctica containing a 1 million year record of the Earth's climate. The project is one of four recommended by the International Partnerships in Ice Core Sciences – a recently formed group of ice core climate researchers from 12 nations, including Australia. A 1 million year record is significant because it would provide information such as climatic temperature and atmospheric greenhouse gas concentrations over a period of fundamental change that occurred in the ice age cycle some 900 000 years ago.

For about 2.5 million years, ice ages had come and gone in a regular 41 000 year cycle. But about 900 000 years ago, something in the Earth's climate system changed and the cycles mysteriously switched to an ice age every 100 000 years (see figure). These glacial cycles are linked to small variations in the Earth's orbit around the sun, which produce changes in the amount of solar radiation reaching the Earth. However, these changes in solar radiation are too small to directly produce the large temperature changes needed to move in and out of ice ages. Rather, a range of natural 'amplifying' phenomena (feedback mechanisms, thresholds and resonance) in the Earth's climate system must be driving the switch. We need to understand these amplifiers to better understand the climate system and make realistic predictions of future natural or human-induced changes.

Our knowledge of long-term climate variability comes from sources such as ice cores and ocean sediment cores that store data in layers that can be accessed by drilling. Sediment cores provide records that extend back millions of years but, so far, the oldest ice core is that drilled at Dome C during the European Project for Ice Coring in Antarctica (EPICA) – dating back 804 000 years.

Recent data from a sediment core suggests that the ice age cycle switch may have been due to a change in the carbon dioxide (CO_2) concentration in the atmosphere. Because CO_2 is a greenhouse gas that helps the atmosphere trap solar heat, a change in CO_2 will alter the global heat balance and so could alter the amount of heat necessary to trigger a jump into or out of an ice age. Ice cores contain samples of the atmosphere in bubbles, which can be analysed to determine atmospheric composition. Currently, CO_2 levels in the atmosphere are higher than they have been for at least 450 000 years. A long ice core record of atmospheric composition would therefore allow us to directly test the role of greenhouse gases in causing the mysterious ice age period switch.

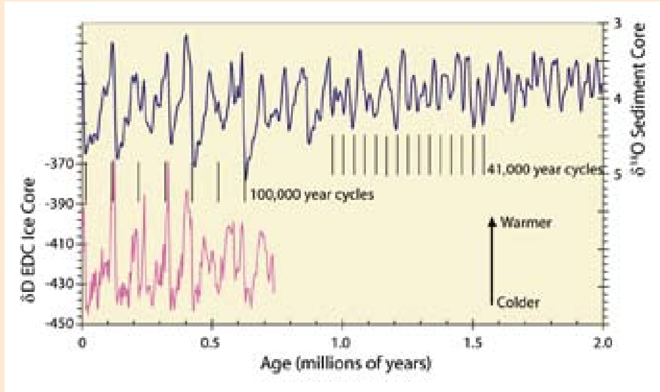
Drilling a 1.2 million year ice core is a large undertaking and would most likely be carried out by an international consortium. Drilling is likely to start around 2011, but before then we need to identify a suitable site (or sites – since two cores are necessary to confirm that the deepest part of the record is a true record of climate and not distorted by uneven ice flow over the bedrock hills). The Aurora Basin, 700 km inland of Casey station, has ice sheet properties that may be suitable (see box). In 2008-09, we propose to drill a 600 m pilot ice core over Aurora Basin to investigate ice sheet properties in the area. This pilot core will also provide a climate record midway between the inland Dome C site (where the 800 000 year core was drilled) and the coastal Law Dome site (where a 90 000 year core was retrieved by Australian Antarctic Division glaciologists between 1989 and 1993), allowing us to compare the different climate records.

The pilot core project proposal has already gained international interest, with the offer of a Danish ice core drill. At this stage, international participation depends on commitments of other national programmes and also on our ship and air transport options. Fortunately, Aurora Basin is within convenient reach of our new CASA 212-400 aircraft from Casey. The advent of the Australian-Antarctic Airlink will also greatly facilitate the project and encourage collaboration.

—VIN MORGAN
Antarctic Climate and Ecosystems Cooperative Research Centre and Ice, Oceans, Atmosphere and Climate Programme, AAD

Predicting the age of ice cores

The age of cores from an ice sheet depends primarily on the rate of snow accumulation and the ice thickness. For example, at Dome C the current accumulation rate is 2.7 cm of ice per year and the ice thickness is 3136 m. The bottom of the Dome C ice core obtained during EPICA is 804 000 years old. This age is greater than that obtained simply by dividing the depth by the surface accumulation, because the annual ice layers get thinner with depth, due to ice flow. There are areas of Antarctica where accumulation rates are even lower (resulting in thinner ice layers), and there are areas where the ice thickness is over 4000 m. One of these deep areas is Aurora Basin. Here, accumulation rates vary from about 10 cm at the coastal boundary to less than 2.5 cm at the inland edge. With a similar accumulation rate to the Dome C site, and with some 900 m more ice, we anticipate that an ice core recording 1–1.2 million years of climate history will be obtainable.



ICE AGE CYCLE This figure shows sediment core and ice core climate records over the last 2 million years. $\delta^{18}O$ is a change in the chemical signature of small organisms (foraminifera) in the sediment core, and is a proxy for the size of the Northern Hemisphere ice sheets during ice ages. δD is the ratio of hydrogen isotopes in the Dome C ice core and is a proxy for global temperature. Ice sheet size and temperature track each other with a 100 000 year cycle over the 800 000 years for which there is ice core data. The sediment core shows the change to 41 000 year cycles prior to 900 000 years ago.

SEDIMENT CORE DATA FROM: AC MIX *ET AL.*, IN *PROC. OCEAN DRILL. PROG. SCI. RESULTS* 138. NG PISIAS, L MAYER, T JANECEK, A PALMER-JULSON, TH VANANDEL, EDS. (OCEAN DRILLING PROGRAM, COLLEGE STATION, TX, 1995), PP. 371-412. DOME C DATA: <WWW.NCDC.NOAA.GOV/PALEO/ICECORE/ ANTARCTICA/DOMEC/DOMEC_EPICA_DATA.HTML>

New telescope aids climate studies

A new telescope recently installed on the Davis LIDAR (Light Detection and Ranging), is enhancing the quality of climate-related data collected by the instrument. The new data will be used in the international Climate and Weather of the Sun-Earth System Programme to examine large-scale climate processes in the Antarctic atmosphere.

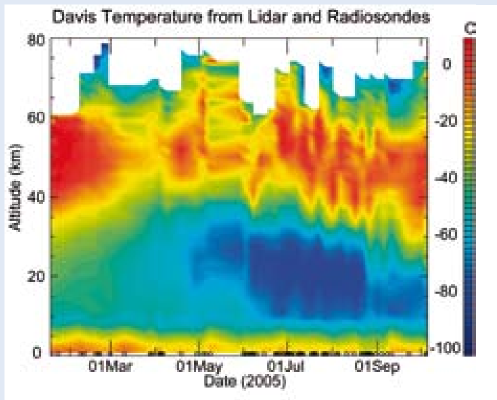
The LIDAR uses laser light to remotely sense atmospheric temperature as well as the properties of aerosols (fine solid particles and large molecules) from near the ground to about 100 km altitude. The new telescope allows us to collect more laser light that is scattered back from the atmosphere than before, extending the altitude range of the instrument and reducing the amount of time needed to attain more precise measurements.

One focus of the LIDAR research programme is on the temperature structure of the atmosphere. In the figure (right), temperatures obtained by the LIDAR above 25 km altitude are shown combined with measurements from balloons (radiosondes), flown by the Bureau of Meteorology. Part of the seasonal cycle in the lower atmosphere can be seen, with temperatures cooling to as low as -95°C during winter. At altitudes above 45 km, warm summer temperatures earlier in the year gave way to considerable variability, particularly in late winter and early spring. During July and August, the variability was associated with 'planetary-scale' waves which periodically influenced temperatures above Davis every 15 days or so. These waves are natural atmospheric oscillations that arise in the polar region due to climate processes occurring in the lower atmosphere.

It is becoming apparent that planetary-scale waves propagating in the stratosphere (10–50 km above the Earth) can influence weather patterns at the surface. This is important in developing long-range weather and climate forecasts, as planetary wave propagation at high latitudes is expected to be influenced by changes in atmospheric circulation associated with global warming and ozone depletion. Indeed, changing rainfall patterns in Australia have been linked with a shift in stratospheric circulation patterns over Antarctica.

The LIDAR will continue this observing programme during 2006, when an additional telescope will be installed to further investigate stratospheric processes.

—ANDREW KLEKOCIUK, JOHN INNIS and ANDREW CUNNINGHAM
Ice, Oceans, Atmosphere and Climate Programme, AAD



Atmospheric temperatures (degrees Celcius) above Davis synthesised from LIDAR and balloon measurements. The LIDAR observation times are shown by diamonds above the date axis. Features during mid-May are smeared by a gap in the LIDAR observations due to instrument adjustments.

ANDREW KLEKOCIUK & ANDREW CUNNINGHAM

FURTHER INFORMATION:
Climate and Weather of the Sun-Earth System Programme: <http://www.bu.edu/cawses/>
Stratosphere-troposphere coupling in the southern hemisphere: <http://www.nwra.com/resumes/baldwin/pubs/Thompson_Baldwin_Solomon_2005.pdf>
Stratospheric memory and extended range weather forecasts: <http://www.nwra.com/resumes/baldwin/pubs/Baldwin_etal_1Aug2003.pdf>
Climate change – An Australian guide to science and potential impacts: <http://www.greenhouse.gov.au/science/guide/>
Polar vortex linked to declining rainfall in Australia: <http://www.abc.net.au/catalyst/stories/s948858.htm>