Meeting report

The key to the future is in the past

How good are our predictions of future climate change? This is a question which has been hotly debated in international climate conferences, government committees, across all aspects of the media and in many a taxi and hairdresser's across the land!

It is clearly of fundamental importance and interest to scientists and policy-makers alike; unfortunately, it is also extremely difficult to answer. One area of study which can shed light on this problem is that of palaeoclimatology. How well can our computer models (exactly the same models as those used to predict future climate change) simulate the diverse climates of the Earth's history? The key to answering this question is the comparison of modelling results with palaeodata, for example ice-cores and fossilised vegetation, and this was the theme of the RMetS meeting on Palaeoclimates, held in London on 18 January 2006.

The meeting was organised and introduced by *Paul Valdes* of Bristol University. He highlighted the main motivations behind the study of palaeoclimates. As well as providing a test-bed of the models used for future climate prediction, he emphasised that palaeoclimatology is a very interesting subject in its own right – collecting and interpreting palaeodata, and then attempting to understand it in terms of fundamental physical and biogeochemical principles is a fascinating process. He also pointed out that those looking for direct analogues for future climates would be disappointed – no period in Earth's history is identical to that we are now experiencing, or which we may experience over this coming century.

The first speaker was *David Beerling* from the University of Sheffield. He described his recent work on understanding the climate of the Early Eocene Climatic Optimum, approximately 50 million years ago. This was a time in which atmospheric carbon dioxide was much higher than at the present, but exactly how high is still unknown – data from different sources (such as the isotopic composition of soils, or fossilised leaves) disagree. However, David described the importance of also considering the role of changes to other atmospheric gases, such as methane. He emphasised the importance of the whole Earth system – traditionally future climate models have concentrated on the ocean and the atmosphere, but he showed that the interplay between vegetation, biogeochemistry and atmospheric chemistry, was critical to understanding this past warm period. He finished by highlighting the fact that even by including these additional greenhouse gases, the models still made predictions which underestimated the warming seen in the palaeodata record – a stark warning for the future perhaps?

Alan Haywood from the British Antarctic Survey then gave an overview of the Pliocene Epoch, spanning an interval between 2 and 5 million years ago. This again was a relatively warm period in the Earth's history, in fact the last great warm period before the onset of the glacial/interglacial cycles that have characterised the last two million years. It was during this time period that the Greenland ice-sheet started to form, Tibet was uplifting as well as the Rockies and the Andes, and our early ancestors took their first steps onto the African plains. Alan presented some modelling studies which focused on the characteristics of the ocean during this time – in particular, was there any evidence for a permanent El-Niño-like state, as had been suggested from sediment cores drilled across the Pacific Ocean? Examining the behaviour of El Niño in past warm intervals may provide us with clues to how it may respond to greenhouse gas emissions. His work suggests that the Pliocene probably wasn't characterised by a permanent El Niño-like state. The variability of the El Niño Southern Oscillation may in fact have been stronger in the Pliocene than it is today. The work questioned the validity of drawing conclusions about decadal to sub-decadal oceanic and atmospheric events from a small number of ocean sediment cores which provide only a snapshot of changes to the mean state of the oceans.

Eric Wolff, also from the British Antarctic Survey, then gave a summary of the importance of ice-cores to understanding past climate change (Figure 1). Ice-cores are a fantastic record as they are relatively easy to date (especially near the surface where the annual layers of ice can be counted), and include information on many different climatic factors, including the chemical and physical contents of the atmosphere (for example the levels of carbon dioxide and other greenhouse gases). In particular he concentrated on the recent core from 'Dome

Figure 1. Ice core drilling at Berkner island, Antarctica (Credit: Chris Gilbert/BAS).

Weather – March 2007, Vol. 62, No. 3

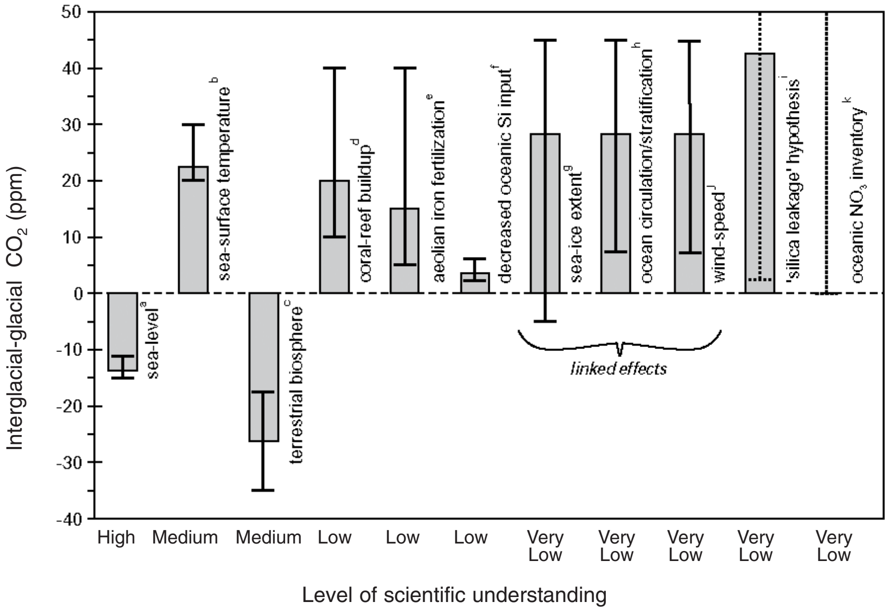

Figure 2. Summary of possible contributions to the difference in atmospheric carbon dioxide in glacial times (eg. the Last Glacial Maximum, 21 000 years ago) and interglacial times (eg. the pre-industrial), of approximately 100 ppm. Also indicated is our current level of understanding for each process (Credit: Andy Ridgewell/University of Bristol).

C' in Antarctica, which is unrivalled in that it goes back over 800 000 years. It has revealed that the main climatic fluctuations between glacials and warmer interglacials, which occur about every 100 000 years, have changed their characteristics over time. However, the relationship between carbon dioxide and temperature has remained remarkably constant – whenever levels of greenhouse gases have been high, temperature has been high, whenever greenhouse gases have been low, temperature has been low. However, he emphasised that although it is well understood how greenhouse gases can affect climate (global warming!), it is not well understood how climate can in turn affect greenhouse gases.

Tim Lenton, from the University of East Anglia, continued the theme of Quaternary climate change (the last 1.5 million years), and in particular glacial/interglacial cycles, observed in ice-core and sediment records. These Milankovitch cycles are thought to be driven by small wobbles in the Earth's orbit around the sun, which occur because of the presence of the moon and other planets in the solar system. They are periodic (having principal periods of approximately 100 000; 40 000; and 20 000 years), and can be predicted for the future as well as for the past. Tim gave a review of work, principally with conceptual or simple models, carried out to understand the effect of these cycles on climate. Again, the theme was that many processes were needed to be considered, in addition to the atmosphere and ocean, in order to understand the past changes (for example, carbon dioxide, see Figure 2). In particular, ice-sheets are thought to be one of the main amplifiers of the relatively weak orbital forcing. Tim finished by showing some recent work which has suggested that human-induced global warming may be disturbing these natural cycles, and as a consequence we may have already delayed the onset of the next climate cycle.

Michel Crucifix from the Met Office gave an overview of the Last Glacial Maximum, which occurred about 20 000 years ago, at the end of the last glacial period of the most recent glacial/interglacial cycle. As the name implies, it was globally cooler than the present; in fact, massive ice-sheets extended right down to central and southern England. Much of our beautiful landscape is a result of the movement of glaciers which occurred around this time. Michel described how as well as being cooler, this was a time period when there may have been large differences in the ocean circulation compared to modern times; in particular, the thermohaline circulation. However, he explained that almost none of our models can agree on the magnitude of the difference, and even the sign! Some models predict a shallower penetration of North Atlantic water masses, and some a deeper penetration. Once again, this highlights some of the problems associated with the prediction of future climate change. Michel highlighted that one of the key ways of determining which models were more believable was by a quantitative comparison to the palaeodata.

This led directly into the final presentation, by *Sandy Harrison* of Bristol University. Sandy highlighted the huge wealth of palaeodata which has now been collected and analysed by groups from all over the world, in particular for the Last Glacial Maximum and mid-Holocene (6000 years ago, a relatively warm period in the Earth's recent history). However, she emphasised that these data are not of standard meteorological variables such as temperature and precipitation. Instead, the data show climate-induced changes in, for example, lake level, or vegetation type. In order for the models to be validated against these data, it is necessary to use stand-alone models that translate climate variables into an environmental record, or to include hydrological or vegetation processes within the climate model. The inclusion of these processes in climate models is just beginning, and is opening the door to a more direct and quantitative comparison between models and data.

In conclusion, many of the speakers highlighted the essential process of looking at the whole Earth-System when attempting to understand past climate change. This includes ice-sheets, vegetation, atmospheric chemistry, and ocean sediments, as well as the more traditional atmosphere and oceans. By inference, the same is surely true for understanding and predicting future climate change. A further message which came out of many of the talks, was that in nearly all cases, the models are underpredicting past climate change, relative to the data. This fact should be used as context when interpreting future climate change predictions.

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doi: 10.1002/wea.6