If predictions are correct, global temperatures will soon reach levels not experienced for over 20 million years. **Dave Tappin** and **Alan Haywood** (University of Leeds) describe a new project, entitled 'Our Greenhouse World', designed to find out how these temperatures were attained.

Extreme 'deep-time' climates

Much is known of Quaternary climates at increasingly higher resolutions. But with carbon dioxide levels predicted to rise to over 500 parts per million by volume (ppmv) by the end of the century we have to look farther back in time to understand past warm climates more fully. What were the climatic drivers and palaeoenvironmental consequences of these warmer periods, and how long did they last? These questions require answers because they relate to our assessment of the causes and implications of recent atmospheric changes in carbon dioxide. Study of deep-time climate is essential if we are to understand the Earth's natural climate system in order to provide a context for man's impact on the modern climate.

The BGS together with the British Antarctic Survey (BAS), the University of Leeds and the University of Bristol have embarked on a new collaboration to study the extraordinarily warm climates of the Cretaceous and Cenozoic, when carbon dioxide levels were 1000 to 1500 ppmv. BAS, the University of Bristol and the University of Leeds are recognised leaders in modelling climate and the BGS, based on its geological expertise, will provide new data for improving the existing models.

The approach of modellers and geologists to deep-time climate and palaeoenvironmental research is very different. Modellers tend to programme the processes and then view the results, whereas geologists tend to use the data to interpret the processes. A primary objective of the new project is, therefore, to develop a synergy between the two disciplines. We plan an iterative approach, in which geological data is used to identify where models are working well and where they are not. We can thus identify what changes are required to improve the model results.

The Cretaceous world (144 to 65 million years ago) is considered to have experienced a greenhouse climate with levels of atmospheric CO_2 many times higher than pre-industrial levels. Conventional wisdom states that the equator-to-pole temperature gradient was low during the Cretaceous, and that polar temperatures precluded the presence of ice and were warm enough to support lush forests. Existing palaeoclimate modelling simulations have been unable to reproduce the magnitude of high-latitude temperature change

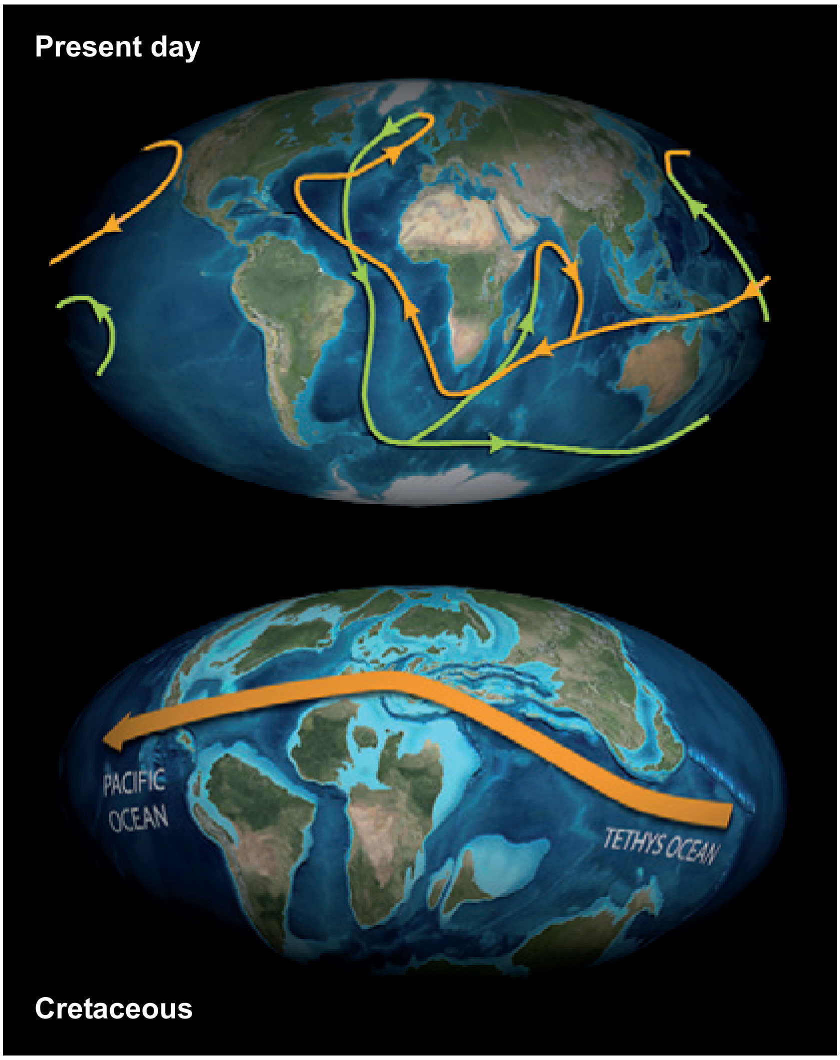
Cretaceous forests 120 million years ago in Antarctica. Reconstruction based on PhD studentship of Jodie Howe (Leeds).

suggested by geological data. Furthermore continental interiors are too cold and arid. Does this indicate a problem with the models or an incorrect interpretation of the geological record?

" by studying the evolution of the ocean basins over a 100 million year timescale we can address the major questions about the drivers of global cooling "

Global climates during the Eocene (55 to 34 million years ago) were perhaps the most homogeneous of all the Cenozoic; the temperature gradient from equator to pole was only half that of today, and deep-ocean temperatures were exceptionally warm. The polar regions were much warmer, perhaps as mild as the modern-day Pacific Northwest. Warm temperate forests extended right to the poles, while rainy tropical climates extended as far as 45° north. The processes sustaining the homogenous climates of the Eocene are poorly constrained. It may have been that increased tropical storm frequency and intensity helped to enhance the transfer of heat from the tropics to polar regions, but this has yet to be explored within a palaeoclimate modelling context. An increase in the frequency and magnitude of tropical storms during past warm intervals may provide a guide to the behaviour of such storms in the future.

A substantial transient warming of the Earth's surface occurred about 55.5 million years ago (the 'Palaeocene–Eocene thermal maximum' or 'PETM'), synchronous with a carbon isotopic excursion interpreted as recording a massive release of carbon to the ocean and atmosphere. Although the PETM represents a potential analogue for future global change, little is currently certain about the source, quantity, or rate of carbon release, nor of the impact of major reorganisations in ocean circulation that took place at this time. Of particular future relevance is whether methane (CH_4) hydrate destabilisation was involved, particularly in terms of what triggered it and how strong the feedbacks between global warming and CH_4 release are. The PETM also represents a possible case study into the impacts of ocean acidification on calcifiers such as foraminifera, coccolithophores, and corals. However, we need to characterise the nature of the carbon release better before implications for future ocean acidification can be safely drawn.



Distribution of continents and oceans illustrating global oceanic circulation with shallow, warm currents in orange and deep cold currents in green. Top image: present day, Bottom image: Cretaceous. Plate tectonic maps and continental drift palaeoreconstructions after C R Scotese, PALEOMAP Project (www.scotese.com).

During the Pliocene (5 to 1.8 million years ago), the world was warmer than at present. The ancient distribution of warm-climate ocean plankton, and of animal and plant fossils on land, shows that mean annual temperatures in the mid-latitudes were often several degrees higher than they are now. The greatest warming seems to have been in the Arctic and cool temperate latitudes of the Northern Hemisphere, where temperatures were often warm enough to allow species of animals and plants to exist hundreds of kilometres north of the ranges of their nearest present-day relatives. The causes of the generally warmer climates of the Pliocene remain a mystery. The warmth may have been related to changes in ocean circulation patterns, perhaps combined with higher concentrations of greenhouse gases in the atmosphere.

For further information, contact:

Dave Tappin, BGS Keyworth,
Tel: +44(0)115 936 3449
e-mail: drta@bgs.ac.uk