Warm worlds

Alan Haywood and Mark Williams ask: 'What controlled the climate three million years ago?'

The North Atlantic may have been up to 5°C warmer than it is now.

During the Pliocene era, three million years ago, the world was warmer than it is today. The degree of warming wasn't uniform, and appears to have been greatest at the mid to high latitudes (30° to 90° north and south of the equator). If you'd taken a summer swim off the southern coast of Great Britain at this time, the waters would have felt almost Mediterranean.

We can tell the world was warmer from a range of fossil information. For example, tiny foraminifera—organisms a bit like an amoeba with a chalk shell—can be used to map out the surface temperature of the sea waters in which they lived. This is because different species, or assemblages of species, thrive at different temperatures. By comparing fossil foraminifera in seafloor samples from the Pliocene with foraminifera alive today, we can reconstruct how warm the surfaces of the oceans were. The technique suggests that the North Atlantic may have been up to 5°C warmer than it is now.

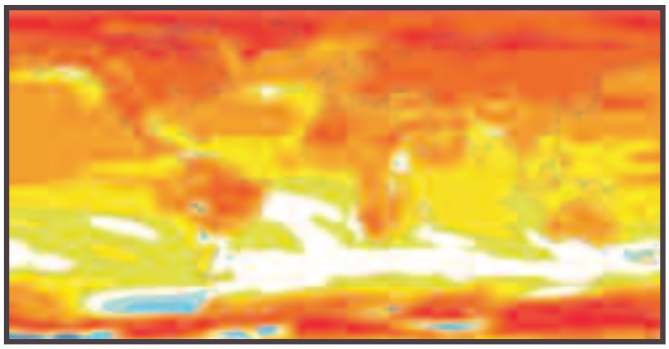
Why were mid and high latitudes so warm? There are two main ideas. One suggests that ocean circulation was stronger at this time, and that currents flowing from the tropics towards the poles carried more warm surface waters with them. The other explanation suggests that there was more carbon dioxide in the atmosphere, warming the world through a greenhouse effect.

The pattern of sea surface temperature change three million years ago gives a clue to the correct explanation. If Pliocene warmth was due only to the ocean currents, we would expect to see the tropics cooler and the higher latitudes warmer than they are today. This is indeed the pattern fossil foraminifera show.

But sophisticated numerical models of climate, known as general circulation models, and which are run on powerful super computers, suggest that both the tropics and the higher latitudes warmed. This result is now supported by new evidence which also suggests that sea surface temperatures were higher everywhere, including the tropics.

Tiny haptophyte algae that live near the sea surface produce alkenones—carbon-based compounds from a group called methyl ketones. Alkenones have 37 carbon atoms and two, three, or four of these are joined together with double bonds. The proportion of the molecules with each number of double bonds depends on the temperature of the water in which they are synthesized. Alkenones decay only slowly, so the chemicals are incorporated into the seafloor mud. If you analyse a core taken from the seafloor, the proportions of the three molecules in the alkenones lets you estimate sea surface temperatures when the algae were alive (and the general levels of alkenones at each depth within the core tell you if conditions at the time favoured the algae). Alkenone temperature estimates for the Pliocene sometimes disagree with those from foraminifera. They suggest that the sea surface was warmer in both the tropics and higher latitudes three million years ago—the same pattern of warming predicted by climate models. The pattern is also consistent with the greenhouse explanation, rather than the ocean currents idea, because carbon dioxide will cause warming at all latitudes.

So now there appears to be evidence that high levels of the greenhouse gas carbon dioxide were at least partly responsible for Earth's warmer climate three million years ago. Exploring the Pliocene world with advanced computer models, and investigating climate signals derived from fossils, is a good way to understand what Earth's climate may be like in the future, as a result of man-made greenhouse gas emissions.



The Pliocene world of three million years ago, as seen by an advanced computer-based general circulation model. It shows the much warmer conditions at higher latitudes. By modelling the warm Pliocene world we can learn what might happen to our world as global warming takes hold.

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