

Letter from the Desk of David Challinor
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The Pleistocene epoch lasted for about a million years and ended roughly 12,000 years ago. This was the age of the great glaciations when much of the temperate northern hemisphere was covered with ice. So much of the earth's water was solid (ice) that the ocean level was hundreds of meters lower than today, and continental margins extended far beyond their present limits, e.g. one could walk from Siberia to Alaska or from France to Britain. The world has been warming ever since. Warm and cold cycles have regularly dominated earth's climate as far back as we can measure, but the causes for these cycles are hard to understand and theories explaining them abound. Since coal deposits now exist in Greenland, Spitsbergen and even Antarctica, there must have once been vast vegetated areas there that generated the carbon mass to produce coal. Did the earth tilt on its axis enough to shift these lands from the tropic to the polar regions? Or did these lands move to the poles through tectonic plate actions? Was the whole globe so warm that forests grew everywhere? Despite the lack of clear explanations for these climate changes, our world continues to become warmer. This month's letter will consider how we measure the current warming trend and address the controversial issue of how this trend might be attributed to our ongoing human activities.

A recent article in *Nature*^{*} has shed light on the timing of these warm/cold cycles. The author and his large team of 47 European scientists succeeded in drilling an ice core 10cm (4in) in diameter and 3.1km (2 miles) deep into Antarctic ice. It was a long, slow, five-year process. Every two or three meters the drill had to be pulled and the core extracted. Near the bottom of the hole, it took an hour to retrieve each core. When only a few hundred meters from the ice/rock interface, the ice was nearing its melting point from geothermal heat.

When drilling resumes next spring (Nov. 2004) after shutting down for the winter, the team hopes to reach the bottom; they will use a bag of ethanol as antifreeze for the drill bit. Core extraction from the final section would produce ice laid down 900,000 years ago or more. The value of this core is that by analyzing the changes in the relative proportions of hydrogen isotopes in the ice layers, the scientists will be able to determine Antarctic temperatures when each ice layer was laid down.

The current depth (3,100m) gives scientists a record of eight ice ages that have occurred over the past 740,000 years. This record depth is important because it shows that the duration of the warm/cold cycle has changed. When combined with information gained from deep sea sediment cores, scientists calculated that about 430,000 years ago a long warming period called Termination V began that is similar to our current warming period. This ancient warming cycle lasted 28,000 years, an unusually long time; prior to about 1 mya (million years ago) cold/warm cycles were shorter (about 40,000 years) and

^{*} Wolff, Eric W. *et al* "Eight glacial cycles from an Antarctic ice core" NATURE 429, 623-628 (2004)

coincided with a similar time scale variation in the tilt of earth's axis of rotation (now $22\frac{1}{2}^\circ$). Since 1 mya, and particularly in the past half-million years, the cycles are closer to 100,000 years and are thus similar to cyclical variations in the shape of the earth's orbit. Today, our orbit around the sun is elliptical with the earth being closest to the sun at the vernal and autumnal equinoxes and farthest at midsummer and midwinter. Every 100,000 years or so the elliptical orbit slowly becomes circular for reasons still unknown. The longer cycles, such as the one we have now, will result in ice ages becoming colder and more extensive than the earlier (pre mya) 40,000-year cycles. We can anticipate our current interglacial period to be milder than the ones before Termination V, lasting until about 16,004 AD!

The new Antarctic core has painted a clearer picture of the past than previous shorter cores. The past 500,000 years have seen greater glacial conditions as represented in the vast extent of the last ice age. In like manner, these longer cycles have caused the four mildest interglacial intervals of the past four million years, and the current one undoubtedly helped spark the growth and spread of human civilizations.

Analysis of the core's air bubbles has confirmed that atmospheric CO₂ content 430,000 years ago was close to earth's preindustrial level of 200 years ago. The earth in Termination V was in an elliptical orbit similar to the present one, which indicates that the climate at that distant past was similar to today's mild interglacial one. Still subject to controversy is the long-term effect of an unprecedented rise in atmospheric CO₂ in the past century. Balloon and satellite measurements have confirmed not only a rapid increase in atmospheric CO₂, but a rise in greenhouse gases such as oxides of nitrogen and sulfur. The greatest anthropic sources of these gases are burning carbon petroleum products, auto exhausts, power plant emissions, wood burning stoves in the Third World, and the nitrous oxides emitted from the exhausts of high altitude jets. With ever more people on earth cooking and heating with wood on the one hand, and in prosperous countries buying more cars and trucks on the other, the prospects of reducing anthropic greenhouse gas emissions seems dim, especially given the opposition of the United States and Russia to the Kyoto Protocol.

Various ways have been suggested to reduce CO₂ and other greenhouse gas emissions. A global carbon tax, for example, might help achieve this goal, but economically a heavy tax today for an anticipated benefit a century or more hence is not supportable. Rather than trying to find an economic justification, many scientists and others consider it a moral or ethical issue—we owe future human generations a healthy planet.

The Arctic and Antarctic ice cover that stores two-thirds of the planet's fresh water is noticeably melting. The outer edge of Greenland's ice cap has shrunk by almost a third and this may lead to a serious problem as it could change the global ocean circulation pattern (discussed in my June 1998 letter). If enough of the polar ice caps

melted, global sea levels would rise and flood low coastal areas. Moreover, increasing the fresh water content of the ocean between southern Greenland and the British Isles could interrupt the ocean's present flow pattern. Warm salt water from the tropics flows north in the eastern Atlantic. While passing through the tropics, much surface water evaporates, leaving the ocean saltier and thus heavier. In the north Atlantic, heat from the tropically heated ocean dissipates into the air, warming Britain, Norway and Iceland. The very dense saline ocean water then sinks and flows south deep in the western Atlantic until it turns east into the Indo-Pacific to be rewarmed and continue its conveyor belt-like cycle. A large volume of cold fresh water from melting Arctic glaciers could overlay the north-flowing salty warm water (fresh water floats on salt water) and prevent the ocean-to-air heat exchange so crucial to northwest Europe. Or, the added fresh water might dilute the salty warm water enough to keep it from sinking, thereby interrupting the energy source for the global ocean conveyor belt. Whatever happens will probably occur slowly enough to span many human generations. *Homo sapiens* are so adaptable that I am optimistic they can handle the change. That said, I also believe strongly that as "a" or perhaps "the" dominant species on earth, we have an ethical obligation to husband all energy sources, particularly non-renewable ones.

As I have often reiterated, change is the only condition that we can predict with certainty. I have been blessed with having lived long enough to witness extraordinary variations in the lifestyle and behavior within the culture into which I was born. These variations are not necessarily better or worse than the ones they replaced; they are merely different. Let us gracefully accept them and do our individual best to ensure minimum damage to all who inhabit planet earth.

David Challinor
Phone: 202-673-4705
Fax: 202-673-4686
E-mail: ChallinorD@aol.com