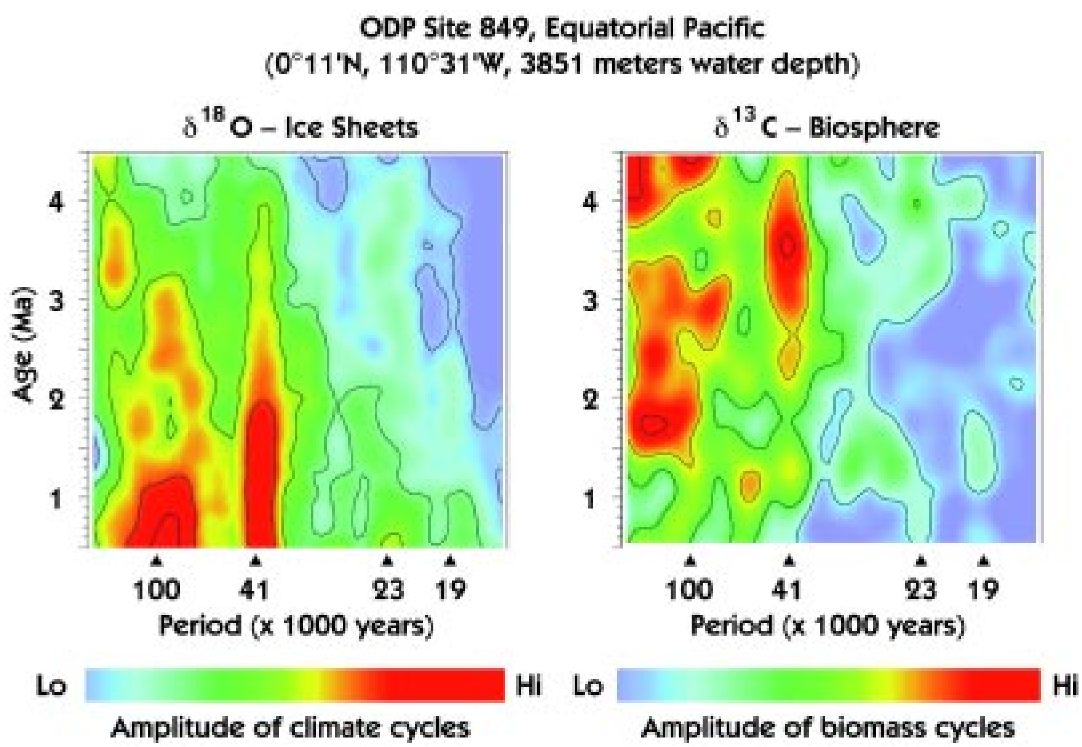
DOES EARTH'S BIOSPHERE SET CLIMATE SENSITIVITY?

Alan C. Mix, College of Oceanic and Atmospheric Sciences, Oregon State University

How did the ice ages begin, and why did they end? Does the biosphere amplify or stabilize climate change? Clues to these questions are found in the isotopic ratios of oxygen ($^{18}O/^{16}O$, or $\delta^{18}O$) and carbon ($^{13}C/^{12}C$, or $\delta^{13}C$) preserved in the skeletal remains of seafloor dwelling microorganisms (foraminifera) recovered from ODP Site 849, in the deep Pacific Ocean [*Mix et al.,* 1995]. Changes in $\delta^{18}O$ primarily track the size of continental ice sheets, while those in the $\delta^{13}C$ mostly reflect global variations in the amount of carbon stored in organic matter — Earth's biomass.

The most persistent signal in ice-sheet fluctuations has a periodicity of 41,000 years, which matches cyclic changes in the tilt of Earth's rotational axis. The amplitude of this climate signal, that is, the size of the undulations from large to small ice sheets, has increased towards the present (see figure). Additional climate periodicities, near 100, 23, and 19 thousand years, which correspond to other changes in Earth's orbital geometry, have also grown stronger through time. On the other hand, a long-period cycle near 400,000, observed prior to 3 Ma, when Earth's only major ice sheet was in Antarctica, weakened after 3 Ma when ice sheets first began to cover the Northern Hemisphere as well. Although isotopic cycles occur throughout the record, their total amplitude has grown over time. Why? Maybe the biosphere ($\delta^{13}C$) is responsible.

Cycles with similar periods are observed in the $\delta^{13}C$ data, but swings in the size of Earth's biomass have decreased with time, unlike those in ice sheet size. For example, at the 41,000 period, the greatest amplitudes in $\delta^{13}C$ predate 3 Ma, while the opposite is true for $\delta^{18}O$. Longer-period $\delta^{13}C$ cycles were also strongest in the distant past, between about 1.5 and 3 Ma and prior to 4 Ma. One explanation for these $\delta^{13}C$ patterns is that global biomass was larger (and thus more changeable) in the past, and herein may lie the link to climate. A more active biosphere might stabilize climate by regulating carbon dioxide, a greenhouse gas, absorbing it when atmospheric and oceanic levels were high, and releasing it when they were low. When ice sheets began to invade the polar regions of North America and Europe, about 3 Ma they stripped off a thick mantle of forests and soils, and desiccated large land masses. This long-term loss of biomass may have sensitized Earth's climate system to change, and over time amplified the ice-age cycles.



Statistical analyses of microfossil isotope data reveal the changing strengths of climate and biosphere rhythms over the past 4.5 m.y. Warmer colors indicate stronger cycles, with larger amplitudes.

Reference:
Mix, A.C., N.G. Pisias, W. Rugh, J. Wilson, A. Morey, T. Hagelberg, Benthic foraminifer stable isotope record from Site 849 (0-5 Ma): Local and global climate changes. In: Pisias, N.G., Mayer, L.A., Janecek, T., Palmer-Julson, A., and van Andel, T. (eds.), *Proc. ODP, Sci. Results, 138,* 371-412, 1995.