N89-21308

ABRUPT CLIMATE CHANGE AND EXTINCTION EVENTS

Thomas J. Crowley, Applied Research Corporation, 305 Arguello Dr., College Station, TX 77840

There is a growing body of theoretical and empirical support for the concept of instabilities in the climate system (North, 1984; Broecker et al., 1985; Berger and Labeyrie, 1987), and indications that abrupt climate change may in some cases contribute to abrupt extinctions (Crowley and North, 1988). Theoretical indications of instabilities can be found in a broad spectrum of climate models - energy balance models, a thermohaline model of deep-water circulation, atmospheric general circulation models, and coupled ocean-atmosphere models. Abrupt transitions can be of several types and affect the environment in different ways. A sudden change in ice cap size is associated with albedo discontinuities of snow and ice (North, 1984). Incremental changes in precipitation or evaporation could affect surface salinity (and density) of ocean surface waters, thereby affecting production rates of deep water. Changes in deep-water circulation could alter heat transport and affect carbon storage and oxygen levels, both in deep waters and in the atmosphere. Abrupt transitions also occur in the planetary circulation.

There is increasing evidence for abrupt climate change in the geologic record and involves both interglacial-glacial scale transitions and the longer-term evolution of climate over the last 100 million years. O-18 records from the Cenozoic clearly show that the long-term trend is characterized by numerous abrupt steps where the system appears to be rapidly moving to a new equilibrium state. The long-term trend probably is due to changes associated with plate tectonic processes, but the abrupt steps most likely reflect instabilities in the climate system as the slowly changing boundary conditions caused the climate to reach some threshold critical point (North and Crowley, 1985; Crowley and North, 1988).

A more detailed analysis of abrupt steps comes from high-resolution studies of glacial-interglacial fluctuations in the Pleistocene. Transitions have occurred in less than 1,000 years. Detailed studies of the Greenland Dye 3 ice core indicate that at the end of the last glacial maximum the atmosphere may have shifted states in less than 100 years. Studies of the last interglacial-glacial transition indicate that the end of the last interglacial occurred within 1,000-2,000 years. Over a core depth of 3-6 cm, ice volume increased by 10 X 10^6 km^3. Comparison of the rate of climate change at this time with the K-T iridium anomaly from Gubbio indicates that both events occurred over comparable spans of sampling resolution (Crowley, 1988).

Comparison of climate transitions with the extinction record (Crowley and North, 1988) indicates that many (but by no means all) climate and biotic transitions coincide - the Late Ordovician, Late Devonian, Early Permian, Eocene-Oligocene, Miocene, and Pliocene. The Cenomian-Turonian and Toarcian extinction events also coincide with ocean anoxic events that may reflect instabilities in the ocean system. However, at the present time the Cretaceous-Tertiary extinction is not a candidate for an extinction event due to instabilities in the climate system. The K-T is not associated with evidence for either ice cap growth or thermohaline instabilities, nor is the event associated with any significant long-term step in the geologic record. It is quite possible that more detailed comparisons and analysis will indicate some flaws in the climate instability - extinction hypothesis, but at present it appears to be a viable candidate as an alternate mechanism for causing abrupt environmental changes and extinctions.

REFERENCES

Berger, W. H., and Labeyrie, L. D. 1987: Abrupt Climate Change (Reidel, Dordrecht).

Broecker, W.S., Peteet, D.M., and Rind, D., 1985: Does the ocean-atmosphere system have more than one stable mode of operation? Nature, 315:21-26.

Crowley, T.J., 1988: Rate of climate change at the end of the last interglacial. Science (submitted)

Crowley, T.J., and North, G.R., 1988: Abrupt climate change and extinction events in earth history. Science, 240:996-1002

North, G. R., 1984: The small ice cap instability in diffusive climate models, Jour. Atmos. Sci., 41:3390-3395.

North, G.R., and Crowley, T.J., 1985. Application of a seasonal climate model to Cenozoic glaciation. Jour. Geol. Soc. (London), 142:475-482.