Title: Nonlinear Dynamics of Global Atmospheric and Earth-System Processes

Investigators:

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Significant Accomplishments:

During the past year we focussed on two major areas:

1) GCM Studies of the Atmospheric Response to Change Boundary Conditons. In a series of papers, listed below as publications (2, 4, 5, 6, 7), we report the results of an extensive series of numerical studies based on the NCAR-CCMI general circulation model. In these studies we have determined the response (a) to systematic changes in atmospheric CO_2 ranging from 100 to 1000 ppm, (b) to changes in the prescribed sea surface temperature (SST) in the Gulf of Mexico, such as occurred during the deglaciation phase of the last ice age, (c) to changes in soil moisture over North America, and (d) to changes in sea ice extent in the Southern Hemisphere. These latter three surface boundary conditions (SST, soil moisture, and sea ice coverage) are all measurable from systematic satellite observations. Among the significant results from these studies, we note the following: (i) It is shown that the response of surface temperature and other variables is nearly logarithmic, with lower CO_2 levels implying greater sensitivity of the atmospheric state to changes in CO_2, (ii) the surface temperature of the Gulf of Mexico exerts a considerable control on the storm track and behavior of storm systems over the North Atlantic through its influence on evaporation and the source of latent heat, and (iii) reductions in soil moisture can play a significant role in amplifying and maintaining North American drought, particularly when a negative soil moisture anomaly prevails late in the Spring.

2) Dynamics of Long-Term Changes in the Global Earth-System. Publications (3, 9, 10) listed below represent the first attempts to provide a unified theory for the onset and maintenance of the ice-age oscillations that emerged about 800,000 years ago. This work involves the consideration of complex nonlinear internal interactions between the atmosphere, hydrosphere, cryosphere, and bio-lithosphere that can combine under the influence of long-term radiative forcing due to earth-orbital (Milankovitch) variations to produce the most significant changes recorded in the earth-system. Of key importance is the role of atmospheric CO_2 as a forced and free variable.

Focus of Current Research and Future Plans:

We have now undertaken the systematic study of the equilibria of GCMs as a function of initial and boundary conditions, with the aim of determining the transitivity or intransitivity of the GCM. Of particular interest are questions concerning the ultimate equilibration of a GCM when run for very long periods (say 100 years or longer), and the possibility that for similar boundary conditions multi-modal equilibria can exist.

More generally, we are continuing our analyses of large-scale dynamical models of the atmosphere to establish their sensitivity to satellite signatures of soil moisture, sea-surface temperature, snow cover, and sea ice in determining global weather variability.

Publications: (1990-1991)

1) Ebisuzaki, W., 1991: Vertical tilts of tropospheric waves: Observations and theory. *J. Atmos. Sci.*, in press.

2) Maasch, K. A., Oglesby, R. J., 1990: Meltwater cooling of the Gulf of Mexico II: A GCM simulation of climatic conditions at 12 ka. *Paleoceanography*, **5**, 977-996.

3) Maasch, K. A., Saltzman, B., 1990: A low-order dynamical model of global climatic variability over the full Pleistocene. *J. Geophys. Res.*, **95**, 1955-1963.

4) Oglesby, R. J., 1991: Springtime soil moisture, natural climatic variability, and North American summertime drought. *J. Climate*, in press.

5) Oglesby, R. J., 1991: A GCM investigation of the West Antarctic precipitation hole. *Antarctic Science*, in press.

6) Oglesby, R. J., 1991: The influence of sea ice extent on the Southern Hemisphere oceanic and atmospheric circulation. *EOS*, **71**, 1368.

7) Oglesby, R. J., Saltzman, B., 1990: Sensitivity of the equilibrium surface temperature of a GCM to systematic changes in atmospheric carbon dioxide. *Geophys. Res. Lett.*, **17**, 1089-1092.

8) Pandolfo, L., Sutera, A., 1991: Rossby waves in a fluctuating zonal flow. *Tellus*, in press.

9) Saltzman, B., Maasch, K. A., 1990: A first-order global model of late Cenozoic climatic change. *Trans. Roy. Soc. Edinburgh*, **81**, 315-325.

10) Saltzman, B., Maasch, K. A., 1991: A first-order global model of late Cenozoic climatic change II: A simplification of CO_2 dynamics. *Clim. Dyn.*, in press.