N93-20076

Title: Nonlinear Dynamics of Global Atmospheric and Earth System Processes

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Background:

During the past eight years, we have been engaged in a NASA-supported program of research aimed at establishing the connection between satellite signatures of the earth's environmental state and the nonlinear dynamics of the global weather and climate system. Co-investigators over this period, including postdoctoral associates and graduate students, are W. Ebisuzaki, A. R. Hansen, K. A. Maasch, R. L. Nagle, R. J. Oglesby, L. Pandolfo, and C.-M. Tang. Thirty-five publications and four theses have resulted from this work, which include contributions in five main areas of study: 1) Cloud and latent heat processes in finite-amplitude baroclinic waves, (2) application of satellite radiation data in global weather analysis, (3) studies of planetary waves and low-frequency weather variability, (4) GCM studies of the atmospheric response to variable boundary conditions measurable from satellites, and (5) dynamics of long-term earth system changes.

Significant Accomplishments:

Three main lines of investigation were pursued during the past year:

1) Planetary Atmospheric waves and Low-Frequency Variability. A study showing that Rossby waves can be confined to middle latitudes on a spherical earth due to the "localizing" property of a fluctuating zonal mean flow was completed (publication [6]). This provides a significant justification for the use of a mid-latitude beta-plane in treating simple models of planetary wave behavior, at the same time pointing to possible errors in studies in which a fixed zonal wind profile is prescribed. Since the results are dependent on spatial resolution of the zonal flow, some suggestions are made concerning a possible source of systematic error in low resolution models. In addition, a major review of observational studies of low-frequency, intraseasonal, planetary wave variability is made in publication [5],and some important insights concerning the energy source of traveling planetary waves in the atmosphere is obtained in publication [1], based on an observational and theoretical study of the vertical tilts of these waves.

2) GCM Studies of the Atmospheric Response to Changed Boundary Conditions. Two studies aimed at helping establish the sensitivity of the atmosphere to satellite signature of soil moisture, sea-surface temperature, snow cover, and sea ice cover were completed, some of the results of which appeared in publications [2] and [4].

3) Dynamics of Long-Term Changes in the Global Earth-System. Significant strides were made in developing a dynamical systems framework for treating the evolution

of the slower-response parts of the earth-systems (e.g., the ice sheets, deeper ocean, carbon-dioxide content of the atmosphere). Two publications were completed in which a model of the ice-age fluctuations of the past few million years were accounted for as a combined response to radiative and tectonic forcing and free internal variability of the atmosphere - hydrosphere - cryosphere - biolithospheric components of the complete earth-system (publications [7] and [8]).

Focus of Current Research and Plans for Next Year:

Systematic studies are continuing to determine the transitivity properties of a GCM (the NCAR CCM), particularly the very long term (greater than 150 years) equilibration properties including long period fluctuations and the possibility for multi-modal states. In this latter connection, we are exploring the possibility for modelling abrupt changes in weather and climate as a consequence of possible instabilities in the climate system implied by such multi-modal states. We are also continuing our program of using the GCM to establish parameterizations and sensitivity functions that can be used to formulate and improve low-order dynamical models for the evolution of the full climatic system over secular (multi-year) time scales and for a range of externally imposed conditions (e.g., CO_2, solar radiation) much wider than are presently imposed. The role of stochastic forcing as a proxy for unrepresented or unrepresentable physics in the complete system is being studied.

Publications: (1991-1992)

[1] Ebisuzaki, W., 1991: Vertical tilts of tropospheric waves: Observations and theory. *J.Atmos. Sci.*, 48,2373-2381.

[2] Oglesby, R. J., 1991: Springtime soil moisture, natural climatic variability, and North American summertime drought. *J. Climate*,

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

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

[5] Pandolfo, L., 1992: Observational aspects of the low-frequency intraseasonal variability of the atmosphere in middle latitudes. *Adv. Geophysics*, in press.

[6] Pandolfo, L., Sutera, A., 1991: Rossby waves in a fluctuating zonal flow. *Tellus*, 43A, 257-265.

[7] Saltzman, B., Maasch, K. A., 1991: A first-order global model of late Cenozoic climatic change II: A simplification of CO_2 dynamics. *Climate Dynamics*, 5, 201-210.

[8] Saltzman, B. and Verbitsky, M., 1992: Asthenospheric ice load effects in a global dynamical-system model of the Pleistocene climate. *Climate Dynamics*, in press.