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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., CO₂, 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 CO₂ 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.