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FIRST YEAR PROGRESS REPORT ON RESEARCH PROJECT ON CO₂-INDUCED CLIMATE CHANGE

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Office of Research Services
Stony Brook, New York 11794-0001
Tel. No. 516-632-6960
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Research Site: State University of New York at Stony Brook, N.Y. 11794

Principal Investigator: Robert D. Cess
Leading Professor of Atmospheric Sciences, Tel. No. 516-632-8321
Sultan Hameed
Professor of Atmospheric Sciences, Tel. No. 516-632-8319

Robert D. Cess, Principal Investigator
11/26/91
Date

Sultan Hameed, Principal Investigator
4/26/91
Date

MASTER

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INTRODUCTION

The following pages summarize the work completed to date in the first year of the Research Project on CO₂-Induced Climate Change which is funded by the Department of Energy Grant No. DEFG0285ER60314. The first year of the project began on March 1, 1991.

Professor Robert D. Cess has devoted 23 percent of time and effort to the project since the beginning of the current term of the agreement and expects to continue at the same level during the remainder of the term. The corresponding figure for Professor Sultan Hameed is 40 percent.

The three major areas of study are discussed separately. The first task deals with an intercomparison of general circulation model capabilities with the aim of improving their parameterizations of important physical processes, so that model predictions of CO₂ induced climate change become more reliable. Task 2 encompasses analysis of climate data for the purpose of understanding climate change and climate variability. The third task is concerned with analyzing climatic variability in General Circulation Models and its comparison with observations.

TASK 1: GCM Intercomparison

Progress has proceeded as planned regarding the GCM intercomparison project. A summary of snow-climate feedback was published in the 23 August 1991 issue of Science, and a more detailed manuscript is presently being prepared for submission to JGR. A manuscript has also been ~~submitted to~~ *accepted by* JGR entitled "Intercomparison and Interpretation of Surface Energy Fluxes in Atmospheric General Circulation Models". This project is now called FANGIO (Feedback Analysis for GCM Intercomparison and Observations).

The next FANGIO workshop will be held during February 1992, and the primary emphasis will be placed on intercomparing CO₂ forcing as produced by the participating GCMs. Particular emphasis will be placed on the role of the hydrological cycle, because the CO₂ bands are strongly overlapped by water vapor absorption. A plan for interfacing FANGIO with ARM will also be proposed at this workshop. The rationale for this is discussed in a paper entitled "The Impact of Clouds on the Shortwave Radiation Budget of the Surface-Atmosphere System: Interfacing Measurements and Models" that has been submitted to the Journal of Climate. In this paper a single GCM (ECMWF) was interfaced with coupled satellite/surface measurements of shortwave radiation to demonstrate a procedure for validating one aspect

of the GCM as pertains to cloud/climate interactions. It will be proposed at the workshop that similar GCM studies, using all participating GCMs, be performed for locations corresponding to possible ARM sites.

TASKS 2 AND 3: Analysis of Climate Data and Comparisons with General Circulation Model Results

Our investigation of the interannual variability of climate in the Oregon State University GCM has made progress in two directions.

(1) We have evaluated the GCM in terms of the simulated winds, ocean currents and thermocline depth variations in the paper "Surface Currents and Equatorial Thermocline in a Coupled Upper Ocean-Atmosphere GCM", by K. R. Sperber, S. Hameed and L. Gates, *Climate Dynamics* (in press). It was found that the zonal wind velocities in the model are underestimated by a factor of about three and zonal current velocities are underestimated by a factor of about five, but the model qualitatively simulates the major features of gyral scale currents, and the phases of the seasonal variation of the principal equatorial currents are in reasonable agreement with observations. The simulated tropical currents are dominated by Ekman transport and the eastern boundary currents do not penetrate far enough equatorward, while the western boundary currents do not penetrate far

enough poleward. The subtropical wind belt and mid-latitude westerlies are displaced equatorward of observations; hence, the mid-latitude eastward currents, principally the Kuroshio-North Pacific Drift and the Gulf Stream-North Atlantic Current are displaced equatorward. In spite of these shortcomings the surface simulation of this two-layer upper ocean model is comparable with that of other GCMs of coarse resolution. The model successfully simulates the deepening of the thermocline westward across the Pacific as a consequence of the prevailing Walker circulation. The region of most intense simulated surface forcing is located in the western Pacific due to a southwestward displacement of the northeast trade winds relative to observations; hence the equatorial Pacific is dominated by eastward propagation of thermocline depth variations. The excessively strong Ekman divergence and upwelling in the western Pacific cools the local warm pool, while incorrectly simulated westerlies in the eastern Pacific suppress upwelling and inhibit cooling from below. These features reduce the simulated trans-Pacific sea-surface temperature gradient, weakening the Walker circulation and the anomalies associated with the simulated Southern Oscillation as documented in our earlier work.

(2) An application of the OSU GCM to the study of inter-annual variability of regional climates has been made in the

paper "Teleconnections of the Southern Oscillations in the Tropical Atlantic Sector in the OSU Coupled Upper Ocean-Atmosphere GCM", by S. Hameed, K. R. Sperber and A. Meinster, submitted to J. Climate. A composite analysis of the warm and cold events simulated in this 23-year integration has been performed. During the low phase of the Southern Oscillation, when warm anomalies occur in the eastern Pacific the model simulates for the Atlantic region in the northern spring season (1) a deficit of precipitation over the tropical South American Continent, (2) Caribbean and Gulf of Mexico sea-level pressure and sea-surface temperature are in-phase with the eastern Pacific anomalies, while those east of the Nordeste region are out-of-phase, (3) northeast tradewinds are weaker than normal and southwest trade winds are stronger than normal (inferred from surface current anomalies). During the high phase of the simulated Southern Oscillation conditions in the atmosphere and ocean are essentially the reverse of the low phase. Thus the model produces a response in the South American region during the opposing phases of the Southern Oscillation which is in general agreement with observations.

We followed the work described above on the Atlantic sector climate in the OSU GCM by an analysis of the inter-annual variability of observed precipitation data in the Northeast section of Brazil, called the Nordeste in the

paper "Time Scales of Variability Associated with Nordeste Precipitation" by K. R. Sperber and S. Hameed, presented at the Fifth Conference on Climate Variations held in Denver, October 14-18, 1991. We found that although this region has large amplitudes of interannual variability of precipitation, the variations are represented by a simple power spectrum, in which only a few frequencies contain substantial variance. Furthermore, these frequencies are phase locked with their counterparts in the sea-surface temperatures of specific basins in the North Atlantic, South Atlantic and the equatorial Pacific Ocean.