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

Submitted to: Carbon Dioxide Research Division
Office of Basic Energy Sciences
Department of Energy
Washington, D.C. 20545

Submitted by: State University of New York
Office of Research Services
Stony Brook, New York 11794-0001
Tel. No. 516-632-6960
(Congressional District #1, IRS #14-1368361)

Research Site: State University of New York at Stony Brook, N.Y. 11794

Principal Investigator: Robert D. Cess,
Distinguished Professor of Atmospheric Sciences, Tel. No. 516-632-8321

Sultan Hameed
Professor of Atmospheric Sciences, Tel. No. 516-632-8340

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MAR 20 1995
1/27/94

Robert D. Cess, Principal Investigator

Sultan Hameed, Principal Investigator
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SUMMARY OF CURRENT PROGRESS

This summary of current progress in the research project at SUNY Stony Brook on CO₂-induced climate change is classified into three tasks corresponding to the task categories in the US DOE/PRC CAS cooperative project on climate change. Task 1, led by Dr. Robert Cess, is concerned with intercomparison of CO₂-related climatic warming in contemporary general circulation models. A summary of work accomplished in Task 1 in the current funding period begins on page 1. Task 2, directed by Dr. Sultan Hameed, aims at understanding the natural variability in climatic data and comparing its significant features between observations and model simulations. A summary of current progress in Task 2 begins on page 4. Task 3, also directed by Dr. Hameed focuses on analysis of historical climate data developed at the Institute of Geography of the Chinese Academy of Sciences. A summary of current research in Task 3 begins on page 7.

TASK 1: ANALYSIS AND INTERCOMPARISON OF GENERAL

Work that has been completed during the past year has resulted in the following publications:


A major effort of the current research has focused on the GCM intercomparison, or FANGIO, project. In 1990 we published an analysis of cloud feedback as produced by 19 atmospheric general circulation models. This study demonstrated dramatic differences (by nearly a factor of three) in the magnitude of cloud feedback as produced by the models. Most GCMs, however, are in a continual state of evolution, so that the cloud feedback comparison represented a snapshot at that particular time. In the ensuing four years virtually all of the GCMs have undergone substantial revision, particularly with regard to cloud parameterizations. Thus it was logical to repeat the cloud-feedback intercomparison so as to understand the suite of current GCMs.

Interestingly, the current GCMs all produce quite comparable cloud feedback, the magnitude of which is roughly zero. This result should not, however, be construed as proof that cloud feedback is negligible; it may simply mean that the current models are all making the same error, whereas the earlier versions were producing different errors.

In fact a related intercomparison has demonstrated a large divergence in model results. This pertains to an intercomparison of the seasonal variation in cloud-radiative forcing (CRF). What is important here is the availability of Earth Radiation Budget Experiment (ERBE) data against which the models have been compared. Thus unlike the above-discussed cloud-feedback intercomparison, here observational "truth" is available.

Only a few of the GCMs reasonably replicate the ERBE CRF data. Moreover, a diagnosis of the reasons for the differences shows that a first-order problem with the models concerns the seasonal cycle in cloud amount, in contrast to deficiencies in cloud optical properties.
A major effort has been devoted to collocating satellite and surface measurements of shortwave radiation so as to better understand SW absorption by clouds. There has been a long history of unexplained anomalous SW absorption by clouds, and this has been quantified by the collocated satellite and surface measurements, which show significant SW absorption by clouds, resulting in about 25 W m$^{-2}$ more global-mean absorption by the cloudy atmosphere than theoretical models predict. Although its physical cause is unknown, enhanced cloud absorption substantially alters our understanding of the atmosphere's energy budget. This quantification of enhanced cloud SW absorption has resulted in an observational program, to be conducted as part of ARM, to determine the physical cause of the absorption.

**TASK 2: COMPARISONS OF GCM SIMULATIONS OF CLIMATE VARIABILITY WITH DATA**

**Summary of Work Completed in the Current Funding Period**

This year's progress is reported in the following papers:


General Circulation Models that are used to simulate the response of climate to external forcings, such as the increase in atmospheric burden of carbon dioxide, have improved considerably in the sophistication of their parameterizations of atmospheric processes and also in the numerical algorithms used in their implementation. The utility of GCM prognostications of climate change depends to a large extent in the reliability of their forecasts of the regional climate. An important step in the validation of GCM performance on the regional scale is to understand simulation of processes that contribute to variation of regional rainfall in the present climate. In paper 1, we have investigated the ability of the ECMWF (cycle 33) model to simulate summer monsoon over India and China at resolutions T21, T42, T63 and T106. We took the approach that a model be able to simulate the observed sequence of processes that characterize the Asian monsoon. On time scales of a month or longer T42 and higher resolutions were found to give simulations largely consistent with observation and T21 was seen to be significantly inadequate. However, when comparison with the evolution of synoptic events was made only the high resolution of T106 was seen to describe it realistically. This is noteworthy because previous studies have suggested that the T42 resolution is adequate for climate studies (Tibaldi et al., 1990; Boyle, 1993; Gleckler and Taylor, 1993). The results presented in paper 1 indicate that the monthly averaged monsoon of T42 arises from synoptic scale variations that are different in character from observations and T106.

It is generally known that atmospheric motion is chaotic and small errors in the specification of the initial state can amplify rapidly, thus limiting the predictability of weather to about two weeks. Since climate is the statistical average of weather, the question arises if the limits on predictability of weather imply corresponding limits on predictability of climate.

Paper 2 presents evidence that on time scales of months to decades climate variations are characteristic of a weakly nonlinear system and not that of a chaotic system. This result emerges from application of the Fourier transform to over 6000 monthly air
pressure series simulated by two different versions of the OSU coupled ocean-atmosphere GCM. The variations of monthly averaged sea level pressure over twenty years are characterized by (i) the annual cycle and its harmonics at 6, 4, 3, 2.4 and 2 months, (ii) subharmonic frequencies with periods $T_1 = 40$ months the Quasi-triennial oscillation (QTO), $T_2 \approx 26$ months the Quasi-biennial oscillation (QBO), and $T_3 \approx 14$ months the Atmospheric Pole Tide (APT). $T_1$, $T_2$, $T_3$ have previously been reported in meteorological literature in analyses of observed series. (iii) The Fourier spectra of SLP also yield evidence for a further 33 significant frequencies which are the summation and difference tones caused by the interaction of frequencies in (i) and (ii) above. The frequencies of these combination tones are given by the formula

$$f_{i\pm j} = 1/T \pm (j+1)/12$$

cycles per months, where $j = 0, \ldots, 5$ represent the frequencies of the annual cycle and its harmonics, and $i = 1, 2, 3$ are the subharmonics discussed in (ii) above. The only requirement physically for these interactions is that the climate system be weakly nonlinear.

The conclusion that limits on the predictability of weather do not imply similar limits on climate prediction is also reached in papers 3 and 4 in which the three variable Lorenz (1980) model of atmospheric circulation issued to demonstrate that the rapid divergence of weather states does not necessarily imply similar rates of divergence of their statistical averages. In a chaotic regime of the model where errors grow rapidly, climate signals are shown to be retained regardless of the specific realization of weather states. The calculations in papers 3 and 4 also point out that some climate variables are more regular than others, suggesting the possibility and importance of identifying climate variables which have greater predictability.
TASK 3: ANALYSIS OF CLIMATE VARIATIONS IN CHINA

Summary of Work Completed in the Current Funding Period

Friis-Christensen and Lassen (1991) have shown a close relationship between the long term variations of the solar cycle length and air temperature over land areas of the Northern Hemisphere, thus suggesting a direct influence of solar activity on climate and pointing out that cycle length, rather than sunspot number, is an indicator of long term changes in solar activity. In view of the importance of the debate over the comparative influence of changes in solar activity and the greenhouse forcing in anticipating the climate of next several decades, it is necessary to check the hypothesis of Friis-Christensen and Lassen (1991) by comparing the long term variation of solar cycle length with other indices of long term climate change. Such a comparison is presented with variations in phenological dates (as proxy for spring air temperatures) in the middle and lower Yangtse River valley in the following paper:


The relatively large number of historical records originating from this region in the late Ming dynasty and the Qing dynasty allowed an estimation of decadal averaged phenological dates from the end of the 16th century to 1920, with some gaps in the 18th and 19th centuries. Reconstruction of proxy spring temperatures using other data are presented during the 18th, 19th and 20th centuries. The overall curve of proxy spring temperatures agrees in its broad outline with that of the solar cycle length. In future work we expect to examine additional indices of long term climate change in China.

REFERENCES


