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RECENT DEVELOPMENTS OF THE UCLA COUPLED ATMOSPHERE-OCEAN GCM

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1. Introduction

A fundamental component of an Earth System Model under development at UCLA for studies on global change is a coupled general circulation model (GCM) of the atmosphere-ocean system. This paper reviews the most recent developments of the coupled GCM. We emphasize the revisions of the parameterization of cloud processes.

2. Model Description

The UCLA coupled GCM consists of the UCLA global atmospheric GCM (AGCM) coupled to the tropical Pacific version of the GFDL Modular Ocean Model (Bryan, 1969; Cox, 1984). Kim (1996) has a detailed description of the most recent version of the AGCM.

3. Revised Formulation of PBL Processes

Our sensitivity studies have demonstrated that some of the systematic errors produced by the coupled GCM are linked to the parameterizations of cloud processes in the AGCM. This finding motivated work on the formulations of PBL and stratocumulus processes in the AGCM of the model (Li and Arakawa 1997).

Previous versions did not produce realistic simulations of the subtropical marine stratocumulus and overpredicted the mean cloudiness in the layer above the PBL. These deficiencies were alleviated by the following three model revisions: (i) redetermining the properties of the air being entrained into the PBL, (ii) reformulating the process associated with layer cloud instability, and (iii) introducing a "drizzle" effect. Revision (i) affects the specific humidity in the PBL, which has an impact on both the formation of stratus clouds and the strength of the evaporation. Revision (ii) and (iii) affect stratus cloud formation and dissipation.

Uncoupled AGCM simulations with this revised PBL formulation have shown a reduction of the overpredicted cloudiness above the PBL, and a better agreement with observations in the geographic distribution and frequency of stratus clouds (Fig. 1). A one-year long coupled GCM integration with this revised PBL formulation shows dramatic improvements in the simulated SST in the tropical Pacific (Fig. 2).

4. Revised Shortwave Radiation Scheme and Ozone Determination

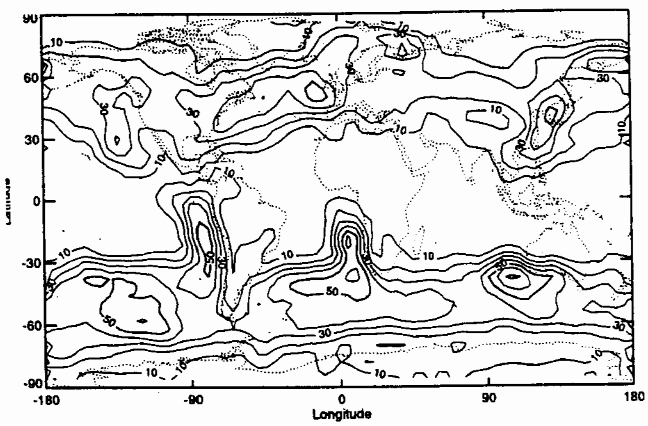

FIG.1 January stratus cloudiness simulated with the UCLA AGCM using the revised PBL formulation.

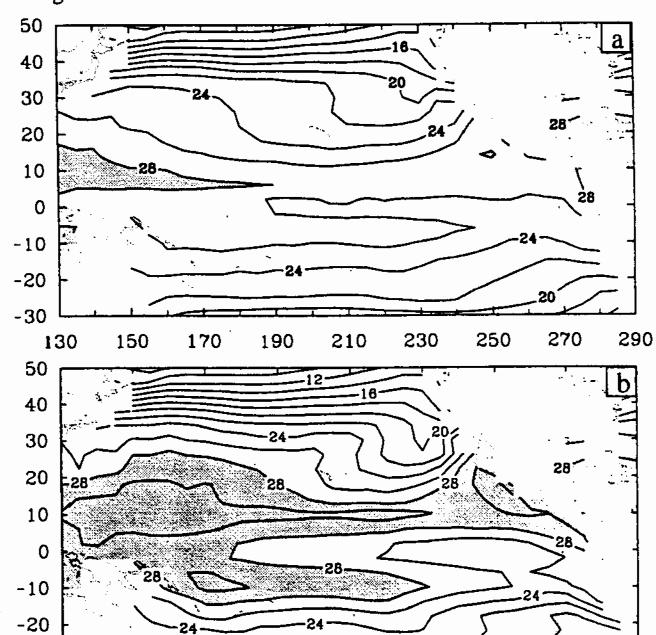

FIG.2. October SST produced by the coupled GCM in the: (a) control simulation and (c) the simulation with the new version of the UCLA coupled GCM.

In the previous versions of the UCLA AGCM, the ozone concentration was predicted and tended to be substantially underestimated in the upper troposphere/lower stratosphere. The shortwave absorptivity of ozone was also determined to be too large. To improve these problems, two revisions were adopted: (i) switching the determination of shortwave absorptivity of ozone from the formulation of Katayama (1972) to that of Lacis and Hansen (1974); and (ii) prescribing ozone from a zonally averaged climatology.

In addition, we adopted the parameterization of Manabe and Moller (1961) for calculation of the shortwave absorption by water vapor, and added momentum to the list of variables that are vertically mixed in dry convectively unstable layers (Farrara et al. 1997).

5. Prognostic Determination of Cloud Water

Another effort aimed to improve cloud representation in the UCLA AGCM is the development of the prognostic cloud water parameterization scheme (Köhler et al. 1997). The current emphasis of this effort is a better understanding of ice cloud generation, maintenance and decay. Results from sensitivity experiments have shown that the cloud ice autoconversion time-scale is important for the simulated cloud ice mass, and that the model displays little sensitivity to the cloud ice sublimation process. These results have motivated further study on the processes involved in snow production in particular and ice

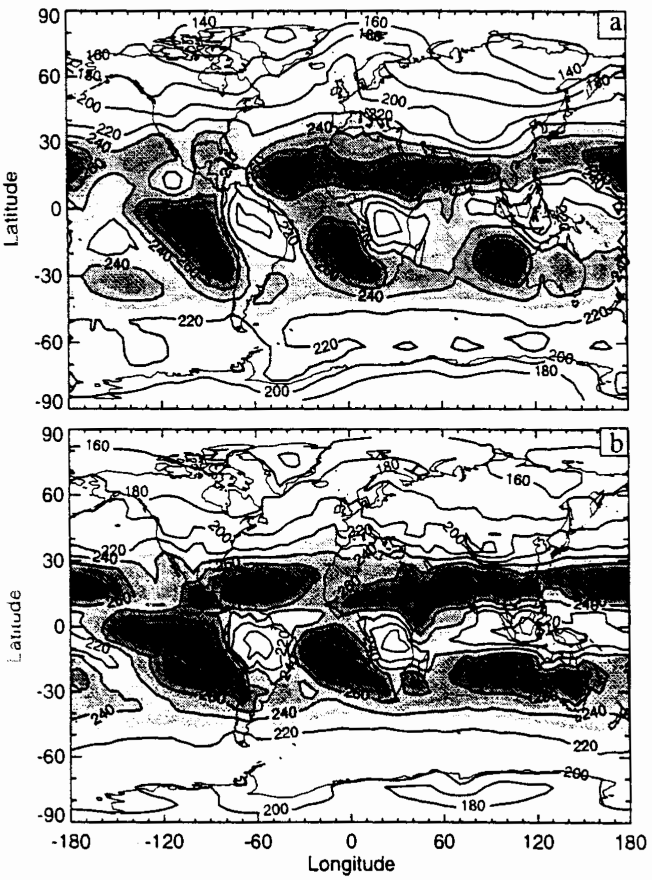

FIG.3 Outgoing longwave radiation (a) observed from ERBE and (b) simulated with the UCLA AGCM using the new prognostic cloud water parameterization

cloud decay in general. After these development, this new parameterization will be implemented in the UCLA coupled GCM, and we expect a further improvement of the simulated cloud radiation budget (Fig. 3).

6. Conclusions

We reviewed in this paper some of our recent model development of the UCLA coupled GCM. The revisions of PBL formulation have resulted in a realistic simulation of the distribution and extent of subtropical stratus. Revisions were also made in the specification of ozone mixing ratio used in the radiation calculation, as well as in the methods to obtain the shortwave absorptivity of ozone and water vapor. The combination of the revised formulations of PBL and shortwave processes, the determination of ozone and its radiative effects, and vertical mixing of momentum in dry convectively unstable layers has produced a new version of the UCLA AGCM. Simulations with this model are improved in several aspects compared to those performed with earlier versions.

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