B-5.5.1 Quantitative evaluation of the variation characteristics of the climate system using a climate model

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Abstract An atmospheric general circulation model for climate studies (CCSR/NIES AGCM) was used for quantitative evaluation of climate system variability. An initial ten year integration based on observed SST, and performed as part of the AMIP (atmospheric model intercomparison project) is presented here briefly. Analysis of a number of variables shows that the model provides a reasonable reproduction of observed climatology. The simulation of hydrological cycles and cloud-radiation interactions, while not unreasonable, leaves several problems in need of further improvement. Considering interannual variability, temporal correlations between simulated and observed anomalies are reasonably good in the tropics but not statistically significant in the mid-latitudes. In a second integration, the AGCM coupled to an ocean mixed layer model was used to examine climate change under conditions of doubled atmospheric CO_2 concentration.

Key Words climate model, atmospheric general circulation model, climate change, inter-annual variation, global warming

1. Introduction

An atmospheric general circulation model for climate studies (CCSR/NIES AGCM) was used for quantitative evaluation of climate system variability. An initial ten year integration based on observed SST, and performed as part of the AMIP (atmospheric model intercomparison project) is presented here briefly. Analysis of a number of variables shows that the model provides a reasonable reproduction of observed climatology. The simulation of hydrological cycles and cloud-radiation interactions, while not unreasonable, leaves several problems in need of further improvement. Considering interannual variability, temporal correlations between simulated and observed anomalies are reasonably good in the tropics but not statistically significant in the mid-latitudes. In a second integration, the AGCM coupled to an ocean mixed layer model was used to examine climate change under conditions of doubled atmospheric CO_2 concentration.

2. Overview of the model

The model is based on the primitive equation in global domain and uses spectral transformation method in horizontal and grid differentiation on sigma coordinate in vertical. The semi-implicit leap-frog time integration scheme is used. The physical parameterization includes a sophisticated radiation scheme, simplified Arakawa-Schubert cumulus scheme, prognostic cloud water scheme, Yamada-Mellor level 2 turbulence closure scheme with cloud effect, orographic gravity wave drag, and a simple land-surface submodel. Detals can be found in Numaguti *et al.* (1997).

Radiative transfer scheme is based on the two-stream discrete ordinate method and the k-distribution method (Nakajima and Tanaka, 1986). The radiative fluxes at each level interface is calculated considering solarincidence, absorption, emission and scattering by gases, clouds and aerosols. The calculation of the flux is done in 18 separate bands. Band absorption by H_2O, CO_2, O_3, N_2O, CH_4 are considered by k-distribution method with one to six sub-channels in each band. As for cloud, randomly overlapped partial cloudiness is included.

The cumulus parameterization scheme is based on Arakawa and Schubert (1974) with a few simplifications. One simplification is based on Moorthi andSuarez(1992) and that the vertical mass flux is assumed as a linear function of height. Other simplifications are that the precipitation efficiency is specified as a function of height, and that the bottom mass flux is determined by a relaxation of cloud work function to zero in a specified time scale.

The prognostic cloud water scheme with large-scale condensation is developed based on the scheme of Le Treut and Li (1991). The actual prognostic variable is the total water mixing ratio and it is diagnostically divided to water vapor and liquid water assuming a subgrid distribution of total water mixing ratio.

3. Interannual variability during the AMIP period

To examine the the simualted natural variablity by AGCM, the numerical experiment according the AMIP preriod was conducted by specifying the observed SST data as the boundary condition. AMIP period was from 1979 to 1988, and two complete ElNino cycles were included within this periods,

CCSR/NIES AGCM 5.4 with T21 L20 resolution was used in this study. Then the interannual variabilities simulated by the model are compared with observed circulation patterns. Overall magnitude of interannual variance in the troposphere is comparable, but somewhat smaller than, the observations. Temporal correlations between simulated and observed monthly-mean anomaliesare significant (0.64 for 850hPa zonal wind) in eastern equatorial Pacific(Figure 1), but the correlation drops to insignificant values outside the tropical Pacific.

Figure 2 compares correlations between simulated and observed OLR fields with observed NINO3 SST index. The response of eastern Pacific is reasonable but the signal in Indonesian region is weak and is shifted eastward. There is a moderate signal in Indian region in the model whereas the signal is very weak in the observation. It appears important to simulate accurately the spatial distributions of convective anomaly not only in the immediate neighborhood of the largest SST anomalies but also in some key regions such as the western Pacific and Indian monsoon regions.

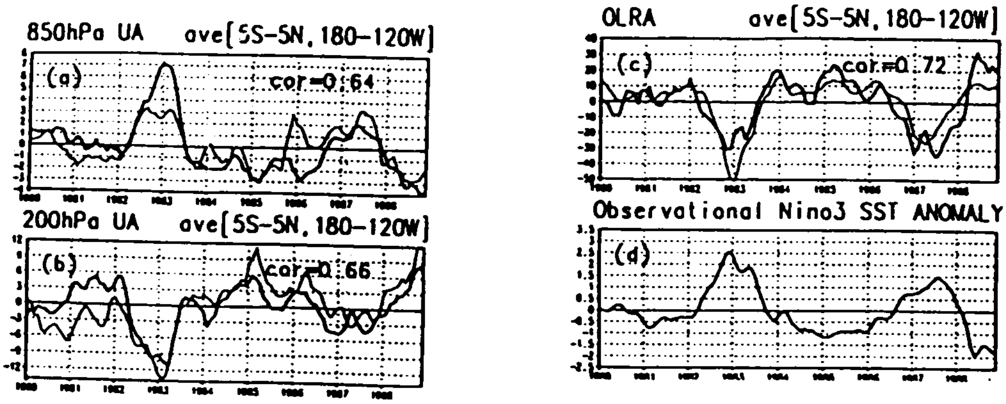

Figure1 Time-series of anomalies averaged over 5S-5N, 180W-120W for (a) 850hPa zonal wind , (b) 200hPa zonal wind , (c) OLR , (d) observational Nino-3 SST anomalies. 3-month running means are applied and thick lines for observations, thin lines for simulated results , "cor" indicates the simultaneous correlation coefficients between observations and simulations

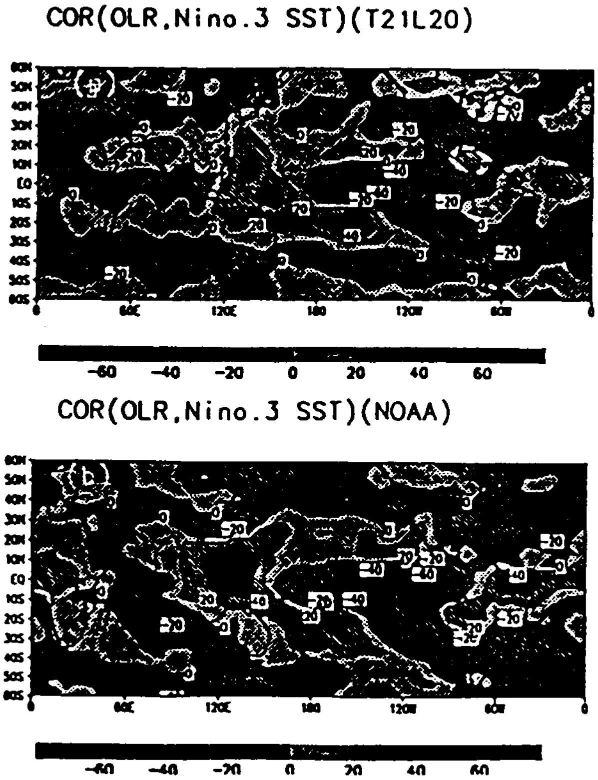

Figure2 Mean correlation of the NINO3 SST with OLR (a) model result, (b) observation.

4. Response of CCSR/NIES AGCM with mixed layer ocean model

CCSR/NIES AGCM 5.4 with T21L20 resolution was used with the mixed layer ocean model to simulate the climate value when CO_2 concentration becomes twice. The mixed layer ocean is a heat balance model with the thickness of 50 cm. Sea ice is predicted by a thermodynamic model that describes freeze and melt process, but haven't included compactness and dynamic processes. A heat flux transported by ocean currents is prescribed, and assigned to the mixed layer ocean in order to obtain a realistic distribution of sea surface temperature. Equilibruim expements with a stnadard and doubled CO_2 concentration are performed, assuming that the heat flux of ocean currents would not change in doubling of CO_2.

Figure 3 showed the annual averaged surface temperature distribution by the equilibruim expements with a doubled CO_2 concentration. Figure 4 showed the annual averaged zonal mean temperature distribution by the equilibruim expements with a doubled CO_2 concentration.

As reported in previous studies on CO_2 doubling experiments, large temperture increase in higher latitutes of a winter hemisphere is well simulatedin the model. Convecxtive rainfall largely increased in the tropics. Land surface condition should have not a little effect on climate changes.

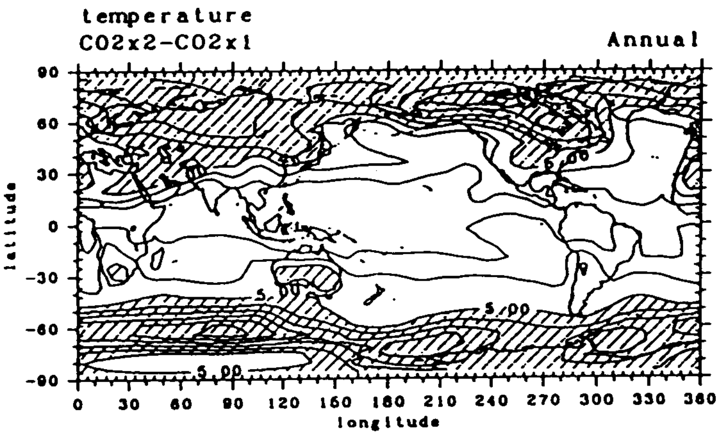

Figure 3 Annual averaged surface temperature distribution by the equilibruim expements with a doubled CO_2 concentration.

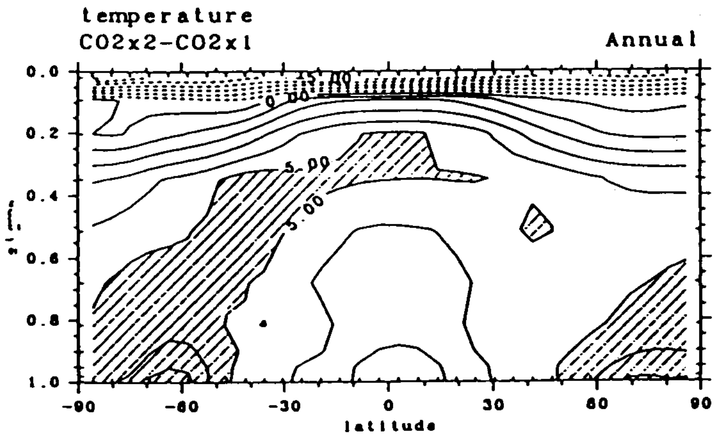

Figure 4 Annual averaged zonal mean temperature distribution by the equilibruim expements with a doubled CO_2 concentration.

5. Summary

An atmospheric general circulation model for climate studies (CCSR/NIES AGCM) was used for quantitative evaluation of climate system variability. An initial ten year integration based on observed SST, and performed as part of the AMIP (atmospheric model intercomparison project) is presented here briefly. Analysis of a number of variables shows that the model provides a reasonable reproduction of observed climatology. The simulation of hydrological cycles and cloud-radiation interactions, while not unreasonable, leaves several problems in need of further improvement. Considering interannual variability, temporal correlations between simulated and observed anomalies are reasonably good in the tropics but not statistically significant in the mid-latitudes. In a second integration, the AGCM coupled to an ocean mixed layer model was used to examine climate change under conditions of doubled atmospheric CO_2 concentration.

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