Development of a Coupled Atmosphere-Ocean-Land General Circulation Model (GCM) at the Frontier Research Center for Global Change

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This study aims at improving various physical parameterizations of a CCSR/NIES/FRCGC coupled model for reliable climate simulations. This year, we have started developing an atmospheric boundary layer turbulent model for the reduction of dry biases over subtropical regions. For more realistic representation of quasi-biennial oscillation in the equatorial lower stratosphere, the role of gravity wave in an atmospheric model was investigated. The behavior of the North Pacific Subtropical Anticyclone in the model was focused to understand the model performance for climate studies and to find the model deficiencies, because it is one of the important factors of climate changes in the Eastern Asia. Moreover, outputs from high-resolution models were examined for future improvement of the convection scheme adopted in the atmospheric model. For climate models by which local climate changes are predicted on long-term scale, the diurnal changes have to be reproduced by the climate model.

Keywords: global warming, coupled model, atmospheric model, atmospheric boundary layer, subtropical anticyclone

1. Introduction

Physical parameterization schemes of a CCSR/NIES/FRCGC atmospheric model (MIROC) are examined for more accurate climate simulations with the medium-resolution model. We analyze the model outputs by comparing those by other models whose resolution is higher than the MIROC. All of these models were integrated by using the Earth Simulator computer. In the previous year, we have replaced a radiation scheme by that developed by Nakajima and Sekiguchi (2004) and investigated the reproducibility of the coupled model in terms of climatological mean fields by comparing with observations. In this year, we have started introducing a new scheme of atmospheric boundary layer to the MIROC model.

2. Development of an atmospheric boundary layer turbulent model

As pointed out in the previous report, there are severe dry biases at the surface of 850 hPa in the eastern part of the Pacific Subtropical Anti Cyclones. Since the cloud amount lessens in accordance with this (Fig. 1), the warm biases of SST appear in the areas of upwelling along the western coast of the American Continents as a result of absorption of insolation into the oceans near sea surface. To eliminate the dry biases in the lower layers of the model, we have started improving the turbulence model for atmospheric boundary layer. According to observations, heights of low-level stratus gradually increase as leaving the coast of the Continents. The model fails in reproducing such features. Therefore, the treatment of shallow cumulus in the model was examined together.

A single column model (SCM) has been developed in this year. To examine impacts of a revised Mellor-Yamada closure scheme (Nakanishi and Niino, 2004) over these regions, we have made a program code of the scheme. The treatment of shallow convection in the model affects the heights of low-level status, according to a study with the regional climate model at IPRC. It is necessary to focus on the treatment of shallow convection in this study. Since the IPRC model well reproduces low-level clouds off Peru, we will perform comparison studies of physical processes between CCSR/NIES/FRCGC AGCM and the IPRC regional climate model.

3. Reproducibility of QBO

The results from an AGCM without gravity wave (GW) drag parameterization show quasi-biennial oscillation (QBO)-like oscillations in the equatorial lower stratosphere. The westerly acceleration of the QBO is associated with the zonal forcing due to resolved waves of all components, and GWs account for about 60% of the forcing. The vertical flux of the zonal momentum of GWs in the upper troposphere

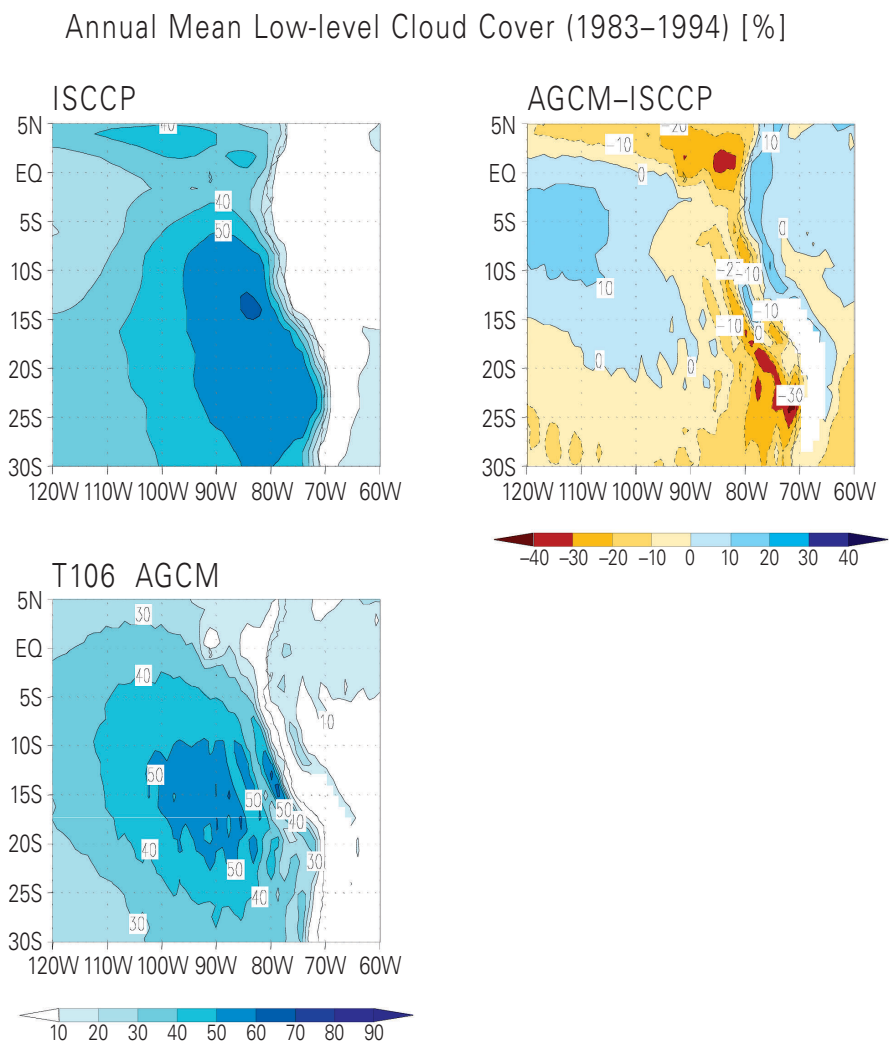

Fig. 1 The distribution of cloud water (%) off the coast of the South America. The left panels show ISCCP satellite observation (upper) and model-generated cloud, and the difference (model minus observation) in the right panel.

has a non-uniform distribution. Large (relatively small) magnitude upward fluxes with westerly (easterly) momentum dominate in the Eastern (Western) Hemisphere. The model results reveal that westerly acceleration of the zonal wind due to GWs in the Eastern Hemisphere is much greater than that in the Western Hemisphere. The modeled wind is stronger than the observed wind. A more accurate simulation of the zonal wind in the equatorial troposphere is necessary for a more quantitative evaluation of GW activity (Kawatani et al. 2005).

4. Behavior of North Pacific Subtropical Anticyclone

The Behavior of the North Pacific Subtropical Anticyclone (NPSH) simulated in CCSR/NIES/FRCGC AGCM is investigated and compared with ECMWF reanalysis data (ERA-40), which is closely related to the accurate simulation of the eastern Asian monsoon. Interannual variation in June (Fig. 1) and July elongates along the northwestern rim of the NPSH, which is quite similar to that in ERA-40. In August, the isolated-variation is simulated in the northwestern rim of the NPSH, but its position in the real atmosphere exists in the southwestern rim of the NPSH. This discrepancy is closely related with climatological pattern of the NPSH. Baiu-like precipitation zone is reasonably simulated in June. However, precipitation zone penetrates inside of the western rim of the NPSH. Improved suppression mechanism of the cumulus parameterization is required. Intra-monthly variations of the NPSH are well simulated in June-July, but not well in August. This might be related with inadequate simulation of typhoons, weaker monsoon trough and stronger geopotential height in the western rim of the NPSH. The simulation of the NPSH variability both interannual and intra-monthly time-scales is most difficult in August in the present AGCM.

5. Diurnal cycle of convective activity over the Maritime Continent

We focused on the convective activities occurring over the Maritime Continent for the improvement of the model reproducibility of atmospheric disturbances. A diurnal cycle is

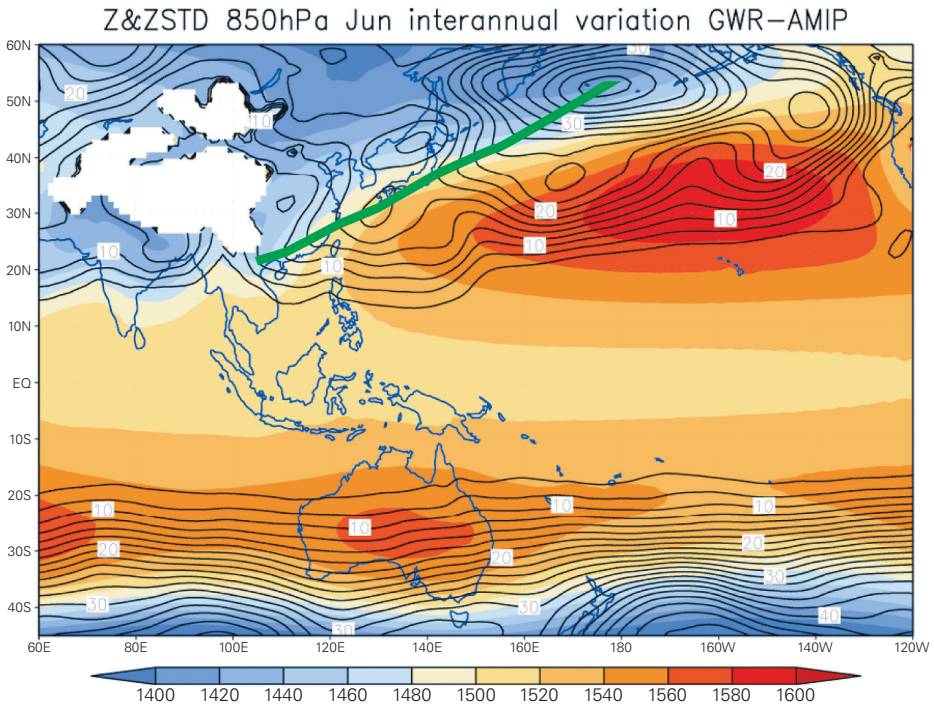

Fig. 2 Climatological geopotential height at 850 hPa (color) and standard deviation (contour). Green line shows a ridge of interannual variability of the NPSH.

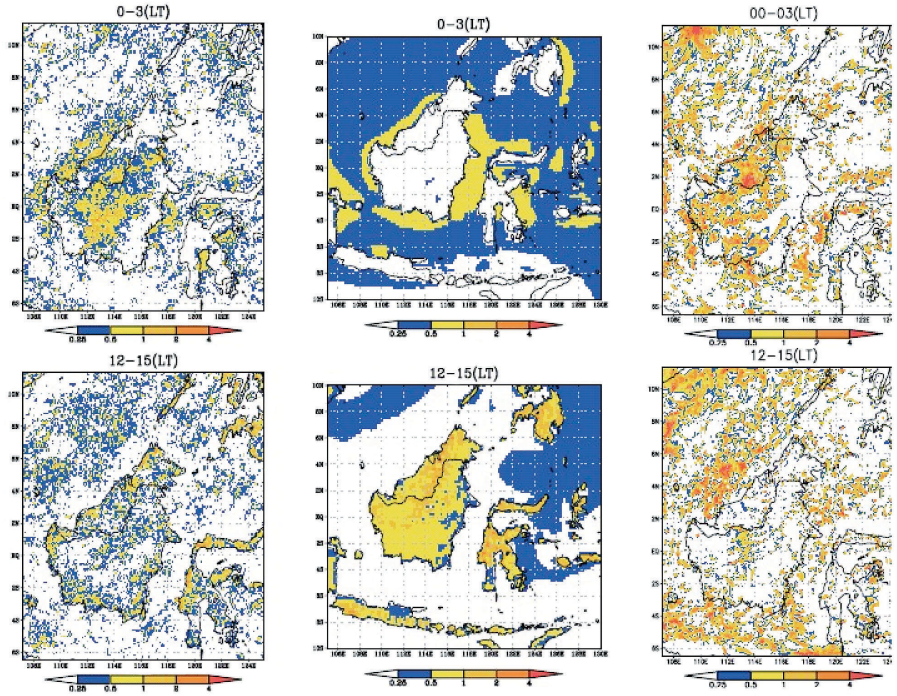

Fig. 3 Long-term averaged precipitation (mm/hr) for 00-03 LT (upper) and 12-15 LT (lower): Six-year averages of TRMM 2A25 near-surface rain (left), 10-year averages of 20km-resolution MRI-GCM (middle), and 1-month averages of MM5 precipitation (right).

clearly seen in 6-year mean fields of the TRMM satellite observation over Borneo; strong precipitation appears along the western coast and the central part of Borneo in 00-03 LT (the upper left panel of Fig. 3), minimum precipitation in 08-11LT, the precipitation increases in 12-15LT over the coastal part of the island (lower left), and the convection system moves to the central area by 20-03 LT. A 20-km-mesh global spectral model conducted in the Earth Simulator (MRI-AGCM; Mizuta et al., 2006) reproduced realistic precipitation thanks to fine-scale topography to some extent, but it failed to reproduce precipitation over the ocean originated from multi-cell clusters (middle panels). A non-hydrostatic model (MM5) experiment with horizontal grid scale of 5 km (Hara 2005) shows some improvements over Sulawesi and Java Islands and over the seas near the islands (right panels) but the phase of the diurnal cycle was delayed by a few hours.

6. Summary

We will continue this study for reduction of errors and biases in the climate-model simulation. High-resolution and non-hydrostatic models provide hints for realistic simulation of climate change by the medium-resolution MIROC model.

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地球環境フロンティア研究センターにおける大気・海洋・陸面結合大循環モデルの開発

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共生課題1で開発したモデル(CCSR/NIES/FRCGCモデル)の放射、積雲対流、雲、大気境界層の物理過程に着目してモデル出力の解析を進め、現有の結合モデルの問題点を整理し、気候モデルのバイアスと誤差の低減のための調査を継続している。今年度は、亜熱帯域下層における乾燥バイアスを除去するために、新しい大気境界層モデル開発とその導入の作業に着手した。また、赤道の下部成層圏における準二年振動の再現性を高めるために、大気モデルでの重力波の役割について調査をした。さらに、余り研究が進められていない北太平洋の亜熱帯高気圧のモデル内での振舞いに着目して、観測データと対比しながら、東アジア地域の気候研究のためのモデルとしての性能を評価する調査を行なった。今後、局所的な気候変化の長期的予測についての研究を進めていくにあたり、気候モデルが現実的な日変化を再現できるようにする必要がある。今年度は、高解像モデルと非静力モデルの出力の海洋大陸における降水の日変化を調べて、その再現のためのモデルの要件についても調査した。

キーワード：地球温暖化, 結合モデル, 大気モデル, 大気境界層, 太平洋高気圧