JST Basic Research Programs

C R E S T

(Core Research for Evolutional Science and Technology)

Annual Report for Research Work in the fiscal year 2006

Research Area :

High Performance Computing for Multi-scale and Multi-physics Phenomena

Research Theme

Global Cloud Resolving Model Simulations toward Numerical Weather Forecasting in the Tropics

Name of Research Director, Belonging and Title:

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§1. Outline of Research Work

The “global cloud resolving simulation” in which cumulus convection in the atmosphere is directly resolved with a few km horizontal mesh over the global domain is succeeded by our group for the first time using the Earth Simulator. A newly developed Global Cloud Resolving Model (GCRM), called NICAM, overcomes the difficulties in existing atmospheric global models where cumulus convection is not resolved and is represented in parameterized forms. This research project promotes development of NICAM by aiming that NICAM is practically used as a next generation weather forecasting and climate prediction model by collaborating with wide range of research groups of observational, modeling, and data analysis studies. Toward this goal, we concentrate on improvements of representation of convective-precipitation systems in the tropics and the Asian monsoon region, which directly affects meteorology around Japan.

In this fiscal year, we ran the first 3.5km-mesh global cloud resolving simulation with realistic land/sea distribution and initial condition. This experiment was carried out for one-week and shows realistic large-scale organization of cloud-clusters and development of tropical cyclones. In addition, a long term experiment was also performed to obtain climatology of global cloud resolving simulations. The experimental result shows a fine scale structure of precipitation field which is similar to that obtained by satellite observations. In the next stage, we will improve physical processes to get more reliable simulations and focus on intra-seasonal variability in the tropics (Madden-Julian Oscillation; MJO) and cyclogenesis of tropical cyclones.

§2. Content of Research Work

The aim of this project is to promote development of the Global Cloud Resolving Model, NICAM, by improving representations of cloud-precipitation systems in the tropics. Through this project, realistic global cloud resolving experiments with land/sea distribution and topography are conducted. The experimental results will be compared with satellite and field observational data and outputs of other existing atmospheric models.

In this year, following three types of experiments are being conducted:

1. Exp. Apr. 2004: A short-term experiment is conducted by giving realistic initial and surface boundary conditions. The highest-resolution experiment with 3.5km-mesh on the global domain is performed. The integration time is one-week. This is the first 3.5km-mesh global cloud resolving model under the realistic condition.
2. Exp. Perpetual July: To study statistical and climate properties of NICAM, a numerical

simulation is conducted under the perpetual July condition giving an initial condition obtained by an spin-up run with a low-resolution atmospheric global model. To obtain a statistical result, we integrated 14km-mesh model for 200 days, and examined sensitivities to various processes.

3. Exp. MJO: We aim to simulate Madden-Julian Oscillation (MJO) by NICAM. An intensive MJO was observed in the end of December, 2006. Giving an initial data of middle of Dec. 2006, we perform about one-month simulations. Although this is an undergoing experiment, an interesting result is now being obtained, where eastward propagation of organized cloud system is captured.

Experiments 1 and 2 are continued from last year, and experiment 3 is newly started. Two of our main targets are MJO simulations and cyclogenesis of tropical cyclones, since simulations of these events are week points of existing atmospheric general circulation models.

Figure 1 shows cloud images of the 3.5km-mesh global cloud resolving simulation by NICAM of Exp. 1 and the corresponding geostationary satellite image. The numerical simulation starts from Apr. 1st, 00UTC, 2004, and Fig. 1 is for the Apr. 6th, 00UTC. The results show that organized cloud clusters and development of tropical cyclones are realistically simulated, and their structure is very similar to the satellite image. Fig. 2 shows resolution dependency of the same experimental series. The mesh size is 3.5km, 7km, and 14km and physical processes are the same irrespective of the mesh size where explicit cloud physics are used. From this, large-scale organized cloud clusters are similarly seen in three figures. It is a surprising result since it has been thought that the 14km-mesh resolution is not sufficient for cloud-resolving simulation. This implies that we can save computational cost by using the 14km-mesh model for numerical simulations of cloud clusters in the tropics.

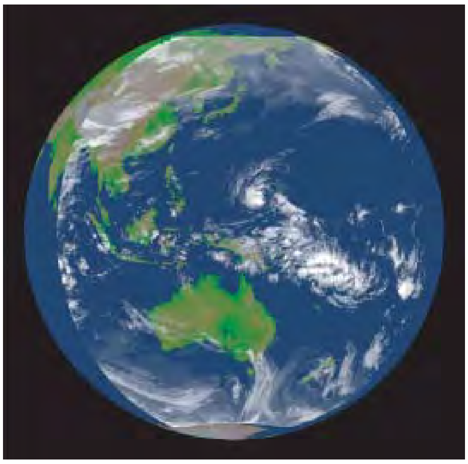

Fig. 1. Global views of cloud image obtained by the 3.5km-mesh global cloud resolving simulation using NICAM (left) and of GMS/GOES-9 at Apr. 6, 2004, 00UTC. Numerical simulation starts from 00UTC, Apr. 1.

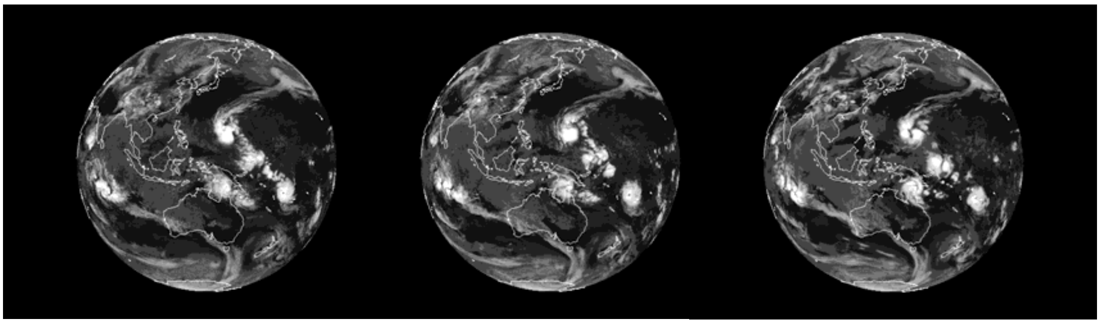

Fig. 2. Resolution dependency of global cloud resolving simulations. Left: 3.5km-mesh, middle: 7km-mesh, and right: 14km-mesh. The same experiment as in Fig. 1. Global view of OLR at Apr. 6th, 00UTC, 2004.

The second experiment is for perpetual July condition to obtain climatology of cloud resolving simulations. It requires longer days of numerical integration. We found that about 200 days are required to obtain a statistically equilibrium state. Figure 3 shows one-month average of precipitation field and compares with the corresponding satellite data (TRMM and other source combined data). Although the simulation is not intended to be compared to a particular month of year, fine scale distribution of precipitation is simulated quite well, particularly in the Pacific. We may note that there is a difference in the region from the Philippines to the Indian Ocean where a clear region prevails in the simulation. This series of experiments started from last year, and many of improvements have been made; we examined boundary layer processes to reduce strong precipitation reported in last year. The strong precipitation is known as a “Red Spot” problem in the Multiscale-Modeling Framework (MMF). The results suggest superiority of our approach for climate simulation.

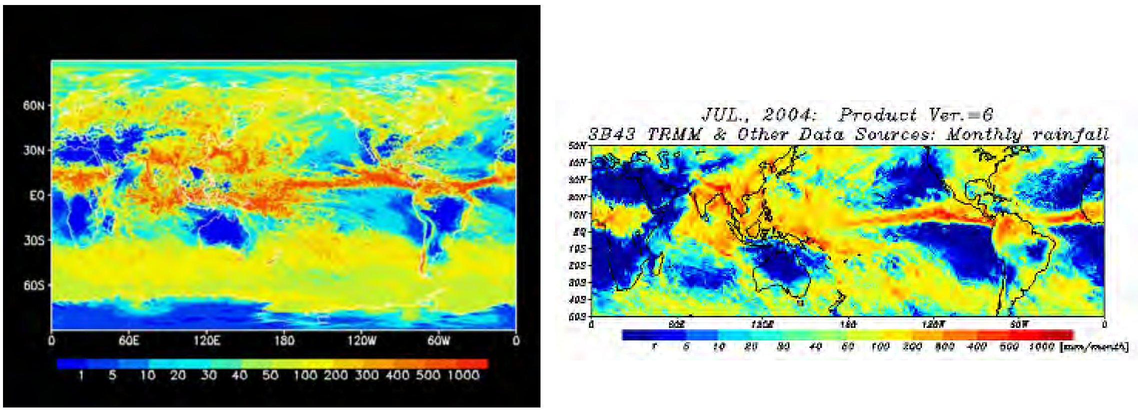

Fig. 3. Precipitation field of perpetual July condition experiment. Left: one-month average of the 14km-mesh model result; right: observed precipitation for July, 2004, obtained by TRMM and other data sources (3B43; JAXA).

The third experiment on MJO (Madden-Julian Oscillation) is one of challenging themes of this project. MJO is intra-seasonal variability seen in the tropics. It has been pointed out that almost all the existing atmospheric general circulation models have difficulty in simulating MJO. In this year, as a first experiment of MJO, we chose an intensive MJO event occurred very recently. Stating from an initial data of middle of December, 2006, we run experiments for one-month using the 14km-mesh resolution. The results show that an organized cloud-precipitation system propagate eastward at a phase speed similar to the observation (not shown here). Since intensive observation experiments are carried out in this period, we will compare the model results with observational data to validate the global cloud resolving results.

In this fiscal year, we first ran the 3.5km-mesh global cloud resolving experiment on the realistic condition. We can say that the development phase of GCRM is almost completed, and that we are now in a new phase of validation and improvement phase of GCMR. From now on, we need more satellite and field observation data to validate model results, and need improvements of physical processes such as cloud microphysics and boundary layers. For numerical weather prediction experiments of tropics, we will examine model properties of cloud-precipitation systems in the Tropics, particularly of MJO, tropical cyclones, and the Asian monsoon.

§3. Formation of Research Work

- Masaki Satoh, Japan Agency for Marine-Earth Science and Technology, Frontier Research Center for Global Change, Global Environmental Modeling Research Program, Sub-leader, Global cloud resolving modeling and data analysis
- Takao Yoshikane, Japan Agency for Marine-Earth Science and Technology, Frontier Research Center for Global Change, Hydrological Cycle Research Program, Researcher, Cloud resolving modeling and data analysis
- Yoko Tsushima, Japan Agency for Marine-Earth Science and Technology, Frontier Research Center for Global Change, Global Warming Research Program, Researcher, Global atmospheric modeling and data analysis
- Shuichi Mori, Japan Agency for Marine-Earth Science and Technology, Institute of Observational Research for Global Change, Hydrological Cycle Observational Research Program, Sub-leader, Cloud resolving modeling and data analysis

- Teruyuki Nakajima, The University of Tokyo, Center for Climate System Research, , Director , Professor, Global atmospheric modeling and data analysis
- Tetsuo Nakazawa, Head, Japan Meteorological Agency, Meteorological Reseach Institute, Typhoon Research Department, The Second Research Laboratory, Data analysis

§4. Publication of Research Results

(4－1) **Publication of Thesis (The original Work)**

① Number of Publications (0 times-Domestic, 0 times-International)

② Detailed Information of Thesis

(4－2) **Patent Application**

None.