Study of Cloud and Precipitation Processes Using a Global Cloud-system Resolving Model

Project Representative

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In order to well understand the cloud-precipitation system over the globe, we have been conducting the global cloud resolving simulations. In this fiscal year, we updated several physical schemes to represent more precise mechanism of cloud and precipitation processes and validated the new schemes. Changing the microphysical scheme from three categories to six categories, the climatology of cloud is improved. Using the new schemes, we tried to conduct the simulation of typhoon Fengsheng, which is known as its difficult prediction. In this case, we found that the track is sensitive not only to the initial conditions but also to the planetary boundary layer scheme.

Keywords: cloud and precipitation processes, global cloud-system resolving model

1. Introduction

For the future precise projection of cloud-precipitation processes over the globe, it is very important to investigate and understand its essential processes in the present climate. Our subject is to clarify the essential mechanism of cloud-precipitation system over the globe, time scale of which ranges from the diurnal to the seasonal cycles. For this study, we use the global cloud-system resolving model NICAM (Satoh et al. 2008[1]) and conducts long integrations of half year for medium resolution (~10 km) and short integration of 10 days for the highest resolution (3.5 km).

Another important aspect of our project is collaboration with ongoing international observation projects, e.g., YOTC (Year Of Tropical Convection), AMY (Asia Monsoon Year). Comparing with observational data obtained by such observations, we quantitatively estimate our numerical results and exchange information each other. Furthermore, based on these knowledges, we improve the physical schemes of NICAM.

In FY2009, we first performed several sensitivity studies of newly implemented physical schemes, focusing on the cloud properties. After that, we mainly conducted the simulations of Typhoon Fengshen (TY0806), investigating the dependency of physical schemes and initial conditions.

2. Update of physical schemes in NICAM

From this fiscal year, we replaced several physical schemes by newly developed ones. For the microphysics, three categories scheme (Grabowski 1998[2]) is replaced by six categories Lin-type scheme (Tomita 2008[3]). For the PBL scheme, we implemented the Mellor-Yamada-Nakanizhi-Niino (MYNN) level 2.5 (Mellor and Yamada 1974[4], Nakanishi and Nino 2004[5], Noda et al. 2010[6]). The land process model is also changed from the bucket model to MATSIRO model (Takata et al. 2003[7]).

Figure 1 shows the comparison of results between old and new physics runs for the cloud amount by ISCCP simulator. The bias of lower cloud amount that appears in the old physics is drastically improved in the new physics. The mid-level cloud amount in the new physics is also improved over the tropical region. On the other hand, the upper cloud amount of the new physics increases slightly comparing with the old physics and seems to be worse than the old physic. However, we found that this upper cloud amount is sensitive to microphysics parameters, for example, the threshold value in the process of change from ice to snow, and it can be tuned by the relatively easy way. Figure 2 shows the zonal mean of ice water contents. This figure indicates that the new physics improves the excessive cloud ice

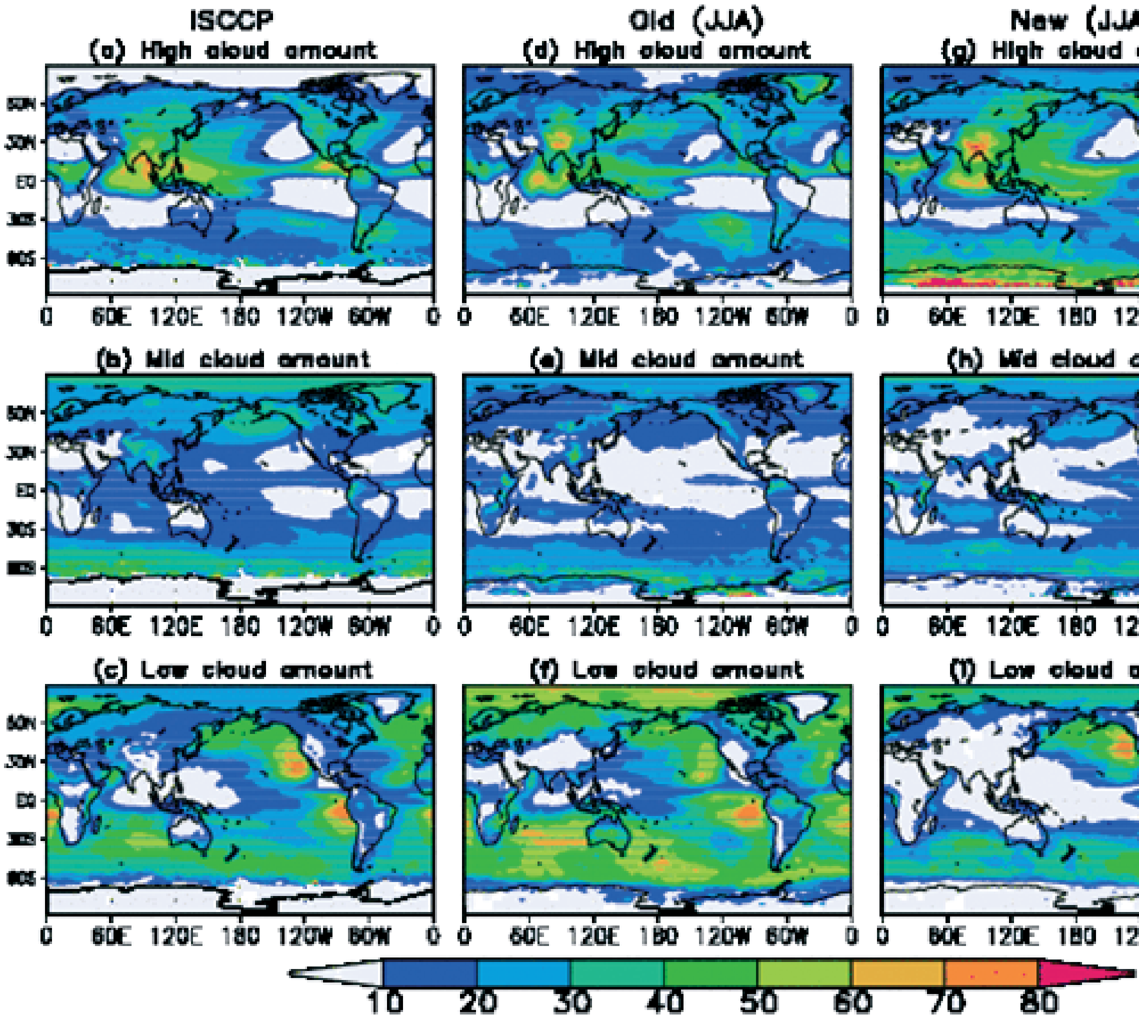

Fig. 1 The comparison of cloud amount between old and new physics runs and the observation (ISCCP).

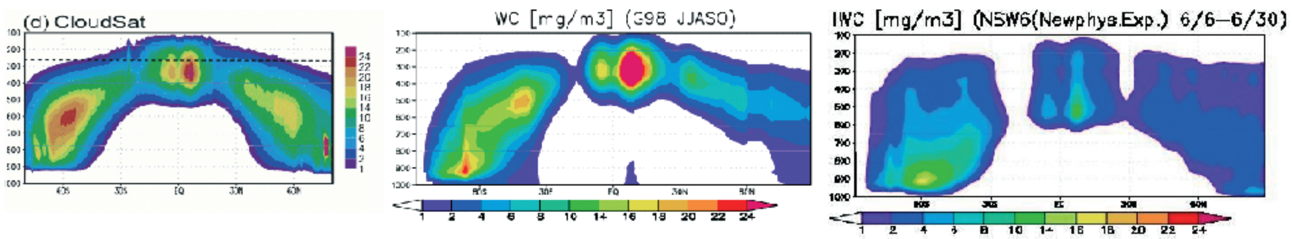

Fig. 2 The comparison of zonal mean ice water contents between old and new physics runs and the observation (CloudSat).

over the tropics that appears in the old physics.

3. Simulation of Typhoon Fengshen (TY0806)

In order to evaluate the performance of NICAM, series of simulations of field campaigns leaded by JAMSTEC (e.g., Mirai Indian Ocean cruise for the Study of the MJO-convection Onset [MISMO], Pacific Area Long-term Atmospheric observation for Understanding of climate change [PALAU] 2008) have been executed. In FY2009, we have conducted numerical simulations of typhoon Fengshen (TY0806), generation process of which had been observed during intensive observation period of PALAU2008 (Yamada et al. 2009[8]). The observation period was also included in an international project Year of Tropical Convection (YOTC). Research collaboration and contributions to international community is planned with the simulations of Fengshen.

Fengshen is known as one of the most difficult typhoons to forecast their tracks in 2008 (Fig. 3). Based on studies using NICAM with stretched grid system (Yanase et al., 2009[9], Fig. 3, red line), we have investigated sensitivity of typhoon tracks to turbulent processes in the model.

The simulations were performed with horizontal mesh size of 14 km and vertically 40 layers for 10-day period. Physical processes were renewed as described in section 2. As to the turbulent processes, MYNN level 2 / 2.5 schemes were used for sensitivity study. The level 2 scheme was used as default (hereafter referred to as 'standard mixing'). In this study vertical diffusion coefficient used for level 2.5 scheme leads to larger vertical mixing than level 2 scheme (hereafter referred to as 'strong mixing'). Atmospheric initial data was interpolated from ECMWF YOTC operational analysis (0.5 x 0.5 degree) on 15 June 2008.

Figure 4a shows observed and simulated tracks of Fengshen. The forecast error was reduced in a simulation with strong mixing (red line). However, sensitivity to initial date was also significant (blue line). Figures 4b show central pressure of simulated Fengshen. It was found that typhoon intensity simulated with strong mixing were weaker than those with standard mixing. These suggest the importance of appropriate initialization and vertical mixing process to accurate simulation of typhoon intensity and tracks.

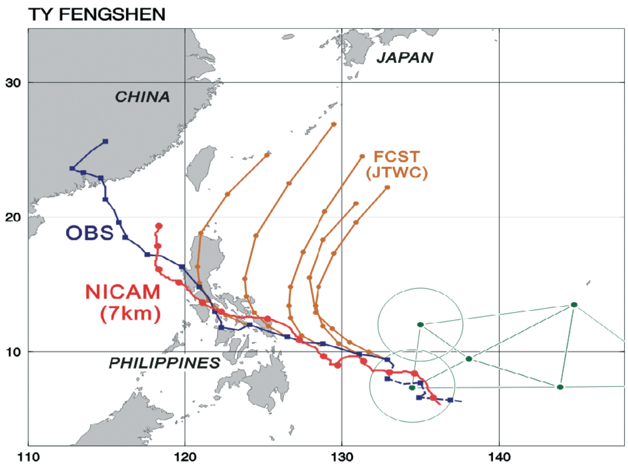

Fig. 3 Observed (black) and simulated (red) tracks of Typhoon Fengshen. Simulated tracks by Joint Typhoon Warning Center (JTWC) and by 7-km mesh NICAM with stretch grid system are shown.

Impacts of different turbulent mixing processes were also found in horizontal distribution of clouds and precipitation (Fig. 5). Spiral rainbands were more realistically simulated with the strong mixing because more amount of moisture was available in the lower troposphere by enhanced vertical transport than the standard mixing case. However, this leads to the weaker typhoon intensity (i.e., concentration of convection) through competition among abundant convective regions. In future study (FY2010), we plan to investigate the generation process of Fengshen by 3.5-km mesh experiment and also examine sensitivity to horizontal resolution (Fig. 6).

4. Summary

By the beginning of this fiscal year, the cloud-precipitation process study using global cloud-system resolving model had been done within the previous project in the old ES era, the

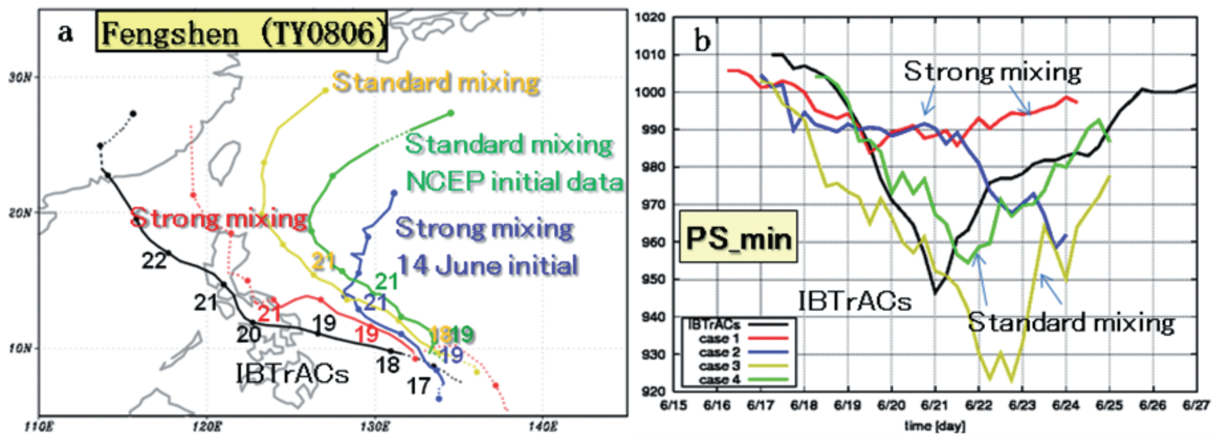

Fig. 4 (a) Tracks of Fengshen simulated by 14-km mesh NICAM in comparison with observation (black): simulations with strong turbulent mixing with MYNN level 2.5 scheme (red, blue) and those with standard mixing with MYNN level 2 (yellow, green). Initial data is interpolated from ECMWF YOTC operational data on 2008/6/15 00UTC (red, yellow) or 6/14 00UTC (blue) or National Center for Environmental Prediction (NCEP) final analysis on 2008/6/15 00UTC (green). Observed track (IBTrACs) is also drawn (black). (b) Time series of central pressure. Colors are same as in (a).

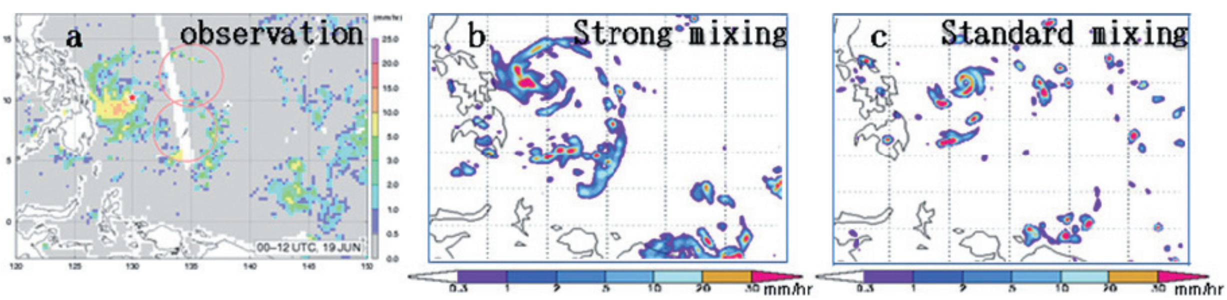

Fig. 5 (a) Microwave rain observed during PALAU2008, and rainfall intensity simulated by 14-km mesh NICAM: simulation with (b) strong turbulent mixing (red in Fig. 2) and (c) standard turbulent mixing (yellow in Fig. 2).

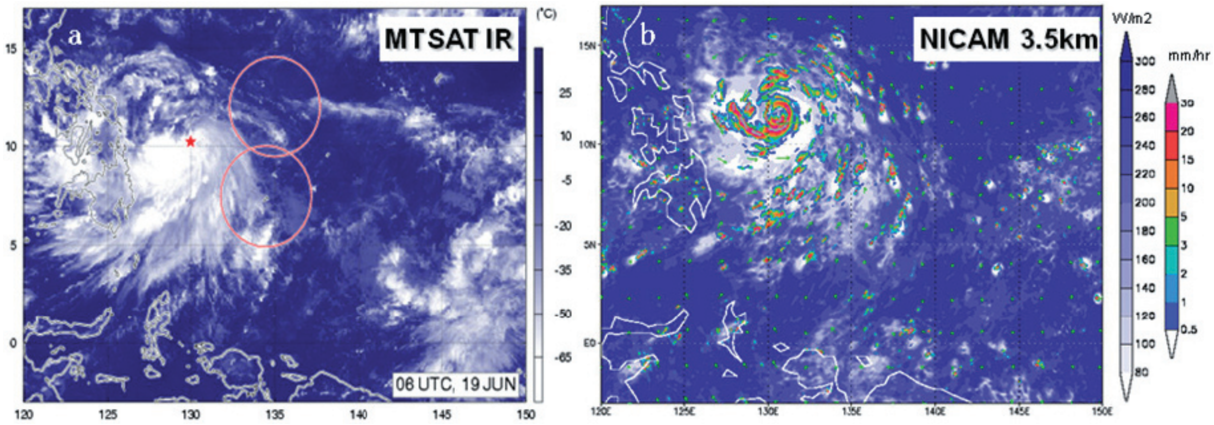

Fig. 6 Horizontal view of Fengshen (a) observed by Multi-functional Transport Satellite (MTSAT) and (b) simulated by 3.5-km mesh NICAM. In (b) color shows surface rainfall intensity.

title of which is "Development of a High-Resolution Coupled Atmospheric-Ocean-Land General Circulation Model for Climate System Studies". In order to enhance the understanding of the cloud process using the global cloud-system resolving model NICAM, the current project study derived from it and was restarting from this fiscal year, based on the results from the previous project. In this year, we first replaced the old physical schemes by the new ones to more precisely represent the cloud-precipitation system over the globe. The climatology for the new physics is in good agreement with observation, comparing with the old ones. We were mainly focusing on the Typhoon Fengshen and performed the several simulations changing the resolution, initial conditions, and physical schemes. We found that in this difficult prediction case the results depends not only on initial condition but also on the planetary boundary schemes. The results will be discussed much more intensively with the other international communities.

We also continue to analyze the simulation data which are not only obtained in this year but also obtained in the ES era. Especially, the convective momentum transports in the Madden-Julian Oscillation are currently analyzed. The diurnal cycles over the ocean and land are also intensively examined. Although we cannot describe the detail of the analysis due to space limitation, we will report them for the other publications or the next year report.

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全球雲解像モデルを用いた雲降水プロセス研究

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全球での雲降水システムのよりよい理解のため、我々はこれまで、全球雲解像シミュレーションを行ってきた。今年度は、より正確な雲降水プロセスを表現するため、物理過程のいくつかについてスキームを刷新し、テストを行った。雲微物理スキームを 3 カテゴリースキームから 6 カテゴリースキームに変更したところ、雲量についての気候値が改善した。これらの新しいスキームを使って、台風 Fengshen の計算を行った。この台風は進路の予測が難しいことで知られているものである。様々な初期条件と物理スキームを使って計算を行ったところ、このケースの場合、進路は、初期条件だけではなく、境界層スキームに非常に依存することが分かった。この Fengshen 再現実験においては、最高解像度の 3.5km の実験も実施し、現在解析中である。

キーワード: 雲降水プロセス, 全球雲解像モデル