15.9 SIMULATION OF A SUMMER MONSOON OVER KOREA IN 2003

Yu-Bin Yhang and Song-You Hong*
Department of Atmospheric Science, Global Environmental Laboratory,
Yonsei University, Seoul, Korea

1. INTRODUCTION

The most important climate feature over East Asia is the summer monsoon. The dominant characteristics of the East Asian summer monsoon are the seasonal variation of large-scale circulation and its associated persistent and heavy precipitation. Typically, as a result of the seasonal evolution of atmospheric circulation, the monsoon rain belt arrives in the southern China coast in early May, abruptly jumps to the north several times, reaches northeast China in early August, and quickly retreats to the south in the fall.

Understanding the East Asian summer monsoon is much improved during the last few decades. However, an accurate prediction of monsoon precipitation is still a challenging task. Difficulties arise from the complexities associated with the thermal and mechanical effects of mountain ranges (Ding 1994), multiscale interactions involving planetary scale, synoptic scale, and mesoscale, and various physical and dynamical processes that govern the circulation characteristics of different scales at tropical, subtropical, and midlatitudes (Lau and Yang 1996).

To realistically simulate the monsoonal system in Asia a great challenge has been performed for existing GCMs (e.g., Kang et al. 2002) and regional climate models (Kida et al. 1991; Liu et al. 1996; Hong et al. 1999; Leung et al. 1999; Sasaki et al. 2000; Wang et al. 2003). Although significant progresses have been made in the areas of regional climate modeling, the most common problem is the relatively low skill in simulating the regional features such as precipitation (Leung et al 2003). One of the major uncertainties of current regional climate models is the representation of physical processes. In addition to the result in GCM (Zhang 1994) showing a great sensitivity of simulated monsoon circulation to different cumulus parameterization scheme, results with the regional climate models also indicated that some existing physical processes such as cumulus parameterization scheme do not seem to work well in the East Asian monsoon region (Leung et al. 1999; Lee and Suh 2000).

The regional climate modeling approach has also been shown to be useful for improving our understanding of many climate processes, such as cloud-radiation forcing, cumulus convection, and land surface processes, and importance of external forcings such as vegetation, soil moisture on the climate (Hong and Kalnay 2002; Park and Hong 2004). Thus, further revisions to the existing parameterization methods and development of revised physical processes are necessitated in improving the predictability of the East-Asian monsoon and in understanding the climate processes embedded within the monsoonal circulations.

In this study, we implement the newly developed physical parameterization methods into a regional climate model and assess the capability in improving the skill of seasonal forecasts. The summer of 2003 is selected. In 2003, Korea has experienced abnormal wet summer. The summer mean rainfall over the peninsula is the third, and the averaged rainfall frequency is the first during the 30 years. Especially, after the mid-August, the Northern Pacific High (NPH) is still maintained the strength and stationary front is formed and results in increasing the duration of the stationary rainfall over the Korea peninsula. The simulation period of sensitivity tests is a month, August 2003, and the National Centers for Environmental (NCEP) Regional Spectral Model (RSM) (Juang et al. 1997) is used in this study.

*Corresponding author address: Song-You Hong, Yonsei University, Department of Atmospheric Science, Yonsei University, Seoul, 120-749, Korea. E-mail: shong@yonsei.ac.kr

2. MODEL AND EXPERIMENTAL DESIGN

The NCEP RSM is a limited-area hydrostatic atmospheric model with a perturbation method in spectral computation. A detailed description of the RSM is available in Juang et al. (1997).

The RSM domain covers the East Asian monsoon region centered over the Korean peninsula. The number of grid points is 109 (west-east) by 86 (north-south), and 50-km resolution is chosen. NCEP/DOE reanalysis Ⅱ data (Kanamitsu et al. 2002) are employed to provide the large-scale forcings during model integration. Model precipitation is compared with the daily Global Precipitation Climatology Project (GPCP) [Huffman et al. 1997] data with a 1° x 1° spatial resolution.

Table 1. A summary of sensitivity experiments

EXP	land (Chen and Dudhia)	PBL (Hong et al)	cumulus (Byun and Hong)
CTL	X	X	X
LSM	O	X	X
PBL	X	O	X
CPS	X	X	O
ALL	O	O	O

Four runs are designed to investigate the sensitivity of the simulated monsoon to the surface process, horizontal diffusion, and convective parameterization schemes (Table 1). The control experiment (CTL) employs the physics package used in the NCEP/DOE reanalysis. Each of the following experiments changes an option from the CTL experiment. The LSM experiment uses more realistic distribution of land use conditions and vegetation (Chen and Dudhia 2001) instead of homogeneous land use properties and vegetation fraction. In the PBL experiment, new PBL results in less mixing than that of the CTL run. The CPS experiment employs revised sub-grid scale processes in the simplified Arakawa-Schubert (SAS) scheme (Byun and Hong 2005). The modification includes a multiple cloud top, convective momentum transport, and large-scale destabilization effect.

3. RESULTS

3.1 Control simulation

The precipitation of observed data from the 1° x 1° rainfall analysis represents two major rain bands in which one is over the sub-tropics and the other in mid-latitudes (Fig. 1a). However, these two rain bands are not distinct in the CTL experiment (Fig. 1b). Particularly, heavy precipitation over Korea is not reproduced. The CTL experiment yields cooler condition compared to reanalysis data (Fig. 2). The CTL experiment warms the lower troposphere and cools down the middle atmosphere (Fig. 3). This induces that the midlatitude trough over the north central part of the model domain is more intense and the subtropical high over the northwestern Pacific Ocean is weaker. The strong midlatitude East Asian trough over the land is partly related to the underestimated precipitation in the central part of the model domain.

a) OBS b) CTL

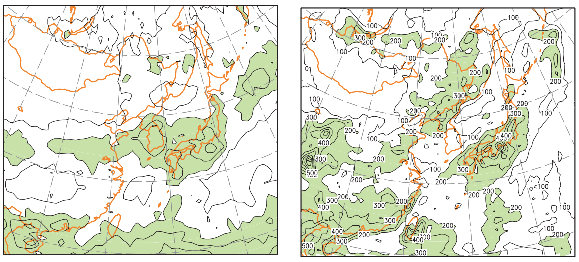

Fig. 1. Monthly precipitation (mm) for August of 2003, obtained from (a) GPCP and (b) the CNTL experiments.

a) RA2 b) CTL

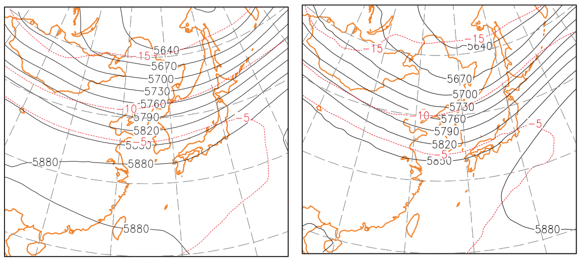

Fig. 2. Monthly mean 500-hPa geopotential height (m) and temperature (K) from (a) reanalysis data, (b) the CTL experiment. Contour intervals are 30 m and 5 K.

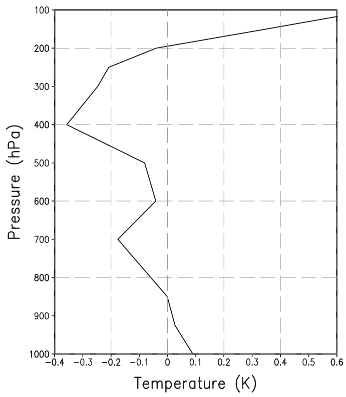

Fig.3. Difference of temperature averaged over the model domain during August 2003 (CTL-RA2).

3.2 Sensitivity experiments

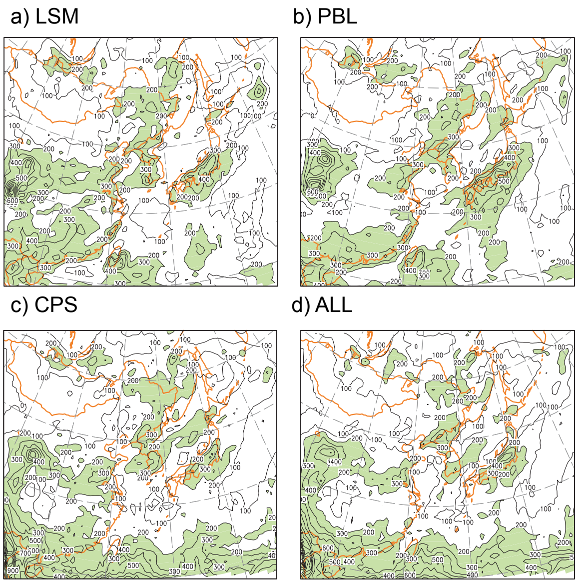

Fig. 4. Monthly precipitation (mm) for (a) LSM, (b) PBL, (c) CPS, and (d) ALL experiments. Contour intervals are 100 mm and shaded areas are over 200 mm.

The LSM experiment improves the distributions of precipitation in mid-latitudes, in particular, over the Korea peninsula (Fig. 4a). The reason was due to the fact that higher temperature and geopotential height was simulated in the LSM experiment (Fig. 5a). This results in better simulation of the NPH and trough than in the CTL experiment.

On the other hand, in the PBL experiment, slightly decreased rainfall is represented (Fig. 4b). This is from less mixing due to the new scheme. In Fig 5b, it is apparent that temperature and moisture in the lowest layer below 950 hPa become colder and wetter due to the new PBL scheme. Above it generally appears warmer and drier air between 950 and 850 hPa, such a feature reflects the effect of the new PBL scheme. Less mixing induces weaker convection over the ocean. This restrains the growth of the NPH.

The CPS experiment reproduces similar patterns to that of observed precipitation (Fig. 4c). Especially, the CPS experiment improves rain band over subtropics. Also, this is showed in the ALL experiment (Fig. 4d). In the CPS and ALL experiments, vertical structures for temperature and humidity in upper level are similar (Fig. 5c, 5d). This similarity indicates that cumulus parameterization is dominant in upper level. And the experiments show cooling and moistening condition in upper level, which is the effect of consideration of multi-cloud top.

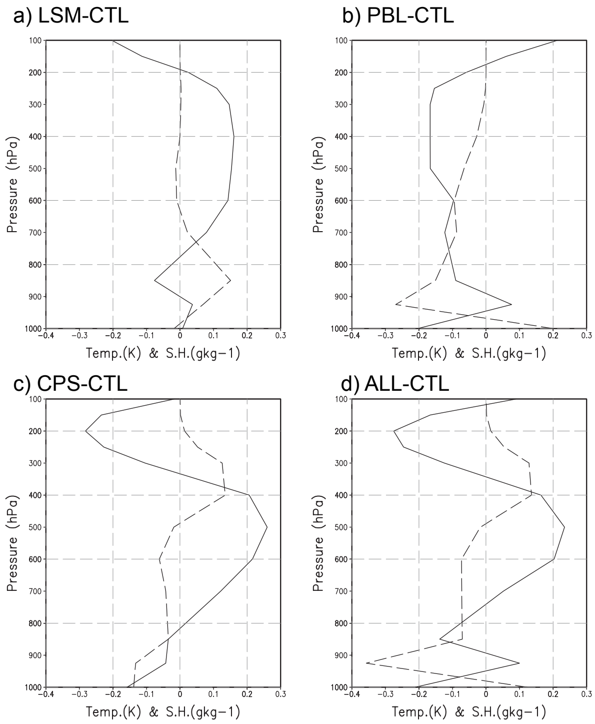

Fig. 5. Differences of domain-averaged temperature (K), specific humidity (gkg-1) (left) and geopotential height (m) (right) between the (a) CTL and the LSM, (b) PBL, (c) CPS, and (d) ALL experiments. Solid line is temperature, and dashed line is specific humidity.

In table 2, all experiments performed in this study overestimate the amount of precipitation. However, the amount and root mean square errors (RMSE) decrease from the CTL, LSM, PBL, CPS and ALL experiments in order. Also, the CPS and ALL experiments improve the time correlation over Korean peninsula.

4. SUMMARY AND CONCLUDING REMARKS

In this study, we performed the simulation of the East Asian monsoonal precipitation using the NCEP Regional Spectral Model with newly developed physical parameterization methods and examined its capability in improving skill of the forecasts. The NCEP/DOE reanalysis and observed SST are used as lateral and surface boundary forcings to minimize the boundary effects.

The control experiment, which employs the physics package used in the NCEP/DOE reanalysis, does not simulate the major precipitation bands. As well, the CTL experiment appeared to be deficient in Korea. The LSM experiment improves the distribution of precipitation in mid-latitude. This is due to an intense sub-tropical high. The use of improved PBL reduces precipitation in Korea because of less mixing of heat and moisture. In the CPS and ALL experiments, the model simulates distinct two rain bands shown in observed precipitation.

Our results indicate that the simulation of the East Asian monsoonal precipitation is sensitive to the treatment of physics process. This implies that care has to be taken in selecting accurate physics formulations, especially for the representation of convective processes, and in correctly characterizing surface conditions when applying a limited-area model to regional climate simulations.

Table 2. Statistics of the Root Mean Square (RMS) Errors, time correlation and pattern correlation for simulated precipitation averaged over the whole domain. Observation rainfall is 146.4 mm. The values in parenthesized passages are the time correlation over the Korean peninsula (34-41°N, 124-129°E).

EXP	rainfall (mm)	RMSE	time correlation	pattern correlation
CTL	172.5	18.7	0.59 (0.01)	0.47
LSM	169.2	18.9	0.54 (0.25)	0.42
PBL	165.6	17.3	0.59 (0.04)	0.49
CPS	162.9	17.1	0.4 (0.35)	0.46
ALL	159.8	16.9	0.42 (0.38)	0.44

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