# Diurnal Cycle of the Simulated Precipitation in WRF : Physics Sensitivity

Myung-Seo Koo and Song-You Hong

*Department of Atmospheric Sciences, Yonsei University, Seoul, Korea*

mskoo@yonsei.ac.kr

## 1. Introduction

The ability to correctly simulate the diurnal cycle of precipitation is an important test for atmospheric models. Studies of the diurnal cycle in carefully controlled model experiments can serve to validate the physical parameterizations (Slingo et al., 1987; Lee et al. 2007; Wang et al. 2007; Clark et al. 2007). The investigation of the model results can enhance our understanding of the important mechanisms that drive the diurnal cycle. (e.g., Randall et al. 1991).

Although current atmospheric models simulate reasonably well the broad-scale characteristics of the diurnal cycle of precipitation, there are still many features that are poorly represented or unsolved for the amplitude or phase of diurnal cycle. Many studies that compared the satellite derived diurnal cycle of precipitation with the model-predicted one has found a mismatch in phase between them, about a lag of 3h (Coller and Bowman 2004; Dai and Trenberth 2004; Basu 2007). To better simulate the diurnal cycle, recent studies reported that its phase or amplitude can be improved from the multimodel superensemble among different cumulus parameterization algorithms (Krishnamurti et al. 2008), or revising the PBL parameterization which dominates diurnal variation of heat flux near the surface, (Hong et al. 2008) and convective parameterization scheme (Wang et al. 2007). However, it is still not clear in what and how much physics package have influence on the diurnal cycle of precipitation.

This study examines the sensitivity of the simulated precipitation over East Asia to physical parameterizations in the WRF model, within the context of regional climate modeling. For evaluation of the simulated precipitation, the version-6 3B42 of the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (hereafter TMPA) data is used to characterize precipitation amount, frequency, and intensity focusing on the diurnal variation.

To begin with, section 2 provides a synoptic overview on the East-Asian summer monsoon in July 2006, and the validity of the TMPA observation over East Asia. In section 3, the numerical experiments conducted in this study are described, with their results being discussed in section 4. Concluding remarks appear in the final section.

## 2. Synoptic overview of the July 2006 over East Asia

Figure 1 shows the synoptic features averaged during a period of July 2006, obtained from NCEP Final Analysis (FNL

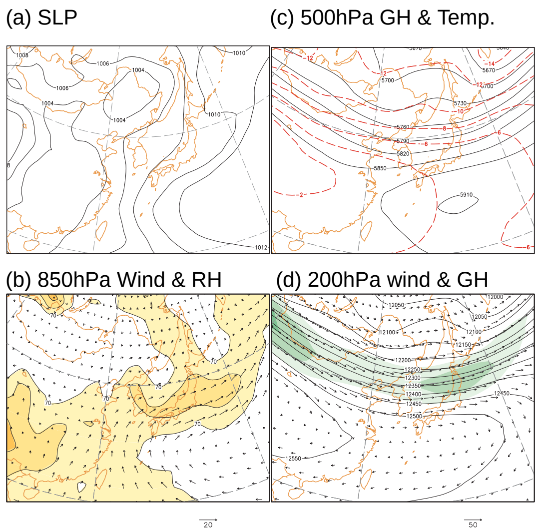


Figure 1. (a) Sea level pressure (hPa), (b) 850 hpa wind (ms-1) and relative humidity (%), (c) 500hPa geopotential height (m) and temperature (K), and (d) 200hPa wind (ms-1) and geopotential height (m) averaged during a period of July 2006.

(a) GPCP (b) TMPA (c) AWS

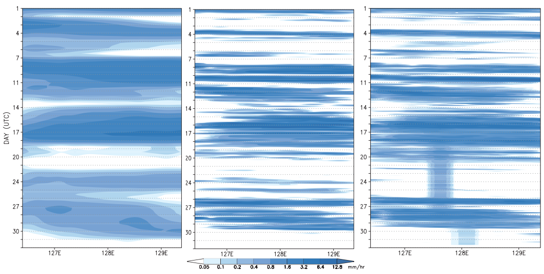

Figure 2. Time-longitude cross section over South Korea (33.0N~38.5N) of precipitation amount from the (a) GPCP, (b) TMPA, (c) AWS

from GFS). Low pressures are located over southern and central China whereas a high pressure system is located over the south-east region of Japan, which is a typical pressure distribution associated with a summer monsoon in July. In the lower troposphere, it is analyzed that warm and moist airs are advected from south-west to South Korea, intensifying convection instability in that region. A mid-level trough appears to the west of the Korean peninsula, continuing to provide dynamic environment which is dynamic environment which is favorable for inducing heavy rainfall. The existence of upper-level just in the up-right side of South Korea is analyzed to reveal typical synoptic feature associated with heavy rainfall over South Korea.

On the other hand, the TMPA data is a calibration-based sequential product combining precipitation estimates from multiple satellites, as well as gauge analyses where feasible, at fine scales of 0.25 degrees in horizontal and 3 hourly in time. It can be used a core tool in understanding precipitation mechanisms embedded in convective systems over the mid-latitude as well as tropics (Zhou et al. 2008). Evaluation of the TMPA over the raingauge data over Korea was good in terms of the spatial distribution (now shown). The diurnal cycle of the area-averaged precipitation over Korea also showed a good agreement between the rain-gauge and TMPA observation (Fig. 1).

## 3. Experimental Setup

The WRF model version 3.0 is used in this study. Initial conditions were obtained from the NCEP FNL analysis. The model

Table1. Abbreviation for experiment

| | CPS | PBL | MP |
|---|---|---|---|
| CTL | KF | YSU | WSM3 |
| CP1 | BMJ | YSU | WSM3 |
| CP2 | Grell | YSU | WSM3 |
| BL1 | KF | MYJ | WSM3 |
| BL2 | KF | ACM2 | WSM3 |
| MP1 | KF | YSU | WSM6 |
| MP2 | KF | YSU | Thompson |

domain covers the East Asian monsoon region centered over the Korean Peninsula with a 48-km resolution on a Lambert conformal map projection. The number of grid points in Cartesian coordinates is 109 (west-east) by 86 (north-south). The vertical resolution employed is 27 layers. Model outputs are produced every 3hrs, and interpolated onto a 0.25-degree resolution, to be consistent with the TMPA observation.

Seven sets of experiments are described in Table 1. For the control run (CTL), the physics packages include the Kain-Fritsch cumulus parameterization scheme (CP) (Kain and Fritsch, 1993), the YonSei University planetary boundary layer (BL) (Hong et al., 2006), and the WSM3-class simple ice microphysics (MP) scheme (Hong et al. 2004), which are default options in the version 3.0. For CP sensitivity tests, the Betts-Miller-Janjic scheme (Betts and Miller 1986, Janjic 1992) and Grell-Devenyi ensemble scheme are used, and the Mellor-Yamada-Janjic turbulent kinetic energy (TKE) and ACM2 (Pleim) PBL for BL sensitivity, and the WSM6 (Hong and Lim, 2006) and Thompson schemes for MP sensitivity.

## 4. Results and discussion

The simulated precipitation from the CTL run captures the distribution of the two major

(a) OBS (b) CTL

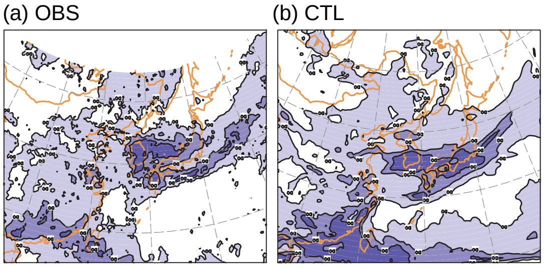

Figure 3. Amount (mm) of accumulated precipitation over East Asia region during a month of July 2006, obtained from (a) TMPA observation, and (b) CTL experiment.

Table2. Skill score of the simulated precipitation.

| | Bias | RMSE | PC |
|---|---|---|---|
| CTL | 0.66 | 4.34 | 0.64 |
| CP1 | -0.82 | 3.83 | 0.55 |
| CP2 | -1.43 | 3.95 | 0.58 |
| BL1 | 0.80 | 3.62 | 0.72 |
| BL2 | -0.13 | 4.07 | 0.59 |
| MP1 | 0.27 | 4.20 | 0.67 |
| MP2 | 0.47 | 4.06 | 0.68 |

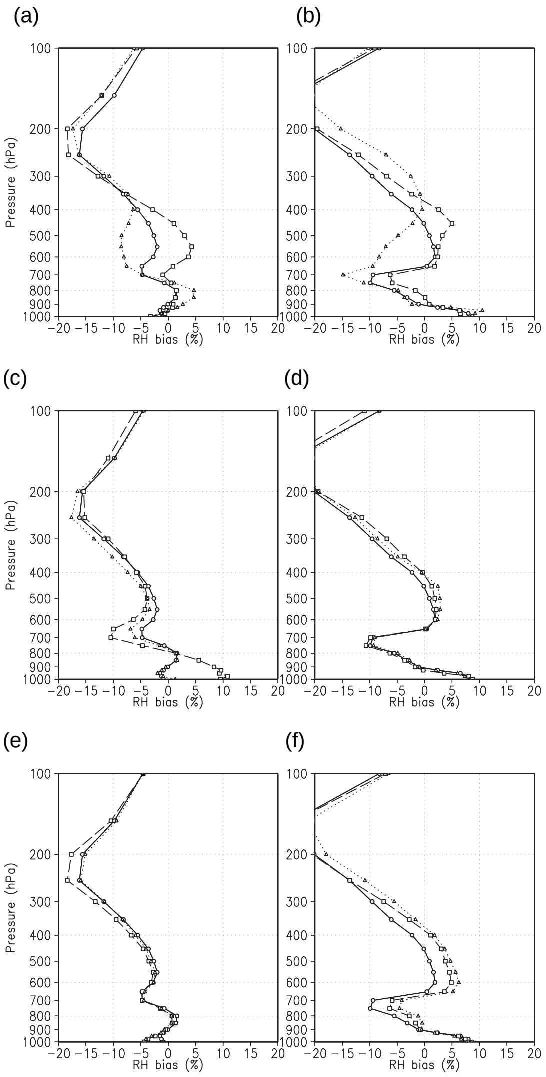


Figure 4. Vertical bias errors profile of relative humidity for (ab) CP, (cd) BL, (ef) MP over (ace) land and (bdf) the oceans.

bands pretty well (Fig. 3). Table 2 shows the overall performance of the sensitivity experiments. Comparison of the skill scores for the monthly simulated precipitation (bias, root-mean-square-error, pattern correlation) shows high pattern correlation between the observed and the simulated precipitation.

Each physics affect on a change of large-scale features in different way. Figure 4 shows how relative humidity (RH) is vertically changed by calculating the bias between the simulated and FNL data. RH variation is relatively large in CP experiments whereas BL and MP have small influence upon RH variation except for BL at the surface over land. Vertical variation of temperature also has similar pattern to the case of RH (now shown).

Simulated diurnal variation of precipitation is considered by three features, which are amount, frequency, and intensity. Amount indicates accumulated precipitation, frequency is derived by counting precipitation amount over 0.02 mm threshold, and intensity is to be divided amount by frequency. Figure 5 shows that all of experiments well simulate the diurnal variation of precipitation compared to the observation in all of terms for precipitation. At a glance, it seems that amount and frequency has diurnal cycle in the period of 24 hours. The diurnal cycle of the simulated precipitation can be better depicted by harmonic analysis. It provides the information about amplitude and phase of sub-daily cycles. The 1st and 2nd harmonic can be filtered out for diurnal cycle and semidiurnal cycle, respectively.

The strong amplitude of 1st harmonic in observation appears in most areas except for the South oceans of Japan and the Northern China (not shown). Most experiments have similar pattern with high pattern correlation, but for BL1 the amplitude of diurnal cycle in the Southern China tends to be reinforced. In terms of phase, observation indicates the afternoon maximum over land and the night maximum over the oceans. Experiments are consistent with the phase arrows of observation, but tend to concentrate the maximum phase toward 1-way in both land and oceans. The amplitude of 2nd harmonic is relatively weak compared to that of 1st harmonic in both observation and simulation whereas phases for observation are better arranged. However, simulations tend to underestimate semidiurnal cycle with low amplitude and pattern correlation.

For verification of physics sensitivity focusing on diurnal cycle, figure 6 shows ensemble spread (standard deviation) among different schemes in a physic. In terms of amount, CP is most dominant from night to

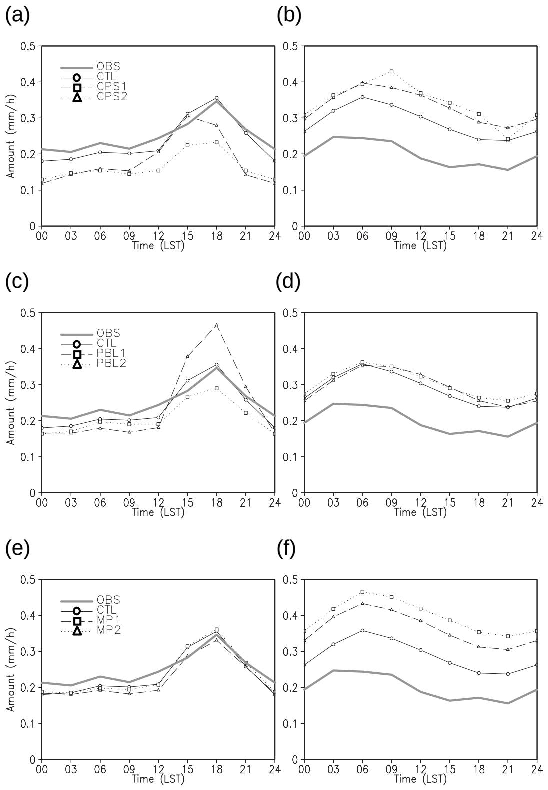


Figure 5. Diurnal variation of precipitation amount for (ab) CP, (cd) BL, (ef) MP over (ace) land and (bdf) the oceans.

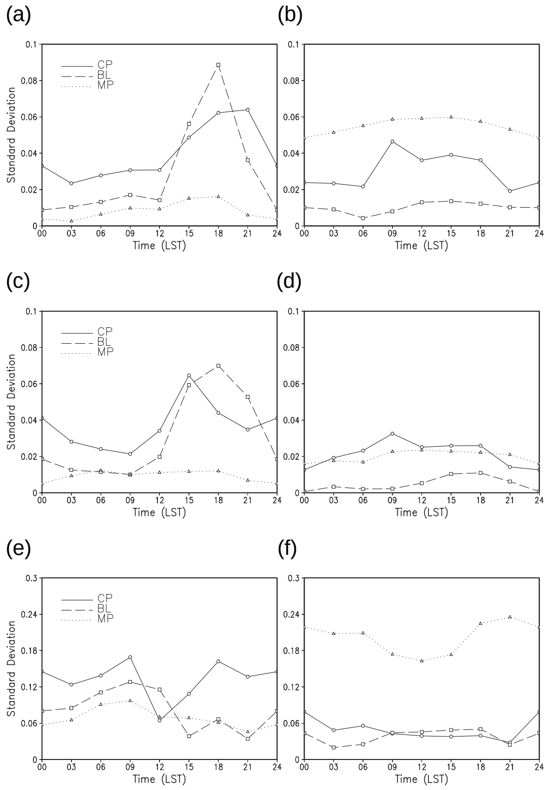


Figure 6. Standard deviation with respect to diurnal variation of precipitation (ab) amount, (cd) frequency, (ef) intensity over (ace) land and (bdf) the oceans.

the noon whereas BL has large influence on it over land in the afternoon. On the contrary, MP gives large effect over the oceans in broad time. Spread in terms of frequency is alike to that of amount except that for MP it is not sensitive as in amount over the oceans. Intensity is also most sensitive in CP experiments over land, whereas it is strongly controlled by MP over the oceans.

In conclusion, it is found that CP has the biggest sensitivity over land regardless of terms for precipitation, and intensity of diurnal cycle over the oceans is governed by MP. BL gives small effect on diurnal cycle, but have strong influence on afternoon peak of amount and frequency of precipitation over land.

## 5. Concluding remarks

This study examined physics sensitivity of diurnal cycle simulated by the WRF model. The TMPA data was used as an observation data to evaluate the simulated precipitation focusing on diurnal cycle.

It is shown that the model well simulates diurnal cycle of precipitation as well as accumulated precipitation amount. By harmonic analysis, the simulated diurnal cycle is well consistent with the observation whereas the simulated 2$^{nd}$ harmonic amplitude for semidiurnal cycle is somewhat weakened.

For sensitivity test, seven sets of experiments are conducted for cumulus parameterization (CP), boundary layer (BL) scheme, microphyscis (MP). As a result, it is shown that CP can be considered as most important trigger to simulate diurnal cycle of precipitation over land in the WRF model, diurnal cycle over the oceans is strongly governed by MP being sensitive to intensity of precipitation, and afternoon peak of diurnal cycle is controlled by BL.

## Acknowledgements

This research was supported by the Korean Foundation for International Cooperation of Science & Technology (KICOS) through a grant provided by the Korean Ministry of Science & Technology (MOST) in 2007, also supported by the Brain Korea 21 Project in 2008.