Use of Radar Observations to Evaluate WRF Cloud Microphysics Scheme

Ki-Hong Min[1,2], Seonhee Choo[1], Daehyung Lee[1,3], and Gyuwon Lee[1,3]

[1]*Department of Astronomy and Atmospheric Sciences, Kyungpook National University, Daegu, 702-701 Korea*
[2]*Department of Earth, Atmospheric, and Planetary Sciences, Purdue University,West Lafayette, IN, 47907 U.S.A.*
[3]*Research and Training Team for Future Creative Astrophysicists and Cosmologists (BK21 Plus Program), Kyungpook National University, Daegu, 702-701 Korea*

(Dated: 18 July 2014)

1 Introduction

The representation of clouds in mesoscale numerical models (NMs) is one of the major uncertainties in current predictions of short- and long-term weather or climate. Cloud microphysics parameterization is required in most NMs because a sophisticated, explicit prediction of the evolution of cloud microstructure is impractical even with the most advanced computing resources. Cloud microphysics scheme calculates precipitation amount and intensity and simulates the growth and development of water droplets in warm and cold rain processes. In addition, it redistributes energy, momentum, and moisture among model grid points and interacts closely with radiation process and atmospheric boundary layer.

In the early stage, cloud parameterization schemes diagnosed ice and water droplets using temperature profile and determined the amount of cloud with moisture profile. However, these approximations have many issues and as high resolution Numerical Weather Prediction (NWP) became available, the traditional diagnostic approach has shown many limitations. Recently, increase in computing power and NWP technology have led to more accurate and detailed description of cloud microphysical processes and the trend has been to prognostically calculate hydrometeor types and sizes explicitly (Hong et al. 2004, Lim and Hong 2010).

Recent trend in evaluating NWP models is using data obtained from remote sensing equipment such as satellite (CloudSat), radar, and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO, Konsta et al. 2012). The use of these active sensors makes it possible to evaluate the three- dimensional structure of clouds and precipitation. The increase in spatial- temporal resolution of numerical mesoscale models is making possible of direct comparison between model simulated radar reflectivity (SR) with that of weather radar

The purpose of this paper is to evaluate Weather Research and Forecasting (WRF) model cloud microphysics schemes and to determine their strengths and weaknesses. We compare the melting layer and bright band signatures obtained from ground based KMA S-band Doppler radar with two cloud microphysics scheme which will be adapted in Korea’s next generation global model. Comparison of contoured frequency by altitude diagram (CFAD), time-height cross section, and vertical profile of hydrometeors are utilized to assess the two schemes in simulating summer monsoon and convective precipitation cases of 2011 in Korea.

2 Method and Data Used

We used WRF v3.5 and nested the domain twice to achieve 4 km resolution from 1 degree NCEP Final Analysis (FNL) data. The 4 km resolution is needed to account for the complexity of local topography and to compare directly with radar data. There are 60 vertical levels, and 130 by 169 grid points in domain 3. We selected four cases for the evaluation of WSM6 and WDM6. The first and third cases are of summer monsoon known as Changma front in Korea that occurred towards the end of June and early July 2011. The second and fourth cases are scattered convection events which occurred after the end of summer monsoon in mid-August due to atmospheric instability.

The method we employ to calculate simulated radar reflectivity follows the recommendation provided by Koch et al. (2005) and Stoelinga (2005). Their paper discussed the use of simulated reflectivity products to compare model fields with radar observations and reported that this comparison have advantage over radar estimated precipitation fields because there is less uncertainty involved in the calculation of reflectivity. To compare WRF single-moment 6-class (WSM6) and double-moment 6-class (WDM6) schemes using radar, we analyzed CFAD for bright-band detection and time- height cross section to supplement CFAD which gives no time information. To further understand the mechanism responsible for the differences in the two schemes we investigated the vertical profiles of hydrometeors and temperature with humidity profiles. Radar data are quality controlled using Fuzzy algorithm developed at KNU to remove non-meteorological echoes such as anomalous propagation, ground clutter, and chaffs (Ye, 2013). In addition, systematic error (mean bias) of each radar site has been corrected based on annual radar climatology.

3 Results

The 12 hr accumulated rainfall for AWS (Automated Weather Station) and WSM6/WDM6 for Case 1 is shown in Fig. 1. The Changma front propagated southward from the middle of Korean Peninsula and the major precipitation band is located between Seoul (37°1'N, 126°58'E) and Kunsan (35°59'N, 126°45'E), South Korea. Thus, we chose Gwangdeuksan (GDK), Kwanaksan (KWK), and Kunsan (KSN) radar sites for comparison with WRF simulations. Each dot represents the location of radar sites and the circle of 100km radius used in this study.

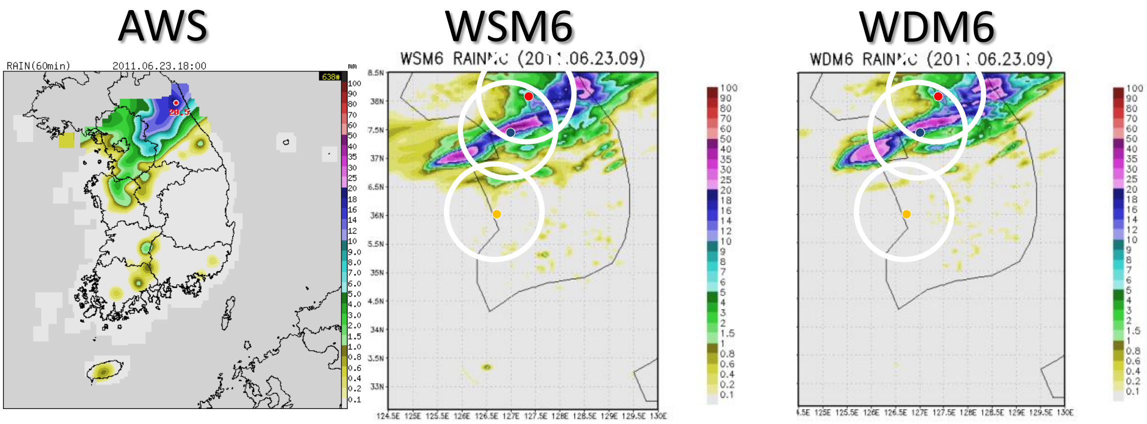

Figure 1 The 12 hr accumulated rainfall for AWS and WSM6/WDM6 for Case 1 of summer 2011. Each dot represents the location of Gwangdeuksan (GDK, red), Kwanaksan (KWK, blue), and Kunsan (KSN, orange) radar sites and the circle of 100km radius used in this study.

The results show that for monsoon cases, WSM6 shows a systemic bias of simulating smaller reflectivity values beneath the melting layer when compared to radar data, while WDM6 has a tendency to simulate higher reflectivity. For convective cases, there are still rooms for improvement in the height of melting layer, hydrometeor types, and various precipitation aspects (timing, location, and intensity etc.) of model simulations. Overall, WSM6/WDM6 schemes have tendency to overestimate the location of the melting level and the BB height when compared to radar observations. The accuracy of WDM6 scheme over WSM6 when compared to radar observations can be attributed to the difference in the sedimentation process simulated by the double moment number concentrations of liquid phase particles. This in turn creates larger rain drops and increase relative humidity beneath the melting level allowing WDM6 scheme to simulate more realistic reflectivity profile than WSM6 scheme. However for the convective case, both schemes under predict precipitation and there is resolution dependence in WRF model's ability to simulate convective type precipitation.

This study shows the possibility of utilizing radar data to validate mesoscale model's output and cloud microphysics scheme in detail. The results obtained herein can fine tune the cloud microphysical schemes and eventually improve numerical weather prediction model's performance and accuracy.

Acknowledgement

This study was partially supported by Korea Institute of Atmospheric Prediction Systems (KIAPS) and by the Basic Science Research Program through the National Research Foundation (NRF) of Korea funded by the Ministry of Education (NRF-2013R1A1A2061689).

References

Hong, S.-Y., J. Dudhia, and S.-H. Chen. A revised approach to ice microphysical processes for the bulk parameterization of clouds and precipitation//Mon. Wea. Rev., 2004, 132(1), 103–120.

Koch, S. E., B. Ferrier, M. Stoelinga, E. Szoke, S. J. Weiss, and J. S. Kain. The use of simulated radar reflectivity fields in the diagnosis of mesoscale phenomena from high-resolution WRF model forecasts//Preprints - 11th Conference on Mesoscale Processes, 2005, Albuquerque, New Mexico.

Konsta D., JL. Dufresne, H. Chepfer, A. Idelkali, G. Cesana. Evaluation of clouds simulated by the LMDZ5 GCM using A-train satellite observations (CALIPSO-PARASOL-CERES)//Climate Dynamics, 2012.

Lim, K.-S. S., and S.-Y. Hong. Development of an effective double-moment cloud microphysics scheme with prognostic Cloud Condensation Nuclei (CCN) for weather and climate models//Mon. Wea. Rev., 2010, 138, 1587–1612.

Stoelinga M. T. Simulated equivalent reflectivity factor as currently formulated in RIP: Description and possible improvements//White paper, 2005, 5pp.

Ye, B.-Y. Quality control of radar moment data by combining moment-based fuzzy logic algorithm and radar signal processing//M.S. thesis, KNU, 2013, 72pp.