The assimilation of rain rates on MM5 and WRF with latent heat nudging method

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1. Introduction

Latent heat release can play a important role in the evolution of tropical and extratropical cyclones (Manobianco et al. 1994). On the assumption that the majority of water condensing in a cloud precipitate out, the latent heat profile of model can be scaled with satellite-derived rain rates(Jones and Macpherson, 1997). Assimilation of the satellite observations in high temporal and spatial resolution can improve the model evolution. Chang and Holt (1994) found that the improvement by assimilation of rainfall rates was sensitive to errors in geographic location of the precipitation. This study investigates assimilation of the rain rates derived from SSM/I (Special Sensor Microwave/Imager) on MM5 and WRF for a convective system over the oceans near the Korean Peninsula and a typhoon case.

2. Methodology of data assimilation

Manobianco et al.(1994) studied the impact of assimilating satellite-derived precipitation rate by polar-orbit satellite and geostationary satellite and Alexander et al.(1999) and Chang et al.(2001) evaluated the effect of combined lightning data and micro radiometer data on mesoscale model forecasts of the extratropical cyclone. Those studies showed the positive impacts on the simulation of extratropical cyclone evolution by latent heat nudging process. Davolio and Buzzi(2004) modified the model specific humidity profiles to improve short-range forecasting. The rainfall assimilation method in this study is based on those of Manobianco et al.(1994) and Chang et al.(2001). Where the total precipitation of model is less than the satellite-derived rain, we assume that the latent heating of model does not simulate appropriately the real latent heating and scale the model profile of latent heating proportional to the ratio of the difference between satellite and model precipitation as

$$\Delta T_i^{assim} = (1+\alpha)\Delta T_i^{model} \quad ,$$

$$\alpha = \frac{R_s - R_m}{R_m} \quad ,$$

where i represents the index for vertical model levels, ΔT_i the changes in temperature, R_s precipitation inferred from satellite data and R_m the model predicted rainfall. Temperature tendency at each levels are increased in grid where satellite-derived rain rate is greater than model predicted rain rate. If $R_s > 3R_m$ or $R_m = 0$, the predicted latent heating profile is assumed to be unreliable. Model grid points are then searched for a more closely matching rainfall rate and the latent heating profile at that grid point is used for scaling. In this study the rainfall data from microwave observations of SSM/I by RSS (Remote Sensing Systems) are used. The horizontal resolution of RSS SSM/I products is 0.25° × 0.25° and its range is from 0mm/h to 25 mm/h.

3. Numerical Experiments

The model grid resolution of this study is 18km with a mesh of 148×148 in the horizontal and 35 levels in the vertical and the model top is 50 hPa. We used the Reisner II microphysics, the new Kain–Fritsch cumulus parameterization, and MRF PBL for MM5 and Lin microphysics, Kain-Fritsch cumulus parameterization, and YSU PBL for WRF. The initial and lateral boundary conditions are provided by KMA GDAPS (Global Data Analysis and Prediction System) 6-hourly analyses available at 0.56° × 0.56° resolution. Rain rates data over equal spaced latitude-longitude grid are interpolated into model grid. Model main program reads satellite-derived rain rates. If the integration time step reaches to satellite observation, total rain rates from microphysics and cumulus parameterization is compared with observed rain rates. Temperature tendency is then scaled according to the ratio of observed rainfall to model rainfall.

Two cases are tested for the study. In the first case mesoscale convective system developed in synoptic-scale disturbances along the Monsoon (Changma) front for the period 24–25 June 2004. In southern coastal areas of the Korean Peninsula precipitation occurred with a maximum of 118 mm/24hrs. The 30-h integration of model is initialized at 0000 UTC 24 June 2004. Satellite-derived rainfall is assimilated during 30 minutes from 0054 UTC to 0124 UTC 24 June 2004. The typhoon chosen for the second case study is Dianmu(0406). The 66-h integration of model is initialized at 0600 UTC 17 June 2004. Rainfall assimilation is applied from 0912 UTC to 0942 UTC 17 June 2004.

4. Results and Discussion

Fig. 1 shows hourly accumulated rainfall with 1-hour interval for convective system case. Assimilation experiment simulates the rainfall system in the southern ocean of the Korea, which is recognized in satellite images. But control run dose not simulated precipitation distribution in observation. This effect lasts for about 6 hours. Latent heat nudging method is able to simulate more reasonable rainfall pattern to the observation. The time series of mean fields within 30°N~35°N, 120°E~130°E indicate that temperatures in assimilation run increase but the effect lasts within 12 hours, the increases of mixing ratio appears instantly at all lower level, and vertical velocity enhances after assimilation(not shown).

The 10-minute accumulated precipitation over the target domain and the ratio of precipitation by cumulus parameterization scheme and microphysics scheme are shown in Fig. 2. The accumulated precipitation increases after assimilation and it takes about 2 hours for spin up times in control run. After assimilation of rain rates, accumulated precipitation increases mainly due to the portion of convective rain. The reason is that nudging of latent release causes the increase of temperature tendency and intensifies the vertical motions.

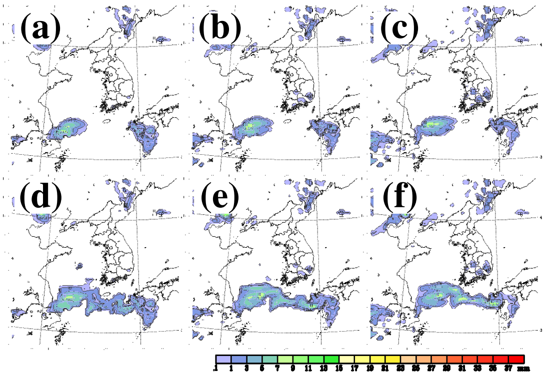

Fig. 1. The 1-hour accumulated precipitation at (a) 0100, (b) 0200, and (c) 0300 UTC 24 June 2004 for the control run; the 1-hour accumulated precipitation at (d) 0100, (e) 0200, and (f) 0300 UTC 24 June 2004 for the assimilation run.

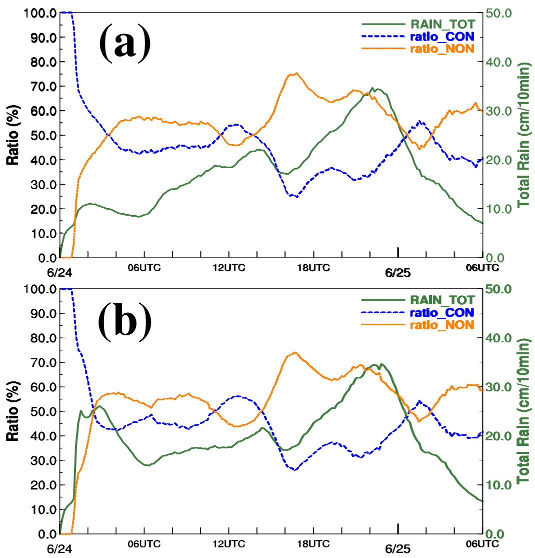

Fig. 2. The 10-minute accumulated precipitation over 30°N~35°N and 120°E~130°E area and the ratios of precipitation by cumulus parameterization scheme and microphysics scheme for control experiment (a) and assimilation experiment (b).

Fig. 3 illustrates the time series of surface central pressure for the typhoon case from 0600 UTC 17 to 0000 UTC 20 June 2004. There is a great difference of surface central minimum sea level pressure between model and observation at initial time. As model evolves, the results of assimilation run approaches to the observed pressure. At 0600 UTC 18 June 2004 central pressure of observation is 925hPa, those of control run and assimilation run are 944 hPa and 938 hPa respectively. Distance error of typhoon center position is smaller in assimilation experiment than in control run at the start of the integration period. But distance error of assimilation experiment increases, so mean distance error during integration of assimilation experiment is greater than that of control experiment. The effect of assimilation lasts longer for typhoon case compared with convective system case.

As new source of satellite data increases and new retrieval algorithms are being developed, the predictability of severe weather can be improved by assimilating these data.

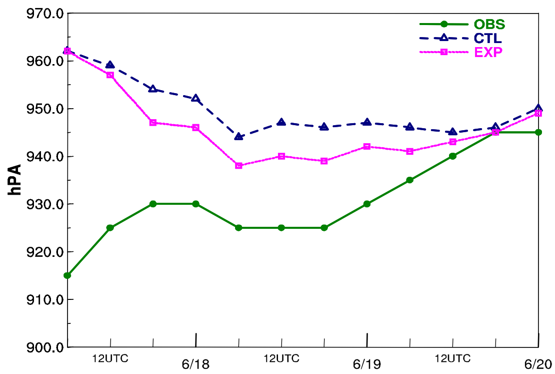

Fig. 3. Time series of surface central pressure forecasts for typhoon Dianmu.

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