A cloud resolving 4DVAR data assimilation system based on the JMA non-hydrostatic model

Takuya KAWABATA[1a], Hiromu SEKO[a], Tohru KURODA[d], Yasutaka WAKATSUKI[c], Yuki HONDA[b], Kyuichiro TAMIYA[a], Kazumasa AONASHI[a], Yoshinori SHOJI[a], Kazuo SAITO[a], Tadasi TSUYUKI[b]
[a]Forecast Research Department of Meteorological Research Institute / JMA,
[b]Numerical Prediction Division of Japan Meteorological Agency
[c]Advanced Earth Science and Technology Organization
[d]Meteorological Research Institute / JST Cooperative System for Supporting priority Research

1. Introduction

Since April 2002, the Forecast Research Department of the Meteorological Research Institute (MRI) and the Numerical Prediction Division of Japan Meteorological Agency (JMA) have been developing a 4DVAR system based on the JMA non-hydrostatic model. MRI develops the system with a horizontal resolution less than 2 km to apply to the convective cloud systems. Because JMA-NHM adopts fully compressible non-hydrostatic equations and cloud microphysics, this cloud resolving assimilation system is expected to reproduce structures of convective cells in rainfall systems. A prototype of 4DVAR system that includes dry dynamics was developed (Honda et al. 2003). This system has been further developed to include the advection of water vapor (Kawabata et al., 2004). In this paper, this cloud resolving 4DVAR system is explained, and then the results of assimilation experiments using GPS-derived precipitable water vapor (PWV) and the radial wind observed by Doppler radars (RW) are introduced.

2. Background error

Our target scale is 2 km horizontal resolution and 1-hour assimilation window. We discuss the difference of background errors between 2km model and 5km model. The statistics of background error were obtained by NMC method (Parrish et al., 1992). Namely, we performed several runs of JMA-NHM with horizontal resolutions of 2 km and 5km, and then, calculated the statistics of background error. The time lags of the initial fields in 2 km model and 5 km model were set to 1 hour and 6 hour, respectively.
Figure 1 shows the horizontal correlation between east-west component of horizontal wind and pressure. We can see the geostrophic balance modes in the correlation of 5 km error. On the other hand, there is not any balance mode in 2km error. We can see some correlation mode in 2km error, but its scale is very different from the geostrophic balance mode in 5km error. These results indicate that 2km errors mainly include the scale of the meso convective rainfall system and 5 km error also include the synoptic scale feature.

3. Assimilation experiment

Our purpose of the development of this assimilation system is to investigate the mesoscale convective rainfall system and to forecast the heavy rainfall. As the target for data assimilation experiments of this study, the small thunderstorm, which generated over the Tokyo and developed into heavy rainfall, was adopted. Generally, the convections are generated by the low-level convergence of humid airflow. Thus, PWV and RW, which have information of water vapor and the low-level convergence, are expected to improve the forecast of heavy rainfalls. In this study, GPS-derived PWV and RW of Doppler radars were used as assimilation data.

3.1. Experiment design

To reproduce the generation of the thunderstorm, the horizontal interval of 2km was adopted and then the horizontal domain of the assimilation was set to be 44km x 44km to cover the convergence zone. Because the thunderstorm began to be generated at 06UTC, the assimilation window from 0600UTC to 0620UTC was adopted. We assimilated the GPS PWV at every 5 minutes and RW at every 1 minute.

3.2. Assimilation result

Figure 2 shows the observed horizontal wind field by dual Doppler radars, at 1km level. The thunderstorm indicated by the black square was developed into the heavy rainfall. In the precipitation region of the thunderstorm, the southerly flow converged with the northerly flow in the precipitation area.

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1 e-mail : tkawabat@mri-jma.go.jp

Figure 3 shows the first guess field and the analyzed field of horizontal wind and precipitable water vapor. In the guess field, southwesterly flow converged with weak southwesterly flow. When the GPS PWV and RW were assimilated, wind direction of the northern part of the domain was changed from southwesterly to northerly. Namely, the analyzed wind distribution became similar to observed one. For this change, the convergence of horizontal wind was more intensified than that of guess field. The intense convergence was maintained during the assimilation window. The convergence of water vapor was also stronger in the analyzed filed.

4. Future plan

We are to improve this system to assimilate the radar data and to investigate the mesoscale rainfall system or heavy rainfall. For this purpose, we are going to write tangent linear codes and adjoint codes of cloud microphysics.

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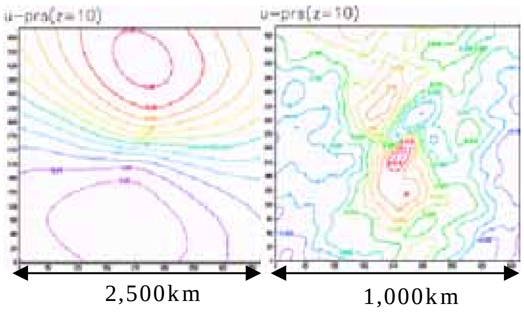

Fig. 1. Horizontal correlations between east-west component of horizontal wind and pressure. Left and right panels show 5km error and 2km error. Domain sizes of 5km and 2km error are 25000 km and 1000km, respectively.

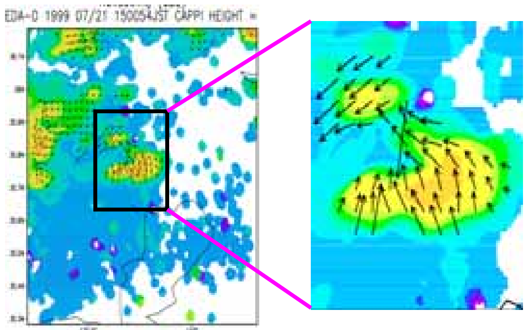

Fig.2. Observed horizontal wind field by dual Doppler radars, at the height of 1km . Right panel shows an enlarged area near the assimilation area.

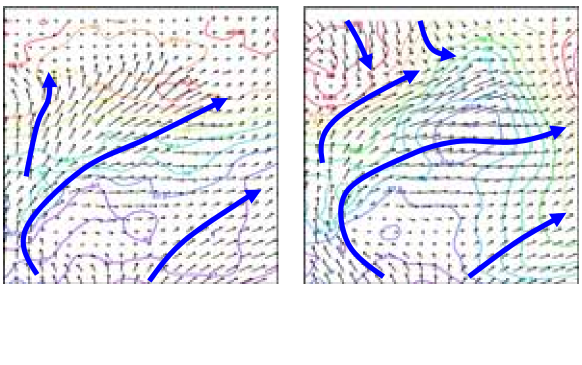

Fig. 3. Fist guess field (left) and analyzed filed (right) at 0600 (UTC) 21 July 1999. Arrows and contour lines indicate horizontal wind and PWV at 1000 m.