Data assimilation experiment of the Kobe thunderstorm by using NHM-LETKF

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1. Introduction

In ensemble Kalman filter (EnKF), data assimilation is performed with considering the error structure that fluctuates from day to day, and the initial perturbations of ensemble forecasts are produced by reflecting the analysis error properly. EnKF provides the probability of the occurrence of the significant phenomena. EnKF is expected to reduce the miss of the significant phenomena by using the forecast of ensemble members. In addition, the data assimilation of EnKF is easier than that of the variational method, because the adjoint model is not needed. Due to these merits, EnKF is expected to become one of useful techniques for mesoscale numerical prediction.

On 28 July 2008, the intense rainfall band was developed at Kobe Japan (Fig. 1), and 5 people in the river beach were claimed by the rapid rising of the Toga River. Unfortunately, this intense rainfall was not reproduced by the operational forecast model of JMA. In this study, the ensemble forecast was performed to reproduce this rain band by the assimilation of the GPS-derived precipitable water vapor (PWV). The object of this paper is to show the usefulness of the ensemble forecast and the impact of the PWV data on the forecast of heavy rainfall.

2. Methodology

In this study, a Local Ensemble Transform Kalman Filter (LETKF) (Miyoshi and Aranami, 2006) was used. The horizontal grid interval of LETKF was set to 20 km. This horizontal resolution was adopted to reproduce the mesoscale environment around the rainfall band within the limits of the computer resources. The domain of the experiments was 3300 km x 3000 km that covers the Japan main islands. Number of the ensemble member was 20. The cycle of the analysis and forecast was started at 72 hours before the occurrence of the intense rainfall band. The assimilation window period and assimilation slot interval were set to 6 hours and 1 hour, respectively.

As mentioned in the introduction, the intense rain band was not reproduced by the forecast of which initial condition was produced by the assimilation of the operational observation data. Thus, PWV data that were obtained from the GPS Earth Observation Network system of Geographical Survey Institute with the real time analysis methods (Shoji, 2009) was assimilated. Although the effect caused by the difference of the GPS receivers' heights and model topography was removed, the error produced by the assumption remained. To further reduce this error, the GPS-derived PWV, of which receivers' heights exist within ±50 m from those of the model topography heights of the GPS receivers' positions, was assimilated. To show the impact of the PWV data, two assimilation experiments were performed. In the first experiment, only operational observations, such as surface and upper sounding data, were assimilated. GPS-derived PWV was assimilated in addition to the operational data in the second experiment.

Non-hydrostatic model (NHM) of the Japan Meteorological Agency was used as the forecast model. Because the intense rainfall was composed of intense convections, downscale forecasts from the analyzed fields were also performed by NHM with the horizontal grid intervals of 5.0 km and 1.6 km.

3. Result of assimilation

Figure 2 shows the weather map at 09 JST (00 UTC) 28 July 2007. Baiu front extended north of the western Japan. The warm moist airflow (indicated by a thick arrow) moved around the western Japan, and then was supplied to the rainfall system of the front. At the 500 hPa, the cold air mass (indicated by a broken) was expanded to the Japan. Thus, the atmosphere over the western Japan had favorable condition for the generation and development of the thunderstorm.

Next, the observed PWV is compared with the first guess value (Fig .3). First guess value is the forecasted value from the former cycle's analysis fields. This comparison indicates that water vapor of the first guess was less humid than the observed ones at many GPS receivers over the Japan. Thus, rainfall is expected to be intensified by the assimilation of PWV.

Figure 4a shows the ensemble mean distribution of rainfall and surface pressure that was obtained by the assimilation of only the operational data. The synoptic scale features, such as a typhoon located near Taiwan, were reproduced. However, the rainfall was much weaker than the observed one. When this PWV data assimilated, the ensemble mean near Kobe was slightly expanded (Fig. 4b). This larger rainfall region indicates that PWV data has the positive impact for the forecast of the intense rainfall.

Next, the downscale experiments were performed with the grid interval of 5 km and 1.6 km. When the down scale experiments were performed, a few members reproduced the intense rainfall band (Fig. 5b). This result indicates that misses of severe events can be reduced by the performing the ensemble forecast. Because the environment (vertical profile of temperature etc.) around the rainfall band affects the rainfall amount, the relation between the rainfall amount and environments were plotted (Fig. 6). This scatter diagram shows that the temperature and equivalent potential temperature at the height of 500 hPa significantly influenced the rainfall amount. This result also indicates that ensemble forecasts provide the information of factors that cause the intense rainfall.

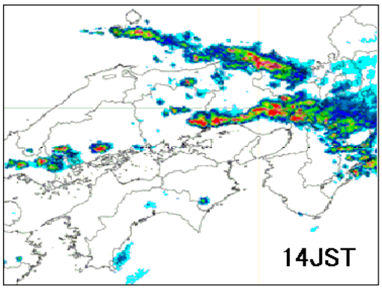

Fig. 1 Rainfall distribution observed by operational radar at 14 JST (05 UTC) 28 July 2008.

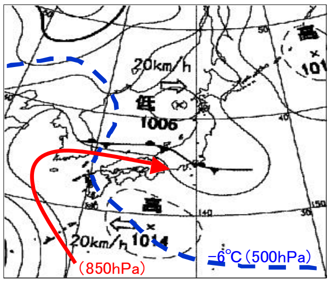

Fig. 2 Surface weather map at 09 JST (00 UTC) 28 July 2008.

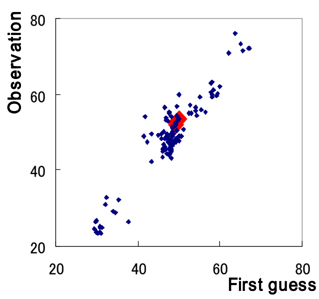

Fig. 3 Scatter diagram of the observed PWV and the first guess.

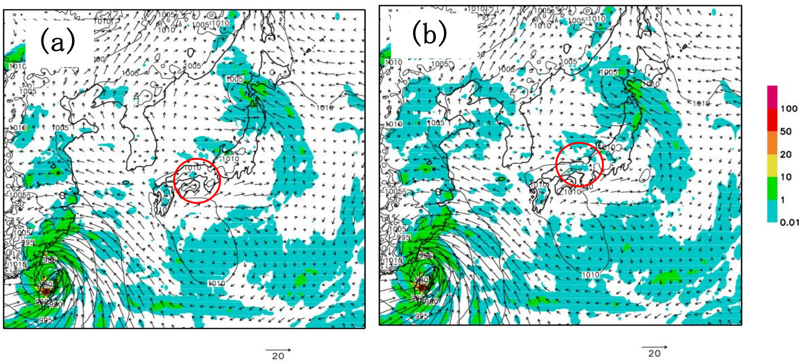

Fig. 4. Ensemble mean of rainfall and surface pressure at 15 JST (06 UTC) 28 July.

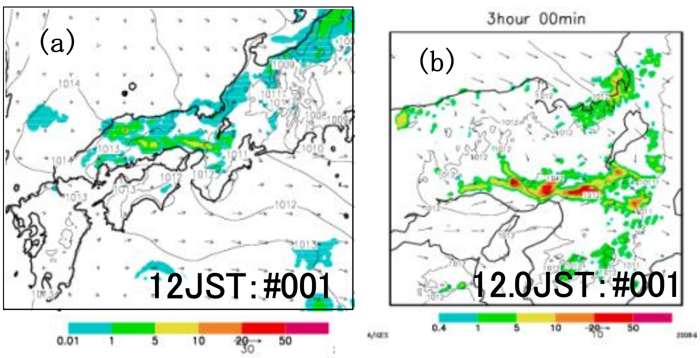

Fig. 5. Rainfall distribution at 12 JST (03UTC) reproduced by the downscale experiments using the NHM with the grid intervals of 5km and 1.6 km.

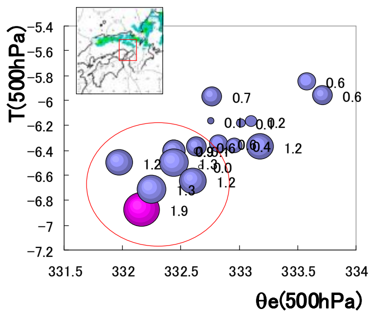

Fig. 6. Relations between average rainfall amount during 14-15 JST and the temperature or equitable potential temperature at 500 hPa in the read square region.