Data Assimilation Experiments of Vertical Gradient of Refractivity Observed by Wind Profiler Network

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1. Introduction

The Japan Meteorological Agency (JMA) deployed the nation wide network of wind profiles (WINDAS) to observe the mesoscale airflow distribution. Because the horizontal wind observed by the WINDAS helps to specify the position of the low-level convergence, the accuracy of the rainfall forecast was improved when these data were used as assimilation data. Besides the convergence of the airflow, water vapor plays important roles on the generation or development of heavy rainfalls, i.e., the abundant supply of low-level humid air causes heavy rainfalls and the middle-level dry air affects the development of the convection. The vertical profiles of water vapor are conventionally observed by the rawinsonde. However the time interval of the rawinsonde observation was as long as 12 hour, and then rewinsonde data does not necessarily catch the mesoscale severe phenomena whose time scale is generally less than 12 hours.

Recently, the estimation method of the vertical gradient of refractivity from the wind spectrum and signal-to-noise ratio observed by wind profiler was developed through the feature of the turbulence echo that depends on the vertical gradient of refractivity (e.g. Tsuda et al., 2001). When these data observed by WINDAS are used as assimilation data, the accuracy of the rainfall forecast is expected to be improved.

In this study, the vertical refractivity profiles were estimated from the WINDAS data and the impact of these data was investigated by using the Meso-4DVar Data assimilation system of JMA (Koizumi et al., 2005).

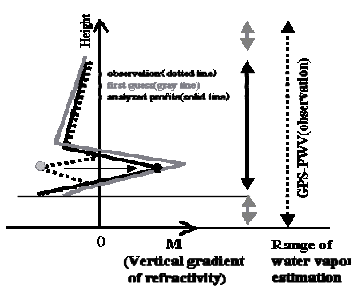

Fig.1 Schematic illustration how to determine the sign of vertical gradient of refractivity

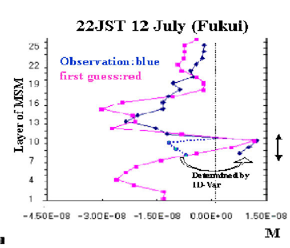

Fig. 2 vertical profile of gradient of refractivity at 22JST 12 July at Fukui

. Vertical profile of the water vapor

In the estimation of vertical gradient of refractivity, we followed the method of Sasaoka (2003). Namely, the vertical gradient of refractivity was estimated using next relations;

$$|M| = \alpha |\varepsilon|^{-1/3} |N| \eta_{turb}^{1/2},$$

$$\varepsilon = 0.5N(\sigma_{turb}/2)^2$$

$$\eta_{turb} = 10^{0.1SNR}$$

where M is the vertical gradient of refractivity, SNR the signal-to-noise-ratio, σ_{turb} the width of the spectrum and N the Brunt-Visala frequency.

Firstly, the profile of M was calculated with the vertical resolution of MSM (JMA operational hydrostatic Mesoscale model). α was determined so that the sum of the absolute value of M was equal to one calculated from the first guess, which was the outputs of MSM. The sign of the vertical gradient was not determined by the observation. Thus, one-dimensional variational analysis (1DVar) was performed to determine the signs of M. When the number of layers where M is positive was investigated using the rawinsonde data at Wajima during July 2004, a few layers are positive at the maximum. So, the combination of the signs that minimizes the following cost function was found by changing the sign of M.

$$J = \frac{1}{2}\sum (M - M_g)^2 + \frac{1}{2}\sum_{inside\ of\ obs.range} (M - M_{obs})^2 + \frac{1}{2}\left(\sum_{inside\ of\ obs.range} \rho_g q_v \Delta z + \sum_{outside\ of\ obs.range} \rho_g q_{vg} \Delta z - PWV \right)^2$$

where ρ and q_v is the density and mixing ratio of water vapor, respectively. PWV is GPS-derived precipitable water vapor, which was obtained by interpolation of PWV data of GEONET. The suffix g indicates first guess

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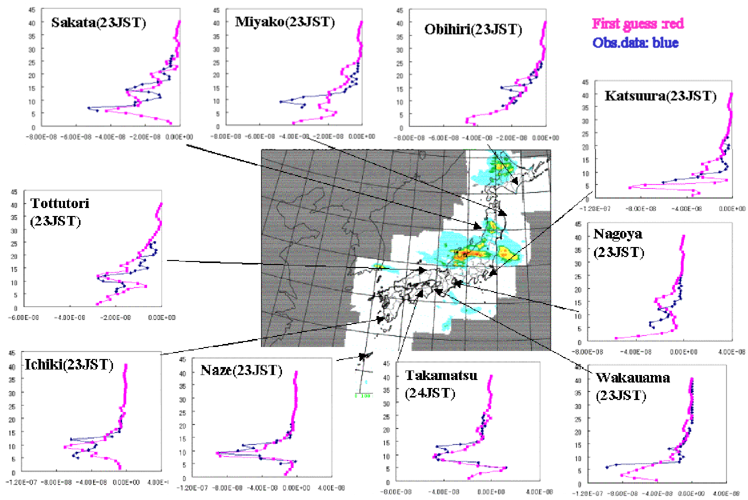

Fig. 3 Precipitation and vertical profiles of vertical gradient of refractivity at 23JST 17 July 2004.

value.

One example of the results of the 1DVar analysis is shown in fig. 2. The vertical profile of M whose sign was determined by 1DVar became close to that of the first guess. This profile indicates that the 1DVar analysis determined the signs of observed M correctly. The temperature and mixing ratio of water vapor can be estimated by the 1DVar analysis. However, the observed M whose sign was changed by the 1DVar was used as assimilation data.

3. Impacts of the vertical gradient of refractivity profiles observed by WINDAS

On 17-18 July 2004, the Baiu front, which is the stationary front extending from China to Japan in early summer, crossed the central Japan. Figure 3 shows precipitation distribution and the vertical gradient profiles of the refractivity observed by WINDAS. At 23JST, the well-developed line-shaped convective band crossed the central part of Japan and wide weak precipitation region existed on the northern side of the band. This convective band was developed by the low-level southwesterly flow over the Sea of Japan (not shown). On the southern side to the convective band (e.g., Ichiki, Naze and Takamatsu), the profiles of vertical gradient were similar to those of first guess. There was a layer with the minimum vertical gradient at the height of k=10. This minimum layer indicates the top of the boundary layer where the water vapor changed drastically.

These gradient data were assimilated into MSM. The grid interval of 10 km was adopted to resolve the mesoscale convective systems that caused the heavy rainfall. When the vertical gradient was assimilated, the precipitation region extended westward. However, this distribution was different from the observed one.

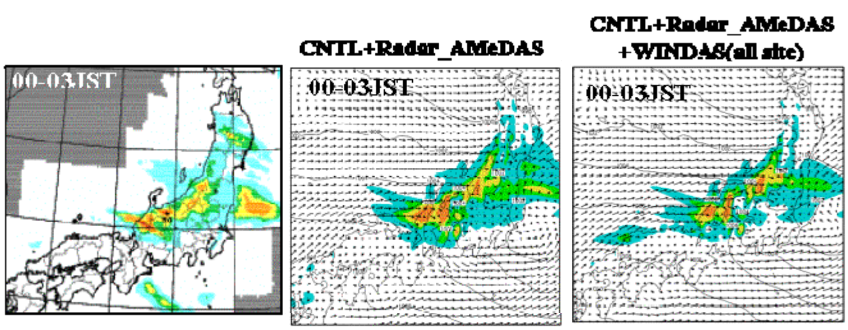

Fig.4 Observed precipitation during 00-03JST 17 July 2004 and the precipitation predicted from the assimilated fields of (left) conventional data and radar AMeDAS precipitation, and (right) convectional data and all wind profiler data.

5. Summary

The vertical gradient of the refractivity was estimated from WINDAS data. When the observed gradient was compared with the first guess, the feature of the boundary layer was similar to the observed ones in the upstream side of the low-level inflow. However, when this data were assimilated into MSM, the precipitation regions extended westward and the predicted precipitation distribution was different from the observed one. The accuracy of the observed vertical gradients of refractivity should be investigated and further data assimilation experiments should be conducted to reduce the observation error.

References

Koizumi, K,, Y., Ishikawa and T. Tsuyuki; Assimilation of Precipitation Data to the JMA Mesoscale Model with a Four-dimensional Variational Method and its Impact on Precipitation Forecasts, 2005; *Sola,* **1**,45-48.

Sasaoka, M., Estimation of water vapor profile in the convective boundary layer, 2003; *Proc. of the Autumn Conference of J. Meteor. Soc.*, **84**, 310, (in Japanese).

Tsuda, T., M. Miyamoto and J. Furumoto (2001): Estimation of a humidity profile using turbulence echo characteristics. *J. Atmos, Oceanic Technol*. **18**. 1214-1222.