

# Data Assimilation Experiments of Vertical Gradient of Refractive Index Observed by Wind Profilers

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## 1. Introduction

Water vapor is one of key factors for the improvement of the accuracy of rainfall forecasts. For instance, the impact of GPS-derived precipitable water vapor (PWV) data has been investigated by using the 4-dimensional data assimilation system (e.g. Seko et al., 2004). Besides GPS-derived PWV, the refractivity has information of water vapor. Furumoto et al. (2007) developed the method for estimation of the vertical profile of water vapor from vertical gradients of refractivity observed by the wind profiler by using the one-dimensional variational method. The Japan Meteorological Agency deploys 31 wind profilers (Wind Profiler Network and Data Acquisition System; WINDAS), in Japan. In this study, the vertical gradients of refractivity observed by WINDAS were assimilated by the 3-dimensional data assimilation system (JNoVA0) for non-hydrostatic model (NHM), and the impact of vertical gradients of refractivity on the forecast of intense rainfall is presented.

## 2. Thunderstorm observed at Osaka

At 06UTC 5th September 2008, an intense thunderstorm developed at the southern part of Osaka plain. Due to this intense thunderstorm, the 1-hour rainfall exceeding 90 mm was observed at the City of Sakai. This thunderstorm was generated by convergence of humid airflow that was enhanced by the thermo-dynamically-generated low-pressure area. So, this thunderstorm was chosen as the object for the data assimilation experiment.

## 3. Reproduction of the large-scale convergence and assimilation of Doppler data.

Because the first guess field given by the deterministic forecast could not reproduce the position of the convergence properly, the thunderstorm was not developed even in the forecast from the JNoVA0 analysis. Therefore, Local Ensemble Transform Kalman Filter (LETKF) was used to modify the large scale convergence. The analysis field among the ensemble members closest to the observed one was selected as the first guess field. The radial winds of Doppler Radar at Kansai and Osaka airports were assimilated by JNoVA0. Based on the statistics between the water vapor in the rainfall regions and updraft velocities, the atmosphere in the observed rainfall regions where the analyzed updraft velocities exceeded 0.15 m/s were assumed to be saturated. Besides this cloud scale water vapor modification, the mixing ratio of rain and snow estimated from the observed reflectivity with Z-R relation and analyzed temperature were placed at the grid points of NHM where it was observed in the domain of NHM. When these assimilation and modification were performed (Radial Wind (RW) case), the thunderstorm was reproduced (Fig. 2a).

## 4. Assimilation of the GPS data and the vertical gradient of the refractivity data

Besides the radial wind data and convective scale water vapor modification, the GPS-derived PWV and slant water vapor (SWV) were assimilated. When PWV or SWV were assimilated (PWV case and SWV case, respectively), the water vapor at the low levels was decreased, and then the thunderstorm was not reproduced (Fig. 2b). The comparison with the first guess and observed PWV shows that observed PWV/SWV around Osaka was smaller than first guess. Even if the PWV and SWV were smaller than the first guess, the

thunderstorm might be generated if the lower layer was more humid. To modify the vertical distribution of water vapor, the refractive index observed by WINDAS was assimilated as follows:

- (1) The signs of vertical gradient of refractivity ( $M$ ), which are not obtained by the wind profiler observation only, are determined by the 1d-Var. The cost-function of 1d-Var is composed of two parts: the difference from analyzed  $M$  and first guess  $M$ , and the difference of the analyzed  $M$  and the observed  $M$ . The combination of the sign of  $M$  whose cost-function is minimum is adopted (Fig. 1).
- (2) The observed  $M$  with estimated signs is assimilated by JNoVA0.

When the vertical gradient of refractivity was added to assimilation data (PWV+M case), the rainfall region in the Kii Peninsula extended to Osaka Plain (Fig. 2c). Although the rainfall region was not reproduced perfectly, this result indicates that information of the refractive index may improve the rainfall forecast. The vertical cross-section of the analysis increment (difference between analyzed field and first guess field) indicates that the water vapor was increased below the height of 1 km in the region where the PWV was decreased in the PWV case (Fig. 3). This increment can be contributed to the northward extension of the rainfall region. The improvement was larger than that obtained by the assimilation of the slant water vapor data. When all signs were set to negative, the water vapor was unnaturally increased at the height of 5 km. This result indicates that proper estimation of the combination of signs of  $M$  is important.

### References

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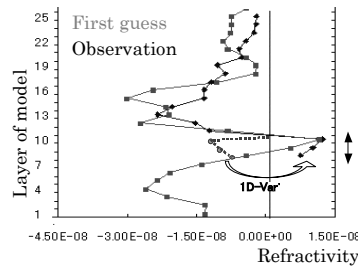


Fig.1: Schematic illustration for signs estimation of vertical gradient of refractivity ( $M$ ).

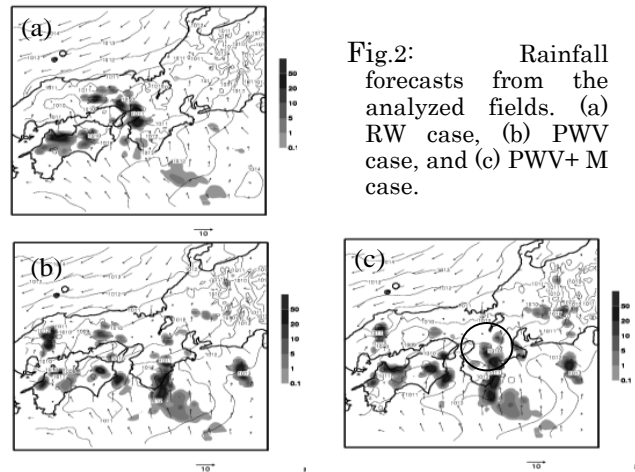


Fig.2: Rainfall forecasts from the analyzed fields. (a) RW case, (b) PWV case, and (c) PWV+M case.

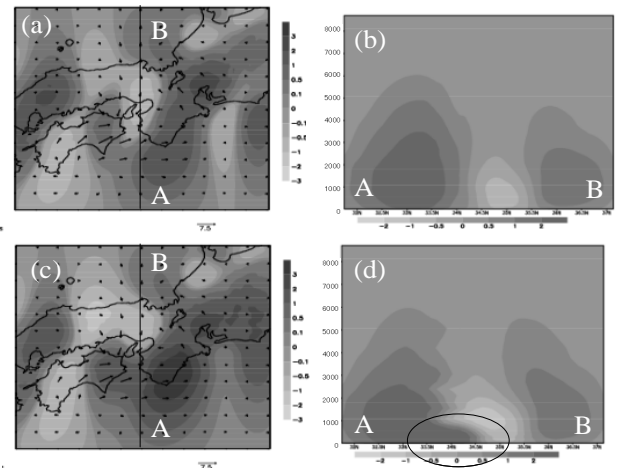


Fig. 3: Increment of water vapor at the lowest level. (a) PWV case and (c) PWV+M case. (b) and (d) Vertical cross-sections of the increment of water vapor along the lines in (a) and (c).