DATA ASSIMILATION EXPERIMENTS IN NERIMA HEAVY RAINFALL
- HOW USEFUL ARE DOPPLER RADAR RADIAL WIND AND GPS-DERIVED WATER VAPOR? -

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1. Introduction

In summer, the thunderstorms that developed in the urban area sometimes cause the heavy rainfall. The generation and development of the thunderstorms are affected by the low-level convergence and the moist air supply. Radial wind (RW) data from Doppler radars and water vapor data from GPS (Global Positioning System) ground receivers are useful for capturing mesoscale wind and moisture fields, respectively. However, their benefits for mesoscale numerical weather prediction have not been well demonstrated so far.

In this study, to investigate the impacts of the RW that was observed by two Doppler radars and the GPS-derived water vapor, data assimilation experiments on the heavy rainfall event that occurred in Tokyo on 21 July 1999 (Nerima heavy rainfall) were performed by the 4-dimensional variational data assimilation (4d-Var DA) system for the Mesoscale model of the Japan Meteorological Agency (JMA). RW is expected to have a great impact, because it can provide the information of the horizontal wind in the small precipitation region where the horizontal wind can not be retrieved by the simplified VVP method and so on. The GPS-derived water vapor data used in this study are PWV and Slant water vapor (SWV). SWV is the water vapor amount from the GPS satellite and GPS receivers. Because the slant path of this data contains the information of the three dimensional distribution of water vapor, it is expected that the moist air supply at lower levels will be better reproduced by assimilating SWV data.

2.'Nerima heavy rainfall'

On 21 July 1999, the Baiu front crossed the northern part of the Japan and moved southward slowly. On the southern side of the Baiu front, the convections that had a scale of several ten kilometers were generated at the northeastern part of the Kanto area (the central part of the Mainland of Japan) at 15JST. The convections moved southeastward, and the intense hourly precipitation of 111.5 mm/hour was observed at Nerima, Tokyo at about 16JST. When the intense convections were developed, the easterly and northerly flows were generated in the precipitation regions (Fig.1). These flows and the southwesterly inflow from the south converged on the southern edge of the precipitation regions. Although this precipitation began to decay from 17JST, it lasted until 21JST over the southern part of the Kanto area.

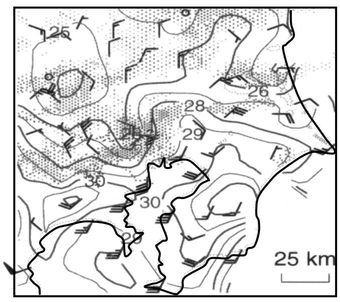

Fig.1 Horizontal distribution of precipitation region (shade), surface temperature (solid line) and horizontal wind at 16JST 21 July 1999.

3. Results of the data assimilation experiments

The precipitation regions moved southward, and came into the observation ranges of the Doppler radars at 15JST. Thus, the assimilation of the RW of the Doppler radars and GPS-derived water vapor was performed with the data from 9JST to 15JST. The analyzed fields at 15JST that were estimated by 4d-Var DA were used as the initial conditions of the numerical prediction. The impacts of the data assimilation of RW, PWV and SWV were investigated by comparing with the predicted hourly precipitation from the analyzed fields of 15JST and the observed one.

When the assimilation was not performed, no precipitation region was generated at the southern part of the Kanto area (Fig. 2a). When the conventional meteorological data was assimilated (Fig. 2b), the southeasterly flow in the precipitation region was reproduced. However, it did not last for long time. The scattered small precipitation regions were generated in the mountainous region far from Tokyo, and no precipitation region appeared at the Kanto area.

When PWV or SWV data was assimilated (Fig. 2c or 2d), the low-level inflow became more humid. The humid inflow generated the precipitation along the low-level convergence zone. However, in both experiments, the position of the precipitation was shifted eastward from the observed one. It is evident that the precipitation regions coincided with this convergence zone. The error of the precipitation position was due to the inaccurate prediction of the wind fields. When the RW was assimilated (Fig. 3a), the northerly wind was reproduced at the northwest of Tokyo. Because the northerly flow intensified the low-level convergence, the precipitation region was generated. The position of this precipitation region was almost the same as the observed one. However, the generation of the precipitation was delayed by one hour, because the low-level inflow from the south was less humid than the observed one.

When GPS-derived water vapor and RW were added to the assimilation data simultaneously (Figs. 3b and 3c), there were large improvements in the position and extent of the

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precipitation region. In both experiments, the positions of the predicted precipitation regions were closer to that of the observed one. In addition, the extent of the precipitation region increased substantially. This is due to the changes in the wind field. The assimilation of RW data produced the northerly flow northwest of Tokyo, which intensified a low-level convergence. This convergence generated the precipitation where the observed heavy rainfall occurred. This precipitation lasted until 21JST (FT=6hour), and the position and extent of the precipitation region were well predicted until 21JST.

The benefit of SWV data was also investigated by comparing the vertical distribution of water vapor. On the inflow side of the heavy rainfall (i.e. southern side), the water vapor above the height of 1km was reduced when SWV data was assimilated (Fig.4). The lower-layer water vapor was also reduced when PWV data was assimilated. The vertical water vapor distribution of the former experiment was more realistic, although the positions and appearance times of the precipitation regions were almost the same.

4. Summary

The assimilation of RW data of the Doppler radar and GPS-derived water vapor data was performed and their impacts on the prediction of the precipitation were investigated. When both data were used as the input data of 4d-Var DA, the prediction of the precipitation was improved significantly. It was also shown that the SWV data has the potential of the reproduction of the vertical structure of the water vapor. In order to confirm the impact of SWV data, a further study is needed with more number of rainfall events.

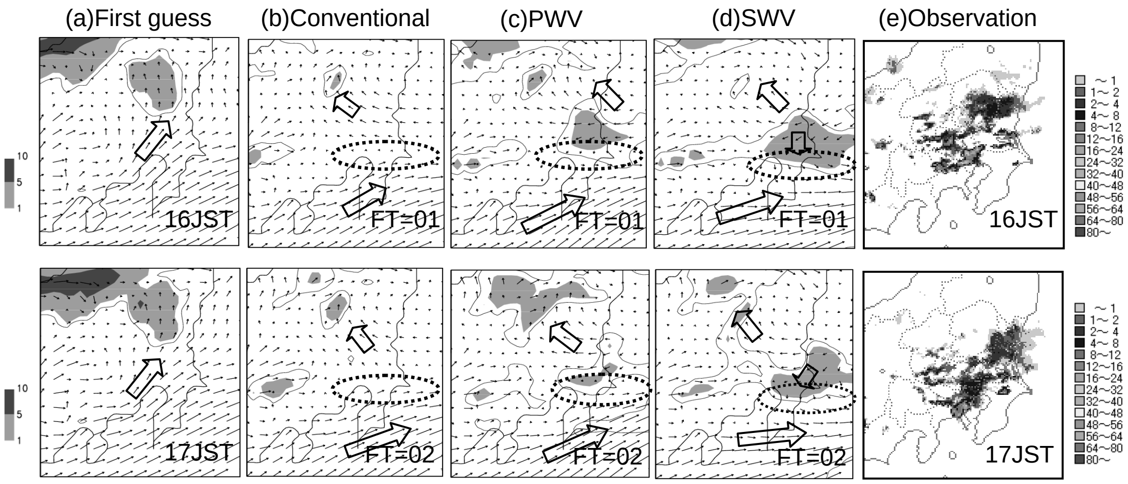

Fig. 2 Prediction of hourly precipitation and horizontal wind at 0.5 km from 15JST, July 21, 1999. Upper row is 1 hour forecast valid at 16JST and lower row is 2 hour forecast valid at 17JST. From left to right columns are (a) the first guess fields, (b) prediction from 4d-Var DA of the conventional data (rawinsonde etc), (c) prediction from 4d-Var DA with PWV added, (d) prediction from 4d-Var DA with SWV added, and (e) the rainfall intensity observed by JMA radars. Contour lines indicate hourly precipitation and arrows are horizontal wind at 0.5 km. Large arrows show major flows.

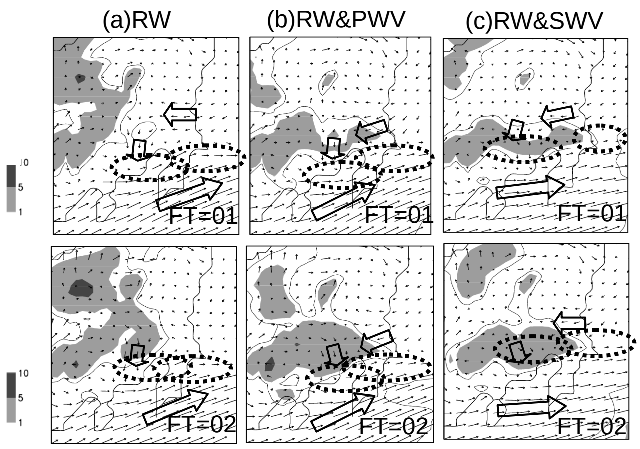

Fig. 3 Same as Fig. 2 but for, (a) prediction from 4d-Var DA with RW added, (b) prediction from 4d-Var DA with PWV and RW added and (c) prediction from 4d-Var DA with SWV and RW added from left to right columns.

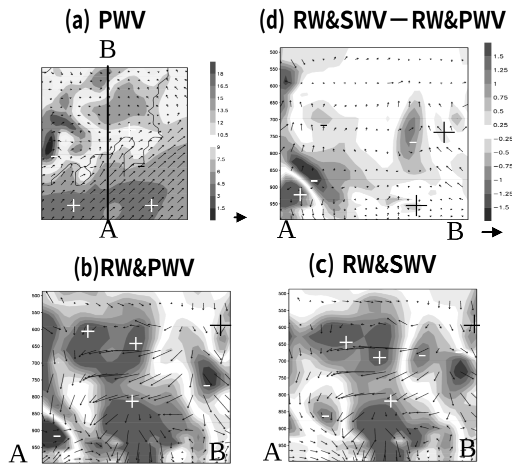

Fig. 4 (a) PWV fields of the first guess. A line A-B is the position where cross sections cut across. (b) and (c) are vertical cross-sections of the difference of specific humidity of ‘RW&PWV’ and ‘RW&SWV’ from the first guess. (d) is the vertical distribution of the difference between these experiments.