Synergistic effect of the assimilation of Radio occultation data and ground-based GPS data

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1. Introduction

Radio waves transmitted from GPS satellite are delayed by atmosphere. Vertical profiles of refractivity and precipitable water vapor (PWV) are obtained from radio wave data received by low earth orbit satellites (LEO) and by GPS receivers on the ground. Because these data have the information of atmosphere, the assimilation methods for these data have been developed so far, and their impacts on heavy rainfalls or typhoon developments have been reported (e.g. Seko et al, 2004; Seko et al. 2009).

Seko et al. (2004) reported the impacts of GPS-derived water vapor data and radial wind of Doppler radar on the heavy rainfall. According to their results, PWV influenced the generation time of the rainfall region. When the slant water vapor (SWV) that is water vapor amount along the path from ground-based GPS receiver to GPS satellite were used, instead of PWV, water vapor distribution became more realistic one because slant water vapor data contains the information of vertical positions. As for vertical profiles of refractivity, they are estimated from the GPS radio occultation data (RO). Seko et al. (2009) reported the impact of RO data by using the method in which the path data from LEO to GPS satellite was assimilated in consideration of the vertical correlation of the observation error. They also showed that the intense rainfall was well reproduced by the assimilation of the occultation data.

Although the impacts of the RO data and PWV/SWV data were so far, synergistic effect has been not investigated. RO is high-resolution data in vertical direction. However, there is little information in the horizontal direction because the average of the path is assimilated (Fig. 1). On the other hand, SWV/PWV is high-resolution data in the horizontal direction. However, they have little information in the vertical direction. Thus, simultaneous assimilation of both data is expected to improve water vapor distribution because the information of both directions are used. In this study, we focus on the refractivity data of CHAMP (Challenging Mini-satellite Payload for Geoscientific Research and Application) and GPS-derived SWV to investigate the synergistic impact of these data.

2. Methodology

Figure 2 shows the rainfall amount from 12 JST to 15 JST 16 July 2004. On 16 July, intense rainfall band extending from west to east over the northern Japan developed. The methods used in this study are same as Seko et al (2004) and Seko et al (2009). The path between a GPS satellite and CHAMP passed south of this intense rainfall band. The lowest point of the path that was referred to as a tangent point reached the height of 2.8 km. When observed refractivity was compared with the first guess, the refractivity of the path data was larger below the height of 5 km (Fig. 3). The intensification of the rainfall is expected when RO data is assimilated. Figure 3 indicates the positions of ground-based GPS receivers. The GPS data of which receivers' heights exists within ±50 m were used to reduce the error caused by the assumption for the correction of height difference.

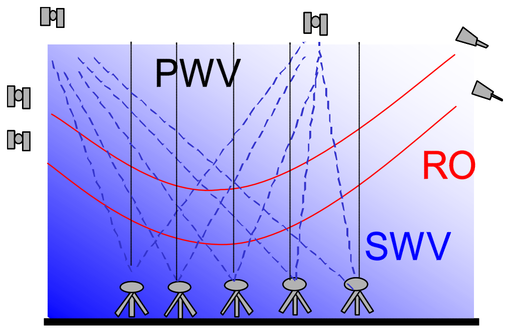

Fig.1 Schematic illustrations of assimilations of RO and SWV data.

3. Results of assimilation of RO and SWV data

Figure 5 indicates the results of the assimilation. When RO data was assimilated, the rainfall intensities over the northern Japan were intensified. However, the horizontal distribution extended more widely than observed one. When the SWV was assimilated, the rainfall region became similar to the observed one. However, the intensification remained weaker than the observed one. When RO and SWV were assimilated simultaneously, the shape and intensity were well reproduced. These improvements of the horizontal distribution and intensity of the rainfall band indicate that both data are needed to improve the horizontal distribution and intensity of the rainfall (the synergistic effect).

Next, the increments of the water vapor are explained. The assimilation of RO enhanced the contrast of the vertical distribution. Namely, water vapor of the lower layer near the rainfall band was more increased. The assimilation of SWV data intensified the horizontal contrast of the increment of the water vapor. The water vapor north of the rainfall region was decreased, while water vapor near the rainfall region was increased. This modified water vapor made the rainfall distribution similar to the observed one. When both data were assimilated, the contrast of increment was intensified in both directions.

Acknowledgements: CHAMP data and GPS data were provided from the GFZ and GSI. The authors would like to express the appreciation to GFZ and GSI.

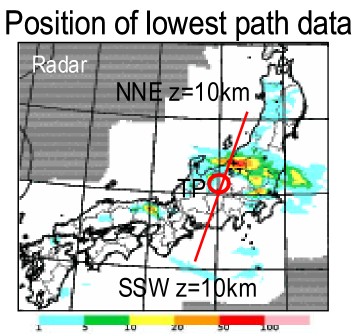

Fig. 2 Rainfall region at 15-18 JST 16 July observed operational radars. Red circle and line indicate the positions of a tangent points and the lowest path below 10 km.

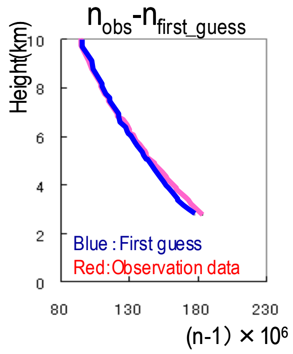

Fig. 3 Vertical profiles of observed refractivity at the tangent point and the corresponding first guess value.

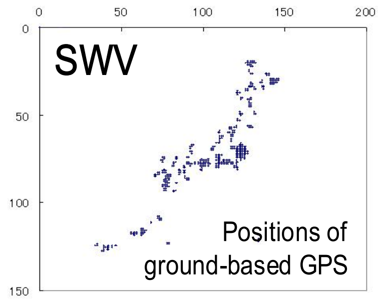

Fig. 4 Horizontal distribution of GPS receivers. GPS data of which receivers' heights exist within ±50 m are used in this study.

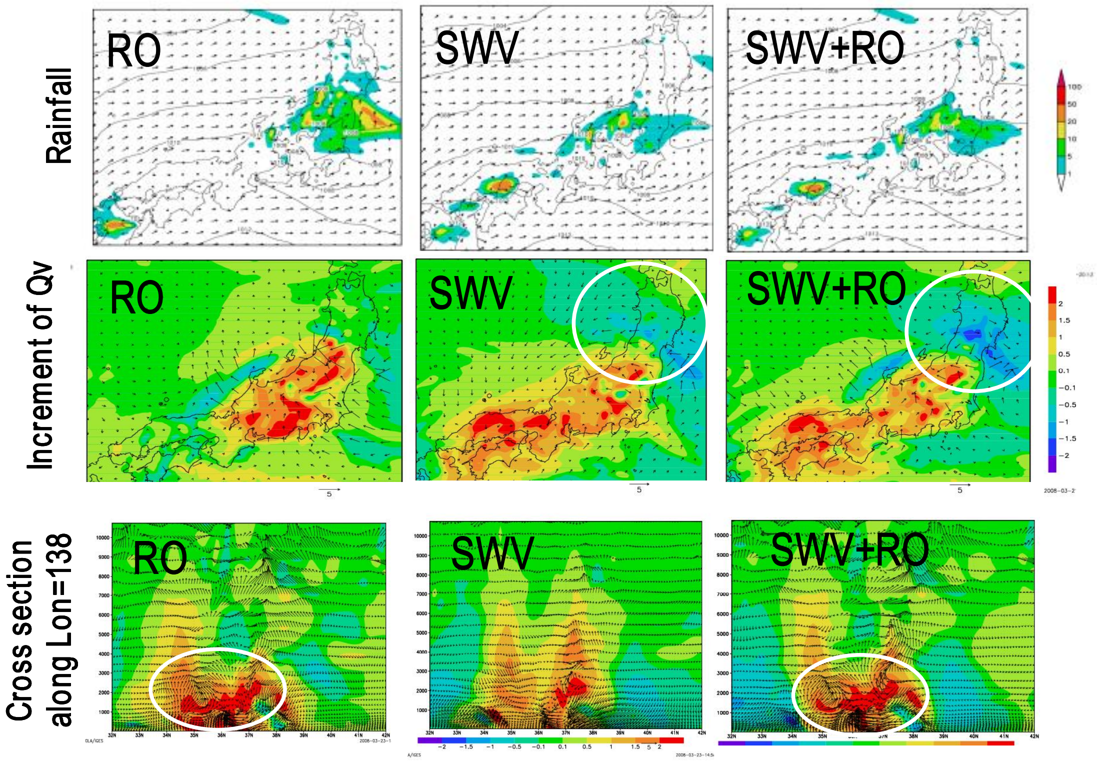

Fig. 5 (Upper panels): Rainfall distribution predicted from the initial fields obtained by assimilation of RO, SWV and both data. (Middle panels) Horizontal distributions of the increments of water vapor and horizontal wind at the lowest layer of the model. (Lower panel) Vertical cross sections of the increments of water vapor, northerly and vertical wind along the longitude of 138 degree.