Observation System Simulation Experiments of Quasi-Zenith Satellite

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1. Introduction

Radio waves transmitted from GPS satellites are delayed before arriving at GPS receivers due to water vapor in the atmosphere. GPS-derived Precipitable Water Vapor (PWV) (water vapor amount above a GPS receiver), which is obtained from the delays of the radio waves, improves rainfall forecasts when this data is assimilated into initial conditions of numerical forecasts. However, GPS-derived PWV does not always express the water vapor amount in the zenith direction (Zenith Water Vapor (ZWV)) because GPS satellites positions are not static. If the PWV obtained by satellites that stay around zenith direction, such as the Quasi-Zenith Satellite (QZS), can be used in the assimilation, this PWV is expected to be closer to ZWV and to improve the rainfall forecast. QZS stays not only around the zenith direction but also at low-elevation angles for long periods. Because the low elevation data has the information of anisotropy of water vapor distribution (namely, water vapor amounts along slant paths (SWV) with low elevation angles have the information of directions where humid air exists), SWV is also expected to improve rainfall forecasts. In this study, the potential of QZS, whose position stays around the zenith direction and in low-level elevations for long periods, of the improvements on rainfall forecasts is investigated by the observation system simulation experiments (OSSE).

2. Outline of the observation system simulation experiments

In the observation system simulation experiments, artificial data is obtained from the outputs of numerical models in which the phenomenon of interest was well reproduced (Truth data). The truth-derived artificial data (hereinafter, truth-derived data) is then assimilated into the fields in which the phenomenon of interest was not reproduced (First guess data). The impacts of the truth-derived data are investigated by checking how it improves the fields. In this study, impacts of QZS data on the assimilation of rainfall forecasts were investigated by adopting the nested Local Ensemble Transform Kalman Filter (LETKF, Miyoshi and Aranami, 2006) to a local heavy rainfall that developed in the Osaka Plain, Japan, on 5th September 2008.

a. Truth data and first guess data

Figure 1a shows the horizontal distributions of 1-hour rainfall amount and wind distribution at the height of 20 m at 17 JST 5th September 2008 (Japan Standard Time, 9 JST corresponds to 0 UTC), at which the local heavy rainfall just occurred. This distribution is the analyzed fields of the nested LETKF (ensemble member #007) obtained by the assimilation of horizontal wind of Doppler radar and GPS-PWV data that were actually observed by "the Geospatial Information Authority of Japan" (GSI). Because the position and int ensity of the rainfall and northwestward extension of the rainfall region were similar to the observed ones, this distribution was used as the truth data. Figure 1b shows the horizontal distribution of results of LETKF obtained by assimilation of only the conventional data. Although the weak rainfall region extended to northwest, intense rainfall region extended in north-south direction developed in the northwestern part of the rainfall region. Because the intense rainfall region was not reproduced, this data was used as first guess fields.

b. Truth-derived SWV and PWV data

From this truth data, GPS-derived SWV data (truth-derived GPS-SWV) and QZS-derived SWV (truth-derived QZS-SWV) were produced by integrating of water vapor along the path from GPS receivers to the satellites. The paths to the satellites were obtained on the assumption of the straight paths. In the estimation of truth-derived GPS-SWV data, the actually observed azimuth and elevation angles were used. As for truth-derived QZS-SWV, QZS position that is expected to be observed in Japan was used.

In the OSSE, not only the truth-derived SWV data, but also the truth-derived PWV was assimilated. The

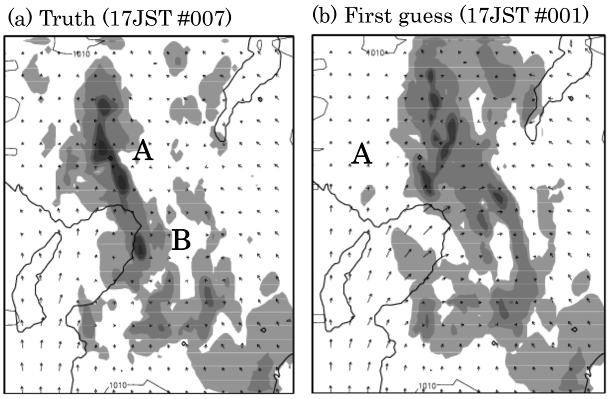

Fig. 1. Horizontal distributions of rainfall (shaded regions) and surface wind (vectors) of (a) truth data and (b) first guess data.

truth-derived GPS-PWV data of each GPS receivers were obtained by converting the truth-derived GPS-SWV into the values of the zenith direction and by applying a gradient mapping function to them (Fig. 2a). The QZS-PWV data was estimated by the same method of the GPS-PWV data except that the QZS-SWV was added to the GPS-SWVs in the estimation of PWV (Fig. 2b).

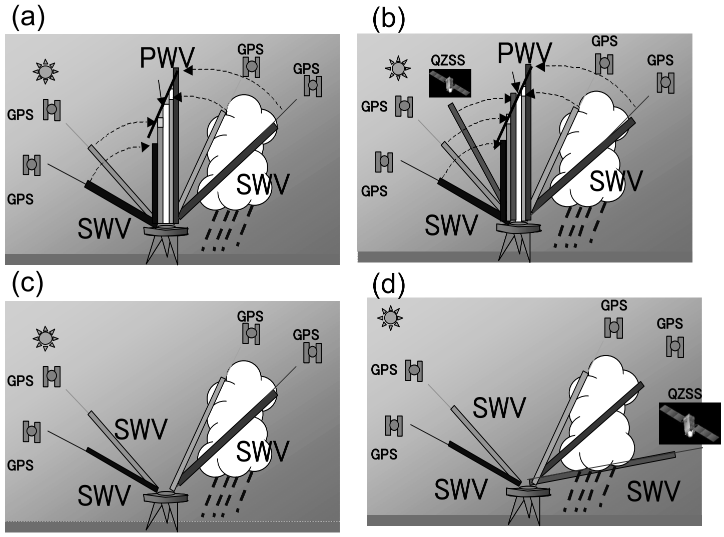

Fig. 2. Schematic illustrations of the assimilation data of (a) GPS-PWV and (b) QZS-PWV, and (c) GPS-SWV and (d) GPS-SWV and QZS-SWV.

3. Impacts QZS-derived PWV and SWV data on the local heavy rainfall

In the experiments on the PWV data, GPS-PWV and QZS-PWV were assimilated from 09 JST to 15 JST of 5th. As for QZS- SWV, the QZS data whose elevation angles were more than 60 degree were used. Figure 3 shows the analyzed rainfall regions obtained by assimilations of GPS-PWV or of QZS- PWV. When GPS-PWV or QZS-PWV was assimilated, the rainfall distribution became closer to the truth. Namely, the intense rainfall region (indicated by **A** in Fig. 3) had a branch extending southeastward, and the intense rainfall region south of **A** was also reproduced (indicated by **B** in Fig. 3). When QZS-PWV was assimilated, the intense rainfall **A** is more intensified and **B** became weaker, compared with those that were obtained by assimilation of GPS-PWV. These distributions obtained by the assimilation of QZS-PWV were more similar to the truth data. These results indicate that QZS- PWV data has the potential to improve the rainfall forecasts, though the impact was not larger because many GPS-derived data was already assimilated.

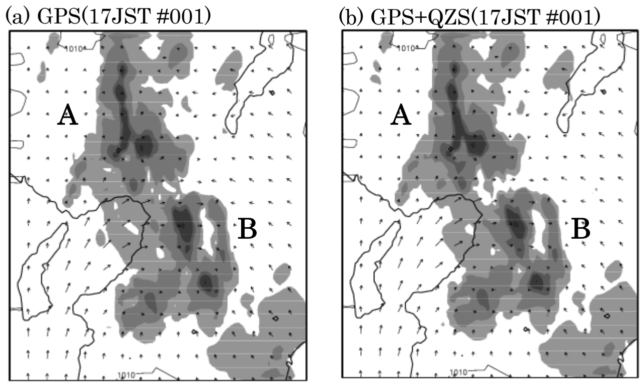

Fig. 3. Rainfall and horizontal wind distribution at 17 JST when (a) GPS-PWV and (b) QZS-PWV were assimilated.

Impacts of the low-elevation data of QZS were shown in Fig. 4. Although the reproduced distribution was different from those of Fig. 3, the rainfall distributions became similar to the truth when GPS-derived or QZS-derived SWVs were assimilated. When QZS-derived data were added, the intense rainfall **A** is more intensified and **B** became weaker. Namely, the rainfall regions became more similar to the truth data. This result also indicates that QZS-derived SWV data also has the potential to improve the rainfall forecasts.

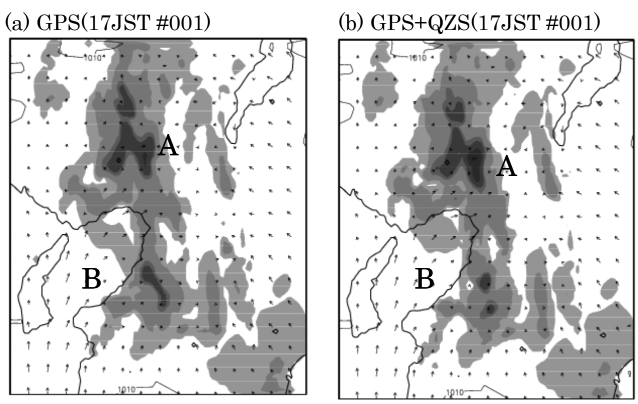

Fig. 4. Same as Fig. 3 except assimilations of (a) GPS-SWV and (b) QZS-SWV and GPS-SWV.

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Reference

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