

Impacts of RO Data on Rainfall Forecasts of Heavy Rainfalls and Typhoon Developments

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Abstract

Radio waves (RWs) that are transmitted from satellites of the Global Navigation Satellite System (GNSS) are delayed and bent by atmosphere in which the paths of the RWs pass before reaching low earth orbit (LEO) satellites. In radio occultation (RO) observations of GNSS satellites, information of water vapor and temperature is obtained from the bending angle or delay of the RWs. In this presentation, the results of data assimilation (DA) experiments of GNSS RO data in the Meteorological Research Institute (MRI) and the recent usage progress of GNSS RO data in the operational global DA system of the Japan Meteorological Agency (JMA) are explained.

Keywords : Radio Occultation, Data Assimilation, Rainfall Forecast, Heavy Rainfall.

1. Introduction

In the Japan, humid airflows supplied from the sea often cause heavy rainfalls. Middle-level dry layers also enhance heavy rainfalls, because they increase convective instability. Thus, water vapor distribution over the sea and its vertical profiles are needed to increase accuracy of the numerical forecasts. Global Navigation Satellite System (GNSS) radio occultation (RO) data were used as data assimilation (DA) data because it provides vertical profiles of refractivity. To show the impact of the RO data on the numerical forecasts, it was applied to events of heavy rainfalls and typhoons. Apart from RO, ground-based GNSS data, such as precipitable water vapor (PWV) or slant water vapor (SWV) (Fig. 1), are also expected to improve water vapor distributions in the analyzed fields. To show synergy effects of RO and ground-based GNSS data, simultaneous assimilations of these data was also performed. RO data was also expected to be a useful data that improves temperature distributions. The 'Yamase' phenomenon, in which cold airflows cause stratus clouds east of the northern Japan, was also adopted as a target of RO DA experiments.

2. Data assimilation experiments of RO data

DA methods of RO data and PWV, SWV have been developed so far (Seko et al., 2010; Seko et al., 2004), and their impacts on rainfall forecasts were investigated with the Mesoscale 4-dimensional Variational DA system (Meso-4DVar) of the Japan Meteorological Agency (JMA). These methods were applied to a heavy rainfall that occurred at the northern Japan on 16 July 2004 (Seko et al., 2010). Figures 2-4 show the distributions of predicted rainfall regions and increments of the analyzed water vapor fields. When PWV data were assimilated, water vapor in the rainfall region was increased and on the northern sides was decreased, and then

the shape of the rainfall region became similar to the observed one. However, the reproduced rainfall amount remained smaller than the observed one. When the RO data were assimilated, the low-level water vapor was increased so that the rainfall amount was largely increased. When PWV and RO data were assimilated simultaneously, low-level water vapor in the rainfall region and on its southern side was increased, and then shapes of rainfall region and the rainfall amount became similar to the observed ones.

RO data was also used to investigate impacts on the development of a tropical cyclone (TC), 'Usagi' that occurred in July 2007 (Kunii et al., 2012). Impacts of the RO refractivity are compared against the JMA's global analysis (GA) by conducting forecasts using the JMA non-hydrostatic model (Fig. 5). When the GA was used for the initial field, no typhoon was formed in the forecast model. In contrast, when the GA was replaced by the Meso-4DVar analysis (MA), the generation of the TC was successfully simulated. When RO data was assimilated, the intensity forecast was significantly improved (MA_RO). The results indicate that RO data is beneficial for the TC forecast.

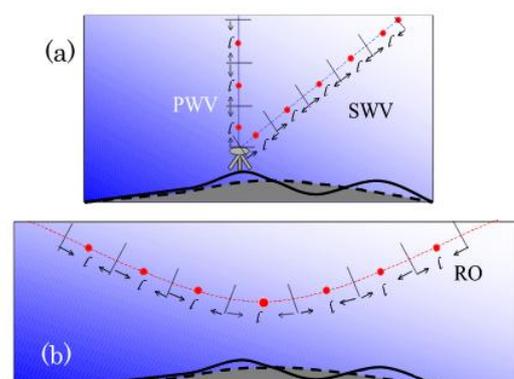


Fig. 1. Schematic illustrations of the observation operators of (a) PWV and SWV, and (b) RO data. Thick solid and broken lines indicate actual topography and model topography, respectively.

Third target is a cold weather (Yamase) in summer over the northeastern Japan, which is produced by a cool polar maritime air mass that develops over the North Pacific, including the Bering Sea and the Sea of Okhotsk. It usually accompanies boundary layer clouds (Yamase clouds) on east of the northern Japan. Yamase also influences the agricultural crops. It is needed to predict Yamase accurately. In this study, RO data was assimilated by the nested Local Ensemble Transform Kalman Filter (LETKF) system (Miyoshi and Aranami, 2006). When conventional data of the JMA was assimilated by the LETKF system, Yamase clouds were reproduced in all of the ensemble members. However, impacts of RO data on the Yamase clouds remained relatively small because the positions of RO data were far from the Yamase clouds. The number of Yamase events to which RO assimilation experiments are applied should be increased in order to show the impact of RO data more clearly.

3. Recent usage progress of RO data in the operational global DA system of the JMA

The JMA began assimilating RO refractivity data into its operational global NWP system on March 22, 2007, and revisions to this process were implemented in the system on December 18, 2012. A bias correction procedure had been implemented in the preprocessing of RO data due to the presence of systematic biases in the tropical and polar regions (Owada et al. 2012). As the biases were reduced via updates of the observation operators, the correction procedure was eliminated. Observation system experiments for the new assimilation configuration, which includes these updates, showed that analyses and forecasting of temperature and sea surface pressure were improved, especially in the Southern Hemisphere. Most of the improvements were brought about by the observation operator updates.

Acknowledgements

The CHAMP data and ground-based GPS data were provided from the GFZ and GSI. The COSMIC refractivity we used was calculated at the COSMIC Data Analysis and Archive Center.

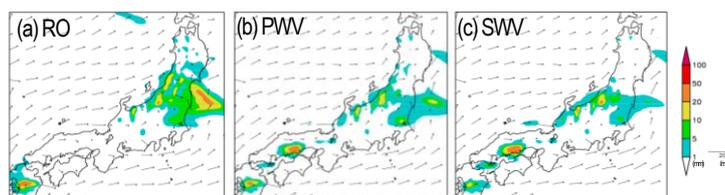


Fig.2 Reproduced 3-hour rainfall of forecast time from 0 to 3 hours reproduced from the analyzed fields. Valid time is 15 to 18 JST 16 July 2004.

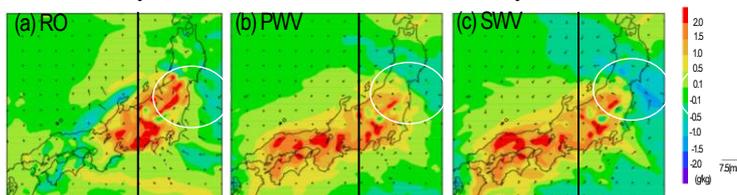


Fig.3 Horizontal distributions of the difference of water vapor from 'CNTL' at the height of 21 m. Black lines indicate the position of the vertical cross sections of Fig. 4.

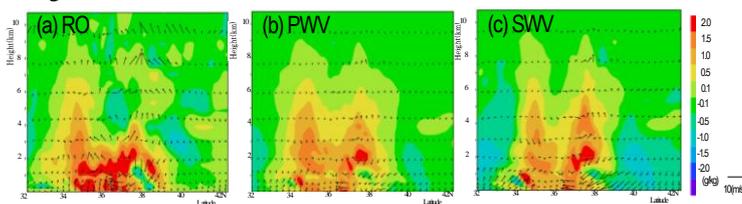


Fig.4 Vertical distribution of the difference of water vapor from 'CNTL' at the latitude of 138 deg. Vectors represent horizontal wind direction and velocity.

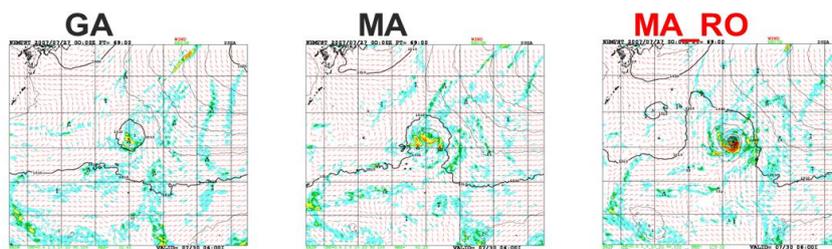


Fig.5 Distributions of sea-level pressure (contour, hPa), surface wind (vector, ms^{-1}), and 3 h accumulated precipitation (color, mm) at 1800 UTC 29 July 2007 predicted by NHM using different initial fields. (a) GA, (b) MA, and (c) MA_RO.

The Meso-4DVar system was developed by the Numerical Prediction Division of the JMA.

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