Assimilation of GNSS RO data into JMA's mesoscale NWP System

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1. Introduction

The Global Navigation Satellite System (GNSS) forms a very important part of today's meteorological observation network. GNSS Radio Occultation (RO) data exhibit fairly uniform distribution worldwide, in contrast to data from radiosondes and aircraft, producing vertical profiles of atmospheric parameters that can be assimilated into numerical weather prediction (NWP) systems without bias correction. The Japan Meteorological Agency (JMA) has been assimilating RO data into its global NWP system since March 2007, and began using GNSS RO refractivity data in its operational mesoscale NWP system in March 2016. This report outlines the impact of GNSS RO data on JMA's mesoscale NWP system.

2. Methods

In JMA's mesoscale NWP system, RO data from GRACE-A, GRACE-B, Metop-A, Metop-B, COSMIC, TerraSAR-X and TanDEM-X are assimilated after application of gross-error quality checking. The one-dimensional observation operator in the Radio Occultation Processing Package (ROPP) is used for data assimilation.

Assimilation in consideration of bending angles often produces better performance than that based on refractivity data, as the latter is derived from bending angle observation. However, a greater wealth of upper-layer NWP model information is necessary for bending angle assimilation. If the NWP model top is under 10 hPa, the use of refractivity profiles is reasonable (Healy 2008). The model top in the mesoscale NWP system is about 40 hPa. Comparison of experiment results regarding assimilation of RO refractivity and RO bending angle data showed slightly better improvement with the former, while improved first-guess temperature profiles were seen with both, especially in the upper troposphere. These results suggest that the upper-layer information of the current mesoscale model may be insufficient for bending-angle assimilation due to the limited model-top height. Accordingly, RO refractivity data are assimilated into the mesoscale NWP system.

3. Impacts on the mesoscale NWP system

Observing system experiments were performed over periods of a month in each of summer 2015 and winter 2014 – 2015 to evaluate the impacts of RO refractivity data in the mesoscale NWP system. The configuration of the control experiment (CNTL) was the same as that of the operational system, and additional use of RO refractivity data was implemented in the test experiment (TEST). As shown in Figure 1, changes in the normalized standard deviation of the first-guess departure indicate consistent improvement in the temperature field. Figure 2 shows profiles of mean errors (ME) and root mean square errors (RMSE) against the radiosonde observation of geopotential height. The ME and RMSE reductions are particularly remarkable around the upper troposphere. This improvement covered a lead time of around 21 hours.

Based on these findings, RO refractivity data were assimilated into JMA's operational mesoscale NWP systems as of 24 March 2016.

References

Healy, S., 2008: Assimilation of GPS radio occultation measurements at ECMWF. *Proceedings of the GRAS SAF Workshop on Applications of GPS Radio Occultation Measurements, ECMWF, June 16 – 18.*

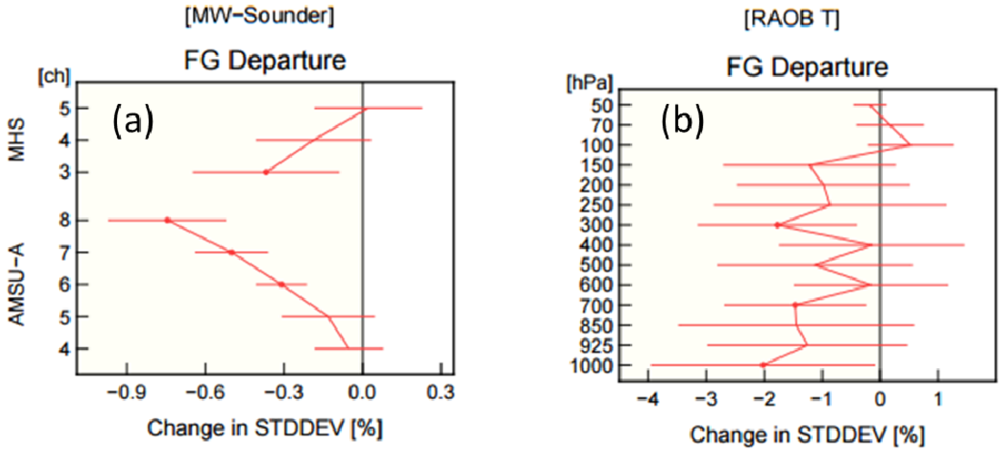

Figure 1: Normalized changes in the standard deviation of first-guess departures from (a) AMSU-A and MHS and (b) radiosonde temperature observation in the summer 2015 experiment. Negative values represent improvement. The horizontal axis indicates normalized STDV differences, error bars represent a 95% confidence interval, and red dots represent statistical significance.

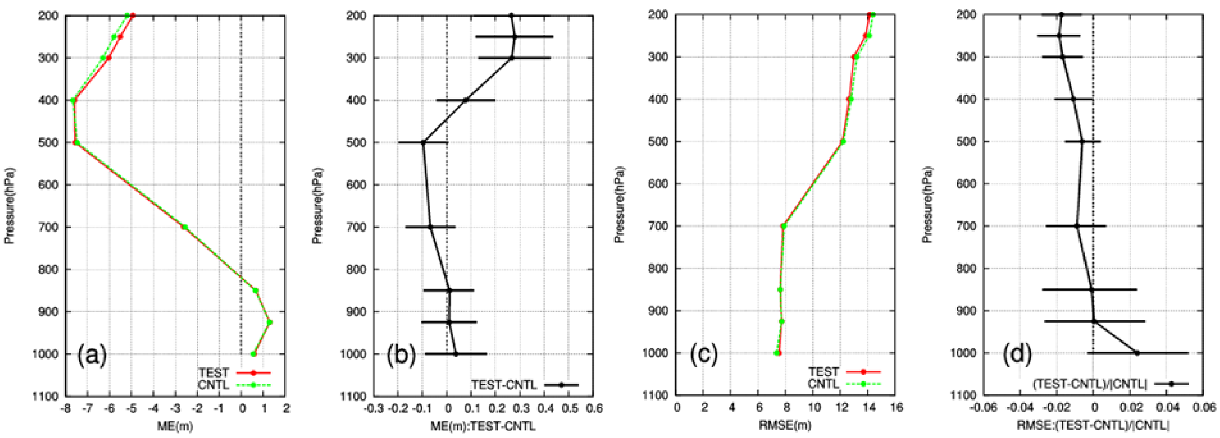

Figure 2: Fits to RAOB for 21-hour forecasting of geopotential height from the summer 2015 experiment. (a) Vertical profile of ME, (b) TEST-CNTL of ME, (c) vertical profile of RMSE, (d) rate of RMSE change ((TEST-CNTL)/|CNTL|). The red and green lines represent TEST and CNTL, respectively, and error bars represent a 95% confidence interval.