Data Assimilation Experiments of Radio Occultation Refractivity Data by using a Mesoscale LETKF System

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1. Introduction

An assimilation method of radio occultation (RO) data for a mesoscale Local Ensemble Transform Kalman Filter (LETKF) (Miyoshi and Aranami, 2006) system has been developed in this study. There are the following two difficulties in the assimilation of RO data: (1) An assumption of uniform distribution of refractivity, which is used in the estimation of refractivity profiles at tangent points, is not always valid, and (2) path-averaged data is difficult to be assimilated by LETKF system because data assimilation using LETKF is conducted by each grid point. To solve these difficulties, (1) the path-averaged refractivity was reproduced from the tangent point data and (2) path-averaged refractivity was divided into the refractivity at grid points around the path by using the ensemble average and spread obtained by LETKF system. This developed method was applied to the RO data observed on 29 July 2011. The assimilation result of this RO data indicated that the sign of the difference between the first guess and observation may be changed when the large mesoscale perturbation of refractivity exists around the tangent points, and that the temperature and water vapor are modified more widely when the path-averaged refractivity is assimilated.

2. Assimilation method of RO refractivity data

The assimilation method for a mesoscale LETKF system is composed of the following three steps: (a) a reproduction of path-averaged refractivity data, (b) a division of the path-averaged refractivity data into the grid-point refractivity around the path, and (c) data assimilation of the grid-point refractivity. Each step of the data assimilation is explained briefly in this section.

a. Estimation method of path-averaged refractivity data

The RO data at the tangent points is estimated by assuming the uniform distribution of atmosphere. Namely, RI_{tp3} is assumed to be equal to RI'_{tp3} in Fig. 1. However, this assumption is not always valid. Then, the path-averaged refractivity is produced from the tangent-point refractivity by using the following equation;

$$RI_{p1} = \frac{L_{3a}RI_{tp3} + L_{2a}RI_{tp2} + L_{1}RI_{tp1} + L_{2b}RI_{tp2} + L_{3b}RI_{tp3}}{L_{3a} + L_{2a} + L_{1} + L_{2b} + L_{3b}} \quad (1)$$

where RI_{tp} and RI_{p} are tangent-point refractivity and path-averaged refractivity, respectively. L is the path length in each layer.

b. Division method of path-averaged refractivity into grid-point refractivity around the path

The path-averaged refractivity data was divided into the grid point values (GPVs) around the path, because it is difficult to assimilate the path-averaged data by the LETKF. The refractivity around the path is estimated by using the assumption that the modification of grid point values from the ensemble mean profile of refractivity becomes wider when the spread of refractivity and absolute values of the coefficients between the first-guess grid-point refractivity and the first-guess path-averaged refractivity are larger (Fig. 2). The grid-point refractivity is estimated by changing the ratio of the modification in order that the path-averaged refractivity obtained from the modified values becomes equal to the observed value.

c. Data assimilation by using the mesoscale LETKF system

The horizontal grid interval and domain size of the mesoscale LETKF system of this study was 15 km and 1200 x 1200 km, respectively. The ensemble size was 12. The data assimilation using LETKF started at 00 UTC 29 July 2011. The conventional observation data of the

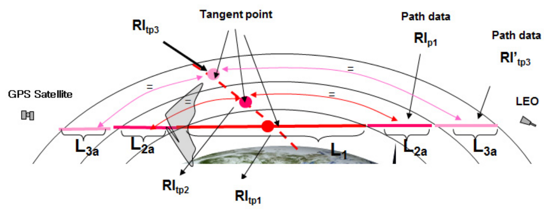

Fig. 1. Schematic illustration of the producing method of path-averaged data from the tangent-point data

Japan Meteorological Agency was used as assimilation data. The assimilation window was 6 hours and the conventional data was assimilated every hour. Three experiments were performed by changing the assimilation data. In CNTL, the conventional data was assimilated. The tangent-point refractivity data or the path-averaged refractivity data (the grid-point refractivity around the path) was added to the conventional data, and they were assimilated in TP and PA, respectively.

3. Results of data assimilation experiments

a. Vertical profiles of tangent-point and path-averaged refractivity data

In this study, FORMOSAT3 /COSMIC data was used as the assimilation data. The tangent point of this RO passed east of northern Japan at 15 JST 29 July 2011 and its path extended from southeast to northwest (Fig. 3). The profiles of tangent-point and path-averaged refractivity were compared with first guess values, which were produced from water vapor and temperature of the ensemble mean.

The path-averaged and tangent-point refractivity were increased as their tangent points were lower. The difference between them became larger because the path-averaged refractivity includes small values at upper atmosphere. The observed tangent-point refractivity was larger than that of the first guess, and the observed path-averaged refractivity was larger than that of the first guess. This result shows that the sign of the difference between the first guess and observation may be changed when there were mesoscale perturbations of refractivity around the tangent points.

b. Assimilation results of refractivity data

The overall cloud distributions of TP and PA were similar to that of CNTL because the difference between them was only one data. When the tangent-point and path-averaged refractivity profiles were assimilated, a small cloud region appeared east of northern Japan and the cloud regions indicated by an arrow in Fig. 4c became smaller, respectively (Fig. 4). These changes of the cloud regions were consistent with the differences between the observed and first guess data (Fig. 3). Figure 5 shows temperature distribution at the height of 10 km. There were large mesoscale perturbations over and around Japan. This distribution supports the change of the sign of difference. The different distributions of increment of temperature from CNTL (Fig. 6) show that the wider area along the path was modified when the PA data was used. The comparisons of observed and first guess profiles between TP and PA and the wider modified regions along the path indicate that PA data should be used in the mesoscale assimilation of RO data.

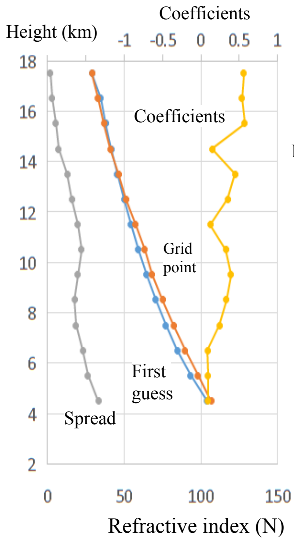

Fig. 2 Schematic illustration of producing method of grid-point refractivity from path-averaged data.

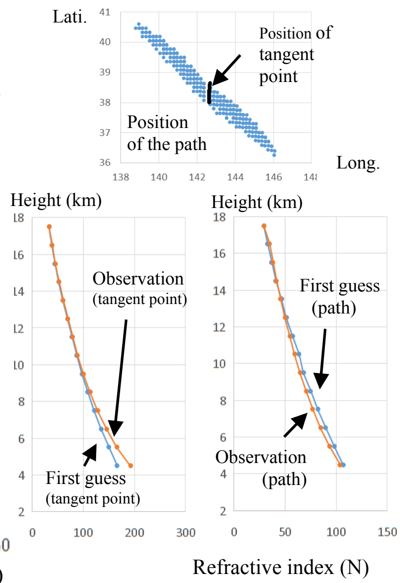

Fig. 3 Observed and first guess refractivity profiles and the positions of tangent point data and path-averaged data

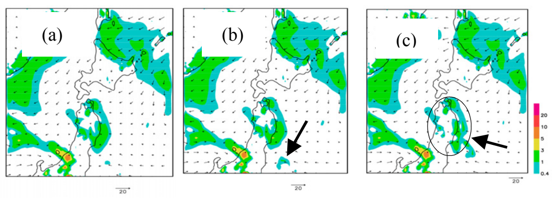

Fig. 4 Cloud distributions obtained in (a) CNTL and (b) TP and (c) PA.

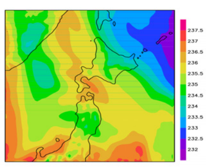

Fig. 5 Temperature of the first guess at the height of 10 km.

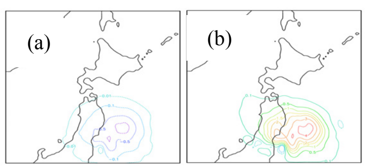

Fig. 6 Difference distributions of increment of temperature between CNTL and (a) TP and (b) PA.

Acknowledgements

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References

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