Data Assimilation Experiments using CHAMP Refractivity Data

Hiromu SEKO*[1], Yoshinori SHOJI[1], Masaru KUNII[1], Kazuo SAITO[1], Yuichi AOYAMA[2]
[1] Meteorological Research Institute, Japan Meteorological Agency, Tsukuba, Japan
[2] National Institute of Information and Communications Technology, Koganei, Japan

1. Introduction

It is well known that the abundant supply of low-level water vapor causes the heavy rainfalls and the middle-level water vapor also affects the development of the convection. Therefore the prediction of heavy rainfall events is expected to be improved when the vertical profile of water vapor is the assimilation data. The vertical profiles of water vapor can be obtained by rawinsonde. However, the position of rawinsonde data existed only on land except for the several points in oceans observed by meteorological vessels. Because Japan was surrounded by oceans, the humid airflow from the ocean often caused the heavy rainfalls. So, the observation of the vertical profile over the sea is desired. Recently, the refractivity profile estimated from the occultation data of a low earth orbit (LEO) satellite CHAMP launched by GeoForschungs Zentrum Potsdam (GFZ)) became available. In this study, the impact of the refractivity data on the prediction of the heavy rainfall is examined.

2. Numerical model and refractivity data observed by CHAMP

CHAMP receives the signal transmitted from the Global Positioning System (GPS) satellites which are rising from or sinking to the earth. Thus, the occultation data have the information along the path of the signal that slices the atmosphere. The general estimation procedures of occultation data are as follows; (1) the angle bended by the atmosphere is estimated from the temporal variation of the signal delay which was caused by the atmosphere, and then (2) the profiles of refractivity are estimated from the bending angles. So far, it was shown that the forecast was improved when the bending angle data was assimilated into the Global Spectrum Model of JMA (Ozawa et al. 2005). In this study, the refractivity profile of the data was assimilated into the Meso-scale Spectrum Model (MSM) of JMA by using the Meso-4DVar Data Assimilation System (Koizumi et al., 2005). MSM is the operational hydrostatic model to perform the short-range forecast of the severe weather. A grid interval of 10 km was adopted to resolve the mesoscale convective systems that caused the heavy rainfall.

We used the refractivity profile data estimated by GFZ. Firstly, the D-value, which is the difference of the observation and first guess value, was investigated. The field predicted by MSM was used as the first guess value. Figure 1 shows the position of CHAMP data in July 2004. The area indicated by blue rectangle is the domain of MSM. The average and RMS profiles are shown in fig. 2. The number of data was decreased at the lower layer and the bias and RMS are large below the height of 2km. Therefore, the data above the height of 2km were used as the assimilation data.

3. Impacts of RW and GPS-derived PWV

On 16 July 2004, Baiu front, which is the stationary front extending from China to Japan in the early summer, crossed the northern Japan. At about 12JST (Japan Standard tome, 9JST corresponds to 0UTC), the observation point, which was the nearest point to the earth on the path, passed through the Baiu front. The profiles of the refractivity are shown in fig. 3. The refractivity below the height of 4 km was larger than that of the first guess value. When these data were used, the water vapor below the height 2 km is expected to be increased.

Left panels of fig. 4 show the precipitation region observed by the convectional radars. Besides the precipitation along the western coast lines, the intense convective band associated with the Baiu front crossed the northern Japan. This convective

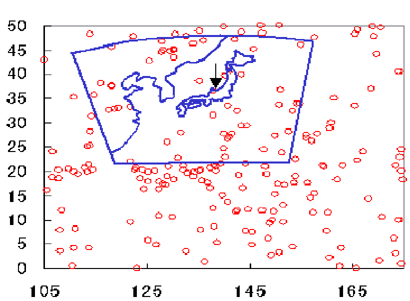

Fig.1 Distribution of CHAMP data in July 2004. Black arrow indicates the position of data that was assimilated into MSM

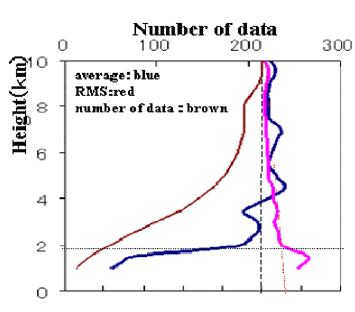

Fig.2 Vertical profile of average, RMS and data number of CHAMP data

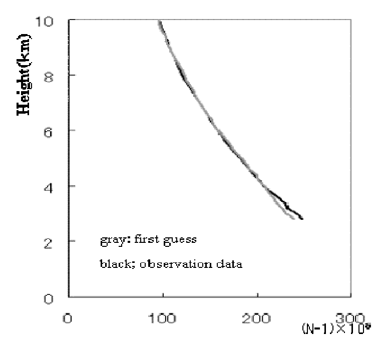

Fig.3 Vertical profile of CHAMP data and first guess data on 16 July 2004

* hseko@mri-jma.go.jp, phone +81-29-853-8640; fax +81-29-853-8649

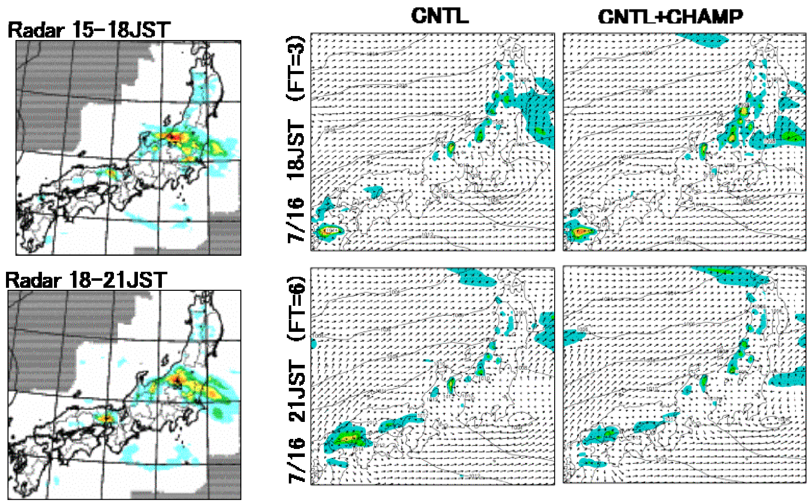

Fig.4 (Right) Observed precipitation and (center and right) precipitation predicated from the initial fields, into which (center) convectional data and (right) conventional data and CHAMP data were assimilated

band maintained without decaying until 21JST. Right panels are precipitation regions simulated by MSM. The initial condition of MSM was produced by the assimilation of the convectional data and the CHAMP-derived refractivity data. In this case, two assimilation windows from 9HST to 12JST and 12JST to 15JST were used. The analyzed fields of 15JST were used as the initial data. The observation error of the CHAMP-refractivity data was proportional to the RMS profile of the d-value. Its absolute value was determined by trial and error.

When the convectional data were assimilated, the position of precipitation region was shifted northward and precipitation intensity was weaker than the observed one. When the CHAMP data and convectional data were used, the precipitation region was more similar to the observed one and precipitation became more intense, although the precipitation was not maintained until FT=6hour in the both cases.

One of the merits of occultation data is the high vertical resolution. Additional experiments were performed by changing the vertical resolution of data and eliminating the lowest data. When the vertical resolution of the refractivity data was set to be 600 m that is three times of the aforementioned ones, the precipitation region became smaller. When the lowest data of the observed refractivity profile were further removed from the assimilation data, the precipitation region was more close to the only-conventional-data-assimilated case. This result indicates that (1) the optimal vertical resolution should be considered in the assimilation and (2) the lowest data are important for the prediction of the heavy rainfall because the data in low-layer have information of the low-level humid air supply.

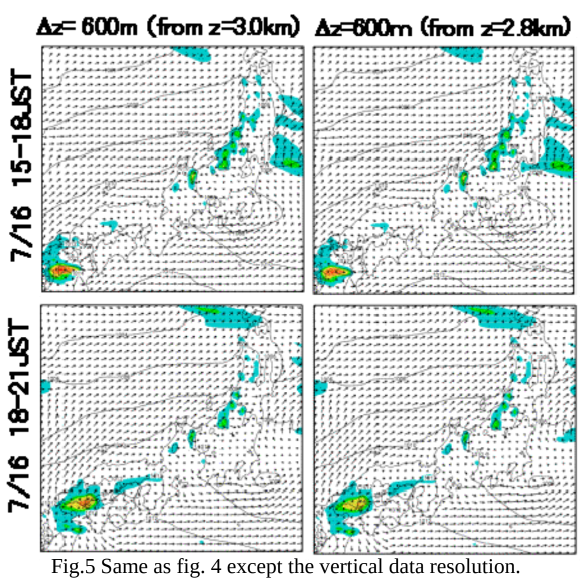

Fig.5 Same as fig. 4 except the vertical data resolution.

4. Summary

When the CHAMP-derived refractivity data was assimilated, the precipitation regions became similar to the observed ones and the precipitation intensity also became more intense. Thus, the CHAMP-derived data have potential to improve the rainfall forecast. To reduce the observation error, the number of data should be increased. The vertical correlation of observation error should be also investigated to make the best use of the vertical high-resolution data.

Acknowledgments

CHAMP data were provided from GFZ. The initial and boundary conditions of MSM were provided from the Numerical Prediction Division (NPD) of JMA. We also used MSM and Meso-4DVar system developed by NPD/JMA. We would like to thank Dr. Wickert of GFZ and members of NPD/JMA.

References

Koizumi, K,, Y., Ishikawa and T. Tsuyuki; Assimilation of Precipitation Data to the JMA Mesoscale Model with a Four-dimensional Variational Method and its Impact on Precipitation Forecasts, 2005; *Sola*,**1**,45-48.

Ozawa. E, Y. Sato, H., Tada and Y., Aoyama, Assimilation of space based GPS occultation data for JMA GSM, 2005, *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Models*,**36**, (in this volume)