Application Research of radiance data assimilation in precipitation prediction based on WRFDA

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Abstract: In order to test the effect of radiance data assimilation on precipitation prediction, the Weather Research and Forecasting (WRF) model data assimilation system (WRFDA) was used to assimilate AMSU radiance and radiosonde data. Compared background fields and analysis fields, both of radiosonde and radiance data assimilation had a certain effect on the wind and height fields, and radiance data assimilation had more impact on background fields than radiosonde's. In two assimilation experimentations, the analysis fields from radiosonde and radiance data assimilation were inputted into WRF model to predict precipitation, respectively. In control experiment, just the first guess field was inputted the WRF model to predict precipitation. The three prediction results were compared with precipitation observation. The results showed (1) the precipitation centre predicted from the control experiment was away from the actual centre, (2) the precipitation centre from the radiosonde data assimilation experiment could be predicted correctly, however the prediction precipitation was low, (3) the precipitation centre and amount from the radiance data assimilation experiment coincided with the real observation.

Key words： WRFDA, radiance data assimilation, precipitation prediction

1. Introduction

1.1 WRFDA

Data assimilation is the technique by which observations are combined with an NWP product (the first guess or background forecast) and their respective error statistics to provide an improved estimate (the analysis) of the atmospheric (or oceanic, Jovian, whatever) state. Variational (Var) data assimilation achieves this through the iterative minimization of a prescribed cost function. Differences between the analysis and observations/first guess are damped according to their perceived error. MMM Division of NCAR supports a unified (global/regional, multi-model, 3/4D-Var) model-space variational data assimilation system (WRFDA) for use. The system can assimilate conventional, radar and satellite observations.

1.2 Satellite radiance data and preprocess

The second satellite of the advanced NOAA (National Oceanic and Atmospheric Administration) polar orbiting satellite series, NOAA-16, was launched in 2000. The Advanced Microwave Sounding Unit (AMSU) on NOAA-16 consists of type A (AMSU-A) with 15 channels and type B (AMSU-B) with 5 channels, which are used to improve the vertical sounding of the atmospheric temperature and humidity and to monitor the surface parameters. In comparison with the conventional infrared and visible sounding units, the AMSU units have the unique ability to penetrate heavy clouds to sound the vertical structure of the atmospheric temperature and humidity (Weng and Grody, 2000).

AMSU radiance data are obtained from the L1d dataset of the National Satellite Meteorological center (NSMC). This dataset is created using the advanced TIROS Operational Vertical Sounder (ATOVS) preprocessing software package after decoding, calculating the orientation, scaling (Zhang, 2002). The AMSU-A and AMSU-B microwave radiance data of NOAA-16 on June 6, 2008 was used in the present study.

Quality control, bias correction and data thinning were implemented before the AMSU radiance data were assimilated. These process could be performed in WRFDA (Liu, 2008). The AMSU-A data at bands 5-15 and AMSU-B data at bands 3 -5 were selected in the assimilation experiments.

2. Numerical experiment of a heavy rainfall

2.1 The experiment designs

A heavy rainfall procedure lasted from June 5 to 7, 2008 in Guangdong province, China. There were 6 meteorological sites whose rainfall amount was more than 400mm, 15 more than 300mm, 78 more than 200mm. In order to understand the performance of the WRFDA in assimilating the ATOVS radiance data, three regional experiments (control experiment, radiosonde assimilation experiment and AMSU-A/B assimilation experiment) were carried out. The background fields are the 1° x 1° NCEP reanalysis data in each experiment, including the geopotential height, the temperature, the horizontal wind velocity and the relative humidity. The cost function, background error and observation error matrix were defined as default in the WRFDA system. The analysis domain was 18°-30° N, 100°-120° E with a resolution of 30 km in the horizontal and 28 layers in the vertical. The time window of WRFDA was set as three hours. The radiosonde and AMSU radiance data were assimilated at 0UTC on June 6, 2008, respectively, and the output (analysis field) of WRFDA was inputted into the WRF model to make a 24 hour precipitation forecast.

2.2 The impact of data assimilation on wind and pressure fields

2.2.1 Wind field

Figure 1 shows the increment of wind fields at 500 hPa from the radiosonde data assimilation experiment (a) and AMSU radiance data assimilation experiment (b). The assimilation results demonstrated that the two assimilation experiments significantly adjusted the background fields which would be inputted into the WRF model for rainfall forecast. The maximal increment of wind field from the radiosonde data assimilation was 6 m s^{-1}, however the maximal increment from the AMSU radiance data assimilation was 10 m s^{-1}. The increment of wind fields from the two assimilation experiments in Guangxi province were consistent; however the increment of cyclonic wind field was higher from the AMSU radiance data assimilation than radiosonde data assimilation. An increment of wind field at south-east direction happened at AMSU radiance data assimilation experiment which would result in increase of rainfall forecast.

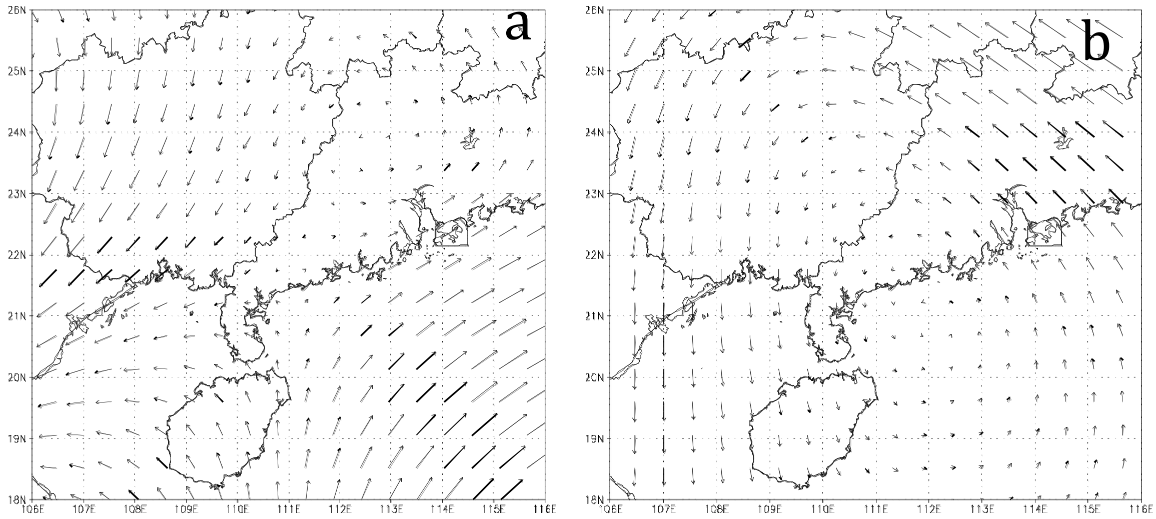


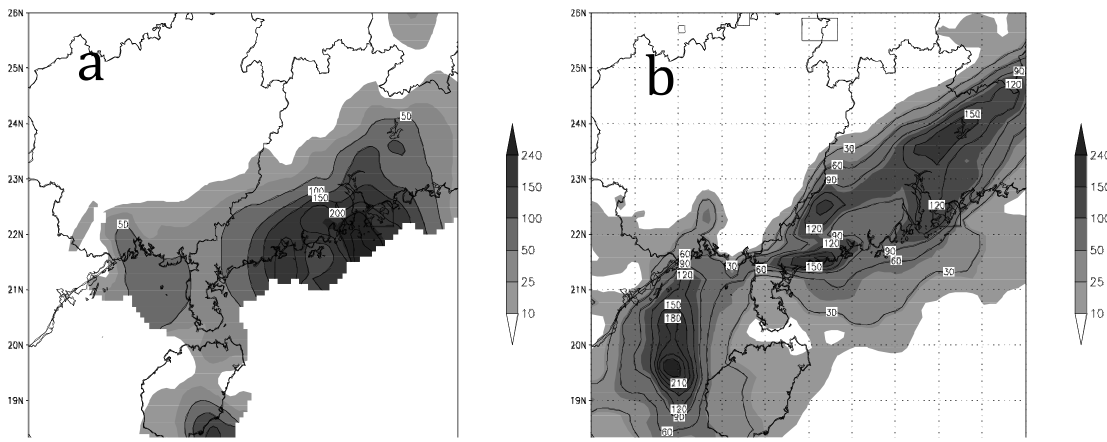
Figure 1 increment of wind fields from radiosonde (a) and AMSU radiance (b) data assimilation

2.2.2 Pressure field

The analysis fields were inputted into the WRF model to forecast the pressure fields of 800 hPa at 0UTC on June 7. Comparing the pressure fields from NCEP reanalysis data, control experiment, radiosonde data assimilation experiment and AMSU radiance data assimilation experiment, the result showed the AMSU radiance data assimilation experiment obtained the optimal results.

2.3 Analysis of the experimental results of the rainfall

The analysis fields from the radiosonde and AMSU radiance data assimilation were inputted into the WRF model to forecast rainfall. The 24 hour accumulation rainfall amount was shown at Figure 2. Figure 2(a), (b), (c) and (d) were the 24 hour accumulation rainfall from the Tropical Rainfall Measuring Mission (TRMM) satellite data, the control experiment, the radiosonde data assimilation experiment and AMSU radiance data assimilation, respectively. Forecast results showed that the control experiment and assimilation experiments could predict the distribution of rainfall. In the control experiment, the position of rainfall region was north away from the real position, and the rainfall rate was lower than the real value. The position of rainfall region was also north away from the real position from the radiosonde data assimilation experiment. However, the AMSU radiance data assimilation experiment accurately forecasted the central position of rainfall and rainfall rate.



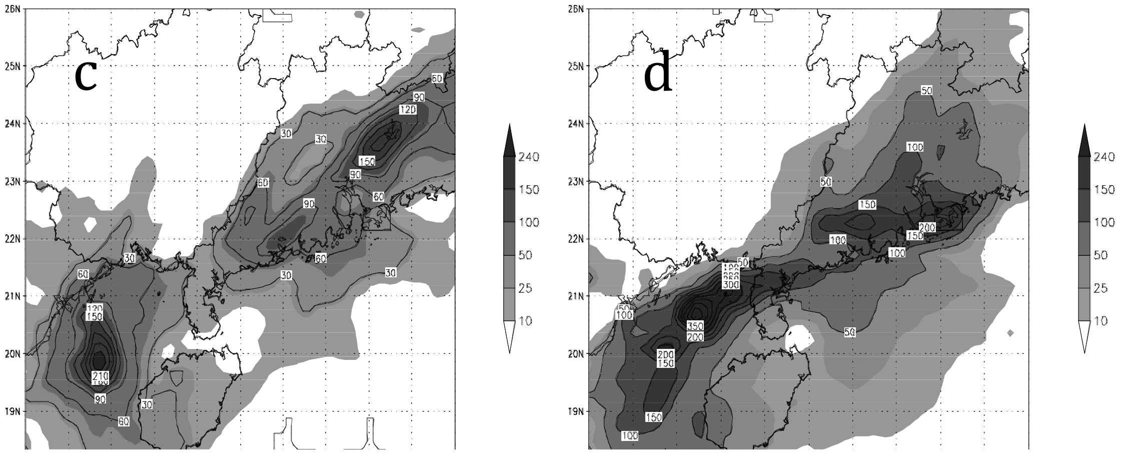


Figure 2 The 24 hour accumulation rainfall from TRMM (a), the control experiment (b), the radiosonde data assimilation experiment (c) and AMSU radiance data assimilation experiment (d)

3 Conclusions

In the present study, two conclusions could be drawn. Firstly, radiosonde data and AMSU radiance data assimilation had obvious impact on background fields. Comparing the increment fields, the results from AMSU radiance data assimilation were more reasonable. Secondly, AMSU radiance data assimilation provided better analysis field for precipitation forecast than radiosonde data assimilation. In the present experiments, the AMSU radiance data assimilation experiment more accurately forecasted the distribution, central position and rate of the rainfall than the control experiment and radiosonde data assimilation experiment.

References

Weng, F., and N. Grody, 2000: Retrieval of ice cloud parameters using a microwave imaging radiometer. J. Atmos. Sci., 57, 1069-1081.

Zhang, F, 2002: Characteristics of the new atmospheric sounder ATOVS and its data processing method. Tech. Rep, National Satellite Meteorological Center, 56pp. (In Chinese)

Liu, Z. Q., 2008. Radiance Data Assimilation for WRF model: Overview and Results. http://cimss.ssec.wisc.edu/itwg/itsc/itsc16/posters/6.10_Zhiquan_Liu.pdf

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