Assimilation of AMSU-A Microwave Observations Over Land

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Abstract: Remote sensing satellite microwave observation data has a wide range of coverage and high observation density, which has made the highest proportion of the observed data used in data assimilation. However, due to the uncertainty of the surface emissivity, mostly observations over the sea and observation of high-peaking channels are assimilated, resulting in a large number of land and lower-peaking channel satellite observations are abandoned. Based on the WRF system and the characteristics of AMSU-A microwave observation data, this paper realizes the application of AMSU-A observation data over land in WRFDA assimilation system. The preliminary experiment shows that the addition of AMSU-A observation data over land has a positive effect on the numerical weather forecast.

Keywords: satellite data assimilation, AMSU-A observations over land, WRF model

1 Introduction

Numerical Weather Prediction (NWP) is numerically solving the basic equations of atmospheric motion based on the known atmospheric initial conditions and boundary conditions, thus predicting the atmospheric state of the future. For numerical weather prediction, the accuracy of the atmospheric initial condition is very important[1].

At present, mostly only the data observed over sea is assimilated because the land surface emissivity cannot be accurately calculated. The premise of assimilating microwave remote sensing data over land is to obtain the more accurate surface emissivity.

The Weather Research and Forecast (WRF) model is a weather prediction system developed by National Center of Atmospheric Research (NCAR), National Centers for Environmental Predictions (NCEP) as well as other research institutes. WRFDA is the data assimilation system of WRF[2].

The Advanced Microwave Sounding Unit-A (AMSU-A) is a 15-channel cross-track, stepped-line scanning, total power microwave radiometer. The instrument has an instantaneous field-of-view of 3.3° at the half-power points providing a nominal spatial resolution at nadir of 48 km. The antenna provides a cross-track scan, scanning ±48.3° from nadir with a total of 30 Earth fields-of-view per scan line.

For using satellite microwave observation data over land, Karbou et al. retrieved a global monthly averaged land surface emissivity[3]. The global surface emissivity map is called emissivity atlas. Currently, two kinds of emissivity atlases are widely used, namely the TELSEM atlas and the CNRM atlas. The major difference between these two kind of atlases is that they are retrieved from different satellite observations. The TELSEM atlas is calculated using SSM/I observations while the CNRM atlas is calculated using AMSU-A/B observations.

The structure of this paper is listed as follows. Chapter 1 introduces data assimilation, land surface emissivity and other background information. Chapter 2 discusses the settings of WRF system and experiment configures. Chapter 3 gives the results and the evaluations of the experiments. Chapter 4 gives a brief discussion and conclusion.

2. Method

2.1 Radiative transfer model

To directly assimilate microwave observation data, the atmospheric variables must be converted to background radiance by the radiative transfer model[4,5]. The radiative transfer model used in our experiment is Radiative Transfer for TOVS (RTTOV).

In order to introduce emissivity atlas into RTTOV, data reading interfaces must be set up. Also for matching the position of observation points and the grid points in emissivity atlas, an interpolation method must be implemented. This method can be expressed as follows: for each observation point, set up a 1° multiplies 1° grid centered on it, and then calculated the averaged emissivity in this grid as the emissivity of the observation point. The emissivity atlas being used in experiment is the CNRM atlas.

2.2 Bias correction

At present, there are mainly two kinds of satellite observation bias correction schemes, namely variational adaptive bias correction scheme and off-line bias correction scheme. The off-line bias correction scheme was first proposed by Eyre[6], which includes bias correction methods depend on scan position and air mass. Variational bias correction scheme introduces the bias correction factor into the objective function and through minimization to get the best estimate[7]. This paper uses variational bias correction method.

2.3 Experiment settings

In order to show the influence of AMSU-A observations over land to the assimilation result and the prediction result, a set of assimilation and prediction experiments was carried out. The experiments focuses on the 10^{th} typhoon of year 2014, named as ‘Matmo’, which is a landing typhoon. The experiments perform a cycle prediction, takes July 23^{nd}, 2014, 00:00 (UTC, if no special explanations, the same below) as the start time. The time window is 6 hours and the prediction step is 6 hours. Typhoon ‘Matmo’ was formed in west Pacific, and its trace covered west Pacific and Taiwan province, Fujian province, Jiangxi province, Anhui province and Jiangsu province of China, so the assimilation area is confined to 15°S to 45°N, 90°E to 150°E. The number of horizontal grid is 177x177, the horizontal distance of the grid is 36km. The vertical layer number of the pattern is 36.The set of experiments includes 3 different experiments, the detailed descriptions are listed as follows:

Table.1 Experiment configure

EXPERIMENT NUMBER	EXPERIMENT NAME	THE DATA BEING ASSIMILATED
1	CNTL	CONVENTIONAL OBSERVATIONS
2	AMSUA-ATLAS	CONVENTIONAL OBSERVATIONS + AMSUA OBSERVATIONS + ATLAS
3	AMSUA-NOATLAS	CONVENTIONAL OBSERVATIONS + AMSUA OBSERVATIONS

3 Result

In order to evaluate the impact of AMSU-A observations over land on assimilation output and prediction accuracy, the result of both assimilation and prediction are listed and discussed.

3.1 Assimilation results

We choose the assimilation result of July 24^{th}, 2014, 12:00 to analyze. Fig. 1 shows the temperature at 900hPa, from left to right are of experiment 1, 2 and 3 respectively. From the figures we can see that after introducing AMSUA observations over land, the temperature at 900hPa has a significant increase (in the blue frame area). Also, using emissivity atlas makes the output temperature more accurate, for example, the temperature of the Bohai sea is significantly colder in experiment 2 than in experiment 3 (in the red frame area).

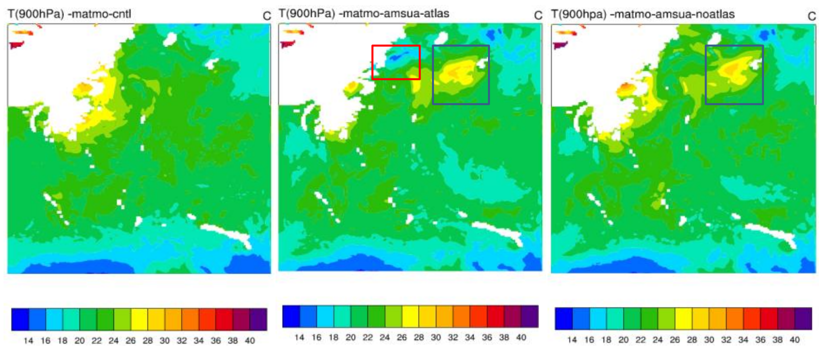

Fig.1 Temperature at 900hPa

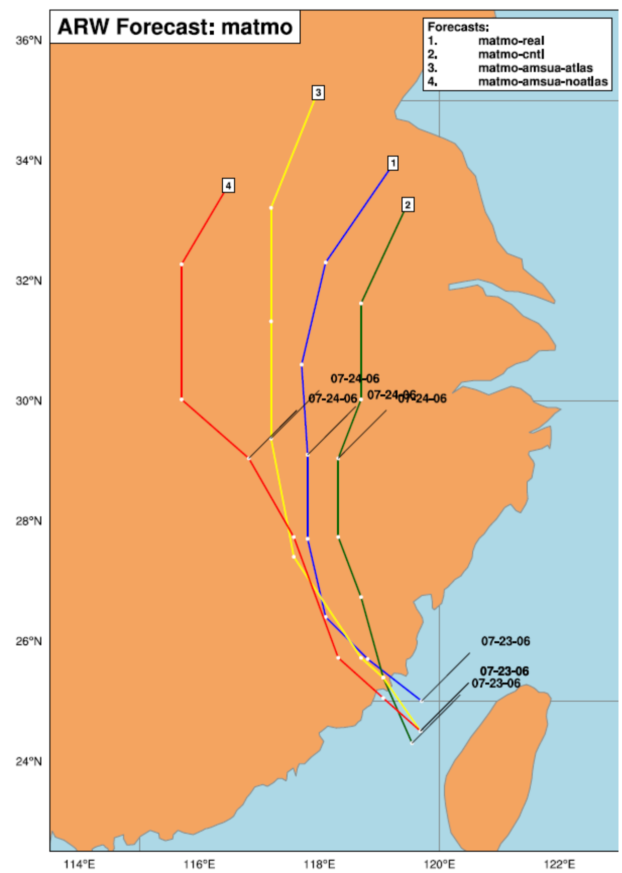

Fig.2 Track comparison of typhoon ‘Matmo’

3.2 Prediction results

In each experiment, the track of typhoon ‘Matmo’ is generated. Fig. 2 is the track comparing graph, in which there are 4 tracks: track No.1, real track of typhoon ‘matmo’; track No.2, track generated in exp.1; track No.3, track generated in exp.2; track No.4, track generated in exp.3.

Fig.3 shows the distances between predicted position of typhoon ‘Matmo’ in each experiment and the real position of typhoon ‘Matmo’. Fig.4 shows the deviation between the real air pressure in the center of typhoon ‘Matmo’ and that of the experiment predictions.

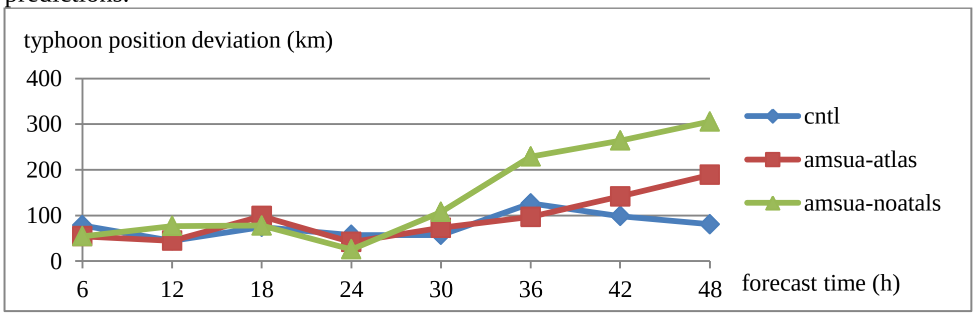

Fig.3 forecast position deviation of typhoon ‘Matmo’

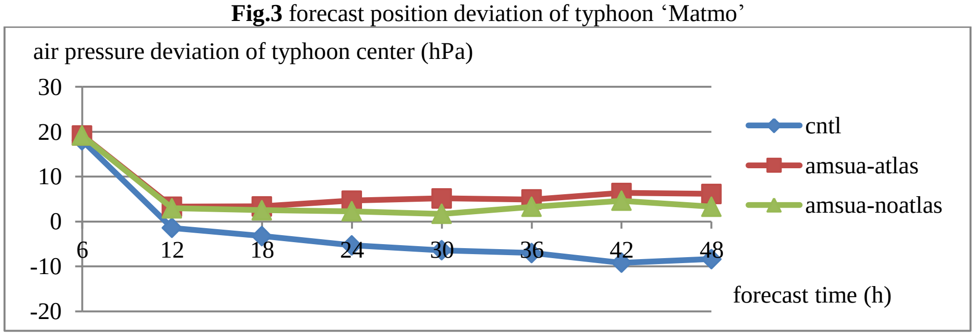

Fig.4 forecast air pressure deviation of the center of typhoon ‘Matmo’

From Fig.2~4 we can see that the introduction of a combination of AMSU-A observations over land and emissivity atlas can significantly improve the accuracy of the typhoon track prediction. It is worth mentioning that the prediction accuracy of using AMSU-A observations without emissivity atlas is not satisfactory. When assimilating AMSU-A observations over land, the introduction of emissivity atlas can increase the accuracy of typhoon ‘Matmo’ track prediction, but the increase in the accuracy of the air pressure prediction is not very satisfactory.

4. Discussion and conclusion

Based on WRF system and RTTOV system, this paper focuses on the use of emissivity atlas, implements the assimilation of AMSU-A observations over land in WRFDA system. A set of experiments is carried out and evaluations are made. The paper briefly introduces data assimilation and land surface emissivity in chapter 1 at first, and then comes to the point that when assimilating satellite observations over land, the use of surface emissivity is necessary. To assimilate AMSU-A observations over land using WRFDA, emissivity atlas must be appropriately used, and the radiative transfer model as well as the WRF system should be correctly set, which is discussed in chapter 2. Meanwhile, the detailed experiment settings are explained in Chapter 2. Chapter 3 gives the results and the evaluations of the experiments.

Further work can focus on the following points:

1. Instead of using emissivity atlas, surface emissivity can be calculated dynamically using satellite observations.

2. This paper concerns about the assimilation of the AMSU-A observations over land, other instruments' observations can be discussed later.

Acknowledgements

The work was supported by the Natural Science Foundation of China (Grant No. 41375113).

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