The Use of ATOVS Microwave Data in the Grapes-3Dvar System

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Abstract

With the development of Grapes-3Dvar, a three-dimensional variational data assimilation system developed by the Research Center for Numerical Meteorological Prediction, Chinese Academy of Meteorological Sciences, ATOVS microwave radiance data is directly incorporated in the data analysis for numerical weather prediction to mainly investigate its impact on short range numerical weather forecast. Several main components for the use of the ATOVS microwave data (including the Grapes-3Dvar system, the fast radiative transfer model, bias correction scheme, quality control and channel selection, land emissivity model, verification scheme) are briefly described in this paper. Following some preliminary result and discussion are presented.

Introduction

Numerical weather forecast has been developing rapidly, especially in recent years, playing a more and more important role in the operational and research fields. It is a special focal point how to utilize a variety of observational data, especially unconventional observations to improve the accuracy of numerical weather prediction. The use of satellite observation, among them, is now being of great importance in that it could provide a larger covering area, even distributive and higher spatial resolution atmospheric information and increase the observational information for the wide zones of ocean, plateau and desert with few conventional observations. The way of using satellite data has already migrated from to assimilate the retrieved temperature and moisture profiles to the assimilation of the radiance data from the satellite directly. At the same time, the assimilation scheme also concentrates on the frame of variational data assimilation system (3Dvar or 4Dvar).

It has been shown that the impact on medium range weather forecasts from using ATOVS data in numerical weather prediction now exceeds that from the radiosonde network. The potential impact in the assimilation of ATOVS data in local area models, yet it is still in the early stages. In this report, the use of ATOVS Microwave Data in the Grapes-3Dvar System, a three-dimensional data assimilation system developed by the Research Center for Numerical Meteorological Prediction, Chinese Academy of Meteorological Sciences, to mainly investigate its impact on short range numerical weather forecasts in local area model is presented.

Several main components for the use of ATOVS microwave data

(1) The Grapes-3Dvar system

The Grapes-3Dvar system is a new three-dimensional variational data assimilation system developed by the Research Center for Numerical Meteorological Prediction, Chinese Academy of Meteorological Sciences. Its main features are as followings:

- Latitude-longituded grid space consistent with the Grapes prediction model.
- Non-staggered Arakawa-A grid for the horizontal arrangement of the analysis variables

and analysis conducted in standard pressure level.

- Incremental approach is adopted. The model variables are wind (U and V), temperature (T) or geopotential height (Φ) and RH or q. The analysis variables are defined as ψ, χ, Φ_u, RH or q.
- The recursive filter is approximately used for the background error horizontal correlation and the EOFs is used for the vertical correlations.
- A simple geostrophic relationship or a linear balance equation for the mass/wind balance.
- Limited memory BFGS method for optimization of the algorithm.

(2) The fast radiative transfer model

The fast radiative transfer model currently being used is RTTOV developed by ECMWF. The forward observational operator and its tangent linear and adjoint for satellite radiance are adopted from this software package. This model requires the vertical temperature and moisture profiles on 43 pressure levels from 1013.25 hPa to 0.1 hPa. It results in an additional interpolation of the background profile in the vertical. Here the background field is the short term (6 or 12 hours) prediction of the global model T213 of the National Meteorological Center of China. The exclusion of the data for those high peaking channels is brought about for the top of the model atmosphere (10 hPa).

(3) Bias correction scheme

An independent bias correction scheme is supplied to correct the bias in the observation. This scheme is following the algorithms proposed by Harris and Kelly (2001). Two kinds of bias in the observation are corrected, including the bias depending on scan angles and the bias depending on the categories of air mass. The correction to the scan angle related bias changes with latitudes. The air mass related bias is predicted with linear regression based on the statistics of innovation vectors derived from recent cases. The predictors are the thickness between 1000-300 hPa and 200-50 hPa, the surface temperatures and the integrated water vapor. It could be seen from Fig. 1 that the distribution of the observation departure from first guess with bias correction is much normal than that without bias correction.
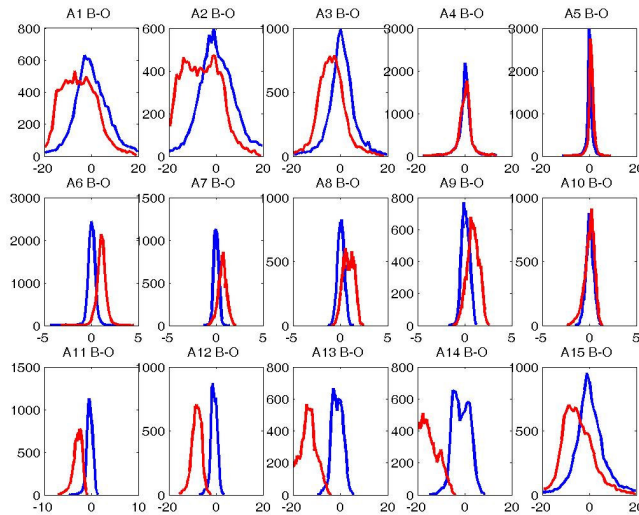

Fig. 1: The distribution of the observation departure from first guess for AMSU A channels 1-15. Red: without bias correction; Blue: with bias correction.

(4) Quality control and channel selection

Quality control is vital for the use of any type of data. It is conducted in three steps to reject the bad radiance data before they are passed to channel selection. The three steps are: ① the radiance brightness temperature data outside of the interval 150-350K are rejected, then ② the

point whose background profiles of temperature and humidity outside limits or unphysical is rejected and finally ③ the data whose departure between the simulated observation and actual value outside certain threshold are removed.

The use of certain channel is determined by the conditions of each channel that are the same as that at Météo-France, following the table 1 and table 4 in the presentation of Élisabeth Gérard and Florence Rabier et al. (2003). In general, channels 1-4, 15 of AMSU A and channels 1-2 of AMSU B are currently not used because of uncertainties on the description of the surface properties. Channels 12-14 of AMSU A are also excluded for the lack of information above the model top. For the channels used, special caution is given to low peaking channels over land and over sea ice, also in cloudy condition. An example of used data coverage after Quality control and channel selection is presented in Fig. 2.
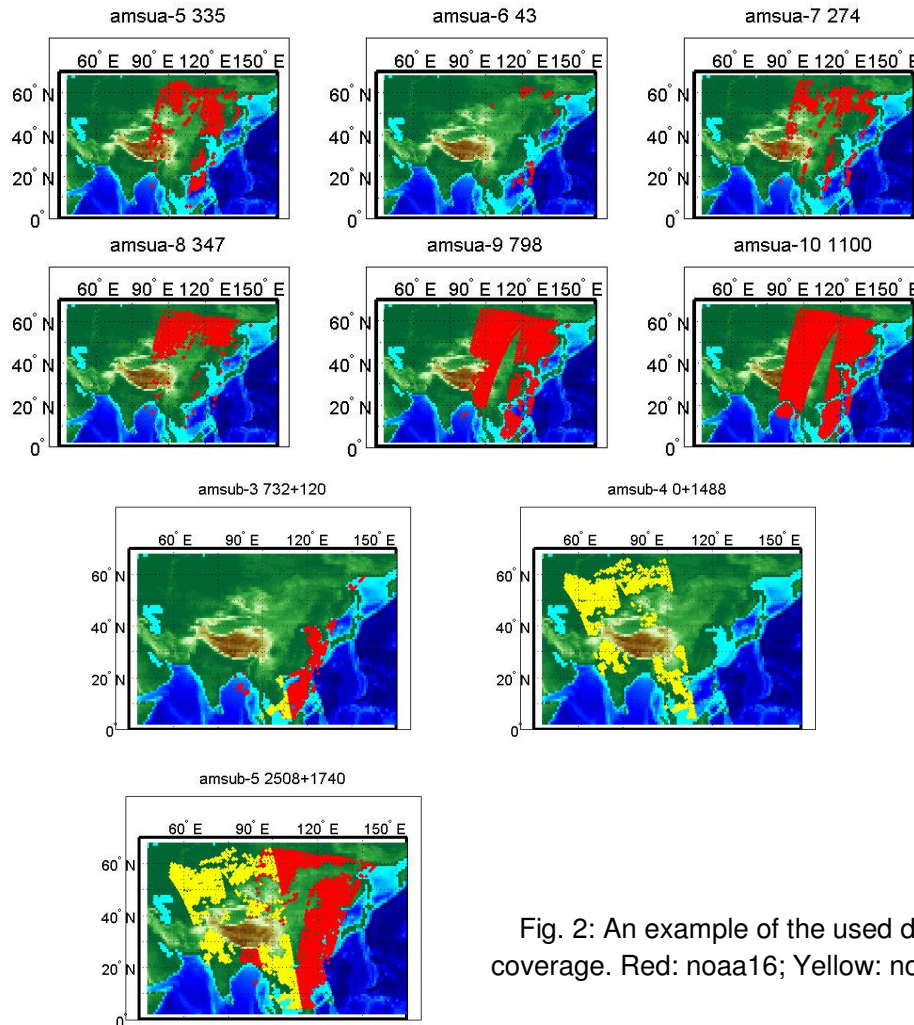

Fig. 2: An example of the used data coverage. Red: noaa16; Yellow: noaa17.

(5) Land emissivity model

To improve the calculation of land surface emissivity in the fast radiative transfer model, the NOAA/NESDIS microwave land emissivity model developed by F. Weng (2001) is introduced into the Grapes-3Dvar to replace the previous scheme in RTTOV. However, the microwave land emissivity model needs some surface parameters, which are crucial for the accuracy of calculation. These surface parameters are produced from a global data assimilation system (GDAS) including a boundary layer model in NOAA/NESDIS.
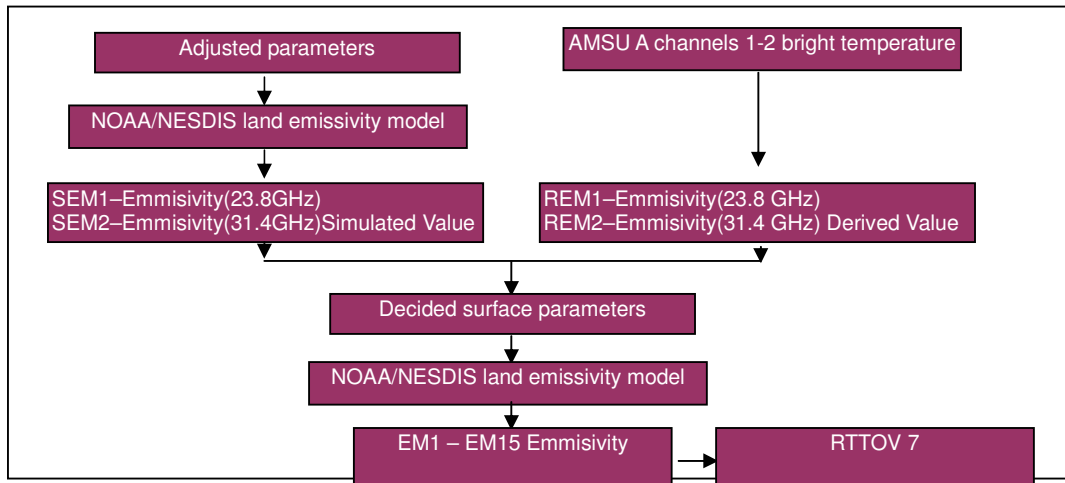
Fig. 3: The flow chart of the adjusted parameter scheme for using of the microwave land emissivity model.

An adjusted parameter scheme is designed to provide the surface parameters for using of the microwave land emissivity model. The flow chart of the scheme is shown in Fig. 3. Firstly, the land surface emissivities at AMSU A channels 1-2 are first derived from radiance brightness temperature. Certain surface parameters, which are selected according to different surface type, are adjusted to make the calculation of the microwave land emissivity model match the derived emissivity. Then the surface emissivities of all channels could be calculated on the basis of these adjusted surface parameters.
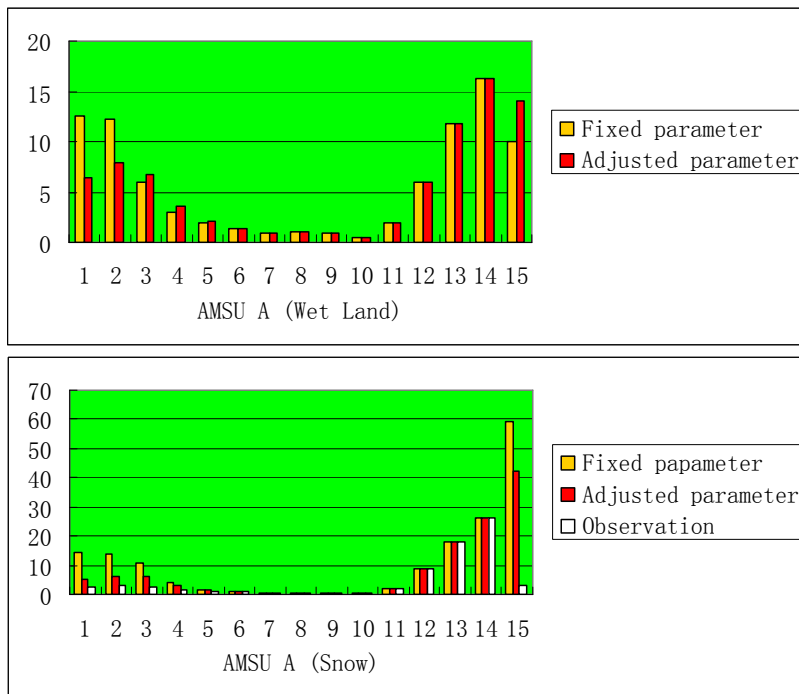

Fig. 4: The mean square deviation of the observation departure from first guess calculated from differ land surface emissivity scheme for AMSU A channels 1-15. (Top: wet land; Bottom: snow)

The improvement of the calculation of land emissivity is illustrated by a reduction in the mean square deviation of the observation departure from first guess. The results of wet land and snow type are given in Fig. 4. It could be found that some improvement is obtained to a certain extent. The microwave land emissivity model then could be used under the circumstances that no surface parameters are provided. Of course, the observation departure

from first guess is also affected by other factors, e.g. surface temperature, which should be introduced into the control variable to better describe surface properties. In addition, the Observation scheme developed by F. Weng (2003) is applied for two complex land surface type snow and ice. Much improvement could be seen in Fig. 4.

(6) Verification scheme

Verification scheme to evaluate the impact of satellite data on analyses and forecasts is developed at the same time. Details on the verification schemes are list in Table 1.

Table 1: The list of verification schemes

Use √	Analysis	Forecast
Fit to the satellite data	√	
Fit to the radiosonde	√	√
Against analysis		√
Ts		√

For the analyses, the fit to the satellite or radiosonde data is to compare the fits to the brightness temperature or radiosonde for the background fields with analyses using the radiance data. The fit to the radiosonde data is also taken for the forecasts with and without the assimilation of satellite data. Additionally, the forecasts are measured by comparing forecasts against their own analyses. Ts is taken to evaluate the forecast precipitation.

Preliminary result

As an indication of the quality of the analysis, the fits to the brightness temperature for the background fields and analyses using the radiance data are compared. It is illustrated in Fig. 5. A better fit to the radiance observations is evident for the analysis.
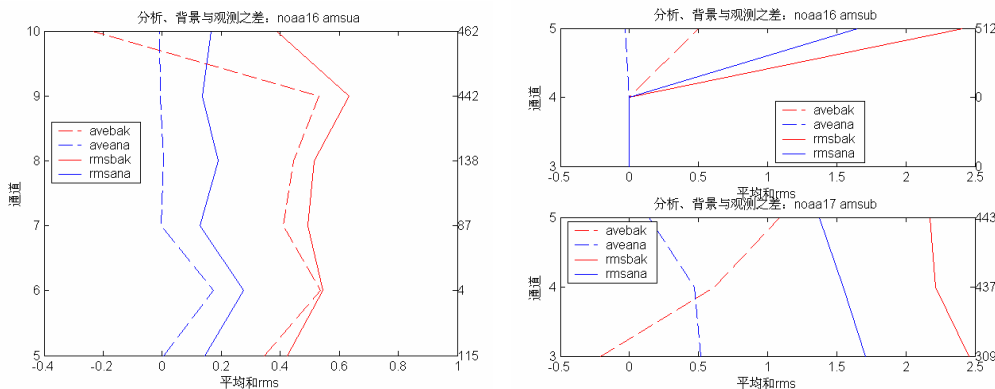

Fig. 5: The fits to the brightness temperature for the background fields and analyses using the radiance data. (Left: AMSU A; Right: AMSU B)
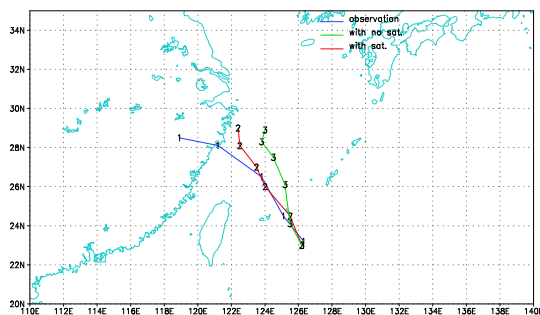

An example of the impact of satellite data on the track forecast of Typhoon Rananim 2004 is shown in Fig. 6. It could be seen that the skill of the track forecast is improved by the use of ATOVS microwave radiance data.

Another experiment using ATOVS data has been run on a summer monsoon period (10-30 June 2004). The Meiyu rainfall over

Fig. 6: Tracks of Typhoon Rananim 2004.

Yangtze River occurred and maintained in this period. From Fig. 7, it could be found that twenty days averaged Ts is improved for the 24h prediction of heavy rainfall (25-50 mm) and torrential rain (50-100 mm) except that of moderate rain (10-25 mm), whose Ts is a little degraded when satellite data is used. Taking one day as example, the rain belt of Meiyu front is more evident for the forecast with the assimilation of satellite data than that without satellite data.
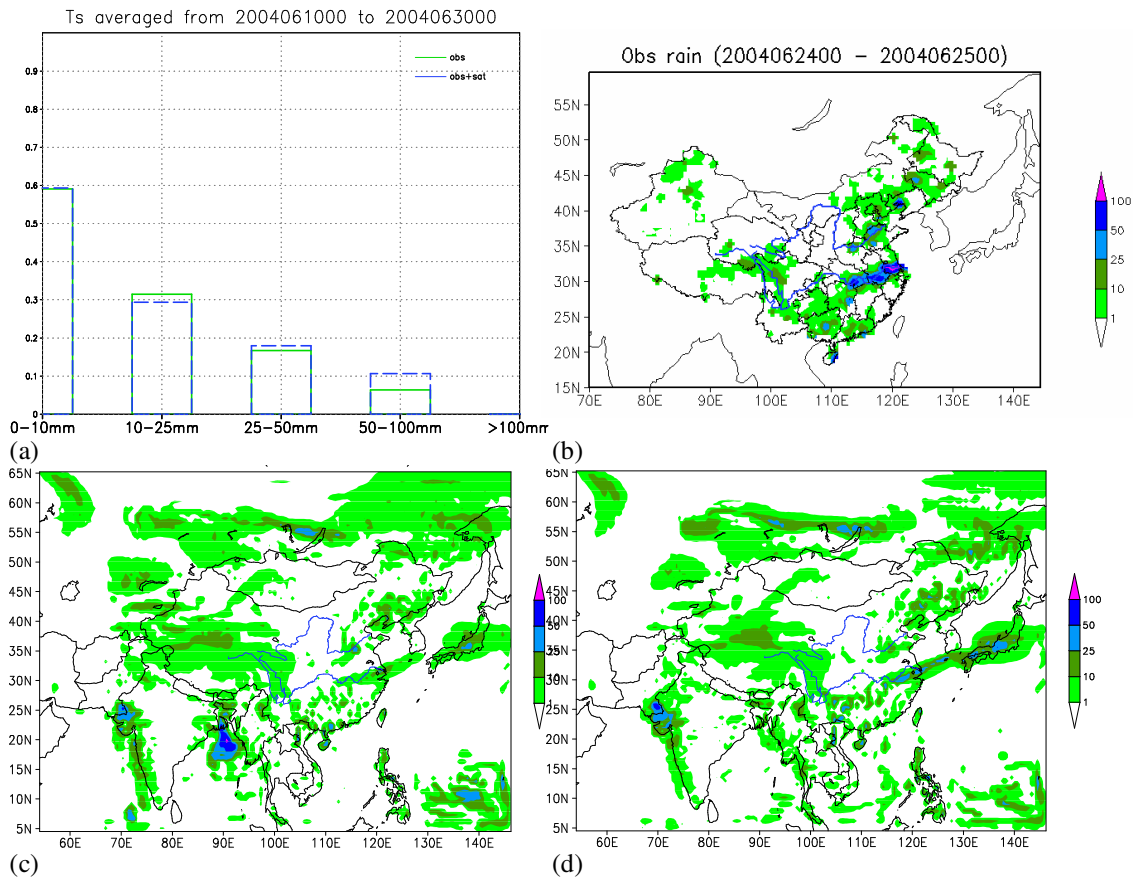

(a)

(b)

(c)

(d)

Fig. 7: Ts averaged on the period (10-30 June 2004) (a) and 24h accumulated precipitation for 25th June 2004. (b) is the observation, (c) and (d) are the prediction without and with the assimilation of satellite data, respectively.

Preliminary result indicates that the use of ATOVS microwave data in the short range numerical weather forecast is promising. However, it should be pointed also that the impact of satellite data is mixed. Some verification of analyses and forecasts produced using satellite data are slightly worse (Derber, J. C. and W. S. Wu, 1998). It is probably too early to draw conclusions from case and short term experiment. More tests will be needed in an operational environment and improvement of the scheme using satellite data should be carried out simultaneously.

Discussion
(1) ATOVS microwave data is currently being used in the Grapes-3Dvar system. Preliminary result indicates that the use of satellite data in the short range numerical weather forecast is promising. However, the impact is mixed. More work need to be carried out further.
(2) The NOAA/NESDIS microwave land emissivity model developed by F. Weng is

introduced into the Grapes-3Dvar. The calculation of land emissivity is improved by the adjusted parameter scheme designed companying with Observation scheme. Those satellite observations strongly affected by surface emissivity could be utilized into assimilation system to investigate their impacts.

(3) Some issues will be emphasized in the future research. E.g., the introduction of surface temperature to control variable in order to improve the description of surface properties and use of more channels in the assimilation system. Measure of the impacts of the satellite data will be investigated further.

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