Operational use of ATOVS radiances in global data assimilation at JMA

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1. Introduction

The Advanced TIROS Operational Vertical Sounder (ATOVS) radiances have been operationally assimilated in the Japan Meteorological Agency (JMA) global 3D-Var data assimilation system since 28 May 2003. It replaced TOVS/ATOVS retrievals, which had been assimilated in the JMA global data assimilation system. The direct assimilation of ATOVS radiances is superior to its retrieval assimilation because the retrievals have some error in their conversion from radiance to analysis variables such as temperature and relative humidity.

Data assimilation experiments, which was conducted before the operational use of ATOVS radiances demonstrated significant impacts on forecasts and analyses.

This report describes the ATOVS data used at JMA and some results of the assimilation experiments.

2. ATOVS

ATOVS instruments are sensors on the National Oceanic and Atmospheric Administration (NOAA) series of polar-orbiting satellites. ATOVS instruments are composed of three independent sensors; a High-resolution Infra-Red Sounder (HIRS) which has 20 channels and two Advanced Microwave Sounder Units (AMSU-A, AMSU-B) which have 15 and 5 channels, respectively. HIRS and AMSU-A measure mainly temperature profile and AMSU-B measures moisture profile. National Environmental Satellite and Data Information System (NESDIS) produces ATOVS radiance data (HIRS and AMSU-A) and thinned AMSU-B radiance data. These data are pre-processed Level 1D data (Reale 2001) and have temperature and moisture retrievals. In the previous retrieval assimilation, temperature was converted to thickness and then assimilated in 3D-Var. In the current direct assimilation, HIRS, AMSU-A and AMSU-B radiances are assimilated directly.

The Level 1D data undergo a re-mapping procedure in which AMSU-A field of view (FOV) is interpolated into HIRS FOV by NESDIS and has the cloud flag and the skin temperature. In addition, these data are thinned at 250km resolution in equal distance in a preprocess step of the JMA data quality control system. As for AMSU-B, the data are selected at 180km resolution. These distances are kept constant for all over the globe. Figure 1 shows comparison of data coverage used in the previous retrieval assimilation and the current radiance assimilation. The ATOVS data on land are assimilated in current direct assimilation system. However, AMSU-A channels 1-3 (all the globe) are not used because these channels observe surface conditions. AMSU-A channels 4-5 are not used over land. AMSU-A channel 6 and channel 7 are not assimilated if the elevation of observation point is over 1,500 meter and 2,500 meter, respectively. No land data had been used in previous retrieval assimilation. As for moisture data, GMS moisture data, which was retrieved from GMS radiance statistically, had been assimilated jointly in the previous retrieval assimilation. Instead of the GMS moisture data, AMSU-B radiances are assimilated in the direct assimilation system.

Cloud contaminated data are rejected by a cloud cost method based on AAPP procedure (Okamoto et. al. 2002) because an accuracy of radiative transfer model (RTTOV-6, Saunders, 1998; Saunders, 2000) are degraded by cloud and rain presence. The surface type (sea, land or coast) is defined by 0.25-degree land mask data set. Coastal data are not used. Identification of sea ice is based on the JMA sea surface temperature analysis: an area where SST< 274.15K is regarded as sea ice.

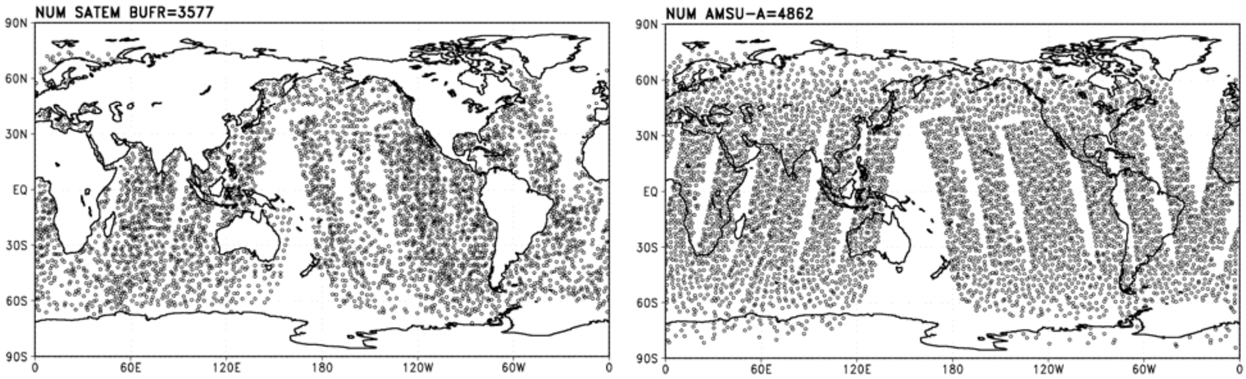

Fig. 1: Data coverage in a six-hour assimilation time from ATOVS instruments on NOAA15 and NOAA16 satellites. Left panel is for retrieval assimilation (500 hPa geopotential). Right panel is for direct assimilation (AMSU-A channel 6).

In order to use radiances from ATOVS, biases between observed radiances and simulated ones from first guess must be corrected. The JMA scheme for ATOVS radiance-bias correction relies on the total column water vapor from first-guess, the JMA SST analysis, and the calculated brightness temperatures from AMSU-A channels 5,7 and 10. They are used as linear predictors of the bias for each channel. The biases are removed before assimilation with 3D-Var.

3. Design of experiments

Data assimilation experiments were carried out for two periods: 27 June 2002 – 9 August 2002, and 27 November 2001 – 9 January 2002. Data configurations of the experiments were:

- Retrieval assimilation (CNTL)
- Direct assimilation + (new cumulus parameterization scheme) + (new background-error covariance) (TEST)

No use of ATOVS retrievals and relative humidity profile retrieved from GMS-5 brightness temperature in the TEST.

In these experiments, the JMA Global Spectral Model (GSM) at resolution T213L40 and the 3D-Var assimilation system were used. ATOVS data from NOAA15 (AMSU-A, AMSU-B) and NOAA16 (HIRS, AMSU-A and AMSU-B) were used. Moreover a new cumulus parameterization scheme of the global model and a new 3D-Var background-error covariance were jointly used for TEST. In the TEST, ATOVS moisture channels, i.e. HIRS channel 10,11 and 12 and AMSU-B channel 3, 4, and 5 were assimilated instead of retrieved relative humidity profile from the GMS-5 brightness temperature.

4. Results

As for temperature field, large impact was found in the upper stratosphere from 30 hPa to 0.4 hPa. Figure 2 show the monthly zonal mean temperature for July 2002. By using radiances directly, profile of temperature became smooth. Figure 3 shows a verification of analyzed temperature and first-guess temperature against radiosonde observation. Better fits were found in the troposphere and lower stratosphere in the TEST.

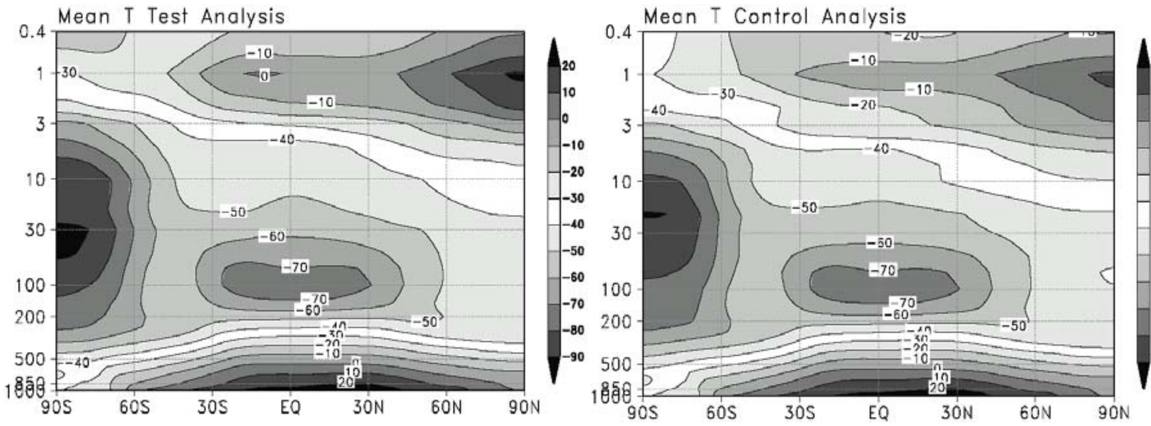

Fig. 2: Zonal mean of temperature in the experiments averaged over July 2002. The left panel is TEST and the right panel is CNTL. The contour interval is 10K.

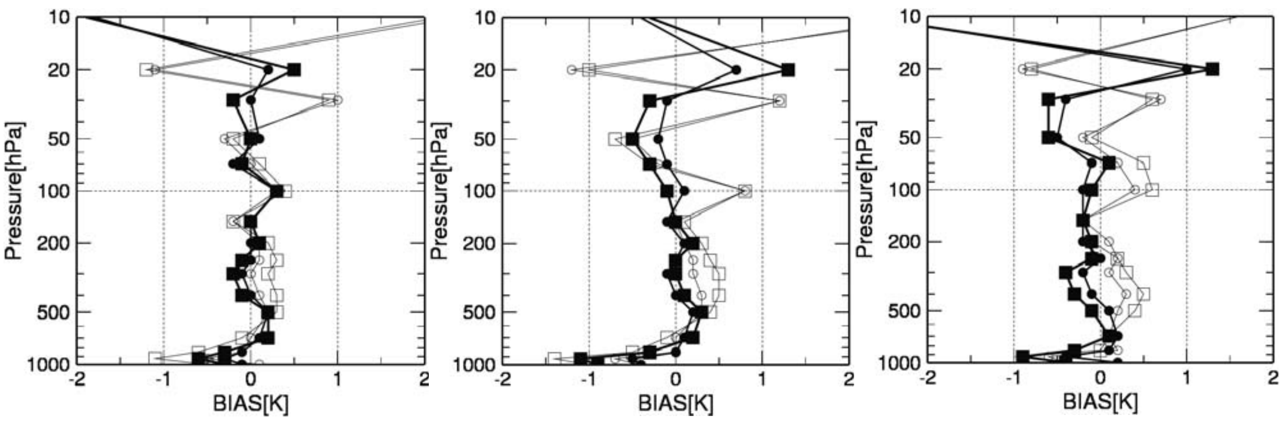

Fig. 3: Mean difference of the first guess (TEST: ○, CNTL: □) and the analyzed fields (TEST: ●, CNTL: ■) from radiosonde temperature observations for July 2002. The left panel is the Northern Hemisphere (90°N-20°N), the middle panel is the tropics (20°N-20°S), and the right panel is the Southern Hemisphere (20°S-90°S).

Figure 4 shows a difference between analyzed total precipitable water and SSM/I retrieval. Because SSM/I data are not assimilated, they are independent data. The upper panel is the difference for TEST and the lower panel is that for CNTL for 15 July 2002. In the TEST case, the difference became small in tropical region. This result indicates that humidity field became realistic by assimilating ATOVS moisture channels.

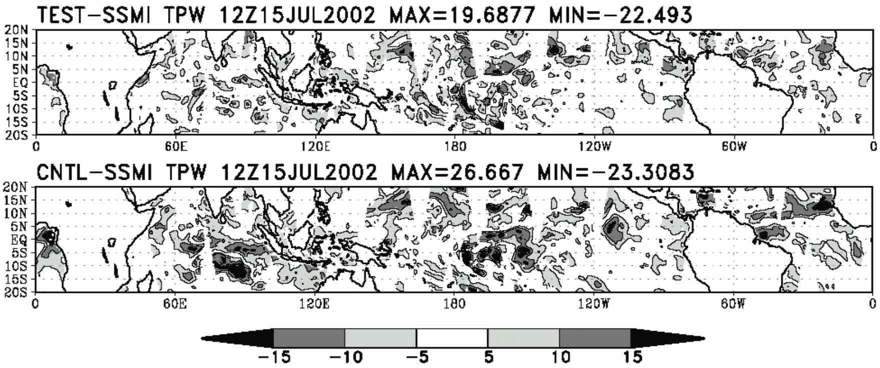

Fig. 4: Difference between analyzed total precipitable water and that retrieved from SSM/I observations for 12UTC 15 July 2003. The upper panel is TEST-SSM/I, and the lower panel is CNTL-SSM/I. The contour interval is 5mm.

As for impact on forecast, the TEST run has demonstrated positive impacts for the geopotential height at 500 hPa (Fig 5). Particularly, substantial positive impacts were found in the Southern Hemisphere and in the tropical region. Figure 6 shows a monthly mean difference between RMSE of 24-hour forecasts from TEST and those from CNTL. The negative value means positive impact. Obviously, the positive impact on forecasts in the Southern Hemisphere is larger than other area.

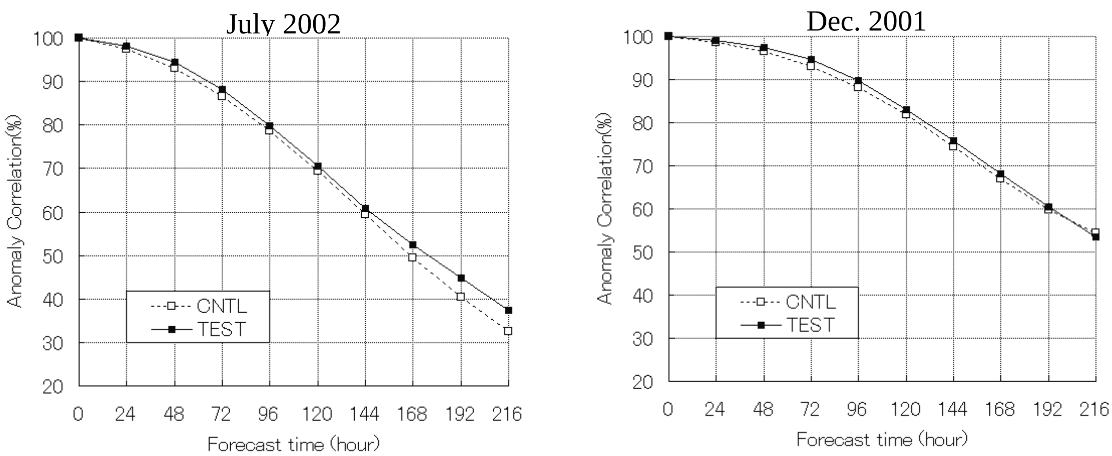

Fig. 5: Mean anomaly correlations for 500hPa geopotential height over the globe. The left panel is for July 2002 and the right panel is for December 2001. Each score is calculated by averaging 31 cases.

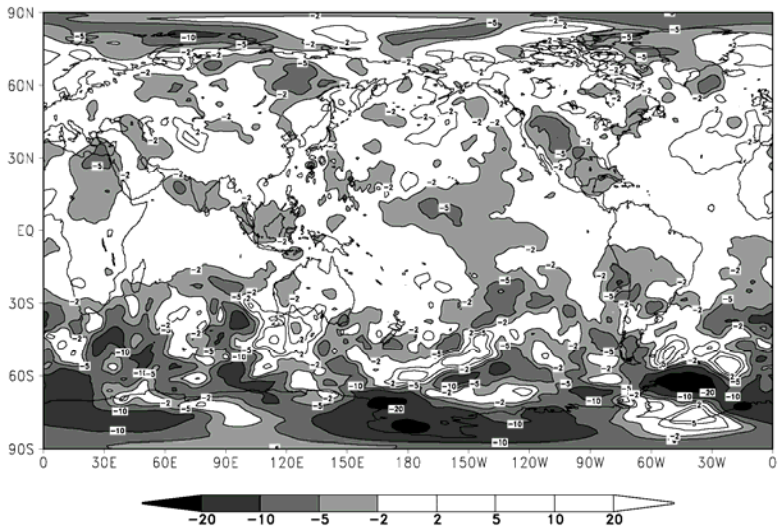

Fig. 6: Monthly mean difference of RMSEs between TEST and CNTL 24-hour forecasts for July 2002. Negative value (Gray color) shows positive impact.

The TEST forecast scores of temperature at 850 hPa, wind speed at 250 hPa and sea level pressure were similarly higher than CNTL.

Positive impacts were also found in prediction of the typhoon tracks. Figure 7 is a comparison of typhoon track prediction between TEST forecast and CNTL forecast. Because the underestimation in the forecast of strength of the subtropic high pressure was reduced, the typhoon track prediction was corrected westward. Similar position impacts for other typhoon events were also found.

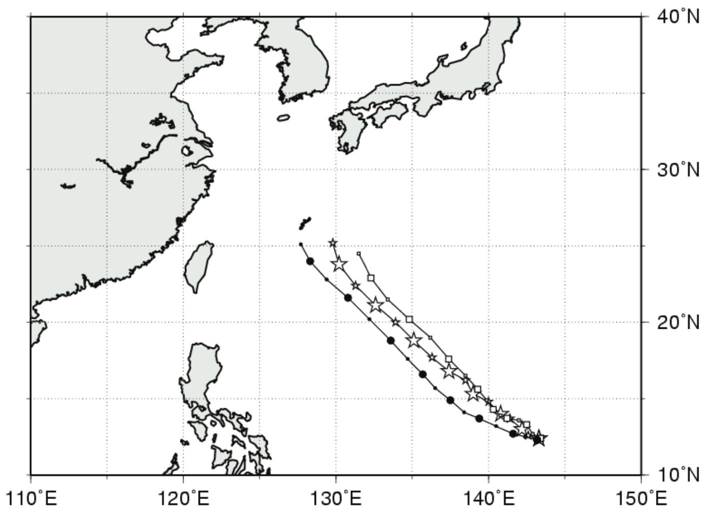

Fig. 7: A comparison of typhoon T0207 (HALONG) track prediction. Initial time is 12UTC 10 July 2002. ●:Best Track, ☆:TEST, □:CNTL.

5. Summary and Future prospect

JMA has started operational use of ATOVS radiances in the global data assimilation on 28

May 2003. The use of ATOVS retrievals and GMS-5 retrievals was discontinued. Experiments prior to the operational use have demonstrated dramatic positive impacts. The temperature profiles in the upper stratosphere and the global humidity fields in the troposphere were improved. The higher accuracy of initial fields of temperature and humidity were confirmed by comparing with radiosonde observations and the total precipitable water estimated from SSM/I. As for forecast skill, positive impacts were found for the geopotential height at 500 hPa in the Southern Hemisphere and in the tropical region. The improvement in short-range forecast was remarkable. Moreover better results on the typhoon track prediction were also found.

The direct assimilation of ATOVS data expanded moisture observation coverage and improved the quality of temperature and humidity analysis. Then, direct assimilation led to higher performance of the prediction globally. JMA has achieved considerable progress in ATOVS data assimilation, but some unpreferable changes in temperature analysis are seen at some levels in the stratosphere and the excessive concentration of rainfall in 6-hour forecast is also seen in the tropics. To solve these problems, we continue to improve the bias correction scheme of ATOVS brightness temperature. Moreover, we are going to assimilate ATOVS Level 1B data to avoid intrinsic errors in the level 1D data. And we have a plan to update the radiative transfer model from RTTOV-6 to RTTOV-7.

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