

Operational use of the ATOVS radiances in global data assimilation at the JMA

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Introduction

ATOVS radiances have been assimilated operationally in the Japan Meteorological Agency (JMA) global data assimilation system since 28 May 2003. It replaced TOVS/ATOVS retrievals, which had been assimilated in the JMA global data assimilation system since 1982. An Optimum Interpolation (OI) method had been used in the assimilation system. But, since September 2001, 3D-Var method has been operational in the system. The current operational system of ATOVS radiances assimilation at the JMA is composed of two steps. One is the 1D-Var pre-process step (Okamoto, K., Takeuchi Y., Kaido Y., and Kazumori M. 2002) and the other is main 3D-Var-analysis step. Before being supplied to the main 3D-Var analyses, radiance data should be passed the 1D-Var pre-process step. In the 1D-Var, thinning, quality control, channel selection, and bias correction are applied to the radiance data. Level-1D data (Reale 2001) pre-processed by NOAA/NESDIS are used for the assimilation. As a radiative transfer model, RTTOV-6 (Saunders, 1998 and RTTOV-6 SCIENCE AND VALIDATION REPORT, 2000) is used in both 1D-Var and 3D-Var.

Before the operational use of ATOVS radiances, some cycle experiments were performed. These experiments demonstrated dramatic impacts on forecasts and analyses. As these finding, the assimilation of ATOVS radiance became operational. This paper focuses on some upgrades in 1D-Var preprocessor and results of experiments.

1D-Var as a preprocessor

NESDIS 120km ATOVS radiance product (HIRS/3 and AMSU-A), which is pre-processed Level 1D data, is used in JMA. The data undergoes a re-mapping procedure in which AMSU-A FOV is interpolated into HIRS/3 FOV by NESDIS and has the cloud flag and the skin temperature. These data are thinned at 250km in equal distance. As for AMSU-B, the data are selected at 180km resolution. This distance is kept constant for all over the world. Beside, clear radiance, closer to analysis time data is preferred in two satellites data overlapped region. Figure 1 shows the change of used data coverage from retrieval assimilation to radiance assimilation.

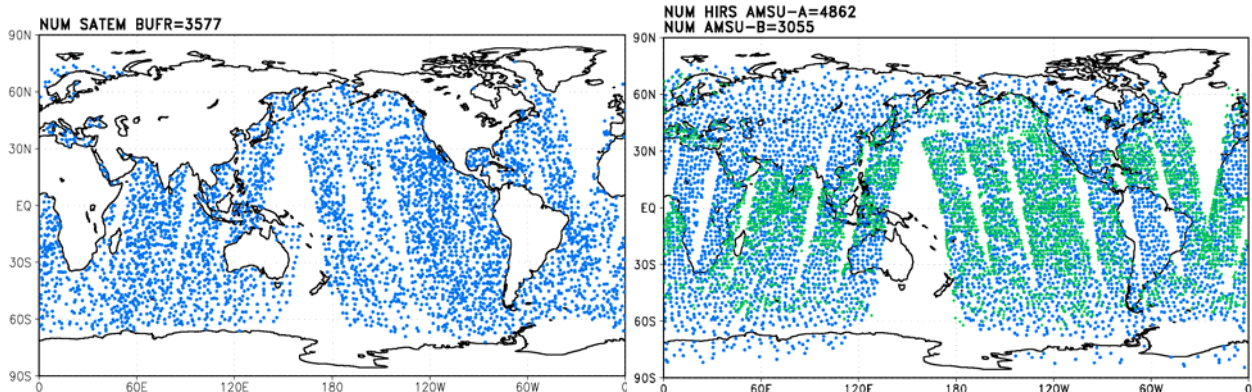


Fig. 1: Coverage in a six-hour data assimilation window of data from ATOVS instruments on NOAA15 and NOAA16 satellites. Left panel is for retrieval assimilation (500 hPa geopotential). Right panel for direct assimilation (Blue:AMSU-A channel6,Green:AMSU-B channel4).

Cloud contaminated data are rejected by cloud cost method based on AAPP procedure (Okamoto et. al. 2002). The surface type (sea, land or coast) is defined by 0.25-degree land mask data set. No coastal data are used. Identification of sea ice affected data is based on SST analysis. The data on the SST less then 274.15K are identified as data on sea ice.

As for channel selection, no lower peaking channel is used, that is AMSU-A channel 4,5 on land. As for AMSU-A channel 6,7, some altitude thresholds are set on land and on sea ice. As for AMSU-A channel 6, over 1500-meter altitude is allowed and over 2500-meter altitude for channel 7. And clear channels of HIRS/3 and AMSU-B and stratosphere channels of HIRS/3 are also selected for the assimilation.

In order to use radiances from ATOVS, biases between the observed radiances and those simulated from a first guess must be corrected. The JMA scheme for ATOVS radiance-bias corrections relied on the model first-guess total column water vapor, the analyzed JMA sea surface temperature, and the calculated brightness temperatures from AMSU-A channels 5,7 and 10 as linear predictors of the bias in all channels that were used. The bias is represented by

$$\text{BIAS}_j(n) = a_{j0} + \sum_{i=1}^5 a_{ji}(n)X_{ji}(n)$$

a_{j0} are constant, X_{ji} are the predictors, j is channel number and n is scan position index. These coefficients a_{ji} are obtained by satellite and radiosonde collocation for one-year (2002) period. To calculate brightness temperature, profiles of radiosonde observations were used. A first guess was used to complement the profiles at no radiosonde observation level. The each coefficients were made for each scan position. This bias correction scheme contains effects of scan dependence and air mass dependence (Harris and Kelly 2001). Because of moisture bias and temperature bias at upper stratosphere in the JMA global model, this bias correction scheme is not applied to HIRS/3 channel 11,12, AMSU-A channel 12,13,14 and AMSU-B channels 3,4,5. Figure 2 shows an effect of this bias correction. There is complicated scan dependent bias around edge of Level 1D AMSU-A data. But these biases are removed by this scheme.

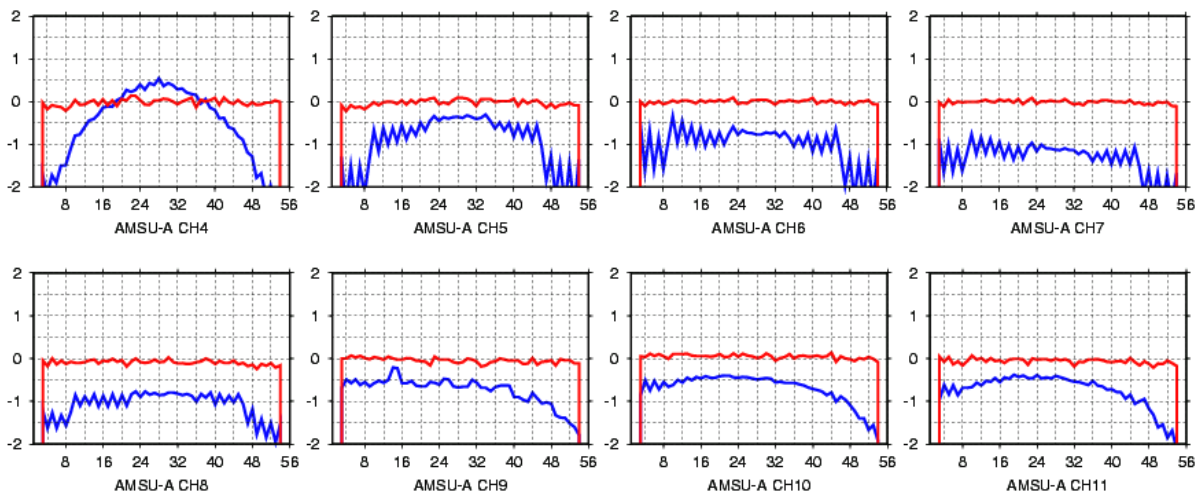


Fig. 2: Uncorrected bias (Blue line) and corrected bias (Red line) by scan position for each channel, NOAA16, AMSU-A, from 27 Jun 2003 to 30 Jun 2003.

Results of experiments

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

- Retrieval assimilation(CNTL)
- Direct assimilation without ATOVS retrievals and GMS-5 moisture retrievals (TEST)

In these experiments, JMA GSM (Global Spectral Model) T213L40, 3D-Var assimilation systems were used. NOAA15 (AMSU-A, AMSU-B) and NOAA16 (HIRS/3, AMSU-A and AMSU-B) were used. Moreover new cumulus parameterization scheme of global model was jointly used. The direct assimilation of ATOVS data expanded moisture observation coverage and improved the quality of temperature and humidity analysis. Then, that led to higher performance of the prediction globally.

As for temperature field, a dramatic impact was found in upper stratosphere from 30hPa to 0.4hPa. Figure.3 shows monthly zonal mean temperature for Jul 2002. By using radiances directly, profile of temperature became very smooth. Figure 4 shows a verification of analyzed temperature and first-guess temperature against radiosonde observation. Better fits were found in the troposphere and lower stratosphere.

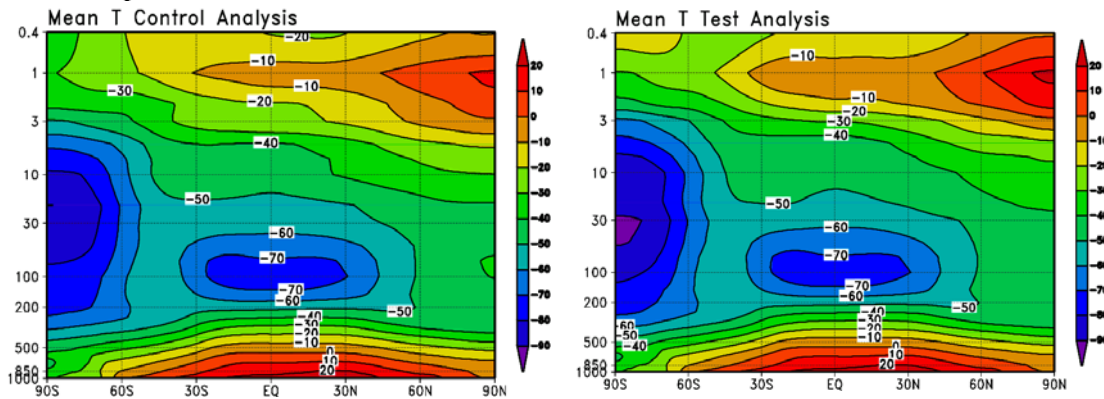


Fig. 3: Zonal mean of temperature in the Experiments averaged over the July 2002 and over longitude. TEST is right panel and CNTL is left panel. The contour interval is 10K.

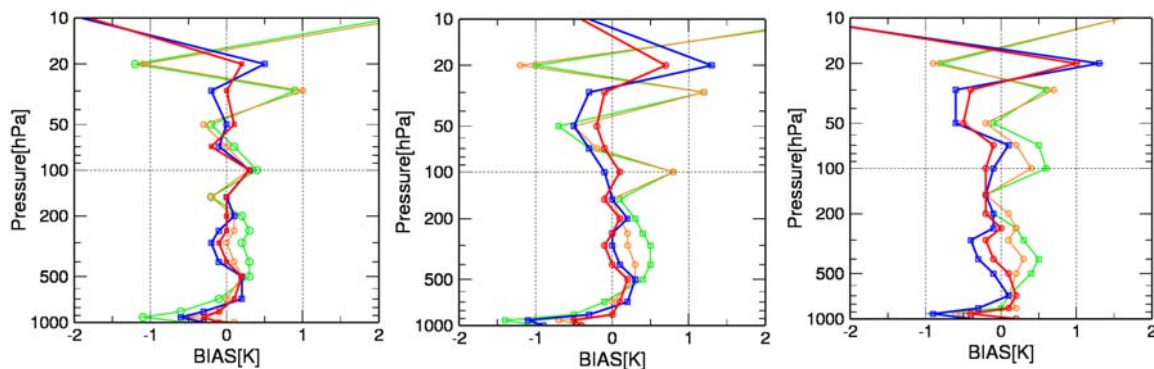


Fig. 4: Mean fit of the background (TEST: blue, CNTL: green) and analysis (TEST: red, CNTL: orange) to radiosonde temperature observations for July 2002. Left panel is Northern hemisphere, middle panel is Tropics, and right panel is Southern hemisphere)

In the TEST case, ATOVS moisture channels, i.e. HIRS/3 channel 10,11,12 and AMSU-B channel 3,4,5 were assimilated instead of GMS-5 retrieved relative humidity. Figure 5 shows a difference between analyzed total precipitable water and SSM/I retrieval. The left panel is the difference for CNTL and the right panel for TEST for 15 July 2002. In the TEST case, the difference became small clearly and particularly this trend is large in tropical region. The result means humidity field became

realistic by assimilation of ATOVS moisture channel. Because SSM/I data is not assimilated, that can be considered as independent data.

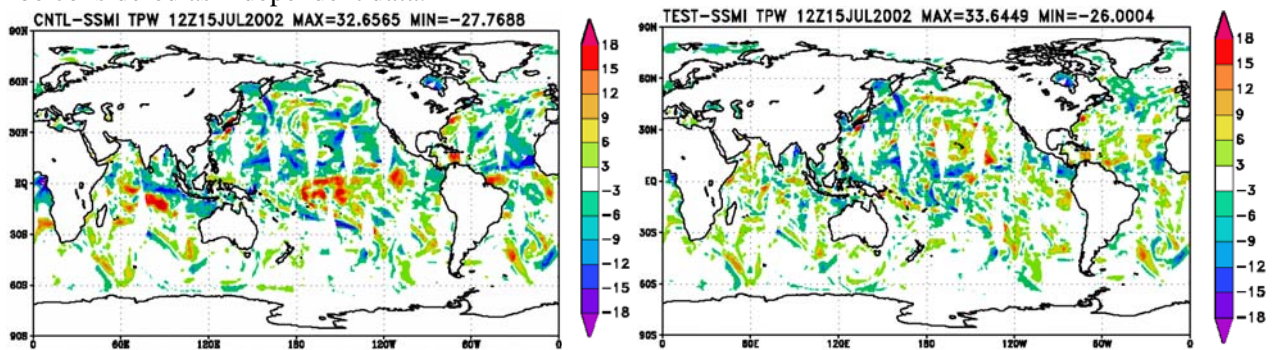


Fig. 5: Difference from analyzed total precipitable water to SSM/I observation for 12UTC 15 July 2003. Left panel is CNTL-SSMI, and right panel is TEST-SSMI. The contour interval is 3mm.

As for forecast impact, the TEST case has demonstrated positive impacts for the geopotential height at 500 hPa (Fig. 6). Particularly, substantial positive impacts were found in the southern hemisphere and in the tropical region. Figure 7 shows a monthly mean difference between RMSE of 24-hour forecasts from TEST and those from CNTL. The negative value means positive impact. Obviously, impact on dynamics in southern hemisphere is larger than other area.

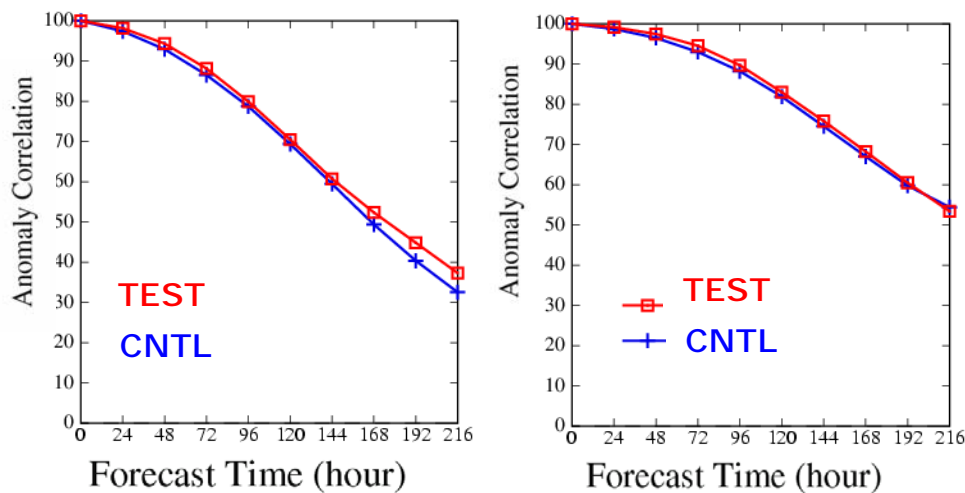


Fig. 6: Mean anomaly correlations for 500hPa geopotential height for the global. Left panel is for July 2002 and right panel is for December 2001. Each score was calculated by averaging 31 cases.

The forecast scores of the temperature at 850 hPa, wind speed at 250 hPa and sea level surface pressure were similarly good. Better predictions of the typhoon track were also found out during pre-operational run in May 2003. Fig. 8(a) is the analyzed field of 500hPa height, Fig. 8(b) is the 24-hour forecast of 500hPa height for TEST (ATOVS radiances assimilation), Fig. 8(c) is difference from Fig. 8(b) minus Fig. 8(a), Fig. 8(d) is the 24-hour forecast of 500hPa height for CNTL (ATOVS retrieval assimilation), Fig. 8(e) is difference from Fig. 8(d) minus Fig. 8(a). Fig. 8(f) is comparison of typhoon track. Red line is TEST, blue line is CNTL, black line is Analyzed track. Dotted circle in Fig. 8 showed the change of forecast for peripheral area of subtropic high pressure (5880-meter contour at 500hPa). Forecast of strength of subtropic high pressure became realistic and typhoon track prediction

was corrected westward. Many good impacts for other typhoon events were also found out.

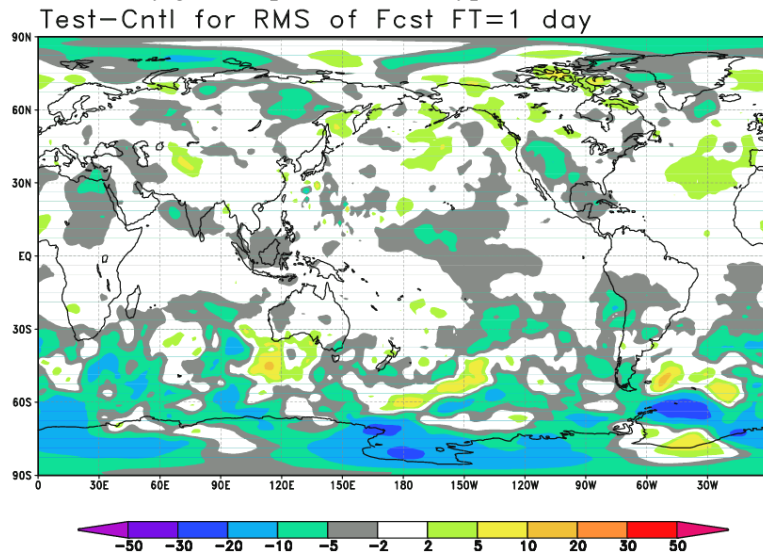


Fig. 7: Monthly mean difference of RMSE from TEST to CNTL at 24-hour forecast. Negative value (Blue color) shows positive impact.

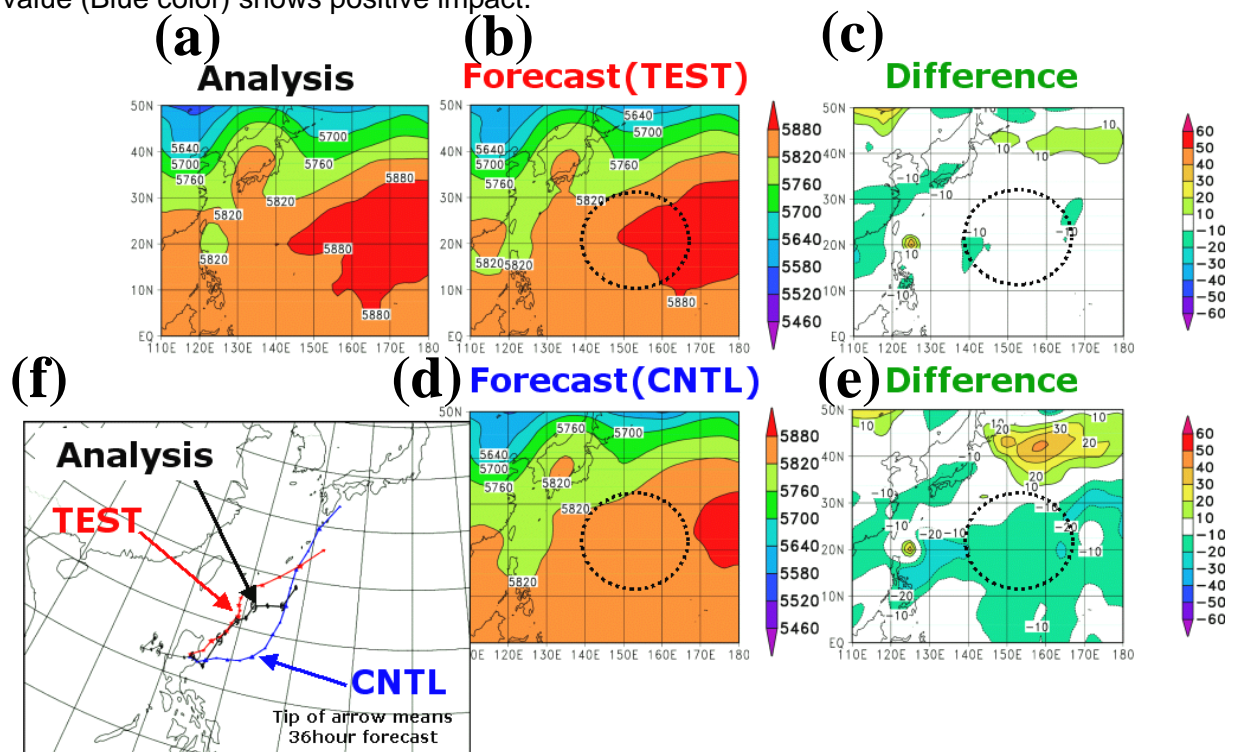


Fig. 8: Typhoon track prediction during pre-operational run. (a): Analyzed field of 500hPa height, (b): 24-hour forecast of 500hPa height for TEST (ATOVS radiances assimilation), (c): Difference from (b) minus (a), (d): 24-hour forecast of 500hPa height for CNTL (ATOVS retrieval assimilation), (e): Difference from (d) minus (a). (f): Track of Typhoon. Red: TEST, Blue: CNTL, Black: Analysis.

Summary and Future prospect

JMA has started operational use of ATOVS radiances in the global data assimilation on 28 May 2003. No retrievals from ATOVS radiances and that from GMS-5 have not been used since then. Experiments prior to the operational use have demonstrated dramatic impacts. The temperature

profiles in the upper stratosphere and the global humidity field in the troposphere were improved. The higher accuracy of initial fields of temperature and humidity were confirmed against radiosonde observation and the total precipitable water from SSM/I. As for forecast skills, positive impacts were found for the geopotential height at 500 hPa in the southern hemisphere and in the tropical region. The improvement of short-range forecast was remarkable. And better results on the typhoon track prediction were also found out.

JMA has achieved considerable progress in ATOVS data assimilation, but some un-preferable features are still seen: anomalous change of temperature at some levels in the stratosphere and the excessive concentration of rainfall in 6-hour forecast. To solve these problems, we continue to carry out some experiments and improve the bias correction scheme of ATOVS brightness temperature. Moreover, we are going to assimilate ATOVS Level 1B data to avoid intrinsic errors in level 1D data. And we have a plan to update the radiative transfer model from RTTOV-6 to RTTOV-7. A preparation on Aqua/AIRS data assimilation is underway.

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