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ASSIMILATION OF HIMAWARI-8 ATMOSPHERIC MOTION VECTORS INTO THE NUMERICAL WEATHER PREDICTION SYSTEMS OF JAPAN METEOROLOGICAL AGENCY

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Abstract

The Meteorological Satellite Center of Japan Meteorological Agency (JMA/MSC) has produced operational Himawari-8 Atmospheric Motion Vectors (AMVs) since July 7, 2015. The AMVs are produced using three sequential satellite images at intervals of 10 minutes, as opposed to the 30~60 minute intervals of images used for MTSAT-2 AMVs. The quality of its AMVs has been improved by employing new tracking and new height assignment algorithms.

For the effective use of Himawari-8 AMVs, the pre-processing system for AMVs was updated. To investigate the impact of Himawari-8 AMVs with the revised pre-processing system comparing with the impact of MTSAT-2 AMVs, observing system experiments using the JMA's operational Numerical Weather Prediction (NWP) systems were performed over periods of approximately two months in summer, a month in winter 2015 and a month in winter 2016. The OSEs using the global NWP system revealed that wind forecast errors over the Himawari-8 observation area, especially around Japan, were reduced and mean positional errors for ten typhoons in summer were also reduced with 24-hour to 48-hour and 90-hour to 120-hour forecast lead time. The reduction rate was around 6 % with 24-hour to 48-hour forecast lead time. The OSEs conducted with JMA's meso-scale NWP systems also showed improvement in rain forecasting as well. The Himawari-8 AMVs with the revised pre-processing system have been incorporated into the JMA's operational NWP systems since March 17, 2016 in place of MTSAT-2 AMVs.

1. INTRODUCTION

At the 12th International Winds Workshops, it was reported that the Meteorological Satellite Center of JMA (JMA/MSC) specially produced MTSAT Rapid Scan AMVs (RS-AMVs) from the MTSAT-1R satellite images taken at intervals of 10 minutes in October 2013 for the research purpose. The RS-AMVs were processed with the super-observation pre-process procedure (SPOB) for Japan and its surrounding areas while they were thinned by 200 square km. Observing system experiments (OSEs) of RS-AMVs using JMA's global numerical weather prediction (NWP) system showed that the observation and forecast errors in Japan and its surrounding areas were reduced and mean positional errors of the six typhoon track forecasts were reduced about 8 % with 30-hours to 84-hours forecast lead time (Yamashita 2014). Moreover, in October 2014, the JMA/MSC specially produced RS-AMVs from the MTSAT-1R satellite images as same domain as in 2013 for confirming an accuracy of AMVs using new tracking and height estimation algorithm for Himawari-8. OSEs also were performed using JMA's global NWP system which emploied the SPOB for Japan and its surrounding areas. The same results of OSEs to those of OSEs in 2013 were obtained.

The JMA/MSC has produced operational Himawari-8 AMVs since July 7, 2015. The AMVs are produced using three sequential satellite images at intervals of 10 minutes, as opposed to the 30~60 minute intervals of images used for MTSAT-2 AMVs. The quality of its AMVs has been improved by employing new tracking and new height assignment algorithms (Bessho et al. 2016). Himawari-8 AMVs had to be assimilated with JMA's operational global meso-scale and local NWP systems in place of MTSAT-2 AMVs. For the effective use of Himawari-8 AMVs, it needed to check the quality of Himawari-8 AMVs comparing with MTSAT-2 AMVs in detail and it needed to revise the quality control (QC) suitable for the Himawari-8 AMVs. Furthermore, it needed to employ the SPOB for Japan and its surrounding areas considering the good performance of the SPOB shown in results of above-mentioned OSEs using JMA's operational global NWP system.

In this paper, results of OSEs using JMA's operational global and meso-scale NWP system are shown mainly[1]. First, the outline of JMA's global and meso-scale NWP system is described in the section 2. The characteristics of Himawari-8 AMVs evaluated statistically are reported in the section 3. These are shown by comparison between Himawari-8 AMVs and MTSAT-2 AMVs. The QC for Himawari-8 AMVs and experimental design are described in the section 4. The results of the experiments are discussed in the section 5, and summary and future plans are provided in section 6.

2. OUTLINE OF THE GLOBAL AND MESO-SCALE NWP SYSTEM S AT JMA

The configuration of JMA's global NWP system as of September 4, 2014 and its meso-scale NWP system as of December 24, 2015 are listed in Table 1 and Table 2 respectively. Hereafter, "Global Data Assimilation System" and "Meso-scale Data Assimilation System" are abbreviated to "GSM-DA" and "MSM-DA", respectively.

***Table 1*: Configuration of the global NWP system at JMA**

Data Assimilation System for Global Spectral Model (GSM-DA)	
Method	four-dimensional variational data assimilation (4D-Var)
Resolution and Layers (inner model)	TL319L100 (hydrostatic reduced Gaussian grid, horizontal resolution approx. 55 km, model top 0.1 hPa)
Assimilation window	6 hours (±3hours, time slots approx. 1 hour)
Typhoon bogus data	Used

Global Spectral Model (GSM)	
Resolution and Layers	TL959L100 (hydrostatic reduced Gaussian grid, horizontal resolution approx. 20 km, model top 0.01 hPa)
Forecast domain	Globe
Forecast range (initial time)	84 hours/264 hours (00, 06, 18 UTC/12 UTC)

***Table 2*: Configuration of the meso-scale NWP system at JMA**

Data Assimilation System for Meso-Scale Model (MSM-DA)	
Method	4D-Var
Resolution:Outer/Inner/Layers	5 km/15 km/48+2 layers (non-hydrostatic grid model, model top 21,800 m, 48 layers for the atmosphere and 2 layers for the upper and lower boundaries)
Assimilation window	3 hours (-3 hours, time slots approx. 1 hour)
Typhoon bogus data	Used

Meso-Scale Model (MSM)	
Resolution/Layers	5 km (non-hydrostatic grid model, model top 21,800 m)/48+2 layers
Forecast domain	Japan and its surrounding areas
Forecast range (initial time)	39 hours (00, 03, 06, 09, 12, 15, 18, 21 UTC)

3. CHARACTERISTICS OF HIMAWARI-8 AMV DATA

The characteristics of Himawari-8 AMVs were evaluated statistically against the first guesses of the GSM-DA and MSM-DA systems. Figure 1 shows a histogram of the normalized difference (O-B) between the relevant wind speeds and first guesses in the GSM-DA system for the Northern Hemisphere (NH) at levels above 400 hPa from February 5 to March 20, 2015. These were compared with O-B for MTSAT-2 AMVs, which are already assimilated in the operational GSM-DA and MSM-DA systems. As shown in Fig. 1, the histograms of O-B for NH AMVs in the GSM-DA system exhibit Gaussian distribution. Those for other

[1] Results of OSEs using JMA's operational local NWP system were also showed improvement in precipitation forecasts as well.

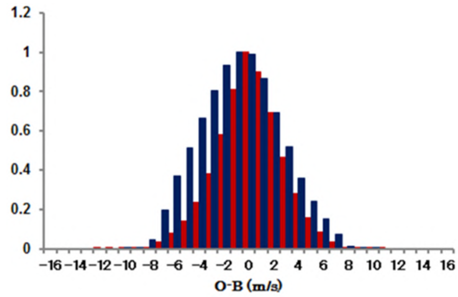

Figure 1. O-B normalized histograms of infrared AMVs at levels above 400 hPa in the Northern Hemisphere (poleward of 20°N) from February 5 to March 20, 2015. The red and blue bars correspond to Himawari-8 and MTSAT-2 AMVs, respectively.

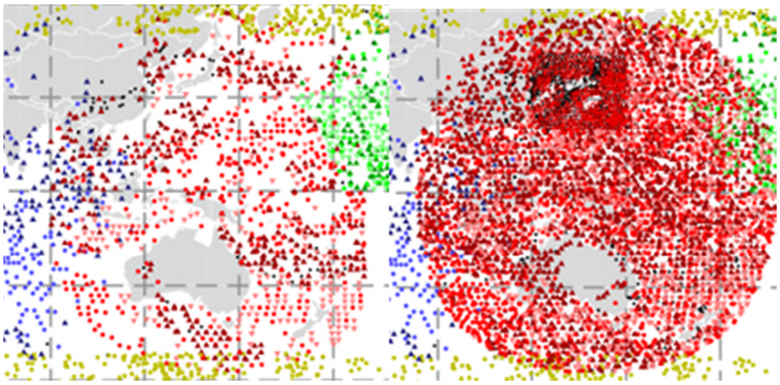

Figure 2. Assimilated AMV data coverage in the GSM-DA system for the 60°S – 60°N and 90°E – 170°W region at 00 UTC on July 20, 2015. Left: MTSAT-2 AMVs (red plots); right: Himawari-8 AMVs (red plots).

regions and those in the MSM-DA systems have the same characteristics (not shown). The standard deviation (STD) of O-B is around 0.5 m/s less than that of the MTSAT-2 AMVs, suggesting improved data quality. Data coverage is also improved (Fig. 2).

4. QC FOR HIMAWARI-8 AMV DATA AND OSES

To support the effective use of Himawari-8 AMVs, the AMV pre-processing system has been updated in three main ways.

Firstly, the quality indicator (QI, Holmlund 1998) thresholds for low-quality AMV rejection were revised in consideration of Himawari-8 AMV characteristics. Secondly, climatological checking was revised to use more AMVs in the middle troposphere and rejection of infrared and visible AMVs over land below 700 hPa. Thirdly, a 100-km SPOB (Yamashita 2014), as described in section 1, was introduced into the global NWP system for Japan and its surrounding areas from 120°E to 150°E, 20°N to 45°N (introduced a 200-km thinning scheme for the other regions). Details of other QC measures are provided on the NWP SAF AMV monitoring page[2].

To determine the impact of Himawari-8 AMVs with the revised pre-processing system in comparison with that used for MTSAT-2 AMVs, OSEs using JMA's global NWP system were performed for the periods from January 17 to March 11, 2015 (winter 2015) and from July 3 to September 11, 2015 (summer 2015). OSEs using JMA's meso-scale NWP system were performed for the periods from August 2 to September 11, 2015 (summer 2015) and from December 24, 2015 to February 3, 2016 (winter 2016). The term TEST is used to refer to the experiments with assimilation of Himawari-8 AMVs and without that of MTSAT-2 AMVs, and CNTL is used to refer to those with assimilation of MTSAT-2 AMVs. The results of the two tests were compared, and other observations were used in both experiments as in the actual operational systems. Typhoon track forecasts were verified using the typhoon best track (BST) provided by the Regional Specialized Meteorological Centre (RSMC) Tokyo – Typhoon Center.

5. OSE RESULTS

The OSEs were performed using JMA's global NWP system and revealed reduced O-B wind speed differences between TEST and CNTL over the Himawari-8 observation area (especially around Japan; Fig. 3). Figure 4 shows zonal mean meridional cross section differences on analysed field of U-component and V-component winds around Japan between TEST and CNTL. Shown are enhancement of wind speed to the northward and enhancement of jet stream, and shift of the stream to the southward. It is considered that these results are brought by modification of atmospheric general circulation, especially over the Himawari-8 observation area. Figure 5 shows the normalized RMSE difference around Japan between TEST and CNTL forecasts for the forecast range of one to eleven days for 850 hPa and 250 hPa wind vectors in summer

[2] https://nwpsaf.eu/monitoring/amv/amvusage/jmamodel.html

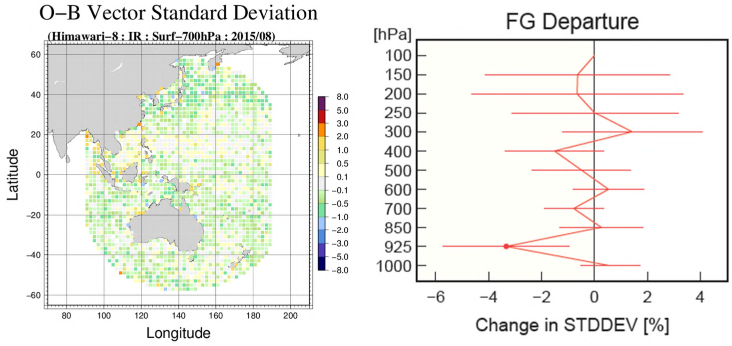

Figure 3. O-B wind speed differences between Himawari-8 and MTSAT-2 AMVs below 700 hPa for summer 2015 (left; negative values indicate better scores) and normalized O-B wind speed standard deviation differences between TEST and CNTL against wind profiler observations for summer 2015 (right; negative values indicate better scores, error bars represent a 95% confidence interval, and red dots indicate statistical significance).

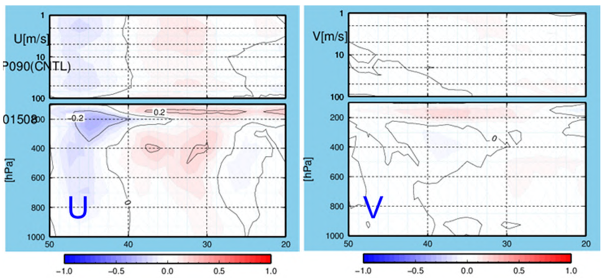

Figure 4. Zonal mean meridional cross sections on analyzed field differences of U-component and V-component winds around Japan (from 110°E to 160°E, 20°N to 50°N) between TEST and CNTL. Positive values (red) indicate TEST is larger than CNTL. Negative values (blue) indicate TEST is smaller than CNTL.

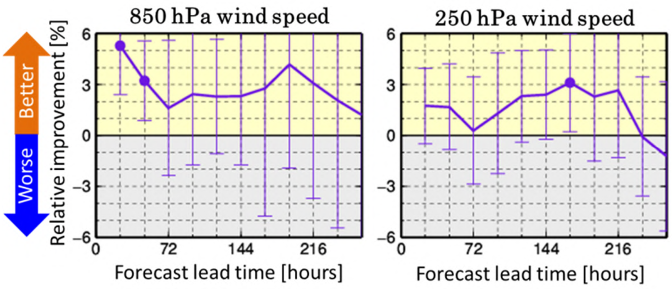

Figure 5. Normalized RMSE differences (y-axis) around Japan (from 110°E to 160°E, 20°N to 50°N) between TEST and CNTL covering periods from one to eleven days (x-axis) for 850 hPa and 250 hPa wind vectors in summer 2015. Positive values indicate better scores. Error bars represent a 95% confidence interval, and dots indicate statistical significance.

2015. Their improvements are seen until eleven days. Especially significant improvements (up to 3 – 6% on average) for 850 hPa are seen until two-day forecasts for summer 2015. Positive or neutral impacts are seen for other physical elements and heights/regions (not shown). Mean positional errors for ten typhoons in summer were also reduced with 24-hour to 48-hour and 90-hour to 120-hour forecast lead times. The reduction was around 6% with 24-hour to 48-hour forecast lead times (Fig. 6). In a case study of typhoon NANGKA track forecast initialized at 12 UTC on July 13, 2015, TEST is closed to BST until 72-hours forecast lead time (Fig.7). Positive impacts on most physical elements and heights in the Southern Hemisphere were also seen in four-day forecasts for winter 2015 (not shown).

The OSEs conducted using JMA's meso-scale NWP systems also showed improvement in precipitation forecasts (Fig. 8). There was improvement of precipitation forecasts from 1 to 15 mm per 3 hours compared with CNTL in both seasons. Figure 9 shows 3-hour forecasts of two experiments initialized at 03 UTC 9 September 2015 in a case study of Kanto and Tohoku heavy precipitation in eastern part of Kanto. Heavy precipitation pattern which indicates blue dash line area of TEST using Himawari-8 AMV is similar to the observed one. Because analyzed and forecast fields were improved by cycle analysis using Himawari-8 AMVs. And convergent winds were strengthened along 140°E at 03 UTC September 9, 2015 (not shown).

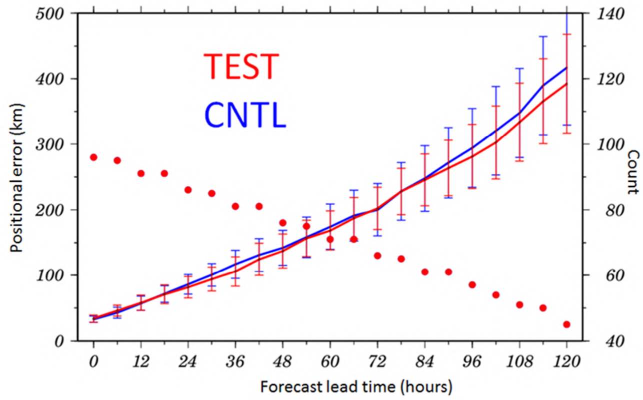

Figure 6. Average typhoon track forecast errors for summer 2015. The red line is for TEST values, the blue line is for CNTL values, and the red dots are sample data numbers. Error bars represent a 95% confidence interval.

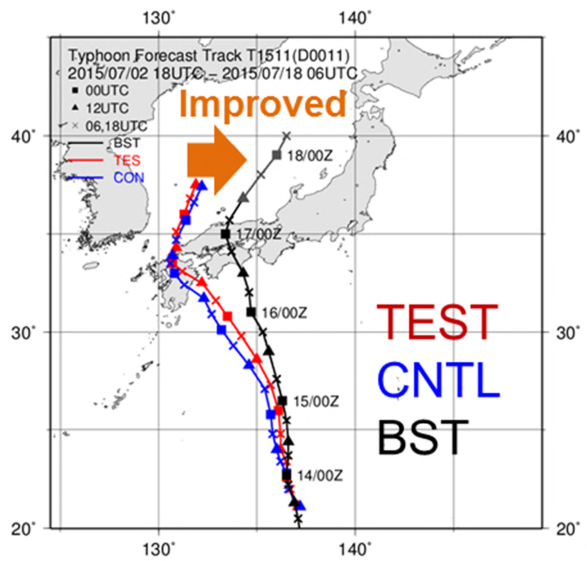

Figure 7. Typhoon track TEST (red), CNTL (blue) and BST (black) forecasts of NANGKA (T1511) initialized at 12 UTC on 13 July 2015.

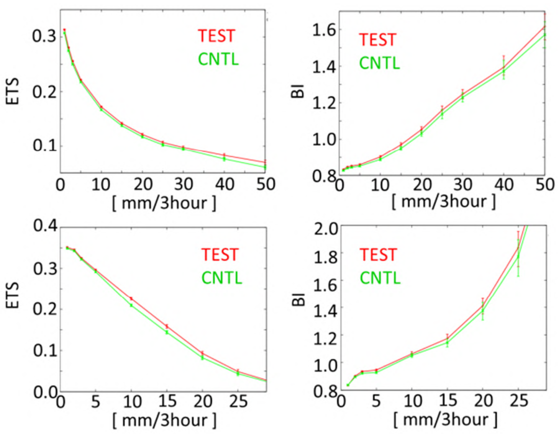

Figure 8. Equitable threat score (ETS: left) and bias score (BI: right) against Radar-Rainfall composite precipitation for each threshold of precipitation. Upper panel shows score of summer 2015. Lower panel shows score of winter 2016. The red line is for TEST values, the green line is for CNTL values. Error bars represent a 95% confidence interval.

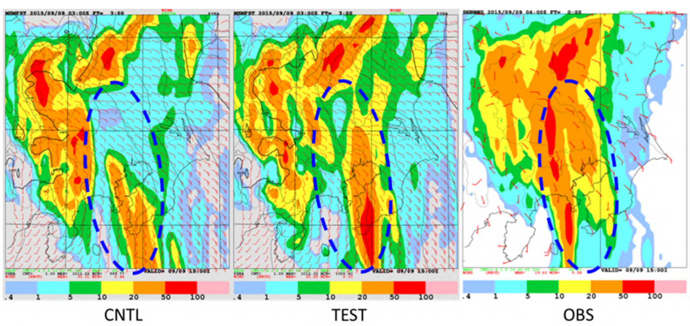

Figure 9. 3-hour forecasts of TEST and CNTL experiments and Radar-Rainfall composite precipitation (OBS) initialized at 03 UTC 9 September 2015 in a case study of Kanto and Tohoku heavy precipitation in eastern part of Kanto The blue arrows represent remarkable heavy precipitations.

6. SUMMARY AND FUTURE PLANS

OSEs of Himawari-8 AMVs using JMA's operational global and meso-scale NWP systems with revised QC for the AMVs were performed for winter 2015, summer 2015 and winter 2016. In the global NWP system, reduced O-B wind speed differences between TEST and CNTL over the Himawari-8 observation area was brought. Positive or neutral forecast impacts are seen for almost physical elements and heights/regions. Mean positional errors for ten typhoons in summer were also reduced. In the meso-scale operational NWP system, it showed improvement in precipitation forcasts. It was revealed that good performances in the global and meso-scale NWP systems were brought by Himawari-8 AMVs.

Himawari-8 AMVs with the revised pre-processing system have been introduced into JMA's operational global, meso-scale and local[1] NWP systems since March 17, 2016.

JMA has a plan to introduce a new QC of rejection of Himawari-8 AMVs with u-component wind speed biases associated in jet stream in the global NWP system around November 2016.
The other future plans for Himawari-8 AMVs are as follows. These are to adopt the SPOB method which expanded to proper region from Japan areas into the global NWP system and to introduce SPOB method into the meso-scale and local NWP systems.

7. REFERENCES

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