Assimilation of Himawari-8 data into JMA's NWP systems

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1. Introduction

The new-generation Himawari-8 geostationary meteorological satellite of the Japan Meteorological Agency (JMA) was launched on 7 October 2014 (Bessho et al. 2016). Since 7 July 2015, JMA's Meteorological Satellite Center (MSC) has used data from the satellite to operationally produce Clear Sky Radiance (CSR) data and Atmospheric Motion Vector (AMV) data, which are both disseminated to the numerical weather prediction (NWP) community via the Global Telecommunication System (GTS).

Himawari-8 carries the new Advanced Himawari Imager (AHI), which has 16 bands as opposed to the 5 of its MTSAT-2 predecessor. Full-disk observation periodicity has also been improved from 60 minutes to 10 minutes. Table 1 provides further information on the Himawari-8 and MTSAT-2 imagers.

Table 1 General specifications of the Himawari-8 and MTSAT-2 imagers

	Himawari-8	MTSAT-2
Radiometer	AHI	IMAGER
Bands	16 VIS: 3; NIR: 3; IR: 10	5 VIS: 1; IR: 4
Spatial resolution at sub-satellite point	VIS: 0.5 km; NIR: 1 km; IR: 2 km	VIS: 1 km; IR: 4 km
Full-disk observation frequency	Every 10 minutes	Every 60 minutes

VIS: visible bands; NIR: near infrared bands; IR: infrared bands

2. Data and Quality Control

(1) Atmospheric Motion Vectors (AMVs)

Himawari-8 AMVs are derived using three sequential satellite images taken at intervals of 10 minutes, as opposed to the 30 – 60-minute intervals for MTSAT-2 AMVs. The images of bands 3 (VIS), 7, 8, 9, 10 and 13 (IR) are used for Himawari-8 AMVs, while only three bands were used for MTSAT-2 AMVs. The horizontal resolution of Himawari-8 AMVs is around 50 km, which is the same as that of MTSAT-2 AMVs.
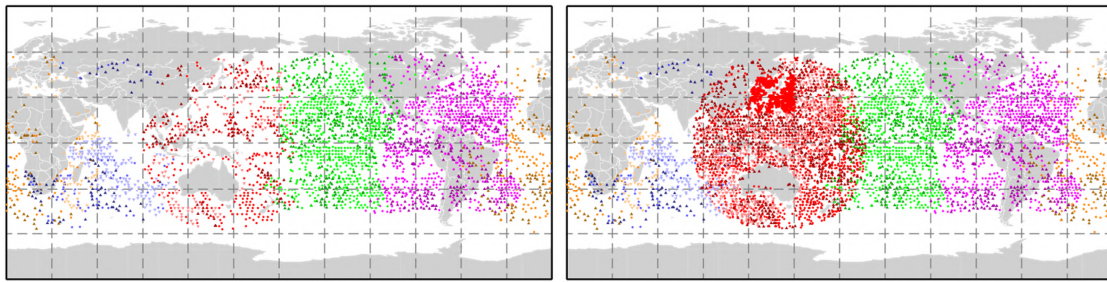
Figure 1 Map of geostationary satellite AMV coverage at 9:00 (JST) on 20 July 2015. Red points indicate data from MTSAT-2 (left) and Himawari-8 (right).

To support the effective use of Himawari-8 AMVs, the AMV pre-processing system has been updated in three main ways (Yamashita 2016). First, the quality indicator (QI, Holmlund 1998) thresholds for low-quality AMV rejection were revised in consideration of Himawari-8 AMV characteristics. Second, climatological checking was revised to involve the use of more AMVs in the middle troposphere. Third, a 100-km super-observation technique (Yamashita 2014) was introduced into the global NWP system for Japan and the surrounding areas.

The characteristics of Himawari-8 AMVs were evaluated statistically against the first guesses of JMA's global NWP system (referred to here as GSM-DA), into which MTSAT-2 AMVs are already assimilated. The normalized histograms of Himawari-8 AMVs and MTSAT-2 AMVs both exhibit Gaussian distribution. The standard deviation (STD) of FG departures of Himawari-8 AMVs is around 0.4 m/s less than that of the MTSAT-2 AMVs, suggesting improved data quality. Similar statistical results are observed for AMVs derived using other bands at different levels. Data coverage is also improved (Fig. 1).

(2) Clear Sky Radiance (CSR)

The Himawari-8 AHI has three IR water vapor absorption bands, while the MTSAT-2 IMAGER had only one. Data from these bands (6.2, 6.9 and 7.3 micrometers, referred to as bands 8, 9 and 10, respectively) are provided. The horizontal resolutions of Himawari-8 CSR data and MTSAT-2 CSR data are 32 and 64 km, respectively. Full-disk data from both satellites are provided every hour.

Improved cloud detection in CSR data production at JMA's Meteorological Satellite Center increases the number of available CSR data, especially over land (Fig. 2). Further cloud detection using the preprocessor of the GSM-DA system based on the clear-pixel ratio of Himawari-8 band 13 (10.4 micrometers) has also been introduced. Oceanic data exclusively from Himawari-8 bands 9 and 10 are used to avoid land surface signal contamination in dry atmospheric conditions.
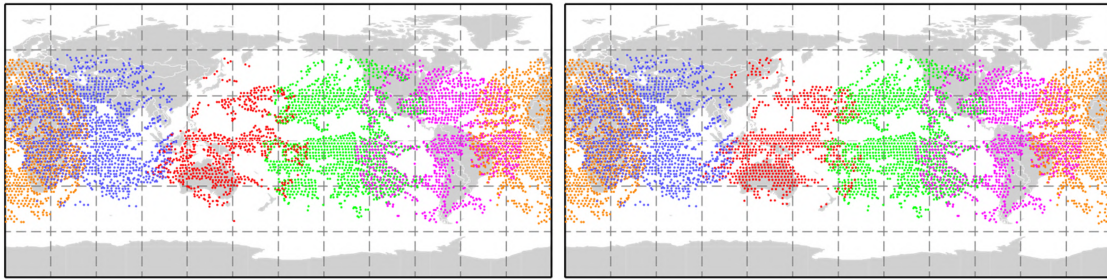
Figure 2 Map of geostationary satellite CSR coverage at 9:00 (JST) on 20 July 2015. Red points indicate data from MTSAT-2 (left) and Himawari-8 (right).

The quality of Himawari-8 CSR data was evaluated against the first-guesses of GSM-DA. The normalized histograms for the FG departures of both Himawari-8 CSR data and MTSAT-2 CSR data exhibit Gaussian distribution. The quality of Himawari-8 band 8 CSR data is comparable to that of MTSAT-2 CSR data. Overall, Himawari-8 CSR data quality is superior to that of MTSAT-2 (Kazumori 2016).

3. Impact Evaluation: Observation System Experiments (OSEs)

(1) OSE Configuration

OSEs for Himawari-8 AMV and CSR data were conducted using GSM-DA for the period from December 2015 to January 2016 (winter 2015) and from July to September 2015 (summer 2015). The term CNTL is used to refer to an experiment with MTSAT-2 data assimilation, while TEST is used to refer to one with assimilation of Himawari-8 data based on improved quality control processes. Other observation data for both experiments were the same as those used in JMA's operational global NWP system.

The AMV data were thinned with a square box measuring at least 2 degrees larger than 200 km. One data point in the box was selected for the assimilation period of six hours. However, the above super-observation technique was applied for the Japan area, thereby involving the use of much more AMV data. For CSR data, the thinning distance was set as 220 km and hourly data were assimilated.

(2) OSE Results

The FG departures of AMV/CSR data and various other types of observation data (especially those sensitive to water vapor) were improved (not shown).

The root mean square errors (RMSEs) of geopotential height at 500 hPa were improved for the whole forecast range to 84 hours, especially in the tropical region in the summer experiment and in the Southern Hemisphere in the winter experiment (Fig. 3). The RMSEs of horizontal winds at 250 hPa were improved for the first half of the forecast range in the tropics and the Northern Hemisphere (Fig. 4). In the Southern
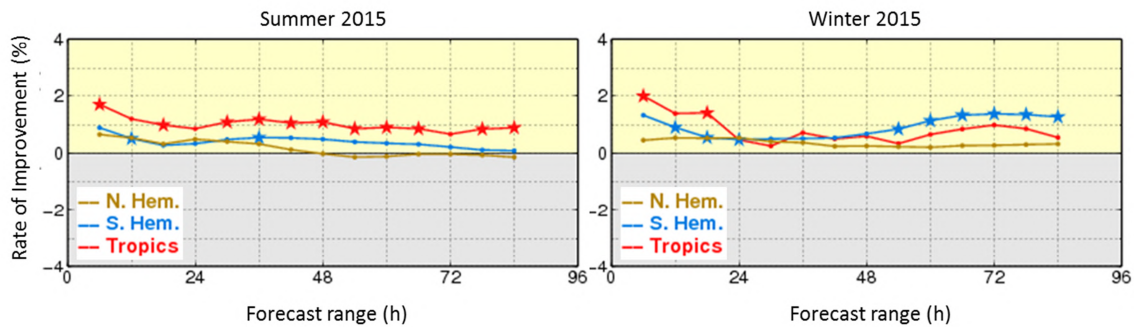
Figure 3 Improvement ratio ((CNTL – TEST) / CNTL) [%] for the RMSE of geopotential height at 500 hPa verified against the experiment's own analysis. Positive values indicate forecast error reductions of TEST against CNTL. The figures on the left and right show results for summer and winter 2015, respectively. Brown, blue and red lines show verification results for the Northern Hemisphere (20°N – 90°N), the Southern Hemisphere (20°S – 90°S) and the Tropics, respectively. Stars indicate statistically significant verification results.
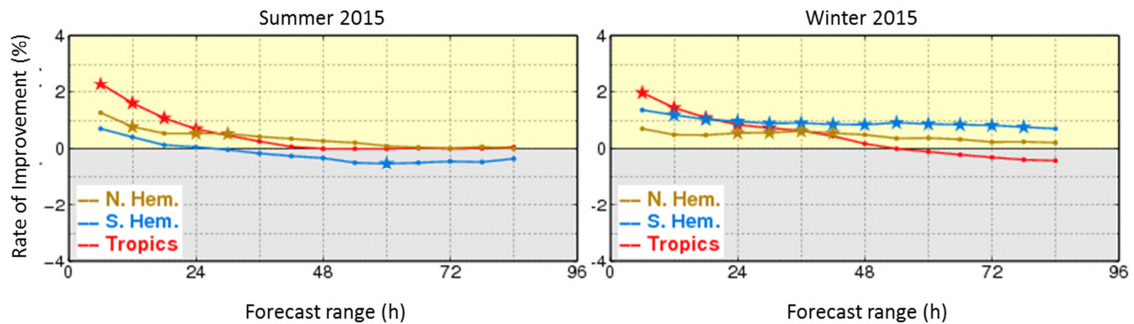

Figure 4 As per Fig. 3 but with verification of winds at 250 hPa

Hemisphere, horizontal wind forecast skill at 250 hPa was significantly improved for the whole forecast range in the winter experiment, while that in the summer experiment showed slight deterioration in the second half of the range.

Figure 5 shows improvement in average track forecast skill for 16 typhoons (T1508 to T1523) observed during summer 2015. This stems from improved GSM forecast skill for atmospheric general circulation thanks to the use of Himawari-8 AMV and CSR data rather than MTSAT-2 data.

4. Summary

JMA's new-generation Himawari-8 geostationary meteorological satellite was launched on 7 October 2014. It carries the cutting-edge Advanced Himawari Imager (AHI), which has 16 bands and the capacity for full-disk scanning every 10 minutes.

AMV and CSR data from Himawari-8 show significant quantitative and qualitative improvement over those from MTSAT-2. The quality control processes for these data
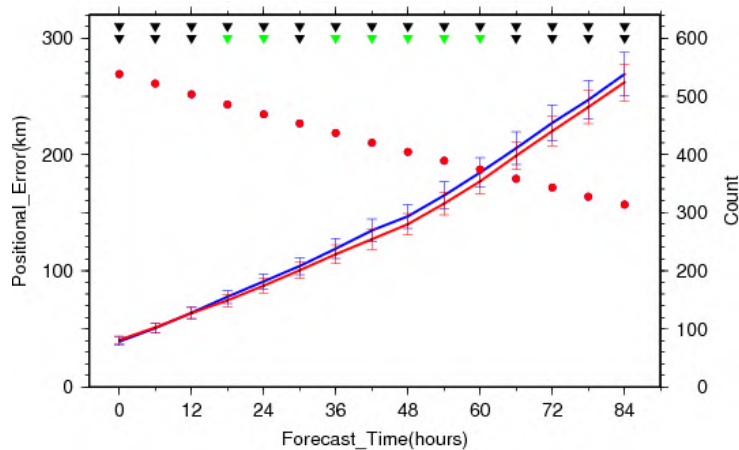
Figure 5 Average typhoon track forecast errors for summer 2015. The red line is for TEST values, the blue line is for CNTL values, and the red dots are sample data numbers. Error bars represent a 95% confidence interval.

have also been improved to support even more effective usage.

The results of OSEs proved that assimilation of Himawari-8 AMV and CSR data with enhanced quality control processes helped to improve GSM analysis and forecasting more than assimilation of the corresponding MTSAT-2 data.

Assimilation of Himawari-8 AMV and CSR data into GSM-DA was begun in March 2016.

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