Upgraded Usage of MODIS Polar Atmospheric Motion Vectors in the JMA Operational Global NWP System

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1. Introduction

MODIS is the Moderate Resolution Imaging Spectroradiometer on board the Terra and Aqua satellites, and MODIS polar Atmospheric Motion Vectors (AMVs) are estimated using MODIS sequential images over the polar regions. These AMVs have been produced by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) since 2001, and have been assimilated in the Arctic since 27 May, 2004, with the Japan Meteorological Agency (JMA)'s operational global Numerical Weather Prediction (NWP) system (Kazumori and Nakamura 2004). CIMSS-AMVs in the Antarctic have also been used since 16 September, 2004. The data are acquired via anonymous FTP on CIMSS.

The National Oceanic and Atmospheric Administration (NOAA)/the National Environmental Satellite, Data, and Information Service (NESDIS) recently started producing MODIS polar AMVs (NESDIS-AMVs) on an operational basis. The data are broadcast internationally via the Global Telecommunication System (GTS). CIMSS also started producing new direct broadcast (DB) MODIS polar AMVs (CIMSS-DB-AMVs) to improve on the timeliness of CIMSS-AMVs. To enable the use of NESDIS-AMVs and CIMSS-DB-AMVs (the new AMVs) stably and instantly in operational global four-dimensional variational data assimilation (4D-VAR) on the NWP system (GSM-DA), we made several revisions to our quality control (QC) system. One-month observing-system experiments (OSEs) for the new AMVs were performed using GSM-DA with the revised QC system during January 2010 and August 2010.

2. Characteristics of the new AMV data

Figure 1 shows the data acquisition times for NESDIS-AMVs, CIMSS-DB-AMVs and CIMSS-AMVs for Terra in September 2008. The times for Terra CIMSS-DB-AMVs are much shorter than for the others, and those for NESDIS-AMVs are the same as those for CIMSS-AMVs. The new AMV data are expected to produce an increase in the volume of AMVs and to improve coverage in polar regions (Fig. 2).

The qualities of the new AMVs were evaluated statistically against the first guess of the GSM-DA. The standard deviation (STD) of the difference between the new AMVs and the first guess (O-B) is 3 – 4 m/s (not shown). The qualities of the new AMVs are as accurate as those of CIMSS-AMVs, but the spatial and time-error correlation distance of O-B in NESDIS-AMVs is longer than those of the other types (Fig. 2).

3. Revised QC for the new AMV data and OSEs

The major differences in QC between the operational method (CNTL) and the revised method (TEST) are shown in Table 1. We prioritize CIMSS-AMVs and CIMSS-DB-AMVs based on the results outlined in Section 2. Blacklisting in space was statistically decided by the mean error (ME) and STD of O-B in 2008. The criteria for O-B STD are 5 m/s for levels above 400 hPa, 4 m/s for levels from 400 to 700 hPa, and 2 m/s for levels below 700 hPa. An ME of below 2 m/s was adopted (Yamashita 2008). New IR AMVs, which showed statistically good quality for the 600 – 900 hPa level, were available for use.

OSEs were performed to evaluate the impact of the revised QC for the new AMVs using GSM-DA. Global 4D-VAR data assimilation cycles were run every six hours, and 216-hour forecasts were executed from 12 UTC using the operational global spectral model (JMAGSM), which is a hydrostatic spectral model with a horizontal resolution of 20 km (the resolution of the inner model for GSM-DA is 80 km) and 60 levels in the vertical direction with the top level at 0.1 hPa. The OSE periods were January and August of 2010.

4. OSE results

Figure 3 shows the forecast rate of improvement[1] with respect to RMSEs for forecasts covering periods from one to nine days in January 2010. Significant positive impacts are seen on three-day forecasts, especially in the Southern Hemisphere (SH), reaching up to 2 – 4% on average in January 2010. The RMSE of wind forecasts was reduced in the SH, especially below 300 hPa, against radiosonde observations in January 2010 (not shown). In August 2010, positive impacts were seen on typhoon track forecasts over 48 forecast hours (Figure 4), while the impact on the global forecast was almost neutral. In light of these OSE results, the revised QC system for polar AMVs was introduced into the JMA operational NWP system on 2 February, 2011.

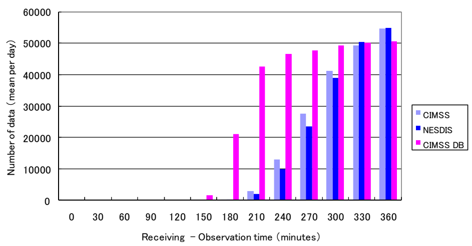
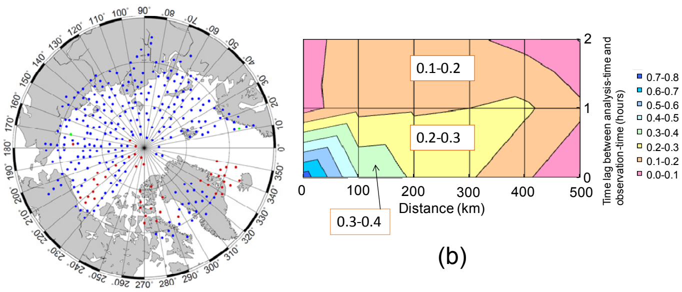


Figure 1. Data acquisition times for Terra NESDIS (blue), CIMSS DB (pink) and CIMSS operational (light blue) MODIS polar AMVs in September 2008



(a)

Figure 2. (a) Polar AMVs used for the 400-hPa level in the North Pole region in JMA's NWP system at 00 UTC on August 29, 2010. The blue dots are for CIMSS-AMVs, the red dots are for CIMSS-DB-AMVs, and the green dots are for NESDIS-AMVs. (b) Spatial and time O-B error correlation for distance in Terra IR NESDIS-AMVs above 400 hPa in May 2009. The values show the O-B correlation coefficient.

Table 1: Major differences in QC between the operational method and the revised method

	Operational method (CNTL)	Revised method (TEST)
Data used	1. CIMSS- AMVs	1. CIMSS- AMVs 2. CIMSS-DB- AMVs 3. NESDIS- AMVs
Thinning	1. Thinning interval: 150 km 2. One AMV selected per box in the six-hour time window	1. Thinning interval: 150 km 2. Priority of CIMSS- AMVs and CIMSS-DB-AMVs 3. One AMV selected per box in the six-hour time window
Blacklisting in space *IR: infrared sensor *WV: water vapor sensor *CWV: clear sky WV	1. All AMVs over land below 400 hPa 2. All WV AMVs below 550 hPa over sea 3. All IR AMVs below 600 hPa over sea	1. IR* AMVs for NH above 300 hPa or below 900 hPa 2. WV* and CWV* AMVs for NH above 300 hPa or below 550 hPa 3. IR* and WV* AMVs for SH above 300 hPa or below 550 hPa 4. CWV* AMVs for SH above 350 hPa or below 550 hPa 5. All AMVs poleward of 88°N or 88°S
Observation error adjustment	Use	Not in use

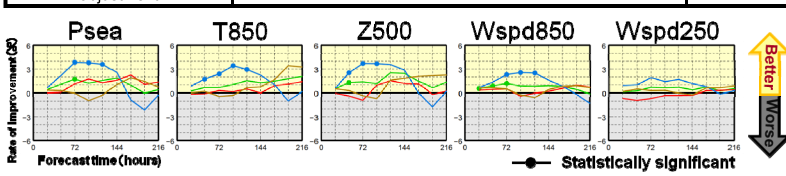


Figure 3. Forecast improvement rate with regard to RMSEs for 1 – 9-day forecasts in January 2010. The graph labeled Psea shows surface pressure, T850 shows 850-hPa temperatures, Z500 shows 500-hPa geopotential heights, Wspd850 shows 850-hPa wind speeds, and Wspd250 shows 250-hPa wind speeds. Positive values mean better scores. The green, brown, red and blue lines show the forecast improvement rate for the global, Northern Hemisphere (poleward of 20°N), tropical (20°S – 20°N) and Southern Hemisphere (poleward of 20°S) regions, respectively.

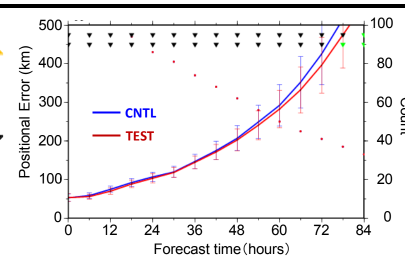


Figure 4. Average typhoon track forecast errors in August 2010. The red line is for TEST values, the blue line is for CNTL values, the red dots are sample data numbers, and the error bars represent a 95% confidence interval.

References

Kazumori, M. and Y. Nakamura, (2004): MODIS polar winds assimilation experiments at JMA, *Proceedings of 7th IWW*, Finland.

Yamashita, K., (2008): Upgraded Usage of Atmospheric Motion Vectors Geostationary Satellites in the Operational Global and Meso-Scale 4D-Var Assimilation System at JMA, *Proceedings of 9th IWW*, USA.

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[1] $(RMSE_{CNTL} - RMSE_{TEST}) / RMSE_{CNTL}$