Introduction of LEO-GEO and AVHRR Polar Atmospheric Motion Vectors into JMA's Operational Global NWP System

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1. Introduction

LEO-GEO atmospheric motion vectors (AMVs) are derived in the latitudinal zone from approximately 60° to 70° using composite satellite imagery (a combination of geostationary (GEO) and polar-orbit (LEO) images) because there is a gap in coverage between middle-latitude and tropic AMVs derived from GEO images and those for polar regions derived from LEO images (Lazzara et al. 2014). LEO-GEO AMVs have been produced by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) since November 2010. AVHRR (Advanced Very High Resolution Radiometer) polar AMVs (AVHRR AMVs) are estimated using AVHRR sequential images for areas over polar regions, and have been produced by CIMSS since 2006 (Key et al. 2008). The National Environmental Satellite, Data, and Information Service (NESDIS) of the National Oceanic and Atmospheric Administration (NOAA) has also been producing such AMVs on an operational basis since 2009. A specific quality control (QC) system was created to enable the use of LEO-GEO AMVs and AVHRR AMVs (the new AMVs) in operational global four-dimensional variational data assimilation (4D-VAR) on the NWP system (GSM-DA). Three-month observing system experiments (OSEs) for these new AMVs were performed using GSM-DA with the QC system in the summer and winter of 2012.

2. Characteristics of the new AMV data

The qualities of the new AMVs were evaluated statistically against the first-guess of the GSM-DA. Figure 1 shows a normalized histogram of the difference between their wind speeds and first-guess (O-B) data for the Northern Hemisphere (NH) in September 2011. These were compared with O-B data from CIMSS Moderate Resolution Imaging Spectroradiometer (MODIS) Terra AMVs, which are already assimilated in the operational GSM-DA. As shown in Fig. 1, the histograms of O-B for NH AMVs exhibit Gaussian distribution, and those for other regions have the same characteristics (not shown). The standard deviation (STD) of the O-B is 0.5 – 1.0 m/s larger than the MODIS Terra AMV values. The new AMVs have a negative bias against the first guess as with MODIS Terra AMVs. These AMVs are expected to increase the volume of such vectors available and to improve coverage poleward of 50° (Fig. 2).

3. QC for the new AMV data and OSEs

Development of the QC system for the new AMVs was based on the results outlined in Section 2. In this system, new AMVs with statistically large negative biases and STDs are rejected in pre-processing on the NWP system. The criteria settings for rejection of the new AMVs are the same as those for operational assimilated AMVs. The specific criteria for O-B STDs are 5 m/s above 400 hPa, 4 m/s from 400 to 700 hPa, and 2 m/s below 700 hPa. The other criterion setting for the O-B mean error is a level below 2 m/s (Yamashita 2008). QC settings are detailed on the NWP SAF AMV monitoring page[1].

OSEs were performed to evaluate the impact of the new AMVs using GSM-DA. Global 4D-VAR data assimilation cycles were run every six hours, and 264-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 about 20 km (the resolution of the inner model for GSM-DA is about 55 km) and 60 vertical layers with the top level at 0.1 hPa. The OSE periods were from December 2011 to February 2012 (winter 2012) and from July to September 2012 (summer 2012). The terms TEST and CNTL are used to refer to the experiments with and without assimilation of the new AMVs, respectively. OSE results were compared to those of TEST against CNTL. Operationally

[1] http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/amvusage/jmamodel.html

assimilated observations, including GEO AMVs and MODIS AMVs, were used in both experiments.

4. OSE results

Figure 3 shows the normalized root mean square error (RMSE) difference of the u-component wind in the first-guess and analysis field against aircraft observation in global area for summer 2012. The new AMVs bring reduced RMSEs between 300 and 600 hPa. The first-guess and analysis values of major components (wind, temperature and specific humidity) are generally improved against conventional and satellite observations (not shown). Figure 4 shows the normalized RMSE difference between forecasts covering periods from one to eleven days at 500 hPa geopotential height and wind vectors at 250 hPa for summer 2012. Significant positive impacts are seen until three-day forecasts, especially in the tropical and Southern Hemisphere, reaching up to 1 – 2% on average for summer 2012. Similar impacts on other physical elements and heights are also seen as described previously. Positive impacts were seen on typhoon track forecasts in the forecast period from 36 to 66 hours for summer 2012 (Fig. 5). Positive impacts were also seen for winter 2012 (not shown).

Based on these OSE results, the new AMVs were introduced into JMA's operational NWP system on 1 July, 2013.

References

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Lazzara, M. A., R. Dworak, D. A. Santek, B. T. Hoover, C. S. Velden and J. R. Key, 2014: High-latitude Atmospheric Motion Vectors from Composite Satellite Data. *Journal of Applied Meteorology and Climatology,* **53**, 534 – 547.

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

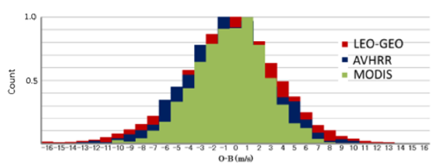

Figure 1. O-B normalized histograms of polar AMVs at levels above 400 hPa in the Northern Hemisphere (poleward of 20°N) for September 2011. The red, blue and green bars correspond to LEO-GEO, AVHRR in NOAA-18 and MODIS Terra AMVs, respectively.

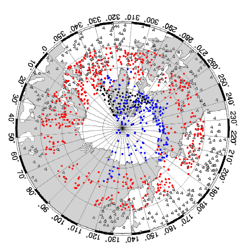

Figure 2. Polar AMVs used in the North Pole region in JMA's NWP system at 00 UTC on September 4 2012. The blue dots are for AVHRR AMVs, and the red dots are for LEO-GEO AMVs.

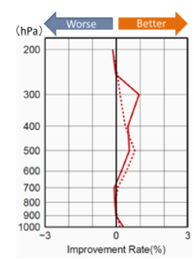

Figure 3. Normalized RMSE difference between u-component wind in the first-guess (red line) and analysis (dashed red line) fields against aircraft observation over the globe from July to September 2012.

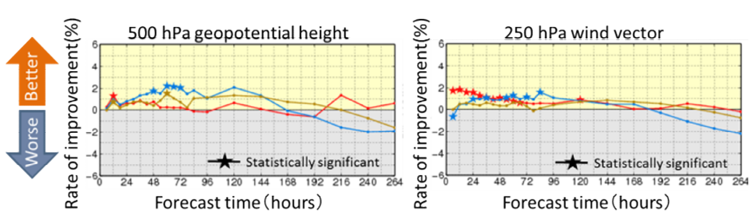

Figure 4. Normalized RMSE differences between forecasts covering periods from 1 – 11 days at 500 hPa geopotential height and 250 hPa wind vectors from July to September 2012. Positive values indicate better scores. The brown, red and blue lines show forecast improvement rates for the Northern Hemisphere (poleward of 20°N), tropic (20°S – 20°N) and Southern Hemisphere (poleward of 20°S) regions, respectively. The star plots indicate statistical significance.

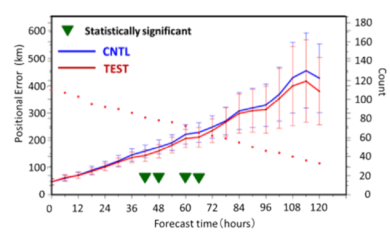

Figure 5. Average typhoon track forecast errors from July to September 2012. The red line is for TEST values, the blue line is for CNTL values, and the red dots are sample data numbers. The error bars represent a 95% confidence interval.