Operational use of Dual-Metop AMVs at high latitudes in JMA's global NWP system

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1. Introduction

JMA's global numerical weather prediction (NWP) system involves the use of assimilated atmospheric motion vectors (AMVs) generated from geostationary (GEO) and low-earth-orbiting (LEO) satellite imagery. GEO AMVs are available for the area between around 60°S and 60°N, while LEO and LEO-GEO AMVs are used in analysis by the system for high latitude region (Yamashita 2014). LEO AMVs from sources such as MODIS and AVHRR, are derived from sequential single LEO satellite images scanned over polar regions, where there is an overlap. LEO-GEO AMVs are derived from GEO/LEO synthetic imagery by the Cooperative Institute for Meteorological Satellite Studies (CIMSS), covering high latitude bands (50 – 70° north and south), where there is a coverage gap between GEO and LEO AMVs (Lazzara et al. 2014).

Dual-Metop AMVs are an AVHRR wind product provided by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) (Hautecoeur and Borde 2017). These are derived from two sequential AVHRR images of tandem Metop-B and -C, with coverage of the globe including both poles. Images are scanned approximately 50 minutes apart, which is shorter than the periodicity of single AVHRR AMVs (approx. 100 min). There are more vectors and less acquisition latency due to the use of these higher temporal resolution images, providing advantages in use of the data in NWP systems.

Against this background, JMA explored the use of Dual-Metop AMVs to supplement high-latitude coverage of global analysis. This report outlines quality control for assimilation of the new data and its effects on forecast fields of observing system experiments (OSEs) in the global NWP system.

2. Dual-Metop AMVs

In JMA's global NWP system, cycle analysis and early analysis are operated on a six-hourly basis. Early analysis is performed for operational forecasting with shorter cut-off times (2 hrs at 00, 06, 12 and 18 UTC) than cycle analysis (12 hrs at 00 and 12 UTC and 8 hrs at 06 and 18 UTC). Figure 1 shows an example of the northern polar AMV distribution used in cycle analysis (left) and early analysis (right). Dual-Metop AMVs dominate coverage around the Arctic Ocean in early analysis because the acquisition time is shorter than that of LEO AMVs.

Dual-Metop AMVs are provided with quality indexes (QI) attached to each vector (Holmlund 1998), both with and without forecast checking. While standard AMV products and related QIs are calculated from three sequential images, Dual-Metop AMVs and related QI calculation are generated from two.

In this context, JMA researched the use of Dual-Metop AMVs with QI at high latitudes including polar areas (poleward from 50° north and south) in global analysis.

3. Dual-Metop AMV quality control

In this work, Dual-Metop AMV quality was statistically evaluated against global NWP forecast first-guess values. QIs with forecast checking (QIF) were used to screen out low-quality vectors, as it was found that observation values minus the first-guess (O-B) tended to decrease with QIF values. Figures 2 (a) and (b) show O-B zonal means of Dual-Metop AMV u-components without QIF screening for periods of around a month in summer 2019 and winter 2020, respectively. Figures 2 (c) and (d) are as per (a) and (b), but with large (> 85) QIF vectors. (a) and (b) show significant biases, especially in the upper troposphere (negative bias) and the lower layer (positive bias). (c) and (d) show that QIF screening effectively reduces these biases.

As biases above 300 hPa and below 700 hPa over land were observed even after QIF screening, Dual-Metop AMVs at these heights were set to not be used in global analysis.

4. OSEs and summary

OSEs were conducted to assess Dual-Metop AMV effects on global NWP based on JMA's operational system as of September 2020. Assuming that the LEO AMVs used in analysis to date would become unavailable due to the retirement of legacy satellites (such as Terra and Aqua), control experiments (CNTL) were performed without the use of polar MODIS and AVHRR AMVs to determine the effects of assimilating only the new data. Test experiments (TEST) were also run with the

Dual-Metop AMVs used in CNTL. The OSEs were for August 2019 and January 2020.

Figure 3 shows zonal means of relative improvement in root mean square errors (RMSEs) of u-component wind and geopotential height for 48-hour forecasts against own analysis (12 UTC initial). Errors in forecast fields for the troposphere are significantly mitigated in TEST at high latitudes in the Northern and Southern Hemispheres in summer and winter.

Dual-Metop AMVs have been operationally used over high-latitude regions in the global NWP system since 30 June 2022.

References

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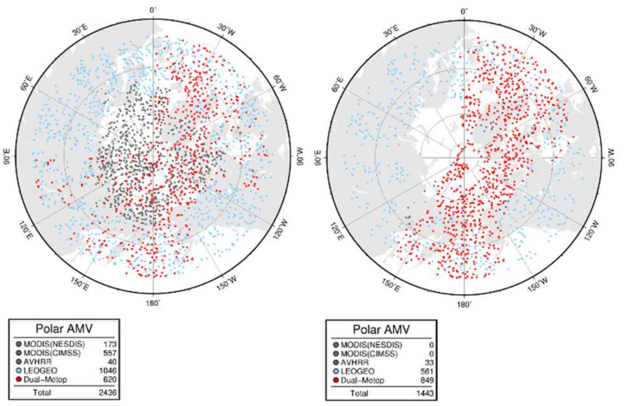

Figure 1: North polar AMVs used in global analysis for 00 UTC on 1 Jul. 2020. Points indicate Dual-Metop (red), MODIS (grey) and LEO-GEO (light blue) AMVs. Left and right are polar AMVs used in cycle analysis and early analysis, respectively.

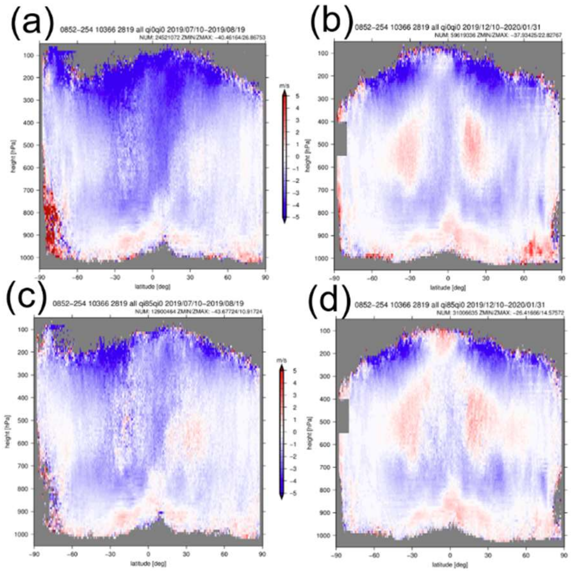

Figure 2: Zonal means of u-component wind differences between Dual-Metop AMVs and first guess (O-B) [m/s]. a/b: without QIF screening; c/d: with large QIF values (> 85). Left and right are for 10 Jul. – 19 Aug. 2019 and 10 Dec. 2019 – 31 Jan. 2020, respectively. The horizontal and vertical axes indicate latitude [deg.] and pressure [hPa], respectively.

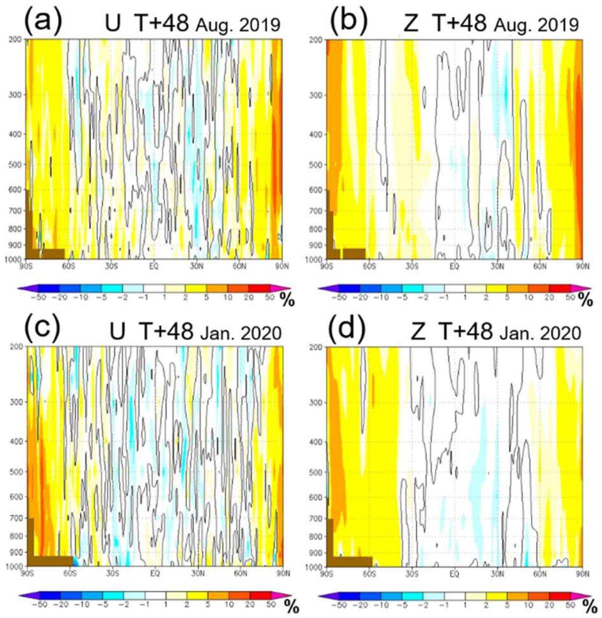

Figure 3: Zonal means of relative improvement [%] in terms of root mean square error (RMSE) with u-component wind and geopotential height for 48-hour forecasts from a 12 UTC initial against own analysis. a/b: Aug. 2019; c/d: Jan. 2020. The horizontal and vertical axes indicate latitude [deg.] and pressure [hPa], respectively. Warm colors indicate improved TEST results over CNTL.