UPGRADED USAGE OF MODIS-DERIVED POLAR WINDS IN THE JMA OPERATIONAL GLOBAL 4D-VAR ASSIMILATION SYSTEM

Koji Yamashita

Japan Meteorological Agency / Numerical Prediction Division
1-3-4, Otemachi, Chiyoda-ku, Tokyo 100-8122, Japan

Abstract

Polar winds data derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the Terra and Aqua satellites produced by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) have been assimilated in the Japan Meteorological Agency (JMA) operational global four-dimensional variational data assimilation (4D-Var) system since 2004. The data are acquired from the public via anonymous FTP on CIMSS.

Recently, MODIS polar winds are produced operationally by National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite, Data, and Information Service (NESDIS). The data are also broadcast internationally in BUFR format through the Global Telecommunication System (GTS) in the same way with other Atmospheric Motion Vectors (AMVs). To reduce the entire processing time, CIMSS also produces direct broadcast (DB) MODIS data.

The qualities of NESDIS and CIMSS DB MODIS polar winds data (new AMVs data) were investigated statistically against first-guess of the JMA model. The qualities of these winds was almost equivalent to the CIMSS MODIS polar winds data.

To acquire the new AMVs data stably and instantly via GTS and to use them in the operational global 4D-Var system, we made several revisions to our quality control (QC) system. Firstly, the thinning interval of the new AMVs was decided by investigation of the spatial error correlation distance using the departure of the new AMVs from the first-guess (O-B). The thinning intervals in the Southern Hemisphere (SH) and Northern Hemisphere (NH) were 250 km and 150 km respectively. Secondly, we also gave priority of using AMVs with short spatial error correlation distance. Thirdly, blacklisting in space was statistically decided by mean error (ME) and standard deviation (STD) of O-B in 2008. Although blacklisting in space for the new AMVs was almost same as the operational CIMSS MODIS winds, the new IR AMVs which were statistically good quality on 600-900 hPa level were available. Observing-system experiments (OSEs) for revised QC using the JMA operational global spectral model (GSM) were performed in September 2008.

The revised QC brought slightly positive impacts on nine-day GSM forecast in SH. The reason seems that the expanded thinning interval to 250 km was effective in SH. On the other hand, negative impacts up to 1-2% on an average in NH compared to control-case which assimilated operational CIMSS MODIS winds were found. We need to re-examine QC for new AMVs in NH.

1. INTRODUCTION

In 2001, an experimental polar wind product was developed using imagery from MODIS on NASA's Terra satellite. Early the next year, two numerical weather prediction centers demonstrated a positive impact of the MODIS winds on forecasts not only in the polar regions, but globally. Routine generation of the Terra MODIS winds began in 2002, with Aqua MODIS winds following soon thereafter. Today the MODIS winds are produced operationally at NOAA/NESDIS, and eleven NWP centers in seven countries use the data in their operational forecast systems. MODIS wind processing systems also have been implemented at direct broadcast sites in the polar regimes to improve the timeliness of the wind data for numerical weather prediction applications, and to provide local forecasters with real-time products in CIMSS. (Key et al. 2009). Terra MODIS and Aqua MODIS polar winds produced by CIMSS in the Arctic have been operationally assimilated at JMA since 27 May 2004 (Kazumori and Nakamura 2004) and in the Antarctic since 16 September 2004. The data are acquired from the public via anonymous FTP on CIMSS.

To acquire the new AMVs data stably and instantly via GTS and to use them in the operational global 4D-Var system, we also made several revisions to our quality control (QC) system. Observing-system experiments (OSEs) for revised QC were performed in September 2008.

In this paper, section 2 introduces outline of the global NWP system briefly. Section 3 is shown the character of the new AMVs data. Section 4 is described about the revised QC. The results of the experiments for revised QC are discussed in section 5, and a summary is provided in section 6.

2. OUTLINE OF THE GLOBAL NWP SYSTEM AT JMA

The outline of the global NWP system is listed in Table 1. Hereafter, "Global Data Assimilation System" and "Global Spectral Model" are abbreviated to "GSM-DA" and "GSM", respectively.

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

Global Data Assimilation System (GSM-DA)	
Method	4D-Var
Resolution and Layers (inner model)	T106L60 (hydrostatic Gaussian grid, horizontal resolution approx. 120 km, model top 0.1 hPa)
Assimilation window	6 hours (±3hours, time slots approx. 1 hour)
TC bogus data	Used

Global Spectral Model (GSM)	
Resolution and Layers	TL319L60 (hydrostatic reduced Gaussian grid, horizontal resolution approx. 60 km, model top 0.1 hPa)
Forecast range (initial time)	84 hours/216 hours (00, 06, 18 UTC/12 UTC)

3. CHARACTER OF THE NEW AMVS DATA

Figure 1 shows an example of number of received data as a function of time for Terra NESDIS, CIMSS DB and CIMSS operational MODIS polar winds data in September 2008. The maximum cut off times from observation time is 330 minutes for the early analysis at JMA. We see from Fig. 1 that Terra CIMSS DB MODIS winds have arrived much earlier than other winds. The NESDIS MODIS polar winds data have been received in the almost same timing as the CIMSS MODIS polar winds.

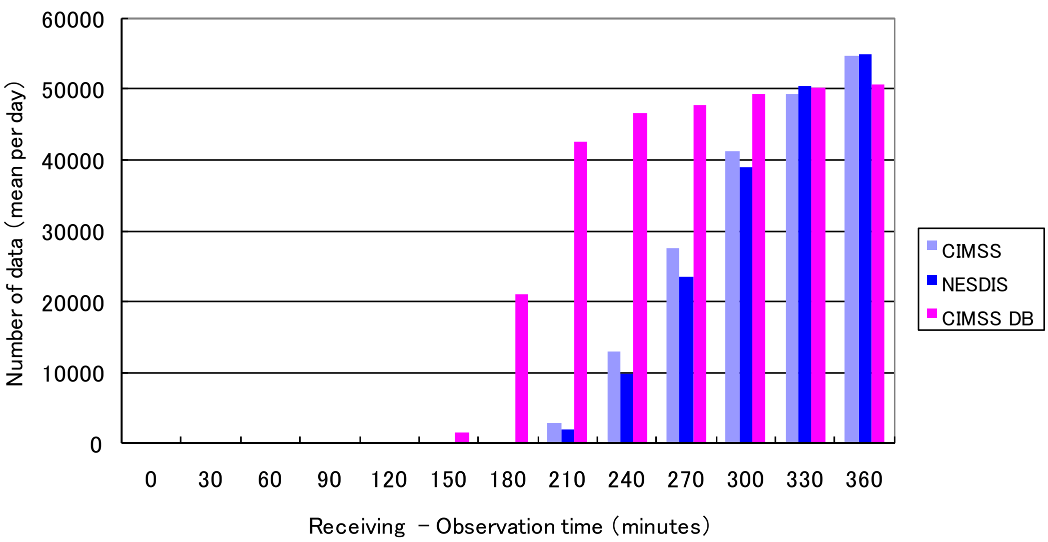

***Figure 1*: An example of number of received data as a function of time for Terra NESDIS (blue), CIMSS DB (pink) and CIMSS operational (thin blue) MODIS polar winds data respectively in September 2008.**

STD of O-B in the new AMVs data was 3-4 m/s per one analysis (not shown). The new AMVs data were as accurate as the CIMSS MODIS polar winds data used operationally in JMA.
To save the computational cost of 4D-Var, the new AMVs data should be thinned to ignore observation error covariance terms in the matrix in the cost function of 4D-Var. Therefore, the new AMVs data thinning procedure is important. To decide thinning interval of these AMVs, we investigated observation error correlation. Since to calculate observation error correlation directly was difficult, O-B error correlation was statistically examined. O-B error correlation is empirically good indicator to decide the thinning distance. An example of spatial and time O-B error correlation or distance in Terra NESDIS MODIS IR winds above 400 hPa is shown in Fig.2. We see from Fig. 2 that spatial and time error correlation of O-B remains in the far distance. This also holds for the new AMVs data on 400-1,000 hPa levels. The spatial error correlation distances of O-B were empirically set for the correlation under 0.2 and are summarised in Table 2. We see from Table 2 that the spatial error correlations of SH and NH are approximately 250 km and 150 km respectively. Table 2 also shows temporal error correlations and they are over above 0.2 mainly in the SH and NH.

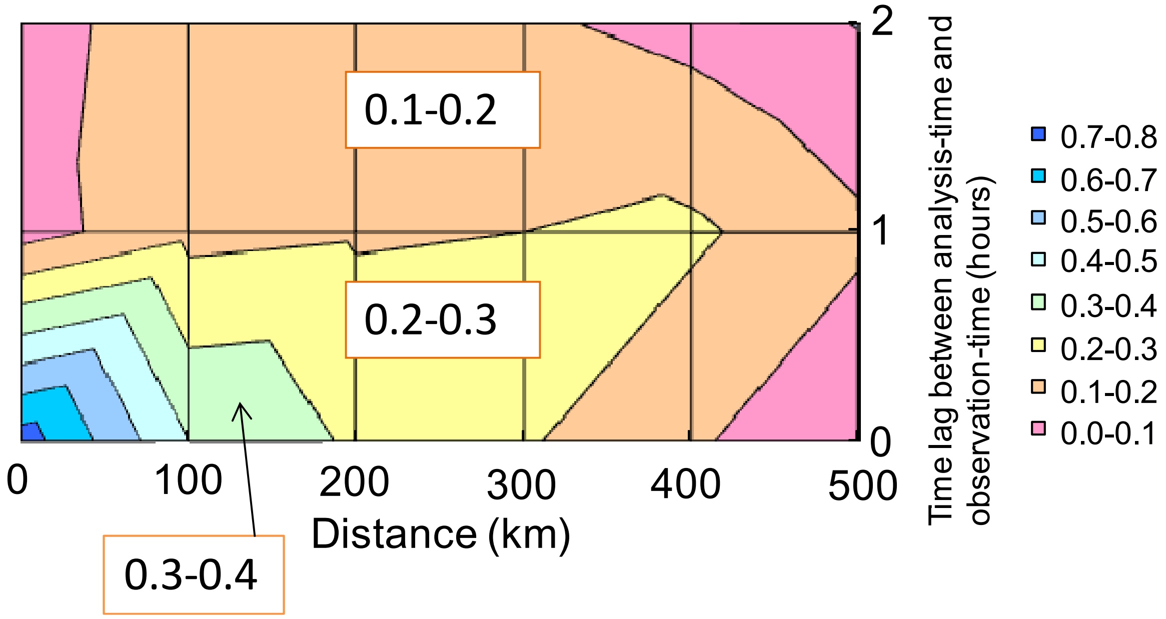

***Figure 2*: Spatial and time O-B error correlation or distance in Terra NESDIS MODIS IR winds above 400 hPa in May 2009. The values show correlation coefficient of O-B.**

4. REVISED QC FOR THE NEW AMVS DATA

The main difference of QC between operational method and trial method is shown in Table 3. Criteria of thinning distance in the SH and NH were set to 250 km and 150 km, respectively, based on the results of Section 3. For the difference of spatial error correlation distance was also found in Table 2, we prioritized the use of the new AMVs with short space error correlation distance. Blacklisting in space was statistically decided by ME and STD of O-B in 2008. Criteria of O-B STD is 5 m/s for above 400 hPa, 4 m/s for 400-700 hPa, 2 m/s for below 700 hPa. ME below 2 m/s was adopted (Yamashita, 2008). Although blacklisting in space for the new AMVs was almost same as the operational CIMSS MODIS winds, the new IR AMVs which were statistically good quality on 600-900 hPa level were available. Since the time error correlation values above 0.2 were also mainly found in the SH and NH, we adopted the thinning in the six-hour time window instead although we did not consider the thinning in the hourly time window.
Experiments of GSM-DA were performed to evaluate an impact of the revised QC of the new AMVs. The experimental period was in September 2008.

Table 2**: Spatial and time O-B error correlation or distance in Terra MODIS winds in May 2009. (a) NESDIS MODIS polar winds in NH. (b) CIMSS DB MODIS polar winds in NH. (c) NESDIS MODIS polar winds in SH. (d) CIMSS DB MODIS polar winds in SH. The spatial error correlation distances of O-B were set when correlation under 0.2 is ignored empirically. IR is AMV generated from infrared sensor. WV is AMV generated from infrared sensor of water vapor. CWV is AMV generated from infrared sensor of clear sky water vapor.**

(a) NESDIS in NH HL: 10-400 hPa ML: 400-700 hPa LL: 700-1,000 hPa	Spatial error correlation distance (SECD) (km)	Error correlation in each time lag between analysis-time and observation-time when the SECD is equal to 0 km.		
		No time lag	1-hour time lag	2-hour time lag
IR-HL	300	0.75	0.06	0.04
WV-HL	300	0.77	0.15	0.16
CWV-HL	200	0.72	0.31	0.28
IR-ML	100	0.71	0.13	0.17
WV-ML	350	0.85	0.08	-0.19
CWV-ML	150	0.74	0.29	0.32
IR-LL	150	0.81	0.38	0.37

(b) CIMSS DB in NH	Spatial error correlation distance (km)	Error correlation in each time lag between analysis-time and observation-time when the SECD is equal to 0 km.		
		No time lag	1-hour time lag	2-hour time lag
IR-HL	150	0.65	0.28	0.01
WV-HL	150	0.66	0.25	0.04
CWV-HL	200	0.82	0.31	0.27
IR-ML	150	0.73	0.23	0.20
WV-ML	150	0.76	0.25	0.09
CWV-ML	Greater than 500	0.82	0.35	0.33
IR-LL	Greater than 500	0.79	0.26	0.12

(c) NESDIS in SH	Spatial error correlation distance (km)	Error correlation in each time lag between analysis-time and observation-time when the SECD is equal to 0 km.		
		No time lag	1-hour time lag	2-hour time lag
IR-HL	250	0.81	0.25	0.33
WV-HL	Greater than 500	0.77	0.39	0.41
CWV-HL	200	0.79	0.29	0.26
IR-ML	350	0.78	0.30	0.32
WV-ML	250	0.60	0.38	0.37
CWV-ML	250	0.80	0.36	0.31
IR-LL	200	0.82	0.41	0.40

(d) CIMSS DB in SH	Spatial error correlation distance (km)	Error correlation in each time lag between analysis-time and observation-time when the SECD is equal to 0 km.		
		No time lag	1-hour time lag	2-hour time lag
IR-HL	200	0.82	0.13	0.21
WV-HL	250	0.79	0.36	0.24
CWV-HL	Greater than 500	0.82	-0.14	0.37
IR-ML	200	0.76	0.23	0.30
WV-ML	250	0.79	0.40	0.37
CWV-ML	250	0.79	0.29	0.31
IR-LL	200	0.79	0.26	0.12

***Table 3*: Main difference of QC between operational method and trial method**

	Operational method (CNTL)	Trial method (TEST)
Used data	1. CIMSS MODIS polar winds data	1. NESDIS MODIS polar winds data 2. CIMSS DB MODIS polar winds data
Thinning	1. Thinning interval : 150 km 2. One AMV selected per box in the six-hour time window	1. Thinning interval : 150 (250) km for NH (SH) 2. Priority of AMVs with short space correlation distance 3. One AMV selected per box in the six-hour time window
Blacklisting in space	1. All winds over land below 400 hPa 2. All WV winds below 550 hPa over sea 3. All IR winds below 600 hPa over sea	1. IR wind speeds less than 10 m/s below 650 hPa for NH 2. IR winds for NH above 300 hPa or below 900 hPa 3. WV and CWV winds for NH above 300 hPa or below 600 hPa 4. All winds for SH above 300 hPa or below 600 hPa

5. RESULTS OF THE EXPERIMENTS

Figure 3 shows forecast improvement rate with respect to RMSE for 1-9 day forecasts in September 2008. The horizontal axis is forecast hours and the vertical axis is the rate of improvement, which is calculated with the next formula.

$$\frac{\left(RMSE_{CNTL} - RMSE_{TEST}\right)}{RMSE_{CNTL}} \quad (1)$$

We see from Fig. 3 that slightly positive impacts on nine-day GSM forecast in SH. The reason seems that the expanded thinning interval to 250 km was effective in SH. On the other hand, negative impacts in NH up to 1-2% on an average were found. The cause was that RMSE of wind forecast was increased in NH especially above 500hPa against radiosonde observations (not shown). Figure 4 also shows the averaged typhoon track errors in September 2008. TEST shows slightly worse typhoon track forecast in the late-forecast time. We need to re-examine the revised QC system for the new AMVs in NH.

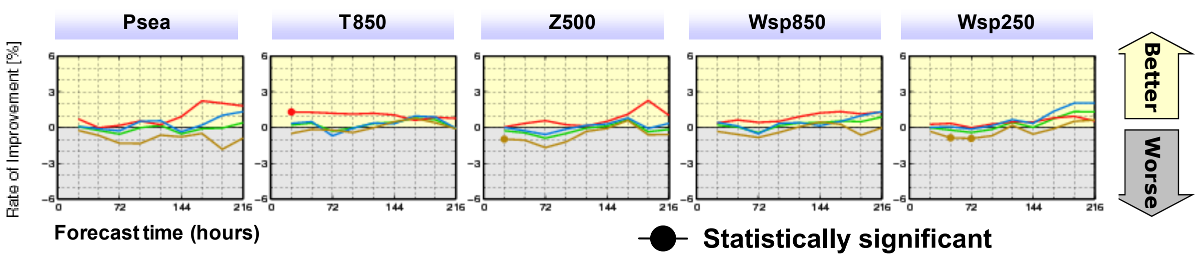

***Figure 3*: Forecast Improvement Rate with regard to RMSE for 1-9 day forecasts in September 2008. "Psea" is surface pressure. "T850" is 850 hPa temperatures. "Z500" is 500 hPa geopotential heights. "Wsp850" is 850 hPa wind speeds. "Wsp250" is 250 hPa wind speeds. Positive value means better score. Green, brown, red and blue lines show the forecast improvement rate of global, northern hemisphere (polewards of 20N), tropical (20S-20N) and southern hemisphere (polewards of 20S) regions respectively.**

6. SUMMARY

OSEs for the new AMVs using the global NWP system of JMA were conducted in September 2008. The revised QC system for these AMVs data was performed. The main revised QC is as follows:

(Ⅰ) The thinning intervals of SH and NH were 250 km and 150 km respectively.

(Ⅱ) We gave priority for using the new AMVs with short spatial error correlation distance.

(Ⅲ) The new IR AMVs which were statistically good quality on 600-900 hPa level were available.

As the results of OSEs, the revised QC brought slightly positive impacts on nine-day GSM forecast in SH. The reason seems that the expanded thinning interval to 250 km was effective in SH. On the other hand, negative impacts up to 1-2% on an average compared to CNTL in NH were found. The cause was that RMSE of wind forecast increased in NH especially above 500hPa against radiosonde observations. The averaged typhoon track errors slightly increased in the late-forecast time. We need to re-examine QC for new AMVs in NH.

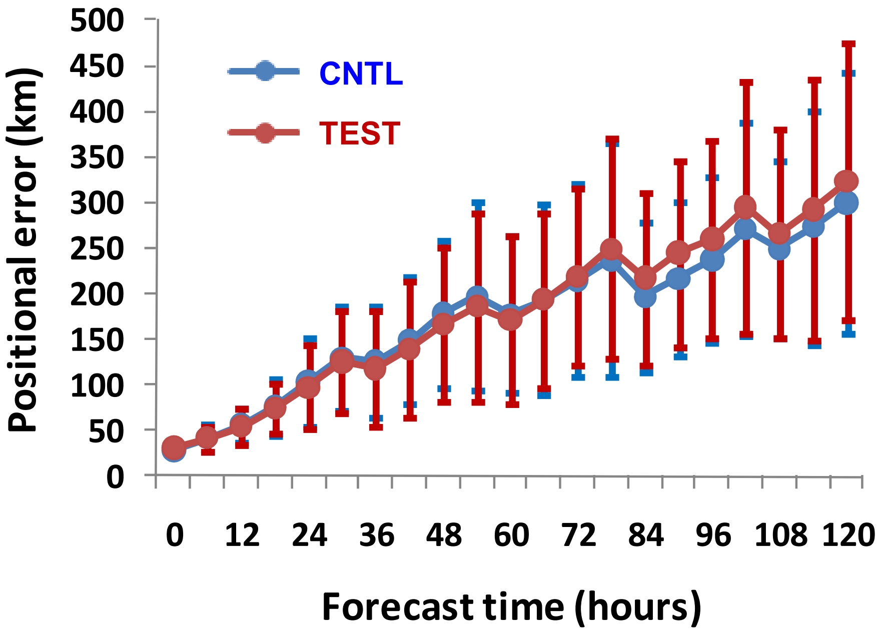

***Figure 4*: Average typhoon track forecast errors in September 2008. The red line is for TEST. The blue line is for CNTL. Error bar means a 95% confidence interval.**

7. 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.