STATUS OF AND FUTURE PLANS FOR JMA'S ATMOSPHERIC MOTION VECTORS

Ryo OYAMA and Kazuki SHIMOJI

Meteorological Satellite Center of Japan Meteorological Agency
3-235 Nakakiyoto, Kiyose, Tokyo 204-0012, Japan

ABSTRACT

The Meteorological Satellite Center (MSC) of the Japan Meteorological Agency (JMA) has been producing Atmospheric Motion Vectors (AMVs) using MTSAT-1R images since 15 July 2005. A new height assignment scheme for IR (10.8 micro-meter) and WV (6.8 micro-meter) AMVs in the upper troposphere was introduced at 06 UTC on 30 May 2007. In the new scheme, the H2O-IRW intercept method is revised to adjust opaque cloud radiances simulated from Numerical Weather Prediction (NWP) fields in accordance with observed radiances, and the most frequent cloud height within a template image is assigned to AMVs. The new scheme contributes to reducing the large slow-wind-speed bias previously observed in upper-height-level AMVs over the middle latitudes.

The computation of AMVs from 3.8 micro-meter images taken at nighttime is being developed. It is recognized that the number of the AMVs in the lower troposphere is approximately 10% larger than that of IR AMVs while preserving the same accuracy.

To contribute to the T-PARC (THORPEX-Pacific Asian Regional Campaign) study, JMA plans to provide AMVs computed from the rapid scanning images of MTSAT-2, which is currently the back-up satellite for MTSAT-1R. During the study, MTSAT-2 will capture cloud images at the intervals of 15 minutes or less. AMV computation from the shorter-interval images remains a matter of research, since small cloud movement should be tracked with a high degree of accuracy. The application of the new cloud-tracking method known as "*optical-flow*" is planned for the computation.

1 INTRODUCTION

Atmospheric Motion Vectors (AMVs) product is one of the most important observational wind data for Numerical Weather Prediction (NWP). The Meteorological Satellite Center (MSC) of Japan Meteorological Agency (JMA) has been producing AMVs by using MTSAT-1R images since 15 July 2005 following the utilization of GMS and GOES-9 images. Table 1 shows the list of AMVs. JMA generates four types of AMVs associated image types, IR (10.8 micro-meter), WV (6.8 micro-meter), VIS (0.63 micro-meter) and 3.8 micro-meter images. The IR, WV and VIS AMVs for full disk domain are generated every six hours at 00, 06, 12 and 18 UTC by using three successive images at 15-minutes intervals (i.e. six-hourly AMVs), and distributed via the Global Telecommunication System (GTS) in BUFR format. In addition, AMVs over the Northern Hemisphere are generated by using images at 30- or 60-minutes intervals every hour between the six-hourly AMVs (i.e. hourly AMVs). These hourly AMVs are currently used in JMA's NWP system.

This paper reports on the current status of and future plans for JMA's AMVs. In section 2, AMVs quality in recent years is reported in terms of monthly statistics against sonde observation. In section 3, the outline of the current JMA's scheme to compute AMVs is described including new height assignment which was implemented at 06 UTC on 30 May 2007 (CGMS35-WP06, JMA; Imai and Oyama, 2008). In section 4, JMA's ongoing and future activities are reported.

Kind of AMVs	Level of height	Time (UTC)	Image sector	Image interval (minutes)	Distribution
Infrared (10.8 micro-meter)	Upper, middle, lower	00, 06, 12, 18	Full Disk	15	BUFR via GTS *1
	Upper, middle, lower	02-05, 08-11, 14-17, 20-23	Northern Hemisphere	30	Internal use only
	Upper, middle, lower	01,07,13,19	Northern Hemisphere	60	Internal use only
Water Vapor (6.8 micro-meter)	Upper, middle	00, 06, 12, 18	Full Disk	15	BUFR via GTS *1
	Upper, middle	02-05, 08-11, 14-17, 20-23	Northern Hemisphere	30	Internal use only
	Upper, middle	01, 07, 13, 19	Northern Hemisphere	60	Internal use only
Visible (0.63 micro-meter)	Lower	00, 06	Full Disk	15	BUFR via GTS *1
	Lower	02-05, 08, 09 21-23	Northern Hemisphere	30	Internal use only
	Lower	01, 07	Northern Hemisphere	60	Internal use only
3.8 micro-meter *2	Lower	12, 18	Full Disk	15	Internal use only
	Lower	08-11, 14-17, 20-23	Northern Hemisphere	30	Internal use only
	Lower	13, 19	Northern Hemisphere	60	Internal use only

***Table 1*: MTSAT-1R AMVs generated by JMA**

*1 JMA terminated SATOB at 06 UTC on 1 April 2008.

*2 JMA started to generate 3.8 micro-meter AMVs in operation on 25 March 2008.

2 CURRENT STATUS OF JMA'S AMV

This section describes the quality of JMA's AMVs computed from MTSAT-1R images since July 2005. Figure 1 (a) and (b) show the time series of monthly statistics (Root Mean Square Vector Difference (RMSVD) and wind speed bias (BIAS)) with reference to sonde observations for upper-height-level (above 400 hPa) IR and cloudy-region WV AMVs (Quality Indicator (QI) >0.85) respectively. In the statistics, AMVs at 00 and 12 UTC, when sonde observations are available, are used under conditions described in Table 2, which are defined based on the CGMS proposals.

Conditions required for AMVs		Criteria
Acceptable Distance from sonde observations	Horizontal	within 150 km
	Vertical	within ±35 hPa for AMVs above 700 hPa height level within ±50 hPa for AMVs below 700 hPa height level
Filtering by comparing to sonde observations	Wind speed Diff.	less than 30 m/s
	Wind direction Diff.	less than 90 degrees
Filtering by QI (with forecast check)		AMVs with QI larger than 0.85

***Table 2*: Required conditions of AMVs for monthly statistics against sonde observations at JMA**

Figure 1 (a) shows that RMSVDs and BIASes of upper-height-level IR AMVs are large in winter for both the Northern and Southern Hemispheres respectively. The RMSVDs and BIASes from July 2007 have been less than those in 2005 and 2006, particularly for Southern Hemisphere in winter. The improvement of AMV quality is due to the introduction of new height assignment scheme into upper-height-level IR and cloudy-region WV AMVs on 30 May 2007. The outline of the new scheme is described in Section 3.2.

Figure 1 (b) is the same as Figure 1 (a), but for upper-height-level cloudy-region WV AMVs. The RMSVDs of the AMV data are around 10 m/s in the winter hemisphere. Slow BIASes in winter are smaller than those of the IR AMVs which are seen in Figure 1 (a), while small fast BIASes are recognized in the summer hemisphere. No accuracy change regarding WV AMVs is recognized between before and after the implementation of the new height assignment scheme. However, the number of high-quality WV AMVs by the new height assignment scheme is much more than that by previous one. This feature is described in Section 3.2.

(a)

(b)

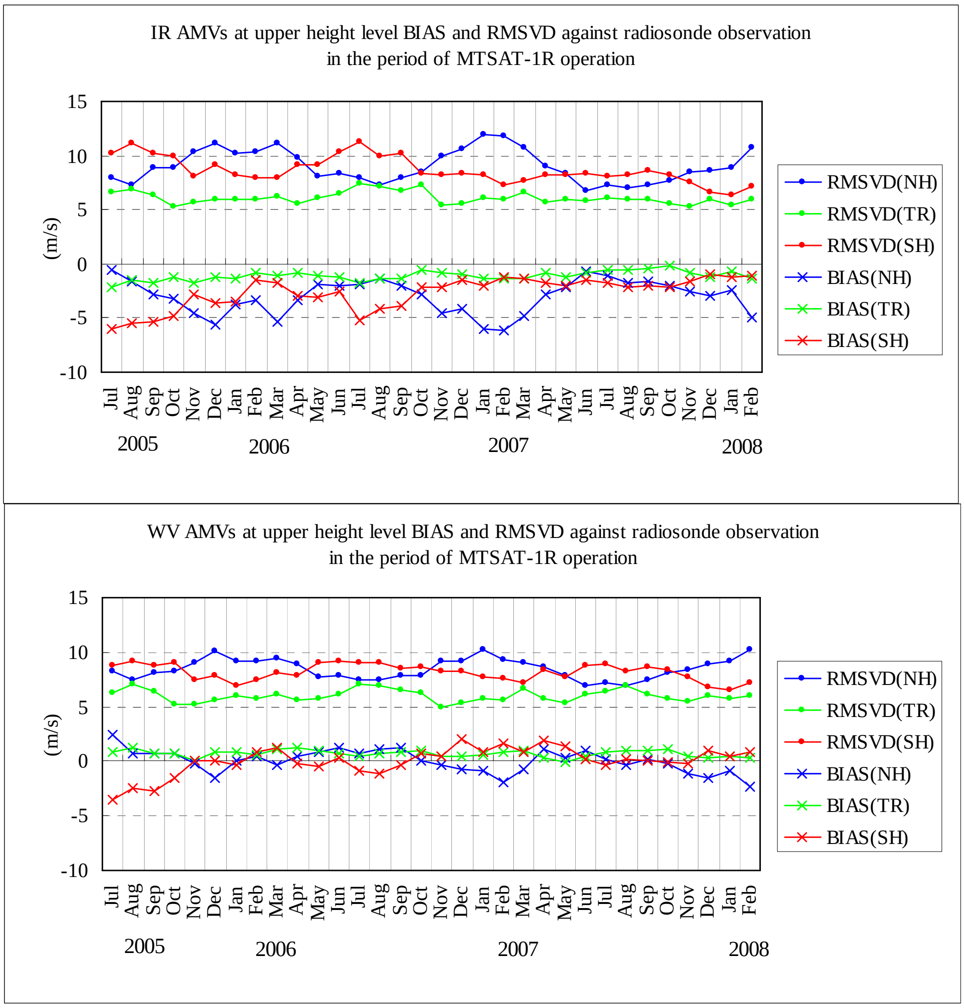

Figure 1**: Time series of RMSVDs and BIASes of (a) IR AMVs and (b) cloudy-region WV AMVs (QI>0.85) at upper-height level over Northern Hemisphere (20N-50N, blue lines), Southern Hemisphere (50S-20S, red) and Tropics (20S-20N, green) with reference to sonde observations. 6-hourly AMVs at 00 and 12 UTC are used for the statistics.**

3 CURRENT JMA'S AMV DERIVATION SCHEME

3.1 OUTLINE OF CURRENT AMV COMPUTATION SCHEMES

This section reviews the current JMA's AMV computation method. The method is divided into four processes, target selection, feature tracking, height assignment, and attachment of QI and Recursive Filter Quality Flag (RFF) to AMVs.

(a) Target Selection

All JMA's AMVs are computed on 0.5-degree latitude / longitude grids. The AMV computation area is limited inside 60-degree satellite zenith angle. VIS AMVs are computed over the region of solar zenith angle less than 85-degrees, and 3.8 micro-meter AMVs are over the region of solar zenith angle more than 85-degrees. Lower-height-level AMVs (IR, VIS and 3.8 micro-meter AMVs) are not computed over the land.

After the geophysical screenings, a template image (size=32) for respective AMVs is determined on the grid-point. The centers of lower-height-level IR, VIS and 3.8 micro-meter AMVs templates are placed on the grid points, whereas, the positions of upper-height-level IR and WV AMVs are optimally determined around the respective original grid points by using entropy. Then, by analyzing the histogram of IR Equivalent Black Body Temperature (EBBT) from the template image, the targets for IR AMVs (for upper (and middle) AMVs and lower AMVs, individually), VIS AMVs and 3.8 micro-meter AMVs are nominated. The targets for WV AMVs are nominated by analyzing WV channel EBBT histogram. Finally, targets for all kinds of AMVs containing cumulonimbus clouds are rejected.

(b) Feature Tracking

After target selection, feature-tracking by cross-correlation matching is conducted using the first and second images, and the second and third images to derive two wind vectors. The template image size is 32-pixels by 32-lines, and searching area size is 64-lines by 64-pixels. Each matching for a wind vector is performed in two steps. Finally, the derived second vector is used for the final output.

(c) Height Assignment

JMA introduced a new height assignment scheme which is applied to the upper and middle height-level IR AMVs and cloudy-region WV AMVs in operation at 06 UTC on 30 May 2007. In the new scheme, the application of the H2O-IRW intercept method (Nieman et al., 1993) is improved from the previous scheme, and the most frequent cloud-height-level in the template image is selected. The details of the scheme will be explained in section 3.2. Clear-sky-region WV AMVs are assigned to the heights from the average of WV EBBT. The heights of lower-height-level IR AMVs, VIS and 3.8 micro-meter AMVs are assigned to cloud-base height computed by using IR EBBT histogram (Tokuno, 1998). In these schemes, JMA's NWP (GSM (Global Spectral Model)) data are used as the reference.

(d) Attachment of QI and RFF

After completing (a) to (c), QIs and RFFs are attached to respective AMVs. QIs and RFFs are computed with reference to JMA's NWP data under EUMETSAT's and CIMSS's guidelines, respectively. And then, IR, WV and VIS AMVs for 00, 06, 12, and 18 UTC are distributed to users in BUFR format.

3.2 NEW HEIGHT ASSIGNMENT SCHEME SINCE 30 MAY 2007

This section describes the outline of new AMV height assignment scheme which was introduced at 06 UTC on 30 May 2007. The main purpose of the implementation is to reduce the slow BIASes observed in the upper and middle height-level (above 700 hPa) IR AMVs, particularly in winter hemisphere. This problem is mainly due to the inappropriate height assignment for cirrus clouds. The new scheme has been applied to upper and middle height level IR AMVs and cloudy-region WV AMVs. The new scheme is described below.

1) Improvement of height correction procedure for semi-transparent cloud

The H2O-IRW intercept method has been utilized by JMA to calculate the height of semi-transparent cloud within the template image. In the process, the height is estimated by referring to the profile of IR and WV radiances from opaque clouds, which are simulated using a Radiative Transfer Model (RTM) and forecast profiles of temperature and humidity. In the previous scheme, the profile of simulated radiances from opaque clouds was used without any modifications in the H2O-IRW intercept procedure. With the new scheme, the value is corrected using the observed IR and WV radiances, and is then used as a profile for reference in the H2O-IRW intercept method. The correction value for each cloud height level is decided on the basis of the difference between the Clear Sky Radiance (CSR) product and surface radiance which is estimated from the two-dimensional histogram of the observed IR and WV radiances.

2) Use of the most frequent cloud height level

In the new scheme, the AMV height is assigned to the most frequent cloud height within template image. The height is computed by using height-histogram which is accumulated in 50-hPa intervals. In the previous scheme, AMVs were assigned to the highest cloud-height-level which was computed using 0.1 % coldest pixel temperature for IR AMVs and 10 % coldest pixel temperature for WV AMVs, respectively. The height computed by the new scheme tends to be lower than that by previous scheme. The lower height by the new scheme mainly leads to the reduction of slow BIAS over the middle latitudes, which is observed in upper-height-level IR AMVs.

Table 3 shows the accuracy of the IR AMVs (QI>0.85) generated under the new and previous schemes. The statistics are computed with reference to sonde observation data. The statistical period spans nearly one month, running from 00 UTC on 1 May to 18 UTC on 29 May 2007. The RMSVDs and BIASes of the new AMVs are apparently smaller than those of the previous AMVs. The number of the new AMVs is approximately equal to or larger than those of the previous AMVs. There is a large increase of number in the middle troposphere (700 hPa to 400 hPa) in particular.

Table 4 shows the accuracy of cloudy-region WV AMVs (QI>0.85) generated under the new and previous schemes. There is no significant difference in either the RMSVDs or BIASes between the two schemes. However, the number of WV AMVs under the new scheme is approximately twice as that under the previous scheme. The increase of high-quality data indicates the better accuracy of the new WV AMVs.

(a) Upper-height-level (above 400 hPa)

AMV (QI>0.85) Statistics against sonde wind	NH (50N - 20N)		TR (20N - 20S)		SH (20S - 50S)	
	New	Previous	New	Previous	New	Previous
RMSVD (m/s)	7.39	8.50	5.11	5.96	7.29	8.40
BIAS (m/s)	-1.47	-2.22	-0.78	-1.20	-0.80	-2.11
Number	52377	53123	36913	29325	39672	39632

(b) Middle-height-level (700 to 400 hPa)

AMV (QI>0.85) Statistics against sonde wind	NH (50N - 20N)		TR (20N - 20S)		SH (20S - 50S)	
	New	Previous	New	Previous	New	Previous
RMSVD (m/s)	6.36	7.50	3.84	4.56	6.41	7.43
BIAS (m/s)	-1.02	-1.20	-0.50	-1.74	-0.76	-1.68
Number	5854	3093	1669	840	8836	5962

***Table 3*: Statistical comparison of IR AMVs (QI>0.85) against sonde observations between the new and previous schemes: (a) at upper height level (above 400 hPa) and (b) at middle-height- level (700 to 400 hPa). NH, TR and SH stand for Northern Hemisphere (20N-50N), Tropics (20S-20N) and Southern Hemisphere (50S-20S) respectively. The statistics are calculated under conditions in Table 2. The statistical period is from 00 UTC on 1 May 2007 through 18 UTC on 29 May 2007.**

Upper-height-level (above 400 hPa)

AMV (QI>0.85) Statistics against sonde wind	NH (50N - 20N)		TR (20N - 20S)		SH (20S - 50S)	
	New	Previous	New	Previous	New	Previous
RMSVD (m/s)	7.40	7.95	5.44	5.53	7.17	7.79
BIAS (m/s)	0.21	0.36	0.27	-0.06	1.17	1.25
Number	91495	56982	53801	18708	52777	27196

***Table 4*: Same as Table 3 (a), but for cloudy-region WV AMVs**

Figure 2 (a) shows the height dependencies of the BIASes and the number of IR AMVs under the previous scheme (QI>0.85), while Figure 2 (b) shows the same values under the new scheme. The BIASes are computed with reference to JMA's NWP wind fields. The BIASes of the new AMVs at levels of 100 to 400 hPa are much smaller than those of the previous AMVs. However, relatively large fast BIASes are newly found in the new AMVs at levels of 500 to 700 hPa. To solve the problem, JMA plans to introduce the follow-on height assignment for IR AMVs in the near future (described in Section 4.3).

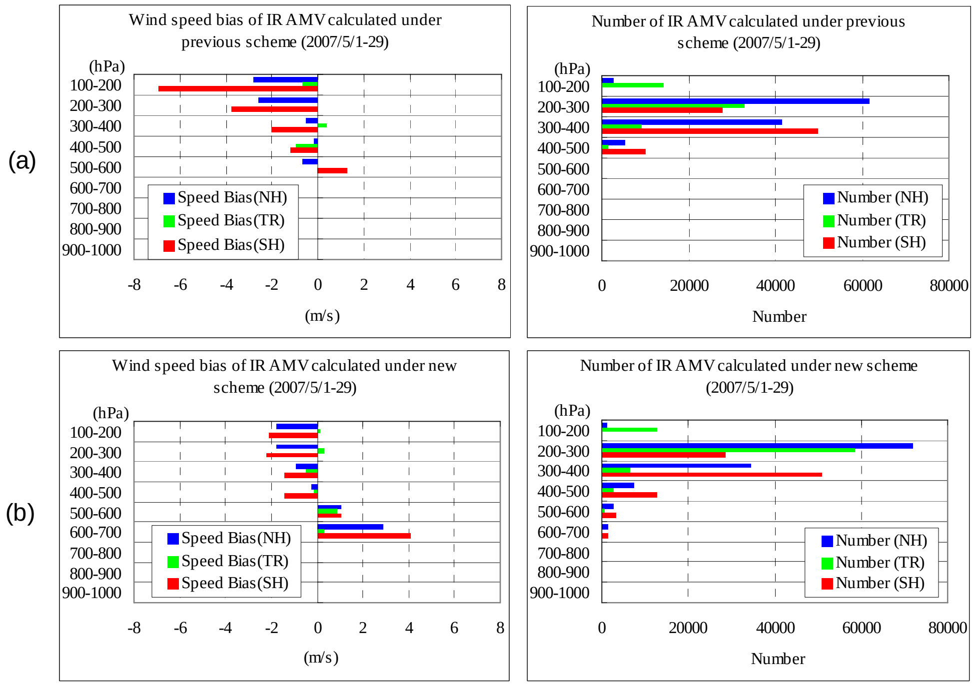

***Figure 2*: BIAS and number of IR AMVs (QI >0.85) calculated under (a) the previous scheme and (b) the new scheme against JMA's NWP first-guess at each height level. NH, TR and SH stand for Northern Hemisphere (20N-50N), Tropics (20S-20N) and Southern Hemisphere (50S-20S), respectively. The statistical period is from 00 UTC on 1 May 2007 through 18 UTC on 29 May 2007.**

Figure 3 is the same figure as Figure 2, but for cloudy-region WV AMVs. The BIASes at levels of 100 to 400 hPa are nearly same between previous and new schemes. In contrast, the numbers of new AMVs are much more than those of previous AMVs over all regions because the new AMVs are assigned to more relevant height-levels.

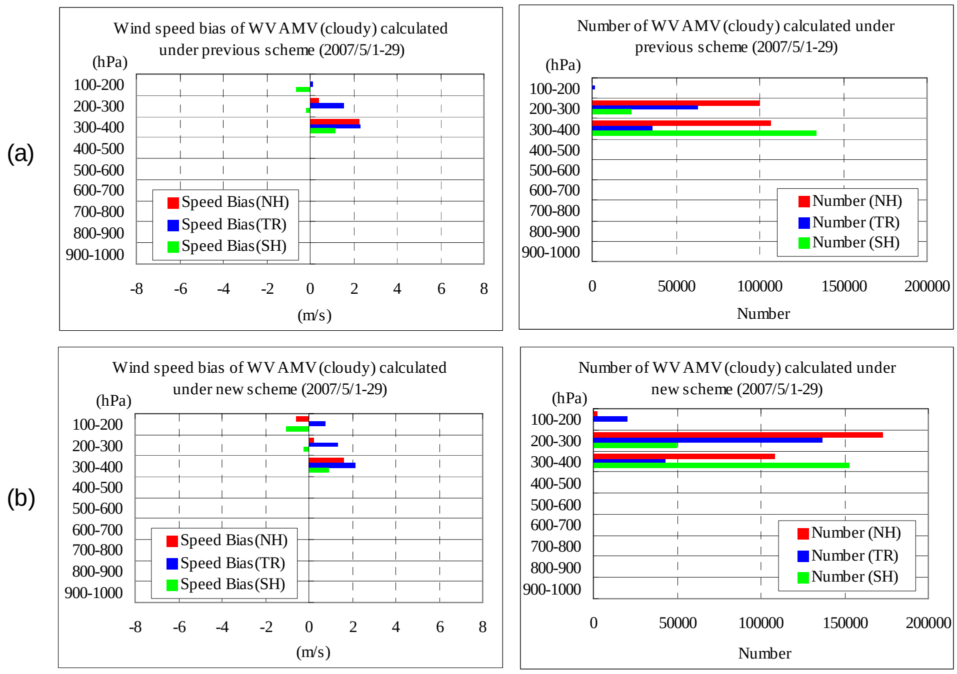

***Figure 3*: Same as Figure 2, but for cloudy-region WV AMVs.**

4 CURRENT ACTIVITIES

4.1 INTRODUCTION OF 3.8 MICRO-METER AMVs

JMA started to produce new lower-height-level (below 700 hPa) AMVs computed using images from 3.8 micro-meter channel of MTSAT-1R as shown in Table 1. In the computation, three successive 3.8 micro-meter images are used for tracking lower-height-level cloud, while the AMV heights are assigned to cloud-base height using IR (10.8 micro-meter) images (Tokuno, 1998). The AMVs are computed at the same locations as lower-height-level IR and VIS AMVs but for only at nighttime.

Figure 4 shows the time series of monthly statistics (RMSVDs, BIASes and Numbers) of IR AMVs and 3.8 micro-meter AMVs (below 700 hPa height level, QI>0.85) against sonde observation winds at 12 UTC. The number of 3.8 micro-meter AMVs is approximately 10 % larger that of IR AMVs. The RMSVDs and BIASes are nearly same between IR AMVs and 3.8 micro-meter AMVs. JMA started to use the 3.8 micro-meter AMVs in JMA's NWP on 25 March 2008 (Yamashita, 2008).

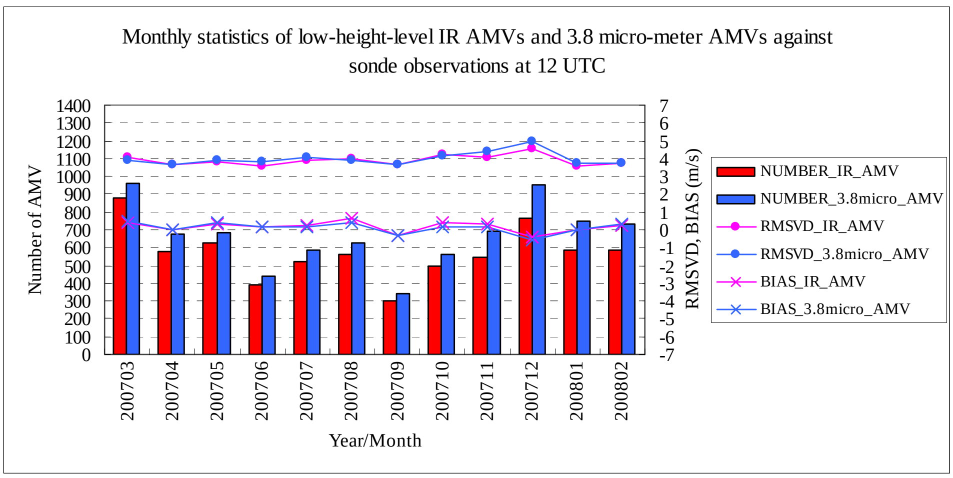

***Figure 4*: Monthly statistics (RMSVDs, BIASes and Numbers) of IR AMVs and 3.8 micro-meter AMVs (below 700 hPa height-level) against sonde observations from March 2007 through February 2008. The statistics are calculated under the conditions described in Table 2.**

4.2 COMPUTATION OF AMV FROM RAPID-SCAN IMAGES OF MTSAT-2

Currently stand-by MTSAT-2 located at 145 E (MTSAT-1R is at 140 E) is equipped with rapid-scan imaging function. AMVs computed by using MTSAT-2 images at several-time intervals (15, 7 and 4-minutes) are expected to contribute to T-PARC (Thorpex- Pacific Asian Regional Campaign) study scheduled in the summer of 2008. Here, the current status of the AMVs is reported.

Figure 5 (a) shows the wind vectors of VIS AMVs which are computed by using images at 4-minute and 15-minute intervals (hereafter called 4-min and 15-min AMVs, respectively). 15-min AMVs shows slightly more uniform flows than 4-min AMVs although the vector distributions are almost same between 4-min and 15-min AMVs. Figure 5 (b) shows the QI distributions of 4-min and 15-min VIS AMVs. QIs of 4-min AMVs generally tend to be lower than those of 15-min AMVs.

In the same comparisons for IR and WV AMVs, the number of 4-min AMVs is much less than that of 15-min AMVs due to the lower spatial resolutions of IR and WV images. Recently, JMA/MSC has been newly developing *optical-flow* method as another available tracking scheme. Figure 6 (a) and (b) show the wind vectors of 4-min WV AMVs which are computed by cross-correlation matching and *optical-flow* method, respectively. It is recognized that *optical-flow* method gives larger data coverage than cross-correlation matching in the feature-tracking process even using images at 4-minute intervals. JMA/MSC is currently developing wind extraction scheme by using *optical-flow* method focusing on the height assignment and quality check.

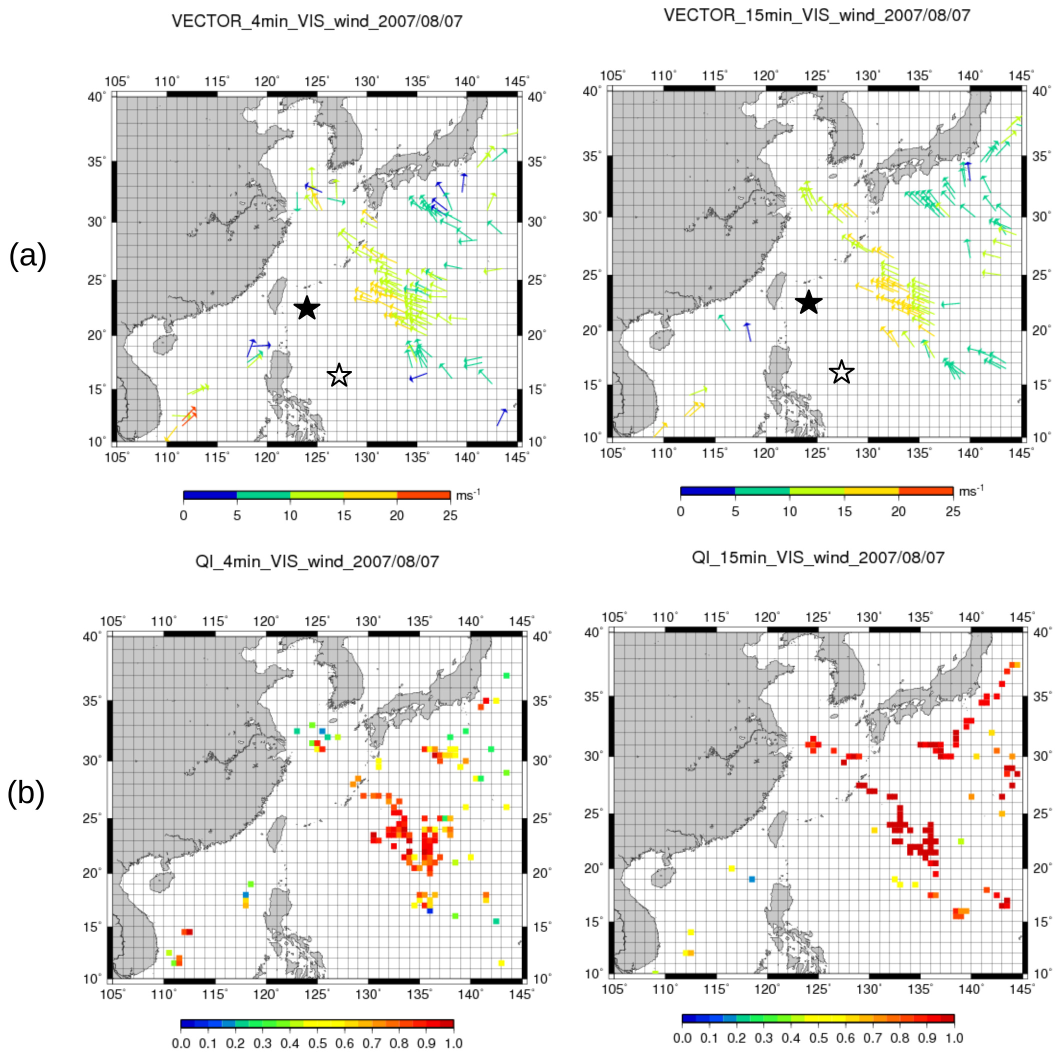

***Figure 5*: (a) Wind vectors and (b) QIs of respective VIS AMVs (QI>0) computed by using MTSAT-2 images at 4-min (Left) and 15-min (Right) intervals between 0500 UTC and 0530 UTC on 7 August 2007. Black and white stars mean the positions of typhoons T0706 and T0707, respectively.**

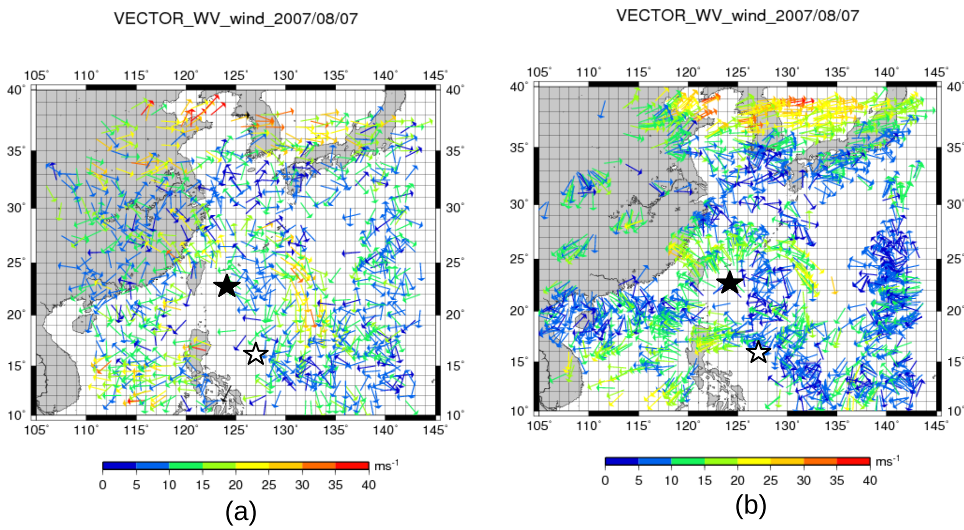

***Figure 6*: Wind vectors of WV AMVs from MTSAT-2 images at 4-minute intervals between 0500 UTC and 0530 UTC on 7 August 2007, which are computed by (a) cross-correlation matching and (b) *optical-flow* method. Black and white stars mean the positions of typhoons T0706 and T0707, respectively.**

4.3 DEVELOPMENT OF HEIGHT ASSIGNMENT DIRECTLY LINKED TO FEATURE TRACKING

One of the main problems in height assignment is what pixels for height assignment are picked out of the template image without any information on the feature-tracking. JMA/MSC has been developing a new height assignment scheme directly linked to feature-tracking in collaboration with EUMETSAT since 2006 (Borde and Oyama, 2008). Some experiments show that the information on feature-tracking can reduce the fast BIAS of IR AMVs at the levels of 700 to 500 hPa which is observed in current JMA's IR AMVs. The current status of the study is reported by Oyama et al. (2008).

4.4 RESPONSE TO RECOMMENDATION 34.15

In response to CGMS Recommendation 34.15 on a comparison of the operational algorithms for the height assignment of AMVs, JMA calculated AMVs using METEOSAT-8 0.8, 10.8 and 6.2 micro-meter images at 12:00, 12:15 and 12:30 UTC on 18 August 2006 by the current JMA's algorithm. The AMV qualities with reference to JMA's NWP are comparable to those of MTSAT-1R AMVs (CGMS35-WP06, JMA). The AMV data were sent to CGMS study coordination team in August 2007 for study to compare the assigned height with cloud LIDAR observations and so forth.

5 SUMMARY AND FUTURE PLANS

By introducing new height assignment scheme since 30 May 2007, JMA could reduce the slow wind speed bias of upper-height-level IR AMVs, which are observed over middle latitudes. And new cloudy-region WV AMVs with high quality (QI>0.85) is more than previous ones. To improve the quality of IR AMVs furthermore, JMA is currently developing a follow-on height assignment scheme directly linked to feature-tracking.

AMVs reprocessed by using the images of GMS series were used in 25-year Japan long-term Reanalysis (JRA-25) (Onogi, 2007). JMA/MSC plans to reprocess AMVs by using the images of GMS- 3 to 5, GOES-9 and MTSAT-1R under using available best height assignment scheme again. By this work, it is expected that the quality of AMVs from the past satellites will be improved and the AMV data will contribute to future global reanalysis projects.

3.8 micro-meter AMVs for lower-height-level winds computed at nighttime have been used in JMA's NWP since 25 March 2008. According to the monthly statistics against sonde observations, the number of high quality (QI>0.85) 3.8 micro-meter AMVs is approximately 10 % larger than that of IR AMVs. The result means that the usage of 3.8 micro-meter AMVs could lead to increase of the available data at lower-height-level at nighttime.

AMV computation using the shorter time interval images of MTSAT-2 presently remains a matter of research, particularly, for IR and WV AMVs. Hereafter, JMA will continue investigating to find the best parameters (template size and so on) for computing the AMVs. In the preliminary research, feature-tracking by *optical-flow* method could generate spatially high-density AMVs in using IR and WV images at shorter time intervals. JMA will continue to seek the possibility of *optical-flow* method.

REFERENCES

Borde, R. and R. Oyama, 2008: A direct link between feature tracking and height assignment of operational AMVs, Proceedings of 9th International Winds Workshop.

Imai, T. and R. Oyama, 2008: Developments for Quality Improvement of Atmospheric Motion Vectors product, Meteorological Satellite Center technical note, 51, 41-55 (in Japanese).

JMA, 2007: JMA's Atmospheric Motion Vectors, JMA-WP-06, CGMS35.

Nieman, N. J., Schmetz and W.P. Menzel, 1993: A comparison of several techniques to assign heights to cloud tracers, J. Appl. Meteorol., 32, 1559-1568.

Onogi, K., J. Tsutsui, H. Koide, M. Sakamoto, S. Kobayashi, H. Hatsushika, T. Matsumoto, N. Yamazaki, H. Kamahori, K. Takahashi, S. Kadokura, K. Wada, K. Kato, R. Oyama, T. Ose, N. Mannoji and R. Taira, 2007 : The JRA-25 Reanalysis. J. Meteor. Soc. Japan, 85, 369-432.

Oyama, R., R. Borde, J. Schmetz and T. Kurino, 2008: Development of AMV height assignment directly linked to feature tracking at JMA, Proceedings of 9th International Winds Workshop.

Tokuno, M., 1998: Improvements in the method to extract operational cloud motion winds and water vapor motion winds of the GMS-5 system, Proceedings of 4th International Winds Workshop, EUMETSAT, 61-68.

Yamashita, K., 2008: Upgraded usage of AMVs from all geostationary satellite in the operational global and meso-scale 4D-VAR assimilation system at JMA, Proceedings of 9th International Winds Workshop.