RECENT UPGRADES OF AND ACTIVITIES FOR ATMOSPHERIC MOTION VECTORS AT JMA/MSC

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ABSTRACT

The Meteorological Satellite Center (MSC) of the Japan Meteorological Agency (JMA) generates Atmospheric Motion Vectors (AMVs) using the successive images of MTSAT-1R. This paper reports the recent upgrades of and activities for MTSAT-1R AMVs at JMA/MSC.

JMA started to disseminate AMVs in BUFR at 03, 09, 15 and 21UTC to users via GTS, in addition to ones at 00, 06, 12 and 18UTC, on 18 August 2009. With this change, the scan start and end times of images for deriving two intermediate vectors, AB (from the first and second images) and BC (from the second and third images), and the wind speeds and directions of the vectors, were newly stored in BUFR.

To improve AMV quality, JMA performed several upgrades on AMV derivation in 2008 and 2009. JMA started to use GPVs with higher time and spatial resolutions from the JMA's Global Spectral Model (GSM) forecast fields in the computation of AMVs at 05UTC on 9 October 2008 with the upgrade of GSM in 2007. The introduction of the new GPVs slightly improved the qualities of AMVs against sonde observation and GSM first-guess fields. At 05UTC on 19 May 2009, JMA introduced three new derivation algorithms. Firstly, a new height assignment scheme, where individual-pixel contribution rate to feature tracking is used, was introduced into the computation of IR AMVs. The introduction of the new scheme led to increase of number above 400 hPa level and improved the large fast wind speed biases at levels between 500 and 700 hPa in the previous AMVs. Secondly, the image segment to track clouds/ water vapor pattern (target box) was resized from 32 pixels to 16 or 24 pixels depending on the time interval of images. This resizing led to mitigating slow wind speed biases of high- and middle-level AMVs. And thirdly, the AMV derivation area was expanded from 50S-50N and 90E-170W to 60S-60N and 90E-170W. Finally, at 05UTC on 15 September 2009, JMA improved starting point errors of a wind vector derived from cross-correlation matching scheme. The improvement led to the increase of number of high-quality AMVs.

As a follow-up work for T-PARC (THORPEX-Pacific Asian Regional Campaign) held in summer of 2008, JMA has been seeking the proper size of target box image to compute AMVs using images at intervals less than 15 minutes.

JMA is reprocessing AMVs from the images of past geostationary satellites, i.e., GMS, GOES-9 and MTSAT-1R using the latest derivation algorithms to contribute to the Japanese 55-year reanalysis project (JRA-55) and the Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM).

For future plans on AMVs, JMA plans to perform satellite switch the operational satellite to MTSAT-2 from MTSAT-1R between July and August in 2010. Following the switch, JMA will distribute the AMVs to users via GTS every hour in 2010.

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. Table 1 shows the list of AMVs. JMA generates four types of AMVs associated with image types, IR (10.8 micro-meter), WV (6.8 micro-meter), VIS (0.63 micro-meter) and SWIR (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 an interval of 15 minutes (i.e. six-hourly

AMVs), and distributed to users via the Global Telecommunication System (GTS) in BUFR format. AMVs over the Northern Hemisphere (NH) are generated by using images at intervals of 30 or 60 minutes every hour between the six-hourly AMVs (i.e. hourly AMVs). Hourly AMVs for NH at 03, 09, 15 and 21 UTC have been distributed to users via GTS since 03UTC on 18 August 2009. In addition, JMA started to compute hourly AMVs for the Southern Hemisphere (SH) by using three successive full-disk images at an interval of 60 minutes at 01UTC on 17 February 2010 for JMA's internal use.

This paper reports on the current status focusing on the recent upgrades of and activities for JMA's AMVs. In Section 2, the recent quality of MTSAT-1R AMVs to sonde observations is reported with referring to recent AMV upgrades. In Section 3, the upgraded AMV derivation algorithms are described. In Section 4, recent activities are shown, and finally future plans are shown in Section 5.

AMV type
Infrared: IR (10.8 micrometer) Level: High, middle, low
Water Vapor: WV (6.8 micrometer) Level: High, middle
Visible: VIS (0.63 micrometer) Level: Low
Short-wave Infrared: SWIR (3.8 micrometer) Level: Low

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

Observation Time (UTC)	Image interval for AMV computation (minute)	
	NH (EQ-60N)	SH (60S-EQ)
0	15	15
1	60	60 (*2)
2	30	60 (*2)
3	30 (*1)	60 (*2)
4	30	60 (*2)
5	30	60 (*2)
6	15	15
7	60	60 (*2)
8	30	60 (*2)
9	30 (*1)	60 (*2)
10	30	60 (*2)
11	30	60 (*2)
12	15	15
13	60	60 (*2)
14	30	60 (*2)
15	30 (*1)	60 (*2)
16	30	60 (*2)
17	30	60 (*2)
18	15	15
19	60	60 (*2)
20	30	60 (*2)
21	30 (*1)	60 (*2)
22	30	60 (*2)
23	30	60 (*2)

***Table 2*: The generation and dissemination of MTSAT-1R AMVs. Red-shaded cells stand for AMVs distributed to users via GTS.**

*1 AMVs at 03, 09, 15 and 21UTC have been distributed to users via GTS since 03UTC on 18 August 2009.
*2 The computation of AMVs was started for JMA's internal use at 01UTC on 17 February 2010.

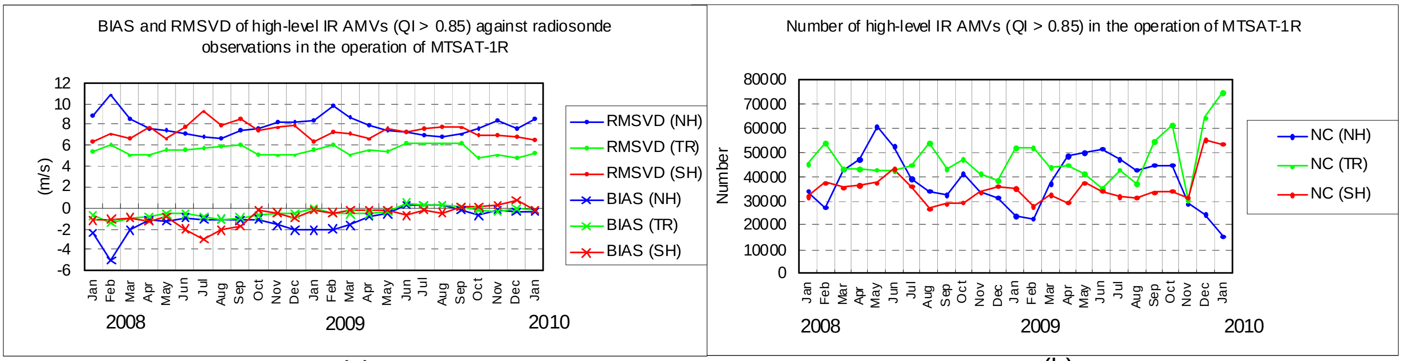
2 Status of MTSAT-1R AMVs

This section describes the recent quality of MTSAT-1R AMVs between 2008 and 2010.

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 high-level (above 400 hPa) IR AMVs (QI>0.85). In the statistics, AMVs at 00 and 12UTC, when sonde observations are available, were used. Figure 1 (a) shows that RMSVDs and BIASes of high-level IR AMVs were improved in October 2008, May 2009 and September 2009. These points correspond to the three upgrades of AMV derivation which are shown in Section 3, i.e., (1) Introduction of high-resolution GPVs in the AMV computation in October 2008, (2) Change of height assignment scheme for high- and middle-level IR AMVs, resizing target box (i.e. small image segment for tracking clouds/WV patterns) for IR, WV and SWIR AMVs, and expansion of AMV derivation area in May 2009, and (3) Upgrade of tracking algorithm in September 2009. Figure 1 (b) shows the slight increase of number by the upgrade of tracking algorithm in September 2009.

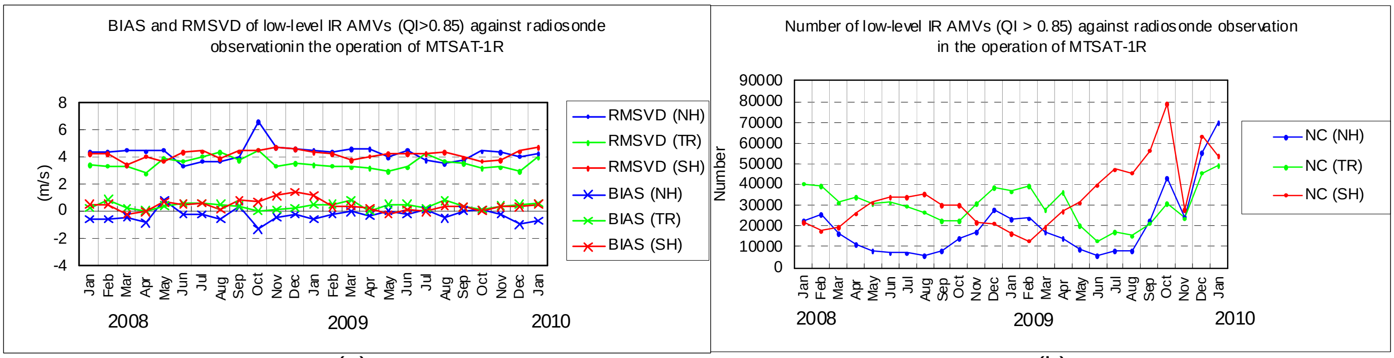
Figure 2 (a) and (b) are the same figures as Figure 1 (a) and (b) respectively, but for low-level (below 700 hPa) IR AMVs. Figure 2 (a) shows slight improvement of RMSVDs by the upgrade of tracking algorithm in September 2009. Figure 2 (b) shows a significant increase of number by the upgrade of tracking algorithm.

For information, monthly statistics of MTSAT-1R AMVs to sonde observations (i.e. CGMS report) can be seen on the website (http://mscweb.kishou.go.jp/product/report/amv/index.htm) at JMA/MSC.



(a) (b)

***Figure 1*: Time series of (a) RMSVDs and BIASes and (b) Number of high-level (above 400 hPa) IR AMVs (QI>0.85) over Northern Hemisphere (20N-60N, blue graph), Southern Hemisphere (60S-20S, red graph) and Tropics (20S-20N, green graph) with reference to sonde observations. AMVs at 00 and 12 UTC are used for the statistics.**



(a) (b)

***Figure 2*: Same figures as Figure 1, but for low-level (below 700 hPa) IR AMVs.**

3 UPGRADES OF AMV DERIVATION SINCE 9TH IWW

This section introduces the recent upgrades of AMV derivation at JMA/MSC. Between 2008 and 2009, JMA upgraded the AMV derivation three times, i.e., (1) Start of using high-resolution GPVs in the AMV computation in October 2008, (2) Three upgrades of derivation algorithms in May 2009, and (3) Upgrade of tracking algorithm in September 2009. They are described in the below three sections.

3.1 INTRODUCTION OF HIGH-RESOLUTION GPVS IN THE AMV COMPUTATION

The higher time- and spatial-resolution NWP GPVs for temperature, water vapor and wind profiles (from the first-guess of JMA's Global Spectral Model (GSM)) were introduced into the computation of AMVs at 05UTC on 9 October 2008. This change was done in accordance with an upgrade of JMA's GSM (i.e., change of spatial grid from 60km to 20km and increase of forecast initial times from 2 times to 4 times) in November 2007. By the upgrade, the frequency of initial times of GPV data increased from 2 times (00 and 12UTC) to 4 times (00, 06, 12 and 18UTC). This change led to a shorter forecast time in using GPVs in the AMV computation. In addition, the spatial resolution of GPVs became finer from 2.5 degrees to 0.5 degrees. These upgrades altogether led to the slight improvement of wind speed bias and RMSVD, and slight increase of number of high-quality AMVs. It is considered that the improvement was due to the improvement of height assignment and more proper quality control of AMVs by QI.

3.2 UPGRADES OF AMV DERIVATION ALGORITHMS IN MAY 2009

JMA performed three upgrades of AMV derivation algorithms at 05UTC on 19 May 2009, as shown in (a) to (c) below. The upgraded algorithms were described by Oyama (2010). Figure 3 shows the zonal plots of BIAS and number for IR AMVs (QI>0.8) before and after the upgrade. It is recognized that the three upgrades altogether led to mitigation of slow wind speed bias, reduction of middle-level large fast wind speed bias, and expansion of data coverage toward higher latitudes. Similar improvements to these ones were seen for UKMO NWP model (Cotton and Forsythe, 2010).

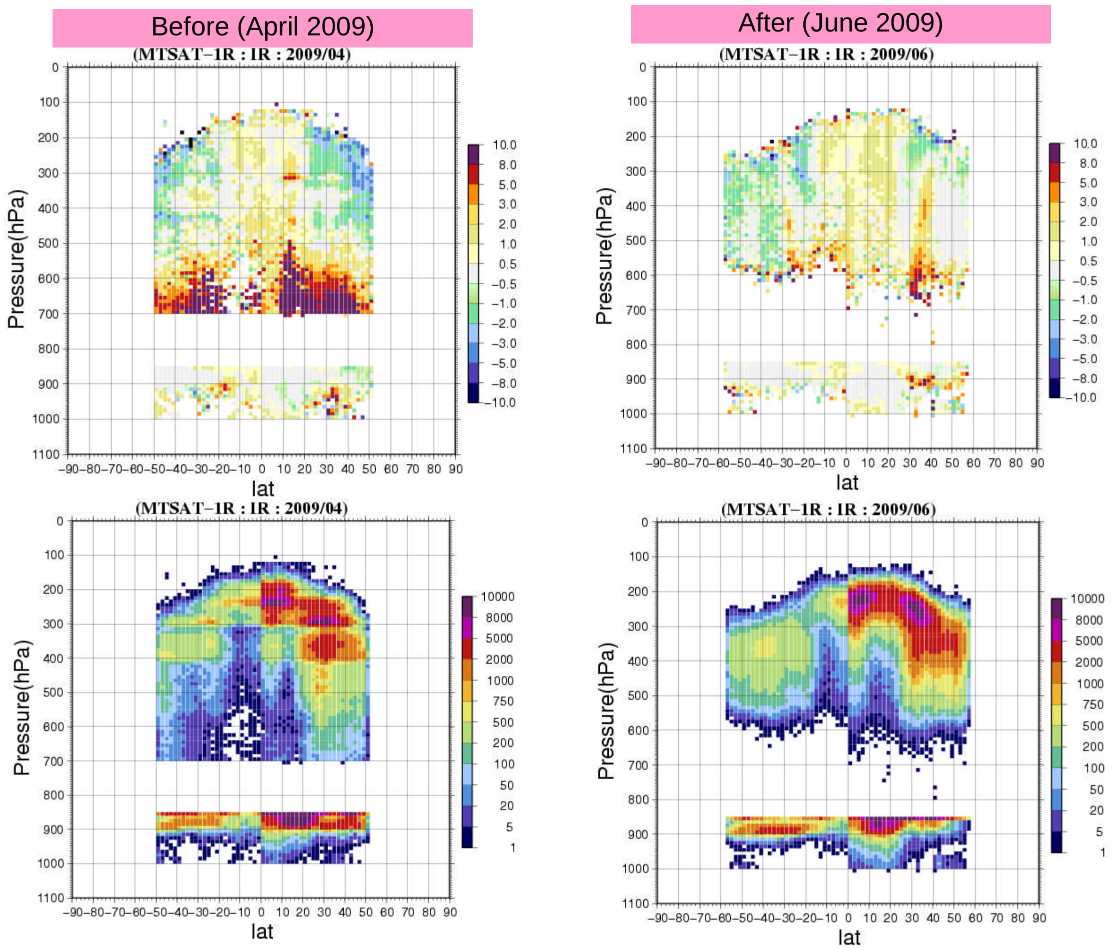


***Figure 3*: Zonal plots of monthly averaged wind speed bias to JMA's GSM first-guess fields (top) and monthly number (bottom) for MTSAT-1R IR AMVs before (Left; April 2009) and after (Right; June 2009) the upgrade at 05UTC on 19 May 2009. The statistics were taken for AMVs with QI above 0.8.**

(a) Change of height assignment scheme for high- and middle-level IR AMVs

The new height assignment scheme and the effectiveness on AMV quality were reported by Oyama et al. (2008) in 9th IWW. Before the upgrade, the heights for high- and middle-level IR AMVs were computed as the most frequent peak of height-histogram from target box. In the new scheme, the height is computed by using the individual-pixel contribution rates to feature tracking (CCij) within the target box (Borde and Oyama, 2008; Oyama et al., 2008).

Figure 4 shows a derivation of CCij using a case of tracking cirrus clouds. In this case, the cirrus clouds have larger CCij than lower-level clouds and the surface. CCij enables AMV producers to use truly-tracked cloud pixels in the pixel selection of height assignment. In the new scheme, the weighted mean of IR radiances (corrected by H2O-IRW intercept method) of individual pixels in target box (without background pixels and pixels with negative CCij) is computed, and the heights of high- and middle-level IR AMVs are computed from the value. Figure 5 shows the improvement of AMV quality by introducing the new height assignment scheme. The significant reduction of fast wind speed bias between 700 and 500 hPa is remarkable.

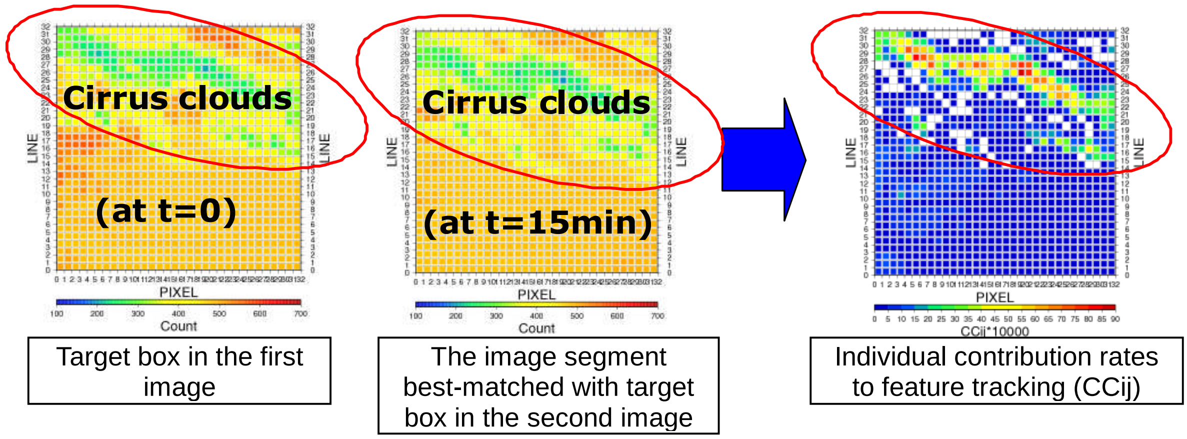


Figure 4: **Derivation of individual contribution rates to feature tracking (CCij). CCij is the components of the maximum cross-correlation coefficient obtained in the cross-correlation matching from two successive images.**

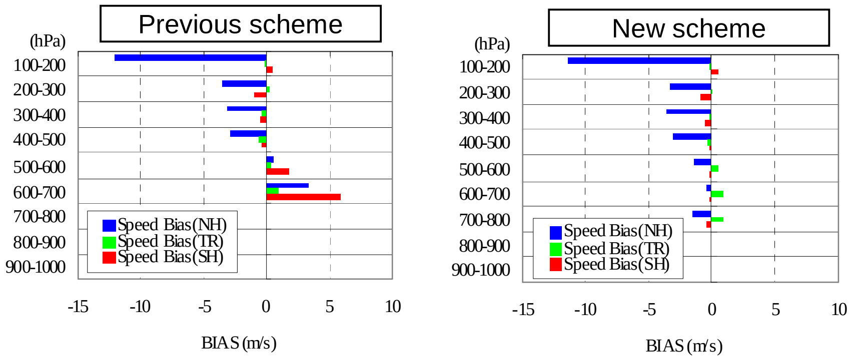


Figure 5: **Height dependency of wind speed bias to JMA's NWP (60km GSM) for IR-AMVs in March 2007 (Oyama et al., 2008). Left: AMVs by previous height assignment, Right; AMVs by new height assignment scheme**

(b) Resizing target box sizes of IR, WV and SWIR AMVs

Sizes of target box for IR, WV and SWIR AMVs were resized from 32 pixels to smaller sizes, i.e., 16 pixels for 15-min AMVs, and 24 pixels for 30-min and 60-min winds. The merits of minifying target box size are: (1) Increase of probability that single-layer cloud will dominate the image (this interpretation was indicated by Sohn and Borde (2008) too), (2) Capturing respective air-parcel movement on streamlines properly, even in flows with large curvatures, and (3) Less correlation between adjacent two target box images (JMA/MSC computes AMVs on 0.5-degree latitude/longitude grids).

Figure 6 shows the effectiveness of minifying target box size on the AMV quality to sonde observations. Minifying target box size led to reductions of BIAS and RMSVD, particularly for high-level IR AMVs.

Target box size of 24 pixels is used for derivations of 30-min winds (from 30-min interval images) and 60-min winds (from 60-min interval images), because the decrease of numbers of 30-min and 60-min winds was large when the target box size was set to 16 pixels, particularly for AMVs with large wind speeds (e.g. high-level AMVs). The decrease of number is related to the lifetime of clouds and the longer distance of cloud movement for 30-min and 60-min winds. It is considered that another approach, e.g. a new tracking scheme by J. Daniels and W. Bresky (2010) could solve the problem.

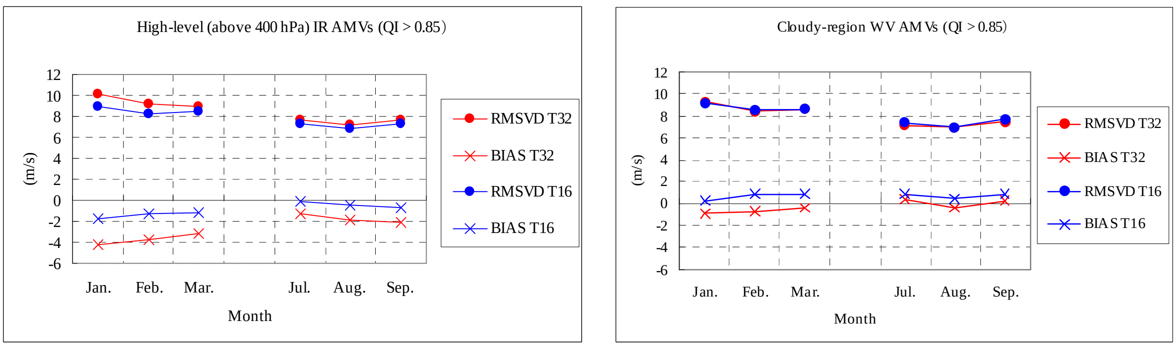


Figure 6: **Monthly quality (RMSVD and BIAS) to sonde observations for high-level (above 400hPa) IR AMVs (Left) and cloudy-region WV AMVs (Right). Red and blue graphs stand for the statistics for AMVs computed by 32- and 16- pixel target box sizes respectively. The threshold of QI is 0.85.**

(c) Expansion of AMV derivation area

The derivation area of MTSAT-1R AMVs was expanded from 50S-50N and 90E-180W to 60S-60N and 90E-180W, and the threshold of satellite zenith angle for limiting derivation area was changed from 60 degrees to 65 degrees. These changes led to availability of AMV data in higher latitudes.

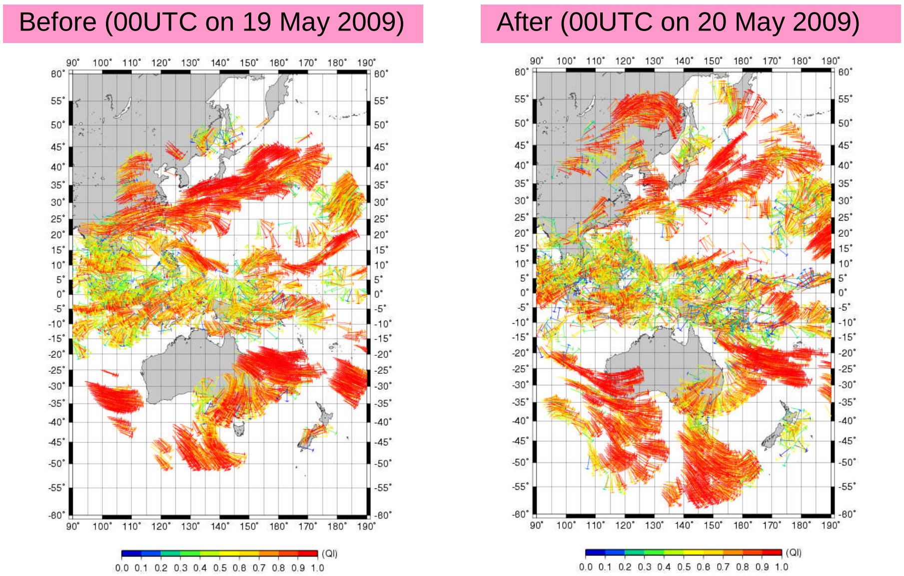


***Figure 7*: AMVs before (Left; 00UTC on 19 May 2009) and after (Right; 00UTC on 20 May 2009) the expansion of derivation area**

3.3 UPGRADE OF TRACKING ALGORITHM

JMA upgraded the tracking algorithm to solve a defect in the tracking process by cross-correlation matching at 05UTC on 15 September 2009. JMA uses two-step matching scheme to derive a wind vector (Oyama, 2010). Namely, in the two-step matching, a matching for each wind vector is performed in coarse and fine matching. Coarse matching gives the large-scale wind fields under using the coarse images which are spatially sampled by rates n and m (n and m are integer values) respectively. Fine matching gives fine displacement vector under using the original spatial-resolution images. The final wind vector is computed as the vector sum of vectors from the coarse and fine matching. Before the upgrade, there were estimation errors of ±0.5 pixels at maximum at the starting points of wind vectors derived from the coarse and fine matching. The estimation errors were improved by the upgrade. The upgrade on tracking process led to improvements of BIAS and RMSVD, and increase of number, particularly for weak winds due to the better tracking accuracy.

4 CHANGES OF MTSAT-1R AMV GENERATION AND DISSEMINATION SINCE 9TH IWW

Since 9th IWW, JMA conducted two changes of the AMV generation and dissemination.

First, JMA increased the frequency of AMV dissemination for Northern Hemisphere (EQ-60N) to users via GTS, from 4 times (00, 06, 12 and 18UTC) to 8 times (00, 03, 06, 09, 12, 15, 18 and 21UTC) at 03UTC on 18 August 2009. With the increase of dissemination, JMA started to store the scan and end times of images for deriving two intermediate vectors, AB (from the first and second images) and BC (from the second and third images). At JMA/MSC, BC vector is dealt as the final output of AMV. In addition, the wind speeds and directions of AB and BC vectors were stored in BUFR. It is expected that these information will contribute to more advanced usage (quality control and so forth) in NWP.

Second, JMA started generating hourly AMVs for Southern Hemisphere (60S-EQ) by using successive full-disk images at an interval of 60 minutes only for JMA's NWP at 01UTC on 17 February 2010. Although the number of 60-min winds is less than 15-min winds due to the difficulty of the computation related to the lifetime of clouds and the longer distance of cloud movement, it is expected that the increase of AMV generation will allow NWP users to use more AMV data in time.

4 RECENT ACTIVITIES

4.1 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. To contribute to T-PARC (Thorpex- Pacific Asian Regional Campaign) study in summer of 2008, JMA observed the Pacific and Asian regions including typhoons at several time intervals (15, 7 and 4 minutes). AMVs were computed by using the images. Figure 8 shows the examples of high-level IR AMVs (QI>0.85) from images at intervals of 15 minutes and 4 minutes respectively in the T-PARC study. Using shorter time-interval (e.g. 4 minutes) images could lead to the availability of data with new characteristics different from 15-min winds in quality and coverage.

As for reports on the AMVs computed for the T-PARC study, the investigation on AMV quality to sonde observations (Hoshino, 2010), new approach of tracking scheme (Shimoji, 2010) and effectiveness of AMVs on JMA's NWP (Yamashita, 2010) were reported in 10th IWW.

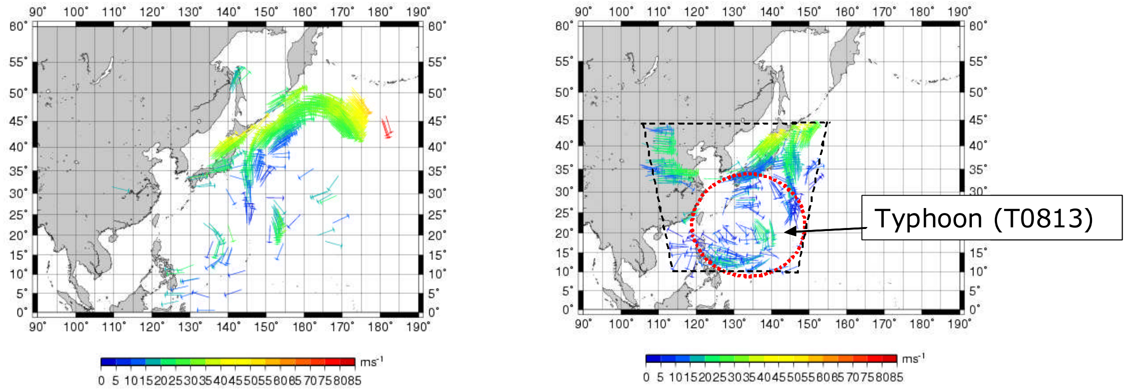


***Figure 8*: (a) Wind vectors of high-level IR AMVs (QI>0.85) computed by using successive MTSAT-2 images at intervals of 15 minutes (Left) and 4 minutes (Right) which were observed between 2230UTC and 2315UTC on 12 September 2008. The scale of color bars is wind speed in m/s. Dotted line in the right-side figure stands for the border of captured image.**

4.2 REPROCESS OF AMVS FROM PAST GEOSTATIONARY SATELLITES

JMA has been computing AMVs from the past geostationary satellites (GMS, GOES-9 and MTSAT-1R between 1979 and 2009) using the latest AMV derivation algorithms (Oyama, 2010). Table 3 shows the outline of the ongoing AMV reprocess. The reprocess period was expanded from the first reprocess conducted on behalf of use in the Japanese 25-year Reanalysis project (JRA-25). The data set of AMVs generated in the ongoing reprocess will be provided for JRA-55 reanalysis project scheduled between 2009 and 2012, and the Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM). The computation will be completed by 2010.

Figure 9 shows the examples of high-level IR AMVs from the first and second (ongoing) reprocesses. Main quality differences of AMVs between the first and second reprocesses are: (1) Expansion of derivation area toward higher latitudes (from 50S-50N to 60S-60N), (2) Mitigation of slow wind speed bias in winter hemisphere due to the improvement of height assignment and minifying target box size.

The information on the ongoing AMV reprocess can be seen on the information website (http://mscweb.kishou.go.jp/product/reprocess/index.htm) at JMA/MSC.

The second reprocess for JRA-55 (Ongoing)

	AMV type	Period		
GMS-1	IR	January 1979	~	November 1979
GMS-3	IR, VIS	March 1987	~	December 1989
GMS-4	IR, VIS	December 1989	~	June 1995
GMS-5	IR, VIS, WV	June 1995	~	May 2003
GOES-9	IR, VIS, WV	May 2003	~	June 2005
MTSAT-1R	IR, VIS, WV	June 2005	~	September 2009

Pink-coloured cells stand for the periods newly added in the second reprocess.

***Table 3*: Outline of the second reprocess (ongoing) for JRA-55**

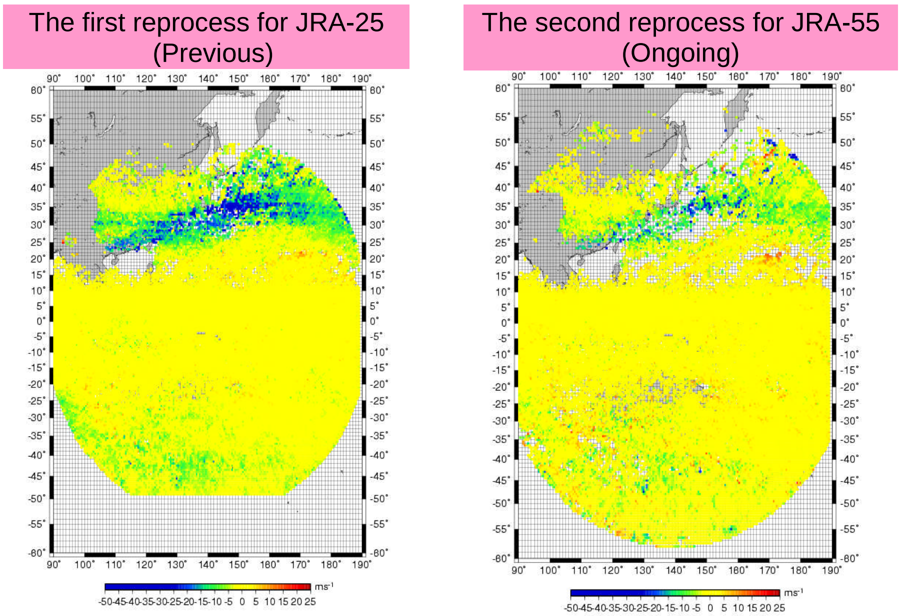


***Figure 9*: Wind speed bias (QI>0.85) of high-level IR-AMVs to JRA-25 analysis fields (January 1990, GMS-4). Left: the first reprocess for JRA-25, right: the second reprocess (ongoing) for JRA-55**

5 FUTURE PLANS

The operational observation of MTSAT-1R will be replaced with one of MTSAT-2 between July and August in 2010. After checking the quality of MTSAT-2 AMVs for one and a half months before the switch, JMA will start to distribute MTSAT-2 AMVs to users via GTS.

JMA also plans to start distributions of AMVs every hour to users via GTS after the switch to MTSAT-2 AMVs in 2010. Further, JMA will revise BUFR from ver.3 to ver.4 between 2010 and 2011.

As for a research on AMVs in the future, JMA plans to compute AMVs using METEOSAT-7 images provided by EUMETSAT in a data exchange agreement, and investigates them in terms of effectiveness on JMA's NWP. As for developments, JMA considers it is needed to improve height assignment scheme of low-level AMVs, target selection scheme and tracking scheme (including optimizing target box size).

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