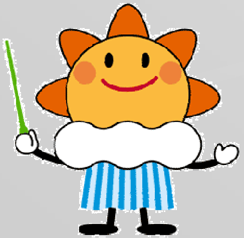
Recent upgrades of and Activities for Atmospheric Motion Vectors at JMA/MSC

Ryo OYAMA

Meteorological Satellite Center (MSC) of Japan Meteorological Agency (JMA)



10th International Winds Workshop in Tokyo, Japan

22-26 February 2010

Topics

1. Status of MTSAT-1R AMVs

2. Upgrades and Changes of MTSAT-1R AMVs since 9th International Winds Workshop
   - Upgrades of AMV derivation algorithms (including quality change)
   - Changes on the generation and distribution of MTSAT-1R AMV

3. Activities

4. Future plans

1. Status of MTSAT-1R AMVs

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

High: above 400hPa

Middle: 400-700hPa

Low: below 700hPa

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)

(red): IR-AMV, WV-AMV and VIS-AMV are distributed to GTS users in BUFR.

*1 AMVs at 03, 09, 15 and 21UTC have been distributed since 03UTC 18 August 2009.

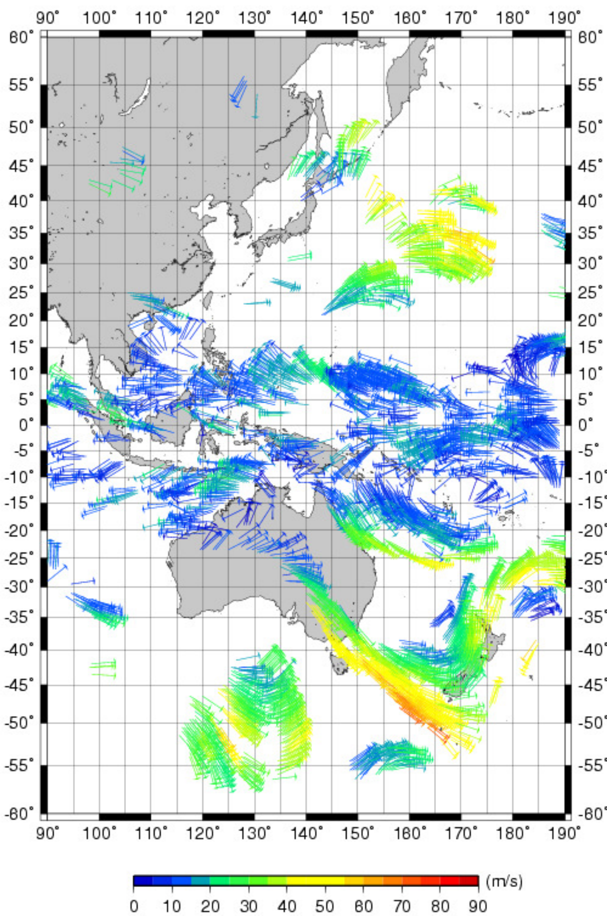
*2 The computation started for JMA's internal use at 01UTC 17 February 2010.

1. Status of MTSAT-1R AMVs

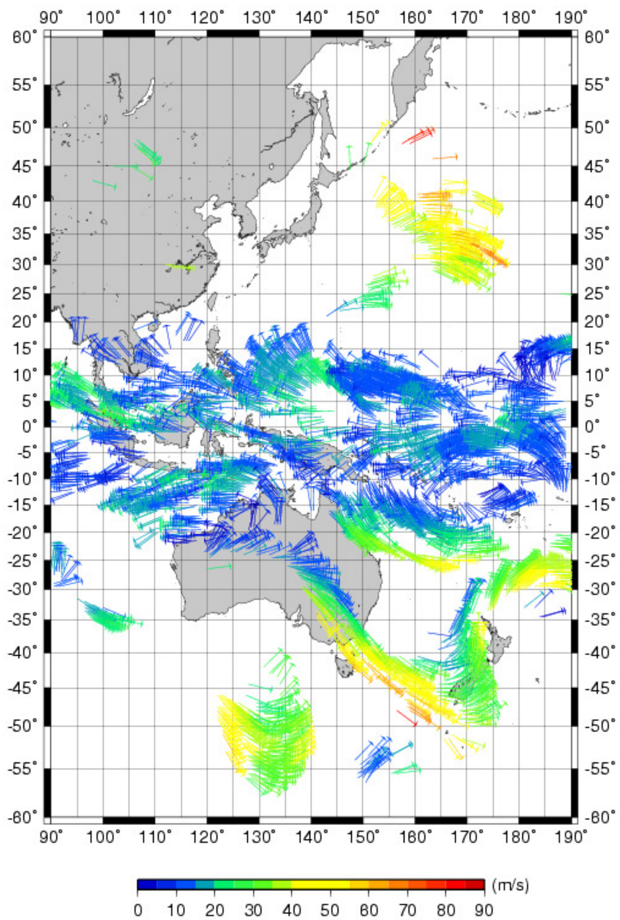
Example of MTSAT-1R AMVs (QI>0.85)

00UTC on 13 January 2010

High- and middle-level IR AMVs



WV AMVs (cloudy-region)

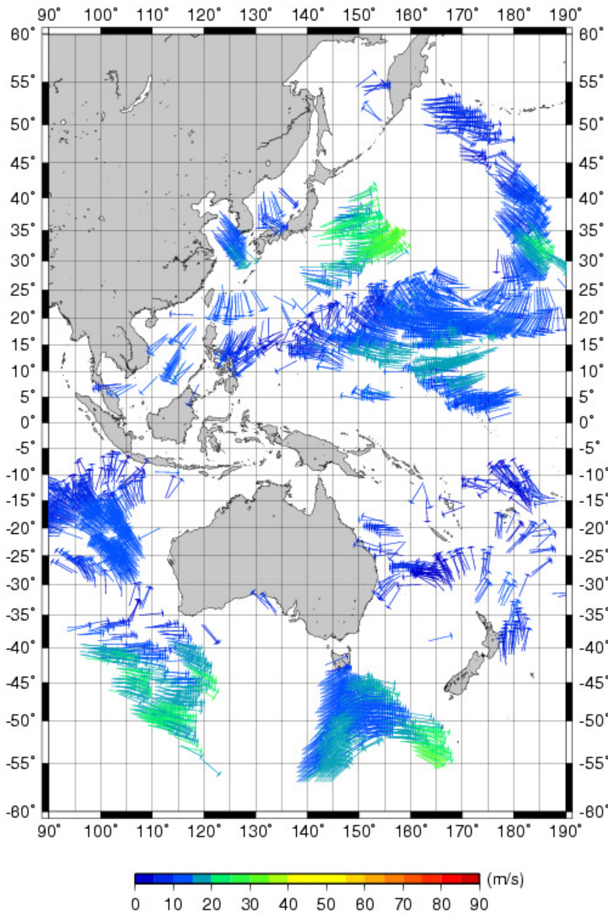


1. Status of MTSAT-1R AMVs

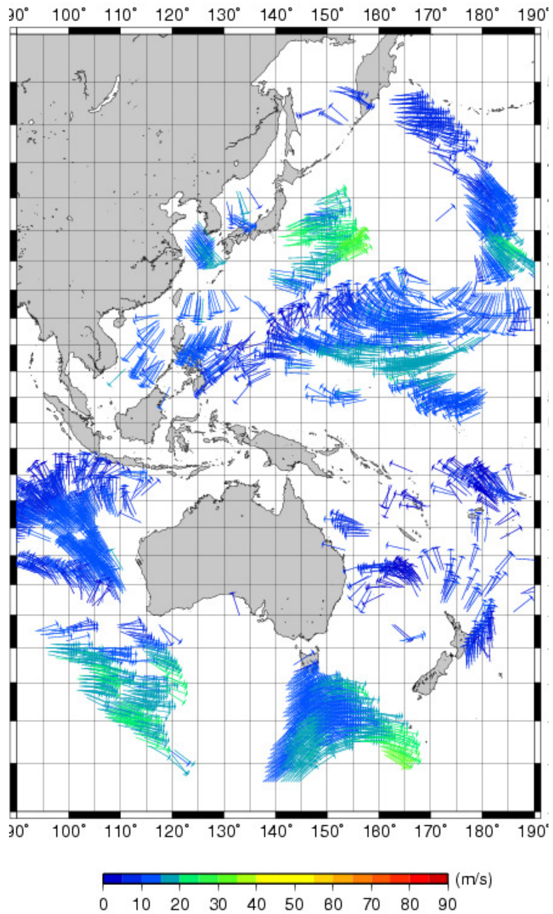
Example of MTSAT-1R AMVs (QI>0.85)

00UTC on 13 January 2010 | **12UTC on 13 January 2010**

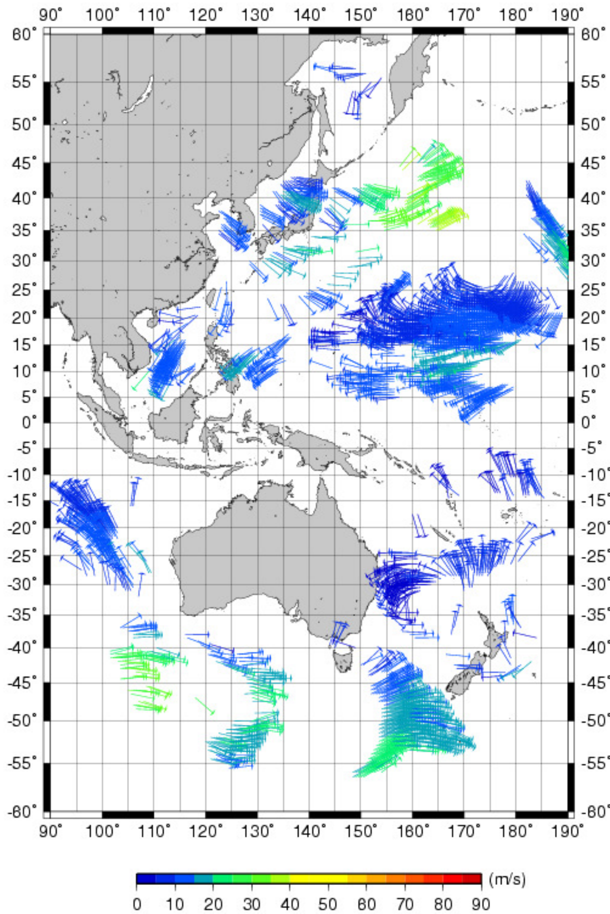
Low-level IR AMVs



VIS AMVs (for daytime)



SWIR AMVs (for nighttime)



2. Upgrades and changes of MTSAT-1R AMVs since 9th IWW

Upgrade of AMV derivation since IWW9
Change on AMV generation and dissemination since IWW9

	Mission by GOES-9	
15 June 2005	Start of MTSAT-1R mission	
06UTC on 30 May 2007	◆Upgrade of height assignment for high and middle -leve IR and WV AMVs ◆Introduction of a scheme to optimize the position of target box image for high- and middle-level IR AMVs and cloudy-region WV AMVs using entropy	
07UTC on 25 Mar 2008	◆Start of generating SWIR AMVs at nighttime	
	9th IWW in Annapolis U.S.A	
05UTC on 9 Oct 2008	◆Start of using high-resolution GPVs in the AMV computation	UPGRADE-1
05UTC on 19 May 2009	◆Upgrade of height assignment scheme for high and middle -level IR AMVs ◆Resizing target box size for IR, WV and SWIR AMVs ◆Expansion of AMV derivation area	UPGRADE-2
03UTC on 18 Aug 2009	◆Start of disseminating AMVs at 03, 09, 15 and 21UTC to users via GTS	CHANGE-1
05UTC on 15 Sep 2009	◆Upgrade of tracking algorithm	UPGRADE-3
01UTC on 17 Feb 2010	◆Start of generating hourly AMVs for Southern Hemisphere	CHANGE-2

2-1. Upgrades of AMV derivation since 9th IWW

(1) Introduction of high-resolution GPVs in the AMV computation (at 05UTC on 9 October 2008) : UPGRADE-1

- Start using GPVs with higher temporal and spatial resolutions in computing AMVs

(2) Upgrade of AMV derivation algorithms (at 05UTC on 19 May 2009) : UPGRADE-2

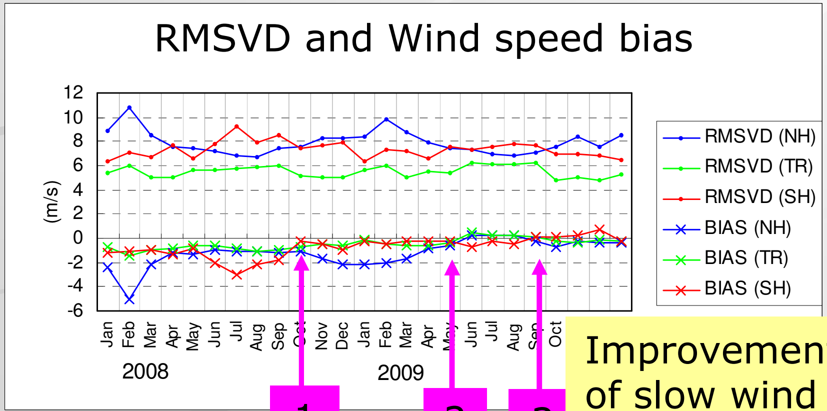
1. Upgrade of height assignment scheme for high and middle-level IR AMVs using contribution rate to tracking clouds
2. Resizing target box to track clouds/WV patterns
3. Expansion of AMV derivation area

(3) Upgrade of tracking algorithm (at 05UTC on 15 September 2009) : UPGRADE-3

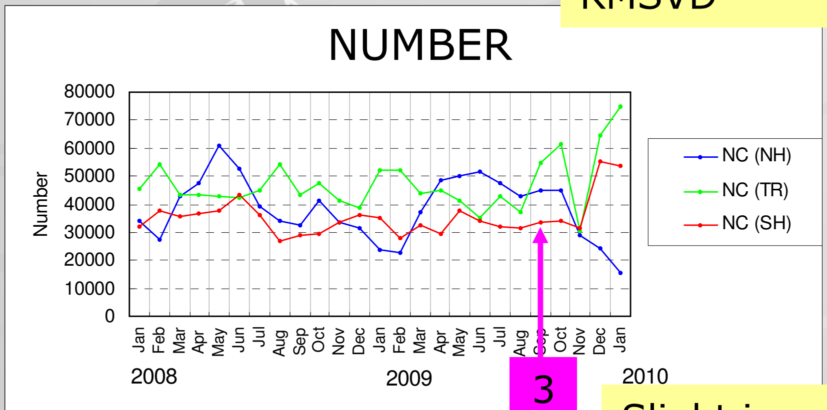
- Upgrade of tracking algorithm to improve a sub-pixel estimation error of wind vectors

Improvements of MTSAT-1R AMV quality to sonde observations (QI>0.85) in 2008-2009

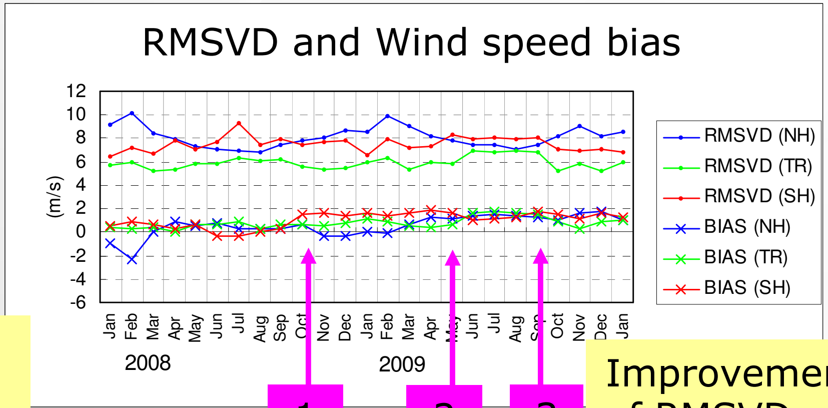
High-level (above 400hPa) IR AMVs



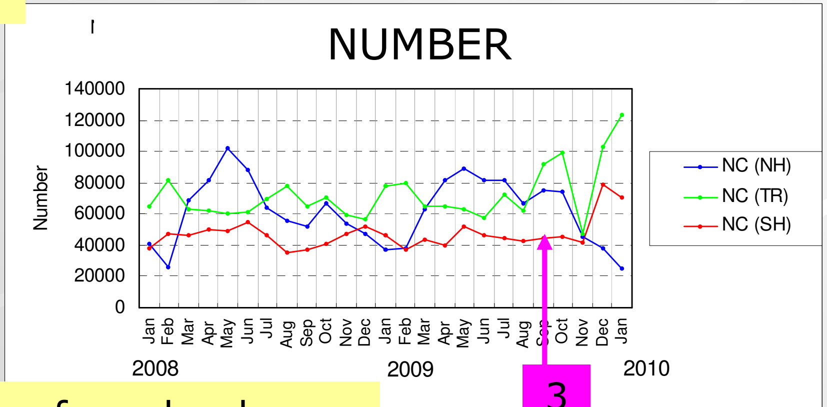
Improvements of slow wind speed bias and RMSVD



WV AMVs (Cloudy-region)



Improvement of RMSVD



Slight increase of number by upgrade of tracking algorithm

Blue: NH (20N-60N)

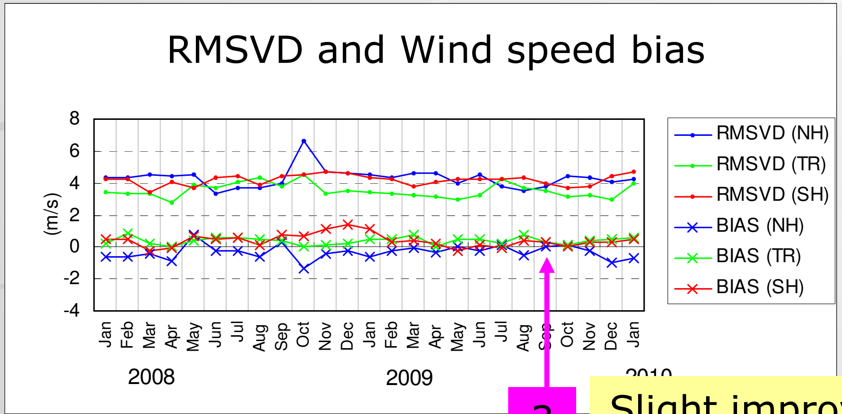
Green: TR (20S-20N)

Red: SH (60S-20S)

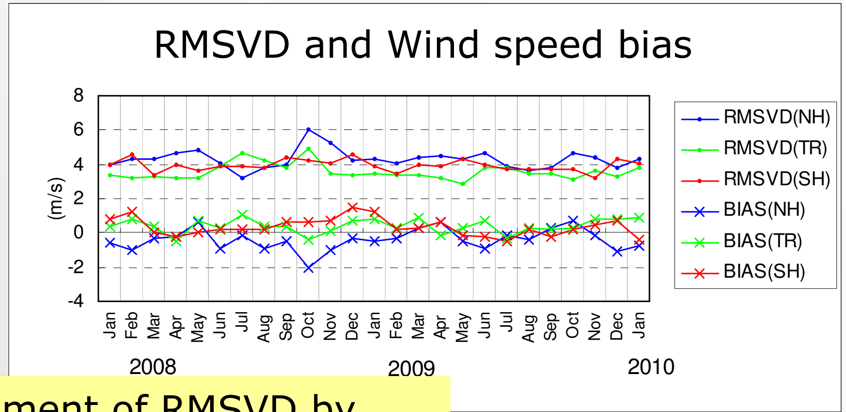
Each AMV (QI>0.85) is compared with sonde observations within the 150km-radius at 00 and 12 UTC.

Improvements of MTSAT-1R AMV quality to sonde observations (QI>0.85) in 2008-2009

Low-level (below 700hPa) IR AMVs

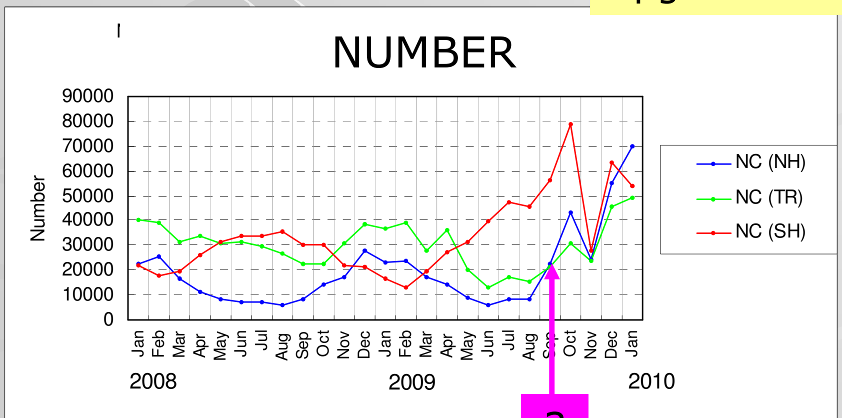


VIS AMVs

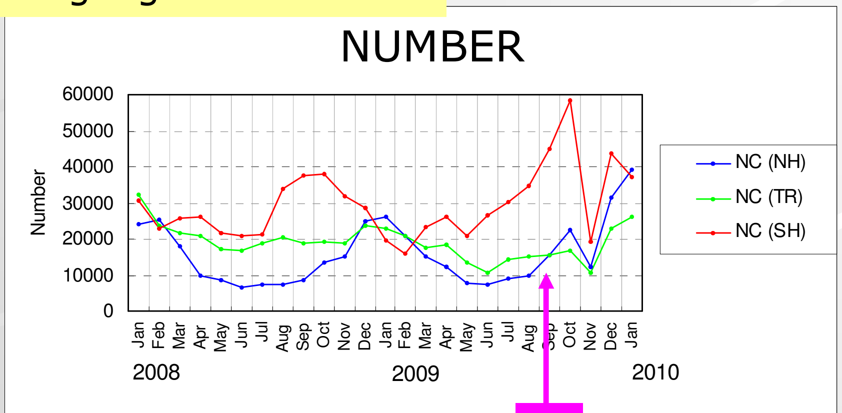


3

Slight improvement of RMSVD by upgrade of tracking algorithm



3



3

Significant increase of number by upgrade of tracking algorithm

Blue: NH (20N-60N)

Green: TR (20S-20N)

Red: SH (60S-20S)

CGMS report on JMA/MSC HP:
http://mscweb.kishou.go.jp/product/report/amv/index.htm

UPGRADE-1:
Introduction of high-resolution GPVs in the AMV computation

The higher time- and spatial-resolution GPVs for temperature, water vapor and wind profiles (from the first-guess fields of JMA's Global Spectral Model (GSM)) were introduced into computing AMVs at 05UTC on 9 October 2008.

This change was done in accordance with an upgrade of JMA's GSM (change of spatial grid from 60km to 20km) in November 2007.

	Previous GPVs		**New GPVs**
Initial times of NWP data	00 and 12UTC	→	00, 06, 12 and 18UTC
Spatial resolution	2.5 degrees	→	0.5 degrees

This change led to shorter forecast time in using GPV in AMV computation.

→ **UPGRADE-1 Led to the slight improvement of BIAS and RMSVD, and slight increase of high-quality AMVs.**

-> This is due to the improvement of the height assignment, and more proper quality control (by QI)

UPGRADE-2 (1):

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

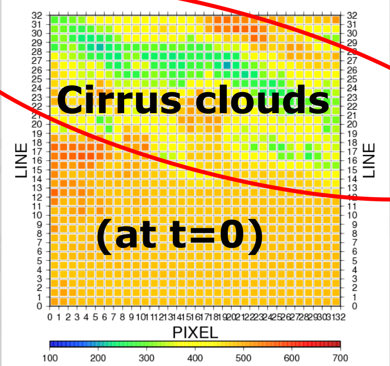
Before

The height was computed as the most frequent peak of height-histogram from target box.

After

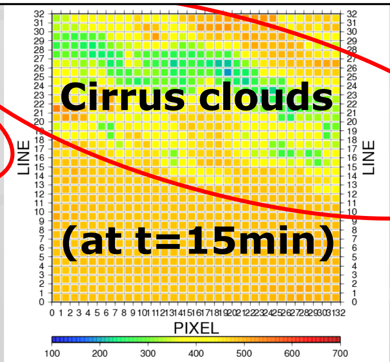
The height is computed by using the each-pixel contribution rate to tracking (CC_{ij}). (Oyama et al., 2008)

target box in the first image



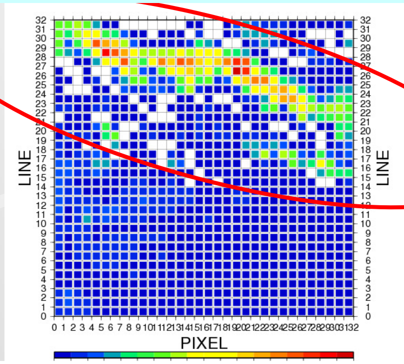
(Count)

The image segment best-matched with target box in the second image



(Count)

By using CC_{ij}, we can know that cirrus clouds have large contribution rate to the tracking.



Pixel-contribution rates to tracking clouds (CC_{ij})

CC_{ij} is computed as the components of the maximum correlation coefficient obtained in the cross-correlation matching.

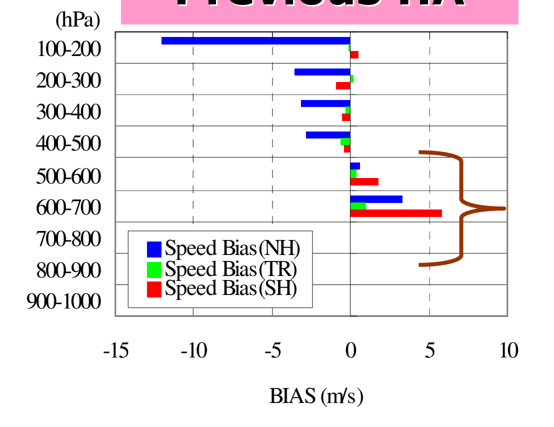
Improvement of AMV quality by new height assignment scheme

Monthly quality of high- and middle-level IR AMVs to JMA's NWP (60-km GSM) first-guess for March 2007 (target box size = 32 pixels) (Oyama et al. ,2008).

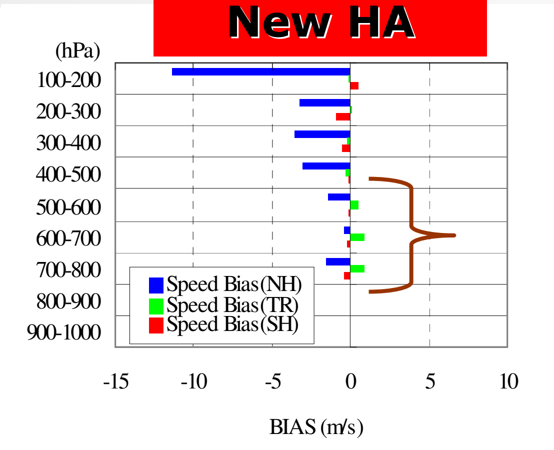
Wind speed bias

(QI>0.85)

Previous HA



New HA



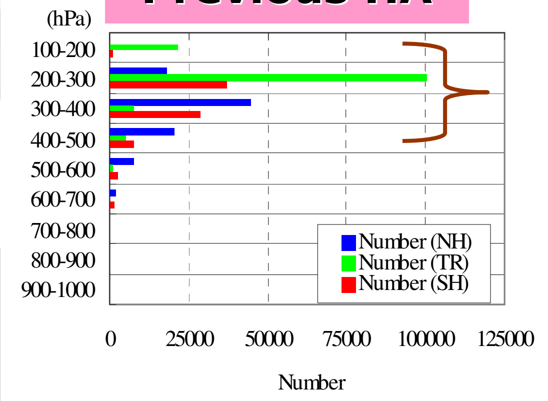
Fast BIASes found for the previous in 500-700 hPa are resolved for the new height assignment.

-> Use of CC_{ij} corrected the middle-level AMV heights properly.

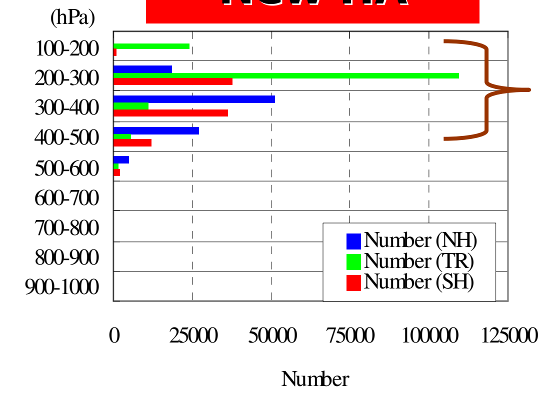
Number

(QI>0.85)

Previous HA



New HA



Number for the new height assignment is larger than that for the previous, particularly at high level.

UPGRADE-2 (2):

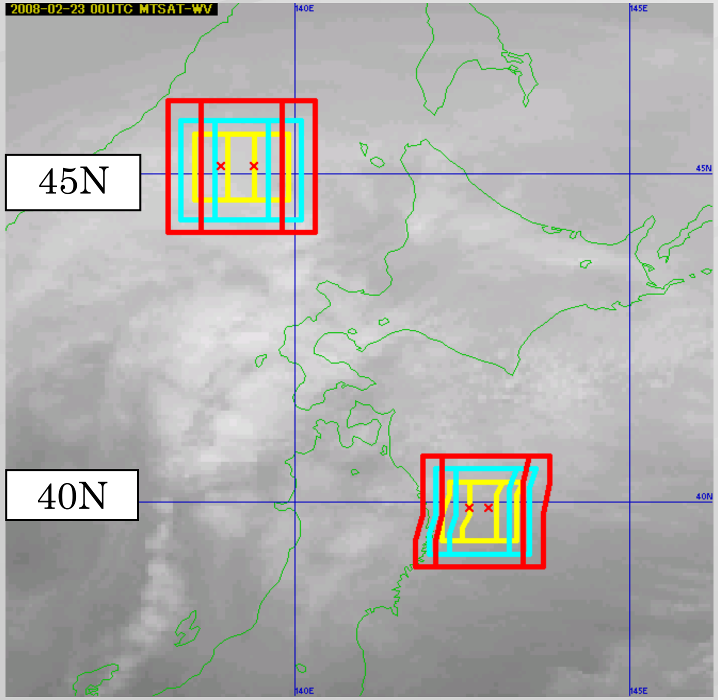
Resizing target box sizes of IR, WV and SWIR AMVs

Sizes of target box (small image segment to track clouds/WV patterns) for IR, WV and SWIR AMVs were resized from 32 pixels to smaller sizes.

15-min winds (6-hourly AMVs): **16 pixels x 16 pixels**

30- and 60-min winds (except for 6-hourly AMVs): **24 pixels x 24 pixels**

Examples of adjacent two target boxes at an interval of 0.5 degrees



Red: 32 pixels x 32 pixels

Aqua: 24 pixels x 24 pixels

Yellow: 16 pixels x 16 pixels

Merits of minifying target box size are:

◆Increase of the probability that single-layer cloud will dominate the image (indicated by Sohn and Borde (2008) too).

◆Capturing respective air-parcel movement on streamlines properly, even in flows with large curvatures.

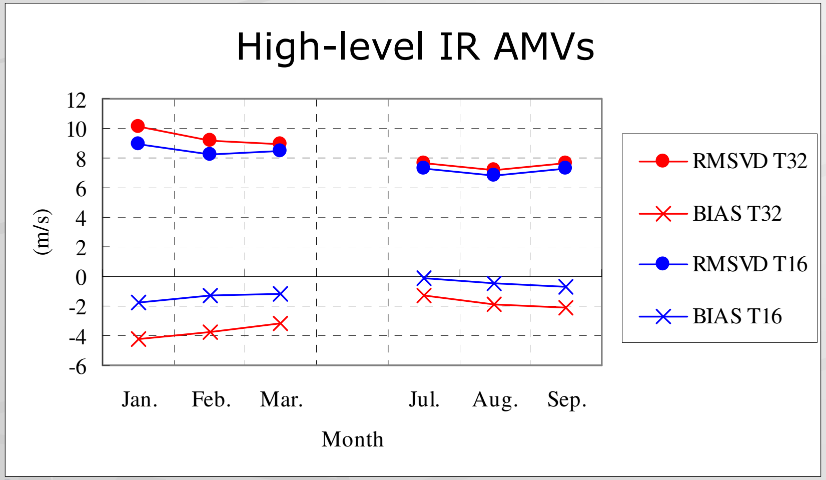
◆Less correlation between adjacent two target box images.

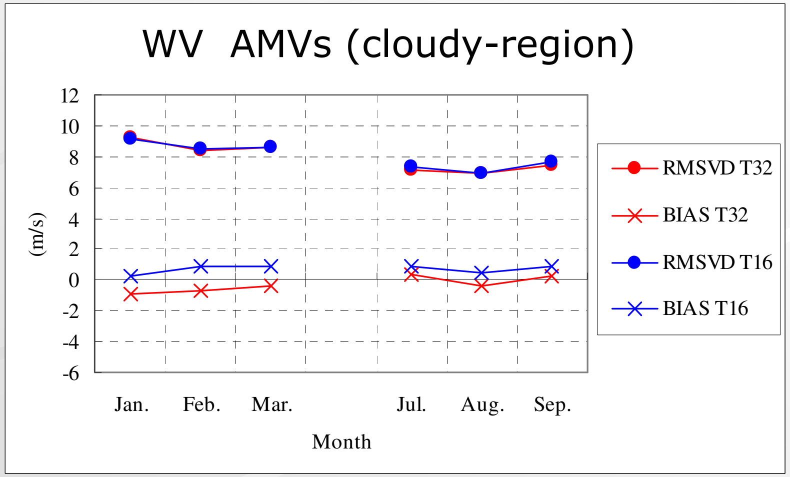
Effectiveness of minifying target box size on the AMV quality to sonde observations for 2007

(16 pixels v.s. 32 pixels for 15-min winds)

Wind speed bias (BIAS) and RMSVD (QI>0.85);

Northern Hemisphere (20N-50N)





Minifying target box size leads to reductions of BIAS and RMSVD, particularly for high-level IR AMVs.

Comparison of target box size between AMVs generated by the different AMV producers (Iliana et al., 2008)

	EUMETSAT	CIMSS	JMA	
Target box size (pixel)	24X24	15X15	16X16 (for 15-min winds)	24X24 (for 30 and 60-min winds)
Pixel size of IR image at Nadir	3km (MSG)	4km (GOES)	4km (MTSAT)	4km (MTSAT)
Target box size at Nadir	72 km	60 km	64 km	96 km

KMA and Brazil use 32 pixels for their target box size.

Discussion: Why is the target box size for 30- and 60-min winds set to 24 pixels ?

The decrease of numbers of 30- and 60-min winds is large, when the target box size is set to 16 pixels, particularly for AMVs with large wind speeds (e.g. high-level AMVs).

We consider the difficulty of computing 30- and 60-min winds is related to the lifetime of clouds and the longer distance of cloud movement.

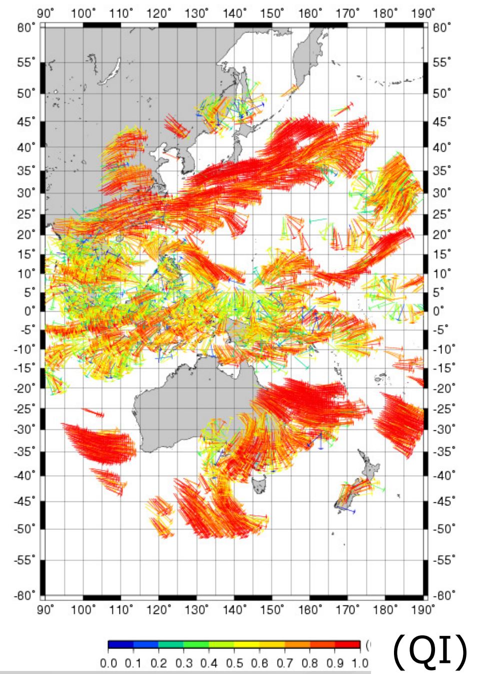
To minify target box size for 30- and 60-min winds, we need to seek better target box size and better tracking procedure (e.g., a scheme by J. Daniels and W. Bresky (2010) in 10IWW).

UPGRADE-2 (3):
Expansion of AMV derivation area

- The derivation area of MTSAT-1R AMVs was expanded from 50S-50N to 60S-60N.
- The threshold of satellite zenith angle for limiting derivation area was changed from 60 degrees to 65 degrees.

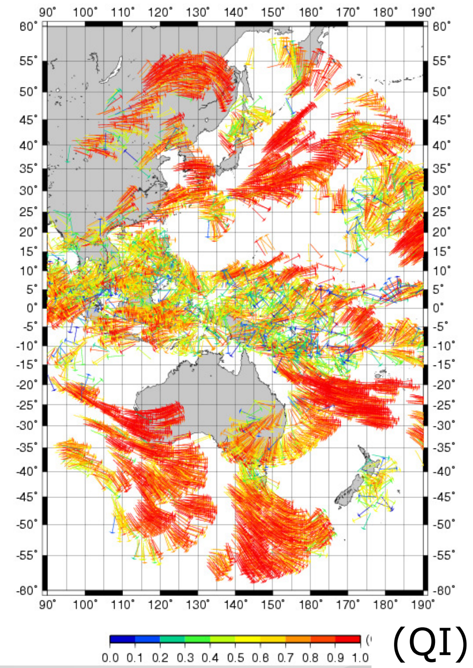
➡ **The changes led to availability of AMV data in higher latitudes.**

Before (00UTC on 19 May 2009)



(QI)

After (00UTC on 20 May 2009)



(QI)

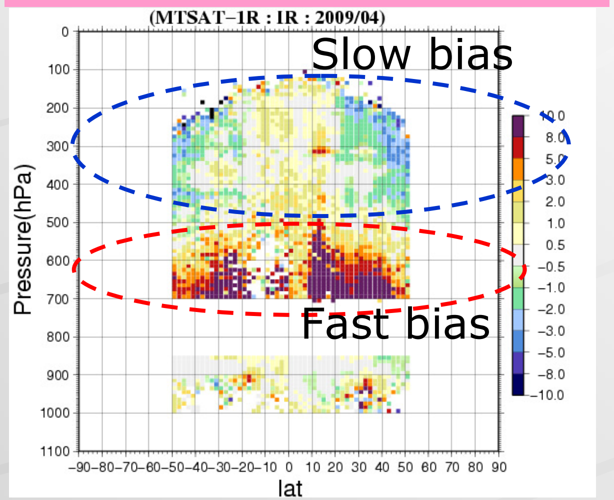
Improvements of AMV (IR-AMVs) quality by UPGRADE-2

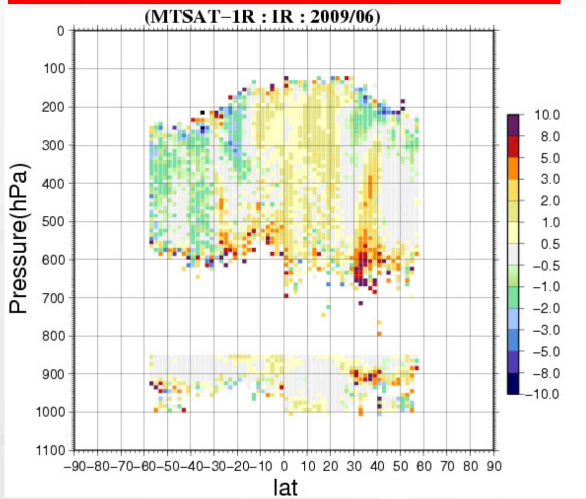
To JMA's GSM first-guess (provided by Mr. Noboru Nemoto, JMA)

Before (April 2009) | **After** (June 2009)

Wind speed bias

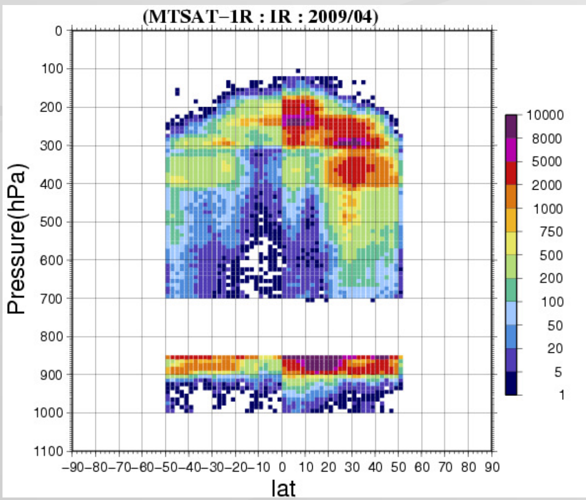
(QI>0.8)

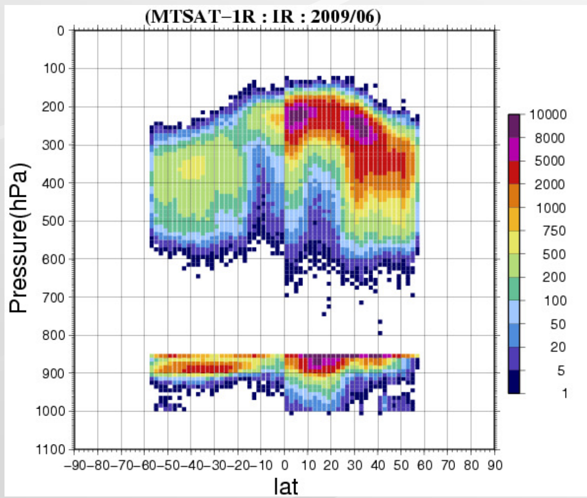




Number

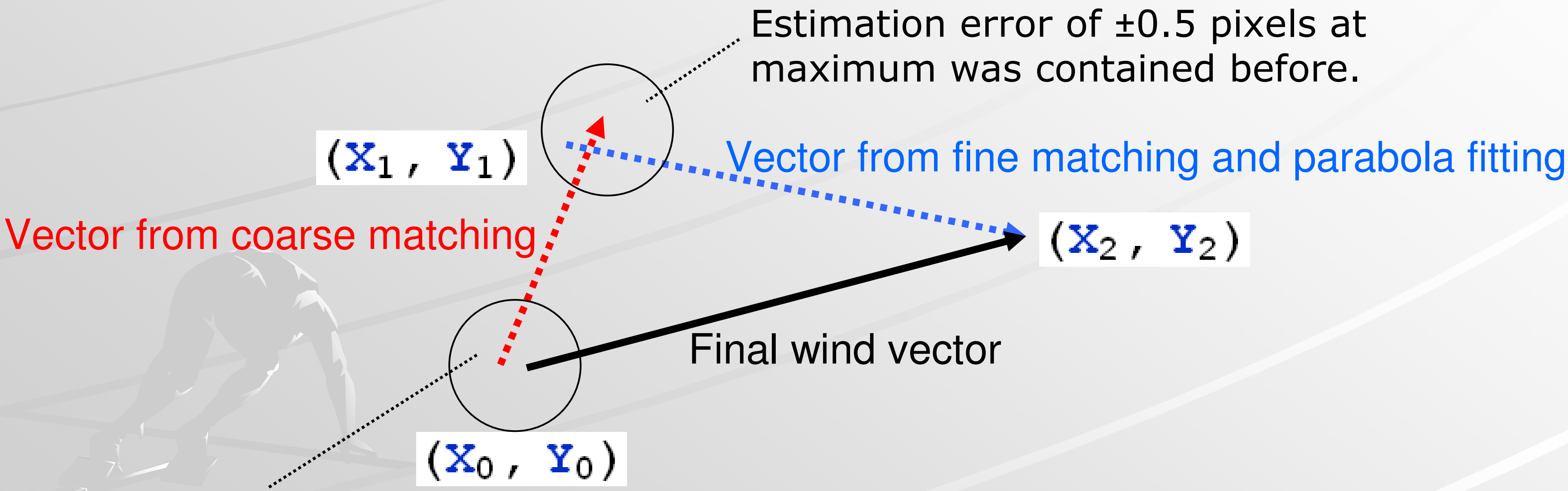
(QI>0.8)





UPGRADE-3:
Change of tracking algorithm

JMA/MSC uses two-step matching to derive a wind vector. The estimation errors of vectors from the coarse and fine matching were improved.



Estimation error of ±0.5 pixels at maximum was contained before.

$$((X_1, Y_1) - (X_0, Y_0)) + ((X_2, Y_2) - (X_1, Y_1))$$
$$= (X_2, Y_2) - (X_0, Y_0) \quad \text{:Final wind vector}$$

UPGRADE-3 Led to better tracking accuracy, and the improvement of BIAS and RMSVD, and increase of number, particularly for weak winds.

2-2. Changes of MTSAT-1R AMV generation and dissemination since 9th IWW

CHANGE-1: Change on AMV distribution (at 03UTC on 18 August 2009)

- JMA/MSC started disseminating AMVs for Northern Hemisphere to GTS users in BUFR at 03, 09, 15 and 21UTC.
- Furthermore, JMA/MSC 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; dealt as the final output), and the wind speeds and directions of the vectors in BUFR.

CHANGE-2: Start of generating hourly AMVs for Southern Hemisphere (at 01UTC on 17 February 2010)

- JMA/MSC started generating hourly AMVs for Southern Hemisphere (60S-EQ) by using successive Full disk images at an interval of 60 minutes for JMA's internal use.
- For a future plan, the hourly AMVs for northern and southern hemispheres will be distributed to GTS users in summer of 2010.

Red-colored cell:

AMVs distributed to users via GTS

Current

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)

From summer of 2010

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)

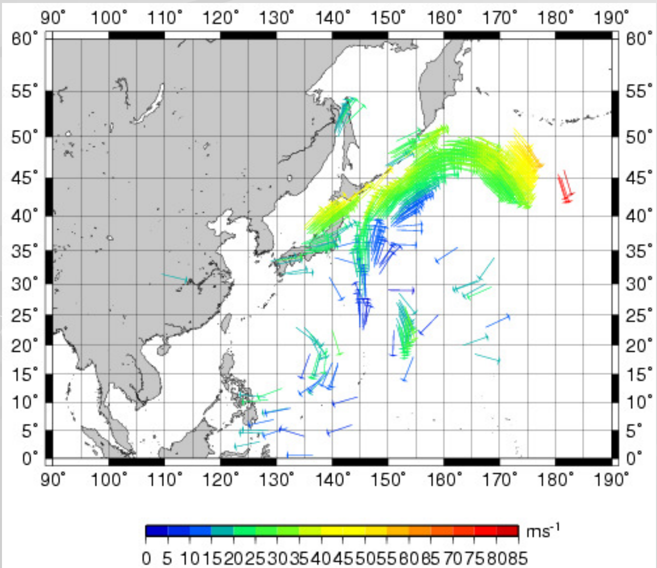
3. Recent activities

(1) AMVs from MTSAT-2 for T-PARC study

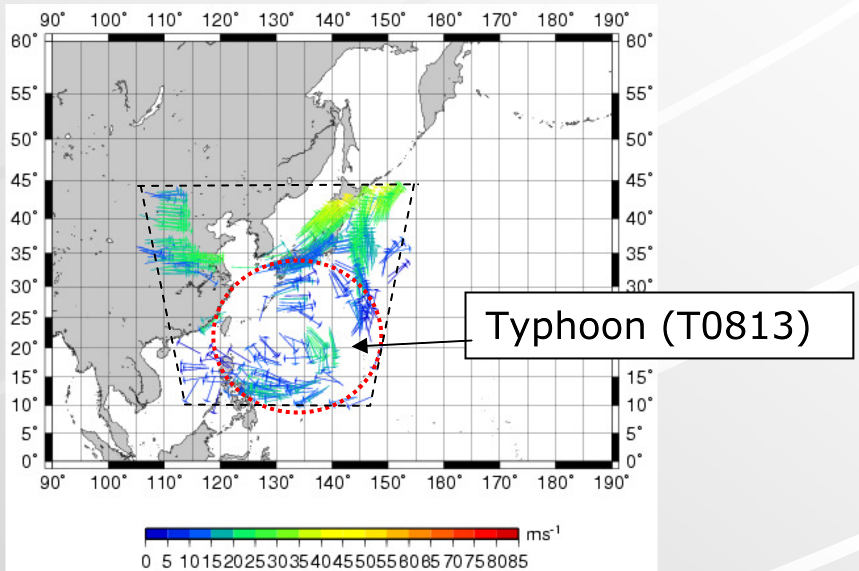
To contribute to T-PARC (Thorpex-Pacific Asian Regional Campaign) study in summer of 2008, JMA/MSC observed the Pacific and Asian regions including typhoons at several time-intervals (4, 7 and 15 minutes) by using MTSAT-2, and computed AMVs from the images.

-> The details (derivation algorithms, quality and effectiveness on NWP) of AMVs from rapid-scan images will be presented by Mr. K.Shimoji, Mr. K.Yamashita and Mr. S.Hoshino in the meso-scale session on Wednesday.

Examples of high-level IR AMVs (QI>0.85) in T-PARC2008



From images at an interval of **15 minutes** (2315UTC 12 Sep. 2008)



From images at an interval of **4 minutes** (2230UTC 12 Sep. 2008)

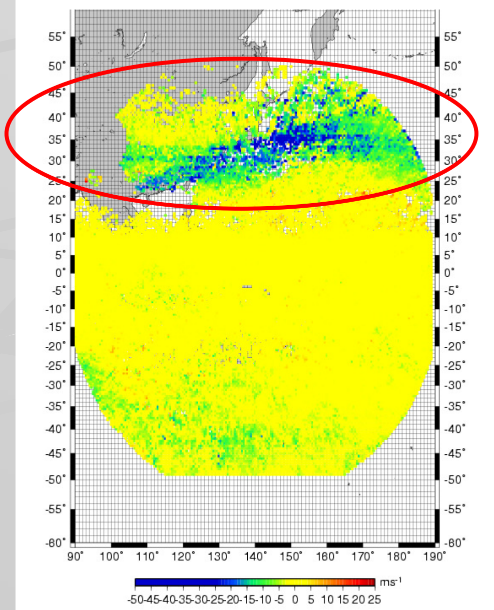
3. Recent activities

(2) Reprocess of AMVs from past geostationary satellites

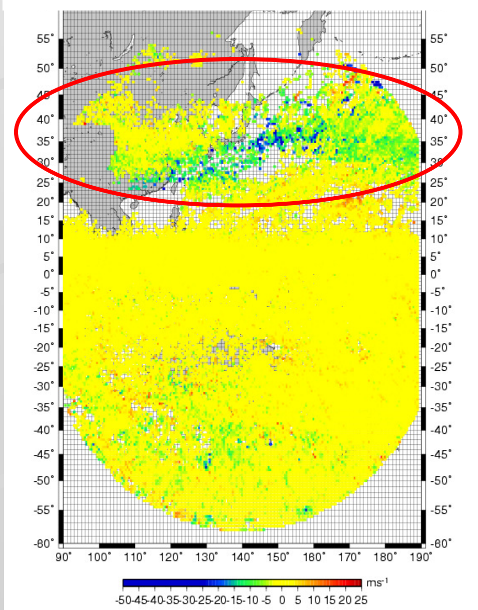
JMA/MSC has been computing AMVs from the past satellites (**GMS, GOES-9 and MTSAT-1R** between 1979 and 2009) using the latest AMV derivation algorithms. The data set of AMVs will be provided for the Japanese 55-year Reanalysis Project (**JRA-55**) scheduled between 2009 and 2012, and the Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (**SCOPE-CM**). The computation will be completed by 2010.

Wind speed bias (QI>0.85) of high-level IR-AMVs to JRA-25 analysis fields (Jan.1990, GMS-4)

for JRA-25 (Previous)



for JRA-55 (New)



Main quality difference between the previous reprocess (for JRA-25) and the current:

- Expansion of derivation area (from 50S-50N to 60S-60N).
- Mitigation of slow wind speed bias in the winter hemisphere, due to the height improvement of height assignment scheme and resizing target box size.

Information website: http://mscweb.kishou.go.jp/product/reprocess/index.htm

Algorithm document: Oyama (2010).

4. Future plans

(1) Switch to MTSAT-2 AMVs (planned in July - August 2010)

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

(2) Start of disseminating AMVs to users via GTS every hour (planned in summer of 2010, after switch to MTSAT-2)

(3) Revision of BUFR edition (from Ver.3 to Ver.4) (planned in 2010-2011, by the deadline, November 2012)

(4) Research using METEOSAT-7 images

Using METEOSAT-7 images provided by EUMETSAT in a data exchange agreement, JMA/MSC plans to compute AMVs, and investigate them in terms of effectiveness on JMA's NWP.

-> The progress will be mentioned in Mr. Shimoji's presentation on Wednesday.

(5) Development of AMV derivation algorithms to improve quality of MTSAT AMVs

Height assignment of low-level AMVs, target selection, tracking scheme (including optimizing target box size)

End

Thank you !

Mt.Fuji from JMA/MSC, by Mr. Takahito Imai

Reference

Borde, R. and R. Oyama, 2008: Direct link between feature tracking and height assignment of operational Atmospheric Motion Vectors, Proceedings of 9IWW, Annapolis, U.S.A. .

Cotton, J. and M. Forsythe, 2010: Fourth Analysis of the data displayed on the NWP SAF AMV monitoring website.

Iliana, G., R. Borde, J. Schmetz, J. Daniels, C. Velden and K. Holmlund, 2008: Global Atmospheric Motion Vector inter-comparison study, Proceedings of 9IWW, Annapolis, U.S.A. .

Jaime Daniels and Wayne Bresky, 2010: A nested tracking approach for reducing the slow speed bias associated with atmospheric motion vectors (AMVs), Proceedings of 10IWW, Tokyo, Japan.

Oyama, R., R. Borde, J. Schmetz and T. Kurino, 2008: Development of height assignment directly linked to feature tracking at JMA, Proceedings of 9IWW, Annapolis, U.S.A. .

Oyama, R., 2010: Upgrade of Atmospheric Motion Vector derivation algorithms at JMA/MSC, MSC technical note, 54, in printing.

Shimoji, K., 2010: The development for MTSAT Rapid Scan High Resolution AMVs at JMA/MSC, Proceedings of 10IWW, Tokyo, Japan.

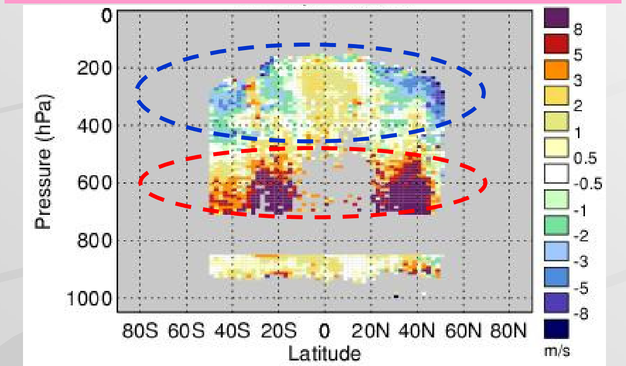
Sohn,E. and R. Borde, 2008: The impact of window size on AMV, Proceedings of 9IWW, Annapolis, U.S.A. .

Improvements of AMV (IR-AMVs) quality by UPGRADE-2

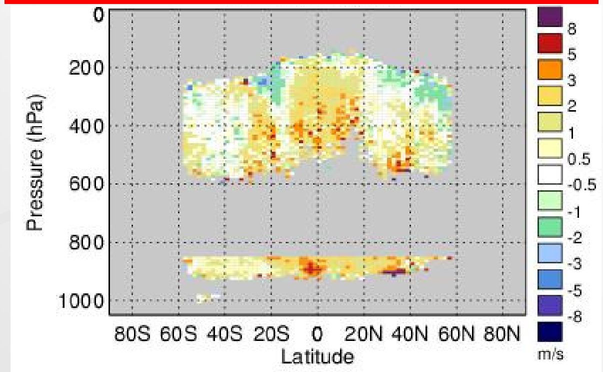
(From NWP SAF monitoring website)

Wind speed bias (QI>0.8) to UKMO NWP model

Before (April 2009)

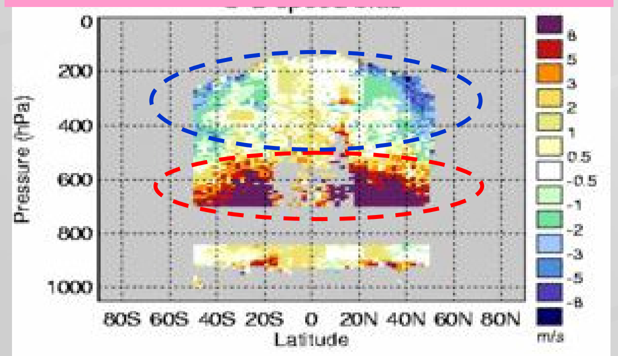


After (June 2009)

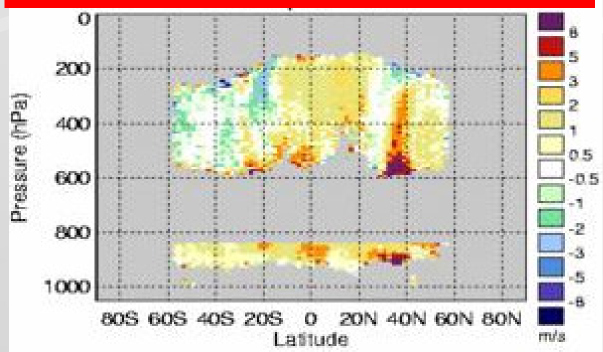


Wind speed bias (QI>0.8) to ECMWF NWP model

Before (April 2009)



After (June 2009)



Change of AMV quality by introducing high-resolution GPVs

(to sonde observations at 00 and 12UTC)

Period : From 16 September to 24 September in 2008
Region: Northern Hemisphere (20N-50N)

High-level IR AMVs

Type of GPV	Previous GPV	High-resolution GPV	Test GPV
Grid size of GPV	2.5 degrees	0.5 degrees	0.5 degrees
Forecast time from the initial	12 hours	6 hours	12 hours
MEAN SPEED (m/s)	25.70	26.04	24.78
BIAS (m/s)	-1.86	-1.40	-1.54
RMSVD (m/s)	8.03	7.81	8.14
Number of AMVs	9497	10283	9288

Pink colored cell:

better than the previous AMV (by previous GPV) in quality

Low-level IR AMVs

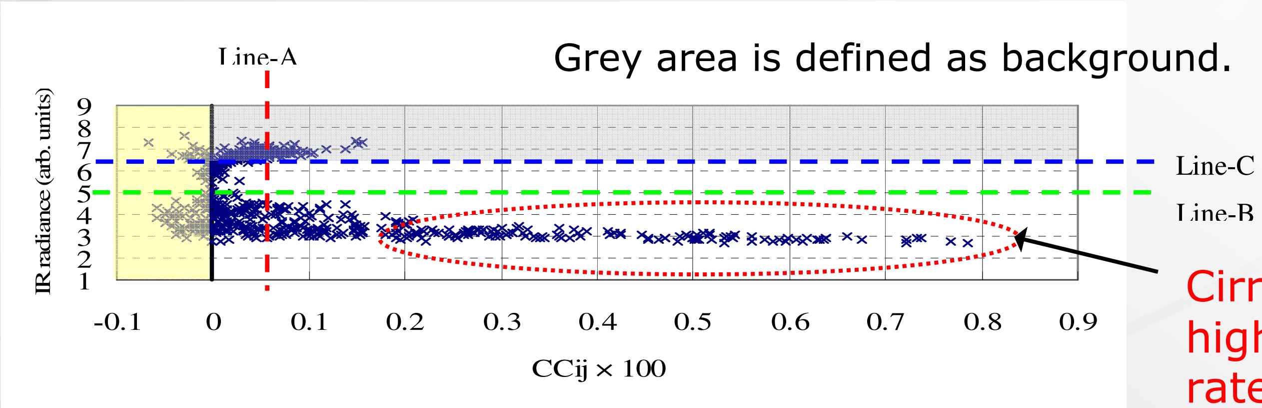
Type of GPV	Previous GPV	High-resolution GPV	Test GPV
Grid size	2.5-degree grid	0.5-degree grid	0.5-degree grid
Forecast time from the initial	FT = 12 hour	FT = 6 hour	FT = 12 hour
MEAN SPEED (m/s)	7.06	7.18	7.35
BIAS (m/s)	0.52	0.39	0.73
RMSVD (m/s)	3.43	3.60	3.58
Number of AMVs	2258	2350	2175

◆Use of the high-resolution GPV led to the improvement of AMV quality.

◆Mainly, shortening forecast time more lead to the improvement of AMV quality than change of GPV spatial resolution.

Application of CCij to height assignment

Scatter plot of CCij against IR radiance for the target box image
(For the case in the slide one before)



Cirrus clouds have high contribution rate !

Representative radiance for an AMV height:

$$L1 \equiv \frac{1}{\sum_{0<CCij\,(except\,for\,background)} CC_{ij}} \sum_{0<CCij\,(except\,for\,background)} L_{ij}^{cor} \times CC_{ij} \qquad \text{(Eq.1)}$$

CCij: Each-pixel contribution rate to feature tracking (the component of the maximum correlation coefficient)

Lij^{cor}: IR Radiance (corrected by H2O-IRW intercept method)

Excluded pixels for Eq.1 are:

Pixels with negative CCij (the yellow area)

Pixels defined as the background (the grey area)

UPGRADE-3:
Change of tracking algorithm

Monthly statistics of the previous and new AMVs (QI>0.85) to sonde observations for May 2009

High level IR AMV (above 400hPa)	NH (20N-60N)		TR (20S-20N)		SH (60S-20S)	
	Previous	New	Previous	New	Previous	New
MEAN SPEED (m/s)	29.07	26.50	14.39	12.10	33.36	30.28
BIAS (m/s)	-0.17	-0.51	-0.10	-0.27	0.39	0.12
RMSVD (m/s)	7.40	7.10	5.56	5.12	7.52	7.28
Number of AMVs	53480	70878	36342	65412	44402	55936

Low level IR AMV (below 700hPa)	NH (20N-60N)		TR (20S-20N)		SH (60S-20S)	
	Previous	New	Previous	New	Previous	New
MEAN SPEED (m/s)	9.69	8.27	8.86	7.91	11.38	10.28
BIAS (m/s)	0.10	-0.18	0.42	0.31	-0.05	-0.51
RMSVD (m/s)	3.98	3.85	3.13	2.98	4.15	3.94
Number of AMVs	8728	21627	15666	41172	37328	74125

VIS AMV (below 700hPa)	NH (20N-60N)		TR (20S-20N)		SH (60S-20S)	
	Previous	New	Previous	New	Previous	New
MEAN SPEED (m/s)	8.22	8.07	8.14	7.99	10.89	10.88
BIAS (m/s)	-0.46	-0.43	0.25	0.34	-0.28	-0.24
RMSVD (m/s)	4.21	4.26	2.83	2.88	4.07	3.93
Number of AMVs	9362	10258	13354	14741	24210	25293

Red-colored cell:
New AMV is better than previous AMV

◆The RMSVD and number were improved by introducing UPGRADE-3, particularly low-level IR AMVs significantly increased.

◆This improvement enabled to compute AMVs from rapid-scan images (e.g. 4-minute interval images taken in T-PARC2008).