Himawari-8 Atmospheric Motion Vector

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1.Introduction

The Japan Meteorological Agency (JMA) launched Himawari-8 satellite in 2014 and started its operation in July 2015. It is the next generation Japanese geostationary meteorological satellites following to previous operational satellite MTSAT-2 (Himawari-7). The agency also plans to launch Himawari-9 in 2016 as a backup for Himawari-8.

Himawari-8 and -9 carry Advanced Himawari Imager (AHI) units comparable to the Advanced Baseline Imager (ABI) on board GOES-R of the National Ocean and Atmosphere Administration / the National Environmental Satellite, Data, and Information Service (NOAA/NESDIS) in the United States. The observing functions of AHI were significantly enhanced from those of MTSAT-2: multispectral capacity (16 bands), high spatial resolution (0.5 – 1.0 km for visible and 1 – 2 km for infrared), fast imaging (within 10 minutes for full disk), and rapid scanning with flexible area selection and scheduling (figure 1).

These upgrades to imager enable us to retrieve more Atmospheric Motion Vectors (AMVs) with more accuracy than before. AMVs are satellite-derived wind vectors obtained from consecutive satellites images by tracing cloud features and estimating its clouds height. AMVs are computed and disseminated by satellite operation centers and assimilated by numerical weather prediction centers for computing analysis field and contributing to improvement of weather forecast.

Channels of the Advanced Himawari Imager (AHI) to be carried by Himawari-8/9

Channel	Central Wavelength [µm]	Spatial Resolution	
1	0.43 – 0.48	1 km	RGB Composited True Color Image
2	0.50 – 0.52	1 km	
3	0.63 – 0.66	0.5 km	
4	0.85 – 0.87	1 km	
5	1.60 – 1.62	2 km	
6	2.25 – 2.27	2 km	
7	3.74 – 3.96	2 km	
8	6.06 – 6.43	2 km	Water Vapor
9	6.89 – 7.01	2 km	
10	7.26 – 7.43	2 km	
11	8.44 – 8.76	2 km	SO_2
12	9.54 – 9.72	2 km	O_3
13	10.3 – 10.6	2 km	Atmospheric Windows
14	11.1 – 11.3	2 km	
15	12.2 – 12.5	2 km	
16	13.2 – 13.4	2 km	CO_2

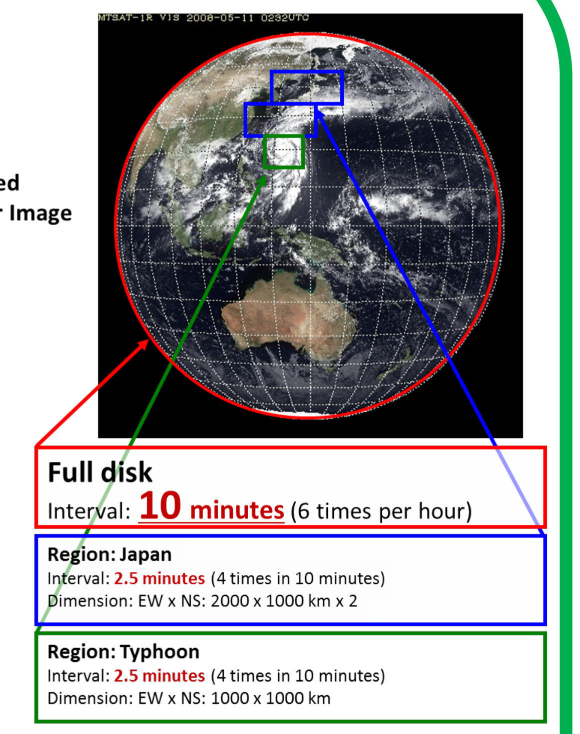

Figure 1 : Specification of Advanced Himawari Imager (AHI)

Flow Chart for Himawari-8 AMV

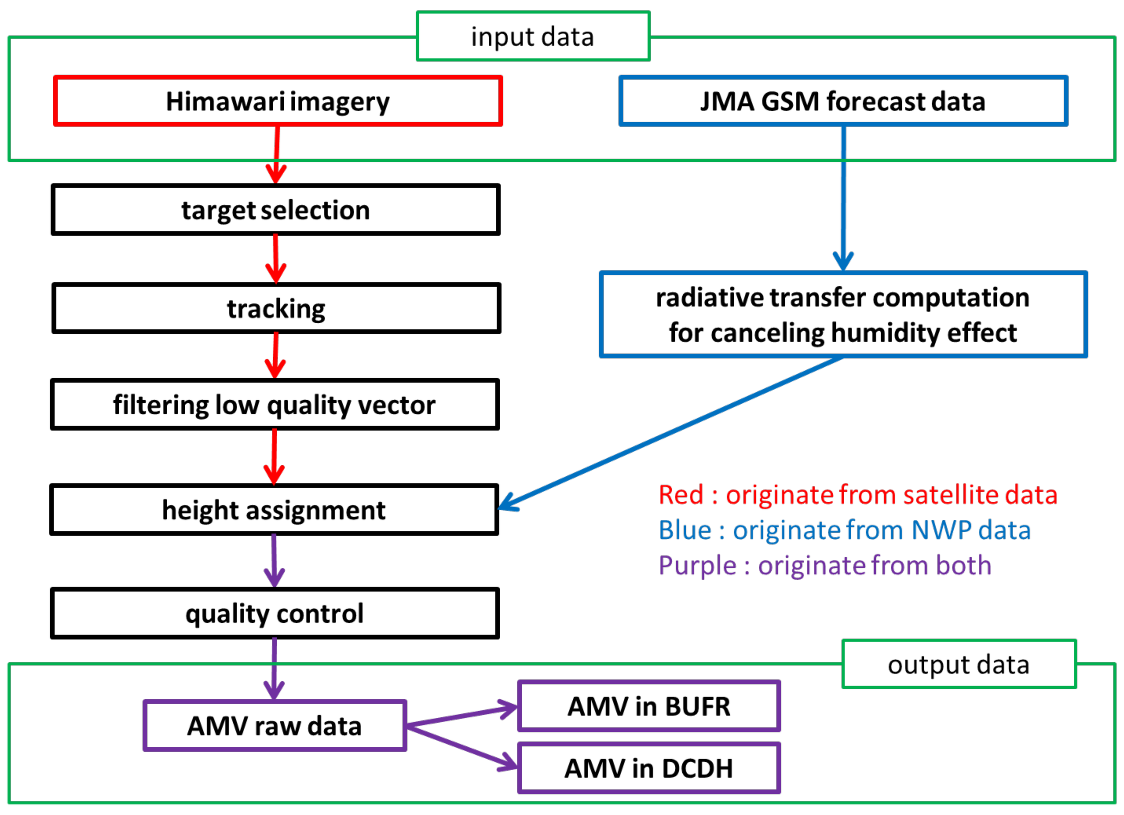

Figure 2 : Flowchart of Himawari-8 AMV derivation system

The Meteorological Satellite Centre of the Japan Meteorological Agency (JMA/MSC) developed new tracking and height estimation algorithm for Himawari-8 Atmospheric Motion Vector (AMV). The algorithm is designed for effective utilization of high spatial temporal and spectral resolutions of AHI.

Major changes of the algorithm are applied to cloud feature tracking and cloud height estimation process. In the tracking method, small and large target boxes are prepared respectively for computing two correlation surfaces. Correlation surface from small target box is used as prior information for estimating wind vector, and another correlation surface derived from large target box is used as auxiliary information for determining optimal wind vector which is consistent with both of small and large scale atmospheric motion.

Approach to height estimation method for Himawari-8 AMV is based on optimal estimation to minimize the difference between observed radiance values and the theoretical ones determined from cloud assignment and radiative transfer model parameters using three or more channels. The method has been applied to upper-, medium and low-level clouds for Himawari-8/9 wind vectors.

This poster outlines tracking and height estimation algorithm and characteristics of Himawari-8 AMVs.

2. Tracking Algorithm

It is considered that using small target box for AMV derivation is easy way to retrieve small scale wind. But use of small target box size does not lead to good results necessarily because tracking error is significantly increased. In such case, spurious peak on cross correlation surface can be appeared. This means that information included in very small target box is not enough for pattern matching.

In order to compensate this lack of information, Auxiliary information which can exclude spurious maxima is required. In tracking algorithm of Himawari-8 AMV, averaged surfaces of four correlation surfaces computed in forward and backward matching for small and large target box under assumption that natural atmospheric motion should have temporal and spatial continuity. Way to compute cross correlation itself is the same as MTSAT AMV tracking algorithm. The only difference is that motion vectors for quality control and final output are derived from averaged surfaces.

Correlation values on surface is considered as likelihood (or log likelihood) function which represents matching degree between target and searched pattern. If correlation surface can be regarded as log likelihood function, the most probable vector temporally and spatially consistent is expected to be derived by finding maximum position of summed likelihood function.

Figure 3 on the right hand side shows all of correlation surfaces and its average computed in tracking process. There are too many peaks on not averaged surfaces, but suspicious peaks disappeared after averaging process. It is thought that spurious maxima are mitigated by considering temporal and spatial consistency of natural wind through averaging process regarding correlation as likelihood function. Natural motion vector should satisfy forward and backward matching by small and large target box simultaneously.

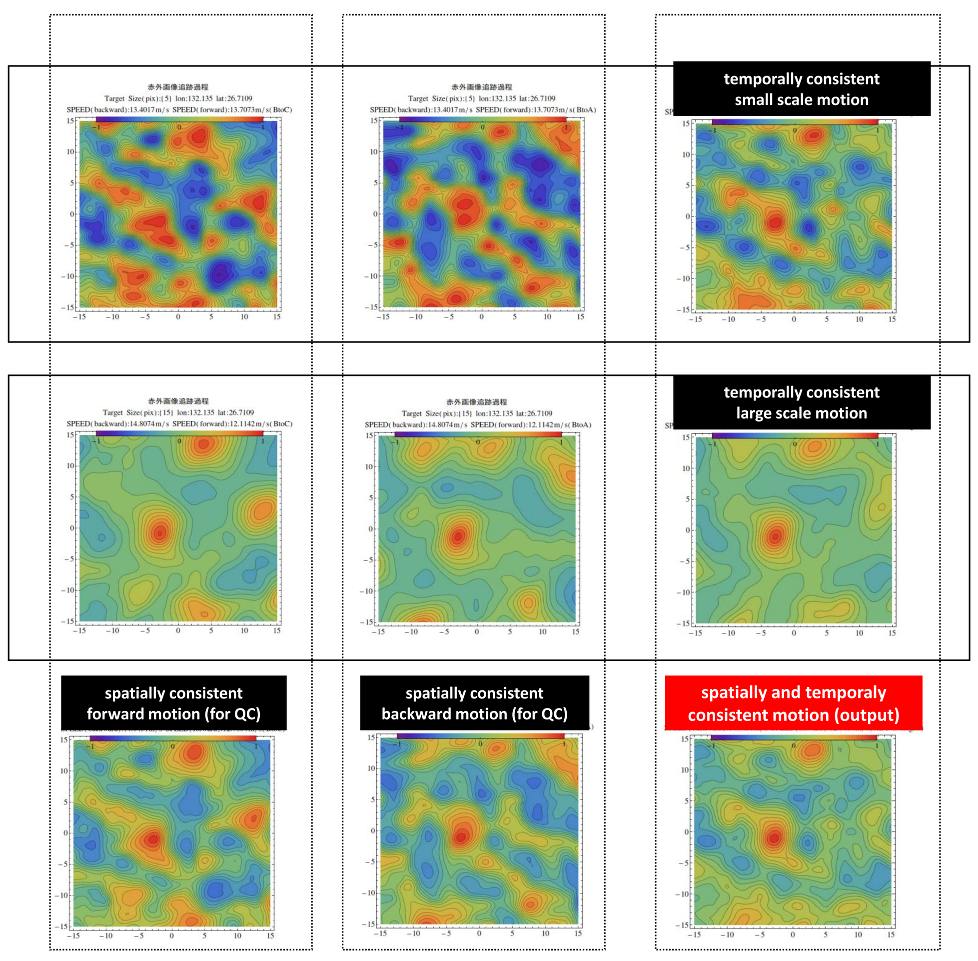

Figure 3 : Correlation surfaces computed in tracking process
warm color corresponds to high correlation, cold color means low correlation.
In Himawari-8 AMV, three motion vectors are computed from three correlation surfaces. First vector is derived from averaged surfaces by small and large target box in forward matching. Second vector is also same but in backward matching. Those two vectors are used for quality control. Last vector as final output is derived from average of those two averaged surfaces previously computed for first and second vectors. Surface on bottom left is for forward motion , bottom middle is for backward motion and bottom right corresponds to surface for final vector used as output. In refference, averaged surfaces of forward and backward matching to each target box size are shown on right side column. Spurious maxima are mitigated especially in case using small target box.

3. Cloud Height Estimation

Height assignment method for Himawari-8 AMV is based on maximum likelihood estimation method as same as tracking process. The height assignment consists of five processes.

1. modeling equation for forward model connecting observables and latent variables
2. modeling inequality for constraint for latent variables
3. conversion equation/inequality to likelihood using scaled probability density function and its CDF
4. search optimal latent variables which maximize sum of log likelihood functions
5. select layer corresponding to motion vector

In AMV computation process, satellite observables are radiances and motion vectors derived in tracking process. Optimal cloud alignment which is consistent with satellite observables and NWP humidity and temperature profiles is derived by differential evolution method.

Estimated cloud height by this methods matches to CALIPSO products very well shown as following figure. (figure 5)

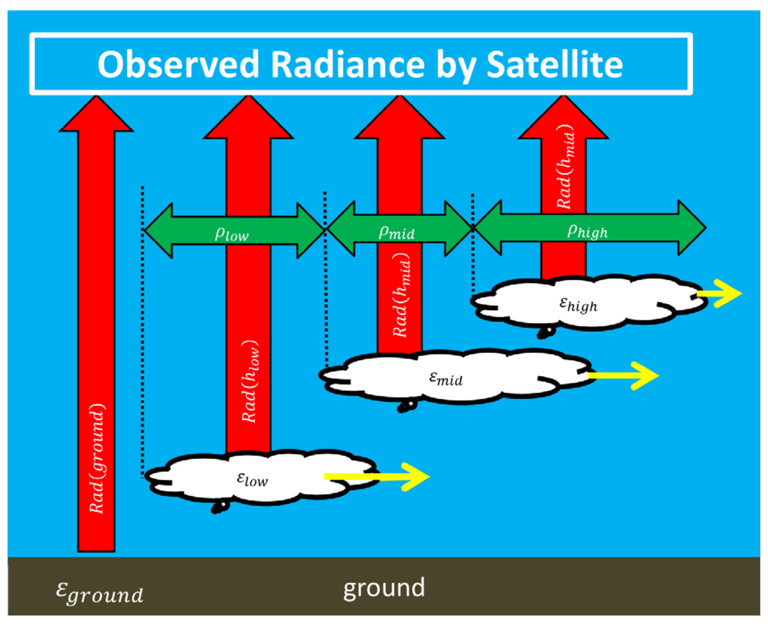

Figure 4 : Conceptual diagram of forward model for Himawari-8 height assignment method. This methods needs assumption that radiance observed by satellite is total of radiances emitted from three layer clouds and ground. Optimal cloud alignment is retrieved from radiances of six bands (10.8, 12.0, 6.2, 7.0, 7.2 and 13.3 um) and motion vectors derived in tracking process under this forward model.

Calipso 523 nm total backscatter Calipso 523 nm total backscatter

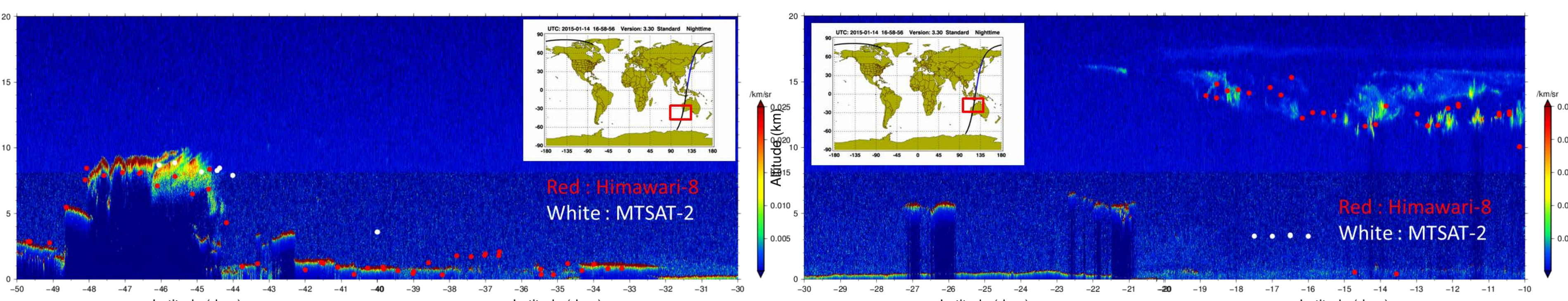

Figure 5 : Above two figures shows collocation plot of Himawari-8 AMV height (red dots), MTSAT AMV height (white dots) and CALIPSO 523nm total back scatter for 17UTC 14th January 2015. Height of dense clouds estimated by Himawari-8 algorithm is consistent with CALIPSO. Right panel shows collocation for upper semi transparent cloud. Most of cloud height are estimated accurately but some clouds are assigned to low level.

4. Characteristics of Himawari-8 AMV

AMV data coverage has been improved as follows (figure 6) by upgrade to AHI and introduction of new tracking algorithm. In comparison with MTSAT AMVs, middle level (400-700hPa) winds are retrieved well in Himawari-8 winds. Root Mean Square Vector Difference (RMSVD) of Himawari-8 IR AMV against sonde (Table 1) is about 5-6m/s at high level (100-400hPa), 4-5m/s at middle level (400-700hPa) and 4m/s at low level (700hPa-1100hPa) for June 2015. Wind speed BIAS (AMV - sonde) of IR AMV against sonde is less than at most 1 m/s for all levels. Looking at IR AMV statistic against JMA GSM first guess (figure 7), RMSVD over land area is larger than over sea/ocean area.

As for WV AMV (table 2 and figure 8), characteristics of sonde statistic is similar with IR AMV, but in sonde statistic against JMA GSM first guess, RMSVD of WV wind and positive wind speed BIAS (AMV – First Guess) is larger than that of IR winds.

Himawari-8 B13 and MTSAT-2 IR AMV (QI>60, 17UTC 14th January 2015)

Himawari-8 AMV using Himawari-8 imagery and new algorithm

MTSAT-2 AMV using MTSAT-2 imagery and heritage algorithm

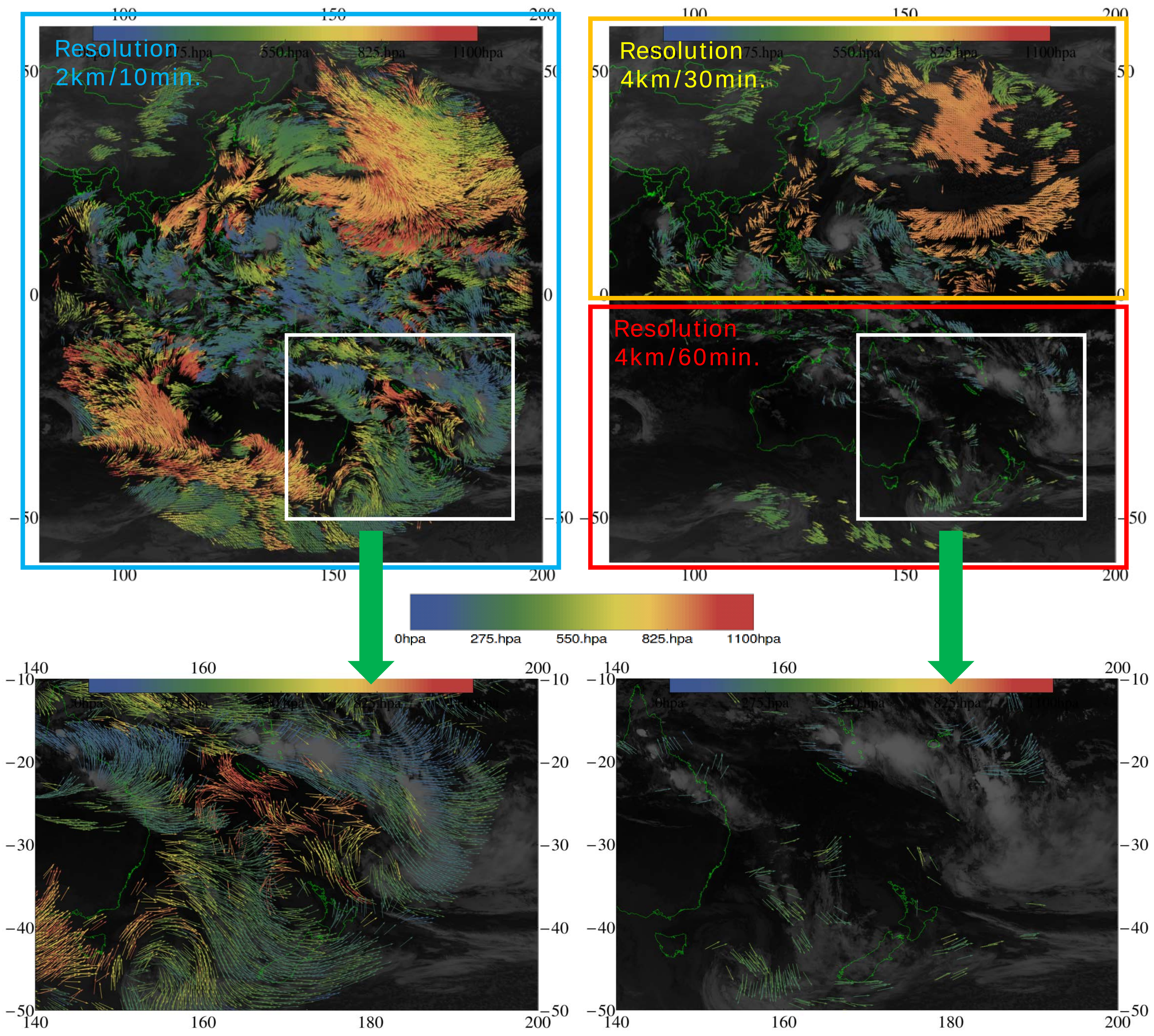

Figure 6 : Spatial distribution of Himawari-8 AMV by new algorithm (left row) and MTSAT AMV computed by heritage algorithm (right row).
Data coverage of Himawari-8 AMV is larger than that of MTSAT AMV. Observation data over southern hemisphere is very precious for data assimilation because of observatory is not so many. Himawari-8 AMV is expected to improve NWP skills over southern hemisphere.

Himawari-8 B13 (10.8um, IR) AMV statistics against sonde and JMA GSM first guess for June 2015

10.8um HIGH-LEVEL (-400hPa)	ALL	NH	TROP	SH
MVD	4.86	5.33	4.22	4.83
RMSVD	5.77	6.26	5.04	5.67
BIAS	-0.2	-0.06	-0.37	-0.64
SPD	22.52	28.12	14.7	28.11
NC	430079	146859	205038	78182

10.8um MID-LEVEL (400-700hPa)	ALL	NH	TROP	SH
MVD	4.09	4.43	3.44	4.41
RMSVD	4.86	5.27	3.95	5.25
BIAS	0.02	0.19	-0.34	0.28
SPD	12.8	15.47	7.96	14.31
NC	5689	3204	1933	552

10.8um LOW-LEVEL (700-1100hPa)	ALL	NH	TROP	SH
MVD	3.14	3.05	3.03	3.54
RMSVD	3.86	4.14	3.67	4.15
BIAS	0.68	0.54	0.86	0.25
SPD	9.23	7.79	9.17	10.88
NC	4238	840	2571	827

Table 1 : Himawari-8 10.8um (IR) AMVs sonde statistics for June 2015 (QI>85)
ALL S60-N60 , NH: N20-N60 , TR : S20-N20 , SH :S20-S60

Note: AMV minus ground truth (sonde)
MVD = Mean Vector Difference (m/s)
RMSVD = Vector Difference RMS (m/s)
BIAS = Speed Bias (m/s)
SPD = Wind Speed (m/s)
NC = Number of collocation

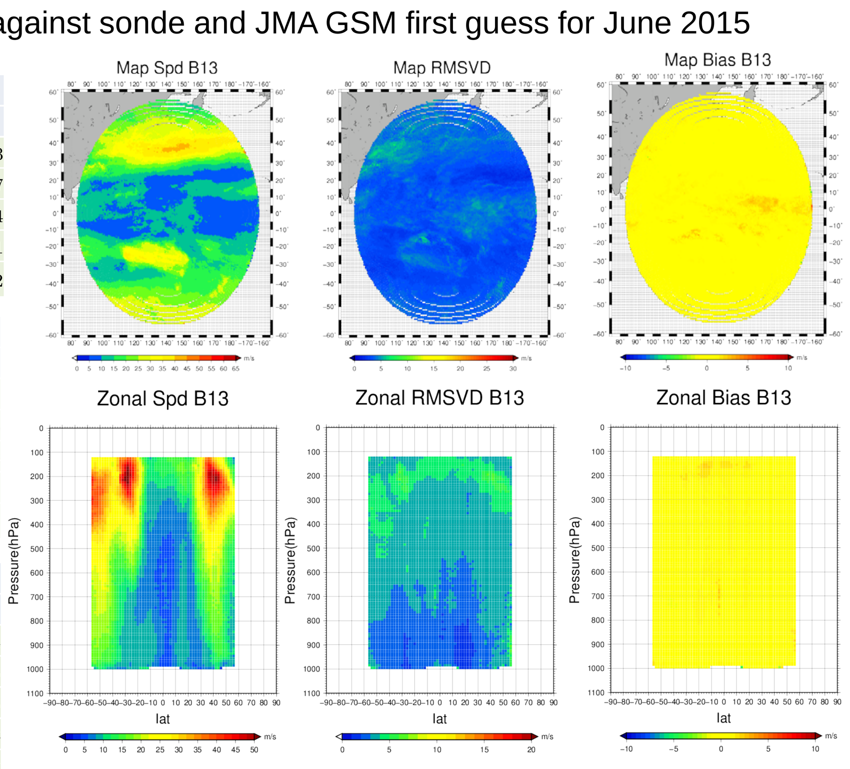

Figure 7 : O-B statistics of Himawari-8 10.8um (IR) AMV and JMA Global Spectrum Model (GSM) first guess for June 2015. Top left, middle and right corresponds to mean speed, root mean square vector difference and wind speed BIAS respectively. Bottom column is also same but for vertical map.

Himawari-8 B09 (6.9 um, WV) AMV statistics against sonde and JMA GSM first guess for June 2015

7.0um HIGH-LEVEL (-400hPa)	ALL	NH	TROP	SH
MVD	4.91	5.42	4.29	4.98
RMSVD	5.83	6.38	5.11	5.92
BIAS	0.22	0.43	-0.01	-0.34
SPD	23.37	29.11	16.23	30.61
NC	79285	42320	35514	1451

7.0um MID-LEVEL (400-700hPa)	ALL	NH	TROP	SH
MVD	4.73	5.33	3.74	4.88
RMSVD	5.57	6.23	4.25	5.78
BIAS	0.72	1.16	0.02	0.77
SPD	14.97	18.36	8.83	17.56
NC	41232	10299	10752	20181

Table 2 : Himawari-8 6.9um (WV) AMVs sonde statistics for June 2015 (QI>85)
ALL S60-N60 , NH: N20-N60 , TR : S20-N20 , SH :S20-S60

Note: AMV minus ground truth (sonde)
MVD = Mean Vector Difference (m/s)
RMSVD = Vector Difference RMS (m/s)
BIAS = Speed Bias (m/s)
SPD = Wind Speed (m/s)
NC = Number of collocation

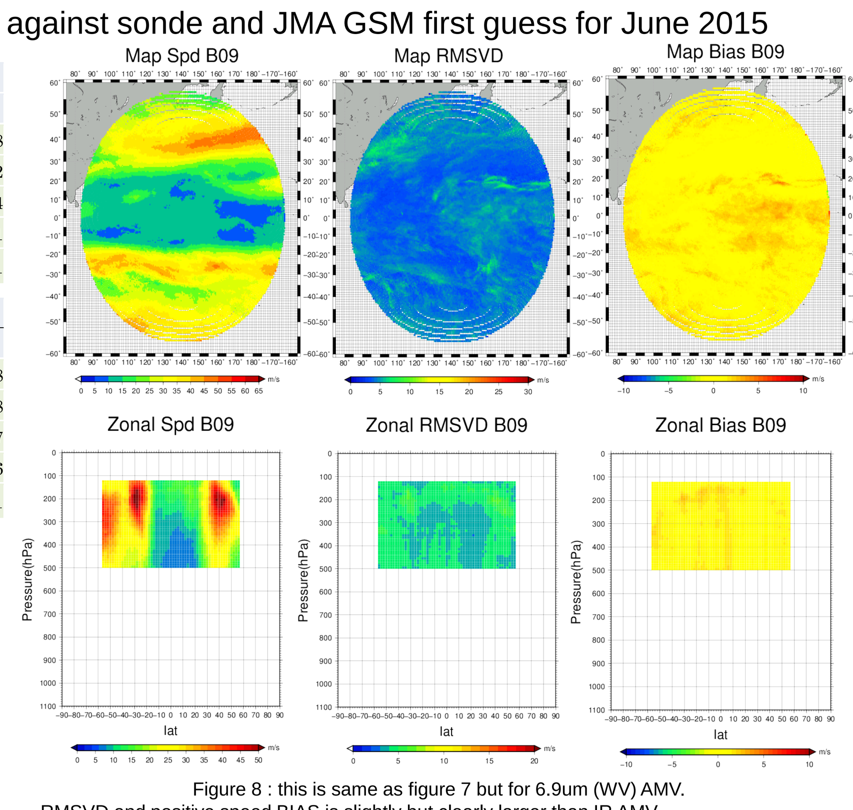

Figure 8 : this is same as figure 7 but for 6.9um (WV) AMV.
RMSVD and positive speed BIAS is slightly but clearly larger than IR AMV.

References

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