Sensitivity tests of target box sizes and height assignment methods for GK-2A AMV algorithm

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❖ Introduction

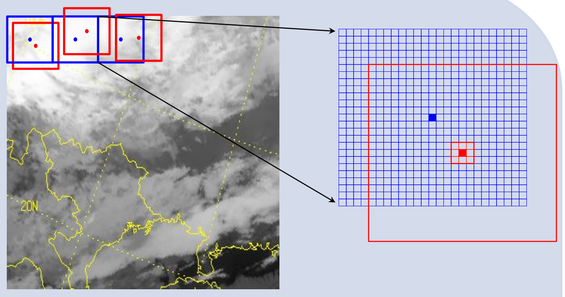
NMSC/KMA has developed AMV algorithm for GEO-KOMPSAT-2A/Advanced Meteorological Imager (GK-2A/AMI) which will be launched in November 2018. GK-2A AMV algorithm consists of four steps: target selection, feature tracking, height assignment, and quality indicator evaluation. The target box size in target selection is highly related to speed and direction of AMV. And height assignment has the greatest effect on the accuracy of AMV. Thus, sensitivity tests were performed to find the optimum target box size and height assignment method with 2km/10minite in spatial and temporal resolution for GK-2A AMV algorithm. The AMVs were compared with radiosonde and NWP forecast wind fields for various box 8 x 8, 16 x 16, 24 x 24, 32 x 32, 40 x 40, and 48 x 48 in size, and for several height assignment methods such as CCC, EBBT, IR/WV rationing, CO2 slicing for cloudy target and NTC and NTCC for clear target. The preliminary results showed that 16 x 16 box size and the combination of EBBT and IR/WV height assignment method has the smallest MVD, RMSVD, bias and RMSE compared with other methods.

❖ GK-2A AMV Algorithm

Step1 Target Selection

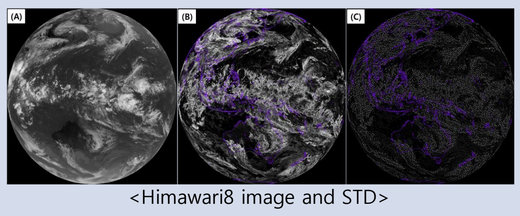
<Optimal selection method>

A target is selected from the second of three consecutive images. The wind speed depends on the target size or temporal resolution of the images. The search area used for the target selection is a square box with M×M (54×54) pixels and the target area for tracking suitable features in the search area is N×N (16×16) pixels in size.



$$STD_{m,n} = \sqrt{\frac{1}{9}\sum_{i=-1}^{1}\sum_{j=-1}^{1}(BT_{m+i,n+j} - \overline{BT}_{m,n})^2}$$

$BT_{i,j}$: BT in ith row and jth column of N_x by N_y target box at t_0.
$\overline{BT}$: Average of $BT_{i,j}$.
N_x, N_y : Size of target box.



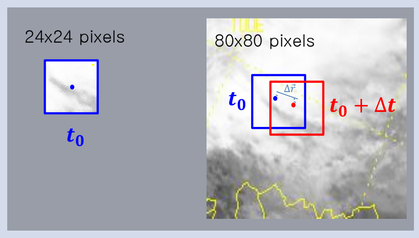
<Himawari8 image and STD>

- Cloud Target : defined when the proportion of cloud pixels is greater than 20% in the target.
- Clear Target : All clear pixels or CTP is lower than threshold altitude in WV.

Step2 Target Tracking

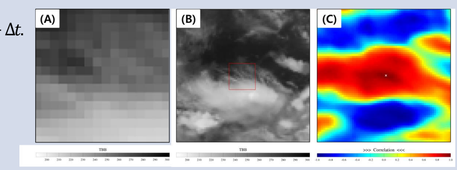
<Cross Correlation Coefficient method>

Once targets are selected, we can estimate vectors through the displacement of each target calculated from cross-correlation coefficients.



$$CC_{m,n} = \frac{1}{N_x N_y}\sum_{i=1}^{N_x}\sum_{j=1}^{N_y}\left(\frac{a_{m+i,n+j} - \bar{a}_{m,n}}{(\sigma_a)_{m,n}}\frac{b_{i,j} - \bar{b}}{\sigma_b}\right)$$

$a_{i,j}$: BT in ith row and jth column of N_x by N_y target box in search area at $t_0 + \Delta t$.
$\bar{a}$: Average of $a_{i,j}$.
σ_a : Standard deviation of $a_{i,j}$.
$b_{i,j}$: BT in ith row and jth column of N_x by N_y target at time t_0.
$\bar{b}$: Average of $b_{i,j}$.
σ_b : Standard deviation of $b_{i,j}$.
N_x, N_y : Size of target box.

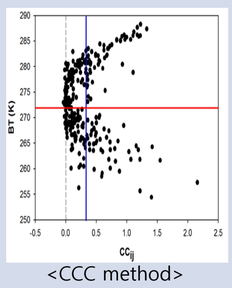


<The calculated cross correlations>

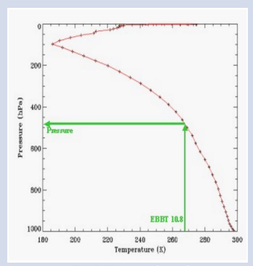
Step3 Height Assignment

<The accuracy of an AMV is dependent on its height>

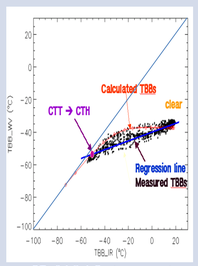
▪ **Cloud Target for IR, WV and VIS**
- Cross-Correlation Coefficient Method : CTP is weighted in Ccij.
- Equivalent Blackbody Temperature Method : Comparison between model TB and observed TB.
- IR/WV rationing method : Height correction for semi-transparent clouds.
- CO2 slicing method : Radiance ratio between CO2 absorption channel and window channel.
- Inversion Layer correction for AMVs with final heights lower than 600 hPa.



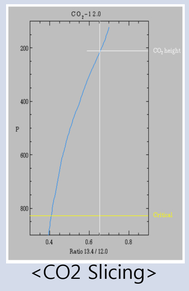
<CCC method>



<EBBT method>

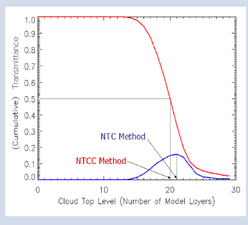


<IR/WV Intercept>

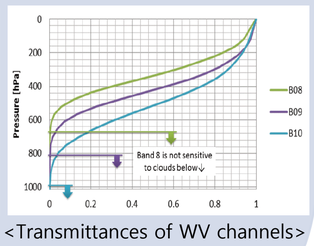


<CO2 Slicing>

▪ **Clear Target for WV**
- Normalized Total Contribution
  - The biggest transmittance
- Normalized Total Cumulative Contribution
  - The cumulative transmittance is 0.5.



<NTC and NTCC>



<Transmittances of WV channels>

Step4 Quality Control

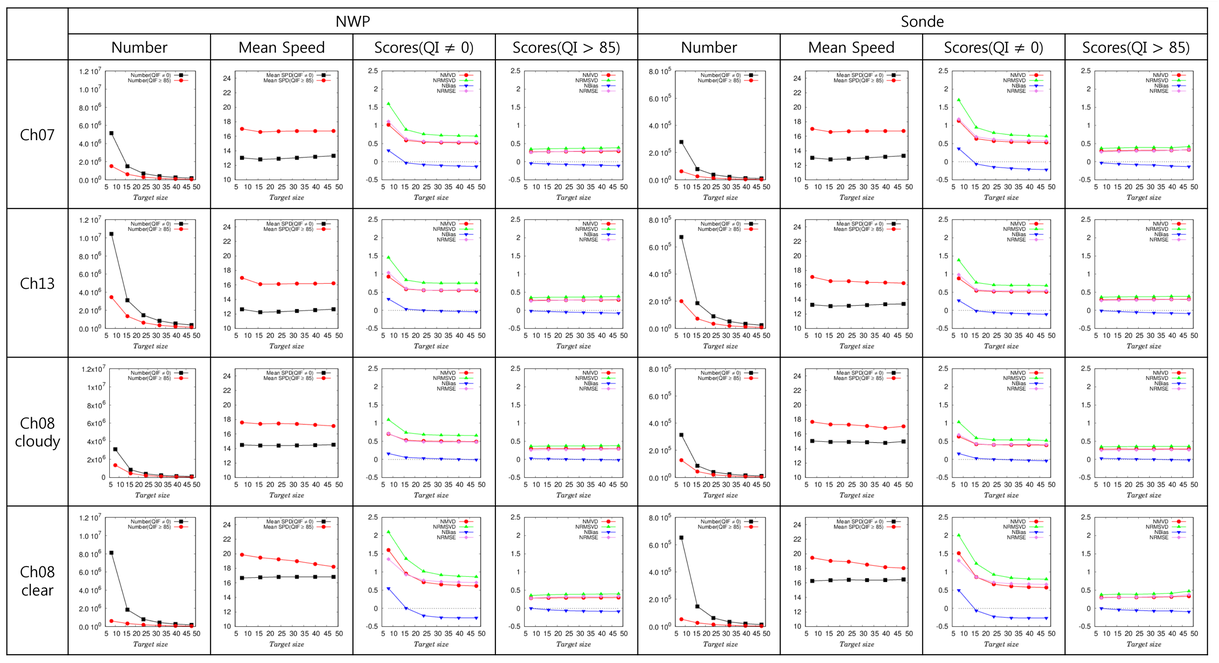
<Quality Index>

The statistically based QI estimates the reliability of each derived AMV based on five consistency tests.

➔ The consistency in space and time and the height and temperature of the tracers
➔ Direction consistency, Speed consistency, Vector consistency, Spatial vector consistency Forecast consistency(Optional)

❖ Target box sizes sensitivity

Target box sizes	8 × 8	16 × 16	24 × 24	32 × 32	40 × 40	48 × 48
Search box sizes	46 × 46	54 × 54	62 × 62	70 × 70	78 × 78	86 × 86

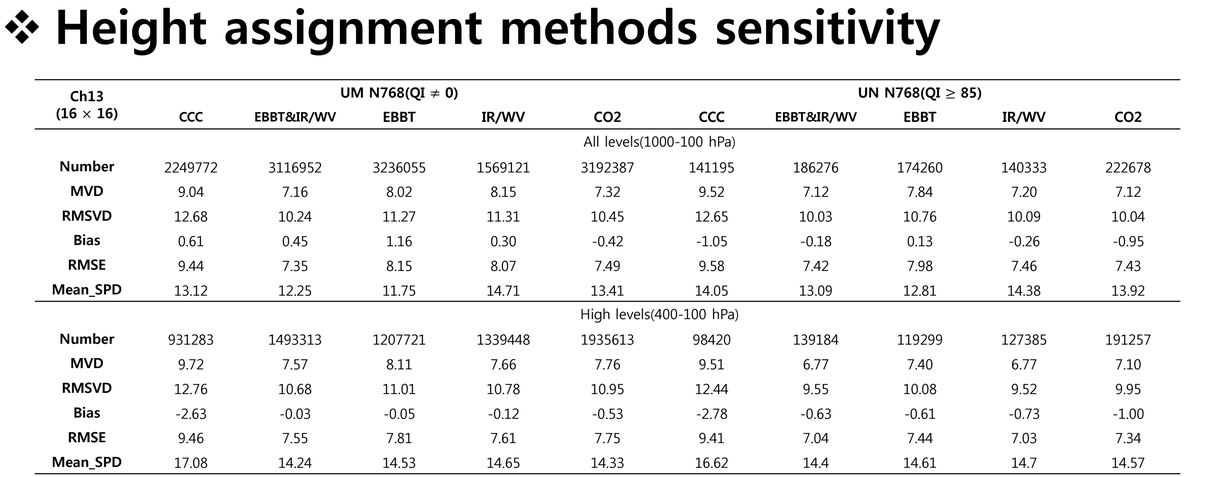


We consider validation scores with target boxes size varying **from 8 × 8 to 40 × 40** and temporal gap fixed at 10 minute.

→ For QI ≠ 0, smaller sizes produce more positive bias and larger sizes produce more negative bias. As target box size increases, **validation scores without bias become smaller and converge to specific values. The best statistics is shown in 16 × 16.**
→ **For QI ≥ 85, validation scores become almost independent of target box sizes.**
→ These results are consistent with the results in the reference.
(Ref. : J. Garcia-Pereda and R. Borde 2014: "The Impact of the Tracer Size and the Temporal Gap between Images in the Extraction of Atmospheric Motion Vectors", Journal of Atmospheric and oceanic technology, Vol 31, 1761.)

❖ Height assignment methods sensitivity

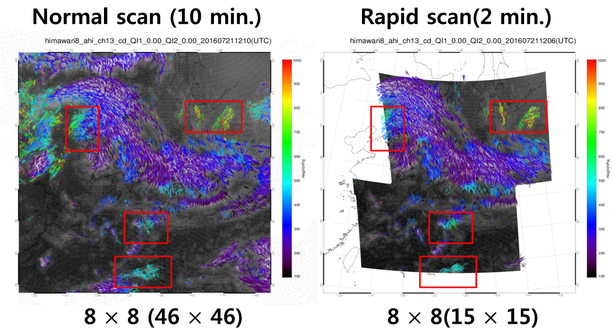
Ch13 (16 × 16)	UM N768(QI ≠ 0)					UN N768(QI ≥ 85)				
	CCC	EBBT&IR/WV	EBBT	IR/WV	CO2	CCC	EBBT&IR/WV	EBBT	IR/WV	CO2
	All levels(1000-100 hPa)									
Number	2249772	3116952	3236055	1569121	3192387	141195	186276	174260	140333	222678
MVD	9.04	7.16	8.02	8.15	7.32	9.52	7.12	7.84	7.20	7.12
RMSVD	12.68	10.24	11.27	11.31	10.45	12.65	10.03	10.76	10.09	10.04
Bias	0.61	0.45	1.16	0.30	-0.42	-1.05	-0.18	0.13	-0.26	-0.95
RMSE	9.44	7.35	8.15	8.07	7.49	9.58	7.42	7.98	7.46	7.43
Mean_SPD	13.12	12.25	11.75	14.71	13.41	14.05	13.09	12.81	14.38	13.92
	High levels(400-100 hPa)									
Number	931283	1493313	1207721	1339448	1935613	98420	139184	119299	127385	191257
MVD	9.72	7.57	8.11	7.66	7.76	9.51	6.77	7.40	6.77	7.10
RMSVD	12.76	10.68	11.01	10.78	10.95	12.44	9.55	10.08	9.52	9.95
Bias	-2.63	-0.03	-0.05	-0.12	-0.53	-2.78	-0.63	-0.61	-0.73	-1.00
RMSE	9.46	7.55	7.81	7.61	7.75	9.41	7.04	7.44	7.03	7.34
Mean_SPD	17.08	14.24	14.53	14.65	14.33	16.62	14.4	14.61	14.7	14.57
	Middle levels(700 hPa-400 hPa)									
Number	371666	864902	1195296	229673	724506	14993	32645	37871	12948	19203
MVD	10.19	8.28	9.52	10.97	7.68	9.59	8.88	9.44	11.49	7.31
RMSVD	13.72	11.37	12.95	14.02	10.71	12.75	12.10	12.78	14.57	10.66
Bias	3.63	1.19	2.48	2.73	-0.84	3.03	1.81	2.35	4.41	-1.01
RMSE	10.52	8.33	9.54	10.40	7.92	9.62	8.97	9.53	10.83	7.91
Mean_SPD	12.43	11.87	11.16	15.1	13.81	10.04	10.1	9.67	11.2	11.39
	Low levels(1000-700 hPa)									
Number	946823	758737	833038	-	532268	27782	14447	17090	-	12218
MVD	7.93	5.06	5.74	-	5.22	9.53	6.51	7.35	-	7.11
RMSVD	12.16	7.65	8.77	-	7.94	13.32	9.33	10.48	-	10.50
Bias	2.61	0.55	1.02	-	0.53	2.85	-0.34	0.40	-	-0.10
RMSE	8.99	5.61	6.34	-	5.83	10.13	7.13	7.86	-	8.09
Mean_SPD	9.5	8.77	8.58	-	9.52	7.1	7.21	7.12	-	7.63



CCC	EBBT&IR/WV	EBBT	IR/WV	CO2
1. The worst statistics among the 5 methods 2. Dependent on quality of CTP product	1. The best statistics among the 5 method 2. Better than EBBT 3. Better than IR/WV	1. Positive speed bias as shown in map bias image 2. Assigned lower than actual height	1. Negative speed bias as shown in map bias image 2. Assigned higher than actual height	1. Similar quality to EBBT&IR/WV 2. The best statistics in the middle layers among 5 methods

❖ Normal scan vs. Rapid scan AMVs

Normal scan (10 min.) **Rapid scan(2 min.)**



8 × 8 (46 × 46) **8 × 8(15 × 15)**

- As shown in red boxes, vectors have a better spatial consistency in the case of rapid scan(2 min.) compared with normal scan(10 min.).
- This is one proof that tracer tracking is better at 2 minute intervals than 10. We plan to perform validation quantitatively.

❖ Summary and Further Study

- We have developed AMV algorithm for GK-2A/AMI using Himawari8/AHI as proxy data.
- About target box sizes sensitivity, the best statistics is shown in 16 × 16 with no QC. But there is no dependence on target box sizes If QC(QIF ≥ 85) process is added.
- Our algorithm has many height assignment methods and advantage that we can choose optionally a method to produce better AMVs. The algorithm is estimated reasonable wind vector for all height assignment methods.
  - The best statistical score is the combination of EBBT and IR/WV intercept method for this study.
  - However, more tests are needed to improve the accuracy in height assignment process.
- In further study, we will have to optimize height assignment and the other processes such as target selection and make it possible to produce data with better quality.