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The Development for MTSAT Rapid Scan High Resolution AMVs at JMA/MSC

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Abstract

This paper introduces development for Rapid-Scan-AMVs at Meteorological Satellite Center (MSC) of Japan Meteorological Agency (JMA). JMA/MSC has operated 2 geostationary satellites, MTSAT-1R and MTSAT-2. Both of the 2 satellites have Rapid-Scan function which is able to obtain satellite imageries with high time-resolution like 1-5 min steps. It means that the improvement to time resolution of satellite image let satellite-derived-products have high time resolution. Recent improvement to time-resolution of meteorological satellite seems to be more distinct than the improvement to space-resolution of that. But space and time resolution of the satellite-derived-products should be concurrently improved for Numerical Weather Prediction (NWP). Atmospheric Motion Vectors (AMVs) derived from sequentially observed satellite images are one of the most important product for NWP. Fine time resolution AMVs-datasets are obtained by using the rapid-scan, but Space resolution of AMVs is not concurrently improved with time resolution as written on bellows. Purpose of this study is to utilize the excessive time resolution of AMVs realized by rapid-scan as space resolution of AMVs.

1) Introduction

AMVs which are assimilated into NWP, are derived from 3 sequence of satellite images, motion of selected targets (clouds or water vapor patterns) are estimated by pattern matching method for motion tracking. The target motion vectors dataset is derived from a couple of images, so two AMVs datasets are derived from the 3 images and the two AMVs datasets are compared with each other for consistency check. More specifically, timely consistent motion vectors during 3 images are being observed are selected (are allowed to survive) as completed AMV product to NWP.
But, recently, time resolution of meteorological satellites has been significantly improved. This improvement to time resolution of meteorological satellite can let us produce new methods which potentially improves AMVs. On this paper, it is shown proposal method utilizing multiple rapid-scan satellite images for AMVs, and results of comparisons between the AMVs derived by proposal method from 3 images and the AMVs by normal method from 2 images.

2) Method to improve space resolution of AMVs by sacrificing time resolution of AMVs

1: The tracking method for AMVs at the moment, utilizes just two images for one dataset of motion vectors. Namely, the tracking method computes AMVs by processing information which is included in just two satellite images. If it is possible to process information included in more than two images for one dataset of motion vectors in same time, the AMVs derived from multiple images are expected to be more accurate than AMVs derived from just two images. But time resolution of the AMVs is sacrificed by assumption that the motion vectors should be timely-consistent throughout the multiple images used for the AMVs.

2: For improvement to space resolution of AMVs, it is required to narrow target box size down for avoiding harmful correlated errors. But small target box leads quality debasement of AMVs. Because, in case of using small target box, information included in target box is basically less than that included in larger target box. Small sample number generally increases error of correlation-coefficient which is regarded as a similarity of matched targets on sequential satellite images. But if it is possible to enlarge

target box to “chronological direction”, the sample number can be increased. As its result, it is expected that accuracy of correlation-coefficients increase.
Figure 1 shows relationships between numbers of images and fluctuation of correlation-coefficient. Horizontal axes means the numbers of images, vertical axes means correlation-error-index which is almost same as standard deviation of correlation-coefficients. Correlation error index decrease with an increase in the numbers of images and target box size because accuracy of correlation-coefficient depends on its sample numbers.

For accurate high space resolution AMVs, It is needed to compensate for quality debasement with narrowing size of target box down by consuming quality improvement which can be provided from using multiple images in same time for tracking process. That is, to substitute excessive time resolution of rapid-scan for poor space resolution of satellite observation.

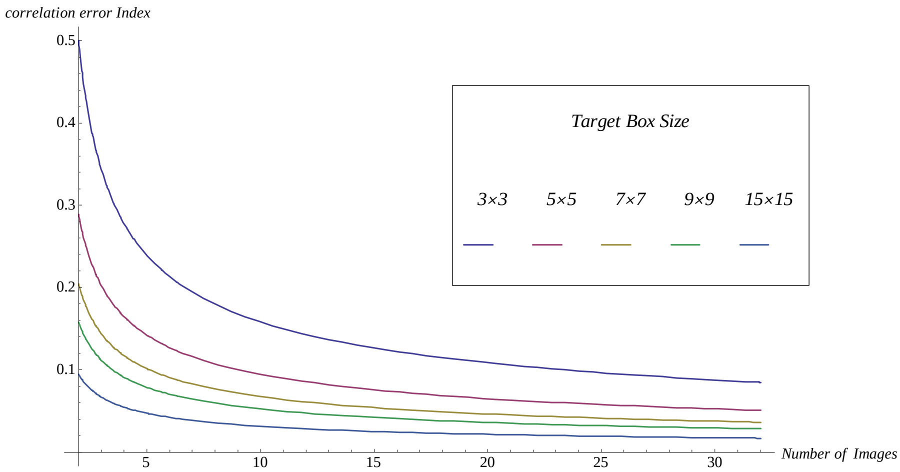


Figure 1: Relationships between errors of correlation-coefficients for pattern matching and number of images for each target box size. The error of correlation-coefficient is prominence in case of smaller target box size, but the error of correlation-coefficient can be decreased by using number of images for enlarging target box to chronological direction.

3) Mathematical formalization of the proposal method

Proposal method for high resolution AMVs needs multiple satellite images obtained by the rapid-scan observation. In case of the rapid-scan, time consistency of AMVs is assumed to be high because the multiple satellite images are observed in very short time.

Target positions on the multiple sequent images are determined from observation times of each sequent images and target velocity and acceleration as follows. The target velocity and acceleration are assumed as timely consistent in the observation.
t_n is time that nth image was observed, t_tgt is time of origin(targeted time). v and a are velocity and acceleration vectors of the target. r_n means target position on nth image.

$$\vec{r}_n(\vec{v},\vec{a},t_n) \equiv \vec{r}_{tgt} + \vec{v}(t_n - t_{tgt}) + \frac{1}{2}\vec{a}(t_n - t_{tgt})^2$$

Correlation coefficients of patterns of target images, which are regarded as similarities of targets, can be computed from pairs of timely neighboring images. Statistical mean can be computed from a set of the correlation-coefficients. The mean of the correlation-coefficients means timely consistent similarity of targets on motion-trajectory which is determined by given velocity and acceleration.

I_n is image pattern on nth image around position r_n, C(x,y) means correlation-coefficient of image patterns of x and y. C_mean(v,a) is mean of the correlation-coefficients at velocity v and acceleration a.

$$C_{mean}(\vec{v},\vec{a}) \equiv \cos\left(\frac{1}{N-1}\sum_{n=1}^{N-1}\cos^{-1}\left(C(I_n(\vec{r}_n), I_{n+1}(\vec{r}_{n+1}))\right)\right)$$

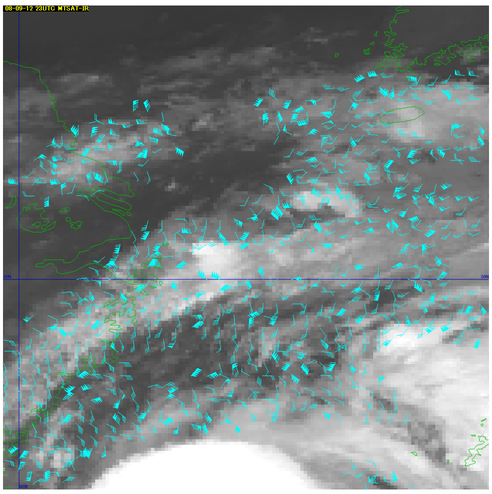
This statistical mean of correlation-coefficients is maximized at condition that given velocity and acceleration are accurate.

4) Experiment for the proposal method

For understanding the effect by the proposal method, experimental IR-upper-AMVs are derived from 3 continuous 4min rapid-scan satellite images observed by MTSAT-2 for THORPEX T-PARC campaign on September 2008, with 3x3 pixels target box. 3x3 target box size is too small to derive appropriate AMVs, but AMVs with 3x3 target box size are seemed to be strongly improved by the proposal method which utilize not only spatial information of target but also time-information of that because spatial information included in small 3x3 target box is very poor to determine statistically significant correlation-coefficient for AMVs. First guess wind from JMA NWP and AMVs derived by normal method with 16x16 target box size from 2 images are compared with experimental AMVs for evaluation of this experiment. Reason to compare with the AMVs with 16x16 target box from 2 images is for canceling height assignment effect to the comparison. All wind vectors are not quality-controlled.

At first, figure 2 is one of space distribution of AMVs from 2 images with 3x3 target box size, and figure 3 is that of AMVs by proposal method from 3 images with same 3x3 target box size. As it can be seen from these figures, AMVs from 2 images in figure 2 is noisier and less coherent than AMVs from 3 images in figure 3.

Leftmost scatter plot in figure4 show relationship between AMVs derived with 3x3 target box from 2 images and first guess wind from NWP. Second scatter plot from the left in figure3 shows the relationship AMVs by proposal method with 3x3 target box from 3 images and the first guess. Vertical axes mean a wind speed (m/s) from AMVs and horizontal one mean wind speed (m/s) of the first guess. In the comparisons with the first guess wind, large errors are suppressed significantly. Also in the comparisons with AMVs from 2 images with 16x16 target box, tendency is same as the comparisons with first guess.



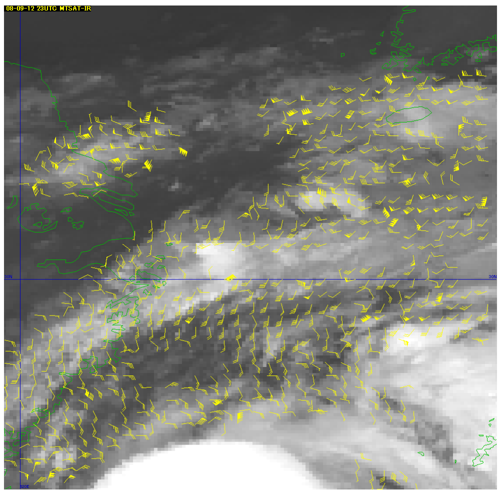


Figure 2(left) and figure 3(right): left figure2 is example of spatial distribution of AMVs derived from 2 images. And right figure3 is example of spatial distribution of proposal AMVs from 3 images. Quality control for AMVs is not applied. Noisy vectors caused from smallness of target box in left figure2 are improved by using 3 images like in right figure3.

First guess wind vs AMVs(3x3) from 2 images	**First guess wind vs proposal AMVs(3x3) from 3 images**	**AMVs(16x16)from 2images vs AMVs(3x3) from 2 images**	**AMVs(16x16)from 2images vs AMVs(3x3) from 3 images**

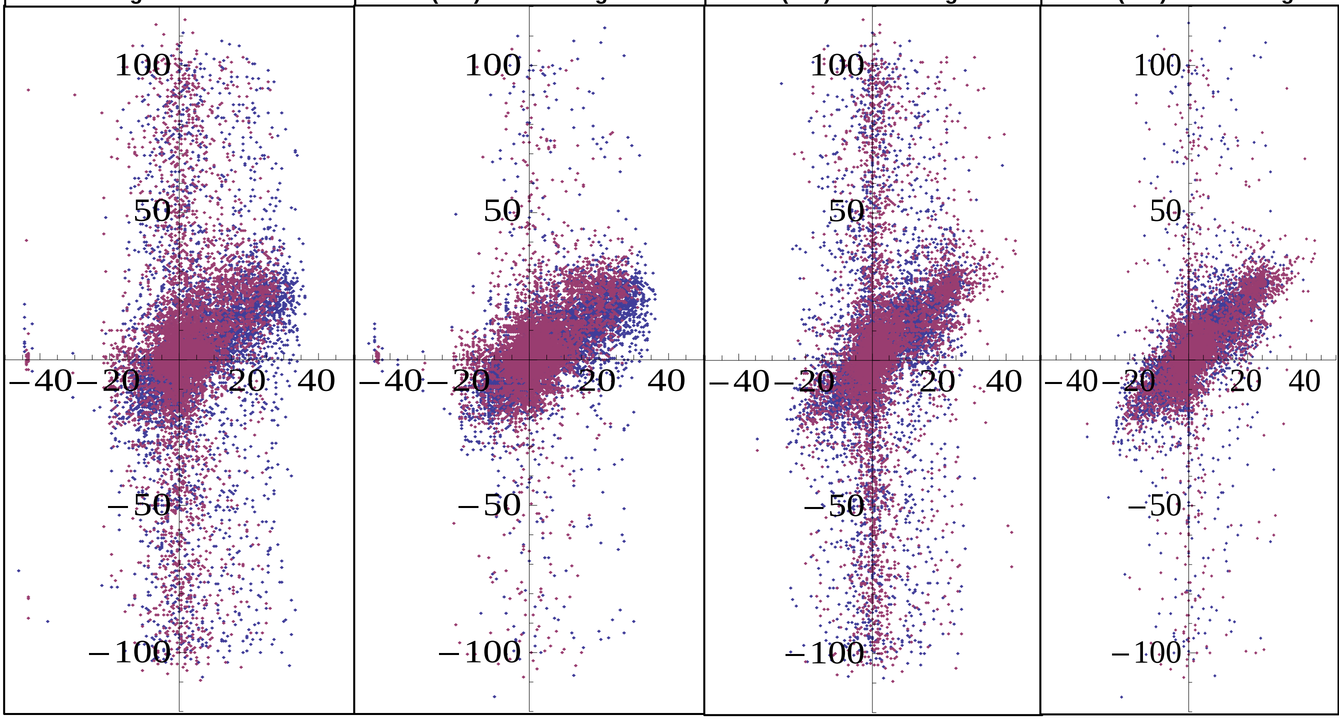


Figure 4: comparisons between AMVs with 3x3 target box and first guess and AMVs with 16x16. Vertical axes mean speed of AMVs (m/s), horizontal axes mean NWP first guess wind speed (m/s). Blue point means u component of wind vector, red one means v component of that.

Table 1 and table 2 shows statistical values computed from the result of this experiment. Regarding with Correlation, bias and standard deviation, the proposal AMVs from 3 images shows better result than AMVs from 2 images.

AMVs(3x3) VS first guess wind	AMVs from 2 images	AMVs from 3 images
Correlation of U component	0.200	0.371
Correlation of V component	0.174	0.377
Bias (m/s) : U(AMVs) – U (first guess)	-1.635	-0.680
Bias (m/s) : V(AMVs) – V (first guess)	0.660	0.657
Standard Deviation (m/s) : U component	30.424	18.610
Standard Deviation (m/s) : V component	29.808	14.991

Table 1: statistical values of comparison between AMVs and first guess

AMVs(3x3) VS AMVs(16x16)	AMVs from 2 images	AMVs from 3 images
Correlation of U component	0.258	0.513
Correlation of V component	0.248	0.504
Bias (m/s) : U(3x3 AMVs) – U (16x16 AMVs)	-0.646	0.309
Bias (m/s) : V(3x3 AMVs) – V (16x16 AMVs)	0.051	0.049
Standard Deviation (m/s) : U component	28.060	14.146
Standard Deviation (m/s) : V component	29.155	13.769

Table 2: statistical values of comparison between AMVs and first guess

5) Conclusions

By using not only 2 images but also 3 images for AMV derivation, errors of motion vectors which arise from inaccuracy in correlation-coefficient are specifically decreased. It is thought that the results partially prove that excessive time resolution of rapid-scan can be used in place of space resolution of AMVs.

6) Future plans

JMA/MSC is planning to increase rapid-scan observation by MTSAT-1R from summer of 2010. And continuously rapid-scanned multiple satellite images will be obtained for the rapid-scan-AMVs by proposal method.
The continuously rapid-scanned multiple satellite images will be used for case of more than 3 images and quality-control for AMVs. The quality-control for AMVs is essential process but in this paper it was not able to apply because the rapid-scan images used for this experiment is consist of 3 images.
In second experiment for rapid-scan-AMVs, more than 3 continuously rapid-scanned images and quality-control will be applied.