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ESTIMATION OF THE SEA SURFACE WIND IN THE VICINITY OF TYPHOON USING HIMAWARI-8 LOW-LEVEL AMVS

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Abstract

Himawari-8, Japan Meteorological Agency (JMA)'s current operational geostationary orbit satellite, carries the Advanced Himawari Imager (AHI) which has notably higher radiometric, spectral, spatial and temporal resolution than those of the previous JMA's satellites. The Atmospheric Motion Vectors (AMVs) derived from Himawari-8 imagery are more frequent and denser than previous ones. Tokyo Typhoon Center and the Meteorological Satellite Center of JMA (MSC/JMA) are currently developing the utility for sea surface winds monitoring around a typhoon using Himawari-8 AMVs. MSC/JMA investigated the relation between Himawari-8 low-level AMVs and the sea surface winds that are derived from scatterometers such as ASCAT and RapidScat in the vicinity of typhoons in a period from May to December 2015. As a result of regression analysis, the relations show simple linearity between the sea surface winds and the low-level AMVs. We confirmed that the accuracies of the sea surface winds estimated from Himawari-8 low level AMVs are within 2 m/s against the scatterometer winds. In this paper, we introduce the result and our future plans.

INTRODUCTION

Tokyo Typhoon Center of Japan Meteorological Agency (JMA) provides information on tropical cyclones in the western North Pacific and the South China Sea, including present and forecast positions as well as the movement and intensity of tropical cyclones. Sea surface wind data are used for important for the analysis of tropical cyclones. In situ observations, such as ships and buoys, are sparse especially on the ocean. Therefore, the forecasters use the ocean surface winds that are retrieved from microwave scatterometers on-board polar-orbiting satellites, such as ASCAT and RapidScat, as a major ancillary resource for the typhoon analysis, even though the sea wind data are not always around a typhoon and temporal resolution is not enough (e.g., ASCAT on-board Metop/NOAA passes the same place twice a day).

On the other hand, the Atmospheric Motion Vectors (AMVs) of geostationary orbit satellites are frequently obtained on the same ocean area. If we are able to estimate sea surface winds from Himawari-8 AMVs, this information is very helpful for the typhoon analysis. Previous works compared sea surface winds and AMVs using the in-situ observation measurements and suggested possibility of the estimating of sea surface winds in the vicinity of tropical storms from AMVs (e.g., Ohshima et al, 1991; Dunion and Velden, 2002).

The Advanced Himawari Imager (AHI) on board Himawari-8 has progressive observation function and it improve the resolution of AMVs that are derived from the imagery to be spatially and temporally higher than that of the previous satellites, MTSAT series. The frequency to obtain the low level AMVs have been increased, because the ability to track rapid shape-changing clouds and smaller size of clouds is improved using the enriched satellite images with the optimal algorithms for Himawari-8 AMV. Tokyo Typhoon Center and the Meteorological Satellite Center of JMA (MSC/JMA) are currently investigating to utilize the high resolution AMVs operationally, especially low-level Himawari-8 AMVs, for monitoring surface winds around typhoons. AHI also has the target observation function which enables us to provide the regional satellite imagery around a typhoon every 2.5 minutes. We can obtain higher resolution AMVs using this rapid scan regional imagery. JMA also plans to utilize this regional high resolution AMVs for typhoon analysis.

This paper shows the result of the comparison between the low-level AMVs and the scatterometer winds and the accuracy of the estimated wind from Himawari-8 AMVs. Finally we mention the current status and our plans.

COMPARISON BETWEEN LOW LEVEL AMVS AND SCATTEROMETER WINDS

We compared Himawari-8 low-level AMVs from AHI full disk imagery of B03 (VIS; 0.64 μm), B07 (SWIR; 3.9 μm) and B13 (IR; 10.4 μm) with the scatterometer winds around typhoons that generated from May to December 2015 (T1506–T1527). These three bands AMVs are able to capture the low level cloud motion relatively than the others. We used ASCAT and RapidScat winds as the observed sea surface winds. These winds data are utilized as major ancillary information for typhoon monitoring operationally as previously mentioned. We selected the AMVs that are located within 1,000 km from the centre of tropical cyclones and are assigned below 700 hPa and which EUMETSAT Quality Indicator (QI) (Holmlund, 1998) without forecast are more than 0.8 as the low-level AMVs. For estimation of the centre of typhoons, the JMA best track (2015) is used. The low-level AMVs are collocated with the sea surface winds (ASCAT and RapidScat) within 0.2° in both latitude and longitude from position of the AMVs. Summary of the dataset selection and the collocation condition is following:

- The investigation period is from May to December 2015 during typhoons existing.
- Himawari-8 full-disk AMVs whose height are assigned below 700 hPa and locate within 1,000 km from centre of typhoons are selected. (Using the JMA's best track data for the estimation of the centre of typhoon)
- Himawari-8 full-disk AMVs whose QI without forecast are more than 0.8 are selected.
- Scatterometer winds within 0.2° (both of latitude and longitude) from AMV are collocated.
- One scatterometer wind is finally collocated whose observation time is the nearest to AMV within 1 hour before.

Comparison of Wind Direction

Using the matched up dataset between Himawari-8 low-level AMVs and ASCAT/RapidScat winds, we performed the correlations of wind direction between the low-level AMVs and the scatterometer winds. Figure 1 shows strong correlations between them for wind direction and the correlation coefficients are approximately 0.87 for both of them. Confirming for the differences between the sea surface winds and the low-level AMVs derived from the AHI's three bands imagery, the statistical values are generally consistent among them.

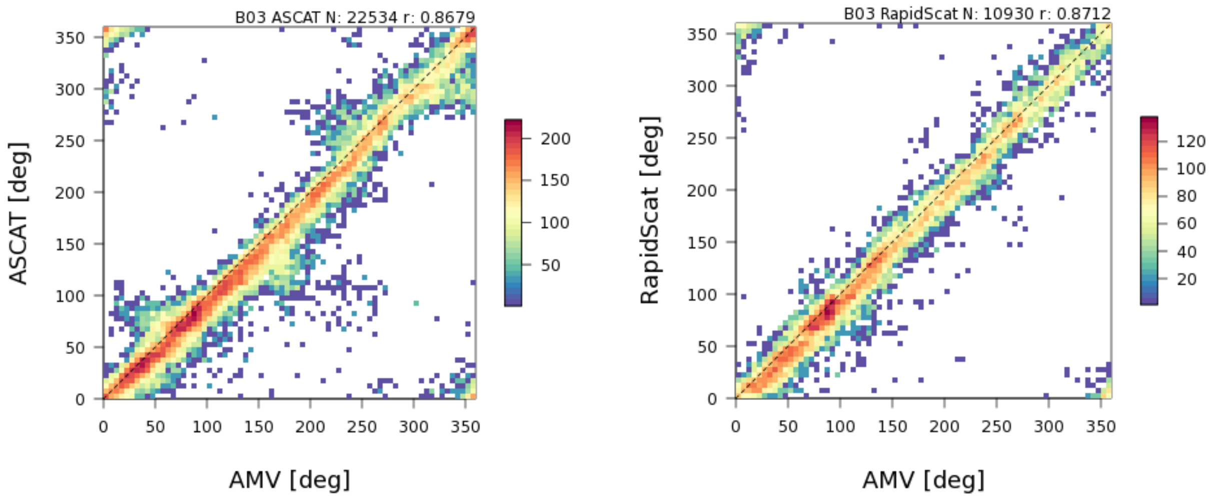

Figure 1: **Wind direction correlations between Himawari-8 low-level AMVs from 0.64μm (B03) imagery and the sea surface winds (left: ASCAT, right: RapidScat)**

We calculated statistics for the dataset that AMVs are faster than 5 m/s. These results are shown in Table 1. It is compatible between the results of ASCAT and RapidScat. The standard deviations of the differences between the sea surface winds and the low-level AMVs are within 13° to 19°. The biases are 8° to 10° (clockwise) more than the scatterometer winds. That is the sea surface winds are directed generally 9° inward to the centre of a typhoon on basis of the low-level AMVs.

	Stdv [°]	Bias [°]
VIS (0.64 µm)	14.7	+8.18
SWIR (3.9 µm)	17.2	+9.23
IR (10.4 µm)	18.6	+8.57

	Stdv [°]	Bias [°]
VIS (0.64 µm)	13.1	+8.65
SWIR (3.9 µm)	16.9	+9.70
IR (10.4 µm)	18.7	+9.22

Table 1: **Statistics of the wind direction differences between Himawari-8 low-level AMVs and the scatterometer winds (AMVs speed >= 5 m/s) (left: ASCAT, right: RapidScat)**

Comparison of Wind Speed

Figure 2 shows the correlations of wind speed between the low-level AMVs from Himawari-8 0.64 µm imagery and ASCAT/RapidScat winds. Close correspondences are found in both of the correlations and each of their correlation coefficients is about 0.89. The low-level AMVs tend to be faster than the scatterometer winds. It indicates the possibility of approximately estimating the sea surface wind speed from the low-level AMV using linear regression. The regression coefficients were calculated between Himawari-8 0.64 µm AMVs and the scatterometer winds and they are approximately 0.76 for the both.

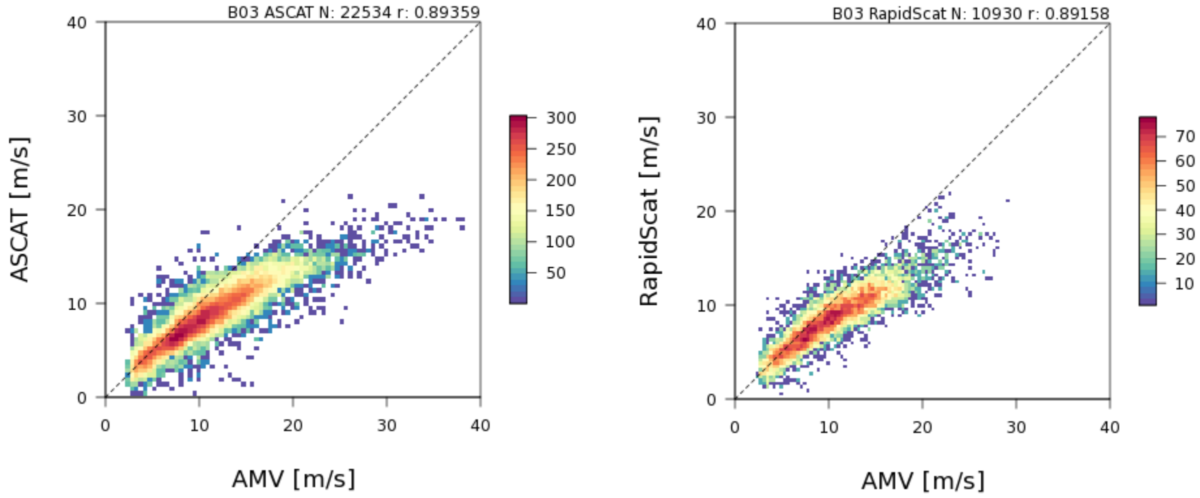

Figure 2: **Wind speed correlations between Himawari-8 low-level AMVs from 0.64µm (B03) imagery and the scatterometer winds (left: ASCAT, right: RapidScat)**

SEA SURFACE WIND ESTIMATION AND ACCURACY OF THE ESTIMATED WIND

We estimated the sea surface winds from Himawari-8 low-level AMVs by multiplying the calculated regression coefficient 0.76. In Figure 3, the grey histogram is the wind speed difference between the low-level AMVs from Himawari-8 0.64 µm imagery and the scatterometer winds. In this figure, the blue one is the wind speed difference between the estimated sea surface winds and the scatterometer winds. We can find the wind differences are clearly reduced by this estimation.

We expected the accuracies of the estimated sea surface winds against the scatterometer winds. The results are shown in Table 2. We find the estimated wind from the VIS (0.64 µm) AMV is the most accurate and the RMSE is within 1.5 to 1.6 m/s in the comparisons with ASCAT and Rapidscat. For the infrared bands (IR and SWIR), the errors are less than 2.0 m/s (RMSE). Figure 4 shows an example of distribution of the estimated sea surface winds around Typhoon Soudelor for the three bands (0.64, 3.9 and 10.4 µm).

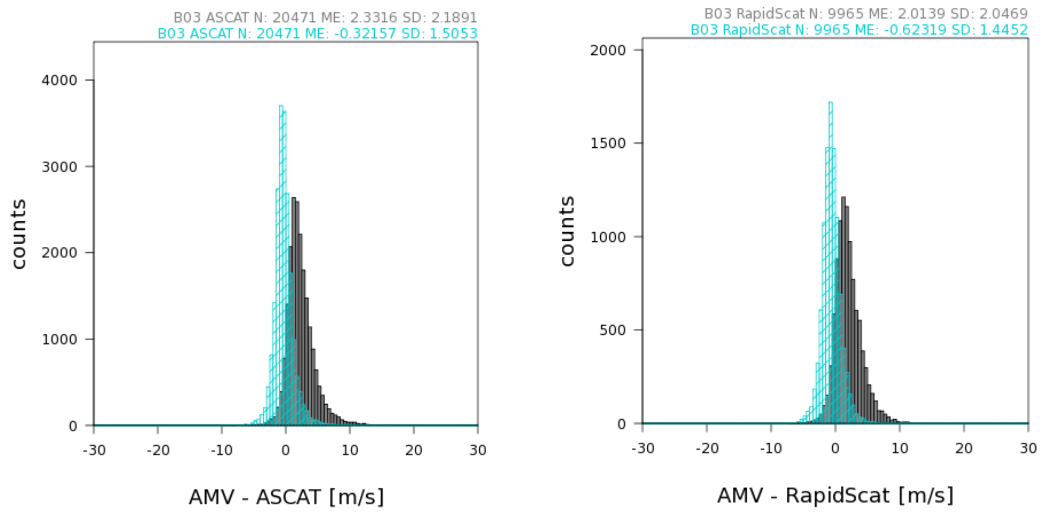

Figure 3: **The differences of wind speed between Himawari-8 low-level AMVs from 0.64 µm (B03) imagery and the scatterometer winds. The grey histogram is the differences between the low-level AMVs and the scatterometer winds. The blue one is the differences between the estimated sea surface wind using reduced factor (0.76) and the scatterometer winds (AMVs speed >= 5 m/s) (left: ASCAT, right: RapidScat)**

	RMSE [m/s]	Bias [m/s]
VIS (0.64 µm)	1.54	-0.322
SWIR (3.9 µm)	1.63	-0.441
IR (10.4 µm)	1.72	-0.630

	RMSE [m/s]	Bias [m/s]
VIS (0.64 µm)	1.57	-0.623
SWIR (3.9 µm)	1.90	-0.765
IR (10.4 µm)	1.96	-0.844

Table 2: **Accuracies of the estimated sea surface winds from Himawari-8 low-level AMVs against the scatterometer winds (AMVs speed >= 5 m/s) (left: ASCAT, right: RapidScat)**

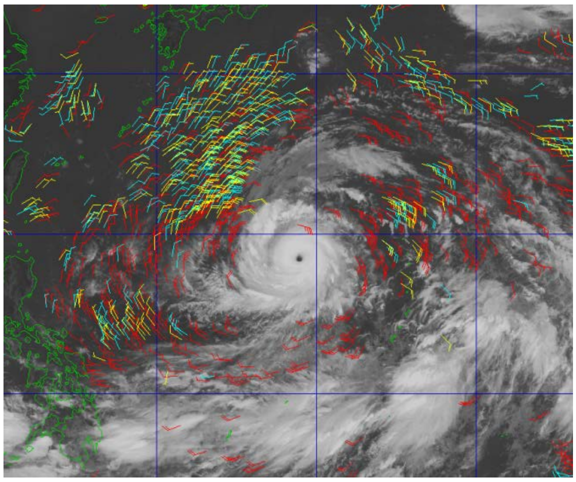

Figure 4: **Distribution of the estimated sea surface winds from the low level AMVs around Typhoon Soudelor, overlaid on Himawari-8 10.4 µm image (03 UTC on 4 August 2015) (red: 0.64 µm, yellow: 3.9 µm, blue: 10.4 µm).**

CURRENT STATUS AND FUTURE PLANS

MSC/JMA previously conducted a study to compare ASCAT wind and the low-level AMV that is retrieved from the rapid scan images that MTSAT-1R observed every 5 minutes around a typhoon (Hayashi, 2012). The result of this study is almost consistent with the comparison between Himawari-8 AMV and ASCAT (or

RapidScat). We currently provide the estimated sea surface winds from Himawari-8 low-level AMVs to Tokyo Typhoon Center and use them experimentally for typhoon monitoring.

As seen in Figure 2, fewer low-level AMVs are derived where the AMVs are faster than about 20 m/s. It is inferred that the region corresponds to the area which is within 400 km from the centre of a typhoon and is often covered with uniform dense overcast where the derivation of the low-level AMVs is difficult. It is not suitable for monitoring purpose and we also need the further investigation in this high speed region.

JMA plans to use the higher temporal and spatial resolution AMVs that are derived from Himawari-8 target observation images for the typhoon analysis. The target observation is AHI's flexible observation function to scan the optional target area every 2.5 minutes. It enables us to enhance the conditions of AMV calculation (e.g., reducing the target size and shortening the time interval of using images). The target observation AMVs have the ability to capture short-lived and rapid changing form cloud motions such as near the centre of typhoons. Figure 5 is an example of the distribution of the estimated sea surface winds from the high resolution target observation AMVs around a typhoon using the previously mentioned reduced factor. It shows clearly that the target observation AMVs are increased even near the centre of the typhoon. Currently we conduct a study to compare the target observation AMVs and the scatterometer winds and also plan to operationally distribute them to Tokyo Typhoon Center for utilizing of the typhoon analysis.

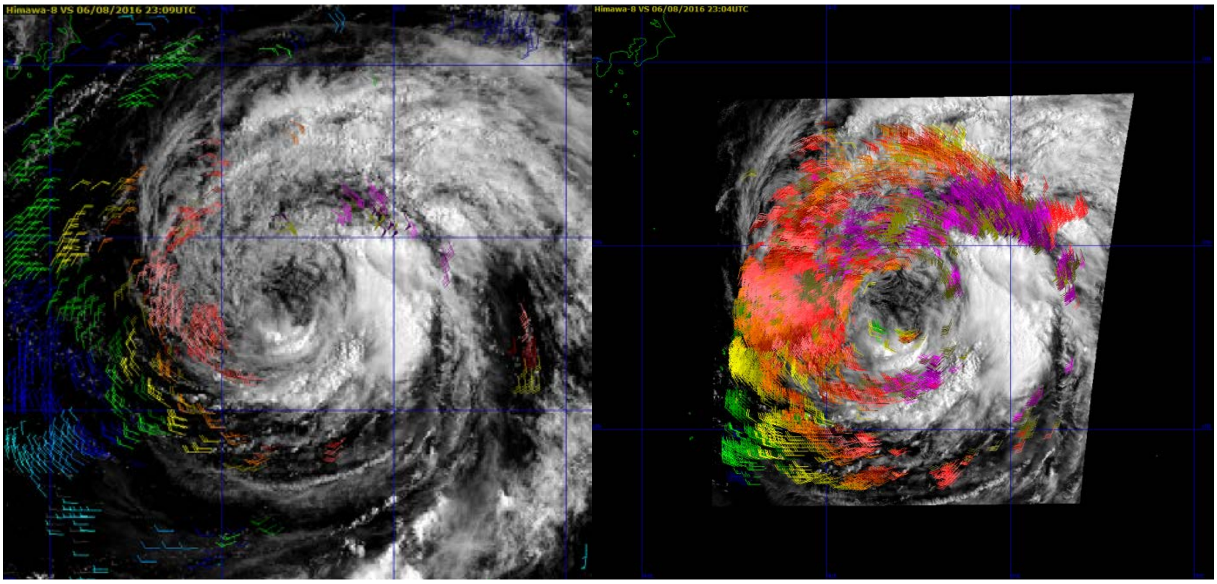

Figure 5: **Distribution of the surface winds estimated from the low-level AMVs using Himawari-8 full-disk 0.64 µm imagery (left) and target observation imagery (right) around Typhoon Omais at 23 UTC on 6 August 2016 (burbs' colours mean wind speed).**

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