Operational use of Scatterometer Winds at JMA

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Abstract

Scatterometer wind vectors have been used not only for operational Numerical Weather Prediction (NWP) but also for various applications such as weather map, typhoon and wave analysis at Japan Meteorological Agency (JMA).

The JMA operates global and mesoscale models with four-dimensional variational data assimilation system in which scatterometer winds are assimilated. We have started to use Metop-A/ASCAT winds data operationally in the global model in July 2009, but so far the usage is limited due to the wind speed inconsistency between NWP and scatterometer. To use the scatterometer data more effectively so as to improve the forecasts further, a bias correction method for ASCAT wind speed is examined. Observing system experiments show that bias-reduced data provide robust analysis fields and lead to forecast improvements.

1. INTRODUCTION

Ocean surface vector winds derived from scatterometers provide valuable information for the Data Assimilation (DA) system used in Numerical Weather Prediction (NWP) models owing to their high-accuracy and wide data coverage over the ocean (Liu et al., 2006). Various studies to assess the accuracy of scatterometer winds have been carried out. Verspeek et al. (2010) compared the winds derived from the ASCAT on board the Metop-A satellite with the European Centre for Medium-Range Weather Forecasts (ECMWF) winds and found the Root Mean Square (RMS) difference was 1.3 m/s. Ebuchi et al. (2002) compared the winds derived from the SeaWinds on board the QuikSCAT satellite (hereafter, referred to as "QuikSCAT") with buoy observations and found that the RMS difference of wind speed was about 1.0 m/s without systematic bias except for very high speeds. A comparison of QuikSCAT winds with GPS dropwindsonde data deployed by Dropwindsonde Observations for Typhoon Surveillance Near the Taiwan Region (DOTSTAR) by Chou et al. (2010) showed the RMS difference of wind speed (above 17.2 m/s) was 4.1 m/s.

The Japan Meteorological Agency (JMA) has started the operational use of scatterometer winds derived from the AMI on board the ERS-2 satellite (from July 1998 to January 2001), from the QuikSCAT (from May 2003 to November 2009), and from ASCAT (since July 2009) in the global model. However, ASCAT winds above 15 m/s are not assimilated in the current JMA DA system due to a gap of wind speed between QuikSCAT and ASCAT data shown by Bentamy et al. (2008) and a slow speed bias against JMA first guess winds.

It is widely recognized that the use of observations without biases among the same kind of sensors or instruments is very important for DA system. Several operational NWP centers apply a bias correction method to scatterometer winds (e.g., Cotton, 2009; ECMWF, 2009), while no correction is taken into account at JMA. In this study, we examine a wind speed bias correction for ASCAT data.

This report presents a status of scatterometer data usage at JMA and the results from Observing System Experiments (OSEs) of bias-reduced ASCAT winds.

2. CURRENT USAGE OF SCATTEROMETER WINDS AT JMA

Quality control and data thinning to approximately 100-km intervals are applied to the scatterometer winds in a preprocessing step. The former is performed as follows: First, low-quality data are rejected according to attached flags such as land/sea and rain. Next, the most likely wind vector is selected in the ambiguity removal step using a median filter method initialized by nudging with JMA's first guess. Finally, data with large departures in wind speed and direction from the first guess winds are screened out. The latter is to avoid using observations with highly correlated errors each other.

Figure 1 shows two-dimensional histograms of JMA's first guess of ocean surface vector winds versus scatterometer winds derived from ASCAT and QuikSCAT, respectively. Both scatterometer winds closely match the NWP winds, although high-speed ASCAT winds are underestimated.

To evaluate the impacts of ASCAT data on analysis and forecasting, OSEs in a low-resolution (TL319L60) global DA and forecast system were carried out. Figure 2 shows the improvement rate of the RMS forecast error against the initials in August 2007. All experiments with scatterometer data significantly improved forecast scores in the short-to medium-range forecast period over the Northern and Southern Hemispheres. The best improvement of forecast is the experiment with QuikSCAT and ASCAT. It can be attributed to the increased data coverage, which provides more valuable information to correct the initial field in one analysis. Forecast scores of the experiment with ASCAT only is comparable with that using only QuikSCAT, indicating that the use of at least one scatterometer (ASCAT) still assures forecast improvement even if QuikSCAT data become unavailable. However, the end of QuikSCAT nominal mission in November 2009 points to a need for assimilating ASCAT high wind speed data. In the next section, a bias correction scheme for ASCAT wind speed is described.

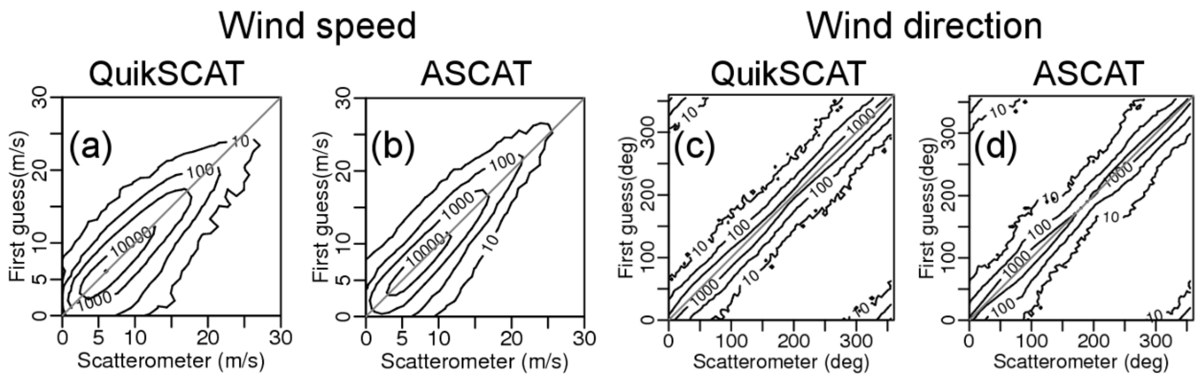

Figure 1: **Two-dimensional histograms of JMA's first guess for ocean surface winds versus scatterometer winds derived from ASCAT (b, d) and QuikSCAT (a, c) for 1 － 31 January 2009. Scatterometer winds after quality control and data thinning are used. The contour lines are on a logarithmic base-10 scale.**

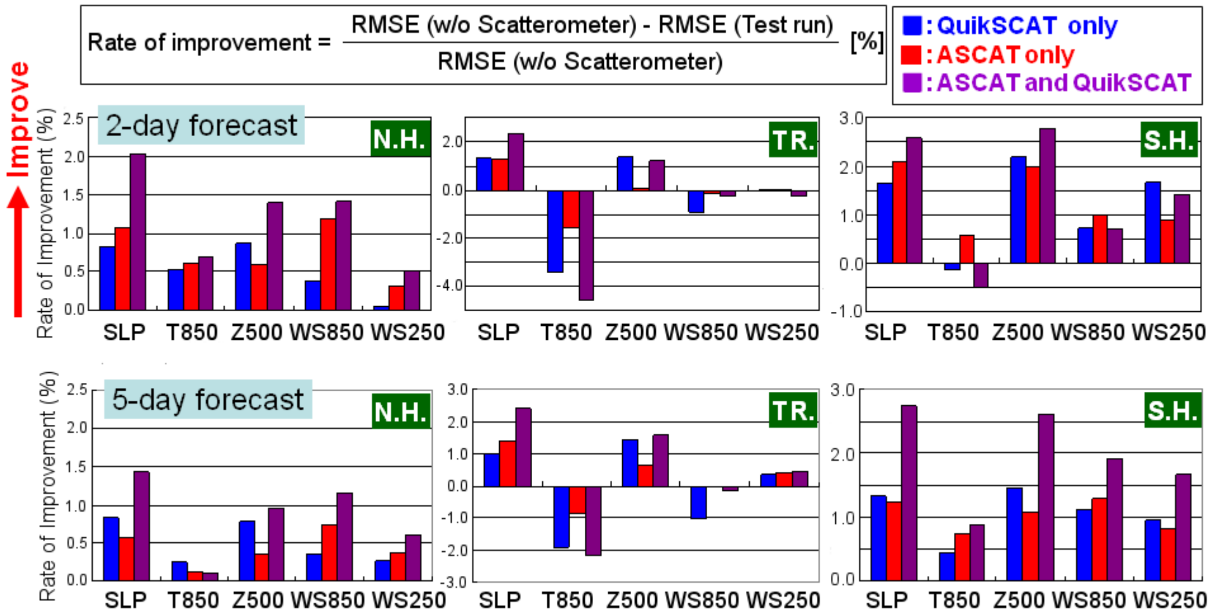

Figure 2: **Improvement rate of the RMS forecast error against the initials for forecast of Sea Level Pressure (SLP), temperature at 850-hPa, geopotential height at 500-hPa, and wind speed at 850-hPa and 250-hPa, averaged over the Northern Hemisphere (left), the tropics (center) and, the Southern Hemisphere (right) for August 2007. The improvement rate is defined as (CNTL－TEST) / CNTL, where CNTL and TEST are the RMS forecast errors of the experiments without and with scatterometer usage, respectively. A positive value of the bar indicates the improvement of forecast.**

3. ONGOING DEVELOPMENT OF ASCAT WIND SPEED BIAS CORRECTION

3.1 METHOD AND EXPERIMENTAL DESIGN

A schematic diagram of a bias correction method is shown in Figure 3. This method is based on the idea to adjust the Probability Density Function (PDF) of ASCAT wind speed to that of QuikSCAT. It consists of two processing steps: First, JMA's first guess wind speed data for a half year (1 January 2009 to 30 June 2009) are interpolated to QuikSCAT and ASCAT observation points. ASCAT and QuikSCAT winds with 25-km cell spacing retrieved respectively by the Royal Netherlands Meteorological Institute (KNMI) and the Jet Propulsion Laboratory (JPL) are used in this study. Next, mode calculation is performed for QuikSCAT and ASCAT data which are binned into 1 m/s bins for interpolated first guess. If a difference of the mode between QuikSCAT and ASCAT is larger than 0.6 m/s, we use this discrepancy as an amount of ASCAT wind speed bias correction. Otherwise, no correction is applied. Look-up table of the bias correction derived from this methods are shown in Table 1. ASCAT wind speed is corrected with this table.

In order to research the impacts of bias corrected ASCAT winds, three experiments in the low resolution global model have been carried out. Table 2 shows the experimental design. Figure 4 shows total ASCAT data number assimilated during the experimental period. Over the Southern Ocean, the number in AS25BC is approximately 10% increased over that in AS15.

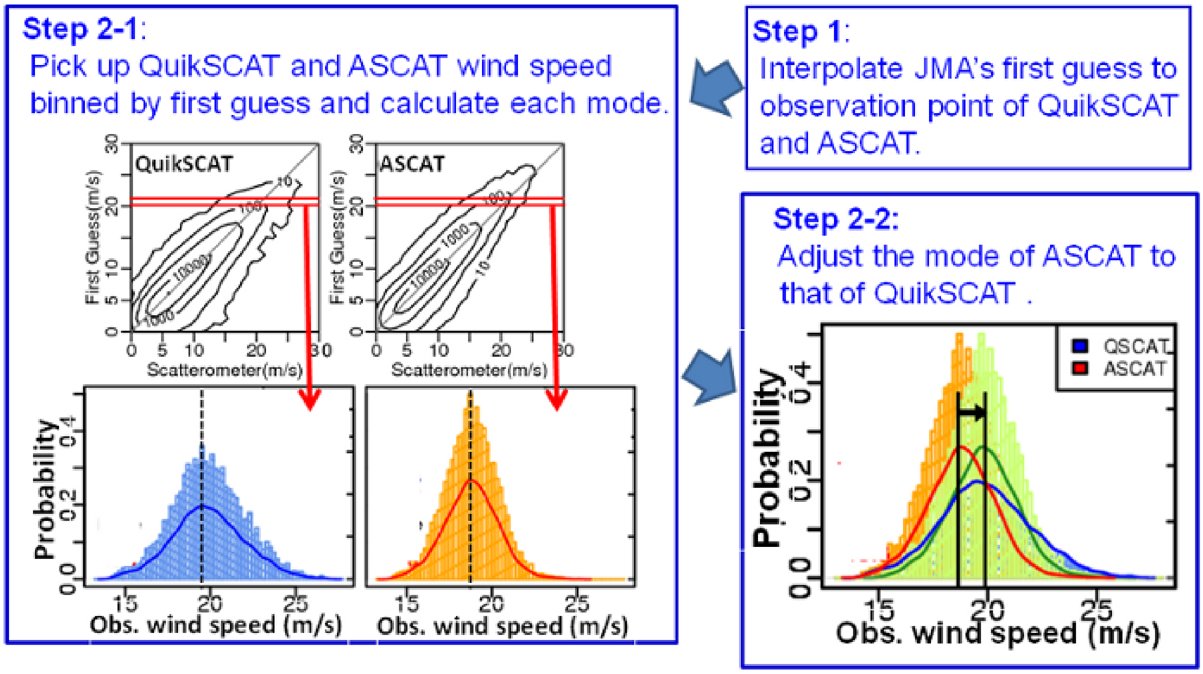

Figure 3: **Schematic diagram of a bias correction of ASCAT wind speed.**

Interpolated first guess (m/s)	0 - 3	3 - 15	15 - 17	17 - 20	20 - 21	21 - 22	22 - 23	23 - 24	24 -
Value of bias correction (m/s)	0.4	0.0	0.4	0.6	0.8	1.0	1.6	1.8	2.0

Table 1: **Look-up table of ASCAT wind speed bias correction.**

	Experimental			Operational
	AS25BC	AS25	AS15	
Experimental Period	Assimilation: 2009/07/20 – 2009/09/09 (00, 06, 12, 18UTC) Forecast (216 hour): 2009/08/01 – 2009/08/31 (12UTC)			
Resolution of forecast	TL319L60			TL959L60
Resolution of DA (outer/inner model)	TL319/T106			TL959/T159
Scatterometer Usage	w/ ASCAT wind speed bias correction			
ASCAT	0 – 25 m/s	0 – 25 m/s	0 – 15 m/s	0 – 15 m/s
QuikSCAT	0 – 30 m/s			

Table 2: **Design of Observing System Experiments.**

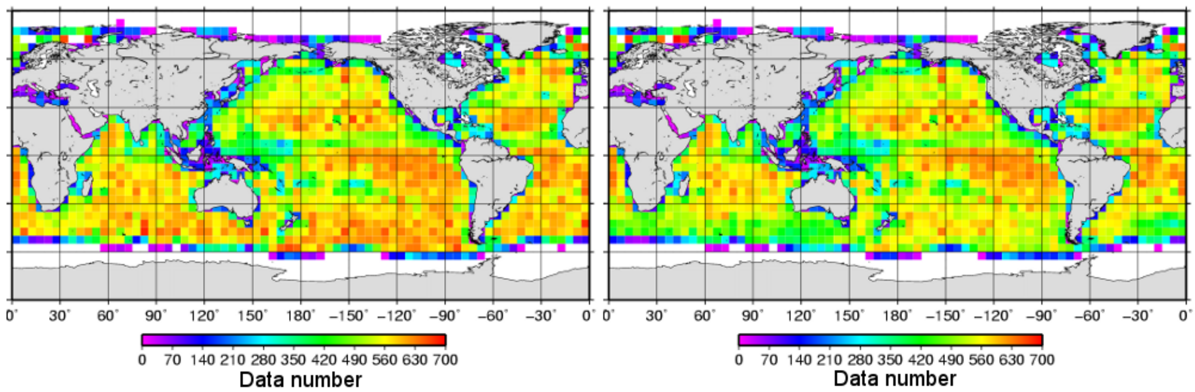

Figure 4: **Accumulated data number of ASCAT within 5 x 5 degree grid box for August 2009 in AS25BC (left) and AS15 (right). Assimilated data are only used in both panels.**

3.2 RESULTS

Two-dimensional histograms of JMA's first guess of ocean surface winds versus scatterometer winds derived from ASCAT and QuikSCAT in AS25BC and AS25 are shown in Figure 5. O-B (Observation minus Background) of ASCAT wind speed over the Southern Hemisphere decreases from -0.10 m/s in AS25 to -0.01 m/s in AS25BC. A large gap at high speed between ASCAT and QuikSCAT is obviously reduced in AS25BC. Wind speed O-B of ASCAT and QuikSCAT averaged within each 5 x 5 degree grid box is shown in Figure 6. Note that the discrepancy of O-B between ASCAT and QuikSCAT in AS25BC over the tropics still remains. It is probably caused by a fast speed bias of QuikSCAT over a wind range from 3 to 15 m/s, which is not reduced in this bias correction method.

One month averaged RMS of SLP analysis increment in AS25, its difference between AS25BC and AS25, and a time series of them are shown in Figure 7a, 7b, and 7c, respectively. Figure 7a shows a large analysis increment over the Southern Ocean and the Antarctic. Over the Southern Ocean, there has been a scarcity of observations to be assimilated: a small number of conventional observations, a gap of Atmospheric Motion Vectors (AMVs) derived from polar orbiting and geostationary satellites around 60S to 70S zone and so on. Scatterometer data result in relatively high impacts on the analysis. On the Antarctica, a contribution to the SLP analysis is dominated by the surface pressure observations from SYNOP stations. In Figure 7b, the shaded area in blue indicates that a discrepancy in SLP between the first guess and the observation is reduced by applying the bias correction in AS25BC. Figure 7c also shows the decrease of analysis increment while some spikes exist in the middle of the experimental period. These findings suggest that AS25BC provides more stable field than AS25 and the analyzed field in AS25 is somewhat noisy due to the wind speed inconsistency between ASCAT and QuikSCAT.

Figure 8 shows forecast scores with respect to anomaly correlations of geopotential height at 500-hPa averaged over the Southern Hemisphere for August 2009. As shown in Figure 8a, comparable or slightly better forecast scores were obtained by AS25BC than those by AS15. In contrast, AS25 degraded the scores in the medium-range forecast. Some remarkable spikes in AS25 shown in Figure 8b can be attributed to the non-robust analysis fields.

Figure 9 shows forecast position error for Tropical Cyclone (TC) averaged over the North Western Pacific region, and both the East Pacific and the North Atlantic region. AS25BC improved TC track forecasts in the medium-range (Figure 9a and 9b). This suggests the importance of using high-speed ASCAT winds, which provide valuable information to analyze the initial position of tropical cyclone and its environmental flow. The smallest error was obtained by AS25 in the short-range forecast (Figure 9b).

However, ASCAT winds with slow speed bias have weakened TC intensity in the analysis, leading to a failure of TC tracking (not shown). We conclude that AS25BC comprehensively improves TC forecasts.

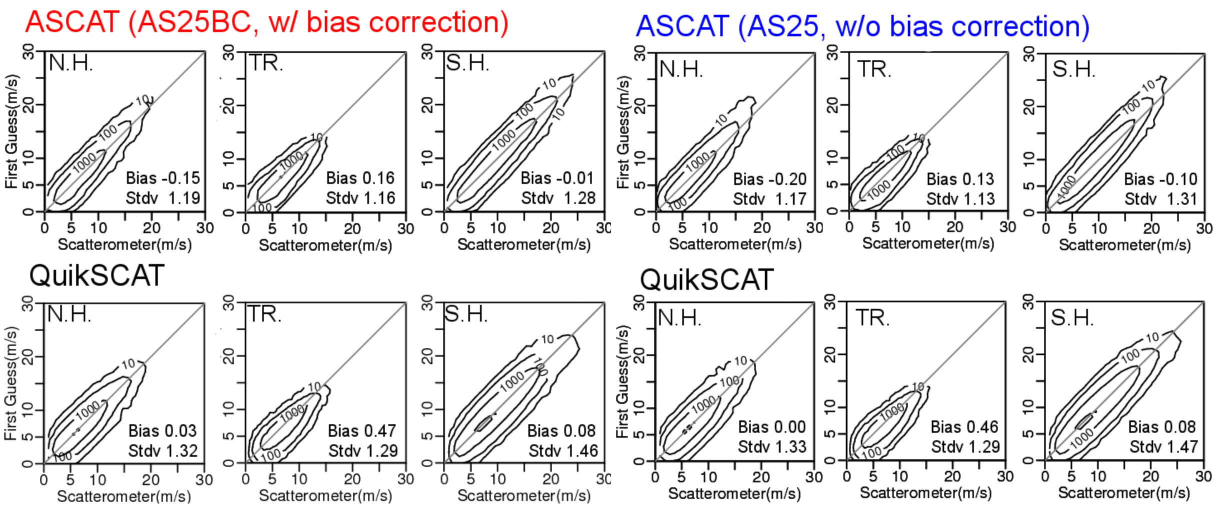

Figure 5: **Two-dimensional histograms of JMA's first guess for ocean surface winds versus scatterometer winds derived from ASCAT (upper) and QuikSCAT (lower) for 1 — 31 August 2009 in AS25BC (left) and AS25 (right). Scatterometer winds after quality control and data thinning are used. The contour lines are on a logarithmic base-10 scale.**

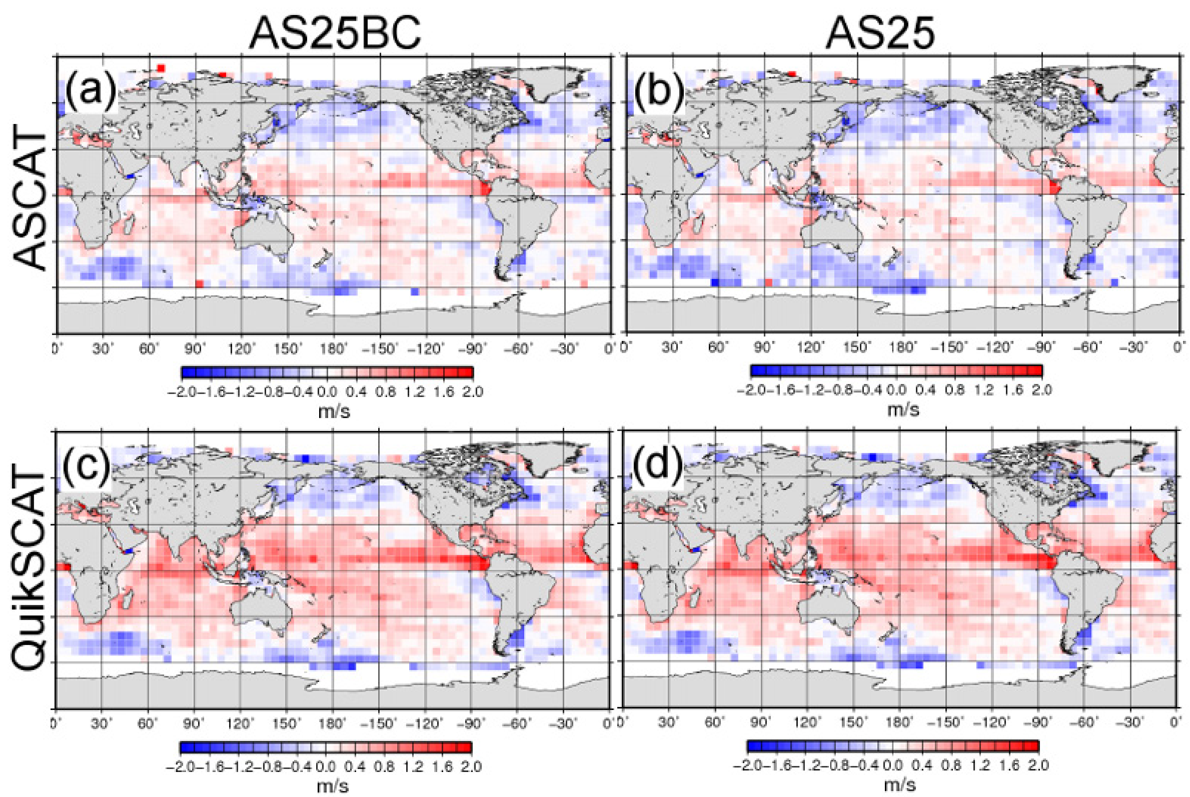

Figure 6: **Wind speed O-B for ASCAT (upper) and QuikSCAT (lower) averaged within each 5 x 5 degree grid box in ASBC25 (left) and AS25 (right).**

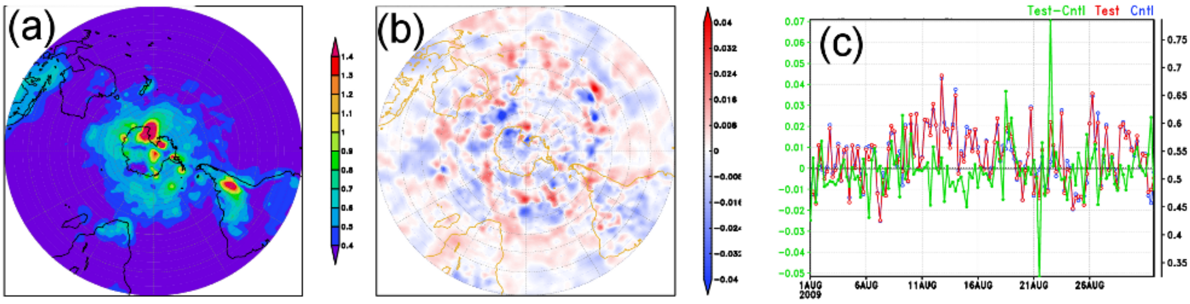

Figure 7: **RMS of analysis increment for SLP. (a) Averaged value for August 2009 in AS25. (b) Difference of averaged value (AS25BC minus AS25). (c) Time series of AS25BC (red), AS25 (blue), and the difference between AS25BC and AS25.**

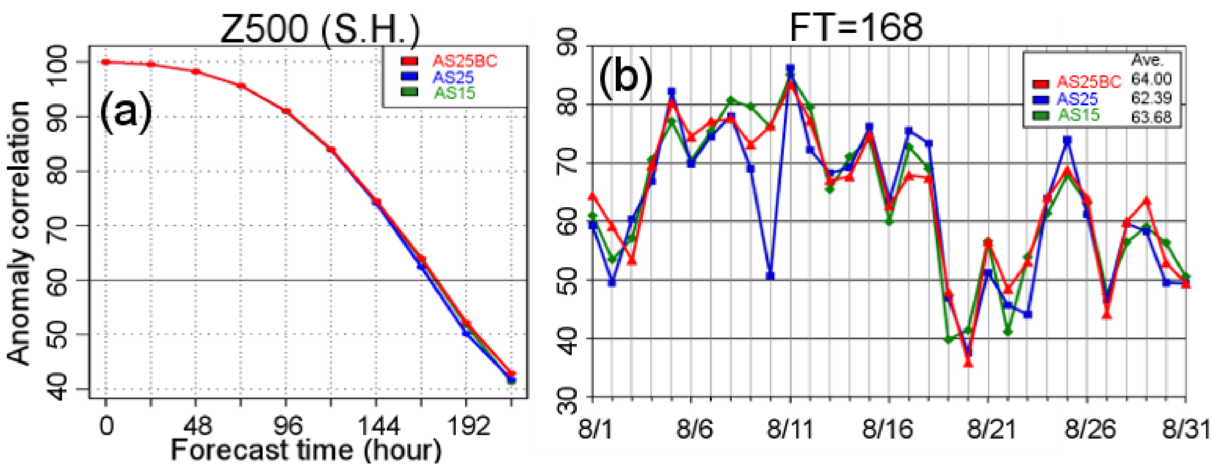

Figure 8: **Anomaly correlations of geopotential height at 500-hPa averaged over the Southern Hemisphere for August 2009. Average of 31 initials (a) and time series for seven-day forecasts (b) are shown. Lines in red, blue, and green are the result of AS25BC, AS25 and AS15, respectively.**

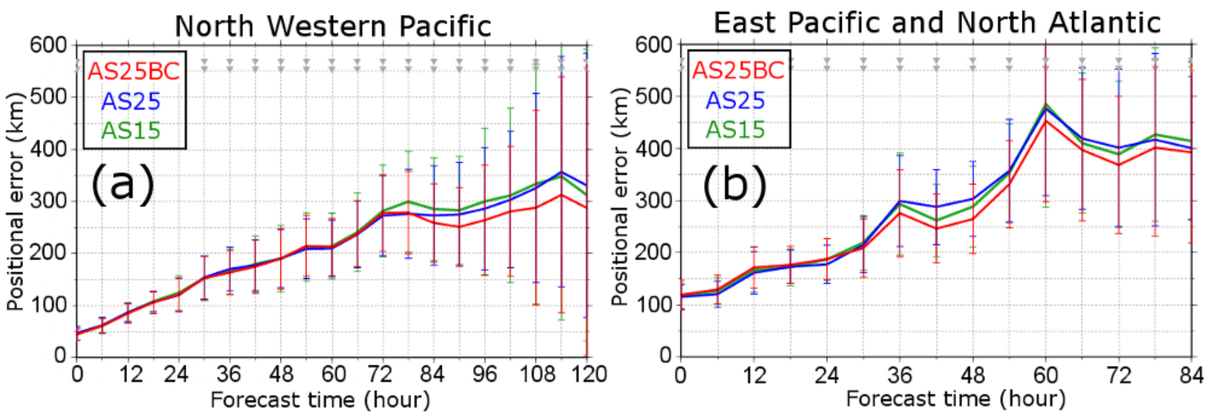

Figure 9: **Forecast position error (km) for tropical cyclone averaged over the North Western Pacific (a), and both the East pacific and the North Atlantic (b). Color of each line means the same as shown in Figure 8. Error bars indicate 95% confidence interval.**

4. SUMMARY

The study is intended to reduce the speed bias between ASCAT and QuikSCAT and check the impact on the analysis and forecast. The bias correction method adjusting the PDF of ASCAT wind speed to that of QuikSCAT was examined. The result obtained by the OSEs shows that the inconsistency of wind speed between them leads to degradation of the forecast, while the experiment with bias-corrected ASCAT winds has neutral or slightly positive impact on the short-to medium-range forecast. However, not all biases are removed in this scheme because it is focused on the correction of high-speed ASCAT data. The selection of reference data in a bias correction is also important. In the next step, we will investigate the spacial and temporal representativeness of scatterometer and NWP winds in order to improve the bias correction method. .

5. REFERENCES

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