OBSERVING SYSTEM EXPERIMENTS OF MTSAT-2 RAPID SCAN ATMOSPHERIC MOTION VECTOR FOR T-PARC 2008 USING THE JMA OPERATIONAL NWP SYSTEM

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Abstract

A special observation experiment project that examines the effectiveness of next generation forecast technology, “Interactive forecast system”, has been performed under THORPEX Pacific Asian Regional Campaign (T-PARC) for track forecasts of three typhoons in the summer of 2008 at Japan Meteorological Agency (JMA) (T-PARC 2008). Special observations for T-PARC 2008 are dropwindsonde observations, extra radiosonde observations at JMA observatories and ships observations. Meteorological Satellite Center (MSC) of JMA produced MTSAT-2 Rapid Scan Atmospheric Motion Vectors (MTSAT-2-RS-AMVs) for T-PARC 2008. Observing-system experiments (OSEs) targeted for typhoons Sinlaku and tropical depression (TD) with MTSAT-2-RS-AMV data thinned to 100 km were performed using the operational global and meso-scale models of JMA (GSM and MSM). The special observational data and typhoon bogus data are not used in OSE to evaluate the impact of only MTSAT-2-RS-AMV data.

As the results of OSEs, mean error (ME) and root mean square error (RMSE) of wind against radiosonde observations in GSM and MSM were reduced. This better wind analysis improved Sinlaku and TD predictions in GSM and MSM up to 9-12% on an average compared to control-case which did not assimilate MTSAT-2-RS-AMVs.

1. INTRODUCTION

The research of Rapid Scan AMVs has been carried out in America mainly. The OSEs of GOES-11 rapid scan AMVs for Tropical Storms Cindy and Gert in 2005 using three-dimensional variational data assimilation (3D-Var) on the Weather Research and Forecasting (WRF) model were performed. Pu and Li (2008) showed GOES-11 rapid scan AMVs were necessary for improved forecasts of intensity and precipitation. Langland et al. (2009) examined the impact of GOES Rapid-scan Wind Observations using 3D-Var on the Navy Operational Global Atmospheric Prediction System (NOGAPS) forecast of Hurricane Katrina. GOES Rapid-scan AMVs reduced errors in numerical forecasts of Katrina landfall position at 1200 UTC 29 August 2005 by an average of 12% compared to control cases. In the Europe, METEOSAT-8 Rapid Scan AMVs have been generated operationally from the EUMETSAT since May 2008.

T-PARC 2008 project has been conducted under THORPEX between the North American, Asian and European THORPEX Regional Committees (WMO, 2008) in the summer of 2008 around Japan to investigate effectiveness of next generation forecast technology, "Interactive forecast system". The objectives of T-PARC include both the improvement of regional prediction in Asia and North America and the study of the impact of the mechanism of genesis, recurvature and extra-tropical transition for TCs on the downstream flow of global atmospheric circulation. JMA contributed to the provision of forecast sensitivity analysis and special observations. Dropwindsonde observations and extra radiosonde observations at JMA observatories and ships were implemented for three typhoons, Nuri, Sinlaku and Jangmi. The positive impacts of special observations in JMA operational GSM mainly at the before-recurvature stage of Sinlaku and Jangmi were found. In the verification of sensitivity analysis system, special observations on the high sensitive area were more effective to improve the tropical cyclone (TC) track forecast. The high possibility of their use as interactive forecast system tools was indicated. (Yamashita et al, 2010).

MSC produced MTSAT-2 Rapid Scan Atmospheric Motion Vectors (MTSAT-2-RS-AMV) from three images of the intervals of 15-minutes (MTSAT-2-RS-AMV_15MIN), 7-minutes (MTSAT-2-RS-AMV_7MIN) and 4-minutes (MTSAT-2-RS-AMV_4MIN) for T-PARC 2008 (Oyama, 2010; Shimoji, 2010) . The OSEs for MTSAT-2-RS-AMV were also conducted to achieve the objectives of T-PARC.

In this paper, section 2 introduces outline of the global and meso-scale NWP system briefly. Section 3 is shown the experimental design. Section 4 is presented the procedure for MTSAT-2-RS-AMV. The results of the experiments are discussed in section 5, and a summary is provided in section 6.

2. OUTLINE OF THE GLOBAL AND MESO-SCALE NWP SYSTEM AT JMA

The outline of the global and meso-scale NWP system is listed in Table 1 and Table 2. More details on the system are found in Nakagawa (2009), Honda and Sawada (2008, 2009). Hereafter, "Global Data Assimilation System", "Global Spectral Model", "Meso-scale Data Assimilation System" and "Meso-scale Grid Model" are abbreviated to "GSM-DA", "GSM", "MSM-DA" and "MSM", respectively.

***Table 1*: Outline of the global NWP system at JMA**

Global Data Assimilation System (GSM-DA)	
Method	four-dimensional variational data assimilation (4D-Var)
Resolution and Layers (inner model)	T159L60 (hydrostatic Gaussian grid, horizontal resolution approx. 80 km, model top 0.1 hPa)
Assimilation window	6 hours (±3hours, time slots approx. 1 hour)
TC bogus data	Not used in TEST and CNTL experiments but assimilated in operational run

Global Spectral Model (GSM)	
Resolution and Layers	TL959L60 (hydrostatic reduced Gaussian grid, horizontal resolution approx. 20 km, model top 0.1 hPa)
Forecast range (initial time)	84 hours/216 hours (00, 06, 18 UTC/12 UTC)

***Table 2*: Outline of the meso-scale NWP system at JMA**

Meso-scale Data Assimilation System (MSM-DA)	
Method	4D-Var
Resolution:Outer/Inner/Layers	5 km/15 km/50 layers (non-hydrostatic Grid Model, model top 21,800 m)
Assimilation window	3 hours (-3 hours, time slots approx. 1 hour)
TC bogus data	Not used in TEST and CNTL experiments but assimilated in operational run

Meso-scale Grid Model (MSM)	
Resolution/Layers	5 km (Non-hydrostatic Grid Model, model top 21,800 m)/50 layers
Forecast range (initial time)	15 hours/33 hours (00, 06, 12, 18 UTC/03, 09, 15, 21 UTC)

3. EXPERIMENTAL DESIGN

Experimental design is outlined in Table 3. We performed two kinds of numerical experiments that differed in their use of MTSAT-2-RS-AMVs: (I) MTSAT-2-RS-AMVs were assimilated (TEST), and (II) MTSAT-2-RS-AMVs were not assimilated (CNTL). To evaluate the effect of using MTSAT-2-RS-AMVs, dropsonde observations and TC bogus data are not used. The experimental periods were from 18 UTC on 10 September 2008 (1018; hereafter the date and time are abbreviated as ddhh without the month) to 1306 for Sinlaku and TD and from 1718 to 1812 for Sinlaku.

Figure 1 shows Sinlaku and TD tracks. Sinlaku formed in the Philippine Sea, then it headed towards Taiwan where it caused severe flooding, recurved east of China and passed south of Japan on its way eastwards. The storm had peak typhoon intensities of category four according to the Saffir-Simpson Scale before hitting Taiwan. TD approached Japan and moved in the eastern-sea of Japan toward the north, when Sinlaku had peak typhoon.

In the following OSEs, Sinlaku track forecasts were verified using the TC best track provided by RSMC Tokyo-Typhoon Center. TD track forecasts were verified using the early positional analysis in JMA.

Table 3**:Experimental design of OSEs for MTSAT-2 Rapid Scan AMV**

	TEST	CNTL
TC bogus data	Not used	Not used
Special observations	Not used	Not used
MTSAT-2 Rapid Scan AMVs	Used	Not used
Other observations	Used	Used

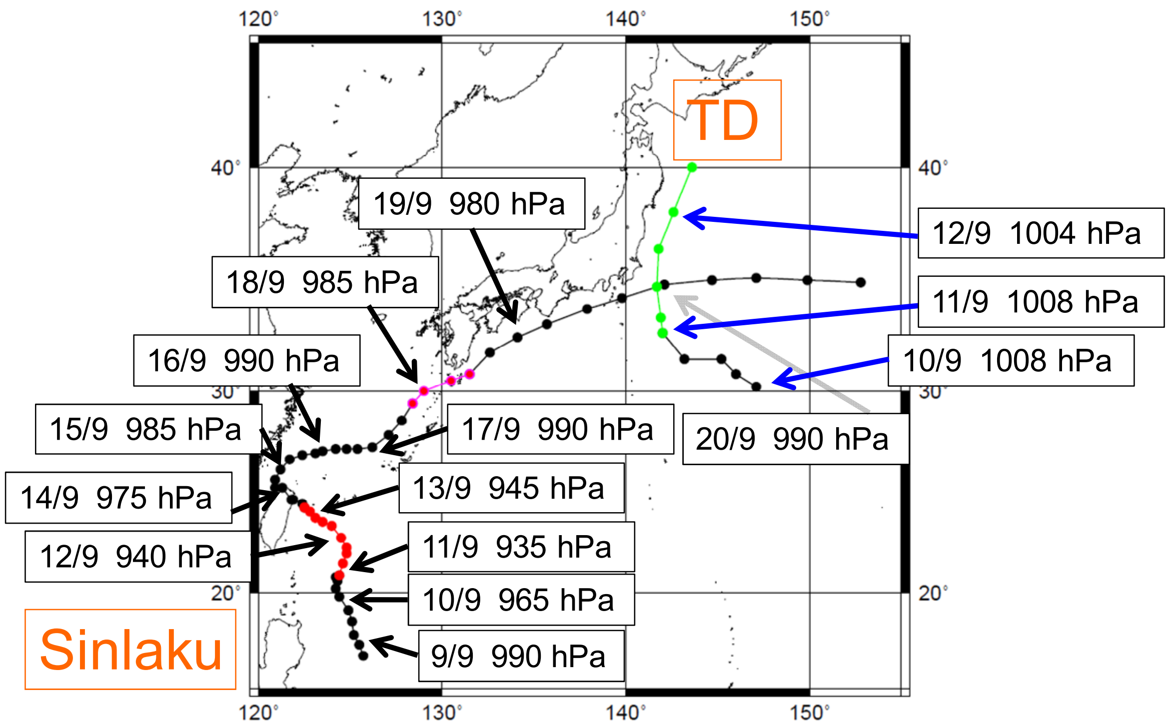


Figure 1**: The observed tracks of Sinlaku and TD. The data in the white square are date and mean sea level pressure of TC center at 00 UTC. The red, pink and green colors show TC positions that MTSAT-2 rapid scan observations were available.**

4. PROCEDURE FOR MTSAT-2-RS-AMV

It was found that MTSAT-2-RS-AMV_4MIN and MTSAT-2-RS-AMV_7MIN are highly independent from operational AMVs by investigation of the spatial and time error correlation distance using the departure of AMVs from the first-guess (O-B). Therefore, to use many independent AMVs, a two-step thinning scheme for loosened thinning of MTSAT-2-RS-AMVs was used as a trial in TEST. In this method, MTSAT-2-RS-AMV_4MIN and MTSAT-2-RS-AMV_7MIN are thinned to a resolution of 100 km (one AMV in each 1 deg. x 1 deg. x 100 hPa box in the hourly time window) after 200-km thinning (one AMV in each 2 deg. x 2 deg. x 100 hPa box in the six-hour time window) of other AMVs. Other quality control (QC) procedures are the same as that for operational AMVs. More details on the QC of AMVs can be found in JMA (2007) and Yamashita (2008). MTSAT-2-RS-AMVs have almost as accurate as MTSAT-1R ones (Hoshino et al, 2010). Figure 2 shows examples of the adoption of the two-step thinning scheme on 300 hPa. Using this thinning scheme, the increase of AMVs was brought in the vicinity of Japan where AMVs data were sparse.

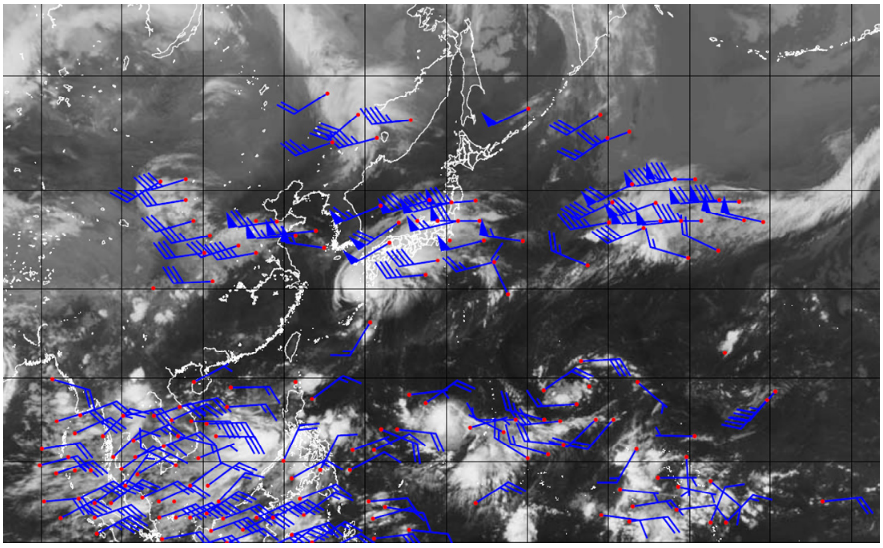
5. RESULTS OF THE EXPERIMENTS

(A) RESULTS FOR GSM-DA

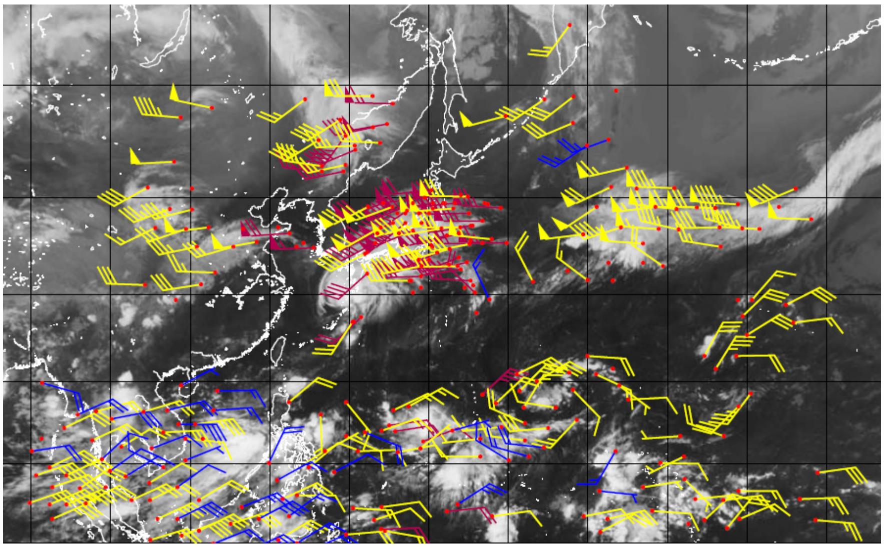
Figure 3 shows U-component wind speed biases verified against radiosonde observations in Japan area (20N–50N and 110E-160E) from 1100 to 1306. TEST is nearer to zero than CNTL in analysis and first guess above 400 hPa. It means that the increase of MTSAT-2-RS-AMVs reduced ME and RMSE of wind speed in analysis fields in GSM-DA. Figure 4 shows forecast improvement rate with respect to RMSE for 1-3 day forecasts in Japan area from 1100 to 1306. The horizontal axis is forecast hours and the vertical axis is the rate of improvement, which is calculated with the next formula.

$$\frac{\left(RMSE_{CNTL} - RMSE_{TEST}\right)}{RMSE_{CNTL}} \quad (1)$$

Figure 4 shows many positive values or large improvement. In particular there is a clear improvement in three-day forecast ability in terms of 250 hPa winds. These characteristics are also shown in Northern Hemisphere (not shown). Figure 5 shows the averaged typhoon track errors in the three sections.



(a)



(b)

***Figure 2*: MTSAT-1R IR image at 1718 and distribution of MTSAT AMVs wind barbs after QC on 300 hPa from 1717 to 1719. (a) CNTL. (b) TEST. Red, yellow and blue barbs are MTSAT-2-RS-AMVs_4MIN or MTSAT-2-RS-AMVs_7MIN, MTSAT-2-RS-AMVs_15MIN and MTSAT-1R AMVs, respectively. The unit of wind barbs is knots. Wind half-barbs are 5 knots, and full- barbs are 10 knots. Wind flags are 50 knots.**

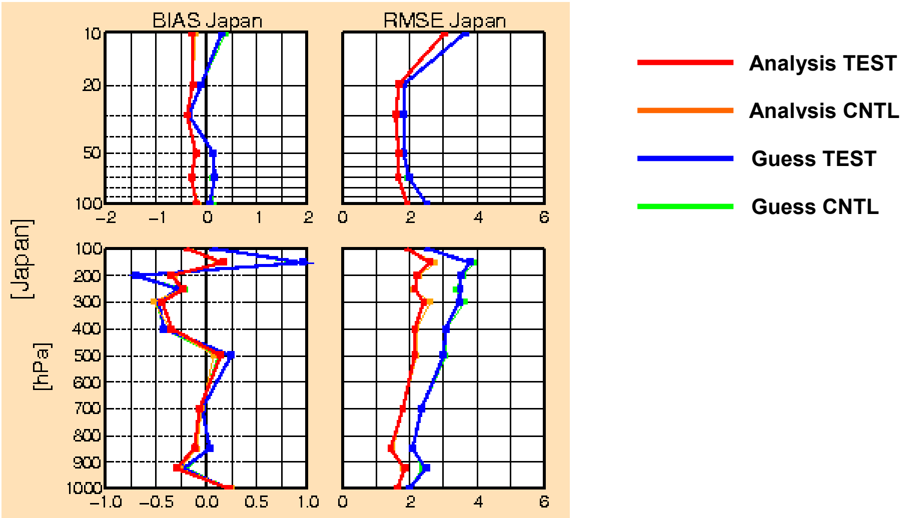


Figure 3: **U-component wind speed biases (m/s) and RMSE (m/s) against radiosonde observations from 1018 to 1306.**

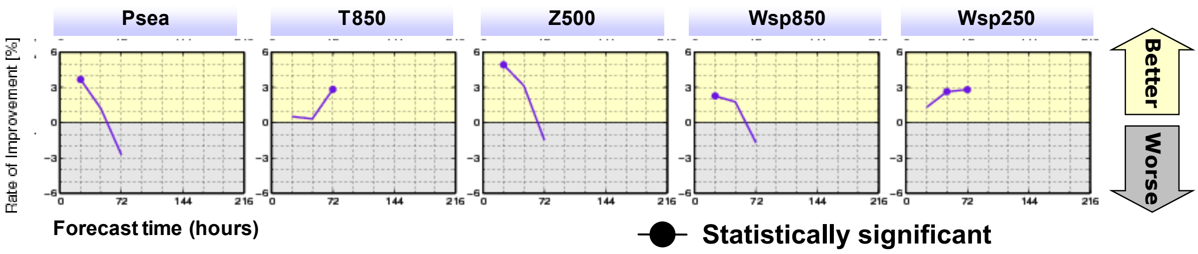


Figure 4: **Forecast Improvement Rate with regard to RMSE for 1-3 day forecasts from 1018 to 1306. "Psea" is surface pressure. "T850" is 850 hPa temperatures. "Z500" is 500 hPa geopotential heights. "Wsp850" is 850 hPa wind speeds. "Wsp250" is 250 hPa wind speeds. Positive value means better score.**

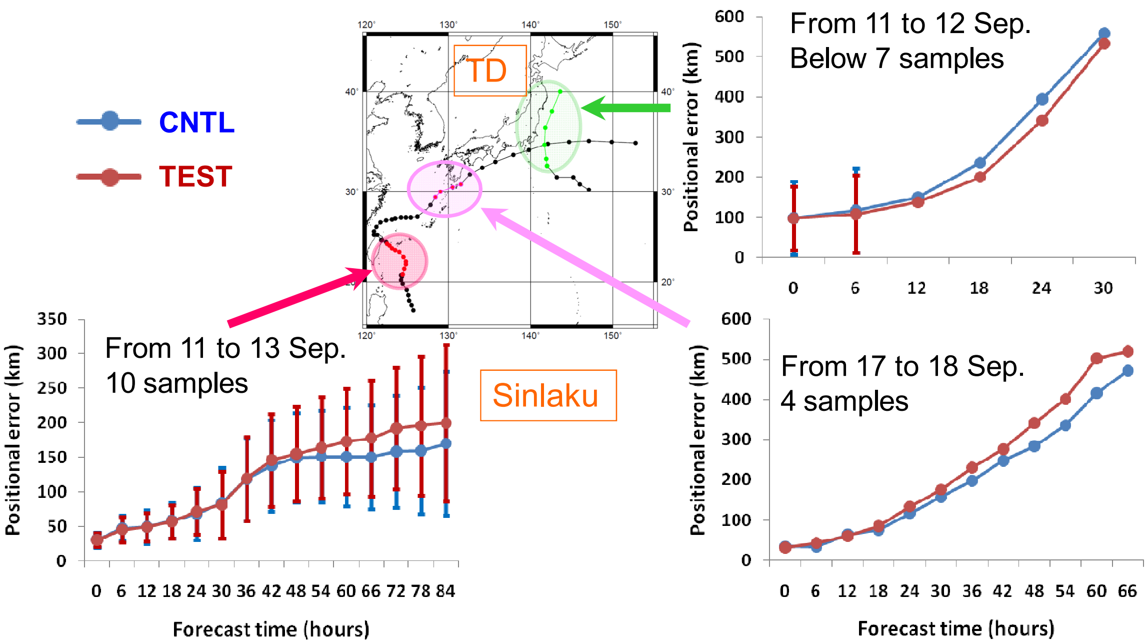


Figure 5: **Positional errors for Typhoon Sinlaku and TD in the three sections in GSM. The red line is for TEST, in which MTSAT-2-RS-AMVs were assimilated. The blue line is for CNTL, in which MTSAT-2-RS-AMVs were not assimilated. Error bar means a 95% confidence interval. The red, pink and green colors show TC positions that MTSAT-2 rapid scan observations were performed.**

Sinlaku track errors increased by approximately 12-18% compared to CNTL in the late-forecast time. The reason seems that the timing in the atmospheric flow by Sinlaku late-forecast was not better in zone of westerly. However, it is not clear whether the rapid scan AMVs caused the problems. These problems need to be investigated. On the other hand, TD track errors reduced by an average of 9% compared to CNTL for mainly 12- to 30-hour forecasts.

(B) RESULTS FOR MSM-DA

Figure 6 shows RMSEs and biases of forecasts at initial times verified against winds speed of Japanese radiosonde observations for 10-13 and 17-18 September 2008. Although slightly increase of negative bias is shown in Fig. 6, RMSE above 500 hPa level were reduced, where many MTSAT-2-RS-AMVs were assimilated. Figure 7 shows the equitable threat scores verified against Radar-Rainfall composite precipitation data in Japan for 10-13 and 17-18 September 2008. The left panel is the score for each threshold of precipitation. The right panel is the one for each forecast time for 10 mm per 3 hours of precipitation. Horizontal resolution of this verification is in 10 km grid. There was the improvement of rain in one-day forecasting for precipitation over 1-15 mm per three hours around Japan. Figure 8 shows the averaged typhoon track errors in the three sections. Sinlaku track errors reduced by an average of 12% compared to CNTL for mainly first-21-hour forecasts in the after-recuvature stage. TD track errors reduced by an average of 12% compared to CNTL for mainly first-21-hour forecasts.

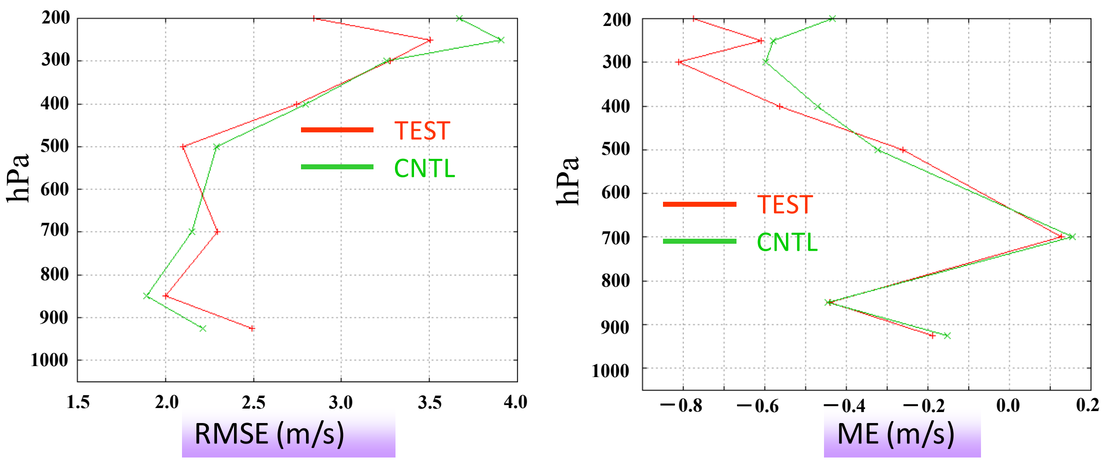


***Figure 6*: RMSE of AMVs (left side figure) and ME of AMVs (right side figure) against Japanese Radiosonde Wind speeds at initial time of 00,06,12 and 18 UTC for 10-13 and 17-18 September 2008.**

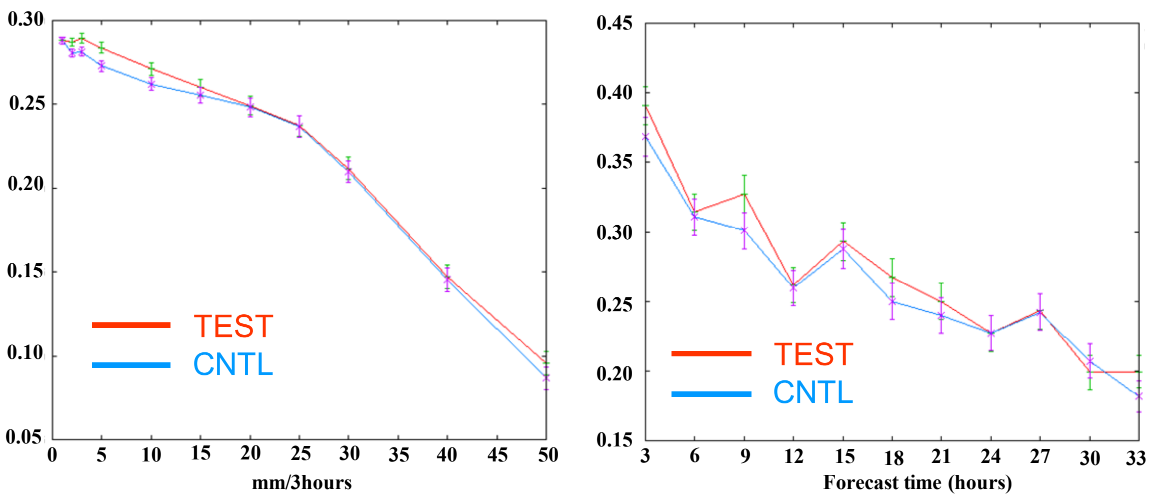


***Figure 7*: Equitable threat score against Radar-Rainfall composite precipitation data in Japan at 00,06,12 and 18 UTC for 10-13 and 17-18 September 2008. Left side figure is equitable threat score for each threshold of precipitation. Right side figure is equitable threat score for each forecast time for10 mm precipitation per 3 hours. Horizontal resolution for this verification is in 10 km grid. Error bar means a 95% confidence interval.**

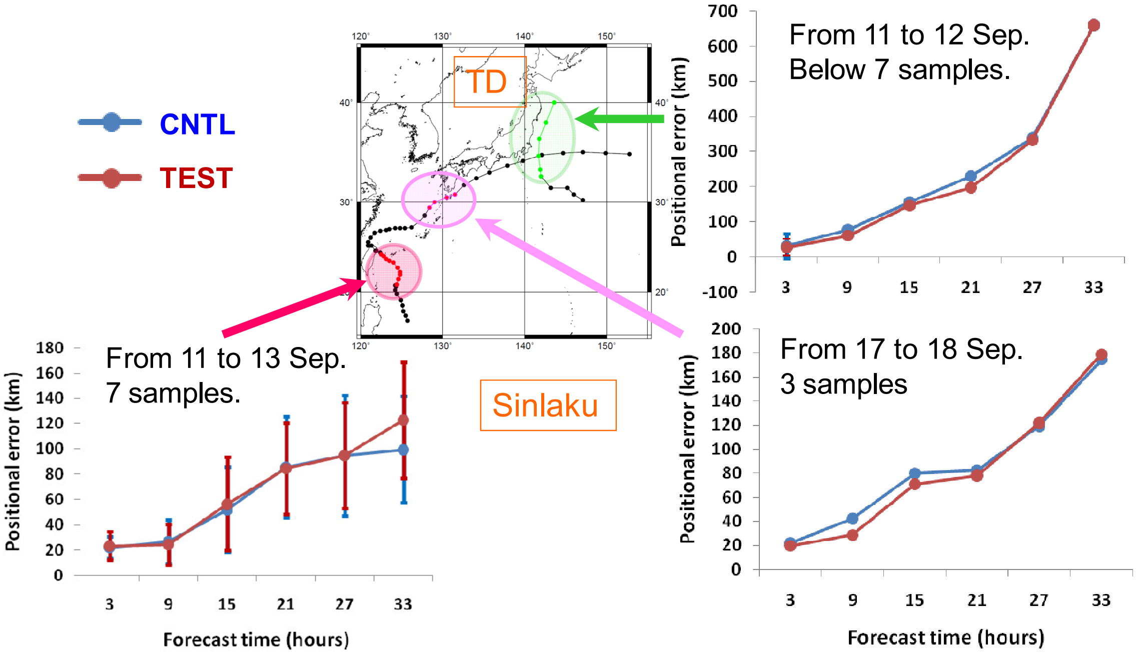


***Figure 8*: Positional errors for Typhoon Sinlaku and TD in the three sections in MSM. Others are same as Figure 5.**

6. SUMMARY

The OSEs for MTSAT-2-RS-AMVs using the global and meso-scale NWP system were conducted as a first step to achieve the objectives of both the improvement of regional prediction and the study of the impact of the mechanism of TCs in T-PARC 2008 project. The trial of a two-step thinning scheme for loosened thinning of MTSAT-2-RS-AMVs was performed to use many independent AMVs. The scheme contributed to increasing the number of AMV data in the vicinity of Japan where AMVs data were sparse. As the results of OSEs, ME and RMSE of wind against radiosonde observations in GSM and MSM were approximately reduced. This better wind analysis improved Sinlaku and TD predictions in GSM and MSM up to 9-12% on an average compared to CNTL. On the other hand, Sinlaku track errors in GSM increased by approximately 12-18% compared to CNTL in the late-forecast time. We need to investigate what made worse the timing in the atmospheric flow. As a whole, MTSAT-2-RS-AMVs contributed to improving the analysis fields and forecasts in the case studies.

7. REFERENCES

Honda, Y. and K. Sawada, (2008): A New 4D-Var for Mesoscale Analysis at the Japan Meteorological Agency. CAS/JSC WGNE Res. Activ. Atmos. Oceanic Modell., 38, 01.7-01.8.

Honda, Y. and K. Sawada, (2009): Upgrade of the Operational Mesoscale 4D-Var System at the Japan Meteorological Agency. CAS/JSC WGNE Res. Activ. Atmos. Oceanic Modell., 39, 01.11-01.12.

Hoshino, S., K. Shimoji, R. Oyama and T. Nakazawa, (2010): Verification of AMVs in the T-PARC period, *Proceedings of 10th IWW*, Japan.

JMA, (2007): Outline of the Operational Numerical Weather Prediction at the Japan Meteorological Agency March 2007, 1-194.

Langland, R. H., C. Velden, P. M. Pauley and H. Berger, (2009): Impact of Satellite-Derived Rapid-Scan Wind Observations on Numerical Model Forecasts of Hurricane Katrina. Mon. Wea. Review, 137, 1615-1622.

Nakagawa, M., (2009): Outline of the High Resolution Global Model at the Japan Meteorological Agency. *RSMC Tokyo-Typhoon Center Technical Review,* **11**, 1-13.

Oyama, R., (2010): Recent upgrades of and activities for atmospheric motion vectors at JMA/MSC, *Proceedings of 10th IWW*, Japan.

Pu, Z., X. Li, C. Velden, S. Aberson, and W. T. Liu, (2008): The impact of aircraft dropsonde and satellite wind data on the numerical simulations of two landfalling tropical storms during Tropical Cloud Systems Processes Experiment. Wea. Forecasting, 23, 62–79.

Simoji, K., (2010): The development for MTSAT rapid scan high resolution AMVs at JMA/MSC, *Proceedings of 10th IWW*, Japan.

Yamashita, K., (2008): Upgraded Usage of Atmospheric Motion Vectors Geostationary Satellites in the Operational Global and Meso-Scale 4D-Var Assimilation System at JMA, *Proceedings of 9th IWW*, USA.

Yamashita, K., Y. Ohta, K. Sato and T. Nakazawa, (2010): Observing-system experiments using the operational NWP system of JMA. *RSMC Tokyo-Typhoon Center Technical Review*, **12**, in press.

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