AN OBSERVING SYSTEM EXPERIMENT OF MTSAT RAPID SCAN AMV USING JMA MESO-SCALE OPERATIONAL NWP SYSTEM

Koji Yamashita

Japan Meteorological Agency / Numerical Prediction Division
1-3-4, Otemachi, Chiyoda-ku, Tokyo 100-8122, Japan

Abstract

In 1st July 2010, Meteorological Satellite Centre of Japan Meteorological Agency (JMA/MSC) switched the operational geostationary satellite of JMA from MTSAT-1R to MTSAT-2 and the MTSAT-1R became a backup satellite. Using the backup satellite, a test operation of Rapid Scan Observations (RSOs) was conducted in summer and autumn 2010. JMA/MSC produced MTSAT-1R Rapid Scan Atmospheric Motion Vectors (RS-AMVs) from the satellite images with the intervals of 5 minutes. For the validation of the two-step thinning scheme as same method for T-PARC 2008 (Nakazawa 2010), additional Observing System Experiments (OSEs) were performed using MTSAT-1R RS-AMVs in JMA meso-scale operational Numerical Weather Prediction (NWP) system. Also OSEs for investigation of the super-observation procedure were carried out. The super-observation procedure is a method which is used an average of AMVs (RS-AMVs and other AMVs) with certain intervals (100km or 200km) in hourly time window. Averaging of AMVs are carried out about time, level, space, wind directions and speeds.

The results of the OSEs brought that mean error (ME) and root mean square error (RMSE) of wind analysis in the JMA meso-scale NWP system against radiosonde observations reduced in both the two-step thinning scheme and super-observation procedure. And the improvement of 15-hours rain forecast for moderate precipitation was led.

1. INTRODUCTION

In the 10th International Winds Workshops (IWW10), results of OSEs of MTSAT-2 RS-AMVs for T-PARC 2008 improving the performance of NWP for tropical cyclones were reported using the JMA operational NWP system (Yamashita 2010). In the OSEs, a two-step thinning scheme was tested, which is a combination of the 100 km thinning of MTSAT-2 RS-AMVs and the 200 km thinning of all the operational AMVs from MTSAT-1R, GOES and Meteosat. The OSEs showed the use of RS-AMVs reduced RMSE of wind analysis against radiosonde observations. This improved wind analysis have positive impact on tropical cyclone track predictions (ave. 9-12% compared to control case) in this test. This test is only one case. To verify this positive impact, the further OSEs are needed.

Using the backup satellite, MTSAT-1R, a test operation of RSOs was conducted in summer and autumn 2010. JMA/MSC produced MTSAT-1R RS-AMVs from the satellite images with the intervals of 5 minutes. The OSEs for the further validation of the two-step thinning scheme were performed using MTSAT-1R RS-AMVs (hereafter "MTSAT-1R RS-AMV" referred to as the "RS-AMV").

Moreover, RSOs can catch shorter lifetime clouds than the standard geostationary satellite observations with the interval of 15 minutes or shorter. Therefore the more numerous and more accurate AMVs can be derived by RSOs (EUMETSAT 2008). But JMA‘s NWP system does not have a capability to use such a large number of RS-AMVs efficiently. Therefore JMA started investigation of the super-observation procedure averaging the close individual AMVs to utilize the information of RS-AMVs more and to use the larger number of AMVs in the JMA operational NWP system. The super-observation procedure for AMV use have used in the Naval Research Laboratory Atmospheric Variational Data Assimilation System (Pauley 2003). As a trial, OSEs were carried out to improve the performance of NWP using RS-AMVs in the JMA operational NWP system.

In this paper, section 2 introduces outline of the global and meso-scale NWP system. Section 3 shows the verification of RS-AMV. Section 4 describes the experimental design. 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 configuration of the JMA global and meso-scale NWP system is listed in Table 1 and Table 2 respectively. The first guess of the Global NWP system is used in verification of AMVs. 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*: Configuration of the global NWP system at JMA**

Data Assimilation System for Global Spectral Model (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	Used

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*: Configuration of the meso-scale NWP system at JMA**

Data Assimilation System for Meso-scale Grid Model (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	Used

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. VERIFICATION OF RS-AMV

The qualities of the RS-AMVs and MTSAT operational AMVs (RTN-AMVs) with the intervals of 15 or 30 minutes were evaluated statistically against the radiosonde observations and the first guess of the GSM-DA. And the evaluation of RS-AMVs was compared with RTN-AMVs. Study period is from 12th August to 3th September in 2010. Quality Indicator (QI) value with first guess check for evaluated AMV is used value of more than 85. QI developed at EUMETSAT (Holmlund 1998). Verification area is from 120° E to 150° E, 20° N to 45° N (Figure 1). Figure 2 shows some results of RS-AMV wind speed scatter plots against radiosonde observations compared with RTN-AMVs for water vapor channel AMVs (WV-AMVs) above 400 hPa and infrared channel AMVs (IR-AMVs) below 700 hPa. RS-AMVs are almost equal to correlation coefficient against radiosonde observations compared with RTN-AMVs. Then accuracy of RS-AMVs including other channel RS-AMVs (not shown) is almost same as RTN-AMVs. Figure 3 shows histograms of RS-AMV and RTN-AMV wind speeds minus the first guess of the GSM-DA (O-B), Mean Error (ME) and Standard Deviation (STD). The distributions of both RS-AMVs and RTN-AMVs have Gaussian distribution which is suitable for 4D-Var systems. WV-RS-AMVs have positive bias against the first guess. RS-AMVs above 400 hPa have smaller STD than RTN-AMVs. On the other hand, RS-AMVs below 700 hPa have larger STD than RTN-AMVs. These results are within acceptable range of JMA DA. The acceptable ranges are as follows: O-B STD is up to 5 m/s above 400 hPa, up to 4 m/s between 700 hPa and 400 hPa, up to 2 m/s below 700 hPa. O-B BIAS is up to 2 m/s with all AMVs. Figure 4 shows error correlation distance of both RS-AMV and RTN-AMV wind speeds, using RS-AMV or RTN-AMV wind speeds minus the first guess of the MSM-DA (O-B_MSM). The O-B_MSM error correlations distance as alternative Observation Error Correlation Distance (OECD) was calculated because OECD was difficult to evaluate.

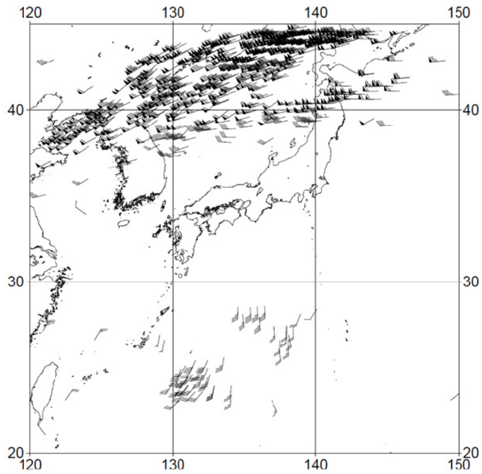


Figure 1 : Verification area

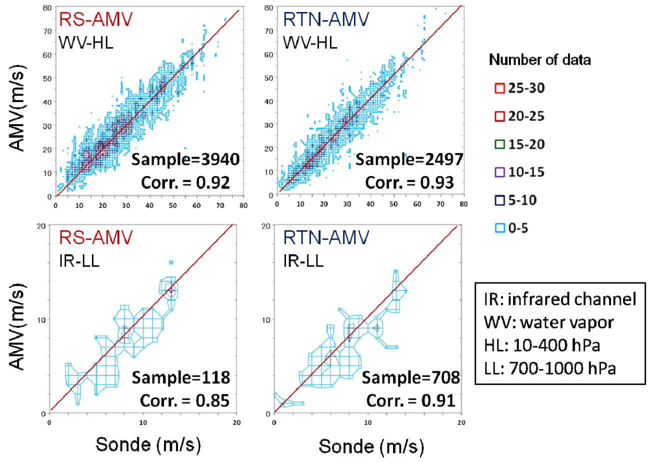
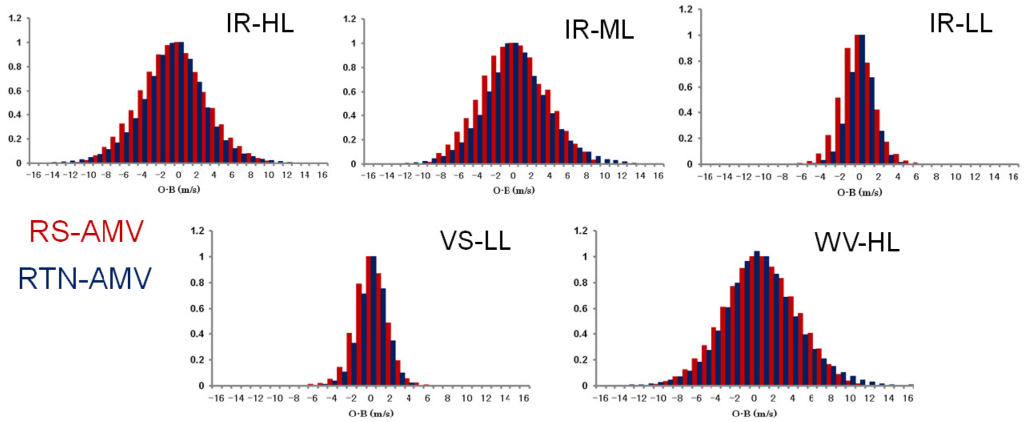


Figure 2 : RS-AMV wind speeds scatter plots against radiosonde observations compared with RTN-AMVs from 12th August to 3th September in 2010.



IR: infrared channel
VS: visible channel
WV: water vapor
HL: 10-400 hPa
ML: 400-700 hPa
LL: 700-1000 hPa

	RS_AMV			RTN-AMV		
TYPE	COUNT	ME (m/s)	STD (m/s)	COUNT	ME (m/s)	STD (m/s)
IR-HL	84588	-0.44	3.67	201842	-0.76	3.75
IR-ML	7673	0.08	3.49	16771	0.13	3.78
IR-LL	17495	-0.10	1.79	91486	-0.09	1.42
VS-LL	11395	0.09	1.70	20795	-0.01	1.47
WV-HL	152747	0.77	3.73	248160	0.58	3.98

Figure 3 : RS-AMV and RTN-AMV wind speeds minus the first guess of the GSM-DA (O-B) as histogram, Mean Error (ME) and Standard Deviation (STD) from 12th August to 3th September in 2010.

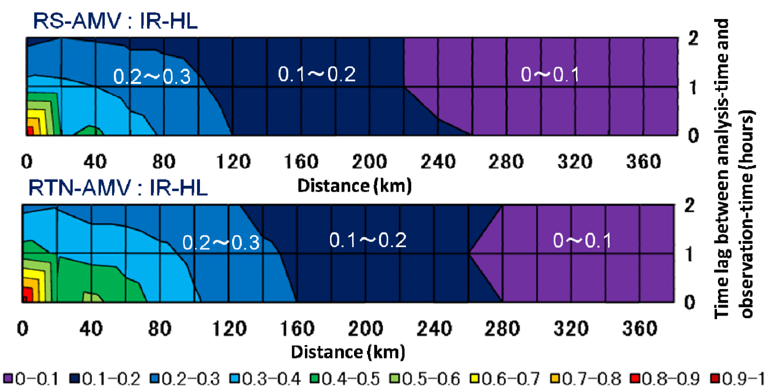


Figure 4 : Spatial and time O-B_MSM error correlations distance of both RS-AMV and RTN-AMV wind speeds in IR-HL from 12th August to 3th September in 2010.

AMVs are needed to have short OECD to avoid the observation error correlation among neighbor observations for saving the computational cost of 4D-Var system. The spatial and time-error correlation distance of O-B_MSM in RS-AMVs is shorter than those of RTN-AMVs.

4. EXPERIMENTAL DESIGN

Experimental design is outlined in Table 3. Four kinds of numerical experiments that differed in their usage of RS-AMVs using the MSM-DA were performed. A two-step thinning scheme and a super-observation procedure were used as a trial. In the two-step thinning scheme, RS-AMVs 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 3-hour time window) of other AMVs. The super-observation procedure is a method which is used an average of AMVs (RS-AMVs and other AMVs) with 100 or 200 km intervals in hourly time window. Averaging of AMVs are carried out about time, level, space, wind directions and speeds. A case study is Heavy Rain and Typhoons (LIONROCK,KOMPASU and NAMTHEUN) in Okinawa, the western and northern part of Japan. Typhoon tracks are shown with brown, purple and greeen lines (Figure 5). Period of verification is from 25 August to 3 September in 2010.

***Table 3*: Experimental design of OSEs for RS-AMV**

Name	Specification
RTN	A scheme of the 200 km thinning of RTN-AMVs in the 3 hour time window
2STP	two-step thinning scheme A combination scheme of the 100 km thinning of RS-AMVs in hourly time window and the 200 km thinning of RTN-AMVs in 3 hour time window
200kmSuper-ob	Super-observation procedure Average of AMVs (RS-AMVs and RTN-AMVs) directions and speeds with 200 km intervals in hourly time window. Averaging about time, level, space, wind directions and speeds.
100kmSuper-ob	Same as above with 100 km intervals

5. RESULTS OF THE EXPERIMENTS

Figure 5 : Typhoon (LIONROCK,KOMPASU and NAMTHEUN) tracks between 12th August and 3th September in 2010.

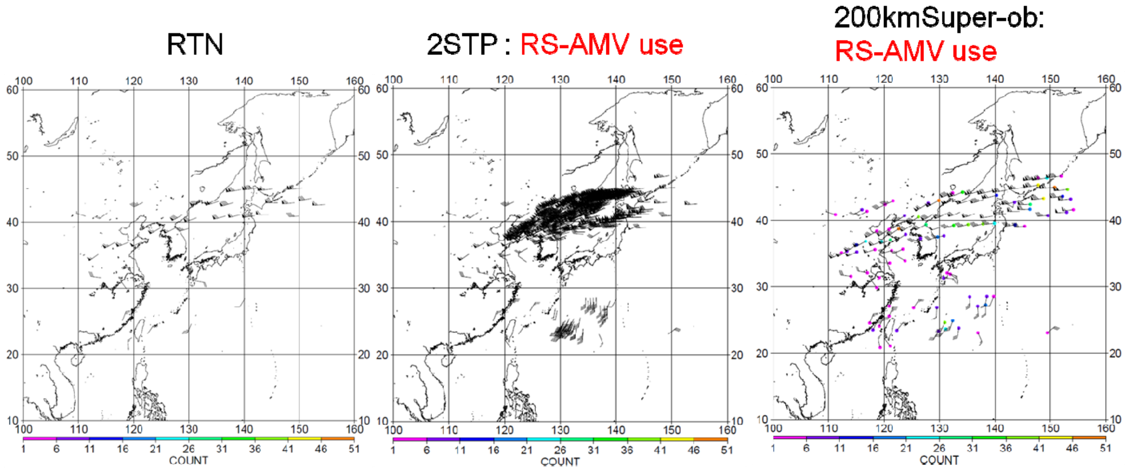


Figure 6 : Distribution of MTSAT AMVs after QC on 300 hPa at 06 UTC 26 August 2010. Left figure shows in RTN, center figure shows in 2STP, right figure shows in 200kmSuper-ob. The color range is shown number of AMVs used for super-observation scheme. The unit of wind barbs is knots. Wind half-barbs are 5 knots, and full- barbs are 10 knots. Wind flags are 50 knots.

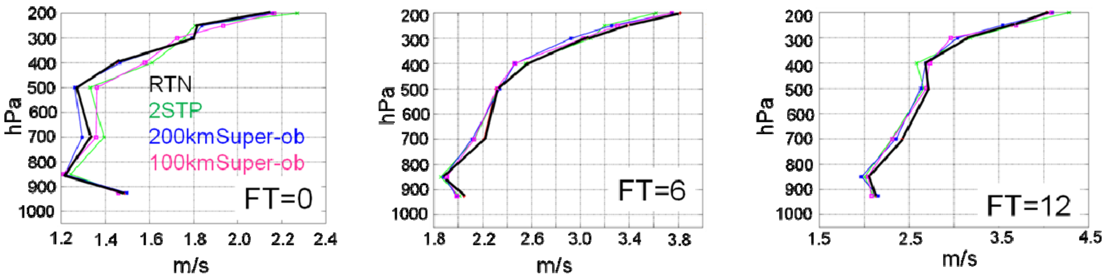


Figure 7 : RMSE of AMVs against Japanese radiosonde wind speeds at initial time of 00,06,12 and 18 UTC

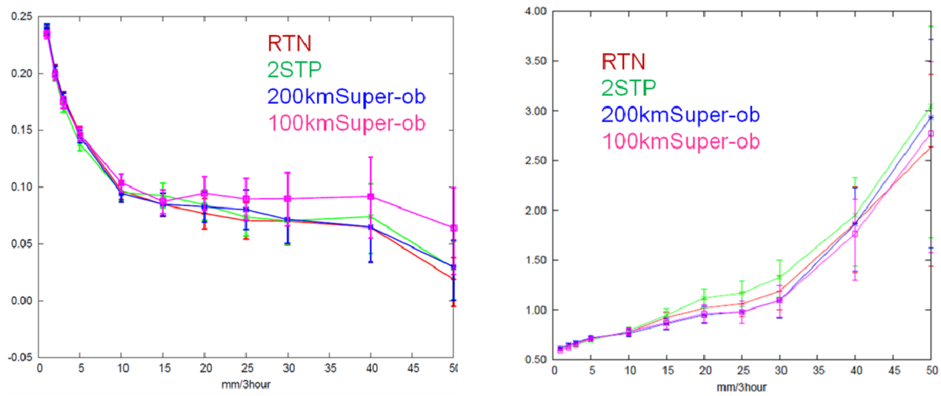


Figure 8 : Equitable Threat Score (left) and Bias Score (right) against Radar-Rainfall composite precipitation for each threshold of precipitation at initial time of 00,06,12 and 18 UTC.

Figure 6 shows AMV examples of the adoption of two-step thinning and 200km super-observation schemes on 300hPa compared with RTN. Using these schemes, the increase of AMVs was brought in 40° N belt and southern sea of Japan where AMVs data was sparse heretofore.

Figure 7 shows RMSEs of forecasts against Japanese radiosonde observations. RMSEs of forecasts in almost all level were slightly reduced in OSEs of RS-AMV (2STP, 200kmSuper-ob and 100kmSuper-ob) compared with RTN except initial forecast time (FT=0). RMSEs of Initial forecasts increase mainly middle level. These results are thought that the strain by assimilation of RS-AMVs is shown. But, after that, subsequent forecasts are shown good performance by advection effect of RS-AMVs. Figure 8 shows

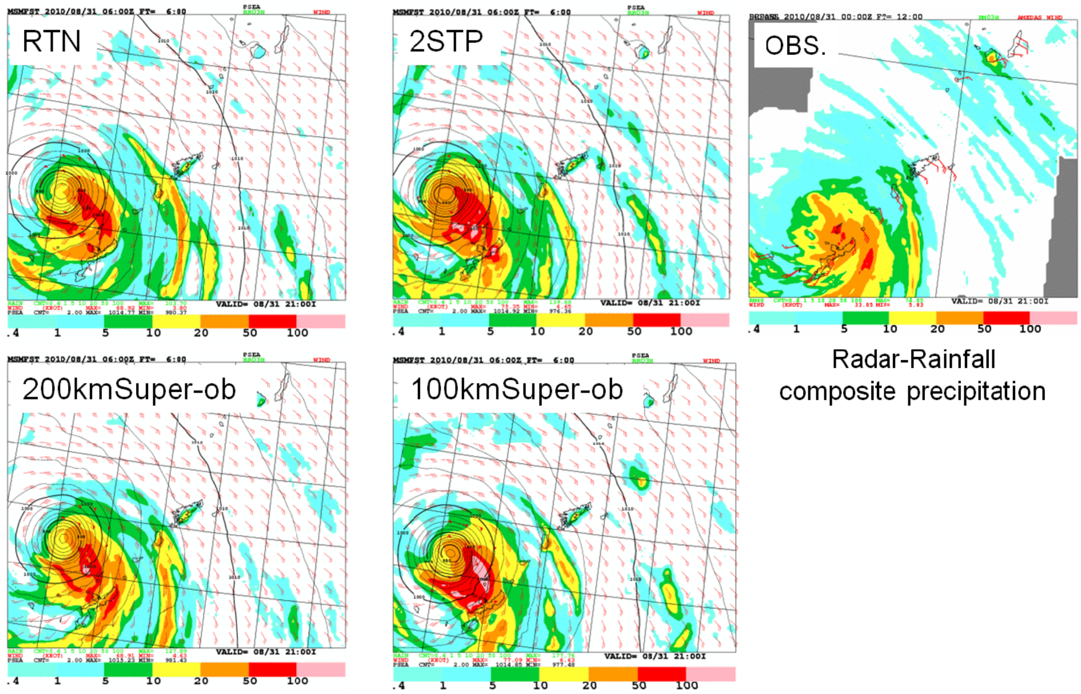


Figure 9 : A case study of 6-hour forecasts (FT=6) at initial time of 06 UTC 31 August 2010. The color range is shown precipitation per 3 hours.

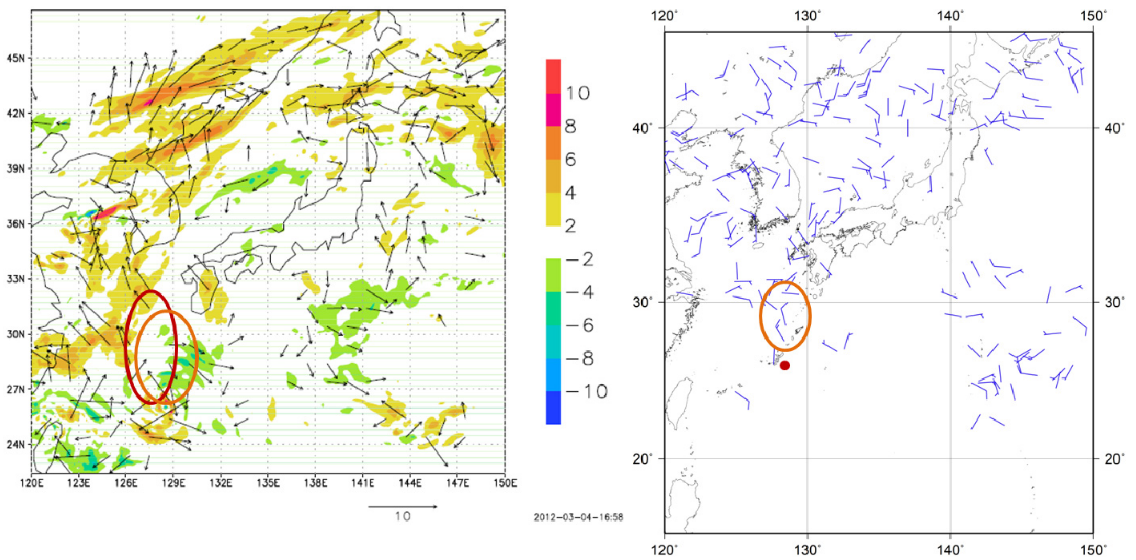


Figure 10 : Description of RS-AMV effect. Left side figure shows wind speed differences (m/s: color ranges) and wind vector differences (m/s) of 100kmSuper-ob minus RTN in 400 hPa at initial time of 06 UTC 31 August 2010. Right figure shows O-B of RS-AMVs for 100kmSuper-ob in 400 hPa at same initial time. The unit of wind barbs is knots. Wind half-barbs are 5 knots, and full- barbs are 10 knots. Wind flags are 50 knots. A red point in right side figure is shown position of typhoon KOMPASU at 06 UTC 31 August 2010.

Equitable Threat Score and Bias Score against Radar-Rainfall composite precipitation for each threshold of precipitation. Initial forecast time is 00,06,12 and 18 UTC. Resolution of this verification is in 20 km grid. There was improvement of precipitation forecasts over 15 mm per three hours in 15-hours forecast in RS-AMV use (especially 100kmSuper-ob) compared with RTN.

Figure 9 shows a case study of 6-hour forecasts (FT=6) at 06 UTC 31 August 2010. There is shown that heavy precipitations around Okinawa brought by typhoon KOMPASU in this case study. Because assimilation of RS-AMVs (orange color circle in Figure 10) around Okinawa strengthened divergence fields (red color circle in Figure 10) in the northern part of the typhoon, the precipitation distribution patterns of RS-AMVs use (2STP, 200kmSuper-ob and 100kmSuper-ob) were similar. These results are

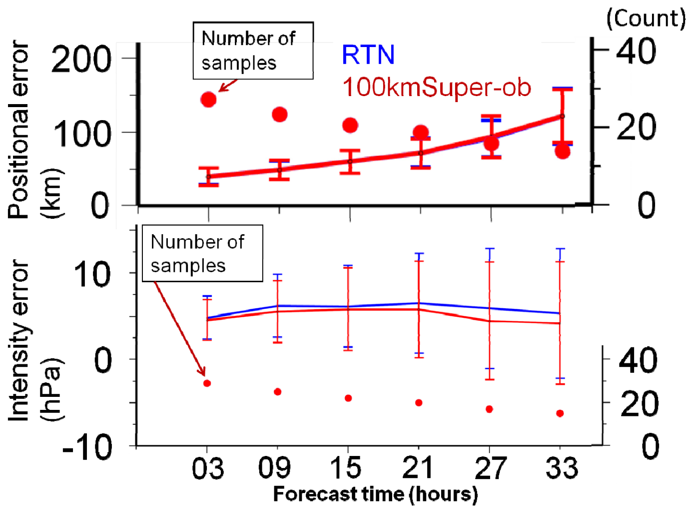


Figure 11 : Mean four typhoons track (upper figure) and intensity (bottom figure) forecast errors for RS-AMV with 100kmSuper-ob against RTN.

considered the better atmospheric analysis by assimilation of RS-AMVs around the typhoon brought good precipitation forecasts, although detailed mechanism could not be confirmed. Figure 11 shows the mean four typhoons track and intensity forecast errors. The typhoon track errors are shown no impact in this case study, but the typhoon intensity forecast errors are shown slight improvement.

6. SUMMARY

JMA/MSC produced MTSAT-1R RS-AMVs from the satellite images with the intervals of 5 minutes. Wind speeds of RS-AMV were verified with RTN-AMV in summer 2010. An accuracy of RS-AMVs was confirmed to be almost same as RTN-AMVs. The OSEs for the validation of the two-step thinning and super-observation scheme for RS-AMVs were performed using the JMA meso-scale operational NWP system in 2010. RMSEs of forecasts against Japanese radiosonde observations in almost all level were slightly reduced in OSEs of RS-AMV with both of schemes. There was improvement of precipitation forecasts over 15 mm per three hours in 15-hours forecast (especially 100km super-observation scheme). The typhoon track errors are shown no impact, but the typhoon intensity forecast errors are shown slight improvement.

JMA has an plan to perform more OSEs for MTSAT RS-AMVs to investigate the further performance of procedures, although 100km super-observation has good scheme in this case study. The consideration of procedure is two-step thinning scheme and some super-observations. A good performance scheme from many case studies will be selected. JMA has an plan to use RS-AMVs in the JMA operational NWP system from March 2013.

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