OPERATIONAL ASSIMILATION OF QUIKSCAT/SEAWINDS OCEAN SURFACE WIND DATA AT JMA

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ABSTRACT

To assimilate QuikSCAT winds in the operational 3D-VAR system at JMA, impact studies using QuikSCAT winds in December 2001 and July 2002 were performed with T213L40 version of the global NWP model. Throughout the experiment, QuikSCAT winds after the ambiguity removal and quality control were recognized to have a good enough quality to be used for NWP. The evident positive impacts on forecast performance were not recognized over all regions, but small positive impact on the northern hemisphere in summer. In addition, the remarkable positive impacts were recognized for forecasting track of typhoons. JMA started to use QuikSCAT wind data operationally in the global NWP system at 12 UTC on 5 May 2003.

Furthermore, impact studies using QuikSCAT winds in 4 June to 18 2003 and in 2 February to 14 were performed with the operational meso-4D-Var at JMA. The accuracy difference between the experiment and the control is neutral for all elements observed at 00 UTC and 12 UTC in 19 radiosonde stations around Japan in both seasons. However, surface wind fields derived from SeaWinds were analyzed more correctly in severe weather regions. Due to the effectiveness, the impact of QuikSCAT winds on the model was noticeable on the moderate rain (10 mm / 3h) and the heavy rain (30 mm / 3h) forecasts over Japan by 12 hour forecast in summer. It is also recognized that appropriate QuikSCAT winds observation error settings are important to improve rainfall forecast with Meso 4D-VAR.

1. INTRODUCTION

A space-born scatterometer observes wind vectors over the ocean surface, and it provides precious information to numerical weather prediction (NWP) over the ocean, where conventional observations are sparse. A new scatterometer SeaWinds was launched onboard QuikSCAT satellite by National Aeronautics and Space Administration (NASA) / Jet Propulsion Laboratory (JPL) in 19 June 1999, as "quick recovery" mission to fill the gap created by the loss of data from NASA Scatterometer (NSCAT), when the Japanese Advanced Earth Observation Satellite (ADEOS) lost power in June 1997 (JPL 2001). The QSCAT satellite was launched into a sun-synchronous, 98.6 degrees inclination 803 km, and circular orbit with a local equator crossing time at the ascending node of 6:00 a.m. plus and minus 30 minutes. The recurrent and orbital periods of the orbit are four days and 101 minutes, respectively. The mission caries a Ku-band scatterometer, named SeaWinds.

The SeaWinds instrument on the QSCAT satellites is a microwave scatterometer that measures near-surface wind speed and direction under all weather and cloud conditions over the global oceans. The instrument can measure vector wind over a swath of 1800 km with a nominal spatial resolution of 25 km. Daily coverage is about 92% of the global ice-free oceans. It is designed to observe wind vectors with an accuracy of 20 degrees in direction and 2 m/s or 10 % in speed. However, scatterometer do not measure the marine surface wind directly but measure the electromagnetic radiation signal backscattered from the sea surface. Winds are estimated using a Geophysical Model Function (GMF) that relates the backscatter to 10 m neutral equivalent winds. Validation of the observed wind vectors to buoy data was performed to evaluate the quality of the wind vectors and it was concluded that the mission requirements for wind speed and direction are satisfied (Ebuchi et al., 2002).

JMA performed the impact study for SeaWinds data in the global model. As the results, it is evident that forecast scores and typhoon track forecasts are improved by using SeaWinds data. JMA started to use QuikSCAT wind data operationally in the global NWP system on 6 May 2003.

In this paper we show the results of assimilation of the QuikSCAT data in the global NWP model and the effectiveness of the data for forecasting track of a typhoon. We also show the result of impact studies using QuikSCAT winds in the operational meso-4D-Var at JMA.

2. QUALITY CONTROL SYSTEM FOR SCATTEROMETER DATA

JMA receives the QuikSCAT/SeaWinds Operational Standard Product (Level 2.0B(L2B)) from NOAA/NESDIS (Leidner et.al., 2000) in near real-time, and keep uniform quality by the following quality control procedures (Tahara, 2000).

Firstly, we reject the low quality data over land or sea ice and the data flagged as rain (Huddleston and Stiles, 2000) since the data in heavy rain areas have less accuracy due to scatter noises by raindrops.

Secondly, we determine the most likely wind vector among a set of 2 to 4 potential wind vector solutions (known as “ambiguities”) retrieved from original backscattered cross section data by both NWP nudging technique and median filter technique. The former technique chooses the vector closest to the first guess wind and the latter selects the vector similar to adjacent data.

Thirdly, we check wind speed and direction by comparing with first guess winds. It is called as the conventional QC. However, it occasionally rejects correct wind data in and around severe weather systems such as cyclones and fronts since wind direction and speed vary sharply there and the difference between the first guess field and observations tends to be large. We introduce to a QC scheme called as “Group QC” to save those important data.

The Group QC consists of two steps. Firstly, we divide scatterometer data into some groups consisting of adjacent data, which have the similar wind directions and speeds. Then we check the wind distribution of a group against the first guess field. The group QC saves a lot of correct scatterometer data in and around severe weather systems successfully.

Finally winds data are thinned on 1 x 1 degree (lat./long.) in the global 3D-Var analysis and on 50 x 50 km in the meso-4D-Var analysis.

3. IMPACT STUDY FOR SEAWINDS DATA IN THE GLOBAL MODEL

We conducted data assimilation experiments of SeaWinds using the T213L40 version of the JMA global model (GSM0103; JMA 2002) for December 2001 and July 2002. Data assimilation was started from 00 UTC 1 December 2001 (1 July 2002) and continued to 18 UTC 31 December 2001 (31 July 2002). We carried out nine days forecasts started from 12 UTC analysis for the period from 8 December (8 July) to 22 December (22 July). In the experiment for July 2002, relative humidity profiles retrieved from the GMS-5 brightness temperature were not used. Experiments with and without SeaWinds data are referred to as Test run and Control run, respectively.

3.1. Seawinds wind data

Ebuchi et al. (2002) compared SeaWinds L2B data with buoys. They indicated that the root-mean-squared differences of the wind speed and direction were about 1 m/s and 23 degrees, respectively with no systematic biases.

After the QC procedure, we compared between SeaWinds wind data and first guess winds fields. The results showed that RMSE and BIAS in wind speed is 1.91 m/s and 0.81 m/s in December, and 1.87 m/s and 0.66 m/s in July, while RMSE and BIAS in wind direction is 20.18 degrees and 0.81 degrees in December, and 19.70 degrees and 0.81 degrees in July. Those BIASs are similar to those between buoy data and first guess. Thus the SeaWinds wind data have good enough accuracy to be used in NWP. Numbers of SeaWinds data, which pass QC in the cycle analysis and the early analysis are about 10,000 and 6,000, respectively.

3.2. Impact on analysis

Figure 1 shows the impact of the SeaWinds wind data on the analysis fields. The sea surface wind speed difference between the analysis and the first guess field was up to 4 m/s (Figure 1(a)). The impact of SeaWinds DATA is also seen in the difference between the analysis field in Test and that in Control (Test – Control (Figure 1(b)). The result shows that a cyclonic circulation was intensified and sea level pressure was decreased over 45 – 55 S and 120 – 135 W by SeaWinds data assimilation. Thus we can understand that QuikSCAT data contribute to strength cyclonic and anti-cyclonic circulation in the southern hemisphere owing to strength wind speed in the surface.

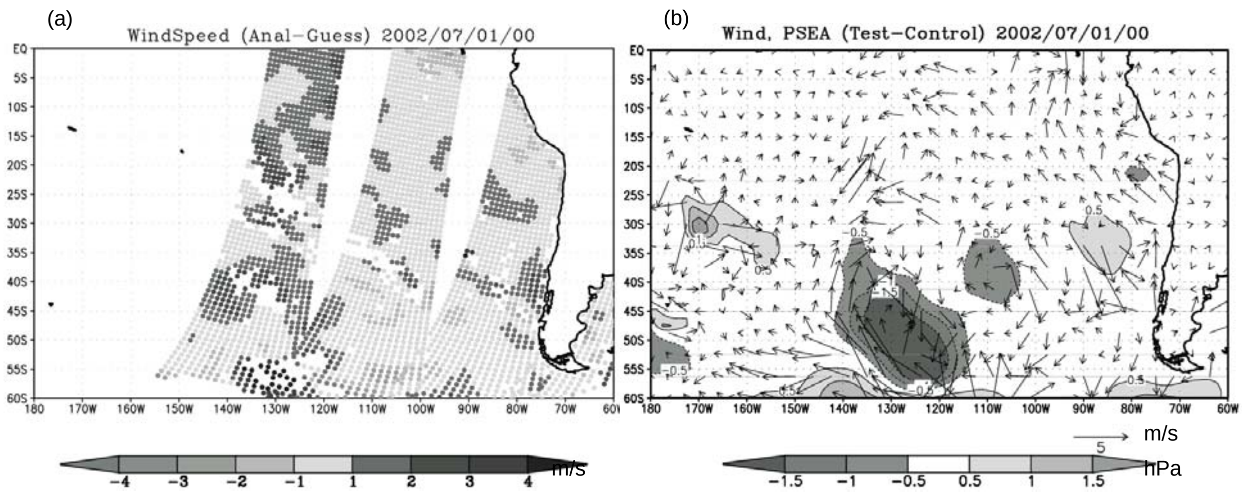

Figure 1. Impact of SeaWinds data on analysis fields at 00 UTC 1 July 2002. (a) Increment of sea surface wind speed (m/s) (Analysis – First guess). (b) Difference of analysis (Test – Control) of sea surface wind vectors (m/s) and sea level pressure (hPa).

3.3. Impact on forecasts

We investigated impact of SeaWinds data on forecasts in July 2002 and in December 2001. Figure 2(a) shows RMSE of surface wind speed calculated from differences between forecast field and initial field for Test and Control in the Northern Hemisphere (20 – 90 N) for July 2002. SeaWinds data has slightly positive impact after 6 days. Positive impact was also recognized in the anomaly correlation of 500 hPa geopotential height particularly in the Northern Hemisphere (Figure 2(b)).

Impacts on almost all elements were neutral in December 2001. However, obvious improvement was seen in the Mean Error of 850 hPa geopotential height in the global and tropical (20 N – 20 S) regions (Figure 2(c)). Improvement was expected in the Southern Hemisphere because of sparsity of conventional data. However, impacts on 500 hPa geopotential height and sea level pressure were almost neutral or slightly negative at the end of forecast times.

3.4. Impact on typhoon track forecasts

We performed the experiment to examine the impact on typhoon track forecasts for July 2002. While the impact depends on forecast cases, position errors of typhoon track forecasts decreased in many cases.

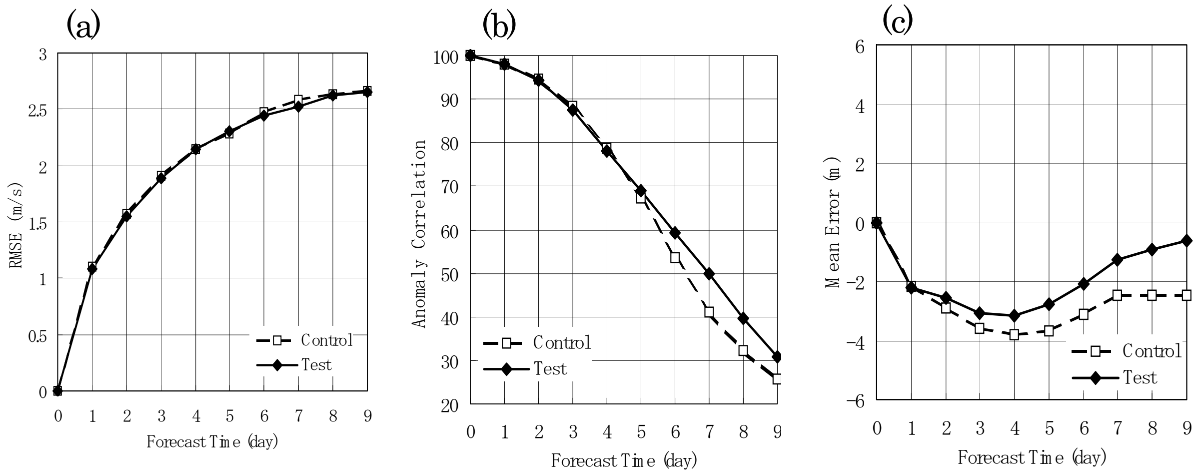

Figure 2. Forecast scores for Test (solid line) and Control (dashed line). (a) RMSE of surface wind speed in the Northern Hemisphere (20 –90N) for July 2002. (b) Anomaly correlation of 500 hPa geopotential height in the Northern Hemisphere for July 2002. (c) Mean error of 850 hPa geopotential height in the tropical region (20N – 20S) for December 2001. The forecasts were started from 12 UTC for the period of 8 to 22 July 2002 (December 2001).

Figure 3 shows QuikSCAT wind data (left) and the enlarged area around typhoon T0207 (HALONG) (right) in the closed square area by red line in the left figure. It seems that QuikSCAT wind data intensify the circulation of the typhoon.

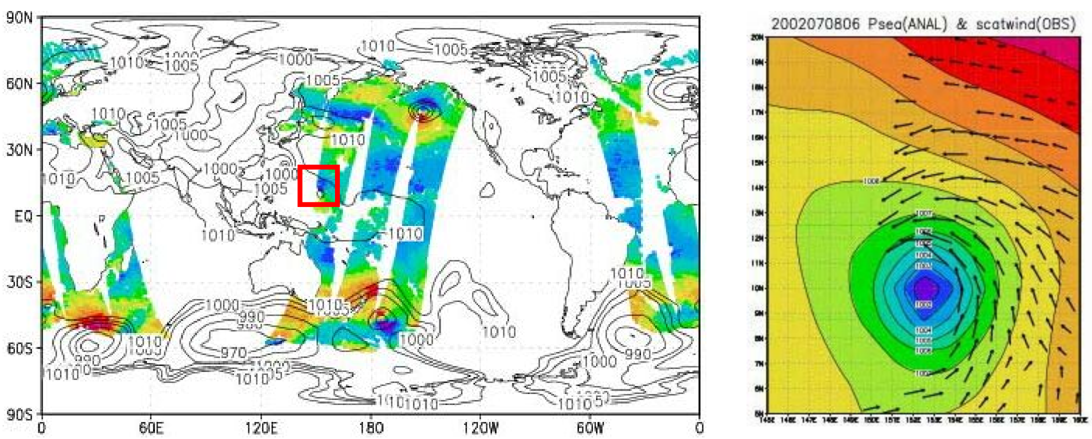

Figure 3. QuikSCAT wind data assimilated at 06 UTC 8 July 2002 (left). The enlarged area around the typhoon (right). QuikSCAT winds are overlayed on the surface pressure field analyzed.

We performed the track forecasts for the typhoon by GSM0103 from the initial time 12 UTC 10 July 2002 assimilating these QuikSCAT wind data 6 hourly. The result shows that the position error of forecasted typhoon track in Test is reduced by as much as 100 km to the best track as shown in Figure 4.

We also performed statistics of the position error of typhoon track forecasts in Test and Control in 36 cases for six typhoons during July 2002. As shown in Figure 5, the mean position error in Test is significantly reduced after 60 hour forecast.

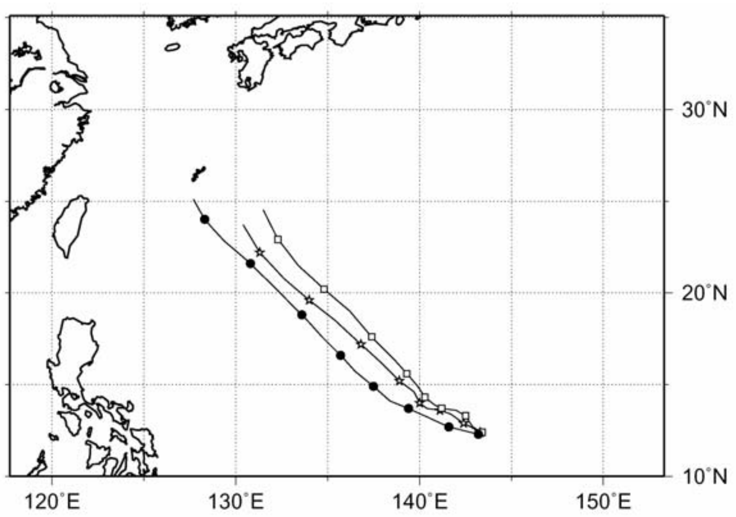

Figure 4. The result of track forecasts for typhoon T0207 (HALONG). Initial time is 12 UTC 10 July 2002. Black circles, squares and stars denote the best track, Control and Test. The symbols are plotted every 12 hours.

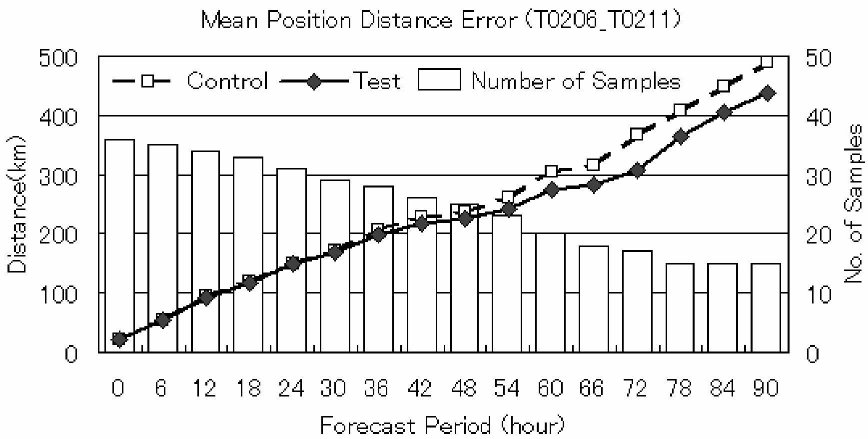

Figure 5. The mean position distance error of forecasted track of typhoons in July 2002 Dash line, solid line and bar denote Control, Test and the number of samples.

4. IMPACT STUDY FOR SEAWINDS DATA IN THE MESO-SCALE MODEL

We conducted data assimilation experiments of SeaWinds using the Meso-analysis with a 4D-VAR scheme (Meso 4D-VAR) in the JMA Meso-Scale Model (MSM) for June 2003 and February 2004. We applied 3 m/s to the observation error of SeaWinds data in the first study and 1 m/s in the second study.

The experiment was started from 00 UTC 4 June 2003 (2 February 2004) and continued to 18 UTC 18 June 2003 (14 February 2004). The observation data except SeaWinds data are conventional observation data (upper air sounding data, surface observationally data, aircraft data, hourly wind profiler data and Rader-AMeDAS precipitation data) and both rain rates (RR) and total column precipitable water (TCPW) retrieved from TRMM, TMI and SSM/I. These data are assimilated hourly in Meso 4D-VAR with 3-hour assimilation windows. We perform 6-hour continuous data assimilation by coupling two sequential Meso 4D-VAR data assimilation and MSM forecast every 6 hours for the 18-hour forecast period. Experiments with and without SeaWinds data are referred to as Test run and Control run, respectively.

4.1. Impact on analysis

Figure 6 shows the impact of the SeaWinds wind data on the analysis fields in the first study. The sea surface wind speed difference between the analysis and the first guess field were up to 3 m/s (Figure 6(a)). The impact of SeaWinds data is also slightly seen in the surface pressure with about 1 hPa difference between the analysis and the first guess field. These impacts are seen clearer in the second study. The accuracy difference between the experiment and the control is neutral for all elements observed at 00 UTC and 12 UTC in 19 radiosonde stations around Japan in both seasons.

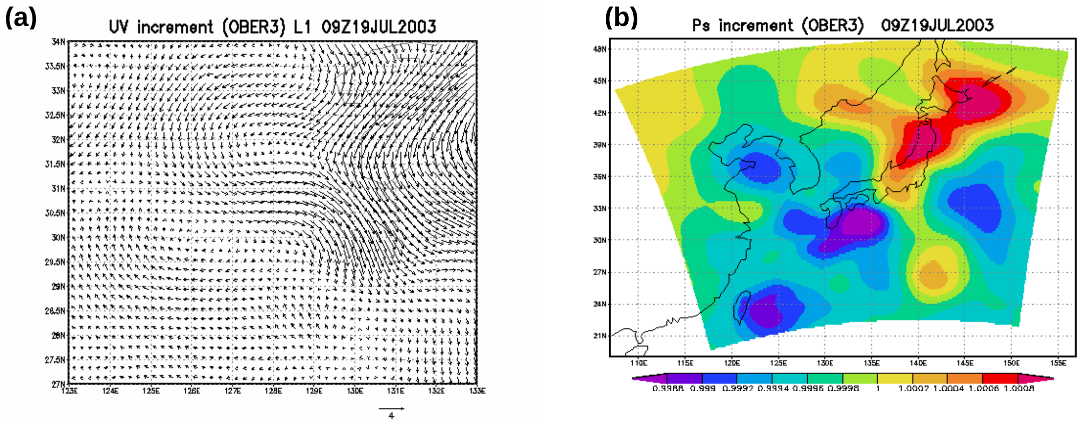

Figure 6. Impact of SeaWinds data on analysis fields at 09 UTC 19 July 2003. (a) Increment of sea surface wind speed (m/s) (Analysis – First guess). (b) Same as (a) except for surface pressure (hPa)

4.2. Impact on forecasts

We investigated impact of SeaWinds data on forecasts in June 2003 and in February 2004.

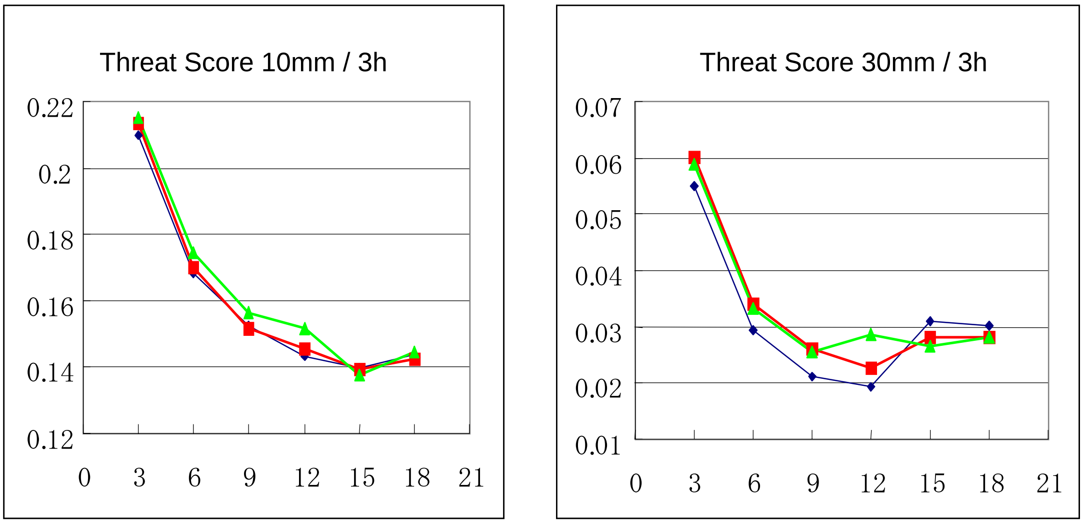

Figure 7. Threat scores of moderate (10 mm / 3h) and heavy (30 mm / 3h) rain for June 2003. Blue line, red line and green line denote Control, First Test and Second Test.

Figure 7 shows the threat scores of moderate (10 mm / 3hour) and heavy (30 mm / 3hour) rain over Japan for June 2003. We compared precipitation accumulated for 3 hours in a 10 km by 10 km box with Radar-AMeDAS precipitation data. The both threat scores show that SeaWinds data have positive impact by 12 hour forecast. It is evident that the positive impact in the second study is greater than that in the first study.

Figure 8 is the same as Figure 7 except for February 2004. The threat score of moderate rain has clearly positive impact by 12 hour forecast, while that of heavy rain has positive impact by 6 hour forecast. However, it fluctuates every forecast, as there are not many cases of moderate and heavy rain over Japan in winter.

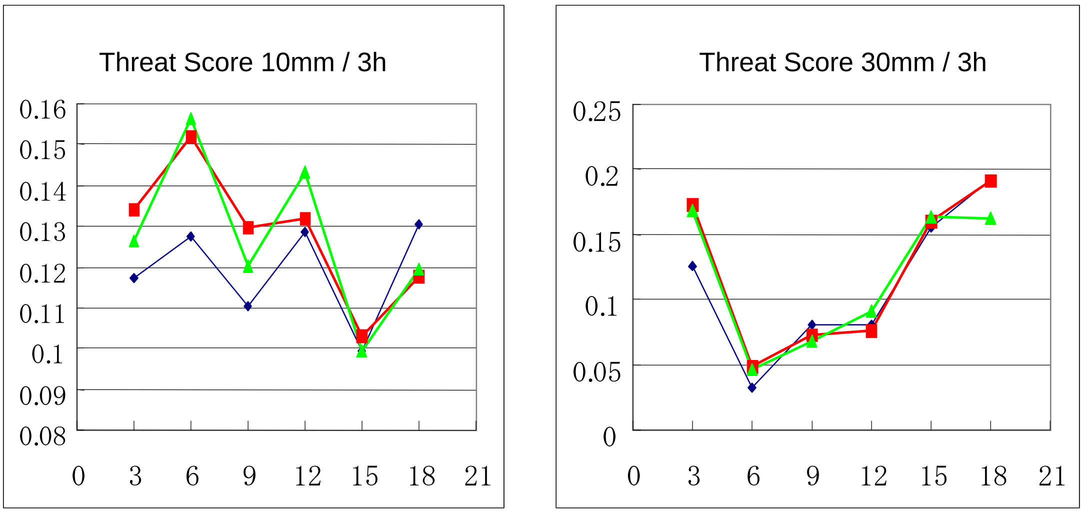

Figure 8. The same as Figure 7 except for February 2004.

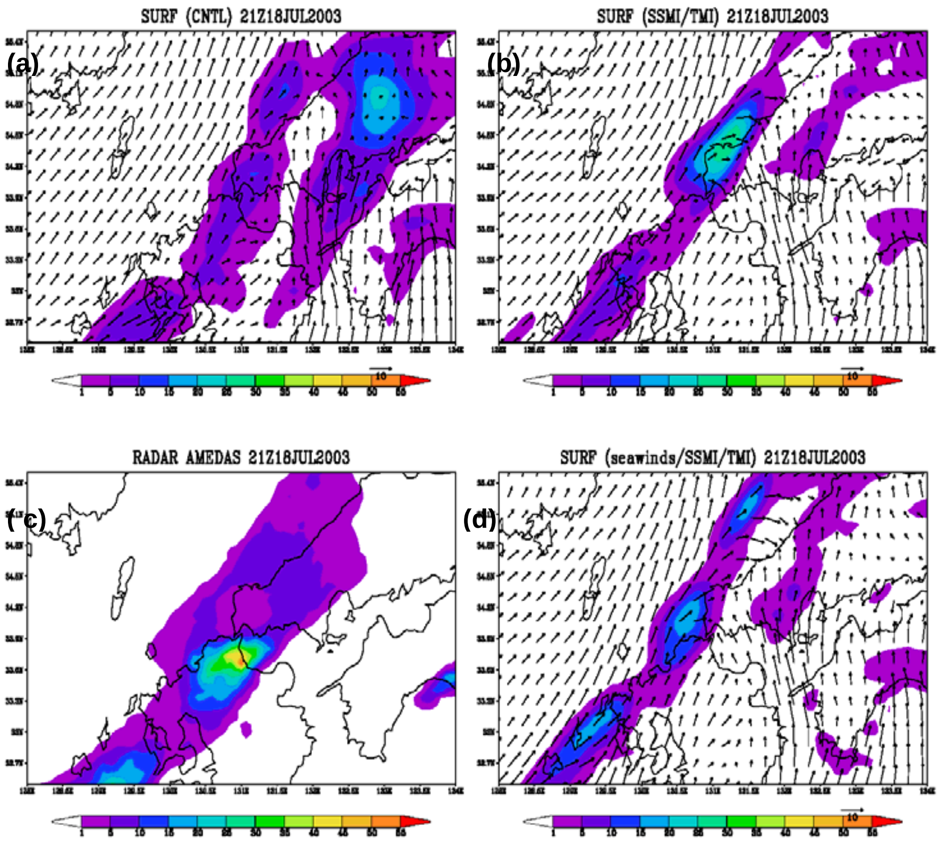

Figure 9. The distribution of precipitation at 9 hour forecast from 12UTC 18 July 2003 (a) conventional data assimilation (b)conventional data, RR and TCPW assimilation (c) Rader-AMeDAS precipitation (real state) (d) conventional, RR , TCPW and SeaWinds data assimilation.

Figure 9 shows the difference of precipitation forecasts by different data assimilation in the first study. Two convective heavy precipitation cells are forecasted in the case of SeaWinds data assimilation so that its distribution is fairly close to that of Rader-AMeDAS precipitation although its intensity remains insufficient (Figure 9 (c) and (d)).

5. CONCLUSIONS

From the results of the impact study for SeaWinds data in the global model, it is evident that forecast scores and typhoon track forecasts are improved by using SeaWinds data. Based on those findings, SeaWinds data have been used in operation since 6 May 2003 at JMA. Further improvement is expected by using data of multiple scatterometers in the future. The National Space Development Agency of Japan (NASDA) launched the ADEOS-II satellite, which carried the same type scatterometer SeaWinds as QuikSCAT/SeaWinds in December 2002, but it lost power in October 2003 and the data could not be distributed. ESA will launch the Meteorological Operational Polar Satellite (METOP), which carries the Advanced Scatterometer in 2005.

At the present, the wind vector data contained in Level 2B data are used in the JMA 3D-Var. To use the data more effective for forecasts, assimilation of the original backscattered cross section data or development of a more sophisticated observation operator will be needed.

In addition, it is evident that SeaWinds data are effective to improve both moderate and heavy rainfall forecast in JMA Meso-Scale Model together with Meso 4D-VAR. Owing to the 4D-Var system, surface wind fields derived from SeaWinds data in severe weather regions such as fronts are analyzed more correctly because observation time is correctly taken into account. It is also recognized that appropriate QuikSCAT winds observation error settings are important to improve rainfall forecast with Meso 4D-VAR.

6. REFERENCES

Ebuchi, N., Graber, C. H. and Caruso, M. J., (2002) Evaluation of wind vectors by QuikSCAT / SeaWinds using ocean buoy data. *J. Atomos. Oceanic Techno*., **19**, 2049-2062.

Huddlestom, J. N. and Stiles, (2000) Multi-dimensional Histogram (MUDH) Rain Flag Product Description, Version 3.0, JPL, Pasadena, CA. http:// podaac.jpl.nasa.gov/quikscat/qscat_doc.html

JMA, (2002) Outline of the operational numerical weather prediction at the Japan Meteorological Agency. Appendix to WMO Numerical Weather Prediction Progress Report, 157pp.

Leidner, S. M., Hoffman, N. R. and Augenbaum, (2000) SeaWinds Scatterometer Real-Time BUFR Geophysical Data Product. NOAA / NESDIS

Tahara, Y., (2000) The preliminary study of the impact of QuikSCAT/SeaWinds ocean surface wind data to the JMA global model. Proc. Fifth International Winds Workshop, Lone, Australia, 169 – 176.