Assimilation of QuikSCAT/SeaWinds Ocean Surface Wind Data into the JMA Global Data Assimilation System

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1. Introduction

A satellite-borne scatterometer obtains the surface wind vectors over the ocean by measuring the radar signal returned from the sea surface. It provides valuable information such as a typhoon center for numerical weather prediction (NWP) over the ocean, where conventional in situ observations are sparse. Observational data from the European Remote-Sensing Satellite 2 (ERS2) /Active Microwave Instrument (AMI) scatterometer launched by the European Space Agency (ESA) was used operationally at the Japan Meteorological Agency (JMA) from July 1998 to January 2001. A new scatterometer named SeaWinds was launched onboard the QuikSCAT satellite by the National Aeronautics and Space Administration (NASA)/Jet Propulsion Laboratory (JPL) on 19 June 1999. It was a "quick recovery" mission to fill the gap created by the loss of data from the NASA Scatterometer (NSCAT), when the Japanese Advanced Earth Observation Satellite (ADEOS) lost power in June 1997. The width of swath of QuikSCAT/SeaWinds is 1800 km, which is wider than that of ERS2/AMI by three times, with a spatial resolution of 25 km. Daily coverage is more than 90% of the global ice-free oceans.

Figure 1 shows an example of QuikSCAT/SeaWinds observation. The QuikSCAT/SeaWinds observes with higher density than ship or buoy. A cyclonic

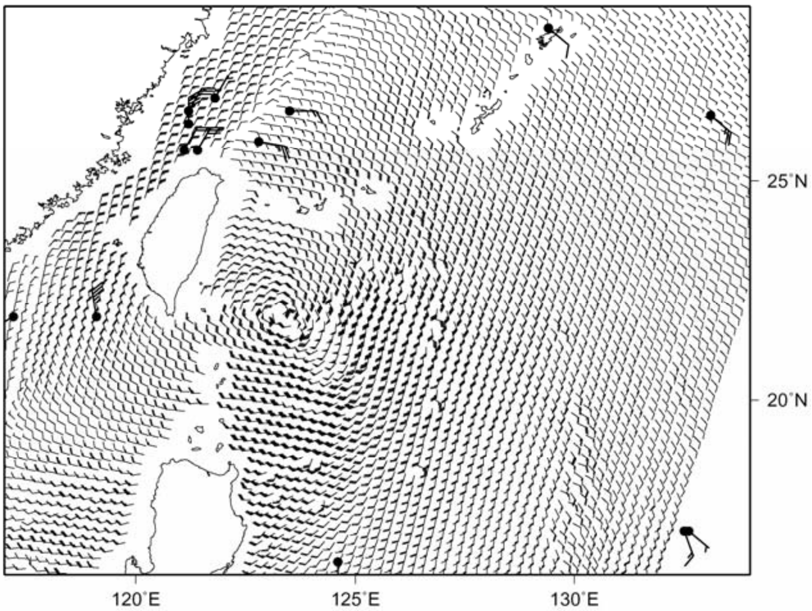

Fig.1 Wind data around typhoon T0306 (SOUDELOR) observed by QuikSCAT/SeaWinds. Observation time is about 10 UTC 17 June 2003. A full wind barb is 10 knots and a half wind barb is 5 knots. Observations by ships are plotted as dots with large barbs.

circulation around the center of a typhoon is apparent.

In section 2, a quality control system for SeaWinds data is described. In section 3, results from data assimilation experiments are presented. In section 4, conclusions and future plans of assimilation of scatterometer data are provided.

2. Quality control system for scatterometer data

In order to assimilate scatterometer data effectively, a quality control system for SeaWinds data (Tahara 2000) was built up (Fig.2). The QuikSCAT/SeaWinds Operational Standard Data Product (Level 2.0B(L2B)) from the National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite Data and Information Service (NESDIS) (Leidner et al. 2000) is received at JMA in near real-time. First, the low quality data over land or sea ice are rejected. Because the data in heavy rain areas have less accuracy due to scatter noises by rain drops, the data flagged as rain (Huddleston and Stiles 2000) are rejected. The next is the ambiguity removal step. The wind retrieval process from original backscattered cross section data produces a set of 2 to 4 potential wind vector solutions (known as “ambiguities”). Those ambiguity vectors have nearly the same speed, but quite different wind directions. To determine the most likely wind vector, NWP nudging technique which chooses the vector closest to the first guess wind and median filter technique which selects the vector similar to adjacent data are used. Then wind speed check and wind direction check are performed. In the wind direction check step, a QC scheme called “Group QC” is introduced. The conventional QC occasionally rejects correct wind data in and around severe weather systems such as cyclones and fronts, because wind direction and speed varies sharply there and the difference between the first guess field and observations tends to be large. The group QC

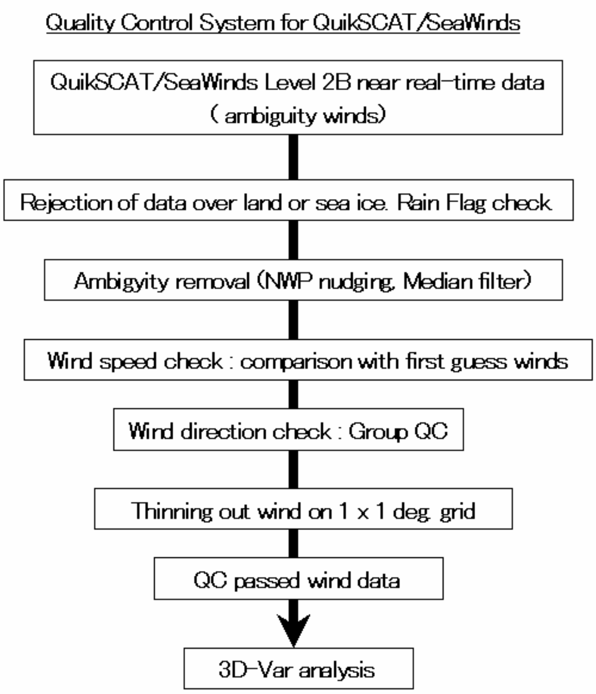

Fig.2 Quality control procedure for QuikSCAT/SeaWinds data.

is a technique to save those important data. It consists of two steps. The first is a grouping step, in which scatterometer data are divided into some groups consisting of adjacent data which have the similar wind directions and speeds. The next is a testing step, in which the data are checked group by group against the first guess field. Correct data which would be rejected by the conventional QC are saved by comparing with surrounding correct data. The group QC saves a lot of correct scatterometer data in and around severe weather systems successfully. Finally wind data are thinned on 1 x 1 degree (lat./lon.) grid and used in the data assimilation procedure.

3. Impact study for SeaWinds data

Data assimilation experiments of SeaWinds were conducted 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). Nine days forecasts started from 12 UTC analysis have been carried out 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.

(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°, respectively, with no systematic biases.

After the QC procedure, SeaWinds data were compared with first guess wind fields. The results showed that RMSE and BIAS in wind speed were 1.91 m/s and 0.81 m/s in December, and 1.87 m/s and 0.66 m/s, respectively, in July. RMSE in wind direction were 20.2° in December and 19.7° in July. Because those BIASs are similar to those between buoy data and first guess, the SeaWinds wind data have good accuracy enough to be used in NWP. Numbers of SeaWinds data which pass QC (Fig.2) in the cycle analysis and the early analysis[1] are about 10,000 and 6,000, respectively.

(2) Impact on analysis

Figure 3 shows the impact of the SeaWinds wind data on the analysis fields. Using the SeaWinds data, the increment from the first guess field was up to 4 m/s (Fig.3(a)). The impact of SeaWinds data is also seen in the difference between the analysis field in Test and that in Control (Test－Control) (Fig.3(b)). The result shows that the analysis field of surface wind and that of sea surface pressure were changed mainly over SeaWinds observation areas. It is apparent that a cyclonic circulation was intensified and sea level pressure was decreased over 45°S-55°S and 120°W-135°W by SeaWinds data

[1] The JMA global 3D-Var operational assimilation system consists of cycle analysis conducted four times a day (00,06,12,18 UTC) with longer data cut off times and early analysis for the GSM forecasts (00,12 UTC).

assimilation.

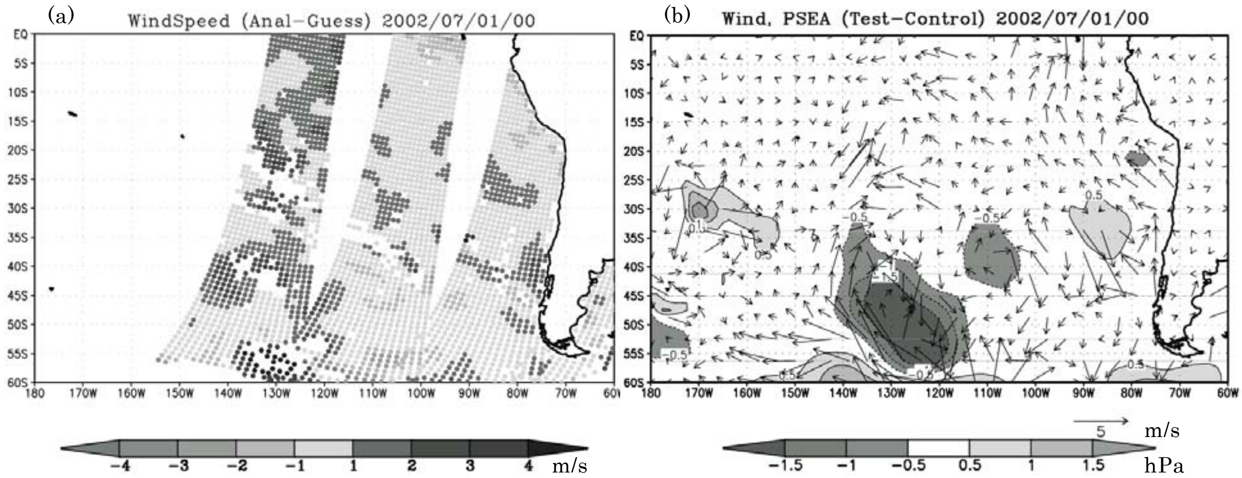

Fig.3 Impact of SeaWinds data on analysis fields at 00 UTC 1 July 2002. (a) Increment of sea surface wind speed (m/s) (Analysis－First guess). (b) Differences of analysis (Test－Control) of sea surface wind vectors (m/s) and sea level pressure

(3) Impact on forecasts

Impact of SeaWinds data on forecasts was investigated. Figure 4(a) shows RMSE of surface wind speed calculated from differences of forecast field and initial field for Test and Control in the Northern Hemisphere (20°N-90°N) for July 2002. SeaWinds data has slightly positive impact after day 6. Positive impact was also recognized in the anomaly correlation of 500 hPa geopotential height particularly in the Northern Hemisphere (Fig.4(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 (Fig.4(c)). Improvement was expected in the Southern Hemisphere because of sparsity of conventional data. However, impacts on 500

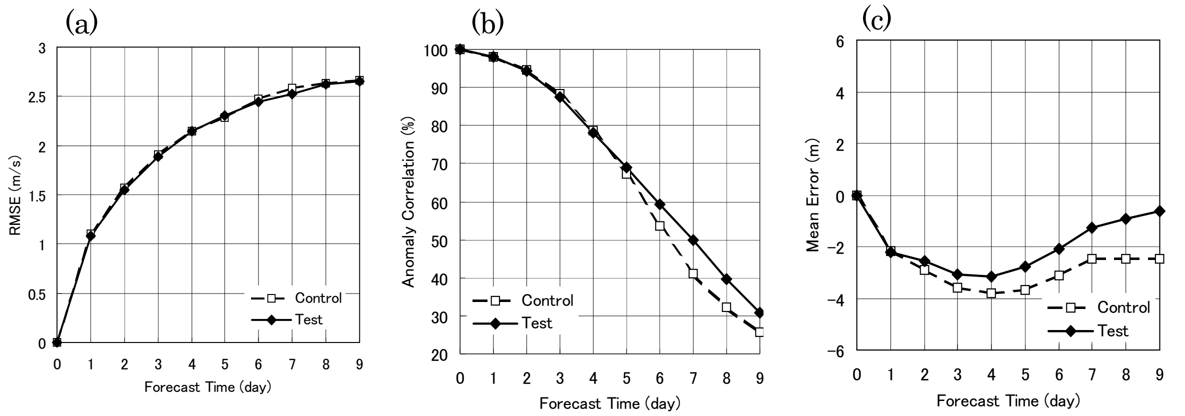

Fig.4 Forecast scores for Test (solid line) and Control (dashed line). (a) RMSE of surface wind speed in the Northern Hemisphere (20°N-90°N) for July 2002. (b) Anomaly correlation of 500 hPa geopotential height in the Northern Hemisphere for July 2002. (c) Mean error of 850 hPa geopotential height in the tropical region (20°N-20°S) for December 2001. The forecasts were started from 12 UTC for the period of 8 to 22 July 2002 (December 2001).

hPa geopotential height and sea level pressure were almost neutral or slightly negative at the end of forecast times.

The experiment was performed 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 5 shows the result of the track forecasts for typhoon T0207 (HALONG) by GSM0103 from the initial time 12 UTC 10 July 2002. The position error of forecasted typhoon track in Test is reduced by as much as 100 km. Figure 6 shows the mean position error of typhoon track forecasts in Test and Control in 36 cases for six typhoons during July 2002. The position error in Test is significantly reduced after 60 hour forecast.

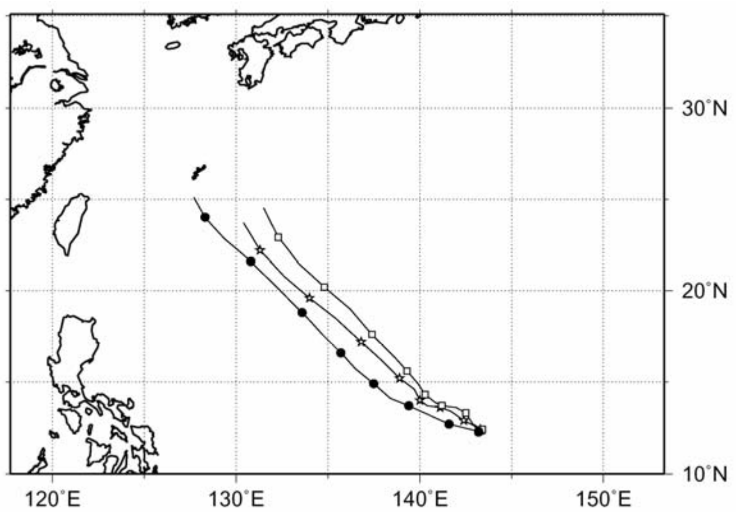

Fig.5 The result of track forecasts for typhoon T0207 (HALONG). Initial time is 12 UTC 10 July 2002. Black circles denote the best track, squares denote Control, and stars denote Test. The symbols are plotted every 12 hours.

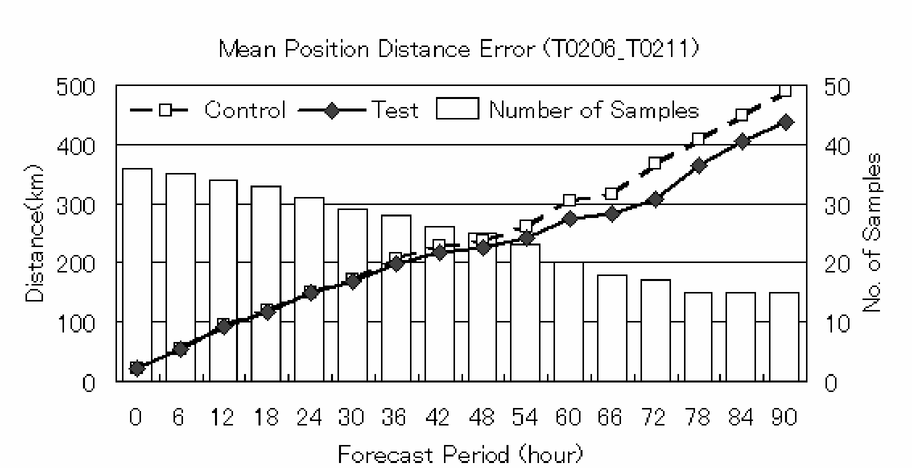

Fig.6 The mean position distance error of forecasted track of typhoons in July 2002. Dashed line denotes Control, solid line denotes Test, and bar denotes the number of samples.

4. Conclusions

From the results of the impact study for SeaWinds data, it is evident that forecast scores and typhoon track forecasts are considerably 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 ADEOS-II satellite which carried the same type scatterometer SeaWinds as QuikSCAT/SeaWinds was launched by the National Space Development Agency of Japan (NASDA) in December 2002. Unfortunately the spacecraft has not made observations since October 2003 due to its power failure and the data has not been distributed. The Meteorological Operational Polar Satellite (METOP) which carries the Advanced Scatterometer (ASCAT) will be launched by ESA in 2005.

A global 4D-Var data assimilation system is under development as the next operational global data assimilation system at JMA. Using the 4D-Var system, the data in severe weather regions such as fronts or typhoons will be analyzed more correctly because observation time is correctly taken into account.

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.

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