THE PRELIMINARY STUDY OF THE IMPACT OF QUIKSCAT/SEAWINDS OCEAN SURFACE WIND DATA TO THE JMA GLOBAL MODEL

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ABSTRACT

A new scatterometer SeaWinds was launched onboard QuikSCAT satellite in June 1999. It observes surface wind vectors over the ocean with the swath of 1800km, which is more than three times wider than that of ERS-2 scatterometer. Hence its large contribution to numerical weather prediction (NWP) is expected. Using preliminary observation data of QuikSCAT, an impact study was performed with the JMA global NWP system. The results showed large positive impact over the southern hemisphere and small positive impact over the tropics and the ocean of the northern hemisphere.

1. Introduction

A space-borne 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. In addition to ERS-2 scatterometer launched by European Space Agency (ESA) in April 1995, a new scatterometer SeaWinds was launched onboard QuikSCAT satellite by National Aeronautics and Space Administration (NASA) / Jet Propulsion Laboratory (JPL) in June 1999. It is designed to observe wind vectors with an accuracy of 20 degrees in direction and 2 m/s or 10% in speed, and a horizontal resolution of 25km. These are almost the same as ERS-2 scatterometer. Meanwhile the observational swath of SeaWinds along the satellite track is 1800km, which is more than three times wider than that of ERS-2, 500km. Therefore it is expected to bring larger impacts to analysis and forecast than ERS-2.

2. Assimilation system for scatterometer

In order to assimilate scatterometer data effectively, an assimilation system for ERS-2 scatterometer shown in Figure 1 was built up. The system consists of three parts.

1) Wind retrieval ERS-2 scatterometer data are received at JMA from ESA in near real-time through the Global Telecommunication System (GTS). However the quality of the wind direction data is not acceptable for use in NWP. Therefore the scheme of wind retrieval from ERS-2 backscatter measurements, which are also included in the real-time data, was built up. The retrieval method is based on the techniques described in Stoffelen and Anderson (1995). A maximum likelihood estimator is used to transform backscatter measurements into winds. Median filter and NWP nudging techniques are used in order to remove ambiguities of wind direction data. Owing to the scheme, the accuracy of wind direction data is improved significantly.

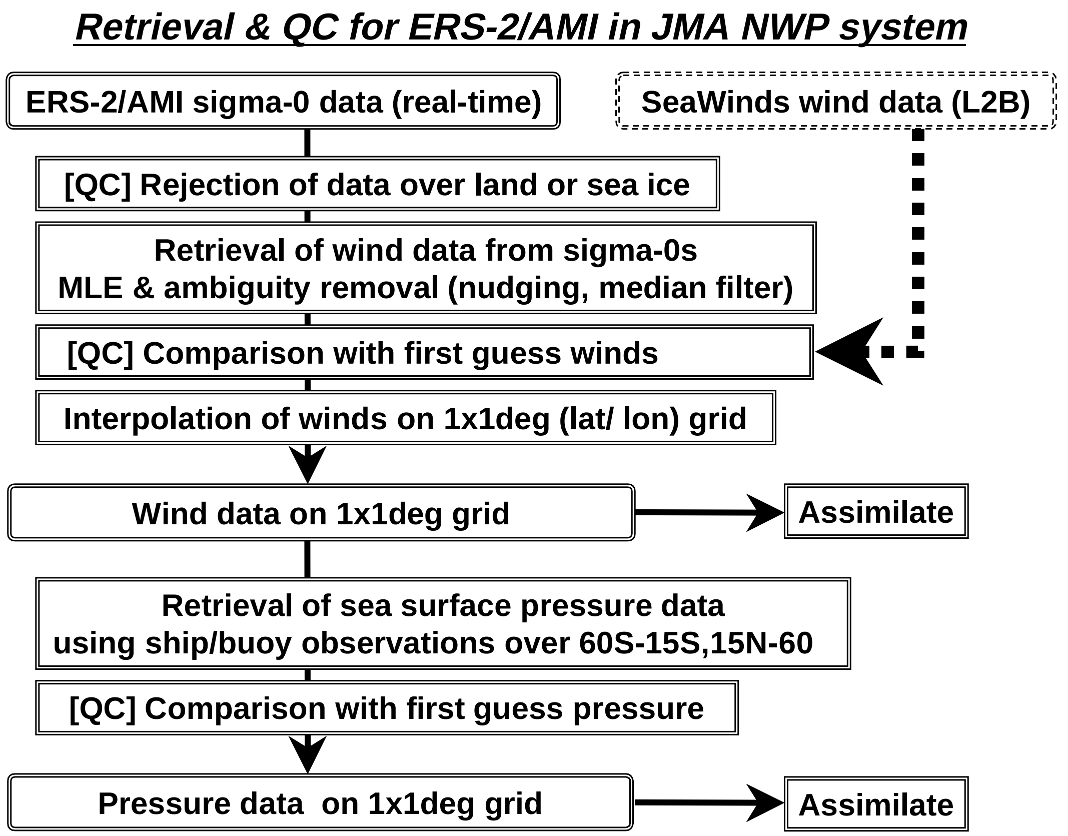

Figure 1: Wind retrieval and quality control system for ERS-2 scatterometer used in the JMA NWP system. In QuikSCAT experiment this system were used except the wind retrieval part.

2) Quality control A new quality control (QC) scheme called "group QC" is introduced in addition to conventional QC, in which observaton data are checked comparing with a first guess field individually. The conventional QC occasionally rejects correct wind data in and around severe weather system such as cyclone and front, since wind direction and speed varies sharply there and the difference between a first guess and a observation tends to be large. The observational information of these phenomena is very important for analysis. The group QC is a technique to save such important data. It consists of two steps. The first is grouping step, in which scatterometer data are divided into some groups consisting of adjacent data which have the similar wind directions and speeds. According to the grouping, the data are divided into the groups of burst error data, sporadic error data and correct data. The next is testing step, in which the data are checked group by group. Correct data, which would be rejected by 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 system successfully.

3) Surface pressure retrieval Scatterometer data represent fine structures of wind field with a high spatial density over the ocean; surface pressure patterns can be easily imagined from them. However it is not easy to represent the atmosphere states on analyzed fields through data assimilation. Because the sea surface winds reflect the phenomena at the bottom of atmosphere and complicated boundary layer physics prevents to transmit effects of the surface wind data to upper layers inside a model. In order to transfer the information of scatterometer data to analysis field effectively, we try to estimate surface pressures from surface winds and assimilate them.

The data used for pressure retrieval are scatterometer wind data interpolated into 1x1 degree latitude and longitude mesh. The retrieval method is based on Brown (1995). The scheme consists of two steps. At first a gradient field of surface pressure over a satellite swath are calculated from dense surface wind data. To calculate a gradient field of surface pressure, the geostrophic relation is used with some modifications for an effect of surface frictions. The gradient field can be easily converted to a surface pressure field by calibration using conventional marine observations such as buoys and ships. Since the geostrophic relation is assumed, the area to calculate pressures is limited to middle latitude (60S - 15S, 15N - 60N).

Figure 2 shows the example of QuikSCAT wind and pressure data. Cyclones and anti-cyclones seen in the wind data are represented in the pressure data. Figure 3 shows the impacts of the QuikSCAT data on a sea surface wind and pressure analysis. The left of Fig 3 shows the impact of only the wind data and the right shows the impact of both the wind and pressure data. The difference of the two is apparent; pressure data can transfer the information of scatterometer data to an analysis field strongly. The similar difference can be recognized in upper atmosphere too.

By adopting the system, a positive impact was obtained by assimilating ERS-2 scatterometer data in the global model, and the operational use was started from summer 1998 at JMA.

3. Impact study for QuikSCAT data

3.1 Configuration of the experiment

An observation system experiment for QuikSCAT data was performed in order to investigate the impact of the data on analysis and forecast performance. We used 6 hourly intermittent global data assimilation system, which is the same as the operational one. The forecast model was a reduced version (T63L30) of the operational global spectral model (T213L30). The analysis scheme was three dimensional multivariate optimum interpolation. Data assimilation was started from 00UTC August 1 1999 and continued to 12UTC August 31. 8days forecasts started from 12UTC analyses have been carried out for all experimental assimilations from August 6 to August 31. Two experiments were conducted, Control run and Test run. The observation data used in Control run were conventional data, NOAA14 data, winds obtained tracking cloud and water vapor images observed by geostationary satellites and moisture bogus data statistically retrieved from black body temperature and cloud amount data observed by GMS-5. In addition to these data, QuikSCAT data were used in Test run. The assimilation system for QuikSCAT data is almost the same as that for ERS-2 scatterometer, which is used in the operational system excepted that the wind retrieval scheme was not used (Fig 1).

3.2 QuikSCAT preliminary data

QuikSCAT data used in the experiment were the preliminary data produced by JPL for the purpose of calibration and validation. The official distribution of the data is planned from the end of January 2000. Because of the design of SeaWinds wind observing method, the quality of wind data near the far swath and nadir (along the ground track of the satellite) was considered to be worse compared with the data between the middle of far swath and nadir, where QuikSCAT could observe winds skillfully and the area is called sweet spot. The decline of the quality in far swath and nadir was recognized for the preliminary observation data in

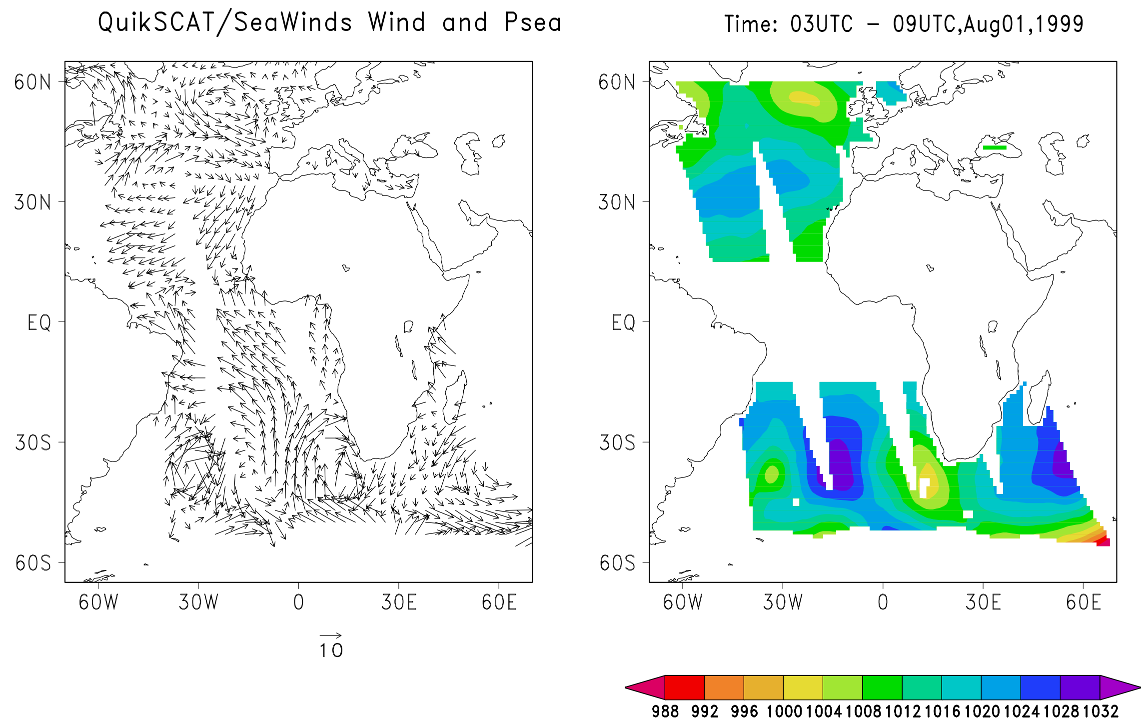

Figure 2: The left figure shows the wind data observed by QuikSCAT/SeaWinds. The right figure shows the surface pressure retrieved from the wind data in the left figure. The unit of wind vector length is m/s and that of pressure is hPa.

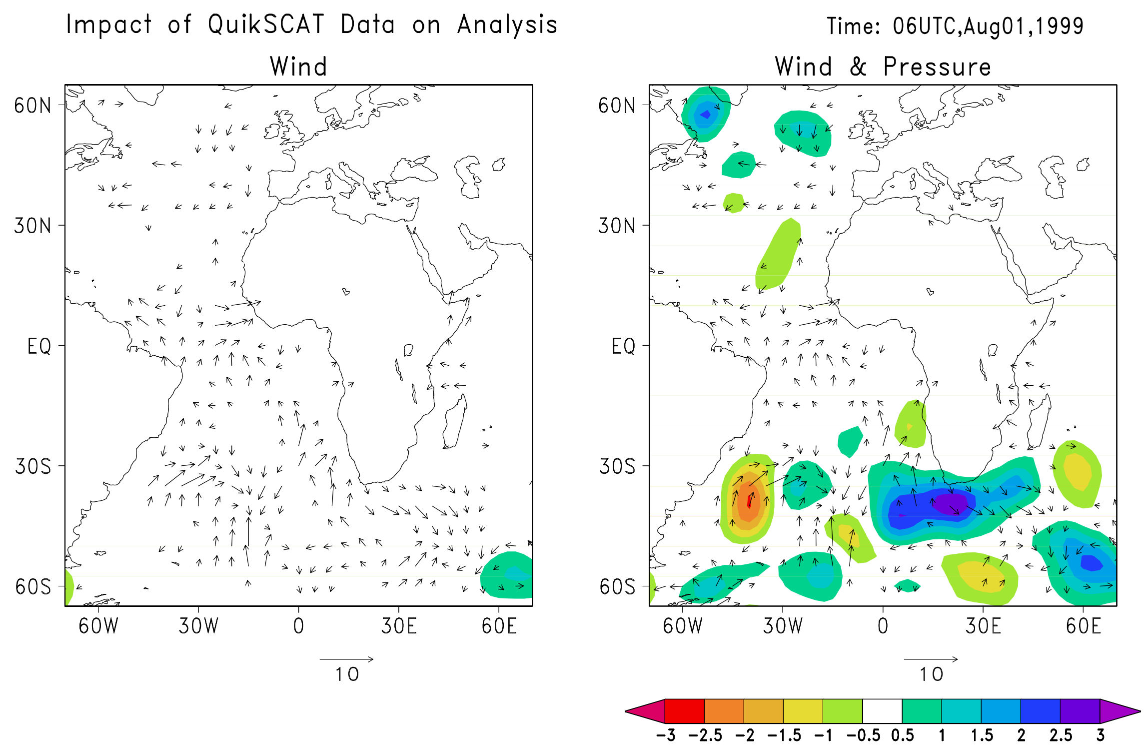

Figure 3: The figures show the impacts on analyses carried by the QuikSCAT data drawn in Figure 2, an analysis using QuikSCAT data minus an analysis without the data. The left figure shows the impact by only the wind data, and the right shows the impact by using both the wind and pressure data. The unit of wind vector length is m/s and that of pressure is hPa.

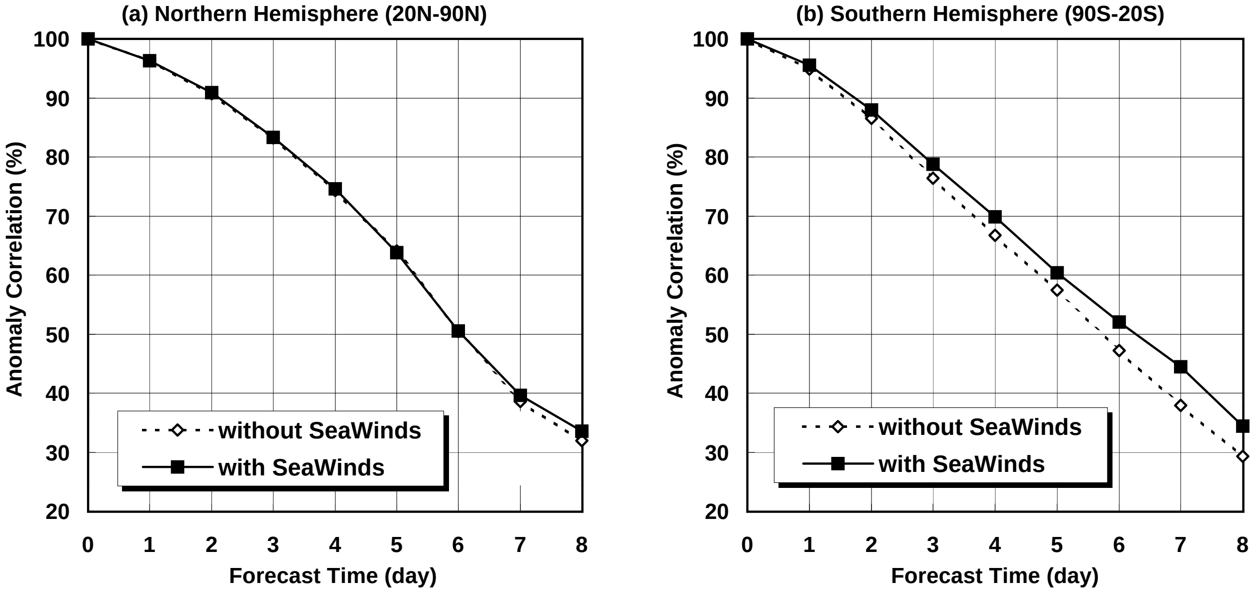

Figure 4: Mean anomaly correlation of forecasted sea surface pressure against initialized analysis over (a) the northern hemisphere (20N-90N) and (b) the southern hemisphere (20S-90S). The forecasts are carried out at every 12UTC from August 6th to 31st 1999. Dash line indicates Control run and solid line indicates Test run.

SeaWinds/QuikSCAT calibration workshop held in November 1999. Moreover other problems were found such as biases contained in backscatter measurements, rain contamination and poor observation outside 3 to 30 m/s range. However it was also recognized that the data in sweet spot had the good accuracy as expected before the launch. In the experiment these problems were ignored and whole data were treated as having the same quality.

A comparison between QuikSCAT wind data interpolated into 1x1 degree mesh and first guess wind fields resulted in 21.5 degree RMS error in wind direction and 1.92 m/s RMS error and +0.18 m/s mean error in wind speed. It means that the QuikSCAT data have good enough accuracy to be used in NWP, even if they are preliminary data.

A comparison between surface pressure data retrieved from QuikSCAT winds and first guess pressure fields resulted in 2.7 hPa RMS error and +0.28 hPa mean error. The quality check schemes used in the data assimilation system detected erroneous data of 12% in the pressure data. However 88% of the data were recognized to have a good quality, and a comparison between the data having passed the quality checks and first guess fields showed that RMS error was decreased to 1.5 hPa and mean error to 0.0 hPa.

3.3 Impacts to forecasts

Obvious positive impact to model's performance is obtained over the southern hemisphere by using QuikSCAT data. Figure 4 (b) shows mean anomaly correlations of forecasted sea surface pressure field over the southern hemisphere extra tropics (20S - 90S). The anomaly correlation is a score that evaluates agreement of patterns between analyzed field and forecasted field. The higher value indicates better forecast performance, the value of 100% means the forecast is perfect and that over 60% means useful. The figure shows that the score drops to 60% at 5.1 forecast day for Test run, but 4.7 forecast day for Control run. It means that period of useful forecasts is extended by 0.4 day by using the QuikSCAT data. Figure 4 (a) shows the same as Fig 4 (b) but over the northern hemisphere extra tropics (20N - 60N). The similar results for forecasted 500hPa geopotential height field can be seen over both the southern and northern hemisphere too. It means that QuikSCAT surface wind data improve the NWP performance of not only surface field but also upper atmosphere. A small positive impact is also seen on 850 hPa temperature field over the tropics (20S - 20N, the figure is not shown).

Figure 5 (a) shows the difference map of the mean RMS errors of forecasted sea surface pressure fields between Test run and Control run. Forecast time is 6 day. The area in red or orange indicates an area where the forecast error of Test run is smaller than that of Control run. And the area in blue or green indicates the forecasts of Control run are better than the Test run. The red or orange area can be seen wider than the blue or green area over the middle latitude of the southern hemisphere, where QuikSCAT data improve the analysis and forecast skill significantly. Fig 5 (b) shows the same map as Fig 5 (a) but for surface wind vector fields. A similar impact by QuikSCAT data can be recognized over the southern hemisphere. Moreover a small but evident positive impact can be seen over the northern Pacific and Atlantic ocean.

4. Conclusion

The impact study for QuikSCAT data using the JMA global NWP system was performed. The assimilation method for QuikSCAT data was almost the same as operational one used for ERS-2 scatterometer except that wind retrieval scheme was not applied. Throughout the experiment, QuikSCAT data were recognized to have a good enough quality to be used for NWP, even if they were preliminary data. Pressure data retrieval from QuikSCAT winds was successfully performed, and 88% of the data were assimilated. The evident positive impacts on forecasts were recognized over the southern hemisphere and small positive impacts over the northern hemisphere and the tropics.

The official distribution of QuikSCAT data is planned from early 2000. The data will be calibrated according to the results of discussion in the QuikSCAT/SeaWinds workshop held in November 1999. We plan to receive the QuikSCAT real-time data, and we will continuously investigate the quality of QuikSCAT/SeaWinds data and their impact on NWP.

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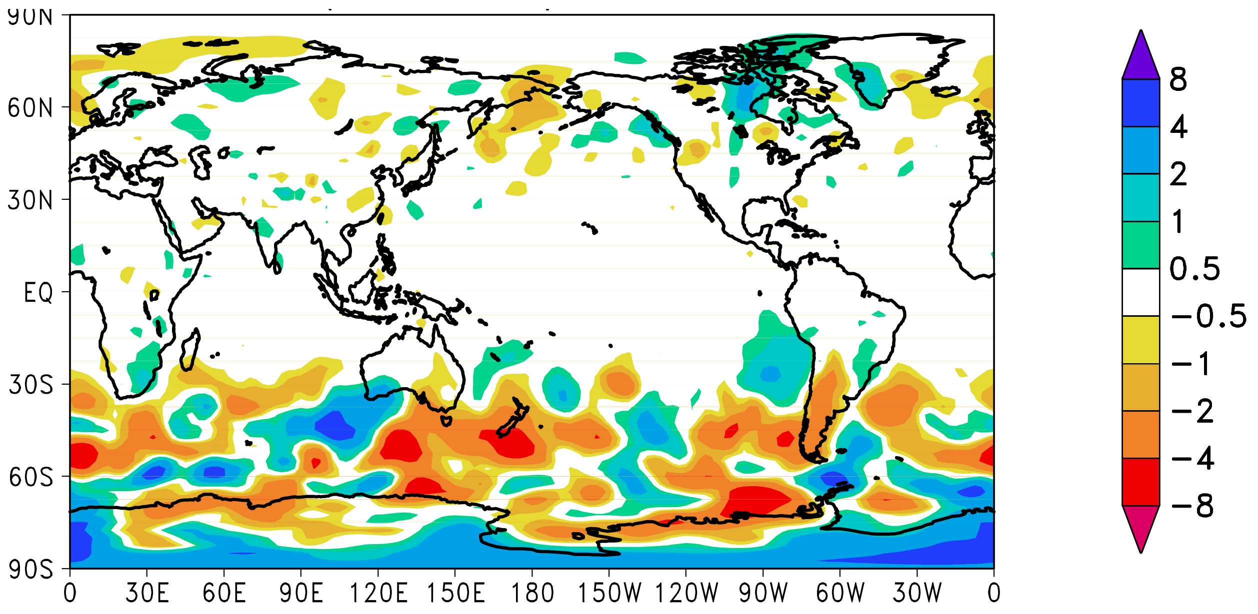
(a)



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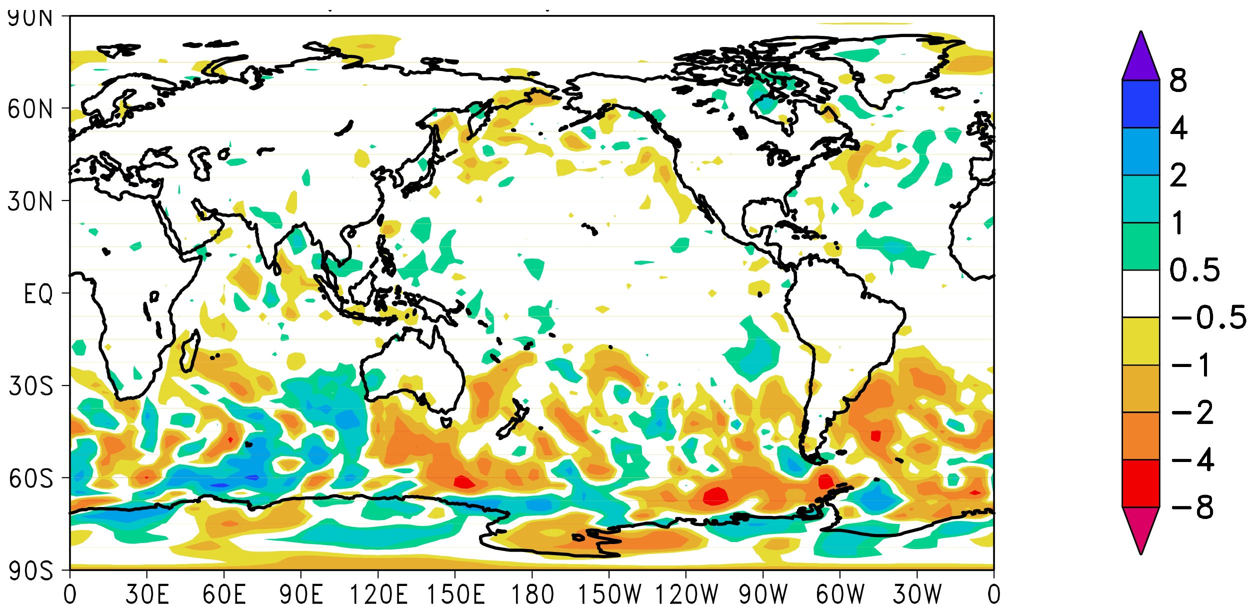

Figure 5: These figures show the differences of the mean RMS errors of 6 day forecasts between Test run and Control run. An area shaded in orange or red represents that the forecast error of Test run is smaller than that of Control run, and an area shaded in green or blue represents the forecast error of Test run is larger. Figure (a) shows a comparison over sea surface pressure field and figure (b) shows over surface wind field. The unit of pressure is hPa and that of wind speed is m/s.

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