Use of QuikSCAT SeaWinds in the NCEP Global Data Assimilation System

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Abstract

This paper discusses preliminary results of data assimilation and forecast experiments designed to investigate the impact of QuikSCAT SeaWind data in the NCEP atmospheric analysis and forecast system. The NCEP global data assimilation system used in this study is briefly described, and the characteristics of the SeaWind data discussed. Results are presented of several sensitivity data assimilation and forecast experiments of one-week period, designed to investigate the effects on analyses and forecasts of observation errors and quality control criteria assigned to the QuikSCAT wind data. Data assimilation and forecast experiments for a period of two-months are being conducted, starting 0000 UTC July 19, and ending 0000 UTC September 19, 1999, using QuikSCAT SeaWind data in the NCEP global data assimilation system. Results of these assimilation and forecast experiments are being evaluated, and the impact of QuikSCAT wind data on numerical weather prediction will be discussed.

1. Introduction

The U.S. NASA QuikSCAT satellite was launched on June 19, 1999, carrying onboard the SeaWinds instrument which is a specialized microwave scatterometer radar that can measure near surface wind speed and direction over the oceans under all weather and cloud conditions. The QuikSCAT wind data, having more than 40,000 data points for every six-hourly synoptic cycle, and featuring a 25 km resolution and a 1800 km swath, represent the largest data volume and aerial coverage, when compared to those of European Space Agency's ERS-1/2 scatterometer wind data and the U. S. Defense Meteorological Satellite Program's SSM/I wind data. Both the ERS-1/2 and SSM/I surface wind data are being operationally used in the numerical weather prediction operations at National Centers for Environmental Prediction (NCEP), after these satellite wind data have been extensively tested in the NCEP global data assimilation systems (Yu, et al 1996, Yu, et al, 1997).

The accuracy of QuikSCAT wind data has been evaluated by comparison with collocated buoy reports, and the impact of these wind data on numerical weather prediction is currently under investigation using global data assimilation systems developed at NCEP and at the Data Assimilation Office (DAO) in NASA (Atlas, et al, 1999). If implemented operationally, the QuikSCAT wind data will undoubtedly improve NCEP atmospheric analyses and numerical weather forecasts. Most of the assimilation and forecast experiments are currently being run in the Data Assimilation Office at NASA Goddard Space Flight Center. This paper discusses preliminary results from this impact investigation.

2. Nature of the QuikSCAT SeaWinds

The QuikSCAT SeaWinds are radar backscatter measurements through which ocean surface winds can be retrieved. The wind retrieval procedure typically involves some geophysical model functions. These functions are empirically derived relations and they generally have the form: $\sigma^\circ = f(S, \theta, \chi, P)$, where σ° is the backscatter measured by a given antenna, S is wind speed, χ is relative angle of surface wind direction with respect to the radar beam from the antenna, θ is the incidence angle of the radar beam to the ocean surface, and P is the polarization of the radar beam. Multiple measurements of σ° from different looking angles in space could provide enough information for retrieving a surface wind vector by inverting the geophysical model function.

The SeaWind instrument uses a rotating dish antenna which illuminates two spots on the ocean surface, each of the two spots having an approximately constant incident angle. This should lead to simpler geophysical model functions, and thus to more robust wind retrievals. With this dual scanning approach, SeaWind sweeps out a swath of about 1800 km wide, 900 km on each side of the satellite track, with a 25 km resolution. Fig.1 shows a schematic of the QuikSCAT SeaWind track. Within this track are three subregions, each of which having a different sampling nature: the nadir track which extends from the center to 250 km off each side, the so called "sweet spot track" which extends from 250 km to 700 km from nadir, and the outer edge which covers the area from 700 km to 900 km from nadir. The retrieved wind vectors have different error characteristics (Shirtliffe, et al, 1999) within the three subregions.

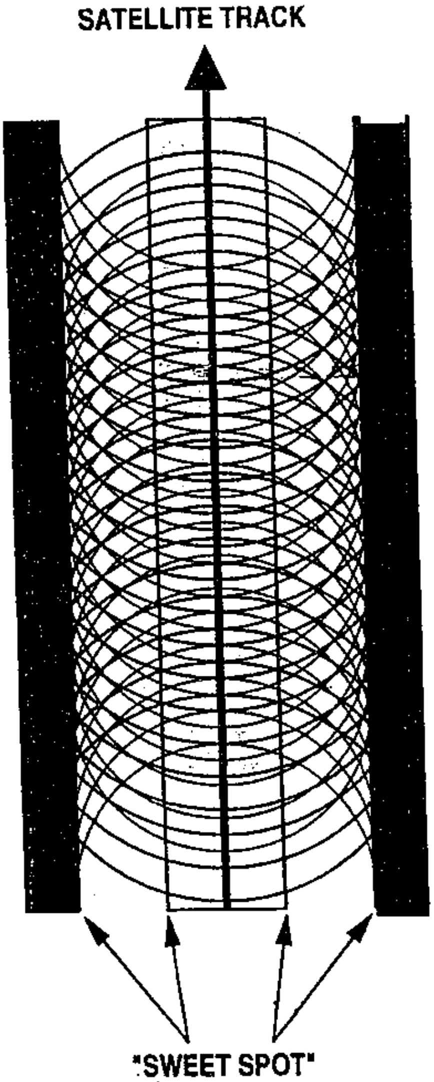

Figure 1. Schematic of the QuikSCAT SeaWinds Swath

To assess the quality of the QuikSCAT winds, more than two-months (from July 19, 1999 to September 30, 1999) of collocation data between buoy and QuikSCAT winds were collected. Based on a total of 19,715 collocation data points, the statistics show a wind speed RMS error of 2.0 m/sec, with virtually no bias, and a wind direction RMS error of about 37 degrees and a nearly zero bias. The overall error characteristics are quite comparable to those for the ERS-1/2 scatterometer wind data. However, when compared the QuikSCAT retrieved wind speed and direction for each scanning cell against NCEP global analyses, the error characteristics are cell-dependent. By calculating bias and RMS differences between NCEP wind analyses and QuikSCAT winds for a period of two months in the summer of 1999, Chang et al (1999) show that over the nadir and the outer edge areas, the bias and RMS differences are larger than those over the sweet spot region (Fig. 2). Thus, design of the data assimilation and forecasting experiments which will make effective use of the QuikSCAT SeaWinds and take into account of their error characteristics at the three subregions of the swath presents a great challenge.

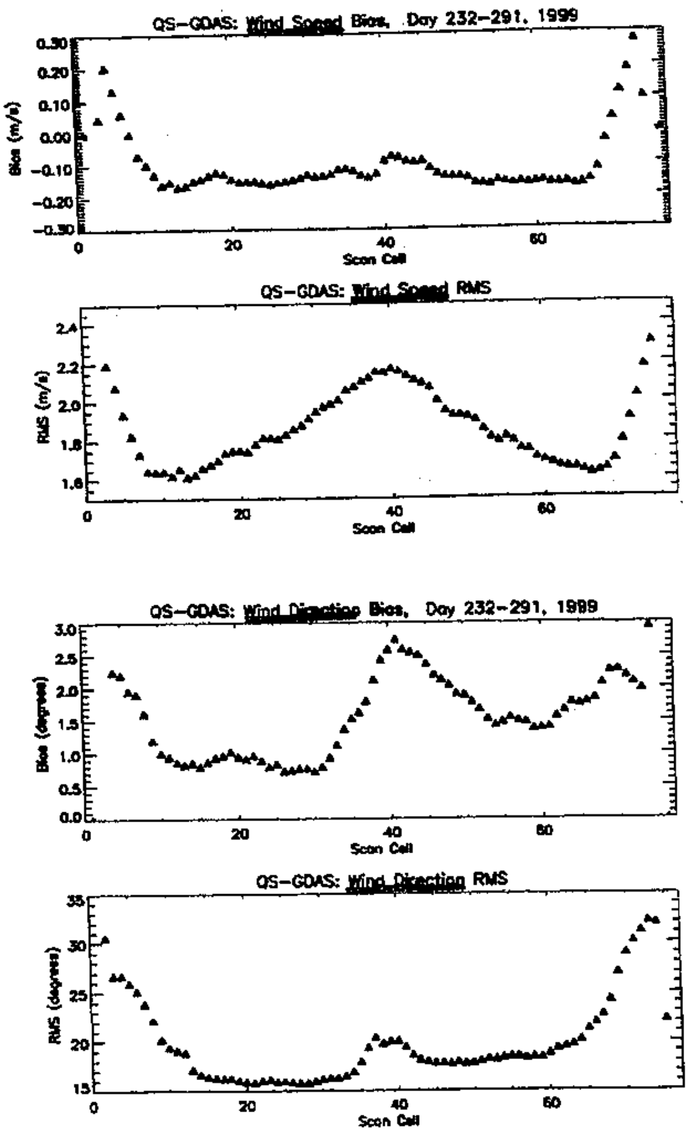

Figure 2. Bias and RMS differences between QuikSCAT winds and NCEP GDAS analyses (after Chang et al, 1999)

3. Assimilation and Forecast Experiments

To investigate the impact of the QuikSCAT wind data on numerical weather prediction, the NCEP T126 operational global data assimilation system (GDAS) was used. Details of the NCEP GDAS were given in Kanamitus (1989) and Kanamitsu et al (1992). Briefly stated, the GDAS consists of a global spectral forecast model with a horizontal T126 wave resolution and a 28 sigma layers in the vertical, and a Spectral Statistical Analysis Scheme (SSI) (Parrish and Derber, 1992). An assimilation experiment is proceeded by a six hour forward integration of the forecast model, starting from the beginning of the data assimilation period, to produce first guess fields of winds, temperatures, and specific humidity. The observations within a +/- 3 hour window are then used by the SSI scheme to update the first guess fields and complete the analyses. This process of a six hour model forecast followed by an analysis update is repeated four times a day, once every six hour interval.

The NCEP SSI analysis scheme is a three-dimensional variational method designed to find a model solution, which is as close as possible in the least square sense, to observations, the six-hour forecast and a set of dynamical constrains. The analysis scheme is to minimize a cost function, J, which represents the misfit to the available data and the six-hour forecast valid at the analysis time, i.e.,

$$J=[(L(x_o)-y)^T O^{-1}(L(x_o)-y)+(x_o-x_b)^T B^{-1}(x_o-x_b)+d^T D^{-1}d]/2.$$

Here x_b is a background estimate of the model state x_o at the analysis time, which is typically a six-hour forecast from a dynamical model, y is vector of observations distributed in space at the analysis time, L is an operator which predicts observations from the analysis variables, O is the covariance matrix of the observations and representative errors, B is the covariance matrix of the forecast errors, d are a set of dynamical constraints, and D is covariance matrix for the dynamical constraint.

Currently, use of satellite surface winds such as ERS-1/2, SSM/I, and QuikSCAT SeaWind data in the SSI analysis scheme, requires an observation error be assigned to each type of observations. Moreover, these observations errors are assumed uncorrelated in space. The forecast and observation errors define the relative weights each observation is given along with the relative amounts of information projected onto the analysis variables. For this reason, they are of vital importance to the analysis procedure.

Before the QuikSCAT wind data are used in an extended period of data assimilation and forecast experiment, several sensitivity tests were conducted. This is done in view of the different error characteristics of the QuikSCAT wind data over the three subregions of the satellite track. There is also this question of rain contamination problem associated with the retrieved QuikSCAT winds, but it is not clear to what extent the rain contamination affects the quality of the data. Five experiments (see Table 1) are designed to test the sensitivity of forecasts with respect to various observation errors and quality control criteria assigned to the QuikSCAT wind data and used in the SSI analysis scheme. The quality control criteria is specified through a parameter, OIQC. A observation datum is given an accept or reject status depending on the ratio between analysis error variance and the specified OIQC variances of winds (Woolen, 1991). For these short data assimilation experiments, the assimilation of the QuikSCAT data started on 0000 UTC, July 19, 1999, and ended on 0000 UTC, July 25, 1999, and a five-day forecast was made using as the initial condition the analyses valid at 0000 UTC, July 25, 1999.

Table 1. Description of Various Experiments

Exp. No.	Description of Experiments
Exp.1	Use sweet spot QuikSCAT winds Obs wind error u, v =2.5 m/sec OIQC wind error u, v =2.5 m/sec
Exp.2	Use sweet spot QuikSCAT winds Obs. wind error u,v =3.0 m/sec OIQC wind error u,v = 3.0m/sec
Exp.3	Use sweet spot QuikSCAT winds Obs. wind error u, v = 2.5 m/sec OIQC wind error u, v = 2.0 m/sec
Exp.4	As Exp.1, except use full swath QuikSCAT wind data
Exp.5	without the use of QuikSCAT Wind data (NCEP operational run)

Table 2. Anomaly correlations for 5-day forecasts for various sensitivity experiments

	N.H. 1000 mb	S.H. 1000 mb
Exp.1	.6894	.6700
Exp.2	.6349	.6486
Exp.3	.6279	.6575
Exp.4	.6256	.6724
Exp.5	.5971	.7150

Table 2 shows anomaly correlations calculated for 5-day (120 hours) forecast from these sensitivity experiments. The forecast skills are clearly seen to be quite sensitive to the observation errors and quality control criteria assigned to the QuikSCAT wind data. For this one case forecast, the QuikSCAT winds seem to have some significantly positive effect on the 1000 mb height forecast skills at day-5 forecast over the Northern Hemisphere, but have some negative impact over the Southern Hemisphere. Based on the results of these sensitivity experiments, the observation error of u,v =2.5 m/sec, and OIQC wind error of u,v =2.5 m/sec are considered to be the most appropriate values for the QuikSCAT wind data. Two-months of data assimilation experiments, starting 0000 UTC, July 19, 1999, and ending 0000 UTC September 19, 1999 are being conducted for Exp.1, Exp.4, and Exp.5, and a number of forecasts are being made within the assimilation period. Results of these extended data assimilation and forecast experiments will be reported at the conference.

4. Summary

The new NASA QuikSCAT SeaWind data which have a resolution of 25 km and cover a 1800 km swath, can provide more than 40,000 observations of ocean surface winds, and represent the largest data volume and aerial coverage, when compared to those of European Space Agency's ERS-1/2 scatterometer wind data and the U. S. Defense Meteorological Satellite Program's SSM/I wind data. These SeaWinds data present a great potential for improving NCEP operational weather analyses and forecasts.

Evaluation of QuikSCAT SeaWind data against in situ buoy observation shows that the data are of reasonably good quality over the sweet spot region, but depict much larger bias and RMS errors over the nadir and outer edge areas. Several short period of data assimilation experiments have been conducted to investigate the sensitivity of various observation errors and quality control criteria for the use of QuickSCAT wind data. Data assimilation and forecast experiments for an extended period of two-months are being conducted to investigate the impact of the QuikSCAT wind data on the numerical weather prediction.

Acknowledgments:

Fig. 2 of this paper has been reproduced from a paper by Chang et al (1999) cited in the references. The assimilation and forecast experiments are being run at the Data Assimilation Office of the NASA Goddard Space Flight Center in Greenbelt Maryland.

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