P2.21

Use of ERS-1 Scatterometer Backscatter Measurements in Atmospheric Analyses

T.-W. Yu, J. C. Derber

Development Division, National Meteorological Center, NWS, NOAA, Washington, D. C. 20233

R. N. Hoffman

Atmospheric and Environmental Research, Inc., Cambridge, Massachusetts 02139

OPC Contribution No. 71

1. Introduction

The scatterometer on board the ERS-1 satellite is an active radar designed to measure ocean surface wind speed and direction. The measurements taken by the scatterometer are normalized radar backscattered radiations, σ^0, a measure of the roughness of the sea surface induced by the surface winds. The ERS-1 scatterometer has three antennas pointing at angles of 45^0, 90^0, and 135^0 degrees from the satellite direction of travel to measure a cell over the ocean surface. These three measurements of σ^0 in each cell, one from each antenna, can be used to determine ocean surface wind vectors. However, the wind vectors thus derived contain directional ambiguities. With a 500 km wide swath, the ERS-1 scatterometer can provide more than 50,000 backscattered radiation measurements in a six hour window, with each observation being representative of a 50 km cell over the ocean surface. These data are routinely available at the National Meteorological Center (NMC).

This paper discusses a technique based on a variational approach particularly designed for the use of the ERS-1 scatterometer σ^0 data in the NMC's Statistical Spectral Interpolation (SSI) analysis scheme (Parrish and Derber, 1992). Our technique is similar to the three-dimensional variational assimilation scheme currently under active development at ECMWF (Thépaut et al, 1993). In particular, the analysis component of the assimilation system is designed to perform analyses while simultaneously retrieving the scatterometer winds and removing their attendant ambiguity in the wind directions. The analysis scheme minimizes the misfit to the data and other dynamical constraints as measured by a cost function. Section 2 describes the cost function for the scatterometer σ^0 data associated with the analysis procedure in the SSI scheme. Some preliminary results concerning the quality control of the ERS-1 backscattered radiation measurements data before their use in the variational analyses are discussed in Section 3.

2. The Variational Procedure for Using the σ^0 Data

The reader is referred to Parrish and Derber (1992) for a detailed description of the operational global Spectral Statistical Analysis (SSI) scheme at NMC. The analysis scheme, briefly stated, is based on a three-dimensional variational principle to find a model solution, which is as close as possible in the least square sense, to observations and the six-hour forecast available at the analysis time. The misfit to the available data and the six-hour forecast is measured by a cost function,

$$J = \{(L(x_0)-y)^T O^{-1}(L(x_0)-y) + (x_0-x_b)^T B^{-1}(x_0-x_b)\}/2. \quad (1)$$

Here x_b is a background estimate of the model state x_0 at the analysis time, which is typically a six-hour forecast from a dynamic model, y is a vector of observations distributed in space at the analysis time, L is an operator which predicts the observations from the analysis variables, O is the covariance matrix of the observation and representative errors, and B is the covariance matrix of the forecast errors.

To use the σ^0 data in the analysis, a new observation cost function J_{scat} is added to J. Assuming that the ERS-1 scatterometer observation errors are uncorrelated in space, the scatterometer cost function J_{scat} takes the form,

$$J_{scat} = \{ \sum_i (\sigma^0_{i\,model}-\sigma^0_{i\,obs})^2 / (K_p\sigma^0_{i\,obs})^2 \} / 2. \quad (2)$$

Here σ^0_{model} is calculated by a transfer function dependent on the satellite's aspect and incidence angles, and the NMC model wind speed and direction at the ocean surface, and σ^0_{obs} is the measurement given by the scatterometer. $K_p\sigma^0_{obs}$ represents the observational standard errors, which in principle should account for several error sources including communication noise, radar equation and model function uncertainties and representative errors.

The analysis procedure then is to find a model state, x_0, such that the sum of the two cost functions J and J_{scat} is a global minimum. The SSI analysis scheme at NMC is being modified to include the σ^0 data.

3. Preliminary Results

Before the scatterometer σ^0 data are used in the analysis scheme, it is important to have a quality control procedure for the data. We first investigate the variability of the ERS-1 σ^0 data with respect to the NMC's 10 meter wind analysis during an analysis cycle. For the results presented here, there were 52561 σ^0 data during a six hour window centered on March 7, 1800 UTC 1993 analysis time. Theses data cover the global oceans, except that the data points north 60^0 N and south of 60^0 S latitudes were not used in the calculation to eliminate any possible ice contamination on the observations. At each σ^0 observation location, the model wind speed and direction for the calculation of the model transfer function are obtained from the NMC 10 meter wind analysis. The model transfer function σ^0_{model} of the equation (2) is based on the CMOD2 empirical model as given in Stoffelen and Anderson (1992). The center point of each figure represents the point at which the u and v components of the winds are taken from the NMC wind analysis. The points to the right (and left) of the center point have a u-component wind increasing (and decreasing) at an interval of 1 m/sec with respect to the u-component of the NMC winds. Similarly, the points to the top (and bottom) of the center point have a v-component wind increasing (and decreasing) at interval of 1 m/sec with respect to the v-component of the NMC's winds.

The characteristics of the bias (σ^0_{model} -σ^0_{obs}) for each of the three antenna beams are shown in Fig. 1a (the fore beam), Fig. 1b (the mid beam), Fig. 1c (the aft beam), and Fig. 1d (the total bias of the three beams). For each beam, there exists a minimum (of about 1 db) positive bias near the area where the u-wind speed is about 4 m/sec greater than the NMC's u-wind and v-wind speed is about 1 m/sec less than the NMC's v-wind speeds. Moreover, large positive biases of greater than 3 db are exhibited near the left upper and lower edges of each antenna beam, which corresponds to about 3 m/sec from the u- and v- components of the NMC's 10 meter wind analysis. This suggests that it may be plausible to design a quality control procedure based on a certain threshold value of the difference between σ^0_{model} and σ^0_{obs}. The total RMS differences from the three beams and the corresponding J_{scat} cost function as discussed previously in equation (2) are shown respectively in Fig. 2a and Fig. 2b. As expected, the minimum values of both the RMS and J_{scat} cost function are near the center point where the winds are close the NMC's 10 meter winds.

To test the sensitivity of the quality control procedure discussed above, the calculations were repeated where the ERS-1 scatterometer data were rejected when an observed σ^0 of each antenna beam was greater than 3 db of the corresponding model σ^0 value. The results show that about 50% of the data points were not used (total number of data used in the calculation became 23476), indicating that the threshold value of 3 db is not realistic. A number of the threshold values are being tested for the quality control procedure. As expected, values of the RMS differences and J_{scat} cost function are reduced (Fig. 2c and Fig. 2d).

4. Summary

This paper describes a variational procedure currently under development to use the ERS-1 σ^0 observations directly in the NMC's operational global data assimilation system. A quality control procedure based on certain threshold values of the difference between σ^0 calculated by the model and observed σ^0 values are considered. Preliminary results based on one synoptic analysis cycle of a six hour window are presented. Other quality control procedures are also being investigated.

REFERENCES

Parrish D., and J. C. Derber (1992): The National Meteorological Center's Spectral Statistical Interpolation Analysis Scheme, Mon. Wea. Rev., 120, pp. 1747-1763

Stoffelen, A., and D. L. T. Anderson (1992): ERS-1 scatterometer calibration and validation activities at ECMWF: The quality and characteristics of the radar backscatter measurements. European Space Year Conference, Munich, Germany, 1992.

Thépaut, J-N., R.N. Hoffman, and P. Courtier (1993): Interactions of dynamics and observations in a four-dimensional variational assimilation, submitted to Mon. Wea. Rev.