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TECHNICAL NOTE

Assimilation Experiments With ERS-1 Winds: Part (I)-Use of
Backscatter Measurements in the NCEP Spectral
Statistical Analysis System

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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 backscatters, σ^0 , which are 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° , 90° , and 135° 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 using empirically derived transfer functions which relate wind speed and direction to the three backscatter measurements. However, the wind vectors thus derived contain directional ambiguities which preclude the use of these data in real time operational weather prediction models. 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).

Two approaches are currently being investigated in using the ERS-1 scatterometer wind data at NMC. One approach is to use the ERS-1 backscattered measurements directly in the analyses through a variational analysis scheme. This approach can apply the data globally in the atmospheric analyses without appealing to any additional correction schemes. The present study is Part (I) of this investigation which discusses results of analysis and assimilation experiments using this approach for treating the ERS-1 σ^0 data. The other approach is to apply a vector retrieval algorithm to the ERS-1 backscattered measurements and then use an ambiguity removal scheme to select correct vector winds before using them in atmospheric analyses and data assimilation. The details of this selection process are described in Gemmill et al (1994). The results of assimilation and forecast experiments using the objectively derived ERS-1 vector winds from this approach are reported in Part (II) of this investigation (see Yu (1995)).

Section 2 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 (Thepaut 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 problems in the wind directions. The analysis scheme minimizes the misfit to the data and other dynamical constraints as measured by a cost function.

A quality control procedure is described in Section 3, which is applied to the ERS-1 backscattered measurement data before the data are used in the analyses and data assimilation. The impact of the ERS-1 scatterometer wind data on global analyses and forecasts are addressed in Section 4, in which results of data assimilation experiments using two weeks of the ERS-1 scatterometer data in the NMC global data assimilation system are discussed. Finally, case analysis results applying the ERS-1 backscattered radiation measurements data to better resolve storm circulations are discussed in Section 5.

2. The Variational Procedure for Using σ^0 Data

The reader is referred to Parrish and Derber (1991) and Derber and Parrish (1992) for a detailed description of the operational global Spectral Statistical Analysis (SSI) scheme at NMC. The analysis scheme, briefly stated, is a three-dimensional variational problem 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 constraints. The misfit to the available data and the six hour forecast available at the analysis time is measured by a cost function,

$$J = \{(L(x_0)-y)^T O^{-1}(L(x_0)-y) + (x_0-x_b)^T B^{-1}(x_0-x_b)\}/2 + 0.5 d^T D^{-1}d \quad (1)$$

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