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USE OF ERS-1 SCATTEROMETER DATA to Derive Ocean Surface Winds AT NMC

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1. INTRODUCTION

The ERS-1 satellite, launched on July 17, 1991, has a scatterometer on board as part of its total sensor package. The scatterometer is an active radar radiating at the C-band frequency. The measurements taken by the scatterometer are normalized radar cross-sections (radar backscatter), a measure of the roughness of the sea surface generated by the surface winds. Three measurements in each cell, one from each antenna on ERS-1, are required to provide the information necessary to determine a wind speed and direction at a measurement cell. The resolution of each backscatter measurement cell is 50 km. The measurement locations (cells) are separated by 25 km. There are 19 cross track cells giving a data swath about 500 km wide. The polar orbital period for a local area on the Earth's surface is roughly 100 minutes.

What is important for operational and marine forecasting is that ESA delivers a "fast-delivery" stream of scatterometer data to NMC and other numerical weather prediction centers in buffer format for assimilation into their models. The ERS-1 scatterometer wind data stream contains both the backscatter values and the retrieved wind vectors. The early wind data product, however, was based on an empirical algorithm derived from pre-launch ERS-1 aircraft/buoy experimental data. The current operational ERS-1 scatterometer wind products reflect global satellite to surface observation evaluations/validations and subsequent algorithmic modifications.

During the validation phase of ERS-1, several new empirical algorithms based on post ERS-1 data were developed by ESA, ECMWF, METEO-France, IFREMER, NASA-JPL/Oregon State University, and the University of Hamburg investigators (Attema, 1992, Feilich and Dunbar, 1992, and Stoffelen *et al.*, 1992). Some of these newer algorithms are based on data from analyzed wind fields and wind data from dedicated, highly-instrumented experiments off the coast of Norway (Attema, 1992).

The scatterometer backscatter is a measured response to mostly the high frequency waves of the ocean surface caused and driven by the winds. For ERS-1, these algorithms convert the radar backscatter measurements to winds using an empirical transfer function. The scatterometer retrieved wind vectors are computed at an equivalent height of 10 meters above the sea surface.

Normally, solutions for up to four directions (frequently called ambiguities or aliases) are derived for a single cell observation. This is a result of the biharmonic characteristic of the backscatter measurement magnitude as a function of the scatterometer antenna look angle relative to the wind direction. These solutions are found using a maximum likelihood estimate or a sum-of-squares algorithm. Usually, two of the scatterometer solutions are the most probable and differ in direction by 180 degrees. Several techniques are being tested to discriminate between these 2 solutions to arrive at a single marine wind vector for assimilation into models (Offiler, 1992).

2. EVALUATION and VALIDATION

Six algorithms are currently being evaluated. One will be selected for the processing of scatterometer data at NMC. These algorithms may be further refined to provide closer-to-optimum results, particularly in direction. Preliminary analysis indicates that ESA's CMOD4 operational algorithm (developed at ECMWF) is the leading candidate for implementation at NMC.

3. PRELIMINARY RESULTS

Shown in Table 1. below are preliminary statistical results from analysis of ERS-1 wind speeds that were recorded on ESA's "fast-delivery" product we received at NMC. The comparisons were made with NMC analysis fields for the same period. Wind speeds up to 24 ms^{-1} were included in the sample that was evaluated.

TABLE 1.

No. of points = 219,981

Std. Deviation = 2.19 ms^{-1}

Bias (SCAT - NMC) = -0.24 ms^{-1}

Correlation (SCAT to NMC) = 0.84

Statistics are also being generated to compare scatterometer data with buoys.

These gross statistics are promising. However, upon examining the trend of agreement between the scatterometer data and the NMC analysis wind speeds as a function of the NMC wind speeds, it is noted that: (a) for winds less than 4 ms^{-1} the ERS-1 winds tend to be higher in magnitude than the NMC analysis speeds, (b) for wind speeds greater than 12 ms^{-1} the ERS-1 wind speeds are lower in magnitude than the NMC winds, and (c) the winds between 4 and 12 ms^{-1} tend to agree the best. These trends, of course, are based on the empirically-based transfer-function models relating scatterometer backscatter-to-winds. Similar comparisons between NMC and scatterometer data will be evaluated in the future with the different scatterometer algorithms referenced above.

The current ESA fast delivery product contains only one of the possible wind vector solutions. The scatterometer data to compute other possible wind vector solutions (up to 4, although more are possible but not probable as the correct wind vector) are now being processed at NMC. The dealiasing capability to reduce scatterometer results to a single wind vector is currently being evaluated. A sample of scatterometer data processed at NMC to a single wind vector solution is shown in Figure 1 (The processing generally follows that used operationally by the UK Met. Office, Offiler, 1992).

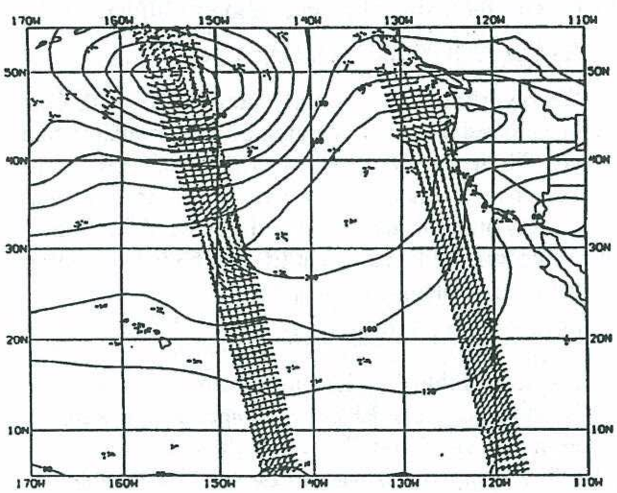

Figure 1. *A sample of ERS-1 scatterometer wind vector data is superimposed over a 1000 mb height field analysis for 12 GMT, April 27, 1993, west of the North American coast. For this region, the surface winds from ships and buoys are also plotted.*

Although major flow patterns are well defined, preliminary results show that there are some small blocks of retrieved wind vectors inconsistent with these patterns. We are attempting via algorithms to recognize these "failures" in wind direction and to either correct them or to remove them from the data stream. These erroneous vectors, however, are easily recognized by meteorological analysts and forecasters. Case studies to examine both the strength and weakness of the scatterometer data for use at NMC and other numerical weather centers are in progress.

These results indicate great promise for the use of the ERS-1 scatterometer wind vector data in numerical weather and ocean forecast models, and also for their use in meteorological and oceanographic climate research.

Preliminary experiments in assimilating scatterometer data into numerical models have begun and the impact of the scatterometer data is being evaluated.

4. ACKNOWLEDGEMENTS

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