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THE USE OF SATELLITE DERIVED WIND DATA IN HIGH-RESOLUTION REGIONAL OCEAN SURFACE WIND FIELDS

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1. INTRODUCTION

Accurate high-resolution regional and coastal ocean wind analyses are required with the advent of high- resolution ocean modeling capabilities, for waves, circulation, and storm surges. Further, high-resolution ocean surface wind satellite data, from several satellite systems, are now available in sufficient quantity for real-time operational applications. However, the science of converting satellite measured parameters into ocean surface winds is far from being exact. It is necessary to be able to assess the impact of various transfer functions or data sources on wind analyses and to determine how to blend the data from these different satellite systems to produce accurate meso-scale ocean surface wind fields.

Currently, most ocean surface wind fields are available from global data assimilation systems. Even when satellite surface wind data are used in these analyses, the satellite data are made into "super-obs" at the scale of the model. But since the model resolution is less than the observation resolution the meso-scale wind information will be lost through this process. Therefore, an analysis technique is being developed and tested to provide objective analyses of high-resolution ocean surface wind fields over selected U. S. coastal regions. This method is based on a reanalysis procedure in an attempt to regain some additional information from the observations which has been lost in the larger-scale global analysis system. This analysis is an extension of an earlier ocean surface wind analysis program (Gemmill, 1991). Those wind analyses were initially based on the reanalysis of real-time ocean surface wind data using ships, fixed buoys, coastal stations, on a high-resolution grid, with the initial wind analysis interpolated from a coarse grid from the global data assimilation system (GDAS) at 2.5 X 2.5 latitude and longitude. This paper presents the methodology of the current technique which is based on a higher resolution initial grid of GDAS (at 1.0 X 1.0 latitude/longitude) and the incorporation of satellite data.

Bumke and Hasse (1989) showed that it was possible to improve the resolution of a low-resolution global ocean surface wind analysis directly by reanalyzing surface observations of sea level pressure and surface wind. Sanders (1990) has pointed out that obtaining an accurate detailed sea level pressure analysis is no easy task, even when sufficient surface data (ERICA drifting buoys) are available. However, those studies were based on only direct surface measurements (buoys and ships), whereas today we have high-resolution real-time (25km-50km) satellite derived wind data available over wide swaths. These data are measured aboard two DMSP satellites using the SSM/I sensor to provide wind speed data across a 1500 km swath, and the ERS1 satellite using the scatterometer sensor to provide wind vectors across a 500 km swath. There is now extensive real-time coverage never before available.

2. THE DATA

In-situ ocean surface wind measurements are sparse. These data have been studied in some detail to determine their accuracy by Wilkerson and Earle (1990) and Pierson (1990). The basic conclusion of these studies is that ship data when compared to buoy data are not adequate for accurate analysis of the ocean wind field. In fact, whether or not the wind measurement was by anemometer, the quality was about the same. Gilhousen (1987) reports that the buoy wind data, although not without some problems, are within the NDBC error specifications of 1 m/s or 10% for speed and 20 degrees for direction. Coastal stations can be used for analysis, but the exposure must be known. Some of these platforms sit over the water, while others may be on high cliffs at the water's edge. Unfortunately, there is no uniform height for wind measurements over the ocean. Buoy heights' range from 3.8 m. to 14m, and ships somewhat higher at 20m, but that height depends on the size of the ship and its "load", and the coastal stations have already been noted.

The DMSP satellite (SSM/I) provides wind speeds over periodic 102 minute polar orbits in swaths of 1500 km and at a resolution of 25 km at a height of 20m above the sea. It is a passive microwave instrument. In mid-latitudes the satellite will pass over the same region twice a day on its ascending and descending passes. There are two SSM/I satellites (F10 & F13) which are approximately in the same orbit 4 ½ hours apart. The "standard" SSMI wind algorithm, which converts brightness temperatures to wind speed through multiple linear regression, and will be referred to as (MLR) was calibrated to meet the error requirement for speed of 2 m/s or 10% (Goodberlet, Swift and Wilkerson, 1989). But, these SSMI wind speed data have two important limitations: winds cannot be measured 1) above 20 m/s and 2) for moderate moisture and rain events. Hence, a new "all-weather" algorithm has been developed using the non-linear approach of neural networks (Krasnapolski, Breaker & Gemmill, 1995) and will be referred to as (NN). This algorithm gives improved wind speeds over the 5-15 m/s range for a wide range of moisture conditions. But, it too has limitations at high wind speeds.

The ERS1 satellite (with its scatterometer) provides wind vector data over periodic 102 minute polar orbits in swaths of 500 km and at a resolution of 50 km at a height of 10m above the sea. This is an active microwave instrument. In mid-latitudes the satellite will pass over the same region twice a day on its ascending and descending passes. The "standard" scatterometer algorithm (which converts radar backscatter to wind speed through empirical functions) was calibrated to meet the error requirement for speed of 2 m/s or 10%, and for wind direction of 20 degrees (ref). NMC has been receiving the "fast-delivery" wind data from ESA in real-time for operational use. However, although the wind speeds were of sufficient accuracy, the wind direction selection from that data was found to be poor. Since the raw radar backscatter data were also provided from ESA, NMC decided to reprocess these data by themselves (Peters et al, 1994). Substantial improvement in the wind direction was obtained as shown in a study by Gemmill et al (1994). In that study, we also compared various proposed transfer functions and showed that the transfer function used by ESA was best for providing wind speeds.

3. THE ANALYSIS PROCEDURE

The first guess for the wind field is generated by interpolation from the analyzed wind fields obtained from the NMC Global Data Assimilation System (Derber, Parrish and Lord, 1991) on a 1.0 X 1.0 degree latitude/longitude grid. These winds are obtained from the midpoint of the lowest sigma layer (LSL) of the model (about 45 m above the ocean surface), and are reduced to 20m using the neutral log-profile for a constant flux layer. The fine mesh grid was chosen to be ½ degrees in longitude and 1/3 degrees in latitude. The region selected is the Northwestern Atlantic Ocean adjacent to the U. S, east coast. The technique used to reanalyze the winds is based on a conditional relaxation method, which is applied as follows. The wind fields are separated into their "u" and "v" components, and each component is analyzed independently. The Laplacian of the first guess field components is formed to be used as the forcing function. Wind data, by components, are used to correct the wind field at the nearest grid point, which then are set as fixed internal grid points. Winds at non-corrected internal ocean grid points are determined by numerical relaxation against the forcing function. A conditional relaxation method is applied in two steps; first, after ERS1 scatterometer wind vector data have been inserted, and then after the SSMI wind speed data for the final analysis. The use of the Laplacian as the forcing function essentially preserves the original first guess shape of the field at grid points where no data was available. Appendix A briefly outlines the conditional relaxation procedure. Figure 1 summarizes the flow of the analysis procedures.

The conventional surface data of buoys, ships and c-man stations were withheld from the analysis. Buoys were to be used for validation.

During the reanalysis process, the satellite data