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Developments to Improve Satellite Derived Ocean Surface Winds for Use in Marine Analyses.*

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I. INTRODUCTION

One of the basic weather products used by the operational marine community is the ocean surface weather analysis. These analyses are prepared in "real-time," using fixed buoy and ship data, along with satellite cloud imagery, by marine meteorologists every 6 hours. These analyses consist of contours of sea level pressure to locate storm centers, fronts and other important marine weather features to identify areas of gale and storm force winds. However, because ocean surface wind and pressure data are sparse, a good analysis is extremely difficult to construct (Sanders, 1990). These ocean surface winds are also required for data assimilation systems used in numerical weather prediction.

Abundant ocean surface wind data have recently become available in "real-time'', within 3-5 hours from measurement time, from both passive and active microwave satellite systems. We briefly review efforts at NCEP to provide improved satellite derived ocean surface winds for operational use from both types of satellite sensors. This is done through 1) transfer function development for the Special Sensor Microwave/Imager (a passive microwave instrument which can retrieve wind speeds and flown aboard the Defense Meteorological Special Platform (DMSP) satellite series) and 2) a data processing system for the scatterometer (an active microwave instrument which can retrieve wind vectors and flown aboard the European Remote Sensing (ERS1) satellite). These instruments are flown on polar orbiting satellites with one ascending and one descending pass over a region during a one day period. Table 1 gives a brief summary of the satellite characteristics.

TABLE 1

	SSM/I	ERS1
Swath	1492km	500km
Footprint	25km	50km
Wind	speeds	vectors
Mode	passive	active

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Also, at present wind data are available from two DMSP SSM/I satellite systems. Thus, there is now a vast amount of ocean surface wind data for the marine meteorologist never before available.

However, these data sets have various problems. Some of these problems are obvious and simply need quality control procedures to remove duplicate data, erroneous data, etc. But the main problem is usually due to difficulties in the transfer functions themselves. This is because the transfer functions (from satellite sensor measurement to wind measurement) are empirically derived, using buoy data as "sea" truth. In order to improve these transfer functions one needs a long time series of collocated high quality satellite data and buoy data. However, these data are hard to acquire during pre-launch exercises and during the few months of validation after the launch. One key problem that occurs in most of these data sets is the lack of buoy matchups at high wind speeds, which are of particular interest. This deficiency produces a large uncertainty in satellite derived high wind speeds.

The satellite data received at NCEP fortunately contain both the meteorological (SSMI wind speeds or scatterometer wind vectors) as well as the basic satellite measurements (SSM/I brightness temperatures or scatterometer radar backscatter values) so that it is possible to rederive wind estimates from the satellite sensor measurements using improved transfer functions.

II. SSM/I DATA

The SSM/I derived wind speed data have been available since the late 1980's. The initial transfer function was in the form of a linear multiple regression (LMR) equation (Goodberlet, et al, 1989) which converts brightness temperature to wind speed data. It was determined to be adequate for "fair" weather conditions and has been used as the " operational" algorithm. But, the effects of moisture could not be effectively handled by this algorithm, so that its retrievals are limited to a "low" moisture atmosphere.

Our original attempt to improve the SSM/I wind retrievals was to apply neural networks (NN) as a basis for developing the retrieval algorithm (Krasnopolsky, et al, 1995). Since NN can deal with more complex physical relationships without prior knowledge of the functional form, moisture was no longer a serious problem in retrieving accurate wind retrievals. Using the training set applied to LMR, the original NN (ONN) showed significant improvements for all-weather coverage and accuracy. However, because of the lack of high wind speeds (> 18 m/s) in the training set, the ONN was not capable of reproducing high wind speeds when applied to "real time" satellite data. We then retrained NN with more weight placed on the few high wind speeds that were available in the data and additionally applied a bias correction to obtain an improved NN (INN) which extended the upper wind speed range (~ 27 m/s) with greater accuracy (Krasnopolsky et al, 1996). Table 2 summarizes collocated data for each of the various methods (using the same data) within 1 hour of buoy time and within 25 km radius, for the winter period 14 January - 11 March, 1996. To make direct comparisons the data are the low moisture conditions

TABLE 2

SSMI F10	Speeds (m/s)			
	BUOY	LMR	ONN	INN
AVG Speed	8.8	9.2	7.9	8.1
SD Speed	3.5	3.7	2.4	3.3
Max Speed	23.6	23.0	15.6	20.5

BUOY vs	LMR	ONN	INN
RMS	2.23	2.41	2.11

SSMI F13	Speeds (m/s)			
	BUOY	LMR	ONN	INN
AVG Speed	8.7	9.2	7.8	8.1
SD Speed	3.7	3.6	2.7	3.3
Max Speed	21.1	21.6	15.2	19.1

BUOY vs	LMR	ONN	INN
RMS	2.15	2.19	2.06

It can be seen from the comparisons above that wind speed errors in the algorithms have decreased with the improved NN.

III) ERS1 DATA

The ERS1 scatterometer wind data has been available since 1992 as a "fast delivery" (FD) product from the European Space Agency (ESA). However, a serious problem with the scatterometer is that it gives multiple solutions for the wind direction. Although the wind speeds met the original specification, the wind direction selections were poor and could not be used. Quality control procedures were identified and a reprocessing system was implemented at NCEP which obtained 1) wind speeds with the same transfer function (CMOD4) used by ESA, but 2) directions with the minimization and directional ambiguity technique developed and used by the U.K. Meteorological Office using the NCEP global model surface winds as a background. . Table 3 summarizes collocated satellite derived wind directions for the ESA FD data and the NCEP reprocessed data within 1 hour of buoy time and within 25 km radius, during a one year study period from 9 September 93 - 7 September 1994 (Gemmill et al, 1994).

TABLE 3

	FD	NCEP
BUOY vs	ERS1	ERS1
RMS Direction (Degrees)	61	27

It can be seen that quality of the reprocessed scatterometer wind direction retrievals scatterometer has improved.

IV) CONCLUSIONS

The SSM/I wind speed data and the ERS1 wind vector data have been improved and are now available for operational use in ocean surface wind analyses by marine meteorologists for routine subjective analyses and in data assimilation for objective analyses.

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