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WIND-WAVE RELATIONSHIP IN THE BAY OF BENGAL AND ARABIAN SEA USING *SEASAT* DATA

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ABSTRACT

The problem of extraction of sea state in monsoon season from satellite spectrometer derived wind data is addressed in this paper. The results show that the correlation coefficient between the sum of scatterometer derived wind generated wave height and average climatic swell, and the altimeter derived total wave height values is 0.8. The derived wave height values over the Arabian Sea are found to be reasonable. This indicates the possibility of preparing total wave height maps using scatterometer data over large swath areas. This can be done through a regression equation developed with large quantity of concurrent sea truth data. Use of satellite scatterometer rather than altimeter for extraction of wave height has been suggested.

Key-words: Wave height, wind speed, swell, Seasat, scatterometer, altimeter.

INTRODUCTION

For defining a relationship between wind speed and wave height, a large amount of good quality data over a significant period of time and space is required. It has been well established that satellite-borne radar altimeters, though developed primarily for measurement of the sea surface elevation, can also be used to infer total significant wave height quite accurately (Queffeulou, Braun and Brossier, 1981; Fedor and Brown, 1982). Radar scatterometers are able to provide sea surface wind speed and direction to an accuracy of ± 2m/s and $\pm 20°$ respectively (Jones, Schroeder, Boggs, Bracalente, Brown, Dome, Pierson and Wentz, 1982). Such sensors as altimeters and scatterometers on board satellites can provide synoptic, repetitive and uniformly accurate data. NASA's *Seasat* satellite launched in 1978 had scatterometer, altimeter and synthetic aperture radar among other primary sensors. In a short span of three months, it provided a large amount of well validated wind and wave data, which, in the absence of actual observations can be considered as sea truth.

In this paper *Seasat* satellite's scatterometer and altimeter data over the north Indian Ocean for the month of August 1978 were used to establish a wind vs total wave height relationship in the monsoon season. Such relationship can be useful in preparing wave maps from scatterometer wind data, which has a swath as large as 1500 km.

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Wind-wave relationship: Wave height and wave period in the open sea depend upon the strength of wind, its fetch and duration and presence of swell from the generating areas. Most graphs constructed for this purpose are based on empirical data, using as many observations as possible. It is seen that for a given wind speed and fetch the waves attain saturated growth after a definite duration.

During the monsoon season, mean wind conditions in the Indian waters are generally found to be steady, and rapid variations are rare. Hence duration and fetch for a mean wind input can be assumed to be above their limiting values. The wind and wind-wave data collected in the Indian seas during the Indo Soviet Monsoon Experiment (ISMEX-1973) and Monsoon Experiment of 1977 were analysed by Thiruvengadathan (1984) with the above assumptions. He derived a second order relationship between wind speed and wind-wave height and observed that the curve fits very well for all points above a height value of 0.5 meter.

The equation can be represented as

$$H = 0.17 + 0.87\times10^{-2}\,W + 1.4167\times10^{-2}\,W^2 \qquad \text{... (1)}$$

where H is a characteristic wave height of wind generated waves in meter, and W is wind speed in m/sec.

The validity of this expression had been tested using observations made by Russian research vessels during MONEX 1979 (Thiruvengadathan, 1984). The mean wave height samples were found to generally lie within ± 0.2 m of the values given by the above relationship and nearly 90% of observed values lie within 0.5 m of the computed values. Pandey, Gairola and Gohil (1986) have also developed a wind-wave relationship using *Seasat* altimeter data. In view of the high accuracy, equation (1) had been used by us.

EXTRACTION OF TOTAL WAVE HEIGHT FROM *SEASAT* SCATTEROMETER DATA

The *Seasat* scatterometer values have been first extracted for the month of August. The data sets have been averaged in $2^\circ \times 2^\circ$ grids over the entire region covering the Bay of Bengal, Arabian Sea and Indian Ocean (lat. 26°N to 6°S and long. 60° to 90°E). The wind speed values were then substituted in equation (1) to derive characteristic wave height (CWH). Among the wind wave heights thus computed, only those averaged wave heights whose standard deviations are less than 20% (in the averaging process) are retained for our analysis. The *Seasat* altimeter, a nadir looking pulse radar, gives estimate of significant wave height (SWH) from the stretching of the leading edge of the mean return wave forms. The SWH however is a mixture of wind-waves and swell. On the other hand, wave heights computed through equation (1) using scatterometer data will represent only wind-waves.

In order to derive the significant wave height, both swell and wind wave height are required. In the absence of measurements of swell available with us, monthly mean values of swell given in wave (swell) atlas (1982) of National Institute of Oceanography, Goa were used. With this, it was possible to estimate average swell height values for the month of August in $5^o \times 5^o$ grids, which are coarser than the grids used for wind-wave heights.

The significant wave height has then been derived using the energy conservation equation, i.e.

$$E_{total} = \frac{1}{16}(CWH)^2 + \frac{1}{16}(SWELL)^2$$

where E represents energy.

Hence, derived significant wave height (SWH) can be expressed as

$$SWH_{Derived} = [(CWH)^2 + (SWELL)^2]^{\frac{1}{2}}$$

As the average swell heights are not expected to change drastically in the neighbouring grids, data points upto 6^oS have been included. The swell heights to the south of Equator (which are not provided in the atlas), are assumed to be same in the adjacent grids north of Equator.

RESULTS AND DISCUSSION

The colocated wave heights computed from scatterometer and altimeter data are represented as scatter plots (Fig.1). Preliminary results of this

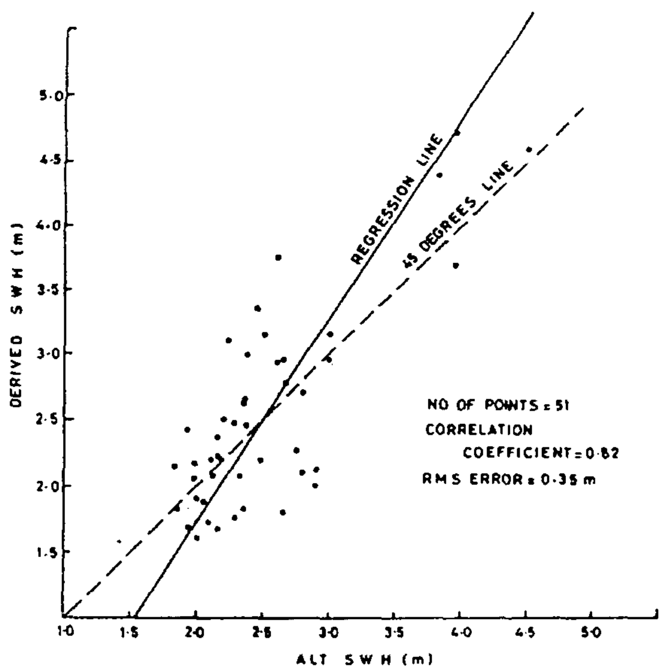

Fig.1. Scatterplot of scatterometer derived significant wave height vs. significant wave height as given by Altimeter.

study were presented by Sarkar and Raj Kumar (1987). Comparison of wave heights obtained from the two methods indicates a root mean square deviation of 0.35 m. This may be attributed to the addition of swell from climatic map averaged for large space and time. The average swell height for that period was found to be 1.7 m. The bias has been found more in data points lying in the areas south of Equator, where assumed values of swell heights have been used. Hence scatter will be smaller, if actual simultaneous wave mesurements (averaged over grids) are used for comparison.

There are 52 data points. The correlation coefficient between wave height by altimeter and total wave height by scatterometer as defined above for the total data set is 0.8, validating the original equation (1) as well as the use of scatterometer wind data for deriving wind-wave height. On application of t-test, correlation was found to be at 99% confidence level. Regression equation between the CWH and SWH has found to be CWH = 0.89+0.64×SWH.

Since the scatter plots were generated by data from two independent sensors, scatterometer and altimeter, the high correlation coefficient cannot be an artifact of the procedure. With more satellite and *in situ* data, an accurate regression equation can be hoped to be generated and wave height maps can be generated for the whole area similar to the one shown in Fig.2. Due to large coverage (~ 1500 km) of spaceborne scatterometer, mapping of ocean wave heights by the present technique is effective and useful.

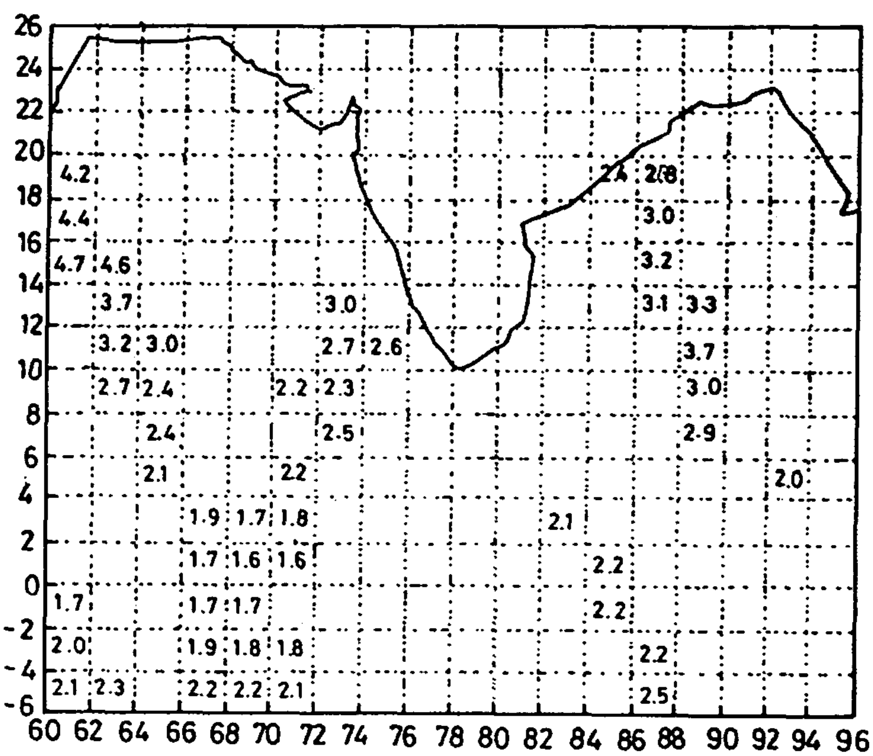

Fig.2. Scatterometer derived wave height map for August 1978.

The satellite derived wave height values over both the Bay of Bengal and Arabian Sea for the period considered (August 1978) are generally found to be between 2 to 3 m. This agrees well with the observations made by Mukherjee and Sivaramakrishnan (1982), who have reported the wave heights to be decreasing gradually from around 4 m in July to about 1.5 m in September in the Arabian Sea.

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