

Comparison of ERA-Interim waves with buoy data in the eastern Arabian Sea during high waves

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Wave data during extreme conditions is required for planning structures and shipping routes. Since the measured wave data is still sparse in the eastern Arabian Sea, wave information is mainly derived from wave model dataset and satellite derived data. Hence, it is important to know the performance of these dataset during high wave conditions. A study is carried out to compare the wave height, period and direction during high waves obtained from wave model dataset: ERA-Interim and that measured by the buoy at two locations in the eastern Arabian Sea. One location is a deep water location and another one is a shallow water location. The comparison of significant wave height (SWH) between ERA dataset and buoy data at both the locations shows good correlation (correlation coefficient=0.85) with root mean square error of 0.87 and 0.53 m. But the maximum SWH based on ERA dataset in deep water is 15% less than that measured by the buoy, whereas in shallow water ERA datasets over predicts the maximum SWH by 9%. The comparison of wave period and direction at both locations shows significant scattering.

[Keywords: Significant wave height, Wave period, West coast of India, Model dataset]

Introduction

The ocean wave climate and especially the occurrence of high wave energy levels generated by severe storms, is important to the operation and safety of shipping, drilling exploitation of natural resources in the deep sea, design of harbours and estimation of sediment transport in the coastal zone. The importance on good estimate of wave climate for construction of marine structures has been highlighted by many researchers^{1,2}.

Northern Indian Ocean region is characterized by seasonally reversing monsoon wind systems-South-West monsoon (SW, June to September) and North-East monsoon (NE, November to February). The waves along the west coast of India are influenced by the wind condition in the North Indian Ocean and largely by the SW monsoon³. Along the west coast of India, significant wave height (SWH) up to 6 m was reported⁴ during the summer monsoon period and SWH was normally less than 1.5 m during rest of the period. The wave information is generally obtained through several ways and each source has its own limitations. For example, the in-situ measurements provide information on spot samples and are expensive, whereas recently originated remote sensing techniques provides global coverage data with less temporal coverage and deriving the accurate

wave parameter requires good algorithms. Hindcasts with ocean wave models have therefore become a common tool to complement the limited observational record. Usually, such hindcasts are validated with the limited observations available and are later regarded as a reality substitute from which information can be drawn on variables that has either not been measured directly or which have been sampled only insufficiently in space and time⁵.

Since the measured wave data is still sparse in the eastern Arabian Sea, wave information is mainly derived from wave model dataset and satellite derived data. Hence, it is important to assess the performance of these dataset during high wave conditions, generally during the SW monsoon season. Recently originated model datasets provide good data, but apparent in homogeneities can be noticed in the datasets during the high waves and also due to the different assimilation of the satellite. To detect and correct these in homogeneities we need high quality in-situ measurements.

There have been many studies around the globe on the correction of these reanalysis product⁶⁻⁸. Present study aims to evaluate the performance of recently developed ERA-Interim reanalysis data product of the European Centre for Medium-Range Weather Forecasts (ECMWF), during high waves off the west

coast of India. The available measured buoy data at two locations in the eastern Arabian Sea, one at deep water and other at shallow water is compared with the model datasets to evaluate the performance of the model datasets during high waves.

Materials and Methods

ERA-Interim reanalysis data

The wave model datasets used in this study are from the ECMWF (<http://www.ecmwf.int/research/era/do/get/index>). ERA-Interim is the most recent re-analysis provided by ECMWF⁹. ERA-Interim is the first re-analysis using adaptive and fully automated bias corrections of satellite radiance observations¹⁰. Parameters used in the study are significant wave height, mean wave period and mean wave direction, which are downloaded for a period from 7 to 21 June during 2004 for deep water location and 14 to 20 June during 1996 for shallow water location at 6 hourly intervals with a resolution of $0.75^\circ \times 0.75^\circ$ latitude/longitude.

Buoy data

Waves measured at two locations off along the west coast of India were analyzed to study the wave characteristics in the deep as well as near shore regions during SW monsoon seasons. Measured wave data off Goa at a deep water (about 3000 m water depth) location (15.50° N; 69.27° E) and a shallow water (water depth 23 m) location (15.465° N; 73.683° E) using a moored wave buoy is used in the present study for comparison of the model dataset (Fig. 1). The data recorded for 30 min duration at 1.28 Hz interval at shallow water location and for 20 min duration at 2 Hz interval at deep water location. Wave spectrum is obtained through Fast Fourier Transform (FFT). FFT of 8 series, each consisting of 256 measured vertical elevations of the buoy data, are added to obtain the spectra. The high frequency cut-off is set at 0.5 Hz and the resolution is 0.005 Hz. SWH and mean wave period (T_z) is obtained from the wave spectrum.

Results and Discussion

Details of the locations and the wave parameter measured by the buoy and that obtained through model datasets are given in Table 1. During 1996 at deep water location, the maximum SWH obtained from the model datasets and that with buoy measured shows considerable variation. The maximum SWH observed for ERA-Interim data for the period is 5.8 m with mean value of 4.1 m, whereas high value of SWH of 6.7 m with little higher average SWH of 4.8 m is observed in buoy datasets. On the other hand, at shallow water the maximum SWH observed for ERA-Interim data is 6.1 m which is about 9% higher than that observed with buoy. Mean SWH observed for buoy and ERA-Interim data are 3.9 and 4.2 m respectively.

We present the results based on the detailed attempt to quantitatively compare the available buoy data with ERA-Interim model data at deep water (3000 m depth) and shallow water location (23 m depth) off Goa. This is done through some statistical computations. The parameters used for the comparisons are Bias, Root Mean Squared Error (RMSE), Scattering Index (SI) and the Correlation coefficient (r).

The results of the comparison statistics is presented in Table 2. Fig. 2 and Fig. 3 represent the linear regression analysis of buoy measured SWH and wave period with ERA-Interim model datasets.

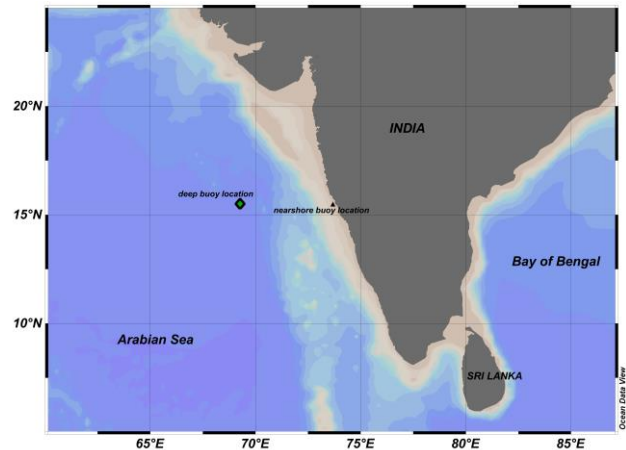


Fig.1. Study locations

Table 1: Basic statistics of measured buoy data and ERA-Interim model data

Period	Location	Water depth (m)	SWH measured by buoy (m)			SWH from model data (m)		
			Maximum	Mean	Std deviation	Maximum	Mean	Std deviation
7-21 June 2004	15.50° N; 69.27° E	3000	6.72	4.8	0.98	5.8	4.1	0.79
14-20 June 1996	15.465° N 73.683° E	23	5.6	3.9	0.93	6.1	4.2	0.92

The comparison of significant wave height (SWH) between ERA-Interim dataset and buoy data at both the locations shows good correlation (correlation coefficient=0.85) with root mean square error of 0.87 and 0.53 m. At deep water location a positive bias of 0.73 m is obtained for SWH which shows that ERA-Interim data under predicts (Fig. 2) the measured data at 3000 m, whereas a negative bias in shallow water (23 m water depth) shows the over prediction by the model datasets (Fig. 3).

At deep water depth, even though less correlation (0.43) in wave period is observed between ERA-Interim data and measured data, small RMSE (0.46 s) and bias (0.04 s) is observed. Scattering is relatively small with SI of 0.04. However, the comparison with shallow

water buoy shows higher correlation (0.76), but larger scattering and RMSE is observed (SI is 0.33 and RMSE 2.48 s).

The other parameter, mean wave direction shows correlation coefficient of 0.57 and -0.55 respectively for deep and shallow water locations. The model data shows positive bias of 6.1 deg at deep water depth, which reflects the under prediction of the model dataset, whereas large RMSE and negative bias of 9.4 deg is obtained at shallow water depth.

The results show that SWH model datasets are reliable at both deep and shallow water locations with greater accuracy whereas, other parameters (wave period and wave direction) require good algorithm to use these data for practical application.

Table 2: Comparison statistics analysis between buoy and model datasets at two locations

Location and period	Parameter	Bias	RMSE	SI	r
At 3000 m depth during 7-21 June 2004	SWH	0.71 m	0.87 m	0.18	0.85
	Mean wave direction (dp)	6.1 deg	6.9 deg	0.02	0.57
	T_z	0.04 s	0.46 s	0.04	0.43
At 23 m depth during 14-20 June 1996	SWH	-0.22 m	0.53 m	0.13	0.86
	Mean wave direction (dp)	0.84 deg	9.14 deg	0.04	-0.55
	T_z	-2.44 s	2.48 s	0.33	0.76

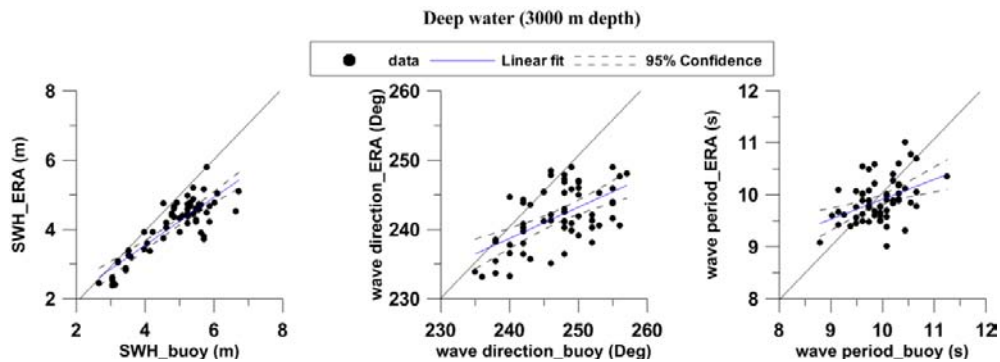


Fig. 2. Regression analysis of ERA-Interim model datasets with measured buoy data at water depth of 3000 m location

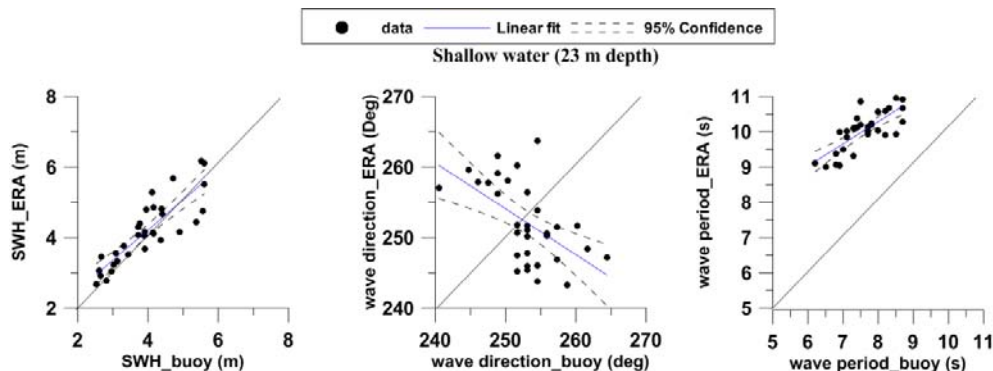


Fig. 3. Regression analysis of ERA-Interim model datasets with measured buoy data at water depth of 23 m location

Conclusions

The ERA-Interim data during high waves along the west coast of India for the year 2004 and 1996 have been compared with measured buoy datasets at two locations. The significant wave height data match closely with in-situ observation at both locations, whereas large scattering is observed in mean wave period and mean wave direction which need to be corrected with good algorithm before using in any practical application. The under prediction of ERA-Interim data suggests, that high wave events mainly due to the cyclones are difficult to capture in model dataset.

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