Ocean Engineering 81 (2014) 150–157

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Short Communication

Spatial and temporal variation of surface waves in shallow waters along the eastern Arabian Sea

T.R. Anoop, V. Sanil Kumar *, P.R. Shanas

Ocean Engineering, CSIR-National Institute of Oceanography, (Council of Scientific and Industrial Research), Dona Paula 403 004, Goa, India

ARTICLE INFO

Article history:
Received 17 August 2013
Accepted 17 February 2014
Available online 6 March 2014

Keywords:
Significant wave height
Wave period
Wave direction
Wave spectral energy
West coast of India

ABSTRACT

We studied the spatial and temporal variation of surface waves along the eastern Arabian Sea during 2011 and 2012. Measured directional wave data at two shallow water locations and re-analysis datasets (ERA-Interim) at 0.75° intervals at four locations were used for the study. The study region covers 270 km along the west coast of India and lies between Karwar and Ratnagiri. The temporal variations of wave parameters were less than 10% at both locations for temporal intervals up to 12 h except during the monsoon/storm period. During the storm period, the variation in significant wave height within 3 h was around 13% and was up to 26% inside 12 h. Comparatively low ($<10\%$) spatial variation was found for wave height during the monsoon season and higher variation ($>20\%$) was observed during the non-monsoon season. The pattern of spatial variation of wave parameters was similar during both the years for the measured and re-analysis datasets. The study shows that during the monsoon period, the wave characteristics were similar for the 270 km long stretch since the waves along this part were predominantly ($\sim 72\%$) swells.

1. Introduction

Engineers involved in the planning and design of marine structures require information on waves at a specific location. To derive the wave climate at a location or region, time series wave data covering many years are necessary. Wave data at a specific location is obtained through (i) wave measurements, (ii) numerical models, or (iii) satellites (Cavaleri and Sclavo, 2006). The wave data obtained from numerical models and satellites need to be verified by the measured data. But due to the high expense towards the installation and maintenance of wave measuring instruments, in-situ measurements at many locations remain a challenge even today. Also, carrying out wave measurements in shallow water locations over a long-term basis is a difficult task due to the intense fishing activity in the near-shore area. Entanglement of the fishing vessels/nets with the moored buoy results in damage to the buoy and the moorings. Similarly, the coastal domain represents a challenging target for exploiting satellite information, where accuracy is degraded due to a number of factors including issues of land contamination in the altimeter and radiometer footprints (Andersen and Scharroo, 2011). In the absence of measured data for a specific location, numerical models are calibrated with the data available for the nearest location; hence it is important to know the spatial variation of wave parameters. The re-analysis datasets and the satellite data have limitations in temporal and spatial resolutions. Hence, it is necessary to understand the variation of each parameter with respect to time and location.

The present study is focused on the eastern Arabian Sea, mainly from Karwar to Ratnagiri (Fig. 1). The waters off the west coast of India are exposed to seasonally reversing winds, with winds from the south-west (SW) during the SW/summer monsoon (hereafter monsoon) period (June to September) and from the north-east (NE) during the post-monsoon period (October to January). The period between the NE and SW monsoon is the pre-monsoon period or the fair weather (FW) period. The seasonal changes in winds produce similar changes in the surface waves and hence it is important to know the variations in wave parameters seasonally and inter-annually. Kumar et al. (2012) reported that the seasonal average wave height and period did not vary significantly between three stations covering 200 km along the Karnataka coast, India. Glejin et al. (2012) compared the wave parameters at three locations along the eastern Arabian Sea from June to August 2010 covering the monsoon period and found that the wave height increased from the south to the north. Since the study of Kumar et al. (2012) covered only the data for one month representing each of the three seasons and that by Glejin et al. (2012) covered only the monsoon period, we have conducted a fresh

* Corresponding author. Tel: +91 832 2450 327;fax: +91 832 2450 602.
E-mail address: sanil@nio.org (V. Sanil Kumar).
URL: https://www.nio.org (V. Sanil Kumar).

http://dx.doi.org/10.1016/j.oceaneng.2014.02.010
0029-8018

Annexure: Notations used

B_m	directional spread
D_p	wave direction corresponding to spectral peak
D_{ps}	peak direction of swell
D_{pw}	peak direction of wind-sea
E_{max}	maximum spectral energy density
ECMWF	European Centre for Medium-range Weather Forecast
ERA	ECMWF Re-Analysis
H_{max}	maximum wave height
H_s	significant wave height
H_{ss}	significant height of swell
H_{sw}	significant height of wind-sea
PD	percentage difference
Swell (%)	Swell percentage
T_{Hmax}	maximum wave period
T_p	Peak wave period
T_z	mean wave period
T_{zs}	mean period of swell
T_{zw}	mean period of wind-sea

study covering a larger spatial interval with continuous data covering a 2 year period. The objective of the study was to understand the spatial and temporal variation in surface wave parameters between two locations spaced at 270 km along the eastern Arabian Sea. The variations in surface waves in the near-shore waters were studied with the data obtained from simultaneous measurements carried out at two locations using moored directional wave rider buoys and those for the offshore waters were done with the ERA-Interim dataset.

The locations selected for the study were (i) off Karwar (southern location) at 15 m water depth (geographic position 14.8217°N, 74.0524°E) and (ii) off Ratnagiri (northern location) at 13 m water depth (geographic position 16.9801°N; 73.2584°E). The distance of the locations from the west coast of the Indian mainland is 5 km at Karwar and 2 km at Ratnagiri. The distance between Karwar and Ratnagiri is around 270 km and these locations are exposed to deep-water swell waves from the south Indian Ocean. Tides in the study region are mixed and are predominantly semi-diurnal and the average tidal range at Karwar is 1.58 m during spring tide and 0.72 m during neap tide. At Ratnagiri, the average spring tidal range is about 1.8 m and the neap tidal range is 0.9 m (Glejin et al., 2013).

2. Data and methodology

Waves were measured using the Datawell directional wave rider buoy (Barstow and Kollstad, 1991) for a period of 2 years from 1 January 2011 to 31 December 2012. Measurements were made in Coordinated Universal Time (UTC) and the time referred in the paper is UTC. The data were recorded continuously at 1.28 Hz and the data for every 30 min were processed as one record. The collected time series was subjected to standard error checks for spikes, steepness and constant signals (Haver, 1980) and a total 17,418 records measured simultaneously at both locations during 2011 and 17,416 records during 2012 were used for further analysis. Zero-crossing analysis of the surface elevation time series was used to estimate maximum wave height (H_{max}) and the wave period corresponding to maximum wave height (T_{Hmax}). Fast Fourier Transform values of eight series, each consisting of 256 measured vertical elevations of the buoy data, were added to obtain the wave spectrum. The high frequency cutoff is set at 0.58 Hz and the resolution is 0.005 Hz. Significant wave height (H_s) which equals $4\sqrt{m_o}$and the mean wave period (T_z) which equals $2\pi\sqrt{m_0/m_2}$were obtained from the spectral moment. Where m_n is the nth order spectral moment and is given by $m_n = \int_0^\infty f^n S(f)df$,

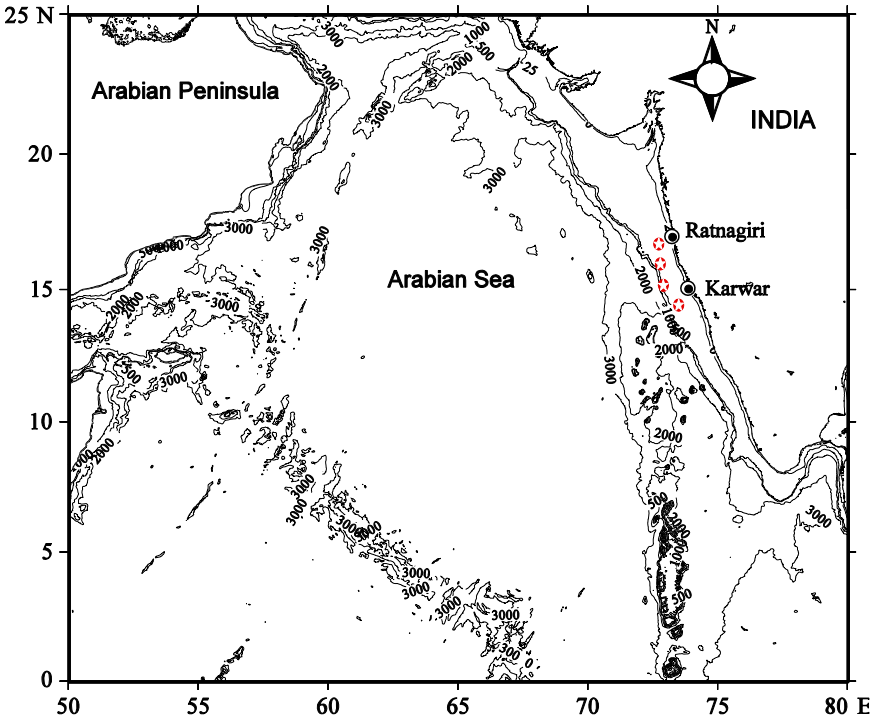

Fig. 1. Study locations in the eastern Arabian Sea. Red marks show the ERA-Interim locations. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)