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Seasonal and interannual changes of significant wave height in shelf seas around India during 1998–2012 based on wave hindcast

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ABSTRACT

Present study examines the interannual changes of significant wave height (H_s) in shelf seas around Indian mainland based on the 15-year (1998–2012) wave hindcast data obtained from numerical model. Validation of the hindcast data with buoy-measured data shows that hindcast H_s is reasonably in good agreement with the observation (Pearson correlation coefficient values of 0.92–0.97). Annual average H_s varied from 0.9 to 1.4 m and the wave heights are higher (~20%) in western shelf seas compared to eastern shelf seas. The analysis reveals seasonal fluctuations of wave climate, with a strong influence of Asian summer monsoon in the western shelf seas compared to the eastern shelf seas of India. Maximum H_s varied from 3.65 to 7.36 m and these maximum values were during the tropical cyclones. During 1998 to 2012, a statistically significant positive trend of 0.8–1.4 cm yr^{-1} in annual mean H_s is observed and the increasing trend is higher (~0.7–2.5 cm yr^{-1}) during the Asian summer monsoon period (June–September). The average trend of annual mean wind speed is also positive and is higher (~1.67 cm s^{-1} yr^{-1}) for the western shelf seas than that for eastern shelf seas (~0.93 cm s^{-1} yr^{-1}).

1. Introduction

The shelf seas of the Indian subcontinent are being explored for oil and gas and minerals due to the rising demands of these commodities. The wind generated ocean waves play a significant role in all aspects of coastal and offshore activities (Semedo et al., 2013). Waves also cause erosion of the coastlines and the coastline erosion is expected to be intensified by future sea level rise (Hinkel et al., 2013) along with potential changes in the wave climate (Seneviratne et al., 2012). Hence, it is important to know the changes in wave climate in the shelf seas of India. Generally, significant wave height (H_s) is used as an indicator to study the wave climate at a location and the variations in annual mean H_s during different years are examined to know the change in wave climate. Estimating reliable trends in wave height from measured buoy data are limited because they are sparse point measurements and are not available for long period. Hence, the long-term and decadal trend of wave climate in the different parts of major oceans are studied based on voluntary observing ships, global datasets produced within wave reanalysis, satellite altimetry or wave model hindcasts (Carter and Draper, 1988; Allan and Komar, 2000; Gulev and Grigorieva, 2004; Young et al., 2011; Semedo et al., 2011; Appendini et al., 2014; Aarnes et al., 2015).

The waters of the North Indian Ocean (NIO) are exposed to seasonally reversing winds; winds from the southwest (SW) during the Asian summer monsoon period (June to September) and from the northeast (NE) during the winter monsoon period (October to January). These seasonal changes in winds produce similar changes in the surface waves in NIO (Anoop et al., 2015). During the annual cycle, monsoon is the dominant mode of variability and it covers 92% of the total variability (Anoop et al., 2015). In the NIO, the swell heights are greater than those associated with the wind waves and remote influences propagating from the subantarctic region of the south Indian Ocean are observed (Anoop et al., 2015). The Indian subcontinent divides the NIO into two semi-enclosed seas, the Arabian Sea (AS) and the Bay of Bengal (BoB). AS and BoB, are the only sea areas in the Northern Hemisphere with larger summer than winter

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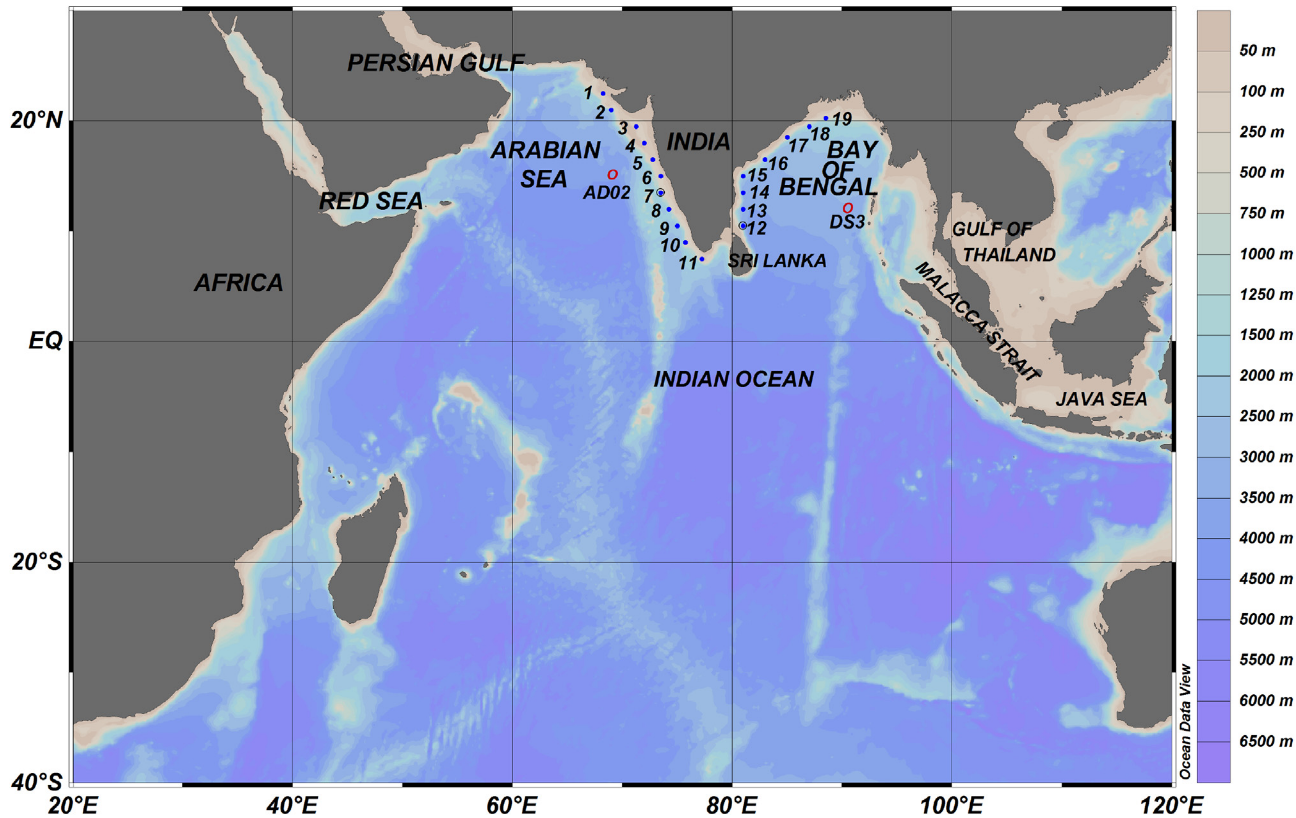

Fig. 1. Map showing the model domain and the 19 locations studied in the shelf seas around Indian mainland. AD02 and DS3 are buoy measurement locations used in the study. DS1 buoy location is 0.5 deg east of AD02.

Table 1
Results of the sensitivity analysis carried out by varying the southern model boundary.

Parameter	Location	Statistics	30° S	40° S	50° S	60° S	70° S
Significant Wave Height	Arabian Sea	Correlation Coefficient	0.975	0.977	0.970	0.968	0.970
		MAE (m)	0.417	0.341	0.316	0.312	0.308
		RMSE (m)	0.545	0.485	0.463	0.447	0.451
	Bay of Bengal	Correlation Coefficient	0.916	0.899	0.882	0.882	0.887
		MAE (m)	0.538	0.443	0.356	0.32	0.327
		RMSE (m)	0.671	0.574	0.493	0.448	0.463
Mean Wave Period	Arabian Sea	Correlation Coefficient	0.838	0.901	0.888	0.884	0.895
		MAE (s)	0.746	0.544	0.524	0.569	0.518
		RMSE (s)	1.013	0.721	0.713	0.785	0.719
	Bay of Bengal	Correlation Coefficient	0.590	0.627	0.61	0.567	0.631
		MAE (s)	1.357	0.940	0.932	1.082	0.971
		RMSE (s)	1.403	1.019	1.319	1.23	0.988

MAE - mean absolute error.
RMSE - root mean square error.

energy levels, due to a combination of stronger summer monsoon winds and higher swell influx during southern ocean winter and hence have large seasonality (Barstow et al., 2011). Waves in the BoB are frequently influenced by tropical cyclones, whereas the occurrence of the tropical cyclone in AS is less compared to BoB, and the ratio of their frequencies is around 1:4 (Dube et al., 1985).

In the NIO, the long-term trend in wave height is estimated based on European Centre for Medium-Range Weather Forecasts (ECMWF) global atmospheric re-analysis product (ERA-I) during 1979–2012 (Shanas and Kumar, 2014; 2015; Kumar and Anoop, 2015; Anoop et al., 2015; Aarnes et al., 2015) and satellite altimeter data during 1993–2010 (Kumar et al., 2013a), 1992–2012 (Bhaskaran et al.,