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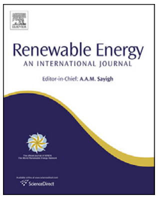

Data bank

Wave energy resource assessment for the Indian shelf seas

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A B S T R A C T

As a renewable energy, the assessment of wave power potential around a country is crucial. Knowledge of the temporal and spatial variations of wave energy is required for locating a wave power plant. This study investigates the variations in wave power at 19 locations covering the Indian shelf seas using the ERA-Interim dataset produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). The ERA-Interim data is compared with the measured wave parameters in the Arabian Sea and the Bay of Bengal. Along the western shelf seas of India, the seasonal oscillations lead to variation of the wave power from the lowest seasonal mean value (2.6 kW/m) in the post-monsoon period (October–January) to the highest value (25.9 kW/m) in the south-west monsoon (June–September) period. Significant (10–20%) inter-annual variations are detected at few locations. The mean annual wave power along the eastern Indian shelf seas (2.6–9.9 kW/m) is lower than the mean annual wave power along the western part (7.9–11.3 kW/m). The total annual mean wave power available along the western shelf seas of India is around 19.5 GW. Along the eastern shelf seas, it is around 8.7 GW. In the Indian Shelf seas, the annual mean wave power is highest (11.3 kW/m) at the southern location (location 11), and the seasonal variation in wave power is also less. Hence, location 11 is a better location for a wave power plant in the Indian shelf seas.

1. Introduction

Amongst renewable energy sources, ocean waves contain the highest energy density and have the potential to become a commercially viable energy source [1]. Progress from full-scale testing to the commercialisation of wave energy projects has been relatively slow. This slowness has been partly due to the financial risks associated with uncertainty in quantifying the wave energy resource over a variety of timescales [2]. Based on the analysis of wave data collected from buoys, satellites, numerical wave hindcasts, or a combination of these sources, wave energy resource assessments have been made for the Black Sea [3], the Baltic Sea [4], the Hawaiian Islands [5], the North Sea [2] and the Persian Gulf [6]. In addition, wave energy resource assessments have been made for the seas around Australia [7], Canada [8], California [9], Canary Islands [10], China [11], Europe [2,12], Iran [13], Ireland [14], Malaysia [15], Portugal [16,17], Taiwan [18], the United Kingdom [2,19] and the United States [20,21]. Wave energy resource assessment is also carried out globally [22,23].

India has a long coastline of 5423 km along the mainland and receives around 5.7 million waves per year [24,25]. Hence, the country has large wave energy resources. Along the Indian coast, the Indian Institute of Technology Madras in Chennai has conducted studies on wave energy resources and wave energy conversion devices [26]. In addition, a wave energy plant is located at Vizhinjam based on the near-shore oscillating water column [27].

Kumar et al. [28] examined variations in near-shore wave power at four shallow water locations along the east and west coasts of India. Their findings were based on the measured wave data covering a one-year period. However, since the spatial and temporal variation in wave energy covering the entire Indian shelf seas is not known, the purpose of this research is to assess the wave energy resources in the Indian shelf seas. Nineteen deep water locations (11 locations in the western Indian shelf seas and 8 locations in the eastern Indian shelf seas) are selected for the study (Fig. 1). Information on the monthly and annual variability of the wave power is required when selecting a wave power plant location. Hence, the variations in wave power over a 34-year period at the 19 deep water locations are also studied.

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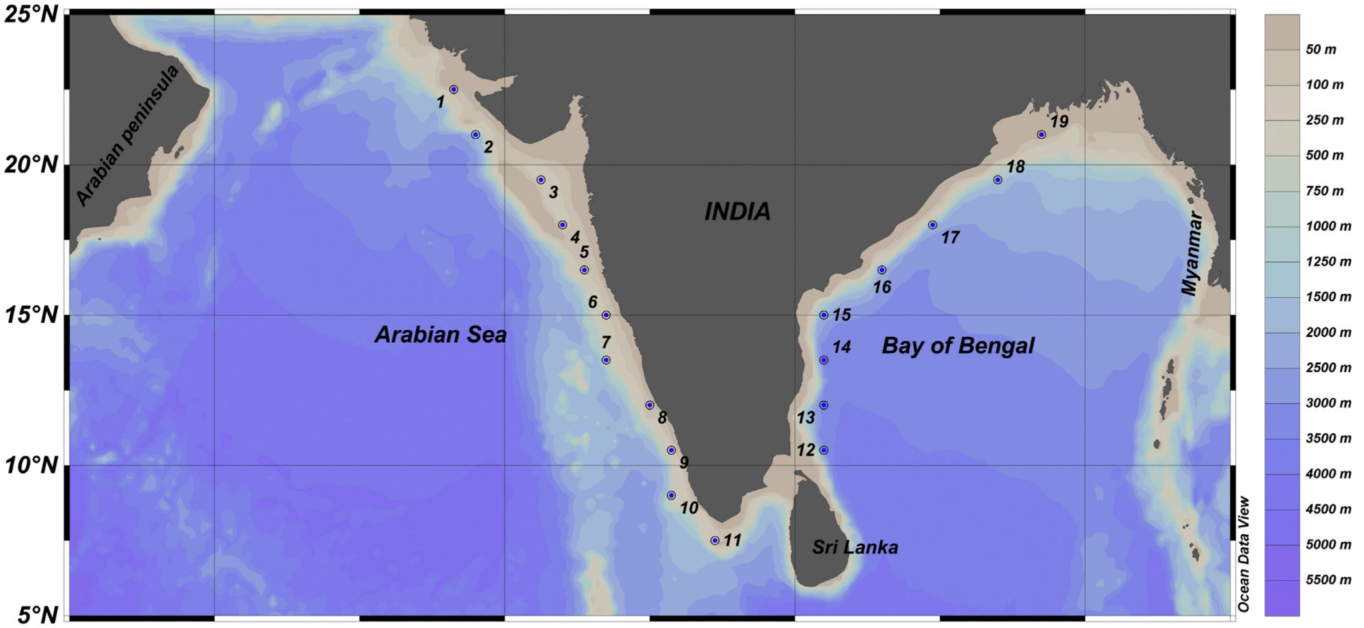

Fig. 1. Map showing the locations considered in the study.

2. Materials and methods

2.1. Data

The ERA-Interim (ERA-I) global atmospheric re-analysis dataset, the most recent reanalysis dataset produced by the European Centre for Medium-Range Weather Forecasts (ECMWF), is used in the study [29]. An updated atmospheric model (the Integrated Forecast System Cycle 31r2) is used in the data analysis, which includes increased pressure levels and additional cloud parameters that maximize improved model physics [30]. The incorporated wave model is based on the WAM (global ocean WAve prediction Model) approach [31]. Significant wave height (H_s) and wave period (T_e) data with a grid resolution of 0.75° × 0.75° are extracted for the period January 1, 1979 to December 31, 2012 at 6-h intervals for the selected locations.

Although the ERA-I datasets are validated with measured buoy data for different regions [32], the ERA-I H_s and T_e data are compared with the measured buoy data at two locations in the Arabian Sea (AS) and at one location in the Bay of Bengal (BoB) before estimating wave power in the Indian shelf seas. The location of the buoys and the details of the data collected are presented in Table 1. Using the heave data recorded by the buoy, the wave spectrum is obtained via Fast Fourier Transform (FFT). The H_s and the energy wave period (T_e) are obtained from the spectral moments as shown in Equations (1) and (2).

$$\text{Significant wave height } (H_s) = 4\sqrt{\mathrm{m_o}} \tag{1}$$

$$\text{Energy period}(T_e) = \frac{m_{-1}}{m_0} \tag{2}$$

where m_n is the nth order spectral moment and given by $m_n = \int_0^\infty f^n S(f)\mathrm{d}f$, $n = 0$ and -1, and $S(f)$ is the spectral energy density at frequency f.

2.2. Comparison of ERA-I data with buoy-measured data

Comparisons of the H_s from the ERA-I and the buoy-measured data show good agreement (Fig. 2). The quantitative assessment is done based on the error indices (bias, correlation coefficient and root mean square error). The correlation coefficient (r) value for the H_s is 0.96 with a bias value of 0.17 m. For the shallow water location in the AS, the maximum H_s value is the same (4.4 m) for buoy-measured and ERA-I data. In contrast, in deep water, the ERA-I data underestimate the H_s for values more than 3.5 m in the AS and for values more than 2.5 m in the BoB (Fig. 2). For example, the average value of the buoy-measured H_s at 2 locations in the AS is 2.1 and 2.5 m, while the average value of the H_s from the ERA-I data for the same period is 1.9 and 2.6 m. In addition, the average value of buoy-measured H_s in the BoB is 1.5 m, whereas the H_s determined by ERA-I is 1.4 m. The difference between the mean value of the

Table 1
Details of buoy data used for comparison with ERA-Interim data.

Buoy location	ERA-Interim data	Period	Instrument used for wave measurement	Data recording	Details of data analysis
16.953° N, 71.047° E (Arabian Sea: location 1)	17.25° N, 71.25° E	May–December 2005	Seatex buoy (Oceanor, Norway)	17-min duration at 2-Hz interval	National Data Buoy Programme [33]
13.978° N, 83.260° E (Bay of Bengal)	14.25° N, 83.25° E	July 2004–May 2005			
20.740° N, 70.658° E (Arabian Sea: location 2)	20.50° N, 70.50° E	June–August 2009	Directional waverider buoy (Datawell, Netherlands)	30-min duration at 1.28-Hz interval	Kumar et al. [34]