Surface waves generated by shamal and easterly winds off Qatar

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ABSTRACT: Waves in the Arabian Gulf (Gulf) are primarily controlled by the regional winds, for example, shamal winds during winter and early summer. Though Gulf wave characteristics have been heavily utilized for the design of offshore platforms and structures, wave features associated with various wind systems are not explicitly covered scientifically, say, for the Exclusive Economic Zone (EEZ) of Qatar. Therefore, we made an attempt to identify the features associated with different wind systems by analyzing the measured waves off Fuwairit, north coast of Qatar during 29 Oct – 26 Nov 2019. The analyses have been further extended to the Gulf using the reanalysis waves obtained from the COPERNICUS Marine Environment Monitoring Services (CMEMS) to describe the monthly, seasonal and annual characteristics. The results indicate that the easterly waves generated due to Nashi winds influence the east and northeast coasts of Qatar, and shamal waves show clear dominance in the northern and northeastern offshore boundaries of the EEZ of Qatar. We find exceptional easterly (Nashi) waves during March 2019 contributing to the highest monthly mean significant wave height, which is a deviation from the known long-term wave climate of the Gulf.

Keywords: Waves off Qatar, Arabian/Persian Gulf, Nashi winds, Shamal winds, Shamal waves

1. INTRODUCTION

Surface waves are one of the primary factors controlling the coastal dynamics (eg. longshore current and sediment transport). Similarly, activities such as design of coastal and offshore structures, exploitation of conventional energy resources, loading/unloading in tankers, navigation and coastal recreation rely heavily on accurate information of surface waves. Wave characteristics on marginal seas gained more attention in recent years, particularly because of their links with dominant local/regional features and global climate indices[1]. The Arabian Gulf being a semi-enclosed sea, waves in the Gulf follow the prevailing wind patterns with relatively high impact on shamal events. The wider deflection in the orientation of the coastline adjacent to the Strait of Hormuz prevents the long-period swells from the Arabian Sea entering the Gulf. However, interaction between young swells/wind seas generated on either side of the Strait of Hormuz and the complex bottom topography may produce complex wave conditions near the Gulf entrance. The impact of such interaction may be minor as far as the wave climate of the central Gulf is concerned. Although previous studies provide a brief overview of the wave conditions in the Gulf, the systematic variations in wave parameters in the EEZ of Qatar due to different wind systems are yet to be studied. Therefore, This work presents the wave variabilities within the EEZ of Qatar based on the analysis of measured wave parameters off Fuwairit, north coast of Qatar and numerical wave model results.

2. STUDY AREA

Waves measured off Fuwairit (Figure 1), north coast of Qatar has been analyzed in this study.

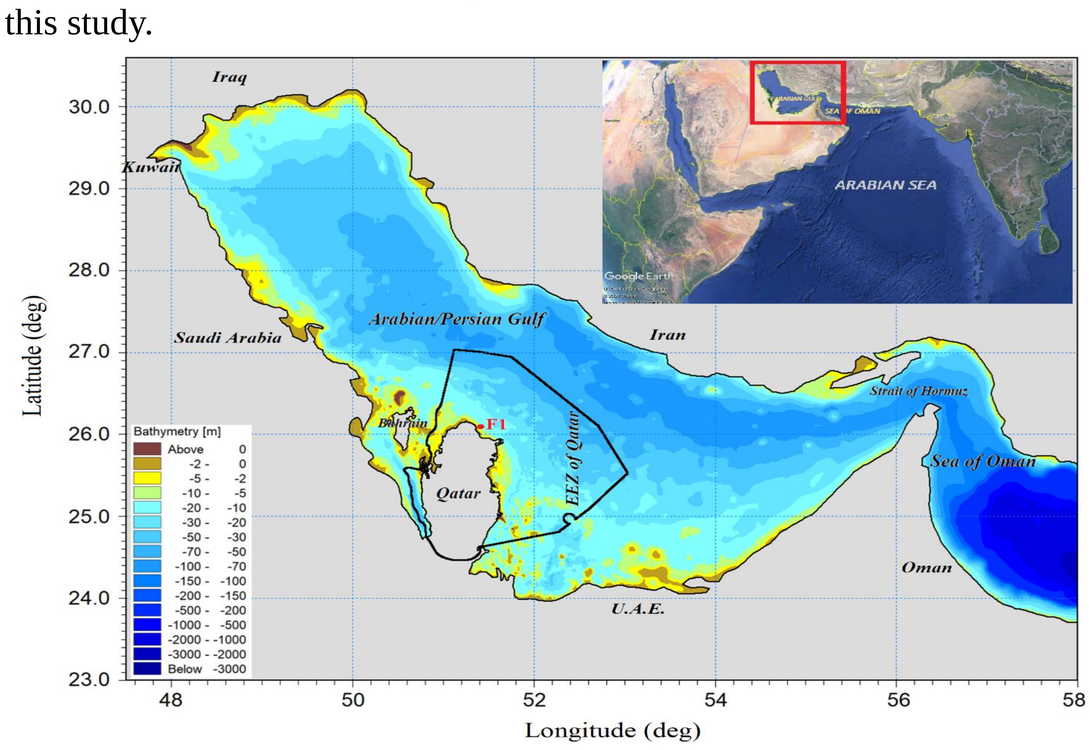

Figure 1. Study area: Wave measurement location off Fuwairit, F1 (marked in red). The thick black line indicates boundary of the EEZ.

3. DATA AND METHODS

Measurements have been carried out using Seaguard Recording Current Meter (RCM) and Signature 1000 Acoustic Doppler Current Profiler (ADCP) placed within a horizontal distance of 150 m between them. The wave data were sampled at every 10 minutes interval. The RCM was moored 2m above the seabed during 29 October – 26 November 2019, while the ADCP was deployed in the seabed for a short period (29 October – 01 November 2019). The water depth in the measurement location is 7.0 m. We processed the non-directional wave parameters significant wave height (Hs) and peak period (Tp) from the RCM, while the directional wave parameters Hs, Tp and mean wave direction (MWD) have been obtained from the ADCP. We used the ERA5 reanalysed winds in the present study to characterize the winds in the EEZ of Qatar. The CMEMS (COPERNICUS Marine Environment Monitoring Services) provides 3-hourly global analysis and forecast waves in 0.083° × 0.083° (~ 9 km) resolution driven by the winds from the ECMWF Integrated Forecasting System (IFS, 6-hourly analysis and 3-hourly forecast). The CMEMS also provides 3-hourly reanalysis waves in 0.2° × 0.2° resolution (~ 22 km) driven by the ERA5 winds. The CMEMS uses Météo-France wave model (MFWAM) incorporating the ECWAM-IFS-38R2 computing code with dissipation terms developed by Ardhuin et al.[2], where, the model mean bathymetry is generated by using ETOPO2 (National Geophysical Data Center, 2006). The wave spectrum is discretized in 24 directions and 30 frequencies starting from 0.035 Hz to 0.58 Hz. In this study, both 9 km and 22 km resolution wave model outputs (during Jan 2019 – April 2020) have been used to characterize the waves in the EEZ of Qatar. The wave measurement location (off Fuwairit) falls in a dry grid in 9 km resolution model, while it falls in a wet grid in 22 km resolution model.

4. RESULTS AND DISCUSSION

The Qatar peninsula and the offshore experience winds from various directions. The northwesterly/north-northwesterly (NW/NNW) winds are predominant along the north coast of Qatar throughout the year, in which the shamal winds are dominant. In an annual cycle, the wind speeds show high variability during winter, driven by shamal and easterly winds. There are typically two high wave conditions off Fuwairit, which are associated with (i) shamal winds and (ii) easterly winds. During the measurement period, three shamal events (namely, Shamal I: 31 October – 02 November, Shamal II: 05 – 07 November and Shamal III: 20 – 21 November) and two easterly wind events (Easterly I: 10 – 11 November and Easterly II: 16 – 18 November) were identified (Fig. 2a). Wave parameters obtained from the CMEMS have been compared with the measurements off Fuwairit (Figure 2b-d). The comparison shows that the CMEMS wave parameters match reasonably well with the measurements. The time series of wave parameters off Fuwairit extracted from CMEMS for the year 2019 indicate that there are several peaks with Hs higher than 1.5 m (Fig. 3).

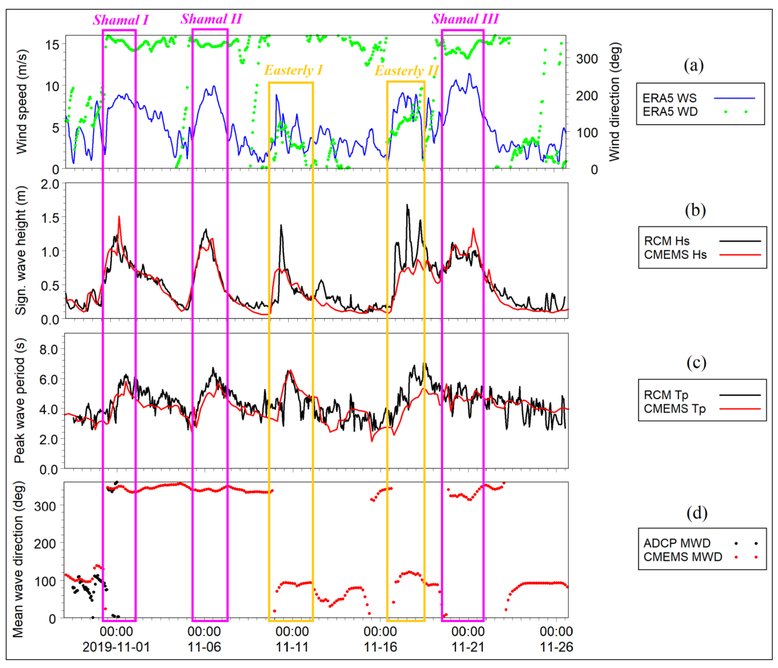

Figure 2. Time series of ERA5 winds (speed and direction) off Fuwairit during 2019

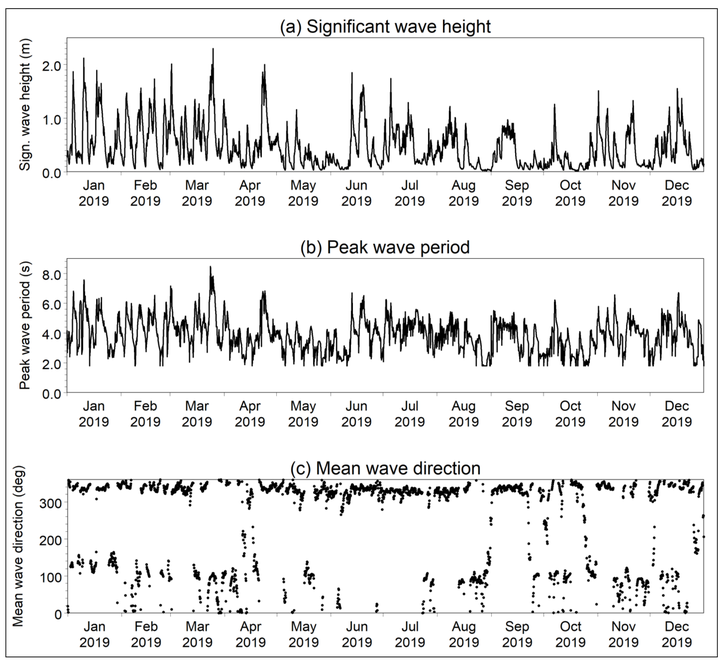

Figure 3. Time series of CMEMS wave parameters off Fuwairit during 2019: (a) significant wave height, (b) peak wave period and (d) mean wave direction

The associated peak wave periods are between 6.0 and 8.5 s. Most of these peaks are from the NNW, while a few from the E. The higher NNW waves are due to shamal winds, while the higher E waves are due to easterly wind events. The shamal induced maximum Hs is 2.12 m and the corresponding Tp is 7.0 s. The easterly winds are either due to the NE monsoon winds or by the Nashi winds. Waves in the Gulf are higher during winter than summer. The winter mean Hs is higher in the northeastern offshore boundary of the EEZ (upto 0.76 m), whereas the summer mean Hs is higher in the northern offshore boundary of the EEZ (upto 0.56 m). Kamranazad[3] identified that the Hs hotspots are in the central Gulf during winter shamal, while they move to the northwest region during summer shamal. Shifting of these hotspots is reflecting in the seasonal mean Hs in the EEZ of Qatar. The nearshore processes are not well executed in the given results because of relatively coarser spatial resolution of the model. Future study is planned to unravel the spectral behaviour of waves within the EEZ of Qatar using fine scale spectral wave modelling.

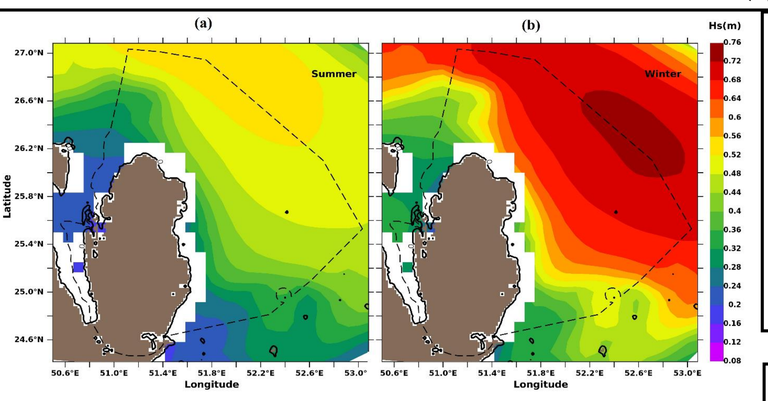

Figure 4. The seasonal mean significant wave height in the EEZ of Qatar: (a) summer (May – Oct 2019) and (b) winter (Nov 2019 – Apr 2020).

5. SUMMARY

The wave characteristics in the EEZ of Qatar were analysed using the measured waves off Fuwairit and the reanalysis waves obtained from CMEMS. Results indicate that Nashi winds influence the east and northeast coasts of Qatar with higher waves than those generated by shamal winds. This is because: (i) shamal waves have fetch limitations within the east and northeast coast of Qatar, while the easterly waves have sufficient fetch, of the order of 350 – 450 km to dominate over the shamal waves and (ii) the northern and northeastern offshore boundaries of the EEZ of Qatar are in the central strip of the Gulf, which are highly exposed to strong shamal winds with relatively longer fetch.

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