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Measurement of tidal and residual currents in the Strait of Hormuz

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ABSTRACT

Quantifying the current in the Strait of Hormuz (SH) is vital for understanding the circulation in the Persian Gulf. To measure the current in the strait, four subsurface moorings were deployed at four different stations close to SH from early November 2012 to the end of January 2013. Tidal current were dominant in the SH. The tides in the SH were complex partially standing waves and the dominant pattern varied from being primarily semi-diurnal to diurnal. The phase difference between tidal constituents of current and sea level elevation time series was used as an index to show the partially progressive wave pattern inside the study area. At mooring positions 3 and 4, located to the left of SH, the phase differences were close to 160° and 100°, respectively. It indicates partially progressive waves in opposite direction at these stations. K_1 and M_2 were the two main constituents at all stations inside the study area. At surface, the magnitude of semi-major axis of ellipses for M_2 constituent was larger than corresponding value for K_1 whereas at the bottom layer, the opposite pattern was observed. The M_2 rotary coefficients at mooring 1 illustrated that current vector at the bottom layer rotated in opposite direction compared to current vectors at the middle and surface layers. The rotation was counterclockwise in the bottom layer, while it was clockwise in the surface and middle layers.

1. Introduction

The Persian Gulf (PG) is a shallow, semi-enclosed basin with a mean depth of approximately 40 m. The PG is connected to the deep Gulf of Oman through the narrow Strait of Hormuz (SH). It consists of a shallow and wide shelf along its southern part (depths of less than 50 m), and a deep northern part with a maximum depth of 100 m separated from the coast by a narrow shelf (Pous et al., 2015).

Circulation in the PG is composed of two spatial scales: basin scale and meso-scale (Thoppil and Hogan, 2010). The circulation in the PG is primarily driven by the Shamal wind and heat fluxes, while thermohaline forcing, and tides exert secondary impacts on that. Although tide is important for moving and vertical mixing of water on a horizontal scale of order 10 km, it is not important in the large-scale residual circulation of the PG and SH. In terms of temporal scales, tide is important on periods of less than 24 h (Reynolds, 1993). Influence of tide in basin scale circulation of the PG is insignificant, except in the vicinity of SH and along its northern coast close to Iran (Blain, 1998; Pous et al., 2015). Over the short time scales, the strait circulation is dominated by tides (Reynolds, 1993).

In the past few decades, some numerical studies have been carried out on currents and circulation in the PG and SH using finite difference and finite element methods (Blain, 1998; Kämpf and Sadrinasab, 2006; Lardner et al., 1982, 1993; Lardner and Das, 1991; Pous et al., 2012; Pous et al., 2015; Yao and Johns, 2010). In addition, several short period measurements have been conducted exclusively for the SH (Johns et al., 2003; Matsuyama et al., 1998; Pous et al., 2004) and some limited measurements exist in which SH was part of the basin-wide survey (Brewer and Dyrssen, 1985; Emery, 1956; Reynolds, 1993). This study presents the results of the first long time field measurements of currents in the Iranian part of the SH. The objective of this study is to present a more realistic view of the hydrodynamics close to SH using the measured currents at its northern part. Characteristics of tidal currents will be presented in terms of the tidal ellipse parameters, and the spectral analysis will be performed on the current time series to obtain the energy contents at tidal frequencies.

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2. Measurements and methods

2.1. Field of study

The SH is a relatively narrow waterway located at the mouth of the PG, with an average width of almost 56 km and the maximum depth of approximately 120 m in its southern part. At its narrowest section, the strait width is less than 39 km. It extends between 25.5° N and 27.3° N and between 55.5° E and 57° E (Fig. 1), and connects PG to the Gulf of Oman and Indian Ocean. It is one of the most important waterways in the world due to petroleum export of oil-rich countries around the PG. Iran borders the northern flank of SH, while on the south, the United Arab Emirates and Musandam, an exclave of Oman, are located. Almost 20% of the world's petroleum, and approximately 35% of the petroleum traded by sea, passes through the SH.

Close to the SH, there is a boundary between the extra-tropical weather system from the northwest, and the tropical weather system of the Arabian Sea and Indian Ocean from southeast, which are affected mainly by monsoon circulation. The southerly wind dominates in summer and north-west wind occurs frequently in winter (Reynolds, 1993).

2.2. Observation

The *in situ* measurements of current and sea level fluctuations over the SH are rare and fragmentary. This study reports a long-term monitoring of currents (more than one month) which was conducted in the east, west and middle part of the SH in four subsurface mooring lines (Fig. 1). Mooring 1 included three RCM9 (AANDERAA) and was deployed at 110 m depth. One of the current meters was close to the bed (~8 m above bottom), the next one was close to the mid depth (50 m from surface) and the last one was near the surface (25 m from surface). The 3 other moorings (2, 3 and 4) hosted two current meters, one close to the surface and another one close to the bed (50, 65 and 75 m of water depth, respectively). The surface current meters were located in depth between 25 and 32 m to avoid any interference with passing ships. The moorings locations were selected based on ship traffic zone, and also political and scientific considerations. All RCM9 were equipped with temperature, conductivity and pressure sensors. The subsurface moorings also contained temperature/depth sensors, which provided vertical profiles with a 10 m resolution. Sampling intervals for all instruments were set to 20 min. The moorings were deployed early in November 2012 and continued sampling for approximately 3 months (Table 1).

Table 1
Position and deployment period of moorings used in this study.

	Latitude	Longitude	Period
Mooring 1	25°53.807′N	57°6.652′E	3.Nov.2012–5.Feb.2013
Mooring 2	26°48.595′N	56°37.812′E	2.Nov.2012–29.Jan.2013
Mooring 3	26°26.394′N	55°48.307′E	4.Nov.2012–30.Jan.2013
Mooring 4	25°56.391′N	55°2.390′E	4.Nov.2012–31.Jan.2013

2.3. Data processing

For all RCM9 data, quality control was carried out by removing spikes and bad data using phase-space method (Goring and Nikora, 2002). The missing data within the gaps lasting less than 3 h were linearly interpolated.

Harmonic analysis was utilized to determine the tidal

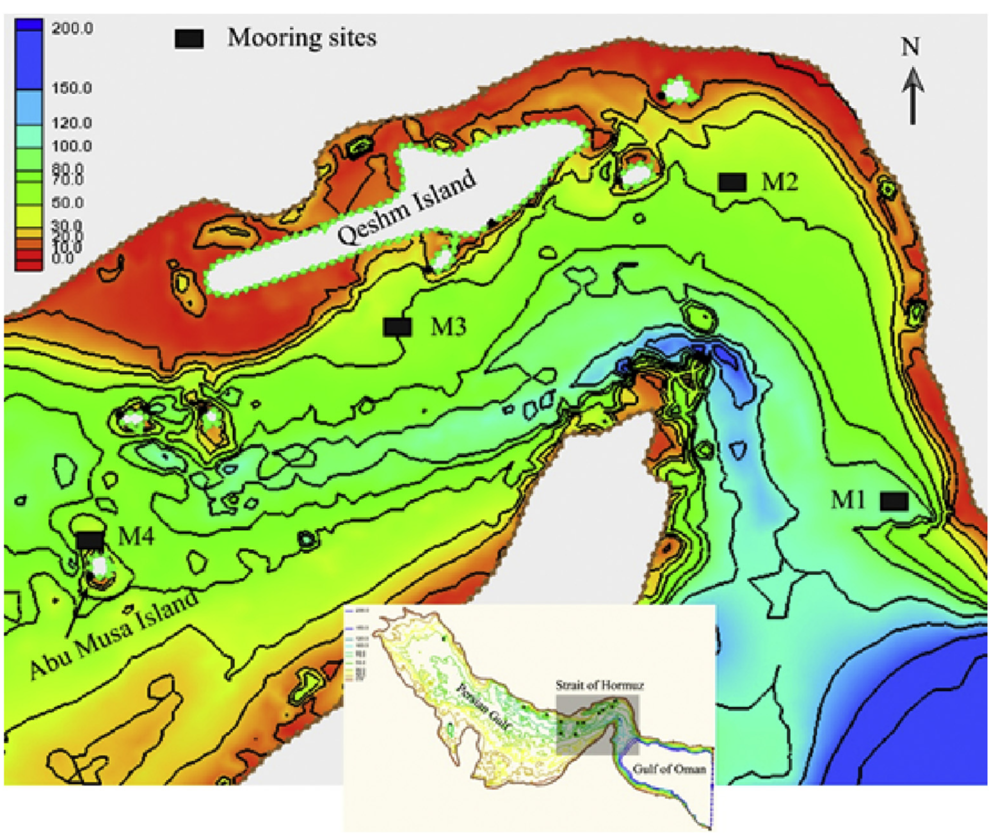

Fig. 1. Study area, the moorings locations and the isobaths (GEBCO_08, 2010). The inset shows the location of SH with respect to the Persian Gulf and the Gulf of Oman.