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Temperature–salinity modeling for Ruwais coastal area in United Arab Emirates

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ABSTRACT

A three dimensional rectangular grid model is applied to resolve the temperature–salinity dynamics of Ruwais, a segment of the UAE coast which is well known as dense water formation zone. The model employs a heat flux module and a turbulence closure scheme that facilitate realistic calculation of temperature–salinity dynamics. A field survey campaign is carried out to support the modeling study, involving measurements of tide, currents, temperature, and salinity. Investigation is done for two meteorologically extreme conditions, i.e. summer and winter. The model study showed that the western flux develops an anticlockwise circulation in the study area. The water industrial discharges elevated the temperature and salinity of the water near the southeastern shoreline. This water mass propagated towards north under the influence of gravity.

1. Introduction

With the rapid development of the coastal zone, the environmental issues in UAE have drawn significant attention in recent days. It is important to understand the nature of the mixing conditions for precise investigations of the local water quality. The shallow coastal shelf of the UAE is known as dense water formation zone. Denser water formed in the shallower water moves towards the deeper part as density current (Chao et al., 1992; Reynolds, 1993; Swift and Bower, 2003; Alosairi et al., 2011). Temperature–salinity distribution in this part of the southern Arabian Gulf influences the water quality. A comprehensive understanding of the characteristics of natural dynamics of the coastal waters of Ruwais (an industrially developed segment of UAE coast) while taking into consideration the industrial effluents component contribution, is essential for any assessment of the related ecological impacts at the area.

The geographical configuration (Fig. 1) characterized by an array of tidal flats and an island few kilometers apart from the main land makes the flow condition of the area much complex. Typically, in the southern Arabian Gulf, the salinity gradually decreases in the seaward direction as the depth increases (Reynolds, 1993). The coastal water temperature is higher in the summer and the trend reverses in the winter. Such horizontal gradients can potentially develop three dimensional residual flow (Elshorbagy et al., 2008). In Ruwais coast, the shoreward density variation is more pronounced as a number of industrial facilities are discharging warm and/or brine effluents close to the shore line which in return affects the temperature and salinity distribution of the area.

Elshorbagy et al. (2006) demonstrated through a series of tests using a well calibrated mathematical model that density gradient and wind are the most important factors generating mean circulation in the Arabian Gulf. The density current is more prominent in the north and in the central region whereas the wind governs the current along the coast of Saudi Arabia and UAE. The wind also influences the density current and plays a regulating role on the fresher water influx from the Arabian Sea.

A numerical modeling study was carried out by Azam et al. (2006a) to resolve the tidal dynamics of the coastal area of Ruwais. The study, which employed a sigma level model with curvilinear grid, did not include the density variation and, thus, skipped illustrating the dynamics of temperature–salinity, an important feature for a sheltered industrialized coast. In the present study, a three dimensional parallel layer model is applied to resolve the flow dynamics by taking into account the advection and dispersion of temperature and salinity. The study is conducted both for the summer and winter conditions.

2. Site description and characteristics

The coast of the United Arab Emirates (UAE) is characterized by a series of Sabkhas (Sabkha is the Arabic word for a salt flat) that stretch

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Fig. 1. Ruwais location and coastline configuration.

for some 320 km along reaching up to 24 km wide. These flats, which are found as extended part of the main lands or as islands, experience flooding up to 2 m during spring tide. The sediments are dominantly carbonate muds that have become colonized by blue-green algae that bind the sediment to form thick algal mats. These mats are subject to intense surface evaporation and heating. Such features may influence the water quality in the vicinity of the flat areas.

Several major industrial facilities are located along the coast of Ruwais. This includes an oil refinery, a gas production plant, a sulfur production unit, a power plant, a wastewater treatment plant, and water desalination plant. Transportation of refined and crude oils keeps the coastal water of Ruwais fairly busy. The loading and unloading in offshore and near the coast take place through different sizes of vessels and pipelines. The Bani Yas Island, which is only 5 km off the coast of Ruwais, is rich in flora and fauna. The landscape and the wild life have given the island a distinct status. Diversified and plentiful marine life characterizes the coastal water of Bani Yas. Several kilometers long stretch of reef is located in the south part of the island (Admiralty Chart 3179). However the oil-related activities in the offshore and coastal areas of UAE always pose a potential threat to the eco-system.

The passage between the Sir Bani Yas island and the head land is very shallow (2–3 m) (Fig. 2). This prevents free movement of tidal water across the area. The coastal dynamics of Ruwais is predominantly governed by the tides from the north and west (Azam et al., 2006a). Due to differential depth and shoreline configuration of the Arabian Gulf, the semidiurnal component of the tide is eliminated at the north of the Ruwais coast and diurnal tide becomes dominant. The tidal average range is found to be about two meters near the coast. Azam et al. (2006a) have shown that a mean current of magnitude 20 cm/s enters from the western passage and leaves the study area moving towards north and yet does not develop any significant flow in the central basin. An anticlockwise eddy is formed in the north.

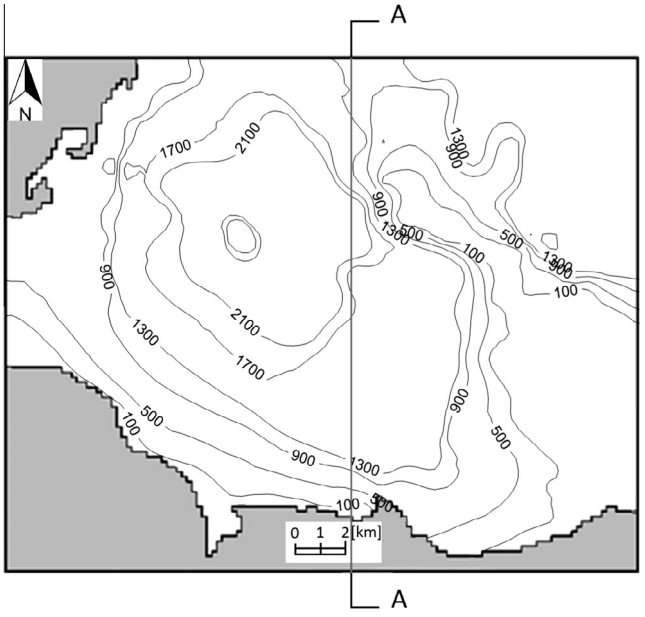

Fig. 2. Bathymetry of the study area (depth in cm).

3. Field observations

A field survey was carried out to measure the flow condition and the temperature and salinity distribution of the study area The salinity and temperature measurements were done using a CTD meter (Valeport 602). The probe was attached to a heavy object to keep it vertical during measurement. The survey was conducted using Tugboats with wide deck suitable for marine observations. The measurements were done with 2 m interval from the surface to the sea bottom. Readings were recorded from the display board located on the ship deck. Depth measurements were also done by the CTD. A handy GPS was used to locate the positions of the measurement points.

As the Ruwais coastal zone is sheltered in the west by Bani Yas Island and in the east by salt marshes, waves were not considered in the measurements due to its limited significance on the mixing process. In general the waves in the area are calm due to the effect of the shallow shadow region of the Qatar peninsula which highly

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