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Research paper

Development of a coastal information system for the management of Jeddah coastal waters in Saudi Arabia

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ABSTRACT

This paper presents results of the development and application of a web-based information system, Jeddah CIS, for assisting decision makers in the management of Jeddah coastal waters, in Saudi Arabia. The system will support coastal planning, management of navigation and tackle pollution due to accidents. The system was developed primarily to nowcast in quasi-real time and to deliver short-term forecasts of water levels, current velocities and waves with high spatial and temporal resolution for the area near Jeddah. Therefor it will hasten response when adverse weather conditions prevail. The Jeddah-CIS integrates sensors transmitting in real time, meteorological, oceanographic and water quality parameters and operational models for flow and waves. It also provides interactive tools using advanced visualization techniques to facilitate dissemination of information. The system relies on open source software and has been designed to facilitate the integration of additional components for enhanced information processing, data evaluation and generation of higher water level, current velocity and wave for the general public. Jeddah-CIS has been operational since 2013. Extensions of the system to speed operations and improving the accuracy of the predictions to the public are currently underway.

1. Introduction

Many coastal regions around the world have been facing threats from uncontrolled use of the resources as a result of demand from population growth and various forms of human interferences. As a consequence of climate change further damage is anticipated and is likely to worsen many of the existing problems. The sea level rise, potential enhancement of storm intensity and frequency, shoreline erosion and coastal inundation will affect the coastal areas and coastal ecosystems severely. Reclamation of land, harbor construction, exploitation of natural resources and environmental pollution can damage the sustainability of the coastal regions in the absence of careful planning and management. To improve our ability to manage coastal areas with sustainability in mind, there is an urgent need for requisite tools capable of predicting the adverse effects in order to take action.

In the past, coastal planning and management relied mainly on field observations and historical data. With the rapid development of computers, numerical methods and surveying technologies, numerical models have revolutionized our ability to understand complex interaction of coastal processes and to manage the resources of the coastal zone more effectively. As a result of the progress in oceanography, measuring and monitoring techniques, numerical modeling, remote sensing and information technology, there has been a rapid development and application of operational models. National institutes and agencies around the world have been developing global and oceanic operational models for nowcasting and forecasting of complex meteorological and hydrodynamic processes (Brasseur et al., 2005; Daniel et al., 2005; Dick and Kleine, 2007; Müller-Navarra and Knüpper, 2010, Müller-Navarra and Knüpffer, 2011). In spite of the impressive developments in global models, operational models for shallow water areas of the coastal regions require further alternatives. Recently there has been an intensification of efforts towards operational models applied to coastal areas (Schiff et al., 2002; Doong et al., 2007; Fernández and Mayerle, (2008); Wu et al., 2012; Stanev et al., 2011). The majority of them have been developed for the prediction of water levels and waves. Some works works have been done integrating model results into a more comprehensive information and management systems (Werner et al., 2009; De Kleermaeker et al., 2012).

Information concerning management systems can simply be in the form of digital maps and datasets with supplementary tables and illustrations that systematically show the coastal

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environment, often with cartographic and decision support tools (O'Dea, 2007). Most useful and powerful information systems are those accessible on-line. The recent generation of information systems integrates multiple servers of data and operational models, and provides interactive tools for using the latest visualization technology. They are used to support decision-makers in the prediction of natural and human impacts on the environments and in the selection of the most adequate course of action. These information systems are also for monitoring the execution and effects of operations, for proposing adaptation strategies, for arriving at cost-effective solutions to deal with various of problems and for dissemination of information.

To enhance coastal management there is a need to develop tools for improving the understanding of the physical system. Moreover, systems should, in addition to hydrodynamics, be extended to provide predictions of sediment transport and morphodynamics. This is particularly relevant to navigation and maritime security, and also for the industry pertaining to oil, gas and offshore wind power. The capability of obtaining predictions of bed level changes in quasi-real time is becoming important and can enhance efficiency as well as reduce maintenance costs of large-scale operations.

In this paper the set-up and components of an information system developed for the coastal waters of Jeddah in Saudi Arabia are described and the results of its application are presented. Focus is given to the hindcasting, nowcasting and forecasting of water levels, current velocities and waves with high spatial and temporal resolution in the vicinity of Jeddah. The system has been tailored primarily to provide a sound scientific understanding of the dynamics of flow and transport processes due to flow in the Red Sea and to assist managers to deal with the main threats in the coastal region involving hydrodynamics.

2. Red Sea and Jeddah coastal waters

The Red Sea is an elongated basin separating the African and Asian continents. It is about 2000 km long with an average width of about 220 km (see Fig. 1). At the northern end it bifurcates into the gulfs of Suez and Aqaba. The flow through the Suez Canal is negligible; the strait of Bab el Mandeb at the southern end of the Red Sea is the only significant interface with the open ocean. The mean water depth in the Read Sea is about 190 m and can reach up to 2400 m (see Fig. 2).

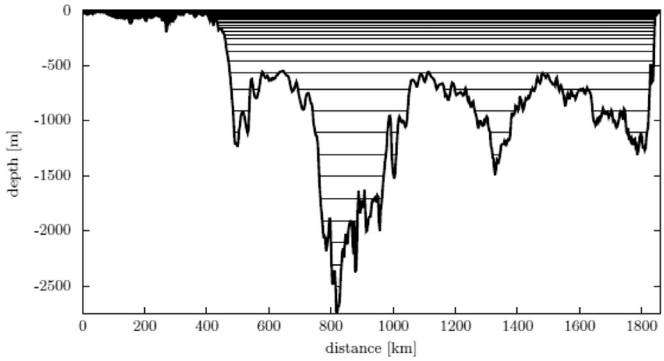

Fig. 2. Bathymetric transect of the Red Sea and grid resolution (σ-layers) over the vertical dimension.

The Red Sea and the adjacent coastal areas are among some of the least explored in the northern hemisphere. Most of the available observations are patchy and sparse, and there is a lack of understanding about the physical processes (Sofianos and Johns, 2003). In the absence of integrated process-based research and modeling for the prediction for flow and transport, coastal planning and management have become tedious and expensive. The Red Sea is a major shipping lane linking some of the world's major oceans. Navigation is facing problems and so the establishment of official traffic lanes and separation schemes to deal with the heavy ship traffic has become important. The city of Jeddah located at about the middle of the Red Sea, is the second largest city and is an important industrial centre in Saudi Arabia. During the last decades Jeddah metropolitan area has experienced significant increase of population from about 300 000 inhabitants in the early 1970's to ca. 3.4 million in 2010. It is expected that by the year 2030 over 6 million people will be living in the area (Jeddah Municipality, 2009). The Jeddah Port has expanded significantly from a few operational berths in the mid seventies to over 60 berths of international standard today. The port accounts for over

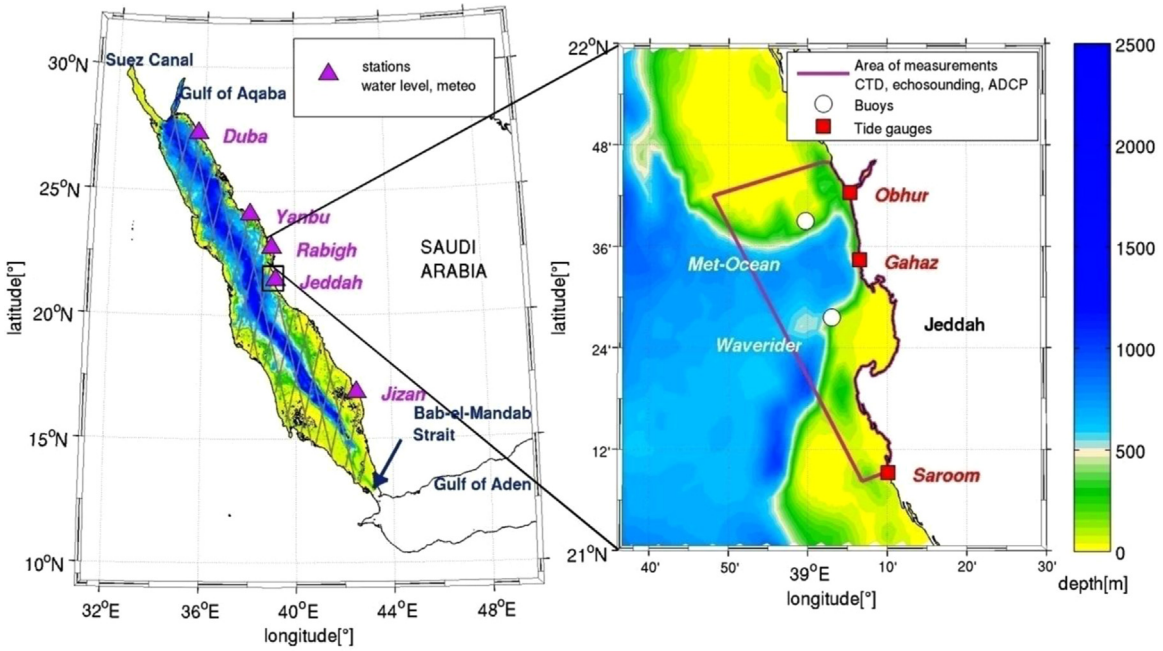

Fig. 1. Red Sea (left) and Jeddah Coastal Area (right) with details of the surveyed area and location of in-situ measuring devices.