Operational Hydrodynamic Numerical Model Covering Sri Lanka Waters

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Abstract: As a part of ongoing project on development of operational hydrodynamic model covering Sri Lanka Waters and Northern Indian Ocean (67.5-99.5 E and 1.5 S to 24.5 N), we employed a Princeton Ocean Model, NOAA (POM 08) to simulate wind driven circulation, sea surface topography, sea level setup, upwelling and possible storm surge conditions. The JEBCO 0.5 min bathymetry was interpolated to generate high resolution horizontal and vertical grid domain. For the model initial salinity and temperature data were extracted from World Ocean Atlas 2005 (WOA '05). Seasonal wind driven circulation simulations were carried out by forcing monthly mean NCEP climatologically winds. Experimental model runs were carried out with different wind speeds and directions to examine the possible storm surge conditions. The model runs with SW winds reveals significant sea level setup on the Bangladesh coast. The model results of SSH are compared with observational data from the TOPEX altimeter. The model successfully captures many of the important circulation features observed in the region. This includes the reversing wind driven circulation, upwelling off south of Sri Lanka during SW monsoon, strong currents south of Sri Lanka. The long term goal of this project is the establishment of an operational hydrodynamic model to forecast physical process including storm surge conditions covering Sri Lanka Waters and Northern Indian Ocean.

Keywords: Circulation, Northern Indian Ocean, POM model, Dynamic height

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1. Introduction

Sri Lanka experiences a strong monsoon climate based on two seasonal wind regimes separated by two periods of light and varying winds. Sea surface pressure around the Island is a maximum during December-January and a minimum in July - August with a seasonal range of 5-10 mb (Wijeratne, 2003). The hydrography around the island varies strongly seasonally with an associated upper mixed layer depth variation. During early summer (March - April), the mixed layer of the Bay of Bengal cools and deepens. In October-November, the mixed layer in the upper parts of the Bay of Bengal is about 100 m thick with salinities of

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about 32 psu. The waters around the island are subjected to seasonal reversals of currents forced by the monsoons.

The Southwest Monsoon Currents (SMC) in the North Indian Ocean is eastward and Northeast Monsoon Currents (NMC) is westward. During the Southwest Monsoon, the currents in the western Arabian Sea flows toward northeast as an extension of the Somali Current and southeast-ward in the eastern Arabian Sea along the west coast of India. The extension of SMC continues eastward south of Sri Lanka where one part of it turns towards north, entering the Bay of Bengal, while rest continuous eastward. The variability of the hydrography, SSH and the currents in the Indian Ocean are strongly linked to the reversing monsoons. On the other hand Sri Lanka is located between relatively low saline Bay of Bengal and relatively high saline Arabian Sea. The circulation of the northern Indian Ocean have been studied both observationally and using numerical models (Schott et al., 1994, Simmons et al., 1988; Molinari et al.; 1990; McCreary et al., 1993). According to the observations by Schott et al. (1994), the SMC are confirmed to the surface layer to a depth of about 200 m and an average transport rate to the south of Sri Lanka of 8-15 Sv (1 Sv=10^6 m^3s^{-1}). From a large set of recording current meters (RCM's), also found that the annual-mean flow in the south Sri Lanka was weakly westward with transport rate of only 2-3 Sv. Based on expandable bathy-thermograph (XBT) and altimeter data along the Sri Lanka-Malaca section and by using a general circulation model, Vinayachandran et al. (1999) argued that a major part of the SMC turns around Sri Lanka and flows into the Bay of Bengal with an average transport rate of 10 Sv. They also found that the region east of Sri Lanka and India is forced by the Ekman pumping because of strong monsoonal winds as well as the Rossby wave radiation from the eastern boundary. This fits with the low sea levels during the SWM, i.e. from May/June to September. In this study, we have applied POM model covering Sri Lanka Waters with high resolution horizontal and vertical grids to simulate physical processes and storm surges.

2. Methodology

2.1 Model Setup

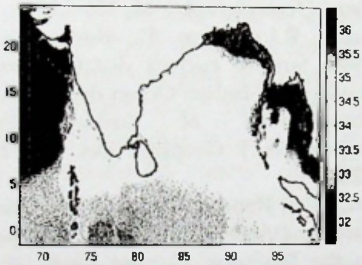
The model domain (67.5-99.5 E, 1.5 S-24.5 N) along with bathymetry and land topography is shown in figure 1. Bathymetry data are extracted from JEBCO 0.5 min. The horizontal equal grids were chosen, $\Delta x = \Delta y = 1/20$ deg both north-south and east-west directions. The vertical grids are based on sigma coordinates with and chosen 16 layers. The time step, Δt of 12 sec was chosen. The model initial salinity and temperature data were derived from World Ocean Atlas 2005 (WOA '05). For the seasonal wind driven circulation simulations, NCEP 0.25 deg monthly climatologically winds were used.

Figure 1. The Model Region and Bathymetry

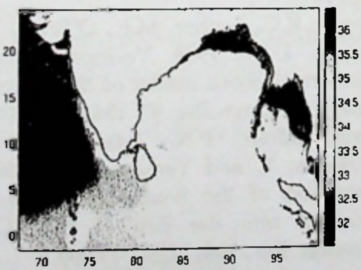
3. Results

3.1 Seasonal Hydrography and Circulation Simulations

The model simulations reveal surface currents are strongly linked to the reversing monsoons. The strong currents south of Sri Lanka are noticeable feature during both monsoons as observed by Schott et al (1994). The model results of surface salinity distributions during NE (January) and SW (August) are shown in figures 2.a and b, respectively. During both monsoons, low saline water confined to east coast of Bengal implies clockwise circulation forced by Coriolis.



(a)

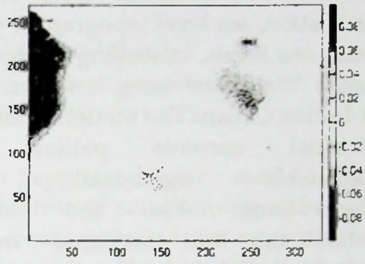


(b)

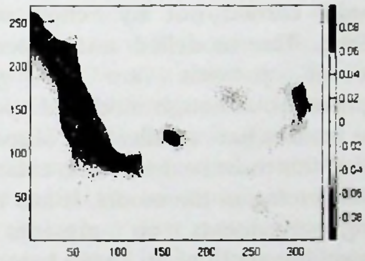
Figure 2. Model Simulated Salinity a. during NE Monsoon b. during SW Monsoon

3.2 Sea surface Topography simulations

The model results of sea surface topography during January and August are shown in figures 3.a and b, respectively. The results clearly indicating main contribution of sea surface topography is from dynamic topography (steric sea levels). The steric sea level range on the west coast of Sri Lanka is about 15 cm.



(a)



(b)

Figure 3. Model Simulated Steric Height (a). during NE Monsoon (b). during SW Monsoon

3.3 Wind Setup Sea Level simulations

The POM model has been used to determine seasonal sea levels forced by monsoon winds. It can be clearly seen that the maximum wind setup sea levels are on the Bangladesh Coast during SW monsoon. Sea level range gradually decreases towards east coast of Sri Lanka. There is significant sea level setup on the west coast of India during SW monsoon; however setup over west coast of Sri Lanka is relatively week. The experimental model runs with strong SW winds reveals significant sea level setup on the east coast of Bay of Bengal though not shown.

4. Discussion

In this study, we applied POM model to study the seasonal cycle of the circulation, sea level topography, wind setup sea levels, upwelling around Sri Lanka Waters covering northern part of Indian Ocean. The model simulated seasonal currents pattern are reasonable agreement with observations. For the model validation, we compared model simulated SW and NE currents with current meter records south of Sri Lanka carried out by Schott et al (1994). The modelled and observed current patterns are in good agreement, although modelled speeds are somewhat smaller to observed vales, this must be due to non extant of tidal forcing in the model. It has been long arguments on presents of upwelling south of Sri Lanka based on satellite image analysis and modelling by Vinayachandran et al (2004) and Ram et al (2005). Our model results indicate development of cool water patches during south west monsoon and distinguish vertical currents south of Sri Lanka. However, further studies, including direct measurements of hydrography and currents are required to confirm coastal upwelling caused by Ekman transport. The comparison of sea surface topography and dynamic topography implies that the steric height contribution is dominating the seasonal sea level range around Sri Lanka Waters.

5. Conclusions

The model is capable of producing most of large scale and seasonal physical process covering Sri Lanka and northern part of Indian Ocean. Incorporating real time atmospheric, gravitational and hydrological forcing agents, model could be developed towards a forecasting model.

Acknowledgement

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