A Modeling Study of Circulation and Eddies in the Persian Gulf

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ABSTRACT

The circulation and mesoscale eddies in the Persian Gulf are investigated using results from a high-resolution (~1 km) Hybrid Coordinate Ocean Model (HYCOM). The circulation in the Persian Gulf is composed of two spatial scales: basin scale and mesoscale. The progression of a cyclonic circulation cell dominates the basin-scale circulation in the eastern half of the gulf (52°–55°E) during March–July. This is primarily the consequence of density-driven outflow–inflow through the Strait of Hormuz and strong stratification. A northwestward-flowing Iranian Coastal Current (ICC; 30–40 cm s^{-1}) between the Strait of Hormuz and north of Qatar (~52°E) forms the northern flank of the cell. Between July and August the ICC becomes unstable because of the baroclinic instability mechanism by releasing the potential energy stored in the cross-shelf density gradient. As a result, the meanders in the ICC evolve into a series of mesoscale eddies, which is denoted as the Iranian coastal eddies (ICE). The ICE have a diameter of about 115–130 km and extend vertically over most of the water column. Three cyclonic eddies produced by the model during August–September 2005 compared quite well with the Moderate Resolution Imaging Spectroradiometer (MODIS) SST and chlorophyll-*a* observations. The remnants of ICE are seen until November, after which they dissipate as the winter cooling causes the thermocline to collapse.

1. Introduction

The Persian Gulf (also known as the Arabian Gulf) is a shallow, semienclosed basin with a mean depth of about 35 m and is connected to the Gulf of Oman through the Strait of Hormuz (Fig. 1). The circulation in the Persian Gulf is primarily driven by the prevailing northwesterly winds and the associated momentum and buoyancy fluxes, secondarily by thermohaline forcing, and thirdly by the tides. A typical basin-scale circulation of the gulf is cyclonic and composed of a northwestward-flowing Iranian Coastal Current (ICC) from the Strait of Hormuz along the northern side of the basin with speeds greater than 10 cm s^{-1} (Hunter 1983) and a southeastward-flowing current in the southern portion of the gulf (Fig. 34 of Reynolds 1993). The former, which flows against the prevailing northwesterly winds, is primarily driven by the pressure gradient (Chao et al. 1992; Lardner et al. 1993; Blain 2000). The tidal influence on the circulation in the Persian Gulf is insignificant, except in the Strait of Hormuz and along the Iranian coast (Blain 1998).

Circulation and water mass formation in the Persian Gulf have been the subject of several previous modeling studies (Lardner et al. 1987, 1988, 1989, 1993; Lardner and Das 1991; Chao et al. 1992; Horton et al. 1992; Song et al. 1994; Blain 2000; Azam et al. 2006; Elshorbagy et al. 2006; Kämpf and Sadrinasab 2006). Several of these studies used either hydrodynamic numerical models or spectral models of coarse to moderate horizontal resolutions (20–5 km) and were driven by density only or monthly atmospheric forcings. Although the cyclonic nature of basin-scale circulation in the Persian Gulf is well established, the details of the interior circulation remain essentially unknown. To our knowledge, it was only Reynolds (1993) who briefly noted the existence of eddies in the gulf using satellite images. In this paper, we use model results to show that the ICC can deform into a series of mesoscale eddies during late summer and use a variety of observations to verify their existence. The main goal of this work is to show the seasonal evolution of the ICC, its transformation into mesoscale eddies, and their dissipation and to discuss their formation mechanisms briefly. The approach is to use results from a high-resolution (~1 km), regional Hybrid Coordinate Ocean Model (HYCOM) of the Persian Gulf. Model results are complimented by observations of satellite-derived Moderate

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