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New observations of eddies and boundary currents in the Red Sea

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Physical oceanographic studies of the Red Sea have often focused on the large-scale overturning circulation, in which water entering the sea from the Gulf of Aden becomes cooler, saltier and more dense as it flows northward, due mainly to strong evaporation ($\sim$2 m/y), and then flows back southward and exits the sea as a dense overflow through Bab al Mandeb. Less attention has been focused on the details of the horizontal circulation, in large part due to the dearth of high-resolution observations of the three-dimensional structure of water properties and currents. Two high-resolution hydrographic and current surveys were recently carried out in the eastern Red Sea, in March 2010 and September-October 2011. Of particular note are the continuous measurements of current velocity, taken along the cruise tracks from the sea surface to 600 m with a hull-mounted Acoustic Doppler Current Profiler, which revealed the presence and structure of several basin-scale eddies and eastern boundary currents.

In March 2010, a strong, 200-km diameter anticyclonic eddy was found centered near 23^{o}N, with peak azimuthal velocities of nearly 1 m/s, a transport of 6-7 Sv and eddy currents extending to $\sim$400 m depth. The eddy's core was in solid body rotation, with six-day rotation period and a relative vorticity of $0.5f$ (i.e., 1/2 the local Coriolis parameter). Surface drifters deployed in the eddy core remained trapped for their entire lifetimes (up to 5 months). An eddy was observed several times previously in this location—20 years of satellite-derived altimetric measurements of sea level anomaly indicate that it is a quasi-permanent feature of the Red Sea circulation and that there is an annual cycle in its strength. This may be linked to the annual cycle in buoyancy forcing and the strength of the cyclonic circulation in the northern Red Sea.

In September 2011, cross-basin transects in the southern Red Sea (17-19^{o}N) revealed a layer of relatively cold, fresh, low-oxygen, high-nutrient Gulf of Aden Intermediate Water (GAIW) being advected rapidly northward near the eastern boundary by a subsurface jet with a transport of $\sim$0.35 Sv, and with speeds of order 0.2 m/s in the depth range 35-100 m. The GAIW layer overlapped with the euphotic zone and contributed to enhanced productivity in the 35-75 m depth range. Most of the intrusion entered deep channels between coral reef islands and shoals in the Farasan Bank region off Saudi Arabia, while a fraction was advected into the basin interior by a mesoscale eddy. The shoreward intrusion of GAIW could have significant implications for the coral reef ecosystems in the Red Sea.

Numerical model results and some drifter trajectories from this and previous studies suggest that major elements of the large-scale circulation in the Red Sea are located near the western boundary, emphasizing the need for an international effort to survey the entire Red Sea from coast to coast.