A combination of thermohaline circulation and monsoon-modulated winds drive advection in the Red Sea. Biogeochemical processes are closely coupled with the physical dynamics of the sea, yet to date remain poorly resolved and understood. Given the Red Sea’s size (~2,000 km × 250 km), frequently occurring eddies can provide a mechanism for significant exchange between the open sea and its abundant coastal coral reef regions. Because no international waters exist within the Red Sea, and geopolitical restrictions allow only limited access, our most complete understanding of the Red Sea until recently has come from remote sensing and numerical modeling studies (e.g., Sofianos and Johns, 2002; Raitsos et al., 2013; Yao et al, 2014; Racault et al., 2015), although occasional ship expeditions have provided in situ observations with limited temporal and/or spatial coverage (e.g., Naqvi et al., 1986; Sofianos and Johns, 2007; Bower and Farrar, 2015; Kürten et al., 2016).

To better understand the physical and biogeochemical characteristics of the Red Sea, King Abdullah University of Science and Technology’s (KAUST’s) Integrated Ocean Processes (IOP) laboratory is employing autonomous platforms coupled with coastal surface current mapping systems. The sustained, quasi-synoptic view provided by the data collected will permit IOP to address the following questions:

- What is the annual cycle of physical and biogeochemical variability in the Red Sea?
- What are the roles of mesoscale and submesoscale eddies in structuring the physical and biogeochemical dynamics of the Red Sea?
- How do winter mixing, convection, and related eddy activity affect Red Sea circulation and biogeochemical processes?
- What are the distribution and variability of the transport and what are the forcing functions that determine the Red Sea basin’s transport?

The observing elements consist of (1) autonomous underwater gliders distributed along three sampling lines (Figure 1), (2) three profiling Biogeochemical-Argo floats, and (3) coastal surface current mapping using high-frequency radar operating at 16 MHz (CODAR; Figure 1). The floats, although not indicated on the Figure 1 map, were deployed in the central (one float) and northern (two floats) Red Sea. The three glider lines are intended to provide sustained observations that will yield insights into the seasonal, annual, and interannual scales of variability in the Red Sea, and enable evaluation of the role of along-basin transport. Instrumentation on the autonomous platforms provides measurements of temperature, salinity, dissolved oxygen, chlorophyll, chromophoric dissolved organic matter (CDOM) fluorescence, and multi-wavelength optical backscatter; two of the floats also measure downwelling irradiance at four wavelengths. CODAR pairs, each of which covers an area approximately 100 km in diameter, are located in the north near Duba, in the central Red Sea between KAUST and Rabigh, and in the southern Red Sea, north of Jazan.

Several criteria were used in selecting the locations for observations. First, each must be a region where significant oceanographic processes occur that are essential for understanding the overall dynamics of the Red Sea. Second, the region must have socioeconomic importance because of existing urban and industrial activities or significant planned or already underway development, such as near Jazan in the south. Third, the region must meet the very practical need for access to maintenance facilities and areas where ship-based observations can be made.
Ship-based efforts supplement the autonomous platform observations. These in situ biological, chemical, and optical measurements both validate the autonomously gathered data and provide measurements that cannot be obtained by the autonomous platforms. The ship-based measurements have already yielded insights into major gradients in plankton species composition and its variability in the Red Sea, into trophic interactions, and into the role of physical processes in transporting waters into the Red Sea, especially from the Gulf of Aden. Stratification and eddies that occur along much of the sea are also subjects of ship-based investigations (Kürten et al., 2016; Kheireddine et al., 2017; Pearman et al., 2017).

To illustrate this point, glider observations and surface current mapping in the north central Red Sea have validated the presence and influence of the eastern boundary current (EBC). Models show the EBC to be a relatively persistent feature in the region (e.g., Sofianos and Johns, 2003; Yao et al., 2014), but validation of the EBC and its role in the transport of Gulf of Aden surface and/or intermediate water (GASW and GAIW, respectively) has until recently been limited (e.g., Churchill et al., 2014). Figure 1 shows the glider coverage areas. Velocity vectors from surface current mapping (Figure 2a) and from sustained glider observations (Figure 2b) show the presence of a nearshore current both within the CODAR coverage area and about 160 km to the north where the glider provides coverage. One of the contributions of the northward EBC is the transport of inflow water from the Gulf of Aden, the Red Sea’s primary connection with the global ocean. In the glider section, two components of Gulf of Aden inflow are evident. Near the coast in the region of northward flow, a warm, low-salinity water mass is evident in the surface layer (Figure 3, indicated by the black ellipse). This water mass is identified as GASW that typically enters the Red Sea from September through May (Sofianos and Johns, 2015). Farther offshore, westward of 37.7°E, a thin lower salinity and higher chlorophyll layer is observed between 50 m and 80 m depth. This layer is consistent with GAIW that enters the Red Sea from June to September. Churchill et al. (2014) show that in the southern Red Sea, this low-salinity water is elevated in chlorophyll, low in oxygen, and enriched in inorganic nutrients. By the time this water reaches this latitude in the Red Sea, its signature has weakened due to mixing and biological productivity that occur during its northward transit. However, this advection of the GAIW into the northern half of the Red Sea contributes to the region’s productivity, which is otherwise limited by high stratification from spring through fall. A submesoscale cyclonic eddy can be seen immediately west of the GASW. Such eddies appear to be relatively common occurrences along the eastern boundary of the Red Sea. Zarokanellos et al. (2017) discussed the presence of mesoscale eddies and their interaction with the EBC during the winter-summer transition using a combination of ship observations and our earliest glider observations. These eddies are important in steering or blocking the northward transport of the EBC along its northward transit.

The observations obtained to date are already yielding significant insights into the functioning of the Red Sea. The effort will be sustained and, if resources permit, expanded to continue the development of a holistic view of Red Sea dynamics, including responses to interannual and longer-term processes as well as global change phenomena.

REFERENCES


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AUTHORS
Burton H. Jones (burton.jones@kaust.edu.sa) is Professor, King Abdullah University of Science and Technology and Saudi Aramco’s Environmental Protection Division. Yasser Kattan is Senior Environmental Consultant, Environmental Protection Department, Saudi Aramco, Dharan, Saudi Arabia.

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