SEASONAL VARIATIONS IN STRUCTURE
AND CIRCULATION IN THE RED SEA

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ABSTRACT

A study of the monthly mean variations in the oceanographic structure and surface circulation in the Red Sea, occurring along the north-south axis of the Sea and extending from the Gulf of Suez to the Gulf of Aden, demonstrates that variations in structure and circulation in the Sea are closely associated with wind stresses acting on the sea surface.

Although wind direction in the northern Red Sea is from the north-northwest throughout the year, during the winter (from October to May) the winds weaken, and south of 19°N they are strongly from the south-southeast. During this time, surface transport of water through Bab-el-Mandeb is \(-4.9 \times 10^{12} \text{ cm}^3 \text{ s}^{-1}\), and directed toward the north. Surface flow is convergent in the northern Red Sea and is to the north-northwest against the winds. Flow beneath the surface layer is toward the Gulf of Aden. Monthly mean sea levels are now highest in the Gulf of Suez (Port Suez) and central Red Sea (Port Sudan). This is the fully developed winter cellular pattern of surface inflow and subsurface outflow.

During the summer (June to September), the direction
of the surface winds over the southern Red Sea and the Gulf of Aden reverses, and surface currents everywhere in the Sea flow toward the Gulf of Aden. The surface outflow \((-.13 \times 10^{-12} \text{ cm}^3 \text{s}^{-1})\) is confined to a shallow surface layer (-20 m depth); beneath this layer, between 30- and 80-m depth, a cool, low-salinity (T=18.0°C, S=36.0°/oo) tongue of Gulf of Aden water flows northward. This cool tongue of water is caused by the reversal in the pressure gradient over the sill, due to: (1) summer heating of the water column in the southern Red Sea that decreases the density of waters north of Bab-el-Mandeb; and (2) the wind-induced upwelling of heavy water in the Gulf of Aden that increases the density of waters south of Bab-el-Mandeb. In July, this cool tongue moves north and by October can be found at 19°N, almost 700 km north of the shallow sill (-100 m depth) located at 13°40'N. Since, in the summer, the surface flow is out of the Red Sea causing the density structure in the north to be raised, while the subsurface flow in the south is northward, the cellular pattern of winter is completely reversed, and thus the flow is divergent. At this time, monthly mean sea levels are lowest everywhere.

To help in understanding the forces that drive the circulation of the Red Sea, the horizontal equations of motion are simplified in accordance with observed conditions. Calculations of sea-surface topographies for
each month along the central axis of the Sea show that
surface flow is almost always with the wind and against the
slope of the Sea, indicating that the distribution of mass
is not the main cause of the surface circulation in the Red
Sea, but rather the surface circulation is primarily wind-
driven.