Buoyancy and heat budgets and mixing rates in the upper Indian Ocean

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The Indian Ocean can be divided into three regions according to climatological mean air-sea fluxes. The Northeast and Central Region gains heat and fresh water and hence produces less dense water. The Subtropical Region (15S to 45S) loses heat and fresh water and hence produces dense water. The Northwest Region around the Arabian Sea gains heat and loses freshwater. The Climatological mean steady state requires a balance within the ocean between production of light and dense waters. As a first step to understand the water mass formation and distribution processes, the diapycnal and cross-isotherm (diathermal) diffusivities (K_rho, K_theta) are calculated in the upper layer of the Indian Ocean using buoyancy/heat budget for the water volume enclosed by an isopycnal or isotherm, the sea surface and solid boundaries, using a modification of Speer and Tziperman (1992) and Niiler and Stevenson's (1982) methods. The air-sea fluxes are from da Silva et al. (1994), and hydrographic data are from Levitus et al. (1994). The estimates rates are helpful for the parameterization of mixing in GCMs.

The Bay of Bengal has the freshest and lightest water with isopycnals outcropping southwest- and southward. The estimated K_rho is 1.3 cm^2/s for sigma_theta = 20.2 (Bay of Bengal, ~20 m depth) to sigma_theta = 22.0 (Northeast Indian Ocean, ~60 m depth). Further south (across the equator) and at greater depth, K_rho decreases from 0.9 cm ^2/s for sigma_theta=23.0 (north of 20S, ~75 m depth) to 0.5 cm^2/s for sigma_theta = 25.0 (north of 35S, ~120 m depth). For the Indian-Pacific, K_rho = 0.1 cm^2/s for sigma_theta=25.0 (40N to 40S, ~17- m depth). Isotherms outcrop poleward from the equator. K_theta computed form the heat budget is large at the equator and near the surface (K_theta = 4.0 cm^2/s for 28.5C from 10N to 5S and at depth ~40m) but decreases rapidly poleward and with depth (K_theta=1.3 cm^2/s for 27.0C from 20N to 20S and at depth ~60m). This indicates stronger mixing near either the equator or the surface, or a possible isopycnal mixing component in the diathermal diffusivity, as isotherms do not follow isopycnals in the upper Indian Ocean north of 10S. For 21.0C (the Indian Ocean north of 235S) which closely follows sigma_theta = 25.0, the heat budget yields a K_theta again of 0.5 cm^2/s.