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Seasonal variation of the South Indian tropical gyre

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The South Indian tropical gyre receives and redistributes water masses from the Indonesian Throughflow (ITF), a source of Pacific Ocean water which represents the only low-latitude connector between the world oceans and, therefore, a key component in the global ocean circulation and climate system.

We investigate the seasonal variation of the South Indian tropical gyre and its associated open-ocean upwelling system, known as the Seychelles-Chagos Thermocline Ridge (SCTR), based on satellite altimeter data (AVISO) and global atlases of temperature and salinity (CARS09), wind stress (SCOW) and wind-driven circulation.

Two novel large-scale features governing the upper geostrophic circulation of the South Indian tropical gyre are revealed. First, the seasonal shrinkage of the ocean gyre. This occurs when the South Equatorial Countercurrent (SECC) recirculates before arrival to Sumatra from winter to spring, in apparent synchronization with the annual cycle of the ITF. Second, the open-ocean upwelling is found to vary following seasonality of the overlying geostrophic ocean gyre, a relationship that has not been previously shown for this region.

An analysis of major forcing mechanisms suggests that the thermocline ridge results from the constructive interaction of basin-scale wind stress curl, local-scale wind stress forcing and remote forcing driven by Rossby waves of different periodicity: semiannual in the west, under the strong influence of monsoonal winds; and, annual in the east, where the southeasterlies prevail. One exception occurs during winter, when the well-known westward intensification of the upwelling core, the Seychelles Dome, is shown to be largely a response of the wind-driven circulation.

Broadly speaking, the seasonal shrinkage of the ocean gyre (and the SCTR) is the one feature that differs most when the geostrophic circulation is compared to the wind-driven Sverdrup circulation. From late autumn to spring, the eastward SECC recirculates early in the east on feeding the westward South Equatorial Current, therefore closing the gyre before arrival to Sumatra. We find this recirculation longitude migrates over 20° and collocates with the westward advance of a zonal thermohaline front emerging from the encounter between (upwelled) Indian Equatorial Water and relatively warmer and fresher Indonesian Throughflow Water. We suggest this front, which we call the Indonesian Throughflow Front, plays an important role as forcing to the tropical gyre, generating southward geostrophic flows that contribute to the early recirculation of the SECC at longitudes more westward than predicted from the barotropic wind-driven circulation.

Because our findings are based on time-averaged seasonal fields from 22 years of satellite altimeter data and from about 60 years of non-systematic sampling of ocean temperature and salinity data (CARS09), we stress the importance of further study on the possibility that interanual variability in the seasonal ITF may cause changes in the seasonal resizing of the ocean gyre and its associated upwelling ridge.