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In situ observations of mesoscale undercurrents off eastern Madagascar

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The South-West Indian Ocean (SWIO) presents one of the most intriguing western boundary regions of all subtropical gyres. Unlike other gyres, in the SWIO the Madagascar island imposes a physical barrier to the westward flowing South Equatorial Current (SEC), which reaches the Madagascar coast between 17°S and 20°S. At this location, the SEC bifurcates into two branches: the poleward branch feeds into the East Madagascar Current (EMC), which further south will feed the Agulhas Current (AC); on the other hand, the poleward branch feeds into the North Madagascar Current (NMC), which turns around Cape Amber, at the northern tip of Madagascar, and continues westward towards the east coast of Africa.

Besides the patterns of the boundary currents described above, undercurrents flowing opposite and beneath the mentioned surface currents are also reported to occur: the equatorward East Madagascar Undercurrent (EMUC) and the poleward North Madagascar Undercurrent (NMUC). This work is based on field studies of both undercurrents.

We deployed a cross-slope array of five moorings at 23°S off eastern Madagascar, which was maintained from late 2010 till early 2013 (∼2.5 years). A total of 6 Acoustic Doppler Current Profiles and 10 Recording Current Meters were coupled to the moorings. Direct measurements were made from near surface (∼50 m) to deep in the water column (∼4000 m). The observations reveal a recurring equatorward EMUC with its core hugging the continental slope, at a depth of 1260 m and at an approximate distance of 29 km from the coast. The core velocity has a mean value of 4.1 ($\pm$6.3) cm s^{-1}, while maximum speeds reach up to 20 cm $^{-1}$. The volume transport is estimated to be 1.33 ($\pm$1.14) Sv with maxima up to 6 Sv.

At the northern tip of Madagascar, off Cape Ambar, we present the first observational evidence of a poleward NMUC. These results are based on a hydrographic cruise (March 2001), where vertical profiles of velocity were sampled across the continental slope. The data show an NMUC also hugging the continental slope, but its core is observed at 460 m depth. Its core velocity reaches over 0.7 m s^{-1} and its volume transport is estimated to be around 3.5 Sv. The thermohaline characteristics show a saltier and warmer NMUC, compared to the surrounding offshore waters, transporting mainly South Indian Central Water.

Two dominant frequency bands were found in the time series of EMUC volume transport: nearly semi-annual and nearly bi-monthly. The NMUC is concurrent with an inshore cell of coastal downwelling due to Ekman Transport towards the coast, which may be associated, at least in part, with the NMUC variability. The comparison between both results stresses the importance of long-term direct observations at fixed locations.