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A description of eddy-mean flow feedbacks in equatorial and boundary current systems of the South Indian Ocean

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While many observational and modeling efforts have addressed eddy-mean flow interactions acting over nearly idealized zonal jets, little is know about whether findings in those studies can be extended to current systems with different configurations in the real ocean. This topic is of special interest for ocean-climate models where eddy interactions with the mean flow may be unresolved, demanding further insight on the mechanism by which the eddy field and the mean circulation should feed back in a realistic representation of future climate change scenarios.

Following this motivation, we investigate local exchange of momentum and kinetic energy operating in a variety of eddy-mean flow systems of the South Indian Ocean (SIO). To this aim we use 21 years (1993-2013) of newly processed satellite altimetry observations, and adopt a definition of the mean flow as a seasonally-dependent temporal mean where the eddy field encompasses the daily instantaneous deviation from the altimeter-derived velocities. This approach allows time-varying feedbacks to evolve throughout the year.

We find that the eddy field feeds back on the mean circulation, contributing importantly to the overall seasonal strengthening and weakening of all current systems involved in the tropical and subtropical gyre of the SIO. Although significant contributions to the momentum and energy balances were also obtained along the Agulhas (Return) Current and the Antarctic Circumpolar Current (ACC), they exhibit a weak/absent seasonal cycle, suggesting that the strength of these dynamical processes is mostly persistent throughout the year.

Spatial distribution of the eddy kinetic energy conversion rates and the convergence of horizontal eddy momentum fluxes indicate that over regions where the eddy field draws energy from the mean flow through barotropic instabilities, the current is importantly decelerated by alongstream eddy forces on its upstream side, while further downstream the situation reverses with accelerating alongstream eddy forces and kinetic energy being transferred from the eddy field to the mean flow. This is the case for 1) the meandering Indonesian Throughflow, ITF (winter and spring); 2) the southward along-slope flow crossing the narrows of the Mozambique Channel and shedding anticyclonic eddies; 3) the southern South East Madagascar Current shedding dipoles; and, 4) the Agulhas Retroflection, shedding Agulhas rings into the Atlantic Ocean.

Additionally, we observe a well-known feature of the eastward-flowing Agulhas Return Current and the ACC, also along the South Equatorial Countercurrent, the ITF and the North East Madagascar Current. In all cases (either eastward- or westward-flowing), these nearly zonal currents exhibit convergence (divergence) of the cross-stream eddy momentum forces acting over its left-hand (right-hand) side, looking downstream, pointing to a systematic drift of the mean flow towards its left-hand side by cross-stream eddy forces.

Quantitative estimates and qualitative spatial patterns from this study provide a unique tool for testing the performance of eddy-resolving models on predicting realistically eddy-mean flow feedbacks in the SIO.