Internal waves and Equatorial Ocean dynamics

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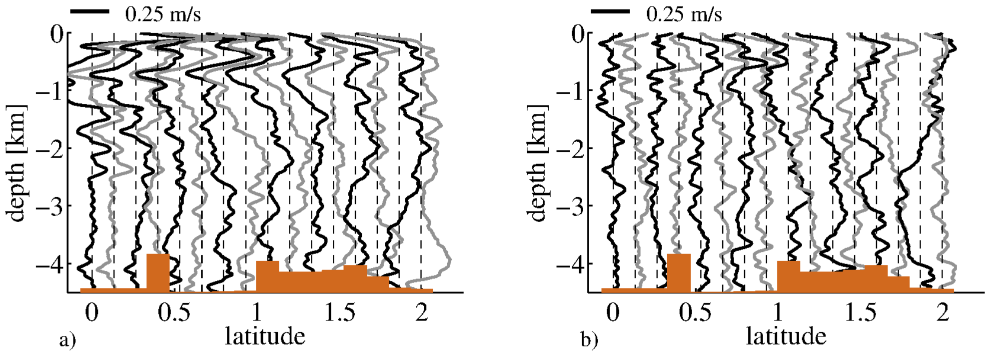

Figure 1: (a) zonal and (b) meridional velocities, as measured in the Equatorial Atlantic by LADCP, are referenced to measurement locations, indicated by dashed lines. The Equatorial Deep Jets are present up to 1°N and down to 2500 m depth.

Despite huge topographical and climatological differences, the Atlantic, Pacific and Indian Equatorial Oceans present a peculiar dynamics compared to off-equatorial regions, concerning their mean flow, internal wave field and mixing properties. On the one hand, the measured internal wave field is considered to be anomalous, since, despite high levels of internal wave energy and shear, mixing appears to be weaker than at mid latitude [1,2]. On the other hand, the Equator is characterized by strong, zonal, basin-scale currents, known as the Equatorial Deep Jets (fig. 1, as observed in the Atlantic), presenting a very complex temporal, meridional and vertical structure.

Interestingly, a satisfying description of these equatorial features, able to capture the unique dynamical aspects characterizing this area (e.g. the inertial frequency goes here to zero), is still lacking, not only because of the few dedicated observational datasets available but also because no clear mechanism of generation and maintenance of the jets and of large scale-small scale interaction has been clearly identified yet.

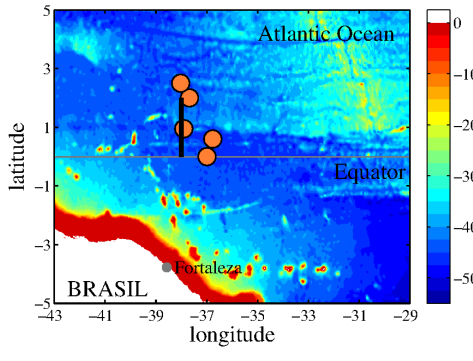

Figure 2: Study area. Circles: approximately 1.5 year long moorings, thick line: CTD/LADCP transect.

In this study observations, collected in the deep Equatorial West Atlantic Ocean (fig. 2), are used to characterize and understand the peculiarities of the equatorial belt over the whole frequency spectrum. The dataset consists of approximately 1.5 year long time series of current velocities, measured acoustically and with current meters, moored between 0°and 2.5°N, at 38°W, off the Brazilian coast. The time series cover the whole water column, even if not continually. The complete depth range is captured by means of a quasi synoptic CTD/LADCP meridional transect (fig. 1), where the anisotropy of the equatorial mean flow field is evident.

In particular, we aim to investigate the possible presence and role of internal wave trapping and focusing in determining the equatorial ocean dynamics, which may drive zonal mean flows due to mixing of angular momentum, as suggested in [3]. Strong and highly coherent zonal mean flows are indeed ubiquitously observed not only in the oceans but also in the equatorial regions of fluid planets, suggesting that their existence could be more likely related to general properties of these systems such as shape, stratification and rotation, rather then to local weather systems.

Internal waves are in fact present in all kinds of stratified and rotating fluids, and are thought to play a key role in diapycnal mixing, because of their oblique propagation, geometric focusing and angular momentum mixing, with consequent triggering of significant zonal flow. Moreover, recent ray tracing studies [3,4] have shown that the equatorial regions of stratified and rotating spherical shells (such as our ocean) are possibly affected by instabilities due to internal wave location, at places where the simplest shaped and most energetic internal wave attractors occur (an example is shown in fig. 3). Suggestions from ray tracing studies are therefore here compared to observational evidence of wave-mean flow interaction by means of spectral analysis and temporal and spatial characterization of the internal wave and mean flow field.

Though the Equatorial Ocean plays a crucial role in the global ocean circulation and in our climate, mechanisms behind its peculiar dynamics are still to be understood, with consequent poor performances of global numerical models in this area. We propose that the use of a new framework of interpretation, focused on the wave-mean flow interaction, together with long term, *in situ* measurements can shed some light on the processes taking place in this region, and constitutes a step towards a better understanding of energy fluxes in the ocean, as well as in other stratified, rotating fluid domains.

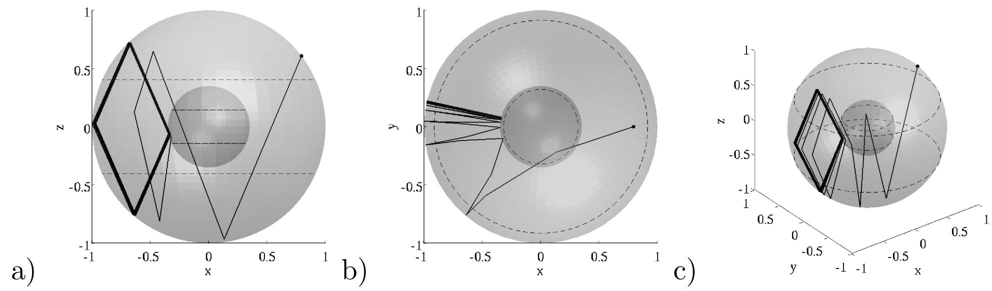

Figure 3: (a) side view, (b) top view and (c) 3D view of three dimensional ray tracing in a homogeneous, rotating spherical shell, showing a simple, diamond shaped "equatorial" attractor at frequency $\omega = 0.4051/2\Omega$. The wave attractor is marked with a thicker line. Dashed lines correspond to critical latitudes. From [4].

References:

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