BETA-PLUMES AND ORIGIN OF STRIATED PATTERNS IN THE OCEAN

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ABSTRACT

Improved mean dynamics ocean topography allowed detection of a global pattern of quasi-zonal jet-like features (striations). In search of common dynamics of the striations, which extending westward from eastern coasts of oceans or from islands, relevance of the dynamic of a nonlinear beta-plume to the Hawaiian Lee Countercurrent, Azores Current, and striations in the eastern subtropical North and South Pacific is evaluated. Analysis of the eddy statistics reveals a similar striated pattern in their density. However, thorough consideration does not confirm that eddy could be a possibly a source or a maintenance mechanism of the striations.

1. MEAN DYNAMIC OCEAN TOPOGRAPHY AND STRIATIONS

Success of a set of altimetry and geodetic satellite missions, complemented by accumulation of large dataset of trajectories of drifting buoys, allowed recently significant improving of the mean dynamic ocean topography (MDOT; Fig. 1a). Improved MDOT offers much more “crispy” map of main ocean fronts and their systems as well as reveals new quasi-zonal jet-like features (striations [2]; Fig. 1b) in eastern parts of all subtropical oceans. The features are not zonal jets, predicted by the theory of freely evolving turbulence and formed through inverse energy cascade due to nonlinear eddy interactions. Axes of the striations (Fig.1) are tilted meridionally and are crossing lines of MDOT, indicating currents at the base of the mixed layer. Therefore, these features are not currents in common definition, i.e. they do not carry water parcels along their axes but only disturb motion of equator-ward

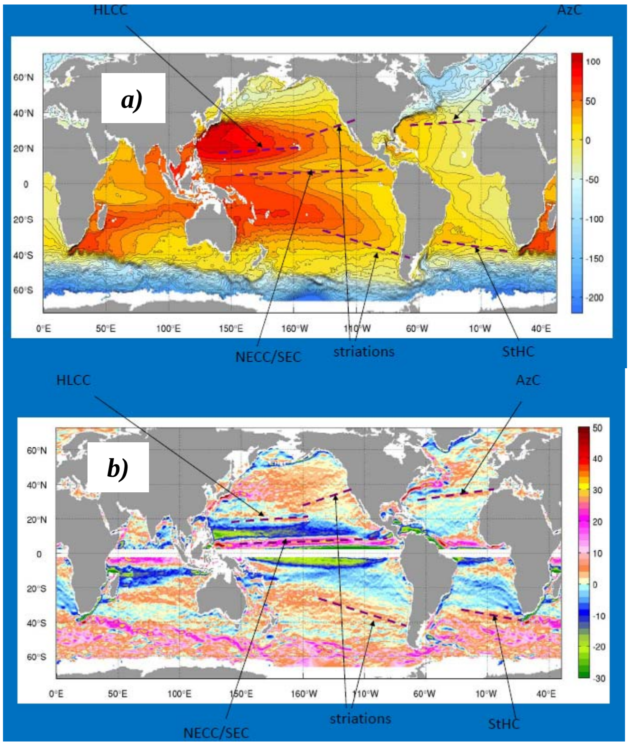

Figure 1. (a) Mean dynamic ocean topography of [1] and (b) mean zonal geostrophic velocity, derived from (a). Units are dyn.cm and cm/s, respectively.

motion of the parcels, advected by the mean large-scale flow. Interestingly, not only new striations but also such well-known currents as the Azores Current (AzC), Hawaiian Lee Countercurrent (HLCC), St Helena Current [3], and currents in the equatorial Pacific (Fig.1) appear to be a disturbance of the meridional circulation.

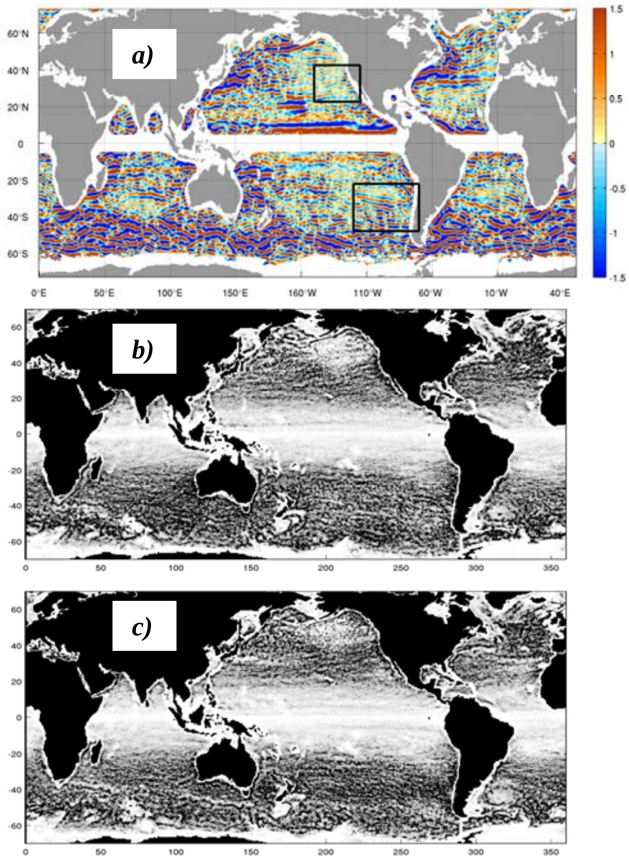

Figure 2. (a)Mean zonal geostrophic velocity, high-pass filtered with a two-dimensional 4-degree filter, density of cyclonic (b) and anticyclonic (c) ocean eddies in the dataset of [8].

In this study we attempt identifying common internal dynamic of a group of features, separated geographically.

Results of previous studies suggest that some of these features have a source at their eastern tips and are produced and maintained through the dynamic of a beta-plume. AzC is believed (e.g., [4]) to be a beta-plume, induced by the Mediterranean water, flowing out to the North Atlantic through Gibraltar Strait and sinking along the continental slope. The “jets” off of the California coast are interpreted by [5] as beta-plumes, generated by nonlinear interaction between the mean Ekman flow and baroclinic permanent meanders of the California Current. HLCC is suggested to be a beta-plume, forced by the wind stress curl in the lee of Big Island of Hawaii.

2. IDEALIZED ROMS MODEL

Simulations of [7] with the idealised ROMS, forced by Gaussian wind in the rectangular at mid-latitudes demonstrate that in the stratified ocean, even without

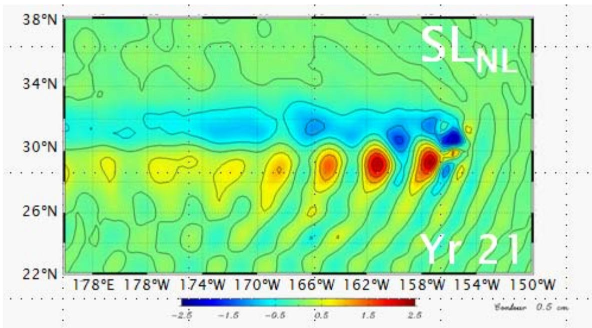

Figure 3. Snapshot of sea level in the ROMS model run in a nonlinear regime [7].

background flow and eddy mixing, while vertically integrated transport remains zonal and steady as suggested by theory, surface signature of a linear beta-plume (set by weak winds) decays fast with the distance from the source due to effects of vertical diffusion and, in particular, vertical viscosity. Detection by [8] of ubiquitous long-living ocean eddies suggests that nonlinear beta-plume, maintained by eddies may better correspond to the dynamic of observed long striations.

Experiments with the model reveal strong modification of the plume in the source area due to large eddy fluxes. West of the formation area, eddies form trains of eddies that are seen as a continuous plume on long-time averages. Important to note is that to cyclones/anticyclones. Establishing an eastward-flowing jet are located on the poleward/equatorward side of the jet.

3. STRIATIONS IN EDDY STATISTIC

Density of ocean eddies in the dataset of [8], shown in Figs. 2b and 2c demonstrates well pronounced stripes pattern with scales comparable to striations in MDOT (Fig. 2a). Comparison between the two datasets is done in four regions.

In the HLCC region (Fig.4), eddies of both signs are pronounced better (Figs.4b and c) along the Subtropical Countercurrent and Subtropical Front, located north of HLCC than along the HLCC itself. Weaker eddy trails can be seen along the axis of HLCC, with cyclones/anticyclones dominating the southern/northern side of HLCC. This is in contrast to model solution in Fig. 3 and rather corresponds to the eddy distribution induced by the meandering HLCC jet.

Eddy trajectories, originating from a smaller and larger areas close to the source region (rectangles in Fig. 4d), are fanning widely in wide range of directions. Meridional spread of eddies largely exceeds the width of HLCC while no eddy lives long enough to produce a trajectory as long as HLCC. Therefore, eddy statistic

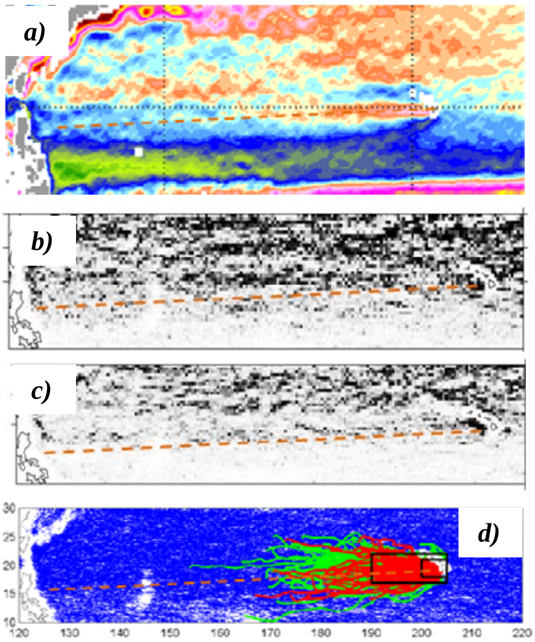

Figure 4. (a) Mean zonal geostrophic velocity, dencity of cyclones (b) and anticyclones (c) in [8], and eddy trajectories originating from the source regions. Dashed line marks the axis of HLCC.

does not support the hypothesis of eddy role is generation of striations.

Similar conclusion can be drawn in the region of AzC (Fig. 5). Eddy trails along AzC are pronounced better than pathways along HLCC, with the maxima of both cyclones and anticyclones aligned along the southern flank of AzC. Similarly to HLCC, eddies generated in the source region (close to Gibraltar Strait) do not read the western end of AzC and scatter rather broadly in the meridional direction.

Even more interesting eddy patterns have been found in the eastern domains of Subtropical North and South Pacific, marked in Fig. 2a. In both areas (Figs. 6 and 7, respectively), densities of eddies of both signs (Figs. 6b,c and 7b,c) contain clear crests and troughs, spaced and oriented the same way as striations in the high-pass filtered MDOT (Figs. 6a and 7a). At the same time, the correspondence between the eddy signs and collocated striation signs are opposite. Meridional distributions of corresponding properties in Figs. 6d and 7d show that cyclonic eddies (blue lines), associated with negative sea level anomalies (SLA), prefer to move along striations with higher values of MDOT. Analogously, cyclones having positive SLA are concentrating along the trough in MDOT. This anticorrelation excludes the possibility for striations to be a result of averaging in time of eddies drifting along the striations.

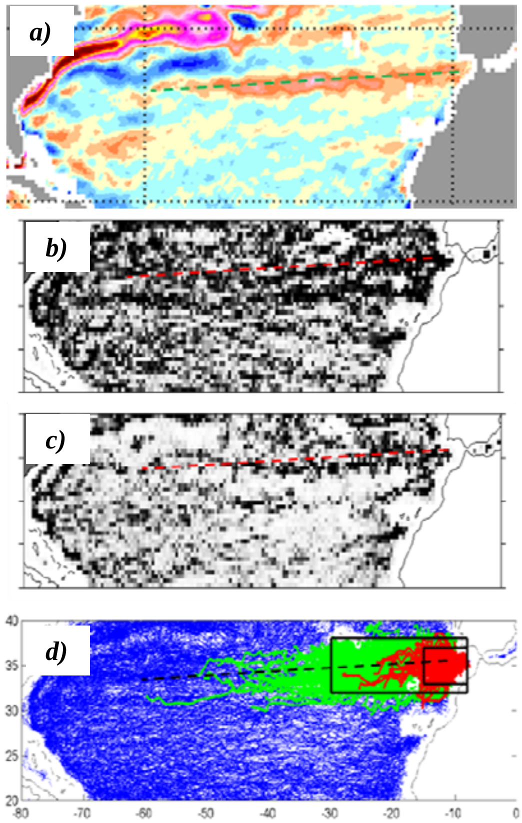

Figure 5. Same as Fig.4 but for AzC.

4. CONCLUSIONS

Comparison between striations and eddy statistics of [8] in four regions, demonstrates that eddies cannot be a mechanism, supporting the striation through the dynamic of a nonlinear beta-plume or through direct time averaging.

While eddy distribution shows striated patterns similar to striations in MDOT, consistent physics of eddy-striation interaction and mechanisms sustaining narrow ocean striation are still to be understood.

5. ABBREVIATIONS AND ACRONYMS

HLCC – Hawaiian Lee Countercurrent
AzC – Azores Current
MDOT – mean dynamic ocean topography
SLA - sea level anomaly
NECC – North Equatorial Countercurrent
SEC – South Equatorial Current
StHC – St Helena Current

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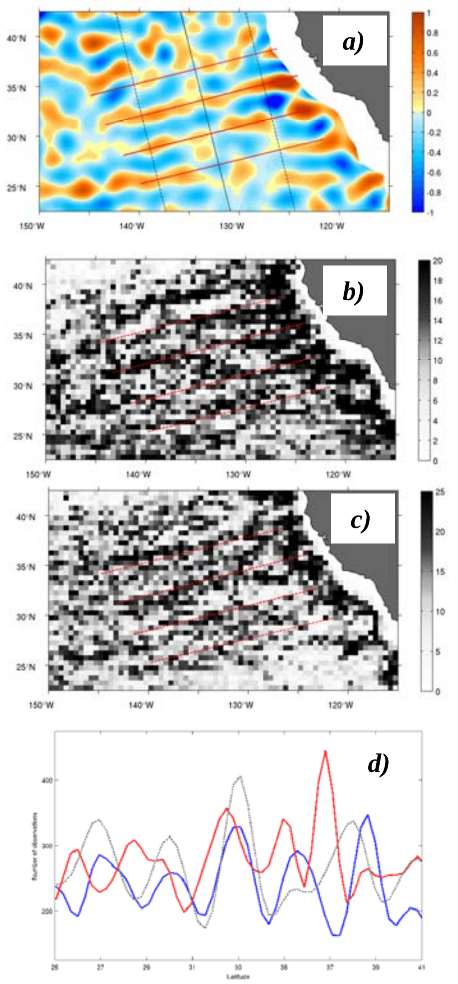

Figure 6. (a) MDOT, high-pass filtered with two-dimensional 4-degree filter, density of cyclones (b) and anticyclones (c) in the North Pacific domain, shown in Fig.3a. Red lines mark crests of striations. (d) Cross-striation structure of (a, black), (b, blue), and (c, red), averaged along axes in the band, shown in (a).

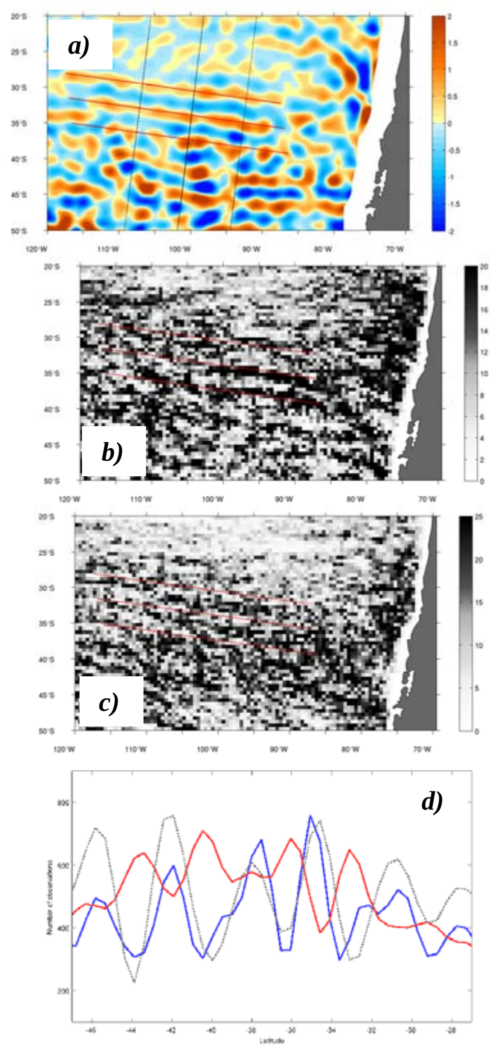

Figure 7. The same as Fig. 6 but for the South Pacific domain, shown in Fig. 3a.

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