Beta-plumes and origin of striated patterns in the ocean

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Dynamics of "striations" quasi-azal-like features seen on maps of multi-year mean geostrophic velocity (see Figure), is analyzed in the framework of beta-plumes, ocean circulations generated by localized sources of vorticity. Beta-plumes are exemplified by the Azores Current (AZC) induced by the outflow of Mediterranean water from Gibraltar, the Hawaiian Lee CounterCurrent (HLLC) generated by the orographic wind stress curl in the lee of Big Island of Hawai‘i, and features off the California coast resulting from nonlinear interaction between baroclinic meanders of the California Current and Dinaric flow. Experiments with the idealized ROMS model demonstrate formation of the system of jets west from the source area in linear regime and of system of eddy trains in nonlinear regime. In the presence of the background meridional flow, common in the regions populated by striations, beta-plumes change orientation. Axes of beta-plumes are tilted by the large-scale advection in the same manner both in linear and non-linear regimes. In linear case, tilted axes allow trapped Rossby waves to propagate meridionally along the flow. In nonlinear case, the tilt is achieved by a superposition of westward drift of eddies and their meridional advection by the flow.

References:

Figure 1. (a) Mean dynamic ocean topography (MDOT), (b) mean geostrophic zonal velocity, derived from MDOT, and (c) the same velocity after application of two-dimensional high-pass filter with half-width of 0.5°. Notations on (a) HLLC – Hawaiian Lee CounterCurrent, AZC – Azores Current, SMC – St. Helena Current.

Figure 2. (a) Schematic of beta-plume forced by wind stress curl dipole, (b) mean currents and winds around Hawai‘i, generating HLLC, (b) ROMS solution in the California Current System, where nonlinear interaction between Dinaric flow and baroclinic meanders produces off-shore striations, and (c) schematic of the Azores Current induction by sinking Mediterranean water.

Figure 3. Model runs of a simplified baroclinic ROMS, forced by a localized (Gaussian) wind stress monopole: (a) analytical mean vertically-integrated transport, transport in linear (b) and non-linear (c) regimes, mean sea surface height in linear (d) and non-linear (e) regimes, and (f) transport in nonlinear SH.

Figure 4. Schematic of lifting of linear (left) and non-linear (right) beta-plume due to interaction with meridional flow.

Figure 5. (a) MDOT, high-pass filtered with two-dimensional 4-degree filter, (b) and (c) density of cyclones and anticyclones.

Figure 6. (a) MDOT, high-pass filtered with two-dimensional 4-degree filter, (b) and (c) density of cyclones and anticyclones in the South Pacific domain, shown in Fig. 1c. (d) cross-station structure of high-pass filtered MDOT (dashed), density of cyclones (blue) and anticyclones (red).

Figure 7. (a) MDOT, high-pass filtered with two-dimensional 4-degree filter, (b) and (c) density of cyclones and anticyclones in the North Pacific domain, shown in Fig. 1c. (d) cross-station structure of high-pass filtered MDOT (dashed), density of cyclones (blue) and anticyclones (red).

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