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A Search for Propagating Quasi-Zonal Jets (Striations)

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Abstract

Fourteen years of satellite sea level anomaly observations and realistic data from the Ocean General Circulation Model for the Earth Simulator (OFES) are used to examine properties of propagating quasi-zonal jet-like structures (striations) in the Pacific Ocean. These features with mesoscale meridional scale and extending for thousands of kilometers in length are found to populate low and middle latitudes. Rare exceptions are found in the eastern parts of sub-polar regions. We put forward the interpretation of the striations as low-frequency waves with nearly meridional orientation of the wave number vector. Their amplitudes tend to be larger in areas where the overall eddy kinetic energy level is higher. The wavelengths are in general decreasing with latitude. The averaged ratio of the striations wavelength to the first-mode deformation wavelength is 1.8. Geographically, this ratio tends to be smaller in low latitudes and increases toward the poles. Zonal phase speeds are westward and decreasing with latitude, qualitatively in agreement with the Rossby wave dynamics. There are large quantitative discrepancies, however, suggesting that linear dynamics may not be appropriate.

Remarkably, good agreement in all parameters of the striations is found between the observations and the OFES hindcast. Analysis of much longer time series from the model suggests that propagating striations are highly intermittent in both space and time. A slight asymmetry between the eastward and westward flowing striations is also observed.

Data Sources:

Observations: The geostrophic velocity anomaly was calculated from the weekly sea level anomaly data provided on the 1/3º Mercator grid by Aviso.

Model: The OGCM for the Earth Simulator (OFES), based on the Modular Ocean Model (MOM3), was jointly developed by the Earth Simulator Center and Frontier Research Center for Global Change (Japan). The computational domain is near-global (75ºS-75ºN), with 54 vertical levels and 0.1º horizontal grid spacing. A 50-year spin-up simulation was forced by monthly climatology of NCEP/NCAR reanalysis data, starting from the WOD'98 temperature and salinity fields without motion. A hindcast simulation from 1950 to 2007 was forced by daily mean NCEP/NCAR reanalysis data, starting from the last output of the spin-up simulation (Sasaki et al., 2008).

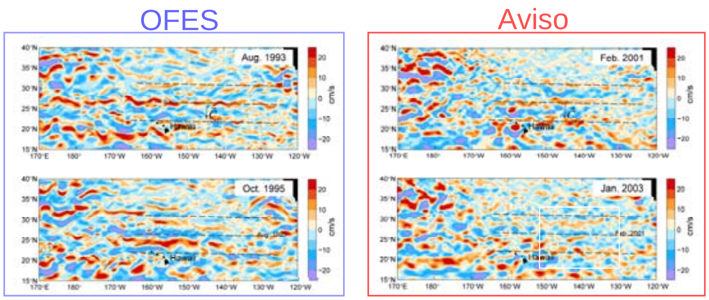

Figure 1. Monthly mean zonal geostrophic velocity at the sea surface in OFES (left) and satellite (right) data. Quasi-zonal jet-like structures (L=500 km, T=4-5 years) propagating southward (0.3 km/day) in the eastern subtropical Pacific remain coherent for several years.

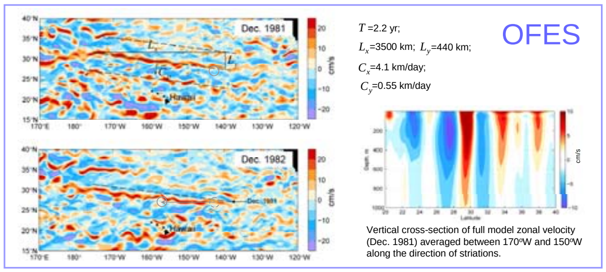

Figure 3. Snapshots of the OFES zonal geostrophic velocity (sea surface) in December 1981 and December 1982. Vertical structure of zonal velocity is shown on the right panel. In the model, eastward flowing striations tend to be narrower and stronger. There is an analog observed in Aviso data (1997-1998), however the asymmetry between the eastward and westward flowing striations is not detected, perhaps due to the limited spatial resolution and substantial smoothing during the interpolation procedure.

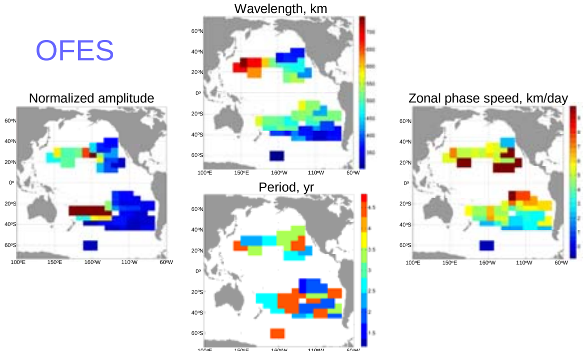

Figure 5. 54 years of the OFES hindcast were divided into four 14-year periods. Some parameters of propagating striations detected in the 1991-2003 data series are shown.

Examples:

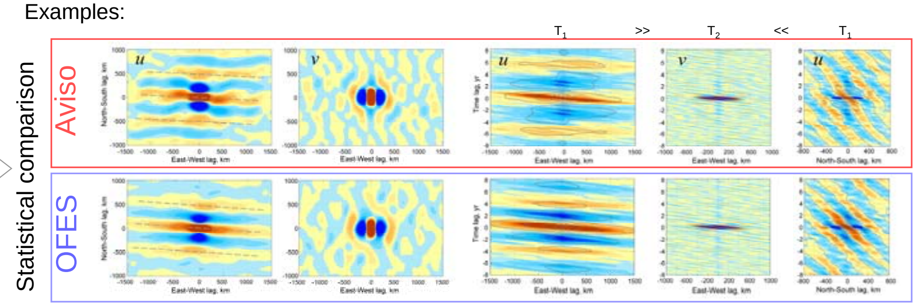

Figure 2. Model vs. observations: statistical comparison. Space and time lagged autocorrelations of zonal and meridional components of geostrophic velocity calculated from Aviso (1993-2006) and OFES (1983-1996) sea level anomaly. Autocorrelations are calculated using data within white box shown in Fig. 1 to the east of Hawaiian islands. There are two distinct and well separated time scales: T_1 ~4-5 years, associated with the quasi-zonal striations and T_2~4-5 months, associated presumably with mesoscale eddies. In plots of space-time lagged correlations of zonal velocity, gray contours (contour interval is 0.2) show correlations of band-passed (with periods of 7-2.7 yr) velocity.

Properties:

A search for propagating striations: (1) moving 3D FFT window; (2) search for isolated spectral maximum (if any) in the low-frequency band; (3) check for asymmetry between negative and positive frequencies (should be clear propagation, no standing jets or shifting back and forth); (4) band-pass filter; (5) check for long-range correlation in one direction and wavy correlation in the perpendicular direction; (6) estimation of parameters using Radon transform.

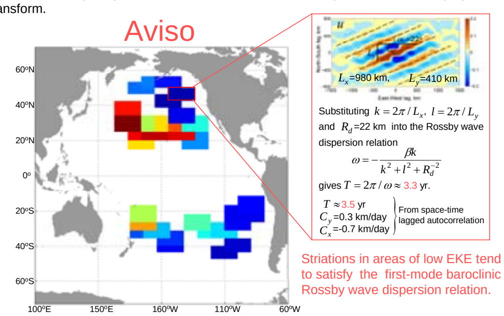

Figure 4a. Geography of propagating striations (Aviso): normalized amplitude.

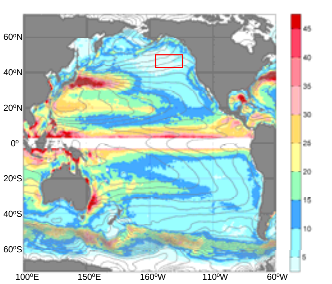

Figure 4b. For the reference: Aviso root-mean-square velocity (color, cm/s) and 1992-2003 Mean Dynamic Ocean Topography (contours).

Summary

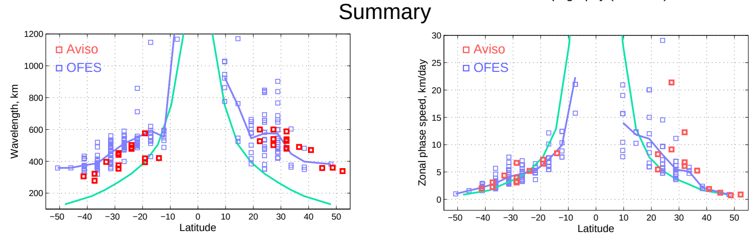

Figure 6. Wavelengths (left) and zonal phase speeds (right) of propagating striations detected in Aviso (red) and OFES (blue) data. First-mode Rossby deformation wavelength and theoretical long Rossby wave phase speed are shown by green lines.

Propagating striations resemble zonally elongated Rossby waves whose meridional scales closely follow the scale of the most energetic mesoscale variability (approximately twice the first internal radius) commonly associated with large oceanic eddies. This makes separation of the two processes difficult (if possible) and suggests that their dynamics are coupled.

Acknowledgments

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