How deterministic are the deep zonal jets?

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Eddy-resolving oceanic general circulation models (OGCMs) often show eastward and westward alternating flows below the main thermocline in the velocity field averaged over one year or longer. They are commonly termed the "deep jets". They are fairly coherent zonally, extending tens of degrees, and vertically, extending down to 1000–2000 m. Their meridional wavelength (distance between eastward flows) is typically 3º–5º. Although they tend to be masked by the general circulation near the surface, their pressure anomalies exist there and has been detected in satellite-observed sea-surface height fields. Recently, a compilation of high-resolution ADCP sections and an analysis on geostrophic velocity based on Argo showed the horizontal and vertical structure of the jets (Cravatte et al. 2017).

In an analysis of OFES , an eddy resolving model, deep jets tend to systematically migrate toward the equator between 20º–30ºN and S (Richards et al. 2006) with a period of approximately 4 years. On the other hand, Qiu et al. (2013) proposed a mechanism that generates a series of stationary deep jets at fixed distances from the equator.

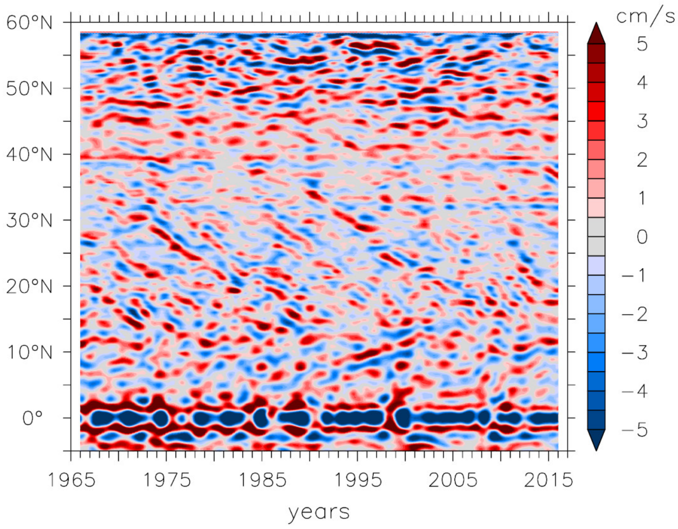
A number of mechanisms have been proposed to explain the existence and the properties of these deep jets, some of them suggesting that the positions and strengths of the jets are determined by external forcing ("deterministic") and others, that they are (or should be) only statistically determined ("stochastic").

To determine how deterministic the deep jets are, we use a 10-member ensemble of runs of OFES 2, an OGCM for the Earth Simulator version 2, which is a semi-global model with a 0.1º horizontal resolution. Its surface forcing is based on JRA55-do, a timeseries of atmospheric conditions derived from a reanalysis product. The ensemble runs are started from the beginning of 1965 and extended to the end of 2016; their difference comes solely from slight differences in their initial conditions.

As the left panel of the figure below shows, equatorward phase propagation of deep jets is clear between 20º–30ºN, whereas poleward propagation is discernible between 5º–15ºN. Along 33º and 40ºN are rather persistent eastward jets flanked by westward jets on their equatorward sides. North of 40ºN, the jets tend to be somewhat stronger and less stable and to have shorter meridional wavelengths.

The variance among the ensemble members initially grows rapidly but stabilizes in 5–10 years (not shown). The right panel of the figure below indicates how well the positions of eastward jets agree among the ensemble members. Except for the equatorial currents (like the primary and secondary Tsuchiya Jets) and those stable jets near 33º and 40ºN, the axes of the jets more or less vary among ensemble members. Nevertheless, some coherence is also evident; in particular, the poleward-propagating jets in the 5º–15ºN band tend to agree among themselves. In the equatorward-propagating regime 20º–30ºN, coherent propagation sometimes emerges. If the tropical (equatorward of 15ºN) jets are deterministic, their migration may be due to some slow change in external forcing.

Keywords: deep jets, chaos, eddy-resolving OGCM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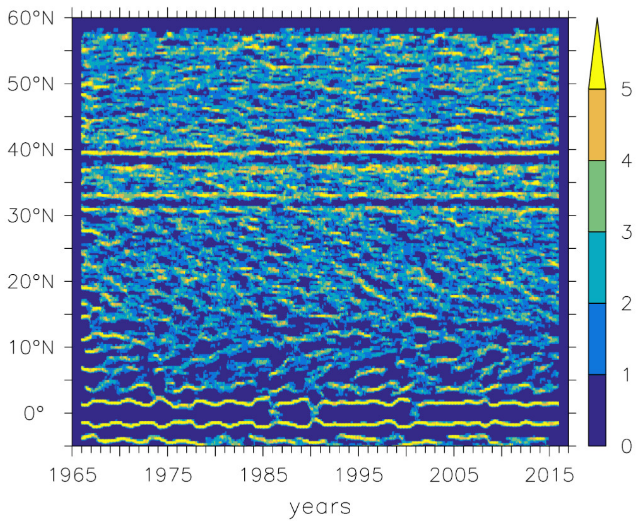
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