Sensitivity of the Yoshida Jet to the Parameterization of Vertical Mixing. Do Easterly Winds Imply Equatorial Upwelling?

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Abstract

This study investigates the sensitivity of the dynamics of the equatorial ocean to the parameterization of vertical mixing and focuses on the circulation in the meridional–vertical plane driven by easterly winds: the Yoshida jet. A new high resolution, numerical model of a zonally independent, equatorial channel helps explore this question and includes three parameterizations, all of which increase mixing for decreasing Richardson numbers. It compares the smooth increase of eddy coefficients traditionally used in general circulation models, the dramatic increase of the eddy coefficients for small Richardson numbers recently observed in the equatorial Pacific, and a combination of a mixing mechanism based on the diagnostic adjustment of the water column to noncritical Richardson numbers and of a bulk mixed-layer model.

The main numerical result is that the meridional and vertical velocity fields in the surface layer are very sensitive to the strength of mixing implied by the different parameterizations. For the smooth Richardson number dependence of the eddy coefficients, equatorial upwelling due to easterly winds reaches the surface. The dramatically increasing eddy coefficients for small Richardson numbers yield reduced equatorial upwelling rates in the surface layer. The diagnostic adjustment of the Richardson number shows downwelling in response to easterly winds!

A simple model explains the wind drift at the equator in the presence of a meridional density gradient and reproduces this reversal of the meridional and vertical flows. The density gradient causes a vertically dependent pressure gradient force which is partially balanced by the meridional component of the Coriolis force, indicating that

the zonal flow and the density are nearly in geostrophic balance. The residual of this balance determines the sign of the meridional shear and depends critically on the size of the eddy coefficient. A critical value at which the residual and the vertical velocity change signs is of the order of $10^{-3} m^2 s^{-1}$. This value is of the same order as measured in the surface equatorial Pacific and used in general circulation models. The physics of the reversal of the meridional circulation are so basic it is likely they are active in the ocean and three dimensional circulation models.