Abstract View

Volume 27, Issue 8 (August 1997)

Journal of Physical Oceanography
Article: pp. 1713–1728 | Full Text | PDF (506K)

Boundary Mixing and the Dynamics of Three-Dimensional Thermohaline Circulations

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(Manuscript received August 6, 1996, in final form February 10, 1997)

DOI: 10.1175/1520-0485(1997)027<1713:BMATDO>2.0.CO;2

ABSTRACT

Boundary mixing is implemented in an ocean general circulation model such that the vertical mixing coefficient k_v is nonzero only near side boundaries and in convection regions. The model is used in a highly idealized configuration with no wind forcing and very nearly fixed surface density to investigate the three-dimensional dynamics of the thermohaline circulation. For $k_v = 20 \times 10^{-4}$ m^2 s^{-1} and lower, the meridional overturning strength to great accuracy is proportional to $k^{2/3}_v$; meridional heat transport is proportional to $k^{1/2}_v$. The circulation patterns resemble those from runs with uniform vertical mixing, but vertical motion is entirely confined to the boundary regions. Near the western boundary, there is upwelling everywhere. Near the eastern boundary, there is a consistent pattern of downwelling above upwelling, with downwelling reaching deeper at high latitudes; this pattern is explained by convection and vertical advective–diffusive balance underneath.

For $k_v = 30 \times 10^{-4}$ m^2 s^{-1} and higher, no steady solutions have been found; the meridional overturning oscillates on a timescale of about 25 years. A time-averaged thermally direct overturning cell is not supported dynamically because convection extends longitudinally across the entire basin, and upwelling near the western boundary does not lead to densities higher than at the eastern boundary.

Assuming uniform upwelling in the west, level isopycnals near the equator, and level isopycnals along the eastern boundary south of the outcropping latitude permits the analytic determination of convection depth at the eastern wall and hence the density difference between the eastern and western walls. This difference is at most one-quarter the surface density difference between high and low latitudes, and agrees in magnitude and latitudinal dependence with the numerical experiments. Scaling arguments estimate overturning strength as of the order of 10×10^6 m^3 s^{-1} and confirm the 2/3 power dependence on k_v. The derivation also gives a dependence of overturning strength with

latitude that agrees qualitatively with the numerical results. The scaling for the dependence of meridional heat transport on latitude agrees well with the model results; scaling for heat transport amplitude agrees less well but correctly predicts a weaker dependence on k_v than maximum overturning.

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