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Mesoscale eddy - internal wave coupling and closure of the thermocline circulation

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The standard paradigm for oceanic dynamics is to consider the stratified interior as an ideal fluid and place all dissipative processes in either the bottom boundary layer or associate them with eddy/mixed layer interactions. On the other hand, background potential vorticity gradients are clearly documented in hydrographic data, e.g. [1], and current meter data [2] also document the presence of downgradient eddy fluxes of potential vorticity. Thus we arrive at an essential conundrum: what is the frictional or diabatic process that permits the material modification of potential vorticity within the stratified oceanic interior associated with the downgradient fluxes? It is clear that diabatic processes are far too weak. A case will be made here that a coupling between mesoscale eddies and the internal wavefield acts as a frictional process.

The case to be presented will focus on the interpretation of observations. These include current meter array data obtained as part of the POLYMODE Local Dynamics Experiment (LDE). [3] found correlations between internal wave momentum fluxes (stresses) and eddy rate of strain estimates that they interpreted in terms of a horizontal viscosity ν_h = 200 - 400 m^2 s^{-1}.A revised estimate of this horizontal viscosity (ν_h = 50 m^2 s^{-1})and a vertical viscosity (ν_v = 3 $\times$ 10^{-3} m^2 s^{-1})estimate will be presented. Viscosity coefficients of this magnitude indicate that transfers of energy, momentum and potential vorticity between internal waves and mesoscale eddies are a significant part of the eddy energy[4] and eddy enstrophy (potential vorticity squared) budgets. Spectral fluxes computed from altimetry data[5] reveal that at horizontal scales greater than the Rossby radius of deformation an inverse cascade of kinetic energy towards larger horizontal scales takes place, while at horizontal scales less than the deformation radius, a forward cascade towards smaller scales takes place. Numerical simulations using an idealized 2-layer quasigeostrophic model indicate the pattern and magnitude of energy cascades in the satellite altimetry data are replicated with a horizontal viscosity (ν_h) of O(50 m^2 s^{-1}),but not if a horizontal viscosity of O(5 m^2 s^{-1})is used. Significantly larger values of horizontal viscosity, of O(500 m^2 s^{-1}),result in a model eddy field that is less energetic, too baroclinic and has larger length scales relative to midlatitude observations. Somewhat surprisingly, dissipation associated with a horizontal viscosity operator of O(50 m^2 s^{-1})plays a dominant role in the model energy budget at horizontal length scales one to two times larger than the deformation radius. We interpret the forward cascade as a result of mesoscale eddy - internal wave coupling.

Our results have implications for eddy dynamics, the ocean energy budget, for the strength of the meridional overturning circulation, which is sensitive to the spatial distribution of dissipation, and for ocean general circulation models, which often use closures guided by numerical, rather than physical, considerations.

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[5] Scott and Wang, 2005: Direct evidence of an oceanic inverse kinetic energy cascade from satellite altimetry. *J. Phys. Oceanogr.*, **35**, 1650–1666.