Geophysical Research Abstracts
Vol. 14, EGU2012-6384, 2012
EGU General Assembly 2012

The apparent efficiency of gravitational potential energy generation by diapycnal mixing in the ocean

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Large scale overturning in the ocean is sustained by gravitational potential energy (GPE) generation. The direct impact of GPE generation on the circulation is most readily recognised through the equivalence between the GPE and depth-integrated pressure of a water column. The efficiency of GPE generation due to turbulent kinetic energy (TKE) dissipation is commonly quoted as Γ, the fraction of TKE used to mix the water column (the remaining energy is dissipated as heat). However, this is only correct if there is no exchange between GPE and available internal energy (AIE), due to contraction or expansion following mixing. Such exchange does occur due to the non-linearity of the equation of state. If the ratio of GPE-to-AIE conversion to mixing-energy from TKE dissipation is $(1 - \xi)$, then the ratio of GPE generation to TKE dissipation is $\xi\Gamma$.

In this study, ξ is determined globally from World Ocean Atlas data. It is found that the regime $\xi < 1$ dominates in the pycnocline, where contraction associated with cabbelling results in the loss of GPE. In the abyssal ocean, where there are weak positive conservative temperature gradients, the regime $\xi > 1$ dominates due to expansion associated with thermobaricity. The mean of ξ is 0.6 at 400 m depth, and 1.6 at 5000 m depth, indicating that TKE dissipation is typically 2-3 times as effective at supplying GPE to the local water column if it occurs in the abyssal ocean. The effect of this result on published estimates of GPE generation from turbulence observations is presented.

Finally, a numerical model is used to explore how the circulation and surface buoyancy fluxes respond to exchange between GPE and AIE associated with mixing. It is found that GPE converted to/from AIE during mixing is not recovered locally, and is only recovered globally on centennial timescales. Therefore, $\xi\Gamma$, as opposed to Γ, is the quantity of most use in determining the role of TKE dissipation in large scale ocean circulation.