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On the Potential Vorticity Structure of Weakly Ventialted Isopycnals: A Theory of Subtropical Mode Water Maintenance

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ABSTRACT

A two-layer model of the general circulation including wind and thermal forcing is discussed. The flow in each layer is geostrophic, hydrostatic and obeys linear potential vorticity constraints. The equations are developed in spherical coordinates and reduce to a surprisingly simple, coupled, nonlinear set. Analytic solutions of this system are obtained in the quasi-geostrophic limit. The novel feature in this model is a weakly ventilated and weakly dissipative lower layer.

The quasi-geostrophic model predicts homogenized potential vorticity is regions of the lower layer which are not directly ventilated. These are also regions of locally minimum value in potential vorticity. The net balance determining the potential vorticity structure is between the diabatic forcing of the lower layer and eddy-drive mixing. As such, the structure of the solution depends on the sign of the eddy diffusion of potential vorticity (positive) and the sign of the diabatic potential vorticity source (negative). It is therefore argued that these features and not dependent on quasi-geostrophy.

A comparison of model results with data is encouraging. The 26.5 sigma-theta isopycnal is argued to be a density surface to which this theory applies. The potential vorticity structure on this surface obtains a bowl-like shape and agrees well with the model. The subtropical mode water of the North Atlantic (18°C water) is centered on this isopycnal and is identified in the model as the homogenized local potential vorticity minimum. The stability of 18°C water characteristics, documented elsewhere, is explained in terms of a gyre-scale response to variability.

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