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What controls stratification, overturning, and water masses in an ocean with a fully adiabatic interior?

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Adiabatic theories of ocean circulation and density structure have a long tradition – from the concept of the ventilated thermocline to the notion that deep ocean ventilation is controlled by westerly winds over the Southern Ocean. In this study we explore these ideas using a recently developed Lagrangian ocean model (LOM), which simulates ocean motions by computing trajectories of water parcels. A unique feature of the LOM is its capacity to model ocean circulations in the adiabatic limit, in which water parcels exactly conserve their densities when they are not in contact with the ocean surface (the zero-diffusion limit). We show that when such an idealized ocean with a circumpolar channel in the South is exposed to a realistic zonal wind stress and surface density restoring, the resulting ocean stratification, water mass distribution, meridional overturning and poleward heat transport look very much like those observed in the Atlantic. The developed stratification amounts to a layering of water masses formed at different latitudes. The main conclusion of our study is that the adiabatic limit for the ocean interior provides the leading-order solution for ocean overturning and density structure, with tracer diffusion contributing first-order perturbations. We can precisely quantify the changes in stratification and circulation that result from adding a moderate amount of tracer diffusion in our idealized ocean, and these include an increase in the amplitude of the deep meridional overturning cell of several Sverdrups, a 10-20 % increase in northern hemispheric northward heat transport, a stronger stratification just below the main thermocline, and a more realistic bottom overturning cell. Finally, we show that ocean stratification is very sensitive to the range of shared density surfaces that outcrop in both the channel region and the northern high-latitudes.