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Eddy-balanced buoyancy gradients on boundaries and their role in the thermocline and the meridional overturning circulation

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A model of the thermocline linearized around a specified stratification and the barotropic linear wind-driven Stommel solution is constructed. The forcings are both mechanical (the surface wind stress), and thermodynamical (the surface buoyancy boundary condition). The effects of weak diapycnal diffusivity and of eddy fluxes of buoyancy (parametrized as isopycnal diffusion) are included. These effects are especially important near the boundaries where they mediate the transport in and out of the narrow ageostrophic down/upwelling layers. The dynamics of these narrow layers can be replaced by effective boundary conditions on the geostrophically balanced flow. The effective boundary conditions allow buoyancy gradients along all solid boundaries, including the eastern one. A special focus is on the buoyancies along the eastern and western walls, since their difference determines the meridional overturning The advection of buoyancy by the barotropic flow is most effective on the western boundary. Because the buoyancy is coupled all along the boundaries, the barotropic flow advection affects the buoyancy everywhere, including the eastern wall. This leads to a complex interweaving of buoyancy patterns, with stacked counter rotating cells of the meridional overturning circulation. Quantitative scaling arguments are given for each of these cells, which show how the buoyancy forcing, the wind-stress and the diapycnal diffusivity, as well as the other imposed parameters, affect the strength of the overturn.