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Understanding the thermohaline circulation with linear theory

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Linear analytical models of the wind-driven circulation are familiar in ocean theory and are routinely used to interpret observations and model results. But linear models are much less familiar in the context of the buoyancy-driven circulation. We examine such a model, to see whether it can reproduce the time mean circulation in an idealized basin generated by (fully nonlinear) numerical models. We focus in particular on the three-dimensional velocity field. Like the numerical models, the linear model exhibits boundary-intensified upwelling and downwelling. Because of this, the overturning strength is dependent on the choice of viscosity and of boundary conditions; similar dependencies have been noted in numerical simulations. In addition, the overturning strength alters the horizontal circulation. So there may be either one or two gyres at the surface; the numerical models likewise have one or two gyres. The linear model is in some ways limited by its dynamical simplifications, but unlike with the numerical models, boundary layers, which are of primary importance, are fully resolved. So the linear model may be useful for the interpretation of the numerical models and for instance in choosing sub-grid scale parameterizations.