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On the Dynamics of Thermohaline Staircases

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We present the recent findings of ongoing studies on the dynamics of thermohaline staircases, the well-defined stepped structures in temperature and salinity profiles commonly observed in regions of the ocean where double diffusion is active. We examine the evolution of staircases over time through spontaneous layer-merging events. A theoretical model is introduced that pertains to both diffusive convection (cold and fresh fluid overlying warm and salty fluid) and salt fingering (warm and salty fluid overlying cold and fresh fluid) and which is based on a stability analysis for a series of identical steps. This model is given further credence through its agreement both with observations and a series of two- and three-dimensional numerical experiments. We also consider the interaction of double diffusion and shear in the context of recent observations taken in the Weddell Sea (MaudNESS), where diffusive convection is active. The model employed consists of an initial state with slightly perturbed linear temperature and salinity gradients. We introduce shear that is both periodic and sinusoidal in nature, with shear velocity defined so that the Richardson number is less than 0.25 for some portion of the shear period. Numerical modeling describes layer formation, merging, destruction and reformation consistent with observations. A "steppedness" parameter is described relating shear amplitude and the formation of layers. Numerical analyses lead to vertical heat fluxes that are also consistent with observations. Comparison is made to the case where double diffusion is essentially "switched off" i.e. the Lewis number is set to unity. In this instance, density fluxes are considerably lower, confirming the importance of double diffusion as a vertical mixing process. We also describe further results quantifying the vertical transport of heat through staircases (with application to the Beaufort Gyre) and numerical experiments that give insight to the resilience and surface signature of thermohaline staircases.