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Numerical simulations of dense water cascading on a steep slope

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Flows of dense shelf waters down the continental slope – cascades – contribute to the formation of intermediate and bottom waters and are believed to be influential in the off-shelf transport of carbon and other suspended or dissolved matter. We study cascading over steep bottom topography in numerical experiments using POLCOMS, a 3-D ocean circulation model employing a terrain-following s-coordinate system. The model setup is based on a laboratory experiment of a continuous dense water flow from a central source on a steep conical slope (39°) in a rotating tank. The descent of the dense water mass as characterised by the length of the plume as a function of time is studied for a range of experimental parameters, mainly the density difference between plume and ambient water, the flow rate and the speed of rotation. Very good agreement between the model and the laboratory results is shown in dimensional and nondimensional variables.

Our results demonstrate that a hydrostatic model is capable of reproducing the essential physics of cascading on a very steep slope if the model correctly resolves velocity veering in the bottom boundary layer. Our 3-D modelling confirms findings previously obtained by reduced physics models for a 2-layer flow. We further explore the dynamics of cascading outside of the controlled laboratory conditions in model runs where viscosity and/or diffusivity are modified. The limits of the reduced physics theory are identified in simulations with increased diffusivity where the cascade has a blurred interface between plume and ambient water and can no longer be considered a 2-layer flow. We show that downslope transport is reduced when the plume interface is strongly diffused, but enhanced in a regime that simulates cascades with increased turbulence where diffusivity and viscosity are both increased.

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