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Laboratory experiments of freshwater discharge into the ocean

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Laboratory experiments have been conducted to explore the evolution of freshwater discharged on top of salt water in a rotating table. These experiments are motivated by the need to develop fundamental understanding of the dynamics of glacial melt water released into the ocean. They have been performed on a turntable with 2-m diameter and flat bottom in the GFD Laboratory at WHOI. The experimental protocol is as follows. The table includes a pie-shaped basin (representing the North Atlantic Ocean) and filled with salt water. The salt water in the basin is brought to solid body rotation, so it is at rest in the rotating frame. Once solid body rotation is established, freshwater colored with a dye is pumped at a constant rate into the basin along the left wall. The evolution of the freshwater in the basin is then observed with a camera that co-rotates with the table. We find that the freshwater discharged along the left wall turns to the right and forms a thin buoyant current along the wall, consistent with the effects of rotation (counterclockwise in our experiments). On the other hand, freshwater is also transported away from the wall, but at a very slow rate compared to the rotation rate.

The freshwater transport away from the wall which we observe in the laboratory is examined in the light of a f-plane theory of a two-layer fluid: a thin light layer over an infinitely deep dense layer. Each layer has a uniform density, and is subject to a balance between rotation, pressure, and viscosity forces. The theory is nonlinear as the variations of the depth of the upper layer (h) are of order one. In this theory the governing equation for h is a diffusion equation with an asymmetric diffusion tensor. In the limit where the layer is much thicker than the Ekman layer, this equation reduces to a linear equation with constant diffusivity. In the opposite limit, it reduces to an equation with a scalar diffusivity that increases quadratically with h. Predictions about the transport in the surface layer away from a source in each limit are compared to our observations in the laboratory.