Some effects of topography and wind stress on the Nordic Seas overflow

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Abstract:

The overflow of the dense water mass across the Greenland-Scotland Ridge (GSR) from the Nordic Seas is a primary driver of the lower limb of the Atlantic Meridional Overturning Circulation (AMOC). So the stabilities of the AMOC and the overflow transport are intimately tied. In this study, we examine some effects of topography and wind stress on the Nordic Seas outflow of dense water over the Greenland-Scotland Ridge (GSR). Our approach is a nonlinear and two-layer model with both idealized and realistic topography. First we have investigated the Nordic Seas' reservoir capacity to supply overflow. The volume of the dense water in the upper layer above the GSR sill depth in the Nordic Seas, according to previous estimates, is sufficient to supply decades of overflow transport. This large capacity buffers overflow's responses to atmospheric variations and prevents an abrupt shutdown of the dense-water transport to the Atlantic Ocean. In this study, we use a numerical and an analytical model to show that the effective reservoir capacity of the Nordic Seas is actually much smaller than what was estimated previously. Basin-scale oceanic circulation is nearly geostrophic and its streamlines are basically the same as the isobaths. The vast majority of the dense water is stored in inside closed geostrophic contours in the deep basin and thus is not freely available to the overflow. The positive wind-stress curl in the Nordic Seas forces a convergence of the dense water toward the deep basin and makes the interior water even more removed from the overflow-feeding boundary current. Eddies generated by the baroclinic instability help transporting the interior water mass to the boundary current. But in absence of a robust renewal of deep water, the boundary current weakens rapidly and the eddy-generating mechanism becomes less effective. Our study indicates that the Nordic Seas has a relatively small capacity as a dense water reservoir and thus the overflow transport is sensitive to climate changes. Second, we have examined the upstream pathways that lead to the overflow over the GSR sill. We are particularly interested in a branch for the Denmark Strait overflow along the coast of Iceland – the North Icelandic Jet. The existence of this branch is very robust. It is always present regardless where and how

the dense water is formed in the upstream Nordic Seas. The existence of this branch is supported by two dynamical constraints. The potential vorticity is not conserved along the streamline as shown in several previous studies. A positive torque of friction is required in order to `permit' an outflow over the sill. So the dense water is more likely to approach the sill as an anti-cyclonic boundary current from the deep basin, i.e., approaching Denmark Strait sill from the Iceland side instead of the Greenland side. Another constraint is the momentum integral around a closed isobath. For a marginal sea that has two deep outlets, i.e., the Denmark Strait and Faroe Bank Channel, one can find a closed isobath that connects both passages. The integral constraint requires that the circulation can not be unidirectional around this closed path. So there must a westward flow along the northern slope of the Iceland as long as there is an outflow through the Faroe Bank Channel. These two constraints are tested by model experiments.