Ventilation, pathways and exchanges of the Nordic Seas

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The Gulf Stream system, including the Norwegian Atlantic Current, can be described as the upper limb of an Atlantic Meridional Overturning Circulation (AMOC). The AMOC transports large amounts of heat northwards from the Tropical Atlantic. This excess heat is gradually lost to the atmosphere in the Gulf Stream system, thus contributing critically to the temperate climate of our region. The net northward flow in the upper layer is balanced by a cold return flow at depth. The Nordic Seas play a crucial role in this as much of the actual overturning takes place here. The Norwegian Atlantic Current is transformed during its journey through the Nordic Seas. The transformation of this warm inflow into a deeper and colder outflow has to take place at a rate that matches the overturning circulation. Without this balance, the properties of the overturning circulation are perturbed, and the associated heat transport may change critically.

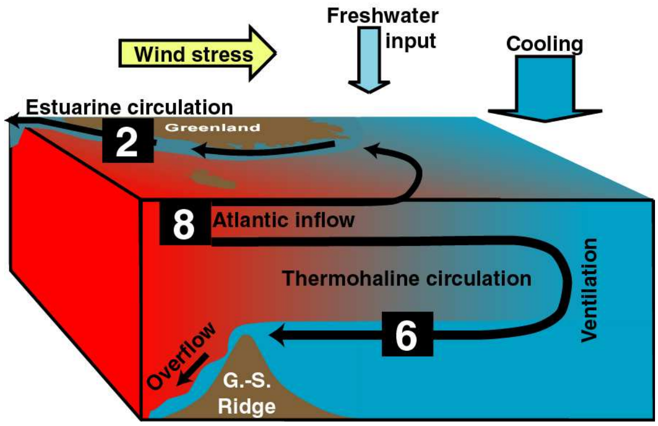

Figure 1: A schematic of the exchange between the North Atlantic and the Nordic Seas across the Greenland-Scotland Ridge (Hansen and Østerhus, 2000). The warm Atlantic inflow looses its excess heat and a dense overflow across the ridge is a result.

Research on two very different aspects of the overturning circulation of the Nordic Seas has been conducted. The first part is a detailed study of the actual water mass transformation process, and the second describes the pathways of the cold return flow from the northernmost part of the Nordic Seas and into the Atlantic proper. Both approaches combine unique observational data sets with state of the art numerical ocean models.

The Greenland Sea is a well-known location for transforming surface waters into denser and deeper water. During winter, the ocean surface layer can be cooled to the extent that it becomes denser then the water below. Vigorous vertical mixing and a transformed water mass is the result. Johannessen et al. (2005) offer a unique case study of this from the Boreas Basin of the Greenland Sea. The analysis of field data, supported by experiments with an ocean model, reveals the detailed organization of the mixing: The vertical motion involved in the mixing takes place within plumes of some hundred meters horizontal width. The plumes seem to organize themselves into coherent structures on a kilometer scale. The whole mixing region, the "chimney", has a radius of about 20km.

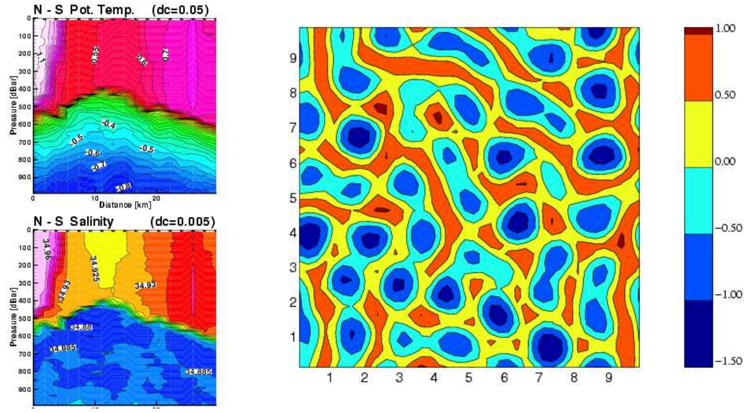

Figure 2: A vertical hydrographic section through the "chimney" ventilating the Greenland Sea during the winter of 1994 (left). The right panel shows the horizontal temperature structure inside the chimney produced by the ocean model. Red is dense water sinking, blue is the compensating upward motion of lighter water.

In the summer of 1996 a patch of the tracer sulphur hexafluoride (SF_6) was purposefully released in the central Greenland Sea. This unique experiment provides fundamental insights to the deeper pathways of the Nordic Seas. In particular, it provides an ideal benchmark for ocean models covering the region. This interplay between observations and model is the subject of Eldevik et al. (2005). Their ocean model compares very favourably with the observed tracer distribution. Proven skilful, the model is then used to interpret the SF_6 observations, and to diagnose the deeper pathways of the Nordic Seas in general. It is found that the export pathways can change dramatically between different scenarios. This accordingly changes the composition of the overflow water, as well as its transience time from the high latitudes of the Nordic Seas to the Atlantic Ocean.

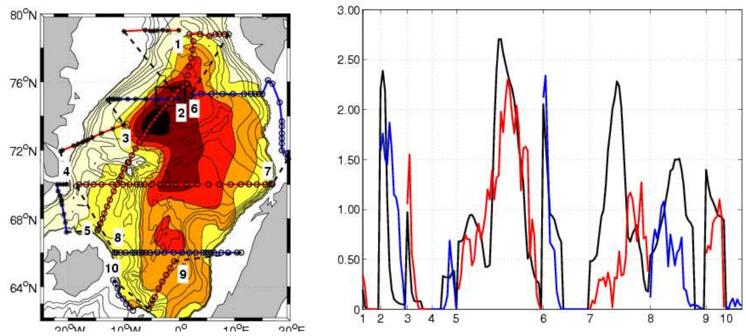

Figure 3: The modelled SF_6 distribution for the summer of 2002 (left). The model concentration (black curve) is compared with observations (coloured) to the right. The numbers 1-10 give the start of the ten hydrographic section of the survey.

Eldevik et al., 2005: Ventilation and spreading of Greenland Sea Water. *The Nordic Seas: An integrated perspective*, Drange et al., Eds., Geophysical Monograph Series, AGU, 89-103.

Hansen and Østerhus, 2000: North Atlantic-Nordic Seas exchanges. *Prog. Oceanog.*, 45, 109-208.

Johannessen et al., 2005: Convective chimneys and plumes in the northern Greenland Sea. *The Nordic Seas: An integrated perspective*, Drange et al., Eds., Geophysical Monograph Series, AGU, 251-272.