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Changes in the Norwegian Sea Deep Water

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Abstract

This paper deals with observed changes in the Norwegian Sea Deep Water (NSDW) after the cessation of bottom water formation in the Greenland Sea. Current measurements indicate that the deep water flow from the Greenland Sea to the Norwegian Sea has reversed. The Deep Water in the Norwegian Sea is warming in the entire layer below 1000m depth and down to the bottom. The thickness of the adiabatic layer is decreasing. The salinity of the homohaline layer is constant but the thickness is decreasing. The overflow water in the Faroe-Shetland Channel is freshening.

Introduction

The monitoring of the salinity of the Norwegian Sea Deep Water (NSDW) requires the ultimate accuracy in salinity measurement. During the last Working Group on Oceanic Hydrography (WGOH) meeting changes in the homohaline NSDW were reported by Bennekom and Østerhus. The working group therefore decided to ask Bennekom, Blindheim, Hansen, Turrell and Østerhus (chairman) to scrutinise salinity data from the Norwegian Sea and report back to the WGOH. This report summarises the group findings.

Data

The two main data sets used in this report are the hydrographic data from the CCS Hudson expedition in 1982 and the R/V Johan Hjort WOCE cruise in 1994, figure 1. In addition we use data from the Transient Tracer in the Ocean/North Atlantic Study (TTO/NAS), R/V Håkon Mosby hydrographic data from 1994, and data provided by Bennekom. The long time series of temperature and salinity from the Faroe Shetland Channel and Ocean Weather Ship M are also used.

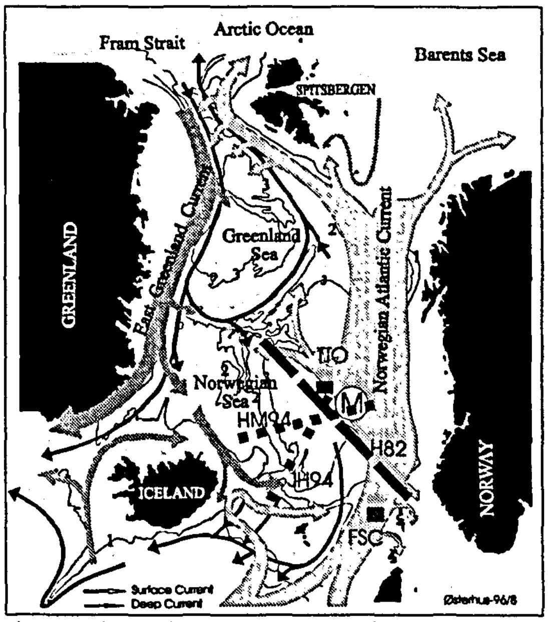

Fig. 1. The main current system (schematic) in the Nordic Seas with the positions of the Hudson 1982 (H82), the R/V Johan Hjort (JH94), the R/V Håkon Mosby (HM94) sections and the position of OSW M (M) and the Faroe Shetland Channel (FSC) time series.

The TTO/NSA expedition in 1981 reported a salinity of 34.907 to 34.912 for the NSDW in the Norwegian Basin (station 144), and a potential temperature in the adiabatic layer of -1.058 to -1.060°C.

In this study we have used stations 106 to 132 (figure 1) from the CCS Hudson 1982 cruise 82-001. As for this section the salinity varied from 34.908 to 34.912 in the NSDW in the Norwegian Basin. The potential temperature in the adiabatic layer varied from -1.054 to -1.057°C.

The R/V Håkon Mosby bottle data from 1984 have a salinity from 34.908 to 34.912 and a potential temperature of -1.039°C in the adiabatic layer.

The R/V Johan Hjort data from 1994 have a salinity of 34.909 (bottle data from 34.908 to 34.911) and a potential temperature between -1.036 to -1.037°C in the adiabatic layer.

Bennekom reported salinities from 34.9086 to 34.9105 for stations Enam 2,3,4 in the NSDW and a potential temperature from -1.036 to -1.037°C in the adiabatic layer in 1994.

Results

From the data listed above, one may conclude that the temperature in the adiabatic layer has increased by 15 to 20 mK between 1982 and 1994 (Figure 2). This change is equal to a heat flux of 170 to 230 mW/m^2 for a 1000m thick layer. Figure 2 also shows that the thickness of the adiabatic layer has decreased by 200-300 metres between 1982 and 1994.

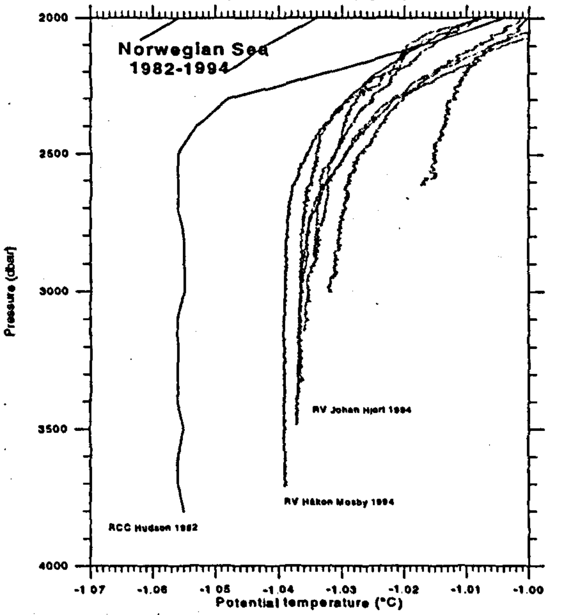

Fig. 2. Temperature profiles from 1982 and 1994 of the adiabatic deep water in the central part of the Norwegian Basin.

The CCS Hudson 1982 data have an average salinity between 34.910 and 34.911, figure 3, but the TTO/NAS data indicate an average salinity of 34.909 in the deep NSDW. The "Johan Hjort" data and Bennekom's data from 1994 accord very well with each other. The average salinity of these two data sets are between 34.909 and 34.910. The "Håkon Mosby" bottle data from 1994 have an average salinity of about 34.910. The 1994 salinity data are between 0.001 to 0.002 lower than the "Hudson" 1982 data.

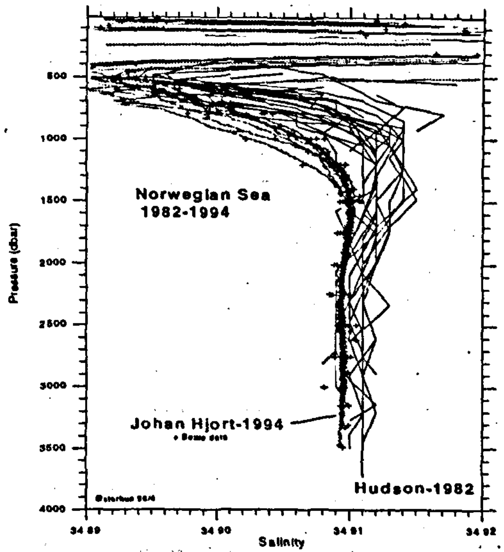

Figure 3. Salinity profiles along the CCS Hudson 1982 and R/V Johan Hjort 1994 sections in the Norwegian Basin.

Both data sets from 1994 show a salinity maximum at about 1500 dbar, the same as the "Hudson" data from 1982 show, figure 3. The high resolution data (R/V Johan Hjort and Bennekom stations from 1994) also show a weak salinity minimum at 2200 dbar. If we consider this slight salinity maximum and minimum as part of the homohaline layer, it reached from 900-1000 dbar in 1982 and between 1400-1500 dbar in 1994. Salinity data from OWS Mike show that the reduction in the thickness of the homohaline layer started after 1982, figure 4.

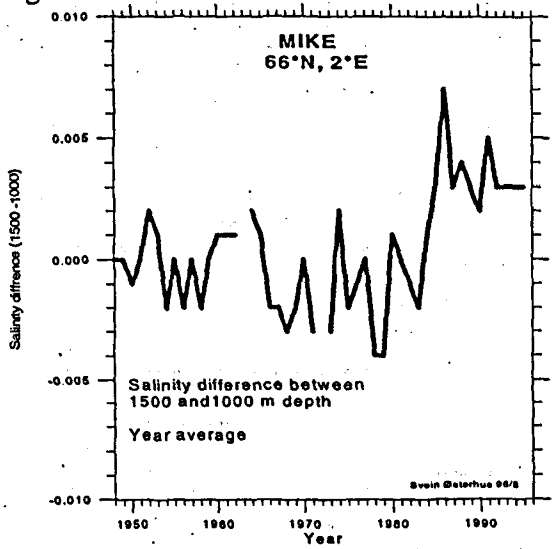

Figure 4. Time series of the salinity difference between 1500 and 1000 metre depth at OWS M.

Discussion

The low temperature of the Norwegian Sea Deep Water (NSDW) is maintained by the contribution of the Greenland Sea Deep Water (GSDW). The bottom water in the Greenland Sea is renewed locally by surface cooling of relative fresh water, resulting in the coldest bottom water found in the deep ocean. NSDW is formed by mixing GSDW and the deep water from the Arctic Ocean. The recent warming of the NSDW has its forerunner in an even more markedly warming of the GSDW, consonant with the idea that the deep water formation in the Greenland Sea has ceased (Schlosser et al., 1991). The Greenland Sea and the Norwegian Sea basins are separated by the Mohn Ridge (Figure 1), and the exchange of water masses between the two deep basins takes place through a channel which has a threshold depth of 2200 m and is situated just north of Jan Mayen. Østerhus and Gammelsrød, 1996, have showed the transport through the Jan Mayen Channel may have reduced or even reversed, cutting off the deep Norwegian Sea from the influence of the GSDW and its changes.

Assuming that the formation of new NSDW is reduced. The heating of the deep adiabatic layer may be the result of two inputs: direct input from the geothermal heating and mixing down of heat by the resulting convection. The heat flow from the ocean floor in the Norwegian Basin is about 60 mW/m^2 (Vogt 1986, Sundvor, pers. com.). This can explain about one third of the observed warming. The remaining heat can be brought down by convection driven by the heat flow from the ocean floor. This can also explain the reduced thickness of the adiabatic layer.

Mixing between the NSDW and the fresher water above (figure 3) will reduce the thickness and the salinity of the NSDW. But the salinity changes are less convincing since any change is right at the limit of the accuracy for the best salinity determinations. Reduced thickness of the NSDW will also reduce the amount of NSDW in the Faroe Shetland Channel, figure 5, Turrell et al., 1996.

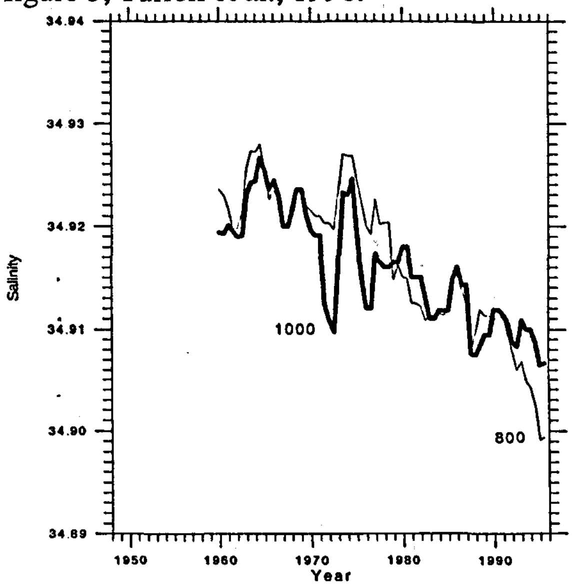

Figure 5. Time series of the salinity at 800 and 1000 m depth in the Faroe-Shetland Channel.

Conclusions

The potential temperature in the adiabatic NSDW has increased by 20 mK between 1982 and 1994 and the thickness of the adiabatic layer has decreased by 200-300m. The salinity of the homohaline layer is constant or reduced by 0.001 to 0.002 (psu). The thickness of the homohaline layer has decreased by 400-500m. The salinity of the overflow water in the Faroe Shetland Channel has decreased.

References

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