2.13 Transformation of Atlantic Water in the Barents Sea between 1948 and 2002

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1.INTRODUCTION

Water of Atlantic origin forms a layer of several hundred meter thickness (between 200m and 1000m depth) in the Arctic Ocean. After a passage of up to several decades along cyclonic loops in the Arctic Ocean basins it leaves the Arctic via Fram Strait to be one of the source waters of the meridional overturning circulation. The hydrographic characteristics, pathways and distribution of the Arctic Ocean's Atlantic Water layer have experienced significant changes in the last decades due to variations of local and remote atmospheric conditions (e.g. Swift et al., 1997; Karcher et al., 2003a).

Two branches of Atlantic Water feed this mid-depth Atlantic Water layer: one enters via Fram Strait, the other one crosses the Barents Sea and northern Kara Sea (Fig. 1). During this passage the latter branch is subject to mixing processes with coastal and polar watermasses, strong winter heat-loss, ice formation and melt and shifts of pathways on the shelf. The intensity of these processes are variable on seasonal to decadal timescale and add to the variability which has been imposed on the advected Atlantic Water in the Nordic Sea.

We use a hindcast run of a coupled ice-ocean model covering a period from 1948 to 2002 to analyze the factors relevant for the large scale transformation processes and compare with available data.

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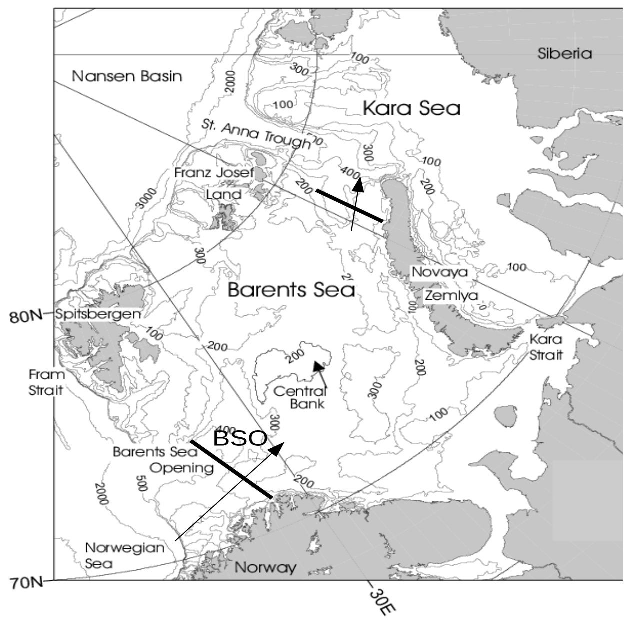

Fig. 1: Topography of the Barents Sea. Thick lines refer to in- and outflow sections referred to in the text.

2. UPSTREAM SIGNALS

Observations at the inflow of Atlantic Water on to the Barents Sea Shelf between Spitsbergen and the Norwegian mainland exhibit variations of depth mean temperatures of about 1 °C and salinities of about 0.1 - 0.2 on an interannual timescale (e.g. Furevik, 2001). The source of these fluctuations is variability of Atlantic Water inflow across the Iceland-Scotland Ridge, of freshwater supply and atmospheric heatflux in the Nordic Seas. In addition variability in the partitioning of Atlantic Water flow between the inflow to the Barents Sea and the West Spitsbergen Current influences the intensity of heat input into the Barents Sea (Karcher et al. 2003a).

3. RESULTS

The modelled timeseries of yearly mean salinity, averaged from 40m to the bottom at the BSO inflow section is shown in Fig. 2a. High salinities around 1960 and 1970 are followed by a dramatic drop to low salinities in the 1970s.

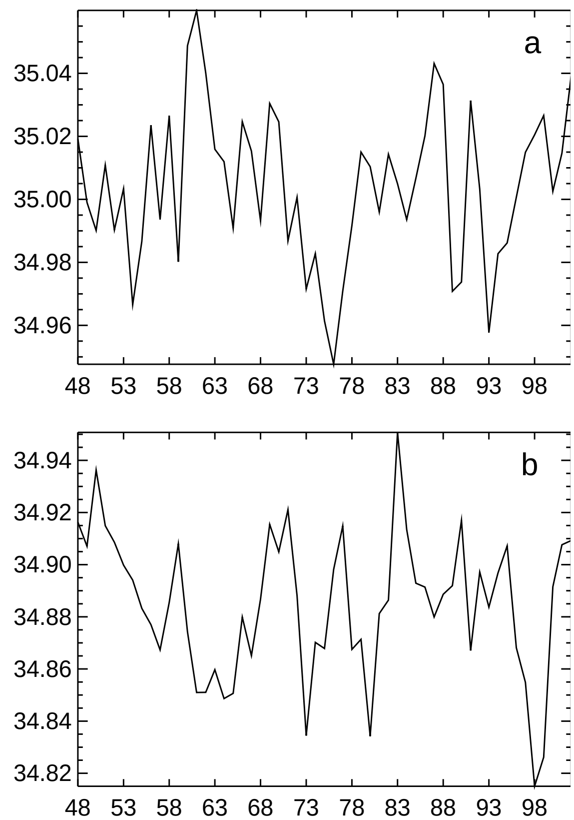

Fig. 2: Yearly means of salinity between 40 m and the bottom at a) the inflow to the Barents Sea at the Barents Sea Opening (BSO) and b) the outflow at the section between Franz-Josef-Land and Nowaya Zemlya. Figure 2 a has been detrended (trend +0.02 over 55 years).

In the last two decades salinities rise to maximum values in the late 1980s, early 1990s and late 1990s, with a distinct minimum in the mid 1990s. In comparison with observations (not shown) the modelled anomalies at the inflow are smaller in amplitude by about 1/3 to 1/2 but the sequence of the largest anomalies in the five decades is captured. The reduced amplitudes are a consequence of the restored surface salinity with a timescale of half a year which damps the surface salinity variability.

During the multiyear passage of the water across the Barents Sea Shelf the anomalies are significantly altered (Fig. 2b). At the outflow of deep water through the section between Nowaya Zemlya and Franz-Josef-Land the 1960s are a period of persistent low salinities which were not evident in the inflowing water. The surplus of freshwater responsible for the salinity minimum stems from an anomalously large net import of ice from the Nansen Basin and the northern Kara Sea (Fig. 3). It lasts from 1961 to 1967 and leads to additional icemelt in the Barents Sea. It amounts to a mean of about 300 km^3/y over the seven years period. This is an equivalent of 2/3 of the runoff from a river like the Yenisei.

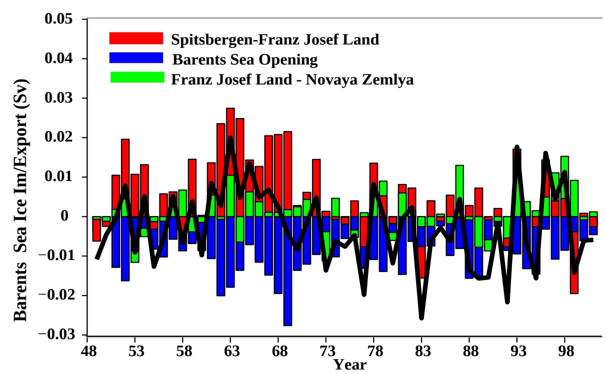

Fig. 3: Ice import into the Barents Sea shown as winter-centered yearly means across the color-coded sections. The black line denotes the net im- or export into the Barents Sea proper.

After the late 1960s a strong decline lasts until the late 1970s at the BSO inflow section. This late 70s minimum is attributed to the Great Salinity Anomaly returning low salinity water northward with the Norwegian

Atlantic Current. While the maximum of 1970 reappears at the outflow section, the GSA-derived minimum, however, is not discernible at the outflow, as also deduced by Schauer et al. (2002) from observations in the eastern Barents Sea. The strong damping of the 70s salinity minimum in the Barents Sea is the consequence of a net export of ice, mainly via the Barents Sea Opening and a minimum of net icemelt in the Barents Sea proper which characterize the entire 70s in the model simulation.
Similarly in most of the 1980s and early 1990s net ice export occurred from the Barents Sea and adds to the risen inflow salinities after 1980 to result in high salinities in the outflowing water from 1984 to 1995.
This period ended when from 1996 to 1998 the balance of ice transport switched to net import again, with similar magnitude as had occurred in the 1960s. Since the mid 1990s had been low in inflow salinities the resulting salinities at the outflow reached lowest values in the entire period around 1998.

After the transformation processes in the Barents Sea the lighter components of the shelf water feed the upper ocean and the halocline of the Arctic Ocean. The densest water formed on the shelves enters the central Arctic via the deep St. Anna Trough.

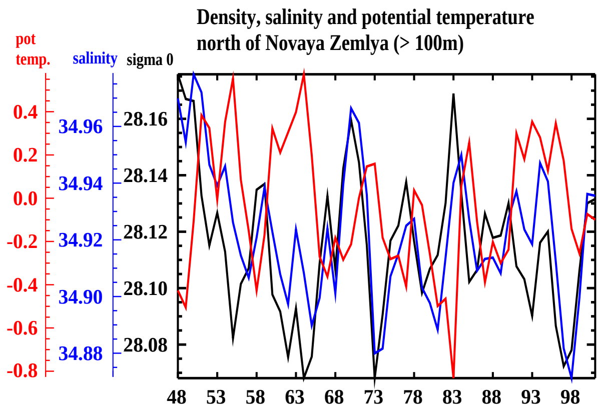

Fig. 4: Yearly means of potential density (sigma0), potential temperature and salinity in the deep water at the outflow section between Franz-Josef-Land and Nowaya Zemlya.

Its density, which determines its final position in the water column of the Arctic basins, is mainly determined by the salinity (Fig. 4). The salinity minima in the 1960s and late 1990s and the maxima around 1970 and around 1983 which were apparent in the vertically integrated outflow, also show up in the deep water.

An analysis of the yearly mean salinities of the outflowing deep water may, however, obscure the strong high-frequent variability. Short-term high-density peaks are apparent in the maximum salinity simulated in the deep outflowing water on a monthly mean basis (Fig. 5). These are not necessarily synchronous with high yearly mean salinities in the outflow, but bear a close similarity with the timeseries of local ice-growth rates at the west coast of Nowaya Zemlya (not shown). This area is subject to intense ice formation in a recurring polynia in the westward wake of the Island, as has also been noted from observations (e.g. Martin and Cavalieri, 1989, Schauer et al, 2002).

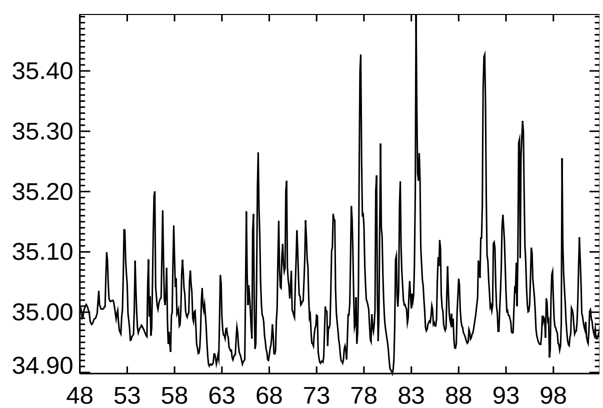

Fig. 5: Monthly mean maximum salinities in the deep outflow from the Barents Sea at the section between Franz-Josef_land and Nowaya Zemlya.

4. CONCLUSIONS

Our investigations have highlighted the importance of the ice mass balance of the

Barents Sea for the final density of the deep water produced on the shelf. These were able to obscure anomalies advected with the inflowing Atlantic Water, a results which may however be influenced by a weak restoring of the sea surface salinity to climatology.
Maximum salinities in the outflowing deep water showed large variability on monthly to interannual timescales. These were influenced by local ice formation at the west coast of Nowaya Zemlya. It remains to be investigated whether changes in the pathways of Atlantic Water between northern and southern routes on the Barents Sea passage (Karcher at al., 2003b) influence the final characteristics of the outflowing water.

5. ACKNOWLEDGEMENTS

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