13.4 RETURN OF DEEP SHELF/SLOPE CONVECTION IN THE WESTERN BARENTS SEA?

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1. INTRODUCTION

Shelf/slope convection at and from the Arctic shelf seas constitutes part of the thermohaline overturning in the North Atlantic. It is driven by densification of surface waters through their enrichment with brine due to persistent freezing. This process is very efficient in off-shore polynyas in shelf seas and it may lead to high densities in areas with high initial salinity like the Barents Sea. Initially small volume of brine-enriched-shelf water increases considerably due to entrainment of ambient water during the flow of a dense plume along the shelf and continental slope bottom.

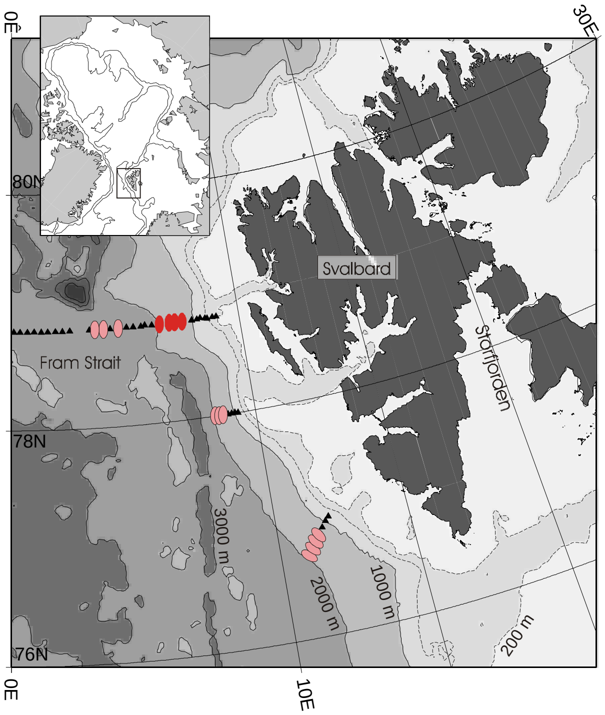

Figure 1: Site of measurements during Polarstern cruise ARKXVIII/1 in summer 2002. Red and rose marks show the location of strong and weak plume signals, respectively. Black triangles mark observation <u>locations with no plume evidence</u>.

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Andersen et al. (1999) suggest from a simple model an Arctic-wide ventilation below 500 m of 1.5 Sv and Quadfasel et al. (1988) concluded an annual production rate of deep water of 0.07 Sv from Storfjorden only.

2. OBSERVATIONS IN STORFJORDEN

Direct observations of ventilation of the deep ocean are, however, rare. Besides small spatial scale of the plumes, their intermittent occurrence makes their detection difficult with occasional cruises. In 1986, Quadfasel et al. (1988) observed plumes of high salinity and elevated temperature in Fram Strait between 1000 m and 2000 m depth and ascribed them to outflow from Storfjorden in the Svalbard archipelago (Fig. 1) where in that year bottom water salinities were 35.4 (Table 1).

Year - month	Max. Sal. in psu	Reference or cruise
1981 - Aug	35.3	Midttun (1985)
1985 -Jul	35.2	Lance
1986 - Aug	35.4	Quadfasel et al. (1988)
1991	35.2	Schauer (1995)
1993-1994	< 35.0	mooring in southern Storfjord (Schauer and Fahrbach, 1999)
1995 - Oct	34.8	Haarpaintner et al. (2001)
1997 - Jun	< 35	Valdivia #166, Quadfasel pers. comm.
1998 - Apr	35	Haarpaintner et al. (2001)
1999 - Apr	35.1	Haarpaintner et al. (2001)
1999 - Jul	35.2	Haarpaintner et al. (2001)
2000	35.45	Skogseth and Haugan (2003)
2001	35.2	Hakon Mosby
2002 - Apr	35.83	Oden 2002
2002 - Aug	35.5	Hakon Mosby

Table 1: Maximum bottom water salinities observed in Storfjorden

Subsequent systematic or casual observations revealed that this seems to have been a single event which was not repeated for years. During the entire 1990s, salinities in the Storfjord were considerably lower than in 1986. During this period the water – despite being at the freezing point – was not dense enough to sink below the Atlantic layer in the West Spitsbergen Current but remained in that level where it acted as fresh water source (Schauer and Fahrbach, 1999). Only after 2000, bottom water salinities in the Storfjorden became high again and brine-enriched shelf water ventilated the Norwegian Sea through a saline plume extending in summer 2002 down to 2500 m depth.

3. DEEP VENTILATION

Since 1997, hydrographic sections were taken every year at 78°50'N across Fram Strait between the West Spitsbergen shelf edge at 250 m and the East-Greenland shelf. Usually, these sections were run in late August or September, only in 2001 the section was done in July. From 1997 to 2001, no indication of dense shelf water was found at this latitude. In September 2002, a plume of high density was detected in the deep Fram Strait (Fig. 2). It was most pronounced at 1950 m water depth at West Spitsbergen continental slope at 78°50'N. The plume was about 60 m high, the salinity anomaly was 0.03 in psu and the temperature anomaly was 0.25 °C. The plume had also an elevated turbidity. Also further south, at 78°N and at 77°N, a plume was observed, although the anomalies were much weaker than in the northern section. At all sections, no signal was detected at smaller water depths than 1000 m. We suggest that the deep plume in 2002 stems from brine-enriched shelf water produced in the preceeding winter in Storfjorden. In spring 2002, observations from Oden showed the highest ever observed bottom water salinities in the inner Storfjord of 35.8. This salinity was high enough to enable the plume to sink to great depths despite being diluted by entrainment. Since the plume reached 2000 m water depth about 100 km downstream of the shelf edge which is at 350 m we may conclude on a strong ageostrophic component of the flow.

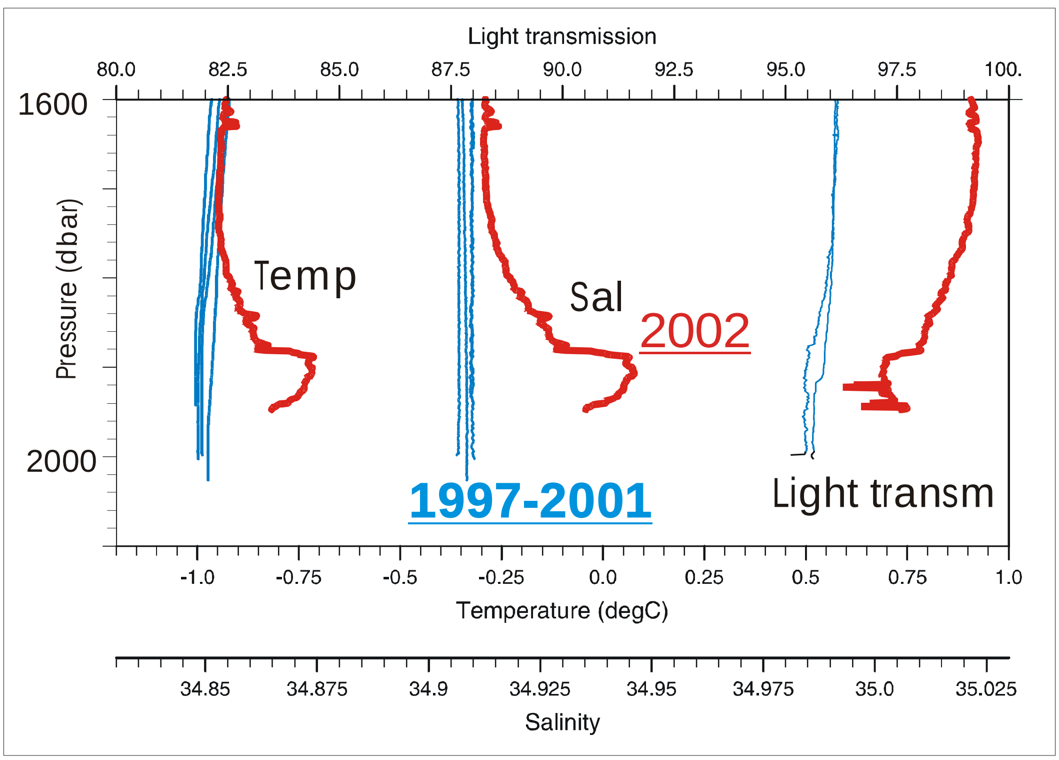

Figure 2: Lowest part of profiles of temperature, salinity and light transmission in the eastern Fram Strait at 78°50'N, 6°30'E from 6 years. The red curves from 2002 show the presence of a warm saline plume.

The presence of the plume in the Fram Strait at three sections with narrow station spacing (Fig. 1) allows a rough estimate of its spatial distribution. Since it was visible on all sections it is possible that we observed one coherent feature extending over a length of more than 100 km. South of 78°50N the plume had bifurcated. Its width was 22 km at 77°N and at 78°50N and 8 km at 78°N. With an average thickness of 30 m this corresponds to a volume of the order of 10^{11} km^3. Repetition of the two southern sections one month later revealed no sign of the plume; it has obviously spread further northwards following the West Spitsbergen Current. Outflow from Storfjord typically starts in spring and ceases in early autumn (Schauer, 1995). We might have observed in 2002 the late part of a new event of deep reaching ventilation from an Arctic shelf. While the deep ventilation from Storfjord in the 1980s occurred during a period of low temperatures in the West Spitsbergen Current, the recent observed deep ventilation took place during very warm flow of Atlantic water. The associated change in sources, forcing and preconditioning of western Arctic shelf water is not yet understood.

4. REFERENCES

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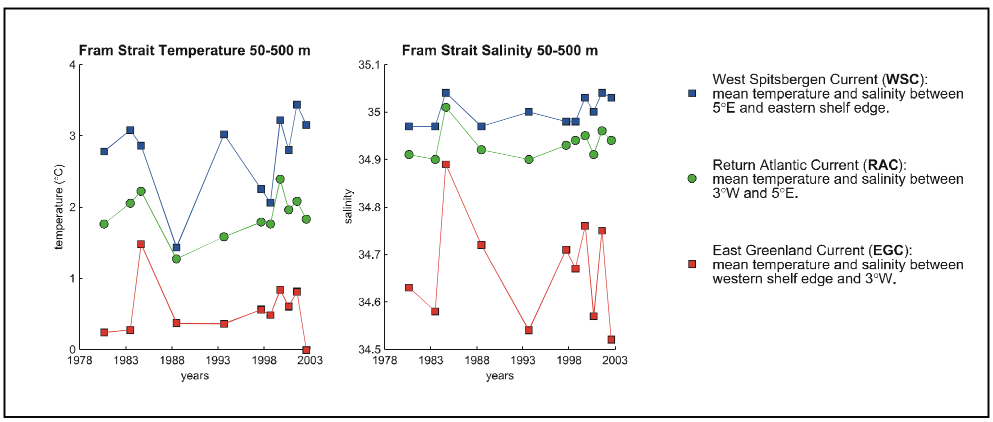

Figure 3: Mean temperatures from 1978 to 2002 from Lance, Polarstern and Ymer cruises

The Polarstern cruise WARPS (Winter ARctic Polynya Study, http://www.awi-bremerhaven.de/Polar/Polarstern/ARK-XIX-1/ExpeditionSummary/ark-XIX-1.html), taking place in winter 2003, will enable us to extend the study of dense water formation in Storfjorden and slope convection right in time in a phase of returning deep ventilation.

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