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Variations in the cascading Barents Sea bottom water into the Norwegian Sea.

by

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Abstract

Based on observations variations of the bottom water in the Bear Island Channel and the faith of this water downstream in the Norwegian Sea is investigated in relation to the Atlantic Water flow into the Barents Sea. On the annual scale there is a marked seasonality both for temperature and current. The outflow of bottom water in the Bear Island Channel to the Norwegian Sea is at maximum during fall. The seasonal variation in the Atlantic Inflow is less clear except of a marked minimum in April. The bottom water in the Bear Island Channel has become markably lighter since 1990 compared to the period 1965-89, and the trace of this water in the Norwegian Sea has disappeared in terms in the T-S plane. A major cause of these variations in the bottom water in the Bear Island Channel can be linked to variations in the properties of Atlantic Water flowing into the Barents Sea less than 1 year earlier.

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1. Introduction

The formation of salt bottom water Barents Sea through brine rejection by freezing was first observed by Knipowitsch (1905). Midttun (1985) stated that formation of dense bottom water occur regularly in the Barents Sea, particularly on the Novaya Zemlya shelf but also on other shallow shelves.

The outflow takes place mainly through the St. Anna Through in the north-east (Loeng et al., 1993), and through the Bear Iceland Channel (Blindheim, 1989; Sarynia 1969). Sarynia (1969) found bottom water on the Svalbard Bank, and concluded that this water contributed to the bottom water in the Bear Island Channel.

Midttun (1985) found large inter-annual variation in the volume of this water, and Midttun and Loeng (1987) suggested that these fluctuations might depend on the properties of the inflowing water. They suggested that after a period with high inflow, the transformation by winter cooling requires more than one year before the density of the bottom water is high enough for outflow to occur. Similarly, Blindheim (1989) found significant changes in the bottom water in the FB channel for the period 1968-1986. Blindheim (1989) also traced this water into the Norwegian Sea at 600-800m depths. To extent to what this water contributes to the intermediate water that eventually flows of the Greenland-Scotland Ridge thus feeding the Global conveyor circulation is unclear.

Since the investigation cited above there has been a major observational effort in the Bear Island – Fugløya (FB) section including repeated hydrography as well as current meter moorings from 1997 to date. These measurements provide the opportunity to extend some of the previous work, in particular the work of Blindheim (1989) dealing with the dense water flow in the Bear Island Channel.

The main focus here is to investigate the variations of the dense water flow in the Bear Island Channel in relation to the inflowing Atlantic Water and the water mass transformation within the Barents Sea. In particular we will investigate the hypothesis that AW anomalies that enters the Barents Sea preserve their properties as anomalies when exported. Further, the trace of the dense water flow in the Bear Island Channel in the Norwegian Sea is investigated.

2. Data

Current meter data are from the BF array of current meters. Here we have used the instruments at 50 m depth and the instruments near the bottom capture the spatial variations (Fig. 1). The instruments near the bottom are used to capture the near bottom annual variations in the inflow of Atlantic Water in the south and dense outflow in the north (Fig. 2).

Temperature and salinity data in the Bear Island Trench are used to capture the characteristics of the dense outflow (Figs. 3, 4 and 5), and in the Bear Island West section to follow its downstream signature (Figs. 6 and 7). The

3. Results and discussion

The characteristic mean spatial current structure in the FB section, going nearly N-S at about 20^{o}E is inflow to the Barents Sea in the south to about 73^{o}N, and a deep outflow to the Norwegian Sea in the Bear Island Channel (73^{o}30'N) and northward on the slope toward Bear Island (Fig. 1).

There near bottom currents have a marked annual cycle both in velocity and temperature (Fig. 2). The temperature of the inflowing AW has a maximum in late fall and minimum values about April. In contrast the dense outflowing water in the BIC have a minimum in late fall and maximum in April. Thus the south to N-S temperature gradients have the maximum during fall and minimum during spring.

For the inflowing AW (about south of 73oN) the current meter data indicate maximum inflow in Nov-Feb and a minimum in April. In the Bear Island Channel the out-flowing water are at maximum in the fall. The seasonality on the Bear Island slope is less clear. Thus, to first order, the seasonality in the currents vary in phase with the large-scale temperature (and density) gradient in the FB section.

Observations of water mass in the Bear Island Channel show large variations; between the individual profiles, and on inter-annual and decadal time scales (Fig. 3). With the reservation of rather few observations until the mid 1960ies, the temperature is relatively warm in the 1950ies, then a cooling in the second half of the 1960ies, fluctuations between relatively warm and cold into the 1980ies. In the late 1980ies the temperature increase substantially, at a similar level as of the 1950ies, and have remained warm except of a cold period in the second half of the 1990ies. The salinity in general varies in phase with the temperature; i.e. warm/saline and cold/fresh. However, the increase in temperature from about 1990 is not accompanied by a similar increase in salinity. The density shows less variation, due to the compensating effect of T and S on the density. However, there is a transition to substantially lighter bottom water from 1990, due to the increase in temperature.

A major cause of the variation in the Bear Island Channel bottom water are due to the variations in the properties of the inflowing Atlantic Water (Fig. 4). The variations in the bottom water follow the variations in the inflowing AW water with a lag of < 1 year. Compared to the suggested response time of Midttun and Loeng (1989) of more than one year of winter cooling, these observations suggest that for the Bear Island Channel outflow the response is more rapid.

In the T-S plane the most pronounced result is the transition in the bottom water from relative dense in the 1960ies through the 1980ies, to lighter since 1990. Also the return of the Great Salinity Anomaly to the Barents Sea about 1979 is clearly seen as an exceptional event during the record.

Blindheim (1989) showed that the Bear Island Channel bottom water could be traced into the Norwegian Sea in the Bear Island West section at about 600-800. Repeated profiles chosen at periods with dense bottom water, 1986 and 1987, and periods with light bottom water, 1991 and 2003, (see Fig. 3) show marked differences (Fig. 6). The profiles from 1986-7 both have a pronounced relative salinity maximum (about S=34.94 and T=[0-0.5] ^{o}C). This is similarly as found by Blindheim (1989) using data from 1986. However, there is no trace of the bottom water in the profiles from 1991 and 2003, the period of the light bottom water. Further, the profile 2003 is significantly fresher at the intermediate and lower depths (T < 2^{o}C).

This similar picture is found in the two sections from the Bear Island West section from 1986 and 2003. In 1986 patches of relative salinity maxima are evident below the saline Atantic Water defined as S>35. In 2003 there are no relative salinity maxima at intermediate depths. Most marked in this section is the low salinity Arctic Intermediate Water (S < 34.90) that is evident for depths > 800m.

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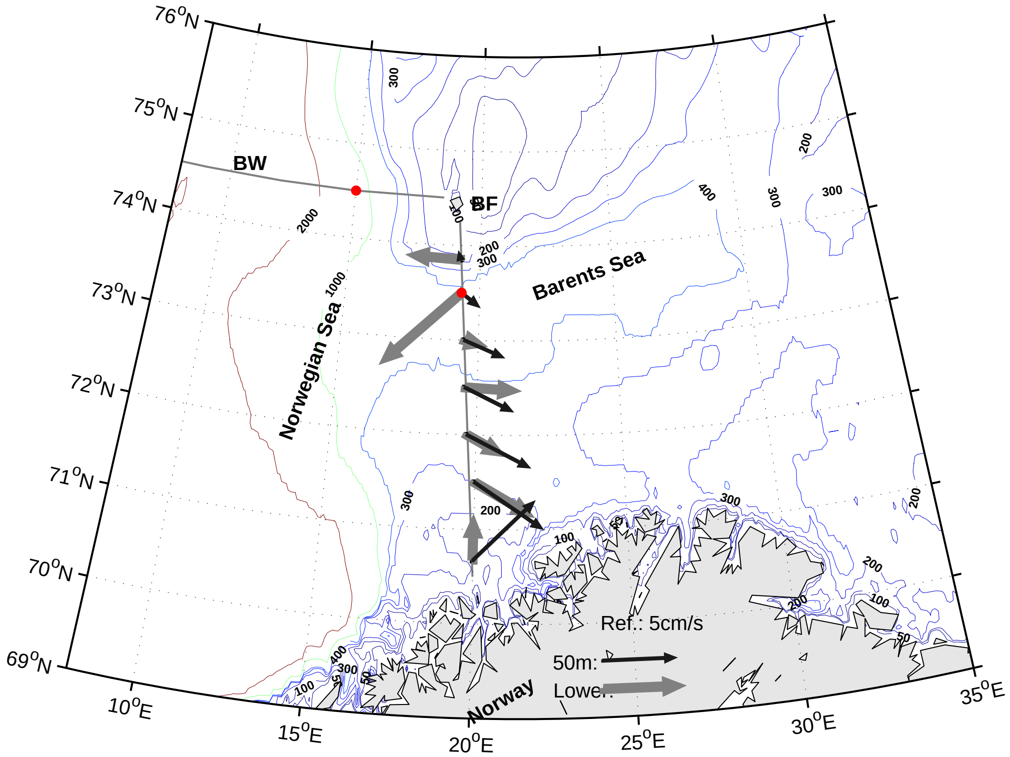

Figure 1. Map of the eastern part of the Barents Sea, including the Bear Island – Fugløya section (BF), and the Bear Island West section (BW). The arrows represent annual mean velocity from current meter in the BF at 50 m, and near bottom (15 m above). Hydrographic variations are shown for positions (73.50N, 19.33E) and (74.50N, 15E) indicated by red bullets.

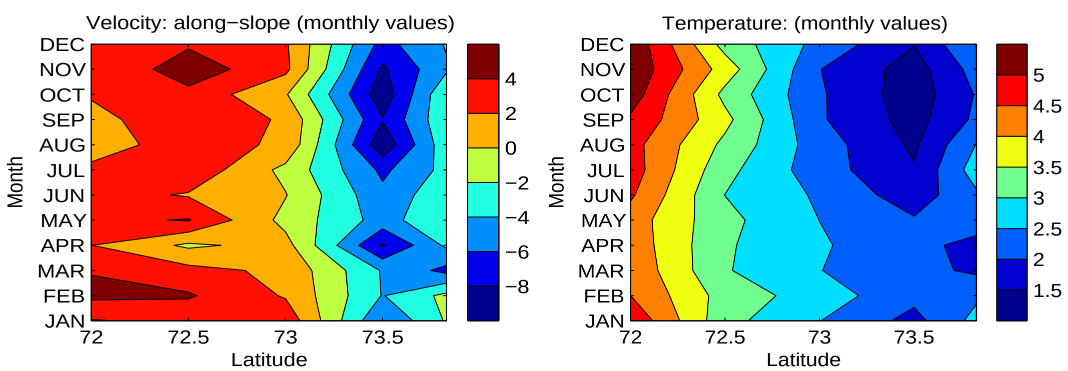

Figure 2a-b. FB annual variations versus latitude in the near bottom a) along-slope velocity (positive into the Barents Sea) in cm/s, and b) Temperature in ^{o}C based on current meter moorings.

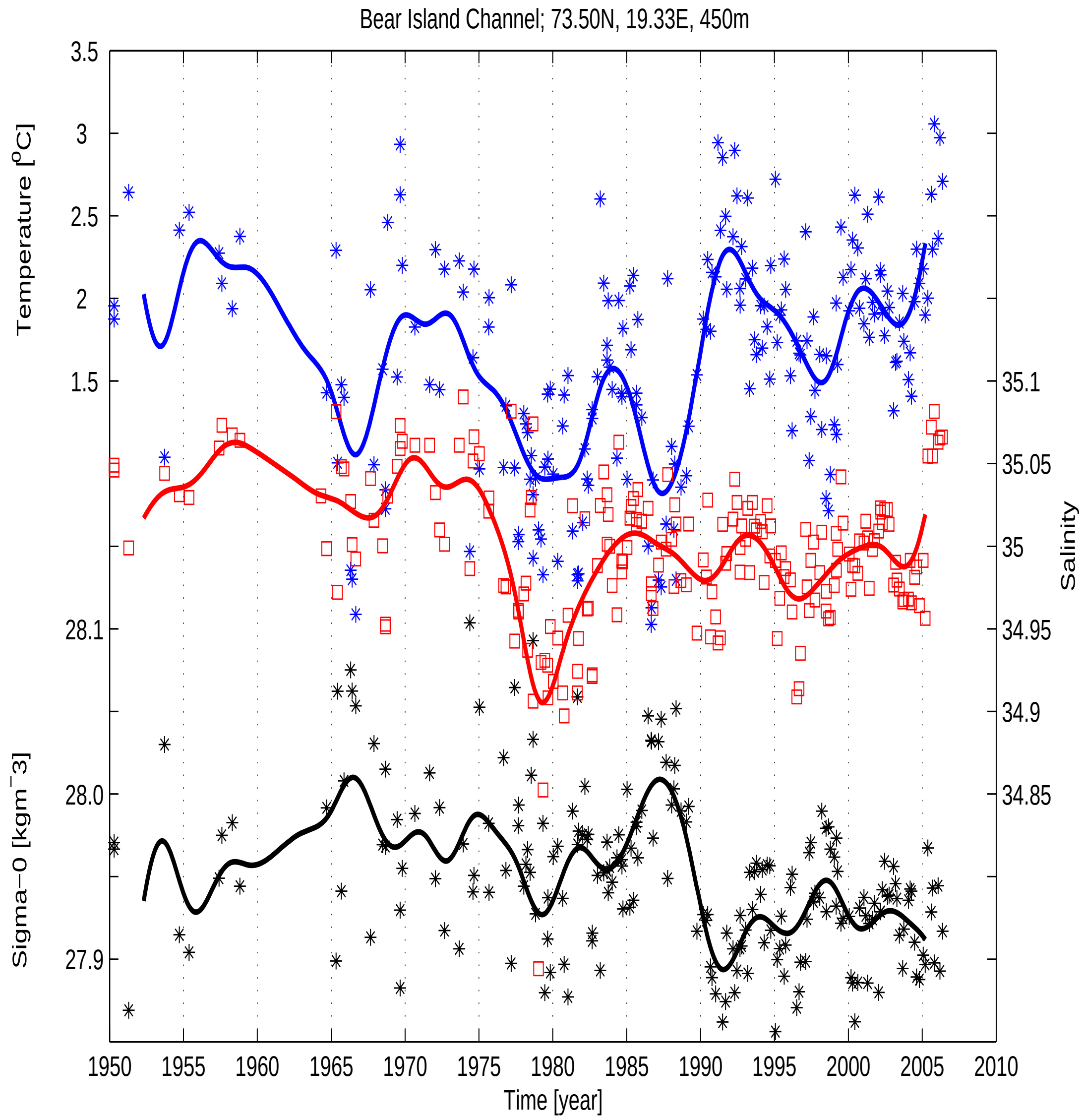

Figure 3. Temperature, salinity and sigma-0 in the Bear Island Channel at 450 m depth in position 73°30'N, 19°20'E (Fig.1). The dots are the raw data, and two-year low-pass filtered data are solid lines.

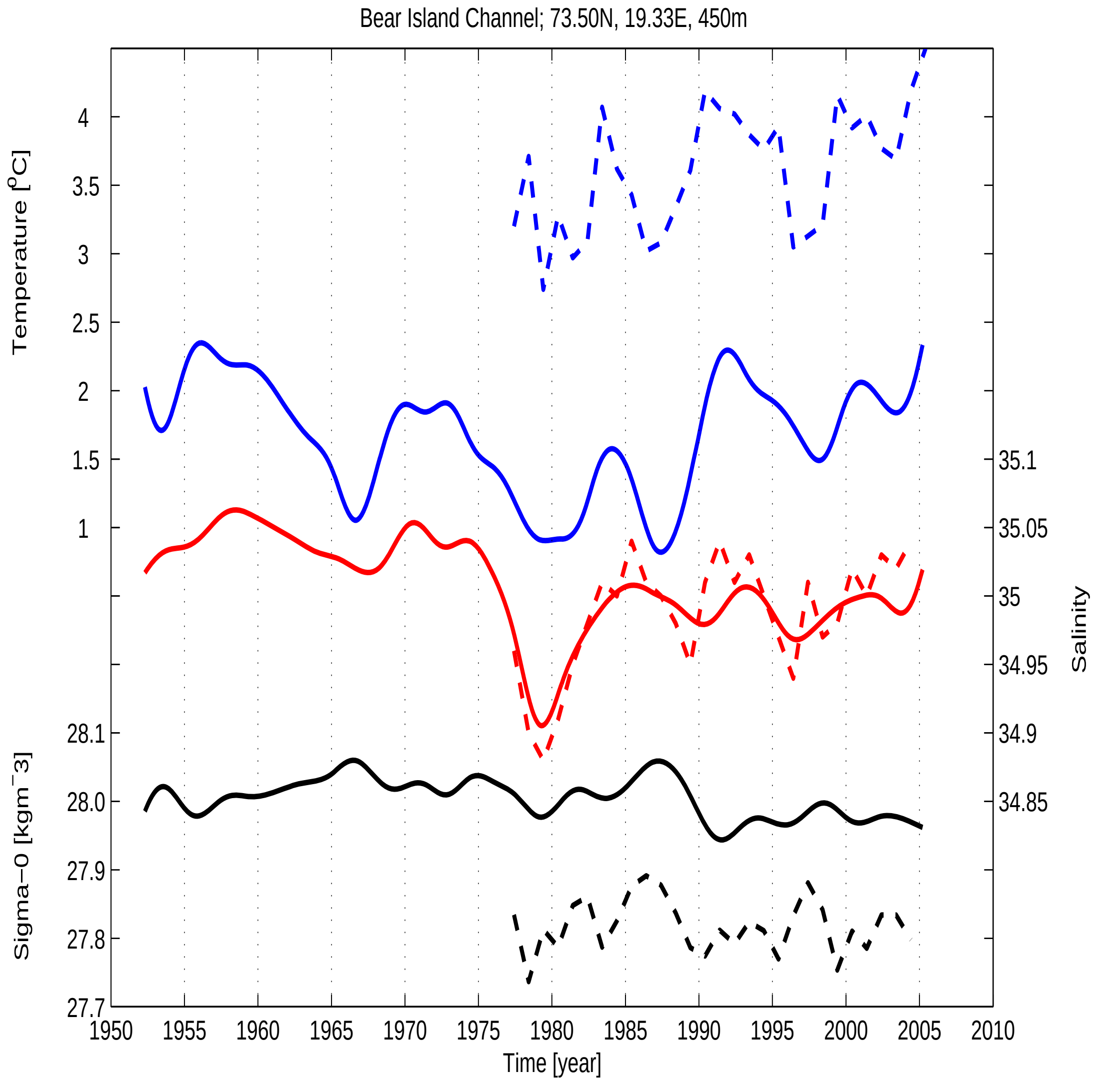

Figure 4. Solid line are the two-year low pass filtered temperature (blue), salinity (red) and sigma-0 (black) in the Bear Island Channel at 450 m depth in position 73 °30'N, 19°20'E (Fig.1). Dashed lines are the Atlantic Water Barents Sea Inflow index. Defined as average between 71°30N-73°30' N over the depth range 50-200m.

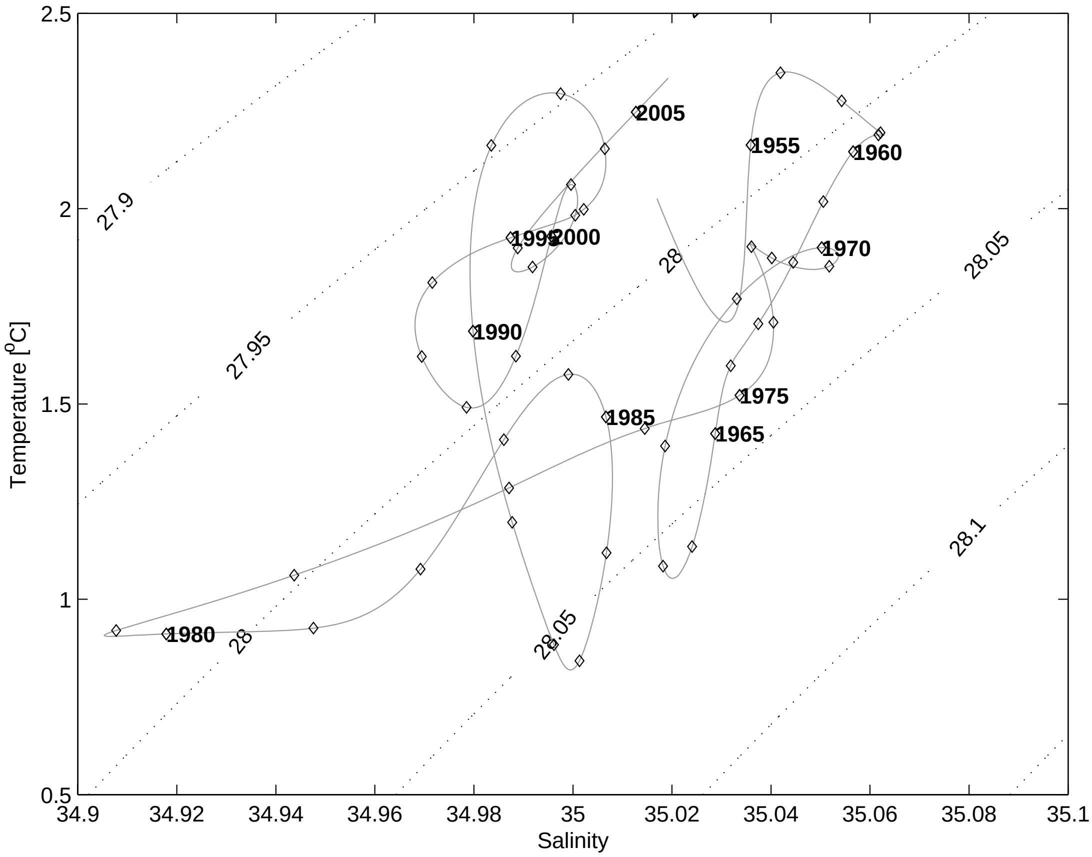

Figure 5. T-S diagram in the Bear Island Channel at 450 m depth in position 73 ^{o}30'N, 19^{o}20'E. Two year low-pass filtered data, dots for each year, and label every fifth year.

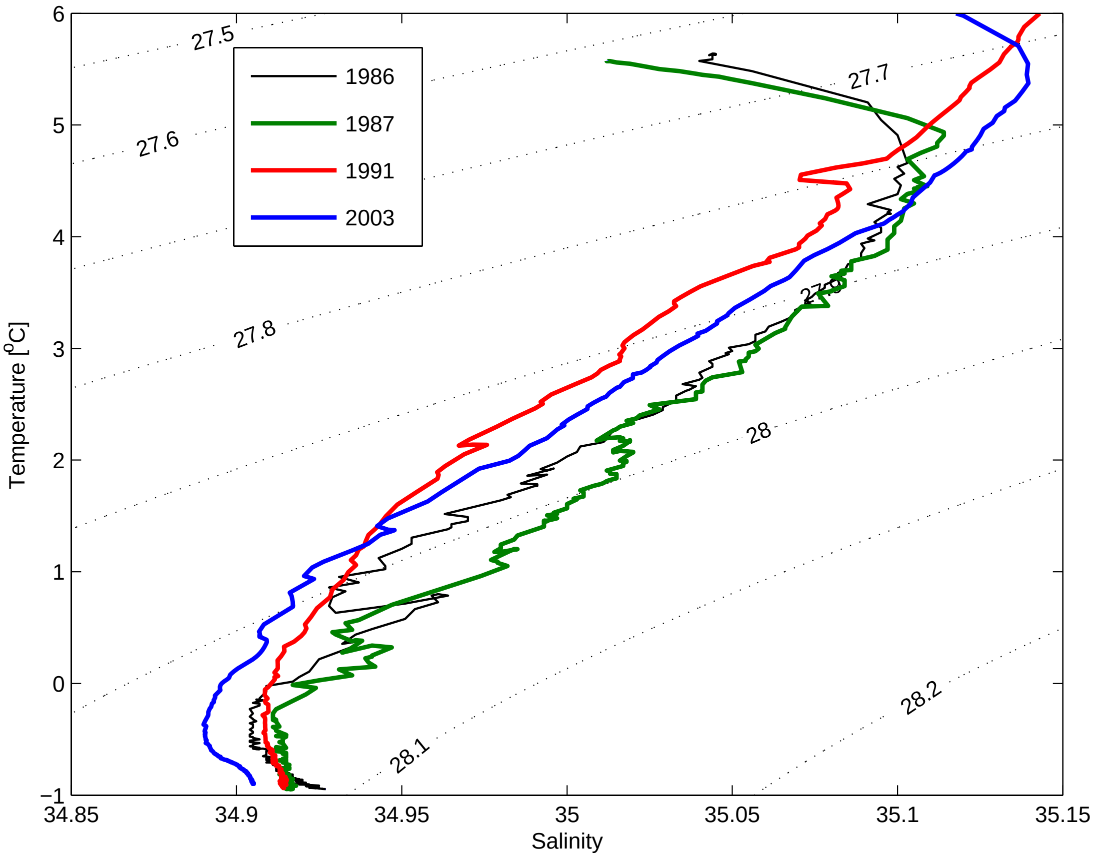

Figure 6 T-S diagram for hydrographic profiles in the Bear Island West section at 1500 m depth in position 74 °30'N, 15°00'E.

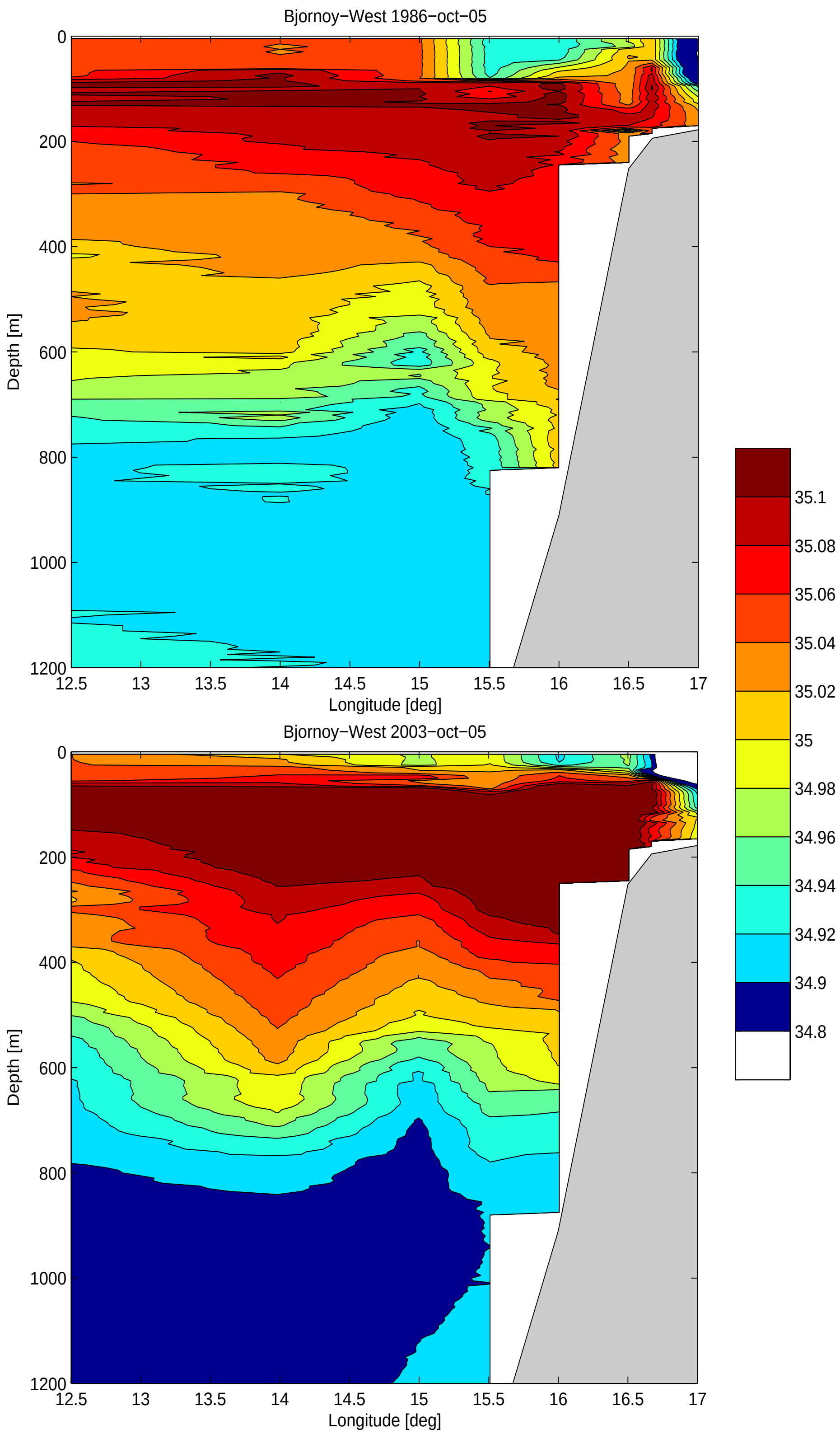

Fig 7 a-b Contour plots of salinity in the Bear Island West section for the years a) 1986-oct. and b) 2003-oct