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Anomalous hydrographic conditions in the western Barents Sea observed in March 2014

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ABSTRACT

Observational data have been collected during a cruise to the western Barents Sea in March 2014 covering 33 stations along three west–east sections at 76.34°N, 77.26°N and 78.49°N and along one south–north section at 19.47°E. Our observations suggest a wedge-like water masses structure with colder and fresher Arctic Water moving southward, gliding over warmer and more saline Atlantic Water which below the surface moves to the north. Atlantic Water in the Storfjorden Trench reached farther north than 76.5°N and was present on the eastern and western slopes of the Spitsbergen Bank. Our measurements indicate limited dense water formation in the Storfjorden. A comparison with historical data over the years 1923–2011 reveal an anomalous northern location of the Polar Front for this time of the year in March 2014. A point by point comparison with ten historical stations in 1983 and 1986 shows significantly warmer (by up to 3.8 °C) and saltier (by up to 2.49 psu) conditions in 2014 for nine out of ten stations. Moreover, stations dominated by the Atlantic inflow experienced the largest changes, whereas in stations located in the area of the Arctic outflow the changes were smallest. Furthermore, we used satellite and decadal reanalysis data to estimate the climate variability defined by a range of two standard deviations. We found that in the Storfjorden Trench in March 2014 the water transport was within the range, while the water temperature exceeded the upper limit of climate variability. The sea ice extent in the western Barents Sea was below the lower limit of climate variability from mid-February to mid-March 2014. Combining in situ, satellite and model data, we were able to attribute the warm anomaly observed in March 2014 to two main reasons: (1) an increase of Atlantic water temperature which was evident already in the beginning of 2014 and (2) very little cooling in February and March 2014. From these results we conclude that the north-western Barents Sea is a key region to monitor local response on climate change signals in the Arctic Ocean.

1. Introduction

The Barents Sea is a marginal sea connecting the Arctic Ocean and the North Atlantic. It extends from the Norwegian and Russian coastline in the south to approx. 81.5°N, where the shelf slope between Spitsbergen and Franz-Josef Land defines the boundary with the Arctic Ocean. Following Lind and Ingvaldsen (2012) it will be referred to as the Northern Barents Sea Opening (NBSO) in the following. The western border is defined by the shelf slope to the Norwegian Sea including the Bear Island Trough which plays an important role for the water mass exchange between the Barents Sea and the Norwegian Sea. In the following, this western boundary to the Norwegian Sea will be called Barents Sea Opening (BSO) in agreement with Smedsrud et al. (2013) and other authors. These two inflow areas are topographically separated by a saddle point lying between the Olga Basin and the Hopen Trench at approx. 77.5°N. The eastern border towards the Kara Sea is given by a transect through the strait between Franz Josef Land and Novaya Zemlya called Barents Sea Exit (BSX; e.g. Gammelsrod et al., 2009; Lind and Ingvaldsen, 2012). Oceanographic investigations of the Barents Sea started already at the beginning of last century (Nansen, 1906) and have continued since then. The general physical conditions in the Barents Sea have been compiled in Loeng (1991).

The conditions in the investigation area are strongly influenced by the confluence of Atlantic and Arctic water masses. The transition zone between these two water masses is called Polar Front. It can be clearly identified from the water mass characteristics (Gawarkiewicz and Plueddemann, 1994). In the vicinity of the Polar Front significant mixing takes place (Harris et al., 1998; Smolyar and Adrov, 2003) in particular also due to the vertical wedge-shape structure of the Polar Front. Based on the in situ observations in May 2008 across the Polar Front near Hopen, Fer and Drinkwater (2014) investigated different mixing mechanisms

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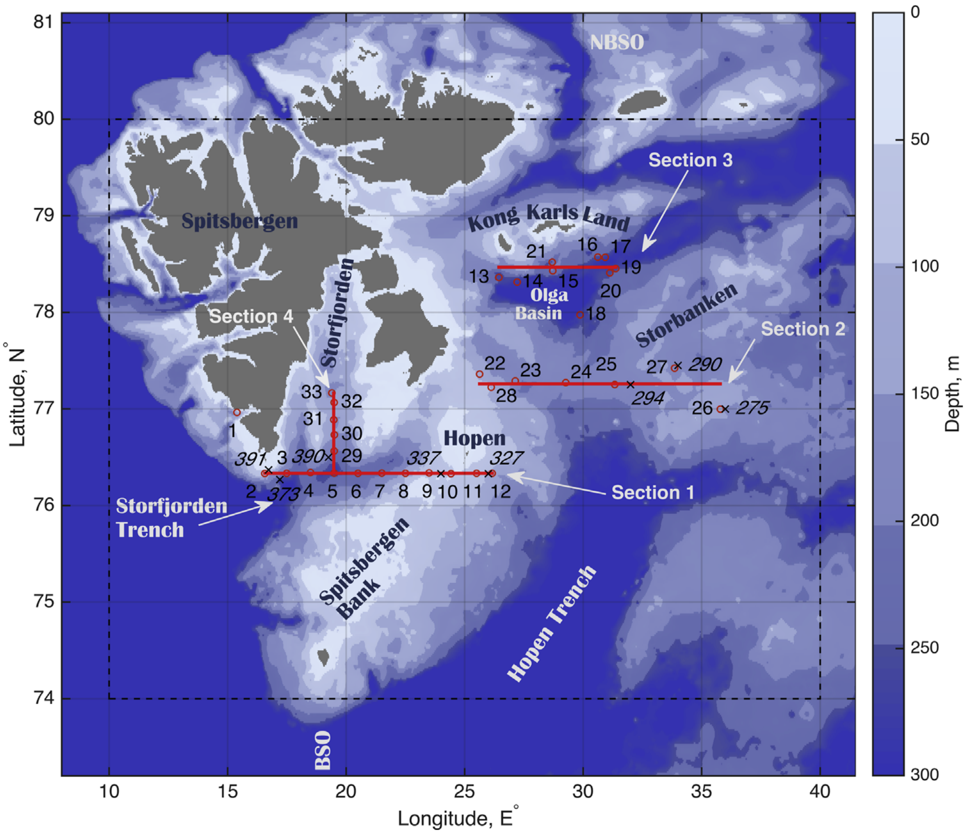

Fig. 1. Region of measurements in the north-western Barents Sea in March 2014 during the IRO-2 cruise. Location of IRO-2 CTD stations (red circles), sections (red lines) and selected historical stations taken for comparison (black ×). Dashed line box shows an area were the sea ice extent was calculated. Underlying is the ETOPO1 bathymetry. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this paper.)

in the Polar Front such as wind and tidal currents, bottom friction and isopycnal processes. Thermohaline properties and halocline water formation were analysed in more detail in Steele et al. (1995). The location of the Polar Front and its variability are one of the most prominent features of the Barents Sea, since not only the water mass characteristics but also the complex system of currents are strongly related to it.

There are two major pathways through which warm and saline Atlantic water enters the Barents Sea. Before reaching the latitude of Bear Island, the Norwegian Atlantic Current splits up into the West Spitsbergen Current (Figs. 1 and 4) continuing its flow to the north and an eastward current, which enters the Barents Sea through the BSO (Ingvaldsen et al., 2002). According to Skagseth (2008) this inflow splits up into the eastward flowing North Cape Current and a branch following the southern flank of the Bear Island Trough and finally entering the Hopen Trough forming the Hopen-Bear Island Current (Fig. 2). Recent investigations indicate that a considerable fraction of water entering the BSO recirculates directly at the northern flank of the Bear Island Trough (Skagseth, 2008). According to Pfirman et al. (1994), an additional minor inflow of Atlantic Water takes place at the southern flank of the Storfjorden Trench in the northern part of the BSO. Since the water masses directly leave the Barents Sea again along the northern flank of the trench, this inflow has no significant contribution to the volume flux to the inner Barents Sea. However, this loop current covers a considerable part of our investigation area, and hence, should be accounted for in our study. A second more significant inflow of Atlantic Water contributing approx. 10% to the volume as well as the heat transport occurs through the NBSO (Smedsrud et al., 2013). In Lind and Ingvaldsen (2012) it was shown that the wind stress curl and the related Ekman transport are mostly responsible for this cross shelf break transport of water from the West Spitsbergen Current. In contrast to this secondary import of Atlantic Water, the East Spitsbergen Current (Fig. 2) and the Persey Current entering the Barents Sea from the north and from the north-east, respectively, transport low-salinity and low-temperature Arctic Water to the south (Pfirman et al., 1994; Schauer et al., 1997). For further information on the general circulation conditions in the Barents Sea and its impact on the Arctic climate system, see the review in Smedsrud et al. (2013) and references therein.

The sea ice decline in the western Barents Sea is mostly controlled by the inflow of the warm Atlantic Water (Arthun et al., 2012; Smedsrud et al., 2013). However, atmospheric conditions, such as sea level pressure and wind, also play an important role and contribute almost equally as the water temperature to the variability of the sea ice extent during the winter (Pavlova et al., 2014). Following changes in the atmospheric circulation, the inflow of Atlantic Water into the Barents Sea shows a strong interannual variability. In particular, in the previous decade (2001–2005) a significant shift in the atmospheric circulation over the Barents Sea has been reported by Zhang et al. (2008). In this context, the temperature of the inflowing Atlantic Water shows a pronounced positive trend over the last 40 years (Lind and Ingvaldsen, 2012), increasing the northward heat transport to the Barents Sea and reducing the sea ice coverage (Arthun et al., 2012; Smedsrud et al., 2013). Due to its role as a major conveyor of ocean heat in this area and its strong sensitivity to climatic changes, the Barents Sea is expected to be one of the key areas, influencing the climate development of the entire Arctic Ocean in the near future (Koenigk and Brodeau, 2014).

Observations of water temperature and salinity from the western Barents Sea collected during the IRO-2 cruise are reported. Following anomalous meteorological and oceanographic