Hydrographical conditions in Isfjorden and the West Spitsbergen Current in April 2018

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1 Hydrographical conditions in Isfjorden and the West Spitsbergen Current

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Abstract

In this work we continue the long time series of conductivity-temperature-depth (CTD) measurements in the Isfjorden, West Spitsbergen current (WSC) area during a scientific cruise in April 2018. We find the WSC core at around 100m depth with a temperature of around 3.5 °C in the eastern part of the WSC. In Isfjorden we find atlantic water at the entrance and colder water extending down to around 200 m in the entrance-mouth area with a minimum temperature of around -0.5 °C. Furthermore, we give a a description of the hydrography in the area and discuss the origin of the different watermasses in Isfjorden. Here we propose two different hypotheses for the origin of the colder water in Isfjorden; the polar current or an internal circulation. There is no conclusive evidence for either with our current data set.

1.1 Introduction

The West Spitsbergen Current (WSC) transports warm and saline Atlantic Water (AW) from the Alantic Ocean northward along the coastline of western Spitsbergen, as seen in Figure 1.1. In general, the properties of the WSC can influence the local climate and arctic sea ice extent. The temperature and heat transport of the WSC influences the air temperature, especially in winter, and also the extent of the sea ice cover north of Svalbard (Walczowski and Piechura, 2011). Between WSC and the coast is the Spitsbergen Polar Current (SPC), as named by Helland-Hansen and Nansen (1909). The SPC is a prolongation of the East Spitsbergen Current and South Cap Current, which transports Arctic Water (ArW) from the Barents Sea and Storfjorden (Nilsen et al., 2016).

As for the West Spitsbergen Shelf (WSS) and the fjords extending from it, the presence of AW, ArW and freshwater heavily influences the hydrography. From Atlantic dominance (warm and saline) in summer to an Arctic dominance (cold and fresh) in winter. Being in the Arctic, the most typical freshwater input in fjords are glacier ablation and calving, melt of sea ice, precipitation, and river runoff (Nilsen et al., 2008). The coolig of the water in the fjord system during winter and spring gives rise to the formation of Winter Water (WW). An overwiev of the hydrographical conditions in arctic fjords are of importance for our understanding of the local marine ecology, biology and the icreased melting of ocean-terminating glaciers (Nilsen et al., 2016, 2008).

Important for guiding AW into the shelf area and Isfjorden is the Isfjorden trough, which is one of the deepest troughs on the WSS. Futhermore, Isfjorden har no shallow sill that could hinder the intruition of AW. As the AW reaches onto the shelf it mixes with ArW and decreases in salinity and temperature. We can regard this new watermass as

Transformed Atlantic Water (TAW) (Nilsen et al., 2016). Related to the reach of AW into the fjord we make a distinction between the terms "fjord mouth" and "fjord entrance". The mouth is located between station 39 and 41, whereas the entrance lays east of the mouth. While the mouth is influenced by AW year round and thus acts as the western boundary of Isfjorden, the entrance is influenced by AW only seasonally (Nilsen et al., 2008).

In this report we use CTD profiles collected during the period 16th - 22nd of April (see Figure 1.2) to describe the hydrography of Isfjorden, the WSS, and the WSC. Starting with the methods section we describe the CTD instrument (Seabird 19plus v2) we used, how we extracted and processed data, and which definitions of watermasses we used. We then move on to presenting our findings in the results section, where we begin by showing the temperature and salinity transects over the whole Isfjorden, WSS, and WSC area.

After that we show both cross transects in Isfjorden, before we present watermasses in the form of a TS-diagram and a profile. Moving on to the discussion section, we look at the intrusion of AW into Isfjorden this year.

Lastly, we conclude this section and the report by discussing two different scenarios for the origin of a cold water mass in the mouth-entrance area.

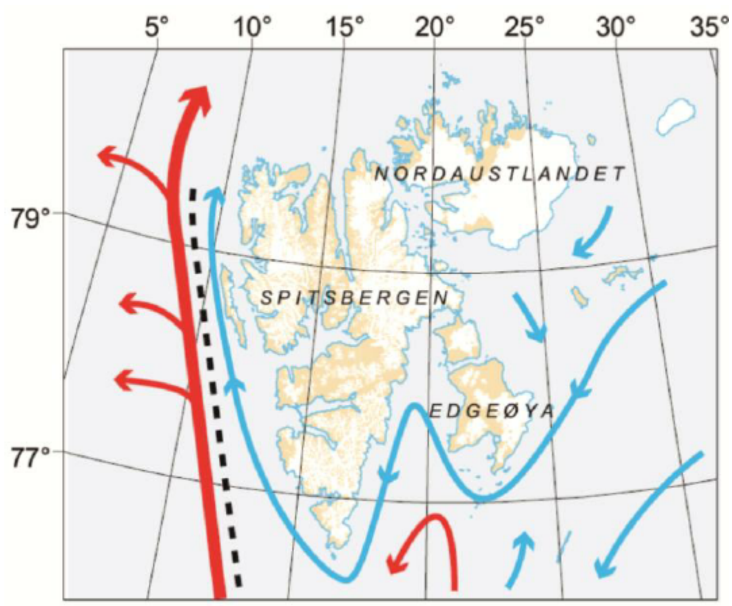

Figure 1.1: Map of Svalbard showing the West Spitsbergen Current (red) and the Spitsbergen Polar Current (blue) off the west coast of Spitsbergen. After Svendsen et al. (2002)

1.2 Methods and instrument

1.2.1 Instrument

In this report we present data collected with a SBE 19plus V2 SeaCAT Profiler CTD. The CTD instrument is manufactured by Sea-Bird Electronics, and measures conductivity, temperature and pressure. Conductivity is measured in order to determin the salinity of the sea water. The initial accuracy of the CTD instrument is given by Kollstuen (2018).

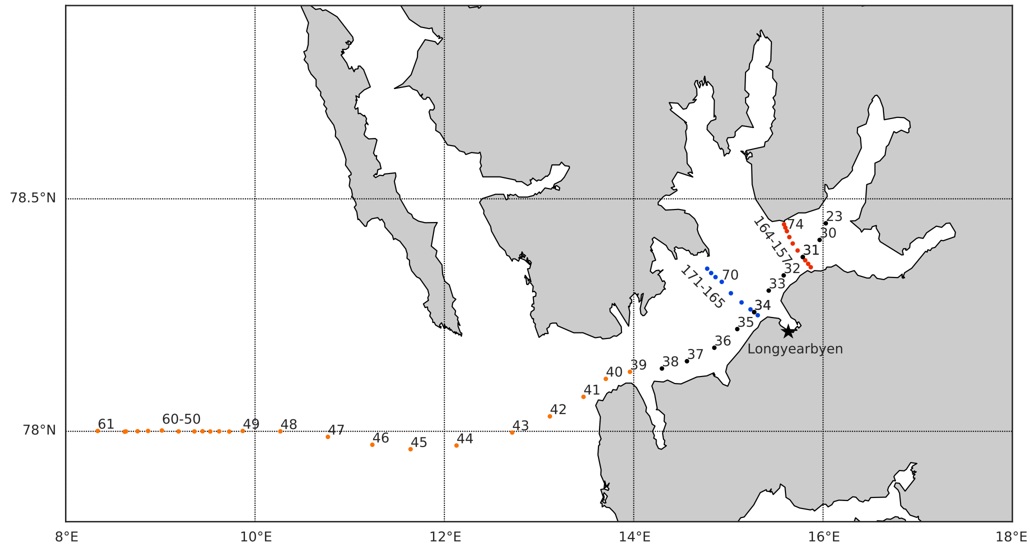

Figure 1.2: Map of study site, showing the three transects.

In order to perform the CTD measurements the ship was positioned at the pre-defined UNIS stations, shown in Figure 1.2. At the station we submerged the CTD instrument to about 1 m under the water surface and waited approximately 1 minute to let the pump prime. Once the pump had started we lowered the instrument at a speed of 0.8 m/s until the lenght of the line was 15 m shorter than the measured echo depth. This was to prevent the instrument from hitting the ocean floor. We then lifted the instrument back up at the same speed.

For the first 24 stations we took a water sample at every other station. This was done at the maximum depth with a Niskin bottle, which was fastened above the CTD instrument. These water samples was later analysed and could be used for calibrating the salinity measurements.

1.2.2 Data processing and definitions

The data retrieved from the CTD instrument was processed using Seabird Scientific's SBE data processing software. Table 1.1 list the modules used for processing.

The data processing results in one upcast and one downcast file. We here present the data from the downcasts. To produce the figures in this report we used Python 2.7 and 3.6, with the modules Pandas, Numpy, Scipy, Matplotlib, Seaborn and Basemap.

A very small fraction of the data points (28 of 20025) show wery low salinity in the range of 26-34.4 PSU relative to the rest of the measurements. Most of these salinities were measured during our transect of the WSC, but some are from the two cross transects in Isfjorden. All these measurements are for either 0 or 1 dbar depth, and the upcast files do not show the same feature. This indicates that these measurements are resulting from the CTD being lowered before the pump was ready. Therefore, outliers with salinity below 34.4 PSU are not displayed in the TS-diagram, Figure 1.5. In all other figures outliers were handled by using a moving average with windowsize 15 on each station's data, as

Module name	**Module description**
Data conversion	Convert raw data from .hex file to .cnv file
Align CTD	Align data from different components relative to pressure
Bin average	Statistical estimate of data value at interval of 1 dbar
Cell thermal mass	Perform conductivity thermal mass correction
Derive	Calculate variables based on EOS-80 (PSU)-equations
Filter	Low-pass filter columns of data
Loop edit	Mark scan with *badflag* if scan fails pressure reversal (loops in the instrument's trajectory) or minimum velocity tests
Split	Split data in .cnv file into upcast and downcast files

Table 1.1: Data processing sequences applied (SBE data processing, 2016)

this lets us smoothen out smaller spikes not handled in the SBE data processing (see 1.1) while keeping the overall structure of the dataset. In order for the data to be filled out to the the boundaries, we use a linear interpolation over each depth.

As for watermasses, we used pre-existing definitions taken from Nilsen et al. (2008), shown in Table 1.2. The definiton for ArW is taken from Helland-Hansen and Nansen (1909).

Watermass	**Temperature**	**Salinity**
Atlantic Water (AW)	T > 2.5°C	S > 34.9 PSU
Transformed Atlantic Water (TAW)	T > 1°C	S > 34.7 PSU
Winter Water (WW)	T < 1°C	
Arctic Water (ArW)	T < 0°C	

Table 1.2: Different watermasses expected to be found in the Isfjorden-WSC area defined by temperatures and salinities bounded by their origins.

1.3 Results

1.3.1 Transect of Isfjorden and the West Spitsbergen Shelf

In Figure 1.3 we present the temperature and salinity data gathered from our measurements taken during our first transect out of Isfjorden (see Figure 1.2, colorcoded as black and orange). In general we find the warmest, most saline water in the WSC (stations 49 - 61) and the freshest, coldest water in Isfjorden and mouth area (stations 23-41). The WSC appears to be quite homogeneous in temperature and salinity, while Isfjorden looks more stratified. The shelf area is even more homogeneous with the exception of two areas (station 46-48 and station 44) of warmer water and and one area (station 47) of saltier water.

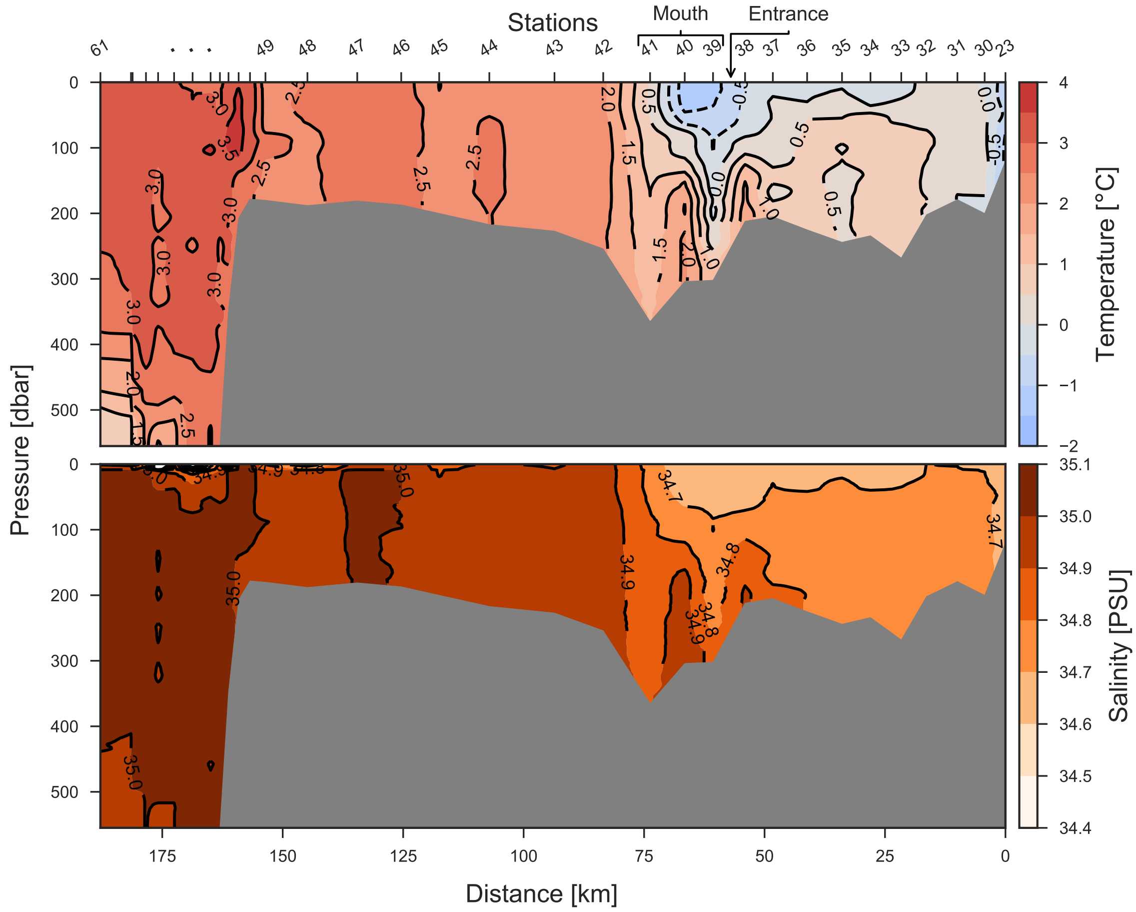

Figure 1.3: Temperature (top) and salinity (bottom) distributions taken during our transect from Isfjorden to the West Spitsbergen Shelf. After station 49 the depth increases significantly, but with our equipment we stopped the descent at around 500 m.

We measure the coldest water at around -1.5°C in the mouth of Isfjorden between station 39 and 40, and the warmest at 3.5°C in the proximity of station 51 located at around 100m depth at the start of the WSC. Comparatively, we find the freshest water at around the same place as the former with a salinity of 34.7 PSU, and the saltiest water with a salinity of 35.0 PSU throughout most of the WSC as well as some intermediate between Isfjorden and the WSC with a salinity of 34.9 PSU.

1.3.2 Cross transects of Isfjorden

In Figure 1.4, we show the data gathered during the two cross transects of Isfjorden (stations 171-165 and stations 164-157, see Figure 1.2). Comparing the two transects, we

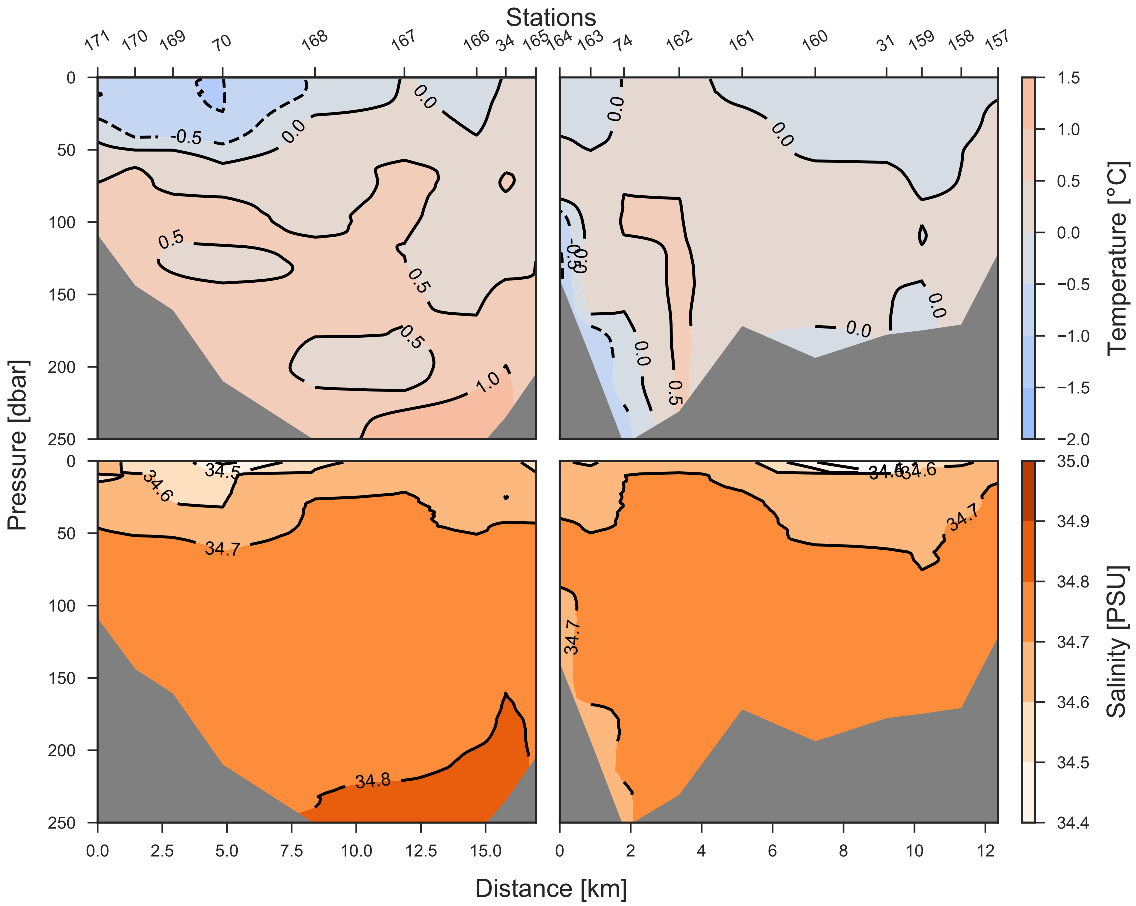

Figure 1.4: Temperature (top) and salinity (bottom) distributions taken from two cross transects of Isfjorden. Where the plots on the left show the outer transect and the plots on the right show the inner transect. North is to the left.

see that in general the water appears to be more stratified in the outer transect, showing colder temperatures and lower salinities close to the surface than the inner transect. However, looking at the whole profile, we see that there is in general warmer water in the outer transect after around 50 m depth. Furthermore, while we find warmer water in the deepest part of the section in the outer transect, we find colder water with negative temperature in the deepest part of the inner section.

1.3.3 Watermasses in Isfjorden and the West Spitsbergen Shelf

In the following temperature-salinity-diagram (Figure 1.5) (TS-diagram) we identify different watermasses as defined in Table 1.2. For the Isfjorden-WSC transect (black and

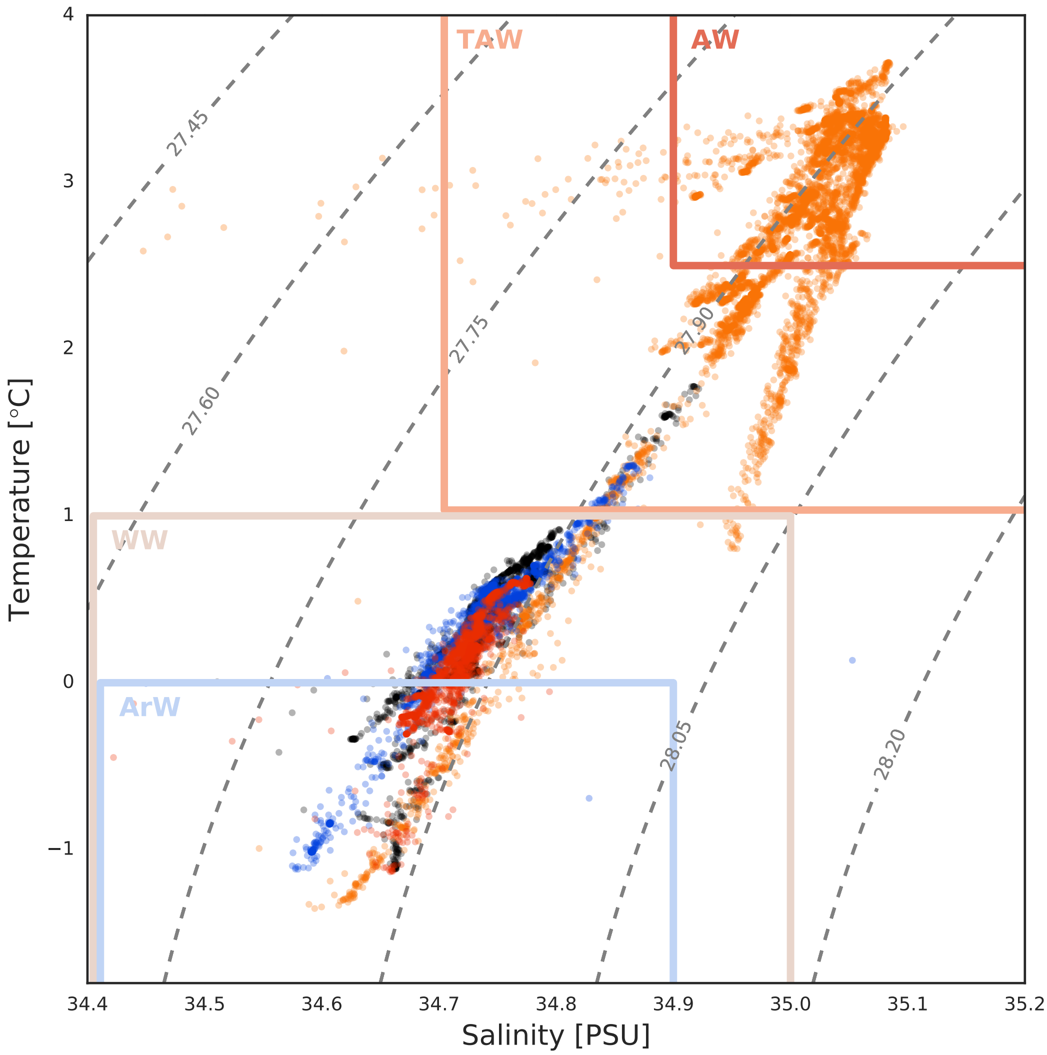

Figure 1.5: TS-diagram for the three different transects. Black and orange is respectively the fjord and the shelf. Red is the easternmost cross-transect while blue is the westernmost. The dashed contours show potential density anomality with a reference pressure of 0 dbar.

orange) we have two large watermasses: AW and WW, with a significant amount of TAW as well. The two ross-transects (red and blue) show mostly WW, with a significant amount of measuremets cold enough to be classified as ArW. Furthermore, in Figure 1.6 we show the spatial distribution of watermasses in the Isfjorden, WSC area. We see that the bulk of the watermasses is either AW in the WSC or WW in Isfjorden with TAW inbetween in the shelf area. We see some sections of AW within the shelf area as well. In Isfjorden

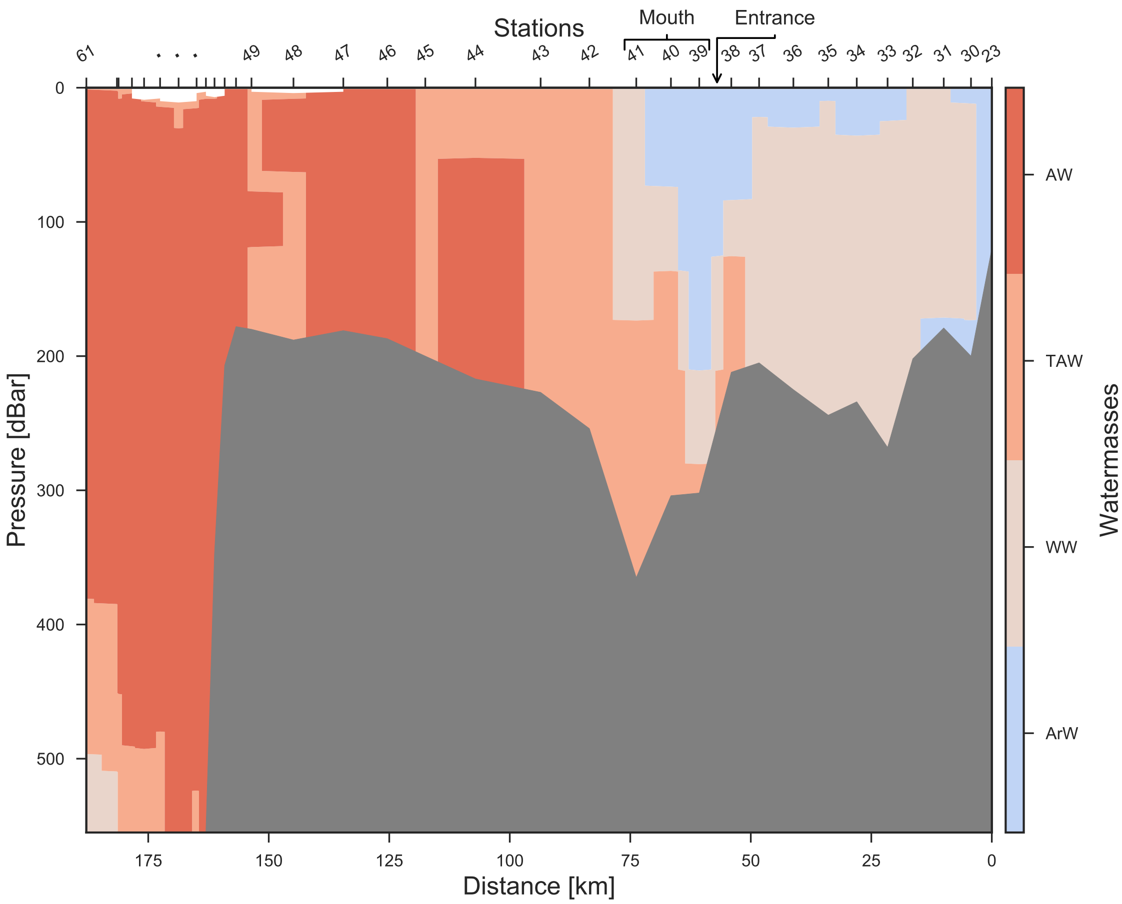

Figure 1.6: Contourplot showing the different watermasses identified throughout Isfjorden and the WSC. From colder and fresher (blue) to warmer and saltier (red).

we also identify possible ArW or colder WW.

1.4 Discussion

1.4.1 Depth and temperature of the core of WSC

We identify the core of the WSC in the area between staton 50 and 52 extending from the surface to around 100m depth with a temperature in the proximity of 3.5 °C (see Figure 1.3). The characteristics of the core is hypothesised to influence the water temperature in Isfjorden, and while the mechanism remains unclear, a statistical model was proposed from Pavlov et al. (2013). This regression model shows that there is a correlation between the core temperature, the mean sea-level pressure, and the maximum temperature in the fjord. The core temperature is especially significant for the temperature in the fjord below 200 m.

1.4.2 Reach of atlantic type water into Isfjorden

AW and TAW dominates the water column all the way in to station 42, and at depths below 150 m in the mouth area between station 41 and 38 (see Figure 1.6). Deep slopes are able to guide AW from the WSC into the Isfjorden Trough. As described by Nilsen et al. (2008), the steep topography at station 42 and the density difference between the lighter WW and the heavier AW may cause a geostrophic adjustment with a southward current in the lower Atlantic layer. This in turn creates a shear between the lower southern current and the northward costal current, which reduces geostrophic control, and AW can be topographically steered into the mouth of the fjord.

As can be seen in the TS-diagram in Figure 1.5 there is mixing between AW and WW which results in TAW. The two distinct lines in the TS-diagram, one (a) longer consisting of measurements from all transects and one (b) steeper and shorter with measurements from only outside the fjord, may describe two forms of mixing. Since (a) consists of measurements both within and outside the fjord entrance this is likely horizontal mixing, while (b) can be signs of vertical mixing in the fjord mouth and on the shelf.

1.4.3 Origin of sub-zero water

As can be seen in Figure 1.6 we observed colder and less saline water near the surface at station 40 and 39 in the mouth of Isfjorden. This water mass fits with the definition for ArW, as well as colder WW (see Figure 1.5), and thus we present two hypotheses regarding the origin of this watermass.

The Polar Current

The source of this water could be the SPC, which carries water with temperatures below zero along the coast of Spitsbergen east of the WSC. A cross section further west in the mouth of Isfjorden could have shown if the SPC is following a path going into the mouth of the fjord, as we would expect to observe the current crossing this outer transect. As for now we do not have the data to strengthen or confirm this hypothesis.

Internal circulation

The observed colder and fresher water could also be explained by an internal circulation in the fjord. Isfjorden is classified as a broad fjord, which means that rotational dynamics are important (Nilsen et al., 2008). This means that in general water masses will flow eastward along the southern side of the fjord and westward along the northern side. In winter the surface layer will lose heat to the atmosphere from radiation due to the cold air temperature. Freshwater input from land results in freshening of the surface water, and it may therefore be less dense than the underlying water even though it is colder.

A colder and fresher surface layer is also observed in the two cross-transects of Isfjorden in Figure 1.4, especially to the north in the westernmost cross-transect. This may be observations of the same internal circulation as proposed above. The colder water in the westernmost cross-transect may be due to the proposed current flowing out of Nordfjorden, where it is subject to substantial cooling.

The colder water near the bottom at station 163-164 and 74 could also have its origin at the surface as cooled down surface water. This water mass is fresher than the warmer water beneath the surface layer, but not fresh enough to compensate for the buoyancy loss due to cooling.

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