CTD data Report
K/V Svalbard
Van Mijenfjorden and Storfjorden
Mars 18 to 31 2006

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Introduction

The aim was to sample concurrent atmospheric and water properties in the area of open water in Storfjorden that is termed a polynya. Such a polynya forms due to winds, and partly currents, that transport sea ice away from land or fast ice areas. Figure 1 shows how the polynya in Storfjorden was developed the day before we left.

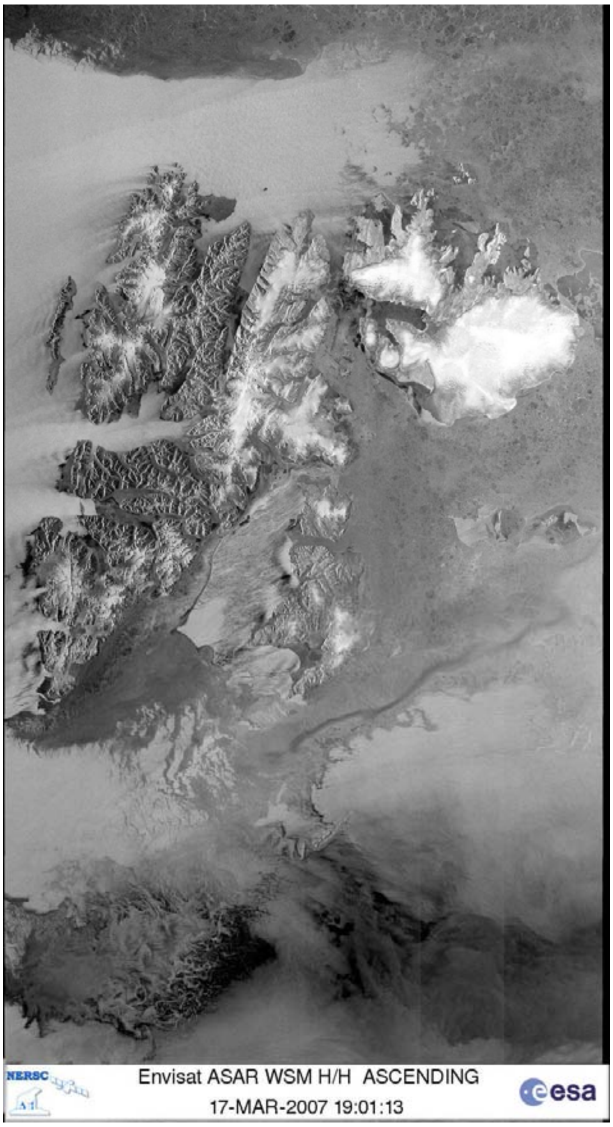

Figure 1. SAR image on Mars 17 2007 from Storfjorden and the Svalbard Archipelago. The polynya is well developed, and frazil ice streaks are seen along the entire polynya length. (Copyright European Space Agency).

In order to enter the polynya area we were lucky to utilize the large and powerful icebreaker, K/V Svalbard. During the first days of the cruise the weather conditions were favourable for polynya activity, with strong north-easterly winds pushing the pack ice out of Storfjorden. Unfortunately, the wind became strong southerly when we left Van Mijenfjorden and entered Storfjorden and the polynya area. This gradually closed the polynya with thin ice and pack ice from south. Warmer and less saline water was measured to enter the shallow polynya area from south, while dense brine water formed on the shallow polynya area during the frazil ice polynya event, prior to the cruise, was measured along the bottom towards the deeper basin in Storfjorden.

Participants

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Field Narrative

CTD station 0 was obtained in Van Mijenfjorden March 20 at the first ice camp. While entering Storfjorden on Mars 23, we made CTD station 1 just north of the sill because of ice free conditions in the area. Brine-enriched shelf water was found below about 70 m depth. CTD station 2 was made by the fast ice boarder in Freemansundet in the vicinity of the second ice camp on Mars 23. Then on Mars 23, we continued to make CTD stations 3 to 12 from the fast ice boarder in Freemansundet towards the deeper basin in Storfjorden with 0.5-1 km distance between them to resolve any downflow. At CTD station 9 and 10, the CTD was pulled under the ice by the boat propellers, and at CTD station 10, the winch engine broke when the CTD got stuck under the ice while the boat propellers accidentally and suddenly were pulling with heavy force. Due to efficiency and bad weather, we went as far as we could get towards the deep basin in Storfjorden during the night on Mars 23 and early morning on Mars 24 while the meteorologists measured atmospheric fluxes with instruments on K/V Svalbard. In the morning on Mars 24, we made CTD stations 13 to 27 on the return to the ice camp in Freemansundet with better conditions for CTD casting and fulfilled the along-polynya-length section. On the way out of Storfjorden towards the sill area, CTD station 28 was made on Mars 25 at the deepest position in Storfjorden (195 m depth). On Mars 26, CTD stations 29 to 37 were made across the western part of the sill overflow with 0.5-1 km distance between them to resolve the effect of horizontal mixing that can be induced by the Ekman transport. Large temperature gradients in the profiles at the sill induced spikes in salinity and were impossible to process due to varying descent rate of the CTD sonde when we had to lower and heave the CTD sonde manually.

Hydrography

Methods

The hydrographical sampling was made with a SeaBird SBE 19 SEACAT profiler (serial number 2787) and a Niskin bottle of 1.7 litres. A plummet was used to close the Niskin bottle at depths with homogeneous water, and one water sample was taken at 20 stations for calibration.

To avoid freezing of the conductivity and temperature sensors between stations, a CTD box was made to fit the CTD, and the Niskin bottle, a compartment and a personal heater for heating of the CTD box, and a laptop for viewing the CTD data while profiling. K/V Svalbard provided power supply.

To lower and heave the CTD and to connect directly to a laptop for viewing the data while profiling, a CTD winch system from KC Denmark was used.

In total, 38 CTD profiles were taken during the research cruise. Stations 00 were made in Van Mijenfjorden, Stations 01 to 28 were made in Storfjorden, and Stations 29 to 37 were made at the Storfjorden sill. A list of the CTD stations with the depths of the water samples is given in Table 1, and the positions of the Stations are mapped in Figure 2.

Table 1: List of CTD stations and water sample depths.

Date	Time	Station	Longitude E	Latitude N	Water Sample Depth
20/03/2007	14:47:27	00	15.95032	77.81170	38 m
22/03/2007	10:53:32	01	19.30816	77.08238	140 m
23/03/2007	11:54:54	02	20.82809	78.13017	-
23/03/2007	12:17:36	03	20.77893	78.11782	-
23/03/2007	13:17:01	04	20.69641	78.10549	-
23/03/2007	13:50:46	05	20.69671	78.10251	-
23/03/2007	14:19:36	06	20.67164	78.09585	-
23/03/2007	15:12:52	07	20.67888	78.09859	23 m
23/03/2007	15:51:17	08	20.65472	78.09531	-
23/03/2007	16:19:16	09	20.64290	78.09069	24 m
23/03/2007	16:46:32	10	20.62566	78.08834	-
23/03/2007	19:02:14	11	20.56172	78.07782	17 m
23/03/2007	19:44:45	12	20.52815	78.07054	18 m
24/03/2007	08:54:52	13	19.04230	77.69220	79 m
24/03/2007	09:47:14	14	19.14049	77.72825	44 m
24/03/2007	10:30:37	15	19.22107	77.76618	59 m
24/03/2007	11:07:30	16	19.33372	77.77958	30 m
24/03/2007	11:38:15	17	19.44226	77.81094	39 m
24/03/2007	12:02:51	18	19.52420	77.83529	30 m
24/03/2007	12:35:31	19	19.63852	77.86775	-
24/03/2007	13:06:48	20	19.74381	77.89340	27 m
24/03/2007	13:35:05	21	19.94043	77.91036	-
24/03/2007	13:59:47	22	20.06424	77.91421	45 m
24/03/2007	14:35:46	23	20.21833	77.93672	60 m
24/03/2007	15:04:09	24	20.33746	77.96546	66 m
24/03/2007	15:29:56	25	20.35511	78.00209	46 m
24/03/2007	15:59:46	26	20.36799	78.03069	30 m
24/03/2007	16:27:23	27	20.53447	78.06535	154 m
25/03/2007	21:07:01	28	19.09084	77.56587	-
26/03/2007	01:48:54	29	18.79442	76.94620	-
26/03/2007	02:12:01	30	18.80963	76.94720	-
26/03/2007	02:34:50	31	18.84295	76.94882	-
26/03/2007	02:58:10	32	18.87804	76.94953	-
26/03/2007	03:20:29	33	18.89682	76.95129	-
26/03/2007	03:43:37	34	18.91192	76.95203	78 m
26/03/2007	04:02:10	35	18.93278	76.95258	-
26/03/2007	04:26:18	36	18.96324	76.95470	-
26/03/2007	04:53:05	37	19.00484	76.95631	-

Calibration of CTD sensors

SeaBird Electronics calibrated the conductivity and temperature sensors on August 8 2003 for the SEACAT 2787. This is considered to be sufficient for the temperature sensor, while the conductivity sensor has to be merged with salinity bottle samples to achieve the accuracy needed. The SEACAT pressure sensor is a strain gauge pressure sensor type and was calibrated by SeaBird Electronics on August 11 2003. The accuracies of the pressure, temperature and conductivity sensors are *0.1%* of full-scale range, 0.005 °C and 0.0005 S/m respectively.

Data processing

Seasoft, a standard SeaBird Electronics software, is used for data processing of the CTD data. A brief description of the modules and parameters used can be summarized as follows:

1. SEASAVE acquires the raw data.
2. DATCNV converts the raw data to pressure, temperature and conductivity to physical units in ascii format using calibration files modified for air pressure and conductivity slope factor.
3. FILTER forces conductivity to have the same response as temperature. Conductivity was low passed with a time constant of 0.5 seconds and pressure was low passed with a time constant of 2 seconds. This increased the pressure resolution for LOOPEDIT.
4. ALIGNCTD advances temperature relative to pressure 0.6 seconds. This value is dependent on the lowering rate.
5. LOOPEDIT marks scans where the CTD is moving less than 0.2 m/s.
6. BINAVG averages data into 1-dbar pressure or depth bins.
7. DERIVE computes salinity, density and potential temperature.
8. ASCIIOUT exports converted data into an ascii data file with only a simple label above each column of the data parameters, and a header file with all station information.

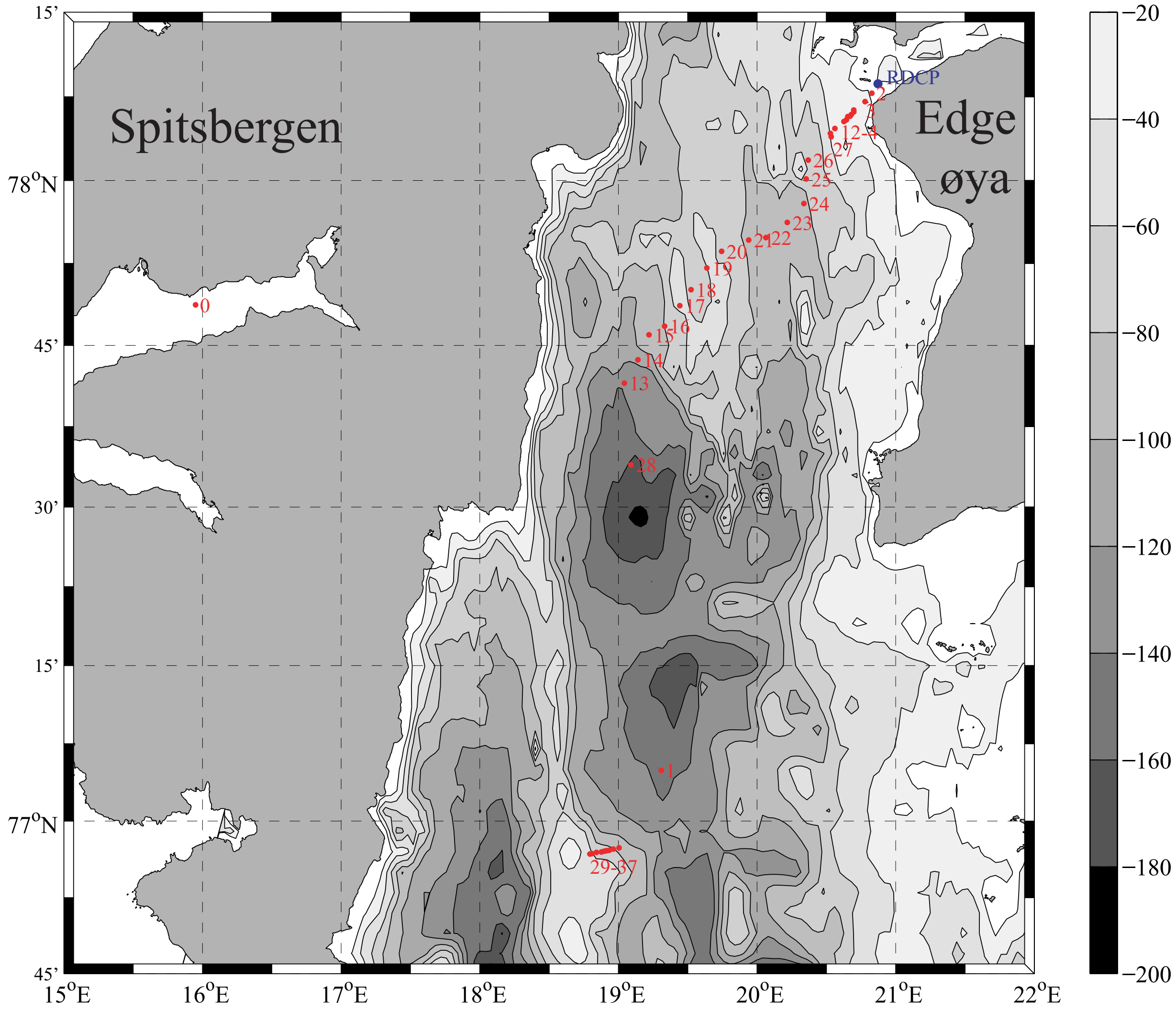


Figure 2. The mapped positions of the CTD stations and the RDCP current meter.

Merging CTD data with salinity bottle data

A total of 20 salinity bottle samples were taken during the cruise, whereas 18 of them were taken for calibration of the CTD conductivity (excluding bottles from Stations 0 and 34). They were analyzed at UNIS with a Guildline Portasal 8410 salinometer during May 2007. Every bottle salinity and conductivity were merged with corresponding CTD data stored on MRK-files when the Niskin bottle was closed. The comparison is summarized in Table 2. Bottle conductivity is calculated from bottle salinity, CTD-pressure and CTD temperature using the formulas in SEACALC in the SEASOFT software.

Table 2: Salinity bottle data and corresponding CTD data.

CTD Sta	CTD Pressure	CTD Temp.	CTD Cond.	CTD Salinity	Ni. Btl.	Btl. ID	Btl. Cond.	Btl. Salinity	CTD-Btl. Cond.	CTD-Btl. Salinity
0	38.0	-1.8234	2.720926	34.5921	1	0	2.742585	34.8955	-0.021659	-0.3034
1	140.0	-1.8932	2.752052	35.0441	1	1	2.753919	35.0703	-0.001867	-0.0262
7	23.0	-1.9352	2.757439	35.2467	1	2	2.759960	35.2823	-0.002521	-0.0356
9	24.0	-1.9169	2.745950	35.0626	1	3	2.747316	35.0818	-0.001366	-0.0192
11	17.0	-1.8964	2.739800	34.9563	1	4	2.738990	34.9450	0.000810	0.0113
12	18.2	-1.8754	2.739431	34.9257	1	5	2.739614	34.9283	-0.000183	-0.0026
14	79.0	-1.9151	2.738796	34.9237	1	6	2.737282	34.9024	0.001514	0.0213
15	44.0	-1.9111	2.736664	34.9119	1	7	2.738233	34.9340	-0.001569	-0.0221
16	59.0	-1.9152	2.739663	34.9492	1	8	2.739400	34.9454	0.000263	0.0038
17	30.0	-1.9084	2.734508	34.8875	1	9	2.735439	34.8817	-0.000931	0.0058
18	39.0	-1.9122	2.736879	34.9195	1	10	2.736215	34.9102	0.000664	0.0093
19	30.0	-1.9127	2.736086	34.9149	1	11	2.736136	34.9156	-0.000050	-0.0007
21	27.0	-1.9107	2.741597	34.9920	1	12	2.740672	34.9790	0.000925	0.0130
23	45.0	-1.9215	2.746458	35.0621	1	13	2.745916	35.0537	0.000542	0.0084
24	60.0	-1.9199	2.747266	35.0609	1	14	2.746198	35.0459	0.001068	0.0150
25	66.0	-1.9180	2.744655	35.0181	1	15	2.744129	35.0106	0.000526	0.0075
26	46.0	-1.9140	2.743435	35.0099	1	16	2.744085	35.0184	-0.000650	-0.0085
27	30.0	-1.8180	2.726590	34.6702	1	17	2.725183	34.6505	0.001407	0.0197
28	154.0	-1.9258	2.754103	35.1017	1	18	2.754253	35.1045	-0.000150	-0.0028
34	78.0	-1.2285	2.785542	34.7701	1	19	2.794545	34.8941	-0.009003	-0.1240

Figure 3 is a plot of the difference between bottle conductivity and CTD conductivity versus salinity bottle number for the 18 salinity bottles. The standard deviation of bottle-CTD conductivity is 0.001200 S/m and the mean is -0.000087 S/m.

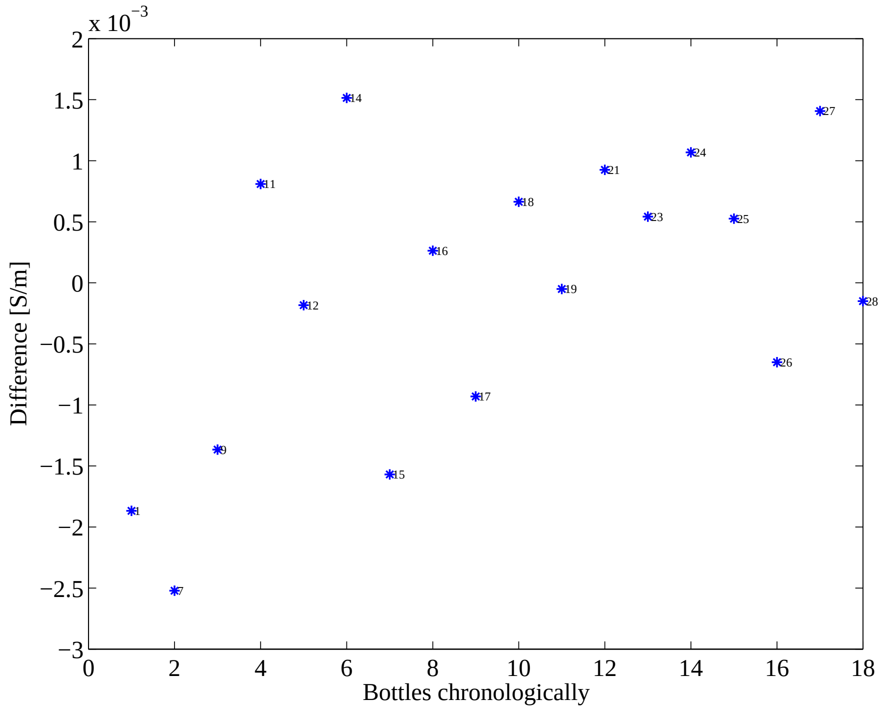


Figure 3: Difference between bottle conductivity and uncorrected CTD conductivity plotted versus increasing salinity bottle number, from Table 2. Station number is indicated to the right of data points.

Figure 4 shows a histogram of the same data. Due to few data, it is hard to say what kind of distribution it is, but we assume a Gaussian normal distribution with peaks at -0.1×10^{-3} S/m and 0.5×10^{-3} S/m. For all the data, the average and the standard deviation are -0.000087 S/m and 0.001200 S/m, respectively. The 95% confidence interval for a Gaussian normal distribution is given by ([average]±2×[standard deviation]). For this data set this gives (-0.002400 S/m, 0.002300 S/m). Following the procedure recommended by UNESCO (1988), only data within the 95% confidence interval should be used to correct the calibration of the CTD conductivity. This excludes 1 bottle (Station 7), and the remaining 17 data points are presented in Figure 5 versus pressure, temperature and CTD conductivity.

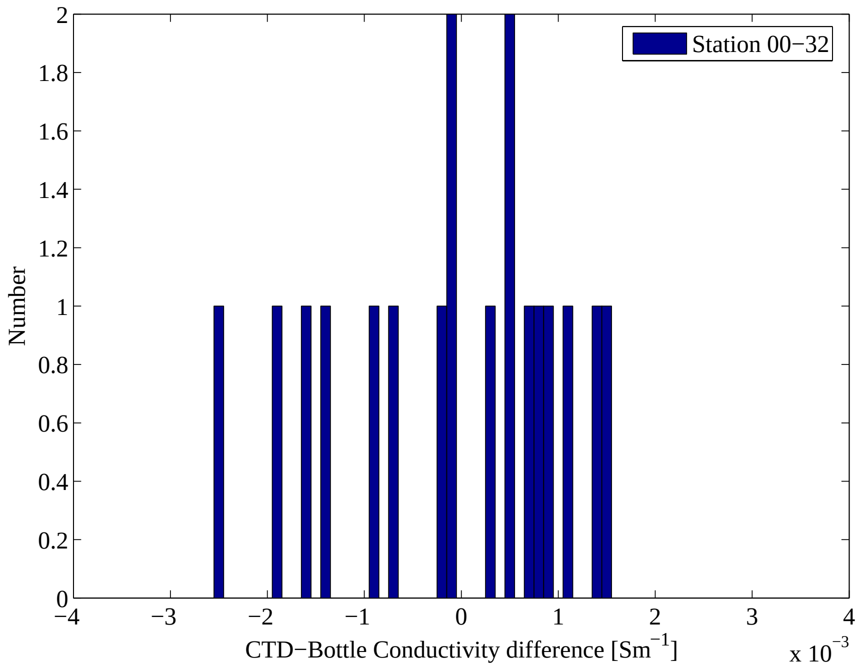
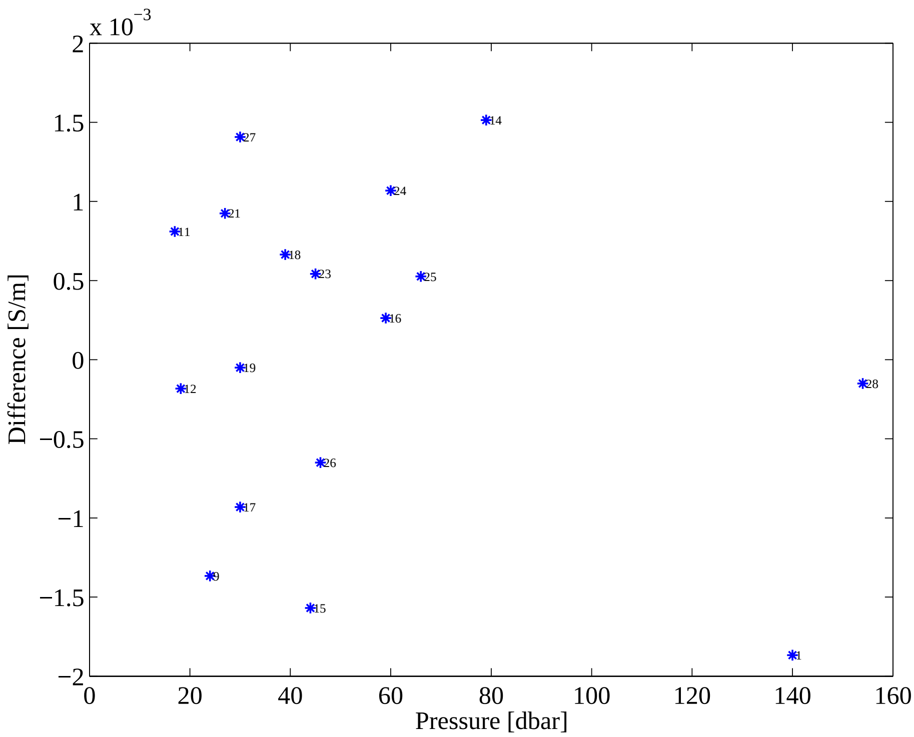


Figure 4: Histogram of the difference between bottle conductivity and uncorrected CTD conductivity from Stations 01 to 28 with increments of 0.1×10^{-3} S/m.



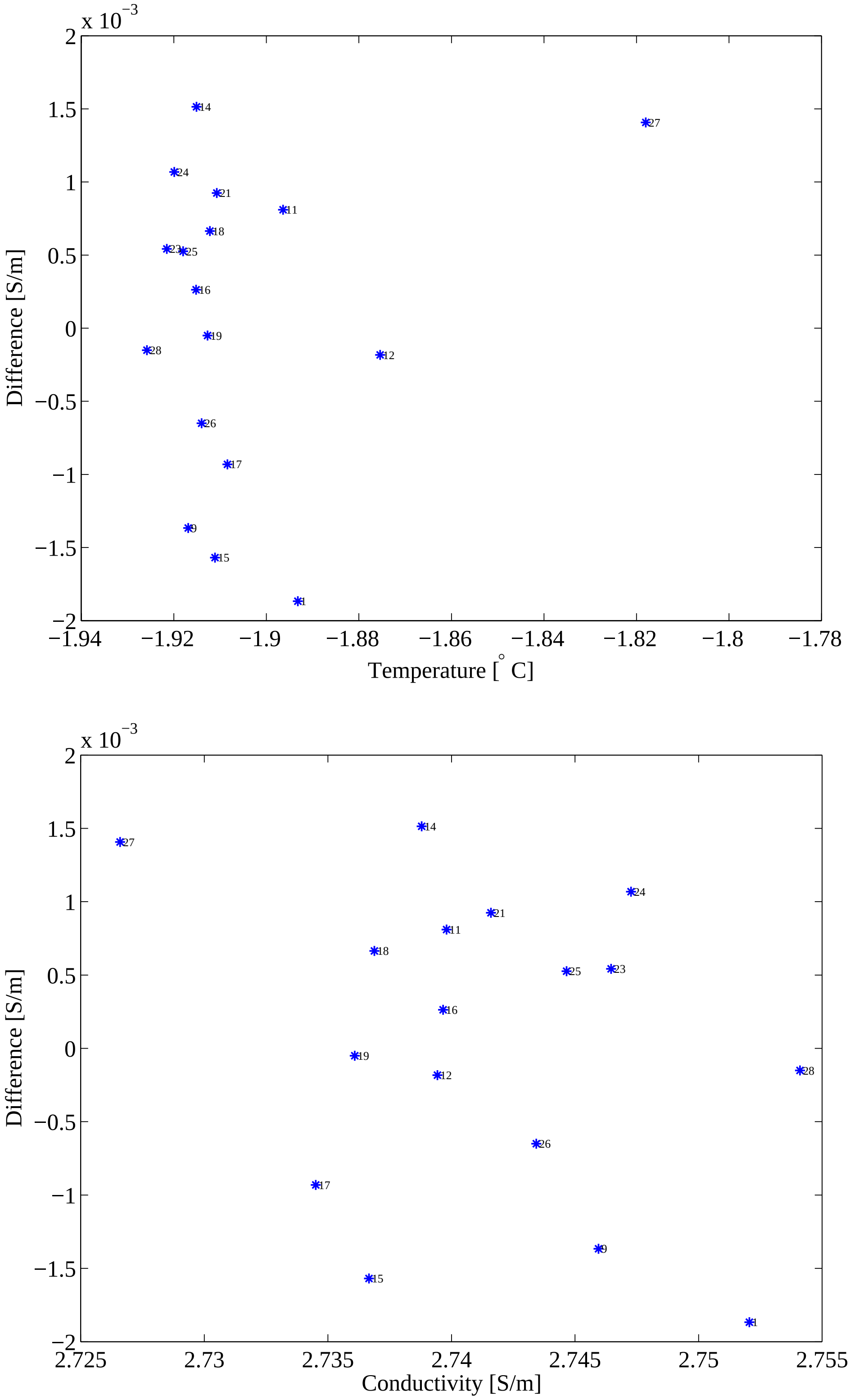


Figure5: All values within the 95% confidence interval of the difference between uncorrected CTD and bottle conductivity plotted versus CTD pressure, temperature and conductivity, from Table 2. Station numbers are indicated to the right of the marks.

Figure 5 reveals no clear dependency of the difference in conductivity on CTD pressure, temperature and conductivity since the range in values are small. Following the recommendations given by Seabird Electronics, the conductivity values *C* are corrected by the formula

$$C_{new} = slope \times C_{old},$$

where the *slope* is calculated by the formula

$$slope = \frac{\sum_{i=1}^{n} a_i \times b_i}{\sum_{i=1}^{n} a_i \times a_i}.$$

Here a_i and b_i are the CTD conductivity and the bottle conductivity from Table 2, respectively. Using the 17 values inside the 95% confidence interval, the value for the slope is calculated to be

$$slope = 0.999980.$$

The conductivity difference from theses 17 bottles has an average of 0.000056 S/m and a standard deviation of 0.001000 S/m. As an indication on how the corresponding difference in salinity would be the difference between bottle salinity and CTD salinity from Table 2 is presented in Figure 6.

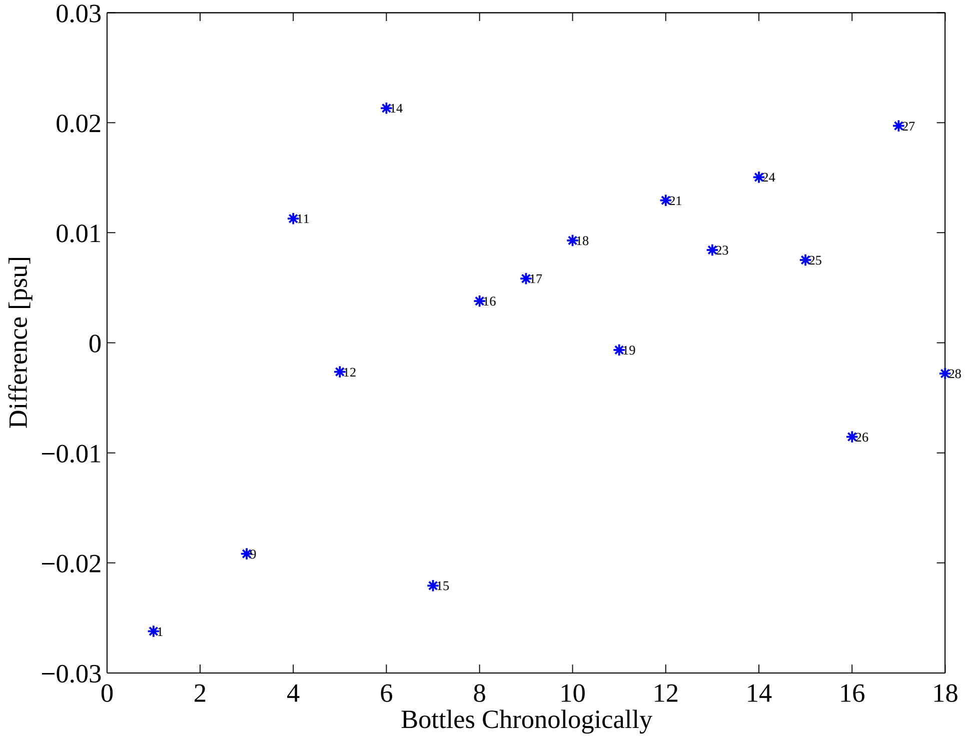


Figure 6: All values within the 95% confidence interval of the difference between uncorrected CTD and bottle salinity plotted versus increasing salinity bottle number, from Table 2. Station numbers are indicated to the right of data points.

Results

The calibrated CTD profiles are shown in Figure 7 and reveal a water column close to the freezing point in the Polynya area and interior of Storfjorden, whereas warmer water is present in intermediate depths above the overflow at the sill. Van Mijenfjorden is also affected by warmer inflowing water in the surface layer. The stability is clearly governed by the salinity, which is between 34.43 and 35.49. The water column close to the fast ice in Freemansundet is colder and more saline than the water column at similar depths towards the interior of Storfjorden. The coldest and saltiest water is present between 70 and 90 m depths along the bottom towards the deeper basins in Storfjorden. This is Downflow of brine-enriched shelf water (BSW) produced during the polynya activity around 17 Mars 2007 as shown in Figure 1. The deepest profiles in Storfjorden have less saline BSW and indicate that the polynya activity prior to the last one has produced less frazil ice or that the source water was fresher then.

The whole water column is BSW in the shallow polynya area except the profile made at Station 27, which was made 21 hours after the profile at Station 12 at nearly the same position. The profiles close to Station 12 and 27 increased gradually in temperature towards them from both sides, indicating a warmer coastal current forced by the Ekman transport and accompanying surface elevation due to the strong southerly wind during CTD casting inside Storfjorden.

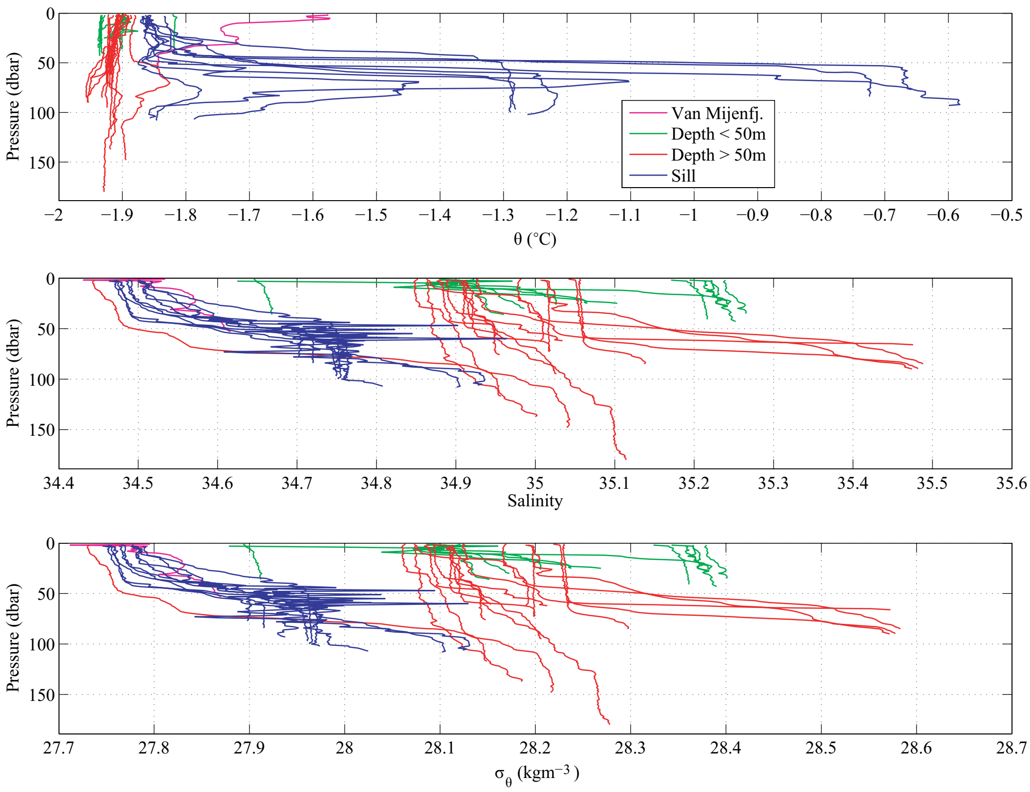
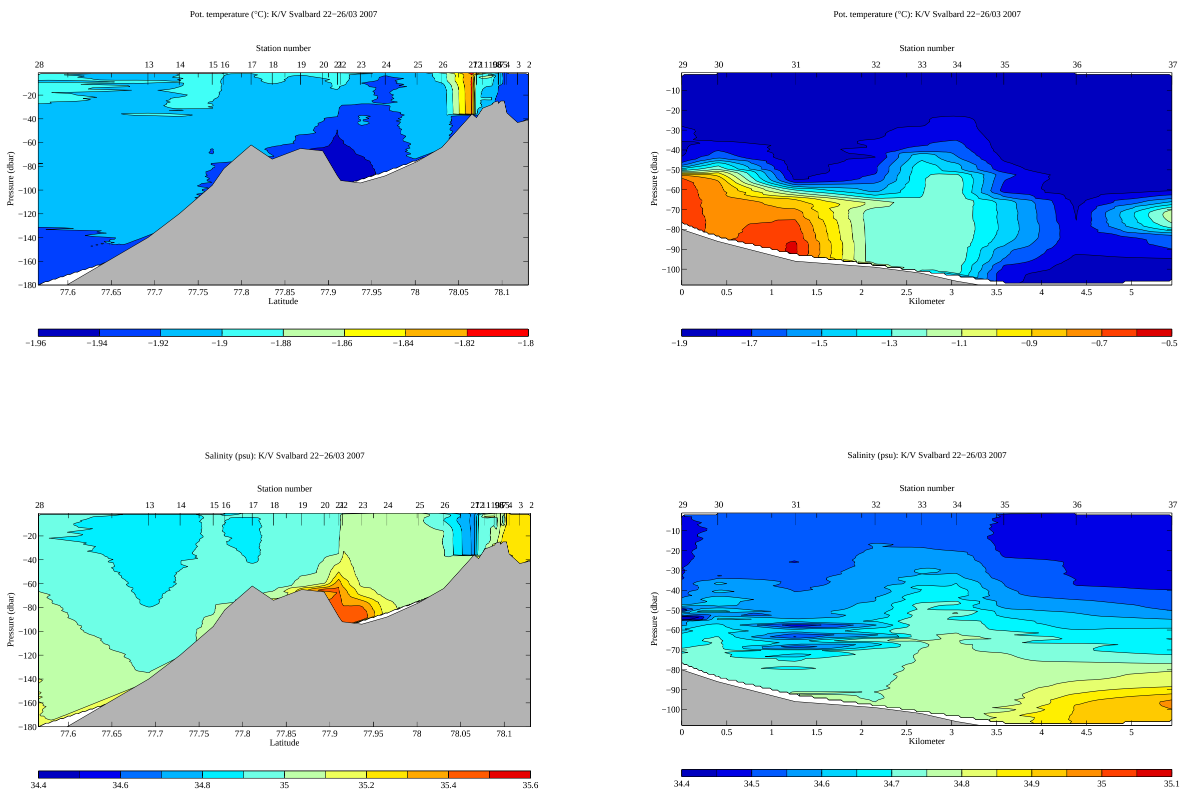


Figure 7: Potential temperature, salinity and density profiles from Stations 00 to 37 made during the research cruise with K/V Svalbard 18 to 31 Mars 2007. Magenta is the profile in Van Mijenfjorden, greens are shallow profiles less than 50 m deep in the polynya area close to the fast ice in Freemansundet, reds are deeper profiles towards the interior of Storfjorden and blues are profiles at the sill.

Sections of potential temperature, salinity and sigma theta from the fast ice in Freemansundet and along the polynya length towards the interior of Storfjorden, and across the western part of the sill overflow are presented in Figure 8. The colder and more saline water is seen at the shallow polynya area close to the fast ice in Freemansundet and is separated from the interior polynya water by the warmer and less saline coastal current probably set up during the strong southerly wind. The coldest and saltiest BSW is present between Stations 18 and 24 along the bottom as a downflow towards the deeper basins inside Storfjorden where less saline BSW is present from earlier polynya activities during the freezing period. At the sill, warmer water with temperatures up to -0.5 °C is present west of the BSW overflow, which creates density front and intensive mixing. The profiles are quite spiky in salinity which is mainly caused by the large gradients in temperature and hence, giving problems with processing the conductivity data properly.

The sill section was made to find if the density gradient at the western edge of the BSW overflow was neutral with depth due to horizontal mixing caused by the Ekman transport. Unfortunately, the profiles are quite spiky in salinity, but the section indicates neutral density in the profiles towards the core of the overflow. The salinity of the overflow is between 34.9 and 35.95, and the profile just north of the sill (Station 1) shows salinity of 34.95 being consistent with the overflow.



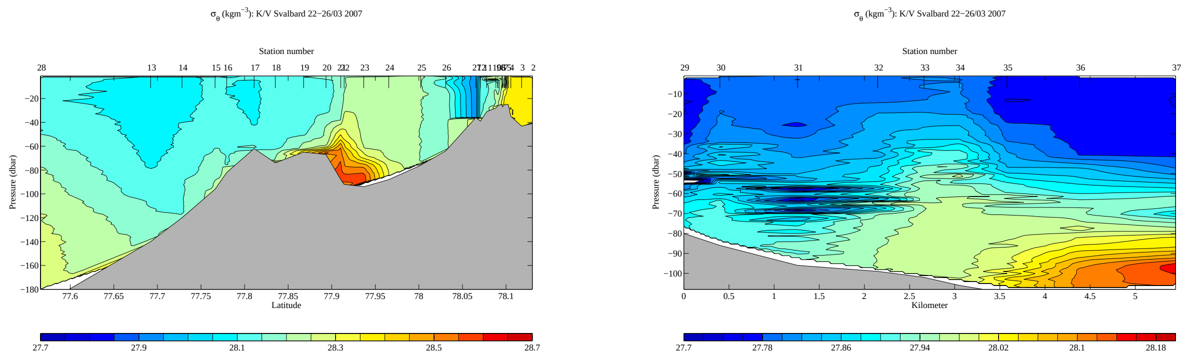


Figure 8: Section of pot. Temperature (upper), salinity (middle) and sigma theta (bottom) in Freemansundet (left) and along the fast ice border in the polynya (right). For station location see Figure 8.

Figure 9 shows the potential temperature and salinity diagram of all the CTD profiles taken during the research cruise.

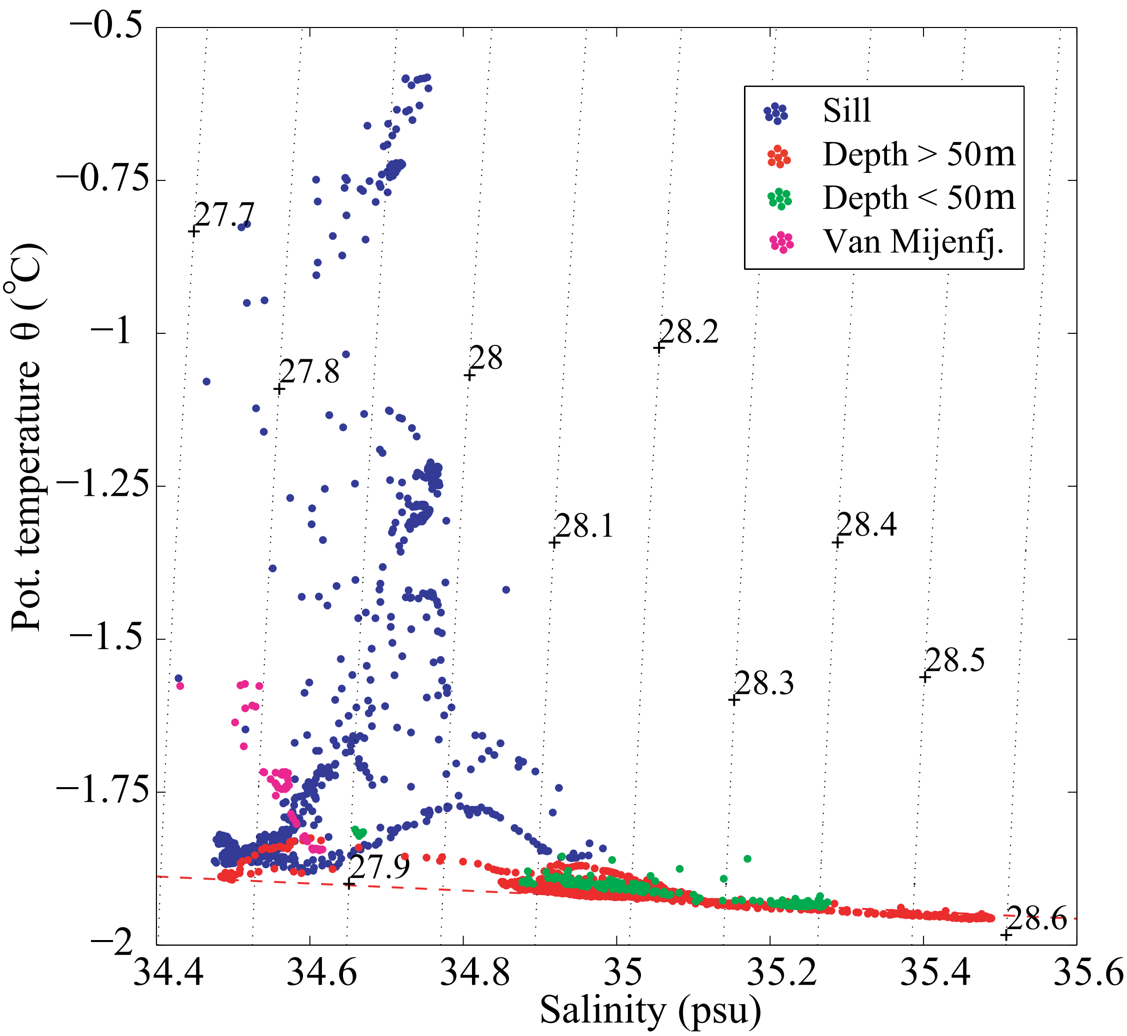


Figure 9: θS-diagram of all the CTD profiles made during the reasearch cruise with K/V Svalbard 18 to 31 Mars 2007. Magenta is the profile in Van Mijenfjorden, greens are shallow profiles less than 50 m deep in the polynya area close to the fast ice in Freemansundet, reds are deeper profiles towards the interior of Storfjorden and blues are profiles at the sill.

The warm water at the sill with temperatures up to -0.5 °C is present and mixes both isopycnally and vertically with the BSW overflow. The salinity increases and the temperature decreases in the surface layer from the sill area towards the shallow polynya area close to the fast ice in Freemansundet. The warmer and less saline surface water towards the sill area is most likely due to inflow of warmer water from the south during the strong southerly winds. The polynya or brine-enriched shelf water is close to the freezing point which is dependent on the salinity. The CTD profile at Station 27 is shown as warmer and less saline than the other profiles in the polynya area, and indicates that the northward coastal current forced by the strong southerly winds became warmer during the measuring period.