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Forsmark site investigation

Oceanographic measurements

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Abstract

Oceanographic measurements of temperature, conductivity (salinity), current velocity and direction were conducted at distinct points within an area approximately 20×25 km along the coast in the vicinity of Forsmark nuclear power plant. Data were continuously measured at different depths over a period of one year. This report describes the instruments which were used, their calibration and regular function control and the survey history. Positioning of the rigs within the survey area as well as details about the instruments are given in tabulated form. The data are presented as graphs. For access to the original data the reader is referred to the SICADA database. Regarding outcome of the measurement campaign, it can be stated that nearly all of the data obtained were considered reliable after a first quality control. There are some exceptions when equipment malfunctioned, mainly because of battery failure.

Sammanfattning

Oceanografiska mätningar av temperatur, konduktivitet (salthalt), strömhastighet och -riktning har genomförts på olika platser inom ett område som täcker omkring 25×20 km nära Forsmarks kärnkraftverk. Mätningarna genomfördes under ett år. Rapporten beskriver mätinstrumenten, deras kalibrering och funktionskontroller liksom undersökningens historik. Riggarnas positionering inom undersökningsområdet och detaljer om instrumenten presenteras i tabellform. Data presenteras i figurer och för tillgång till originaldata hänvisas till SKB:s databas SICADA. Angående mätkampanjens utfall kan sägas att nästan alla data som erhållits bedömdes som tillförlitliga efter en första kvalitetsgranskning. De få undantagen är tillfällen då mätinstrument inte fungerade, främst på grund av batterifel.

Contents

1 Introduction

This document reports the oceanographic measurements which were one of the activities performed within the site investigation at Forsmark. The work was carried out in accordance with activity plan AP PF 400-03-105. In Table 1-1 controlling documents for performing this activity are listed. Both activity plans and method descriptions are SKB's internal controlling documents.

The survey is part of the site investigations for a deep repository in the Forsmark area. The survey was conducted between the end of April 2004 and April 2005. This period was interrupted for short times when data were read out, batteries were changed and instruments were checked for functionality. Interruptions occurred around July 20th, October 18th and January 4th The position of the different rigs is shown in Figure 1-1.

The data from this activity are stored in the SICADA database and are traceable by the activity plan number.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Insamling av oceanografiska parametrar	AP PF 400-03-105	1.0
Method descriptions	**Number**	**Version**
Oceanographic measurements	SKB MD 364.009	1.0

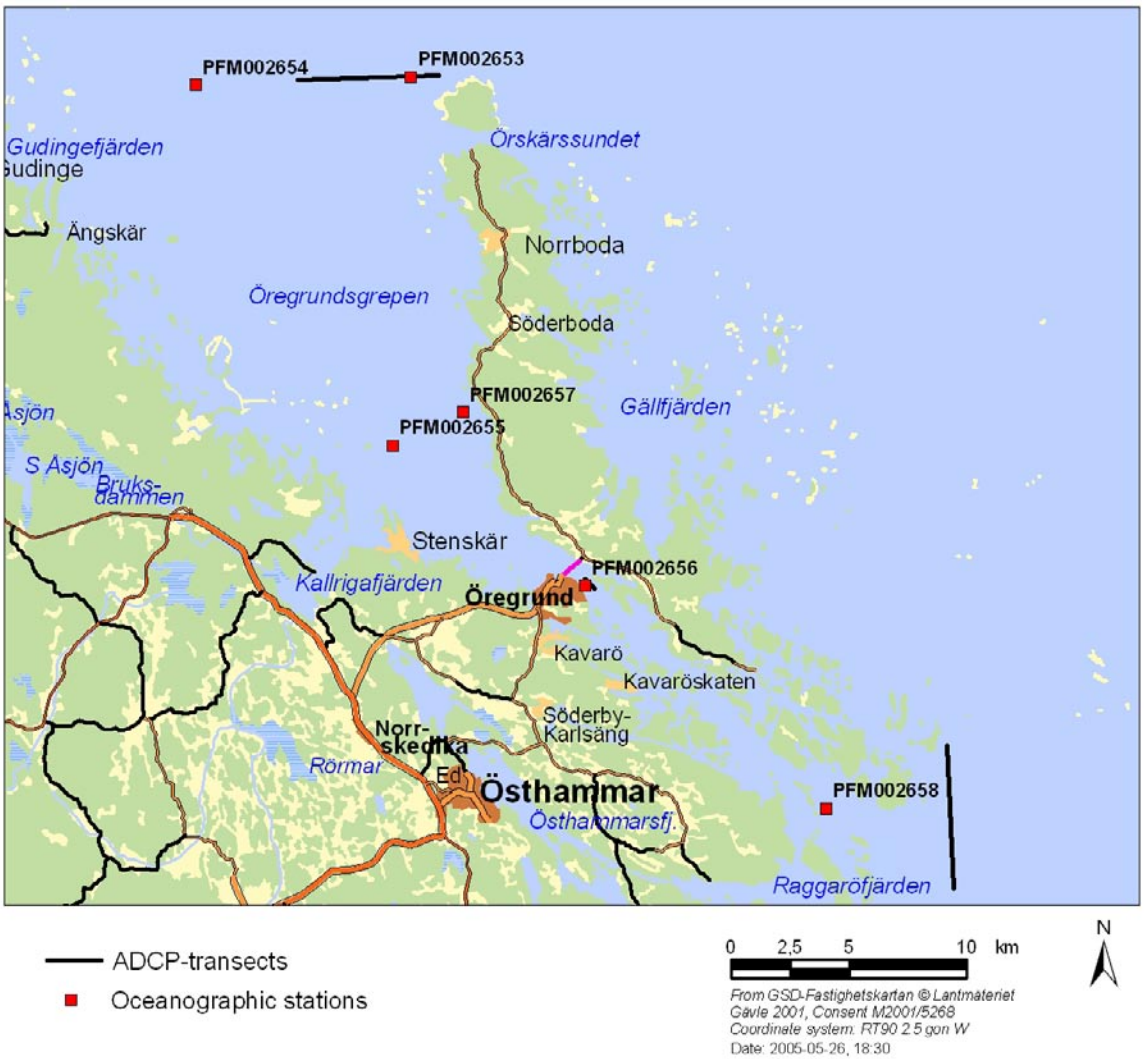

Figure 1-1. *General overview over Forsmark site investigation area with positions of the oceanographic measurement sites.*

2 Objective and scope

SKB conducts site investigations intended to examine whether the Forsmark site is suitable for a deep repository facility. One part of the investigation is oceanographic measurements and this activity includes measurements of temperature, salinity and currents at six positions located along the coast in the vicinity of the Forsmark nuclear power plant. The measurements will be used to validate an oceanographic model of the Forsmark area. Activities conducted by the SMHI as a subcontractor include deployment of equipment intended to collect oceanographic data, function control and operation of the equipment as well as registration of data and an initial quality control of the data before delivery. Positions and parameters measured are given in Table 2-1 below.

Table 2-1. Positions, depths and measured parameters for stations in the Forsmark area.

Station	Position (RT90 2.5 gon V)	Vertical extension	Parameter	Instrument
PFM002653, Northern boundary E	6715529 N 1639497 E	1.5 m (5 m while ice covered); 10 m; 17.5 m; 25 m	temperature, conductivity, pressure	Aanderaa RCM7
PFM002653, Northern boundary E	6715529 N 1639497 E	upward, cell size 2 m	velocity components east, north	RDI ADCP
PFM002654, Northern boundary W	6715187 N 1630350 E	12 m	speed, direction, temperature, conductivity, pressure	Aanderaa RCM9
PFM002655, Inner point	6699864 N 1638722 E	2 m (5 m while ice covered); 10 m; 17.5 m	temperature, conductivity, pressure	Aanderaa RCM7
PFM002656, Öregrundssund	6693906 N 1646893 E	upward, cell size 2 m	speed, direction velocity components east, north	Nortek ADP
PFM002656, Öregrundssund	6701283 N 1646893 E	25 m	temperature, conductivity	Seabird microcat SBE37
PFM002657	6701283 N 1641702 E	from 27 m up in 2.6 m intervals (only during ice free period)	temperature	Aanderaa TR7
PFM002658, Southern boundary	6684441 N 1657120 E	1.5 m; 10 m; 18 m	temperature, conductivity, pressure	Aanderaa RCM7

3 Equipment

3.1 Description of equipment/interpretation tools

The survey was conducted from moored rigs equipped with instruments measuring temperature, conductivity and flow velocity and direction. Data were averaged over 3–5 minutes every half or full hour. Instruments used are described in Table 3-1 below. Current metres were standing on the bottom at most stations while temperature and conductivity were measured at 3–4 different depths in the water column. For details on deployment depths, see Table 2-1, and for sketches on the rigs, see Appendix 1. On calibration and handling of the instruments, see Chapter 4.2.

Table 3-1. Description of instruments used during the survey.

Station	Manufacturer	Instrument	Parameter	Range	Resolution	Accuracy
PFM002654	Aanderaa	RCM9	Current-speed	0 to 300 cm/s	0.3 cm/s	±1% of reading ±0.15 cm/s
	Aanderaa	RCM9	Current-direction		0.35°	±5° within tilt angles 0° to 15°; ±7.5° within tilt angles 15° to 35°
	Aanderaa	RCM9	temperature	–2.7°C to +21.77°C	0.1% of range	±0.05°C
	Aanderaa	RCM9	conductivity	0 to 74 mS/cm	0.1% of range	±0.2% of range
	Aanderaa	RCM9	pressure	0 to 700 kPa	0.1% of range	±0.25%
PFM002653, PFM002655, PFM002658	Aanderaa	RCM7	temperature	–0.34°C to +32.17°C	0.1% of range	±0.05°C
	Aanderaa	RCM7	conductivity	0 to 74 mS/cm	0.1% of range	±0.025 mS/cm
PFM002657	Aanderaa	TR7	temperature	–0.34°C to +32.17°C	0.1% of range	±0.05°C
PFM002656	Nortek	ADP	Current-speed	Max. depth 20 m	0.1 cm/s	1% of measured value, ±0.5 cm/s
	Nortek	ADP	Current-direction	360°	0.1°	2°
	Seabird	microcat SBE37	pressure	0 to full scale range	0.002% of full scale range	0.15% of full scale range
	Seabird	microcat SBE37	temperature	–5°C to +35°C	0.0001°C	0.002°C
	Seabird	microcat SBE37	conductivity	0 to 7 S/m	0.0001 S/m	0.0003 S/m
PFM002653	RDI	Broadband ADCP, selfcontained, 600 mHz	current	Max. depth 60 m	Depends on depth and current velocity.[1]	
transects	RDI	Workhorse ADCP, vessel-mounted, 600 mHz	current	Max. depth 60 m	Depends on depth and current velocity.	
comparisons	SAIV A/S	STD/CTD-model SD204	temperature	–2°C to 40°C	0.001°C	±0.01°C
	SAIV A/S	STD/CTD-model SD204	salinity	0 to 70 mS	0.01 mS/cm	±0.02 mS/cm
	SAIV A/S	STD/CTD-model SD204	density	500 m	0.01% of range	±0.2% of range

[1] Concerning accuracy for the Acoustic Doppler Profilers from RDI the following can be stated: According to the manufacturers manual a single ping typically has an accuracy of about 0.8 cm/s. Averaging the results of multiple pings reduces the short term random error, the long-term bias is about 0.2 cm/s, setting a lower limit for error reduction.

Accuracies given in Table 3-1 are those given by the manufacturer and can be obtained only under ideal circumstances during calibration in the laboratory. Under working conditions the ranges given in the method description are reasonable. Under certain circumstances it may be possible to achieve accuracies that are better than stated in the method description, as was the case for current measurements in the surveillance area.

4 Execution

4.1 General

During one calendar year continuous measurements of temperature, conductivity (salinity) and currents were conducted at five positions throughout the survey area.

The following method description has been used: Method description for Oceanographic Measurements (SKB MD 364.009, SKB internal document).

4.2 Preparations

Oceanographic instruments deployed by the SMHI during surveys are sent to the manufacturer at certain intervals for calibration. In between, a function and performance control is conducted before every new assignment. This is done at the SMHI. Below a short description of tests conducted for different instruments used during this survey is given.

4.2.1 Temperature and salinity sensors

Sensors are tested in a plastic bucket containing water with a given salinity. Salinity in the bucket is analysed at regular intervals at an accredited laboratory. Temperature is measured by a temperature sensor calibrated at regular intervals. When instruments are deployed or recovered, a control measurement with a CTD probe calibrated at regular intervals is conducted.

4.2.2 Currentmeter, electromagnetic (Interocean Systems, type S4)

The instrument is checked by performing a simple zero test as described in the manufacturers manual. The test is carried out in a plastic container at least 50 cm in diameter, holding approximately 150 l of water.

4.2.3 Currentmeter, acoustic (ADCP, manufactured by Aanderaa (type RCM 9), RDI or Nortek)

The technical performance of the instruments is controlled according to the manufacturers manual, and during deployment and recovery additional current measurements for the purpose of comparison are conducted.

4.3 Execution of field work

Various types of rigs (see Appendix 1 for sketches) were deployed at five different positions throughout the survey area (see Figure 1-1 and Table 2-1). Measurements of temperature, conductivity and current were conducted during one calendar year between April 2004 and April 2005. Battery changes and data recovery were conducted 4 times during this period: Between July 20th and July 30th, October 18th and October 21st 2004, January 4th and February 8th and on April 25th/26th 2005. For details see Table A4-1 (Appendix 4).

4.4 Data handling/post processing

At SMHI the raw data were converted to ASCII and tabulated in Excel®-files. Data collected during deployment and recovery were removed. Data obviously out of the expected range were excluded as well. No spikes were left out in temperature and salinity data records. Concerning flow measurements, some of the data were obviously erroneous, probably due to the vicinity of sea level changes or wave activity, and these were eliminated from the data set. Over all, removal of data was only conducted for the most obvious cases. Otherwise comments were added in the Excel®-files. Further analysis and interpretation will take place during a later stage of the project when data are used to build and calibrate a model of the survey area. Salinity was calculated from conductivity by a MATLAB® seawater toolbox routine (release 1.1) using the UNESCO recommendations as outlined in /1/.

4.5 Nonconformities

In this chapter a detailed description of unforeseen obstacles during the survey is given. The numbers in the last column in Table A4-1 (Appendix 4) refer to the incidents listed here.

4.5.1 PFM002653, northern boundary E

1) When the current metre was recovered, it was observed that a leakage had occurred in the battery container resulting in no registrations during the period February 8th to April 26th 2005. Battery containers are going to be refurbished to avoid future leakages.

4.5.2 PFM002655, inner point

2) During the period October 18th 2004 to January 4th 2005 the registered conductivities were faulty for no apparent reason. After recovery, the conductivity sensor was sent to the manufacturer.
3) The data registered at 6 m depth in the end of the last period contain gaps of up to 6 hours (during nighttime) for no apparent reason. As the oceanographic conditions at this station during this time of the year are fairly stable, missing data were filled in by hand.
4) Between January 4th and April 26th 2005 the conductivity sensor at 10 m depth didn't perform satisfactorily. This happened even though the sensor had been tested and calibrated by the manufacturer. Aging may be the reason why the sensor performed irregularly.

4.5.3 PFM002656, Öregrundssund

While nautical charts showed a depth of 20 m in the middle of the sound, the actual depth was considerably less. The instrument deployed isn't designed for depths larger than 20–30 m. Therefore it was decided to move the station to higher ground to be able to guarantee a certain quality of the velocity data. In hindsight one shouldn't have trusted in the charts but run a transect to decide the optimal position of the instrument.

5) Current metre measurements close to the sea surface are not reliable and excluded from the data delivered to SKB. According to the manual of NORTEKs ADP instrument, about 10% of the depth range should be excluded which in this case would be about 2.2 m.

6) According to the activity plan (AP PF 400-03-105) a current metre with temperature and salinity sensors should be installed at this position. The ordered equipment arrived delayed, and it was only then detected that the temperature and conductivity sensors were not compatible with the current metre. SMHI decided to deploy the current metre without attached temperature or conductivity sensors. This decision wasn't communicated with SKB. A later discussion made clear the importance of temperature and salinity measurements in this area. It was decided to add appropriate sensors to the rig during week 30.

7) On April 14th 2005 a boat got entangled in the mooring lines of the rig and the current metre was detached from the rig and lost. The stand including the temperature and conductivity sensors was brought ashore at the nearest harbour. On April 25th a diver recovered the current metre. All data up to April 14th are OK.

4.5.4 PFM002658, southern boundary

8) During the period October 18th 2004 to January 4th 2005 the CTD-probe at 10 m didn't work due to battery failure. The battery supplier was contacted to check on the delivery.

9) During the same period the CTD-probe at 18 m depth malfunctioned. Data stored during the last 10 days were not readable. The reason seemed to be an erroneous memory. The memory was sent to the manufacturer for check-up.

5 Results

All temperature and salinity data are presented as Excel®-diagrams in Appendix 2. Some examples are described here.

Figure 5-1 shows a typical annual cycle for sea water temperature. During late winter and spring the temperature rises due to solar radiation. Later, during early summer the water column gets layered with the temperature rising faster and higher in the upper layers than further down in the water column. This layering can be dissolved in shallower waters (water depth between 20 and 25 m) in late summer, especially when stronger winds or long warm periods are present. This can be seen not only in Figure 5-1 but also at the other stations in the investigated area (Appendix 2). During the autumn the temperature in the whole water column decreases to about 0°C where it remains during winter.

In this region salinity shows limited annual variation, see Figure 5-2. Typical values are between 5 to 5.5 psu. The most striking feature in the figures displayed here and in Appendix 2 is the sudden drop in salinity mainly in the upper part of the water column in late summer. This is not a physical feature but caused by barnacles growing on the probes. Unfortunately this means that there are no reliable surface salinity data during a two month period between roughly September 1st and November 1st.

Some examples of measured velocities are given below, Figures 5-3 and 5-4. Generally velocities are low (mostly less than 25 cm/s during autumn and up to 50 cm/s during winter) and show high directional variability. Data are either stored as direction and speed or as the north-south going part (east-west, up-down) of the current. It can clearly be seen in Figure 5-3 that the uppermost cells are influenced by waves and water level changes (see also 4.5.3 5).

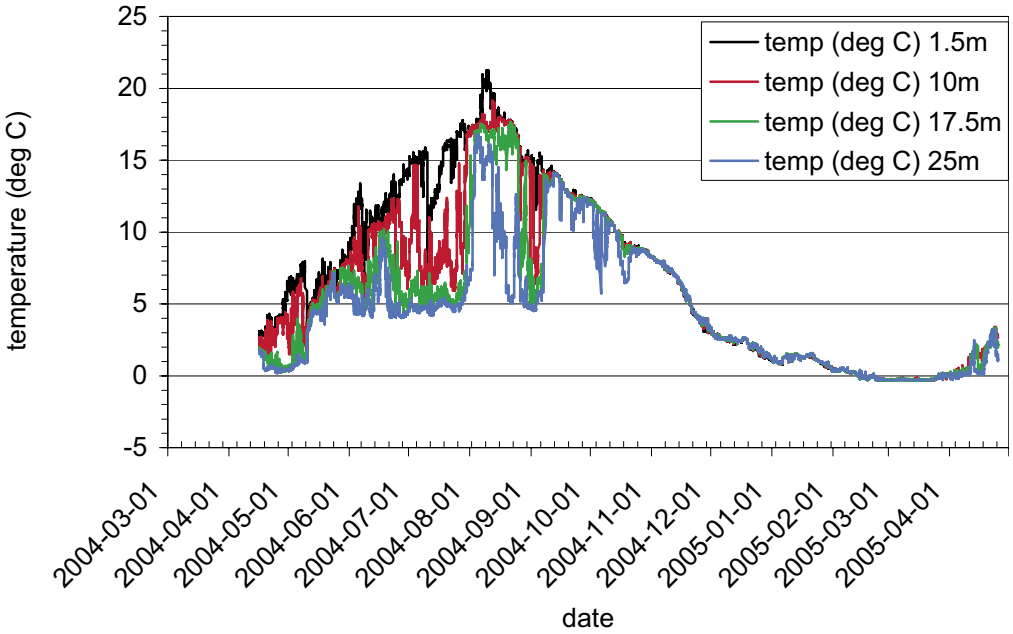

Figure 5-1. *Temperature at station PFM002653.*

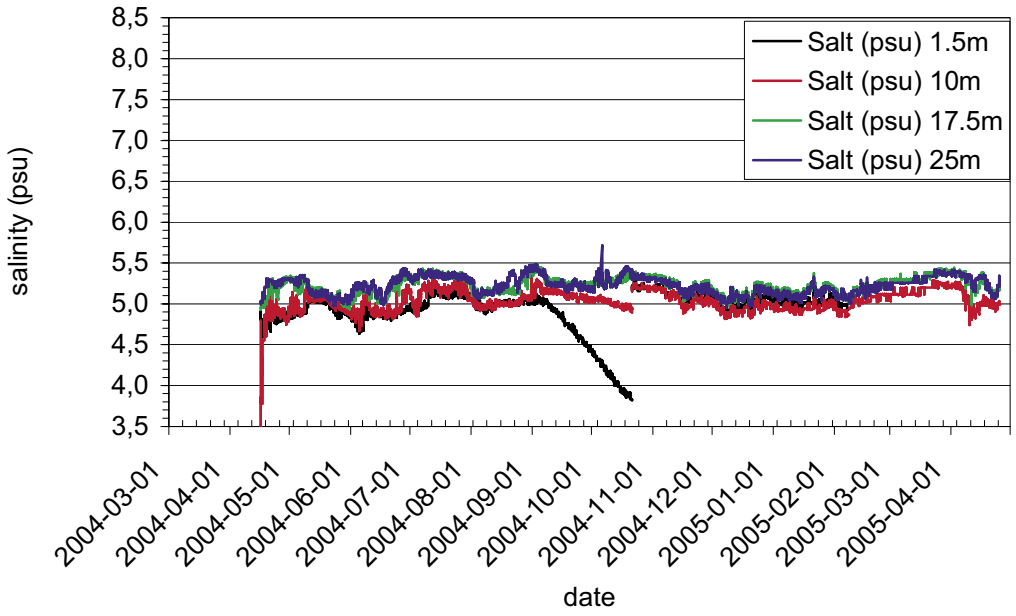

Figure 5-2. *Salinity at station PFM002653.*

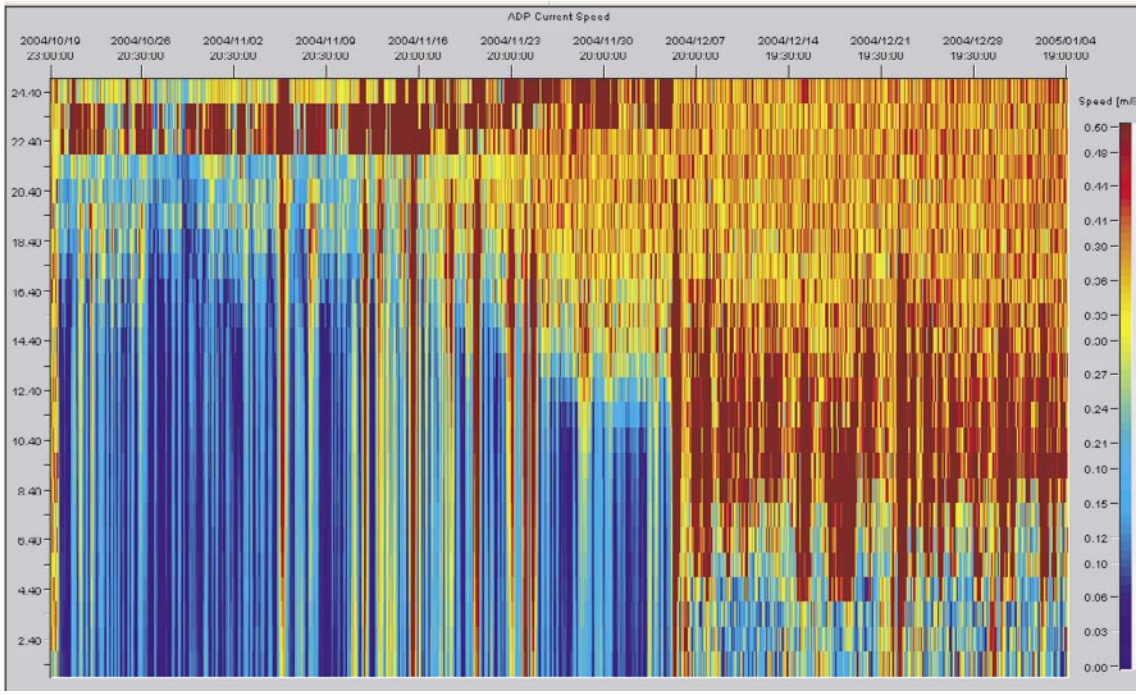

Figure 5-3. *Example of velocity measurements at PFM002656 between October 19th 2004 and January 4th 2005.*

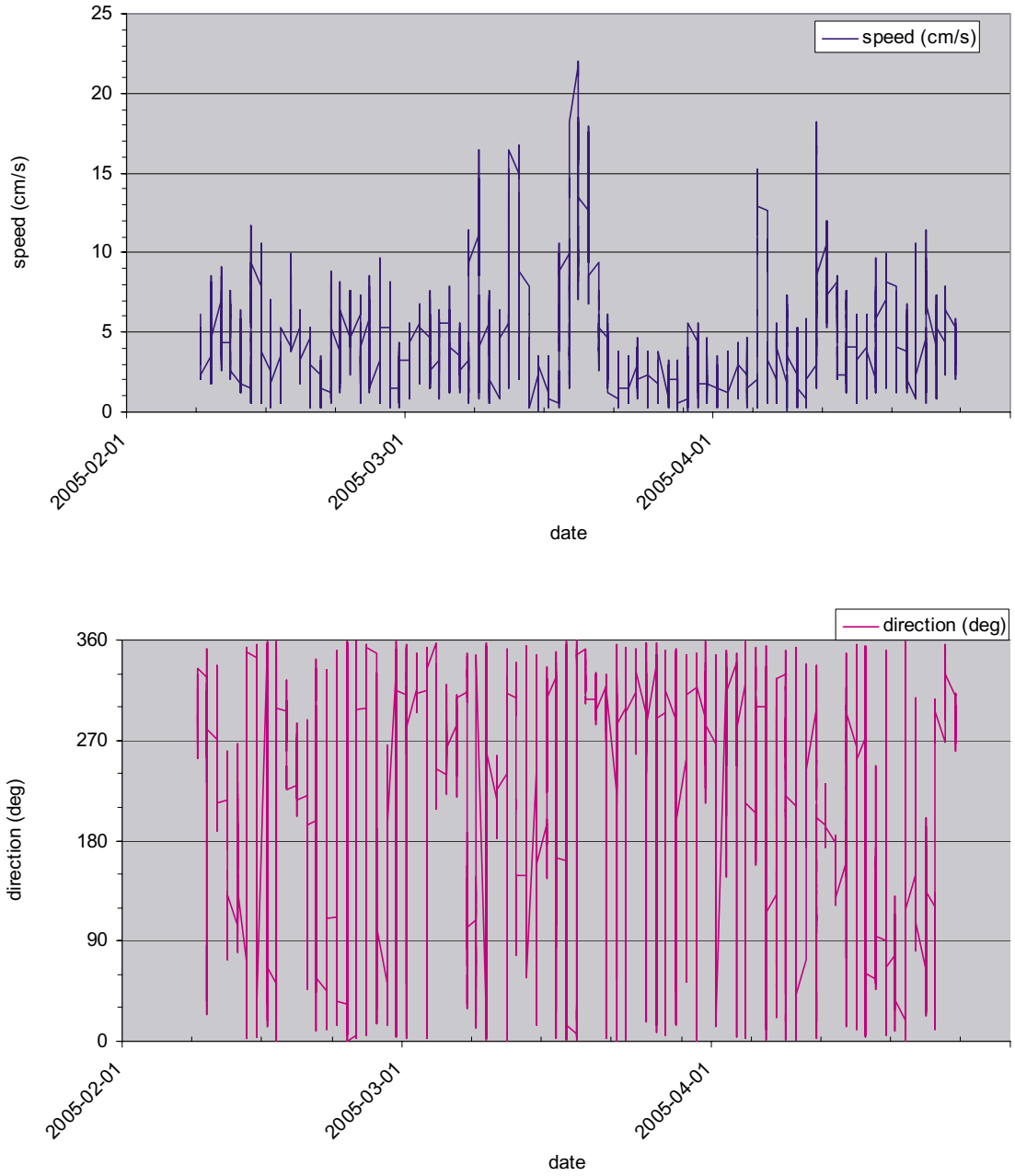

Figure 5-4. *Magnitude (top) and direction (bottom) of currents at PFM002654 between February 8th and April 25th 2005.*

Original data are stored in the SICADA database. Data are traceable by the Activity Plan number (AP PF 400-03-105). A list of file names and contents is given in Table 5-1 below.

Table 5-1. File names and contents.

Period	Station	File name	Contents
2004-04-16 to 2004-07-22	PFM002653	AaCTD 107 Fo11-1,5m.xls	T, cond, S
		AaCTD109 Fo11-17,5m.xls	T, cond, S
		AaCTD 108 Fo 11-10m.xls	T, cond, S
		AaCTD110 Fo11-25m.xls	T, cond, S
		ADCPBBSC Fo11-001.xls	velocity easting and northing
	PFM002654	S 3033 Fo12-12m.xls	T, cond, S
	PFM002655	AaCTD104 Fo13-1,5m.xls	T, cond, S
		AaCTD 105 Fo13-10m.xls	T, cond, S
		AaCTD 106 Fo13-17,5m.xls	T, cond, S
	PFM002656	ADP Fo14- 001.xls	velocity direction and speed
	PFM002657	T3034 Fo15 april-juli2004.xls	T
	PFM002658	AaCTD 101 Fo16-1,5m.xls	T, cond, S
		AaCTD102 Fo16-10m.xls	T, cond, S
		AaCTD103 Fo16-18m.xls	T, cond, S
2004-07-20 to 2004-10-21	PFM002653	AaCTD 111 Fo 11-1,5m.xls	T, cond, S
		AaCTD 112 Fo11-10m.xls	T, cond, S
		AaCTD 113 Fo 11-17,5m.xls	T, cond, S
		AaCTD114-Fo11-25m.xls	T, cond, S
		ADCPSC Fo 11-002.xls	velocity easting and northing
	PFM002654	S3035 Fo12-12m.xls	T, cond, S
	PFM002655	AaCTD118 Fo13-1,5m.xls	T, cond, S
		AaCTD119 Fo13-10m.xls	T, cond, S
		AaCTD 120 F013-17,5m.xls	T, cond, S
	PFM002656	ADP Fo14- 002.xls	velocity direction and speed
		Seabird Fo14-25m.xls	T, cond, S
	PFM002657	T3037 Fo15.xls	T
	PFM002658	AaCTD 115 Fo16-1.5m.xls	T, cond, S
		AaCTD 116 Fo16-10m.xls	T, cond, S
		AaCTD 117 Fo16-18m.xls	T, cond, S
2004-10-19 to 2005-02-08	PFM002653	AaCTD 126 Fo 11-1,5m.xls	T, cond, S and p
		AaCTD 127 Fo 11-10m.xls	T, cond, S
		AaCTD 128 Fo 11-17,5m.xls	T, cond, S
		AaCTD 129 Fo11-25m.xls	T, cond, S
	PFM002654	AaS S3037 Fo12-12m.xls	velocity dir. and speed, T, cond, S and p
	PFM002655	AaCTD 121 Fo13-1,5m.xls	T, cond, S
		AaCTD122 Fo 13-10m.xls	T, cond, S
		AaCTD123 Fo 13-17,5m.xls	T, cond, S
	PFM002656	ADP Fo14-003.xls	velocity easting and northing
		FO141020Seabird.xls	T, cond, S
	PFM002657	AaT 3039 Fo15 1m-27m.xls	T

Period	Station	File name	Contents
	PFM002658	AaCTD 124 Fo 16-1,5m.xls	T, cond, S
		AaCTD125 Fo 16-18m.xls	T, cond, S
2005-01-04 to 2005-04-26	PFM002653	Fo11-4_AaCTD-130_10m.xls	T, cond, S
		Fo11-4_AaCTD-131_17.5m.xls	T, cond, S
		Fo11-4_AaCTD-132_25m.xls	T, cond, S
	PFM002654	Fo12-4_AaS3040_15m.xls	velocity dir. and speed, T, cond, S and p
	PFM002655	Fo13-4_AaCTD-133_6m.xls	T, cond, S
		Fo13-4_AaCTD-134_10m.xls	T
		Fo13-4_AaCTD-135_17.5m.xls	T, cond, S
2005-01-04 to 2005-04-26	PFM002656	FO14-4_ADP.xls	velocity easting and northing
		Fo14-4_SBE37_24m.xls	T, cond, S
	PFM002658	Fo16-4_AaCTD-136_6m.xls	T, cond, S
		Fo16-4_AaCTD-137_10m.xls	T, cond, S
		Fo16-4_AaCTD-138_18m.xls	T, cond, S

To be able to evaluate the measured time series, comparative measurements were conducted. At positions where temperature and salinity were measured frequently, CTD-casts were done when instruments were recovered for data collection. Additional velocity transects were carried out along the boundaries of the survey area. Appendix 3 shows plots of the CTD-casts grouped after position. Times and distances along the transects are found in Table 5-2.

Table 5-2. Transects, start and stop positions and file names.

Filename	Description	Date	Start N (RT90 2.5 gon V)	E (RT90 2.5 gon V)	Stop N (RT90 2.5 gon V)	E (RT90 2.5 gon V)
Fors042	northern boundary	2004-04-16	6715822	1640589	6715458	1636919
Fors074	northern boundary	2004-07-21	6715565	1639920	6715514	1636940
Fors111	northern boundary	2004-11-10	6715610	1640630	6715375	1634656
Fors110	PFM002653	2004-11-10	6715603	1639728	6715602	1639727
Fors001	northern boundary	2005-04-26	6715600	1640605	6715449	1636672
Fo27001	Öregrundsund SW-NE	2005-04-27	6693797	1647273	6694214	1646840
Fo27003	Öregrundsund NE-SW	2005-04-27	6694103	1647260	6693778	1646803
Fo27005	Öregrundsund SW-NE	2005-04-27	6693772	1646804	6694109	1647260
Fo27007	Öregrundsund SW-NE	2005-04-27	6694114	1647249	6693778	1646803
Fo27008	Öregrundsund NE-SW	2005-04-27	6693778	1646803	6694081	1646332
Fo28000	eastern boundary S-N	2005-04-27	6681069	1662512	6687106	1662244

References

/1/ **Fofonoff N P, Millard Jr R C, 1983.** Algorithms for computation of fundamental properties of seawater. Unesco technical papers in marine sciences 44.

Appendix 1

Rigs

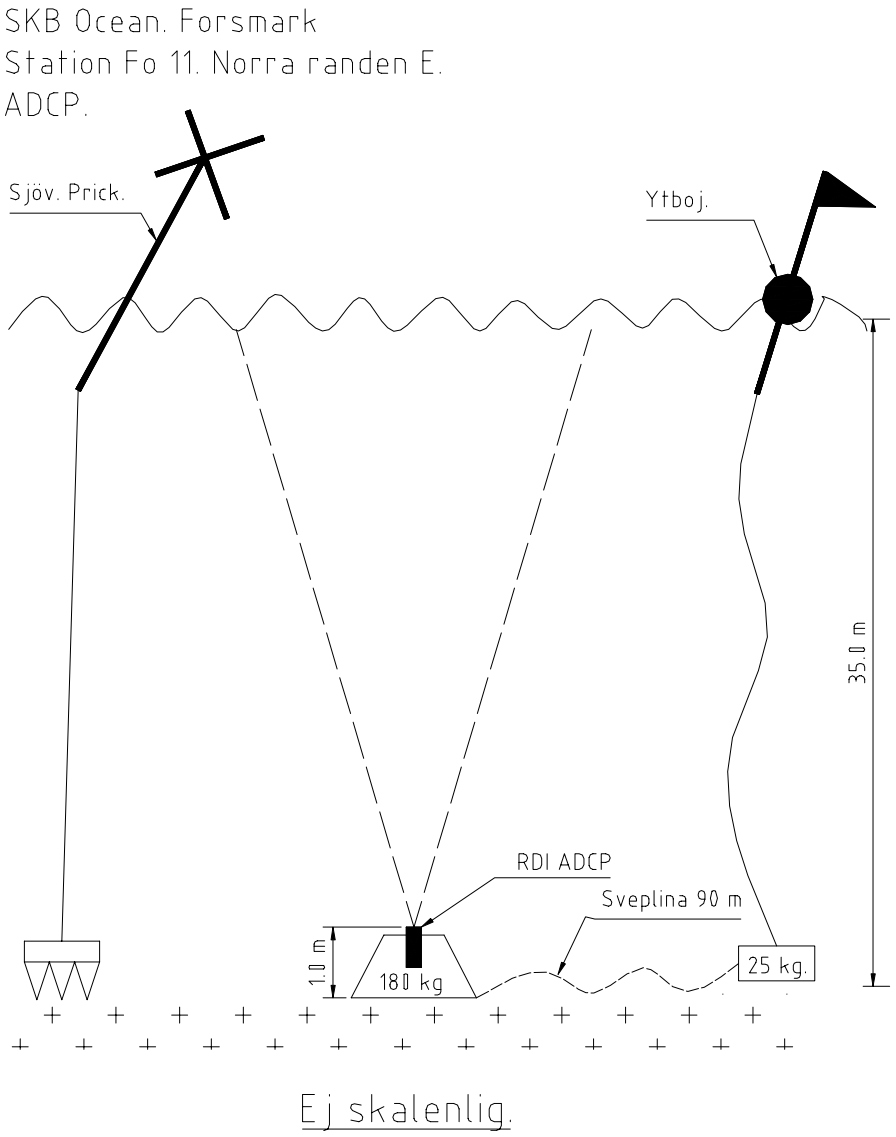

Figure A1-1. *ADCP rig at position PFM002653, not to scale.*

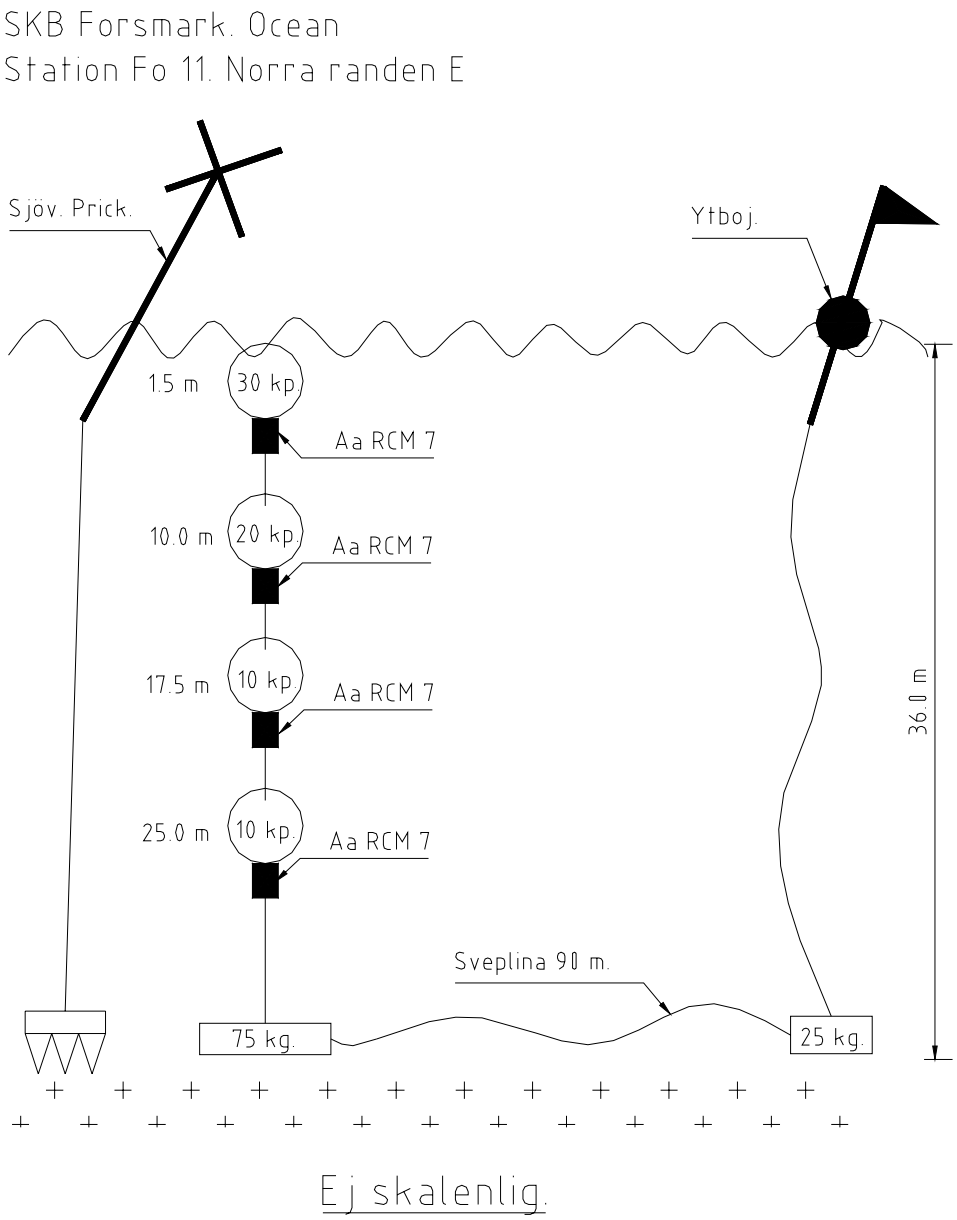

Figure A1-2. *Temperature and conductivity sensors at position PFM002653, not to scale.*

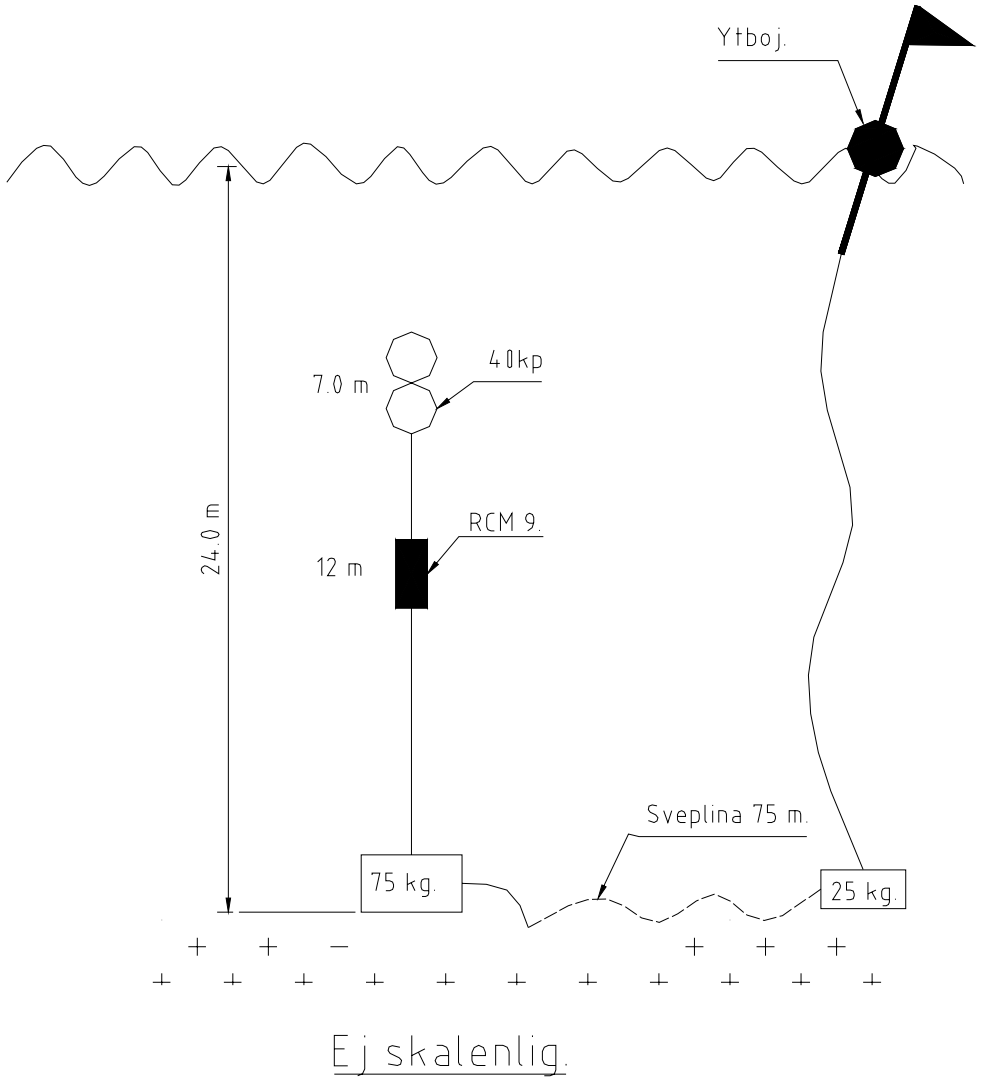

Figure A1-3. *Current, temperature and conductivity sensors at position PFM002654, not to scale.*

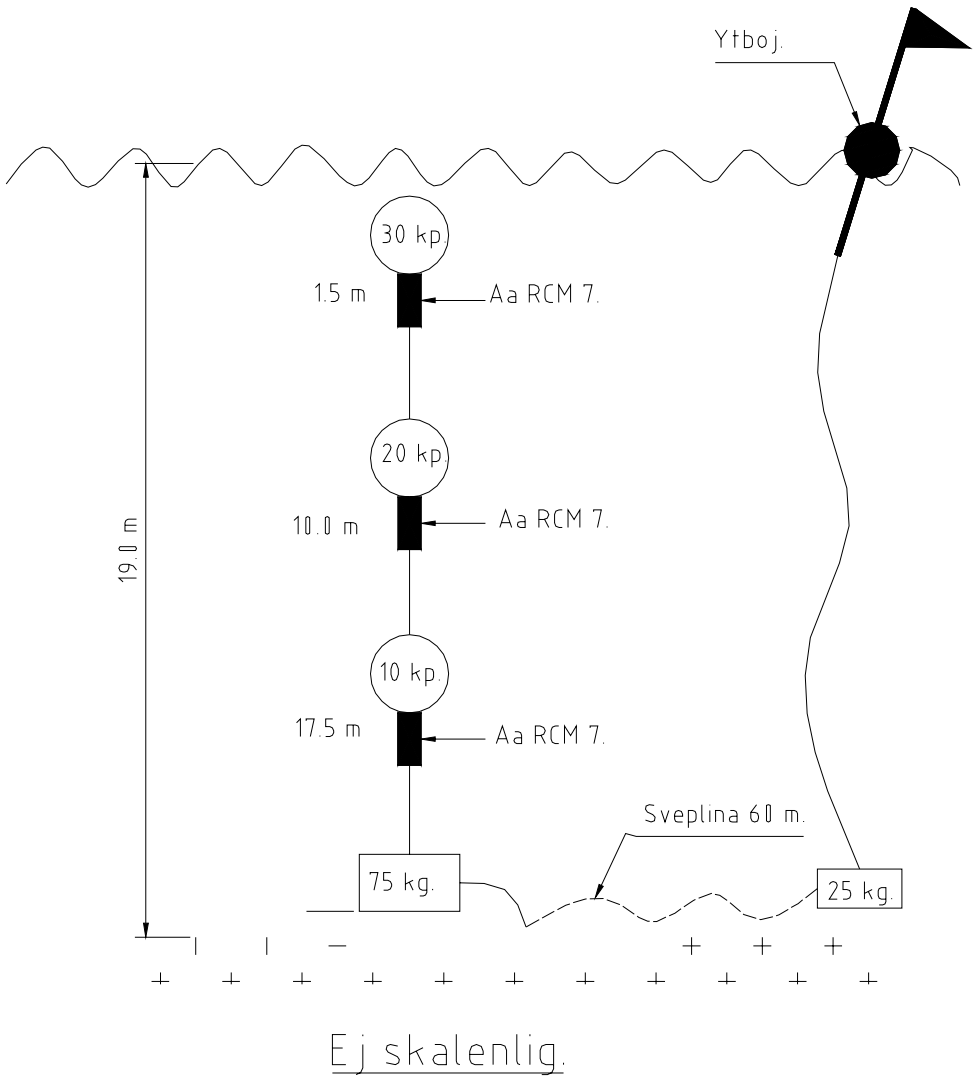

Figure A1-4. *Temperature and conductivity sensors at position PFM002655, not to scale.*

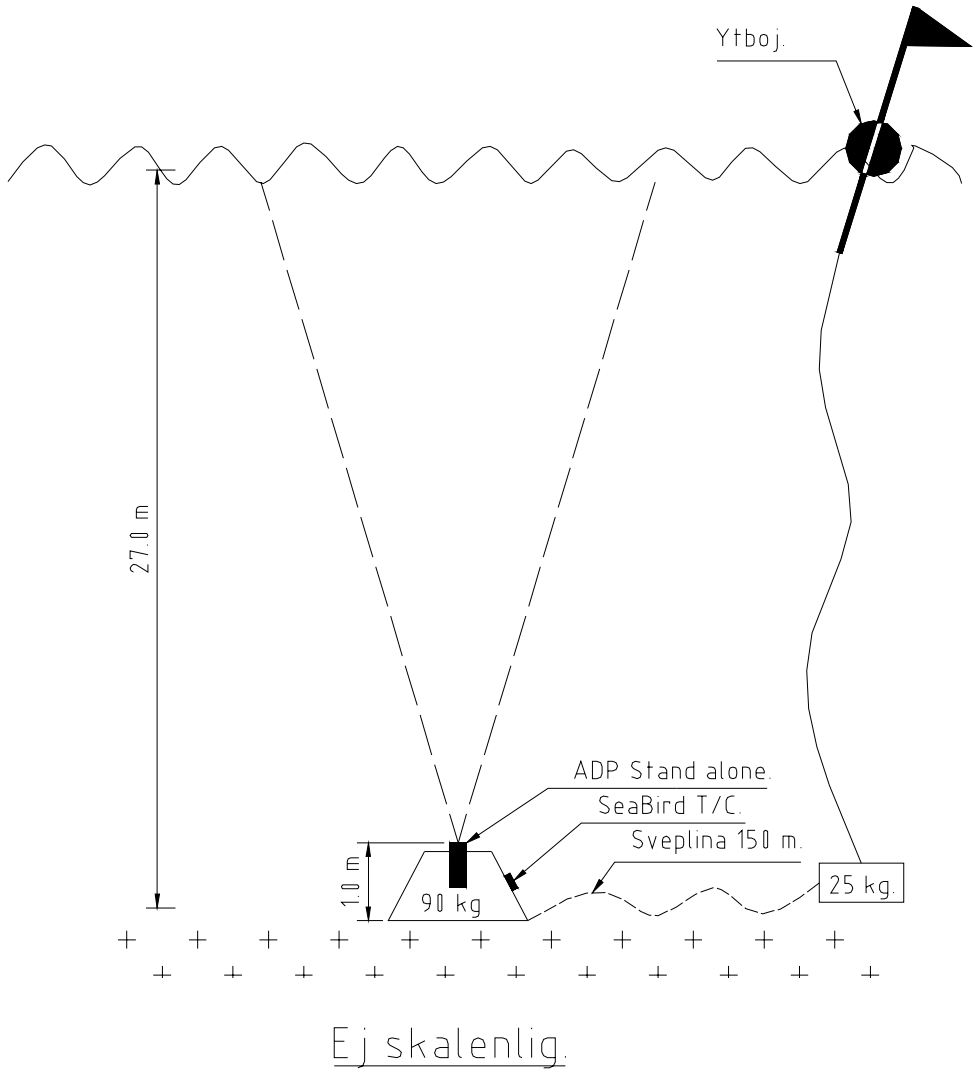

Figure A1-5. *ADCP rig at position PFM002656, not to scale.*

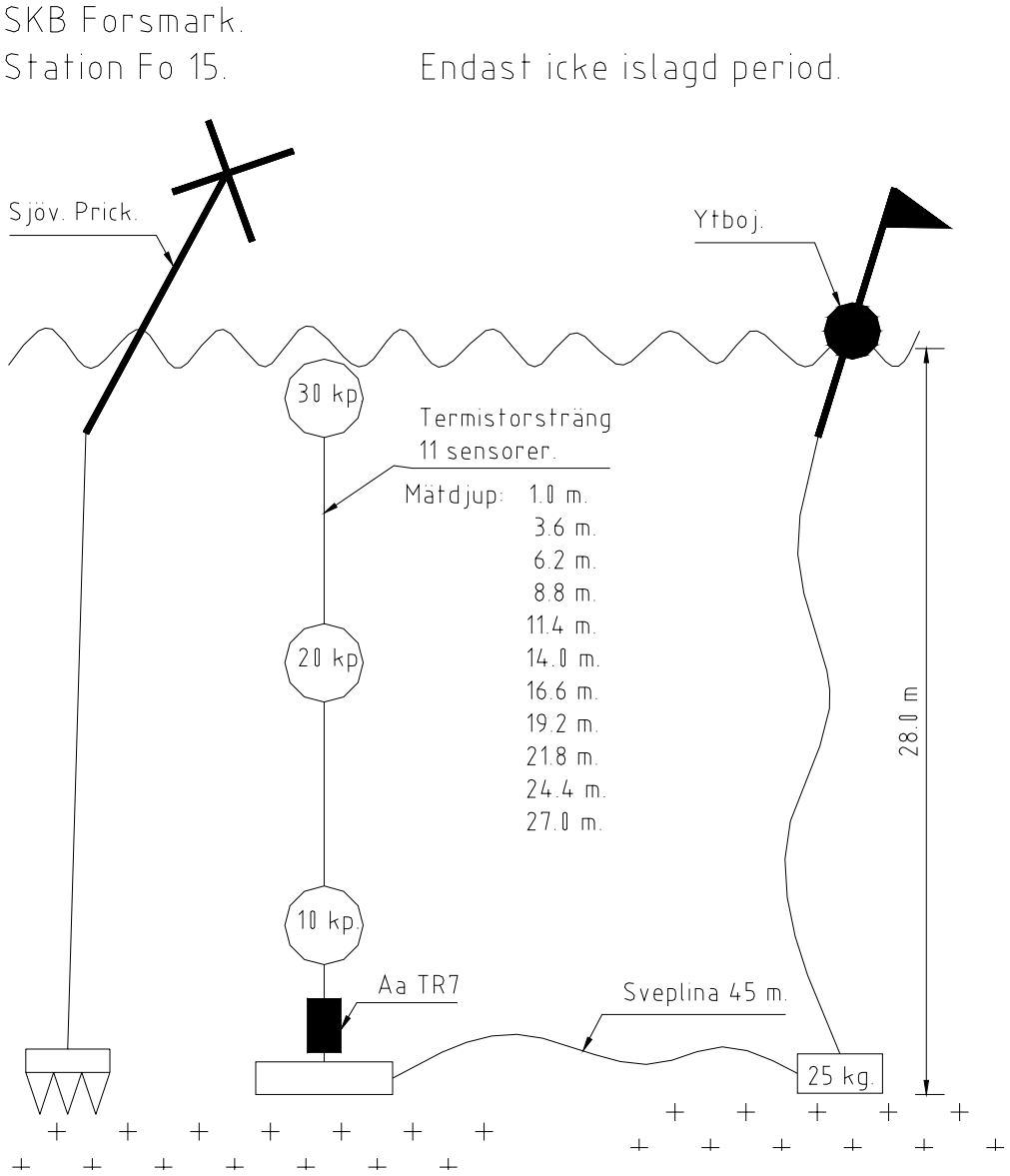

Figure A1-6. *Temperature rig at position PFM002657, not to scale.*

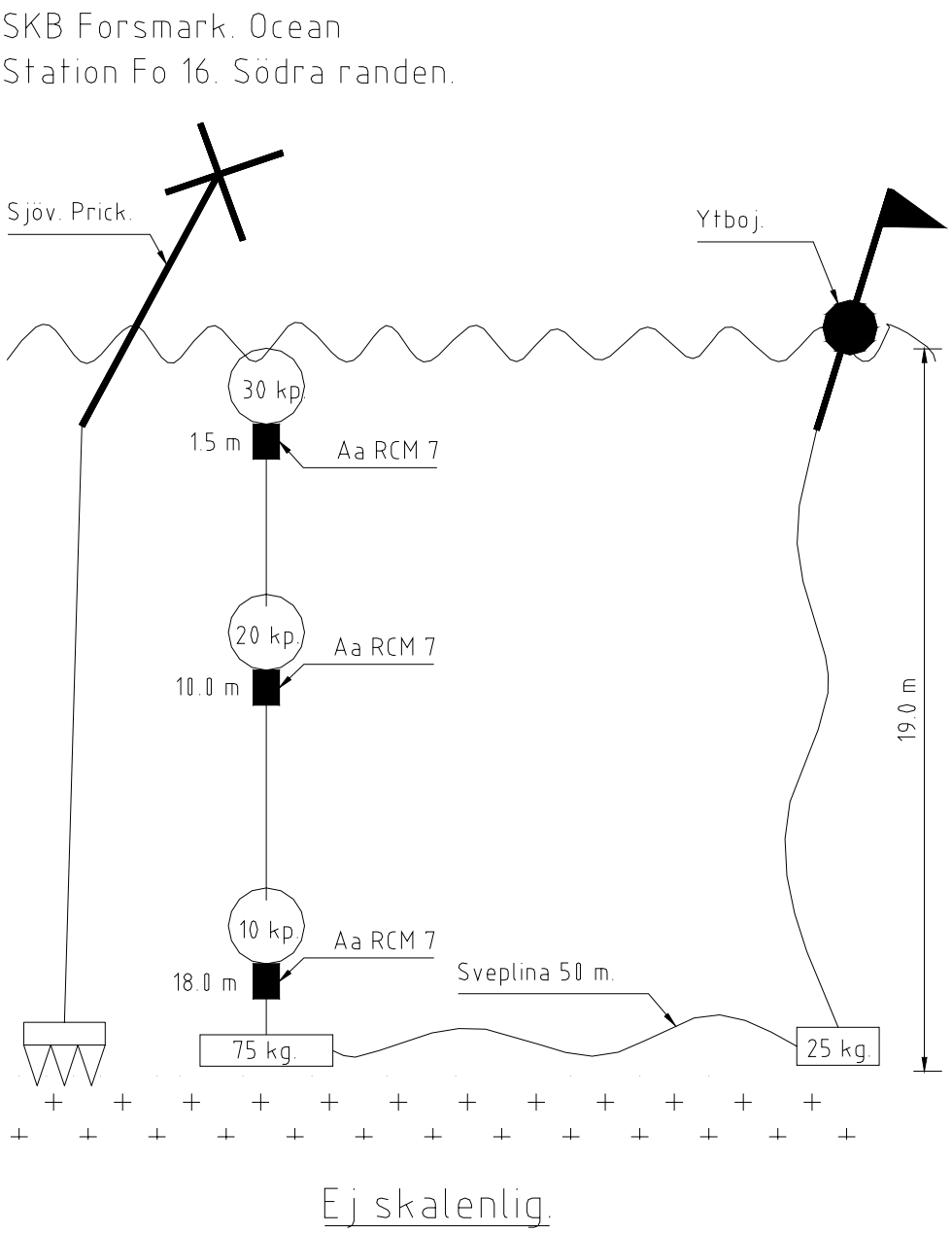

Figure A1-7. *Temperature and conductivity sensors at position PFM002658, not to scale.*

Appendix 2

Temperature and salinity plots

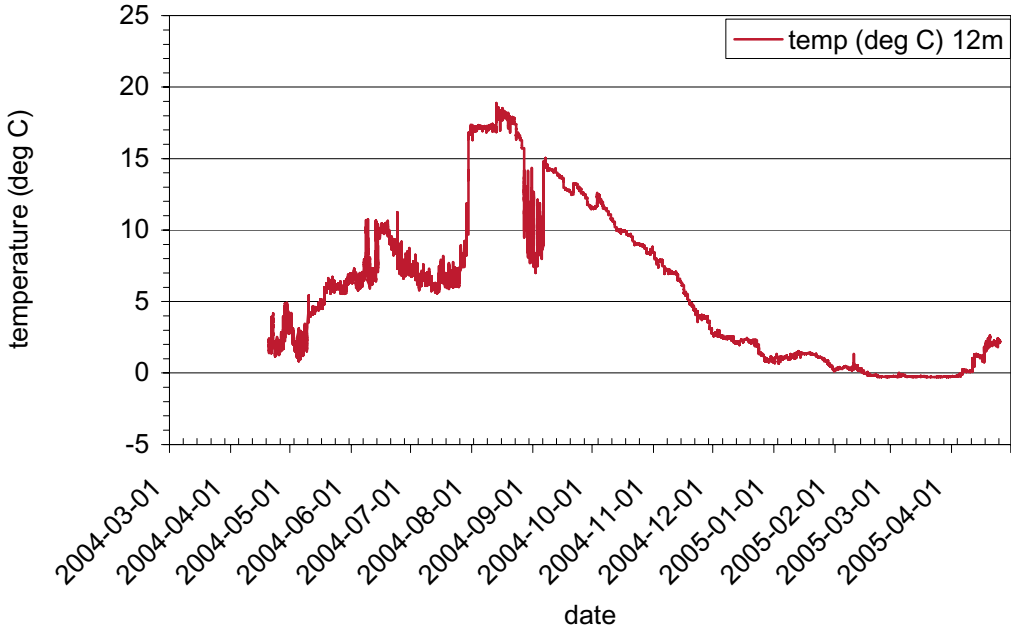

Figure A2-1. *Temperature at station PFM002654.*

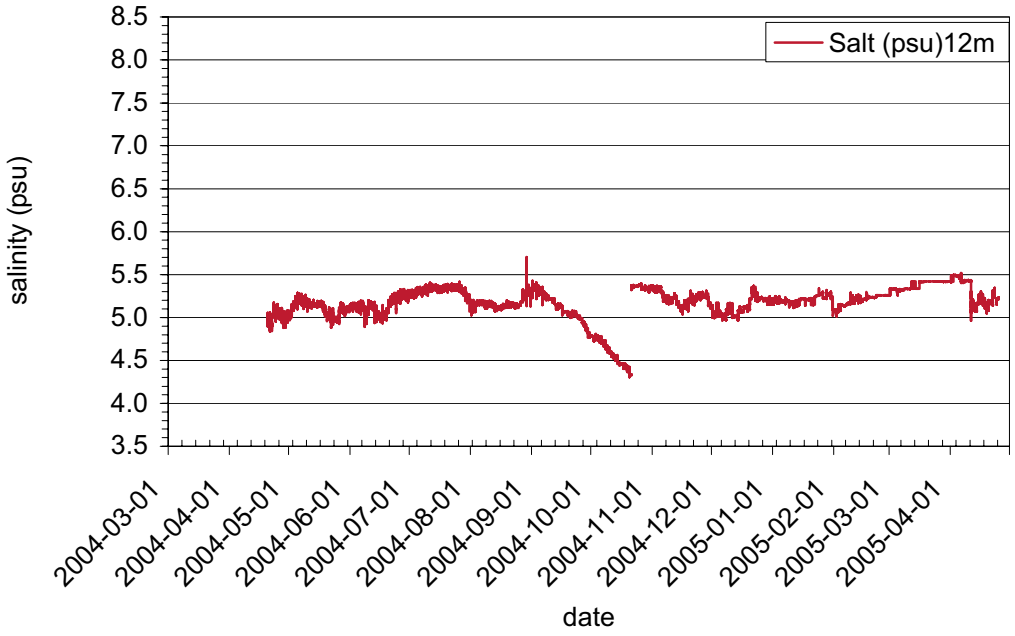

Figure A2-2. *Salinity at station PFM002654.*

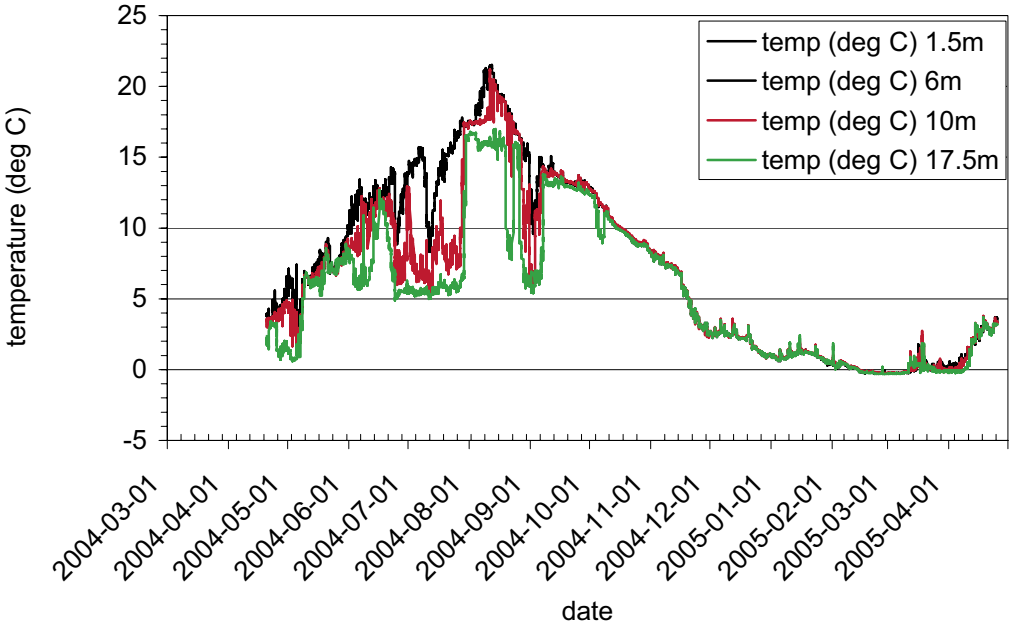

Figure A2-3. *Temperature at station PFM002655.*

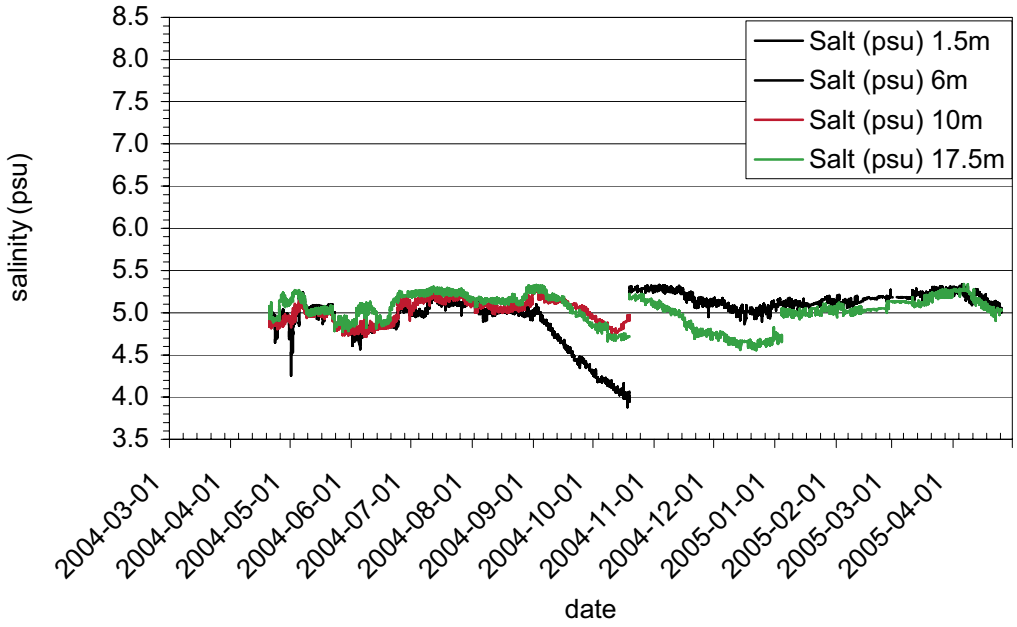

Figure A2-4. *Salinity at station PFM002655.*

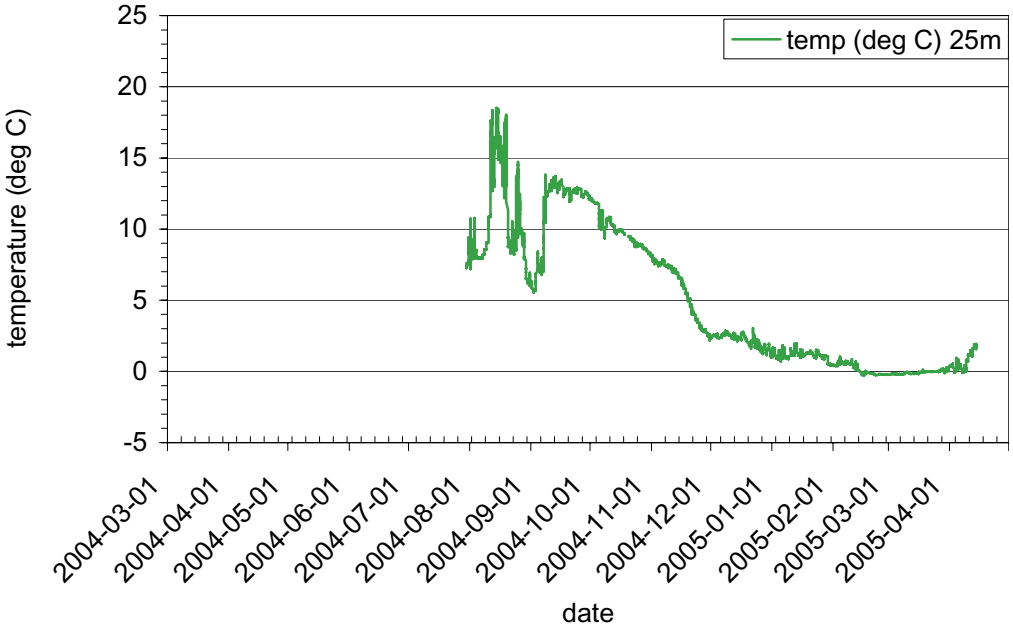

Figure A2-5. *Temperature at station PFM002656.*

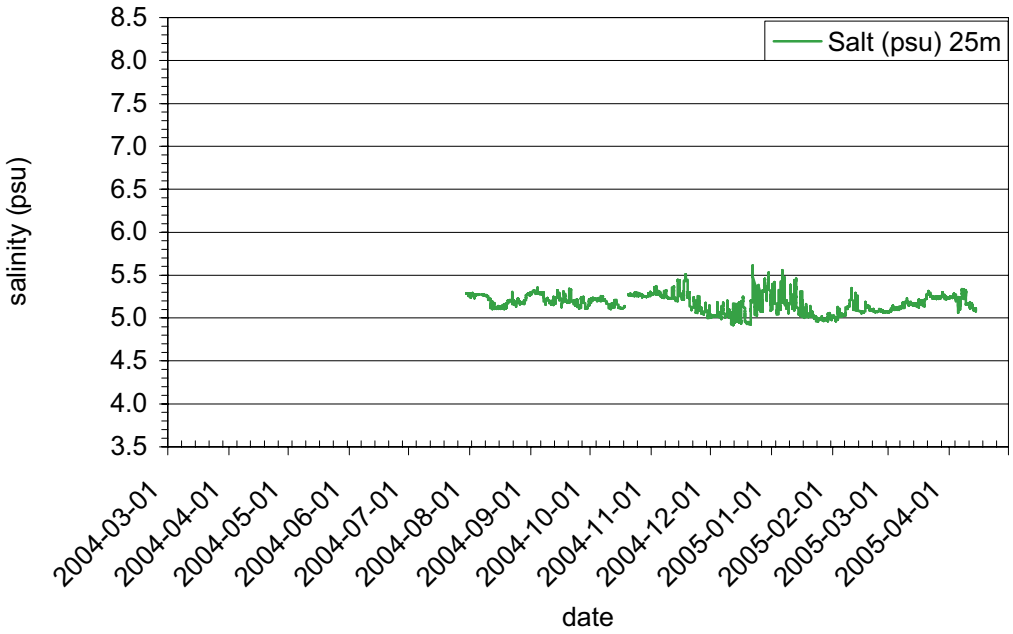

Figure A2-6. *Salinity at station PFM002656.*

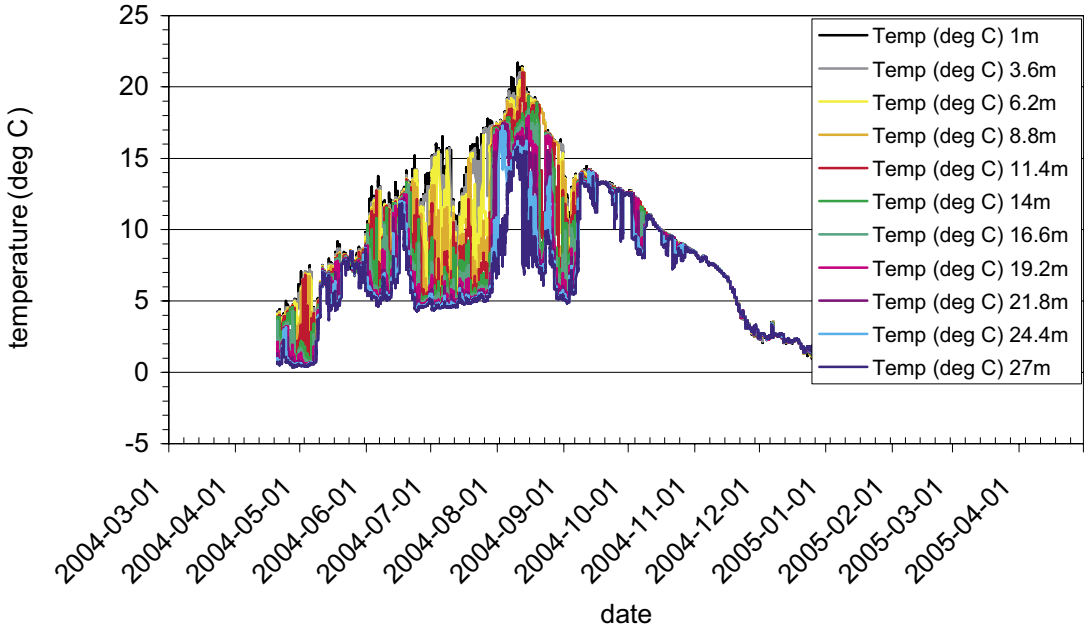

Figure A2-7. *Temperature at station PFM002657.*

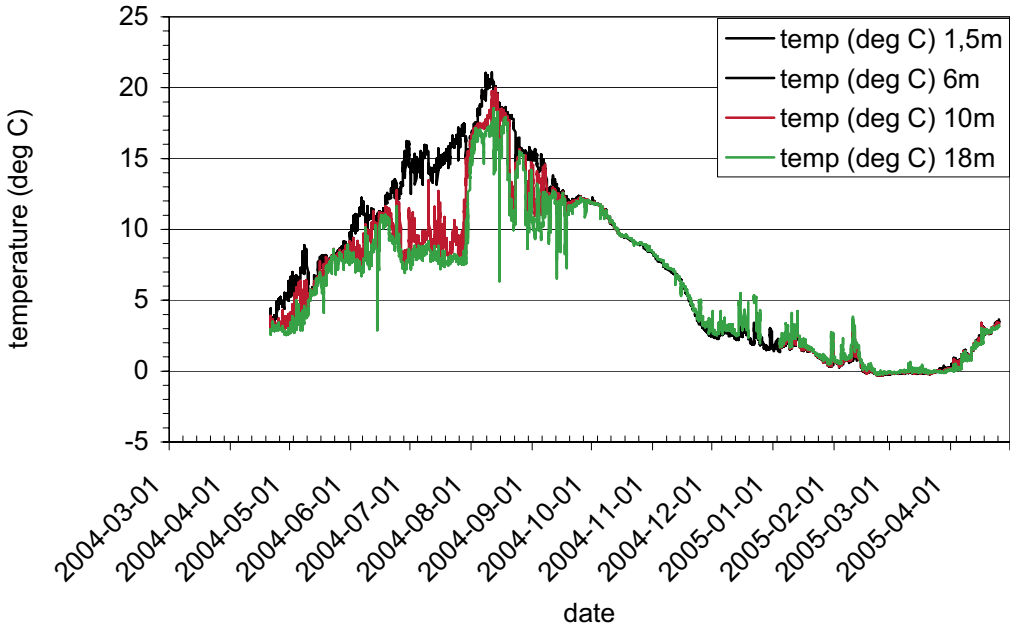

Figure A2-8. *Temperature at station PFM02658.*

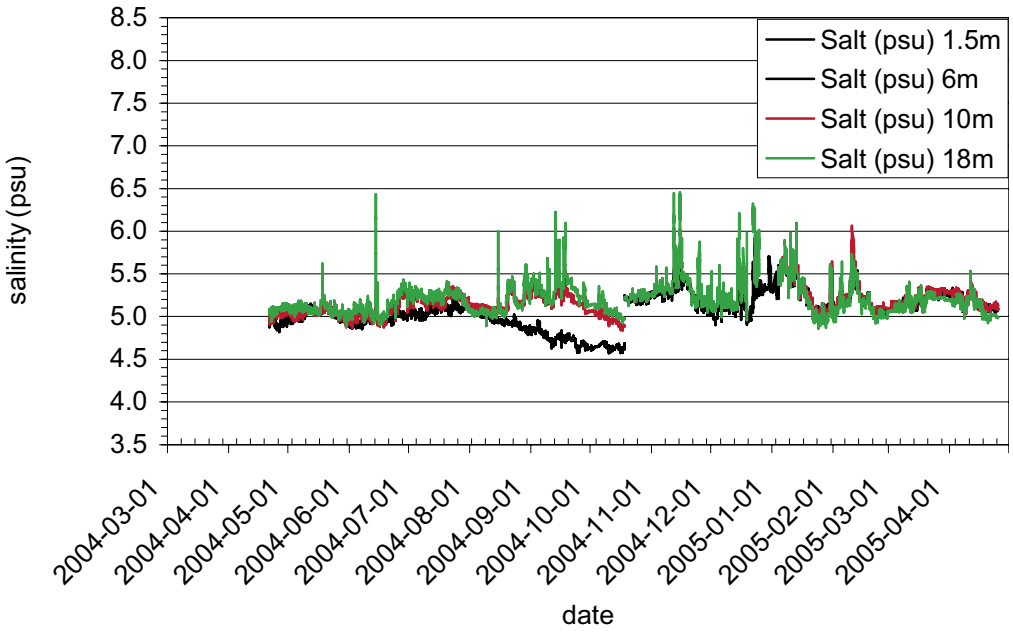

Figure A2-9. *Salinity at station PFM002658.*

Appendix 3

CTD-casts

For comparison with the continuously measured temperatures and salinities, a CTD-probe was frequently lowered from the boat when equipment was deployed, checked or when memory was read out during the campaign. Data from these measurements are displayed in this appendix grouped after station (Figures A3-1 to A3-6). Sometimes two CTD casts are conducted at the same day, the first one usually was done when the rig was recovered, the second one when it once again was deployed. In the method description (SKB MD 364.0009) the required accuracies for temperature and salinity are given as 0.1°C and 0.1 psu respectively. The Tables A3-1 to A3-6 list temperature and salinity values as measured at a station at the beginning and end of a period as close in time to the CTD casts as possible (headings PFM0026*xx*-S, PFM0026*xx*-T respectively). Columns marked CTD-S and CTD-T show temperature and salinity as measured by the CTD probe at the same depth as the probes on the rig ore close to it. Comparision between results from the CTD-probe and data collected continuously shows that these accuracies were achieved in most cases. If they aren't that doesn't necessary mean that instruments are faulty. Oeason may be barnacles on the salinity sensor as repeatedly was the case at station PFM002654. Strong layering may be a reason for higher differences in temperature measurements. An exact correlation of times and depths isn't possible at all times, and with strong layering circumstances can vary on short space and time scales.

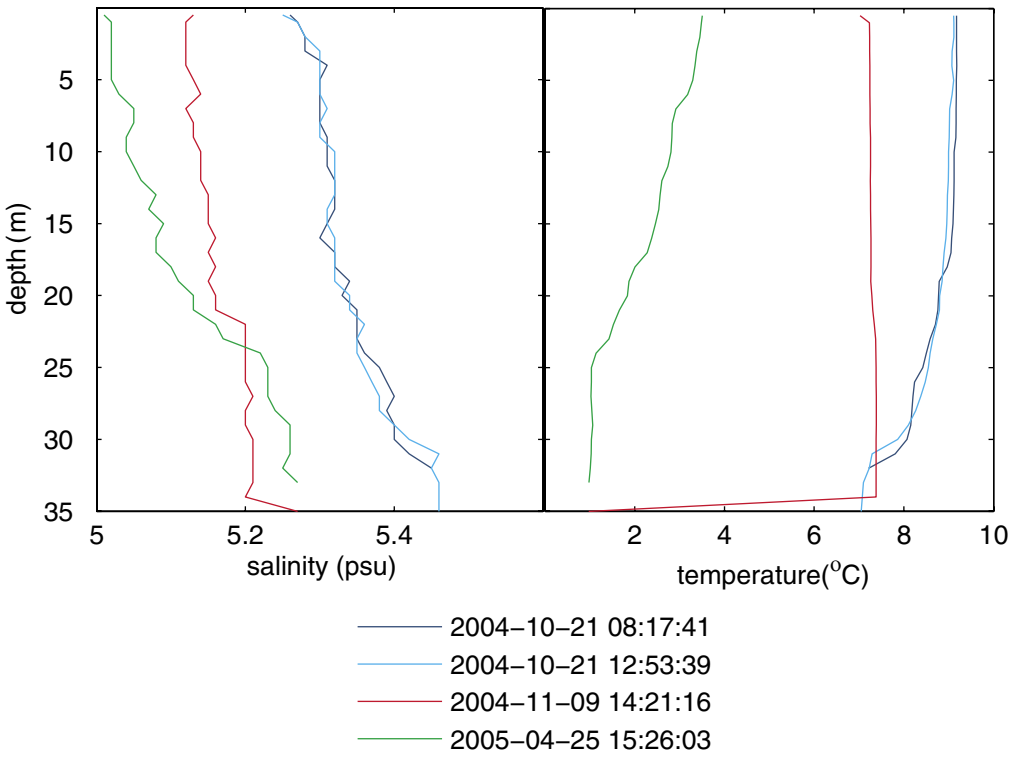

Figure A3-1. *Salinity and temperature versus depth at station PFM002653, northern boundary E.*

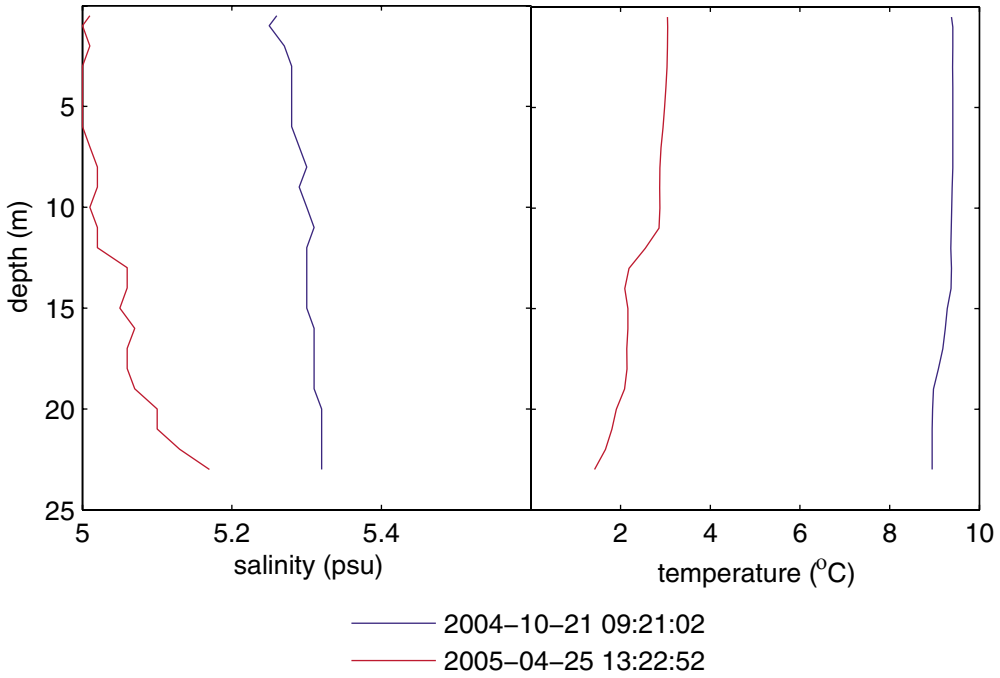

Figure A3-2. *Salinity and temperature versus depth at station PFM002654, northern boundary W.*

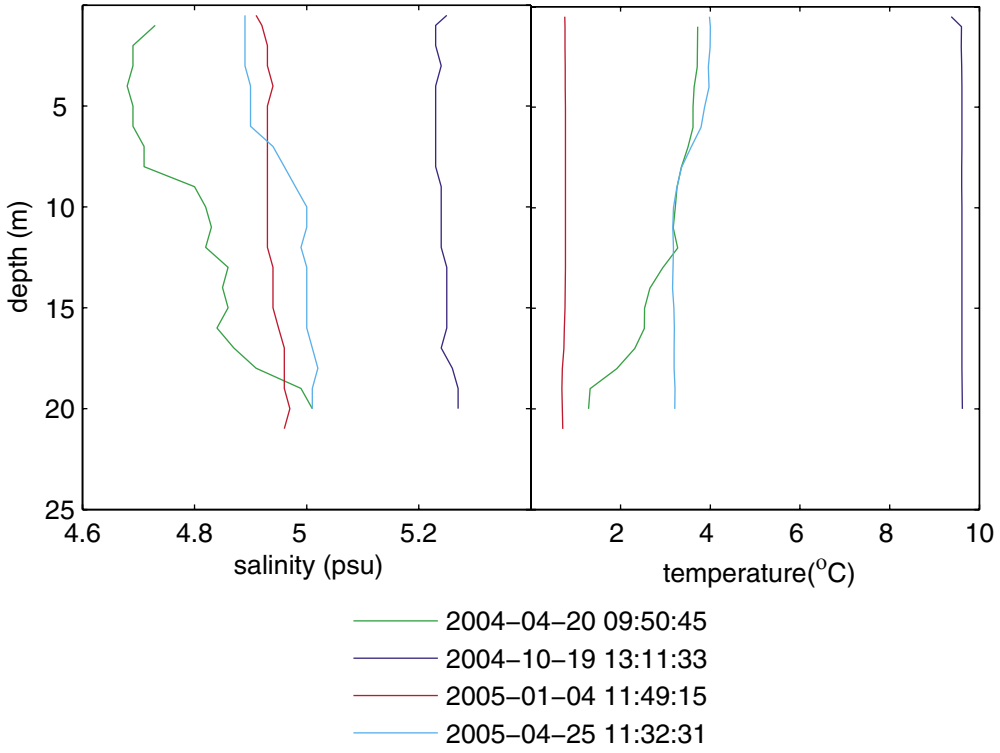

Figure A3-3. *Salinity and temperature versus depth at station PFM002655, inner point.*

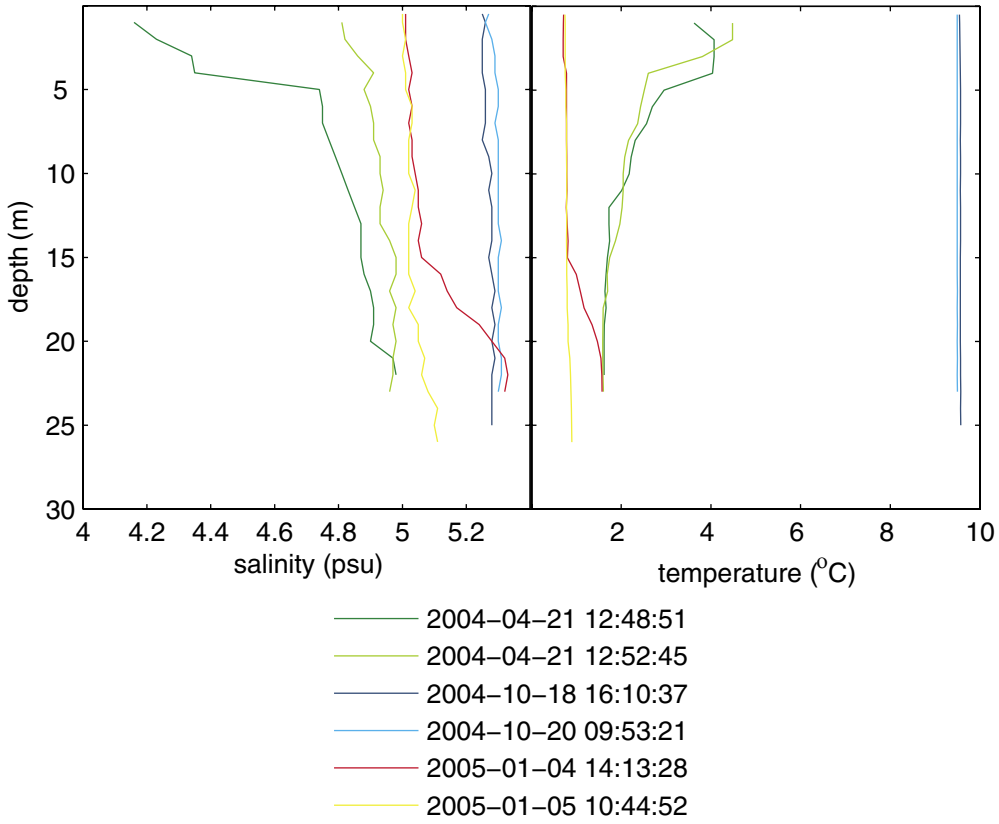

Figure A3-4. *Salinity and temperature versus depth at station PFM002656, Öregrundsund.*

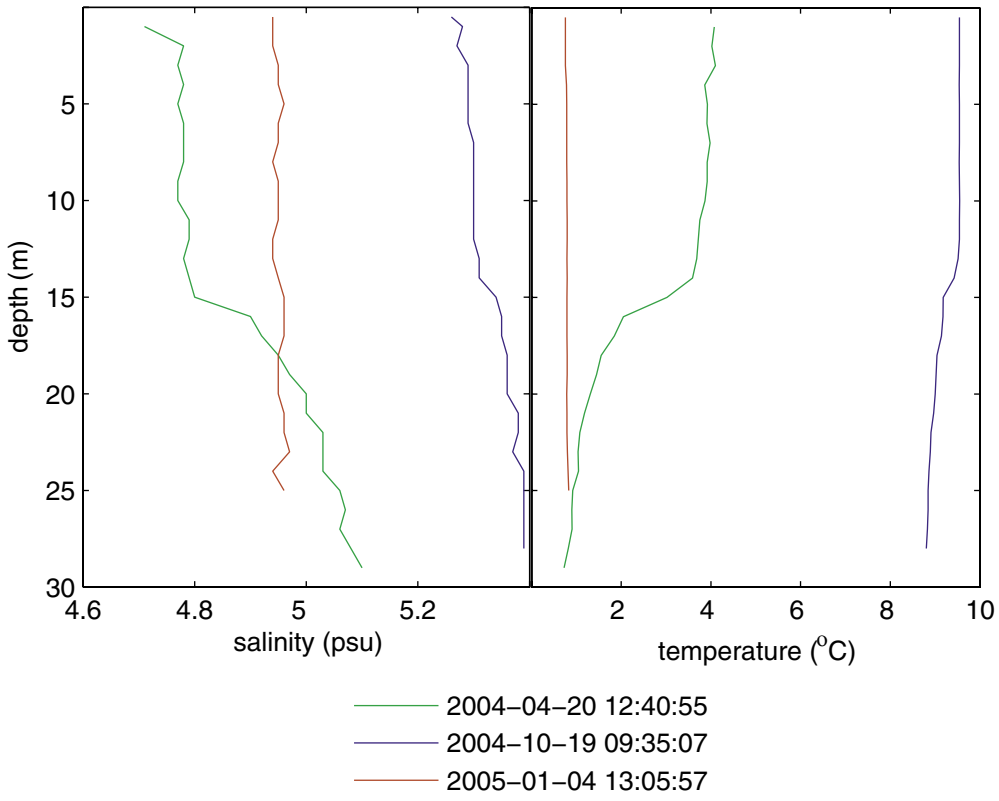

Figure A3-5. *Salinity and temperature versus depth at station PFM002657, no ice cover.*

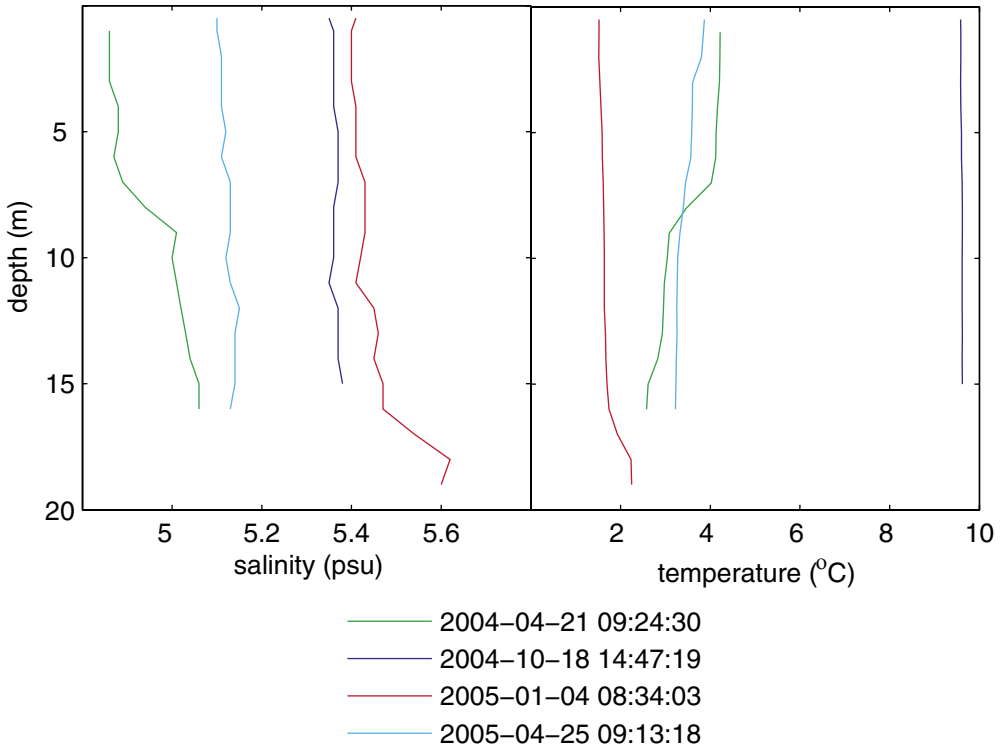

Figure A3-6. *Salinity and temperature versus depth at station PFM002658, southern boundary*

Table A3-1. Comparison of temperature and salinity as measured by CTD/rig respectively at approximately identical times and depth. Times and depths given are for the CTD probe deployed. Each small table corresponds to one line in Figure A3-1. Measurements conducted at station PFM002653.

2004-10-21 08:17	Depth	CTD-S	PFM002653-S	CTD-T	PFM002653-T
	1	5.270	–	9.18	–
	10	5.310	–	9.12	–
	17	5.320	–	9.05	–
	25	5.380	–	8.42	–

2004-10-21 12:53	Depth	CTD-S	PFM002653-S	CTD-T	PFM002653-T
	1	5.270	5.19	9.11	9.21
	10	5.320	5.20	9.00	9.19
	17	5.320	5.32	8.90	8.89
	25	5.360	5.35	8.55	8.44

2004-11-09 14:21	Depth	CTD-S	PFM002653-S	CTD-T	PFM002653-T
	1	5.120	5.09	7.23	7.24
	10	5.140	5.10	7.26	7.25
	17	5.150	5.23	7.27	7.32
	25	5.200	5.25	7.38	7.37

2005-04-25 15:26	Depth	CTD-S	PFM002653-S	CTD-T	PFM002653-T
	1	5.020	–	3.49	–
	10	5.040	4.9898	2.81	2.91
	17	5.080	5.1871	2.28	2.23
	25	5.230	5.2706	1.04	1.02

Table A3-2. Comparison of temperature and salinity as measured by CTD/rig respectively at approximately identical times and depth. Times and depths given are for the CTD probe deployed. Each small table corresponds to one line in Figure A3-2. Measurements conducted at station PFM002654.

2004-10-21 09:21	Depth	CTD-S	PFM002654-S	CTD-T	PFM002654-T
	12	5.300	4.335	9.36	9.46
	15	5.300		9.29	

2005-04-25 13:22	Depth	CTD-S	PFM002654-S	CTD-T	PFM002654-T
	12	5.020		2.55	
	15	5.050	5.228	2.16	2.17

Table A3-3. Comparison of temperature and salinity as measured by CTD/rig respectively at approximately identical times and depth. Times and depths given are for the CTD probe deployed. Each small table corresponds to one line in Figure A3-3. Measurements conducted at station PFM002655.

2004-04-20 09:50	Depth	CTD-S	PFM002665-S	CTD-T	PFM002665-T
	1	4.730	4.912	3.72	3.82
	10	4.820	4.864	3.22	3.17
	17	4.870	4.975	2.32	2.38

2004-10-19 13:11	Depth	CTD-S	PFM002665-S	CTD-T	PFM002665-T
	1	5.230	–	9.60	9.61
	10	5.240	–	9.61	9.67
	17	5.240	–	9.61	9.50

2005-01-04 11:49	Depth	CTD-S	PFM002665-S	CTD-T	PFM002665-T
	1	4.920	5.098	0.76	0.73
	10	4.930	–	0.77	0.80
	17	4.960	4.653	0.74	0.71

2005-04-25 11:32	Depth	CTD-S	PFM002665-S	CTD-T	PFM002665-T
	6	4.900	5.015	3.79	3.61
	10	5.000	–	3.18	3.28
	17	5.010	5.031	3.19	3.20

Table A3-4. Comparison of temperature and salinity as measured by CTD/rig respectively at approximately identical times and depth. Times and depths given are for the CTD probe deployed. Each small table corresponds to one line in Figure A3-4. Measurements conducted at station PFM002656.

2004-04-21 12:48	Depth	CTD-S	PFM002656-S	CTD-T	PFM002656-T
	22	4.980	–	1.62	–
	23				
	24				
	25				
	26				

2004-04-21 12:52	Depth	CTD-S	PFM002656-S	CTD-T	PFM002656-T
	22	4.970	–	1.60	–
	23	4.960	–	1.60	–
	24				
	25				
	26				

2004-10-18 16:10	Depth	CTD-S	PFM002656-S	CTD-T	PFM002656-T
	22	5.280		9.57	
	23	5.280		9.57	
	24	5.280		9.57	
	25	5.280	5.140	9.57	9.59
	26				

2004-10-20 09:53	Depth	CTD-S	PFM002656-S	CTD-T	PFM002656-T
	22	5.310		9.49	
	23	5.300	5.273	9.50	9.53
	24				
	25				
	26				

2005-01-04 14:13	Depth	CTD-S	PFM002656-S	CTD-T	PFM002656-T
	22	5.330		1.57	
	23	5.320	5.330	1.57	1.50
	24				
	25				
	26				

2005-01-05 10:44	Depth	CTD-S	PFM002656-S	CTD-T	PFM002656-T
	22	5.060		0.87	
	23	5.080		0.88	
	24	5.110	5.134	0.89	0.81
	25	5.100		0.89	
	26	5.110		0.90	

Table A3-5. Comparison of temperature and salinity as measured by CTD/rig respectively at approximately identical times and depth. Times and depths given are for the CTD probe deployed. Each small table corresponds to one line in Figure A3-5. Measurements conducted at station PFM002657.

	Depth	CTD-S	PFM002657-S	CTD-T	PFM002657-T
2004-04-20 12:40	1	4.710	–	4.08	4.13
	4	4.780	–	3.87	4.03
	6	4.780	–	3.91	3.96
	9	4.770	–	3.92	3.82
	11	4.790	–	3.76	3.69
	14	4.790	–	3.59	3.28
	17	4.920	–	1.85	2.24
	19	4.970	–	1.45	1.37
	22	5.030	–	1.08	1.05
	24	5.030	–	1.05	0.91
	27	5.060	–	0.90	0.73

	Depth	CTD-S	PFM002657-S	CTD-T	PFM002657-T
2004-10-19 09:35	1	5.280	–	9.54	9.57
	4	5.290	–	9.54	9.57
	6	5.290	–	9.54	9.57
	9	5.300	–	9.54	9.57
	11	5.300	–	9.54	9.57
	14	5.310	–	9.42	9.44
	17	5.350	–	9.14	9.12
	19	5.360	–	9.02	9.05
	22	5.380	–	8.91	8.92
	24	5.390	–	8.87	8.89
	27	5.390	–	8.83	8.83

	Depth	CTD-S	PFM002657-S	CTD-T	PFM002657-T
2005-01-04 13:05	1	4.940	–	0.76	0.70
	4	4.950	–	0.78	0.77
	6	4.950	–	0.79	0.73
	9	4.950	–	0.79	0.70
	11	4.950	–	0.79	0.73
	14	4.950	–	0.79	0.73
	17	4.960	–	0.79	0.77
	19	4.950	–	0.79	0.73
	22	4.960	–	0.79	0.73
	24	4.940	–	0.82	0.77
	27		–		0.88

Table A3-6. Comparison of temperature and salinity as measured by CTD/rig respectively at approximately identical times and depth. Times and depths given are for the CTD probe deployed. Each small table corresponds to one line in Figure A3-6. Measurements conducted at station PFM002658.

2004-04-21 09:24	Depth	CTD-S	PFM002658-S	CTD-T	PFM002658-T
	1	4.860	4.912	4.22	4.19
	10	5.000	5.038	3.04	3.06
	15	5.060		2.62	
	16	5.060		2.58	
	17				
	18		5.082		2.60

2004-10-18 14:47	Depth	CTD-S	PFM002658-S	CTD-T	PFM002658-T
	1	5.360	5.235	9.59	9.61
	10	5.360		9.62	
	15	5.380		9.62	
	16				
	17				
	18		5.210		9.65

2005-01-04 08:34	Depth	CTD-S	PFM002658-S	CTD-T	PFM002658-T
	1	5.400	5.271	1.52	1.47
	10	5.420		1.64	
	15	5.470		1.70	
	16	5.470		1.74	
	17	5.540		1.93	
	18	5.620		2.23	

2005-04-25 09:13	Depth	CTD-S	PFM002658-S	CTD-T	PFM002658-T
	6	5.110	5.066	3.57	3.64
	10	5.120	5.130	3.27	3.40
	15	5.140		3.23	
	16	5.130		3.22	
	17				
	18		4.983		3.22

Appendix 4

Overview

Table A4-1. Overview over all measurements conducted during the survey (sorted by station).

Station	Period (UTC) start	stop	Position north (RT90 2.5 gon V)	east (RT90 2.5 gon V)	Depth (m)	Interval (min)	Instrument	Parameter	Comparison measurements	Incidents and comments
PFM002653, northern boundary E	2004-04-16 11:00	2004-07-21 07:00	675569	165078	1.5	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure	CTD 2004-04-16 11:05; ADCP section Fo042 2004-04-16	rig ca 10 m to the north seen from the ADCP's surface marker buoy.
					10					
					17.5					
					25					rig recovered for data collection; marker buoy missing.
	2004-07-21 15:00	2004-10-21 08:30	675577	165064	1.5	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure	ADCP section Fo074 2004-07-21 (terminated a little early, lost ground contact); CTD 2004-10-21 08:17	new marker buoy set. Conductivity cell covered by barnacles which affected the measurements in the end of the period.
					10					Minor cover of barnacles on conductivity cell.
					17.5					
					25					rig recovered for data collection.
	2004-10-21 12:45	2005-02-08 08:50	675593	165073	1.5	60	AanderaaRCM7 (only CTD sensors)	temperature, conductivity, pressure	CTD 2004-10-21 12:53	rig recovered for data collection.
					10					
					17.5					
					25					
	2005-02-08 11:05	2005-04-25	675606	165104	10	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure	CTD 2005-04-25 15:26	marker buoy removed.
					17.5					
					25					

Station	Period (UTC) start	stop	Position north (RT90 2.5 gon V)	east (RT90 2.5 gon V)	Depth (m)	Interval (min)	Instrument	Parameter	Comparison measurements	Incidents and comments
PFM002653, northern boundary E	2004-04-16 10:00	2004-07-21	675563	165062	surface-36 (interval 2)	30	RDI ADCP	current		rig recovered for data collection and battery change.
	2004-07-21 15:45	2004-10-21 06:45	675563	165062	surface-36 (interval 2)	30	RDI ADCP	current		rig recovered for data collection and battery exchange.
	2004-11-09 13:20	2005-02-08	675570	165052	surface-36 (interval 2)	30	RDI ADCP	current	ADCP section Fo111 2004-11-10	rig recovered for data collection and battery change.
	2005-02-08 15:25	2005-04-26	675575	165076	surface-36 (interval 2)	30	RDI ADCP	current	ADCP section Fo111 2005-04-15	No data available, leak in the battery pack, see 4.5.3 1).
PFM002654, northern boundary W	2004-04-20 08:35	2004-07-20 16:40	675502	163555	12	30	Aanderaa RCM9	current, temperature, conductivity		rig recovered.
	2004-07-20 17:15	2004-10-21 09:20	675502	163555	12	30	Aanderaa RCM9	current, temperature, conductivity	CTD 2004-10-21 09:21	rig recovered for battery change.
	2004-10-21 10:15	2005-02-08 16:15	675500	163555	12	30	Aanderaa RCM9	current, temperature, conductivity		rig recovered.
	2005-02-08 17:15	2005-04-25 13:27	675519	163554	15	30	Aanderaa RCM9	current, temperature, conductivity	CTD 2005-04-25 13:22	no marker buoy.
PFM002655, inner point	2004-04-20 09:45	2004-07-20 14:02	672953	164945	1.5 10 17.5	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure	CDT 2004-04-20 09:50	rig recovered for data collection.
	2004-07-20 15:30	2004-10-19 11:10	672953	164945	1.5 10 17.5	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure		rig recovered for data collection.
	2004-10-19 13:10	2005-01-04 12:55	678962	1649451	1.5 10 17.5	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure	CTD 2004-10-19 13:11; CTD 2005-01-04 11:49	rig recovered for data collection. Faulty conductivity data, see 4.5.2 2).

Station	Period (UTC) start	stop	Position north (RT90 2.5 gon V)	east (RT90 2.5 gon V)	Depth (m)	Interval (min)	Instrument	Parameter	Comparison measurements	Incidents and comments
PFM002655, inner point	2005-01-04 13:45	2005-04-25 11:28	672948	164948	6 10 17.5	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure	CTD 2005-04-25 11:32	no marker buoy. Missing registrations, see 4.5.2 3). Faulty conductivity data, see 4.5.2 4).
PFM002656, Öregrundsund	2004-04-21 14:50	2004-07-22 06:20	671959	166307	surface - 26 (intervall 1)	30	Nortek ADP	current	CTD 2004-04-21 12:48; CTD 2004-04-21 12:52	See 4.5.3 5). About missing temperature and conductivity data see 4.5.3 6). Rig recovered and taken to SMHI, problems collecting data.
	2004-07-30 16:15	2004-10-18 16:00	671966	166300	surface - 24 (intervall 1)	30	Nortek ADP	current	CTD 2004-10-18 16:10	Seabird microcat added to rig.
	2004-07-30 16:15	2004-10-18 16:00	671966	166300	25	30	Seabird microcat SBE37	temperature, conductivity		rig recovered for data collection and battery change.
PFM002656, Öregrundsund	2004-10-20 10:50	2005-01-04 15:20	671965	166285	Surface - 22.5 (intervall 1)	30	Nortek ADP	current	CTD 2004-10-20 09:53	
	2004-10-20 10:50	2005-01-04 15:20	671965	166285	24	30	Seabird microcat SBE37	temperature, conductivity	CTD 2005-01-04 14:13	rig recovered for data collection and battery change.
	2005-01-05 11:25	2005-04-14 09:30	671960	166293	surface - 23.5 (intervall 1)	30	Nortek ADP	current	CTD 2005-01-05 10:44	marker buoy removed. See 4.5.3 7) for information on recovery.
	2005-01-05 11:25	2005-04-14 09:30	671960	166293	24	30	Seabird microcat SBE37	temperature, conductivity	Separate current measurement at 5.5 m (55 min) 36 cm/sec 135deg	After a collision with a boat the rig including instrument was landed, see 4.5.3 7).
PFM002657, no icecover	2004-04-20 12:35	2004-07-20 12:00	673192	165436	1–27 (intervall 2.6)	60	Aanderaa TR7	temperature	CTD 2004-04-20 12:40	rig recovered for data collection; marker buoy disappeared.
	2004-07-20 13:45	2004-10-19 09:40	673192	165436	1–27 (intervall 2.6)	60	Aanderaa TR7	temperature	CTD 2004-10-19 09:35	new marker buoy. rig recovered for data collection and battery change.
	2004-10-19 10:30	2005-01-04 14:30	673196	165444	1–27 (intervall 2.6)	60	Aanderaa TR7	temperature	CTD 2005-01-04 13:05	rig recovered.

Station	Period (UTC) start	stop	Position north (RT90 2.5 gon V)	east (RT90 2.5 gon V)	Depth (m)	Interval (min)	Instrument	Parameter	Comparison measurements	Incidents and comments
PFM002658, southern boundary	2004-04-21 09:10	2004-07-20 09:30	670397	168005	1.5 10 18	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure	CTD 2004-04-21 09:25	rig recovered for data collection.
	2004-07-20 10:20	2004-10-18 13:00	670397	168005	1.5 10 18	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure		rig recovered for data collection; memory card changed.
	2004-10-18 14:40	2005-01-04 09:45	670390	167996	1.5 10 18	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure	CTD 2004-10-18 14:47; CTD 2005-01-04 08:34	rig recovered for data collection. instrument malefunction at 10 m (see 4.5.4 8)), possible data loss (no spare instrument). instrument malefunction at 18 m, no data registered after 2004-12-25 21:00, see 4.5.4 9).
	2005-01-04 10:55	2005-04-25 09:31	670390	167997	6 10 18	60	Aanderaa RCM7 (only CTD sensors)	temperature, conductivity, pressure	CTD 2005-04-25 09:13	no marker buoy.