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Measurements of near-bottom Turbidity and Currents at Svale, Block No. 6608/10, June-August 2003

Norwegian Institute for Water Research

REPORT

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Abstract

Statoil ASA is conducting design studies for the Svale oil field which is located on the shelf at 66^{o}N, 8^{o}E. In connection with this, measurements of water current and turbidity near bottom were performed during the period 15 June-4 August, 2003. In addition, grab samples of sediments were collected for further analysis. Currents at 2 m above the bottom ranged between close to zero and up to 12 cm/s, with average speed of 4 cm/s. Currents at 7.5 m above the bottom showed a highest measured value of 17 cm/s. The direction of the dominating water transport (volume flux) was towards the NW. The most dominant particle size of grains were around 4 µm (32%). 61.6% were classified as silt and 36.2 % as clay. Turbidity values at 2 m above the bottom were mostly in the range 0.1 – 0.5 FTU and at 6.5 m above the bottom the values were around 0.4-0.5 FTU, with a slightly increasing trend with time. The minimum required steady current for remobilization of the bulk of the sediments is probably around 80 cm/s. It was concluded that no episodes of suspended sediments were recorded at Svale.

4 keywords, Norwegian	4 keywords, English
1. Svale feltet	1. Svale Field
2. Norne	2. Norne field
3. Turbiditet	3. Turbidity
4. Bunnstrøm	4. Bottom currents

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Preface

Statoil ASA is in the development phase of the Svale oil field in the Norwegian Sea NW of Brønnøysund. As part of the preparations, Statoil asked the Norwegian institute for water research, NIVA, to perform measurements of current and turbidity near the seabed at the site of planned installations. A contract agreement was made 15 May 2003, and the measurements commenced 15 June, ending on 4 August.

Contract responsible and key contact to NIVA at Statoil was Einar Nygaard. Deployment of the mooring and bottom sampling was excellently performed from M/V “Normand Mjølne” while pickup was done likewise, by R/V “Edda Fonn”. Thanks are due to the crews, and to Statoil/DeepOcean representatives on the vessels, Jan Søberg, Svein Ullekleiv and Arve Haaland, for their co-ordination and timing of necessary activities with NIVA. Thanks also hereby forwarded to the staff at Statoil Vestbase Kristiansund for safely storing and handling of equipment.

Mooring preparations and offshore deployment was made by Arild Sundfjord, NIVA. Tom Chr. Mortensen prepared the equipment and Jo Økedal investigated the sediment samples. Lars Golmen was the project manager and responsible for the reporting.

Bergen/Oslo, October 2003

Lars G Golmen

Contents

Summary

Statoil ASA is presently conducting design studies for the Svale oil field which is located on the shelf at 66°N, 8°E, approximately 200 km west of Brønnøysund in North Norway. In connection with this, the Norwegian Institute for Water Research, NIVA, conducted measurements of water current and turbidity near bottom at Svale during the period 15 June - 4 August, 2003. In addition, grab samples of sediments were collected for further analysis.

The currents were modest, ranging between close to zero and up to 12 cm/s during the period of measurements for the instrument at 2 m above the bottom. The average speed there was ca 4 cm/s. Currents at 7.5 m above the bottom showed the highest measured value of 17 cm/s.

Dominating current directions were towards 240-300° (SW-NW) and towards 60-120° (NE-SE). The direction of the dominating water transport (volume flux) was towards the NW.

Turbidity values at 2 m above the bottom were low, mostly in the range 0.1 – 0.5 FTU. Turbidity at 6.5 m above the bottom also showed low values with an average around 0.4-0.5 FTU, but with a slightly increasing trend with time. Between 13 and 28 July, the level increased to about 0.6 - 1.4 FTU, and later to above 2 FTU after an intermittent drop. The gradually increasing level may be due to natural debris sinking from upper layers, accumulating either in the bottom water layer, or possibly directly on the turbidity sensor. In this respect, there does not seem to have been any events of resuspension during the time of measurements.

The analyses of the two sediment samples showed that about 97-98% dry weight was composed of particles < 63 µm. The most dominant particle size of grains were around 4 µm (32%). 61.6% were classified as silt and 36.2 % as clay. These two constituents represent particles < 63µm.

Following the data and sample analyses, a set of calibration and calculations were conducted to try to assess whether any of the measured turbidity values did represent suspended particles from the bottom, and further to assess the threshold value for sediment mobilisation to begin, based on the sediment characteristics.

Small particles (typically less than 20 µm) will always be present in seawater. For the Atlantic water type like at Svale values may be around 0.5 mg/l according to previous studies. The calibration of one of the turbidity sensors showed that added sediments to the water in the range 1-3 mg/l reflected FTU values of 1-3. A concentration of 0.5 mg/l would theoretically correspond to a measured FTU value of 0.56, so all readings below this threshold level should reflect water with no suspended sediments.

At Svale, fluctuating background currents in the form of “bursts” will probably be the only remobilization mechanism. Calculations on the necessary minimum currents to mobilise fine-grained sediments like at Svale for wave-induced currents showed values on the order of 13-14 cm/s, which is above the maximum measured value at 2 m above the bottom (12 cm/s). A tentative suggestion for the minimum required steady current at Svale for remobilization is 80 cm/s, i.e. much higher that the highest values recorded during the period of measurements at Svale.

It is concluded that no episodes of suspended sediments were recorded at Svale. The likelihood of such events to happen due to intermittent current bursts have not been assessed. Statistical calculations from other fields in the area show extreme maximum currents of around 55 cm/s ocurring with a 100 year return period, which is below the indicated threshold value of 80 cm/s at Svale.

1. Introduction

The Svale oil field is located on the shelf at 66°N, 8°E, approximately 200 km due west of Brønnøysund in North Norway. The nearest neighbouring field already in operation is the Norne field, ca 10 km to the SW. Statoil ASA is now in the design phase of the Svale field and as part of this Statoil needed some data on currents and turbidity near the seabed.

The main reason for this was to assess the risk of bottom sediments being suspended into the water column either intermittently or for prolonged periods, e.g. during periods of strong currents. If this was the case, it would affect the quality of the seawater at the planned intakes near the bottom where the main structures are to be placed.

In March 2003, Statoil ASA asked the Norwegian institute for water research, NIVA, for a proposal to perform the necessary measurements of current and turbidity at the site and a contract agreement was made on 15 May, 2003.

2. Equipment and field work

2.1 Instruments

Three types of instruments were applied, two that measured seawater turbidity, and one conventional current meter. **Table 1** gives an overview over sampling parameters.

Table 1. Overview over instruments and the parameters they measured. All instruments logged the data internally, along with time.

Instr. type	Depth above the bottom	Turbidity	Cond/Sal	Temp	Current	Pressure
Aanderaa RCM7	7.5 m.		X	X	X	
SAIV SD204	6.5 m	X	X	X		X
Aanderaa RCM9	2 m	X	X	X	X	X

2.1.1 Aanderaa RCM 7

The uppermost instrument was of the traditional Aanderaa RCM7 type, see **Figure 1**. The measurement accuracy for the various channels (parameters) are given in **Table 2**.

Table 2. Sensor specifications for Aanderaa RCM7 current meters (Aanderaa instruments 1983):

Conductivity:	±0,1 mmho/cm
Temperature:	±0,05°C
Compass:	±7,5° at speed of 2.5-5 cm/s
	±5° at speed of 5-100 cm/s
Current speed:	±1 cm/s or ±2 % of measured speed.
Speed threshold:	1.1 cm/s

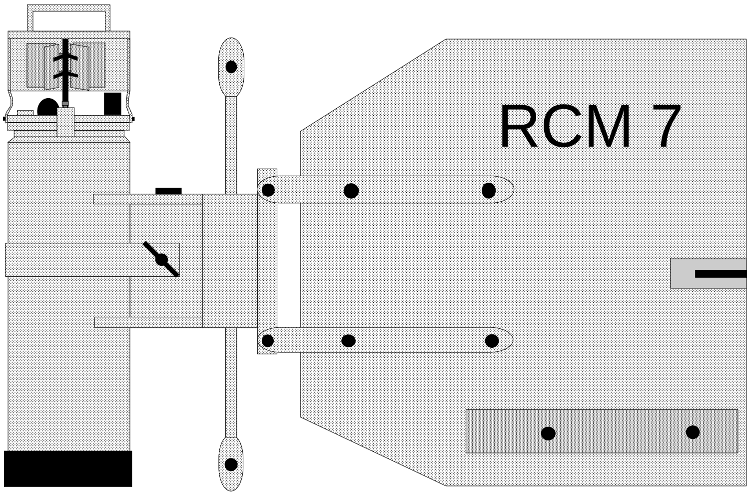


Figure 1. Sketch of Aanderaa RCM7 type current meter, with the wane. (E. Nygaard, NIVA).

Figure 2. The Aanderaa RCM9 Doppler current meter, with turbidity sensor to the right.

2.1.2 Aanderaa RCM9

The Aanderaa RCM9 type instruments are commonly used by NIVA e.g. in connection with monitoring of sediment resuspension in harbours. The Doppler Current Sensor is placed on top of the instrument (**Figure 2**). The sensor uses an algorithm to auto-detect flow direction, focusing flow measurements along two upstream axis (forward pinging). Sampling area is two ±1 degree cones separated by 90 degrees. See **Table 3** for specs. on the various sensors.

Turbidity is measured by an optical (infra-red light) backscatter sensor. Calibrated data are given in FTU or NTU (Nephelometric Turbidity Unit) units.

Table 3. Technical specifications of the Aanderaa RCM9 (Aanderaa instruments 1999).

Conductivity, accuracy:	±0.8% of range
Temperature accuracy:	±0.05°C
Compass:	±5° at tilt < 15°
Current speed accuracy:	±2 cm/s or ±2 % of measured speed (whatever is largest).
Current speed resolution:	0.3 cm/s
Current speed threshold:	0.5 cm/s
Turbidity meas. range:	0.1 – 20 FTU
Turbidity accuracy:	2% of range (full scale = 20 FTU)

2.1.3 SAIV

The SAIV instrument is primarily an internally logging SD204 that can be fitted with other sensors as well, by mounting the optional sensor unit 106. **Table 4** gives technical specifications. The turbidity sensor is produced by Seapoint, USA.

Table 4. Technical specifications of the SAIV SD 204 instrument (SAIV AS 2002).

Conductivity, accuracy:	±0.2 mS/cm
Temperature accuracy:	±0.01°C
Turbidity meas. range:	0 – 12.5, 0-62.5, 0-250, 0-750 FTU (automatic setting)
Turbidity linearity:	< 2%

The Seapoint turbidity sensor.
The Seapoint Turbidity Meter detects light scattered by particles suspended in water, generating an output voltage proportional to turbidity or suspended solids. Range is selected by two digital lines which are microprocessor controlled, thereby dynamically setting the appropriate range and resolution for measurement of extremely clean to very turbid waters. The 880 nm wavelength IR light is identical to the Aaanderaa turbidity sensor. The following specifications on the Seapoint turbidity sensor is taken from the Seapoint web page:

Power Requirements: 7-20 VDC, 3.5 mA avg., 6 mA pk.
• Output 0-5.0 VDC
• Output Time Constant 0.1 sec.
• RMS Noise < 1 mV
• Power-up Transient Period < 1 sec
• Light Source Wavelength 880 nm
• Sensing Distance (from windows) < 5 cm (approx.)
• Linearity < 2% deviation 0-750 FTU
• Sensitivity/Range Gain Sensitivity (mV/FTU) Range (FTU)

2.2 Mooring

The backbone of the mooring was composed of pieces of 5/16" chain, a 200 kg bottom weight and 17" Benthos type floats (glass spheres) to provide necessary uplift. The instruments were shackled in at intervals, the lowest one at 2 m above the bottom, and the upper one at ca 7.5 m above the bottom. An acoustic release to be used for retrieval of the mooring was mounted below the lower current meter. A sketch of the mooring is shown in **Figure 3**. The total height above seabed was about 16 m.

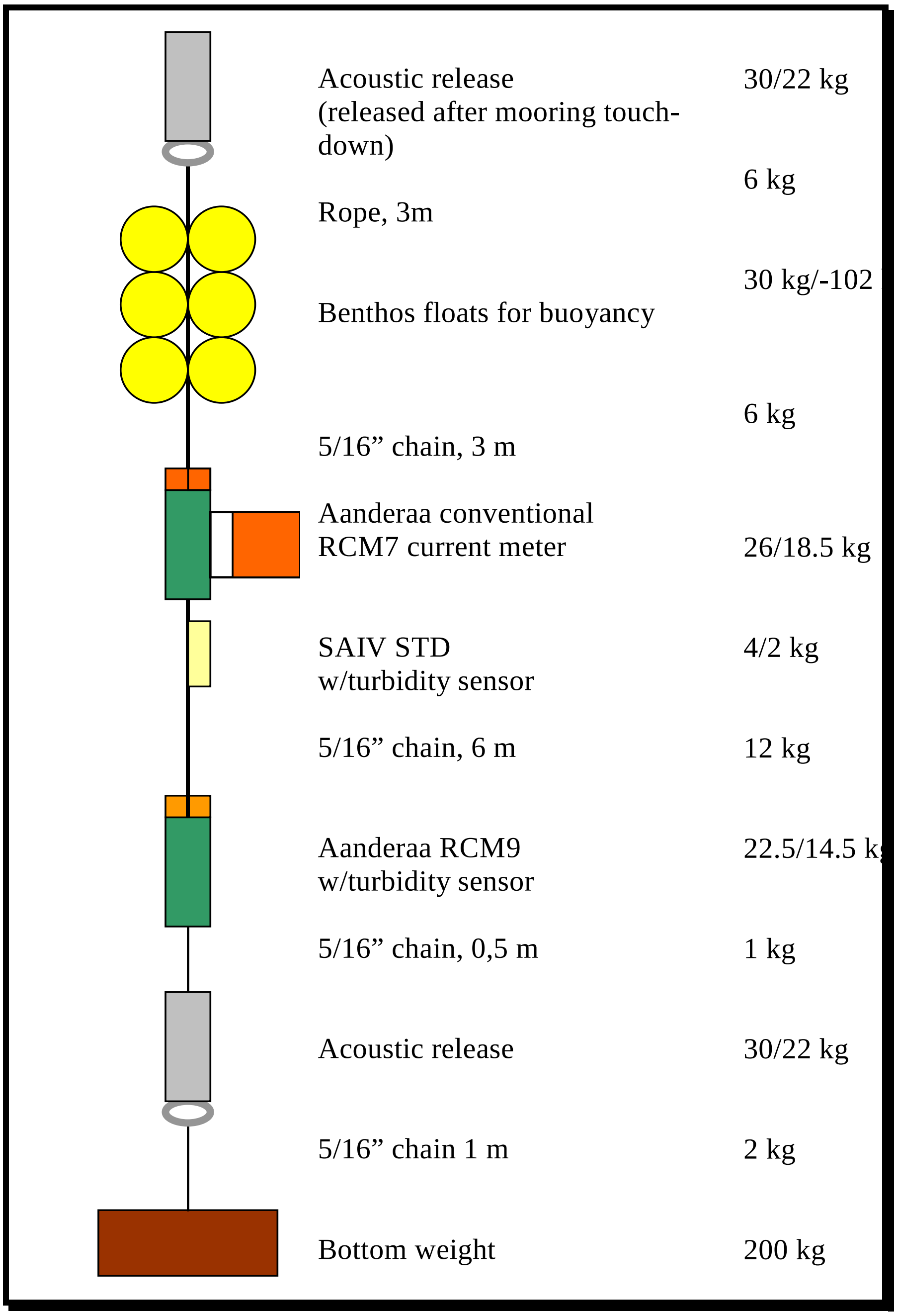


Figure 3. Mooring layout at Svale. The upper release was applied only during deployment, and then disconnected and retrieved. Numbers to the right indicate weight of units in air/water.

2.3 Mooring deployment and pick-up

The mooring was assembled on board M/V "Normand Mjølne" on the outbound trip from Kristiansund to the Norne/Svale location. All instruments were tested and then started on board the vessel a few hours before deployment. No irregularities were detected.

The mooring was lowered from the main crane, while a ROV monitored the decent and the touch-down, upon which the upper release was activated and recovered with the cable. A short video film of the descent and the mooring on the seabed was recorded.

Mooring Position:
The final position of the mooring was taken from the GPS on the vessel at the first sediment sampling position, "SVAL 1":

	WGS-84	**ED-50**
Northing:	66^o 04' 25" N	7328490
Easting:	08^o 15' 20" E	466310

Actually, the mooring came to rest about 40 m to the SSW of this position.

Mooring depth:
The water depth at the mooring site was determined from the vessel to be 378 m.
Time of mooring in position:
15 June 2003 at 03:20 UTC

2.3.1 Mooring pick-up

The mooring was recovered on 04 August 2003, from another vessel, M/V "Edda Fonn". This was performed by the crew, with only remote assistance from NIVA. The pickup was assisted by an ROV, as was done during deployment. The ROV hooked the crane rope to the upper ring in the mooring and the whole rig was recovered without applying the acoustic release.

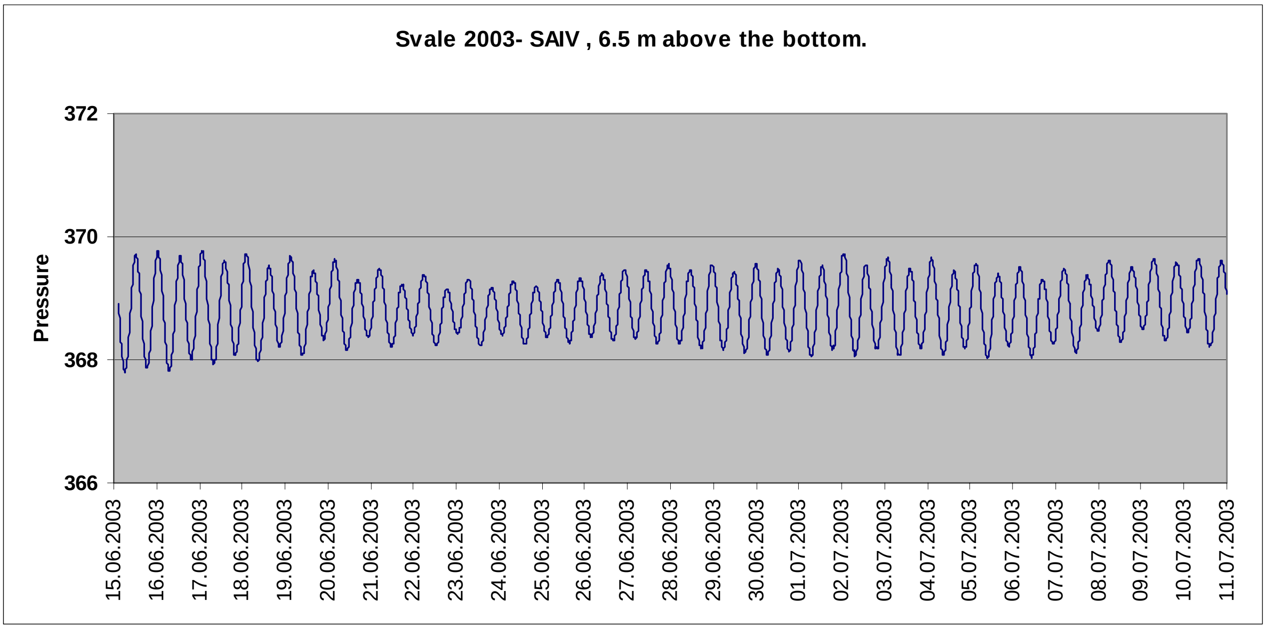
The mooring was reported to be in good condition upon recovery. It was dismounted and all equipment stored on the vessel until it docked at CCB base near Bergen about 1 week later. The pressure measurements by the SAIV SD204 indicates the mooring has been in place all the time, with the mean pressure (sea level) remaining constant (**Figure 4**).

2.4 Data return

The three instruments were all logging upon return to NIVA. Data readout could not commence until a couple of weeks after mooring recovery, so the instruments had been logging in air for some time.

Table 5. Overview over instruments, measurements and performance. All instruments logged at 10 min intervals. For a full series this corresponded to about 7,280 individual data records. Time is in local time (UTC + 2 hrs) except for the SAIV that run in Norwegian time, I.e. UTC + 1 hr.

Instrument #	**Depth of meas.**	**First good data**	**last good data**	**Remarks**
RCM7 # 900	7.5 m a. b.	15 June 03:25	04. Aug. 15:35	Cond. sensor failed after 16 June.
SAIV SD204	6.5 m a. b.	15 June 02:30	04. Aug. 14:10	All sensors OK
RCM9 # 693	2 m a. b.	15 June 03:25	04. Aug. 15:35	All sensors OK



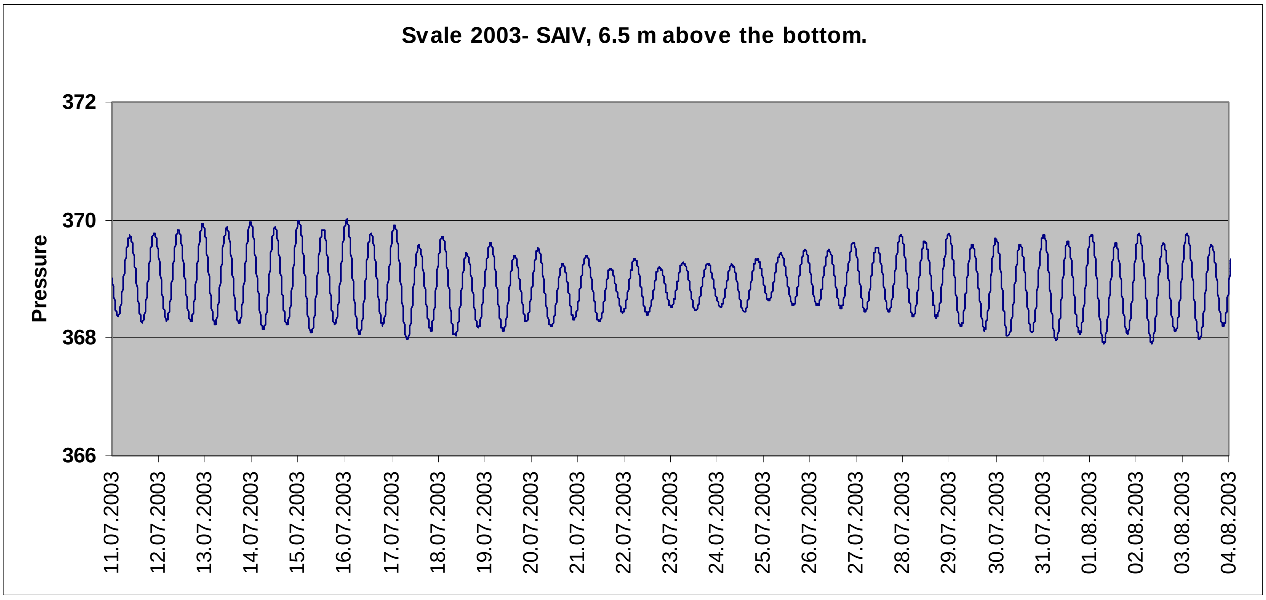


Figure 4. Pressure measurements from the SAIV STD at 6.5 m above the bottom.

2.5 Sediment sampling

Prior to deployment of the mooring, grab samples were collected at the site at two positions; SVAL 1 which was ca 40 m from the mooring position, and SVAL 2 about 300 m further south. A Van Veen 0.1 m^2 bottom grab was used for the sampling.

Sediment was collected in 3 hauls at SVAL 1 and one haul at SVAL 2. No difference was seen from one location or sample to the other. Part of the sediment was stored for subsequent analyses at the laboratory.

3. Results from moored instruments

3.1 Temperature measurements

The recorded seawater temperatures are shown in **Figure 5**, for the uppermost instrument. Temperature data from the other two instruments were quite similar. The values ranged between 6.9 and 7.6 ^{o}C.

3.2 Salinity (from conductivity)

Shown in **Figure 6** are measured salinity at 7.5 m above the bottom, as recorded by the SAIV SD instrument. The salinity was almost constant, around 35, gently varying by +/- 0.1. The calculated density, expressed as sigma-t, was in the range 27.5 – 27.7 during the period of measurements (data not shown here).

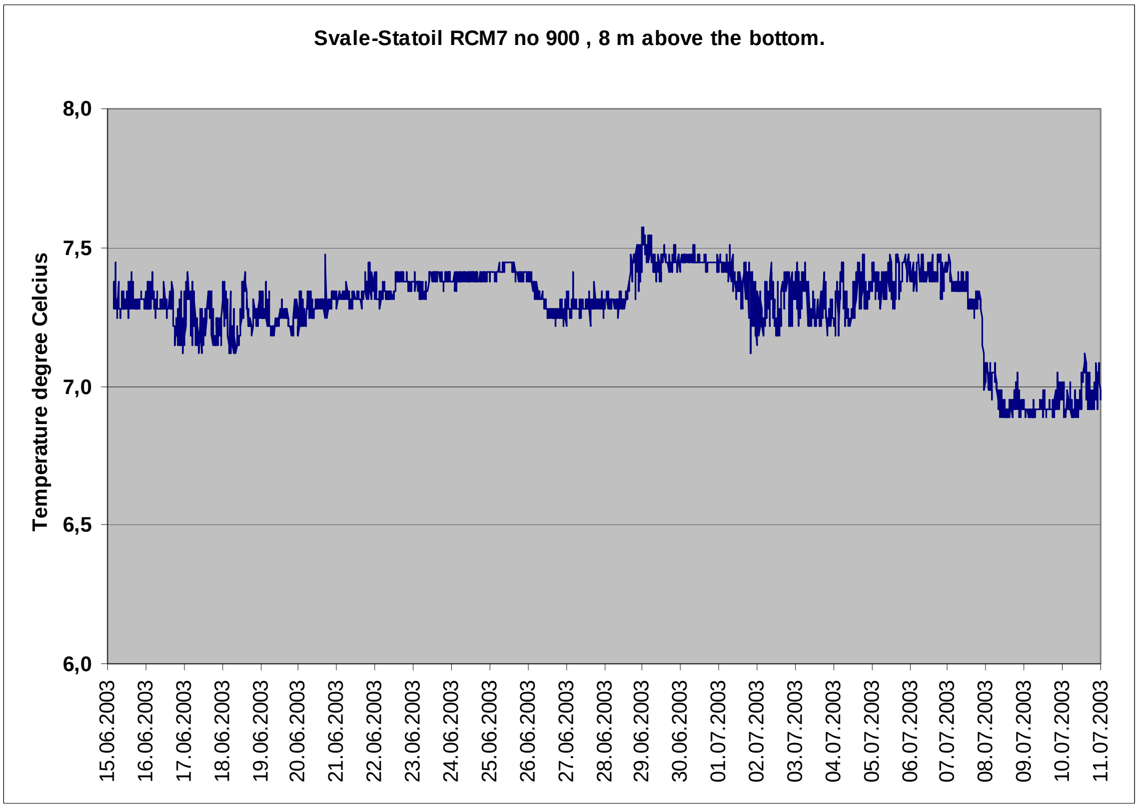
3.3 Current speed

Results from the measured current speed at 2 m above the bottom are shown in **Figure 7**. Currents were modest, ranging between close to zero and up to 12 cm/s during the period of measurements. The average speed was ca 4 cm/s. The semidiurnal tide was heavly modulating the currents, with two peak and slack periods per day. Apparently there were only short periods during turn of the tide with very low or “zero” current. Similarly, the periods of peak currents were also shortlasting.

Currents at 8 m above the bottom as measured by the RCM7 showed similar magnitudes, while the highest measured value was 17 cm/s on 29 July, i.e. at the same time as the maximum value at 2 m above the bottom was measured (**Figure 7**). The statistical distribution of current speed for the RCM7 and RCM9 as shown in **Figure 11** illustrates a normal distribution of values below the highest value recorded.

3.4 Current direction and residual velocity

Graphs of the measured current direction at 2 m above the seabed is shown in **Figure 8**. The semidiurnal tide was heavily influencing the current, if not always totally reversing the current. Dominating directions were towards 240-300^{o} (SW-NW) and towards 60-120^{o} (NE-SE). The direction of the dominating water transport (volume flux) was towards the NW (see **Figure 9** and **Figure 10**).



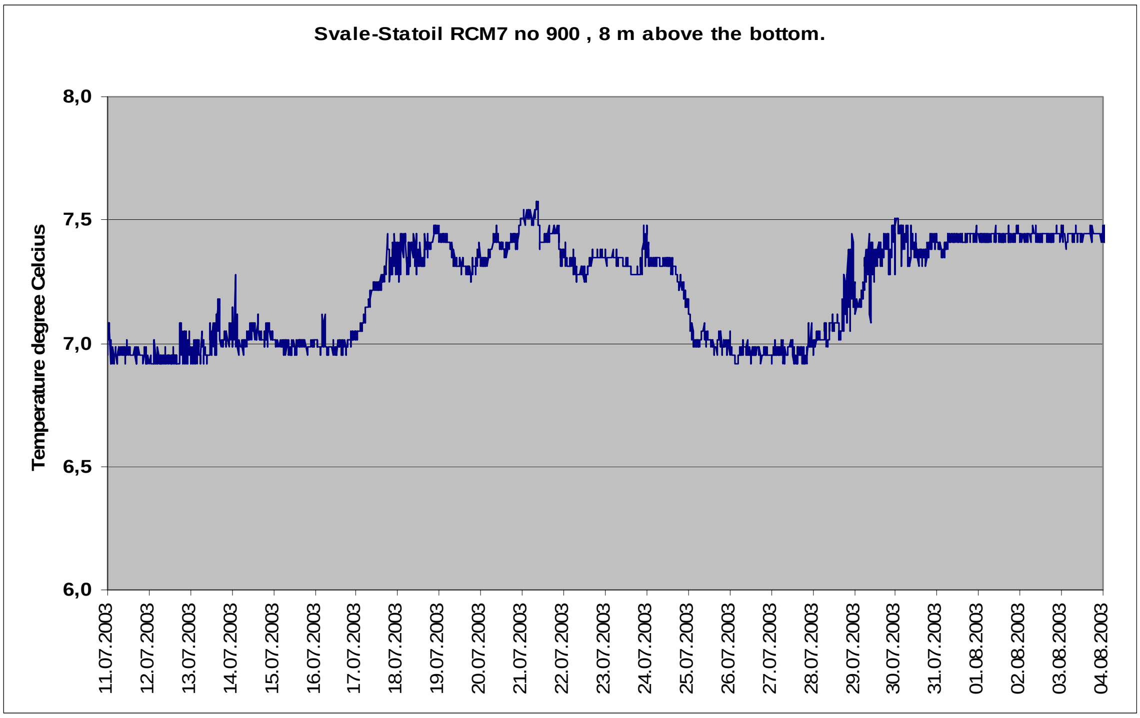
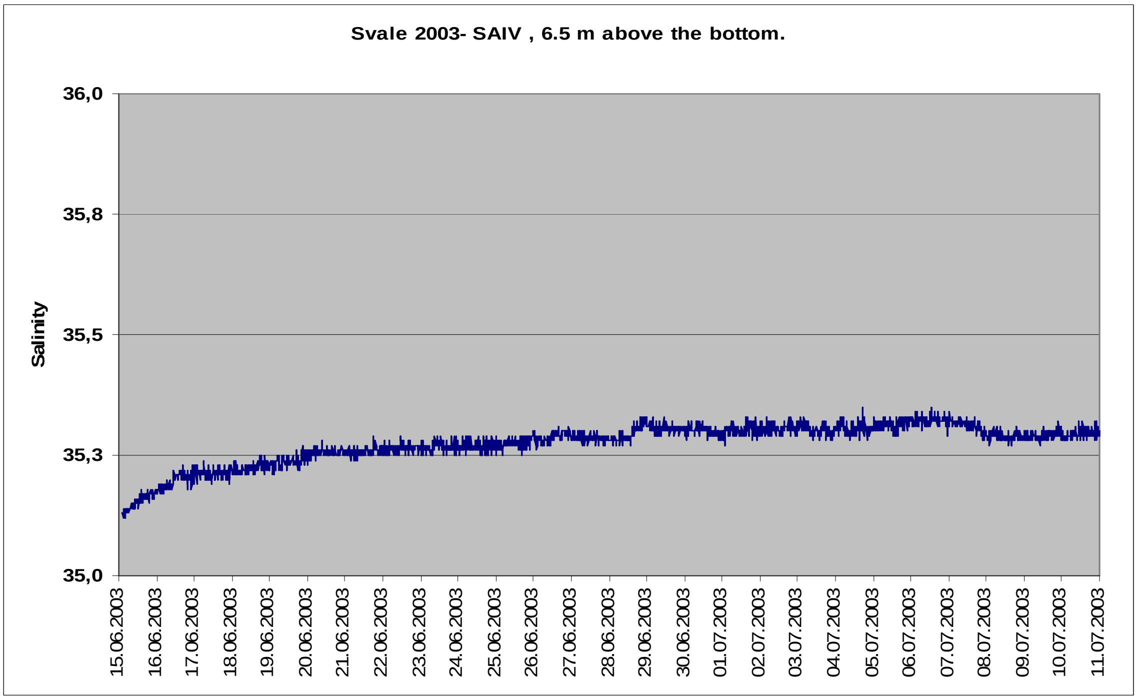


Figure 5. Results of temperature measurements at the uppermost instrument, RCM7 # 900 at 8 (7.5) m above the bottom.



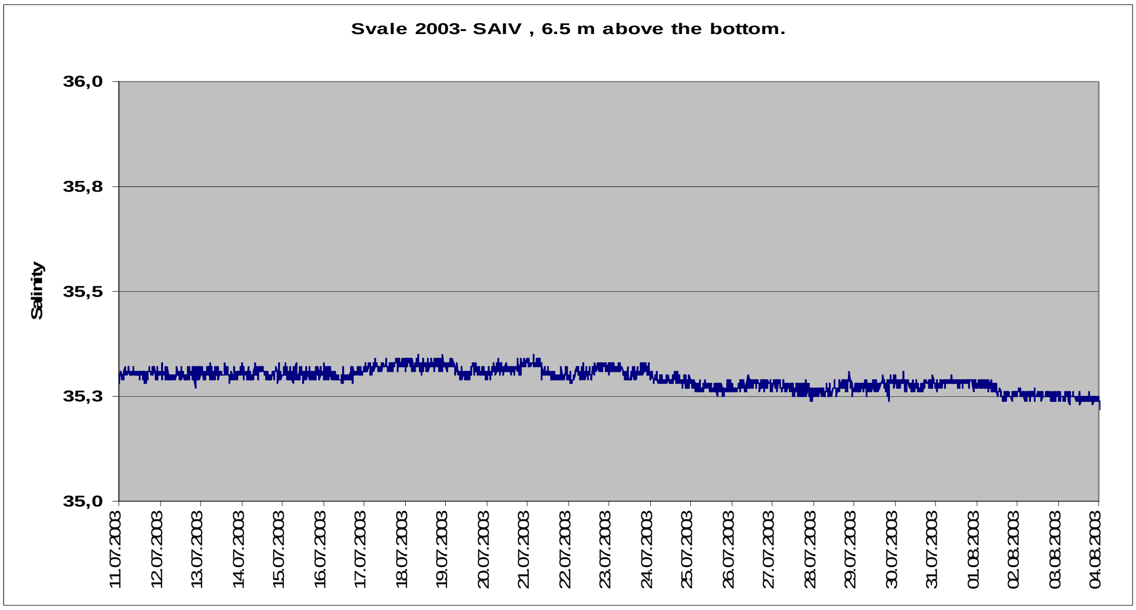
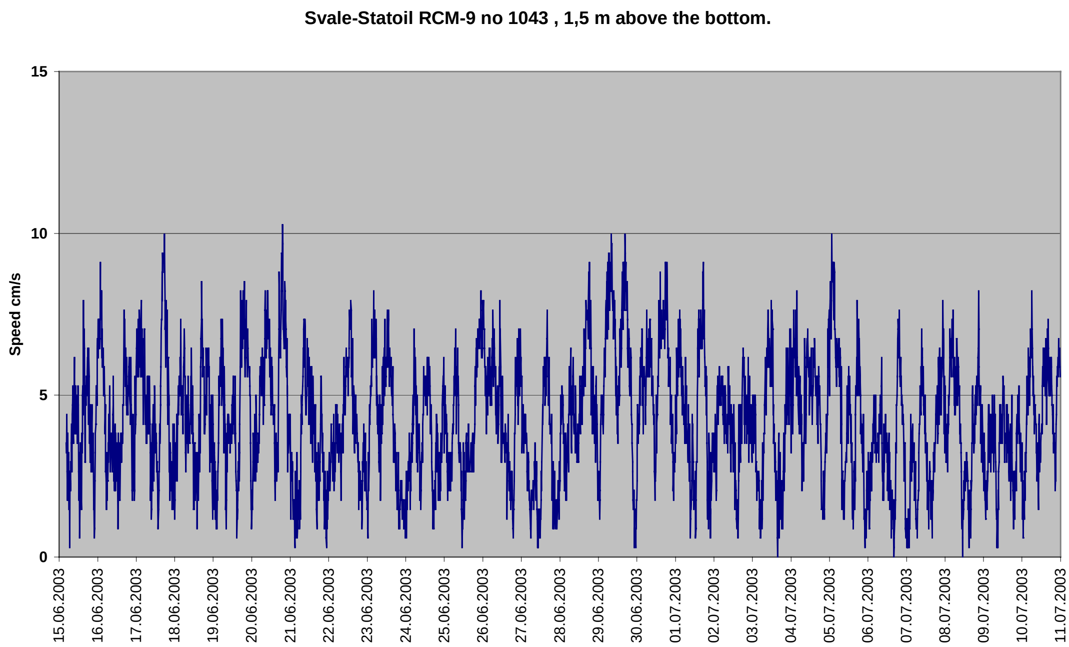


Figure 6. Salinity as calculated from conductivity, temperature and pressure, at 6.5 m above the bottom. Data are from the SAIV SD204 instrument.



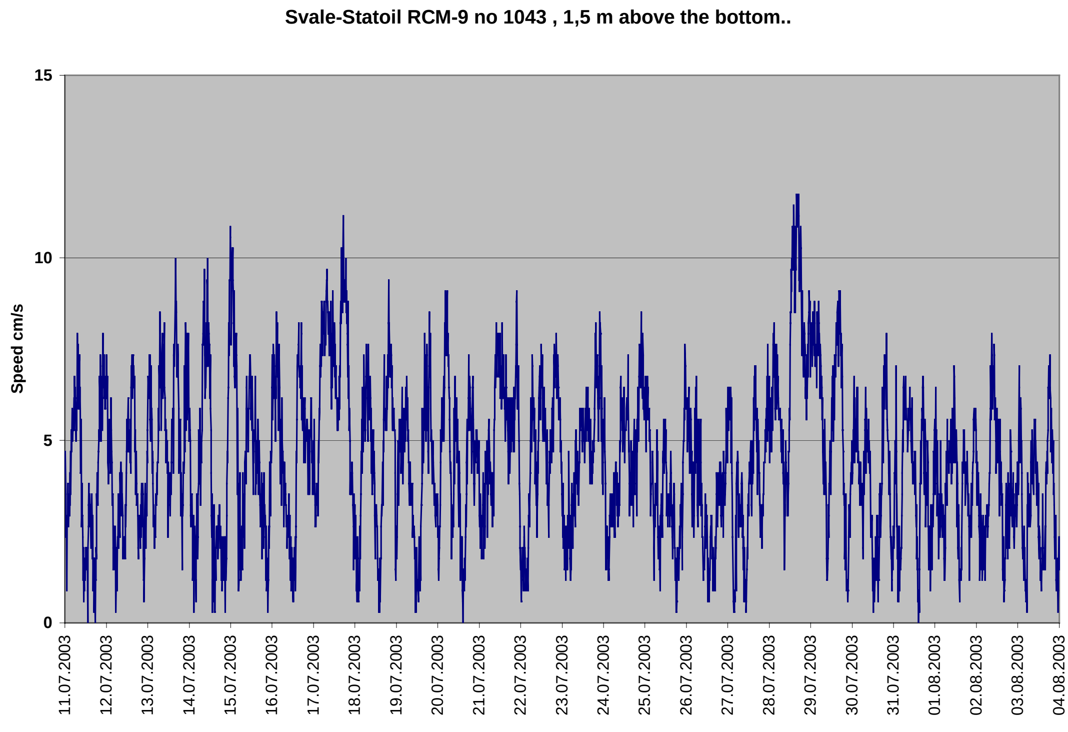
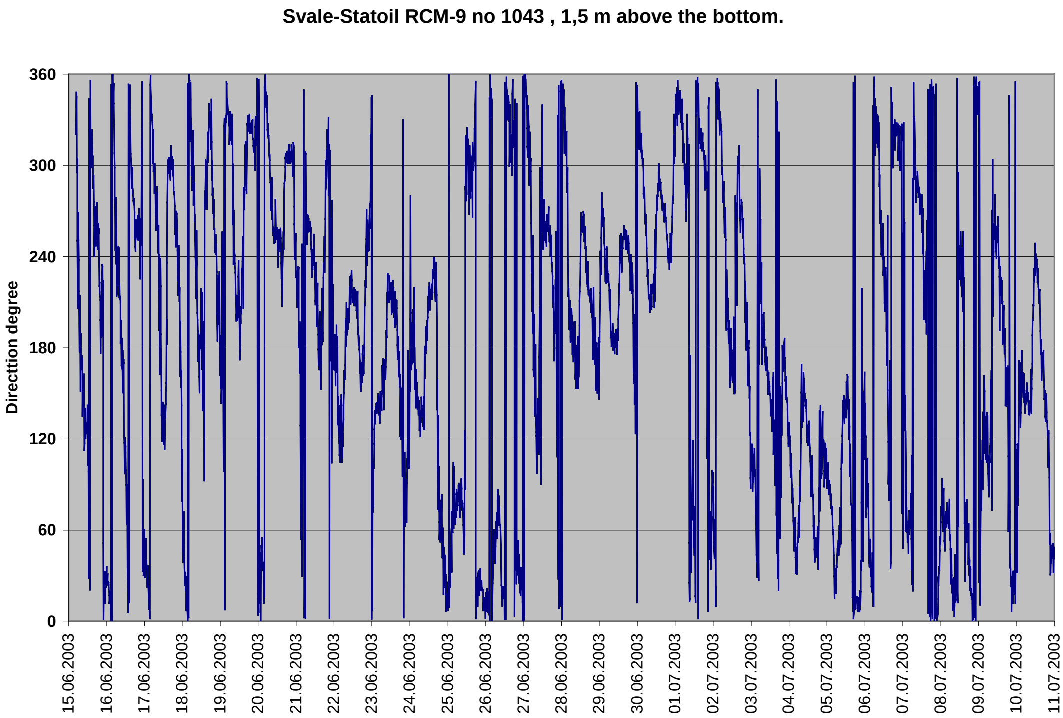


Figure 7. Measured current speed (cm/s) at 1.5 - 2 m above the seabottom by the RCM9 instrument.



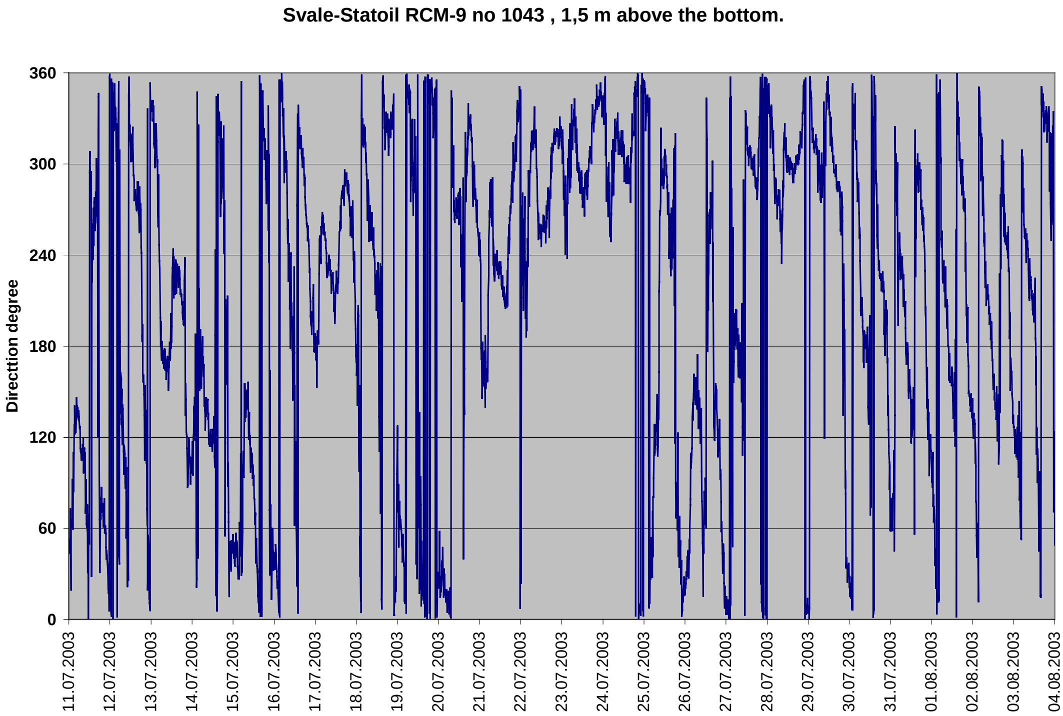
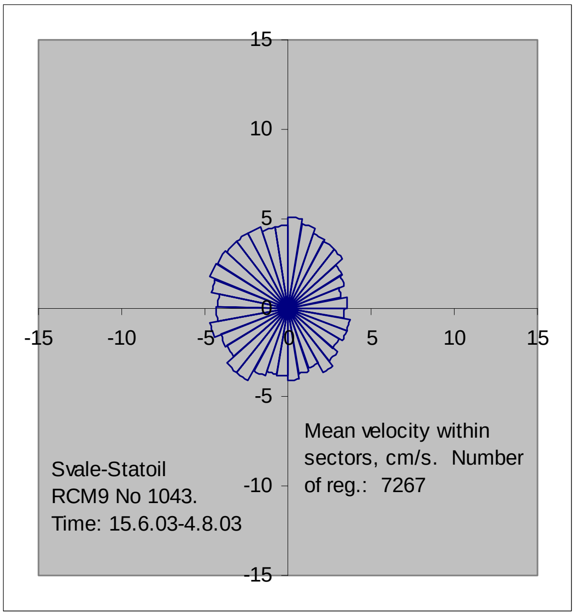


Figure 8. Measured current direction at 1.5-2 m above the seabottom by the RCM9 instrument. Readings show the direction of flow. E.g. a value of 145^{o} means the current flows towards SE.



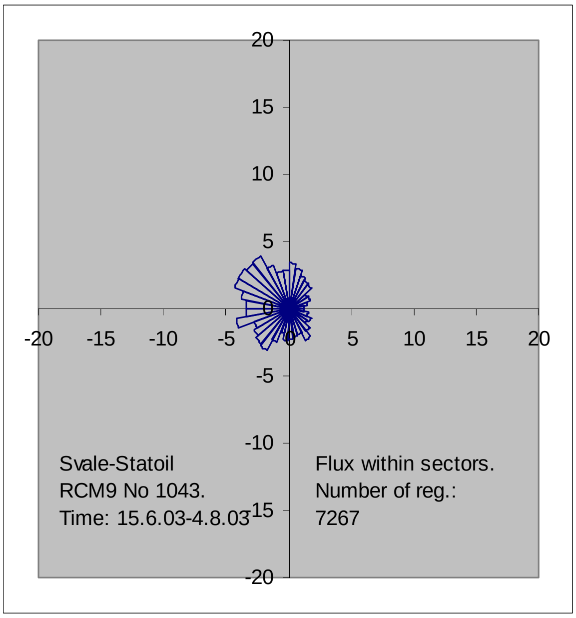


Figure 9. Diretional distribution of mean currrent speed and flux, within sectors for the RCM9, ca 2m above the bottom.

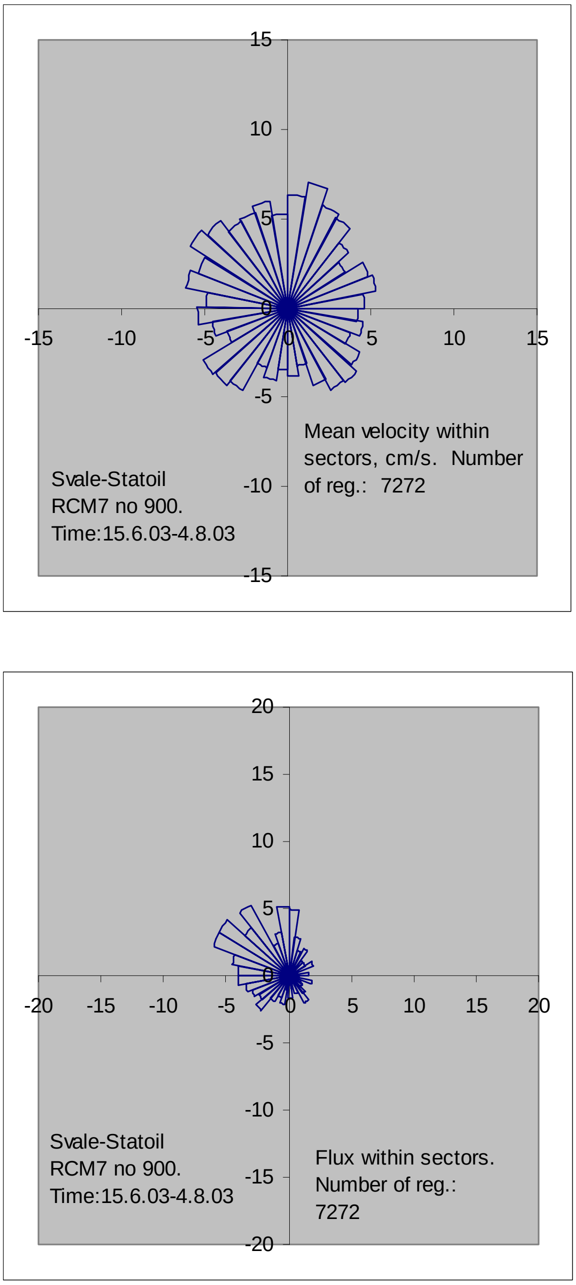
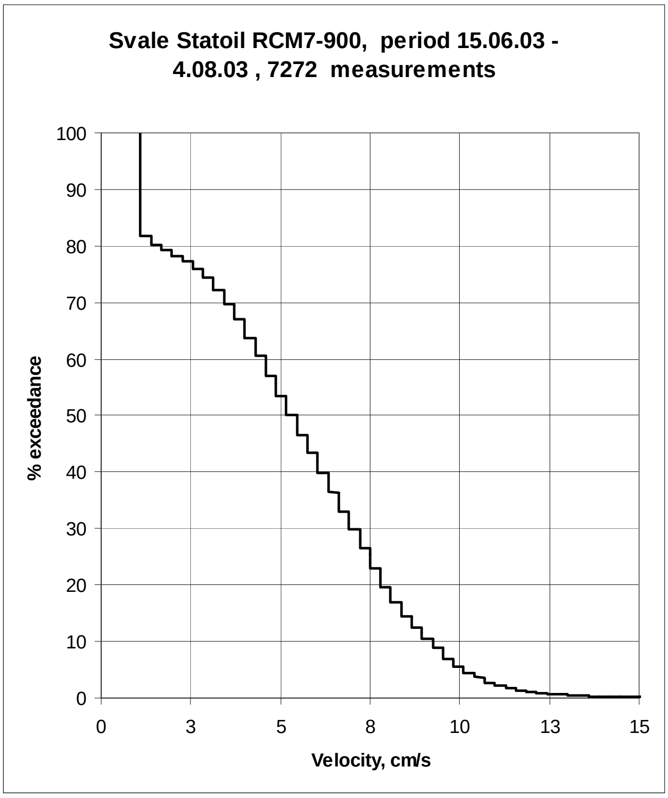


Figure 10. Diretional distribution of mean currrent speed and flux, within sectors for the RCM7, 7.5 m above the bottom.



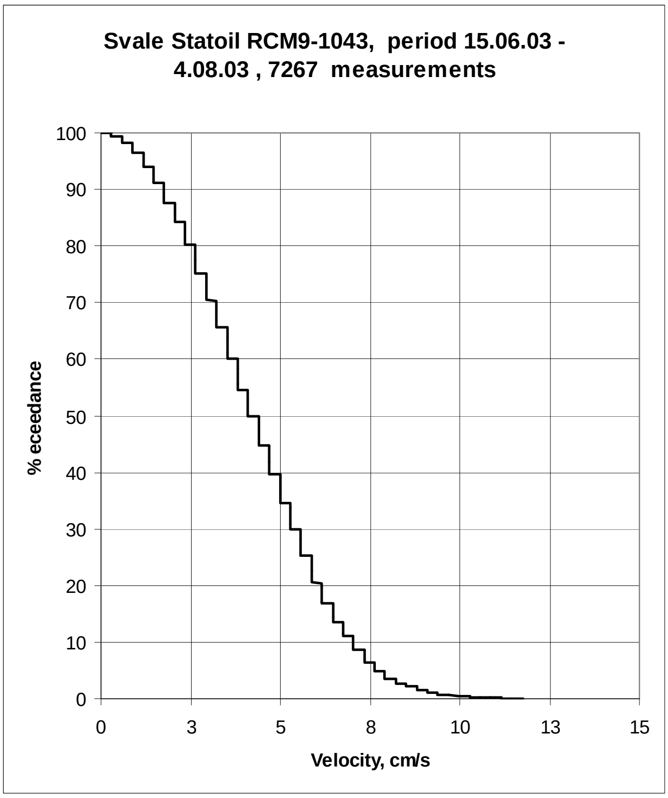


Figure 11. Cumulative distribution of current velocity observations at 2 m above bottom (lower figure) and at 7.5 m above the bottom.