REPORT

Measurements of currents, temperature and salinity from moorings at the southern Weddell Sea continental slope: February 2010 – February 2011

Ilker Fer

Geophysical Institute
University of Bergen

23 January 2017

1. Background

The data set described herein is collected as a part of the International Polar Year project entitled "Bipolar Atlantic Thermohaline Circulation (BIAC)". BIAC was led by the Geophysical Institute, University of Bergen (Tor Gammelsrød) and received funding from the Research Council of Norway for the period 2007 to 2011. The measurements from moorings were a part of the working theme WT3: "Downslope processes, pathways, cascading and mixing", led by Ilker Fer.

In BIAC-WT3, the Southern Ocean part of the fieldwork aimed to collect moored time series and shipboard data from cruises to the southern Weddell Sea. The objective was to study the dynamics and mixing of the dense overflow plume on the continental slope of the Weddell Sea, northwest of the Filchner Depression [*Foldvik et al.*, 2004].

In the first year of BIAC, the Weddell Sea fieldwork was conducted from RRS Ernest Shackleton (ES033, 22 January - 7 March 2009). A cruise report together with the shipboard measurements of currents, hydrography and ocean microstructure can be obtained from *Fer et al.* [2015]. During the ES033 cruise, oceanographic moorings were also deployed, which returned 1-year long (2009-10) time series. The 2009-10 data can be accessed from *Fer* [2016] where a detailed data report is also available. During the recovery cruise of the first year moorings, a second set of moorings were deployed to sample for another year. The present report gives the details regarding the second year of mooring data (2010-11). While the 2009-10 data were from the central Crary Fan and farther to the east (because of difficult ice conditions), the 2010-11 data are from the Filchner outflow region.

This report summarizes the details of the 2010-11 moorings, instrument setups and processing, and gives an overview of the data collected. The data set covers the period from mid-February 2010 to mid-February 2011, and includes time series of ocean temperature, salinity and currents at approximately 1400 m and 1850 m isobaths near 74°S, 36°W. The data set is available from Fer (2017, DOI pending).

2. Moorings

2.1. Overview

In total, three bottom-anchored oceanographic moorings were deployed at the continental slope of the southern Weddell Sea. The deployment work was led by Svein Østerhus (Bergen), during the cruise of British Antarctic Research Vessel RRS Ernest Shackleton in February 2010. The positions are detailed in Table 1 and shown in Figure 1. Of the three moorings, only two (W2 and W3) could be retrieved. The retrieval work was led by Svein Østerhus, in February 2011, from RRS James Clark Ross. For reference, Figure 1 also shows the locations of the 2009-2010 moorings (PI: Ilker Fer) as well as the longer-term mooring position S2 (PI: Svein Østerhus).

Each mooring is equipped with instruments logging temperature, salinity and currents. The details of the instrumentation are given in Table 2 and in the mooring diagrams in the Appendix. Because W1 is considered lost and no data is available from W1, we exclude it from this report.

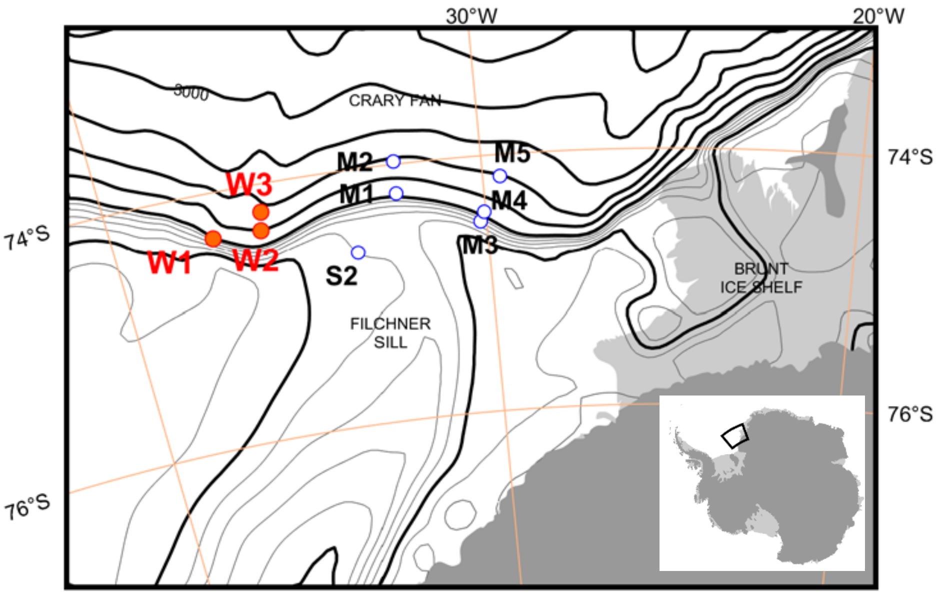


Figure 1. Locations of moorings W1 to W3 (red) shown over the Bedmap isobaths drawn at 500 m intervals as thick contours and at 100 m intervals to 1000 m as thin contours. Dark gray is land and light gray is ice shelf. Inset shows the location in Antarctica. For reference the position of the 2009-2010 moorings, M1 to M5, as well as the longer-term monitoring location S2 are also shown (blue).

Table 1. Mooring deployment details. Deployment time is when the mooring is at the seabed (anchor drop time can be up to a couple of hours earlier). Bottom depth is the best estimate using the ship's echo sounder measurement, instrument pressure records and the mooring part lengths.

Mooring	Deployed Recovered (UTC)	Longitude Latitude	Bottom Depth (m)	Echo depth (m) In situ.
W1	16.02.2010 Not recovered	037°18.981' W 74°21.220' S	n/a	872
W2	16.02.2010 16:45 14.02.2011 08:06	036°01.209' W 74°21.686' S	1411	1465
W3	16.02.2010 13:00 14.02.2011 12:50	035°55.301' W 74°13.105' S	1844	1879

2.2. Instrumentation

The moorings were equipped with Sea-Bird Electronics temperature (SBE39) and conductivity and temperature recorders (SBE37 Microcat), Aanderaa Instruments (AADI) recording current meters (RCM-7/8 and Seaguard RCM), and acoustic Doppler current profilers (ADCP, RD-Instrument 300 kHz Sentinel and 75 kHz Longranger, and AADI 600kHz RDCP600). The details of the mooring instrumentation are given in Table 2. Instrument depths listed in Table 2 are corrected using the instrument pressure records and the mooring part lengths, and may differ from the planned target heights.

The sampling rate was set to 5 min for the Microcat and SBE39, 1 h for the RCM-7/8, 20 min for the RDI ADCPs. The RCMs averaged 50 evenly distributed samples per hour. The Seaguard RCMs and RDCP6000 (2 m vertical bins) recorded data at 20 min intervals. All RDI ADCPs (300 kHz and 75 kHz) sampled an ensemble of 30 pings collected in burst mode for the first 60 s, and collected profiles in 27 bins of 4-m thickness. Ensemble average profiles are obtained every 20 minutes. The 75 kHz instrument was thus deployed in error, apparently initialized using a 300 kHz deployment file. (The original plan was hourly ensembles with 40, 16-m thick bins.)

Both 300 kHz RDI ADCPs (serial numbers, SN10149 and 11434) were 1000 m rated and equipped with T/P sensors and 576MB memory cards. The Longranger (SN8645) on W2 was unfortunately set up for only 27 bins of 4 m size (giving a much shorter range than the nominal 500 m). This was an operator mistake. The Longranger stopped logging on 2 January 2011 (approximately 12 days before recovery) as a result of low battery power. Another operator mistake regarding the RDI ADCPs was to leave the memory card unereased before deployment. While the Longranger had enough memory capacity to record until its battery limited the data quality (until 12 days before recovery), 300 kHz SN10149 stopped logging on 17 December 2010 0800 UTC because of full memory (approximately 2 months before recovery). Similarly, the 300 kHz SN11434 at W3 stopped logging on 17 December 2010 1600 UTC, because of full memory.

AADI RDCP600 stopped logging on 18 May 2010 because of low battery power.

Table 2. Mooring instrument details. Height is measured in meters above bottom (m.a.b.) and corrected using mooring line lengths and pressure records from the instruments. 198:4:234 means from 198 to 234 m.a.b. at 4 m increments. Parameters are temperature (T), conductivity (C), pressure (P), horizontal velocity (V) and vertical velocity (W). Instruments are given with their serial numbers (SN).

Mooring	Height (m.a.b.)	Parameter	Instrument
W2	25, 84	T, V	RCM-7, SN01586, SN10805
	28, 257	T, C	Microcat SN5409, SN5398
	50, 94, 181, 287	T, C, P	Microcat SN7372, SN7373, SN6017, 6018
	63	T, P	SBE39 SN3282
	138	T	SBE39 SN3572
	244	T, P	RDI 300 kHz SN10149
	198:4:234	V, W	------- // ------- downlooking profile
	289	T, P	RDI 75kHz Longranger, SN8645
	296:4:400	V, W	------- // -------, uplooking profile
W3	25	T, P, V	Seaguard RCM SN240
	28, 160	T, C	Microcat SN6297, 7335
	70, 109, 190, 277	T, C, P	Microcat SN7222, 7224, 5451, 5452
	82	T	SBE39 SN3574,
	93	T, V	RCM-8 SN09907
	214	T, C, P	AADI RDCP600 SN229 [EXCLUDED]
	214	V	------- // ------- … profile [EXCLUDED]
	278	T, P	RDI 300 kHz SN11434
	200:4:272	V, W	------- // ------- downlooking profile

3. Data preparation

Data from the instruments are read and converted to physical units using the manufacturers' standard softwares and will not be detailed here. The raw data is available upon request from Ilker.Fer@uib.no. Quality controlled data set at full temporal resolution is submitted to the PANGAEA and is freely available. Following details were applied in finalizing the data set.

Velocity

All instruments recorded in Earth coordinates. For 4-beam instruments (RDI), 3-beam solutions are allowed. Any ensemble with the "percent-good" parameter less than 50% and clearly erroneous data with pitch and roll in excess of 20°, error velocity exceeding 1 m s^{-1}, vertical velocity exceeding 1 m s^{-1} and horizontal velocity exceeding 2 m s^{-1} are flagged as bad. After removing these points, together with the times prior to and after the deployment and recovery, the following quality control is applied. A smoothed version of the error velocity is calculated by moving averaging in time and range using 20 point length vertical and time windows. The standard deviation (std) of the un-smoothed data at each bin is calculated. At each bin, outliers are identified as data points exceeding the ±3 (std) envelope of the smoothed values. Remaining spikes, identified as velocity measurements exceeding ±3 std in 40 ensemble windows at each bin, are removed. Gaps less than one-hour length are interpolated. The instruments did not experience excessive tilt (>10°) that would affect the data quality. The first bins of the Longranger (SN8645) and 300kHz (SN10169) at W2 were affected by side-lobe reflections and excluded from the data set. Furthermore the depth records from instruments SN11434 and SN8645 showed significant offsets relative to that inferred from nearby, accurate pressure sensors (SBE instruments). ADCP depth records are corrected by constant offset of -29 m (SN11434) and -21 m (SN8645). In all calculations, care was taken to convert pressure to depth, and depth to height above bottom as appropriate.

RCM SN10805 at W2 84 m.a.b. has a gap in the time series between 19 June and 8 August 2010, for unidentified reasons. Upon recovery, the RCMs' DSU clocks were found to be slow by 9 min (RCM8 SN9907), 15 min (RCM7,SN 1586) and 11 min (RCM7, SN10805). No correction was made (current meters recorded hourly-averaged data).

RDCP600 returned only 5 good bins (10 m range) and only for a short duration until 18 May 2010. Because the RDI SN11434 looking downward from approximately 80 m above the RDCP600,returned good quality data, there is longer time series from a nearby depth bin. A comparison of the two time series from a distant bin of SN11434 shows excellent agreement with the RDCP600. We therefore exclude the RDCP600 from the data set. (It can be used for a high vertical resolution analysis if necessary.)

Magnetic declination is not large at the site. For completeness, however, we made the following declination corrections to all current measurements in the data set: W2, 4.2°E; W3, 4.1°E. The declination values are obtained from https://www.ngdc.noaa.gov/geomag-web/ at the corresponding mooring location, for the date 15 February 2010.

Salinity and temperature

Salinity measurements from the RCM conductivity sensors are excluded (C parameter for RCMs are not listed in Table 2, but several instruments were equipped with C sensors). None of the Microcats were pumped and caution is advised in interpreting the salinity data from the Microcats.

The overflow site is characterized by periodic energetic events near the bottom several hundred meters. After careful inspection, we found no convincing reason to exclude these events as bad data. Further analysis is required: however, the events can be associated by turbulent overturns in the overflow plume. To retain the variance in the salinity measurements, only a very basic salinity despiking is applied. Significant outliers are detected and removed in two passes. In the first pass smoothed salinity (S_{mov_av}) and std over moving windows (S_{mov_std}; a continuous std, similar to the moving average operation) are calculated using 600 data point windows. Measurements exceeding a $S_{mov\_av} \pm 7S_{mov\_std}$ envelope are removed. In the second pass the procedure is repeated with 120 point windows and 5 std threshold. This procedure accounts for and retains the high-variable episodic large variances observed in the time series.

Time-averaged profiles of the salinity are examined and minor offset corrections were applied to obtain a smooth, stable profile: Salinity at 257 mab at W2 was corrected by 0.009, and at W3, at 109 mab (SN7224) by -0.0062 and at 190 mab (SN5451) by 5×10^{-4}.

Temperature from the uppermost RDI ADCP at W3 is excluded because there is a SBE 1 m below the ADCP. Time-average profiles of temperature are also examined to detect anomalous levels. No adjustment was necessary.

4. Overview of Appendices

The appendices include:

Section 6, Appendix: Mooring drawings
Section 7, Appendix: Data overview; Time-average profiles
Section 8, Appendix: Data overview; Time series
Section 9, Appendix: Overview of RDI ADCP data quality

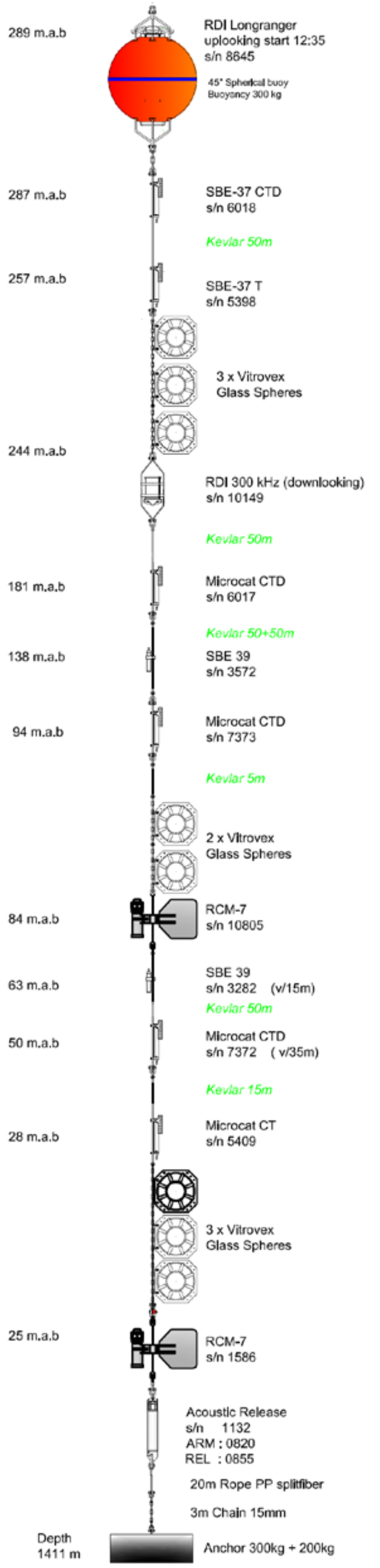
The time series are presented for each instrument and each mooring for pressure, temperature, salinity and velocity.

5. Acknowledgements

BIAC was funded by the Research Council of Norway, project number 176082. Deployment and recovery operation was led by Svein Østerhus. We are grateful for the assistance of the crew and scientific party onboard RRS Ernest Shackleton (February 2010) and RRS James Clark Ross (February 2011). Helge Bryhni and Steinar Myking provided the technical mooring assistance. Help from Lisbeth Håvik and Kjersti Strand, who participated in the operations, are appreciated. Kjersti Daae prepared an initial version of this data set, carefully working out the instrument positions on the mooring, and performed initial quality controls.

6. Appendix: Mooring drawings

Read WIF2 = W2, and WIF2 = W3 The uppermost buoy with ADCP at W3 is at 278 m.a.b.



UNIVERSITY OF BERGEN
Geophysical Institute

Project: WIF - 2

Location:

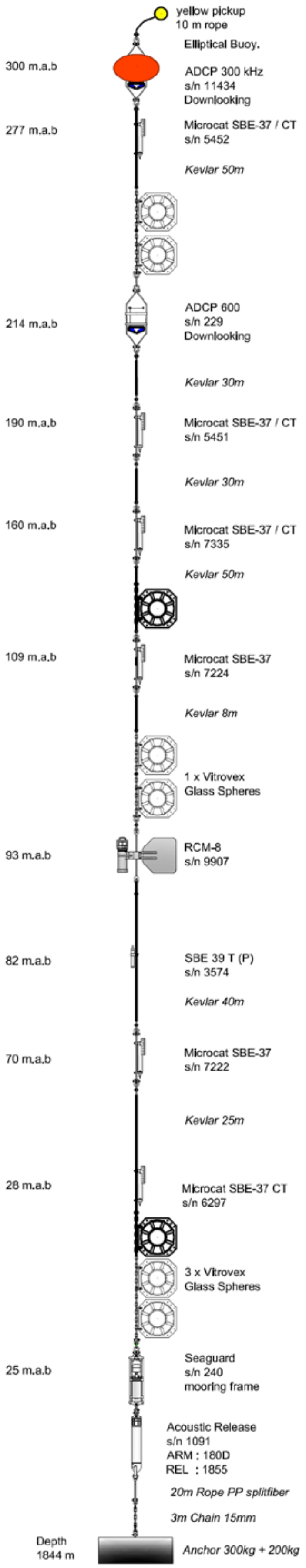
Position: S74 21.662 W036 01.209

Depth: Depth 1411m

Deployment: 16.02.2010 kl. 16:36 UTC

Retrieval: 14.02.2011 kl. 08:06 UTC

Comments:



UNIVERSITY OF BERGEN
Geophysical Institute

Project: WIF - 3

Location: Weddellhavet

Position: S 74 13.105 W 035 55.301

Depth: 1844m

Deployment: 16 februar 2010 - kl.08:35 GMT (-3)

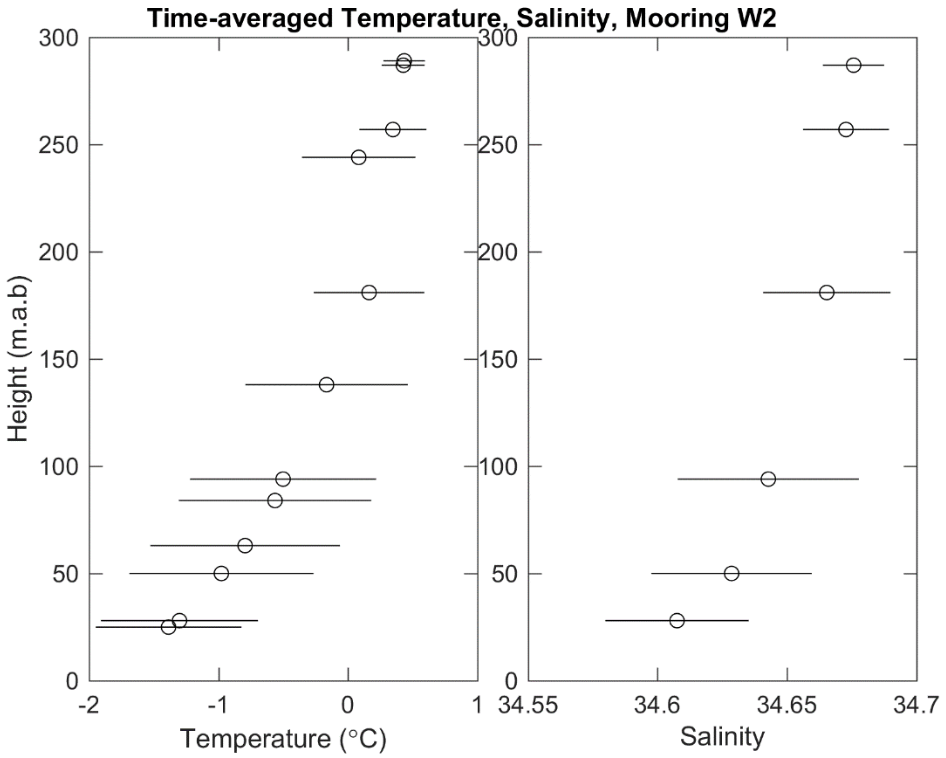
Retrieval:

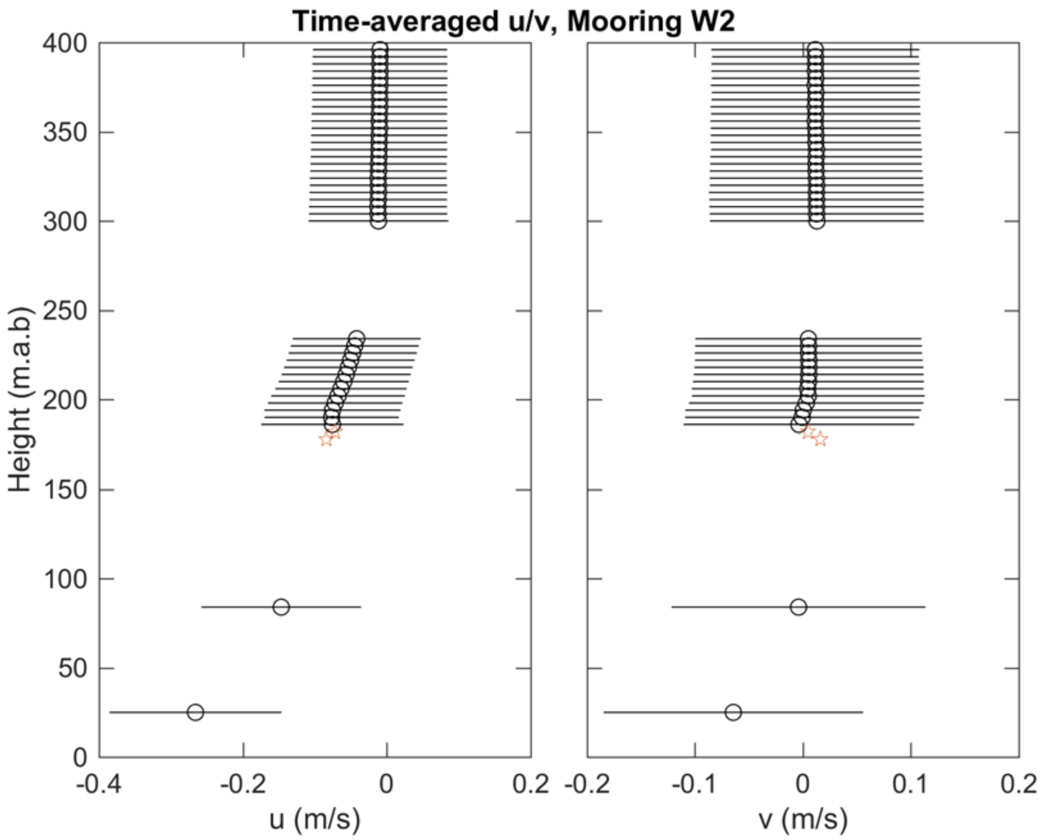
Comments: Anchor droped 09:35

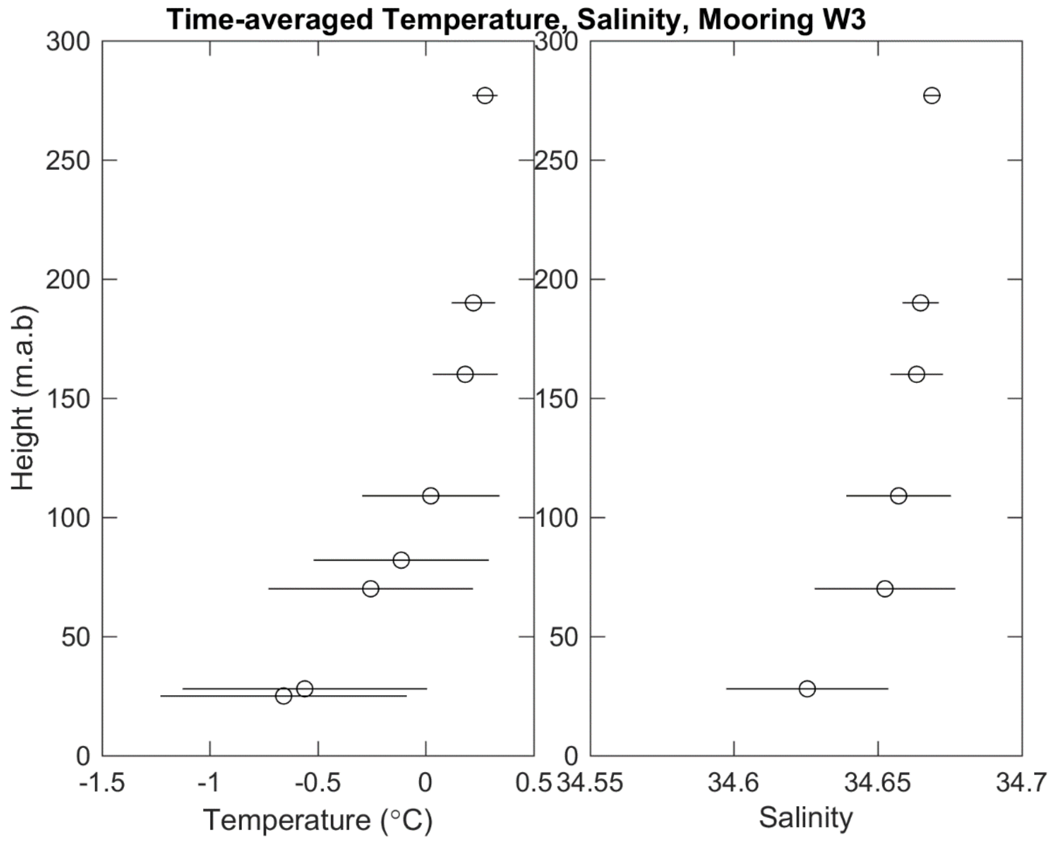
Mrk. Seaguard: Sort POM beskyttelsesring er brukket

7. Appendix: Data overview; Time-average profiles

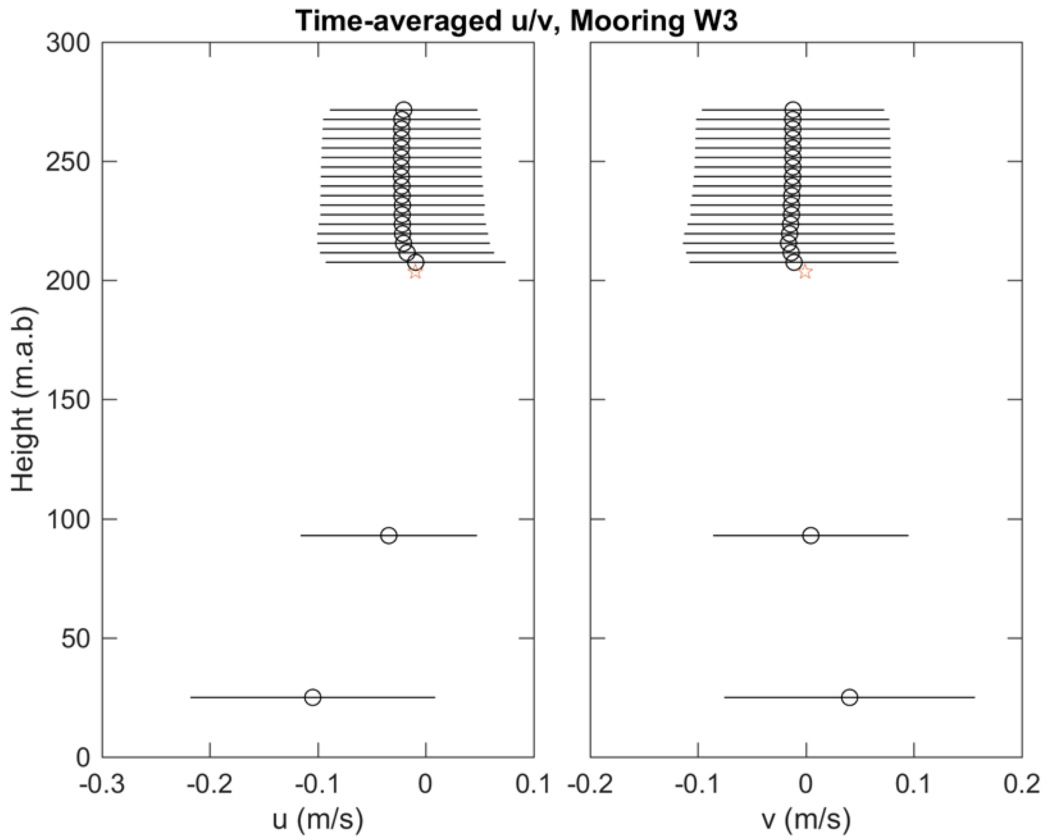
Any level with data time coverage percentage less than 5% is excluded. Any level with data time coverage percentage between 5% and 20% is marked by pentagrams (and can be biased relative to the full time average).





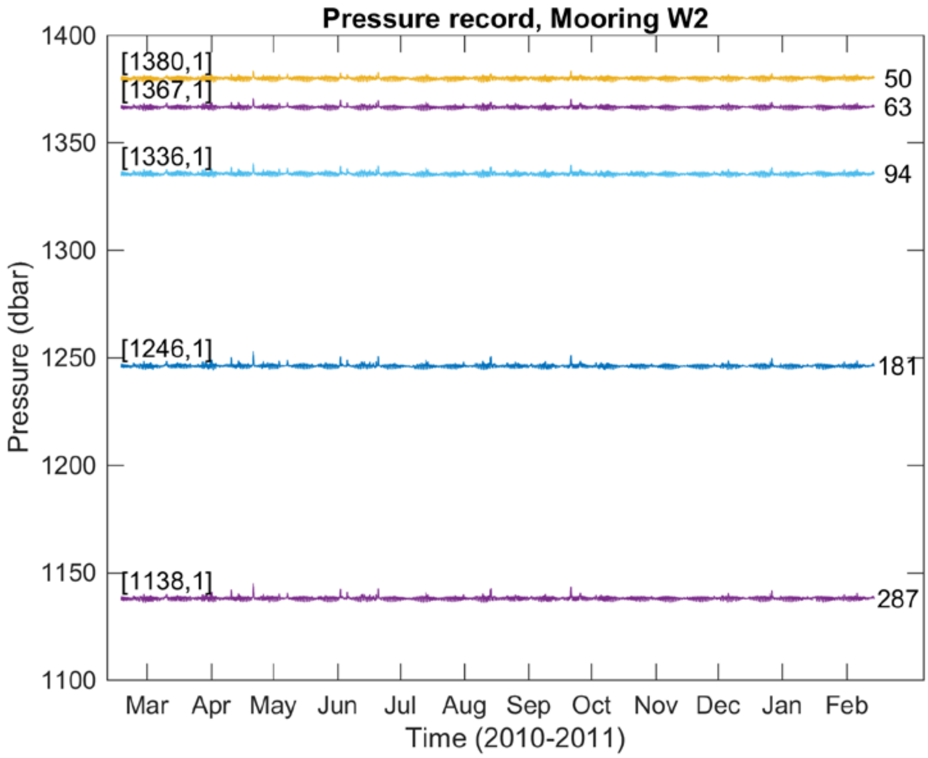


Time-averaged Temperature, Salinity, Mooring W3
Height (m.a.b)
Temperature (°C)
Salinity



Time-averaged u/v, Mooring W3
Height (m.a.b)
u (m/s)
v (m/s)

8. Appendix: Data overview; Time series



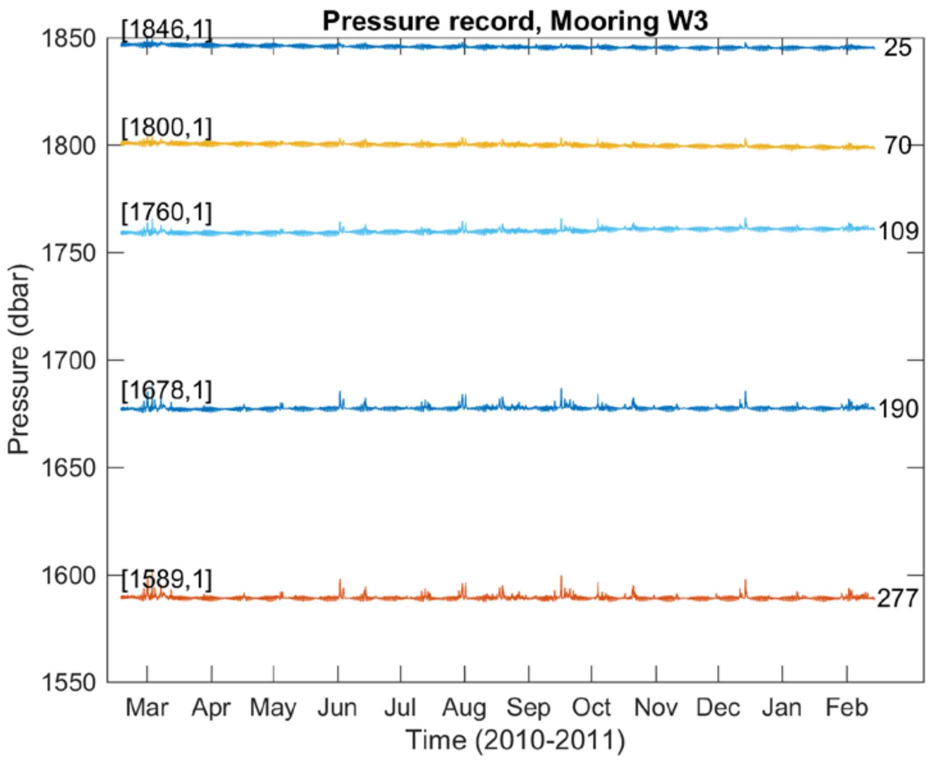


Figure 2. Pressure time series from instruments equipped with pressure sensors, for moorings W2 to W3 as indicated. Time average and one standard deviation values are given in square brackets. The numbers at the end of each record is the height (m.a.b) of the sensor.

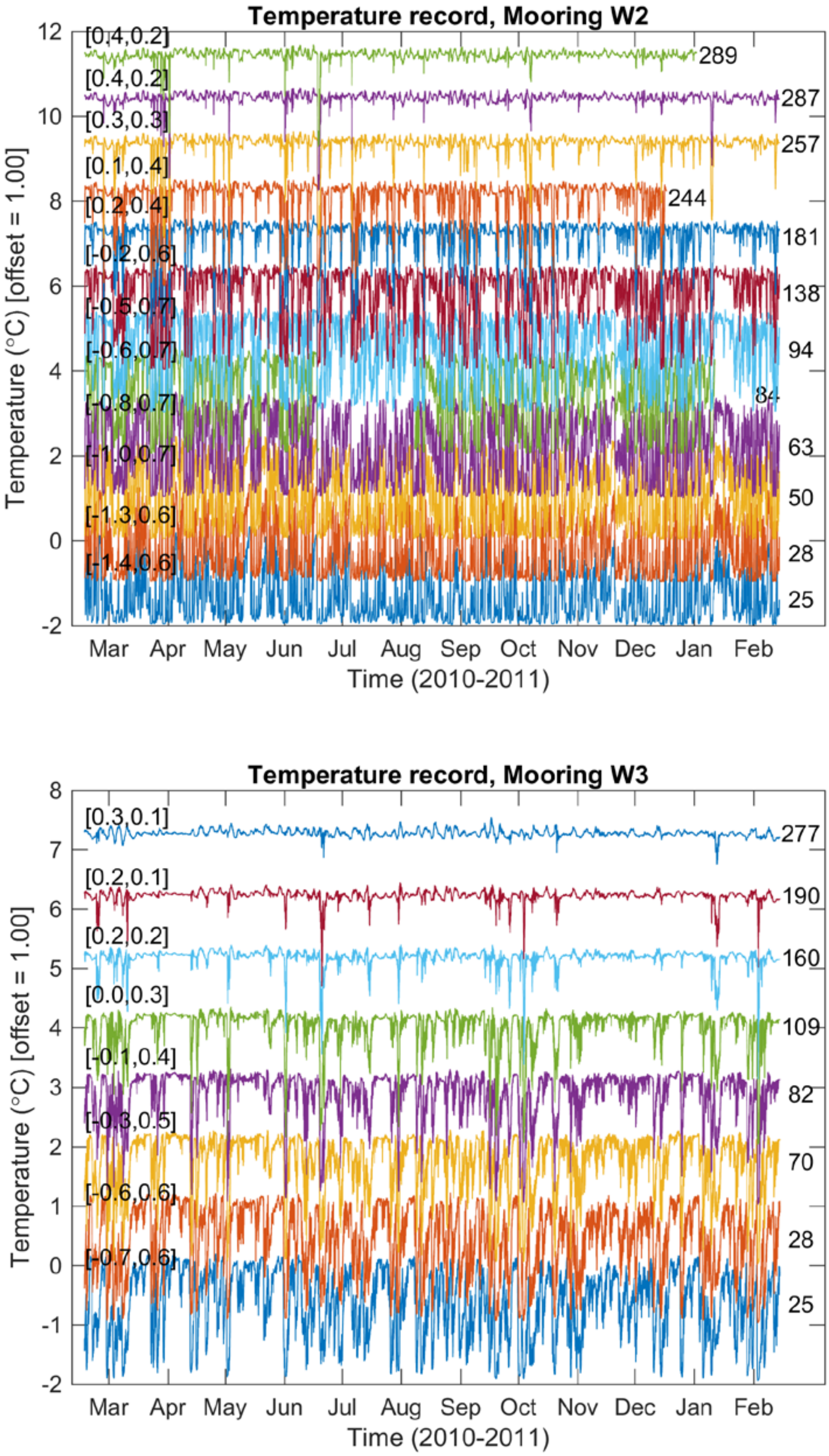


Figure 3. Time series of temperature measured at W2 and W3 (one panel for each mooring as indicated). Time series are offset vertically from the lowest level with the value indicated in the y-axis. Time-average value and one standard deviation are given in square brackets. The height (m.a.b.) of the sensor is indicated at the end of the record.

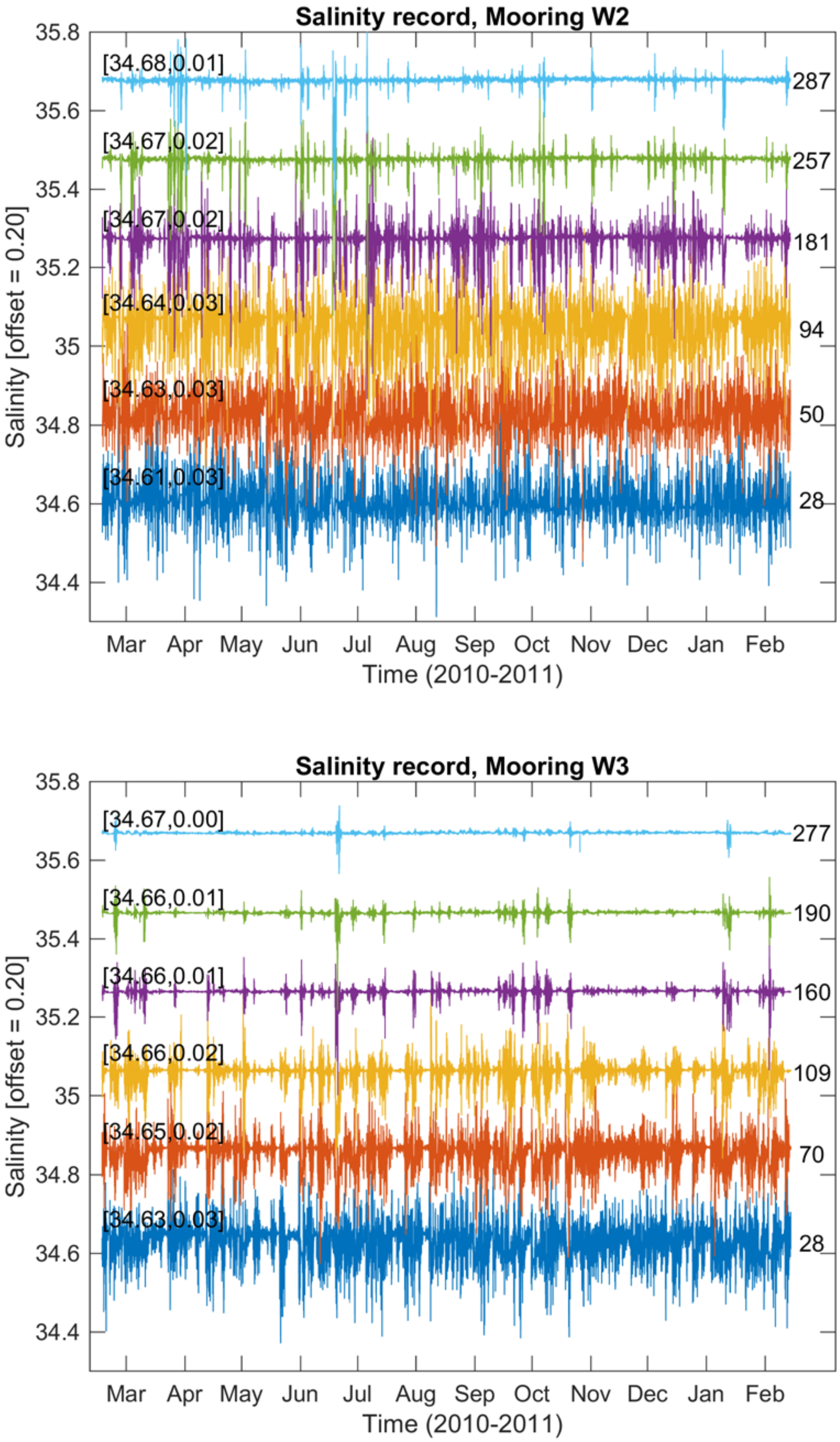
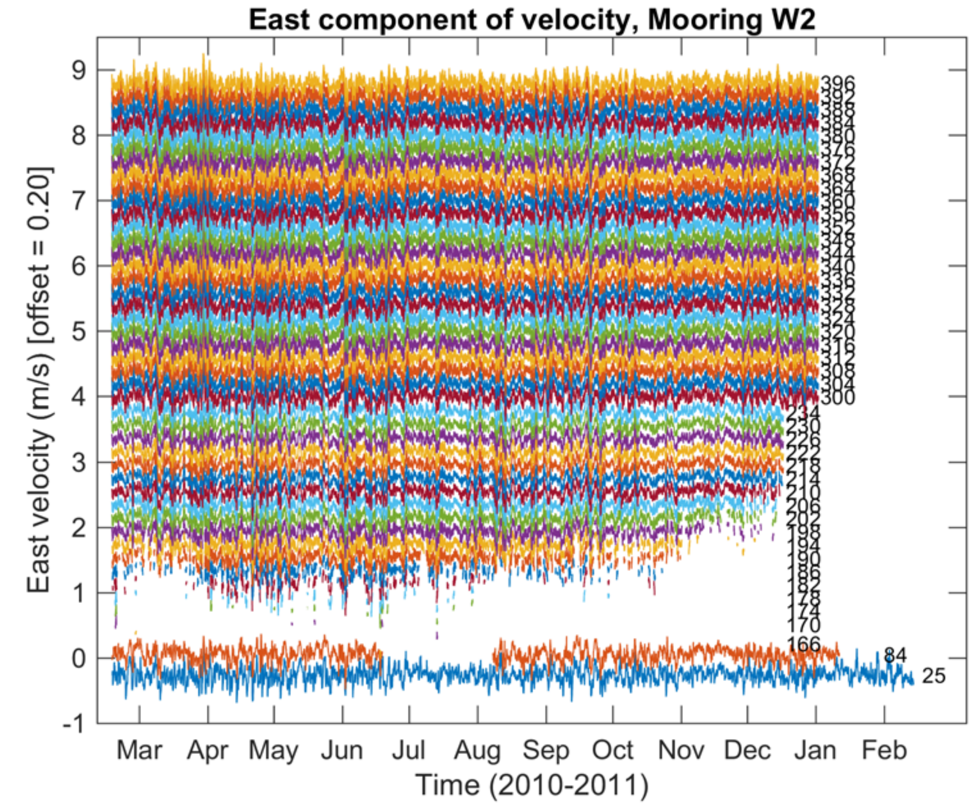


Figure 4. Same as Figure 3 but for salinity.



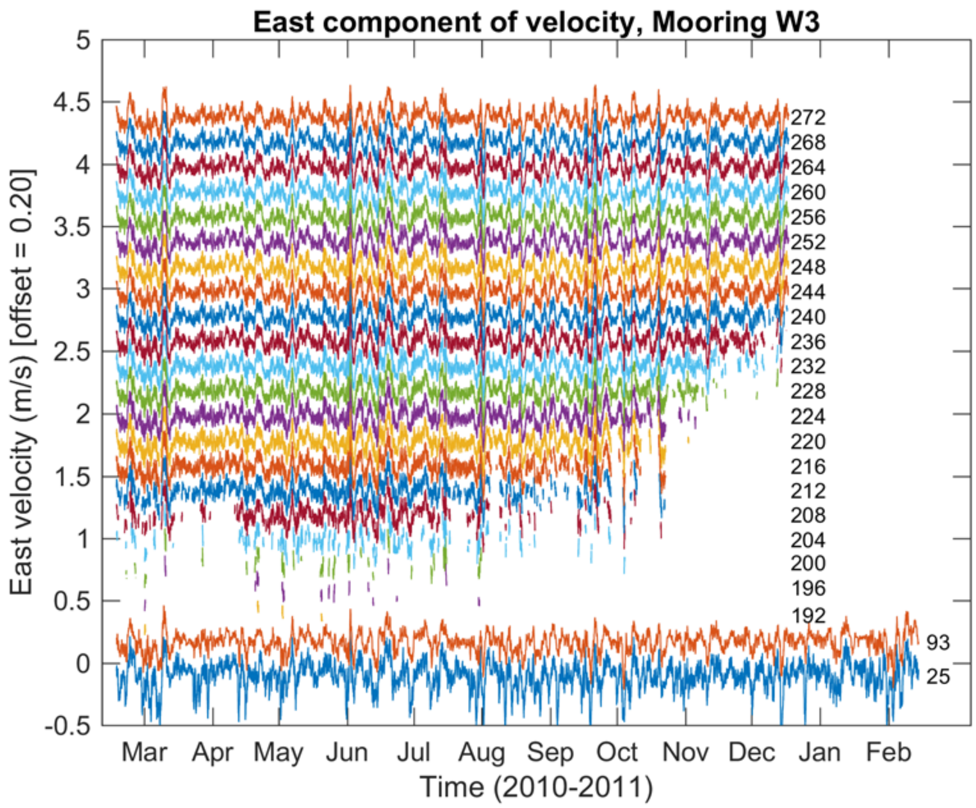
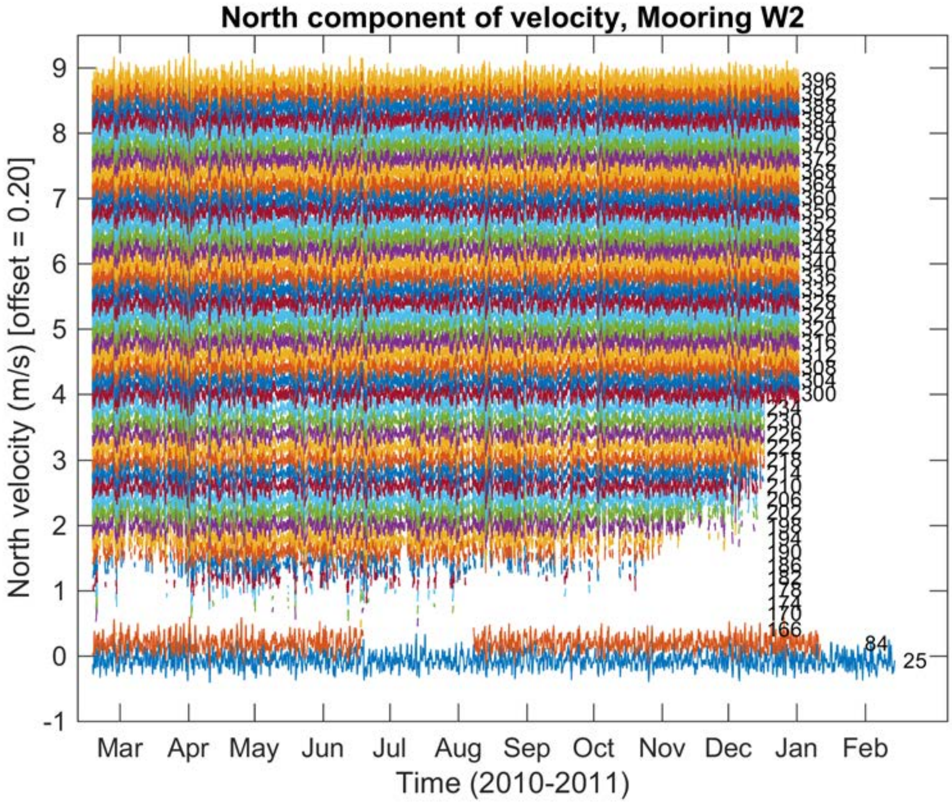


Figure 5. Same as Figure 3 but for the east component of velocity.



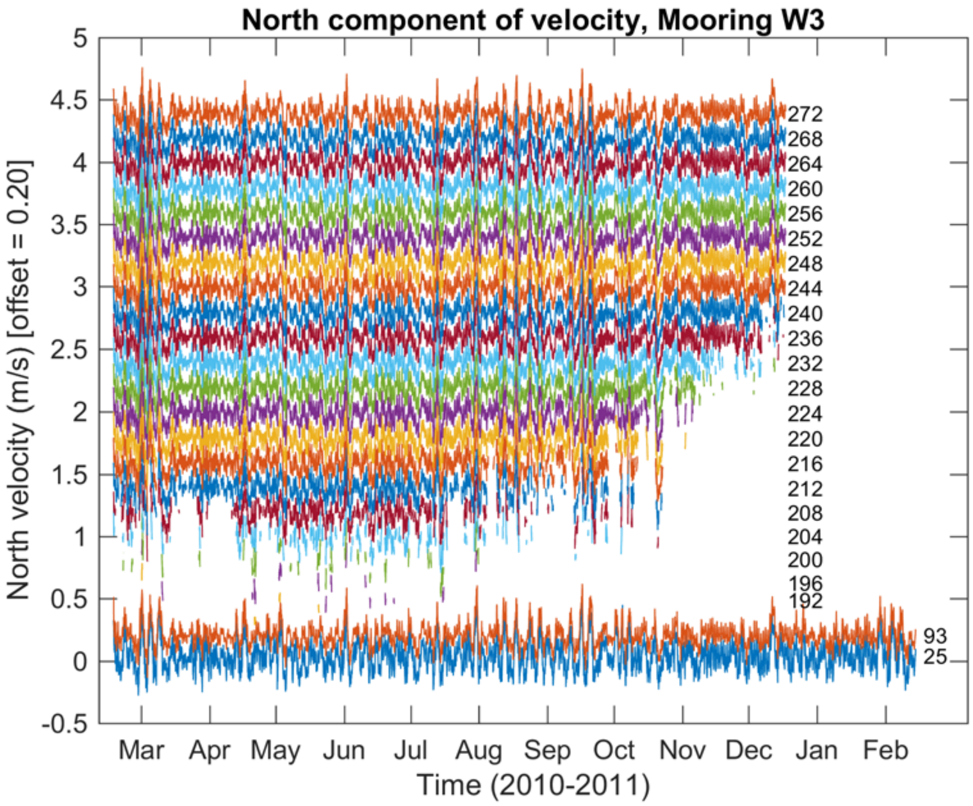


Figure 6. Same as Figure 3 but for the north component of velocity.

9. Appendix: Overview of RDI ADCP data quality

For each RDI ADCP instrument, we present 3 figures. The first shows range/time maps of quality control parameters, together with their time average profile. The second shows time series from selected sensors, such as tilt and temperature. The final figure shows the range/time map of clean U/V velocity fields and their time average profiles

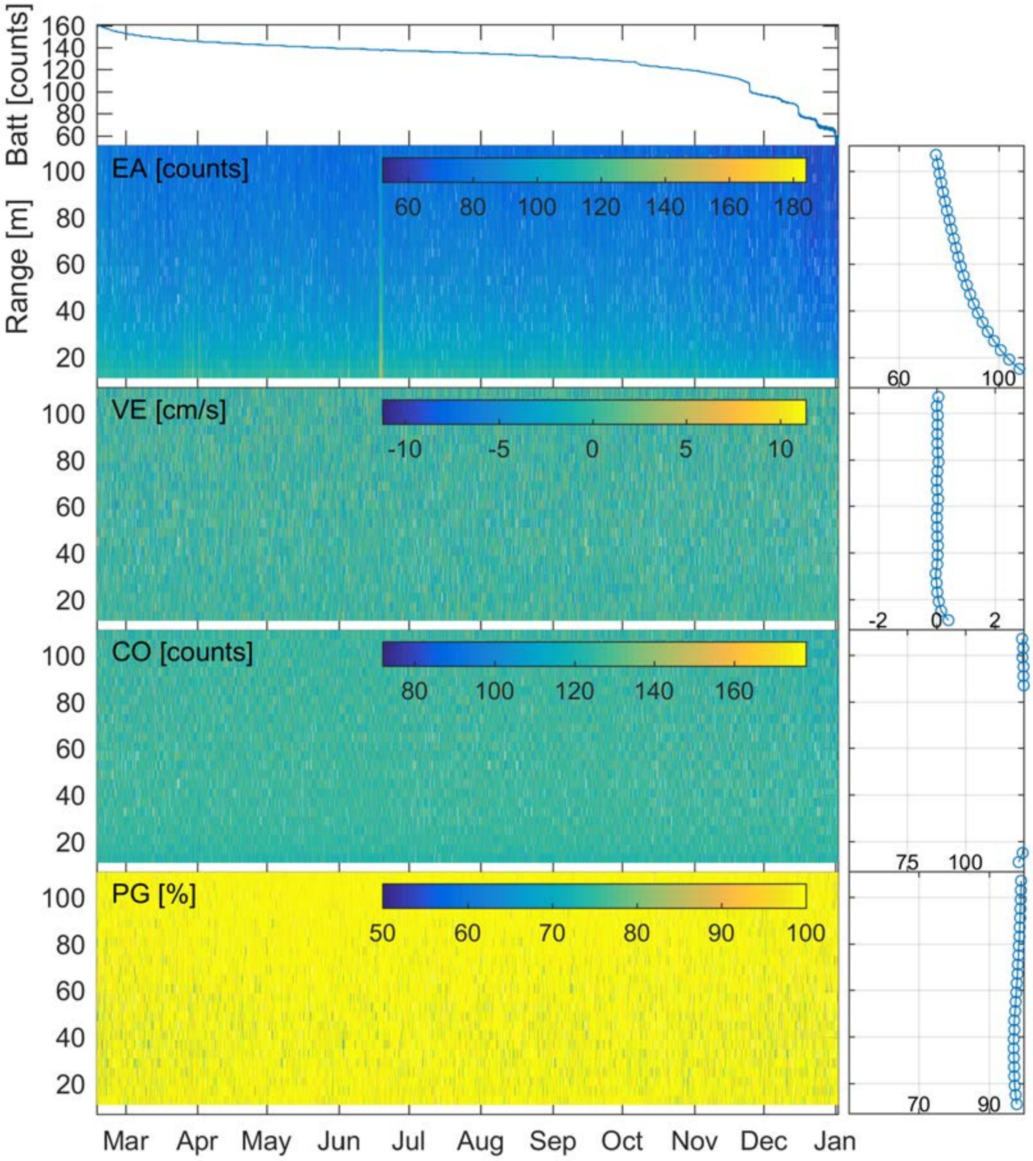


Figure 7. RDI ADCP SN 8645 (Longranger). Time series of battery power in counts followed by vertical range-time maps of echo amplitude, error velocity, coherence (all averaged over 4 beams) and percent good parameter. Rightmost panels show their time average profiles.

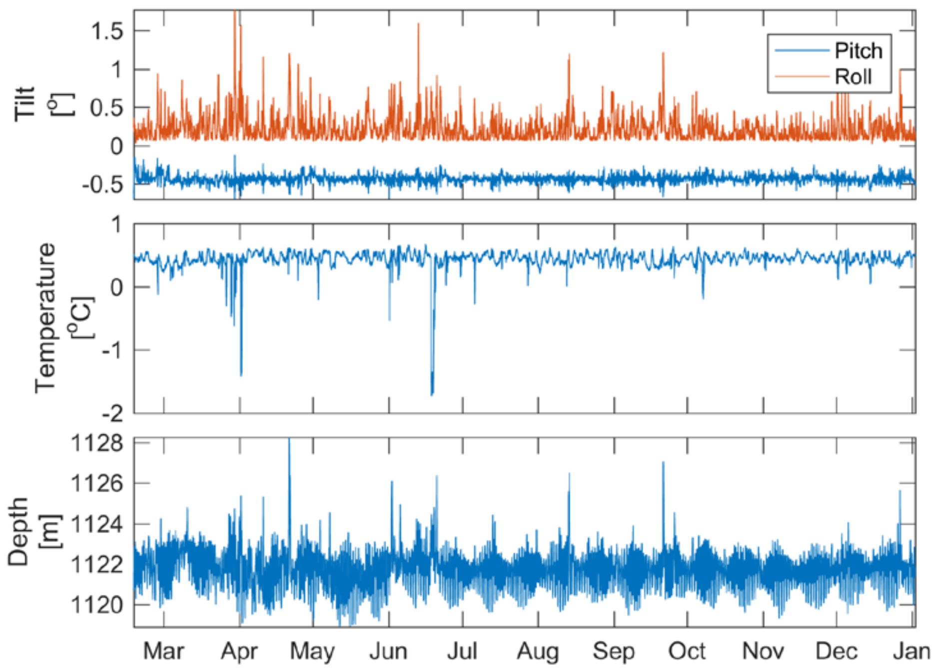


Figure 8. RDI ADCP SN 8645 (Longranger). Time series from tilt, temperature and depth sensors.

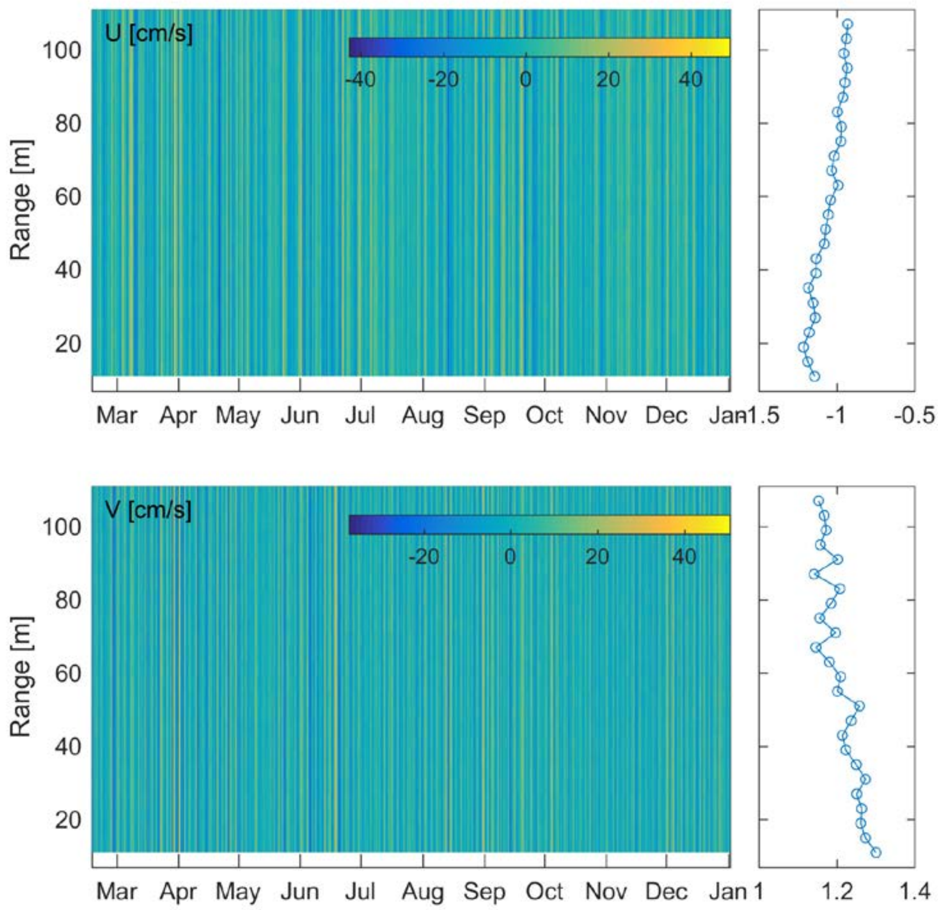


Figure 9. RDI ADCP SN 8645 (Longranger). Vertical range - time maps of east and north velocities and their time average profiles

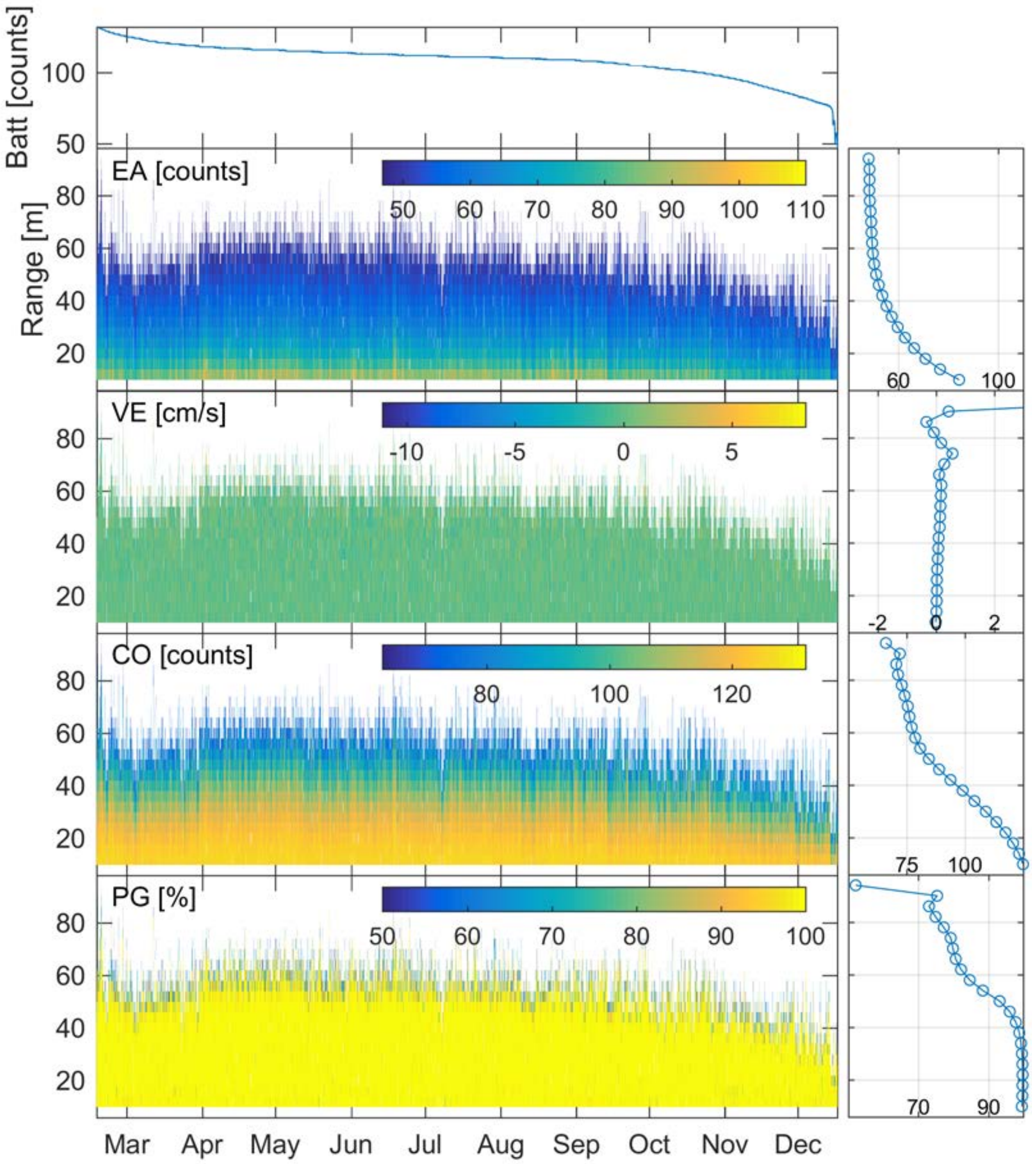


Figure 10. RDI ADCP SN 10149. Time series of battery power in counts followed by vertical range-time maps of echo amplitude, error velocity, coherence (all averaged over 4 beams) and percent good parameter. Rightmost panels show their time average profiles.

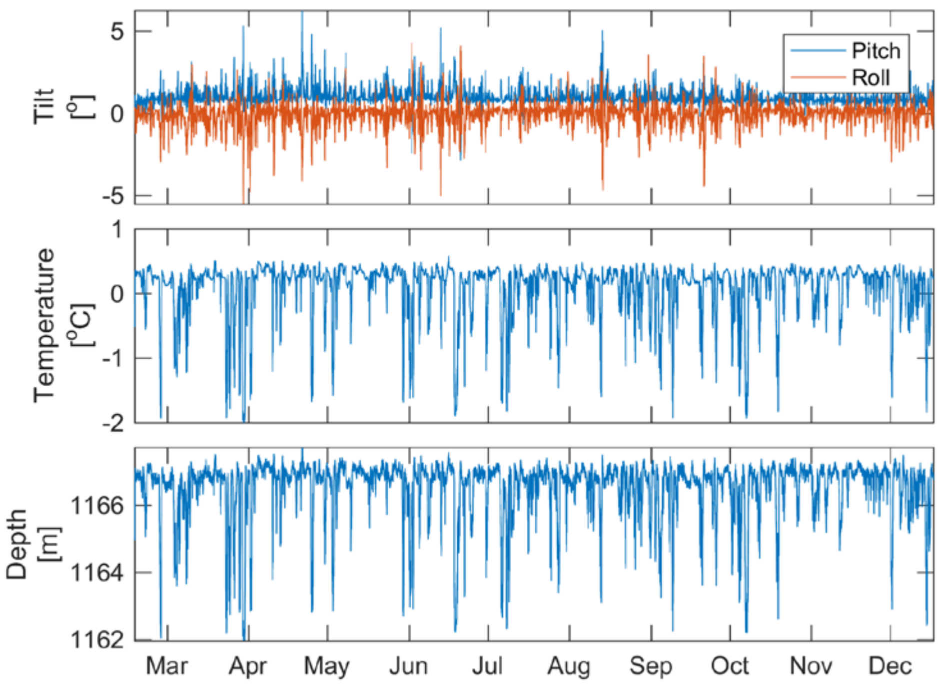


Figure 11. RDI ADCP SN 10149. Time series from tilt, temperature and depth sensors.

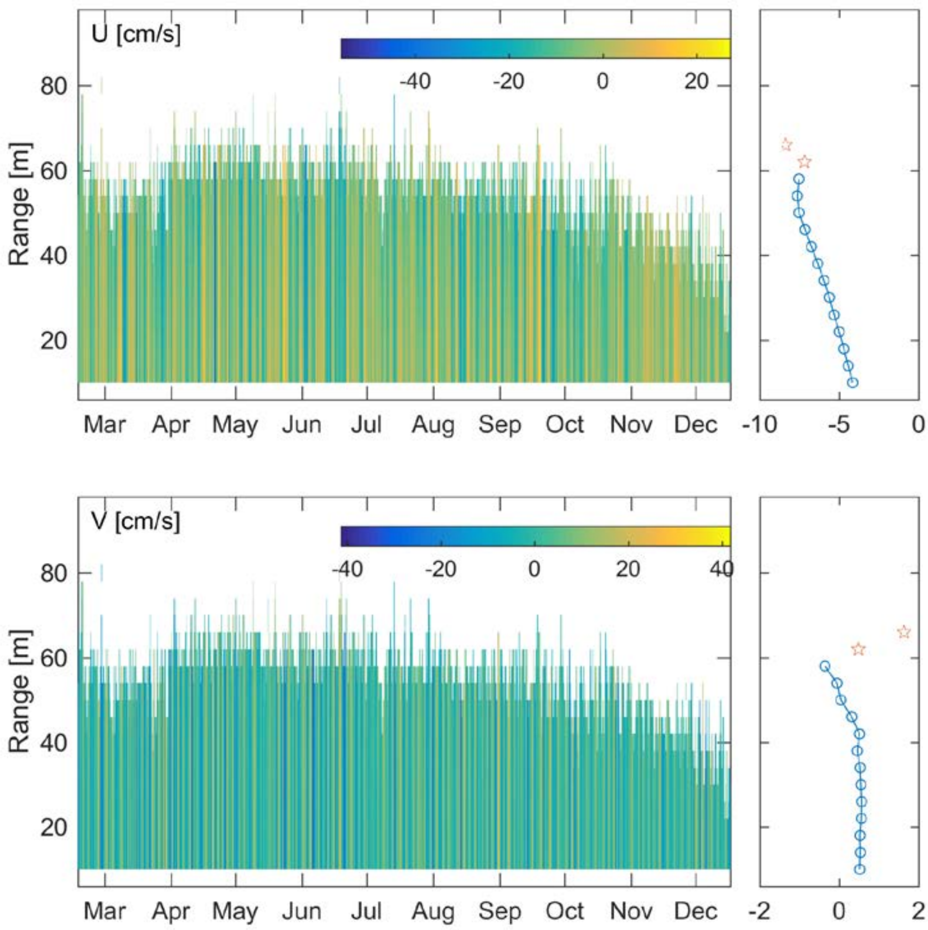


Figure 12. RDI ADCP SN 10149. Vertical range - time maps of east and north velocities and their time average profiles. Pentagram: time coverage between 5-20%.

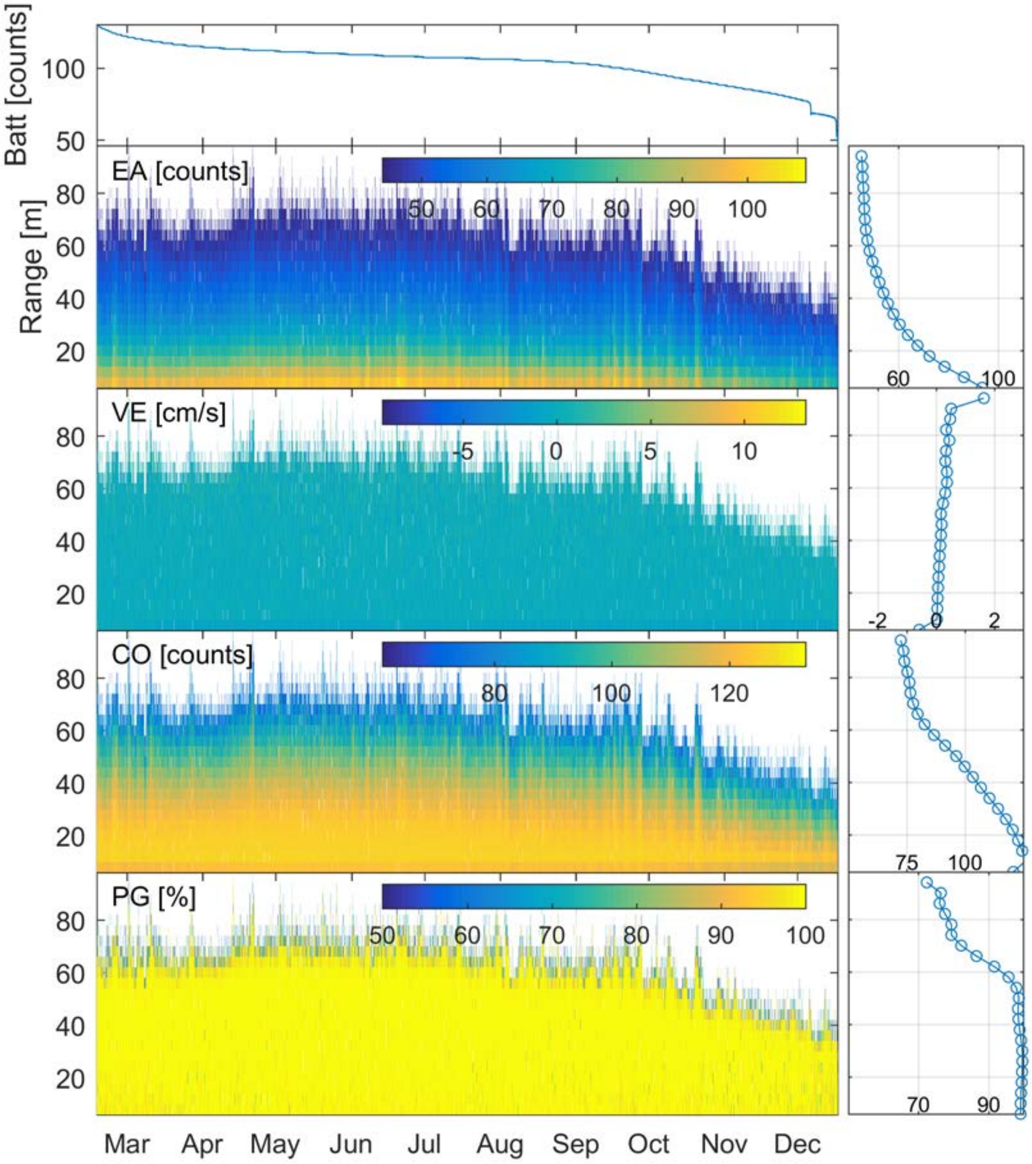


Figure 13. RDI ADCP SN 11434. Time series of battery power in counts followed by vertical range-time maps of echo amplitude, error velocity, coherence (all averaged over 4 beams) and percent good parameter. Rightmost panels show their time average profiles.

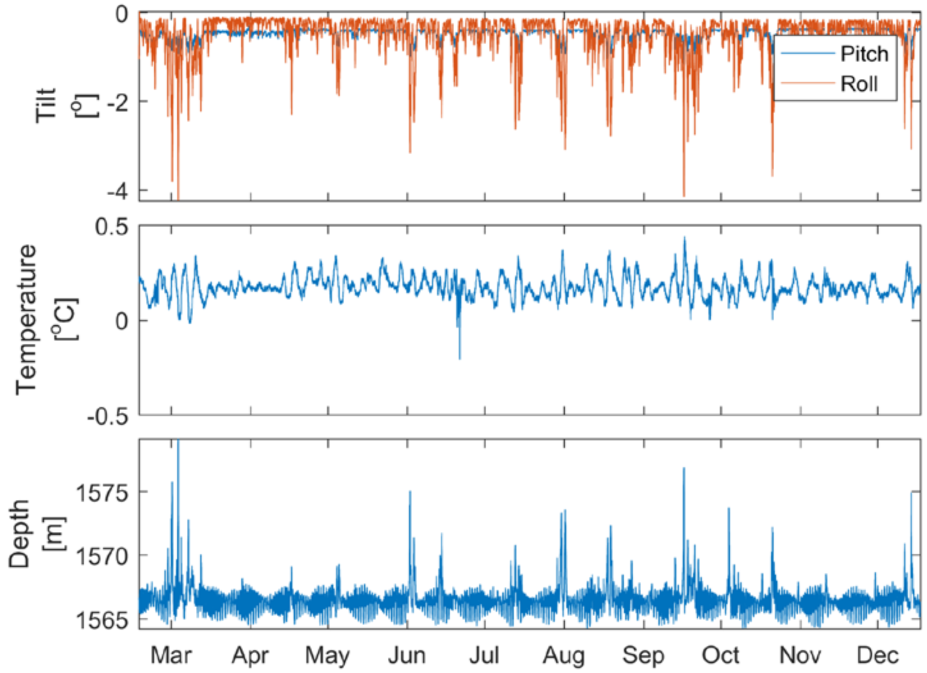


Figure 14. RDI ADCP SN 11434. Time series from tilt, temperature and depth sensors.

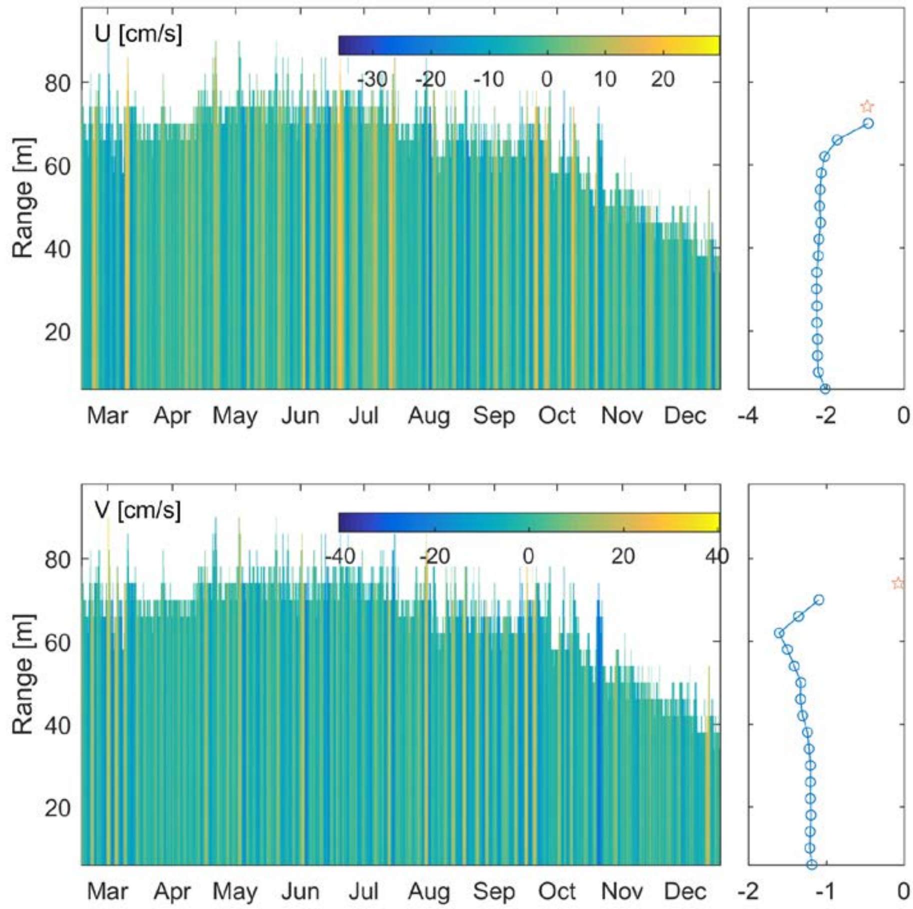


Figure 15. RDI ADCP SN 11434. Vertical range - time maps of east and north velocities and their time average profiles. Pentagram: time coverage between 5-20%.

10. References

Fer, I. (2016), Moored measurements of current, temperature and salinity in the southern Weddell Sea, January 2009-January 2010, U. o. B. Geophysical Institute, doi: 10.1594/PANGAEA.869799.

Fer, I., K. W. Nicholls, and E. Darelius (2015), Measurements of ocean microstructure, physical oceanography and current in the Weddell Sea, Antarctica, during the RRS Ernest Shackleton cruises ES033 and ES060, U. o. B. Geophysical Institute, doi: 10.1594/PANGAEA.854379.

Foldvik, A., T. Gammelsrød, S. Østerhus, E. Fahrbach, G. Rohardt, M. Schröder, K. W. Nicholls, L. Padman, and R. A. Woodgate (2004), Ice shelf water overflow and bottom water formation in the southern Weddell Sea, *J. Geophys. Res.*, *109*, C02015, 10.1029/2003jc002008.

11. Acknowledgements

BIAC was funded by the Research Council of Norway, project number 176082. Deployment and recovery operation was led by Svein Østerhus. We are grateful for the assistance of the crew and scientific party onboard RRS Ernest Shackleton (February 2010) and RRS James Clark Ross (February 2011). Helge Bryhni and Steinar Myking provided the technical mooring assistance. Help from the students Lisbeth Håvik and Kjersti Strand who participated in the operations are appreciated. Kjersti Daae prepared an initial version of this data set, carefully working out the instrument positions on the mooring, and performed initial quality controls.