REPORT

Moored measurements of currents, temperature and salinity in the southern Weddell Sea

January 2009 – January 2010

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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 at the Geophysical Institute, University of Bergen (Tor Gammelsrød) and is funded by the Research Council of Norway (project number 176082) for the period 2007 to 2011. The moored measurements were conducted under the working theme WT3: "Downslope processes, pathways, cascading and mixing", led by Ilker Fer.

During BIAC-WT3, the Southern Ocean part of the field work was planned 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 Filchner Depression. The southern Weddell Sea is an important area for the formation of Antarctic Bottom Water [*Foldvik et al.*, 2004; *Orsi et al.*, 1999]. The inclination of the continental slope, tidal dynamics near the critical latitude and the proximity of the upper continental slope to the critical latitude acting together lead to conditions favoring enhanced mixing on the continental slope of the southern Weddell Sea [*Daae et al.*, 2009; *Fer et al.*, 2016; *Robertson*, 2001]. This in turn influences the mixing of Warm Deep Water with shelf waters, hence the regional heat budget and the circulation.

Weddell Sea field work is conducted during the cruise of British Antarctic Research Vessel 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 Pangaea [*Fer et al.*, 2015]. Due to difficult ice conditions, the Filchner outflow site could not be accessed. Moorings were instead deployed on the southeastern Weddell Sea, on the central Crary Fan and further to the east. The positions were chosen to capture the variability associated with the slope current in the region, basin-shelf exchange as well as the tidal band variability. This report summarizes the details of the moored instrumentation. Data from moored instruments were recovered covering the period February 2009 to February 2010. Data set includes time series of ocean temperature, salinity and currents on the continental slope of the southeastern Weddell Sea at five locations in the region 74-75°S; 29-33°W. The observations from these moorings were reported in *Jensen et al.* [2013] who discuss the subinertial mesoscale variability attributed to trapped vorticity waves. The data set is submitted to Pangaea (Fer 2016, DOI pending).

2. Moorings

2.1. Overview

Five bottom-anchored oceanographic moorings were deployed on the continental slope of the southern Weddell Sea during the cruise of British Antarctic Research Vessel RRS Ernest Shackleton (ES033, 22 January - 7 March 2009). Deployment work was led by Ilker Fer. The positions are detailed in Table 1 and shown in Figure 1. All moorings were retrieved in February 2010, again from RRS Ernest Shackleton (cruise ES052). The recovery was led by Svein Østerhus (Bergen).

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 Appendix.

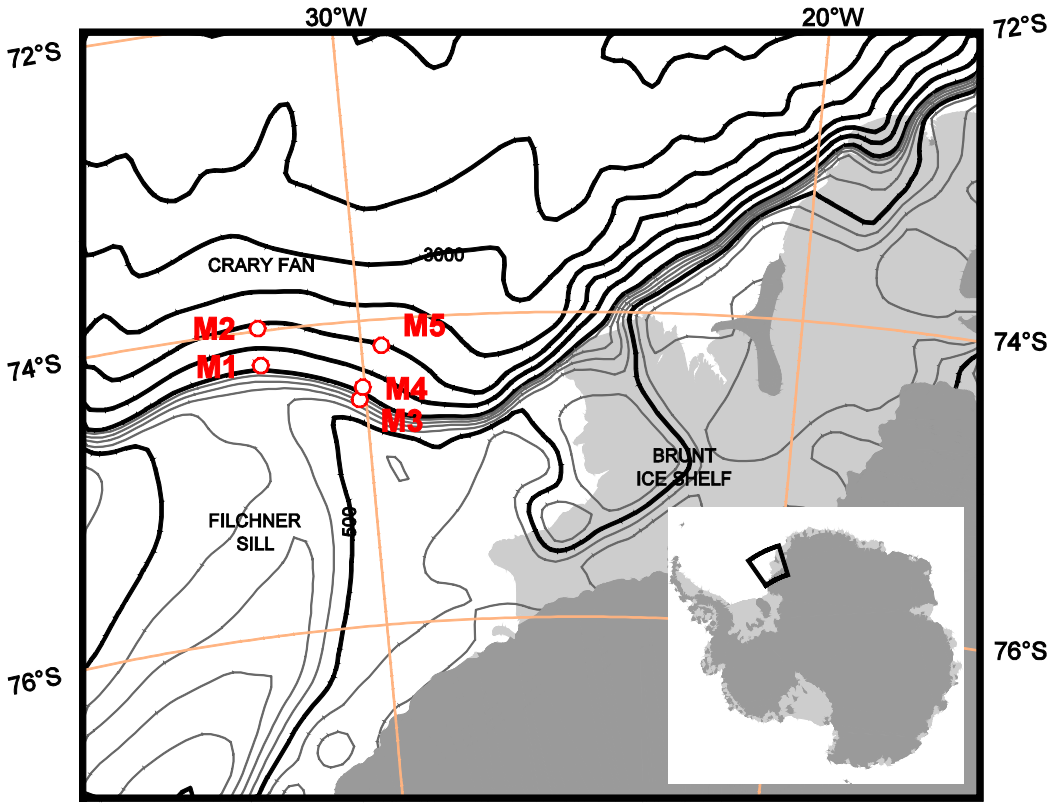


Figure 1. Locations of moorings M1 to M5 shown over the Bedmap isobaths drawn at 500 m intervals as thick contours and at 100 m intervals to 1000 m as thin contours. Dark gray is land and light gray is ice shelf. Inset shows the location in Antarctica.

Table 1. Mooring deployment details. Deployment time is anchor drop. Bottom depth is the best estimate using corrected echo sounder, instrument pressure records and mooring lengths. Echo depth is listed as measured in situ and the value corrected using the measured sound velocity profile.

Mooring	Deployed Recovered (UTC)	Longitude Latitude	Bottom Depth (m)	Echo depth (m) In situ / correct.
M1	10.02.2009 17:39 10.02.2010 22:00	032°19.19' W 74°13.68' S	967	1096 / 1070
M2	11.02.2009 18:05 10.02.2010 22:00	032°16.68' W 73°58.68' S	1898	1960 / 1913
M3	13.02.2009 16:30 09.02.2010 18:00	030°09.91' W 74°30.63' S	725	753 / 728
M4	13.02.2009 13:19 09.02.2010 15:00	030°02.64' W 74°26.28' S	1051	1093 / 1059
M5	12.02.2009 22:43 10.02.2010 22:00	029°32.60' W 74°10.15' S	1917	1976 / 1928

The bottom depth listed in Table 1 differs from the corrected echo sounder depth logged during deployment (see also deployment notes). The bottom depth is obtained after considering the mooring line lengths and the pressure records from instruments. Instrument depths, as listed in mooring details in Table 2 are also corrected accordingly and differ from the planned target heights (marked on the mooring drawings). For instance, the uppermost instrument at M1 is corrected to 136 m (from 170 m).

2.2. Notes from deployment.

The moorings are prepared on the helideck, with instruments being prepared in the dry lab. All moorings are deployed from the stern.

M1: Deployed anchor first, on 10022009 1739UTC, at 74° 13.681'S, 032° 19.194'W. Echo depth was 1096 m, corrected 1070 m and 1081 dbar.
Release is AR261 SN:50 with codes, INT: 9636, REL: 9635.
The knot attaching a gash nylon rope to the top of the mooing for the final part of the deployment came undone, which meant that the final part of the release was not fully controlled.

M2: Anchor-first deployment of the original M2 was not successful. Halfway through the deployment a 100 m Kevlar line broke in the middle. The line was loaded with about 660 kg anchor weight and parted on 11/02/2009 at 0140 UTC, at 73° 58.9'S, 032° 24.5'W (echo depth 1887 m) before any flotation elements were attached to the line. The following instruments were lost: AR191 SN006 Acoustic release; SBE37s SN 5399 / 5450 / 5407; SBE39s SN 3567 / 3568; RCM7 SN 3651; Aquadopp 1.2kHz SN 0649. The original M2 drawing and details are not shown.

Using the remaining instruments and mooring material, a shortened mooring was designed and deployed successfully. M2 was deployed, anchor last, on 11/02/2009 at 1805 UTC, at 73° 58.678'S 032° 16.682'W. Echo depth was 1960 m, corrected to 1913 m and 1940 dbar. Release used is AR661 SN:264 (INT: 9170; REL: 9179).

The Kevlar line that parted on M2 had been used on an unknown number of moorings in the past, and might have suffered damage. The suspicion therefore fell on the line itself. However, anchor-first deployments with reused Kevlar line are routine on Norwegian ships, and free of incidents. It is therefore possible that some responsibility might lie with the methods used in the deployment: the lack of equipment on the Shackleton makes anchor-first an awkward technique.

M3: Deployed anchor last. 13/02/2009 1630 UTC, 74° 30.633'S 030° 09.906'W, Echo depth 753 m, corrected 728 m, 735 dbar.
Release Ixsea Oceano 2500 SN 950. Arm+range: 1814. Release: Arm + 1855.

M4: Deployed anchor last. 13/02/2009 at 1319 UTC, 74° 26.278'S 030° 02.639'W, Echo depth 1093 m, corrected 1059 m, 1071 dbar.
Release Ixsea Oceano 2500 SN 949. Arm+range: 1813. Release: Arm + 1855.

M5: Deployed anchor last. 12/02/2009 2243 UTC, 74° 10.15'S 029° 32.60'W, Echo depth 1976 m, corrected 1928 m, 1956 dbar.
Release Ixsea Oceano 2500 SN 948. Arm+range: 1812. Release: Arm + 1855.

2.3. Instrumentation

The moorings were equipped with Sea-Bird Electronics temperature (SBE39) and conductivity and temperature recorders (SBE37 Microcat), current meters (Aanderaa Recording Current Meter RCM-7/8, Nortek Aquadopp), and acoustic Doppler current profilers (ADCP, RD-Instrument 300 kHz Sentinel and 75 kHz Longranger, Nortek 190 kHz Continental). The details of the mooring instrumentation are given in Table 2.

The sampling rate was set to 5 min for the Microcat and SBE39, 1 h for the RCM-7/8, Longranger, and Continental, and 20 min for the Aquadopp and Sentinel. The RCMs averaged 50 evenly distributed samples per hour, whereas the Aquadopp averaged velocity measurements from the first 180 s. The RDI ADCPs sampled an ensemble of 30 pings collected in burst mode for the first 60 s (Sentinel) or 150 s (Longranger). For the Continental, 300 s of profile averaging was done at the start of each interval. The setup commands and deployment files are listed in the Appendix for the SBE, RDI and Nortek instruments.

All 300 kHz RDI ADCPs were 1000 m rated and equipped with T/P sensors and 576MB memory, and passed al tests in the lab. The serial numbers SN were 10147, 10148, 10149 and 10150, with deployment names Dpl1_ to Dpl4_. Of the four 300 kHz ADCPs, two instruments SN10148 and SN10150 leaked and did not return any data. These instruments are apparent in planned mooring drawings but are not listed in Table 2. Furthermore, the velocity measurements at 380--410 meters above bottom (m.a.b.) from the Continental were obstructed by flotation elements and excluded from the final data set.

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. 78:4:150 means from 78 to 150 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
M1	10, 67	T, C	Microcat SN5397, SN5398
	24	T, C, V	RCM-7, SN1586
	46	T, P, V	Aquadopp, SN0645
	87	T	SBE39 SN3566
	123	T, C, P	Microcat SN5449
	136	T, P	SBE 39 SN3251
M2	19	T, P, V	RCM-7, SN12313
	68	T	SBE39 SN3571
	114	T, C, P	Microcat SN5452
	156	T, P	RDI 300 kHz SN11434 (in-line frame)
	78:4:150	V, W	------- // ------- downlooking profile
M3	10	T, C	Microcat SN5408
	25	T, V	RCM-7 SN6798
	77, 154, 360	T, C, P	Microcat SN5446, SN5447, SN5448
	102, 128, 257	T	SBE39 SN3570, SN3569, SN3576
	205	T, P	RDI 300 kHz SN10149 (in-line frame)
	123:4:199	V, W	------- // ------- downlooking profile
	308	T, P	Continental 200kHz SN6103 (in-line frame)
	310:5:505	V, W	------ //-------- uplooking profile
M4	9, 78, 314	T, C, P	Microcat SN6018, SN5451, SN6097
	25	T, V	RCM-8 SN9907
	104	T	SBE39 SN3572
	156	T, C	Microcat SN6106
	183, 261	T, P	SBE39 SN3683, SN3252
	419	T, P	RDI 75kHz Longranger, SN 8645 (in 45' buoy)
	442:16:986	V, W	------- // ------- uplooking profile
M5	10, 415	T, C	Microcat SN6297, SN5409 (on the ADCP frame)
	26	T, C, V	RCM-7 SN3160
	52, 104, 311, 363	T	SBE39 SN3746, SN3748, SN3574, SN3573
	78, 259	T, P	SBE39 SN3282, SN3143
	155	T, C, P	Microcat SN6017
	415	T, P	RDI 75kHz Longranger, SN10740 (in-line frame)
	55:16:391	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. Quality controlled data 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 a ratio of error velocity to measured speed exceeding 0.5 are flagged as bad. Remaining spikes, identified as points exceeding 3 standard deviations 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.

3-beam Continental ADCP at M3 suffered from an obstruction near bin 17, which contaminated bins 15 to 21. These bins are removed. Furthermore bins away from the instrument showed exceptionally large variability after 4 August 2009, attributed to weakening battery and transmission power. Bins 34 and on are therefore removed following this date. At M5, the distant bins of Longranger pointing downward were affected by the seabed and side lobe effects; bins 23 and downwards are excluded.

Magnetic declination is typically much less than the accuracy of the compass (about ±2°) on the current meters and ADCPs. For completeness, however, we made the following declination corrections to the data set:

M1, 1.78°E
M2, 1.68°E
M3, 0.45°E
M4, 0.36°E
M5, 0.04°E

The declinations are obtained from https://www.ngdc.noaa.gov/geomag-web/

Salinity

Several sensors are excluded from the final data set. None of the Microcats were pumped. At M1, the conductivity sensor of RCM7 did not return reliable salinity data. Furthermore, the bottommost Microcat at 10 m.a.b was too noisy. These salinity data are removed from M1. At M5, again the RCM conductivity sensor is excluded. Finally, the Microcat SN6017 at 155 m.a.b showed several unexplained abrupt offsets in the time series. An accurate correction was not possible, hence the salinity from this Microcat is excluded from the data set. Salinity time series are despiked using 60 data point windows where fluctuations (obtained after detrending the window) exceeding 3 standard deviations are removed. This is done in two passes.

Temperature

Time-average profiles of temperature are examined to detect anomalous levels, identified (by eye) as those deviating from an expected smooth profile. All SBE instruments returned reliable temperature data. The sensors on several current meters had to be adjusted using a constant offset. The following offsets were applied:

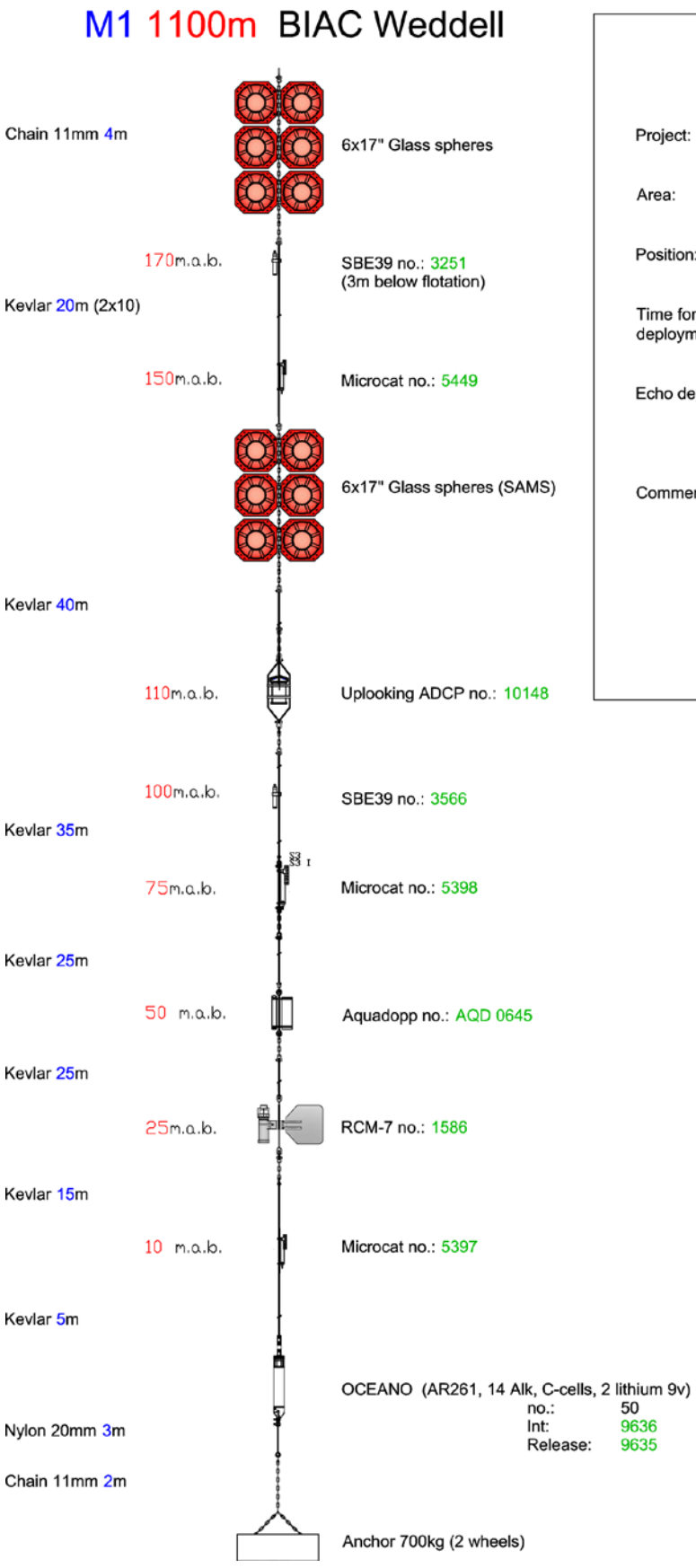
M1, Aquadopp SN0645; offset by -0.07°C
M3 Continental, offset by -0.4°C
M4 RCM8 SN9907, offset by +0.08°C;
M5 RCM7 SN3160, offset by +0.03°C
M5 Longranger SN10740, offset by +0.04°C

4. Overview of Appendices

The appendices include:

Section 5, Appendix: Mooring drawings
Section 6, Appendix: Sea-Bird Electronics instrument set up details
Section 7, Appendix: LADCP and VMADCP Deployment Files
Section 8, Appendix: Data overview; Time series
The time series are presented for each instrument and each mooring for pressure, temperature, salinity and velocity.

5. Appendix: Mooring drawings



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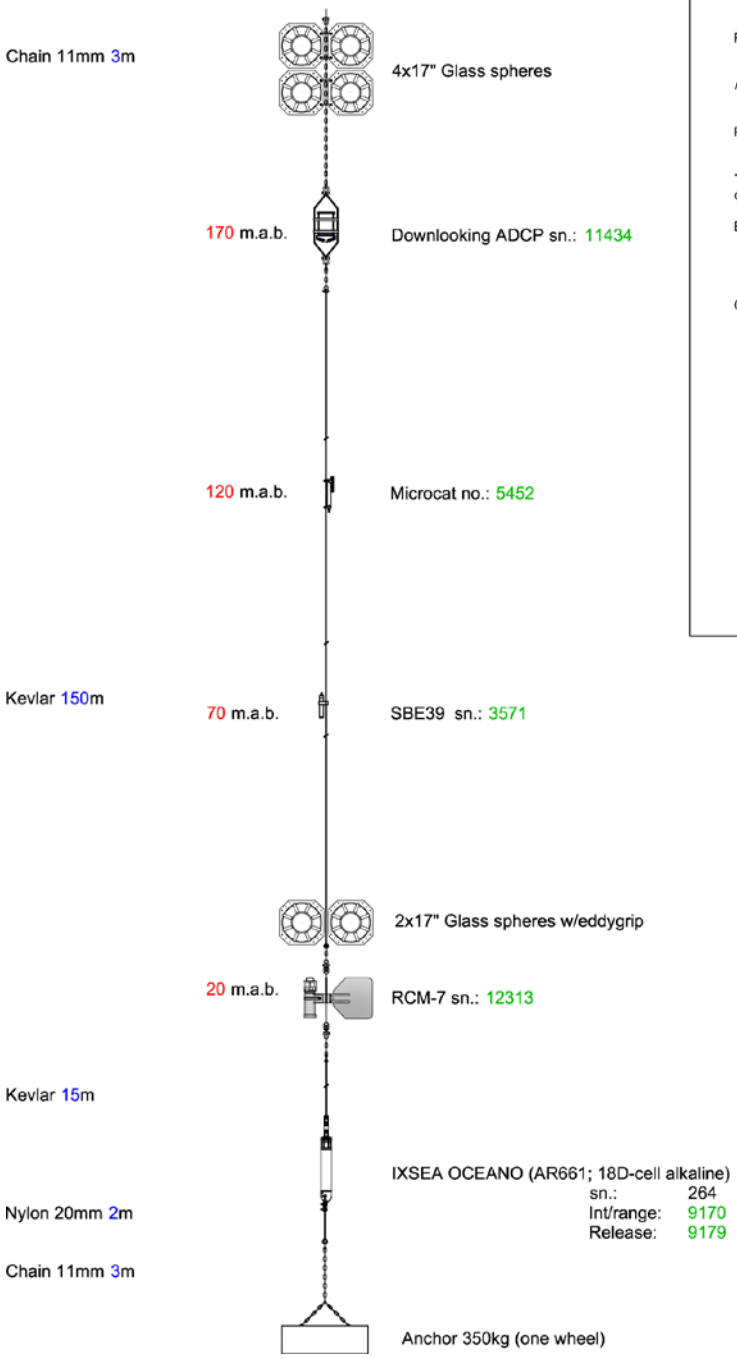
Project:	BIAC Weddell sea/R.R.S. E.Shackleton
Area:	M1
Position:	74°13.681`s 032°19.194`w
Time for deployment:	10. Feb 2009 17:39UTC
Echo depth:	1096m, corrected 1070m corrected pressure 1081dbar
Comment:	Deployed with anchor first. 20 m. 18mm nylon at top flotation.

M2S 1900m BIAC Weddell



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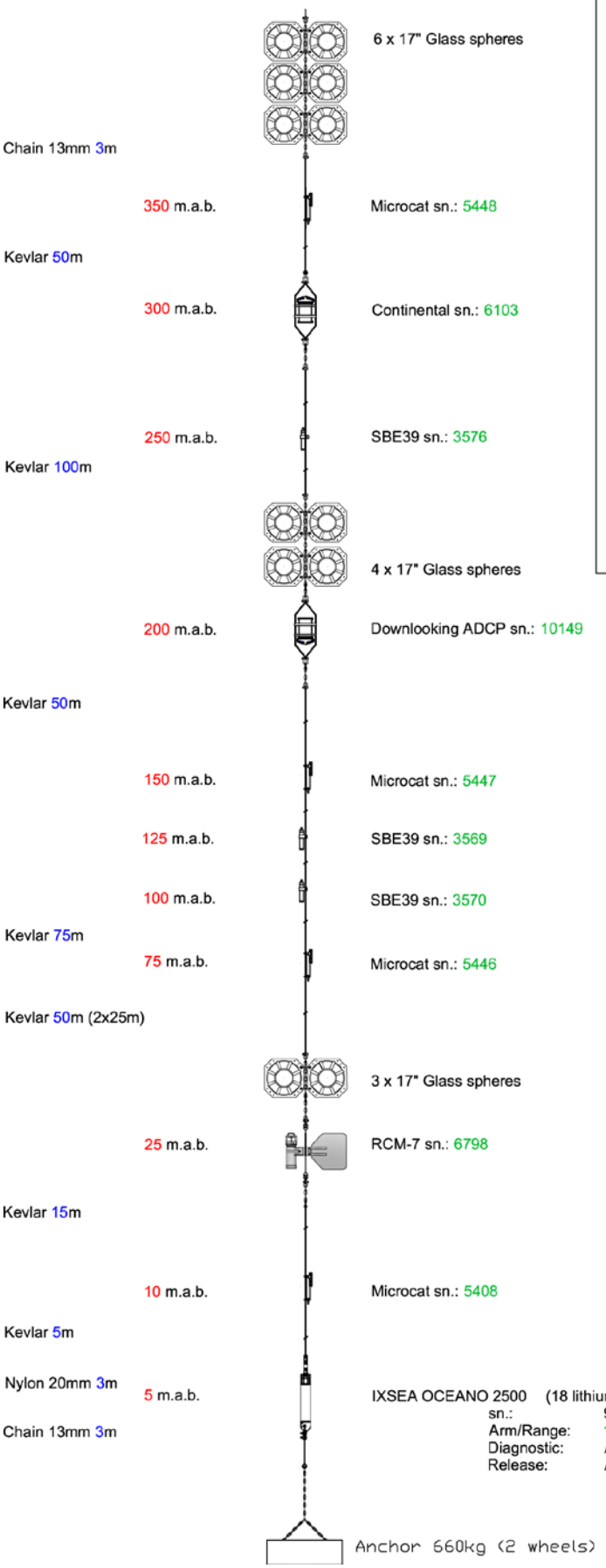
Project:	BIAC Weddell sea 2009/R.R.S E.Shackleton
Area:	M2S (shortened), Weddell sea
Position	73°58.678`s 032°16.682`W
Time for deployment	11. Feb 2009 18:05UTC
Echo depth	1960m, corrected 1913m corrected pressure 1940dB
Comment:	Shortened version of the original (partly lost) M2 mooring. Releaser (from S. Østerhus), serviced with alkaline D-cells (18pz) and 9v batt. Deployed with anchor last.

M3 750m BIAC Weddell



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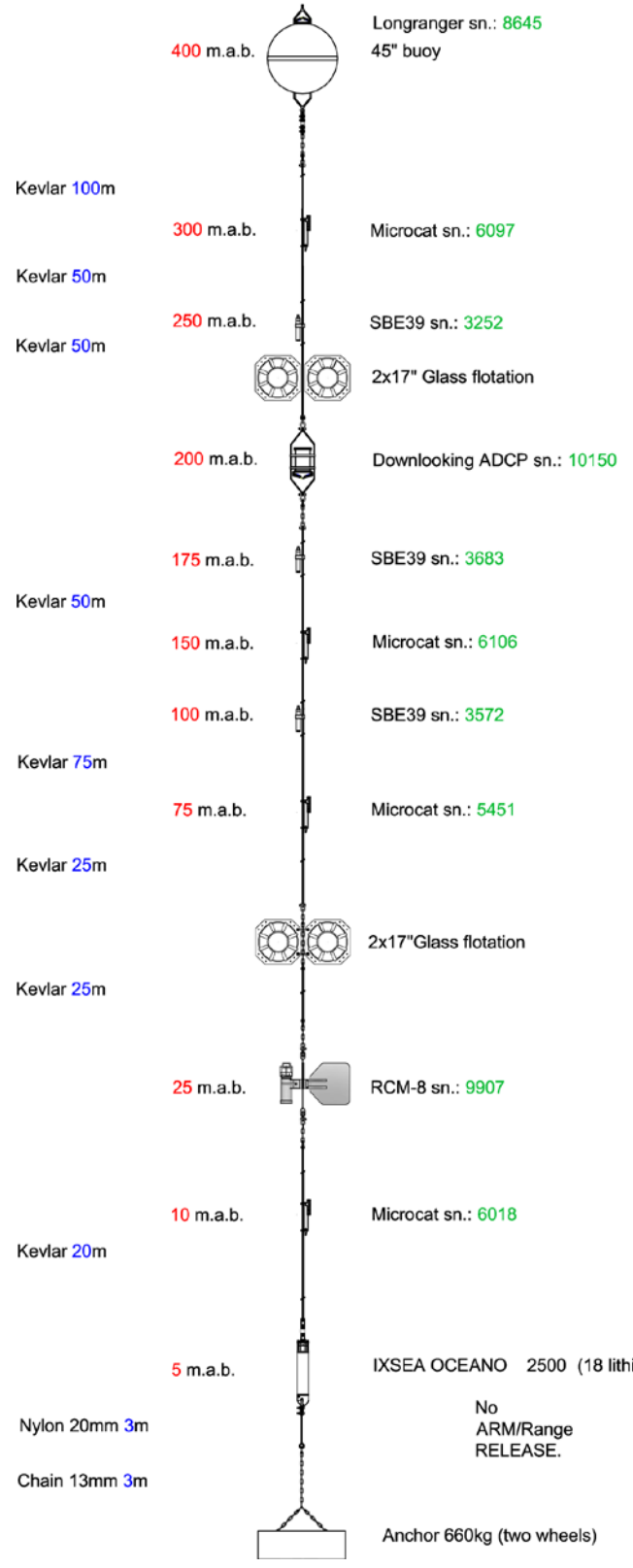
Project:	BIAC Weddell sea 2009/R.R.S. E.Shackleton
Area:	M3
Position	74°30.633`s 030°09.906`w
Time for deployment	13. Feb. 2009 16:26UTC
Echo depth	753m, corrected 728m, pressure 735dbar
Comment	Anchor last deployment. 5m nylon for recovery. Parts of flotation borrowed from SAMS/NERC.

M4 1100m BIAC Weddell



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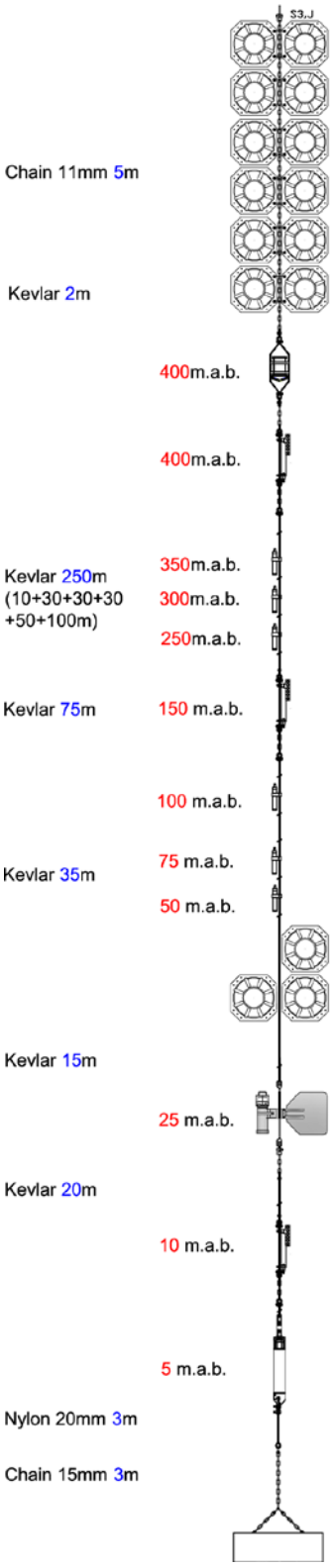
Project	BIAC Weddell sea 2009/R.R.S E.Shackleton
Area	M4
Position	74°26.278`s 030°02.639`w
Time for deployment	13. Feb. 2009 12:37UTC
Echo depth	1093m, corrected: 1059m corrected pressure 1071dbar
Comments	Deployed with anchor last in open water. Recovery rope attached.

M5 1900m BIAC Weddell



Chain 11mm 5m

10 x 17" Glass spheres

Kevlar 2m

2 x 17" Glass spheres with eddygrip above L.

400m.a.b. Downlooking Longranger sn.: 10740

400m.a.b. Microcat sn.: 5409 attached to Longranger frame

Kevlar 250m (10+30+30+30 +50+100m)

350m.a.b. SBE39 sn.: 3573

300m.a.b. SBE39 sn.: 3574

250m.a.b. SBE39 sn.: 3143

Kevlar 75m

150 m.a.b. Microcat sn.: 6017

100 m.a.b. SBE39 sn.: 3748

Kevlar 35m

75 m.a.b. SBE39 sn.: 3282

50 m.a.b. SBE39 sn.: 3746

3 x 17" with eddygrip

Kevlar 15m

25 m.a.b. RCM-7 sn.: 3160

Kevlar 20m

10 m.a.b. Microcat sn.: 6297

5 m.a.b. IXSEA OCEANO 2500 (18 lithium D-cells)

sn.: 948
ARM/Range: 1812
RELEASE: ARM+1855

Nylon 20mm 3m

Chain 15mm 3m

Anchor 660kg (two wheels)

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Project	BIAC Weddell sea 2009/R.R.S. E.Shackleton
Area	M5
Position	74°10.15`s 029°32.60`w
Time for deployment	12.Feb 2009 22:43 UTC (Start 21:41UTC)
Echo depth	1976m, corrected 1928m
Comment	Deployed with anchor last in open water.

6. Appendix: Sea-Bird Electronics instrument set up details

SBE37s and SBE39s were armed through the Seaterm terminal following the commands:

DDMMYY =
HHMMSS = (all syncronized using PC time, UTC)
SAMPLENUM=0
INTERVAL=300
NAVG=1 Microcat only
STORETIME=Y Microcat only
TXREALTIME=N
STARTMMDDYY=020609
STARTHHMMSS=000000
STARTLATER
DS
QS

Microcats with new firmware have slightly different syntax:

DateTime = MMDDYYYYhhmmss
SampleNumber= 0
SampleInterval=300
Txrealtime=N
Startdatetime=02062009000000 ….

7. Appendix: LADCP and VMADCP Deployment Files

Table 3. RDI Sentinel deployment files. Left column for 300 kHz instruments, right column for 75kHz Longrangers.

FILES: Dpl1, Dpl2, 3 and 4_.whp (IDENTICAL for 300 kHz)

```
CR1
CF11101
EA0
EB0
ED0
ES35
EX11111
EZ1111111
WA50
WB0
WD111100000
WF176
WN27
WP30
WS400
WV175
TE00:20:00.00
TP00:02.00
TF09/02/06 00:00:00
CK
CS
;

;Instrument       = Workhorse Sentinel
;Frequency        = 307200
;Water Profile    = YES
;Bottom Track     = NO
;High Res. Modes  = NO
;High Rate Pinging  = NO
;Shallow Bottom Mode= NO
;Wave Gauge       = NO
;Lowered ADCP     = NO
;Beam angle       = 20
;Temperature      = 0.00
;Deployment hours  = 8880.00
;Battery packs    = 1
;Automatic TP     = NO
;Memory size [MB]  = 512
;Saved Screen     = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range  = 6.17 m
;Last cell range   = 110.17 m
;Max range         = 103.73 m
;Standard deviation = 0.65 cm/s
;Ensemble size     = 694 bytes
;Storage required  = 17.63 MB (18488160 bytes)
;Power usage       = 388.50 Wh
;Battery usage     = 0.9
;
; WARNINGS AND CAUTIONS:
; Advanced settings have been changed.
```

FILES: LRG1_and 2 .whp (IDENTICAL for 75 kHz)

```
CR1
CQ255
CF11101
EA0
EB0
ED0
ES35
EX11111
EZ1111111
WA50
WB1
WD111100000
WF704
WN42
WP30
WS1600
WV175
TE01:00:00.00
TP00:05.00
TF09/02/06 00:00:00
CK
CS
;
;Instrument       = Workhorse Long Ranger
;Frequency        = 76800
;Water Profile    = YES
;Bottom Track     = NO
;High Res. Modes  = NO
;High Rate Pinging  = NO
;Shallow Bottom Mode= NO
;Wave Gauge       = NO
;Lowered ADCP     = NO
;Beam angle       = 20
;Temperature      = 0.00
;Deployment hours  = 8640.00
;Battery packs    = 4
;Automatic TP     = NO
;Memory size [MB]  = 512
;Saved Screen     = 2
;
;Consequences generated by PlanADCP version 2.04:
;First cell range  = 24.45 m
;Last cell range   = 680.45 m
;Max range         = 684.77 m
;Standard deviation = 1.38 cm/s
;Ensemble size     = 994 bytes
;Storage required  = 8.19 MB (8588160 bytes)
;Power usage       = 2240.14 Wh
;Battery usage     = 5.0
;
; WARNINGS AND CAUTIONS:
; There are not enough battery packs for the deployment. (4 battery pack(s) will last 289 days).
; Advanced settings have been changed.
```

Table 4. Deployment summary for NORTEK instruments; left column for Aquadopp current meter, irht column for Continental ADCP

Deployment : Wed1 [AQUADOPP] Current time : 26.01.2009 22:46:15 Start at : 06.02.2009 Comment: --- Measurement interval (s) : 1200 Average interval (s) : 180 Blanking distance (m) : 0.37 Diagnostics interval(min) : N/A Diagnostics samples : N/A Measurement load (%) : 4 Power level : HIGH Compass upd. rate (s) : 5 Coordinate System : ENU Speed of sound (m/s) : MEASURED Salinity (ppt) : 35 File wrapping : OFF --- Assumed duration (days) : 360.0 Battery utilization (%) : 333.0 Battery level (V) : 11.5 Recorder size (MB) : 81 Recorder free space (MB) : 81.000 Memory required (MB) : 1.0 Vertical vel. prec (cm/s) : 0.8 Horizon. vel. prec (cm/s) : 0.5 --- Aquadopp Version 1.28 Copyright (C) 1997-2004 Nortek AS ==========	Deployment : Wed09 [CONTINENTAL] Current time : 30.01.2009 13:48:34 Start at : 06.02.2009 Comment: --- Profile interval (s) : 3600 Number of cells : 40 Cell size (m) : 5.00 Average interval (s) : 300 Blanking distance (m) : 2.00 Measurement load (%) : 100 Power level : HIGH Diagnostics interval(min) : N/A Diagnostics samples : N/A Compass upd. rate (s) : 2 Coordinate System : ENU Speed of sound (m/s) : MEASURED Salinity (ppt) : 35 Seasonal sampl. (dd/mm:s) : DISABLED Analog input 1 : NONE Analog input 2 : NONE Analog input power out : DISABLED Delayed start : DISABLED File wrapping : OFF --- Assumed duration (days) : 360.0 Battery utilization (%) : 407.0 Battery level (V) : 17.7 Recorder size (MB) : 26 Recorder free space (MB) : 26.000 Memory required (MB) : 4.0 Vertical vel. prec (cm/s) : 0.4 Horizon. vel. prec (cm/s) : 1.2 --- Instrument ID : PRP 624 Head ID : CNL 6103 Firmware version : 1.10 --- Continental Version 1.27 Copyright (C) 1997-2007 Nortek AS ==========

8. Appendix: Data overview; Time series

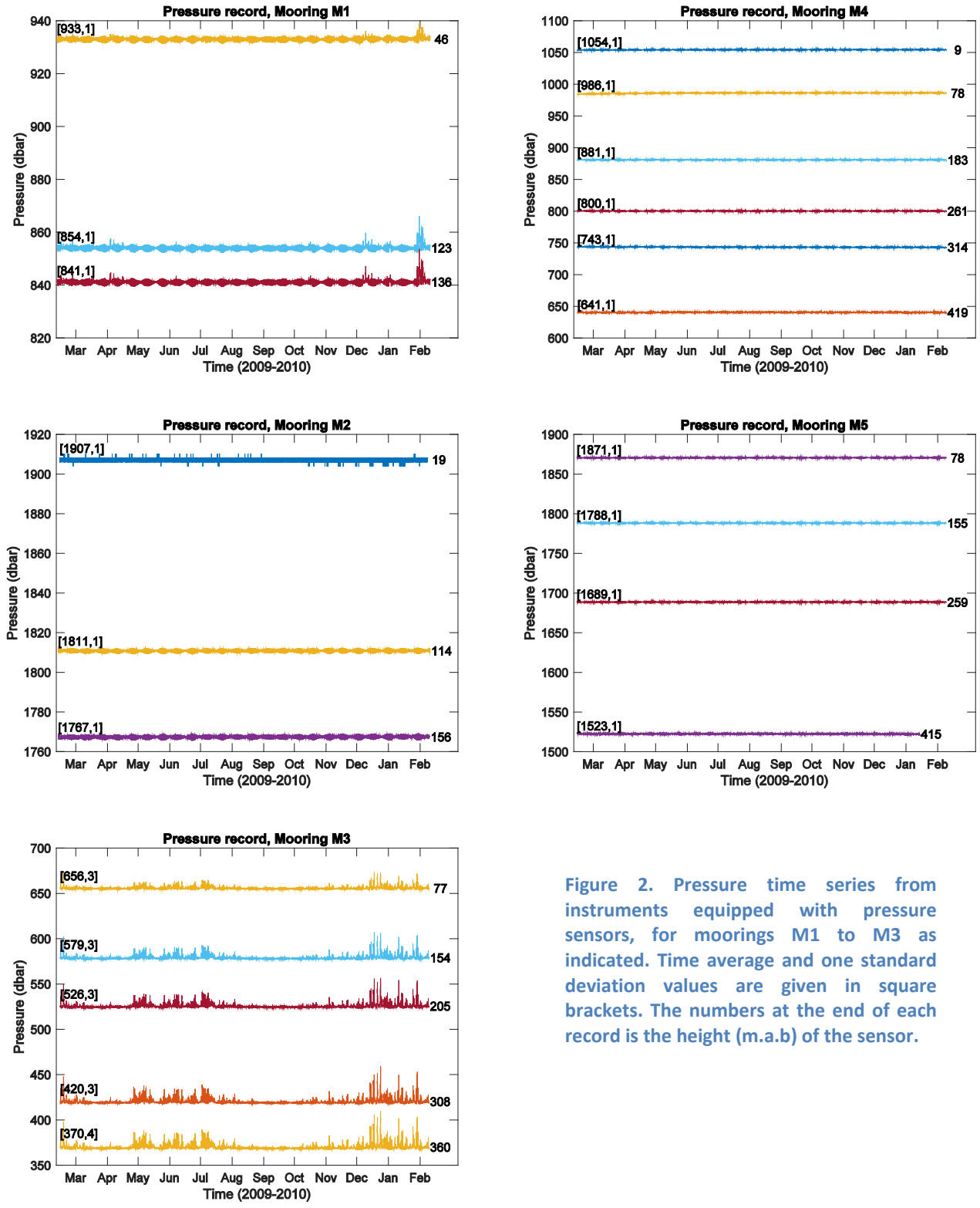


Figure 2. Pressure time series from instruments equipped with pressure sensors, for moorings M1 to M3 as indicated. Time average and one standard deviation values are given in square brackets. The numbers at the end of each record is the height (m.a.b) of the sensor.

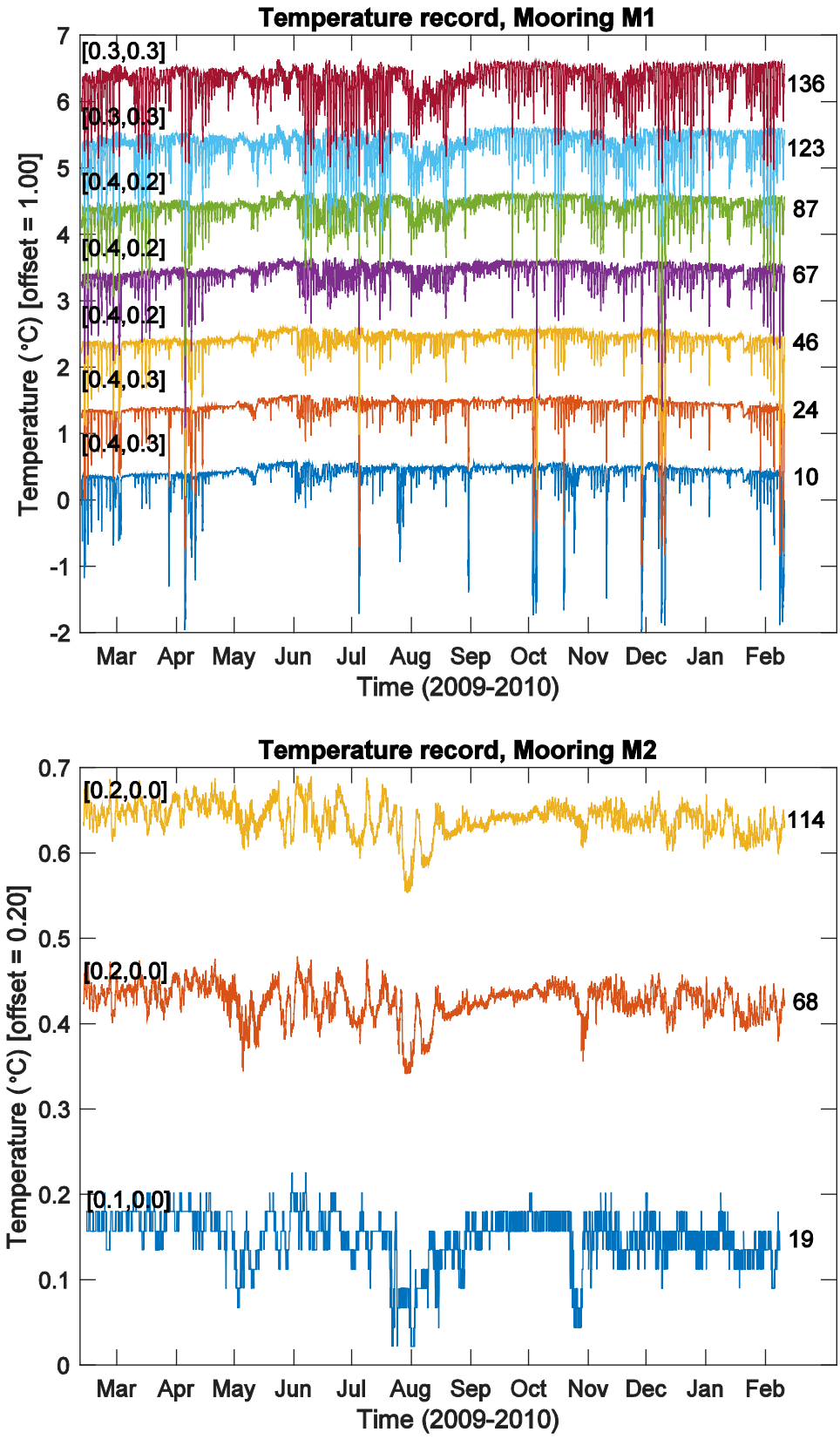
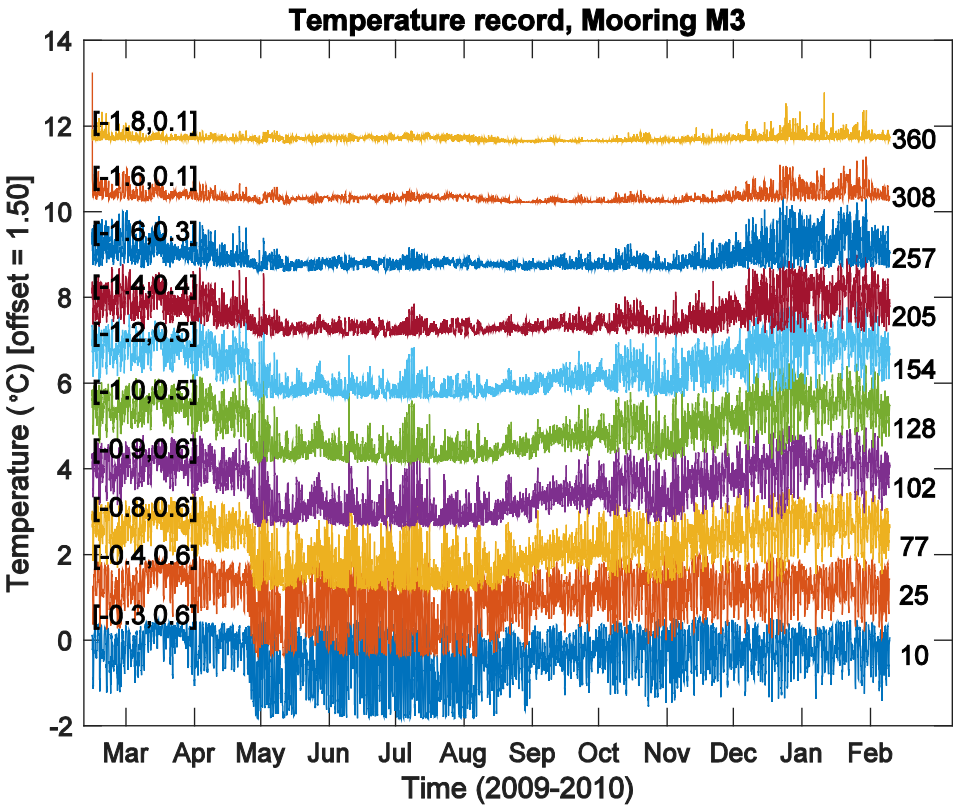


Figure 3. Time series of temperature measured at M1 to M5 (one panel for each mooring as indicated). Time series are offset vertically from the lowest level with the value indicated in y-axis. Time-average value and one standard deviation are given in square brackets. The height (m.a.b.) of the sensor is indicated at the end of the record.



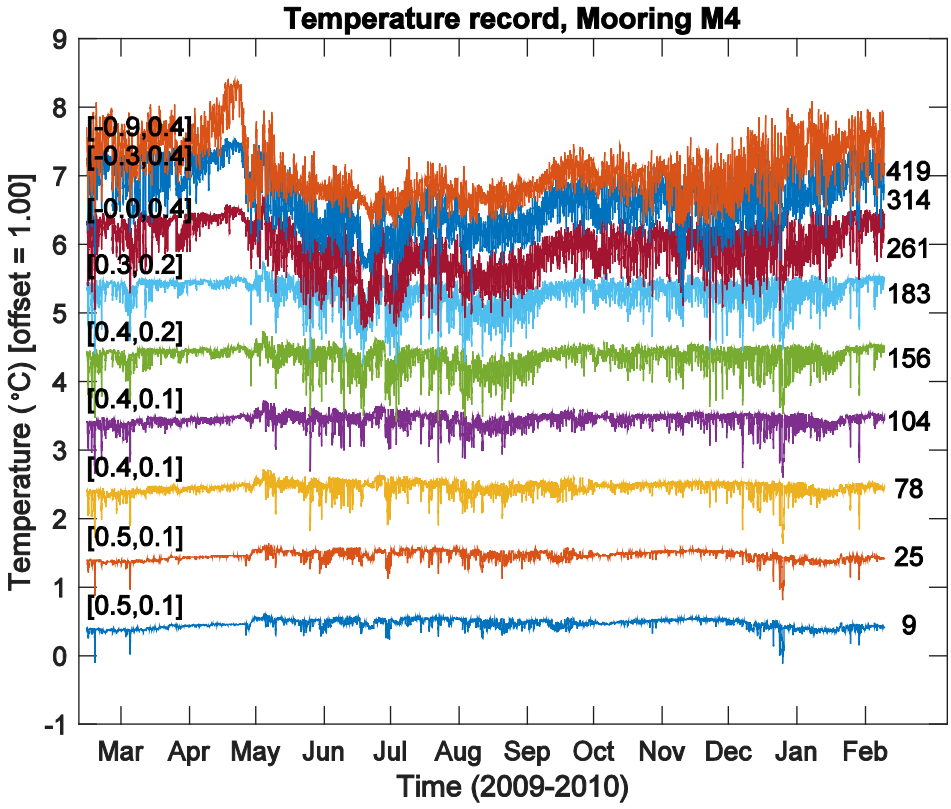


Figure 3 continued.

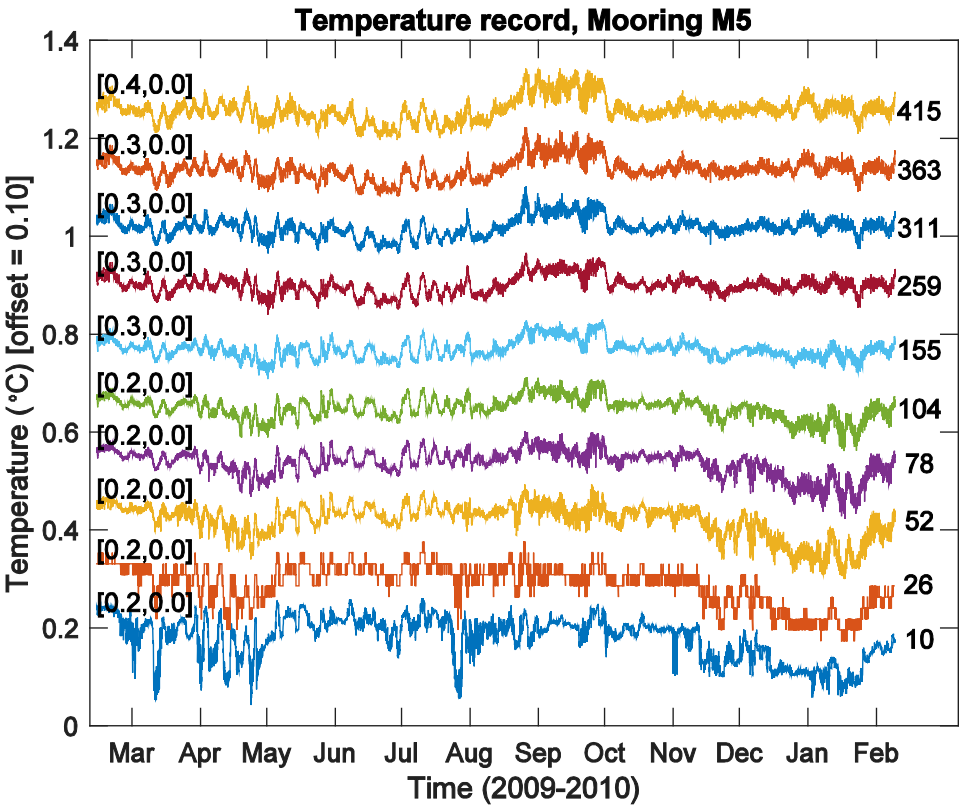


Figure 3 continued.

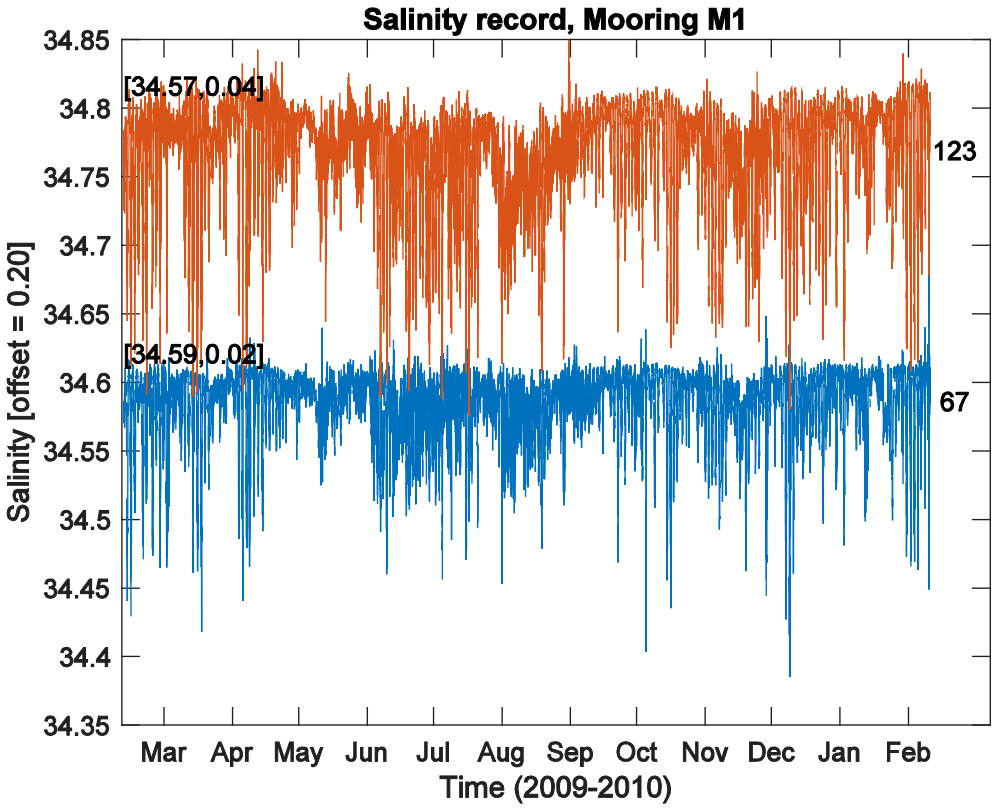


Figure 4. Same as Figure 3 but for salinity.

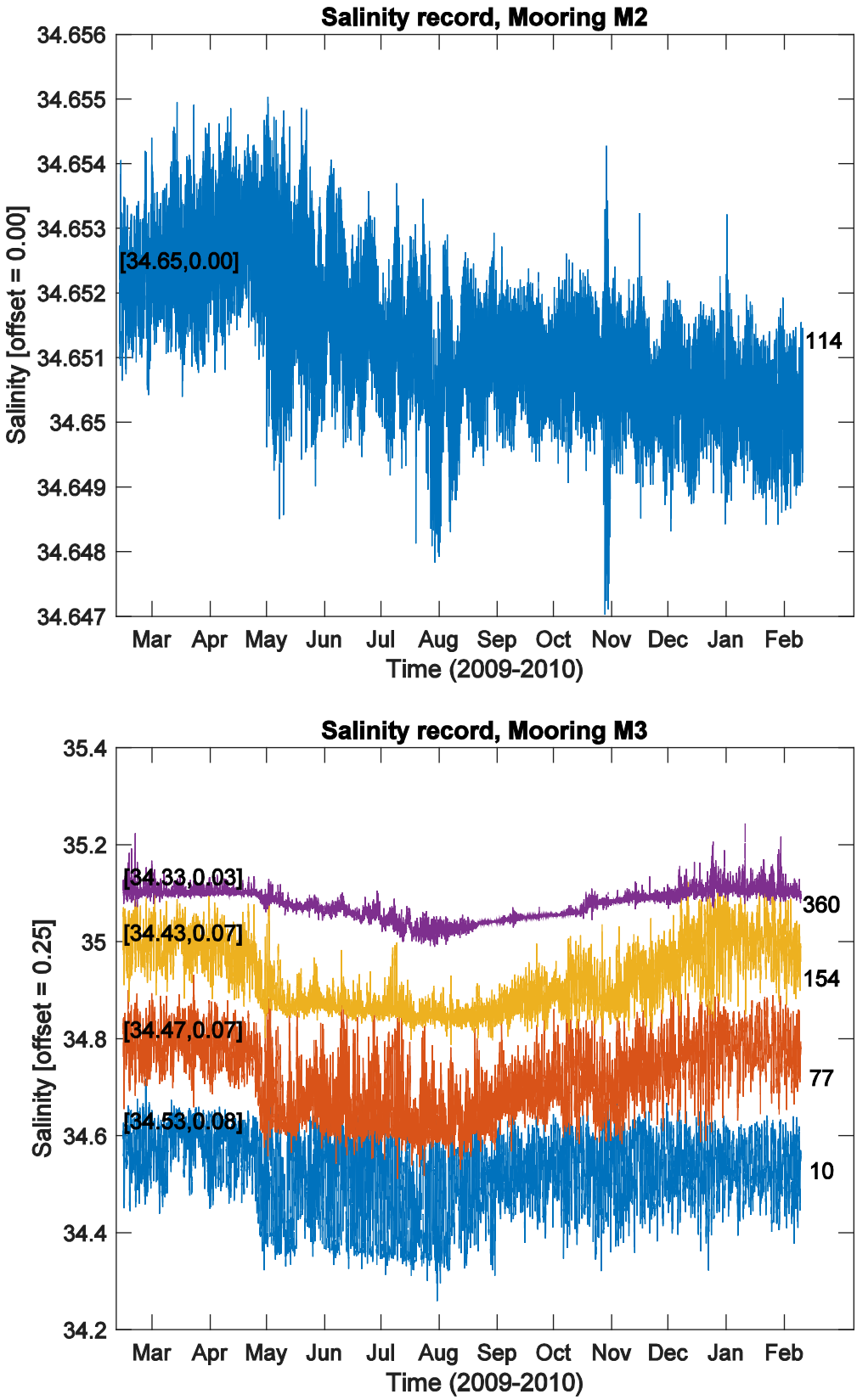


Figure 4 continued.

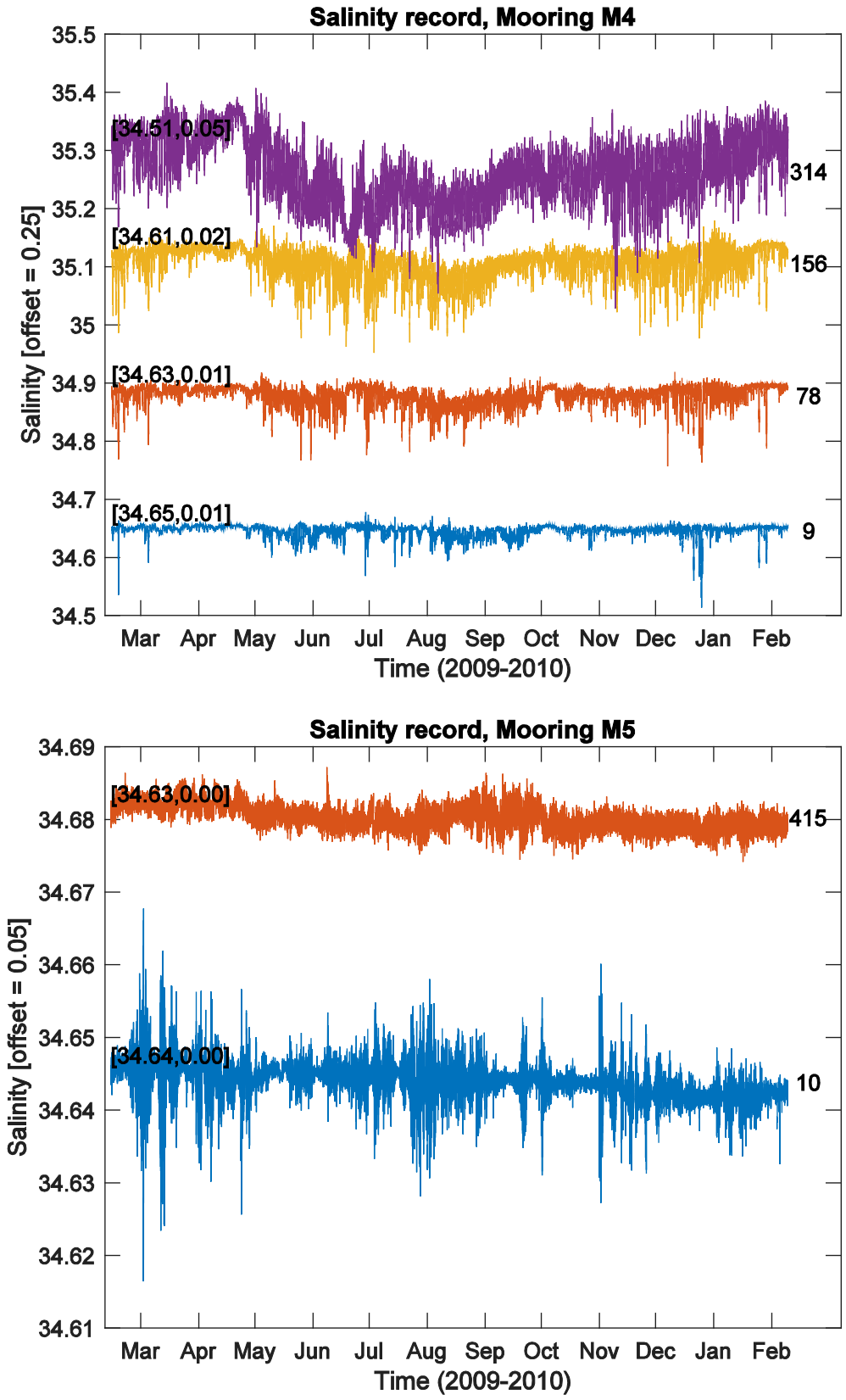


Figure 4 continued.

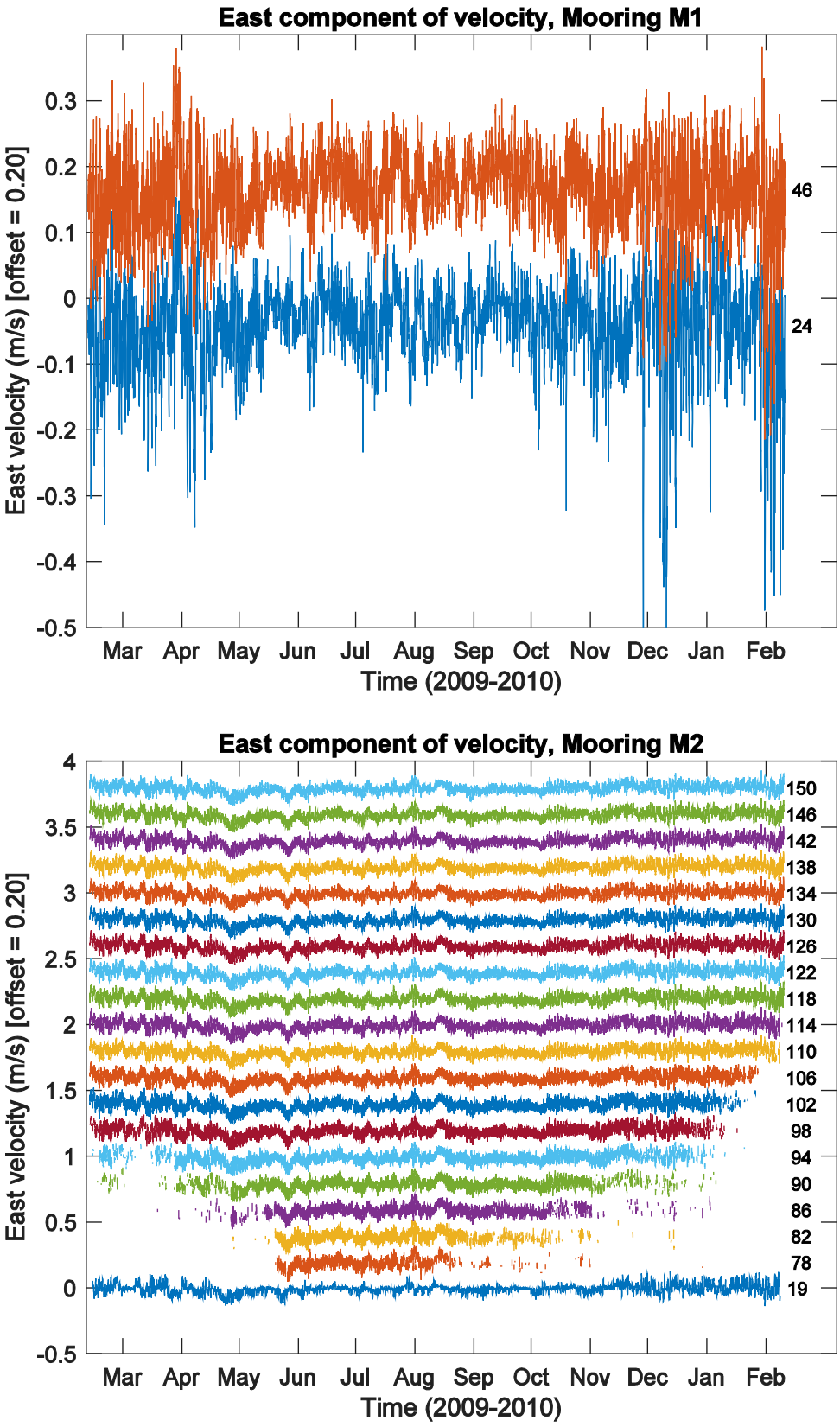
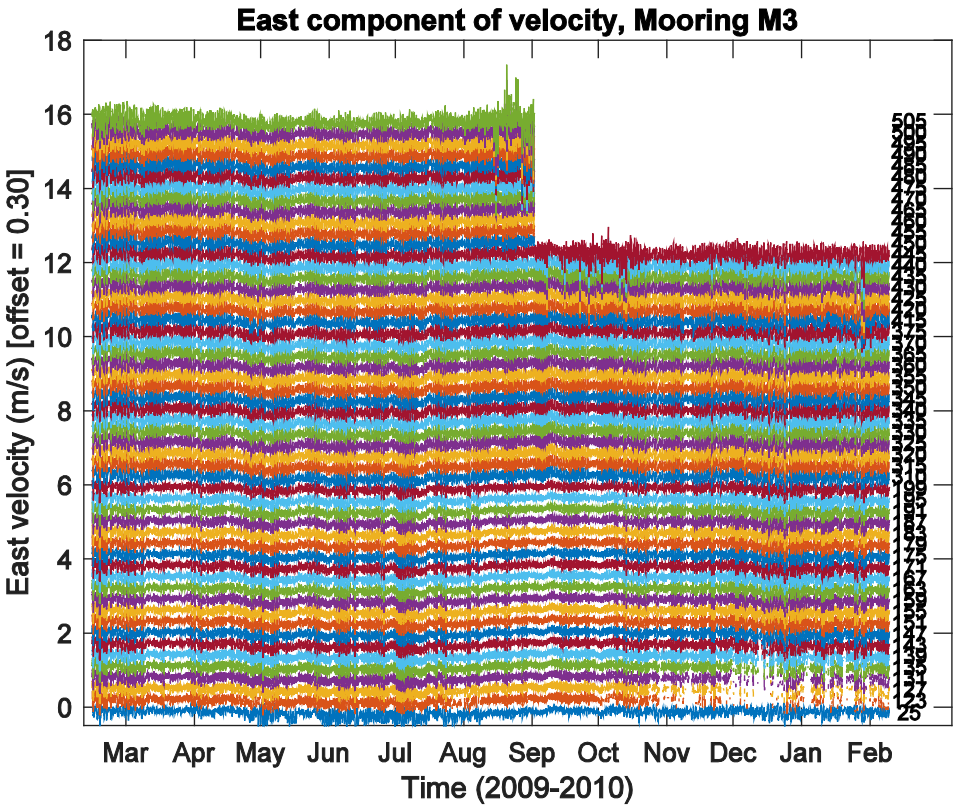


Figure 5. Same as Figure 3 but for the east component of velocity.



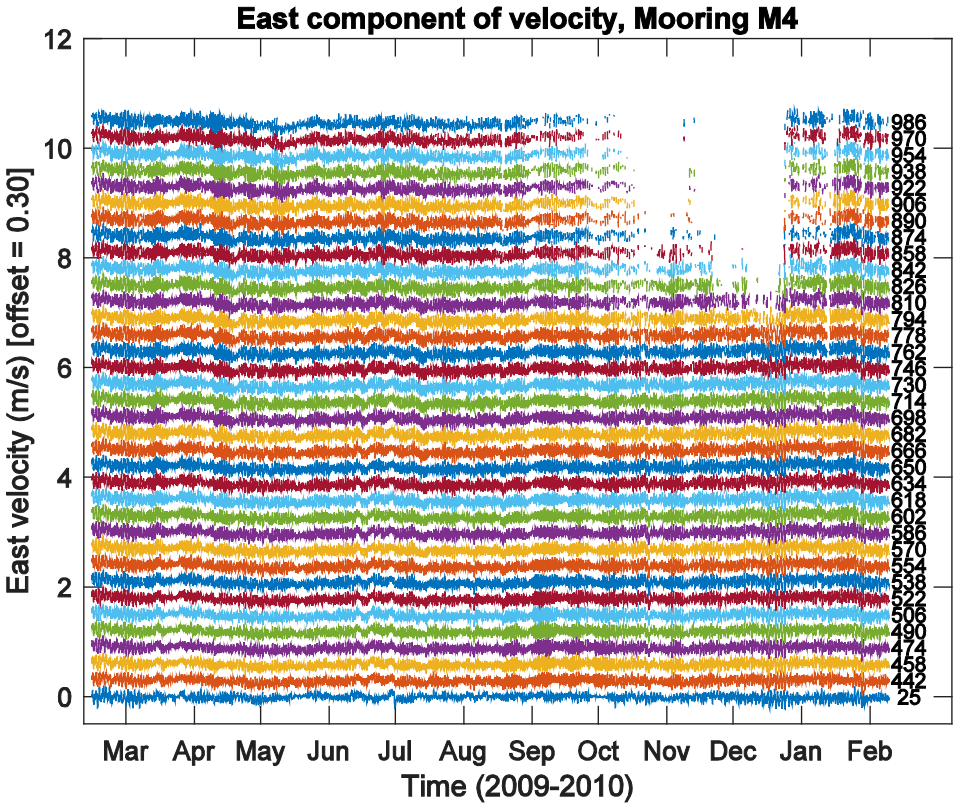


Figure 5. continued

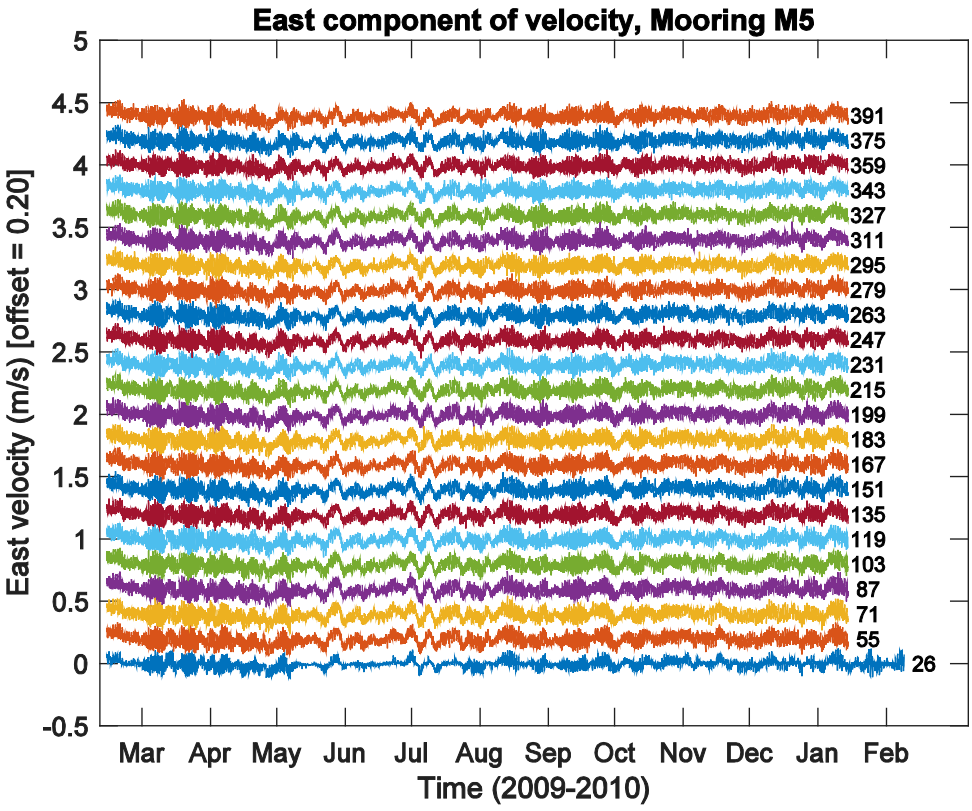


Figure 5. continued

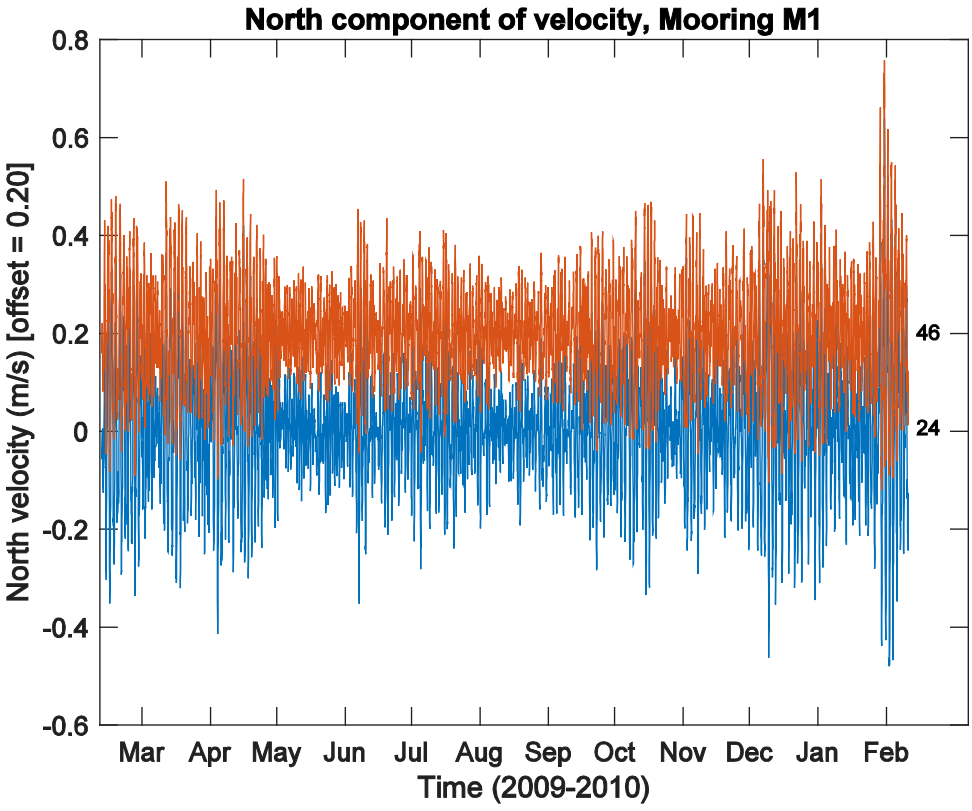
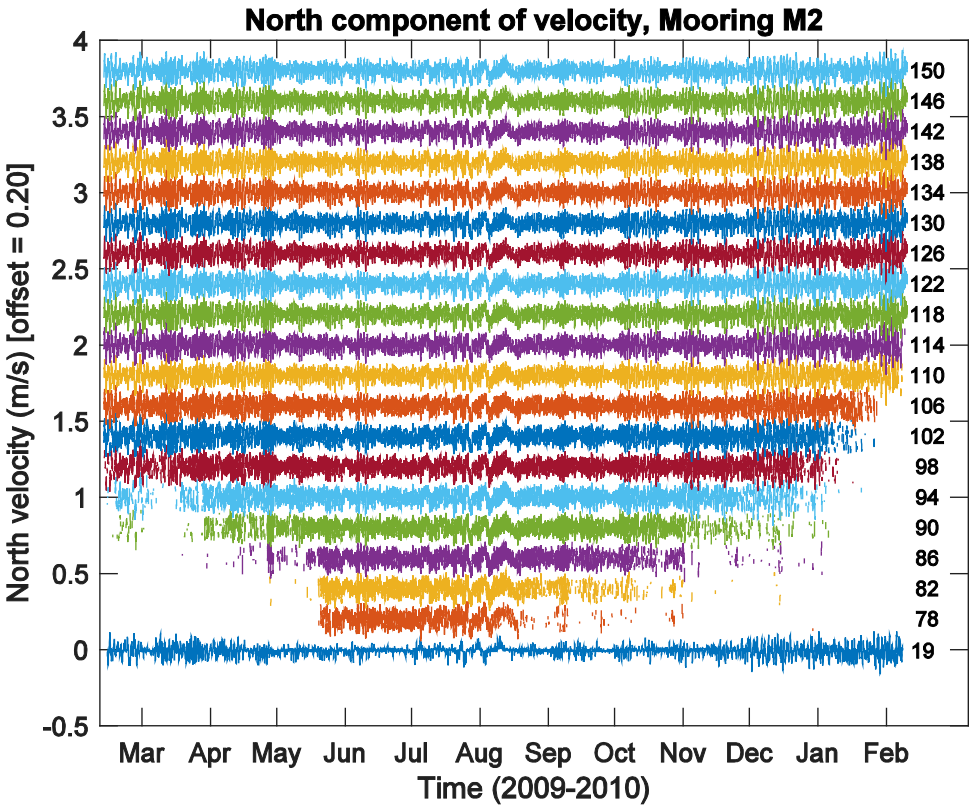


Figure 6. Same as Figure 3 but for the north component of velocity.



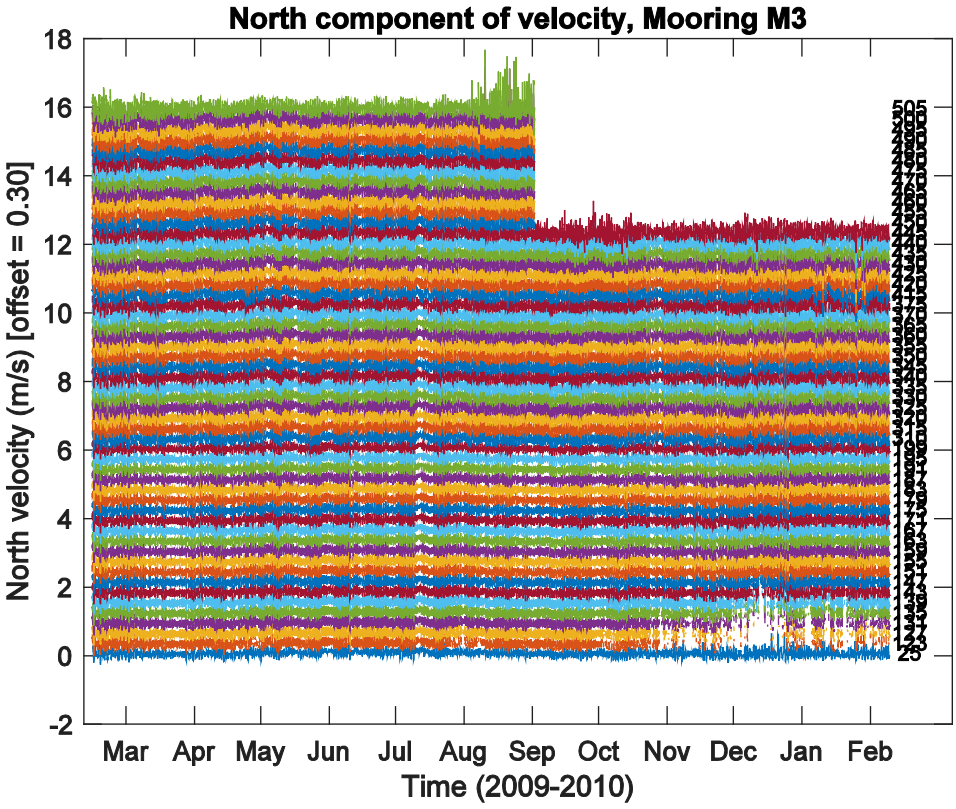
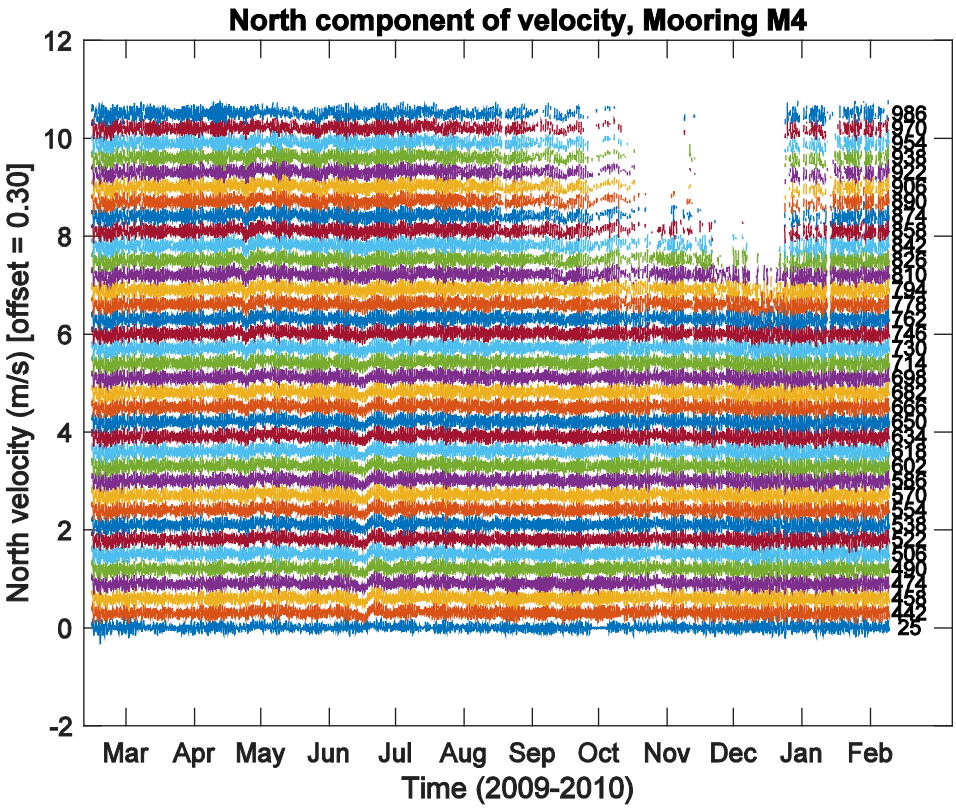


Figure 6, continued.



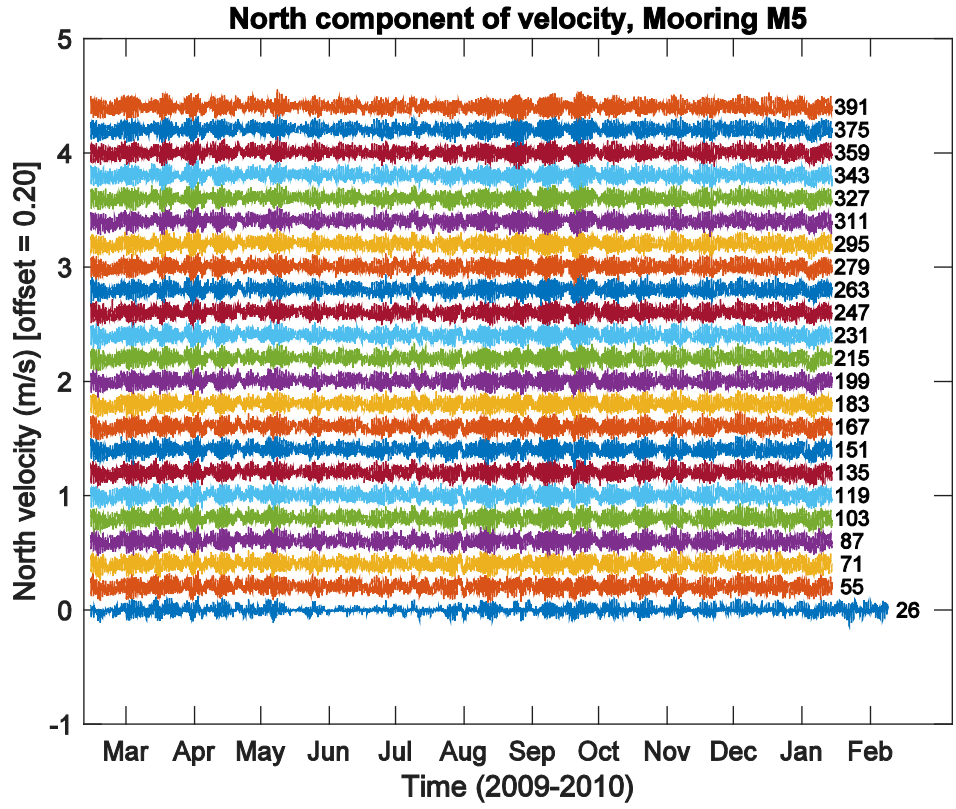


Figure 6, continued.

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