



**National  
Oceanography Centre**  
NATURAL ENVIRONMENT RESEARCH COUNCIL

## **National Oceanography Centre**

### **Cruise Report No. 40**

### **RRS *Discovery* Cruise DY054**

27 JUL – 17 AUG 2016

Reykjavik to Southampton

OSNAP 2016 mooring refurbishment cruise, Leg 2

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2016

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## DOCUMENT DATA SHEET

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<b>ABSTRACT</b>  <p>Cruise DY054 was the second leg of the 2016 UK OSNAP mooring refurbishment programme on RRS <i>Discovery</i>. Following the first leg (DY053, Cunningham et al 2016) which serviced and re-deployed US and UK moorings in the Iceland Basin and Rockall Trough, the scientific objectives of DY054 were:</p> <p>To service (recover and re-deploy) the 5 UK OSNAP moorings in the western Irminger Sea (the Deep Western Boundary Array, M1-M5) To service the 5 Dutch OSNAP moorings in the eastern Irminger Sea (the Irminger Current Array, IC0-IC4) To service the Dutch LOCO mooring in the central Irminger Sea To complete a CTD/LADCP section across the Irminger Basin, from the Greenland coast to the mid-Atlantic Ridge To collect and freeze nutrient samples from CTD stations for later analysis by NIOZ To deploy an Argos float for the UK Met Office To deploy a series of OSNAP RAFOS floats in the overflow waters To deploy a new WHOI sound source in the Maury Channel of the Iceland Basin To collect material for outreach programmes, including film footage, audio recordings and photography for a US OSNAP website, and material to be used in an art project</p> <p>All objectives were achieved.</p> <p>All OSNAP moorings were previously deployed in 2014, refurbished in 2015, and will be recovered in 2018. The moorings and the CTD profiles will be used to measure the mean and variability of the surface-to-seafloor currents, and to compute the volume, heat and freshwater transport within the currents. They are part of a large international programme, OSNAP (Overturning in the Subpolar North Atlantic Programme) which has other moorings in the Labrador Sea, Iceland Basin and Rockall Trough.</p>	
<b>KEYWORDS</b>	
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## 1. Personnel

### Scientific and Technical Personnel

HOLLIDAY	PENNY	Principal Scientist, NOC
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LI	FEILI	Duke University
MACKAY	NEILL	NOC
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SIMPSON	ANNA	Undergraduate, University of New Hampshire
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WITTE	YVO	NIOZ, Netherlands
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WHITTLE	STEVE	NMFSS Sensors and Mooring Technician
BENSON	JEFF	NMFSS Sensors and Mooring Technician
CHILDS	DAVE	NMFSS Sensors and Mooring Technician
CROWE	CHRIS	NMFSS Sensors and Mooring Technician
LEADBEATER	ANDY	NMFSS Base engineering Technician
CHEESEMAN	DEAN	NMFSS Base engineering Technician
NEMETH	ZOLTAN	NMFSS Scientific Systems Technician



*Figure 1.1. DY054 Science and Technical Team Photograph*

## **Ships Personnel**

GATTI	ANTONIO	Master
VOADEN	EVELYN	C/O
WILLIAMS	TOM	2/O
MULLER-TOLK	DOMINIK	3/O
BILLS	JIM	C/E
FRANKLIN	NICK	2/E
HAY	DEREK	3/E
MURREN	MICK	3/E
BRAZIER	TOM	ETO
WATTERSON	IAN	PCO
NICHOLAIDIS	SAM	Cadet
DEACY	CALLUM	Cadet
SPENSLEY-CORFIELD	ELLIOTT	Cadet
MACDONALD	JOHN	CPOS
COOK	STUART	CPOD
GREGORY	NATHAN	POD
CRABB	GARY	SG1A
CANTLIE	IAN	SG1A
PEPPIN	CHRIS	SG1A
BYRNE	NICK	SG1A
LAWES	DUNCAN	ERPO
LYNCH	PETER	H/Chef
LINK	WALLY	Chef
DOCHERTY	TOMMY	Stwd
TOLTON	JOHN	A/Stwd

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## 2. Cruise Narrative

27 July 2016 (Day 209) - Left Reykjavik in the sunshine at 0830, heading towards Greenland and start of the OSNAP section. At 1315 we were requested by Iceland Coastguard to divert over to a yacht in trouble, and stand by as it motored back towards Iceland, until Coastguard vessel took over. Non-toxic supply switched on at 1335. Science meeting at 1500, boat drill at 1600. One GPS data stream (posmv) had been down since Sunday 24th, due to problems with one antenna - Ship System Technician got the data stream running again, but it is unreliable so all instrument data streams (CTD and underway) switched to receive a different GPS (seapath). 4 RAFOS floats deployed overnight as we came into deeper water.

28 Jul, (Day 210) - Test CTD station at 0830: no problems, and physics team trained up with salts and nutrient sampling. Continued steaming towards start of section in fair weather.

29 Jul (Day 211) - Steaming towards start of section. Calm conditions. Slowed in hours of darkness as we approached Greenland and potential ice.

30 Jul (Day 212) - CTD section started with CTD 'a' (cast 002) at 0425, before proceeding to the most in shore station (CTD 'b'). Recovered M1 successfully, setting off for M2 at 1430. M2 also recovered successfully. CTDs 'e', 'f' completed overnight.

31 July (Day 213) - Start day work with CTD 'j' (releases test), go on to deploy M1, then M2 and complete trilateration of both. Steam to CTD h to re-start CTD section. Decided to omit CTD g in order to save steaming further west.

1 August (Day 214) - Overnight and through the morning completed CTD h, CTD i, RAFOS deployments 13-8. CTD k started at 1100 with microcats and releases attached. Proceed to recovery of M3. RAFOS deployments 7 and 6 and CTD-l completed.

2 August (Day 215) - CTD-m completed before commencing steam to M3 for early deployment and trilateration. Arrive at LOCO site about 1700 and completed recovery of LOCO mooring by 1930. Very calm conditions. Calibration CTD completed at LOCO site, and hove to overnight with plan to deploy LOCO mooring at around midday next day.

3 August (Day 216) - Instruments and equipment from LOCO mooring serviced and checked in the morning, deployment commenced late morning. Trilateration completed by mid afternoon, deployed Argo float for Met Office, commenced to station CTD-n and CTD-o overnight.

4 August (Day 217) - M4 recovered, re-deployed and trilaterated in the continuing good weather. CTDs overnight.

5 August (Day 218) - M5 recovered, redeployed and trilaterated, CTDs overnight.

6 August (Day 219) - IC0 recovered, followed by a calibration CTD for IC0 microcats, and re-deployed late in the afternoon. CTDs and RAFOS deployments en route to IC1 for recovery first thing in the morning.

7 August (Day 220) - on station at IC1 at 0800, releases contacted and activated, but it took a couple of hours to find the buoys at the surface, some distance from original position. After

recovery completed, we proceeded to IC2 for recovery. CTDs and RAFOS deployments overnight.

8 August (Day 221) - IC3 and IC4 recovered during day, CTDs and RAFOS through evening and overnight.

9 August (Day 222) - IC1 and IC2 deployed successfully, followed by trilateration survey. CTDs overnight.

10 August (Day 223) - IC3 and IC4 deployed successfully, followed by trilateration surveys of each, and then by the last two CTD stations (the final one being a repeat of the westernmost station taken on DY052). 3 sperm whales spotted by the Bridge, very close to the ship. Last CTD station finished shortly before midnight, and scientist's watches stood down.

11 August (Day 224) - transit to location of the WHOI Sound Source mooring to be deployed in the Maury Channel. Deployed the mooring slightly northwest of the planned location in order to complete the work in daylight hours - all finished by 2130.

12-16 August (Days 225-229) - passage to Southampton, arrived 1000 at NOC, de-mob during the day.



### 3. Cruise Track and Station Map

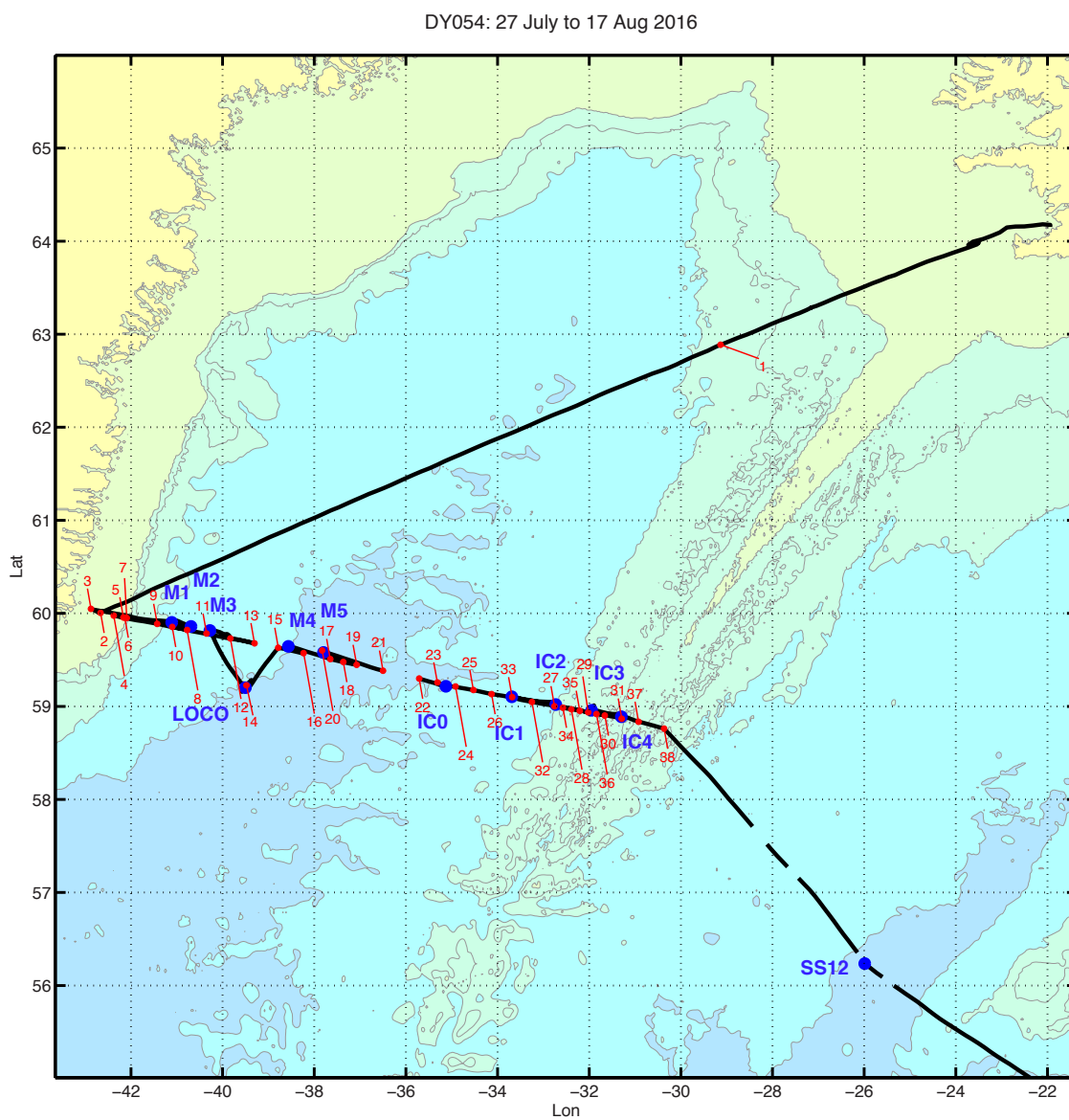


Figure 3.1. DY054 Cruise track (black line), with CTD stations (red dots) and mooring positions (blue dots).

Table 1. CTD Station List.

*cdep* is corrected water depth (m); *maxd* is maximum CTD depth (m); *alt* is CTD height off bottom (m); *wire* is maximum winch wireout (m); *pres* is maximum CTD pressure (dbar); *nd* is number of bottles fired; *sal* and *nut* are number of salinity and nutrients samples taken.

stn	yy/mo/dd	hhmm	dg	min	lat	dg	min	lon	cdep	maxd	alt	res	wire	pres	nd	sal	nut	Comments
001	16/07/28	0928	62	53.24	N	29	08.03	W	1655	1504	-9	-999	1500	1524	1	12	7	Test station
002	16/07/30	0432	60	00.32	N	42	39.80	W	201	192	12	3	190	194	5	5	5	
003	16/07/30	0557	60	02.99	N	42	52.31	W	169	162	10	3	160	163	5	5	5	
004	16/07/30	2307	59	58.60	N	42	22.61	W	197	189	10	2	186	190	5	5	5	
005	16/07/31	0044	59	57.39	N	42	09.96	W	491	483	10	2	482	488	6	6	6	
006	16/07/31	0226	59	57.23	N	42	08.14	W	1039	1018	11	-10	1017	1030	0	8	8	
007	16/07/31	0416	59	56.99	N	42	05.54	W	1479	1472	7	-1	1470	1491	10	10	10	
008	16/07/31	1054	59	49.28	N	40	46.50	W	2567	2540	24	-3	2535	2580	10	10	6	
009	16/08/01	0240	59	53.18	N	41	25.59	W	1902	1894	8	0	1890	1920	12	12	8	
010	16/08/01	0627	59	51.26	N	41	06.01	W	2087	2077	9	-1	2074	2107	12	12	8	
011	16/08/01	1223	59	46.88	N	40	20.99	W	2569	2557	13	0	2550	2597	11	11	6	NMF caldip and releases test
012	16/08/01	2048	59	43.78	N	39	49.82	W	2727	2717	13	2	2711	2761	11	11	6	
013	16/08/02	0106	59	40.73	N	39	18.26	W	2846	2837	10	1	2834	2883	11	10	6	
014	16/08/02	2245	59	13.57	N	39	28.65	W	3007	3004	5	2	2999	3054	12	11	5	NIOZ microcat caldip
015	16/08/03	1954	59	37.74	N	38	47.00	W	2953	2945	8	1	2940	2994	12	12	6	
016	16/08/04	0008	59	34.25	N	38	13.80	W	3052	3042	10	0	3040	3093	12	11	6	
017	16/08/04	1951	59	30.49	N	37	39.13	W	3107	3097	10	1	3093	3150	12	12	6	
018	16/08/04	2321	59	28.60	N	37	21.95	W	3136	3127	9	0	3123	3181	12	12	6	
019	16/08/05	0258	59	26.76	N	37	04.45	W	3121	3111	9	0	3108	3164	12	12	6	
020	16/08/05	1536	59	36.03	N	37	49.60	W	3132	3115	11	-7	3110	3168	12	12	6	NMF microcat caldip
021	16/08/06	0041	59	23.01	N	36	29.95	W	3099	3091	9	0	3086	3143	12	12	6	
022	16/08/06	0648	59	17.93	N	35	42.64	W	3099	3091	9	1	3087	3144	12	12	6	
023	16/08/06	1507	59	15.48	N	35	18.87	W	2969	2954	14	-1	2950	3003	12	12	6	NIOZ microcat caldip
024	16/08/06	2134	59	12.84	N	34	54.97	W	2494	2485	9	-0	2480	2523	10	10	5	
025	16/08/07	0134	59	10.47	N	34	31.61	W	2656	2649	8	0	2642	2691	11	11	6	
026	16/08/07	0512	59	07.97	N	34	07.83	W	2459	2451	8	0	2447	2489	10	10	6	
027	16/08/07	1941	59	00.10	N	32	45.43	W	2019	2014	8	2	2010	2043	8	8	6	
028	16/08/07	2251	58	58.19	N	32	23.39	W	1988	1973	9	-6	1970	2001	12	12	8	NIOZ microcat caldip
029	16/08/08	0248	58	56.11	N	32	01.36	W	1775	1768	9	1	1766	1792	11	11	8	
030	16/08/08	0537	58	54.10	N	31	39.46	W	1444	1435	6	-3	1430	1453	10	10	8	
031	16/08/08	1516	58	52.11	N	31	17.41	W	1424	1415	11	2	1410	1433	7	7	6	
032	16/08/09	0004	59	02.85	N	33	14.89	W	2163	2152	9	-1	2150	2184	9	9	6	NIOZ microcat caldip
033	16/08/09	0401	59	05.95	N	33	40.91	W	2504	2495	10	1	2490	2534	11	11	6	
034	16/08/09	2153	58	59.14	N	32	34.36	W	2124	2117	9	2	2113	2148	9	9	6	
035	16/08/10	0055	58	57.17	N	32	12.33	W	1471	1463	9	1	1460	1482	10	10	8	
036	16/08/10	0349	58	55.11	N	31	50.43	W	1688	1679	10	0	1677	1702	11	11	8	
037	16/08/10	1834	58	50.06	N	30	55.40	W	1306	1292	15	0	1290	1308	7	7	6	
038	16/08/10	2217	58	45.67	N	30	21.96	W	1635	1622	12	-0	1620	1644	11	11	8	



#### **4. NMF-SS Sensors Report**

*Jeff Benson, Dave Childs*

##### **4.1 CTD system configurations**

i) One CTD system was prepared. The initial water sampling arrangement was an NMF 24-way stainless steel frame system (s/n SBE CTD8), and the initial sensor configuration was as follows:

Sea-Bird 9plus underwater unit, s/n 09P-39607-0803  
Sea-Bird 3P temperature sensor, s/n 03P-4381, Frequency 0 (primary)  
Sea-Bird 4C conductivity sensor, s/n 04C-3054, Frequency 1 (primary)  
Digiquartz temperature compensated pressure sensor, s/n 93896, Frequency 2  
Sea-Bird 3P temperature sensor, s/n 03P-4712, Frequency 3 (secondary)  
Sea-Bird 4C conductivity sensor, s/n 04C-3529, Frequency 4 (secondary)  
Sea-Bird 5T submersible pump, s/n 05T-6320, (primary)  
Sea-Bird 5T submersible pump, s/n 05T-6916, (secondary)  
Sea-Bird 32 Carousel 24 position pylon, s/n 32-60380-0805  
Sea-Bird 11plus deck unit, s/n 11P-24680-0589 (main)  
Sea-Bird 11plus deck unit, s/n 11P-34173-0676 (back-up/spare)

Primary sensors attached to the frame's fin, secondary sensors position in-frame

ii) The auxiliary input initial sensor configuration was as follows:

Sea-Bird 43 dissolved oxygen sensor, s/n 43-2575 (V0, primary)  
Benthos PSAA-916T altimeter, s/n 59494 (V3)  
Chelsea Aquatracka MKIII fluorometer, s/n 088244 (V6)  
WETLabs C-Star transmissometer, s/n CST-1759TR (V7)

iii) Additional instruments:

TRDI WorkHorse Sentinel 300kHz LADCP, downward-looking, s/n 21028  
TRDI WorkHorse Sentinel 300kHz LADCP, upward-looking, s/n 21029  
NOCS LADCP battery pack, s/n WH006T  
SBE35 Deep Ocean Standards Thermometer, s/n 35-34173-0048

iv) Changes to instrument suite: none

v) Sea-Bird *9plus* configuration file DY054\_0803\_SS.xmlcon was used for all CTD casts.

vi) The spare water sampling equipment was an NMF 24-way stainless steel frame system (s/n SBE CTD1), and the spare sensors were as follows:

Sea-Bird 9plus underwater unit, s/n 09P-71442-1142  
Digiquartz temperature compensated pressure sensor, s/n 124216  
Sea-Bird 9plus underwater unit, s/n 09P-34173-0758

Digiquartz temperature compensated pressure sensor, s/n 90074  
Sea-Bird 3P temperature sensor, s/n 03P-4782  
Sea-Bird 3P temperature sensor, s/n 03P-5660  
Sea-Bird 3P temperature sensor, s/n 03P-5700  
Sea-Bird 3P temperature sensor, s/n 03P-5785  
Sea-Bird 4C conductivity sensor, s/n 04C-2571  
Sea-Bird 4C conductivity sensor, s/n 04C-4138  
Sea-Bird 4C conductivity sensor, s/n 04C-4139  
Sea-Bird 4C conductivity sensor, s/n 04C-4140  
Sea-Bird 5T submersible pump, s/n 05T-3085  
Sea-Bird 5T submersible pump, s/n 05T-5301  
Sea-Bird 5T submersible pump, s/n 05T-7371  
Sea-Bird 5T submersible pump, s/n 05T-7514  
Sea-Bird 32 Carousel 24 position pylon, s/n 32-24680-0346  
Sea-Bird 32 Carousel 24 position pylon, s/n 32-34173-0493

vii) The auxiliary spare sensors were as follows:

Sea-Bird 43 dissolved oxygen sensor, s/n 43-0619  
Sea-Bird 43 dissolved oxygen sensor, s/n 43-0709  
Sea-Bird 43 dissolved oxygen sensor, s/n 43-0363  
Sea-Bird 43 dissolved oxygen sensor, s/n 43-2831  
Benthos PSAA-916T altimeter, s/n 59493  
Benthos PSAA-916T altimeter, s/n 62679  
WETLabs C-Star transmissometer, s/n CST-1720TR  
Chelsea Alphasacka MKII transmissometer, s/n 161-2642-002  
Chelsea Aquatracka MKIII fluorometer, s/n 088195  
Chelsea Aquatracka MKIII fluorometer, s/n 88-2050-095

viii) Additional instruments:

TRDI WorkHorse Monitor 300kHz LADCP, s/n 4275  
TRDI WorkHorse Monitor 300kHz LADCP, s/n 10607  
TRDI WorkHorse Monitor 300kHz LADCP, s/n 13399  
TRDI WorkHorse Monitor 300kHz LADCP, s/n 13400  
NOCS LADCP battery pack, s/n WH005  
SBE35 Deep Ocean Standards Thermometer, s/n 35-34173-0037

Total number of casts – 38  
Casts deeper than 2000m - 22  
Deepest cast – 3127m



*Fig. 4.1 DY054 Sensors arrangements. Primary sensors on the fin, secondary in-frame. 12 niskin bottles in place, and straps present for attaching microcats for calibration dips.*

## 4.2 Technical detail report

S/S CTD: SBE35 DOST set to sample for 9.9 seconds during water sampler closing period. First cast DY054\_001 all rosette positions closed, and ‘fired’ in rapid succession. As a consequence only five DOST readings taken. Rosette position 8 closed in error on deployment DY054\_038.

CTD2 used for all casts.

Deep Tow CTD Lemo connections in Main Lab re-soldered prior to DY050, but movement of connections/wires still causes open circuit/underwater unit error on SBE 11P.

Occasional “Unsupported Modem Message from SBE Carousel” displayed in SeaSave; possible cause noise interference on Deep Tow sea cable.

Transmissometer not calibrated in situ prior to DY052; values entered for M and B are factory default calculations.

### 4.3 LADCP

The command files used during the cruise were provided by RSMAS, and were the same as on DY053:

file: whm300\_aeh\_os1606

```
WV250          ; ambiguity velocity [cm/s]
WN25           ; number of depth cells; NBP0402
WS1000         ; bin size [cm]; NBP0402: WS1000
WF0           ; blank after transmit [cm]; NBP0402
WB1           ; narrow bandwidth mode
EZ0011101     ; Sensor source: (NBP0402: EZ0111111)
EX00100       ; coordinate transformation: (NBP0402: 11111)
WP1           ; single-ping ensembles; NBP0402: WP3 most of the time
TP 00:00:90   ; time between pings; NBP0402
TE 00:00:01.50 ; time per ensemble
CF11101       ; Flow control:
SM1           ; set to master
SA011         ; send pulse before ensemble
SW5500        ; master waits .5500 s after sending sync pulse
RNmast_CK     ; keep params as user defaults (across power failures)
W?
T?
CS            ; start pinging
```

file: whs300\_aeh\_os1606

```
WV250          ; ambiguity velocity [cm/s]
WN25           ; number of depth cells; NBP0402
WS1000         ; bin size [cm]; NBP0402: WS1000
WF800         ; blank after transmit [cm]; NBP0402
WB1           ; narrow bandwidth mode
EZ0011101     ; Sensor source: (NBP0402: EZ0111111)
EX00100       ; coordinate transformation: (NBP0402: 11111)
WP1           ; single-ping ensembles; NBP0402: WP3 most of the time
TP 00:00:00   ; time between pings; NBP0402
TE 00:00:01.50 ; time per ensemble
CF11101       ; Flow control:
SM2           ; set to slave
SA011         ; waits for pulse before ensemble
ST120         ; waits 120s for ma-signal before running single RNslav_
CK            ; keep params as user defaults (across power failures)
W
T?
CS            ; start pinging
```

## 4.4 AUTOSAL

A Guildline 8400B, s/n 68958, was installed in the Salinometer Room as the main instrument for salinity analysis. A second Guildline 8400B, s/n 71126, was installed in the Salinometer Room as a spare instrument. The Autosol set point was 24C, and samples were processed according to WOCE cruise guidelines: The salinometer was standardized at the beginning of the first set of samples on DY053 (the OSNAP cruise immediately before DY054), and checked with an additional standard analysed prior to setting the RS. Once standardized the Autosol was not adjusted for the duration of sampling, unless the set point was changed. Additional standards were analysed approximately every 16 samples to monitor & record drift. These were labeled sequentially and increasing, beginning with number 9057. Standard deviation set to 0.00002.

*(see section 12 for more on salinometer data and performance).*

## 4.5 Stainless CTD frame configuration files

Instrument configuration file:

C:\Users\sandm\Documents\Cruises\DY054\Data\Seasave Setup  
Files\DY054\_0803\_SS.xmlcon

Configuration report for SBE 911plus/917plus CTD

```
-----  
Frequency channels suppressed : 0  
Voltage words suppressed      : 0  
Computer interface            : RS-232C  
Deck unit                     : SBE11plus Firmware Version >= 5.0  
Scans to average              : 1  
NMEA position data added      : Yes  
NMEA depth data added         : No  
NMEA time added               : Yes  
NMEA device connected to     : PC  
Surface PAR voltage added     : No  
Scan time added               : Yes
```

### 1) Frequency 0, Temperature

```
Serial number : 03P-4381  
Calibrated on : 21 July 2015  
G             : 4.42359050e-003  
H             : 6.44917114e-004  
I             : 2.26674159e-005  
J             : 1.97655514e-006  
F0            : 1000.000  
Slope         : 1.00000000  
Offset        : 0.0000
```

### 2) Frequency 1, Conductivity

```
Serial number : 04C-3054  
Calibrated on : 16 June 2015  
G             : -9.80759366e+000  
H             : 1.42268693e+000  
I             : -2.32442769e-004  
J             : 8.20502779e-005  
CTcor         : 3.2500e-006  
CPcor         : -9.57000000e-008  
Slope         : 1.00000000
```

Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 93896  
Calibrated on : 9 July 2014  
C1 : -8.331332e+004  
C2 : -3.281962e+000  
C3 : 2.216060e-002  
D1 : 2.906000e-002  
D2 : 0.000000e+000  
T1 : 3.005232e+001  
T2 : -3.843669e-004  
T3 : 4.436390e-006  
T4 : 0.000000e+000  
T5 : 0.000000e+000  
Slope : 1.00001000  
Offset : -1.35810  
AD590M : 1.289250e-002  
AD590B : -8.106440e+000

4) Frequency 3, Temperature, 2

Serial number : 03P-4712  
Calibrated on : 21 July 2015  
G : 4.40403756e-003  
H : 6.33214711e-004  
I : 1.90723282e-005  
J : 1.14981012e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 04C-3529  
Calibrated on : 21 July 2015  
G : -9.91877058e+000  
H : 1.57004159e+000  
I : -2.20163146e-003  
J : 2.65000201e-004  
CTcor : 3.2500e-006  
CPcor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 43-2575  
Calibrated on : 31 July 2015  
Equation : Sea-Bird  
Soc : 4.41200e-001  
Offset : -4.67000e-001  
A : -4.32580e-003  
B : 2.14910e-004  
C : -2.87190e-006  
E : 3.60000e-002  
Tau20 : 1.00000e+000  
D1 : 1.92634e-004  
D2 : -4.64803e-002  
H1 : -3.30000e-002  
H2 : 5.00000e+003  
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Altimeter

Serial number : 59494  
Calibrated on : 29 November 2012  
Scale factor : 15.000  
Offset : 0.000

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Transmissometer, WET Labs C-Star

Serial number : CST-1759TR  
Calibrated on : 22 December 2015  
M : 21.3083  
B : -0.1705  
Path length : 0.250

13) A/D voltage 7, Fluorometer, Chelsea Aqua 3

Serial number : 088244  
Calibrated on : 6 August 2014  
VB : 0.236800  
V1 : 2.151000  
Vacetone : 0.305900  
Scale factor : 1.000000  
Slope : 1.000000  
Offset : 0.000000

Scan length : 45



## 5. NMF-SS Ship Scientific Data Systems

*Zoltan Nemeth*

Data were logged and converted into NetCDF file format by the TechSAS datalogger. The format of the NetCDF files is given in the file: **dy054\_netcdf\_file\_descriptions.docx**. The instruments logged are given in **dy054\_ship\_instrumentation\_overview.docx**. Data were additionally logged in the RVS Level-C format, which is also described in: **dy054\_netcdf\_file\_descriptions.docx**.

TechSAS started by 2016.07.26 21:10:00 and running until Southampton arrival 2016.08.16

### 5.1 Position & Attitude

The main GNSS and attitude measurement system, Applanix POS MV was broken in the first day in the cruise and replaced with the Sepath330 run throughout the cruise. SEAPATH position and attitude was used by the EA/EM (echosounders) System.

#### *Kongsberg Seapath 330*

The Seapath is the vessel's primary navigational GPS, it outputs the position of the ship's common reference point in the gravity meter room.

Seapath acquisition crashed at 20160805@01:22 restarted 06:32

Longer than 10 minutes gaps:

time gap : 16 217 09:11:52 to 16 217 09:44:57 (33.1 mins)  
time gap : 16 217 14:10:38 to 16 217 14:44:15 (33.6 mins)  
time gap : 16 219 01:21:13 to 16 219 06:32:56 (5.2 hrs)  
time gap : 16 220 01:04:23 to 16 220 01:44:21 (40.0 mins)  
time gap : 16 220 04:37:39 to 16 220 05:30:13 (52.6 mins)  
time gap : 16 220 22:12:42 to 16 220 23:05:28 (52.8 mins)  
time gap : 16 222 22:41:39 to 16 222 22:55:58 (14.3 mins)  
time gap : 16 222 23:23:18 to 16 223 00:28:25 (65.1 mins)  
time gap : 16 223 01:25:21 to 16 223 02:04:21 (39.0 mins)  
time gap : 16 223 02:21:28 to 16 223 02:32:51 (11.4 mins)  
time gap : 16 223 04:22:47 to 16 223 04:37:48 (15.0 mins)  
time gap : 16 224 08:45:00 to 16 224 09:32:02 (47.0 mins)  
time gap : 16 224 12:22:38 to 16 224 12:41:32 (18.9 mins)  
time gap : 16 224 18:45:02 to 16 224 18:56:44 (11.7 mins)  
time gap : 16 224 19:24:38 to 16 224 19:37:51 (13.2 mins)  
time gap : 16 224 23:24:13 to 16 224 23:42:53 (18.7 mins)  
time gap : 16 225 13:40:00 to 16 225 14:10:27 (30.4 mins)  
time gap : 16 225 14:39:28 to 16 225 15:52:15 (72.8 mins)

#### *Applanix POSMV*

The POSMV is the primary scientific GPS, and is used on the SSDS displays around the vessel. A TechSAS data logging module for the iXSea PHINS and Seapath 330 attitude data is under development.

Longer than 10 minutes gaps:

time gap : 16 206 11:19:17 to 16 209 06:32:52 (2.8 days)  
time gap : 16 209 06:57:53 to 16 209 18:42:36 (11.7 hrs)  
time gap : 16 211 07:39:32 to 16 211 07:53:44 (14.2 mins)



time gap : 16 217 10:24:24 to 16 217 10:52:18 (27.9 mins)  
time gap : 16 217 11:21:04 to 16 217 11:34:42 (13.6 mins)  
time gap : 16 217 16:29:57 to 16 217 16:50:40 (20.7 mins)  
time gap : 16 218 08:45:44 to 16 218 09:02:12 (16.5 mins)  
time gap : 16 225 13:43:35 to 16 225 13:57:09 (13.6 mins)  
time gap : 16 226 02:28:19 to 16 226 05:35:13 (3.1 hrs)

#### *iXBlue PhINS*

A surface inertial navigation system that uses a FOG (Fibre-Optic Gyro) to output accurate position, attitude, and velocity data.

PhINS supplies the ADCP OS75 and OS150 with position and attitude data.

## **5.2 Underway Instrumentation**

#### *SurfMet*

SurfMet comprises two sets of scientific instruments: Meteorological; and Surface Water Sampling, along with ADCs and a PC hosting SurfMet data conversion software that passes data to the Data Systems for event logging.

Freshly calibrated SBE38 remote temperature sensor replaced the out of call sensor. Also, an HMP155 Temperature and humidity sensor and a PTB110 barometer fitted.

**dy054\_surfmet\_sensor\_information.docx** for details of the sensors used and the calibrations that need to be applied.

Calibration sheets are included in the directory:

`\ship_fitted_scientific_systems\surfmet\SurfMet_calibration_sheets\fitted\`

#### *SurfMet: Surface Water System*

The system cleaned on 2016.07.26 11:30 and rinse with freshwater.

The non-toxic water supply was ON from 2016.07.27 13:35 to 2016.08.15

The transmissometer optic cleaned at jd 09:00-09:10

The fluorimeter cleaned at jd 09:00-09:10

The whole system cleaned after end of the cruise.

#### *SurfMet: Met Platform System*

Light sensors glass covers cleaned during the ports of call at Glasgow.

#### *SurfMet: PYTHON*

Longer than 10 minutes gaps:

time gap : 16 206 08:21:59 to 16 206 08:32:20 (10.3 mins)  
time gap : 16 218 01:46:55 to 16 218 05:09:30 (3.4 hrs)  
time gap : 16 218 20:50:53 to 16 218 21:05:44 (14.8 mins)  
time gap : 16 221 09:31:41 to 16 221 10:01:01 (29.3 mins)  
time gap : 16 221 12:55:02 to 16 221 13:05:25 (10.4 mins)  
time gap : 16 221 20:32:35 to 16 221 20:48:38 (16.1 mins)  
time gap : 16 222 03:33:00 to 16 222 03:54:00 (21.0 mins)  
time gap : 16 222 04:41:41 to 16 222 05:00:49 (19.1 mins)  
time gap : 16 223 00:37:30 to 16 223 00:48:45 (11.2 mins)  
time gap : 16 223 23:47:59 to 16 224 00:20:40 (32.7 mins)

time gap : 16 224 02:43:24 to 16 224 03:34:34 (51.2 mins)  
time gap : 16 224 15:21:05 to 16 224 15:51:43 (30.6 mins)  
time gap : 16 226 02:24:52 to 16 226 02:57:05 (32.2 mins)  
time gap : 16 226 03:27:00 to 16 226 05:35:59 (2.1 hrs)

### 5.3 Hydroacoustics

*Kongsberg EM122 (multi-beam swath bathymetry)*

The raw data processed daily; data available from NMFSS on request.

### 5.4 Teledyne RDI Ocean Surveyor ADCPs

*Ocean Surveyor 75kHz*

Onshelf running in Bottom Tracking mode and offshelf running on non Bottom Tracking mode.

*Table 5.1 Configuration for Ocean Surveyor 75 kHz ADCP*

Non Bottom Tracking Settings	Bottom Tracking Settings
Blank (WF) 8.00 m	Blank (WF) 8.00 m
Min PGood (WG) 0	Min PGood (WG) 0
Ref Layer (WL) 1, 1 first bin, last bin	Ref Layer (WL) 1, 1 first bin, last bin
Mode (WM) 10	Mode (WM) 10
Bins (WN) 60	Bins (WN) 100
Pings/Ens (WP) 43	Pings/Ens (WP) 96
Bin Size (WS) 16.00 m	Bin Size (WS) 16.00 m
Head Align (EA) -45.00 degrees	Head Align (EA) -45.00 degrees
Head Bias (EB) 0.00 degrees	Head Bias (EB) 0.00 degrees
Coord Xform (EX) 11111 Earth Coordinates Using Tilts, 3 Beam Solutions, and Bin Mapping	Coord Xform (EX) 11111 Earth Coordinates Using Tilts, 3 Beam Solutions, and Bin Mapping
Sens Source (EZ) 1011101 cdhprst	Sens Source (EZ) 1011101 cdhprst
Sens Avail 0000001 cdhprst	Sens Avail 0000001 cdhprst
Time/Ping (TP) 00:01.50	Time/Ping (TP) 00:01.50
Hardware 4 Beams	Hardware 4 Beams
Lag 21 elements	Lag 21 elements
Code Reps. 0	Code Reps. 0
Lag Length 1.42 m	Lag Length 1.43 m
Xmt Length 16.00 m	Xmt Length 16.00 m
1st Bin 23.93 m	1st Bin 23.95 m
	BT Pings/Ens (BP) 39
	BT Ens Delay (BD) 0
	BT Cor.Thres. (BC) 220 counts
	BT Eval. Thres. (BA) 30 counts
	BT PG Thres. (BG) 0
	BT Mode (BM) 1
	BT Err Thres. (BE) 1000 mm/s
	BT Max Range (BX) 12000 dm

*Ocean Surveyor 150kHz.*

Onshelf running in Bottom Tracking mode and offshelf running on non Bottom Tracking mode.

Table 5.2 Configuration for Ocean Surveyor 150 kHz ADCP

Non Bottom Tracking Settings	Bottom Tracking Settings
Blank (WF) 4.00 m	Blank (WF) 4.00 m
Min PGood (WG) 0	Min PGood (WG) 0
Ref Layer (WL) 1, 1 first bin, last bin	Ref Layer (WL) 1, 1 first bin, last bin
Mode (WM) 10	Mode (WM) 10
Bins (WN) 60	Bins (WN) 60
Pings/Ens (WP) 66	Pings/Ens (WP) 38
Bin Size (WS) 8.00 m	Bin Size (WS) 8.00 m
Head Align (EA) -45.00 degrees	Head Align (EA) -45.00 degrees
Head Bias (EB) 0.00 degrees	Head Bias (EB) 0.00 degrees
Coord Xform (EX) 11111 Earth Coordinates Using Tilts, 3 Beam Solutions, and Bin Mapping	Coord Xform (EX) 11111 Earth Coordinates Using Tilts, 3 Beam Solutions, and Bin Mapping
Sens Source (EZ) 1011101 cdhprst	Sens Source (EZ) 1011101 cdhprst
Sens Avail 0000001 cdhprst	Sens Avail 0000001 cdhprst
Time/Ping (TP) 00:01.00	Time/Ping (TP) 00:01.00
Hardware 4 Beams	Hardware 4 Beams
Lag 11 elements	Lag 11 elements
Code Reps. 0	Code Reps. 0
Lag Length 0.74 m	Lag Length 0.74 m
Xmt Length 8.00 m	Xmt Length 8.00 m
1st Bin 11.94 m	1st Bin 11.95 m
	BT Pings/Ens (BP) 36
	BT Ens Delay (BD) 0
	BT Cor. Thres. (BC) 220 counts
	BT Eval. Thres. (BA) 30 counts
	BT PG Thres. (BG) 0
	BT Mode (BM) 1
	BT Err Thres. (BE) 1000 mm/s
	BT Max Range (BX) 8000 dm



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## 6. NOC Moorings operations and data

David Smeed

### 6.1 NOC mooring recoveries

Five NOC moorings were recovered during the cruise. These are summarised in Table 6.1. All of these moorings were deployed from the RV *Pelagia* in July 2015 during cruise PE400.

*Table 6.1. List of NOC moorings recovered during cruise DY054. The recorded duration is the time from release of the mooring to the recovery of the last instrument/release.*

<b>Mooring</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Release date</b>	<b>Time of release</b>	<b>Time recovery complete</b>	<b>Duration (hh:mm)</b>
NOCM1	59°54.18	41°06.71	30/07/16	11:45	14:16	02:30
NOCM2	59°51.55	40°41.33	30/07/16	16:00	17:26	01:25
NOCM3	59°48.89	40°16.59	01/08/16	14:40	16:40	02:00
NOCM4	59°38.80	38°33.94	04/08/16	07:55	09:45	01:50
NOCM5	59°34.63	37°47.95	05/08/16	08:10	10:00	01:50

The designs of the moorings is illustrated in Appendix E of the Pelagia 400 cruise report and are not repeated here. The design is essentially the same as those deployed on DY054 shown in Appendix A.

Communications with the acoustic releases were made via the hull-mounted transducer. This worked well for all but one of the moorings. When recovering M5 no ranges were obtained after commanding the release and a transducer was lowered over the side to confirm that the releases were rising.

Mooring M1 rose to the surface with the buoyancy package well separated but for the other moorings several packages were close to one another on the surface resulting in a number of tangles.

All instruments were recovered intact and full data records were obtained from each. A summary of the recovered instruments is given in Table 6.2.

### On-board mooring instrument processing

On board processing and checking of the data followed the procedures used in RAPID mooring cruises.

After download from instruments data were copied to the workstation SAMS-EEL in the path */home/mstar/osnap/data/moor/raw/dy054/* where there is a sub-directory for each instrument type.

Meta-data for each deployment are recorded in a file named *<deployment>info.dat* stored in directory */home/mstar/osnap/data/moor/proc/<deployment>* where subsequently processed data are also stored. The deployment name include the name of the mooring, the number of the deployment and the year of deployment; e.g. *nocm1\_02\_2015*. The meta-data includes the location of the mooring, and the start and end time of the deployment. These times are

adjusted after inspection of the data so that the launch and recovery periods are excluded. The corrected water depth and the magnetic declination are recorded too. Magnetic declination was obtained from <http://www.ngdc.noaa.gov/geomag-web/> using a time of January 2016, approximately half-way through the deployment. At these mooring locations declination typically changes by  $0.3^{\circ}\text{E}$  per year and has a stated accuracy of  $\pm 0.45^{\circ}$ .

The first stage of processing for each instrument type is to convert the data into the RODB format and merge metadata from the <deployment>info.dat file. Time-series plots are produced which can be used to identify the launch and recovery periods and may highlight any significant issues with the data. In the second stage of processing the launch and recovery periods are removed from the data.

### **Microcat calibration**

Each of the deployed and recovered instruments were calibrated on a “cal-dip” CTD cast. Some of the deployed instruments were calibrated on the preceding cruise DY053 and two calibration cast were conducted during dy054. These were casts 11 and 20.

During calibration casts the Microcats were set to record at 10 second intervals and the data were compared to the primary sensor pair on the CTD frame. Comparisons are made at the time of bottle stops which are about 5 minutes each. Data from the deepest bottle stop are summarised in Table 6.3.



Table 6.2. Instrument records lengths. The instrument codes are: 337 = microcat CTD, 370 = Nortek current meter, 324 = ADCP 300kHz.

Mooring	Instr. code	Serial number	Nominal depth	Median pressure	Start date	End date	Number of records	Comments
nocm1	370	11042	51	52	25/07/15	31/07/15	8931	Setup to start 12 hours after deployment
	337	11340	57	68	24/07/15	30/07/16	8925	Hairy growth
	337	11336	295	309	24/07/15	30/07/16	8923	
	370	11021	530	543	25/07/15	31/07/15	8931	Setup to start 12 hours after deployment
	337	9374	536	553	24/07/15	30/07/16	8925	
	337	8080	771	794	24/07/15	30/07/16	8925	
	370	11029	1011	1032	25/07/15	31/07/16	8929	Setup to start 12 hours after deployment
	337	8081	1017	1043	24/07/15	30/07/16	8925	
	337	11326	1251	1282	24/07/15	30/07/16	8925	
	370	11026	1491	1524	25/07/15	30/07/16	8913	Setup to start 12 hours after deployment
	337	10561	1497	1532	24/07/15	30/07/16	8926	
	370	11028	1731	1770	25/07/15	30/07/16	8912	Setup to start 12 hours after deployment
	337	11328	1736	1775	24/07/15	30/07/16	8926	
	337	11330	1962	2004	24/07/15	30/07/16	8926	
	324	20957	1970	2035	24/07/15	30/07/16	8928	
nocm2	337	9378	1470	1486	22/07/15	30/07/16	8973	
	337	11287	1685	1706	22/07/15	30/07/16	8974	Slid down wire during tangled recovery
	370	11030	1896	1924	22/07/15	30/07/16	8977	
	337	11341	1901	1924	22/07/15	30/07/16	8974	
	337	10578	2115	2146	22/07/15	30/07/16	8974	
	337	10579	2324	2360	22/07/15	30/07/16	8974	
	324	20961	2332	2401	22/07/15	30/07/16	8993	
Nocm3	337	9376	1290	1304	22/07/15	01/08/16	9027	
	337	10560	1580	1602	22/07/15	01/08/16	9027	Two short periods with offset conductivity
	370	11023	1865	1898	22/07/15	01/08/16	9029	Recorded as 11021 on deployment
	337	11288	1871	1897	22/07/15	01/08/16	9027	

	337	10577	2159	2195	22/07/15	01/08/16	9027	
	337	11335	2444	2485	22/07/15	01/08/16	9027	
	324	20959	2452	2519	21/07/15	02/08/16	9057	
nocm4	370	9859	1513	1534	20/07/15	04/08/16	9147	
	337	11342	1519	1530	20/07/15	04/08/16	9144	Plug lost during recovery
	337	11343	1864	1879	20/07/15	04/08/16	9144	
	370	9854	2194	2247	20/07/15	04/08/16	9147	
	337	11320	2204	2230	20/07/15	04/08/16	9144	
	337	11290	2542	2574	20/07/15	04/08/16	9144	
	337	11289	2872	2921	20/07/15	04/08/16	9144	
	324	20960	2881	2957	19/07/15	04/08/16	9156	
nocm5	337	9371	1578	1586	20/07/15	05/08/16	9168	
	337	9375	1939	1955	20/07/15	05/08/16	9168	
	370	11047	2294	2327	20/07/15	05/08/16	9175	Recorded as 11097 on deployment
	337	9377	2300	2324	20/07/15	05/08/16	9168	
	337	11327	2558	2692	20/07/15	05/08/16	9168	
	337	11338	3013	3059	20/07/15	05/08/16	9169	
	324	20958	3020	3105	19/07/15	06/08/16	9179	

## Data issues

A preliminary inspection of the data indicated a few issues that should be examined further when processing the data:

### *Microcats*

11287 appears to have a large drift during the year on M2. During the caldip this instrument had larger variability of conductivity than other instruments. This instrument slid along the wire during recovery to tangles on M2

11338 had a temperature offset of 0.003°C during the caldip

10560 had low conductivity for data cycles 5455-5550 and 7382-7390

### *ADCPs*

Comparison with other instruments suggests that the pressure recorded by each ADCP is about 30db greater than expected. The first bin of data looks not to be useable. Good data appears to have been recorded in the following bins close to the instruments, but the quality decreases with increasing range and there is a noticeable reduction in range in the spring-time, presumably due to a reduced number of scatterers in the water column.

Table 6.3. Summary of the cal-dips. The mean difference and standard deviation of the difference between each Microcat and the primary CTD sensors are shown the data are for the deepest bottle stop only.

		Conductivity (mS/cm)		Temperautre (°C)		Pressure (dbar)	
Serial							
number	Samples	Mean	S.D.	Mean	S.D.	Mean	S.D.
Cast 11 - Differences evaluated at 2596 db (except 8078 at 2543 db)							
CTD-2		0.0054	0.0008	-0.0019	0.001		
8078	34	0.0041	0.0004	-0.0008	0.0005	3.0	0.18
8079	55	0.0101	0.0010	-0.0007	0.0010	3.4	0.30
8080	55	0.0012	0.0012	-0.0011	0.0013	3.7	0.24
8081	55	0.0031	0.0010	-0.0009	0.0011	2.1	0.30
9374	55	0.0029	0.0013	-0.0011	0.0015	1.4	0.19
10561	55	0.0030	0.0013	-0.0008	0.0015	3.9	0.17
11326	55	0.0035	0.0012	-0.0007	0.0014	3.0	0.19
11328	55	0.0006	0.0013	-0.0013	0.0015	3.2	0.25
11330	55	0.0101	0.0011	-0.0010	0.0013	3.1	0.35
11336	55	0.0009	0.0012	-0.0007	0.0014	-0.7	0.22
11340	55	0.0005	0.0012	0.0006	0.0013	-2.3	0.15
9378	55	0.0030	0.0012	-0.0010	0.0013	3.1	0.30
10578	55	-0.0039	0.0011	-0.0010	0.0013	5.0	0.19
10579	55	-0.0017	0.0012	-0.0008	0.0013	4.2	0.42
11287	55	0.0045	0.0039	-0.0004	0.0013	3.3	0.25
11341	55	0.0046	0.0011	0.0006	0.0013	0.0	0.42
Cast 20 - Differences evaluated at 3167 db							
CTD-2		0.0048	0.0002	-0.0021	0.0002		
9376	24	0.0136	0.0003	-0.0015	0.0002	1.9	0.67
10560	24	-0.0026	0.0004	-0.0014	0.0003	3.4	0.67
11288	24	0.0028	0.0003	-0.0015	0.0002	3.8	0.63
10577	24	0.0015	0.0003	-0.0015	0.0002	5.4	0.65
11335	24	0.0055	0.0003	-0.0007	0.0002	3.8	0.70
11342	24	0.0023	0.0003	-0.0003	0.0002	-2.6	0.66
11343	24	0.0015	0.0003	-0.0010	0.0002	-1.1	0.68
11320	24	0.0009	0.0003	-0.0014	0.0002	3.7	0.66
11290	24	0.0027	0.0003	-0.0013	0.0002	0.0	0.70
11289	24	0.0026	0.0003	-0.0015	0.0002	4.6	0.68
9371	24	0.0107	0.0002	-0.0013	0.0002	1.3	0.66
9375	24	0.0047	0.0003	-0.0014	0.0002	3.0	0.68
9377	24	0.0042	0.0003	-0.0017	0.0002	2.6	0.71
11327	24	0.0033	0.0003	-0.0014	0.0002	3.6	0.62
11338	24	0.0044	0.0003	-0.0029	0.0002	5.1	0.65



## 6.2 Mooring Deployments

A new mooring was deployed at the site of each recovered mooring. Details are summarised in Table 6.4 and the schematic Figure 6.1. Diagrams for each of the moorings are shown in Appendix A. Note that the design of mooring M3 was for a water of 2766m but the actual water depth was 210m shallower, and for M5 the water depth was 80m greater than the design depth.

After deployment each mooring was trilaterated from three locations each about 3km horizontal distance from the anchor drop. The hull-mounted transducer was used to obtain the acoustic ranges. The drop keel was lowered when ranging M1 and M2 only as difficulties were encountered when operating the drop keel later on. The Matlab script Anchor5 was used to calculate the position and information about the trilaterations is recorded in files stored on the cruise workstation in the path:

*/home/mstar/osnap/data/moor/raw/dy054/moor\_positions*

*Table 6.4. Mooring deployment table. The recorded duration is from the time the first instrument was deployed until the anchor release (includes towing).*

Mooring	Date	Anchor drop			Corr. Depth (m)	Trilaterated position		Setup dist. (miles)	Fallback (m)	Duration (hh:mm)
		Time	Latitude	Longitude		Latitude	Longitude			
NOCM1	31/07/16	18:44	59°54.26	41°06.48	2086	59°54.18	41°06.71	2.7	271	02:10
NOCM2	31/07/16	14:28	59°51.61	40°41.19	2423	59°51.58	40°41.43	2.1	226	01:50
NOCM3	02/08/16	09:22	59°48.97	40°16.51	2557	59°48.87	40°16.63	2.1	231	01:20
NOCM4	04/08/16	14:01	59°38.89	38°33.94	2985	59°38.76	38°33.99	2.0	251	01:45
NOCM5	05/08/16	13:59	59°34.68	37°47.65	3121	59°34.73	37°47.97	2.2	313	01:50



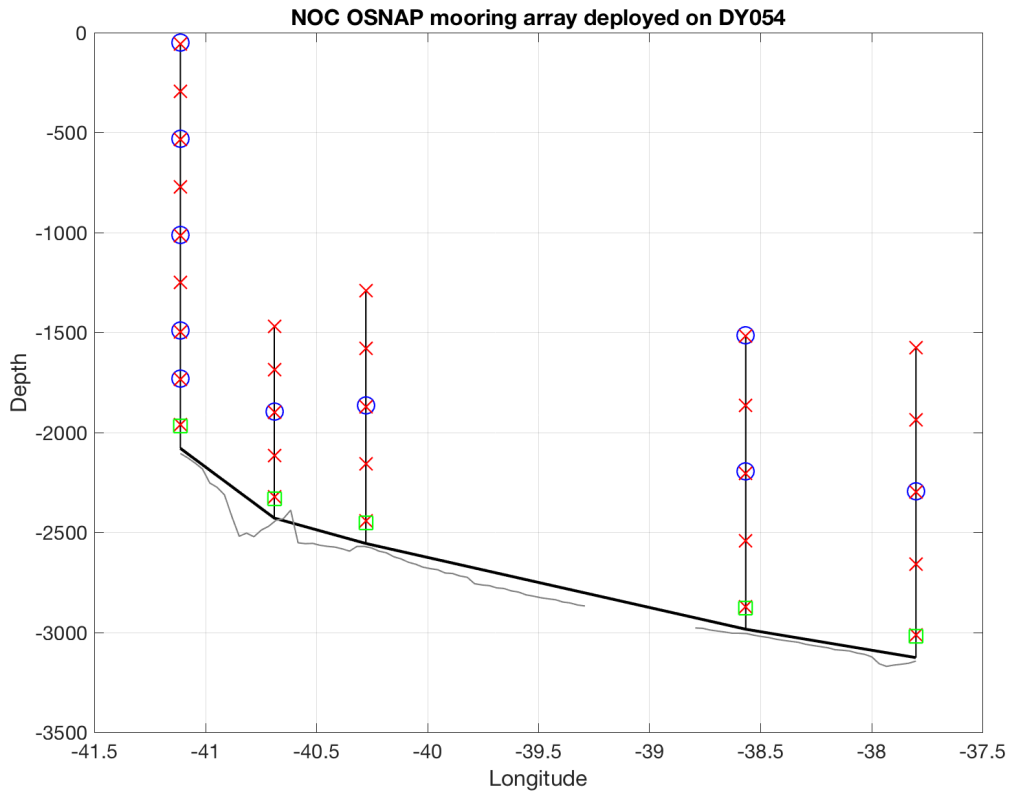


Figure 6.1. Schematic of the deployed array. Microcats are shown by red crosses, Nortek current meters are shown by blue circles, and downward ADCPs are shown by green circles. The light grey line shows bathymetry from the ship's echo sounder note however these depth measurements maybe up to 5km away from the line connecting the mooring positions because the CTD section is slightly to the south of the mooring array.

### Setup details of deployed instruments

Files containing the setup parameters for each instrument have been saved in the path /home/mstar/osnap/Documents/DY054\_setup\_files. The main parameters only are recorded here.

All SBE37 Microcats were setup to record at hourly intervals.

The Nortek current meters were configured to have a measurement interval of 1800s and an average interval of 60s. Using these parameters the expected endurance is 910 days.

ADCPs on M1, M2 and M3 were configured with the following parameters and had a projected endurance of over 900 days.

TE = 01:00:00.00 -----	Time per Ensemble (hrs:min:sec.sec/100)
WF = 0176 -----	Blank After Transmit (cm)
WN = 028 -----	Number of depth cells (1-128)
WP = 00042 -----	Pings per Ensemble (0-16384)
WS = 0400 -----	Depth Cell Size (cm)

After inspection of data from the recovered ADCPs it was decided to increase the bin size to 8m for M4 and M5. However this reduced the projected endurance and so the ensemble time and pings per ensemble were changed as follows.

TE = 01:12:00.00 -----	Time per Ensemble (hrs:min:sec.sec/100)
WF = 0176 -----	Blank After Transmit (cm)
WN = 014 -----	Number of depth cells (1-128)
WP = 00036 -----	Pings per Ensemble (0-16384)
WS = 0800 -----	Depth Cell Size (cm)



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## **7. NIOZ Moorings operations and data**

*Femke de Jong, Yvo Witte, Roald van der Heide*

### **7.1 LOCO 2-12 recovery**

We recovered the 12<sup>th</sup> record of the LOCO mooring. LOCO was deployed by the 64PE400 Pelagia cruise on 19 July 2015.

Two SBE37s (also called microcats) are fitted in the mooring at nominal pressures of 135 and 3063 dbar. Both recorded a full deployment of data. The two microcats were placed on the CTD frame for a caldip on station 014. At max pressure the offsets were <0.1% in pressure, <0.001 °C in temperature and <0.02 in salinity. A more detailed calibration will be done once the calibrated CTD is available.

Two downlooking ADCPs are fitted in the mooring at 115 and 2425 dbar. Both ADCPs recorded a full deployment of velocity data. However, the pressure sensors on the lower ADCPs did not record a pressure record and is likely broken. The instrument depth will be reconstructed from the cable length above the bottom and pressure records of the instruments above.

A McLane Moored Profiler (MMP) was programmed to ride along the mooring cable between 140 and 2420 dbar once a day. Upon recovery it was apparent that the spring that holds the drive wheel on the cable was broken. Inspection of the profiles revealed that the spring broke on the second day of deployment, after completion of the first downward profile. For the remainder of the deployment the instrument and sensors started as programmed, but was unable to move along the cable. It gradually moved from the bottom of its range to its neutral depth of 1100 dbar.

### **7.2 LOCO 2-13 deployment**

LOCO was redeployed on the 2<sup>nd</sup> of August 2016 at 59° 12.18'N, 39° 30.18'W at a corrected depth of 3018m.

Both microcats were fitted with new lithium batteries and were redeployed for two years. The ADCP, usually fitted with alkaline batteries, were refitted with lithium batteries for the extended deployment. The MMP was completely opened and inspected, but there was no obvious cause for the broken spring. It was refitted with a new spring and lithium batteries and programmed to traverse the cable every 2.5 days.

### **7.3 The NIOZ IC moorings**

The IC moorings are located in the Irminger Sea over the western flank of the Mid Atlantic Ridge. They were deployed by the Pelagia 64PE400 cruise on the 14<sup>th</sup> and 15<sup>th</sup> July 2015.

#### ***IC0***

IC0 is a short mooring fitted with two SBE37s and two RCM11s 50 and 650 m above the seafloor (2940 m). The microcats were fitted on the CTD frame for a caldip on station 23. Their offsets were found to be within specs. IC0 was redeployed in the same configuration.

### ***IC1***

IC1 is the tallest IC mooring reaching from the seafloor at 2500 m to 70 m below the surface. It is fitted with an uplooking ADCP to profile the velocities in the upper 400 m as well as five Nortek Aquadopps, five microcats/SBE37 and two thermistors/SBE56.

All IC1 instruments recorded a full deployment of data. The five microcats were fitted on the CTD frame for a caldip on station 028 and again for a deeper caldip on station 033. Two microcats were found to have significant offsets in conductivity that led to an offset in salinity of ~0.2. These microcats were replaced by spares brought along from NIOZ.

The upper SBE37, designed to be at a depth of 70 m, was found to have regularly recorded pressures shallower than 10 dbar. About half of this difference could be explained by a shallower depth of the bottom instrument. The other half may have been due to inaccurate cable lengths. In order to prevent such shallow depths in the new deployment we took out a 35 m section of cable in the redeployed mooring. Two extra thermistors were fitted in IC1 in the redeployment.

### ***IC2***

IC2 reaches from the seafloor at 1980 m to the 70 m below the surface. It is fitted with an upward looking ADCP to profile the velocities in the upper 400 m as well as five RCM11, five microcats/SBE37 and two thermistors/SBE56.

Nearly all IC2 instrument recorded a full deployment of data, one RCM11 had an unexplained data gap of one week after which the instrument started again. The SBE37 were fitted on the CTD frame for a caldip at station 028. One microcat was found to have an offset in conductivity that led to an offset of 0.045 in salinity. This microcats was replaced by a spare in the redeployment.

Similar to IC1, the upper SBE37 in IC2 is designed to be at a depth of 70 m. This microcat was found to have regularly recorded pressures shallower than 8 dbar. In order to prevents such shallow depths in the new deployment a 80 m section of cable was replaced by the 35 m section of cable taken out of IC1. An extra thermistor was fitted in IC2 in the redeployment.

### ***IC3***

IC3 reaches from the seafloor at 1640 m to the 70 m below the surface. It is fitted with an upward looking ADCP to profile the velocities in the upper 400 m as well as three RCM11, four microcats/SBE37 and two thermistors/SBE56.

Nearly all instruments recorded a full year of data, one RCM had a small gap after which the instrument restarted. The microcats were fitted to the CTD frame for a caldip on station 33. One microcat was found to have an offset with the CTD of over 0.8 in salinity. The deployment time series shows various wild excursions on top of the offset. This microcat has been replaced with a spare.

The top of IC3 was at a more acceptable depth of 25 m, however it is still slightly shallow. A section of cable of 15 m was replaced by a section of cable of 2 m for redeployment. The titanium frame which holds the upper CPR buoyancy in which the ADCP is fitted had several broken welds. It was declared to be unfit for redeployment. In lieu of a spare frame we decided to deploy one of the IC moorings without an ADCP. Since IC3 is closer to the current core then IC4 the IC4 ADCP frame and buoy were deployed as part of IC3.

#### **IC4**

IC4 reaches from the seafloor at 1470 m to the 70 m below the surface. It is fitted with an upward looking ADCP to profile the velocities in the upper 400 m as well as three RCM11, four microcats/SBE37 and two thermistors/SBE56.

All instruments in IC4 recorded a full year of data. The microcats were fitted to the CTD frame for a caldip at station 033. Their offsets were found to be within specs.

Since the IC4 buoy/ADCP was redeployed in IC3 three spare RCM11s brought along from NIOZ were fitted in the upper part of IC4. One RCM11 was fitted at the formed ADCP depth, one at approx. 100m depth and one halfway in between. Sections of cable of 80, 50 and 15 m (either taken out of the other IC moorings or brought along as spare) were used to extend the cable. A spare CPR buoy, fitted with titanium center bar instead of a frame, was used as main buoyancy. The Dewey program was used to calculate additional buoyancy needed in the new configuration. It was decided to include five benthos buoys in the top as buoyancy.

*Table 7.1 NIOZ mooring recovery information*

<b>Mooring ID</b>	<b>Latitude</b>	<b>Longitude</b>
LOCO 2-12	59° 12.05' N	39° 30.24' W
IC0-2	59° 12.99' N	35° 07.41' W
IC1-2	59° 06.50' N	33° 41.40' W
IC2-2	59° 01.40' N	32° 43.63' W
IC3-2	58° 57.35' N	31° 57.17' W
IC4-2	58° 53.37' N	31° 17.84' W

*Table 7.2 NIOZ mooring deployment information*

<b>Mooring ID</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Depth</b>	<b>Fallback</b>	<b>Trilaterated</b>
LOCO 2-13	59° 12.18' N	39° 30.18' W	3018 m	245 m	Y
IC0-3	59° 13.02' N	35° 07.51' W	2930 m	-	N
IC1-3	59° 06.26' N	33° 41.20' W	2494 m	493 m	Y
IC2-3	59° 01.29' N	32° 43.56' W	1873 m	231 m	Y
IC3-3	58° 57.40' N	31° 57.08' W	1633 m	290 m	Y
IC4-3	58° 53.38' N	31° 17.90' W	1471 m	230 m	Y

## 8. CTD data processing

*Penny Holliday, Neill Mackay, Ryan Peabody, Feili Li*

### 8.1 Data Processing

The CTD data were collected in the Sea-Bird Seasave version 7.23.2 software, and saved as .hex (data in binary format), .bl (bottle firing record), .XMLCON (configuration file), and .hdr (header information input manually). The data were then processed using Sea-Bird software and the mstar software suite (also known as mexec), developed at NOC.

The first stage of the processing was carried out on the CTD computer using the Seabird software SBEDataProcessing-Win32 Version 7.23.2. The following modules were run:

**DatCnv:** this tool converts the raw frequency and voltage data to engineering units by applying the sensors manufacturer's calibrations stored in the XMLCON, and outputs the data in an ascii format (cast data as a .cnv file, and bottle data as .ros). The oxygen hysteresis correction option was not selected, as this is done later on by mstar.

**Align:** this script shifts selected sensors' data in time, relative to pressure. This is required for sensors with a slower response time, and when extra time is required for the water parcel to reach the sensor (e.g. going through additional lengths of hose). In our setup, only the oxygen SBE43 sensor required this step. The primary and secondary conductivities also require a small shift of 0.073 seconds, but this was done in real-time by the deck-unit. A thorough investigation of the alignment to apply to the oxygen sensor was conducted during the recent cruise DY052. The same CTD package and sensors were used on that cruise and DY053, and the data were collected in an area with very similar oceanographic conditions. After a quick visual check, the DY052 value of +6s was deemed appropriate and applied here.

**CellTM:** this module is run to remove conductivity cell thermal mass effects from the measured conductivity. Sea-Bird recommended constants of  $\alpha=0.03$  and  $1/\beta=7$  were used.

The processed CTD data were then copied on the shared network drive DISCOFS. The script *ctd\_linkscript\_dy054* was used to copy files from the network drive to the mstar computer and set up additional symbolic links to filenames following mstar convention.

For each cast, the first step of the Matlab mstar processing was run using the wrapper script *ctd\_all\_part1*, which called the following scripts:

- **msam\_01:** creation of empty sample files *sam\_dy054\_nnn.nc* for all casts *nnn*. These files were generated from the list of variables indicated in the file *~/cruise/data/templates/sam\_dy054\_varlist.csv*.
- **mctd\_01:** conversion of raw 24Hz cnv data file to netCDF
- **mctd\_02a:** converts variable names from SBE names to mstar names using *data/templates/ctd\_dy054\_renamelist.csv*.
- **mctd\_02b:** applies oxygen hysteresis correction using the default Sea-Bird coefficients [-0.033 5000 1450].
- **mctd\_03:** average to 1Hz and calculation of salinity and potential temperature.
- **msam\_putpos:** adds Techsas position at the start of the cast to the files.
- **mdcs\_01:** creates an empty data cycles file (*dcs\_dy054\_nnn*), used to store the cast start, bottom and end metadata.
- **mdcs\_02:** copies relevant data in dcs file.



The script *mdcs\_03g\_v2* was then run to inspect profiles, hand-select cast start and end times, and input the new values in the dcs file.. The start of the cast was selected when the CTD package was about to start its descent after being brought back to near surface following the initial 10m soak. The end of the cast was chosen as the last point with a pressure value above 0.

Next the wrapper script *ctd\_all\_part2* was run, executing:

- *mctd\_04*,: averages data to 2db bins
- *mfir\_01*, *mfir\_02*, *mfir\_03*, *mfir\_04*: get bottle firing information from the Sea-Bird bl file and extract the matching ctd data based on scan numbers.
- *mbot\_00*, *mbot\_01*, *mbot\_02*: create bottle files (*bot\_dy054\_nnn*); add ctd data, bottle firing codes and quality flag at the time of the bottles firings in the bot and sam files.

1Hz-averaged datafiles are then generated by the script *list\_ctd\_1hz*, for use in the LADCP processing.

The CTD data were visually checked using the script *mctd\_checkplots*. In case of large spikes the individual data points were flagged using *mctd\_rawedit*, the values set to NaN and the scripts *mctd\_02b*, *mctd\_03*, *mctd\_04*, *mfir\_03* and *mfir\_04* rerun for that cast.

Once the processed underway and VMADCP data were available the following scripts were run:

- *mcod\_03new*: extracts VMADCP data during the ctd cast
- *mcod\_stn\_out\_new*: generates VMADCP mat files for the cast
- *mdep\_01*: extracts the bottom depths from the LADCP data and from the ctd (using pressure and altimeter readings), and lets the user choose which one to use. The chosen depth gets copied as 'bestdep', and all bottom depth values are added to the station depth file (*cruise/data/station\_depths/station\_depths\_dy054.mat*). Finally, the chosen depth value is pasted into all the ctd files previously generated.

- *mdcs\_04*, *mdcs\_05*: extract position from the bestnav file (*cruise/data/nav/posmvpos/pos\_dy054\_01.nc*) and paste it into all the ctd files previously generated.

Appending the sbe35 and the discrete sample data to the bot and sam file were done as follows:

- *msal\_01\_dy054*, *msal\_02\_dy054*: read the csv files from analysis of the salinity samples (*data/ctd/BOTTLE\_SAL/sal\_dy054\_nnn.csv*) and paste the data into the sample files.
- *mnut\_01\_dy054*, *mnut\_02\_dy054*: nutrients discrete samples references (ie indications of samples taken, with samples to be analysed ashore) were recorded in csv files for each cast (*cruise/data/ctd/BOTTLE\_NUT/nut\_dy054\_nnn.csv*). The two scripts read the csv file, create the nutrients netCDF file (*nut\_dy054\_nnn.nc*) and paste the nutrients sample reference to the sam file.

The SBE35 temperature data can be logged when a Niskin bottle is fired. Data are stored internally and must be downloaded at the CTD deck unit as a separate process from the CTD data transfer. The SBE35 data are then transferred as an ASCII file per station. On DY054, this file is found in *data/ctd/SBE35/ascii/*. The script *sbe35\_linkscript\_dy054* is run and



creates links to the raw data in the SBE35 directory. The script **msbe35\_01\_dy054** reads the data for a single station. It reads the ASCII file and extracts data cycles for the station based on the start and end times. The script **msbe35\_02** pastes the SBE35 data from one station (in *data/ctd/SBE35/sbe35\_dy054\_nnn.asc*) into the master sample file (*data/ctd/sam\_pe399\_nnn.nc*).

- **msam\_append\_dy054** OR **msam\_updateall**: if the cast sam file has not been added to the global sam file (*sam\_dy054\_all.nc*) then add it by running **msam\_append\_dy054**. In case of a reprocessing use **msam\_updateall** so that the cast is not duplicated into the global sam file.

## 8.2 CTD Calibration

We used the script *ctd\_evaluate\_temp\_dy054* to compare the SBE35 temperature measurements taken each time a bottle is fired with the coincident measurements by the CTD temperature sensors. The CTD and the SBE35 were found to be in acceptable agreement. The median SBE35 minus CTD value suggested that the SBE35 readings are generally slightly warmer than the primary CTD sensor, by  $1.0417 \times 10^{-3} \text{ }^{\circ}\text{C}$  and cooler than the secondary CTD sensor, by  $0.9509 \times 10^{-3} \text{ }^{\circ}\text{C}$ . This may be attributed to the accuracy of each sensors ( $0.002 \text{ }^{\circ}\text{C}$  for the SBE3,  $0.0005 \text{ }^{\circ}\text{C}$  for the SBE35) and the fact the thermometers are not mounted tip-to-tip (not possible).

In the case of the conductivity calibration, the conductivity observation for each bottle was subtracted from the conductivities measured by the primary and secondary conductivity sensors. The residuals were plotted versus station number and pressure to check for any possible temporal drifts or pressure effects on the conductivity calibration. This was done using the script *ctd\_evaluate\_sensors\_dy054*.

Neither a time nor pressure dependence was detected in the DY054 residuals. However, there was a small and constant offset between the conductivity in both sets of CTD sensors and the bottle data. After removing all CTD minus bottle residuals that fell outside of a  $\pm 2$  standard deviation envelope around the mean residual, the mean residuals were recomputed as  $0.0057 \text{ mS/cm}$  and  $-0.0017 \text{ mS/cm}$  for the primary and secondary sensors, respectively. A similar average residual was derived for only data below 1000 m resulting in offsets of  $0.0053$  and  $-0.0017$ , which are not substantially different from the offsets computed from all data.

Since there was no pressure or temporal variation in the conductivity residuals, the conductivity calibration for both  $C_1$  and  $C_2$  was decided to be simply a constant offset using the offsets derived from all residuals (shallow and deep). This offset was applied to the data with the wrapper script **mctd\_condcal**, which, in turn, calls **cond\_apply\_cal**, a script designed to hold the exact parameters of the conductivity calibration. The calibration was applied to the 24 Hz data for each station which then had to be reprocessed with **mctd\_03**, **mctd\_04**, **mfir\_03**, and **mfir\_04** (using *smallscript\_dy054.m*).

After calibration the mean  $\pm$  stdev salinity residuals for primary and secondary sensors were  $0.000 \pm 0.002$  and  $0.000 \pm 0.002$  respectively (excluding outliers).

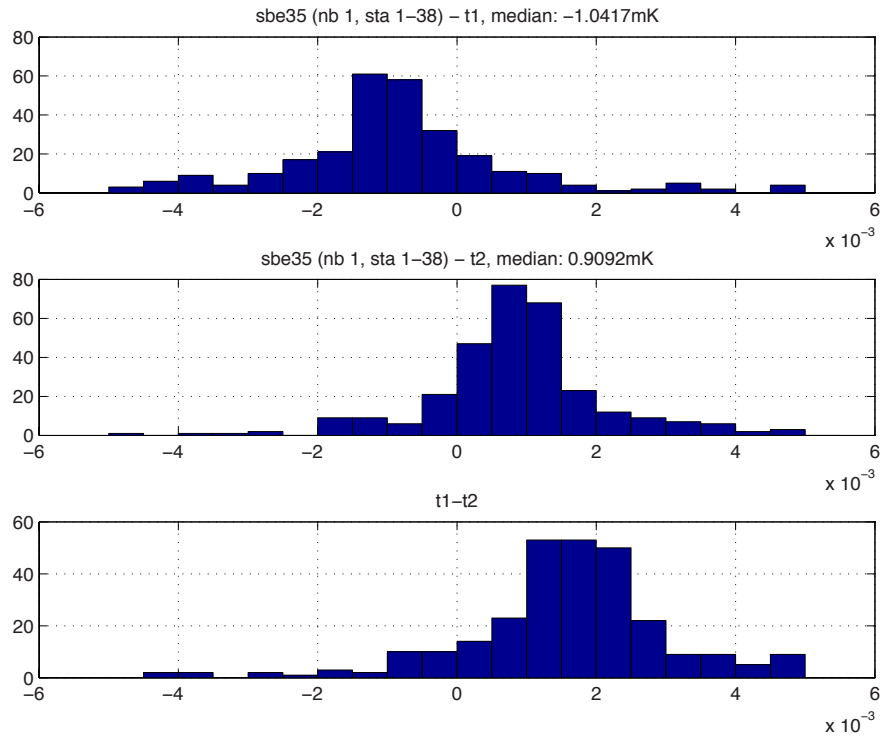


Figure 8.1 Distribution of temperature difference between SBE35 and CTD temperature sensors. Top panel: SBE35 minus temp1. Mid panel: SBE35 minus temp2. Bottom panel: temp1 minus temp2.

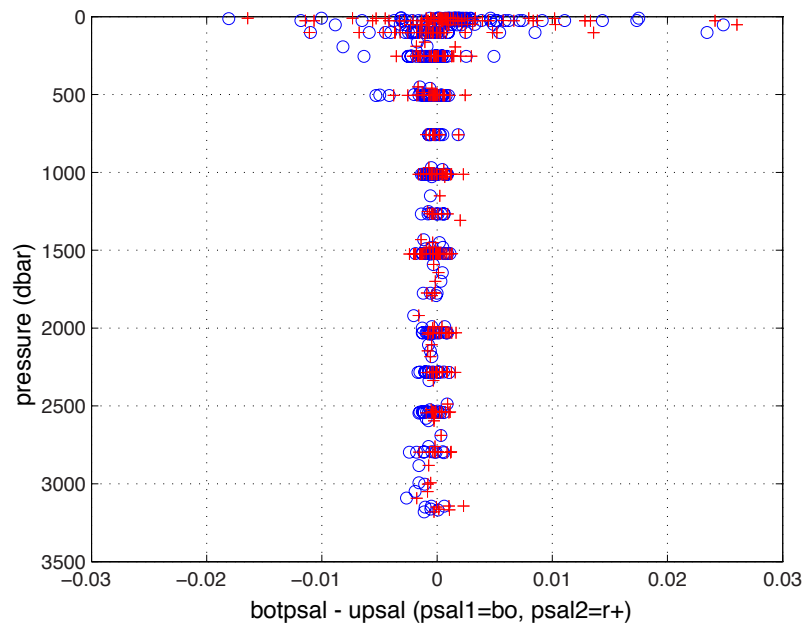


Figure 8.2 Salinity residuals for all stations after conductivity calibration. Primary sensor pair in blue, secondary sensor pair in red.

## 9. VM-ADCP setup and processing

*Anna Simpson, Penny Holliday*

There are two VMADCPs; the 150 kHz and the 75 kHz. There are many acoustic instruments on the ship, such as the EM122 Deep Water Multibeam Echosounder, EM710 Shallow Water Multibeam Echosounder (not used on DY054), SBP120 Sub-bottom Profiler (not used on DY054), EA640 Single Beam Echosounder, EK60 Multi-frequency Echosounder ('fish-finder', not used on DY054) and the Kongsberg SU16 Synchronisation Unit (K-Sync). The VMADCP's were triggered and running as normal with K-Sync.

The ADCPs usually receive position information from the posmv navigation file; early in DY054 they were switched to receive position data from seapos file. They receive heading data from the iXBlue PhINS system (not recorded in a Techsas file, see section 7, ships systems report) which was unaffected by the problems with posmv.

The ADCPs were run with the same configuration files DY053. See the Ships System report (section 7) for details of the water track and bottom track settings. Both the 150kHz and the 75kHz ADCPs worked well throughout DY054.

The data processing followed the usual steps:

### ***Stage A. Initial Processing***

i) Copy data from the ship server:

```
cd data
cd vmadcp
cd v150
```

Remove the directory and data with the largest sequential number. You need to do this because the linkscript also copies data that is still being collected, creating a new incomplete rawdataNNN directory, and if a directory is already present it does not get updated with new data. *To copy the most up to date data (once the logging has been restarted) it is necessary to remove the directory with the largest sequential number before running 'vmadcp\_linkscript'.*

eg for file 001:

```
> /bin/rm -r rawdata001
```

On DY054, the raw data were held in:

```
~cruise/data/vmadcp/raw_OS150
```

Now copy the new data files:

```
vmadcp_linkscript150_dy054.sh
```

*This redistributes raw data from rawdata to rawdataNNN; rawdataNNN is automatically created if necessary (may need to edit movescript so that it parses the file names correctly).*

Now do the same for the os75:

```
cd data
cd v75
```

Delete unwanted files:

```
> /bin/rm -r rawdata001
```

Now copy the new data files:

```
vmadcp_linkscript75_dy054.sh
```

The following steps are repeated for each v150 and v75 data file.

ii) Create a new directory containing all the output files:

```
cd v150 (or v75)
```

```
adcptree.py dy054NNNnbenx --datatype enx
```

iii) Copy calibration files into the directory for each data file (there is a template file called q\_py.cnt in data/v150 and data/v75):

```
cd dy054NNNnbenx
```

```
cp ../q_py.cnt .
```

Generally, only the dbname and datadir for each NNN need to be updated.

For information, an example q\_py.cnt file is

```
# q_py.cnt is
## comments follow hash marks; this is a comment line
--yearbase 2016
--dbname dy054001nnx
--datadir /local/users/pstar/cruise/data/vmadcp/v75/rawdata001
#--datafile_glob "*.LTA"
--datafile_glob *.ENX
--instname os75
--instclass os
--datatype enx
--auto
--rotate_angle 0.0
--pingtype nb
--ducer_depth 5
#--verbose
# end of q_py.cnt
# end of q_py.cnt
```

At the start of the cruise check yearbase, dbname, os75 or os150 and datatype enx (glob ENX). dbname should be of form dy031NNNPTT where P is n for narrowband, b for broadband. The instrument should be operated in narrow unless there is a good reason to choose broad. TT is “nx” for ENX; “ns” for ENS; “nr” for ENR; “lt” for LTA; “st” for STA. Standard processing is to process ENX. As far as I can tell, dbname must not exceed 11 chars. So if we use 9 for dy054NNNn, there are only two left to identify ENX, ENS, LTA, STA.

Without calibration information the angle can be left as zero. The transducer depth was set as 7m.

iv). Process in CODAS (with no calibration)

**quick\_adcp.py --cntfile q\_py.cnt**

v) To access data in Matlab type in the command line:

```
>> m_setup
>> codaspaths
>> cd edit
>> gautoedit
```

This allows you to view the data and do a quick check for quality. Note that the JDAY on the plots is our DOY minus 1. Alter the time step and tick the list of variables to plot on the figures (including using depth as x axis), then "show now" in order to get plots up on the screen.

**Gautoedit** does allow you to clean up data as follows. We didnt do this on DY054, but here we retain the information from JC086 in these notes.

Select day and step to view, then "show now". "show now" may have to be done twice to get the surface velocity plot. "show next" to step through the file. "Del bad times" sets "bad" flags for a section of time, or for a whole profile. "rzap" allows single bins to be flagged. Note that "list to disk" must be clicked each time for the flags to be saved.

To end gautoedit tidily:

```
>> close all
```

Applying edits identified in gautoedit:

The gautoedit process in Matlab sets flags, but does not change the data.

To apply the flags and recalculate a calibration:

**quick\_adcp.py --cntfile q\_pyedit.cnt**

*Note two dashes before cntfile.*

Where q\_pyedit.cnt contains

```
# q_pyedit.cnt is
## comments follow hash marks; this is a comment line
```

```
--yearbase 2016
--steps2rerun apply_edit:navsteps:calib:matfiles
--instname os75
--auto
```

```
# end of q_pyrot.cnt
```

## Stage B. Finding the ADCP misalignment angle (the calibration).

### i). Finding the calibration information

This can come from BT (bottom track) or WT (water track) files - the latter from sharp turns in the ship's track, especially coming on or off station.

Any calibration information produced can be found in the "cal" directories of the processing directories (eg jc086001nbenx/cal/\*/\*out). Note that a calibration is not always achieved, for example if the ship has made no manoeuvres while the ADCP is in water tracking mode, so there may be no \*out file). Note also that additional calibration information maybe saved after flags applied after gautoedit process.

On DY054 we had the following calibration information:

*Table 9.1 Calibrations obtained from water-tracking for v150. Means derived from files more than a few hours in length (excluding those marked \*)*

	Start Time		Amp			Phase		
			Median	Mean	std	Median	Mean	std
000	27/07/16	0845	1.0070	1.0090	0.0072	0.1410	0.0333	0.5052
002	27/07/16	1902	0.9935	0.9935	0.0092	-1.2120	-1.2120	1.1766
003	28/07/16	0751	0.9955	0.9955	0.0177	0.5150	0.5150	0.8712
004	29/07/16	0814	none					
005	30/07/16	0051	0.9950	0.9953	0.0021	1.0895	0.6430	1.5747
006	30/07/16	0840	0.9950	0.9953	0.0072	0.1010	-0.0545	0.9809
007	31/07/16	0734	1.0020	1.0015	0.0093	0.4810	0.6671	1.0410
008	01/08/16	0748	0.9980	1.0020	0.0128	-0.3220	-0.6207	1.0924
009	02/08/16	0705	0.9950	0.9950	0.0113	0.1540	0.1540	0.1598
010	03/08/16	0918	0.9970	0.9990	0.0073	0.1450	0.0892	0.3612
011	04/08/16	0743	1.0020	1.0023	0.0098	0.2260	0.1003	0.2775
012	05/08/16	0709	1.0125	1.0153	0.0158	-0.4790	0.0470	1.0180
013	06/08/16	0711	1.0000	0.9996	0.0077	0.2385	0.1598	0.5259
014	07/08/16	1109	0.9950	0.9972	0.0180	0.1675	0.1503	0.8300
015	08/08/16	0736	0.9990	0.9970	0.0085	0.8845	0.5940	1.0669
<b>Mean</b>			<b>0.9990</b>	<b>0.9998</b>	<b>0.0103</b>	<b>0.0151</b>	<b>0.4574</b>	<b>0.7483</b>

*Table 9.2 Calibrations obtained from bottom-tracking for v150.*

	Start Time		Amp			Phase		
			Median	Mean	std	Median	Mean	std
000	27/07/16	0845	0.9958	0.9962	0.0018	0.1156	0.1175	0.1337
005	30/07/16	0051	0.9950	0.9953	0.0015	0.1617	0.1768	0.1079
<b>Mean</b>			<b>0.9954</b>	<b>0.9958</b>	<b>0.0017</b>	<b>0.1387</b>	<b>0.1472</b>	<b>0.1208</b>

*Table 9.3 Calibrations obtained from water-tracking for v75. Means derived from files more than a few hours in length (excluding those marked \*)*

	Time Range		Amp			Phase		
			Median	Mean	std	Median	Mean	std
000	27/07/16	0845	1.0340	1.0330	0.0075	0.5590	0.3683	0.4906
002	28/07/16	0751	1.0175	1.0175	0.0163	1.0060	1.0060	0.8683
003	29/07/16	0814	none					
004	30/07/16	0051	1.0230	1.0237	0.0031	1.4415	1.0777	1.6351
005	30/07/16	0840	1.0240	1.0228	0.0064	0.3775	0.5115	0.4409
006	31/07/16	0734	1.0160	1.0153	0.0150	0.8210	0.9526	0.6611
007	01/08/16	0748	1.0060	1.0087	0.0064	0.8070	0.2860	1.0404
008	02/08/16	0705	1.0140	1.0140	0.0042	0.7735	0.7735	0.1195
009	03/08/16	0918	1.0190	1.0238	0.0070	0.5340	0.3970	0.5172
010	04/08/16	0743	1.0670	1.0504	0.0284	0.6520	0.3767	0.7578
011	05/08/16	0709	1.0300	1.0367	0.0227	-0.2580	-0.0770	0.3885
012	06/08/16	0711	1.0160	1.0195	0.0180	0.2515	0.3915	0.5582
013	07/08/16	0932	1.0180	1.0174	0.0177	0.2880	0.5199	0.5245
014	08/08/16	0736	1.0160	1.0216	0.0194	0.3800	0.4738	0.8673
<b>Mean</b>			<b>1.0231</b>	<b>1.0234</b>	<b>0.0132</b>	<b>0.5812</b>	<b>0.5787</b>	<b>0.7067</b>

*Table 9.4 Calibrations obtained from bottom-tracking for v75.*

	Time Range		Amp			Phase		
			Median	Mean	std	Median	Mean	std
000	27/07/16	0845	1.0131	1.0133	0.0027	0.6413	0.6472	0.1712
004	30/07/16	0051	1.0145	1.0148	0.0025	0.6877	0.6904	0.1462
<b>Mean</b>			<b>1.0138</b>	<b>1.0141</b>	<b>0.0026</b>	<b>0.6645</b>	<b>0.6688</b>	<b>0.1587</b>

*Table 9.5. Start Time for subsequent data files*

#### **v150**

016 09/08/16 1205  
 017 11/08/16 0730  
 018 12/08/16 0740  
 019 13/08/16 0725  
 020 14/08/16 0654 end: 15/08/16

#### **v75**

015 09/08/16 1205  
 016 11/08/16 0730  
 017 12/08/16 0741  
 018 13/08/16 0725  
 019 14/08/16 0029 end: 15/08/16

ii). Select the most reasonable looking values of the amplitude and phase.

"Reasonable" might mean the values from a large file, or from BT rather than WT, or an average of all the median values produced. You can take into account values from previous cruises on the same ship, as long as the ADCP has not been refitted since then. On DY054 we chose to use the mean the BT median values which is consistent with the method from recent cruises. It is also useful to note that the BT median shows a very similar value to the BT mean.

Put them into edit control files ("q\_pyrot.cnt"), one for each v150 and v75, and if required, different values for file groups that have different EA values in the command files.

An example `q_pyrot.cnt` contains:

```
# q_pyrot.cnt is
## comments follow hash marks; this is a comment line
--yearbase 2016
--rotate_angle 0.2245
--rotate_amp 0.9984
--steps2rerun rotate:navsteps:calib
--auto
# end of q_pyrot.cnt
```

iii). Apply the calibration (repeat for both ADCPs and for each data file)

Still in directory `/dy054NNNNbenx`, apply the final calibration ONLY ONCE (adjustments are cumulative, so if this step is done twice, the cal is applied twice) when you have done the edits.

**quick\_adcp.py --cntfile q\_pyrot.cnt**

*Note two dashes before cntfile..*

### **Stage C. Get the data into MSTAR:**

i). Still in directory `/dy054NNNNbenx` open Matlab window and type into command line:

**>> mcod\_01**

*Produces output file `os75_jr265NNNNnx.nc`, which has a collection of variables of dimensions  $N \times 1 \times M \times M$*

**>> mcod\_02**

*Will calculate water speed and ship speed and get all the variables onto an  $N \times M$  grid.*

ii). Append individual files using:

**>> mcod\_mapend**

This script will append individual files to create a single cruise file ("`os150_dy054_01.nc`"). It does seem to depend on the files having the same bin number and bin depths.

If this is done periodically, the new `.nc` file needs to be manually added to the '`nc_files`' text file, which contains a list of all the processed ones.

iii). Create `.mat` files for time spent on CTD stations:

**>> mcod\_03** (answer 'ctd' then 'nnn' then '75' or '150')

**>> mcod\_stn\_out('ctd',nnn,75)**

*Where nnn is the CTD cast number. This will generate the `.mat` files in:*

*~/data/vmadcp/dy054\_os75*

iv). A final step is to make the data available for LADCP processing.

Create symbolic links to the `.mat` files in `/ladcp/ix/data/SADCP` with the format '`os75_dy054_ctd_nnn.mat`'.

These final steps make data available for comparison with LADCP data (the `.mat` files are automatically picked up by the '`process_cast`' script).



## 10. Lowered ADCP processing

*Anna Simpson, Penny Holliday*

### 10.1 Introduction and Data Processing

Data from the LADCP instruments was processed as soon as possible between stations to allow early detection of any problems. Data quality was checked in WinADCP by the NMF CTD operators, Jeff and Dave, immediately after download from the LADCPs. They copied the data files and the predeployment log txt files from the LADCP PC onto the Public server. The instruments performed well and there were no problems.

Processing was via the Lamont-Doherty IX path, as follows. Bold text denotes commands to enter at the X-window/terminal prompt. '>>' preceding bold text indicates commands to be entered in the Matlab window. Notes are in italics.

The LADCP data can be processed with different parameter scenarios (LADCP-only, with CTD, with CTD+VMADCP) and this is described in "set\_cast\_params.m".

To change the parameters used, we replace set\_cast\_params.m with one of the following:

set_cast_params_v40.m	for LADCP only
set_cast_params_v41.m	for LADCP and CTD
set_cast_params_v30.m	for LADCP, CTD and VMADCP(75kHz)

These files have cruise id and filenames hardwired into them so at the start of the cruise we must edit them with our details. On DY054 our preferred parameter file was set\_cast\_params\_v41.m

a) Move to the appropriate location on the Unix system. The linkscript creates a new directory for that cast and creates a symbolic link with the filename structure that the processing expects.

**cd data**

**cd ladcp/raw**

**rsync -av /mnt/discofs/Sensors\_and\_Moorings/LADCP/\* .**

**lad\_linkscript\_ix\_dy054** (gets data files into the right directory with the right filenames)

If the CTD data have been processed, run the following step to gain access to the CTD 1hz ascii data

**cd ladcp/ix/data/raw**

**ladctd\_linkscript\_ix**

b) Open Matlab window, move to the processing directory, setup paths, and process the cast:

**>> m\_setup**

**>> mcd ladcp**

**>> cd ix/data**

**>> ixpath**

**>> process\_cast(nnn)**

*The Matlab processing script produces and automatically saves .ps image files. These can be viewed by typing:*

```
cd data  
cd ladcp/ix/data/ULDL_BT/processed  
display filename
```

The processing steps described above can be performed before the CTD casts have been processed as far as 1hz files, to check the LADCP performance.

Once the CTD casts have been processed as 1hz files, the ‘process\_cast’ script can be run again and the CTD files will automatically be read in. Check that the corresponding CTD links are in place by typing:

```
cd data  
cd ladcp/ix/data/CTD  
ls -ltr
```

Each cast should have a corresponding link in the format ‘ctd\_dy054\_nnn\_1hz\_txt’.

We did not save the processed files without the CTD data, so all data and ps files are found in **ladcp/ix/data/ULDL\_BT/processed**

c) The ‘process\_cast’ script can also be re-run after the vessel-mounted ADCP data has been processed, and these are added to the cast. Check that the corresponding .mat files have been generated in **/ladcp/ix/data/SADCP** in the format ‘os75\_dy054\_ctd\_nnn.mat’.

## **10.2 LADCP preliminary quality checks**

Some of the figures generated by the processing script are particularly useful to provide early indication of poor quality data, possible faults, and incorrect transfer of the raw data.

Figure 1 : Make sure that the bottom track velocities (bottom part of the plot on the left hand side) match those of the water track (plot on the left hand side). Also check if time and depth of the cast indicated in Figure 1 match with the corresponding logged data.

Figure 2: Check the performance of the four beams from the bottom-left plot. This figure also indicates the CTD heading direction. This can represent valuable information for the CTD operator, in case it is spinning excessively.

Figure 4: Compare profiles from down and up casts and check if they are both complete. If not, this could indicate a fault. This figure also indicates the depths of the cast, which can be checked against logged information.

Figure 11: This figure provides a list of processing errors and warnings.

## 11. Underway processing

*Sotiria Georgiou, Penny Holliday*

The underway observations include data-streams from navigation, echo sounding bathymetry, meteorological observations, and sea surface observations.

Much of the processing has followed the steps used during last year's Extended Ellett Line cruise (DY031) with some changes to account for changes in data-streams. Extracts of these notes are based on cruise DY031.

### 11.1 Daily Processing (Stage A)

The daily processing for DY054 involved the following steps:

i) The techsas link script was run to create a directory of symbolic links to the netCDF files in the TechSAS stream.

**~/mstar/dy054/data/exec/techsas\_linkscript\_dy054.sh**

ii) To confirm that the linking script properly updated the available data-streams to process a full day, in Matlab run

**>> mtlookd**

223838	16/07/26	208 21:10:12	to	211 13:24:10	16/07/29	CLAM-CLAM_DY1.CLAM
142443	16/07/27	209 08:34:13	to	211 13:24:10	16/07/29	EA600-EA640_DY1.EA600
228670	16/07/26	208 21:10:10	to	211 13:24:14	16/07/29	Light-DY-SM_DY1.SURFMETv2
228672	16/07/26	208 21:10:10	to	211 13:24:16	16/07/29	MET-DY-SM_DY1.SURFMETv2
222221	16/07/26	208 21:10:10	to	211 13:24:18	16/07/29	SBE45-SBE45_DY1.TSG
228676	16/07/26	208 21:10:10	to	211 13:24:20	16/07/29	Surf-DY-SM_DY1.SURFMETv2
230428	16/07/26	208 21:10:11	to	211 13:24:23	16/07/29	cnav-CNAV.GPS
149241	16/07/27	209 06:33:16	to	211 13:24:25	16/07/29	gyro-GYRO1_DY1.gyr
1152872	16/07/26	208 21:10:10	to	211 13:24:27	16/07/29	gyro-SGYRO_DY1.gyr
589748	16/07/26	208 21:10:10	to	211 13:24:29	16/07/29	logskippervdvw-SkipLog.winch
153380	16/07/27	209 06:33:02	to	211 13:24:31	16/07/29	position-Applanix_GPS_DY1.gps
230437	16/07/26	208 21:10:10	to	211 13:24:33	16/07/29	position-Seapath330_DY1.gps
153384	16/07/27	209 06:33:02	to	211 13:24:35	16/07/29	satelliteinfo-Applanix_GPS_DY1.gps
230442	16/07/26	208 21:10:11	to	211 13:24:37	16/07/29	satelliteinfo-CNAV.gps
230443	16/07/26	208 21:10:10	to	211 13:24:39	16/07/29	satelliteinfo-Seapath330_DY1.gps
57783	16/07/27	209 08:34:39	to	211 13:24:39	16/07/29	sb_depth-EM120_DY1.depth
153503	16/07/27	209 06:31:14	to	211 13:24:43	16/07/29	shipattitude-Applanix_TSS_DY1.att
153505	16/07/27	209 06:31:14	to	211 13:24:45	16/07/29	shipattitude_aux-Applanix_TSS_DY1.att
476	16/07/27	209 13:28:56	to	211 13:21:53	16/07/29	wamos-WaMoS.wamos

iii) To extract the appropriate 24 hours of data from each stream run

**m\_dy054\_daily\_processing(nnn)** where nnn is the Julian Day (DY054 start 209). This script calls the routine **mday\_00\_get\_all** and **mday\_00** for each data-stream, skipping any streams not present for the current cruise. The output will be a series of daily files with the raw data from each stream (e.g., attposmv\_dy054\_d157\_raw.nc) which will be stored in the following directories within /home/mstar/dy054/data/

/em120  
/log\_skip  
/met/\*  
/nav/\*  
/sim  
/tsg

The daily processing script does some further processing of specific streams:

**mgyr\_01** is used to remove any data cycles with non-monotonic times from the ship gyro data-stream (nav/gyros)

**msim\_01** is used to run a median clean and 5-minute averaging of the EA640 echo sounder data and the EM122 (mem120\_01).

**msim\_plot** is used to interactively remove spikes from the echo sounder derived depths. Additional files were saved to log which data were rejected.

**mmet\_01** is used to correct the units of wind speed stored in the netCDF header. Although the header originally reported the speed in knots, comparison against the on-board live streams showed that the units were in fact m/s.

The script runs **mday\_02\_run\_all** to append the daily file onto the cruise master file for each stream (e.g., nav/gyros/gyp\_dy054\_01.nc).

Further details on individual streams is given below.

#### Navigation (nav)

As part of the routine daily processing six navigation streams were extracted from TechSAS (attposmv, cnav, gyropmv, gyros, posmvpos, seapos). Note that there is duplicated information among some of the streams. On *Discovery*, the master position source is usually posmv. However on DY054 posmv frequently failed and contained bad data, so for this cruise our master navigation file is seapos (*seapos\_dy054\_01.nc*).

Seapos position information was streamed directly into the CTD and VMADCP units (replacing the posmv data).

There was no editing of positional information, except for the removal of any non-monotonic times with the routine **mgyr\_01**

Finally the "mbest" scripts were edited to generate a master bestnav file from the seapos position information (**mbest\_01\_seapos, mbest\_02\_seapos, mbest\_03\_seapos, mbest\_04\_seapos**). These generate a complete file containing position, heading, course and speed made good, and distance run. The data are reduced to a 30-second time base and heading is properly vector averaged. This is the definitive cruise navigation file. In order to avoid the problem of housekeeping variables like distrun across daily files, the bestnav processing is rerun from the start of the cruise each time it is required. There is therefore only ever one master file.

#### Bathymetry

The EA640 data were read into mexec directory 'data/sim', and the EM122 data into the mexec directory 'data/em120'. The data were routinely processed within the script **m\_dy054\_daily\_processing.m**. Daily files of raw data and smoothed data were preserved.

The key stages are:

**msim\_01** and **mem120\_01** to read raw data for given day number and discard data outside the depth range 20m to 10000m, then take the median depth in 300 second bins to discard noise.

Input: data/sim/**sim\_dy054\_dnnn\_raw.nc**

Output: data/sim/**sim\_dy054\_dnnn\_smooth.nc**

Output: data/sim/**sim\_dy054\_dnnn\_edited.nc**

The **\_edited.nc** file is an exact copy of the **\_smooth.nc** file, for later use in **msimplot.m**.

**msim\_02** cross-merges bathymetric data streams, bringing em120 data into the **sim\*.nc** file.

Input: data/sim/**sim\_dy054\_dnnn\_edited.nc**

Input: data/em120/**em120\_dy054\_dnnn\_edited.nc**

Output: data/sim/**sim\_dy054\_dnnn\_edited.nc**

**msim\_plot** for graphical editing of the data for spike removal. This allows editing of both (sim and em120) data streams since they've already been merged.

Input: data/sim/**sim\_dy054\_dnnn\_edited.nc**

Output: data/sim/**sim\_dy054\_dnnn\_edited.nc** – selected values are changed to NaN

Output: data/sim/**mplxied\_<time>\_sim\_dy054\_dnnn** – records of which values were selected by the user.

Note: it is not necessary to run **mem120\_plot.m** since **msim\_02** cross-merged the data.

**mday\_02** to append edited daily files are appended into a single file:

Input: data/sim/**sim\_dy054\_dnnn\_edited.nc**

Output: data/sim/**sim\_dy054\_01.nc** (with em120 as **swath\_depth**)

### Surface Atmosphere and Ocean Observations (met)

The 'met' streams are divided into three TechSAS streams: met/surfmet, met/surflight, and met/surftsg. The SeaBird SBE45 thermosalinograph data is logged in separate data stream (in the directory cruise/data/tsg or mexec abbreviation M\_TSG).

### SurfMet

Ship speed, position and heading from the seapos navigation file were merged onto the wind data in the surfmet stream.

The absolute wind speed is calculated and vector averaged with **mtruew\_01\_dy054.m**. As with bestnav processing, this is rerun for the entire cruise each time the data are updated. The output files from this processing are

data/met/surfmet/met\_dy054\_true.nc

data/met/surfmet/met\_dy054\_trueav.nc

The latter file is reduced to 1-minute averages, with correct vector averaging when required. In order to avoid ambiguity, variable units are explicit in whether wind directions are

‘towards’ or ‘from’ the direction in question.

As stated earlier, **mmet\_01** is used to correct the units of wind speed stored in the netCDF header. Although the header originally reported the speed in knots, comparison against the on-board live streams showed that the units were in fact m/s.

#### - SurfLight

PA irradiance and thermal-IR data are found in the surflight stream, which also contains surface pressure. These streams were ingested and stored, but no further processing was undertaken.

#### - SurfTSG

The daily processing creates two sets of raw files and two concatenated cruise master files related to the underway thermosalinograph (TSG) stream:

data/met/surftsg/met\_tsg\_dy054\_d???.nc  
extracted from TechSAS data stream Surf-DYS-SM\_DY1.SURFMETv2  
including variables time, temp\_h, temp\_m, cond, fluo, trans

data/tsg/tsg\_dy054\_d???.nc  
extracted from TechSAS data stream SBE45-SBE45\_DY1.TSG  
including variables time, temp\_h, temp\_r, cond, sndspeed, salin

The surftsg stream does not log the actual temperatures (temp\_h and temp\_m) or conductivity (cond). These data streams are logged as constant values

#### Thermosalinograph (TSG, SurfTSG)

The TSG stream contains the logged temperatures, conductivity, and derived salinity from the TSG. The salinity values were recalculated from the housing temperature and conductivity (using **mtsg\_make\_sal.m**) to confirm that the salinity values stored in the files was reliable and the conductivity units (S/m) as reported in the netCDF attributes.

#### Data gaps due to network problems

The surfmet and tsg Techsas data streams suffered many repeated interruptions whenever the ship's network failed. This has led to many short periods of absent data.

### **11.2 Calibration of TSG salinity (Stage B)**

Calibration of TSG salinity used the following steps:

i) Edit **mtsg\_cleanup.m** to hardcode the times when the pumps were switched off, such as the start and end of the cruise, and any periods of maintenance. This routine will be run later as part of **mtsg\_medav\_clean\_sal.m**.

ii) Run **mcd('M\_TSG')** to move to the TSG directory within MatLab.

iii) Run **mtsg\_findbad\_dy054.m** to interactively remove spikes and bad data from the temp\_h, cond and salin variables. The commands to select periods to be marked as bad are explained on running the routine. Note the use of 'n' to store the start and end of the bad data and move on to the next segment. The output file with bad times is appended every time this routine is run, so can be done throughout the cruise.

Input: data/tsg/tsg\_dy054\_01.nc

Output: data/tsg/bad\_time\_limits.mat

iv) Run **mtsg\_medav\_clean\_cal\_dy054.m** to create 1-minute median-binned data and remove known bad data identified in the previous step (the times stored in bad\_time\_limits.mat).

Input: data/tsg/tsg\_dy054\_01.nc

Output: data/tsg/tsg\_dy054\_01\_medav\_clean.nc

v) Check for updates to the TSG salinity bottle samples, in data/ctd/BOTTLE\_SAL/. When new crates have been processed run **cruise/data/exec/modsal\_unix\_dy054** (in a terminal) to convert the csv file from a Mac format to a unix compatible format (this just adds end-line characters), unless the csv file was created on linux. You may first need to create the CSV file from the AutoSal-produced spreadsheet using Excel or LibreCalc.

Also, to this file, add a sample number for each underway salinity sample using the format DDDHHMMSS (recorded in the underway logsheets) for TSG samples, and sample number 99#### for standards, where #### is the bottle number.

Input: data/ctd/BOTTLE\_SAL/tsg\_dy054\_nnn.csv

Output: data/ctd/BOTTLE\_SAL/tsg\_dy054\_nnn.csv\_linux

vi) Run **mtsg\_01\_dy054.m** to convert TSG salinity bottle samples from ASCII to netCDF. First the routine had to be updated with a cruise specific bath temperature. For DY054, the same settings were used as had been agreed for the CTD salt sample processing. This step can be run as each TSG crate has been processed.

Input: data/ctd/BOTTLE\_SAL/tsg\_dy054\_nnn.csv\_linux

Output: data/ctd/tsg\_dy054\_nnn.nc

Output: data/ctd/tsg\_dy054\_all.nc

vii) Run **mtsg\_bottle\_compare\_dy054.m** to merge the clean 1-minute data onto bottle samples. This should first be run with the switch at the top of the script set to uncalibrated. Individual bottle residuals are plotted, as well as a smoothed time series of the residuals, (see Fig. 13.2) which can then be used as a slowly-varying adjustment to the TSG salinity in the next step.

Input: data/ctd/tsg\_dy054\_01\_medav\_clean\_cal.nc

Output: data/tsg/tsg\_dy054\_01\_medav\_clean\_cal\_botcompare.nc

viii) Run **mtsg\_apply\_salcal\_dy054.m** to smooth the differences in botcompare, interpolates and adds them to the uncalibrated salinity data. You can run mtsg\_bottle\_compare\_dy054.m after this to check the residuals are acceptable.

calls **mtsg\_salcal\_dy054.m**

Input: data/met/surf\_tsg/met\_tsg\_dy054\_01\_medav\_clean.nc

Input: data/met/surftsg/met\_tsg\_dy054\_01\_medav\_clean\_botcompare.nc

Output: data/met/surftsg/met\_tsg\_dy054\_medav\_clean\_cal.nc

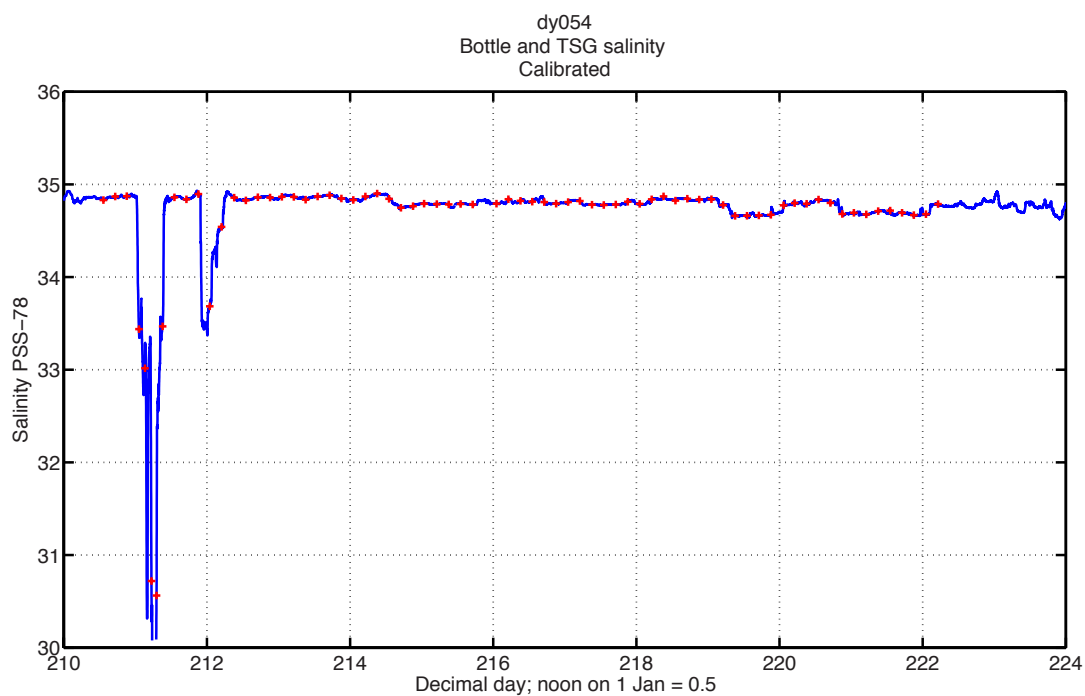
ix) Rerun **mtsg\_bottle\_compare\_dy054.m** to merge the clean 1-minute data onto bottle samples. This should now be run with the switch at the top of the script set to calibrated.

x) Run **met\_tsg\_av\_addnav\_dy054.m** to merge with navigation data (lat and long) on variable time. Run **mbest\_all.m** prior to this to update the best navigation file bst\_dy054\_01.nc.

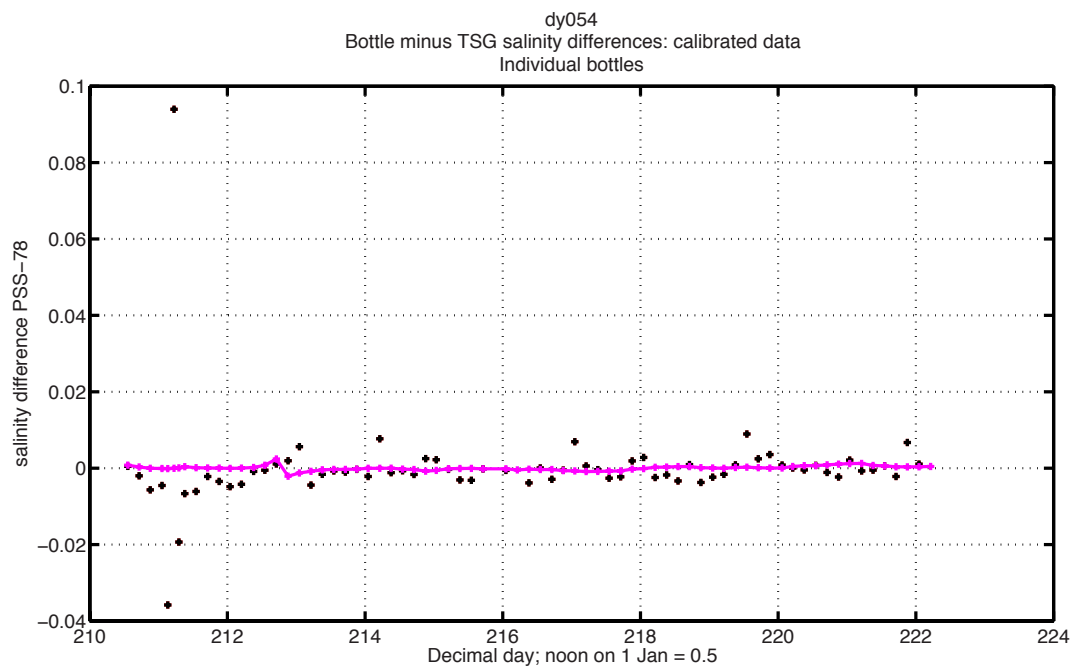
Input: data/tsg/tsg\_dy054\_01\_medav\_clean\_cal.nc

Input: data/nav/posmvpos/bst\_dy054\_01.nc

Output: data/tsg/tsg\_dy054\_medav\_clean\_cal\_nav.nc (final file)







*Figure 11.1 Calibrated DY054 TSG salinity and bottle samples*

## 12. Salinity samples and Autosol

*Neill Mackay, Penny Holliday, Jeff Benson*

Salinity samples from the CTD were collected using a 12 bottle rosette system containing 10 litre Niskin bottles. Salinity samples were drawn from each unique depth. These samples were subsequently analyzed on a Guildline Autosol salinometer (serial number 68958) using NMF software in Labview for the automated reading of the digital output of the Autosol. Handwritten paper logs were kept of the Autosol readings as a backup but were not needed during the cruise. The Autosol water bath was maintained at 24°C and the room at approximately 21°C. The Autosol operators for DY054 were Jeff Benson and Neill Mackay.

Over the course of the cruise, 22 crates of up to 24 bottles and 39 OSIL seawater standards (SSW, all batch 159) were processed. The SSW samples were numbered 57 onwards, following on the SSW samples from DY053 (1:56). Some crates from shallow CTD casts when not all 12 Niskin bottles were fired were not full. Of the 22, 4 crates were underway samples and the rest were from CTD casts. For each crate, a standard was run before and after the crate. For some crates an additional standard was run in the middle. The Autosol laboratory had nearly constant temperature and the stability of the Autosol was within the acceptable range, but not as good as it can be. While the mean offset from the SSW label conductivity was relatively stable over time, the conductivity of SSW samples slowly reduced through a series of 3-4 bottles run over 2-3 crates, and the scatter was notably higher compared with the earlier samples on DY053 (Figure 14. 1). Additionally, before the last 3 crates were processed, the Autosol had to be switched off and opened up to replace a drive belt for the water bath stirrer which had snapped. Once the Autosol had been powered up again, it was left for 24 hours before processing the remaining samples.

Once the Autosol analysis was complete, the .xls files created by the NMF software were modified to manually enter the station number and rosette position number for each Autosol reading. The .xls files were then saved as .csv files using a Windows laptop. The process followed on DY054 is given below.

### *A. Prepare the bottle salinity files*

We need to edit the Autosol spreadsheets to give them a specific format, and to add the information to link the salinity samples with the CTD cast and niskin number.

- i. Autosol spreadsheets can be found on the ship's server at  
discofs/dy054/Sensors\_and\_Moorings/CTD/Data/CTD/Autosol\_data

The files will be named by crate number and the date they were analysed.  
To work on them, drag and drop them onto your laptop

- ii. The original is saved as a new filename and edited as an .xls file.  
For example "**DY054 CTD37 02 August 2016.xls**" may be saved as:  
**sal\_dy054\_001.xls**  
even though it contains data for stations 001 and 002 and 003.

- iii. Remove any blank header lines; there must be exactly 10 header lines in the new .xls file.

iv. The first column should already include the CTD crate number (or cast number) and the salinity bottle number (ie the number written on the bottle in the crate).

For example   CTD01\_596  
                  CTD01\_597

v. A new last column (J) needs to be manually added to indicate the CTD station number and niskin bottle - this is the unique identifier for that sample and is called "**sampnum**". The format is **NNnn** where NN is cast number and nn is rosette position number.

For example   sampnum  
                  0101  
                  0103  
                  0105

This information can be found on the CTD sampling logsheets.

SSW samples should be given sampnum starting at **999001** and increasing sequentially.

vi. The corrected spreadsheet needs to be save as an xls file, and also as a single or as multiple comma-delimited files (.csv):

If the file contains more than one station's worth of samples save it as a csv for each of those stations eg

    sal\_dy054\_001.xls contains data from stations 001 and 002 so is  
    saved as sal\_dy054\_001.csv and sal\_dy054\_002.csv

The mstar scripts use the sampnum to identify data for each station, and expect one csv per station.

*B. Get the data files into the right place and format.*

vii. The original autosal file, the new xls file and the new csv files should all be saved to:  
    //discofs/public/dy054\_public/DY054\_Salinity/

viii. On workstation *sams-eel*, rsync **all** the files to ~/cruise/data/ctd/BOTTLE\_SAL  
    cd data  
    cd ctd/BOTTLE\_SAL  
    rsync -av /mnt/public/dy054\_public/DY054\_Salinity/ .

(Note that if you want to replace a file already present BOTTLE\_SAL you will need to delete it first).

*C. Read the ascii data into mstar netcdf:*

At the start of the cruise, edit "msal\_01.m" to ensure the salinometer bath temperature is set to the correct temperature used on the cruise (24°C on DY054).

Next check the cruise-specific conductivity ratio offset to be applied to create a new adjusted salinity variable. The offset is derived from the SSW samples run through the salinometer. At the start of the cruise this should be set to zero for all stations, and you will change this later on when you have evaluated the salinometer performance with the SSW data.

> matlab &

```
>> m_setup
>> msal_01_dy054.m reads ascii file into matlab, saves sal_dy054_nnn.nc
>> msal_02.m pastes the bottle salinity into sam_dy054_nnn.nc.
```

#### *D. Evaluate the Autosol performance using the SSW samples*

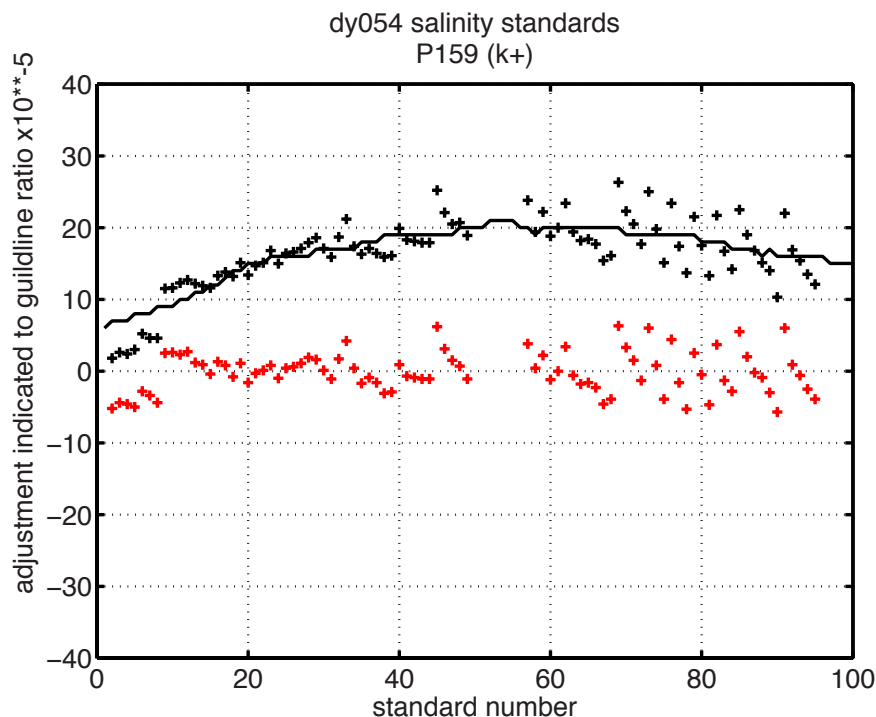
Before using the salinity data to calibrate the CTD conductivity data, you need to see whether the bottle salinities need adjusting for the autosol offset.

First pick out all the information from the standards and save as a text file:

```
/data/ctd/sal_dy054_standards and run
>> msal_evaluate_standards_dy054.m
```

mevaluate\_standards generates a plot of the adjustment indicated by the samples to the Guideline Ratio of the SSW batch. The script can be edited to account for more than one batch of SSW used during the cruise. The figure allows the user to look for drift in the salinometer over time and to decide on an appropriate offset to use in **msal\_01.m**.

The performance of the salinometer on DY054 is shown in Figure 12.1. The red crosses indicate the uncorrected difference between the SSW batch ratio and the ratio measured by the Autosol. The black line indicates the suggested offset and the black crosses indicate the difference after than correction has been made.



*Figure 12.1 Salinometer performance as indicated by the standard seawater (SSW) bottles run at the start and end of crates of salinity samples. The variable plotted is the difference between the salinometer reading and the SSW ratio of the batch (listed on the bottle) ( $\times 10^{-5}$ ) (black crosses); the red line indicates the correction applied to the bottle sample data and the red crosses give the difference with the correction applied. The drift during a single run of samples increased about halfway through the cruise, though is still within acceptable range.*

### *E. Apply the SSW-derived adjustment to bottle salinities*

Edit the cruise-specific case adjustments in **msal\_01.m**, then  
run **msal\_01** and **msal\_02** for all the affected stations.

### *F. Collate the sample files for CTD conductivity evaluation and calibration*

After applying the SSW-derived adjustment to bottle salinities, the revised sam files can all be collated to look at the CTD data.

The individual sample files (eg sam\_dy054\_001.nc) can be appended using:

**mapend.m**

Output: **sam\_dy054\_all.nc**

Input: type in the sam file names (or copy and paste) or prepare a text file list

See Section 8 for conductivity calibration using the salinity samples.

## **13. Nutrients samples**

*Femke de Jong, Neill Mackay*

Nutrient samples were collected for comparison with earlier AR7E hydrographic sections and as preliminary data for bio-optical instruments proposed to be added to the NIOZ moorings in 2018.

### **13.1 Taking samples**

Nutrient samples were taken from the CTD Niskin bottles at standard depths  $\geq 1000$  dbar (1000, 750, 500, 250, 100, 50, 25, 10 dbar). A total of 239 samples were collected over 38 CTD stations. Samples were filtered using a 0.8/0.2  $\mu\text{m}$  Acrodisk filter, stored in 5 ml vials in the freezer. The samples will be taken to NIOZ where they will be analyzed.

### **13.2 Getting sampling information into mstar files**

We generated individual station .csv files for recording sampling information in the mstar sample files. To do this each station file must be identical in format and following these rules:

The format is two header lines and 24 data rows eg:

botnum	statnum	sampnum	niskin	nutrient	label	Flag
number	number	number	number	number	number	woceflag
1	1	101	1	1	2	
2	1	102			9	
3	1	103	2		9	
etc						

Botnum is the position on the frame

Statnum is the CTD cast number

Sampnum is combination of Statnum and Botnum (00101 for SSSBB)

Niskin is the number of the niskin bottle label

Nutrient sample is the number of the nutrient sample bottle

Flag needs to be 9 where there is no sample, and 2 where there is a sample

The spreadsheets were saved as **nut\_dy054\_nnn.xlsx** and **nut\_dy054\_nnn.csv**. They were saved to *//discofs.discovery/local/public/dy054\_public/DY054\_Nuts* and copied to the workstation:

```
cd data/ctd/BOTTLE_NUTS
rsync -av /mnt/public/dy054_public/DY054_Nuts/* .
```

Next **mnut\_01\_dy054** was run to read the csv into mstar, then **mnut\_02\_dy054** to paste into the sample file (**sam\_dy054\_nnn.nc**)



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## 14. RAFOS float deployments

*Ryan Peabody, Heather Furey*

Approximately 140 subsurface acoustically tracked RAFOS floats are being released during the 2014, 2015, and 2016 OSNAP cruises to directly observe pathways of Overflow Waters through the subpolar North Atlantic. An array of 10 260-Hz sound sources moored during the 2014 OSNAP cruises is being used to track the floats until all the moored arrays are recovered in 2018 (Figure 14.2, open bullets labeled 1:10).

This year's float seeding was similar to the 2015 deployment, with a few differences. 10 of the 51 floats intended to be deployed in Summer 2016 were held back and will be sent with *Virginie Thierry* in Summer 2017, to re-seed the deep Charlie-Gibbs Fracture Zone. These floats will have 1-year mission lengths only. Additionally, the 2800-dbar float level has been removed due to greater sound source attenuation depth than anticipated.

Deployments for the 41 RAFOS deployments in Year 3 are as follows:

- DY053, East Reykjanes Ridge: 16 RAFOS on the eastern flank of the Reykjanes Ridge programmed for 730-day missions. No monitor floats were deployed, as all our sound source inventory is now in the water, no replacements for failed sources are possible.
- DY054, West Reykjanes Ridge: 11 RAFOS over the western flank of the Reykjanes Ridge programmed for 730-day missions. The single 2500-dbar station was removed from the deployment plan based on poor sound source acoustics at depth.
- DY054, East Greenland: 14 RAFOS floats over the east Greenland slope programmed for 730-day missions. All 2800-dbar East Greenland floats were removed from the deployment scheme due to poor source acoustics. One single 2500-dbar float was moved to a position off the East Reykjanes Ridge. Four 1000-dbar floats, which were previously to be used as monitors, were deployed in the Northern Irminger Basin, on the Iceland continental slope.

Floats deployed during DY054 were deployed along the OSNAP line (**Figure 14.1**). Latitudes were allowed to deviate from the planned deployments, due to the generally meridional flow of the Denmark Strait Overflow Water and Iceland-Scotland Overflow Water at the deployment sites. At some deployment sites, floats were moved farther east to ensure a larger vertical buffer between the ballasted depth and the seafloor, with special attention paid to unwired floats. Floats released on the western flank of the Reykjanes Ridge were ballasted for 1800, 2000, and 2200-dbars (Figure 14.2). The general deployment strategy was to release them 100-200 meters above the seafloor of the ridge flank to target the thin Iceland-Scotland Overflow Water layer flowing northward at that location, generally repeating the Year 2 deployment sites less one 2500-dbar float. Floats released on the East Greenland Slope were ballasted for 1800, 2200, and 2500-dbars, targeting the Denmark Strait Overflow Water flowing southward at that location. Year 2 deployments were generally repeated, with a few exceptions: all 2800-dbar floats were removed, one 2500-dbar float deployment was moved to the East Reykjanes Ridge, and one repaired 1800-dbar float was added that malfunctioned prior to its planned Year 2 deployments. Table 14.1 lists the full deployment information for the DY054 floats.

2015 deployments worked as intended: the ballasting adjustments were kept in place, and floats near to the bottom have tail wires. Thin, two-meter lengths of plastic-coated SS wire weighing approximately 10 grams were added to eight of the DY054 floats. This wire hangs vertically from the float bottom and will contact the seafloor first. Because the wire is flexible, if a float gets near to the bottom, it will partially rest on the seafloor, effectively lessening the weight of the float, and increasing float buoyancy. The flexible wire prevents the float itself from coming in contact with the bottom and picking up sediments.

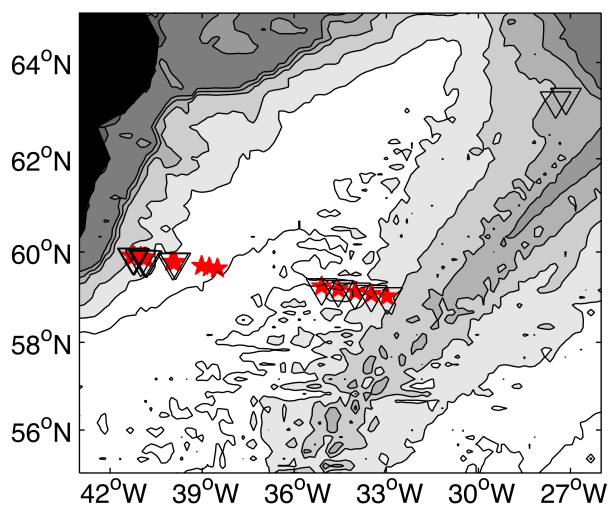
All of the RAFOS floats were released using the “holey tube” made out of ~0.25-m diameter, 2.5-m long PVC pipe, using a starch ring release mechanism that triggered when the tube (and firing pin) were submerged. On last year’s Pelagia cruise, the floats were dropped off the stern, using the tube as a chute to prevent contact with the hull. As the *Discovery*’s deck is higher off the water than the Pelagia, the firing pin was used, and the floats were lowered off the starboard side. It is worth noting that during one float’s deployment (1417), the attachment point for the rope that held the tube closed (a grey ring glued to the tube’s frame) broke and slid several feet down the tube’s length. Following that deployment, the tie-off points were changed so the rope was attached to the tube itself, rather than the glued-on rings.

*Table 14.1. RAFOS float deployment metadata, OSNAP East Leg 2 2016, RRS Discovery, Irminger Sea*

S/N	Ballast / target depth (m)	Wire d float	Mission length (days)	Deployment date	Deployment time (UTC)	Decimal latitude (°N)	Decimal longitude (°W)	Corrected water depth (m)	Iridium IMEI Number
<b>Northern Irminger Basin</b>									
1223	1000	N	730	28-Jul-2016	02:12	63.285	27.152	1269	300234060307210
1224	1000	n	730	28-Jul-2016	02:20	63.287	27.148	1269	300234060304480
1233	1000	N	730	28-Jul-2016	03:48	63.213	27.485	1198	300234060306470
1246	1000	N	730	28-Jul-2016	03:50	63.213	27.483	1199	300234060775720
<b>East Greenland</b>									
1422	2500	n	730	1-Aug-2016	19:12	59.780	39.873	2676	300234063532590
1423	2500	N	730	1-Aug-2016	19:13	59.780	39.873	2676	300234063537510
1433	2500	Y	730	1-Aug-2016	18:40	59.768	39.958	2675	300234063531380
1437	2500	Y	730	1-Aug-2016	18:41	59.768	39.958	2675	300234063737830
1432	2200	N	730	1-Aug-2016	09:22	59.823	40.810	2380	300234063534310
1427	2200	N	730	1-Aug-2016	09:21	59.823	40.810	2380	300234063530370
1425	2200	n	730	1-Aug-2016	09:09	59.825	40.813	2375	300234063538590
1426	2200	N	730	1-Aug-2016	09:12	59.825	40.813	2375	300234063532580
1429	2200	Y	730	1-Aug-2016	08:50	59.830	40.872	2298	300234063538290
1421	2000	N	730	1-Aug-2016	08:00	59.843	40.997	2182	300234063535600
1424	2000	N	730	1-Aug-2016	07:59	59.843	40.997	2182	300234063534360
1348	1800	N	730	1-Aug-2016	05:00	59.877	41.217	1993	300234061820870



1420	1800	N	730	1-Aug-2016	04:57	59.877	41.217	1993	300234063533600
1428	1800	Y	730	1-Aug-2016	04:28	59.885	41.258	1964	300234063530290
<b>West Reykjanes Ridge</b>									
1405	2000	Y	730	8-Aug-2016	22:07	59.022	32.974	2221	300234063533590
1407	1800	N	730	8-Aug-2016	22:07	59.022	32.974	2221	300234063539520
1404	2000	Y	730	9-Aug-2016	2:10	59.070	33.491	2295	300234063531520
1408	1800	N	730	9-Aug-2016	2:11	59.070	33.492	2296	300234063534590
1415	2200	Y	730	7-Aug-2016	6:52	59.124	34.020	2822	300234063533580
1417	2000	N	730	7-Aug-2016	6:53	59.124	34.020	2822	300234063535360
1409	1800	N	730	7-Aug-2016	6:56	59.124	34.020	2822	300234063537590
1414	2200	Y	730	7-Aug-2016	0:03	59.178	34.565	2834	300234063533610
1418	2000	N	730	7-Aug-2016	0:04	59.178	34.565	2834	300234063532600
1416	1800	N	730	7-Aug-2016	0:05	59.178	34.565	2834	300234063538370
1419	2200	n	730	6-Aug-2016	19:43	59.216	35.114	2943	300234063531360



*Figure 14.1. RAFOS deployment locations over bathymetry. Triangles mark the position of the 2016 deployment locations. Red pentagrams show the 2015 deployment locations.*

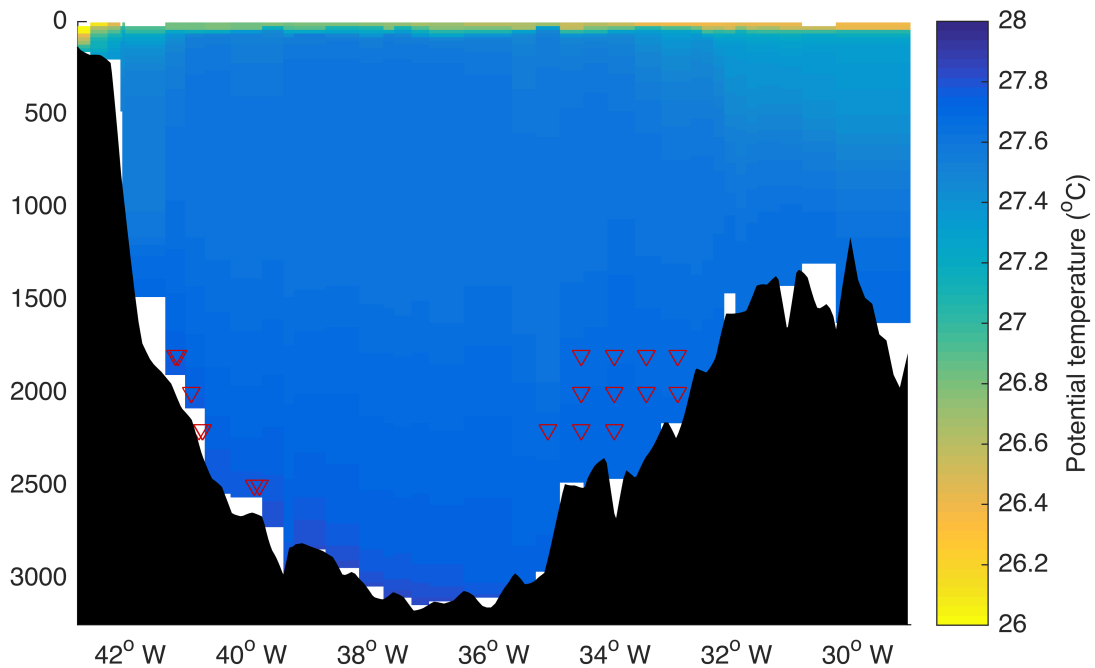


Figure 14.2. 2016 RAFOS deployment depths and longitudinal positions along the OSNAP line (Northern Irminger Basin floats not shown). Potential density (**note incorrect label on axis**) from the DY054 CTD casts is shown for reference.

## 15. WHOI Sound Source mooring

Ryan Peabody, Heather Furey

An array of 10 260-Hz sound sources moored during the 2014 OSNAP cruises is being used to track the OSNAP RAFOS floats until all the moored arrays are recovered in 2018 (Figure 16.2). This is the final year of RAFOS deployments off the OSNAP line. Based on short-mission float results from the 2014 deployment, a few adjustments are being made this year to the sound source array. The acoustic signals collected by the RAFOS floats so far have been of relatively poor quality: the attenuation of the sound source signals due to the rough ocean surface was greater than expected. To address this problem, we will deploy three additional sound source moorings this summer (Figure 15.1). Information on the new sound source deployed on DY054 is given in Table 15.1.

Sound Source 12 was deployed during DY054, to better sonify the Iceland Basin. Initial plans called for the sound source to be deployed in 3310 m of water, placing the sound source at 1200 m depth. To better accommodate the NMF mooring team's working schedule, the deployment was moved farther west into shallower (3133 m) water. To ensure that the sound source still sat at an appropriate depth, 100 m of 3/16" Jac.Nil. Wirerope was removed from the mooring base, resulting in an approximate sound source depth of 1277 m. The mooring was deployed without an acoustic release, so it will not be recovered.

Table 15. 1 New Sound Source mooring deployed on DY054

S/N	Latitude (°N)	Longitude (°W)	Water Depth (m)	Source Depth (m)	Pong Schedule (UTC)
Sound Source 12: URI-WHOI S/N 22	56° 14.26	025° 59.03	3133	1200	01:00

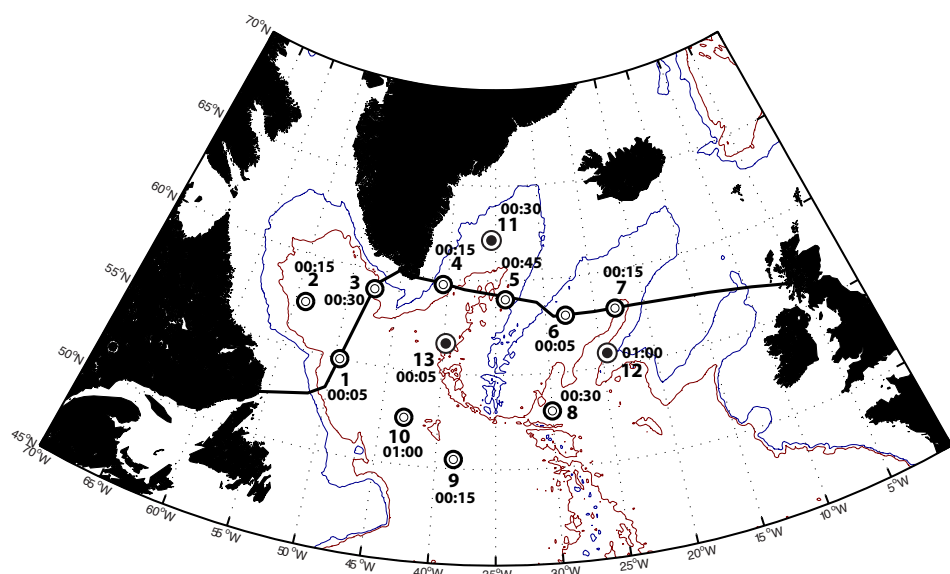


Figure 15.1. Sound source mooring positions and pong times (once daily) for 13 sound sources deployed as part of the OSNAP program. The 2000- and 3000-m isobaths are drawn.

## 16. Argo float

Penny Holliday

The UK Met Office requested that we deploy a single Argo APEX profiling float in the central Irminger Basin; the final float of a series released on DY052, DY053 and DY054. The remaining float was lowered on a line from the starboard quarter while the ship was steaming at 1.5 knots in calm, sunny conditions.

We 'named' this float Feili, and plan to track it's progress throughout OSNAP. The successful test period, WMO number and first profile were confirmed by Katie Gowers, BODC.

Table 16.1. DY054 Argo float deployment

Date	Time (UTC)	Lat (N)	Lon (W)	Serial No.	WMO No.
03/08/16	1406	59° 13.53N	39° 28.55W	7577	6901194

## **17. Photography and Video documentation**

*Amanda Kowalski*

During the DY054 cruise I gathered the following materials:

- approximately one hundred digital photographs of cruise operations, scientists, and technicians.
- series of descriptive videos about the scientific operations during the cruise including: Mooring Retrieval, Mooring Deployment, CTD, RAFOS Deployment.
- five audio interviews with technicians and scientists about why they feel their work is important and what their perception is of how people will adapt to climate change.
- conducted three filmed interviews with: Principal Scientist Penny Holliday, Femke de Jong, and Senior Scientist David Smeed.

All materials will be used to populate a new OSNAP outreach website designed to appeal to a general audience including students ages twelve to eighteen. The website will be launched in early 2017 and will focus specifically on the human impact of the AMOC and how people are adapting to the changing climate.

## **18. Different perspectives**

*Mia Taylor*

On the DY054 OSNAP research cruise I hoped to learn about the North Atlantic circulation and its relation to climate change and observe the instruments and methods involved in collecting data and observing the currents. I was also interested in the RRS *Discovery* ship, its engineering and systems and its role in providing a high functioning base for the scientists and crew.

Whilst on the cruise I have absorbed information from a variety of people and sources, made preliminary artworks and collected a wide range of material such as photographs, moving image and audio.

My activities have involved documenting the scientific processes, the ship and the local environment. This has included photographing, filming and observing the moorings, CTD's, the deployment of floats during the day and at night. In many cases the documentation suggests a faithful representation of the activities, in others I have attempted to suggest an alternative vision of the ship and its activities, for example, through the use of photographic gels.

To better understand the data resulting from the scientific processes, I appropriated and mimicked some of the scientific methods. This includes, collecting my own water samples from the CTD and mixing them with watercolour paint to create painted graphs that interpret the temperature and salinity data from specific CTD stations. The paintings were also to test how the salinity from different depths reacted with watercolour paint and to explore the imaginative potential of using seawater from parts of the ocean that are inaccessible to many people. Going forward, I intend to use data from a number of individual CTD locations that

span the length of the line to build a broader representation of the area, which I then plan to combine with information on the depth of the CTD locations and explore how these different sets of information can be visually represented in relation to each other.

Additionally, I have collected audio files that include abstract sounds from around the ship and interviews with members from both the science team and the crew. The interviews explore ideas around circulation, the open ocean, the ship and personal experience. Aspects of the ship that have been of particular interest include its engineering, how it is mapped and diagrammed and its water supply system. This led to my working with one of the crew to paint hazard lines on the ship, exposing me to another set of working methods.

The collected material will be reviewed and edited on land and will be developed into a new art work/s that explores the research themes and connects it to the wider experience of the DY054 cruise.

## 19. Acknowledgements

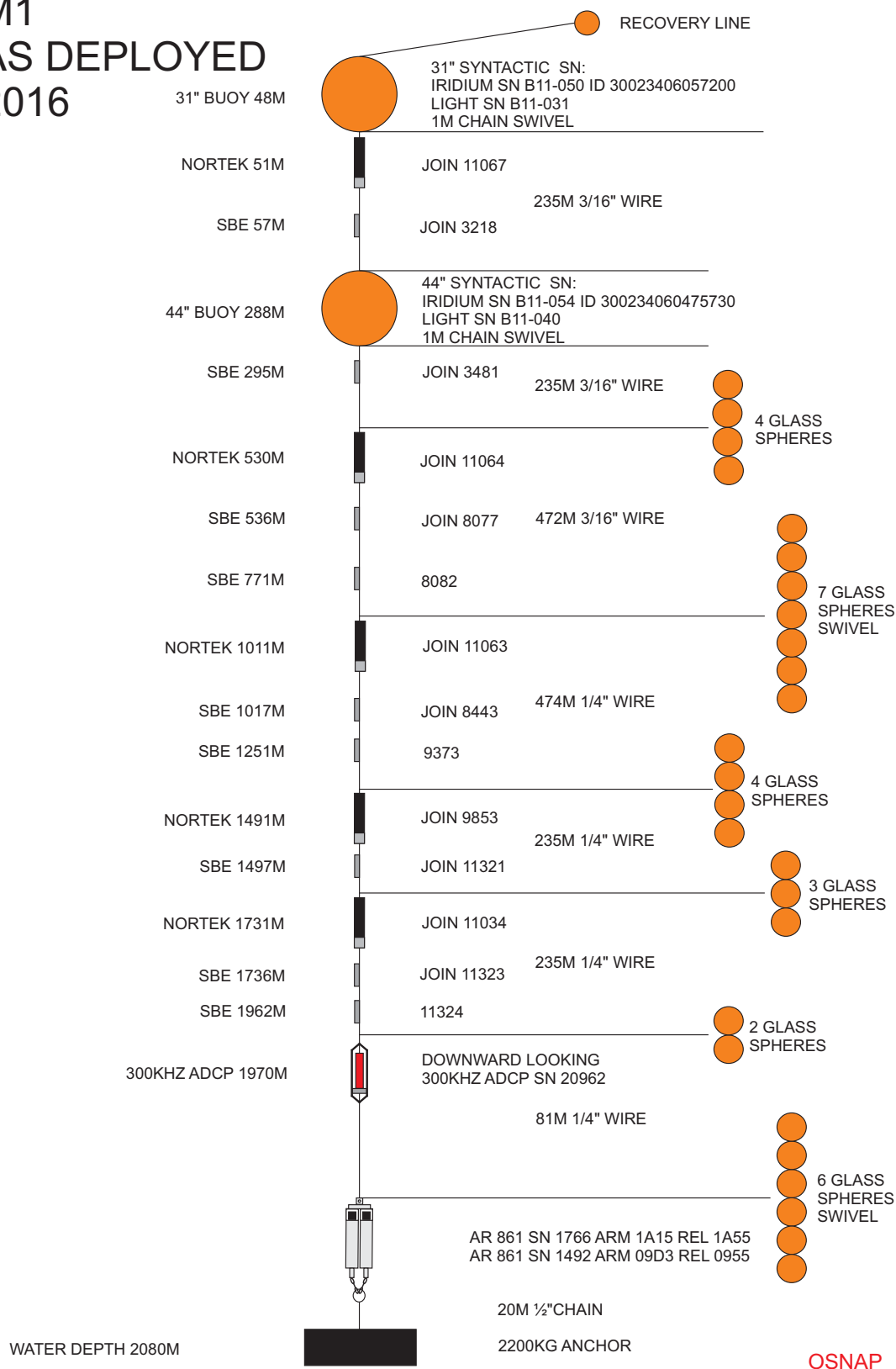
This was a successful cruise with good weather and all objectives achieved. We would like to thank the Master, Antonio Gatti, for his support during the trip, and to thank all the ship's crew for their professionalism and good humour. The skill of the bridge officers, the engineers, the catering staff and the crew was very much appreciated. Special thanks to the NMF-SS technicians who sailed on DY054; their skill, support and patience was much appreciated. Thanks also to Dan Comben, Darren Rayner and the Sensors and Moorings team for the planning, co-ordination and preparation work before the cruise.

Finally we say many thanks to the scientific and technical teams of DY052 and DY053 for the prep work that they did for us during their own cruise, including the mooring equipment, floats, the workstations in the main lab, and the sweets and polystyrene cups they left us as they went home.

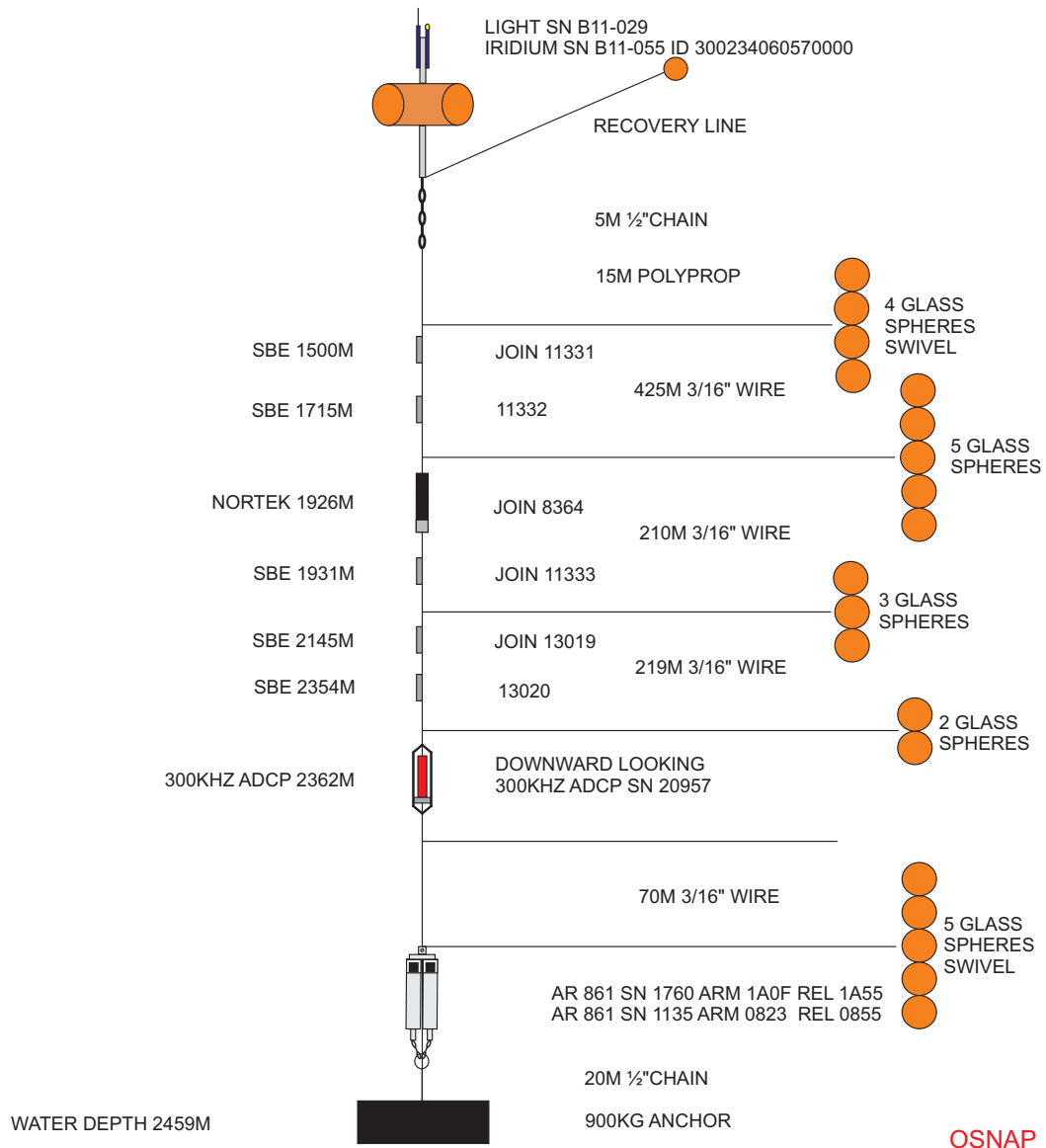


## Appendix A: NOC Mooring diagrams

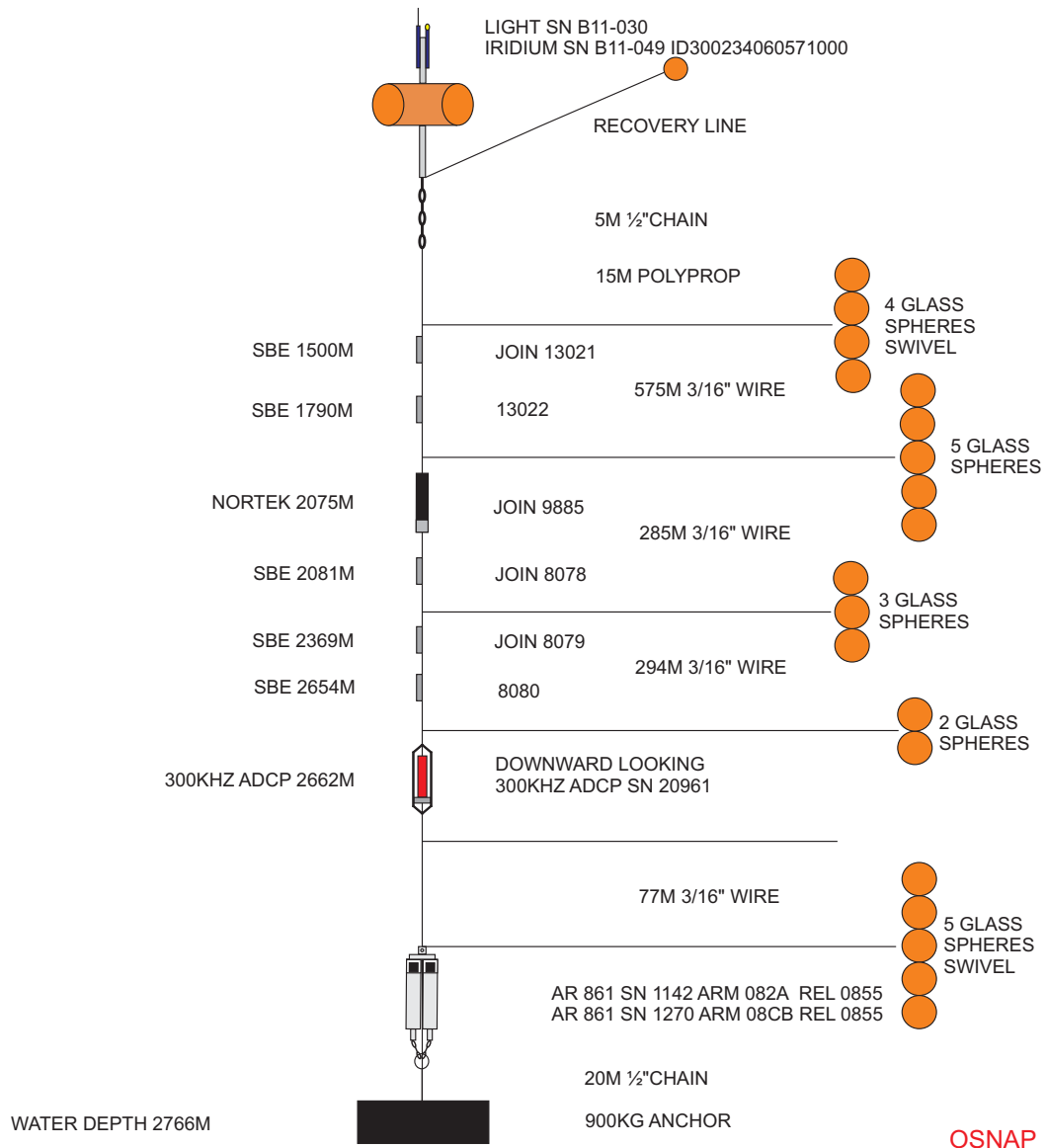
### M1 AS DEPLOYED 2016



# M2 AS DEPLOYED 2016

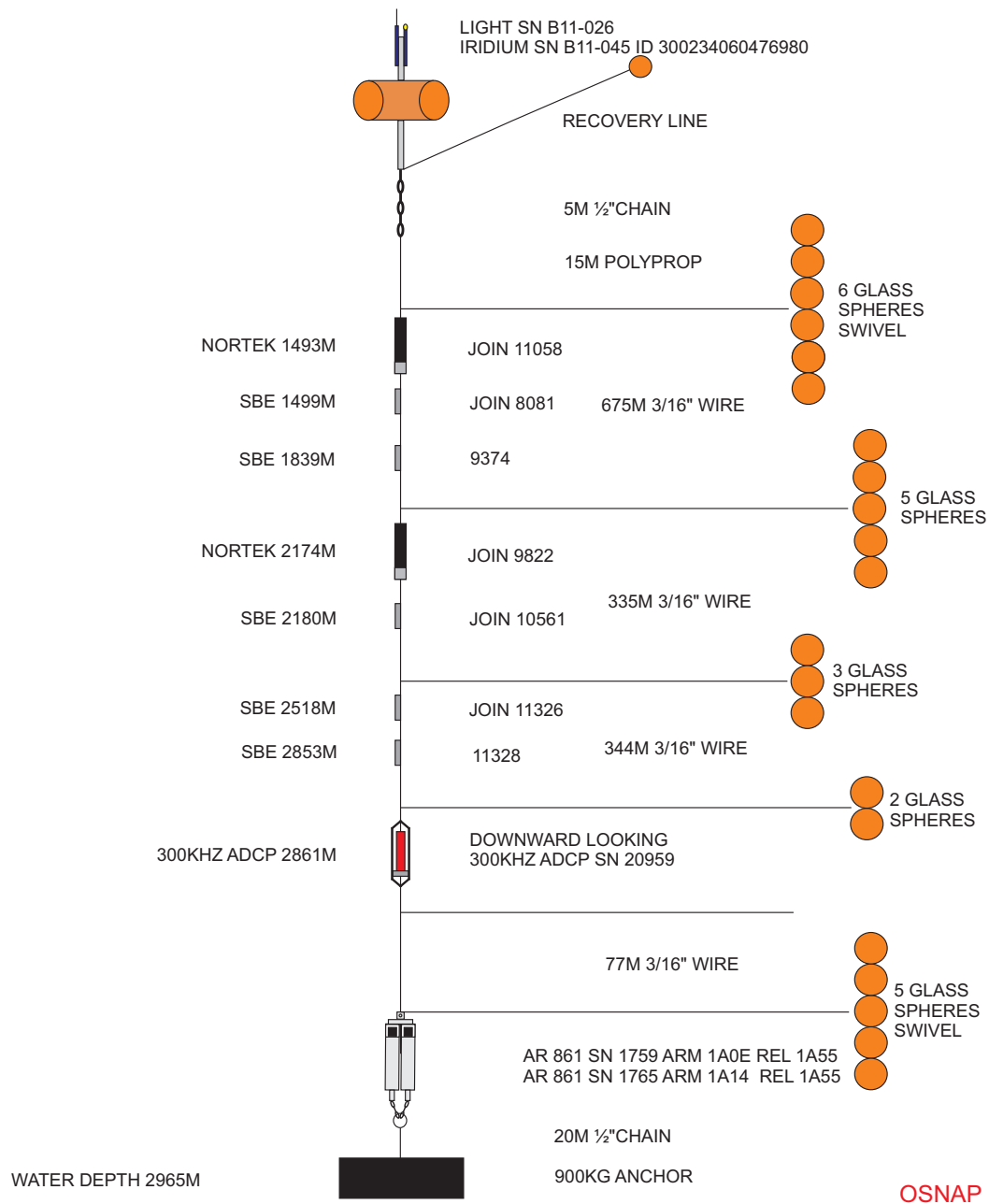


# M3 AS DEPLOYED 2016

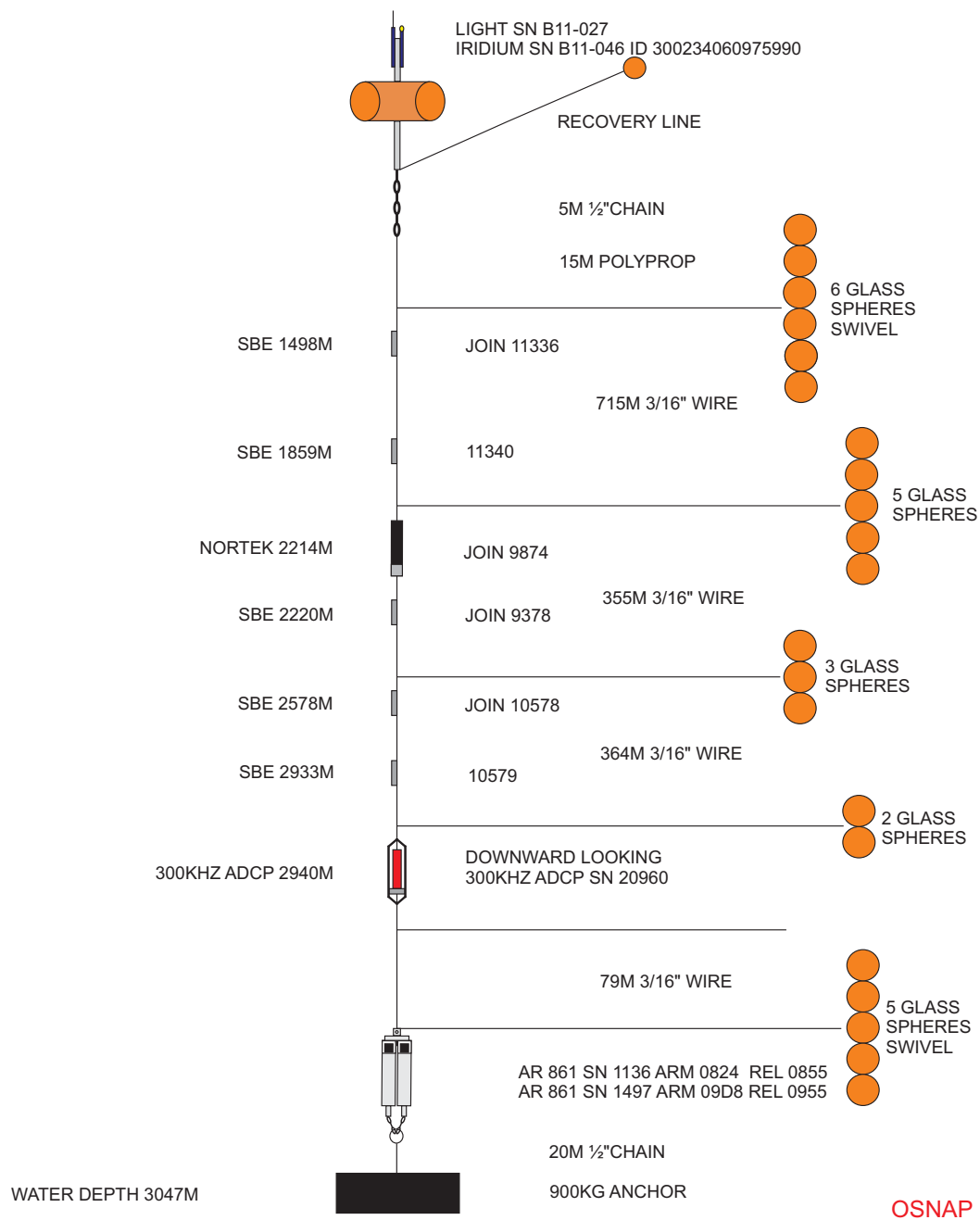




# M4 AS DEPLOYED 2016



# M5 AS DEPLOYED 2016



OSNAP

## Appendix B: NIOZ Mooring diagrams

Final version 11 August 2016

OSNAP 2016 mooring IC-0

Depth 2938 m

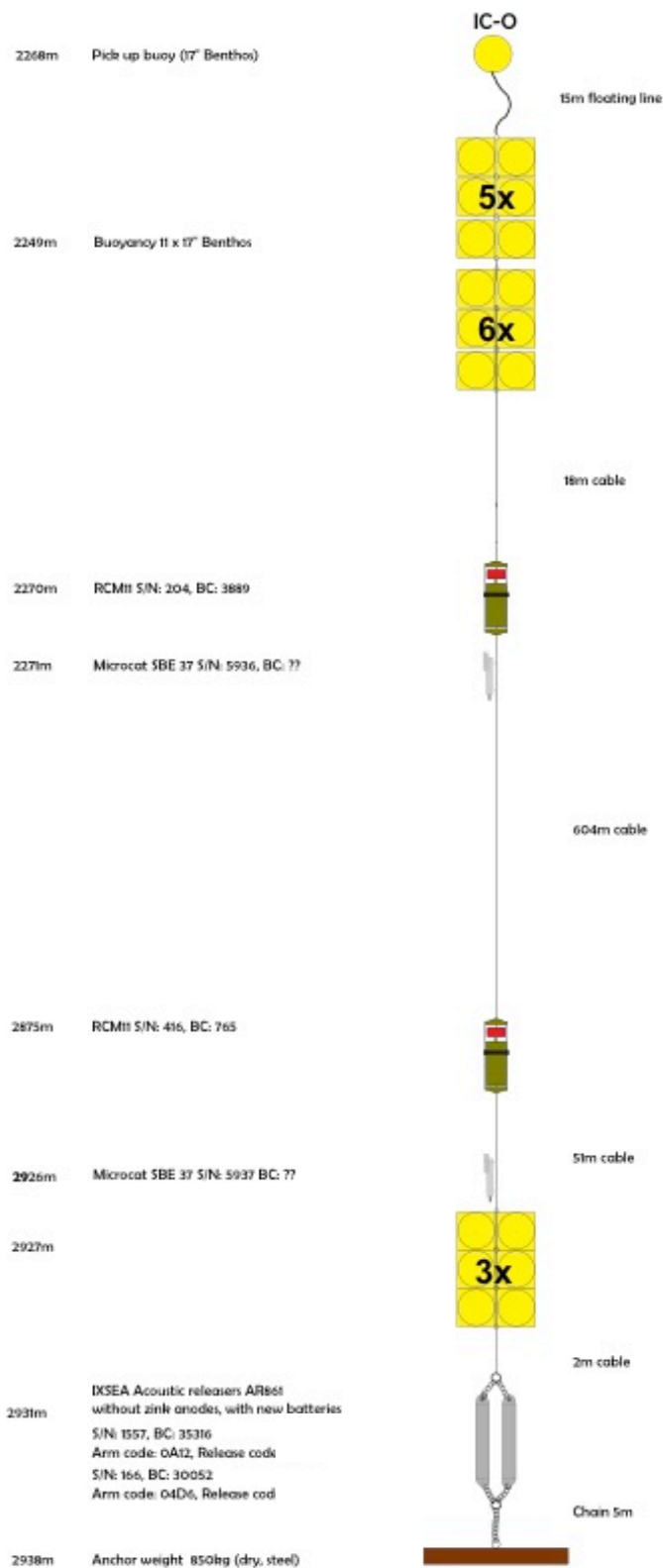
Deployed 6 August 2016

Anchor Drop:

Lat 59°13.02' N

Lon 35°07.51' W

Cable 5mm steel (+2mm)



Final version 13 August 2016

OSNAP 2016 mooring IC-1

Depth 2493 m

Deployed 9 August 2016

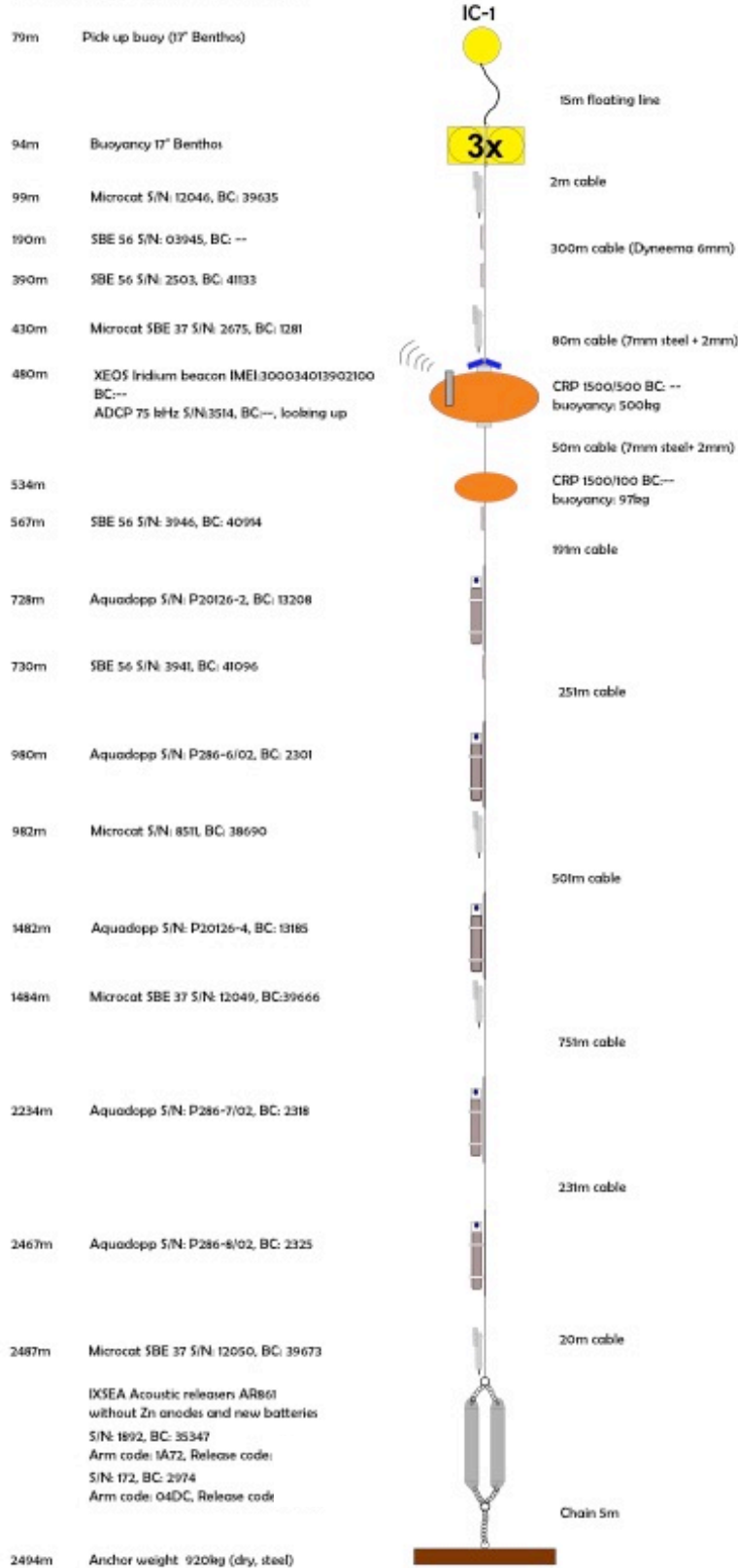
Fallback weight: 493 m

Location:

Lat 59°6.264'N

Lon 33°41.202'W

Cable 5mm steel (+2mm)



# Final version 13 August 2016

## OSNAP 2016 mooring IC-2

Depth 1873 m

Deployed 9 August 2016

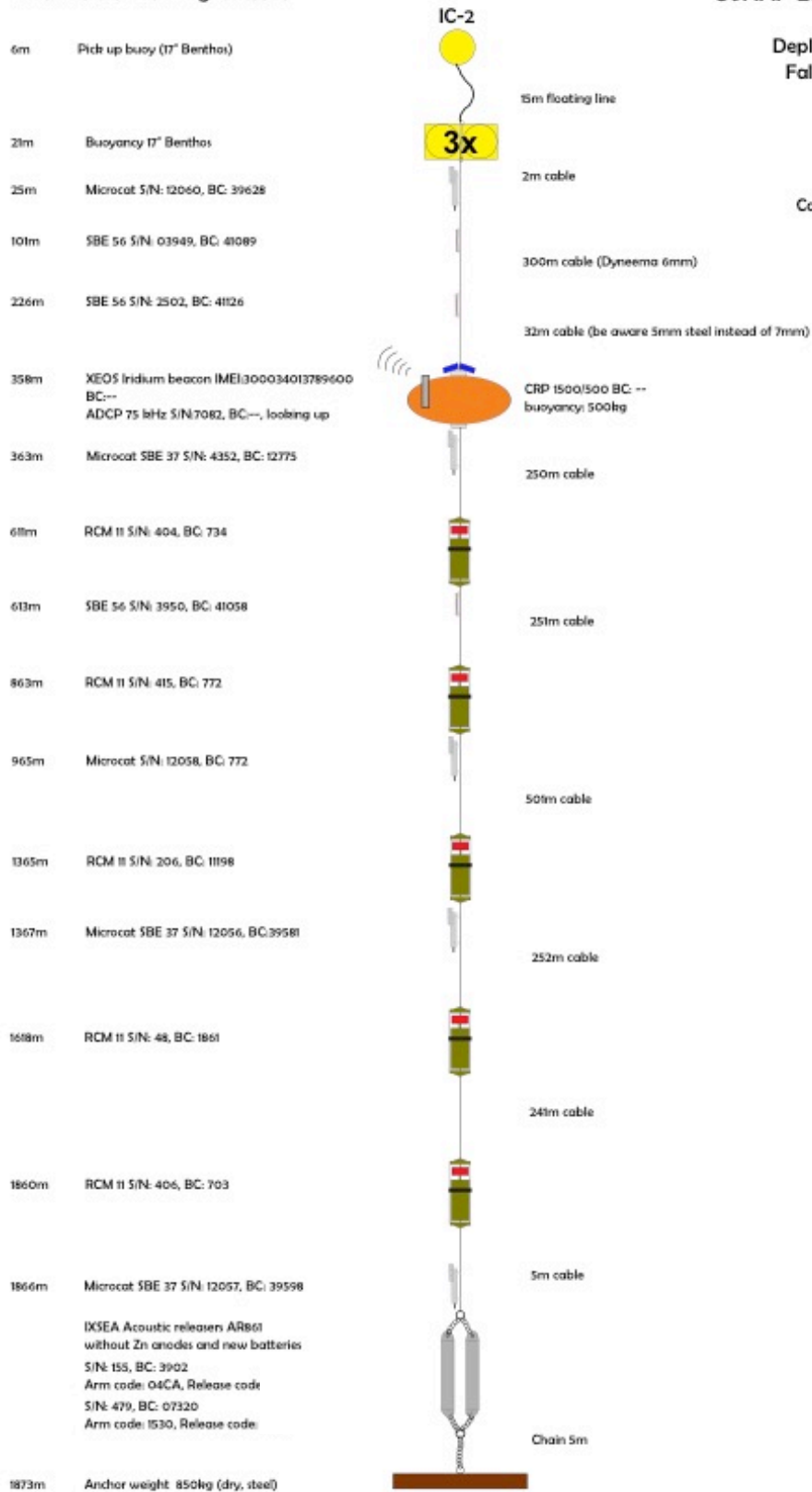
Fallback weight: 231 m

### Location:

Lat 59°1.29'N

Lon 32°43.56'W

Cable 5mm steel (+2mm)



# Final version 13 August 2016

## OSNAP 2016 mooring IC-3

Depth 1633 m

Deployed 10 August 2016

Fallback weight: 290 m

### Location:

Lat 58°57.40'N

Lon 31°57.08'W

Cable 5mm steel (+2mm)

69m	Pick up buoy (17" Benthos)	IC-2	20m floating line NOC
89m	Buoyancy 17" Benthos	3x	2m cable
93m	Microcat S/N: 12052, BC: 39543		300m cable (Dyneema 6mm)
214m	SBE 56 S/N: 03947, BC: 40884		80m cable (7mm steel + 2mm)
474m	XEOS Iridium beacon IMEI:300034012279280 BC:--- ADCP 75 kHz S/N:3641, BC:--, looking up		CRP 1500/500 BC: 3032 buoyancy: 500kg
479m	Microcat SBE 37 S/N: 12053, BC: 39550		50m cable (7mm steel + 2mm)
530m			CRP 1500/500 BC: 7894 buoyancy: 97kg
727m	RCM II S/N: 405, BC: 727		194m cable
729m	SBE 56 S/N: 3951, BC: 41027		25m cable
979m	RCM II S/N: 193, BC: 1946		495m cable
981m	Microcat SBE 37 S/N: 12054, BC:39567		100m cable
1475m	RCM II S/N: 417, BC: 789		50m cable
1477m	Microcat SBE 37 S/N: 2656, BC: 3797		
	IXSEA Acoustic releasers AR861 without Zn anodes and new batteries S/N: 1394, BC: 35026 Arm code: 0971, Release code: S/N: 430, BC: 7344 Arm code: 1478, Release code:		Chain 5m
1633m	Anchor weight: 850kg (dry, steel)		

Final version 13 August 2016

OSNAP 2016 mooring IC-4

Depth 1471 m

Deployed 10 August 2016

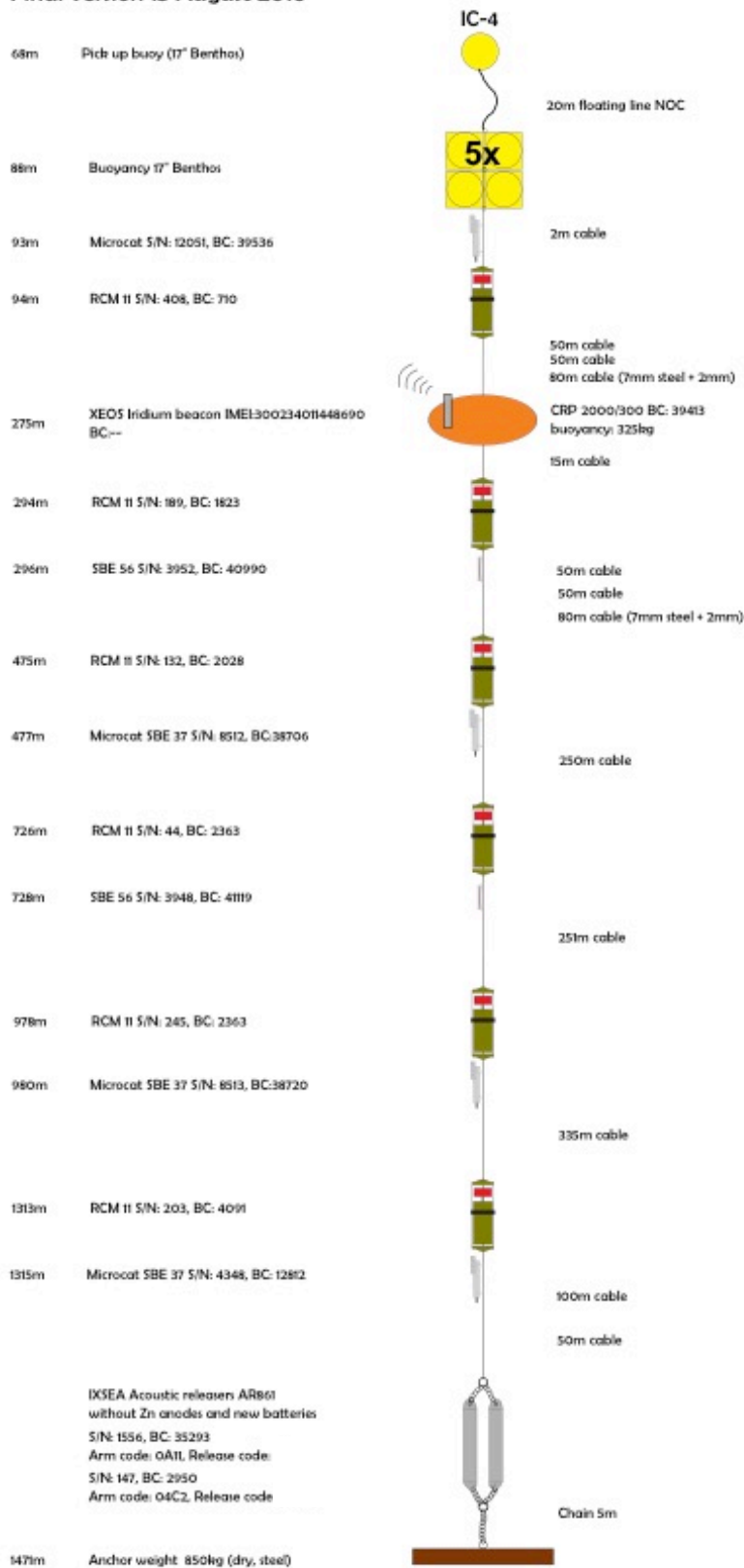
Fallback weight: 230 m

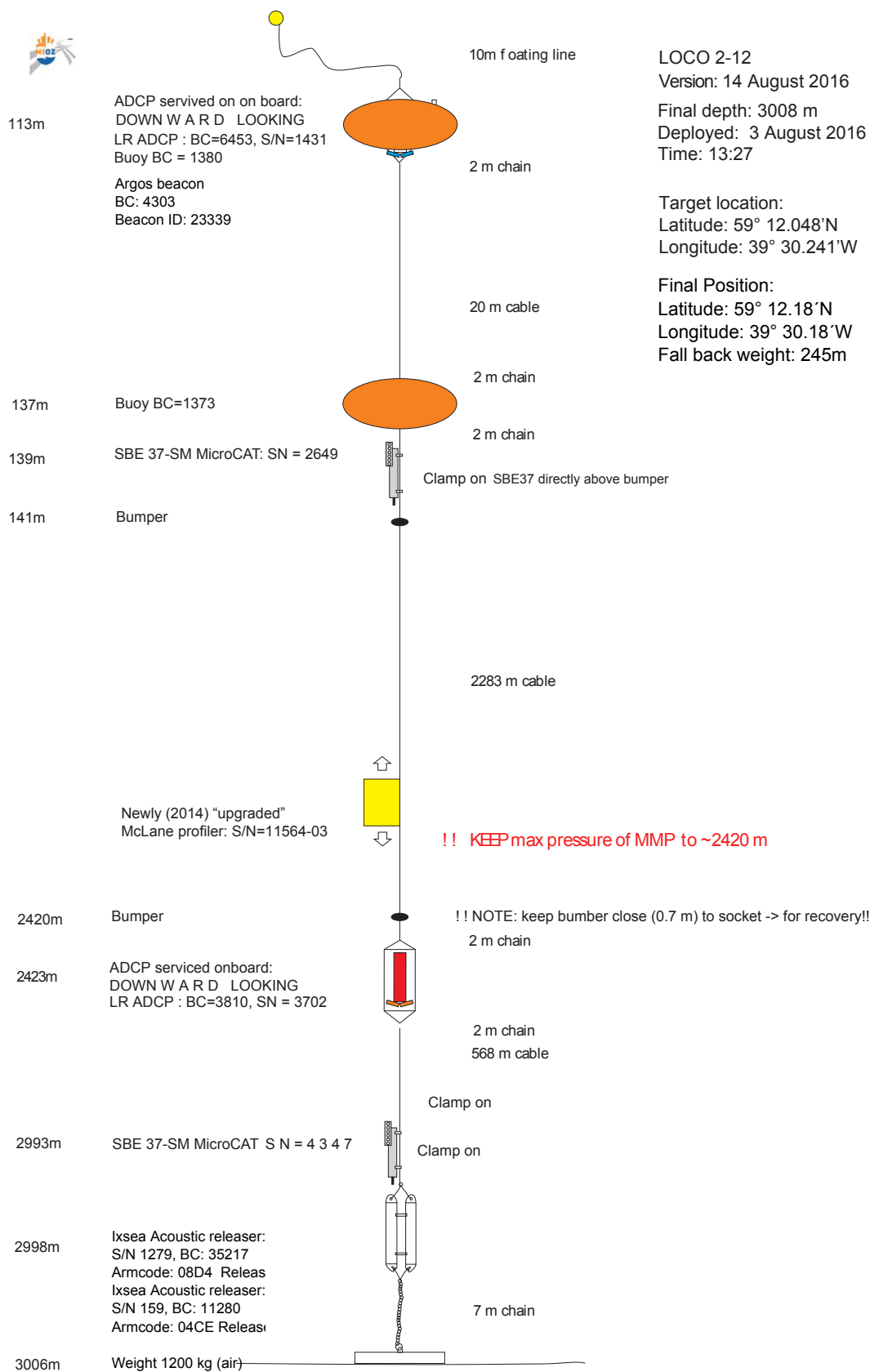
Location:

Lat 58°53.38'N

Lon 31°17.90'W

Cable 5mm steel (+2mm)







## Appendix C: WHOI Mooring diagram

