RAPID cruise report for Cruise DY129

8 December 2020 - 26 January 2021
RRS *Discovery* Cruise DY129

B. I. Moat

2021

Cruise report 72

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Abstract
The purpose of RRS Discovery cruise DY129 was to refurbish the RAPID 26°N array of moorings that span the Atlantic from the Bahamas to the Canary Islands. The cruise started in Southampton on Tuesday 8th December 2020 and ended on Tuesday 26th January 2021 at Southampton, UK.

The moorings are part of a purposeful Atlantic wide array that observes the Atlantic Meridional Overturning Circulation and the associated heat and freshwater transports. The RAPID-MOCHA-WBTS array is a joint UK- US programme.

During DY129 moorings were removed at sites: MAR3, MAR3L, NOG, MAR1, MAR0 and WB6. Moorings were serviced at sites: WB4, WB4L, WBH2, WB2, WB2L, WB1, WBADCP and WBAL. Sites with suffix 'L' denote landers fitted with bottom pressure recorders.

Moorings were equipped with instruments to measure temperature, conductivity and pressure, and a number of moorings were also equipped with current meters and/or oxygen sensors. Chemical sensors used in the ABC fluxes project were recovered and not redeployed. The RAPID telemetry system deployed adjacent to mooring WB2 was recovered.

CTD stations were conducted throughout the cruise for purposes of providing pre- and post-deployment calibrations for mooring instrumentation (including oxygen and carbonate chemistry sampling).

Shipboard underway measurements were systematically logged, processed and calibrated, including: surface meteorology, 5m depth sea temperatures and salinities, water depth, and navigation. Water velocity profiles from 15 m to approximately 800 m depth were obtained using two vessel mounted Acoustic Doppler Current Profilers (one 75 kHz and one 150 kHz).

Abstract
Atlantic Meridional Overturning Circulation, AMOC, RAPID, moorings, mooring array, North Atlantic

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1. Scientific and ship's personnel

Name	Position	Affiliation
Antonio Gatti	Master	
James Huteson	Chief Officer	
Graham Stringfellow	2nd Officer	
Rachel Astell	3rd Officer	
Gregor Arthur	Chief Engineer	
Christopher Kemp	2nd Engineer	
Daniel Evans	3rd Engineer	
Sean Rooney	3rd Engineer	
Tomas Brazier	ETO	
Emlyn Williams	ERPO	
Valerija Forbes-Simpson	Purser	
Craig Lapsley	CPOS	
Andrew Mclean	CPOD	
Marshall Mackinnon	POD	
Crag Gilfillan	POS	
Chris Devitt	SG1A	
Terry Burke	SG1A	
Colin McMaster	SG1A	
Mark Ashfield	Head chef	
Charlotte Ray	Chef	
Carl Piper	Steward	
Denzil Williams	Steward	
Ben Moat	Chief Scientist	NOC
Pete Brown	Scientist	NOC
Eleanor Frajka-Williams	Scientist	NOC
David Smeed	Scientist	NOC
Paul Provost	Senior Technical Officer	NOC/NMFSS
Dave Childs	Technician (Moorings)	NOC/NMFSS
Andrew Cotmore	Technician (Engineering)	NOC/NMFSS
Christian Crowe	Technician (Moorings)	NOC/NMFSS
Colin Hutton	Technician (Moorings)	NOC/NMFSS
William Platt	Technician (Moorings)	NOC/NMFSS
Thomas Roberts	Technician (Moorings)	NOC/NMFSS
John Wynar	Technician (Moorings)	NOC/NMFSS
Oliver Twigge	Trainee	NOC/NMFSS
Jade Garner	Trainee	NOC/NMFSS
Nickolas Harker	ITO	NOC/NMFSS

2. Itinerary

The RAPID 26N expedition aboard the RRS Discovery DY129 left Southampton, UK on Tuesday 8th December 2020 and ended on 25th January 2021 at Southampton, UK. The Eastern boundary array was completed during JC192 in March 2020.

Work on the mid-Atlantic array started on the 18th December 2020. All moorings and landers were recovered and not redeployed, ending the continuous record since 2004 at this location. Four Argo floats were deployed at MAR3, MAR1, MAR0 and WB6 with calibration CTD's for the floats' RBR sensors. A deep Argo float was deployed on Christmas day between MAR0 and WB6. After recovery of WB6 at 70° 31W the ship proceeded to Nassau to complete clearance for work in Bahamian waters.

Following departure from Nassau work on the Western boundary array was completed between 1st Jan 2021 and 8th Jan 2021. This included the recovery of the MYRTLE telemetry lander at WB2. Unfortunately, lander WB2L12 could not be recovered. Both releases appeared to release ok, but ranges indicated that they did not rise from the sea floor. An attempt was made to drag for a lander WBAL5 lost in 2014, but was not successful. Ship proceeded to Southampton on the 8th Jan 2021 and docked on the 26th Jan 2021.

A full itinerary is given in Table 2.1.

Date	Operation	Start time	End time	Durat. (hrs)	Latitude (°N)	Long. (°W)	Notes
Tue 8 Dec	Depart Southampton, UK	10:00					
Wed 16 Dec	Test CTD0	14:12	14:38	00:26	28°22.64	31°59.30	
	Transit MAR3						
Fri 18 Dec	Recover MAR3L11	17:14	18:42	01:28			
	Deploy ARGO 9137	18:51			23°51.44	41°05.93	
	CTD1	19:22	21:13	02:11	23°51.38	41°05.88	For Argo float 2000m
	CTD2	22:10	23:01	00:51	23°51.38	41°05.88	Water collection 900m
Sat 19 Dec	Recover MAR3L12	08:56	10:15	01:19			
	Recover MAR3	10:33	15:30	04:57			
	Recover NOG	16:34	18:37	02:03			
	Transit MAR1						
Mon 21 Dec	Recover MAR1L11	13:18	14:37	01:19			
	Recover MAR1L12	14:43	16:05	01:22			
	Deploy Argo 9136	16:05			24°10.96	49°44.03	
	CTD3	17:53	23:13	05:20	24°10.96	49°43.84	MicroCats
Tue 22 Dec	CTD4	00:04	03:34	03:30	24°10.95	49°43.86	MicroCats
	Recover PIES	05:37	07:57	02:20			Time from release
	Recover MAR1	10:27	15:19	04:52			
	CTD5	16:58	21:17	04:19	24°09.94	49°44.58	MicroCats
	Transit MAR0						
Wed 23 Dec	Recover MAR0	10:30	12:24	01:54			

	Deploy Argo 9187	13:23			25°08.65	52°01.79	
	CTD6	14:34	17:53	03:19	25°08.62	52°01.73	MicroCats (3500m)
	CTD7	18:31	23:05	04:34	25°08.64	52°01.74	MicroCats
	Transit Deep Apex						
Fri 25 Dec	Deploy Deep Apex	11:24			25°32.98	59°15.77	
Sun 27 Dec	Recover WB6	17:36	19:51	02:15			
	Deploy Argo 7625	20:00			26°29.57	70°30.99	
	CTD8	22:09	02:41	04:32	26°29.59	70°30.95	MicroCats
Tue 29 Dec	Arrive Nassau	16:00					
Thu 31 Dec	Sail Nassau	12:30					
Fri 1 Jan	CTD 913	02:02	05:33	03:31	26°26.77	75°45.23	Pre WB4
	Recover WB4	12:31	16:48	04:17			
	Deploy WB4L14	18:03	18:10	00:07	26° 28.47	75° 42.81	
	CTD10	18:42	19:52	01:10			Water collection 1500m
Sat 2 Jan	Deploy WB4	14:10	20:02	05:52	26° 27.04	75° 43.54	Current increased during deployment
	CTD11	20:37	00:53	04:16	26°29.93	75°42.26	Post WB4
Sun 3 Jan	Trilateration WB4	23:06	01:36	02:30			
	Transit WBH2						
	CTD12	06:41	10:09	03:28	26°29.17	76°38.39	Pre WBH2
	Recover WBH2	12:08	16:59	04:41			Slow ascent . 7 imploded glass
	Deploy WBH2	18:41	21:42	03:01	26° 28.79	76° 37.61	
	CTD 13	22:37	01:58	03:21	26°27.73	76°37.68	Post WBH2

Mon 4th Jan	Trilaterate WBH2	01:30	03:24	01:54			
	Transit WB2						
	Recover WB2L12	12:07					Good comms, and release ok but no movement
	Recover WB2	13:00	15:34	02:34			
	Transit WBADCP						
	Recover WBADCP	18:10	19:10	01:00			
	Transit WB2						
	Deploy WB2L14	20:32	20:39	00:07	26°30.21	76° 44.62	
	Wire test for dragging						
	CTD14	22:21	00:02	01:41	26°30.20	76°43.48	Cal dip for RBR instruments (1700m)
Tue 5th Jan	Recover Myrtle	10:12	13:50	03:38			rose at 35 m/min
	Deploy WB2	14:41	18:38	03:57	26° 31.00	76° 46.44	
	Transit WBAL						
	Trilaterate missing landers						No response from WBAL5 or WBAL6
	Transit WB2						
	Trilaterate WB2	22:22	22:13	00:51			
	CTD15	23:30	02:49	03:19	26°30.46	76°43.29	MicroCats 3500m
Wed 6 Jan	Transit WBAL						
	Dragging for lost WBAL landers						Dragging for WBAL5
	Deploy WBADCP	20:05	20:11	00:06	26° 31.80	76° 52.05	
	Deploy WBAL9	20:51	20:57	00:06	26° 32.29	76° 51.98	

	Trilaterate WBAL and WBADCP	21:16	22:08	00:52			
	Transfer WBH2						
	CTD 16	23:57	04:01	04:04	26°28.95	76°36.71	MicroCats 4700m
	Transit WB1						
Thu 7 Jan	Deploy WB1	14:09	16:12	02:03	26° 29.85	76° 48.93	
	Boat Transfer	18:30	18:45				
	Trilaterate WB1	19:57	20:39	00:42			
	CTD 17	21:01	22:44	01:43	26°30.01	76°47.98	Post WB1
	Transit WB4						
Fri 8 Jan	CTD18	05:00	09:07	04:07	26°26.99	75°40.79	MicroCats
	Transit Southampton, UK.						
Sun 10 Jan	CTD19	12:43	17:10	04:27	29°38.52	65°47.42	MicroCats
	Transit Deep Argo recovery						
Fri 15 Jan	Deep Argo float recovery	13:00	13:15	00:15	36°12.68	43°18.75	
	Transit Southampton, UK						
Tue 26 Jan	Arrive Southampton, UK.	10:00					

Table 2.1 Cruise Itinerary (time in GMT).

3. Introduction

This cruise report is for cruise DY129 conducted aboard RRS *Discovery* in winter 2020/2021. The primary purpose of the cruise was to service the UK contribution to the RAPID-MOC/MOCHA mooring array. The RAPID-MOC/MOCHA array was first deployed in 2004 to measure the Atlantic Meridional Overturning Circulation (AMOC) at 26°N and has been maintained by regular service cruises since then. The array and associated observations are funded by NERC, NSF and NOAA. The NERC contribution to the first four years of measurements was funded under the directed programme "RAPID Climate Change". Following an international review NERC continued funding to 2014 under the programme "RAPID-WATCH". The servicing and redeployment of the UK moorings on this cruise are conducted under the "RAPID-AMOC" programme, which is funded until 2020. NSF and NOAA have also continued funding and commitments so that the system can continue operating at the same level of activity.

RAPID-AMOC continues the measurements at 26°N and extends these to include biological and chemical measurements in order to determine the variability of the AMOC and its links to climate and the ocean carbon sink on interannual-to-decadal time scales. The ABC Fluxes project is also funded under RAPID-AMOC and is adding biogeochemical samplers and sensors to the array.

Further information on the RAPID-MOC/MOCHA array please see previous cruise reports (detailed in Table 3.1).

As on previous cruises we deployed four Argo floats supplied by the UK Met Office. A deep Argo float was also deployed in the western Atlantic basin. All Argo data is freely available online see http://www.argo.net/ for further details.

3.1 Results and Data Policy

All data and data products from RAPID 26°N project are freely available. The NERC data policy may be found at http://www.bodc.ac.uk/projects/uk/rapid/data policy/. Access to data and data products can be obtained via http://www.rapid.ac.uk/rapidmoc/ and http://www.rsmas.miami.edu/users/mocha/index.htm). Data may also be obtained directly from http://www.bodc.ac.uk/.

A full list of published papers is available on the programme website at http://www.rapid.ac.uk/publications.php.

3.2 Previous RAPID-MOC Cruises

Table 3.1 details the previous cruises completed as part of the RAPID-MOC project with information on the relevant cruise reports for reference, note this does not include all NOAA WBTS hydrography cruises.

Cruise	Vessel	Date	Objectives	Cruise Report
D277	RRS *Discovery*	Feb - Mar 2004	Initial Deployment of Eastern Boundary and Mid-Atlantic Ridge moorings.	Southampton Oceanography Centre Cruise Report, No 53, 2005
D278	RRS *Discovery*	Mar 2004	Initial Deployment of UK and US Western Boundary Moorings.	Southampton Oceanography Centre Cruise Report, No 53, 2005
D279	RRS *Discovery*	Apr – May 2004	Transatlantic hydrography (125 CTD stations).	Southampton Oceanography Centre, Cruise Report, No 54, 2005
P319	RV *Poseidon*	Dec 2004	Emergency deployment of replacement EB2 following loss.	Appendix in National Oceanography Centre Southampton Cruise Report, No. 2, 2006
CD170	RRS *Charles Darwin*	Apr 2005	Service and redeployment of Eastern Boundary and	National Oceanography Centre Southampton Cruise Report, No. 2, 2006

			Mid-Atlantic Ridge moorings.	
KN182-2	RV *Knorr*	May 2005	Service and redeployment of UK and US Western Boundary Moorings and Western Boundary Time Series (WBTS) hydrography section.	National Oceanography Centre Southampton Cruise Report, No. 2, 2006
CD177	RRS *Charles Darwin*	Nov 2005	Service and redeployment of key Eastern Boundary moorings.	National Oceanography Centre Southampton Cruise Report, No. 5, 2006
WS05018	RV *F.G. Walton Smith*	Nov 2005	Emergency recovery of drifting WB1 mooring.	No report published
RB0602	RV *Ronald H. Brown*	Mar 2006	Service and redeployment of UK Western Boundary moorings and WBTS hydrography section.	National Oceanography Centre Southampton Cruise Report, No. 16, 2007
D304	RRS *Discovery*	May - Jun 2006	Service and redeployment of Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre Southampton Cruise Report, No. 16, 2007
P343	RV *Poseidon*	Oct 2006	Service and redeployment of key Eastern Boundary moorings.	National Oceanography Centre Southampton Cruise Report No. 28, 2008.
P345	RV *Poseidon*	Nov – Dec 2006	Emergency redeployment of EB1 and EB2 following problems on P343.	National Oceanography Centre Southampton Cruise Report No. 28, 2008.
SJ-14-06	RV *Seward Johnson*	Sep – Oct 2006	Recovery and redeployment of WB2 and US Western Boundary moorings, and WBTS hydrography section.	Appendix G in National Oceanography Centre, Southampton Cruise Report, No 29
RB0701	RV *Ronald H. Brown*	Mar - Apr 2007	Service and redeployment of UK Western Boundary moorings and WBTS hydrography section.	National Oceanography Centre, Southampton Cruise Report, No 29
D324	RRS *Discovery*	Oct – Nov 2007	Service and redeployment of Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre, Southampton Cruise Report, No 34
SJ0803	RV *Seward Johnson*	Apr 2008	Service and redeployment of the Western Boundary moorings.	National Oceanography Centre, Southampton Cruise Report, No 37
D334	RRS *Discovery*	Oct-Nov 2008	Service and redeployment of the Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre, Southampton, Cruise Report No. 38, 2009
RB0901	RV *Ronald H. Brown*	Apr – May 2009	Service and redeployment of the UK and US Western Boundary moorings and the WBTS hydrography section.	National Oceanography Centre, Southampton Cruise Report, No 40, 2009
D344	RRS *Discovery*	Oct – Nov 2009	Service and redeployment of the Eastern Boundary	National Oceanography Centre, Southampton, Cruise Report No. 51, 2010

			and Mid-Atlantic Ridge moorings.	
D345	RRS *Discovery*	Nov – Dec 2009	Recovery and redeployment of US Western Boundary moorings, and WBTS hydrography section.	RAPID/MOCHA Program Report (W. Johns, RSMAS).
D346	RRS *Discovery*	Jan – Feb 2010	Transatlantic hydrography (135 CTD stations).	National Oceanography Centre Cruise Report, No 16, 2012
OC459	RV *Oceanus*	Mar – Apr 2010	Service and redeployment of the Western Boundary moorings.	National Oceanography Centre Cruise Report, No 01, 2010
RB1009	RV *Ronald H. Brown*	Nov – Dec 2010	Recovery of WB4 and WB3L3. Redeployment of WB4.	Appendix in: National Oceanography Centre Cruise Report, No -01, 2010
D359	RRS *Discovery*	Dec 2010 – Jan 2011	Service and redeployment of the Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre Cruise Report, No. 09, 2011
KN200-4	RV *Knorr*	Apr – May 2011	Service and redeployment of Western Boundary Moorings and WBTS hydrography section.	National Oceanography Centre Cruise Report, No 07, 2011
JC064	RRS *James Cook*	Sep – Oct 2011	Service and redeployment of the Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Cruise Report, No. 14, 2012
RB1201	RV *Ronald H. Brown*	Feb – Mar 2012	Service and redeployment of Western Boundary Moorings and WBTS hydrography section.	National Oceanography Centre, Cruise Report No. 19, 2012
EN517	RV *Endeavor*	Sep – Oct 2012	Service of US moorings in Western Boundary.	RV Endeavor Cruise EN-517 Cruise Report
D382	RRS *Discovery*	Oct – Nov 2012	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report No. 21, 2012
AE1404	RV *Atlantic Explorer*	Mar 2014	Service of US moorings in Western Boundary.	RV Atlantic Explorer Cruise AE-1404 Cruise Report
JC103	RRS *James Cook*	Apr – Jun 2014	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report No. 30, 2015
EN570	RV *Endeavor*	Oct 2015	Service of US moorings in Western Boundary.	RV Endeavor Cruise EN-570 Cruise Report
DY039	RRS *Discovery*	Oct – Dec 2015	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report, 37
DY040	RRS *Discovery*	Dec - 2015 – Jan 2016	Transatlantic hydrography.	National Oceanography Centre Cruise Report, XX

EN598	RV *Endeavor*	May, 2017	Service of US moorings in Western Boundary.	RV Endeavor Cruise EN-598 Cruise Report
JC145	*RRS James Cook*	Feb – Apr 2017	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report, 52
JC174	*RRS James Cook*	Oct-Nov 2018	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report, 59
JC192	*RRS James Cook*	March 2020	Service and redeployment of eastern boundary of the UK RAPID array.	National Oceanography Centre Cruise Report, 71
DY129	*RRS Discovery*	Dec 8 2020 - 25th Jan 2021	Service and redeployment of MAR and Western boundary of the UK RAPID array.	This report

Table 3.1 Cruises conducted as part of the RAPID 26°N project.

4. Scientific computing systems

David Smeed

The Linux workstations used for scientific processing of data were replaced prior to the cruise. The two new workstations, running Centos 7, taken to sea were:

- 'Koaekea' a Dell T5820, and,
- 'Akeake' a Dell T3420

All processing was done on 'Koaekea' and 'Akeake' was kept as a backup. A script 'keep_akeake_in_sync' was run every 6 hours (using cron) to keep the 'programs', 'cruise', 'rapid', and 'users' directories in sync. Both workstations were connected to one UPS which also powered one monitor that could be used if needed when turning the workstations on or off (it is not necessary to have a monitor and keyboard connected to each all of the time).

Mexec v3 software was used for most data processing, see data processing sections of the report for further details. Git was used to keep track of changes to the software.

Matlab v2011a was used. This and some other software packages must be loaded using 'module'. It was found that putting module commands in the .cshrc file caused issues with some Matlab programs and it is better to keep these in the .login file.

5. NMFSS Ship Systems Computing and Underway Instruments

Nick Harker

5.1 Overview

The information in this section has been taken from the NMF Scientific Ship Systems Cruise Report where full details can be found.

The ship-fitted instruments are listed in Table 5.1, the data were logged by the Techsas 5.11 data acquisition system. The system creates NetCDF and ASCII output data files. Data were additionally logged onto the legacy RVS Level-C format and raw NEMA strings from the instruments were time stamped and logged. Data gaps in continuous ocean monitoring data (underway, multibeam and ADCP) were due to entry into non international waters.

Manufacturer	Model	Function/data types	Logged? (Y/N)	Comments
Meinberg	M300	GPS network time server (NTP)	N	Not logged but feeds times to other systems
Applanix	POS MV320 V5	Position/attitude	Y	Primary scientific GPS
C-Nav	3050	DGNSS	Y	DGNSS (for Applanix)
Kongsberg Seatex	Seapath 330	Position/attitude	Y	Secondary scientific GPS
Fugro	Fugro 9205 DGNSS Seastar	DGNSS	Y	DGNSS (for Seapath330)
iXSea	PHINSIII	Inertial Navigation System	Y	
Sonardyne	Fusion USBL	USBL	N	
Sperry Marine		Ship gyrocompasses x 3	Y	
Kongsberg Maritime	Simrad EA640	Single beam echo sounder (STDB Drop-Keel)	Y	10(active) & 12KHz (in passive mode) logged
Kongsberg Maritime	Simrad EM122	Multibeam echo sounder (deep)	Y	MMO rules, not continuous mode
Kongsberg Maritime	Simrad EM710	Multibeam echo sounder (shallow)	N	
Kongsberg Maritime	Simrad SBP120	Sub bottom profiler	N	
Kongsberg Maritime	Simrad EK60	Scientific echo sounder (fisheries)	N	
NMFSS	CLAM	CLAM system winch log	Y	
NMFSS	Surfmet	Meteorology suite	Y	
NMFSS	Surfmet	Surface hydrography suite	Y	
SKIPPER	DL850	Skipper log (ship's velocity)	Y	
OceanWaveS GmbH	WaMoS II	Wave Radar	Y (non calibrated)	Logged by Techsas and RAM
Teledyne RD Instruments	Ocean Observer 75 kHz	VM-ADCP	Y	UHDAS BT in shallow
Teledyne RD Instruments	Ocean Observer 150 kHz	VM-ADCP	Y	UHDAS BT in shallow
Microg Lacoste	Air-Sea System II	Gravity	N	
Meinberg	M300	GPS network time server (NTP)	N	Not logged but feeds times to other systems

Table 5.1 Ship-fitted instruments.

There are several gaps in the data from the EA640 and EM122 due to isolation of the systems during release and ranging of moorings.

5.2 Position and attitude

GPS and attitude measurement systems were run throughout the cruise.

The ***Applanix POSMV*** system is the vessel's primary GPS system, outputting the position of the ship's common reference point in the gravity meter room. The POSMV is available to be sent to all systems and is repeated around the vessel. The position fixes attitude and gyro data are logged to the Techsas system. True Heave is logged by the Kongsberg EM122 & EM710 systems.

The ***Kongsberg Seapath 330+*** system is the vessel's secondary GPS system. This was the position and attitude source that was used by the EM122 & EM710 due to its superior real-time heave data. Position fixes and attitude data are logged to the Techsas system.

The ***CNav 3050*** GPS system is the vessel's differential correction service. It provides the Applanix POSMV and Seapath330+ system with RTCM DGPS corrections (greater than 1m accuracy). The position fixes data are logged to the Techsas system.

The ***Fugro Seastar*** system is the correction service for primary and secondary GPS and dynamic positioning. The position fixes data are logged to the Techsas system.

5.3 Meteorology and sea surface monitoring package

The NMF Surfmet system was run throughout the cruise, excepting times for cleaning, entering and leaving port and whilst alongside (Table 5.2).

The Surfmet system is comprised of:

- Hull water inlet temperature probe (SBE38 – s/n 0416).
- Sampling board conductivity, temperature salinity sensor (SBE45 – s/n 0233).
- Sampling board transmissometer (CST – s/n 1131PR).
- Sampling board fluorometer (WS3S – s/n 246)
- Met platform temperature and humidity probe (HMP155 – s/n K0950056).
- Met platform port and starboard ambient light sensors (PAR – s/n 48927 (port) s/n 28563 (starboard), TIR – s/n 962276 (port) s/n 962301 (starboard)).
- Met platform atmospheric pressure sensor (PTB110 – s/n N0930256 (installed 10/112020), N0930257 (installed 10/12/2020).
- Met platform anemometer (Windsonic – s/n 10280018).

Date	Start Time	Stop Time	Cleaned	Transmissivity (v)	
				High	Low
06/Dec/2020	13:00	14:21	Yes	In Southampton	
08/Dec/2020	10:00	--		Departed Southampton	
12/Dec/2020		12:15		Underway turned off upon exit of international waters	
14/Dec/2020	09:06	--		Underway turned on upon entry of international waters	
28/Dec/2020	--	12:15		Underway turned off upon exit of international waters	
30/Dec/2020	15:31	16:28	Yes		
31/Dec/2020	16:09			Underway turned on upon entry of Bahaman waters	
21/Jan/2021		12:11		Underway turned off upon exit of international waters	
25/Jan/2021	09:38	10:23	Yes		

Table 5.2 Underway water logging events.

5.4 Hydro-acoustic systems

The EA640 single-beam echo-sounder was run throughout the cruise apart from during release and ranging of moorings when it was turned off to avoid interference. Both the 10 kHz and 12 kHz were run in active mode triggered by K-Sync. Pulse parameters were altered during the cruise in response to changing depth. It was used with a constant sound velocity of 1500 ms^{-1} throughout the water column to allow it to be corrected for sound velocity in post processing.

The EM122 multibeam echo sounder was run throughout the cruise apart from during release and ranging of moorings triggered by K-sync. The position and attitude data were supplied from the Seapath 330+ due to its superior real-time heave. Applanix PosMV position and attitude data is also logged to the .all files as the secondary source and True Heave *.ath file are logged to allow for inclusion during reprocessing. Sound velocity profiles were derived from a statistical model using SHOM & Ifremer's DORIS programme, derived from CTD data.

The surface Sound Velocity (SV) sensor (AML SmartSV) mounted on the drop keel was used throughout providing SV data to the EM122. The port drop keel remained flush with the hull for the duration of the cruise.

Both the 75 and 150 kHz were run consistently during the cruise.

5.5 Other systems

The single axis bridge Skipper Log and the dual axis Chernikeef science log were logged throughout the cruise.

6. Underway data and processing

Ben Moat and David Smeed

6.1 Overview

Below is an overview of the daily underway processing. The bold text refers to MatLab scripts in the Mexec Suite. A watch keeping log was filled out every 6 hours between 0800 and 2000 (ship time, noted down in UTC) checking a number of the underway systems were functioning as expected over the course of the day. Bottle samples from the underway system were taken every 4 hours.

6.2 Daily processing of underway data streams

Each day **techsas_linkscript** was run. This sorts all the Techsas files from the previous day. Following this **m_daily_proc** processes all the underway streams listed in mtnames. After applying preliminary quality control the day's data are appended to a file.

Once **m_daily_proc** has been run **mday_plots_all(*ddd*)** (where *ddd* refers to Julian day) was run. This creates plots for each of the streams of the underway data to check that the data are reasonable and highlight any issues. The following plots where created:

(1-4) The ship's path as seen by POSMVPOS, CNAV and SEAPOS. The main scientific stream that was being used was the POSMVPOS however each navigation stream was still checked on a daily basis so that if a backup was needed the other data streams showed a good match to the main stream

(5) The main scientific heading from the GYRO_S data stream

(6) The ships speed is plotted through the Chernikeef Log (CHF). The CHF has not been properly calibrated recently so doesn't give exact values of the ships speed. It does however give a good approximation and is useful for checking against other variables that may change if the ships speed changed such as heading, windspeed due to winds shadow etc. These changes line up well with changes in other data streams.

(7) The surfmet data shows wind speed, wind direction, humidity and air temperature.

(8) Shows true wind speed and true wind direction. Although mounted on the foremast the true wind speed and direction are influenced by influenced by the vessel's superstructure when the predominant wind direction is from astern. (Moat et al, 2008 and 2009).
(9-10) The underway water sampling split into **met_tsg** and **tsg** streams. These show transmission, fluorescence, conductivity, speed of sound through water and salinity (psu).

6.3 Navigation

The data acquisition system was started whilst docked at Southampton UK during the mobilization. This allowed for three days of data to be collected whilst the ship was stationary. Between the 5th Dec – 8th Dec each of the three main navigation streams (Posmvpos, Seapath, Furgo and CNAV) were compared with the aim of deciding the most accurate system. Maximum drift from the mean was in the Seapos system and was 4 m in both the x and y directions. The Posmvpos system had the lowest overall drift from the mean (±1m).

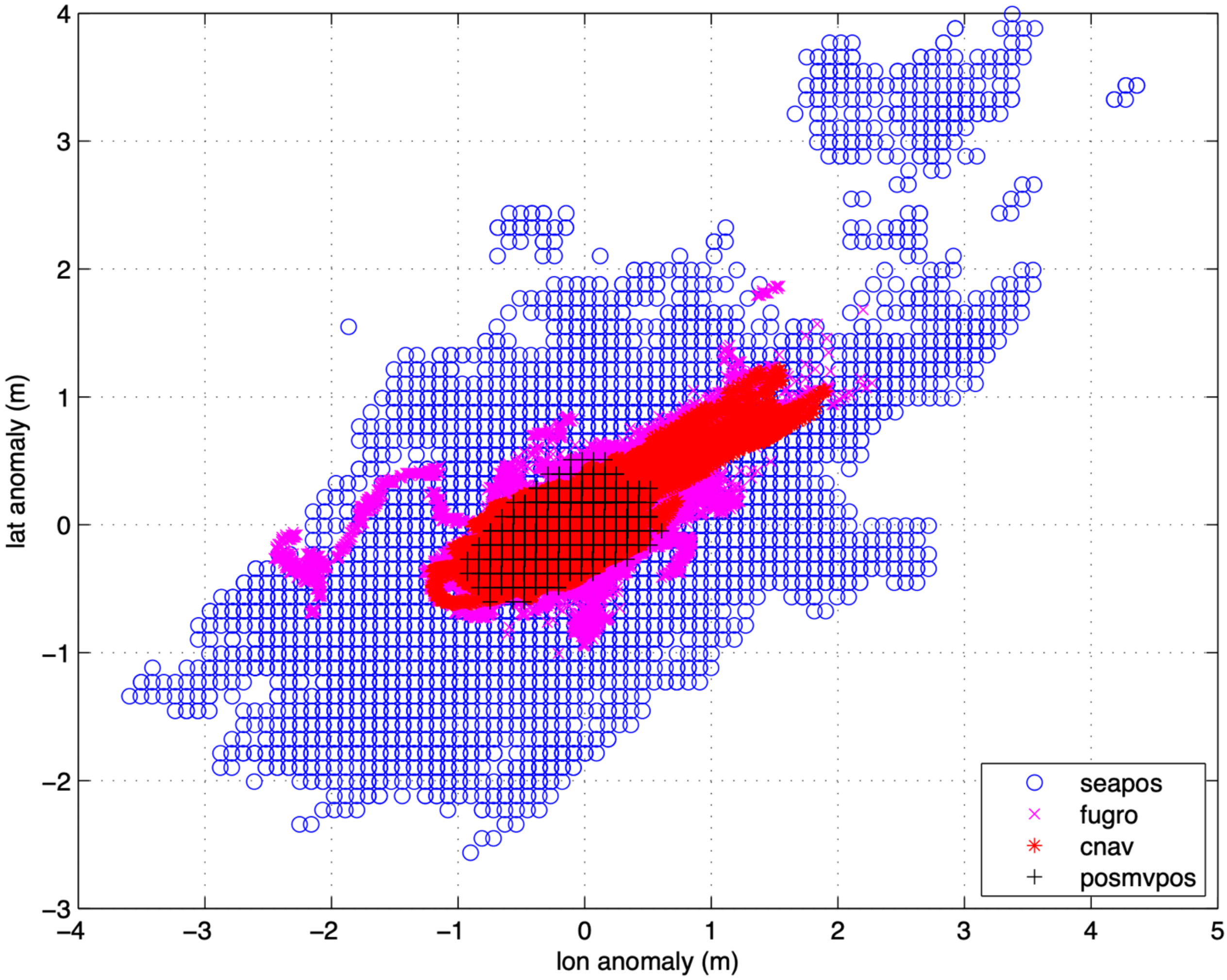


Figure 6.1 Comparison of navigation systems

6.4 Bathymetry data

Bathymetry data were collected throughout the cruise, apart from when the ship was in port. For the most part, data from the two streams, EA600 and EM120, agreed well. In areas of rapidly changing bathymetry the single beam showed a lot of noise when the azimuth thruster was in use, mainly during deployment and recovery of moorings and CTD casts.

Quality control was based on the comparison between the two streams and an understanding of what caused noise in each stream. Suspect data from each stream were removed using **msim_plot** and **mem120_plot**.

6.5 TSG salinity calibration

Water samples were taken every 4 hours (0800, 1200, 1600 and 2000 ship's time) every day between 12th December 2020 (day 347) and 18th January 2021 (day 18). A total of 121 bottle samples were taken. After being left in the temperature-controlled electronics workshop for a minimum of 24 hours the salinity from the bottles was measured using the same Autosal as the CTD samples and compiled in *sal_dy129_01.csv*. The times and dates of the samples were edited into this before using **mtsg_01** to load the bottle values. **mtsg_bottle_compare** was used to compare the salinity calculated from the bottles to the salinity from the TSG samples (Figure 6.2). Residuals are calculated and plotted against Julian day, TSG housing temperature and sea surface salinity. The calibration applied is shown as the black line in Figure 6.2 (lower panel).

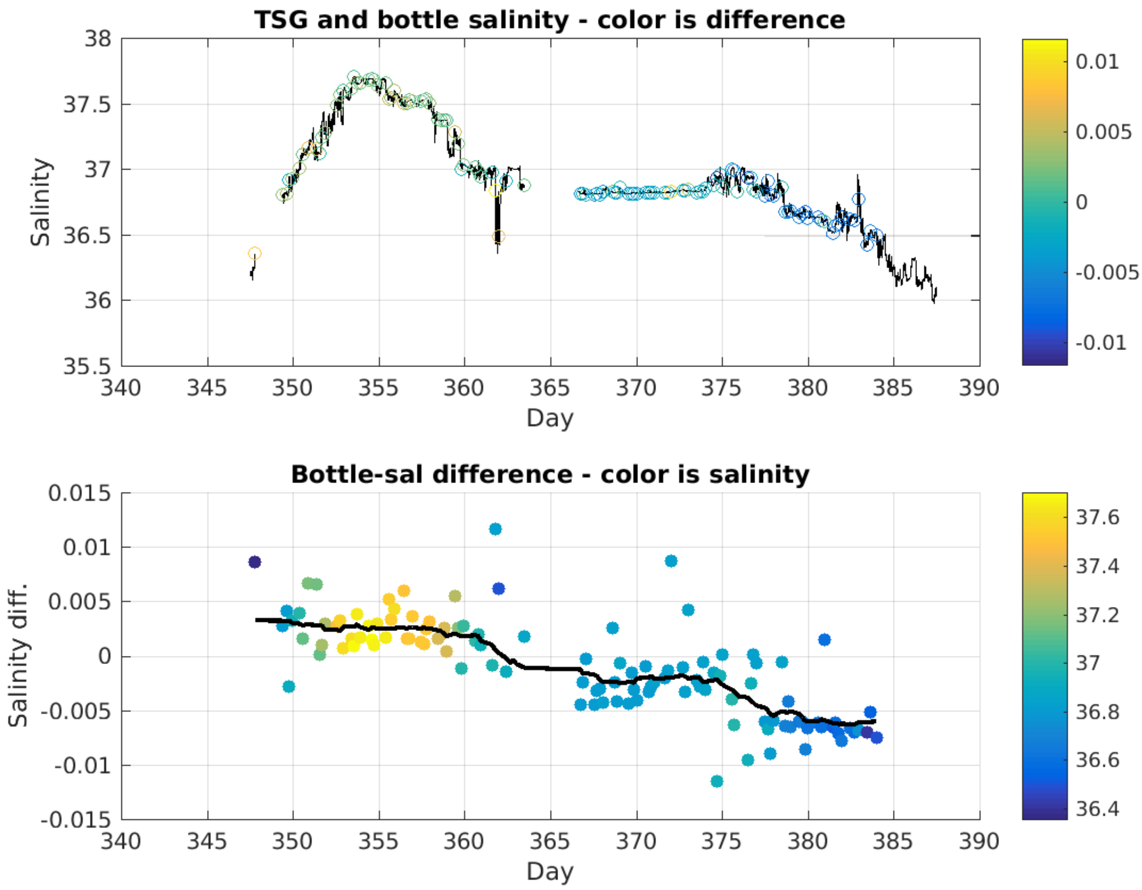


Figure 6.2 TSG salinity and bottle salinity (top), salinity residual against time (lower).

6.6 SST Calibration

The sea surface temperature (SST) was measured at a depth of 5m below the surface close to the non-toxic sea water inlet on the ship's hull. A comparison of the SST with the CTD temperature (Figure 6.3) at a depth of 5 dbar showed that the SST was overestimated by 0.06±0.02 °C (SST temperature range of 22 to 26 °C). Only 1 non-toxic pump was used throughout, i.e. the non-toxic pumps were not set to swap every 12 hours.

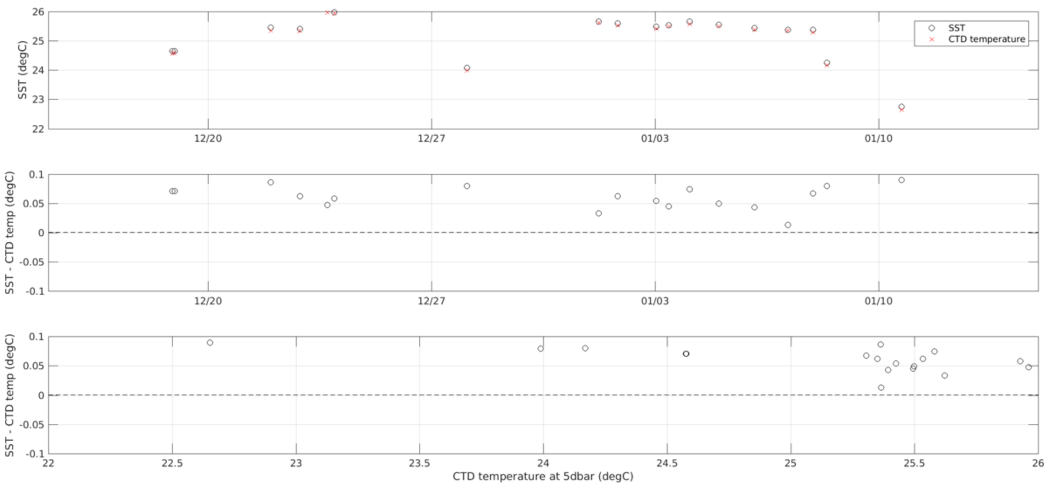


Figure 6.3 Sea surface temperature (SST) calibration.

6.7 Vessel mounted Acoustic Doppler Current Profiler (ADCP)

Data from the 75 kHz and 150 kHz vessel mounted ADCPs were acquired during the cruise. The frequencies determine the penetration through the water column and the measurement resolution. The higher frequency instrument, whilst providing a higher resolution (smaller depth bin size), the penetration through the water column is less than the lower frequency instrument. For comparison, the 150kHz penetrates up to 400m and the 75kHz instrument penetrates up to 800m (depending on sea state and water properties). There were though gaps when passing through EEZs of European nations at the start and end of the cruise and also on entry into Bahamian waters before clearance in Nassau. Both instruments operated in 'narrow band' mode. The 150khz (75khz) instrument had 40 (60) bins of 8m (16m) below the 4m (8m) blanking distance. Bottom tracking was used when the water depth was not too great. Full parameter setup is shown in Figure 6.4. Automatic acquisition and processing were performed by the University of Hawaii Data Acquisition system (UHDAS).

Figure 6.4 Settings for the VMADCPs.

The UHDAS system generates daily plots which are inspected in case of any data issues (http://currents01ukdy/adcp/). The 150khz generally had good returns down to a depth of 150m-200m; and the 75khz provided data down to c. 550m, however there was often a band between 300m and 450m with no data due to low signal return. A detailed analysis was not made, but, during mooring operation, when ships speed was low and direction was variable, some suspect features with large vertical shear were apparent in the data.

The data were copied to the workstation Koaekea and 5 minute averages were imported into the MEXEC NetCDF files. The procedure uses scripts in "~pstar/programs/mexec_exec" and is as follows:

- Mount the data server on the MEXEC workstation as "~pstar/mounts/uhdas_data"
- Create a file "~pstar/cruise/data/vmadcp/cruise_segments". The segment names should match the directory names on the data server (~pstar/mounts/uhdas_data). A single segment with name "DY129" was made for this cruise.
- Run shell script "uhdas_00" . This uses rsync to copy the data to the workstation in the folder "~pstar/cruise/data/vmadcp/atsea". This step can be set to run automatically using cron.

Python is required for some of following steps. Use shell command "module load anaconda2" to enable Python programs to run (this may already be done in the .cshrc file).

- Run shell script "uhdas_01" this has one argument which is the directory name for the output (in this case "DY129"). This is the name from which MEXEC reads data and should set "cname" in the cruise options file to be the same.
- Then run uhdas_02, and uhdas_03
- If manual editing is needed: cd proc_editing; cd osXXnb; bash; dataviewer.py -e; (none was done during this cruise)
- Then run uhdas_04, and uhdas_05
- Then, after checking cruise options (see above), in Matlab, run MEXEC script "mvad_01".

References

Moat, B. I. and M. J. Yelland, 2008, Going with the flow: state of the art marine meteorological measurements on the new NERC research vessel, *Weather*, 63, 158-159.

Moat, B. I. and M. J. Yelland, 2009, The Air Flow distortion at anemometer sites on the RRS James Cook, Research and consultncy Report 11, National Oceanography Centre, Southampton, UK. 44pp.

7. CTD operations

John Wynar and Billy Platt

7.1 CTD Operation

All casts were carried out using CTD1, which was re-terminated during DY120. The CTD cable was electrically tested both through the swivel and without the swivel. It had an insulation figure of > 999MΩ o/c and a s/c value of 75Ω after the last cast. The Deep Tow wire was terminated at the beginning of the voyage as a back-up in case of the failure of CTD1. Values for insulation of > 999MΩ o/c and continuity 92 Ω s/c were obtained after terminating. The Active Heave Compensation (AHC) was used on all casts.

A SBE35 self-recording temperature sensor was fitted to the CTD and triggered (via a Y cable) when a water sampler was tripped. It was attached to a vertical stanchion on the CTD frame, the tip being 110cm higher and 120cm vertically away from the primary SBE 3P. It was set up to average 20 cycles per measurement.

7.2 Salinity Measurement

A Guildline Autosal 8400B salinometer, s/n: 68426, was used for salinity measurements. The salinometer was sited in the Salinometer lab. Initially, the bath temperature was set at 21°C, the ambient temperature being approximately 19°C. The salinometer was standardised at the beginning of the first set of samples, and checked with an additional standard analysed prior to setting the RS. Once standardized the Autosal was not adjusted for the duration of sampling. A standard was analysed after each crate of samples to monitor & record drift (second standard analysed after sample 24, third standard analysed after sample 48, etc). Standards were recorded in the spreadsheet as '0' and had a standard salinity value of 34.994. Standard deviation was set to 0.00002.

8. CTD Data

David Smeed

8.1 Introduction

A total of 19 CTD casts were completed during the cruise (Table 8.1). The majority of the casts were performed to calibrate the MicroCAT CTDs, but some were completed before and after recovery of moorings with oxygen sensors to enable in water calibration of oxygen. Two stations were used to gather water to be used as standards for CO2 analysis, on these stations (2 and 10) all bottles were closed at the same depth. During station 3 there were problems with winch spooling on the upcast and the CTD had to be lowered a short distance during the upcast, around depths 1700m and 1150m.

Station	Start Date	Start Time	End time	Latitude (N)	Longitude (W)	Water depth (corr. m)	Profile depth (m)	Number of bottle stops	Active Heave compensation
1	18-Dec	19:22	21:13	23°51.38	41°05.88	5052	2003	12	yes
2	18-Dec	22:10	23:01	28°51.38	41°05.88	5052	903	12	yes
3*	21-Dec	17:53	23:13	24°10.96	49°43.84	5220	5207	12	yes
4*	22-Dec	00:04	03:34	27°10.95	49°43.86	5221	5204	12	yes
5*	22-Dec	16:58	21:17	24°09.94	49°44.58	5208	5196	12	yes
6*	23-Dec	14:34	17:53	25°08.62	52°01.73	5397	3504	12	yes
7*	23-Dec	18:31	23:05	25°08.64	52°01.74	5429	5417	12	yes
8*	27-Dec	22:09	02:41	26°29.59	70°30.95	5495	5470	12	yes
9	01-Jan	02:02	05:33	26°26.77	75°45.22	4705	4688	12	yes
10	01-Jan	18:42	19:52	26°28.33	75°43.66	4704	1501	12	yes
11	02-Jan	20:37	00:53	26°26.93	75°42.26	4690	4676	12	yes
12	03-Jan	06:41	10:09	26°29.17	76°38.39	4702	4691	12	yes
13	03-Jan	22:27	01:58	26°27.73	76°37.68	4767	4745	12	yes
14*	04-Jan	22:21	00:02	26°30.20	76°43.48	3856	1703	12	yes
15*	05-Jan	23:30	02:49	26°30.46	76°43.39	3866	3503	12	yes
16*	06-Jan	23:57	04:01	26°28.93	76°36.71	4786	4779	12	yes
17	07-Jan	21:01	22:44	26°30.01	76°47.98	1481	1472	12	yes
18*	08-Jan	05:00	09:07	26°26.99	75°40.79	4693	4680	12	yes
19*	10-Jan	12:43	17:10	29°38.52	65°47.42	5121	5109	12	yes

Table 8.1 CTD station summary. An asterisk (*) next to the station number indicates that the cast was used for MicroCAT calibration.

8.2 Water samples

There were 12 bottles on the frame and on most deep casts they were all used to obtain samples to calibrate oxygen and salinity. Bottle stops were each 5 minutes long when MicroCATs were being calibrated, otherwise they were for 2 minutes. The depths of the samples are illustrated in Figure 8.1. As noted above, the bottles on stations 2 and 10 were all closed at the same depth and these profiles were not used for MicroCAT calibration. It was therefore decided to exclude these bottles from the calibrations so as not to bias the calibration to a particular depth level. Differences were examined to check that they were within the expected ranges.

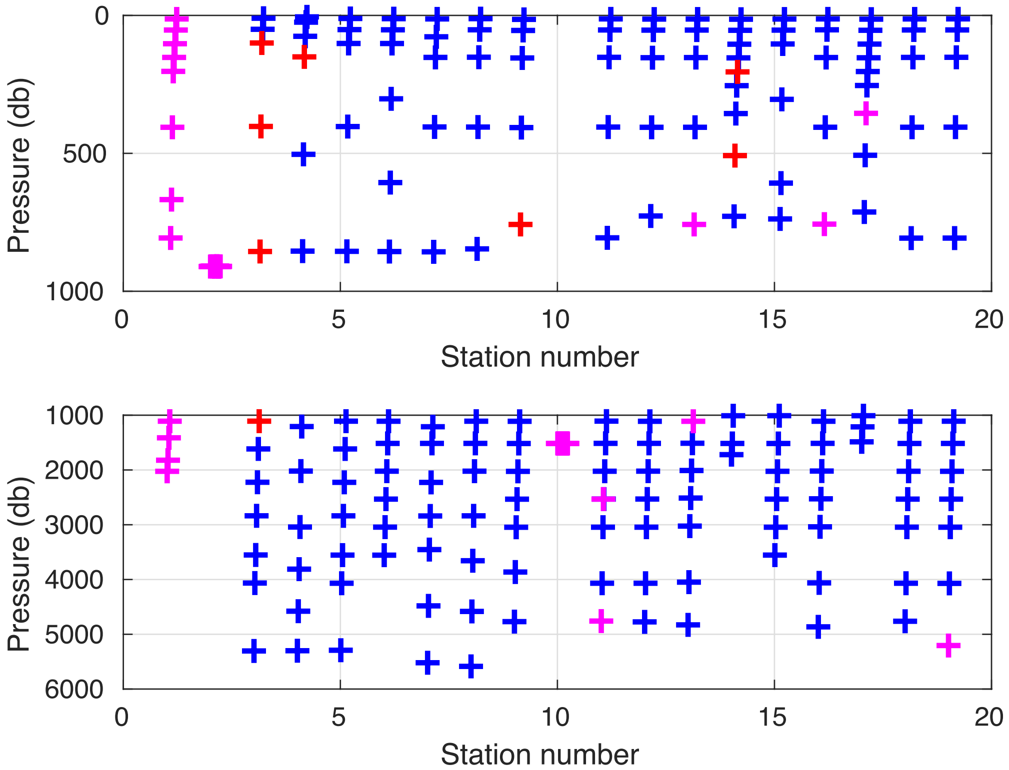


Figure 8.1 Depths of bottle stops for each CTD station. Bottles used for calibration of conductivity are shown in blue. Excluded outliers are in red. Other bottle stops that were not used are shown in magenta, these include stations 1, 2 and 10 and some stops where bottles did not close properly.

8.3 Analysis of salinometer standard seawater samples

A total of 27 standards were used to calibrate the bottle salinity measurements made by the salinometer. A standard was used before each crate of salinity samples, and at the completion of each salinometer session. All standard seawater samples were from batch P163 with 2*K15 = 1.99970 (Practical salinity 34.994). When the first standard was run it was found that an offset of -0.000011 was needed. From the offset and K15 value it can be deduced that the sample average was 1.999662. This deduced value was added as the first line of the sal_dy129_01.csv file and given sample number 999000. In this file following standard samples are indicated by sample numbers from 999001 to 999026.

The inferred offsets from the standard samples are shown as red and blue crosses in Figure 8.2, red denotes a sample at the start of a salinometer session. From these the offsets applied to the salinometer readings for samples from the CTD and underway were determined by linear interpolation using MEXEC routine 'msal_standardise_avg' (called by msal_01).

The temperature and humidity in the constant temperature lab, where the salinometer was setup, were monitored with an uncalibrated self-logging sensor. The temperature was found to be stable throughout the cruise at about 18.5°C.

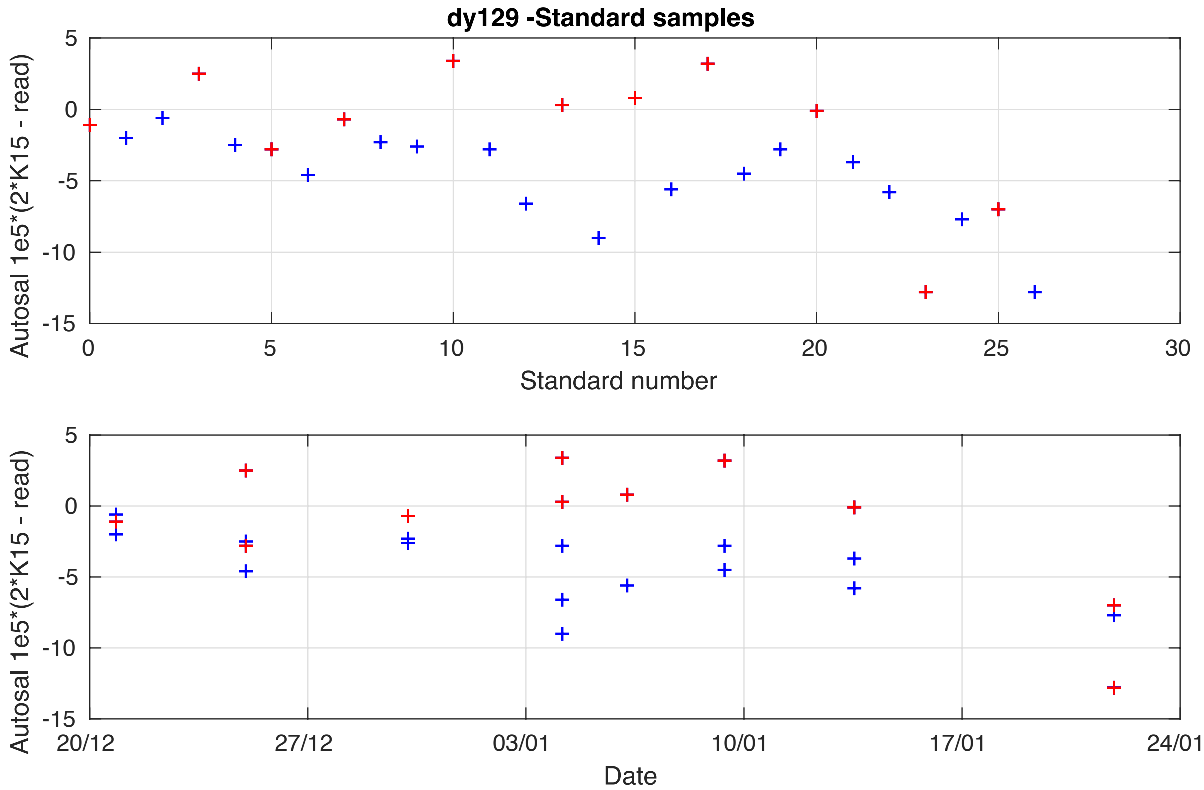


Figure 8.2 Inferred offset calculated as 2xK15 – salinometer average is shown a) as a function of the standard number and b) as a function of the date on which the samples were analysed. Red indicates a standard at the start of a new crate. Note a change of $5e^{-5}$ corresponds with a salinity difference of 0.001.

8.4 Accuracy of temperature measurements

A SBE35 was mounted on the side of the CTD frame for stations 1 to 18. The sensor of the SBE35 was located above those of the CTDs and so the SBE35 temperature values were almost always greater (Figure 8.3). This difference was assessed using data from bottle stops between 150db and 1500db where the temperature gradient was between 0 and 0.05°C/db. A linear regression of temperature difference between the SBE35 and the CTD sensors versus temperature gradient (determined from the downcast) found a regression coefficient of 0.86db (±0.12db for 95% confidence interval) for sensor 1 and 0.99db (±0.18db) for sensor 2. This is roughly consistent with the vertical separation of the instruments, but it is likely that the 'effective separation' is affected by mixing induced by the CTD rosette, and this perhaps explains why different values were found for sensors 1 and 2. Adjusting the SBE35 values to take into account the separation reduces the magnitude of mean difference from 0..016°C (sensor 1) and 0.019°C (sensor 2) to about 0.001°C for both sensors. Means and standard deviations of differences, both with and without adjustment of SBE35 values, are shown in Table 8.2 for different pressure ranges. From these we conclude that the temperature gradient effect is small below 3750db where sensor 1 agrees well with the SBE35 but sensor 2 appears to be about 0.001°C too cold. Significant further analysis would be required to determine whether there is a detectable pressure or temperature dependence of the offsets.

It was concluded that sensor 1 gave the best results and agrees with the SBE35 to within 0.001°C. A correction of + 0.001°C was added to the data from sensor 2.

Pressure range	**150-1500db (85 (samples)**		**1500-2500db (40 samples)**		**2500-3750db (27 samples)**		**3750-6000db (27 samples)**	
SBE35* – sensor 1	15.8 (16.4)	0.8 (12.4)	0.2 (1.5)	-0.5 (1.6)	1.1 (1.5)	0.6 (1.5)	0.2 (0.4)	0.2 (0.4)
SBE35* – sensor 2	18.5 (21.4)	1.3 (17.9)	1.5 (2.0)	0.5 (2.7)	2.2 (2.6)	1.7 (2.7)	1.1 (0.7)	1.0 (0.7)
sensor 1 – sensor 2	2.7 (13.7)		1.3 (1.4)		1.2 (1.5)		0.9 (0.6)	

Table 8.2 Mean (standard deviation) of temperature differences in milli-degrees for different pressure ranges. For differences with the SBE35 two values are shown, the second figure is the difference after an adjustment is made using the temperature gradient to account for the different location of the sensor on the CTD frame.

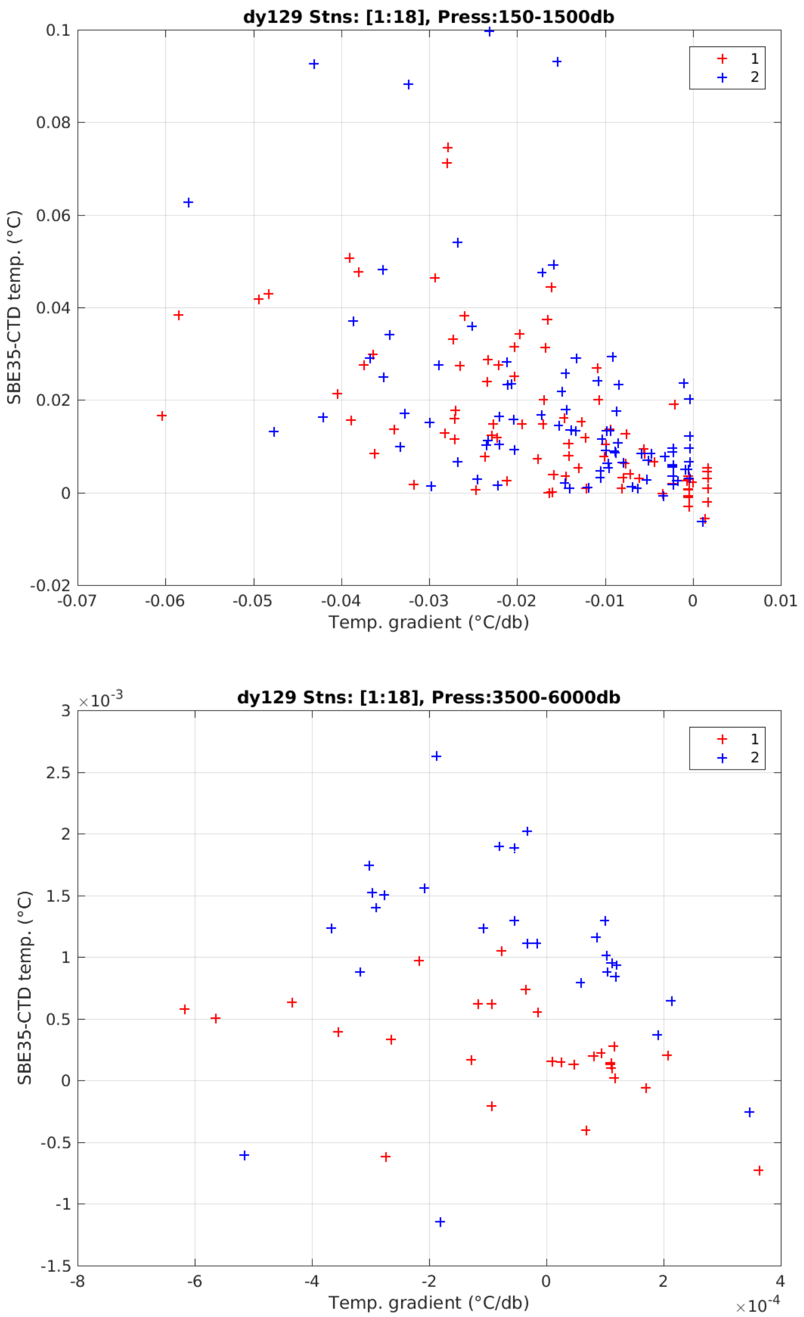


Figure 8.3 Temperature difference SBE35 – CTD as a function of temperature gradient. Upper panel is for samples with pressure between 150 and 1500db and the lower panel is for samples with pressure between 3500db and 6000db.

8.5 Calibration of conductivity

Before calibration of conductivity an adjustment of +0.001°C was made to the temperature on the secondary sensor pair.

With no calibration applied (Figure 8.4), for both sensor sets, the mean difference is close to zero but a clear pressure dependent offset is seen. The two sensor sets agreed well, except during the first three stations. Salinity difference were larger on stations 1 and 2 where there are also appeared to be some difference in temperature and these stations were excluded from the calibration.

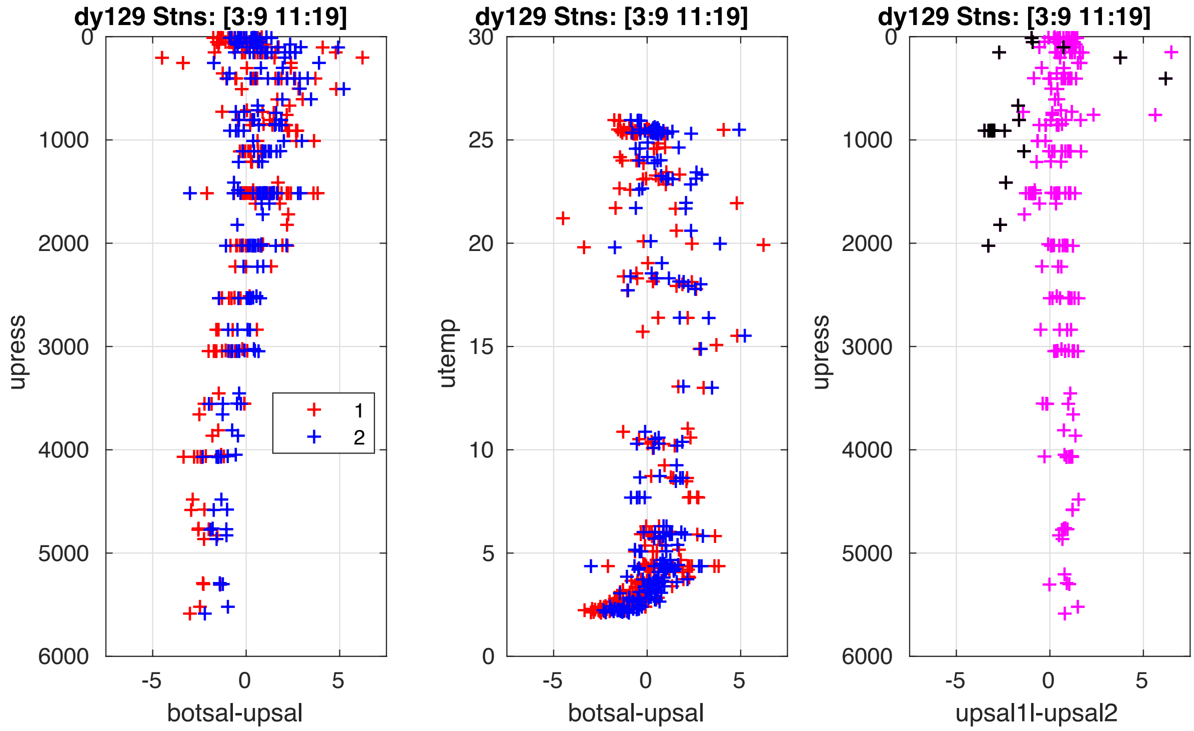


Figure 8.4 Comparison of CTD salinity with bottle salinity before calibration as a function of pressure (left) and temperature (centre). Also shown (right) is the difference in salinity calculated from the two sensor sets; on this plot stations 1 to 2 are highlighted with black crosses.

A calibration for each conductivity sensor was derived in the following form

Cond_cor = Cond_raw*(1 + A + B*Press/1000 + C*Temp)/1000

The coefficients A, B and C were determined in parallel using least squares multiple linear regression (Matlab function 'regress') that minimised the sum of the squares of the residuals. The residual was defined as:

Res = (Cond_sam / Cond_raw) – 1 – (A + B*Press/1000 + C*Temp)/1000

The coefficients of the calibration are shown in Table 8.3. After calibration the standard deviation between of the difference between CTD and bottle salinity was about 0.001 for both sensors and the difference between the two sensors had a standard deviation less than 0.001. The difference between sensors 1 and 2 is on stations 1 and 2 (an perhaps a smaller difference on station 3) is still evident after the calibration (Figure 8.5).

Sensors	A	B ($dbar^{-1}$)	C (°C^{-1})	Mean sal. diff ($x10^3$) pre cal.	RMS sal diff ($x10^3$) post cal.	No. of samps.	No. of Out-liers
Sens 1	0.06573	-0.02614	-0.00269	0.2	1.1	178	8
Sens 2	0.06508	-0.02136	-0.00184	-0.4	1.0	178	8

Table 8.3 Details of the conductivity calibrations. For each sensor set the parameters A, B, C and D were determined by multiple linear regression. The mean salinity difference (x 10^3) between bottle sample and sensor is shown pre-calibration (after calibration the difference is identically zero). Also shown is the RMS difference post calibration (x 10^3) and the number of samples used. Outliers further than 0.006 from the mean difference were excluded from the calculation.

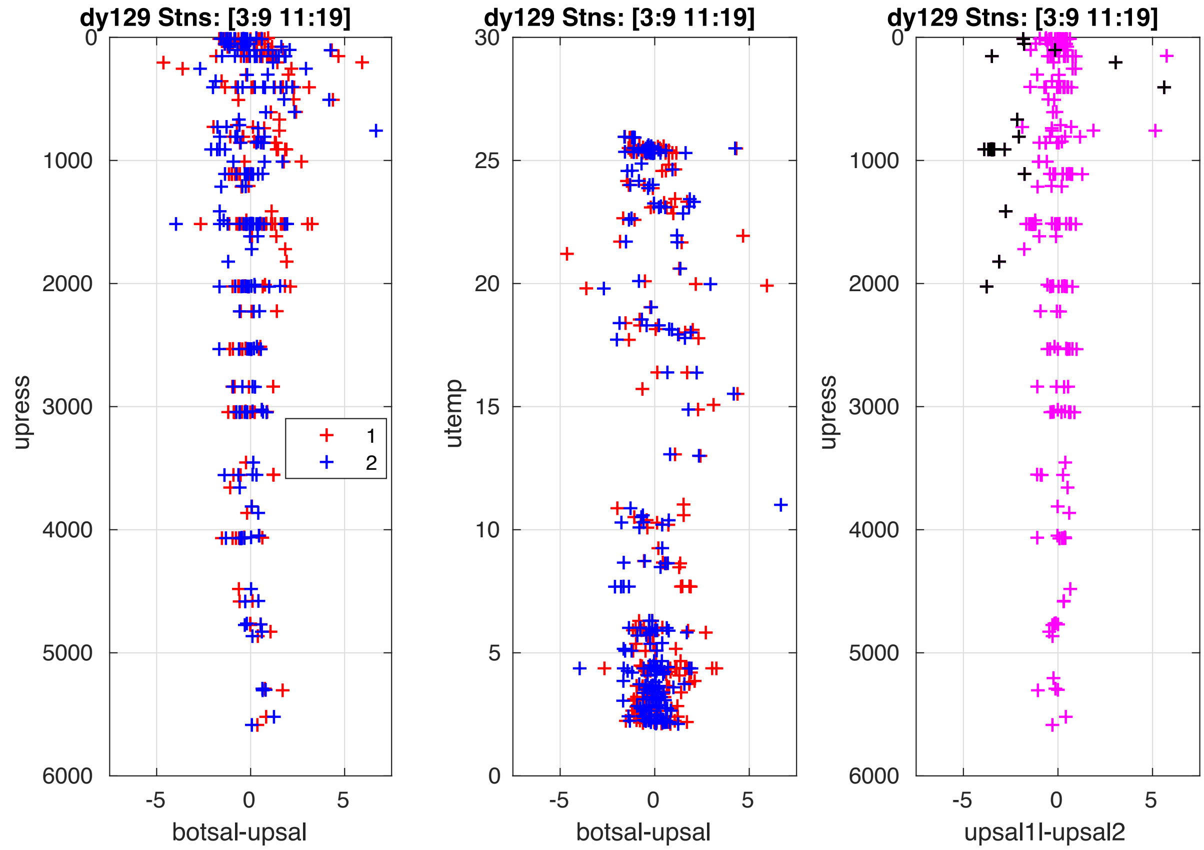


Figure 8.5 Comparison of salinity measurements at bottle stops after calibration. Red = bottle minus sensor 1, blue = bottle minus sensor 2. Left panel, as a function of pressure, middle panel as a function of temperature and right panel difference between the two sensors as a function of pressure.

8.6 Choice of sensors

For stations 4 to 19 sensor pair 1 is chosen as the primary sensor as its position on the CTD frame results in less noise on the up cast and the temperature had the best agreement with the SBE45, however, on stations 1 to 3 there was a difference in salinities calculated from the two sensor pairs and, whilst it is not possible to identify with certainty the source of this difference, the comparisons with bottle samples suggest that sensor pair 2 is more likely to give the better results.

9. Argo Float

Ben Moat and David Smeed

9.1 Deployment

Four 2000 dbar standard APEX floats were deployed during the cruise. These floats were installed with RBR sensors and CTD profiles were conducted at the deployment locations. One Deep APEX float with RBR sensors was deployed on Christmas day.

Float number	date	Time GMT	Latitude (N)	Longitude (W)	Water depth (m)
9137	18 Dec 2020	18:51	23° 51.44	41° 05.93	5043
9136	21 Dec 2020	16:05	24° 10.96	49° 44.03	5170
9187	23 Dec 2020	13:23	25° 08.65	52° 01.79	5297
0007*	25 Dec 2020	11:24	25° 32.98	59° 15.77	6000
7625	27 Dec 2020	20:00	26° 29.57	70° 30.99	5500

Table 9.1 Argo Float deployment. * indicates a deep APEX float.

9.2 Recovery

Deep Argo float s/n 25 was recovered on the 15th January 2021 at a position of 36° 12.68N, 43° 18.75 W. The float was deployed on JC174 in 2018 and developed a leak soon afterwards. It had been drifting on the surface since deployment.

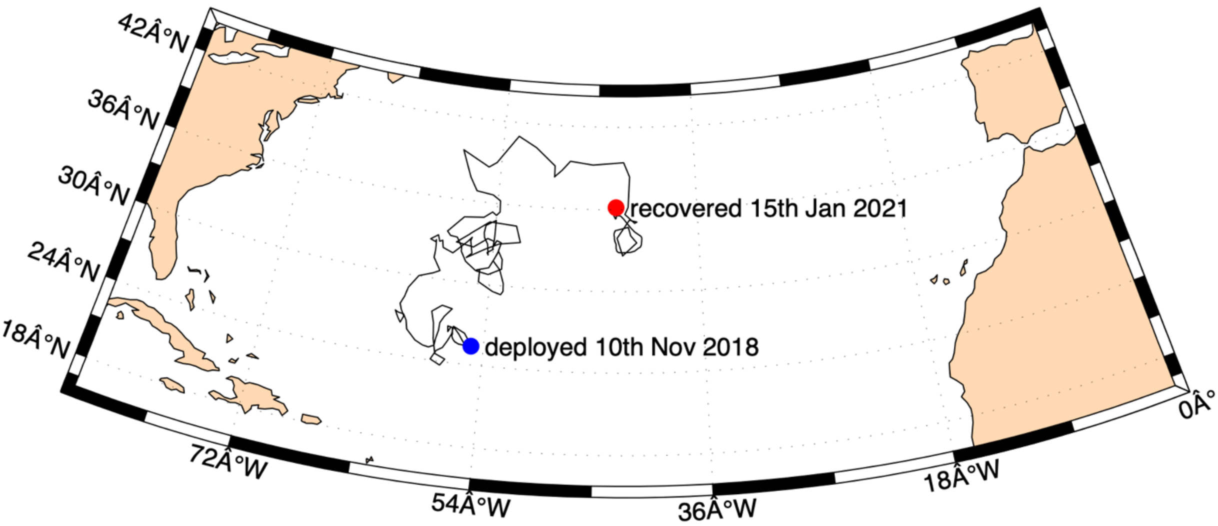


Figure 9.1 Trajectory of recovered deep Argo float #25.

10. Dissolved Oxygen analysis

Pete Brown, Eleanor Frajka Williams

Dissolved oxygen (DO) samples were collected during DY129 to calibrate both CTD DO sensors (primary and secondary), correct for drift, temperature and pressure influences, and to help in the calibration of oxygen sensors deployed on moorings. They were also used to help identify misfired or leaking Niskin bottles.

Samples were taken from every cast, with every Niskin bottle being sampled excluding known misfires and those observed obviously leaking on CTD recovery. Duplicates were taken from a minimum of 1 Niskin per cast. Discrete water samples collected were subsequently analysed by automatic Winkler titration using a Metrohm Ti-Touch titration system and amperometric endpoint detection.

10.1 Sample collection

Water sampling was carried out according to the guidelines by Langdon (2010) and Dickson (1994) with seawater being collected directly into pre-calibrated Pyrex iodine titration bottles (either 125 ml flasks with flared necks or 100mL standard reagent bottles). This is analogous to previous cruises (see RAPID cruise reports No. 30, 37, 52 for more details). The key steps were as below:

- Prior to sampling each station, the reagent dispensers were emptied and refilled 2-3 times to remove any bubbles that had formed in the chemical lines. This minimizes the risk of bubble injection into samples.
- Silicon Tygon tubing (S3 E-3603 - 8mm [5/16”] ID x 11.2mm [7/16”] OD) was attached to the Niskin spigot to transfer water to the flask. The tubing was kept submerged in sea water between stations to reduce the tendency of bubbles to form within it.
- Bottles and stoppers were rinsed three times with Niskin water prior to sample collection beginning.
- Bottles were filled slowly to minimize water turbulence, water flow decreased by pinching the tubing. When full, the bottles were overflowed by three flask volumes of water (approximately 15 seconds at full flow).
- The bottles were held at the neck to minimise transferal of heat to the water.
- Prior to addition of chemicals, the fixing temperature was measured with a digital thermometer (RS 206-3738 calibrated chromel alumel thermocouple thermometer S/N 63001993). This temperature is used to correct the bottle volume due to glass expansion/contraction, and to convert the oxygen concentration measured from umol/L to umol/kg.
- 1mL of manganese chloride was carefully added to the bottle, immediately followed by 1mL of alkaline iodide solution. Dispenser tips were lowered beneath the water surface to eliminate the loss of chemical through splashing, and the entrainment of bubbles into the sample.
- Stoppers were inserted slowly and at an angle to stop bubbles getting trapped beneath.
- Bottles were vigorously shaken for 15-30 seconds (twisted about 20 times) to facilitate the mixing and formation of the precipitate (manganese hydroxides). A second shake was performed after 30 min.
- Deionised water was added to the necks of the conical flasks to act as an additional gas-tight seal. This was maintained until analysis. All bottles were kept in the dark in their crates until analysis.
- Sample storage varied between 1-4 days. Analysis in batches of stations is more time, chemical and standard efficient, and improves accuracy compared to immediate analysis.
- Each stopper is unique to each flask. Regular checks were made to ensure each stopper/flask pair had the same number attached to them. Cracks and chips in both the bottles and stoppers were regularly checked for.

10.2 Blank analysis

Prior to the analysis sf seawater samples, the system blank was measured and calculated. This represents the signal produced by the addition of the chemical reagents. Bottles were ¾ filled with deionized water and a stirrer bead, and chemicals were added in reverse order with stirring in between (1mL sulphuric acid, 1mL alkaline iodide solution, 1mL manganous chloride). 1mL of iodate standard solution (1.667 mol/L, OSIL) was then added and titrated with thiosulphate solution up to an endpoint of current $0.1x10^{-6}$ A. The titration of a minimum of 3 further additions of 1mL iodate standard was carried out and the difference between these and the first analysis was calculated as a single estimate of the blank. Three further blank estimates would then be carried out, or more if the estimated blank was not stable. Figure 10.1 shows the output of the blank outputs throughout DY129.

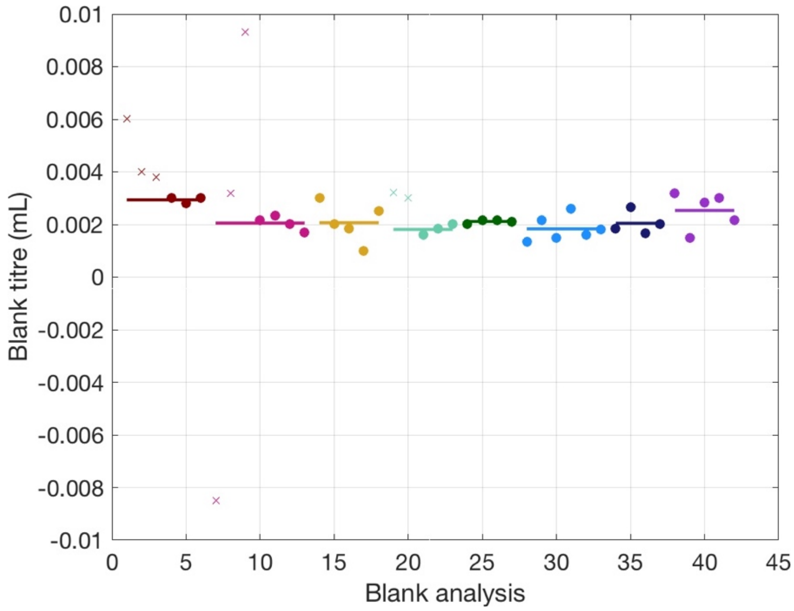


Figure 10.1 Output of blank analyses during DY129. Unique colours indicate different days of analysis. 'x' marks analyses that were classified as outliers and not used to calculate the blank mean (lines).

10.3 Standard Analysis

After blank analyses were complete, 5mL of iodate standard would be added to the analysis bottle and titrated with thiosulphate. This would be repeated a further three times as a minimum and used to estimate the concentration of the thiosulphate solution. The effect of any blanks would be removed (if chemicals had been added prior to the iodate standard) before titration concentration calculation. Figure 10.2 shows the output of the standard analyses throughout DY129.

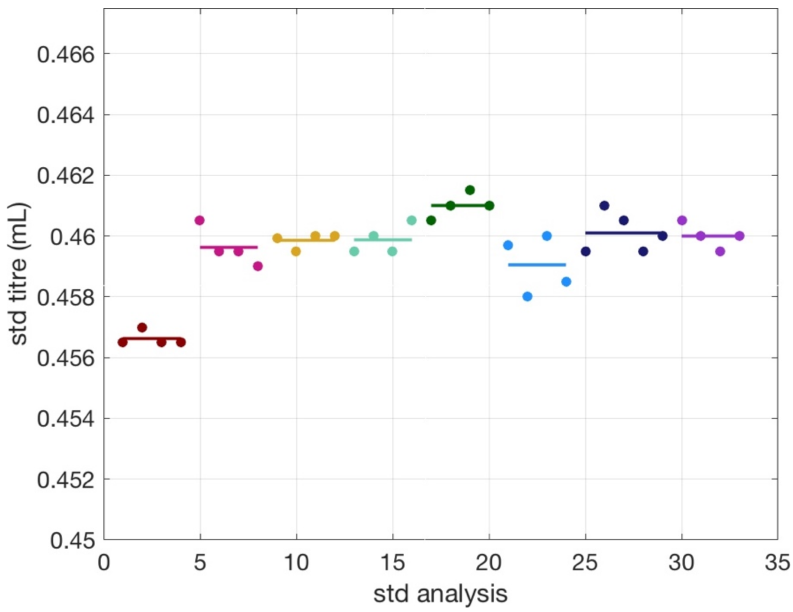


Figure 10.2 Output of 5mL iodate standard analyses during DY129. Unique colours indicate different days of analysis. 'x' marks analyses that were classified as outliers and not used to calculate the standard mean (lines).

10.4 Sample analyses

After blank and standard analyses batches of samples were run, typically 2-3 stations at a time. When ready to titrate, the Milli-Q water seal was poured away, the neck dried and the stopper of the flask carefully removed. A 1 ml aliquot of 5 M sulfuric acid was dispensed, immediately followed by a clean magnetic stirrer. The flask was placed on the stir plate and the electrode and burette were carefully inserted to place the tips in the lower-middle depth of the sample flask. The initial volume of sodium thiosulphate for each sample was 0.3 ml before continuing to be titrated at 0.0005 ml intervals using the amperometic end-point detection electrode (Culberson and Huang, 1987) to the end current of 0.1 x 10^{-6} A. The resultant volume of titrant was recorded both by manual logging and automatically on the Ti-Touch. Following this the value was converted to a DO concentration. Figure 10.3 shows a summary of the vertical distribution of oxygen concentrations measured on DY129.

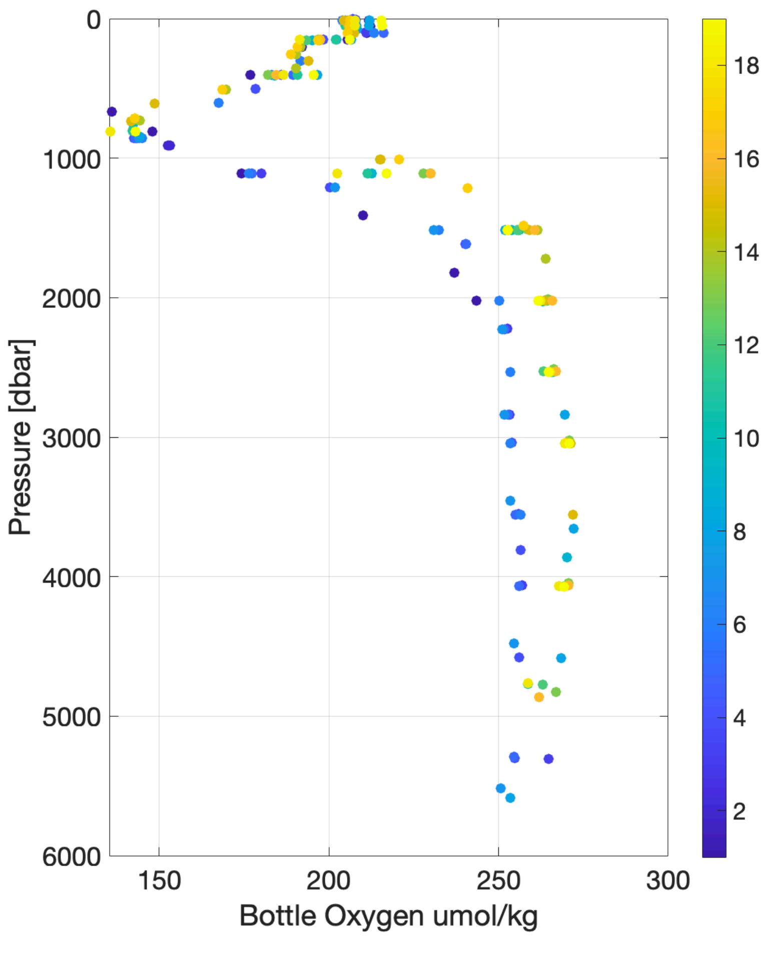


Figure 10.3 DY129 oxygen profile. Colour scale is CTD number.

10.5 Precision and accuracy

We collected 36 duplicate samples in total, 21 from the same Niskin. Of those from the same Niskin, a mean absolute difference of 0.295 umol/kg and standard deviation of 0.208 umol/kg was calculated. This indicates measurement precision within individual casts, as duplicates were always analysed in the same session. However, for CTDs 2 and 10, all 12 Niskins on the rosette were fired at the same depth. This enables investigation of the effect of different Niskin bottles and samplers on precision. For CTD 2 (Figure 10.4a) a standard deviation of 0.192 umol/kg from 8 analyses was calculated, whereas for CTD 10 (Figure 10.4b) a standard deviation of 0.159 umol/kg from 12 analyses was calculated. These compare well to the stated aim of a precision of 0.15 umol/kg (Langdon, 2010).

Combined with same-Niskin duplicates (Figure 10.5) gave an estimate of precision across CTD, niskin, analysis-day, sampler and operator. were sampled in duplicates by different samplers and analysed in different sessions by different operators. A mean absolute difference of 0.268 umol/kg and standard deviation of 0.177 umol/kg was calculated.

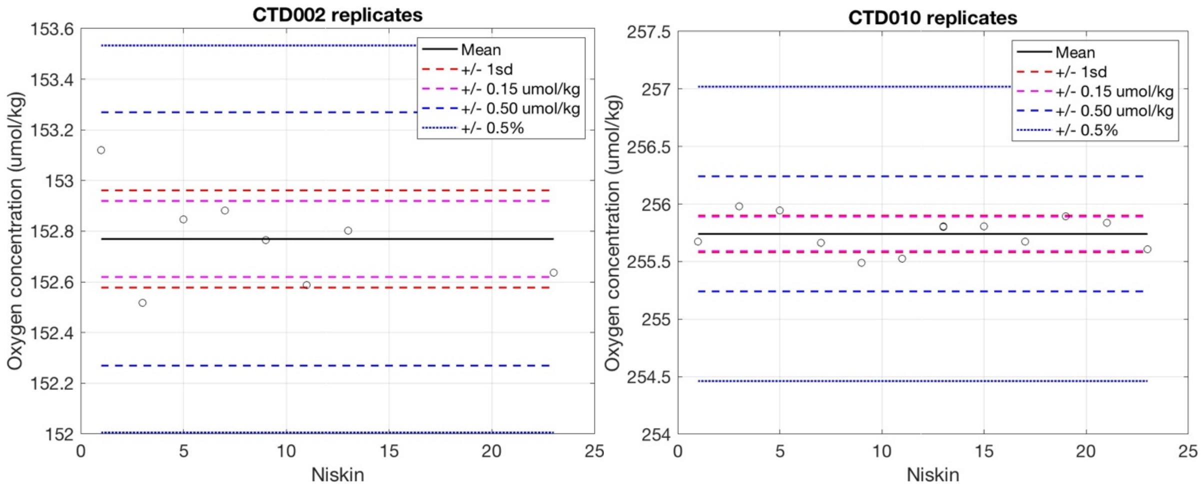


Figure 10.4 (a) Left, CTD 002 replicate analyses. (b) right, CTD10 replicate analyses.

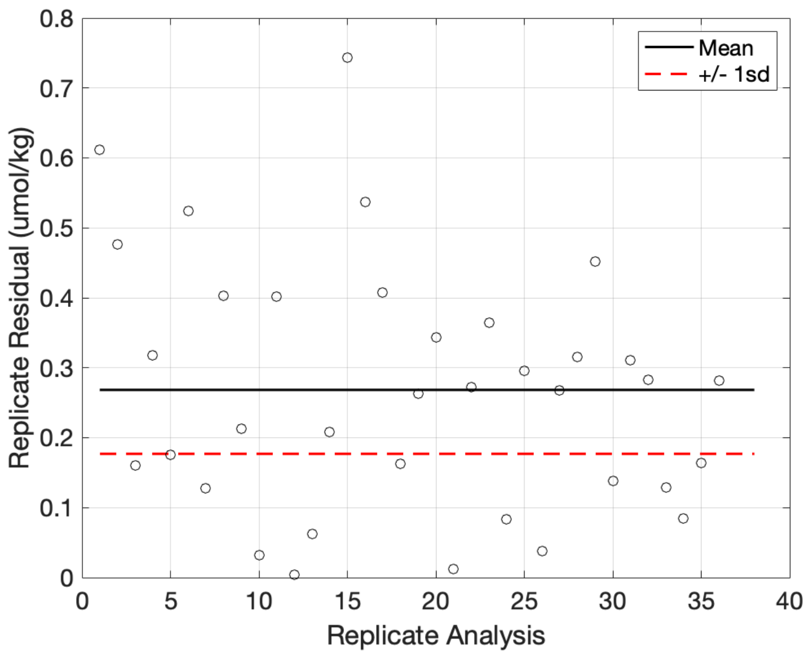


Figure 10.5 Absolute residual differences of replicate analyses during DY129.

10.6 Comparison of bottle measurements to CTD outputs

Bottle concentrations will be used to calibrate the two sensors attached to the CTD rosette. Figure 10.6 shows a comparison between the two before calibration. Post-cruise calibration will help correct the sensor profiles for influences due to temperature, pressure and drift.

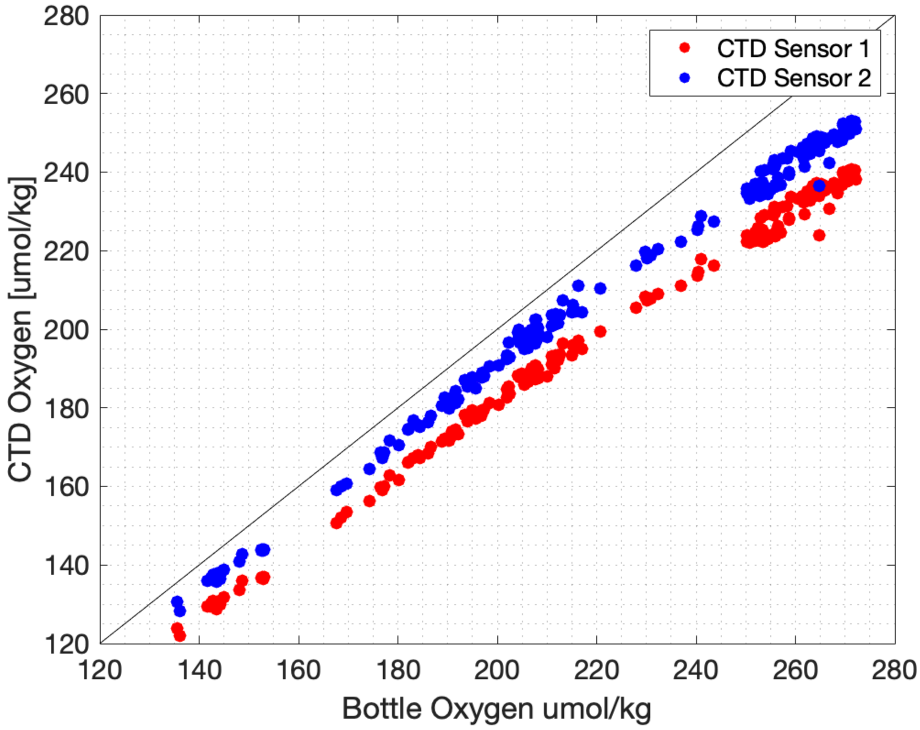


Figure 10.6 Pre-sensor calibration comparison with bottle concentrations during DY129.

References

Culberson, C.H. and Huang, S. (1987). Automated amperometric oxygen titration. Deep-Sea Res. Pt A 34(5-6), 875-880. doi:10.1016/0198- 0149(87)90042-2

Dickson, A.G. (1994). Determination of dissolved oxygen in seawater by Winkler titration. Technical report, WOCE operations manual, WOCE report 68/91 Revision 1 November 1994.

Langdon, C. (2010). Determination of dissolved oxygen in seawater by Winkler titration using the amperometric technique. The GO-SHIP repeat hydrographic manual, IOCCP report 14, version 1.

11. Discrete chemical sampling

Pete Brown

Discrete bottle samples were collected on all CTD stations for the analysis onboard of oxygen, and also the later analysis of dissolved inorganic carbon (DIC), total alkalinity, and inorganic and organic nutrients and organic nitrogen in laboratories at home. Not all parameters were sampled for on all stations, and a number were only from one depth. Two stations (2 & 10) were solely for the benefit of collecting multiple bottle samples for carbon analysis from a single depth/water mass. This is to use as a secondary calibration standard, due to the global shortage of primary calibration reference materials caused by the COVID-19 pandemic. For one station (12), nutrient samples were collected in bulk from deep and shallow water surfaces with the aim of using them for organic nutrient analysis procedure testing at NOC.
A summary of the station locations and chemical parameters sampled for these is given in Table 11.1. In total, 19 CTDs were carried out, all being sampled for oxygen, 4 for DIC and alkalinity, and 5 for inorganic and organic nutrients.

The methods followed for sample collection were as described in the DY039 cruise report (Rayner et al, 2016). DIC and alkalinity were kept at lab temperature after being preserved using mercuric chloride solution, while nutrient samples were immediately frozen for storage.

ALK | DIC | DI13C | NUTS

Date	18-Dec	18-Dec	21-Dec	22-Dec	22-Dec	23-Dec	23-Dec	27-Dec	01-Jan	01-Jan	03-Jan	03-Jan	04-Jan	04-Jan	06-Jan	07-Jan	07-Jan	08-Jan	10-Jan	Date
Lat	23.51	23.51	24.1	24.1	24.09	25.08	25.08	26.29	26.27	26.38	26.27	26.29	26.27	26.3	26.3	26.29	26.3	26.27	29.39	Lat
Lon	41.05	41.05	49.44	49.43	49.44	52.01	52.01	70.3	75.45	75.43	75.42	76.38	76.38	76.44	76.43	76.36	76.48	75.4	65.47	Lon
Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Station
Depth (m)																				Depth (m)
~5500								O												~5500
~5400							O													~5400
~5200			O	O	O															~5200
~4750													O			O				~4750
~4700									O		O	O						O		~4700
~4500				O				O												~4500
~4400							O													~4400
~4000			O		O						O	O	O			O		O	O	~4000
3800									O											3800
~3750				O																~3750
~3600								O												~3600
~3500			O		O	O									O					~3500
~3400							O													~3400
~3000				O					O		O	O	O		O	O		O	O	~3000
~2800			O		O		O	O												~2800
~2500						O			O		O	O	O		O	O		O	O	~2500
~2200			O		O		O													~2200
~2000	O			O		O		O	O		O	O	O		O	O		O	O	~2000
Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Depth (m)
Station																				Station

Date	27-Oct	29-Oct	31-Oct	03-Nov	06-Nov	08-Nov	09-Nov	10-Nov	12-Nov	13-Nov	14-Nov	17-Nov	19-Nov	20-Nov	20-Nov	21-Nov	21-Nov	22-Nov	22-Nov	24-Nov	25-Nov	Date
Lat	24.55	23.44	23.23	23.46	24.12	24.11	24.11	25.22	24.4	25.52	26.3	26.26	26.28	26.3	26.3	26.3	26.31	26.31	26.31	26.3	26.3	Lat
Lon	21.1	24.11	30.57	41.5	49.44	49.45	49.46	55	62.45	68.5	70.33	75.45	75.44	76.36	76.49	76.37	76.49	76.44	76.37	76.49	76.49	Lon
Station	5	7	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Station
Depth (m)																						Depth (m)
~1600			A C I N		A C N		N															~1600
~1500	A C I N			A C I N				A C I N	N	A C I N	N	N	A C I N			A C N		N				~1500
~1390																	N			N		~1390
1299																				N		1299
1199																				N		1199
1152	A C I N																					1152
~1100			A C I N	A C I N	A C N		A C I N	A C I N	N	A C I N		N	A C I N			A C N	N	N	N	N		~1100
1046														A C N								1046
998																				N		998
~900							A C I N													N		~900
~850					A C N			A C I N		A C I N												~850
~800				A C I N					N		N	N	A C I N							N		~800
771																A C N						771
~750	A C I N		A C I N														N	N				~750
698																				N		698
597																				N		597
497																				N		497
~400	A C I N	A C N	A C I N	A C I N	A C N	A C N	A C I N	A C I N	N	A C I N	N	N	A C I N	A C N		A C N	N	N				~400
346																A C N						346
298																				N		298
~150	A C I N			A C I N	A C N		A C I N	A C I N	N	A C I N	N			A C N				N	N			~150
~100		A C N				A C N									A C N						A C N	~100
~80		A C N													A C N						A C N	~80
~60		A C N				A C N									A C N						A C N	~60
~50	A C I N		A C I N	A C I N	A C N		A C I N			A C I N	N		A C I N	A C N		N	N	N		N		~50
~40		A C N				A C N									A C N						A C N	~40
~20		A C N				A C N									A C N						A C N	~20
~10	A C I		A C I N	A C I N	A C N		A C I N	A C I N	N	A C I N	N		A C I N				N					~10
	5	7	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

Table 11.1 Location of CTD samples collected for chemical analysis during DY129. Key: A - alkalinity, C - DIC, O - oxygen, N – inorganic and organic nutrients.

References

Rayner, D.; et al, . 2016 RRS Discovery Cruise DY039, 17 Oct - 01 Dec 2015, Southampton, UK to Nassau, Bahamas. RAPID moorings cruise report. Southampton, UK, National Oceanography Centre Southampton, 183pp. (National Oceanography Centre Cruise Report, 37)

12. Contros HydroC CO_2 sensors

Pete Brown

12.1 Background

Contros HydroC pCO_2 sensors were deployed on JC174 at approximately 40-50 m depth on the moorings EB1, MAR1 and WB1. They were paired with Deep SeapHOx combined pH-oxygen-temperature-salinity-pressure sensors, and installed on a sensor frame attached to the bottom of a remote access sampler (RAS) with a further MicroCAT CTD installed for good measure. They were deployed with HydroB battery packs (84 x Lithium D cells) and set to sample once per day. As before, the sensors were configured with flow-through head and pumps (in this instance low-power Seabird Electronics 5M pumps) that directly move seawater across the anti-fouling copper-protected membrane, speeding up the equilibration and response time. As the ABC Fluxes program was at an end, no further deployments were made.

12.2 Recovery of sensors deployed on JC174

EB1 (S/N CO2-0918-001):
This was recovered in March 2020 on JC192. For full details see JC192 cruise report.

MAR1 (S/N CO2-1114-001):
The sensor was heavily fouled on retrieval. Due to the curtailment of the JC192 cruise, this sensor was collected 9 months later than previously planned for. Despite this, communication with the sensor was immediately possible when connected to the mains. The sensor collected a full 2-year long dataset, up to and including the day before recovery. Further investigation revealed it appeared to have stopped zeroing / flushing properly from the end of May 2019, with an immediate jump in CO2 output from that point. The sensor was installed in an underway fashion in a sink in the CTD annex to allow for comparison to two other pCO2 systems being run in a similar fashion. This would be to see if the offset was till present. During this process it was found that the pump was not functional, possibly related to the zero/flushing issues /change in performance of the system in May 2019. When separated from the sensor and powered independently the pump was operational. The cable too was able to transfer power; instead, it appears that no power was being provided by the sensor to the pump. Operation in underway mode is described in more detail in the underway pCO_2 section.

WB1 (S/N CO2-1114-003):
The mooring at WB1 became detached from its anchor in October 2019. Both beacons were communicative but prior to recovery there was a further a parting in the wire. Instruments beneath 95m were recovered on an initial recovery cruise. The topmost part was recovered on a second trip but unfortunately there was no RAS or biogeochemical sensors (CONTROS, SeaBird SeapHOx) attached to the buoyancy recovered.

13. Satlantic SeapHOx sensors

Pete Brown

13.1 Background

The SeaBird Deep SeapHOx sensor combines a Deep SeaFET pH sensor with a SeaBird SBE37 MicroCAT CTD and SBE63 oxygen optode (MicroCAT-ODO). Three of these sensors were deployed on JC174 in a bespoke frame beneath the Remote Access Sampler at ~40m depth on moorings EB1, MAR1 and WB1

13.2 Recovery of sensors deployed on JC174

EB1: SeaFET S/N 721-0004, MicroCAT-ODO S/N 12906, Deployed 29 Oct 2018

This was recovered in March 2020 on JC192. For full details see JC192 cruise report.

MAR1: SeaFET S/N 721-2002, MicroCAT-ODO S/N 12903 – Deployed 8 Nov 2018. Recovered 22 Dec 2020
The sensor was heavily fouled on retrieval. Due to the curtailment of the JC192 cruise, this sensor was collected 9 months later than previously planned for. Despite this, communication with the sensor was immediately possible when connected to the mains. The sensor collected a full 2-year

long dataset, up to and including the day before recovery. Further investigation revealed problems with the performance of its conductivity sensor part-way through deployment, with knock-on effects on the pH outputs. As a standalone MicroCAT-ODO was also deployed on the RAS frame and has a full, non-compromised dataset it will be possible to recalculate pH values from raw electrode voltages using the new salinity dataset. Subsequent to retrieval the SEAFET part of the sensor was paired with an operational MicroCAT-ODO and deployed in an underway mode. For more details see the underway pCO_2 section.

WB1: SeaFET S/N 721-2006, MicroCAT-ODO S/N 20312 – Deployed 25 Nov 2018

The mooring at WB1 became detached from its anchor in October 2019. Both beacons were communicative but prior to recovery there was a further a parting in the wire. Instruments beneath 95m were recovered on an initial recovery cruise. The topmost part was recovered on a second trip but unfortunately there was no RAS or biogeochemical sensors (CONTROS, SeaBird seapHOx) attached to the buoyancy recovered.
in September 2019.

14. Remote Access Samplers (RAS)

Pete Brown

14.1 Background

The McLane Research Laboratories Inc. (www.mclane.com) Remote Access Sampler (RAS) 3-48-500 is an instrument for the autonomous collection of seawater samples. It works by pumping water out of the bottom of an acrylic sample cylinder in which an evacuated sample bag is installed. A pressure gradient is created, and the removed volume is replaced by local seawater being pushed into the sample inlet, through a multi-position valve and into the bag. A movement of the valve back to its home position isolates the sample collected until recovery. Pre-injection of a sample preservative (1 mL of 20% saturated mercuric chloride solution; Dickson et al., 2007) allows the sample to be stored safely on the instrument indefinitely without compromising sample integrity. The sampler is capable of collecting 48 samples, from a frequency of 3 samples an hour to a deployment period of 18 months (aprox. 1 sample every 11 days).

Four McLane Research Laboratories Remote Access Samplers (RAS) were deployed during JC174 across the subtropical North Atlantic as part of the NERC-funded Atlantic BiogeoChemical (ABC) Fluxes program. These were located at ~40m depth on moorings EB1, MAR1 and WB1, and at ~1500m depth on WBH2. As the ABC Fluxes program was at an end, no further deployments were made

14.2 Recovery of RAS systems deployed as part of JC174

EB1 – Sampler S/N 14520-01 Deployed 29-10-2018

This was recovered in March 2020 on JC192. For full details see JC192 cruise report (Moat, 2020).

MAR1 – Sampler S/N 13278-02 installed in frame 14520-02
Deployed 08-11-2018 Recovered 22-12-2020

The final sampling event had been programmed for 14/05/2020, so recovery was more than 7 months after this. The system was in a fouled condition on recovery and had sustained some damage: while all tubing on the topside of the instrument was intact and in position, tubing fittings to the bottom of the sample bottles had become detached in 24 of 49 locations, indicating single or multiple events of large energy of some sort. Tubing detachments were for samples 2, 3, 5, 7, 9, 10, 11, 13, 21, 22, 23, 25, 27, 30, 31, 32, 33, 35, 41, 43, 45, 46, 47, 48. The tubing attached to the pump outlet had also detached; depending on timing this raises the (albeit very low) likelihood of effluent freshwater being entrained in with sample seawater.

Data downloaded from the system suggested that it completed its sampling schedule, pumping 500 mL for each sample event. All pump and valve information appeared normal. Removal of sample bags revealed water had been collected in 42 of 48 locations. Low water volumes were found at positions:

- 31 (scheduled sampling date 23-Oct-19),
- 33 (16-Nov-19), and
- 36 (22-Dec-19).

Empty bags were found at positions:

- 22. (scheduled sampling date 07-Jul-19)
- 25. (12-Aug-19)
- 39. (27-Jan-20)
- 46. (20-Apr-20)
- 47. (02-May-20), and
- 48. (14-May-20)

All the bags were removed successfully and of those with water in all seemed to have maintained a vacuum (so no holes in/leaking bags).
It is postulated that the bottom tubing possibly became detached sometime in mid-April 2020, as the last three scheduled samples were not collected.

WB1 – Sampler S/N 13278-01 Deployed 25-11-2018 Not Recovered

The mooring at WB1 became detached from its anchor in October 2019. Both beacons were communicative but prior to recovery there was a further a parting in the wire. Instruments beneath 95m were recovered on an initial recovery cruise. The topmost part was recovered on a second trip but unfortunately there was no RAS attached to the buoyancy recovered.

WBH2 – Sampler S/N 14520-02 on frame 13278-02. Deployed 21-11-2018 Recovered 03-01-2021

The system was recovered without fouling, due to its deep deployment depth. There was some corrosion of the frame, but nothing that threatened structural integrity. One bolt connecting the bottom frame to the top frame was sheared. All topside tubing and that to the bottom of the sample cylinders was intact and still in position. The first four sample bags were full, the bag at position 5 was half full, but all remaining sample bags on the system were empty. It was noticed that the valve position was located at position 5. Communication could not be made with the electronics controller unit. Opening and removal of the controller housing revealed a small amount of water inside, along with salt deposits. A number of batteries had salt at their terminals and the checking of all battery voltages found that all were <0.4V. It appears that water ingress caused shorting of the batteries, although the water ingress appeared to be only minor as there was no apparent water damage to the electrical boards.

All samples collected will be returned to NOC for analysis for inorganic and organic nutrients, before being transported to the University of Exeter for inorganic carbon and alkalinity analysis.

References

Brown, P. J., and D. Rayner, 2015, Standard operating procedure for the pre-deployment setup of the McLane Remote Access Sampler (RAS)Rep., National Oceanography Centre, Southampton, UK.

Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.) 2007, Guide to Best Practices for Ocean CO2 Measurements. PICES Special Publication 3, 191 pp.

Moat, B, 2020, RRS James Cook Cruise JC192, 9-28 March 2020 RAPID cruise report for Cruise JC192. Southampton, National Oceanography Centre, 109pp. (National Oceanography Centre Cruise Report, 71)

15. Underway carbon analysis

Pete Brown

15.1 Introduction

During the course of DY129 four systems (Table 15.1) were used to observe the carbon system of the non-toxic underway seawater supply. The system was turned on ~08:50 UTC 14th December 2020, turned off 12:17 UTC 28th December 2020 and turned on ~15:58 UTC 31st December 2020.

Manufacturer	Model	Serial Number	Parameter	Location	Install date
SubCTech	OceanPack MK2 Flow-Through Analyzer	CO2-DLZEGAMK2-19-0-1803-01	pCO2	Deck Lab (Fig 1.)	9th Dec 2020
Pro-Oceanus	CO2-Pro CV	40-774-75	pCO2	Sink in CTD annex. Direct U/W feed through flow-through head (Fig 3.)	14th Dec 2020
CONTROS	HydroC	CO2-1114-001	pCO2	Plastic container in Sink in CTD annex that U/W feed overflows (Fig 3)	26th Dec 2020
SeaBird	Deep SeapHOx2	0002002 (SEAFET); 03714116 (MicroCAT-ODO)	pH / T / S / P / O_2	Plastic container in Sink in CTD annex that U/W feed overflows (Fig 3)	4th Jan 2021

Table 15.1 Instruments used to measure carbon from the non-toxic seawater supply.

15.2 SubCTech

- Firmware updated with new version to fix problems observed on previous cruise (DY116) that caused measurement schedule to not be followed correctly.
- Uninterruptible power supply installed in front of system in order to eliminate problems thought to occur with power spikes/drops on previous trip that caused system to reset.
- System connected to single standard gas (422ppm) located in rack in ship's hangar via stainless steel tubing.
- Non-toxic supply not turned on for first 6 days of trip as ship in territorial waters. Manufacturers advised turning on system despite this and running without water flow-through. This enabled check of system performance. When turned on, the flow rate of the water supply was set to within recommended range of 12 +/- 4 L/min
- Recurring 24-hour 'phases' schedule set: measure water for 2 hours, zero for 5 minutes, span gas 1 (422ppm) for 5 minutes, measure water for 21 hours 50 minutes

- Water supply to instrument switched off on afternoon of 16th December due to flooding of Deck Lab floor caused by leaking drainage system. Supply not switched on again until 22nd December, this was due to having to wait for water leak to dry sufficiently for repairs to be made / sealant curing.
- Issues with the recognising of USB sticks in order to download data. Last data download via this route 26th December.

Figure 15.1 SubCTech system installed next to sink in Deck Lab, and its standard calibration gas cylinder in Hangar.

- 28th December, after switching off of non-toxic supply due to entry into Bahamian territorial waters, error notification relating to datalogging became visible on system screen. Data storage availability showing as 0MB indicating full memory card and inability to save data. System had also lost memory of its 'Phases' schedule but was still measuring CO2 levels. Due to inability to recognise USB sticks to download data advice was sought from manufacturer.
  - System was subsequently switched off, and Micro SD card (located in SD card adaptor) removed from slot on top of system.
  - SD card adaptor showed some evidence of corrosion, possibly due to water ingress. Reading of memory card on separate computer found file system intact including calibration and configuration details, and 3.2 GB of available space. Reinsertion into SubCTech system did not result in memory card being read.
  - SD card adaptor was changed followed by use of different Micro SD card with identical file structure with both original and different SD card adaptors. No combination remedied the situation. A 3rd blank memory card was tried but with the same results.
  - Further advice was to remove the system cover to look for any clues as to the system behaviour inside. This revealed salt build-up on the main processing board, concentrated particularly under the location of the SD card slot and where the cable from the USB port joined the board. Removal of the ribbon cable connecting to the SD card port showed further evidence of water/salt. It is likely that during use of the adjoining sink for sensor cleaning (and from/to which the SubCTech drew/eluted its water) some seawater managed to drop into the top of the system through the SD card port. See Figure 15.2 for photos.

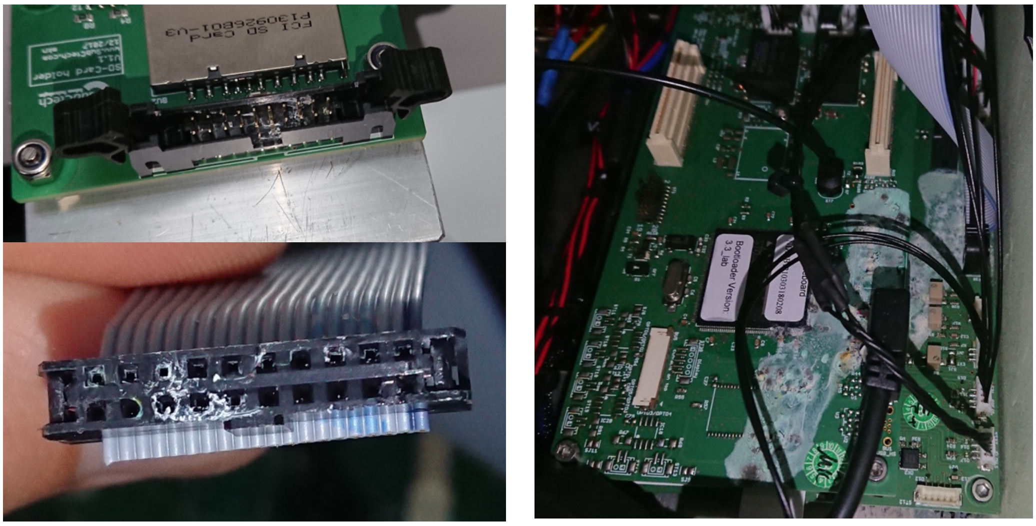


Figure 15.2 Salt damage to SD card port, cable and main board.

- As the system was still able to measure CO2 just not save it, a standalone PC laptop was connected to the SubCTech through Serial cable-RS232-USB in order to log the live 1Hz outputs. The original phase schedule was reprogrammed enabling measurement of zero and span 1 gas (422 ppm). Due to its memory issues though, only raw, uncalibrated data were output and saved, thus requiring substantial post-cruise calibration processing.

15.3 Pro-Oceanus

The CO2-Pro CV was installed in the CTD annexe in a sink that output directly over the side of the ship (Figure 2.). It's flow-through head enabled direct connection to the non-toxic supply and a steady flow to be set without use of a standalone pump. Flow rate was set at 2 +/-1 L/min, though if checks revealed gas/bubbles accumulating in the tubing then the flow was raised sufficiently to eliminate this, and any residual gas flushed through the tubing/sensor. The sensor was directly connected through serial-RS232-USB to a laptop secured alongside the sink to enable direct readout of outputs, and quick communication with the Pro-Oceanus and the other sensors to be set up in the sink. It was set-up to do a daily zero, and save data on a 1-minute frequency.

A number of initial teething problems of working with the sensor were found:

- The Oceanus View software provided with the sensor was found to not be reliable for communication. It was slow to respond to input and frequently crashed. Data download was also interminably slow (multiple hours for a day of data) so it was decided to simply capture live output and download the full complement of data at the end of the trip.
- On 16th December there were problems with the laptop power supply and battery leading to an inability to restart the laptop. This thus was switched out for a replacement.
- Upon reconnection to the new laptop the sensor was found to get stuck in a warming-up loop, despite its temperature being above the set 30degC operating temperature (at 33degC). Power cycling both the sensor and laptop did not managed to solve this issue. Communication with the manufacturer revealed that if the sensor started the warm-up cycle above or very close to the threshold then it would never be able recognise when it got there. This faulted was related due to the fact the sensor had been set up in the factory to work in much cooler water temperatures rather than 25degC+ subtropical temperatures. The sensor was thus turned off and allowed to cool for a number of hours before successfully retrying the initiation cycle.
- Due to ongoing problems with the response lag and crashes of the Oceanus View software, sensor communication was instead switched to using the McLane Term Terminal software. This worked perfectly, and enabled live logging without software glitches. Data was

downloaded daily. Live logging of sensor outputs does not allow any calibration to be applied, meaning data will require substantial post-cruise calibration post-processing.

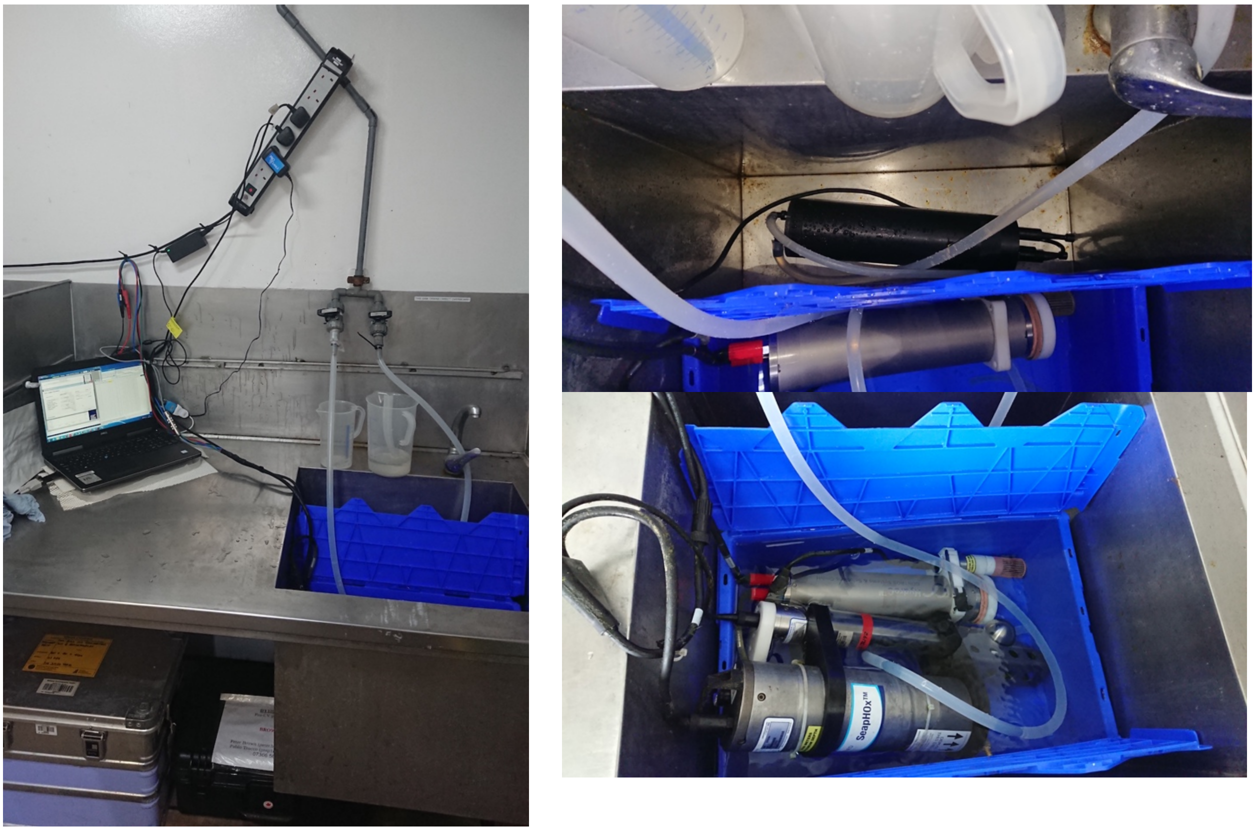


Figure 15.3 Left, location of Pro-Oceanus, CONTROS and SeaBird Deep SeapHOx sensors in right-hand sink of CTD Annex. Top rigt, Pro-Oceanus directly connected to underway non-toxic supply. Bottom right, CONTROS and SeaBird Deep SeapHOx in crate being overflowed with on-toxic supply.

15.4 CONTROS

The successful recovery of the MAR1 mooring on 22nd December 2020 enabled the potential deployment of the returned biogeochemical sensors in an underway fashion for the remainder of the trip. Following removal of biofouling and download of stored data the sensor was installed in a plastic crate in the same sink as the Pro-Oceanus in the CTD Annex (Figure 15.3). Using a separate water feed to the Pro-Oceanus, the crate was filled and overflowed at a rate of approximately 12L/min. The sensor was switched on to measure continuously on 26th December; initial checks revealed that water was not being pumped through the flow-through head. Water passing across the semi-permeable membrane was thus restricted to that stimulated by the inlet of the underway supply. The sensor took approximately 3 days to equilibrate from ~430 ppm to the level of the other pCO2 sensors (~375 ppm), an inordinately long time. It was noticed that the sensor was not fulfilling its programmed zeroing schedule, also noticed for the latter half of the mooring deployment data. It was thought this could possibly be related to the issue with the pump. On Jan 6th after the vast majority of science mooring work was completed it was suggested to try replacing the pump with a similar one used on the CTD rosette. First, a separate cable between the CONTROS and the pump was tested but to no avail. Then, upon removal of the original pump it was tested with an independent power supply and found to still be operational. The power pins for the pump on the CONTROS sensor were subsequently tested using a multimeter and were found to not be supplying any current. Thus, the problem appears to be internal to the sensor rather than directly pump-related. The CONTROS sensor was reinstalled with its original pump and placed back into the crate to continue operating continuously. The sensor will be returned to the manufacturers post-cruise to help in calibration of deployment data, and fixing of operational problems.

15.5 Deep SeapHOx

As for the CONTROS sensor, the successful recovery of the Deep SeapHOx sensor from the MAR1 mooring on 22nd December 2020 gave the potential for running it in an underway fashion for the remainder of the trip (located in CTD Annex sink, Figure 15.3).

- Following cleaning for biofouling and data download, data analysis of the mooring deployment data revealed that the conductivity sensor had failed during deployment, arbitrarily dropping by 2 psu after 7 months before dropping to a general output of ~0.5 psu after 9 months. So that the sensor could be included on a CTD caldip for calibration of the temperature and pressure sensors (and to see if simple cleaning/flushing brought the conductivity sensor back to life), the original MicroCAT-ODO (S/N 12903) was removed and replaced with sensor S/N 12906.
- After integration of the SEAFET and ODO together it was found that the pin output from the ODO was of an older configuration than the cable used by the SEAFET. As this cable was unique to the SeapHOx combination, the ODO was swapped out for another with the correct pin configuration, this time S/N 14116.
- As the SEAFET-ODO combination had originally been set in the factory it was necessary to reset/resynchronise the communication between the new sensor pair. This was attempted by using the UCI software, and the terminal communication dialog. The recommended 'resync' command failed, indicating that the ODO was not set up to communicate with a SEAFET.
- Using the Sea-Bird SeaSoft software, the ODO was connected directly to the laptop and communication initiated. The baud rate was changed to 9600 to enable SEAFET communication. This was a two-step process, the initial setting and command being sent to the sensor within SeaSoft, followed by disconnection, reconnection at the new baud rate and the sending of the command 'BaudRate=9600' again to confirm the change. Following this the below settings were also changed:
    - OutputFormat=2
    - OutputTemp=Y
    - SetTempUnits=0
    - OutputSal=Y
    - OutputOx=Y
    - SetOxUnits=1
    - OutputPress=Y
    - SetPressUnits=0
    - AdaptivePumpControl=N, OxNTau=7
    - OutputExecutedTag=n
    - txrealtime=1
- The ODO was reconnected into the original dual cable and initiation with the UCI software started. The 'resync' command was this time successful, and oxygen, temperature and salinity calibration coefficients were successfully loaded by the SEAFET, and SeapHOx outputs started.
- The sensor was tested for autonomous sampling and problems were encountered with the deployment settings. Following those used for pre-mooring deployment did not lead to samples being collected beyond the initial sample. Repeated attempts were not successful until the 5th Jan 2021 when the sensor was set to sample at 5 minute intervals and 'deployed' according to the settings below: baud rate 19200; CTD Power=false; TempUnits=Celsius; PresUnits=dbar; CondUnits=S/m; OxyUnits=mg/L; Transmit Data Realtime=false; Sample interval=300; PumpTime=38s. This successfully collected data autonomously. Each data logging was stopped, data downloaded and the deployment restarted, with the lengthening of the sampling frequency to 30 minutes the only change being made.

- On 10-11th January no data was collected despite identical deployment settings being used. So as not to lose any more data, it was decided to keep the sensor connected at all times to the laptop at all times and collect data in real time.
- On 13th January the sampling frequency was increased to every 15 minutes.

15.6 Water sampling from underway supply for carbon parameters.

To help in the calibration of the underway pCO2 and pH systems, samples were collected from the non-toxic supply on a daily basis for the time that the non-toxic supply was operational. These were preserved for dissolved inorganic carbon and total alkalinity analysis by addition of 50uL of saturated mercuric chloride solution, and for inorganic/organic nutrients analysis by freezing. Figure 15.4 shows the timing of when calibration samples were taken.

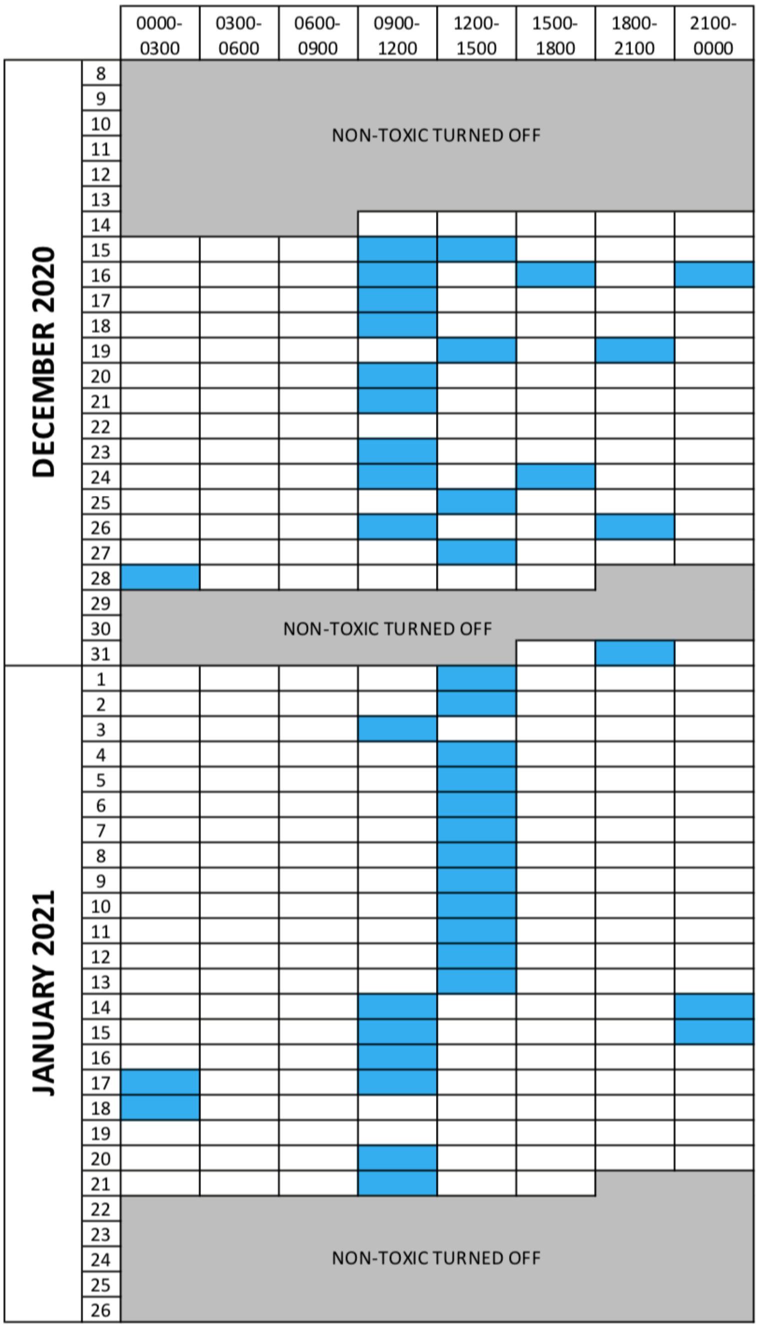


Figure 15.4 Timing of collection of discrete samples for DIC, alkalinity, inorganic and organic nutrients from the non-toxic supply. Blue colouring indicates time of day of bottle filling.

15.7 Initial results

Initial uncalibrated outputs from the four sensors packages are shown in Figure 15.5. While drift and zero effects need accounting for they all typically exhibit the same short-term features and co-variability, and despite being uncalibrated outputs all generally remain within a +/- 10ppm range. The pump issues highlighted with the CONTROS are apparent in its response, taking much longer to get to operating capacity and respond to short-term pCO_2 variability.

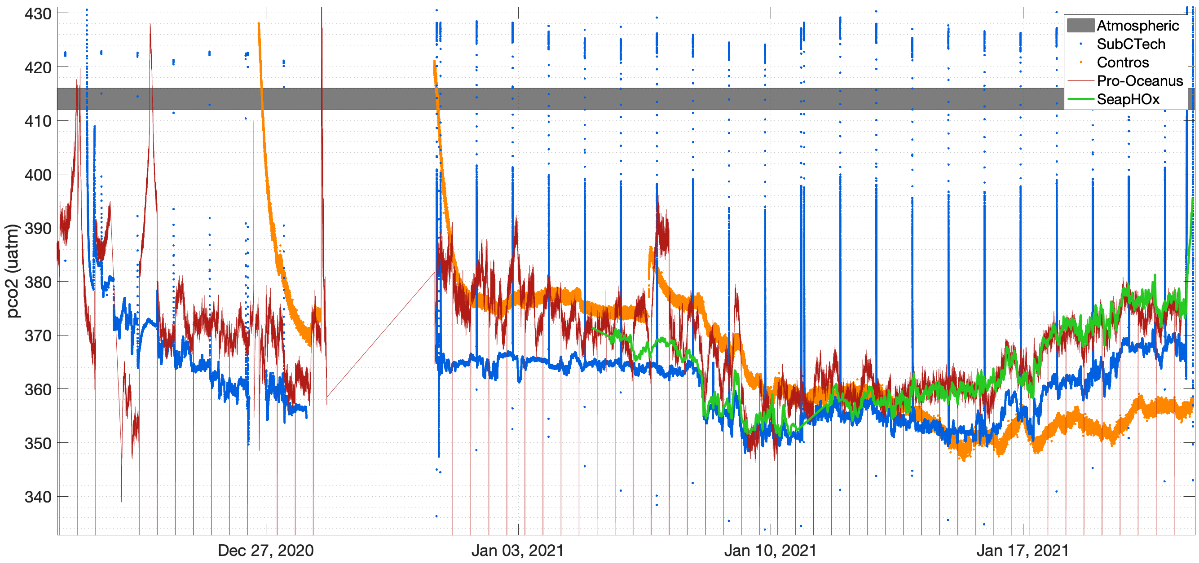


Figure 15.5 Initial uncalibrated underway pCO_2 outputs.

16. Data telemetry system

Darren Rayner

On cruise JC174 a telemetry system was deployed on mooring WB2. The system comprised a bespoke syntactic float that housed the buoy controller, an additional battery pack, an inductive modem, an acoustic modem, and inductive swivels to maintain an electrical connection along the mooring. The buoy controller was designed to interrogate the moored instruments through the inductive modem and pass the received data to an acoustic modem along with diagnostic engineering data from the buoy controller. The data could then be retrieved from a surface acoustic modem either on a vessel, or as was intended here a MYRTLE-X lander on the ocean floor. MYRTLE-X retrieves the mooring data via acoustic modem and periodically releases pods to the surface, which transmit the data to shore via Iridium. Further details of the deployed system can be found in the JC174 cruise report (Smeed, 2019).

The MYRTLE-X lander was deployed on the 22/11/2018 at 18:49 by lowering it to the seabed on the ship's trawl warp, with an acoustic release used to disconnect the wire from the lander when in position. The lander controller was set to initiate the first acoustic download from the mooring at 00:40 on the 22/11/2018, and then repeat downloads every 24 hours. There were 8 (out of a possible 12) data pods fitted to the lander. The first was scheduled to release a few days after deployment when the ship could be on position to recover it. One was approximately 5 weeks later and another 5 were spaced at equal 11-week intervals. The final pod was secured to the frame so that it could not be released and we would therefore be able to recover it with the frame. However, when the lander was recovered pod 7 was also still attached to the lander meaning the release of this unit had failed. Details of the pod timings are given in Table 16.1.

Pod number	Planned surfacing date/time (GMT)	Comment
1	25/11/18 11:00	Recovered on deployment cruise
2	03/01/19 11:00	Surfaced as planned
3	21/03/19 11:00	Nothing heard from pod
4	06/06/19 11:00	Nothing heard from pod
5	22/08/19 11:00	Nothing heard from pod
6	07/11/19 11:00	Nothing heard from pod
7	23/01/20 11:00	Still attached to frame – didn't release
8	n/a	Secured to frame

Table 16.1 Summary of telemetry data pods.

The WB2 buoy controller was set to start at 01:20 on 22/11/2018 and the mooring was deployed at 19:04 on the 23/11/2018, with the final anchor position being 600m from the lander. Sampling was set to be hourly polling of the moored instruments through inductive communication, with the data then averaged into 12-hour periods. There were 24 Sea-Bird SBE37 IMP CTDs deployed on the mooring, with 8 Nortek Aquadopp current meters fitted with inductive modems.

Pod 1, that surfaced 3 days after deployment, did not send any messages, and when recovered we found there were no data on the pod memory card. There should have been a "pod on surface" message even if no data were present, but this can sometimes be missed if there are difficulties registering on the Iridium network and this message isn't repeated (whereas data messages can be). The lander was recovered with just one pod remaining, confirming that all the intended pod releases worked.

Pod 2 surfaced as planned and transmitted 8 emails before stopping. The first message was the "POD2 on surface" message and the subsequent emails were correctly numbered 1-8 so no emails were missed at the start. All data emails contained the maximum expected 256 Bytes, possibly indicating that the last message received was not the last block of data on the pod. The decoded data only had 2 buoy controller records from 30/11/18 00:20 and 30/11/18 12:20 when there should have been 2 from each day up till release. The corresponding MicroCAT data from these times was also present along with 13 out of 17 records from the 1/12/18 00:20, but no current meter data were sent.

We have since found that the Norteks were incorrectly set to output data in binary format rather than the intended ASCII, so the buoy controller was unable in interpret the inductive replies from these instruments. One MicroCAT was also set to the wrong output format and although ASCII, the data fields are not in the expected locations in the transmitted string.

The missed records may be indicative of difficulties with the acoustic transmission from mooring to lander, or the infrared transmission from the lander controller to the pod. A quick check of the pressure records from the shallowest MicroCAT at the time of successful transmissions suggests the mooring was leaning over and at the depth of the buoy controller (and assuming no shear in the current), the mooring would have been 300-350m horizontal distance from the anchor. The currents at this time were predominantly to the north, and with the lander deployed 600m south of the mooring the mooring was leaning away from the lander. Some simple trigonometry suggests the mooring acoustic modem would have had an approximate slant range of 1860m to the lander – well within the expected range of the modems.

The MicroCAT records recorded on the buoy controller memory card were nearly complete: 10 had full records; 3 instruments stopped early due to battery failures but all available data was received from them; 1 had the wrong format; and 3 appear to have had problems with the inductive communications and missed parts of the record. The latter 3 instruments were all on the upper section of wire above the telemetry buoy. This wire was only 270m long, so covered only a short section of the total mooring length. There were 4 MicroCATs on this section of wire and the amount of missing records increases with length along the wire. The first instrument (4070 @250m) had a complete record; the second (7361 @175m) was missing just over 3,000 records; the third was missing 14,000 records; and the shallowest (4062 @50m) was missing 15,000 records. This suggests the insulated path is compromised meaning the inductive communications were sometimes unable to sufficiently operate. This could either have been the jacket of the wire rope, or a problem with the terminations, the pass through of the buoy or the swivel mounted on the underside. There was no swivel on the topside of this buoy.

The MYRTLE.DAT files recovered from the lander controller only had one record from the buoy controller and one set of MicroCAT records. The date on these was from the 13th May 2019 but a bug has since been discovered that was causing the files on this memory card to overwrite each other rather than appending into one file. The lander controller clearly did receive more data than the one record as there were more present on the pod secured to the frame.
One of the lander controller electronics spheres had some drops of water present and a slight patch of corrosion evident on the MYRTLE lander controller PCB. This may have been sufficient to stop the operation of the lander controller, hence the last recorded record being dated 13th May 2019.

The converted data from pod 8 initially showed no valid records, but on inspection it was found that there were a handful of records (34) spread sporadically between the 30th November 2018 and the 1st of May 2019, but they all failed the CRC check during transmission to the pod and are therefore likely to have corruption of the data. Comparing this to pod 7 which did not suffer any problems with corruption (34 records all passed CRC check) shows that the two pods had the same number of buoy controller records and the sequence of data can be lined up by spotting the valid fields in each row. The same corruption can be seen in the SBE records which for pod 7 have the expected number of SBE records per timestamp from the buoy controller records (except when the inductive communications missed some instruments as discussed earlier).

Summary:

- 1 MicroCAT and all 8 Norteks had the wrong output format so could not be properly polled by the buoy controller (though the MicroCAT sent data only the sample time was in the correct field position so the binary encoded data values are incorrect).
- 3 MicroCATs at the top of the mooring have data gaps where inductive communications were unsuccessful.
- The remaining 13 MicroCATs had complete records transferred to the buoy controller memory (though 3 of these ended before the end of the deployment due to battery failure).
- The buoy controller had a complete record of housekeeping data, with no significant change in the internal humidity or battery voltage suggesting all was operating well.
- The acoustic modem memory buffer has yet to be checked, but this should have a duplicate set of data that the buoy controller has logged, but with samples averaged into 12-hour periods.
- The MYRTLE-X controller memory only had 1 record due to a bug meaning subsequent records were overwriting each other.
- The lander controller PCB shows some signs of water damage evident in a slight patch of corrosion on the board.
- There were 2 pods still attached to the frame (one of which was a release failure of currently unknown cause).

- Both of these pods had about the same amount of data, but this was only a tiny fraction of the expected amount (34 12-hour averages out of a possible 1458 if the telemetry system had worked for the full deployment), and one pod had data corruption affecting every record.
- 6 data pods were released from the frame: one released 2 days after deployment and recovered to the ship had no data on it; one released 39 days after deployment had 1.5 days of data and the other 4 were not heard from.
- It is not yet possible to say how much data were transferred by the acoustic modems and whether this was more than was written to the data pods on the lander. Once the MYRTLE electronics can be checked it may give more information.

References

Smeed, D. (2019), RAPID cruise JC174 20th October – 26th November 2018, RAPID cruise report for JC174, National Oceanography Centre cruise Report No. 59, National Oceanography Centre, UK. 185pp.

17. Moorings

Eleanor Frajka-Williams and Darren Rayner

Mooring operations were conducted on the aft deck using the NMF double barrel winch and reelers with mooring lines passing through a block suspended on the end of a stern crane. Acoustic releases had all been tested on JC192 and so were not re-tested on DY129.

Moored CTDs were checked before deployment (MicroCATs and one RBRconcerto-3) and after recovery (MicroCATs) to provide functionality checks and end-point reference calibrations.

Summaries of the deployment and recovery times are given in Table 17.2 and 17.3, with details of instruments lowered on CTD calibration dips given in Table 17.4. Table 17.5 summarises the instrument record lengths from initial inspection on the cruise (not fully QC'd data).

17.1 Updates to moorings deployed: Temporary (for evaluation purposes)

wb1_15_2020: Two instruments were added to WB1 -- a Nortek aquadopp and microCAT pair -- just above the anchor at 1350m. This was to check whether the assumption used in vertically interpolating velocities to zero at the bottom is appropriate (Johns et al., 2008). To compensate for the extra weight of the Nortek (the MicroCAT is nearly negligible), an extra glass sphere was added to the pack at 1200m to make a pack of 3. This is anticipated to be a temporary change to the mooring, and after recovery can likely be returned to the previous design with the deepest instruments at 1200m.

wb2_16_2020: Several additional RBR instruments were added to WB2. RBR solo T (temperature loggers) depth-rated to 1700m were added between 450m and 1150m, providing a vertical resolution of 50m over this depth range, between the temperature loggers and MicroCATs. An RBR Concerto3 was added to WB2 at 1700m, paired with a Sea-bird MicroCAT. Both changes to wb2 are anticipated to be temporary and for evaluation purposes only.

The RBR temperature loggers will be used to evaluate whether the nominal vertical resolution of instrument placement on WB2 is sufficient to resolve the thermocline gradients at this location. To do this, the MicroCATs will be gridded following the standard practice to produce a vertical profile with 20m resolution. The gridded profile of temperature will then be compared against the measured variability in the temperature profile using the soloTs to see whether it adequately resolves the structure of the thermocline for transport calculations. Note that the RBR soloTs may have a bias offset relative to the true temperatures (based on the caldip data) which will need to be corrected before the variability is evaluated. Twelve (12) loggers were dipped. One did not record the dip (100265) and two others were not deployed (100259, 100273).

Logger and position on rosette for caldip:

100279	adjacent to deep standard thermometer, near top of frame
100268	adjacent to deep standard thermometer, near top of frame
100273*	on horizontal bar in rosette, near secondary sensor
100259*	on horizontal bar in rosette, near secondary sensor
100275	on horizontal bar in rosette, near secondary sensor
100255	on frame for vane, near primary sensor
100266	on frame for vane, near primary sensor
100272	on frame for vane, near primary sensor
100277	on vertical upright by vane, near top of frame
100265*	on vertical upright near top of frame
100274	on vertical upright near top of frame
100269	on vertical upright near top of frame

The RBR Concerto3 was used to evaluate the suitability of RBR moored CTDs for RAPID-type transport applications. The Concerto3 has an inductive conductivity cell which (i) requires less power than the microCAT due to being unpumped and (ii) apparently is subject to offset errors/biases rather than drift errors. Due to the lower power requirement, it was set up to sample every minute, and can be used to evaluate sub-hourly variability at the WB2 location (though this is not anticipated to influence transport calculations). The instrument is, however, subject to contamination by objects passing within a 20 cm sphere from the inductive cell. For the cal-dip, it was installed with the inductive sensor facing up and away from the rosette, though 20cm clearance was not achieved. See Figure 17.1 (top). On the mooring, the instrument was installed using long-ish clamps. See Figure 17.1 (bottom) for the deployment configuration.

Figure 17.1 (top) RBR Concerto3 positioned on the CTD frame. (bottom) Hand for scale (6 inches from heel to fingertip), showing clamp distance of about 6 inches, compared to the 8 inches recommended by RBR. Deployment on the wire with the RBR inductive cell pointed down and positioned below the Sea-bird MicroCAT.

17.2 Mooring issues

All of the moorings at the Mid-Atlantic Ridge (MAR1, MAR3, MAR1L11, MAR1L12, MAR3L11, MAR3L12, NOG) were recovered.

- MAR1 had 2 implosions in the bottom pack of 9 glass. The ascent rate was 89 m/min.
- While MAR3 was being recovered, the wire parted between the top MicroCAT and 24" syntactic float. A second recovery line was attached and the rest of the mooring was recovered successfully.

At the western boundary, no landers were recovered for various reasons (below).

- WBADCP was recovered but the instrument was flooded.

- WBAL7 surfaced early, and was recovered to Miami by a University of Miami professor. The cause of early surfacing is not known, but both BPRs, beacon and acoustic releases were recovered.
- There was no WB4L to recover since the one from JC145 (2017) had used the new design and had been recovered on JC174 (2018) to check how well the design had worked.
- WB2L12 responded to acoustic commands but did not surface. Suspected implosions as this design (deployed on JC145) still used glass flotation (3 packs of 4 spheres + billings).
- WB4 had an implosion of 1 sphere in the bottom 10-pack of glass. The ascent rate was 83 m/min. No responses were heard from acoustic release s/n 0364.
- WB2H2 had 2 implosions on the 5-pack of glass at 3000m and 5 implosions on the 5-pack of glass at 4600m. The ascent rate was 20m/min. No e-mail was noted from beacon IMEI 300234061662220 (s/n C02-052).
- WB2 had some instances of shredding on the plastic jacked of the wire (around 200m). Figure 17.2.

Figure 17.2 Showing shredding of the plastic jacket on the wire at WB2 around 200m.

17.3 Instrument problems

17.3.1 ABC Fluxes instruments

For problems with the Contros Hydro-C pCO_2, SeaBird Deep SeapHOx and McLane RAS instruments please refer to the individual Sections (12, 13 and 14) on these instruments.

17.3.2 RAPID instruments

On MAR3, the S4 current meter, s/n 35612577, would not talk. RCM11 current meters on MAR3 (and generally) had incorrect temperature and salinity.
On NOG, the Norteks had pressure drift and incorrect pressure readings.
The PIES that was deployed at MAR1 on JC174 returned sensible travel times, but no pressure or temperature records.
On MAR1, the RCM11 current meter at 1500m (s/n 507) stopped early on 30 Jan 2020. The microcat s/n 6828 was recovered with a missing end cap (flooded).

On WB6 the salinity records were unusual. In particular, without correction of salinity values, it appears that there is a non-monotonic salinity profile between 4800 – 5500m.
On WB4, one Nortek stopped early (s/n 6743 at 2000m, stopped on 22 Dec 2020).
On WBH2, several MicroCAT ODOs (s/n 12832, 12907, 3628) potentially suffered from oxygen drift.
On WB2, an inductive mooring, three of the MicroCAT IMPs stopped early: s/n 4800, 4797 and 4799 (stopping 9 July 2020, 19 August 2020 and 2 August 2020, respectively). The longer deployment and extra battery power required for inductive communications could have contributed to the stoppage. Initially, data could not be downloaded and when batteries were reinstalled, the instruments had forgotten the date/time and settings. However, data were not overwritten and were able to be downloaded by using an end samplenum that was large enough to encompass the full record.

17.3.3 Calibration casts

As per the usual practice, MicroCATs were caldipped prior to deployment and after deployment. These were used to determine which MicroCATs to deploy on which moorings and at what depths. Criteria used were that conductivity offsets at the deepest stop (from the primary sensor on the CTD) were less than 0.02 mS/cm, temperature offsets were less than 0.005, and pressure offsets were less than 5 dbar at the deployment depth. Additionally, I discarded instruments that showed unusual pressure variability at bottle stops, and

Unusual conductivity behaviour. Several instruments were redipped on DY129 that had previously been dipped on JC192 in March 2020. Of these, most of the offsets relative to the calibration casts were stable, apart from s/n 11744 which was out-of-spec on JC192 (conductivity high by +0.08 mS/cm) but in spec on DY129.
Upon further investigation by Darren Rayner, it appears that MicroCAT s/n 11744 was previously paired with an ODO s/n 12963 on EB1_15_2018 at 250m. Comparing the conductivity between s/n 11744 and the ODO 12963 (Figure 17.3), there appears to be some anomalous drift towards elevated values around February – May 2019. The offset between the two then recovers towards 11744 being mildly elevated relative to 12963 through January 2020. At the end of the deployment, the two instruments appear to be reading the same values. This behaviour does not match expectations for conductivity cells: that they may have unusually low values when biological material gets stuck in the cell, or otherwise suffer from drift which is linear with time.

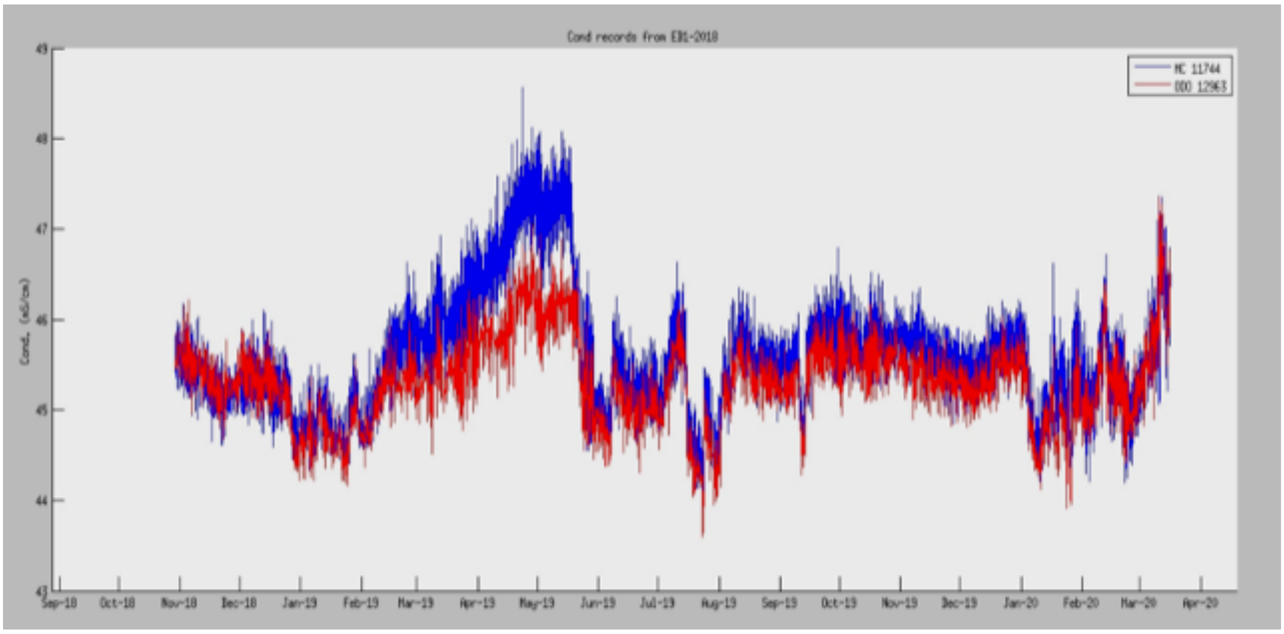


Figure 17.3 Conductivity record from two microcats: 11744 and ODO 12963. Note the period around Feb – mid-May 2019 when the MicroCAT (blue) is elevated relative to the ODO (red). This offset then reduces in mid-May 2019, and appears to decrease to negligible levels by the end of the deployment (April 2020).

17.3.4 WBA Landers – deployment history (up till Dec 2020)

Deployment details

Lander	Deployed	Cruise	Lat. (°N)	Lon. (°W)	Recovered	Cruise
WBAL1	03/04/10	OC459	26.5250	76.8761	29/02/12	RB1201
WBAL2	30/04/11	KN200-4	26.5262	76.8759	21/11/12	D382
WBAL3	29/02/12	RB1201	26.5223	76.8760	03/05/14	JC103
WBAL4	22/11/12	D382	26.5247	76.8760	04/05/14	JC103
WBAL5	04/05/14	JC103	26.5364	76.8732	Not recovered	Attempted on JC145
WBAL6	24/11/15	DY039	26.5268	76.8756	Buoyancy surfaced 25/01/16. Lander still in position and not recovered.	n/a
WBAL7	28/03/17	JC145	26.5377	76.8666	Surfaced 05/08/20 and recovered to Bahamas	n/a
WBAL8	19/11/18	JC174	26.5243	76.8667	Still in water	n/a

Table 17.1 WBA lander Deployment details.

Design changes

- The design of WBAL1 used 2 x 4-packs of glass with a Billings and pickup float. Subsequent designs have all increased the buoyancy to use 3 x 4-packs of glass.
- A stainless steel frame was used for landers from WBAL5 onwards.
- A 600kg anchor was used for WBAL1 – WBAL4 and a 1200kg anchor was used from WBAL5 onwards (except WBAL6 which reverted back to 600kg).
- All buoyancy was separated using polyprop rope until WBAL7 where it was changed to using chain throughout (except the pickup line).
- At some point a layer of plastic was inserted between the lander frame and the anchor weight, but I do not have details of which landers had it and which didn't. This was in response to a suggestion that breakdown of the paint and corrosion of the frame was causing the lander to be "glued" down to the anchor.

Problems recorded

WBAL1 – nothing untoward noted apart from moderate fouling on the lander frame

WBAL2

- BPR records show jumps where lander appears to move downslope to slightly deeper water – it was proposed that this was possibly due to an underweight anchor, hence the increase to 1200kg after this was seen in the recovered data.
- The frame had severe corrosion and the releases almost slipped out of the frame when pulling the lander from the water. It looks like this was accelerated by the mild steel frame being in contact with stainless steel bolts used in the clamps. Landers deployed on this cruise had a safety line added to secure the frame to the bracket at the top of the releases in case the clamps failed again. Plastic bushing has been used in landers deployed after this cruise.
- There was significant crevice corrosion on the acoustic releases in another lander recovered on the same cruise. This was seen where the brackets clamped tight against the pressure housing.

WBAL3

- The lander would not surface initially despite firing both releases. It was given up as lost and the cruise continued. The lander then surfaced 15 hours later and was recovered. It is thought that whatever was the frame down was freed when the tide changed and exerted different forces on the frame.
- Inspection of the bottom of the tripod frame showed strong corrosion of the anchor/frame base with the blistering paint and rust probably providing sufficient force to hold the frame to the anchor despite the releases having let go. Jamming of the releases or biofouling cannot be ruled out though.
- Corrosion almost caused the lander frame to slip off the releases as recovered to the ship (this lander was deployed on the cruise before WBAL2 was recovered, so the mitigation safety line had not been added).
- There was a large amount of corrosion staining around the join between the release pressure case and hook plate. The corrosion scrubs off the stainless releases, but significant crevice corrosion occurred on the face of the hook plate inside of the staining

WBAL4

- This was recovered 18 months early due to corrosion concerns having seen WBAL3 and previously WBAL2. Corrosion was less than on WBAL3, but it had been in the water for 6 months less time.

- The release link jammed in the jaws of one release meaning the other had to be fired too. This jamming of the link was only apparent once the mooring had surfaced and was recovered to the deck. A slight pull was enough to free the link as the release had operated correctly. This problem could have been worsened by the relatively small amount of buoyancy on the lander moorings meaning there is little tension on the release link, whereas the larger moorings have more upwards pull to free the link when the release is triggered. Beveled edges were introduced to the release links for all subsequent moorings and cruises.

WBAL5 – The lander did not leave the seabed despite both releases being fired with confirmation received by the deck unit. There have been no messages received from the beacons. This lander was deployed on the same cruise that WBAL4 was recovered, so it may not have had the bevelled-edge release links.

WBAL6 – The buoyancy from the lander surfaced two months after deployment. The frame was confirmed to still be at the deployment position on the subsequent cruise. Photos of the recovered rope end are inconclusive (see below, Figure 17.4)

Figure 17.4 Recovered rope end from WBAL6.

WBAL7 – the whole lander (buoyancy and frame) was recovered to Abaco by small boat. Photos appear to show one of the releases has been triggered (see photo below, Figure 17.5). The cause of the release was down to release s/n 822 moving ¼ turn and releasing the lander from the ocean floor. The releases did not respond when tested on board the ship. And further testing will be conducted back at NOC. There were no messages from the Argos beacon but the lander was found adrift by a passing fishing boat near the Pelican Sea Reserve off Abaco.

Figure 17.5 Photo of WBAL7 lander frame as recovered by a University of Miami professor.

Different failure modes/problems

1. Corrosion of mild steel frames – should now be mitigated by using super-duplex frames
2. Non-surfacing of lander – cause unknown and could be through corrosion, fouling, release link jamming, loss of buoyancy (either through ropes breaking or buoyancy imploding) or something not thought of. All of these except fouling and the unknown have been addressed in subsequent deployments.
3. Disconnection of buoyancy from frame – it is unclear how the rope failed, but this should now be mitigated by using chain instead
4. Unintended opening of the release hook – I think the 3 possible causes here are 1. The unit mistakenly interpreted acoustic noise as the arm and release command; 2. The release was inadvertently triggered by the right commands sent by a third party using a compatible deck unit; 3. The hook was incorrectly set, but held for over 3 years; 4. The hook mechanism failed through corrosion –we need to see the releases to check this further.

Mooring	Deployment cruise	Deployment data	Recovery date	Recovery start time (UTC)	Recovery duration
nog	jc174	2018-11-04	2020-12-19	16:31	02:07
mar3	jc174	2018-11-04	2020-12-19	10:22	05:08
mar3L11	jc145	2017-03-15	2020-12-18	17:11	01:31
mar3L12	jc174	2018-11-04	2020-12-19	08:54	01:20
mar1	jc174	2018-11-08	2020-12-22	10:15	05:04
mar1L11	jc145	2017-03-18	2020-12-21	13:18	01:19
mar1L12	jc174	2018-11-06	2020-12-21	14:41	01:24
marP1	jc174	2018-11-07	2020-12-22	05:37	02:20
mar0	jc174	2018-11-09	2020-12-23	10:30	01:54
wb6	jc174	2018-11-14	2020-12-17	17:28	02:23
wb4	jc174	2018-11-18	2021-01-01	12:26	04:48
wb4l12	jc145	2017-04-02		Recovered on JC174	
wbh2	jc174	2018-11-20	2021-01-03	12:00	04:59*
wb2	jc174	2018-11-23	2021-01-04	12:56	02:38
wb2l12	jc145	2017-03-29	2021-01-04	Not recovered	
wb2m	jc174	2018-11-22	2021-01-05	10:12	03:38
wb1	jc174	2018-11-24		Recovered September 2019	
wbadcp	jc174	2018-11-19	2021-01-04	18:10	01:00
wbal7	jc145	2017-03-28		Recovered August 2020	

Table 17.2 Mooring recovery table. Imploded glass and slow ascent is indicated by '*'.

Mooring	Latitude	Longitude	Depth (m)	Fallback (m)	Date	Time anchor drop	Deploy-ment duration
wb4	26° 27.04	75° 43.54	4692	614	2021-01-02	20:02	05:52
wb4l14	26° 28.47	75° 42.81	4690	427	2021-01-01	18:10	00:05
wbh2	26° 28.79	76° 37.61	4740	165	2021-01-03	21:42	03:01
wb2	26° 31.00	76° 46.44	3916	302	2021-01-05	18:39	03:57
wb2l14	26°30.21	76° 44.62	3888	59	2021-01-04	20:39	00:07
wb1	26° 29.85	76° 48.93	1401	153	2021-01-07	16:12	02:03
wbadcp	26° 31.80	76° 52.05	566	56	2012-01-06	20:11	00:06
wbal9	26° 32.29	76° 51.98	602	15	2012-01-06	20:57	00:06

Table 17.3 Mooring deployment table.

CAST NO.	Allocated	MICROCAT S/N	COMMENT (C in mS/cm, P in dbar, T in °C)
CAST 3	WB2	3225	OK.
		3228	T off by +0.003. P off by +12.5 dbar at bottom
		3248	C high (0.025). P off by -13.0 dbar at bottom
	WB1	3270	OK. P off by -20.4 dbar at bottom. OK for P<850
		3271	Sample rate was 1 min. Redip
		3910	Sample rate was 1 min. Redip
		4549	C high (+0.05). Don't like how pressure looks at stops.
	WB4	4719	OK.
	WB4	5246	OK. P off by -18.4 dbar at bottom. OK for P<1000dbar
	WB4	5762	OK. P off by +9.9 dbar at bottom OK at 1100 dbar
	WB4	5763	OK. P off by +9.9 dbar at bottom
		5784	OK. P off by +9.5 dbar at bottom
		5789	OK. P off by 10.9 dbar at bottom
	WB1	6121	OK
		6127	OK. P OK at depth
	WB4	6323	OK
	WB4	6326	OK
	WB1	6335	OK. P off by -11.1 at bottom. OK for P<1500
		6805	OK. P off by +9.5 dbar at bottom
	WB4	6819	C high (0.022). Use if necessary. P off by -14.7 dbar at bottom.
	WB1	6822	OK
		6830	OK. P variable.
	WB4	7363	C borderline (0.021).
	WB4	11424	OK
CAST 4	WB2	3282	OK. P off by -6.8 dbar at bottom. Ok for P <=2000
	WB4	4464	OK. P off by -10.6 dbar at bottom. Don't like P behaviour shallow.
	WB1	4471	OK. P off by +17.4 dbar at bottom
	WBH2	4712	OK. P off by +9.9 dbar at bottom
	WB4	4713	C high (0.026). P off by +14.6 at bottom. Pair with ODO.
	WB2	4717	OK. P off by +7.9 dbar at bottom. OK for P<=3000
	WB1	4720	OK. P off by +9.8 dbar at bottom

	WB4	5978	OK. P off by +7.9 dbar at bottom. Don't like P behaviour shallow.
	WB2	5981	OK. P off by -6.4 dbar at bottom. OK for P<=3800
	WB2	5982	OK
		5987	Redip.
		7469	OK, but probably needed new battery pack.
	WB1	10543	OK
	WB1	10544	OK
	WB1	10555	C low (-0.022), use if necessary.
	WB1	12833	OK
	WB1	12963	OK
	WB4	12965	OK
	WB4	12966	OK
		12968	Flooded
	WB1	12998	OK. P off by +9.4 dbar at bottom
		14116	OK.
	WB4	14147	OK. P off by +7.7 dbar at bottom
	WBH2	20253	OK
CAST 5	WBH2	3215	OK. P off by +8.3 dbar at bottom
		3911	C high (+0.023) at bottom. P off by +10.9 dbar at bottom. P variability at 100 dbar stop.
	WB2	3913	OK
	WB2	5239	OK. P off by -8.2 dbar at bottom. Ok for P<=3500
	WB2	5243	OK
	WBH2	5767	OK. P off by +6.3 dbar at bottom
	WB2	5776	OK. P variability at shallow stops (100 dbar).
	WB2	5782	OK. P off by +7.0 at bottom. OK for P<=3500
	WB2	5983	OK
		6117	C high temporarily (0.13). Redip.
	WBH2	6120	OK. P off by -9.5 dbar at bottom
	WB2	6126	OK. P off by -6.8 dbar at bottom. OK for P <=3500
	WB2	6798	OK
	WB4	6800	OK
	WB4	6801	OK. P off by 7.9 dbar at bottom
	WBH2	6804	C is borderline (+0.02). P variability at 100 dbar stop.
	WB2	6808	OK. P off by -5.4 dbar at bottom
	WB2	6814	OK. P variability at shallow stops (100 dbar)

	WBH2	6824	OK
	WB4	6826	OK. P off by +8.5 dbar at bottom
		6836	OK. P off by -8.3 dbar at bottom. A lot of P variability at shallow stops (100 dbar).
	WBH2	20254	OK
	WBH2	20255	C low (-0.025) at bottom. Pair with 37.
CAST 6 (3500 m)	WB1	3220	OK. P off by -6.5 dbar at bottom
		3221	C low (-0.08).
		3239	C high (+0.034)
		4066	C low (-0.05).
	WB1	4068	OK
	WB1	4071	OK
		4072	C high (+0.027)
CAST 7	WB4	3214	OK. P off by +10.7 dbar at bottom
		3219	P off by +39.9 dbar at bottom.
		3233	C low (-0.05). P off by +11.2 dbar at bottom.
	WBH2	3251	P off by +6.5 dbar at bottom. P variable at 150 m stop.
		3254	C high (+0.04). P variable at 150m stop.
		3257	C high (0.07). P off by +11.5 at bottom. P variable at 150m stop.
		3264	C high (+0.07). P off by -12.4 dbar at bottom.
	WB4	3265	P off by +7.1 dbar at bottom. P variable at 150m stop.
		3483	C high (+0.03). P off by -15.2 dbar at bottom.
		3486	C high (+0.07). P off by -13.1 dbar at bottom
		3904	C low (-0.04).
		3912	C low (-0.05)
		3916	Flooded.
	WB2	3928	OK. P off by +6.6 dbar at bottom
	WB4	3934	OK
		4180	C high (0.05), P off +8.7 dbar at bottom.
	WB2	4305	OK
		4307	P off by +15.1 dbar at bottom
		5484	Stopped and re-started (low batt?). P variable at 150m bottle stop.
	WB2	5768	OK.
	WB4	5773	P off by +7.4 dbar at bottom
	WBH2	5779	C high (+0.022), use if necessary.
	WBH2	6840	P off by +5.7 dbar at bottom
CAST 8		3207	C low (-0.055). P off by +11.7 dbar at bottom.
		3209	OK

		3268	P of by +9.0 dbar at bottom
		3280	P off by +9.3 dbar at bottom
		4306	OK
		5987	OK. P off by +9.2 dbar at bottom
		6117	C variable.
		6123	C high (0.024).
		6128	OK
		6137	OK
		6322	C low (-0.023)
		6325	OK
		6333	OK
	WB4	12834	OK
	WB4	12835	OK
		12901	C broken +4.39
		12902	OK.
		12908	C high (0.067)
	WB4	12910	OK
		12911	C high (+0.030)
		13000	C high (+0.089)
CAST 11		3213	P off by +20.3 dbar at bottom
		3216	P off by +19.6 dbar at bottom
		3230	C high (+0.022). P off by +5.2 dbar at bottom.
		3244	C high (+0.031). P off by +20.9 dbar at bottom.
		3249	C high (+0.066). P off by -11.4 dbar at bottom.
		3252	P off by +9.4 dbar at bottom. P variable at stops < 1000m.
		3271	Sample rate was set to 10 sec, but instrument did 1 min till at the surface. Redip with fresh batts.
		3277	OK
		3910	Data file missing. Redip.
		3933	OK
		5484	C high (+0.059). P off by +10.3 dbar at bottom. P variable at stops < 400m.
		5780	C high (+0.028).
		5785	T low (-0.0029). P off by +8.6 dbar at bottom.
		6815	P off by -7.0 dbar at bottom. P variable at stops < 1000 m.
		6820	P off by +5.5 dbar at bottom.
		6825	OK
		10519	OK

		10547	OK
		12903	C way off (-32.7). P off by +5.5 dbar at bottom.
		14114	OK
		14115	C high (+0.027).
		14148	C high (+0.043). P off by +5.2 dbar at bottom.
CAST 14	WB2	100255	T high (0.005)
	WB2	100269	T high (0.005)
	WB2	100266	T high (0.005)
	WB2	100268	T high (0.003)
		100259	T low (-0.001)
	WB2	100272	T high (0.003)
		100273	OK
	WB2	100274	T high (0.001)
	WB2	100275	T high (0.005)
	WB2	100277	T high (0.005)
	WB2	100279	T high (0.004)
	WB2	100265	No cast was recorded
	WB2	203219	Need software to compare.
CAST 15		4060	C is high (+0.094). Pressure is off by +6.2 dbar at bottom.
		4062	C is high (+0.035). Pressure is off by +10.6 dbar at bottom.
		4070	C is high (+0.062).
CAST 16		3255	P is off by +7.0 dbar at bottom.
		3900	P is off by -5.4 dbar at bottom.
		4178	OK
		4461	OK
		4475	P is off by +5.1 dbar at bottom. OK at deployment depth.
		4710	C is high (+0.023). P is off by +9.3 dbar at bottom / 8.0 dbar at deployment depth.
		4797	P is off by -9.2 dbar at bottom. OK at deployment depth.
		4799	OK
		4800	P is off by -7.8 dbar at bottom. OK at deployment depth.
		5989	OK
		5991	OK
		5992	OK
		5993	P is off by -7.8 dbar at bottom. OK at deployment depth.

		6802	OK
		7361	C is high (+0.031).
		7362	OK
		7470	OK
		10517	OK
		10520	OK
		10545	Not setup or dipped.
		10546	Not setup or dipped.
		12832	Not setup or dipped.
		12907	Not setup or dipped.
		12999	Not setup or dipped.
CAST 18		3271	P off by +8.1 dbar at bottom.
		3893	C high (+0.077). P variable at stops < 400m.
		3910	C high (+0.10). P off by -9.6 dbar at bottom.
		3916	Not dipped. Was flooded on first caldip.
		4472	C high (+0.051). P off by +12.3 dbar at bottom.
		5238	Instrument not found onboard.
		5245	C low (-0.043). P off by -8.6 dbar at bottom. P variable at stops < 1000 m.
		5247	C high (+0.031). P off by +20.0 dbar at bottom. P variable at stops < 1000m.
		5485	C high (+0.045). P off by +5.3 dbar at bottom. P variable at stops < 400m.
		5765	P off by 11.7 dbar at bottom.
		5770	T high by 0.01. P off by -9.7 dbar at bottom. P variable at stops < 400m.
		5772	C low (-0.061). P off by -10.1 dbar at bottom. P variable at stops < 400m.
		5783	C low (-0.044). P off by -9.7 dbar at bottom. P variable at stops < 1000m.
		6112	C low (-0.064). P variable at stops < 400m.
		6115	C low (-0.092).
		6799	OK
		6810	C high (+0.036). P off by +9.7 dbar at bottom.
		6817	C low (-0.059).
		6821	C high (+0.028).
		6831	C low (-0.07). P off by +8.6 dbar at bottom.
		7468	C low (-0.034).
		7681	OK
		11744	OK
		12968	Not dipped. Was flooded on first caldip.

CAST 19		4070	C high (+0.047). P off by +7.5 dbar at bottom
		4462	C low (-0.082).
		10545	OK
		10546	OK
		12832	OK
		12907	OK
		12999	OK

Table 17.4 Calibration casts, instrument serial numbers and notes on calibration checks.

Mooring	Nominal depth (m)	Inst. code	Serial number	Mean pressure (dbar)	Start date	End date	No. records	Comments
mar3_13_2018	50	337	3910	27.6	04/11/2018	19/12/2020	18618	P drift (reduction) of 4 dbar
mar3_13_2018	100	337	4549	69.6	04/11/2018	19/12/2020	18618	P drift (reduction) of 7 dbar
mar3_13_2018	175	337	6819	154.2	04/11/2018	19/12/2020	18608	P drift (reduction) of 5 dbar
mar3_13_2018	250	337	5246	230.5	04/11/2018	19/12/2020	18618	P drift (reduction) of 5 dbar
mar3_13_2018	325	337	3248	305.9	04/11/2018	19/12/2020	18618	P drift (reduction) of 5 dbar
mar3_13_2018	400	337	3271	382.7	04/11/2018	19/12/2020	18618	P drift (reduction) of 4 dbar
mar3_13_2018	600	337	5762	585.4	04/11/2018	19/12/2020	18618	P drift (reduction) of 5 dbar, then a sharp increase around Oct 1, 2020 - moved on wire?
mar3_13_2018	800	337	5763	800.4	04/11/2018	19/12/2020	18618	P drift ~ 3 dbar
mar3_13_2018	1000	337	7363	998.5	04/11/2018	19/12/2020	18618	P drift ~ 3 dbar
mar3_13_2018	1200	337	6323	1202.3	04/11/2018	19/12/2020	18618	P drift ~ 3 dbar
mar3_13_2018	1500	310	516	1512.6	04/11/2018	19/12/2020	9308	Some problems with P. Values shallower than 1511.5 dbar are truncated. Salinity wrong
mar3_13_2018	1600	337	4719	1611.5	04/11/2018	19/12/2020	18618	P drift ~ 3 dbar
mar3_13_2018	2000	337	6127	2014.4	04/11/2018	19/12/2020	18618	OK
mar3_13_2018	2500	337	11424	2508.2	04/11/2018	19/12/2020	18618	OK
mar3_13_2018	3000	337	6830	3030.3	04/11/2018	19/12/2020	18618	S shaped pressure drift
mar3_13_2018	3500	337	6822	3544.5	04/11/2018	19/12/2020	18618	OK
mar3_13_2018	4000	337	6805	4075.2	04/11/2018	19/12/2020	18618	Exponential pressure increase of 5 dbar in the first 5 months
mar3_13_2018	4500	337	6121	4581.4	04/11/2018	19/12/2020	18618	OK
mar3_13_2018	5000	337	6326	5101.9	04/11/2018	19/12/2020	18618	OK
mar3_13_2018	5000	302	35612577					Instrument would not talk

Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
mar3l11_11_2017	5039	465	56	5136.4	15/03/2017	16/12/2020	32925	OK
mar3l11_11_2017	5039	465	426	5137	15/03/2017	16/12/2020	32925	OK
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
mar3l12_12_2018	5039	465	59	5207.3	05/11/2018	19/12/2020	18590	OK
mar3l12_12_2018	5039	465	38	5208.2	05/11/2018	19/12/2020	18590	OK
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
nog_2018	2900	370	6765	2924.2	04/11/2018	19/12/2020	37240	P drift of +36 dbar
nog_2018	3000	370	9956	2153.1	04/11/2018	19/12/2020	37240	P wrong.
nog_2018	4250	337	3911	4287.9	04/11/2018	19/12/2020	18620	Exponential P drift of +7 dbar in the first 3 months. Salinity noisy.
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
mar1p1_1_2018	5200	316	136	0	07/11/2018	22/12/2020	111672	TT ok. No P or T.
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
mar1_13_2018	50	**375**	**2002**					**ABC instruments**
mar1_13_2018	50	337	3257	40.4	08/11/2018	22/12/2020	18591	Pressure shoals by 5 dbar. Salinity drop on 27/Jan/2020 at 04:00. Looks questionable until 4/Sep/2020 at 19:30
mar1_13_2018	50	348	1114001					**ABC instruments**
mar1_13_2018	100	337	3264	86.1	08/11/2018	22/12/2020	18591	Pressure shoals by 5 dbar. Salinity dropout between 3/Aug/2019 04:00 and 9/Aug/2019 13:00

mar1_13_2018	175	337	3486	158.3	08/11/2018	22/12/2020	18591	Pressure shoals by 5 dbar
mar1_13_2018	250	337	3483	236.5	08/11/2018	22/12/2020	18591	Pressure shoals by 4 dbar. Possible S drift between 3483 and 12908.
mar1_13_2018	250	335	12908	235.6	08/11/2018	22/12/2020	4648	Pressure shoals by 4 dbar. Possible S drift between 3483 and 12908.
mar1_13_2018	325	337	5484	313.5	08/11/2018	22/12/2020	18591	Pressure shoals by 4 dbar
mar1_13_2018	400	337	3214	388.3	08/11/2018	22/12/2020	18591	Pressure shoals by 4 dbar
mar1_13_2018	400	335	12911	387.6	08/11/2018	22/12/2020	4648	Pressure shoals by 4 dbar
mar1_13_2018	600	337	3254	594.4	08/11/2018	22/12/2020	18591	Pressure shoals by 4 dbar
mar1_13_2018	600	335	12902	589.5	08/11/2018	22/12/2020	4648	Pressure shoals by 4 dbar. Oxygen dropout between 3/Sep/2019 08:30 and 16:30 and between 29/Feb/2020 04:30 and 13:00
mar1_13_2018	800	337	4307	802.1	08/11/2018	22/12/2020	18591	Pressure shoals by 3 dbar
mar1_13_2018	800	335	12901	798.6	08/11/2018	22/12/2020	4648	Pressure shoals by 3 dbar
mar1_13_2018	1000	337	5779	1004.5	08/11/2018	22/12/2020	18591	Pressure shoals by 2 dbar
mar1_13_2018	1000	335	13000	1004.4	08/11/2018	22/12/2020	4648	Pressure shoals by 2 dbar
mar1_13_2018	1200	337	3928	1211.2	08/11/2018	22/12/2020	18591	Pressure shoals by 2 dbar
mar1_13_2018	1500	335	12835	1514	08/11/2018	22/12/2020	4648	Pressue shoals by 2 dbar
mar1_13_2018	1500	310	507	1511.9	08/11/2018	**30/01/2020**	5375	Stopped early. Pressure looks odd. Temperature & Salinity wrong. Last current sample looks unusual.
mar1_13_2018	1600	337	5773	1616.5	08/11/2018	22/12/2020	18591	OK
mar1_13_2018	2000	337	4305	2023.5	08/11/2018	22/12/2020	18591	Pressue shoals by 1.5 dbar
mar1_13_2018	2000	335	12834	2023.4	08/11/2018	22/12/2020	4648	Pressue shoals by 1.5 dbar
mar1_13_2018	2500	337	3934	2540.4	08/11/2018	22/12/2020	18591	Pressue shoals by 1.5 dbar
mar1_13_2018	3000	337	3265	3048.4	08/11/2018	22/12/2020	18591	OK
mar1_13_2018	3500	337	5768	3559.3	08/11/2018	22/12/2020	18591	OK
mar1_13_2018	3500	335	12910	3560.1	08/11/2018	22/12/2020	4648	one has P drift of 1 dbar

mar1_13_2018	4000	337	3251	4078.2	08/11/2018	22/12/2020	18591	Initial exponential P drift of 3 dbar over 1 month
mar1_13_2018	4500	337	6828					Flooded
mar1_13_2018	5000	337	6840	5108.1	08/11/2018	22/12/2020	18591	OK
mar1_13_2018	5100	310	515	5214.4	08/11/2018	22/12/2020	9257	Temperature & Salinity wrong.
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
mar1l11_11_2017	5222	465	432	5331.9	18/03/2017	21/12/2020	32971	OK. Not hourly sampling?
mar1l11_11_2017	5222	465	34	5330.3	18/03/2017	21/12/2020	32971	Apparent nonlinear drift, but small amplitude (<1 dbar). Not hourly sampling?
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
mar1l12_12_2018	5222	465	13	5326	06/11/2018	21/12/2020	18620	OK. Not hourly sampling.
mar1l12_12_2018	5222	465	14	5323.9	06/11/2018	21/12/2020	18620	OK. Not hourly sampling.
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
mar0_10_2018	4700	337	6325	4779.1	09/11/2018	23/12/2020	18591	OK
mar0_10_2018	4900	337	6322	4958.9	09/11/2018	23/12/2020	18591	Low C on caldip
mar0_10_2018	5070	337	6137	5149.9	09/11/2018	23/12/2020	18591	Very slight pressure increase (1dbar)
mar0_10_2018	5250	337	6128	5333.5	09/11/2018	23/12/2020	18591	Very slight pressure increase (1dbar)
mar0_10_2018	5370	310	518	5472.3	09/11/2018	23/12/2020	9295	Pressure nil. Temperature way off (+18 deg C)
mar0_10_2018	5440	337	6123	5543.4	09/11/2018	23/12/2020	18591	Very slight pressure increase (1dbar). High C on caldip
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**

wb6_11_2018	4800	337	6333	4845.7	14/11/2018	27/12/2020	18564	Large knockdown (50m) in Nov 2019. Salinity is lower than s/n 3280?
wb6_11_2018	4975	337	3280	5032.9	14/11/2018	27/12/2020	18573	OK
wb6_11_2018	5150	337	3209	5212.1	14/11/2018	27/12/2020	18573	OK
wb6_11_2018	5325	337	4306	5396.3	14/11/2018	27/12/2020	18573	OK
wb6_11_2018	5400	370	5490	5531.5	14/11/2018	27/12/2020	37147	P drift of 35 dbar, mostly linear. Currents of 25 cm/s during the knockdown event.
wb6_11_2018	5490	337	3268	5583.6	14/11/2018	27/12/2020	18573	Exponential P drift at beginning.
wb6_11_2018	5497	465	36	5609.5	14/11/2018	27/12/2020	18573	OK
wb6_11_2018	5497	465	414	5609.6	14/11/2018	27/12/2020	18573	Sample rate isn't quite an hour?
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
wb4_14_2018	50	337	3893	61.7	18/11/2018	01/01/2021	18581	Heavy fouling. Salinity spike (remove) at 22/Feb/2020 07:30, 3 spikes between 10/Mar/2020 10:30 to 11/March/2020 09:00, and at 15/Mar/2020 04:40. Also spike at 31/Dec/2020 at 08:00 700m knockdown from 1/Jun/2019 to 24/Jun/2019
wb4_14_2018	50	335	14148	61.5	18/11/2018	01/01/2021	4647	Heavy fouling. Oxygen is a bit noisy.
wb4_14_2018	100	337	5485	106.8	18/11/2018	01/01/2021	18587	Fouling
wb4_14_2018	100	370	5611	101.7	18/11/2018	01/01/2021	37181	Fouling. 80 cm/s current speeds during knockdown event.
wb4_14_2018	250	337	3249	254.8	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	250	335	14115	255	18/11/2018	01/01/2021	4648	OK
wb4_14_2018	400	337	3244	409	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	400	335	14114	408.2	18/11/2018	01/01/2021	4648	OK

wb4_14_2018	400	370	9420	407.1	18/11/2018	01/01/2021	37181	OK
wb4_14_2018	600	337	3216	609.6	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	600	335	10519	608.9	18/11/2018	01/01/2021	4648	OK
wb4_14_2018	800	337	3213	812.6	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	800	335	10547	813	18/11/2018	01/01/2021	4648	OK
wb4_14_2018	800	370	5879	815.9	18/11/2018	01/01/2021	37181	OK
wb4_14_2018	1000	337	5780	1009.5	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	1000	335	10517	1012	18/11/2018	01/01/2021	4648	OK
wb4_14_2018	1200	337	3252	1226.4	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	1200	370	9427	1233.5	18/11/2018	01/01/2021	37181	OK
wb4_14_2018	1500	335	10545	1513	18/11/2018	01/01/2021	4648	OK
wb4_14_2018	1500	370	11024	1517.6	18/11/2018	01/01/2021	37181	OK
wb4_14_2018	1600	337	5785	1615.7	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	2000	337	6815	2012.1	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	2000	335	10546	2022	18/11/2018	01/01/2021	4648	OK
wb4_14_2018	2000	370	6743	2040.6	18/11/2018	**22/12/2020**	36678	OK
wb4_14_2018	2500	337	3277	2532.2	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	3000	337	3230	3044.3	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	3000	370	5955	3095.4	18/11/2018	01/01/2021	37176	OK
wb4_14_2018	3500	337	6820	3554.5	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	3500	335	12999	3556.3	18/11/2018	01/01/2021	4648	OK
wb4_14_2018	4000	337	6825	4063.2	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	4000	370	5963	4147.3	18/11/2018	01/01/2021	37181	Corroded end cap connector. Temporary swap to download dta.
wb4_14_2018	4500	337	3933	4668.3	18/11/2018	01/01/2021	18591	OK
wb4_14_2018	4600	370	6050	4706.6	18/11/2018	01/01/2021	37181	OK
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**

wbh2_11_2018	1500	335	12832	1644.6	21/11/2018	03/01/2021	4647	Salinity dropped out between 10 March 2019 09:00 and 11 March 2019 05:00. Oxygen drift?
wbh2_11_2018	1500	370	8052	1643.2	20/11/2018	03/01/2021	37181	OK
wbh2_11_2018	2000	335	12907	2137.8	21/11/2018	03/01/2021	4647	Oxygen drift of -7 umol/kg over the record.
wbh2_11_2018	2200	337	3255	2347.9	20/11/2018	03/01/2021	18591	OK
wbh2_11_2018	2200	370	9435	2343	20/11/2018	03/01/2021	37181	OK
wbh2_11_2018	3000	337	3900	3135.5	20/11/2018	03/01/2021	18591	OK
wbh2_11_2018	3000	370	8483	3147.9	20/11/2018	03/01/2021	37181	OK
wbh2_11_2018	3500	335	10520	3628.4	21/11/2018	03/01/2021	4647	Oxygen drift of -7 umol/kg over the record.
wbh2_11_2018	3800	337	6802	3930.4	20/11/2018	03/01/2021	18591	OK
wbh2_11_2018	3800	370	8492	3941.7	20/11/2018	03/01/2021	37181	OK
wbh2_11_2018	4300	337	7681	4417	20/11/2018	03/01/2021	18591	OK
wbh2_11_2018	4600	370	9204	4714.6	20/11/2018	03/01/2021	37181	OK
wbh2_11_2018	4690	337	6799	4776.9	20/11/2018	03/01/2021	18591	OK
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
wb2_15_2018	50	337	4062	103.9	23/11/2018	04/01/2021	18545	(Worm in cage guard). Salinity noisy.
wb2_15_2018	100	337	4060	153.2	23/11/2018	04/01/2021	18545	Lightly fouled.
wb2_15_2018	100	370	12700	150.2	23/11/2018	04/01/2021	37091	Lightly fouled.
wb2_15_2018	175	337	7361	225.6	23/11/2018	04/01/2021	18542	OK
wb2_15_2018	175	370	14732	220.7	23/11/2018	04/01/2021	37091	Growth
wb2_15_2018	250	337	4070	298.9	23/11/2018	04/01/2021	18545	OK
wb2_15_2018	325	337	5992	369.6	23/11/2018	04/01/2021	18545	OK
wb2_15_2018	400	370	14736	434.8	23/11/2018	04/01/2021	37091	OK
wb2_15_2018	500	337	4800	544.3	23/11/2018	**09/07/2020**	14238	OK

wb2_15_2018	700	337	4461	744.2	23/11/2018	04/01/2021	18545	OK
wb2_15_2018	800	370	14766	833.5	23/11/2018	04/01/2021	37091	OK
wb2_15_2018	900	337	5991	945.8	23/11/2018	04/01/2021	18545	OK
wb2_15_2018	1100	337	5993	1146.3	23/11/2018	04/01/2021	18545	OK
wb2_15_2018	1200	370	14787	1227.8	23/11/2018	04/01/2021	37091	OK
wb2_15_2018	1300	337	4475	1350.8	23/11/2018	04/01/2021	18545	OK
wb2_15_2018	1500	337	4797	1547.9	23/11/2018	**19/08/2020**	15238	OK
wb2_15_2018	1500	370	9433	1569.2	23/11/2018	04/01/2021	37091	OK. 2 files on recorder - also 2017
wb2_15_2018	1700	337	5989	1754.5	23/11/2018	04/01/2021	18545	OK
wb2_15_2018	1900	337	7470	1954.1	23/11/2018	04/01/2021	18542	OK
wb2_15_2018	2050	370	12722	2092.4	23/11/2018	04/01/2021	37091	OK. Faulty end cap
wb2_15_2018	2300	337	4799	2358.8	23/11/2018	**02/08/2020**	14821	OK
wb2_15_2018	2800	337	4178	2872.1	23/11/2018	04/01/2021	18545	OK
wb2_15_2018	3000	370	9409	3093.5	23/11/2018	04/01/2021	37091	OK
wb2_15_2018	3300	337	7362	3380.1	23/11/2018	04/01/2021	18545	Ok
wb2_15_2018	3850	337	4710	3934.7	23/11/2018	04/01/2021	18545	Ok

Mooring	Nominal depth (m)	Inst. code	Serial number	Mean pressure (dbar)	Start date	End date	No. records	Comments
wbadcp_14_2018	610	324	15579		19/11/2018			Flooded

Mooring	Nominal depth (m)	Inst. code	Serial number	Mean pressure (dbar)	Start date	End date	No. records	Comments
wbal7_7_2017	500	465	54		28/03/2017			Recovered to Miami
wbal7_7_2017	500	465	428		28/03/2017			Recovered to Miami

Mooring	Nominal depth (m)	Inst. code	Serial number	Mean pressure (dbar)	Start date	End date	No. records	Comments
wb2l12_12_2017	3877	465	57		29/03/2017			Did not surface
wb2l12_12_2017	3877	465	64		29/03/2017			Did not surface

Table 17.5 Mooring instrument record lengths.

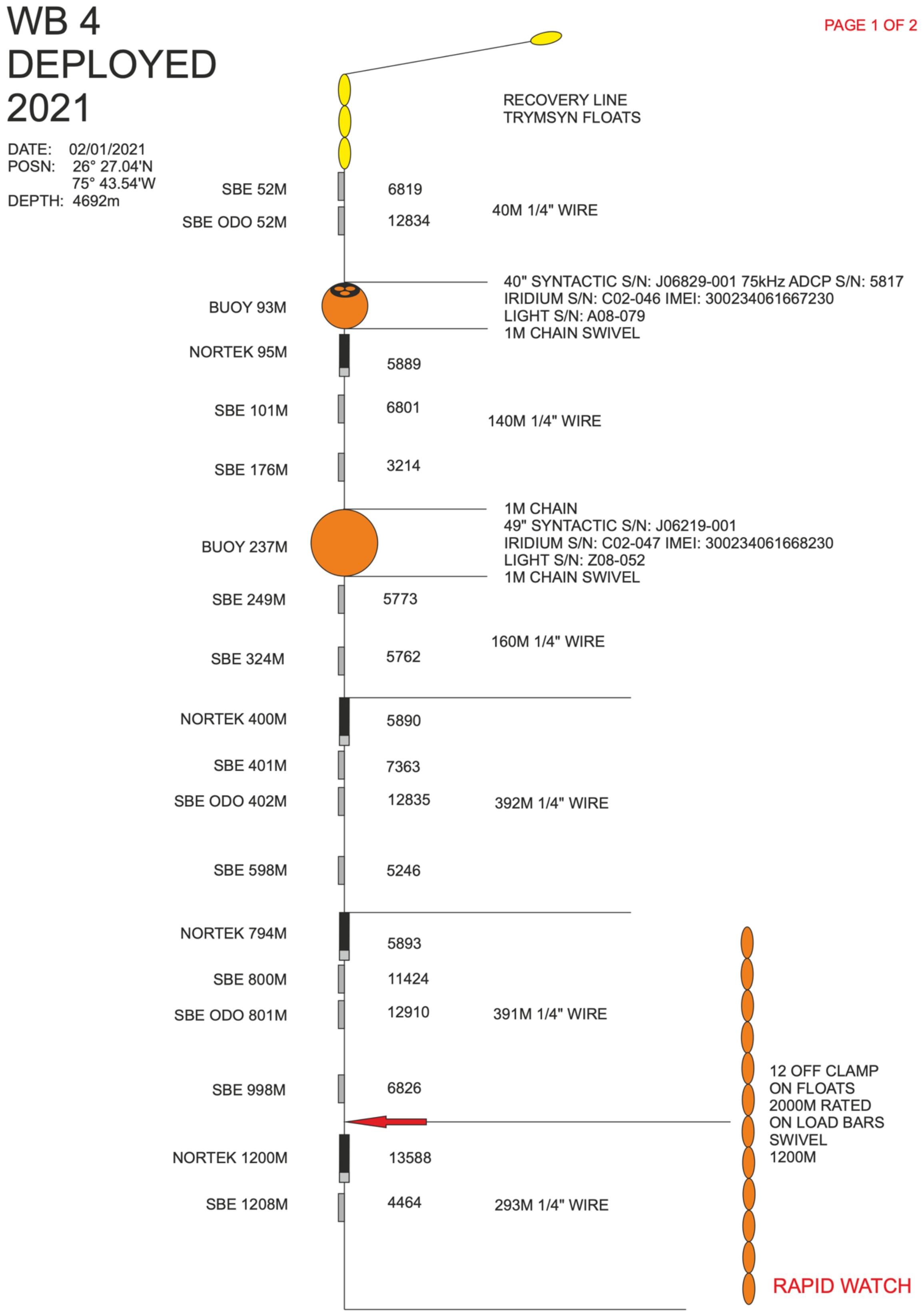
18. PIES recovery

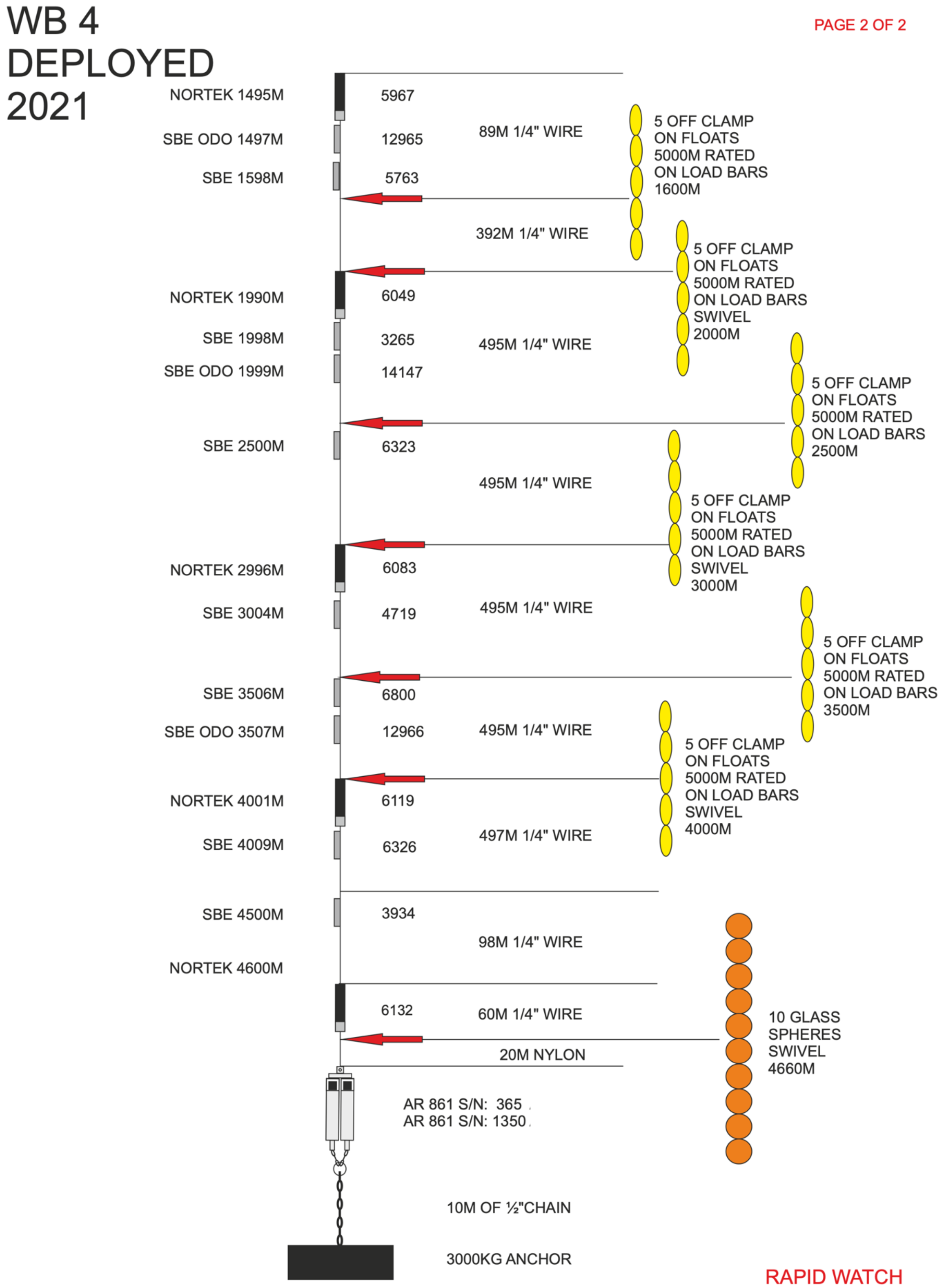
Smeed

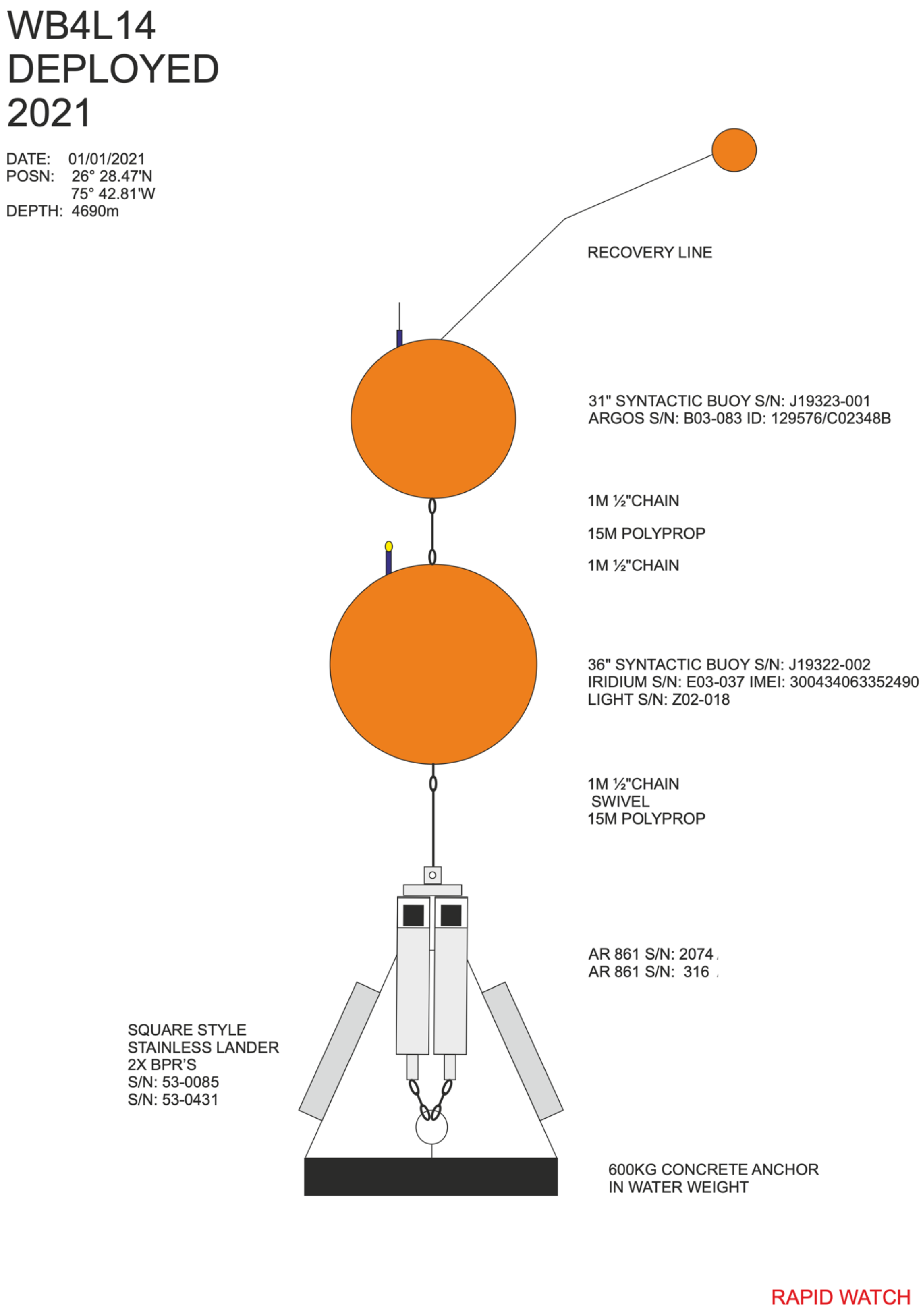
The PIES at MAR1 was recovered on Tuesday 22 December 2020.

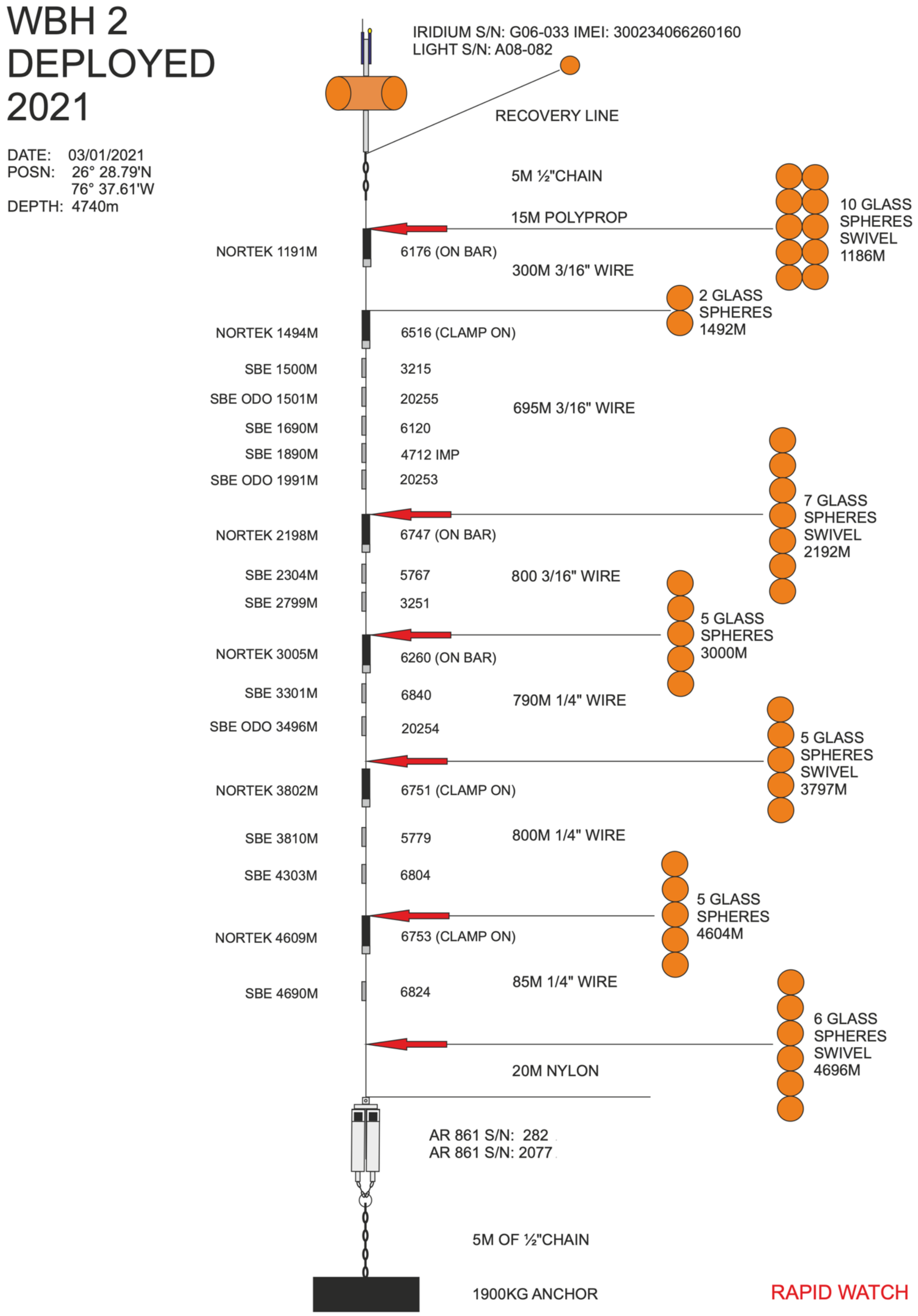
05:37 Release sent. Did not hear 6 ping reply
05:47 Probable 4 second ping repeat.
06:40 Very clear 4s ping. No trace on échange sounder
07:26 On surface
07:57 On deck
Stopped pinging a few minutes later. Rinsed freshwater.

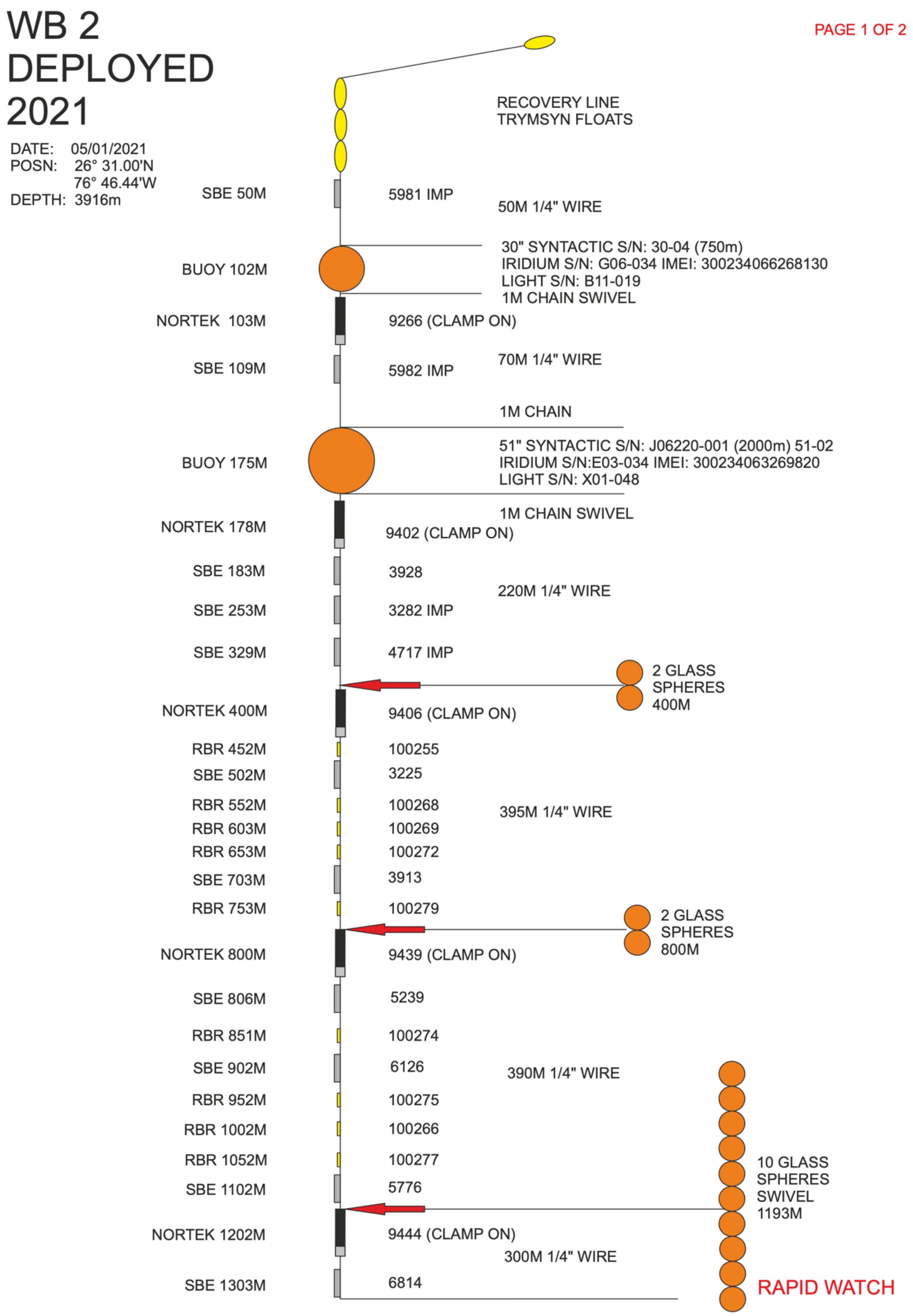
Appendix A: Diagrams of deployed moorings

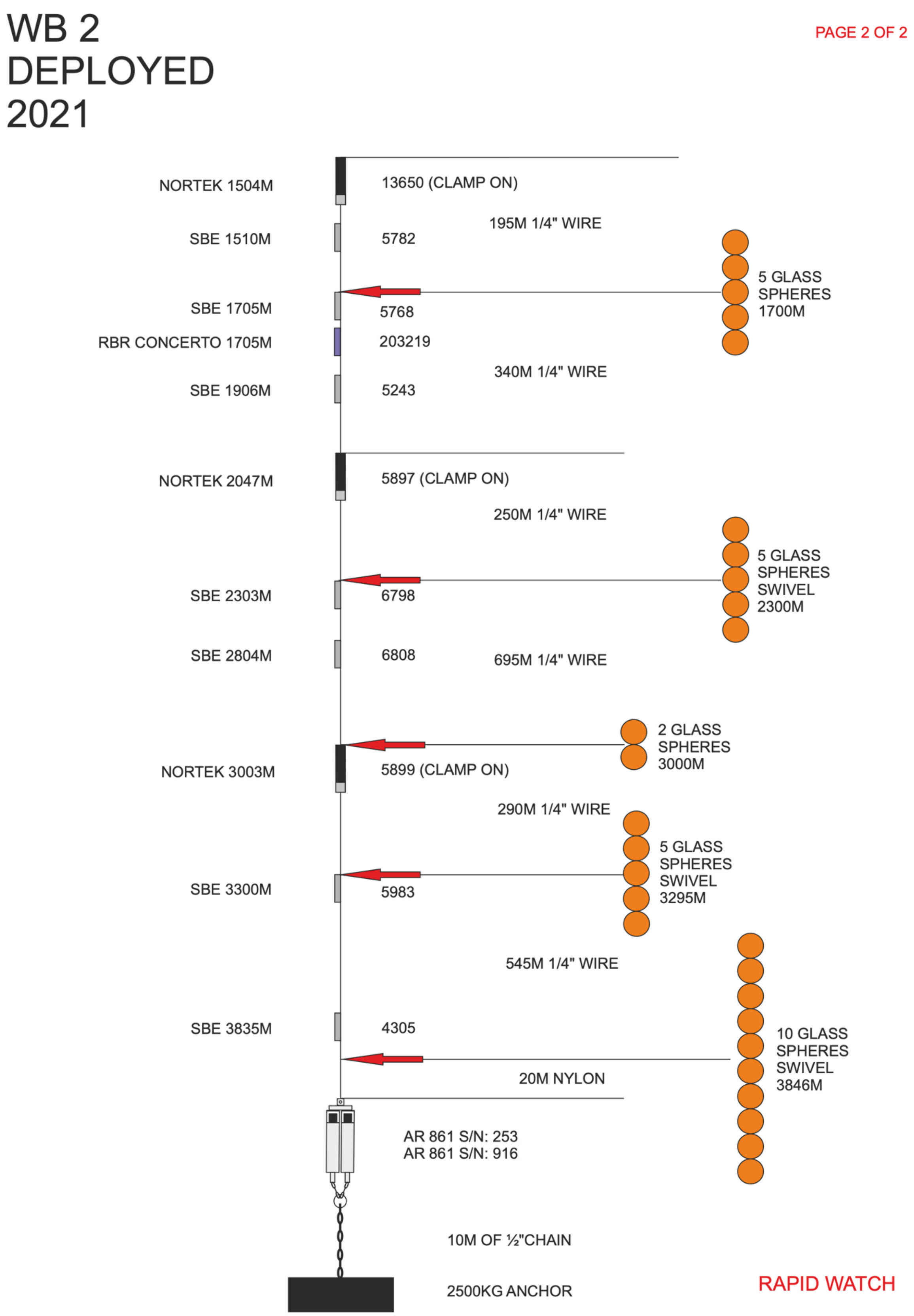



WB 4
DEPLOYED
2021
PAGE 2 OF 2
NORTEK 1495M
5967
SBE ODO 1497M
12965
89M 1/4" WIRE
5 OFF CLAMP
ON FLOATS
5000M RATED
ON LOAD BARS
1600M
SBE 1598M
5763
392M 1/4" WIRE
5 OFF CLAMP
ON FLOATS
5000M RATED
ON LOAD BARS
SWIVEL
2000M
NORTEK 1990M
6049
SBE 1998M
3265
495M 1/4" WIRE
SBE ODO 1999M
14147
5 OFF CLAMP
ON FLOATS
5000M RATED
ON LOAD BARS
2500M
SBE 2500M
6323
495M 1/4" WIRE
5 OFF CLAMP
ON FLOATS
5000M RATED
ON LOAD BARS
SWIVEL
3000M
NORTEK 2996M
6083
SBE 3004M
4719
495M 1/4" WIRE
5 OFF CLAMP
ON FLOATS
5000M RATED
ON LOAD BARS
3500M
SBE 3506M
6800
SBE ODO 3507M
12966
495M 1/4" WIRE
5 OFF CLAMP
ON FLOATS
5000M RATED
ON LOAD BARS
SWIVEL
4000M
NORTEK 4001M
6119
SBE 4009M
6326
497M 1/4" WIRE
SBE 4500M
3934
98M 1/4" WIRE
NORTEK 4600M
6132
60M 1/4" WIRE
10 GLASS
SPHERES
SWIVEL
4660M
20M NYLON
AR 861 S/N: 365
AR 861 S/N: 1350
10M OF ½"CHAIN
3000KG ANCHOR
RAPID WATCH


WB4L14
DEPLOYED
2021
DATE: 01/01/2021
POSN: 26° 28.47'N
75° 42.81'W
DEPTH: 4690m
RECOVERY LINE
31" SYNTACTIC BUOY S/N: J19323-001
ARGOS S/N: B03-083 ID: 129576/C02348B
1M ½"CHAIN
15M POLYPROP
1M ½"CHAIN
36" SYNTACTIC BUOY S/N: J19322-002
IRIDIUM S/N: E03-037 IMEI: 300434063352490
LIGHT S/N: Z02-018
1M ½"CHAIN
SWIVEL
15M POLYPROP
AR 861 S/N: 2074
AR 861 S/N: 316
SQUARE STYLE
STAINLESS LANDER
2X BPR'S
S/N: 53-0085
S/N: 53-0431
600KG CONCRETE ANCHOR
IN WATER WEIGHT
RAPID WATCH

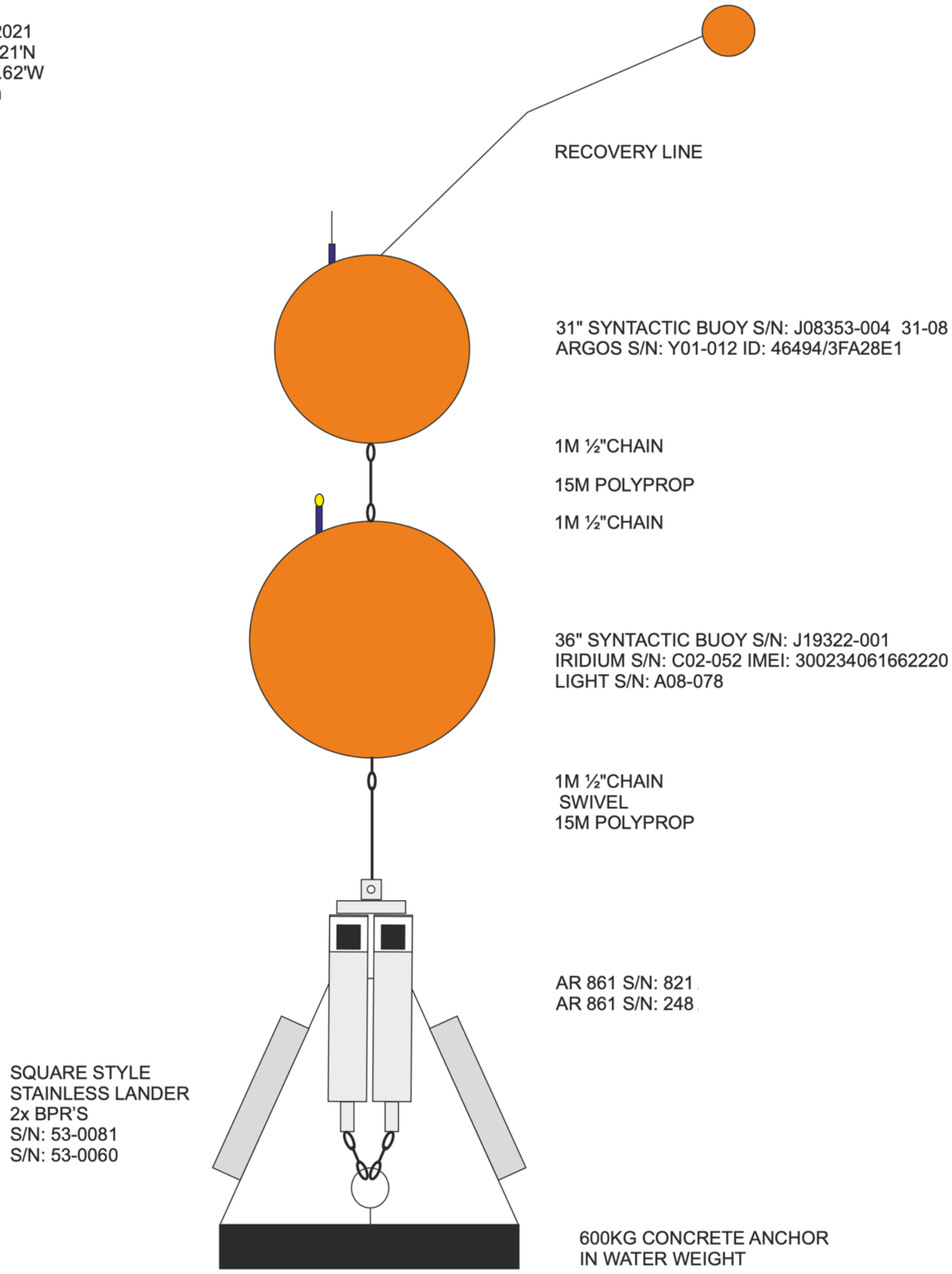

WBH 2
DEPLOYED
2021
DATE: 03/01/2021
POSN: 26° 28.79'N
76° 37.61'W
DEPTH: 4740m
IRIDIUM S/N: G06-033 IMEI: 300234066260160
LIGHT S/N: A08-082
RECOVERY LINE
5M ½"CHAIN
15M POLYPROP
10 GLASS
SPHERES
SWIVEL
1186M
NORTEK 1191M
6176 (ON BAR)
300M 3/16" WIRE
2 GLASS
SPHERES
1492M
NORTEK 1494M
6516 (CLAMP ON)
SBE 1500M
3215
SBE ODO 1501M
20255
695M 3/16" WIRE
SBE 1690M
6120
SBE 1890M
4712 IMP
SBE ODO 1991M
20253
7 GLASS
SPHERES
SWIVEL
2192M
NORTEK 2198M
6747 (ON BAR)
SBE 2304M
5767
800 3/16" WIRE
SBE 2799M
3251
5 GLASS
SPHERES
3000M
NORTEK 3005M
6260 (ON BAR)
SBE 3301M
6840
790M 1/4" WIRE
SBE ODO 3496M
20254
5 GLASS
SPHERES
SWIVEL
3797M
NORTEK 3802M
6751 (CLAMP ON)
SBE 3810M
5779
800M 1/4" WIRE
SBE 4303M
6804
5 GLASS
SPHERES
4604M
NORTEK 4609M
6753 (CLAMP ON)
SBE 4690M
6824
85M 1/4" WIRE
6 GLASS
SPHERES
SWIVEL
4696M
20M NYLON
AR 861 S/N: 282
AR 861 S/N: 2077
5M OF ½"CHAIN
1900KG ANCHOR
RAPID WATCH


WB 2
DEPLOYED
2021
DATE: 05/01/2021
POSN: 26° 31.00'N
76° 46.44'W
DEPTH: 3916m
PAGE 1 OF 2
RECOVERY LINE
TRYMSYN FLOATS
SBE 50M
5981 IMP
50M 1/4" WIRE
30" SYNTACTIC S/N: 30-04 (750m)
IRIDIUM S/N: G06-034 IMEI: 300234066268130
LIGHT S/N: B11-019
1M CHAIN SWIVEL
BUOY 102M
NORTEK 103M
9266 (CLAMP ON)
SBE 109M
5982 IMP
70M 1/4" WIRE
1M CHAIN
51" SYNTACTIC S/N: J06220-001 (2000m) 51-02
IRIDIUM S/N:E03-034 IMEI: 300234063269820
LIGHT S/N: X01-048
BUOY 175M
1M CHAIN SWIVEL
NORTEK 178M
9402 (CLAMP ON)
SBE 183M
3928
220M 1/4" WIRE
SBE 253M
3282 IMP
SBE 329M
4717 IMP
2 GLASS
SPHERES
400M
NORTEK 400M
9406 (CLAMP ON)
RBR 452M
100255
SBE 502M
3225
RBR 552M
100268
395M 1/4" WIRE
RBR 603M
100269
RBR 653M
100272
SBE 703M
3913
RBR 753M
100279
2 GLASS
SPHERES
800M
NORTEK 800M
9439 (CLAMP ON)
SBE 806M
5239
RBR 851M
100274
SBE 902M
6126
390M 1/4" WIRE
RBR 952M
100275
RBR 1002M
100266
RBR 1052M
100277
10 GLASS
SPHERES
SWIVEL
1193M
SBE 1102M
5776
NORTEK 1202M
9444 (CLAMP ON)
300M 1/4" WIRE
SBE 1303M
6814
RAPID WATCH

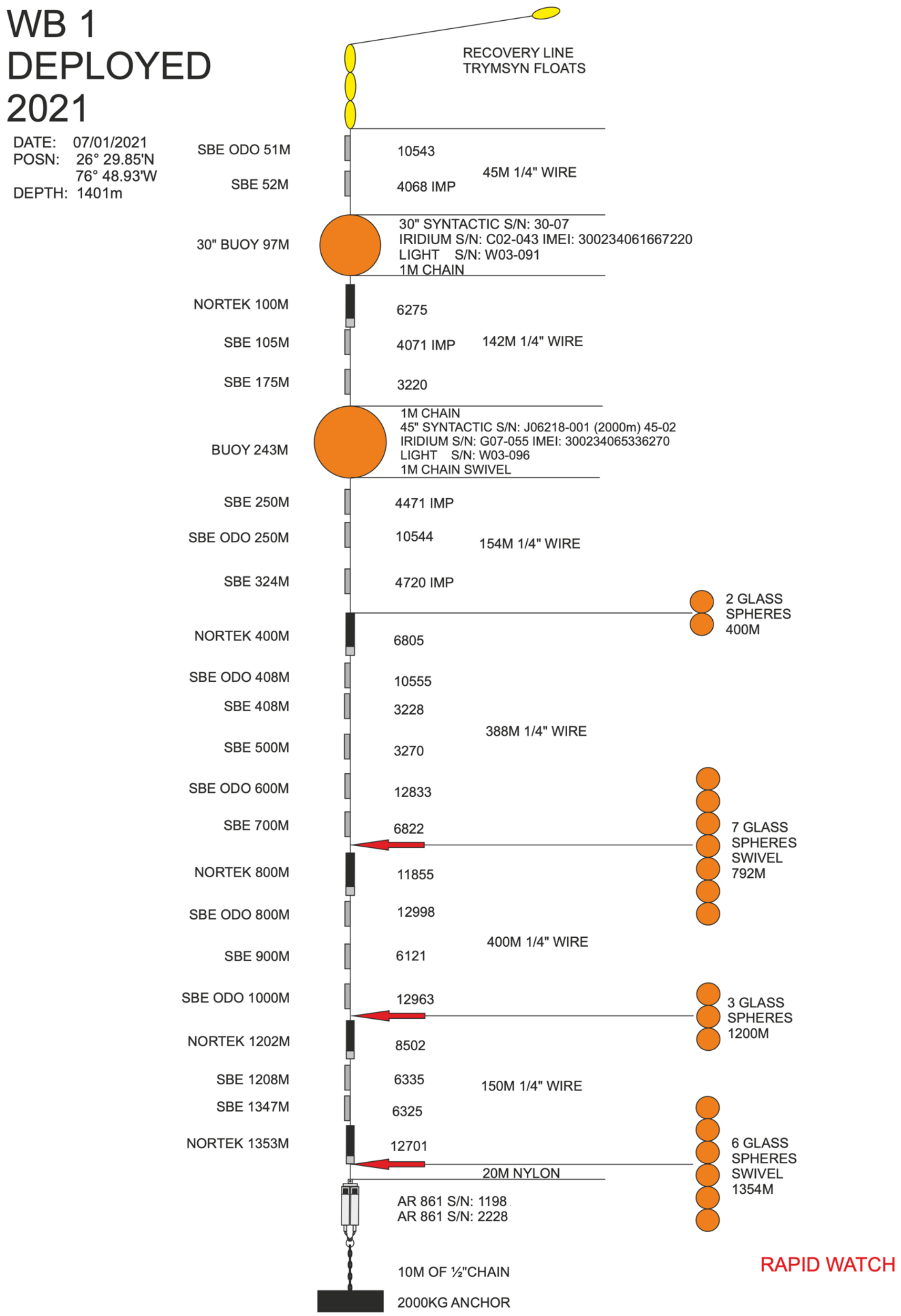

WB 2
DEPLOYED
2021
PAGE 2 OF 2
NORTEK 1504M
13650 (CLAMP ON)
195M 1/4" WIRE
SBE 1510M
5782
5 GLASS
SPHERES
1700M
SBE 1705M
5768
RBR CONCERTO 1705M
203219
340M 1/4" WIRE
SBE 1906M
5243
NORTEK 2047M
5897 (CLAMP ON)
250M 1/4" WIRE
5 GLASS
SPHERES
SWIVEL
2300M
SBE 2303M
6798
SBE 2804M
6808
695M 1/4" WIRE
2 GLASS
SPHERES
3000M
NORTEK 3003M
5899 (CLAMP ON)
290M 1/4" WIRE
5 GLASS
SPHERES
SWIVEL
3295M
SBE 3300M
5983
545M 1/4" WIRE
SBE 3835M
4305
10 GLASS
SPHERES
SWIVEL
3846M
20M NYLON
AR 861 S/N: 253
AR 861 S/N: 916
10M OF ½"CHAIN
2500KG ANCHOR
RAPID WATCH

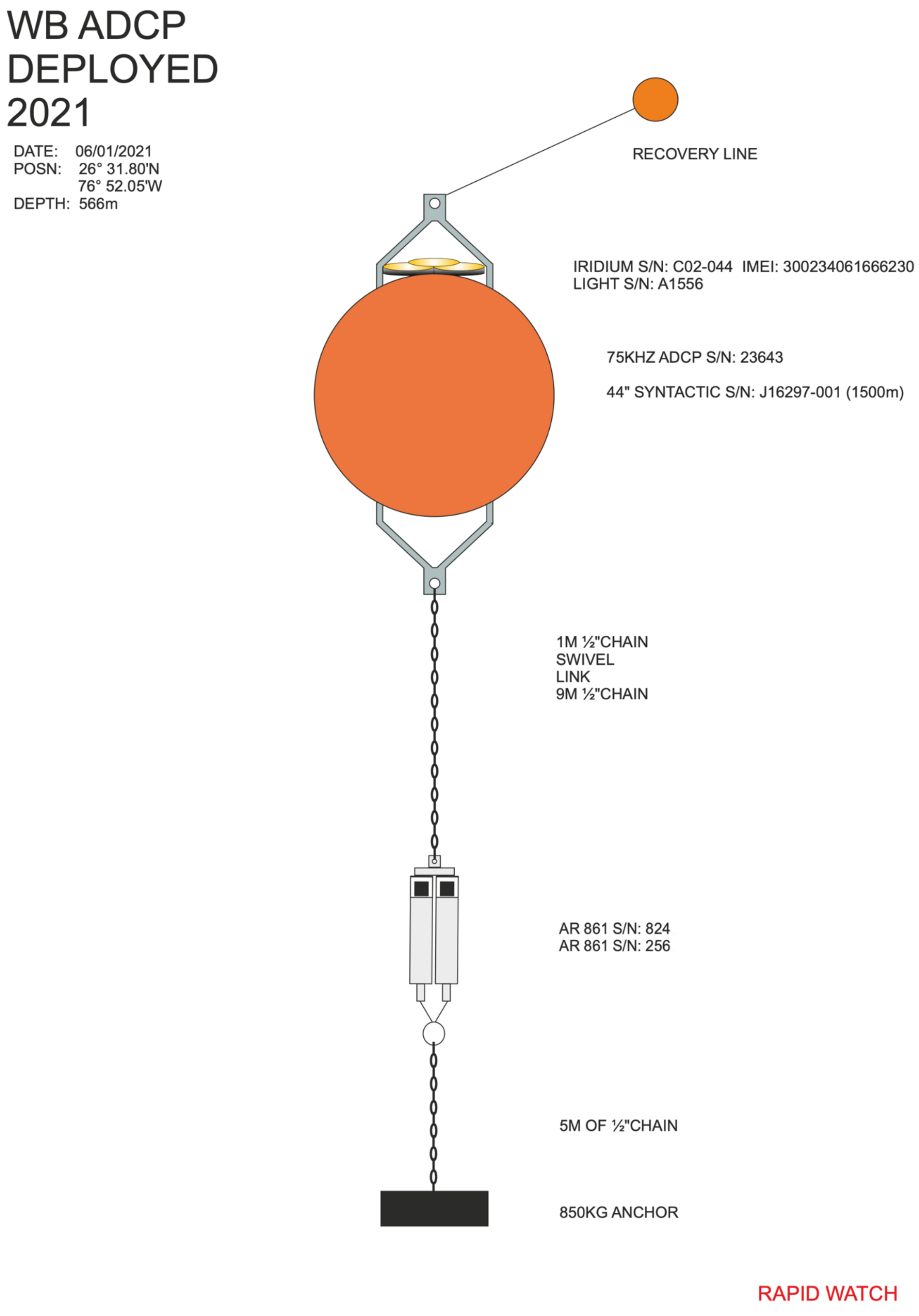
WB2L14 DEPLOYED 2021

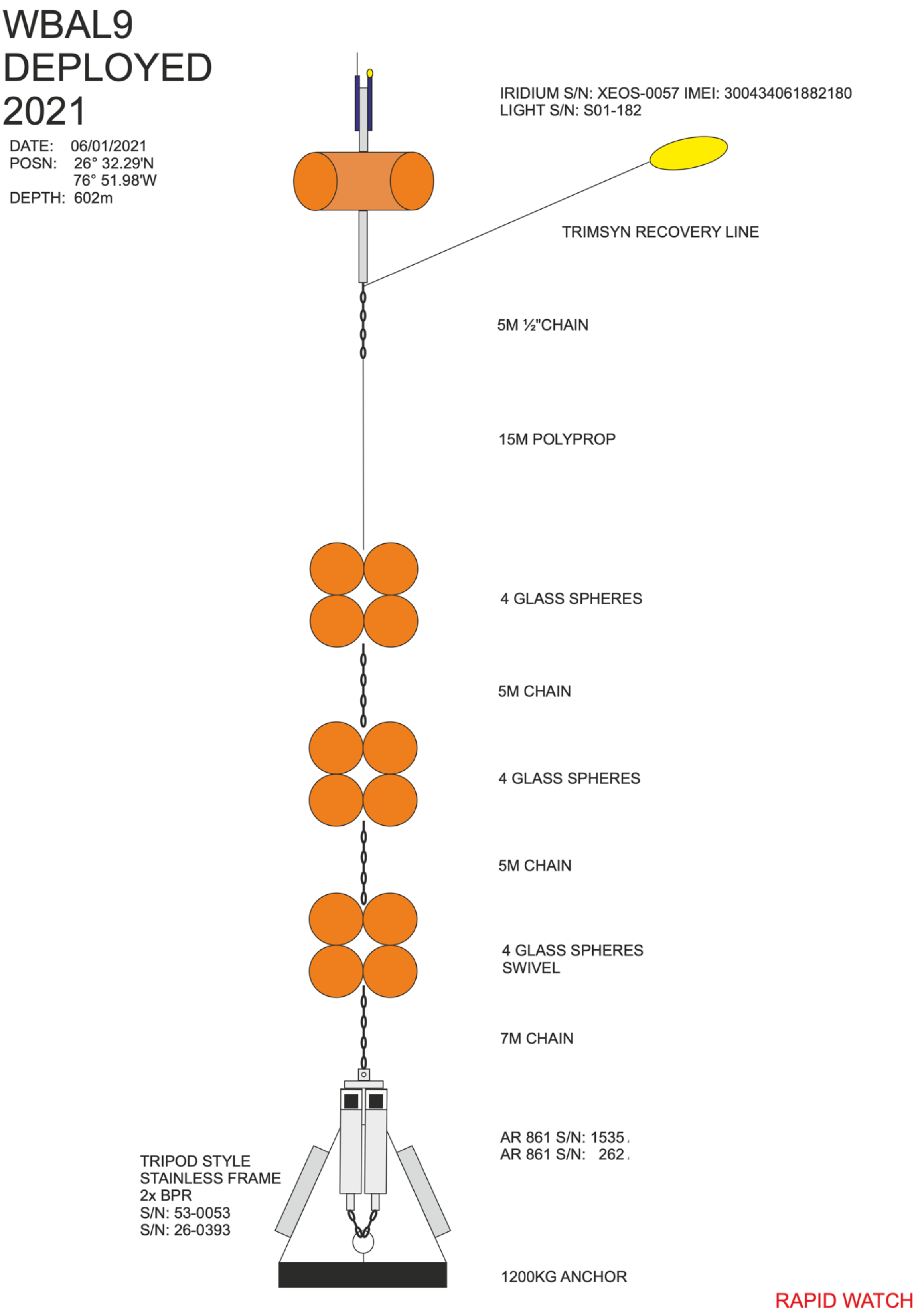
DATE: 04/01/2021
POSN: 26°30.21'N
76° 44.62'W
DEPTH: 3888m



RAPID WATCH


WB 1
DEPLOYED
2021
DATE: 07/01/2021
POSN: 26° 29.85'N
76° 48.93'W
DEPTH: 1401m
RECOVERY LINE
TRYMSYN FLOATS
SBE ODO 51M
10543
45M 1/4" WIRE
SBE 52M
4068 IMP
30" BUOY 97M
30" SYNTACTIC S/N: 30-07
IRIDIUM S/N: C02-043 IMEI: 300234061667220
LIGHT S/N: W03-091
1M CHAIN
NORTEK 100M
6275
SBE 105M
4071 IMP
142M 1/4" WIRE
SBE 175M
3220
1M CHAIN
45" SYNTACTIC S/N: J06218-001 (2000m) 45-02
IRIDIUM S/N: G07-055 IMEI: 300234065336270
LIGHT S/N: W03-096
1M CHAIN SWIVEL
BUOY 243M
SBE 250M
4471 IMP
SBE ODO 250M
10544
154M 1/4" WIRE
SBE 324M
4720 IMP
2 GLASS
SPHERES
400M
NORTEK 400M
6805
SBE ODO 408M
10555
SBE 408M
3228
388M 1/4" WIRE
SBE 500M
3270
SBE ODO 600M
12833
SBE 700M
6822
7 GLASS
SPHERES
SWIVEL
792M
NORTEK 800M
11855
SBE ODO 800M
12998
400M 1/4" WIRE
SBE 900M
6121
SBE ODO 1000M
12963
3 GLASS
SPHERES
1200M
NORTEK 1202M
8502
SBE 1208M
6335
150M 1/4" WIRE
SBE 1347M
6325
NORTEK 1353M
12701
6 GLASS
SPHERES
SWIVEL
1354M
20M NYLON
AR 861 S/N: 1198
AR 861 S/N: 2228
10M OF ½"CHAIN
2000KG ANCHOR
RAPID WATCH


WB ADCP
DEPLOYED
2021
DATE: 06/01/2021
POSN: 26° 31.80'N
76° 52.05'W
DEPTH: 566m
RECOVERY LINE
IRIDIUM S/N: C02-044 IMEI: 300234061666230
LIGHT S/N: A1556
75KHZ ADCP S/N: 23643
44" SYNTACTIC S/N: J16297-001 (1500m)
1M ½"CHAIN
SWIVEL
LINK
9M ½"CHAIN
AR 861 S/N: 824
AR 861 S/N: 256
5M OF ½"CHAIN
850KG ANCHOR
RAPID WATCH


WBAL9
DEPLOYED
2021
DATE: 06/01/2021
POSN: 26° 32.29'N
76° 51.98'W
DEPTH: 602m
IRIDIUM S/N: XEOS-0057 IMEI: 300434061882180
LIGHT S/N: S01-182
TRIMSYN RECOVERY LINE
5M ½"CHAIN
15M POLYPROP
4 GLASS SPHERES
5M CHAIN
4 GLASS SPHERES
5M CHAIN
4 GLASS SPHERES
SWIVEL
7M CHAIN
AR 861 S/N: 1535
AR 861 S/N: 262
TRIPOD STYLE
STAINLESS FRAME
2x BPR
S/N: 53-0053
S/N: 26-0393
1200KG ANCHOR
RAPID WATCH

Appendix B: Log sheets of recovered moorings

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **MAR3L11**
Cruise [redacted] DY129

NB: all times recorded in GMT

Date 18/Dec/2020
Site arrival time 17:10
Time of first ranging 17:11

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	hooked @ 18:27, tangled	18:33
31" Syntactic	31-10 ✓	J08353-001	18:33
with Argos Beacon	Y01-009 ✓	Beacon ID: 46491 aerial bent	
36" Syntactic	34-03 ✓		18:39
with Light	A08-087 ✓	flashing	
BPR	0056 ✓		18:42
BPR	0426 ✓		
Acoustic Release #1	2219 ✓		
Acoustic Release #2	265 ✓		

switch

Ascent Rate 68 m/min

Ranging

Surfaced at 18:10

Time	Range 1	Range 2	Command/comment
~~17:03~~			
17:11	4992	—	
17:12	4993	4993	
17:14:25	4993	~~4994~~ ARM release	release ok.
17:15:25	4928	4913	ARM Release 65 m/min.
17:17:25	4752	4738	ARM + ARM 88 m/min.
17:18:25	4664	4652	" "
17:25	4093.3	4081.5	" "

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **MAR3L12** Cruise **DY129**

NB: all times recorded in GMT

Date 19/Dec/2020 **Site arrival time** overnight.

Time of first ranging 08:54

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grap@1004	10:05
31" Syntactic	J18250-003		10:09
with Argos Beacon	B11-025 ✓	Beacon ID: 134366/C93E1E1	
36" Syntactic	J18251-002		10:12
with Light	A08-086 ✓		
BPR	53-0038 ✓		10:15
BPR	53-0059 ✓		
Acoustic Release #1	0910 ✓		
Acoustic Release #2	2072 ?		

Ascent Rate 110 m/min.

Ranging

on Surface: 9:56 streamed out.

9.0

Time	Range 1	Range 2	Command/comment
08:54	—	5378	ARM ARM.
08:54	5352	5344	" "
08:55	5316	5311	" "
08:56:20	5275	5269	ARM Release release ok.
08:57:10	5171	5153	ARM ARM.
08:58:20	—	5017.	" "
08:59:17	4945	4944	" "
09:00:17	4833	4813	" "
09:01:17	4723.	4709	" "
09:03:20	4528	4518	" "

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **MAR3** Cruise [redacted] DY129

NB: all times recorded in GMT

Date 19/Dec/2020 **Site arrival time** 10:22

Time of first ranging 10:22

on Surface: 10:36

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		11:28
3 x Mini-Trimsyn	n/a		11:38
MicroCAT	3910 ? ✓	Check SN wires ~~cut~~	
24" syntactic float	24-02		12:19
with Light	S01-185 ✓		
and Iridium Beacon	E03-037 ✓	Beacon ID: 300234063352490	
MicroCAT	4549 ✓		12:18
37" Steel Sphere	260005614		12:27
with Light	T05-079 ✓		
and Argos Beacon	094 ✓	Beacon ID: 24027	
Swivel	n/a		
MicroCAT	6819 ✓		12:29
MicroCAT	5246 ✓	Locking sleeve Missing.	12:32
MicroCAT	3248 ✓	Locking sleeve missing. = LSM	12:34
MicroCAT	3271 ✓		12:36
MicroCAT	5762 ✓	LSM	12:42
10 x 17" glass	n/a	Tangled	12:48
MicroCAT	5763 ✓		12:54
MicroCAT	7363 ✓	LSM	12:59
MicroCAT	6323 ✓		13:04
RCM11	516 ✓		13:13
MicroCAT	4719 ✓		13:17
9 x 17" glass	n/a		13:22
MicroCAT	6127 ✓		13:32
4 x 17" glass	n/a	* Tangle! mcat w/ square cage	13:47
MicroCAT	11424 ✓		13:51
4 x 17" glass	n/a		
MicroCAT	6830 ✓	← Reel change @ 14:12 →	1409
4 x 17" glass	n/a		1431
MicroCAT	6822 ✓		1434
4 x 17" glass	n/a	tangle 14:47	14:48
MicroCAT	6805 ✓		14:47
MicroCAT	6121 ✓		15:07
4 x 17" glass	n/a	tangle	~~14:48~~ 15:13
MicroCAT	6326 ✓		15:27
~~SA~~ S4	35612577 ✓	chipped plastic	15:28

Wire ~~cut~~ Parted → (24" syntactic float)

2nd Recovery Line – After 4549 12:09

* Tangled bit tied off incl S4 + 7 glass

[redacted]

7 x 17" glass	n/a		15:28
Acoustic Release 1	0930 ✓	}	15:30 ✓
Acoustic Release 2	1194 ✓	}	

Ascent Rate ____________

Ranging

(margin note)	Time	Range 1	Range 2	Command/comment
	10:22:00	~~44~~ —	4411	ARM ARM.
s/n 0930	102345	5039	5038	
s/n 1194 {	102430	~~5019~~ /	5019	
	1025	/	/	
s/n 930	102640	5010	5010	
	103300	—	1022 —	ARM Release release ok
	103400	4953	—	
	103500	4853	—	
	103600	4752	—	

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **NOG**
NB: all times recorded in GMT

Cruise [redacted] DY129

Date 19/Dec/2020
Time of first ranging 16:30
Site arrival time 16:30

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		1734
Billings Float	n/a		
with Light	W03-095		1740
12 x 17" glass	n/a	~~Only 10~~	1746
Sediment Trap	11804-03 ✓		1750
Nortek	6765 ✓		1750
Sediment Trap	11804-02 ✓		1756
Nortek	9956 ✓		1756
10 x 17" glass	n/a		1822
MicroCAT	3911 ✓		1832
Acoustic Release #1	0321		1877
Acoustic Release #2	1749		

Ascent Rate 90 m/min.

Ranging

Time	Range 1	Range 2	Command/comment
16:31:00	4205	/	ARM ARM. 321
16:31:30	4206	4207	ARM ARM "
16:32:08	/	/	ARM ARM. 1749.
16:32:45	4209	4209.	ARM ARM "
16:34:27	/	/	ARM Release " no response
16:35:27	/	/	" " " "
16:36:27	/	/	
16:37:24	3965	3955	ARM ARM. 321
16:38:24	3867	3857	" " "
16:40:24	3685	3 /	

on Surface: 17 17 Bottom pack
17 21 Top pack

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **MAR1L11** Cruise [redacted] DY129

NB: all times recorded in GMT

Date 21/Dec/2020 **Site arrival time** 13:07

Time of first ranging 13:18

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		14.28
31" Syntactic	31-07	(J08353-002)	1432
with Argos Beacon	Y01-013	Beacon ID: 46498	14
34" Syntactic	34-04	(J08352-001)	1434
with Light	Y01-014		
BPR	0432		1437
BPR	0034		
Acoustic Release #1	2229		
Acoustic Release #2	2243		

Ascent Rate 86 m/min.

Ranging

Time	Range 1	Range 2	Command/comment
13:18:20	—	—	ARM + Release
13:19:20	5131	5120	ARM + Release
13:20:20	5046	5032	" "
13:22:20	—	—	ARM → ARM
13:25:20	4789	4776	

T

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **MAR1L12** Cruise **DY129**

NB: all times recorded in GMT

Date 21/12

Time of first ranging 14:41

Site arrival time 15:13 but released before leaving Mar1L11

1st grap @15:51

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled @ 15:54	15:54
31" Syntactic	J18250-002		16:00
with Argos Beacon	B11-021	Beacon ID: 134362/C93E1AD	
36" Syntactic	J18251-003		16:02
with Light	N08-027		
BPR	53-0013 ✓	}	16:05
BPR	53-0014 ✓		
Acoustic Release #1	0825		
Acoustic Release #2	1732		

Ascent Rate 85.6 m/min

on surface 15:43
expected 15:45

Ranging

good comms both releases

Time	Range 1	Range 2	Command/comment
1441			1A1C
1443	5512	5517	~~1A55~~ Release ok
1444	—	—	
1445	—	5368	
1509	2937.6	2927.8	
15:11:00	2824.3	2816.7	
15:12:00	2738.7	2731.3	
15:14:00	2568.6	2560.8	

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **MAR1** Cruise [redacted] DY129

NB: all times recorded in GMT

Date 22/12/2020 **Site arrival time** overnight

Time of first ranging 10:15

on Surface: 10:32

ITEM	SER NO	COMMENT	TIME
Mini-Trimsyn	n/a	no float - cut?	11:34
24.5" syntactic float			11:44
with Light	X01-052		
and Iridium Beacon	C02-046	ID: 300234061667230	
8 x 17" glass	n/a		11:44
RAS-500	13278-02		} 11:48
Contros pCO2	1114-001		
SeaFET	2002		
MicroCAT-ODO	12903		
MicroCAT (in frame)	3257		
MicroCAT	3264 ✓		11:54
37" McLa. SS			11:55
with Light	S01-189		
and Argos Beacon	A08-069	Beacon ID: 121990	
MicroCAT	3486 ✓	no lock shield	11:58
MicroCAT	3483	34?? No sticker	} 12:00
MicroCAT-ODO	12908 ✓	Was first off, shallower by ~½m + length meet	
MicroCAT	5484 ✓		12:03
MicroCAT	3214 ✓		
MicroCAT-ODO	12911 ✓	lsm - lock shield missing wire guide missing	} 12:05
MicroCAT	3254 ✓	3m sep	
MicroCAT-ODO	12902 ✓		} 12:11
9 x 17" glass	n/a		12:17
MicroCAT-ODO	12901 ✓		} 12:22
MicroCAT	4307 ✓		
MicroCAT	5779 ✓		
MicroCAT-ODO	13000 ✓		} 12:28
MicroCAT	3928 ✓		
RCM-11	507 ✓		12:42
MicroCAT-ODO	12835 ✓		12:44
MicroCAT	5773 ✓		12:48
12 x 17" glass	n/a		12:53
MicroCAT	4305 ✓		
MicroCAT-ODO	12834 ✓		} 1304
8 x 17" glass	n/a		13:18
MicroCAT	3934 ✓	1333 reeler issue till 13.39	13:21
MicroCAT	3265 ✓		13:42

switched over wire

[redacted]

drum change 14:07

3 x 17" glass	n/a	tangle w/ winch @ 4500m	13:57
MicroCAT-ODO	12910 ✓	}	14:17
MicroCAT	5768 ✓	}	14:17
4 x 17" glass	n/a		1430
MicroCAT	3251 ✓		14:32
MicroCAT	6828 ✓	no end cap / wire guard	14:00 !
4 x 17" glass	n/a	Tangle 15:01	~~14:30~~
MicroCAT	6840 ~~325~~ ✓	15 02	~~14:30~~ ~~14:32~~
RCM11	515 ✓	~~15 16~~	1516
9 x 17" glass	n/a	2 implosions	1518
Acoustic Release #1	2076 ✓		1519
Acoustic Release #2	1383 ✓		

one implode →

89 m/min

Ranging

expected all up ~~18~~:25 gmt

Time	Range 1	Range 2	Command/comment
1016	—	—	
1017	—		No responses 0966
1021	5165	5168	
1022	—	—	
10:27:00	5166	12884	Release – no answer
10:28:00	5090	5077	Coming up – Rel OK
10:29:00	4992	4977	
10:31:04	—	4776	Diagnostic
10:32:00	4719	4707	

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **MAR0** Cruise [redacted] DY129

NB: all times recorded in GMT

Date 23/Dec/2020 **Site arrival time** 10:10

Time of first ranging 10:30

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		11 50
5 x Rugby Ball floats	n/a		11 55
MicroCAT	6325 ✓		12 02
MicroCAT	6322 ✓		12 07
MicroCAT	6137 ✓		12 11
MicroCAT	6128 ✓		12 16
RCM11	518 ✓		12 20
MicroCAT	6123 ✓		12 22
36' Syntactic	J18251-001		12 24
Acoustic Release #1	0319		〃
Acoustic Release #2	2073		〃

Ascent Rate ~~104~~ 90 m/min.

Ranging

Time	Range 1	Range 2	Command/comment
10:04:40	—	—	ARM ARM
10:08:30	—	—	
10:10:00	—	—	
10:30:00	5406	5406.	
10:30:06	5405	5405	ARM + REL release ok.
10:31:08	—	5298	
10:32:08	—	5194	
10:34:08	—		
10:35:20	5021	5027	
10:36:08	4923	4910	
10:38:08	4731	4719.	
10:40:08	4573	4566	
			On surfac 11 28
			Thn 11 38

2073

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **WB6** Cruise [redacted] DY129

NB: all times recorded in GMT

Date 27th/Dec/2020 **Site arrival time** 17:27
Time of first ranging 17:28

ITEM	SER NO	COMMENT	TIME
Recovery Line	n/a		1912
31" syntactic ✓	J18250-001		1921
with light ✓	T05-078		
And Iridium becaon ✓	C02-047	30024061668230	
MicroCAT	6333 ✓		1921
MicroCAT	3280 ✓		1928
MicroCAT	3209 ✓		1933
MicroCAT	4306 ✓		1938
Nortek	5490 ✓	No locking sleeve	1940
MicroCAT	3268 ✓	Tangled	1945
31" SYNTACTIC	J08353-003		1945
34" SYNTACTIC	n/a		1945
BPR #1	0414 ✓		1951
BPR #2	0036 ✓		
Acoustic Release #1	0324		
Acoustic Release #2	1461		

Ascent Rate 72 m/min.
Time at end of recovery ________

Ranging

Time	Range 1	Range 2	Command/comment
17:28:52	5464	5466	ARM+ARM. 0324
17:29:27		5465	ARM + ARM 1461
17:31:20	5466	5468	ARM + ARM 0324
17:36:00	5467	5467	ARM+ REL release ok 0324
17:37:00	5411	5401	" " " "
17:38:00	5338	5327	ARM+ ARM " "
17:39:00	5266	5255	" " " "

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **WB4** Cruise [redacted] DY129

NB: all times recorded in GMT

Date 1/Jan/2021 **Site arrival time** overnight

Time of first ranging 12:26

ITEM	SER NO	COMMENT	TIME
Recovery Line	n/a		13:33
3 TRYMSYN floats	n/a		13:34
MicroCAT	3893 ✓	Heavy fouling	13:37
MicroCAT-ODO	14148 ✓	Heavy fouling	13:37
40" syntactic + ADCP	J07216/10311	Check beacon	13:49
with Iridium beacon	G06-033 ✓	ID: 300234066260160	
and light	W03-097 ✓		
Nortek	5611 ✓	Fouling	13:51
MicroCAT	5485 ✓	Much fouling	13:52
49" syntactic	J08203-003		13:56
with Iridium beacon	G06-034 ✓	ID: 300234066268130	"
and light	Z02-021 ✓		"
MicroCAT	3249 ✓	Guard screw sheared	13:58
MicroCAT-ODO	14115 ✓		"
Nortek	9420 ✓		14:03
MicroCAT	3244 ✓		14:03
MicroCAT-ODO	14114 ✓		14:03
MicroCAT	3216 ✓	Plastic color arrow top broken	14:10
MicroCAT-ODO	10519 ✓		14:11
Nortek	5879 ✓		14:16
MicroCAT	3213 ✓		14:18
MicroCAT-ODO	10547 ✓		14:18
MicroCAT	5780 ✓	No locking sleeve	14:23
MicroCAT-ODO	10517 ✓		" "
11 x Orange CF-16s	n/a		14:29
1 x Yellow CF-16	n/a		"
Nortek	9427 ✓		14:34
MicroCAT	3252 ✓		" "
Nortek	11024 ✓		1443
MicroCAT-ODO	10545 ✓		1443
5 x yellow CF-16s	n/a		1448
MicroCAT	5785 ✓		1450
5 x yellow CF-16s	n/a ✓		1502
Nortek	6743 ✓		1502
MicroCAT	6815 ✓		1526
MicroCAT-ODO	10546 ✓		"

Shackle obscure head?

5 x yellow CF-16s	n/a		Chang dfun	152
MicroCAT	3277	✓		1534
5 x yellow CF-16s	n/a			1542
Nortek	5955	✓	Slid down bar	" "
MicroCAT	3230	✓		1550
5 x yellow CF-16s	n/a			1605
MicroCAT	6820	✓		1607
MicroCAT-ODO	12999	✓		"
5 x yellow CF-16s	n/a			1620
Nortek	5963	✓		1622
MicroCAT	6825	✓		1624
MicroCAT	3933	✓		1640
Nortek	6050	✓		1640
10 x glass	n/a		1 imploded	1644
Acoustic Release 1	0364			} 1648
Acoustic Release 2	1733			

83 m/min.

Ranging

	Time	Range 1	Range 2	Command/comment
0364	12:26:20	—	—	ARM + ARM
"	12:27:00	—	—	" "
"	12:27:33	—	—	" "
1733	12:28:35	—	4664	" "
"	12:29:10	4664	4663	" "
"	12:30:00	4664	4665	ARM + Release release ok
	12:32:00	—	—	" " no answer
	12:33:07	—	—	
	12:34:06	—	—	
0364	12:35:20	—	—	ARM + ARM
1733	12:36:56	—	—	" "
"	12:38:06	3969	—	" "
	12:39:00	3885	3875	" "
	12:40:00	3802	3752	" "
	12:41:00	—	3691	

RAPID-AMOC
MOORING LOGSHEET **RECOVERY**

Mooring **WBH2** Cruise [redacted] DY129

NB: all times recorded in GMT

Date 3/JAN/2021 **Site arrival time** overnight

Time of first ranging ____________

ITEM	SER NO	COMMENT	TIME
Recovery Line	n/a	grappled at 14:46	14:47
Billings float	n/a		14:55
with light	Y01-018		14:55
and Iridium beacon	C02-052	ID: 300234061662220 no email from Beacon.	14:55
12 x 17" glass	n/a		15 05
RAS-500	14520-02		15 09
Nortek	8052 ✓		" "
MicroCAT-ODO	12832 ✓		15 11
MicroCAT-ODO	12907 ✓		15 30
7 x 17" glass	n/a		15 35
Nortek	9435 ✓		15 37
MicroCAT	3255 ✓		15 39
5 x 17" glass	n/a ✓	2 implosions	1600
Nortek	8483 ✓		" "
MicroCAT	3900 ✓		1604
MicroCAT-ODO	10520 ✓		16 17
5 x 17" glass	n/a ✓		16 25
Nortek	8492 ✓		" "
MicroCAT	6802 ✓		16 27
MicroCAT	7681 ✓		16:45
5 x 17" glass	n/a ✓	5 imploded.	16:50
Nortek	9204 ✓		16:50
MicroCAT	6799 ✓		16:56
6x 17" glass	n/a ✓		16:57
Acoustic Release #1	0246 ✓	released.	16:59
Acoustic Release #2	1465 ✓		16:59

Ascent Rate 20 m/min.

Ranging

	Time	Range 1	Range 2	Command/comment	
0246	12:00:00	—	4765	ARM + ARM	
1465	12 01:50	4764	—	" "	
	12:02:30	—	4765	" "	
	12:03:10	4765	4765	" "	
0246	12:08:00	4764	4765	ARM + Release release OK.	
	12:09:00	4725	4718	" " "	
	12:10:00	4681	4676	ARM ARM.	
	12:11:00	4648	4643.	" "	
	12:12:00	4614		" "	
	12:13:00	4589	4585	" "	
	12:15:00	4537	4534	" "	
	12:16:00	4513	4510		
	12:18:00	4466	4464		
	12:23:00	4349	4346.		
	12:24:00	4328	4320		
1465	12:25:00	4305	4304	ARM DIAG vertical	
	122600	4284	4281	VERT - 8.3 batt v.	1465 release
	12:28:00	4243	4240		
	12:29:00				
0246.	12:53:00	3820	3819.	ARM ARM	
	12:54:00	3800	3799	" " 20m/min.	
	13:00:00	3774	3773	pings on.	
	13:03:00	3767	3766		
	13:04:00	3766	3766.		
	130600	3766	3766.	suil moved @ 13:09.	
	131100	3755	3755		
	131400	3737	3735.		
75.	132000	3662	3660.		
10 60	132400	3602	3601		
15 44	132700	3558	3556		830m
96	133300	3462	3460		ship moved
16 31	133500	3431	3429		Release Rope
	133800	3398	3398		368m
	134100	3413	3413		
	134200	3419	3419	X	
	1343	3425	3425		Moving SW

134900	3421	3421	
135000	3412	3411	
135100	3403	3402	
135200	3391	3389	
135300	3378	3377	
135400	3361	3364	x
1355	3353	3353	
1358	3317	3316	
1401	3277	3276	

MOORING SIGHTED

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **WB2**

Cruise [redacted] DY129

NB: all times recorded in GMT

Date 4 JAN 2021

Site arrival time overnight.

Time of first ranging ___________

ITEM	SER NO	COMMENT	TIME
Recovery Line	n/a	13:48 grappled	13:48
30" Syntactic	30-05		13:56
with Iridium beacon	C02-043 ✓	ID: 300234061667220 ✓	
and light	A08-080 ✓		
MicroCAT	4062 ✓	worm in cage/guard	13:57
Nortek	12700 ✓	lightly fouled	14:00
MicroCAT	4060 ✓		14:00
Nortek	14732 ✓	areas of shredding	14:05
MicroCAT	7361 ✓	← on plastic jacket	14:05
MicroCAT	4070 ✓	tangle (mcat 4800)*	14:12
49" telemetry syntactic	J08541-001 ✓	tangles – cut white wire	14:24
with Argos beacon	Y01-010 ✓	ID: 46492 antenna intact	
and light	B11-018 ✓		
MicroCAT	5992 ✓		14:26
5 x clamp-on glass	n/a		14:33
Nortek	14736 ✓		14:38
MicroCAT	4800 ✓		1412*
MicroCAT	4461 ✓		14:50
6 x clamp-on glass	n/a		14:52
Nortek	14766 ✓		14:52
MicroCAT	5991 ✓		15:02
MicroCAT	5993 ✓		15:08
4 x clamp-on glass	n/a		15:11
Nortek	14787 ✓		15:14
MicroCAT	4475 ✓		15:18
Nortek	9433 ✓		15 26
MicroCAT	4797 ✓		15:26
5 x clamp-on glass	n/a	tangled w/orange 10 @ bottom (KX)	15:34
MicroCAT	5989 ✓		15:34
MicroCAT	7470 ✓	tangled w/ tied-off wire	15:50
Nortek	~~12701~~	12722	15:55
49" telemetry syntactic	J17050-002	tangled	16:08
with Argos beacon	A08-076 ✓	antenna intact was on	
and light	W03-092 ✓	"	

MicroCAT	4799 ✓	swapping reels	1608
MicroCAT	4178 ✓		1640
2 x clamp-on glass	n/a		1642
Nortek	9409 ✓		1644
4 x clamp-on glass	n/a		1657
MicroCAT	7362 ✓		1657
MicroCAT	4701	→ 4710 ?	15:34
10 x 17" glass	n/a		1534 (**)
Acoustic Release #1	0920		15:34
Acoustic Release #2	1345		

All finished 17:17

Ranging

	Time	Range 1	Range 2	Command/comment
	12:			
920	12:56:00	3900	2778	ARM + ARM.
"	12:58:15	3900	3900	" + "
"	12:59:70	3901	3901	ARM + DIAG vertical 8.4V.
	13:00:15	3901	3901	ARM + REL release ok
	13:01:15	3805	3791	" + " release ok
	13:02:15	3 —	3081	ARM + ARM.
	13:03:15	3578	—	
	13:04:15	—	3463	
	13:05:15	3374	—	≈ 100 m/min.

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **WBADCP** Cruise [redacted] DY129

NB: all times recorded in GMT

Date 4th JAN 2021 **Site arrival time** 18:00

Time of first ranging 18:10

ITEM	SER NO	COMMENT	TIME
Recovery Line	n/a	grappled at 19:01	19:02
ADCP in float	J17041-002 / 15579		19:06
with light	X01-050 ✓		
and Iridium beacon	C02-04 ✓	ID: 300234061666230	
Acoustic Release #1	1201 ✓	Rusty staining	19:10
Acoustic Release #2	1491 ✓	Rusty staining	19:10

Ascent Rate 90 m/min

Time at end of recovery ____________

Ranging

	Time	Range 1	Range 2	Command/comment	
1201	18:11:10	836	839	ARM + DIAG vertical	8.5V
1491	18:12:00	853	854	" + " vertical	8.0V
		Delay: testing D.P. System.			
	18:42:00	717	717	ARM + REL release ok	Pingers on!
	18:43:00	633	624	" " release ok.	
1201	18:44:00	544	536	ARM + ARM	
	18:45:00	469	464	" "	
	18:47:00	408	—	" "	
				Surface 18:48	

Appendix C: Logsheets of deployed moorings

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **WB4L** 14 Cruise **DY129**

NB: all times recorded in GMT

Date 1/JAN/2021 **Site arrival time** 18:00

Setup distance 0 at location

Start time 18:03 **End time** 18:10

Start Position

Latitude 26.47185 **Longitude** -75.71025

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		18:03
31" syntactic float	n/a		18:05
with Light	Z02-018		
Argos or ~~Iridium Beacon~~	B03-083	Beacon ID = 129576/C02348B	
36" syntactic float	n/a		18:07
with Light			
~~Argos or~~ Iridium Beacon	E03-037	Beacon ID = 300434063352490	
SBE26/53	0085		
SBE26/53	0431		
Acoustic Release #1 (tripod)	2074	Record codes below	
Acoustic Release #2 (tripod)	0316	Record codes below	
600kg Anchor	n/a		18:10:25

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code
Argos beacon #1 ID 129576/C02348B.

Anchor Drop Position
Latitude 26.47185 N **Longitude** 75.71024 W.

Uncorrected water depth 4655 ~~4545~~ m (at anchor launch)
Corrected water depth ~~4683 m~~ (at anchor launch)
4690 m

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **WB4** Cruise ~~DY129~~ DY129

NB: all times recorded in GMT

Date 2/JAN/2021 **Site arrival time** overnight

Setup distance 4.59nm

Start time 14:10:48 **End time** ________

Start Position

Latitude ~~26°27.0~~ 26.50932 N **Longitude** ~~75°43.~~ 75.77964 W

ITEM	SER NO	COMMENT	TIME
Recovery Line	n/a		14:10
3 TRYMSYN floats	n/a		14:11
MicroCAT	6819		14:11
MicroCAT-ODO	12834		14:11
40" syntactic + ADCP	J06829-001	ADCP 5817	14:21
with beacon	C02-046	ID: 300234061667230	
and light	A08-079		
Nortek	5889		14:21
MicroCAT	6801	plug facing forward + down	14:23
MicroCAT	3214	PFF	14:27
49" syntactic	J06219-001		14:34
with beacon	C02-047	ID: 300234061668230	
and light	Z08-052		
MicroCAT	5773		14:36
MicroCAT	5762		14:39
Nortek	5890	bouncing on deck	14:46
MicroCAT	7363		14:46
MicroCAT-ODO	12835		14:46
MicroCAT	5246		14:52
Nortek	5893		14:59
MicroCAT	11424		15:01
MicroCAT-ODO	12910		15:01
MicroCAT	6826		15:07
12 x Orange CF-16s	n/a	~~Only~~, 12 ✓ all orange	15:16
Nortek	13588		15:24
MicroCAT	4464	300m in 11 min	15:25
Nortek	5967		15:36
MicroCAT-ODO	12965		15:36
5 x yellow CF-16s	n/a		15:44
MicroCAT	5763	before ~~glass~~ floats	15:40
5 x yellow CF-16s	n/a	~~glass after~~	15:57
Nortek	6049		15:59
MicroCAT	3265	plug facing up	16:02
MicroCAT-ODO	14147	plug facing down	16:02

5 x yellow CF-16s	n/a	} 500m wire + floats = 15min	16:17
MicroCAT	6323	}	16 19
5 x yellow CF-16s	n/a		16:36
Nortek	6083		16:38
MicroCAT	4719		16 39
5 x yellow CF-16s	n/a		16 59
MicroCAT	6800		17 01
MicroCAT-ODO	12966		17 01
5 x yellow CF-16s	n/a		17 17
Nortek	6119		17 19
MicroCAT	6326		17 21
MicroCAT	3934		17 35
Nortek	6132		17 40
10 x glass	n/a		17 47
Acoustic Release 1	365		20:02:00
Acoustic Release 2	1350		20:02:00
2800kg Anchor	n/a		20:02:00

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code
both iridium **~~Argos~~ beacon #1 ID** 300234061667230
~~Argos~~ beacon #2 ID 300234061668230

Anchor Drop Position
Latitude 26.44629 N **Longitude** -75.72198 W

Uncorrected water depth 4657m (at anchor launch)
Corrected water depth 4693m (at anchor launch)

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **WBH2** Cruise **DY129**

NB: all times recorded in GMT

Date 3/1/2021 **Site arrival time** 18:30 cranes or

Setup distance ~~2.46 nm~~ 2.75Nm

Start time 18:41:01 **End time** 21:42:49

Start Position

Latitude ~~26~~ 26.52857N **Longitude** 76.52857W

ITEM	SER NO	COMMENT	TIME
Recovery Line	n/a		18:41
Billings float (4)	n/a		18:41
with Light	A08-082		
and Beacon Iridium	G06-033	ID: 300234066260160	
10 x 17" glass		6+4	18:44
Nortek	6176		
2 x 17" glass			18:59
Nortek	6516		
MicroCAT	3215		19:01
MicroCAT-ODO	20255	200m in 5min	
MicroCAT	6120		19:07
MicroCAT	4712		19:13
MicroCAT-ODO	20253		19:20
7 x 17" glass	n/a	200m in 8 min	19:27
Nortek	6747		19:28
MicroCAT	5767		19:32
MicroCAT	3251		19:47
5 x 17" glass			19:54
Nortek	6260		19:56
MicroCAT	6840	(67 min to run widget)	20:04
MicroCAT-ODO	20254		20:10
5 x 17" glass	n/a	(46 min to run widget)	20:21
Nortek	6751		20:21
MicroCAT	5779	end clamp replaced	20:29
MicroCAT	6804		20:43
5 x 17" glass	n/a		20:54
Nortek	6753		20:54
MicroCAT	6824		20:58
6x 17" glass	n/a		21:02
Acoustic Release #1	282		21:35
Acoustic Release #2	2077		
1900kg Anchor	n/a		21:42:49

Release #1 arm code

Release #1 release code

Release #2 arm code
Release #2 release code
Iridium ~~Argos beacon #1 ID~~ 300234066260160
~~Argos beacon #2 ID~~

Anchor Drop Position
Latitude 26.48043N Longitude 76.62530 W.

Uncorrected water depth 4701 m (at anchor launch)
Corrected water depth 4738 m (at anchor launch)

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
		013000			5242	—
		013100			5244	5244
		013730			—	—
		013500			—	5256
		025830			5342	5351
		~~025710~~				
		025815			5402	5408
		032245			5215	5224
		032400			5272	5276

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **WB2L14** Cruise **DY129**

NB: all times recorded in GMT

Date 4 JAN 2021 **Site arrival time** ________

Setup distance ØNm ontarget

Start time 20:32 **End time** 20:39:10

Start Position

Latitude 26.50336 N **Longitude** 76.74368 W

ITEM	SER NO	COMMENT	TIME
			20:32
Recovery line	n/a		20:34
31" syntactic float	n/a	J08353-004	
~~with Light~~			
Argos ~~or Iridium Beacon~~	Y01-012	Beacon ID = 46494/3FA28E1	
34" syntactic float	n/a	J19322-001	20:37
with Light	A08-078		
~~Argos or~~ Iridium Beacon	C02-052	Beacon ID = 300234061662220	
SBE26/53	0081		
SBE26/53	0060		
Acoustic Release #1 (tripod)	821	Record codes below	
Acoustic Release #2 (tripod)	248	Record codes below	
600kg Anchor	n/a		20:39:10

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code
Argos beacon #1 ID ________

Anchor Drop Position

Latitude 26.50344N **Longitude** 76.74423 W

Uncorrected water depth 3849 m (at anchor launch)
Corrected water depth 3868 (at anchor launch)

22:22:00 5061 5055
~~22:23:20~~
22 23 30 5012 5008
2430 – 4465
2510 4975 4979
23 10 00 4373 4373
10 45 4373 4373
03 25 50 4108 4111
2620 4123 4125.

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **WB2** Cruise **DY129**

NB: all times recorded in GMT

Date 5/DEC/2021 **Site arrival time** overnight.

Setup distance 4.0 Nm.

Start time 14:30 **End time** ~~1#~~ 18:38:47

Start Position

Latitude 26.46402N **Longitude** 76.69241W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		14:41
3 x Mini-Trimsyns	n/a		14:41
MicroCAT	5891		~~B~~
30" syntactic	30-04		14:49
with Light	B11-019		
~~Argos or~~ Iridium Beacon	G06-034	Beacon ID = ?	
Nortek	9266		14:49
MicroCAT	5982		14:51
51" syntactic	51-02		15:00
with Light	X01-048		
~~Argos or~~ Iridium Beacon	E03-034	Beacon ID = 300234063269820	
Nortek	9402		15:00
MicroCAT	3928		15:02
MicroCAT	3282		15:06
MicroCAT	4717		15:11
2 x 17" glass	n/a		15:17
Nortek	9406		15:17
RBR-SoloT	100255	2 cable ties + duct tape, sensor down	15:20
MicroCAT	3225		15:23
RBR-SoloT	100268		15:25
RBR-SoloT	100269		15:27
RBR-SoloT	100272		15:29
MicroCAT	3913		15:32
RBR-SoloT	100279		15:34
2 x 17" glass	n/a		15:40
Nortek	9439		15:40
MicroCAT	5239		15:42
RBR-SoloT	100274		15:43
MicroCAT	6126		15:45
RBR-SoloT	100275		15:48
RBR-SoloT	100266		15:51
RBR-SoloT	100277		15:53
MicroCAT	5776		15:57
10 x 17" glass	n/a		16:03
Nortek	9444		16:07

MicroCAT	6814		16:11
Nortek	13650		16:20
MicroCAT	5782		16:21
5 x 17" glass	n/a		16:32
MicroCAT	5768	+ RBR C3 203219	16:37
MicroCAT	5243		16 45
Nortek	5897		16 50
5 x 17" glass			16 59
MicroCAT	6798	No mark	1700
~~RBR Concerto3~~			
MicroCAT	6808		1714
2 x 17" glass			1722
Nortek	5899		1722
5 x 17" glass	n/a		1732
MicroCAT	5983		1734
MicroCAT	4305		1750
10 x 17" glass	n/a		1755
Acoustic Release #1	916	Record codes below	
Acoustic Release #2	253	Record codes below	
2500kg Anchor	n/a		18:38:47

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code
Iridium **~~Argos~~ beacon #1 ID** ________
Iridium **~~Argos~~ beacon #2 ID** 300234063269820

Anchor Drop Position
Latitude 26.51857 **Longitude** 76.74329W.

Uncorrected water depth 3754 (at anchor launch)
Corrected water depth 3771 (at anchor launch)

No reply from release #2 while triangulating

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **WBADCP** Cruise **DY129**

NB: all times recorded in GMT

Date 6th JAN 2021 **Site arrival time** 18:10

Setup distance at target

Start time 20:05 **End time** 20:11:22

Start Position

Latitude 26.53034 N **Longitude** 76.86754W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		20:05
Syntactic float	n/a	516297-001	20:07
with Light	A1556	1	
Iridium Beacon		Beacon ID = 300234061666230	
ADCP	23643		
Acoustic Release #1	824	Record codes below	
Acoustic Release #2	256	Record codes below	
800kg Anchor	n/a		20:11:22

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code
IRIDIUM ~~**Argos**~~ **beacon #1 ID** 300234061666230
~~**Argos**~~ **beacon #2 ID** –

Anchor Drop Position
Latitude 26.53055 N **Longitude** 76.86754W

Uncorrected water depth 560 m (at anchor launch)
Corrected water depth 568 m (at anchor launch)

21:16:00 – 1391
21:16:30 1410 1417
21 18:10 – 1566
21 19 1616 1624
21 49 20 1070 1072
21 50 35
21 52 45 958 952
22 06 00 1047 1056
22 07 00 1133 1142

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **WBAL9** Cruise **DY129**

NB: all times recorded in GMT

Date 6th JAN 2021 **Site arrival time** 20:48

Setup distance 100m

Start time 20:51 **End time** 20:57:58

Start Position

Latitude 26.53708N **Longitude** 76.86661W

ITEM	SER NO	COMMENT	TIME
Mini-Trimsyn	n/a		20:51
Recovery line	n/a		
Billings 3 sphere	n/a		20:51
with Light	S01-182		20:51
XEOS ~~Argos or Iridium~~ Beacon	0057	Beacon ID = 300 ~~343~~ 434061882180	20:51
4 x 17" glass	n/a		20:52
4 x 17" glass	n/a		20:52
4 x 17" glass	n/a		20:54
SBE26/53	0393		
SBE26/53	0053		
Acoustic Release #1 (tripod)	1535	Record codes below	20:57:58
Acoustic Release #2 (tripod)	262	Record codes below	20:57:58
1200kg Anchor	n/a		

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code
XEOS **~~Argos beacon~~ #1 ID** 300434061882180
~~Argos beacon~~ #2 ID —

Anchor Drop Position
Latitude 26.53805N **Longitude** 76.8665W.

Uncorrected water depth 603m (at anchor launch)
Corrected water depth 612 m (at anchor launch)

21 20 30 — 1013
21 21 45 1064 1068
22 45 — —
23 30 1084 1083
~~21 24~~
21 46 00 869 874
21 48 15 1001 1007
22 07 59 1121 1126
22 08 30 1150 1155

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **WB1** Cruise **DY129**

NB: all times recorded in GMT

Date 7/1/2021 **Site arrival time** overnight

Setup distance 2nm

Start time 14:09 **End time** 16:12

Start Position

Latitude 26.53238N **Longitude** 76.81550W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		14:09
3 x Mini Trimsyns	n/a		14:10
MicroCAT-ODO 50m	10543		14:10
MicroCAT 52m	4068		14:10
30" syntactic float	n/a 30-07		14:15
with Light	W03-091		
and Beacon	C02-043	Beacon ID = 300234061667220	
Nortek 100m	6275		14:15
MicroCAT 105m	4071		14:18
MicroCAT 175m	3220		14:20
45" syntactic float	n/a 45-02		14:27
with Light	W03-096		
and Beacon	G07-055	Beacon ID = 3002 3406 5 336 270	
MicroCAT 250m	4471	? added later	14:30
MicroCAT-ODO 250m	10544		14:30
MicroCAT 324m	4720		14:33
2 x 17" glass			14:37
Nortek 400m	6805		14:37
MicroCAT-ODO 408m	10555		14:40
MicroCAT 408m	3228		14:40
MicroCAT 500m	3270		14:43
MicroCAT-ODO 600m	12833		14:47
MicroCAT 700m	6822		14:50
7 x 17" glass			[illegible]
Nortek 800m	11855	re-positioning clamps	15:02
MicroCAT-ODO 800m	12998		15:07
MicroCAT 900m	6121		1507
MicroCAT-ODO 1000m	12963		15:10
3 x 17" glass	n/a		15 19
Nortek 1202m	8502		15 19
MicroCAT 1208m	6335		15 20
Nortek 1347m	12701		15 ~~30~~ 25
MicroCAT 1353m	6325		15 30
6 x 17" glass	n/a		15 33
Acoustic Release #1	1198	Record codes below	

16:12:18

Acoustic Release #2	2226	Record codes below	
2000kg Anchor	n/a		16/12/18

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code
Argos beacon #1 ID ____________
Argos beacon #2 ID ____________

Anchor Drop Position
Latitude 26.49621 N **Longitude** 76.81502 W

Uncorrected water depth 1397m (at anchor launch)
Corrected water depth 1405m (at anchor launch)