National Oceanography Centre

National Oceanography Centre

Cruise Report No. 71

RRS *James Cook* Cruise JC192
9th to 28th MARCH 2020

RAPID cruise report for Cruise JC192

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2020

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ABSTRACT

The purpose of RRS James Cook cruise JC192 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 Santa Cruz de Tenerife on Monday 9th March 2020 and ended on Saturday 28th November 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 JC192 moorings were serviced at sites: EBH4, EBH4L, EBH3, EBH2, EBH1, EBH1L, EBHi, EB1, EB1L. Sites with suffix 'L' denote landers fitted with bottom pressure recorders. Two Pressure Inverted Echo Sounder (PIES) landers were deployed for NOAA AOML.

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. The ABC Fluxes project extends the measurements on the RAPID 26°N array to include biological and chemical measurements.

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) and for testing mooring releases prior to deployment.

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).

KEYWORDS

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

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Name	Position	Affiliation
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Iain Macleod	Chief Officer	
Tom Williams	2nd Officer	
Ewan McMillian	3rd Officer	
Keith Sneddon	Chief Engineer	
Michael Murren	2nd Engineer	
Mitchell Hamber	3rd Engineer	
Connor Higgins	3rd Engineer	
David Hawksworth	ETO	
Duncan Lawes	ERPO	
Paula McDougall	Purser	
John Hopely	CPOS	
Andrew Mclean	CPOD	
Iain Forbes	POD	
Marshall Mackinnon	SG1A	
Brian Ray	SG1A	
Peter Smyth	SG1A	
Amy Whalen	Head chef	
Peter Clarke	Chef	
Denzil Williams	Steward	
Norman O'Toole	Steward	
Patrick Blunn	Cadet	
Lisa Hunter	Cadet	
Ben Moat	Chief Scientist	NOC
Lidia Carracedo	Scientist	IFREMER
Eleanor Frajka-Williams	Scientist	NOC
Emmy McGarry	Scientist	NOC
David Smeed	Scientist	NOC
Matthew Clark	PhD student	Univ. of Southampton
Fraser Goldsworth	PhD student	Univ. of Oxford
Paul Provost	Senior Technical Officer	NOC/NMFSS
Jennifer Ward-Neale	ITO	NOC/NMFSS
Dean Cheeseman	Technician (Engineering)	NOC/NMFSS
Dave Childs	Technician (Moorings)	NOC/NMFSS
Colin Hutton	Technician (Moorings)	NOC/NMFSS
Richard Phipps	Technician (Engineering)	NOC/NMFSS
William Platt	Technician (Moorings)	NOC/NMFSS
Thomas Roberts	Technician (Moorings)	NOC/NMFSS
John Wynar	Technician (Moorings)	NOC/NMFSS
Michael White	Trainee	NOC/NMFSS
Stephen Corless	Trainee	NOC/NMFSS

2. Itinerary

The RAPID 26N expedition aboard the RRS James Cook JC192 left Santa Cruz de Tenerife on Monday 9th March 2020 and ended on 28th March 2020 at Southampton, UK. The eastern boundary array was completed by Tuesday 17th March. The expedition was cancelled on the 18th March and the ship was redirect back to the UK due to the global COVID-19 pandemic. A full itinerary is given in Table 2.1.

Date	Operation	Start time	End time	Durat. (hrs)	Latitude (°N)	Long. (°W)	Notes
Mon 9 Mar	Depart Santa Cruz	10:00					
	Test CTD0	13:12	13:34	00:12	28°43.90	15°47.80	
	CTD1	14:57	18:38	04:21	28°43.90	15°47.80	8 releasses, 24 microcats
	CTD2	19:33	23:19	03:46	28°43.90	15°47.80	8 releasses, 24 microcats
	Transit to EBH3						
Tue 10 Mar	CTD3	11:30	13:07	01:37	27°48.07	13°45.82	For calibration of deployed ODOs
	Recover EBH3	13:57	15:21	01:24	28°48.52	13°44.79	
	Deploy EBH3	17:05	19:10	02:05	28°48.50	13°44.80	
	Trilateration EBH3	20:16	21:07	00:51			
	CTD4	21:32	23:07	01:35	27°49.08	13°43.89	For calibration of deployed ODOs
	Transit to EBH2						
Wed 11 Mar	CTD5	02:33	04:52	02:19	27°37.24	14°11.69	10 microcats
	transit EBH4						
	CTD6 EBH4	08:55	09:59	01:04	27°50.99	13°33.49	For calibration of deployed ODOs
	recover EBH4	10:47	11:21	00:34	27°51.39	13°32.45	
	recover EBH4L7	12:28	12:47	00:19	27°51.15	13°30.65	
	Deploy EBH4	13:46	15:22	01:36	27°51.00	13°32.45	
	Deploy EBH4L9	16:25	16:30	00:05	27°52.00	13°30.85	
	Deploy PIES 1	17:20	17:22	00:02	27°52.08	13°31.90	
	Trilaterate						

	CTD7	20:18	21:29	01:11	27°53.99	13°24.97	for JC191
	CTD8	22:42	23:28	00:46	27°54.97	13°32.00	for JC191
Thu 12 Mar	CTD9	01:00	02:25	01:25	27°52.08	13°31.92	JC191 sampling Calibration of deployed ODOs
	Transit EBH2						
	Recover EBH2	08:53	09:05	00:12	27° 51.40	13° 32.46	
	Deploy EBH2	09:50	10:23	00:33	27° 48.52	13° 44.79	
	Trilaterate						
Fri 13 Mar	recover EBH1	08:58	09:30	00:32	27°13.36	15°25.33	
	Recover EBH1L12	11:07	11:12	00:05	27°12.25	15°25.00	
	Deploy EBH1	12:29	12:55	00:26	27°13.35	15°25.35	
	Deploy EBH1L14	13:49	13:56	00:07	27°12.20	15°25.30	repositioned EBH1L14
	Trilaterate moorings	14:25	15:35	01:10			clocks -1 hour
Sat 14 Mar	Transit EBHi						
	CTD10	23:36	04:06	04:30	24°55.10	21°16.58	8 releases, 24 MicroCats
Sun 15 Mar	recover Ebhi	10:43	11:20	00:37	24°55.98	21°15.93	Imploded glass resulted in slow ascent
	deploy EBHi	12:22	13:29	01:07	24°56.00	21°16.00	
Mon 16 Mar	CTD11	06:16	10:54	04:38	23°43.69	24°11.52	
	Recover EB1	12:16	15:29	03:13	23°44.15	24°10.66	
	Recover EB1L12	18:55	19:06	00:11	23°47.94	24°08.62	
	Deploy PIES 2	19:48	19:50	00:02	23°46.39	24°09.51	
Tue 17 Mar	Deploy EB1	11:36	16:09	04:33	23°45.40	24°09.50	

	Deploy EB1L14	16:57	16:58	00:01	23°48.00	24°08.50	
	CTD12	17:35	22:33	04:58	23°46.66	24°09.50	8 releases, 24 MicorCats
	Trilaterate moorings						
	transit MAR3						
Wed 18 Mar	Deploy Argo 8583	06:43	06:45	00:02	23°44.80	25°30.27	
	CTD13 - 3500m	12:53	16:17	03:24	23°53.04	26°15.68	6 MicroCats (shallow 3500 m)
	CTD14 - 5600m	16:53	21:22	04:29	23°53.04	26°15.68	24 MicroCats (5600 m)
	Depart for the UK						
Mon 23 Mar	Deploy Argo 8585	09:10	09:11	00:01	36°22.31	13°32.28	
Fri 27 Mar	Boat transfer Brest	08:00					
Sat 28 Mar	Arrive Southampton, UK	10:00					

Table 2.1 Cruise Itinerary (time in GMT).

3. Introduction

This cruise report is for cruise JC192 conducted aboard RRS *James Cook* in spring 2020. 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). Two Pressure Inverted Echo Sounders (PIES) landers were deployed for NOAA AOML, USA.

As on previous cruises we deployed two Argo floats supplied by the UK Met Office. 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.	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

Jenifer Ward Neal

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.

Manufacturer	**Model**	**Function/data types**	**Logged? (Y/N)**	**Comments**
Steatite	MM3S	GPS network time server (NTP)	N	Not logged
Applanix	POS MV	DGPS and attitude	Y	

C-Nav	3050	DGPS and DGNSS	Y	
Kongsberg Seatex	DPS116	Ship's DGPS	Y	
Kongsberg Seatex	Seapath 330+	DGPS and attitude	Y	
Sonardyne	Fusion USBL	USBL	N	
Sperry Marine		Ship gyrocompasses x 2	Y	
Chernikeef Instruments	Aquaprobe Mk5	Electromagnetic speed log	Y	Needs Calibration
Kongsberg Maritime	Simrad EA640	Single beam echo sounder (hull)	Y	
Kongsberg Maritime	Simrad EM122	Multibeam echo sounder (deep)	Y	
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 log (ship's velocity)	Y	
OceanWaveS GmbH	WaMoS II	Wave Radar	N	
Teledyne RD Instruments	Ocean Observer 75 kHz	UHDAS	Y	
Teledyne RD Instruments	Ocean Observer 150 kHz	UHDAS	Y	
DGS	AT1M	Gravity	N	
Micro g LaCoste	S84	Gravity	N	

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.

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).
- Sampling board conductivity, temperature salinity sensor (SBE45).
- Sampling board transmissometer (CST).
- Sampling board fluorometer (WS3S)
- Met platform temperature and humidity probe (HMP45).
- Met platform port and starboard ambient light sensors (PAR, TIR).
- Met platform atmospheric pressure sensor (PTB110).
- Met platform anemometer (Windsonic).

Date	Start Time	Stop Time	Cleaned	Transmissivity (v)	
				High	Low
09/Mar/2020	11:00	--		departing Santa Cruz de Tenerife	
20/Mar/2020		13:01		Underway turned off upon exit of international waters	
23/Mar/2020	09:01	--		Underway turned on upon entry of international waters	
23/Mar/2020	--	13:00		Underway turned off upon exit of international waters	
23/Mar/2020	13:07	13:46	Yes	4.7502	0.0584

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

Fraser Goldsworth and Matthew Clark

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 2 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 Santa Cruz de Tenerife during the mobilization. This allowed for three days of data to be collected whilst the ship was stationary. Between the 1st March – 7th March each of the three main navigation streams (POSMVPOS, SEAPATH and CNAV) were compared with the aim of deciding the most accurate system. Mean positions were very similar for the systems: 28.4610°N, -16.2449°E for POSMVPOS and SEAPOS, and 28.4609°N, -16.2449°E for CNAV. Maximum drift from the mean was 2.5m in the x direction, 3m in the y direction. The CNAV system had the lowest overall drift from the mean and SEAPOS had the greatest.

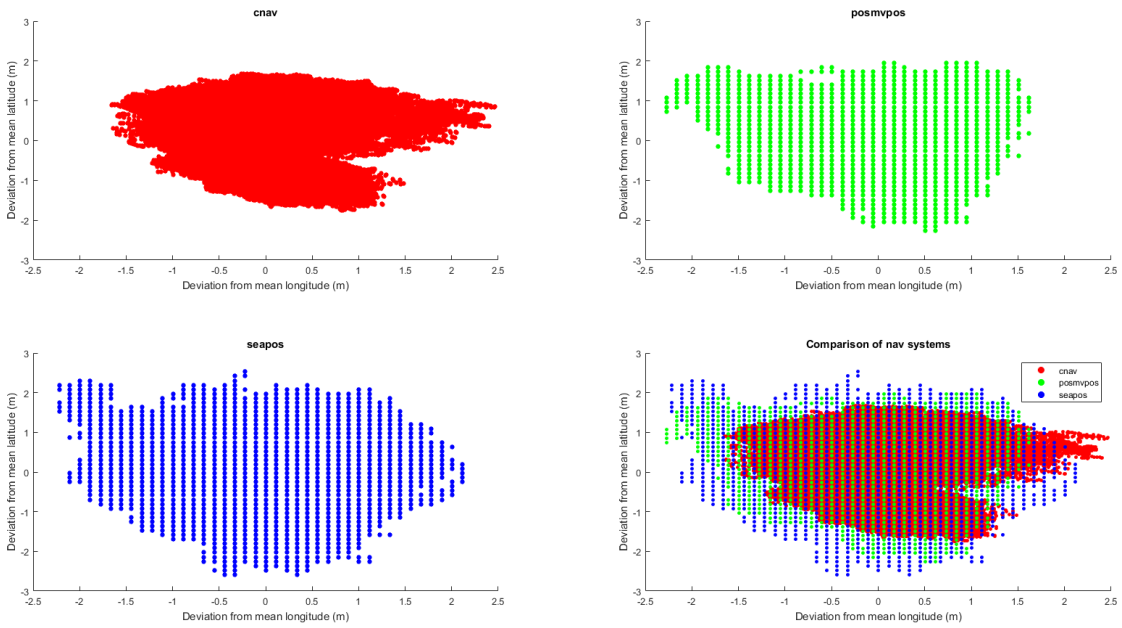

Figure 6.1 Comparison of navigation systems

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.

The first check of the bathymetry data involves bringing the EA600 single beam and EM120 swath streams together for comparison using **msim_02** and **mem120_02**. 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 days 293 to 327. A total of 133 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_jc192_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 negligible.

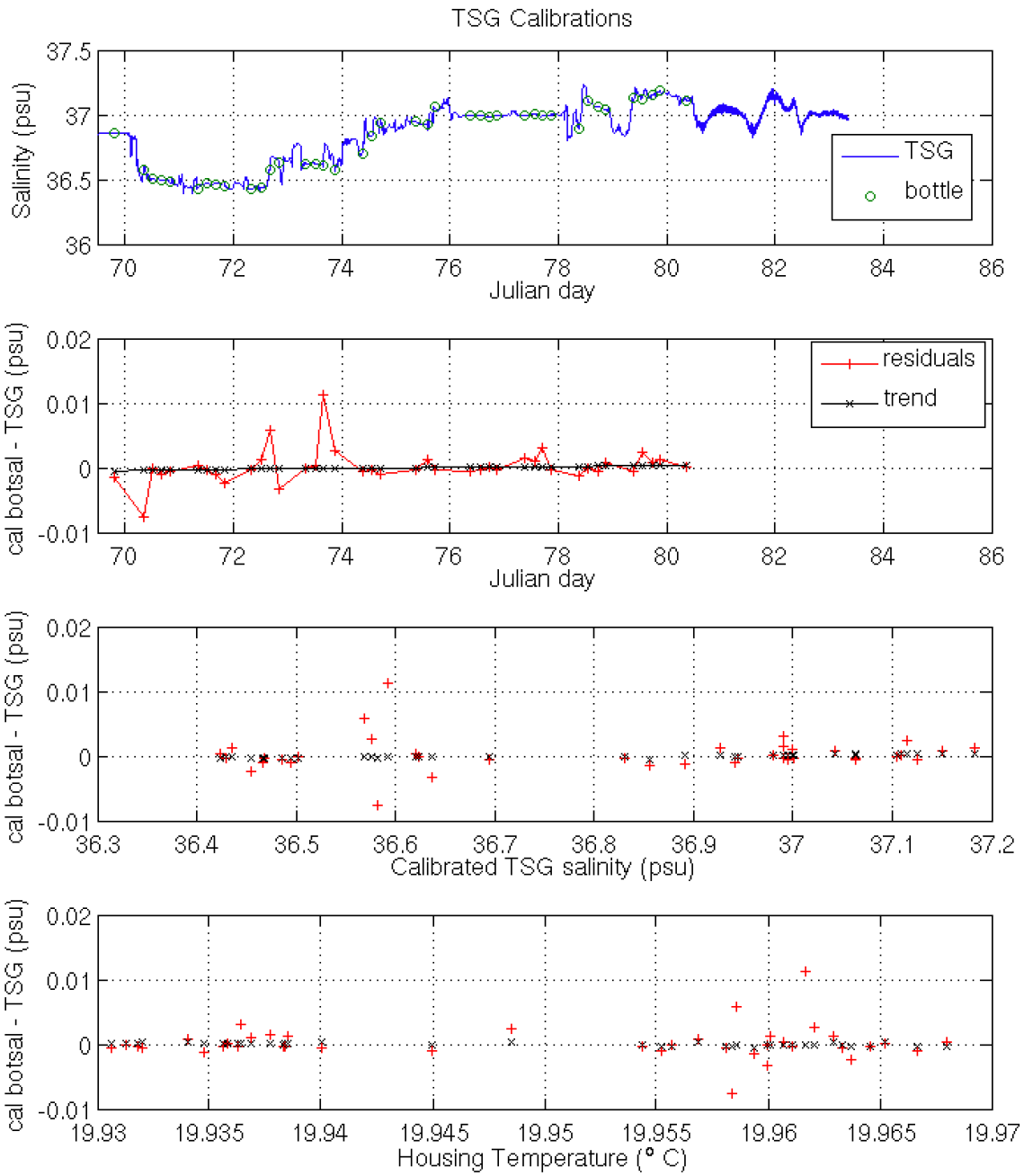

Figure 6.2 TSG salinity and bottle salinity (top), salinity residual against time (upper middle), salinity residual against salinity (lower middle), and salinity residual against temperature (bottom).

6.6 Vessel mounted Acoustic Doppler Current Profiler (ADCP)

6.6.1 Introduction

The RRS James Cook is fitted with 2 Teledyne RD Instruments Ocean Surveyor (OS) VMADCPs for measuring the horizontal velocity field: one at 150kHz (os150nb) and the other at 75kHz (os75nb). These are both mounted on the port drop keel. Both VMADCPs were operated almost-continuously for the duration of 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).

6.6.2 Data acquisition

Acquisition of VMADCP data was done automatically by the University of Hawaii Data Acquisition system (UHDAS). Both ADCP systems were activated on leaving the Port of Tenerife (09/Mar/2020, 09:47 GMT) on bottom tracking mode. Both were switched to water tracking mode using narrow band on 12/Mar/2020 at 10:10 GMT. The ADCP systems remained active until 13:00 GMT 20/Mar/2020, before the ship entered Spanish territorial waters. Data logging was resumed around 10:00 GMT 23/Mar/2020 once we re-entered international waters but was turned off for the final time at 13:00 GMT on the same day.

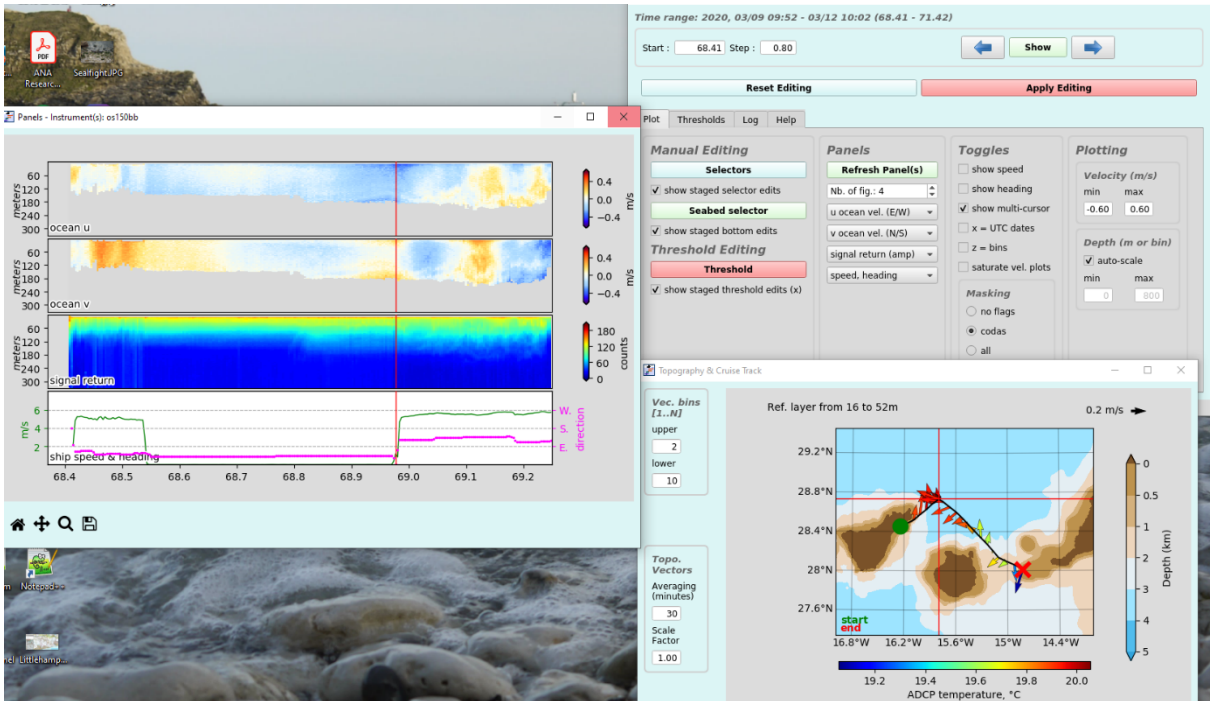

Figure 6.3 Screen grab of example dataviewer.py interactive panels.

6.6.3 Real-time monitoring

The UHDAS interface displayed on a screen in the main lab has all the control and monitoring options. As part of the 2-hourly systems watchkeeping, the UHDAS monitor interface was checked for any errors or data acquisition problems. UHDAS automatically generates a series of contour and vector plots, which were also visually inspected for errors.

6.6.4 Data processing

Daily processing of both VMADCP systems is handled automatically by UHDAS, based on the calibrations set at the start of the cruise (see calibration section).

Post-cruise processing is mostly automated but needs activation in the form of Shell and Python scripts (as part of the UHDAS package) manually executed on the command line. Before executing, the working directory must be set to the VMADCP postprocessing directory. For this cruise, this was: /local/users/pstar/rpdmoc/jc192/mcruise/data/vmadcp/postprocessing
VMADCP processing was completed on 25/Mar/2020.

The processing steps/scripts are summarised below and are run in order. The '>' symbol indicates the command prompt only and does not need to be entered:

1. > uhdas_01
2. > uhdas_02
3. > uhdas_03
4. > cd proc_editing
5. > cd osXXww *where XX is the frequency (75/150) and ww is the bandwidth (bb/nb)*
6. > bash
7. > dataviewer.py -e
8. *Manual checking and editing within the interactive dataviewer GUI.*
9. > exit
10. > uhdas_04
11. > uhdas_05
12. *(in Matlab)* > mvad_01

Steps 1-3 synchronised the UHDAS server files with the koekea machine in the postprocessing directory. Once this had been completed, the postprocessing folder had been populated with a new directory JC192, with an editing and archive directory. Upon navigating to the proc_editing directory, open each of the subdirectories in turn and run dataviewer.py with the -e flag (editing mode). Viewing one day at a time, the data was visually checked for any anomalies. The dataviewer application automatically filters the data using the default parameters, which users are advised not to change and also not to remove data other than very bad data points not filtered automatically. This was repeated for each frequency and bandwidth. Whilst there was a distinct lowering of the quality of VMADCP data whilst underway (due to the sea state and ship's motion generating bubbles), no data was removed for this cruise. Once all files had been checked, the bash shell was exited, before running UHDAS_04/05 to export the data to the archive directory.

To convert the archive files to useable netCDF files, the Mstar MATLAB script mvad_01 was run from the mproc directory:
/local/users/pstar/rpdmoc/jc192/mcruise/data/vmadcp/mproc
The script would not run, due to the file structure from the previous steps not being as expected. The mvas_01 script was opened and the file structure variables 'fnin' and 'datadir' were set manually.

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 JC187. The CTD cable was electrically tested both through the swivel and without the swivel. It had a 'Megger' value of > 1000 MOhms for both. The wire resistance through just the CTD wire was 73.3 Ohms and 73.5 Ohms when the swivel was connected.
During cast 003 it was noticed that the Active Heave Compensation (AHC) wasn't active even though it was turned on. The cast was paused at 580m and 1400m to switch off and back on the AHC. This did not make the AHC run. It was noticed that there was little swell at this time and

possibly too small to meet the set requirements for the AHC to activate. Further evidence to support this theory was later gathered by the Ships Scientific Systems Technician by comparing all casts with AHC running against the height of measured heave. It is believed that the AHC is set to only work when the maximum heave is greater than 1m. AHC remained inactive until cast 010 when heave became greater than 1m and it continued running for all remaining 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 set to average 20 measurement cycles, the CTD being held at depth until this was completed after approximately 22 seconds. The instrument was mounted vertically to a stanchion on the CTD frame diametrically opposite to the primary temperature sensor, 133cm away horizontally and 112cm above. (The primary temperature sensor was 9cm below the pressure port.)

7.2 Salinity Measurement

A Guildline 8400B, s/n 72227, was installed in the Electronics Workshop as the main instrument for salinity analysis (the spare s/n 71126, was not installed). The Autosal set point was 21C, and samples were processed according to WOCE cruise guidelines: The salinometer was standardized 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, excepting the first crate of CTD samples (second standard analysed after sample 12, third standard analysed after sample 25). Standards were labelled sequentially and increasing, beginning with number 9000. Standard deviation set to 0.00002. 7 crates of salinity samples were analysed.

8. CTD Data

David Smeed

8.1 Introduction

A total of 14 CTD casts were completed during the cruise (Table 8.1). The majority of casts were for the purpose of calibration of the microcat CTDs, but some were completed before and after recovery of moorings with oxygen sensors to enable in water calibration of oxygen.
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 all 5 minutes each when MicroCATs were being calibrated, otherwise they were for 2 minutes.

Most casts were for the purposes of calibration of the MicroCAT CTDs, but some were completed before and after recovery of moorings with oxygen sensors to enable in-water calibration of oxygen. 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 all 5 minutes each when MicroCATs were being calibrated, otherwise they were for 2 minutes. A total of 14 CTD stations were completed during the cruise. Due to the calm sea state the active heave compensation didn't engage for stations 3 to 9.

Station	Start Date	Start Time	End time	Latitude	Longitude	Water depth (corr. m)	Profile depth (m)	Number of bottle stops	Active Heave compensation
1*	09-Mar	14:57	18:38	28°43.91	15°47.81	3600	3580	12	yes
2*	09-Mar	19:33	23:17	28°43.92	15°47.81	3600	3577	12	yes
3	10-Mar	11:30	13:07	27°48.08	13°45.82	1441	1431	7	no
4	10-Mar	21:32	23:07	27°49.05	13°43.89	1423	1413	7	no
5*	11-Mar	02:33	04:52	27°37.24	14°11.69	2003	1987	8	no
6	11-Mar	08:55	09:59	27°51.00	13°33.49	1109	1099	6	no
7	11-Mar	20:18	21:29	27°53.99	13°24.97	663	653	10	no
8	11-Mar	22:42	23:28	27°54.99	13°22.00	332	322	10	no
9	12-Mar	01:00	02:25	27°52.08	13°31.92	1068	1058	9	no
10*	14-Mar	23:36	04:06	24°55.10	21°16.59	4496	4476	12	yes
11*	16-Mar	06:16	10:54	23°43.69	24°11.52	5120	5100	12	yes
12*	17-Mar	17:35	22:33	23°46.66	24°09.50	5086	5064	12	yes
13*	18-Mar	12:53	16:17	23°53.04	26°15.68	5403	3500	12	yes
14*	18-Mar	16:53	21:22	23°53.04	26°15.68	5403	5382	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 Analysis of standard seawater samples and calibration of the salinometer

A total of 14 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 0.000019 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_jc145_01.csv file and given sample number 999000. In this file following standard samples are indicated by sample numbers from 999001 to 999013.

The inferred offsets from the standard samples are shown as red and blue crosses in Figure 8.1, 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 Electronics workshop, where the salinometer was setup, were monitored with an uncalibrated self-logging sensor. On the morning of 12th March, a drop in temperature of more than 4°C was noted (not shown) and the use of the salinometer was delayed until the temperature had stabilised at the lower temperature. The salinometer was used on 4 occasions between 17th and 22nd March and during this time the temperature in the electronics workshop remained stable (Figure 8.2) and the cell temperature was set to 21°C.

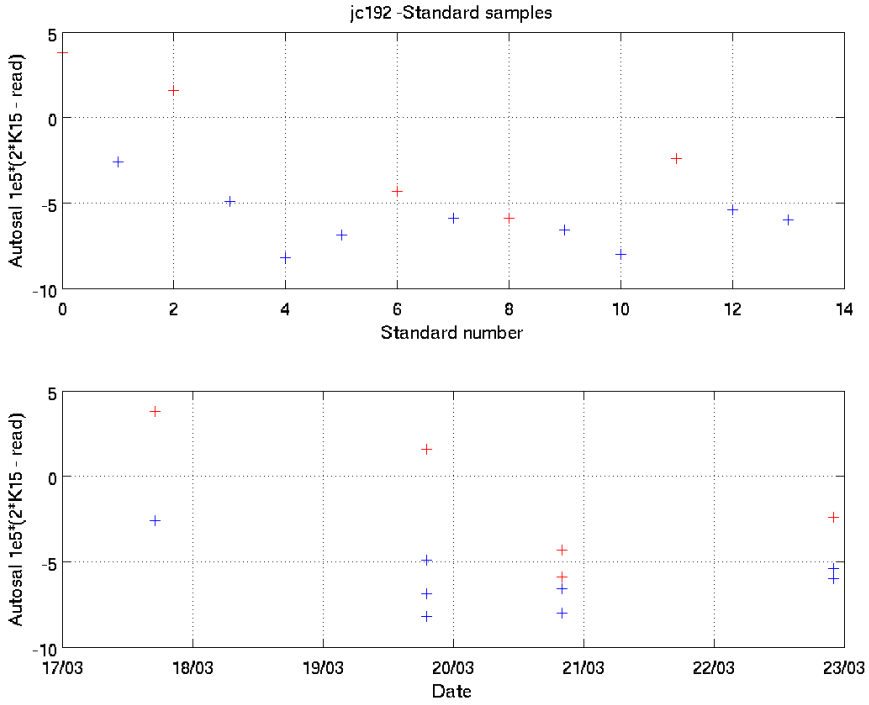

Figure 8.1 Inferred offset calculated as 2xK15 – salinometer average is shown a) as a function of the standard number and b) as a function of the date on which the samples were analysed. Red indicates a standard at the start of a new crate. Note a change of 5e-5 corresponds with a salinity difference of 0.001.

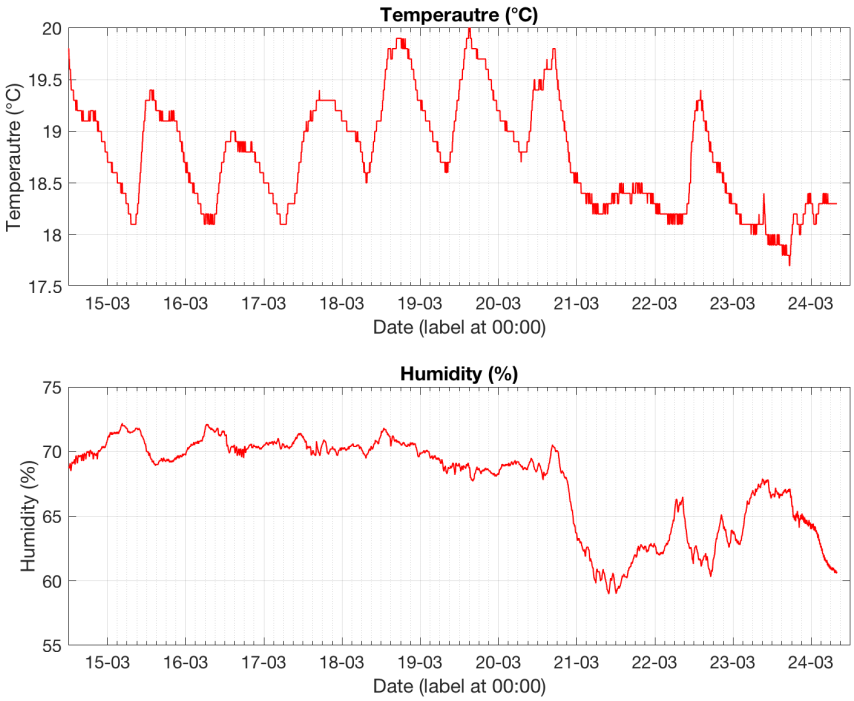

Figure 8.2 Temperature and humidity in the electronics workshop where the salinometer was installed. Neither variable was calibrated. The salinometer was used on 4 occasions between 17th and 22nd March (see Figure 8.1).

8.3 Calibration of conductivity

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

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

The coefficients A, B, C and D were determined in parallel using least squares multiple linear regression (Matlab function 'regress') that minimised the sum of the squares of the residuals. Time was measured in days from the first bottle stop of the first CTD. The residual was defined as:

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

The coefficients of the calibration are shown in Table 8.2. After calibration the standard deviation between of the difference between CTD and bottle salinity was slightly greater than 0.001 for both sensors and the difference between the two sensors had a standard deviation less than 0.001 (Figure 8.3).

Sensors	A	B (day^{-1})	C ($dbar^{-1}$)	D ($°C^{-1}$)	Mean sal. diff ($x10^3$) pre cal.	RMS sal diff ($x10^3$) post cal.	No. of samps.	No. of Out-liers
Sens 1	0.07554	-0.00451	-0.00367	-0.00127	-1.58	1.2	134	10
Sens 2	0.00105	-0.00299	-0.00015	0.00043	0.26	1.1	134	10

Table 8.2 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 0.005 from the mean difference were excluded from the calculation.

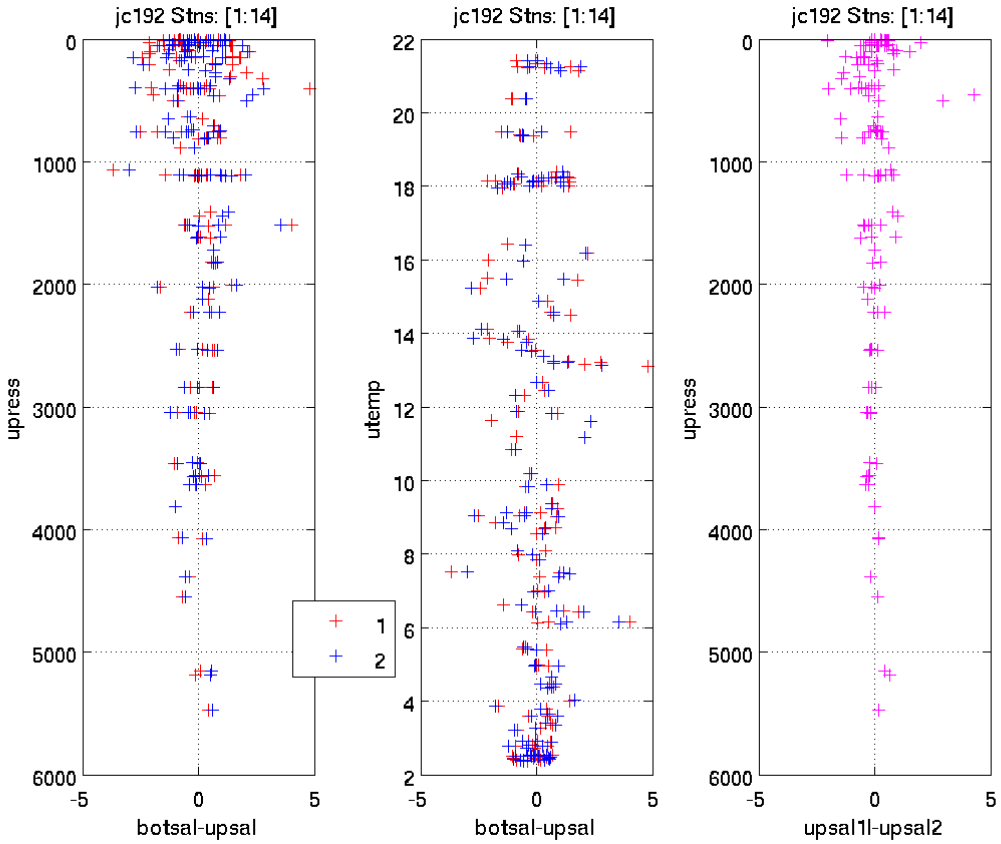

Figure 8.3 Comparison of salinity measurements at bottle stops after calibration. Red = bottle minus sensor 1, blue = bottle minus sensor 2. Left panel, as a function of pressure, middle panel as a function of temperature and right panel difference between the two sensors as a function of pressure.

8.4 Choice of sensors

A slight pressure dependent difference between the temperature sensors was evident with sensor 1 slightly (< 0.001 °C) warmer at the surface and about 0.001 °C cooler at 5000db. In the three samples below 5000db the SBE35 temperature values were between the two sensor values. The small number of samples precludes a detailed analysis, but the sensors appear to agree to within 0.001°C. Sensor pair 1 is chosen as the primary sensor as its position on the CTD frame results in less noise on the up cast.

9. Argo Float deployment

Ben Moat

Two 2000 dbar APEX floats were deployed during the cruise.

Float number	date	Time GMT	latitude	longitude	Water depth (m)
8583	18th March 2020	06:43	23° 44.8N	25° 30.27W	5350
8585	22nd March 2020	09:10	36° 22.31N	13° 32.28W	4400

Table 9.1 Argo Float deployment.

10. Oxygen analysis

Lidia Carracedo, Emmy McGarry

The two oxygen sensors on the CTD were calibrated by means of an automatic Winkler titration of discrete water samples. Dissolved oxygen analyses of the water samples were performed with an automated Ti-touch Titrator, using amperometric endpoint detection.

10.1 CTD sampling

A total of 14 CTD casts were sampled for dissolved oxygen (13 stations plus one test cast). All depths at which a Niskin bottle was fired (usually 12 depths) were sampled. Duplicate samples were drawn at two/three depths on every cast. The Niskin bottles selected for the duplicates changed for each cast, except for the first CTD cast, for which all 12 depths were double-sampled in order to assess reproducibility of the sampling practise of both samplers in charge. The standard deviation of the first-cast duplicates ranged between 0.001 to 0.408 μmol L^{-1}. In total, 43 sets of duplicates were run during the cruise. In addition to the CTD-sampling, 6 underway samples were taken (underway system, chemistry lab) roughly every 2 degrees of longitude.

The oxygen sampling was carried out according to the guidelines by Langdon (2010), analogously to the previous RAPID cruises (see RAPID cruise reports No. 30, 37, 52 and 59 for more details). Specific sampling strategies are outlined below:

- Prior to sampling each station, the reagent dispenser pipette tips (2-3 mL) were emptied and refilled to reduce the risk of injecting bubbles into the sample.
- Silicon Tygon tubing was attached to the Niskin spigot to transfer water to the flask. The tubing was kept wet (submerged in Milli-Q water) between stations to reduce the tendency of bubbles to form within it. A Milli-Q water soak was found to be more effective than a seawater soak at reducing the number of bubbles.
- While sampling, at least three flask volumes (approximately 15 seconds) were allowed to flow though the bottle.
- The bottles were held from the neck to minimise changes in water temperature.
- The fixing temperature was measured with a digital thermometer just before fixing the sample.
- After addition of the chemicals (1mL of manganese chloride, immediately followed by 1mL of alkaline iodide solution), the bottles were vigorously shaken for 15 seconds (twisted about 20 times) to facilitate the mixing and formation of the precipitate (manganese hydroxides). A second shake was performed after 30 min.
- After the second shake Milli-Q was added around the neck of the flasks to create a water seal, which helped to prevent the formation of bubbles as the samples reached room temperature.
- Sample storage varied between 1-2 days. Keeping the samples and analysing them every few days is more time efficient and accurate than immediate analysis after every CTD station.
- 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 also regularly checked for.

10.2 Winkler titration

The Winkler method is an iodometric titration in which oxygen in the seawater sample quantitatively oxygenates iodide ions to form iodine. Manganese chloride ($MnCl_2.4H_2O$) and alkaline iodide (NaOH + NAI), once added to a water sample, create a white-brown precipitate of manganese hydroxides ($Mn(OH)_2$). When acidified to a pH of 1.0 to 2.5 after injection of sulphuric acid, the manganic hydroxide forms manganic sulphate, this releases iodine from the iodide. During titration, the endpoint occurs when the added thiosulphate ($S_2O_3Na_2.5H_2O$) balances the iodate equivalents, thus the oxygen concentration in the sample is calculated by proportion. The dissolved oxygen concentration of seawater is defined as the number of micromoles of oxygen gas per kilogram of seawater, which gives the units μmol kg^{-1}.

A Metrohm 916 Ti-Touch unit, with amperometric end point detection, was utilised to accurately perform titration on board the RSS James Cook during the JC192 cruise. The protocols followed during the analysis are the same as in the previous RAPID JC174 cruise (see RAPID cruise report No. 59 for more details). They include: blanks (*BLK protocol* on the Metrohm 916 Ti-Touch), thiosulphate standardization (*STD protocol* on the Metrohm 916 Ti-Touch), and the Winkler amperometric titration of the oxygen samples (*O2 protocol* on the Metrohm 916 Ti-Touch). Most of the chemical reagents were pre-prepared offshore in accordance with procedures outlined by Dickson (1994). The sodium thiosulphate was weighed off-shore and dissolved in Milli-Q water onboard.

Specific analysis strategies are as below:

- Lab temperature was regularly checked during the analysis (it varied between 21.8-23.8°C).
- At the start of each set of analysis, reagent blanks and standardizations were performed (see sections 2.1 and 2.2).
- Prior to starting the analysis, the Metrohm Ti-Touch unit burettes were fully flushed out using the 'Prepare' mode on the Metrohm 916 Ti-Touch, or until the piston burettes were bubble free.
- The reagent dispensers (manganese chloride, iodide and sulphuric acid) were pumped 2-3 times to remove air bubbles before use.
- For every sample, the pipette tip of the Thiosulphate and the electrode were placed at the same level.
- Between samples, the pipette tip of the Thiosulphate and the electrode were rinsed with Milli-Q water and wiped.
- Pipette tips were placed so that they did not point to the electrode directly.
- The magnetic stirrer speed was held at a constant pace.

10.3 Blank

At the beginning of every analytical session, before any samples were analysed, “blank” samples (this section) and “standards” (section 10.4) were characterized. Blank measurements were made using empty sample bottles, which were thoroughly washed in Milli-Q water three times, then filled with about 100mL of Milli-Q water. 1 mL of sulphuric acid was added before the bottle was placed on the stirrer (speed setting 4). Then 1 mL of alkaline iodide was added before stirring again. The solution was checked at this stage to ensure it was clear and colourless before adding 1 ml of manganous chloride. If the solution became coloured before this point the solution was poured to waste, the bottle was rinsed and this procedure was started again, as most likely the reagents had been added in the incorrect order, or the bottle was contaminated. If the solution remained clear and colourless, 1 mL of the iodate standard was injected using the Dosimat before the mixture was titrated against sodium thiosulphate. Once the titration was finished the volume of titrant was recorded and

another 1ml of iodate standard added to the same bottle. This was repeated three times with a total of 4ml of iodate standard being added to the bottle in 1ml amounts and titrated each time (4 blank samples), looking for a consistency between replicates of at least 0.002 mL. The average of the second to fourth blank samples was subtracted from the first blank sample giving the blank value. Four bottles of blanks (16 blank samples) were run before proceeding to the samples, giving four blank values which were then averaged to give the average blank value used to process the analytical set. The average blank value per analysis set is summarized in Table 10.1. The change in the blank titre over time is shown in Figure 10.1.

10.4 Standardisation of sodium thiosulphate

After the blanks were measured, the thiosulphate molarity was checked against an iodate certified iodate standard of known molarity (1.667 mM, OSIL Scientific). The procedure is similar to that of the Blank measurements except that exactly 5 mL of potassium iodate standard was added to a bottle in one injection and then titrated. Two repeats (or more if needed) were performed per standardization set, until replicates agreed by at least 0.5%. The average titre per analysis set is shown in Table 10.1. The change in the standard over time is shown in Figure 10.1. It was seen throughout the cruise that both the blank and the standard titres decreased steadily.

Analysis set	Date of analysis	CTD stations	Calibration	Volume (mL)
1	**09/03/2020**	**Initial check**	Blank Titre (mL)	0.0017
			Standard Vol (mL)	5
			Standard Titre (mL)	0.456
2	**10/03/2020**	**Test, 1-2**	Blank Titre (mL)	0.0016
			Standard Vol (mL)	5
			Standard Titre (mL)	0.4573
3	**11/03/2020**	**3-4**	Blank Titre (mL)	0.0018
			Standard Vol (mL)	5
			Standard Titre (mL)	0.4561
4	**12/03/2020**	**6-9**	Blank Titre (mL)	0.0012
			Standard Vol (mL)	5
			Standard Titre (mL)	0.4558
5	**15/03/2020**	**10**	Blank Titre (mL)	0.0019
			Standard Vol (mL)	5
			Standard Titre (mL)	0.4552
6	**18/03/2020**	**11-12**	Blank Titre (mL)	0.0012
			Standard Vol (mL)	5
			Standard Titre (mL)	0.4547
7	**19/03/2020**	**13-14**	Blank Titre (mL)	0.0015
			Standard Vol (mL)	5

			Standard Titre (mL)	0.4543
8	**20/03/2020**	**Underway**	Blank Titre (mL)	0.0008
			Standard Vol (mL)	5
			Standard Titre (mL)	0.4547

Table 10.1 Blank and standard average values per analysis set.

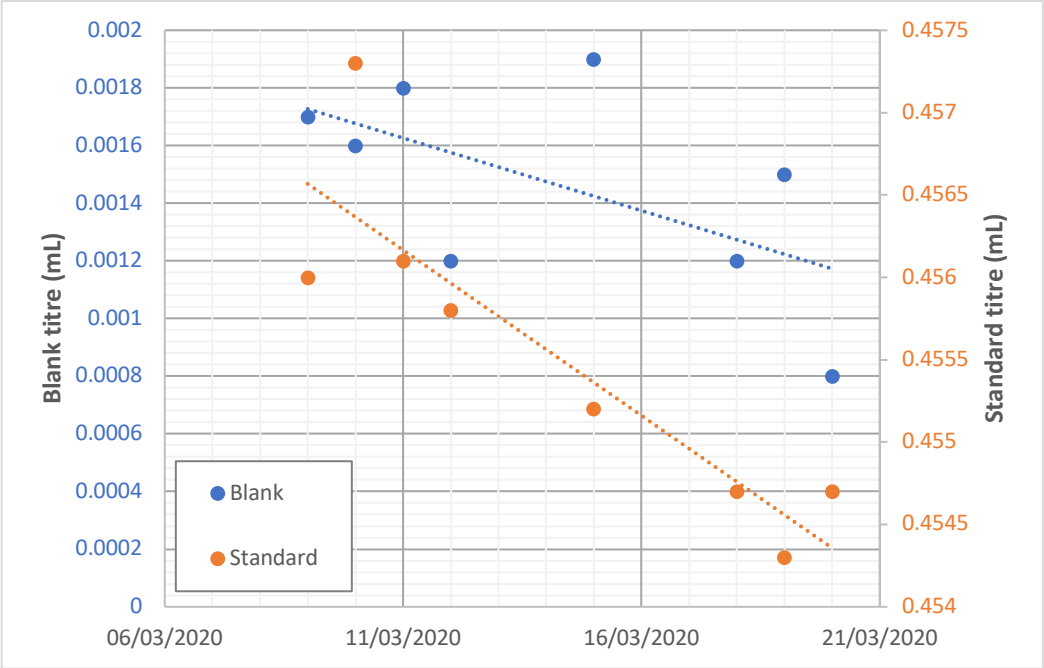

Figure 10.1 Blank and standard titres over time.

10.5 Sample analysis

The basic steps for the sample titration were as follows:
1) Take the sample from the storage box and pour off the water seal trying to avoid disturbing the precipitate.
2) Remove the stopper carefully to avoid sample loss.
3) Add 1ml of sulphuric acid and carefully insert a magnetic stirrer into the sample
4) Stir the sample (speed setting 3.5) until it there is no precipitate remaining.
5) Titrate the liberated iodine against sodium thiosulphate to a dead stop (O2 protocol) and record the volume of added thiosulphate.
6) Repeat procedure until all the stored samples have been analyzed (usually one to three stations).

A total of 180 CTD oxygen samples were analyzed, of which 43 pairs are duplicates (Table 10.2). After finishing the analysis, the corresponding oxygen concentrations were calculated in an Excel file, saved as *CalcSheet_JC192_StnNN.xlsx*, where NN denotes the station number. At each station the sample titration volumes (mL), calculated oxygen concentration values (µmol/L), fixing temperature values (^{O}C), station number and flask numbers were recorded. The calculation accounted for the volumes specific to each oxygen flask. Preliminary quality code flags were

assigned to the data (2=Good, 3=Dubious, 6=Duplicate, 4=Bad, 9=Missing).

Reproducibility was checked, obtaining an average absolute difference between sets of duplicates (43 in total) of 0.25 µmol L^{-1} (and an average median of 0.22 µmol L^{-1}) (Figure 10.2).

Finally, the calculated oxygen concentrations (in µmol L^{-1}, Figure 10.3) were saved to a csv file (*CalcSheet_JC192_StnNN.csv*, where NN denotes the station number). The file contains the bottle number, the station number, the sample number, the fixing temperature, the computed oxygen values, and the oxygen flags. Ultimately, the csv file was imported to MATLAB^{TM} and data incorporated to CTD NetCDF files to perform the CTD sensor calibration.

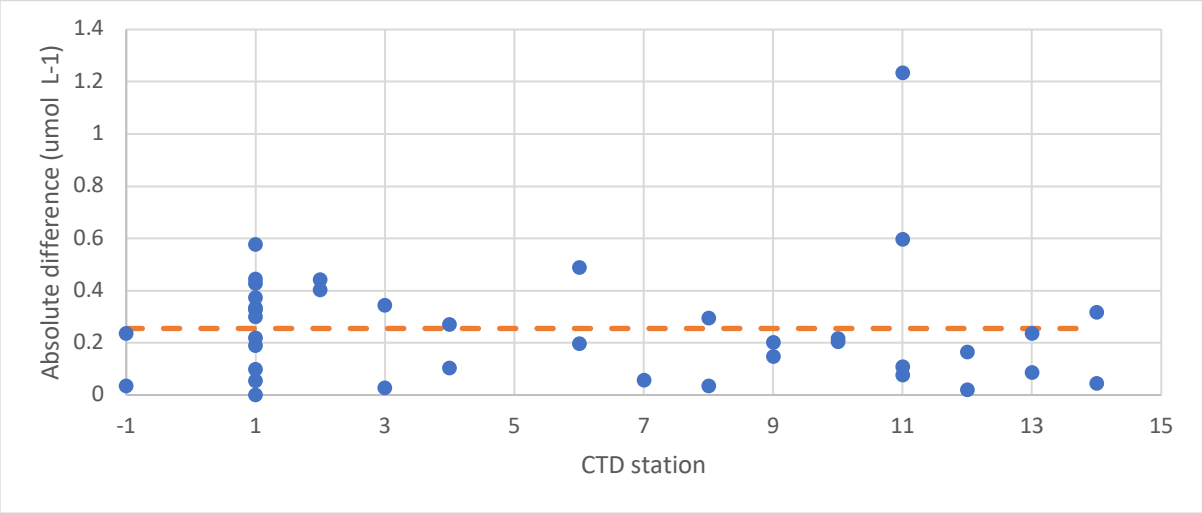

Figure 10.2 Bottle oxygen duplicates. Mean absolute difference of 0.25 shown with red dashed line.

CTD station	Description	Niskin bottles sampled	Number of duplicates	Total number of samples	Excluded samples
Test	Test CTD	2	6	8	
1	Cal-dip deep	12	12	24	
2	Cal-dip deep	11	2	13	1
3	Post-EBH3	7	2	9	
4	Post-EBH3	7	2	9	
5	Pre-EBH2	0	0	0	
6	Pre-EBH4	6	2	8	
7	JC191-CTD137	12	1	13	1
8	JC191-CTD138	10	2	12	
9	Post-EBH4 / JC191-CTD136	12	2	14	
10	Pre-EBHi	12	2	14	
11	Pre-RAS EB1	12	4	14	
12	Post-RAS EB1	12	2	14	
13	Cal-dip shallow	12	2	14	
14	Cal-dip deep	12	2	14	
Total			43	180	2

Table 10.2 CTD oxygen sampling strategy followed in JC192

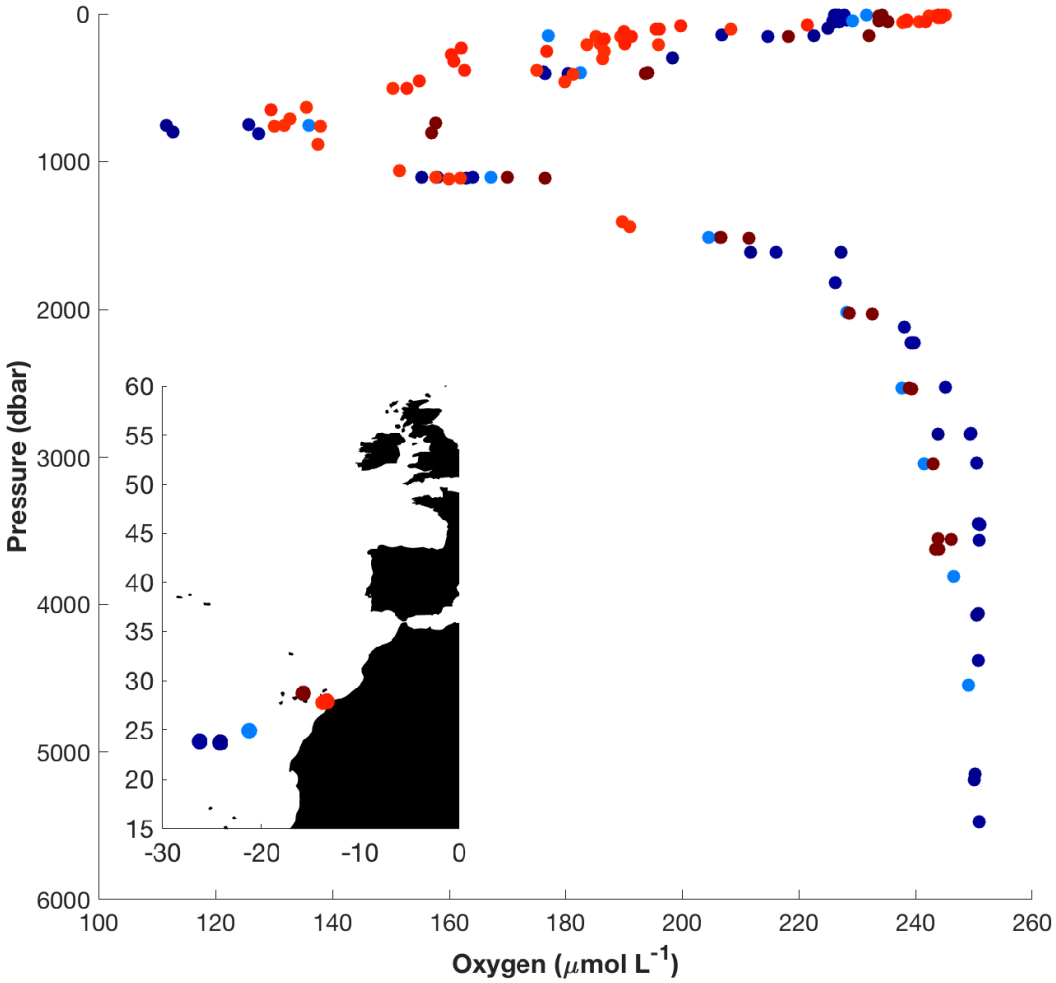

Figure 10.3 Oxygen depth profiles from all 13 CTD stations where oxygen was sampled. Map inset indicates the location of the CTD stations.

References

Culberson, C.H., 1991, Dissolved oxygen. WHP Operations and Methods.

Grasshoff, K., Kremling, K. Ehrhardt, M., 2007, Frontmatter, in Methods of Seawater Analysis. Weinheim, Germany: Wiley-VCH Verlag GmbH.

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 Hydrography Manual: A Collection of Expert Reports and Guidelines, p.134.

11. Discrete chemical sampling

Lidia Carracedo

Discrete bottle samples were collected for the later analysis of dissolved inorganic carbon, total alkalinity, inorganic&organic nutrients on a number of CTD stations. These were either for providing

an independent measurements to compare with the last sample event of the Remote Autonomous Sampler (CTD 11), and to perform a complete chemical characterization of the water column in the easternmost part of the GOSHIP-A05 section (CTDs 7, 8 and 9, in correspondence with JC191 CTDs 137, 138 and 136, respectively).

11.1 Dissolved Inorganic Carbon and Total Alkalinity

Lidia Carracedo

A total of 4 stations were sampled (46 samples in total) for dissolved inorganic carbon (DIC) and total alkalinity (TA). Details of these are given in Table 11.1.

In each case borosilicate glass bottles supplied by the University of Exeter (were samples will be analised afterwards) were used to collect seawater from the rosette immediately after oxygen samples were taken. A short piece of Tygon tubing, pre-soaked in MilliQ water to keep supple and to reduce the build-up of bubbles, was attached to the Niskin spigot and used to draw water into the pre-washed bottles. Bottles were rinsed once, then filled slowly from the bottom and overflown a minimum of a full bottle volume. The stopper was washed using overflowing water prior to being inserted into the bottle, making sure to not trap any bubbles. Samples were fixed in the chem laboratory by first creating a headspace (by removing 1% of bottle volume using Pasteur pipette) prior to preserving with saturated mercuric (II) chloride (HgCl2) (for more details see Dickson et al., 2007). The ground glass of the bottle neck and stopper were then dried with a lint free highly absorbent wipe, Apiezon grease applied and the stopper inserted completely. The stopper was twisted to remove residual air from the grease and to ensure a complete seal was made. Finally, a securing elastic band was placed on the bottle and the sample preservative mixed through by inverting the bottle a three times/four times. Samples were stored in the CT (controlled temperature) laboratory (approximately 19.5±1°C) until the end of the cruise.

6 additional samples were taken from the underway system (Table 11.2), following the same sampling procedure as described above.

Lat: Lon: Date: Time :	27° 54.0'N 13° 25.0'W 11/03/20 21:38				27° 55.0'N 13° 22.0'W 11/03/20 23:28				27° 52.1'N 13° 31.9'W 12/03/20 02:33				23° 43.6'N 24° 11.5'W 16/03/20 10:54			
Niskin	CTD-7				CTD-8				CTD-9				CTD-11			
	Depth	Samples			Depth	Samples			Depth	Samples			Depth	Samples		
1	640	A	C	N	318	A	C	N	1053	A	C	N				
3	500	A	C	N	270	A	C	N	876	A	C	N				
	500d	A	C	N					876d	A	C	N				
5	450	A	C	N	230	A	C	N	752	A	C	N				
					230d	A	C	N								
7	375	A	C	N	171	A	C	N	626	A	C	N				
9	250	A	C	N	120	A	C	N	503	A	C	N				
					120d	A	C	N								
11	200	A	C	N	101	A	C	N	378	A	C	N				
13	150	A	C	N	80	A	C	N	253	A	C	N				
	150d	A	C	N		A	C	N								
15	100	A	C	N	40	A	C	N	203	A	C	N				
									203d	A	C	N				
17	75	A	C	N	25	A	C	N	153	A	C	N				
19	50	A	C	N	5	A	C	N	103	A	C	N	95	A	C	N
													95d	A	C	N
21	25	A	C	N					53	A	C	N	44	A	C	X
23	5	A	C	N					8	A	C	N	10	A	C	N
													10d	A	C	N

Table 11.1 Samples collected for chemical analysys during JC192. Key: C: total inorganic carbon; A, alkalinity; N, nutrients; X, sample not taken.

11.2 Inorganic/organic nutrients

Lidia Carracedo, Emmy McGarry

Same as for DIC/TA, a total of 4 stations were sampled (46 samples in total) for inorganic/organic (Table 11.1). Samples were collected directly (without Tygon tubing) into 125 mL (4 oz) Nalgene plastic screw-top bottles. Each bottle was rinsed out 2-3 times before being filled to approximately 75% full and immediately frozen for later analysis ashore at NOC facilities.

6 additional samples were taked from the underway system (Table 11.2), following the same procedure described above.

Sample	Lat/Lon	Date Time (UTC)	Variable		
UW01	27° 49.2'N / 13° 44.5'W	10/03/20 15:21	A	C	N
UW02	24° 55.1'N / 21° 16.6'W	15/03/20 04:00	A	C	N
UW03	23° 43.7'N / 24° 11.5'W	16/03/20 09:20	A	C	N
UW04	23° 44.9'N / 25° 57.0'W	18/03/20 09:02	A	C	N
UW05	25° 32.4'N / 24° 21.1'W	19/03/20 14:56	A	C	N
UW06	27° 25.2N / 21° 54.5'W	20/03/20 10:29	A	C	N

Table 11.2 Samples collected from the underway system for chemical analysys during JC192. Key: C: total inorganic carbon; A, alkalinity; N, nutrients.

12. Contros HydroC CO_2 sensors

Lidia Carracedo, Emmy McGarry

12.1 Background

Three Contros HydroC pCO2 sensors were deployed on JC174 (EB1, MA1, WB1 moorings), namely at approximately 40-50 m depth and paired with Deep SeapHOx combined pH-oxygen-temperature-salinity-pressure sensors, both installed on a sensor frame attached to the bottom of a Remote Access Sampler (RAS) with a further MicroCAT CTD installed for good measure. The Contros HydroC is capable of taking measurements at intervals of 1s to 1week for a period up to and including 18 months dependent on deployment conditions. Here they were deployed with HydroB battery packs (84 x Lithium D cells) and set to sample once per day at 00. 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. Note sensors were not redeployed due to ABC Fluxes Project termination in September 2020.

12.2 Recovery of sensors deployed on JC174

EB1 (S/N CO2-0918-001)

The system was recovered with minor moderate biofouling. Communication with the instrument was done in the chem lab after recovery by menas of the Contors HydroC® software, and data downloaded and plotted for visual inspection (Figure 12.1). Data recording (see sampling strategy in Table 12.1) was successful for the full period of deployment.

Once data were downloaded, the batteries were removed, and the Contros HydroC pCO2 sensor was cleaned/rinsed with fresh water and packed, once dry, for its long term storage.

Mooring location	Deployment date	Serial number	Sampling time: local (UTC)	Logging settings
EB1	29-10-2018	CO2-0918-001	23:03-00:00 (00:03-01:00)	Zero (Average 5s, Log 10s) Flush (Av. 5, Log 5) Measure (Av. 10, Log 10)

Table 12.1 Sampling strategy on the Contros HydroC pCO2 sensor deployed on JC174 at EB1.

MAR1 (S/N CO2-0918-001)

This sensor was not recovered due to the cruise being cancelled.

WB1 (S/N CO2-0918-001)

Unfortunately, this sensor was attached to the RAS frame located at the top of the mooring at WB1 that became detached from the mooring line in September 2019.

13. Satlantic SeapHOx sensors

Lidia Carracedo, Emmy McGarry

13.1 Background

The SeaBird Deep SeapHOx sensor combines a Deep SeaFET pH sensor with a SeaBird MicroCAT CTD and SBE63 oxygen optode (MicroCAT-ODO). One of these sensors were recovered during JC192 (details below), not being redeployed due to ABC Fluxes Project termination in September 2020.

13.2 Recovery of sensors deployed on JC174

EB1: SeaFET SN 721-0004, MicroCAT-ODO SN 14152, Deployed 29 Nov 2018.

The system was recovered with minor to moderate biofouling. Communication with the instrument was done in the chem lab after recovery with Seabird UCI® software. Data file was downloaded for the full deployment period, and data plotted for visual inspection (Figure 12.1, b to f). Inspection of the SeapHOX unit cables revealed no sign of fish bites that had been previously obswerved on JC174. Once data were downloaded, the batteries were removed, and the SeaFET sensor carefully cleaned with high-purity isopropyl alcohol (90%), following the manual recommendations (Manual of Best Practices for the SeaFET ™ V2 : Optimizing pH Data Quality). The instrument was cleaned (avoiding the contact of the SeaFET sensor with fresh water) and packed for long term storage.

MAR1: SeaFET SN104, ODO SN 12906– Deployed 19 Mar 2017, Not Recovered

This sensor was not recovered due to the cruise being cancelled.

WB1: SeaFET SN 105, ODO SN 14151 – Deployed 30 Mar 2017, Lost

Unfortunately, this sensor was attached to the RAS frame located at the top of the mooring at WB1 that became detached from the mooring line in September 2019.

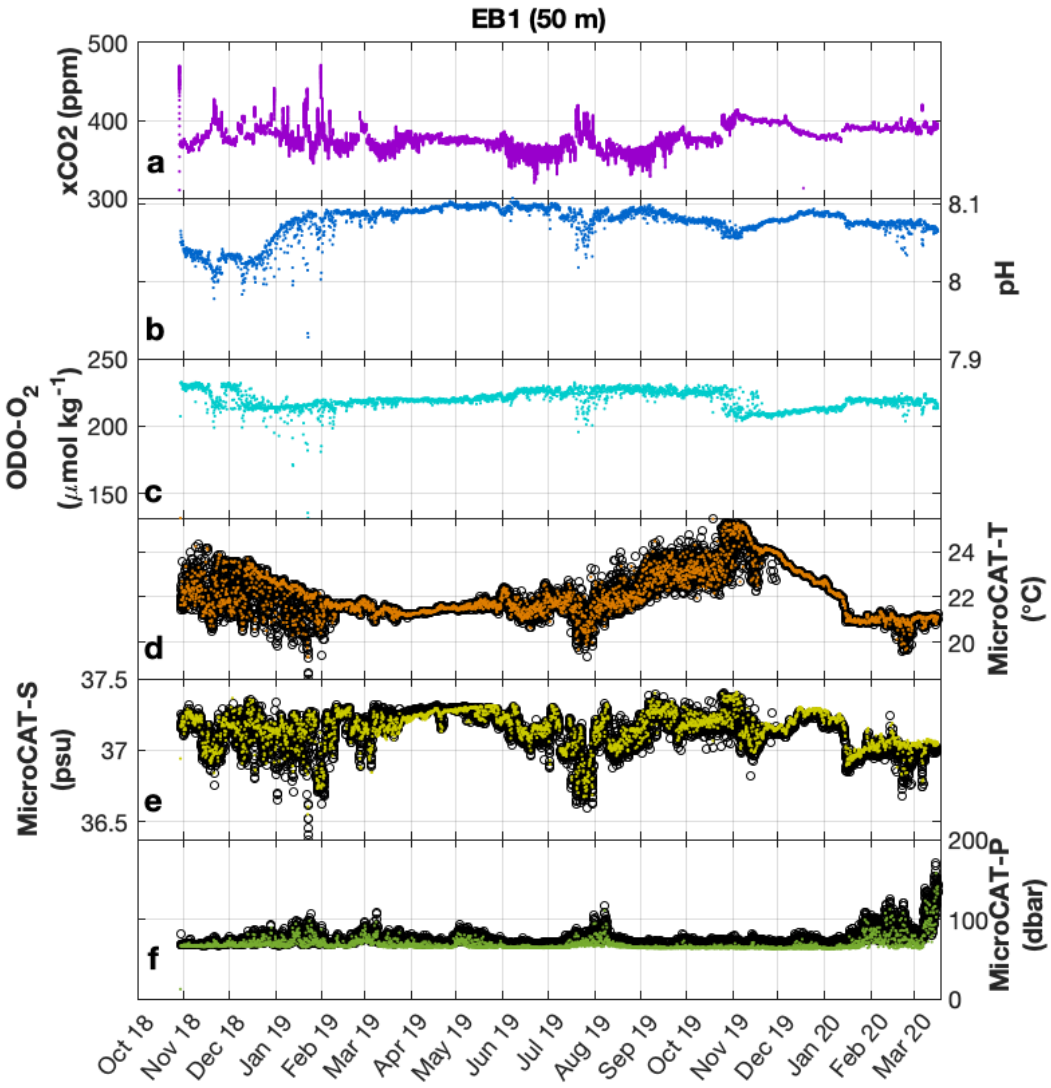

Figure 12.1 Time series of a) xCO2 (Contros pCO2 sensor), b) pH, c) oxygen, d) temperature, e) salinity and f) pressure (SeapHOx sensor, in color; MicroCAT sensor, in black).

14. Remote Access Samplers (RAS)

Lidia Carracedo, Emmy McGarry

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 RAS were deployed during JC174 across the subtropical North Atlantic (at 50 m nominal depth on EB1, MAR1, and WB1 moorings, at 1500 m nominal depth on WBH2) as part of the NERC-funded Atlantic BiogeoChemical (ABC) Fluxes program. This looks to extend the capabilities of the successful RAPID mooring array into a biogeochemical sphere by the use of both autonomous samplers and carbon system sensors (pH, pCO_2).

14.2 Recovery of RAS systems deployed as part of JC174

EB1 – Sampler ML 14520-01 (Deployed 29-10-2018 Recovered 16-03-2020)

The components of the unit are: Electronics controller 14520-01, Pump 14520-01, Valve 14520-01

The system was recovered prior to its sampling event for sample 44 (see Table 14.1). It was in a moderate fouled condition, but none of the tubing fittings on the top or bottom of the unit were detached, none of the compensation tubes were damaged or broken.

Samples were collected by the RAS between positions 1 and 43 with the exception of 12 (valve was opened, no other cause identified at first instance). On initial viewing, all sample volumes appeared to have reached the scheduled 500 mL. Sample bags 1 and 6 lost their cap while being removed from the cylinder. They were sealed straightaway with duct tape. Samples removed were labelled and stored upright in a cool box.

A second inspection of the sample bags was performed in the chemistry lab. This posterior examination revealed that sample bag 6 had a considerable leak in the bottom half of the bag, so the sample was discarded. Sample bags 2 and 26 also presented a leak, but in this case it was a minor leak in the upper side by the valve. Same sort of leakage was identified during the sample bag vacuum tests ran during JC174, when we identified this to be concurrent to approximately 20% of sample bags (which were discarded for use). A vacuum test was performed for the empty sample bag number 12. An important leak was identified by the valve, hence being identified as main reason for the lack of sample event 12. After this second inspection of all sample bags, the coolboxes with the sample bags were placed in the CT (controlled temperature) lab for shipping back to the UK for analysis.

Data downloaded from the RAS system suggested that it had pumped 500 mL for each sample event, and pump and valve information appeared normal. The valve and pump were removed from the RAS frame and installed in a lab sink.

RAS cylinders and pump were removed and disassembled for cleaning and posterior storage.

RAS sampling Date (mm/dd/yy) and Time (UTC)	
Event 1 of 48 @ 10/29/18 19:00:00	Event 23 of 48 @ 07/09/19 00:00:01
Event 2 of 48 @ 10/30/18 00:00:01	Event 24 of 48 @ 07/21/19 00:00:01
Event 3 of 48 @ 11/11/18 00:00:01	Event 25 of 48 @ 08/02/19 00:00:01
Event 4 of 48 @ 11/23/18 00:00:01	Event 26 of 48 @ 08/14/19 00:00:01
Event 5 of 48 @ 12/05/18 00:00:01	Event 27 of 48 @ 08/26/19 00:00:01
Event 6 of 48 @ 12/17/18 00:00:01	Event 28 of 48 @ 09/07/19 00:00:01
Event 7 of 48 @ 12/29/18 00:00:01	Event 29 of 48 @ 09/19/19 00:00:01
Event 8 of 48 @ 01/10/19 00:00:01	Event 30 of 48 @ 10/01/19 00:00:01
Event 9 of 48 @ 01/22/19 00:00:01	Event 31 of 48 @ 10/13/19 00:00:01
Event 10 of 48 @ 02/03/19 00:00:01	Event 32 of 48 @ 10/25/19 00:00:01
Event 11 of 48 @ 02/15/19 00:00:01	Event 33 of 48 @ 11/06/19 00:00:01
Event 12 of 48 @ 02/27/19 00:00:01	Event 34 of 48 @ 11/18/19 00:00:01
Event 13 of 48 @ 03/11/19 00:00:01	Event 35 of 48 @ 11/30/19 00:00:01
Event 14 of 48 @ 03/23/19 00:00:01	Event 36 of 48 @ 12/12/19 00:00:01
Event 15 of 48 @ 04/04/19 00:00:01	Event 37 of 48 @ 12/24/19 00:00:01
Event 16 of 48 @ 04/16/19 00:00:01	Event 38 of 48 @ 01/05/20 00:00:01
Event 17 of 48 @ 04/28/19 00:00:01	Event 39 of 48 @ 01/17/20 00:00:01
Event 18 of 48 @ 05/10/19 00:00:01	Event 40 of 48 @ 01/29/20 00:00:01
Event 19 of 48 @ 05/22/19 00:00:01	Event 41 of 48 @ 02/10/20 00:00:01
Event 20 of 48 @ 06/03/19 00:00:01	Event 42 of 48 @ 02/22/20 00:00:01
Event 21 of 48 @ 06/15/19 00:00:01	Event 43 of 48 @ 03/05/20 00:00:01
Event 22 of 48 @ 06/27/19 00:00:01	

Table 14.1 RAS sampling schedule timetable.

MAR1 – Sampler ML 13278-02 (Deployed 08-11-2018 Not Recovered)

The components of the unit are: Electronics controller 13278-02, Pump 13278-02, Valve 13278-02.

Unfortunately, due to exceptional circumstances the cruise was cancelled, making the recovery of RAS MAR1 not possible.

WBH2 – Sampler S/N 14520-02 Deployed 01-04-2017 Not Recovered

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The components of the unit are: Electronics controller 13278-0, Pump 13278-01, Valve 13278-05.

Likewise, the recovery of RAS WNH2 was not possible due to the cruise cancellation.

WB1 – Sampler S/N 14520-02 Deployed 30-03-2017 Recovered 21-11-2018

The components of the unit are: Electronics controller 14520-02, Pump 13278-01, Valve. 13278-01

Unfortunately, the top of the mooring at WB1 became detached from that below in 28th September 2019, and although the beacon was communicative, there was no RAS attached to the buoyancy when the recovery attempt was made on 21st October, and thus the system is currently lost.

14.3 RAS system usage

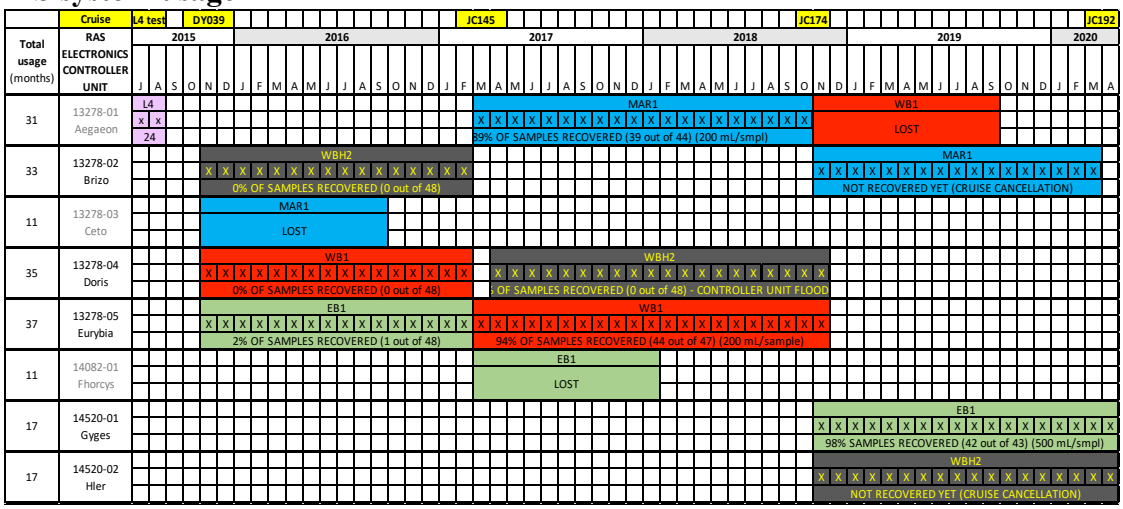


Table 14.2 Overall usage of the RAS systems.

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.

15. Data telemetry system

Darren Rayner

On cruise JC174 a telemetry system was deployed on mooring EBH3. 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 an autonomous service vehicle – a Liquid Robotics Wave Glider carrying a payload that retrieves the data via acoustic modem and then transfers it to shore via Iridium. Further details of the deployed system can be found in the JC174 cruise report (Smeed, 2019).

Shortly after deployment a mistake was discovered with the wiring configuration of the buoy controller's connection to the acoustic modem. This mistake meant that the acoustic modem on the mooring could not receive data from the buoy controller and thus would not have anything to send on to the Wave Glider that was planned for deployment a few months later. The Wave Glider deployment was therefore cancelled.

The buoy controller however continued to poll the moored instruments on schedule and stored the data on its memory card. This was then acting as a backup should any of the instruments have been lost before the mooring was recovered.

Analysis of the recovered files showed that all MicroCAT (including MicroCAT-ODOs) and buoy controller diagnostic data were present on the memory card. The Nortek data were however missing. At first it was thought that maybe the inductive IDs had been set incorrectly, but further investigation revealed that the output data format was actually set to be incorrect. The instruments were all outputting data in binary format whereas the buoy controller was expecting ASCII, so the replies from the polling could not be interpreted.

There were initial concerns over the data fidelity of the oxygen record from one instrument, but this was confirmed to match the data on the instrument itself and was caused by a sensor failure rather than a fault with the data transfer.

The buoy controller diagnostic data showed the buoyancy was rotating freely so the inductive swivels were working as intended. The variations in pitch and roll were small – as would be expected when housed in a large float in a relatively low current area. The buoy controller housing internal temperature was steady with minor variations matching the surrounding water. The internal humidity dropped off exponentially form an initial high of about 55% – probably due to what moisture there was in the trapped air being absorbed by the desiccant pack. And the battery voltage generally remained steady around 24.5V with spikes down to 21V presumably caused when the buoy controller was operating the inductive modem and ancillary sensors. As the batteries used were Lithium cells then we can take the voltage when under load as being more representative of the battery capacity, but there is no evidence of the battery getting anywhere near close to being exhausted during the 18-month deployment.

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.

16. Moorings

Eleanor Frajka-Williams and Darren Rayner

All 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.
Releases were tested on the CTD frame to at least their deployment depth prior to use, and moored CTDs were checked before deployment and after recovery to provide functionality checks and end-point reference calibrations. Communication was done via the ship's transducer with the exception of one cal-dip cast (cast 12) when the dropkeel needed to be lowered.
Summaries of the deployment and recovery times are given in Table 16.1, 16.2 and 16.3, with details of instruments lowered on CTD calibration dips given in Table 16.4. Table 16.5 summarises the instrument record lengths (NB: this is from initial inspection on the cruise, and not fully QC'd data, so there may be erroneous data included in the totals).

16.1 Mooring issues

All of EBH3, EBH4, EBH4L7, EBH2, EBH1, EBH1L12, EBHi, EB1, and EB1L12 were recovered. EBHi had imploded glass (2, at 4000m) and ascended at 40m/min. EB1 had imploded glass (4 from an 8-pack at 5000m, 2 from a 5-pack at 2500m) and recovery was commenced before the mooring was all visible on the surface (only the billings, top sphere + 9-pack and first 4-pack were seen). EBHi, EB1, and EB1L12 had imploded glass and had slow ascents to the surface. EBL14 was repositioned so it is 0.1Nm away from a subsea cable.

Early surfacing and recovery of WB1_2018

Mooring WB1_2018 was deployed on JC174 on the 24th of November 2018. The mooring deployment was intended to be approximately 18 months with recovery in Spring 2020 but this mooring broke loose and surfaced on the 29th September 2019.

Initially messages were only being received by email from the Iridium beacon on the upper buoyancy so it was assumed it was only the top couple of hundred metres that had surfaced. On the 2nd of October the Iridium beacon stopped sending new positions, but the next day it was realised that the Argos beacon on the lower buoyancy had in fact been transmitting – the auto-forwarding system was not setup to pass these messages on by email. This was corrected and the Argos beacon was used to track the mooring as it drifted north of the island of Great Abaco, Bahamas, and a rescue mission was mounted piggybacking on a NOAA AOML Florida Straits cruise. On this cruise the mooring was found and recovered with all instruments from the bottom up to the lower syntactic float being present except for the acoustic releases. The upper buoyancy and instruments in the RAS frame were not found. The nylon rope above the releases had parted.

The recovered instruments were downloaded by colleagues in Miami and processed using the standard RAPID procedures.

After the recovery cruise had returned to port, the Iridium beacon started sending positions again. Believing the RAS and associated ABC Fluxes instruments were still attached to the syntactic buoyancy a second rescue attempt was mounted from Miami. A 3-day trip found the floating buoyancy, but the RAS was no longer attached and therefore lost.

Times of the key events are summarised in the table below.

Date/Time	Event	Comments
Mooring deployed	24th November 2018	From cruise JC174
First Iridium Message received	29th September 2019	
First Argos transmission	29th September 2019	Not seen initially due to problems with auto-forwarding emails
Break in Iridium GPS transmissions	2nd October 2019	A few messages were received after this, but not with new GPS positions
Argos messages found in system	3rd October 2019	
Walton Smith sails from Miami	4th October 2019	
Walton Smith locates drifting mooring	5th October 2019	Mooring from above releases to below RAS recovered
Walton Smith docks	7th October 2019 am	
Iridium transmissions restart	7th October 2019 pm	Message indicate upper buoyancy is close to shore off Great Abaco
Second Walton Smith cruise sails from Miami	21st October 2019	This was the earliest a 2nd attempt could be made after sorting the admin

Walton Smith locates drifting buoyancy	22nd October 2019	Only the buoyancy present, no instruments below
Walton Smith docks	23rd October 2019	

Table 16.1 Event log for the recovery of WB1.

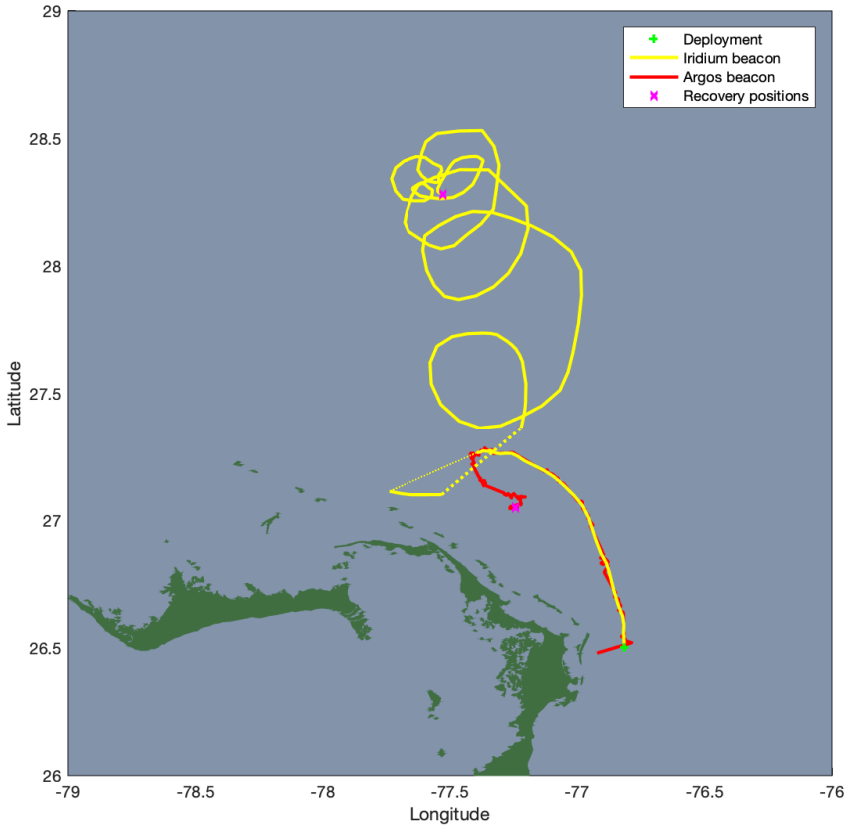


Figure 16.1 The recovery of WB1.

<u>Thoughts on the cause of the breaks</u>

The mooring came apart in three places. Firstly, the nylon rope above the releases parted causing the whole mooring to surface. This rope has a minimum breaking load of more than 5 tonnes, so is unlikely to have parted due to a direct load. It's tricky to see what happened from looking at the recovered end of the rope, but the category 5 Hurricane Dorian passed, and in fact sat over, the area of this mooring at the start of September 2019. It's proposed the motion imparted on the subsurface mooring by this hurricane caused significant abrasion on the synthetic rope, weakening it with it eventually parted a few weeks later.

Figure 16.2 The recovered end of the 16mm diameter 3-strand nylon twist rope that parted above the acoustic releases.

Once the mooring was on the surface the two floats became separated through the failure of the 3/16” diameter mooring wire (minimum breaking load of 2 tonnes). Again the reason is unknown, but with the syntactic sphere and large pack of glass buoyancy at each end of the wire being subject to wave motion, the wire could have been repeatedly flexed and broken, or potentially it was struck by a passing vessel. This probably occurred when the Iridium beacon on the upper syntactic float stopped transmitting as the beacons were tracking together well up till this point.

Figure 16.3 The parted 3/16” outer diameter jacketed wire rope (3x19 construction). The wire parted near the termination attached to the glass buoyancy.

The third separation of the mooring occurred when the RAS became disconnected from the smaller syntactic float with the shackle missing from the mooring link on recovery. It is unknown how this happened as the shackle should have been prevented from shaking loose as it was seized with a

cable tie (though it could have been missed). Another possibility is third-party interference, but this seems unlikely.

16.2 Instrument problems

16.2.1 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.

16.2.2 RAPID instruments

All records were complete. RCM11 temperatures and conductivities were wrong (conductivity of -999 and temperature too high). MicroCAT ODO 12964 had bad conductivity values from Dec 2019.

Mooring	Deployment cruise	Deployment data	Recovery date	Recovery start time (UTC)	Recovery duration
ebh4	JC174	2018-10-23	2020-03-16	10:20	1:01
ebh4L7	JC145	2017-03-01	2020-03-12	11:55	0:52
ebh3	JC174	2018-10-23	2020-03-21	13:27	1:54
ebh2	JC174	2018-10-24	2020-03-24	08:01	1:04
ebh1	JC174	2018-10-25	2020-03-25	08:00	1:30
ebh1L12	JC145	2017-03-17	2020-03-25	09:52	1:20
ebhi	JC174	2018-10-27	2020-03-27	08:32	2:48*
eb1	JC174	2018-10-29	2020-03-28	11:08	4:21*
eb1L12	JC145	2017-03-09	2020-03-23	16:09	2:57*

Table 16.2 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
ebh4	27° 51.05	13° 32.42	1058	110	2020-03-11	15:22	01:36
ebh4L9	27° 52.15	13° 30.65	996	No tri.	2020-03-11	16:30	00:05
ebh3	27° 48.48	13° 44.83	1419	149	2020-03-10	19:04	01:59
ebh2	27° 36.89	14° 12.76	2016	229	2020-03-12	10:23	00:33
ebh1	27° 13.30	15° 25.29	3040	138	2020-03-13	12:55	00:26
ebh1L14*	27° 12.20	15° 25.21	3039	142	2020-03-13	13:56	00:07
ebhi	24° 56.08	21° 15.92	4316	No tri.	2020-03-15	13.29	01:07
eb1[&]	23° 45.45	24° 09.65	5051	485	2020-03-17	16:09	04:33
eb1L14	23° 47.87	24° 08.64	5100	280	2018-03-17	16:57	00:01

Table 16.3 Mooring deployment table. The lander at EBh1 was moved slightly to avoid a subsea cable (indicated by *). EB1 was deployed slightly earlier than the drop location (indicated by [&]).

CAST NO.	Allocated	MICROCAT S/N	COMMENT (C in mS/cm, P in dbar, T in °C)
CAST 1	EBH3	3231	P off at bottom (over-reading by +11.5)
	EBH3	3232	P off at bottom (over-reading by +11.2)
		3233	C low (-0.04)
	EBH3	3253	OK
	EB1	3890	C off (-0.037), P is OK at 1000 dbar. Pair with ODO
		3891	Could not communicate with instrument
	EBH3	3901	OK
	EBH3	3931	OK
	EBH4	4725	OK
	EBH3	5240	OK
		5247	C high (+0.03), P off at bottom (+16.6)
		5772	C low (-0.06), P off at bottom (-8.0)
	EBH3	5777	OK
		5783	C low (-0.04), P off at bottom (-8)
		6115	C is way off (-0.09)
	EBH3	6122	OK
	EBH3	6803	P off at bottom (+8.3), OK shallow
	EB1	6811	OK
	EB1	6813	P off (-16.3) at 2000m, pair with ODO
		6817	C low (-0.06)
		6818	C low (-0.06)
	EBH3	6829	OK
	EBH4	6833	C high (+0.028)
	EBH3	6834	C off (+0.023), P OK at 400m
CAST 2	EBH3	3234	P ok at 50m
	EBH4	3247	OK
		4066	C off (-0.05)
	EBH2	4184	OK
	EBH4	4468	OK
		4472	C off (+0.05)
	EBH1	4473	P ok at 2500m
		4474	C is way off (-0.24)
	EBH4	4708	OK
	EBH4	4795	OK
		5238	P OK at depth but not shallow
	EB1	5241	T is off (-0.007), pair with ODO
	EBH3	5766	OK, P ok at 500m
	EBH4	10518	OK

	EBH3	10542	OK
	EBH3	10556	OK
	EB1	10716	T noisy and off (+.004)
	EBH3	12900	OK
	EB1	14117	OK
	EB1	14145	T noisy and off (+.009)
	EB1	14146	T noisy
	EB1	14149	OK
	EB1	14150	T noisy and off (+.006)
	EB1	14151	OK
CAST 5	*EBH2*	6113	P off at bottom (-7.8)
	EBH4	6118	OK
	EBH4	6119	OK
	EBH2	6125	C off (-0.027)
	EBH4	6332	OK
		6812	Pressure sensor non-functional
	EBH4	6827	C off (-0.026), P off at bottom (+7.8)
		6831	C is off (.067)
	EBH4	6835	OK
	EB1	6839	C is off (-.035), P is off at depth (+11.8), OK shallow
CAST 10	EB1	3206	C off (+.025), P off at depth (+5.8)
		3207	C off (-.05), P is off at bottom (+10.7)
	EB1	3212	P off at dpth (+25.6), OK at 600m
	EB1	3222	P off at depth (+6.5), ok at 2500m
	EB1	3229	OK
	EBHi	3256	OK
	EBHi	3484	OK
		3904	C off (-.04)
	EBHi	3907	OK
		3912	C off (-.05), P is off at bottom (-12.6)
		4462	C off (-.08)
	EB1	4466	P off at bottom (+18.0), OK at 750m
	EB1	4714	OK
	EB1	4722	C off (+.03), P off at depth (+6.8)
		5245	C off (-.04), P off at depth (-8.1)
		5765	T off (+.004), P is off at bottom (+ 11.0)
	EB1	5979	OK
	EB1	5984	OK
	EB1	5985	OK
		7469	OK
		10543	OK

		10544	OK
		10555	OK
		13244 (NMEP)	P is off (+39.4), C is off (-0.008) but both stable so correctable for NOG purposes
CAST 11		3219	P off at bottom (+37.3)
	EB1	3224	OK
		3228	P off at bottom (+13.2)
		3270	P off at bottom (-18.9)
		3905	Pressure is way off (+1393), C off (+.04)
		3916	C off (-0.04), P off at bottom (-8.0)
	EB1	3932	OK
		4712	Started late?
		4713	C off (+0.028), P off at bottom (+14.1)
		4717	P off at bottom (+8.2)
		4718	P off at bottom (+25.0)
		4720	P off at bottom (+10.0)
		4723	P off at bottom (+41.5)
		5242	T went bad on upcast, P off at bottom (+44.3)
		5775	C lag - bad pump?
		5776	OK
		5781	C lag - bad pump?
		6800	OK, but C and T noisy
		6826	OK, but C and T noisy
		6836	P off at bottom (-6.5)
		7468	C off (-0.04)
		12962	C way off (+0.2)
		14116	OK
		14147	P off at bottom (-8)
CAST 12		3282	P off at bottom (-6.0)
		4180	C off (+.06), P off at bottom (+8.6)
		4464	P of at bottom (-9.7)
		4470	C off (+.05), P off at bottom (+9.1)
		4471	P off at bottom (+15.5)
		4724	P off at bottom (+44.9)
		5767	P off at bottom (+7.1)
		5784	P off at bottom (+11.6)
		5981	OK
		5982	OK
		5983	OK
		6112	C off (-0.06)

		6808	OK
		12833	OK
		12963	OK
		12964	P way off (-1023)
		12965	OK
		12966	OK
		12967	T off (+0.007), T noisy
		12968	OK
		12998	P off at bottom (+10.5)
		20253	OK
		20254	OK
		20255	OK, but C and T noisy
CAST 13		3220	P off at bottom (-5.5)
		3221	C off (-0.08)
		3239	C off (+0.03)
		4068	OK
		4071	OK
		4072	C high (0.03)
CAST 14		3215	P off (+9.5)
		3225	OK
		3913	OK
		5239	P off at bottom (-7.3)
		5243	OK
		5770	T off (+0.007), P of at bottom (-5.8)
		5782	P off at bottom (+7.6)
		5789	P off at bottom (+12.9)
		5978	P off at botom (+8.7)
		6117	OK
		6120	P of at bottom (-9.0)
		6126	P off at bottom (-6.3)
		6335	P off at bottom (-10.9)
		6798	OK
		6801	P off at bottom (+8.6)
		6804	P off at bottom (+5.8)
		6810	C high (+0.03), P off at bottom (+7.7)
		6814	OK
		6821	C high (+0.03)
		6824	P off at bottom (+5.9)
		11744	C high (+0.08), P off at bottom (-5.4)
		12906	C high (+0.04)

Table 16.4 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
ebh4_14_2018	100	337	5242	101.5	23/10/2018	11/03/2020	12123	Conductivity spike down ~day 225
ebh4_14_2018	175	337	5775	179.5	23/10/2018	11/03/2020	12123	OK
ebh4_14_2018	250	337	6826	256.4	23/10/2018	11/03/2020	12123	OK
ebh4_14_2018	325	337	3905	328.7	23/10/2018	11/03/2020	12123	OK
ebh4_14_2018	400	337	3270	406.8	23/10/2018	11/03/2020	12123	OK
ebh4_14_2018	500	337	7468	505.3	23/10/2018	11/03/2020	12123	OK
ebh4_14_2018	600	337	3219	615.9	23/10/2018	11/03/2020	12123	CT spike down ~day 400
ebh4_14_2018	700	337	6836	714.9	23/10/2018	11/03/2020	12123	Slight pressure drift (1dbar)
ebh4_14_2018	750	335	12962	765.5	23/10/2018	11/03/2020	3030	OK
ebh4_14_2018	800	337	6800	813.9	23/10/2018	11/03/2020	12123	C spike down ~day 350
ebh4_14_2018	800	310	301	976.4	23/10/2018	11/03/2020	6061	
ebh4_14_2018	1000	337	3228	1018.9	23/10/2018	11/03/2020	12123	OK
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
ebh4l7_7_2017	993	465	447	1009.5	01/03/2017	11/03/2020	26541	P drift up ~0.1 dbar
ebh4l7_7_2017	993	465	3	1009.4	01/03/2017	11/03/2020	26541	P drift down <0.1 dbar
Mooring	Nominal depth (m)	Inst. code	Serial number	Mean pressure (dbar)	Start date	End date	No. records	Comments
ebh3_13_2018	50	337	3239	61.7	23/10/2018	10/03/2020	12093	C spike down ~ d210, ~ d280
ebh3_13_2018	50	335	20253	62.8	23/10/2018	10/03/2020	3022	Oxygen & oxygen T offset
ebh3_13_2018	100	337	4723	107.8	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	175	337	4471	187.1	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	250	337	5981	261.4	23/10/2018	10/03/2020	12093	OK

ebh3_13_2018	350	337	5982	364.8	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	400	335	20254	417	23/10/2018	10/03/2020	3022	OK
ebh3_13_2018	425	337	4464	440.8	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	500	337	4724	517.8	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	500	370	12701	501.8	23/10/2018	10/03/2020	24186	OK
ebh3_13_2018	600	337	5983	616.7	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	700	337	4180	718.7	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	750	335	20255	767.8	23/10/2018	10/03/2020	3022	OK
ebh3_13_2018	800	337	4072	821.6	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	800	370	8465	818.4	23/10/2018	10/03/2020	23635	OK
ebh3_13_2018	950	337	4071	965.3	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	1000	370	11855	1004.6	23/10/2018	10/03/2020	24186	OK
ebh3_13_2018	1100	337	4470	1121.9	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	1200	337	4068	1223.2	23/10/2018	10/03/2020	12093	OK
ebh3_13_2018	1300	370	11846	1316.8	23/10/2018	10/03/2020	24186	T jump ~Dec19
ebh3_13_2018	1400	337	3282	1420.6	23/10/2018	10/03/2020	12093	OK
Mooring	Nominal depth (m)	Inst. code	Serial number	Mean pressure (dbar)	Start date	End date	No. records	Comments
ebh2_13_2018	1600	337	5784	1622.3	24/10/2018	12/03/2020	12118	Initial P drift ~2 dbar
ebh2_13_2018	1800	337	5767	1824.9	24/10/2018	12/03/2020	12118	Initial P drift <1 dbar
ebh2_13_2018	1900	310	302	1933.8	24/10/2018	12/03/2020	6047	
ebh2_13_2018	2000	337	6808	2031.8	24/10/2018	12/03/2020	12118	Initial P drift <1 dbar
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
ebh1_13_2018	2500	337	6112	2546.1	25/10/2018	13/03/2020	12116	P drift (increase) 4 dbar
ebh1_13_2018	2900	310	426	2982.1	25/10/2018	13/03/2020	6058	
ebh1_13_2018	3000	337	3220	3068.8	25/10/2018	13/03/2020	12116	ok

Mooring	Nominal depth (m)	Inst. code	Serial number	Mean pressure (dbar)	Start date	End date	No. records	Comments
ebh1l12_12_2017	3031	465	448	3085.6	03/03/2017	13/03/2020	26542	P offsets in May 2017 & May 2019
ebh1l12_12_2017	3031	465	4	3088.6	03/03/2017	13/03/2020	26542	P drift < 1 dbar
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
ebhi_13_2018	3500	337	5770	3520.2	27/10/2018	15/03/2020	12115	P jump ~Sept 1st 2019, likely when glass imploded. After ths the instruments were 'profiling' over a 100m range
ebhi_13_2018	4000	337	5243	4053.1	27/10/2018	15/03/2020	12115	P jump ~Sept 1st 2019, likely when glass imploded.
ebhi_13_2018	4400	310	428	2981.6	27/10/2018	13/03/2020	6034	Time drift not applied. RCM temperature *wrong*
ebhi_13_2018	4500	337	3225	4575.1	27/10/2018	15/03/2020	12115	P jump ~Sept 1st 2019, likely when glass imploded.
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
eb1_15_2018	100	337	6821	115.9	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	175	337	5978	201.3	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	250	337	11744	269.5	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	250	335	12963	269.4	29/10/2018	16/03/2020	3022	OK
eb1_15_2018	325	337	6824	345.4	29/10/2018	16/03/2020	12089	possible CT offset Jul 2019
eb1_15_2018	400	337	6801	420.8	29/10/2018	16/03/2020	12089	possible CT offset Jul 2019
eb1_15_2018	400	335	12964	421.8	29/10/2018	16/03/2020	3022	C bad vaues frm Dec 2019, some O2 spikes Jan 2020
eb1_15_2018	600	337	6335	622.2	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	600	335	12965	622.4	29/10/2018	16/03/2020	3022	OK

eb1_15_2018	800	337	5789	830.2	29/10/2018	16/03/2020	12089	Multiple have P deepen near end - possible glass implosion ~March 2020
eb1_15_2018	800	335	12966	825.2	29/10/2018	16/03/2020	3022	OK
eb1_15_2018	1000	337	6126	1029.6	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	1200	337	6814	1239.8	29/10/2018	16/03/2020	12089	Possible P drift of 5 dbar
eb1_15_2018	1500	335	12968	1537.6	29/10/2018	16/03/2020	3022	OK
eb1_15_2018	1500	310	443	1546.1	29/10/2018	16/03/2020	6044	RCM with bad T, C
eb1_15_2018	1600	337	5782	1640.1	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	2000	337	6120	2045	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	2000	335	12998	2049.9	29/10/2018	16/03/2020	3022	OK
eb1_15_2018	2500	337	6804	2560.4	29/10/2018	16/03/2020	12089	Possible P drift at beginning of record (8 dbar)
eb1_15_2018	3000	337	5239	3065.6	29/10/2018	16/03/2020	12089	Posible P drift of <5 dbar
eb1_15_2018	3500	337	6117	3583.2	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	3500	335	12833	3579.8	29/10/2018	16/03/2020	3023	OK
eb1_15_2018	4000	337	6798	4095.1	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	4500	337	3913	4609.4	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	5000	337	3215	5131	29/10/2018	16/03/2020	12089	OK
eb1_15_2018	5000	310	444	5119.9	29/10/2018	16/03/2020	6045	RCM with bad T, C
Mooring	**Nominal depth (m)**	**Inst. code**	**Serial number**	**Mean pressure (dbar)**	**Start date**	**End date**	**No. records**	**Comments**
eb1l12_12_2017	5098	465	449	5082.8	10/03/2017	16/03/2020	26446	P sensor problems from ~July 2019
eb1l12_12_2017	5098	465	435	5179.6	09/03/2017	16/03/2020	26471	OK

Table 16.5 Mooring instrument record lengths.

17. NOAA AOML PIES landers

Eleanor Frajka-Williams

Two PIES landers were deployed for NOAA AOML. These were bottom landers with a PIES sensor, data controller and 4 data pods. The first was deployed at EBH4 s/n 327. Just prior to deployment, condensation was noticed inside the glass sphere containing the data controller. The NMF Benthos transducer and NOAA Benthos transducers were used to range to the instrument and verify that it was on the bottom. This was mostly successful, though the Rx Threshold had to be adjusted (to 250) to get reliable responses. It was confirmed at 1067m range.

The second was deployed at EB1 s/n 325 in 5080m of water. Ranging confirmed that it was falling at about 1 m/s (anticipated fall rate). Telemetry was attempted using IESTelemetry.jar (from http://github.com/pedrolpena/) using the NOAA Benthos deck unit UTS-9400M. We were able to hear the PIES sampling on the hour but unable to telemeter data. A transducer was lowered over the side but while we were on DP (dynamic positioning), the transducer was streaming aft with a wire angle of just less than 45 degrees. When we drifted, the transducer was streaming forward with slightly lower wire angle. Telemetry attempts were ended before midnight GMT, when the PIES would go into its daily processing mode.

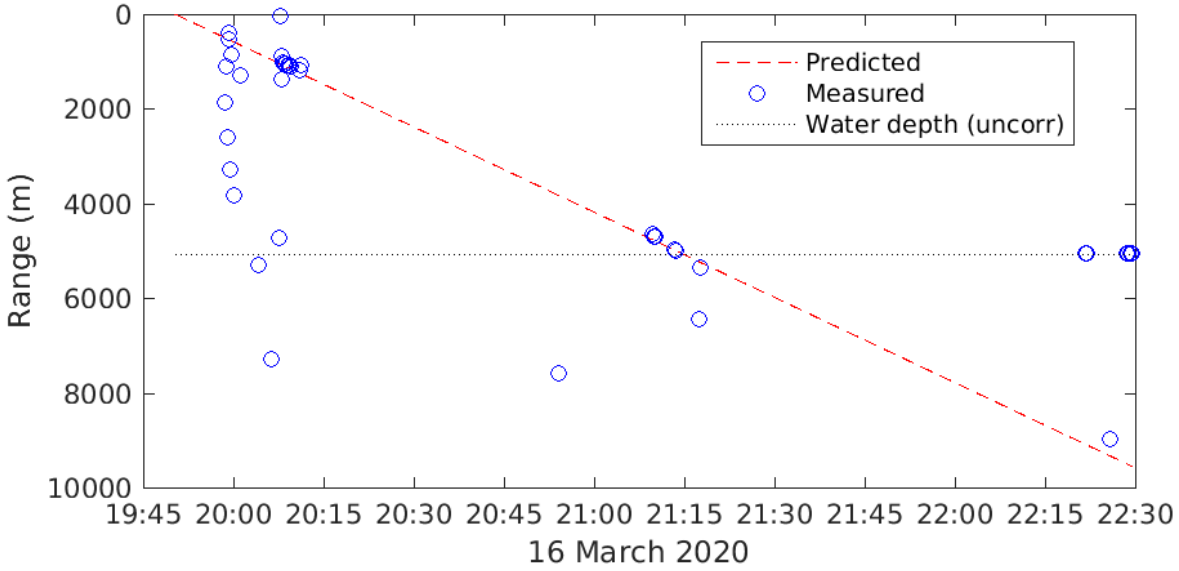


Figure 17.1 Descent of the PIES lander at EBH4.

PIES at EBH4 (s/n 327) Deployment:

Date: 11/3/2020 Site arrival time: 17:05

Start time: 17:20 End time: 17:22:25

Ship position at deployment time:

Latitude 27º 52.1'N Longitude 13º 32.05' W

Between site arrival and commencing deployment, Eleanor noticed condensation in the sphere containing the data controller. We wiped moisture from the outside of the spheres and confirmed noticeable condensation was inside the controller only: consisting of droplets and a broader patch with a film.

Figure 17.2 Photo of condensation inside the PIES buoy controller.

Images were sent to Pedro (NOAA) to confirm whether or not the deployment should go ahead (17:17). Confirmation was received and the PIES deployed at 17:22. Deployment took under 3 minutes from lift to drop. A video was taken of the deployment (GOPR9077.MP4, 500mb).

Ranging:
Two complete setups were trialled for ranging, set up in the CTD hanger on the RRS James Cook. The NMF Benthos DS-7000 deck unit with transducer and a NOAA Benthos UTS-9400M deck unit with transducer. The DS-7000 was used on ship power; the UTS-9400M was on battery. Each deck unit was only used with its own transducer. The transducer was lowered over the starboard side to below the hull depth (6m). Ship's echo sounder and multi-beam were off. The ship was on dynamic positioning during the deployment and ranging.

NMF Benthos DS-7000

- 17:25 The DS-7000 was used first. It was set up with RX Freq of 12.00 kHz and TX Freq of 12.5 kHz, with a gain of 3. The XPND command was sent (71 for s/n 327) at 17:27 and a two-ping response heard on headphones.
- Ranges received included 0.9356 sec at 17:25, and 1.02 s at 17:27:55.
- We did not manage to change the response format from seconds to meters and so switched to the other deck unit. As it turns out, the aux4 label is actually a button, and pressing this changes the units on the ranges.

NOAA Teledyne Benthos UTS-9400M

- 17:33 The NOAA Benthos unit was used. It was set up according to instructions, selecting Release/URI CPIES and transmit/receive frequencies as above. Rx Threshold was initially 10. Filtering was set to block all frequencies except 12.00 kHz. No settings were changed in the 'Advanced' tab (sensitivity adjustment).
- The command was set under the 'Release' top tab to XPND (71 for s/n 327) by holding the send button for 2 seconds. The deck unit did not identify this command as XPND, but only as 'command code'.

- Ranging was then commenced by pressing the 'ping' button under XPND. Initially, ranges varied widely. The Rx Threshold was increased to 100 and then to 250. Ranges were sent at 10 second repeats.

Command	Time	Range (m)	Notes
Ranging	17:41	Lots of ranges	Noisy returns. Increased Rx Threshold to 100
Ranging	17:43	Lots of ranges	Increased Rx Threshold to 200 then 250.
Xpnd (71)	17:46		Got two-ping response
Ranging	17:50	2132	Noisy returns. Increased LOCKOUT to 1000ms
Clear (76)	17:52		Got two-ping response.
Xpnd (71)	17:54		No response
Xpnd (71)	17:55		No response
Xpnd (71)	17:56		Got two-ping response
Ranging	17:58	1067	
10 second repeats		1067	
		2840	
		4456	
		2386	
		1068	
		1480	
		3061	
		1229	
		2232	
		3074	
		1169	
		3015	
		1244	
18:00:20	18:00:20	1067	
		1067	
76 (clear)	18:00:56	2-ping response received	2-ping response received
Ranging	18:02		No response

Table 17.1 Ranging to the PIES at EBH4.

Telemetry setup:
Telemetry was done on Eleanor's Macbook pro running OSX Mojave 10.14.6. IESTelemetry software was installed from http://github.com/pedrolpena/ (iestelemetry-master) prior to sailing. This required Java JDK to be downloaded and installed:

```
java version "13.0.2" 2020-01-14
Java(TM) SE Runtime Environment (build 13.0.2+8)
Java HotSpot(TM) 64-Bit Server VM (build 13.0.2+8, mixed mode, sharing)
```

Compiling the software worked by editing the makeit.sh first line to read:

```
javac -source 7 -target 7 -d ./ -cp
./lib/bsaf.jar:./lib/RXTXcomm.jar:./lib/swing-worker-1.1.jar
src/iestelemetry/*.java
```

A USB to RS232 serial adaptor was needed, which further needed to be plugged in via a USBC to USB adaptor. The initial one trialled did not install (did not appear in /dev/) but the second one did, appearing as `/dev/tty.usbserial-FT06QA8X`. An RS232 extension cable was used, and the Macbook connected to the Benthos UTS-9400M deck unit.
The instructions in the readme.md for iestelemetry were used to get access to the serial port. IESTelemetry.jar was run using the command

```
java -Djava.ext.dirs -jar IESTelemetry.jar
```

From the command line, in the directory iestelemetry-master/dist/

Once the serial port was accessible, the computer was connected to the deck unit (which was already connected to the transducer). Connect was clicked, and IES settings were retained. Based on the experience with the previous ranging, the RX Threshold was initially set to 250. Then 'Configure Deck Box' was clicked.

Telemetry:

Date: 12/3/2020 Site arrival time: 01:00
Start time: 01:10 End time: 02:51
Ship position during telemetry:
Latitude 27º 52.084'N Longitude 13º 31.915' W

Telemetry was attempted while a CTD cast was being taken. The cast started at 01:00, and the telemetry at 01:15. While the PIES responded reliably to the 76 command and Telem commands with a 2-ping response, it does not appear that any data were received. Additionally, we did not hear PIES s/n 327 sampling at 02:00, though we did hear PIES s/n 325 pinging on deck.

Time stamp	WA time	Cmd	Notes	Pings	Rawdata (lines)
			Send configure deck unit	Configure deck unit	L1-125
01:10:26		76	Heard chirping, thought it might be dolphins	Noise	L126-155
01:12:44		76	Turned off the echo sounder and multi-beam	Noise	L155-226
				10 khz 7029.7 ms	L234
01:13:34		76	Two-ping response	Two-ping response	L236+
01:14:14		67	Two-ping response	Two-ping response	L239+
			No data transmitting		
01:27:48		67	Two-ping response	Two-ping response	L248+
			No data transmitting		
	01:31		Lowering threshold to 200		
	01:41		Lowering threshold to 100		
	01:44		Gt a 10 khz ping 512916.5 ms	10 khz 512916.5 ms	L253
	01:46		Lowering transducer further 2m		
01:46:55		67	Two-ping response	Two-ping response	L265+

			No data transmitting		
			Got a 10 khz ping 11076.5 ms	10 khz 11076.5 ms	L270
	01:50		Change Rx Threshold to 10	Configure deck unit	L273-395
				10 khz 130901.9 ms	L402
				10 khz 23862.6ms	L423
01:51:48	01:52	67	Two-ping response	Two-ping response	L430+
	01:56		Got three 12.0 khz pings		L450, 452, 455
01:57:42		76	Two-ping response	Two-ping response	L466+
	02:04		Possible telemetry?	Pings at 10, 11, 12.5 khz	L473-496
	02:07		Sent screen pic to Pedro (L485-492) - identified noise; Raised threshold to 25		
02:09:58		67	Two-ping response	Two-ping response	L512+
02:13:53			Testing keyboard shortcuts (ctrl-2 and ctrl-d)		
02:21:49		67	One ping at 12.5 kHz		L521
02:23:45		65	Two-ping response	Two-ping response	L529+
02:35:42		64	Two-ping response	Two-ping response	L543+
02:36:12		66	Two-ping response	Two-ping response	L552+
02:36:42		68	Xpnd command, Two-ping response	Two-ping response	L561+
02:37:09		69	Xpnd command, two-ping response	Two-ping response	L571+
02:37:40		65	Two-ping response	Two-ping response	L580+
02:38:07		67	Two-ping response	Two-ping response	L589+
02:46:42			Got 10kHz ping at 438461.5 ms	10 Khz 438461.5 kHz	L594
02:50:58		76	Got two ping response	Two-ping response	L599+
			No further response to pings	Noise	L604-end

Table 17.2 Table of communications with PIES. The left four columns have timestamps. The right two are matched lines from within the rawdata.txt file with the commands sent.

PIES deployment at EB1 (s/n 325)

Deployment:

Date: 16/3/2020 Site arrival time: 19:35

Start time: 19:48 End time: 19:50:17

Ship position at deployment time:

Latitude 23º 46.39'N Longitude 24º 0951' W

Deployment of the PIES s/n 325 at the RAPID EB1 site was quick and uneventful. Immediately after deployment, ranging was carried out. Returns were noisy, but confirmed a fallrate of 1 m/s. Since we were ranging during the sampling period (20:00-20:07), we then brought the transducer back onboard and waited until just before 21:00 GMT to listen to the next sampling period while drifting (Table, times 20:58-21:06). After listening, ranging was again carried out, confirming the fall rate and that the PIES was not yet on the bottom. We then repositioned to wait for the 22:00 sampling period, then ranged to verify that the PIES had landed. Telemetry was attempted before and after the 23:00 sampling period. Given that it had only been sampling for 7 days (most of which were on deck), telemetry would only take ~3 minutes to send. While the PIES accepted the telemetry command, good data could not be confirmed.

We had some trouble with communications on EBH4P, and so this time set up with the NOAA Benthos UTS-9400M deck unit with transducer close to the starboard side (just forward of the CTD hanger). All the wire was paid out on the transducer, and a rope was used from the transducer to an eye on the ship railing (to avoid cleating the wire). The ship's echo sounder and multi-beam were off. The CTD was not in the water this time, so we had flexibility regarding being on DP or drifting (see Figures 17.3 & 17.4). However, the surface currents were strong (~1 kt): when we were on DP, the wire on the transducer was streaming aft with an angle of 30-45 deg; when we were drifting it was streaming forward at about 30 deg. We tried both being on DP and drifting, and while it appeared that comms were might have been better while drifting, these also degraded with time (either due to distance or wire angle).

Suggestions regarding PIES comms: We had difficulty when ranging to the PIES both on DP and drifting, though this was likely compounded by the surface currents resulting in a steep wire angle. Adjusting the RX threshold helps with getting clearer responses, though I've tuned it against the clear command which seems to work more robustly, perhaps, than other commands/listening. Possibly to maximise good returns in the future we could try

- Ship following wire angle
- Slightly off PIES location telemetry
- Ship's drop keel?

In addition to using the transducer as near to the water as possible (to maximise the wire over the side). Also for the future, will need to test whether and how the Telemetry software would work with the NMF deck unit.

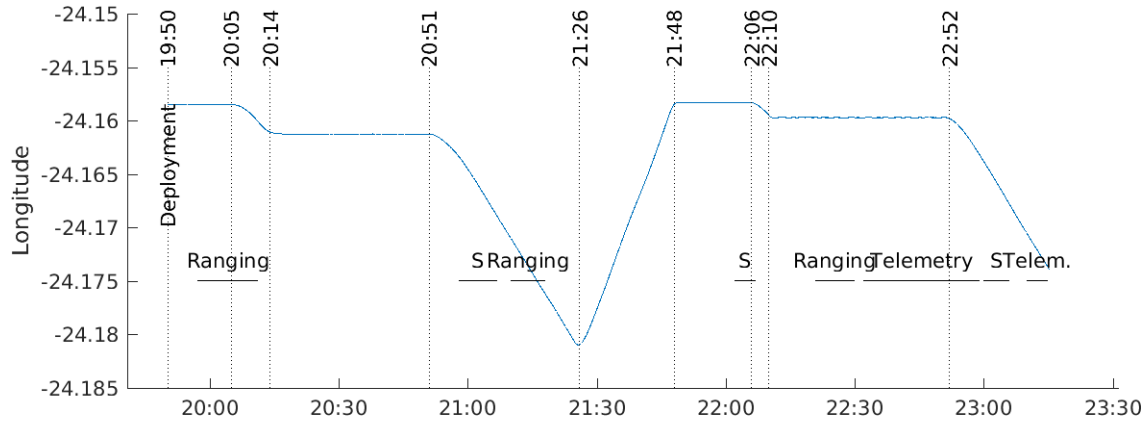


Figure 17.3 Ship's longitude during PIES deployment and communications at EB1 site. Timestamps of ship activity changing are given across the top. Communication activities are shown by black lines with labels of Ranging, S (Sampling) and Telemetry.

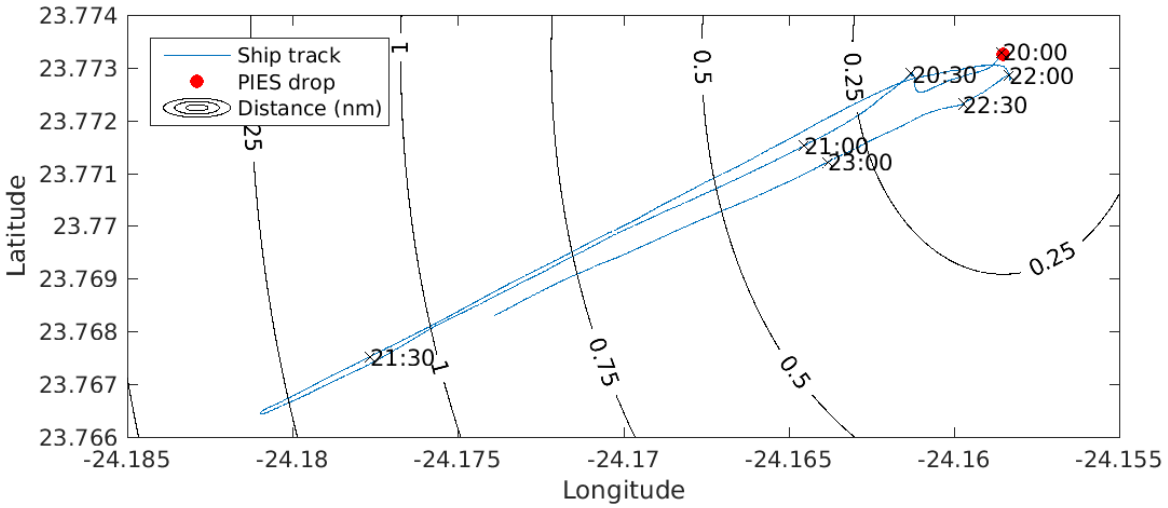


Figure 17.4 Ship's position during PIES comms.

Ranging:
For ranging, the deck box was used without a computer. Ranges were determined between 19:57-20:11, 21:09-21:18 and 22:21-22:30. (See Figure 17.5)

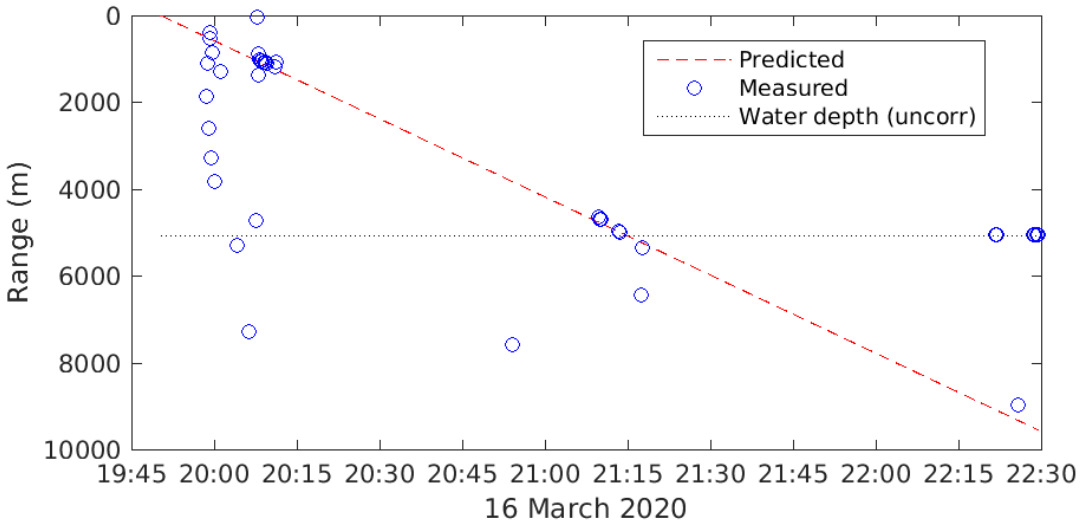


Figure 17.5 The 'Predicted' (red dashed) represents a fall rate of 1m/s, while the blue circles are the ranges received. The uncorrected water depth is given in black dots.

Telemetry & listening to sampling:
Drifting and station keeping were used during telemetry. The RRS James Cook has two props, two stern thrusters, a bow thruster and an azimuth. On station, using dynamic positioning, the thrusters are active and can create noisy conditions for acoustics. The surface currents were strong, however, and so while drifting, the vessel drifted about 1 nm in an hour (Figure 17.4).
Listening to sampling was semi-successful around 21:00, and successful around 22:00. Telemetry was attempted from 22:30 with drifting requested from the bridge at 22:50. Sampling was again seen at 23:00. Telemetry again attempted from 23:10, but given the very short records on the PIES, it's not clear whether we had a good enough connection to get the short transmissions. Operations were ceased at 23:15.

Table of communications with PIES (see next page). Activities are summaries in the left column. Timestamps are from the telemetry software or GMT times for ranging. Time is a rough time estimate. Commands sent are given by their numeric value. Notes are from the Telemetry notes or

added afterwards. Rawdata and pings are noted in the final two columns where activities using the Telemetry software (listening to sampling and telemetry) are recorded by the software.

Activity	Time stamp	Time	Cmd	Notes	Pings	Rawdata (lines)
Ranging	19:57:12		XPND (69)	Ranging commenced		
	20:11:10			Ranging concluded		
Ship		20:51		Ask ship to drift		
Listen to sampling (IESTelemetry)	20:58:25			Send configure deck unit	Configure deck unit	L1-125
					Noise	L126-200
	20:59:29			Changed RX sensitivity to 10		L202-338
	20:59:54			Got two 12khz pings	Two-ping response	
	21:00:53			Various pings to 13.5 khz 88103.6ms		L357
	21:03:24			Rx threshold to 50		L368-372
	21:04:31				12 khz	L373
	21:04:49				12 khz	L374
	21:05:57				12 khz	L375
	21:06:44			Set to 20 Rx		L377-381
	21:06:48			12 khz		L382
Ranging	21:09:47			Ranging commenced		
	21:17:40			Ranging concluded		
Ship		21:25		Ask ship to reposition to PIES		
		21:50		Ship repositioned and on DP		
	21:54:05			Repositioned ship after drifting. Set up wih Rx threshold of 50. Waiting t listen to sample		
	21:54:48			*Sitting on DP. Transducer is streming aft with wire angle about 30-4 deg.*		
Deck box	21:51		CLEAR (76)	Two ping response heard		

Activity	Time stamp	Time	Cmd	Notes	Pings	Rawdata (lines)
Listen to sampling	22:02:13			changed Rx threshold to 10		L to 516
	22:02:34			12 kHz		L517
	22:02:49			12 khz		L518
	22:02:57			12.5 kHz		L519
	22:03:17			changed to 25 rx threshod		L523-L527
	22:04:13			back to 10 rx threshold		L528-532
	22:05:18			12 kHz	63801.0 ms	L533
	22:05:24			12 khz	71290.8 ms	L534
	22:05:34			12 khz	81428.5 ms	L535
	22:05:40			12 khz	87293.7 ms	L536
	22:05:58			12 khz	105294.9 ms	L541
	22:06:15			12 khz 121294.5 ms	121294.5 ms	L546
	22:06:31			129296.3 ms ???		
	22:06:39			12 khz x 2 146707 and 146178		L551-552
Adjust Rx threshold	22:06:59			rx threshold to 20		L557-560
	22:08:55		CLEAR (76)	no response	Noise + Two ping response heard. to 13981.6ms	L575
	22:10:03			set threshold to 150		L586-587
	22:10:41		76	no response		
	22:11:16			rx threshold to 125		L603-604
	22:11:37		76	no response		
	22:12:15			rx threshold to 80		L615-616
	22:12:20		76	no response		
	22:12:56			rx threshold to 70		L627-628
	22:13:01		76	no response		

	22:13:37			rx threshold to 60		L639-640
	22:13:41		76	no response		
	22:14:11			rx threshold to 50		L651-652
	22:14:15		76	no response		
	22:15:12			rx to 30		L663-664
	22:15:17		76	no response		
	22:15:53			rx threshold to 10		L676-677
	22:15:57		76	Two ping response heard.		L680-681
	22:16:26			rx threshold to 15		
	22:16:29		76	Two ping response heard.	Second at 139838 ms	L696
	22:17:07			rx threshold to 17		
	22:17:11		76	Two ping response heard.	second at 14212.4ms	L711
	22:17:42			rx threshold to 20		
	22:17:46		76	Two ping response heard.	second at 14212.4ms	L725
	22:18:21			rx threshold to 30		
	22:18:24		76	no response		
	22:19:10			rx threshold to 25		
	22:19:14		76	Two ping response heard.	second at 14212.7ms	L752
Ranging	22:20:45		69	Ranging commenced		
	22:29:50		76	Ranging concluded		
	22:31:10			Finished ranging - 5043m range		L755-883

Activity	Time stamp	Time	Cmd	Notes	Pings	Rawdata (lines)
Telemetry	22:32:02		TELEM (65)	no response		
	22:32:34		65	1 ping response	1 ping at 12 khz	L896
	22:33:26		65	1 ping response	1 ping at 12 khz	L905
	22:34:02		65	no response		
	22:34:38		65	no response		
	22:35:03		65	1 ping response	1 ping at 12 khz	L922
	22:35:40			set rx threshold to 13		
	22:35:45		65	Waiting until 22:45:45 for data to come in		
	22:44:05				10.00 kHz 473927.1 ms	L940
	22:45:25				10 khz 554706.1 ms	L941
		22:46		When telemetry starts, expecting daily average - one day takes 30 seconds to transmit with a cpies and 24 seconds with a pies		
	22:47:39			LSB was pressure = 195, MSB pressure = -99.9999		
	22:49:38		76	Two ping response heard	Two-ping response	L948-949
		22:50		Sent screenshot to Pedro		
Ship	22:50:57			*Ship requested to drift, anticipated at about 1-2 kts*		
Telemetry	22:51:39		76	Two ping response heard		L961-962
	22:52:11		65	Two ping response heard	Two-ping response, followed by a lot of noise	L974-975
	22:55:40			rx threshold to 17		
	22:59:33			still a bit of noise (12.5, 10.5, 10.5, 11, 11.5, 12.5, 11 - after user:269)		L1007-1066

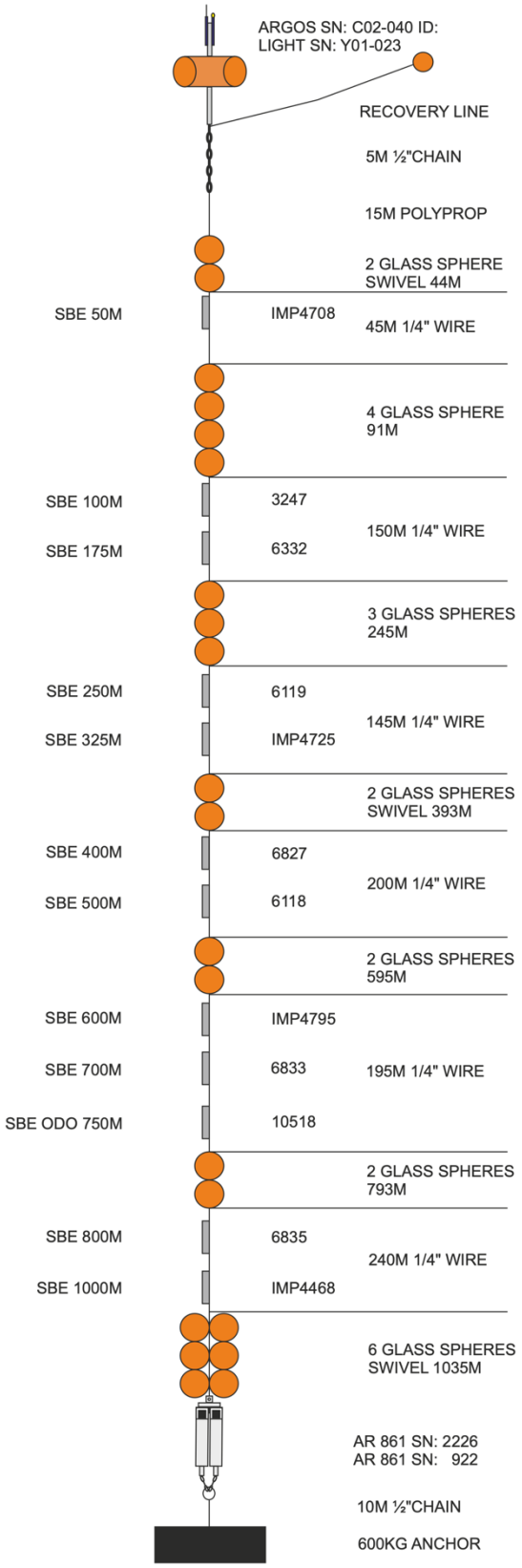
Activity	Time stamp	Time	Cmd	Notes	Pings	Rawdata (lines)
Listen to sampling	23:00:19			12 khz		L1068-1079
	23:00:34			12 khz		
	23:00:51			12 khz		
	23:01:08			12 khz		
	23:01:25			12 khz x 2		
	23:01:42			12 khz		
	23:01:59			12 khz		
	23:02:17			12 khz		
	23:02:21			looks like sampling		
		23:03		At 1200 gmt it stops whatever its doing and does its daily processing		
	23:03:53			trying to parse data.. pressure = -123850		
	23:05:47			trying to parse data.. pressure = -120500		
	23:06:12			set rx threshold to 20	11 khz 171139.4 ms	
Telemetry	23:10:03		65	Two ping response heard		L1088-1089
	23:10:41			11.5, 11.0 khz		L1093-1094
	23:11:26			lsb of pressure = 2000, tau = 0.0751		
	23:13:38		65	got 2 ping response		L1111-1112
		23:14		Telemetering 7 days will take a little over 3 minutes to send; the telemetry will end after 3.5 minutes		
Clear	23:15:15		76	Two ping response heard.		L1127-1128

Table 17.3 Communicating with the PIES lander at EB1

Appendix A: Diagrams of deployed moorings

EBH4
DEPLOYED
2020

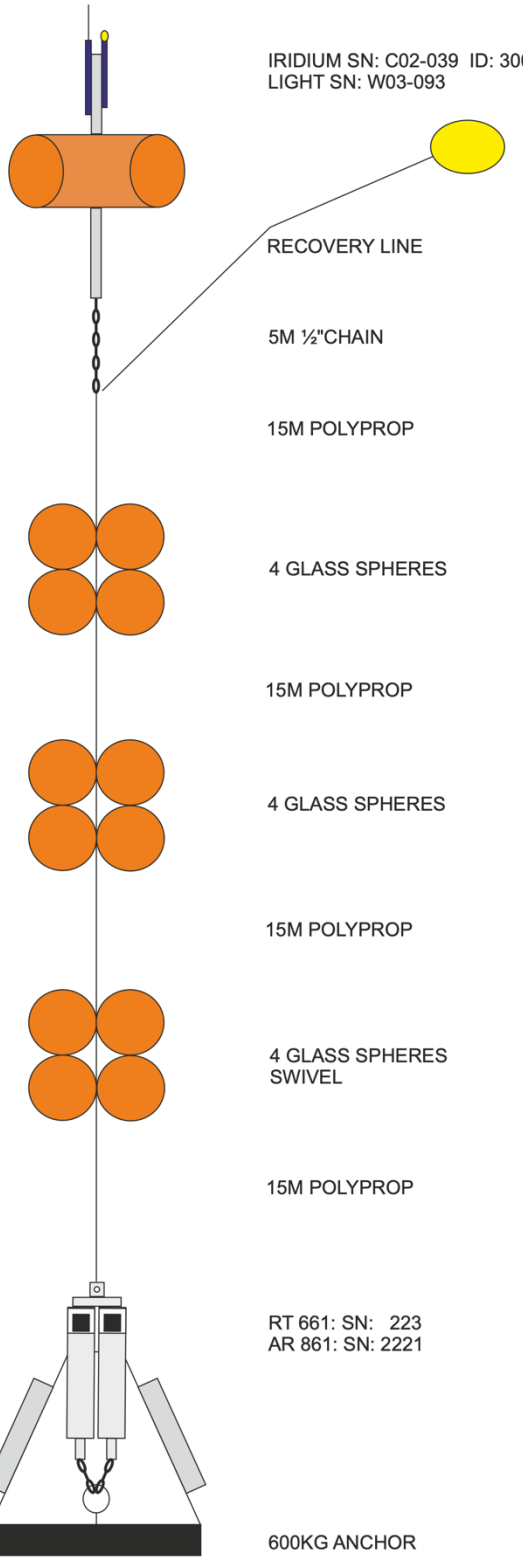
DATE: 11/03/2020
POSN: 27° 51.05'N
13° 32.42'W
DEPTH: 1060m



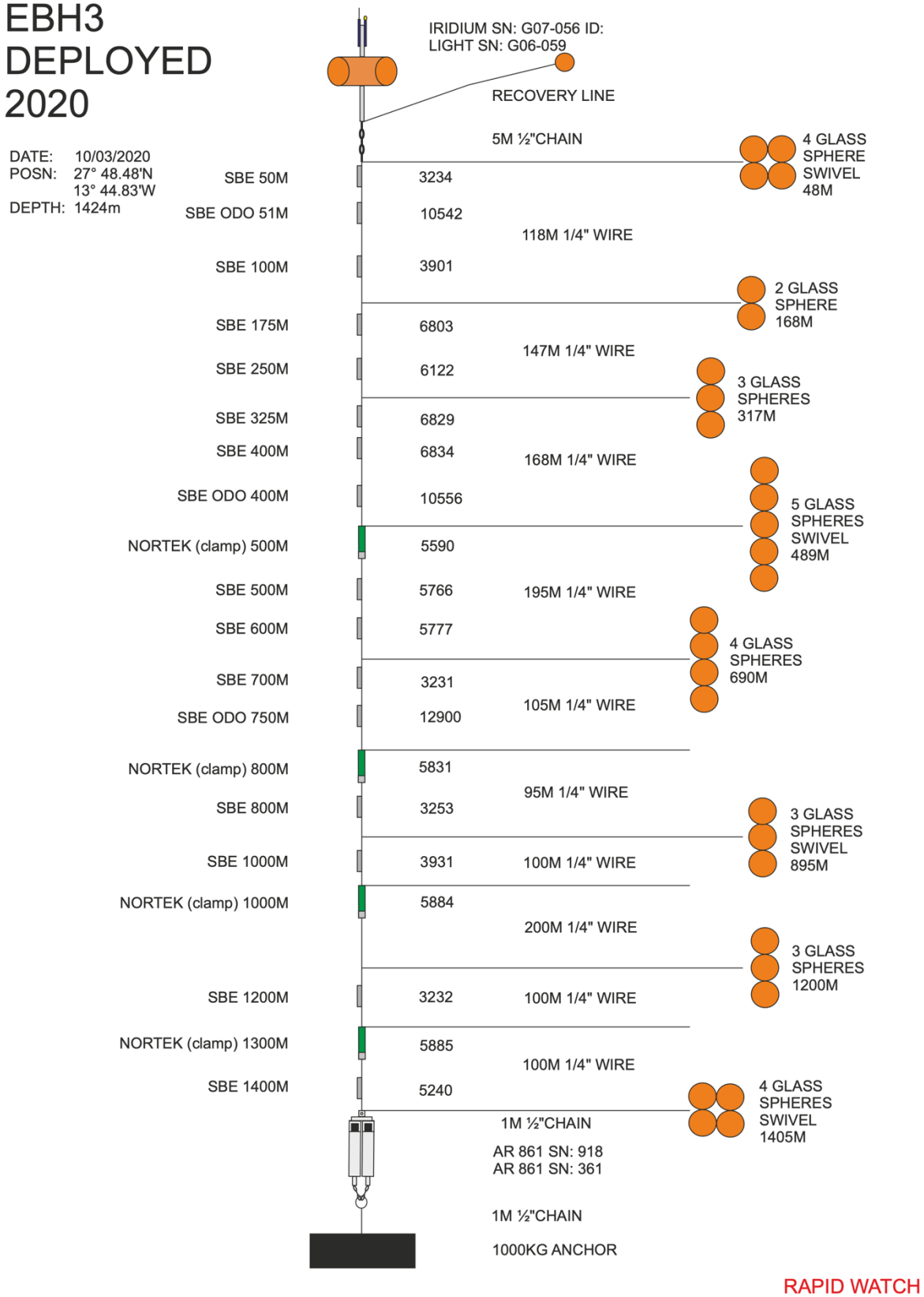
RAPID WATCH

EBH4L9 DEPLOYED 2020

DATE: 11/03/2020
POSN: 27° 52.18'N
13° 30.64'W
DEPTH: 997m

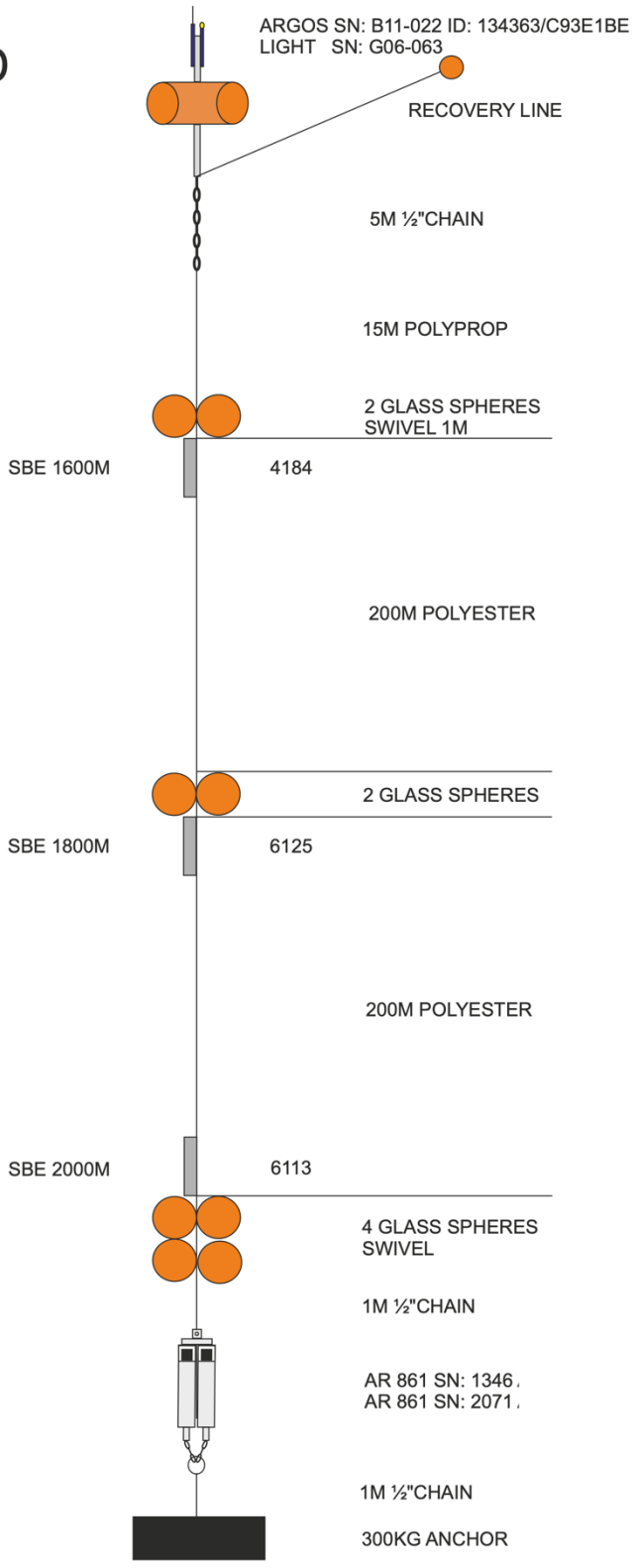


RAPID WATCH


EBH3
DEPLOYED
2020
DATE: 10/03/2020
POSN: 27° 48.48'N
13° 44.83'W
DEPTH: 1424m
IRIDIUM SN: G07-056 ID:
LIGHT SN: G06-059
RECOVERY LINE
5M ½"CHAIN
4 GLASS SPHERE SWIVEL 48M
SBE 50M
3234
SBE ODO 51M
10542
118M 1/4" WIRE
SBE 100M
3901
2 GLASS SPHERE 168M
SBE 175M
6803
147M 1/4" WIRE
SBE 250M
6122
3 GLASS SPHERES 317M
SBE 325M
6829
SBE 400M
6834
168M 1/4" WIRE
SBE ODO 400M
10556
5 GLASS SPHERES SWIVEL 489M
NORTEK (clamp) 500M
5590
SBE 500M
5766
195M 1/4" WIRE
SBE 600M
5777
4 GLASS SPHERES 690M
SBE 700M
3231
SBE ODO 750M
12900
105M 1/4" WIRE
NORTEK (clamp) 800M
5831
95M 1/4" WIRE
SBE 800M
3253
3 GLASS SPHERES SWIVEL 895M
SBE 1000M
3931
100M 1/4" WIRE
NORTEK (clamp) 1000M
5884
200M 1/4" WIRE
3 GLASS SPHERES 1200M
SBE 1200M
3232
100M 1/4" WIRE
NORTEK (clamp) 1300M
5885
100M 1/4" WIRE
SBE 1400M
5240
4 GLASS SPHERES SWIVEL 1405M
1M ½"CHAIN
AR 861 SN: 918
AR 861 SN: 361
1M ½"CHAIN
1000KG ANCHOR
RAPID WATCH

EBH2 DEPLOYED 2020

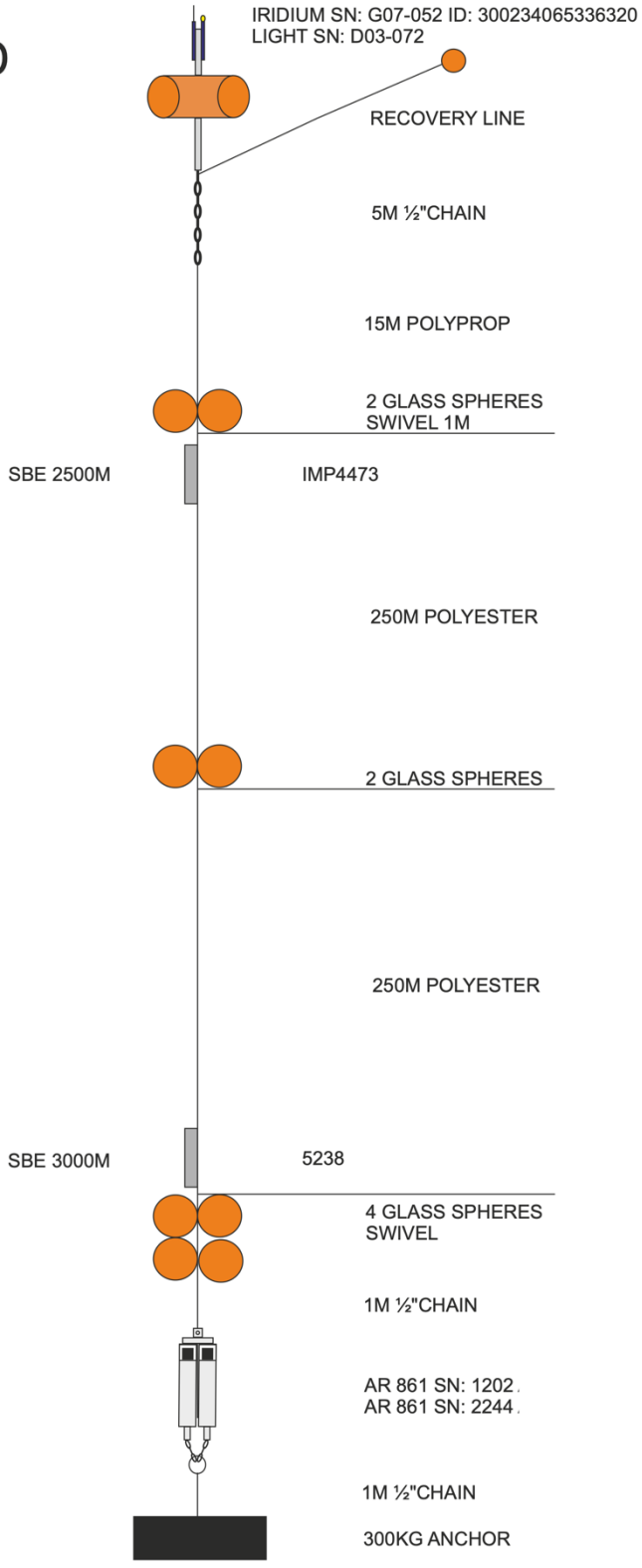
DATE: 12/03/2020
POSN: 27° 36.89'N
14° 12.76'W
DEPTH: 2018m



RAPID WATCH

EBH1 DEPLOYED 2020

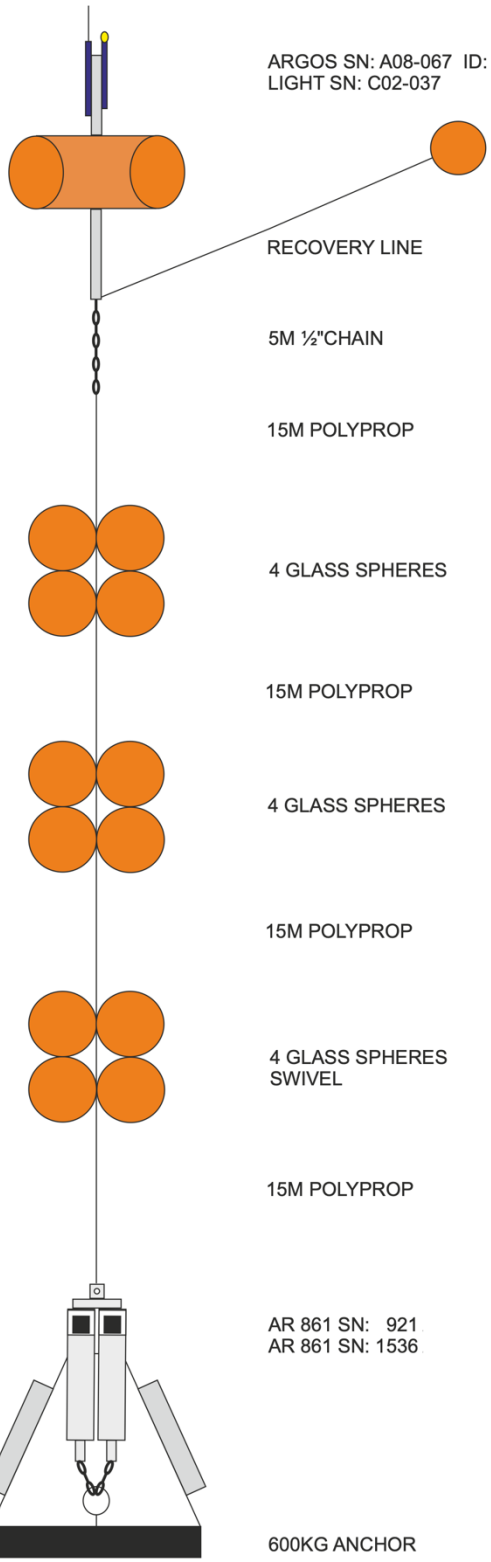
DATE: 13/03/2020
POSN: 27° 13.30'N
15° 25.29'W
DEPTH: 3041m



RAPID WATCH

EBH1L14 DEPLOYED 2020

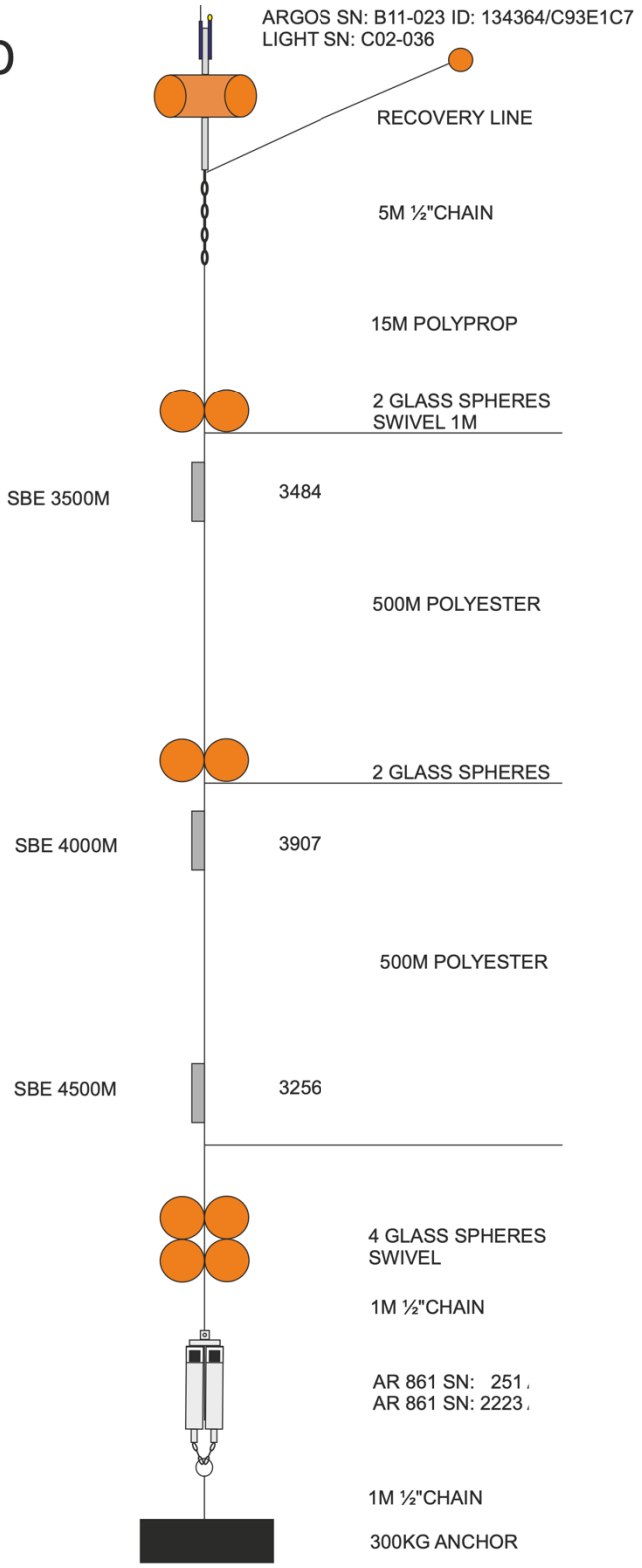
DATE: 13/03/2020
POSN: 27° 12.20'N
15° 25.21'W
DEPTH: 3039m



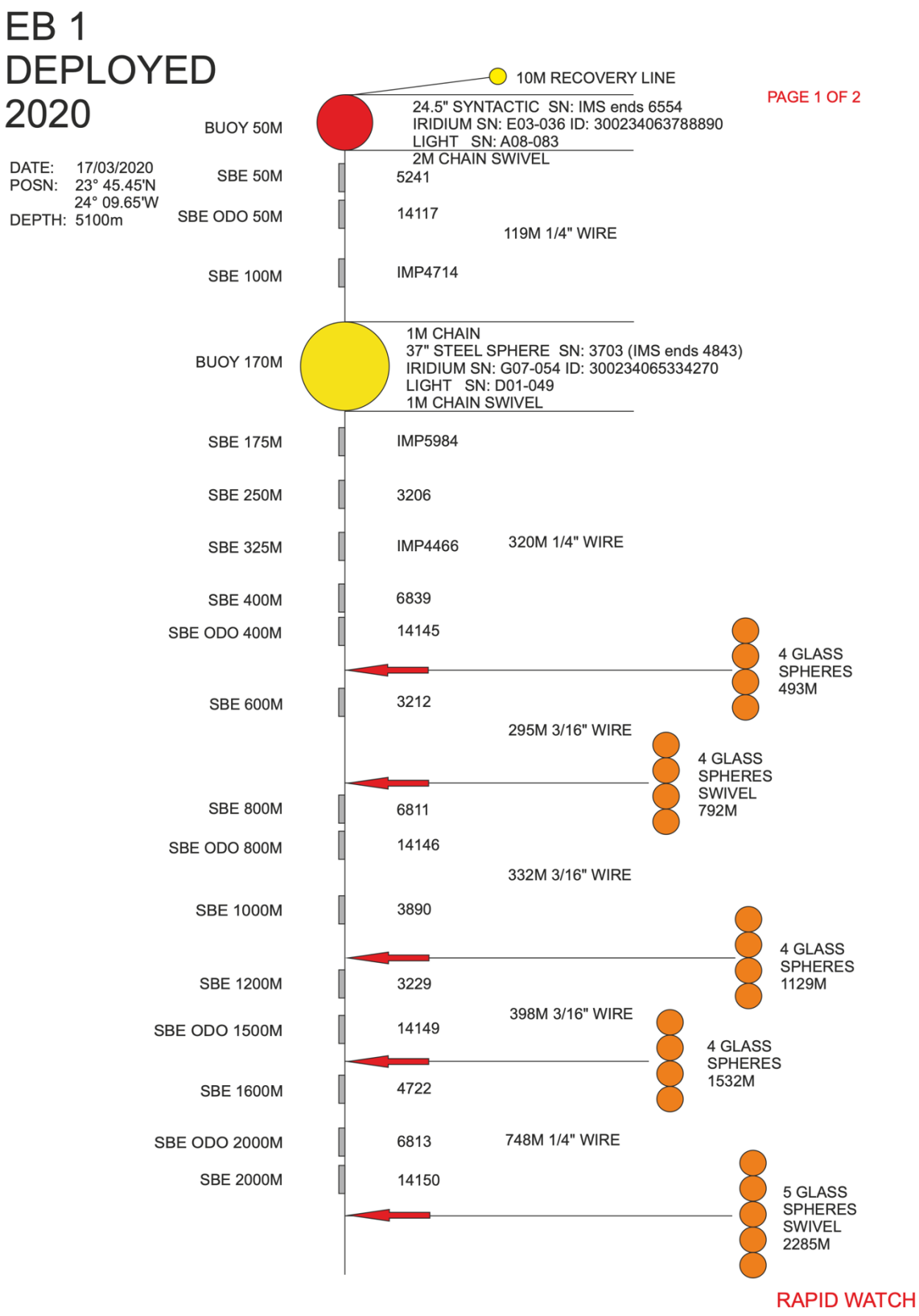
RAPID WATCH

EBHi DEPLOYED 2020

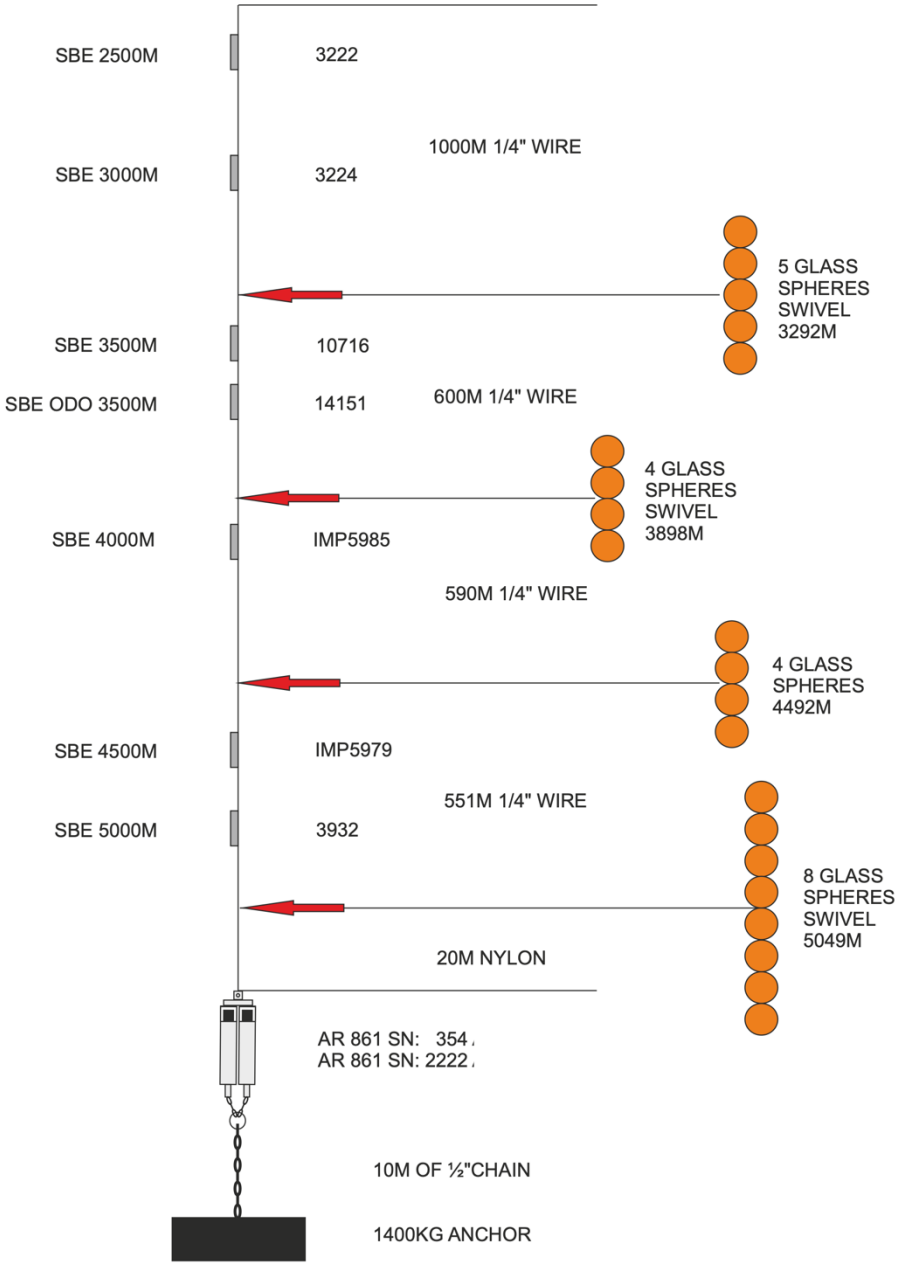
DATE: 15/03/2020
POSN: 24° 56.07'N
21° 15.93'W
DEPTH: 4351m



RAPID WATCH


EB 1
DEPLOYED
2020
DATE: 17/03/2020
POSN: 23° 45.45'N
24° 09.65'W
DEPTH: 5100m
10M RECOVERY LINE
PAGE 1 OF 2
BUOY 50M
24.5" SYNTACTIC SN: IMS ends 6554
IRIDIUM SN: E03-036 ID: 300234063788890
LIGHT SN: A08-083
2M CHAIN SWIVEL
SBE 50M
5241
SBE ODO 50M
14117
119M 1/4" WIRE
SBE 100M
IMP4714
BUOY 170M
1M CHAIN
37" STEEL SPHERE SN: 3703 (IMS ends 4843)
IRIDIUM SN: G07-054 ID: 300234065334270
LIGHT SN: D01-049
1M CHAIN SWIVEL
SBE 175M
IMP5984
SBE 250M
3206
SBE 325M
IMP4466
320M 1/4" WIRE
SBE 400M
6839
SBE ODO 400M
14145
4 GLASS SPHERES 493M
SBE 600M
3212
295M 3/16" WIRE
4 GLASS SPHERES SWIVEL 792M
SBE 800M
6811
SBE ODO 800M
14146
332M 3/16" WIRE
SBE 1000M
3890
4 GLASS SPHERES 1129M
SBE 1200M
3229
398M 3/16" WIRE
SBE ODO 1500M
14149
4 GLASS SPHERES 1532M
SBE 1600M
4722
SBE ODO 2000M
6813
748M 1/4" WIRE
SBE 2000M
14150
5 GLASS SPHERES SWIVEL 2285M
RAPID WATCH

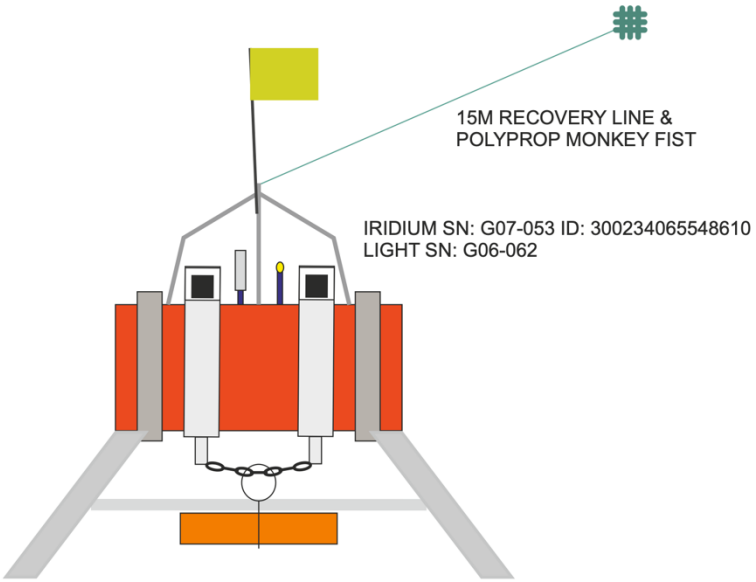
EB 1
DEPLOYED
2020



RAPID WATCH

EB1L14 DEPLOYED 2020

DATE: 17/03/2020
POSN: 23° 47.87'N
24° 08.64'W
DEPTH: 5075m



AR 861 SN: 2069
AR 861 SN: 917

2 OFF BPR
SN: 53-0029
SN: 26-0389

RAPID WATCH

Appendix B: Log sheets of recovered moorings

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH4** Cruise **JC192**

NB: all times recorded in GMT

Date 11/March/2020. **Site arrival time** _____

Time of first ranging 10:20

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled at 10:41	
Billings Float	n/a		1047
with Light	G06-062 ✓		1047
and Iridium Beacon	G07-052 ✓	BEACON ID: 300234065336320	1047
4 x 17" glass	n/a ✓		1052
MicroCAT	5242 ✓		1053
MicroCAT	5775 ✓		1056
3 x 17" glass	n/a ✓		1058
MicroCAT	6826 ✓		1100
MicroCAT	3905 ✓		1102
2 x 17" glass	n/a ✓		1104
MicroCAT	3270 ✓		1106
MicroCAT	7468 ✓		1110
2 x 17" glass	n/a ✓		1113
MicroCAT	3219 ✓		1114
MicroCAT	6836 ✓		1117
MicroCAT-ODO	12962 ✓		1118
2 x 17" glass	n/a ✓	tangled with balls below.	1120
MicroCAT	6800 ✓	tangled with balls below & above	1121
RCM11	301 ✓		1130
MicroCAT	3228 ✓		1128
6 x 17" glass	n/a ✓	tangled with buoyancy above	1120
Acoustic Release 1	0256		1121
Acoustic Release 2	0824		1121

Ascent Rate _____

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH4L7** Cruise **JC192**

NB: all times recorded in GMT

Date 11/March/2020. **Site arrival time** 11:50

Time of first ranging 11:55:00

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled ~~ast~~. 1242.	12:28
Billings Float	n/a	+ 4 glass (tangled)	12:39
with Light	D03-072 ✓		
and Argos Beacon	B11-022	Beacon ID: 134363 antenna OK	
4 x 17" glass	n/a ✓		12:36
4 x 17" glass	n/a ✓	rope very furry	~~12:34~~ ?
4 x 17" glass	n/a ✓		12:44
BPR	0447 ✓	crack in clamp	
BPR	0003 ✓	some corrosion @ clamp	
Acoustic Release #1	1347 ✓		12:47
Acoustic Release #2	1349 ✓		

Ascent Rate 60 m/min.

Ranging

Time	Range 1	Range 2	Command/comment
11:55:00	/	1102.	Range.
11:55:30	1102	1102.	Range
11:56:00	1102	1102	release 04.
11:57:00	1083	1076	
11:58:00	1022	1016	
11:59:00	905	960	

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH3** Cruise **JC192**

NB: all times recorded in GMT

Date Tues 10th March **Site arrival time** 13:05

Time of first ranging 13:09

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled at	1357
Billings Float	n/a		1407
with Light G06-053	G07-053 ✓		
and Iridium Beacon	G06-063 ✓	Beacon ID:300234065548610 wrong serial numbers	
4x17" glass G07-053	n/a		14:10
MicroCAT	3239 ✓	heavy growth	14:12
MicroCAT-ODO	20253 ✓	heavy growth.	14:17
MicroCAT	4723 ✓	growth	14 15
MicroCAT	4471 ✓	low growth	14 18
MicroCAT	5981 ✓	missing 3 screws. from ground.	1420
49" Telemetry buoy	J17050-001	tangled. sat wire and	1425
with Light	C02-036	re terminated.	
And Iridium beacon	G07-054	ID: 300234065334270	
MicroCAT	5982 ✓	tangled with sphere	1425
MicroCAT-ODO	20254 ✓	tangled with sphere	1425
MicroCAT	4464 ✓	tangled with sphere	1425
3 x 17" glass	n/a ✓		1438
Nortek (clamp on)	12701 ✓		1442
MicroCAT	4724 ✓		1444
MicroCAT	5983 ✓		1447
3 x 17" glass	n/a ✓	tangled with glass balls - removed tangle	1451
MicroCAT	4180 ✓	tangled with glass	1451
MicroCAT-ODO	20255 ✓	with untangled.	1458
Nortek (clamp on)	8465 ✓	small wrap in wire.	1500
MicroCAT	4072 ✓		1501
3 x 17" glass	n/a ✓	tangled with glass balls metal bar removed	1504
MicroCAT	4071 ✓	tangled.	1513
Nortek (clamp on)	11855 ✓	tangled	1512
MicroCAT	4470 ✓	tangled	1506
3 x 17" glass	n/a ✓	tangled - wire cut & reterminated	1504
MicroCAT	4068 ✓	tangled -	1517
Nortek (clamp on)	11846 ✓	tangled	1507
MicroCAT	3282 ✓	low growth - weed.	1520
4 x 17" glass	n/a ✓		1520
Acoustic Release 1	0916		1521
Acoustic Release 2	0365		1521

Ranging

Time	Range 1	Range 2	Command/comment
13:09	~~2355~~	2352.7	1Nm from ebh3.
13:27:28	1534.3	1534.2	range
13:28:00	15	1029.	release ok. release
13:29.29	1498	1487	
13:30:00	1393.	1387	
13:			

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH2** Cruise **JC192**

NB: all times recorded in GMT

Date 12/March/2020. **Site arrival time** overnight.

Time of first ranging 8:01:

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled at 08:46	
Billings Float	n/a	Tangled	08:53
with Light	C02-037 ✓		0857
and Argos Beacon	B03-080 ✓	Beacon ID: 129573	0857
2 x 17" glass	n/a		0853
MicroCAT	5784 ✓	Tangled.	0857
2 x 17" glass	n/a ✓	Tangled.	0905
MicroCAT	5767 ✓	Tangled.	0905
RCM11	302 ✓	Tangled.	~~0905~~ 0911
MicroCAT	6808 ✓	Tangled.	0905
4 x 17" glass	n/a ✓	Tangled.	0905
Acoustic Release #1	0370 ✓		0905
Acoustic Release #2	0821 ✓		0905.

Ascent Rate 78 m/min.

Ranging

Time	Range 1	Range 2	Command/comment
8:01:35	1306	1489	RANGE
8:02:00	"	2097	RANGE
8:03:20	✓	2097	Release ok.
8:05:20	2047	2038	" "
8:06:20	1967	1960	
8:07:20	1893	1886	
8:09:20	1754	1747	

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH1** Cruise **JC192**

NB: all times recorded in GMT

Date 13/March/2020 **Site arrival time** overnight

Time of first ranging 08:00.

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled	08:58
Billings Float	n/a	knotted.	0907
with Light	Z08-052 ✓	knotted.	0907
and Argos Beacon	E03-035 ✓	Beacon ID: 300234063352630	0907
2 x 17" glass	n/a ✓		0911
MicroCAT	6112 ✓		0911
2 x 17" glass	n/a ✓		0920
RCM11	426 ✓		0926
MicroCAT	3220 ✓		0930
4 x 17" glass	n/a ✓		0930
Acoustic Release #1	0907		0930
Acoustic Release #2	0253		0930

Ascent Rate 52 m/min

Ranging

Time	Range 1	Range 2	Command/comment
08:00:20	—	—	ARM ARM.
08:01:10	—	3079	ARM ARM.
08:01:46	3079	—	ARM ARM
08:02:33	—	3080	ARM DSAG
08:03:30	—	3080	ARM DIAG vertical
08:04:30	3080		ARM RELEASE
08:05:02	—	10539	" "
08:06:00	2962	—	" " release ok.
08:07:00	—	—	
08:08:10	—		ARM ARM.
08:08:40	2793	—	" "
08:09:40	—	—	" "
08:11:00	—	2004	" "
08:12:00	2552	2546	" "

Surface 08:45

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH1L12** Cruise **JC192**

NB: all times recorded in GMT

Date 13/March/2020 **Site arrival time** 09:50

Time of first ranging 09:52 grappled 10:49

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled	
Billings Float	n/a		1107
with Light	D01-049 ✓		
and Argos Beacon	B11-023 ✓	Beacon ID: 134364	
4 x 17" glass	n/a	All buoyancy together - [illegible]	1054
4 x 17" glass	n/a	2 lots of 3 spliced together	1102
4 x 17" glass	n/a	1 Splice and billings together.	1107
BPR	0004 ✓		1112
BPR	0448 ✓		1112
Acoustic Release #1	1203 ✓		1112
Acoustic Release #2	1350 ✓		1112

Ascent Rate 80 m/min.

Ranging

Time	Range 1	Range 2	Command/comment
09:52:16	—	3134	ARM ARM,
09:52:45	3131	3129	" "
09:54:58	3042	3042	" "
~~0615~~			
10:00:00	3043		ARM Release ok.
10:02:00	2977	2969	" "
10:04:00	2819	2817	
10:06:00	—	—	
10:07:00	2586	2578	

on Surface 10:39 Very windy (30kts)

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBHi** Cruise **JC192**

NB: all times recorded in GMT

Date 15/March/2020 **Site arrival time** overnight

Time of first ranging 08:32

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled at 10:35	
49" telemetry buoy	n/a		1043
with Light	A08-083		1043
and Iridium Beacon	E03-036	Beacon ID:300234063788890	1043
MicroCAT	5770		1047
2 x 17" glass	n/a		1047
MicroCAT	5243		1103
2 x 17" glass	n/a	Rope broke imploded glass	1103
RCM11	428		1115
MicroCAT	3225		1120
4 x 17" glass	n/a		1120
Acoustic Release #1	1354		1120
Acoustic Release #2	0318		1120

Ascent Rate 40 m/min Surface at 10:20.

Slow ascent

Ranging

Time	Range 1	Range 2	Command/comment
08:32:45	—	—	ARM ARM
08:33:25	—	—	" "
08:34:00	—		" "
08:35:00	—	4587	
08:36:35	4580	4587	
08:37:10	4586	4586	ARM DIAG vertical
08:38:30	4587	4587	ARM release OK
08:39:30	4531	45	
08:41:25		4403	ARM ARM
08:42:30	—		ARM ARM
08:43:25	—	—	
08:44:08	—	—	
08:44:50	—	4268	
08:45:50	4241	4236	
08:46:45	4198	4194	
08:47:48	4	4151	
08:48:48	L	4113	No response from Serial/N 1354
08:50:00		4067	
52:00			
09:35:35	—	—	
09:36:20	—	2307	
09:37:20	2276	2272	
09:39:20	2208	2205	

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EB1** Cruise JC192

NB: all times recorded in GMT

Date 16/March/2020 Site arrival time 11:07.

Time of first ranging 11:07 on Surface 11:26

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled at 1209	12 [illegible]16
Billings float	n/a		12 20
With light	A08-084 ✓		
And Iridium beacon	E03-034 ✓	ID 300234063269820	
9 x 17" glass	n/a		1221
RAS-500 frame	14520-01		1225
With Contros CO2	0918-001		
And SeaFET	0004		
And MicroCAT ODO	12906		
And MicroCAT	6810		
MicroCAT	6821 ✓	light fouling.	1229
37" steel sphere	n/a		1231
with light	B11-019		
and Argos Beacon	Y01-027	Beacon ID: 46500	
MicroCAT	5978 ✓	~~glass~~ lost, screw missing.	1233
MicroCAT	11744 ✓		1236
MicroCAT-ODO	12963 ✓		1236
MicroCAT	6824 ✓		1239
MicroCAT	6801 ✓		1241
MicroCAT - ODO	12964 ✓		1241
4 x 17" glass	n/a ✓		1242
MicroCAT	~~5789~~ 6335	ODO came up first	1249
MicroCAT-ODO	12965 ✓		1249
4 x 17" glass	n/a		1254
MicroCAT	5789 ✓		12:57
MicroCAT-ODO	12966 ✓		12:56
MicroCAT	6126 ✓		1303
MicroCAT-ODO	12967 ✓		1303
4 x 17" glass	n/a	not visible until pulled up	1307
MicroCAT	6814 ✓		1311
MicroCAT-ODO	12968 ✓		1320
RCM11	443 ✓		1320
4 x 17" glass	n/a		1323
MicroCAT	5782 ✓		1328
MicroCAT	6120 ✓		1339
MicroCAT-ODO	12998 ✓	Out before the wheat	1339

5 x 17" glass	n/a	2 imploded (couldn't see at surface)	1348
MicroCAT	6804		1356
MicroCAT	5239	change drum for new	1409
5 x 17" glass	n/a		1417
MicroCAT	6117		1437
MicroCAT-ODO	12833	ODO first.	1437
4 x 17" glass	n/a		1448
MicroCAT	6798		1453
4 x 17" glass	n/a		1506
MicroCAT	3913		1508
RCM11	444		1521
MicroCAT	3215		1523
8 x 17" glass	n/a	Last 4 imploded.	1525
Acoustic Release #1	0927		1529
Acoustic Release #2	0358		1529

Ascent Rate

Ranging

Time	Range 1	Range 2	Command/comment
11:07:10 ~~11:08:10~~	—	—	ARM ~~ARM~~ CMD
11:08:00	—	—	
11:09:20	—	—	
11:10:15	—	—	
11:12:44	—	—	
11:15:10	—	—	
11:16:20	—	—	
11:20:00	5118	—	
11:22:00	5125	5125	ARM ~~Release~~ DIAG. vertical.
11:23:00	5132	5132	ARM) Release. OK
11:24:00	5080	5071	
11:25:00	—	—	
11:26:00	—	—	

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EB1L12** Cruise **JC192**

NB: all times recorded in GMT

Date 16 March 2020 **Site arrival time** _____

Time of first ranging 16:09

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	grappled 18:47	
31" syntactic	n/a		18:55
With light	X01-048 ✓		
and Argos Beacon	Y01-011 ✓	Beacon ID: 46493	
4 x 17" glass	n/a		18:58
4 x 17" glass	n/a		19:01
4 x 17" glass	n/a	imploded (4)	19:04
Lander tripod			19:06
With BPR #1	0449 ✓		"
And BPR #2	0435 ✓		"
And Acoustic Release #1	919 ✓		19:06
And Acoustic Release #2	1731 ✓		19:06

Ascent Rate 42 m/min (slow ascent) surface 18:05

Ranging

Time	Range 1	Range 2	Command/comment
15:42:00	—	8536	ARM CMD en route to release position.
15:45:00	—	—	
15:48:30	—	—	
16:09:15	5146	5144	ARM CMD
16:11:24	—	—	
16:12:20	5138	5137	
16:13:00	—	—	
16:13:40	5139	5139	
→ 16:14:30	5141	—	ARM REL
16:15:10	—	—	
16:16:00	—	—	
16:16:55	5043	5035	
16:17:55	4997	—	
16:18:55	—	—	
16:19:55	—	—	
16:20:45	—	—	
16:21:60	—	—	
16:22:55	4787	—	
16:23:55	—	4733	
16:24:55	4694	—	
1630	4249	4240	

Appendix C: Logsheets of deployed moorings

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH4** Cruise **JC192**

NB: all times recorded in GMT

Date 11/MAR/2020 **Site arrival time** ~13:07

Setup distance 1.25 Nm.

Start time 13:46 **End time** 15:22:20

Start Position

Latitude 27° 50.30' N **Longitude** 013° 33.62' W

ITEM	SER NO	COMMENT	TIME
McLane-12"	n/a		13:46
Recovery line	n/a		13:46
Billings 3 sphere	n/a		13:47
with Light	Y01-023		13:47
~~Argos~~ or Iridium Beacon	C02-040	Beacon ID = 300234061660210	13:47
2 x 17" glass	n/a		13:48
MicroCAT	4708		13:49
4 x 17" glass	n/a		13:54
MicroCAT	3247		13:55
MicroCAT	6332		13:59
3 x 17" glass	n/a		14:03
MicroCAT	6119		14:04
MicroCAT	4725		14:07
2 x 17" glass	n/a		14:11
MicroCAT	6827		14:12
MicroCAT	6118		14:16
2 x 17" glass	n/a		14:21
MicroCAT	4795		14:23
MicroCAT	6833		14:27
MicroCAT-ODO	10518		14:29
2 x 17" glass	N/A		14:32
MicroCAT	6835		14:33
MicroCAT	4468		14:39
6 x 17" glass	n/a		14:47
Acoustic Release #1	2226	Record codes below	14:47
Acoustic Release #2	922	Record codes below	14:47
600kg Anchor	n/a		15:22:20

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

27°.85102°N

-013.53920°W

1056.72998 m (water depth) Uncorrected.

Latitude 27.85102 N Longitude 13.5392 W
Uncorrected water depth 1056 (at anchor launch)
Corrected water depth 1059 (at anchor launch)

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
Range on way down	ARM	15:26:00	27.85107	-13-53911	617	634
		15:27:00	27.85107	-13.53911	753	766
		15:28:00	27.85107	-13.53911	877	888
		15:31:00	27.85107	-13.53911	1047	1047
		15:31:40	27.85107	-13.53911	1047	1047
		15:32:15			1047	1047
		~~18 19 15~~				
		18 22 00				
		18 28 40				
		18 30 10			1859	—
		45			—	1277
		31 25				
		18 33 40			1495	1271
	→	18 34 10			2145	2146
		18 34 40			1669	2147
		18 35 10			2148	2149
	→	19 08 00			2077	2076

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH4L9** Cruise **JC192**

NB: all times recorded in GMT

Date 11/March/2020 **Site arrival time** 16:00

Setup distance ~~/~~

Start time 16:25 **End time** 1630 40

Start Position

Latitude 27.86909 **Longitude** -13.51084

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		1625
McLane-12"	n/a		1625
Billings 4 sphere	n/a		1626
with Light	WO3-093		1626
~~Argos~~ or Iridium Beacon	C02-039	Beacon ID = 300234061660230	1626
4 x 17" glass	n/a		1627
4 x 17" glass	n/a		1628
4 x 17" glass	n/a		1628
SBE26/53	0397		
SBE26/53	0396		
Acoustic Release #1 (tripod)	223	Record codes below RT661	
Acoustic Release #2 (tripod)	2221	Record codes below	
600kg Anchor	n/a		1630 40

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 27.8696 **Longitude** 13.51061

Uncorrected water depth 992.37 (at anchor launch) m

Corrected water depth 996 (at anchor launch)

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **PIES at EBH4** 327 s/n Cruise **JC192**

NB: all times recorded in GMT

Date 11/3/2020 Site arrival time 17:05

Start time 17:20 End time 17.22.25

Start Position

Latitude 27°52-0'N Longitude 13°32.05 E

Notes:

	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
	327	1725			.9856	
	71	27			.5490	
		7255			1.02	
	~	17 39 40			649	
		174016			640	
		174235			1067	
		17:56			1068	
					2846	
					1068	
					2840	
					1067	
					?	
		1758		10 sec repeats	1067	
					1067	
					2840	
					4456	
					2386	
					1068	
					1480	
					3061	
					1229	
					2232	
					3074	
					1169	
					3015	
		1			1244	
		1800 20			1067	
					1067	
		180056 send		76	6910/8911	

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH3** Cruise **JC192**

NB: all times recorded in GMT

Date Tues 10 March 2020. **Site arrival time** _____

Setup distance 1.25 Nm.

Start time 17:05 **End time** 19:10

Start Position

Latitude 27°43.39N **Longitude** -13°45.53W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		17:05
McLane-12"	n/a		17:05
Billings 3 sphere	n/a		17:06
with Light	606-059		17:06
Argos or Iridium Beacon	607-056	Beacon ID =	17:06
4 x 17" glass	n/a		17:06
MicroCAT	3234		17:06
MicroCAT-ODO	10542		17:06
MicroCAT	3901		17:11
2 x 17" glass	- N/A. -		17:16.
MicroCAT	6803		17:18
MicroCAT	6122		17:23.
3 x 17" glass	- N/A -		17:28
MicroCAT	6829		17:30
MicroCAT	6934		17:35
MicroCAT-ODO	10556		17:35
5 x 17" glass	n/a		17:41
Nortek	5590		17:44
MicroCAT	5766		17:45
MicroCAT	5777		17:49
4 x 17" glass	n/a		17:54
MicroCAT	3231		17:55
MicroCAT-ODO	12900		17:58
Nortek	5831		18:02
MicroCAT	3253		18:03
3 x 17" glass	n/a		18:09
MicroCAT	3931		18:13
Nortek	5884		18:15
3 x 17" glass	n/a		18:24
MicroCAT	3232		18:24
Nortek	5885		18:30
MicroCAT	5240		
4 x 17" glass	n/a		18:59
Acoustic Release #1	361	Record codes below	
Acoustic Release #2	918	Record codes below	19:04

1000kg Anchor	n/a		

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 ~~27.81046~~ N
27.80981 N
Longitude ~~-13.74539~~
-13.74581

Uncorrected water depth 1417 (at anchor launch)
Corrected water depth 1419 (at anchor launch)

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)	
		19:54:18			1167.6	3750	echo on.
		19:54:45			1677	—	
		19:55:12			1686	1688	
		19:55:30			1693	1694	
		~~20 15 15~~					
		20 16			1469.9	1660.7	
		20 16 30			1667	1669	
		20 33 15			1713	1716	
		20 33 45			1731	1734	
		21 05 00					
		21 06 00			1432	1435	
		21 07 00			1417	1415	

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH2** Cruise **JC192**

NB: all times recorded in GMT

Date 12/March/2020 **Site arrival time** _____

Setup distance 0.25 Nm

Start time 0950 LA **End time** 10:23:16

Start Position

Latitude 27.6125 **Longitude** -14.2162

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		0950
McLane 12"	n/a		0950
Billings 3-sphere	n/a		0951
with Light	906-063		
Argos or ~~Iridium Beacon~~	BIL022	Beacon ID = 134363/C93E1BE	
2 x 17" glass	n/a		0952
MicroCAT	4184		0952
2 x 17" glass	n/a		0958
MicroCAT	6125		0958
MicroCAT	6113		1003
4 x 17" glass	n/a		1003
Swivel	n/a		
Acoustic Release #1	2071	Record codes below	1017
Acoustic Release #2	1346	Record codes below	
300kg Anchor	n/a		~~1017~~

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 27.6152 **Longitude** -14.2104

Uncorrected water depth 2016.8 (at anchor launch)
Corrected water depth 2016.8 (at anchor launch)

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
range after deployment to clock on Seabed		10:27:30				539
		10:28:00			579	588
		10:29:00			671	680
		10:32:00			948	958
		10:39:00			1721	~~1739~~ 1734
moved off.		10:41:00			2093	2115
		10:			2306	2328
		10 50 30			2603	2603
		55			2603	2603
		10 52 00			2603	2603
		11 10 00			2002	2603
		30			2608	2009
		11 25 20 (20)			2483	2488
		11 26 10			2485	2488

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH1** Cruise **JC192**

NB: all times recorded in GMT

Date 13/March/2020 **Site arrival time** 12:25

Setup distance 0.25

Start time 12:29:36 **End time** 12:55:21

Start Position

Latitude 27.2195 **Longitude** -15.4261

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		
Billings 3-sphere	n/a		12:29
with Light	D03-072		
Argos or Iridium Beacon	G07052	Beacon ID = 300234006536320	
2 x 17" glass	n/a		12 30
MicroCAT	4473		1230
2 x 17" glass			12 39
MicroCAT	5238		1249
4 x 17" glass	n/a		1249
Acoustic Release #1	2244	Record codes below	1250
Acoustic Release #2	1202	Record codes below	1250
300kg Anchor	n/a		1255

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 27.2228 **Longitude** -15.4221

Uncorrected water depth 3037.4 (at anchor launch)
Corrected water depth 3040.7 (at anchor launch)

Ranges

Time	Range 1	Range 2
14:34:15	4680	4681
15:05:30	3700	3703
15:27:50	3767	3773

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
		13:00:00			574	584
		14 34 15			4680	4681
		15 05 30			3700	3703
		15 27 50			3767	3773

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH1L14** Cruise **JC192**

NB: all times recorded in GMT

Date 13/March/2020 **Site arrival time** _____

Setup distance _____

Start time 13:49 **End time** 13:56:20

Start Position

Latitude 27.20320N **Longitude** -15.42170W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		13:49
McLane-12"	n/a		13:49
Billings sphere	n/a		13:50
with Light	C02-037		13:50
Argos or Iridium Beacon	A08-067	Beacon ID = 121988	13:50
4 x 17" glass	n/a		13:51
4 x 17" glass	n/a		13:51
4 x 17" glass	n/a		13:52
SBE26/53	~~n/a~~ 399		13:56
SBE26/53	398		13:56
Acoustic Release #1 (tripod)	1536	Record codes below Hitbark of shipduring release.	13:56
Acoustic Release #2 (tripod)	921	Record codes below	13:56
600kg Anchor	n/a		13:56.

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 27.20374N **Longitude** 15.4245-W

Uncorrected water depth _____ (at anchor launch)
Corrected water depth _____ (at anchor launch)

Ranges

Time	Range 1	Range 2
14:32:30	3532	3531
~~15:05:30~~	~~3700~~	~~3703~~
15:03:30	4872	4879
15:30:00	3795	3796

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBHi** Cruise **JC192**

NB: all times recorded in GMT

Date 15/March/2020 **Site arrival time** 1221

Setup distance 1.0 Nm

Start time 12 22 49 **End time** 13 29 56

Start Position

Latitude 24.9207 **Longitude** -21.2785

UTC

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		1222
Billings float	n/a		1222
with Light	C02-036		1222
Argos or Iridium Beacon	B11-023	Beacon ID = 134364 / 8C93E187	1222
2 x 17" glass	n/a		1223
SBE37 MicroCAT	3484 ✓		1223
2 x 17" glass	n/a		12:35
SBE37 MicroCAT	3907 ✓		12:35
SBE37 MicroCAT	3256 ✓	fraying on outer jacket	12:45 towing
4 x 17" glass	n/a		
Acoustic Release #1	251	Record codes below	1329
Acoustic Release #2	2223	Record codes below	1329
300kg Anchor	n/a		1329

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code

Anchor Drop Position
Latitude 24.9347 **Longitude** -21.2652

Uncorrected water depth 4294.0 (at anchor launch)
Corrected water depth 4316.8 (at anchor launch)

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EB1P_325** Cruise **JC192**

NB: all times recorded in GMT

Date 16/3/20 Site arrival time ~~19:35~~ 19:48

Setup distance ∅

Start time ~~19:48~~ End time 19:50:17

Start Position

Latitude 23°46.39'N Longitude 24° 09.51' ~~S~~ W

Uncorrected water depth 5077.3 (at anchor launch)

Corrected water depth _____ (at anchor launch)

Deck unit	Command	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)	
NOAA	76 CLEAR	195620			~~4299~~		
	~~69 XPND~~				5732	7734	✓
	69	195712					
	69	195821			6105	8107	mis
		195840	10sec		1877		
					1112	5137	
					2599	5550	
					526	3958	
					407	3562	
					3275		
					860		
					~		
					3818		
		200027					
		6108			12845		
					4862		
	76	200259			5443.		
		20:03:11					
		0339					
10 Rx scws		04:12			5305	X	
	76	0552					
	1	06:17			7288.5		
		07:08			6776	8778	✓
	69	07:35	10sec		~~4936~~		
					43		
					896	3698	
					1388	6086	
					1030		

2231
try telem

Deck unit	Command	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
NOAA	~~76 CLEAR~~				1039	
	69 XPND				1049	
					1058	
					~	
					1078.9	
		20:09:33			1088	
			+66 min		1099	
		20:11:00			1173	
					1184	
	76	20:15:16			7158	9160
		→ should land 21:15				
~						
	76	205247			~~10224~~	12226
	69	205334				
	69	5401			7575	
	76	5520			10165	12166
		~				
	69	210830				
		0940				
	69	210937			11662ms	
					4659	
					4698	
					4712	
		21:13:24 ~		some no resp.	4962	
					4988	
		21:17:30		not right x	6447	
	2nm —			slant? ?	5366	
	76	2144				
					12494	14495
	76	215140			12217	14217
		2155	waiting for sample			
	69	22:2045				
		2145		very few	5043m	
		2530		responses.	5041m	
	76	2553				
rx 10		2636 →			8987	
	69				5043	
		2835		T 20 sec.	5042	
(rx 15)	76	2950			5043	
		13982 ms			5043	
		13983 ms				

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EB1** Cruise **JC192**

NB: all times recorded in GMT

Date 17th March 2020 **Site arrival time** Overnight

Setup distance 3.5 Nm (strong currents)

Start time 11:27 **End time** 16:09:19.

Start Position

Latitude 23.7359 N **Longitude** 24.2175 W

ITEM	SER NO	COMMENT	TIME
Mini-Trimsyn	n/a		~
24.5" syntactic float	n/a		11:36
with Light	A08-083		
~~Argos~~ or Iridium Beacon	E03-036	Beacon ID = 300234063788890	↓
MicroCAT	5241		11:36
MicroCAT-ODO	14117		11:36
MicroCAT	4714		11:40
37" McLa. SS			11:45
with Light	D01-049		
~~Argos or~~ Iridium Beacon	607-054	Beacon ID = 300234065334270	↓
MicroCAT	5984		11:48
MicroCAT	3206		11:51
MicroCAT	IMP 4466		11:55
MicroCAT	6839		11:59
MicroCATODO	14145		11:59
4 x 17" glass	n/a		12:03
MicroCAT	3212		12:07
4 x 17" glass	n/a		12:15
MicroCAT	6811		12:17
MicroCAT-ODO	14146		12:17
MicroCAT	3890		12:23
4 x 17" glass	n/a		12:28
MicroCAT	3229		12:31
MicroCAT-ODO	14149		12:41
4 x 17" glass	n/a		12:43
MicroCAT	4722		12:46
MicroCAT	6813	[illegible] - in before ODO, contrary to diagram	12:58
MicroCAT-ODO	14150		12:58
5 x 17" glass	n/a		13:07
MicroCAT	3222		13:14
MicroCAT	3224		13:27
5 x 17" glass	n/a		13:37
MicroCAT	10716		13:44
MicroCAT-ODO	14151		13:44
4 x 17" glass	n/a		13:57

MicroCAT	5985		1700
4 x 17" glass	n/a	Next on wire above glass. Required w. rope.	1417
MicroCAT	5979		1418
MicroCAT	3932		1433
8 x 17" glass	n/a	Towing.	1742
Acoustic Release #1	354	Record codes below	
Acoustic Release #2	2222	Record codes below	1501
1400kg Anchor	n/a	discussion about water depth.	1608 1609

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 23.7574N **Longitude** 24.1560W

Uncorrected water depth 5098.8 (at anchor launch)
Corrected water depth 5051.2 (at anchor launch)

38.

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EB1L14** Cruise **JC192**

NB: all times recorded in GMT

Date 17/March/2020 **Site arrival time** 16:54

Setup distance 0

Start time 16:57:00 **End time** 16:57:57

Start Position

Latitude 23.7995N **Longitude** 24.1420W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		16:57:57
DeepWater Buoyancy Lander			
With Light	606-062		
Argos or Iridium Beacon	607-053	Beacon ID =	
SBE26/53	0389		
SBE26/53	0029		
Acoustic Release #1	2069	Record codes below	
Acoustic Release #2	917	Record codes below	16:57:57.

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 23.7995N **Longitude** 24.1420W

Uncorrected water depth 5038 (at anchor launch)

Corrected water depth 5081 (at anchor launch)