National Oceanography Centre

RESEARCH EXPEDITION REPORT

RAPID Report for *RRS Discovery* Research Expedition DY174

28th March 2024 to 3rd April 2024

B.I. Moat, Y.L. Firing and A.J. Smith

2024

Report no. 82

Document Data Sheet

Author	Publication Date
Moat, B. I., Firing, Y. L., Smith A. J.	*9th October 2024*

Title

RAPID report for *RRS Discovery* Research Expedition DY174, 28th March 2024 to 3rd April 2024

Reference

Southampton, UK: National Oceanography Centre, Southampton, 90pp.
(National Oceanography Centre Research Expedition Report, No. 82)

Abstract

The purpose of *RRS Discovery* research expedition DY174 was to refurbish the Eastern Boundary of the RAPID 26°N array of moorings that span the Atlantic from the Bahamas to the Canary Islands. The expedition started in Santa Cruz de Tenerife on Thursday 28th March 2024 and ended on Wednesday 3rd April 2024 at Santa Cruz de Tenerife.

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 DY174 moorings were serviced at sites: EBH3, EBH3L, EBH2, EBH1, EBH1L. A new mooring was deployed at EBH3B as a backup for EBH3. Sites with suffix 'L' denote landers fitted with bottom pressure recorders.

Moorings were equipped with instruments to measure temperature, conductivity and pressure, and a number of moorings were also equipped with current meters and/or oxygen sensors. 'Lab on a chip' sensors deployed 2 years ago as part of the EPOC project were recovered.

CTD stations were conducted throughout the cruise for purposes of providing pre- and post- deployment calibrations for mooring instrumentation.

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

Issuing Organisation

National Oceanography Centre
European Way
Southampton
SO14 3ZH, UK

Email: publications@noc.ac.uk

A pdf of this report is available for download at: http://nora.nerc.ac.uk/id/eprint/538190/

(This page intentionally left blank)

Table of Contents

List of Figures

List of Tables

1. Scientific and Ship Personnel

Name	Position	Affiliation
Stewart Mackay	Master	
Andy Mahon	Chief Officer	
Graham Stringfellow	2nd Officer	
Jonathan Brown	3rd Officer	
Garry McCoy	Chief Engineer	
Derek Hay	2nd Engineer	
Jonathan Gheisari-Miandoab	3rd Engineer	
Ben Fowler	3rd Engineer	
Harles Fisher	ETO	
Paul Quenault	ERPO	
Graham Bullimore	Purser	
Steve Smith	CPOS	
Stuart Cook	CPOD	
Kevin Riley	POD	
Terry Burke	POS	
Martin Wright	SG1A	
Colin Evans	SG1A	
Luke Stalker	SG1A	
Peter Lynch	Head chef	
Neil Burgess	Chef	
Clementina Carrilho Mantinha	Steward	
Kevin Mason	A/Steward	
Benjamin Farrow	Cadet	
Leanna Phillips	Cadet	
Ben Moat	Chief Scientist	NOC
Tillys Petit	co- Chief Scientist	NOC
Yvonne Firing	Scientist	NOC
Jules Kajtar	Scientist	NOC
Sara Fowell	Scientist	NOC
Guillaume Hugg	PhD student	Uni. of Maynooth
Genia Fernanda	MSc student	Univ. of Southampton
Sunke Trace-Kleeberg	PhD student	Univ. of Southampton
Brian King	Scientist	NOC
Dan Bourne	Videographer	NOC
Lauren Noakes	Communications Manager	NOC
Rob Mclachlan	Senior Technical Officer	NOC/NMFSS
Josh Pedder	ITO	NOC/NMFSS
Chris Crowe	Technician (Moorings)	NOC/NMFSS
Dave Childs	Technician (Moorings)	NOC/NMFSS
Simon Jones	Technician (Engineering)	NOC/NMFSS
Richard Phipps	Technician (Engineering)	NOC/NMFSS
Tim Powell	Technician (Moorings)	NOC/NMFSS
Thomas Ballinger	Technician (Moorings)	NOC/NMFSS
Tina Thomas	Technician (Moorings)	NOC/NMFSS
Finn Sougioultzoglou	Trainee	NOC/NMFSS

2. Itinerary

The RAPID 26N expedition aboard the RRS Discovery DY174 departed Santa Cruz de Tenerife on Thursday 28th March 2024 and concluded on 3rd April 2024 in Santa Cruz de Tenerife. The eastern boundary array was completed on Wednesday 2nd April. A full itinerary is given in Table 2.1.

Table 2.1 Cruise Itinerary (time in GMT).

Date	Operation	Start time	End time	Durat. (hrs)	Latitude (°N)	Long. (°W)	Notes
Thu 28 Mar	Depart Santa Cruz	09:00					
	Test CTD1	13:20	14:55		28°44.17	15°47.53	1500m. 8 releases
	CTD2	15:47	19:23		28°44.23	15°47.47	Calibration cast. 8 releases, 15 MicroCATs
	CTD3	20:33	00:22		28°44.30	15°47.43	Calibration cast. 8 releases, 19 MicroCATs
	Transit to EBH2						
Fri 29 Mar	CTD4	11:13	13:04		27°36.49	14°13.08	Pre Oxygen profile. 2000m
	Recover EBH2	14.49	15:30		27°36.91	14°12.70	
	Transit to EBH3						
	CTD5	19:19	20:41		27°48.10	13°45.39	Pre Oxygen profile. 1400m 2 ODO MicroCats
	CTD6	21:44	23:43		27°48.10	13°45.39	Pre Oxygen profile. 1400m
	Transit to EBH2						
Sat 30 Mar	Recover EBH3	09:49	12:49		27°48.45	13°44.86	
	Deploy EBH3	14:47	16:49		27°48.49	13°44.86	
	Deploy EBH3L1	17:25	17:34		27°47.93	13°45.05	
	CTD7	18:21	20:04		27°47.87	13°45.30	Post Oxygen profile. 1400m
	Transit EBH3B						
	Swath survey	21:26	21:54		27°45.00	13°50.00	At EBH3B site

Sun 31 Mar	Deploy EBH3B	08:12	02:25		27°44.99	13°50.01	
	Transit EBH2						
	Deploy EBH2	13:26	13:49		27° 36.94	13° 12.69	
	CTD8	14:15	16:06		27° 36.88	13° 13.38	Post Oxygen profile. 2000m 3 ODO MicroCATS
	Trilaterate						Clocks+1
Mon 1 Apr	CTD9	23:43	02:46		27° 13.68	15° 24.77	Pre Oxygen profile. 3000m
	Recover EBH1L14	07:45	07:58		27°12.20	15°25.21	
	Recover EBH1	10:54	12:24		27°13.35	15°25.33	Mooring snapped.
	Deploy EBH1	13:38	14:42		27°13.37	15°25.39	
	Deploy EBH1L16	15:33	15:34		27°12.27	15°25.21	
	CTD10	16:32	18:58		27° 13.60	15°24.77	Post Oxygen profile. 3000m
	Deploy Argo float 9601	19:15	19:15		27° 13.60	15°24.90	
Tue 2 Apr	CTD11	07:48	11:25		27°10.77	16°47.72	Calibration cast. 11 MicroCATs
	CTD12	12:16	16:23		27°10.77	16°47.72	Calibration cast. 13 MicroCATs
	Deploy Argo float 9600	16:30	16:30		27°10.8	16°47.7	
Wed 3 Apr	Santa Cruz de Tenerife	09:30					

3. Introduction

This cruise report is for cruise DY174 conducted aboard RRS *Discovery* in spring 2024. 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.

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

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 the 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 https://rapid.ac.uk and https://mocha.earth.miami.edu/mocha/results/index.html). 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 https://rapid.ac.uk/publications

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 Mid-Atlantic Ridge moorings.	National Oceanography Centre Southampton Cruise Report, No. 2, 2006
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	National Oceanography Centre,

			moorings and WBTS hydrography section.	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 and Mid-Atlantic Ridge moorings.	National Oceanography Centre, Southampton, Cruise Report No. 51, 2010
D345	RRS *Discovery*	Nov – Dec 2009	Recovery and redeployment of US Western Boundary moorings, and WBTS hydrography section.	RAPID/MOCHA Program Report (W. Johns, RSMAS).
D346	RRS *Discovery*	Jan – Feb 2010	Transatlantic hydrography (135 CTD stations).	National Oceanography Centre Cruise Report, No 16, 2012
OC459	RV *Oceanus*	Mar – Apr 2010	Service and redeployment of the Western Boundary moorings.	National Oceanography Centre Cruise Report, No 01, 2010
RB1009	RV *Ronald H. Brown*	Nov – Dec 2010	Recovery of WB4 and WB3L3. Redeployment of WB4.	Appendix in: National Oceanography Centre Cruise Report, No - 01, 2010
D359	RRS *Discovery*	Dec 2010 – Jan 2011	Service and redeployment of the Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Centre Cruise Report, No. 09, 2011
KN200-4	RV *Knorr*	Apr – May 2011	Service and redeployment of Western Boundary Moorings and WBTS hydrography section.	National Oceanography Centre Cruise Report, No 07, 2011
JC064	RRS *James Cook*	Sep – Oct 2011	Service and redeployment of the Eastern Boundary and Mid-Atlantic Ridge moorings.	National Oceanography Cruise Report, No. 14, 2012
RB1201	RV *Ronald H. Brown*	Feb – Mar 2012	Service and redeployment of Western Boundary Moorings and WBTS hydrography section.	National Oceanography Centre, Cruise Report No. 19, 2012
EN517	RV *Endeavor*	Sep – Oct 2012	Service of US moorings in Western Boundary.	RV Endeavor Cruise EN-517 Cruise Report
D382	RRS *Discovery*	Oct – Nov 2012	Service and redeployment of full UK RAPID array.	National Oceanography Centre

				Cruise Report No. 21, 2012
AE1404	RV *Atlantic Explorer*	Mar 2014	Service of US moorings in Western Boundary.	RV Atlantic Explorer Cruise AE-1404 Cruise Report
JC103	RRS *James Cook*	Apr – Jun 2014	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report No. 30, 2015
EN570	RV *Endeavor*	Oct 2015	Service of US moorings in Western Boundary.	RV Endeavor Cruise EN-570 Cruise Report
DY039	RRS *Discovery*	Oct – Dec 2015	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report, 37
DY040	RRS *Discovery*	Dec 2015 – Jan 2016	Transatlantic hydrography.	National Oceanography Centre Cruise Report, XX
EN598	RV *Endeavor*	May 2017	Service of US moorings in Western Boundary.	RV Endeavor Cruise EN-598 Cruise Report
JC145	*RRS James Cook*	Feb – Apr 2017	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report, 52
JC174	*RRS James Cook*	Oct – Nov 2018	Service and redeployment of full UK RAPID array.	National Oceanography Centre Cruise Report, 59
JC192	*RRS James Cook*	March 2020	Service and redeployment of eastern boundary of the UK RAPID array.	National Oceanography Centre Cruise Report, 71
DY129	RRS *Discovery*	December 2020 – January 2021	Recovery of RAPID MAR array and recovery and redeployment of RAPID western boundary array.	National Oceanography Centre Cruise Report, 72
DY146	RRS *Discovery*	Feb – Mar 2022	Recovery and redeployment of RAPID Eastern Boundary.	National Oceanography Centre Cruise Report, 76
EN697	RV *Endeavor*	Mar – Apr 2023	Recovery and redeployment of UK Western Boundary moorings	R/V Endeavor Cruise EN-697 Cruise Report
EN705	RV *Endeavor*	July 2023	Recovery and redeployment of UK Western Boundary moorings.	R/V Endeavor Cruise EN-705 Cruise Report
DY174	RRS *Discovery*	Mar – Apr 2024		This report

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

4. Scientific Computing Systems and Data Processing

Yvonne Firing

4.1 Workstations and configuration

Three OCP Linux workstations were available on DY174. The primary workstation, *akeake*, was configured with CentOS 7. The two backup workstations – *koaekea* running CentOS 7 and *kolea* running Ubuntu 20.04 -- were used mainly as terminals, with users accessing akeake via ssh. A small laptop running Ubuntu was also set up at the start of the cruise for possible use for data entry by the oxygen team or time logging by the salt team but was not required.

The main change to workstation setup (relative to DY146 and SD025) was a move from a single data processing account (pstar) to an account for each user.

1) Create an account for each user and put all users in the pstar group. In /etc/bashrc (or /etc/bash.bashrc on Ubuntu), set the default umask to 002/022 (or ug+rwX) so that everyone in the pstar group will be able to read/write the data files. Configure each user's home directory with
    a. .bash_profile sourcing /etc/bashrc (or /etc/bash.bashrc) and to /data/pstar/programs/ocp/mexec_exec/commands/mstar_dotbashrc, containing aliases and adding paths to mexec shell scripts (see Shell scripts, below)
    b. .pgpass file (see Access to ship's systems, below)
    c. Documents/MATLAB/startup.m, a symbolic link to /data/pstar/programs/startup_at_sea.m to configure the same MATLAB working environment and paths
2) Move data and processing directories (bin, cruise, datasets, instructions_info, mounts, programs, projects) from /local/users/pstar to /data/pstar, and update references in startup_at_sea.m and other programs as necessary.
3) Reinstall mambaforge (conda), the pycodas environment, and the CODAS SADCP processing libraries under /data/pstar/bin/, and add conda init output to the common mstar_dotbashrc.
4) Install/activate MATLAB with a designated computer license, so it can be run by multiple users. (Note: the documentation online says only one user can run it at a time, but fortunately this did not appear to be the case. If the policy is enforced in future, we would need to either go back to a single multi-user account or get a network license of some sort.)

The pstar account was still used to mount two external hard drives and do regular (every 2 hours) backups via cron, which could be changed to a non-generic user in the future. Another addition for the future would be for more users to set up ssh keypairs to enable automated syncing between workstations as part of processing.

4.1.1 Shell Scripts

Shell scripts from the mexec_exec toolbox (git.noc.ac.uk/OCP/mexec_exec) from the dy174 branch were used to configure the cruise data processing directories before the cruise, to sync CTD and UHDAS data to the workstation and between workstations, and to back up data to external hard drives. These scripts were placed in /data/pstar/programs/ocp/mexec_exec (and added to paths in bash, see above).

4.2 Access to Ship Systems and Data

Access to ship's systems including Wi-Fi, the public drive, and the current cruise drive is now by individual user account configured by NMFSS before the start of the cruise. The public drive and the cruise data drive were both mounted read-only from workstation akeake using stored mount commands but with one user entering their credentials. This means it would need to be redone manually if the workstation were restarted.

Connections between the workstations using their names, and from workstations to the cruise data machine and the RVDAS server, were smooth except when akeake was thrown off the science network and onto the "dirty" default network, as revealed by a change in the IP address range. The NMFSS technician was able to prevent this from happening again.

4.2.1 Tests of Remote Access

In the past we have sometimes provided support to the onboard team from shore, connecting to our workstations on the ship using ssh via a portal set up by onboard IT in order to do some basic (command line and text-based) monitoring and processing. To meet current security needs and to take advantage of improved bandwidth and remote access tools, we used a remote IT app (regularly used by NMFSS) to connect from a computer on ship, to one on shore, and back to the ship and to workstations akeake and kolea. We succeeded with ssh, but the double-distance connection at least was too slow for X forwarding; this will be worth trying again on a single-leg connection (i.e. shore to ship) and after the upgrade to the ship's bandwidth in the next refit. Remote desktop access should also be tested.

4.3 Data Processing Tools

Data processing and plotting used the MATLAB Gibbs Seawater (gsw) toolbox (v3_06_15), neutral density (gamma_n) code (v3_05_10), m_map, and Seawater (ver3_3_1, for sw_dist.m). We also used the pyIGRF package to estimate magnetic declination for Nortek current meter processing. The psql package was used to get data from the RVDAS database.
Shipboard ADCP data are acquired using UHDAS and processed automatically using CODAS installed on the UHDAS machine. Data were synced to akeake and a locally installed version of CODAS was used to review and (where necessary) reprocess and/or edit them.

4.3.1 Hydrography

Hydrographic data – CTD and bottle data, and underway navigation, bathymetry, meteorology and surface ocean time series -- were processed using MATLAB toolbox ocp_hydro_matlab (github.com/NOC-OCP/ocp_hydro_matlab). The main branch was used (starting from commit f362464d). The code was placed in /data/pstar/programs/gitvcd/ocp_hydro_matlab, and was backed up both by rsync to external hard drives and by configuring other workstations as remotes in the .git/config file and pulling changes from akeake to kolea and koaekea. The main change on this cruise was using CF-compliant time units in output .nc files; more scripts were also converted into functions, and some updates were made to table and variable handling for RVDAS data.

4.3.2 Moorings

Moored data as well as cal-dip data were processed using MATLAB toolbox m_moorproc_toolbox (github.com/ScotMarPhys/m_moorproc_toolbox), with calls to ocp_hydro_matlab interface to underway data in RVDAS. The dy174 branch was used (starting from commit 4b099839). The code was placed in /data/pstar/programs/gitvcd/ocp_hydro_matlab, and was backed up both by rsync to external hard drives and by configuring other workstations as remotes in the .git/config file and pulling changes from akeake to kolea and koaekea.
For mooring operations, Anchor6.m was renamed to Anchor_seabed_triang.m and updated to use RVDAS underway data; rapid_widgit_lite.m was also updated for the current version of RVDAS.
The stage1 and stage2 MicroCAT, MicroCAT cal dip, and Nortek processing were updated to look up file paths in a common function, moor_inoutpaths (so if the locations of intermediate data are changed, they only need to be updated in a single place), and to query for mooring/cast (rather than setting these inputs in the script).

5. NMFSS Ship Systems Computing and Underway Instruments

Josh Pedder

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**
Meinberg		GPS network time server (NTP)	N	Not logged
Applanix	POS MV	Primary GPS and attitude	Y	
C-Nav	3050	Correction service for primary and secondary GPS and dynamic positioning.	Y	
Kongsberg Seatex	Seapath 330+	Primary GPS and attitude	Y	
Fugro Seastar / MarineStar		Correction service for primary and secondary GPS and dynamic positioning.	Y	
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	
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	

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
27/Mar/2024	18:10	19:20	Yes	4.868	0.006
28/Mar/2024	12:00	13:01		Underway turned on	
28/Mar/2024	23:37			SBE38 hull intake reading higher SST values than expected.	
29/Mar/2024	10:53	11:04		SBE38 hull intake changed from **SN:0416** to new unit **SN:0475**. Temperature values have to return to within expected range.	
03/Apr/2024	07:57			Underway turned off upon exit of international waters	
03/Apr/2024	08:00	15:00	Yes	4.950	0.005

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

Genia Fernanda, Brian King, Yvonne Firing, Ben Moat

6.1 Overview

Most underway streams are logged by two systems, Techsas and RVDAS, and latest data as well as recent time series are displayed in several formats viewable in the main laboratory as well as on the ship intranet. Vessel-mounted Acoustic Doppler Current Profiler (VMADCP) data acquired by UHDAS are also viewable both online and on dedicated displays, while multibeam (swath) bathymetry data from the EM122 are viewable on displays of the manufacturer data acquisition software in the main lab. These displays were used by watchkeepers to monitor incoming data on a regular basis (checking that data were updating with reasonable values) by watchkeepers. Bottle samples from the underway system were taken every 4 hours between 0800 and 2000 local time.

6.2 Daily Processing of Underway Data Streams

Underway data were accessed from the RVDAS database, via psql commands constructed by Matlab scripts. The wrapper script **uway_daily proc** was called for each day to perform the following steps: get list of data streams to process (based on **mrtables_from_json** configured at the start of the cruise, as well as options in **opt_dy174**); for each stream, load by calling **mday_00_load** and apply preliminary quality control and merge into an appended file by calling **mday_01_edit**; finally, call mnav_best, mtsg_merge_av, and mbathy_edit_av to (respectively) combine the best sources of navigation and attitude data; combine multiple streams of surface underway data (e.g. TSG and fluorometer), cut out times when the underway seawater supply was off, and apply any factory or user-supplied calibrations; and combine the singlebeam and multibeam (centre beam) bathymetry with a graphical user interface for removing bad points.

6.3 Navigation

The data acquisition system was started whilst docked at Santa Cruz de Tenerife during the mobilization. This allowed data to be collected whilst the ship was stationary. During the 28th of 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: 28.4609°N, -16.2449°E for POSMVPOS and SEAPOS, and 28.461°N, -16.2448°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. The POSMV was maintained as the "default" system as recommended by NMF.

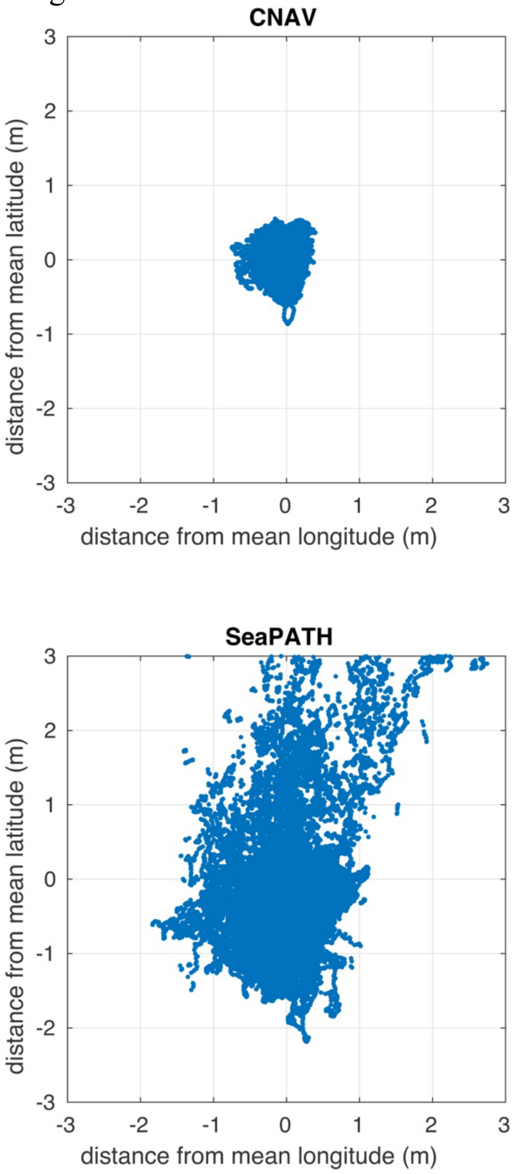


Figure 6.1 Comparison of navigation systems' data before leaving the dock

6.4 Bathymetry Data

Bathymetry data were collected through most of the cruise, with the singlebeam (EA640) switched on in port and the multibeam (EM122) given a soft start following observing with no evidence of marine mammals in the area. Bathymetric echosounder pinging was stopped for less than 10 minutes at a time (following the Environmental Impact Assessment) when required for mooring release communications (comprising testing on cal dips, pinging and release for recovery, and trilateration). For the most part, data from the two streams, EA640 and EM122, agreed well. Noise in the EA640 manifested as inability to find the bottom (reading a depth of 0), while the EM122 centre beam was prone to a comb pattern with spikes to a deeper depth. Both types of noise were edited out by a despiking program and the EA640 data were corrected for regional speed of sound (based on Carter tables) before averaging the data to 5 minutes and inspecting and removing a few remaining points using **mbathy_edit_av.m**. The averaged data show an offset varying from approximately 2 to 6, likely due to residual inaccuracy in one or both instruments' speed of sound.

6.5 TSG Salinity Calibration

Water samples were taken every 4 hours (0800, 1200, 1600 and 2000 ship's time) every day. A total of 20 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_dy174_01.csv*. The times and dates of the samples were edited into this before using **msal_01** to load the bottle values into a mstar-format NetCDF file. The salinity calculated from the bottles was compared to the salinity from the 1-minute averaged TSG data (calculated by mtsg_merge_av) (Figure 6.2). Residuals are plotted against decimal day, TSG housing temperature and sea surface salinity (bottom panels), but since only a small number of samples were collected on this short cruise, a fixed offset of -0.028 psu was applied to the TSG salinity time series to produce the calibrated series (red line, top panel).

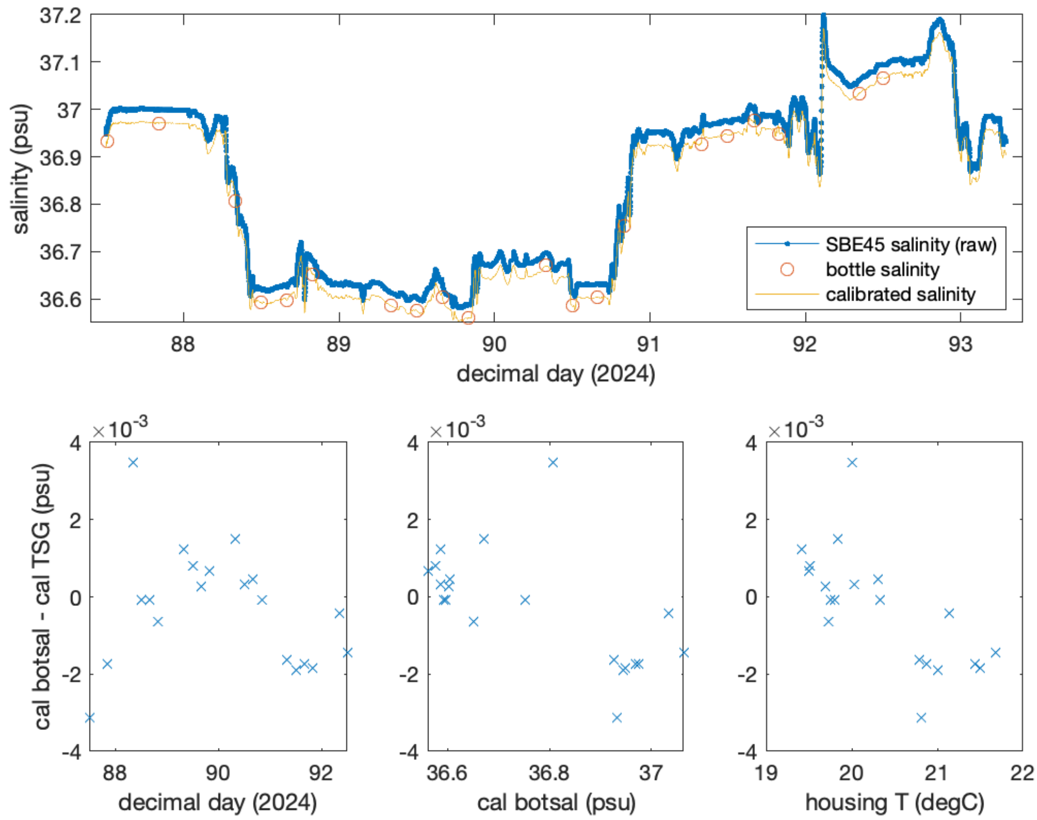


Figure 6.2 TSG salinity (raw and calibrated) and bottle salinity (top), and salinity residual against time (bottom left), against salinity (bottom middle), and against temperature in the SBE45 (bottom right)

6.6 Vessel-mounted Acoustic Doppler Current Profiler (ADCP)

6.6.1 Introduction

The *RRS Discovery* 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. Data acquisition is done automatically by the University of Hawaii Data Acquisition system (UHDAS). Both were configured in narrowband (nb) mode with watertracking pings only, using calibrations derived by the UH currents group based on multiple past cruises. 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 Monitoring and Automatic Processing

The UHDAS interface displayed on a screen in the main lab has all the control and monitoring options. As part of the systems watchkeeping, the UHDAS monitor interface was checked for any errors or data acquisition problems. UHDAS/CODAS applies automatic quality control and automatically generates a series of contour and vector plots, which were also visually inspected for errors. Data quality was generally good, with the 75kHz instrument range back to the nominal ~750 m, a marked improvement after recent work to reduce electrical noise.

6.6.3 Data Processing

Throughout the cruise, several shell scripts on workstation akeake were used to sync data from the UHDAS server to a backup on the workstation, and then to a local processing directory. At the end of the cruise, CODAS utility dataviewer.py was used to inspect the 5-minute ensemble-averaged data from the two instruments separately and together. A small number of additional edits were made and applied to a copy of the database. The pre-configured angle and amplitude calibration and transducer offsets were not changed as the number of watertrack calibration points available from this cruise alone is small. The records of velocity components and signal amplitude are shown in Figure 6.3, and the depth-mean currents between 37 and 181 m from the 75kHz along the cruise track are shown in Figure 6.4. A NetCDF file for each instrument was generated using adcp_nc.py.

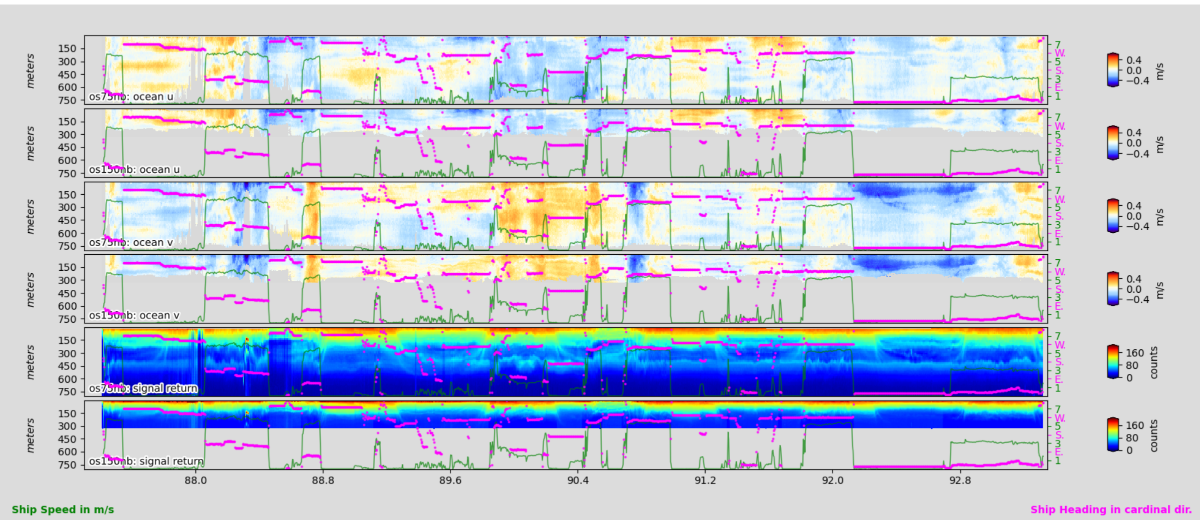


Figure 6.3 Screen grab of example dataviewer.py comparison panels.

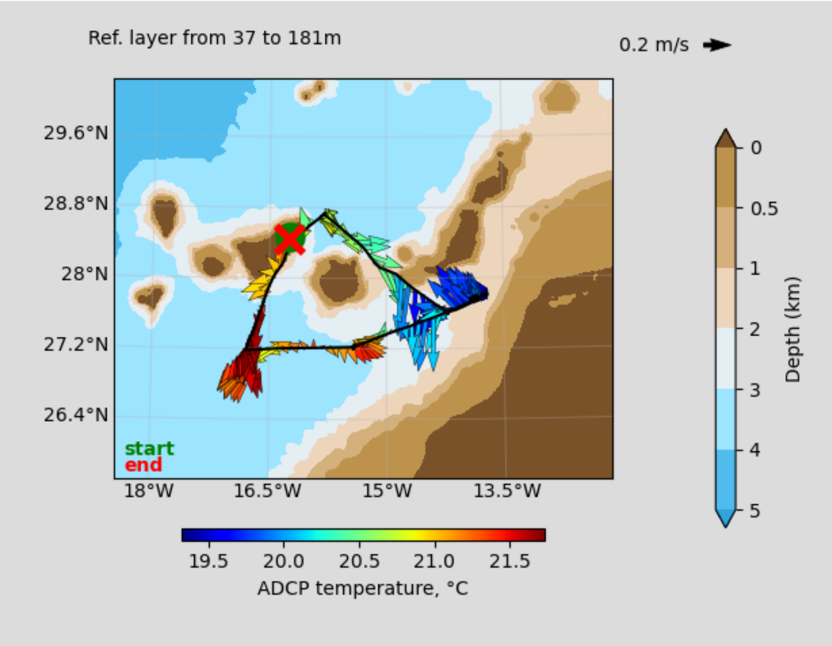


Figure 6.4 Currents over the cruise track, from dataviewer.py.

7. CTD Operations

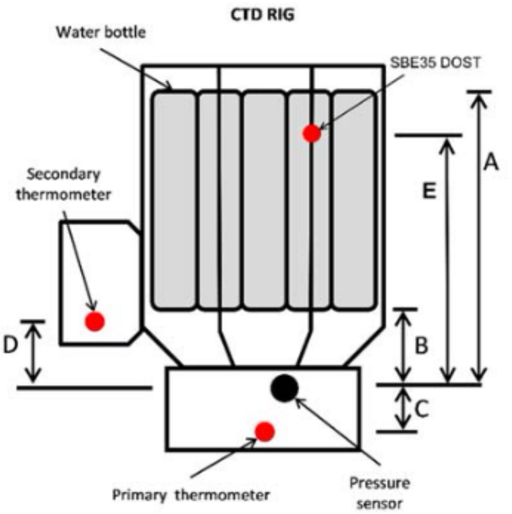
Tom Ballinger and Finn Sougioultzoglou

7.1 CTD Operation

All casts were carried out using CTD2 wire. The CTD wire was electrically tested prior to sailing and had an insulation resistance of > 999 MΩ at 250V. The. Active heave compensator (AHC) was used for the majority of the CTD casts. 12 CTD casts were undertaken with an NMF 24-way Stainless Steel CTD frame with 12 off 10l Niskin water samplers. Only the odd bottles were fitted leaving 12 bottle positions free for Microcat clamps which were utilised for calibration dips. Dual SBE 43 dissolved oxygen sensors were used. The primary temperature, conductivity and dissolved oxygen sensors were fitted to the 9 plus with the secondary sensors mounted on the vane. A SBE 35 was mounted to a vertical stanchion of the CTD frame and programmed to average 8 samples which supplemented the temperature data. There were no major technical issues with the Stainless Steel CTD suite during the cruise and no sensors required changing. During cast 001 bottle 23 failed to seal sufficiently at the bottom cap, cast 002 23 also failed to seal on the bottom and cast 004 bottles 23 and 11 both failed to seal at the bottom. All bottles were leak tested before the start of science and again at the end of science, no issues noticed.

Instrument / Sensor	Manufacturer/ Model	Serial Number	Channel	Casts Used
Stainless steel 24-way frame	NOCS	CTD 6	N/A	All casts
EM Swivel		1267-2	N/A	All casts
Primary CTD deck unit	SBE 11plus	11P-24680-0588	N/A	All casts
CTD Underwater Unit	SBE 9plus	09P-34173-0758	N/A	All casts
24-way Carousel	SBE 32	32-60380-0805	N/A	All casts
Deep Ocean Standards Thermometer (DOST)	SBE 35	35-66264-0070	N/A	All casts
Primary Temperature Sensor	SBE 3P	3P-4383	F0	All casts
Primary Conductivity Sensor	SBE 4C	4C-3874	F1	All casts
Digiquartz Pressure sensor	Paroscientific	90074	F2	All casts
Secondary Temperature Sensor	SBE 3P	3P-5780	F3	All casts
Secondary Conductivity Sensor	SBE 4C	4C-4143	F4	All casts
Primary Pump	SBE 5T	5T-3090	N/A	All casts
Secondary Pump	SBE 5T	5T-3086	N/A	All casts
Primary Dissolved Oxygen Sensor	SBE 43	43-3847	V0	All casts
Secondary Dissolved Oxygen Sensor	SBE 43	43-2831	V1	All casts
Altimeter	Valeport VA500	81629	V2	All casts
Hydro C Co2 Sensor	4H Jena	1019-007	N/A	CTD 008-011
Pump	SBE 5T	11954	N/A	CTD 008-011
Battery Pack	4H Jena	20C-001	N/A	CTD 008-011
Hydro C Co2 Sensor	4H Jena	0319-001	N/A	CTD012
Pump	4H Jena	11752	N/A	CTD012
Battery Pack	4H Jena	20C-002	N/A	CTD012

Table 7.1 The sensors fitted to the CTD frame.



ID	Vertical distance from pressure sensor (m positive-up)
A	1.2 (Top of water samplers)
B	0.34 (Bottom of water samplers)
C	-0.075 (Primary T mounted on 9p)
D	0.085 (Secondary T mounted on Vane)
E	1.025 (SBE35 DOST probe sheath tip)

Figure 7.1 CTD frame geometry

7.2 Salinity Measurement

A Guildline 8400B, s/n 65764 was installed in the Salinometer Room as the main Autosal for salinity analysis. The bath temperature was set to 21°C with the lab ambient temperature ranging between 18°C – 18.5°C. The salinometer was standardised during the mobilisation, then again prior to the start of analysis. Consistently though out the first crate the conductivity cell failed to fill sufficiently. Upon opening and inspection, the capillaries above the conductivity cell had a substantial number of water droplets in them. It is possible the air pump was not strong enough to give the back pressure required. The pumps were inspected but were not serviceable at sea. Important to note it appeared that the feet of the pump had begun to melt, this should be inspected as a matter of urgency. 65764 was used to analyse salinity samples from the first station (and one from the second). 71185 was set up as the spare for DY174, it was decided to switch after the trouble with the conductivity cell. 71185 was used for the remaining CTD samples (6 crates) and 1 crate of TSG samples with no issues. A standard (IAPSO Standard Seawater batch P165, K15 = 0.99986, 2xK15 = 1.99972) was analysed before starting to run samples on a given day, and after each crate of samples to monitor & record drift. Standards and samples were measured by first flushing and filling the conductivity cell three or more times (using up to half the bottle) then using NMF's software to record conductivity ratio readings from three successive fills of the conductivity cell.

8. CTD Data

Brian King, Tillys Petit, Yvonne Firing

8.1 Introduction

A total of 12 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 1 minute.

Station	Start Date	Start Time	End time	Latitude	Longitude	Water depth (corr. m)	Profile depth (m)	Number of bottle stops	Active Heave Compensation
1	28-Mar	13:20	14:55	28°44.17	15°47.53	3589	1508	12	Yes
2*	28-Mar	15:47	19:23	28°44.23	15°47.47	3602	3583	12	Yes
3*	28-Mar	20:33	00:22	27°44.22	15°47.47	3601	3581	12	Yes
4	29-Mar	11:13	13:04	27°36.49	14°13.08	2027	2017	12	Yes
5*	29-Mar	19:09	20:41	27°48.10	13°45.39	1425	1415	12	Yes
6	29-Mar	21:44	23:43	27°48.10	13°45.39	1426	1025	12	Yes
7	30-Mar	18:21	20:04	27°47.87	13°45.30	1420	1411	10	Yes
8	31-Mar	14:15	15:02	27°36.88	14°13.38	2028	2018	10	Yes
9*	31-Mar	23:53	02:46	27°13.68	15°24.77	3024	3015	12	Yes
10	01-Apr	16:32	18:58	27°13.60	15°24.77	3023	3002	12	Yes
11*	02-Apr	07:48	11:25	27°10.77	16°47.72	3591	3592	12	Yes
12*	02-Apr	12:16	16:23	27°10.77	16°47.72	3591	3551	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 Adjustment of Temperature to Reference SBE35

A SBE35 stable temperature sensor fitted to the outside of the CTD frame recorded a reading each time a Niskin was fired. These readings were compared to the two CTD temperature sensors at all depths > 2500 m (to avoid background temperature gradients). An offset of -1.5 m°C was applied to sensor S/N 34383, and +1.5m°C to sensor S/N 35780.

8.3 Analysis of Standard Seawater Samples and Calibration of the Salinometer

A total of 15 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 P165 with 2*K15 = 1.99972. The salinometer S/N 71185 was standardised at the start and based on the values of subsequent bottles of standard seawater, offsets (Figure 8.1) increasing up to 5×10^{-5} counts at the end of the last batch of samples were specified in **opt_dy174.m** and applied to the data in mexec processing. Although there was an overall increase in salinometer offset over several days, a constant offset was used for each set of crates (ignoring the apparent drifts over several hours, which were not consistent in sign).

The temperature and humidity of the salinometer lab were monitored regularly. A thermometer to monitor the bath temperature was installed in the original primary Autosal, but as this salinometer failed early on the record was not used.

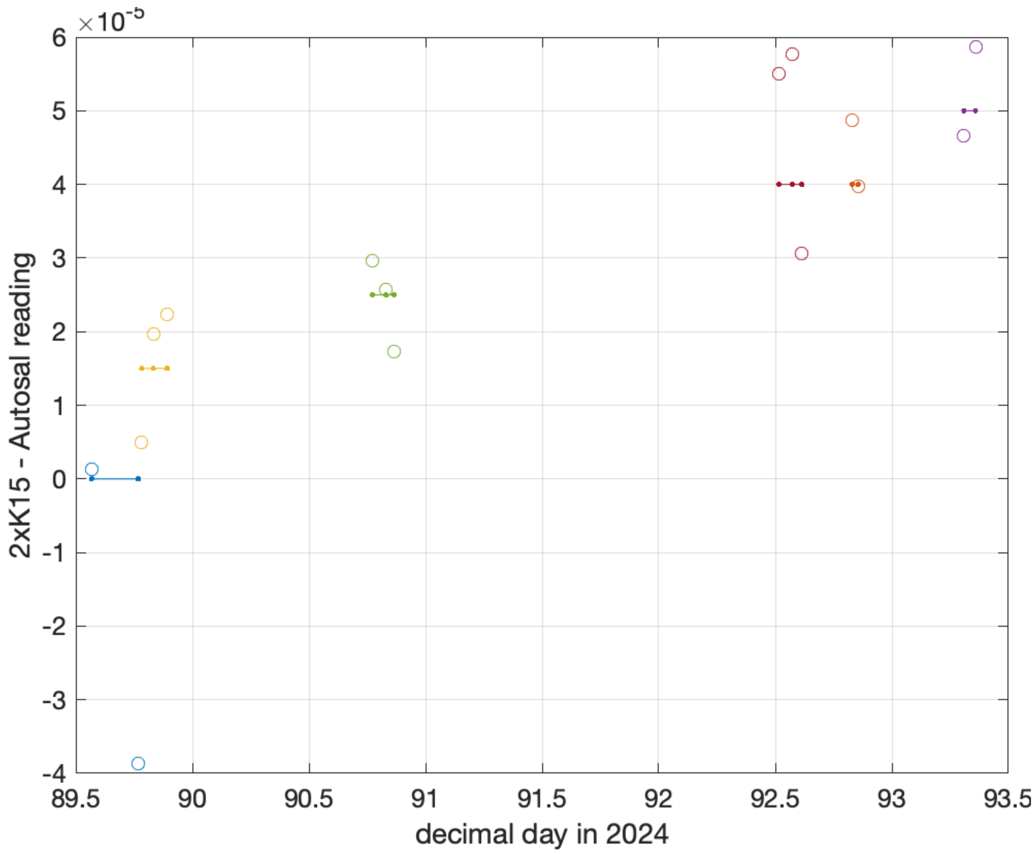


Figure 8.1 Inferred offset calculated as 2xK15 – salinometer average is shown (open circles) as a function of the date on which the samples were analysed. Each colour indicates standards bracketing a crate or set of two crates run one after another (blue: station 1, yellow: stations 2, 3, 4, green: stations 5, 6, 7, red: stations 8, 9 and TSG, orange: station 10, purple: stations 11 and 12), and the horizontal lines are the standard offsets applied to the corresponding samples (rather than applying a drift over the course of a crate or set of two crates, a constant offset was applied for each set). The standards run on salinometer S/N 65784 are in blue, and the rest were run on salinometer 71185. Note a change of 5e-5 corresponds with a salinity difference of 0.001.

8.4 Calibration of Conductivity

The three conductivity ratio readings from each sample bottle were checked for outliers before averaging, adding the offsets derived from standard seawater above, and converting to salinity based on the salinometer set bath temperature. In addition to the sample from each Niskin collected in bottles sealed with plastic inserts, replicate salinity samples were collected from stations 3 and 12 in a second type of sampling bottle (swing-top closure), and the replicates from station 3 were analysed onboard along with the primary samples, but they were not used for calibration.

Conductivity from each of the two CTD sensors was compared with conductivity derived from bottle salinity and CTD temperature (for the corresponding CTD sensor). A calibration for each sensor was sought in the form
Cond_cor = Cond_raw*(1 + (A(statnum) + B(press))/35),
where statnum = station number and press = pressure.
Because of the limited number of samples and the correlation between temperature and pressure, temperature was not considered as a dependent variable. The functions A and B were

allowed to be piecewise linear, resulting in the following forms (interp(x,y,xg) indicates linear interpolation of y from x to xg):
S/N 43874:
A = interp([1 12], [0 -0.002], statnum)
B = interp([-10 1500 4000], [-2 1 0]x10^{-3}, press)
S/N 44143:
A = interp([1 12], [0.001 -0.001], statnum)
B = interp([-10 2000 4000], [1 4 3] x10^{-3}, press)
Although the time dependence is the same for both sensors' calibration functions, and it is comparable to the effect of the salinometer standardisation offset, the residuals do not appear to be correlated with the standards offsets. The relationship between bottle-derived and calibrated CTD conductivity, as a function of station number, temperature, and pressure, is shown in Figure 8.2.

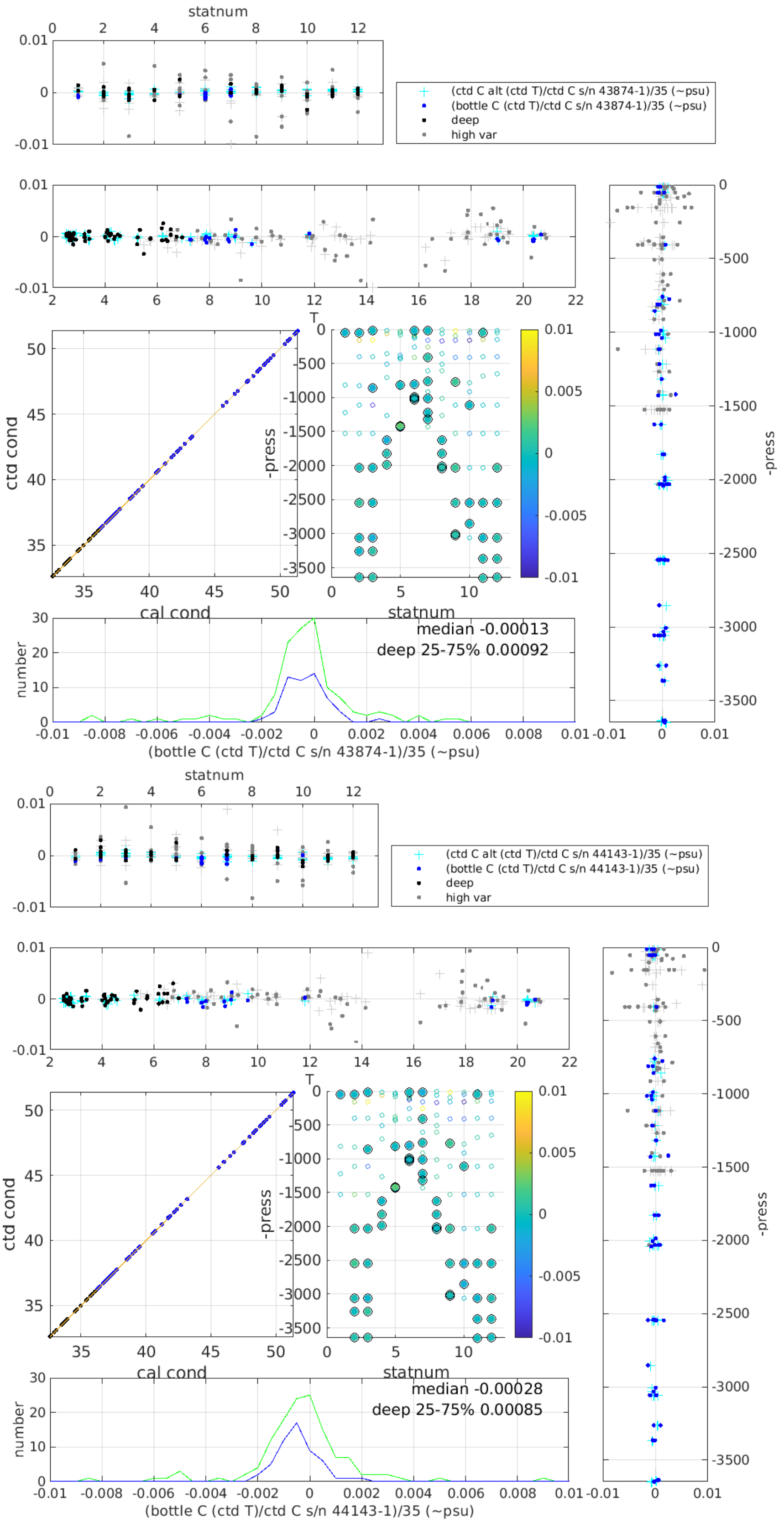


Figure 8.2 Calibrated CTD conductivity at bottle stops compared to conductivity derived from bottle salinity on various axes. The grey dots (or unfilled circles) indicate points with high background variability or gradient. The cyan + show the comparison between the two CTD sensors for reference.

8.5 Hysteresis Correction and Calibration of Oxygen

Based on inspection of the differences between the two CTD oxygen sensors, the default coefficients for oxygen hysteresis correction (applied to the oxygen concentration in umol/kg) were modified, so that the amplitude of the pressure exponential was -0.043 for both sensors and the scale for the exponential of time varied with pressure as follows:
S/N 433847: 200 for 0<=p<=1000; 1000 for 1000<p<=2000; 2000 for p>2000
S/N 432831: 500 for 0<=p<=1000; 3000 for p>1000.

Oxygen Winkler titration data (Section 10) were converted first to concentration in umol/L, using blanks and standards values set in opt_dy174, and then to umol/kg, using the CTD salinity at bottle stops and the sample fixing temperature. Although the first set of computations is also coded into a spreadsheet, recalculating in Mexec enabled us to easily adjust the blanks and standards values, setting them to the mean of the values obtained on different days (see Section N for discussion). Four of the replicate samples differed by over 1 umol/L, and one or both in each case was flagged as questionable based on comparison with the rest of the profile. Good replicates were then averaged, and bottle oxygen data compared with CTD oxygen data, identifying two additional outliers. The oxygen sensor and bottle data from 60 Niskins were first compared in terms of their ratio, and the following factors were applied:
S/N 433847:
O_cal = O_uncal
X (interp([-10 0 800 2000 3500 4000], [1.055 1.055 1.035 1.042 1.052 1.052], press)
X (interp([0 3 4 12], [1.003 1.003 1 1], statnum)
S/N 432831:
O_cal = O_uncal
X (interp([-10 0 800 1500 3000 4000], [1.007 1.007 1.004 1.015 1.030 1.035], press)
A + B(press) + C(statnum))
The calibrated data compared to the bottle data are shown in Figure 8.3. The residuals were also inspected in difference terms, but it was not necessary to apply additional offsets.

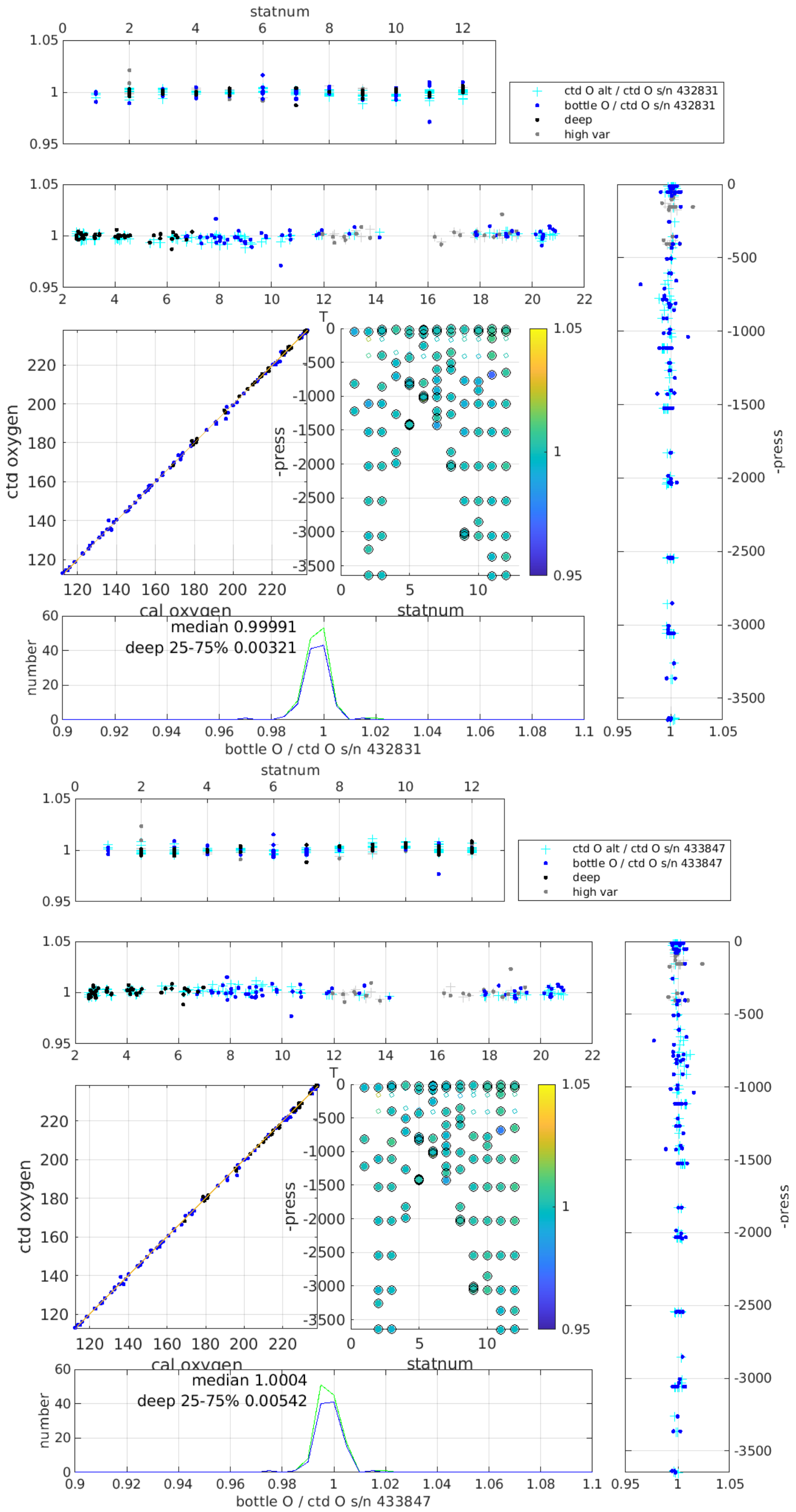


Figure 8.3 Calibrated CTD oxygen at bottle stops compared to Winkler oxygen from bottle samples, on various axes. The grey dots (or unfilled circles) indicate points with high background variability or gradient. The cyan + show the comparison between the two CTD sensors for reference.

9. Argo Float deployment

Brian King

Two 2000 dbar APEX floats were deployed during the cruise.

Float number	Date	Time (GMT)	Latitude	Longitude	Water depth (m)
APEX/SBE 9601	1st April 2024	19:15	27° 13.6N	15° 24.9W	3023
APEX/SBE 9600	2nd April 2020	17:00	27° 10.8N	16° 47.7W	3591

Table 9.1 Argo Float deployment

10. Oxygen Analysis

Sunke Trace-Kleeberg and Yvonne Firing

Dissolved oxygen (DO) samples were collected during DY174 to calibrate both CTD DO sensors (primary and secondary), to correct for drift, temperature and pressure influences. The calibrated CTD oxygen in turn will be used to calibrate oxygen sensors deployed on moorings. Samples were taken from Niskin bottles on every CTD cast throughout the cruise, with the exception of known misfires and bottles observed to be leaking on CTD recovery. Numbers of DO samples and replicates on each CTD cast, as well as when they were analysed, are given in Table 10.1 and discrete sample depths are shown in Tables 11.2 and 11.3 (after DIC/nutrient section). Duplicates were taken from either 1 or 2 Niskin bottles to achieve the 10% duplicate rate. Discrete water samples collected were subsequently analysed by automatic Winkler titration using a Metrohm Ti-Touch titration system with amperometric endpoint detection.

CTD cast	Date	Total samples	Replicates	Date analysed
001	28.03.2024	4	0	29.03.24
002	28.03.2024	13	1	29.03.24
003	28.03.2024	13	1	30.03.23
004	29.03.2024	11	1	30.03.24
005	29.03.2024	14	2	30.03.24
006	29.03.2024	13	1	31.03.24
007	30.03.2024	14	2	31.03.24
008	30.03.2024	14	2	01.04.24
009	01.04.2024	13	1	01.04.24
010	01.04.2024	14	2	02.04.24
011	02.04.2024	14	2	02.04.24
012	02.04.2024	13	1	02.04.24
Total		**150**	**16 (10.6 %)**	

Table 10.1 Summary of CTD casts sampled for oxygen

10.1 Metrohm Ti-Touch Setup and De-bubbling

Two titration instruments were brought on board. The one used during DY174 had serial number S/N 32285. The sodium thiosulphate solution was made at 08:37 on Tuesday 26th March 2024. This was done by adding one vial of pre-weighed (27.3112 g) sodium thiosulphate crystals to 1L of Milli-Q water. The titration system and dosing devices were subsequently set-up. The burettes used for reagent dispensing had been acid washed and calibrated to 1ml on the 22.01.24. The Ti-touch was preloaded with programs for running blanks, standards, and samples. The system was tested by running a blank (see method in 10.3 below). However, the initial result was too high and large air bubbles were present in the dosing chamber. Changes were made to some of the settings, and a process of de-bubbling the dosing units was carried out, which resulted in more consistent and acceptable readings. On Thursday 28th March a series of blanks and standards were run getting the instrument ready to analyse the first discrete water samples collected during the test CTD cast at 14:49. However, on preparing the first sample for analysis an error message popped up on the Metrohm Ti-Touch screen saying "011-003 Electrode Check: either no electrode is connected to measuring input 1 or there is a break within the measuring chain". The electrode was swapped for the spare, but the same error message appeared. Following successful blank and standard titrations it was deemed that the electrode was working and so the electrode check step in the method was switched off. (This spurious Ti-Touch error has been encountered before but not recently.) Therefore, blank runs 1 to 6 and standards 1 to 5 were measured using a different electrode to the remainder of the blanks and standards. All samples were run using the same electrode. The titre and standard dispensers were debubbled again on Monday 1st of April before running any blanks and standards as multiple small bubbles has accumulated in the dispensing units.

Details of the debubbling process and changes made to the settings are described below:

- To get the bubbles off the dosing units, press the hand button from the icons, select Dosing and use manual dosing, dosing fixed vol (with automatic filling switched off) to partially empty the dosing unit. Remove the draw straw from liquid while refilling the dosing unit to draw up a larger air bubble that will subsume the smaller ones. Importantly, return the draw straw to the liquid (reattach unit to bottle) before the end of the filling period. This is to ensure that liquid is fully drawn up the draw straw, and there are no bubbles left in that portion of the device. Start dosing again, then, plugging both vent ports, invert the dosing unit, tap it to dislodge the large bubble to the bottom of the dosing unit (currently the top), rotate so the outlet valve is at the top and dose so the bubble is pushed out the outlet valve, down the straw and out of the burette tip – this will hopefully collect any bubbles within the tubing as well as the bubbles in the piston. Ensure you have righted the dosing unit and bottle before refilling to ensure the base of the draw straw is submerged. This seemed to be successful at removing all bubbles except in some cases one tiny one. However, the dosing unit barrels accumulated more bubbles over the course of hours to a day (whether the machine is in use or not). It was not clear whether they were coming out of solution or being let into the barrel possibly due to uneven greasing of seals. The pistons and to some extent the corresponding cups at the bottoms of the barrels appear to be somewhat adhesive to bubbles. It was found most effective to wait 30 minutes between drawing in a larger air bubble and then dispensing again. Also, a lamp was positioned next to the titration device to better see the bubbles in any of the tubes or dosing barrel (see Figure 10.1).

- To avoid (or reduce) drawing in new bubbles, reduce the maximum dosing and fill speeds from maximum (estimated this is 20-50 mL/min) to 5 mL/min or less. This was done in various parts of various programs, wherever dosing parameters were specified.
- Consistency of blanks and standards is also aided by more vigorous stirring than previously programmed, with the stirrer on a speed of 7 (for the particular magnetic stirrer used here). This is again adjusted in various parts of the different methods (including the method for samples).

10.2 Sample Collection

Water sampling was carried out according to the guidelines by Langdon (2010) with seawater being collected directly into pre-calibrated Pyrex iodine titration bottles (approximately 140 ml flasks with flared necks). This protocol is analogous to previous cruises (see RAPID cruise reports No. 30, 37, 52 and 76 for more details). The key steps were:

- Prior to sampling each station, the reagent dispensers (Brand dispensettes set to 1 mL) were emptied and refilled 2-3 times to remove any bubbles that had formed in the chemical lines. This minimizes the risk of bubble injection into samples. This process was repeated if bubbles were noticed.
- Silicon Tygon tubing was attached to the Niskin spigot to transfer water to the flask. The tubing was kept submerged in Milli-Q water between stations to reduce the tendency of bubbles to form within it. The spigot was pushed in only after attaching the tubing, and the tap opened after that to allow checking for leaks (a good seal will not allow more than a small dribble of water to flow when the spigot is opened, if the top valve is still closed).
- Bottles and stoppers were rinsed three times with Niskin water, while filling the tubing completely by pressing and rolling it to push out any air bubbles.
- The tubing was inserted to the bottom of a bottle and the bottle was filled slowly, from the bottom, to minimize turbulence and bubble formation, with water flow decreased by pinching the tubing. The bottles were overflowed by three flask volumes of water (approximately 15 seconds at full flow).
- During overfilling, the temperature of the sample was measured using a digital thermometer (HANNA Foodcare Thermistor thermometer S/N 07090C7N) whilst the bottle was being overflowed. This temperature is used to correct the bottle volume due to glass expansion/contraction, and to convert the oxygen concentration measured from μmol/L to μmol/kg.
- The bottles were held at the neck to minimise heat transfer to the water.
- 1mL of manganese chloride was carefully added to the bottle, immediately followed by 1mL of alkaline iodide solution. Dispenser tips were lowered beneath the water surface to eliminate the loss of chemical through splashing, and the entrainment of bubbles into the sample.
- Stoppers were inserted slowly and at an angle to stop bubbles getting trapped beneath.
- Bottles were vigorously shaken for 15-30 seconds (twisted about 20 times) to facilitate the mixing and formation of the precipitate (manganese hydroxides). A second shake was performed after 30 minutes.

- Milli-Q water was added to the necks of the conical flasks to act as an additional gas-tight seal. This was maintained until analysis. All bottles were kept in the dark in their crates until analysis.
- Each stopper is uniquely matched to a volume-calibrated 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.

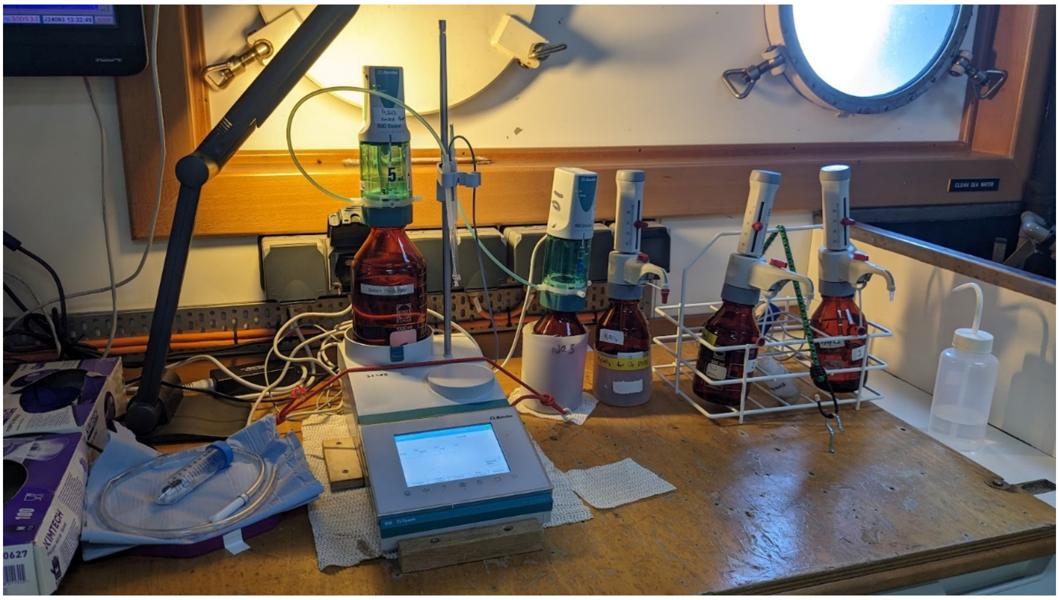


Figure 10.1 Photograph of the lab bench set-up.

10.3 Blank Analysis

Prior to the analysis of seawater samples, the system blank was measured and calculated. This represents the signal produced by the addition of the chemical reagents. Bottles were filled with 90 ml of Milli-Q water and a stirrer bead. The reagents were added in reverse order with thorough stirring in between (1mL sulphuric acid, 1mL alkaline iodide solution, 1mL manganous chloride). 1mL of iodate standard solution (1.667 mol/L, OSIL) was then added by the Ti-Touch dosing unit and titrated with thiosulphate solution up to an endpoint of current 0.1×10^{-6} A; this endpoint was recorded. The titration of 1 further addition of 1 mL iodate standard was carried out. The blank is the difference between the volume of the second addition and the first titre value. Additional blanks were run until four acceptable estimates were obtained where the mean difference between the two blank volumes was less than 0.004. Values greater than 0.004 were excluded from further calculations. The remainder of blank values fall within 0.003 of the median value. Figure 10.2 shows the blank values obtained during DY174 between 28th March and the 2nd of April, when oxygen sample analysis was carried out. The median value calculated from all the suitable blank titres during the cruise was negative 0.0005. Median blank volumes per analysis set are shown in Table 10.2.

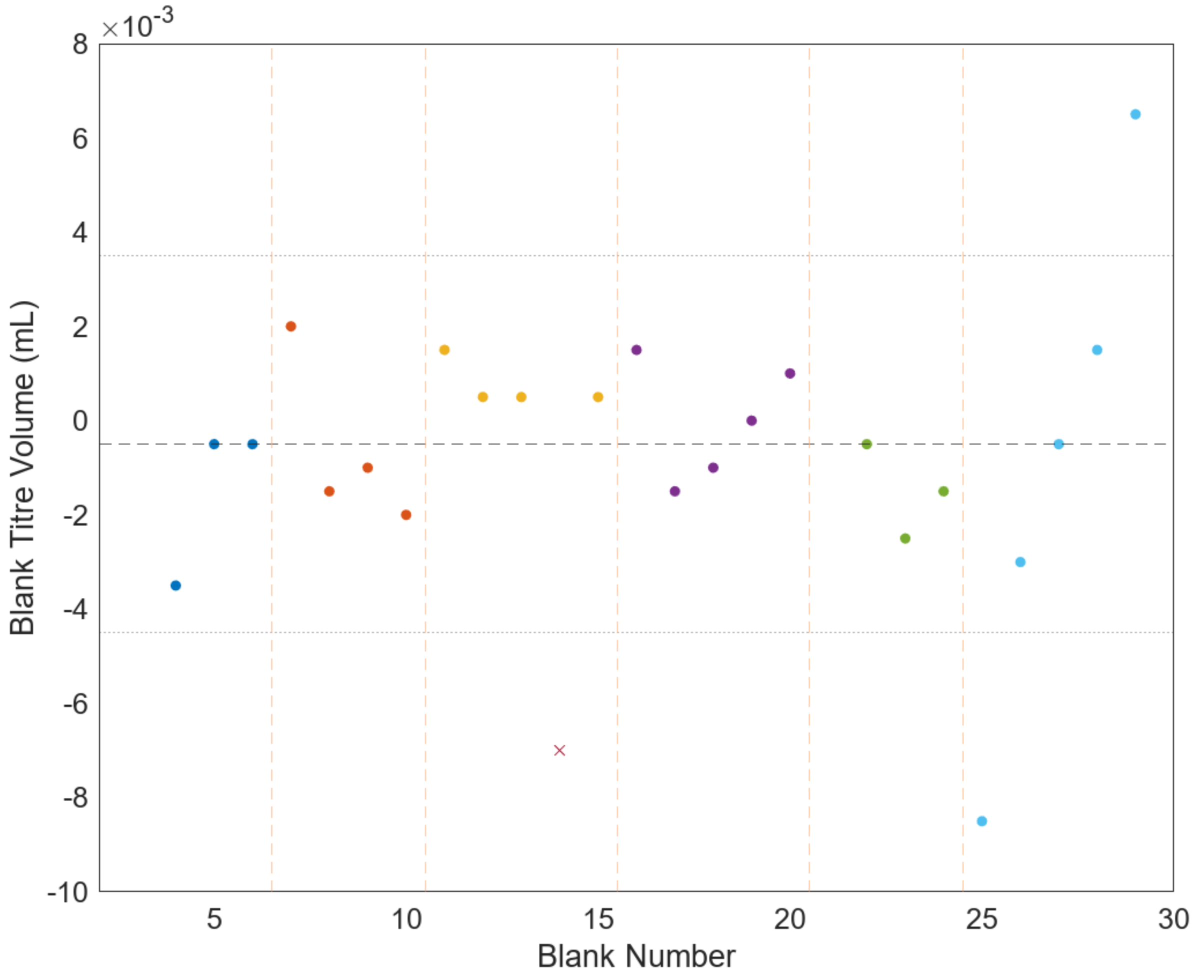


Figure 10.2 Titre volume from blank analyses during DY174. Colours indicate different days of analysis, demarcated by the vertical orange dashed line. 'x' marks analyses that were classified as outliers and not used to calculate the blank median (grey dashed line). The dotted line indicates volumes ± 0.004 from the blank median. The cruise median is displayed as the grey dashed line.

10.4 Standard Analysis

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 once. 5 standard runs were performed per set and values within ± 0.3% of each other were kept for calculation. The median value calculated from all the suitable standard titres during the cruise was 0.4585. Figure 10.3 shows the results of the standard analyses throughout DY174 and the median blank and standard titres per analysis set are shown in Table 10.2.

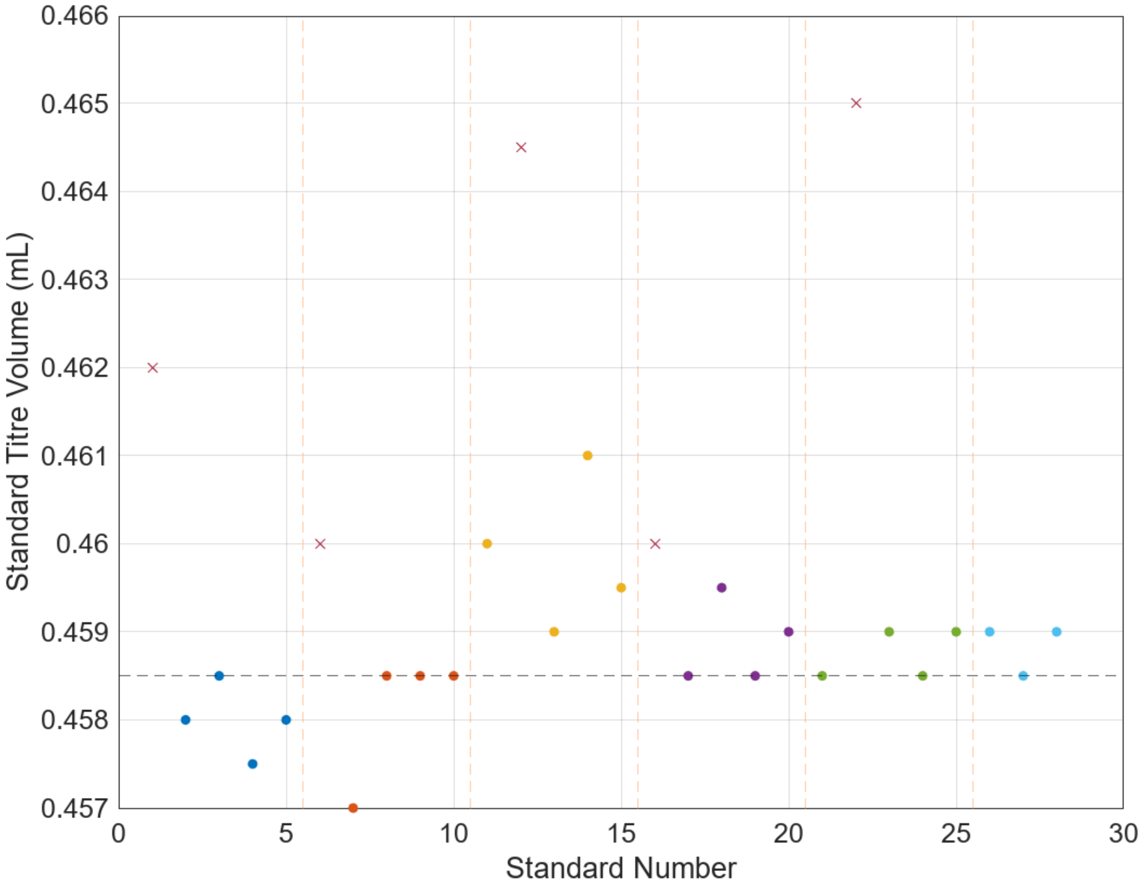


Figure 10.3 Results of 5mL iodate standard titre volumes from DY174. Colours indicate different days of analysis, demarcated by the vertical orange dashed line. 'x' marks values that were not used to calculate the standard median.

The first standard run from set 2 and 4 were omitted from calculations are these were higher than the other values calculated in the remainder of the set. The standard volumes obtained from analysis set 3 show largest spread, this coincides with the standards run just after both dispensers were debubbled. The deviation of standard volume from the median value is negative in analysis sets 1 and 2 and positive in set 4, 5 and 6. This suggests there could be a drift in the standard volume from 0.4580 for the first two analysis sets to 0.4590 for the last three. Although the 0.0005 deviation from the median is the resolution of the instrument and so it is not possible to conclude with confidence that there was a drift in standard titre volumes. Additionally, considering the short time span of the analysis (6 days), it is unlikely that the quality of the standard or titre changed.

Whole Cruise Blank Median	Analysis Set	Day	Blank Median	Standard Median	CTD Casts Analysed
-0.0005	**1**	28.03.24	-0.0005	0.4580	-
	2	29.03.24	-0.0015	0.4585	1 and 2
	3	30.03.24	0.0005	0.4598	3, 4 and 5
	4	31.03.24	-0.0005	0.4588	6 and 7
	5	01.04.24	-0.0015	0.4588	8 and 9
	6	02.04.24	-0.0005	0.4590	10, 11 and 12

Table 10.2 Median values for blanks and standards used in oxygen calculations over the course of the cruise

10.5 Sample Analyses

Samples were stored and analysed within 24 hours following the method outlined by Langdon (2010). Before running each sample batch, blanks and standards were run until satisfactory stability was achieved. Between each flask (blank, standard, or sample), the burette tips, electrode and stirrer were rinsed with Milli-Q and the electrode tip carefully dried, checking for any contamination.

When ready to titrate, the Milli-Q water seal was poured away, the neck dried, and the stopper of the flask carefully removed. A 1 ml aliquot of 5 M sulfuric acid was dispensed, immediately followed by a clean magnetic stirrer. The flask was placed on the stir plate and the electrode and thiosulfate burette were carefully inserted to place the tips in the lower-middle depth of the sample flask. The initial volume of sodium thiosulphate for each sample was 0.3 ml before continuing to be titrated at 0.0005 ml intervals using the amperometic end-point detection electrode (Culberson and Huang, 1987) to the end current of 0.1 x 10^{-6} A. The resultant volume of titrant was recorded both by manual logging and automatically on the Ti-Touch. Following this the value was converted to a DO concentration within an Excel file, using bottle volumes, expansion coefficients and sample temperatures, blank and standard titres, and standard volume, and saved as *DY174_oxygen_calculation.xlsx*. Preliminary quality code flags were assigned to the data (2=Good, 3=Questionable, 4=Bad, 5=Not analysed).

Figure 10.4 shows vertical profiles of oxygen concentrations measured on DY174 for the different CTD casts and Figure 10.5 shows the oxygen concentrations at the discrete depths sampled at each CTD.

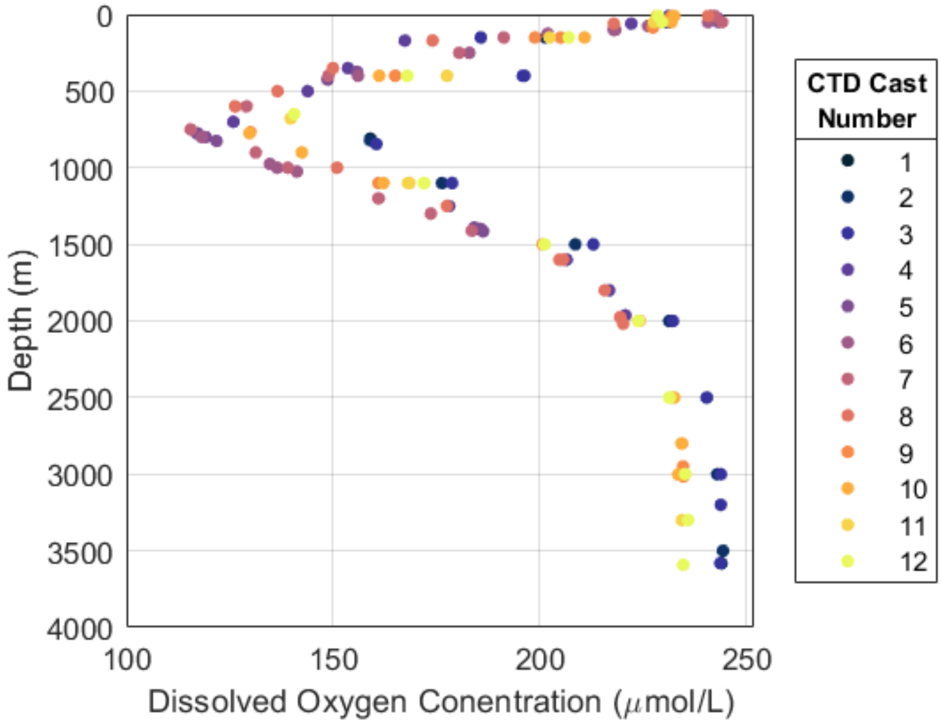


Figure 10.4 DY174 dissolved oxygen concentration profile. Colours correspond the CTD cast number.

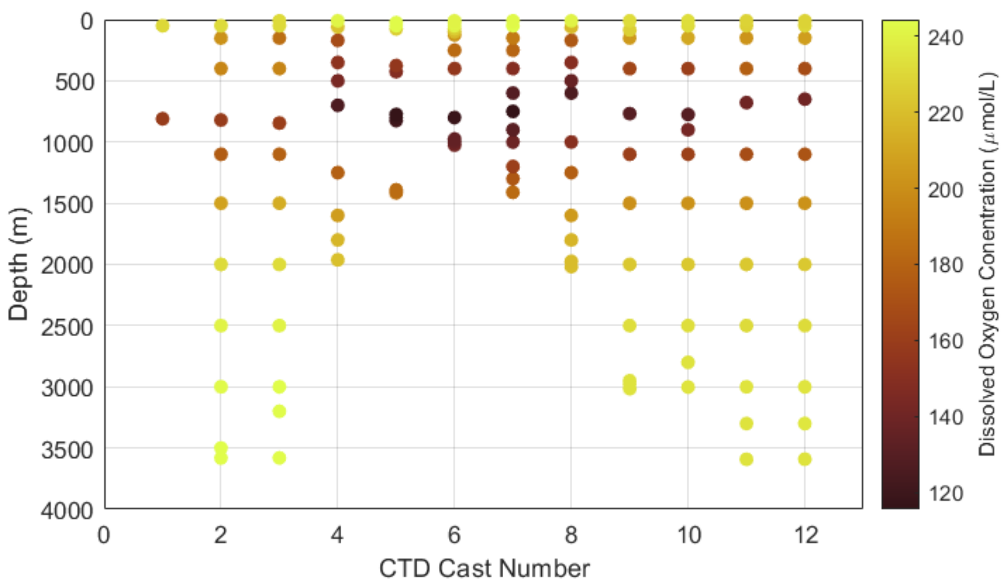


Figure 10.5 Dissolved oxygen concentrations at the sampled depths per CTD cast.

10.6 Duplicate Sample Analysis

A total of 16 replicates were taken. The differences between sample and duplicate bottle results are shown in Figure 10.6, this is obtained by subtracted the duplicate oxygen concentration from the sample oxygen concentration. Of the 16 duplicate differences 3 are questionable due to their large value, these are marked on Figure 10.5 with red crosses. The median duplicate difference was negative 0.1590 µmol L^{-1}. There were more negative differences than positive indicating that the measured oxygen concentration of the duplicate was larger than that measured for the sample. This might suggest the second sample from a Niskin is already "contaminated" by exposure to air, but there are not enough duplicate samples here for confidence.

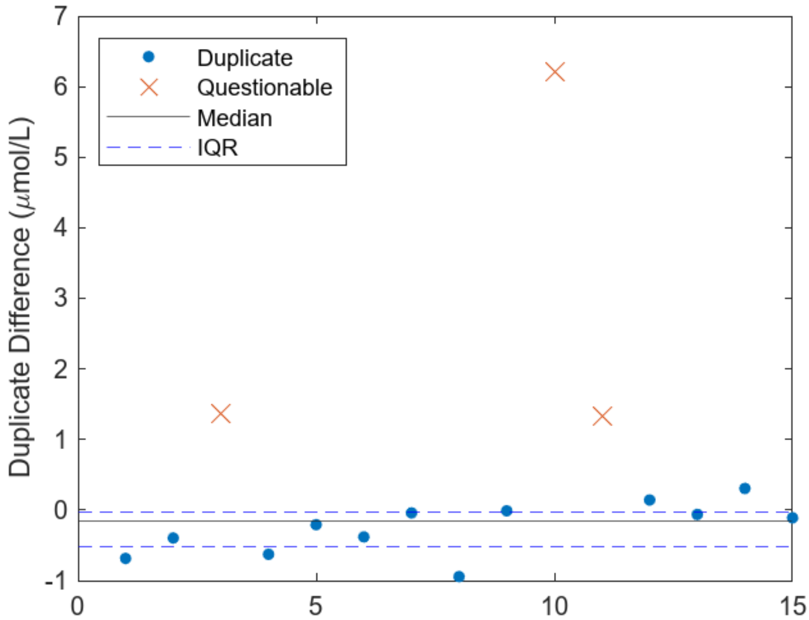


Figure 10.6 Differences between replicate oxygen concentrations on DY174. Red 'x' mark questionable duplicate differences. Blue dotted lines mark the interquartile range (IQR), which represents the middle 50% of the values from the 25th percentile to the 75th percentile.

10.7 References

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

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

11. Discrete Chemical Sampling

Sunke Trace-Kleeberg

Discrete bottle samples were collected for later analysis of dissolved inorganic carbon (DIC), inorganic nutrients, and organic nitrogen at a subset of CTD stations. DIC and nutrient samples were collected from CTD casts pre recovery of EBH1, EBH2 and EBH3 moorings. DIC samples were also taken during the final CTD cast where LOC sensors were attached to the rosette. Details of the stations sampled are displayed in Table 11.1, and further details of discrete sample depths are given in Table 11.2 for depths above 1000m and Table 11.3 for depths below 1000m.

CTD cast	Date	Total Carbon	Carbon Duplicates	Total Nutrients	Nutrient Duplicates	Carbon Notes
004	29.03.24	11	1	12	2	Niskins 1 and 11 leaked so weren't sampled
005	29.03.24	14	2	14	2	
006	29.03.24	13	1	13	1	
009	01.04.24	14	2	14	2	
012	02.04.24	8	2	0	0	
Total		**60**	**8 (13%)**	**53**	**8 (15%)**	

Table 11.1 Summary of CTD casts sampled for carbon and nutrients

11.1 Dissolved Inorganic Carbon and Total Alkalinity

A total of 5 stations were sampled for dissolved inorganic carbon (DIC) (60 samples in total). Details of the number of samples and duplicates taken at each station are given in Table 11.1. Borosilicate glass bottles were used to collect seawater from the rosette immediately after oxygen samples were taken. This was typically within 30 minutes of the CTD being secured in the hangar. A short piece of Tygon tubing was attached to the Niskin spigot and used to draw water into the pre-washed bottles. The tubing was pre-soaked in Milli-Q water to keep it supple and to reduce the build-up of bubbles. The bottles and stoppers were rinsed three times. Then the bottle was filled by reducing the flow and holding the tubing at the bottle of the sample bottle. The bottle was allowed to overflow by at least one full bottle volume. The bottle stopper was inserted into the bottle taking care to avoid introducing bubbles. Once all samples were taken from the CTD, the crate was carried back into the laboratory.

Samples were fixed in the fume cupboard of the deck laboratory. A Pasteur pipette was used to create a headspace in each sample by removing 2.5 ml of bottle volume. The sample was than preserved with 50 µL of saturated mercuric (II) chloride ($HgCl_2$) (for more details see Dickson et al., 2007). The ground glass of the stopper was dried with blue roll. Apiezon grease was applied to the stopper before it was inserted completely into the bottle. The stopper was twisted to remove residual air from the grease and to ensure a complete seal was made. An elastic band and clip were placed on the bottle top to secure the lid in place. Finally, the sample was mixed by inverting the bottle 3 – 4 times. DIC sample bottles were labelled with cruise ID, CTD cast and Niskin bottle number as follows: DY174 CTD#_niskin#. This DIC samples were stored in their boxes in the chemistry lab at approximately 21˚C and stayed there for the transit from Santa Cruz de Tenerife to Southampton.

11.1.1 Some Useful Laboratory Setup Tips:

- The $HgCl_2$ bottle was stored in two zip-lock bags in the cardboard box it was shipped in. Gloves, tissues and used pipette tips were kept in a waste zip-lock bag. At the end this was stored in the box with $HgCl_2$ for disposal on land.
- The pipette used for $HgCl_2$ was placed into a small zip-lock bag after all preservation was finished and transported with the other $HgCl_2$ materials.

Figure 11.1 Photograph of the fume hood setup.

11.2 Nutrients

A total of 4 stations were sampled (53 samples in total) for inorganic/organic nutrients (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 3 times before being filled to approximately 75% full and after all samples were collected then bagged and frozen at approximately -20˚C for later analysis at NOC facilities. Nutrient samples were labelled cruise ID, CTD cast and Niskin bottle number as follows: DY174_CTD#_niskin#.

Table 11.2 Location of samples collected for chemical analysis above 1000m during DY74. Key: DO – dissolved oxygen, DIC - Carbon, NUTS – inorganic and organic nutrients. Note that depths are approximate.

DO | DIC | NUTS

Date	28-Mar	28-Mar	28-Mar	29-Mar	29-Mar	29-Mar	30-Mar	30-Mar	01-Apr	01-Apr	02-Apr	02-Apr	Date
Lat (°N)	28°44.170	28°44.225	28°44.273	27°36.493	27°48.100	27°48.100	27°47.872	27°36.880	27°13.680	27°13.60	27°10.76	27°10.76	Lat (°N)
Lon (°W)	15°47.530	15°47.470	15°47.440	14°13.075	13°45.386	13°45.380	13°45.298	14°13.382	15°24.768	15°24.70	16°47.72	16°47.72	Lon (°W)
Station / Depth	1	2	3	4	5	6	7	8	9	10	11	12	Station / Depth
10		DO	DO	DO, DIC, NUTS		DO, DIC, NUTS	DO	DO	DO, DIC, NUTS	DO	DO	DO	10
25					DO, DIC, NUTS	DO, DIC, NUTS							25
50	DO	DO	DO		DO, DIC, NUTS	DO, DIC, NUTS	DO			DO	DO	DO, DIC	50
60				DO, DIC, NUTS				DO					60
75					DO, DIC, NUTS	DO, DIC, NUTS							75
85									DO, DIC, NUTS				85
100						DO, DIC, NUTS							100
125						DO, DIC, NUTS							125
150			DO				DO		DO, DIC, NUTS	DO	DO	DO	150
170				DO, DIC, NUTS				DO					170
250						DO, DIC, NUTS	DO						250
350				DO, DIC, NUTS				DO					350
375					DO, DIC, NUTS								375
400		DO	DO		DO, DIC, NUTS	DO, DIC, NUTS	DO		DO, DIC, NUTS	DO	DO	DO	400
425					DO, DIC, NUTS								425
500				DO, DIC, NUTS				DO					500
600							DO	DO					600
650											DO	DO, DIC	650
700				DO, DIC, NUTS									700
750							DO						750
775					DO, DIC, NUTS				DO, DIC, NUTS	DO			775
800					DO, DIC, NUTS	DO, DIC, NUTS							800
810	DO												810
820		DO											820
825					DO, DIC, NUTS								825
845			DO										845
900							DO			DO			900
975						DO, DIC, NUTS							975
Depth / Station	1	2	3	4	5	6	7	8	9	10	11	12	Depth / Station

Table 11.3 Location of samples collected for chemical analysis below 1000m during DY74. Key: DO – dissolved oxygen, DIC - Carbon, NUTS – inorganic and organic nutrients. Note that depths are approximate.

Key: DO | DIC | NUTS

Date	28-Mar	28-Mar	28-Mar	29-Mar	29-Mar	29-Mar	30-Mar	30-Mar	01-Apr	01-Apr	02-Apr	02-Apr	Date
Lat	28°44.170	28°44.225	28°44.273	27°36.493	27°48.100	27°48.100	27°47.872	27°36.880	27°13.680	27°13.60	27°10.76	27°10.76	Lat
Lon	15°47.530	15°47.470	15°47.440	14°13.075	13°45.386	13°45.380	13°45.298	14°13.382	15°24.768	15°24.70	16°47.72	16°47.72	Lon
Station / Depth	1	2	3	4	5	6	7	8	9	10	11	12	Station / Depth
1000						DO, DIC, NUTS	DO	DO					1000
1100									DO, DIC, NUTS		DO		1100
1025						DO, DIC, NUTS							1025
1100		DO	DO							DO		DO	1100
1200	DO						DO						1200
1250				DO, DIC, NUTS				DO					1250
1300							DO						1300
1390					DO, DIC, NUTS								1390
1400					DO, DIC, NUTS		DO						1400
1415					DO, DIC, NUTS								1415
1500	DO	DO	DO						DO, DIC, NUTS	DO	DO	DO, DIC	1500
1600				DO, DIC, NUTS				DO					1600
1800				DO, DIC, NUTS				DO					1800
1900				DO, DIC, NUTS									1900
1975								DO					1975
2000		DO	DO						DO, DIC, NUTS		DO	DO	2000
2020								DO					2020
2500		DO	DO						DO, DIC, NUTS	DO	DO	DO, DIC	2500
2800										DO			2800
2950									DO, DIC, NUTS				2950
2975									DO, DIC, NUTS				2975
3000		DO	DO						DO, DIC, NUTS	DO	DO	DO, DIC	3000
3200			DO										3200
3300											DO	DO, DIC	3300
3500		DO											3500
3600		DO	DO								DO	DO	3600
Depth / Station	1	2	3	4	5	6	7	8	9	10	11	12	Depth / Station

12. Moorings

Yvonne Firing, Jules Kajtar, Sara Fowler, Darren Rayner, Guillaume Hug

12.1 Mooring Recoveries

Three moorings and one lander were recovered (Table 12.1). EBH3 had no recovery sphere/line, and a moderate amount of fishing gear wrapped around the top sphere and upper part of the line, while the shallowest sensor frame was significantly deformed to one side and the top clamp on the MicroCAT at 150 m was sheared off. When the top 150 m was recovered it was revealed that the line in the water had parted at some point presumably during the recovery, leaving the remainder of the mooring drifting behind. It was re-grappled and recovered fully. EBH1 had to be grappled in the middle, and the line parted at a termination partway through recovery resulting in a near miss. It was re-grappled and recovered fully.

Mooring	Deployment cruise	Deployment date	Recovery date	Time of first ranging	Recovery start time	Recovery duration [hh:mm]
EBH2	DY146	24 Feb 2022	29 Mar 2024	13:36	14:49	0:41
EBH3	DY146	27 Feb 2022	30 Mar 2024	08:37	09:40	3:09
EBH1L14	JC192	30 Mar 2020	01 Apr 2024	06:28	07:36	0:22
EBH1	DY146	23 Feb 2022	01 Apr 2024	08:33	10:54	1:30

Table 12.1 Moorings recovered on DY174, with deployment dates and recovery details

Instruments (Table 12.2) were recovered without visually obvious damage, although one sensor frame battery pack had exploded. The two MicroCAT-ODOs deployed in the SeapHOX configuration with SeaFETs on EBH3 did not record data on their own recorders but on the SeapHOX recorders. One of the two Seagauge bottom pressure recorders on EBH1L had flat batteries on return so no data was downloaded

Mooring/Lander	Instrument	S/N	Approx Depth (m)	Mean P recorded	Start Date	End Date	Cycles	Comment
ebh2_15_2022	MicroCAT	3271	1600	1512	2022/02/24	2024/03/29	18336	Ok
ebh2_15_2022	MicroCAT-ODO	10545	1600	1512	2022/02/24	2024/03/29	4584	Ok
ebh2_15_2022	MicroCAT	3277	1800	1825	2022/02/24	2024/03/29	18336	Ok
ebh2_15_2022	MicroCAT-ODO	10520	2000	2031	2022/02/24	2024/03/29	4584	Ok
ebh2_15_2022	MicroCAT	3255	2000	2032	2022/02/24	2024/03/29	18337	Ok
ebh3_15_2022	MicroCAT	6821	50	29	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	DeepSeapHox	721-2034 (ODO 14115)	50		2022/02/27	11/03/2023	3685	Instrument seems to break after ~2050 samples. Disconnected during download and cannot reconnect so more data may still be present on recorder.
ebh3_15_2022	OTE LOC N	N130	50		2022/02/27	2022/10/09	1340	Probably bad after the first few days
ebh3_15_2022	MicroCAT	6825	100	80	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	DeepSeapHox	2035 (ODO 14148)	100		2022/02/27	2024/03/30	4573	Ok
ebh3_15_2022	MicroCAT	6820	175	158	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT-ODO	12999	200	206	2022/02/27	2024/03/30	4570	Ok
ebh3_15_2022	MicroCAT	10716	250	235	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT	4466	325	310	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT	6128	400	386	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT-ODO	12911	400	386	2022/02/27	2024/03/30	4569	Increasing spikes in O_2 toward end of deployment, due to bad OT
ebh3_15_2022	Contros Hydro-C	1114-001	400		2022/02/27			Cannot connect to instrument
ebh3_15_2022	OTE LOC N	N128	400		2022/02/27	2022/03/11	72	First few samples don't look good
Mooring/Lander	Instrument	S/N	Approx Depth (m)	Mean P recorded	Start Date	End Date	Cycles	Comment
ebh3_15_2022	OTE LOC P	P64	400		2022/02/27	2022/03/01	13	Ok
ebh3_15_2022	Nortek	9427	500		2022/02/27	2024/03/30	18405	Ok

ebh3_15_2022	MicroCAT	5785	500	483	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT	5772	600	591	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT	5765	700	693	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT	4306	800	790	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT-ODO	10547	800	790	2022/02/27	2024/03/30	4569	Ok
ebh3_15_2022	OTE LOC TA	TA19	800		2022/02/27	2023/01/04	994	Needs processing off ship - raw data indicates at least second half of deployment is not good
ebh3_15_2022	OTE LOC N	N129	800		2022/02/27	2022/03/05	35	Ok
ebh3_15_2022	OTE LOC P	pH47	800		2022/02/27	2023/12/10	1407	Ok
ebh3_15_2022	Nortek	9435	800		2022/02/27	2024/03/30	18405	Ok
ebh3_15_2022	MicroCAT	3933	1000	998	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT-ODO	12907	1000	1000	2022/02/27	2024/03/30	4570	Ok
ebh3_15_2022	OTE LOC TA	TA18	1000		2022/02/27	2023/05/22	1438	Raw file too large to open here, data may or may not be good
ebh3_15_2022	OTE LOC pH	PH48	1000		2022/02/27	2023/03/11	814	Raw file too large to check here
ebh3_15_2022	Nortek	11024	1000	1007	2022/02/27	2024/03/30	18405	Ok
ebh3_15_2022	MicroCAT	3900	1200	1214	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	Nortek	13482	1300	1331	2022/02/27	2024/03/30	18405	Ok
ebh3_15_2022	MicroCAT	3252	1400	1421	2022/02/27	2024/03/30	18279	Ok
ebh3_15_2022	MicroCAT-ODO	10546	1400	1417	2022/02/27	2024/03/30	4569	Ok
ebh1L14_14_2020	SBE26	399			2020/03/13	2024/04/01		
ebh1L14_14_2020	SBE26	398			2020/03/13	2024/04/01		
Mooring/Lander	**Instrument**	**S/N**	**Approx Depth (m)**	**Mean P recorded**	**Start Date**	**End Date**	**Cycles**	**Comment**
ebh1_15_2022	MicroCAT	3229	2500	2530	2022/02/23	2024/04/01	18425	Ok
ebh1_15_2022	MicroCAT-ODO	10519	2500	2537	2022/02/23	2024/04/01	4606	Strong O_2 hysteresis
ebh1_15_2022	MicroCAT	3209	3000	3073	2022/02/23	2024/04/01	18425	Ok
ebh1_15_2022	MicroCAT-ODO	10517	3000	3073	2022/02/23	2024/04/01	4606	Strong O_2 hysteresis
ebh1_15_2022	OTE LOC pH	50	3000		2022/02/23	22/09/2022	899	Ok

ebh1_15_2022	OTE LOC TA	20	3000		2022/02/23			Flooded

Table 12.2 **Mooring instrument record lengths.**

EBH3_15_2022 used Dyneema line, which was also used in the initial 2023 WB1 and WB2 deployments where the moorings surfaced and/or snapped and had to be recovered shortly after deployment, which turned out to be due to the lines being longer than planned. On recovery and inspection of the EBH3 data, the top instruments were also about 18 m shallower than planned, with the depth offset decreasing farther down the mooring (Figure 12.1) to actually be deeper than planned near the bottom.

EBH3_15_2022 also exhibited a sudden step of a few dbar in the pressure of all instruments (Figure 12.1, step is most evident in the deeper sensors where the background signal is smaller) in January 2024. The mooring seems to have been dragged to a slightly deeper seabed position at that point, with this event likely associated with the deformation of the top sensor frame (and possibly with the fouled fishing gear).

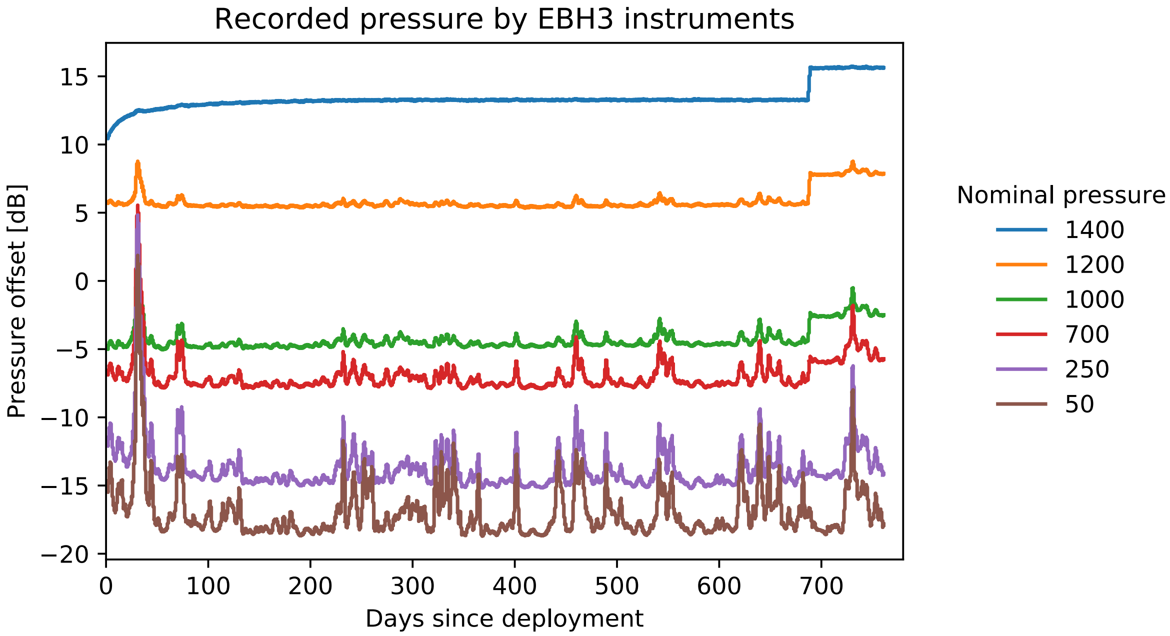


Figure 12.1 **Selected EBH3_15_2022 pressure records as anomalies from their planned pressures (based on mooring deployment diagram depths converted to pressure using sw_pres**

12.1.1 Biogeochemical Sensor Recoveries

All of the biogeochemical (BGC) instruments were successfully recovered from EBH3, including various Lab-on-Chip (LOC) sensors, Deep SeapHox, and Contros instruments. There was a large variability in the length of time the sensors were successfully measuring and logging data during their 2-yearlong deployment (a summary of this can be found in the document “recovered_instruments”).

Observations:

- The 50 m frame was bent on one side and the whole frame and instruments were heavily biofouled (Figure 12.2).
- High volume of reagents remaining on the LOC sensors suggesting the sensors failed before their anticipated Stop Date. Waste volumes were also much lower than anticipated.
- Generally, there was corrosion on the frames, mostly where they had been welded, or the bolts, including some of the screws on the MicroCATS (Figure 12.3). The anodes had completely corroded away, so larger anodes are probably required in the future.

- The battery housing (SN07) connected to pH 48 at 1000 m suffered a catastrophic failure during deployment, resulting in the end cap blowing off (but staying attached via the power cable; Figure 12.4).
- 2 other battery housings had corroded bulkheads (Figure 12.5) and were therefore treated as potentially flooded and kept out on the aft deck pointing towards the water.
- Data files from the LOCs were very large and awkward to download.
- The Contros recovered from 400 m was not responsive, even when connected to external power.
- All nutrient LOC sensors from 400 m and 800 m failed between 1-13 days.
- pH 47 from 800 m has logged data from 27/02/2022-10/12/2023, but unfortunately the preliminary assessment of the data suggests the data is not valid after July 2022.

There were 2 LOCs on EBH1 at 3000 m, both were recovered successfully. However, it was evident that the TA sensor had flooded (Figure 12.6), and judging by the volume of waste NaOH, this happened very close to the beginning of the deployment. The pH sensor measured for a total of 7 months.

From the remaining reference materials on all TA sensors, subsamples were collected in screw top glass bottles to enable TA analysis in the OTE laboratory in order to identify/confirm any potential drift in reference values from the start of the deployment.

Figure 12.2 Biofouling on the 50 m EBH3 frame.

Figure 12.3 Examples of corrosion on the frames and instruments.

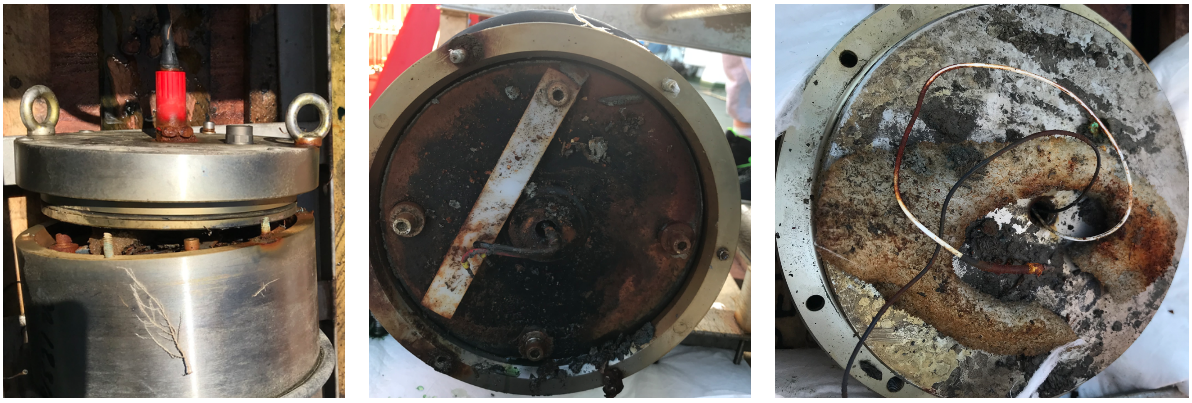


Figure 12.4 Battery housing SN07 on recovery. Bolts have sheared off to open the lid, likely caused by seawater leaking into the housing and reacting with the lithium batteries.

Figure 12.5 Evidence of bulkhead corrosion on titanium battery housings.

Figure 12.6 Pressure pin protruding from TA 20 on recovery, indicating seawater inside the sensor housing.

12.1.2 BGC Sensors: seaFET and Contros

<u>SeaFET 2034 paired with ODO 14115 @50m</u>

This instrument had an incomplete download on the cruise and then wouldn't reconnect to the software. When back at NOC, a magnet swipe caused a red flash of the LED implying it had power in the batteries but had been stopped from logging. On trying with the Windows laptop, it connected straight away (without external power required), and I downloaded a complete record from it. It is unclear why it wouldn't connect on the cruise. Possibly the batteries were low on the cruise and recovered sufficiently to talk when back at NOC, but it had been tried with external power with no success and V2 SeaFETs don't log battery voltage so we can't check if this was getting low. The pH data goes bad around February 2023, but the CTD and O2 data look fine (Figure 12.7). Data have been converted to rodb format with the updated seaphox2rodb_01.m and seaphox_raw2use_01.m routines and are in the ebh3_15_2022 proc folder on the network. This sensor was very difficult to open to remove the batteries. The aluminium housing has badly corroded (Figure 12.8), and the resulting oxide had squashed the O-rings nearly causing this instrument to flood. The endcap at the other end was not as corroded and it looks like the sacrificial anode worked better at that end. This instrument will need repair.

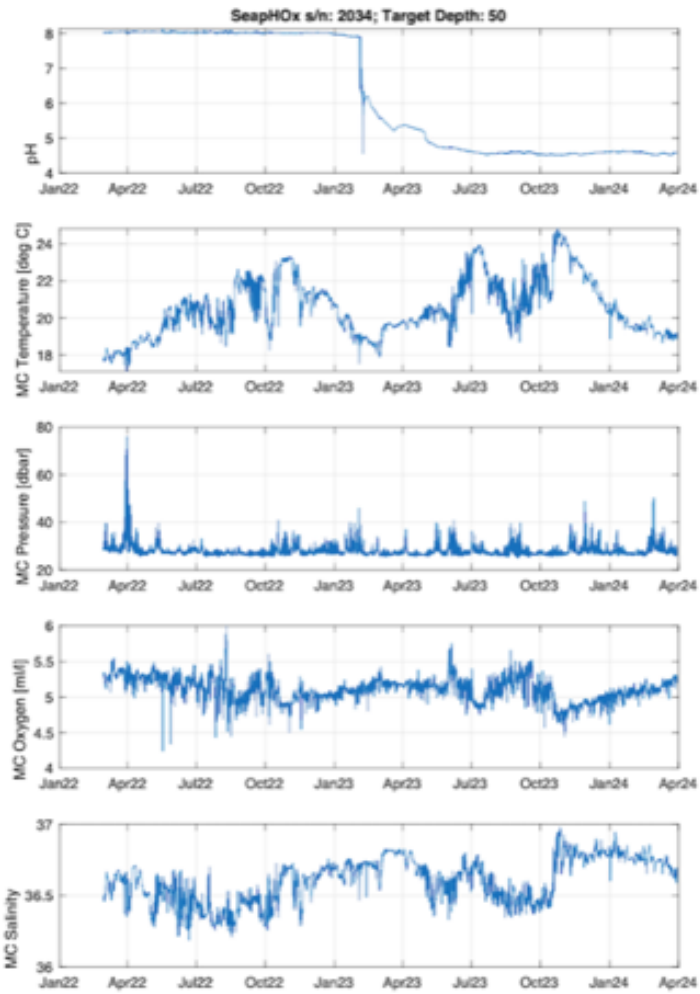


Figure 12.7 SeaFET timeseries data at 50 m.

Figure 12.8 Corroded aluminium housing on SeaFET.

SeaFET 2035 paired with ODO 14148 @100m

This instrument had a complete record downloaded on the cruise. At first glance all the data looks reasonable, though the pressure record jumps from 80-150 dbar in early 2024 (Figure 12.9). This instrument was attached using the MicroCAT clamps rather than in a frame and checking the temperature records of the nearby MicroCATs you can see the temperature was nicely tracking the 100m sensor, then drops a couple of degrees at the same time the pressure increases. The temperature then tracks the MicroCAT at 175 m, so it looks like this unit slid down the wire. Care will need to be taken when interpreting the pH and O2 timeseries. The timing of this coincides with the deepening of the other MicroCATs on the mooring, suggesting it was caused by the impact of fishing gear. The anodising on the housing has been damaged by biofouling but the end caps were not corroded like the other SeaFET.

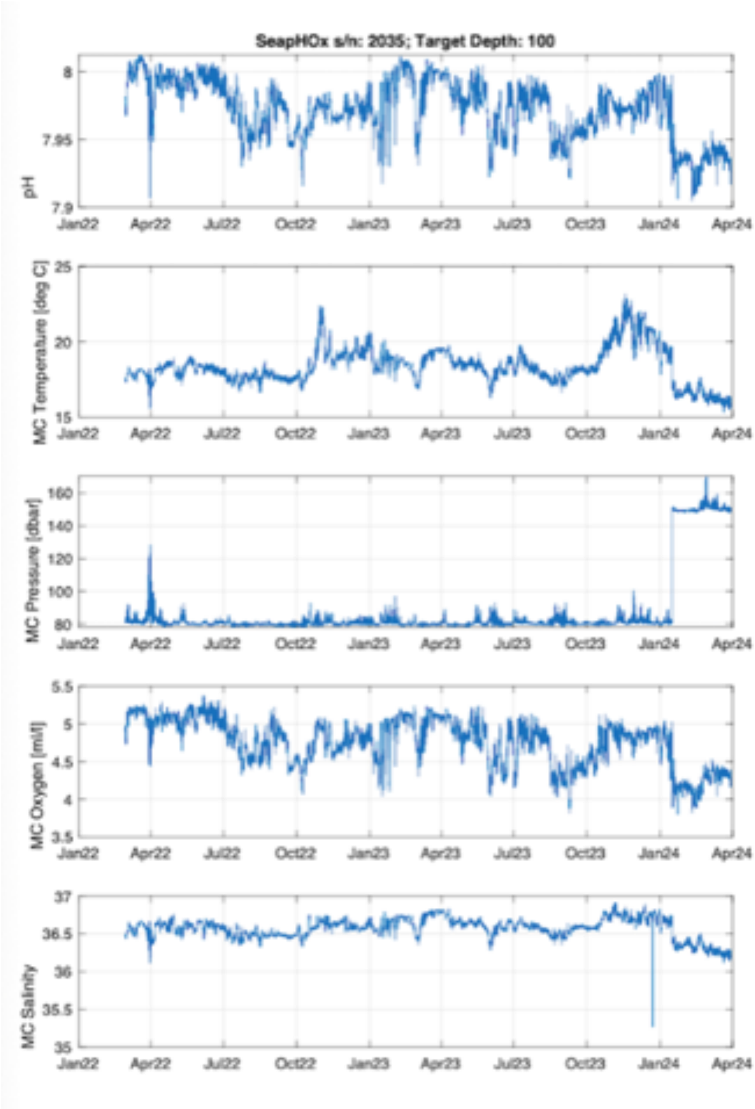


Figure 12.9 SeaFET timeseries data at 100 m.

<u>Contros 1114-002 @50m</u>

This was downloaded successfully on the cruise, but data were not transferred to the network, so it was re-downloaded at NOC. The timeseries is complete and looks good. Initial post-processing using the pre-deployment calibration, and the zeroing measurements takes out the evident drift and this can be further improved when we get the post-recovery calibration completed at Contros. The copper flow head on this sensor is significantly corroded and the pump has lost its copper guard with the plastic beneath broken. The photo of the dented frame shows the pump was oriented inside the frame, but it was potentially damaged at the same time as the frame was dented. The routines to convert the data to rodb format will need modifying to handle raw data from the SD card too (see next sensor) as the badly written software does not allow you to convert the raw format NMEA text file to a csv unless it is done immediately after download.

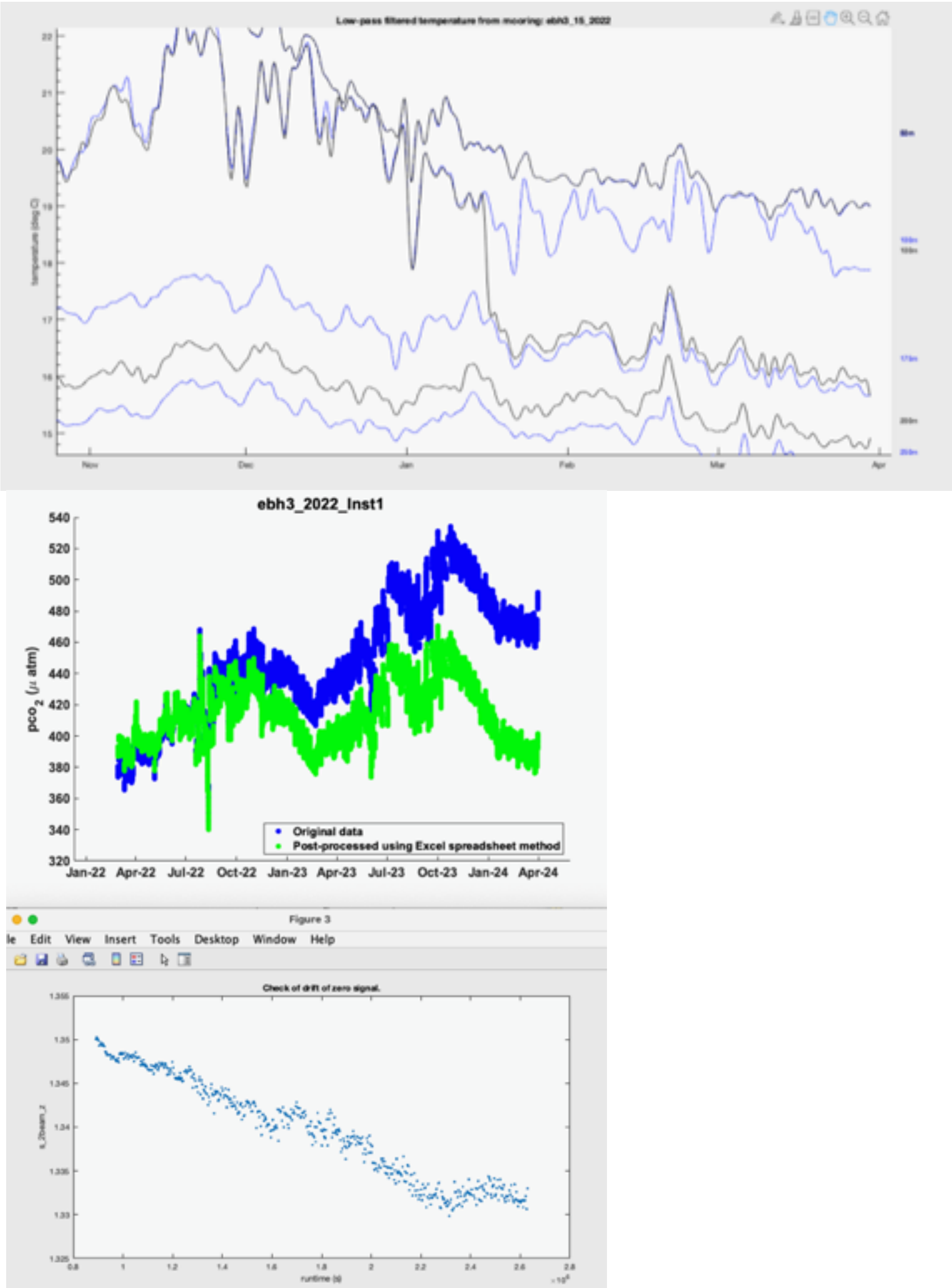


Figure 12.10 Contros timeseries data at 50 m.

<u>Contros 1114-001 @400m</u>
This wouldn't communicate on the cruise and there was no vibration when connecting external power so I suspected it to be flooded. Undoing the bulkhead connector to reveal the O-ring did not relieve any pressure so I assumed it was ok and started to remove the end cap. When loosening the screws the endcap cocked slightly implying there was pressure inside, but it was not high as I could hold the end down with my hand whilst undoing the bolts. This pressure

was then released with a hiss and the sensor opened. The instrument appears to have suffered a low-pressure flood with a small amount of water evident in the housing.
The SD card contained data from February 2024 until September 2023, so I suspect there was a low-pressure flood on deployment which sealed at depth, but the water that got in eventually led to an electronics failure. The data confirms this is likely as there is only a month or two of potentially valid data (further scrutiny required), with the sensor appearing to fail before the logger. The pump clamp bracket was also broken but I have no explanation for this (unless I accidentally mixed the clamps up and this broken one was actually from the shallower unit that got hit). This sensor will need repair or disposal if too severely damaged.

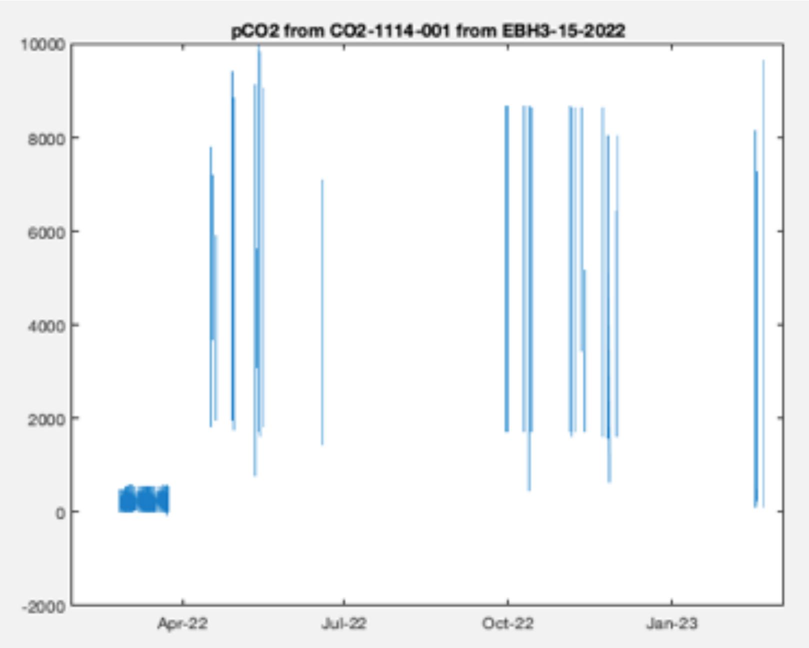


Figure 12.11 Contros timeseries data at 400 m.

12.2 Mooring Deployments

Four moorings (two full-depth and two short) and two landers were deployed (Table N.3). Currents were changeable with what appeared to be eddies reversing the direction of 0.3-0.4 kt currents over the time from positioning to deployment, but all deployments were completed in time for the target positions. Each mooring deployed was ranged to determine its position on the seabed by trilateration (Figure 12.12). EBH3B, a new MicroCAT-only mooring, was sited not far from the EBH3 position as backup to compensate for the removal on DY146 of the former end of the line at EBH4.

	Deployment start	Anchor drop time, position, depth				Trilaterated anchor seabed position		Fall-back [m]
Mooring		**Time**	**Lat [N]**	**Lon [W]**	**Depth [m]**	**Lat [N]**	**Lon [W]**	
EBH3	30 Mar 2024 14:47	30 Mar 2024 16:49:44	27° 48.46'	13° 44.93'	1424	27° 48.49'	13° 44.86'	124
EBH3L1	30 Mar 2024 17:25	30 Mar 2024 17:34:45	27° 47.92'	13° 45.05'	1418	27° 47.93'	13° 45.05'	25
EBH3B	31 Mar 2024 08:12	31 Mar 2024 10:07:00	27° 44.91'	13° 49.98'	1509	27° 44.99'	13° 50.01'	169
EBH2	31 Mar 2024 13:26	31 Mar 2024 13:49:40	27° 36.91'	14° 12.71'	2021	27° 36.94'	14° 12.69'	76
EBH1	01 Apr 2024 13:38	01 Apr 2024 14:42:52	27° 13.35'	15° 25.39'	3041	27° 13.37'	15° 25.29'	166
EBH1L16	01 Apr 2024 15:33	01 Apr 2024 15:34:45	27° 12.19'	15° 25.32'	3038	27° 12.27'	15° 25.21'	232

Table 12.3 DY174 moorings/landers deployed and deployment details

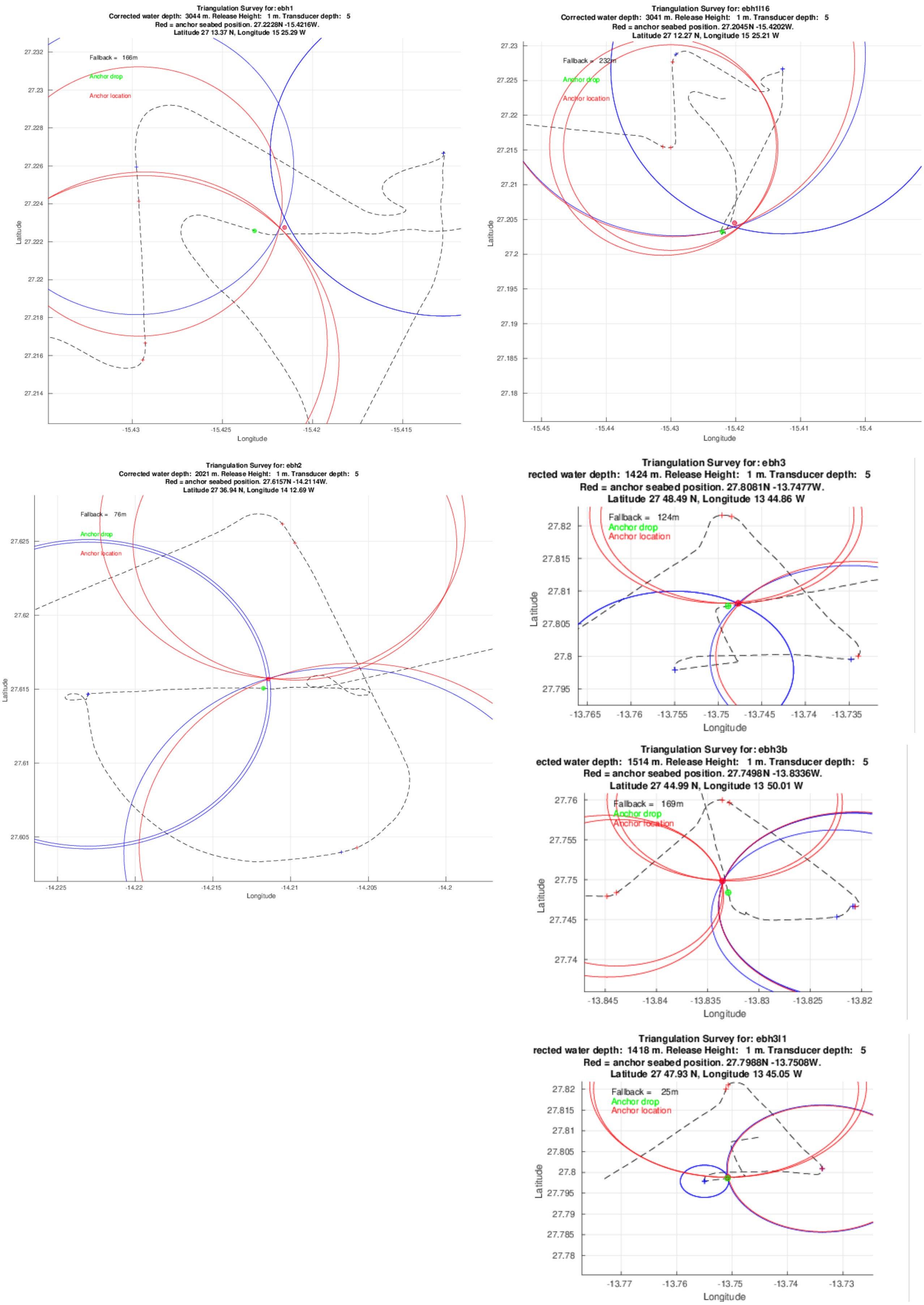


Figure 12.12 Mooring trilaterations.

The deployed sensors and depths are listed in Table 12.4.

Mooring	Target depth	Instrument	S/N
ebh3_16_2024	50	MicroCAT	4800
ebh3_16_2024	50	MicroCAT-ODO	12832
ebh3_16_2024	100	MicroCAT	4797
ebh3_16_2024	175	MicroCAT	5984
ebh3_16_2024	250	MicroCAT	3225
ebh3_16_2024	325	MicroCAT	3483
ebh3_16_2024	400	MicroCAT	4799
ebh3_16_2024	400	MicroCAT-ODO	10556
ebh3_16_2024	500	Nortek	6747
ebh3_16_2024	500	MicroCAT	3931
ebh3_16_2024	600	MicroCAT	5780
ebh3_16_2024	700	MicroCAT	6122
ebh3_16_2024	750	MicroCAT-ODO	10518
ebh3_16_2024	800	Nortek	5831
ebh3_16_2024	800	MicroCAT	5983
ebh3_16_2024	1000	MicroCAT	6322
ebh3_16_2024	1000	Nortek	9210
ebh3_16_2024	1000	MicroCAT-ODO	10545
ebh3_16_2024	1200	MicroCAT	6325
ebh3_16_2024	1300	Nortek	9420
ebh3_16_2024	1400	MicroCAT	6800
ebh3b_1_2024	50	MicroCAT	4475
ebh3b_1_2024	100	MicroCAT	6804
ebh3b_1_2024	175	MicroCAT	4461
ebh3b_1_2024	250	MicroCAT	4713
ebh3b_1_2024	325	MicroCAT	5978
ebh3b_1_2024	400	MicroCAT	7681
ebh3b_1_2024	500	MicroCAT	6822
ebh3b_1_2024	600	MicroCAT	6112
ebh3b_1_2024	700	MicroCAT	11424
ebh3b_1_2024	800	MicroCAT	6335
ebh3b_1_2024	1000	MicroCAT	4796
ebh3b_1_2024	1200	MicroCAT	6814
ebh3b_1_2024	1400	MicroCAT	5776
ebh2_16_2024	1600	MicroCAT	6829
ebh2_16_2024	1600	MicroCAT-ODO	10520
ebh2_16_2024	1800	MicroCAT	3484
ebh2_16_2024	2000	MicroCAT	6835

ebh1_16_2024	2500	MicroCAT	6127
ebh1_16_2024	2500	MicroCAT-ODO	12907
ebh1_16_2024	3000	MicroCAT	6830
ebh3L1_1_2024	1400	SBE53-BPR	426
ebh3L1_1_2024	1400	SBE53-BPR	428
ebh1lL5_15_2024	3000	SBE53-BPR	432
ebh1L15_15_2024	3000	SBE53-BPR	433

Table 12.4 DY174 instruments deployed

12.2.1 Calibration Casts

Two deep casts at the start and two at the end were planned as calibration dips for pre-deployment and post-recovery instruments respectively (Table 12.5). Because an additional ODO on each mooring was added to the plan and the instruments that were shipped did not arrive in time, two ODOs recovered from EBH2 were dipped on the EBH3 post-deployment profile before redeployment on EBH2 and EBH3. While this dip was too shallow to properly calibrate temperature and conductivity, these ODOs will be collocated with MicroCATs that were cal-dipped before deployment, and the shallower profiles allowed us to confirm that the oxygen sensors were still producing sensible profile data. Three MicroCATS recovered on EBH3 were dipped on the EBH3B post-deployment profile to 3000 m before one was redeployed on EBH1; this profile was deep enough to also serve as a calibration dip for T and C.

CTD Cast	Instrument	S/N	Recovered Mooring	Recovered Depth	Deployed Mooring	Deployed Depth	Comment
2	MicroCAT	4800			EBH3	50	
2	MicroCAT	4797			EBH3	100	
2	MicroCAT	5984			EBH3	175	
2	MicroCAT	4713			EBH3B	250	C+0.03 psu
2	MicroCAT	5978			EBH3B	325	C+0.02 psu, P+6 dbar
2	MicroCAT	4799			EBH3	400	
2	MicroCAT	3931			EBH3	500	
2	MicroCAT	5780			EBH3	600	
2	MicroCAT	6122			EBH3	700	
2	MicroCAT	5983			EBH3	800	
2	MicroCAT	6322			EBH3	1000	
2	MicroCAT	6325			EBH3	1200	
2	MicroCAT	6829			EBH2	1600	
2	MicroCAT	3484			EBH2	1800	P-7 dbar at 1000 (good at 2000)
2	MicroCAT	6835			EBH2	2000	
3	MicroCAT	6804			EBH3B	100	C+0.025 psu
3	MicroCAT-ODO	12832			EBH3	50	O+20 but profile shape okay
3	MicroCAT	4475			EBH3B	100	Switch to 50?
3	MicroCAT	4461			EBH3B	175	

3	MicroCAT	3225			EBH3	250	
3	MicroCAT	3483			EBH3	325	
3	MicroCAT	7681			EBH3B	400	C+0.02 psu
3	MicroCAT-ODO	10556			EBH3	400	
3	MicroCAT	6822			EBH3B	500	
3	MicroCAT	6112			EBH3B	600	
3	MicroCAT	11424			EBH3B	700	
3	MicroCAT-ODO	10518			EBH3	750	
3	MicroCAT	6335			EBH3B	800	
3	MicroCAT	4796			EBH3B	1000	
3	MicroCAT	6814			EBH3B	1200	Switch to 1500?
3	MicroCAT	6800			EBH3	1400	
3	MicroCAT	5776			EBH3B	1500	C+0.022, switch to 1200?
3	MicroCAT	6127			EBH1	2500	
3	MicroCAT	6830			EBH1	3000	P noisy
5	MicroCAT-ODO	10520	EBH2	2000	EBH2	1600	O okay, T, C not checked (shallow cast)
5	MicroCAT-ODO	10545	EBH2	1600	EBH3	1000	O okay, T, C not checked (shallow cast)
9	MicroCAT-ODO	10546	EBH3	1400			C-0.025 psu
9	MicroCAT-ODO	10547	EBH3	800			
9	MicroCAT-ODO	12907	EBH3	1000	EBH1	2500	
11	MicroCAT	6825	EBH3	100			
11	MicroCAT	6820	EBH3	175			C+0.023 psu
11	MicroCAT-ODO	12999	EBH3	200			C+0.026 psu
11	MicroCAT	10716	EBH3	250			
11	MicroCAT	4466	EBH3	325			C+0.02 psu
11	MicroCAT	6128	EBH3	400			
11	MicroCAT-ODO	12911	EBH3	400			O still bad (negative and spiky) because of failed OT
11	MicroCAT	5785	EBH3	500			
11	MicroCAT	5772	EBH3	600			
11	MicroCAT	5765	EBH3	700			
11	MicroCAT	4306	EBH3	800			
12	MicroCAT	3229	EBH1	2500			
12	MicroCAT-ODO	10519	EBH1	2500			
12	MicroCAT	3209	EBH1	3000			
12	MicroCAT-ODO	10517	EBH1	3000			
12	MicroCAT	3271	EBH2	1600			C+0.021 psu
12	MicroCAT	3277	EBH2	1800			

12	MicroCAT	3255	EBH2	2000			
12	MicroCAT-ODO	14115	EBH3	50			C+0.025 psu
12	MicroCAT-ODO	14148	EBH3	100			C+0.03 psu
12	MicroCAT	3933	EBH3	1000			
12	MicroCAT	3900	EBH3	1200			
12	MicroCAT	3252	EBH3	1400			C+0.021 psu, P+6 dbar after 5-10 min at 1500 (okay in first 5 min)
12	MicroCAT	6821	EBH3	50			C+0.045 psu

12.2.2 Table 12.5 MicroCAT calibration dips, with comments where one or more parameters differed from CTD by more than the envelope of 0.005 C (0.02 psu) for deep T (S) or 5 dbar for P at the target depth. Biogeochemical Sensors on CTD Casts

LOC sensors pH 53 and TA 18 were deployed on the CTD casts (clipped into Niskin bottle holders) and were powered by connecting the sensors to the Sea-Bird 9+ through a custom electronics hub. The pH sensor was deployed on CTDs 2-12 and the TA sensor on CTD9-12. The sensors were set to Autostart so they start operating as soon as they received power. The automatic deployment state was State 80 (for TA) and State 12 (pH), which were wait states where some valves were opened to allowed pressure equalisation and the Wait Time was set to the number of seconds it was expected to take between powering up and reaching the bottom of the cast. After this wait time, the sensors ran continuously through their State Machine until just before the CTD was brought on deck, so the sensors were not running while out of the water. Generally, the sensors only measuring during the upcast, but during CTD11 and CTD12 the pH ran continuously from the start of the descent. Bottle stops varied from 1-15 minutes, with the 15-minute stops allowing the pH sensor to make replicate measurements during these longer stops. Carbon co-samples can be used to validate the measurements from the LOCs.

Before TA 18 was used on the CTD, it was recovered from the 1000 m mooring on EBH3. It went through a cycle of repair and testing, enabling us to deploy it on the final few CTD casts. For example, the pump kept jamming, so the Hall Sensors were adjusted. Also, it was difficult to raise the voltage of the optical channel even after Decon flushes, so the LED currents were increased to ~4 and ~12 mA – this is higher than usual but still within the safe operating range. CTD data from this TA sensor is yet to be processed, but the raw data suggests it performed well.

Table 12.6 Reference materials used on TA 18 during CTD casts

Name	Material	TA (µmol/kg)	Salinity (psu)	Sensor port label
Reference material 1	Scripps CRM batch 203	2214.54	33.464	CAL1
Reference material 2	OSIL Atlantic Seawater 2 070923	[1]2477.16	35	CRM

Reference material 3	pAqSW250122 (old from TA 18 mooring)	[1]1640.91	32.4	CAL2
Titrant	BPB-28	NA	NA	Titrant

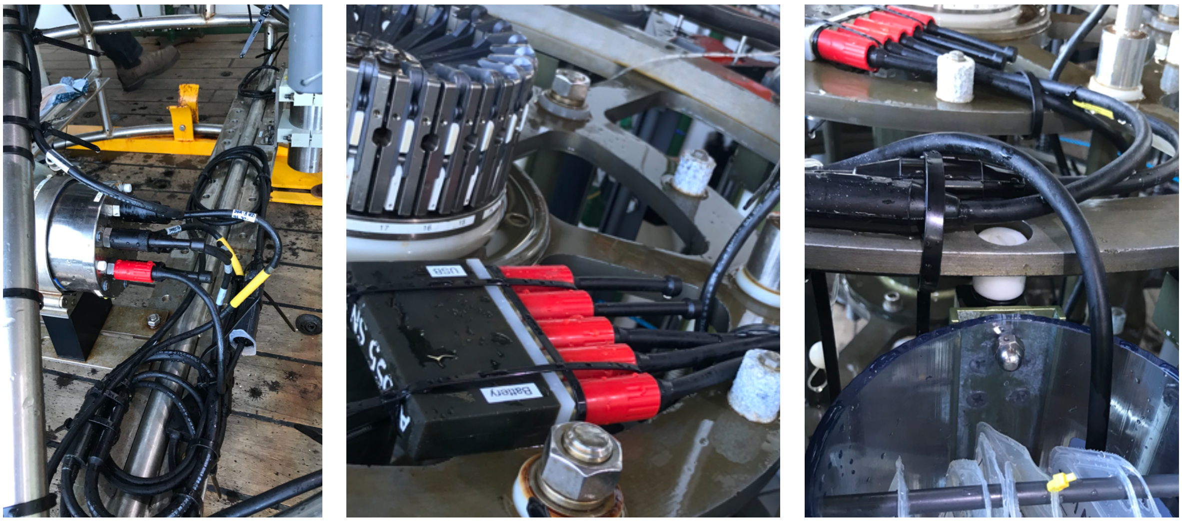
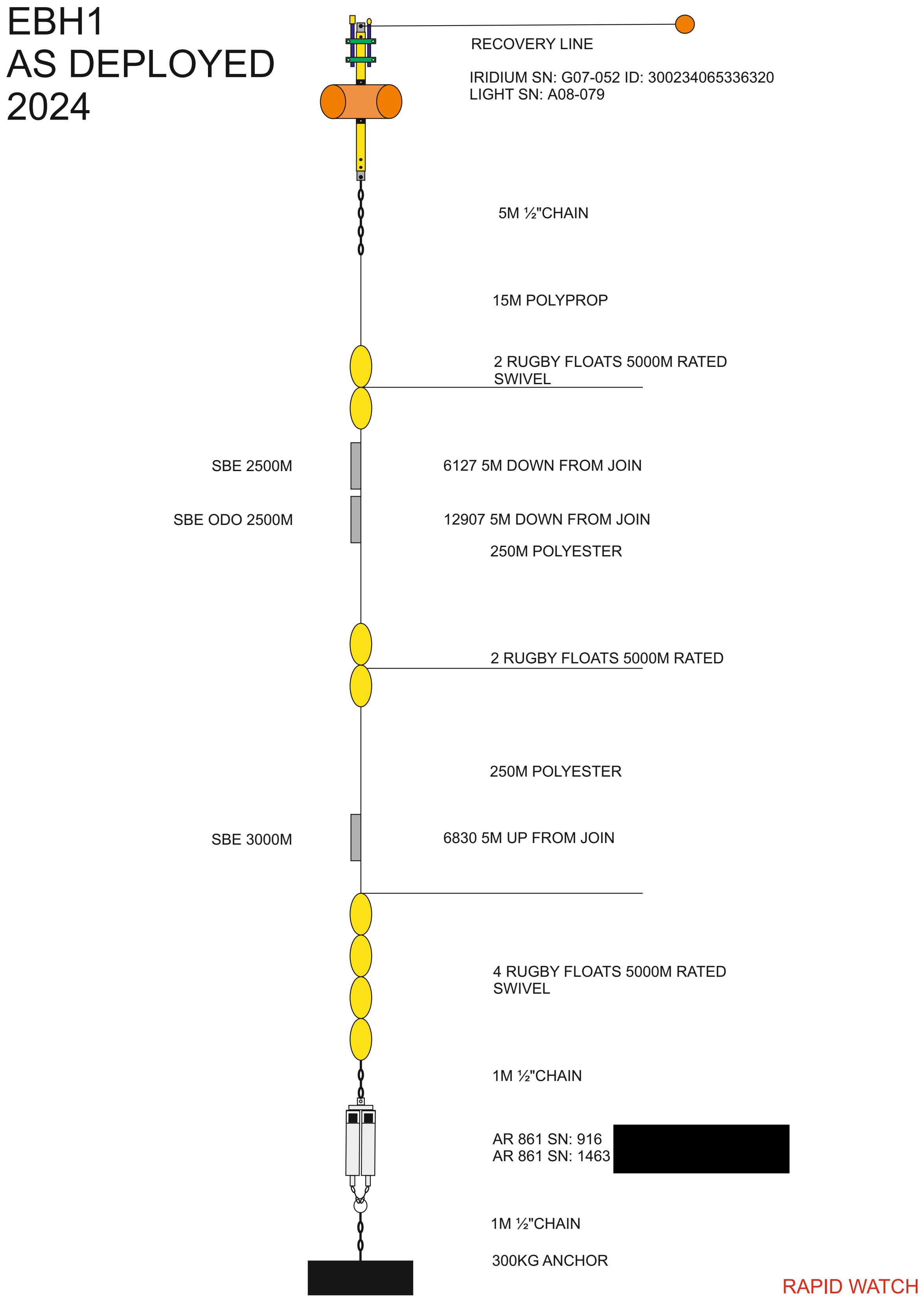
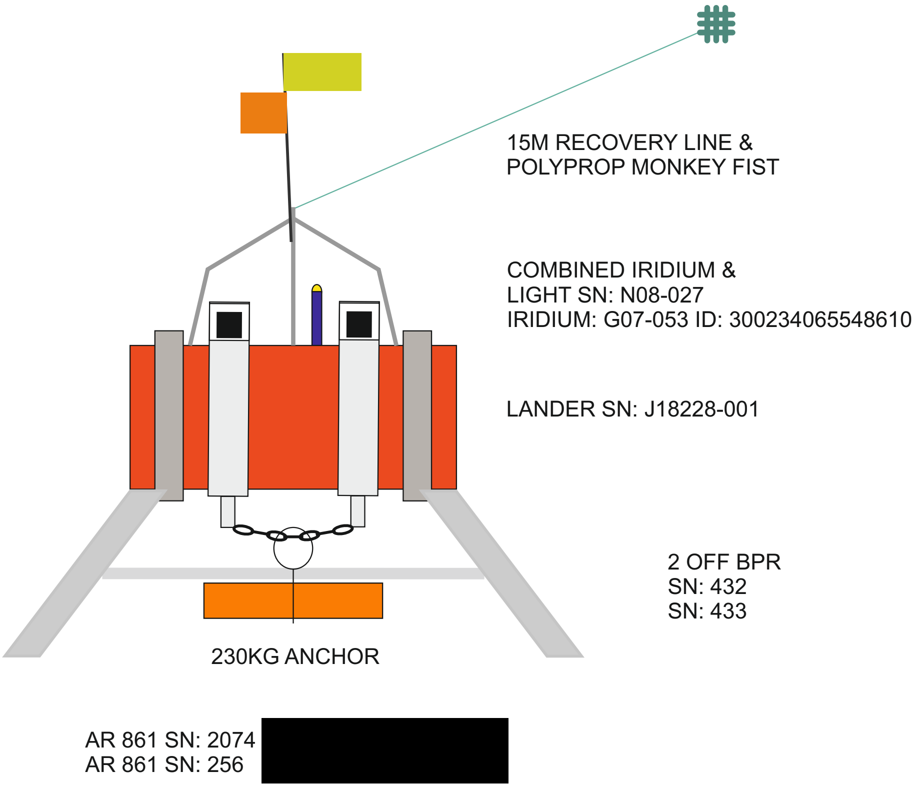


Figure 12.13 **LOC power set up on the CTD**

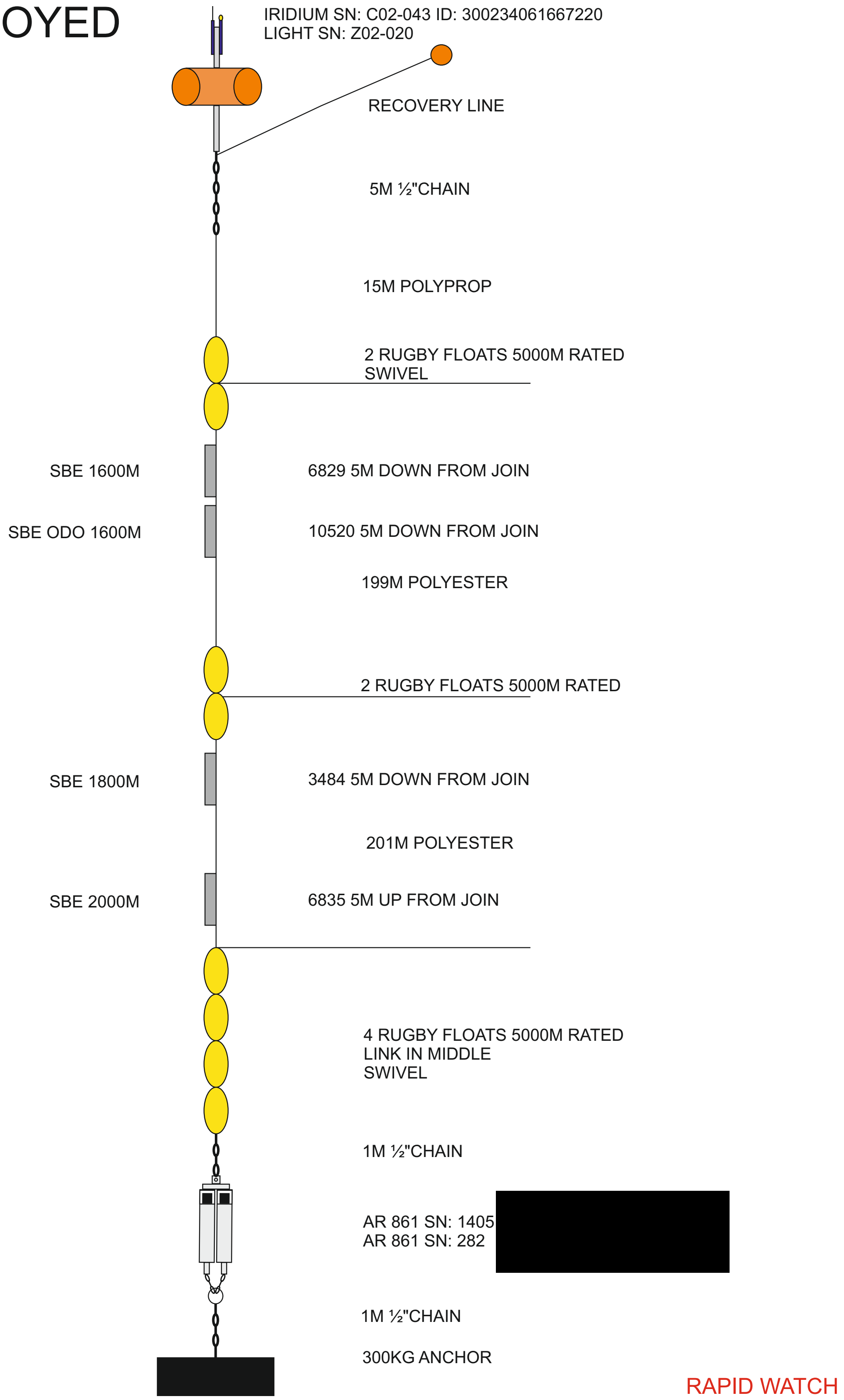
Appendix A: Diagrams of Deployed Moorings

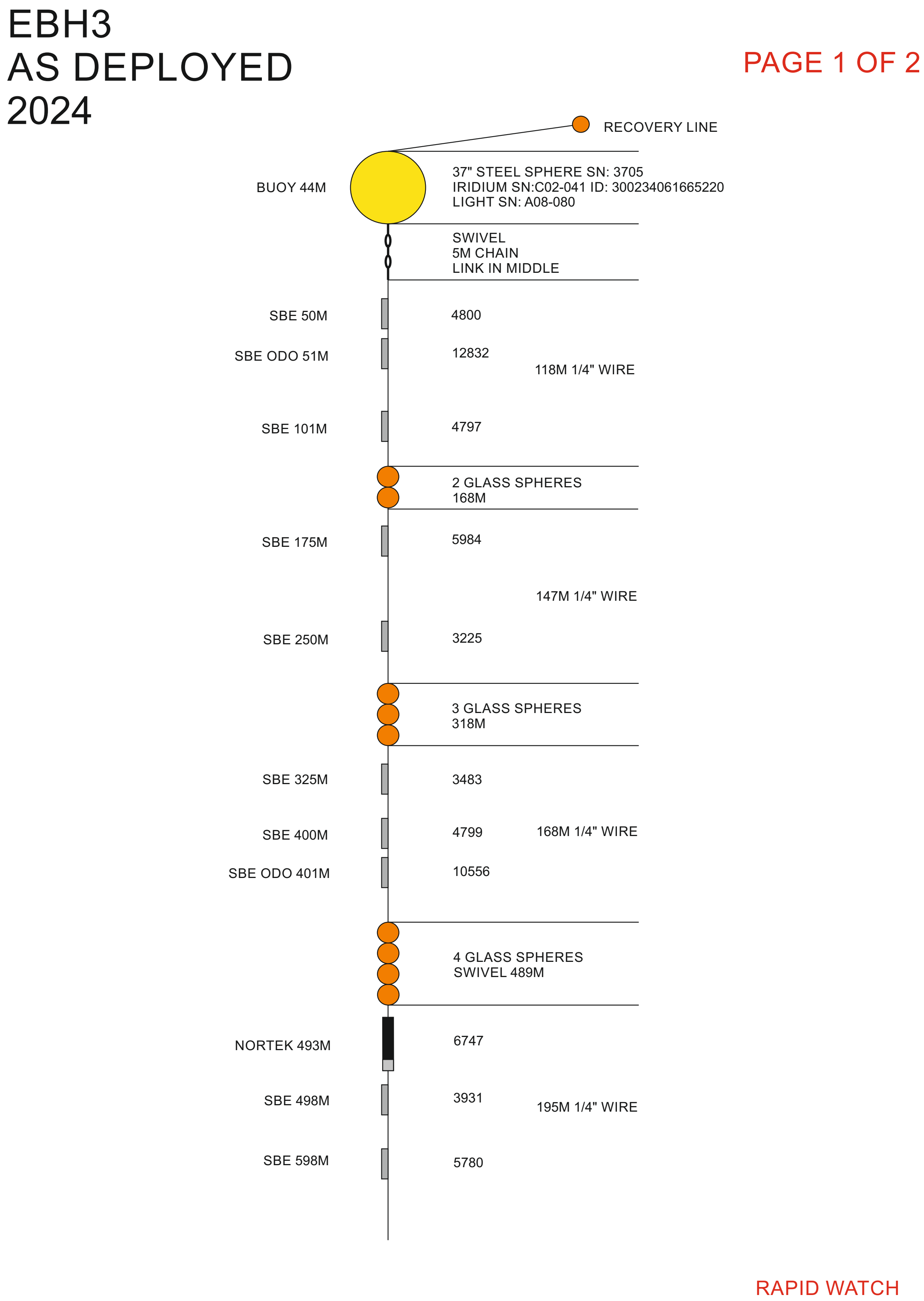


EBH1L16
AS DEPLOYED
2024



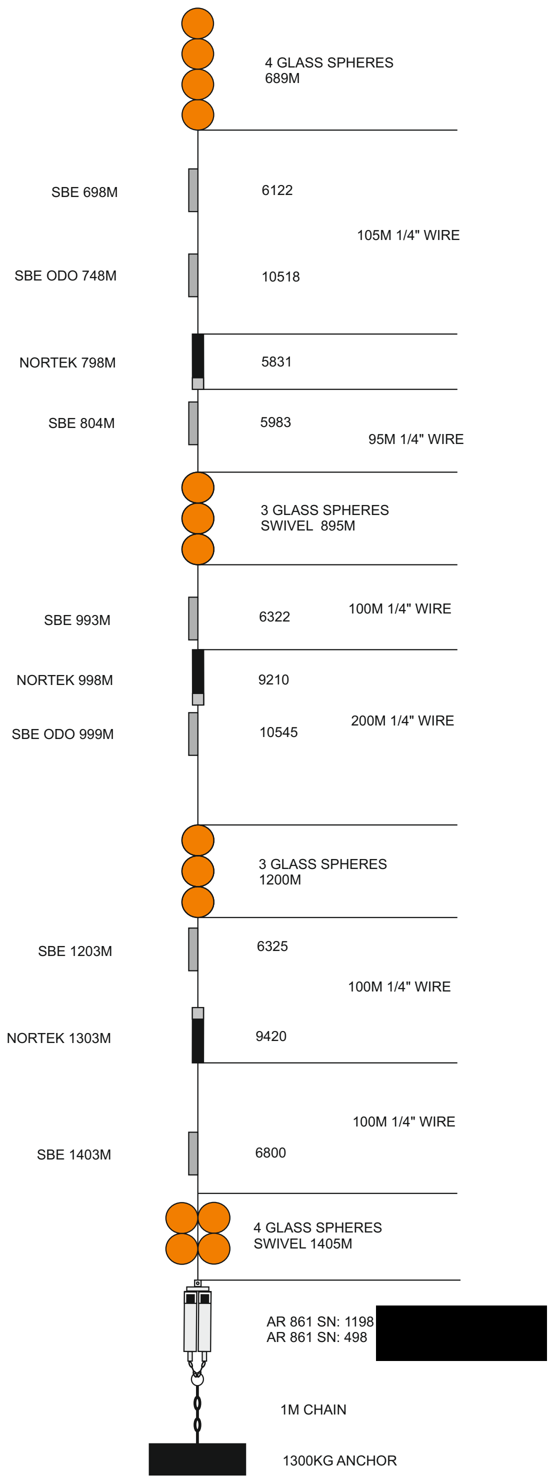
EBH2
AS DEPLOYED
2024




EBH3
AS DEPLOYED
2024
PAGE 1 OF 2
RECOVERY LINE
BUOY 44M
37" STEEL SPHERE SN: 3705
IRIDIUM SN:C02-041 ID: 300234061665220
LIGHT SN: A08-080
SWIVEL
5M CHAIN
LINK IN MIDDLE
SBE 50M
4800
SBE ODO 51M
12832
118M 1/4" WIRE
SBE 101M
4797
2 GLASS SPHERES
168M
SBE 175M
5984
147M 1/4" WIRE
SBE 250M
3225
3 GLASS SPHERES
318M
SBE 325M
3483
SBE 400M
4799
168M 1/4" WIRE
SBE ODO 401M
10556
4 GLASS SPHERES
SWIVEL 489M
NORTEK 493M
6747
SBE 498M
3931
195M 1/4" WIRE
SBE 598M
5780
RAPID WATCH

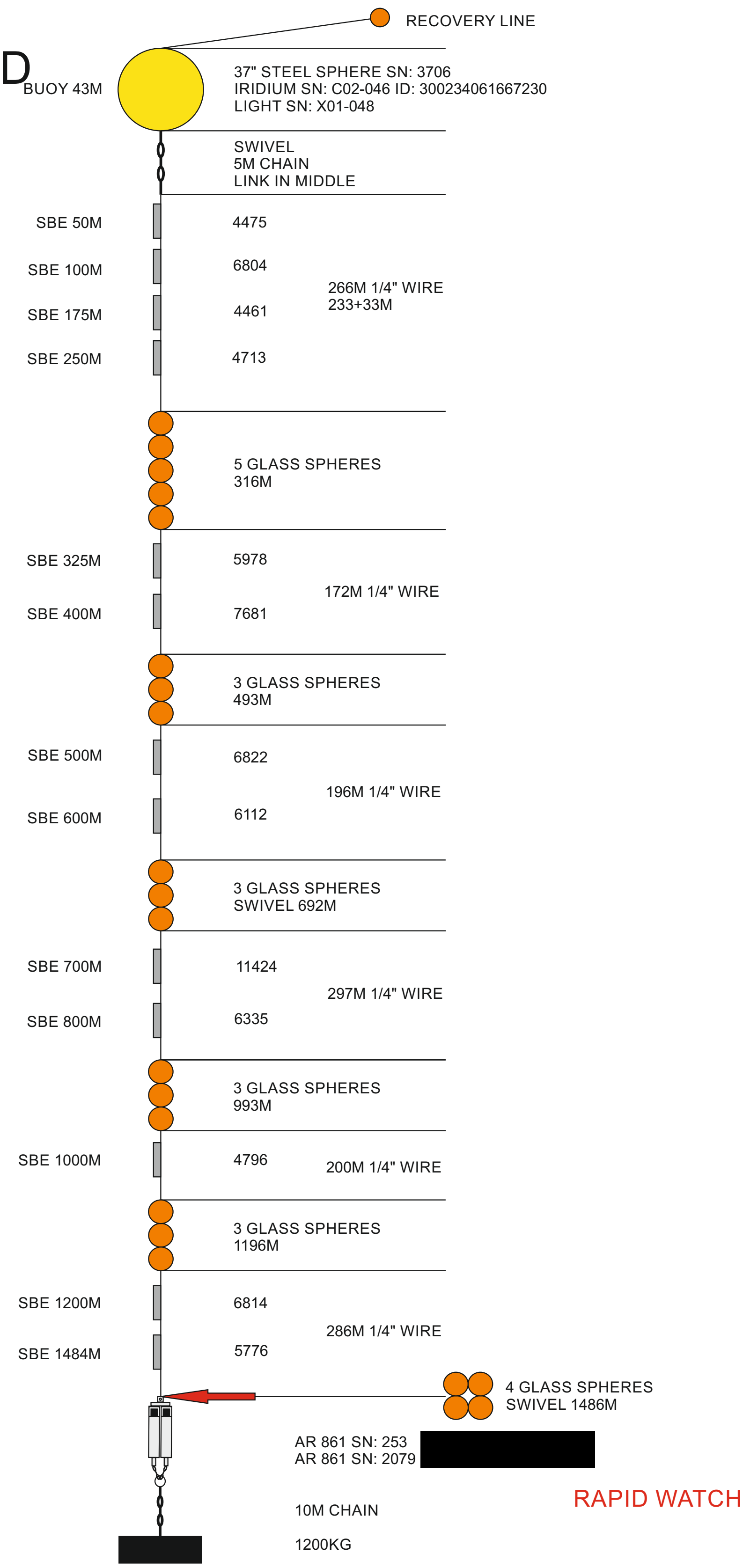
EBH 3
AS DEPLOYED
2024

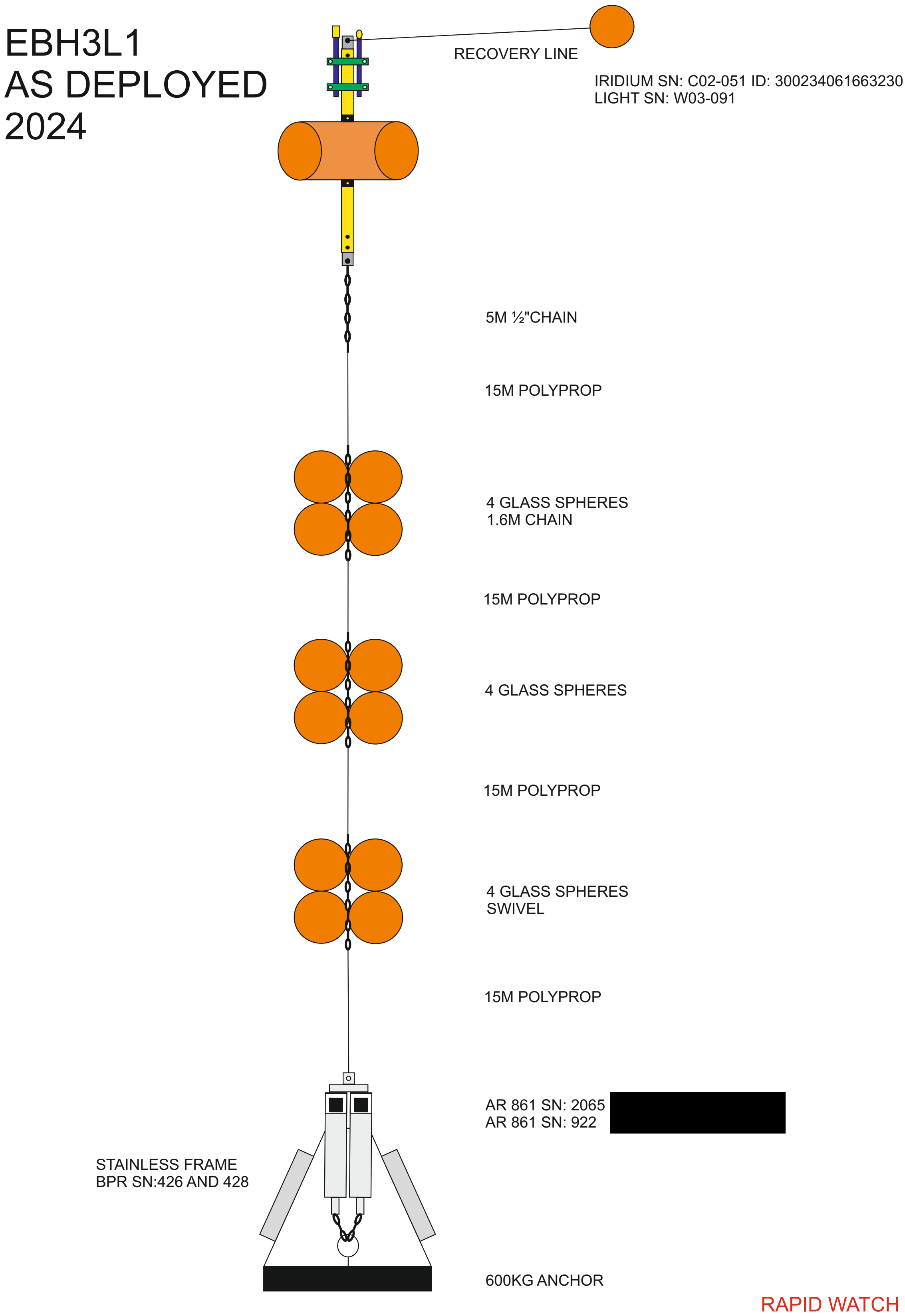
PAGE 2 OF 2



RAPID WATCH

EBH3B
AS DEPLOYED
2024




EBH3L1
AS DEPLOYED
2024
RECOVERY LINE
IRIDIUM SN: C02-051 ID: 300234061663230
LIGHT SN: W03-091
5M ½"CHAIN
15M POLYPROP
4 GLASS SPHERES
1.6M CHAIN
15M POLYPROP
4 GLASS SPHERES
15M POLYPROP
4 GLASS SPHERES
SWIVEL
15M POLYPROP
AR 861 SN: 2065
AR 861 SN: 922
[redacted]
STAINLESS FRAME
BPR SN:426 AND 428
600KG ANCHOR
RAPID WATCH

Appendix B: Log Sheets of Recovered Moorings

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH2** Cruise **DY174**

NB: all times recorded in GMT

Date **28th March 2024** **Site arrival time** overnight

Time of first ranging 1336

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a ✓	grapped up 14:49	14:49
Billings float	n/a ✓		15:10
with light	C01-036 ✓		" "
with Argos	B11-024 ✓	Beacon ID =134365	" "
2x17" glass	n/a ✓		15:05
MicroCAT	3271 ✓	Tangled	15:01
MicroCAT-ODO	10545 ✓	Tangled	15:01
2x17" glass	n/a ✓		15:13
MicroCAT	3277 ✓		15:18
MicroCAT-ODO	10520 ✓	growth	15:28
MicroCAT	3255 ✓	growth	15:28
4x17" glass	n/a ✓	1 glass broken	15:30
Acoustic Release #1	2073 ✓		" "
Acoustic Release #2	1349 ✓		" "

Ascent rate: 70 m/min.

Ranging

Time	Range 1	Range 2	Command/comment
13:35			
13:58	2084	2086	
~~13:58~~			
13:59:05	2085	2085	release ok
14:00:00	2030	2024	" " "
14:01:00	1960	1952	" " "

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH3** Cruise **DY174**

NB: all times recorded in GMT

Date 30/March/2024 **Site arrival time** overnight

Time of first ranging 08:37

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	Grappled at 09:40	
37" Steel sphere	3703 ✓	Fishing gear tangled	09:49
with light	A08-083 ✓		"
with Iridium	G07-052	Beacon ID =300234065336320	"
Sensor cage 1	n/a		09:56
CONTROS			"
MicroCAT-ODO	14115		"
DEEP SEA FET			"
MicroCAT	6821		"
LOC SENSOR	N130	Nitrate	"
Battery pack	SN5		"
MicroCAT	6825 ✓	Heavy growth	10:05
SEA FET	2035 ✓	Tangled	10:09
MicroCAT-ODO	14148 ✓	Tangled	"
3x17" glass	n/a ✓	Tangled	"
MicroCAT	6820 ✓	"	"
MicroCAT-ODO	12999 ✓	Top clamp sheared off	10:19
MicroCAT	10716 ✓		10:17
4x17" glass	n/a ✓	Tangled	10:09
MicroCAT	4466 ✓	Tangled	10:09
10x17" glass	n/a	grappled at ~~[illegible]~~ 11:28	11:35
Sensor cage 2	n/a		
CONTROS			11:43
LOC sensor	N128	Nitrate	"
Battery pack	SN8		"
LOC sensor	P64	Phosphate	"
Battery pack	SN10		"
MicroCAT	6128		"
MicroCAT-ODO	12911		"
4x17" glass	n/a		11:50
NORTEK	9427 ✓		11:50
MicroCAT	5785 ✓		11 52
MicroCAT	5772 ✓		11 56
MicroCAT	5765 ✓		11 58
10x17" glass	n/a		12:03
Sensor cage 3	n/a		"
CONTROS			"
LOC sensor	TA17	Total alkalinity	"

Battery pack	SN4		12:03
LOC sensor	Ph47		〃
Battery pack	SN2		〃
LOC sensor	N129		〃
Battery pack	SN3		〃
MicroCAT	4306		〃
MicroCAT-ODO	10547		〃
NORTEK	9435 ✓		〃
10x17" glass	n/a		12:21
Sensor cage 4	n/a	line tangled around cage	12:26
LOC sensor	TA18		〃
Battery pack	SN11		〃
LOC sensor	Ph48		〃
Battery pack	SN7		〃
MicroCAT	3933		〃
MicroCAT-ODO	12907		〃
NORTEK	11024 ✓		12:27
MicroCAT	3900 ✓	tangled line	12:39
5x17" glass	n/a	〃 〃	12:41
NORTEK	13482 ✓	〃 〃	12:41
MicroCAT	3252 ✓	tangled	12:35
MicroCAT-ODO	10546 ✓	〃	12:35
6x17" glass	n/a		12:49
Acoustic Release #1	2076		〃
Acoustic Release #2	321		〃

Ascent rate: 76 m/min. (20 min)

Ranging

Time	Range 1	Range 2	Command/comment
08:37:40	—	1532.	range
08:38:57	1532	1532	dir. vertical.
08:40:30	1532	1532	—. no release report
08:41:30	1460	1451	no relese report
42:30	1384	1376	

RAPID-AMOC MOORING LOGSHEET **RECOVERY**

Mooring **EBH1L14** Cruise **DY174**

NB: all times recorded in GMT

Date 1st/APRIL/2024 **Site arrival time** overnight

Time of first ranging 06:28

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a	Grappled at 0736	0745
McLane-12"	n/a		"
Billings sphere	n/a		0745
With light	C02-037		"
Argos or Iridium Beacon	A08-067	Beacon ID =	"
4X17" glass	n/a		"
4X17" glass	n/a		"
4X17" glass	n/a		0754
SBE26/53	399 ✓		0758
SBE26/54	398 ✓		"
Acoustic Release #1	1536		"
Acoustic Release #2	921		"

Ascent Rate 80 m/min surface: 07:10

Ranging

Time	Range 1	Range 2	Command/comment
062858		3065	
063040	3066	3065	release OK
063232	3040	3001	
063332	2930	2921	"

Appendix C: Log Sheets of Deployed Moorings

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH3** Cruise **DY174**

NB: all times recorded in GMT

Date 30/March/2024 **Site arrival time** 13:30

Setup distance 2.5 Nmiles

Start time 14:47 **End time** 16:49

Start Position

Latitude 27 49.11 N **Longitude** 13 42.08 W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		14:47
37" steel sphere	3705		14:49
with Light	A08-080		"
~~Argos or~~ [Iridium] Beacon	C02-041	Beacon ID = 300234061665220	"
MicroCAT (50m)	4800		14:51
MicroCAT-ODO (51m)	12832		14:55
MicroCAT (101m)	4797		15:03
2 x 17" glass (168m)	n/a		15:10
MicroCAT (175m)	5984		15:12
MicroCAT (250m)	3225		15:16
3 x 17" glass (318m)	n/a		15:21
MicroCAT (325m)	3483		15:23
MicroCAT (400m)	4799		15:29
MicroCAT-ODO (401m)	10556		15:29
4x17" glass (489m)	n/a		15:34
Nortek (493m)	6747		15:34
MicroCAT (498m)	3931		15:36
MicroCAT (598m)	5780		15:40
4 x 17" glass (689m)	n/a		15:45
MicroCAT (698m)	6122		15:47
MicroCAT-ODO (748m)	10518		15:51
Nortek (798m)	5831	Downwards looking	15:55
MicroCAT (804m)	5983		15:57
3 x 17" glass (895m)	n/a		16:02
MicroCAT (993m)	6322		16:06
Nortek (998m)	9210	Downwards looking	16:07
MicroCAT-ODO (999m)	10545		16:10
3 x 17" glass (1200m)	n/a		16:16
MicroCAT (1203m)	6325		16:17
Nortek (1303m)	9420		16:23
MicroCAT (1403m)	6800		16:26
4 x 17" glass (1405m)	n/a		16:34
Acoustic Release #1	1198	Record codes below	16:34
Acoustic Release #2	498	Record codes below	16:34
1300kg Anchor	n/a		16:34

Release #1 arm code [redacted]
Release #1 release code

RELEASE 16:49:44

Release #2 arm code [redacted]
Release #2 release code

Anchor Drop Position
Latitude 27 48.46 N **Longitude** 13 44.93 W

Uncorrected water depth 1422 (at anchor launch)
Corrected water depth 1424 (at anchor launch)

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
1		~~18:20~~				
		18:21:09	1949	1949		
		18:22:09	1949	1949		
2		20:31:45	2132	2136		
		20:32:45	2142	2140		
3		20:50:30	2045	2048		
		20:51:30	2057	2056		
		2				

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH3L1** Cruise **DY174**

NB: all times recorded in GMT

Date 30/March/2024 **Site arrival time** 17:20

Setup distance 0

Start time 17:25 **End time** 17:34

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		17:25
McLane-12"	n/a		
Billings 4 sphere	n/a		
with Light	W03-091		
~~Argos or~~ Iridium Beacon	C02-05	Beacon ID = 300234061663230	
4 x 17" glass	n/a		
4 x 17" glass	n/a		
4 x 17" glass	n/a		
BPR	0426		
BPR	0428		
Acoustic Release #1 (tripod)	[illegible]922	Record codes below	
Acoustic Release #2 (tripod)	2065	Record codes below	
600kg Anchor	n/a		17:34:45

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code
[redacted]

Anchor Drop Position
Latitude 27 47.92 N **Longitude** 13 45.05 W

Uncorrected water depth 1416 (at anchor launch)
Corrected water depth 1418 (at anchor launch)

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
①		18:23:30	1472	1472		
		18:24:30	1472	1472		
②		18				
		20:33:45	2205	2204		
		20:33:45	2192	~~2190~~	2190	
③		20:52:45	2831	2822		
		20:53:45	2740	2730		

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH3B** Cruise **DY174**

NB: all times recorded in GMT

Date 31/March/2024 **Site arrival time** overnight

Setup distance 3 Nmiles

Start time 08:12 **End time** 10:07

Start Position

Latitude 27 47.92 N **Longitude** 13 50.61 W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		08:12
37" steel sphere	3706		08:16
with Light	X01-048		"
~~Argos or~~ Iridium Beacon	I02-046	Beacon ID = 300234061667230	"
MicroCAT (50m)	4475		08:16
MicroCAT (100m)	6804		08:22
MicroCAT (175m)	4461		08:29
MicroCAT (250m)	4713		08:34
5 x 17" glass (316m)	n/a		
MicroCAT (325m)	5978		08:42
MicroCAT (400m)	7681		08:46
3 x 17" glass (493m)	n/a		
MicroCAT (500m)	6822		08:54
MicroCAT (600m)	6112		08:57
3x17" glass (692m)	n/a		
MicroCAT (700m)	11424		09:04
MicroCAT (800m)	6335		09:09
3 x 17" glass (993m)	n/a		
MicroCAT (1000m)	4796		09:17
3 x 17" glass (1196m)	n/a		
MicroCAT (1200m)	6814		09:25
MicroCAT (1484m)	5776		09:34
4 x 17" glass (1486m)	n/a		
Acoustic Release #1	2079	Record codes below	09:43
Acoustic Release #2	253	Record codes below	"
1200kg Anchor	n/a		1007

Release #1 arm code [redacted]
Release #1 release code
Release #2 arm code
Release #2 release code

Anchor Drop Position

Latitude 27 44.91 **Longitude** -13 49.98

Uncorrected water depth 1507 (at anchor launch)

Corrected water depth 1509 (at anchor launch)

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
1	[redacted]	102744			1928	1932
		103254			1983	1984
		103400			1991	[illegible]
		103500			1998	1998
2		10:46:38			1856	1859
		~~10:46~~				
		10:47:25			1869	1869
3		10:56:30			1816	1822
		10:57:30			1877	1882
		[illegible]				

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH2** Cruise **DY174**

NB: all times recorded in GMT

Date 3/March/2024 **Site arrival time** 1305

Setup distance 0.25 Nmiles

Start time 13:26 **End time** 13:49:40

Start Position

Latitude 27 36.90N **Longitude** 14 12.37 W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		1326
Billings Float			1328
with Light	Z02-020		"
~~Argos or~~ Iridium Beacon	C02-043	Beacon ID = 300234061667220	"
2 Rugby floats	n/a		1332
MicroCAT (1600m)	6829		"
MicroCAT-ODO (1600m)	10520		"
2 Rugby floats	n/a		1341
MicroCAT (1800m)	3484		1340
MicroCAT (2000m)	6835		1348
4 Rugby floats	n/a		1349
Acoustic Release #1	1405	Record codes below	"
Acoustic Release #2	282	Record codes below	"
300kg Anchor	n/a		1349:40

Release #1 arm code
Release #1 release code
Release #2 arm code
Release #2 release code
[redacted]

Anchor Drop Position

Latitude 27 36.91 N **Longitude** 14 12.71 W

Uncorrected water depth 2021 (at anchor launch)

Corrected water depth 2021 (at anchor launch)

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
1		14:20	—			
		14:21:30			2325	2325
		14:22:30			2325	2325
2		163745			2444	2444
		163824			2444	2443
		16:50:18			2202	2268
3		16:51:18			2325	2330

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH1** Cruise **DY174**

NB: all times recorded in GMT

Date 1/April/2024 **Site arrival time** 13:03

Setup distance 1.0 Nmiles.

Start time 13:38 **End time** 14:42:52

Start Position

Latitude 27 13.38 N **Longitude** 15 24.25 W

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		1338
Billings Float			1339
with Light	A08-079		"
~~Argos or~~ Iridium Beacon	G07-052	Beacon ID = 300234065336320	"
2 Rugby floats	n/a		1341
MicroCAT (2500m)	6127		1341
MicroCAT-ODO (2500m)	12907		1341
2 Rugby floats	n/a		1351
MicroCAT (3000m)	6830		1356
4 Rugby floats	n/a	Towing	1442
Acoustic Release #1	1463	Record codes below	"
Acoustic Release #2	916	Record codes below	"
300kg Anchor	n/a		14:42:52

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

[redacted]

Anchor Drop Position

Latitude 27 13.35 N **Longitude** 15 25.39 W

Uncorrected water depth 3038 (at anchor launch)

Corrected water depth 3041 (at anchor launch)

24/04/01

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
1	[redacted]	185227			3177	3177
		185308			3177	3177
2		194008			3152	3149
		194107			3132	3131
3		19:45:15			3192	3195
		19:46:15			3217	3219

RAPID-AMOC MOORING LOGSHEET **DEPLOYMENT**

Mooring **EBH1L16** Cruise **DY174**

NB: all times recorded in GMT

Date 1/APRIL/2024 **Site arrival time** 15:00

Setup distance 0

Start time 15:33 **End time** 15:34:45

ITEM	SER NO	COMMENT	TIME
Recovery line	n/a		1533
Deep water buoyancy lander	J18228-001		1534
with Light	N08-027		"
~~Argos or~~ Iridium Beacon	G07-053	Beacon ID = 300234065548610	"
BPR	432		"
BPR	433		"
Acoustic Release #1 (tripod)	2074	Record codes below	"
Acoustic Release #2 (tripod)	256	Record codes below	"
230kg Anchor	n/a		15:34:45

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

[redacted]

Anchor Drop Position
Latitude 27 12.19N **Longitude** 15 25.32W

Uncorrected water depth 3035 (at anchor launch)
Corrected water depth 3038 (at anchor launch)

EBHFL16 [redacted]

Triangulation Sheet

Location (e.g. 1, 2 3)	Release SN or ARM	Time	Latitude	Longitude	Range 1 (m)	Range 2 (m)
1	[redacted]	185517			4011	4011
		185618			4010	4010
2		193803			4189	4182
		193903			4114	4102
3		1947:20			3444	3447
		19:48:20			3490	3498

National Oceanography Centre, European Way, Southampton, SO14 3ZH
United Kingdom +44 (0)300 131 2321

Joseph Proudman Building 6 Brownlow Street, Liverpool, L3 5DA
United Kingdom +44 (0)151 795 4800

NOC.AC.UK