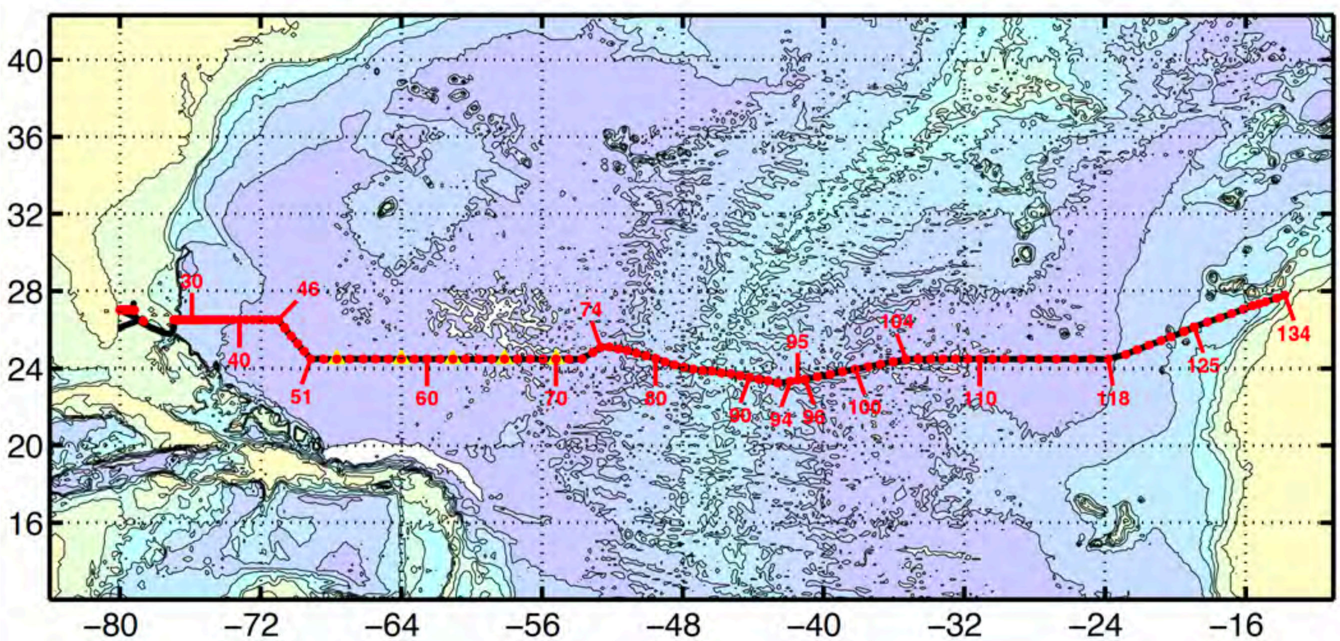
CRUISE REPORT: A05

(Updated AUG 2020)



Highlights

Cruise Summary Information

Section Designation	**A05 (JC191, 24 N)**
Expedition designation (ExpoCodes)	**740H20200119**
Chief Scientists	**Alejandra Sanchez-Franks / NOC**
Dates	2020 JAN 19 - 2020 MAR 01
Ship	*RRS James Cook*
Ports of call	Port Everglades, USA - Santa Cruz de Tenerife, SPAIN
Geographic Boundaries	28° 25' 51.3834" N 80° 0' 4.104" W 13° 13' 39.3234" W 23° 15' 1.296" N
Stations	135
Floats and drifters deployed	5 TWR Deep APEX floats were deployed
Moorings deployed or recovered	

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Final report assembly by Jerry Kappa, SIO/UCSD

National Oceanography Centre

Cruise Report No. 70

RRS *James Cook* Cruise JC191
19 JANUARY - 1 MARCH 2020

Hydrographic sections from the Florida Straits to the Canaries Current across 24ºN in the Atlantic Ocean

Principal Scientist
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2020

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REFERENCE

Southampton, UK: National Oceanography Centre, Southampton, 262pp.
(National Oceanography Centre Cruise Report, No. 70)

ABSTRACT

A hydrographic section across the North Atlantic Ocean at a nominal latitude of 24°N was occupied by the RRS James Cook (cruise identifier: JC191) from 19 January to 1 March, 2020. The ship departed from Port Everglades, USA, completing a total of 135 CTD stations over the Florida Straits, the western basin, Mid-Atlantic Ridge, and eastern basin, before ending the cruise in Santa Cruz de Tenerife, Spain. The main objectives of the JC191 research expedition was to collect physical-, chemical-, and biological-ocean data with the purpose of estimating heat, freshwater and carbon budgets on low frequency time scales.

All CTD stations had measurements from a CTD rosette equipped with temperature, conductivity, pressure, oxygen sensors, in addition to water captured from 24 niskin bottles fired at varying intervals throughout the full depth water column. The water from the niskin bottles was analysed for dissolved oxygen, carbon (DIC/TA), nutrients, and conductivity. Water for methane (CH4), C14, C13, and pigments (filtered) was collected for onshore analysis. The CTD rosette was also equipped with 2 RBR loggers measuring conductivity, temperature and pressure (up to 6,000m), and a lowered Acoustic Doppler Current Profiler (LADCP) making full depth velocity measurements. The 135 CTD stations include 2 carbon blank stations, and 2 bulk water stations for incubations. In addition to the CTD stations, the RRS James Cook has an underway system, which includes an intake for surface water to be pumped into the water bottle annex and the deck lab; two vessel mounted ADCPs (VMADCPs). A thermosalinograph and a fluorometer, installed in the water bottle annex, continually recorded conductivity, temperature and fluorescence. Water from the CTD was collected to calibrate the ship's underway TSG. The VMADCPs, 75Hz and 150HZ, mounted on the drop keel record ocean velocities in roughly the top 300- and 600-m, respectively. Surface carbon and methane measurements were also recorded from the underway systems, and surface meteorological variables were monitored via the meteorological sampling system and the pumped water underway system. Finally bathymetric data were recorded an EA640 echosounder and a Kongsberg EM122 multibeam, both of which are mounted on the ship's hull. Last, 5 Deep Apex Argo floats measuring conductivity, temperature, pressure and oxygen (except for one float not equipped with an optode) were deployed in the western basin.

Many of the science party also engaged in extensive outreach via blogs and social media, heightening visibility of the science teams activities to the oceanographic community and the general public.

This report summarises the data collected and analysed, and the methodology used for the acquisition and processing of the data onboard the James Cook during the JC191 research expedition

KEYWORDS

ADCP, Atlantic Ocean, Canaries Current, carbon, chemistry, chlorophyll, circulation, climate, James Cook, JC191, CTD, 13C, 14C, Gulf Stream, subtropical Atlantic, Mid-Atlantic Ridge, lowered ADCP, AMOC, oxygen, nutrients, Florida Current, Florida Straits, Argo floats, surface meteorology, VMADCP, North Atlantic, CH4, hydrography, radiocarbon.

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Scientific Personnel

	Name	Role	Affiliation
1.	Alejandra Sanchez-Franks	Principal Scientist	NOC
2.	Brian King	Physics	NOC
3.	Jessica Newman	Physics	Newcastle University
4.	Thomas Wilder	Physics	UEA
5.	Katherine Grayson	Physics	University of Cambridge
6.	Charles Turner	Physics	NOC
7.	Peter Brown	DIC/TA	NOC
8.	Anita Flohr	DIC/TA	NOC
9.	Vanesa Romero Kutzner	DIC/TA	Universidad de las Palmas de Gran Canaria
10.	Daniel Kerr	DIC/TA	Dublin City University
11.	Ed Mawji	DO/Nutrients	NOC
12.	Thierry Cariou	Nutrients	Roscoff Biological Station
13.	Maria de la Fuente	DO	NOC
14.	Hannelore Theetaert	DO	VLIZ
15.	Joanna Lester	Carbon Isotopes	IC
16.	Anna Kolomijeca	Methane (CH4)	Sorbonne University
17.	Lukas Marx	Pigments	University of Portsmouth

NOC = National Oceanography Centre
UEA = University of East Anglia
VLIZ = Flanders Marine Institute
IC = Imperial College

Technical Personnel

	Name	Position	Affiliation
18.	Eleanor Darlington	IT/Ship systems technician	NMF
19.	John Wynar	CTD Technician	NMF
20.	Timothy Powell	CTD Technician	NMF

21.	Thomas Ballinger	CTD Technician	NMF

NMF = National Marine Facilities

Ship's Personnel

	Name	Position/Rank
22.	James Gwinnell	Master
23.	Andrew Mahon	Chief Officer/Security
24.	Declan Morrow	2nd Officer/Medical
25.	Bryn Beaurain	3rd Officer
26.	Christopher Uttley	Chief Engineer/Safety
27.	Michael Murray	2nd Engineer
28.	Fraser MacGilp	3rd Engineer
29.	Gary Slater	3rd Engineer
30.	Conrad Laversuch	ETO
31.	Paul Lucas	Purser
32.	Nathan Gregory	CPO (Deck)
33.	Martin Harrison	CPO (Science)
34.	William McLennan	POD
35.	John Allen	SG1A
36.	Colin Atkinson	SG1A
37.	Brian Burton	SG1A
38.	Peter Smyth	SG1A
39.	Sean Angus	ERPO
40.	Darren Caines	Head Chef
41.	Jacqueline Waterhouse	Chef
42.	Jane Bradbury	Steward
43.	Kevin Mason	Assistant Steward

Background and Objectives

The principal aim of the JC191 research expedition was to complete a full depth hydrographic section in the subtropical North Atlantic as part of the LTSS program, Climate Linked Atlantic Sector Science (CLASS), and as a UK contribution to the Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP). The hydrographic section occupied by JC191 was along a nominal latitude of 24ºN, which is a repeat section also known as A05. Previous occupations along this line, A05, include Discovery DY040 (2015), Discovery d346 (2010), Discovery Cruise (2004), Ronald H. Brown (1998), Hesperides HE06 (1992).

During the JC191 expedition data was collected for the core scientific teams: physics, chemistry (oxygen and nutrients), carbon, and for the following science add ons: methane, C14, and pigments. The measurements collected aboard the JC191 will serve to investigate the study of decadal variability, of the present ocean circulation and meridional transport of heat, freshwater and biogeochemistry.

Figure 0.1: Some of the personnel aboard RRS James Cook for JC191 a day before getting into Santa Cruz de Tenerife. Back row left to right: Thomas Ballinger, Timothy Powell, Edward Mawji, Charles Turner, Hannelore Theetaert, Thierry Cariou, Declan Morrow, Paul Lukas, Andrew Mahon, Alejandra Sanchez-Franks, Thomas Wilder, Brian King, Lukas Marx, Vanesa Romero, Jessica Newman, Peter Brown. Front row left to right: John Wynar, Daniel Kerr, Anita Flohr, Anna Kolomijeca, Maria de la Fuente, and Katherine Grayson.

Itinerary and Cruise Track

The RRS James Cook (cruise identifier: JC191) departed from Port Everglades, USA, on the 19th of January 2020 and ended in Santa Cruz de Tenerife on the 1st of March 2020. During JC191 a total of 135 CTD stations were completed over the Florida Straits, the western basin, Mid-Atlantic Ridge, eastern basin and eastern boundary up to Morocco, before ending the cruise in Santa Cruz de Tenerife, Spain. CTD stations positions and station details given in Appendix A.

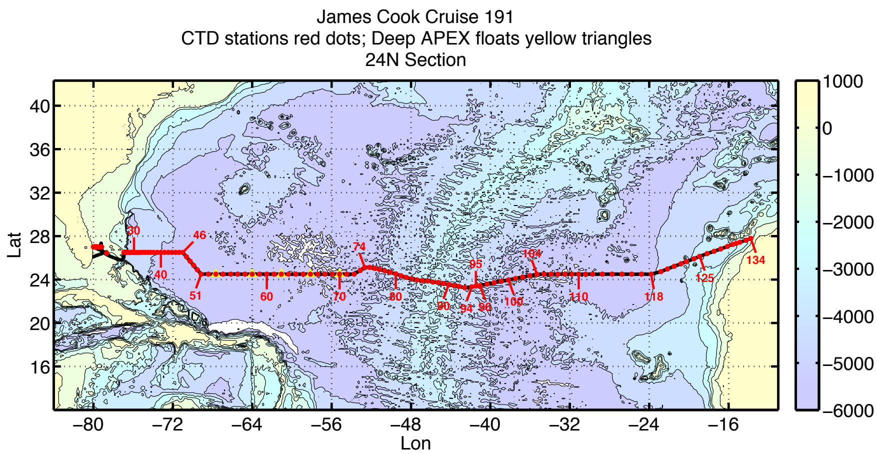


Figure 0.2: Bathymetry and full JC191 cruise track and station positions (red dots) across the North Atlantic at a nominal latitude of 24N. Yellow triangles indicate the location of Deep APEX float deployments in the western basin.

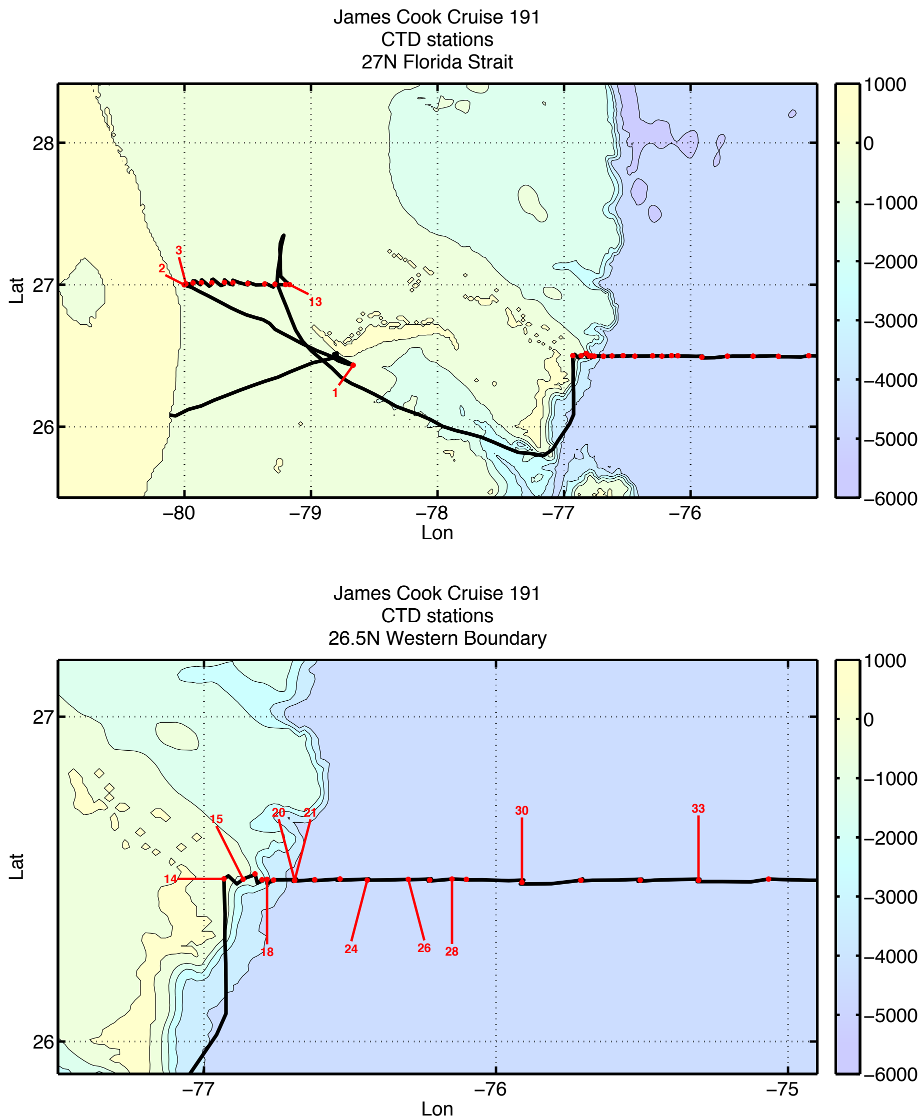


Figure 0.3: Beginning of the JC191 track. Zoom in of the Florida Strait (upper panel) and the Western Boundary at 26.5N (lower panel).

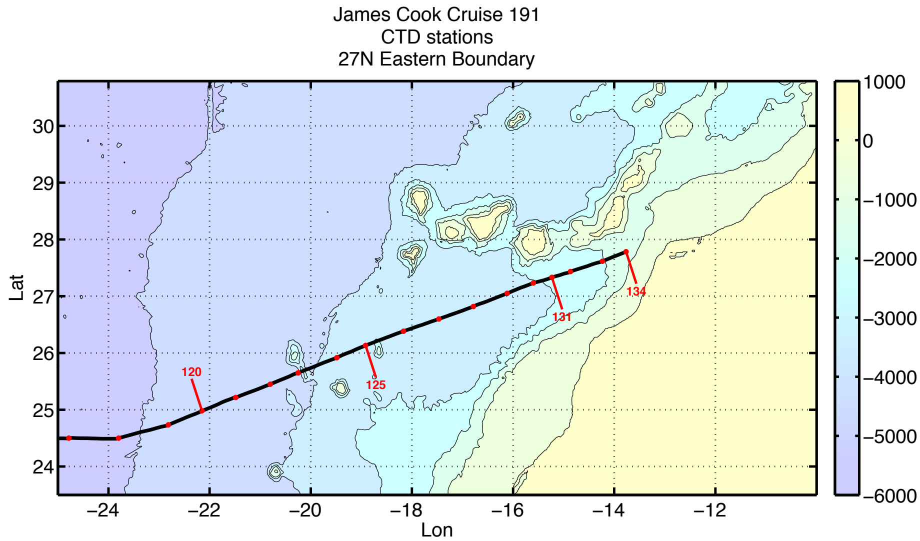


Figure 0.4: End of JC191 track. Zoom in on the eastern boundary and Canary Islands.

Diary

J015 15th January – Arrival

Majority of science team arrive in Miami together to be picked up by the agent and get ferried to the hotel in Fort Lauderdale.

J016 16th January

James Cook arrives in Port Everglades.

Brief catch up with cruise planning manager, Jason Scott. Everything on track with mobilisation.

J017 17th January – In port

Mobilisation begins. Whole science team is transported from hotel to ship at 9 am local.

3 containers arrive to vessel. Team and crew spend most of day unpacking and setting up.

Familiarisation for everyone at 5.30 in the conference room.

Last science party member, Vanesa Romero, arrives on the ship.

J018 18th January – In port

Mobilisation continued. Physics lab and main computer, Koaekea, continues to be setup.

Safety drill in the afternoon (~2pm local) with the U.S coast guard.

Science meeting at 3 pm local in the main lab.

On standby to hear if we have clearance for dipclear for working in the Bahamas EEZ.

J019 19th January – Departed Port Everglades, USA

Departed Port Everglades and sailed towards the Bahamas at 0700 local.

Steamed straight to Freeport for clearance. CTD [test] station 1 was reached shortly after dinner.

CTD Station 001: 762 m depth (J020 00:35) – test station to ensure all equipment and instruments setup correctly. Depths reported here are from the station summary files and should match with those reported in Appendix A.

O2 sensors not so good. Secondary swapped out.

It is discovered that the VMADCP 75 and 150 were plugged in the other way around. OS 150 still giving strange values in the bottom tracking?

Physics and other teams transition to their respective 12 hour shifts.

J020 20th January

Wait on station for CTD 2 to start. This gave everyone on the night shift a little extra time to adjust to their watch and the 24 hr shifts/schedule.

Request to stay at least 2 hours on station for the VMADCP data stream.

CTD Station 002: 37 m depth (14:29 UTC) – Start of Florida Strait section
CTD Station 003: 65 m depth (15:57 UTC)
CTD Station 004: 148 m depth (18:33 UTC)
CTD Station 005: 267 m depth (21:34 UTC)

First cheesecake sighting of the expedition.

Some of the volunteers a little green from seasickness.

J021 21st January

CTD Station 006: 389 m depth (00:42 UTC)
CTD Station 007: 532 m depth (04:03 UTC)
CTD Station 008: 647 m depth (07:01 UTC)
CTD Station 009: 762 m depth (10:09 UTC)
CTD Station 010: 671 m depth (13:02 UTC)
CTD Station 011: 617 m depth (16:00 UTC)
CTD Station 012: 483 m depth (18:26 UTC)
CTD Station 013: 374 m depth (21:07 UTC) – End of Florida Strait section

Weather still a little rough.

J022 22nd January

Day of steaming to transition from the Florida Straits to the main section, east of the Bahamas. Initially started steaming northwards out of the Florida Strait with the intention of transitioning eastward north of the Bahamas Islands, however, a low pressure system resulted in us turning back and taking a route south of the

Bahamas Islands. The route south of the Bahamas was longer but allowed us to steam faster so not much time was lost.

Teams used the time to catch up on samples, tutorials and lab setups.

J023 23rd January

CTD Station 014: 441 m depth (00:14 UTC) – beginning of the main section east of the Bahamas. Active heave compensator (AHC) turned on without incident. A quick look at the CTD showed a reduction from 2m to 0.5m in the CTDs pressure when stationary.
CTD Station 015: 1649 m depth (03:43 UTC) – Heave compensator turned off for bottom ops at the behest of the NMF team for safety reasons.
CTD Station 016: 1283 m depth (06:16 UTC)
CTD Station 017: 1609 m depth (09:37 UTC)
CTD Station 018: 2319 m depth (13:12 UTC) – no LADCP data for some reason.
CTD Station 019: 3714 m depth (18:18 UTC) – Beginning of LADCP inability to produce good profiles at mid-depth (msg: Increased error because of shear – inverse difference).

Due to inclement weather, ship is staying on station till all samplers have finished.

Some volunteers still seasick.

J024 24th January

CTD Station 020: 4532 m depth (00:01 UTC)
CTD Station 021: 4026 m depth (04:12 UTC) – All bottles fired at max depth for carbon team to get enough water for sub standards (carbon bulk sample).
CTD Station 022: 4711 m depth (09:10 UTC)
CTD Station 023: 4842 m depth (14:31 UTC) – The start of alternating (A/B) stations.
CTD Station 024: 4836 m depth (19:39 UTC) – AHC now being used throughout entire cast.

Weather begins to improve.

J025 25th January

CTD Station 026: 4836 m depth (01:28 UTC) – The computer crashed at the bottom of CTD Station 25. The upcast was named station 26, and the data from station 25 was later stitched onto 26. There were some issues with the LADCP data stream, which were indirectly attributed to the break. No NMEA data was

recorded. The Secondary CTD computer was setup as the primary CTD computer.
CTD Station 027: 4816 m depth (06:28 UTC)
CTD Station 028: 4811 m depth (08:04 UTC) – All bottles fired at 40m depth for WHOI incubations.
CTD Station 029: 4807 m depth (12:32 UTC) – 5 niskins didn't fire. NMF team suggests swapping out some of the 20L bottles for 10L ones. 10L bottles generally easier to handle and require less time for setup.
CTD Station 030: 4748 m depth (17:43 UTC)
CTD Station 031: 4691 m depth (23:10 UTC) – niskins 1 to 5 and 10 to 24 were swapped out for 10L ones in preparation for this cast. Bottles 6 to 9 were kept as 20L to ensure there was enough water for incubations.

Issues with the autosal possibly related to the increasing temperatures in the electronics workshop. Continued flushing with standard did little to improve the situation. Decision was taken to up the bath temperature to 27C.

J026 26th January

The bath temperature for the autosal changed to 27C, two crates were successfully run more or less without incident. Standards still giving strange readings. On the third crate it became harder and harder to get stable readings.

CTD Station 032: 4686 m depth (04:04 UTC)
CTD Station 033: 4640 m depth (08:54 UTC)
CTD Station 034: 4614 m depth (14:07 UTC)
CTD Station 035: 4537 m depth (19:22 UTC) – Temperature between primary and secondary sensors noticed over the last few casts. Secondary sensor swapped out pre-deployment of Station 35.

Niskin 1 was found to be consistently not firing between CTD stations 31 and 35 (critically niskin 1 started not firing at all after the 10L one was put on, though incidents of misbehaving had been recorded with the 20L bottle as well). Latch assembly on CTD swapped out for spare.

Spectacularly calm and sunny day.

Continued issues with the oxygen titrations.

The highly respected tradition of chocolate Sunday rigorously observed.

J027 27th January

Latch assembly swap declared a wild success. All niskins, 1 in particular, now closing. A closer inspection of the original latch assembly revealed latch 1 to be particularly stiff; this issue was fixed by NMF techs.

Temperature differences between primary and secondary sensors decreased post-swap of secondary temperature sensors. It was concluded that the original secondary sensor must've been the offending one.

CTD Station 036: 4496 m depth (00:35 UTC)
CTD Station 037: 4544 m depth (05:50 UTC)
CTD Station 038: 4669 m depth (11:14 UTC)
CTD Station 039: 4915 m depth (17:01 UTC)
CTD Station 040: 5045 m depth (23:20 UTC)

First sighting of squid on the midnight watch. The cephalopods were spotted performing their ritualistic 8-arm dance around the CTD under the light of the starboard spotlight.

J028 28th January

Clocks forward 1hr.

CTD Station 041: 5144 m depth (05:48 UTC) – SBE35 sensor joins its other temperature sensor friends, RBR and SBEPx, on the CTD rosette for big temperature sensing party.*
CTD Station 042: 4544 m depth (12:09 UTC)
CTD Station 043: 4669 m depth (18:20 UTC)

*Due to differences in primary and secondary sensors, SBE35 was brought in to give ground-truthing. The sensor works by taking 20-sec samples after the niskin has fired. The averaged discrete samples are then obtained in a separate file.

J029 29th January

CTD Station 044: 5375 m depth (00:24 UTC)
CTD Station 045: 5483 m depth (07:30 UTC)
CTD Station 046: 5489 m depth (13:51 UTC)
CTD Station 047: 5504 m depth (21:08 UTC)

J030 30th January

CTD Station 048: 5515 m depth (04:16 UTC)
CTD Station 049: 5503 m depth (11:55 UTC)
CTD Station 050: 5595 m depth (19:11 UTC)

J031 31st January

CTD Station 051: 5639 m depth (02:42 UTC) – Issues with LADCP files breaking up (Master).

CTD Station 052: 5715 m depth (11:14 UTC)
CTD Station 053: 5705 m depth (19:39 UTC) – Issues with LADCP files breaking up (Slave). NMF tech swaps cable -> immediate success.

J032 1st February

CTD Station 054: 5707 m depth (04:24 UTC) – Deep Argo 12 deployed.
CTD Station 055: 5276 m depth (13:02 UTC)
CTD Station 056: 5556 m depth (21:12 UTC)

J033 2nd February

CTD Station 057: 5714 m depth (05:32 UTC)
CTD Station 058: 5765 m depth (13:56 UTC) – Deep Argo 14 deployed.
CTD Station 059: 5803 m depth (22:26 UTC)

Issues in workshops electronic room again as temperatures reach a roasty 30 deg. C. Standards start to get unstable. Issues resolved as chief engineer repaired the separate electronics workshop AC system and NMF techs clean the autosal connecter again (zero goes from +14 to 10 counts).

J034 3rd February

CTD Station 060: 5880 m depth (06:46 UTC)
CTD Station 061: 5784 m depth (15:25 UTC)
CTD Station 062: 5860 m depth (00:03 UTC) – Deep Argo 24 deployed.

J034 4th February

CTD Station 063: 5843 m depth (08:37 UTC)
CTD Station 064: 5811 m depth (17:06 UTC)
CTD Station 065: 5889 m depth (02:03 UTC)

J036 5th February

CTD Station 066: 5827 m depth (10:52 UTC) – Deep Argo 0015 deployed.
CTD Station 067: 6277 m depth (19:54 UTC) – CTD wire switched for deep tow; come off.

Deviation in primary and secondary sensor readings changed during deep tow casts.

Instruments not pro-rated to > 6,000 m depth, i.e. fluorometer, transmissometer, RBR loggers, LADCPs and the swivel, get taken off the CTD and CTD wire gets replaced with the deep tow. Deep tow operations averaging an extra ~15-20 mins per cast.

Physics team lead, Brian King, surprised with an autosal cake for his 60th birthday.

J037 6th February

CTD Station 068: 6005 m depth (04:40 UTC) – CTD wire switched for deep tow; some instruments come off.
CTD Station 069: 6466 m depth (13:40 UTC) – Deepest station along the transect!! CTD wire switched for deep tow; some instruments come off.
CTD Station 070: 5897 m depth (22:24 UTC) – CTD wire switched for deep tow; some instruments come off. Deep Argo 0013 deployed.

Instruments not pro-rated to > 6,000 m depth, i.e. fluorometer, transmissometer, RBR loggers, LADCPs and the swivel, get taken off the CTD and CTD wire gets replace for the deep tow. Deep tow operations averaging an extra ~15-20 mins per cast.

J038 7th February

Clocks forward 1hr. Local time now UTC – 3 hrs.

Mid-cruise BBQ!

CTD Station 071: 5230 m depth (06:43 UTC) – LADCP uplooker swapped due to low data return and compass issues. Replacement uplooker installed (SN 13399).

Call from the Discovery (Drake Passage) received to do with oxygen titration issues (ti-touch display announcing electrode short).

CTD Station 072: 5965 m depth (15:39 UTC) – Traditional mid-cruise aft deck BBQ. Science team and ship's crew join together on the aft deck for BBQ whilst watching a brilliant sun set over the mid-Atlantic horizon.

J039 8th February

Chief mate reports humpback whale sighting in the morning science meeting.

CTD Station 073: 5834 m depth (07:31 UTC) – replacement uplooker not returning data and also experiencing compass issues.*
CTD Station 074: 5731 m depth (15:24 UTC) – primary temperature sensor swapped (SN5660 off and SN2674 on) with very good results.
CTD Station 075: 5949 m depth (23:30 UTC)

*Turns out the LADCP downlooker had the wrong time stamp in it, and when processing downlooker and uplooker together, it caused the uplooker to look like it was completely off from the downlooker. When having problems with one LADCP WH, always remember to process separately for clues/insight. New filenames JC191_060M_date_fixed.000. Links in UH processing have been changed to point to fixed raw files.

Generally every station taking an extra half hour now due to wind picking up and ship's ground speed now reduced to <8knots instead of its usual 10knots.

J040 9th February

CTD Station 076: 5523 m depth (07:32 UTC)
CTD Station 077: 5796 m depth (15:10 UTC)
CTD Station 078: 5153 m depth (23:13 UTC)

Chocolate Sunday continues to be observed.

J041 10th February

CTD Station 079: 5589 m depth (06:55 UTC)
CTD Station 080: 5957 m depth (14:58 UTC)
CTD Station 081: 5379 m depth (22:48 UTC)

J042 11th February

International women in STEM day observed. Live feed event with female science team broadcast on Facebook and Twitter. The RRS James Cook steams across the MAR and the rift valley, first mapped by Marie Tharp, a woman who was not allowed to participate in fieldwork because of her gender.

CTD Station 082: 5284 m depth (06:12 UTC)
CTD Station 083: 5282 m depth (13:43 UTC)
CTD Station 084: 4568 m depth (20:42 UTC)

Autosal issues again. This time autosal programme is the one causing the trouble – for some reason it keeps asking to save a new file after each bottle was run (instead of just asking once per crate/session). Attempts to stop and restart the programme resulted in it crashing various times. Finally NMF techs made the decision to re-install the programme (after assurances it would not make any difference to standardisation).

J043 12th February

CTD Station 085: 4862 m depth (03:38 UTC) – mid-Atlantic Ridge rift valley station.

CTD Station 086: 5038 m depth (10:50 UTC)
CTD Station 087: 4564 m depth (17:37 UTC)

J044 13th February

CTD Station 088: 4540 m depth (00:22 UTC)
CTD Station 089: 4416 m depth (07:18 UTC)
CTD Station 090: 4932 m depth (14:10 UTC)
CTD Station 091: 4861 m depth (21:25 UTC) – swap RBR665 for RBR666. Continued misfiring on niskin 15 results in CTD pylon also swapped out for spare.

J045 14th February

Clocks forward 1hr. Local time now UTC – 2 hrs.

CTD Station 092: 4819 m depth (04:30 UTC)
CTD Station 093: 5400 m depth (12:01 UTC) - end of mid-Atlantic Ridge
CTD Station 094: 4499 m depth (19:54 UTC)

Valentine's day is observed. Mezz deck covered in hearts.

Spectacular green flash spotted at sunset.

NMF technicians report that the winch/AHC won't do displacements smaller than 5m.

J046 15th February
CTD Station 095: 4953 m depth (00:23 UTC) - Bottle standards for carbon lab*
CTD Station 096: 4880 m depth (06:49 UTC)
CTD Station 097: 5895 m depth (15:14 UTC)
CTD Station 098: 5383 m depth (23:25 UTC)

*At this station only the carbon lab and Lukas (incubations) sample. All bottles swapped for 20L niskins. Half (i.e. 12 niskins) were fired at a depth of 2,000m and the other other half at 40m.

AHC experiments also carried out on CTD station 95 to determine limits in min. depth displacements. It was discovered that what was constraining depth increments is the winch's speed.

J047 16th February

CTD Station 099: 5621 m depth (07:59 UTC)
CTD Station 100: 5164 m depth (16:10 UTC)

J048 17th February

CTD Station 101: 5711 m depth (00:51 UTC)
CTD Station 102: 5029 m depth (09:23 UTC)
CTD Station 103: 5070 m depth (17:46 UTC)

J049 18th February

CTD Station 104: 5373 m depth (02:06 UTC)
CTD Station 105: 5189 m depth (10:21 UTC) – end of MAR; beginning of eastern basin.
CTD Station 106: 6280 m depth (19:20 UTC) – CTD lowered only to 6,000 m.

Several days of slow steaming (<9 knots) due to swell eating up science contingency time.

Electronics workshop temperature dropped 4C below autosal bath temperature (7C); chief engineer called to sort the situation and heating coil turned on as a result. Temperatures monitored throughout the remainder of day remained stable around 26C.

Chief engineer reports that min. displacement is due to winch not AHC. There is a ramp time of 32 seconds constraining the displacement such that min dist = (1/2)*winch acceleration*ramp time^2

J050 19th February

CTD Station 107: 5248 m depth (04:10 UTC)
CTD Station 108: 5916 m depth (13:04 UTC)
CTD Station 109: 5967 m depth (21:59 UTC)

Captain reports slower steaming speeds due to swell and weather to continue for remainder of cruise. Rescheduling of stations in the eastern basin to makeup contingency time.

Banoffee pie, bringer of dreams and destroyer of diets, hits dinner table like a charging ship which has been authorized to steam with all 4 engines on.

J051 20th February

Science team member injured due to losing balance and tripping over yellow frame in staging bay whilst sampling for oxygen. Minor scrapes and bruises sustained. Accident reported through appropriate channels.

CTD Station 110: 5797 m depth (06:45 UTC)
CTD Station 111: 5745 m depth (15:50 UTC)

Noisiness level on met platform sensors (TIR and PAR) observed. The differences in noisiness levels between port- and starboard side radiance sensors investigated. It was decided to remove the effect of the weighted gimble from one of the pyranometers (portside) to observe the difference/effect (if any) of having one sensor fixed parallel to the ship and the other – rotating freely – parallel to the Earth.

Experiment of fixing the [starboard] pyranometer/radiometer left for several days to capture differences measured by the sensors in PAR and total incoming radiation.

Dust from the Sahara Desert observed from and on bridge.

J052 21st February

Clocks forward 1hr. Local time now UTC – 1 hr.

Cloudy, gray/overcast skies with almost no sun. Less than ideal conditions for trying to measure incoming radiation.

CTD Station 112: 5189 m depth (00:20 UTC)
CTD Station 113: 5668 m depth (10:57 UTC)
CTD Station 114: 5605 m depth (21:25 UTC)

J053 22nd February

CTD Station 115: 5464 m depth (07:57 UTC)
CTD Station 116: 5334 m depth (17:53 UTC)

Sandstorm perceived in the distance.

J054 23rd February

CTD Station 117: 5211 m depth (03:06 UTC)
CTD Station 118: 5064 m depth (12:10 UTC)
CTD Station 119: 4894 m depth (21:00 UTC)

Last of the chocolate lovingly distributed amongst labs.

Spectacular electrical storm + burst of hail!

J055 24th February

CTD Station 120: 4771 m depth (04:29 UTC)
CTD Station 121: 4585 m depth (12:18 UTC)

CTD Station 122: 4435 m depth (20:05 UTC)

J056 25th February

CTD Station 123: 4211 m depth (02:56 UTC)
CTD Station 124: 3784 m depth (10:42 UTC)
CTD Station 125: 3454 m depth (17:08 UTC)

J057 26th February

CTD Station 126: 3610 m depth (00:43 UTC)
CTD Station 127: 3649 m depth (08:01 UTC)
CTD Station 128: 3626 m depth (15:38 UTC)
CTD Station 129: 3486 m depth (22:46 UTC)

J058 27th February

CTD Station 130: 3151 m depth (04:48 UTC)
CTD Station 131: 2845 m depth (08:43 UTC) – bulk water station for carbon team substandards
CTD Station 132: 2593 m depth (13:39 UTC)
CTD Station 133: 2037 m depth (19:15 UTC)
CTD Station 134: 1425 m depth (23:44 UTC)

Dolphins sighted at midnight with their (a?) baby playing off starboard deck.

J059 28th February

Rescue boat ops.

Moroccan dip clear denied. Contingency plan to get extra station at the 1000 m mark at waypoint further north (outside of Moroccan EEZ) put in place.

CTD Station 135: 985 m depth (17:23 UTC)

End of cruise BBQ!

J060 29th February – steaming

Leap year!

Steam to Santa Cruz de Tenerife.

J061 1st March – in port

Docked at Santa Cruz de Tenerife.

Day spent demobilising.

Alejandra Sanchez-Franks

1. CTD System Configurations

1.1 Stainless Steel CTD Operations

135 casts were undertaken with an NMF 24-way stainless steel CTD frame using both 10l & 20l Niskin water samplers. Both the CTD wire and Deep Tow wire had been terminated on a previous cruise. These were both tested at the start of JC 191 prior to commencing operations.

The initial values measured for CTD 1 were:

- >1000 M oHms (insulation)
- 75.6 oHms (continuity)

Both terminations lasted the duration of the cruise, both the electrical and mechanical termination were checked regularly throughout the cruise.

In addition to the NMF supplied suite there were user supplied RBR's fitted to the frame, these were self-powered and logged internally, NMF technicians were required to switch them on prior to deployment and switch off on recovery. From cast 41 onwards a SBE 35 Deep Ocean Thermometer was fitted to the frame to provide additional temperature data as there was a discrepancy between the primary and secondary temperature sensors. On casts 61 – 74 the number of measurement cycles on SBE 35 was increased from 20 to 100 to give more data to compare with the temperature sensors. The primary temperature sensor was found to be the issue and this was replaced on cast 75. From casts 75 onwards the number of measurement cycles on the SBE 35 was reduced back to 20.

After each cast the temperature, conductivity and oxygen sensors as well as the pump were flushed with MilliQ. The whole CTD package was regularly washed with particular attention given to the SBE 32 latch assembly.

Only occasionally did the CTD have to return to the hangar prior to sampling, for the majority of the time the weather allowed the CTD to be lashed on deck. The science party sampled the rosette for salinity samples.

Cable CTD1 was used for casts 1 – 66 and also made use of a swivel. The swivel was removed for casts 67 – 70 to allow for casts deeper than 6000m, as a result it was decided to switch to the Deep Tow wire to mitigate the risk of damaging the CTD1 wire. From cast 71 onwards normal operations continued with CTD 1 and the swivel. Usually the normal range of 10m from the bottom for maximum wire out was used. The altitude at which the altimeter provided solid returns varied but was usually around 30 – 40 meters.

1.2 CTD Suite Technical Issues and Instrument Changes

During initial set up it was noted that the CTD frame top tube is slightly distorted, this makes fitting of 20L Niskins a two-person operation as one person is required to pull on the frame whilst the other fits the bottle.

After cast 001 following a request from the science party the primary dissolved oxygen sensor SBE 43-0709 was removed due to differences between the primary and secondary values. Upon removal of the instrument inspection revealed damage to the connector which will require repair.

During cast 025 the primary PC crashed when NMEA serial data dropped out. The cast continued to the seabed with cast data (excluding NMEA) being recorded on the secondary PC. At this point the system was re-configured to use the secondary PC as the main data recorder and data capture was restarted, the upcast was numbered 026.

Between casts 030 and 031 the majority of the 20L Niskins (all except 6,7,8, & 9) were replaced with 10L bottles due to intermittent issues with the 20L Niskins not closing properly.

After cast 034 the secondary temperature sensor 03P-5700 was replaced with 03P-5838.

After cast 035 the SBE 32 latch assembly S/N 0243 was swapped for the spare S/N 1005 due to consistent failure of position 1.

Prior to cast 041 SBE 35 0037 was fitted to the CTD.

Prior to 054 the LADCP star cable was replaced due to intermittent issues with the upward looking LADCP not recording.

For casts 066, 067, 068 & 069 the LADCPs, transmissometer and flourometer were removed as the expected cast depths were greater than 6000m. The instruments were refitted before cast 071 however LADCP S/N 24465 was replaced with S/N 13399 due to beam 2 becoming weak.

After cast 074 the primary temperature sensor 03P-5660 was swapped for 03P-2674.

After cast 090 due to interment firing of bottle 8 SBE 32 S/N 0243 was replaced with S/N 1005.

Before cast 093 the altimeter 41302 was replaced with 47597 due to poor performance, cable connections were inspected, cleaned and re-greased. The new altimeter did not increase the seabed detection distance, lack of performance was assumed to be due to a silty sea floor.

20L Niskin bottles were fitted for casts 095, 096, 097. From cast 098 10L bottles were refitted except in positions 6,7,8 & 9 where 20L bottles remained.

Before cast 104 bottles 5 & 10 were swapped to 20L Niskins leaving 5-10 as 20L and all others 10L.

For casts 112 &113 all bottles were changed to 20L before being returned to the previous arrangement for the rest of the cruise.

1.3 Active Heave Compensation

This was enabled on all casts using CTD1. However in strong surface currents where the wire was at an angle to the oversiding sheave, the winch operators disabled the AHC for better control to reduce the risk of the wire jumping the block. It would be advantageous if this sheave could be modified to allow it to align with the wire angle fore or aft.

AHC is not currently available on the Deep Tow winch system which was used on casts over 6000m deep.

Pro's and con's are summarised in the bullet points below:

1. Greatly improves package stability at a fixed depth with associated improvement in data quality.

2. Potential increased life of the wire (with the caveat that there is more movement of the wire through the traction system and hence may be of detriment to the wire?).

3. Linked to point 2 but just to emphasise that the AHC has at the very least contributed to the longevity of the CTD termination by reducing stress on this potential weak-point (highly probable although this is difficult to ascertain and only further use of the system can confirm this).

4. No or little documentation on the system. This is of concern as it impacts the training of new crewmen.

5. There is a relationship between the set winch speed and the minimum veer that the winch can achieve with the AHC enabled. However there was no knowledge of this on-board until trials were carried out during cast 95. The results are summarised in the table below:

Winch veer speed (m/min)	Minimum veer amount (m)
60	10
55	9
50	9
45	9
40	6
35	5
30	4

6. With the lack of experience and knowledge of this system there is no knowledge about what the default performance of the system is after a breakdown, be it a simple power outage or catastrophic computer failure. This is of particular concern during near sea-bed operations.

1.4 Stainless Steel CTD Sensor Information

SHIP: RRS JAMES COOK	CRUISE: JC191

FORWARDING INSTRUCTIONS / ADDITIONAL INFORMATION:

Checked By: TP/TB	DATE: 13th February 2020

Instrument / Sensor	Manufacturer/ Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-19817-0495	n/a	All casts
CTD Underwater Unit	SBE 9plus	09P-87077-1257	n/a	All stainless casts
Stainless steel 24-way frame	NOCS	SBE CTD 8	n/a	All stainless casts
Primary Temperature Sensor	SBE 3P	03P-5660	F0	Casts 1 - 74
Primary Temperature Sensor	SBE 3P	03P-2674	F0	Cast 75 onwards
Primary Conductivity Sensor	SBE 4C	04C-3698	F1	All stainless casts
Digiquartz Pressure sensor	Paroscientific	134949	F2	All stainless casts

Secondary Temperature Sensor	SBE 3P	03P-5700	F3	Casts 1-34
Secondary Temperature Sensor	SBE 3P	03P-5838	F3	Cast 35 onwards
Secondary Conductivity Sensor	SBE 4C	04C-3873	F4	All stainless casts
Primary Pump	SBE 5T	05T-3085	n/a	All stainless casts
Secondary Pump	SBE 5T	05T-3088	n/a	All stainless casts
24-way Carousel	SBE 32	32-0243	n/a	Casts 1 – 90
24-way Carousel	SBE 32	32-77801-1005	n/a	Casts 91 – onwards
LADCP DWL	TRDI WH 300	24466	n/a	1-66 & 71 onwards
LADCP UWL	TRDI WH 300	24465	n/a	Casts 1 - 66
LADCP UWL	TRDI WH 300	13399	n/a	Casts 71 onwards
LADCP Battery Pack	NOCS	WH011T	n/a	1-66 & 71 onwards
Primary Dissolved Oxygen	SBE 43	43-0709	V0	Cast 001
Primary Dissolved Oxygen	SBE 43	43-0363	V0	Casts 2 onwards
Secondary Dissolved Oxygen	SBE 43	43-0619	V1	All stainless casts
Flourometer	CTG AquaTracka III	088195	V2	1-66 & 71 onwards
Transmissometer	WETLabs C-Star	CST-1719TR	V3	1-66 & 71 onwards
Altimeter	Benthos 916T	41302	V6	Casts 1 - 92
Altimeter	Benthos 916T	47597	V6	Casts 93 onwards
Deep Ocean Thermometer	SBE 35	34173-0037	n/a	Cast 41 onwards
20L Water Samplers	OTE	SET A	n/a	
10L Water Samplers	OTE	SET B	n/a	

1.5 Cast Summary

Cast	Julian Day	Max Depth (m)	Cast	Julian Day	Max Depth (m)	Cast	Julian Day	Max Depth (m)
001	019	700	051	030	5628	101	047	5700
002	020	32	052	031	5703	102	048	5018
003	020	57	053	031	5690	103	048	5058

004	020	140	054	032	5695	104	048	5362
005	020	256	055	032	5269	105	049	5179
006	021	378	056	032	5545	106	049	5998
007	021	521	057	033	5700	107	050	5415
008	021	637	058	033	5754	108	050	5905
009	021	753	059	033	5790	109	050	5954
010	021	669	060	034	5866	110	051	5785
011	021	605	061	034	5764	111	051	5732
012	021	471	062	034	5847	112	051	5179
013	021	360	063	035	5831	113	052	5656
014	022	369	064	035	5799	114	052	5593
015	023	1192	065	035	5880	115	053	5453
016	023	1195	066	036	5816	116	053	5321
017	023	1440	067	036	6265	117	053	5200
018	023	2185	068	037	5993	118	054	5052
019	023	3706	069	037	6455	119	054	4882
020	023	4505	070	037	5850	120	055	4760
021	024	4013	071	038	5217	121	055	4574
022	024	4700	072	038	5954	122	055	4425
023	024	4830	073	039	5821	123	055	4200
024	024	4825	074	039	5721	124	056	3773
025	024	4808	075	039	5938	125	056	3444
026	024	4808	076	040	5512	126	056	3600
027	025	4804	077	040	5786	127	057	3639
028	025	40	078	040	5143	128	057	3615
029	025	4795	079	041	5575	129	057	3476
030	025	4737	080	041	5945	130	058	3140
031	025	4680	081	041	5368	131	058	2004
032	026	4677	082	042	5275	132	058	2583
033	026	4633	083	042	5272	133	058	2028
034	026	4604	084	042	4557	134	058	1414
035	026	4528	085	042	4852	135	059	977
036	026	4485	086	043	5031			
037	027	4534	087	043	4555			
038	027	4662	088	043	4526			
039	027	4905	089	044	4405			
040	027	5033	090	044	4922			
041	028	5133	091	044	4856			
042	028	5174	092	045	4809			
043	028	5258	093	045	5386			
044	028	5364	094	045	4488			
045	029	5472	095	045	2000			
046	029	5478	096	046	4867			
047	029	5491	097	046	5882			
048	030	5503	098	046	5373			
049	030	5492	099	047	5611			
050	030	5583	100	047	5154			

1.6 LADCP Instrument Configuration

Two self-logging Teledyne RDI Workhorse 300kHz ADCP were installed on the Stainless Steel CTD frame in master/slave configuration.

S/N 13399 (casts 1-66) & S/N 24465 (cast71 onwards) were installed as upward looking "slave" units.
S/N 24466 was installed as the downward looking "master" unit and was used for all casts.
The LADCPs were powered by NMF workhorse battery pack S/N WH011T.

1.7 LADCP Deployment Command Scripts

Downward looking LADCP (master)	**Upward looking LADCP (slave)**
PS0 - Display system configuration	*PS0 - Display system configuration*
CR1 - Retrieve parameters (1 = factory)	*CR1 - Retrieve parameters (1 = factory)*
RN JC191 - Set deployment name	*RN JC191 - Set deployment name*
WM15 - Water profiling mode	*WM15 - Water profiling mode*
CF11101 - Flow control	*CF11101 - Flow control*
EA00000 - Heading alignment	*EA00000 - Heading alignment*
ES35 - Salinity	*ES35 - Salinity*
EX00100 - Coordinate transform	*EX00100 - Coordinate transform*
EZ0011101 -Sensor source	*EZ0011101 - Sensor source*
TB00:00:02.80 - Time per burst	*TB00:00:02.80 - Time per burst*
TC2 - Ensembles per burst	*TC2 - Ensembles per burst*
TE00:00:01.30 - Time per ensemble	*TE00:00:01.30 - Time per ensemble*
TP00:00.00 - Time between pings	*TP00:00.00 - Time between pings*
LP1 - Pings per ensemble	*LP1 - Pings per ensemble*
LN25 - Number of depth cells	*LN25 - Number of depth cells*
LS0800 - Depth cell size (cm)	*LS0800 - Depth cell size (cm)*
LF0 - Blank after transmit (cm)	*LF0 - Blank after transmit (cm)*
LW1 - Band width control (1 = narrow)	*LW1 - Band width control (1 = narrow)*
LV400 - Ambiguity velocity (cm/s radial)	*LV400 - Ambiguity velocity (cm/s radial)*
SM1 - RDS3 mode select (1 = Master)	*SM2 - RDS3 mode select (2 = Slave)*
SA011 - Synchronize before/ after ping/ ensemble	*SA001 - Synchronize before/ after ping/ ensemble*
	ST0 - Slave timeout (0 – 10800 seconds)
SB0 - Channel B Break interrupt mode (0 = Disable)	*SB0 - Channel B Break interrupt mode (0 = Disable)*
CK - Keep parameters as user defaults	*CK - Keep parameters as user defaults*
CS - Start pinging	*CS - Start pinging*

1.8 LADCP Deployment & Recovery Procedure

Prior to each deployment a standard checklist was followed:

Pre-deployment

- Create a deployment terminal capture log file named in the form JC191_xxx(M/S).txt

- Change baud rate to 9600 baud (CB411) to ensure correct parsing of command file.
- Check instrument time (TS?) by comparing to GPS time. Reset time if offset > 5s.
- Check free data storage available (RS?), reformatting the card if required.
- Record number of deployments on instrument storage card (RA?)

The command script file is then sent to the instrument to deploy it, once started the battery is then taken off charge and the deck-cables disconnected and blanking plugs fitted for deployment.

Post-deployment

- Reconnect deck-cables. Start charging battery pack.
- Upon recovery at the end of the cast, the instruments are stopped by sending a break in BBTalk.
- The baud rate is changed to 115200 baud (CB811) to reduce the data download time.
- Record number of deployments on instrument storage card (RA?)
- Start download of data using BBTalk 'Recover Recorder' command, selecting appropriate file(s) and noting their number in the default filename sequence JC191xxx.000.
- Rename the downloaded files using the form JC191_xxx(M/S).
- Backup the files to the network archive.
- Check data files in WinADCP:
- Select a region of data with high echo intensity and check for consistent levels for all four beams for echo intensity and beam correlation.
- Check that the start and stop times of the data files corresponds with the deployment and recovery times.
- Record the number of pings (ensembles) in each data file.

1.9 Sea-Bird SBE 35 Deep Ocean Standards Thermometer

A SBE 35 deep ocean standards thermometer S/N 35-34173-0037 was installed on the CTD from cast 41 onwards following a request from the science party, it was initially configured to record 20 measurements per sample.

There was no sea cable found with the instrument so a spare cable packaged with SBE 35-66264-0070 was used.

The interface box S/N 0034 that was packaged with SBE 35-34173-0037 was found to be faulty, therefore the spare interface box S/N 0058 packaged with SBE 35-66264-0070 was used to program the instrument.

The upload data function in Sea Term did not work, following each cast commands were entered manually into Sea Term to retrieve the data.

The post deployment procedure was as follows:

With the 11 plus deck unit still powered on open Sea Term, click connect, click capture and enter file name in the format xxx_file_capture.cap. Type DS and press enter (downloads instrument status), type DC and press enter (downloads the coefficients), type DD (downloads the data). Click capture again to end the data capture then click disconnect.

1.10 Data Processing

Standard Sea-Bird processing of the raw data was completed using Sea-Bird Data Processing software. The BODC "Recommended steps for basic processing of SBE-911 CTD data." Version 1.0 October 2010 instructions were followed for all casts.

The following processes were run:

- Data Conversion
- Bottle Summary
- Align CTD
- Cell Thermal Mass
- Derive
- Bin Average
- Strip

Once completed, all processed and raw data files were backed up onto the network drive and made available to the scientific party.

A further data conversion process was run in order to provide data to the UK Met Office, the variables included were time, depth, pressure, temperature 1 & 2, conductivity 1 & 2 and salinity 1 & 2.

Sound velocity profiles were processed once a day using the Chen-Millero equation.

1.11 Salinometry

Salinity samples were taken from the CTD rosette by the science party using crates of sample bottles (24 bottles per crate). After collection, all samples were stored in the Salinometer lab for a period of at least 24 hours prior to sampling; this is to allow the samples to stabilise at the lab's temperature.

All samples were analysed on Guildline Autosal 8400B S/N 71126. A standard was run as a sample before and after each crate of samples as a control.

The Autosal was standardised using IAPSO Standard Seawater batch P163 (K15=0.99985, 2xK15=1.9997, 34.994 PSU). The machine was standardised at the beginning of the cruise and left throughout the cruise.

A data file from the analysis software was supplied for each crate as an Excel spreadsheet. All measurements were also logged manually on paper log-sheets.

Issues;

During the first use it was reported to the technicians that the standardization knob on 71126 was not responding to adjustments, when a technician investigated it worked as expected. It is likely this is due to a dirty pot; this will require replacing and further investigation post cruise. A few days later 711256 was giving unstable readings, the Auotosal was opened and the internal connectors to the measuring coils were cleaned with nusolve, this resolved this issue.

The zero value steadily increased during the first few weeks this appeared to coincide with an increase in the temperature of the lab. The Chief Engineer inspected the air conditioning unit within the lab, after which the ambient temperature became more stable and the zero value more constant. This will also require investigation during the post cruise calibration as the zero value was consistently reading +9.

1.12 Software Used

Sea-Bird SeaTerm 1.59

Sea-Bird Seasave 7.26.7.121

Sea-Bird SBE Data Processing 7.26.7

TRDI BBTalk 3.09

TRDI WinADCP 1.14

Tom Ballinger, Tim Powell, John Wynar

2. CTD Processing and Calibration

2.1 Mexec processing

Filesystem mounts

Workstation koaekea was set up in the main lab and assigned permanent IP address 198.162.62.110, previously identified as assigned to retired w/s banba.

Koaekea has been attached to the network during trials cruise JC184 in July 2019, and notes about how to mount filesystems was copied from that cruise. The following mount hints were noted, mounts to be carried out as root user

```
mount -t cifs //192.168.62.225/data /mnt/uhdas_data -o guest
mount -t nfs 192.168.62.12:/home/techsas/Data /mnt/techsas
mount -t cifs //cookfs.cook.local/JC191 /mnt/JC191 -o username=
                                          sciguest,password=sciguest
mount -t cifs //cookfs.cook.local/Public  /mnt/public -o username=
                                   sciguest,password=sciguest
```

This resulted in the following entries in /etc/mtab, with long lines abbreviated

```
192.168.62.12:/home/techsas/Data /mnt/techsas nfs rw, …..
//cookfs.cook.local/JC191 /mnt/JC191 cifs rw, …..
//cookfs.cook.local/Public /mnt/public cifs rw,…..
//192.168.62.225/data /mnt/uhdas_data cifs rw,…..
```

Note that in order to write to the public directory, pstar needed to change user to root.

A mount point is needed in /mnt, created using mkdir, before the mount command can be executed. Shortcuts were set up to point from ~pstar/mounts to the mount points in /mnt.

At the start of jc191 a cruise data directory had been already been set up when the workstation was prepared for sea. A few empty directories were missing and were made as needed: met/surfmet; met/surflight, based on the jc159 data structure. A templates directory was set up, linked to mexec_processing_scripts/templates templates.

Some files were copied from jc159. Eg ctd_renamelist.csv, because it was already set up for dual oxygen sensors.

Backups

Directory other_backups was created to allow use of script exec/mexec_cruise_backup_jc191 which was the backup script used for this cruise. Backups were run by crontab twice daily, at 10 minutes after 0100 and 1300 UTC, to 1TB USB external hard drives, formatted to ext4.

Techsas

techsas_linkscript was run by crontab at 2 minutes past 00:00 UTC, so that the latest techsas files would become available. *Techsas_linkscript* does not link files less than 10k bytes, to avoid linking empty or corrupt files with just headers. This has been robust on past cruises. Files with low data rate or few variables fill slowly and do not link immediately. Therefore the crontab also ran at 0010, 0020, 0100 and 0300. 0300 was necessary to ensure the EM120 files were linked. Those files could be linked manually if needed more urgently. *Techsas_linkscript* was modified to write the unused link command in the log file that each run of linkscript creates in *techsas_link_logs*.

Other linkscripts

CTD and LADCP linkscripts were modified as needed. *ctd_linkscript* was modified to copy only the raw 24hz cnv and the _Align_CTM.cnv. Other intermediate files and files created with derived variables were not copied. hex, hdr and XMLCON files were copied to ctd/RAW_CTD_FILES, but not used.

Snctools replacement

The use of the snctools library, width command like *nc_info* and *nc_varget*, has become increasing problematic with compatibility with matlab versions and some calls to a library of compiled commands called *mexnc*. Also, some commands in the snctools library are very slow, especially *nc_info*, which is called very often by mexec.

A new set of commands was written near the start of the cruise, to mimic snctools, but use entirely matlab *netcdf* commands. Instead of changing all the mexec programs that call snctools functions, a new mexec_snctools function was created for each of the snctools fucntions that are used anywhere in mexec. A new library was created, mexec_snctools, which sits under source alongside *mstats*, *msubs*, etc, and is declared in *m_setup*. All the old NetCDF directories are now not needed. The mexec_snctools functions call native matlab *netcdf* commands that are displayed in matlab if you type “help netcdf”. For example
netcdf.inqVar
netcdf.getVar

Commands such as *ncreadatt*, *ncread*, etc were avoided. Only commands that are a suffix to netcdf were used. The Matlab commands *ncinfo* and *ncdisp* may be useful for exploring NetCDF files, but are not used in mexec_snctools. Each mexec_snctools function includes the help info from the snctools function it replaces.

>> *help mexec_snctools* has a lot more information.

Mexec_snctools was tested throughout jc191, and a few glitches found and fixed. It functioned correctly for all data processing options carried out on jc191.

Speed: Testing over thousands of executions showed the new functions are between 2 and 10 times faster than some old snctools functions they replace. In particular read and write of small files with many variables are now very much faster, so *mapend* of small files, and copying of small files is now not a problem. Previously it had been very difficult. Complete reprocessing of a single CTD station, eg to apply calibrations from raw and through to derive 2 dbar files, is now less than one minute per station, meaning this is no longer a problematic task.

strmatch.m

Matlab help warns that *strmatch.m* will be removed in a later release of matlab. New function *m_strmatch.m* was created to provide the same functionality. To edit all mexec functions and scripts to replace *strmatch.m* with *strcmp.m* would be a major task and likely result in errors. *m_strmatch.m* sorts out the arguments and calls *strcmp*, *strncmp*, etc in appropriate circumstances. *m_strmatch.m* was placed in mstats as a convenient place to store it, alongside, for example, *m_nanmean.m.* Part way through jc191, a link was created so that a call to *strmatch.m* called *m_strmatch.m*. A few glicthes around zero length strings were ironed out, and the new mexec version as used for the rest of the cruise. I recommend this is the practice from now on, so that the removal of matlab *strmatch* is not noticed.

data/collected files

The data/collected_files directory was used to accumulate files that will be the main archive at the end of the cruise, and will contain the appended underway data streams, copies of the CTD data for archive, and other useful files and plots.

Git

A git commit was carried out on 26 Feb, and will be carried out again at the end of the cruise.

Lists of changed mexec source and processing scripts

Separate from Git tracking, two files were created in data/users/bak/mexec_script_changes. These two files listed mexec source and

processing scripts that had been changed with notes about what had changed and why.
mexec_processing_scripts_diffs
source_diffs

2.2 CTD and bottle data processing

Routine CTD data processing followed previous cruises. A collection of scripts gatherd in ctd_all_part1.m to read in data from SBE .cnv files, manual selection of the start and end of the cast using mdcs_03g.m, and a second collection in ctd_all_part2.m to reduce data to 1Hz, extract and average down and up casts, and prepare the CTD data and winch data corresponding to bottle closures.

Initial files from datcnv, and Oxygen hysteresis

After a few false starts that required reprocessing, data were converted to SBE cnv files with the following algorithms applied in SeaSoft datcnv:

advance primary conductivity 0.073 seconds (applied in deck unit)
advance secondary conductivity 0.073 seconds (applied in deck unit)
datcnv_ox_hysteresis_correction = no
datcnv_ox_tau_correction = yes
alignctd_adv = sbeox0V 5.000, sbox0Mm/Kg 5.000, sbeox1V 5.000, sbox1Mm/Kg 5.000
celltm_alpha = 0.0300, 0.0300
celltm_tau = 7.0000, 7.0000

Certain variables or units that are not always output by NMF, but are required outputs for mexec processing include
name 0 = timeS: Time, Elapsed [seconds]
name 1 = latitude: Latitude [deg]
name 2 = longitude: Longitude [deg]
name 7 = c0mS/cm: Conductivity [mS/cm]
name 8 = c1mS/cm: Conductivity, 2 [mS/cm]
name 11 = sbeox0V: Oxygen raw, SBE 43 [V]
name 12 = sbox0Mm/Kg: Oxygen, SBE 43 [umol/kg]
name 13 = sbeox1V: Oxygen raw, SBE 43, 2 [V]
name 14 = sbox1Mm/Kg: Oxygen, SBE 43, 2 [umol/kg]
name 19 = scan: Scan Count
name 20 = pumps: Pump Status

Note preferred units for Conductivity and Oxygen, and the output of lat and lon, scan and pumps.

Oxygen hysteresis was not applied in datcnv, so that we could explore and change hysteresis parameters.

A script not really part of the usual mexec suite was brought up from a dy040 archive: *toxy.m*. This allows experimenting with different hysteresis parameters until optimum up/down agreement is achieved.

Default hysteresis parameters, which are applied in *mcoxyhyst*, are [H1, H2, H3] = [-0.033 5000 1450];
Experimentation on the early deep stations found that, as on dy040, better up/down agreement could be achieved by letting H3 vary with depth. Accordingly the following lookup tables for H3 were devised

Oxygen1:
p < 2000: H3 = 1000;
2000 < p: H3 = 3000;

Oxygen2
p < 2000: H3 = 1000;
2000 < p: H3 = 3500;

These values were used throughout the cruise, and provided good upcast/downcast agreement throughout, with up-down differences of order 1 umol/kg for much of the water column.

Processing scripts

Changes and departures from standard scripts in place at the start of the cruise:

ctd_all_part1: Options were added, controlled by opt_jc191, to apply temp, cond, oxy, transmissometer and fluor cals as part of ctd_all_part1. This meant that once calibrations had been determined, they could be applied as data were processed. The default, if no entries are made in *opt_mcruise*, is for no calibration to be applied.

mctd_02a: New code to allow some variables to be set to nan for some stations: fluor and trans for deep stations where instruments were removed.

mctd_fluorcal and mctd_transmisscal, fluor_applycal and transmiss_apply_call: Now set up equivalent to temp, cond, oxygen, so that calibration can be controlled and applied from *opt_mcruise*.

Various minor tweaks were made to bottle data processing, bug fixes or minor enhancements.

Sensors and calibrations, selection of datastream,SBE35

Throughout this report we will refer to primary and secondary sensors as 1 and 2. This is different from the SBE convention of using 0 and 1. The sensors in the SBE primary channel were mounted below the water bottle rosette, and the sensors in the SBE secondary channel were mounted on the vane. The secondary sensors produced the best data and that data stream will be reported as the cruise dataset for T, S, O for all stations.

Temperature calibration

It was apparent from the start that there was a temperature difference between T1 and T2. The character of this difference was a 2 mdeg offset at the surface, and a dependence on pressure. At this stage we could not tell which sensor was showing a pressure response. We waited until station 35 to change one of the sensors, so that we could characterise the difference with a good number of deep stations. For stations 35 and later, we had a second T2 in place. This suggested that it was the T1 that had the pressure dependence, and T1 was changed for stations 75 and later.

We therefore consider two T1 sensors, denoted T11 and T12 (stations 1-74 and 75-end), and two T2 sensors, denoted T21 and T22 (1-34 and 35-end).

When it became apparent that care would be needed to sort out the temperature calibration, an SBE35 was mounted on the frame, and provided data for stations 41 onwards.

T12 and T22 were in close agreement. They were of order 0.5 mdeg different, either side of the SBE35. There was a suggestion of a slightly bigger residual between the SBE35 and T12, so T22 was adopted as well calibrated and the reliable source of temperature data for the cruise.

Describing differences between T sensors from bottle stops recorded in station sam files did not provide sufficiently precise comparisons to describe and characterise the sensors at a level better then 1 mdeg. Therefore script *explore_ctd_jc191.m* was used to compare sensors for the entire downcast of groups of stations. This made it possible to make good determinations of the character of differences between sensors, and the following conclusions were reached, starting with T22 as a ‘good’ sensor. T11 and T21 both required pressure adjustments, expressed here as mdeg per 1000 dbar. T12 and T11 are adjusted to agree with T22. T21 is adjusted to agree with T11.

T12: adjust by + 0.60 mdeg
T11: adjust by + 0.40 – 0.50*p/1000 mdeg. ie +0.4 mdeg at p = 0; -2.6 mdeg at p = 6000.
T21: adjust by + 2.42 – 0.13*p/1000 mdeg

After making these adjustments, agreement between the pairs of sensors, and between the sensors and SBE35, is indistinguishable from zero.

A curious change happened to the T22-T12 difference between stations 83 and 84. Up to station 83, the T2-T21 difference, matched on time and shown for the downcast, had a certain characteristic, shown in black in Fig 2.1 for stations 81 to 83. For station 84 and following, shown by stations 84 to 86 in Fig 2.1, the characteristic changed. We could not identify anything that changed between stations 83 and 84, or any incident involving the CTD frame being stressed. Fig 2.1 is output from *explore_ctd_jc191.m.* Note that the significant negative difference shallower than 1000 dbar is associated with passing through the main thermocline. The point in the figure is not why there is an overall slope in the T2-T1 difference, but that the T2-T1 difference changes.

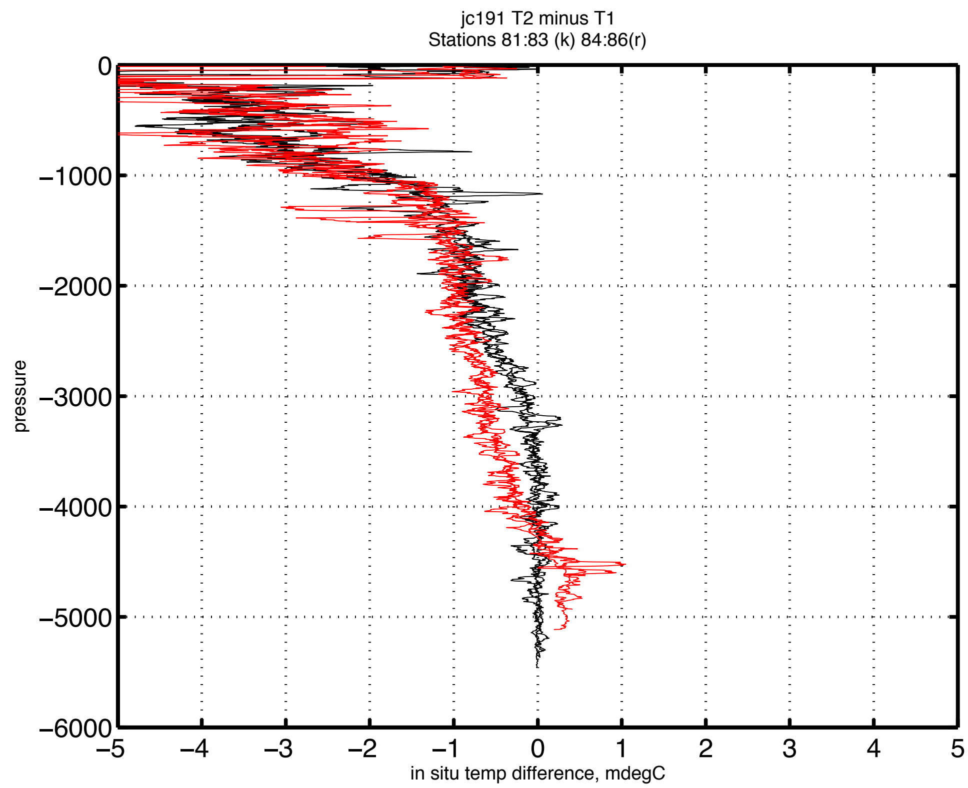


Figure 2.1: *Sensor temperature differences. T22-T12 difference between CTD stations 81 to 83 (black line) and T22-T12 difference for CTD stations 84 to 86 (red line).*

<u>Conductivity and salinity calibration</u>

The same C1, C2 sensors were used throughout, and were stable compared with bottle salinity. Examining the ratio of C2/C1 in *explore_ctd_jc191.m* showed it to be remarkably uniform in the vertical, suggesting that the C sensors had either no residual pressure dependence, or identical residual pressure dependence.

Furthermore the offset between C1 and C2 showed little or no drift over the entire cruise. Two offsets were determined from comparison with bottle salts:

C1 adjust by factor (1 – 0.0003/35)
C2 adjust by factor (1 + 0.0022/35)

The adjustment is written in that way because the 0.0022 coefficient in C2 adjustment is nearly equivalent to a salinity adjustment of +0.0022

After applying the temperature and conductivity adjustments described so far, the bottle minus CTD salinity residuals had zero mean but a distinct pressure-dependent shape. This shape is the residual between the analysed bottle salinity drawn from a Niskin bottle, and the reported CTD sensor salinity. These two measurements are not of the same sample of water. Bottle samples of water inside the Niskin bottle, when closed in the main thermocline where the salinity gradient is strongly increasing as the package moves upwards, generally describe water that the CTD measures at least 5 metres deeper. This is an estimate of the flushing distance of the Niskin bottles. Also, the CTD is exposed to entrainment and wake effects, and this can be different for the frame and vane sensors. Therefore there are good reasons why the CTD and bottle samples may not agree.

The Niskin flushing distance accounts for why bottle salinity in the main thermocline is usually much fresher than CTD salinity. This is not a calibration issue.

But we have no explanation for the highly reproducible shape of bottle-CTD residuals away from the main thermocline. The shape does not match stratification, and we could not fit it to any other explanation of lags or sensor geometry. The same shape was observed in bottle-CTD residuals for C1 and C2.

We conclude that either T1 and T2, or C1 and C2, or possibly a pressure error, must exhibit a pressure dependence, with the same dependence on each sensor of that type. SBE35 comparisons at bottle stops are not tight enough to characterise whether the T sensors have this dependence or not.

The magnitude of the residual is of order 0.001 in S, which could result from 0.001 in T or 0.001 on C, or a departure of reported P from true P of order 2 dbar.

In the absence of a definitive identification of the reason for the residual, an adjustment was made to the C sensors, according to an interpolation lookup table:

A coefficient c was interpolated from
P = [0 1000 4000 6500],
c = [0 +0.0015 -0.0005. -0.0005];
This factor was then turned into a cond scaling factor:
fac = 1 + c/35
Both C1 and C2 were scaled by this factor. One profile of coefficient c for both sensors for the entire cruise. This was equivalent to adding zero to S at the surface, add 0.0015 at 1000 dbar, subtract 0.0005 at 4000dbar and below.

After the single scaling for C2, and then the pressure dependent scaling, the residuals of Bottle minus C2 salinity for the cruise is in Fig 2.2. This histogram of residuals deeper than 2000 dbar is in Fig 2.3.

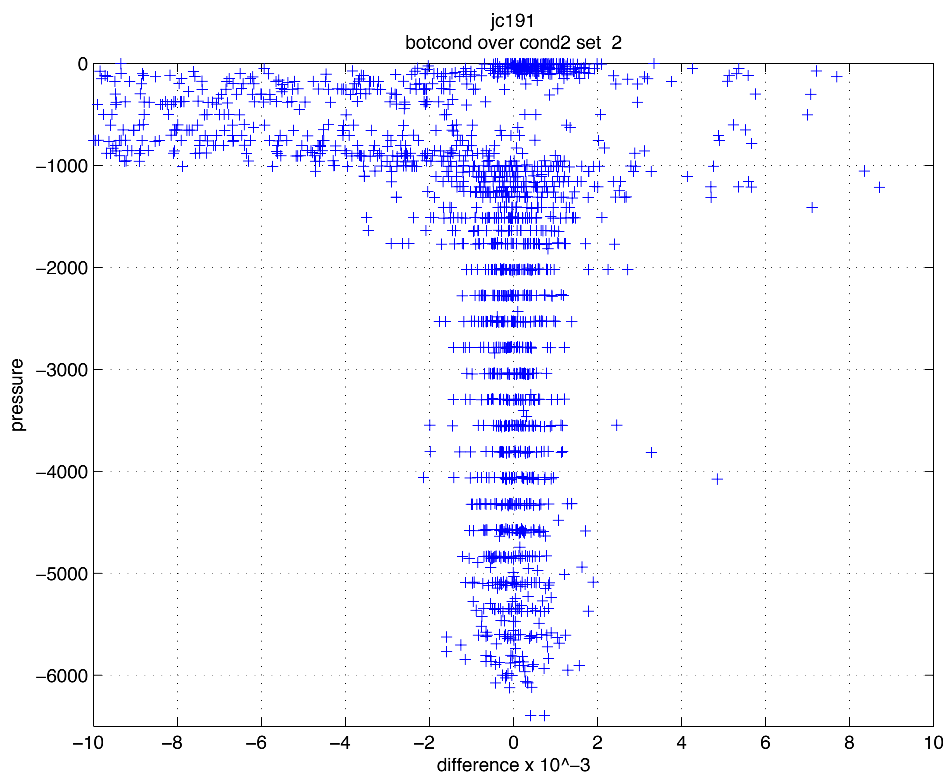


Figure 2.2: *Blue crosses show the residuals of bottle minus CTD2 sensor salinity as a function of depth.*

Sensor C1 had fouling on station 123, a segment of data was removed using mctd_rawedit.

Towards the end of the cruise, it was noticeable that there was a slight divergence between S1 and S2, with S2-S1 drifting slightly positive, by a maximum of 0.001. This was visible in the comparison between the CTD sensors for deep bottles. The comparison with bottle samples suggested that S2 was stable and S1 was drifting. Since we had already decided to report S2, no further calibration adjustments were performed. S2 is preferred, and we consider that S1 is not perfectly calibrated. T2 and S2 are the values reported in variables ‘temp’, ‘psal’, ’asal’, ’potemp’.

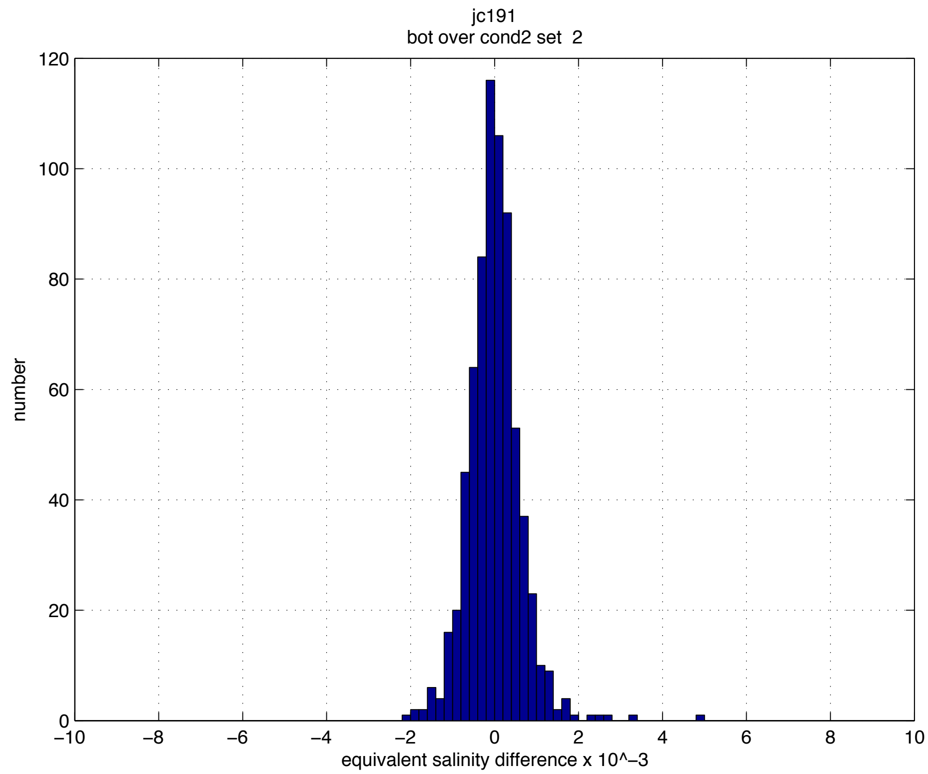


Figure 2.3: *Histogram of residuals (as per Fig. 2.2) deeper than 2000 dbar.*

<u>*SBE35*</u>

An SBE35 was added to the frame at station 41, to enable us to investigate the nature of differences between the SBE T sensors. Each station of data was read from file *nnn_file_capture.cap*, and read into mexec using scripts *msbe35_01* and *msbe35_02*. For stations 060 to 065, there was a day error in the SBE35 files. This was fixed manually for those files.

The initial SBE35 configuration collected 20 samples, at an interval of 1.1 seconds, requiring the CTD to be stopped for 20 seconds after each bottle closure.

In order to try to get some improved comparison points, the SBE35 was set to capture 100 cycles for stations 61 to 74. This required 2-minute bottle stops. The CTD was not kept stopped for 2 minutes after every bottle closure. Instead, 2-minute stops were allowed for 3 levels per station: One at the bottom of the cast, usually the second bottle closed, to avoid a long wait near the seabed; one or near at 3000 dbar, and one in the surface mixed layer, usually at 50 dbar to avoid a long wait very near the surface. The other bottle stops, being shorter than the SBE35 sampling period, would not produce good comparisons.

After the raw sbe35 data had been uploaded to *sam_jc191_all.nc*, script *msbe35_extract_proper_ctd_times.m* was run. This script inspects the CTD pressure record during the time the SBE35 was sampling. If the CTD pressure has a range of more than 5 dbar, the SBE35 value is given a flag of 4. This has two purposes: (1) SBE35 data collected when the CTD did not stop for the full duration of sampling, are flagged as bad. (2) A CTD temperature value for utemp1 and utemp2 are calculated for the full period of SBE35 sampling, and not just the 1Hz CTD value merged onto the time of bottle closure. The output file for *msbe35_extract_proper_ctd_times.m* was *sbe35compare_jc191_all.nc.* There is a working file: *sbe35compare_jc191_allspare.nc*. At the end of the cruise, the SBE35 flags were written back into the *sam_jc191_all.nc* file.

The SBE35 has a maximum collecting cycle of around 100 samples. At some stations with 2-minute samples, extra SBE35 samples were collected. This was achieved by sending a second command to close the same numbered bottle. The SBE35 collected a second sample, saved into the .cap file, but nothing else happened on the rosette. It was hoped these extra samples might give better insight into CTD sensor errors, but nothing conclusive was found.

Oxygen calibration

The calibration for oxygen sensors was determined with script *explore_oxygen2_jc191.m*. At the end of the cruise this was placed in directory *mexec_processing_scripts_v3 /extras_jc191*, which is not in the matlab search path.

explore_oxygen2_jc191.m works in two stages. First, residuals are calculated between bottles and each CTD sensor. The residuals are kept as a scaling factor rather than an offset, since a change in sensitivity is considered a more likely sensor error than an offset. As a first guide, the median residual is calculated for each station and plotted as a time series, with station number as the independent variable. A series of breakpoints is then chosen, which will enable a piecewise linear fit of a scaling factor that will be applied for each station. The breakpoints are entered into the script in a line

b1 = [0 20 70 122 135];

for sensor 1. The form of the scaling factor is an initial offset, and then a series of slopes, continuous at each breakpoint. So in the above example, if the station number is S, the factor is
a + b*S for 0 < S <= 20
a + b * 20 + c * (S-20) for 20 <= S <= 70
a + b * 20 + c * 50 + d * (S-70) for 70 <= S <= 122
and so on. The number of breakpoints can be as many as required.

So a is an offset and b,c,d,e…. are slopes.

The coefficients a,b,c,d,… are determined simultaneously from a single least squares fit to the station median residuals.

On jc191, we believed the oxygen sensors were generally likely to lose sensitivity, so all the slopes b,c,d,… should be positive. The stations up to station 20 were generally shallow, so we considered each station residual to be less well determined. The coefficient b was negative in the first least-squares fit, and this was rejected. In preparation for the least squares fit, a matrix V is prepared from the data, with each column of V corresponding to one coefficient. The line V1(:,2)= 0 was used, which removes from V the influence of b on the least squares fit. The coefficient b is then calculated to be zero. Other coefficients could likewise be removed from the least-squares calculation.

The second step was to apply the station-varying factor, and examine remaining residuals in the vertical, again as a scaling factor. Each sensor showed a highly-reproducible shape of pressure dependence. This could be a genuine response of the sensor, or an artefact of the way the oxygen hysteresis coefficients were chosen, but since it was highly reproducible, we chose a single shape for each sensor and applied it to the whole cruise. Internal to *explore_oxygen2_jc191.m,* these two corrections are applied and final residuals displayed. The script writes the lists of coefficients in a form that can be cut and pasted into opt_jc191. For jc191:

Sensor 1

```
o1rs_s = [ 0 20 70 122 135  ];
o1rs_f = [  1.0410  1.0410  1.0586  1.0663 1.0726  ]; % adjusted after 135
deps = [ -10 2000 3000 4000 5000 6000 6600  ];
o1dfac = [0.9835 0.9959 1.0086 1.0170 1.0223 1.0268 1.0268]; % calculated
with stations up to 116
o1rs_i = interp1(o1rs_s,o1rs_f,stn); % interpolate station factor and scale dep
factor
o1dfac_p = interp1(deps,o1dfac,press);
alpha = o1rs_i.*o1dfac_p;
beta = 0;
oxyout = alpha.*oxyin + beta;
```

Sensor 2

```
o2rs_s = [ 0 20 70 122  135 ];
o2rs_f = [  1.0370  1.0370  1.0671  1.0693 1.0756  ]; % adjusted after 135
deps = [ -10 2000 3000 4000 5000 6000 6600  ];
o2dfac = [0.9822 0.9996 1.0124 1.0186 1.0219 1.0212 1.0212];
```

After applying the station-dependent and pressure-dependent correction factors, the residuals between CTD and bottle oxygens were nearly all less than 2 umol/kg at depths below 200 dbar.

Other notes: oxygen1 on the test station 1 read very low. The sensor was changed, and the data from oxygen1 on station 1 was not further considered; oxygen1 fouled on station 39 and a segment of data was removed with *mctd_rawedit*.

oxygen2 and the oxygen1 sensor for stations 2 to 135, are considered to be well-calibrated and final, subject to any revisions of bottle oxygen data.

Oxygen calibrations are saved in *opt_mcruise* and applied through script *'oxy_apply_cal'.*

Transmissometer calibration

The values exported in SBE datcnv are supposed to be percent transmittance over a 0.25 metre path length, for a 660 nm (red) source. 100% represents pure water. The maximum transmittance on each station was generally over 100%. The calibration of field data should involve determining the maximum air voltage and dark values. For the purposes of this cruise we simply determined the maximum transmittance values of groups of stations,
script *find_max_trans.m*
and scaled the data with a factor to place the maximum transmittance at or slightly below 100%.

The maximum raw value was observed for groups of stations, and a factor chosen for that group of stations. The data were adjusted by dividing by the factor in the table, to ensure transmittance was always less than 100%

Stations	factor
1-13	1.0150
14-60	1.0134
61	1.0105
62-66	1.0116
67-70	No data
71-84	1.0089
85	1.0052
86-105	1.0073
106-118	1.0068
119	0.9970
120-end	1.0005

The factor generally moves downwards over the course of the cruise. There are exceptional stations, 61, 85, 119, where the factor dips and then recovers. It is believed that this is associated with the CTD frame being washed down with fresh water. It seems the transmissometer reported low values after these events: most likely the optics became dirty and took a station, or some part of a station, to be cleaned by seawater.

The transmissometer data in the files is the transmittance over 0.25 metres relative to pure water. The attenuation coefficient per metre, c should be calculated as

$c = -4 \ln(T/100)$

Fluorometer calibration

Bottle samples were taken and filtered and analysed for pigments Chlorophyll-a and Pheophytin-a. These were provided in csv spreadsheets, identified by station and niskin bottle number. Data were read into sam files using new scripts *mpig_01.m* and *mpig_02.m*, into variables chla and pheoa. After station 118, a calibration for the fluorometer on the package was determined by comparing bottle Chla with fluorometer output. Samples were available for 31 stations up to station 118. For each station the Chla sample from the fluorescence maximum was identified, alongside the corresponding fluorometer value.

The bulk of low chla samples suggested an offset of -0.02 should be applied to correspond to the fluorometer dark value. Comparison of samples at the fluorescence maximum suggested a further scaling of 1.85 to convert fluorometer output to Chla in ug/l.

script: *explore_chl_max.m*
Thus a calibration was applied of

ctd_chl = 1.85 * (ctd_fluor_raw – 0.02), based on samples up to station 118.

This was applied to all stations. The CTD and bottle samples are plotted Fig 2.4. The red dots denote the chlorophyll sample maximum for each station with samples. Adjusted CTD fluorometer data were propagated through to all versions of the CTD station data, and sample files, where the variable is called “ufluor”, for CTD-upcast-fluorescence.

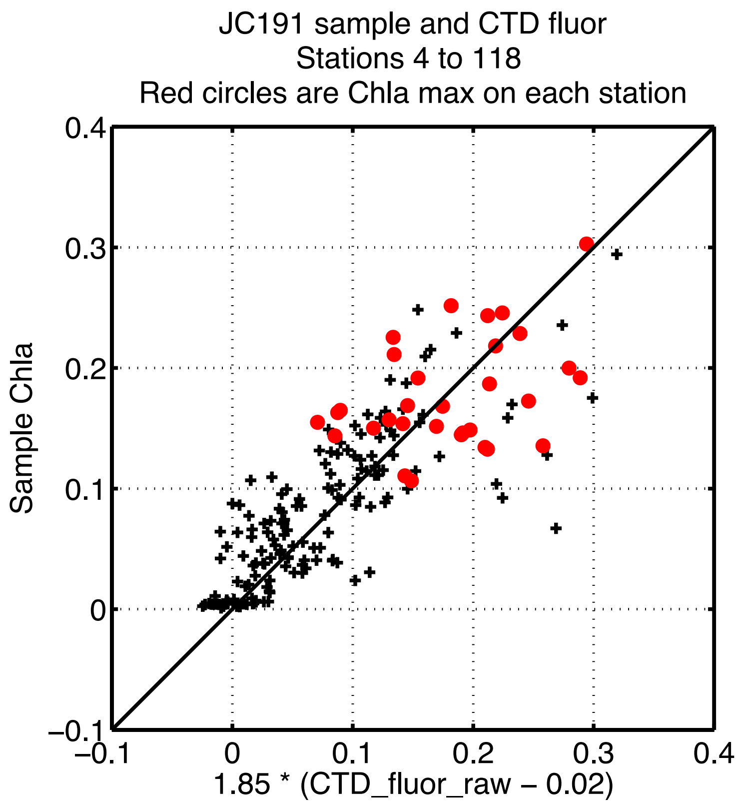


Figure 2.4: *Fluorometer CTD and bottle samples.*

<u>*Station depths and positions*</u>

Station depths were generally taken from the DL_GPS processing path of LADCP_IX processing, after merging with CTD data, so that the depth of the LADCP is correctly known. Bottom depth is output in the log file for each station processed. Bottom depths are entered in the file *bdeps.txt* in the ladcp/ix directory. Each line of bdeps.txt consists of a station number and a corrected water depth.

After bdeps.txt has been prepared, script *populate_station_depths.m* is run to generate *station_depths_jc191.mat* in *data/station_depths*.

populate_station_depths.m has an option in *opt_mcruise.m* in which the value form bdeps.txt can be overwritten. This was done in around 30 cases where there wasn't a good depth from the LADCP processing. In many cases, the depth was taken from CTD depth plus altimeter height off bottom. Using the LADCP as an altimeter is preferred because it often has a greater range of bottom detection. In a few cases, there was no altimeter signal, and bottom depth was taken from the ship echo sounders. For station 15 there was no estimate of bottom depth from any source, and the minimum CTD height off bottom is unknown.

populate_station_depths was updated daily, and bottom depths were written into mexec data file headers using *mdep_01.m*

The water depth estimate from the LADCP appears in the corrected depth column of the station summary file, output by *station_summary.m*. The residual between this water depth, the maximum CTD depth and the minimum altimeter height off bottom is shown, to provide an alert when one of the estimates is bad.

Station positions are determined by interpolating navigation onto the time of maximum pressure of the CTD cast. Station positions are entered into the CTD file header by ctd processing script *mctd_02a.m*. This position is carried forward by CTD processing. The *station_summary.m* script collects the position from the *ctd_mcruise_NNN_psal.nc* file, and writes it into the *station_summary_mcruise_all.txt* and *.nc* files.

Script *mdcs_05.m* writes station position into the mexec CTD file headers. *mdcs_05.m* was modified in jc191 to take position from the *station_summary_mcruise_all.nc* file rather than any other source. This is the master station file, and if any positions need to be modified they could be added as a cropt to *station_summary.m*. *station_summary.m* runs much faster with the new mexec NetCDF library, and can be run daily, so positions are always available there.

Gridded sections, and plotting

CTD and bottle data were gridded into two sections, the Florida Strait and the main 24N section. The Florida Strait section at 27N was comprised of stations 2:13. The main 24N section was comprised of stations [14:20 22:24 26:27 29:94 96:130 132:135]. The station numbers not used were various extra stations for bulk water collection.

Gridded sections of CTD and bottle data were created with msec_run_mgridp. Set regridctd to 0 or 1, depending on whether the CTD data need to be regridded. After the CTD gridded data are available in , for example, ctd_jc191_24n.nc, then a complete gridded file, including gridded bottle data, is created in grid_jc191_24n.nc. Gridding is done by the function *m_maptracer.m*. Some gridding options are now controlled from *opt_mcruise.m*. In order to create the gridded tracer profile at a particular station, the mapping program considers bottle data from adjacent stations, so that nearby measurements at different depths can be used for a best estimate of the tracer concentration at a gridpoint.

kstatgroups, set in *opt_mcruise*, defines groups of stations that correspond to each section.

s.xlim defines how many nearby stations are considered. Eg if *s.xlim* = 2, then 2 stations either side will be considered. Default value = 1.

s.zlim defines the vertical extent of data used in the mapping at a gridpoint. Default value is 4.

scale_x and *scale_z* define the decay of weight in the along-track and vertical directions. A normalized distance is created as *dist = sqrt(xu.*xu+zu.*zu),* where *xu = x*scale_x* and *zu = z*scale_z*. Weight = exp(-dist); x and z are the separation between the gridpoint and the bottle data, measured in stations for x and bottle levels for z. The default for both scales is 1. Choose scales less than 1 for smoother gridded sections.

msec_plot_contrs.m was modified so that it could plot sections with one variable per page. Options were added to add bottom depths, taken from *station_sumamry_mcruise_all.nc*, and bottle depths, taken from *sam_mcruise_all.nc*. The size of dots for bottle depths, and width of lines for bottom depth, is controlled in *opt_mcruise*. Set each to 0 to switch them off.

There remains the problem that selections of colour contours will not work in recent versions of matlab. Old code exists to select colours for unevenly spaced contours, but this was not resurrected and included in the current version of *mcontrnew.m*. This will need to be done before switching to new versions of matlab.

Uploads of data for RBR

Raw SBE data were uploaded to the NOC FTP site, together with the raw RBR data, so that they could be analysed by RBR. The SBE cnv files with Align and ctm were uploaded. RBR were advised of the T and C calibrations that were determined for the cruise, and advised that the secondary sensors (T1, C1 in SBE convention) were preferred.

Bottle data processing

Niskin bottle quality flag

Niskin bottle identifiers are entered into a *bot_mcruise_nnn.nc* file by *mbot_00.m*, with identifiers set in *opt_mcruise*. Niskin bottle quality flags are listed in *opt_mcruise*, and set by *mbot_01.m*, and pasted into the station sam file by *mbot_02.m*.

Salinity

A new script was created: *msal_01_jc191_read_all_with_dnum.m.* This followed the approach of the initial read of carbon and nutrient data in that the entire bottle salinity dataset was read into a single file: *sal_jc191_01.nc*. The complete sal files contains station dtaa, standards and TSG data. Script *msal_02_jc191.m* then pastes from the single sal file into the station sam file. The initial *msal_01* read also reads and saves the time of analysis of both samples and standards. This aids the interpretation of station and standard offsets.

Oxygen

Bottle oxygen data were read following recent cruises. The calculation of oxygen was performed in mexec from the titre volumes, rather than using the value in the spreadsheets.

Nutrients

Nutrients were read from a single csv file. Sometimes there was a need to remove trailing commas from all lines, when the code complained that not all lines had the same number of delimiters. The problem was unlcear, because each line did have the same number of commas, but removing the same number of trailing commas from each line seemed to allow the program to proceed.

Chlorophyll and pigments

A new set of code was created to read pigments data. Directory *BOTTLE_PIG*, scripts *mpig_01.m*, *mpig_02.m*. Variables were Chlorophyll-a, mexec variable chla, and Pheophytin-a, mexec variable pheoa.

Samples to be analysed ashore

Information about samples to be analysed ashore was gathered for carbon isotopes and methane. *msam_ashore_flag.m* was run, with options set in *opt_mcruise*. Flags were set to 1 where samples were collected for: del13c_noc, del13c_imp, del14c_imp, del13c_whoi, del14c_whoi, ch4.

Bottle data lists

Data were exported in CCHDO sample format files so that analysts could access the merged sample and CTD data. For versions were produced. With and without the CTD transmissometer and fluorometer data, and in the order first-bottle-first and first-bottle-last. The first-bottle-first is the conventional order for CCHDO. Stations are listed with the deepest bottles first. Nutrient analysis runs start with the shallowest bottle first, because these are the lowest concentrations, so it was more convenient for that group to have access to the data in the order first-bottle-last.

QC checking

The scripts *msam_checkbottles_01.m* and *msam_checkbottles_02.m* were used to identify possible outliers in bottle sample analyses.

It is possible to zoom in one of the windows created by *msam_checkbottles_02* and then have all the other windows adjust to the same vertical scale. This is achieved with function *bi_rescale.m*. *bi_rescale.m* needs to know the number of subplots in the screen, entered as an argument for the function. It used to automatically count the number of children of the main window, which would be the number of subplots. Sometimes a legend is added if there are bad bottles, which is an extra child,not always present. During the cruise , the number of subplots was entered each time *bi_rescale* was called. Eg *bi_rescale(5).*

When outliers were identified with *msam_checkbottles_01*.m, the questionable bottle values can be written into a file *ctd/ASCII_FILES/ bottle_data_flags.txt*. Script *msam_02b*, when run on each station, will propagate bad Niskin flags onto all samples, and apply flags listed in *bottle_data_flags.txt*.

Brian King

3. Mexec Daily Processing

Script *m_daily_proc.m* was run daily, after midnight UTC at the end of the day to be processed. The syntax is, for example,

>> days = 21; m_daily_proc

In principle multiple days could be run, or the program defaults to the most recent completed day. This was not tested.

For each stream in array *udirs* set by *m_udirs.m*, *m-daily proc* reads the data in from TECHSAS into a *_raw.nc* file, and optionally does some further processing, before appending to a *_01.nc* appended file. If a day is missed or run twice, the appended file will contain days missing, out of sequence, or repeated. In that case, delete the appended file and re-make it.

Techsas data are made available by running *techsas_linkscript*. This was set to run in a cron job. *techsas_linkscript* does not make links for small files, to avoid making links to dead or broken techsas NetCDf files. The slowest techsas file to fill was the em122 stream. Therefore *techsas_linkscript* was run multiple times, to be sure the latest em122 techsas file was available to mexec. The available file data times can be checked with "*mtlookd*" or "*mtlookd f*".

```
2 00 * * *  csh  /local/users/pstar/programs/mexec-exec//techsas_linkscript > /dev/null
10 00 * * *  csh  /local/users/pstar/programs/mexec-exec//techsas_linkscript > /dev/null
20 00 * * *  csh  /local/users/pstar/programs/mexec-exec//techsas_linkscript > /dev/null
00 01 * * *  csh  /local/users/pstar/programs/mexec-exec//techsas_linkscript > /dev/null
00 03 * * *  csh  /local/users/pstar/programs/mexec-exec//techsas_linkscript > /dev/null
```

Between reading data {*mday_01*} and appending the new day {*mday_02*}, *m_daily proc* calls *mday_01_clean_av.m* which will apply QC or averaging to the data stream.

Some bugs were found in *mday_01_clean_av.m*, which meant that a routine call to *medita* to set gross QC limits on a variety of data streams and variables was not being carried out. This had presumably been introduced last time the script was overhauled to new syntax. There were two separate bugs. Variable names were matched to '*h*', instead of '*h.fldnam'*. This could never have worked. This was corrected on day 052, and was therefore applied when day 052 was processed. In a separate bug, the *h.fldnam* was being taken from the *raw.nc* file instead of the edt.nc file. For the bathy streams, variables were renamed between *raw.nc* and *edt.nc*, so the set of variables to have *medita* checks was not being found. This was fixed on day 055, so the *medita* check applied to the bathy streams from day 055 onwards. The entire *met_light* stream was reprocessed, so *medita* checks were applied to that stream, but not retrospectively to the others.

mday_01_clean_av.m had an extra option inserted to allow the application of manufacturer's calibration to the four *met_light* radiometers. This was re-run for all days, so the *met_light* stream had *medita* run for all days.

At the start of the cruise, *udirs* was set up to process the radiometer data as both *surflight* and *met_light*. After day 052, the duplicate *surflight* was removed.

The *m_daily_proc* processed the following streams daily
Navigation, bathymetry, winch, surfmet/light/tsg, log_skip, log_chf.

The *log_chf* and *log_skip* streams had no further processing.

Brian King

4. Autosal: Water Sample Salinity

4.1 Sampling

Bottle salinity sampling was undertaken as a secondary source of salinity measurements to help calibrate the CTDs. For each CTD station a sample was taken at each Niskin bottle that had fired, unless a Niskin was repeated at a certain depth, in which case only one sample was drawn for that depth. The distribution of the bottle samples is shown in Figure 4.1. TSG samples were also collected at 4-hourly intervals and recorded within the watchkeeping logs.

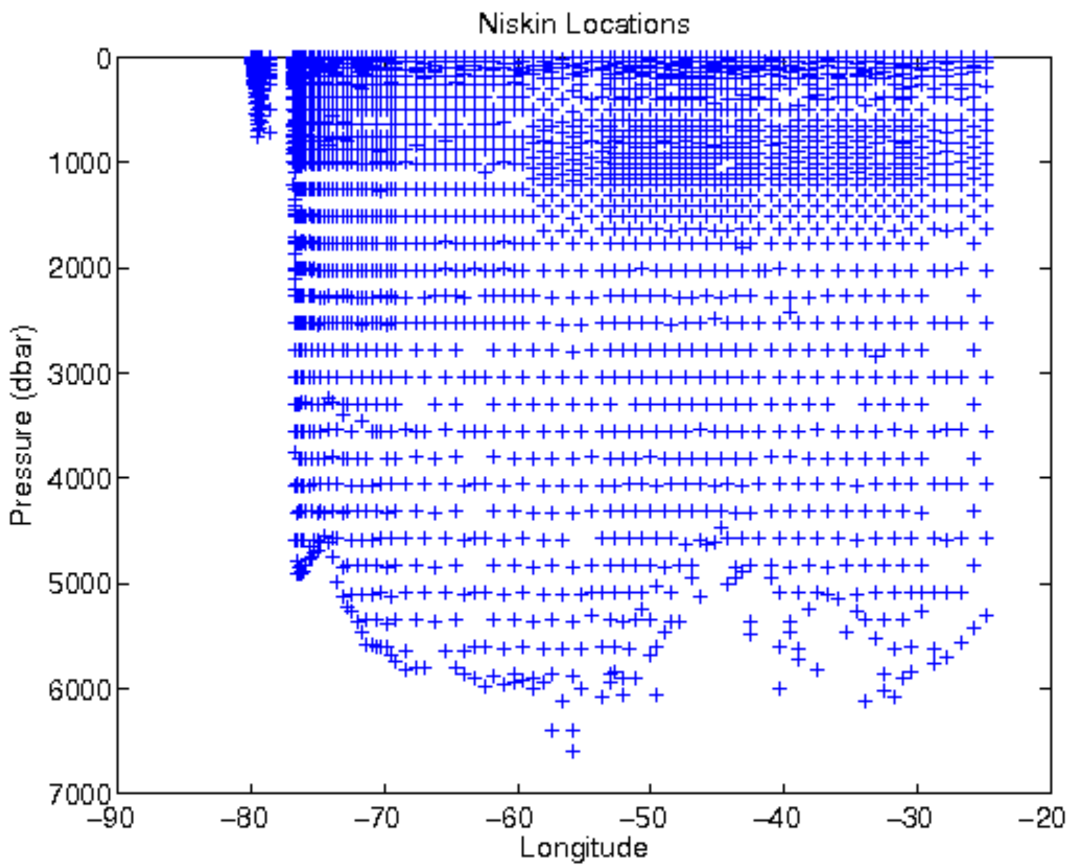


Figure 4.1: *Cross section at 24° N of Niskin bottle depths where salts were drawn and analysed.*

Samples were taken in 200ml glass sample bottles, which were rinsed, along with their cap, three times with water from the Niskin or the underway system. They were filled to just below the next of the bottle. The rim and inside of the lid was subsequently wiped using disposable paper towels to prevent salt crystals forming around the rim of the bottle and providing an artificial salinity enhancement. Each sample bottle was sealed with a disposable plastic stopper and its respective screw cap. The crate was then transferred to the salinometer room. Samples were stored in the salinometer room for a minimum of 24 hours before analysis to allow them to equilibrate to the laboratory temperature. A log sheet was maintained of when crates were moved into the salinometer room to keep track of when they would be ready to analyse.

4.2 Analysis Procedure

Salinity sample analysis was performed on the Guildline 8400B Salinometer, serial number 71126 in the electronics workshop, off the main lab, onboard the RRS James Cook. The salinometer water bath temperature was originally set to 24°C with a Rs setting of 610, however it was changed to 27°C with an Rs of 538 on the 26/01/2020, 7 days after the start of the cruise. It remained on this setting for the remainder of the cruise.

Salinity analyses were carried out by the physics team, following standard procedure. The methodology was explained to all the analysts at the beginning of the cruise. A sample of IAPSO Standard Seawater was run before and after each set of 24 samples for salinometer calibration. The Standard Seawater batch used was P163, with a K15 value of 0.99985, giving a 2xK15 value of 1.9997. By mistake two samples from Standard Seawater batch P161 were used on 26/02/2020. The results from these standards were not used for calibration.

4.3 Differences and Adjustments

Before and after each crate was run a standard seawater sample was taken to account for the drift in readings of the salinometer. The 'difference' was measured as the difference between the known conductivity of the standard seawater and the reading from the salinometer of that standard. An adjustment was then applied to each crate to take account of this difference. The adjustment is made over a few crates by comparing the differences over time in order to smooth any anomalous standard value readings. Once the adjustment is applied, the validity of the value chosen can be checked by comparing the bottle-measured conductivity with the CTD measured conductivity. A plot of the adjustments over time is shown in Figure 4.2.

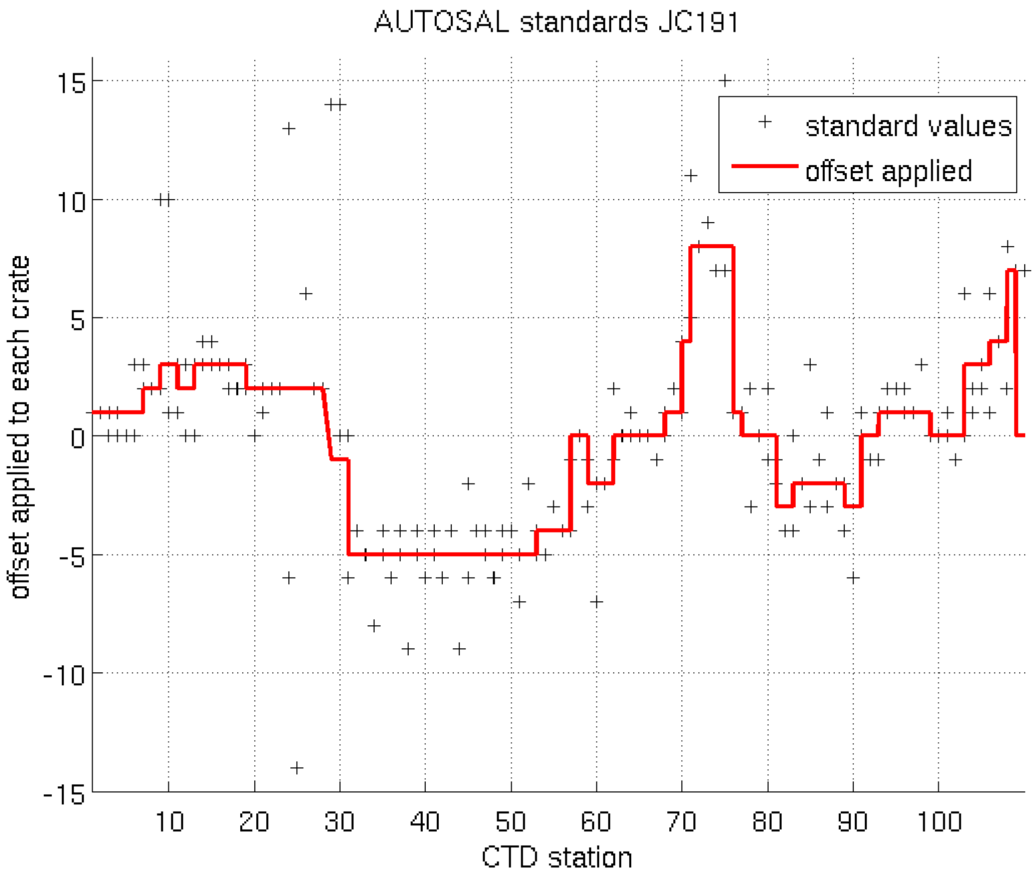


Figure 4.2: *The black crosses show the difference from each standard seawater conductivity ratio measured by the salinometer against the known value of conductivity ratio for that standard seawater sample. The adjustments applied to each crate are shown in red. (This figure was generated using msal_plot_auto_standards_jc191.m).*

4.4 Salinometer Performance

In order for the salinometer to preform consistently it must maintain the water bath inside to ±0.02 °C of the set temperature. The Guildline manual therefore recommends to keep the lab between -4°C and + 2°C of the this temperature, to avoid excess heating or cooling of the sample. At the start of the cruise the salinometer was not preforming well, giving standard values that ranged from 1.99965 to 1.99984 within a 7-day period. Within this time the temperature in the lab fluctuated between 23.2°C and 25.1°C. As we were more concerned with having a laboratory temperature that was too hot, the temperature of the water bath was increased to 27°C, in an attempt to get more consistent readings. This however did not improve the consistency of the readings which continued to fluctuate. Over the next 24 hours 17 standards were run in an attempt to gauge the behaviour of the salinometer, however these ranged between 1.99956 and 1.99971. On the 27/01/2020, before the crate for CTD 30 was run, John Wynar and Brian King cleaned the electrical controls inside the salinometer, after which the consistency of the salinometer readings greatly improved. This is clear from Figure 4.2 where the drift in the standards values after CTD becomes much more stable.

Temperature control in the lab continued to be difficult. After adjusting the bath temperature, the lab temperature fluctuated between 23.4°C and 28.3°C (within the limits of the salinometer) until the 08/02/2020 (CTD 68), whereupon it dropped to 22.0°C. This may explain the large drift in the standard values around this time. Due to this drift the Salinometer was cleaned again on the 10/02/2020 (CTD 76), after which the drift in the readings decreased again.

The temperature then stayed between 22.0°C and 24.1°C until the 18/02/2020. The thermostat controlled heaters were then turned on which kept the temperature in a stable range from 24.8°C to 26.1°C until the end of the cruise. The temperature against standard drift was also plotted to see if there was a noticeable effect on the results during the period when the laboratory was too cold. With the crate adjustments in place no noticeable temperature effect was noted.

About half way through the cruise it was also noticed that the right arm of the sample tube was sometimes not filling correctly as an air bubble would get trapped around the coil and not let water into the tube. This was monitored throughout the cruise to and samples were flushed if the arms did not fill correctly.

4.5 Sample recording and merging with CTD data

Bottle sample data from the salinometer (conductivity and salinity for each bottle) were recorded onto the local computer in the salinometer room as an excel file. This was done using the autosal software. When running a crate the title given for the file was 'JC191 CTDnn dd mm yyyy.xls', where nn was the crate number. During processing a hard copy was also kept of the bottle number, the three conductivity ratios and the average ratio. Each hard copy page was numbered sequentially starting at 01 (this included the TSG crates that were run).

After sampling, the excel files were transferred to the JC191 read only drive. They were then copied across to the public drive 'Public/autosal/' were they were manually edited. A new column was added to each spreadsheet under the heading 'sampnum' in the format sssnn (where sss indicates the station number and nn the bottle number), giving a 5-digit number. Standards were given the sample number value of 999nnn, where nnn was a sequential standard number starting with 001. Table 4.1 below shows an example of one of the sheets. This file is then saved as a comma-separated csv file with the same name.

Table 4.1: *This table illustrates salinity sample data from a typical station, here using salinity standard number 97, and salinity sample bottles 596 and 596 from crate 24,*

drawn from station 53, Niskin bottles 11 and 12, respectively. The sampnum column is added manually to the spreadsheet generated by the Autosal software and sample numbers are entered manually from the logsheets. (The date and time columns are omitted from this example, but not from the real files.)

Bottle_num	Sample 1	Sample 2	Sample 3	Average	Offset	Salinity	sampnum
CTD24_9097	1.999734	1.999741	1.999748	1.999741	-0.000003	34.9948	999070
CTD24_596	1.992192	1.992216	1.992198	1.992202	-0.000003	34.8463	5311
CTD24_597	1.992689	1.992681	1.992679	1.992683	-0.000003	34.8558	5312

This file was then transferred to koaekea via the following commands in the terminal:

- cd ctd/BOTTLE_SAL
- rsync -av public/* ./ - *this copied across the .xls and .csv files from the public network to the JC191 drive*
- ln - s JC191\ CTDnn\dd\ mm\ yyyy.csv sal_jc191_sheetnumber.csv - *this creates a link from each file to the numbered hardcopy sheet*
- modsal_unix - *this creates the .csv_linux file*

The offset assigned to each crate was then entered in MATLAB into the script 'msal_01_jc191.m'. (msal_01_jc191_read_all_with_dnum.m after 19/02/2020). An array 'a_adj' was created for jc191 which consisted of three columns defining the station and Niskin number range, the water bath temperature and the offset applied to that station. For example, the first two lines of 'a_adj' were

101 24 1

199 24 1

Which reads for all bottles relating to station 1, the water bath temperature was 24 with an offset to be applied to the crate of 1. After applying the offset values we ran the following commands in matlab:

- msal_01_jc191.m– *Using the appended csv file sal_jc191_01.csv this script created an individual sal_jc191_sss.nc, (where sss is the station number) file for each station.*

- msal_02.m - *This read each sal_jc191_sss.nc file and created the corresponding sam_jc191_sss.nc file.*
- msam_updateall - *This updated all the msam_jc191_all.csv file with the salt data*

On the 19/02/2020 Brian King created a new version of msal_01_jc191.m called msal_01_jc191_read_all_with_dnum.m. Rather than save the information for each station separately into its respective .nc file, this function read in all the data and saved it into the sal_jc191_01.nc file. This file was then used to update the salinity crate offsets.

Katherine Grayson

5. Inorganic Nutrient Analysis

A 4-channel Seal Analytical AA3 autoanalyser was set up in the Chemistry lab of the RRS James Cook for the analysis of micro-molar concentrations of dissolved inorganic nutrients (silicate, phosphate, nitrate plus nitrite and nitrite).

5.1 Method

Samples were collected directly from the 24 x 20 L stainless steel rosette after the TA/DIC into pre-labelled 15ml centrifuge tubes (rinsed three times with water from the same Niskin). Samples were analysed directly from the collection tubes within 1-8 hour and measured from the lowest to the highest concentration (surface to deep) to reduce any carry over effects. Milli-Q water was used for the baseline and wash solution during each run. All unique sampling depths were sampled and analysed.

Seal Analytical chemistry and cleaning procedure protocols used during JC191 were:

i) Silicate in seawater method No. G-177-96 Rev 10 (Multitest MT19).

ii) Phosphate in water method No. G-175-96 Rev. 15 (Multitest MT 18).

iii) Nitrate and nitrite in seawater method No. G-172-96 Rev. 13 (Multitest MT19).

iv) Nitrite in seawater method No. G-062-92 Rev. 3.

Woking standards were prepared fresh every day by diluting the stock solutions of the different nutrients (table 5.1) in ASW (35 g/l sodium chloride plus 0.2 g/l sodium hydrogen carbonate).

Each run of the system had an 8-point calibration series (first value was ASW + 7 working solutions). Prior to analysis all samples and standards were brought to room temperature of ~20° C. Concentrations of the working standards were kept constant throughout the cruise (Table 5.2).

Table 5.1: *Compounds used to prepare stock standard solutions, weight dissolved in 1 L or 500 ml of Milli-Q water and Molarity of the solution.*

Compound	**Weight (g)**	**Molarity stock solution**
Potassium Nitrate	0.5061 in 1L	5.0009
Sodium Nitrite	0.34545 in 1L	5.0069
Potassium Dihydrogen Phosphate	0.67395 in 1L	4.9524
Sodium Metasilicate pentahydrate	1.07224 in 500ml	10.2060
Sodium Metasilicate pentahydrate	1.06035 in 500 ml	9.9939

Table 5.2: *The standard concentrations used for each chemistry during JC191.*

Chemistry	Standard 1 (µM/L)	Standard 2 (µM/L)	Standard 3 (µM/L)	Standard 4 (µM/L)	Standard 5 (µM/L)	Standard 6 (µM/L)	Standard 7 (µM/L)
NO3+NO2	0.25	0.5	1	5	10	20	40
SiO2	0.4	1	5	15	30	45	60
NO2	0.050	0.10	0.2	0.4	0.6	0.8	1
PO4	0.05	0.1	0.2	0.4	0.8	1.6	2

5.2 Maintenance

At the start of the cruise, installation of the AA3 took approximately two days, involving; the fitting of new pump tubing and new cadmium column and making all regents.

Prior to the cruise all labware was washed with 10% HCl and rinsed with Milli-Q water. Once on board, all labware was re-rinsed several times before use. Following each run, each analytical channel was flushed with wash solutions and the autosampler with Milli-Q water following Seal Analytical cleaning protocols.

At least once per week the instrument was re-tubed and thoroughly cleaned with sodium hypochlorite for approximately 30 minutes (nitrite, nitrate, phosphate and silicate line).

Batches of ASW were prepared every days and the different chemical reagents were prepared from daily, to every 2 or 3 days.

5.3 Quality Controls (QCs) / Analyser Performance

Cadmium column reduction efficiency: The reduction of the nitrate (NO3-) present in a sample to nitrite (NO2-), is achieved by passing the sample through a column filled with granular cadmium (cadmium column); cadmium is oxidised and nitrate is reduced. With use, the capacity of the cadmium column to reduce nitrate diminishes. The reduction efficiency was determined in every run by measuring nitrite and nitrate standards of similar concentrations (10 µM L-1). The ratio of nitrate to nitrite expressed as a percentage provides an indication of the reduction efficiency of the cadmium column. For the analysis to produce reliable results, the oxidation efficiency needs to be >90%. When the efficiency is lower, the cadmium column is typically replaced. New cadmium columns are conditioned by passing a high nitrite standards (2mM L-1) followed by flushing with ammonium chloride. Throughout JC191 the efficiency of the columns did not drop below 96 % however in totally we used 7 Cd columns. In each case, the column was replaced due to a build-up of backpressure probably caused by air entering the column, or due to a drop in sensitivity when measuring the primer.

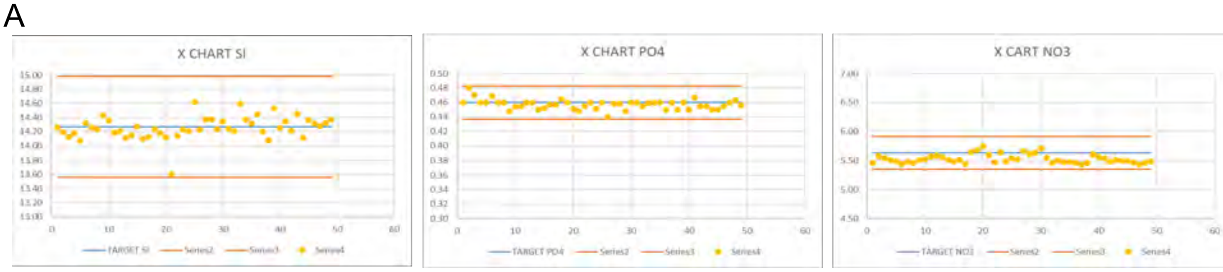
CRM: In order to test the accuracy and precision of the analyses, CRMs from The General Environmental Technos Co., Ltd., (KANSO) were measured in triplicate in every run. For the duration of JC191 KANSO CRMs lot CD, CJ, CI and lot BW were used; certified concentrations are shown in Table 5.3.

Table 5.3: *Certified concentrations converted from µmol kg-1 to µmol L-1 (using salinity provided and 20°C) of KANSO CRMs used during JC191 and our results for each lot (in mmol L-1) n=49.*

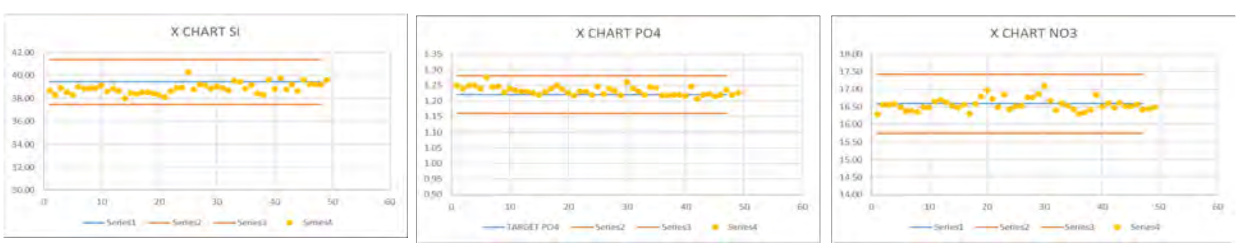
	Nitrate	**Silicate**	**Phosphate**
KANSO BW	25.18 ± 0.21	61.46 ± 0.43	1.58 ± 0.014
KANSO CJ	16.6 ± 0.2	39.43 ± 0.4	1.22 ± 0.02
KANSO CD	5.6 ± 0.050	14.3 ± 0.099	0.46 ± 0.0082
KANSO CI	14.12 ± 0.13	8.88 ± 0.09	0.97 ± 0.013
Measured BW	25.34 ± 0.27	60.33 ± 0.7	1.59 ± 0.01
Measured CJ	16.56 ± 0.17	38.88 ± 0.46	1.23 ± 0.01
Measured CD	5.53 ± 0.07	14.25 ± 0.16	0.46 ± 0.01
Measured CI	14.36 ± 0.12	8.49 ± 0.11	0.96 ± 0.01

The measured values throughout the cruise were plotted in control charts, showing trends in data with time (Figures 1 A, B, C and D).

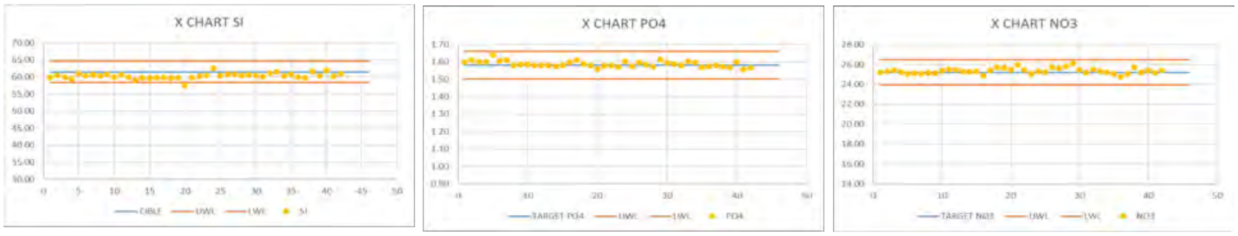
A



B



C



D

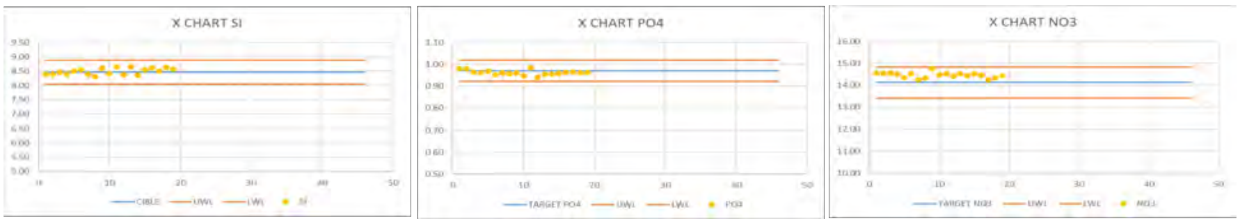


Figure 5.1: *Shows the certified value (vn-blue line) for A) CRM CD, B) CRM CJ, C) CRM BW, D) CRM CI plotted against measured values throughout JC191 (yellow dots). Red lines are upper and lower warning levels (UWL and LWL = vn +/- 2*5/100*vn (5%)). In all cases the measured CRM values lie between the UWL and LWL*

Edward Mawji and Thierry Cariou

6. Dissolved Oxygen Analysis

6.1 Sampling and analysis

6.1.1 Sampling strategy

Dissolved oxygen (DO) samples were collected during JC191 in order to calibrate the DO sensor and correct for drift, temperature and pressure influences. Data was also used to help identify misfired or leaking Niskin bottles.

Samples were collected from every cast except for those designated exclusively for carbon calibration stations or incubations. Every Niskin bottle was sampled excluding known misfires and those with obvious leaks. We aimed to sample 2 Niskins in duplicate for each cast.

6.1.2 Sample collection

Seawater was collected directly into pre-calibrated 125 ml Pyrex Iodine titration flasks with flared necks. Before the sample was drawn, bottles were washed with seawater for several seconds (approximately 3 times the volume of the bottle) while the temperature of the water was recorded using a handheld digital thermometer (Hanna Instruments HI-955502). Throughout the sampling process, care was taken to avoid bubble formation inside the sampling tube and sampling bottle. The fixing reagents (i.e. manganous chloride and sodium hydroxide/sodium iodide solutions) were then immediately added, and the bottle sealed with a glass stopper, taking care not to introduce any air bubbles. Sample bottles were then thoroughly mixed by shaking in order to homogenise the contents, and were then stored in a dark plastic crate for 30 to 40 minutes to allow the precipitate to settle. After collection, a Milli-Q water seal was applied to the neck of the sample flasks in order to prevent ingress of air. Once the precipitate had settled all samples were thoroughly mixed for a second time in order to ensure that the reaction was complete, and the Milli-Q seal was replaced. Analyses were carried out as soon as possible and normally within three to four hours of sample collection.

6.1.3 Analysis

The chemical reagents were prepared in advance at NOCS following the procedures described by Dickson (1994). 5 litres of each reagent were prepared and homogenised using 5-litre glass volumetric flasks, this reduces the batch effect and allowed us to change reagent during analysis. Thiosulfate was weighed into 27.4 g portions at NOCS and all solutions were made during the cruise. Thiosulfate solutions were made at least two days in advance.

When ready to titrate, the Milli-Q seal was dried and the stopper of the flask carefully removed. A 1 ml aliquot of 5 M sulfuric acid was dispensed into the flask, immediately followed by a clean magnetic stirrer. The flask was placed on the stir plate and the electrode and burette were carefully inserted to place the tips in the lower-middle depth of the sample flask. The initial volume of sodium thiosulfate ($Na_2S_2O_3$) for each sample was 0.3 ml before continuing to be titrated at 0.0005 ml intervals using an electrode with amperometic end-point detection (Culberson and Huang, 1987) with an end current of 0.1 x 10^{-6} A. The resultant volume of titrant was recorded both by manual logging and on the Ti-Touch 916 (Metrohm). Following this the value was converted to a DO concentration. Thiosulfate calibrations and reagent blank checks were carried out for each sampling station following the GO-SHIP protocols (Langdon, 2010). At least 3 blank checks of the reagents and 4 standardisations of the sodium thiosulfate were completed using a 1.667 mol l^{-1} certified iodate standard (OSIL) every cast (Fig. 1).

6.2 Problems encountered

During JC191 we experience problems with the Pt electrode, this issue did not occur until cast 14 and the problem was not resolved until CTD 34. For this reason data between CTDs 14-34 will be flagged as questionable. Initially it was thought the electrode had been damaged during analysis, changing the electrode only temporarily resolve the issue. After examining the two affected electrodes a thin white precipitate could be observed on the Pt tip. This precipitate could be removed by cleaning gently with a kimtech wipe. After CTD 34 a daily electrode cleaning protocol was introduced. The source of the precipitate is believed to be a contamination in one of the reagents.

6.3 Results

6.3.1 Blanks and standards

We performed 3 blank measurements and 4 standard determinations before the start of each cast of measurements (Fig. 6.1). The results were generally consistent across the cruise, apart from between casts 14 to 34 where blanks became negative (fig 6.1a) which highlight the specific analytical problems identified.

The blank was evaluated separately for each cast. Four batches of thiosulfate titrant were used, with the batch changed at the start of cast 35, 72 and 103 analysis.

We used average thiosulfate standardisation values of 0.4550 ml from the start of the cruise up to cast 34 inclusive, 0.4586 ml from cast 35 to cast 71, 0.4580 ml from cast 72 to cast 102 and 0.4580 ml onwards to calibrate all of the DO measurements (Fig. 6.1b).

6.3.2 Precision and accuracy

We collected 253 pairs of duplicate samples from the same Niskin in total, which had a mean absolute difference of 0.332 uM/kg. The first precision estimate (from duplicates) indicates measurement precision within individual casts, as duplicates were always analysed in the same session. However for cast 40, all 24 Niskins on the rosette were sampled in duplicates by different samplers and analysed in different sessions by different operators. The standard deviation of these 24 measurements was of 0.341 uM/kg. This helps provides an estimate of our overall measurement precision, also restricted to within a single cast, but including the effect of sampling from different Niskin bottles and different operators.

6.3.3 JC191 transect

The DO measurements plotted across the JC191 transect are shown in Fig. 6.2. They show the expected patterns of variation with depth and latitude and are quantitatively consistent with historical data from this region, within the measurement uncertainty.

6.4 References

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

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

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

a)

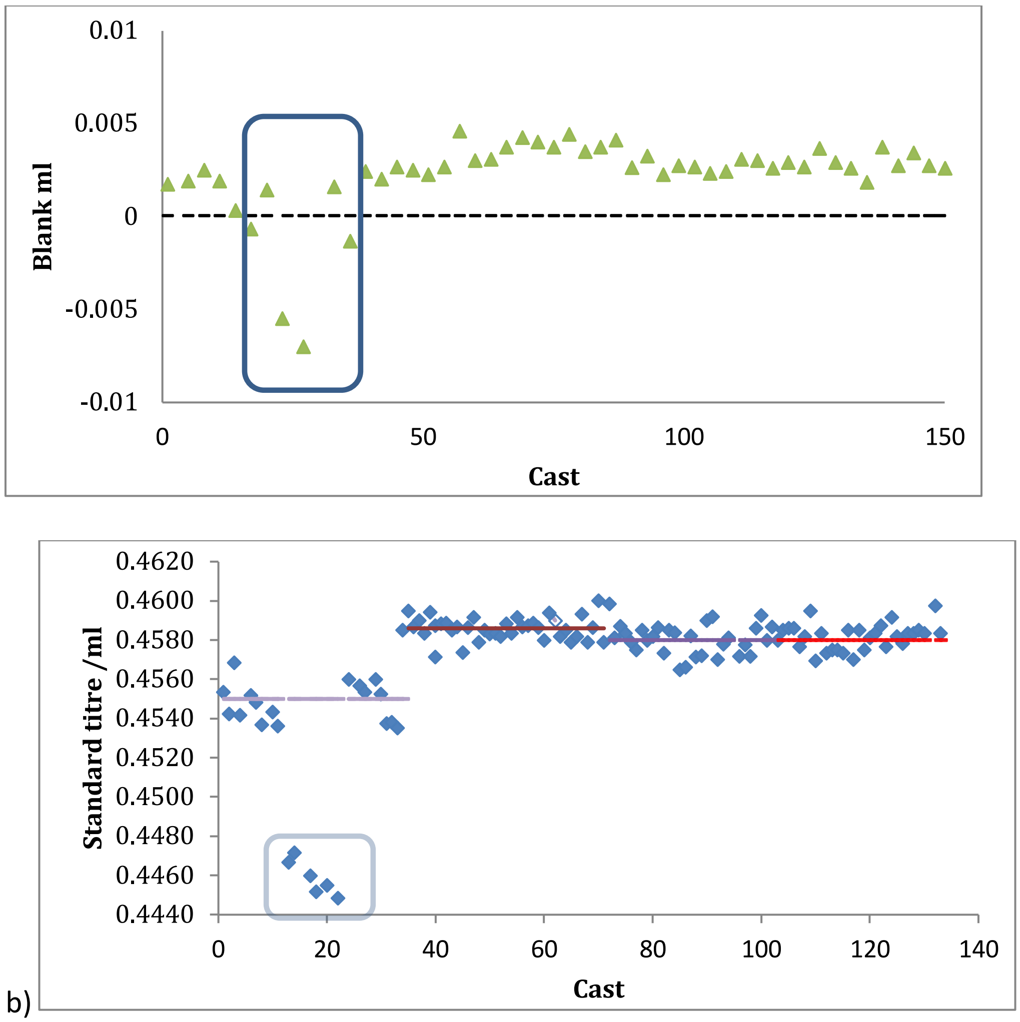


Figure 6.1: *Results of all (a) blank and (b) calibration standard titrations throughout cruise JC191. (a) The triangle markers show the average blank value for each cast. (b) The dotted line shows the average values for the different thiosulfate batches. Rectangle boxes are the period of electrode issues.*

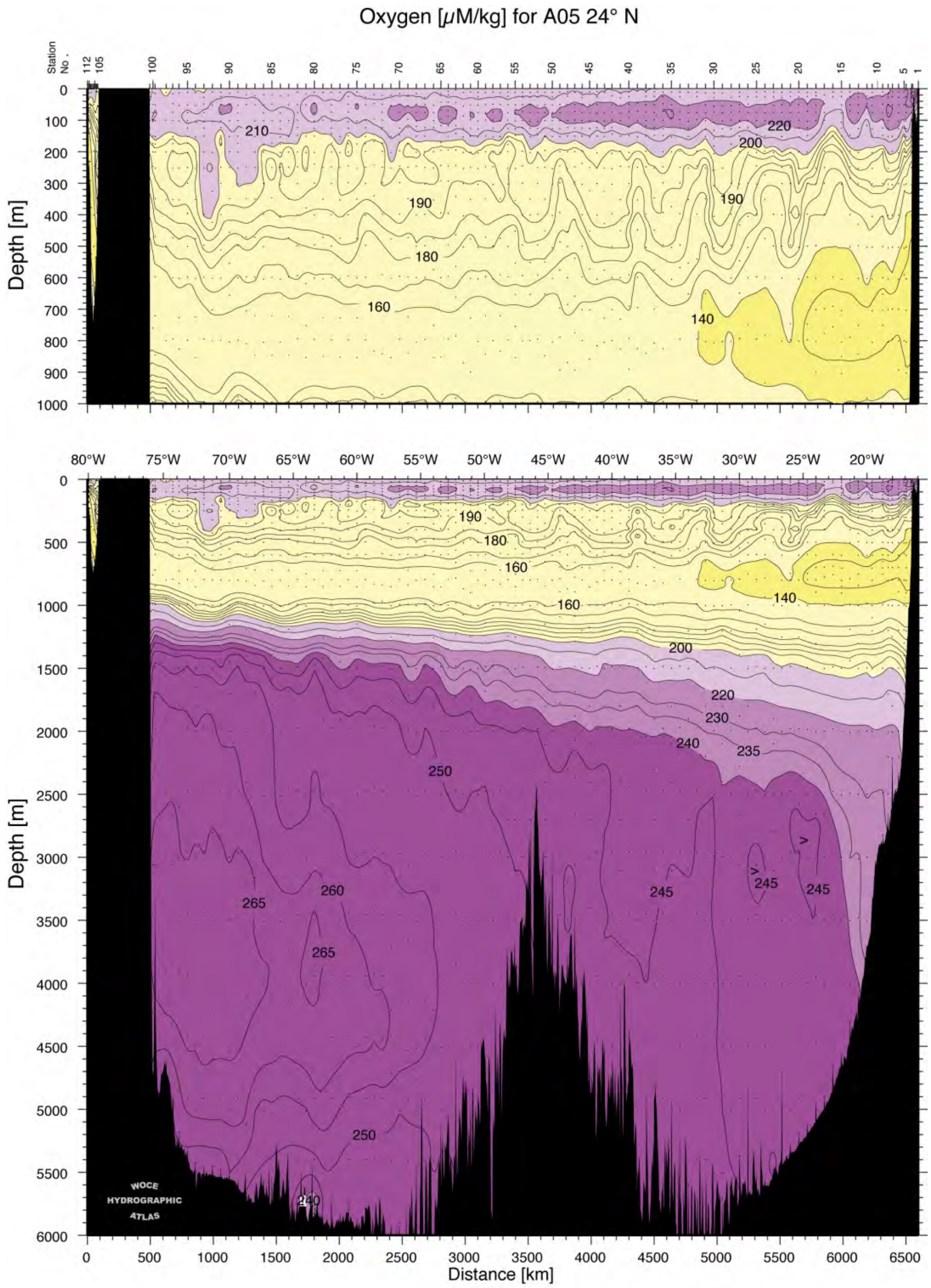


Figure 6.2: *Cross-section of preliminary DO data as measured across A05 24 north on cruise JC191.*

Edward Mawji, Hannelore Theetaert, Thierry Cariou and Maria De La Fuente

7. Inorganic Carbon Parameters: Dissolved Inorganic Carbon and Total Alkalinity

7.1 Analysis background

The analytical equipment for the carbon parameters was set up in the controlled environment laboratory, with discrete CTD samples being analysed for both total dissolved inorganic carbon (DIC) and total alkalinity (TA). Two Versatile Instruments for the Detection of Titration Alkalinity (VINDTA) systems (Mintrop, 2004), version 3C serial numbers #11 & #24 coupled to UIC coulometers were used to this end during JC191. These systems draw water from a single sample and autonomously separate it into two independent analysis lines, one analysing for total alkalinity by potentiometric acid titration, the other quantifying for DIC by the acid-derived extraction of carbon dioxide and subsequent coulometric titration (Johnson et al, 1985,; Johnson et al, 1987; Johnson et al, 1993).

7.2 Methods: CTD Sampling Strategy for Inorganic Carbon

Water samples for the determination of DIC and TA were drawn from 20L/10L Niskin bottles on the CTD rosette and collected in 250ml and 500 ml glass bottles according to the Standard Operating Procedure (SOP) # 01 (Dickson et al., 2007), to avoid gas exchange with the air. Samples were poisoned with mercuric chloride (50 µl per 250 ml of sample) to kill all organisms that may alter the chemistry of the sample. Samples were kept at room temperature until they were placed into a 25°C water bath to bring to this temperature prior to analysis. A total of 3035 samples were drawn from 135 CTD stations with a further 81 samples taken from the underway system both on and as we steamed between stations. Samples for DIC and alkalinity were not taken from all niskins on all stations, but all depths were sampled for. Duplicate samples were collected on all stations, totalling ~500 in all, with the aim being to meet the GO-SHIP-stated recommendation of 10% of niskins. All samples were analysed during the cruise with the exception of additional bottles collected on station 131 to be used as a secondary standard in future analyses. Figure 7.1 shows the depth-longitude grid of samples collected for DIC and TA analysis during the cruise.

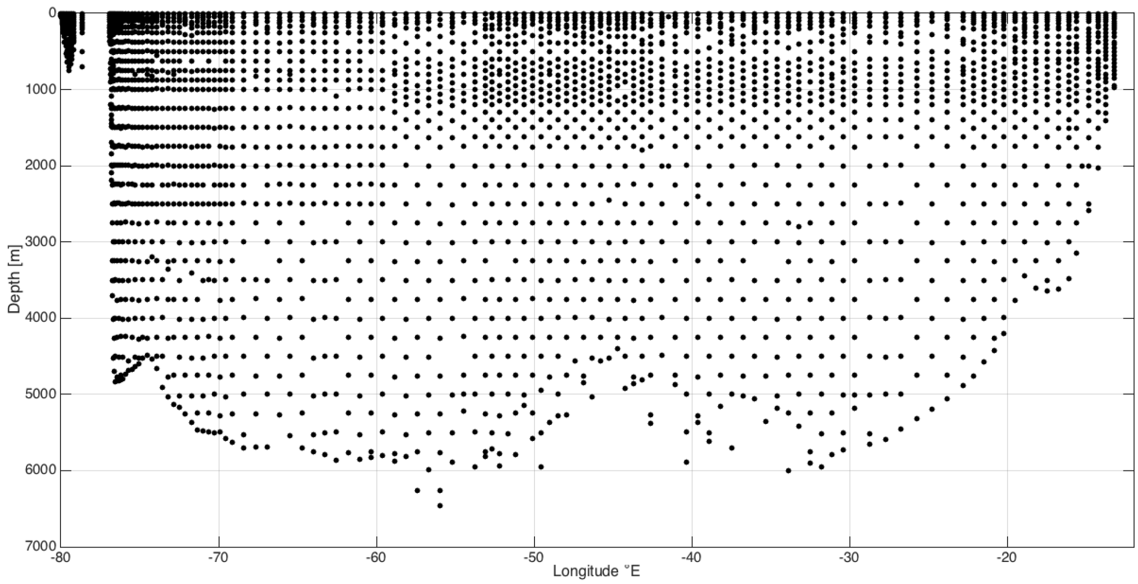


Figure 7.1: *Locations of sampling for the dissolved inorganic carbon system on JC191.*

7.3 Total dissolved inorganic carbon

Total inorganic carbon was analysed by coulometry. All inorganic carbonate was converted to CO_2 (gas) by addition of excess phosphoric acid (1 M, 8.5%, made by dilution on ship of 85% phosphoric acid) to a calibrated volume of seawater sample. Oxygen-free-Nitrogen (OfN) was passed through soda lime and Drierite-8 mesh traps to remove any trace CO_2 from the gas stream prior to entry into the system; the gas was then used to both empty the DIC pipette and to flush and carry the evolving CO_2 from the sample to the coulometer cell. Here, CO_2 was quantitatively absorbed by a dimethylsulfoxide-ethanolamine mixture, forming an acid and leading to a colour change of the solution, that is then coulometrically titrated to return it to its original transmittance. To remove organic gas contaminants, ORBO-53 tubes were used in the gas line (between the Peltier condenser and the analysis cell).

The coulometry solutions accumulate CO_2 over time and thus need to be changed regularly to ensure high performance and remain effective. During JC191 they were changed roughly every 24 hours, although to conserve chemical supplies, this was extended to approximately 27 hours. A set of 7 cells were used in rotation with one being removed immediately following titration issues. Cell preparation was conducted by the addition of cathode and anode solutions (UIC Corp.) to their individual chambers, solid potassium iodide to the anode chamber and a stirrer bar to the main chamber. Platinum (cathode) and silver (anode) electrodes were also used in rotation. As the silver anode is consumed during the analysis, these had to be replaced on occasion with new. Cells were cleaned by Milli-Q water, before passing Milli-Q water through the glass frit under vacuum. This was repeated using acetone and then Milli-Q water again, until all ran clear. Cells were dried at 65°C in an oven prior to next use.

Silver anodes were cleaned with milli-Q water, platinum electrodes were cleaned first with water, then by dipping in 50% Nitric acid for 10 seconds, followed by a water rinse. The sample line in the cell cap was flushed with water and then air before being placed in the oven along with the cells to dry for a minimum of 24 hours before reuse. Just over three bottles of anode solution were used and three of cathode solution. Solutions were kept in the dark and discarded when their levels became low – due to their hygroscopic nature, the absorption of atmospheric moisture was found to make noisy cells that were slow to settle and less stable.

Two types of nitrogen gas were used during the cruise, BOC research-grade nitrogen and BOC oxygen-free nitrogen gas. These were piped from cylinders located in the gas cylinder storage facility off the CTD annex, into the main ship manifold to the CT Lab. Five cylinders were used, 3 of the former followed by two of the latter. The pressure of the gas cylinder in use was checked roughly every 24 hours to ensure that sufficient pressure was available for normal operation and that the inlet pressure did not exceed 1.5-1.6 bar. Cylinders were changed when their pressure reached approximately 350-500 psi. ORBO tubes were replaced every 24-48 hours, or sooner if titration issues related to flow developed. They were completely removed from use on VINDTA 11 after ~2 weeks of the cruise (see below).

7.3.1 Analysis Issues encountered - #11 & #24

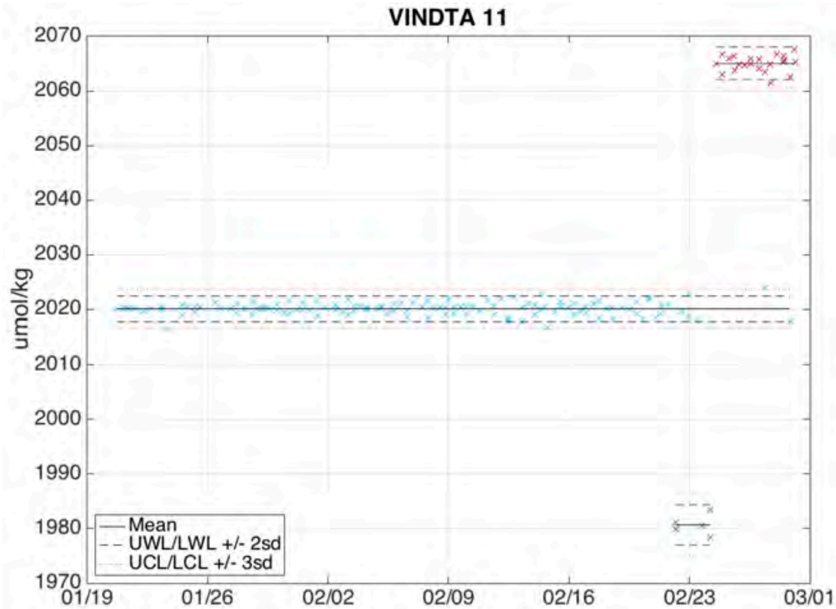
- Due to the lack of a mass flow controller on #11, the coulometer was much more susceptible to any issues relating to gas flow. Regular checks were made at the gas cylinder to ensure sufficient gas pressure was being delivered to the laboratory, and initial coulometer response was tracked at the beginning of titrations to monitor this at the instrument. This varied quite regularly, and it was found that the inlet pressure would rise and lower of its own accord between checks. The cause seemed to be a faulty regulator in the gas store and meant that the regulator setting needed regularly tweaking to bring it back into line.
- ORBO-53 tubes were used to try and remove organic gas contaminants from the gas stream. On #11 it was found that they would repeatedly begin to inhibit gas flow anytime between 4 and 24 hours after being freshly installed (on #24 they lasted up to 3 days). The reduced gas flow would then impact titration length and coulometer response, necessitating corrective calibration methods. If excessive blockage occurred, it would also cause a pressure build-up upstream impacting pipette filling and sample delivery to the stripper, thus completely compromising sample analysis. It was initially thought that insufficient cooling of the gas stream by the Peltier was causing excess moisture to still be transferred through the gas line where it would accumulate in the ORBO tube packing. Due to the Peltier being controlled manually on #11 rather than through software, it was not possible to automatically track its temperature. Insufficient heat removal by the circulating water was investigated as the cause, and as a precaution some parts of its tubing were lengthened on #11 in order to prevent flow

blockages caused by tubing folding. The power supply to the Peltier was also increased in order to increase its cooling, but this did not ameliorate ORBO blocking. A handheld temperature sensor however found the Peltier temperature to be 1.6°C, and so power was reduced until it reached ~5°C. During lower flow events it was also noticed that during stripping some sample was being pushed up the stripper drain – this required the adjustment of the back-pressure flow using the second needle valve at the bottom of the system.

- An additional issue was identified on #11 regarding the Luer-lok fitting used to connect tubing between the condenser and ORBO tube – this became completely blocked on occasion with a white precipitate, but occurred also after the ORBO tube had been removed. The source of this was not definitively identified but it was assumed to be carbonate in origin. Due to the myriad issues arising, the potential for frequent loss of samples and increased difficulty of sample calibration, on 4th Feb the ORBO tube was removed from the gas line of #11 for the remainder of the trip.
- Compromised ORBO-53 tubes were placed in the oven for regeneration. However, it was found that the temperature was not high enough for them to become reusable and so they were stored for return to base for regeneration there.
- On #11 jumping background levels suggested gas stream cooling problems. Although the Peltier was receiving current, it was not able to cool the gas flow, due to the water bath heater not having restarted after a power cut. Water temperature was 1 degC.
- Lower than expected counts were observed for some junk seawater/standard analyses (#11). It was eventually identified as caused by bubbles being in the pipette at the end of filling, sourced from the stripper. A loose screw cap at the top of the stripper was the cause.
- Low-to-no flow was observed at some points in the cell on both instruments. Flow rate checks of the gas moving through the system revealed that blockage of the gas line in the coulometry cell was the cause. Removal, thorough cleaning and replacement remedied this.

7.3.2 Data calibration

The accuracy of the DIC analyses and the coulometer calibration factor were determined regularly by measuring certified reference material (CRM), supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO), Batches #170, #175 and #180. These were typically run across both instruments every 8 hours. This ensured that a minimum of 2-3 CRM analyses were conducted on each coulometric cell. Typically, it was possible to get three combined DIC/TA analyses from a single CRM 500 mL bottle, but the third analysis was not always as high quality for DIC due to this water having had time to interact with the local atmosphere. Control charts for the outputs of the CRMs analyses (in umol/kg) are shown in Figure 7.2, suggesting the analysis was within control, with a few outliers typically the third measurement from a bottle. Three substandard stations were also sampled in bulk (>20 bottles at the same depth) and dropped into the analysis schedule 2-3 times per day on both instruments to further track instrument response. Quality control for DIC is ongoing.



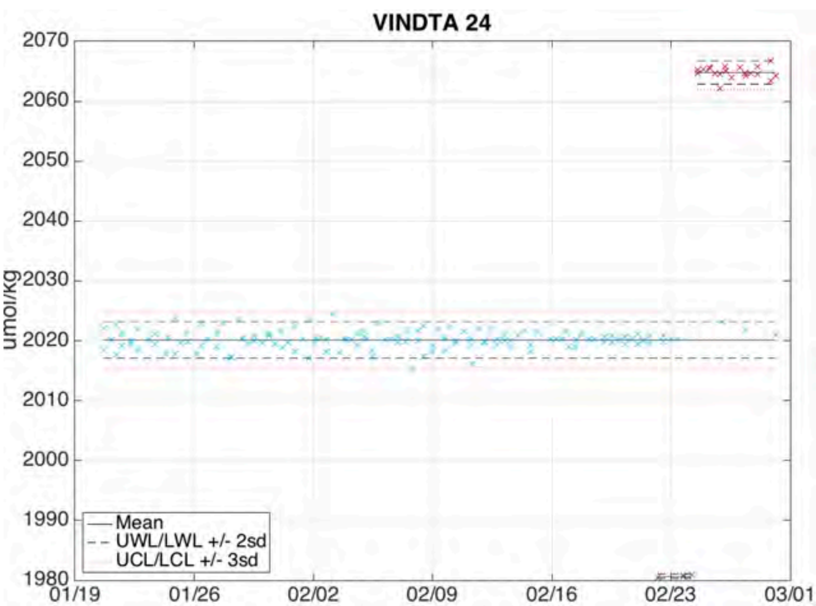


Figure 7.2: *DIC CRM Control charts for the three batches of CRM used on JC191.*

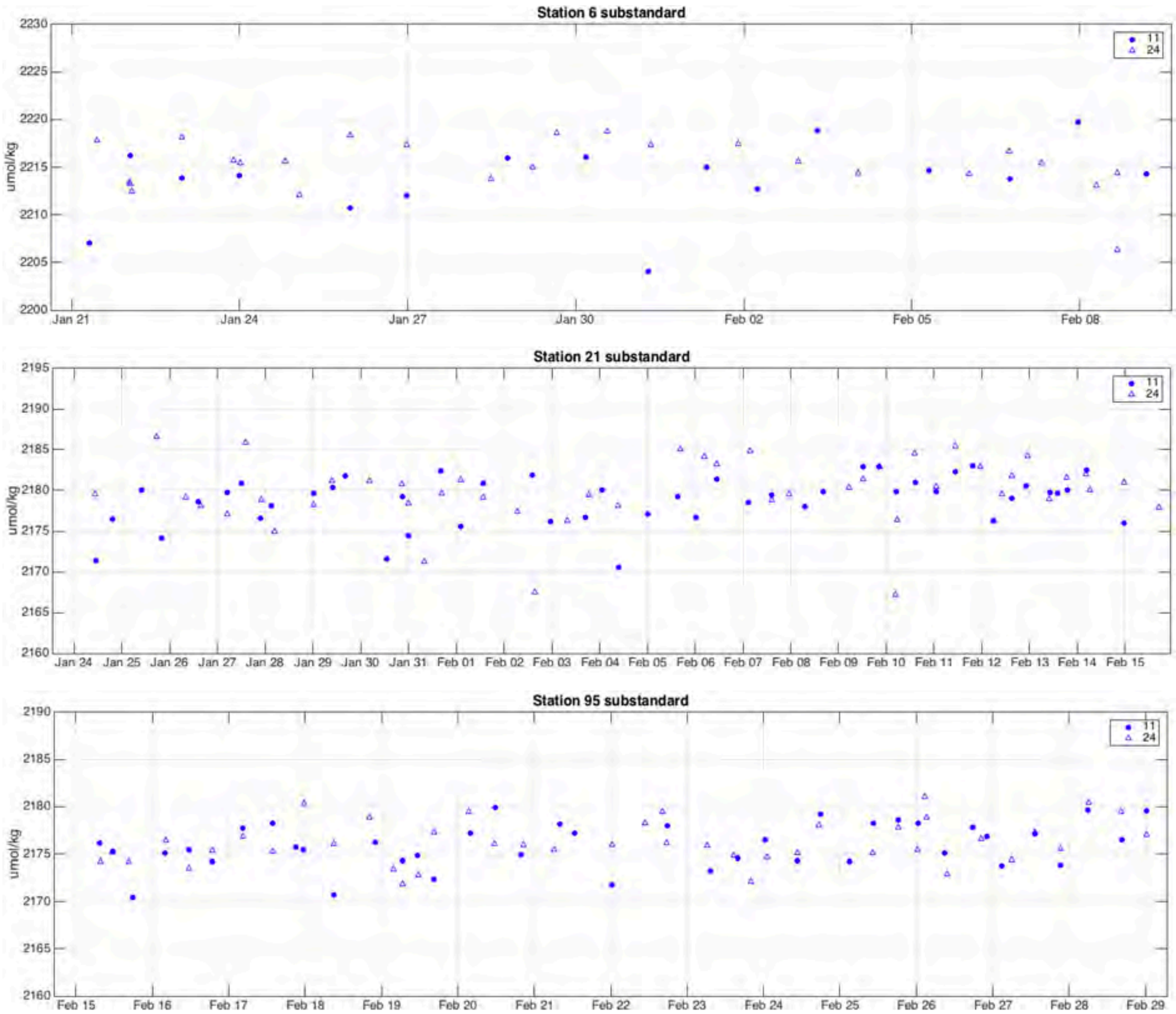


Figure 7.3: *Substandard responses for stations 6, 21 and 95*

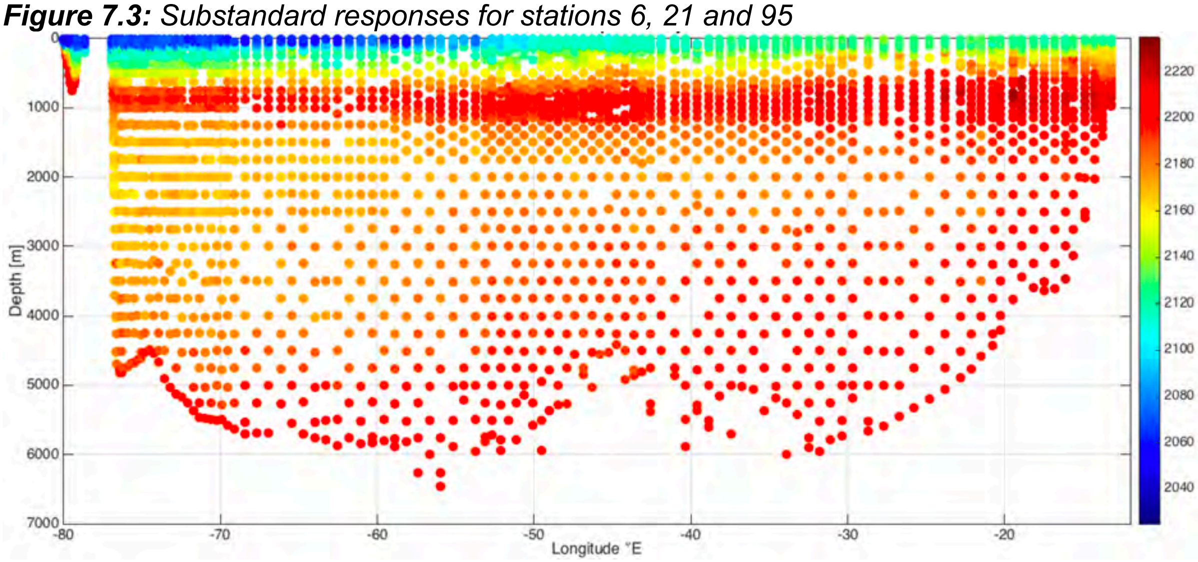


Figure 7.4: *Initial DIC distribution across 24.5N*

7.4 Total alkalinity

Alkalinity measurements were made by potentiometric titration. The s-shaped titration curve produced by potential of a proton sensitive electrode shows two inflection points, characterising the protonation of carbonate and bicarbonate, respectively. The acid consumption up to the second point is equal to the titration alkalinity. From this value, the carbonate alkalinity is calculated by subtracting the contributions of other ions present in the seawater, i.e. nutrients. The systems use highly precise Metrohm Titrinos for adding acid, an ORION-Ross pH electrode and a Metrohm reference electrode. The burette, the pipette (volume approximately 100 ml), and the analysis cell uses a water jacket filled with constantly flowing water controlled at 25°C. Two batches of acid titrant (~0.1 M hydrochloric acid, HCl) were used; both were made at NOC in 20L batches. Electrodes were refilled with 3M KCl and 0.7M NaCl solutions daily. Every 2 weeks the solutions were completely removed and replaced with fresh.

7.4.1 Analysis Issues encountered - #11 & #24

- *the pipette was found to not fully fill* (#11/#24). This was caused by either: the overflow sensor not draining from the previous sample due to the waste water level in the carboy being too high (timely emptying of the waste carboy and shortening of the waste tube precluded from this reoccurring); or valve 1 not responding to input, thus directing sample only into waste rather than the pipette (typically caused by a loose wire connection, corrected by retightening).
- *High titration residuals*. The replacement of electrode solutions or the electrode itself (swapped with the other operational VINDTA and also with new) did not always fix this issue. For #24, it was noticed that the acid inlet tube was sometimes being knocked by the stirrer, or that the strength of the stirrer was generating a vortex that partially uncovered the electrode. Changing the stirrer bar for a smaller one and decreasing its speed improved results. On a separate occasion it was found that a leaking acid inlet was the cause, fixed by tightening the fitting.
- *Zero alkalinity concentration with very long analysis time*. In the instances when it was not the lack of sample that was the culprit (caused by a misfunctioning valve 1) and sample was available for titration, it was found that the stirrer was not operating (not turning on at the beginning of the titration) (#24). The cause of this was not clear, but it is thought that there may be build-up of some impurity on the stirrer motor as it would sometimes eventually start, especially if manually turned off for a few seconds and restarted. It was found that there was some water pooling beneath the stirrer caused by a very small leak in one of the fittings of water batch circulation tubing. Mopping up of this and the use of blue roll to stop it accumulating led to the problem disappearing and not reappearing.

- *Pipette not emptying fully*. The sudden cause of this was not obvious, so the blowout time was extended in the 3C Standard method file.
- On a number of occasions but only during the rinsing of the alkalinity pipette on #11, water pressure built up sufficiently to causing *tubing to either burst or pop off their connector fittings causing sample loss*. The inside of the tubing had become significantly discoloured, with bottle grease and additional grime accumulating along its route into the system, narrowing the tubing. Multiple lengths of tubing were replaced including the sample tubing from the peristaltic pump and between valves 1, 2, 8 and 9. The moving of tubing in valve 9 revealed that this had also become kinked – loosening of this and moving to a fresher part of tubing found the problem did not reoccur.
- On both instruments, *bubbles were occasionally seen to be present in the titration tubing.* This necessitated regular flushing of the lines to remove them
- *The incomplete removal of the 2nd NaCl rinse from the titration cell (#11)*. This seemed to be a perennial problem but the extent to which it affects outputs is not entirely known as it would affect CRMs and samples alike. A comparison of results for bottle and Niskin replicates and substandards analysed across both instruments suggests there may be a slightly lower response from #11 than #24. Further investigations at home will be carried out to identify a solution.

7.4.2 Data calibration

Alkalinity data was calibrated by calculating an acid calibration factor accounting for acid concentration, pipette calibration and titrator and temperature sensor error, optimised to the CRM certified value. Additional post-cruise processing is required to filter out poor CRM titration data and to account for the slight trend in acid factor to finalise the calibration. The increasing trend is thought to be due to slight evaporation of water from the bulk, both as it is in the acid reservoir on the instrument and within the 20L storage carboy. Three substandard stations were also sampled in bulk (>20 bottles at the same depth) and dropped into the analysis schedule 2-3 times per day on both instruments to further track instrument response.

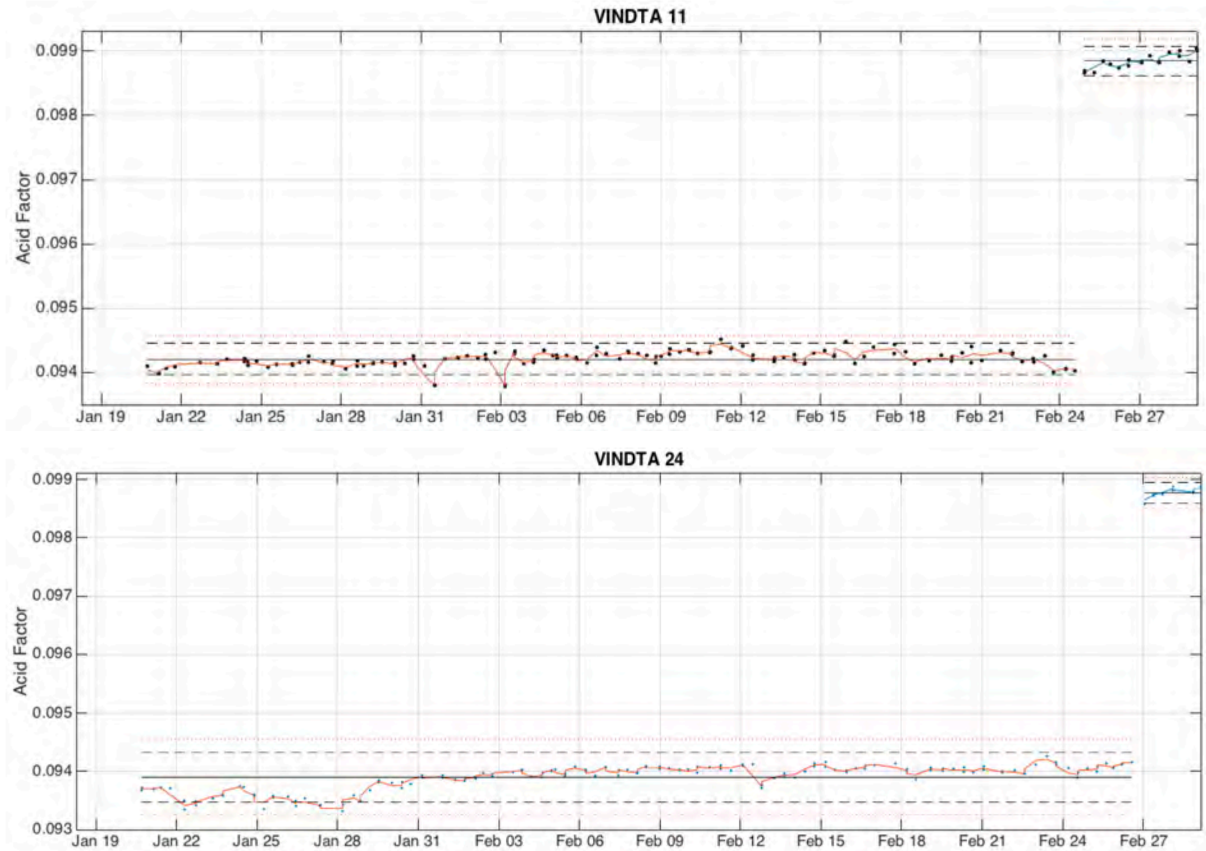
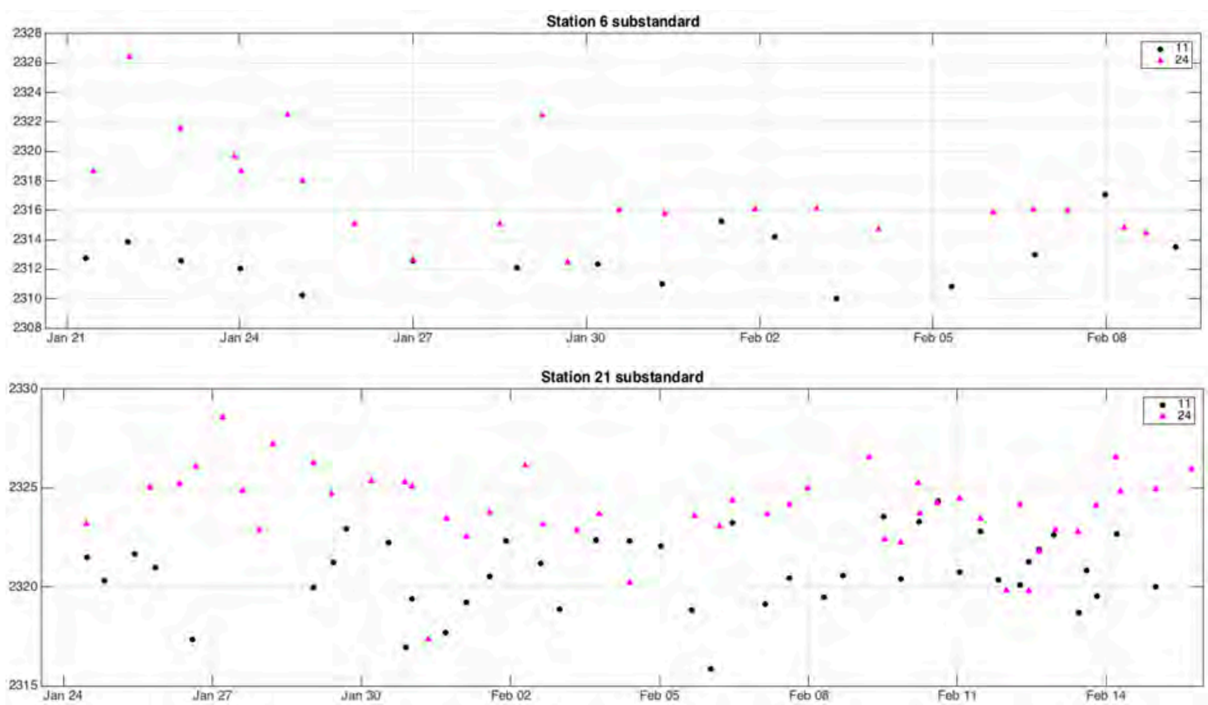


Figure 7.5: *Control charts for acid titrant (two batches)*



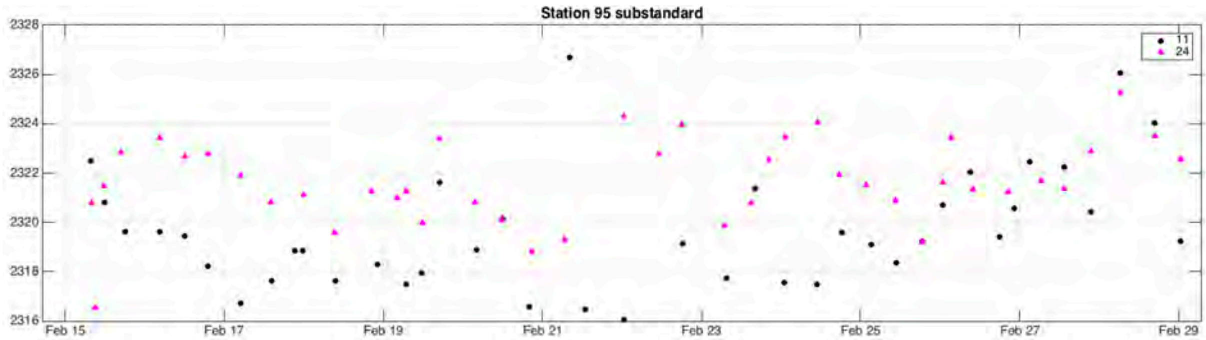


Figure 7.6: *Substandard responses for stations 6, 21 and 95.*

An initial estimate of the alkalinity distribution is given in Figure 7.7. Final alkalinity data await further quality control and final nutrient data.

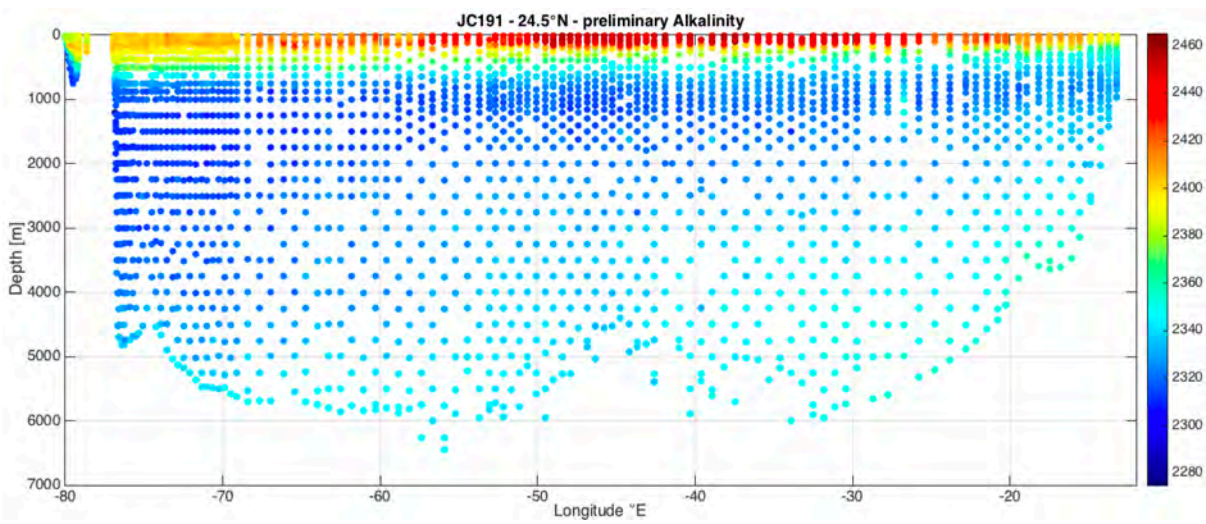


Figure 7.7: *Initial alkalinity field*

7.5 References

Johnson K.M., King, A.E., Sieburth, J.M. (1985) Coulometric TCO2 analyses for marine studies; an introduction. Marine Chemistry 16, 61-82.

Johnson, K.M., Williams, P.J.leB., Brändström, L., Sieburth, J.M. (1987) Coulometric TCO2 analysis for marine studies: automation and calibration. Marine Chemistry 21, 117-133.

Johnson, K.M., Wills, K.D., Butler, D.B., Johnson W.K., Wong, C.S. (1993) Coulometric total carbon dioxide analysis for marine studies: maximising the performance of an automated continuous gas extraction system and coulometric detector. Marine Chemistry 44, 167-187

Mintrop, L. (2004) VINDTA, Versatile Instrument for the Determination of Titration Alkalinity. Manual for versions 3S and 3C. Version 2.0. MARine ANalytics and DAta (MARIANDA), Kiel, Germany, 45 pp.

Peter Brown

8. Scientific Computer Systems and Instrumentation

8.1 Cruise overview

Cruise	Departure	Arrival	Technician(s)
JC191	19/01/20 Fort Lauderdale, USA	01/03/20 Santa Cruz, Tenerife	Eleanor Darlington eledar@noc.ac.uk

Ship Scientific Systems (SSS) is responsible for operating and managing the Ship's scientific information technology infrastructure, data acquisition, compilation and delivery, and the suite of ship-fitted instruments and sensors in support of the Marine Facilities Programme (MFP).

All times in this report are UTC

8.2 Scientific Computer Systems

8.2.1 Acquisition

Network drives were setup on the on-board file server; firstly, a read-only drive of the ship's instruments data and a second scratch drive for the scientific party. Both were combined at the end of the cruise and copied to a disk for both the PI and BODC.

The Ship-fitted instruments that were logged are listed in the below file (includes BODC/Level-C notes):

'JC191_Ship_fitted_information_sheet.docx'
Cruise Disk Location: ***'JC191/CRUISE_REPORTS/'***

Data were logged by the Techsas 5.11 data acquisition system. The system creates NetCDF and ASCII output data files. The format of the data files is given per instrument in the "Data Description" directory:

Cruise Disk Location: ***'JC191/Ship_Systems/TECHSAS/Data_Description/'***

Data were additionally logged into the legacy RVS Level-C format, which is also described in the *NMFSS_NetCDF_Description_Cook_v2_2.docx* document.

There are ASCII dumps of all the Level-C streams included on the data disk in the directory:

Cruise Disk Location: ***'JC191/Ship_Systems/Level-C/pro_data/*ascii/'**

The raw NMEA strings from the instruments were also time stamped and logged. This was using the RVDAS These are included on the data disk in the directory:

Cruise Disk Location: ***'JC191/Ship_Systems/Raw_NMEA*'**

8.2.1.1 Main Acquisition Events/Data Losses

Start	*Stop*	*Event*	*Cause*
20/01/20 16:00	21/01/20 03:15	Applanix PosMV	Acquisition issue with the POSMV.
24/02/2020 14:15	24/02/2020 14:18	Techsas	Techsas NTP issue
24/02/2020 16:28	24/02/2020 16:30	Techsas	Techsas NTP issue

8.2.2 Internet provision

Satellite Communications were provided with both the Vsat and Fleet Broadband (FBB) systems. The Vsat had a guaranteed speed of 1.5 Mbps, bursts greater than this when there is space on the satellite, and unlimited data. The FBB had a maximum un-guaranteed speed of 256 kbps with a fair use policy that equates to 15 GB of data a month. Solid service throughout, interrupted by a few mast blockages when on a northly heading. An unrestricted policy with traffic prioritisation was used throughout.

8.3 Instrumentation

8.3.1 Coordinate reference

8.3.1.1 Datum

The common coordinate reference was defined by the Blom Maritime survey (2006) as:

1. The reference plane is parallel with the main deck abeam (transversely) and with the baseline (keel) fore- and aft-ways (longitudinally).
2. Datum (X = 0, Y = 0, Z = 0) is centre topside of the Applanix motion reference unit (MRU) chassis.

8.3.1.2 Multibeam

The Kongsberg axes reference conventions are (see **Error! Reference source not found.**) as follows:

1. X positive forward,
2. Y positive starboard,
3. Z positive downward.

The roll reference is set to follow the convention of Applanix PosMV.

8.3.1.3 Applanix PosMV Primary scientific position and attitude system

The translations and rotations provided by this system have the following convention:

1. Roll positive port up,
2. Pitch positive bow up,
3. Heading true,
4. Heave positive up.

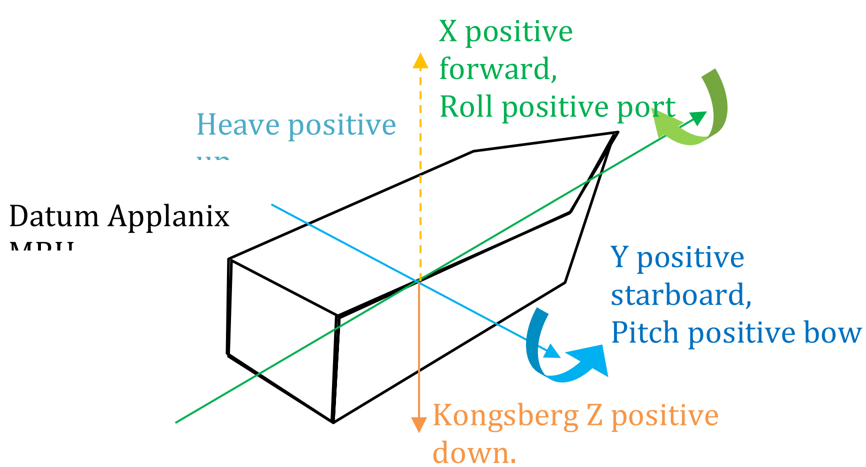


Figure 8.1: *Conventions used for position and attitude.*

8.3.2 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.

8.3.2.1 POS/ATT Instrument Events

PosMV issues on 20/01/2020 – Gap in Techsas from 16:00 – 03:15

8.3.3 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. Please see the separate information sheet for details of the sensors used and whether calibrations values have been applied:

'JC191_Surfmet_sensor_information_sheet.docx' Cruise Disk Location: ***'JC191/CRUISE_REPORTS/'***

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).

Instrument calibration sheets are included in the directory:

Cruise Disk Location:
'JC191/Ship_Systems/Met/SURFMET/calibrations/'

8.3.3.1 Surfmet Instrument Events

19/01/2020 -New Skye PAR sensors were installed
20/02/2020 16:30 – 17:00 Port light sensors had gimbal weight removed and the gimbal strapped down. This was to make it stationary as an experiment to understand how much the gimbals affect the light measurements. This remained in place until 01/03/2020.

29/02/2020 15:00 – end of cruise – the light data during this time should be disregarded. The TIR sensors were being changed for data QC testing – the serial numbers documented will not match that of those in use.

8.3.3.2 Underway Water Events

Date	Stop Time	Start Time	Cleaned	Transmissivity (v)	
				High	Low
19/01/20		15:45	Y		
28/01/20	21:50				
28/01/20		22:25	Y	4.6227	0.0548
29/01/20	14:20				
29/01/20	14:50		N		
10/02/20	18:52				
10/02/20		19:31	Y	4.6102	0.0522
17/02/20	15:30				
17/02/20		16:15	Y	4.6066	0.0580
23/02/20	11:35				
23/02/20		15:15	Y	4.7824	0.0584

8.3.3.3 Drop Keel Sound Velocity Sensor

The surface Sound Velocity (SV) sensor (AML SmartSV) mounted on the drop keel was used throughout providing SV data to the EM122. The port keel was lowered to 2.37 m on 20/01/2020 14:00 and raised on 29/02/2020 at 14:00.

Depth corrections were not added to the 12kHz EA640, 75 kHz ADCP & 150 kHz.

8.3.4 Hydro Acoustic Systems

8.3.4.1 Kongsberg EA640 10/12 kHz Single-beam

The EA640 single-beam echo-sounder was run throughout the cruise apart from during release and ranging of moorings. Both the 10 kHz and 12 kHz were run in active mode triggered free running. 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. Kongsberg Raw files and XYZ files are logged and depths were logged to Techsas and Level-C.

Until 22/02/20 17:00 only the 12 kHz (on the deployed drop keel) was giving accurate readings. Following deployment of the starboard drop keel on 22/02/20 the 10 kHz provided far more reliable readings. The starboard keel was returned to be flush with the hull.

8.3.4.2 Kongsberg EM122 multi-beam echo sounder.

The EM122 multibeam echo sounder was run throughout the cruise.

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 files are logged to allow for inclusion during reprocessing if required.

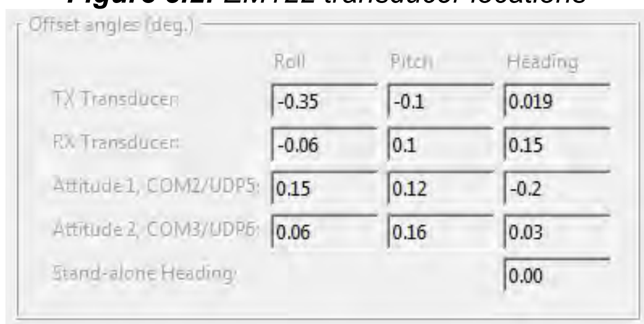
Sound velocity profiles were derived from a statistical model using SHOM & Ifremer's DORIS had a first pass cleaning process in Caris HIPS and SIPS 10.4. The data from 17/02/2020 onwards is generally of poor quality due to weather conditions.

The following figures show the system installation configuration. The values are from the ships Parker survey report, which is included on the data disk. The attitude angular corrections for use with the Seapath 330+ system was derived from a post refit trial calibration on JC108 Sept 2014. The attitude angular corrections for use with the Applanix Posmv system are from calibration during JC103 May 2014.

Location offset (m)

	Forward (X)	Starboard (Y)	Downward (Z)
Pos. COM1:	0.00	0.00	0.00
Pos. COM3:	0.00	0.00	0.00
Pos. COM4/UDP2:	0.00	0.00	0.00
TX Transducer:	19.205	1.830	6.934
RX Transducer:	14.094	0.950	6.932
Attitude 1, COM2/UDP5:	0.00	0.00	0.00
Attitude 2, COM3/UDP6:	-0.350	0.056	-0.373
Waterline:			1.376

Figure 8.2: *EM122 transducer locations*



Offset angles (deg.)

	Roll	Pitch	Heading
TX Transducer:	-0.35	-0.1	0.019
RX Transducer:	-0.06	0.1	0.15
Attitude 1, COM2/UDP5:	0.15	0.12	-0.2
Attitude 2, COM3/UDP6:	0.06	0.16	0.03
Stand-alone Heading:			0.00

Figure 8.3: *EM122 transducer offsets*

The system was setup to give the best resolution possible as per the manufactures manual.

8.3.4.3 ADCP's

The vessel mounted 150 and 75 kHz ADCPs were run throughout the cruise. This was acquired using the UHDAS system.

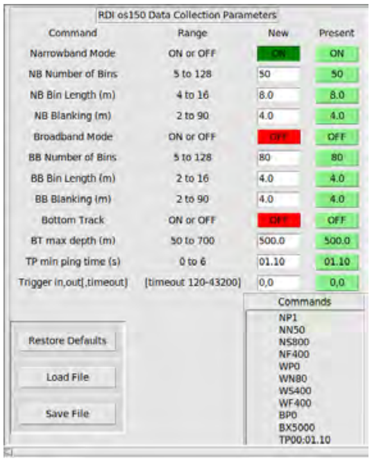
Cruise ID: JC191

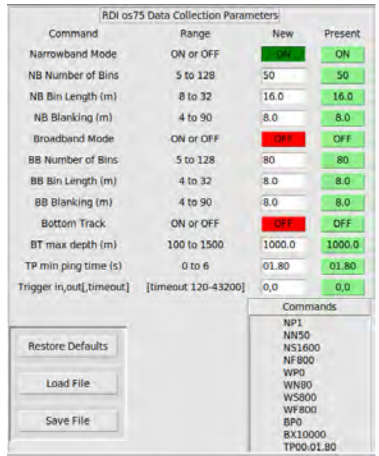
This initial section of the cruise, the serial cables into the PC were switched around. Therefore, the data marked as 75 kHz is actually the 150 kHz, and sampling as such.

Cruise ID: JC191_02

This is the primary cruise data, following the cable switch. The port drop keel was deployed on 20/01/2020 13:59 UTC to 237 cm. The drop keel was raised on 29/02/2020 at 14:00 UTC.

In the Florida Straits, the instruments were run with narrowband and bottom track on. On 23/01/2020 bottom track was turned off once in deep water. All changes to the configuration are saved un the UHDAS file structure.





8.3.5 Other Systems

8.3.5.1 EM Speed logs

The single axis bridge Skipper Log and the dual axis Chernikeef science log were logged throughout the cruise. The Chernikeef log was calibrated in December 2017 offshore of Tenerife with an additional adjustment on 21/03/2018 as below.

RPM	True Speed	True Speed (21/03/18)	Measured Speed
Cruise Disk Location: ***'JC191/Ship_Systems/Acoustics/*****ADCP-UHDAS/'**			
R0030	S0301	0274	A0079
R0050	S0500	0455	A0126
R0080	S0767	0698	A0192
R0110	S1015	0924	A0257
R0001	N/A	S0001	A0001
R0140	N/A	S1617	A0450

The data was seen to be unreliable with respect to the Skipper log and ADCP's and should be disregarded.

8.3.5.2 CTD2MET

The CTD2MET service was run, sending thinned CTD profiles to the Met Office for ingestion into near real time models. In total 99/135 (73%) of CTD profiles were transmitted. There was a break between 3 – 11th March due to a change in the ship's public IP address, requiring reconfiguring the smtp mail system in Southampton.

Eleanor Darlington

9. Underway Temperature and Salinity

9.1 TSG Sensor

A single SBE45 thermosalinograph (TSG) sensor (s/n 0229) was used throughout JC191 to measure temperature, conductivity, salinity and sound velocity of the sea surface water. This instrument, along with the other underway instrumentation, is outlined in the reference underway instrumentation section. The depth of the sea water intake is estimated to be 5.5 m below sea level at normal loading. The underway instruments, located in the bottle annex, were cleaned once a week by Eleanor Darlington while on station to avoid gaps in the data while underway. At these times the pumps were off so there was no flow rate through the system.

Figure 9.1: *The underway instrumentation located in the bottle annex onboard the James Cook. The SBE45 TSG sensor can be seen in the middle of the board.*

9.2 Salinity samples

The ships underway sea water supply was sampled in the bottle annex as part of routine watch keeping duties: nominally at hours 01, 05, 09, 13, 17 and 21 local ship time. The actual sampling time varied, particularly if the CTD was on deck being sampled, but is noted on the logsheet, scanned copies of which are on the Public drive.

No samples were taken while the supply was switched off when the ship was in shallow waters or in port. While the supply was active the flow through the sampling tube was continuous and samples were drawn as per [reference CTD salinity samples section] and analysed as per [references water sample salinity analysis]. The time and date at which each sample was taken was recorded on a log sheet next to the supply tap.

Before taking the sample best practice required checking of the underway instrumentation system sensor flow rate meters to ensure they were at the recommended levels. For the sampling little variation in the flow rate was recorded.

9.3 Data processing of Salinity samples

Once the TSG crate had been run in the autosal and given a sheet number, the sheet was processed along with the CTD data in the terminal. After syncing the data into the BOTTLE_SAL the following commands run in terminal were:

- ln - s JC191\ TSGnn\dd\ mm\ yyyy.csv sal_jc191_00sheetnumber.csv *- this creates a link from each file to the numbered sheet*
- modsal_unix - *this creates the .csv_linux file*
- ln -s sal_jc191_00sheetnumber.csv_linux tsg_jc191_nnnn.csv_linux *this creates a symbolic link to rename the sheet as a tsg crate*

Once this link had been created data was processed using mexec matlab tools (initialised by starting Matlab and running m_setup at the prompt) under the 'pstar' used id on koaekea. The first step was to edit the salinity crate offsets. This was done in mtsg_01_jc191.m, where each crate number was given its appropriate offset under the variable g.adj.

The following mexec routines were then used:

1. mtsg_01_jc191.m – *Reads analysed bottle salinity values into ctd/tsg_jc191_[crate number].nc and ctd/tsg_jc191_all.nc files*.
2. mtsg_medval_clean_cal.m - *This runs on the appended cruise file tsg_jc191_01.nc. The data are first reduced to 1-minute bin medians. Cleanup and calibration is applied using mcalib2 with the function mtsg_cleanup. The file met_tsg_jc191_01_medav_clean.nc is output. The output from this script is shown in Figure 8.2*
3. mtsg_bottle_compare.m – *Plots bottle sample salinity values (from ctd/tsg_jc191_all.nc) with TSG salinity and residuals. The plot also includes the proposed calibration that is hardcoded in the script. Visual inspection of this plot ensures the times have been assigned to bottles correctly and any outliers can be removed from the calculation (done by hard-coding outlier indices into opt_jc191.m). Times when the underway pumps were switched off are also hard-coded in to opt_jc191.m.*

9.4 Calibration

TSG salinity was calibrated by comparison with bottle salinities. Currently no calibration has been applied as there is a very good agreement with the TSG and the bottle values.

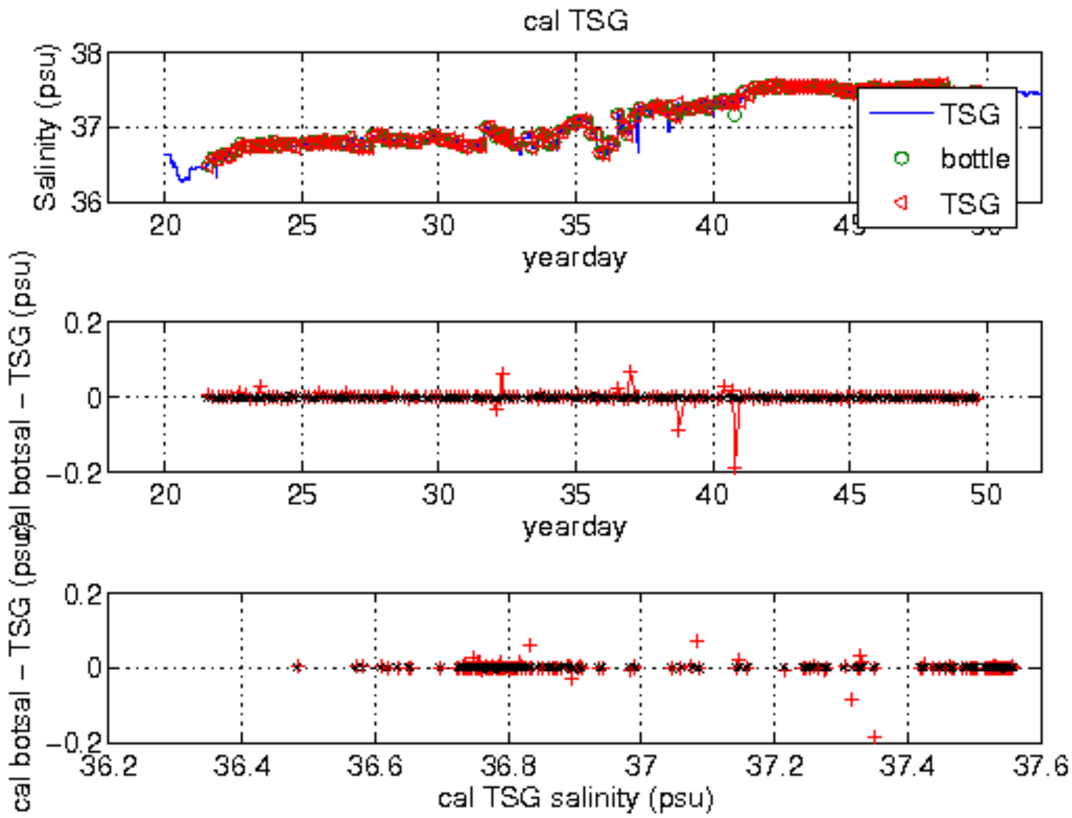


Figure 9.2: *Output from mtsg_medavg_clean_cal.m showing the calculated salinity over the cruise from the TSG with a comparison with the bottle samples. Other than a couple of outliers from the bottles, the agreement is very good and requires no calibration.*

Katherine Grayson

10. Surface Meteorological Sampling System (SURFMET)

10.1 Sensors and Data Collection

The meteorological data recording on board the RRS James Cook includes air temperature, humidity, true and relative wind speed and direction and atmospheric pressure (as well as TIR and PAR, see Surflight section 10.4). The air temperature, wind and atmospheric pressure sensors (Table 10.1) are located on the starboard side of the Surfmet platform on the bow of the ship, indicated in Figure 10.1. The location of the sensors allows performance and readings to be most accurate when the bow of the ship is facing the wind. A wind blowing directly on to the bow allows for a more accurate reading of relative wind speed and direction when compared with wind blowing towards the aft deck due a shadowing effect from the Bridge deck and VSat platform.

Figure 10.1: *Location of the Surfmet platform on the front deck of the RRS James Cook. Orange ring indicates the location of the Gill Windsonic and the Vaisala HMP45.*

The surface sea water properties, such as sea surface temperature (SST), conductivity, and therefore salinity, sound speed, fluorescence and transmittance were continuously measured on board using the thermosalingraph (TSG, see section 9); see Table 10.1. This is with the exception of an additional SST sensor (Seabird 38) located on the hull of the ship. In addition, the flow rate through the

TSG system was continuously logged and maintained at optimum rate. This is with the exception of times of cleaning, where data at these times has been removed from the data set, see Section 10.2.1.

Table 10.1: *Variables of the surface seawater properties and their corresponding sensors and data files.*

Variable	Sensor	Location	Directory and file data assigned to
Air temperature	Vaisala HMP45	Starboard side of the Surfmet platform	met/ surfmet/ surfmet_jc191_01.nc
Humidity	Vaisala HMP45	Starboard side of the Surfmet platform	met/ surfmet/ surfmet_jc191_01.nc
Wind speed (relative to ship)	Gill Windsonic	Starboard side of the Surfmet platform	met/ surfmet/ surfmet_jc191_01.nc
Wind direction (relative to ship)	Gill Windsonic	Starboard side of the Surfmet platform	met/ surfmet/ surfmet_jc191_01.nc
Atmospheric pressure - barometric	Vaisala PTB110	Starboard side of the Surfmet platform	met/ surflight/ met_light_jc191_01.nc
Photosynthetically Active Radiation (PAR)	Skye PAR SKE510	1x Port and 1x Starboard side of the Surfmet platform	met/ surflight/ surflight_jc191_01.nc
Total Irradiance (TIR)	Kipp and Zonen TIR CM6B	1x Port and 1x Starboard side of the Surfmet platform	met/ surflight/ surflight_jc191_01.nc
Sea surface temperature	Seabird 38	Hull	ocl/ tsg/ tsg_jc191_01.nc
Sea surface temperature - TSG	Seabird 45	TSG	ocl/ tsg/ tsg_jc191_01.nc
Conductivity	Seabird 45	TSG	ocl/ tsg/ tsg_jc191_01.nc

Sound Speed	Seabird 45	TSG	ocl/ tsg/ tsg_jc191_01.nc
Fluorescence	WetLabs WS3S	TSG	ocl/ tsg/ met_tsg_jc191_01.nc
Transmittance	WetLabs C-Star Transmissometer	TSG	ocl/ tsg/ met_tsg_jc191_01.nc
Flow rate		TSG	ocl/ tsg/ met_tsg_jc191_01.nc

10.2 Data Processing

10.2.1 Surfmet and TSG

Processing and calibration of surfmet data was carried out using 'mexec', a Matlab processing system within */local/users/pstar*. Data produced by their respective sensors were first logged through the ship TechSAS system and stored as NetCDF files and saved into *jc191/mcruise/data/*, with the respective directories outlined in Table 10.1. Surfmet data was collected throughout the cruise and data was stored on a day by day basis. Surfmet data files start at midnight (00:00 UTC) and continue for 24 hours until the start of the next file again at midnight, recording data in 1Hz (~ one second frequency). Each TechSAS file has a data time origin of 1st January 2020 (737791), found using the *'data_time_origin'* global attribute, with units of time in seconds after this time origin.

The files within the Surfmet directories (surfmet, surflight and tsg) are labelled as per their directories in correspondence with the Julian day in which the data were recorded e.g. for Jday 20, the file is named surfmet_jc191_d020_raw.nc. Edited files were also created and saved in the same directory, labelled 'surfmet_jc191_d???_edt.nc', 'met_light_jc191_d???_edt.nc', 'tsg_jc191_d???_edt.nc' or 'met_tsg_jc191_d???_edt.nc'. In addition, larger whole transect files were created and named as per their directory with '01' instead of the day number, e.g. 'surfmet_jc191_01.nc'.

Variables within the *'tsg'* and *'met_tsg'* files required further processing. These files were calibrated using the mexec scripts in Table 10.2 which also averaged the data set into one-minute frequency bins.

Table 10.2: *mexec scripts used to process tsg and met_tsg transect files.*

Input file	Mexec script	Output file
tsg_jc191_01.nc	mtsg_medav_clean_cal.m	tsg_jc191_01_medav_clean_cal.nc
met_tsg_jc191_01.nc	mtsg_merge_and_listing.m	tsg_psal_fluo_trans.nc'

To utilise the wind data, calculating the true wind speed and direction relative to the earth (as opposed to the ship) are a necessity. In addition, for analysis purposes converting these variables to east and north components are required, before averaging, if one is wishing to avoid regular switches between 0 and 360° when plotting. To process the wind data, the *'surfmet_jc191_01.nc'* file was coupled with the ship speed and directional data from *jc191/mcruise/data/nav/posmvpos_jc191_01.nc*, were used to produce *'surfmet_jc191_true.nc'.* This data stream contained ship direction and speed variables with u and v components, as well as for true wind (relative to the earth) and relative wind (to the ship) components, plus latitude and longitude. Finally, true wind file was averaged into one-minute bins to be used for analysis, output file *'surfmet_jc191_trueav.nc'.*

Final data files used for processing:

'surfmet_jc191_01.nc',
'met_light_jc191_01.nc',
'tsg_jc191_01_medav_clean_cal.nc',
'tsg_psal_fluo_trans.nc',
and *'surfmet_jc191_trueav.nc'*

These files were copied into a new directory for processing to avoid editing or deleting raw files. Data from these '*surfmet'* and '*met_light'* files were interpolated to the coarser resolution of the 'surfmet_jc191_trueav.nc' file of one-minute frequency to allow for comparison, within '*surfmet_transect_v1.m'*. The Savitzky-Golav smoothing filter, '*sgolayfilt'*, was applied to each data set presented in this section of the report.

Table 10.3: *Variables within the Surfmet directories and their corresponding names.*

Variable	Directory and file data assigned to	Variable name in file

Wind direction (relative to ship)	met/ surfmet/ surfmet_jc191_01.nc	*direct*
Air temperature	met/ surfmet/ surfmet_jc191_01.nc	*temp*
Humidity	met/ surfmet/ surfmet_jc191_01.nc	*humid*
Wind speed (relative to ship)	met/ surfmet/ surfmet_jc191_01.nc	*speed*
Delta T	met/ surfmet/ surfmet_jc191_01.nc	*deltat*
Atmospheric pressure	met/ surflight/ met_light_jc191_01.nc	*pres*
Photosynthetically Active Radiation (PAR)	met/ surflight/ surflight_jc191_01.nc	*ppar* *spar* (Port and Starboard)
Total Irradiance (TIR)	met/ surflight/ surflight_jc191_01.nc	*ptir* *stir* (Port and Starboard)
Salinity	ocl/ tsg/ *tsg_jc191_01_medav_clean_cal.nc*	*salin*
Sea surface temperature	ocl/ tsg/ *tsg_jc191_01_medav_clean_cal.nc*	*temp_r*
Sea surface temperature - TSG	ocl/ tsg/ *tsg_jc191_01_medav_clean_cal.nc*	*temp_h*
Conductivity	ocl/ tsg/ *tsg_jc191_01_medav_clean_cal.nc*	*cond*
Sound Speed	ocl/ tsg/	*sndspeed*

	tsg_jc191_01_medav_clean_cal.nc	
Fluorescence	ocl/ tsg/ *tsg_psal_fluo_trans.nc*	*fluo*
Flow rate	ocl/ tsg/ *tsg_psal_fluo_trans.nc*	*flow*
Transmittance	ocl/ tsg/ *tsg_psal_fluo_trans.nc*	*trans*

10.3 Surfmet conditions

10.3.1 Atmospheric conditions

Local weather patterns were relatively calm throughout the cruise with the Beaufort regularly reading approximately 4 or lower, winds speeds were often between 0 and 10 m/s for the most part of the transect (Figure 10.3). Towards the beginning of the cruise we experienced a larger swell and slightly enhanced wind systems passing through as we moved through the Florida Strait and Bahamian Islands. During sailing through the western basin climate was calm with minimal precipitation or significant wind speeds. As we progressed over the halfway mark and into the eastern basin, we experienced more varied weather patterns with the Beaufort reading at 7 and then 3 on consecutive days. The air temperature from around this time began to gradually decrease until February 23rd. The scientists onboard witnessed a lightning storm approximately 200 m from the ship in multiple directions on the night of the 24th February.

10.3.2 Air temperature, humidity and pressure

Figure 10.2 shows the air temperature (red), humidity (yellow) and air pressure (orange) across the whole transect against time. At the beginning of the cruise there was a low-pressure system moving through the region. After the 26th January there are two big dips in air temperature that coincide with a decrease in the humidity. Around the 2nd February we see a gradual increase in air temperature which could have potentially caused an increase in evaporation, spiking the humidity profile around the 4th February. Air pressure oscillated around 1010 to 1030 dbar throughout the cruise. During the first half the transect air pressure regularly read between 1010 and 1020 dbar. As we approached

~50W (9th February), an increase in air pressure (1020-1030 dbar) was coupled with a decrease in humidity.

Additionally, there was a significant decrease in radiation captured from the PAR and TIR sensors on the 29th January. Figure 10.3 highlights this day clearly showing a dip in air temperature and humidity causing an increase in pressure relative to the day before and after. During the 28th January, there was a gradual increase in the air temperature, potentially causing an increase in evaporation explaining the increase in humidity.

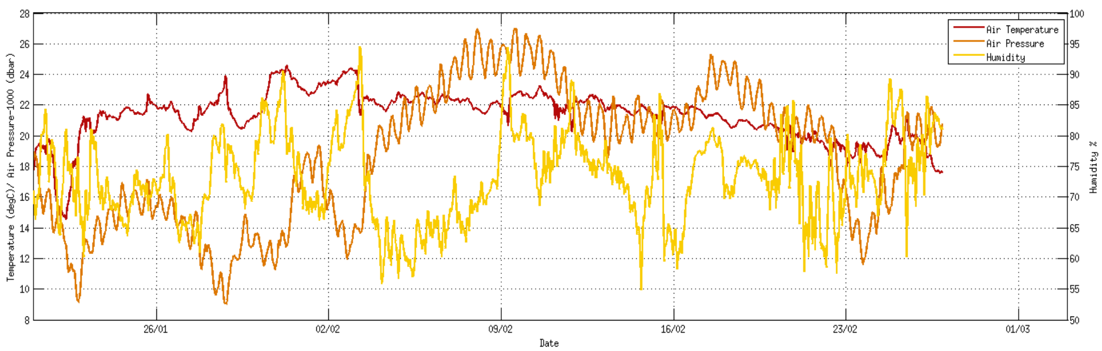


Figure 10.2: *Atmospheric conditions across the JC191 24N transect. Air temperature (red), air pressure (orange), humidity (yellow).*

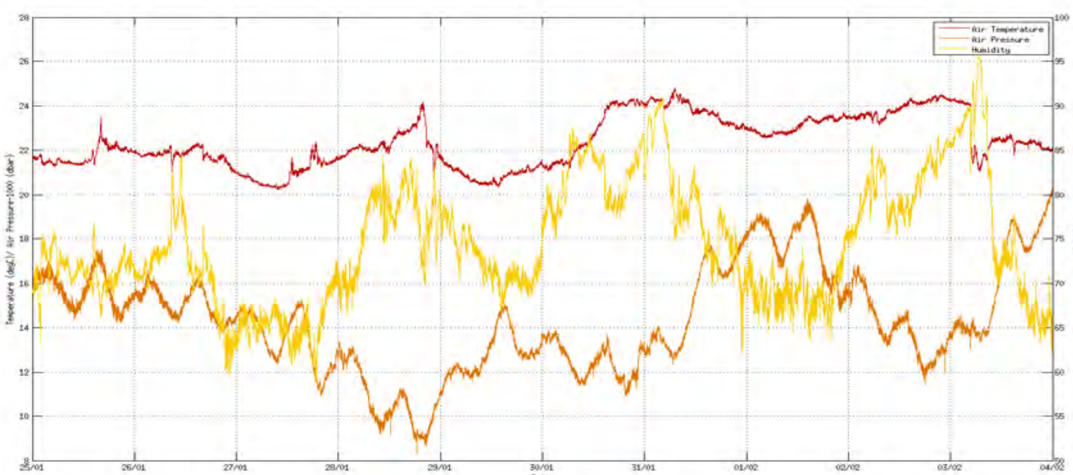


Figure 10.3: *Atmospheric conditions across the JC191 24N transect between 25th January and the 4th February. Air temperature (red), air pressure (orange), humidity (yellow). Julian day 29 is highlighted using the red bands.*

10.3.3 Wind data

Wind data from the file *'surfmet_jc191_trueav.nc'*, was read into Matlab and plotted using the latitude, longitude and u and v wind components. The data is plotted for reading every two hours along the whole transect. Each quiver is coloured in relation to the true wind speed experienced at the origin the arrow/ on the transect. The size of each wind vector correlates to the true wind speed of the same origin. At the start of the cruise the ship travelled north of 26°N, with strong wind speeds reaching 18 m/s on 22nd January. This occurred as we travelled across the Florida strait, where the data suggest a strong wind flowing towards the south. The strong winds displayed on Figure 10.4 correlate with the lower air temperature experienced towards the start of the cruise, shown in Figure 10.2. In the western side of the basin, we experienced varying wind patterns and speeds. As we approached the Mid-Atlantic Ridge (~50°W) wind direction became slightly more constant, with air flowing in a slight south easterly direction oscillating between 220-280°.

From the 17th to the 22nd Feb we experienced winds of increasing strength of up to 15 m/s towards the 21st and 22nd, Beaufort readings on these dates reached 6 and 7 (Strong breeze and High winds, respectively). This was strong enough to require ship streaming speed to be reduced for a couple of days. In addition, on the 22nd February (~35°W), strong wind patterns had transported Saharan sand over 3000 nm to our location depositing on the Bridge deck. On the 22nd Feb, we discovered that large parts of the Canaries had experienced their worst Calima event in the last 30 years. Therefore, it is quite likely that these sand deposits could have been a result of entering the periphery of this phenomenon.

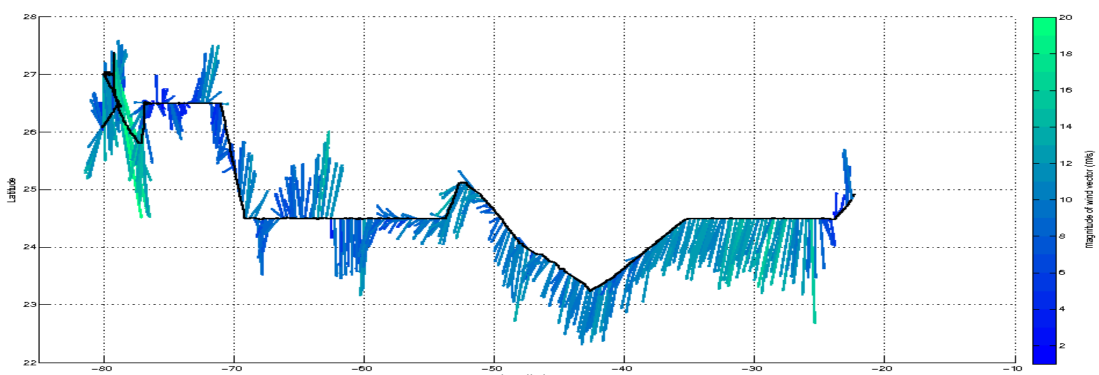


Figure 10.4: *Wind direction and speed quiver for the JC191 transect plotted against latitude and longitude.*

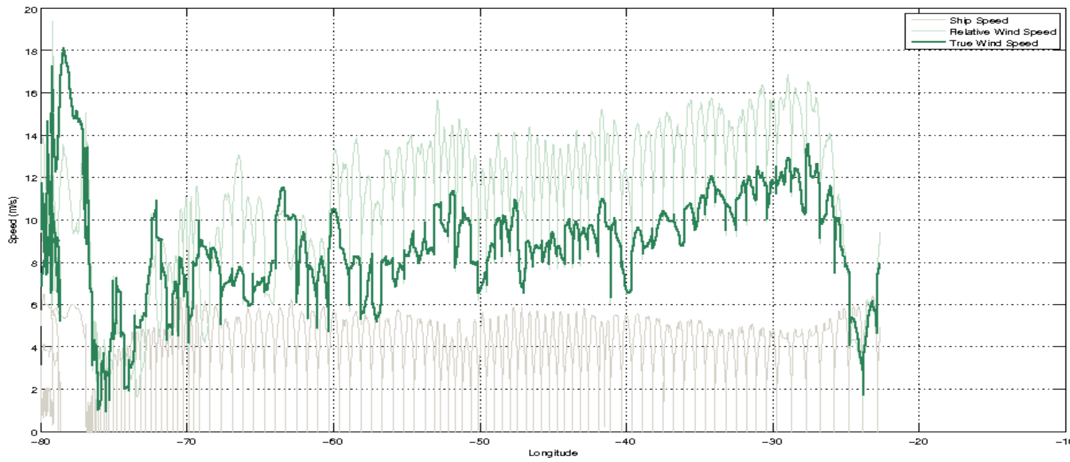


Figure 10.5: *True (dark green) and relative (light green) wind speed with the ships speed underlaid (grey) for the whole JC191 transect.*

10.3.4 Sea Surface Temperature and Salinity

The change in temperature in the two temperature sensors as part of the TSG system is shown in figure 10.6. SST recorded from the hull of the ship is thought to present the 'true' SST relative to the Seabird 45 reading that is located on the TSG 'wall' in the water bottle annex. It must be noted that the requirement for the Seabird 45 is to record underway conductivity and temperature at the same time. The Seabird 38 records sea surface water temperature from the top 5 m of the water column. When comparing the two sensors it is clear the housed Seabird 45 sensor reads higher than the SST recorded by the Seabird 38 on the hull of the ship. We believe this increase is as a result of travel through pipes and not an offset in the sensors and their readings. Figure 10.6 shows the difference in the two sensors over time.

The sea surface temperature decreased at the beginning of the transect to 26.5°C to just below 24°C towards the 26th January (~26° N, 70° W). After this date there was a small peak followed by a dip and then a gradual increase to just under 26°C at the beginning of February, figure 10.6. After these changes, the SST appeared to gradually decline as we approached the Mid-Atlantic Ridge and into the eastern basin. As we crossed into the eastern basin, we also saw a large increase in the SSS from less than 36.75 PSU on the 4th February (24° 30N, 58°. W) to over 37 PSU from the approximately 11th to the 17th February. This coincides with the RRS James Cook passing over the Sea Surface Salinity Maximum of the eastern Atlantic. This occurs due to the higher temperatures, causing high rates of evaporation, coupled with minimal precipitation events.

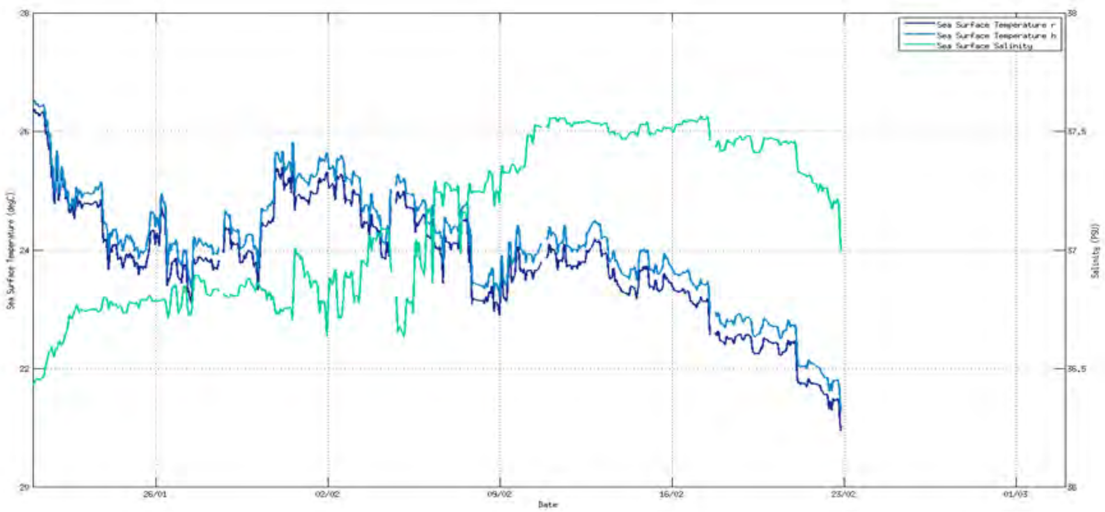


Figure 10.6: *Sea surface temperature recorded from the Seabird 38 on the hull of the ship (SST r, dark blue) with the SST (h, light blue) and sea surface salinity (SSS, turquoise) recorded from the Seabird 45.*

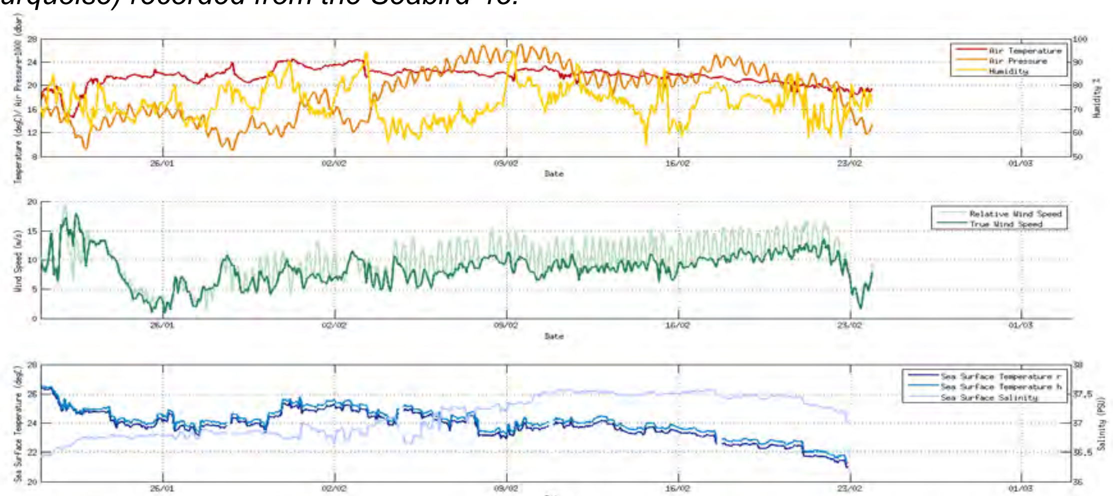


Figure 10.7: *Sea surface temperature recorded from the Seabird 38 on the hull of the ship (SST r, dark blue) with the SST (h, light blue) recorded from the Seabird 45. Overlaid is the difference between these two sensors (h-r, i.e. TSG SST – Hull TSG).*

10.4 Surflight data

Photosynthetically active radiation (PAR) and total irradiance (TIR) were measured using the ships port and starboard pyranometers, located on the Foscle Deck and Met Platform. This surflight data was accessed from pstar/jc191/mcruise/data/met/surflight through the files met light jc191 d* raw.nc.

The data was read in and plotted using a Python script, surfmet light v3.py and package met packages.py. The output data from the pyranometer was read in with units of 10^{-5} V. To find the PAR and TIR values in W/m2, the output data was divided by the sensitivity (10^{-5} V/W/m2) of the pyranometer, and multiplied by 10. Further details can be found in the Kipp and Zonen sensor manual, CM6B.pdf and the Skye manual, SKE510.pdf in Ship Systems/Met/SURFMET.

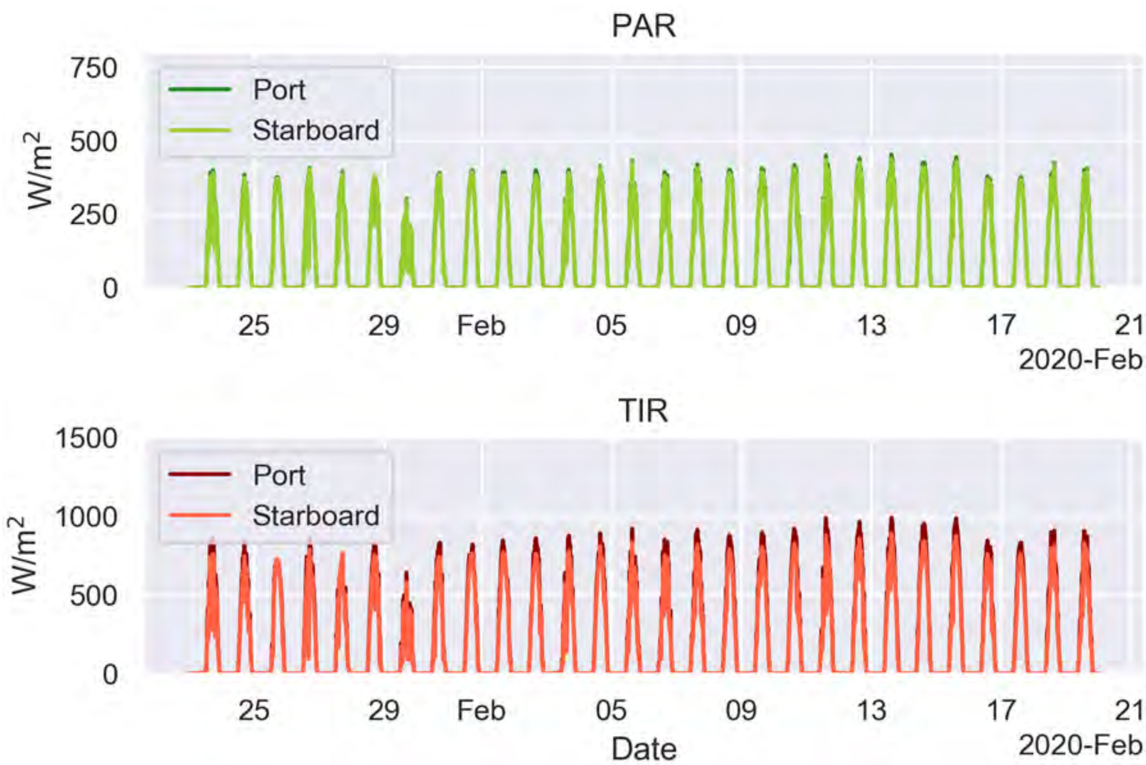


Figure 10.8: *Time series of photosynthetically active radiation (top panel) and total irradiance (bottom panel) across 24N for port and starboard sensors, from 23rd January to 19th February. Units in W/m2.*

Both the PAR and TIR data underwent a fourth-order low pass filtering method by Savitzky-Golay, and this was done using the function, Savitzky Golay Filter.py in met packages.py. The Savitzky-Golay maintains much of the original shape to the data, where smoothing by a moving window average might reduce important features.

10.4.1 Data Analysis

In Figure 10.8, readings for PAR and TIR are plotted for dates from 23rd January to 19th February. Looking at the data in Figure 2.1, it is not smooth, but does hold on to many of its high amplitude features, giving us a sense that radiation varies throughout the day, dependent on atmospheric conditions. The daily energy input for PAR and TIR does remain consistent, around 400 W/m2 and 800 W/m2, respectively, although there does appear to be an exception on the 29th January, which sees a drop to 250 W/m2 and 500 W/m2. This could be caused by a drop in air pressure and rise in humidity. See section on Surfmet for further details.

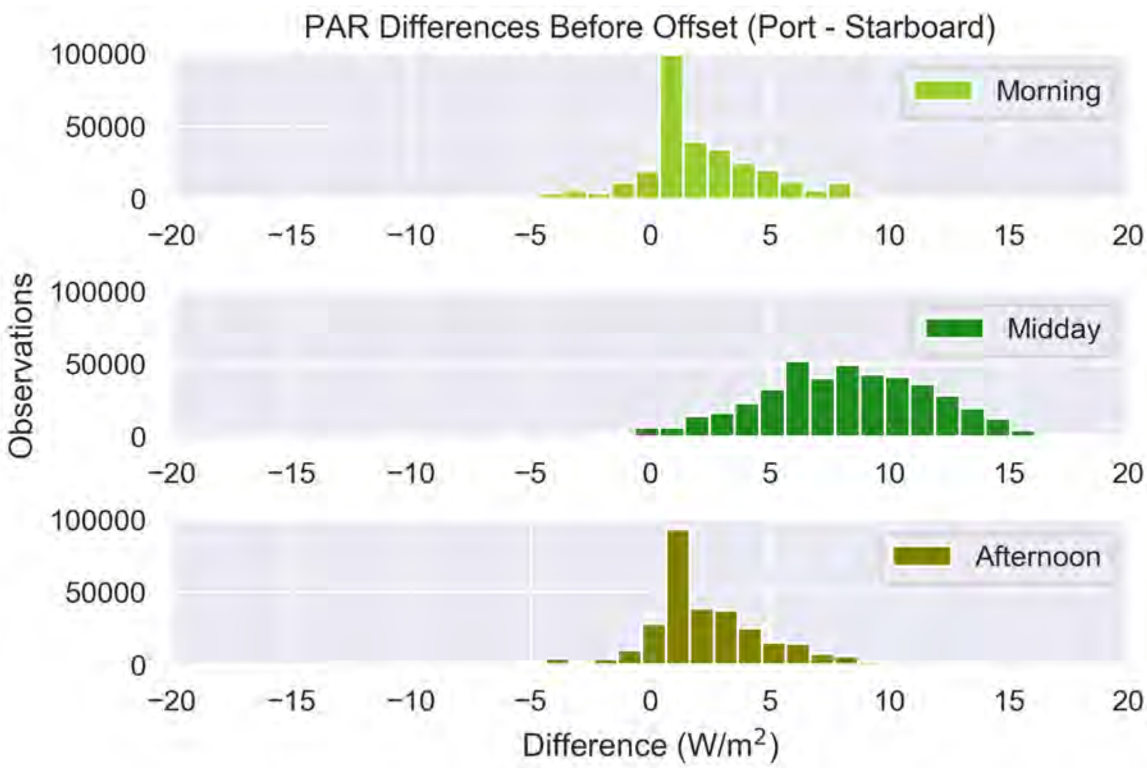


Figure 10.9: *Total observations of PAR differences between port and starboard for morning, midday and afternoon, before applied offset, from 23rd January to 19th February. Units W/m2.*

PAR differences were examined for three time periods during the day, defined by the suns azimuth angle (ϕ); morning (ϕ < 135º), midday (135 º < ϕ < 225 º) and afternoon (ϕ > 225 º). The suns azimuth angle was calculated using the Python package Pysolar at the ships location and local mean solar time. Figure 10.9 is a histogram plot of PAR differences (Port - Starboard) from 23rd January to 19th February and the number of observations for each difference and for each time period. There is an obvious port side bias in all time periods, which indicate that one sensor is reading higher / lower than should be.

To examine this further, Figure 10.10 shows scatter plots of the PAR readings against the suns elevation for each time period. To avoid overcrowding the scatter plot, only points at every 1000'th interval were used. As the sun rises (sets) in the morning (afternoon), the PAR values increase (decrease) and the readings become broader (narrower). For midday readings, the spread of data is much wider than the morning and afternoon readings, and values are highest – 400 W/m2 - when the suns elevation is at its maximum, around 50 º at this time of year. Regression lines for each period are also plotted against the scatter, highlighting a slight difference between port and starboard measurements, with this difference increasing with elevation. These differences suggest why there is a port side bias in Figure 10.9.

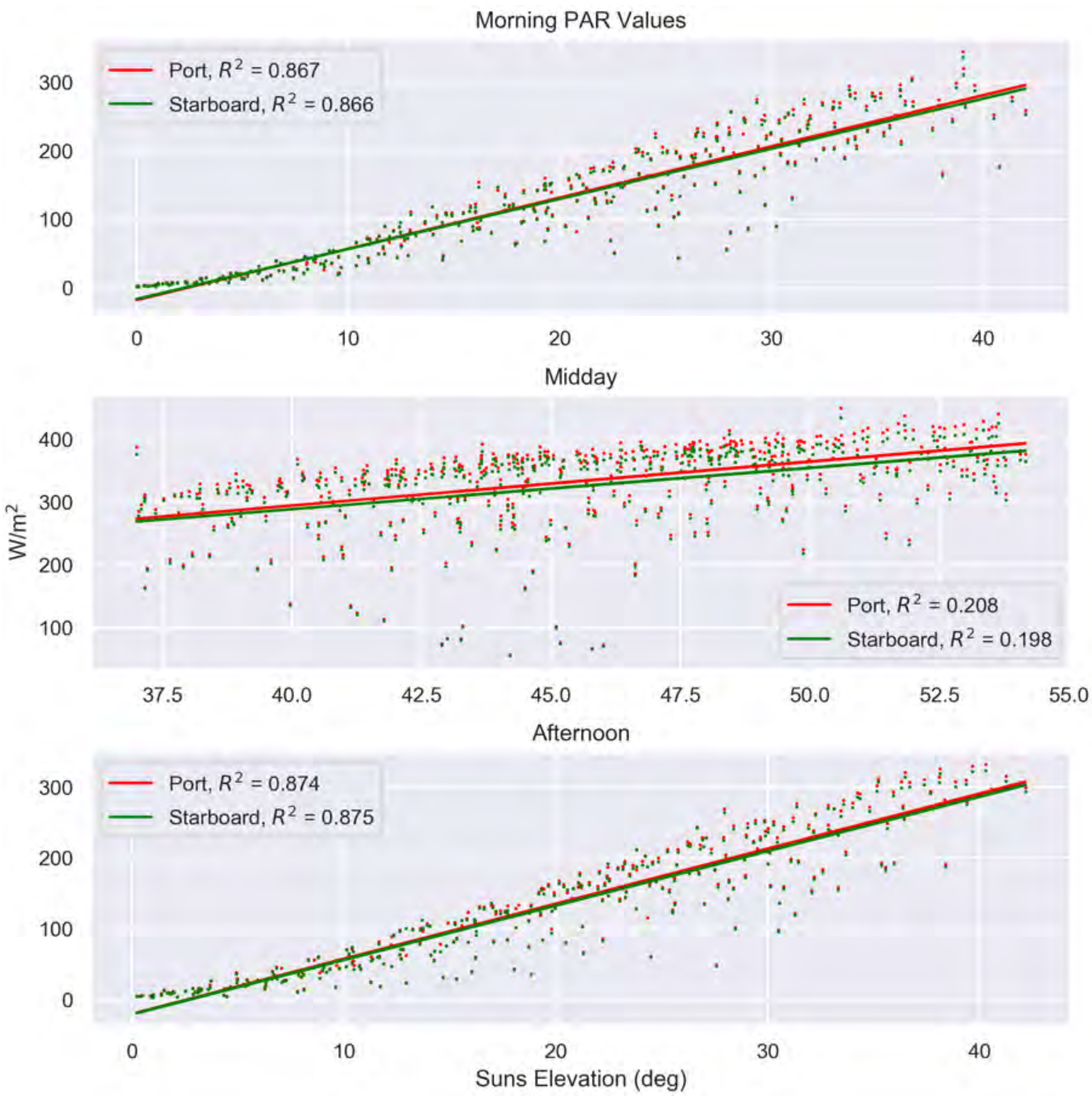


Figure 10.10: *Scatter of morning, midday and afternoon total PAR measurements in W/m2, plotted alongside a linear regression line showing the correlation and offset between port (red) and starboard (green) sensors, from 23rd January to 19th February.*

A diagnosis on the PAR sensors has not been made, so it is difficult to ascertain whether there are technical or calibration issues at play. In any case, to account for this bias the difference between port and starboard regression lines are added to the starboard PAR data. The result of this are shown in Figure 10.11. The readings are now spread more evenly over positive and negative values, with no clear bias towards port or starboard measurements.

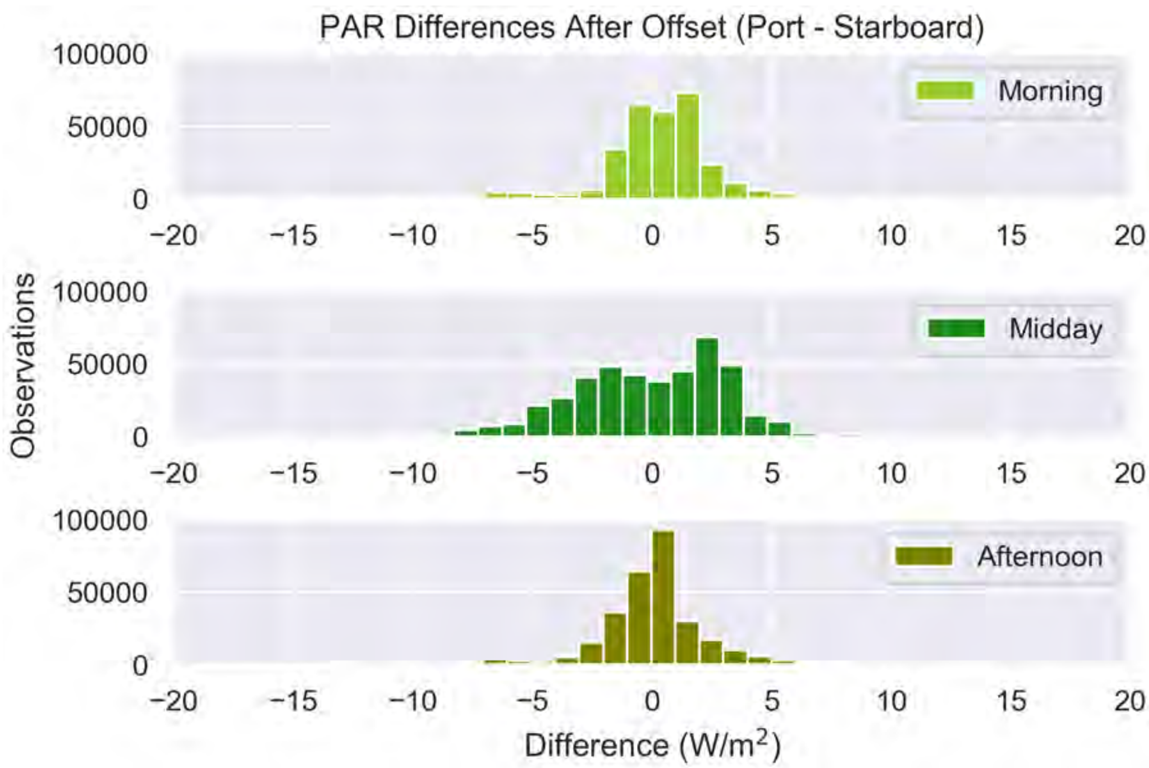


Figure 10.11: *Total observations of PAR differences between port and starboard for morning, midday and afternoon, after applied offset, form 23rd January to 19th February. Units in W/m2.*

On 20th February around 4pm, the weights under the sensors were removed and the sensors themselves were strapped down to prevent any tilting with the ship. It was supposed that this may be a possible cause to the port side bias. Figure 10.12 shows a timeseries for three days of PAR and TIR measurements. There is still a clear indication for a port side bias throughout days 21 to 23, suggesting that the alterations to the sensors fixture has had negligible effect for that time period.

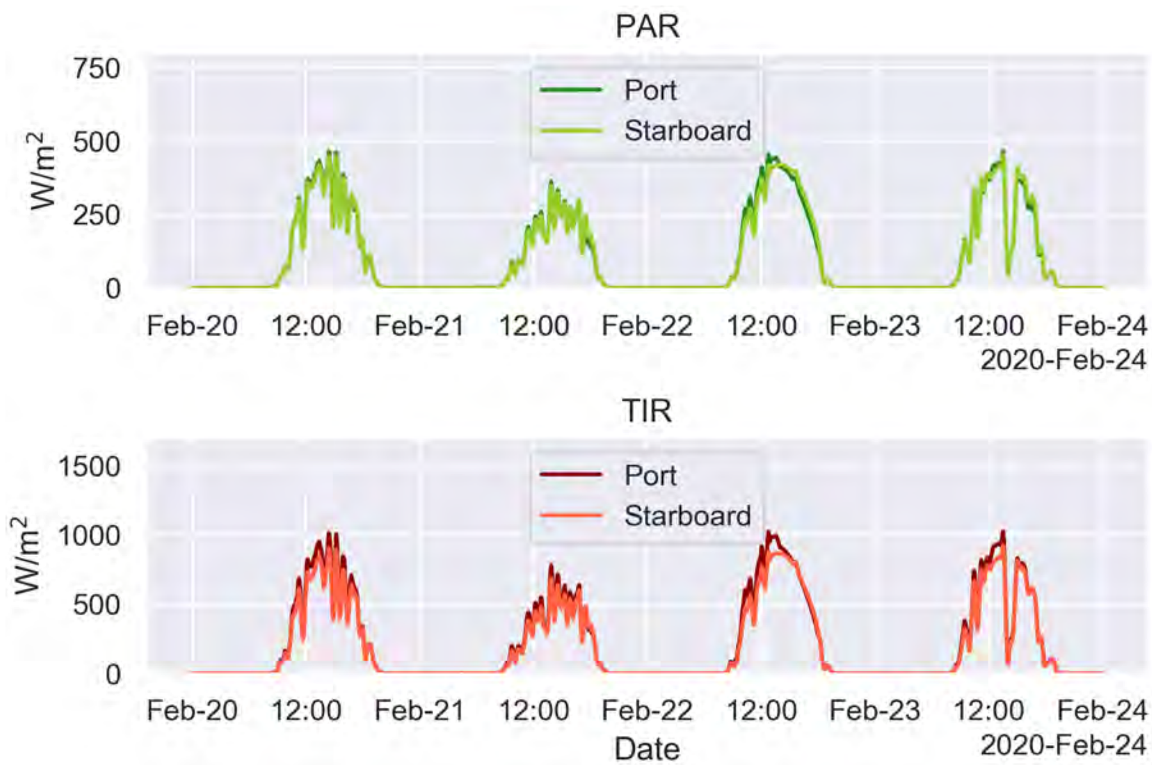


Figure 10.12: *Time series of photosynthetically active radiation (top panel) and total irradiance (bottom panel) across 24N for the port and starboard sensors from 20th to 23rd February. Units in W/m2.*

Jessica Newman and Thomas Wilder

11. RBR and SBE CTD data

11.1 Introduction

Four 6000 dbar RBR CTDs were tested interchangebly alongside primary and secondary SBE CTDs on all sub 6000 m stations along 24N transect. Recent design updates on the RBR CTDs warranted testing at high pressure to evaluate how hydrostatic pressure affects conductivity measurements. Using the SBE CTDs as the benchmark will provide a measure towards RBRs performance. Serial numbers, regions of use and measured frequency for each RBR instrument were as follows: 662, whole transect not exceeding 6000 m and 8 Hz; 545, western basin and 16 Hz; 665, central Atlantic Ridge and 16 Hz; 666, Eastern basin and 8 Hz. RBR 665 was later applied at 18W due to 666 encountering some technical difficulties.

Data files used for the SBE profiles were ctd jc191 d* 1hz.nc and dcs jc191 d*.nc found in pstar/jc191/mcruise/data/ctd and the .rsk files were located in jcnas1/public/rbr/PLAY. Analysis was made in MATLAB 2019b with scripts vertical profiles v4.m and sbe rbr ctd comparison v2.m and functions sbe2rbr.m, rbrprof2data.m and sbectdprof.m. The RBR profiles and data were read in using the Ruskin toolkit, which required the TEOS-10 toolkit to execute some functions, like RSKderivesalinity. The function sbe2rbr.m was used to match the RBR downcast profiles with the correct SBE downcasts. The other two functions were used to read in the data profiles.

11.2 Data Analysis

11.2.1 RBR 662 and SBE Sensor 2 Profiles

Figure 11.1 shows temperature, salinity and pressure downcast profiles at CTD station 080 for SBE sensor 2 and RBR 662, plotted using sbe_rbr_ctd_comparison_v2.m. Temperature and pressure profiles are found to be in good agreement with each other, with only small negative variations in temperature at the surface and negative pressure variations of around 1 dbar near to 6000 m (Figure 11.4). RBR 662 was supplied with a missing conductivity calibration coefficient. A conductivity coefficient, c1 = 180 was supplied by Ruskin after making contact, and was applied to the data in the native RBR programme afterprofiles were sampled.

It is clear in Figure 11.1 that salinity RBR profiles are not well aligned with SBEprofiles, yet no obvious discrepancy in variability is present. To find an offset between the SBE and RBR salinity profile, the average difference between all CTD profiles were found, with an overall mean difference of 1.31 PSU and a standard deviation of 0.0063 PSU. This offset was then added to each RBR salinity profile. A line of best fit – fifth order polynomial - was then calculated for the difference between the two profiles, and finally it was added to the RBR salinity profile. The results are shown in Figure 11.5, and both the SBE and RBR salinity profiles nicely agree.

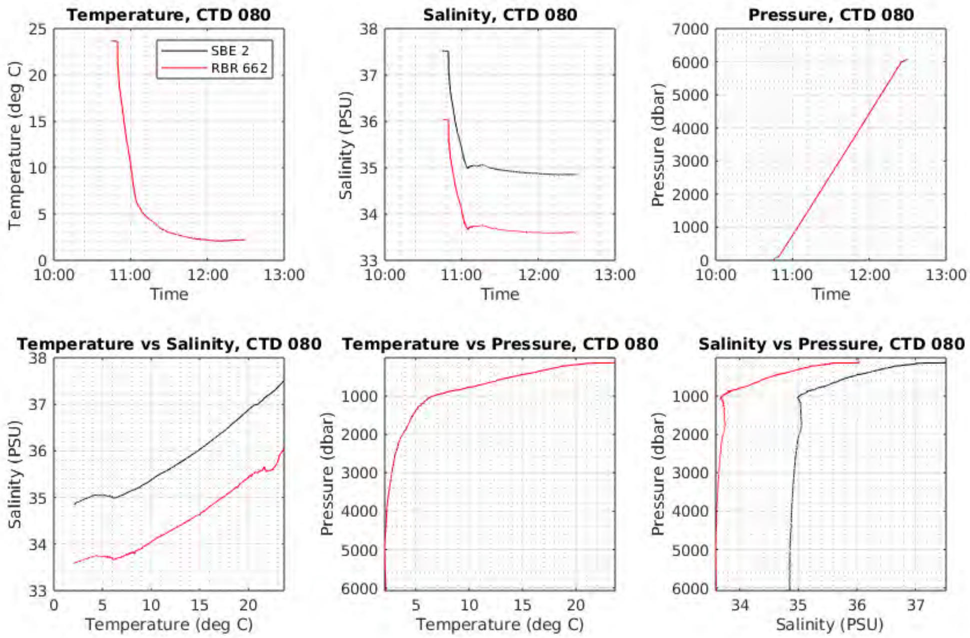


Figure 11.1: *Downcast profiles of SBE 1Hz sensor 2 and RBR 662 for CTD 80, located at 24_N, 49_W. Top, left to right: timeseries of temperature (deg C), salinity (PSU) and pressure (dbar) are compared. Bottom, left to right: temperature against salinity, temperature against pressure and salinity against pressure.*

11.2.2 Transects

Temperature and salinity transects across 24N have been plotted in Figures 11.2 and 11.3 for the RBR 662 and SBE 1Hz using vertical profiles v4.m. There is a notable decrease in surface temperatures west to east with each CTD instrument recording the same features, such as a depression of warmer waters east of 30_W. The salinity transects also show very similar features, displaying the North Atlantics sea surface salinity maximum at around 40_W, although the SBE manages to pick up on more variation in surface salinity than the RBR. This could be because of the salinity offset discussed in Section 11.2.1.

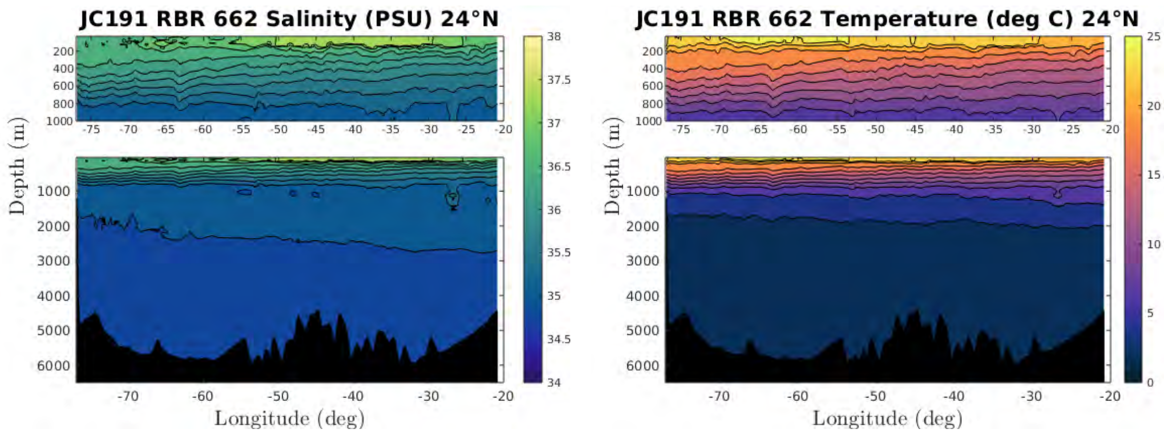


Figure 11.2: *a) Temperature (deg C) and b) salinity (PSU) transects for RBR 662.*

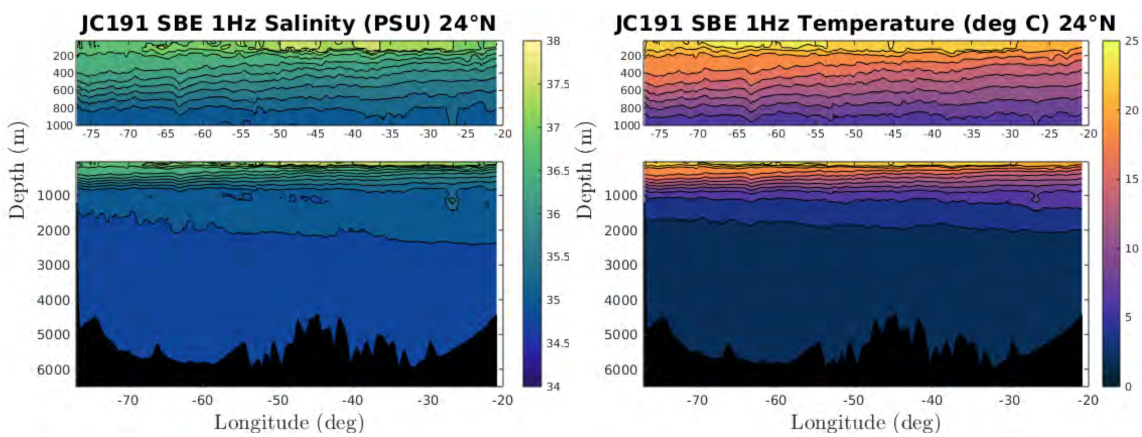


Figure 11.3: *a) Temperature (deg C) and b) salinity (PSU) transects for SBE 1Hz sensor across 24N.*

11.2.3 Lag in Pressure Time Series

Time lags in the pressure time series of RBR 662 and SBE sensor 1 were examined. This was done using the function, sbe rbr ctd comparison v2.m. To find when the SBE data matched the RBR data, SBE pressure time series were interpolated over a 3 second interval either side of the RBR clock. Vertical velocities were found for the RBR clock and each SBE interpolated series using,

$$w = \frac{\partial P}{\partial t}$$

where, P is pressure and, t is time. Correlation coefficients were then found for each SBE series against the RBR clock at around half way down each water column. Figure 11.6a shows the correlation coefficients for each pressure series over a 6 second interval. The maximum coefficient occurs at around t = -0.3 seconds, implying that the SBE pressure series has a time lag behind the RBR. Figure 11.6b shows the maximum correlation coefficients for 79 CTD stations with colour coding for station depth. There is a high correlation for shallow waters in the early stations, found in the Florida Strait, and as the depth of each station increases, the correlation reduces. These differences could be due to changes in ocean current speeds and water mass properties. The time lag for each station is also shown in Figure 11.6c, suggesting that the time lag for the SBE sensor changes from a negative to a positive lag as depth increases and water masses change.

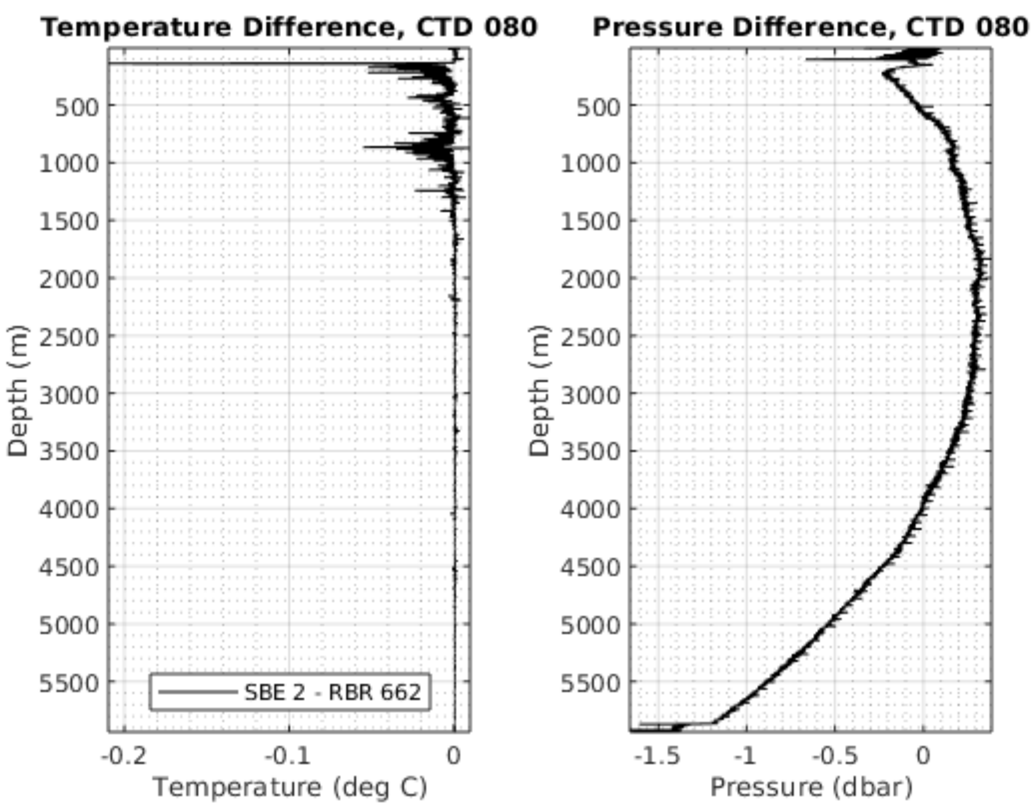


Figure 11.4: *Downcast differences between SBE 1Hz sensor 2 and RBR662 for CTD 80, located at 24N, 49W. Left: temperature (deg C) against depth (m). Right: pressure (dbar) against depth (m).*

Figure 11.7 shows lag corrected pressure and temperature profiles for CTD 008 and CTD 080, from the Florida Strait and Western Basin respectively. An immediate observation is the change between uncorrected (black line) and corrected (red line) time series. The lag corrected time series all appear to have smaller amplitude differences, particularly in the pressure series in Figures 11.7a and 11.7c. CTD 008 does seem to show greater variability between the uncorrected and corrected series comapred to CTD 080, perhaps as a consequence of the changed water masses. CTD 080 has a time lag of around t = -0.3 seconds, whereas CTD 008 is around t = -1 second (not shown), which could be another reason for the differences in time series between the stations.

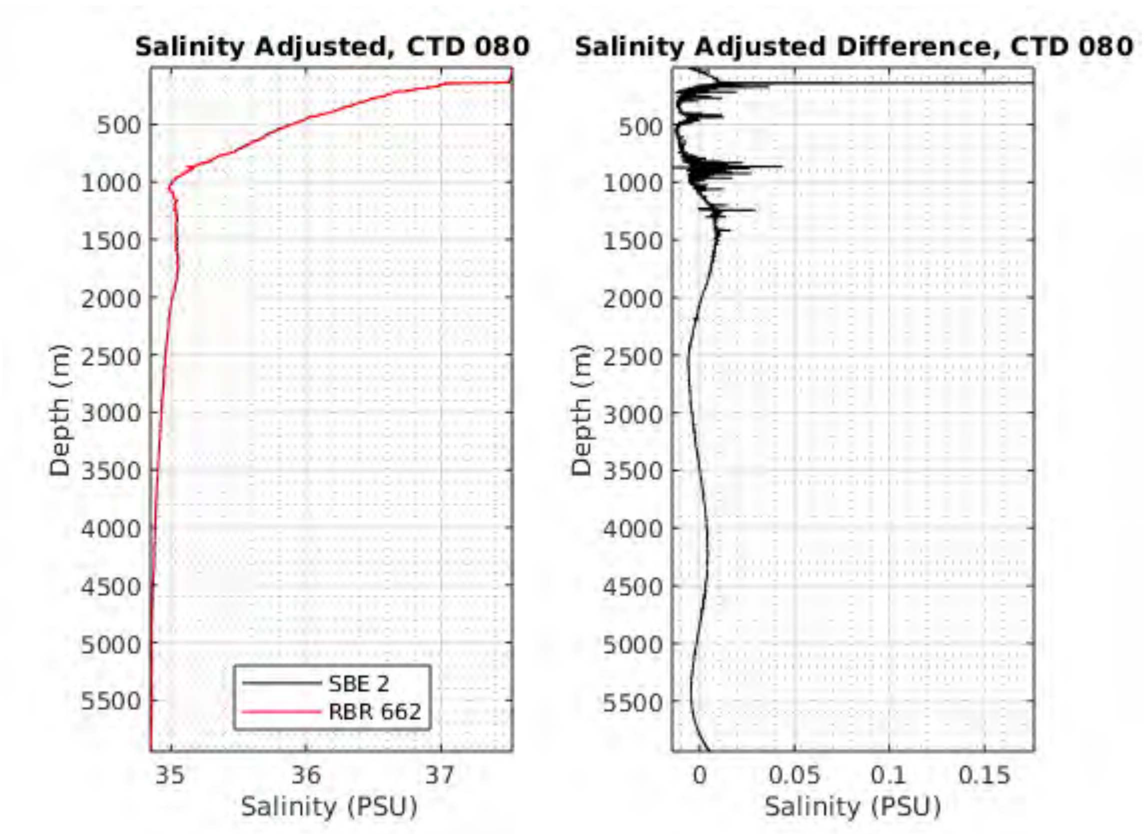


Figure 11.5: *Downcast salinity (PSU) profile after offset adjustment between SBE 1Hz sensor 2 and RBR 662 for CTD 80, located at 24N, 49W. Left: salinity adjusted RBR against SBE. Right: salinity difference.*

11.2.4 RBR Pressure Calibration

So that the Ruskin programme can determine downcast profiles for the sensor, correct pressure calibration coefficients are required. These were not supplied to RBR sensors 665 and 545, and so coefficients from 662 were applied instead. The coefficients are:

c0 = -177.2264000
c1 = 12.5209780E3
c2 = -376.7889400
c3 = 67.2847440

Figure 11.8 compares RBR 665 with SBE sensor 2 for CTD 080. There is a clear pressure anomaly between the RBR and SBE sensors, probably due to the incorrect calibration coefficients. However, each pressure profile is in near agreement and has minimal variability, suggesting that the RBR 665 is capable of calculating hydrostatic pressure.

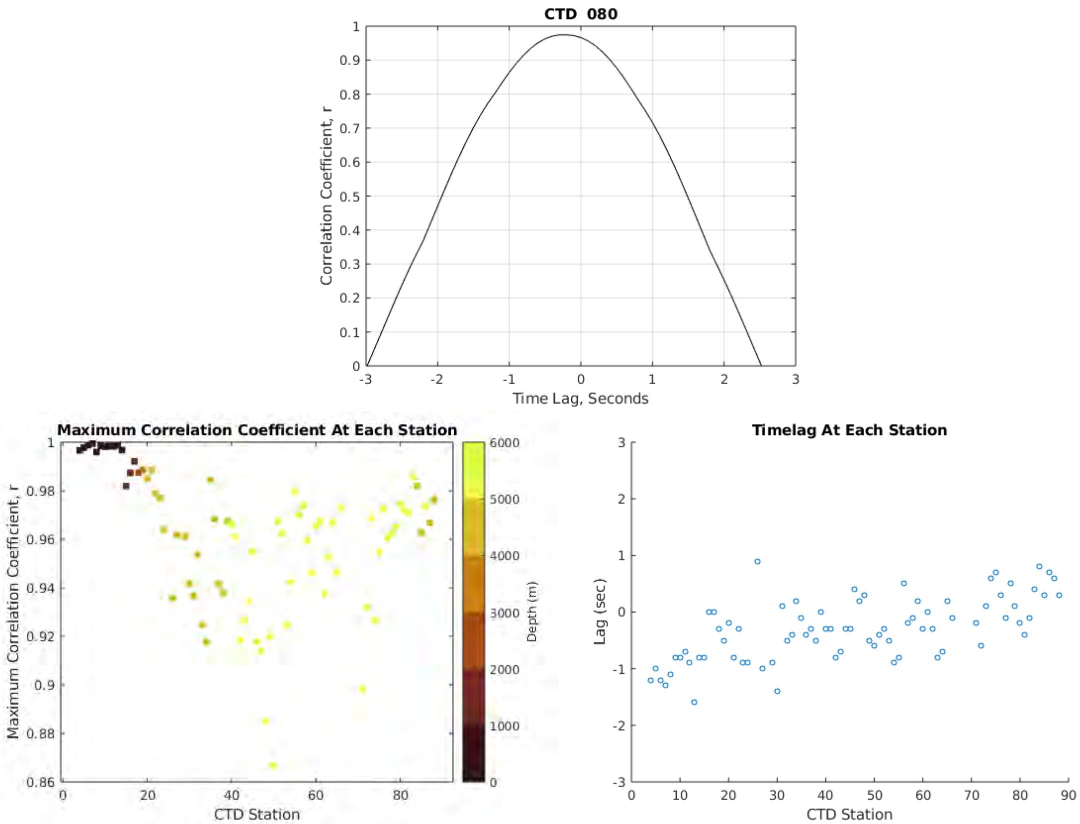
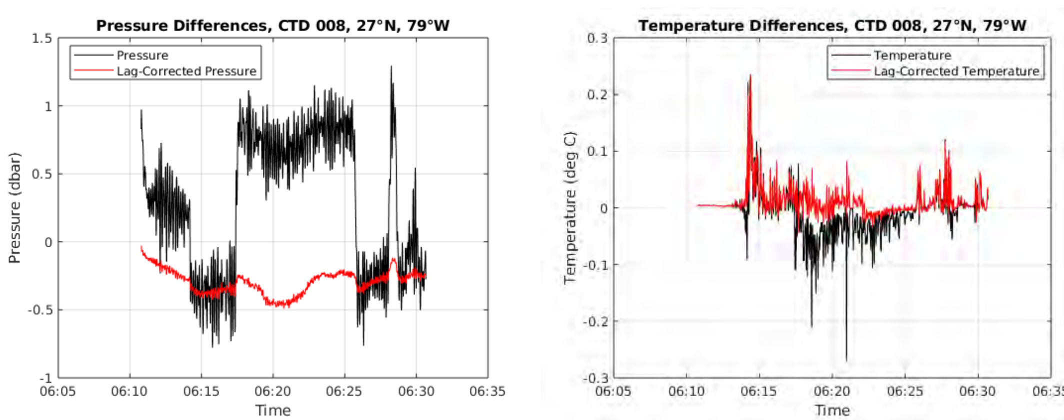


Figure 11.6: *a) Correlation coefficients between RBR 662 and SBE sensor 1 pressure series for CTD 080, b) maximum correlation coefficients for 79 CTD stations, colour coded by station depth, c) timelags for 79 CTD stations.*



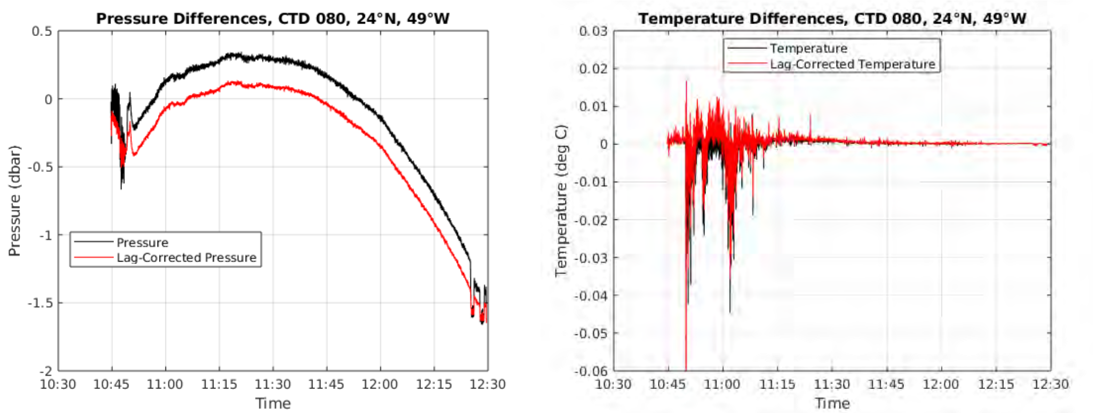


Figure 11.7: *a) Lag corrected pressure for CTD 008 (Florida Strait), b) lag corrected temperature for CTD 008 (Florida Strait), c) lag corrected pressure for CTD 080 (Western Basin), d) lag corrected temperature for CTD 080 (Western Basin). Uncorrected (black line), corrected (red line).*

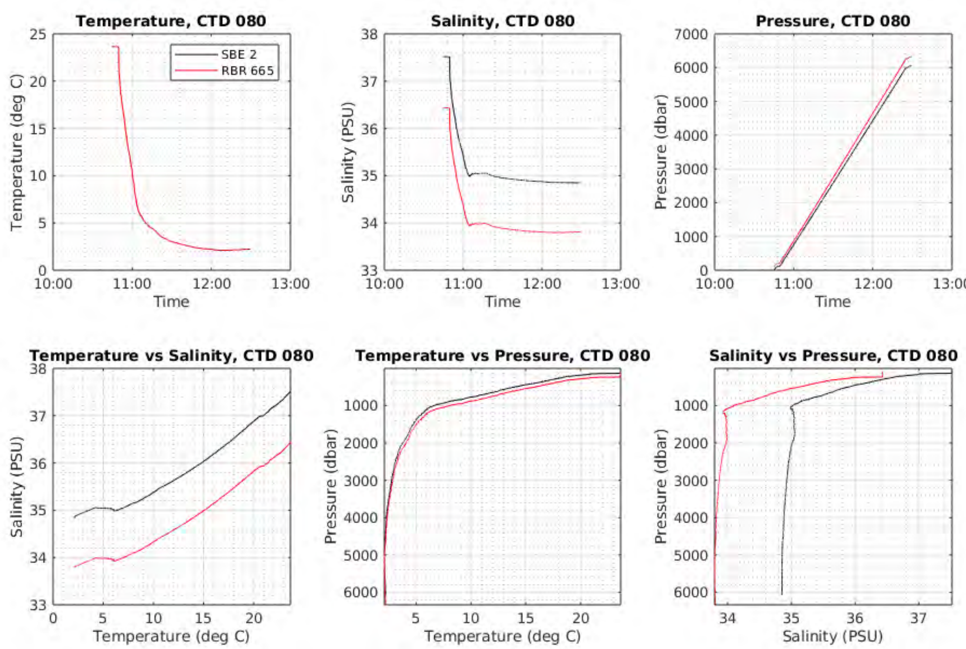


Figure 11.8: *Downcast profiles of SBE 1Hz sensor 2 and RBR 665 for CTD 80, located at 24_N, 49_W. Top, left to right: timeseries of temperature (deg C), salinity (PSU) and pressure (dbar) are compared. Bottom, left to right: temperature against salinity, temperature against pressure and salinity against pressure.*

Thomas Wilder

12. Bathymetry

Bathymetry was recorded from the EA640 and centre beam of the EM122 swath system. Swath bathymetry was logged, but not processed by the scientific party. Generally, the EM122 provided a more reliable single-point depth estimate than the EA640.

Data were read in from TECHSAS as part of *m_daily_proc.m*. Daily processing selects the median bathymetry reported in 5-minute time bins and places the result in, eg, *sim_jc191_d020_edt.nc* for day 020. Initial processing created files for each bathymetry source that has the other source merged onto it. This aids comparison for visual identification of data that may be bad.

The processing paths were modified so that EA640 depths corrected for Carter Area were merged onto the EM122. This meant the two sources of bathymetry should agree closely, rather than having an 'expected offset'. The processing scripts were also tweaked to make them robust if either stream was absent.

The EM122 was not working at the start of the cruise, and became available from 022/1254.

Scripts *msim_plot* and *mem120_plot* respectively allow interactive editing of the bathymetry streams. An interactive editing screen is created for editing using *mplxyed*, as well as an extra plot showing the two data streams, and a gridded bathymetry.

The choice of gridded bathymetry is set in *opt_jc191*, and the following file was in use early in the cruise:
/data/pstar/dy040/backup_20160123160346/data/ubak/planning/n_atlantic.mat.
This was switched to
/local/users/pstar/programs/general_sw/topo_grids/topo_jc191_2020/GMRTv3_7_20200110topo_1954metres.mat
later in the cruise.

Note that in *msim_plot* and *mem120_plot*, reply '2' to the prompt, and edit the red data stream. The black curves are for reference only.

The plot/editing acts on the files with suffix *_edt.nc*.

New scripts were written
msim_append_and_merge_nav
mem120_append_and_merge_nav
To create a list of all the edt files, append them, selecting only the edited variables, and merge on navigation from *bst_mcruise_01.nc.*

The resulting files are

sim/sim_jc191_01.nc
em120/em120_jc191_01.nc
and can be considered as the primary bathymetry files for the cruise.

The full EM122 swath dataset was not retrieved by the science party. It may be passed directly from NMF to swath data centres. Sound speed profiles were regularly updated in the EM122. There were some times when the EM122 data were clearly bad, with systematic anomalies in the dataset, that would require careful QC before they can be used for scientific purposes.

Brian King

13. Navigation

Navigation data from multiple TECHSAS streams were read in as part of *m_daily_proc*. This was run daily, by manual command, after midnight UTC at the end of the day in question.

The primary navigation stream was *posmvpos*.

At the end of *m_daily_proc*, the series of mbest_0x scripts runs to produce file bst_jc191_01.nc in directory *nav/posmvpos*.

The default source for ship heading for this cruise was the *attposmv* stream.

The *bst_jc191_01.nc* file contains position, heading and ship speed on a 30-second timebase, ready to be used for many purposes, including calculation of true wind from ship relative wind.

There was a gap in the *gyropmv* TECHSAS stream from 020/16:03:21 to 021/03:01:15. Raw data could have been recovered from NMEA messages but this was considered unnecessary.

Brian King

14. Lowered Acoustic Doppler Current Profiler (LADCP)

14.1 Setup summary

For the 24N CLASS GOSHIP research expedition (JC191), 2 lowered acoustic doppler current profilers (LADCPs) were deployed for every CTD cast throughout the cruise (exceptions in Table 14.1). The LADCPs, an uplooker (UL; slave) and downlooker (DL; master), were installed on the rosette and powered by an external battery. The slave waits for the master to send a command and then they both ping together. Both LADCPs were titanium casing Teledyne RDI 300kHz Workhorse ADCPs. The upward looking LADCP instrument sits on the side of the frame and the down looking workhorse sits at the bottom within the frame. The LADCPs were configured to have a standard 25 x 8 m bins, with one water track and one bottom track ping in a two second ensemble, and no blanking distance (distance between the ADCP and the bin closest to the instrument).

Prior to each station the ADCPs were connected to a laptop in the deck lab for pre-deployment tests and programming. After the end of each station they were reconnected to the laptop for data retrieval. The battery package was charged between stations. The list below shows the parameters used to configure the ADCPs:

PS0
CR1 – retrieve parameters (1. = On)
RN JC191 – cruise name JC 191
WM15 – sets some defaults for lowered ADCP
CF11101 - flow
EA00000 – heading alignment (-179.99 to 180 deg)
ES35 – salinity (0 to 40)
EX00100 – coordinate transformation (none: leave in beam coordinates)
EZ0011101 – sensor source: internal heading, pitch, tilt, temp
TB00:00:02.80 – time interval per burst of pings (hh:mm:ss)
TC2 – two ensembles per burst
TE00:00:01.30 – time per ensemble (hh:mm:ss)
TP00:00.00 – minimum time per pings (mm:ss)
LP1 – single ping per ensemble
LN25 – number of depth cells
LS0800 – size of depth cells (cm)
LF0 – blank after transmit
LW1 – narrow band
LV400 – ambiguity velocity (cm/s radial)
SM2 – RDS3 mode select (2 = slave)
SA001 – synchronise: wait for pulse before a water ping
ST0 – slave timeout

SB0 – disable hardware-break detection on channel B
CK – keep parameters as user defaults
CS – start pinging

14.2 Performance and deployment

LADCPs were switched off during shallow (< 200 m) casts due to noisiness. File availability and issues with performance are noted: there was no Slave data for CTD stations 10, 18, 23, and 51. Issues with interrupted/truncated LADCP files for CTD stations 51 and 53 prompted the NMF team to switch cables – effective starting CTD station 54. See Table 14.1. LADCP (and other instruments: fluorometer, transmissometer, RBR loggers and swivel) were removed for deep (>6,000m) stations numbers 67 to 70 because instruments are not pro-rated for waters deeper than 6000 m. Due to poor beam (2) performance, the LADCP uplooker was swapped at CTD station 71.

After CTD Station 71, it appeared as if no data was being recorded by the UL LADCP and that the compass was stuck at the same reading. Further investigation determined that the LADCP downlooker had the wrong time stamp in it, and when processing downlooker and uplooker together, it caused the uplooker to look as if it were not functioning. The issue was corrected, and new filenames produced: JC191_nnnM_date_fixed.000.

Links in UH processing were changed to point to fixed raw files.

Table 14.1: *LADCP issues and performance per CTD stations.*

Station	**LADCP: RDI workhorse unit (S/N)**	**Notes**
2:4	DWL – 24466 UWL – 24465	Turned off because water too shallow
10		No slave file
18		No slave file
23		No slave file
25		Non-existent since CTD25 data was merged with CTD26
51		Truncated master; no slave file
53		Truncated slave file
54		Cables were switched
67:70		Depths > 6,000 m so LADCPs taken off rosette
71	DWL – 24466 UWL – 24465	LADCP uplooker replaced
60:73		Downlooker set to wrong day.

The LADCP data was then processed using 2 software packages: the LDEO velocity inversion method and the UH shear method, as described below.

The first software package used is the velocity inverse solution method from the Lamont-Doherty Earth Observatory (LDEO). This software package is designed to obtain bottom track profiles, monitor the beams of instruments to estimate the velocities by the inversion method (for reference see LDEO IX How-to.pdf). The second software package was developed at the University of Hawaii (UH) to calculate the current velocities (computes shear, then using integrated instrument relative velocity and ship navigation to compute the depth-averaged velocity reference) and provide information about the heading and tilt of the CTD package.

All processing for the LADCP was carried out on linux operating machine, koaekea. Details of the LADCP processing routine for each method are outlined below.

14.3 The LDEO inverse-solution: data processing

To setup of the software, we followed the LDEO_IX_how-to.pdf. Directories were setup as in previous cruises.

The LDEO processing can first be carried out without the CTD data to monitor results and performance of the beams. It is strongly recommended to read the LDEO_IX_how-to.pdf (details on all plots produced from the following command lines are described therein).

<u>Commands</u>

To run the LDEO inverse method, the following commands were run (> *indicates commands* typed in terminal and >> *commands* typed in matlab):

1. >*lad_linkscript_ix* This command creates symbolic links from the binary *000 files to the actual raw files, and puts the master and slave ladcp files in the ~/cruise/data/ladcp/rawdata/ master and slave directories in ix/ (and uh/), for processing by the LDEO IX inversion method or the UH WOCE shear method, respectively. On JC191 it's MASTER DATA and SLAVE DATA folders. Both methods also use ascii files of CTD data, which are generated as part of the standard CTD processing (somewhere in the ctd_all_part1 wrapper script).
2. >> *~/cruise/data/ladcp/ix* to be in the correct directory.
3. >> *cfgstr.orient = 'DL';* DL refers to files from the downlooker ADCP, you can also specify UL for uplooker and DLUL for both files processed together.
4. >>*process_cast_cfgstr(nnn,cfgstr) .* This will bring up the following plots for either cfgstr.orient = 'DL'; or cfgstr.orient = 'UL'; It is important to

process both separately (DL and UL) daily to diagnose issues early on and swap instruments if needed.

a. Fig. 4: DL_GPS is the downlooker with gps added as a constraint. Shows you the location of the LADCP package in the water column and the sections for which we got bottom distance data for the LADCP (once package gets too close to seabed, the bottom track is too noisy). There is also a plot of best lag between CTD and ADCP, calculated by plotting the vertical velocity of each package and finding the max correlation between w_ladcp and w_ctd in time.
b. Fig. 2: top panel to get a sense of how good the data is based on the vertical velocity profiles. We also get tilt and heading information from the CTD/techsas. And finally a diagnostic for how well each of the beams is performing and the range of good data.
c. Fig. 14: Data editing diagnostics. Plots show the number/range of data (raw signal strength) per bin before and after automated data editing. Red is good. Blue is little/poor.
d. Fig. 7: CTD and ocean velocities vs ship's velocity. We also get information about the CTD's movement/distance relative to the ship.
e. Fig. 3: Error, median, standard deviation in U and V per bin number. Compared with U_ocean and V_ocean. As we get into deeper waters it becomes almost impossible to look at the dotted line.
f. Fig 11: is an LADCP warning: increased error because of difference between shear and inverse solutions. These warnings are common once we are profiling in the abyssal plains and there are less scatterers for the LADCP to ping off of.
g. Fig. 12: constraints applied to ocean and CTD velocities.
h. Fig. 13: bottom tracking. Detailed bottom track diagnostics.
i. Fig. 1: Eastward velocities (u; solid red line) and Northward velocities (v; dashed blue line). Thin line is downcast and thick line is upcast. Dotted line is shear. Target strength, range of instruments, and velocity error are shown in right hand panels. There is also a plot of CTD and ship drift during cast.

5. If you run *cfgstr.orient = 'DLUL'* (don't run ULDL or it will create a separate folder!); *process_cast_cfgstr(nnn,cfgstr);* you will get all the plots from point 4, as well as the following plots:
    a. Fig. 6: Heading offset, pitch offset and roll offset.
    b. Fig. 5: heading correction for uplooking LADCP based on rotation velocity, rotation compass, and rotation used.
    c. Fig. 10: U and V offset. And tilt error consistent with offset.
6. We first addressed the data without the inclusion of the vessel mounted ADCP to verify how the data performed. However, the LDEO inverse solution can be run with the following constraints cfgstr.constraints = {'BT'} for bottom tracking; cfgstr.constraints = {'SADCP'} for vessel mounted

ADCP. (Before trying to constrain with SADCP data, read 75os VMADCP subsection first.). Note that the LDEO IX software automatically runs the data with a GPS constraint (more on this in sections below).

Figure 14.1 shows an example of typical profiles produced by the LDEO IX software (i.e. output from step 4.i above). In this example, the left hand side graph shows velocity profiles taken from CTD stations in the Florida Current (Fig. 13.1). The plot on the right hand side shows velocity profiles taken from a deep (>5500 m) station in the western basin. In deeper waters, there are less scatterers and the quality of the profile at mid-depths decreases and the differences between the LDEO inverse and shear methods increase.

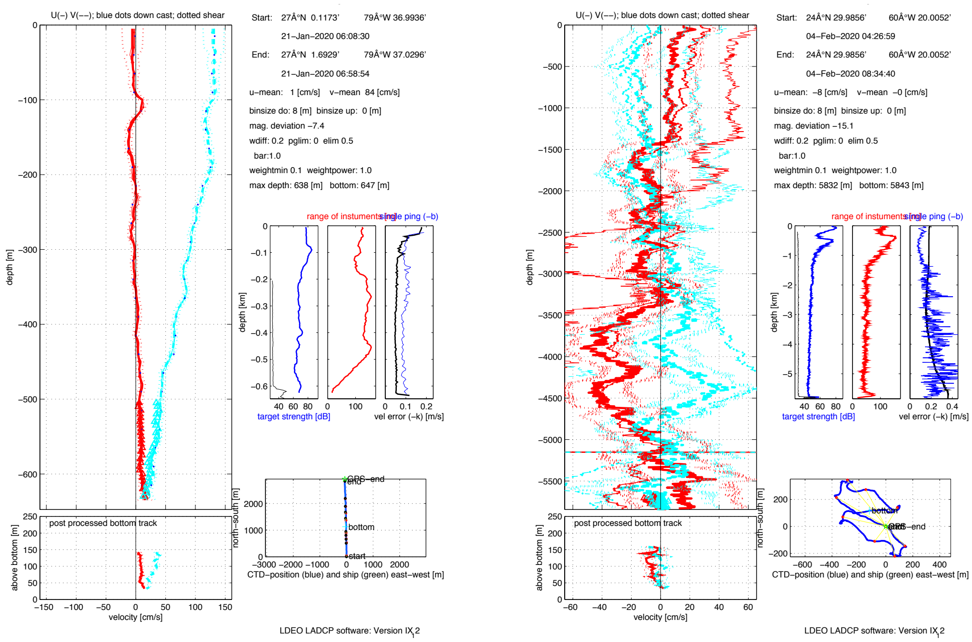


Figure 14.1: *Eastward (red) and northward (green) velocities, including shear and the inverse solution, from LDEO IX software (procFig. 1). Target strength, instrument range and velocity error are shown in the right-hand middle plots. Bottom track velocities are shown in bottom left, and ship and CTD drift shown on bottom right.*

<u>Notes</u>

Resulting/generated files include: figures (.ps and .png), log files and .mat files stored in /cruise/data/ladcp/ix/UL_GPS or DL_GPS or ULDL_GPS

The files above include CTD and nav data.

Note wrt to uplooker: it is quite common for the uplooker to not be as good as the downlooker since it is facing away from the seabed. In general, the downlooker is the primary instrument we obtain velocity from, and the uplooker can be treated as an extra constraint for the downlooker ADCP.

Steps followed by process_cast_cfgstr script:
1: LOAD LADCP DATA
2: FIX LADCP-DATA PROBLEMS
3: LOAD GPS DATA
4: GET BOTTOM TRACK DATA
5: LOAD CTD PROFILE
6: LOAD CTD TIME SERIES
7: FIND SURFACE AND SEABED
8: APPLY PITCH/ROLL CORRECTIONS
9: EDIT DATA
10: FORM SUPER ENSEMBLES
11: REMOVE SUPER ENSEMBLE OUTLIERS
12: REFORM SUPER ENSEMBLES
13: (RE)LOAD SADCP DATA
14: CALCULATE INVERSE SOLUTION
15: CALCULATE SHEAR SOLUTION
16: CALCULATE DIFFUSIVITY PROFILE
17: PLOT RESULTS & SHOW WARNINGS
18: SAVE OUTPUT

Reference: How to Process LADCP Data with the LDEO software (Version IX.7) – A. M. Thurnherr.

14.4 The UH shear method

14.4.1 UH processing

Disclaimer: The UH shear method calculates shear from LADCP data; however, this method is discontinued/no longer maintained. The sole purpose for continuing to use it here is for comparison with the LDEO IX method, during instances in which we think the LDEO method is not producing good velocity values. The UH shear method is more reliable/robust at diagnosing what parts of the water column the LADCP is not measuring successfully and what the maximum depth of cut off should be. More information about this method can be found in Fischer and Visbeck, 1993.

UH processing was setup by copying over the previous directory and subdirectories from DY040 into the jc191 directory and editing the LADall and lad_linkscript_uh for this cruise and deleting any files/data from DY040.

Commands

To run the UH processing, the following commands were executed (> *indicates commands* typed in terminal and >> *commands* typed in matlab) in a newly opened terminal window:

1. >*cd ~cruise/data/ladcp/uh/*
2. >*source LADall* to setup paths required for processing.
3. >*lad_linkscript_uh* to link all the files across to the ladcp uh directory i.e. create symbolic links from the binary *000 files to the real raw file. Change to the directory proc/Rlad/ to see access/check raw files.
4. >*cd proc.* This should take you to */local/users/pstar/cruise/data/ladcp/uh/pro/jc2001/ladcp/proc (*if this doesn't work then something went wrong with source LADall.)
5. >*perl -S scan.prl nnn_02* (scans the raw data and creates a station specific directory in proc/casts, where *nnn* is the station number, to scan the raw data. Data printed to screen should be checked to ensure the details of the cast (i.e. depth, downcast/upcast times) agree approximately with the CTD logsheet). 02 pertains to downlooker.
6. >>*m_setup; uhlad_putpos(nnn,02)* gets station position and the magnetic variation correction are entered. This updates stations.asc and magvar.tab for the downlooker LADCP (02).
7. >*perl -S load.prl nnn_02* loads the raw data, using magvar.tab for the magnetic correction. Type *y* twice to append data to proc.dat and proceed with load. It its very important that this step is only carried out once. If it needs to be repeated the database files (proc/casts/dnnn_02/scdb) must be deleted first.
8. >*perl -S domerge.prl -c0 nnn_02* to merge the velocity shear profiles from individual pings into full upcast and downcast profiles. The option -c0 refers to the fact that CTD data has not yet been included.
9. >>*cd Rnav; make_sm* to update the navigation file.
10. >>*cd ~/jc191/mcruise/data/ladcp/uh/pro/jc2001/ladcp/proc; plist = nnn.02; do_abs;* to calculate relative velocity profiles. A series of plots are generated. Check that these plots look sensible, i.e. reasonable agreement between downcast and upcast and that the vertical velocity changes sign between downcast and upcast (it may be necessary to rescale some of the plots). Also monitor the number of pings throughout the profile. Once the CTD data has been processed this can be incorporated into the LADCP processing to make more accurate estimates of depth and sound velocity and to obtain a final absolute velocity profile. The following figures correspond to the downlooker.
    a. Fig. 1: Downcast (--), upcast (:) and mean (-) for the U and V components fo the LADCP.
    b. Fig. 2: vertical velocity (w)
    c. Fig. 3: U and V components plotted against depth.
    d. Fig. 4: What is the color scheme?
    e. Fig. 5: heading and tilt.
11. >>*cd proc/Rnav; ctd_in(nnn,02)* this reads the 1Hz CTD in. (set directory in *ctd_in* script to get data from */cruise/ladcp/ctd/ctd.nnn.02)*
12. >>*plist=nnn.02; fd;* to align the LADCP and CTD data sets in time. This is done by finding and comparing the vertical velocity of the LADCP and

CTD packages. Besttlag.m finds the max correlation between w_ladcp and w_ctd and makes an adjustment for the correct lag.

13. *>cd proc; perl -S add_ctd.prl nnn_02* to add CTD data to the *.blk LADCP files in the casts/jnnn_02/scdb directory.

*pause to read section *inclusion of true depths* before proceeding…*

14. *>>populate_station_depths* This step doesn't need to necessarily be run every time.
15. *>>update_proc_dot_dat.* Type n. Copy paste station depth line from proc2.dat into proc.dat
16. *>perl -S domerge.prl -c1 nnn_02* to merge single pings into corrected shear profiles. The -c1 option indicates CTD data has been included.
17. *>> cd ~/jc191/mcruise/data/ladcp/uh/pro/jc2001/ladcp/proc; plist = nnn.02; do_abs;* to produce final absolute velocity profiles with CTD data included.
    a. Fig. 1: Downcast (--), upcast (:) and mean (-) for the U and V components fo the LADCP.
    b. Fig. 2: vertical velocity (w)
    c. Fig. 3: U and V components plotted against depth.
    d. Fig. 4: What is the color scheme? What is the Xducer T?
    e. Fig. 5: heading and tilt.

Repeat the above steps from 4 to 17 for the uplooker LADCP processing and define the filenames as nnn_03.

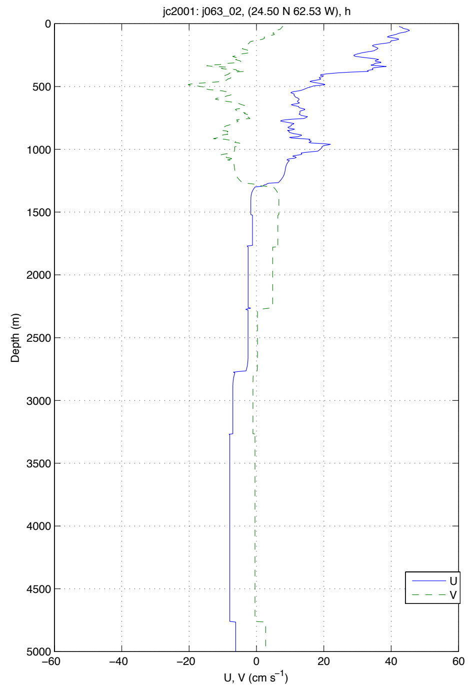


Figure 14.2: *Wns063202h.ps – U (solid blue line) and V (green dashed line) components from the UH shear method. The lines are the average of the upcast and the downcast for CTD station 63.*

<u>Notes</u>

For JC191, the UH shear method was only run for a select group of casts in order to compare them with LDEO IX solution. We never ran it for the uplooker.

Figures saved in the following directory:
/cruise/data/ladcp/uh/pro/jc2001/ladcp/casts/jnnn_02/merge/

14.5 Inclusion of Station True Depths

In the UH software package, the depth of the stations is recorded in the proc.dat file when the *perl -S load.prl nnn_02* step is carried out. Then *perl -S add_ctd.prl nnn_02* commands adds CTD data to the UH LADCP processed files. Once the ctd_in command is run, the programme writes the proc2.dat file with the new/corrected depths from the CTD. After this stage, the user must manually update the proc.dat file with the new corrected depths in the proc2.dat file. Original depths must be left in place but commented out, so they are not used when the file is read. Finally, when the *perl -S domerge.prl -c1 nnn_02* step is run, the new depths are incorporated in Matlab using *plist= nnn.02;* and *do _abs* rerun. The plots absolute velocity profiles with CTD data and corrected depths are then produced.

In the LDEO software package that includes CTD data, the bottom depth recorded in the log files is the integral of the vertical velocity measure by the LADCP. In the LDEO IX software figure 4 provides a diagnostic plot for how well the LADCP detecting sea bottom pings. If the sea floor is not successfully detected, then the LADCP can derive/record incorrect bottom depths. For example, this is observed in CTD station 084, where the LADCP is failing to detect the bottom (Fig. 14.3). In some part of the programme (populate_station_depths.m and opt_jc191.m) the LADCP derived bottom depths are compared against the CTD depth + altimeter – this allows us to diagnose which value is the correct one to use.

When neither LADCP or CTD + altimeter provide correct depths, the depth recorded should be from the EM122 average values.

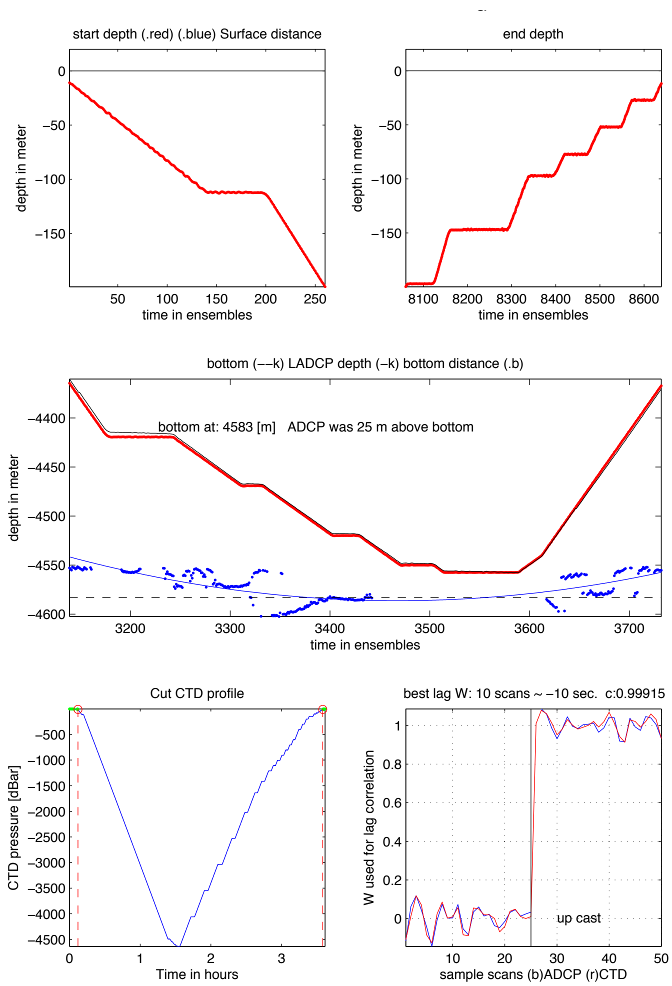


Figure 14.3: *From LDEO IX (procFig. 4) LADCP issues detecting bottom distance (middle panel) at CTD station 083.*

Based on procFig. 4 (from LDEO IX output) detection of true depths starts being bigger issue around CTD station 83 (Fig. 13.3). Issues detecting bottom distance apparent in CTD station: 14, 15, 16, 17, 20, 57, 61, 73, 75, 78, 83, 84, 85, 86, 87, 90, 91, 92, 100, 101, 107, 108.

14.6 Preliminary results and brief overview of issues

14.6.1 Comparison of LADCP LDEO IX vs UH methods

Shear

The LADCP velocity profiles from the LDEO IX and UH shear methods are compared here to determine what the difference is between methods, if any, and which method is most appropriate for final velocity profiles per station.

To compare the velocity solutions calculated by LDEO IX (inv and shear) vs UH shear method, go to /cruise/data/ladcp/ix and run in matlab *>>stn = nnn; ix_uh_shear.m* where nnn indicates desired station. Up to this point, both LDEO and UH compared here are constrained only by GPS. (Bottom track and VMADCP are compared later on.)

The comparison between the 2 methods is first done by inspecting the LDEO and UH shear velocity profiles to establish the max depth of best agreement. Near the boundaries (e.g. the Florida Straits) where the ocean is shallower and there are sufficient scatterers in the water column, the LDEO inverse solution provides good absolute velocity estimates for the entire profile/water column (Fig. 14.1, left panel). However, in the deeper ocean, over the abyssal plains, there are less scatterers but the LDEO solution continues to try an estimate velocity values even when there are very few scatterers. As a result, the LDEO solution can ‘blow up’ showing unrealistic velocity values in the mid-water column when the instrument is not within appropriate range of the ocean surface or the ocean floor (Fig. 14.1, right panel). The UH shear method, on the other hand, has a more restrictive algorithm for determining when there are insufficient scatterers (i.e. determining the quality of bins acceptable to compute a velocity shear) to produce good velocity estimates and in general will provide a better estimate of the depth at which there are too few pings to produce reliable velocity estimates (Fig. 14.2).

Whilst in the Florida Straits, the inverse solution from the LDEO inverse solution was robust because waters shallower and there were sufficient scatterers as well as strong currents. However once in the western basin (approx. CTD station 16 and greater), the velocity profiles from the LDEO IX software began to deteriorate past 1500 m (compare profiles in Fig. 14.1). A selection of random deep profiles were then selected for comparison with the UH shear method to assess which of the 2 software packages yielded more reliable velocity profiles. For CTD station 063, there was good agreement between the LDEO and UH-shear method u and v components (Fig. 14.4). A cut-off depth was chosen based on when the mean UH-shear u and v components went to zero. Then the u and v components from the LDEO shear solution were interpolated onto the UH-shear depth and compared in Fig. 14.4. where high correlation, small offsets, and slope of 1 indicate good agreement between methods. For the v (north-south) component, the agreement between LDEO and UH is was found to be very good (r = 0.93 using Pearson's correlation coefficient) and with an offset of about 0.15. For the u (east-west) component, the agreement was also good (r=0.90), though slope << 1. The offset values calculated here reflect how different the barotropic components estimated from LDEO are from those estimated by the UH method. We expect offsets to increase as we move into portions of the profile/water column where scatterers are scarce. (The VMADCP could potentially be investigated further to give insight into the error associated with the barotropic estimates made by each of the methods: LDEO vs UH.)

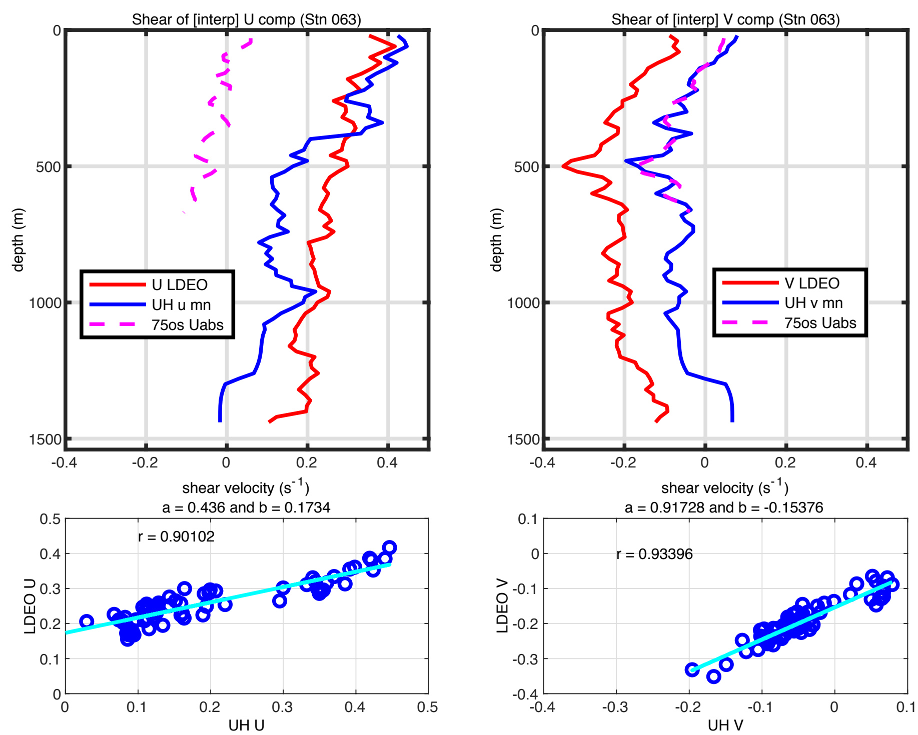


Figure 14.4: *Velocity profiles from the LDEO shear solution (red line) and the UH shear method (blue line) and the VMADCP (dashed magenta line) for CTD station 068. Bottom panels show scatter, correlation, slope, offset comparison between LDEO and UH shear solutions for u and v components.*

We note that for the V component, the UH method showed almost 1 to 1 agreement with the 75os VMADCP, whilst the LDEO v velocity had a constant offset of ~15 s^-1 to both. For the u component, both LDEO and UH methods showed an offset of ~0.35 s^-1. In the following subsection the VMADCP constraint on LDEO is explored. In general, we found the LDEO shear solution compares well with the UH shear method for surface velocities, even during stations where the LDEO IX is 'blowing up' mid-water column (not shown). Due to this favourable comparison, we decided to eschew the UH shear method since it is cumbersome and no longer maintained, in favour of the LDEO IX solution exclusively. In the following section we assess how to clean up and determine profile cut-off depths for the LDEO inverse solution.

Notes

ix_uh_shear.m script also tells you when there is no bottom tracking velocity (CTD Stations: 15, 18, 21).

14.6.2 LADCP LDEO IX inverse solution with VMADCP constraint

On the JC191, there were two vessel mounted ADCPs: os75 and os150 (see section 13). For the purposes of comparison with the LADCP, we use UHDAS post-processed data from the os75 (coarser but deeper data profiles compared to os150). To ensure the LDEO process_cast_cfgstr script reads in the vmadcp data, you must configure set_cast_params to read in files from the correct directory. For this cruise, the mkSADCP script was included to be called at the beginning of set_cast_params_cfgstr; input directory and files (UHDAS produces matfiles of the vmadcp data) and output directories were set in mkSADCP as ~/cruise/data/vmadcp/postprocessing/jc191_01/proc_archive/os75bb/contour/ and ~/cruisedata/ladcp/SADCP/os75_jc191_ctd_all.mat respectively.

As mentioned previously, there are generally two types of profiles you can get from the LDEO ix solution: complete full velocity profiles of the entire water column where water is relatively shallow, there are strong currents and lots of scatterers (hereafter referred to as shallow profiles). The second type of profile is a partial velocity profile, where it is apparent that in the mid-depth water column the velocity values are unrealistically high (this can go up to 1x10^18 m/s); this type of profile (hereafter referred to as deep profiles) occurs when we are in deeper waters and there are less scatters for the LADCP to ping – in these cases only the surface profile and the bottom velocity are reliable, and it is necessary to determine where the cut off depth of the surface profile should be.

To evaluate the profiles station by station, run *stn=nnn; ldeo_constraint_assess.m.* Currently in this script, I've hardcoded which stations correspond to shallow or deep categories, and I've flagged issues such as availability/quality of bottom tracking and stations for which there was no ladcp data.

Shallow profiles: GPS constraint

For the above-defined shallow (<1,500m) profiles, the *stn=nnn; ldeo_constraint_assess.m* script was run with only the GPS constraint on since

GPS data can provide depth-integrated velocity estimates. It is important to note that the LDEO IX software always runs with the GPS constraint on (it is hardcoded) so all output files from the LDEO have GPS constraint automatically applied.

As an example, we plot the GPS constrained LDEO inverse solution for CTD station 9 (within the Florida Straits; Fig. 14.5). The max depth for this station is 760?m. The profile shows reasonable values, with a high northward component (~1m/s) on par with expected Florida Current velocities and compares well with the profile from the VMADCP 75os (Fig. 14.5). A closer inspection of velocity error, number of ensembles and uncertainty values (Fig. 13.6) reveals very few pings and higher error and uncertainty values in the surface 100 m and the point of max depth. In these cases, the *ldeo_constraint_assess2.m* script will flag and nan any data such that vel_error > 0.2; nvel < 10; uerr > 0.15. The cleaned up u and v components (Fig. 14.7) are then appended to the other LDEO output variables and saved together as a netcdf file under */cruise/data/ladcp/ix/ladcp/ix/final/.*

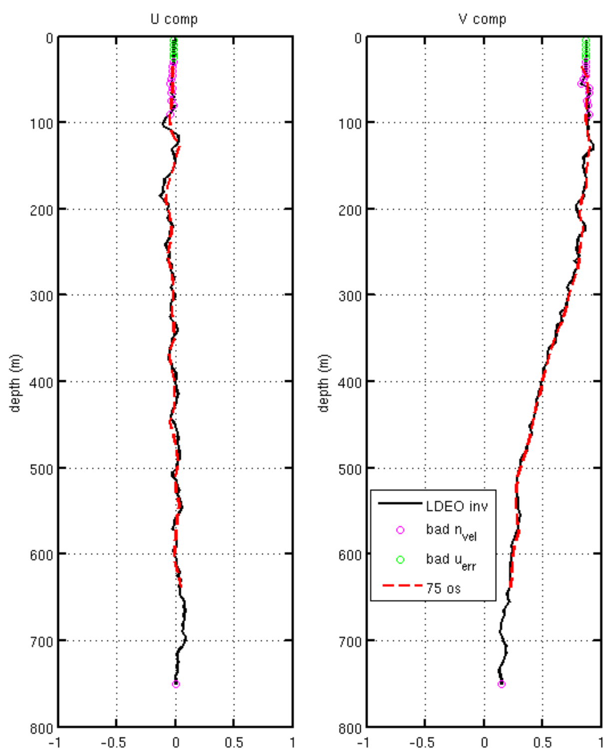


Figure 14.5: *LDEO IX inverse u and v velocity components (dashed black line) constrained with GPS for CTD station 009. The coloured circles indicate data that has been flagged for too few ensembles (magenta circles) or too high uncertainty values (green circles).*

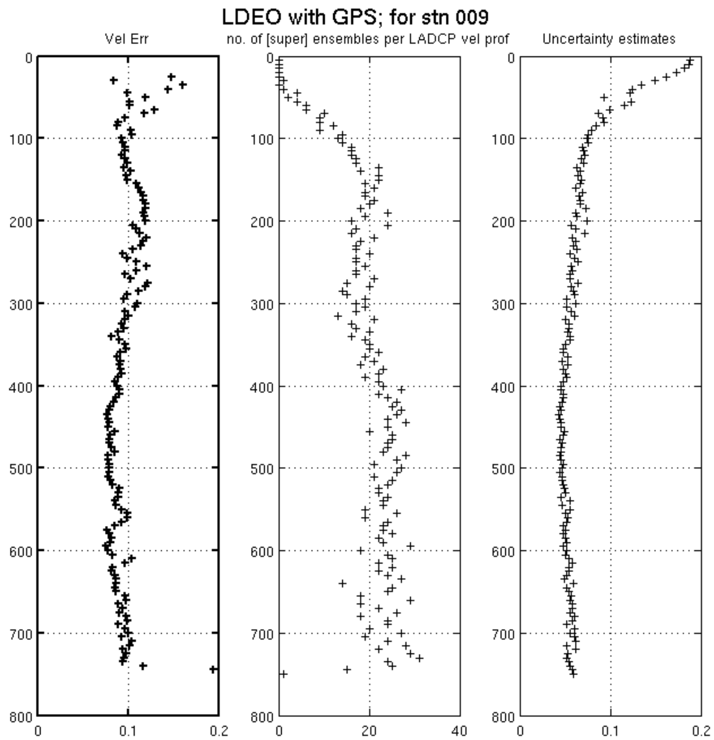


Figure 14.6: *Vel error, ensemble numbers and uncertainty estimates from the LDEO IX inverse solution for CTD station 009. Constrained only with GPS.*

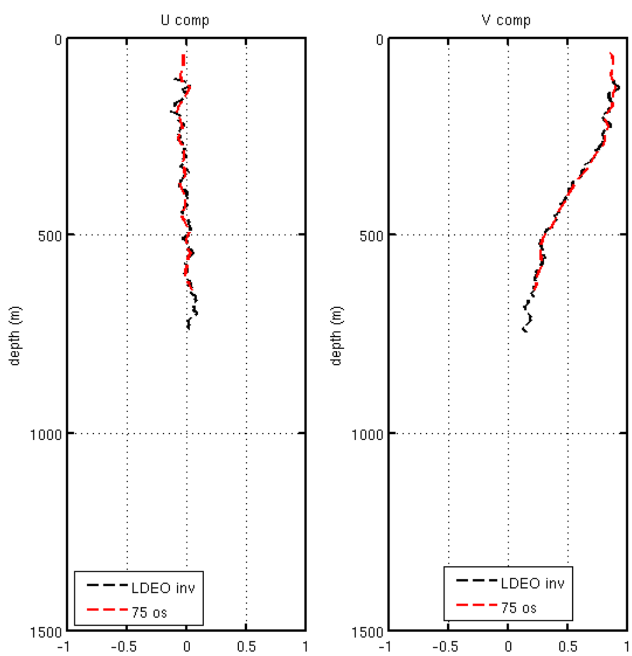


Figure 14.7: *Post processed LDEO IX inverse u and v velocity components (dashed black line) constrained with GPS and the 75os SADCP (red dashed line) for CTD station 009.*

Deep (>1,500m) profiles: SADCP constraint

For deeper profiles, it is advised to proceed with caution when setting constraints. If you apply a GPS constraint on a velocity profile where the mid to bottom depth velocity values are bad/unrealistic, the constraint will try and restrain the bad values in the mid-water column and can introduce noise into the surface and bottom part of the profiles. In these cases, where the values in the mid-water column are unrealistic, it is better to constrain the profile using only the SADCP. To constrain using only SADCP, it is necessary to turn off the GPS constraint default in the LDEO software. For JC191, I have now added a new constraint to remove GPS that can be called: *cfgstr.constraints = 'noGPS';* (or *cfgstr.constraints = {'noGPS' 'SADCP'};* if running SADCP without GPS) before running *process_cast_cfgstr(nnn,cfgstr)*.

Comparison of the LDEO inverse solution constrained with SADCP and GPS on vs constrained with SADCP and GPS off shows solutions diverging just below the depth of availability of SADCP data (Fig. 14.8) – the trick is to determine how much is too much divergence.

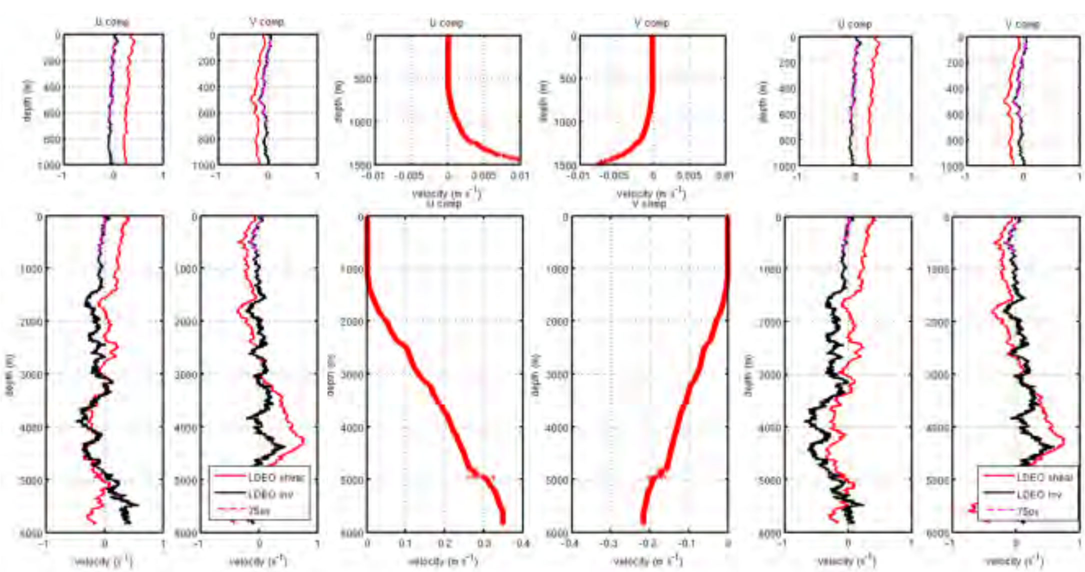


Figure 14.8: *Left 2 plots are the u and v components of the LDEO solution constrained with SADCP and GPS; the right hand side plots are the u and v components of the LDEO solution constrained with SADCP and no GPS. The 2 middle plots are the differences between using the SADCP constraint and toggling GPS on and off.*

For reasons given above, we focus on the SADCP with GPS off and flag all bad values (as described in previous subsection) within the profile (Fig. 14.9). The cleaned-up u and v components (Fig. 14.10) are then appended to the other LDEO output variables and saved together as a netcdf file under */cruise/data/ladcp/ix/ladcp/ix/final/.*

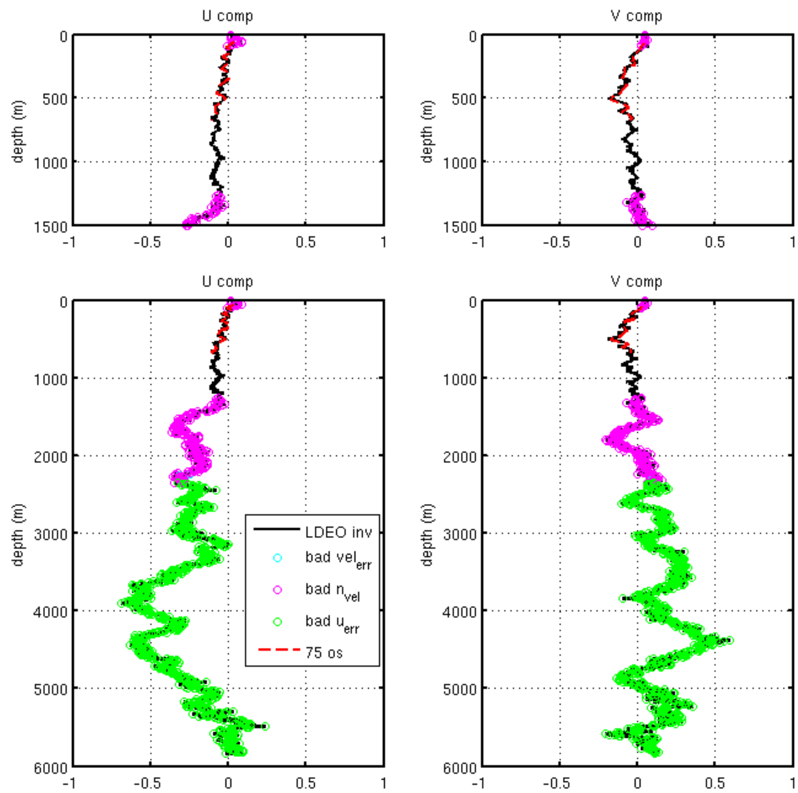


***Figure 14.9:** LDEO IX inverse u and v velocity components (dashed black line) constrained with SADCP (no GPS) for CTD station 063. The coloured circles indicate data that has been flagged for too few ensembles (magenta circles) or too high uncertainty values (green circles).*

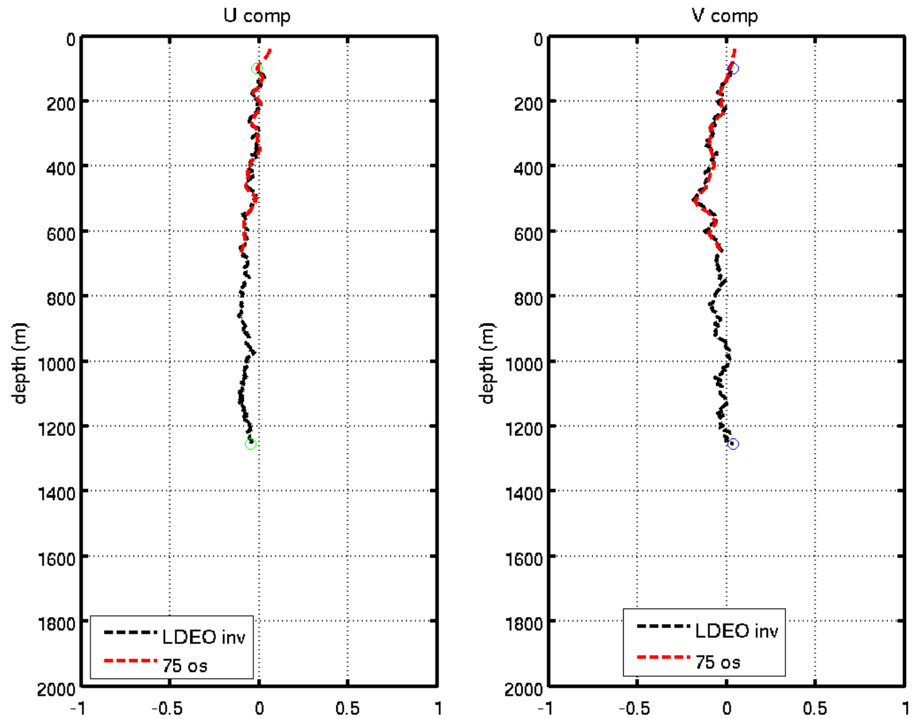


Figure 14.10: *Post processed LDEO IX inverse u and v velocity components (dashed black line) constrained with SADCP (no GPS) and the 75os SADCP (red dashed line) for CTD station 063.*

Notes

The LDEO inv method and the steps described here reliably extend the VMADCP os75 surface profiles at least an extra 600m in the water column.

Surface 100 metres of LADCP profiles tend to be quite noisy, so it is pretty standard for these values to be flagged as bad.

In general, we've found you can really only every get reliable estimates of surface ~1500 m, as well as bottom velocities, from the LADCP.

Though most of the LADCP velocity profiles were reasonable throughout JC191, this method was also tested and found to work with stations that are fully 'blown up' (e.g. 60x10^19 cm/s). In these cases, you can set *ldeo_constraint_assess2.m* to also run a comparison of the LDEO shear profile with the UH shear method for extra check (you need only run the UH shear method for the station in question and the *ldeo_constraint_assess2.m* should automatically pick it up and run a comparison).

14.7 Near Bottom Velocities

The LADCP performs best near the ocean surface and near the ocean floor. Once the LADCP is profiling deeper water columns, the decrease in backscatter in the oceans interior results in unrealistic velocity values. Compared to the ocean's interior, however, the ocean floor has a lot of backscatter and can be detected from great distances. In particular, as the LADCP downlooker descends into the water column with the CTD package, the reflections from the ocean floor allow the LADCP to do 'bottom tracking', i.e. obtain estimates bottom velocity based on the instrument's movement/speed (-u_ctd) relative to the stationary ocean floor. From this, the LADCP is capable of deriving absolute velocity profiles when the instrument is within range of the ocean floor.

Here the LDEO IX bottom track velocities (u,v) were plotted and evaluated for each cast (e.g. Fig. 14.11). In general bottom track velocity values were found to be reasonable/good quality. We note that for CTD stations: 15, 18, 21, 106 there was no bottom tracking velocity.

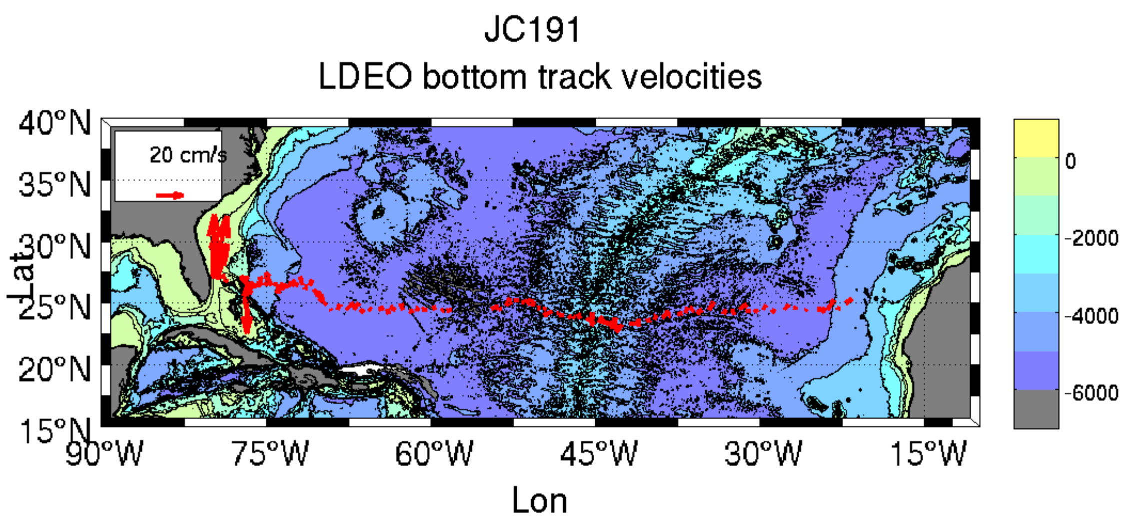


Figure 14.11: *LADCP bottom track velocity vectors, for the bottom 50 m, processed by the LDEO IX software. Here shown only up to CTD station 120.*

Alejandra Sanchez-Franks

15. Vessel Mounted ADCP

15.1 Introduction

Two vessel-mounted Acoustic Doppler Current Profilers (ADCPs) onboard RRS James Cook were used throughout the cruise to measure the horizontal velocity field (cross-track and along-track). The 75kHz and 150kHz Ocean Surveyor (OS) instruments were supplied by Teledyne RD Instruments, and fitted to the port drop keel of the ship at a depth of 2.37m. Both transducers are phased-array, which means that they are made up of many elements each transmitting in different phase. This is advantageous, because it means that the accuracy of the velocities, derived from the Doppler shifted return signals, is not affected by speed of sound changes throughout the water column. However, the range and accuracy of the instruments has been observed in this cruise, as it has previously, to be affected by exposure to bubbles.

The different frequencies of the two instruments affect both their depth range and resolution. The 150kHz allows smaller depth bins and consequently higher vertical resolution, but the signal is more rapidly attenuated and typically only penetrates to approximately 250-350m. The 75kHz lacks such good vertical resolution but penetrates to approximately 600-750m.

15.2 Real Time Data Acquisition

Shipboard ADCP data acquisition and processing were handled by UHDAS (University of Hawaii Data Acquisition System), as opposed to the VMDAS software package used in previous cruises. This software was installed on a computer in the main lab, handling both profilers. This software package handles both acquisition and CODAS (Common Ocean Data Access System) first pass processing, as it is more tightly integrated than the previous software. Data was collected continuously: the UHDAS software writes to a new file every 100,000 cycles. However, on 2020/01/21 12:38 UTC, data collection was stopped and restarted whilst the two ADCP's were switched to the correct inputs, having previously been in `back to front'.

15.2.1 Real Time Monitoring

In the main laboratory, the UHDAS software displays the cycle count for both ADCP's, as well as the gyro, POSMV, seapath and CNAV instruments. The displays are color coded, with green indicating datastreams working correctly, and red indicating errors. During the 4 hourly watchkeeping checks, the counts for the os75nb and os150nb were inspected to check that they were increasing at approximately the expected rate. The monitors were also visually inspected to ensure all data streams were still green, indicating correct function.

Additionally, another monitor in the main lab displays data from first pass/prelimary processed data (steps 1-3 in post processing section) (see Fig. 14.1, available http://192.168.62.225/adcp/index.html). These were regularly visually inspected for unexpected behaviour.

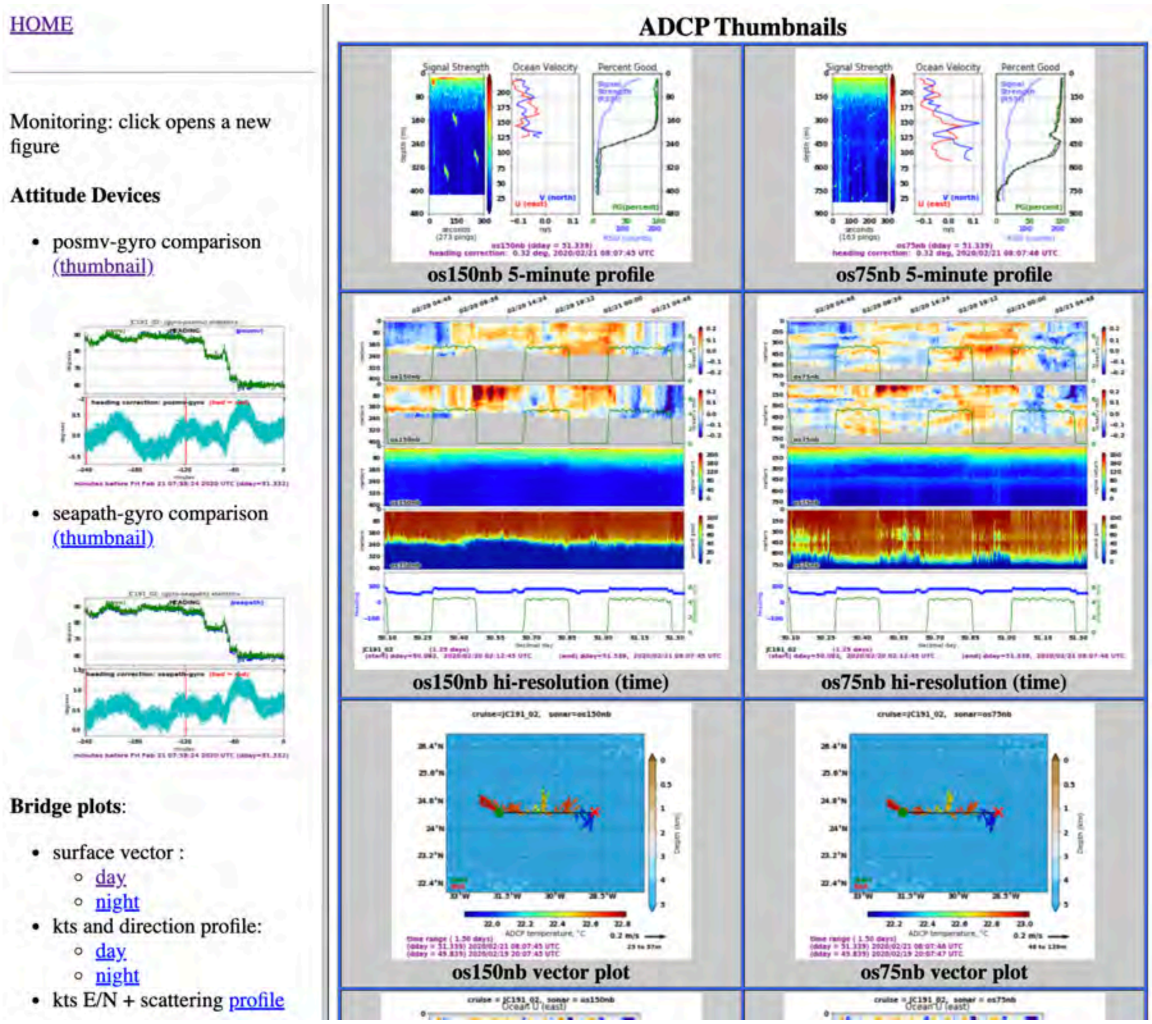


Figure 15.1: *The figures displayed on the ADCP monitoring page. The hi-resolution (time) plots can easily be eyeballed to check for data issues, as can the 5-minute profiles.*

15.2.2 First pass processing

Using the VMDAS suite, removal of ship velocity, heading correction and angle and amplitude calibration was done using VMDAS output files. UHDAS automates this process. Calibration data is stored /pstar/mounts/uhdas_data/JC191_02/raw/config

15.2.3 Settings

The UHDAS suite allows for the instrument to be used in bottom tracking (BT) or water tracking (WT) modes. Both instruments were run in BT until 2020/01/23 15:17 UTC, and then switched to WT. Both instruments were set to ping in self triggered mode, rather than using the K-sync unit, with 50 16-m bins and an 8-m blanking distance for the OS75, and 50 8-m bins and a 4-m blanking distance for the OS150. As mentioned in section 12.2, the two units were initially setup with the wires crossed. As a result, the continuous feed was stopped and restarted when this was corrected on 2020/01/21 12:38 UTC.

15.3 Post Processing

Final onboard data processing was done the CODAS processing suite. This comprises 4 main steps, the first three of which are handled automatically by the UHDAS software package before syncing to Koakea:

1. Removal of ship velocity.
2. Correction of heading with GPS derived heading.
3. Calibration to estimate heading misalignment using ``bottom track'' or ``water track'' data.
4. Manual inspection and removal of bad data.

Although these processes have been largely automated with the introduction of UHDAS, brief descriptions of each phase of post processing and a diagram illustrating the data transfer structure are included. Steps 1-3 are described in Section 15.2.2, and 4 in Section 15.3.2.

15.3.1 Syncing data

This is handled by 3 shell scripts: uhdas_01, uhdas_02, uhdas_03, run in order on Koakea. These scripts were run pstar/jc191/mcruise/data/vmadcp/post_processing/jc191_0\$N/proc_editing/os\$Mnb where $N is 1 prior to switching the instruments on 21 January, and 2 afterwards, and $M is 75 for the 75kHz instrument and 150 for the 150kHz instrument.

15.3.2 Inspection and manual editing

This is handled by the dataviewer.py application, run from a bash terminal as dataviewer.py -e. This loads the data in a GUI application which allows the user to inspect the ACDP data and remove data if flagged as ``bad''. Data are flagged as bad if below the bottom, below a threshold or manually. Flagged data can then be removed. In order to manually remove data, timeseries were inspected on a range of timescales, varying from 1 day down to 0.2 days to heuristically assess whether data ought to be flagged as bad. Typically, bad data can be seen at lengths of 0.5 days or even longer, but are more easily seen, selected and removed at shorter timescales. In the Florida Straits, a timescale of 0.2 days was necessary to remove bad data, increasing somewhat in the main transect.

The dataviewer.py application loads by default with *u, v* velocities, signal return and percent good shown by default (see Figure 15.2), and at a timescale of 0.8 days. Generally, the toggles ``show speed'' and ``show heading'' were ticked in order to clearly delineate arriving on/leaving stations, as these tend to produce sudden jumps in both *u* and *v* which may otherwise be interpreted as bad data.

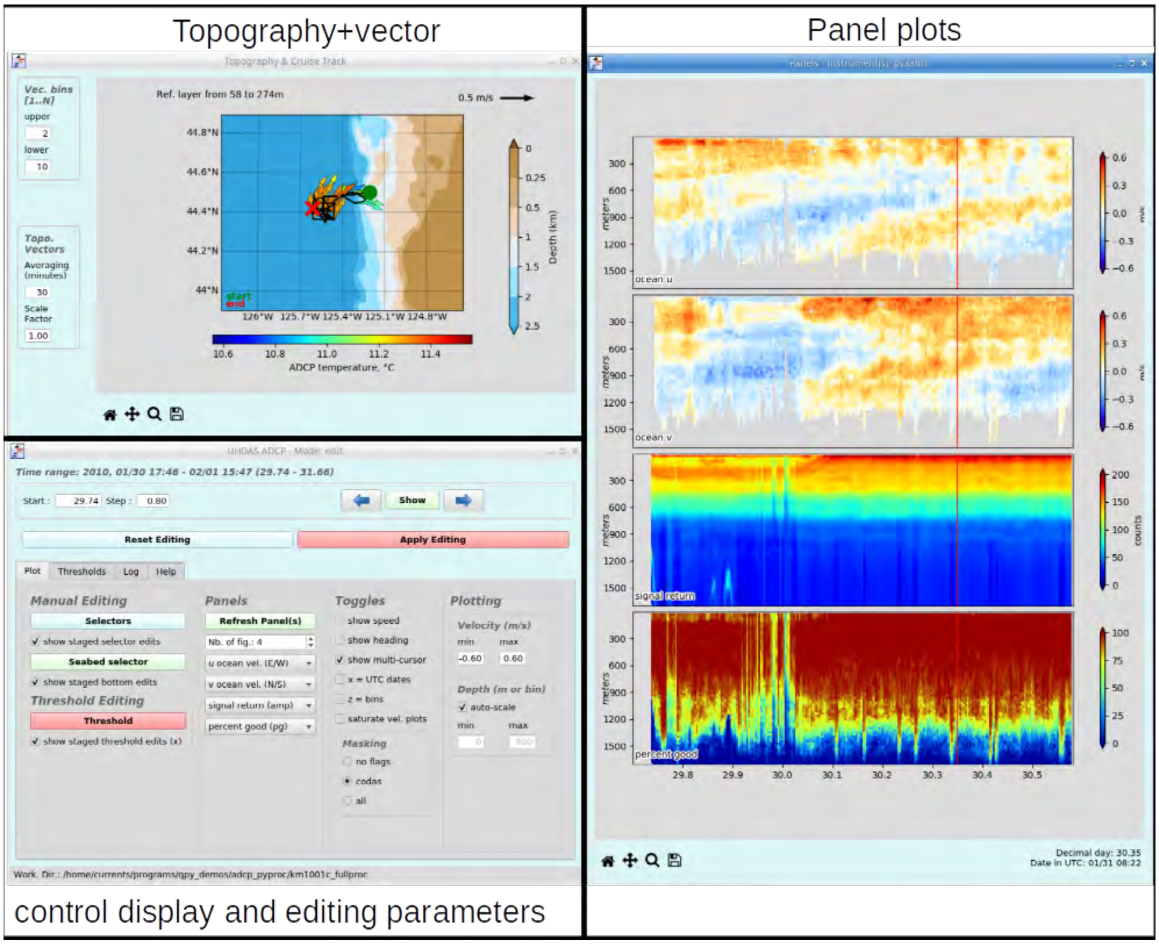


Figure 15.2:*The default layout when running dataviewer.py -e.*

15.3.3 Edit application

After editing is complete, edited data were exported back to the archive using the 2 shell scripts uhdas_04, uhdas_05.

15.3.4 Summary

The entire post processing procedure using UHDAS may be summarised as follows:

> uhdas_01

```
> uhdas_02
> uhdas_03
> bash
$ dataviewer.py -e
Make edits, exit dataviewer
$ exit
> uhdas_04
> uhdas_05
```

15.3.5 Creating output files

Once the UHDAS processing had been completed, the final velocities were collated into mstar files (NetCDF format) using the mexec program mvad_01. To do so, MATLAB was opened from the folder pstar/jc191/mcruise/data/vmadcp/mproc before running mvad_01 from the command line. The mvad_01 program then prompts for OS type, before writing .nc files containing time, lat, lon, depth, uabs, vabs, uship, vship, decday, speed, shipdspd variables for the duration of each station, named os\$Nnb_jc191_ctd_\$M.nc, with $N being 75 or 150, and $M station number.

For cast times less than two hours (1-18), the ship waited on station until two hours had elapsed before leaving to produce better current estimates. The file pstar/jc191/mcruise/data/vmadcp/mproc/mvad_03_jc191_times.txt contains timestaps of arrival on station and departure. These times were determined using ship speed and heading data from /pstar/jc191/mcruise/data/nav/posmvpos/bst_jc191_01.nc heuristically. In these cases, mvad_01 would create files named os\$Nnb_jc191_wait_\$M.nc

These files were then averaged over each station using the mexec program mvad_03, which creates a final profile averaged over the cast or wait time, titled os\$Nnb_jc191_ctd_\$M_ave.nc (Replace ctd with wait for stations 1-18).

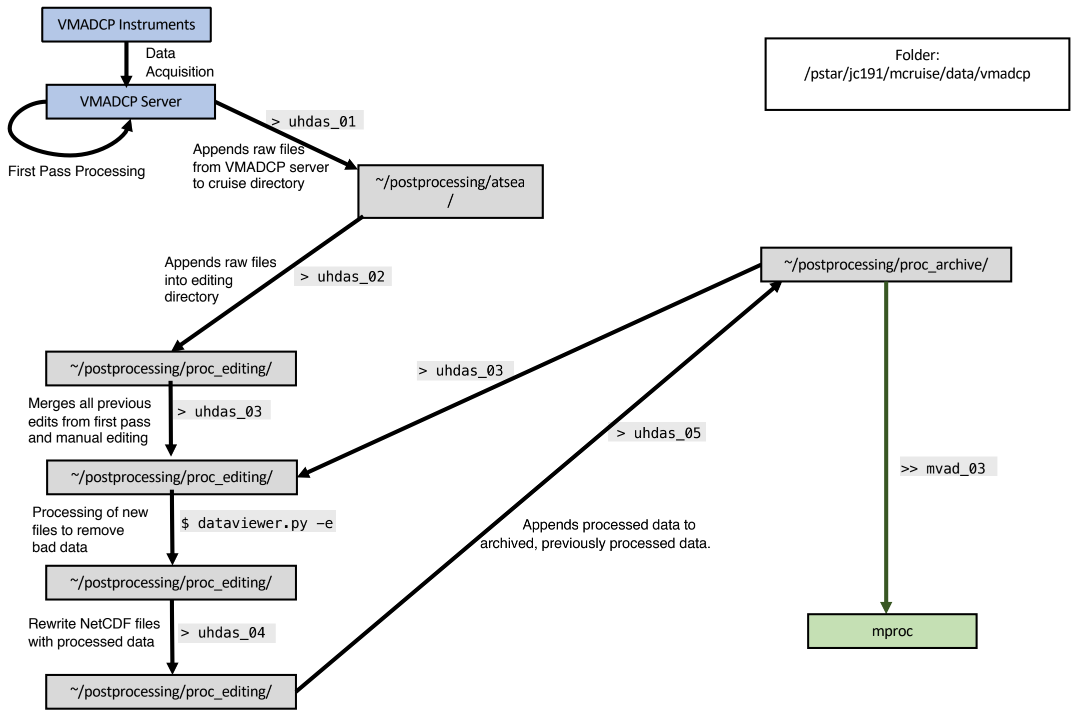


Figure 15.3: *The data structure and processing steps within the data acquisition and processing sequence.*

Charles Turner

16. Biogeochemistry

Anthropogenic induced climate change is having a major impact on the world´s oceans, not only raising the temperature and sea level but it is also increasingly acidifiying the water body. Nutrients within the marine environment are involved in complex cycles, which maintain the biological community and ultimately mediate atmospheric carbon dioxide concentrations (Longhurst, 1991). Yet, there has been little focus on the impact on the biogeochemical cycling of the nutrients, nitrogen and phosphorus. The isolated open ocean is often characterised by exhausted concentrations of both, already being phosphorus limited, and with progressing climate change these supplies will reduce further. Inputs of anthropogenic-derived nutrients into the oligotrophic ocean are limited to the atmospheric deposition of nitrogen only (Duce et al., 2008). Ultimately, without concurrent input of phosphorus this leads to further phosphorus limitations. There is still much uncertainty into how these complex ecosystems will respond to such pressures and how the dynamics and cycling of these vital nutrients will be impacted in the future. The aim during this cruise is to assess the impact of climate change on nutrient resources in the open ocean environment, and their implications on the planktonic community. Bioassay incubation experiments with further induced phosphorus limitation are conducted to investigate the effects of changing nutrient resources. Additionally, CTD stations are sampled along the transect to produce nutrient and chlorophyll maps in order to investigate the present planktonic community. This methodology will provide insight into how the community will respond to inputs of nitrogen without a concurrent input of phosphorus, as well as the subsequent impact on nutrient biogeochemistry. As incubations were already being conducted during the cruise, in collaboration with the Woods Hole Oceanographic Institution additional incubations are being carried out with the aim to increase alkalinity in the seawater and to measure the effects on the planktonic community.

This proposed project addresses impacts of climate change induced nutrient perturbations in the surface oligotrophic Atlantic Ocean and will provide evidence of how the microbial community and biogeochemistry of the nutrient and carbon pools will respond. This insight will provide further quantitative detail into the microbial functioning of the North Atlantic sub-tropical gyre and the subsequent resource allocation into the various dissolved and particulate organic pools of nitrogen, phosphorus and carbon. The data outputs will provide constraints required in the biogeochemical modelling of future oligotrophic oceans.

This project will complement the CLASS programme with concurrent aims to gain further understanding in the Atlantic Oceans response to climate change. Specifically, the proposed research will benefit the CLASS research theme ‘How natural and anthropogenic drivers of basin and decadal changes are altering the Atlantic ecosystem, and the consequences for ecosystem functioning and services. The addition of the biogeochemical and biological parameters that will be analysed as part of this project, will be an additional data set that can be added to the global GO-SHIP programme.

16.1 CTD sampling

CTD stations (Table 16.1) were sampled for the shallow part of the water column (up to 375 m water depth). At each station sampling aimed to follow the fluorescence profile from the AquaTracka III fluorometer (Chelsea Technologies) mounted on the CTD rosette. Samples were collected at six depths:

- (I) surface
- (II) 50 m depth
- (III) upwards slope of fluorescence
- (IV) fluorescence maximum
- (V) downwards slope of fluorescence
- (VI) fluorescence minimum at the end of euphotic zone

For each depth 5L of water was sampled, from which the following subsamples were collected: Flowcytometry (FCM), Particulate and dissolved organic Carbon (POC/DOC), Nitrogen (PON/DON), Phosphorus (POP/DOP) and Chlorophyll a. For each depth 4ml of sample for FCM were transferred into 4.5 ml Cryovials and fixed with 0.5 % Glutaraldehyde solution (Sigma Aldrich) to reach a final concentration of 1% fixative. Samples were stored in the fridge for 12 hours and then transferred to a -80 °C freezer. Particulate and dissolved nutrients and chlorophyll samples were collected by filtration via a peristaltic pump (Cole-Palmer). For Phosphorus, two litres were filtered onto pre-combusted (4h at 450 °C) and acid-washed 25mm GF/F filters (Whatman). DOP was sampled from the filtrate into 60 ml HDPE bottles and stored frozen at -20 °C. The filter for POP was placed into 2ml Eppendorf tubes and stored frozen at -20 °C. Carbon and Nitrogen were sampled similar by filtering two litres of water onto pre-combusted and pre-weighted GF/F filters. DOC/N samples were collected from the filtrate into 20 ml pre-combusted HPLC vials and fixed with 20 µl high-grade 0.1 M HCl and stored in the fridge. The filter for POC/N was placed into combusted Aluminium foil and stored at -20 °C. For Chlorophyll a, 200 ml were filtered onto GF/F and the filters placed into borosilicate vials. 10 ml of Acetone (Fisher Scientific) were added for extraction. The filters were placed overnight into the -20 °C freezer. Chlorophyll a was analysed on the following day with the AU-10 Fluorometer (Turner Designs) by using 5 ml of extract measured initially and after acidification with 150 µl 0.1 M HCl. All other samples were preserved as described and will be analysed at the University of Portsmouth.

16.2 On-deck incubations with further induced phosphorus limitation

At chosen stations along the transect (Table 16.1), water from 40 metres depth was collected and spiked with additions of Nitrogen in the form of a combination of Ammonium Sulphate/Potassium Nitrate and addition of Urea. The additions were made up previously to the first incubation:

- 10,11 g of Potassium Nitrate dissolved in 100 ml Milli-Q water
- 13,21 g of Ammonium Sulphate dissolved in 100 ml Milli-Q water
- 6 g of Urea dissolved in 100 ml Milli-Q water
- all stocks were then diluted to 1/100, resulting in 1 µmol/L final concentration
- all stocks were stored in the fridge once made up

The designated stations were chosen to be sampled between midnight and 4 am to have the least biological active condition. From 40 m depths, 60 L of water was collected in 20 L carboys covered in black to prevent any form of light activation. 5 L were processed as T0 for each of the samples mentioned in CTD sampling. Additionally, samples for determination of nanomolar nutrients were taken and directly stored frozen at -20 °C. For setting up the incubation, 9x10 L cubitainers were filled with 6 L of the sampled water, of which three remained untreated, three received addition of NH4/NO3 addition, three addition of Urea. 600 µl of Urea stock were added, 300 µl of each NH4 and NO3 stock to reach a final concentration of 1 µmol/L. Nutrient samples from the six bags with the addition were taken and analysed directly on the ship (see nutrient analysis). The cubitainers were then placed into the on-deck incubator on the back deck of the RSS James Cook, which were previously covered with filters mimicking the light attenuation at the depth of origin (Fig. 15.1). The incubators were attached to the underway seawater supply to maintain stable temperature within.

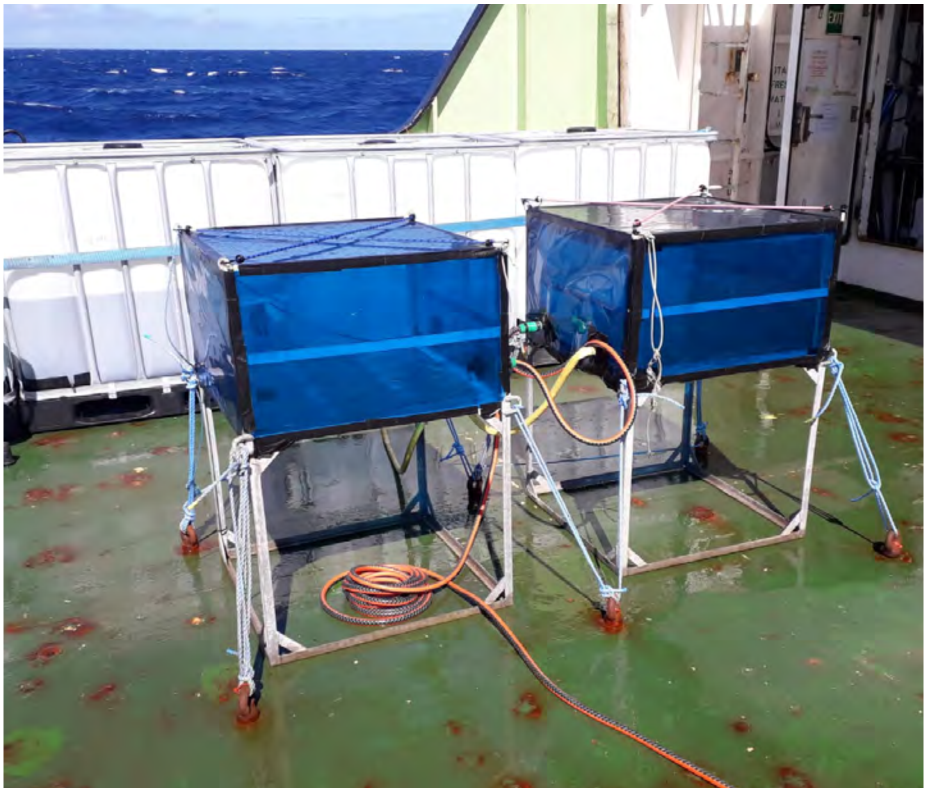


Figure 16.1: *On-deck incubators on the back deck of RSS James Cook with flow through underway seawater supply for stable temperature.*

Each incubation ran for 48 hours, after which every bag was sampled as the baseline T0 and according to the same protocol as for the CTD sampling. Nanomolar nutrient samples were taken for all the incubation bags and stored frozen.

16.3 Alkalinity incubations in collaboration with Woods Hole Oceanographic Institution

At stations 28 and 95 (Table 16.1) additional incubations were set up in collaboration with the Woods Hole Oceanographic Institution. These incubations aimed to increase the alkalinity in the seawater and its implications on the planktonic community. At both stations, 160 L seawater was collected from 40 m depth. Both stations required an extra dip with the CTD due to the big volume needed for the incubations and were not sampled by the core teams on the RSS James Cook. At station 28, all Niskin bottles were fired for the incubation, whereas at station 95 only half the bottles were fired for the incubation and half for the carbon team in order to take substandard measurements for DIC/TA analysis at 2000 m.

16x10 L cubitainers were filled with 9,5 L seawater each, leaving no headspace. Four cubitainers functioned as control; of the remaining, every four received a different level of Bicarbonate/Carbonate addition.

Incubation	Bicarbonate (mg)	Carbonate (mg)	Ratio
AOI-1-1	982.4	409.9	2.397
AOI-1-2	980.8	413.3	2.373
AOI-1-3*	982.1	414.8	2.368
AOI-2-1	1909.4	857.4	2.227
AOI-2-2	1912.9	857.6	2.231
AOI-2-3*	1912.5	857.4	2.231
AOI-3-1	3666.9	1814.5	2.021
AOI-3-2	3668.6	1815.9	2.020
AOI-3-3*	3669.4	1813.6	2.023
* not used as only two incubations could be conducted			

The pre-weighted additions were dissolved in 50 ml Milli-Q water and every treatment cubitainer received 12.5 ml of the respective addition. All 16 cubitainers were then spiked with 234 µL ^{13}C-bicarbonate, which was pre-weighted (268.5 mg) and dissolved in 15 ml Milli-Q water. Out of the control and each treatment, one cubitainer was sampled for T0, whereas the remaining 12 were placed in the on-deck incubator for an incubation period of 96 hours after which all were sampled. From each cubitainer (T0 and T96) samples for DIC/TA, Nutrients, Imaging FlowCytobot (IFCB), Flowcytometry (FCM) and PIC/POC were collected. Samples for DIC/TA were taken according to the protocol already used by the carbon team, collecting 250 ml of water sample and poisoning with HgCL. These were stored in darkness until analysis back in the UK, as the alkalinity exceeded the concentration measurable on ship. Nutrient samples were directly analysed on board. IFCB samples were collected in 15 ml Falcon tubes, fixed with 37.5 µL Glutaraldehyde solution to achieve 0.25% final concentration of fixative. After filling up the tubes without headspace, these were immediately stored at 4 °C. 2 ml of sample was taken for FCM and fixed with 0.5% Glutaraldehyde solution, placed in the fridge for 12 hours and then transferred into the -80 °C freezer. Finally, 7 L were filtered via the peristaltic pump onto pre-combusted 25 mm GF/F filters for PIC/POC analysis. After filtration, the filters were placed in combusted Aluminium foil and stored at -20 °C.

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Table 16.1: *List of CTD stations samples for the euphotic zone with depth sampled and corresponding Niskin bottle mounted on the CTD rosette.*

Station #	Depth	Niskin #
Test	D1 – 25 m	21
Lat: 26°26’	D2 – 50 m	19
Lon: 78°40’	D3 – 110 m	15
	D4 – 150 m	11

4 Lat: 27°00' Lon: 79°55'	D1 – 5 m D2 – 25 m D3 – 40 m D4 – 55 m *Fluorescence max.* D5 – 90 m D6 – 120 m	23 19 15 13 9 5
8 (Incubation 1) Lat: 27°00' Lon: 79°37'	40 m	20, 21, 22 for incubation 19 for T0 baseline
12 Lat: 27°00' Lon: 79°12'	D1 – 5 m D2 – 25 m D3 – 35 m *Fluorescence max.* D4 – 55 m D5 – 80 m D6 – 110 m	23 21 19 17 15 13
22 (Incubation 2) Lat: 26°29' Lon: 76°37'	40 m	21, 22, 23 for incubation 20 for T0 baseline
23 Lat: 26°30' Lon: 76°33' *Niskin 24 (surface) did not fire*	D1 – 25 m D2 – 50 m D3 – 75 m D4 – 125 m *Fluorescence max.* D5 – 175 m D6 – 250 m	23 22 21 20 19 18
28 (WHOI incubation 1) Lat: 26°30' Lon: 76°9'	40 m	
30 Lat: 26°30' Lon: 75°54'	D1 – 5 m D2 – 25 m D3 – 50 m D4 – 75 m D5 – 100 m *Fluorescence max.* D6 – 175 m	24 23 22 21 20 19
35 Lat: 26°30' Lon: 74°48'	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 125 m *Fluorescence max.* D5 – 145 m D6 – 175 m	10 9 8 7 6 5
39	D1 – 5 m	10

Lat: 26°30' Lon: 73°34'	D2 – 50 m D3 – 100 m D4 – 130 m *Fluorescence max.* D5 – 150 m D6 – 250 m	8 7 6 5 4
43 Lat: 26°30' Lon: 72°05'	D1 – 5 m D2 – 50 m D3 – 75 m D4 – 90 m D5 – 105 m *Fluorescence max.* D6 – 140 m	10 9 8 7 6 5
47 Lat: 26°6' Lon: 70°38'	D1 – 5 m D2 – 50 m D3 – 95 m D4 – 106 m *Fluorescence max.* D5 – 130 m D6 – 175 m	10 9 8 7 6 5
48 (Incubation 3) Lat: 25°41' Lon: 70°15'	40 m	7, 8, 9 for incubation 6 for T0 baseline
50 Lat: 24°54' Lon: 69°32'	D1 – 5 m D2 – 50 m D3 – 100 m *Fluorescence max.* D4 – 130 m D5 – 175 m D6 – 250 m	10 9 8 7 6 5
53 Lat: 24°30' Lon: 67°40'	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 125 m *Fluorescence max.* D5 – 150 m D6 – 175 m	10 9 8 7 6 5
55 Lat: 24°30' Lon: 66°10'	D1 – 5 m D2 – 50 m D3 – 90 m D4 – 115 m *Fluorescence max.* D5 – 130 m D6 – 175 m	10 9 8 7 6 5
59	D1 – 5 m	10

Lat: 24°30’ Lon: 63°15’	D2 – 50 m D3 – 90 m D4 – 115 m *Fluorescence max.* D5 – 175 m D6 – 250 m	9 8 7 6 5
61 Lat: 24°30’ Lon: 61°48’	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 130 m *Fluorescence max.* D5 – 175 m D6 – 250 m	10 9 8 7 6 5
64 Lat: 24°30’ Lon: 59°36’	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 130 m *Fluorescence max.* D5 – 150 m D6 – 250 m	10 9 8 7 6 5
67 Lat: 24°30’ Lon: 57°24’ *No fluorometer on CTD*	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 130 m D5 – 200 m D6 – 300 m	10 9 8 7 6 5
70 Lat: 24°30’ Lon: 55°12’ *No fluorometer on CTD*	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 130 m D5 – 175 m D6 – 250 m	10 9 8 7 6 5
71 (Incubation 4) Lat: 24°30’ Lon: 54°28’	40 m	7, 8, 9 for incubation 6 for T0 baseline
72 Lat: 24°30’ Lon: 53°44’	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 130 m *Fluorescence max.* D5 – 250 m D6 – 375 m	10 9 8 7 6 5
75 Lat: 25°07’ Lon: 52°10’	D1 – 5 m D2 – 50 m D3 – 100 m	10 9 8

	D4 – 140 m *Fluorescence max.* D5 – 200 m D6 – 375 m	7 6 5
78 Lat: 24°48’ Lon: 50°48’	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 150 m *Fluorescence max.* D5 – 175 m D6 – 250 m	10 9 8 7 6 5
81 Lat: 24°20’ Lon: 49°00’	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 150 m *Fluorescence max.* D5 – 175 m D6 – 250 m	10 9 8 7 6 5
84 Lat: 23°58’ Lon: 47°24’	D1 – 5 m D2 – 75 m D3 – 100 m D4 – 146 m *Fluorescence max.* D5 – 200 m D6 – 300 m	10 7 6 5 4 3
87 Lat: 23°46’ Lon: 45°48’	D1 – 5 m D2 – 50 m D3 – 100 m *Fluorescence max.* D4 – 150 m D5 – 175 m D6 – 250 m	10 9 8 7 6 5
89 (Incubation 5) Lat: 23°38’ Lon: 44°44’	40 m	6, 7, 8 for incubation 9 for T0 baseline
91 Lat: 23°26’ Lon: 43°40’	D1 – 5 m D2 – 50 m D3 – 115 m D4 – 162 m *Fluorescence max.* D5 – 200 m D6 – 300 m	10 9 7 6 5 4
94 Lat: 23°20’ Lon: 41°53’	D1 – 5 m D2 – 50 m D3 – 100 m	10 9 7

	D4 – 128 m *Fluorescence max.* D5 – 175 m D6 – 250 m	6 5 4
95 (WHOI incubation 2) Lat: 23°24’ Lon: 41°28’	40 m	
97 Lat: 23°34’ Lon: 40°19’	D1 – 5 m D2 – 50 m D3 – 110 m D4 – 125 m *Fluorescence max.* D5 – 175 m D6 – 250 m	10 9 8 7 6 5
100 Lat: 23°58’ Lon: 38°10’	D1 – 5 m D2 – 50 m D3 – 125 m D4 – 150 m *Fluorescence max.* D5 – 175 m D6 – 250 m	10 9 8 7 6 5
103 Lat: 24°21’ Lon: 36°2’	D1 – 5 m D2 – 50 m D3 – 100 m D4 – 155 m *Fluorescence max.* D5 – 175 m D6 – 250 m	10 9 8 7 6 5
104 (Incubation 6) Lat: 24°29’ Lon: 35°18’	40 m	7, 8, 9 for incubation 6 for T0 baseline
106 Lat: 24°29’ Lon: 33°54’	D1 – 5 m D2 – 50 m D3 – 110 m D4 – 150 m *Fluorescence max.* D5 – 175 m D6 – 250 m	10 9 8 7 6 5
109 Lat: 24°29’ Lon: 31°48’	D1 – 5 m D2 – 50 m D3 – 107 m *Fluorescence max.* D4 – 175 m D5 – 250 m D6 – 375 m	10 9 8 7 6 5

112 Lat: 24°30' Lon: 29°42'	D1 – 5 m D2 – 50 m D3 – 91 m *Fluorescence max.* D4 – 125 m D5 – 175 m D6 – 250 m	10 9 8 7 6 5
114 Lat: 24°29' Lon: 27°43'	D1 – 5 m D2 – 40 m D3 – 60 m *Fluorescence max.* D4 – 128 m D5 – 175 m D6 – 250 m	10 9 8 7 6 5
116 Lat: 24°29' Lon: 25°45'	D1 – 5 m D2 – 35 m D3 – 75 m *Fluorescence max.* D4 – 100 m D5 – 150 m D6 – 250 m	10 9 8 7 6 5
117 (Incubation 7) Lat: 24°30' Lon: 24°47'	40 m	6, 7, 8 for incubation 9 for T0 baseline
118 Lat: 24°29' Lon: 23°48'	D1 – 5 m D2 – 25 m D3 – 50 m *Fluorescence max.* D4 – 75 m D5 – 150 m D6 – 200 m	10 9 8 7 6 5
122 Lat: 24°29' Lon: 27°43'	D1 – 5 m D2 – 25 m D3 – 40 m *Fluorescence max.* D4 – 75 m D5 – 150 m D6 – 200 m	
125		
129		
One more incubation		
…		

Lukas Marx

17. Radiocarbon

17.1 Sample Collection and Storage

Water samples to be used for onshore radiocarbon analysis were collected from 20 litre and 10 litre Niskin bottles attached to the CTD sampling rosette. This report only details the ship-based sampling procedure. The radiocarbon (^{14}C) data will be available in six months to two years after the cruise. Data will be reported in $\Delta^{14}C$ notation, which represents the sample $^{14}C/C$ ratio normalized to the Modern standard and corrected for fractionation and sample age (Δ in Stuiver and Polach, 1977).

Two methods of sample collection were used. The primary sample collection method follows Bryant et al. (2013). Seawater samples are collected in foil bags and preserved by freezing. These samples will be analysed at the NERC Radiocarbon Facility in East Kilbride, Scotland. Further details on this method are given later in this section. The second sample collection method uses glass flasks from Woods Hole Oceanographic Institute (WHOI) and samples are preserved by poisoning. These samples will be analysed at the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) laboratory at WHOI in Woods Hole, USA. The recommended sampling procedure for flasks for NOSAMS was used, exactly as stated in the guidance report “Collection and Measurement of Carbon Isotopes in Seawater DIC” (McNichol et al., 2010). The samples collected in flasks for NOSAMS are for intercomparison with the samples collected in bags for the NERC Radiocarbon Facility. NOSAMS have been collecting and analysing seawater flask samples for radiocarbon for many years, whereas the foil bag sampling is a relatively new technique.

We collected 400 foil bag samples and 16 flask samples. A sampling strategy was developed in advance to ensure the most relevant of the 135 stations and depths on JC191 were sampled and that the intercomparison flask samples covered different depths and locations. The sampling strategy was designed based on where radiocarbon data were collected on previous nearby hydrographic surveys (A05 in 1992 and 1998, and various iterations of A22, A20 and A16), and the oceanographic features along the section. The samples were collected on 19 stations that are shown in Figure 1, along with the locations of the intercomparison flask sample locations. A number of foil bag duplicates were also collected, at random stations and depths.

For foil bag sampling, seawater samples of approx. 0.5 litres were collected in 1 litre foil bags (see Figure 2a, FlexFoil Plus cat no. 253-01), composed of 4 layers (polypropylene, polyethylene, aluminium foil, and polyethylene). The foil bags were modified at Imperial College London to allow easy introduction of the liquid sample by removing the stainless steel fitting and the rubber septum, leaving only a stainless steel tube inlet to the bag. Approximately 10 cm length of

Tygon® tubing (Tygon E-3603, 10 mm outer diameter (OD), 7 mm internal diameter (ID), P/N ACF1S1505-C) was attached to the stainless steel tube and secured in place with a cable tie. A 6.4 mm ID acetal plastic inline valved female hose barb coupling (cat no. cPMCD17-04) was added to the end of tubing and the sample bags were flushed two times with nitrogen gas. A 6.4 mm ID acetal plastic inline valved male hose barb coupling (cat no. cPMCD22-04) connected to more Tygon tubing was used to connect the Nitrogen gas supply to the foil bags for flushing. Then the bag was filled with nitrogen gas and sealed to check for leaks. To seal the bag, the male coupling was removed and a plastic clip (WeLoc PA 50 white, cat no. 1205001) fastened across the tubing. Bags were left for several hours to check for deflation that would indicate a leak in the bag. If no leaks were found, the bag was flattened to remove the nitrogen gas and prepare for shipping. The bags were shipped with the plastic clip fastened over the tubing and the female coupling in place at the end of the tubing.

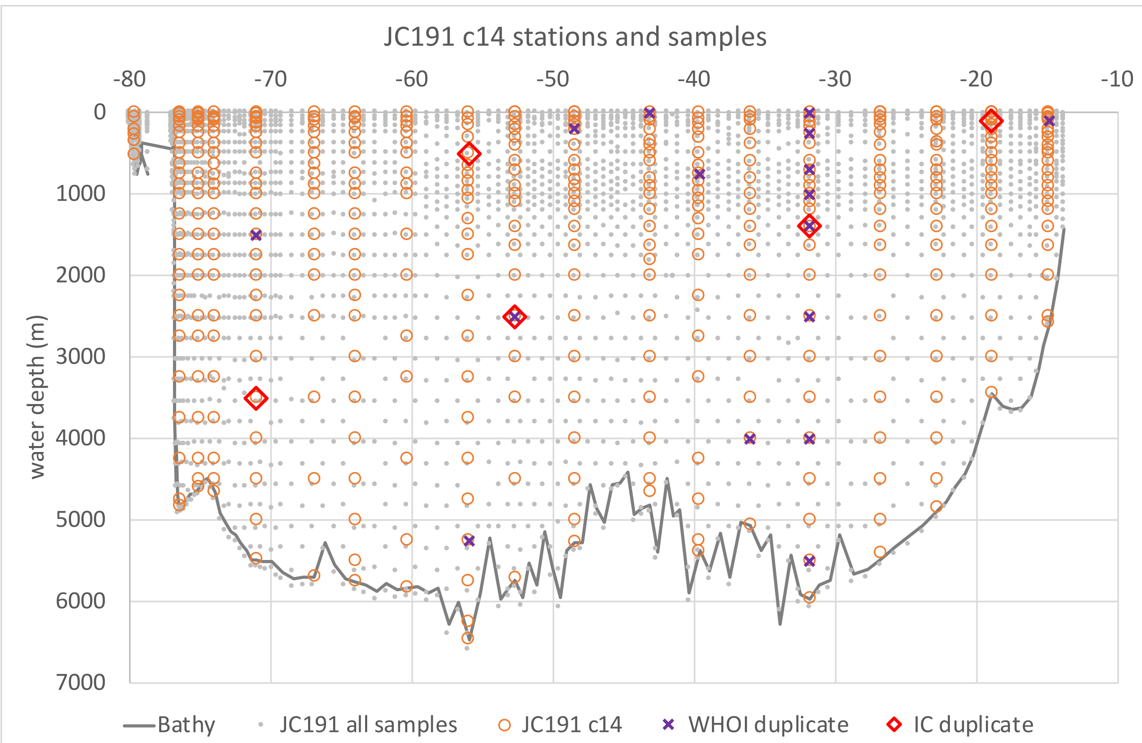
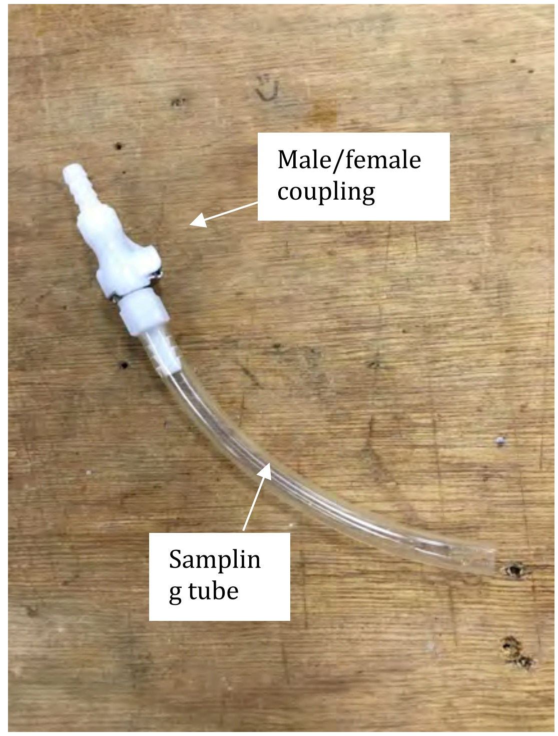


***Figure 17.1**: Locations of samples collected for radiocarbon analysis at the NERC Radiocarbon Facility (orange circles) and at NOSAMS (purple crosses). For reference, the locations of all CTD samples are shown in grey dots and the seabed is shown with a black line.*

To connect the foil bags to the Niskin bottle spigot, we used a 15 cm length of the same Tygon tubing used to adapt the foil bags. A connected male/female coupling is also needed to flush through the tubing prior to taking sample (Figure 2b). For the few Niskins when biological sampling followed radiocarbon sampling, a length of silicon tubing was joined to the Tygon tubing with a straight-stepped tubing connector, to avoid contaminating the spigot.

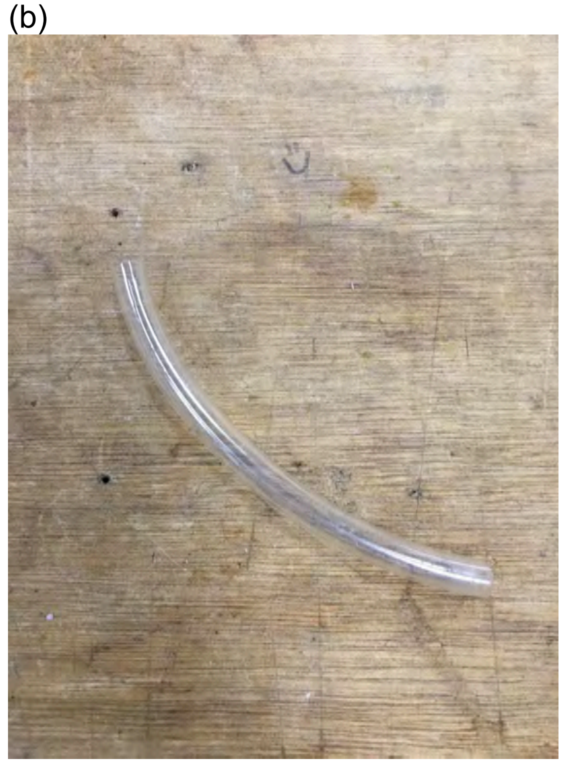

Female
couplin
Foil bag
Plastic
clip
SKC
73139
391
Sample
number
Station-
Niskin-

(a)


Male/female
coupling
Samplin
g tube

(b)

(c)



(d)

***Figure 17.2**: (a) Foil sample bag showing female coupling, foil bag tube and plastic clip, (b) sampling tube with male/female coupling attached, (c) standalone male/female coupling, (d) sampling tube.*

The foil sample bags were labelled sequentially from 001 to 159, then 760 to 1000. This was to distinguish the sample IDs from a previous cruise. The foil bag sampling method used on JC191 is outlined below.

1. Collect the upcoming station depths to decide how many bags will be needed at the station.
2. Fill out sample bag labels in advance of sampling to save time while at the station, and because the labels can be difficult to write on after they get wet.
3. Take the following to the CTD:
    a. Two large empty plastic tubs to store the sample bags in when full.
    b. Two large plastic tubs with lids, with correct number of foil bags for the station inside the tub. When the bags are empty the wind on deck can easily carry them away if there is no lid.
    c. The sampling tube, and separate male/female coupling (Figure 2b).
    d. Scales.
    e. A clipboard with log sheets, permanent marker and pencil.
4. Put on vinyl gloves for sampling. Change gloves regularly throughout the station to avoid contamination.
5. Select correct bag from plastic tub for station/Niskin and go to CTD.
6. Attach sampling tube to Niskin spigot (Figure 2d).
7. Open spigot and flush sampling tube with Niskin water for approx. 10 seconds, washing the male/female coupling (Figure 2c) with Niskin water at the same time.
8. Attach male/female coupling to sampling tube by the male end (Figure 2b), and flush for a further 5 to 10 seconds, to ensure no water from previous Niskin bottle remains in tubing or coupling.
9. While the sampling tube is being flushed, work along the length of tube squeezing to ensure there are no air bubbles fixed to the inside of the tube.
10. Disconnect the female coupling from the end of the sampling tube using the metal release button, which will stop the flow of water. This female coupling is no longer needed, so for now discard, and collect later for use another time.
11. Attach the male coupling at the end of the sampling tube to the female coupling on the foil bag.
12. Remove the plastic clip on the foil bag tubing to allow the Niskin water to enter the bag. Note: the foil bags have a capacity of 1 litre, but Bryant et al. (2013) specify that each bag should only be filled to around 500 ml capacity when frozen, to ensure they do not burst in the freezer. Similar guidance from the NERC radiocarbon facility suggested the bags should be filled to between 500 to 800 ml when frozen. I therefore deemed that a

range of between 500 and 650 ml would be an acceptable sample volume to freeze.

13. Initially overfill the foil bag with between 650 and 800 ml of Niskin water (I give a range because it is difficult to fill to an exact amount by eye). The excess sample will later be used to flush out any remaining N in the bag, but for now reattach plastic clip back to the foil bag tube to stop flow and seal sample.
14. Close Niskin spigot, remove sampling tube from Niskin spigot.
15. Remove sampling tube from the end of the male/female coupling, leaving male/female coupling (now the female coupling from the foil bag) on the end of the foil bag tubing.
16. Attach sampling tube to next Niskin bottle.
17. Weigh foil bag sample to check it contains between 650 and 800 ml of seawater. Recall that each foil bag weighs approximately 35 grams when empty, the plastic clip weighs around 5 grams. [1 ml of seawater ≈ 1 gram].
18. To squeeze out the excess seawater, and any N or air that remains in the foil bag after sampling (visible as bubbles in the Tygon tubing attached to the foil bag), remove plastic clip sealing foil bag tubing, and maintaining a gentle pressure on the face of the bag at all times to ensure no air enters the bag, squeeze out any bubbles which may've collected at the top of the bag. The male/female coupling on the end of the foil bag tubing will ensure the water can only leave the bag slowly and air cannot enter the bag.
19. When bubbles stop exiting the foil bag tube, reattach plastic clip to foil bag tubing, having maintained pressure on the bag to ensure no air enters.
20. Straighten out the bag, and repeat the squeeze again, as usually a new batch of bubbles will emerge.
21. Check the sample still weighs between 500 and 650 ml. If too much sample has been removed from the foil bag, return to the correct Niskin bottle and top up the sample using the procedure previously described. If the sample weighs more than 650 ml, continue to squeeze out any excess until the correct weight is reached.
22. Remove male/female coupling fixed into the end of the foil bag tube, for use with next Niskin bottle. (The female coupling is also removed so the sharp parts cannot damage the foil bags while in storage).
23. Place foil bag into plastic tub ready to carry to freezers. I carried them to the freezers in batches of 12 (thus the need for 2 tubs at a station of 24 Niskin bottles), so the weight is manageable, and time isn't wasted going to the freezer after each Niskin.
24. When arranging the foil bags in the freezer, I found that they were best placed face down, so the foil bag tubing doesn't freeze pointing upwards, as can make it difficult to stack more bags on top.
25. Return to step 7 to continue sampling the next Niskin bottle.

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Joanna Lester

18. Methane

The current document describes measurement and sample collection procedure for the analysis of dissolved methane in the sea water during 6 weeks of JC 191 cruise from Fort Lauderdale, USA to Tenerife, Spain. The measurements of the surface sea water were carried out on board of the vessel, using in-situ membrane inlet mass spectrometer (MIMS). Additionally, water samples and air samples were collected from approximately 70 CTD stations for on shore examination with gas chromatographer (GC).

18.1 Introduction

In the contest of global warming and climate change the methane gas is of a high scientific interest because it produces much stronger greenhouse effect then CO_2. Most of the methane in the ocean is stored at the sea floor. Usually it comes out via cold seeps or hydrothermal vents, as well as dissociation of hag hydrates. In the water column almost all methane is oxidized by bacteria and rarely passes though the thermocline zone in the ocean. When methane concentration in the surface water is high it is called "methane paradox" and believed to be produced by bio organisms. There are three main methane sources in the global ocean carbon cycle:

1. Biogenecally formed CH4 in the reduced sediments of shelf and continental slopes
2. "Fossil" CH4 coming from fluid and gas seeps
3. Abiogenically produced CH4 coming from hydrothermal vents of Mid Oceanic Ridges and Black Arc spreading rift zones

Most of the methane formed in sediments is oxidized by methanotrophic bacteria in the upper layers of sediments, whereas a considerable part of methane from hydrothermal vents and cold seeps is oxidized in the water column. The result of microbial methane oxidation is: enrichment of biogenic methane and products of it's oxidation (organic matter of microbial biomass, CO2, and Carbone minerals).

<u>Anaerobic oxidation of methane (ocean)</u>: CH4 + SO42- + 2 H+ CO2 + H2S + 2 H2O
<u>Aerobic oxidation (involves bacteria, ocean):</u> CH4 + 2 O2 + CO2 + 2 H2O;

However, due to global environmental changes and temperature rise some of the ocean methane may not be fully oxidized before it reaches surface waters and can escape into the atmosphere. This topic as well as "methane paradox" phenomena has not been fully studied because of the vast areas of the Oceans.

The “methane research” task on JC191 cruise is to detect and evaluate methane distribution along water column in the areas of continental shells and ridges as well as trying to detect methane (and attribute it to the “methane paradox”) in the areas of deep ocean. If high quantities of the ocean methane will be detected in the surface waters, there will be a chance that some of the ocean methane is escaping into the atmosphere, further contributing into climate change. Two different techniques has been used to accomplish this task: first, conventional water and air sampling (with post on shore gas chromatography analysis) to evaluate methane distribution along water column; second, on-board measurements of the surface sea water using portable membrane inlet mass spectrometer (MIMS).

18.2 Equipment

MIMS represents an optimal technique for mixed environmental gas analysis, having a high degree of sensitivity and precision, with minimal sample perturbation. It consists of a high-pressure membrane inlet with small volume seawater pumping system, a quadrupole mass spectrometer and oil-less vacuum pumping system. The membrane inlet assembly consisted of a circular sheet (0.625 in. diameter) of Teflon™. The membrane is supported by a sintered stainless steel frit (5µm pore size, Applied Porous Materials, Tariffville, CT), which was in turn supported by the titanium body of the inlet housing. Sample water is pushed through the inlet housing assembly at a flow rate of ~20 to 300 ml/min by the pressure in the laboratory pipe. The water flow is regulated using water flow regulator or via aquarium water pump (see Figure 1).

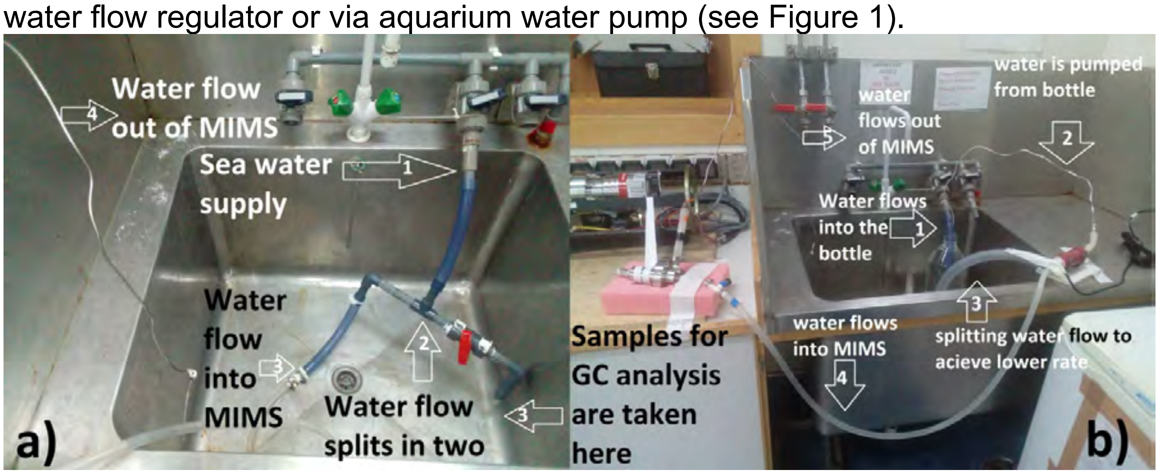

Figure 18.1: *Surface sea water supply into MIMS; a) via water regulator, b) using aquarium pump.*

The membrane assembly was connected to a Stanford Research Systems Residual Gas Analyzer (SRS RGA100) via standard vacuum flanges. Within the vacuum system, a pressure of ~ 10e-5 Torr was maintained by a turbo-molecular pump (model: ATH 31+; Alcatel, France) and backed by a diaphragm roughing pump. Open source electron impact ionization was carried out with a thoriated iridium wire filament. The mass spectrometer and pumps were protected from membrane failure by a high-pressure / high-vacuum solenoid valve (Circle Seal, Inc., Corona, CA), which is actuated upon intrusion of water. 24 VDC power and two independent RS-232 channels (for serial communications with the turbo pump control board and continuous feedback from the RGA analyzer) were supplied via a wet-connect underwater cable (SubConn, Inc., North Pembroke, MA). The entire apparatus consumes about 60W of power continuously.

The MIMS on board sensor was developed in Harvard three month before the start of the cruise. Initial laboraory experiments were succesfull and MIMS was ready to be tested in the field. JC 191 was perfect opportunity to test MIMS sensor in the field before assambling it into housing and running in situ experiments. MIMS design is presented in figure 2 below.

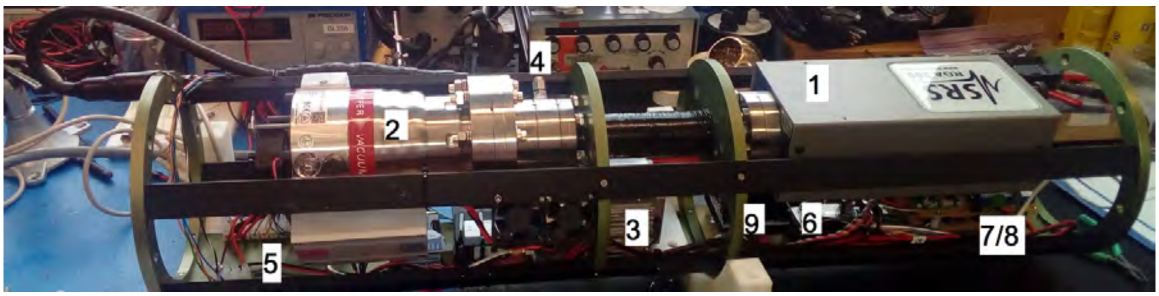

Figure 18.2: *Design of on board MIMS 1.Mass spec, 2.Turbo pup, 3.Rafting pump, 4.Membrane inlet connector, 5.Terminal strip for all connection communications, 6.Ardurino – communicates to control board-communicates trough the housing to the user, 7.Electronic controls / analog sensor output / power control board, 8.Voltage changer to 24 V and gives it to the mass spec, 9.Power management, change voltage 24-12 V or what's coming to 24 V.*

18.3 Cruise tasks and research objectives:

- Collect sea water samples from approximately every second CTD station for in lab on shore analysis of dissolved methane gas with GC. The samples has to be taken along all water column in the areas of continental shells, mid. Atlantic ridge and surface top 400 m in the areas of deep ocean.

- Test newly developed MIMS in the laboratory on board. During the testing I should see how instrument is behaving in "moving environment". Note power consumption, possible overheating, behavior of the Teflon membrane (for example, if gas permeability trough the membrane is changing with time), efficiency of sea water supply through the pipe, try to reduce amount of water which passes through the membrane (water peak overlaps with the methane peak), test field operation of the instrument. Detect additional problems. All data and recorded spectra should be processes on shore after the cruise.

- Objective: analyze methane distribution along water column in the areas of continental shells and mid. Atlantic ridge. Does all the methane gets oxidized before it reaches surface water? Does any of the ocean methane escape into the atmosphere?

- Objective: Try detecting methane in the surface waters in the areas of the deep ocean (not on continental shells or ridges).

18.4 What has been done:

Approximately 1000 sea water samples have been collected from ~70 stations: two duplicates of 20ml were collected from every sampled Niskin bottle. Every second Niskin bottle has been sampled in the area of Continental margin / Mid Atlantic ridge and 5 Niskin bottles from surface water top 400 m in the areas of the deep ocean. This means that full water depth profile has been sampled in about 25 stations and surface 400 m in the remaining 55 stations. Additionally, two air samples has been collected at every station (injected by syringe into MQ water, see figure 3) to analyze atmosphere methane concentration. As well as two sea water samples at every station and in transfer were taken from the laboratory tap for the cross reference with the mass spec measurements.

Figure 18.3: *Collecting an air sample.*

All collected water samples will be sent to France (Station biologique de Roscoff) after the cruise for GC analysis. Figure 4a represents 24 sea water samples (12 depths, two replicates each), being collected from one of the CTD stations along full water column as well as air samples and surface water samples from the lab tap; figure 4b shows one of the 12 labeled boxes of collected water samples that will be sent for GC analysis on shore.

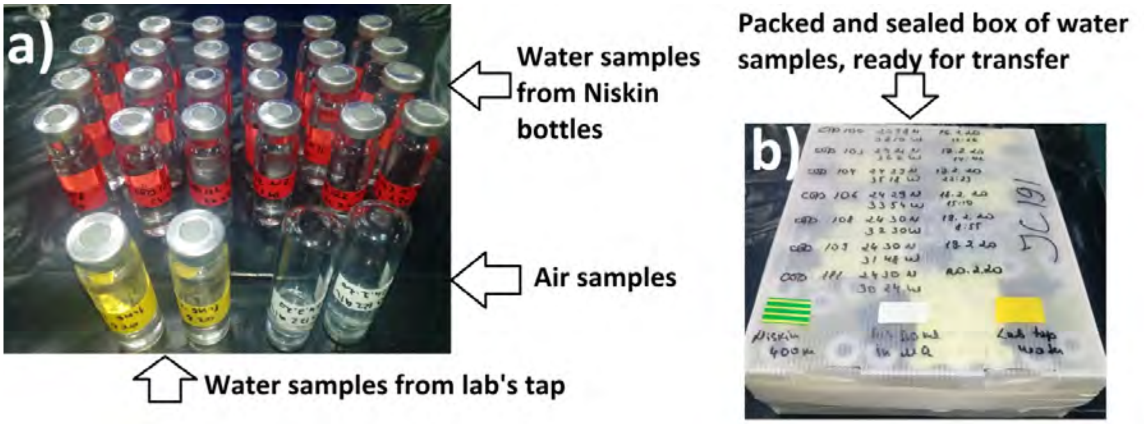

Figure 18.4: *Sea water samples, collected from one of the station on JC 191 cruise a) sea water from different depth (red), surface water from lab (yellow) and air samples in MQ water (white); b) box filled with water samples ready to be transported to France.*

Over 500 individual spectra were taken by MIMS with 5 readings in every sampled station, in some non-sampled stations and in transfer. An example of the MIMS reading of the surface sea water is presented in figure 5 below.

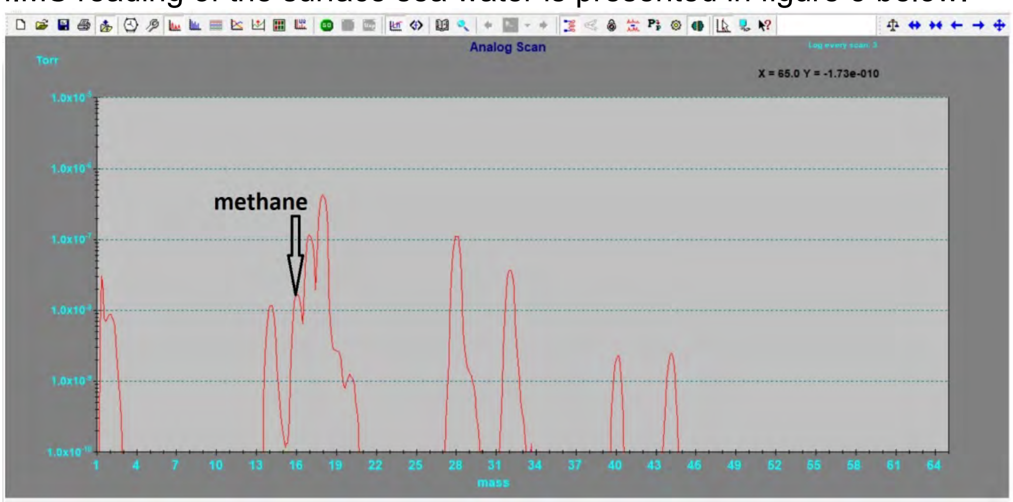

Figure 18.5: *MIMS spectra of the surface water.*

The data will be analyzed on shore after post-calibration of the instrument. A Teflon membrane was changed in a weekly basis for gas penetration-in-time analysis. A water absorber (molecular sieve 5 A) was installed between the membrane and gas analyzer for reducing amount of water in the sample (also regenerated/re-installed weekly). Sea water supply was first performed using aquarium pump, later it was switched with water regulator for the water flow testing.

18.5 Problems & Solutions:

There were no problems with collecting water samples.

There were no problems in the instrument performance during the entire cruise; however there were some tasks and small faults that occurred during instrument testing.

First, I needed to replace filament in MIMS before the beginning of the cruise. Two on board technicians helped me with that. Because the filament was burned in the instrument just before the cruise, I was unable to calibrate the instrument. Therefore, I will have to do post-calibration and analysis of the readings (bring delay in result processing).

Second, I used 5A molecular sieve as a water absorber between the membrane and mass spec, but the connections weren't very tight, so a lot of air got into the analyzer and it produced high noise for the measurements. I still should be able to extract methane readings. The sieve was removed after 2/3 of the cruise, therefore I will be able to compare my readings with/without the sieve and see if the data are strongly affected.

Fourth, I have been using aquarium water pump for the controlled water flow into MIMS, but then I've noticed that water in the pipe is warm, means the pump heated the water. Since the methane solubility in the sea water depends on the temperature, this did affect my results (but I don't know how much). Luckily, I only used pump for the first few days, so most of the cruise data should not be affected.

The last problem was water pressure change in the lab tab pipe. Unfortunately, for 2/3 of the cruise I didn't pay attention to that and I need to know the water flow rate for calculating the methane concentration. When I realized that water pressure was changing I started to measure water flow at each MIMS reading. I might be able to use an average flow rate for earlier readings (?).

Other notes: The power consumption of the instrument rises by 30 mlA every two days of continuous operation. It helps to switch turbopump off and leave it overnight to "rest" once every few days. Also the area of turbopump must stay out of housing otherwise it overheats very quickly.

18.6 Data processing and timing:

I expect to process MIMS data within 3 month after the cruise. Hopefully, I will be able to extract useful information that can be combined with GC-analyzed-station data. It would be very beneficial to present complimentary results of dissolved methane from both techniques and compare efficiency/accuracy of the measurements. Analysis of station samples depends on the laboratory schedule and availability of the GC instrument, but should take also around 3-4 month. If results will be publishable, I expect to make a publication in about 6-9 month after the cruise.

18.7 End notes and conclusions:

In overall, the JC 191 was very successful with good resolution of the sampling stations, very good technical and scientific support. There was enough lab space, convenient access to the sink/sea water, enough power plugs and storage space. Approximately 1200 water samples have been collected from 70 CTD stations, lab tap and air samples for on shore analysis with GC. Over 500 individual spectra of surface sea water has been taken with on board MIMS during the cruise. All data (GC and MIMS) should be analyzed onshore within 3-4 month after the cruise.

Anna Kolomijeca

19. Underway pCO2

Setup VLIZ (Flanders Marine Institute)

Equipment that is used on the RRS James Cook UW non-toxic water supply:

System	Supplier (if commercial)	Comment
UW pCO2		Equilibrator based/CRDS Picarro G2201-i
HydroC-CO2 FT	Kongsberg Contros	Membrane based
HydroFIA TA	Kongsberg Contros	In situ Total Alkalinity

pCO2:

The non-toxic seawater supply is coupled with a VLIZ custom made Underway pCO2 system equipped with Picarro CRDS (G2201-i) analyzer, coupled to a marble showerhead equilibrator (Frankignoulle et al. 2001). The measurements are checked once a day with 3 standard gasses (250-400 and 800 ppm CO2) and a zero (nitrogen). Air from the equilibrator is recirculated with a standard KNF piston pump.

The Kongsberg Contros HydroC-CO2 FT is a membrane based flow through sensor installed very close to the Picarro.

Total Alkalinity:

The Kongsberg Contros HydroFia-TA measures total alkalinity by VIS absorption spectrometry. The sensor is calibrated with CRM's from Dickson.

Issues for setting up the equipment:

No big issues. Just had to make sure that the gas standards for the picarro were installed as close as possible to the setup and that there were enough water inlets available for the 3 systems.

Issues during the cruise:

Due to a combination of factors the Picarro and the vacuum pump flooded on the 22nd of January. It took nearly 4 days to dry everything oud and get the system up and running again.

The non-toxic pump tripped on the 28th of January at the moment when the HydroFia-TA was taking its water sample. Air got stuck inside the inlet tubing of the HydroFia, it took a couple of hours to get the system working again. The system needed to be recalibrated with CRM.

Because the non-toxic pump tripped, the second non-toxic pump was started. This pump gives a lower waterflow. The difference in pCO2 between the picarro and the FT was significantly higher than the days before. After increasing the waterflow the difference in pCO2 between the two systems was the same as before.

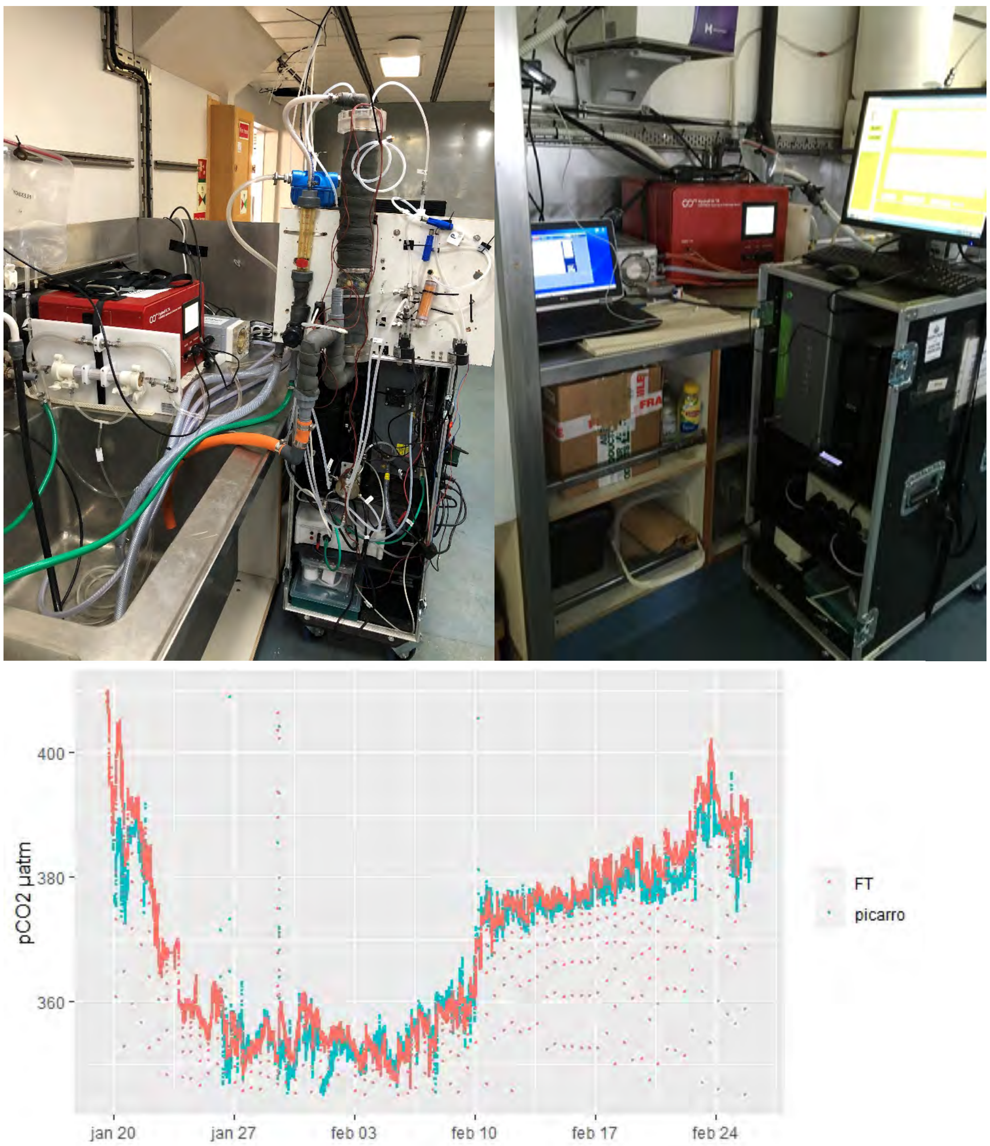

Figure 19.1: *Setup of the three systems.*

Hannelore Theetaert

20. Argo Floats

Five TWR Deep APEX floats were available, and deployed as per the table below. Floats were deployed with the starboard pedestal crane over the starboard side, and a no-load release was operated as the float arrived at the sea surface. Floats were deployed at a speed of 1 to 2 knots as the ship left a CTD station.

The floats were equipped with a 60cm grounding chain, the first Deep APEX deployed by NOC with this option. TWR notified us that the chain was equivalent to 1000 dbar of buoyancy, so it could halt the descent of the float without the body of the float touching the seabed, so long as the float was programmed to descend no more than 1000 dbar below the seabed.

Deep APEX s/n 12 to 15 were prepared at NOC and shipped to the cruise with the rest of the cruise scientific equipment by container freight. TWR had included environmental loggers in the float crates, to assess exposure to high temperature during transit. The loggers were recovered when the floats were tested on deck before leaving port for JC191, and mailed to TRW in the FEDEX envelopes provided with the loggers. A fifth float, Deep APEX s/n 24, was shipped from TWR to Ft Lauderdale, and tested in the same way. Its environmental logger was also returned to TWR.

All floats were tested on deck before leaving port. Floats passed system self test, modem tests and iridium comms tests. The primary RUDICS number worked reliably; the secondary DIALUP number less so, but this was considered usual.

S/n 12 to 15 were programmed with a mission provided by TWR. After confirmation from TWR, this mission was also transferred to s/n 24.

Float deployments were notified to the Met Office and BODC after each deployment. All floats were deployed with a mission to Park at 4000 dbar and DeepDescent to 5400 dbar on a 3-day cycle.

There were many mission updates during the early cycles of each float to adjust buoyancy counts to match the selected Park and DeepDescent depths.

Notes on early cycles of each float:

Deep 14

IdleTimerInterval 5400 at deployment. P-activated at 555 dbar.

When it reported in after cycle 2, it was apparent that it had a buoyancy leak problem. The buoyancy counts would drop to the minimum of 740 whenever the float was descending for any length of time. The following cycles were used to experiment with park depths to try to characterise the circumstances under which it leaked. This float will be picked up if possible on JC192. We are currently experimenting to assess whether the float will lose more buoyancy during park if it parks shallow or if it parks deep.

Comms between the float controller and the oxygen sensor on Deep 14 are intermittent, and oxygen profiles are gappy, although the data appear to be good when reported.

Deep 12

IdleTimerInterval 5400 at deployment. P-activated at 844 dbar. The float arrived at the surface just as the PRELUDE was ending, and it did not report in after cycle 0.

It was clear after the first full cycle, cycle 2, that this float, like all the others, was ballasted so that the initial setting of Park and DeepDescent counts took the float far deeper than intended. The initial park count, intended for 4000 dbar took the float to the seabed at 5989 dbar during ParkDescent. It lifted off the seabed during Park, when the counts reached 1202, compared with the factory settings of 1165 for park at 4000 dbar and 842 for DeepDescent to 5400.

Analysis of the park data on the next few cycles led to a stable mission cycle with Park at 4000 dbar and DeepDescent to 5400. Before cycle 8, a mission was uploaded to take the float to the seabed (or 6000 dbar) during DeepDescent. The float followed the mission and remained on the seabed at 5944 dbar for 16 minutes before starting Ascent. Before cycle 10, it was set to a 10-day cycle. At the time of writing we are waiting for the end of cycle 9.

Also note that the float does not detect grounding if it reaches the seabed during ParkDescent.

Deep 24

IdleTimerInterval 5400 at deployment. P-activated at 80 dbar. This float started normally, and behaved normally, except for wrong ballasting counts. Buoyancy counts were updated to what was required for its Park and DeepDescent depths. A mission was uploaded before cycle 8 for it to descend to 5700, and before cycle 9 for it to descend to 6000 dbar or the seabed. At the time of writing we are waiting the end of cycle 9.

Deep 15

IdleTimerInterval 1800 at deployment. P-activated at 197 dbar. Before this float was deployed, we understood that the IdleTimerInterval on Deep 12 had allowed it to dive too deep before p-activation. An IdleTimerInterval of 5400 is reasonable in transit, but since expert users were available, a change to 1800 ensured timely p-activation. IdleTimerInterval was changed to 1800 shortly before deployment. Several new missions were uploaded during early cycles to make it cycle correctly at 4000/5400 dbar. A mission was uploaded for cycle 8 to descend to 5800, and for cycle 9 to descend to 6000 dbar or the seabed. At the time of writing we are waiting for the end of cycle 8

Deep 13

IdleTimerInterval 1800 at deployment. P-activated at 169 dbar. Before this float was deployed, we knew that several other floats were set with buoyancy counts that would take them far deeper than intended. Therefore the Park count was modified before deployment to be similar to what was known to be correct for earlier floats. The pre-deployment guess turned out to be very close to what was required, but before Deep 13 completed cycle 2, the guess was revised and made slightly worse. By cycle 4 the float was cycling correctly. A 5800 dbar mission was uploaded before cycle 7, and a 6000 dbar mission uploaded before cycle 8. In fact, the float grounded at 5676 dbar for 16 minutes during DeepDescent of cycle 7.

Summary and recommendations

Some useful timing information:

Deep 12 cycle 8: DeepDescent from 5400 to 5950: 489 minutes. Ascent from 5950, 821 minutes, with AscentRate 0.12.

Deep 24 cycle 8: DeepDescent from 5400 to 5700: 549 minutes. Ascent from 5700, 787 minutes. This cycle made a slower approach to DeepDescentPressure.

The manufacturer has been asked what the maximum depth rating of the float and instruments are: 6000 metres or 6000 dbar. Note that 6000 metres = 6124 dbar.

Some floats entered PRELUDE and following mission modes unexpectedly. During Ft. Lauderdale testing, we used “m_idle” before disconnecting from the floats after testing. TWR now recommend “m_bye” before disconnecting. Deep 13 had started its mission in the box, after disconnecting after testing in Ft Lauderdale. If we hadn’t connected to the float to modify IdleTimerInterval and ParkDescentCount, the float would have been deployed during a PARK phase with buoyancy count at MinBuoyancyCount.

The ballasting of the floats was very far from expected. Indeed, during the first full cycle, cycle 2, the ParkDescentCount took some floats 2000 dbar past the set ParkPressure, sometimes to the seabed. If the water depth had happened to be greater than 6000metres, this could have been catastrophic. The ballasting problem does not show up on the deep dive first, cycle 1, because the float descends to ParkPressure and then immediately to DeepDescentPressure where it turns round and returns to the surface. It does not overshoot DeepDescentPressure.

We suggest that the initial ParkDescentCount should be deliberately set significantly shallower than the expected required count. This is safe, and will prevent the float overshooting ParkPressure on the first full cycle. The same problem does not occur with a badly set DeepDescentCount because the float monitors pressure and moves to Ascent when DeepDescentPressure is reached. At Park, the float does not adjust counts until 3 times the ParkTimerInterval has elapsed. If this is 3 times 1 hour, then the float can go a long way past ParkPressure before changing buoyancy.

A second advantage of deliberately setting ParkDescentCount too shallow is that the float will step down during the first park, and provide information on the depth change for each ParkBuoyancyNudge. For these five floats this was between 23 and 27 counts per 100 dbar. Changing buoyancy while hunting for the set pressure enabled almost perfect prediction of the counts required for any other deep pressure. These five floats provided similar information while searching upwards for the set pressure, but this is much less safe and uses unnecessary energy. If the float is searching for the correct park depth, with an ParkTimerInterval of 1 hour and a ParkBuoyancyNudge of 10, the buoyancy nudge will be activated 8 times per 24 hours, resulting in a descent of around 300 dbar per 24 hours. Therefore the ParkDescentCount could be set 500 counts higher than thought correct for the set ParkPressure, and the float will make this adjustment over 50 nudges or 150 hours, equal to 6.25 days.

Deep APEX s/n	CLS comms ID	WMO number	Day/Time of deployment (UTC)	Lat (°N)	Lon (°W)	Water depth (m)	Notes
14	f0047	6903718	2020/01/31 1949	24°30.0	67°40.1	5716	O2, CTD 053
12	f0048	6903719	2020/02/02 1402	24°30.1	63°59.9	5775	O2, CTD 058
24	f00060	6903720	2020/02/04 0010	24°30.0	61°04.0	5895	CTD 062
15	f0046	6903722	2020/02/05 1100	24°30.1	58°07.9	5825	O2, CTD 066
13	f0049	6903721	2020/02/06 2243	24°30.0	55°11.9	5904	O2, CTD

							070

Brian King

21. Active Heave Compensator

The main purpose of the active heave compensator (AHC) is to remove or reduce vertical movement of the package when stationary, give a more uniform descent or ascent rate of the package when the winch is set to veer or haul, and remove both low- and high- tensions conditions in the wire. The AHC was used on the JC191 research expedition and contributed significantly to the aims of the science programme by a) improving the overall quality of the CTD data, and b) extending the life of the CTD termination (and thus reducing downtime and increasing the achievable number of CTD casts).

Performance on JC191

During JC191, the AHC was turned on starting with CTD Station 014 (the first station east of the Bahamas on the shelf, water depth of ~400 m), without incident. The AHC remained on for all CTD stations from 14 to 66 and 70 to 137. The only time the AHC was turned off was during CTDs 67 to 70, when we were in waters deeper than 6,000 m, and required the use of the deep tow (the swivel on CTD wire is not pro-rated to >6,000 m, and there was no software available on ship for use of AHC on deep tow).

In total, the AHC was on for 135 CTD stations over ~40 days with varying weather conditions, including swells of up to 4 meters and winds up to 25 knots, and in water depths up to 6,000 m. The AHC operations were generally found to be smooth, and no major issues were recorded. In general, over the course of the expedition the use of the AHC reduced vertical movement of the package from about ±2 m to ±0.5 m. This translated into an improvement in the overall quality of the data. Damage to the CTD wire was also minimized as the AHC reduced the number of kinks and turns the CTD wire normally experiences over the course of a hydrographic cruise with > 100 CTD stations. This eliminated down time that would have otherwise been needed for CTD wire re-terminations, and thus allowed us to achieve more of the science objectives.

Alejandra Sanchez-Franks and Jessica Newman

22. Outreach

The public outreach onboard aims to boost the visibility of the science carried out on RV James Cook, JC191, as we travelled along the 24N hydrographic section. This is done by providing a summary of the scientific goals and day to day experiences of the expedition. The main approach involved posting highly visual eye-catching photos and videos along with an insight into the feelings of scientists onboard in response to their research at sea, whether it was their first time or their fifth time.

The outreach approach combines the use of social media (Twitter: @CLASS_UKRI and Facebook: @NationalOCeanographyCentre) alongside with regular blog posting on the official UK CLASS (Climate Linked Atlantic Sector Science) project website (https://projects.noc.ac.uk/class-project/blog).

22.1 Twitter

Twitter has become a must in the scientific landscape, becoming the fastest way of social reach out and networking. During the expedition we have been actively tweeting from the official account @CLASS_UKRI as well as from the personal accounts of some on the scientists on board the RV James cook (e.g., @JesSea_Oceanog, @Daniel_Kerr_, @thelocale_ale, @hanneloret4, @Efdarlington and @MariaFR_90). Along with this each scientist with their own official accounts have been interreacting with the @CLASS_UKRI twitter handle and vice versa, thus signal boosting for everyone. We have also noticed great support from many individual accounts related to NOC employees, this also gives a massive boost to the reach further maximising our outreach efforts.

Among the tweets published during the cruise, the main topics of interest can be summarized in the following bullet points:

- Personal profiles of the scientists and technicians on board.
- Personal profiles of the crew members.
- Interaction between technicians and scientists during CTD deployment and recovery.
- Picturing CTD sampling.
- Brief review of the CTD rosette instrumentation.
- Documentation of the deepest station sampled along the transect.
- Emphasis on the international range of the group of scientists.
- Drone footage.
- Deployment of deep argo floats.
- Role of the female scientists and technicians on board.

From the beginning of the cruise, the Twitter analytics have increased showing a positive impact of the public outreach efforts from the scientists onboard. Figure 21.1 shows a summary of the percentage increases in the running and impressions of the @CLASS_UKRI during JC191, these numbers were produced by Twitter.

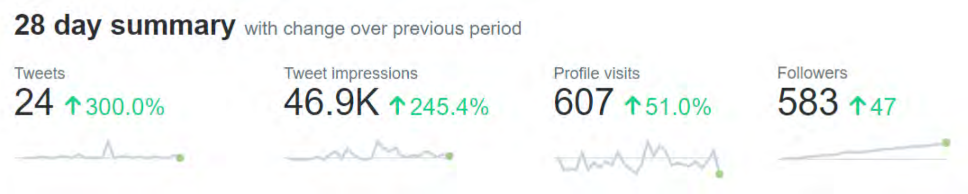

Figure 22.1: *Twitter analytics for the account @CLASS_UKRI for the first 28 days of the cruise*

Figure 22.2 shows a summary of the top tweet from the @CLASS_UKRI account along with the top posts that mentioned the account for January 2020 and February 2020. All four posts contain either a photo/s or a video. The use of hashtags and mentions related to the post, ocean science, companies involved in our marine technology and/ or any particular national/ international recognition days e.g. CTD Appreciation day and Women in STEM, massively boost the reach for each post. We also shared links to the blog posts on the twitter account as they were posted to direct the audience towards the blog posting (see section 22.3).

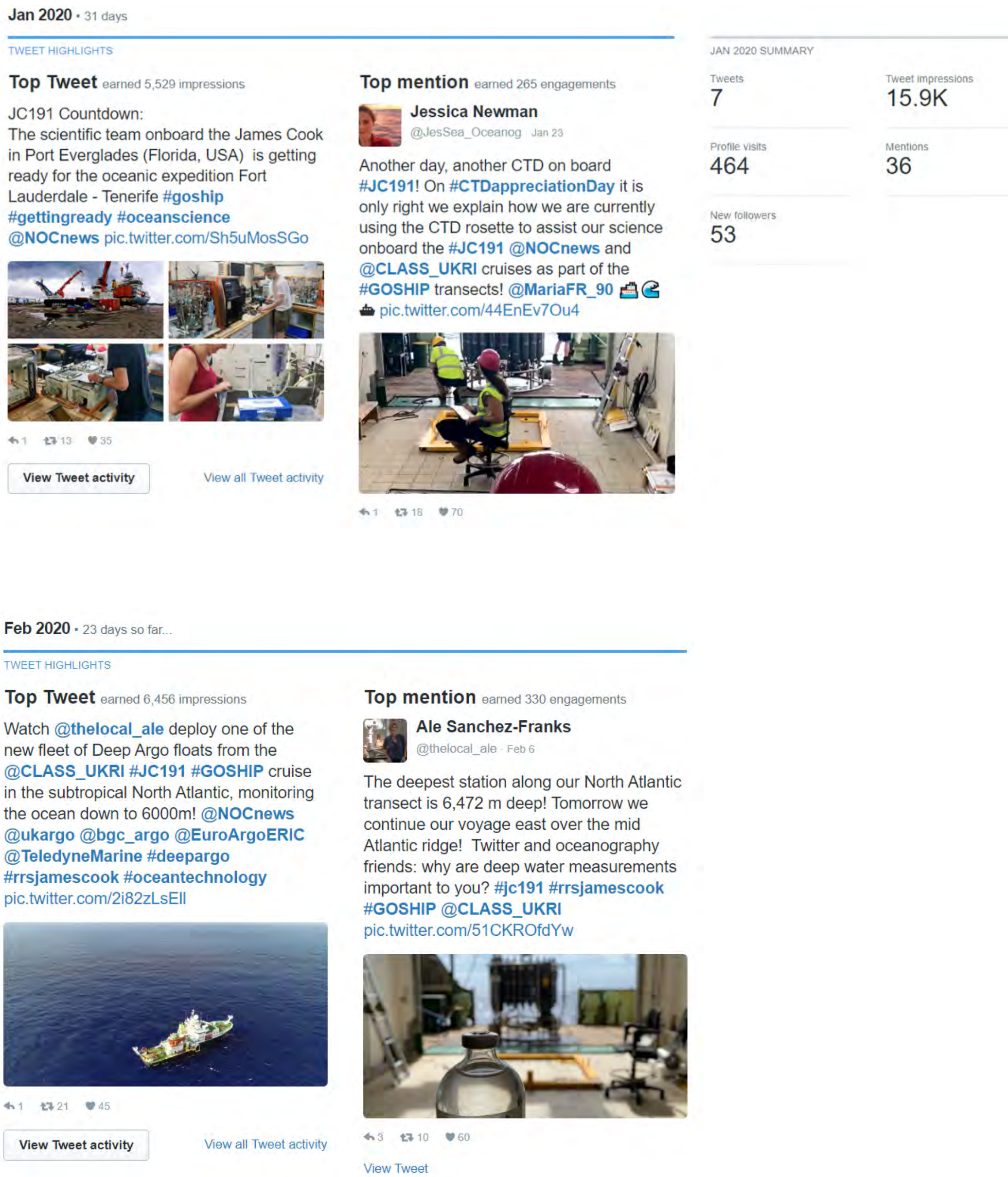

Figure 22.2: *Twitter analytic highlights for the account @CLASS_UKRI relating to the top tweet and mention for January 2020 (top) and February 2020 (bottom).*

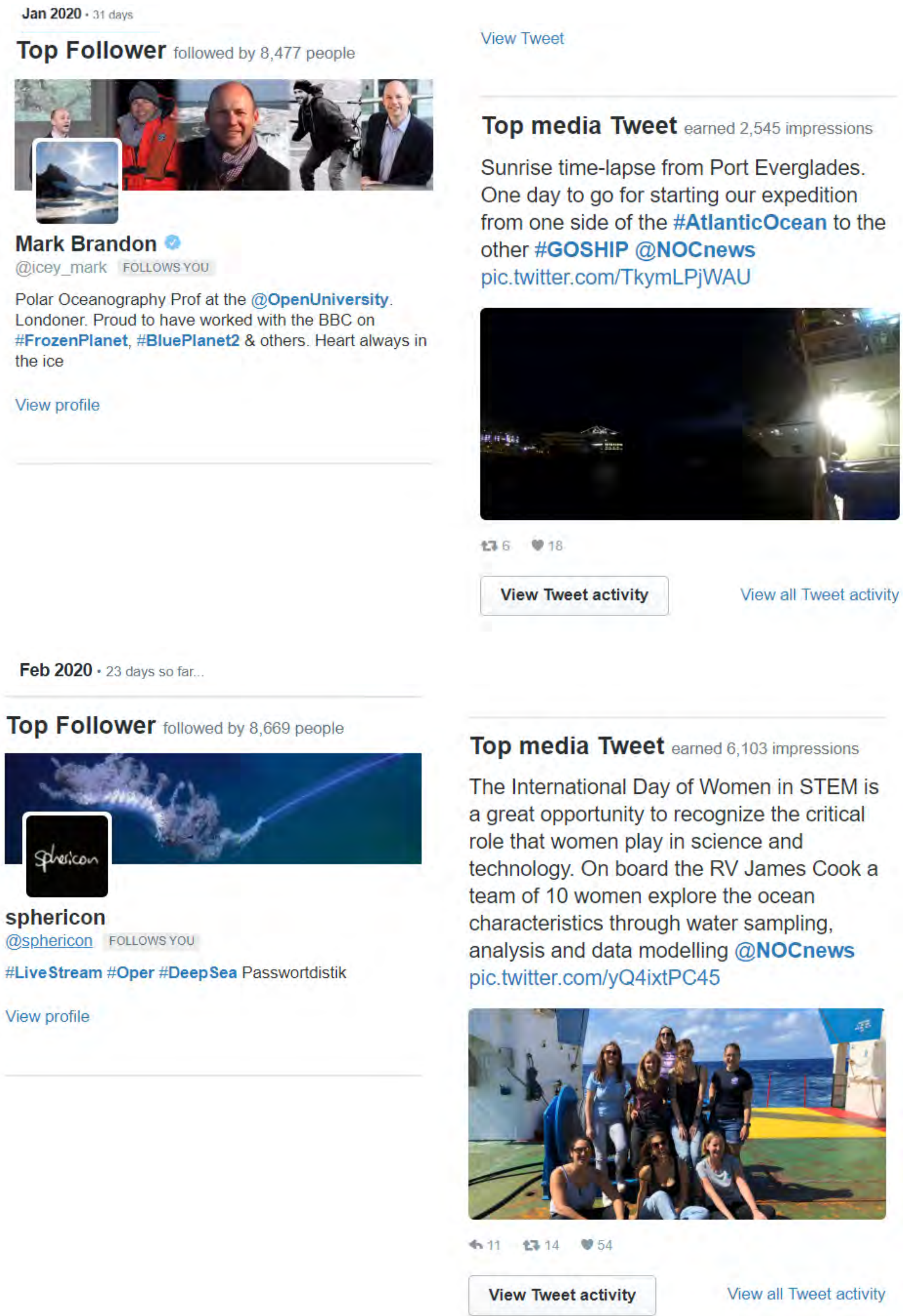

Figure 22.3: *Additional Twitter analytics for the account @CLASS_UKRI relating to the top follower and top media tweet for January 2020 (top) and February 2020 (bottom).*

22.2 Facebook

The official Facebook account from the National Oceanography Centre was used to Live stream from the Mid Atlantic Ridge on the international day of women and girls on STEM. In the video the female scientists on board the vessel briefly explained their background and role in the expedition. Live streaming from the remote Atlantic Ocean was possible thanks to the great Satellite internet connection that was managed by the RV JC technician team.

22.3 Blog content

During the expedition, blog content has been posted weekly on the UK CLASS project website. A total of 7 blog posts can be found under the titles:

- A brief overview of the JC191 Expedition (CLASS Cruise Date: 2020-01-24) written by Peter Brown and Maria De La Fuente
- James Cook Passes the Eddy Graveyard (CLASS Cruise Date: 2020-01-29) written by Thomas Wilder
- 20000 leagues under the sea (CLASS Cruise Date: 2020-02-03) written by Katherine Grayson
- Women in STEM day (CLASS Cruise Date: 2020-02-12) written by all female scientist and technicians on board the RV JC.
- The nightshift on JC191 (CLASS Cruise Date: 2020-02-17) written by Hannelore Theetaert.
- JC191 – Day 24 on sea (CLASS Cruise Date: 2020-02-20) written by Lukas Marx.
- Minimizing the ups and downs of the CTD (CLASS Cruise Date: 2020-02-24) written by Jessica Newman.

Among these blog titles, the blog post dedicated to the international day of women and girls in STEM has had particular success on the social media. The blog content summarizes the qualifications, scientific experience as well as the role in the expedition of the 10 female scientists onboard the RV James Cook. The blog and twitter posts related to the text and has been shared from the National Oceanography Centre Facebook account (https://www.facebook.com/NationalOceanographyCentre/posts/2798018346931678) and the Challenger Society´s blog (https://challengercaptainsblog.wordpress.com/2020/02/14/women-in-stem/).

22.4 Summary and outlook

After producing content for the outreach of JC191, we have found it exciting and fun to create content for the social media platforms, it has allowed us to delve deeper into life at sea. In the future we believe it is important to utilise this tool, building upon individual science communication skills while boosting the audience of ocean sciences.

Maria de la Fuente Ruiz and Jessica Newman

Appendix A: Station Summary

stn	yy/mo/dd	hhmm	dg	min	lat	dg	min	lon	cordep	maxd	minalt	resid	maxw	maxp	ndpths	nsal	noxy	nnut	nco2	ndel13c_noc_shore	ndel14c_shore	Comments
	19/01/2020	2343																				
001	20/01/2020	0002	26	26.01	N	78	40.02	W	762	704	-9	-999	700	709	12	24	0	24	5	0	0	Test station
	20/01/2020	0034																				
	20/01/2020	1415																				
002	20/01/2020	1419	26	59.98	N	80	00.07	W	37	33	4	0	30	33	5	5	5	5	7	0	0	Start of Florida St
	20/01/2020	1429																				
	20/01/2020	1532																				
003	20/01/2020	1545	27	00.33	N	79	59.30	W	65	58	7	-0	55	58	7	7	6	7	8	0	0	
	20/01/2020	1557																				
	20/01/2020	1759																				
004	20/01/2020	1814	27	00.75	N	79	55.95	W	148	142	7	1	140	142	12	12	12	12	11	0	0	
	20/01/2020	1833																				

	20/01/2020	2056																				
005	20/01/2020	2113	27	00.87	N	79	51.97	W	267	259	8	-1	260	260	12	12	12	12	12	0	0	
	20/01/2020	2134																				
	21/01/2020	0002																				
006	21/01/2020	0017	27	00.83	N	79	47.02	W	389	380	9	-0	383	382	11	10	11	10	13	0	0	
	21/01/2020	0042																				
	21/01/2020	0319																				
007	21/01/2020	0336	27	00.98	N	79	41.03	W	532	525	7	0	525	530	12	12	12	12	13	13	6	
	21/01/2020	0403																				
	21/01/2020	0610																				
008	21/01/2020	0631	27	00.82	N	79	37.01	W	647	638	10	1	640	643	12	12	11	12	13	0	0	
	21/01/2020	0701																				
	21/01/2020	0925																				
009	21/01/2020	0942	27	00.50	N	79	29.95	W	762	754	7	-1	754	761	12	12	12	12	13	0	0	
	21/01/2020	1009																				
	21/01/2020	1217																				
010	21/01/2020	1235	27	00.32	N	79	21.93	W	671	669	2	-0	670	675	12	12	12	12	12	0	0	
	21/01/2020	1302																				
	21/01/2020	1511																				
011	21/01/2020	1529	27	00.22	N	79	17.06	W	617	606	11	1	605	611	12	12	12	12	12	0	0	

	21/01/2020	1600																				
	21/01/2020	1744																				
012	21/01/2020	1757	27	00.10	N	79	12.04	W	483	472	11	0	470	476	12	12	12	12	13	0	0	
	21/01/2020	1826																				
	21/01/2020	2033																				
013	21/01/2020	2045	27	00.07	N	79	10.14	W	374	362	12	-1	360	364	12	11	12	12	12	0	0	End of Florida St
	21/01/2020	2107																				
	22/01/2020	2331																				
014	22/01/2020	2348	26	30.04	N	76	55.88	W	441	369	-9	-999	367	372	12	12	12	12	12	0	0	Start of main section; AHC on
	23/01/2020	0014																				
	23/01/2020	0212																				
015	23/01/2020	0254	26	29.98	N	76	51.95	W	-9	1198	-9	-999	1190	1209	12	10	12	12	12	0	0	
	23/01/2020	0343																				
	23/01/2020	0510																				
016	23/01/2020	0537	26	30.96	N	76	49.52	W	1283	1196	-9	-999	1195	1207	12	12	0	12	12	0	0	
	23/01/2020	0616																				
	23/01/2020	0817																				

017	23/01/2020	0848	26	29.89	N	76	48.07	W	1609	1443	-9	-999	1448	1458	14	13	14	14	14	0	0	
	23/01/2020	0937																				
	23/01/2020	1118																				
018	23/01/2020	1210	26	29.96	N	76	47.03	W	2319	2186	-9	-999	2191	2212	15	14	15	15	15	0	0	no LADCP data
	23/01/2020	1312																				
	23/01/2020	1516																				
019	23/01/2020	1643	26	29.83	N	76	45.70	W	3714	3708	6	0	3695	3766	21	21	21	21	20	0	0	
	23/01/2020	1818																				
	23/01/2020	2031																				
020	23/01/2020	2213	26	29.78	N	76	41.36	W	4532	4526	7	0	4510	4605	23	21	22	22	18	0	0	
	24/01/2020	0001																				
	24/01/2020	0143																				
021	24/01/2020	0300	26	29.76	N	76	41.38	W	4026	4014	12	1	4003	4079	1	0	0	0	12	0	0	Carbon bulk sample
	24/01/2020	0412																				
	24/01/2020	0549																				
022	24/01/2020	0720	26	29.88	N	76	37.25	W	4711	4700	10	-1	4685	4784	21	21	21	21	19	0	0	
	24/01/2020	0910																				
	24/01/2020	1057																				
023	24/01/2020	1229	26	30.03	N	76	32.03	W	4842	4832	10	0	4824	4920	24	21	21	22	22	0	0	Start of

																						alternating (A/B) stations
	24/01/2020	1431																				
	24/01/2020	1622																				
024	24/01/2020	1751	26	29.80	N	76	26.45	W	4836	4826	10	0	4806	4913	24	24	24	24	24	24	24	
	24/01/2020	1939																				
	24/01/2020	2125																				
026	24/01/2020	2331	26	29.96	N	76	18.02	W	4836	4825	10	-1	4809	4912	24	0	24	24	24	0	0	Data acquisition fault on 25
	25/01/2020	0128																				
	25/01/2020	0309																				
027	25/01/2020	0436	26	29.83	N	76	13.63	W	4816	4804	11	-1	4787	4891	24	23	24	23	21	0	0	
	25/01/2020	0628																				
	25/01/2020	0757																				
028	25/01/2020	0802	26	30.00	N	76	09.04	W	4811	43	-9	-999	40	44	1	0	0	0	0	0	0	WHOI Incubation bulk sample
	25/01/2020	0804																				
	25/01/2020	0916																				
029	25/01/2020	1045	26	29.96	N	76	06.09	W	4807	4794	12	-1	4781	4881	24	18	16	18	18	0	0	
	25/01/2020	1232																				

	25/01/2020	1420																				
030	25/01/2020	1548	26	29.39	N	75	54.67	W	4748	4737	9	-2	4639	4822	23	22	23	23	22	0	0	
	25/01/2020	1743																				
	25/01/2020	1943																				
031	25/01/2020	2115	26	29.79	N	75	42.56	W	4691	4680	10	-0	4664	4764	24	21	21	21	21	0	0	Niskins at 01:05 and 10:24 switched for 10L
	25/01/2020	2310																				
	26/01/2020	0049																				
032	26/01/2020	0214	26	29.80	N	75	30.39	W	4686	4677	9	0	4661	4761	24	23	23	23	23	0	0	
	26/01/2020	0404																				
	26/01/2020	0543																				
033	26/01/2020	0710	26	29.76	N	75	18.40	W	4640	4633	7	0	4620	4715	24	21	20	21	19	0	0	
	26/01/2020	0854																				
	26/01/2020	1056																				
034	26/01/2020	1218	26	30.00	N	75	04.01	W	4614	4604	9	-2	4581	4685	24	23	23	23	21	23	23	Temp2 sensor swapped after station
	26/01/2020	1407																				

	26/01/2020	1609																				
035	26/01/2020	1733	26	30.04	N	74	48.06	W	4537	4529	8	-0	4510	4608	24	23	23	23	22	0	0	
	26/01/2020	1922																				
	26/01/2020	2128																				
036	26/01/2020	2249	26	29.98	N	74	31.04	W	4496	4485	9	-2	4471	4563	24	24	24	24	21	0	0	
	27/01/2020	0035																				
	27/01/2020	0240																				
037	27/01/2020	0403	26	29.95	N	74	14.14	W	4544	4534	10	0	4510	4613	24	24	24	24	24	0	0	
	27/01/2020	0550																				
	27/01/2020	0755																				
038	27/01/2020	0926	26	29.99	N	73	56.01	W	4669	4661	7	-1	4641	4744	24	24	24	24	24	0	23	
	27/01/2020	1114																				
	27/01/2020	1339																				
039	27/01/2020	1506	26	30.06	N	73	34.01	W	4915	4905	8	-1	4881	4995	24	24	24	24	24	0	0	
	27/01/2020	1701																				
	27/01/2020	1942																				
040	27/01/2020	2122	26	29.97	N	73	12.04	W	5045	5034	11	-1	5014	5128	24	24	24	24	22	24	0	
	27/01/2020	2320																				
	28/01/2020	0207																				

041	28/01/2020	0339	26	30.05	N	72	50.36	W	5144	5133	9	-2	5114	5230	24	24	24	24	24	0	0	SBE35 installed
	28/01/2020	0548																				
	28/01/2020	0830																				
042	28/01/2020	1008	26	30.11	N	72	28.04	W	5182	5174	8	-1	5150	5272	24	24	24	24	23	0	0	
	28/01/2020	1209																				
	28/01/2020	1431																				
043	28/01/2020	1606	26	30.01	N	72	05.97	W	5270	5257	12	-1	5231	5358	24	24	24	24	20	0	0	
	28/01/2020	1820																				
	28/01/2020	2040																				
044	28/01/2020	2218	26	30.01	N	71	43.91	W	5375	5363	10	-2	5336	5467	24	24	24	24	24	0	0	
	29/01/2020	0024																				
	29/01/2020	0334																				
045	29/01/2020	0515	26	29.84	N	71	22.07	W	5483	5472	10	-2	5445	5579	24	23	24	24	21	0	0	
	29/01/2020	0730																				
	29/01/2020	0952																				
046	29/01/2020	1136	26	29.77	N	70	59.91	W	5489	5478	10	-0	5449	5586	24	24	24	24	23	24	23	
	29/01/2020	1351																				
	29/01/2020	1713																				
047	29/01/2020	1856	26	05.99	N	70	37.99	W	5504	5492	12	-0	5465	5600	24	24	24	24	24	0	0	

	29/01/2020	2108																				
	30/01/2020	0028																				
048	30/01/2020	0208	25	41.74	N	70	15.89	W	5515	5503	11	-1	5473	5611	21	21	21	21	21	0	0	
	30/01/2020	0416																				
	30/01/2020	0754																				
049	30/01/2020	0932	25	17.99	N	69	54.00	W	5503	5492	10	-1	5462	5600	24	24	24	24	24	0	0	
	30/01/2020	1155																				
	30/01/2020	1519																				
050	30/01/2020	1659	24	53.98	N	69	31.94	W	5595	5584	11	-0	5550	5695	24	24	24	24	24	0	0	
	30/01/2020	1911																				
	30/01/2020	2247																				
051	31/01/2020	0027	24	30.01	N	69	09.01	W	5639	5629	10	-1	5598	5740	24	24	24	24	22	0	0	
	31/01/2020	0242																				
	31/01/2020	0705																				
052	31/01/2020	0846	24	30.00	N	68	24.89	W	5715	5704	10	-1	5671	5818	24	24	24	24	23	24	0	
	31/01/2020	1114																				
	31/01/2020	1536																				
053	31/01/2020	1723	24	30.02	N	67	40.07	W	5705	5691	13	-1	5656	5805	24	23	22	24	23	0	0	
	31/01/2020	1939																				

	01/02/2020	0027																				
054	01/02/2020	0210	24	29.86	N	66	56.22	W	5707	5696	11	-1	5661	5810	24	24	24	24	24	0	19	
	01/02/2020	0424																				
	01/02/2020	0912																				
055	01/02/2020	1052	24	30.01	N	66	10.08	W	5276	5269	6	-1	5251	5370	24	24	24	24	24	24	0	
	01/02/2020	1302																				
	01/02/2020	1719																				
056	01/02/2020	1900	24	29.99	N	65	28.06	W	5556	5546	9	-1	5526	5655	24	24	24	24	24	0	0	
	01/02/2020	2112																				
	02/02/2020	0135																				
057	02/02/2020	0319	24	29.94	N	64	44.06	W	5714	5700	11	-3	5666	5814	24	24	24	24	24	0	0	
	02/02/2020	0532																				
	02/02/2020	0955																				
058	02/02/2020	1142	24	30.04	N	63	59.95	W	5765	5754	10	-1	5721	5870	24	24	24	24	24	24	23	
	02/02/2020	1356																				
	02/02/2020	1820																				
059	02/02/2020	2003	24	30.03	N	63	15.90	W	5803	5790	11	-2	5753	5908	24	23	23	24	24	0	0	
	02/02/2020	2226																				
	03/02/2020	0244																				
060	03/02/2020	0434	24	30.00	N	62	31.88	W	5880	5866	12	-1	5836	5986	24	24	24	24	23	0	0	

	03/02/2020	0646																				
	03/02/2020	1117																				
061	03/02/2020	1306	24	30.00	N	61	48.04	W	5775	5764	11	0	5741	5880	24	24	23	24	22	0	0	
	03/02/2020	1525																				
	03/02/2020	1946																				
062	03/02/2020	2134	24	29.99	N	61	04.00	W	5858	5848	7	-3	5821	5967	24	24	24	24	23	0	0	
	04/02/2020	0003																				
	04/02/2020	0427																				
063	04/02/2020	0614	24	29.99	N	60	20.01	W	5843	5832	10	-2	5807	5951	24	24	24	24	24	24	17	
	04/02/2020	0837																				
	04/02/2020	1305																				
064	04/02/2020	1448	24	30.01	N	59	36.09	W	5811	5800	9	-2	5776	5917	24	24	24	24	24	0	0	
	04/02/2020	1706																				
	04/02/2020	2145																				
065	04/02/2020	2330	24	30.04	N	58	52.04	W	5889	5880	8	-1	5852	6000	24	24	23	24	24	0	0	
	05/02/2020	0203																				
	05/02/2020	0633																				
066	05/02/2020	0818	24	29.99	N	58	08.01	W	5827	5816	9	-2	5788	5935	24	23	24	24	24	24	0	
	05/02/2020	1052																				

	05/02/2020	1530																				
067	05/02/2020	1727	24	29.97	N	57	23.74	W	6277	6268	9	1	6259	6402	24	23	24	24	23	0	0	Deep tow wire; some instruments off
	05/02/2020	1954																				
	06/02/2020	0026																				
068	06/02/2020	0218	24	29.95	N	56	40.07	W	6005	5995	10	-0	5982	6119	24	24	24	24	23	0	0	Deep tow wire; some instruments off
	06/02/2020	0440																				
	06/02/2020	0916																				
069	06/02/2020	1112	24	30.00	N	55	57.01	W	6466	6456	10	0	6442	6597	24	24	24	24	23	24	23	Deep tow wire; some instruments off
	06/02/2020	1340																				
	06/02/2020	1807																				
070	06/02/2020	1949	24	30.01	N	55	12.04	W	5897	5887	10	-0	5874	6007	24	24	24	24	24	0	0	Deep tow wire; some instruments off
	06/02/2020	2224																				
	07/02/2020	0303																				
071	07/02/2020	0442	24	30.01	N	54	28.38	W	5230	5218	11	-2	5195	5317	21	20	21	21	21	0	0	

	07/02/2020	0643																				
	07/02/2020	1125																				
072	07/02/2020	1317	24	30.00	N	53	44.01	W	5965	5954	9	-1	5923	6077	24	24	23	24	24	0	0	
	07/02/2020	1539																				
	08/02/2020	0310																				
073	08/02/2020	0502	24	50.35	N	53	06.11	W	5834	5821	12	-1	5796	5940	24	23	24	23	23	23	0	
	08/02/2020	0731																				
	08/02/2020	1117																				
074	08/02/2020	1304	25	06.62	N	52	40.08	W	5731	5721	6	-4	5695	5836	24	24	24	24	24	0	19	
	08/02/2020	1524																				
	08/02/2020	1919																				
075	08/02/2020	2106	25	07.51	N	52	10.05	W	5949	5937	6	-6	5906	6060	24	24	24	24	24	0	0	
	08/02/2020	2330																				
	09/02/2020	0340																				
076	09/02/2020	0518	25	01.32	N	51	40.02	W	5523	5512	11	0	5487	5621	24	24	24	24	23	0	0	
	09/02/2020	0732																				
	09/02/2020	1105																				
077	09/02/2020	1251	24	56.24	N	51	10.03	W	5796	5786	8	-2	5758	5903	24	24	24	24	24	0	0	
	09/02/2020	1510																				

	09/02/2020	1928																				
078	09/02/2020	2104	24	47.91	N	50	37.94	W	5153	5144	6	-3	5121	5240	24	24	24	24	24	0	0	
	09/02/2020	2313																				
	10/02/2020	0304																				
079	10/02/2020	0448	24	40.14	N	50	05.43	W	5589	5575	13	-1	5552	5686	24	24	23	24	24	24	0	
	10/02/2020	0655																				
	10/02/2020	1044																				
080	10/02/2020	1229	24	31.25	N	49	32.06	W	5957	5946	10	-1	5918	6068	24	24	24	24	24	0	0	
	10/02/2020	1458																				
	10/02/2020	1853																				
081	10/02/2020	2033	24	20.95	N	49	00.54	W	5379	5368	10	-1	5343	5471	24	24	24	24	24	0	0	
	10/02/2020	2248																				
	11/02/2020	0234																				
082	11/02/2020	0409	24	11.81	N	48	28.37	W	5284	5276	8	-0	5252	5376	24	24	24	24	24	0	23	
	11/02/2020	0612																				
	11/02/2020	0952																				
083	11/02/2020	1136	24	03.97	N	47	56.57	W	5282	5272	10	-0	5247	5372	24	24	24	24	24	24	0	
	11/02/2020	1343																				
	11/02/2020	1713																				
084	11/02/2020	1838	23	58.52	N	47	24.53	W	4568	4558	10	-0	4538	4637	24	22	22	23	23	0	0	

	11/02/2020	2042																				
	12/02/2020	0001																				
085	12/02/2020	0139	23	53.96	N	46	52.55	W	4862	4853	11	2	4829	4940	24	24	24	24	24	0	0	
	12/02/2020	0338																				
	12/02/2020	0710																				
086	12/02/2020	0843	23	52.43	N	46	20.07	W	5038	5031	7	0	5008	5124	24	23	24	24	23	0	0	
	12/02/2020	1050																				
	12/02/2020	1417																				
087	12/02/2020	1543	23	46.06	N	45	48.14	W	4564	4556	9	1	4536	4635	24	23	22	23	21	0	0	
	12/02/2020	1737																				
	12/02/2020	2105																				
088	12/02/2020	2228	23	43.94	N	45	16.12	W	4540	4526	10	-4	4507	4604	24	24	24	24	24	0	0	
	13/02/2020	0022																				
	13/02/2020	0403																				
089	13/02/2020	0527	23	38.13	N	44	44.13	W	4416	4406	9	-2	4389	4480	21	21	21	21	21	0	0	
	13/02/2020	0718																				
	13/02/2020	1044																				
090	13/02/2020	1215	23	32.10	N	44	12.52	W	4932	4923	6	-3	4901	5013	24	23	23	23	23	23	0	
	13/02/2020	1410																				

	13/02/2020	1747																				
091	13/02/2020	1918	23	27.00	N	43	40.34	W	4861	4856	1	-4	4836	4943	24	24	24	24	24	0	0	
	13/02/2020	2125																				
	14/02/2020	0057																				
092	14/02/2020	0229	23	22.39	N	43	08.50	W	4819	4812	7	-0	4791	4898	24	24	24	24	24	0	22	
	14/02/2020	0430																				
	14/02/2020	0802																				
093	14/02/2020	0943	23	15.02	N	42	36.03	W	5400	5387	11	-2	5362	5491	24	24	24	24	24	0	0	
	14/02/2020	1201																				
	14/02/2020	1630																				
094	14/02/2020	1752	23	20.02	N	41	53.02	W	4499	4489	8	-2	4471	4566	24	24	24	24	24	24	0	
	14/02/2020	1954																				
	14/02/2020	2236																				
095	14/02/2020	2333	23	24.01	N	41	28.02	W	4953	2097	-9	-999	2090	2121	2	3	0	0	10	0	0	Bulk water station
	15/02/2020	0023																				
	15/02/2020	0304																				
096	15/02/2020	0444	23	27.00	N	41	03.00	W	4880	4868	11	-1	4848	4955	24	23	23	23	22	0	0	
	15/02/2020	0649																				
	15/02/2020	1115																				

097	15/02/2020	1258	23	34.78	N	40	20.00	W	5895	5884	10	-2	5858	6004	24	23	23	23	23	0	0	
	15/02/2020	1514																				
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098	15/02/2020	2120	23	42.57	N	39	37.00	W	5383	5373	9	-1	5348	5477	24	23	23	23	22	0	22	
	15/02/2020	2325																				
	16/02/2020	0356																				
099	16/02/2020	0538	23	50.34	N	38	54.01	W	5621	5612	9	-0	5586	5723	24	24	24	24	24	24	0	
	16/02/2020	0759																				
	16/02/2020	1228																				
100	16/02/2020	1403	23	58.14	N	38	10.95	W	5164	5155	9	-1	5129	5251	24	24	24	24	24	0	0	
	16/02/2020	1610																				
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101	16/02/2020	2240	24	06.05	N	37	28.43	W	5711	5701	10	-1	5679	5815	24	24	24	24	24	0	0	
	17/02/2020	0051																				
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	17/02/2020	1404																				
103	17/02/2020	1538	24	21.50	N	36	02.01	W	5070	5059	9	-2	5041	5152	24	24	24	24	24	24	17	
	17/02/2020	1746																				

	17/02/2020	2226																				
104	18/02/2020	0002	24	29.33	N	35	18.93	W	5373	5362	10	-1	5343	5466	21	20	21	21	21	0	0	
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	18/02/2020	0635																				
105	18/02/2020	0810	24	30.00	N	34	36.03	W	5189	5179	9	-0	5162	5277	24	24	24	24	22	0	0	
	18/02/2020	1021																				
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	18/02/2020	1920																				
	19/02/2020	0011																				
107	19/02/2020	0154	24	30.00	N	33	12.00	W	5428	5416	11	-1	5396	5521	24	24	24	24	24	0	0	
	19/02/2020	0410																				
	19/02/2020	0856																				
108	19/02/2020	1045	24	29.98	N	32	30.01	W	5916	5906	8	-2	5884	6027	24	24	24	24	23	24	0	
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	19/02/2020	1750																				
109	19/02/2020	1937	24	30.00	N	31	48.00	W	5967	5954	10	-3	5932	6077	24	24	24	24	24	0	24	
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110	20/02/2020	0429	24	30.00	N	31	06.13	W	5797	5786	10	-1	5765	5903	24	24	24	24	24	0	0	
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111	20/02/2020	1333	24	30.04	N	30	23.99	W	5745	5732	10	-3	5711	5848	24	23	24	24	24	24	0	
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113	21/02/2020	0843	24	29.94	N	28	43.09	W	5668	5657	10	-1	5639	5770	24	24	24	24	23	0	0	
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114	21/02/2020	1908	24	29.99	N	27	44.00	W	5605	5594	10	-1	5574	5704	24	23	23	23	22	0	0	
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115	22/02/2020	0544	24	29.98	N	26	45.03	W	5464	5454	10	-1	5436	5560	24	24	24	24	23	24	22	
	22/02/2020	0757																				
	22/02/2020	1409																				
116	22/02/2020	1545	24	29.98	N	25	46.00	W	5334	5321	12	-1	5302	5423	24	24	24	24	24	0	0	
	22/02/2020	1753																				

	22/02/2020	2333																				
117	23/02/2020	0106	24	30.00	N	24	46.98	W	5211	5201	9	-1	5181	5299	21	21	21	21	21	0	0	
	23/02/2020	0306																				
	23/02/2020	0840																				
118	23/02/2020	1013	24	29.98	N	23	48.00	W	5064	5053	9	-2	5037	5147	24	24	24	24	24	24	0	
	23/02/2020	1210																				
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119	23/02/2020	1855	24	44.01	N	22	48.95	W	4894	4883	10	-1	4869	4972	24	24	24	24	23	0	21	
	23/02/2020	2100																				
	24/02/2020	0108																				
120	24/02/2020	0234	24	58.88	N	22	09.09	W	4771	4760	9	-1	4746	4845	24	24	24	24	24	0	0	
	24/02/2020	0429																				
	24/02/2020	0902																				
121	24/02/2020	1025	25	12.97	N	21	29.08	W	4585	4574	10	-1	4560	4654	24	24	24	24	24	24	0	
	24/02/2020	1218																				
	24/02/2020	1644																				
122	24/02/2020	1805	25	27.01	N	20	48.00	W	4435	4425	9	-1	4412	4501	24	24	0	24	24	0	0	
	24/02/2020	2005																				
	24/02/2020	2351																				

123	25/02/2020	0109	25	39.00	N	20	15.00	W	4211	4201	10	-0	4187	4271	24	24	24	24	24	0	0	
	25/02/2020	0256																				
	25/02/2020	0754																				
124	25/02/2020	0900	25	54.99	N	19	29.04	W	3784	3773	10	-1	3762	3832	24	24	24	24	24	24	0	
	25/02/2020	1042																				
	25/02/2020	1426																				
125	25/02/2020	1529	26	08.00	N	18	55.00	W	3454	3444	9	-1	3435	3495	24	24	24	24	23	24	21	
	25/02/2020	1708																				
	25/02/2020	2201																				
126	25/02/2020	2305	26	23.01	N	18	09.96	W	3610	3600	10	-0	3591	3655	24	24	24	24	24	0	0	
	26/02/2020	0043																				
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127	26/02/2020	0625	26	35.98	N	17	28.03	W	3649	3639	10	-1	3630	3695	24	24	24	24	24	0	0	
	26/02/2020	0801																				
	26/02/2020	1250																				
128	26/02/2020	1356	26	49.11	N	16	47.09	W	3626	3614	9	-2	3604	3670	24	24	24	24	23	0	0	
	26/02/2020	1538																				
	26/02/2020	2009																				
129	26/02/2020	2113	27	02.97	N	16	07.04	W	3486	3476	9	-1	3467	3528	24	24	24	24	24	0	0	
	26/02/2020	2246																				

	27/02/2020	0219																				
130	27/02/2020	0318	27	13.98	N	15	36.01	W	3151	3141	10	-0	3135	3186	21	0	21	0	20	0	0	
	27/02/2020	0448																				
	27/02/2020	0715																				
131	27/02/2020	0802	27	19.98	N	15	14.02	W	2845	2004	-9	-999	2001	2027	1	0	0	0	1	0	0	Bulk water station
	27/02/2020	0843																				
	27/02/2020	1130																				
132	27/02/2020	1219	27	26.02	N	14	52.02	W	2593	2583	9	-1	2576	2616	24	0	24	0	24	0	23	
	27/02/2020	1339																				
	27/02/2020	1721																				
133	27/02/2020	1758	27	37.01	N	14	14.01	W	2037	2028	9	-0	2024	2051	24	0	24	0	2	0	0	
	27/02/2020	1915																				
	27/02/2020	2221																				
134	27/02/2020	2251	27	47.00	N	13	46.00	W	1425	1415	10	-1	1411	1429	24	0	24	0	0	0	0	
	27/02/2020	2344																				
	28/02/2020	1601																				
135	28/02/2020	1622	28	25.86	N	13	13.66	W	985	977	8	-0	976	986	24	0	0	0	0	0	0	
	28/02/2020	1723																				

Appendix B: Instrument Configuration Files

The Seasave Instrument Configuration files used are shown below:

JC191_ss_nmea.xmlcon - Cast 1	**CTD JC191_a.xmlcon – Casts 1-34**
<?xml version="1.0" encoding="UTF-8"?>	<?xml version="1.0" encoding="UTF-8"?>
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<FrequencyChannelsSuppressed>0</FrequencyChannelsSuppressed>	<FrequencyChannelsSuppressed>0</FrequencyChannelsSuppressed>
<VoltageWordsSuppressed>0</VoltageWordsSuppressed>	<VoltageWordsSuppressed>0</VoltageWordsSuppressed>
<ComputerInterface>0</ComputerInterface>	<ComputerInterface>0</ComputerInterface>
<!-- 0 == SBE11plus Firmware Version >= 5.0 -->	<!-- 0 == SBE11plus Firmware Version >= 5.0 -->
<!-- 1 == SBE11plus Firmware Version < 5.0 -->	<!-- 1 == SBE11plus Firmware Version < 5.0 -->
<!-- 2 == SBE 17plus SEARAM -->	<!-- 2 == SBE 17plus SEARAM -->
<!-- 3 == None -->	<!-- 3 == None -->
<DeckUnitVersion>0</DeckUnitVersion>	<DeckUnitVersion>0</DeckUnitVersion>
<ScansToAverage>1</ScansToAverage>	<ScansToAverage>1</ScansToAverage>
<SurfaceParVoltageAdded>0</SurfaceParVoltageAdded>	<SurfaceParVoltageAdded>0</SurfaceParVoltageAdded>
<ScanTimeAdded>0</ScanTimeAdded>	<ScanTimeAdded>0</ScanTimeAdded>
<NmeaPositionDataAdded>1</NmeaPositionDataAdded>	<NmeaPositionDataAdded>1</NmeaPositionDataAdded>
<NmeaDepthDataAdded>0</NmeaDepthDataAdded>	<NmeaDepthDataAdded>0</NmeaDepthDataAdded>
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<NmeaDeviceConnectedToPC>1</NmeaDeviceConnectedToPC>	<NmeaDeviceConnectedToPC>1</NmeaDeviceConnectedToPC>
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<TemperatureSensor SensorID="55" >	<TemperatureSensor SensorID="55" >
<SerialNumber>5660</SerialNumber>	<SerialNumber>5660</SerialNumber>
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<B>0.00000000e+000</B>	<B>0.00000000e+000</B>
<C>0.00000000e+000</C>	<C>0.00000000e+000</C>
<D>0.00000000e+000</D>	<D>0.00000000e+000</D>
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<H>6.25123676e-004</H>	<H>6.25123676e-004</H>
<I>1.89680862e-005</I>	<I>1.89680862e-005</I>
<J>1.37377133e-006</J>	<J>1.37377133e-006</J>
<F0>1000.000</F0>	<F0>1000.000</F0>
<Slope>1.00000000</Slope>	<Slope>1.00000000</Slope>
<Offset>0.0000</Offset>	<Offset>0.0000</Offset>
</TemperatureSensor>	</TemperatureSensor>
</Sensor>	</Sensor>
<Sensor index="1" SensorID="3" >	<Sensor index="1" SensorID="3" >
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<CalibrationDate>13-Mar-18</CalibrationDate>	<CalibrationDate>13-Mar-18</CalibrationDate>
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<!-- Cell const and series R are applicable only for wide range sensors. -->	<!-- Cell const and series R are applicable only for wide range sensors. -->
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<CellConst>2000.0000</CellConst>	<CellConst>2000.0000</CellConst>
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      <H>1.43889874e+000</H>
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    <C2>-2.691791e-001</C2>
    <C3>1.143300e-002</C3>
    <D1>3.349300e-002</D1>
    <D2>0.000000e+000</D2>
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    <T2>-3.372510e-004</T2>
    <T3>3.990980e-006</T3>
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    <AD590M>1.280330e-002</AD590M>
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    <D>0.00000000e+000</D>
    <F0_Old>0.000</F0_Old>
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    <H>6.28603819e-004</H>
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      <H>1.43889874e+000</H>
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      <CPcor>-9.57000000e-008</CPcor>
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->
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    <T3>3.990980e-006</T3>
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      <Tau>0.0</Tau>
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     <CalibrationCoefficients equation="1" >
      <!-- Coefficients for Sea-Bird equation - SBE calibration
in 2007 and later. -->
      <Soc>4.4530e-001</Soc>
      <offset>-0.4843</offset>
      <A>-3.9219e-003</A>
      <B> 2.1940e-004</B>
      <C>-3.5163e-006</C>
      <D0> 2.5826e+000</D0>
      <D1> 1.92634e-004</D1>
      <D2>-4.64803e-002</D2>
      <E> 3.6000e-002</E>
      <Tau20> 1.1900</Tau20>
      <H1>-3.3000e-002</H1>
      <H2> 5.0000e+003</H2>
      <H3> 1.4500e+003</H3>
     </CalibrationCoefficients>
    </OxygenSensor>
   </Sensor>
   <Sensor index="6" SensorID="38" >
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     <SerialNumber>0619</SerialNumber>
     <CalibrationDate>11 Jul 2018</CalibrationDate>
     <Use2007Equation>1</Use2007Equation>
     <CalibrationCoefficients equation="0" >
      <!-- Coefficients for Owens-Millard equation. -->
      <Boc>0.0000</Boc>
      <Soc>0.0000e+000</Soc>
      <offset>0.0000</offset>
      <Pcor>0.00e+000</Pcor>
      <Tcor>0.0000</Tcor>
      <Tau>0.0</Tau>
```

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      <A>0.00000000e+000</A>
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      <C>0.00000000e+000</C>
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      <M>0.0</M>
      <CPcor>-9.57000000e-008</CPcor>
     </Coefficients>
     <Coefficients equation="1" >
      <G>-1.01951474e+001</G>
      <H>1.35763254e+000</H>
      <I>-1.05488175e-003</I>
      <J>1.41891865e-004</J>
      <CPcor>-9.57000000e-008</CPcor>
      <CTcor>3.2500e-006</CTcor>
      <!-- WBOTC not applicable unless ConductivityType = 1. -
->
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     </Coefficients>
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     <CalibrationDate>13-Jun-18</CalibrationDate>
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      <Soc>0.0000e+000</Soc>
      <offset>0.0000</offset>
      <Pcor>0.00e+000</Pcor>
      <Tcor>0.0000</Tcor>
      <Tau>0.0</Tau>
     </CalibrationCoefficients>
     <CalibrationCoefficients equation="1" >
      <!-- Coefficients for Sea-Bird equation - SBE calibration
in 2007 and later. -->
      <Soc>4.5860e-001</Soc>
      <offset>-0.5039</offset>
      <A>-4.2496e-003</A>
      <B> 2.2034e-004</B>
      <C>-3.4945e-006</C>
      <D0> 2.5826e+000</D0>
      <D1> 1.92634e-004</D1>
      <D2>-4.64803e-002</D2>
      <E> 3.6000e-002</E>
      <Tau20> 1.0700</Tau20>
      <H1>-3.3000e-002</H1>
      <H2> 5.0000e+003</H2>
      <H3> 1.4500e+003</H3>
     </CalibrationCoefficients>
    </OxygenSensor>
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     <CalibrationDate>11 Jul 2018</CalibrationDate>
     <Use2007Equation>1</Use2007Equation>
     <CalibrationCoefficients equation="0" >
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      <offset>0.0000</offset>
      <Pcor>0.00e+000</Pcor>
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      </CalibrationCoefficients>
      <CalibrationCoefficients equation="1" >
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in 2007 and later. -->
        <Soc>5.9800e-001</Soc>
        <offset>-0.4937</offset>
        <A>-3.5976e-003</A>
        <B> 1.5702e-004</B>
        <C>-2.6880e-006</C>
        <D0> 2.5826e+000</D0>
        <D1> 1.92634e-004</D1>
        <D2>-4.64803e-002</D2>
        <E> 3.6000e-002</E>
        <Tau20> 1.2000</Tau20>
        <H1>-3.3000e-002</H1>
        <H2> 5.0000e+003</H2>
        <H3> 1.4500e+003</H3>
      </CalibrationCoefficients>
    </OxygenSensor>
  </Sensor>
  <Sensor index="7" SensorID="5" >
    <FluoroChelseaAqua3Sensor SensorID="5" >
      <SerialNumber>088195</SerialNumber>
      <CalibrationDate>01-Oct-2018</CalibrationDate>
      <VB>0.151240</VB>
      <V1>2.083250</V1>
      <Vacetone>1.176100</Vacetone>
      <ScaleFactor>1.000000</ScaleFactor>
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  </Sensor>
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    <WET_LabsCStar SensorID="71" >
      <SerialNumber>CST-1719TR</SerialNumber>
      <CalibrationDate>30-March-2018</CalibrationDate>
      <M>21.6814</M>
      <B>-0.0802</B>
      <PathLength>0.250</PathLength>
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  </Sensor>
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      <CalibrationDate></CalibrationDate>
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      <OutputType>2</OutputType>
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  <Sensor index="12" SensorID="0" >
    <AltimeterSensor SensorID="0" >
      <SerialNumber>41302</SerialNumber>
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      <CalibrationCoefficients equation="1" >
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in 2007 and later. -->
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        <offset>-0.4937</offset>
        <A>-3.5976e-003</A>
        <B> 1.5702e-004</B>
        <C>-2.6880e-006</C>
        <D0> 2.5826e+000</D0>
        <D1> 1.92634e-004</D1>
        <D2>-4.64803e-002</D2>
        <E> 3.6000e-002</E>
        <Tau20> 1.2000</Tau20>
        <H1>-3.3000e-002</H1>
        <H2> 5.0000e+003</H2>
        <H3> 1.4500e+003</H3>
      </CalibrationCoefficients>
    </OxygenSensor>
  </Sensor>
  <Sensor index="7" SensorID="5" >
    <FluoroChelseaAqua3Sensor SensorID="5" >
      <SerialNumber>088195</SerialNumber>
      <CalibrationDate>01-Oct-2018</CalibrationDate>
      <VB>0.151240</VB>
      <V1>2.083250</V1>
      <Vacetone>1.176100</Vacetone>
      <ScaleFactor>1.000000</ScaleFactor>
      <Slope>1.000000</Slope>
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    </FluoroChelseaAqua3Sensor>
  </Sensor>
  <Sensor index="8" SensorID="71" >
    <WET_LabsCStar SensorID="71" >
      <SerialNumber>CST-1719TR</SerialNumber>
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      <M>21.6814</M>
      <B>-0.0802</B>
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      <Offset>0.000</Offset>
    </AltimeterSensor>
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</Sensor>	</Sensor>
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</Instrument>	</Instrument>
</SBE_InstrumentConfiguration>	</SBE_InstrumentConfiguration>

CTD JC191_b.xmlcon – Casts 35 - 74	**CTD JC191_c.xmlcon – Cast 75 onwards**
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<FrequencyChannelsSuppressed>0</FrequencyChannelsSuppressed>	<FrequencyChannelsSuppressed>0</FrequencyChannelsSuppressed>
<VoltageWordsSuppressed>0</VoltageWordsSuppressed>	<VoltageWordsSuppressed>0</VoltageWordsSuppressed>
<ComputerInterface>0</ComputerInterface>	<ComputerInterface>0</ComputerInterface>
<!-- 0 == SBE11plus Firmware Version >= 5.0 -->	<!-- 0 == SBE11plus Firmware Version >= 5.0 -->
<!-- 1 == SBE11plus Firmware Version < 5.0 -->	<!-- 1 == SBE11plus Firmware Version < 5.0 -->
<!-- 2 == SBE 17plus SEARAM -->	<!-- 2 == SBE 17plus SEARAM -->
<!-- 3 == None -->	<!-- 3 == None -->
<DeckUnitVersion>1</DeckUnitVersion>	<DeckUnitVersion>1</DeckUnitVersion>
<ScansToAverage>1</ScansToAverage>	<ScansToAverage>1</ScansToAverage>
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<ScanTimeAdded>0</ScanTimeAdded>	<ScanTimeAdded>0</ScanTimeAdded>
<NmeaPositionDataAdded>0</NmeaPositionDataAdded>	<NmeaPositionDataAdded>0</NmeaPositionDataAdded>
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<SensorArray Size="13" >	<SensorArray Size="13" >
<Sensor index="0" SensorID="55" >	<Sensor index="0" SensorID="55" >
<TemperatureSensor SensorID="55" >	<TemperatureSensor SensorID="55" >
<SerialNumber>5660</SerialNumber>	<SerialNumber>2674</SerialNumber>
<CalibrationDate>13-Mar-18</CalibrationDate>	<CalibrationDate>16-Feb-19</CalibrationDate>
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<A>0.00000000e+000</A>	<A>0.00000000e+000</A>
<B>0.00000000e+000</B>	<B>0.00000000e+000</B>
<C>0.00000000e+000</C>	<C>0.00000000e+000</C>
<D>0.00000000e+000</D>	<D>0.00000000e+000</D>
<F0_Old>0.000</F0_Old>	<F0_Old>0.000</F0_Old>
<G>4.33125757e-003</G>	<G>4.35661451e-003</G>
<H>6.25123676e-004</H>	<H>6.41897351e-004</H>
<I>1.89680862e-005</I>	<I>2.32451148e-005</I>
<J>1.37377133e-006</J>	<J>2.25383594e-006</J>
<F0>1000.000</F0>	<F0>1000.000</F0>
<Slope>1.00000000</Slope>	<Slope>1.00000000</Slope>
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</TemperatureSensor>	</TemperatureSensor>
</Sensor>	</Sensor>
<Sensor index="1" SensorID="3" >	<Sensor index="1" SensorID="3" >
<ConductivitySensor SensorID="3" >	<ConductivitySensor SensorID="3" >
<SerialNumber>3698</SerialNumber>	<SerialNumber>3698</SerialNumber>
<CalibrationDate>13-Mar-18</CalibrationDate>	<CalibrationDate>13-Mar-18</CalibrationDate>
<UseG_J>1</UseG_J>	<UseG_J>1</UseG_J>
<!-- Cell const and series R are applicable only for wide range sensors. -->	<!-- Cell const and series R are applicable only for wide range sensors. -->
<SeriesR>0.0000</SeriesR>	<SeriesR>0.0000</SeriesR>

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      <CellConst>2000.0000</CellConst>
      <ConductivityType>0</ConductivityType>
      <Coefficients equation="0" >
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        <B>0.00000000e+000</B>
        <C>0.00000000e+000</C>
        <D>0.00000000e+000</D>
        <M>0.0</M>
        <CPcor>-9.57000000e-008</CPcor>
      </Coefficients>
      <Coefficients equation="1" >
        <G>-1.01559199e+001</G>
        <H>1.43889874e+000</H>
        <I>-3.18978077e-003</I>
        <J>3.20528503e-004</J>
        <CPcor>-9.57000000e-008</CPcor>
        <CTcor>3.2500e-006</CTcor>
        <!-- WBOTC not applicable unless ConductivityType = 1. -
->
        <WBOTC>0.00000000e+000</WBOTC>
      </Coefficients>
      <Slope>1.00000000</Slope>
      <Offset>0.00000</Offset>
    </ConductivitySensor>
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  <Sensor index="2" SensorID="45" >
    <PressureSensor SensorID="45" >
      <SerialNumber>134949</SerialNumber>
      <CalibrationDate>25-Mar-19</CalibrationDate>
      <C1>-3.695717e+004</C1>
      <C2>-2.691791e-001</C2>
      <C3>1.143300e-002</C3>
      <D1>3.349300e-002</D1>
      <D2>0.000000e+000</D2>
      <T1>3.049225e+001</T1>
      <T2>-3.372510e-004</T2>
      <T3>3.990980e-006</T3>
      <T4>3.875890e-009</T4>
      <Slope>0.99992000</Slope>
      <Offset>-0.73690</Offset>
      <T5>0.000000e+000</T5>
      <AD590M>1.280330e-002</AD590M>
      <AD590B>-9.092840e+000</AD590B>
    </PressureSensor>
  </Sensor>
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      <CalibrationDate>11-Jul-19</CalibrationDate>
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      <B>0.00000000e+000</B>
      <C>0.00000000e+000</C>
      <D>0.00000000e+000</D>
      <F0_Old>0.000</F0_Old>
      <G>4.34192025e-003</G>
      <H>6.69165470e-004</H>
      <I>2.67238681e-005</I>
      <J>2.13345314e-006</J>
      <F0>1000.000</F0>
      <Slope>1.00000000</Slope>
      <Offset>0.0000</Offset>
    </TemperatureSensor>
  </Sensor>
  <Sensor index="4" SensorID="3" >
    <ConductivitySensor SensorID="3" >
      <SerialNumber>3873</SerialNumber>
      <CalibrationDate>14-Mar-18</CalibrationDate>
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        <D>0.00000000e+000</D>
        <M>0.0</M>
        <CPcor>-9.57000000e-008</CPcor>
      </Coefficients>
      <Coefficients equation="1" >
        <G>-1.01559199e+001</G>
        <H>1.43889874e+000</H>
        <I>-3.18978077e-003</I>
        <J>3.20528503e-004</J>
        <CPcor>-9.57000000e-008</CPcor>
        <CTcor>3.2500e-006</CTcor>
        <!-- WBOTC not applicable unless ConductivityType = 1. -
->
        <WBOTC>0.00000000e+000</WBOTC>
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  </Sensor>
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      <C2>-2.691791e-001</C2>
      <C3>1.143300e-002</C3>
      <D1>3.349300e-002</D1>
      <D2>0.000000e+000</D2>
      <T1>3.049225e+001</T1>
      <T2>-3.372510e-004</T2>
      <T3>3.990980e-006</T3>
      <T4>3.875890e-009</T4>
      <Slope>0.99992000</Slope>
      <Offset>-0.73690</Offset>
      <T5>0.000000e+000</T5>
      <AD590M>1.280330e-002</AD590M>
      <AD590B>-9.092840e+000</AD590B>
    </PressureSensor>
  </Sensor>
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      <C>0.00000000e+000</C>
      <D>0.00000000e+000</D>
      <F0_Old>0.000</F0_Old>
      <G>4.34192025e-003</G>
      <H>6.69165470e-004</H>
      <I>2.67238681e-005</I>
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        <Coefficients equation="0" >
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          <C>0.00000000e+000</C>
          <D>0.00000000e+000</D>
          <M>0.0</M>
          <CPcor>-9.57000000e-008</CPcor>
        </Coefficients>
        <Coefficients equation="1" >
          <G>-1.01951474e+001</G>
          <H>1.35763254e+000</H>
          <I>-1.05488175e-003</I>
          <J>1.41891865e-004</J>
          <CPcor>-9.57000000e-008</CPcor>
          <CTcor>3.2500e-006</CTcor>
          <!-- WBOTC not applicable unless ConductivityType = 1. -->
          <WBOTC>0.00000000e+000</WBOTC>
        </Coefficients>
        <Slope>1.00000000</Slope>
        <Offset>0.00000</Offset>
      </ConductivitySensor>
    </Sensor>
    <Sensor index="5" SensorID="38" >
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        <SerialNumber>0363</SerialNumber>
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          <Soc>0.0000e+000</Soc>
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        </CalibrationCoefficients>
        <CalibrationCoefficients equation="1" >
          <!-- Coefficients for Sea-Bird equation - SBE calibration in 2007 and later. -->
          <Soc>4.5860e-001</Soc>
          <offset>-0.5039</offset>
          <A>-4.2496e-003</A>
          <B> 2.2034e-004</B>
          <C>-3.4945e-006</C>
          <D0> 2.5826e+000</D0>
          <D1> 1.92634e-004</D1>
          <D2>-4.64803e-002</D2>
          <E> 3.6000e-002</E>
          <Tau20> 1.0700</Tau20>
          <H1>-3.3000e-002</H1>
          <H2> 5.0000e+003</H2>
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        <CalibrationDate>11 Jul 2018</CalibrationDate>
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        <CalibrationCoefficients equation="0" >
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        <UseG_J>1</UseG_J>
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        <CellConst>2000.0000</CellConst>
        <ConductivityType>0</ConductivityType>
        <Coefficients equation="0" >
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          <B>0.00000000e+000</B>
          <C>0.00000000e+000</C>
          <D>0.00000000e+000</D>
          <M>0.0</M>
          <CPcor>-9.57000000e-008</CPcor>
        </Coefficients>
        <Coefficients equation="1" >
          <G>-1.01951474e+001</G>
          <H>1.35763254e+000</H>
          <I>-1.05488175e-003</I>
          <J>1.41891865e-004</J>
          <CPcor>-9.57000000e-008</CPcor>
          <CTcor>3.2500e-006</CTcor>
          <!-- WBOTC not applicable unless ConductivityType = 1. -->
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        <CalibrationCoefficients equation="0" >
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          <Soc>0.0000e+000</Soc>
          <offset>0.0000</offset>
          <Pcor>0.00e+000</Pcor>
          <Tcor>0.0000</Tcor>
          <Tau>0.0</Tau>
        </CalibrationCoefficients>
        <CalibrationCoefficients equation="1" >
          <!-- Coefficients for Sea-Bird equation - SBE calibration in 2007 and later. -->
          <Soc>4.5860e-001</Soc>
          <offset>-0.5039</offset>
          <A>-4.2496e-003</A>
          <B> 2.2034e-004</B>
          <C>-3.4945e-006</C>
          <D0> 2.5826e+000</D0>
          <D1> 1.92634e-004</D1>
          <D2>-4.64803e-002</D2>
          <E> 3.6000e-002</E>
          <Tau20> 1.0700</Tau20>
          <H1>-3.3000e-002</H1>
          <H2> 5.0000e+003</H2>
          <H3> 1.4500e+003</H3>
        </CalibrationCoefficients>
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    </Sensor>
    <Sensor index="6" SensorID="38" >
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        <CalibrationDate>11 Jul 2018</CalibrationDate>
        <Use2007Equation>1</Use2007Equation>
        <CalibrationCoefficients equation="0" >
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      <!-- Coefficients for Owens-Millard equation. -->
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      <Soc>0.0000e+000</Soc>
      <offset>0.0000</offset>
      <Pcor>0.00e+000</Pcor>
      <Tcor>0.0000</Tcor>
      <Tau>0.0</Tau>
     </CalibrationCoefficients>
     <CalibrationCoefficients equation="1" >
      <!-- Coefficients for Sea-Bird equation - SBE calibration
in 2007 and later. -->
      <Soc>5.9800e-001</Soc>
      <offset>-0.4937</offset>
      <A>-3.5976e-003</A>
      <B> 1.5702e-004</B>
      <C>-2.6880e-006</C>
      <D0> 2.5826e+000</D0>
      <D1> 1.92634e-004</D1>
      <D2>-4.64803e-002</D2>
      <E> 3.6000e-002</E>
      <Tau20> 1.2000</Tau20>
      <H1>-3.3000e-002</H1>
      <H2> 5.0000e+003</H2>
      <H3> 1.4500e+003</H3>
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     <Slope>1.000000</Slope>
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     <B>-0.0802</B>
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   </Sensor>
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     <CalibrationDate>16 March 2006</CalibrationDate>
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      <!-- Coefficients for Owens-Millard equation. -->
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      <Pcor>0.00e+000</Pcor>
      <Tcor>0.0000</Tcor>
      <Tau>0.0</Tau>
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     <CalibrationCoefficients equation="1" >
      <!-- Coefficients for Sea-Bird equation - SBE calibration
in 2007 and later. -->
      <Soc>5.9800e-001</Soc>
      <offset>-0.4937</offset>
      <A>-3.5976e-003</A>
      <B> 1.5702e-004</B>
      <C>-2.6880e-006</C>
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      <D1> 1.92634e-004</D1>
      <D2>-4.64803e-002</D2>
      <E> 3.6000e-002</E>
      <Tau20> 1.2000</Tau20>
      <H1>-3.3000e-002</H1>
      <H2> 5.0000e+003</H2>
      <H3> 1.4500e+003</H3>
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   <Sensor index="11" SensorID="0" >
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     <CalibrationDate>16 March 2006</CalibrationDate>
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</Instrument>	</Instrument>
</SBE_InstrumentConfiguration>	</SBE_InstrumentConfiguration>

Tom Ballinger, Tim Powell, John Wynar

CCHDO Data Processing Notes

- **File Merge** **CCHSIO**

A05_740H20200119_ct1.tar.gz (download) #3e2c0
Date: 2020-08-18
Current Status: merged

- **CTD data from As Received to Dataset** **CCHSIO**

Date: 2020-08-18
Data Type: CTD
Action: Website Update
Note:

```
    2020 740H20200119 processing - CTD/merge - CTDPRS,CTDTMP,CTDSAL,CTDOXY

2020-08-18

CCHSIO


Submission

filename                 submitted by    date       id
--------------------- ------------- ---------- -----
740H20200119_ct1.zip Brian King     2020-03-03 14878

Changes
-------

A05_740H20200119_ct1.tar.gz
        - renamed files

Conversion
----------

file                    converted from       software
----------------------- -------------------- -----------------------
740H20200119_nc_ctd.zip 740H20200119_ct1.zip hydro 0.8.2-57-g8aa7d7a


Updated Files Manifest
----------------------

file                    stamp
----------------------- --------------
740H20200119_ct1.zip    20200818CCHSIO
740H20200119_nc_ctd.zip 20200818CCHSIO

:Updated parameters: CTDPRS,CTDTMP,CTDSAL,CTDOXY
```

```
opened in JOA 5.4.0 with no apparent problems:
     740H20200119_ct1.zip
     740H20200119_nc_ctd.zip

opened in ODV with no apparent problems:
     740H20200119_ct1.zip
```

- **File Online** **Carolina Berys**

A05_740H20200119_hy.csv.gz (download) #b8a65
Date: 2020-03-04
Current Status: unprocessed

- **File Online** **Carolina Berys**

A05_740H20200119_ct1.tar.gz (download) #3e2c0
Date: 2020-03-04
Current Status: merged

- **File Submission** **Brian King**

A05_740H20200119_ct1.tar.gz (download) #3e2c0
Date: 2020-03-03
Current Status: merged
Notes

```
James Cook Cruise 191
A05
19 Jan 2020 to 01 Mar 2020
Principal Scientist A Sanchez-Franks
Ft Laudersale, USA to Tenerife, Spain
CTD and Bottle data
```

- **File Submission** **Brian King**

A05_740H20200119_hy.csv.gz (download) #b8a65
Date: 2020-03-03
Current Status: unprocessed
Notes

```
James Cook Cruise 191
A05
19 Jan 2020 to 01 Mar 2020
Principal Scientist A Sanchez-Franks
Ft Laudersale, USA to Tenerife, Spain
CTD and Bottle data
```