National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

National Oceanography Centre

Cruise Report No. __

RRS *Discovery* Cruise DY040 (RAGNARoCC)

6 DEC 2015 - 22 JAN 2016

The 2015 transatlantic hydrography
section at 24.5°N

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Editor

2016

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DOCUMENT DATA SHEET

AUTHOR	*PUBLICATION DATE*
King, B. A. et al.	2016

TITLE

RRS Discovery Cruise DY040 (RAGNARoCC), 6 Dec 2015 – 22 Jan 2016. The 2015 transatlantic hydrography section at 24.5°N.

REFERENCE

ABSTRACT

A Hydrographic section was occupied at a nominal latitude of 24.5°N in the Atlantic Ocean during December 2015 - January 2016 on Cruise DY040 of RRS Discovery. The primary objective of this cruise was to measure ocean physical, chemical and biological parameters in order to establish regional budgets of heat, freshwater and carbon, and to infer decadal variability. Two transects were made of the Florida Strait. One with CTD and collecting water samples, and one with CTD stations only.

A total of 145 CTD/LADCP stations were sampled, including one test station and two CFC bottle blank stations. In addition to temperature, salinity and oxygen profiles from the sensors on the CTD package, water samples from a 24 x 20 litre rosette were analysed for the following parameters at all stations: salinity; dissolved oxygen; inorganic nutrients and organic nitrogen; alkalinity and dissolved inorganic carbon; CFCs. Nitrous oxide, methane and isotopes of dissolved oxygen were measured at some stations. Filtering for pigments was carried out at stations where bio-Argo floats were deployed. In addition, samples were collected from the ships' underway system to calibrate and compliment the data continually collected by the TSG (thermosalinograph). Full depth velocity measurements were made at every station by LADCP (Lowered Acoustic Doppler Current Profiler) mounted on the frame of the rosette. Throughout the cruise, velocity data in the upper few hundred metres of the water column were collected by the ship's VMADCP (Vessel Mounted Acoustic Doppler Current Profiler) transducers (75Hz and 150Hz) mounted on the hull. Meteorological variables were monitored using the onboard surface water and meteorological sampling system (SURFMET). Bathymetric data were collected using the EM122 multibeam system and the EA640 echo sounder, both of which are hull-mounted.

This report describes the methods used to acquire and process the data on board the ship during cruise DY040.

KEYWORDS

ADCP, Atlantic Ocean, carbon, CFC, circulation, cruise DYO40 2015, CTD, Discovery, Lowered ADCP, Meridional Overturning Circulation, meteorology, MOC, nutrients, oxygen, vessel mounted ADCP

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NOC = National Oceanography Centre

Technical Personnel

Name	Position	Affiliation
Zoltan NEMETH	Computer/Ship systems Technician	NMF
John WYNAR	CTD Technician	NMF
Julie WOOD	CTD Technician	NMF
Billy PLATT	CTD Technician	NMF
Jeff BENSON	Senior Technician	NMF
Richie PHIPPS	Base engineering	NMF

NMF = National Marine Facilities

Ship's Personnel

Name	Position/Rank
Antonio GATTI	Master
Richard WARNER	Chief Officer
Evelyn VOADEN	2nd Officer
Tom WILLIAMS	3rd Officer
James BILLS	Chief Engineer
Chris UTTLEY	2nd Engineer
Gavin NICHOLSON	3rd Engineer
Nick FRANKLIN	3rd Engineer
Tom BRAZIER	ETO
Ian WATTERSON	Purser
Stuart COOK	CPOD
Mick MINNOCK	CPOS
Nathan GREGORY	POD
Ian CANTLIE	A/B
Simon WILLCOX	A/B
Seamus MACNEIL	A/B
Duncan LAWES	ERPO
Peter LYNCH	Head Chef
Lloyd SUTTON	Assistant Chef
Jacqui WATERHOUSE	Steward
Jane BRADBURY	Assistant Steward

Background, Objectives and Funding

RRS Discovery Cruise DY040 was a repeat occupation of the Atlantic hydrographic section at a nominal latitude of 24.5°N. As such it will enable the study of decadal variability, of the present circulation, and the present transports of heat, freshwater, and biogeochemical tracers. The previous occupations of this line include Discovery Cruise D346 (2010) Discovery Cruise D279 (2004), Ronald H Brown (1998), Hesperides HE06 (1992) The cruise was a contribution to the RAGNARoCC Project (http://www.greenhouse-gases.org.uk/projects/ragnarocc), and end-of-cruise data have been submitted to the CLIVAR and Carbon Hydrographic Data Office (CCHDO).

The data collected during DY040 came from four main scientific teams, physics, chemistry (nutrients and oxygen), carbon, and CFCs.

Figure 1. Personnel on board the Discovery DY040 cruise. From left to right and from upper to lower files: Ute Sucher, Daniel Valla, Ellie, John, Seamus, Jackie, to complete once the final image has been selected.

Itinerary and station listing

Depart from Nassau (Bahamas), 10th December 2015 – arrive in Las Palmas, Spain, 22st January 2016. A full list with the CTD station positions and station details is given in Appendix A.

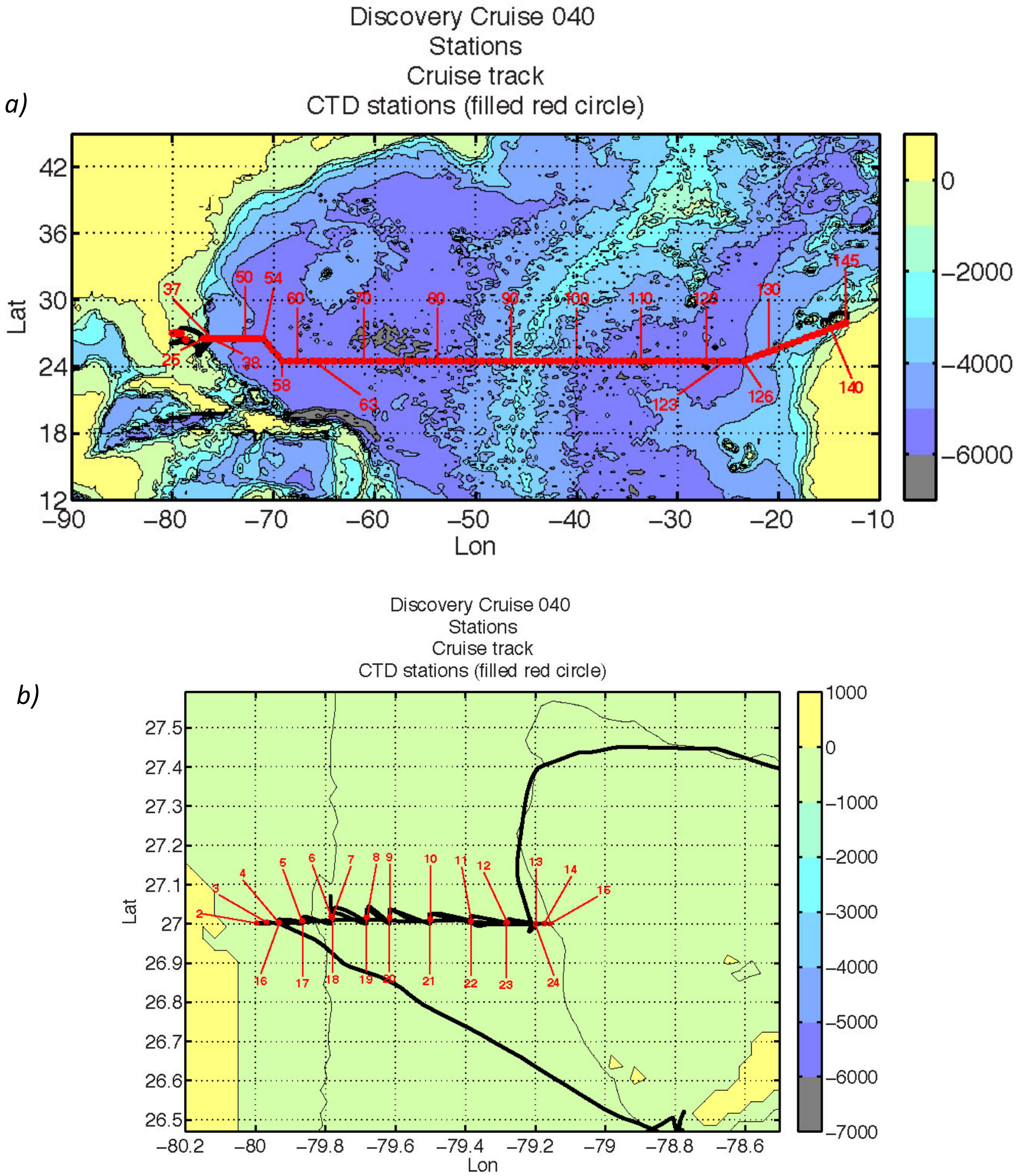
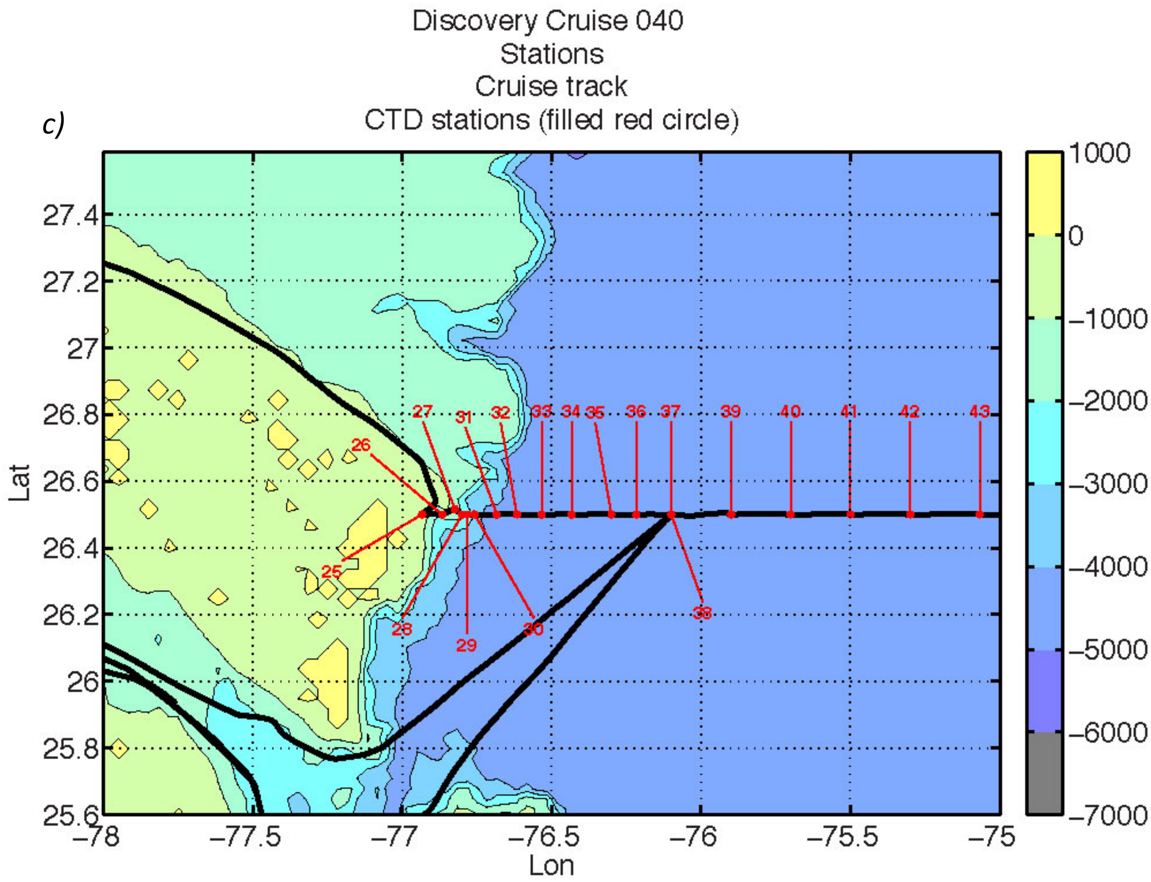


Figure 2. a) Bathymetric map and station positions (red dots) across the North Atlantic basin for Cruise DY040 . Stations 63 and 123 were for CFC bottle blanks. b) Zoom in the Florida Strait. Stations 2 to 15 were CTD with water samples. Stations 16 to 24 were CTD only.

c)



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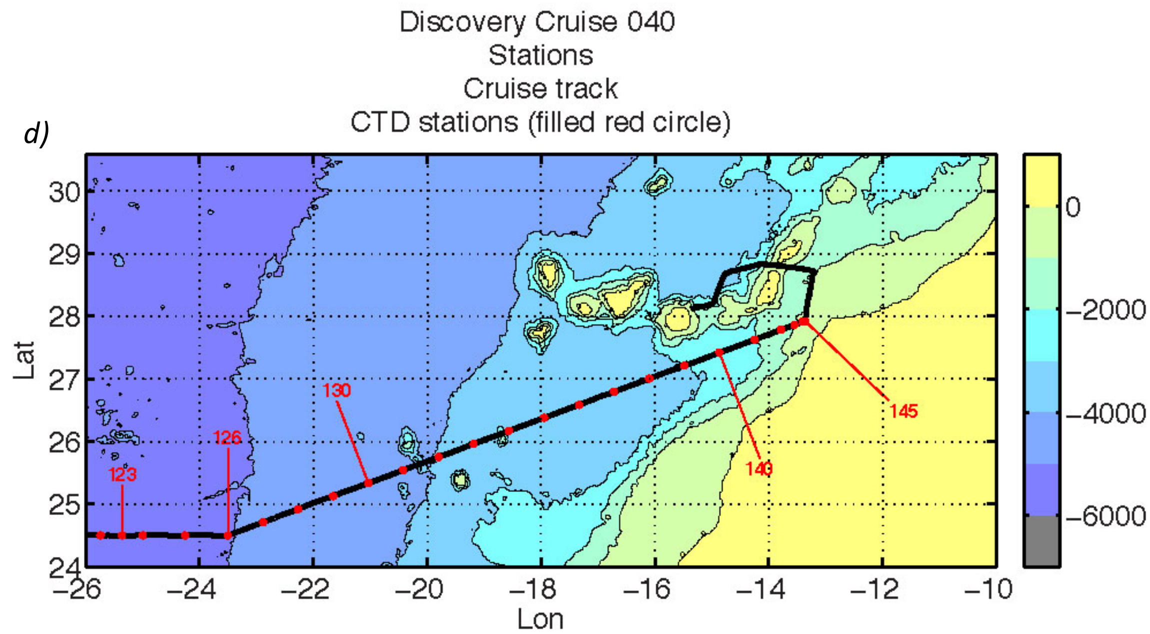


Figure 2 ***(cont).*** c) Zoom in the western boundary of the Atlantic basin (Bahamas Islands region). d) Zoom in the eastern boundary of the Atlantic basin (Canary Islands region).

Narrative, Comments and Incidents of note

1 Dec 2015: Peter Mead, UoE flew to Nassau, to begin prompt mobilisation of UoE containers.

2 Dec 2015: The scientific party arrived in Nassau, Bahamas. Peter Mead, UoE, began mobilisation of UoE containers, with Matt Tiahlo, NMFSS.

3 Dec 2015: The scientific party joined the ship, and began mobilisation, planning to depart in the morning on 6 Dec.

4,5 Dec 2015: Mobilisation continued. The scientific party were allowed to stay on the ship, which is a huge help during mobilisation.

Mobilisation was assisted by Rick Rupan (U of Washington), mobilising 6 floats from UW and assisting with the preparation of 7 other UK floats, and by June Marion (Oregon State) mobilizing chipod turbulence probes on the CTD frame.

6 Dec 2015 : RRS Discovery departs Nassau at 2345 UTC. Ship time is UTC-5. Delay was due to ongoing engine room repairs. Further repairs planned for Port Everglades. Departure was half a day later than scheduled. Tentative plans for a CTD test station en route to Port Everglades were put to one side, to enable arrival Port Everglades on evening on Monday evening.

7 Dec 2015: Arrive Port Everglades 2033 UTC. Immigration formalities cleared that afternoon.

8 Dec 2015: Loading of stores, and completion of Port State Inspection. Ongoing work in Engine Room repairs. Work completed that evening, and departure planned for 9 December, since Engine Room staff have been working long hours on repairs.

9 Dec 2015: RRS Discovery departs Port Everglades 1200UTC, 24 hours later than scheduled, en route to Freeport to clear through Bahamas formalities for work in Bahamas EEZ. AT 2045 UTC, Discovery on station offshore of Freeport to complete diplomatic activities. One seaman is transferred ashore to fly home in response to a family emergency. The Deck department was already one short, so are now two short. CPOS, CPOD plus three, rather than CPOS+6. No replacement is available, so the cruise is completed two short on deck.

Suspicion passed on from DY039 suggested substantial torque in the CTD wire, so a plan was made to use the Deep Tow wire on DY040. After completing formalities, test CTD station 001 was carried out with the Deep Tow wire. The electrical termination failed near the end of the cast, so after the cast the CTD wire was swapped in, and the process of reterminating the Deep Tow wire commenced.

10 Dec 2015: Florida Strait section started with station 002 at 0651 UTC. The station positions were those used by the NOAA/AOML lab, with some extensions at each end into shallower water. The first three stations were in 43, 100 and 144 metres, so the LADCP was not used.

Station 006: CTD wire termination failed near the bottom of the cast, so no samples are possible. Ship waited until CTD wire was reterminated, and station is repeated as station 007. Approx 9 hours delay. Station 006 shows anomalous water properties, seen only rarely in previous sections. A minimum of 2 hours is spent on each station, to gather VMADCP data and allow time for sampling on deck. The section took 39 hours elapsed time, including the 9-hour delay.

11 Dec 2015: Florida Strait section completed at station 015. The exceptional water properties revealed in station 006/007 prompted a repeat of the AOML station positions as fast as possible, with CTD only. No stops to close bottles, and no time required for sampling on deck. Stations 016 to 024 complete this section, with 024 completed 19 hours after station 015 was completed.

12 Dec 2015: Just as station 024 was being completed, a distress signal was received from a nearby yacht. A crew member had been seriously injured. The yacht came alongside Discovery and the casualty was transferred to Discovery. A US Coast Guard helicopter then completed an airlift from the foredeck of Discovery, taking the casualty to safety. Later messages indicated the casualty was making a good recovery after extensive surgical repair of arm injuries. The time taken by assisting in the emergency was no more than a couple of hours. Discovery then proceeded towards the start of the main section at station 025.

13 Dec 2015: Station 25 commenced 22 hours after station 024 ended, the time taken for the emergency and the transit around the north side of Grand Bahama. Care was taken to leave a safe distance between CTD stations and UK and US RAPID/MOCHA moorings. Station 027 was taken at latitude 26°31’ to ensure that any ship drift during the station took the ship away from the nearest mooring location.

15 Dec 2015: One of the ship’s personnel developed a dental problem. While the problem was not an immediate emergency, expert advice from ashore suggested that, if left untreated, it could develop into one. Since a medevac from the middle of the section would be catastrophic for the cruise, the decision was taken to seek dental treatment in the Bahamas. Arrangements were made to put into Freeport, and the section was broken off after station 037.

16 Dec 2015: Discovery arrived in Freeport 1340 UTC, to secure dental treatment for patient, and take on extra fuel, to ensure a comfortable reserve for the length crossing ahead. Note that Discovery fuel capacity is significantly less than James Cook, so the endurance is likewise less. This is apparently because Discovery fuel capacity is kept below 600 cu.m. , where the James Cook is not. The initial dental visit revealed more complex problems than could be treated by any dentist in Freeport. The nearest suitable dentist was in Nassau. Accordingly, the patient was flown to Nassau to receive treatment there, while Discovery waited in Freeport for the arrival of fuel by road tanker. After a long day of inactivity fuel eventually started flowing that evening, and

Discovery left Freeport just after midnight local time, 17/0510 UTC, and headed towards Nassau.

17 Dec 2015: The dental patient was picked up by small boat transfer off Nassau, and commenced 10 hours steaming towards the work area by 17/2010 UTC.

18 Dec 2015: During the Freeport/Nassau diversion, the Deep Tow wire was swapped into use. Station 038 was a repeat of station 037, and ended at 0933 UTC, 2 days and 15 hours after station 037 had ended.

18 to 22 Dec 2015: The 26.5°N section was completed with close station spacing out to 71°W. Station 054 was the corner station, and was the last with the Deep Tow. An electrical fault required a swap to the CTD wire.

The impact of the loss of 3.5 days was now considered: one day late departure from Port Everglades, plus 2.5 days diversion to Nassau for dental treatment. It was apparent that the initial ambition to work at full GO-SHIP resolution was no longer feasible. An enquiry to headquarters about possible extension to the cruise indicated that the science program was expected to absorb the loss. Since the cruise track was fixed, the delays represented a loss of 21 stations at 4hours per station. Furthermore, heading into moderately strong winds, the ship was making around 8 to 8.5 knots between stations, so there was no immediate prospect of making up time by going faster than the nominal passage speed of 10 knots.

Two modifications to the cruise program were introduced to recover the lost time. First, the cruise would go straight across latitude 24.5°N, where Discovery cruise 346 in 2010 had taken a path through the deepest part of the Kane Fracture Zone. The change in track length was small, saving one or two stations and a few hours of steaming, but the stations over the Mid Atlantic Ridge were significantly shallower, resulting in a saving of about 15 hours of wire time. Second, station spacing would be increased from the GO-SHIP standard of 30 miles, to 40 miles. This remained the station spacing for most of the cruise.

25 Dec 2015: Christmas Day. Station 062 ended at 1106 UTC (ship time was still UTC-5). Part way between station 062 and the next full station, a CFC bottle blank station 063 was introduced, ending at 1128 local time. This had the convenient consequence of ensuring Christmas Dinner was during a steaming period, with station 064 starting at 1507 ship time. The galley made every effort to ensure a good time was enjoyed by all, with only a few turned-in watchkeepers missing out.

In the small hours of 25 December, after completing station 061, the first NOC Deep APEX float was deployed. After some trial deployments of deep floats (subsequently recovered by Scripps) in 2014/2015 we believe this event will mark the start of continuous sampling of the deep ocean by the international Argo program.

26 Dec 2015: clocks changed overnight between 26 and 27 Dec. Ship time became UTC-4.

The long business of the main transect then progressed at 40 mile station spacing, with few incidents of note.

29 Dec 2015: Station 075 exceeded 6000 metres water depth. Some instruments were removed from the package (fluorometer, transmissometer, LADCP, chipods), and remained off until after station 080).

2 Jan 2016: At around 3/0100 UTC, the CTD was landed on the seabed. The echo sounders (EM122 and EA640) had reported inconsistent depths, and a poor altimeter return combined with the other misleading data to mean the CTD was landed and some extra wire paid out. An investigation was carried out and report written. On recovery of the CTD, the wire was found to be kinked, and 30 metres were cut off. The electrical properties were undamaged, but the mechanical damage to the last 30 metres was severe. Since the Deep Tow was ready as a spare, no time was lost. Operations swapped to the Deep Tow, and the CTD wire was reterminated so it could take its place as the spare. The Deep Tow remained in use until the end of the cruise.

5 Jan 2016: Station 097. The CTD was again landed on the seabed, but this time while paying out very slowly. Only a few metres were paid out after the CTD depth stopped increasing. A small kink was visible in the Deep Tow wire just above the termination, but neither the mechanical nor electrical terminations were compromised.

6 Jan 2016: Unclear water depths and a cautious approach meant that the downcast on station 101 was stopped at 4700 wire out. The LADCP never saw the bottom, and we later estimated the water depth was probably 5219 metres.

8 Jan 2016: Station 106. It had been noted over a series of stations that the residual of bottle-CTD salinity was positive for stations sampled during the main daytime hours. Many possibilities of commonality were considered, including different operators/delays at the CTD bottle stops, sampling technique on deck, autosal analysts, all of which were more or less locked to the daily shift pattern. The cause was eventually decided to be that those samples were drawn while the CTD was in strong direct sunshine, with possible evaporation into the headspace. Various tests were conducted which tended to support this explanation. Note that while steaming eastwards, the starboard working deck is in direct sunshine on hot subtropical days. Accordingly, if the CTD landed on deck during strong sunshine, it was moved into the hangar from now on. This procedure requires landing the CTD on deck, transferring the weight to a moveable boom, and moving it into the hangar. The round-trip time is about 15 minutes delay, if the package needs to be secured before the ship leaves station.

9 Jan 2016: Station 110 was around 6300 metres water depth. This exceeded the safe working depth for some of the instruments on the CTD package, so that station did not go below 6000 metres wire out.

14 Jan 2016: We were affected by the edge of what was named Hurricane Alex. The storm's wiki entry says the following: "*Hurricane Alex was the first Atlantic hurricane in*

January since Alice in 1955 and the first to form in the month since 1938. Alex originated as an extratropical cyclone near the Bahamas on January 7, 2016. The system initially traveled northeast, passing Bermuda on January 8, before turning southeast. It subsequently deepened and acquired hurricane-force winds by January 10. Slight weakening took place thereafter, and the system eventually turned east and northeast as it acquired tropical characteristics. On January 13, it developed into a subtropical cyclone well south of the Azores, becoming the first tropical or subtropical system during January in the North Atlantic since an unnamed storm in 1978. As it turned north-northeast, Alex transitioned into a full-fledged tropical cyclone on January 14 and became a hurricane." The result for Discovery was a 33 hour delay between stations 119 and 120. Of note for future planning was the limiting factor that delayed our re-start after the shutdown. This was not, as is sometimes the case, the ship's ability to reach the next station position or to deploy or recover equipment without the wire going slack. Rather, the main concern was the possibility of the wire jumping off the main sheave, if the wire angle was large, especially on hauling. Moderate fore and aft wire angles should be accommodated over the sheave by the sheave having a pendulum capability. This functionality does not work, leaving the sheave rigid. This may have cost us 12 or more hours ship time, and will hopefully be addressed soon.

15 Jan 2016: Station 123 was another CFC bottle blank station, with bottles closed at 5000 metres wireout.

20 Jan 2016: The section finished at station 145 at 2155 UTC.

21 Jan 2016: An experiment was conducted in which the ship was swung around the location of the anemometer in the bows, to study the relative wind speed reported by the anemometer when the wind was from different angles.

22 Jan 2016: The ship arrived alongside in Las Palmas, Gran Canaria at 1026 UTC, having achieved everything that is needed to address the objectives of the cruise.

As Principal Scientist I would like to acknowledge the efforts of all the ship's personnel. All the ship side and technical support worked hard to help achieve the objectives of the cruise. I was very appreciative of how quickly everyone got to grips with the scientific rhythm of the station/steaming periods, and embraced it. By any estimation, long CTD cruises are very repetitive. With so many stations, significant amounts of time can be won or lost by the bridge not giving word promptly when we are on station, the deck or the techs not being quite ready, and so on. A few minutes persistently lost here and there because of a casual approach easily adds up to a day of ship time. Once the rhythm was found, the performance of all concerned, maintained with an appropriate level of intensity throughout a long cruise, was outstanding, and equal to the best I have experienced. This efficiency was an important factor in producing a practical modified science program after our loss of time early in the cruise. Cues are always taken from the top, so the example and attitude set by the

Master for the bridge, the Technical Liaison Officer for the technical staff, and the CPOS and CPOD for the deck was critical.

I would particularly like to draw attention to the deck team, led by Mick Minnock (CPOS) and Stuart Cook (CPOD). We sailed from Nassau one short on deck, and this became two short when POD was disembarked because of a family emergency. This left 5 on deck to manage CTD deployments and 12 hours per day of winch work, in addition to other deck duties. The main burden was borne by CPOS and CPOD standing 12-on/12-off shifts, with the other three keeping ship watches. The unfailing good humour of all of them, and long hours of concentration at the winch controls resulted in safe and very efficient operations. My team found them agreeable and helpful in all interactions: a good experience for everyone from myself to the first-time PhD students.

The main science facilities required were the winches and wires, and the CTD. Although they had been tested as far as possible during trials, the winches were an unknown quantity for a cruise of this type (145 full depth stations, including 43 to over 5500 metres). There were minor things requiring remedial action, hydraulic leaks and the like, but the overall mechanical performance was excellent. I am grateful to the engineering department for their contribution to ensuring the winches delivered what was required of them.

Liquid Nitrogen: LN2 is required by the CFC analytical team. The supply of LN2 has often been a headache on cruises, when a single LN2 generator has not supplied enough to keep the CFC analyser running continuously. On this cruise we had two LN2 generators. The value of having two was demonstrated when one of them began to fail, and slowed its production rate of LN2. Because there was a second generator, once could be shut one down, dried out, and restarted, returning it to full production rate and maintaining supply throughout. The cruise benefitted enormously from the second generator being available. Science would likely have been compromised if we had only had a single generator.

1. CTD System Operation: NMF-SS Sensors & Moorings Cruise Report

Jeff Benson, Billy Platt, Julie Wood, John Wynar

1.1. *CTD system configurations*

1) One CTD system was prepared. The initial water sampling arrangement was the Zubkov 24-way stainless steel frame system (s/n 75313), and the initial sensor configuration was as follows:

- Sea-Bird 9plus underwater unit, s/n 09P-39607-0803
- Sea-Bird 3P temperature sensor, s/n 03P-4816, Frequency 0 (primary)
- Sea-Bird 4C conductivity sensor, s/n 04C-3768, Frequency 1 (primary)
- Digiquartz temperature compensated pressure sensor, s/n 93896, Frequency 2
- Sea-Bird 3P temperature sensor, s/n 03P-2674, Frequency 3 (secondary)
- Sea-Bird 4C conductivity sensor, s/n 04C-3258, Frequency 4 (secondary)
- Sea-Bird 5T submersible pump, s/n 05T-6320, (primary)
- Sea-Bird 5T submersible pump, s/n 05T-7517, (secondary)
- Sea-Bird 32 Carousel 24 position pylon, s/n 32-31240-0423
- Sea-Bird 11plus deck unit, s/n 11P-34173-0676 (main)
- Sea-Bird 11plus deck unit, s/n 11P-24680-0589 (back-up logging)

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

- Sea-Bird 43 dissolved oxygen sensor, s/n 43-0363 (V0, primary)
- Sea-Bird 43 dissolved oxygen sensor, s/n 43-0862 (V2, secondary)
- WETLabs light scattering sensor, s/n BBRTD-1055 (V4)
- Benthos PSAA-916T altimeter, s/n 59493 (V5)
- WETLabs C-Star Transmissometer, s/n CST-1602DR (V6)
- Chelsea Aquatracka MKIII fluorometer, s/n 88-2615-124 (V7)

3) Additional instruments:

- CHIpod sensor, s/n 01-09MP (upward facing)
- CHIpod battery pack, s/n Ti44-1
- CHIpod sensor holder, s/n 1
- CHIpod sensor holder, s/n 4
- CHIpod sensor holder, s/n 8
- CHIpod sensor, s/n 10-12MP (upward facing)
- CHIpod battery pack, s/n Ti44-2
- CHIpod sensor, s/n 13-01D (downward facing)
- CHIpod battery pack, s/n Ti44-5
- TRDI WorkHorse Monitor 300kHz LADCP, s/n 22797
- NOCS LADCP battery pack, s/n WH005

4) Changes to instrument suite:

- CHIpod battery pack s/n Ti44-2 replaced with s/n Ti44-3 prior to cast DY040_013.

- CHIpod battery packs s/n's Ti44-1,-3 & -5 replaced with s/n's Ti44-2, -6 & -7 prior to cast DY040_073.
- LADCP s/n 22797 replaced with s/n 13329 prior to cast DY040_025.
- LADCP s/n 13329 replaced with s/n 1855 prior to cast DY040_081.
- LADCP s/n 1855 replaced with s/n 4275 prior to cast DY040_113.
- LADCP s/n 4275 replaced with s/n 13329 prior to cast DY040_131.
- Sea-Bird 3P temperature sensor s/n 03P-2674 replaced with s/n 03P-2729 (Frequency 3, secondary) prior to cast DY040_038.
- Sea-Bird 4C conductivity sensor s/n 04C-3258 replaced with s/n 04C-3874 (Frequency 4, secondary) prior to cast DY040_038.
- All instruments rated to a depth of 6000m (LADCP, LADCP battery pack, CHIpod sensors, BBRTD, fluorometer & transmissometer) removed for deepest stations prior to cast DY040_075.
- All instruments rated to a depth of 6000m (LADCP, LADCP battery pack, CHIpod sensors, BBRTD, fluorometer & transmissometer) re-installed prior to cast DY040_081, except CHIpod sensors.
- CHIpod battery packs s/n's Ti44-3,-6 & -7 installed with sensor s/n's 13-01D, 10-02MP & 10-09MP (downward, upward & upward) prior to cast DY040_083.

5) Sea-Bird *9plus* configuration file DY040_NMEA.xmlcon was used for CTD casts 001 through 037. DY040_ss_NMEA_0803_new2tc.xmlcon was used for CTD casts 038 through 145.

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

- Sea-Bird 9plus underwater unit, s/n 09P-24680-0637
- Sea-Bird 9plus underwater unit, s/n 09P-77801-1182
- Sea-Bird 3P temperature sensor, s/n 03P-2729
- Sea-Bird 3P temperature sensor, s/n 03P-4593
- Sea-Bird 3P temperature sensor, s/n 03P-4814
- Sea-Bird 3P temperature sensor, s/n 03P-5660
- Sea-Bird 4C conductivity sensor, s/n 04C-3054
- Sea-Bird 4C conductivity sensor, s/n 04C-3698
- Sea-Bird 4C conductivity sensor, s/n 04C-3874
- Sea-Bird 4C conductivity sensor, s/n 04C-4139
- Sea-Bird 4C conductivity sensor, s/n 04C-4140
- Digiquartz temperature compensated pressure sensor, s/n 79501
- Digiquartz temperature compensated pressure sensor, s/n 129735
- Sea-Bird 5T submersible pump, s/n 05T-7515
- Sea-Bird 5T submersible pump, s/n 05T-7516
- Sea-Bird 32 Carousel 24 position pylon, s/n 32-24680-0346
- Sea-Bird 32 Carousel 24 position pylon, s/n 32-71442-0940

7) The auxiliary spare sensors were as follows:

- Sea-Bird 43 dissolved oxygen sensor, s/n 43-0619
- Sea-Bird 43 dissolved oxygen sensor, s/n 43-0709

- Sea-Bird 43 dissolved oxygen sensor, s/n 43-2575
- Sea-Bird 43 dissolved oxygen sensor, s/n 43-2831
- Benthos PSAA-916T altimeter, s/n 59494
- Benthos PSAA-916T altimeter, s/n 62679
- WETLabs light scattering sensor, s/n BBRTD-182
- WETLabs light scattering sensor, s/n BBRTD-758R
- Chelsea Alphatracka MKII transmissometer, s/n 161049
- Chelsea Alphatracka MKII transmissometer, s/n 161-2642-002
- Chelsea Aquatracka MKIII fluorometer, s/n 088244
- Chelsea Aquatracka MKIII fluorometer, s/n 88-2050-095

8) Additional instruments:

- TRDI WorkHorse Monitor 300kHz LADCP, s/n 1855
- TRDI WorkHorse Monitor 300kHz LADCP, s/n 4275
- TRDI WorkHorse Monitor 300kHz LADCP, s/n 13329
- NOCS LADCP battery pack, s/n WH006T
- NOCS LADCP battery pack, s/n WH007
- CHIpod sensor, s/n 11-22D
- CHIpod sensor, s/n 14-25D
- CHIpod sensor, s/n 14-26D
- CHIpod sensor, s/n 14-27D
- CHIpod sensor, s/n 14-36D
- CHIpod sensor, s/n 10-02MP
- CHIpod sensor, s/n 10-08MP
- CHIpod sensor holder, s/n 5
- CHIpod sensor holder, s/n 6
- CHIpod sensor holder, s/n 7
- CHIpod battery pack, s/n Ti44-3
- CHIpod battery pack, s/n Ti44-6
- CHIpod battery pack, s/n Ti47-7

Total number of casts - 145
Casts deeper than 2000m - 111
Deepest casts - 6454m on CTD2, 6032m on Deep Tow

2. CTD Data Processing and Calibration

Elaine McDonagh

2.1. *Data Processing*

The CTD data processing followed the methods used on previous NOC MPOC cruises, using the mexec software suite. The initial SeaBird processing software data conversion, align, and cell thermal mass corrections were performed (on the majority of stations) using SBE Data Processing, Version 7.22.4 software. During DY040 an option was added that the align and cell thermal mass corrections could be made in mexec so that profiles could be despiked (particularly large pressure spikes) before these corrections were made – see section 2.1.3 on editing and applying CellTM in mexec.

2.1.1. Dual oxygen sensors

Oxygen processing: On dy040, dual oxygen sensors were installed. The SBE data streams were mapped to oxygen_sbe1 and oxygen_sbe2, being the raw values in umol/kg. The reported oxygen values, after applying hyseteresis correction and other calibrations are carried in variables oxygen1 and oxygen2. All the processing scripts were converted to carry both primary and secondary oxygen. Wherever possible, backwards compatibility with a single oxygen variable was kept, but it is likely that some scripts will require further modification if there is only one oxygen variable. It is recommended that on future cruises, dual oxygen sensors are desirable. Where only one is available, it is recommended that the suffix '1' be carried on the only (primary) sensor.

2.1.2. Standard processing

The network data drives

```
discofs/specific_equipment/CTD/raw data/
discofs/specific_equipment/CTD/processed data/
```

were linked to `ctd/ASCII FILES/shipfs_ctd` and `/shipfs_ctd_raw`, and *ctd_linkscript* was used to copy files to eriu and set up additional symbolic links to filenames following mstar convention. The first step of processing is to generate empty sample files sam_dy040_nnn.nc for all casts nnn using script *msam_01*, as described in the comments at the beginning of msam_01b. For each cast the following m-files were then run, using wrapper-script ctd_all_part1: *mctd_01, mctd_02a, mctd_02b, mctd_03, mdcs_01, mdcs_02*.

The processes completed by these scripts include:

- read ASCII cnv data from ctd/ASCII FILES/ctd_dy040_001_ctm.cnv (or noctm version, see section 2.1.1)
- convert variable names from SBE names to mexec names using data/templates/ctd_dy040_renamelist.csv
- copy raw file to 24hz file
- make oxygen hysteresis adjustment on 24hz file

- average to 1hz
- calculate derived variables psal, potemp
- extract information from bottom of cast identified by maximum pressure.

Subsequently mdcs_03g was run to inspect the profiles and hand-select cast start and end times. The way oxygen time lag is handled in the SBE align algorithm, and the weak dependence of oxygen calculation on salinity, means that when air is ingested into the conductivity cell at the end of the cast, the oxygen becomes biased a few seconds earlier than the psal. Care should therefore be taken to select a cast end time for which all the important variables are free from bias. The start, bottom and end data cycles are stored in files with names like dcs_dy040_001.nc. After selecting the limits for the start and end of the cast, *ctd_all_part2* was run, executing *mctd_04*, *mfir_01*, *mfir_02*, *mwin_01*, *mwin_03*, *mwin_04* in sequence. The processes completed by these scripts include:

- Extract down and upcasts using scan numbers stored in dcs_dy040_001, and average into 2 dbar files (2db and 2up)
- Read the data/ctd/ASCII_FILES/ctd_dy040_001.bl file and extract scan numbers corresponding to bottle firing events.
- Add time from CTD file, merging on scan number
- Add CTD upcast data (P,T1,T2,S1,S2, etc) corresponding to bottle firing events
- Paste these data into the master sample file data/ctd/sam_dy040_001.nc
- Load winch telemetry data from winch SCS file
- Add winch wireout data to the fir_dy040_001 file
- Paste winch wireout data into the master sample file

Processed data could then be examined using *mctd checkplots2* to view sensor and up-down cast differences as well as compare nearby profiles, with particular attention paid to any drift in deep temperature or salinity over time. (Experience must be used to determine whether changes in properties are sensor drift or ocean variability.) The 24-Hz data were checked for spikes in either of the temperature or conductivity sensors using *mctd rawshow* and, if necessary, edited using *mctd rawedit*. It is not necessary to change directory to data/ctd before running these scripts, since the scripts find the directory automatically.

A variety of extra steps are possible after other processing has been carried out; these steps can be run in any order.

After LADCP processing has been completed there is a best estimate of water depth available from the LDEO IX processing. This is found in cast processing log files by searching for “bottom found at”; the list of stations and depths is placed in station_depths/station_depths.txt. populate_station_depths can be run to convert station_depths_dy040.txt to station_depths_dy040.mat, which is the file required by mdep_01. populate_station_depths.m also allows missing depths to be set or bad depths to be overwritten using switch/case for each cruise.

After navigation data processing has been completed the file data/nav/seapos/bst_dy040_01 will be available. mdcs_04 will generate files dcs_dy040_001 pos.nc which include position at start, bottom and end of profiles. mdcs_05 will then paste the position at the bottom of the cast into the header of all relevant files in data/ctd. mdep_01 and mdcs_05 can be run multiple times. The headers will not be updated if the updating values are identical to the values already in the file.

When a conductivity calibration is available, it is applied to the 24Hz files using mctd_condcal, as described below. A subset of scripts should now be rerun, specifically mctd_02b, mctd_condcal with senscal = 1, mctd_condcal with senscal = 2, mctd_03, mctd_04, mfir_03, mfir_04, msam_updateall. This collection of calls can usefully be put in a script like smallscript.m

Selection of data cycle start and end points is preserved by smallscript, as well as edits to the raw file made using mctd_rawedit. Water depth and position data will also be preserved and do not need to be re-entered after conductivity calibration.

Final processed and calibrated CTD data and bottle salinity data can be exported to CCHDO format using mcchdo_02 and mcchdo_01 for uploading to the CCHDO repository. Template files may need to be revised to control the list of variables exported in CCHDO csv exchange format. Temperature and salinity sections from_dy040_are shown in Figure 4.

2.1.3. Applying CTD Align and CellTM in mexec CTD processing

During dy040, some isolated spikes or bad data passed through the SBE standard processing. Severe isolated spikes (single 24Hz frames) could contaminate many seconds of data after passing through the SBE Cell Thermal Mass processing.

In order to clean the data at an appropriate stage, the align and celltm steps were coded into mexec, to be run after cleaning spikes from raw data.

The sequence required to run these steps was coded into *ctd_all_part1*. In practice the need to start with data before CellTM was not identified on any station until after *ctd_all_part1* had been run. Nevertheless, *ctd_all_part1* shows the place where the extra or alternative scripts need to be run.

On dy040, special editing was performed on stations 39, 51, 54, 87, 91, 98.

The basic path for applying Align and CellTM in mexec is

1) Copy or link the SBE cnv file without align or celltm to
data/ctd/ASCII_FILES/ctd_dy040_NNN_noctm.cnv

2)
mctd_01_noctm; % reads raw data from noctm file.
Output to
data/ctd/ctd_dy040_NNN_noctm.nc (instead of ctd_dy040_NNN_raw.nc)

3)
mctd_02a_noctm; % rename SBE variables to mexec variables
file is still called ctd_dy040_NNN_noctm.nc

4)
mctd_celltm

input: ctd_dy040_NNN_noctm.nc
output: : ctd_dy040_NNN_raw.nc

Step 4, *mctd_celltm*, applies the cell thermal mass correction with a function *ctd_apply_celltm*, which is a function of time, temp, cond. It also applies a 5 second lag to oxygen, which is the Align step.

The steps above are equivalent to the align_celltm processing usually applied in SBE software, but allows us to intervene with data cleaning at intermediate stages.

In particular two new scripts were prepared; both are run as functions:
5) *mctd_cleanedita*(NNN,'noctm') ; % apply gross range checks to remove wild spikes; range limits can be set for each cruise or station. Can be applied to 'noctm' or 'raw' file.
6) *mctd_scanedit*(NNN,'noctm'); % sets a selection of variables to NaN, for a range of scans. Eg to remove bad data when the CTD pumps tripped out during a cast. Can be applied to 'noctm' or 'raw'.

Options (5) and (6) allow cleaning of data at a raw stage, either before or after applying CellTM. On previous cruises, and on stations 1, 42 and 48 of dy040, cleaning by scan number had been applied in mctd_03. It is more logical to apply it in the raw data before generating the working 24Hz file. The original is copied to an 'original' file, with a copy in a 'cleaned' file. This is recommended for future processing. Cruise and station numbers are identified in each of options (5) and (6) by switch/case code.

A full editing path can therefore include

Script	Input file	Output file
stn = NNN; mctd_01_noctm	ctd_dy040_NNN_noctm.cnv	ctd_dy040_NNN_noctm.nc
stn = NNN; mctd_02a_noctm	ctd_dy040_NNN_noctm.nc	ctd_dy040_NNN_noctm.nc
mtd_cleanedita(NNN,'noctm')	ctd_dy040_NNN_noctm.nc	ctd_dy040_NNN_noctm_original.nc ctd_dy040_NNN_noctm_cleaned.nc
mctd_scanedit(NNN,'noctm')	ctd_dy040_NNN_noctm.nc	ctd_dy040_NNN_noctm_original.nc ctd_dy040_NNN_noctm_cleaned.nc
stn = NNN; mctd_celltm;	ctd_dy040_NNN_noctm.nc	ctd_dy040_NNN_raw.nc
mctd_scanedit(NNN,'raw')	ctd_dy040_NNN_raw.nc	ctd_dy040_NNN_raw_original.nc ctd_dy040_NNN_raw_cleaned.nc

2.2. *CTD Conductivity and Temperature Calibration*

2.2.1. Temperature calibration

The primary and reported sensor (k11) was used for the whole cruise the secondary sensor was changed after station 37. We refer to the secondary sensor used for the first 37 stations as k21 and the secondary sensor used for station 38 onwards as k22. An offset was apparent between k11 and k21 such that

k11-k21 = 0.002°C

while there was no independent reference for temperature we inferred that k21 was reading low as the necessary adjustment would reduce the k21 minus bottle salinity residual (see next section). There was no systematic disagreement between k11 and k22. There for the final calibration for the temperature sensors was

$$k21_{final} = k21_{raw} + 0.002°C$$

no adjustment was made to k11 and k22. This calibration is applied in temp_apply_cal that is called from mctd_tempcal that is part of ctd_all_part1 or smallscript. The residuals between the primary and secondary sensor are shown in Figure 3 that is generated by *test_condcal*. Residuals are shown for all water below 3000 dbar where we expect the water column to be most stable.

For the end of cruise dataset, and at 693 bottles closed deeper than 3000 dbar, ctd temp1 minus ctd temp2 has a median of -0.0002 K and an iqr of 0.0008 K.

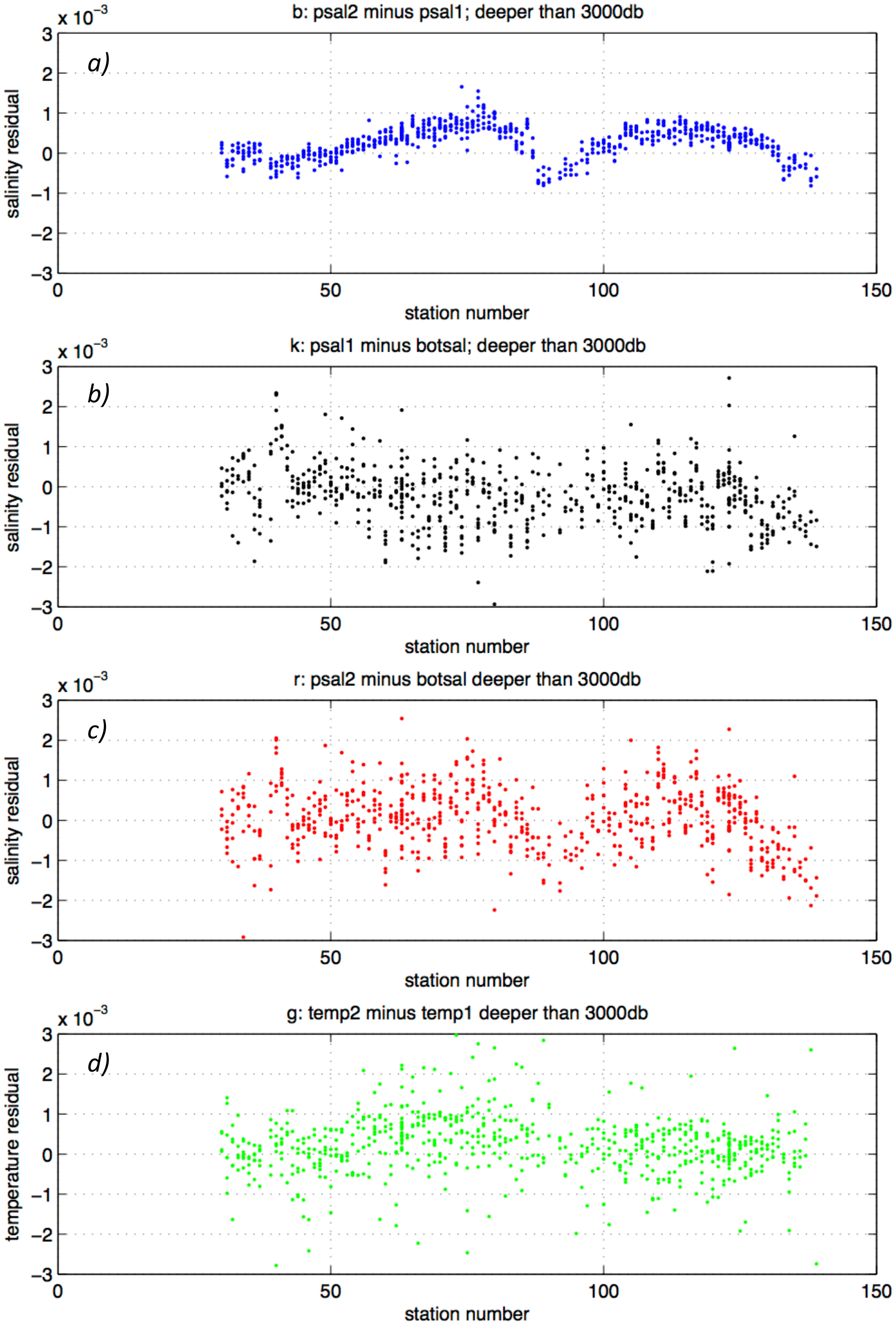


Figure 3. Residuals between a) primary and secondary conductivity (salinity) sensors, b) primary conductivity (salinity) sensors and bottle salinity , c) secondary conductivity (salinity) sensor and bottle salinity , and d) primary and secondary temperature sensors.

2.2.2. *Conductivity calibration*

A single primary conductivity sensor was used for the whole cruise and this is the sensor that has been reported in the dataset. The secondary conductivity sensor was replaced (together with the secondary temperature sensor) after station 37. We refer to the primary sensor as k11; the secondary sensor used up to station 37 as k21 and the secondary sensor used after station 37 as k22.

After the bottle salinity data are copied to sam_dy040_all.nc, ctd_evaluate_sensors.m and test_condcal can be used to examine the difference between the CTD cond1 (primary) and cond2 (secondary) sensors, and the residuals with bottle salinity. ctd_evaluate_sensors performs comparisons in both salinity and conductivity space. test_condcal isolates the ocean deeper than 3000 dbar to focus on this most stable part of the water column. These scripts display residuals and allow the user to select and test adjustments of conductivity ratio. The effect of possible adjustments can be tested without applying any adjustment to the values in the CTD files. Plots are generated to reveal biases between sensors, and either pressure- or station-dependence of bottle minus sensor differences. Once a calibration adjustment has been chosen, it can then be transferred to a switch/case in cond_apply_cal.m.

A further switch is required for each sensor.

On dy040 the adjustments to the conductivity sensors were defined in terms of a salinity offset that varied with pressure. This salinity offset is linearly interpolated on pressure onto the sensor data. The salinity offset is converted to a scaling of the conductivity ratio and applied to the 24Hz data. An initial offset was calculated for each of k11, k21 and k22. The calibration for k1 was further refined for k11 on 14th January 2016 such that the conductivity

$$K11_{final} = k11_{raw} * (k11\ offset_{initial}/35+1) * (k11\ offset_{refine}/35+1)$$

The salinity offsets that are applied to the sensors are as follows:

	k11 offset $_{initial}$	**k11 offset$_{final}$**	**k21 offset**	**k22 offset**
-10 dbar	-0.00375	0	-0.0005	-0.004
0 dbar	-0.00375	0	-0.0005	-0.004
500 dbar	-	-	-	-0.005
1000 dbar	-0.00175	0	-0.002	-0.0025
1500 dbar	-	0.0005	-	-
2000 dbar	-0.0018	0.0005	-0.0025	-
4000 dbar	-0.0028	0	-0.004	-0.003
4500 dbar	-0.0029	0	-	-
5000 dbar	-0.003	0	-0.004	-0.0025
6000 dbar	-	-	-	-0.0015
8000 dbar	-0.003	0	-0.004	-0.0015

The wrapper *smallscript.m* can then be run on a set of stations (see section 2.1 on CTD processing). This will produce calibrated CTD profiles in all the derived files (24hz, 1hz, psal, 2db, 2up) and paste the adjusted CTD data into the sam bottle files. With the exception of the ctd_dy040_nnn raw.nc file, which still contains raw data, adjusted conductivity and associated adjusted salinity will occur in all derived files from the

24hz file onwards.

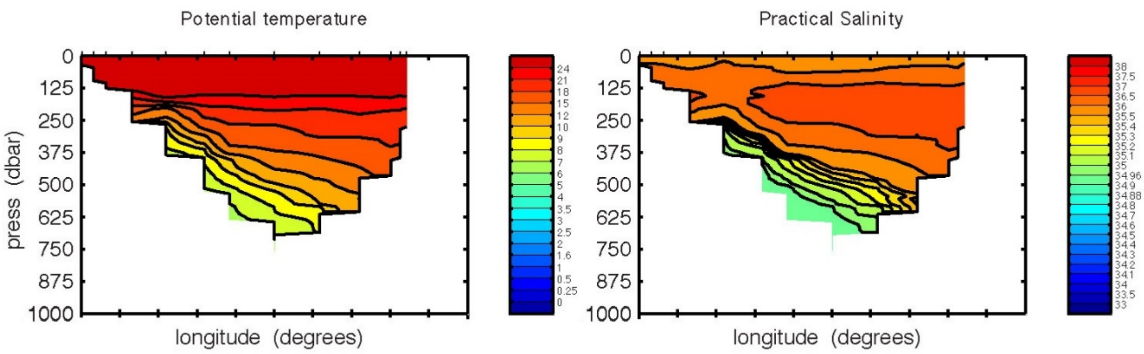
To check that the adjustment was well chosen and has been applied correctly, ctd_evaluate_sensors.m and test_condcal should now be edited to have the trial adjustment removed, so there is no adjustment in that script. The set of residuals now correspond to the data in the sam_dy040_all.nc file, and should have zero mean and no obvious vertical shape. On dy040, the difference between the primary and secondary sensors as well as the difference between each sensor and the bottle data are shown in Figure 3.

The following table summarises the residuals in the end of cruise dataset, examining residuals between the pair of sensors, and between sensors and bottles, at bottles closed deeper than 3000 dbar., where the bottle salinity quality flag is 2.

	number	median	iqr
Bottle - CTD_psal1	679	0.0002	0.0010
Bottle - CTD_psal2	679	-0.0000	0.0010
CTD_psal1 - CTD_psal2	693	-0.0003	0.0005

Structure and size of residual – something about uncertainty in final data.

Figure 4 shows the (calibrated) potential temperature and salinity distributions for the Florida Strait and Atlantic sections.



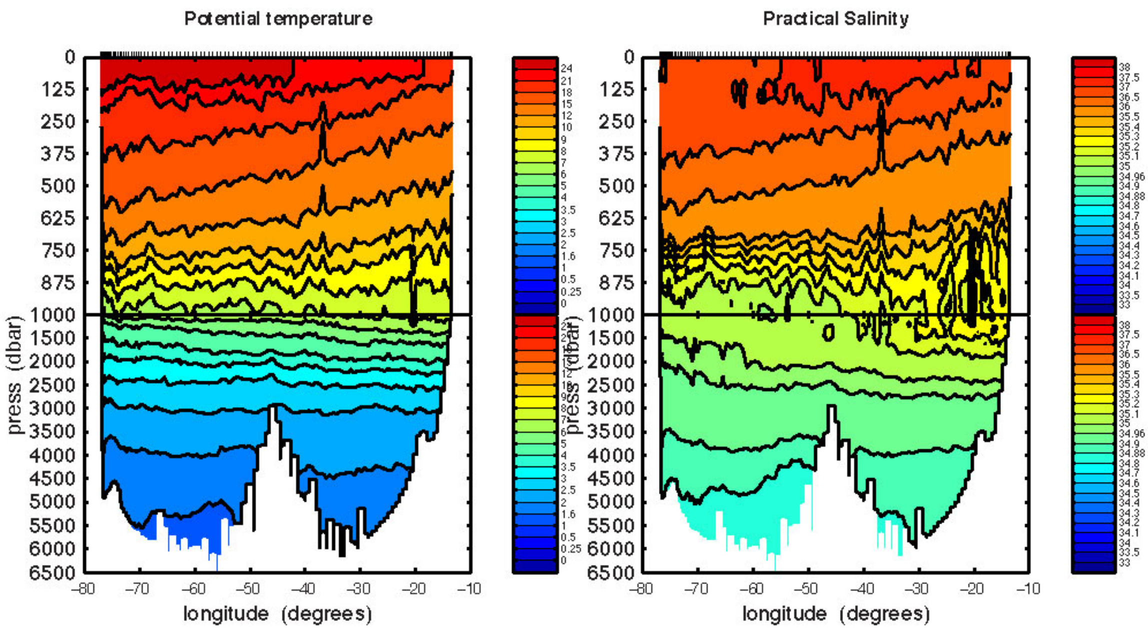


Figure 4. CTD potential temperature and salinity contours (primary sensor) for the Florida Strait (upper panels) and the Atlantic (lower panels) sections.

2.3. *CTD oxygen sensors*

2.3.1. Hysteresis correction

The hysteresis in the oxygen sensor is manifested by a difference between the upcast and downcast for a particular sensor. This difference was minimised by varying the three parameters (H1, H2, H3) included in the Seabird hysteresis correction.

H1 – amplitude of the hysteresis correction function (default = -0.033)
H2 – curvature of the hysteresis correction function (default = 5000)
H3 – time constant for hysteresis (default = 1450)

The correction is most sensitive to varying H3. The best fit (smallest upcast minus downcast residuals) is given by a short time constant at the surface, increasing time constant through the water column and the largest time constant at depth.

The constants used for the hysteresis correction are as follows. H3 (second column in H3_array) is defined at various depths (first column in H3_array) and was linearly interpolated to the appropriate depth to correct the 24Hz data. These constants can be set and applied as a cruise specific case in mcoxyhyst, otherwise the default values are set in mctd_02b and used in mcoxyhyst. mcoxyhyst is called from mctd_02b included in ctd_all_part1 or smallscript.

Sensor1
(the primary and reported sensor)

H1 = -0.045;
H2 = 5000;
H3_array = [-10 300

Sensor 2
(the secondary sensor)

H1 = -0.045;
H2 = 5000;
H3_array = [-10 300

1000 300	1000 300
1001 1000	1001 900
2000 1000	2000 900
2001 1200	2001 2000
3000 1200	3000 2000
3001 2000	3001 3000
4000 2000	4000 3000
4001 3500	4001 3900
5000 3500	5000 3900
5001 4000	7000 5000]
7000 4000]	

The residuals (upcast minus downcast on pressure) following the hysteresis correction are shown in Figure 5 for sensor 1 and Figure 6 for sensor 2. These plots were generated using scripts load_ctd_updown and plot_oxy_updown. The majority of the upcast minus downcast residuals over any depth range (averaged in 1000 dbar intervals) are less than 2 μmol kg^{-1} for any station. However as these data are differenced on pressure and include heave related ocean variability the median value averaged over a number of stations gives a better indicator of the hysteresis related error. The smoothed (solid line) median values do not exceed ±0.8 $\mu molkg^{-1}$ for Sensor 1 and ±1$\mu molkg^{-1}$ for sensor 2.

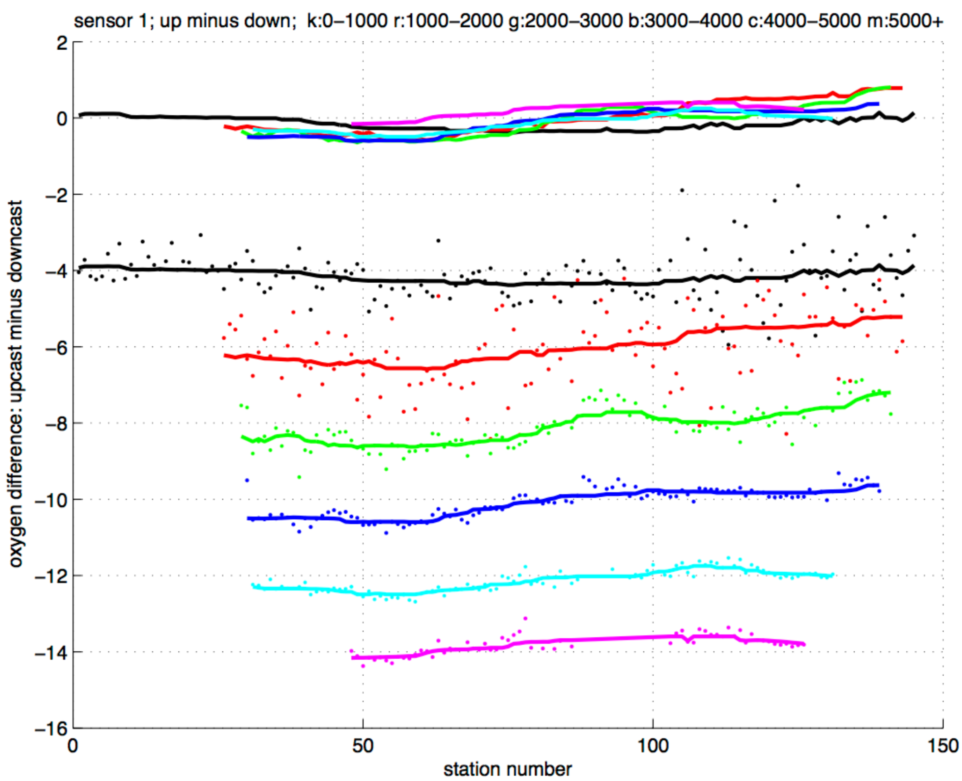


Figure 5. Upcast minus downcast oxygen primary sensor residuals over different depth ranges.

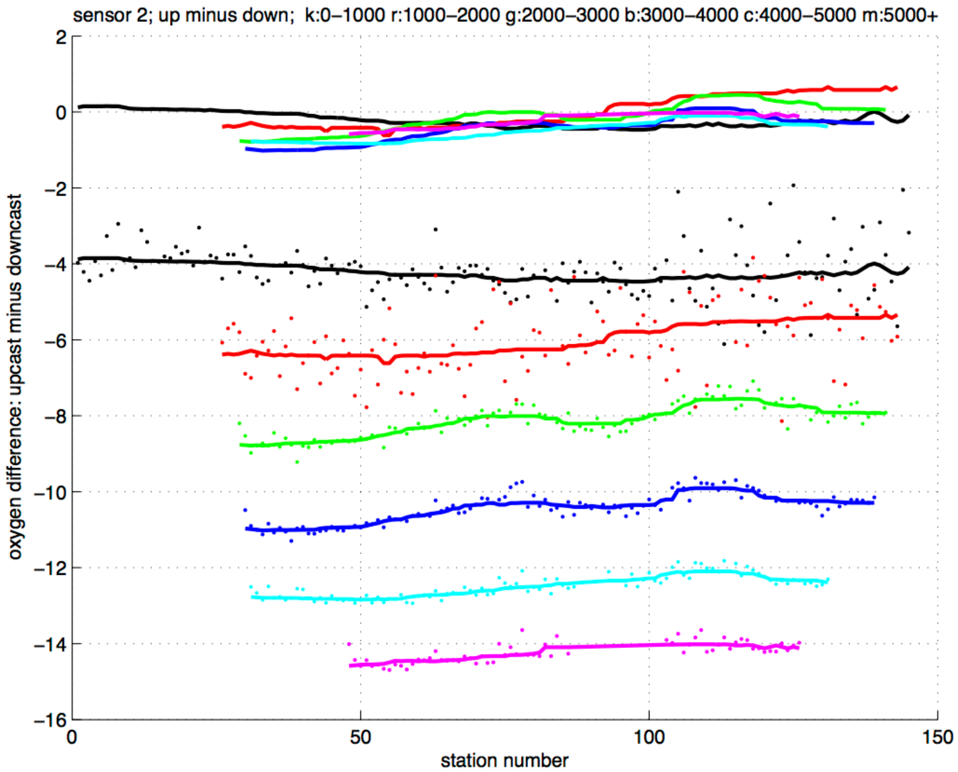


Figure 6. Upcast minus downcast oxygen secondary sensor residuals over different depth ranges.

2.3.2. Calibration

The data from the two sensors were calibrated against bottle oxygen data. Bottle oxygen samples were collected and analysed for every bottle closure. Their analysis is described in Section 4.

Using data up to station 58 an initial calibration was worked for each sensor by comparing the bottle oxygen and ctd sensor oxygen data from the upcast. This calibration corrected the sensitivity of each sensor so that the residual (bottle oxygen/ctd oxygen – 1) was minimised. The calibration correction factor (column 2) was defined at depths (column 1) for each sensor.

Sensor 1 (the primary and reported sensor) calibration correction matrix =		Sensor 2 (secondary sensor) calibration correction matrix =	
[-10	1.055	[-10	1.07
0	1.055	0	1.07
1000	1.057	1000	1.067
2000	1.069	2000	1.08
3000	1.077	3000	1.091
4000	1.083	4000	1.101
5000	1.09	5000	1.11
8000	1.09]	8000	1.11]

This calibration factor was linearly interpolated onto the depth of the sensor oxygen data and applied such that

$$\text{Oxygen}_{\text{initial calibration}} = \text{oxygen}_{\text{raw}} * \text{correction\_factor}.$$

Using data up to station 132 a final calibration was calculated on 19th January. This not only updated the calibration using the most recent data but also accommodated the changes that the final hysteresis correction had made to the sensor data.

The final calibration was interpolated from a grid of correction factors that varied with pressure and station number.

For sensor 1 the final calibration factors were:

	1	**20**	**40**	**60**	**90**	**150**
-10 dbar	0.991	1.000	1.000	1.000	1.014	1.020
500 dbar	0.991	1.000	1.000	1.000	1.014	1.020
1500 dbar	0.991	0.999	0.999	1.005	1.013	1.018
3500 dbar	0.998	0.998	0.998	1.001	1.008	1.013
7000 dbar	0.992	0.996	1.001	1.001	1.006	1.006

For sensor 2 the final calibration factors were

	1	**20**	**40**	**60**	**90**	**150**
-10 dbar	0.993	1.000	1.000	1.000	1.012	1.019
500 dbar	0.993	1.000	1.000	1.000	1.012	1.019
1500 dbar	0.993	1.002	1.002	1.005	1.012	1.017
3500 dbar	1.000	1.000	1.000	1.001	1.007	1.012
7000 dbar	1.000	1.000	1.000	1.001	1.003	1.003

the final calibration factor was bilinearly interpolated onto the sensor data station number and pressure using the matlab function interp2 and applied such that

$$\text{oxygen}_{\text{final}} = \text{oxygen}_{\text{initial calibration}} * \text{final calibration factor}$$

the final calibration factors are applied in script oxy_apply_cal called by mctd_oxycal, called in turn by either smallscript or ctd_all_part1. The final calibration factors generally increased with increasing station number (time), implying a loss of sensitivity in each of the sensors over time.

The discrepancy between the sensor and bottle data is shown as a ratio in Figure 7 and Figure 8 for sensor 1 and sensor 2 respectively, plotted using test_oxycal. The residuals for any bottle stop rarely exceed ± 2% (equivalent to ~4 $\mu molkg^{-1}$). This value includes uncertainty in both the chemical bottle analysis and the sensor calibration. The median values for any depth range (solid lines in Figure 7 and Figure 8) do not exceed ± 0.3% for sensor 1 and ± 0.4% for sensor 2, or equivalently less than 1 $\mu molkg^{-1}$.

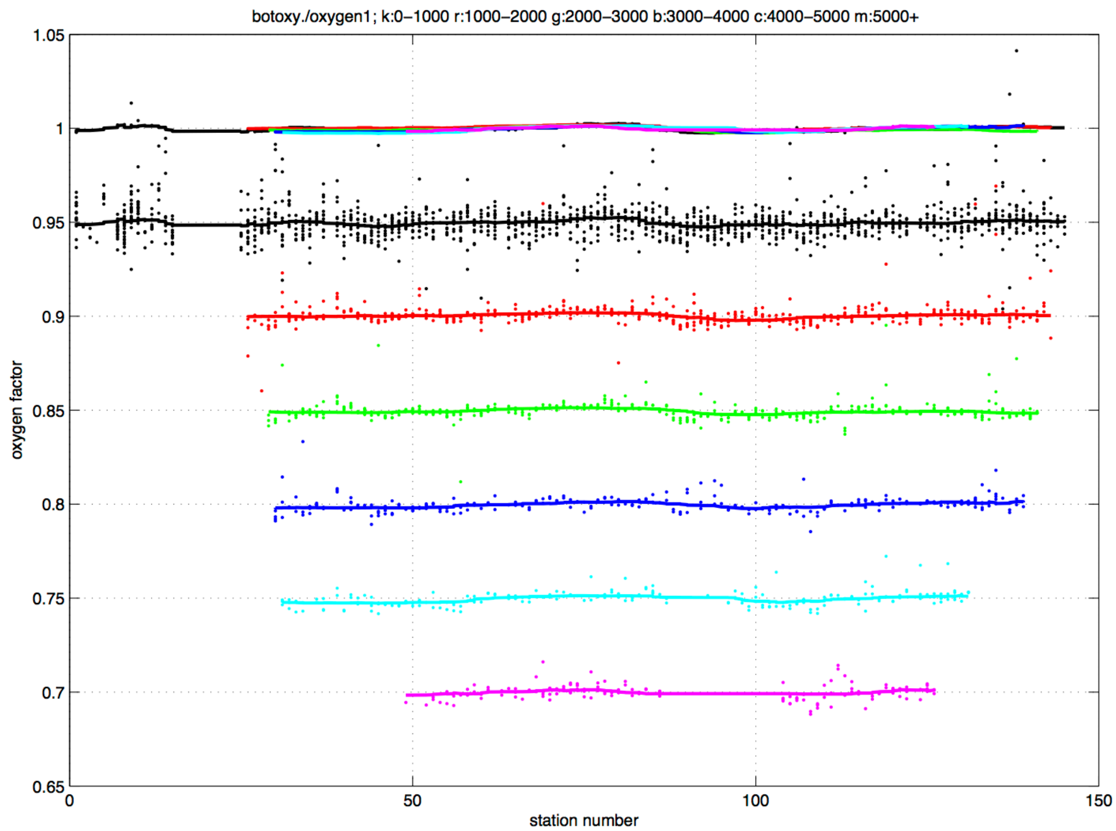


Figure 7. Ratio between bottle sampled oxygen and primary oxygen sensor at different depth ranges.

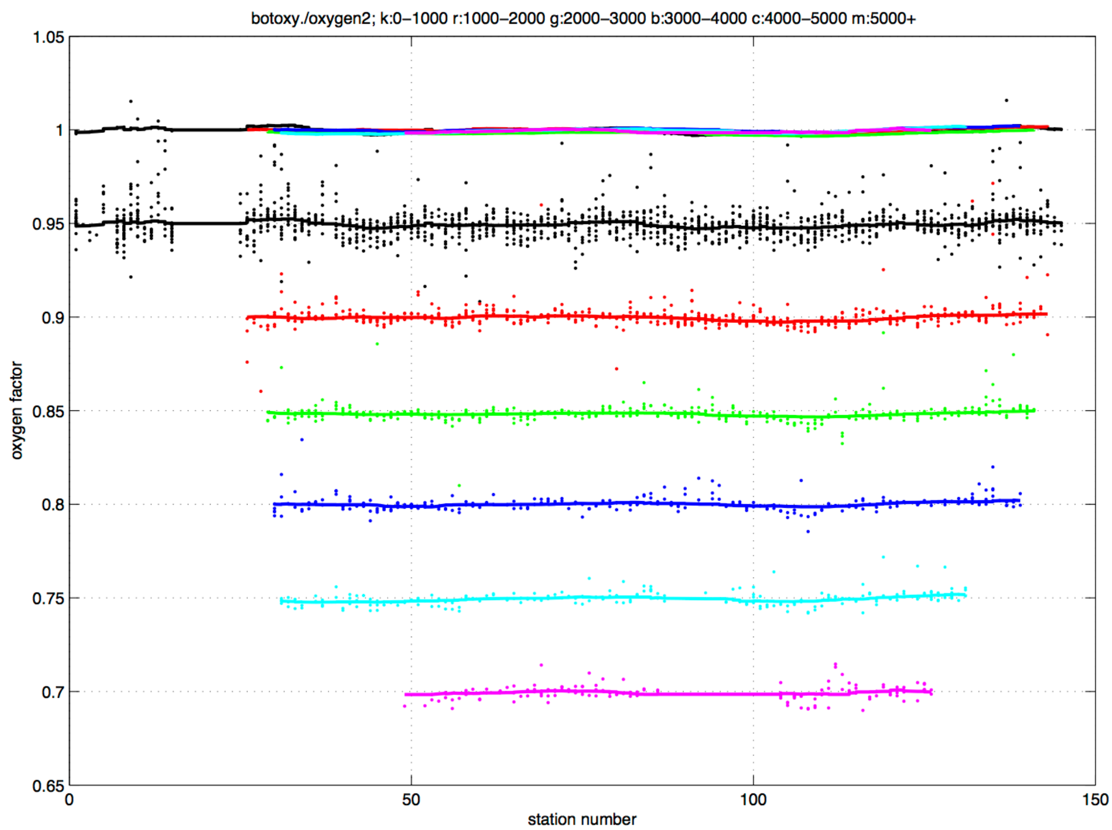
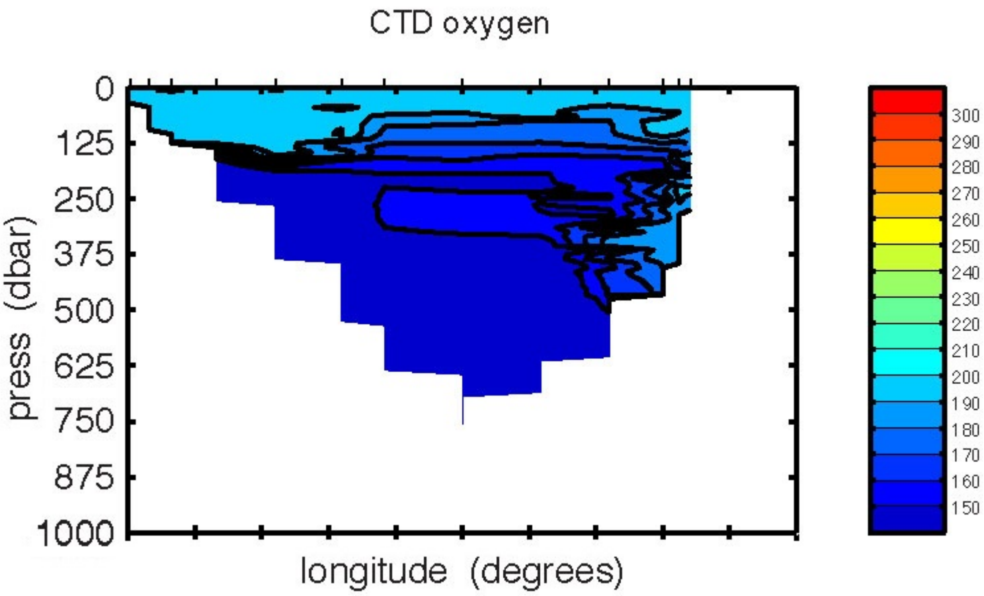


Figure 8. Ratio between bottle sampled oxygen and primary oxygen sensor at different depth ranges.

We report the primary sensor, sensor 1, and given the uncertainty related hysteresis and calibration we estimate the uncertainty in the sensor data to be ± 2 $mmolkg^{-1}$ relative to the accuracy of the bottle data.

The resulting (calibrated) oxygen distribution is shown in Figure 9.



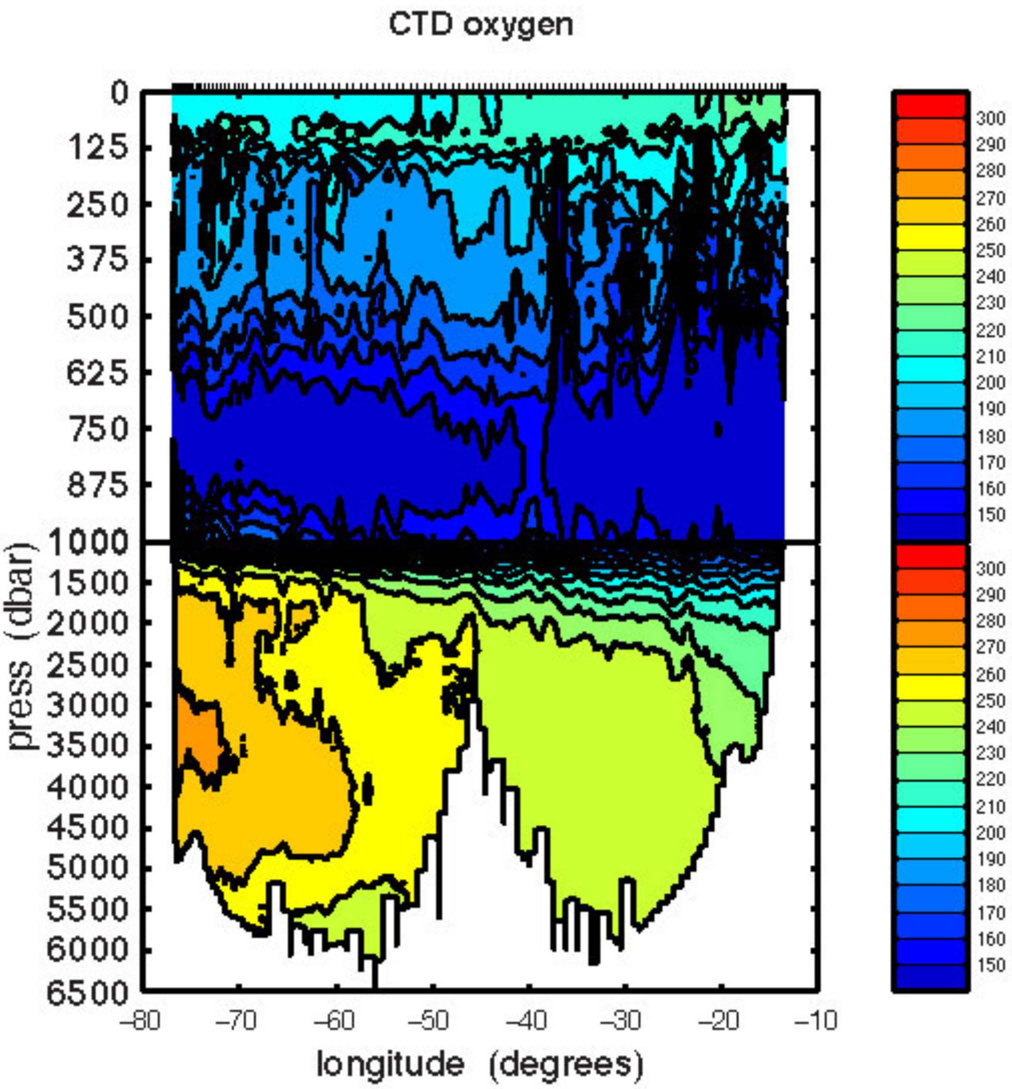


Figure 9. CTD oxygen contours (primary sensor) for the Florida Strait (upper panels) and the Atlantic (lower panels) sections.

2.4. *Forwarding of CTD data to the UK Met Office in near-real-time*

Justin Buck

2.4.1. Introduction

One of the major concerns of the National Centre for Ocean Forecasting was the lack of CTD data from the UK Research Vessel Fleet. These data are useful for ingest into operational models, especially in regions which are data sparse. Currently CTD data are transferred operationally from the RRS James Clark Ross to the UK Met Office in near-real-time. Historically this happened on the previous RRS Discovery and this report describes an attempt to implement the software on the new RRS Discovery.

2.4.2. Implementation on DY040

The transfer of CTD data is done by a package called ctd2met authored Tim Smyth (PML). The software is relatively simple and uses a shell script (ctd2met.sh) to collect .cnv files as they are produced by the seabird software, generate a reduced depth resolution version with the Seabird Seasave software, and lastly email them to the UK Met Office using the address ocean.data@metoffice.gov.uk and additionally Tim Smyth timjsmyth@googlemail.com. Clear installation instructions are included in the 00README included in the software package.

The package was installed on the machine intranet.discovery.local in the folder /home/rvs/ncof with the following parameters set in ctd2met.sh:

- Research_ship was set to "Discovery"
- Location of installation folder (top_dir) was set to "/home/rvs/ncof"
- Data file source (in_dir) set to "/home/rvs/ncof/Met_Office"
- The smtp server for emails was set to "192.168.62.44"

The processed cnv data directory for DY040 includes a space character in the folder name so the in_dir was set to a local directory on the intranet machine with data files copied across from the discofs file system which was accessed via a file system mount set up by the SST. Taking into account the file system mount to discofs the location of the raw data files is:

```
/home/rvs/ncof/mnt_smb_discofs/DY040/processed
data/Met_Office
```

This approach should be considered a temporary measure. The mount can only be created by user root and has to be frequently re-established when there are network issues.

Production of raw data files as per the format prescribed in the 00README file is an additional step for the NMF CTD technicians.

When testing is was found that rvs@intranet.discovery.local was not a valid email address on the shore side mercury.noc.soton.ac.uk email server, once it was added to the white list this issue was resolved.

2.4.3. Additional comments

The installation has been left in place on the intranet machine for future use but the cron deactivated.

3. Water Sample Salinity Analysis

Elaine McDonagh

Salinity sample analysis was performed on the BAS Guildline 8400B Salinometer, Serial No. 71185, in the Salinometer Room. The salinometer water bath temperature was set to 24°C and the laboratory temperature (checked every 4hours as part of the watchkeeping duties) maintained at within 0.5°C of 21.5°C. The only exception to this was when the air conditioning in the salinity room broke on the 5th January 2016 during the analysis of CTD cast 91. The analyst noted a 0.1°C temp increase in the room per sample over the analysis of the final four samples and the standard. The lab temperature got up to 23.2°C. The final four bottle samples were scrutinized and looked good when compared to the sensor data and so were not flagged as bad. Analysis recommenced once the temperature had got down to 21.9° C.

For each CTD cast, one water sample was drawn per Niskin bottle for salinity analysis, from bottles that were fired. The distribution of bottle sample locations is shown in Figure 10.

Samples were taken in 200ml glass sample bottles, which were rinsed three times and sealed with a new clean dry disposable plastic stopper, after drying the neck of the bottle. 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 equilibration to the laboratory temperature. A logsheet was maintained of when crates were moved into the salinometer room to keep track of when they would be ready to analyse.

Salinity analyses were carried out by the four NMFSS techs, following standard procedure. 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 P158, with a K15 value of 0.99970, giving a 2xK15 value of 1.99940.

The standardisation dial was set to 434 after the first standardisation, and not altered during the cruise. The majority of values given by the standards were in the range of 1.99930 to 1.99947. The standby (SBY) and zero numbers varied little, from 5986 to 5990 and -0.00004 to -0.00006 respectively.

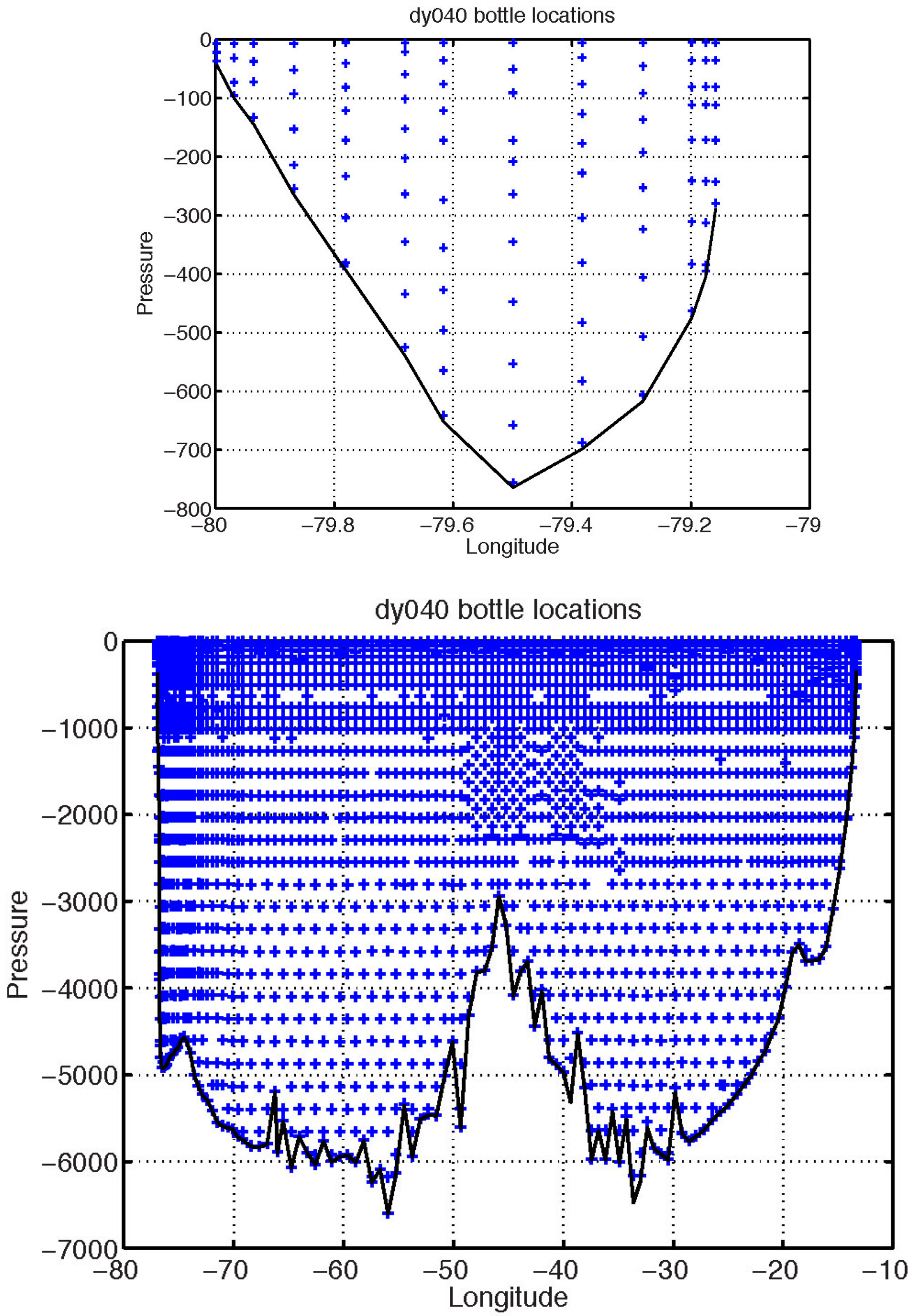


Figure 10. Depth-longitude grid of samples analysed for nutrients, oxygen and salinity samples during DY040 for the Florida Strait (upper panel) and the Atlantic Basin (lower panel).

3.1. *Sample recording and merging with CTD data*

Bottle sample data (conductivity and salinity) are recorded on a laptop into an excel file to which sample numbers are manually entered in the format sssnn (where sss indicates the station number and nn the bottle number), giving a 5-digit number.

A hard copy is also kept of bottle number, the three conductivity ratios and the average ratio. Standards are given the sample number value of 999nnn, where nnn is a sequential standard number starting with 001. Standards are recorded in the Autosal logsheet but then transcribed to a standards log in order to assess Autosal drift and choose an offset (see below) for each crate. The excel file is edited to produce, for instance, Table 1. This file is then saved as a comma-separated csv file, with the name sal_dy040_nnn.csv, which was then copied across to eriu and saved in CTD/BOTTLE SAL/. The csv files are modified by the following shell commands on eriu:

```
mac2unix -n sal_dy040_001.csv sal_dy040_001.csv_linux

echo " " >> sal_dy040_001.csv_linux
```

All csv linux files are then concatenated to sal_dy040_01.csv.

Table 1: This table illustrates salinity sample data from a typical station, here using salinity standard number 14, and salinity sample bottles 164 and 165, drawn from station 012, Niskin bottles 01 and 02, respectively. The sampnum column is added to the spreadsheet generated by the autosal software as column 10, 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.) Flags are assigned for sample analyses, and flags can be applied to standards.

Bottle number Sample 1 Sample 2 Sample 3 Average offset Salinity sampnum sampflag

CTD012 9014 1.999584 1.999638 1.99959 1.999604 -0.000013 34.992 999014 2
CTD012 164 1.976222 1.9762 1.976221 1.976214 -0.000013 34.5321 01201 2
CTD012 165 1.974472 1.974491 1.9745 1.974488 -0.000013 34.4982 01202 2

Offsets to adjust for standardization of the autosal are chosen by station or crate and entered into msal_01 using switch/case to set the offsets for a particular cruise. An array g_adj consists of pairs of rows defining the station number and sample number ranges (e.g. 100 and 599 for stations 1 to 5, 1700 and 1799 for station 17, etc.), bath temperature, and the offsets chosen for each station number range. The offsets used on this cruise are given in Figure 11.

We then run msal_01 to read in the concatenated bottle samples and extract the sample data for each station based on the sample number, generating sal_dy040_nnn.nc. The file msal_02 pastes this information to sam_dy040_nnn.nc.

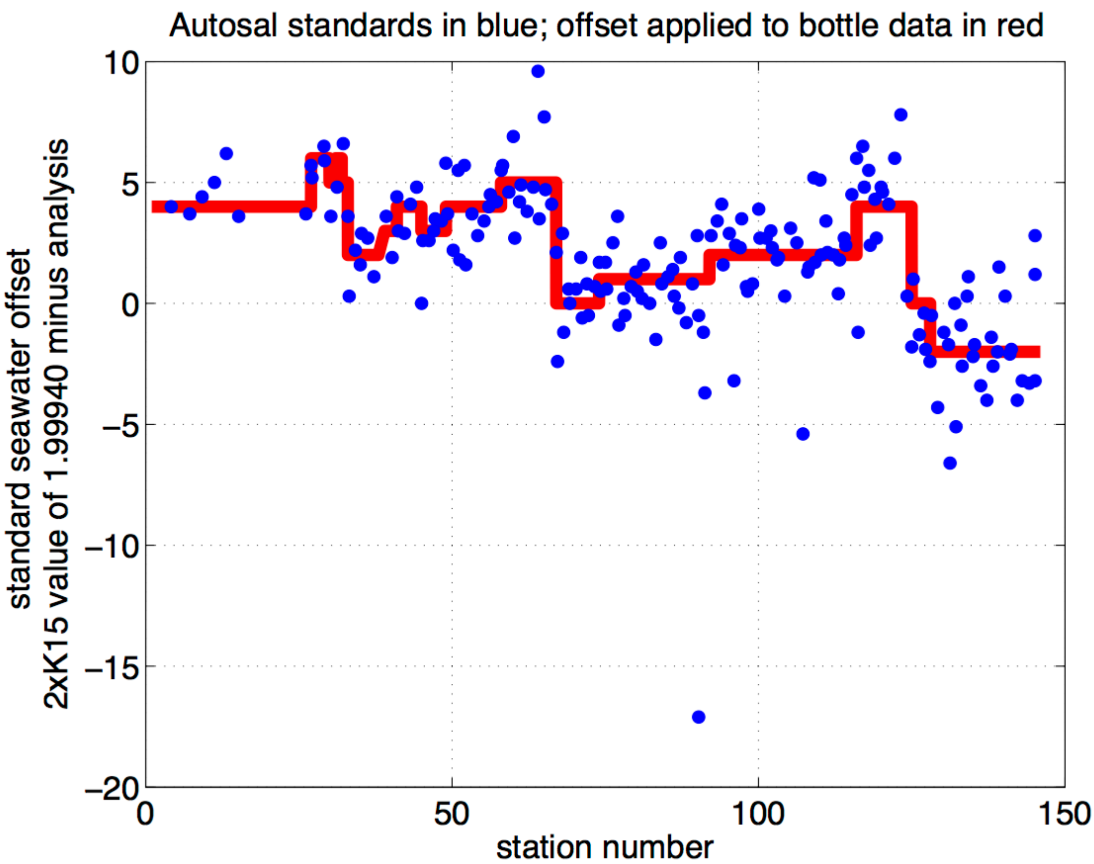


Figure 11. Offsets between bottle salinities and calibrated CTD salinities for Stations 1-145.

4. Dissolved Oxygen

Neela Morarji

Dissolved oxygen samples were obtained for every station dip from all 24 Niskins on the rosette, bar those where a Niskin wasn't fired. Samples were collected second-in-line after samples for CFCs or first where CFC samples were not taken. Two additional samples per dip were taken as duplicates to check the method reproducibility.

The conical glass flasks used for sample collection have an approximate volume of 145ml. The elongated bottle stoppers have a sloping surface to break the water tension of the solution. Each stopper is unique to each flask; each corresponding pair had the same number attached to them. Regular checks were made for cracks and chips in both the bottles and stoppers.

Silicon tubing was attached to the Niskin spigot to transfer water to the flask. For several days before the first station the tubing was soaked and then kept wet between stations to reduce the tendency of bubbles to form within it. At the beginning of each sample collection, once the water was flowing through the tube, it was sometimes necessary to pinch the tubing to push out bubbles. The flask was then inverted and the tube pushed to the base; the resultant rapid flow of water across the inner flask walls ensured effective washing and temperature equilibration. The flask was then righted and filled to overflowing. At least three flask volumes were allowed to flow though the bottle. The fixing temperature was recorded using a temperature probe and the tube removed from the flask before being transferred to the next Niskin spigot.

Prior to sampling each station the first 2 ml from the reagent dispenser pipette tips was discarded to reduce the risk of injecting bubbles into the sample. After collecting each sample it must be "fixed" in the following way. 1 ml of manganese chloride solution was injected into each sample flask, immediately followed by 1 ml of alkaline iodide solution. The tips of the dispensers were slowly eased into the flask below the neck, about 1 cm beneath the surface, to avoid reaction with water that is displaced when the stopper is inserted into the sample. Due to their greater density, the reagents sank to the bottom of the flask. The stopper was then inserted slowly with a firm twisting motion. Care was taken to ensure no bubbles were trapped below the stopper and that a tight seal was achieved. The flask was shaken vigorously for 30 seconds to disperse the manganese precipitate that scavenges oxygen from the sample. This reduces the flocculent size and increases the surface area, increasing the efficiency of the oxidation of $Mn(OH)_2$. The tightness of the stopper was checked before returning the sample to the rack to prevent 'pop back' occurring due to nitrogen escaping the solution. A water seal was added after the sample was fixed and stoppered. Thirty minutes after the sample bottles were returned to the laboratory they were shaken a second time. A water seal was, again, added. The samples were stored in a dark plastic crate and analysed approximately 1 hour later but never more than 12 hours later.

4.1. *Sample Analysis*

Manganese chloride and alkaline iodide, once added to a water sample, create a white precipitate. The reaction results in a brown precipitate of manganese hydroxides. When acidified to a pH of 1.0 to 2.5 after injection of sulphuric acid, the manganic hydroxide forms manganic sulphate, this releases iodine from the iodide. During titration, the endpoint occurs when the added thiosulphate balances with the number of iodate equivalents, thus the oxygen concentration in the sample is calculated by proportion. A Metrohm 916 Ti-Touch unit, with amperometric end point detection, was utilised to accurately perform titration. Chemical reagents were pre-prepared in accordance with procedures outlined by *Dickson* (1994). At the start of each set the Metrohm Ti-Touch unit burette was fully flushed on a slow speed to wash the unit with thiosulphate. The sulphuric acid dispenser was pumped several times at the start of each set to remove air bubbles. Additionally, a dummy sample was titrated at the start of each station set in order to prime the electrode. Consistent procedures were followed at every stage for each sample, the basic outline of which was as follows:

1. The stopper was slowly removed from the flask to avoid any sample loss, where some of the sample remained on the stopper, this last drop was pulled off by dragging it across the top lip of the sample bottle;
2. The magnetic stirrer speed was held at a constant pace;

3. A stir bar was slowly placed into the precipitate;
4. 1 ml of sulphuric acid was added, this was mixed using a magnetic stirrer;
5. The aspirator tip was lowered and positioned slightly lower down but as close as possible to the electrode tip to improve measurement accuracy;
6. The liberated iodine was titrated against sodium thiosulphate as soon as the precipitate had disappeared;
7. The titration volume was recorded.

After the oxygen titration value of each sample was measured, the corresponding oxygen concentration was calculated. The calculation accounted for the volumes specific to each flask. At each station the sample titration volumes (mL), calculated oxygen concentration values (µmol/L), temperature data (^{o}C), station number and flask numbers were recorded. Quality flags were applied to the data such as '2' for good/preferred data, '3' when the sample result is dubious or '4' for bad measurement.

4.2. *Reagent Calibration*

A thiosulphate solution was prepared to carry out titrations, the normality of which is checked against a certified iodate standard (1.667 mM, OSIL Scientific). Each thiosulphate solution was prepared a minimum of 48 hours before in advance by dissolving 50 g in 1 L of Milli-Q water. The reagent blank measurements and standardisations were performed every 2-4 days thereafter to determine possible changes in concentration. These Blank and Standard measurements were then utilised to calculate oxygen concentrations. Measurements were made using empty sample bottles, which were thoroughly washed in tap water three times, then washed again in distilled water before being filled to about the shoulder with distilled water. The exchange burettes for both the thiosulphate and iodate were flushed three or four times in advance.

To perform Blank measurements, 1 mL of sulphuric acid was added before the bottle was placed on the stirrer. Then 1 ml of alkaline iodide was added before stirring again. The solution was checked at this stage to ensure it was clear before adding 1 mL of manganese chloride. Where the solution was not clear, i.e. in the case of manganese contamination, the process was started again. If clear, 1 mL of the iodate standard was injected before the mixture was titrated against sodium thiosulphate. Once the titration had finished the volume of titrant was recorded and another 1 mL of iodate standard added to the same bottle. In total 3ml of iodate standard was added to the bottle in 1 mL amounts and titrated each time. This whole procedure was repeated for a minimum of three bottles until they were consistent to within 0.002 mL.

The Standardisation procedure is similar to that of the Blank measurements except that exactly 10 mL of potassium iodate standard was added to a bottle in one injection and then titrated, rather than 3 additions of 1 mL. The results were repeated until they agreed to within 0.5 % for a minimum of three readings.

The calibration results for each batch of thiosulphate showed no trend in the molarity. It was concluded that the differences between each calibration were likely due to instrument sensitivity. To avoid creating unnecessary noise in the results due to altering oxygen concentration values for each calibration, results were all set to match the average values for each batch of thiosulphate.

4.3. *Problems Encountered*

Occasionally the Metrohm 916 Ti-Touch unit reported an error; the unit was unable to detect the attached probe. In these instances the unit sometimes had to be re-set, thus causing a delay in the analysis of an open sample. This may have altered the resultant titration quantity. The cause of this issue was not determined, but these instances were few and far between and have been noted on the log sheet as "probe error".

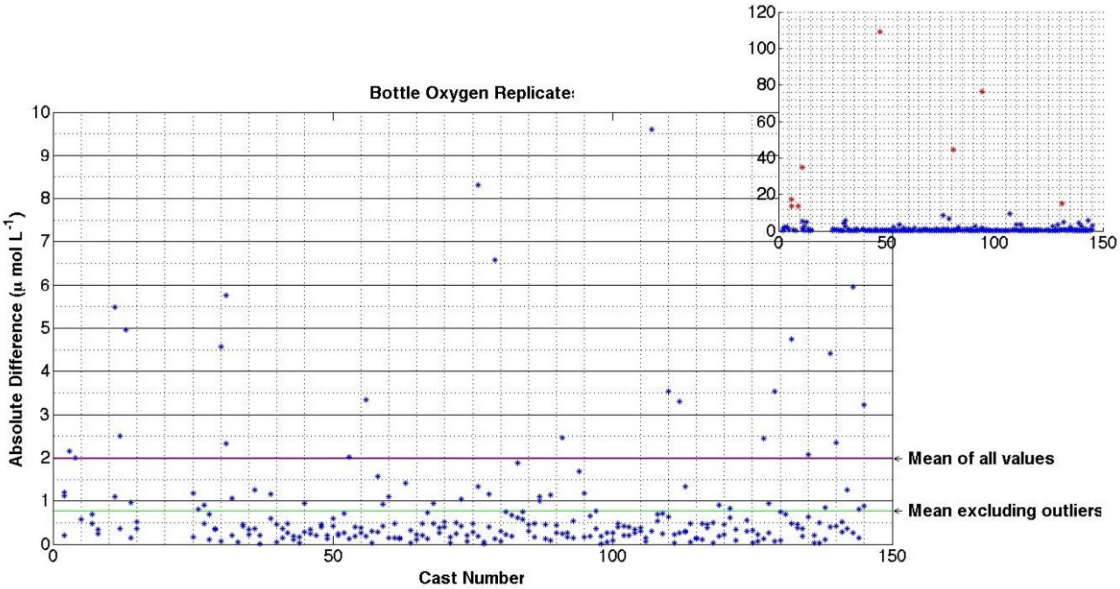


Figure 12. Absolute differences between duplicate samples for each CTD station.

Absolute differences between duplicate samples are shown in Figure 12. For each CTD station two randomly selected Niskins were each sampled twice to assess reproducibility of the method. Absolute differences between duplicate samples (where 2 randomly selected Niskins were each sampled twice to assess reproducibility of the method) for each CTD station.

The mean difference between duplicates was 1.98 µmol/L and the standard deviation 9.04 µmol/L. The mean absolute difference excluding outliers (where outliers were defined as outside 1 standard deviation of the mean for all data) was 0.76 µmol/L. The main plot shows duplicate pairs excluding outliers, the inset plot includes all duplicate pairs.

Table 1. Calibration results for each thiosulphate batch showing the outcome of the blanks and standards, the average for each batch and the molarity. The casts that apply for each batch are also detailed.

	St. No.	Date	Blank	Average Blank	Standard	Average Standard	STD-BLK	Molarity (M)
1 thiosulphate	1	08/12/2015	0.0058	**0.0048**	0.5008	**0.5010**	0.4950	**0.2021**
	-	13/12/2015	0.0050		0.5011		0.4961	**0.2016**

	60	17/12/2015	0.0038		0.5007		0.4969	**0.2013**
		17/12/2015	0.0055		0.5023		0.4968	**0.2013**
		20/12/2015	0.0057		0.5003		0.4947	**0.2022**
		22/12/2015	0.0043		0.5016		0.4973	**0.2011**
		24/12/2015	0.0037		0.5005		0.4968	**0.2013**
2nd thiosulphate batch	**61 - 110**	24/12/2015	0.0053	**0.0043**	0.4992	**0.4982**	0.4939	**0.2025**
		29/12/2015	0.0033		0.4968		0.4935	**0.2027**
		03/01/2016	0.0042		0.4991		0.4949	**0.2021**
		07/01/2016	0.0043		0.4988		0.4945	**0.2023**
		10/01/2016	0.0043		0.4973		0.4930	**0.2029**
3rd thiosulphate batch	**111 - 145**	10/01/2016	0.0049	**0.0056**	0.5010	**0.4997**	0.4961	**0.2016**
		15/01/2016	0.0051		0.4989		0.4938	**0.2025**
		18/01/2016	0.0067		0.4985		0.4918	**0.2034**
		20/01/2016	0.0059		0.5003		0.4944	**0.2023**

5. Inorganic and Organic Nutrients

Sinhue Torres-Valdes, Vlad Macovei, Neela Morarji, Anna Rufas

5.1. *Lab Set up*

For DY040 a 5-channel and a 2-Channel Seal Analytical AA3 autoanalysers were set up in the general purpose lab of the RRS Discovery for the analysis of micro-molar concentrations of dissolved inorganic nutrients (silicate, phosphate, nitrate plus nitrite -hereafter nitrate-, nitrite and ammonium) and total nutrients (total dissolved phosphorus and total dissolved nitrogen). Installation of the AA3 involved the fitting of new pump tubing and new cadmium columns, tubing connections between sampler-pumps-manifold-detectors, and a thorough cleaning with wash solutions as per Seal Analytical protocols. Simultaneously, chemical reagents (stock and working solutions) and standards (stock solutions and calibrants) were prepared. 'Stocks' are concentrated solutions from which working reagents/standards are prepared as required by solution stability or usage. Calibrants were prepared in a saline solution (35 g NaCl in 1 L of Milli-Q water, hereafter artificial seawater or ASW), which was also used as a diluent for the analysis. The nutrient analysers are controlled by the Seal Analytical Software AACE version 7. Nutrient analyses were carried out following the Seal Analytical Methods listed below:

1) Silicate in seawater method No. G-177-96 Rev 10 (Multitest MT19).
2) Phosphate in water and seawater method No. G-175-96 Rev. 13 (Multitest MT 18).
3) Total dissolves phosphorus in seawater method No. MKA-0152-14 Rev. 0.
4) Total dissolved nitrogen in seawater method No. G-218-98 Rev. 12 (Multitest MT23).
5) Nitrate and nitrite in seawater method No. G-172-96 Rev. 13 (Multitest MT19).
6) Nitrite in seawater method No. G-062-92 Rev. 3.
7) Ammonium in water and seawater No. G-327-05 Rev. 6.

5.2. *Calibrants*

Table 2. Compounds used to prepare stock standard solutions, weight dissolved in 1 L of Milli-Q water and Molarity of the solution.Table 2 lists compounds used for the preparation of stock standard solutions, weight of compound dissolved in 1 L of Milli-Q water and the resulting molarity of the solution. Dilutions were then made from stock solutions to prepare a set of five standards to calibrate the analysis. Table 3 shows target concentrations -which are concentrations aimed for when preparing the standards- and actual concentrations –which have been obtained given the molarity of stock solutions, pipette calibrations and/or that result from the combination of related chemical species (e.g., TDN (total dissolved nitrogen), NO_3^-+NO_2^-, NO_2^-, NH_4^+).

Table 2. Compounds used to prepare stock standard solutions, weight dissolved in 1 L of Milli-Q water and Molarity of the solution.

Compound	**Weight (g)**	**Molarity 1 L stock solution**
Ammonium Sulphate	0.3470	**5.2520**
Potassium Nitrate	0.5096	**5.0404**
Sodium Nitrite	0.3461	**5.0163**
Potassium Di-hydrogen Phosphate	0.6870	**5.0483**
Sodium Metasilicate	1.4260	**5.0176**

Table 3. Set of calibration standards (*Std*) used for dissolved inorganic and total dissolved nutrient analysis. Concentration units are µmol L^{-1}. Target concentrations are shown in bold characters. Actual concentrations as calculated from the molarity of the stock solution are shown in normal characters. Concentrations for NO_3^-+NO_2^- are the sum of NO_3^-+NO_2^- and NO_2^-, and concentrations for TDN also include those of NH_4^+.

	Si(OH)₄		**PO_4^{3-}/TP**		**NO_2^-**		**NO_3^-+NO_2^-**		**NH_4^+**		**TDN**
Std 1	**1**	1.00	**0.10**	0.10	**0.10**	0.10	**0.5**	0.61	**0.1**	0.12	0.73
Std 2	**10**	9.80	**1.00**	1.01	**0.25**	0.25	**5**	5.16	**0.5**	0.53	5.69
Std 3	**20**	19.59	**1.50**	1.51	**0.50**	0.50	**10**	10.30	**1.0**	1.05	11.35
Std 4	**40**	39.16	**2.00**	2.02	**1.00**	1.00	**20**	20.59	**1.5**	1.56	22.14
Std 5	**60**	58.73	**2.50**	2.52	**2.00**	2.01	**40**	42.48	**2.0**	2.07	44.55

5.3. *Quality Controls (QCs)*

Reference materials for the analysis of nutrients in seawater (RMNS).

Inorganic nutrients: In order to test the accuracy and precision of the analyses, RMNS from The General Environmental Technos Co., Ltd., (KANSO) were measured in triplicate every run (34 runs for inorganic nutrients). During DY040, KANSO RMNS lot CD, lot CA and lot BW were used; certified concentrations of these three are shown in Table 4. Lot CD is surface seawater from the Pacific Ocean (29.58ºN, 149.15ºE) mixed with water from Suruga Bay, Japan, collected at 397 m depth in 81% and 19% proportions respectively. The reported salinity is 34.484 (certified date 25/09/2015, production date 08/04/2015, expiry date 07/04/2022). Lot CA is water from Suruga Bay, Japan, collected at 270 m depth mixed with surface seawater from the Pacific Ocean (19ºN, 130ºE) in 93.7% and 6.3% proportions respectively. The reported salinity is 34.376 (certified date 18/06/2015, production date 22/02/2013, expiry date 21/02/2020). Lot BW is water from Suruga Bay, Japan, collected at 270 m depth. The reported salinity is 34.330 (certified date 18/06/2015, production date 03/04/2012, expiry date 02/04/2019). Although no certified concentration is reported for TDN, measurements provided consistent values throughout the cruise for this variable.

Table 4. Certified concentrations (in µmol kg^{-1} as reported and in µmol L^{-1}) of KANSO RMNS used during DY040 and results of measurements carried out during DY040 (also in µmol L^{-1}). Results show the cruise global average; i.e., triplicate measurements on each of the 34 runs. 4 batches of CD and CA RMNS, and 2 of BW RMNS produced anomalous results which were not related to the analysis as confirmed by other QCs. Such anomalous results were not considered for the average below.

RMNS	**Silicate**	**Phosphate**	**Nitrate+Nitrite**	**TDN**
Certified conc.				
CD (µmol kg^{-1})	13.93±0.099	0.446±0.008	5.52±0.05	---
(µmol L^{-1})	14.26±0.10	0.457±0.008	5.65±0.05	---
CA (µmol kg^{-1})	36.58±0.22	1.407±0.014	20.29±0.15	---
(µmol L^{-1})	37.45±0.22	1.441±0.014	20.77±0.15	---
BW (µmol kg^{-1})	60.01±0.42	1.541±0.014	24.66±0.20	---
(µmol L^{-1})	61.44±0.43	1.578±0.014	25.25±0.20	---
Measured conc.				
CD (µmol L^{-1})	11.88±0.20	0.438±0.035	5.31±0.28	8.93±0.71
CA (µmol L^{-1})	31.69±0.40	1.431±0.019	19.27±0.41	22.13±0.06
BW (µmol L^{-1})	51.96±0.65	1.560±0.030	24.04±0.05	27.69±0.79
Ratio $RMNS_{cert}$:$RMNS_{meas}$				
CD	1.20±0.02	1.052±0.106	1.07±0.07	
CA	1.18±0.02	1.007±0.014	1.08±0.02	
BW	1.18±0.02	1.014±0.024	1.05±0.02	

Time series of RMNS results, ratios of certified values versus measured RMNS, ratios of certified versus measured RMNS plotted against standards and ratios of measured versus target concentrations of calibrants were all assessed to test for trends in the behavior of the analysis throughout the cruise. These assessments were carried out together with E. McDonagh and Brian King of the physics team. Assessments helped to determine whether nutrient measurements needed to be corrected --given the results of RMNS-- on a run by run basis or whether a global correction was more appropriate. All variability observed from run to run was deemed to be random analytical noise and the global ratio from the highest RMNS concentration (lot BW) was considered the most appropriate to 'calibrate' nutrient data. The ratio used to correct NO3+NO2 data was also applied to TDN data.

Organic standards: Total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP) are measured as nitrate and phosphate respectively following oxidation of the sample by exposure to UV radiation and a wet chemical oxidation with potassium persulphate. During DY040 three organic compounds containing phosphorus and nitrogen (ATP, AMP and GMP) were used to test the efficiency, and above all, the consistency of the oxidation. That is, since these are solutions made out of single chemical compounds of different labilities, they are not directly comparable to the analysis of seawater, which consists of a still not fully identified range of labile, semi-labile and refractory compounds. However, it is expected that the oxidation of each solution is consistent through time. Table 5 lists the compounds used to prepare stock solutions and Table 6 lists the concentration of standards prepared, the average concentration measured during the cruise for each compound, the standard deviation of all measurements, and the percent oxidation efficiency. TDP was not measured due to problems with the colorimeter and erratic flow of liquid through the manifold (see text below in section 'problems encountered'). Although RMNS do not report TDN, this variable was also measured as an additional quality control from reference materials. Results are presented in Table 4**.**

Table 5. Compounds used to prepare stock organic standard solutions to test oxidation efficiency of TDN, weight dissolved in 0.5 L of Milli-Q water and Molarity of the solution.

Compound	**Weight (g)**	**N molarity**
Adenosine triphosphate (ATP)	0.3027	**5.0099**
Guanosine monophosphate (GMP)	0.2055	**5.0195**
Adenosine monophosphate (AMP)	0.1860	**4.6899**

Table 6. Organic standards used to test the oxidation efficiency of the TDN channel. This table shows prepared concentration ([ ]), average concentration ([Av]) of total measurements (n) during DY040 and respective standard deviation of measurements, and average percent (%) oxidation efficiency. Concentration units are µmol L^{-1}.

	N				
	[ ]	[Av]	*Sd*	n	%
ATP	29.3	27.01	0.59	62	92
GMP	5	3.10	0.45	62	62
AMP	5	4.23	0.38	62	85

Cadmium column reduction efficiency: The reduction of the nitrate (NO_3^-) present in a sample or from the oxidation of TDN in a sample, to nitrite (NO_2^-), 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 and thus it has to be monitored. Monitoring of the reduction efficiency was done in every run by measuring nitrite and nitrate standards of similar concentrations (~40 µmol L^{-1} during DY040). The ratio of nitrate to nitrite expressed as a percentage thus provides an indication of the reduction efficiency of the cadmium column. Throughout the duration of the cruise, we did not allow the column efficiency to drop below 95% with the average being 99.09±1.54%

(n=34). Because the total nitrogen analysis uses a combination of photo-oxidation (UV lamp) and oxidation with persulphate (wet chemical oxidation), this method of monitoring the cadmium column efficiency is not applicable since the nitrite gets oxidised to nitrate. However, whenever we changed the column on the 5-channel analyser (i.e., inorganic nutrients), we changed it on the 2 channel total nutrients analyser as well.

5.4. *Analyses*

5.4.1. Tests

Upon installation, the AA3 was tested by carrying out three analytical runs. For the first test, only standards (calibrants) were used to provide an indication of the linearity of calibration curves. This was followed by two runs with a full set of QCs standards and KANSO RMNS to verify the system was working properly. Following the tests, every run was set up as shown in Table 7.

5.4.2. Analysis of samples

Seawater was collected for the analysis of micro-molar concentrations of dissolved inorganic and total nutrients. Samples were collected directly into 15 mL plastic centrifuge tubes. These were rinsed with sample water at least three times before withdrawing the sample. Tubes were stored in a fridge at approximately 4°C until sampling for 3 or more stations was completed; analyses were then carried out for typically 4-9 stations at a time depending on frequency of sampling and number of samples per cast. During the first part of the cruise, the stations in Florida Strait were very shallow and not all Niskin bottles were fired. The high frequency of stations meant that up to 9 stations were analysed in a single run. During the open ocean part of the cruise, we would collect samples from 3 stations before starting the run. The timing of the analysis meant that we could add the fourth station at the end of the run immediately after collection. Analyses of individual casts were thus done from just after sampling to within 20 h after sample collection. This procedure allowed all samples to be analysed within 24 hours of collection as well as minimising the chemical waste produced by the necessity of adding the calibrants and quality control solutions in every run. All unique sampling depths were sampled and analysed. Additionally, 2 random duplicates were withdrawn in every cast to test repeatability of sampling. Furthermore, in the analysis of total nitrogen, an additional 2 randomly selected samples were measured in duplicate for every cast to test analytical repeatability of samples.

At the time of adding the samples to the analysers, extreme care was taken in order to avoid cross-contamination between samples. For the inorganic nutrients we tried to remove a little bit of the sampled water in the centrifuge tube so when the sampler was taking water from the tube water was not over flooding from the tube and was not being spread to neighbouring tubes. The same was applied to the cups holding the samples used for the TDN analyses. Furthermore, avoiding topping up cups and tubes prevents sample spreading due to the movement of the ship. We also took special care to avoid introducing a finger inside the cup (the cups were taken from a bag) and paying attention in whether we accidentally touched sample water from an adjacent cup whilst adding a new cup, which can easily happen due to the proximity of the cups.

Table 7. Analysis template.

ID	Description	Comment
Primer	Initial peak identified by the AA3 software as the start of a run.	
2 Drifts	Separate standard of constant concentration used by the software in combination with 'baseline' checks to correct for potential drifts of the baseline. The first drift is specified as a null since it may be affected by carry over and thus is not taken into account by the software.	Followed by 2 nulls
Baseline	Baseline check	
3 x STD 1	The first standard is specified as a null since it may be affected by carry over and thus is not taken into account by the software.	
3 x STD 2	As above.	
3 x STD 3	As above.	
3 x STD 4	As above.	
3 x STD 5	As above.	Followed by 2 nulls
2 Drifts	As for the drifts above.	Followed by 2 nulls
Baseline	Baseline check	
2 x Low Nutrient Sea Water	Quality control	
2 x 40 μmol L^{-1} NO_2^- STD	The first is specified as a null	Cadmium column efficiency test
1 x 40 μmol L^{-1} NO_3^- STD		Cadmium column efficiency test. Followed by 2 nulls
3 x KANSO CRM lot CD	The first is specified as a null	
3 x KANSO CRM lot CA	The first is specified as a null	
3 x KANSO CRM lot BW	The first is specified as a null	Followed by 2 nulls
2 x ATP	The first is specified as a null	Just for the organic analyser. Followed by a null
2 x AMP	The first is specified as a null	Just for the organic analyser. Followed by a null
2 x GMP	The first is specified as a null	Just for the organic analyser. Followed by a null
2 Drifts	As for the drifts above.	Followed by 2 nulls
Baseline	Baseline check	
Samples	Ordered from surface to deep samples to avoid cross contamination and grouped by CTD cast.	Samples from CTD casts were separated by Drifts and Baselines as above.
Pairs of STD 1 to 5	To test consistency with standards specified as calibrants in the software.	Followed by Drifts and baseline check.
End of run		

5.5. *Observations*

5.5.1. General observations

Prior to the cruise all labware were washed with 10% HCl, rinsed with MQ water and was allowed to dry before packing. Once on board, all labware were rinsed several times before use. Following each run, each analytical channel was flushed with wash solutions and autosamplers with Milli-Q water following Seal Analytical cleaning protocols. The system was thoroughly cleaned with sodium hydroxide (TP lines) and sodium hypochlorite (nitrite, nitrate, TDN, phosphate and silicate line) twice during the cruise. After turning the analysers on, about 1 h or 1.5 h is required before stable baselines are established and a run can be started (approximately 30 minutes of flushing the instrument with solutions and 30 min to 1 h flushing channels with their respective chemical reagents).

5.5.2. Problems encountered

Upon installation, an analysis of calibrants and quality controls was set up to test the systems. From start, the NO3+NO2, the TDP and NH4 channels malfunctioned. In the former, the problem seemed to be related to the electronics of the colorimeter, with the energy of the lamp continually varying while it should be fixed. In the TDP channel the flow of liquid through the manifold was irregular, resulting in the baseline not being stable enough for the analysis to take place. In the case of the NH4 channel, peak shapes and heights from calibrants, samples and quality controls were not stable.

Seal Analytical was contacted and advice was received from their headquarters in the UK, Germany and USA. All suggestions given, such as swapping photometers within the colorimeter, swapping lamp connections, swapping lamps, were tried and none solved the problem. A final suggestion involved using a different colorimeter. Given the TDP channel failed to produce a stable flow and so a stable baseline for any analysis to be done, we swapped colorimeters and used the colorimeter of the TDN and TDP channels, with that of the NO3+NO2 and NO2 channels. The result was that the working colorimeter lost one channel too and by the end of the cruise we still do not understand why. We thus decided to 'sacrifice' the NO2 channel, and used the working side of the colorimeter to measure NO3+NO2 and the working side of the other to measure total nitrogen.

Attempts at fixing the TDP channel were also made, such as extra cleaning and modification of the manifold, and preparation of new reagents, but none worked.

The NH4 channel was also cleaned several times and different batches of reagents were used, but without success. NH4 was measured until CTD cast 43, but results were deemed unusable and so the channel was disconnected to avoid extra chemical waste being produced.

From closure of the ammonium channel, the set of calibrants in Table 8 were used for the remaining of the cruise.

Table 8. Set of calibration standards (*Std*) used for dissolved inorganic and total dissolved nutrient analysis from run 7 (19/12/2015; see text for further information). Concentrations in µmol L^{-1}.

	$Si(OH)_4$		**PO_4^{3-}**		**$NO_3^-+NO_2^-$ and TDN**	
Std 1	**1**	1.00	**0.10**	0.10	**0.5**	0.51
Std 2	**10**	9.80	**1.00**	1.01	**5**	4.91
Std 3	**20**	19.59	**1.50**	1.51	**10**	9.80

Std 4	**40**	39.16	**2.00**	2.02	**20**	19.58
Std 5	**60**	58.73	**2.50**	2.52	**40**	39.15

Sampler failure: The sampler used with the 5-channel analyser failed several times. At times it would get stuck in the middle of a run, which it then needed to be restarted. Sometimes the problem was simple and related to the tubing being out of place, jamming the sampler at certain positions. However, other times it would just do random movements and totally stop. The sampler holds 120 samples and for some reason, it stopped every time it finished drawing a sample from position 4 and then tried to continue to position 5. Because of this, all analysis had to be started from position 5. We also contacted Seal Analytical and explain the problems, but without them being able to inspect it, not much was done about it.

5.6. *Performance of the Analyser*

The performance of the autoanalyser was continuously monitored by producing time series of standards, QCs, RMNS and cadmium column reduction efficiency, ratios of standards versus RMNS and ratios of standards versus target concentrations plotted against run/analysis number, and against each other. The total numbers of Quality Control plots is approximately 70, which are thus not included here. However, average results and associated uncertainties are reported.

The precision of the method employed by each nutrient channel was determined by monitoring the variations of the complete set of standards, QCs (i.e., RMNS) measured throughout the cruise.

Results of the measurement of standards; average concentration, analytical uncertainty (*sd*) and precision of the analysis at the different concentration employed, are summarised in Table 9 and Table 10**.** Table 9 shows the results from standards set up as “calibrants” that the AACE software used to fit a regression line given the signal produced by each standard and then ‘recalculates’ the value, which deviates slightly from the ‘target’ concentration as shown in Table 3. Table 10 shows the results of the same standards measured as unknowns (or samples). That is, these are not specified in the software as calibrants and thus represent a more accurate picture of the analytical noise.

Two random samples were collected in duplicate in every cast to assess repeatability of sampling (n=265 for inorganic nutrients, n=228 for TDN). Additionally, in the case of TDN, two randomly selected samples were analysed in duplicate to assess repeatability of analysis (n=258). Duplicated samples ranged in concentration as follows: from non-detectable to 50.17 µmol-Silicate L^{-1}, non-detectable to 1.825 µmol-Phosphate L^{-1} and non-detectable to 27.54 µmol-Nitrate L^{-1}. The global standard deviation of those duplicates were 0.020, 0.003, and 0.023 µmol L^{-1} for silicate, phosphate, nitrate respectively. In the case of TDN, these were 0.15 and 0.16 µmol L^{-1} for bottle duplicates and sample duplicates, respectively.

Finally, the limits of detection for the different variables, determined as twice the standard deviation of the lowest concentration standard were 0.21, 0.013, 0.11 and 0.33 µmol L^{-1} for silicate, phosphate, nitrate and TDN respectively.

Table 9. Mean, standard deviation and precision of all standards measured as calibrants. These are the result of the regression the AACE software fits from the input of 'target' calibrants and the signal produced by the analysis.

	Si(OH)4	Prec. (%)	PO_4^{3-}	Prec.	NO3+NO2	Prec..	TDN	Prec.
Std 1	0.91±0.12	12.9	0.107±0.007	6.1	0.55±0.07	13.3	0.57±0.04	7.2
Std 2	9.87±0.08	0.9	1.002±0.007	0.7	4.89±0.07	1.4	4.91±0.05	1.0
Std 3	19.65±0.11	0.5	1.504±0.011	0.7	9.76±0.10	1.0	9.76±0.06	0.6
Std 4	39.16±0.32	0.8	2.024±0.010	0.5	19.66±0.21	1.0	19.53±0.1	0.5
Std 5	58.70±0.25	0.4	2.523±0.008	0.3	39.20±0.36	0.9	39.18±0.1	0.3

Table 10. Mean, standard deviation and precision of all calibration standards measured as unknowns (μmol L^{-1}).

	Si(OH)4	Prec. (%)	PO_4^{3-}	Prec.	NO3+NO2	Prec.	TDN	Prec.
Std 1	0.87±0.14	15.9	0.101±0.010	9.4	0.53±0.08	14.5	0.97±0.34	35.0
Std 2	9.87±0.24	2.4	0.989±0.010	1.0	4.82±0.13	2.7	5.17±0.26	5.0
Std 3	19.67±0.36	1.8	1.490±0.014	0.9	9.71±0.17	1.7	9.95±0.37	3.7
Std 4	39.23±0.57	1.4	2.016±0.015	0.8	19.65±0.29	1.4	19.53±0.32	1.6
Std 5	58.78±1.00	1.7	2.527±0.013	0.5	39.24±0.55	1.4	38.89±0.48	1.2

5.7. *Specific tasks*

While all members of the team contributed equally to all sampling and analytical work carried out, data processing was split for efficiency and consistency under the supervision of Sinhue Torres. Neela Morarji looked after dissolved oxygen data processing and wrote the associated cruise report. Anna Rufas Blanco looked after total dissolved nitrogen data processing. Vlad Macovei and Sinhue Torres looked after the inorganic nutrients data processing. All members contributed towards writing the cruise report. The team is extremely grateful to all members of the physics team who helped collecting samples for the analysis of nutrients. We are also grateful to the Captain, officers, crew, technical staff and colleagues on board DY040.

5.8. *Additional Sampling*

100 mL seawater samples were collected directly into pre-cleaned HDPE 125 mL bottles for later analysis of dissolved organic carbon. Samples were taken from all depths and all casts across Florida Strait and from the surface at all sampling stations along the cruise track as part of Vlad Macovei's PhD work.

5.9. *Results*

Final profiles of oxygen, silicate, nitrate+nitrite and phosphate concentration profiles are shown in **Error! Reference source not found.** and **Error! Reference source not found.**.

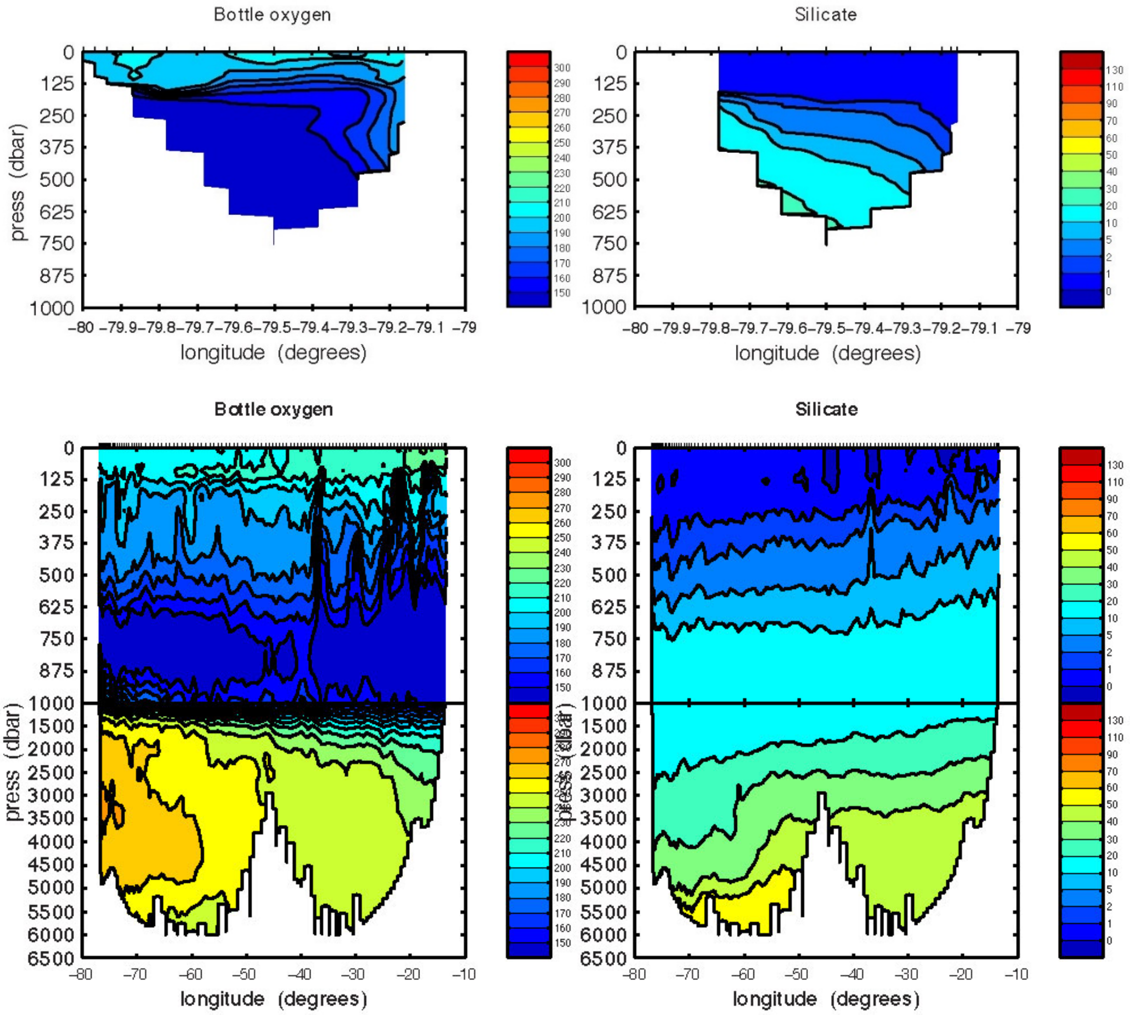
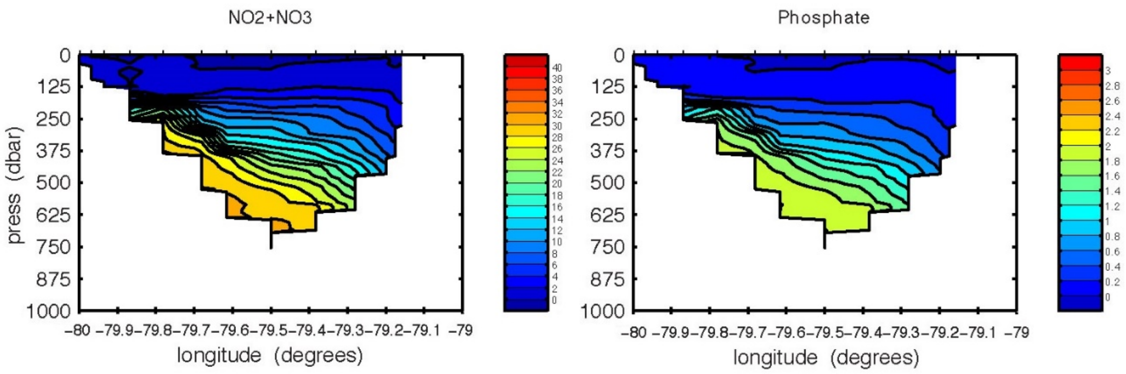


Figure 13. Bottle oxygen and silicate contours for the Florida Strait (upper panels) and the Atlantic (lower panels) sections.



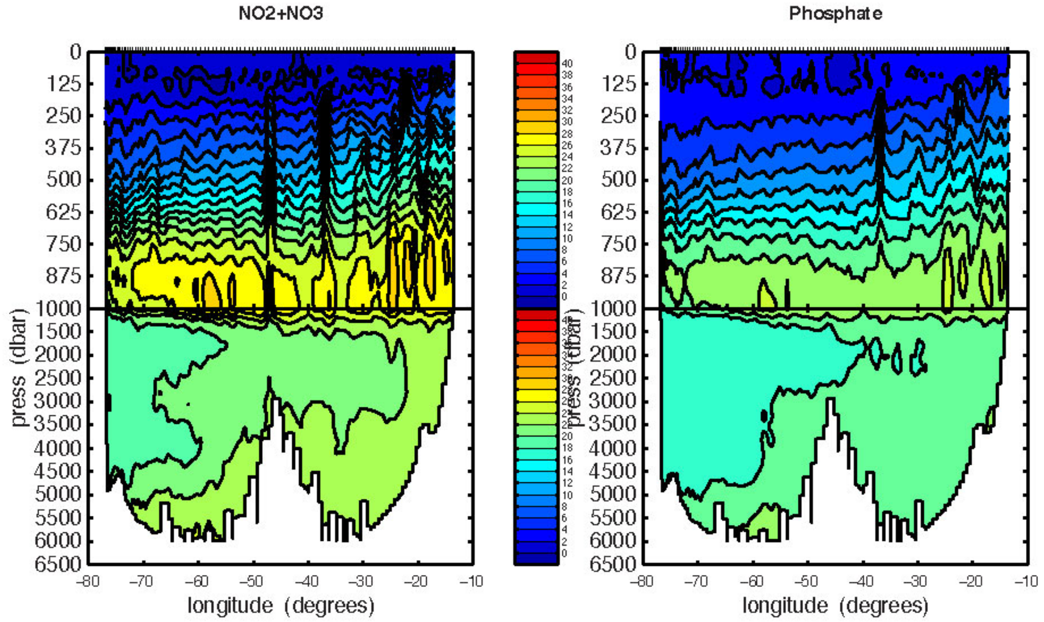


Figure 14. Nitrate plus nitrite and phosphate contours for the Florida Strait (upper panels) and the Atlantic (lower panels) sections.

6. Carbon Parameters

Ute Schuster, Steve Jones, Alice Lebehot and Ellie Morris

The carbon parameter analytical equipment was set up pre-cruise in a seagoing laboratory container belonging to the University of Exeter, Devon, UK. Discrete CTD samples were analysed for total inorganic carbon (DIC) and total alkalinity (TA).

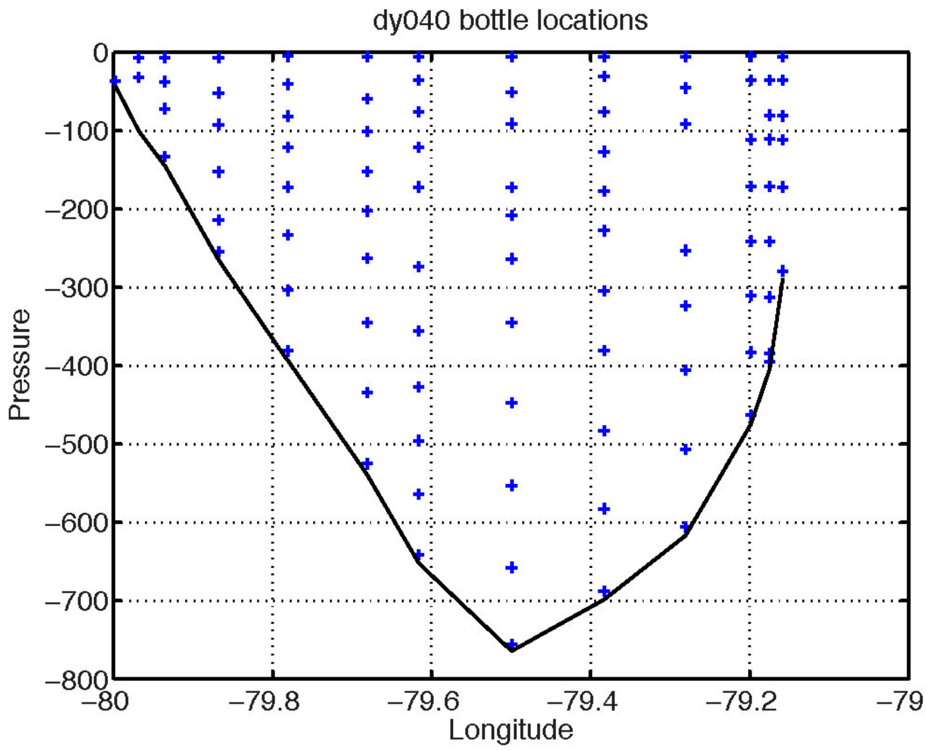
6.1. *Methods*

6.1.1. CTD sampling strategy for inorganic carbon analysis

Seawater samples for the determination of DIC and TA were collected from 20L Niskin bottles on the 24 Niskin CTD rosette in either 500ml or 250ml glass bottles, following the Standard Operating Procedure (SOP) #01 (Dickson et al., 2007) to avoid gas exchange with the atmosphere. All samples were poisoned with saturated mercuric chloride (50μl per 250ml sample) immediately after being drawn from the rosette. Samples were stored in foam lined crates in a temperature controlled laboratory (average temperature 4^{o}C) until prior to analysis where they were bought to an ambient temperature by resting in a 25^{o}C water bath.

Across the Florida Straight, all depths were sampled and analysed. Across the main section, a minimum of 16 depths were sampled from each rosette, always including the deepest and shallowest Niskins; these top and bottom depth were sampled into 500 ml bottles with an additional two other depths selected per station for optimum section interpolation. In addition to station samples, a total of 142 of 500ml bottle samples were taken from stations 39, 53, 54, 55, 56, 59, 60, 61, 69 and 123 to be used as secondary standards and test samples.

Samples of 500ml allow both DIC and TA to be measured twice per sample, thereby allowing testing of internal instrument consistency, and precision of measurements. The remainder of the rosette was sampled in 250ml bottles. Figure 15 shows the depth-station grid for DIC and TA during DY040, following initial first-level shipboard quality control (1st QC).



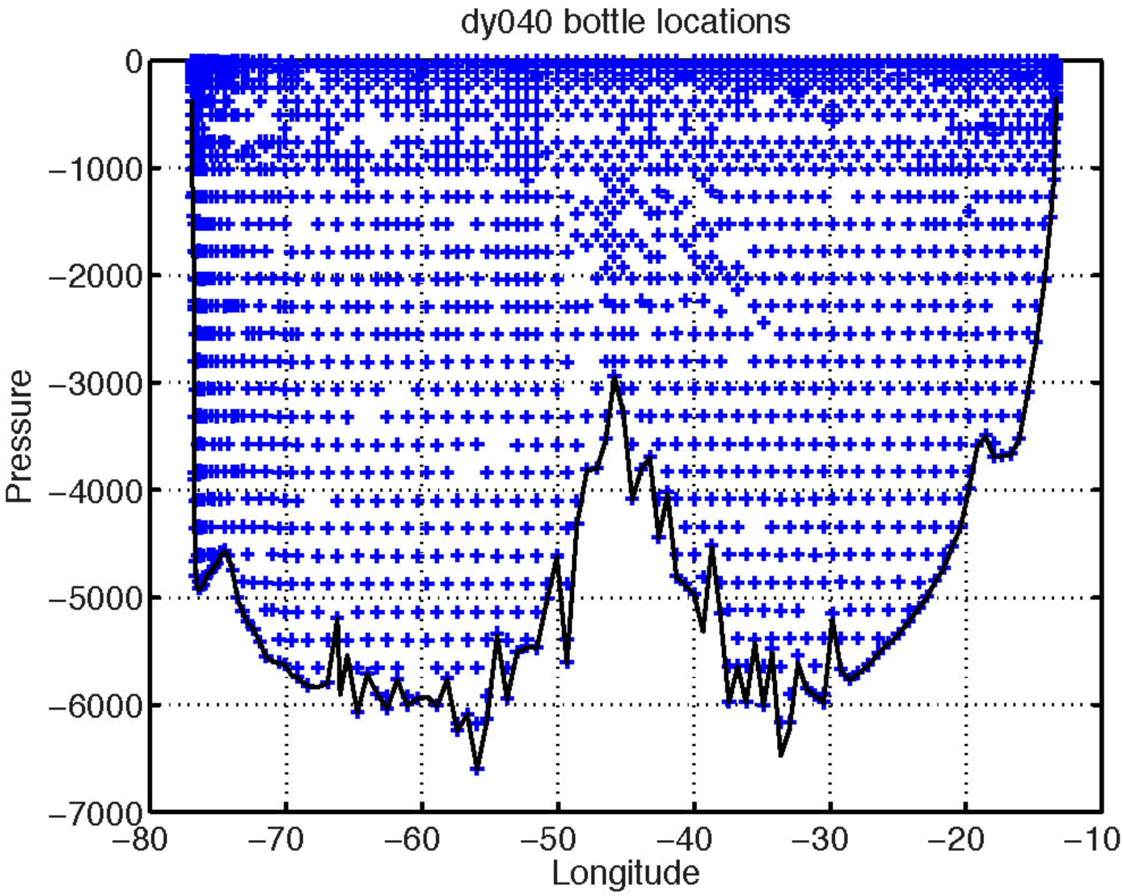


Figure 15. Depth-longitude grid of samples analysed for DIC and TA samples during DY040 for the Florida Strait (upper panel) and the Atlantic Basin (lower panel).

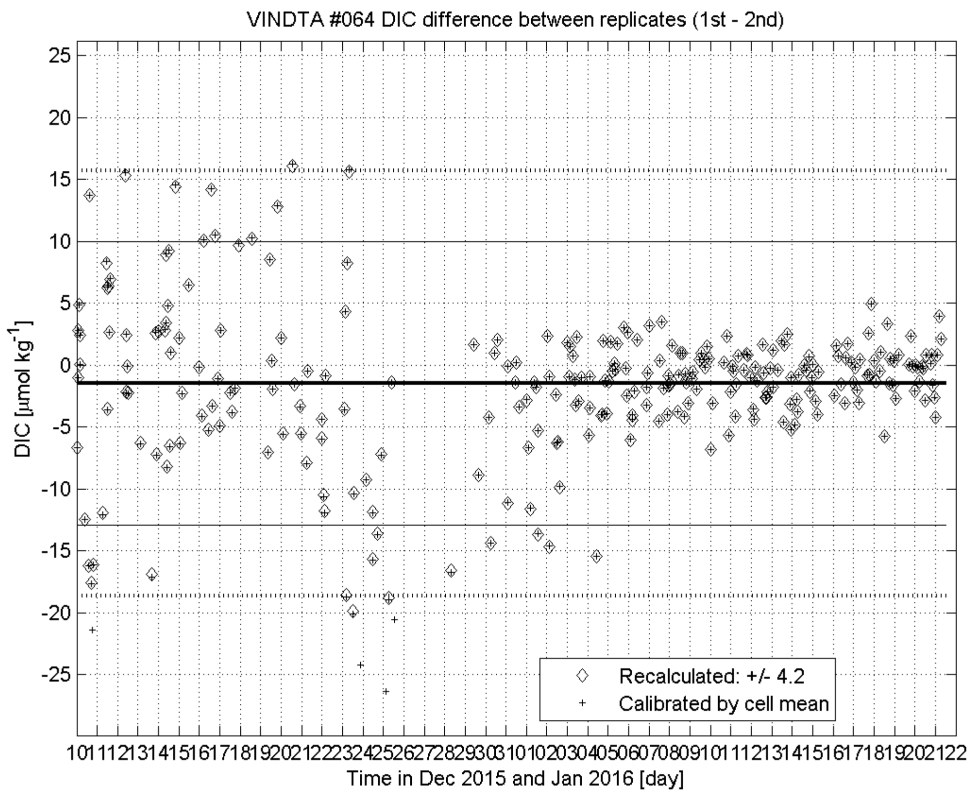
6.1.2. Dissolved Inorganic Carbon analyses

Water samples were first analysed for Dissolved Inorganic Carbon (DIC). Total inorganic carbon was analyses by coulometry (Dickson et al., (2007) SOP #02). All inorganic dissolved carbon is converted to CO_2 by addition of excess phosphoric acid (8.5%) to a calibrated volume of seawater sample. Oxygen-free-nitrogen gas (OfN), passed through soda lime to remove any residual traces of CO_2, is used to carry the evolving CO_2 to the coulometer cell. In the cell, all CO_2 is quantitatively absorbed, forming an acid that is coulometrically titrated.

DIC analysis was performed using two Versatile INstrument for the Determination of Titration Alkalinity (VINDTA version 3C, serial numbers #064 and #065, Marianda, Germany; Mintrop, 2004), each connected to a coulometer (Model 5015, serial numbers 315015020 and 135015019, and Model 5011, serial number 015011001 (on loan from University of East Anglia, Norwich, UK)). Prior to analysis, samples were brought to an ambient temperature of 25^{o}C in a water bath. The DIC pipette is also thermostated at 25^{o}C by a surrounding by a water jacket. Coulometer counts were calibrated against Certified Reference Material (CRM batch 150, certified at 2017.88 ± 0.36 (Prof A Dickson, Scripps Institute of Oceanography, San Diego, USA)) which were run three times per coulometer cell, and against replicate analyses taken from the

500ml bottles. The coulometer cells, ad anode and cathode solutions used were purchased from Cobalt Scientific (Cobalt Scientific, Bensenville, Illinois, United States).

Initial DIC quality control included the removal of any analyses during which technical, instrumental, or chemical malfunction could be identified, the recalculation of all DIC measurements with CTD salinity, and the DIC calibration for each instrument by the mean of all CRMs analysed during a particular coulometer cell set up. Figure 16 shows differences between in-bottle replicate analyses over the time of DY040, together with upper and lower warning and critical levels (Dickson et al., 2007, SOP#22).



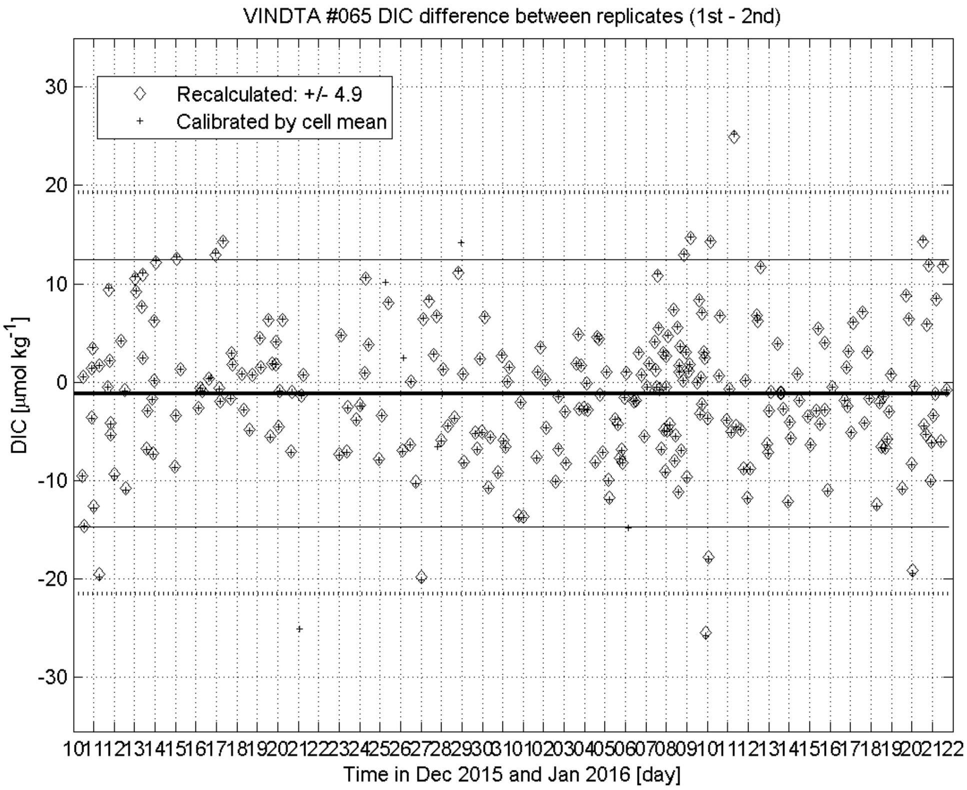


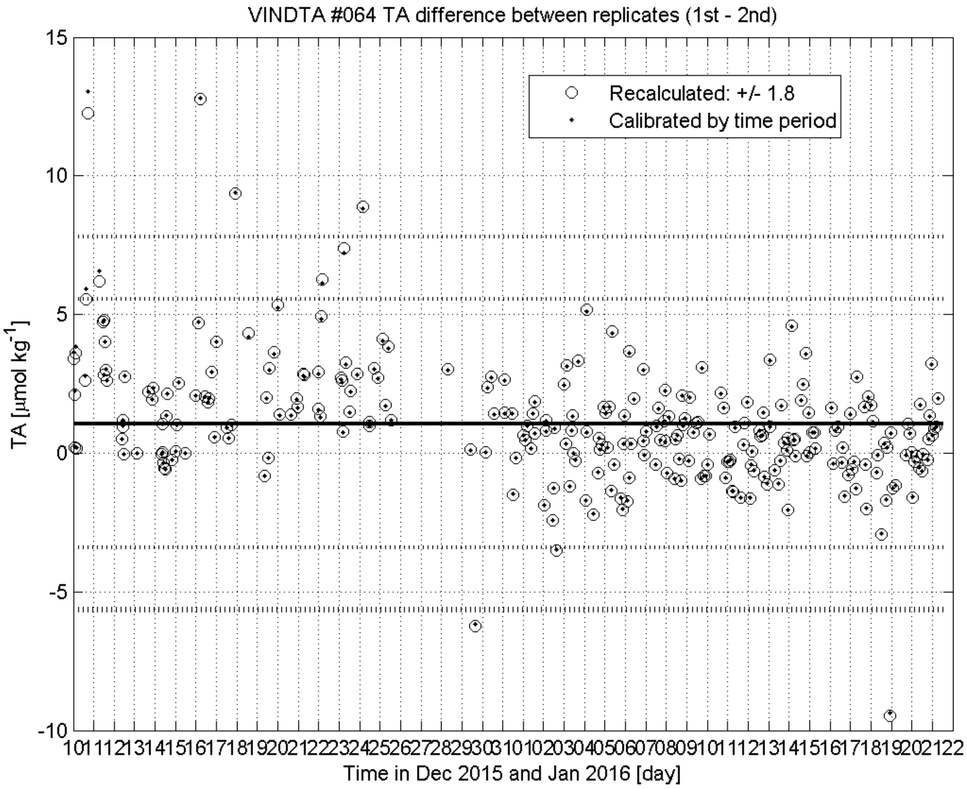
Figure 16. Calibrated CRM-DIC values for the VINDTA #064 (upper panel) and VINDTA #065 (lower panel), showing the mean (bold line), control limits (thin lines) and warning limits (dotted lines).

Post-cruise data quality control will include the recalculation of all DIC values after post-cruise temperature and pipette volume calibrations, the study of CRM changes calibration of the DIC readings for each coulometer cell used during DY040, identification and removal of further outliers and accounting for instruments drift.

6.1.3. Titration Alkalinity Analyses

The alkalinity measurements were made by potentiometric titration (Dickson et al., 2007, SOP #03b) with two VINDA instruments (VINDTA version 3C, serial numbers #064 and #065, Marianda, Germany; Mintrop, 2004). These systems use a highly precise Metrohm Titrino for HCl adding acid, an ORION-Ross pH electrode, a Metrohm reference electrode and an auxiliary electrode. The pipette and analysis cell are surrounded by a water jacket, keeping them at 25^{o}C. Hydrochloric acid (0.1M) made to ionic strength of seawater, according to SOP#3b (Dickson et al., 2007), was used as the alkalinity titrant. Alkalinity values were calibrated using CRM batch 150 (certified at 2214.71kg^{-1} ± 0.87).

Initial TA quality control included the removal of any analyses during which technical, instrumental, or chemical malfunction could be identified, the recalculation of all TA measurements with the salinity measured in each respective Niskin, and the TA calibration for each instrument by the mean of all CRMs analysed during time periods of HCl acid batches used. Figure 17 shows differences between in-bottle replicate analyses over the time of DY040, together with upper and lower warning and critical levels (Dickson et al., 2007, SOP#22).



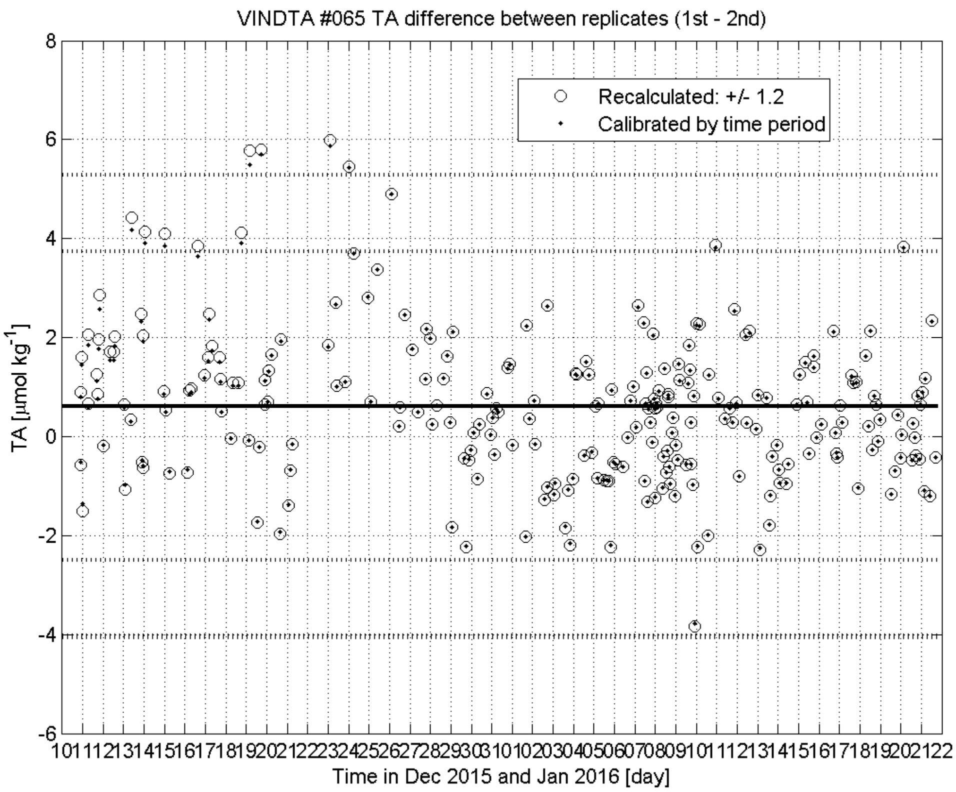


Figure 17. Calibrated CRM-TA values for the VINDTA #064 (upper panel) and VINDTA #065 (lower panel), showing the mean (bold line), control limits (thin lines) and warning limits (dotted lines).

Post-cruise quality control will include recalculation of alkalinities with CTD salinity and nutrients, after recalibration of alkalinity pipettes' volume and temperature sensors. Post-cruise QC will then include identifying and removing further outliers and accounting for drift in the instruments' alkalinity.

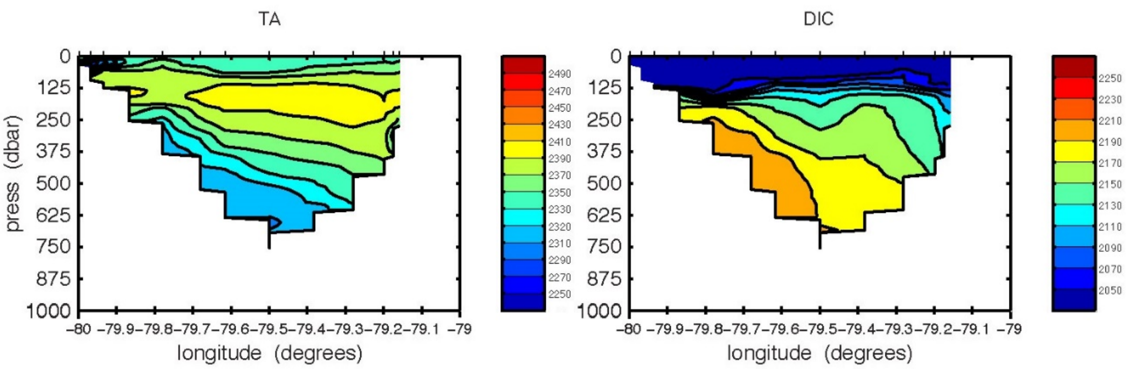
6.1.4. Shipboard Instrumentation Maintenance

VINDTA #064 was initially connected to coulometer 5015 serial number 135015020 and Metrohm Titrino model 6.3026.150, serial number 01270505. DIC pipette volume was 17.6 ml and alkalinity pipette volume was 105.0 ml, as calibrated following SOP#12 (Dickson et al., 2007). On 18th December 2015, the motor in the alkalinity cell valve was replaced due to electrical failure. On 26th December, the Metrohm reference electrode (Model 6.0729.100, Metrohm UK Ltd., Runcorn, UK) was replaced due to instability in alkalinity measurements. Due to unsolvable inconsistent precision of DIC measurements between the 26th and the 28th December, the initial coulometer was replaced by coulometer 5011 serial number 015011001 (on loan from University of East Anglia, Norwich, UK). Additionally from this point on the analysis was changed from dual to single sample analysis. The DIC acid pumping cycle was adjusted accordingly throughout the cruise due to irregularity in the pumping cycle and to guarantee sufficient acid addition.

VINDTA #065 was connected to coulometer 5015 serial number 135015019, CM:5015 and Metrohm Titrino model 6.3026.150 serial number 17850010. DIC pipette volume was 17.9 ml and alkalinity pipette volume was 111.1ml, as calibrated following SOP#12 (Dickson et al., 2007). On the 15th December, the initial Metrohm Titrino failed and was replaced with Titrino model 6.3026.150 (on loan from National Oceanography Centre, Southampton, UK). From the 28th December, analysis was changed from dual to single sample analysis in accordance with analysis on the other VINDTA machine. As with VINDTA #064, the DIC acid pumping cycle was adjusted accordingly throughout the cruise due to irregularity.

6.2. ***Results***

Final profiles of TA and DIC are shown in Figure 18.



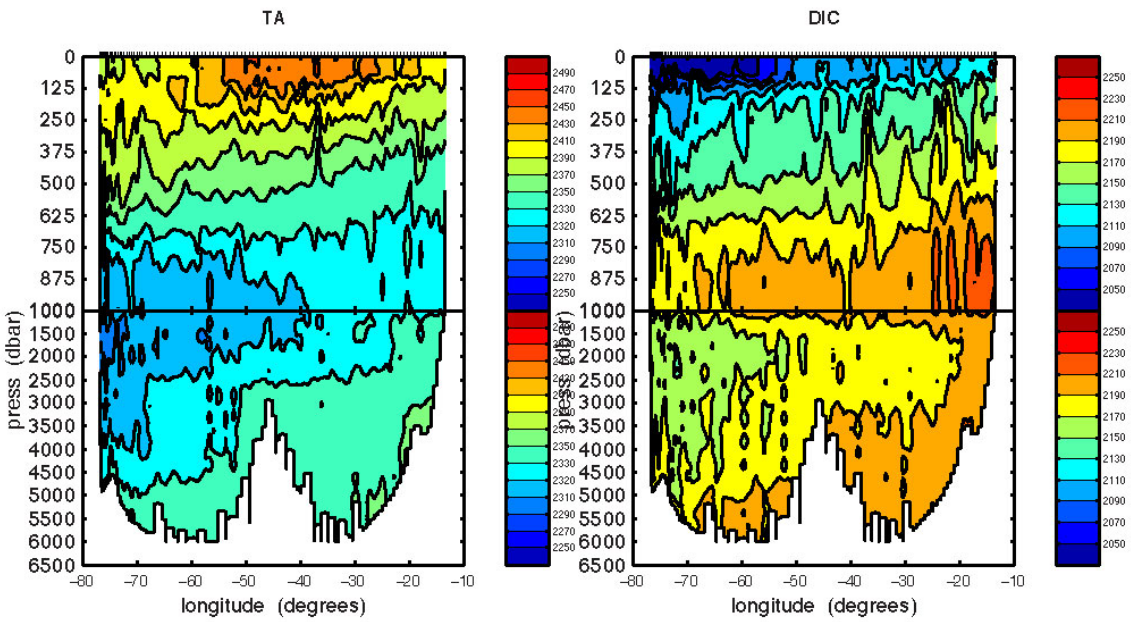


Figure 18. TA and DIC contours for the Florida Strait (upper panels) and the Atlantic (lower panels) sections.

6.3. *References*

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Johnson, K. M., Sieburth, J. M., Williams, P. J. l., and Braendstroem, L. (1987), Coulometric total carbon dioxide analysis for marine studies: automation and calibration, Marine Chemistry, 21, pp. 117-133

Johnson, K. M., and Wallace, D. W. R. (1992), The Single-Operator Multiparameter Metabolic Analyzer for total carbon dioxide with coulometric detection, DOE Res. Summary, 19, pp. 1-4

Johnson, K. M., Wills, K. D., Butler, D. B., Johnson, W. K., and Wong, C. S. (1993), Coulometric Total Carbon-Dioxide Analysis for Marine Studies - Maximizing the Performance of an Automated Gas Extraction System and Coulometric Detector, Marine Chemistry, 44, pp. 167-187

7. Chlorofluorocarbons (CFC's) and sulfur hexafluoride (SF6)

8. Oxygen Isotopes

Israela Musan

8.1. *Rationale*

From previous research, we know that atmospheric O_2 has lower ^{17}O content than expected for O_2 of pure photosynthetic origin (bio-O_2) (Luz et al., 1999). This ^{17}O deficiency is the result of mass independent fractionation in photochemical reactions in the stratosphere. Consequently, bio-O_2 has an excess of ^{17}O ($^{17}\Delta$) with respect to air O_2. Dissolved O_2 in seawater consists of two isotopic end members, one which is derived from gas exchange with air-O_2 and the other which is produced by photosynthesis in the ocean. Unlike O2 concentration, $^{17}\Delta$ is not affected by respiration and preserves the $^{17}\Delta$ signature acquired in the upper water source regions of deep water masses. Thus, $^{17}\Delta$ is a unique conservative tracer in the deep sea (Luz and Barkan, 2000), which could be a new interesting and important archive of past conditions at the source regions.

My interest in this cruise was to study the $^{17}\Delta$ distribution in the deep Atlantic, especially its relationship to ages of water masses.

8.2. *Work plan*

During the cruise, I collected water samples from 4 stations (table 1), creating 4 depth profiles. The stations were chosen so they sampled water from the main water masses in the deep Atlantic: the DWBC, the NADW and AABW in the west basin and the NADW and AABW in the east basin (fig 1). Duplicates were sampled from the surface Niskin bottles (up to 2000 m), and triplicates were sampled from the deep Niskin bottles (deeper than 2000 m).

In addition, I collected water samples in triplicate from the 4,000 m Niskin Bottle every ~500 Km (table 2), to create a west-east transect (fig 1). The age of NADW west of the Mid-Atlantic Ridge is younger than east of the ridge (e.g. Broecker and Peng, 1982), and my purpose was to examine if there is a difference in $^{17}\Delta$ values between the west and east sides of the ridge.

8.3. *Sampling and Analysis*

Water samples were collected from Niskin bottles into 270ml special glass flasks using a Tygon tube with a Tygon cone.

Prior to the cruise the flasks were poisoned (1ml $HgCl_2$) and evacuated. Their sidearm was filled with distilled water and covered with plastic cup, after pumping air bubbles from the O-ring. Just before sampling, the plastic cup and most of the water were removed from the sidearm of the flask, leaving just enough to cover the O-ring. The flask was turned sideways, and the sidearm was filled slowly with seawater, letting it overflow for a few seconds. Then the Tygon cone was pushed against the sidearm to make a tight fit, and the valve was opened slightly, filling the flask halfway to the marked line (about 150ml). The valve was shut while leaving seawater in the sidearm. Immediately after sampling the sidearms were filled with milli-Q water, and the plastic cups were replaced. $\delta^{17}O$ sampling took place after the dissolved oxygen sampling.

All samples will be analysed for $\delta^{17}O$ values at Prof. Boaz Luz's stable isotope lab, Hebrew University Of Jerusalem, Israel.

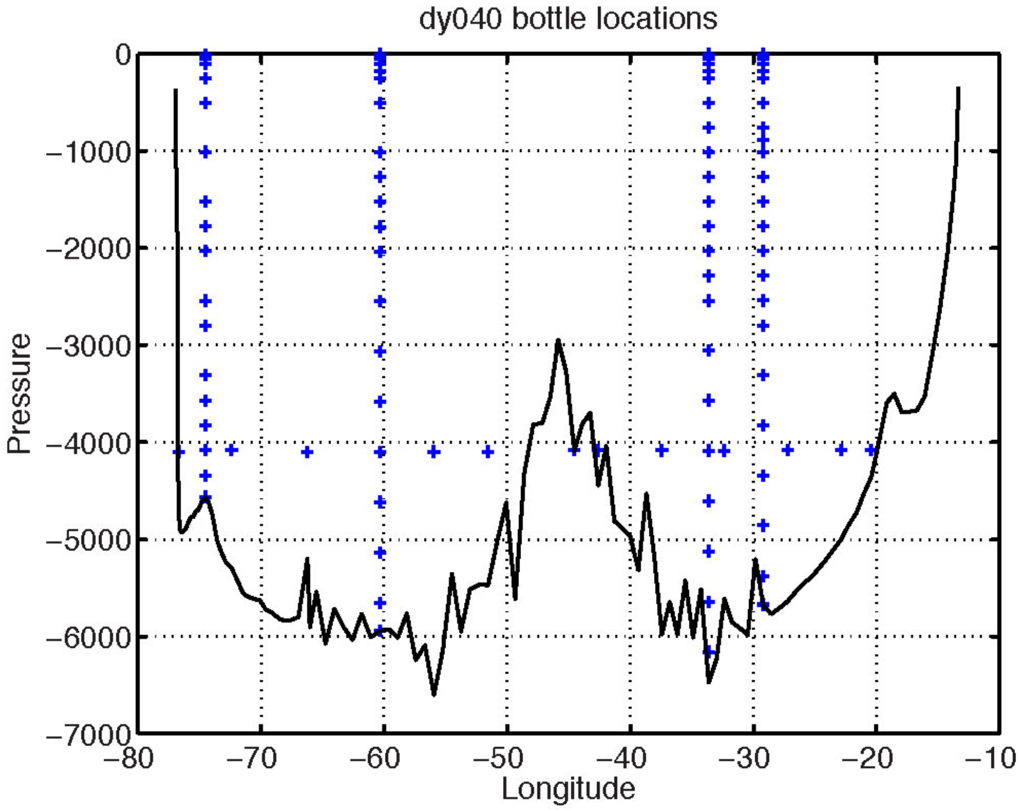

Figure 19. Sampling map. Profile 1 sampled water from the DWBC; profile 2 reach to the AABW in the western basin and profiles 3 and 4 reach to the AABW in the eastern basin. Profile 3 chosen to be a 'A' levels station while profile 4 chosen to be a 'B' levels station.

Table 11. a) List of stations sampled for the 4 depth profiles. b) List of the Niskin bottles sampled in every station. In this stations the deep Niskin bottles (>2000m) were sampled in triplicates, and the shallow Niskin bottles (<2000m) were sampled in duplicates.

a)

Profile num	**Sta num**	**Date ddd hhmm**	**Longitude (W) deg min**	**Latitude (N) deg min**
1	45	353 2255	74 31	26 30
2	71	362 1528	60 21	24 29
3	110	009 2305	33 38	24 30
4	117	012 0340	29 12	24 30

b)

45			**71**			**110**			**117**		
#Niskin	Depth (m)	Triplicate / Duplicates	#Niskin	Depth (m)	Triplicate / Duplicates	#Niskin	Depth (m)	Triplicate / Duplicates	#Niskin	Depth (m)	Triplicate / Duplicates
1	4485	XXX	2	5820	XXX	1	6032	XXX	1	5560	XXX

2	4270	XXX	3	5545	XXX	2	6035	XXX	2	5559	XXX
3	4017	XXX	4	5041	XXX	3	5531	XXX	3	5275	XXX
4	3766	XXX	5	4535	XXX	4	5027	XXX	4	4773	XXX
5	3515	XXX	6	4032	XXX	5	4522	XXX	5	4271	XXX
6	3263	XXX	7	3525	XXX	6	4020	XXX	6	3765	XXX
7	2761	XXX	8	3022	XXX	7	3517	XXX	7	3264	XXX
8	2509	XXX	9	2516	XXX	8	3014	XXX	8	2762	XXX
10	2006	XXX	10	2013	XXX	9	2512	XXX	9	2509	XXX
11	1756	XX	11	1763	XX	10	2269	XXX	10	2257	XXX
12	1506	XX	12	1509	XX	11	2008	XXX	11	2007	XXX
14	1001	XX	13	1257	XX	12	1755	XX	12	1755	XX
18	500	XX	14	1006	XX	13	1506	XX	13	1506	XX
20	256	XX	17	504	XX	14	1256	XX	14	1254	XX
22	101	XX	19	252	XX	15	1004	XX	15	1002	XX
23	51	XX	20	176	XX	17	751	XX	16	876	XX
24	6	XX	22	101	XX	18	502	XX	17	752	XX
			23	50	XX	20	251	XX	18	500	XX
			24	6	XX	21	177	XX	20	249	XX
						22	100	XX	21	174	XX
						23	51	XX	22	100	XX
						24	6	XX	23	50	XX
									24	5.5	XX

Table 12. List of stations sampled for the west-east transect. In this stations only the 4,000 m Niskin bottle was sampled. Sampling in triplicates.

Sta num	Date	Longitude (W)	Latitude (N)	4 Km Niskin num
	ddd hhmm	deg min	deg min	
31	348 1132	76 41	26 30	3
51	355 1332	72 22	26 29	4
62	359 1108	66 13	24 29	3
77	364 1810	55 57	24 30	6
83	001 1829	51 33	24 30	4
93	004 1833	44 33	24 30	2
96	0051502	42 36	24 30	3
104	007 0135	37 26	24 30	6
112	010 1423	32 22	24 30	5
120	014 1241	27 12	24 30	6
127	016 1455	22 53	24 42	5
131	017 1903	20 25	25 32	3

8.4. *References*

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9. Methane and Nitrous Oxide (atmospheric and water column)

Ian Brown

Nitrous oxide and methane are biogenically produced trace gases whose atmospheric concentrations are increasing at a rate in the order of 0.7 ppbv y-1. Both gases are radiatively active, contributing approximately 6% and 15% of “greenhouse effect” respectively, whilst N2O contributes to stratospheric ozone depletion and CH4 limits tropospheric oxidation capacity.

The oceans are generally considered to be close to equilibrium relative to the atmosphere for both gases, however oceanic source/sink distributions are largely influenced by oxygen and nutrient status and regulatory processes are complicated and are currently not well understood. Ocean areas overlying sub-oxic waters and upwelling areas dominate the ocean source and saturations of up to 300% have been reported.

Aim:- To perform vertical profiles of N2O and CH4 concentration in order to assess variability in the source-sink strength and exchange with the atmosphere along the transect.

9.1. *Methods*

Samples were collected from CTD bottles at stations identified below. 1 litre samples were equilibrated with compressed air and headspace analysis performed on-board using FID-gas chromatography and ECD-gas chromatography1 for CH4 and N2O respectively. Atmospheric concentrations were determined by the same methods using samples collected from the ships bow into a sealed Tedlar bag.

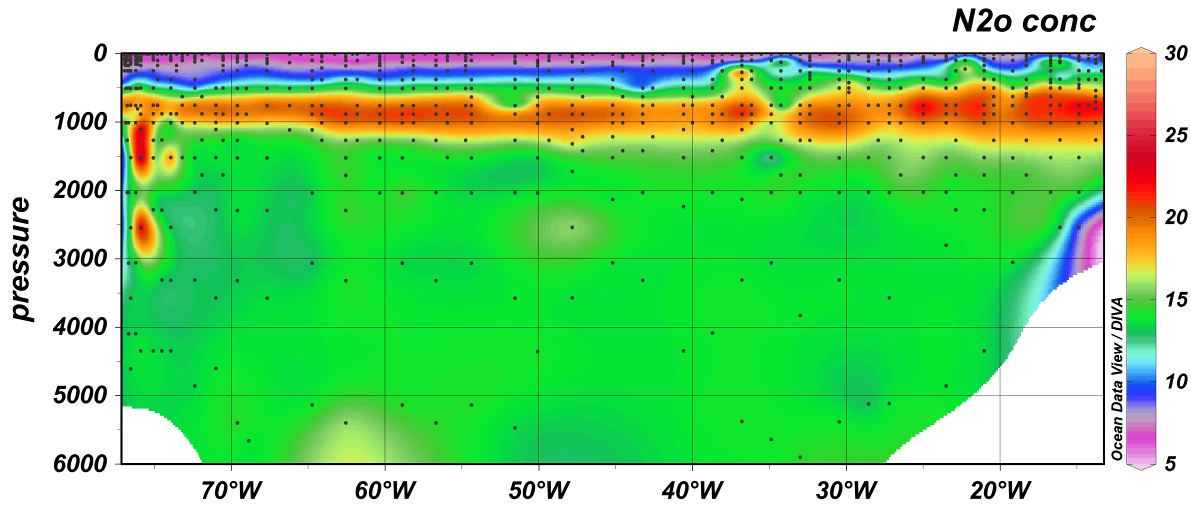

Figure 20. N_2O concentration (nmol L^{-1}) during DY040, December 2015 - January 2016.

Table 13. N_2O, CH_4 Sampling Date and position – DY040.

Julian Day	CTD No	Lat	Lon	Niskin	Depth
344	4	27.00	79.97	1 4 13 16	130 70 37 6.5
344	5	27.00	79.87	18 20	5 5
344	7	27.00	79.78	20 19	5 5
345	8	27.01	79.68	19 23	5 5
345	9	27.01	79.62	23 23	5 5.4
345	9	27.00	79.50	23 1 8	5.4 687 380
345	11	27.00	79.38	1 8 11 14 16 18 21 23	687 380 227 175 125 76 30 5
345	12	27.00	79.28	1 5 10 14 16 19 21	601 402 251 136 91 45 5
345	13	27.00	79.20	3 8 12 16 19	380 240 110 35 5
345	14	27.00	79.18	5 10 14 16 19	313 171 81 36 5
345	15	27.00	79.16	3 13 15 18 20	243 112 80 36 6
346	25	26.50	76.93	4 8 10 12 16 18	250 150 100 50 25 5
346	26	26.50	76.87	11 14 16	120 50 5
346	27	26.52	76.83	2 6 9 10 12 15	1000 500 175 100 50 5
347	28	26.50	76.80	21	5
347	29	26.50	76.77	3 6 9 11 14 17 19 20	2000 1250 750 500 250 75 25 5
348	30	26.50	76.76	24	5
348	31	26.50	76.68	3 7 9 12 16 18 19 21 23 24	4000 3000 2000 1000 500 250 175 100 25 5
348	32	26.50	76.62	24	5
348	33	26.50	76.53	2 4 6 10 14 16 18 19 20 21 23 24	4607 3500 2544 1522 759 507 253 157 120 75 25 4
348	34	26.50	76.43	24	5
349	34	26.50	76.30	24	5
349	36	26.50	76.22	3 6 10 14 16 17 19 21 22 23 24	4000 3000 2000 1000 750 500 250 150 100 50 5
349	37	26.50	76.10	15 17 20 21 22 23 24	803 500 155 104 75 49
352	39	26.50	75.90	2 7 11 13 15 16 17 20 21 22 23 24	4250 2500 1500 1100 875 750 500 175 105 70 40 5
352	40	26.50	75.70	24	5
352	41	26.50	75.50	24	5
353	42	26.50	75.30	24	5
353	43	26.50	75.07	2 9 12 13 15 16 17 18 20 22 23 24	4250 2500 1500 1250 1000 875 750 499 250 90 50 5
353	44	26.50	74.80	16 19 21 22 24	750 375 175 100 5

353	45	26.50	74.53	2 6 9 13 15 24	4250 3250 2250 1250 875 5
354	46	26.50	74.24	24	5
354	47	26.50	73.94	2 4 7 11 14 15 17 18 21 22 23 24	4250 3200 2500 1500 1000 750 500 324 100 75 50 5
354	48	26.50	73.57	15 20 21 24	875 250 175 5
354	49	26.50	73.20	12 14 16 17 22 23 24	1500 1000 750 625 100 50 5
355	50	26.50	72.84	24	5
355	51	26.50	72.38	2 6 10 12 14 16 17 18 21 22 23 24	4750 3520 2000 1500 1020 750 500 375 120 75 50 5
355	52	26.50	71.92	11 13 15 17 22 24	1750 1250 875 625 100 5
355	53	26.50	71.46	24	5
356	54	26.50	71.00	3 5 8 11 13 14 15 16 17	4500 3500 2500 1500 1100 1000 875 750 500
356	55	26.00	70.54	11 13 15 17 19 20 21 22 23 24	1750 1250 875 500 250 175 100 75 50 5
357	57	25.04	69.62	2 6 9 12 13 14 15 16 17 19 21 22 23 24	5295 3500 2500 1500 1250 1000 875 750 500 250 120 75 50 5
357	58	24.50	69.02	15 18 21 22 23 24	875 500 175 100 50 5
358	59	24.50	68.87	24	5
358	60	24.50	67.68	2 6 9 12 14 16 17 19 20 21 22 24	5546 3525 2500 1500 1000 750 500 250 140 110 75 5
358	61	24.50	62.11	24	5
359	62	24.49	66.22	12 15 17 21 24	1100 750 500 130 5
359	64	24.50	65.48	24	5
360	65	24.50	64.75	3 7 10 12 14 16 17 18 19 20 22 24	5000 3000 2000 1500 1100 875 750 500 375 250 100 5
360	66	24.50	64.11	13 14 15 16 18 20 21 23 24 24	1250 1000 875 750 375 210 115 50 5 5
360	67	24.50	63.28	24	5
361	68	24.50	62.56	3 7 10 12 13 14 15 16 18 19 21 22 23 24	5250 3250 2250 1750 1500 1250 1000 875 500 375 175 100 50 5
361	69	24.50	61.82	14 16 17 19 22 24	1250 875 750 375 100 5
362	70	24.50	61.08	24	5
362	71	24.50	60.35	10 12 13 14 15 16 17 18 19 20 21 22 23 24	2000 1500 1250 1000 850 750 500 375 250 175 140 100 50 5
363	73	24.49	58.88	4 8 11 13 15 16 17 18 18 19 22 23 24	5000 3000 2000 1500 1000 875 750 500 500 375 125 50 5
363	74	24.50	58.15	14 15 16 17 18 19 20 21 22 24 24	1250 1000 875 750 500 375 250 175 102 5 5
363	75	24.50	57.42	24	5
364	76	24.50	56.68	3 7 11 14 16 17 18 19 21 22 24	5250 3250 2000 1250 875 750 500 375 175 100 5
364	77	24.50	55.95	13 15 16 18 20 22 23 24 24	1500 1000 875 500 250 100 50 5 5
364	78	24.50	55.22	24	5
365	79	24.50	54.38	1 6 10 12 14 15 16 17 18 19 22 24	5000 3000 2000 1500 1000 875 750 625 500 375 100 5
365	80	24.50	54.75	14 17 18 20 21 22 23 24	1250 750 500 250 178 100 50 5
365	81	24.50	53.02	24 2 5 9 12 14 15 17 18 21 22	5 5000 3500 2000 1250 875 750 500 375 140 110
366	83	24.50	51.55	2 5 9 12 14 15 17 18 21 22 23 24	5000 3500 2000 1250 875 750 500 375 140 110 50 5
1	84	24.50	50.82	24	5
2	85	24.50	50.08	3 9 11 13 14 15 16 17 18 20 21 22 24	4250 2000 1500 1000 875 750 625 500 375 175 125 100 5
2	86	24.50	49.35	14 16 18 20 22 23 24	1250 875 500 250 100 50 5
2	87	24.50	48.62	24	5
3	88	24.50	47.83	3 6 10 12 13 15 16 18 19 22 23 24	3500 2500 1700 1300 1100 875 750 500 375 120 50 5
3	89	24.50	47.15	10 11 13 15 19 21 24	1400 1200 875 625 250 125 5
3	90	24.50	46.50	24	5
4	92	24.50	45.20	3 7 10 12 14 15 16 18 19 21 22 24	3000 2100 1500 1205 1003 875 750 500 375 175 125 5
4	93	24.50	44.55	10 13 14 16 19 23 24	1400 1000 875 625 250 50 5
4	94	24.50	43.90	24	5
5	95	24.50	43.25	3 6 9 11 12 13 14 16 21 22 23 24	3250 2000 1400 1000 875 750 625 500 175 100 50 5
5	96	24.50	42.60	12 16 17 19 21 24	1200 750 500 250 100 5
5	97	24.50	41.95	24	5
6	99	24.50	40.60	3 7 11 13 14 15 17 18 21 22 23 1	4200 2200 1500 1100 875 750 500 375 140 100 50 5
6	100	24.50	40.00	14 16 17 20 22 24	1000 750 625 250 100 5
7	101	24.50	39.35	24	5
7	102	24.50	38.70	3 8 11 13 14 15 17 18 21 22 23 24	4000 2000 1400 1000 875 750 500 375 140 100 25 5

7	103	24.50	38.07	13 15 17 20 22 24	1250 875 625 250 110 5
7	104	24.50	37.43	24 3 7 10 13 15 16 17 18 19 20	5 5250 3250 2100 1500 1100 875 750 500 375 250
8	105	24.50	36.80	3 7 10 13 15 16 17 18 19 20 21 22 23 24	5250 3250 2100 1500 1100 875 750 500 375 250 175 100 50 5
8	106	24.50	36.17	14 16 17 19 20 22 24	1250 875 750 375 250 95 5
8	107	24.50	35.53	24 1 7 10 13 15 16 17 18 20 22	5 5250 3000 2000 1500 1000 875 750 500 250 100
9	108	24.50	34.90	1 7 10 13 15 16 17 18 20 22 24	5250 3000 2000 1500 1000 875 750 500 250 100 5
9	109	24.50	34.27	12 14 17 18 19 20 22 24	1750 1250 750 500 375 250 125 5
9	110	24.50	33.64	24	5
10	111	24.50	33.00	2 6 11 12 14 15 16 17 18 20 22 24	5750 3750 2000 1750 1250 1000 875 750 500 250 100 5
10	112	24.50	32.37	12 15 16 17 18 19 20 21 22 23 24	1250 875 750 500 375 325 250 175 100 50 5
10	113	24.50	31.73	24	5
11	115	24.50	30.47	3 7 11 13 15 16 17 18 19 20 22 24	5250 3250 2000 1500 1000 875 750 500 375 250 110 5
11	116	24.50	29.84	16 17 18 19 20 22 23 24	750 560 500 420 250 90 50 5
12	117	24.50	29.20	24	5
12	118	24.50	28.57	3 11 13 15 17 18 19 20 22 23 24	5000 2000 1500 1000 750 500 375 250 100 50 5
12	119	24.50	27.93	14 17 21 22 24	1250 750 165 105 5
14	120	24.50	27.21	4 7 11 13 15 16 17 18 19 20 22 23 24	5000 3500 2000 1500 1000 875 750 500 375 250 100 50 5
14	121	24.50	26.48	12 14 15 17 18 21 22 24	1750 1250 1000 750 500 175 100 5
15	122	24.50	25.73	24	5
15	124	24.50	24.99	11 13 15 16 17 18 19 21 22 23 24	2000 1500 1000 875 750 500 375 130 75 50 5
15	125	24.50	24.25	24	5
16	126	24.50	23.50	4 9 11 13 15 16 17 18 19 22 23 24	4750 2750 2000 1500 1000 875 750 500 375 100 50 5
16	127	24.71	22.88	10 12 14 16 17 18 20 22 24	2250 1750 1250 875 750 500 250 100 5
16	128	24.92	22.27	19 21 23	215 100 5
17	129	25.13	21.65	24	5
17	130	25.33	21.03	3 8 10 11 13 14 15 17 18 19 20 21 22 24	4250 2250 1750 1500 100 875 750 500 375 250 175 100 75 5
17	131	25.54	20.42	12 14 15 16 17 18 22 24	1250 875 750 625 500 375 75 5
17	132	25.75	19.80	24	5
18	133	25.96	19.18	4 9 11 14 16 17 18 20 22 24	3000 2000 1500 1000 750 625 500 250 100 5
18	134	26.18	18.30	10 12 14 16 17 18 19 21 22 23 24	1750 1250 875 625 590 500 375 175 100 50 5
18	135	26.38	17.95	24	5
19	137	26.79	16.72	7 9 11 13 14 15 16 17 18 19 20 21 22 23 24	2000 1500 1000 875 750 625 500 425 375 250 175 140 100 50 5
19	138	27.00	16.10	6 11 14 16 17 21 22 23 24	2500 1250 750 500 375 132 110 50 5
19	139	27.21	15.48	24 5 7 9 11 13 14 16 17 18 20 22 23 24	5 2500 2000 1500 1000 875 750 500 450 375 250 100 50 5
20	140	27.42	14.87	5 7 9 11 13 14 16 17 18 20 22 23 24	2500 2000 1500 1000 875 750 500 450 375 250 100 50 5
20	141	27.63	14.25	15 18 19 22 24	750 375 250 75 5
20	142	27.79	13.78	5 7 10 12 15 17 19 22 23 24	1250 1000 800 700 540 375 250 140 90 5
20	143	27.87	13.22	24	5
20	144	27.91	13.41	8 14 16 18 10 11 15	250 60 40 5 100 50 5
20	145	27.93	13.37	10 11 15	100 50 5

9.2. *References*

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10. Chlorophyll

Justin Buck

10.1. *Introduction*

To aid in the deployment calibration of the bio-optical sensors installed on the Bio-Argo floats deployed during DY040. Samples were collected for filtering and post cruise analysis at Plymouth Marine Laboratory (PML).

10.2. *Sampling*

4-litre samples were taken at the upper five depths of both stations where Bio-Argo floats were deployed as summarised in Table 14.

Table 14: Summary of stations and depths where samples were collected and filtered for pigments analysis after the cruise at PML.

CTD Station	Rosette position	Wire out (m)
66	20	210
66	21	115
66	22	100
66	23	50
66	24	5
71	20	175
71	21	140
71	22	100
71	23	50
71	24	5

10.3. *Filtering*

All 4 litres of each sample was filtered through GFF filters. The filters were then frozen in liquid nitrogen and placed in plastic 5ml vials before storage at -80°C.

11. Lowered Acoustic Doppler Current Profiler (LADCP)

Daniel Valla

11.1. *Instrument Setup*

Four RDI 300kHz Workhorse (WH) LADCP aluminium cased units were available for use on DY040. WH S/N 22797 was a brand-new unit and WH units S/N 13329, 1855 and 4275 were refurbished. The four units were used for their first time in DY040 and they were all employed individually at some point during the cruise. The instruments were mounted in a downward looking orientation centred on the CTD frame, configured to have a standard 25 x 8m bins and connected to a re-chargeable battery also installed on the CTD frame. The list of deployment commands can be found in the Appendix 1. The Blank after Transmit setting was set to zero in all casts. Data were collected in beam co-ordinates and rotated to earth co-ordinates in post-processing. Prior to each station the LADCP was connected to a laptop in the deck lab (via a serial port) for pre-deployment tests and then programmed for deployment. After each station the instrument was reconnected to the laptop for the retrieval of the data. The battery pack was charged between stations.

The cruise started with the WH unit S/N 22797. The instrument was not used during the shallow stations #2-5 across the Florida Straits. On station #22 the instrument failed to communicate during the pre-deployment tests and so the profile was aborted. Although the instrument was not tampered with in order not invalidate the warranty, inspection after removal indicated that leakage through the communication/charging plug may have caused the instrument to malfunction. The unit was replaced by the WH unit S/N 13329 after station 25, which exhibited a good performance. After station #74 the LADCP was removed, as casts #75 – 80 were all deeper than 6000m and the unit is not rated beyond this depth. At station #81 the WH unit S/N 1855 was installed. This instrument produced good quality data although the external thermistor did not perform well. The LADCP was replaced by WH unit S/N 4275 at station #113. After 5 casts the unit started showing poor beam performance (see “Instrument performance” section) and so it was replaced by WH unit S/N 13329 on station #130. This unit was used for the remainder of the cruise. The use of each LADCP is summarized in Table 15. The stations in which no LADCP unit was installed are summarized in Table 16.

Table 15. RDI WH units employed during DY040.

Station range	**RDI Workhorse unit (S/N)**
1 – 2, 5-21	22797
25-74, 130-145	13329
81-112	1855
113-129	4275
130-145	13329

Table 16. Stations with no LADCP installed in the package.

Station range	**Motive**
3-4	Shallow casts
22-24	Unit replacement

75-80	Stations deeper than 6000 m

11.2. ***Data Processing***

Data for each station were processed on the linux workstation “eriu” as user “pstar” using two different software packages. The first package was developed at the Lamont-Doherty Earth Observatory (LDEO), and uses an inverse method to calculate velocity profiles, optionally including LADCP bottom tracking and/or VMADCP upper ocean velocities as constraints. LDEO (IX.8) processing was performed using only ship navigation (ladcp/ix/data/DL_GPS), navigation and bottom tracking (ladcp/ix/data/DL_BT), and navigation, bottom tracking, and VMADCP (ladcp/ix/data/DL_SADCP). The second software package was developed at the University of Hawaii (UH) and computes shear, then using integrated instrument-relative velocity and ship navigation to compute the depth-averaged velocity reference.

11.2.1. Data processing setup

A single raw data directory was used for both IX and UH processing. Each processing suite could access the raw files by making links to them. Raw data were copied onto eriu in directory `cruise/data/ladcp/raw/`, where there was a link to the ladcp directory on the network data drive, discofs. Two linkscripts were available, *lad_linkscript_ix* and *lad_linkscript_uh*. Each linkscript kept the raw data directory up to date and made links from the raw data directory of each data processing suite to the raw files in `cruise/data/ladcp/raw/` as follows:

- *lad_linkscript_ix*: IX processing uses raw filenames like 001DL000.000 in directory ladcp/ix/data/raw/001/, so the script links ladcp/ix/data/raw/001/001DL000.000 → ../rawdata/DY040_001m.000.
- *lad_linkscript_uh*: UH processing uses raw filenames like d001_02.000, so the script links ladcp/uh/pro/dy1512/ladcp/proc/Rlad/d001_02.000 → rawdata/DY040_001m.000.

11.2.2. Linking to CTD data

Each processing suite also expects CTD filenames to have a certain form. 1-Hz CTD data was exported into ascii using the mexec command *list_ctd_1hz*(*nnn*) within Matlab for station number *nnn*. This exported the variables time, press, temp, psal, latitude, longitude. Note that lat and lon are required for the IX processing, and become the source of navigation data for that suite. After the command *list_ctd_1hz(nnn)* was ran from Matlab, *ladctd_linkscript_ix* and *ladctd_linkscript_uh* were ran in Unix in order to make those ascii files available to the IX and UH processing in the correct data directories and with the correct file names. In IX, links to CTD data were made in ladcp/ix/data/CTD/1Hz/ctd_dy040_001_1hz txt → ctd/ctd_dy040_001_1hz_txt.

11.3. *Linking to VMADCP data*

The codas/mexec processing produced single profiles of VMADCP data acquired during each station and a link was made to the VMADCP directory, ladcp/ix/data/SADCP → vmadcp/dy040_os75. A typical filename of data in the vmadcp directory was ladcp/ix/data/SADCP/os75_dy040_ctd_001.mat.

11.4. *IX processing*

11.4.1. Setting set_cast_params.m

Edits to .m files were required at start of the cruise for IX processing. In addition to setting up directories, links and linkscripts, the *set_cast_params*.m* files must be edited with cruise details. These scripts reside in data/ladcp/ix/data/.

Edits required (lines from dy040 *set_cast_params.m* shown):

- f.sadcp = sprintf('SADCP/os75_dy040_ctd %03d.mat',stn);
- f.ctd = sprintf('CTD/1Hz/ctd_dy040_%03d 1hz txt',stn);
- p.cruise id = 'dy040';

The different versions of *set_cast_params*.m* are called by different versions of *process_cast*.m* to run IX processing of the LADCP data with different constraints:

- process cast v5.m calls *set_cast_params_v5.m* to include only navigation data
- process cast v4.m calls *set_cast_params_v4.m* to include navigation and bottom tracking data
- process cast v3.m calls *set_cast_params_v3.m* to include navigation, bottom tracking, and VMADCP data

11.4.2. Time base for IX

As mentioned before, the IX software uses CTD data as a navigational data source, therefore a precise synchronisation between LADCP and CTD data is required during the processing. The IX software computes the lag between the two data sets by comparing the vertical velocity of the package measured by the LADCP and the vertical velocity estimated from the CTD pressure time series. After processing several LADCP casts using the IX suite, it was noticed that, according to the processing results, the CTD time series would significantly lagged the LADCP time series (> 100 s). Moreover, this lag would monotonically increase in successive stations. However, no differences larger than 1-2 seconds were found between the LADCP internal clock and the NMEA time, which is logged into the CTD file in every scan count. After exploring several Matlab scripts within the IX suite, it was found that the script *besttlag.m*, which is used to find the best lag between the two times series of vertical velocity in step 6 of *process_cast*.m*, would sometimes output spurious lags. Since NMEA time is recorded into the CTD file, it was decided to use Year Day rather than time elapsed in seconds as time base for the IX processing. To this end the parameters *f.ctd_time_base* and *f.nav_time_base* in *set_cast_params.m* were set to 1 and the command *list_ctd_1hz*(*nnn*) was edited to export yet another variable, CTD time in year day. After reprocessing all stations with this time base, no lags between CTD and ADCP time series larger than 1 second were found in the processed stations.

11.4.3. Quick look notes for LADCP processing in IX

- Run unix script *lad_linkscript_ix*. This will find any files in discofs that aren't on pstar, copy them across to the correct place on pstar using rsync, and create links in the IX processing tree so that IX is aware of the raw files: ladcp/ix/data/raw/002/002DL000.000 → ../rawdata/DY040_002m.000 and so on. This script can be run from anywhere, and will echo to the screen the identity of any files copied and any links made.
- Run unix script *ladctd_linkscript_ix*. If the CTD 1-Hz ASCII file is available, this will make a link in the IX processing tree so that IX is aware of the CTD data: ladcp/ix/data/CTD/1Hz/ctd_dy040_nnn_1hz_txt → ctd/ctd_dy040_nnn_1hz_txt. IX can be run without CTD data for first-look checking, but it will produce an error in calculating the magnetic variation, because position is unknown (as this comes from the CTD 1-Hz file). If you know the CTD file is not available, skip this step.
- If you intend to run process cast v3 to use VMADCP data, check that ladcp/ix/data/SADCP/os75_dy040_ctd_002.mat is available.
- Run the IX process:

  >> cd ladcp/ix/data or cd /cruise/data/ix
  >> matlab &
  >> ixpath (in Matlab from now on)
  >> m_setup
  >> mcd ix
  >> process cast(nnn), where nnn is the station number.

11.5. *UH processing*

11.5.1. Quick look notes for LADCP processing in UH

- Run unix script *lad_linkscript_uh*.
- After navigating to the directory /cruise/data/ladcp/uh, type *source LADall* to set up the paths required for the processing.
- In ~/cruise/data/ladcp/uh/pro/dy1512/ladcp/proc; *perl -S scan.prl NNN_02* to scan the raw data and create a station specific directory in the proc/casts directory, where NNN is the station number. 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 log sheet.

- In Matlab; *m_setup*; *putpos(NNN,02)* gets position of the cast by accessing the SCS datastreams; *magvarsm(NNN,02)* obtains the required magnetic correction to the compass on the LADCP. Quit matlab.
- In unix; *perl -S load.prl NNN_02* loads the raw data, using magvar.tab for the magnetic correction to load data. It is 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.
- In Unix; *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.
- The inclusion of CTD data requires an ASCII file containing 1-Hz CTD data for the station. If CTD processing has been completed, *ladctd_linkscript_uh* will make it available in proc/Rctd.
- cd proc/Rnav; *matlab &*; *ctd_in(NNN,02)* will read the 1-Hz CTD data in. *plist=NNN.02*; *fd* aligns the LADCP and CTD data sets in time.
- cd /proc; *perl -S add_ctd.prl NNN_02* adds the CTD data to the *.blk LADCP files in scdb/.
- *perl -S domerge.prl -c1 NNN_02* merges the single pings into corrected shear profiles. The -c1 option now states that we have included CTD data.
- In matlab *cd /proc*; *plist = NNN.02*; *do abs*; calculates the relative velocity profiles. 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).

11.5.2. Inclusion of True Depths

After the true depth was determined for each station, the Matlab script *update_proc_cod_dat_dy040.m* was used to update the file proc.dat in ~/cruise/data/ladcp/uh/pro/dy1512/ladcp/proc/. The original depths were left in place but commented out so they were not used when the file was read. The *perl –S domerge.prl -c1 NNN_02* step was repeated to incorporate the new depths and within Matlab the command *plist = NNN.02* and *do_abs* were re-run. The plots produced then show the corrected depth.

11.5.3. Station true depths

In the IX suite processing including CTD data, bottom depth is calculated by integrating the vertical velocity measured by the ADCP. This value is then recorded into the IX log file. A list of calculated bottom depths can easily be retrieved from the log files by typing, for example,

>> *grep bottom *log | grep found | grep at*

in any of the IX processed data directories, (e.g. the ~/cruise/data/ix/DL/processed). This is a more straightforward way of retrieving true depths than using the CTD maximum depth plus the altimeter measurements because often altimeter data would be noisy. The software also provides a diagnostic plot for detected sea bed points in IX "Figure 4". On occasion, however, the sea bed is not successfully detected by the LADCP and so incorrect bottom depths are derived. An example of a failure to detect bottom depth is depicted in Figure 21. To identify these errors, bottom depths estimated with the LADCP were compared to those estimated from maximum CTD depth + altimeter. Differences larger than 5m were individually inspected and a decision was then made in regards to which source was to be used according to the general quality of the data (Figure 22, Table 17). At stations #101, #110 and #123 the package's maximum depth was too far away from the bottom in order to obtain a true depth from either the LADCP or CTD+altimeter. In these cases the EM122 averaged value was used as true depth.

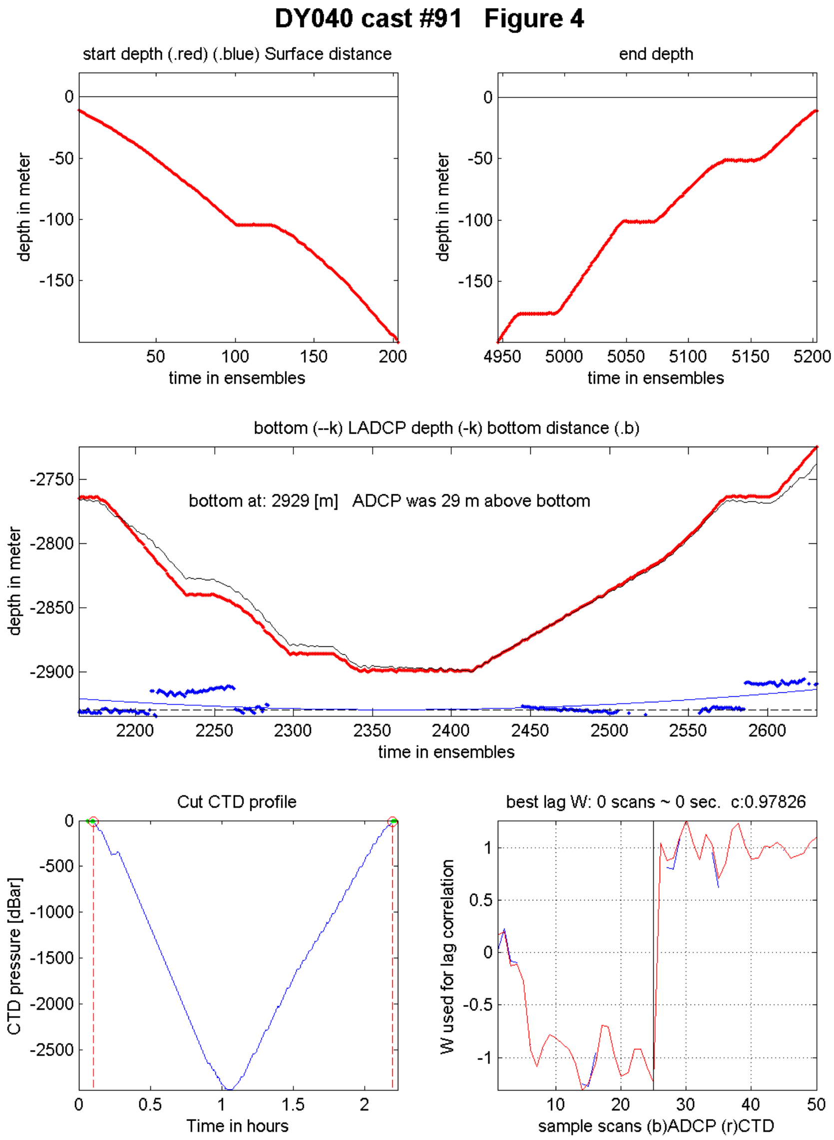


Figure 21. IX software “Figure 4” for station #91. Notice the noisy sea bed detected points in the middle panel.

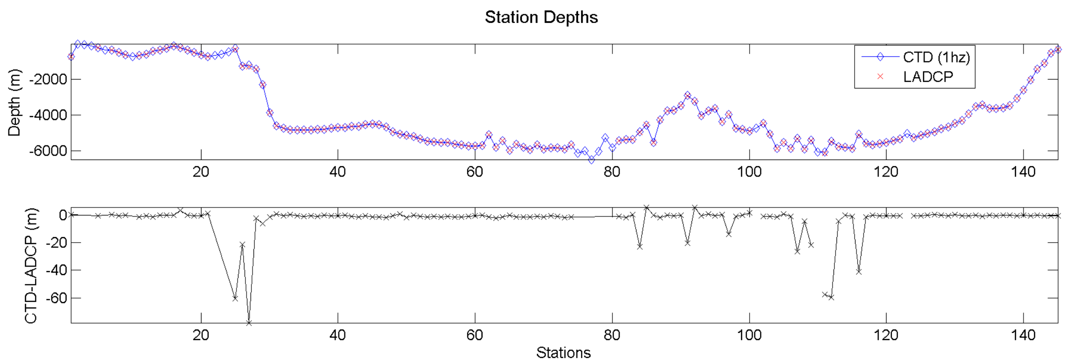


Figure 22. Top panel: bottom depths (m) vs. station number from CTD+altimeter and LADCP. 1Hz binned CTD files were use for the calculation. Bottom panel: CTD minus LADCP difference (m) vs. stations numbers. Differences larger than 5 m are listed in Table 17.

Table 17. List of questionable stations analyzed for true depth. The CTD minus LADCP difference, the source of such difference and the source and value of the final true depths are given.

Station	CTD – LADCP difference (m)	Source of difference	True Depth (m)	True Depth Source (m)
25	-61	Noisy altimeter data	358	LADCP
26	-21	Noisy bottom depths from LADCP	1268	CTD + alttim.
27	-78	Sea bed not detected by altimeter	1311	LADCP
84	-23	Noisy bottom depths from LADCP	4933	CTD + alttim.
91	-20	Noisy bottom depths from LADCP	2908	CTD + alttim.
101	NaN	Package off the bottom	5219	EM122
107	-26	Sea bed not detected by altimeter	5325	LADCP
109	-22	Noisy altimeter data	5409	LADCP
110	NaN	Package off the bottom	6340	EA640/EM122
111	-57	Sea bed not detected by altimeter	6106	LADCP
112	-60	Noisy altimeter data	5504	LADCP
116	-41	Sea bed not detected by altimeter	5742	LADCP
123	NaN	Package off the bottom	5295	EA640/EM122

11.6. *Accumulation of turns*

During DY040 cruise two different CTD wires were used, the “Deep Tow” and the “CTD2”. The IX suite was used to keep track of the number of turns that were being put into the wires on each station because significant twisting could result in the wire developing kinks. The script *saveres.m* was edited in order to save the Matlab structures “l” and “d” as output variables, which contain the LADCP heading for each ensemble. The “l” structure contains data for the full cast, that is, since the LADCP is activated on deck until it is turned off. The “d” structure contains combined LADCP and CTD data and therefore is constrained to the period in which the package is into the water.

The total turns made by the package during each cast as well as the cumulative turns through the successive stations are shown in Figure 23. As a fin was installed on the package in order to prevent excessive rotations, it is useful to discriminate the amount of complete turns accumulated through the full cast from the amount of turns accumulated during just the time in the water. For the CTD2 wire, significant differences were observed between these two values, that is, the package accumulated turns while hanging on deck (e. g. stations #30-37), whereas no such differences were seen with the Deep Tow. Assuming that the number of turns on the winch cable was zero at the start of the cruise, it can be seen from the cumulative plot that the number of anticlockwise turns on the CTD2 cable started to increase from the very beginning. Clockwise turns were accumulated between stations #29-32. The analysis of the heading time series for each of these casts indicated that clockwise turns increased after the paid out wire was more than that of the last station, suggesting that significant twists were stored in the wire. Anticlockwise turns were again accumulated once a nearly constant maximum depth was achieved after station 32. The CTD2 was replace by the Deep Tow between stations 38-54, which showed a significant tendency of accumulating anticlockwise turns. Due to a communication failure, the Deep Tow was replaced by the CTD2 cable after station #54. By station #86 the wire had accumulated a total of 82 clockwise turns. The package hit the bottom in station #87 and the CTD2 developed several kinks, so it was again replaced by the Deep Tow, which was used for the remaining of the cruise. By the end of the cruise the Deep Tow wire had accumulated a total of 112 turns in the anticlockwise direction.

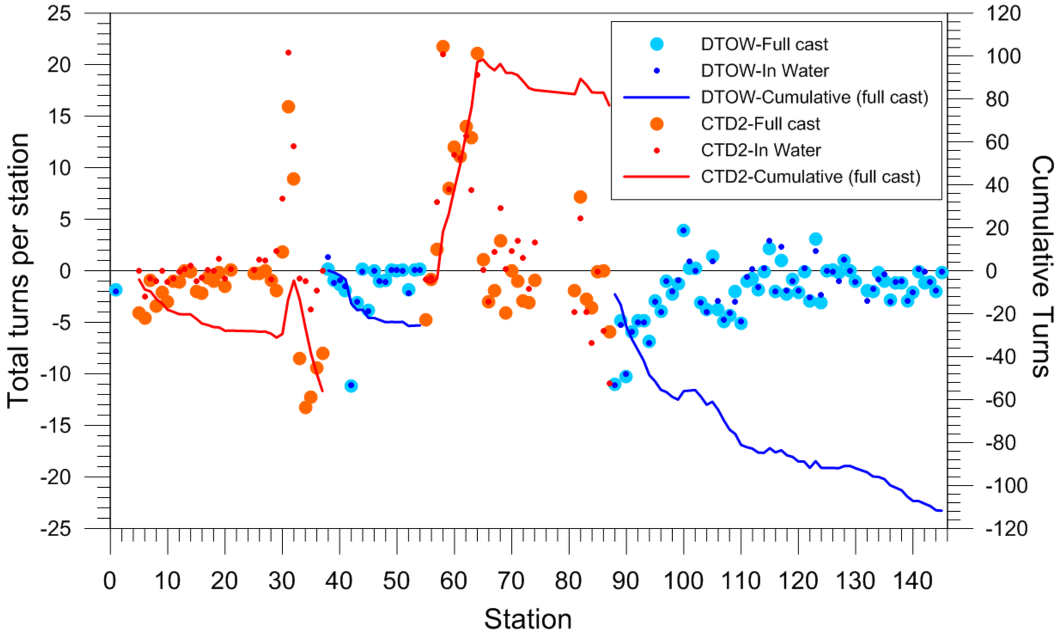


Figure 23. Number of complete turns on the CTD package per station for the CTD2 and Deep Tow (DTOW) cables (left y-axis). The total turns are computed for the full LADCP cast (circles, "full cast") and for the period the package was in the water (dots, "in-water"). Cumulative turns computed from the full casts are shown (solid lines, right y-axis).

11.7. ***Instrument performance***

11.7.1. Beam Performance and adaptation of IX software.

Since all four instruments were used for the first time during DY040, beam performance and correlation were checked after each cast. As mentioned above, the WH unit S/N 22797 failed to communicate after station #21 and was replaced. The unit showed erratic communication behaviour during the dry tests done by the technical team after removal. Nevertheless, good beam performance and correlation was observed in all casts previously recorded, as well as with WH units S/N 13329 and S/N 1855. After station #118 a weakening of the beam echo amplitude from Beam #2 was observed in WH unit S/N 4275. The beam performance decreased in each new cast, although the unit kept producing relatively good quality data in the upper ocean. In order to collect the best possible data at the eastern boundary, it was decided that the best performing unit (WH unit S/N 13329) should be used in the final 15 stations.

IX software provides diagnostic plots of target strength in dB and correlation for the processed cast, which can be found in the two bottom panels in IX "Figure 2". These target strength and correlation profiles represent an average of the full water column, that is, the beam performance in good and poor scattering environments is combined in one single plot. Since the LADCP units were employed in different scattering conditions through the transatlantic section, averaged profiles of target strength and correlation constrained to the upper ocean were produced in order to obtain more equal comparison between casts. To this end, the IX scripts *loadrdi.m* and *plotraw.m* were edited and averaged profiles of the upper 500db were also plotted in IX "Figure 2". The upper 500db beam performance for the last station collected by each LADCP is shown in Figure 24.

The adaptation of beam performance diagnostic panels in IX "Figure 2" is useful in the analysis of beam #2 installed in unit S/N 4275, which started to fail after station #118. The full water column target strength and correlation profiles indicates a very weak performance of this beam, which was even flagged as "broken" by the IX software in cast #119 (Figure 25). However, if upper ocean averages are used, a much healthier target strength and correlation profiles are obtained. This suggests that in good scattering environments this beam may still produce good quality data.

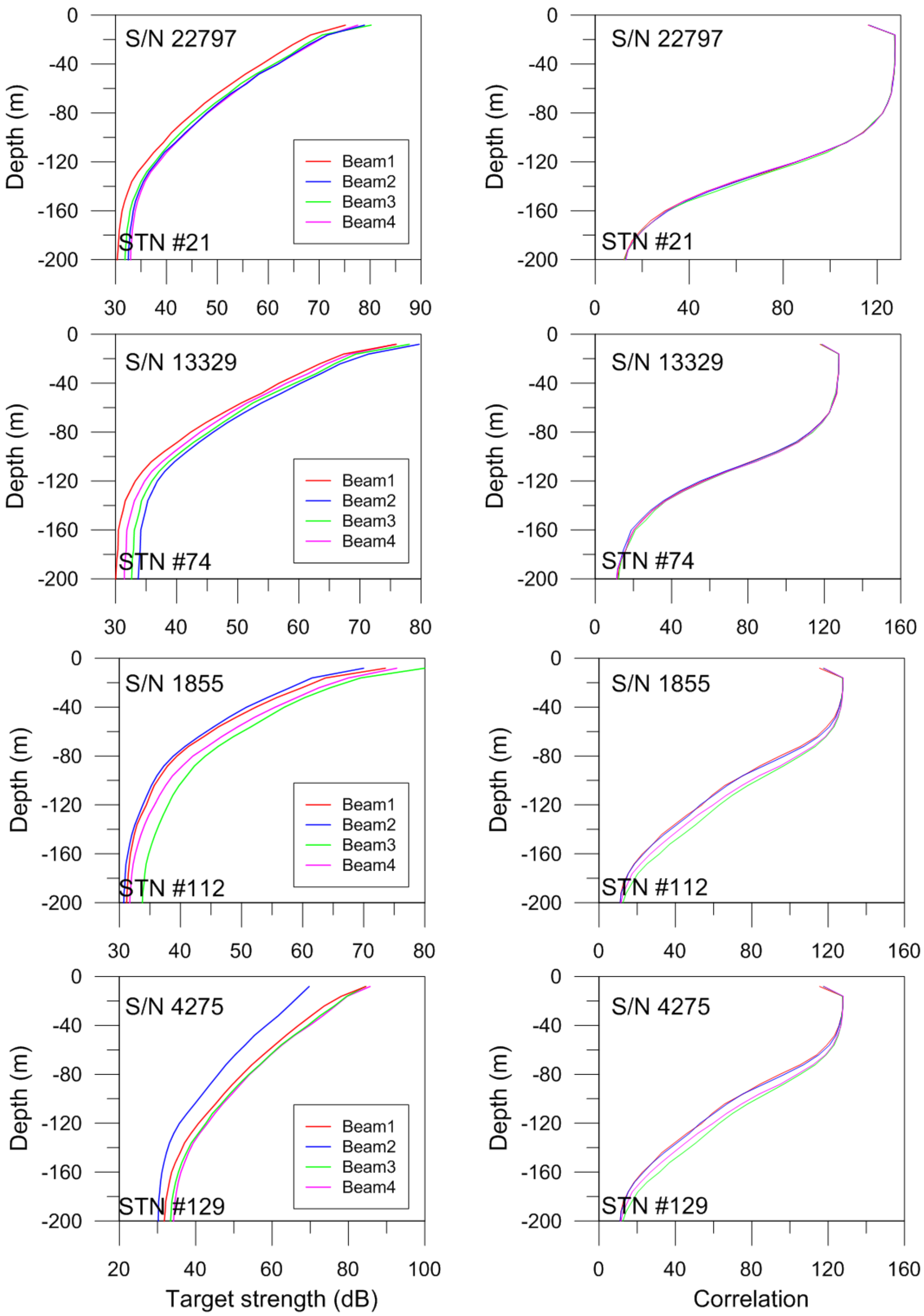


Figure 24. Example plot of echo amplitude (left panels) and corresponding correlations (right panels) with depth for each WH unit. The upper 500db averaged profile from the last recorded cast is shown for each unit.

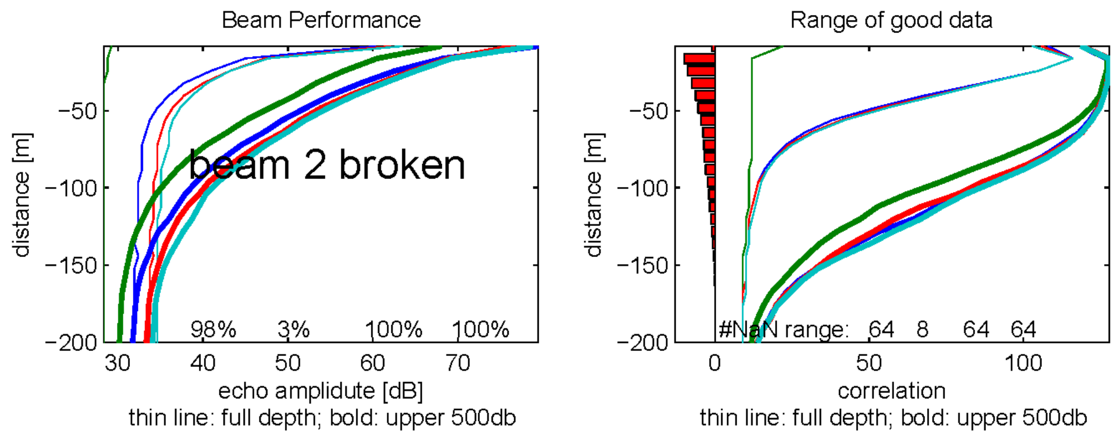


Figure 25 Example of beam performance panels from the adapted IX "Figure 2". Echo amplitude (left panel) and corresponding correlations (right panel) for cast #119. The thin lines in both panels represent the full water column averaged profile and the bold lines are averages of the upper 500db. Notice the poor performance of beam 2 for full water column averages compared to upper ocean averages.

11.8. *Ambient Temperature Performance*

During pre-deployment tests (PT200 command within "BB talk" software), WH unit S/N 1855 showed unrealistic ambient temperatures of ~97 °C. Using the IX software processed data, ambient temperature and CTD temperature profiles were compared in order to assess the performance of the external thermistor on each of the four LADCPs. WH units S/N 22979, 13329 and 4275 exhibited fairly good measurements in comparison to those collected by the primary CTD temperature sensor, whereas ambient temperatures collected by WH unit S/N 1855 largely differ from the CTD (Figure 26). In spite of the thermistor failure, preliminary results indicate that the general performance of the instrument was not altered.

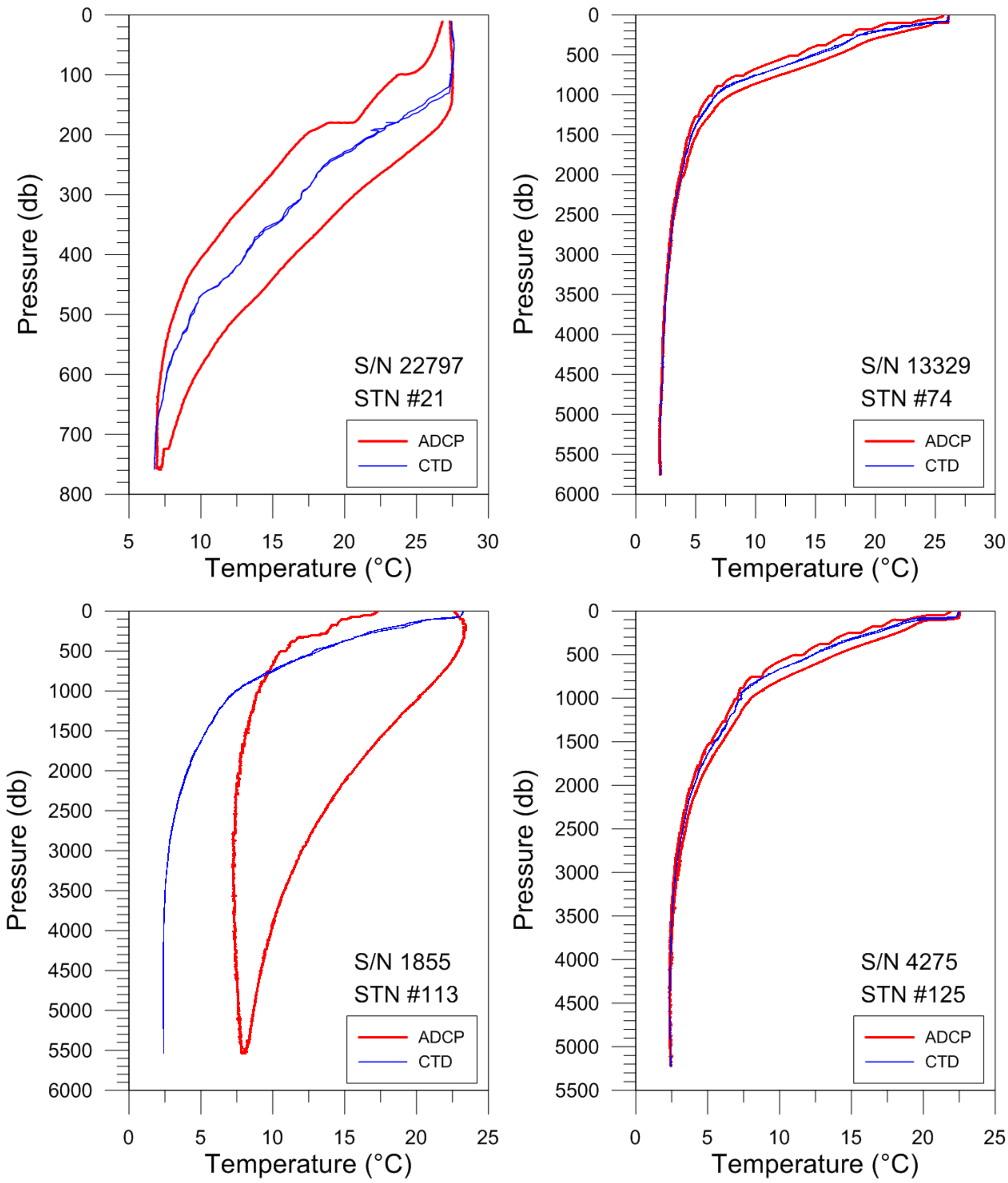


Figure 26. Temperature measurements collected by the external thermistor installed in every LADCP WH unit compared to the primary CTD temperature sensor for selected stations.

11.9. *Data quality*

11.9.1. IX software inverse method

The LADCP profiles collected during DY040 and processed with the IX inverse method can be classified in three main categories. Examples for each category are presented in Figure 27. The best quality profiles are observed at both ends of the section, particularly in the Florida Straits. For this category, the inverse method solution show a relatively low velocity error (<5 cm/s) and good agreement is observed with the shear method solution from the both IX and UH suits as well with the VMADCP profiles. Secondly, as the section moved over the abyssal plain and scatterers in the deep ocean diminished, the inverse method estimated error increased and a poorer agreement with the shear method solution was observed. In the third category we put those casts for which the inverse method solution produced unrealistic velocities. These stations are: 59, 60, 63-72, 74, 81-90, 93-112, 117, 119, 120, and 127. We advise care in interpreting the LADCP data from these stations.

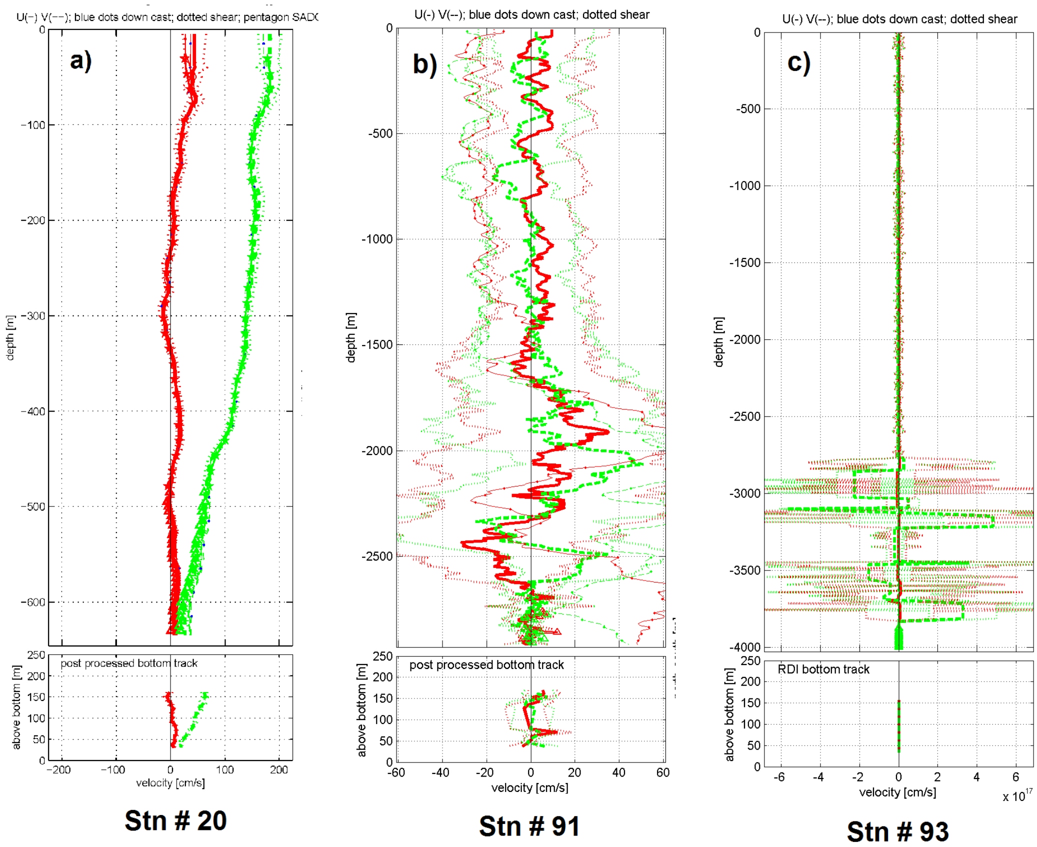


Figure 27. Examples of inverse method solution processed with IX software. a) Best quality type of profile, collected in the western boundary. b) Cast occupied in the Mid Atlantic Ridge, showing larger differences between the inverse and the shear method solutions. c) Poor quality type of profile (note the unrealistic velocities.

11.10. *Comparison IX-UH*

A comparison between the shear method solutions from the IX and UH software was conducted in order to check the consistency of both methods as well as the general quality of the data. Velocity profiles for stations occupied in the western boundary region (with strong currents and sufficient scatterers) show a good agreement through the full water column. Deep casts in the main section, however, show significant differences at depths greater than 1000 db (e. g. Figure 28). The UH software is more rigorous with the quality of the bins required to calculate acceptable velocity shears and therefore the profiles tend to diverge significantly from the IX profiles at depth. In addition, it was observed that the shear method solution from the IX software showed questionable velocities below the depth at which the UH software would no longer produce values.

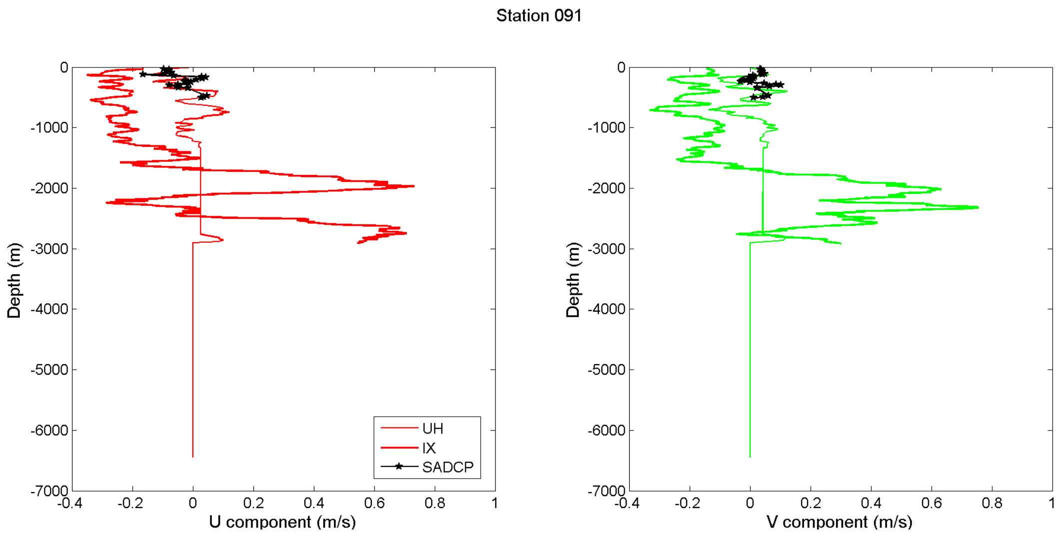


Figure 28. Example velocity profile processed using the shear method from the UH and IX software for station #91. VMADCP mean profile for the station is also shown. The UH software does not provide values below 1172 m depth.

In order to have a better comparison between the IX and UH outputs, a maximum depth of agreement was chosen for each cast after inspecting the profiles. Profiles of the U and V components from the surface to this maximum depth were then plotted along with scatter plots of the UH shear method against the IX for both components (Figure 29). The squared correlation, offset and slope of a linear fit between the two solutions were calculated for each cast. The maximum depth observed for each cast, along with the squared correlation, offset and slope for the linear fit are shown in Figure 30. High correlation and slope values of ~1 indicates good agreement between the IX and UH suits. Examples are the stations occupied in the western boundary (stations 1-25) and in the eastern boundary (stations 140-145). An offset value different from zero indicates that the barotropic component estimated for the IX software differs from that calculated by the UH software. Since the barotropic component calculation is sensitive to the velocities of the full water column, larger differences (and therefore larger offsets) between the UH and IX suit are observed in casts with large differences in the deep portion of the profile. The VMADCP data should be included in this analysis in order to better determine the error associated with the estimation of the barotropic component from each processing suite.

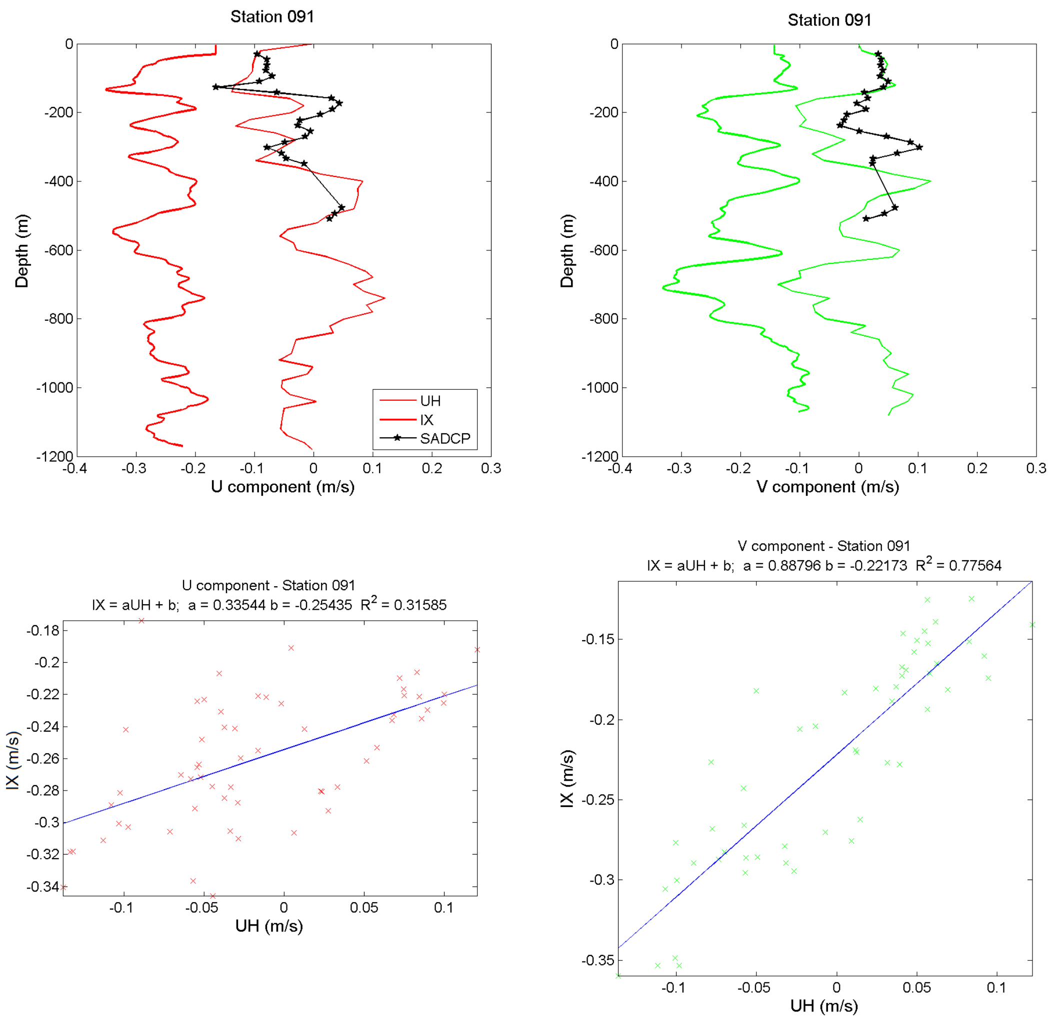


Figure 29. Top panels: Example velocity profile processed using the shear method from the UH and IX software for station the upper 1200m of station #91 (see Figure 8). Bottom panels: scatter plot of the IX solution against the UH solution. The blue line represents a linear fit of the data. The squared correlation, offset and slope are shown. The U (V) component is plotted in the left (right) panels.

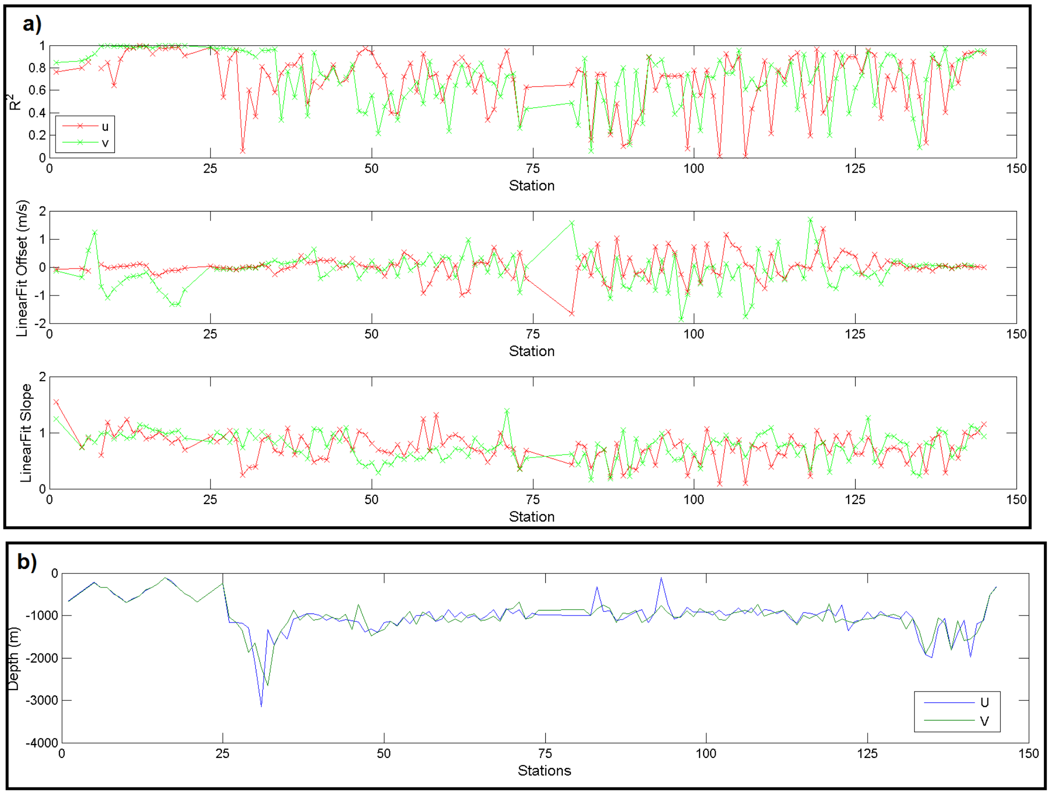


Figure 30. a) Squared correlation (top), offset (middle) and slope (bottom) from calculated linear fits of IX against UH shear solutions (see Figure 29). b) Maximum depth of agreement between the UH and IX shear method solutions for each station.

11.11. ***Bottom-tracked velocities.***

The post processed bottom-tracked velocities from the IX software were inspected for each cast. The profiles show an overall good quality and the averaged velocity is qualitatively coherent through the main section, except for stations 25 and 102 (Figure 31). Further analysis should be conducted in these particular two stations in order to determine the source of error.

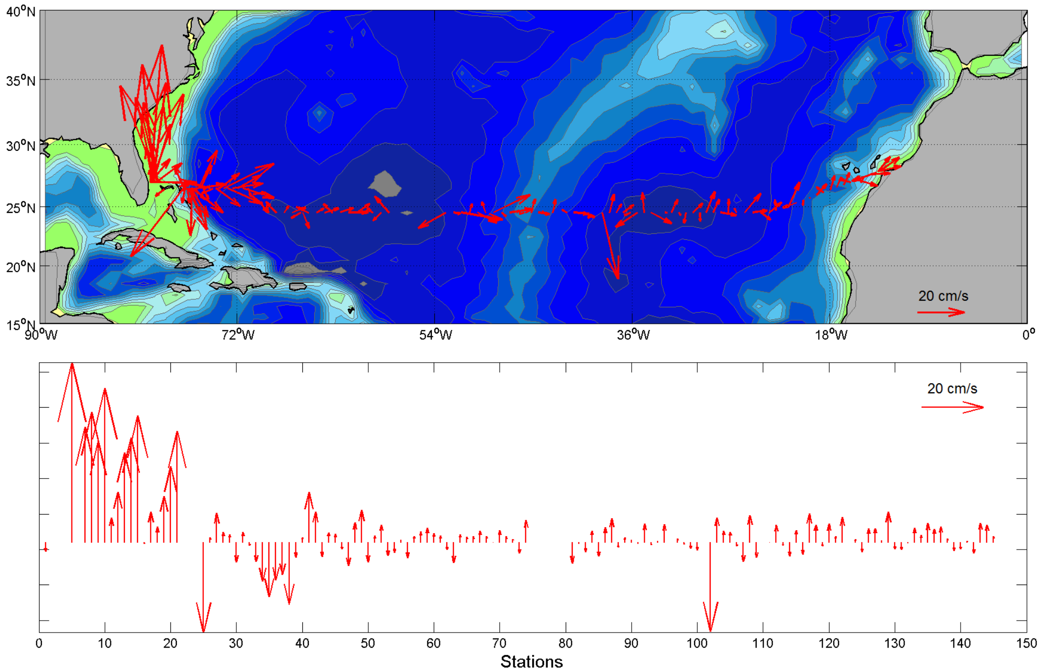


Figure 31. Post-processed bottom-tracked velocities from LADCP casts calculated with IX software. Top panel: averaged bottom-tracked velocities of the bottom 50 m. Bottom panel: averaged bottom-tracked V-component of the velocity of the bottom 50 m vs. station number.

12. RBR CTD

Claire Winder

Along with the Seabird CTD, there was also a CTD from RBR mounted on the rosette. We were provided with the RBR concerto model (serial number 60290), which contained a pressure sensor, two temperature sensors, a conductivity sensor and three internal temperature sensors, and sampled at a rate of 12 Hz. Also provided was the model RBR duet (serial number 95717), which measures pressure and temperature at a sampling rate of 16 Hz. The RBR was taken off the CTD frame before station 75, as the depth was over 6000m and was put back on before station 86 when the stations got shallower as we passed over the Mid Atlantic Ridge. The Ruskin software (version 1.12.1) provided by RBR was used to download and initially study the data. This software was useful for quickly viewing the data, however it proved limiting for detailed analysis. The rsk data files downloaded from the RBR CTD were converted to txt files using the Ruskin software. Matlab was used to study the RBR data in detail and to compare with the data from the Seabird CTD.

12.1. *Data Analysis*

The RBR data were first averaged into seconds, and then the Seabird data were interpolated onto the same time positions as the RBR data. To see how well the RBR clock matched to the Seabird clock, the lag between the two pressure time-series was calculated. This was done by calculating the maximum correlation coefficient between the vertical velocity (change in pressure over time) of the RBR and Seabird CTDs over a period of approximately ten minutes during the cast. The time lag of the RBR was calculated to be 0.8 seconds (i.e. t_{RBR} + 0.8 seconds = $t_{Seabird}$) for station 70 on the down cast and 0.7 seconds on the up cast. This difference of 0.1 seconds was taken to be the precision to which the lag could be calculated, as when the pressure differences were calculated a lag of 0.8 second showed less noise throughout the whole cast. This lag also varied between stations. For stations 30, 50, 52 and 72 it was calculated to be 0.8 seconds, 0.2 seconds, -0.4 seconds and 1.5 seconds respectively.

Using a lag of 0.8 seconds for station 70, the difference between the RBR pressure and the Seabird pressure was calculated and plotted both as a time-series and as a function of Seabird pressure (Figure 32). It was found that the pressure difference ($P_{Seabird}$–P_{RBR}) was -1 dBar near the surface and increased to -5.5 dBar at approximately 5500m. This change in pressure difference was not equal on the down and up casts, which was shown when plotted as a function of Seabird pressure as the pressure difference traced a figure of eight path. The difference between the Seabird and RBR temperatures was constant with depth, at approximately 0.0025 ^{o}C. However, when the CTD was shallower there was more noise in the temperature difference. The conductivity difference starts very noisy near the surface at approximately -0.005 mS/cm and increases with decreasing noise to -0.1 mS/cm at 4300 dBar. This is quite a large difference and leads to a practical salinity difference of 0.1.

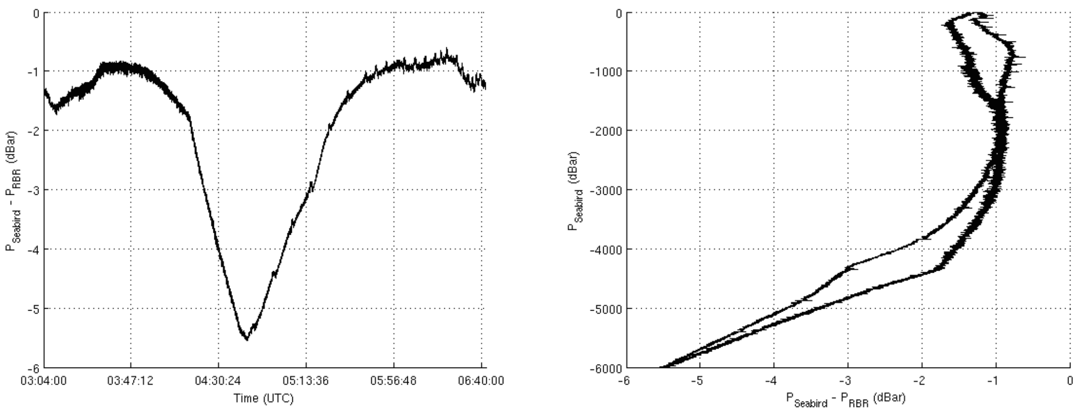


Figure 32. The left-hand plot shows the pressure difference between the Seabird CTD and RBR CTD plotted against time for station 70. The right-hand plot shows the same difference plotted as a function of the Seabird pressure.

It was found that in the deep casts (stations 59 to 74) the conductivity measured by the RBR developed a fault. The raw conductivity was reading as a flat line when the rosette reached a depth below approximately 4500m, and then improved on the up cast. The depth that the fault occurred was not constant and got progressively worse. The fault in the conductivity was not present as we crossed the ridge when the stations became shallower, however when the stations became deeper again this fault reappeared. After contacting RBR the decision was made to remove the unit and replace it with the spare (serial number 60289), this was done before station 122.

13. Chipods

Matthew Couldrey

Oregon State University (OSU) provided cruise DY040 with a set of Chipods for deployment on the CTD frame. Chipods are small sensor packages that measure temperature and instrument motion at 100 Hz. A Chipod sensor package consists of four parts, each with a unique identifier: a sensor; a sensor holder; a datalogger in a pressure case; and a cable (connecting the sensor holder and datalogger). The sensors are fast-response thermistors, which plug into sensor holders, which are then cabled to titanium pressure cases which house the main electronics. The pressure cases hold lithium batteries that were expected to have enough power to last the entire cruise without replacement or recharging. Once the sensor cable is plugged into the pressure case, the unit is powered on and collects temperature and acceleration data automatically.

During mobilisation, June Marion from OSU was present to supervise the initial mounting of the Chipods on the CTD frame, as well as to train the CTD techs and a member of the Physics Team (Matthew Couldrey). No OSU personnel attended the actual cruise and the instruments were left in the care of the science personnel of DY040. The CTD techs were briefed on mounting the units and performing a simple checklist before and after each cast. Matthew Couldrey was tasked with downloading data from the Chipods periodically, and monitoring their performance.

Chipods are deployed as a set of three units. Two of these are ‘uplookers’, and have their sensors mounted at the top, proud of the CTD frame at the outer rim of the rosette and facing upwards. The other ‘downlooker’ is mounted at the bottom of the frame, (not extending beneath the lowest bars of the CTD frame) and faces downward. OSU also left a laptop and USB cables that connect the Chipods to the laptop to perform the data download and some rudimentary analysis. The laptop has software, Minilog Host 200, which is used to communicate with the Chipods

Each Chipod produces data files (with a .mlg extension) that contain five output parameters: UTC time, temperature (T, in volts), temperature time differential (dT/dt, in volts), horizontal acceleration (AX, in volts) and vertical acceleration (AZ, in volts).

13.1. *Chipod Issues and Setup Changes*

The Chipods were attached to the CTD frame during mobilisation and collected data on almost every cast of the DY040 cruise. It was necessary to modify the Chipod setup several times during the cruise due to occasional problems with the instruments. The details of these changes are listed in Table 18. Where a cell is coloured, this indicates that this piece of equipment was changed from the previous entry; uncoloured cells show unchanged equipment. The first changes were made early on, when it was noticed that logger 1010 seemed to be failing to calculate dT/dt correctly. The issue was spotted after the test station (CTD001 on 09/12/2015), but it was not possible to take the time to swap out the logger, and so a new sensor was swapped (MP10-02 replacing MP10-12) instead. This did not resolve the problem, since it is associated with the logger itself, and so after CTD012 on 10/12/2015 1010 was replaced with 2018.

On 29/12/2015 it was found that two of the Chipods (1014 and 2010) would not respond to any commands when the data download was attempted. It is not yet clear what caused the problem, but it is suspected that the sensor cables were unplugged during an internal file-write procedure. This has been observed by OSU previously and is the most probable explanation. The data still on the Chipods can be recovered, but only once the units are returned to OSU. The third Chipod (2018) crashed during a file download, and then became unresponsive to commands. This is also a phenomenon that has been noted by OSU on previous occasions. With all three Chipods inactive, it was necessary to switch each out with the three spare loggers; two of which had not yet been used (2013 and 2016), and the third (1010) was the one that failed to output dT/dt during CTD001. OSU suggested that 1010 be opened up and have its associated circuit board examined for obvious damage and re-soldered if necessary, but no problems were apparent and so no repair was undertaken. As a result, for casts 73 and 74, no downlooker dT/dt trace is available, but all other aspects of the data (from all three Chipods) appear sound.

Following the locking up of 1014 and 2010, the pre- and post-deployment procedures for the Chipods between CTD stations were changed. Prior to 29/12/2015, the Chipods were powered down after each cast (by unplugging the sensor cable from the logger) and powered back up just before each cast. Since it is thought that cutting power to the loggers during a file-write caused the lockups, the practice was then changed such that the Chipods were not unplugged from their sensors in between casts.

After cast 74 on 29/12/2015, a series of deep CTD casts were made, some of which exceeded 6000m. Since the Chipods are rated to 6000m, they were all removed, including the cables, until CTD083 on 01/01/2016, whereupon maximum cast depths no longer exceeded 6000m. In the interim period, it was noted that Chipod 2018 had become responsive again, meaning that it would be possible to deploy a complete set of three fully functioning units for the remainder of the cruise. It was also noted that two of the sensor holders showed signs of oxidisation. The sensor holders are made of aluminium and sealed with a waterproof resin. It is likely that the sealants of holders 4 and 1 were slightly damaged at some point, which only became obvious once oxides appeared. As a result, these two sensor holders were substituted with 7 and 6.

Early on 16/01/2016, when attempting to download the data from 2016 after CTD 125, the Minilog programme crashed during a download of File 32. The programme was closed, and the USB and Sensor cables were unplugged from the logger pressure case and reconnected. When attempting to query the files stored on

2016's SD card using the "di" command, the error "Could not set SD card to idle" was returned with no directory information. Plugging and unplugging the sensor cable did not clear the issue, and so it was decided to leave the Chipod plugged in as normal for the upcoming CTD casts. About 12 hours later on the same day, another download was attempted after the Chipods had been left running for two more CTD casts. When 2016 was queried with the "di" command, it return a list of files, but it had not created any new files since the crash earlier on, meaning this Chipod has no data for casts 126-127. A download of File 33 was attempted (since it seems downloading 32 caused the first crash), but this also caused the software to crash. The programme was closed, and both cables disconnected from and reconnected to the logger. When queried with "di", the logger returned the same list of files, and no error message. The logger was then left plugged into the laptop with no commands issued for 300 seconds, after which it began to create a new file; 34. Seeing that the logger appeared to be creating new a new file as normal, it was deployed for CTD 128 and collected data as expected.

During an attempted download of 2018 on 19/01/2016, the Minilog programme crashed. The USB and sensor cables were unplugged from 2018 and reconnected, but the Chipod was unresponsive to the qqq wakeup command. As a result, no data could be downloaded from the logger from the 19th of January, and no downlooker data were collected for stations 139 to 145.

13.2. *Data Download and Inspection*

Since the data collected by the Chipods are logged onto internal storage, it is necessary to periodically download the stored files via USB for inspection and backup. This was done generally every day or two days as was practical, and the data were stored on the OSU laptop in the directory Desktop/26N/Chipod_Data. In this directory there are separate folders for different loggers, and files are added as they are collected. Whenever a download was done, a logsheet entry noted which files had been downloaded, when the download took place and to which CTD casts the files corresponded. The logsheet also has a note of the Chipods' battery voltage reading and internal clock, to check the health of the units.

Once downloads were completed, some simple Matlab software was run on each file to view the data from each Chipod. This allows for each of the four parameters (T, dT/dt, AX and AZ, each in units of volts) to be viewed against time, as in Figure 33 for a visual check of quality. Once each unit's data had been checked, any issues were noted and relayed to OSU, and the Desktop/26N directory was then backed up onto an external hard drive. Each backup on the hard drive is stored in a folder named with the date of the backup in the format YYYY.MM.DD.HH.MM.SS.

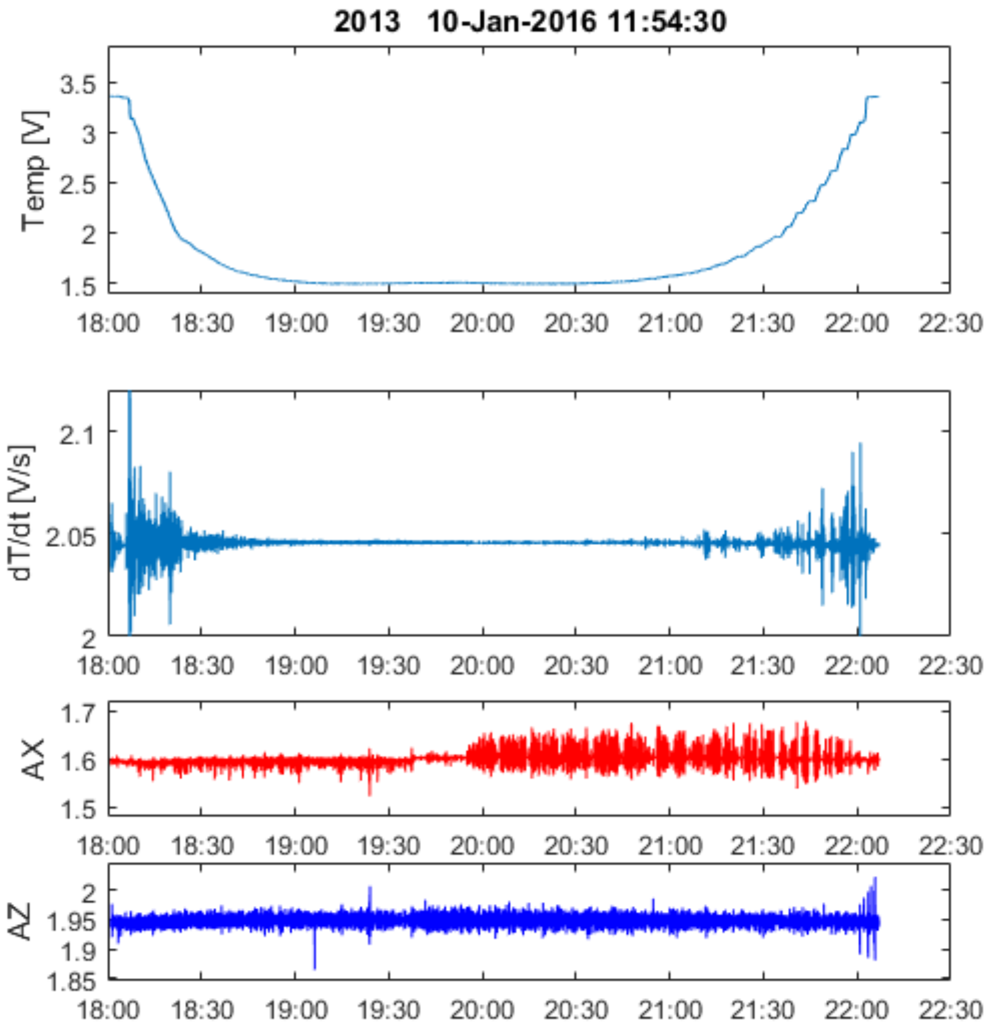


Figure 33: An example of the output of a Chipod for a CTD cast, from 2013 at CTD113. The panels show Temperature, T, in volts (top), change in temperature with time, dT/dt, in volts per second (top middle), horizontal acceleration, in volts (bottom middle) and vertical acceleration in volts (bottom)

Table 18: Log of changes to the setup of Chipods on the CTD frame. Cells highlighted in green show items that were exchanged since the previous entry.

Date	Uplooker				Uplooker				Downlooker			
	Logger	Sensor	Holder	Cable	Logger	Sensor	Holder	Cable	Logger	Sensor	Holder	Cable
09/12/ 2015 Cast: 1	1010 Ti44-2	MP10-12	4	24-6-5	1014 Ti44-1	MP10-09	1	24-4-4	2010 Ti44-5	13-01D	8	24-6-3
10/12/ 2015 Cast: 2-12	1010 Ti44-2	MP10-02	4	24-6-5	1014 Ti44-1	MP10-09	1	24-4-4	2010 Ti44-5	13-01D	8	24-6-3
11/12/ 2015 Cast: 13-72	2018 Ti44-3	MP10-02	4	24-6-5	1014 Ti44-1	MP10-09	1	24-4-4	2010 Ti44-5	13-01D	8	24-6-3
29/12/ 2015 Cast: 72-74	2013 Ti44-7	MP10-02	4	24-6-5	2016 Ti44-1	MP10-09	1	24-4-4	1010 Ti44-2	13-01D	8	24-6-3
01/01/ 2016 Cast: 82	2013 Ti44-7	10-09 MP	7	24-4-4	2016 Ti44-1	10-02 MP	6	24-6-5	2018 Ti44-3	13-01D	8	24-6-3

14. Computing

14.1. *mexec computing*

Workstation eriu was taken on the cruise. Eriu had been used on dy031, but the operating system, incoming ssh sessions, and network disk mounts, had been perceived to have been unstable. Therefore eriu was upgraded to CentOS between dy031 and dy040.

Shared disks were mounted using the following commands as root:

/sbin/mount-cifs
/sbin/mount.cifs //192.168.62.27/ctd /local/users/pstar/mounts/mnt_smb_discofs_rt -o guest
/sbin/mount.cifs //192.168.62.27/dy040 /local/users/pstar/mounts/mnt_smb_discofs -o guest
/sbin/mount.cifs //192.168.62.27/public /local/users/pstar/mounts/mnt_smb_public -o guest

The mount points were above the level of the data directory, to avoid them being backed up by the daily rsync backup

The mnt_smb_discofs_rt mount was necessary to enable access to the raw CTD data immediately after it was copied from the acquisition PC. The copy in the //192.168.62.27/dy040 directory was only mirrored after 20 minutes.

When writing from eriu to the shared public area, it was necessary to write into the area as root. If files were written as userid pstar, the files were visible from eriu, and appeared normal, but were invisible to Macs and PCs reading from the shared area. This seemed to be something to do with permissions and how the shared area was exported and mounted as eriu.

Two versions of Matlab were available on eriu. Matlab2015a, and Matlab2011a. Some mexec programs produce postcript plots that have axes of exact sizes when sent to a ps printer. This worked normally under 2011a. The same scripts run under 2015a produced hardcopy plots of different sizes. Therefore the majority of the cruise was run using 2011a.

There is a Matlab bug in which Matlab sometimes generates low-level erros while calling the built-in NetCDf libraries. This error ocurred occasionally, but certainly less frequently in 2015a. Therefore long runs of CTD data reprocessing were gernerally run under 2015a.

15. Liquid Nitrogen generators

16. Ship's Installed Instrumentation

17. Marine Meteorology: TechSAS underway data acquisition

Elizabeth Kent, Justin Buck, Zoltan Nemeth, Brian King

17.1. *Underway data acquisition using the TechSAS system*

All underway processing is carried out in the matlab-based processing system "mexec" as user "pstar". The input underway data produced by the ship TechSAS system were stored as netCDF under `/mnt/techsas/dy040/NetCDF` linked as `/local/users/pstar/cruise/data/shiptechsas`.

There are directories for each of the underway data types, a new file for each system is started each day at GMT 0900, and further files may be generated if a system is restarted. Each of the TechSAS netCDF underway files is indexed by time with units "days since 1899-12-30 00:00:00 UTC". Most of the data streams contain data logged at approximately 1Hz. ASCII "NMEA" type messages are also stored under: `/mnt/techsas/dy040`.

Mexec files have an index dimension "ncols", the 2nd additional dimension "nrows" is unused for time series files. In mexec time in seconds appears as a variable like any other and the units of time are seconds after a "data_time_origin" included as a global attribute.

The daily processing needs to identify the appropriate set of TechSAS netCDF files, read in the data for the requested day, which is likely to be in more than one TechSAS file, and then write it out with the expected file name in the appropriate directory (

Table 19).

Table 19. Directory locations and names of TechSAS netCDF file names on DY040 (D-T is the date and time in format YYYYMMDD-HHMMSS). The mexec short name provides the link to allow the data to be read into mexec in script *mday_00.m*. mexec command *mtnames* will list the links set up for the cruise. The mexec directory is where the new file will be written, this is set in the MEXEC_G structure field MDIRLIST. The file name prefix is defined with the call to *mday_00.m* and needs to conform to the expected value or subsequent processing scripts will fail (C_D is cruise number and day of year, dy040_dnnn).

TechSAS directory	TechSAS File	mexec short name	mexec prefix abbrev.	mexec directory	mstar file
ATT	D-T-shipattitude-Applanix_TSS_DY1.att	attposmv	attposmv	nav/attposmv "M-ATTPOSMV"	attposmv_C_D_raw.nc
ATT	D-T-shipattitude_aux-Applanix_TSS_DY1.att	attposmvaux	?	-	contains uncertainty information, not read in
CLAM	D-T-CLAM-CLAM_DY1.CLAM	winch	win	ctd/WINCH "M_WINCH"	read in as part of CTD processing
DEPTH	D-T-sb_depth-EM120_DY1.depth	em120	em120	em120 "M_EM120"	em120_C_D_raw.nc
EA600	D-T-EA600-EA640_DY1.EA600	ea600m	sim	sim "M_SIM"	sim_C_D_raw.nc
GPS	D-T-cnav-CNAV.GPS	cnav	cnav	nav/cnav "M_CNAV"	cnav_C_D_raw.nc
GPS	D-T-position-Applanix_GPS_DY1.gps	posmvpos	posmvpos	nav/posmvpos "M_POS"	pos_C_D_raw.nc
GPS	D-T-position-Seapath330_DY1.gps	seapos	seapos	nav/seapos "M_SEAPOS"	seapos_C_D_raw.nc
GPS	D-T-position-usbl_DY1.gps	usbpos	usbl	-	read in as part of CTD processing
GYR	D-T-gyro-GYRO1_DY1.gyr	gyropmv	gyp	nav/gyropmv "M_GYP"	gyp_C_D_raw.nc
GYR	D-T-gyro-SGYRO_DY1.gyr	gyro_s	gyr	nav/gyros "M_GYS"	gyr_C_D_raw.nc
SURFMETV2	D-T-Light-DY-SM_DY1.SURFMETv2	surflight	met_light	met/surflight "M_MET_LIGHT"	met_light_C_D_raw.nc

TechSAS directory	TechSAS File	mexec short name	mexec prefix abbrev.	mexec directory	mstar file
SURFMETV2	D-T-MET-DY-SM_DY1.SURFMETv2	surfmet	met	met/surfmet “M_MET”	met_C_D_raw.nc
SURFMETV2	D-T-Surf-DY-SM_DY1.SURFMETv2	surftsg	tsg	met/surftsg “M_MET_TSG”	met_tsg_C_D_raw.nc
TSG	D-T-SBE45-SBE45_DY1.TSG	SBE45	met_tsg	tsg “M_TSG”	tsg_C_D_raw.nc
WAMOS	D-T-wamos-WaMoS.wamos	wamos	wamos	wamos “M_WAMOS”	wamos_C_D_raw.nc
WINCH	D-T-logskippervdvbw-SkipLog.winch	log_skip	logskip	log_skip “M_LOGSKIP”	logskip_C_D_raw.nc

The daily processing is run within a matlab session. Ensure *m_setup* has been run.

mday_00_get_all_dy040(day#) reads in all of the data streams for a given day of year with an mexec file name listed in Table 19. The script runs *mday_00* for all the required streams. It is designed not to crash if a stream is missing, so care needs to be taken that everything that is needed is read in. On DY040 the day of year was increased over the new year so 1st January 2016 was day 366.

mgyr_01(day#) is then run to remove any non-monotonic data cycles in the gyro file. This produces a file with the same name except that the “_raw” part is dropped.

mday_02_run_all_dy040(day#) appends each of the streams to create a master file, denoted “01”. The 02 scripts check first whether an edited file exists (as for the gyr stream) and if so uses that, if not then the _raw.nc files are appended.

Table 20. Daily processing scripts, input and output files for all the underway data processed each day.

stream	00 (get data)	01 (clean up)	02 (append to master file)
em120 dir: em120	*mday_00*('em120',day) in: D-T-sb_depth-EM120_DY1.depth out: em120_dy040_dnnn_raw.nc		appended as part of depth processing after editing
sim dir: sim	*mday_00*('sim',day) in: D-T-EA600-EA640_DY1.EA600 out: sim_dy040_dnnn_raw.nc		as em120

stream	00 (get data)	01 (clean up)	02 (append to master file)
cnav dir: cnav	*mday_00*('cnav',day) in: D-T-cnav-CNAV.GPS out: cnav_dy040_dnnn_raw.nc		*mday_02*('M_CNAV','cnav',day) in: cnav_dy040_dnnn_raw.nc out: cnav_dy040_01.nc
posmvpos dir: nav/posmvpos	*mday_00*('pos',day) in: D-T-position-Applanix_GPS_DY1.gps out: pos_dy040_dnnn_raw.nc		*mday_02*('M_POS','pos',day) in: pos_dy040_dnnn_raw.nc out: pos_dy040_01.nc
seapos dir: nav/seapos	*mday_00*('seapos',day) in: D-T-position-Seapath330_DY1.gps out: seapos_dy040_dnnn_raw.nc		*mday_02*('M_SEAPOS','seapos',day) in: seapos_dy040_dnnn_raw.nc out: seapos_dy040_01.nc
gyp dir: nav/gyropmv	*mday_00*('gyp',day) in: D-T-gyro-GYRO1_DY1.gyr out: gyp_dy040_dnnn_raw.nc		*mday_02*('M_GYP','gyp',day) in: gyp_dy040_dnnn_raw.nc out: gyp_dy040_01.nc
gyr dir: nav/gyros	*mday_00*('gyr',day) in: D-T-gyro-SGYRO_DY1.gyr out: gyr_dy040_dnnn_raw.nc	*mgyr_01*(day) in: gyr_dy040_dnnn_ raw.nc out: gyr_dy040_dnnn.nc	*mday_02*('M_GYS','gyr',day) in: gyr_dy040_dnnn.nc out: gyr_dy040_01.nc
met_light dir: met/surflight	*mday_00*('met_light',day) in: D-T-Light-DY-SM_DY1.SURFMETv2 out: met_light_dy040_dnnn_raw.nc		*mday_02*('M_MET_LIGHT','met_light',day) in: met_light_dy040_dnnn_raw.nc out: met_light_dy040_01.nc
met dir: met/surfmet	*mday_00*('met',day) in: D-T-MET-DY-SM_DY1.SURFMETv2 out: met_dy040_dnnn_raw.nc		*mday_02*('M_MET','met',day) in: met_dy040_dnnn_raw.nc out: met_dy040_01.nc

stream	00 (get data)	01 (clean up)	02 (append to master file)
tsg dir: tsg	*mday_00*('tsg',day) in: D-T-SBE45-SBE45_DY1.TSG out: met_light_dy040_dnnn_raw.nc		*mday_02*('M_TSG','tsg',day) in: met_light_dy040_dnnn_raw.nc out: met_light_dy040_01.nc
met_tsg dir: met/surftsg	*mday_00*('met_tsg',day) in: D-T-Surf-DY-SM_DY1.SURFMETv2 out: tsg_dy040_dnnn_raw.nc		*mday_02*('M_MET_TSG','met_tsg',day) in: tsg_dy040_dnnn_raw.nc out: tsg_dy040_01.nc
attposmvpos dir: nav/attposmv	*mday_00*('attposmvpos',day) in: D-T-shipattitude-Applanix_TSS_DY1.att out: pos_dy040_dnnn_raw.nc		*mday_02*('M_ATTPOSMV','attposmv',day) in: pos_dy040_dnnn_raw.nc out: pos_dy040_01nc
wamos dir: wamos	*mday_00*('wamos',day) in: D-T-wamos-WaMoS.wamos out: wamos_dy040_dnnn_raw.nc		*mday_02*('M_WAMOS','wamos',day) in: wamos_dy040_dnnn_raw.nc out: wamos_dy040_01.nc
logskip dir: log_skip	*mday_00*('logskip',day) in: D-T-logskippervdvbw-SkipLog.winch out: logskip_dy040_dnnn_raw.nc		*mday_02*('M_LOGSKIP','logskip',day) in: logskip_dy040_dnnn_raw.nc out: logskip_dy040_01.nc
script	*mday_00_get_all_dy040(day)*	*mday_00_get_all* *_dy040(day)*	*mday_02_run_all_dy040(day)*

mbest_01.m takes the 1Hz lat and long variables from the appended "pos" data file and interpolates these to the centre of a 30 second time interval. *mcopya* generates a new file with just the required variables in it. This uses the *msmoothnav* program, which interpolates the lat and long to produce a value at the centre of the time bin using a polynomial fit. The time stamp is the centre of the averaging period.

in: pos_dy040_01.nc

out: pos_dy040_ave.nc

mbest_02.m calculates speed, course and distrun from the output file of *mbest_01.m.* mexec program *mposspd* is first used to calculate east and north components of ship velocity from time, lat and long. The first velocity value is missing, the 2nd value is calculated from the distance between the 1st and 2nd positions. The velocity at a particular time step therefore the distance travelled in the preceding 30 seconds. *muvsd* then calculates ship speed and course from the components. Distance run (distrun) in km is calculated via *mcalc* (the general mstar program that allows the user to define a function to be calculated) using *sw_dist* which calculates the distance on a sphere.

in: pos_dy040_ave.nc

out: pos_dy040_spd.nc

mbest_03.m averages the 1Hz heading information from the gyropmv file to 30s. The timestamp represents the end of the averaging period (c.f. position averaging which is the centre of the averaging period). This ensures that the heading average is calculated over the same period as the speed. The script has several steps (*mcalc* to add a dummy variable with value 1; *muvsd* to calculate components of the heading; *mavrge* to perform the averaging; *muvsd* to recalculate heading from the components and *pcalib* to add half the averaging period to the time variable).

mbest_04.m merges the averaged heading output from *mbest_03.m* onto the averaged file output from *mbest_02.m*. The heading can be merged rather than the components because the timestamps are the same. It would probably be best to merge the components then calculate the heading afterwards but it was not clear whether changing the script would have any consequences for other parts of the processing.

in: pos_dy040_spd.nc

out: bst_dy040_01.nc

17.1.1. Navigation POSMV

Of the many GPS receivers, the POSMV was chosen as the preferred source of position and heading. Position data were logged into the stream known as ‘posmvpos’. A further stream, ‘gyropmv’ contains heading data from the POSMV, and had previously been set up as the source of heading data. However, ‘gyropmv’ has a resolution of 0.1 degree, which is unnecessarily coarse. The stream ‘attposmv’ contains all the attitude variables, with resolution 0.01 for heading. Any application requiring the best resolution for heading should use the ‘attposmv’ stream.

17.1.2. Navigation: IXSEA PHINS

An INXSEA PHINS is mounted in the gravimeter room. Data are not logged to techsas, but 1Hz data are saved as ascii files. On this cruise the files were named phins-jd338_NNN.txt. the 338 was probably the day number on which the data acquisition started.

Each line of the txt file contained about 85 tab-delimited variables. One file was of size 2.4Mbytes and contained an hour of data.

A Matlab script: *phins_txt_to_mat.m* was written to parse the files and save 10 variables of interest to a mat file. Variables saved were: time, head, pitch, roll, lat, lon, alt, heave, surge, sway. One txt file to one mat file.

phins_append.m could append any chosen group of mat files. The PHINS dataset was saved in phins_all.mat in the nav/phins directory.

At one stage in the cruise, a set of PHINS files were examined. The following aspects were noted:

1) The pitch/roll/heave data from PHINS were very close to the equivalent data from the POSMV. We deduce that both systems made good measurements of those parematers.

2) While in port in Nassau, there were periods when the PHINS heading showed almost zero variability, while the POSMV varied by a few tenths. This suggests that the ship was very stable in heading, and the POSMV had some error where the PHINS did not. We therefore tentatively conclude that the PHINS is the best heading source on the vessel.

3) The PHINS should be logged through TECHSAS, and available as a scientific data stream. Not all 85 variables are required. lat, lon, pitch, roll, heading, heave would be a good start.

4) There should be an *mphins_01.m* script to read in PHINS data, either from TECHSAS or from phins txt files, into mexec NetCDF files.

17.2. *Surface Meteorological Sampling System*

Elizabeth Kent, Justin Buck, Zoltan Nemeth, Brian King and Margaret Yelland (ashore)

17.2.1. Sensors and installation

The foremast was instrumented with a variety of meteorological sensors to measure; air temperature and humidity, atmospheric pressure, short wave radiation (TIR), photosynthetically active radiation (PAR) and wind speed and direction. These are logged by TechSAS and processed as part of the daily processing (Table 19 and Table 20). Table 21 lists the sensors and serial numbers. Figure 34 shows a schematic of the sensor positions and Figure 35 photographs of the platform and sensors.

On entry to Port Everglades the foremast platform was observed to vibrate quite violently, presumably as the thrusters were being used to manoeuvre the ship and this was affecting the platform.

Table 21. Sensors and serial numbers for the underway MetOcean sensors installed on DY040. The pumped seawater system flow rate is 1500 ml/min and the intake depth 5.5m. More information on

calibration accuracy can be found on the sensor calibration sheets. More details of the sensor accuracy can be found in the sensor manuals or data sheets.

Sensor	**Manufacturer: Sensor**	**Serial No.**	**Last calibration (DD/MM/YYYY)**	**Comments**
Starboard PAR 400-700 nm	Skye: SKE510	28563	20/02/2014 (2yr)	Calibration required:÷1.093 Cal. accuracy 5% (typically <3%) Linearity error <0.2% Cosine error 3% Azimuth error < 1% Temp. coeff. +0.1%/°C Stability <2% $year^{-1}$
Port PAR	Skye: SKE510	28561	30/04/2014 (2yr)	Calibration required: ÷1.005
Starboard TIR 305-2800 nm	Kipp & Zonen: CM6B	962276	13/11/2014 (2yr)	Cal. required: ÷ 1.014 Cal. accuracy < 3% Non-linearity <±1.2% Temp. sensitivity <±2% Directional error < ±20 Wm^{-2} Tilt error < ± 1% Zero-offset due to IR < 15 Wm^{-2} Zero-offset due to temp. changes < 4 Wm^{-2} at 5K hr^{-1}
Port TIR	Kipp & Zonen: CM6B	973134	19/03/2015 (2yr)	Calibration required: ÷ 1.097
Sonic anemometer, starboard Inv:250006705	Gill: Windsonic Option 3	10280018	N/A (tested 28/09/2015) Tested and within tolerance.	0˚ on the bow Accuracy: speed ±2% @ $12ms^{-1}$; direction ± 3˚ @ $20ms^{-1}$

Sensor	Manufacturer: Sensor	Serial No.	Last calibration (DD/MM/YYYY)	Comments
Air temperature and relative humidity	Vaisala: HMP155	K0950058	16/01/2015 Tested and within tolerance: ± 1.7% humidity; temperature ± 0.1˚C	Humidity accuracy: ±1% RH @ 0-90%; ±1.7 %RH 90-100% RH – temp. range 15-25˚C. Temperature accuracy: ±0.2˚C @ 20˚C see manual for temp. dependence of accuracies
Atmospheric pressure	Vaisala: PTB110	L0650612	06/02/2015 Tested and within tolerance: ± 0.15 hPa	Accuracy: 0-40˚C ± 0.6 hPa
Fluorimeter Inv:240002938	Wet Labs: WS3S	WS3S-246	01/09/2015 voltage output[1]	Chl= scale * (V_{out}-clean) scale = 14.5 mg/l/V clean = 0.053 V
Transmissometer	Wet Labs : CST	CST-112R	26/06/2014 (2yr) voltage output	Tr = (V_{sig}-V_{dark})/(V_{ref}-V_{dark}) V_{dark} = 0.058V V_{ref} = 4.623 V
Sea Surface Temperature	Sea-Bird: SBE38	3854115-0491	25/06/2015 internally calibrated	initial accuracy 1mK stability 1mK /6 month
Housing temperature and conductivity	Sea-Bird: SBE45 TSG	4548881-0229	13/08/2015 internally calibrated	Installed and fresh water tested 20/10/2015 initial accuracy 2 mK; 0.005 psu stability 0.2 mK/month; 0.003 psu/month

[1] TechSAS incorrectly labels fluorescence as being recorded in μg/l rather than V.

All of the streams are logged as transmitted from the sensor without calibrations applied as this is the agreed procedure and avoids confusion as to what calibration might have been applied, if any. The sensors requiring calibration are the radiation sensors, the fluorimeter and transmissometer. All the others are certified as performing to within the expected tolerances.

17.2.2. Calculation of true wind speed

Calculation of 1 minute average true wind speed and direction from platform relative wind speed and direction, ship speed and direction and ship heading is achieved using mexec script *mtruwind_01*. This processing rarely works first time as there are several different combinations of conventions for reporting direction and for orientation of 0/360 of the anemometer relative to the ship. Confusingly the TechSAS wind output is labelled as being in knots but is actually in ms^{-1}. However it is usually clear when the calculation has been done correctly as the true wind speed and direction should not vary abruptly when the ship changes speed, course or heading.

Before running *mtruwind_01*, the following should be checked.

i. what are the units of the relative wind speed, if they are in knots a conversion to ms^{-1} is required. [DY040 = ms^{-1}]
ii. is the anemometer oriented with 0˚ at the bow or 180˚ at the bow? If 0˚ add 180˚ to convert to oceanographic convention then reset the range to 0-360 [DY040 = 0˚]
iii. is the required true wind convention degrees from (meteorological) or to (oceanographic)? If degrees from is required then and final rotation of 180˚ is required. [DY040 = degrees to]

It is necessary to always convert speed and direction to east and north components before averaging or merging to avoid 0/360 problems. For heading this requires the calculation of a dummy variable of unit size to use as the speed.

Figure 36 shows the true wind speed, relative wind speed and ships heading for 4 example days in December 2015. December 21st is the best example showing the true wind speed smoothly corrected for the ship movement and orientation. The relative wind direction on this day is close to 180, wind coming over the bow. On December 14th the correction hasn't produced such a smooth true wind time series, some artefacts of the ship speed remain, especially when the relative wind direction moves further toward the starboard beam. A similar mixed picture is seen on December 15th. On December 16th we see a sharp decrease in true wind speed just after midday as the relative wind moves to come from astern.

This can be explained by a change in the air-flow distortion over the ship varying with relative wind direction. It is well-known that when the wind comes from astern the flow to sensors on the foremast will be partly blocked, this causes the decrease in wind speed seen on December 16th. Winds from ahead are likely to be little affected as the ship is streamlined from the front, although air-flow distortion modeling has shown deceleration over the bow for the similarly-shaped RRS James Cook (Margaret Yelland pers. comm.). However as the wind moves onto the beam it appears that the flow is accelerated up over the side of the ship which presents a solid-wall to the ship. The anemometer is on the starboard side of the foremast and there is a slight indication that the acceleration might be stronger on the starboard than the port side. This might be explained by a slight sheltering of the accelerated flow by the structure of the foremast platform.

To try to get a better estimate of the effect a day with steady winds was chosen and the ship was rotated around the anemometer position at approximately 5˚ min^{-1} using the dynamic positioning system. Figure 37 shows the results of this experiment, mostly confirming the expectation from the time series plots of about a 20% acceleration over the port beam, about 30% over the starboard beam and about 50% deceleration over the stern. Unfortunately there seemed to have been a real increase in the wind speed accompanied by a change in the air temperature affecting the observations between about 280-320˚ where an unrealistic peak of 70% acceleration can be seen.

17.2.3. Construction of a 1 minute average, merged file

In order to bring all the meteorological and underway oceanographic parameters into a single file, a 1 minute median value was produced for each of the streams (met, light & pressure and tsg). These 1 minute median files were merged onto the average truwind file using *mmerge*. Wave data is recorded approximately every 6 minutes so was merged by appending the nearest value onto the 1 minute file, without interpolation, using *ppaste2* (version of *ppaste* adapted for this purpose). This was done using script *mavmet_01* which produces a merged file met_merged_dy040_mstar.nc.

It should be noted that the variables in this file remain uncalibrated (PAR, TIR, fluorescence and transmittance all require calibration as indicated on the sensor calibration sheets and in Table 21. The radiation variables have been adjusted according to the calibration for plotting in Figure 38.

mexec format files are not ideally suited for time series data as time is not a dimension variable (these are nrows1 and ncols1, for data with a single dimension such as time series nrows1 = 1 and ncols1 is the number of data points). Additionally the units for the time variable do not contain the start time, this is stored as a global attribute "data_time_origin" (e.g. data_time_origin = 2015., 1., 1., 0., 0., 0.). In order to generate a time series file in a format more suited to use with programs expecting netCDF files in a more standard format, a script was written to convert the final merged mexec-style netCDF file to use time as the dimension variable with time units in the expected format (e.g. time:units = "seconds since 2015-01-01 00:00:00"). This was achieved using the following commands from the netCDF Operators (NCO) toolkit (nco.sorceforge.net).

ncwa -a nrows1 $infile $outfile

[averages over dimension "nrows1" in the file, thereby eliminating it]

ncrename -h -O -d ncols1,time $outfile

[renames dimension "ncols1" to "time"]

ncrename -h -O -v .long,lon $outfile

[renames longitude variable from "long" to the more standard "lon"] ncatted -O -a units,time,m,c,"seconds since 2015-01-01 00:00:00" $outfile

[adds an attribute changing the time units to a recognized format.]

The desirability of capturing some additional information from the TechSAS when reading in *mexec* files was discussed. TechSAS files contain netCDF attributes “long_name”, often giving useful information about the parameter. *mexec* does not currently copy across that information when reading in the data, but “long_name” is already included in the file. A modification to automatically capture this information and retain it as appropriate through the processing would be advantageous. Storing the time origin in the time variable units as well as in a global attribute should also be considered.

Ideally the TechSAS files should include additional metadata: information on sensor serial numbers, heights above/depths below sea level, more detailed location information, dates of last calibration and potentially a host of other useful pieces of information. A new version of TechSAS is expected soon in which adding more information should be easier than with the present version. It is important to ensure that accurate and complete information is added to the TechSAS files when that becomes possible, and also that this information is retained during the *mexec* processing.

17.2.4. Air temperature, humidity and pressure

It was not possible to make an assessment of the quality of data from these sensors as only a single instrument of each was available. All sensors had been recently assessed (Table 21) and found to be performing with specification. No calibrations are required.

17.2.5. Radiation sensors

Pairs of radiation sensors are installed on the foremast, two measuring photosynthetically available radiation (PAR) and two measuring total incoming radiation (TIR). Output logged by TechSAS has been scaled by 10 to give a nominal value in Wm^{-2}. Sensors require calibration by multiplying the TechSAS value by 10/(output voltage from calibration). All sensors had a negative reading at night which is typical and due to lack of thermal equilibrium within the sensor due to longwave cooling. Figure 39 shows the output of each of the sensors close to zero output, all show a peak at small negative values, the PPAR sensor is noticeably noisier than the SPAR sensor at night. There is no noticeable difference in noise during daytime, but it is harder to identify amongst the real variability.

After calibration the port and starboard sensors sensors show reasonable agreement (see Table 21 for expected accuracy).

17.2.6. Wave Radar

The TechSAS wave radar files record parameters of the wave spectrum (including significant wave height, peak wave period, peak wave length, and peak wave direction) approximately every 6 minutes. The WAMOS system also logs a large volume of data directly to its hard disk. All of the wave radar data collected during DY040 were flagged ("IQ" variable) as having problems of various levels. The "best" data were flagged as "insufficient noise in spectrum; wind is too low" (iq=10), despite winds of up to 18 ms^{-1} and the wave radar reporting waves with significant wave height of over 6 m. Data with higher IQ flag values are assessed as having additional problems, the flags are additive, and only data with flag values of 10 or 11 (as 10 but additionally "radar back scatter signal is too weak") are considered here.

[I need Margaret's help with this when I get back to NOC]

Figure 40 shows ....

Note on changed config

Current measurements

17.2.7. Other data streams logged underway

PHINS navigation

There is a data stream from an inertial navigation system IXSEA Photonic Inertial Navigation System (PHINS) that measures heading using a fibre-optic gyro compass (FOG) and is expected to be more accurate than the ship's mechanical gyro compass (gyro_s). It may also be better than the heading from the gyropmv stream (Applanix Motion Reference Unit) currently used in bestnav, but this is yet to be established. The data are currently captured as text files with header from:

/local/users/pstar/cruise/data/mnt_smb_discofs/scientific_systems/Attitude_and_Position/phins_ph-832

Once these files are read into mexec format it will be possible to analyse them with a view to using the data on future cruises.

Fluorescence and Transmittance

These were both logged throughout DY040 as raw voltages. No calibrations have been applied although current calibrations are available. They are logged in the same file as the TSG data and as part of the TSG processing have been edited to remove measurements when the pumps were switched over (see Section 18).

Skipper log velocities

These were read into *mexec* netCDF files but have not been analysed.

17.2.8. Bridge routine meteorological observations

Discussions with officers on the bridge revealed that they had been reporting temperatures displayed on a display from the skipper speed log as sea surface temperature as part of their weather observations. This temperature reading is required by the speed log to calculate the appropriate speed of sound to use and is not accurate enough to be used as a scientific measure of sea temperature and is therefore not logged by the scientific systems. Figure F8 shows those temperatures transcribed from the bridge log, the same display was used to record sea surface temperature for both the bridge log and the weather report. It's clear the skipper log temperature is a couple of degrees warm, from the fairly narrow range of temperature measured it's not clear whether this is a simple offset or whether there is also a temperature dependency. The Ship Observations Manager at the Met Office confirmed that their monitoring also showed that the sea surface temperature reports from the ship were 2˚C out for this period. It was agreed with the Met Office that whilst the TSG was running that should be reported as the sea temperature and the ship has been instructed by email to do this from now on.

We were also told that there was an independent meteorological system installed by the Met Office on the system. This comprised an air temperature sensor on the aft of the bridge top "monkey island" on the starboard side, the sonic anemometer on the port of the foremast platform (not logged) and a hull sensor measuring sea surface temperature. The hull sensor was reported as also measuring about 2˚C too warm, and the measurements are excluded from Met Office models and analyses. The sensor location was tracked down from a photo (Figure F8) of the sensor installation by the engineers to the engineering workshop. Since it was installed a high-backed work bench has been constructed in front of the sensor which is now out of view. Thermal images were taken of the sensor (over the top of the steel tool rack with the help of a ladder) which showed the sensor fixings to be about 3˚ warmer than the inside of the ship's hull (Figure F8). The sensor box itself was slightly warmer than the hull, but it is not clear what the temperature of the sensor in contact with the hull is reading. Given the temperature of the engine room workshop, the lack of insulation around the sensor, and the high temperature of the surrounding supports, it is perhaps not surprising that the sensor was reading warm, although 2˚ C is quite a large offset.

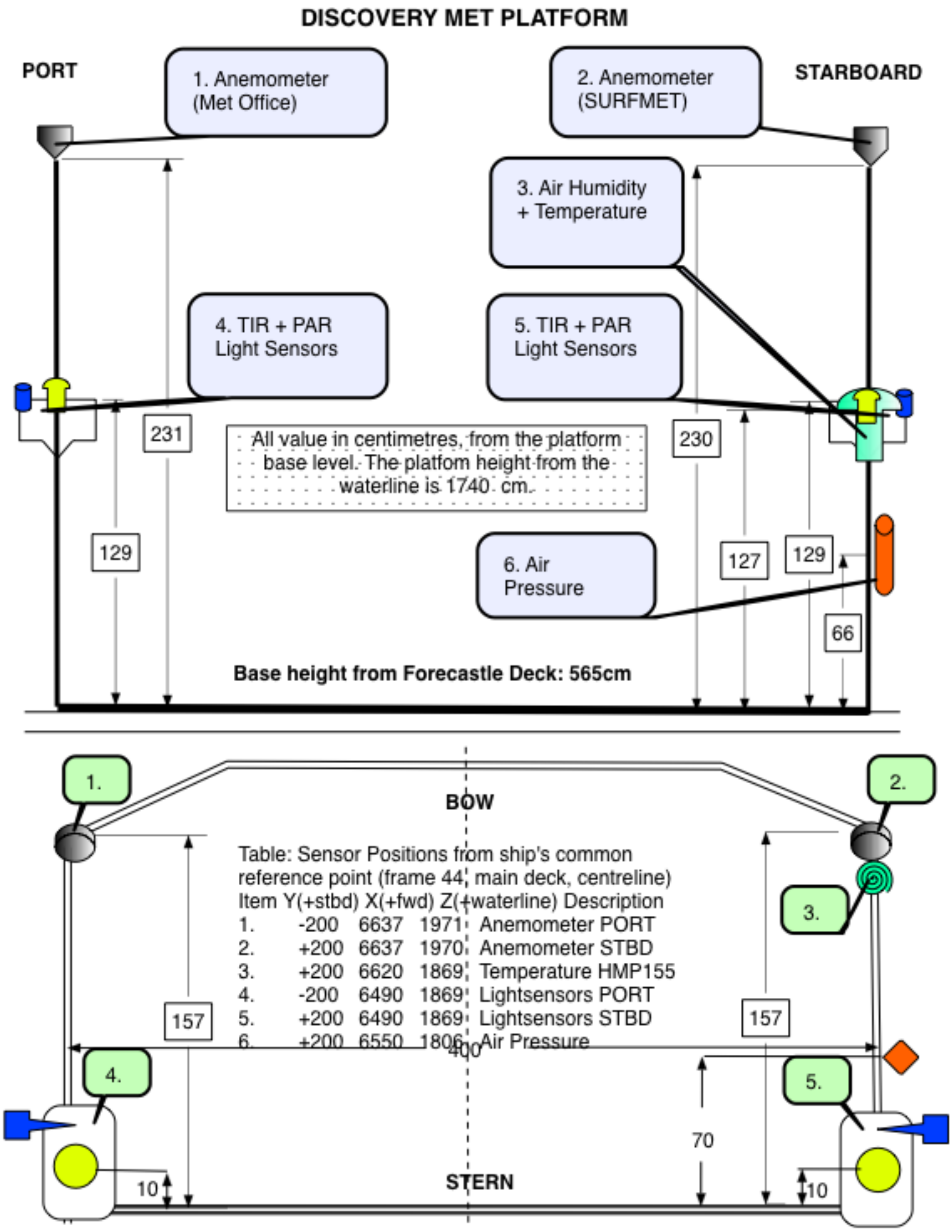


Figure 34. Schematic of sensor locations on the foremast platform: upper – side view; lower plan view. (diagrams by Zoltan Nemeth).

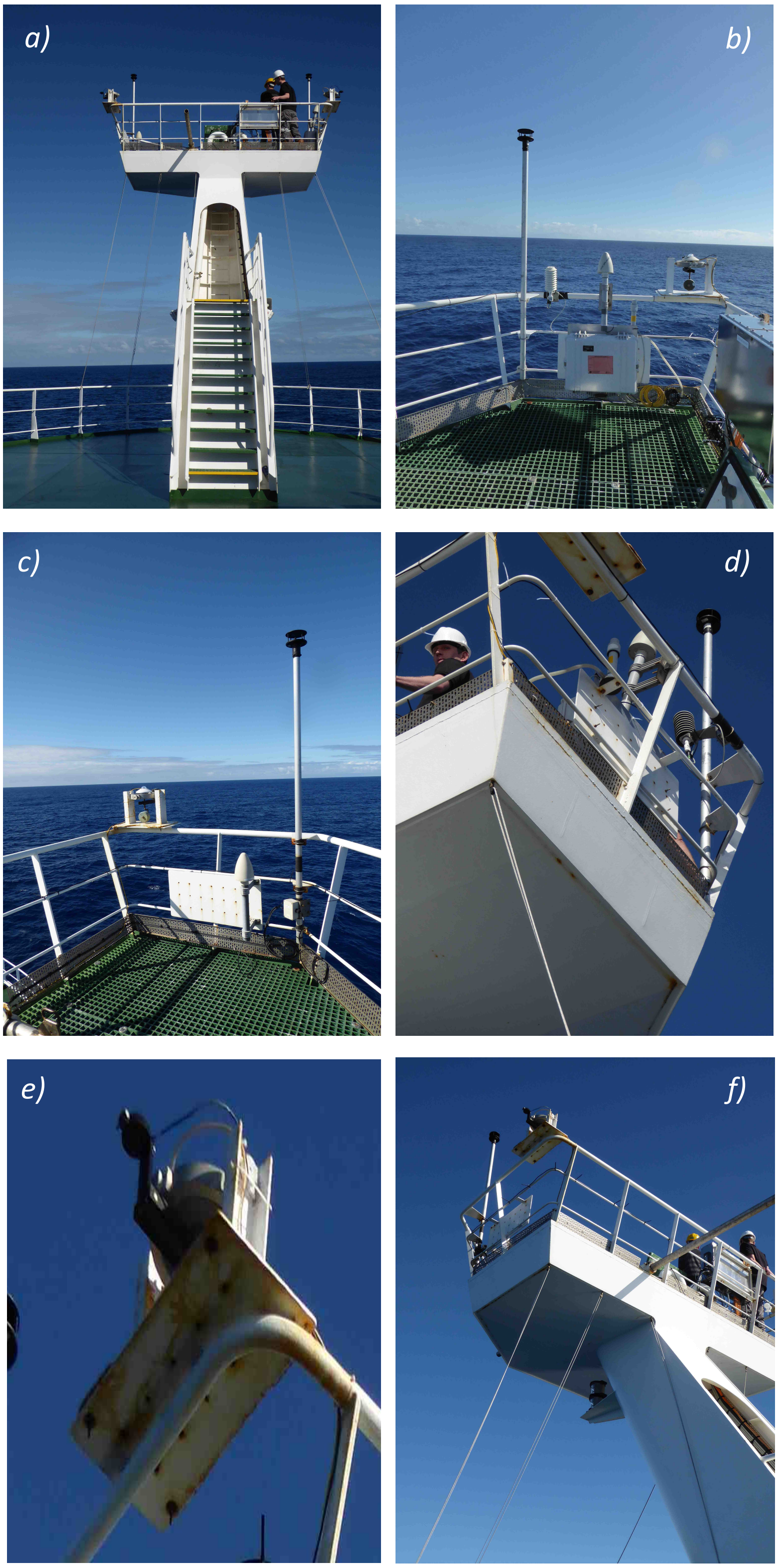


Figure 35. Locations of sensors on foremast platform: *a)* Foremast platform viewed from aft. *b)* Instruments on starboard foremast platform viewed from centre of platform. Left to right: sonic anemometer; combined temperature and humidity sensor with radiation shield; pressure probe to the right and above junction box containing pressure sensor; radiation sensors (inboard TIR, outboard PAR). *c)* Instruments on port side of foremast platform viewed from centre of platform. Left to right: gimbaled radiation sensors (smaller PAR sensor, outboard); clock antenna; sonic anemometer (Met Office, not logged)). *d)* View of starboard-side sensors from deck below and aft of the platform. *e)* Port-side par sensor viewed from deck below. *f)* Port-side sensors viewed from deck below, aft of platform.

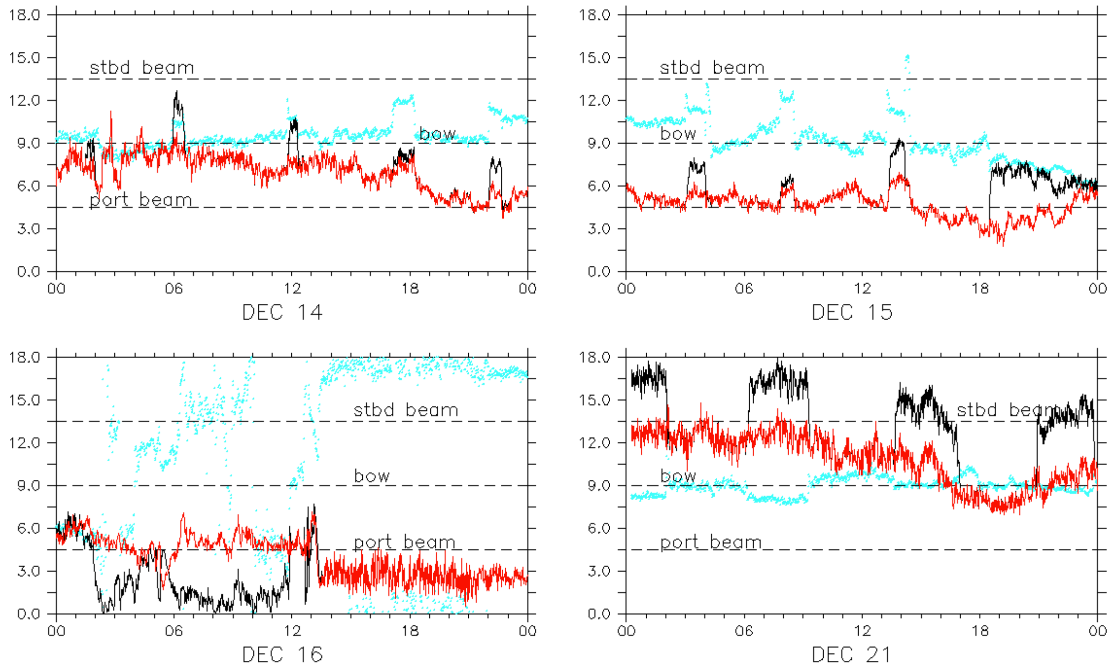


Figure 36. Examples of true wind speed calculation, red is true wind speed, (ms^{-1}) black is relative wind speed (ms^{-1}) and the light blue dots are the relative wind speed (˚/20).

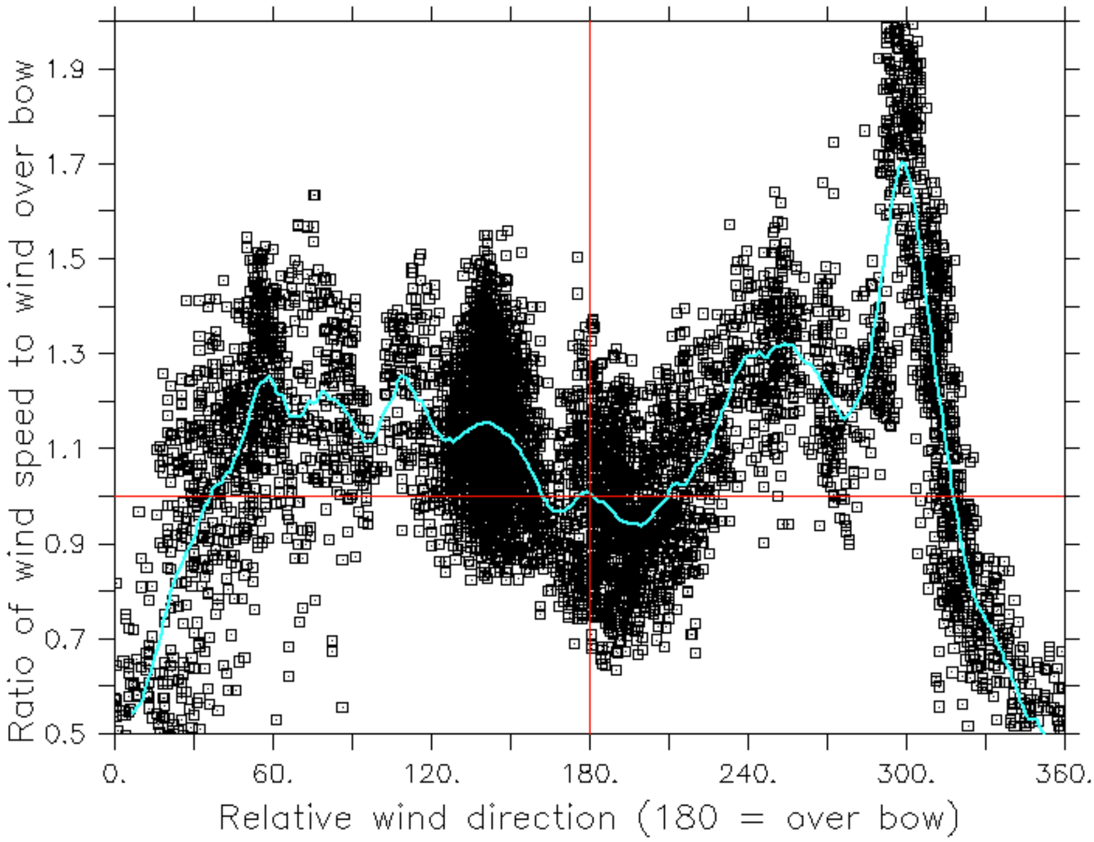


Figure 37. Ratio of wind speed to mean wind speed over the bow. Black squares = individual 1Hz wind samples, blue line = smoothed line fitted to binned values. Values around 300˚ are associated with a

change in air temperature and are thought to be associated with a real change in the true wind speed, but we cannot confirm this.

Plots to be run at the end of the cruise.

Figure 38. Meteorological data for December 4th 2015 to 21st January 2016, in 5-day sections. Top panel - air temperature (red) and sea surface temperature (black). Upper middle panel - downwelling radiation from the two shortwave TIR and PAR sensors (calibrations applied for plotting only). Central middle panel – Atmospheric humidity (black) and atmospheric pressure (red, right-hand scale). Lower middle panel - relative wind direction (black, 0 degrees for a wind onto the bow), true wind direction (pink, degrees to), ship's heading (red). Lower panel – true wind speed (black), relative wind speed (red) and ship speed (green).

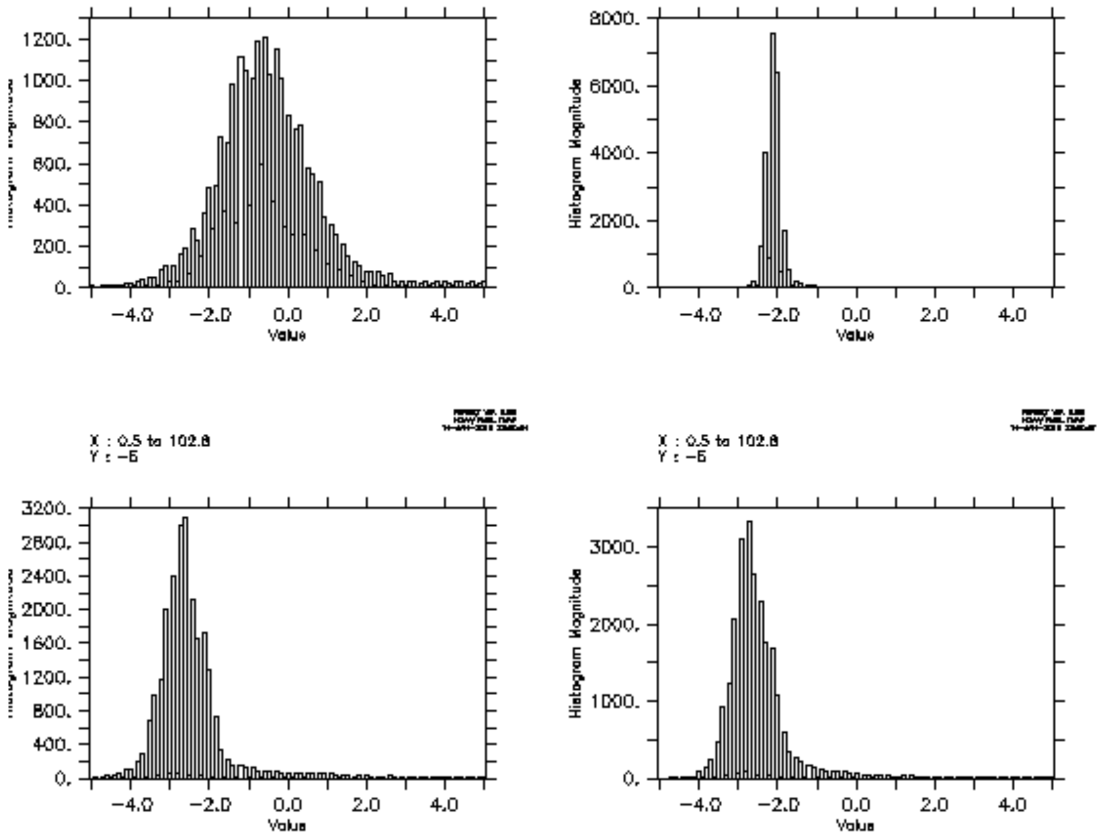


Figure 39. Frequency histograms of radiation sensor output in the range -5 to 5 Wm^{-2}. Top right PPAR, top left SPAR, bottom right PTIR, bottom left STIR.

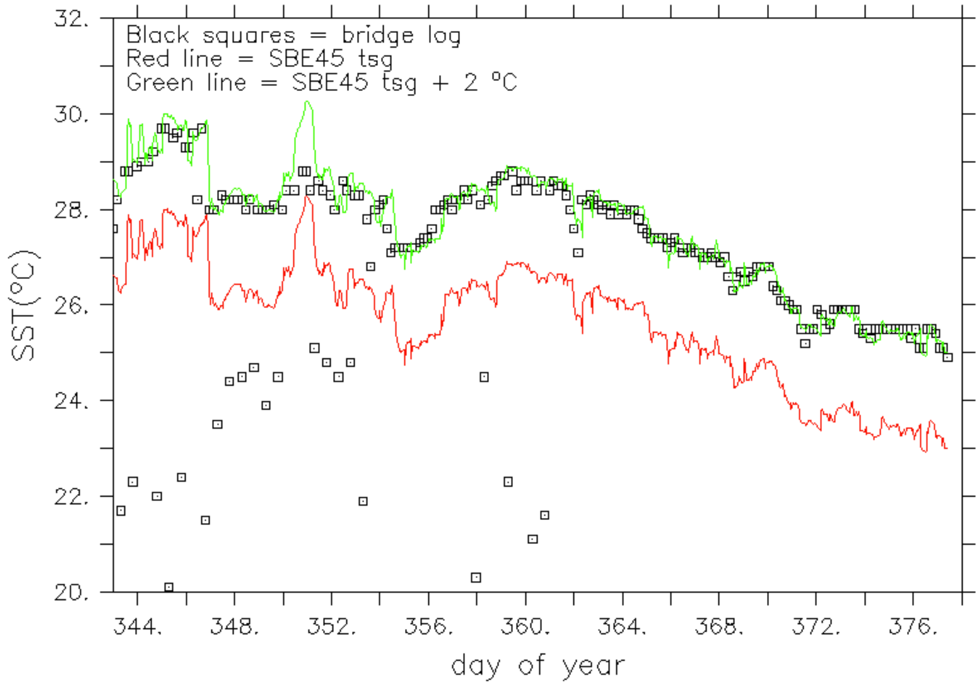


Figure 40. Sea surface temperatures transcribed from the bridge log (black squares), surface temperature from the tsg (red line) and the tsg temperature +0.2˚C (green line). Black squares below the line were occasions where the dewpoint temperature had been written down instead of the sea temperature.

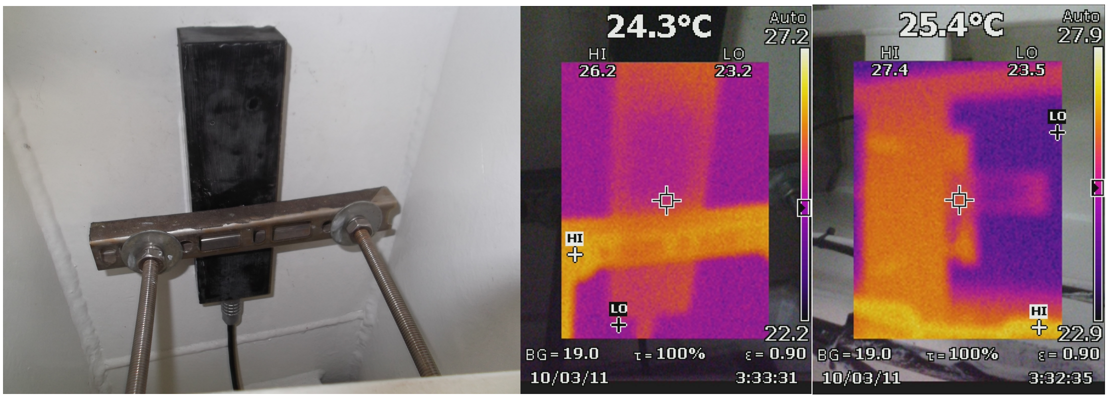


Figure 41. Photo of the hull sea surface temperature sensor supplied by the Met Office (left), close-up thermal image of sensor location (centre) and landscape wider view of the sensor location. The ships hull is the coolest part of the images, the sensor itself slightly warmer and the supports and struts warmer again. The workshop where it was installed was warmer than the ambient temperature of the ship. The tsg was reading 22.8˚C at this time, it is not clear how accurate the thermal imager is [note the dates are wrong on the imager].

18. Underway Thermosalinograph (TSG) and Salinity Samples

Justin Buck, Elizabeth Kent

18.1. *TSG Sensor*

A single SBE45 TSG sensor (s/n 4548881-0229) and SBE38 seawater intake sensor (s/n 3854115-0491) was used throughout DY040. These are outlined in the reference underway instrumentation section Table 20.

The clean sea water intake is estimated to be located 1.8 m beneath the clean sea water pumps where the SBE38 temperature probe is located. The intake protrudes 0.3 m from the hull. It is not known whether intake is insulated in the void between the intake and the pumps room. The depth of the sea water intake is estimated to be 4.6 m below sea level at normal loading.

The instrumentation (including the TSG) in the underway instrumentation lab was cleaned while docked in Freeport on 16th December 2016 (day 350).

18.2. *Salinity samples*

The ships underway non-toxic sea water supply was sampled in the underway instrumentation lab as part of routine watch keeping duties: nominally at hours 01, 05, 09, 13, 17 and 21 ships time. The actual sampling time varies, particularly if the CTD is on deck being sampled, but is noted on the logsheet. No samples were taken while the non-toxic supply was switched off when the ship was in shallow waters or in port. While the non-toxic supply is active the flow through the sampling tube is continuously 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 duly recorded. 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. Little variation in the flow rate was evident.

18.2.1. Data processing

Data were processed using mexec matlab tools (initialised by starting Matlab and running m_setup at the prompt) under the ‘pstar’ used id on the scientific workstation eriu. The following mexec routines were used:

1. mtsg_makesal – The appended DY040 met_tsg_dy040_01.nc cruise file generated during daily underway processing does not include salinity. This script derives salinity from temperature and conductivity and outputs file met_tsg_dy040_01_psal.nc.
2. mtsg_medav_clean_cal – This runs on the appended cruise file DY040 met_tsg_dy040_01.nc and met_tsg_dy040_01_psal.nc. The data are first reduced to 1-minute bin medians. Cleanup and calibration is applied using mcalib2 with the function mtsg_cleanup. This function discards data identified in the bad_time_lims.mat which is populated by the mtsg_findbad routine described next. The file met_tsg_dy040_01_medav_clean.nc is output.
3. mtsg_findbad – This routine plots data and the user interacts with the graphs via the matlab prompt to identify sections of bad data. These are then stored in a bad_time_lims.mat file for the cruise.

4. mtsg_01 – Reads analysed bottle salinity values into ctd/tsg_dy040_[crate number].nc and ctd/tsg_dy040.nc files. The crates and the associated autosal offset are hardcoded into the script by cruise. A crate needs to be hardcoded into the script before it can be run for a given crate.
5. mtsg_bottle_compare – Plots bottle sample salinity values (from ctd/tsg_dy040.nc) with TSG salinity (from met_tsg_dy040_01_medav_clean.nc) and residuals. This optionally plots residuals between bottle samples and calibrated TSG salinity (met_tsg_dy040_01_medav_clean_cal.nc instead). The plot also includes the proposed calibration that is hardcoded in the script. Visual inspection of this plot ensures ensure the times have been assigned to bottles correctly and any outliers can be removed from the calculation (done by hard-coding outlier indices into mtsg_bottle_compare).
6. mtsg_apply_salcal – Applies the calibration to TSG salinity in the met_tsg_dy040_01.nc cruise file. This script includes a case structure for different cruises where the calibration is hardcoded into the mtsg_salcal script. It is important that the hardcoded calibration matches the one in mtsg_bottle_compare. The met_tsg_dy040_medav_clean_cal.nc is output with the calibrated data.

18.2.2. Notable data issues

Bubbles in the TSG system

The TSG system includes a de-bubbler within the pipe work however occasionally the underway pumps needed restarting to remove bubbles upstream of the TSG system that resulted in noisy (+/- 0.1 PSU salinity data). The affected data have been identified and removed when screening data with mtsg_finbad. Trapping of bubbles was a particular problem when arriving on station, presumably due to thruster operation. In these cases removal of the bubble(s) required closing and opening valves in the clean seawater system, this was done by the engineers.

Data spikes when non-toxic sea water supply pump switched

Twice a day the pumps in the non-toxic supply are switched as part of the ships routine engineering activities. This causes stagnant water to flow through the underway instrumentation and is visible in the data as an increase then decrease in in the TSG temperature and associated dip in conductivity (but not the SBE38 SST sensor as this is located upstream of the pumps). An example of one such spike is shown in Figure 42. Affected data are identified and suspect cycles removed from the time series when running mtsg_findbad.

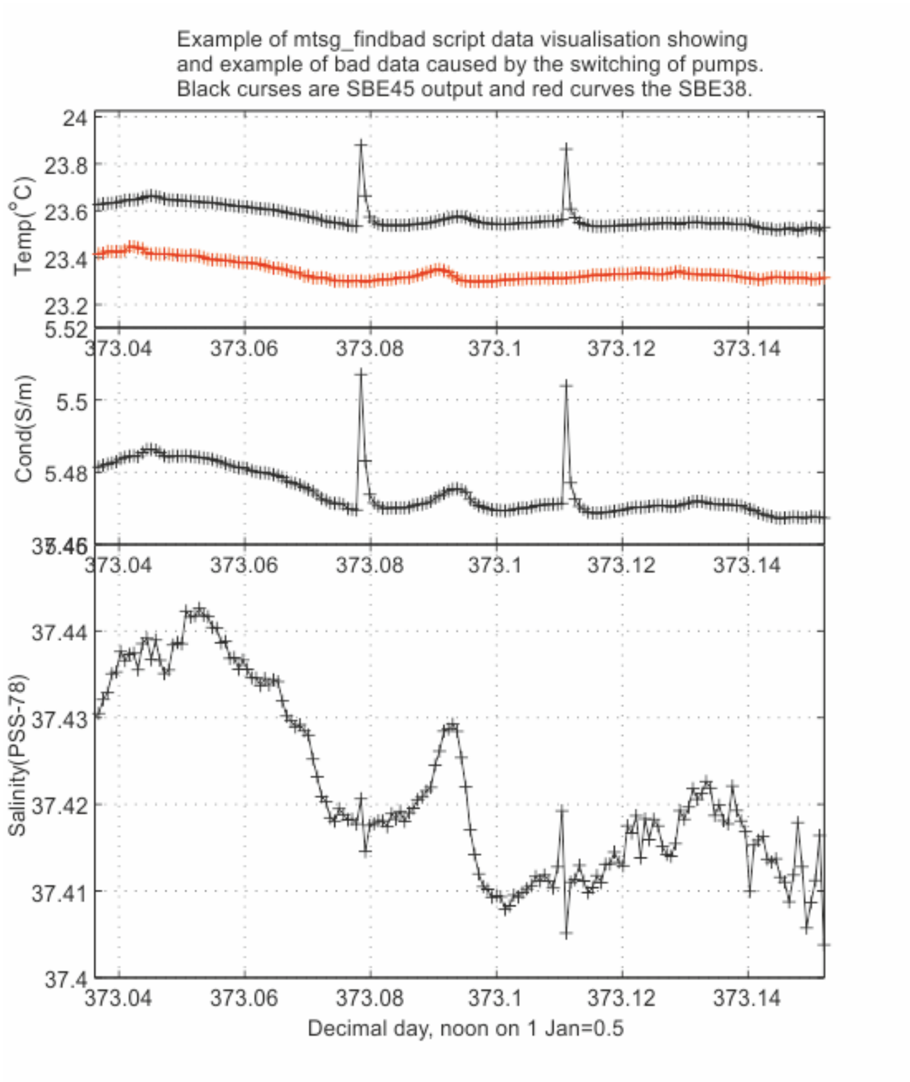


Figure 42: Example of temperature and conductivity spikes introduced into the Underway TSG record when the non-toxic underway supply pumps are switched.

18.2.3. Calibration

TSG salinity was calibrated by comparison with bottle salinities. The calibration is split into 2 sections to take account of the jump in calibration when the TSG was cleaned on day 350. Offsets are filtered twice using a 21 then 41 point median filter by running function filter_bak_median twice and excluding point with a residual greater than 0.02 from the second filter. The uncalibrated TSG salinity with the bottle salinities is shown in Figure 43 and the proposed correction with residuals is shown in Figure 44.

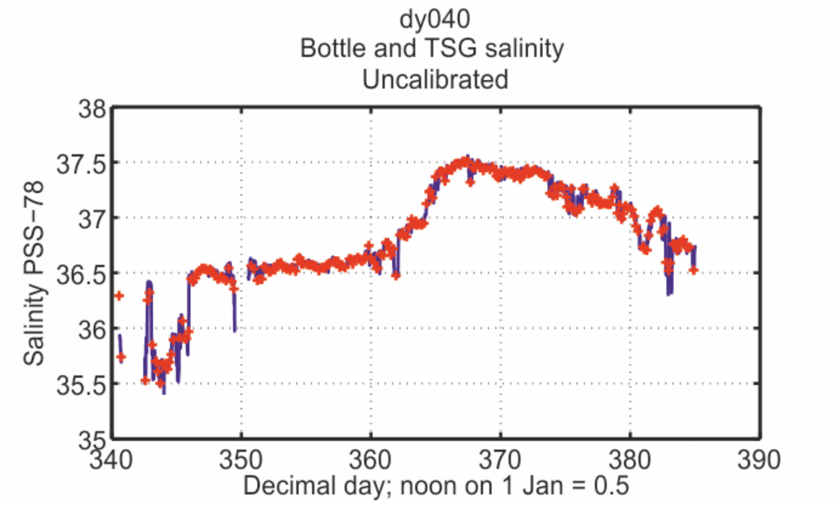


Figure 43: Uncalibrated TSG salinity with sample salinities.

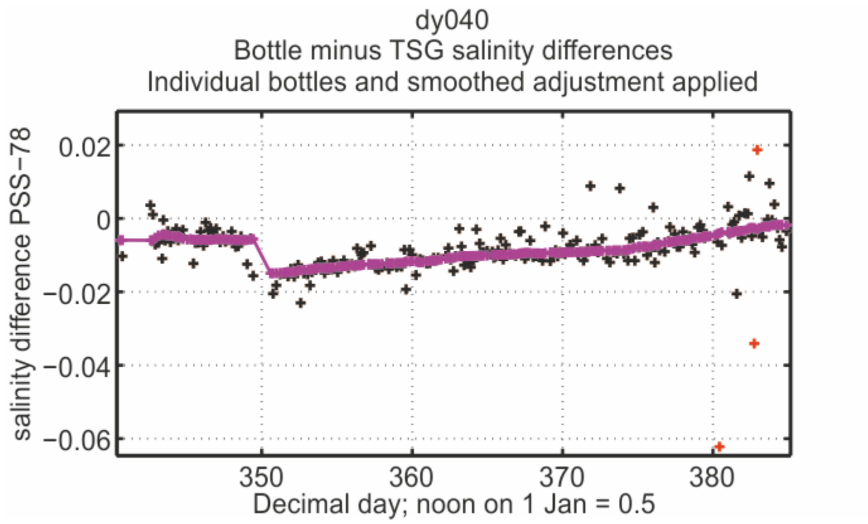


Figure 44: TSG minus bottle salinity values with the proposed TSG correction. Red points are excluded from the proposed correction.

The proposed correction is applied to the uncalibrated TSG salinity by running mtsg_apply_salcal then checked by setting mtsg_bottle_compare to run on calibrated data (hard coded at the start of the script). The calibrated salinity with sample salinity values is shown in Figure 45 and the residuals after correction shown in Figure 46. The offset in the calibrated data is less than 0.001 PSU with an RMS of residuals of 0.0037. The final calibrated data are in the met_tsg_dy040_medav_clean_cal.nc file.

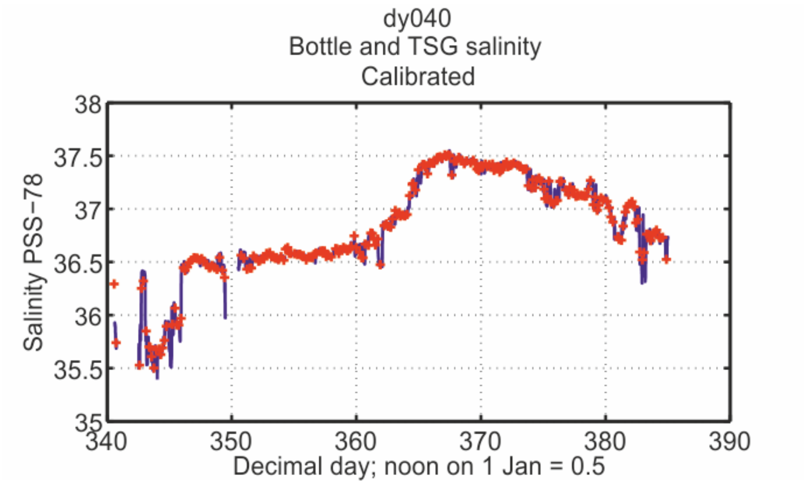


Figure 45: Calibrated TSG salinity data with bottle samples salinity values.

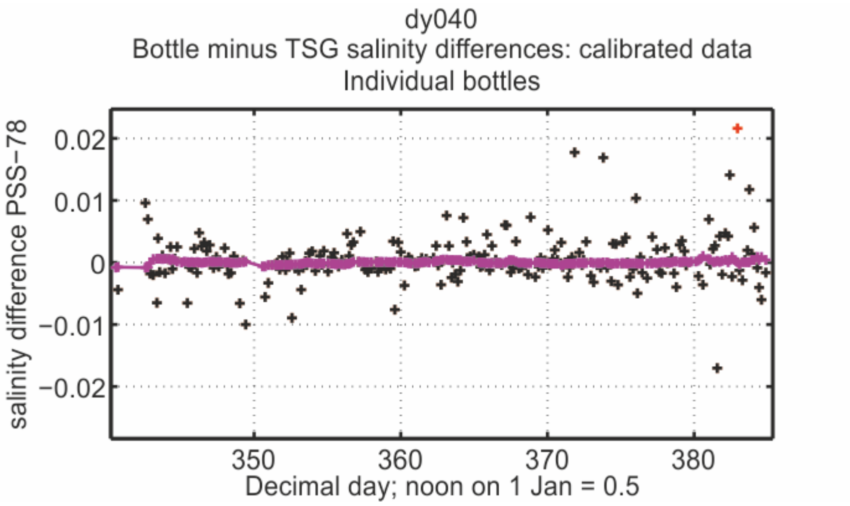


Figure 46: Calibrated TSG minus salinity samples with the new proposed correction.

18.2.4. Comparison of TSG with CTD data

The TSG has been compared with the 5 m CTD data and the results are shown in Figure 47. The calibrated TSG salinity offset is within 0.002 PSU for the duration of the cruise with an RMS of residual values of 0.0041. This supports the calibration of the TSG against bottle samples but the cause of the small, but increasing offset is unknown.

The TSG temperature shows a trend over the cruise which is clearly greater than the noise in the comparison. Tests were done comparing with CTD depths between 3 m and 10 m with no noticeable difference. The difference increases from a warm offset in the TSG of approximately 0.02°C to approximately 0.06°C. One explanation would be a small heating of the water in the pipe between the sea and the sensor. If the ship internal temperature is approximately constant (and probably higher than typical surface temperature) then the temperature change would be a function of water temperature and become increasingly warm as the sea temperature decreases.

Examination of data from DY031 (Ellett Line 2015), where the surface water was colder than encountered on DY040, showed a larger warm offset (about 0.1°C) compared to the CTDs, suggesting that warming in the pipe is a plausible explanation for the differences seen. This size of temperature difference, although small, is significant for some applications, for example accurate measurement of surface pCO_2.

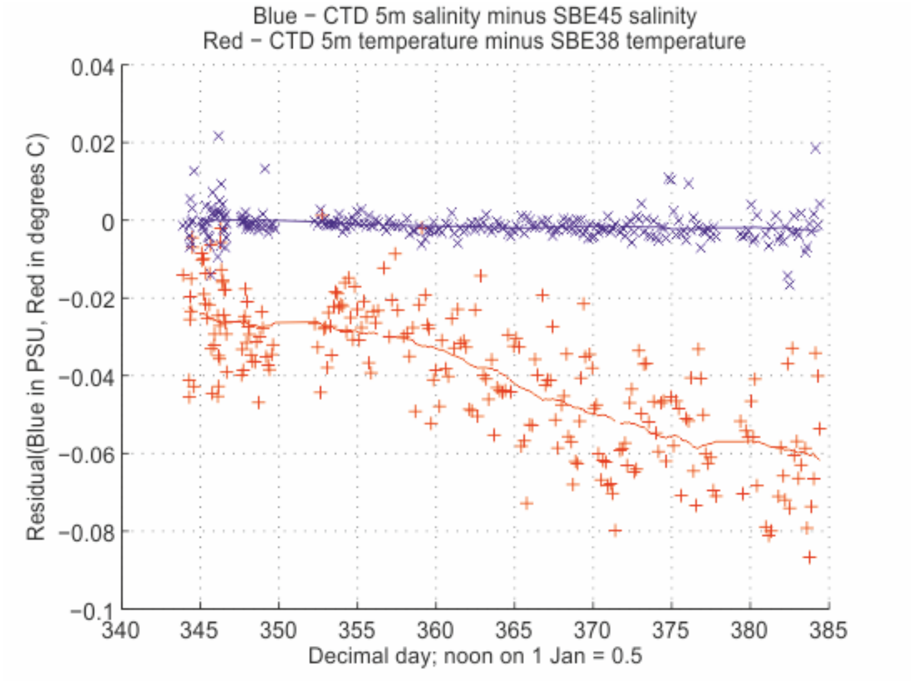


Figure 47: Plot of CTD temperature minus SBE38 temperature and CTD salinity minus TSG salinity with 81 point mean filtered curves.

19. Underway *p*CO_2, Methane and Nitrous Oxide (atmospheric and surface)

Ian Brown

Underway pCO2 analyser – A PML-Dartcom Live pCO2 instrument was set up in the meteorological laboratory on the boat deck (hereafter met-lab). Gas standards (BOC Ltd.; nominal mixing ratios 250, 380, 450 ppmv in synthetic air; calibrated against NOAA primaries) were located in the gas bottle rack in the forward moorings area on the boat deck (port-side) and an air sampling line was taken from the met-lab to the foremast. The system comprises a showerhead equilibrator vented through a second equilibrator, in-line oxygen optode and platinum resistance thermometer, nafion dryer, non-dispersive infrared detector (LiCOR, LI-840) and associated hardware and electronics. The system was linked to the ship's LAN and transmitted data in near-real-time to a server at PML. Underway pCO was measured every 15 minutes, marine air every 45 minutes and standards every hour.

A underway pN20 and pCH4 analyser was set up in the deck laboratory . Gas standards (BOC Ltd.; nominal mixing ratios 317.4, 406.4, 496.7 ppbv N2O and 1.009, 2.058, 3.04 ppmv in synthetic air; calibrated against NOAA primaries) were located in hanger and an airline taken externally starboard side to the met platform. The system comprises a two showerhead equilibrators set at different flow rates for both N2O and CH4, vented through a second equilibrator, platinum resistance thermometer, nafion dryer, Picarro Cavity Ringdown Spectrometer and associated hardware and electronics. The system was linked to the ship's LAN to acquire ancillary and positional data. Underway pN2O and pCH4 were measured approximately every 30 minutes, marine air every 45 minutes and during the night standards every twice daily.

20. Bathymetry

Justin Buck

20.1. *Sensors*

DY040 used the Kongsberg Simrad EA640 echosounder and the Kongsberg EM122 swath bathymetry centre beam for production of the cruise bathymetry time series. The data are initially acquired using the TechSAS system which is outlined in section [underway section.]

The raw full Kongsberg EM122 swath bathymetry dataset will be included in the cruise archive to be lodged at the British Oceanographic Data Centre.

20.2. *Data processing*

Data were processed using mexec matlab scripts (initialised by running m_setup) under the 'pstar' used id.

1) Initial daily processing:

MEXEC routine	**Input file(s)**	**Output file(s)**	**Description**
msim_01	sim_dy040_[day number]_raw	sim_dy040_[day number]_smooth sim_dy040_[day number]_edited	Reads in raw EA640 data, removes bad data outside ocean bathymetry limits, applies a median filter to remove spikes, averages data into 5 minutes bins.
mem120_01	mem120_dy040_[day number]_raw	mem120_dy040_[day number]_smooth	Reads in raw EM122 data, removes bad

		mem120_dy040_[day number]_edited	data outside ocean bathymetry limits, applies a median filter to remove spikes, averages data into 5 minutes bins.
msim_02	sim_dy040_[day number]_edited mem120_dy040_[day number]_edited	sim_dy040_[day number]_edited	Merges the EM122 depths onto the EA640 edited data file. Both msim_01 and mem120_01 need to be run prior to this script.
mem120_02	mem120_dy040_[day number]_edited sim_dy040_[day number]_edited	mem120_dy040_[day number]_edited	Merges the EA640 depths onto the EM122 edited data file. Both msim_01 and mem120_01 need to be run prior to this script.
msim_plot	sim_dy040_[day number]_edited	sim_dy040_[day number]_edited	Plots time series of EA640 and EM122 depths along with Sandwell & Smith bathymetry for interactive editing of bad EA640 data. This includes a user interface at the matlab prompt to edit out bad EA640 data.
mem120_plot	mem120_dy040_[day number]_edited	mem120_dy040_[day number]_edited	Plots time series of EM122 and EA640 depths along with Sandwell & Smith bathymetry for identifiction of bad EM122 data. This includes a user interface at the matlab prompt to edit out bad EM122 data.

The daily processing produces a series of cleaned daily files ready for appending into longer time series with merged navigation and the Carter correction applied (if applicable) in stage 2.

2) Appending of daily files data and application of Carter correction. This sequence has been scripted in the sim_apend_dy040.m and em120_apend_dy040 scripts:
   a) mapend – Used to concatenate sim_dy040_[day number]_edited.nc and em120_dy040_[day number]_edited.nc into sim_dy040_01.nc and em120_dy040_01.nc respectively. These files cover the duration of the cruise.
   b) mernav_sim_dy040 and mernav_em120_dy040 (call mmerge) – Merge navigation data from bestnav file (bst_dy040_01.nc) onto bathymetry. Run separately for sim_dy040_01.nc and em120_dy040_01.nc and creates sim_dy040_01_nav.nc and em120_dy040_01_nav.nc respectively.
   c) carnav_dy040 (EA640 depths only) – Applies the Carter correction to EA640 depths in sim_dy040_01_nav.nc . This outputs sim_dy040_01_nav cordep.nc. The Carter correction is unnecessary in EM122 because the data are already sound speed corrected using CTD sound speed profiles generated from recent DY040 CTD data prior to loading into the TechSASS system.
3) Checks on cleaned up data (scripted in sim_em120_checks_dy040.m)
   a) CTD station times are loaded from ctd/dcs_dy040_all.nc
   b) Station depths are loaded from station_depths/station_depths.mat which is the best estimate of depth once CTD and LADCP processing are complete
   c) EA640 and EM120 data from the appended files are plotted with station depths. Any outlying data are identified using a threshold of 50 m.
   d) Newly identified dad data removed by rerunning msim_plot or mem120_plot routines and editing them from the series
   e) Rerun appending routines on updated sim_dy040_[day number]_edited and em120_dy040_[day number]_edited files

Data issues that were identified and removed from data:

- The EA640 frequently identified a false seabed that differed by over 100 m from the station depths (especially in the mid-Atlantic fracture zone).
- The quality of both the EM122 and EA640 was adversely affected by rough sea states and bubbles generated by the ships forward thruster.

The final bathymetry data files are sim_dy040_01_nav cordep.nc and em120_dy040_01_nav.nc.

21. Vessel Mounted ADCP

Two Teledyne RDI vessel-mounted Acoustic Doppler Current Profilers (ADCPs), 75kHz and 150kHz, were operated on RRS Discovery throughout the DY040 cruise to measure the horizontal velocity field (U-zonal and V-meridional components). The different frequencies affect both their depth range and resolution. 150kHz gives higher vertical resolution, but the signal is more rapidly attenuated and typically only penetrates to approximately 400-500m. 75kHz lacks such good vertical resolution, but penetrates deeper in the water column, to approximately 600-800m.

Both transducers are fitted to the hull of the ship at a depth of 6.6 m. They are phased-array, which 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 in the first/second bins has been observed to be affected by exposure to bubbles (section 1.4.1).

21.1. *Real-time data acquisition*

The data from the instrument were acquired using the RDI VMDAS software package version 1.46.5, installed on a PC in the main laboratory. The software performed preliminary screening and transformation of the data from beam to earth coordinates. VMDAS was run using a selection of preset configuration files (Appendix A), which allowed the instrument to be promptly switched between bottom tracking and water tracking; set for different depth ranges; and set whether the acoustic pings will be self-triggered or triggered by the K-sync unit so as not to interfere with other acoustic measurements. Data collection was typically stopped and restarted to generate a new file segment number on a daily basis during the cruise, thus facilitating and synchronizing the incremental processing in both instruments.

21.1.1. VMDAS files

The files produced have names of the form *OS075_DY040nnn_mmmmmm.ext*, where *nnn* is the file sequence number, *mmmmmm* is the number of the segment file within the sequence and *ext* is the extension. VmDas automatically increments the file segment number every time data collection is stopped and restarted, or when one of the file types (see below) reaches a size of 10 Mb.

The list of files produced have extensions:

- *ENR files*: binary raw data files (in beam coordinates).
- *ENS files*: binary ADCP data after being screened for RSSI and correlation, with navigation data included.
- *ENX files*: ADCP single ping and navigation data after having been bin-mapped, transformed to Earth coordinates and screened for error velocity and false targets.
- *STA files*: binary files of short-term average ADCP data (120 s, user-specified in VmDas).
- *LTA files*: binary files of long-term average ADCP data (600 s, user-specified in VmDas).
- *N1R files*: ASCII text files of raw NMEA navigation data from the NMEA1 stream.
- *NMS :* binary files of navigation data after screening.

- *VMO files*: ASCII text files specifying the option settings used for the data collection.
- *LOG files*: ASCII text files logging all output and error messages.

The raw files were continuously updated via Syncback to a public network drive for scientists, *smb://discofs/dy040/scientific_systems/Hydroacustics*, and secondly rsynced to a directory on eriu using *vmadcp_linkscript*.

21.1.2. Real time monitoring

In the main laboratory, WinADCP software graphical output from the .ENR, .STA and .LTA files were displayed in real time (in 120s time intervals), and later checked in more detail following daily processing. During the 4-hourly regular watchkeeping tasks the VMADCP ensemble number was checked to ensure the expected amount of data recording. Table B1 and B2 (in appendix B) list VMADCP file sequence start and end times (Julian day and time), and the ensemble number. Ensembles refers to number of single-ping ensembles. The ensemble counter reset during sequences 019, 020, 022 and 041, for OS075, and during sequences 079, 080, 082 and 101, for OS150.

21.1.3. Settings

Both VMADCP were run in single-ping mode, with 60 16-m bins and an 8-m blanking distance for the OS75, and 60 8-m bins and a 4-m blanking distance for the OS150.

At the beginning of the cruise, in shallow water (broadly <700 m, in the Florida Strait and eastern and western Atlantic basin shelfs), the instrument was run in bottom track mode to obtain phase and amplitude calibrations (section 1.2.2). Once we reached deeper water in the Atlantic basin, on 17th December, the instrument was switched to watertrack mode, and watertrack calibration data were obtained during CTD station-keeping. The VMADCPs were set to be self-triggered, the os75 pinging every 01’50’’and the OS150 every 01’00’’.

21.2. *Post-processing*

The final onboard processing of the data was done using the (deprecated) Matlab version of the CODAS (Common Ocean Data Access System) suite of software provided by the University of Hawaii. Four main steps characterizes the CODAS VMADCP processing: *i)* Removal of the ship velocity*; ii)* Correction of the gyro heading with the GPS-derived heading; *iii)* Estimate the heading misalignment from either bottom-track (BT) or water track (WT) data; and *iv)* Manual inspection/editing of bad data. CODAS was run on eriu, after rsyncing the raw data into *pstar/dy040/vmadcp/v75/rawdataNNN* and into *pstar/dy040/vmadcp/v150/rawdataNNN*, linked to by *pstar/dy040/vmadcp/dy040_os75* and *pstar/dy040/vmadcp/dy040_os150*, respectively. This processing was performed daily.

21.2.1. Setting up the directories and using quick_adcp

Once loaded into the rawdata directory, the following steps were followed:

1. *vmadcp_linkscript75* (or 150) was typed on the console, from the *pstar/dy040/vmadcp/v75* (or v150) directory. This creates a new directory, *rawdataNNN* (NNN denoting the file sequence), and makes links to the relevant data in this new location.

2. Secondly, the command *adcptree.py dy040NNNnbenx --datatype enx* was typed on the console. This command sets up a directory tree for the CODAS dataset and an extensive collection of configuration files, text files and m_files.

3. The control files *q_py.cnt*, *q_pyrot.cnt*, and *q_pyedit.cnt* were copied to each directory and *q_py.cnt* edited to refer to the relevant NNN.

4. From every dy040NNNnbenx/ directory, the command *quick_adcp.py –cntfile q_py.cnt* was run on the console to load the data and perform routine processing and automatic editing, including estimates of bottom track and water track calibrations.

5. Editing was performed in Matlab, by typing in the following commands in the Command Window:

   m_setup, to set up the environment for mexec processing.

   codastpaths, to set the path for the CODAS scripts/functions.

   gautoedit, to launch the display window for editing VMADCP data.

5. Calibration values in *cal/watertrack/adcpcal.out* and *cal/btrack/btcaluv.out* were examined (Calibration tables in Appendix C) and *q pyrot.cnt* adjusted to use the chosen amplitude and phase calibrations.

6. Once the amplitude and phase have been selected, the following commands were performed on console: first *quick_adcp.py –cntfile q_pyedit.cnt,* for applying the edit performed manually in Matlab, and, secondly, *quick_adcp.py –cntfile q_pyrot.cnt,* to apply phase and amplitude corrections.

More detail of these steps is given in the following subsections.

21.2.2. Angle and amplitude calibration

Two external sources of navigation data provided the heading and attitude (pitch and roll) information: the high resolution PHINS III PH-832 fibre optic gyro system (heading); and a SEAPATH330 receiver (attitude).

From this data, the *quick adcp.py* script estimates amplitude (along-track amplitude, *A*) and phase (misalignment angle, ϕ_{corr}) corrections for each set of data. ϕ_{corr}, is given by:

$$\phi_{corr} = \phi_{ship} - \phi_{ADCP}$$

where

$$\phi_{ship} = \tan^{-1}\left(\frac{v_n}{v_e}\right),\ \phi_{ADCP} = \tan^{-1}\left(\frac{v_{bot,\ n}}{v_{bot,\ e}}\right)$$

and ϕ_{ship} is the direction of motion of the ship, calculated from the V (northwards) and U (eastwards) components of the ship's velocity, $V=(v_n, v_e)$, ϕ_{ADCP} is the observed direction of motion of the seabed, $V_{bot}=(v_n, v_e)$. The speed correction is calculated from the ratio of the known vessel speed and the measured ADCP speed.

$$A = \frac{|V|}{|V_{bot}|}$$

The best (more accurate) calibration estimates are obtained when the velocity data is collected using the seabed as a reference (bottom-track mode, BT). However, bottom track calibration is only obtainable when the water depth is within the ADCP profiling range. During DY040 cruise, bottom tracking was performed over the Florida Strait and western shelf at the beginning the cruise. The amplitude correction factor calculated from Bottom tracking varied from 1.017 to 1.028, for OS75; and between 1.005 and 1.009, for OS150. Mean values for A and ϕ were obtained from the BT data: ϕ = 3.5°; A=1.023 and 1.006, for OS75 and OS150, respectively (Appendix C). In addition to the standard calibration using all available bottom track data, a comparison calibration was done using water track data. Figure 1.2.2 shows both BT and WT values.

The final calibrations, those obtained in BT mode, were introduced in the CODAS control file *q_pyrot.cnt* to be applied after applying the edits (see section 21.2.4.). Post-calibration, the remaining residuals were: ϕ = 0.1007° ±0.3293, A=1.0000± 0.005. Finally, we also examined bottom tracking data obtained by the end of the CTD station transect, in the African shelf, at the end of the cruise. These bottom tracking values showed no significant additional rotation.

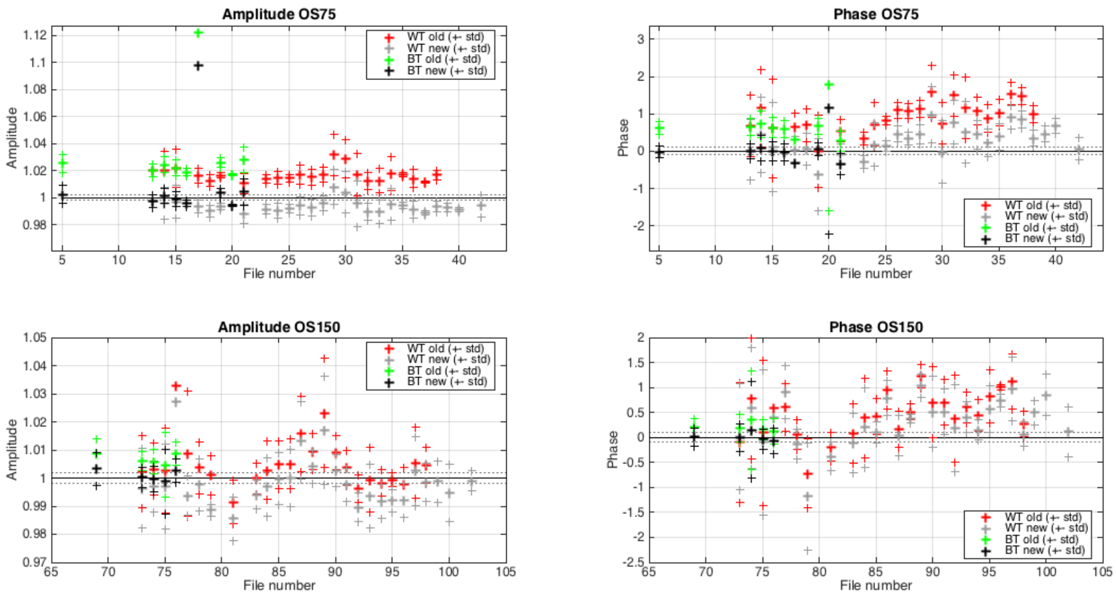


Figure 1.2.2.

21.2.3. Gautoedit

The gautoedit package within CODAS allows the user to review closely the data collected by VM-DAS and flag any data that are deemed to be bad. These flags can then be passed into the next processing stage and, using the *q_pyedit.cnt* control file, the flagged data removed. For each sequence we opened *gautoedit* in Matlab in *dy040NNNnbenx/edit* using *m_setup; codaspaths; gautoedit*. Typically we worked from the start of the data in 0.2-day steps, as this allowed us to see the individual 5-minute ensembles. Upon selecting Show Now, two plots are displayed according to the default plot selections. One contains four subplots: the first displays the absolute east-west (U) velocity component, the second shows the absolute north-south (V) component, the third shows the percent good parameter and the fourth shows the ship speed (in m/s) and an editing parameter called jitter. The second figure contains subplots of the ship's track and mean absolute velocity vectors for the reference layer. We noted that bathymetry in this plot sometimes was not generated until Show Now was pressed again. Routine for editing each section included:

- looking for bad profiles (i.e. those in which the u and/or v had a systematic offset over all depth levels). These were flagged using the *del bad times* button and choosing the select time (or time range) option.
- looking at the jitter parameter in the bottom subplot. A high level of jitter either indicates noise in the navigation and/or rapidly changing velocities (for instance during coming onto station maneuvers).

21.2.4. Applying the edits and rotation

Once the a*.asc files have been created, the edits were applied using the following command at the terminal prompt from within dy040NNNnbenx/: *quick adcp.py --cntfile q_pyedit.cnt*. After applying edits, the calibration was then applied to each file sequence using the command: *quick adcp.py –cntfile q pyrot.cnt*, in the terminal window. This rotates the data by the phase and amplitude specified by the user in the control file *q_pyrot.cnt*. A recalculated calibration (after taking the first calibration into account) is printed to the *.out file(s). Once calibrated, the data were checked in gautoedit to ensure that any vertical striping associated with on/off station differences had been removed by application of the calibration. Any alterations that needed to be made to the files, for example due to bad profiles or bad bins, were made using gautoedit.

21.2.5. Creating the output files

Once the editing and rotations were completed, the final velocities were collated into mstar files (*.nc) using the following commands, run from jr306NNNnbenx/: *m_setup,* for setting up the mstar environment and the relevant paths; *mcod_01,* to get current ADCP data from codas database and create mstar file*;* and *mcod_02*, to calculate ships speed and expand 1D arrays into 2D. Both functions prompt for the file number and instrument number to specify the input file. The first command produces a file of os75_dy040NNNnnx.nc that includes the following variables:

- time - (in seconds since [2015 1 1 0 0 0])
- lon - (0 to 360)
- lat - (-90 to 90)
- depth - (of bin)
- uabs - (absolute u velocity in cm/s)
- vabs - (absolute v velocity in cm/s)
- uship - (u velocity of ship over ground)
- vship - (v velocity of ship over ground)
- decday - (decimal day of year)

The second file is of the form os75_dy040NNNnnx_spd.nc and includes, (in addition to the above variables):

- speed - (scalar water speed, cm/s)
- shipspd - (scalar ship speed over ground, m/s).

The individual os75_dy040NNNnnx_spd.nc files are then appended into a single output file for the cruise using *mcod_mapend*. This command relies on an input file containing the paths of all the individual files to be merged. The final output file was *os75_dy040_01.nc* which contained both appended on-station and underway data.

21.2.6. Extracting station and section (interstation) profiles

The function mcod_03 uses CTD station times from the dcs files to extract VMADCP data corresponding to CTD stations and reduce them to a single profile, in files such as *os75_dy040nnx_ctd_NNN_ave.nc*, where NNN refers to the CTD station number. A useful script, mcod_03_all, shows how to run these two scripts over a large number of stations.

The same way, by creating a file named mcod_03_times.dat, in which the name of the section, the sequential number, and the date and time of start and end, we obtained the inter-station averages to be compared with the geostrophic velocities' estimates.

An example of the file:

atlsec 1 [2015 12 13 14 57 0] [2015 12 13 15 37 0]

atlsec 2 [2015 12 13 17 36 30] [2015 12 13 18 11 0]…

The criterion followed for identifying the start and end of each subsection period was for those transect which a ship velocity higher that 0.9 knots. For the Florida Strait the identification was performed manually as the CTD stations were closely spaced and the ship did not reach high speeds between stations.

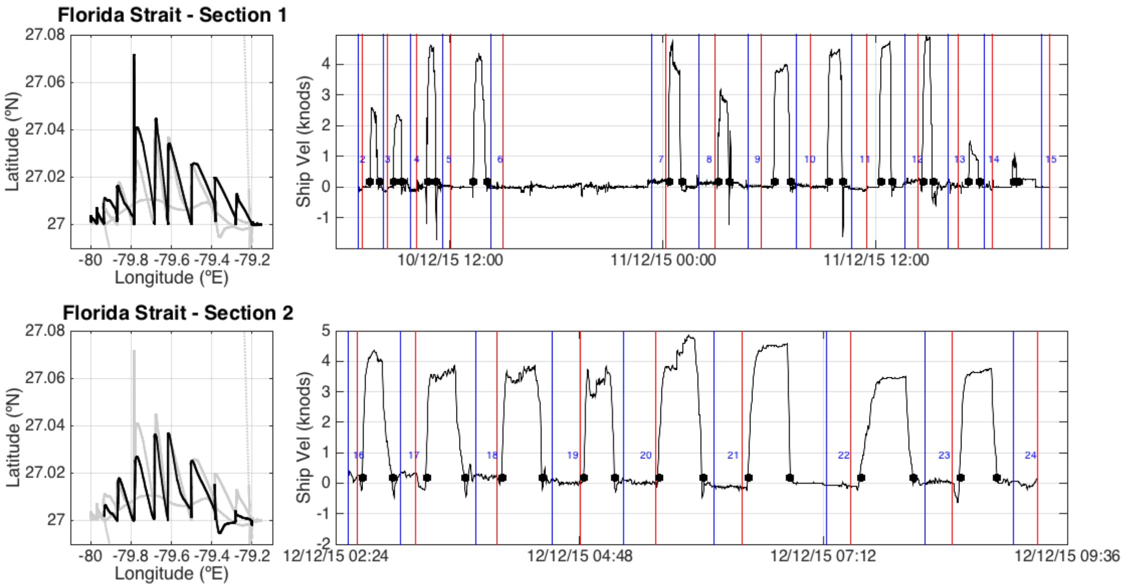
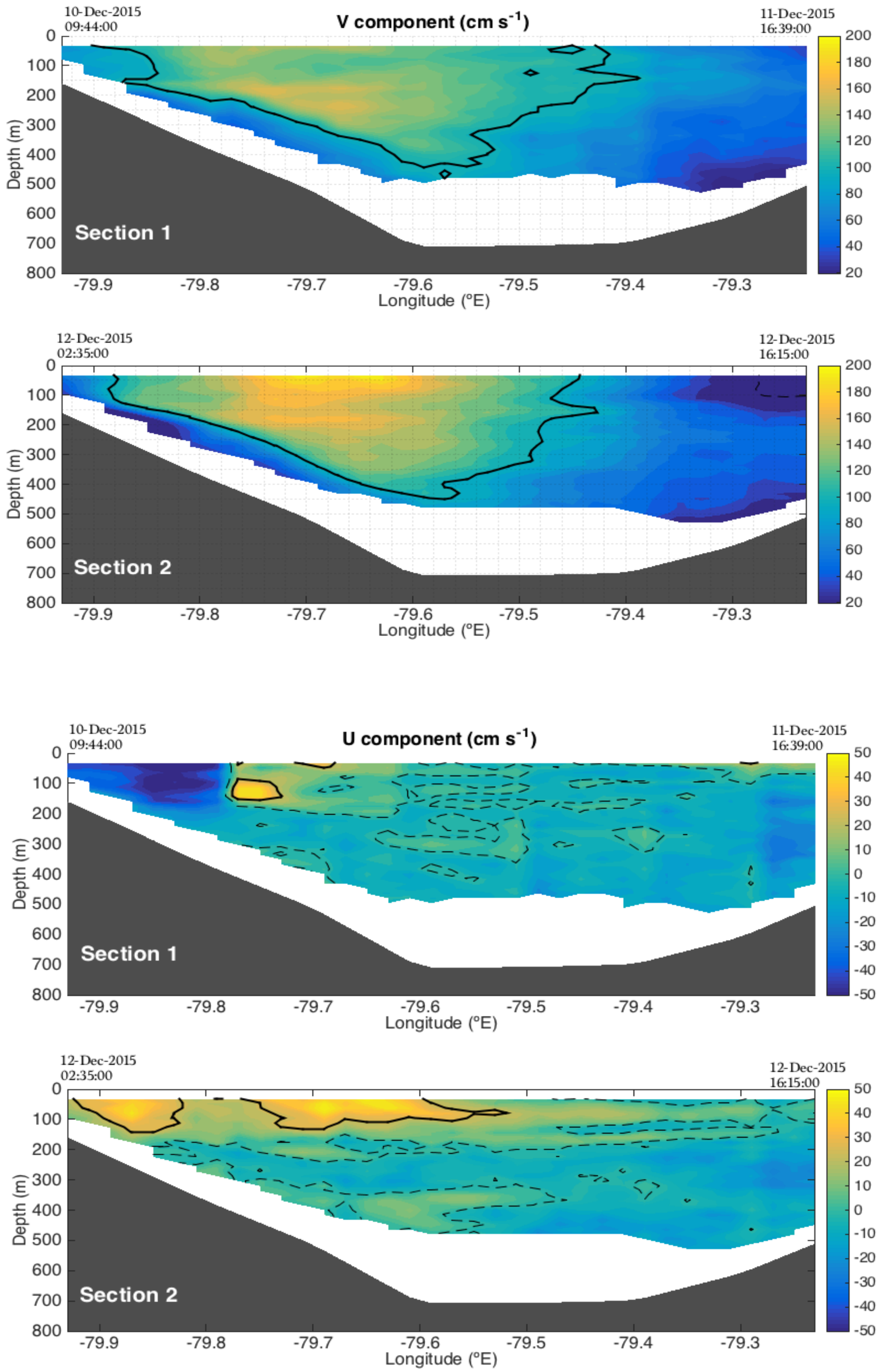


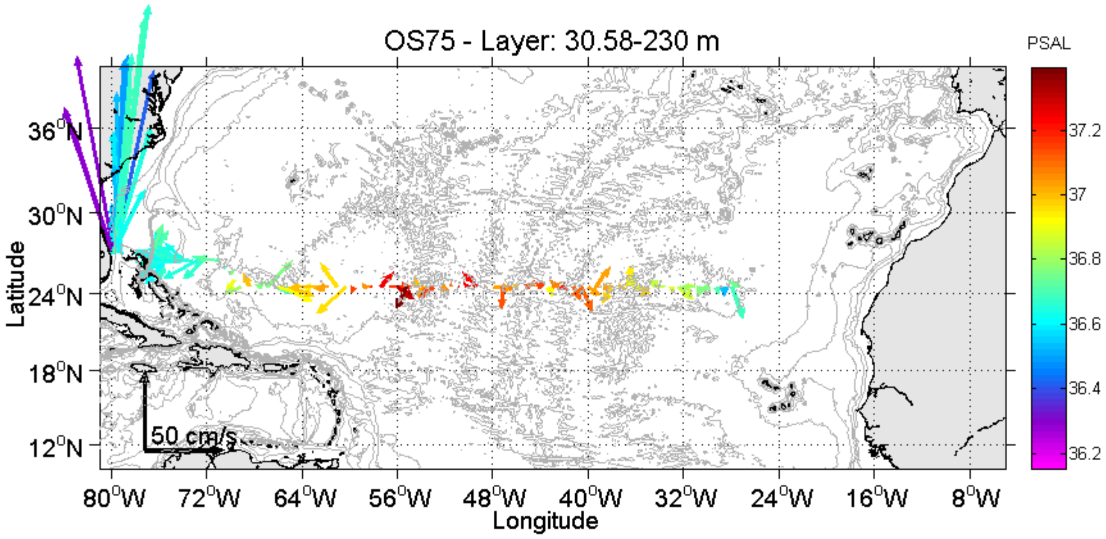
Figure 22.2.6-1. Display of the ship transect for both sections done in the Florida Strait and ship velocity during their realization. Blue and red lines indicate the start and end of each CTD station (station number labelled in blue). Black dots indicate the selected times for the start and end of the intersection tracks.

a) Florida Current



22.2.6-2. SADCP OS75 section plots (0.02º longitude averages) for both repeats of the Florida Strait (V component, in the upper panels, U component in the lower panels). Black thick line represents the 25 cm/s contour and thin back dashed line represents 0 contour.

b) Mid-Ocean Section



22.2.6-3. SADCP OS75 CTD-station-averaged vector plots, for the depth range 30-230 m. Color legend represents the CTD potential salinity average for the before mentioned depth range.

21.2.7. Comparison between VMADCP, LADCP and geostrophy

The VMADCP station profiles were compared to LADCP, and VADCP section profiles were compared to geostrophic velocities, obtained from CTD potential temperature and salinity fields.

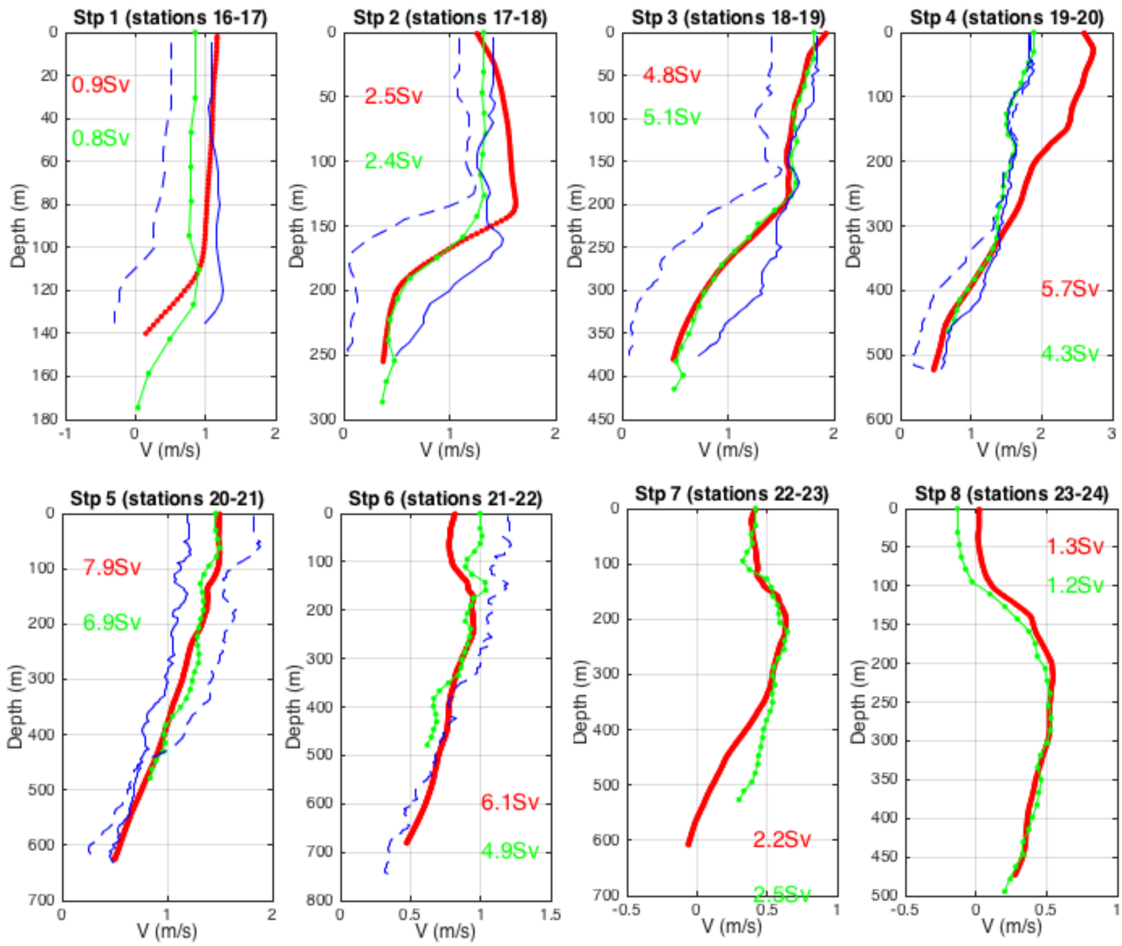


Figure 48. A profile-by-profile VMADCP vs. LADCP comparison is included in Appendix D.

21.3. *Data Quality Issues: Bubble Contamination*

Whilst carrying out gautoedit editing, one quality control issue affecting the first/second bins was identified at the top of the profile. Two potential issues arise from the presence of bubbles immediately below the transducer face. The first is that bubbles can prevent penetration of the transmit pulse and lead to truncated or bad quality profiles. This was not widely observed on our cruise. The second is the problem of bubble bias. It is known that the high amplitude return from bubbles can cause anomalous velocities in the direction of ship steaming (i.e. towards the east on the main 24°N section). It is commonly identified by a relatively low percentage good in the top 1-2 bins, and a red surface stripe in the along-track velocity (see Section 14.4.2). It typically does not affect lower bins of the profile, which remain good.

22. Float deployments

Justin Buck

DY040 included the deployment of 13 Argo floats of varying configuration:

- UK Argo floats from the UK Met Office, National Oceanography Centre (NOC) and Plymouth Marine Laboratory (PML)
  - 2 Teledyne Webb deep APEX floats with oxygen sensors capable of profiling to 6,000m. This was the first operational deployment of these floats as part of the international Argo program.
  - 2 NKE deep Arvor floats with oxygen sensors that are capable of profiling to 4,000m
  - 2 NKE bio-Provor floats with oxygen and biogeochemical sensors
  - 1 Seabird NAVIS BGCi float with biogeochemical sensors
- US Argo floats from the University of Washington (UW)
  - 4 UW APEX with oxygen on an extended mount to improve in-air observations of oxygen expected to improve in-water oxygen calibration
  - 2 UW APEX core Argo mission floats on a new US Argo communications contract

Rick Rupan (University of Washington float technician) setup the UW floats and assisted in the setup of the UK floats during cruise mobilisation.

All DY040 float deployments are summarised in [table floats]

22.1. *Float testing and configuration*

All floats were tested with Rick Rupan. Testing was according to the appropriate float manual and included the following key steps:

1. Establish connection to the float with PC either via serial deck unit supplied with the float or blue-tooth for the NKE floats. NKE list a recommended blue tooth adapter for connection to the floats in their manual but this was found to be too old for use on Windows 7 so a newer adapter from the same manufacturer was used and worked (Belkin F8T065). A terminal emulator such as the freely available 'Tera term' software is required on the PC used to communicate with the floats.
2. Start a log file to record the terminal session.
3. Poll each sensor on the float to ensure they are returning sensible values.
4. A check of the float configuration.
5. Running the float self-test routines. These differ slightly by float and tend to include checking of float sensors, buoyancy engines, communications, and GPS (including an update to the GPS almanac).
6. Once float tests are complete Ensure float is 'armed' or in 'pressure activation mode' ready for deployment.
7. Close, save, and keep the log file from the session in case it is needed in dialogue with float manufacturers.

The dark counts for bio-optics were checked for the Wetlabs MCOMS bio-optics sensor and Wetlabs PUCK bio-optical sensors. This was determined according to "Southern Ocean and Carbon and Climate Observations and Modelling" (SOCCOM) standards. SOCCOM is the US contribution to bio-Argo and the advice was obtained immediately prior to the cruise before it was formally published by SOCCOM. The method dictated that receiver window was covered with electrical tape and the sensor polled 9 times with the dark counts measured stored in the log file. The tape was removed and the window cleaned with Isopropanol Alcohol (whose purity was checked to ensure there were no contaminants). The sensor glass was dabbed rather than wiped to ensure the windows were not scratched.

An issue was identified in the NKE deep ARVOR serial number OIN 14 EN DP 01 where the CTD temperature was registering zero. After consultation with NKE this was determined to be because the upper limit of temperature encoding was 32°C which was less than the ambient air temperature on deck at the time the floats were being tested. When the float was retested with an ambient temperature of 27°C the check was passed.

The NAVIS BGCi float was unable to log into Iridium when tested. After consultation with Seabird further configuration issues were identified with the piston position. This float configuration would have endangered the float if it were deployed in the delivered state. Seabird sent instructions for reconfiguration and full testing of the Navis float and CLS sent login credentials. These instructions were followed and the Navis BGCi float passed all tests and successfully communicated data to CLS.

At the request of Brian King and Elaine McDonagh the Deep APEX floats had their profiling depths reconfigured as follows:

Float type	Park depth	Profiling depth
Deep APEX	5000	5400
Deep ARVOR	3500	4000

Teledyne Webb provided additional configuration changes required for the new target depths which were configured on the floats prior to deployment.

22.2. *Data formats and unpacking of test messages*

The checking of test messages is part of the testing of floats prior to deployment. Floats deployed on this cruise produced 3 different raw data formats.

22.2.1. UW APEX Oxygen floats

These floats used well established APF9 control boards and an Iridium RUDICS server. Test messages are in a human readable ASCII format and were checked by connecting to the RUDICS server (by Rick Rupan).

22.2.2. UW APEX core mission floats

These floats were on a new US Iridium Short Burst Data (SBD) protocol. Success of test messages was checked by Rick Rupan.

22.2.3. Navis BGCi

These floats all use control boards based on the well-established APF9 control boards. Data were checked by accessing the CLS ftp area and downloading the messages. These are in a human readable ASCII format.

22.2.4. Deep APEX floats

Data access was in a similar manner to the NAVIS BGCi floats however data for the Deep APEX floats were not being synchronised to the client facing CLS user accounts. This is the first time CLS have processed data from the new APF11 controller used in the floats and a temporary solution is currently in place pending a full resolution of the issue. Once the messages were accessible they were downloaded. The data were initially in a gzipped files. These were uncompressed in linux using the gunzip command. The vitals and science files were converted to ASCII using the apf11dec Python routine supplied by Teledyne Webb Research.

NKE Bio-Provor floats

These floats also used Iridium RUDICS but transmitted 70 byte SBD messages. These were downloaded from the Villefranche FTP area and converted using an NKE decoder provided by Jean-Philippe Ranou, Ifremer, France.

22.2.5. NKE Deep Arvor floats

These floats transmitted 70 byte SBD messages that were sent direct via email. These were downloaded from Microsoft outlook using a python mail harvesting script and converted using an NKE decoder provided by Jean-Philippe Ranou, Ifremer, France.

22.3. *Float deployment*

Floats were deployed as soon as possible after a CTD cast was recovered to deck with the ship moving ahead at 0.5-1.0 knots. All CTD casts included oxygen sampling and when the Bio-Argo floats were deployed 5 samples from the Niskin bottles closest to the surface were filtered for pigments. These samples will be analysed post-cruise at PML.

Prior to deployment NKE floats were activated by removal of the magnet and completion of deployment checklist supplied with the float by NKE. The Deep APEX floats were activated by connecting a PC and deck unit to the float then running the m_deploy command. The m_deploy command ran pre-deployment once self-tests and started the float mission. This version of deep APEX floats does not report that self-tests are complete to the terminal in the current version of the APF11 control board firmware. The self-test includes inflation of the buoyancy bladders and transmission of test messages. Once tests are passed and the initial surface phase of the mission is complete the buoyancy bladders are deflated to start the descent to park phase. This deflation is an hour after self-tests are finished and the deflation of the buoyancy bladders is currently the only way to be sure that self-tests were passed. As such, the deep APEX floats were deployed once the buoyancy bladders had deflated. The NAVIS and UW APEX floats were in pressure activation mode so no manual mission activation was required.

All sensor covers and caps were removed prior to deployment of floats.

Most floats were deployed from the starboard rear quarter of the ship by lowering to the float to the sea surface with a rope through the hole in the floats stability ring. Deployment was under the supervision of the ships deck crew. The deep APEX and Bio-Provor floats were heavier (up to 50 kg for the deep APEX) so were deployed with a crane and quick release mechanism over the starboard rear quarter.

After deployment the float owners were notified by email. NKE floats were supplied with a specific checklist and deployment information form to comply with requirements for the instrument guarantee. These were duly completed and sent to NKE after each NKE float was deployed.

22.4. *Additional notes*

After deployment data were received from all UK floats and UW confirmed their 6 APEX floats are transmitting and performing well.

Data from the deep floats have been compared to their respective deployment CTD cast and it was found that the Deep APEX sensors are within 0.01 PSU and stabilising after what appears to be Tributyl Tin Oxide (TBTO) contamination of the conductivity cell. The deep Arvor floats appear to have a configuration issue where the CTD salinity is fresh by 0.25 PSU for float OIN 14 EN DP 01 and 0.07 PSU for float OIN 14 EN DP 02. We are liaising with manufactures on both matters.

DY040 float deployments

Float type	Country	Institute	Serial number	Communications identifer	Deployment date and time	Deployment latitude	Deployment longitude	Deployment station
APEX core SBD	USA	UW	7307	11058	23/12/2015 13:30	25° 00.20' N	69° 36.83' W	CTD057
APEX deep	UK	NOC	8	f0039	25/12/2015 02:16	24° 30.13' N	66° 57.22' W	CTD061
PROVOR Bio	UK	PML	OIN 14 EN S4 06	metbio008	26/12/2015 18:52	24° 29.96' N	64° 00.99' W	CTD066*
APEX Oxygen	USA	UW	7404	9726	27/12/2015 13:07	24° 30.19' N	62° 33.21' W	CTD068
PROVOR Bio	UK	PML	OIN 14 EN S4 04	metbio006	28/12/2015 15:42	24° 29.95' N	60° 21.04' W	CTD071*
NAVIS BGCi	UK	Met Office	f0339	f0339	28/12/2015 15:46	24° 29.95' N	60° 20.99' W	CTD071*
APEX deep	UK	NOC	7	f0036	29/12/2015 16:50	24° 29.96' N	58° 09.02' W	CTD074
APEX Oxygen	USA	UW	7446	9754	30/12/2015 18:14	24° 30.01' N	55° 56.98' W	CTD077
APEX Oxygen	USA	UW	7442	9765	02/01/2016 02:23	24° 29.98' N	50° 48.89' W	CTD084
APEX Oxygen	USA	UW	7441	9759	04/01/2016 18:41	24° 30.08' N	44° 33.02' W	CTD093
APEX core SBD	USA	UW	7300	11012	06/01/2016 20:36	24° 30.01' N	39° 59.99' W	CTD100
ARVOR deep	UK	NOC	OIN 14 EN DP 02	3002340616 53240	10/01/2016 14:36	24° 29.81' N	32° 21.90' W	CTD112
ARVOR deep	UK	NOC	OIN 14 EN DP 01	3002340618 52390	15/01/2016 23:53	24° 29.92' N	24° 14.96' W	CTD125

* CTD stations that included the sampling for and filtering of pigments at the upper five levels of the station

Appendix A: CTD station list and details

St. No.	Date (yy/mo/dd)	Time (hhmm)	Lat (Deg Min N)	Lon (Deg Min W)	Water Dep Corr (m)	Max CTD Dep (m)	Altim. (m)	Res	Wire (m)	Max CTD Press (dbar)	Number of Bottle Samples: Dep	Sal	Oxy	Nut	CO_2	CFC	Comments
	15/12/09	212															
1	15/12/09	214	2 26.0	7 40.0	762	753	7	-2	753	759	1	9	1	1	1	0	Test station; DeepTow
	15/12/09	221															
	15/12/10	651															
2	15/12/10	654	2 0.09	7 59.8	43	37	5	0	35	38	3	3	3	3	2	0	Florida St with samples; CTD
	15/12/10	702															
	15/12/10	814															
3	15/12/10	820	2 0.23	7 58.0	100	96	4	0	93	96	4	4	4	4	2	0	Shallow; no LADCP
	15/12/10	829															
	15/12/10	947															
4	15/12/10	957	2 0.29	7 56.1	144	133	9	-2	130	134	4	4	4	4	4	0	Shallow; no LADCP
	15/12/10	100															
	15/12/10	113															
5	15/12/10	114	2 0.47	7 52.0	263	253	9	-1	250	255	7	6	6	6	6	0	Florida St with samples
	15/12/10	120															
	15/12/10	141															
6	15/12/10	143	2 1.14	7 47.0	387	385	1	0	387	388	0	1	0	1	0	0	Termination failed; repeated as
	15/12/10	150															
	15/12/10	232															
7	15/12/10	233	2 0.96	7 46.8	391	381	10	0	380	384	8	8	16	16	8	0	Florida St with samples
	15/12/11	10															
	15/12/11	201															
8	15/12/11	219	2 0.97	7 40.8	535	523	11	0	525	527	10	10	19	19	9	0	Florida St with samples
	15/12/11	256															
	15/12/11	447															
9	15/12/11	503	2 0.81	7 36.9	647	637	10	0	638	642	14	11	20	21	11	0	Florida St with samples
	15/12/11	532															
	15/12/11	732															
10	15/12/11	748	2 0.62	7 29.9	758	750	7	-1	747	756	11	11	21	21	11	0	Florida St with samples
	15/12/11	819															
	15/12/11	103															
11	15/12/11	105	2 0.44	7 22.9	693	682	9	-2	680	688	1	1	1	2	1	0	Florida St with samples
	15/12/11	112															
	15/12/11	133															
12	15/12/11	135	2 0.24	7 16.8	612	602	10	-1	600	607	1	1	1	1	8	0	Florida St with samples
	15/12/11	142															
	15/12/11	160															
13	15/12/11	161	2 0.03	7 11.9	471	461	9	-2	460	464	9	9	9	9	9	0	Florida St with samples
	15/12/11	163															
	15/12/11	180															
14	15/12/11	181	2 0	7 10.5	402	393	9	0	391	396	10	9	9	9	8	0	Florida St with samples
	15/12/11	183															
	15/12/11	211															
15	15/12/11	213	2 59.9	7 9.49	287	277	10	0	276	279	8	7	14	7	6	0	Florida St with samples
	15/12/11	214															
	15/12/12	238															
16	15/12/12	244	2 0.22	7 55.8	150	140	8	-1	140	141	0	0	0	0	0	0	Florida St

	15/12/12	249																	CTDO/LADCP
	15/12/12	340																	
17	15/12/12	349	2	0.37	7	51.9	264	256	11	3	256	258	0	0	0	0	0	0	Florida St CTDO/LADCP only
	15/12/12	358																	
	15/12/12	509																	
18	15/12/12	520	2	0.89	7	46.8	391	380	10	-2	382	383	0	0	0	0	0	0	Florida St CTDO/LADCP only
	15/12/12	534																	
	15/12/12	639																	
19	15/12/12	652	2	0.99	7	41	532	522	9	-1	535	526	0	0	0	0	0	0	Florida St CTDO/LADCP only
	15/12/12	713																	
	15/12/12	804																	
20	15/12/12	819	2	1.04	7	37.0	646	625	20	-1	640	630	0	0	0	0	0	0	Florida St CTDO/LADCP only
	15/12/12	841																	
	15/12/12	950																	
21	15/12/12	100	2	0.72	7	30.1	759	752	8	1	755	758	0	0	0	0	0	0	Florida St CTDO/LADCP only
	15/12/12	102																	
	15/12/12	120																	
22	15/12/12	121	2	0.4	7	23.0	687	681	6	0	680	687	0	0	0	0	0	0	Florida St CTDO only; no LADCP
	15/12/12	123																	
	15/12/12	140																	
23	15/12/12	141	2	0.08	7	17	618	608	10	0	606	613	0	0	0	0	0	0	Florida St CTDO only; no LADCP
	15/12/12	143																	
	15/12/12	154																	
24	15/12/12	155	2	59.9	7	12	484	473	11	-1	470	476	0	0	0	0	0	0	Florida St CTDO only; no LADCP
	15/12/12	161																	
	15/12/13	141																	
25	15/12/13	142	2	30.0	7	56.0	358	287	69	-2	285	289	9	9	9	17	9	0	Start main section
	15/12/13	144																	
	15/12/13	160																	
26	15/12/13	164	2	30.0	7	52.0	126	125	11	0	125	127	15	15	16	15	15	0	
	15/12/13	172																	
	15/12/13	184																	
27	15/12/13	191	2	31	7	49.5	131	122	89	-	121	123	14	14	14	14	14	0	
	15/12/13	194																	
	15/12/13	205																	
28	15/12/13	212	2	30.0	7	48.0	144	143	9	-1	143	145	15	15	15	15	15	0	
	15/12/13	220																	
	15/12/13	233																	
29	15/12/14	14	2	30	7	47.0	230	229	10	-5	227	231	19	19	20	20	15	0	
	15/12/14	122																	
	15/12/14	246																	
30	15/12/14	405	2	30.0	7	45.5	385	384	10	-1	381	390	24	24	24	24	16	0	
	15/12/14	542																	
	15/12/14	737																	
31	15/12/14	906	2	30.0	7	41.0	458	457	8	1	454	465	2	2	2	2	1	0	
	15/12/14	112																	
	15/12/14	133																	
32	15/12/14	145	2	30.0	7	37.0	473	472	10	0	468	480	2	2	2	2	1	0	
	15/12/14	170																	
	15/12/14	183																	
33	15/12/14	200	2	30	7	32	483	482	9	1	480	491	24	23	24	24	17	0	
	15/12/14	215																	

	15/12/14	232																	
34	15/12/15	55	2	30	7	26	483	482	10	0	481	491	24	24	24	24	15	0	
	15/12/15	254																	
	15/12/15	431																	
35	15/12/15	556	2	30.0	7	18.0	483	482	11	0	480	490	24	24	23	24	16	0	
	15/12/15	744																	
	15/12/15	941																	
36	15/12/15	110	2	30.0	7	13	481	480	9	0	477	489	24	24	24	24	23	0	
	15/12/15	130																	
	15/12/15	145																	
37	15/12/15	162	2	30.0	7	6.01	480	479	10	-1	476	488	24	23	24	24	22	0	Last before Nassau
	15/12/15	181																	
	15/12/18	644																	
38	15/12/18	809	2	30.0	7	6.02	480	479	12	0	477	488	0	0	0	0	0	0	Repeat 037; no samples; DeepTow
	15/12/18	933																	
	15/12/18	112																	
39	15/12/18	125	2	30.0	7	54.0	474	473	8	0	471	482	24	24	24	23	17	0	
	15/12/18	152																	
	15/12/18	173																	
40	15/12/18	185	2	30.0	7	42.0	469	468	10	0	465	476	24	24	23	24	12	0	
	15/12/18	210																	
	15/12/18	223																	
41	15/12/19	1	2	30.0	7	30	468	467	11	0	465	475	2	2	2	2	1	0	
	15/12/19	148																	
	15/12/19	336																	
42	15/12/19	456	2	30.0	7	18.0	463	463	1	0	461	471	2	2	2	2	1	0	
	15/12/19	644																	
	15/12/19	830																	
43	15/12/19	959	2	30.0	7	4.03	461	460	10	-1	458	468	24	24	24	24	14	0	
	15/12/19	115																	
	15/12/19	141																	
44	15/12/19	153	2	29.9	7	48.0	453	452	11	0	450	460	24	24	24	24	14	0	
	15/12/19	172																	
	15/12/19	193																	
45	15/12/19	210	2	30.0	7	31.1	449	448	10	0	445	456	24	24	24	24	17	0	
	15/12/19	225																	
	15/12/20	132																	
46	15/12/20	258	2	29.9	7	14.2	454	453	10	-1	450	461	24	24	24	24	14	0	
	15/12/20	449																	
	15/12/20	708																	
47	15/12/20	831	2	30.0	7	56.0	467	466	10	-1	464	474	24	24	24	24	13	0	
	15/12/20	103																	
	15/12/20	132																	
48	15/12/20	150	2	29.8	7	34.0	492	491	10	1	488	500	24	24	24	24	12	0	
	15/12/20	170																	
	15/12/20	194																	
49	15/12/20	211	2	29.9	7	12.1	504	503	9	2	501	513	23	22	22	22	14	0	
	15/12/20	232																	
	15/12/21	230																	
50	15/12/21	403	2	30.1	7	50.5	514	513	10	-1	510	522	24	24	24	24	14	0	
	15/12/21	603																	
	15/12/21	939																	

51	15/12/21	111	2	29.9	7	22.6	520	519	9	1	516	529	2	2	2	2	1	0	
	15/12/21	133																	
	15/12/21	171																	
52	15/12/21	184	2	30.0	7	55.0	532	531	10	0	529	541	2	2	2	2	1	0	
	15/12/21	204																	
	15/12/22	1																	
53	15/12/22	140	2	30.1	7	27.6	544	543	10	0	541	554	24	24	23	24	17	0	
	15/12/22	340																	
	15/12/22	719																	
54	15/12/22	857	2	30	7	0.01	548	548	9	0	545	558	18	17	17	17	11	0	Last with DeepTow
	15/12/22	105																	
	15/12/22	161																	
55	15/12/22	175	2	59.9	7	32.2	550	549	10	-1	545	560	24	23	23	23	16	0	Swap to CTD wire
	15/12/22	195																	
	15/12/23	49																	
56	15/12/23	233	2	30.1	7	4.65	552	551	9	-1	547	562	23	24	24	24	18	0	
	15/12/23	429																	
	15/12/23	928																	
57	15/12/23	110	2	0.21	6	36.9	561	559	11	-1	555	570	24	24	24	24	16	0	
	15/12/23	132																	
	15/12/23	181																	
58	15/12/23	200	2	29.9	6	9.06	563	562	10	-1	558	574	24	23	24	24	17	0	
	15/12/23	220																	
	15/12/24	332																	
59	15/12/24	511	2	30.0	6	25.0	571	570	9	0	565	582	24	24	24	24	15	0	
	15/12/24	712																	
60	15/12/24	123																	
	15/12/24	141	2	30	6	41.1	572	571	10	0	566	582	24	24	24	24	15	0	
	15/12/24	161																	
	15/12/24	221																	
61	15/12/25	1	2	30.0	6	57.2	568	567	9	0	563	579	2	2	2	2	1	0	
	15/12/25	200																	
	15/12/25	734																	
62	15/12/25	906	2	30	6	13.0	510	509	9	-1	504	518	2	2	2	2	1	0	
	15/12/25	110																	
	15/12/25	125																	
63	15/12/25	144	2	29.7	6	1.72	579	578	9	-1	573	589	1	23	3	3	0	0	CFC Bottle blanks
	15/12/25	162																	
	15/12/25	200																	
64	15/12/25	214	2	29.9	6	29.0	543	542	11	-1	537	552	23	24	24	24	16	0	
	15/12/25	235																	
	15/12/26	458																	
65	15/12/26	640	2	29.9	6	45.0	595	594	8	0	589	606	24	24	24	24	24	0	
	15/12/26	841																	
	15/12/26	145																	
66	15/12/26	163	2	29.9	6	1	560	559	11	-1	554	570	24	23	23	23	14	0	
	15/12/26	183																	
	15/12/27	0																	
67	15/12/27	143	2	30.1	6	17.0	578	577	10	0	573	589	24	24	24	24	17	0	
	15/12/27	344																	
	15/12/27	907																	
68	15/12/27	104	2	30.1	6	33.2	591	591	4	-1	586	603	24	23	23	23	23	0	

	15/12/27	125																	
	15/12/27	180																	
69	15/12/27	194	2	29.9	6	49.0	565	564	8	0	560	576	23	24	24	24	16	0	
	15/12/27	215																	
	15/12/28	304																	
70	15/12/28	443	2	30.0	6	5.01	588	587	9	-1	582	599	23	24	24	24	24	0	
	15/12/28	642																	
	15/12/28	113																	
71	15/12/28	132	2	29.9	6	21.0	583	582	10	0	577	594	2	2	2	2	1	0	
	15/12/28	152																	
	15/12/28	201																	
72	15/12/28	215	2	30.0	5	36.9	581	580	10	-1	575	591	2	2	2	2	1	0	
	15/12/29	10																	
	15/12/29	428																	
73	15/12/29	607	2	29.9	5	52.9	589	588	9	-1	583	600	23	24	24	24	17	0	
	15/12/29	809																	
	15/12/29	124																	
74	15/12/29	143	2	30	5	9.03	565	564	10	-1	559	575	23	24	24	24	24	0	
	15/12/29	163																	
	15/12/29	211																	
75	15/12/29	230	2	30.1	5	25.0	611	610	10	0	605	623	24	24	24	24	24	0	
	15/12/19	116																	
	15/12/19	526																	
76	15/12/19	714	2	30	5	41	597	596	9	1	591	608	23	24	24	24	15	0	Deep stations; some
	15/12/19	932																	
	15/12/19	140																	
77	15/12/19	155	2	30	5	57.0	646	645	10	1	640	659	24	24	24	24	20	0	Deep stations; some
	15/12/19	180																	
	15/12/19	222																	
78	15/12/19	21	2	30.0	5	13.1	601	600	11	2	595	612	24	24	24	24	17	0	Deep stations; some
	15/12/19	228																	
	15/12/19	643																	
79	15/12/19	811	2	30.0	5	28.9	525	524	13	2	520	534	24	24	24	24	16	0	Deep stations; some
	15/12/19	101																	
	15/12/19	144																	
80	15/12/19	163	2	29.9	5	45.0	583	582	10	0	577	594	23	24	24	24	24	0	Deep stations; some
	15/12/19	182																	
	15/12/19	230																	
81	16/01/01	40	2	30.0	5	1.08	541	540	10	-1	535	550	2	2	2	2	2	0	Deep stations; some
	16/01/01	232																	
	16/01/01	700																	
82	16/01/01	840	2	30	5	17.0	536	535	10	-2	531	545	2	2	2	2	2	0	
	16/01/01	104																	
	16/01/01	150																	
83	16/01/01	164	2	30.0	5	33.0	537	536	5	1	532	546	24	24	24	24	24	0	
	16/01/01	182																	
	16/01/01	225																	
84	16/01/02	28	2	29.9	5	48.9	493	492	8	-1	488	501	23	24	24	24	15	0	
	16/01/02	215																	
	16/01/02	637																	
85	16/01/02	802	2	30.0	5	5	454	453	13	5	450	461	23	24	24	24	14	0	
	16/01/02	951																	

	16/01/02	141																	
86	16/01/02	155	2	30.0	4	21	550	549	10	-1	545	560	23	24	24	24	16	0	
	16/01/02	174																	
	16/01/02	235																	
87	16/01/03	106	2	29.9	4	37.0	424	424	1	1	425	432	23	24	24	24	13	0	
	16/01/03	255																	
	16/01/03	714																	
88	16/01/03	825	2	30.0	4	53	375	375	9	0	373	380	23	23	24	24	12	0	CTD landed on seabed; CTD wire
	16/01/03	100																	
	16/01/03	142																	
89	16/01/03	153	2	29.9	4	9.02	374	373	9	0	371	379	23	24	24	24	13	0	DeepTow until XXX
	16/01/03	165																	
	16/01/03	205																	
90	16/01/03	215	2	29.9	4	30.0	348	347	11	0	345	352	23	24	24	24	15	0	
	16/01/03	233																	
	16/01/04	317																	
91	16/01/04	414	2	30.0	4	51.0	290	290	9	1	288	293	2	2	2	2	1	0	
	16/01/04	524																	
	16/01/04	913																	
92	16/01/04	101	2	29.9	4	12	323	322	10	7	321	327	2	2	2	2	1	0	
	16/01/04	114																	
	16/01/04	155																	
93	16/01/04	170	2	30.0	4	33.0	402	401	9	1	399	408	23	24	24	24	13	0	
	16/01/04	183																	
	16/01/04	223																	
94	16/01/04	235	2	30	4	54.0	375	374	9	1	372	380	20	21	20	21	13	0	
	16/01/05	115																	
	16/01/05	510																	
95	16/01/05	614	2	30.0	4	15.0	364	363	8	0	361	368	20	20	20	20	15	0	
	16/01/05	746																	
	16/01/05	120																	
96	16/01/05	132	2	30.0	4	36.0	437	436	10	4	434	443	22	22	22	22	16	0	
	16/01/05	150																	
	16/01/05	191																	
97	16/01/05	203	2	29.9	4	57.0	396	396	8	5	395	402	20	21	21	21	15	0	
	16/01/05	221																	
	16/01/06	225																	
98	16/01/06	349	2	30	4	18.0	472	472	9	0	469	480	23	23	23	23	15	0	CTD landed on seabed
	16/01/06	527																	
	16/01/06	929																	
99	16/01/06	110	2	29.9	4	38.9	479	479	9	1	476	487	22	23	22	23	15	0	
	16/01/06	125																	
	16/01/06	165																	
100	16/01/06	183	2	29.9	4	0.05	488	487	9	1	485	496	23	24	24	24	15	0	CTD acquisition failed; Final
	16/01/06	202																	
	16/01/07	31																	
101	16/01/07	202	2	30.0	3	21.0	521	472	49	-	470	480	2	2	2	2	1	0	
	16/01/07	348																	
	16/01/07	734																	
102	16/01/07	859	2	30.1	3	41.9	445	444	11	0	441	451	2	2	2	2	1	0	Unclear water depth
	16/01/07	105																	
	16/01/07	143																	

103	16/01/07	161	2	29.9	3	4.03	506	505	11	0	503	515	24	24	24	24	16	0	
	16/01/07	180																	
104	16/01/07	213																	
	16/01/07	232	2	30.0	3	26.0	586	585	10	-1	581	597	23	24	24	24	16	0	
	16/01/08	134																	
105	16/01/08	509																	
	16/01/08	658	2	29.9	3	48.0	553	552	10	1	549	563	23	24	24	24	17	0	
	16/01/08	915																	
106	16/01/08	125																	
	16/01/08	143	2	30	3	10.0	586	585	9	-1	582	597	23	24	24	24	17	0	
	16/01/08	163																	
107	16/01/08	202																	
	16/01/08	220	2	30.1	3	32.0	532	528	35	-2	526	538	22	23	23	23	14	0	CTD parked in hangar
	16/01/08	235																	
108	16/01/09	331																	
	16/01/09	521	2	29.9	3	53.9	589	587	9	-4	584	599	23	23	23	23	16	0	
	16/01/09	743																	
109	16/01/09	112																	
	16/01/09	131	2	30	3	16.0	540	536	40	-	534	547	23	24	24	24	16	0	
	16/01/09	151																	
110	16/01/09	190																	
	16/01/09	205	2	30.1	3	38.1	634	603	30	-	600	616	23	24	24	24	16	0	CTD parked in hangar
	16/01/09	230																	
111	16/01/10	248																	
	16/01/10	432	2	30.0	3	0	610	603	70	-	600	616	2	2	2	2	1	0	Depth > 6000; Not full depth;
	16/01/10	648																	
112	16/01/10	103																	
	16/01/10	121	2	30.0	3	21.9	550	543	72	-	540	553	2	2	2	2	1	0	
	16/01/10	142																	
113	16/01/10	175																	
	16/01/10	195	2	30.0	3	44.0	574	573	9	-3	569	584	24	24	23	24	16	0	
	16/01/10	220																	
114	16/01/11	145																	
	16/01/11	327	2	30.0	3	5.99	579	579	9	1	575	590	24	24	24	24	15	0	
	16/01/11	524																	
115	16/01/11	858																	
	16/01/11	104	2	29.9	3	28.0	586	585	10	-1	582	597	24	24	24	24	17	0	
	16/01/11	125																	
116	16/01/11	163																	
	16/01/11	181	2	30.0	2	50.0	511	505	56	-	503	515	21	24	24	24	17	0	
	16/01/11	201																	
117	16/01/11	235																	
	16/01/12	144	2	30	2	11.9	557	556	11	-1	553	567	23	24	24	24	16	0	
	16/01/12	339																	
118	16/01/12	729																	
	16/01/12	912	2	30.0	2	34.1	565	564	12	0	561	575	22	24	24	24	15	0	
	16/01/12	111																	
119	16/01/12	153																	
	16/01/12	171	2	29.9	2	56.0	560	559	11	0	556	570	23	23	24	24	16	0	
	16/01/12	192																	
12	16/01/14	855																	
	16/01/14	103	2	30.1	2	12.8	553	552	10	1	549	562	22	24	24	24	15	0	

0	16/01/14	123																	
	16/01/14	170																	
121	16/01/14	184	2	30.0	2	28.4	542	541	12	1	538	551	2	2	2	2	1	0	
	16/01/14	205																	
	16/01/15	111																	
122	16/01/15	245	2	30.0	2	43.9	533	532	9	0	529	542	2	2	2	2	1	0	
	16/01/15	434																	
	16/01/15	652																	
123	16/01/15	829	2	29.9	2	21.4	529	502	26	-	500	512	2	24	0	0	0	0	
	16/01/15	100																	
	16/01/15	122																	
124	16/01/15	140	2	29.9	2	59.5	524	523	10	0	521	533	23	24	24	24	16	0	CFC bottle blanks; not full depth;
	16/01/15	155																	
	16/01/15	201																	
125	16/01/15	214	2	29.9	2	15	513	512	9	-2	510	522	22	24	24	24	16	0	
	16/01/15	234																	
	16/01/16	406																	
126	16/01/16	546	2	29.9	2	30.0	501	500	10	1	498	509	21	24	24	24	16	0	
	16/01/16	747																	
	16/01/16	114																	
127	16/01/16	130	2	42.4	2	53.0	491	490	10	0	487	499	23	24	24	24	15	0	
	16/01/16	145																	
	16/01/16	184																	
128	16/01/16	201	2	55.0	2	16.0	476	475	9	1	473	484	22	23	23	24	16	0	
	16/01/16	221																	
	16/01/17	206																	
129	16/01/17	329	2	7.57	2	38.9	465	464	10	0	461	472	23	24	24	24	15	0	
	16/01/17	504																	
	16/01/17	859																	
130	16/01/17	102	2	20.0	2	2.03	445	444	10	0	442	452	23	24	24	24	16	0	
	16/01/17	120																	
	16/01/17	160																	
131	16/01/17	171	2	32.5	2	25.0	428	427	10	0	425	434	2	2	2	2	1	0	
	16/01/17	190																	
	16/01/17	225																	
132	16/01/18	5	2	45.0	1	48.0	393	392	10	0	390	398	2	2	2	2	1	0	
	16/01/18	135																	
	16/01/18	524																	
133	16/01/18	631	2	57.6	1	11.0	354	353	9	-1	351	358	22	24	24	24	13	0	
	16/01/18	757																	
	16/01/18	115																	
134	16/01/18	125	2	10.0	1	34.0	345	344	10	-1	342	349	22	23	23	24	14	0	
	16/01/18	142																	
	16/01/18	182																	
135	16/01/18	192	2	22.7	1	57.0	363	363	10	0	361	368	21	23	23	23	13	0	
	16/01/18	205																	
	16/01/19	54																	
136	16/01/19	159	2	35.1	1	20.0	363	362	9	-1	360	367	22	23	23	23	13	0	
	16/01/19	322																	
	16/01/19	714																	
137	16/01/19	827	2	47.7	1	43.0	361	360	10	0	359	366	21	23	23	23	14	0	
	16/01/19	957																	

138	16/01/19 16/01/19 16/01/19	135 150 162	2	0.15	1	6.05	347	346	10	0	345	352	23	23	23	23	15	0
139	16/01/19 16/01/19 16/01/19	214 223 235	2	12.6	1	29.0	305	304	10	-1	303	309	22	23	23	23	12	0
140	16/01/20 16/01/20 16/01/20	350 439 551	2	25.2	1	52.1	260	259	9	0	258	262	21	23	23	23	11	0
141	16/01/20 16/01/20 16/01/20	959 104 113	2	37.7	1	15.0	204	203	10	-1	202	205	19	17	19	23	10	0
142	16/01/20 16/01/20 16/01/20	144 151 155	2	47.1	1	47.0	145	144	8	0	144	146	22	15	15	15	10	0
143	16/01/20 16/01/20 16/01/20	173 175 184	2	51.9	1	33.0	110	109	8	0	109	110	12	12	12	12	10	0
144	16/01/20 16/01/20 16/01/20	194 200 203	2	54.8	1	24.5	545	536	9	0	535	540	9	9	9	9	9	0
145	16/01/20 16/01/20 16/01/20	212 213 215	2	55.6	1	22.0	343	333	9	-1	333	335	8	8	8	8	8	0

Appendix B: Technical detail report

S/S CTD

Re-terminated wire CTD2 because of crushed section as cable came out of over-boarding sheave. Approximately 350m removed.
Re-terminated Deep Tow because of short circuit (termination failure). Approximately 55m removed.
Re-terminated Deep Tow because of short & open circuit (short in sea cable; open found in Lemo connectors in Main Laboratory). Approximately 115m removed.
Re-terminated wire CTD2 because of kinked sections as CTD package made contact with bottom. Approximately 33m removed.

LADCP

Prior to cast DY040_022, communication problems arose with s/n 22797. The Star cable, communications cable and power supply/battery pack were all inspected and found to be functioning correctly. Battery pack s/n WH005 was then evaluated, and the 5A fuse holder was discovered to have melted. Further testing of WorkHorse 22797 was not successful; suspect leakage into the LADCP caused failure of the battery pack fuse. The fuse holder was replaced in the battery pack, and the LADCP replaced as well with s/n 13329 from cast DY040_025. Serial number 1855 replaced 13329 from cast DY040_081 (for testing of 1855). Serial number 4275 replaced 1855 from cast DY040_113 (for testing of 4275). Beam 2 on s/n 4275 became weak on cast DY040_118, continued to weaken, removed prior to cast DY040_130. Replaced with s/n 13329 from DY040_131 through cast DY040_145.

AUTOSAL

A Guildline 8400B, s/n 71185, was installed in the Salinometer Room as the main instrument for salinity analysis. A second Guildline 8400B, s/n 71126, was installed in the Salinometer Room as a spare instrument. The Autosal set point was 24C, and samples were processed according to WOCE cruise guidelines: The salinometer was standardized at the beginning of the first set of samples, and checked with an additional standard analysed prior to setting the RS. Once standardized the Autosal was not adjusted for the duration of sampling, unless the set point was changed. Additional standards were analysed every 24 samples to monitor & record drift. These were labeled sequentially and increasing, beginning with number 9001. Standard deviation set to 0.00002

Front heater lamp replaced 20 December.

Appendix C: Configuration files

C.1. Stainless CTD frame

Date: 12/07/2015

Instrument configuration file: C:\Program Files (x86)\Sea-Bird\SeasaveV7\DY040\DY040_ss_NMEA_0803.xmlcon
Configuration report for SBE 911plus/917plus CTD

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

1) Frequency 0, Temperature

Serial number : 03P-4816
Calibrated on : 20 June 2015
G : 4.30506476e-003
H : 6.34451326e-004
I : 2.18965934e-005
J : 2.06998869e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 04C-3768
Calibrated on : 27 May 2015
G : -1.02241639e+001
H : 1.49731996e+000
I : -9.79433411e-004
J : 1.63084762e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

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

Offset : -1.35810
AD590M : 1.289250e-002
AD590B : -8.106440e+000

4) Frequency 3, Temperature, 2

Serial number : 03P-2674
Calibrated on : 2 June 2015
G : 4.35674425e-003
H : 6.42195641e-004
I : 2.34334806e-005
J : 2.29373656e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 04C-3258
Calibrated on : 3 June 2015
G : -1.06622946e+001
H : 1.36202776e+000
I : -2.30937570e-004
J : 8.63976396e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

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

Serial number : 43-0363
Calibrated on : 21 July 2015
Equation : Sea-Bird
Soc : 4.35800e-001
Offset : -5.02700e-001
A : -3.34690e-003
B : 1.84410e-004
C : -2.64440e-006
E : 3.60000e-002
Tau20 : 1.48000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Oxygen, SBE 43, 2

Serial number : 43-0862
Calibrated on : 31 July 2015
Equation : Sea-Bird
Soc : 4.81500e-001
Offset : -4.99400e-001
A : -3.78840e-003
B : 1.32220e-004
C : -2.16280e-006
E : 3.60000e-002
Tau20 : 1.01000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002

H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

9) A/D voltage 3, Free

10) A/D voltage 4, Turbidity Meter, WET Labs, ECO-BB

Serial number : BBRTD-1055
Calibrated on : 13 March 2013
ScaleFactor : 0.002365
Dark output : 0.061000

11) A/D voltage 5, Altimeter

Serial number : 59493
Calibrated on : March 2006
Scale factor : 15.000
Offset : 0.000

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

Serial number : CST-1602DR
Calibrated on : 20 March 2013
M : 19.3483
B : -0.0708
Path length : 0.250

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

Serial number : 88-2615-124
Calibrated on : 21 January 2015
VB : 0.465900
V1 : 2.044300
Vacetone : 0.474400
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000

Scan length : 37

Date: 12/17/2015

Instrument configuration file: C:\Program Files (x86)\Sea-Bird\SeasaveV7\DY040\DY040_ss_NMEA_0803_new2tc.xmlcon

Configuration report for SBE 911plus/917plus CTD

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

1) Frequency 0, Temperature

Serial number : 03P-4816
Calibrated on : 20 June 2015
G : 4.30506476e-003
H : 6.34451326e-004
I : 2.18965934e-005
J : 2.06998869e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 04C-3768
Calibrated on : 27 May 2015
G : -1.02241639e+001
H : 1.49731996e+000
I : -9.79433411e-004
J : 1.63084762e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

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

4) Frequency 3, Temperature, 2

Serial number : 03P-2729
Calibrated on : 27 May 2015
G : 4.35533366e-003
H : 6.42092504e-004
I : 2.35144052e-005
J : 2.29893015e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 04C-3874
Calibrated on : 22 January 2015
G : -1.05095229e+001
H : 1.39126699e+000
I : -1.55182804e-003
J : 1.77247298e-004

CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

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

Serial number : 43-0363
Calibrated on : 21 July 2015
Equation : Sea-Bird
Soc : 4.35800e-001
Offset : -5.02700e-001
A : -3.34690e-003
B : 1.84410e-004
C : -2.64440e-006
E : 3.60000e-002
Tau20 : 1.48000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Oxygen, SBE 43, 2

Serial number : 43-0862
Calibrated on : 31 July 2015
Equation : Sea-Bird
Soc : 4.81500e-001
Offset : -4.99400e-001
A : -3.78840e-003
B : 1.32220e-004
C : -2.16280e-006
E : 3.60000e-002
Tau20 : 1.01000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

9) A/D voltage 3, Free

10) A/D voltage 4, Turbidity Meter, WET Labs, ECO-BB

Serial number : BBRTD-1055
Calibrated on : 13 March 2013
ScaleFactor : 0.002365
Dark output : 0.061000

11) A/D voltage 5, Altimeter

Serial number : 59493
Calibrated on : March 2006
Scale factor : 15.000
Offset : 0.000

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

Serial number : CST-1602DR
Calibrated on : 20 March 2013

M : 19.3483
B : -0.0708
Path length : 0.250

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

Serial number : 88-2615-124
Calibrated on : 21 January 2015
VB : 0.465900
V1 : 2.044300
Vacetone : 0.474400
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000

Scan length : 37

C.2. LADCP script file

```
;------------------------------------------------------------------------------\

CR1
RN DY040
WM15
TC2
LP1
TB 00:00:02.80
TP 00:00.00
TE 00:00:01.30
LN25
LS0800
LF0
LW1
LV400
SM1
SA011
SB0
SW5500
SI0
EZ0011101
EX00100
CF11101
CK
CS
;------------------------------------------------------------------------------\
```

C.3. OS75 VMADCP configuration file

```
;-----------------------------------------------------------------------------\
; ADCP Command File for use with VmDas software.
; ADCP type:     75 Khz Ocean Surveyor
; Setup name:    default
; Setup type:    Low resolution, long range profile(narrowband)
;
; NOTE:  Any line beginning with a semicolon in the first
;        column is treated as a comment and is ignored by
;        the VmDas software.
; NOTE:  This file is best viewed with a fixed-point font (e.g. courier).
; Modified Last: 15/10/15 by das@noc.ac.uk
;-----------------------------------------------------------------------------/
; Restore factory default settings in the ADCP
cr1
; Enable or disable sync with K-Sync. This should come immediately after cr1 command
; CX1,3 enable
; CX0,3 disable
CX0,3
; set the data collection baud rate to 38400 bps, no parity, one stop bit, 8 data bits
; NOTE:  VmDas sends baud rate change command after all other commands in this file, so that it is not     ; made permanent by a CK command.
cb611
; Set for narrowband single-ping profile mode (NP), 60 (NN) 16 meter bins (NS),
; 8 meter blanking distance (NF)
WP0
NN060
NP00001
NS1600
NF0800
;…………………………………………………………………………………………………………..
; Case: BOTTOM TRACK:
; Enable single-ping bottom track (BP),
; Set maximum bottom search depth to 1200 meters (BX)
BP001
BX12000
;…………………………………………………………………………………………………………..
; Case: NO BOTTOM TRACK:
; Disable single-ping bottom track (BP),
; BP000 means NO bottom track (for deep water) which means double the rate of pings
; Set maximum bottom search depth to 1200 meters (BX) if BT enabled
BP000
; BX12000
;…………………………………………………………………………………………………………..
; output velocity, correlation, echo intensity, percent good
ND111100000
; Two seconds between bottom and water pings
TP000150
; Three seconds between ensembles
; Since VmDas uses manual pinging, TE is ignored by the ADCP.
; You must set the time between ensemble in the VmDas Communication options
; Set to 3 seconds to match active period on K-Sync
TE00000300
; Set to calculate speed-of-sound, no depth sensor, external synchro heading, pitch and roll being used, no ; salinity sensor, use internal transducer temperature sensor, downard facing (will look for an EU command ; but ignores # because an OceanSurveyor)
EZ10222010
; Output beam data (rotations are done in software)
EX00000
; Set transducer misalignment (hundredths of degrees)
; Set -45 in VMDAS software
EA00000
; Set transducer depth (decimeters)
ED00066
; Set Salinity (ppt)
ES35
; save this setup to non-volatile memory in the ADCP
CK
```

C.4. OS150 VMADCP configuration file

```
;----------------------------------------------------------------------------\
; ADCP Command File for use with VmDas software.
; ADCP type:     150 Khz Ocean Surveyor
; Setup name:    default
; Setup type:    Low resolution, long range profile (narrowband)
;
; NOTE:  Any line beginning with a semicolon in the first
;        column is treated as a comment and is ignored by
;        the VmDas software.
; NOTE:  This file is best viewed with a fixed-point font (e.g. courier).
; Modified Last: 14/10/2015 das@noc.ac.uk
;----------------------------------------------------------------------------/
; Restore factory default settings in the ADCP
cr1
; CX command for syncing with k-sync comes immediately after the CR1 command
; to enable or disable sync
; CX1,3 enable sync
; CX0,3 disable sync
CX0,3
; set the data collection baud rate to 38400 bps,
; no parity, one stop bit, 8 data bits
; NOTE:  VmDas sends baud rate change command after all other commands in
; this file, so that it is not made permanent by a CK command.
cb611
; Set for narrowband single-ping profile mode (NP), 64 (NN) 8 meter bins (NS),
; 4 meter blanking distance (NF) GDM/DAS edit
WP0
NN060
NP00001
NS0800
NF0400
;…………………………………………………………………………………………………………….
; Case: BOTTOM TRACK:
; Enable single-ping bottom track (BP),
; Set maximum bottom search depth to 800 meters (BX)
BP001
BX08000
;…………………………………………………………………………………………………………….
; Case: NO BOTTOM TRACK:
; Disable single-ping bottom track (BP),
; Set maximum bottom search depth to 800 meters (BX) if BT enabled
BP000
; BX08000
;…………………………………………………………………………………………………………….
; output velocity, correlation, echo intensity, percent good
ND111100000
; 1 seconds between bottom and water pings GDM/DAS edit
TP000100
; Two seconds between ensembles
; Since VmDas uses manual pinging, TE is ignored by the ADCP.
; You must set the time between ensemble in the VmDas Communication options
; Should match the active period in k-sync?
TE00000200
; Set to calculate speed-of-sound, no depth sensor, external synchro heading
; sensor, external pitch and roll being used, no salinity sensor, use internal transducer
; temperature sensor
EZ10222010
; Output beam data (rotations are done in software)
EX00000
; Set transducer misalignment (hundredths of degrees)
; Must set -45 in VMDAS user options
EA00000
; Set transducer depth (decimeters)
ED0066
; Set Salinity (ppt)
ES35
; save this setup to non-volatile memory in the ADCP
CK
```