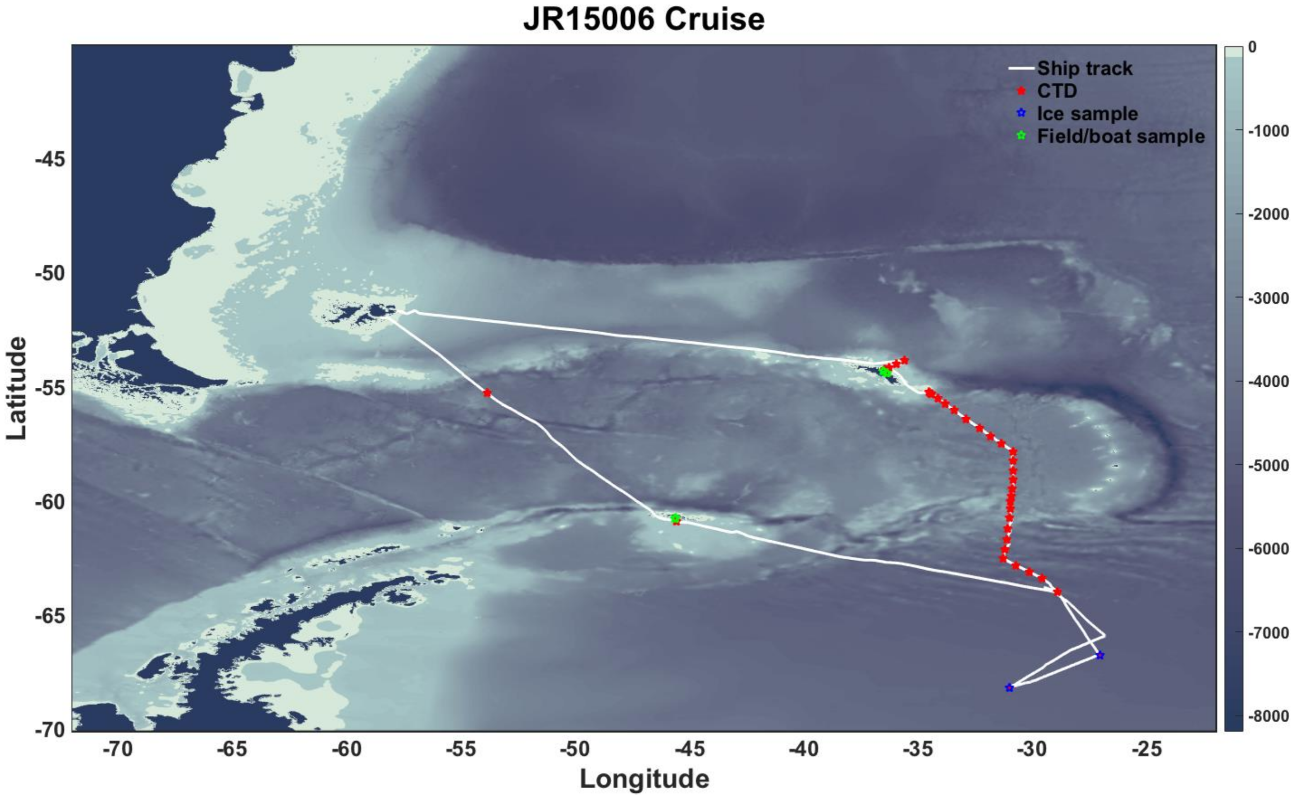
British Antarctic Survey
JR15006 Cruise report

31st March-26th April 2016

A23 repeat hydrography and $\delta^{18}O$ baseline/endmember survey

RRS James Clark Ross

PSO: Andrew Meijers



Frontispiece: JR15006 cruise track and sample sites. Figure courtesy of David Munday. Cover photo shows the RRS James Clark Ross moored at the BAS base at King Edward Point, South Georgia. Photo courtesy of Michael Meredith

Acknowledgements:

It is a pleasure to thank some of the many people and groups that helped to make this voyage the success that it was. Particular thanks are owed to Ralph Stevens and the officers and crew of the JCR, for keeping us moving in the right direction, often in marginal and trying conditions while keeping us safe, fed, and happy. Thanks also to Hugh Venables, Brian King, and especially Andreas Thurnherr for a remarkable level of assistance from shore with technical and computing matters relating to the CTD and LADCP, despite weekends, bank holidays and travels of their own.

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1. Introduction

Andrew Meijers

1.1 Synopsis

This voyage of the RRS James Clark Ross, JR15006, consisted of two components: The semi-annually repeated A23 hydrographic CTD section between the Weddell Sea and South Georgia, combined with six extra science days to collect samples to support the planned working up of the newly installed oxygen isotope auto-analyser connected to the ship underway seawater system. These two components constituted two separate SMEs: 795[1] for A23 and 984 for oxygen isotope collection.

The voyage departed from Mare Harbour, Falkland Islands, on the 31st of April and proceeded immediately to Signy Island in the South Orkneys group. A day of ice/meltwater/shore water sample collection from and around MacLeod Glacier was undertaken, both by shore parties and small boats in front of the glacial terminus, before three CTDs were conducted leading away from the island. We then headed to the southern end of the A23 section and entered the advancing pack ice edge. Proceeding to south of 68°S we found a good example of multi-year sea-ice and took ice core sections from it and adjacent new ice. We also collected surface water samples, along with two CTDs; both within the pack and on its margins. From here we conducted six days of 24 hour CTD operations north along A23, occupying 28 full depth stations at an average spacing of 20-25 Nm.

At the northern end of A23 we steamed to Cumberland Bay, South Georgia, and repeated shore sampling, small boat surface water and ice sampling and CTDs along and across Cumberland Bay East and the entrance to Cumberland Bay West. This work also included shore parties taking glacial cores and water samples from Glacier Col and Gull Lake inland on the island.

Following this work we proceeded back to Stanley in the Falkland Islands, docking on the 26th of April. During all ship operations underway instruments were left on. These included underway water analysis measuring pCO_2, temperature, salinity and $\delta^{18}O$, VMADCP velocity measurements, EM122 swath and EA600 acoustics and a full suite of meteorological readings. The only exception to this was within dense pack ice where underway water supplies had to be turned off to avoid ice damage to the intake/pumps. $\delta^{18}O$ was sampled on all CTD stations, from the underway system and for all field and small boat samples. These were collected alongside water samples for salinity analysis, which was conducted on board, while the $\delta^{18}O$ were stored for later analysis at the British Geological Survey Keyworth.

Overall the voyage was a highly successful one, with an unusual amount of shore and land based work for an oceanographic cruise. This was achieved under tight time constraints and often difficult late season weather. All thanks for the collection of a highly useful and novel dataset must go to the officers and crew of the RRS James Clark Ross who remained highly professional and personable throughout the voyage and who made great efforts to see our science goals met.

1.1.1 Scientific rationale for A23

In 1995, WOCE section A23 was conducted on the RRS James Clark Ross, running from Antarctica (Weddell Sea coastline) northward to Brazil. The part of this section beginning at 64°S, crossing the eastern Scotia Sea and ending at South Georgia has been repeated numerous times since: in 1999 (also from JCR), and in 2005 and 2013 (by the US CLIVAR repeat hydrography/CO2 program), on ANDREX 2010 and by JR272a and JR281, JR299 and JR310 in 2012-2015 respectively. A number of studies have highlighted the usefulness of this section in determining and understanding the changing characteristics and circulation of Weddell Sea Deep Water (WSDW) as it flows from the Weddell Sea through the Scotia Sea, en route to becoming the abyssal layer of the overturning circulation in the Atlantic. This work has already revealed significant changes in WSDW properties and volumes, as well as contributed to estimates of interior mixing in the Scotia Sea though the DIMES tracer release experiment and CFC derived abyssal mixing. Accordingly, the BAS Polar Oceans programme has secured ship time to repeat this section annually through to 2020, extending also into the northern Weddell Sea to capture the AABW in the boundary current of the Weddell Gyre as it flows eastward along the southern edge of the South Scotia Ridge. JR15006 collected another full hydrographic section from 64^{o}S to South Georgia, occupying 28 full depth CTD stations and maintaining the usual underway surface and meteorological datasets. More unusually we also collected δ^{18}O samples from all fired CTD bottles on A23, as well as from the underway surface water source. For more information on this work, see below.

1.1.2 Scientific rationale for δ18O baseline and end-member collection

Water molecules consist of a mix of those containing oxygen 18 atoms and those with oxygen 16 atoms, differing only in their number of neutrons and mass. When in vapour form in the atmosphere the heavier water molecules containing oxygen 18 tend to precipitate out preferentially, while in liquid form oxygen 16 evaporates more readily. As water moves in the atmosphere from the moist tropics to the dryer polar regions, repeated precipitation and evaporation effectively distils and lightens the atmospheric water towards the poles. This continues to the point that the ratio of oxygen 16 to oxygen 18 in the water that falls as snow over the polar ice caps is much higher than precipitation found further north, or indeed of the ratio found in seawater, which tends to be more uniform and well mixed. This raised ratio of oxygen 18 to oxygen 16, more formally given relative to some fixed standard and known as δ^{18}O, can then be used as a ‘fingerprint’ to identify sources and changes in glacial freshwater contributions to the ocean.

In the Southern Ocean, and Scotia/Weddell Seas in particular, there has been a consistent freshening trend in the deepest water masses over the last 20 years (e.g. Jullion et al. 2013). It has been suggested that this may be driven by increased basal melting of ice shelves around Antarctica and the Antarctic Peninsula in response to climate change. However, there have also been substantial changes to sea-ice distribution in this region, which is also known to contribute significantly to bottom water production and salinity (e.g. Holland and Kwok 2012). The observation of ocean δ^{18}O simultaneously with salinity offers a potential resolution to this problem of attribution. While both sea-ice melt and glacial melt will have a salinity input to the ocean of very close to 0, they have distinct δ^{18}O values, as sea-ice is frozen seawater and glacial ice is sourced from the oxygen 18 depleted polar precipitation. By knowing the δ^{18}O and salinity of the three main ‘end member’ for the sources of oceanic freshwater (i.e. glacial ice, sea-ice and deep, well-mixed ocean) it is therefore theoretically possible to construct a set of simultaneous equations and resolve the relative contribution of these sources to any given parcel of seawater with known δ^{18}O and salinity, as well as estimate the impact of glacial vs sea-ice melt/freeze (Figure 1.1).

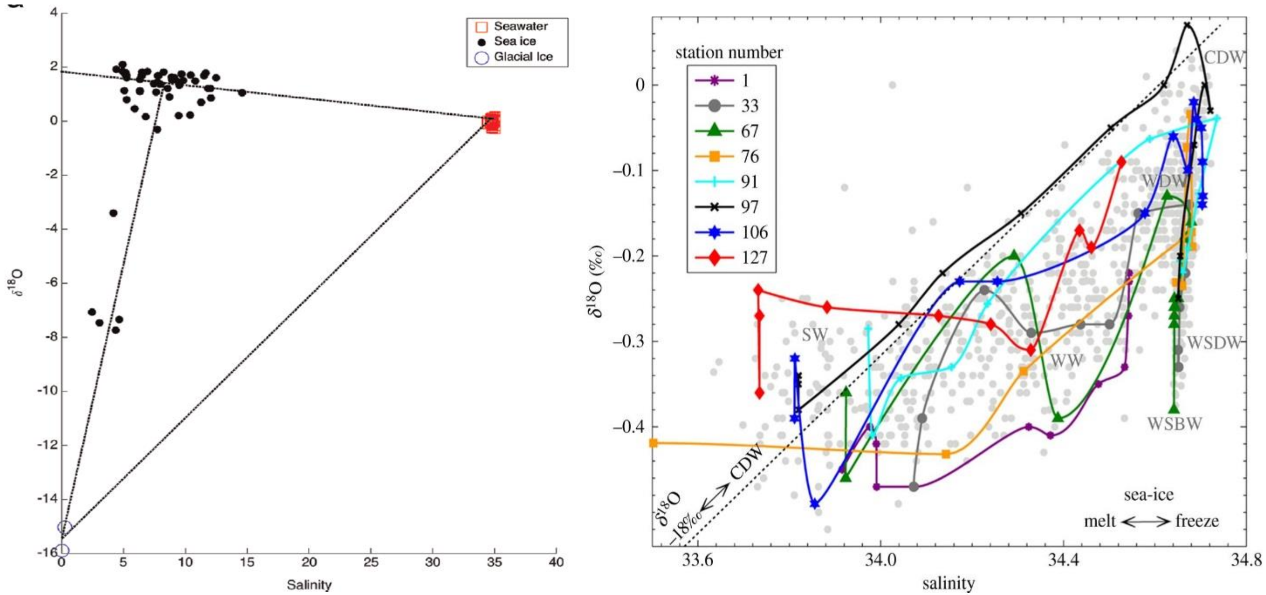

Figure 1.1: Left panel (Alkire et al. 2015) shows the relative salinity and δ^{18}O of glacial, sea-ice and seawater end members. The right panel (Brown et al. 2014) shows the relative movement of typical Southern Ocean water masses in δ^{18}O-salinity space in response to sea-ice or glacial melt/freeze.

In practice this attribution is not as simple, due to spatial and temporal variability in δ^{18}O values both in precipitation and the ocean and the confounding influence of advection from remote sources. In order to make optimal use of the valuable properties of δ^{18}O, this spatial variability must be established through baseline mapping and its temporal variability resolved via repeat voyages. For analysis of δ^{18}O in the Weddell-Scotia Sea and elsewhere around the Antarctic, it is also necessary to establish the salinity-δ^{18}O properties of regional freshwater sources, notably glacial ice, precipitation and sea ice.

This voyage marked the first scientific use of the Underway Stable Isotope Analyser that is now plumbed into the underway seawater system on the RRS James Clark Ross. This instrument was installed in late 2015 and this voyage was its first active ‘workup’ and calibration. The intention for this instrument is ultimately to become part of the semi-autonomous data collection suite of instruments on the JCR, like the underway system, swath, VMADCP etc. It will build up a baseline of continuous measurements of δ^{18}O from surface waters and allow the monitoring of both spatial and temporal variability of this useful metric. The science party of JR15006 included the designer of the system, Robert Mulvaney, who monitored the instrument’s progress, troubleshot as needed and collected notes for improvements so as to make the instrument more fully autonomous in future. We also collected and stored discrete water samples from the underway system at regular watchkeeping intervals. These samples will be processed in a more precise instrument at BGS Keyworth upon the JCR’s return to the UK and used to calibrate the underway isotope analyser.

To support this work a further goal of JR15006 was collect 'end member' samples of oxygen isotopes from freshwater input to the region in order to attribute the freshwater component of underway observations to various percentage contributions from (for e.g.) sea ice melt, precipitation, glacial outflow etc. The range of regions occupied (Signy, South Georgia and deep within the Weddell Sea pack ice) may also help establish the importance of latitudinal variability in δ^{18}O. The intense surveys around Signy and South Georgia will also resolve how rapidly surface freshwater samples mix into the surrounding ocean. In addition oxygen isotopes were collected from CTDs on both A23 and in the vicinity of strong freshwater sources, to establish the deep ocean interior δ^{18}O end member (remotely sourced circumpolar deep water that has not interacted with the atmosphere or surface for centuries) as well as the impact on the deep ocean by local freshwater sources. The repeated collection of δ^{18}O from within the Weddell Sea Deep Water on A23 may also shed some light on the source of freshening observed on this section.

1.2 Cruise participants

Name	Institute	Role
Andrew Meijers	British Antarctic Survey	Principal scientist/LADCP
Michael Meredith	British Antarctic Survey	CTD leader/processing
Robert Mulvaney	British Antarctic Survey	Underway δ18O/fieldwork leader
David Munday	British Antarctic Survey	CTD ops/fieldwork/nav
Daniel Jones	British Antarctic Survey	CTD ops/fieldwork/VMADCP
Erik Mackie	University of Bristol/BAS	CTD ops/fieldwork/salinometer/intern
Ollie Legge	University of East Anglia/BAS	CTD ops/fieldwork/underway/intern
Carson McAfee	British Antarctic Survey	BAS AME
Andrew England	British Antarctic Survey	BAS IT

Table 1.1: Special purpose personnel

Cruise science party 'Team Zissou' at King Edward Point, South Georgia, with Grytviken in the background. From left to right, back to front: Erik Mackie, Michael Meredith, Daniel Jones, David Munday, Ollie Legge, Robert Mulvaney and Andrew Meijers

Name	Role
Ralph Stevens	Master
Carola Rackete	Chief Officer
Waveney Crookes	2nd Officer
Huw Seddon	3rd Officer
Annalaara Kirkaldy-Willis	Extra 3rd Officer
Michael Gloistein	ETO Comms
Neil MacDonald	Chief Engineer
Gert Behrmann	2nd Engineer
Christopher Mannion	3rd Engineer
Marc Laughlan	4th Engineer
Craig Thomas	Deck Engineer
Stephen Amner	ETO
Richard Turner	Purser
Timothy Osborne	Doctor
David Peck	Bosun/Science Operations
Martin Bowen	Bosun
George Dale	Bosun's Mate

Sheldon Smith	AB
Francisco ‘Frankie’ Hernandez	AB
Samuel English	AB
Alan Howard	AB
Graham Waylett	AB
Gareth Wale	Motorman
Ian Herbert	Motorman
John Pratt	Chief Cook
Colin Cockram	2nd Cook
Lee Jones	Senior Steward
Nicholas Greenwood	Steward
Graham Raworth	Steward
Rodney Morton	Steward

Table 1.2: JR15006 RRS James Clark Ross officers and crew

1.3 Principal Scientist’s narrative

March 31st: After a three day flight delay, we arrive at the JCR in Mare Harbour around 4 pm. There is a quick safety briefing and boat drill, during which we depart in fair weather. New sailors seem happy. Everyone exhausted and jetlagged but manage to put up with a tour of the ship and its various instrumentation.

April 1st: Increased nor-westerlies and swell, but good progress on two engines at 14 knots towards Signy to make up time. Rob makes contact with his underway oxygen isotope autoanalyser equipment and immediately runs into issues. The instrument does not work so he sets to task disassembling it. Others busy with usual computing and email issues, as well as familiarising themselves with equipment (the CTD especially). Test CTD at 1400 to 1000 m in middle of Drake Passage goes smoothly despite winds gusting to 50 kts and solid swell. LADCP operated, but not yet processed. No δ18O taken as storage/packing of samples is not coordinated yet. Training on taking of sals undertaken. SBE35 works, but on download we discover its memory was full, so no data. Previous data now erased. Salinometer turned on and briefly tested. Set to bringing up to temperature. Discover that Argo floats do not appear to be aboard. Carola set to find out why. Not sure yet but it appears that they were never embarked? Exhausting day of running around. Significant rolling by evening.

April 2nd: rough weather makes for unpleasant night until ~ 4 am. Serious rolls means em122 fails to log for a section, but caught by Carson. Morning brings clearer skies and reduced wind. First icebergs sighted in morning and light snow in evening. All busy setting up δ18O and salinity sampling pathways, Mike processing CTD data, introduction to log keeping, processing duties, customising logsheets etc. Rob valiantly struggles with his machine and finally gets it logging in the mid afternoon. Cold salinometer room is fixed by Gert the 2nd Engineer and room is soon at comfy 21-22 degrees C. Machine set to 24 and is still warming up. Mike processes CTD data with the BAS/Hugh Venables processing pathway, but finds there is significant noise in both probes. Appears in T&C and both probes so probably related to package movement in swell, but sink rate corrections do not improve data. Evening brings much busyness with packing for Signy call due at 9 am tomorrow. Science talk in evening well received. One of the crew comes down ill. On morphine with Doc attending. Not yet considered serious, but tests underway. Fingers crossed it is ok and does not require evac. Busy, exhausting day, but I feel we are on top of things.

April 3rd: Awake to grey skies and excitement as everyone prepares to launch the boats into Signy. Difficult swell and winds from the south-east, but boats are put in the water and some cargo lowered. However swells moving the boats several m vertically forces us to cancel. Ship moves north towards Stygian Cove, but the swell is bad there too. An attempt is made on Sunshine Glacier on Coronation Island immediately to the north, but despite a fairly close approach and good views, the swell is too serious to launch again. Disappointment, especially as a sou-easterly is an uncommon wind/swell direction. Still, many photographs are taken of spectacular scenery. Decision is made to scrub for the day and try to squeeze all into tomorrow, when better weather is predicted. Will run field and boat teams in parallel. Spare time used to improve the bottle → CTD/underway → sampling pathway and good progress is made. Mike diagnoses CTD noise as almost certainly due to strong vertical CTD package movement in swell, but second opinions sought from Hugh Venables and Brian King in the UK. Good news is the crewmember is on the mend. All feel ready and we are keen to get going with sampling proper tomorrow. Praying for good weather. A showing of 'The life aquatic, with Steve Zissiou' is a great hit with science party.

April 4th: Early start and shore party is are into the boats at 0700 in glorious sunshine and slowly diminishing southeasterly winds. This party of six land at Signy Base and after a short navigational embarrassment climb up to Khyber Pass and proceeded to core their way down the glacier. The JCR meanwhile moves to Clowes Bay intending to launch small boats to sample the sea water immediately at the base of the glacial outflow. However swell in the south facing bay proves too great to put in the boats so the JCR moves back to Signy. Field party finishes sampling; retrieving seven glacial 1 m ice cores, as well as some bonus meltwater pool and shore sea water salinity and δ18O samples plus ice chunks from glacial front. Field party is retrieved at 1500 hrs from Rethval point by ship boats, which collect additional seawater δ18O and sal samples on their approach. Swell has dropped and so the ship moves back to Clowes bay and this time successfully launches the boats which proceed to sample the surface waters between the glacier and JCR standing offshore ~1 km. While boats are out a CTD is conducted to collect a vertical δ18O and sal profile and some extra water samples taken for Uwe Brand. Boats retrieved as darkness falls and the ship proceeds to deeper waters to the south while undertaking two more CTDs, including one in an 'oceanic' regime ~400 m deep. Excellent days work with two days worth of sampling crammed in thanks to superlative effort by officers and crew. Slightly disappointing to find that δ18O underway analyser decided to produce poor results after initially being stable in the morning. Rob back on the case.

April 5th: Proceed south east towards A23 southern end and ice. Fine day with dozens of whale sightings. Scientists busy decanting field samples and transcribing soggy logsheets. Δ18O machine continues to produce problems, but Rob wrestling manfully with it. Analysis of previous days CTD data from calm waters seems to support diagnosis of ship roll induced noise in the package. This is not unusual so the unusually large noise is ascribed to an unlucky fluid resonance around the package during vertical heave. Will monitor in future casts and Mike M is happy with this result. Attempt is made to standardise the salinometer but readings are found to drift downwards rapidly. Backup instrument is brought online, but it seems to have trouble cooling its water bath temperature. Will let it stabilise overnight, but these issues need to be fixed fast, with CTD ops not long away and empty sal bottle supplies dwindling. Others in the science party all make good progress on getting their various underway data processing under control. Weather forecast to worsen over coming days.

April 6th: Feared weather takes longer to arrive than expected, only reaching 40+ kts in the late evening, at which time the JCR arrives on the southern end of the A23 section following an uneventful passage. We are ready to commence CTDs tomorrow morning. The science party makes good use of the downtime. The problem with the salinometers is diagnosed. Instrument one does not drift much at all when regular sals are run, so possibly the fault lies with the standards, which are near their use by date, but also had not been given sufficient time to warm up. Training is given and all new hands run a total of two crates are run, with the intention of restandardising tomorrow with new standards once they come to temperature. The overheating salinometer is due to a broken fan, which cannot be neatly repaired, so it is relegated to emergency only duties. Annoyingly both units are due to be serviced this month, so are a bit dodgy. Rob gets advice from the manufacturer and replaces a coupling in his instrument, seeming to improve the readings...he is getting there! Cold and deep Weddell gyre waters cause the EM122 to bow due to incorrect temperature profiles, so a 'found' XBT left over from a previous voyage is deployed to give an improved profile, which does the trick. Otherwise all make good progress in advancing their data processing...everyone is on top of their work which is excellent! Weather report for next few days is more promising now, so hopefully ice on the 8th!

April 7th: Weather day unfortunately. Constant high nor-westerlies and building swell mean we remain hove to on A23 at 64 South. Decision is made at 4 pm to run south east with the wind, and turn towards the ice edge in the am. Everyone carries on with their data processing. Salinometer recalibrated using slower flow rate and newer, equilibrated standards.

April 8th: A 6:30 am shiptime turn abeam of the swell gives everyone a wakeup call. First pancake ice encountered at midday to the excitement of all and we pass the Antarctic Circle in the early afternoon. Pushing south hoping to encounter something suitable to sample. Thickening pancake ice and deadening swell hopefully means that will be sometime in the morning tomorrow. Two crates of sals run today. Annoyingly the standards run appear fresher than yesterdays calibration. Possibly due to bubbles in the cell?

April 9th: Into the ice in earnest today. Unfortunately the swell had broken up a lot of the ice, which was largely newly formed and thin, with substantial gaps between the relatively small flow sizes. Proceeded south at better than 12 kts through near 100% coverage. Unfortunately no flows suitable for general disembarkation could be found, but by 0900 ship time had found a lump of ridged multiyear ice, probably no more than 20x20 m, but with a good size keel and plenty of snow. At 68S, a good 60-100 Nm into the ice and the most southerly ship on the planet, we decided not to push our luck further so started work. Wor Geordied Mike Meredith and Rob Mulvaney onto the ice, accompanied by Dave Peck. Excellent and quick work rapidly grabbed three cores and some snow bags. Quick tourist runs for those who wanted to stand on the ice ensued, with lots of photos. Dan Jones managed to grab another core as well, relatively high up on the ice. In the meantime the rest of the science party took water and slush sal/δ18O samples via advanced 'buckets over the side' techniques. Once tourism finished, Ollie Legge and Andrew M took some samples of the thinner new ice nearby (4 cores + 2x sal and δ18O samples) for comparison. With curious Minke whales in attendance a 1000 m CTD was conducted to collect a δ18O/sal profile, concentrating on the mixed layer. Once done all speed was made back towards the ice edge, hoping to avoid entrapment and emulating the Shackleton expedition. 100 years ago to the day they got off the ice for the last time and took to the boats, while we got off the ship and took to the ice!

April 10th: We awake on the edge of the ice pack after all speed was made overnight to get clear of the thickening and compressing pack ice. A quick 1000 m CTD and over the side ice/slush bucket samples were made before sadly leaving the ice behind proceeding towards the first station of A23. Science party and ship move onto 24 hour shifts in anticipation of round the clock CTD work.

April 11th: Winds holding steady northerly at 25-35 knots, and sea state remains workable. The first deep CTD overnight was successful, but revealed some worrying leaks on six Niskins. These were inspected by BAS AME Carson and found to be heavily pitted and worn around their end caps. These were replaced and the next CTDs have performed well. δ^{18}O machine continues to run well, though Rob is enjoying tinkering with it to fine tune it. CTD010 was unfortunately deployed without the LADCP logging. The control file has been adjusted to avoid this in future.

April 12th: Lighter winds today along with good progress. Some minor CTD bottle closing issues, but nothing systemic. Progress on processing salinities, Rob decides he is bored with his fully functioning δ^{18}O machine so sets his mind to learning physical oceanography with a textbook and hands on lessons with the salinometer and CTD.

April 13th: A bright morning reveals a calm sea, dotted with penguins and picturesque burgs. During CTDs overnight an intermittent salinity offset on the secondary conductivity sensor was observed, finally degenerating into a large bias on CTD016. Carson woken up to replace the sensor and the offset returns to close to zero on the following cast. δ^{18}O continues to work well. Steadily making good progress on A23, hoping to get as much done before weather due on the 14th afternoon and over the weekend.

April 14th: Another solid days work, despite worsening weather and snow flurries. Several crates of sals run in the morning and CTDs continue to get slightly ahead of schedule. A Southern Right Whale makes an appearance in the morning, happily splashing around on the surface and waving flukes to appreciative spectators. Winds increase overnight making for lumpy seas but do not hinder progress.

April 15th: Some unwelcome excitement comes when in the small hours of the morning the PSO mistakes a noisy altimeter reading on CTD 025 for a false bottom and subsequently does some impromptu lithography of the Scotia Sea floor. Fortunately the winch speed was slow and the only immediate effect was a blocked pump intake, resulting in the loss of the primary temp, conductivity and dissolved oxygen on the upcast. Fortunately the rest of the data is still usable. Carson quickly fixes the blockage and CTD026 appears to behave well with little offset between primary and secondary. Some small damage to the CTD cable above the instrument is detected, but it is fairly minor and both winch operators and Carson deem it suitable for the remainder of the voyage. Slightly more concerning is the bend in the metalwork where the termination connects to package frame. This is likely to have been caused by the package toppling on the bottom (LADCP records a brief 44 degree tilt) before being caught by the cable tension. However, subsequent casts perform with no apparent issue in data quality or operations.

April 16th: Decision on weather and whether or not to attempt the Georgia Passage section is made by a medical decision to transfer the previously ill crew member at KEP to the Pharos for transport back to Stanley. This is precautionary only and the crew member is in no immediate danger. This does mean however, that the Georgia Passage survey will yet again not be conducted. Disappointing, but realistically with the forecast weather we would not be able to work in the open ocean anyway. Better to run to the shelter of Cumberland Bay and attempt to expand the S. Georgia work instead. A23 is completed in the late afternoon and we make all speed to the lee of S. Georgia overnight.

April 17th: Awake immediately offshore of KEP in the spectacular surrounds of S. Georgia. Transfer of crew member occurs around 0730 shiptime and we move to Nordenskjold Glacier front in Cumberland Bay East. Sitting around 1 km from the glacial face we assess the surface as unsuitable for coring, due to the many crevasses and heavy moraine deposition. Instead we decide to launch small boats to take surface samples in front of the glacier face and back towards the ship. Two boats are launched after a small weather delay and quickly collect 24 water samples and several chunks of sea ice. Conditions were very changeable during this work, but all performed admirably. We then conducted five CTDs northwards from the glacier through Cumberland Bay East. The sixth at nearly 1700 was suddenly called off when we received word that the S. Georgia Government had requested our assistance in investigating a report of illegal fishermen to our north. A suspicious radar contact by the legal fisher RAMBLR failed to respond to hails or have an identity beacon on. With the Pharos unavailable we were enlisted to help. We took on a S. Georgia Govt. official and the head of local fisheries around 1800 and headed north west, with all four engines on at better than fifteen knots. Offshore conditions were terrible, with high winds and heavy sea abeam. Despite this, we quickly made radar contact at the supplied coordinates and by 2100 had closed to within a mile or two. Very low visibility made identification difficult, but we eventually determined the illegal fisher to in fact be an iceberg. Quite an anticlimax to an exciting chase that had all spare persons on the bridge to enjoy the show. Winds increased to over 50 kts for the return journey which was extremely uncomfortable. Eventually made Cumberland bay at around 0330 ship time on the 18th.

April 18th: A tired ships compliment awake to thick fog and ongoing snow flurries. High winds continue but conditions in the bay are workable. We offload the officials from the previous night and set to a section of CTDs across the mouth of Cumberland East and West bays. Shallow narrowly spaced stations in high winds and constant snow make for tiring work for an already exhausted ship from the long rocking night previously. Seven CTDs are conducted and sampled between 1000 and 1530, an excellent effort by crew and scientists. We proceed back to sheltered waters and have an enjoyable, if slightly exhausted, 'end-of-cruise' dinner. Tonight was chosen as it seemed more likely that we'd keep our food on our plates and off our laps than later on crossing the ACC.

April 19th: A quiet day spent in Cumberland Bay waiting out the slowly improving weather, processing our collected data and preparing for field work tomorrow. Some late evening concern due to petty bureaucratic quibbling regarding our sample permits, but after several terse email exchanges the permits to sample are approved.

April 20th: Big day at South Georgia. Much excitement as we awake to clearer skies and practically no wind. Moor at around 1000 ship time and after a quick briefing by the SG government official and Base Commander we are released onto the island. Two science parties were deployed, six ascending to Glacier Col, south west of Gull Lake to take ice cores, while another three headed towards penguin river to take river samples. Some hard hiking through difficult conditions including thick snow overlying bogs ensued. However, both teams successfully collected samples and returned with enough time for some well-earned tourism at Grytviken, Shackleton's grave, the museum and postoffice. The latter two kindly reopened for the ship visit despite the recent departure of their regular staff. Under clear night skies and a near full moon, a very enjoyable BBQ was put on in the boat shed by the BAS base with drinks supplied by the JCR.

April 21st: Grey skies and clouds greet us again as we leave KEP at 0900 shiptime. We steam around to Lief whaling station for a quick tourism stop over lunch, before proceeding to sea again to occupy our final three CTD stations up to the continental shelf. These aim to capture the transition from glacial meltwater to oceanic regime. These were completed around 1900 ship time, and all retired for a well-earned rest.

April 22nd: Heavy seas but bright sunshine as we steam westward. All aboard tired from a night and day of heavy rolling, but busy themselves with end of cruise data processing.

April 23rd: Much better conditions today as we make good progress back along the North Scotia Ridge to Stanley. Last icebergs sighted in the afternoon and the Polar Front crossed in the evening. Salinity samples are no longer taken during general watchkeeping as there are more than sufficient datapoints now to calibrate the underway instrument.

April 24th: Another day of data processing, cruise report writing, packing and general tidying up.

April 25th: ANZAC day, the good doctor’s 30th birthday and our last day at sea. Bright skies continue, but 40+ knot southerlies and swell make things a little bumpy and some of the largest rolls of the trip occur to remind us all we aren’t home yet. Work continues on BoLs, cargo stowage, HoR, cruise reports and lab cleaning. We arrive in Port William around 1730 ship/local time and stay on DP overnight, awaiting room at FIPASS tomorrow. An excellent last meal of South Georgian reindeer is pulled out of the bag by the galley staff, and all retire to the bar to help the doctor celebrate.

April 26th: We arrive at FIPASS at 0800 local time. All science is finished now and most science personnel set to exploring Stanley. Except for the PSO who is still writing this bloody cruise report. All eagerly await the flight home on the 29th.

1.4 Event log

See Appendix B for scientific bridge log event list.

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2. Conductivity-Temperature-Depth operations and data processing

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2.1 Introduction

During cruise JR15006, the James Clark Ross' Conductivity-Temperature-Depth (CTD) package was deployed at 49 stations, generally categorized as (1) test station, (2) close to Signy Island, (3) sea ice stations, (4) the A23 repeat hydrographic section, and (5) close to South Georgia. Each of the scientific cruise party was involved at various times in operating the CTD, and in extracting seawater from the Niskin samplers attached for subsequent salinity and stable oxygen isotope ($\delta^{18}O$) analysis.

2.2 Instrument setup and configuration

CTD instrumentation on the James Clark Ross is attached to a 24-bottle frame carrying an SBE32 carousel water sampler. For JR15006, 24 internally-sprung 10-litre Niskin bottles manufactured by General Oceanics were used. The CTD unit itself was an SeaBird Electronics (SBE) 9plus connected to an SBE11plus deck unit, with dual channels (primary and secondary) for both temperature and conductivity. Other instruments attached were a WetLabs C-Star transmissometer, a Chelsea Instruments Aquatracka MKIII fluorometer, an SBE43 dissolved oxygen sensor, a Biospherical Instruments Photosynthetically Active Radiation (PAR) sensor, a Tritech altimeter, and an SBE35 reference thermometer. The CTD instrumentation was mounted at the bottom of the frame, for prioritisation of downcast data, with the exception of the SBE35 thermometer and the PAR sensor that were mounted on framework at the perimeter of the CTD package. The altimeter was downward-looking to enable tracking of seabed approach from 100m distance. In addition, a Lowered Acoustic Doppler Current Profiler (LADCP) was attached to the frame; its operation and data processing is described separately (Chapter 4).

During JR15006, use was made of a fin attached to the side of the CTD package. This reduces horizontal rotation of the package whilst underwater, which has been seen previously to adversely affect the LADCP data in particular. The CTD package was deployed from the mid-ships gantry on a conducting cable, with control of the CTD instrumentation underwater effected using a PC connected to the deck unit, running the SBE Seasave (version 7) software.

Instrument	Serial Number	Last Calibrated
SBE3 temperature (primary)	5766	18 March 2015
SBE4 conductivity (primary)	2289	08 July 2015
SBE3 temperature (secondary)	2705	10 June 2015
SBE4 conductivity (secondary; first unit*)	2248	14 July 2015
SBE4 conductivity (secondary; second unit*)	2222	09 July 2015
SBE9plus pressure	0707	22 June 2015
SBE43 oxygen	0676	02 June 2015
Tritech altimeter	163162	04 June 2015
CI fluorometer	088-249	11 May 2015
C-Star transmissometer	CST-846DR	17 June 2015
Biospherical PAR	7274	24 April 2013
SBE35 thermometer	27735-0024	22 March 2013

Table 2.1: Instrumentation, serial numbers and calibration dates for CTD package equipment used on JR15006. All instrumentation was used for the full duration of the cruise, with the exception of the secondary conductivity sensor (marked), which was replaced on 13 April 2016 following an unexplained failure. Full calibration coefficient information is available from BAS AME or from the header information in the .cnv files output from the SBE processing (see below).*

2.3 Instrument deployment protocol

The deployment procedure for the CTD package used on JR15006 is comprehensively described in the pair of documents “Guide to running a CTD cast on JR15006”, written by Meredith, and “Picking bottle depths on JR15006“, written by Meijers. These are reproduced here verbatim as they form the detailed protocol that was followed for each station.

2.3.1 Guide to running a CTD cast on JR15006

1) Before the cast:-

:: Ensure the CTD package is ready for deployment:-

- Niskins are ***all*** cocked and open, with spigots and top valves closed (pulled out and twisted for spigots, finger tight for top valves).
- Plastic sleeve is removed from SBE35 thermometer
- Check that CTD sensors do not have endcaps on them
- LADCP has had pre-deployment tests run, is turned on, logging and unplugged

:: Start filling out a CTD logsheet. Details required include:-

- CTD cast number/station number. These are the same and increment by one each cast.
- Ship event number. This is NOT the same as CTD station number. The bridge can tell you this, or you can get it from the JCR intranet
- Latitude/longitude etc (read off the SCS display to right of CTD control PC)

:: Set up the CTD data collection software on the control PC:-

- Open Seasave V7 package

- Ensure display windows go deep enough to encompass full depth of cast. (If they don't, right click on the window in question and expand the scale).

- Select "Real time data" from the menu, and click "Start"
- Fill in the details required, starting with output filename. Note that filenames include the CTD station/cast number, which increments by one each station.
- Click "start" (this doesn't start logging yet)

- A second box of input fields opens, into which the header information of the CTD file is entered. This includes:-
    - Cast/station number again
    - Latitude and longitude
    - Julian day (can read Day of Year off SCS display)
    - Time in GMT (from red GPS clock repeaters)
    - Depth from EM122 echosounder (can read off SCS display)
    - Your name (so people know who to ask for details in future)
    - DO NOT click OK yet as this will begin logging.

2) During the cast:-

:: Make sure you tell the winch driver when you are ready to deploy. He will talk with the bridge to ensure ship side are content to deploy. You will need to tell him how deep the CTD is planned for, which on the A23 section will be the bottom depth minus 10m (in calm seas), or further off if rougher (15-20m+).

:: The deck crew will manoeuvre the package over the side of the ship. Give it one last quick visual inspection to ensure all bottles are cocked. If they are not you MUST stop deployment. Once it is free of any human hands, you can power up the CTD deck unit using the red button on the deck unit. This will flash and should settle on a reading ending with 10.

:: Now start logging on the CTD control PC by clicking OK.

:: If you haven't already, now record the information required on the CTD logsheet - time, lat, long etc.

:: Ask winch driver to lower the package to 10m and hold there. This is to allow the sensors to acclimatise, and (importantly) for the conductivity switch to turn the CTD pumps on. You will see when this has happened, because the last digit in "Word Display" on the CTD deck unit changes from 0 to 1. A soak of around 3 minutes is generally sufficient; then ask the winch driver to raise the package the surface then lower to the target (deepest) depth. Keep an eye on the sensor difference window to see the sensors settle down.

:: Ensure you write out the target bottle depths for the cast on the logsheet as the package descends. See picking bottle depth document for details. Do not wait for the package to get to the bottom before picking out depths.

:: The CTD altimeter will start giving changing readings when 100m off the bottom. This is the key guide for how deep the package can be allowed to go. A diagonal green trace will appear in the altimeter window. Make sure to tell the winch driver IMMEDIATELY the CTD package is 100m off the bottom. Then count him down in intervals of 10m from 50m above the bottom, ensuring he knows that you want him to stop at 10m (or further off the bottom if rougher). The driver has no idea where the bottom is, so it is your responsibility not to crash the instrument.

:: When stopped at the bottom, wait 30 seconds for any CTD wakes to dissipate/mix away, then close a bottle by clicking in the dialogue box. The screen should flash and the bottle number should increment. Check that the bottles fired window matches what you write on the logsheet. Wait a further 15 seconds (to extend the non-motion of the CTD package beyond the averaging time of the SBE35 thermometer), recording the relevant information on the logsheet, then ask the winch driver to raise the package to the next target bottle depth. Repeat this up to the surface.

:: After closure of the bottle nearest the surface, tell the winch driver it is okay to recover the package when he is ready.

:: Once the package is out of the water, select "Real time data" and click "Stop", then power off the CTD deck unit using the red button. Ideally this should be done before the deck crew start to maneuver it onboard.

:: Record information on logsheet about the recovery (time, lat, lon etc), and thank the winch driver for their professionalism and charm.

3) After the cast:-

:: Minimise the Seasave window, then backup the data immediately by double-clicking the "BAS_SVP" icon on the desktop. This will prompt for cruise number ("JR15006") and station number.

:: Perform some other routine processing on the data just collected:-

- Open the "SBE Data Processing" software, and select "Data Conversion". Select the config file created for the cast just conducted (e.g. JR15006_NNN.XMLCON, where NNN is the station number) and the data file created (e.g. JR15006_NNN.hex). Ensure output directory is D:\data\JR15006, and enter the filename appropriate the cast number (e.g. JR15006_NNN). Click "Start", and files named JR15006_NNN.cnv and JR15006_NNN.ros will be created. Click "Exit". This routine converts the data collected from hexadecimal format into ASCII.

- Select "Align". Input file is JR15006_NNN.cnv; output file will have _a appended, and therefore be JR15006_NNN_a.cnv. This routine applies a hysteresis correction to the oxygen sensor. Run this, then click "Exit"

- Select "Cell thermal mass". Input file should be JR15006_NNN_a.cnv; output file becomes JR15006_NNN_actm.cnv. Run this, then "Exit".

- Exit the SBE Data Processing software, and copy the four files just created (.cnv, .ros, _a.cnv, _actm.cnv) from D:\data\JR15006 to U:\data\JR15006

:: Download the SBE35 thermometer data.:-

- Once the Niskins have been sampled and LADCP data downloaded, and nobody is working on it (CHECK FIRST), power up the CTD deck unit again.

- Start the Seaterm program, and click "Connect" to establish comms. Click "Status" to get an indication of how many data cycles are onboard the instrument - there should be one for each bottle that has been closed (but can be more if previous casts had not been cleared out of memory).

- Click "Upload", and enter the data cycles wanted into the dialogue box that appears, then enter a filename (of form JR15006_NNN.asc). Then run the routine; this will take a few moments since the baud rate is slow.

- Check the file looks okay (right time stamps etc), then copy it from D:\data\JR15006\SBE35 to U:\data\JR15006\SBE35

- Clear the SBE35 memory. To do this, you have to write at the command line prompt ("S>"), however you will not see your words appear as you type. Type samplenum=0, then hit return. Click "Status" to check memory is cleared.

- Click "Disconnect", then power down the CTD deck unit.

2.3.2. Picking bottle depths on JR15006

General aims

There are two goals to keep in mind when picking bottle depths on JR15006: Firstly we want to resolve the vertical profile of d18O in the water column, and secondly, to provide useful salinity samples and high resolution thermistor (the SBE35) readings that will later be used to calibrate the CTD sensors.

Specifically

δ^{18}O: δ^{18}O in the ocean interior is a conserved property, and can be fairly safely assumed to covary to some degree with other conserved tracers such as temperature and salinity. Therefore the T/S profiles (and dissolved oxygen to a lesser extent) that you observe as the CTD descends give information on the depths at which the various different water masses (i.e. mixed layer, winter water, UCDW, LCDW, AABW etc.) reside. In order to reconstruct such a profile with 24 discrete bottle samples, it is best to fire bottles at turning and inflection points in the T/S profiles. In a typical cast south of the Polar Front (i.e. all of A23) you will want to resolve the surface mixed layer, the winter water (T-min), the Upper CDW (T-max, oxygen min), and any AABW or bottom layer that might be present (often shows as a layer of fresher, higher oxygen water). As we are now late in the season the mixed layer may have merged with the winter water so the T-min will also be the mixed layer. Once these key points are covered, you should look to fill in the bits in between to more finely resolve the δ^{18}O gradients.

Salinity: The CTD conductivity probe does an excellent job of resolving vertical salinity variability, but the two probes can often be offset from one another or exhibit pressure dependencies. In order to calibrate for these we must take and run salinity samples from the Niskins. This calibration is most easily done in depth layers where there is little vertical variability, so the differences between CTD probe and bottle salinity are more likely to come from some inherent bias rather than sampling noise from high vertical salinity gradients. It also helps to sample very deep layers that will have little cast-to-cast variability, as this helps detect sudden changes in CTD cell behavior (such as caused by a frozen or otherwise damaged probe). Eight salt samples is usually figured to be a good minimum number for deep casts such as the A23 section, and they should be selected to be fired with at least four-six in the deep weakly stratified CDW layers, and two to four in the surface mixed layer. A good vertical spread should be obtained in order to capture any pressure dependences in the probes. The SBE35 thermometer is similarly best employed in regions of low vertical temperature gradients to reduce noise.

In practice

In an ordinary profile less than half the CTD's 24 bottles are needed to pick out the major turning and inflection points of a profile (see Figure 2.1).

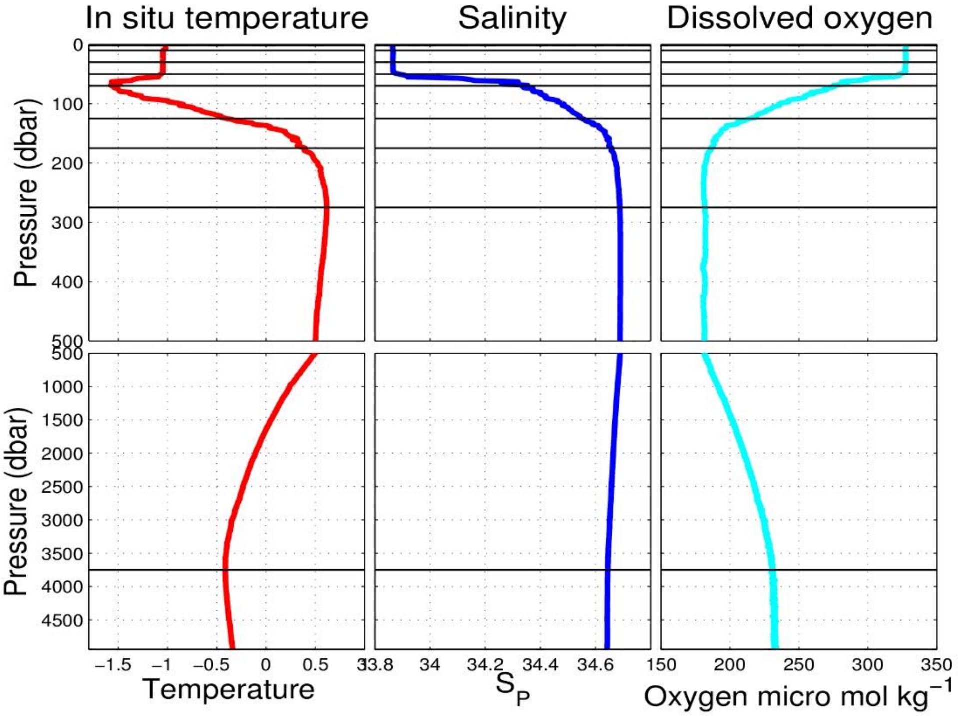

Figure 2.1: Example CTD profile from the southern end of A23 (JR281). Example minimum number of bottle depths to resolve are shown. More are needed between 500-3500 dbar for salinity and SBE35.

This means that the remaining bottles can be used to fill in the gaps, resolve smaller features and pick out stable layers for salinity sampling and useful SBE35 measurements.

The practical steps to picking bottle depths then are:

- There should always be one bottle at 10 m, and another as close to the surface as is practicable depending on swell (2 m if calm, 5 m or even more if really rolling)
- There should always be one bottle at the bottom. If there is a bottom layer this should be resolved with at least two more bottles. Even if there is no obvious bottom layer 2-3 bottles (including the bottom) within 500 m of the bottom is a good idea.
- Pick out the major turning and inflection points with bottles.
- Fill in the gaps between, ensuring that there are sufficient well-spaced bottles (at least 4+) in the weakly stratified deep interior layers and the surface mixed layer (3-4+ including the surface bottles).

You will generally find that you will get roughly 50% of the bottles in the top 500-1000 m (depending on where the T-max is) and the rest spread over the weakly stratified deep waters, with several around any bottom water layer that is present. If you have done all this and still have spare bottles, consider duplicates at particularly interesting points (i.e. a bottom layer) or in weakly stratified layers to test bottle-to-bottle variability (though there should be almost none).

Choosing sample depths

Every bottle fired should have a $\delta^{18}O$ sample taken, and there should be a couple of duplicates taken from bottles on each cast to help establish sample noise later. Salinities should NOT be taken on every bottle (we will run out of standards). Instead eight bottles should be chosen from eight different depths within well-mixed (weakly stratified) layers as discussed in the salinity section above. Every few CTDs however it would be useful to have duplicates taken from the same Niskins in order to establish sampling noise, though 8 bottles only per CTD should still be taken.

- Transcribe all bottle depths from the CTD UIC log to the CTD sample log.
- Mark those bottles to be sampled for salinity with a star in the salinity column, and any $\delta^{18}O$ (or salinity) duplicates with a star in their respective columns.
- Enjoy the heady feeling of pouring freezing bottom water over your hands.

2.4 Data processing

2.4.1. SeaBird CTD processing

For each cast, a set of standard files is produced by the SBE Seasave software. These are:-

JR15006_XXX.hex – a hexadecimal file containing raw (24 Hz) data for cast XXX.
JR15006_XXX.bl – an ASCII file containing bottle firing information.
JR15006_XXX.hdr – an ASCII header file containing sensor information.
JR15006_XXX.xmlcon – an ASCII configuration file with calibration information.

A set of standard routines was used to clean and process the data contained in these files. The first three of these routines were run in the SBE Data Processing module on the CTD control PC (see above), and were:-

Data Conversion – to convert the .hex file into ASCII (output *JR15006_XXX.cnv* and *JR15006_XXX.ros*)
Align – to apply a time shift to the dissolved oxygen data to account for hysteresis effects (output *JR15006_XXX_a.cnv*)
Cell Thermal Mass – to correct the data for the thermal mass of the conductivity cell (output *JR15006_XXX_actm.cnv*).

These files were transferred to the ship's linux network for further processing in the Matlab environment.

2.4.2. Matlab processing

A suite of Matlab programs was used to further process the CTD data. These have evolved over many years, with the version used here obtained from Hugh Venables (BAS) and modified where necessary for JR15006 purposes.

The routines used were:-

ctdread15006 – takes the *JR15006_XXX_actm.cnv* file and reads it into the matlab environment by invoking the *cnv2mat* routine and organizing the subsequent arrays appropriately. Output is *JR15006_ctdXXX.uncal*.

editctd15006 – launches an interactive editor and enables selection and flagging of data to be removed from subsequent processing. This was used particularly to exclude the soak period, the on-deck period after package recovery, and any noticeably problematic conductivity spikes in the data. Output is *JR15006_ctdXXX.edt*.

interpol15006 – applies linear interpolation to fill in gaps created above. Output is *JR15006_ctdXXX.int*.

salcalapp15006 – a dual-purpose routine; used at this stage to derive variables including salinity, potential temperature, potential density. Output is *JR15006_ctdXXX.var.*

splitcast15006 – divides the cast into its downcast profile (*JR15006_ctdXXX.var.dn*) and upcast profile (*JR15006_ctdXXX.var.up*).

fallrate15006 – a routine that removes data from the files where they are deemed to be contaminated by CTD motion effects. Such effects were problematic on JR15006 on more than one occasion (see “Issues” below). The routine is applied only to the downcast profile, and excludes data from pressure levels that have been previously encountered, and data from periods when the CTD package was descending at less than 0.24 m/s. Whilst this functionality removes many erroneous loops and overturns, it did not resolve all the issues encountered when extreme examples of these were observed. Different exclusion criteria were trialled, but with only very minimal additional gain (see report below). Output is *JR15006_ctdXXX.varf*

gridctd15006 – takes the upcast and fallrate-corrected downcast data, and creates 2 dbar averages of all variables. Data are padded to 5999 dbar with NaNs, ensuring CTD variables arrays of equal size for each cast. Output is *JR15006_ctdXXX.2db.mat* and *JR15006_ctdXXX.2db.up.mat*

fill_to_surf15006 – applied to fill in the missing few layers from the surface by copying upward the shallowest layer that contains data. Makes the presumption that the mixed layer depth is deeper than interval of missing data; works on all variables excluding PAR. Useful especially for profiles where the raising of the CTD package after the soak did not bring it completely to the surface. Output is *JR15006_ctdXXX.2db.mat* and *JR15006_ctdXXX.2db.up.mat*

ctdplot15006 – creates a set of standardized profile and potential temperature-salinity plots from the 2 dbar data, to enable assessment of the quality of the data collected.

average_1Hz_15006 – takes the 24 Hz data (both downcast and upcast) from the *JR15006_ctdXXX.var* file, and created 1 Hz averages for inclusion in the LADCP processing. Output is *JR15006_ctdXXX.1Hz*

makebot15006 – reads into the Matlab environment the *JR15006_XXX.ros* and *JR15006_XXX.bl* bottle files produced by the SBE processing. The routine extracts the mean and standard deviation of each CTD variable, including derived variables, and flags warnings to the screen if the standard deviations exceed 0.001. Output is *JR15006_XXX.1st* *sb35read15006* – reads into the Matlab environment the *JR15006_XXX.asc* file produced from the SBE35 thermometer, and plots differences between the SBE35 and the primary and secondary CTD temperatures. Output is *JR15006_XXX.sb35* and *tempcals.all.mat,* the latter being the master file containing all temperature calibration information for the cruise.

readsal15006 – reads salinity data from the Excel spreadsheets into which bottle conductivity measurements had been entered and standard-corrected salinity derived. An output file is created, called *JR15006_salXXX.mat,* containing variables "niskinnums" (the Niskin numbers as ordered in the spreadsheet), "samplesals" (the sample salinity data as ordered in the spreadsheet), "botsal" (the sample salinity data re-ordered by ascending Niskin number), and "salflag" (set to 0 for missing data and 1 for extant data).

addsal15006 – reads the *JR15006_salXXX.mat* file just created, and the corresponding *JR15006_XXX.1st* file, the latter of which contains the bottle data from the CTD. Output stores these in a merged file called *JR15006_XXX.sal*.

setsalflag15006 – loads the file *JR15006_XXX.sal,* and flags those bottles with high standard deviations from temperature and conductivity (variable: "niskflag"). Output file is same as input file, *JR15006_XXX.sal.*

salplot15006 – creates a standard plot of bottle salinity measurements and CTD salinity measurements versus pressure and the standard deviation of their differences.

salcal15006 – appends information to *salcals.all.mat,* being the master file containing salinity calibration data for the cruise as a whole.

2.5 Data calibration

Following the end of the A23 repeat hydrography section, the compiled temperature and salinity offset data (from the SBE35 thermometer and bottle salinities respectively) were examined to test whether calibrations needed to be applied to the CTD data, and if so what those calibrations were. Whilst there were further CTD casts conducted after the A23 section, these were all shallow or very shallow (e.g. Cumberland Bay and across the South Georgia shelf), and so were deemed of little extra value for deriving calibrations in themselves. A number of Matlab scripts were written to explore the data, titled e.g. *calibrations_temperature_15006, calibrations_salinity_15006,* etc.

2.5.1. Temperature calibration.

The offsets between the SBE35 and the primary and secondary CTD temperatures are shown as a function of station number in Figure 2.2, where the panels show comparisons for all depths and below 1000 dbar as marked. Whilst there is some indication of an upward trend in the offset in the upper two panels of this figure, the lower two panels show no such trend. This difference is a consequence of the upper layers have much higher temperature gradients than the deep ocean, hence the offsets here are differentially strongly affected by noise, positioning of the sensors on the frame, CTD wake effects and so on. The changing upper-ocean stratification over the course of the cruise is thus manifest in the upper-ocean offsets, however the absence of a trend in the deep ocean readings indicates that the CTD temperature sensors were actually stable over this period.

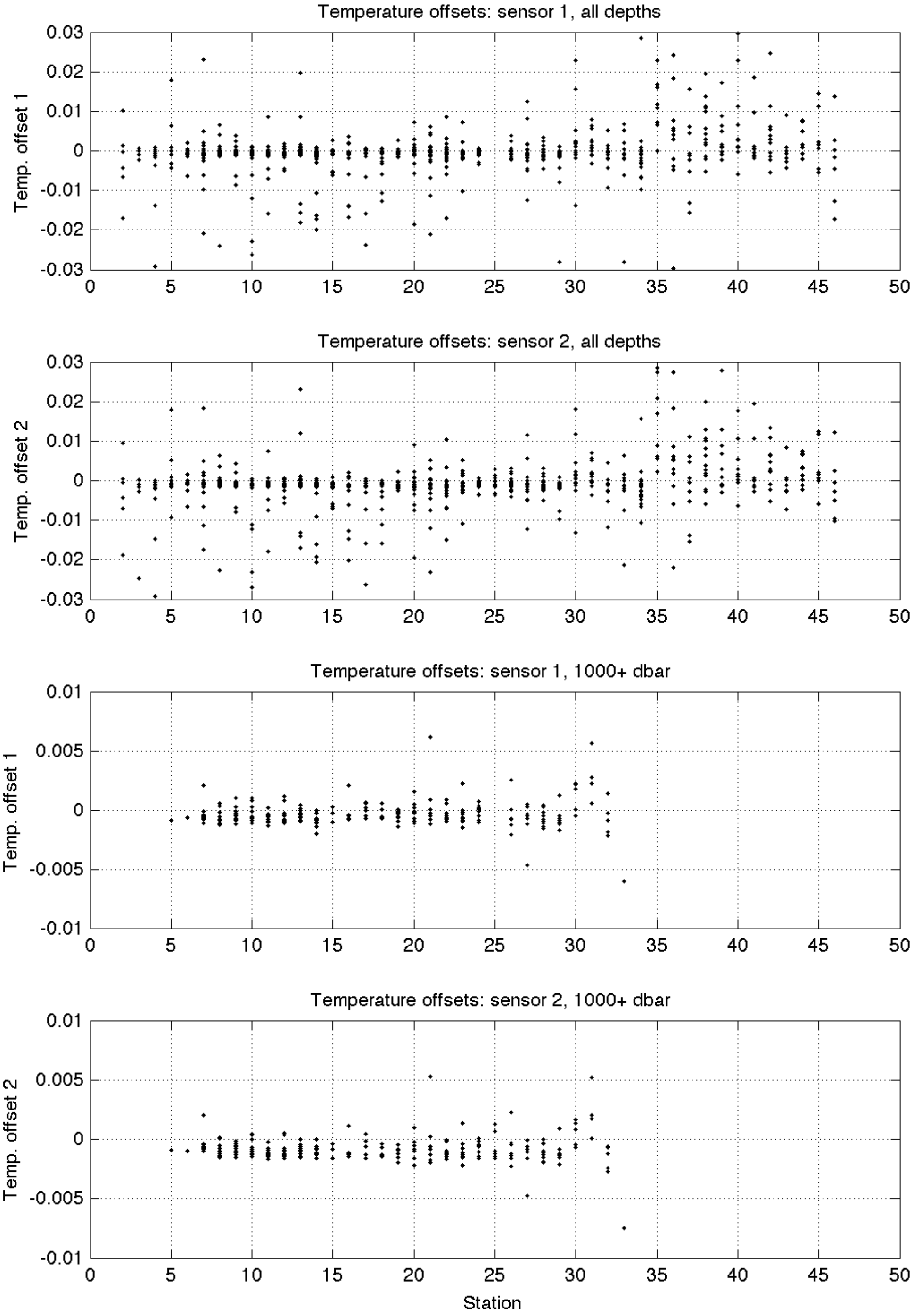

Figure 2.2: Offsets between primary and secondary CTD sensors and SBE35 temperature readings, as a function of station number. Panels are (top) SBE35-CTD primary for all depths, (second) SBE35-CTD secondary for all depths, (third) SBE35-CTD primary for deeper than 1000 dbar, (bottom) SBE35-CTD secondary for deeper than 1000 dbar.

Whilst the scatter in Figure 2.2 prevents accurate assessment of the average offsets, these become more apparent when station-means are determined (Figure 2.3). Note that the bottom two panels of this figure show the stability over time of the offsets, and that secondary temperature is slightly more offset than primary temperature when compared with the SBE35. (Stations 30 and 31 in this plots were significantly shallower than the other stations, hence their apparent positions as fliers).

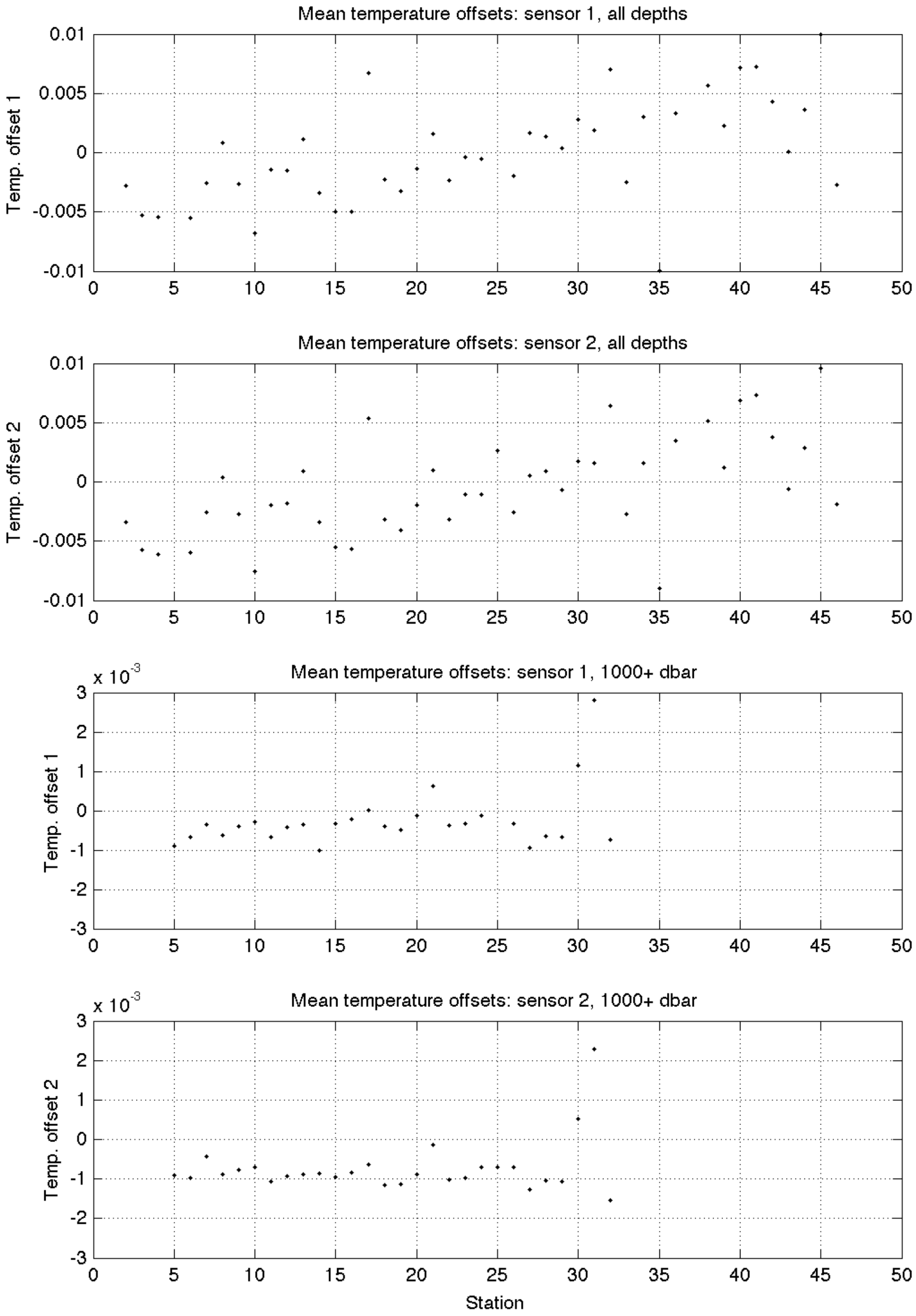

Figure 2.3: As per Figure 2.2, but for temperature offsets averaged by station.

To examine possible vertical (pressure) dependence of the terms, the temperature differences were considered in offset/pressure space, and best-fit linear regressions were determined (Figure 2.4). These showed that neither primary nor secondary temperature offset had a significant dependence on pressure. Mean offsets of -0.00050°C (primary) and -0.00094°C (secondary) were determined. Both of these are smaller than the target accuracy for temperature of 0.001°C, hence no corrections for temperature were applied.

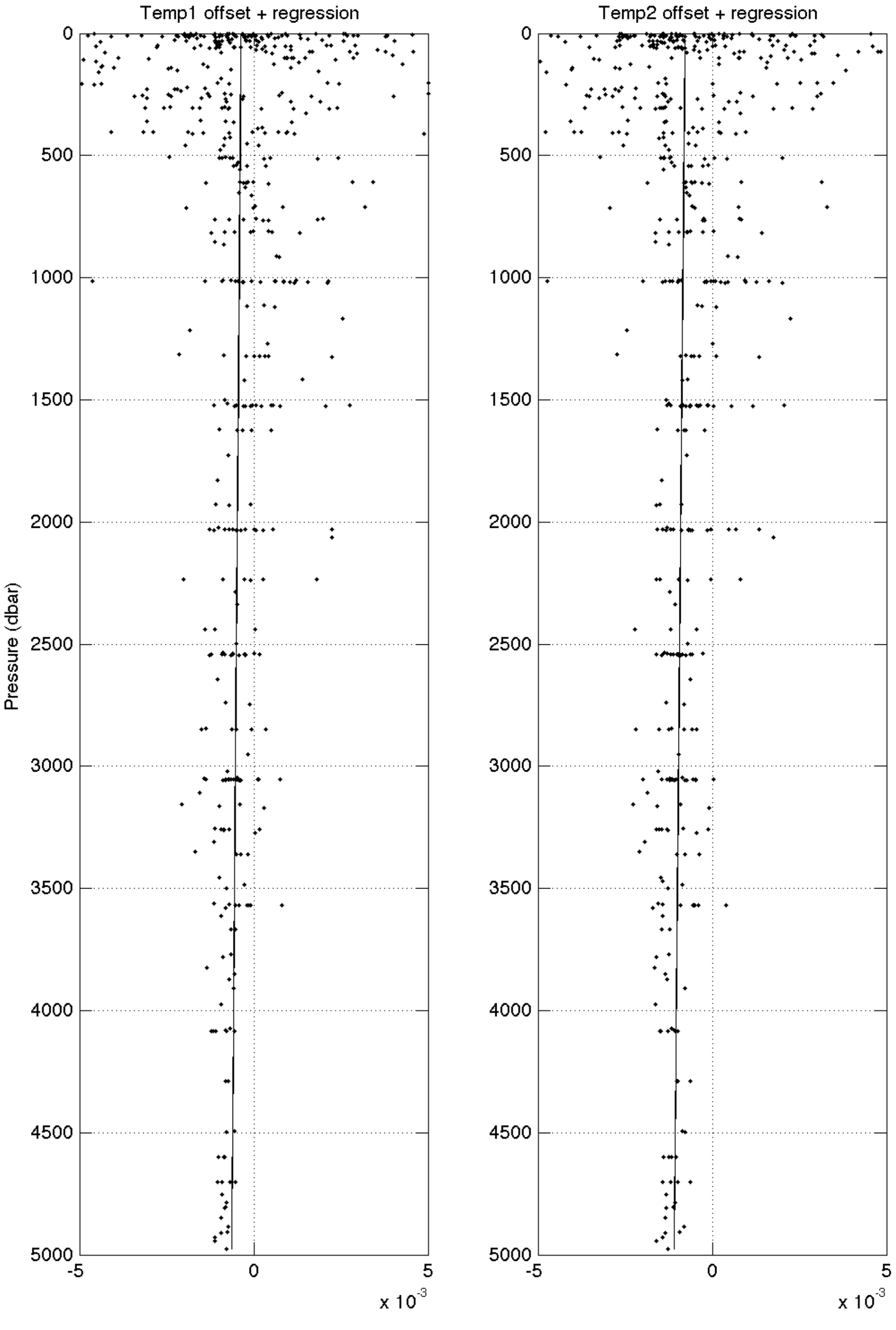

Figure 2.4: (Left) Primary temperature offsets versus pressure, and (Right) secondary temperature offsets versus pressure. Also shown are best-fit linear regressions for the data shown. There is no significant dependence on pressure of the temperature offsets for either CTD sensor.

2.5.2. Conductivity calibration.

Figure 2.5 shows the offsets (bottle-minus-CTD) between conductivity determined from discrete salinity samples (see Chapter 3) and primary and secondary CTD conductivity. The upper two panels show these for all depths as a function of station number; the lower two panels are for depths below 1000 dbar only. Figure 2.6 shows the same properties, but with station averages used instead of all samples. For each of the panels showing data from the secondary sensors, the black dots represent the initial secondary sensor used (up to station 14), whereas the red dots represent the replacement secondary sensor (station 17 onwards). See “Issues” below for details of this switchover.

There is no evidence for changes over time of the conductivity offsets for either primary or secondary conductivity, with the exception of when the secondary conductivity cell was replaced. It is clear that the replacement secondary conductivity cell has a smaller offset than the initial secondary conductivity cell when all the water column is considered (second panel), but this pattern appears reversed when only depths below 1000 dbar are considered (bottom) panel. This is indicative of pressure dependence in one or both of the secondary conductivity cells used. The primary conductivity cell shows no significant evidence of this effect in Figures 2.5 or 2.6.

Possible temperature dependence of conductivity offsets was examined, but found to be insignificant. Instead, the dependence of the secondary conductivity cells on pressure was confirmed by examining the conductivity differences in offset/pressure space (Figure 2.7, right panel). Conversely, the dependence of the primary conductivity on pressure was found to be negligible (Figure 2.7, left panel).

Corrections to be applied to the CTD conductivities were determined:-
- Primary conductivity: 0.9104e-3
- Initial secondary conductivity: 2.8923e-3 – (0.7285e-6*pressure)
- Replacement secondary conductivity: 0.6940e-3 – (0.6751e-6*pressure)

These corrections were applied, and the processing was re-run (in batch mode) from the stage of *salcalapp15006* onwards to re-derive all variables that depend on conductivity. Calibrated CTD files were put in a directory “CTD_data_matlab_calibrated” on the legwork/linux system, to differentiate from the uncalibrated data (left in directory “CTD_data_matlab”). Calibrated bottle files were named *JR15006_XXX.sal.cal.*

The impact of the conductivity calibration on secondary salinity is demonstrated in Figure 2.8, which shows the difference between uncalibrated and calibrated salinity along the A23 repeat hydrographic section. The different calibrations of the different secondary sensors used show as a marked change between stations 14 and 17. The depth dependence of both calibrations is clear.

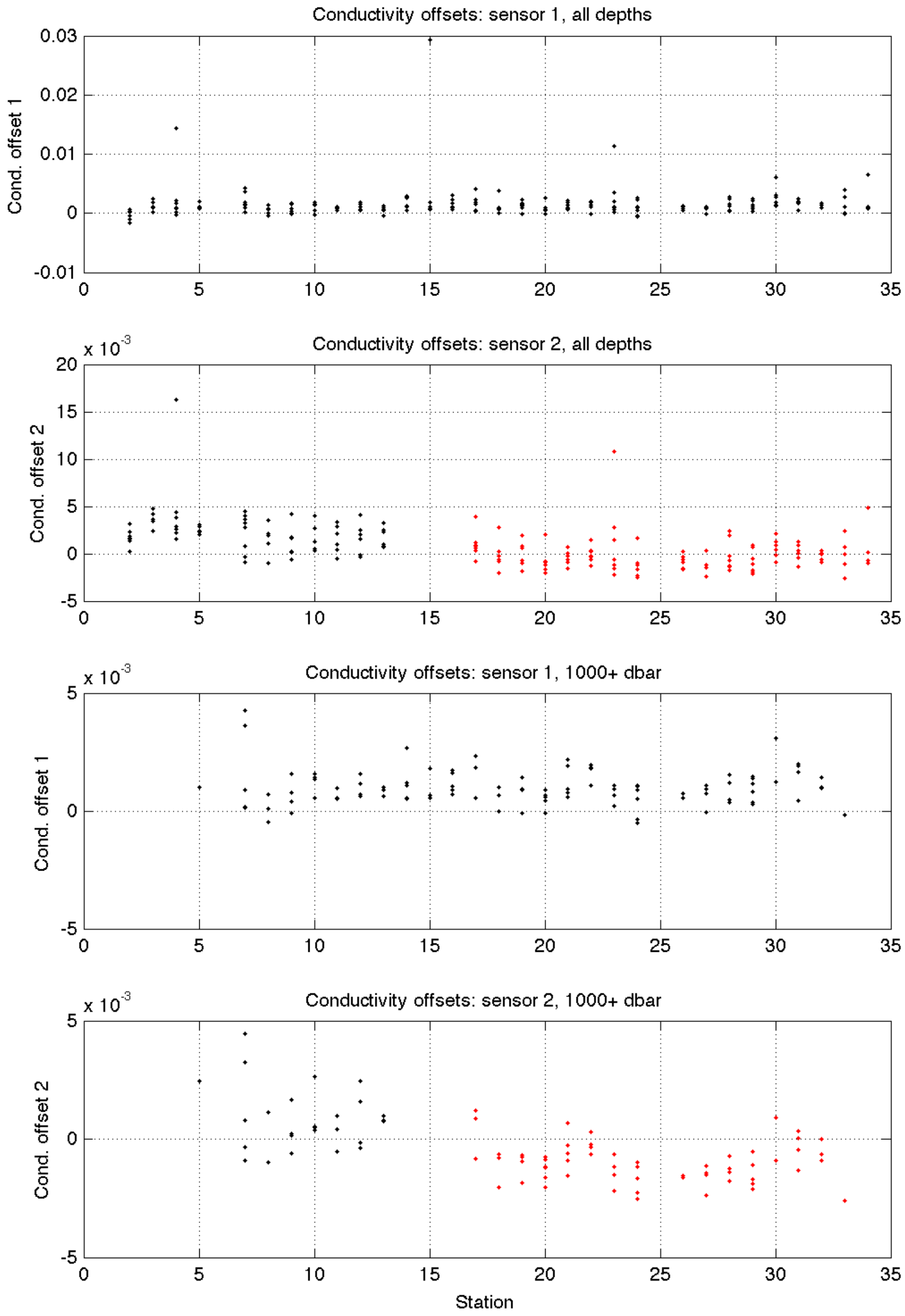

Figure 2.5: Offsets between conductivity determined from bottle salinities and primary and secondary CTD conductivities. Upper two panels are for all data; lower two are for depths below 1000 dbar only. All panels show data plotted versus station number. No stations after the end of the A23 hydrographic section are used, being much shallower (shelf/bay waters).

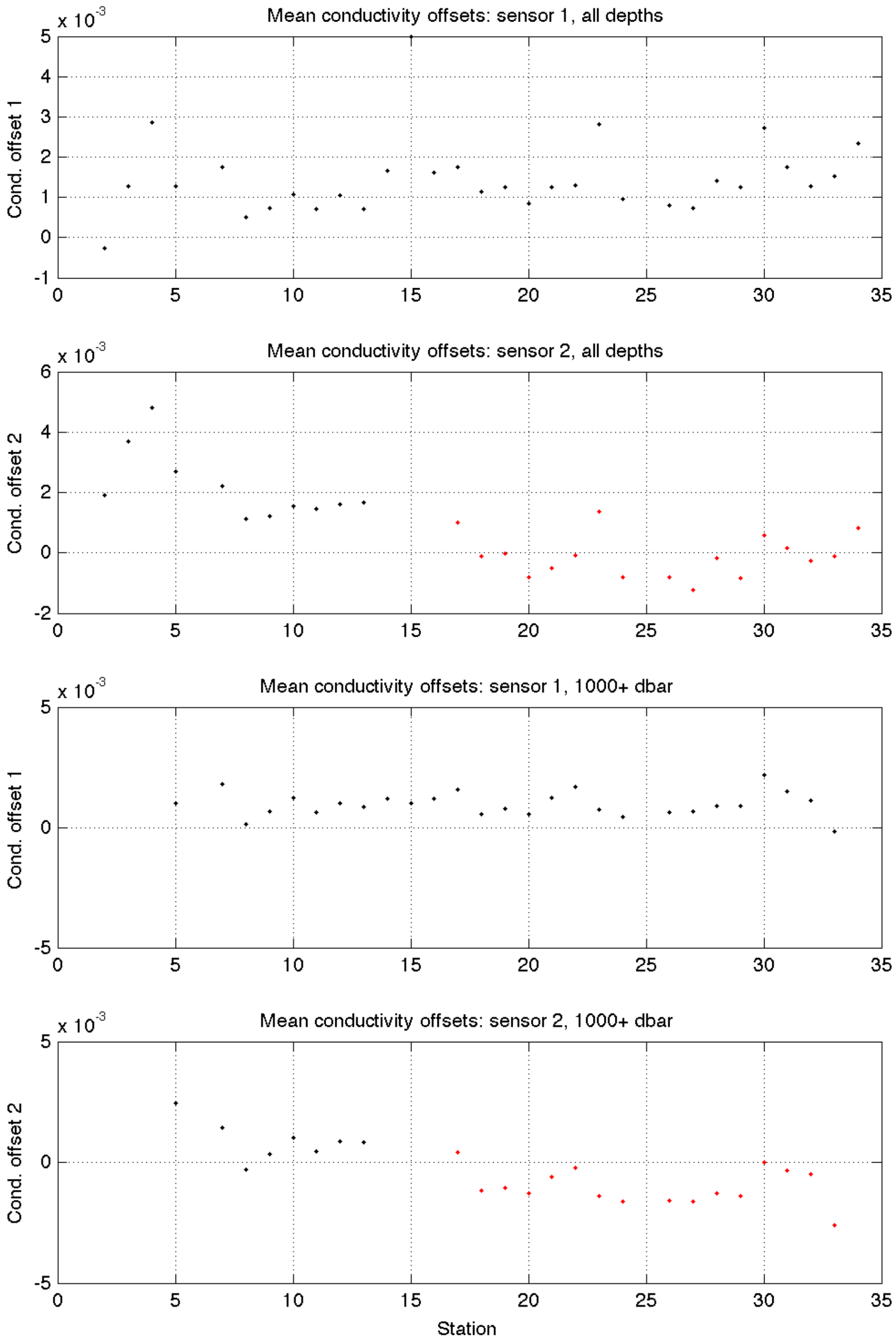

Figure 2.6: As per Figure 2.5, but for station-mean values rather than all data.

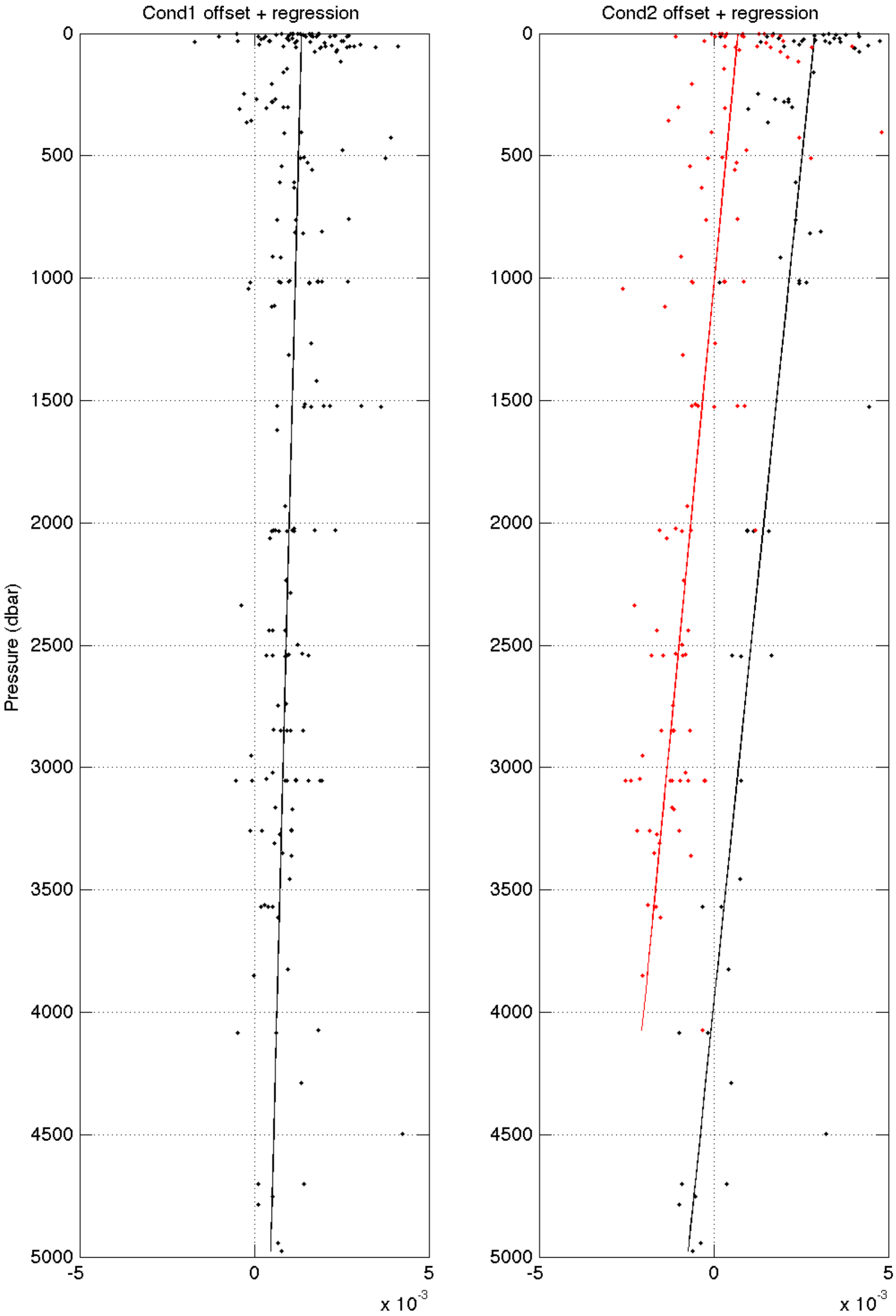

Figure 2.7: Conductivity offsets for (left) bottle-minus-primary CTD and (right) bottle-minus-secondary CTD, as a function of pressure. Lines denote best-fit linear regressions through the data. Regressions are calculated separately for the initial secondary conductivity (black, right) and the replacement secondary conductivity (red). The primary conductivity offset shows insignificant dependence on pressure, whereas both secondary conductivity offsets show significant dependence.

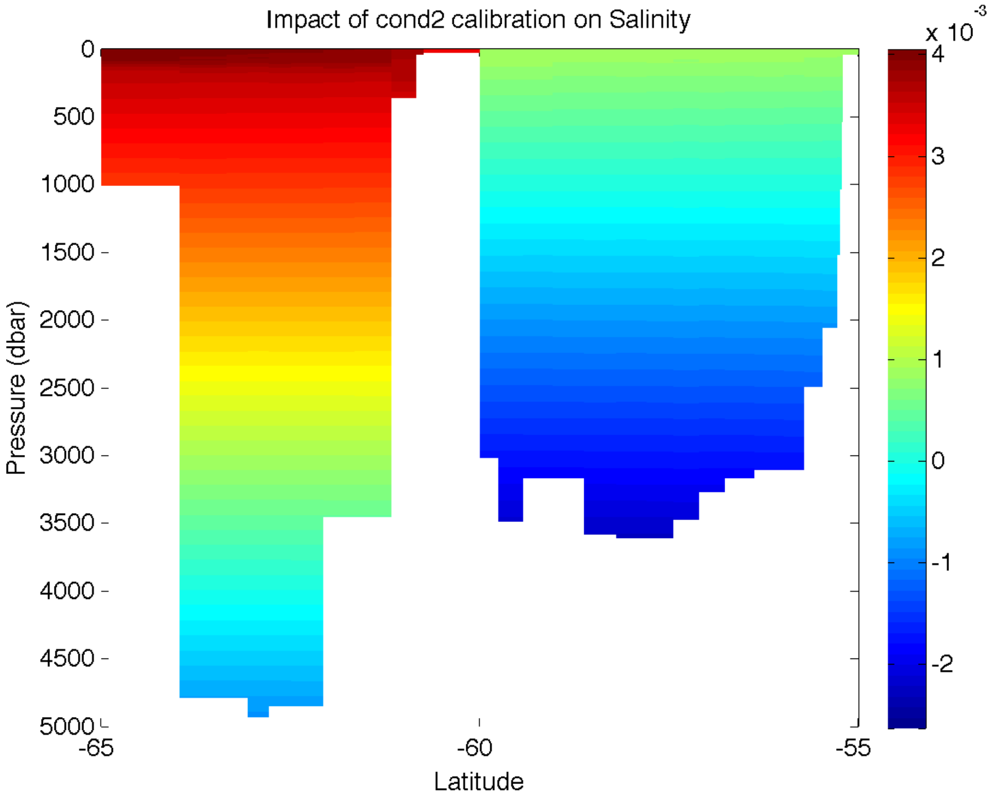

Figure 2.8: The impact of the conductivity calibration on secondary salinity, as illustrated by the data along the A23 repeat hydrographic section.

2.6 Issues and Points of Note

There were a number of events on JR15006 that led to instances of poor or missing data. The first of these occurred on the test CTD (cast 1), when large-amplitude wake effects were observed in the data. These are not uncommon: as the package is lowered, it can pull a wake of water behind it, and variable speed in its downward trajectory can lead to these spilling around the package from above and impacting on the levels at which the sensors reside. In effect, this leads to the CTD measuring water from a height above its actual depth, and water through which it has already travelled.

An example of a section of data affected by this process is shown in Figures 2.9 and 2.10. The former of these shows pressure against scan number (sampled at 24 Hz); sections marked in red are those flagged as uncontaminated by the *fallrate15006* routine, those marked in black are flagged as contaminated. It is clear that the routine does a good job of identifying periods when the package had stalled or risen in height. The impact on density is shown in the latter of these plots, with sections of data coloured black (contaminated) or red (uncontaminated) as above. The *fallrate15006* clearly performs well at excluding some erroneous data, however much of the data that is left shows unrealistic steps and shifts in density. The parameters within *fallrate15006* were varied, and lesser or greater quantities of data can be excluded/retained, however the underlying profile will always include the unrealistic shifts, and the choice becomes one of simply deciding how to subsample this.

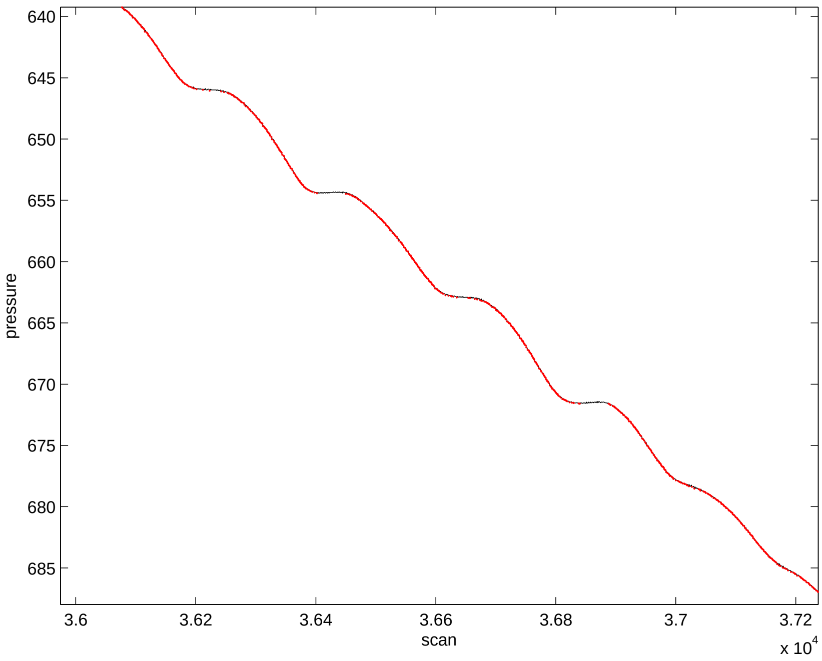

Figure 2.9: Pressure versus scan number for a section of data from the test CTD (cast 1). This CTD was conducted in rough seas, and the ship was rolling heavily; this motion was transmitted to the CTD package as strongly varying descent speeds, with instances of stalling or reversals.

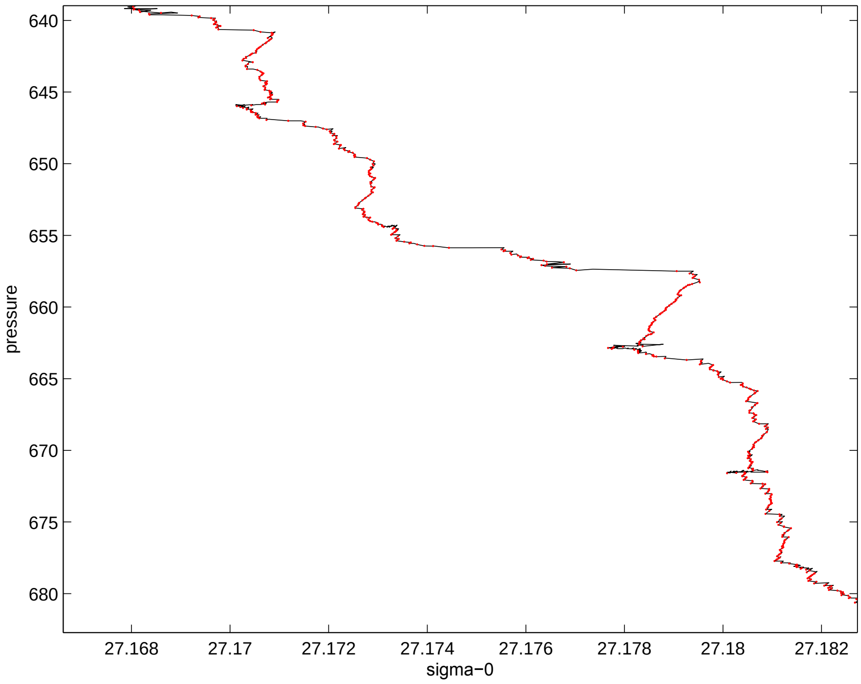

Figure 2.10: As per Figure 2.9, but for density instead of scan number.

The test CTD (cast 1) was conducted in rough seas, when the ship was rolling heavily. However, it was not the only CTD to be affected by the process during the cruise. Dialogue with the bridge helped somewhat, and we are grateful for their efforts to keep the ship bow-to-swell (as opposed to bow-to-wind) during CTD casts. Nonetheless, data from some other casts can be seen to be affected, e.g. from the Scotia Sea (Figure 2.11).

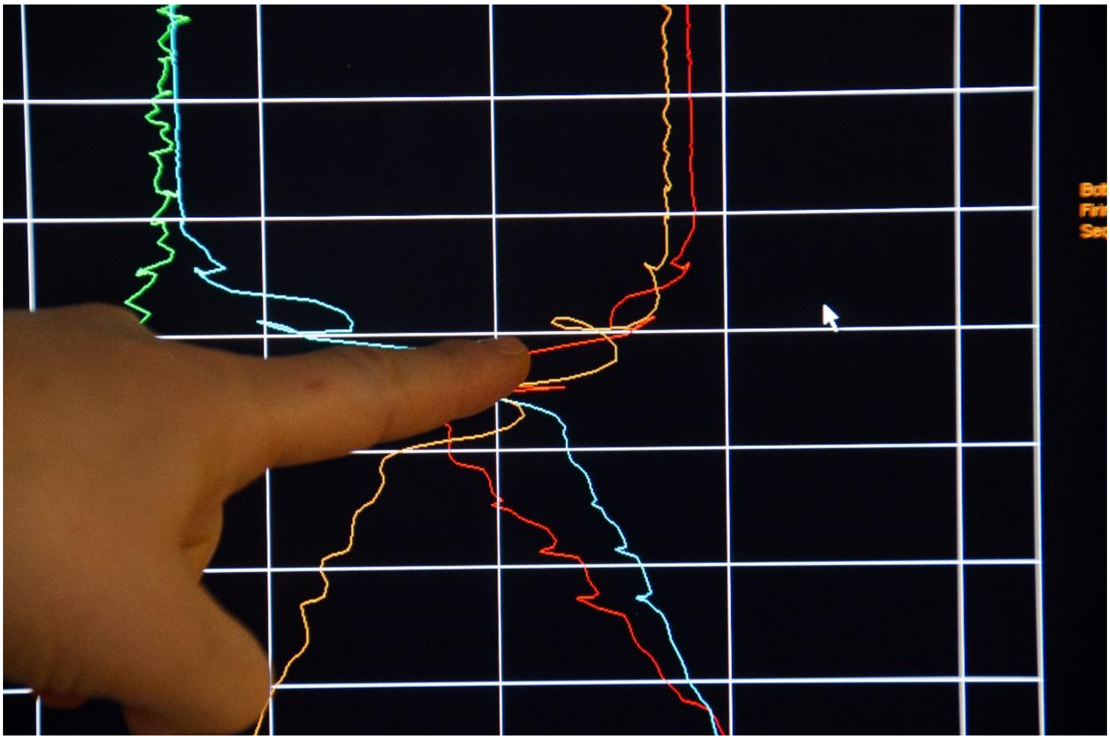

Figure 2.11: SBE Seasave software display for the downcast of a CTD in the Scotia Sea. Heavy rolling of the ship caused some strong reversals in the data, including some remarkable loops.

A further instance of poor/missing data commenced on CTD cast 14. For unknown reasons, the secondary conductivity sensor developed an unrealistic offset at the bottom of the downcast. It continued to function and return data, but with clearly erroneous absolute values on the upcast (Figure 2.12). This conductivity sensor was replaced with a new unit prior to cast 17. Secondary conductivity for the upcast of station 14 and all of stations 15 and 16 were flagged as missing in the final files.

A final instance of note was CTD cast 25. The loss of data here was more readily explainable: the CTD package made contact with the seabed at the bottom of the downcast. Data from the primary sensors were clearly affected on the upcast, but the secondary sensors seemed unaffected. After cleaning and testing, it appeared that no significant damage had been sustained, and the calibrations appeared unaffected, so the decision was taken not to replace sensors. Upcast data from the primary sensors on station 25 were flagged as missing in the final files.

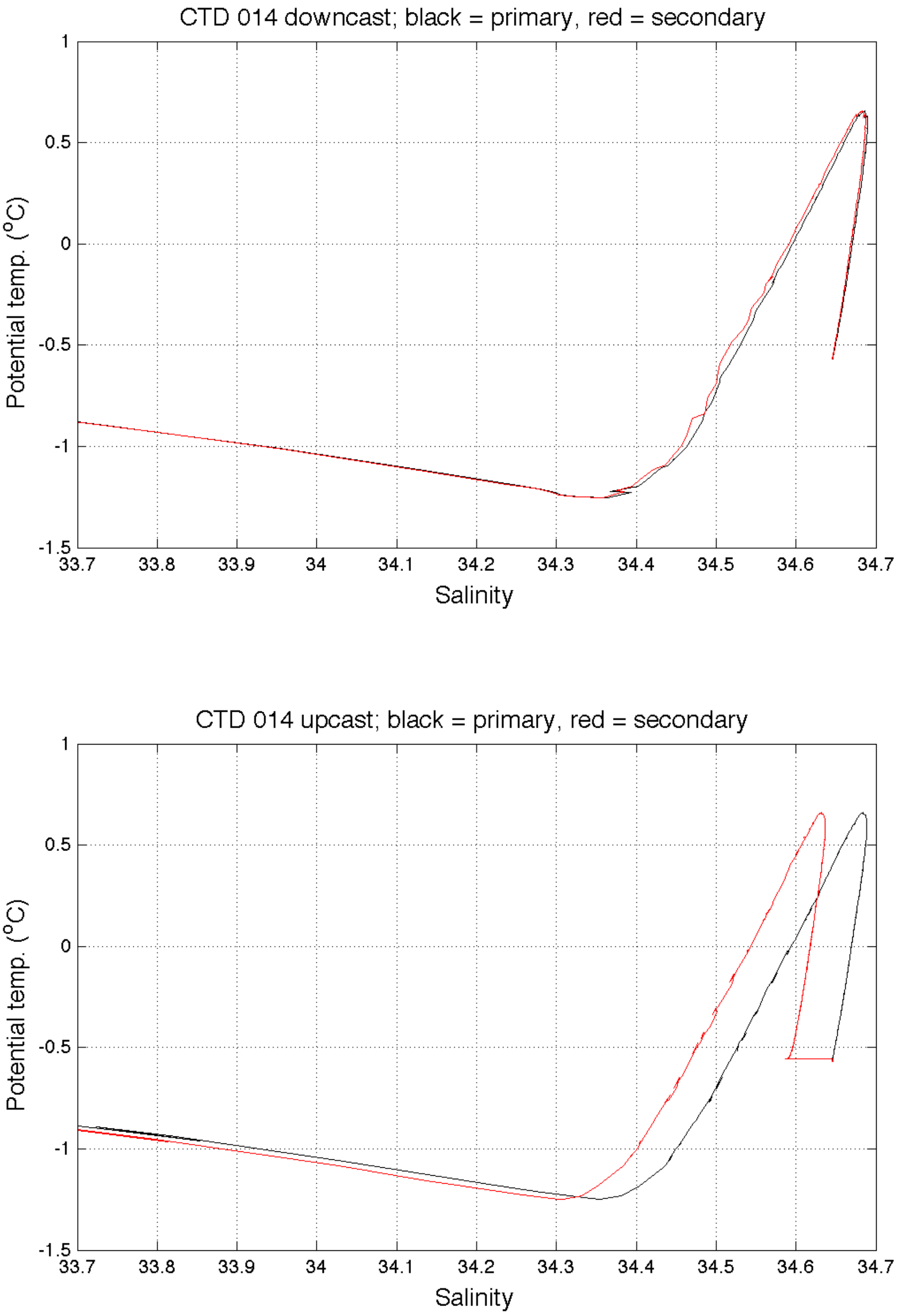

Figure 2.12: Upper panel: downcast profiles of potential temperature versus salinity for both primary (black) and secondary (red) sensor pairs from station 14. Lower panel: as per upper panel, but for upcast data. Note the sudden offset in secondary conductivity that commenced at the start of the upcast.

2.7 Example data

Potential temperature and salinity from along the A23 repeat hydrographic section occupied on JR15006 are shown in Figures 2.13 and 2.14 respectively. Such data will be explored scientifically in the months and years to come, however similarities and differences with previous occupations of this section are already apparent. The traditional water masses and features are all present, including Weddell Sea Bottom Water (colder than -0.7° at depth) and Weddell Sea Deep Water (potential temperature between 0 and -0.7° at depth), and a near-surface temperature minimum associated with the previous winter’s mixed layer (the so-called Winter Water). The Southern ACC Front occupies its customary position close to the slope of South Georgia. A second strong front is apparent in the data close to 59°S; close examination and comparison with LADCP data reveal this to be an eddy-like feature. A further, very narrow eddy is apparent close to 57°S; these are relatively commonplace on this section (and also on the south side of the Drake Passage SR1b section), with one or two examples being typically observed each year.

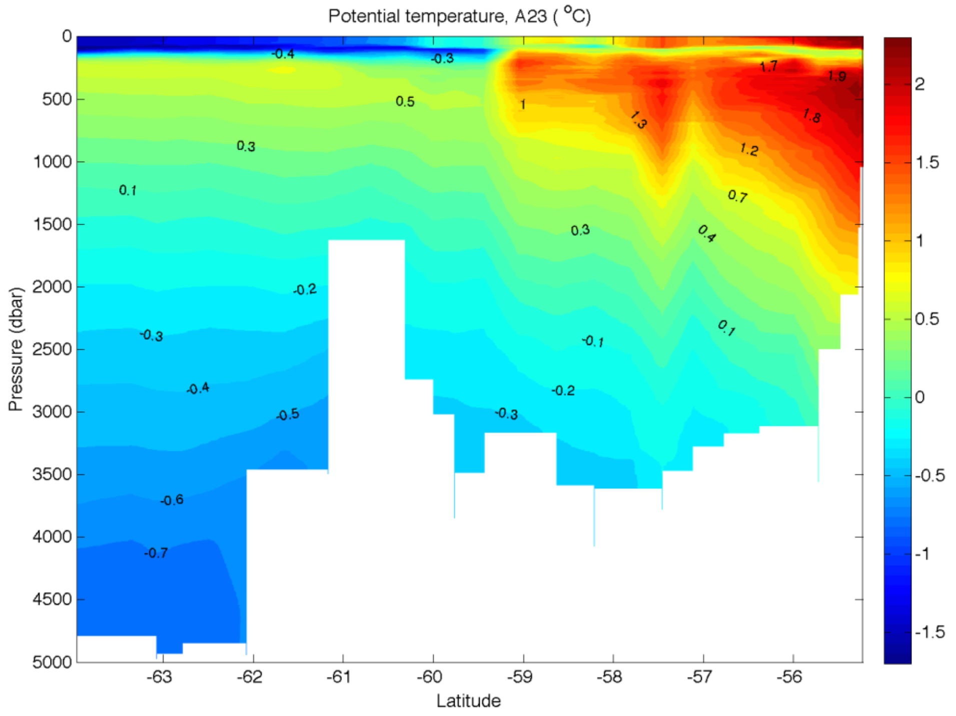

Figure 2.13: Potential temperature along the A23 repeat hydrographic section across the Weddell and Scotia Seas. South Georgia is located at the right edge of this figure; the topographic feature close to 61°S is the South Scotia Ridge.

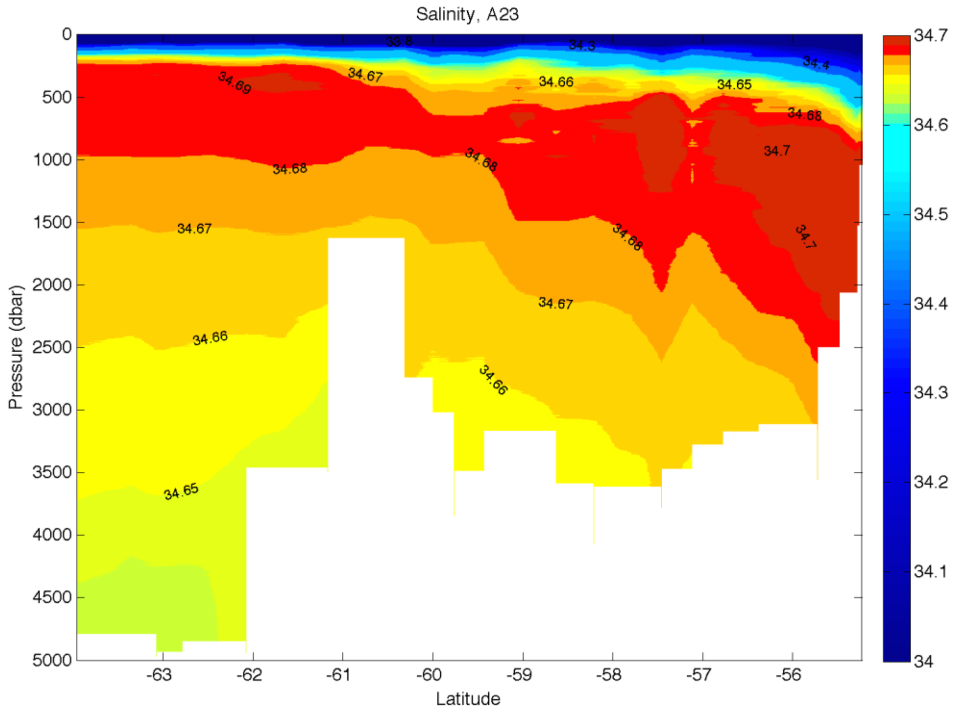

Figure 2.14: As for Figure 2.13, but for salinity rather than potential temperature.

Further example data is shown in Figures 2.15 and 2.16, with potential temperature and salinity sections shown across the entrances to Cumberland West Bay and Cumberland East Bay (left and middle panels respectively), and along the axis of Cumberland East Bay up to the glacier. Of particular note is that the surface water adjacent to the glacier is markedly cool and fresh compared with surface water elsewhere, presumably as a consequence of injection of buoyant glacial meltwater. The freshwater lens extends virtually along the length of Cumberland East Bay, and it is interesting that the water immediately below this lens is the warmest across these sections.

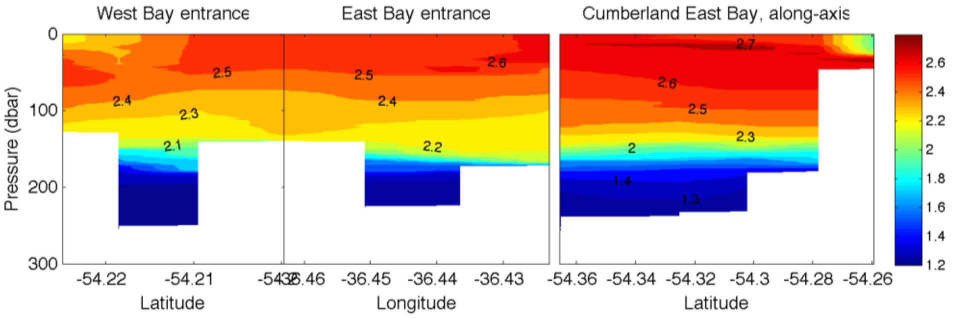

Figure 2.15: Potential temperature sections from Cumberland Bay, South Georgia. Left panel shows data across the entrance to Cumberland West Bay; middle panel shows data across the entrance to Cumberland East Bay. The right panel shows data along the axis of Cumberland East Bay, up to the glacier.

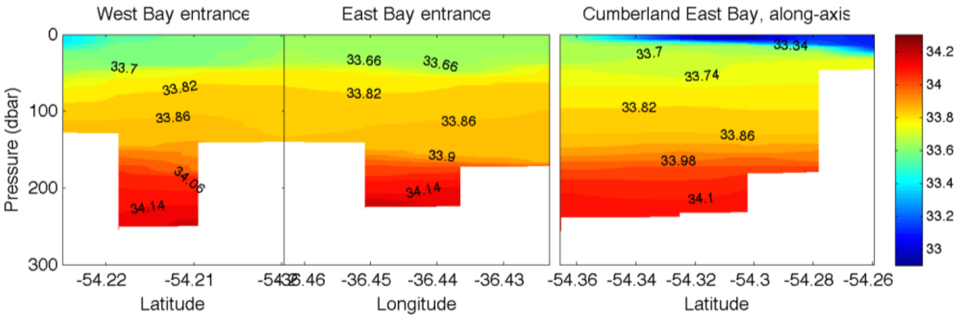

Figure 2.16: As per Figure 2.15, but for salinity rather than potential temperature.

2.8 Closing remarks

Despite the instances reported above that led to loss of data, overall the CTD system worked very well during JR15006, and a large quantity of high-quality data was produced. Our thanks are extended to all on JCR who enabled this, especially Dave, Martin, and the deck crew who deployed the system in all weathers.

In terms of how to approach using these data for science, our strong recommendation is to preferentially use the primary temperature and salinity data from JR15006, and use the secondary data only if absolutely necessary. There are a number of reasons for this:-

- stations 15, 16 and half of station 14 have missing secondary conductivity data.
- the calibrations for the secondary conductivity changed after the sensor was replaced, and there are fewer data available for determining each of these calibrations than there are for the primary conductivity.
- both secondary conductivity sensors used showed significant dependencies on pressure, and whilst these were accounted for in the calibration it is deemed preferable to use the primary conductivity which displayed no such behavior.
- the primary temperature sensor showed offsets relative to the SBE35 data that were smaller than the secondary sensor, with the latter only marginally smaller than the target accuracy.

3. Salinometry

Erik Mackie

On JR15006, salinity samples were taken from every CTD and also during the field and small boat work campaigns at Signy, South Georgia and the sea ice stations. Additionally, one salt sample was taken every 4 hours from the underway water system. The process for taking the salinity samples was the same in all cases: rinse the bottle 3 times, fill it up to the bottom of the neck, dry the top with blue roll, seal the bottle with a stopper, and then screw on the cap (which had also been washed and dried with blue roll). For CTDs, the number of salt samples taken was dependent on the depth of the cast: for deeper casts with the full 24 Niskin bottles fired, up to 8 salt samples were taken per cast, whereas on shallower casts with fewer bottles fired we only took between 4 and 6 salinity samples.

All salinity samples were then run through a Guildline Autosal 8400B salinometer. The Guildline Autosal 8400B measures the conductivity of a water sample with very high precision, in a water bath of known temperature. The readout is given as twice the conductivity ratio between the sample and standard seawater with salinity 35 PSU at 20ºC, and 1 atmospheric pressure (known as the Vienna Standard). The instrument (S/N 63360) was standardised at the beginning of the cruise and set to a reading of 589.5. Once the instrument had been standardised, it was left like this for the duration of the cruise.

Ocean Scientific International Ltd (OSIL) standard seawater (batch numbers P156 & P158) was used to provide calibration readings at regular intervals: before each crate of 24 salt samples and after each crate so that corrections could be applied to the intermediate measurements. Standard procedure was to gently invert each sample/standard bottle a few times in order to mix the contents but avoid the introduction of a large number of air bubbles into the sample. Before the analysis of each sample, the system was flushed (i.e. flooded and drained) three times with the sample, to remove any traces of the previous sample. The same was done with the standards. At least three readings were taken from each sample/standard bottle. Care was taken to allow sufficient time for the readout value to stabilise on a final value. The mean reading was then taken as the accepted value. From these conductivity ratios, the practical salinity of the sample could be calculated using the equation of state from UNESCO (1978). The measurements were loaded into an Excel spreadsheet, where salinities were calculated. One spreadsheet was created per CTD station, or other event (Field/Boat/Underway), which also included further information about the station/event such as location, date, time, station number, and Niskin bottle numbers (for CTDs). The CTD station spreadsheets were then used for calibration purposes in the CTD data processing.

It was important to keep the salinometer room at a constant temperature, which should be as close as possible to, but not exceed, the temperature of the salinometer's internal water bath. The water bath was set to a temperature of 24ºC and the room temperature was kept between approx. 21.5ºC and 23.5ºC. To monitor the room temperature, two thermometers where positioned on either side of the salinometer and their readings where checked every 4 hours as part of watchkeeping duties. Scientists were also instructed not to use the salinometer room as a thoroughfare to prevent a draught from adjacent rooms which could compromise a constant room temperature. On a few occasions it was necessary to prop the doors to the salinometer room open to prevent the room from overheating. This mainly happened when there were several people in the room at once, and their body heat increased the room temperature noticeably. All crates of salinity samples were left in the salinometer room for at least 24 hours before being analysed, to give them time to acclimatise to the room temperature.

When the salinometer was not being used, it was flushed with and then left in milliQ, to avoid the buildup of salt crystals in the system. Before each new use, the system was flushed multiple times with an old standard, so as to remove any traces of milliQ before reading a new standard. Some of the samples we ran were of extremely fresh water (e.g. glacial meltwater), so for these samples the system was flushed with milliQ to remove any traces of salt water before taking a reading.

Overall, the salinometer performed well, however we did have some problems with the readings drifting during measurement sessions. This was particularly noticeable in the readings of the standards at the beginning and end of each analysis session, which were often substantially different. The plot in Figure 3.1 shows how the readings for the standards (from batch P158) varied between sessions, for all the CTD casts along the A23 section (cast numbers 7 through to 34). The red lines indicate the start of a new session, with the date of the session indicated at the top. The value plotted by the blue dots is the anomaly between the salinometer readings for the standards, and twice the known conductivity ratio of the standard, which is 1.99940 for batch P158. It is clear from the plot that the anomaly was consistently smaller for the 2nd (or 3rd or 4th) standard reading at the end of each session, than for the first standard read at the start of the session. The average value between the anomalies at the start and end of each session was applied as a correction to the conductivity ratios of the CTD samples measured during that session, as indicated by the orange dots and respective CTD cast numbers. The largest difference in standard readings at start and end of a session was for CTD casts 23, 24 and 25, where there was a difference of 0.00006 between the standard readings and the average correction applied. This translates to an error in salinity of ±0.00077 PSU. On average, across all the CTD casts in the A23 section, the error in salinity was ±0.0004 PSU, which is better than the accuracy of the CTD salinity measurements.

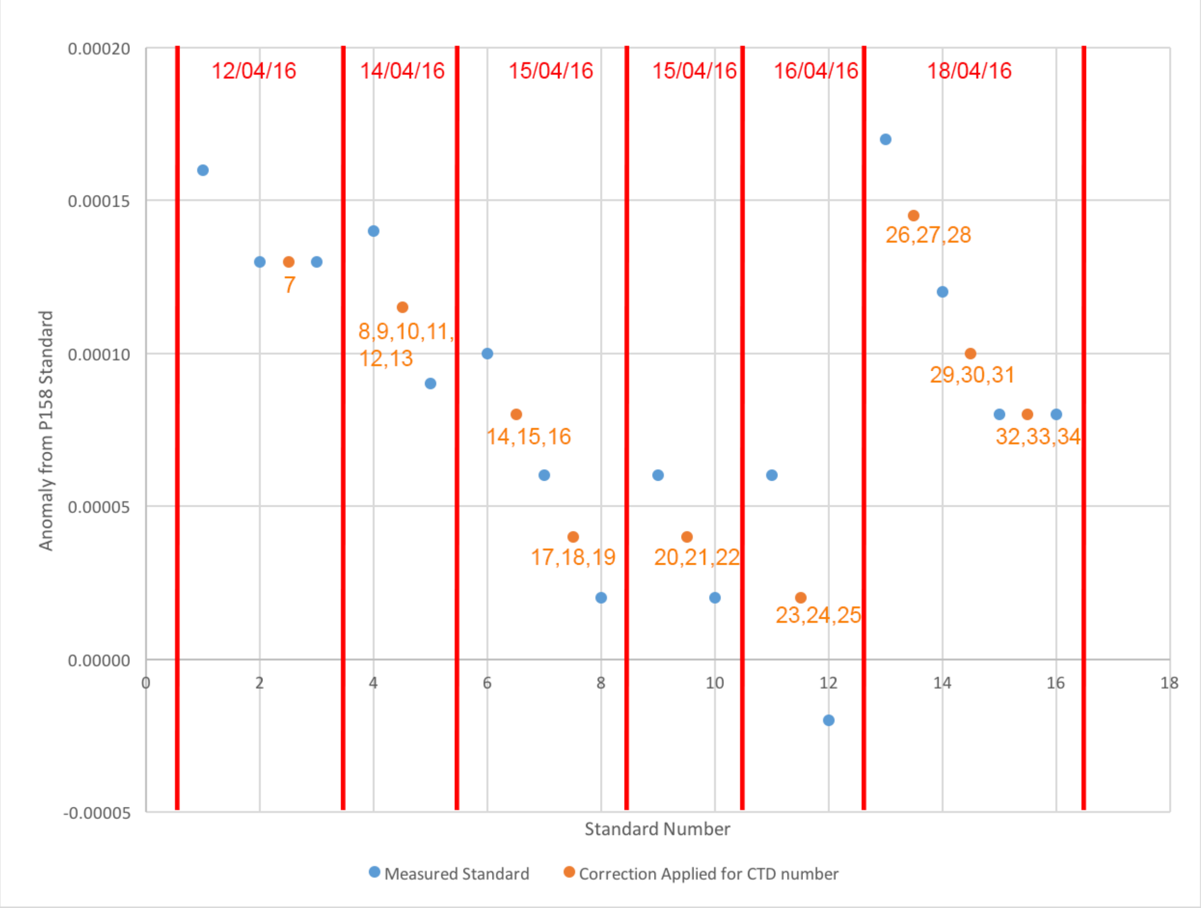

Figure 3.1: Anomaly between measured standards and twice listed conductivity for P158 for all CTDs along A23 section. Red lines indicate discrete sessions when the salinometer was run on a batch of samples.

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4. Lowered Acoustic Doppler Current Profiler

Andrew Meijers

4.1 LADCP Deployment

A single downward looking 300 KHz Workhorse Lowered Acoustic Doppler Current Profiler (LADCP) head was installed on the CTD rosette. The LADCP was connected via serial and charging cable to a BAS AME provided laptop setup in the Chem Lab where communication with the instrument took place using the BBTalk software. Prior to each deployment of the CTD a pre-deployment script (Table 4.1) was run and the operator checked that the instrument was behaving (i.e. the script ran to completion with no errors or failures reported) and logged several key parameters. The logging was largely designed to ensure the operator took note of key statistics; notably that the instrument internal moisture is acceptable (i.e. not leaking!), the battery has sufficient charge and that there is sufficient space on the internal memory card.

Command	**Details**
PS0	Display system configuration on screen
PA	Run pre-deployment test
PT200	Run built-in test (0-200)
PC2	Display results of user interactive test, 2= display sensor data
RS	Display memory card used/available space

Table 4.1: Pre-deployment script commands and explanations

Once the pre-deployment script was run and the CTD was near deployment (typically within 15 minutes) the deployment script (Table 4.2) was run and the serial/charge cable unplugged and the end cap installed. Upon CTD recovery this process was reversed.   BBTalk was used to end logging with a ‘Break’ command and the most recent file downloaded, renamed as necessary using the format JR15006_NNN.000 where NNN is the CTD number and backed up to the ship Legdata directory. Downloading was expedited by changing the baud of the instrument upload, which must be changed back after downloading is complete to allow two way communication again. At this point the instrument battery voltage was checked again and if needed it was put on to charge before its next deployment. A sample deployment logsheet is shown in Appendix A.

Command	**Details**
PS0	Display system configuration
CR1	Place instrument in factory default setup
RN JR15006	Set deployment name
WM15	Set water mode to LADCP
CF11101	Flow control: Automatic ensemble cycling, Automatic ping cycling, binary output, disabled serial output and enable data recorder
EA00000	Heading alignment 0 degrees
EB00000	Heading bias 0 degrees
ED00000	Transducer depth 0 m
ES35	Water salinity 35 psu. Used for sound speed calculations
EX00000	Coordinate transform. Set to 0 (radial beam coordinates). Transformation to earth coordinates done in LDEO-IX post processing
EZ0011101	Source of environmental sensor data. Manual speed of sound and depth. Heading, pitch and roll from internal source, salinity manually set, temperature from internal source.
TE00:00:01.00	Time per ensemble, 1 second
TP00:01.00	Time between pings, 1 second
LD111100000	LADCP data out. Output velocity, correlation, echo intensity and % good
LF0500	LADCP blanking distance. Moves first cell 5 m from transducer head

LN016	Number of bins set to 16
LP00001	Pings per ensemble set to one
LS1000	Bin size set to ten meters
LV300	Ambiguity velocity set to 300 cms^{-1}. Lower is better, but if package velocity relative to water exceeds this it can produce bad data.
LW1	Set to narrowband.
SM1	Set instrument as master
SI0	Synchronisation interval set to 0. I.e. no delay in sending pulse.
SA001	Synchronise before/after ping. Send (wait for) pulse before ping
SW05000	Synchronisation delay set to 5000 * 0.1 milliseconds (0.5 seconds).
CK	Saves setup to internal RAM. Must be second to last command.
CS	Starts deployment and must be last command. Ensure a carriage return is entered after this line in the deployment script or it will not execute.

Table 4.2: Deployment script commands and explanations.

4.1.1 LADCP deployment log

For CTDs 001-004 the pre-existing JR15003 deployment scripts were used (see relevant cruise report for exact details). Differences from the ultimately used script (Table 4.2) are described below.

For CTD 005 the settings were changed based on recommendations within the LDEO-IX processing software and Workhorse command manual. The main differences are the use of single ping ensembles at 1H (TE00:00:01.00 and TP00:01.00). This makes for simpler processing, but does increase the risk of previous ping interference (PPI). However PPI is thought to be less problematic in 300 KHz instruments. Also modified were the bin sizes (now 16 10 m bins) and there is now no coordinate transform done by the instrument (EX00000), as this can be dealt with in the post processing. LV is turned down to LV250. Based on the workhorse manual LV (ambiguity velocity) should be set as low as possible to attain maximum performance, but not too low or ambiguity errors will occur. The rule of thumb is to set LV to the maximum expected relative horizontal velocity between water-current speed and ADCP speed. Previously this was set to 400 cms^{-1}. As the ship will be stopped for LADCPs this is unlikely to exceed the new setting of 250 cms^{-1} even in ACC jets. This might even be turned down further for the fairly quiescent southern end of A23.

No LADCP data was recorded on CTD 010. This was traced to the lack of a carriage return on the end of the deployment script, meaning that unless the operator manually hit enter after initiating the deployment script the instrument would not begin logging. The script was modified after this to include an explicit carriage return so no operator involvement was required after initiating deployment.

From CTD011 LV250 was changed to LV300 due to warnings within the processing software that >2% of bins were being rejected due to ambiguity velocity errors on some casts. This was despite the relatively slow water movement, possibly due to CTD package drift/swing on these deep (~5000 m) casts.

4.2 LADCP data processing

LADCP raw data were saved to the local dedicated LADCP laptop after each cast, and then backed up to the ship server JRLB (Legdata). From here they were processed on the general scientific computing drive ‘Legwork’ using a code package fully written in matlab. This code was originally developed for the Lamont-Doherty Earth Observatory (LDEO) by Martin Visbeck and is now maintained and updated by Andreas Thurnherr. The most recent version of this software, (LDEO-IX.12) was downloaded before the voyage and used here. This software package calculates the LADCP velocities based on both measured shear as well as offering inversions that can incorporate information from any or all of the CTD, GPS and VMADCP data streams to constrain the overall solution. Full step-by-step processing guidance can be found in the LDEO-IX.7 – IX.12) notes made available online by A.M. Thurnherr (2016). The notes below detail cruise and dataset specific modifications made for JR15006.

4.2.1 Modifications to the LDEO-IX software

As is normal most modifications to the software were made in the 'set_cast_params.m' script. The main tasks of this script were to identify and load ancillary data streams to improve the LADCP inversion constraints, as well as to set both general and cast specific processing parameters. To incorporate CTD data each CTD cast had a 1Hz averaged version created (as opposed to the more normal 24Hz or 2 dbar average formats) for specific use with the LADCP software; as recommended in the LDEO-IX manual. These files, which were supplied by Mike Meredith in .mat format were then converted to the LDEO-IX required ASCII format in which CTD temperature, pressure and salinity are given as columns, with each row representing a single 1Hz scan. This was achieved with the custom written script for this voyage 'convert_CTD_to_ascii.m'. The CTD .mat files also contained synchronised NMEA GPS lat/lon and time streams, which were similarly converted to columns in the ASCII output file. set_cast_params.m read in the output file and assigned each column to its respective predefined LDEO-IX variable.

The VMADCP was read in as a .mat file (as required by the software). The LDEO-IX manual specifies a format and name for the time, latitude, longitude, depth, and u and v components of velocity variables. This formatting of the VMADCP .mat data files provided by Dan Jones was achieved using the custom script 'readin_VMADCP.m'. Notably this script sets the time format to Julian days, allowing the LDEO-IX software to extract out the cast relevant time slices from the continuous VMADCP data automagically. The exact format and process of formatting CTD, GPS and VMADCP data for LADCP processing is detailed in the LDEO-IX manual. The issues encountered in setting the offset angle in VMADCP processing (see Chapter 5) are not expected to present a problem for the LADCP, as small offset angles in the VMADCP only significantly impact measured water velocity when the ship is moving. As the ship is effectively stationary for CTD casts the error induced by this is expected to be negligible.

The script 'set_cast_params.m' was further modified on the advice of Andreas Thurnherr to use the first bin in data processing (p.edit_mask_dn_bins = [ ];), as the instrument blanking distance was set to 500 cm. This is opposed to his usual approach of setting the blanking distance to 0 but discarding the data from the first bin, but is supported by RDI.

4.2.2 Problems encountered

Only two issues appeared during processing. The first caused errors to be thrown during step 10 of processing, when super ensembles were being created. This error had the form:

```
Error using prepinv (line 679)
not enough data to process station

Error in process_cast (line 348)
  [di,p,d]=prepinv(d,p);
```

This occurred first on CTD 009 and in most subsequent casts until it was resolved, at which point all casts were reprocessed. A significant amount of time was spent trouble shooting before the data and processing scripts were sent to Andreas Thurnhurr for independent assessment. He was unable to replicate the error, suggesting that it was an issue with local software. Eventually this was traced to the fact that the instance of matlab being used automatically set a path to an unrelated directory of general utility scripts, as well as to the LDEO-IX software directory. Evidently there was an identically named but incompatible script in the utility scripts as in the LDEO software. Once the startup paths were removed the LDEO-IX software worked smoothly.

The other, minor, issue occurred on just two profiles. In step 7, finding the sea bed, CTDs 009 and 025 both produced errors of the form:

```
Error using process_cast (line 288)
Non-finite values in d.izm --- try processing with p.getdepth == 1
```

In both cases p.getdepth was set to one for these casts and processing proceeded well. CTD 025 contacted the bottom, so this may be the cause of detection issues in this case, but it is unclear why CTD 009 produced this error as it was otherwise unremarkable.

4.3 LADCP results

Preliminary results incorporating post processed and calibrated CTD data and uncalibrated VMADCP data for all CTD stations except CTD010 (where no data was collected) show reasonable results. CTD 045 had significant differences between the shear and inverse solution, while CTD 029 had a large up vs down bias. Other than these cases all casts appeared reasonable, with good agreements between the shear solution and full inversion, and generally good agreement between the up and downcasts. Figure 4.1 shows the zonal velocities from the A23 section by way of example.

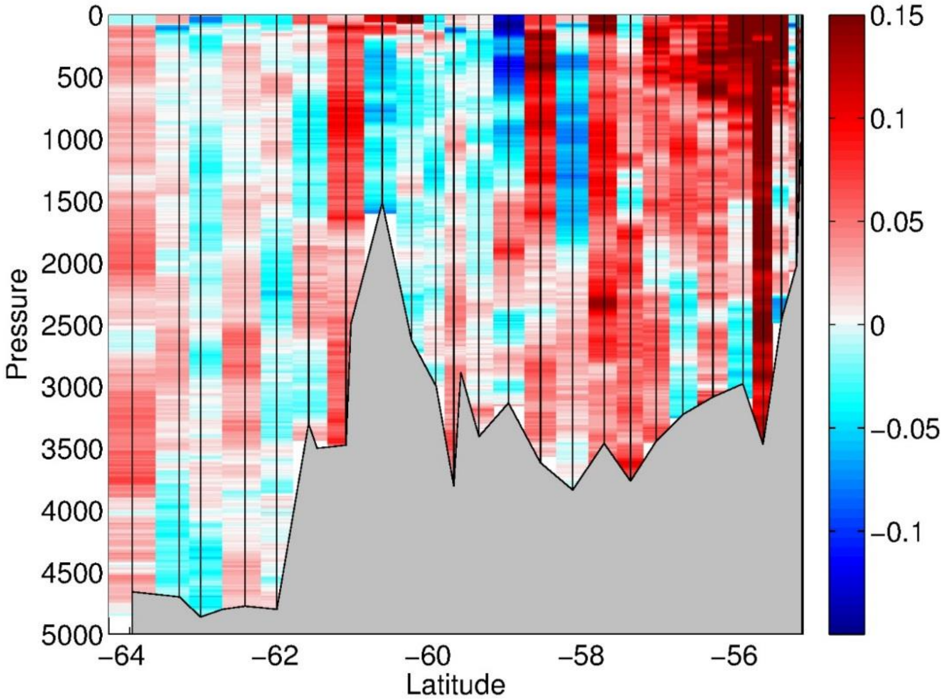


Figure 4.1: LADCP derived zonal velocities for the JR15006 A23 section (ms^{-1}).

The presence of the independent VMADCP velocities allows us to independently assess the skill of the LADCP inversions, which should theoretically be sufficiently constrained by the ship GPS position or bottom track alone. The RMS differences between VMADCP and the LADCP inversion explicitly excluding the VMADCP data (using the LDEO-IX command ps.sadcpfac=0) are shown in Figure 4.2. These show that the RMS difference between the datasets varies between 0.03-0.07 ms^{-1}, with a few profiles between CTD 014-016 reaching around 0.1 ms^{-1} and an overall mean RMS error of 0.049 ms^{-1}. This contrasts with the RMS difference between the VMADCP and LADCP inversion that includes the VMADCP data as a constraint. In this case the data sits around 0.01-0.05 ms^{-1}, with a mean RMS of 0.029 ms^{-1} across all casts. This relatively small change suggests that the addition of the VMADCP data improves the inversion, but not dramatically so. This is particularly the case for the shallow casts within Cumberland Bay (CTD 035-CTD 046) where due to the presence of bottom tracking over the entirety of a LADCP cast the addition of

VMADCP data does not change the inversion much at all. The reasonable agreement between these two independent data sets gives us confidence that the LADCP performed well on JR15006.

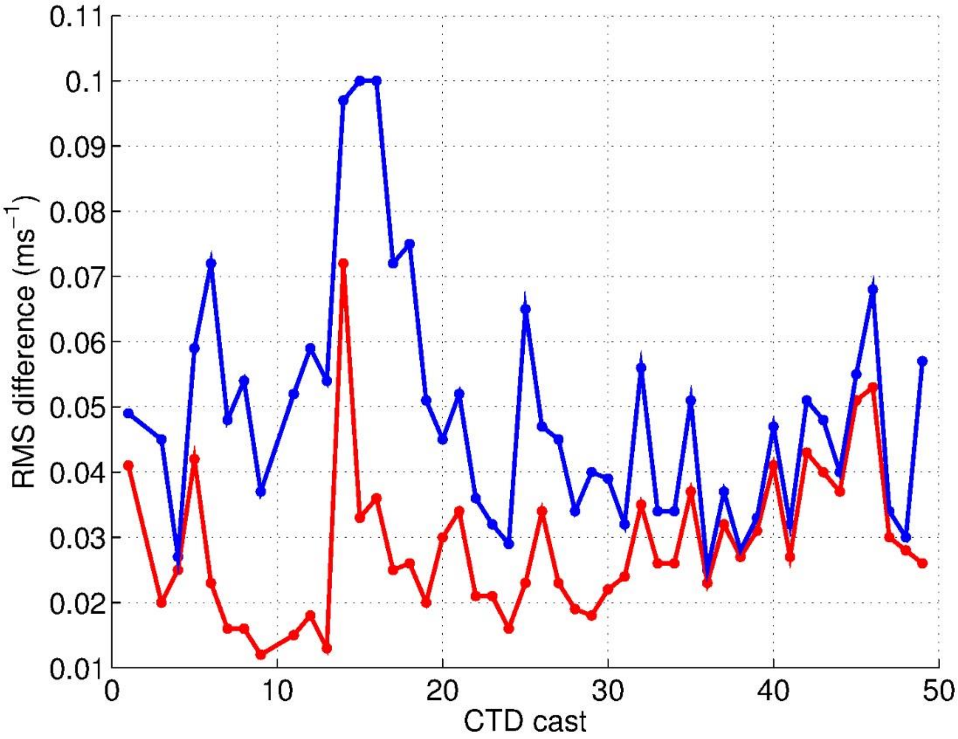


Figure 4.2: RMS difference between the LADCP inversion and VMADCP velocities for depths where they overlap at each cast for (blue) LADCP inversions excluding VMADCP data and (red) LADCP inversion including VMADCP data.

5. Vessel-mounted Acoustic Doppler Current Profiler (VADCP)

Dan Jones

5.1 Introduction

An Acoustic Doppler Current Profiler (ADCP) is an instrument that uses the scattering properties of sound waves to measure water velocities at different depths. The RRS James Clark Ross (JCR) is currently equipped with a Vessel-mounted Acoustic Doppler Current Profiler (VADCP) that measures water velocities below the ship. A computer in the Underway Instrument Control (UIC) room controls and collects data from the VADCP using proprietary software (VmDas3). The following sections describe how the VADCP was used on JR15006.

By any other name
The VADCP on the JCR is sometimes referred to as the Ship-mounted ADCP (i.e. the SADCP). Some documentation also uses the acronym VM-ADCP (for vessel-mounted ADCP).

5.2 Instrument and configuration

The ADCP mounted on the JCR is a 75 kHz RD Instruments Ocean Surveyor (OS75, model 71A-1029-00, SN 2088). Under ideal conditions (i.e. calm seas, bubble-free water, low noise, sufficient density of scattering targets), the OS75 can measure water velocity down to roughly 1000 m below the surface (in practice, usable measurements typically reach up to 800 m below the surface). We turned on the unit and started recording data on 31 March, as the JCR departed from Stanley, FI. We stopped and restarted the data logging approximately once a day to keep files to a manageable size for processing, but in practice the stopping and starting times varied considerably.

5.2.1 Installation

The OS75 unit on the JCR (installed August 2005) is located in the transducer space in the hull. This space is flooded with a mixture of 90% de-ionised water and 10% monopropylene glycol. Shortly after sailing for JR139, Chief Officer Robert Patterson estimated the hull depth to be 6.47 m. Since the distance between the seachest window and the transducer is 0.1-0.2 m and the window is 0.050 m thick, the transducer depth is 6.3 m. This is the value generally assumed, but the transducer depth can be deeper or shallower depending on how the ship's heavy cargo is distributed, which can change from cruise to cruise. The OS75 uses a phased array transducer that produces all four beams from a single aperture at specific angles. Because of the way that the beams are formed, horizontal velocities can be estimated independently from the speed of sound (this is not true for vertical velocities, which still require sound speed).

5.2.2 Control

The OS75 is controlled by proprietary VmDas software (RD Instruments, version 1.42). In addition to commanding the OS75, VmDas also collects, processes, and displays data from the instrument. VmDas is installed on the ADCP computer in the Underway Instrument Control (UIC) room, and it can be quickly configured by selecting from a collection of pre-existing "control files". Each control file contains a collection of commands that set things like bin size, transducer misalignment, and other quantities. An example of the commands used in a control file is shown in Table 5.1. For more information on the available commands, refer to the RD Instruments Ocean Surveyor manuals, especially the volume "Commands and Output Data Format".

5.2.3 Configuration during JR15006

We mostly used 100 bins, each 8 m in size, which gives a maximum depth of 800 m. Around

Signy Island, we used 30 bins, each 8 m in size, which gives a maximum depth of 240 m. Near South Georgia, we used 8 m bins down to 500 m. We ran the OS75 independently from the SIMRAD Synchronization Unit (SSU), i.e. the OS75 was set to use its own internal ping rate.

VmDas Command	Effect
CR1	Restore the ADCP to factory default settings
CB611	Set the data collection baud rate to 38400, no parity, 1 stop bit, 8 data bits
NP1	Switch on narrowband mode
NN100	When in narrowband mode, use 100 bins [at various times, we used 30 bins instead, for a maximum depth of 240 m. See Table 2 for details.]
NS800	When in narrowband mode, use 8 m bins
NF0800	When in narrowband mode, use 8 m blanking depth
W*	Broadband options [not used on this cruise]
BP00	Disable bottom tracking [at various times, we did use bottom tracking by running BP01 instead. See Table 2 for details.]
BX10000	Set maximum bottom search depth to 800 m (only used when bottom tracking is on)
WD111100000	Tells VmDas to output velocity, correlation, echo intensity, and percent good
TP000050	Allow half a second between bottom and water pings
TE00000100	Allow one second between ensembles (this is overridden by VmDas)
EZ1020001	Calculate the speed of sound, no depth sensor, external synchro heading sensor, no pitch or roll used, no salinity sensor, use internal transducer temperature sensor
EX00000	Tells VmDas to output beam coordinate data (rotations are done in software)
EA6008	Set transducer misalignment to 60.08°
ED00063	Set transducer depth (6.3 m on the JCR)
ES0	Set salinity (ppt) [salinity is zero in the transducer well]
CX0,0	Disable external trigger (e.g. from K-Sync or SSU)
CK	Save this setup to non-volatile memory in the ADCP

Table 5.1: Example SADCP command file

5.2.4 Data collection and storage

The ADCP data produced by VmDas is written to two places, specifically 1) a Samba-mounted UNIX network drive (i.e. legdata) and 2) a local drive on the ADCP control computer. The data files produced by VmDas can only be modified using the ADCP computer. From any other machine over the network, the files produced by VmDas are write-protected to prevent accidental deletion or modification.

5.2.5 Alignment

The OS75's transducer is aligned at approximately 60° relative to the centre line, which differs from the manufacturer-recommended 45° relative to beam 3. In the command files, we used the previously set transducer misalignment angle of 60.08° (i.e. the variable EA in the "Heading Correction" section, under the "Transform" tab of the program options in VmDas3).

5.2.6 Interference with other instruments

During the initial trials cruise in the 2005-2006 season, the operators noted that the OS75 interferes with most of the other acoustic instruments on the JCR, including the EM120 swath bathymetry system. To circumvent this, they synchronized the pinging of the ADCP (i.e. the timing of the pulses of sound emitted by the OS75 transducer) with the other acoustic instruments using the SIMRAD Synchronization Unit (SSU). However, the EM122 (swath bathymetry instrument) does not appear to interfere with the OS75. During this cruise, we set the OS75 to use its own internal ping rate, as opposed to taking ping instructions from an external source (e.g. K-Sync, SSU).

5.2.7 Bottom tracking

The VADCP can also be used to estimate the depth of the water column in relatively shallow waters (down to roughly 1100 m), which is referred to as “bottom tracking”. In deep waters, where the sea floor is deeper than 1000 m, the alternative “water tracking” setting (i.e. no bottom tracking) may be sensible. During JR15006, we mainly used water tracking, except 1) during the leg to Signy Island and 2) around South Georgia, when we used bottom tracking.

5.2.8 Narrowband versus broadband

The OS75 can be run in either narrowband (deep) or broadband (shallow) mode. Broadband mode offers higher spatial resolution in the vertical (i.e. smaller vertical bins), but it only measures relatively shallow depths relative to narrowband mode. During JR15006, we only used narrowband mode.

5.2.9 Previous cruises that have used the OS75

See cruise reports for additional documentation and alternative processing methods:

- JR135 (Stansfield 2006)
- JR161 (Hawker 2006)
- JR165 (Shoosmith/Renner 2007)
- JR193 (McCarthy and Venables 2007)
- JR177, JR200, JR218, and JR245 (Venables)
- JR235, JR236, JR239 (Renner)
- JR276 (Watson)
- JR281 (Sallée)
- JR299 (Meijers)
- JR310 (Azaneu)

5.2.10 Format of VmDas output

The ADCP control software (VmDas) creates data files containing ship navigation data, raw instrument data, and other logging information. The nine different types of file produced by VmDas are:

.VMO	VmDas configuration file (ASCII)
.LOG	log of ADCP communication and VmDas error (ASCII)
.ENR	beam coordinate single-ping raw data (binary)
.ENX	Earth coordinate single-ping data (binary)
.LTA	Earth coordinate long-term averaged data (binary)
.STA	Earth coordinate short-term averaged data (binary)
.NMS	navigation and attitude data (binary)
.N1R	navigation data from the ship’s Seatex GPS system (ASCII)

VmDas uses the same file naming convention for each file type:

CRUISExxx_000nnn.aaa,

where CRUISE is the cruise name (in this case, JR15006), “xxx” and “nnn” are counters/indices (explained below), and “aaa” is the file format (e.g. N1R, LOG). Each time you use VmDas to turn on data logging, the software creates a new set of files and the index in “xxx” increases by one. The index “nnn” is also just a counter, because VmDas is set to keep individual file sizes below 10 MB. The “nnn” index is only required if the data files get larger than 10 MB (which they often do). The “xxx” index starts from one (1) and the “nnn” index starts from zero (0).

5.2.11 Things to check regularly while the SADCP is pinging and logging

- ***.LOG files :** if the log file size gets larger than about 10 KB, then it could indicate that an error has occurred. Check the log file for errors (e.g. buffer overloads, timeouts and SADCP resets, problems with the navigation data stream).
- **Data file sizes :** the binary data file sizes should be increasing as VmDas collects data.
- **SADCP log :** it can be helpful to have a table/log sheet for quick reference, in case you want to look up settings for a particular recording sequence (see Table 5.2 for the JR15006 log).
- **GPS data :** check to make sure that VmDas is recording GPS data in the *.N1R files. You can compare this with the navigation repeater on the ADCP computer in the UIC.
- **PC clock** : the difference between the PC clock and the ship clock should be small (less than 0.5 s is typical). The $PADCP lines in the *.N1R files show the difference between the PC clock and the ship clock in seconds.

5.2.12 Errors as reported in the .LOG files

We noted several error messages during JR15006. None of these error messaged had an appreciable effect on the post-processed data.

- CX0,0 ERR: Bad command!
    - This is the “disable external trigger” command. Entering this command (via the scripts) only caused this error twice. It had no obvious effect on the operation of the ADCP or the post-processed data.

- NMEA [Nav] serial buffer full: Storing 300 bytes without processing.
    - Memory issue. This is usually followed a fraction of a second later by a “serial buffer level OK” message. It appears that some memory-management process quickly shuffles memory around when the buffer gets full.

- CScreenNav::ProcessNmea() - Invalid PRDID data.
    - Unclear. There is a Perl script running on the ADCP PC that converts navigation data into NMEA format. There were no obvious errors in the NMEA stream associated with these error messages. A previous cruise suggested that this happens when the ship’s heading angle is near 0°/360°. However, the error message occurs much less frequently than heading values of near 0°/360°.

- NMEA [Nav] communication timeout
    - This error was resolved when Andy England restarted the ADCP computer.

5.3 Post-processing using Matlab

The data acquired/recorded by OS75 via VmDas software needs to be post-processed in order to 1) ensure good data quality and 2) estimate the misalignment of the OS75 device, which can change from cruise to cruise depending on how the heavy cargo in the ship is distributed. On JR15006, we used a set of Matlab scripts for this post-processing. The scripts originally came from IFM Kiel and have been modified by a number of people over the years. The main m-file used during this cruise is named OS75_JCR_jr15006.m. For an introduction to the theory of calibrating shipmounted ADCPs, see Joyce (1989) and Pollard and Read (1989).

5.3.1 Description of how the Matlab scripts operate

Below is a brief description of what the Matlab code does during post-processing. For more detailed descriptions of each m-file, refer to cruise report JR235/236/239.

1. Read the selected .ENX files (Earth coordinate single-ping data; binary) and .N1R files (navigation data; ASCII) into Matlab

2. Remove missing data and data with bad navigation

3. Merge single-ping ADCP data with Seapath attitude data

4. Correct for transducer misalignment and velocity scaling error

    a. If you set “misalignment_nb=0” and “amplitude_nb=1”, then the scripts will *estimate* the misalignment and amplitude. Otherwise, the scripts will apply the misalignment and amplitude values that you provide by setting these two variables
    b. If you are operating in narrowband mode, it is fine to leave the variables “misalignment_bb=0” and “amplitude_bb=1”

5. Derive ship velocity from Seapath navigation data

6. Perform quality control, such that only the four-beam solution is permitted. Quality control also screens data based on maximum heading change between pings, maximum velocity change between pings, and the error velocity

7. Average the data into ensembles (120 seconds for JR15006)

8. Calculate transducer misalignment and velocity scaling error

    a. The ADCP transducer is slightly misaligned, and that misalignment can very from cruise to cruise. To say it another way, we don’t know the correct orientation of the *x*-*y* axes; it needs be calculated during post-processing. The correct velocity scale also needs to be calculated during post-processing.

    b. In order to calculate the correct scaling and reference frame orientation, the code solves a non-linear minimization problem described as follows:

        i. Bottom track (BT) mode: in the correct reference frame, any changes in the velocity of the ocean floor must come from the acceleration of the ship. So in the correct reference frame, the difference between the change in velocity of the bottom (as reported by the ADCP) and the change in velocity of the ship should be very small (i.e. within measurement noise and differing in sign).

        ii. Water track (WT) mode, we make the additional assumption that the water velocity in the reference layer is steady, i.e. it does not change appreciably on the selected averaging timescales. So in the correct reference frame, the difference between the change in velocity of the reference layer (as reported by the ADCP) and the change in velocity of the ship should be very small (i.e. within measurement noise and differing in sign).

        iii. The optimal reference frame is selected by searching for a local minimizer of the squared magnitude $|\boldsymbol{\delta u}|^2 = \delta u^2 + \delta v^2$, where $\boldsymbol{\delta u}$:

$$\boldsymbol{\delta u} = \begin{bmatrix}\delta u\\ \delta v\end{bmatrix} = A\begin{bmatrix}\cos(\alpha) & -\sin(\alpha)\\ \sin(\alpha) & \cos(\alpha)\end{bmatrix}\begin{bmatrix}\delta u_{ref}\\ \delta v_{ref}\end{bmatrix} + \begin{bmatrix}\delta u_{ship}\\ \delta v_{ship}\end{bmatrix} = \begin{bmatrix}\varepsilon_x\\ \varepsilon_y\end{bmatrix},$$

where α is the misalignment angle (independent variable), *A* is the amplitude scaling factor, and the velocity increments are for the reference layer (in water-track mode) or the bottom (in bottom-track mode) and the GPS-derived ship velocity (δu_{ship}). The increments are between two averaging periods, and the 2x2 matrix represents a coordinate transformation (for positive α, it is a clockwise rotation of the coordinate axes). If the assumption of no-motion holds (see above), and if we have chosen the correct reference frame, then the change in velocity should be zero within measurement error (i.e. $\boldsymbol{\delta u} = \boldsymbol{\varepsilon}$), where $\boldsymbol{\varepsilon}^T = [\varepsilon_x \quad \varepsilon_y]$.

Q: Why is the ship velocity change added and not subtracted?

A: Consider the limiting case of a motionless ocean and a changing ship speed of +1.0 m/s. The ADCP will detect a water speed change of -1.0 m/s. So you *add* the change in ship speed to the (rotated, scaled) Doppler-detected change in speed in order to calculate the change in water speed (which in this limiting case is zero).

9. Discard velocities from depths deeper than 86% of the bottom-tracking depth (i.e. set to missing)

10. Determine water velocities (referred to as “absolute velocities”) from either bottom-track ship velocity or Seapath GPS (usually the latter)

11. Plot eastward and northward velocities

5.3.2 Getting started

For processing data for a specific cruise, check the following variables in your main script (for JR15006, the main m-file is named OS75_JCR_jr15006.m):

- **RAWPATH**: should contain the location of the raw data produced by VmDas. This typically sits on a network UNIX drive called “legdata”.
- **PATH**: should contain the location where you want the processed data to be saved. Usually this is saved on the “legwork” drive.
- **filename**: for this cruise, filename='JR15006000_000000'.
- **cruise**: in this case, ‘JR15006’
- **files**: a vector of numbers indicating the files you want to process. Use the “xxx” counter/index in the VmDas filenames to select the ones you want. These selected files will go into the final average file.
- **superaverage**: interval (in s) over which the ping ensembles will be averaged
- **YYYY**: year
- **ref_uplim** and **ref_lowlim**: upper and lower limits of the reference layer. For JR15006, we used ref_uplim = 400 m and ref_lowlim = 600 m.
- **misalignment_yy**: the misalignment of the OS75 unit, which is determined iteratively during post-processing. Here “yy” is either “nb” for narrowband or “bb” for broadband.
- **amplitude_yy**: the scaling factor for post-processing, which is also determined iteratively during post-processing. As with misalignment, “yy” is either “nb” for narrowband or “bb” for broadband.

For a detailed description of the routines in the ADCP Matlab post-processing toolbox, see the ADCP section of the cruise report for JR235/JR236/JR239.

5.3.3 Output files

The final data is stored in Matlab format (*.mat). Below is a brief description of the output files:

- JR15006_cal_pts_wt.mat

  - Contains misalignment angle (phi) and amplitude scaling (scaling) statistics.

- JR15006xxx_000nnnd_att.mat
  - Contains ship's attitude data

- JR15006xxx_000nnn_raw.mat
  - Contains ensemble-averaged data and absolute velocities

- JR15006xxx_000nnn_sgl_ping.mat
  - Contains single-ping data in a structured array

- JR15006xxx_bad_nav.mat
  - Contains counts of bad navigation points

- JR15006xxx_bad_heading.mat
  - Contains counts of bad heading points

- **JR15006000_000000_xxx_abs.mat**
  - Contains absolute horizontal velocity (i.e. water velocity), navigation data, bin depths
  - These files are grouped by segment "xxx"
  - **Use this file to plot results**
  - **This file can also be used during LADCP processing**

5.3.4 Dependency issues

One of the quality control scripts uses "mfilter", a function that requires Matlab's Signal Processing Toolbox. We had to use the version of the quality control script that does not require mfilter.

5.3.5 Results

We performed both bottom-track and water-track calibrations for comparison, with mixed results (see Table 5.2 for results). Although we do have some bottom-track (BT) data for this cruise, the BT calibration statistics are not ideal (e.g. long tails, big gaps, very large standard deviations). Applying the BT median misalignment and amplitude results in rather "stripy" data (i.e. vertical stripes with lots of changes in velocity due to the ship's acceleration). We have substantially more water-track (WT) data than BT data, so the calibration statistics are cleaner (e.g. distributions closer to Gaussian, smaller standard deviations), but the WT-corrected data is also rather "stripy". Unfortuantely, the WT and BT calibrations give very different results for the misalignment angle, and it is unclear which one is correct. The BT value is closer to results from previous cruises, but it is possible that the ADCP may have been touched/moved during the recent refit of the JCR. We have included both WT and BT-calibrated data for this cruise.

Selection	Files used	No. of points	**Amplitude**			**Misalignment angle**		
			Mean	Median	Standard deviation	Mean	Median	Standard deviation
Water-track (WT) calibration	[6:9,11:16, 23:24]	10685	1.020363	1.019632	0.016978	-0.9524	-0.9277	0.6274
Bottom-track (BT) calibration	17:21	501	1.144740	1.041908	0.290186	0.7373	-0.1420	51.8471

Table 5.2: Parameter estimates.

5.3.6.1 Sensitivity to errors in misalignment and scaling

Joyce (1989) estimates the error in the along-track and across-track components of the velocity vector to be:

$$\Delta u_{along} \approx -\left(\frac{\Delta A}{A}\right) u_{ship},$$

$$\Delta u_{across} \approx -\Delta\alpha u_{ship}.$$

In this case, the error we are interested in comes from uncertainty in the misalignment angle and scaling. For typical ship speeds between stations along A23, 2.3% error in *A*, and 0.8° uncertainty in the misalignment angle, we get errors between 10-15 cm/s in the along-track direction and 6-9 cm/s in the across-track direction. These errors are as large as the mean velocity, which suggests that further processing is required before much of this data can be used for scientific purposes. Fortunately, misalignment/scaling errors are only an issue while the ship is moving, so the SADCP data can still be used for comparison with the LADCP, as the ship is typically almost stationary during a CTD cast.

5.3.6 References

Joyce, T.M. (1989) On in-situ “calibration” of shipboard ADCPs, **J. Atmos. Oceanic Technol., 6,** 164-172.

Pollard R. and J. Read (1989) A method for calibrating shipmounted Acoustic Doppler Profilers and the limitations of gyro compasses, **J. Atmos. Oceanic Technol., 10**, 404-409.

3.7) Figures

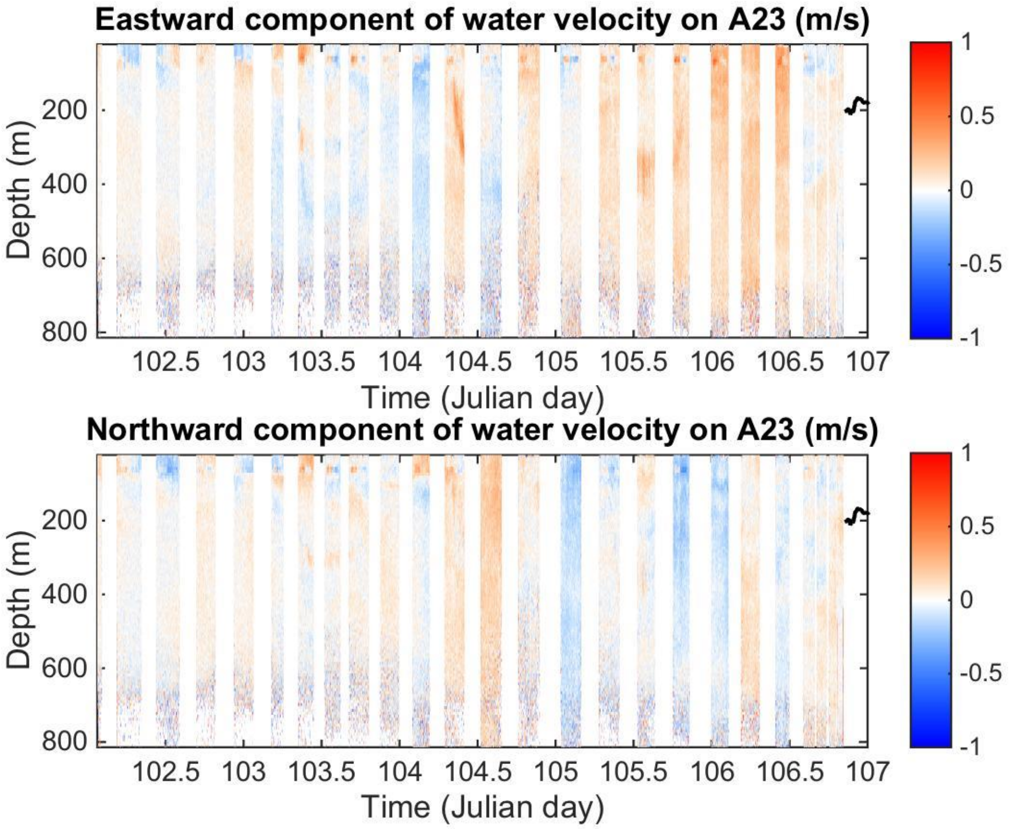


Figure 5.1: Eastward and northward components of water velocity vector along the A23 section of the cruise track. This data uses water track calibration. The black line on the far right is the South Georgia shelf. Only results with an expected error of less than 5 cm/s are shown.

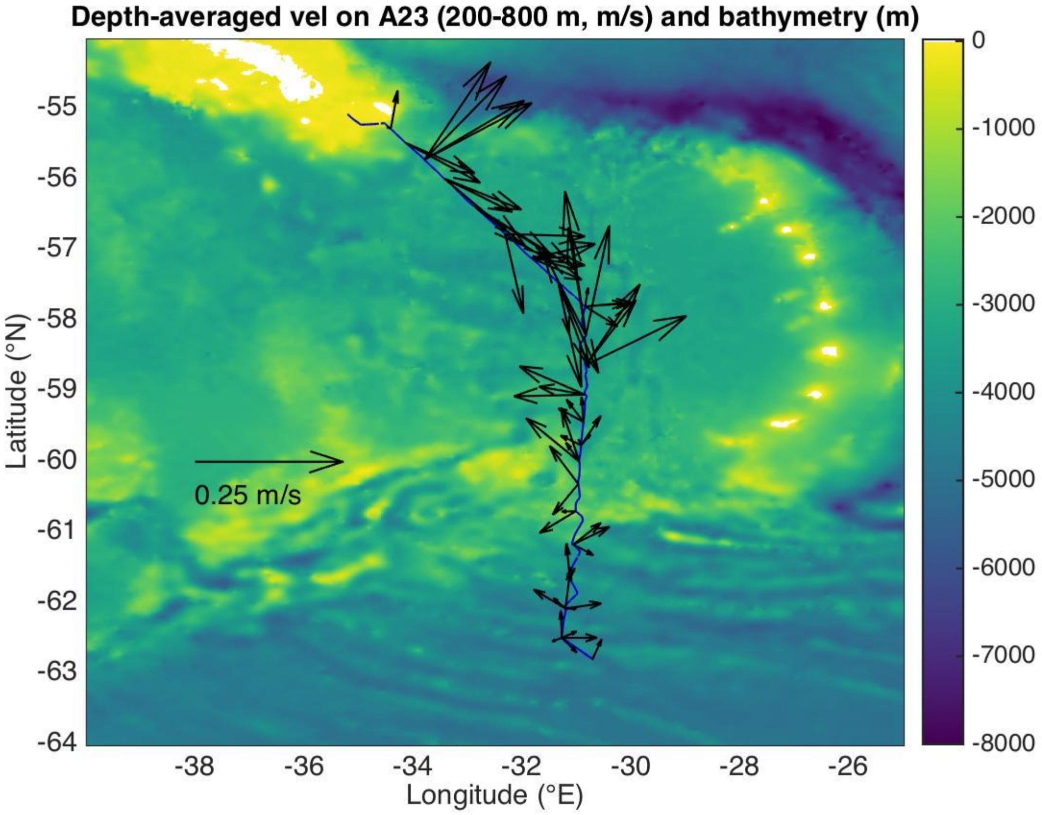


Figure 5.2: Depth-averaged velocity vectors (200-800 m) along the A23 section of the cruise track (blue line). Only results from CTD stations are shown, when the expected error in either component of the velocity vector is less than 5 cm/s.

Table 5.3: Log of ship-mounted ADCP recording periods

Index (xxx)	Start (UTC)	End (UTC)	Bins	Max depth (m)	Bin size (m)	Bottom tracking	Note
001	31/03 23:44	02/04 19:24	100	800	8	On	Left Falkland Islands, towards Signy Island CTD 001
002	02/04 19:24	03/04 12:39	100	800	8	On	Steaming towards Signy Island
003	03/04 12:40	04/04 09:12	30	240	8	On	Signy Island
004	04/04 09:12	05/04 16:32	30	240	8	On	Signy Island CTD 002-004
005	05/04 16:36	06/04 13:10	100	800	8	On	Left Signy Island, steaming to sea ice edge
006	06/04 13:20	07/04 19:16	100	800	8	Off	Waiting for weather to clear
007	07/04 19:16	08/04 16:24	100	800	8	Off	Steaming to sea ice edge
008	08/04 16:24	09/04 16:06	100	800	8	Off	Started in the sea ice
009	09/04 16:07	10/04 10:53	100	800	8	Off	Leaving the sea ice / headed to A23 line CTD 005

010	10/04 10:59	10/04 11:05	100	800	8	Off	AE restarted to diagnose nav data problem **(discard)**
011	10/04 11:05	11/04 21:37	100	800	8	Off	**A23 starts with CTD 007 (day 102, 01:42 UTC)** CTD 006-009
012	11/04 21:37	12/04 21:28	100	800	8	Off	A23 continued CTD 010-013
013	12/04 21:29	13/04 20:05	100	800	8	Off	A23 continued CTD 014-018
014	13/04 20:05	14/04 22:48	100	800	8	Off	A23 continued CTD 019-023
015	14/04 22:48	15/04 23:06	100	800	8	Off	A23 continued CTD 024-027
016	15/04 23:06	16/04 20:40	100	800	8	Off	**A23 ends with CTD 034 (day 107, 20:03 UTC)** CTD 028-034
017	16/04 20:43	17/04 20:52	63	500	8	On	South Georgia Island CTD 035-039
018	17/04 20:52	18/04 19:00	63	500	8	On	South Georgia Island CTD 040-046
019	18/04 19:00	19/04 20:19	63	500	8	On	South Georgia Island Waiting for weather to clear
020	19/04 20:19	20/04 19:34	63	500	8	On	South Georgia Island Field parties deployed, JCR docked at KEP
021	20/04 19:34	21/04 20:31	63	500	8	On	South Georgia Island CTD 047-048
022	21/04 20:31	21/04 20:32	-	-	-	-	Chose wrong config file **(discard)**
023	21/04 20:32	22/04 12:11	100	800	8	Off	From South Georgia to Stanley, Falkland Islands
024	22/04 12:11	23/04 00:26	100	800	8	Off	VmDas software frozen, restart required
025+	23/04 00:26	End of cruise	100	800	8	Off	Continuing to Stanley

6. Underway Navigation Data

David Munday

6.1 Instrumentation and data collection

Navigational data were collected continuously throughout the cruise. Instrumentation whose data stream were processed are as follows:

Ashtec ADU2 GPS: antenna 1 used to determine the ship's position; antennae 2-4 used to determine pitch, roll and yaw.

Ashtec GLONASS GG24 (accurate to ≈15m)

Sperry Mk 37 Model D Gyrocompass

Seatex GPS (Seapath 200)

VT-TSS DMS-05 (heave, pitch, roll)

In addition the data stream from the winch was also processed to look at the effect of the ship rolling on the CTD casts.

A second workflow processed the data stream from the hull-mounted Simrad EA600 Hydrographic 12kHz Echosounder (transducers located approximately 5m below the water level). Contrary to some previous cruise reports, the data stream for this instrument is now correctly named "ea600".

This gps stream wasn't processed:

GPS NMEA

Navigational data were collected every second, whilst the bathymetric data were logged every 10 seconds.

6.2 Processing

The underway navigational data was processed using a combination of Unix, on the ship's own system, and Matlab (R2016a) on a MacBook Pro (OSX Yosemite 10.10.5). The scripts used were provided by Hugh Venables and originally written by Mike Meredith. The Matlab scripts were modified to add some basic error checking (checking that files exists and giving an appropriate error message). The final scripts were stored in /legwork/scientific_work_areas/munday-code

Unix

get_nav - The get_nav script sequentially calls /users/dacon/projects/scs/bin/listit to access data streams that are available in legdata/scs for each data stream, named by instrument. The resulting text files are placed in directories ../../nav/gpsash, ../../nav/gpsglos, ../../nav/gyro, ../../nav/seatex, ../../nav/tsshrp and ../../nav/winch. The script will fail if one of these directories doesn't exist with the error message that "file ../..//nav/seatex/seatex.090 does not exist", for example, rather than the directory itself. The output is named gpsash.NNN, gpsglos.NNN, etc, where NNN is the jday with leading zeroes for jday's of less than 3 characters.

get_ea600 - The get_ea600 script also calls /users/dacon/projects/scs/bin/listit in order get hold of the echo sounder data. It then deposits a file called a600.NNN in ../../ea600, failing if the directory doesn't exist.

Matlab

In order to understand what the matlab scripts were doing I rewrote them and took the opportunity to add some basic error checking, e.g., that the file being accessed really exists. For the nav data one wrapper script was used:

load_daily.m - calls a sequence of scripts, one per instrument, which then reads the the ascii file into matlab and (optionally) saves the data structure as a mat-file. Scripts that are called at load_daily_bestnav.m (untested due to data stream unavailability), load_dailygpsash.m, load_daily_gpsglos.m, load_daily_gpsnmea.m (untested due to data stream unavailability), load_daily_gyro.m, load_daily_seatex.m, load_daily_tsshrp.m and load_daily_winch.m. These produce a series of files called ../../nav/gpsash/gpsashNNN.mat, etc, where NNN is the jday in 3 character format. Each script requires two inputs, the first is the jday as a number and the second is either 1 or 0, with 1 meaning save the resulting data structure to disk and 0 meaning don't.

A series of script were also written to concatenate together all available nav data into a single record. These are called :

concatenate_gpsash.m, etc, and create a file called ../../nav/gpsash_all.mat, etc. Requires one input, either 1 or 0 with 1 meaning save the record to disk and 0 meaning don't.

To process the ea600 data stream two scripts are required.

loadea600.m - reads in the ../../ea600/ea600.NNN file for a specified jday (given by NNN) and outputs it as a mat-file containing the resulting data structure.

cleanea600.m - reads in the file created by loadea600.m for a specified jday and calls the dpsike.m routine, which removes some spikes in the data. An interactive editor is then used to remove remaining spikes and other points that look like noise. This was done to obvious points and no further processing was carried out, since the ea600 would only be used for underway plotting and will be replaced with swath data from the em122 at a later date.

6.3 Problems encountered

The main problem was determining that get_nav was looking for directories at the relative path given by ../../nav.

The unix scripts do not specify their environment. They worked on the ship's system and so weren't altered. When entering the jday, after the prompt, three digits must be entered, i.e. 001, 010, etc, as the script will not append leading zeroes.

The list function is a black box, as it is written in perl.

7. Underway meteorological and surface ocean data

Ollie Legge

7.1 Instrumentation and data streams

Meteorological and surface ocean data were logged at 5 second intervals throughout the cruise. The underway water comes from the ship's uncontaminated water supply which passes through a filter shortly after entering the hull. The water intake is approximately 7m below the surface.

The following table shows the type and location of the underway instruments along with their data stream names on the SCS (scientific computer system).

Measurement	units	Sensor	Sensor location	Data stream in SCS
air temperature	degC		foremast	oceanlogger-airtemp1
air temperature	degC		foremast	oceanlogger-airtemp2
humidity	RH%		foremast	oceanlogger-humidity1
humidity	RH%		foremast	oceanlogger-humidity2
photosynthetically active radiation	umol/s.m2	Parlite Quanum, Kipp & Zonen	foremast	oceanlogger-par1
photosynthetically active radiation	umol/s.m2	Parlite Quanum, Kipp & Zonen	foremast	oceanlogger-par2
total incident radiation	W/m2	Proto1 SPLite, Kipp & Zonen	foremast	oceanlogger-tir1
total incident radiation	W/m2	Proto1 SPLite, Kipp & Zonen	foremast	oceanlogger-tir2
atmospheric pressure	hPa		foremast	oceanlogger-baro1
atmospheric pressure	hPa		foremast	oceanlogger-baro2
water temperature	degC	SBE 45	prep lab	oceanlogger-tstemp
conductivity	S/m	SBE 45	prep lab	oceanlogger-conductivity
salinity		SBE 45	prep lab	oceanlogger-salinity
sound velocity	m/s	SBE45	prep lab	oceanlogger-sound_velocity
chlorophyll a	ug/l	Turner 10-AV fluorometer	prep lab	oceanlogger-chlorophyll
water temperature	degC	SBE 45	prep lab	oceanlogger-sampletemp
water flow rate	l/min	Litremeter	prep lab	oceanlogger-flowrate
sea surface temperature	degC	SBE 38	at water inlet	oceanlogger-sstemp
sea surface temperature	degC	SBE 38	at water inlet	oceanlogger-sstemp2
transmittance	%	Wet labs CST-396DR	prep lab	oceanlogger-trans
wind direction	degrees	Gill Heated WindObserver 70	main mast	anemometer-wind_dir
wind speed	kts	Gill Heated WindObserver 70	main mast	anemometer-wind_speed

7.2 Data processing

The code used here for processing the underway data originates from scripts written by Hugh Venables and Mike Meredith. Data were retrieved from the SCS in unix and were then processed in Matlab. The scripts used here are stored in the folder 'ocl' within the folder 'HJV_processing_code'. Parallel to 'HJV_processing_code' is another folder called 'ocl' into which data and figures are written.

Unix

Log into unix as pstar:
ssh pstar@jrlc
password = pstar

get_underway

Retrieves the met and ocean datastreams for a specific day of year from the SCS and produces data files called oceanlog.NNN and anemom.NNN, where NNN is the day of year. *Get_underway* uses the *listit* command located at /users/dacon/projects/scs/bin/listit.

<u>*Matlab*</u>

Loadunderway.m

calls *loadoceanlog.m* and *loadanemom.m* to read *oceanlog.NNN* and *anemom.NNN*. Data are stored in structure arrays and saved as *oceanlogNNN.mat* and *anemomNNN.mat*. The program then calls *cleanoceanlog.m*, which sets unrealistic values to NaNs and uses *dspike.m* to remove large spikes in conductivity, SBE45 temperature and hull temperature. Data from periods of flow >1.5 l/min or <0.4 l/min are also set to NaNs, as are data from 5 minutes after a drop in flow to allow variables to return to normal. Surface ocean data are further cleaned using *interactive_edit.m* which allows manual removal of bad data. *Ds_salt.m* calculates salinity from quality controlled conductivity and SBE45 temperature, its output is named sal_uncal. Quality controlled data are saved in *oceanlogNNNclean.mat*.

The wind speed and wind direction measured by the anemometer are relative to the ship rather than the true wind. True wind is not currently logged and is therefore calculated by *truewind_derive.m* which is called by *load_underway.m.*

plot_oceanlog_daily.m

loads *oceanlogNNNclean.mat* and *seatexNNN.mat*, finds position from Seatex data, calculates 1 minute averages of underway data and plots maps of sea surface temperature, salinity and fluorescence. Bathymetry data are included in the plots. Output files are *oceanlog_navNNN.mat* and *oceanlog_navNNN_1minave.mat.*
seatex*NNN*.mat *and* gyro*NNN.*mat are produced by the underway navigational data processing and are required for this script to run. *plot_oceanlog_daily.m* can be run for individual days or for batches of days

plot_oceanlog_all_improved.m

concatenates the one minute averages produced by *plot_oceanlog_daily.m* and plots data from the cruise on a map with bathymetry. A .mat and a .txt file are written containing the whole cruise's minute averaged underway data.

Wind_average_daily.m

Matches the anemometer data with the positions from Seatex data and averages the wind vectors over time periods selected by the user. Saves the geolocated data in files named wind_navNNN.mat and saves the time averaged data in files names wind_navNNN_timeave.mat.

Plot_wind_all.m

Concatenates the time average wind data produced by *wind_average_daily.m* and plots data from the whole cruise on a map with bathymetry.

NB. Day of year/ Julian Day time vectors are formatted with noon on Jan 1st being 0.5 whereas in ship logs and sampling logs the 1st Jan is referred to as day of year 1. The underway data files have the ship log day of year in their name and so, as an example, oceanlog092.mat would contain decimal day of year time from 91.0 to 92.0.

7.3 Underway event log

1030 UTC 1st April (DOY 92)	Underway logging turned on.
3rd April (DOY 94)	Arrived at Signy in the morning.
4th April (DOY 95)	Departed Signy in the evening.
6th April (DOY 97)	Very low flows of 0 to 0.25 for approximately one hour. Suspected temporary blockage. Underway data removed.
1330 UTC 8th April (DOY 99)	Started moving in and out of slush/ice.
1608 UTC 8th April (DOY 99)	Underway water supply off as pancakes thicken.
1208 UTC 10th April (DOY 101)	Underway water supply turned back on. Moving through patches of slush and pancakes. Ice thins out to consistent clear water by the end of the day.
17th April (DOY 108)	Arrived at South Georgia
1244 UTC 21st April (DOY 112)	Departed KEP. Underway turned back on.
22nd April (DOY 113)	Underway supply off temporarily due to power trip.
23rd April (DOY 114)	Underway supply off temporarily due to power trip.
25th April (DOY 116)	Underway supply off temporarily due to power trip. Arrived in Port William, Falklands at approx. 1900 UTC.

7.4 Calibration

Underway salinity data were calibrated using discrete sampes taken from the underway supply and run on the salinometer. See Chapter 3 for details of analysis. The following calibration was applied to the minute averaged underway data in plot_oceanlog_all_improved.m. There was no discernable trend in the salinity calibration with time or temperature.

sal_cal = salAll* 1.0191-0.5902

Underway sea surface temperature data were calibrated using CTD temperature from 7m depth. For each of the 49 CTDs the 7m temperature from the calibrated 2db file was matched with the geographically closest underway data point. The following calibration was applied to the minute averaged underway data in plot_oceanlog_all_improved.m

sst_cal = sstAll*1.0055-0.0971

7.5 Lag time between hull inlet and underway lab

The very sharp gradients in temperature caused by glacial melt water around Signy allow us to observe the time lag between water temperature measured at the intake and water temperature measured by the SBE45 in the prep lab. With the flow stable at 0.66 l/min the lag is approximately 100 seconds and this lag time would be different for different flow rates. If the user requires very high temporal or spatial accuracy then data from the underway sensors in the prep room could be corrected to match the hull temperature or vice versa.

7.6 Example figures

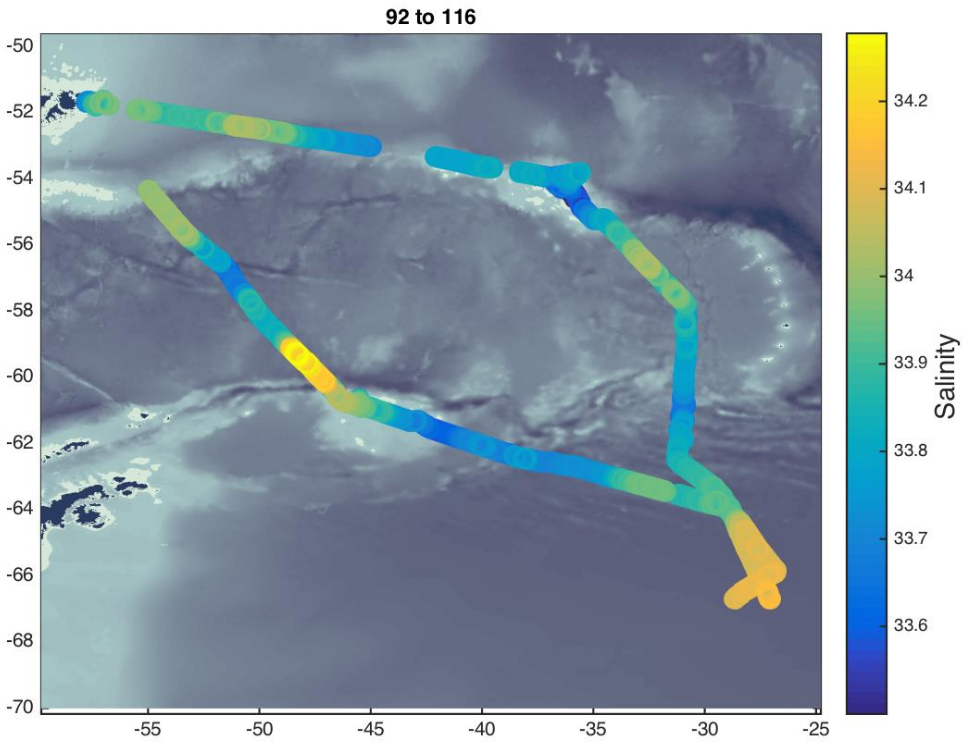


Figure 7.1: Calibrated, minute averaged sea surface salinity for the whole cruise.

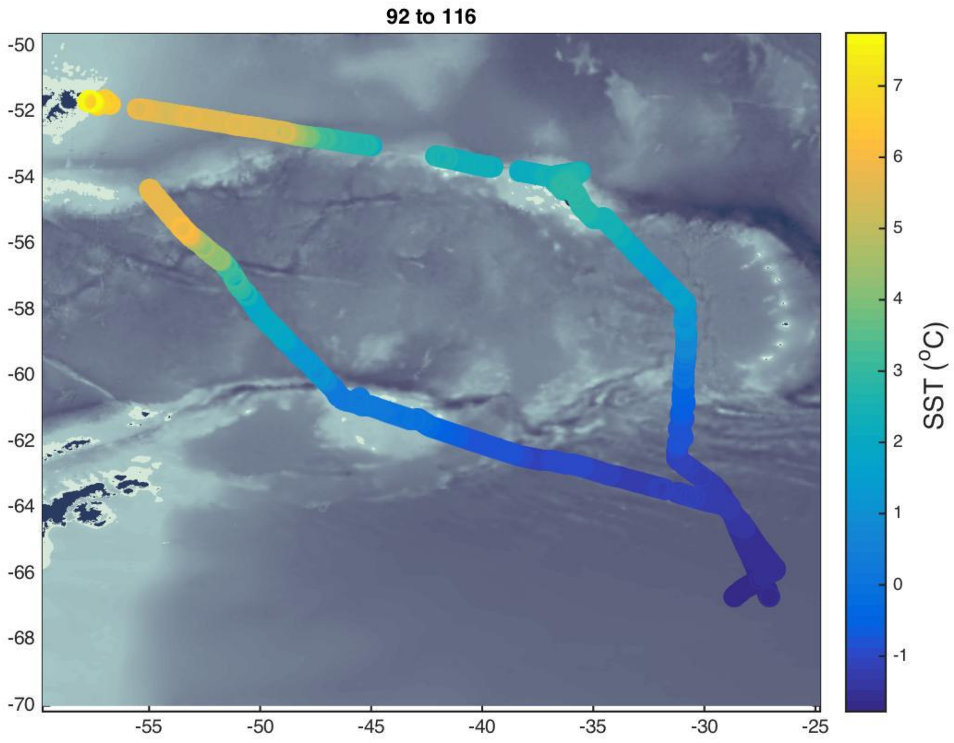


Figure 7.2: Calibrated, minute averaged sea surface temperature for the whole cruise.

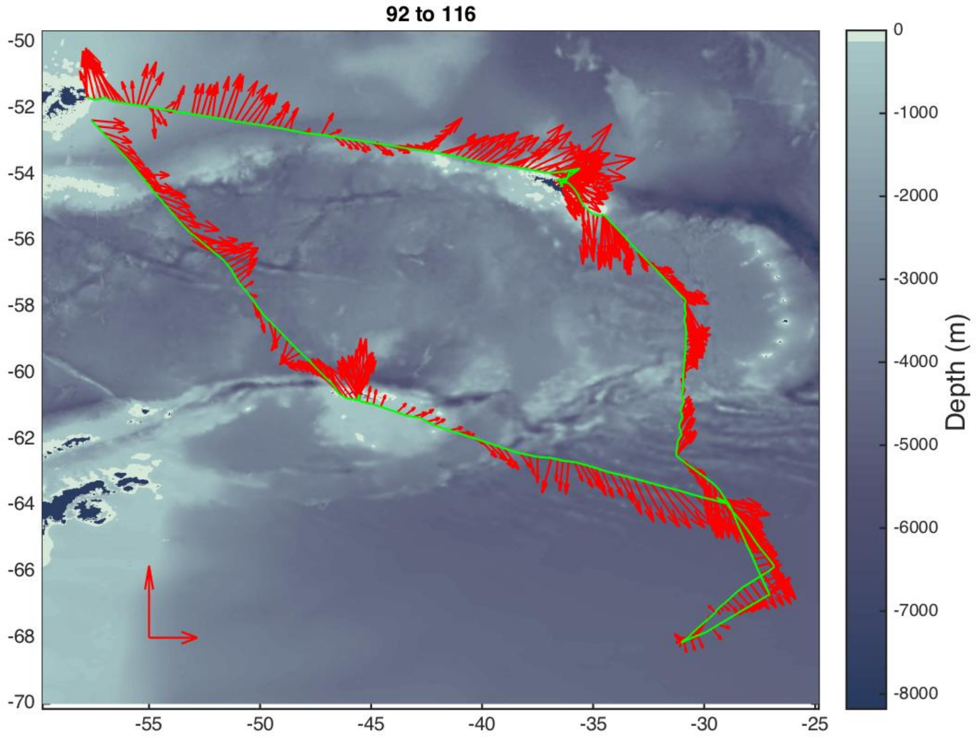


Figure 7.3: True wind speed and direction for the whole cruise. Scale arrows in bottom left corner show 20m/s winds

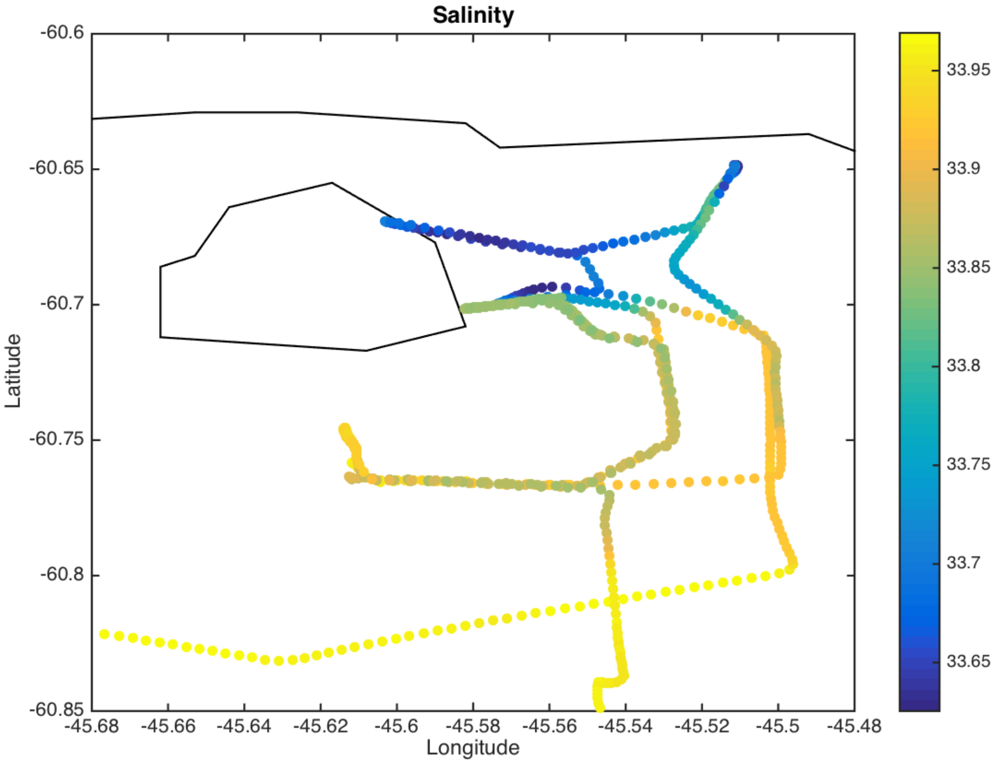


Figure 7.4: Calibrated, minute averaged sea surface salinity around Signy.

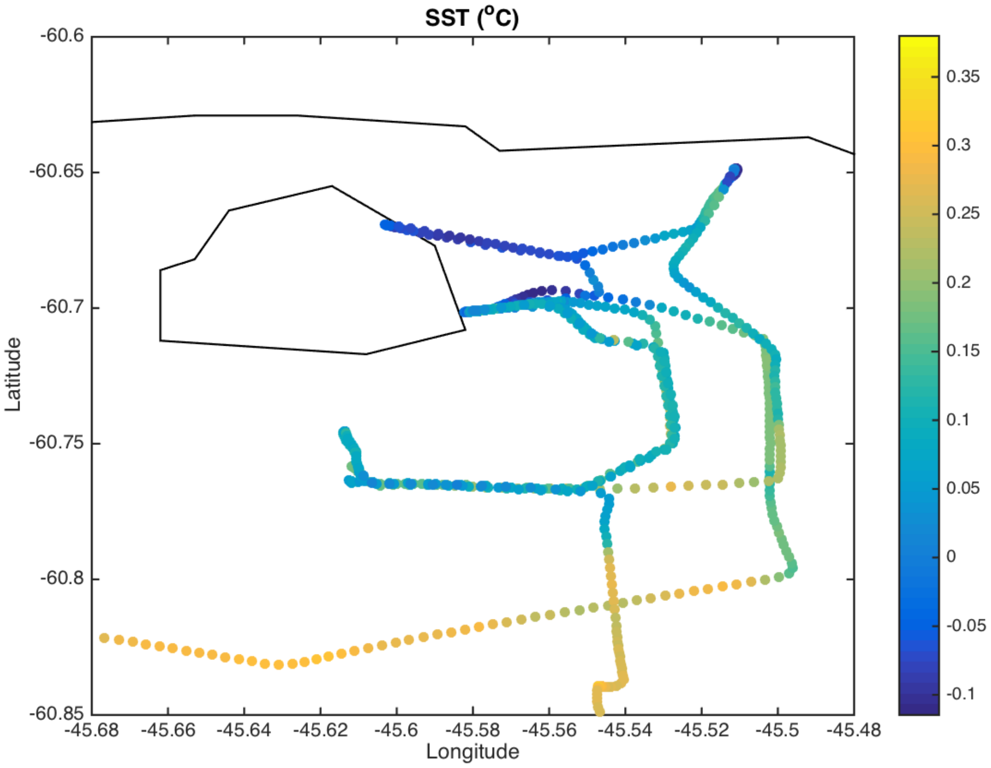


Figure 7.5: Calibrated, minute averaged sea surface temperature around Signy.

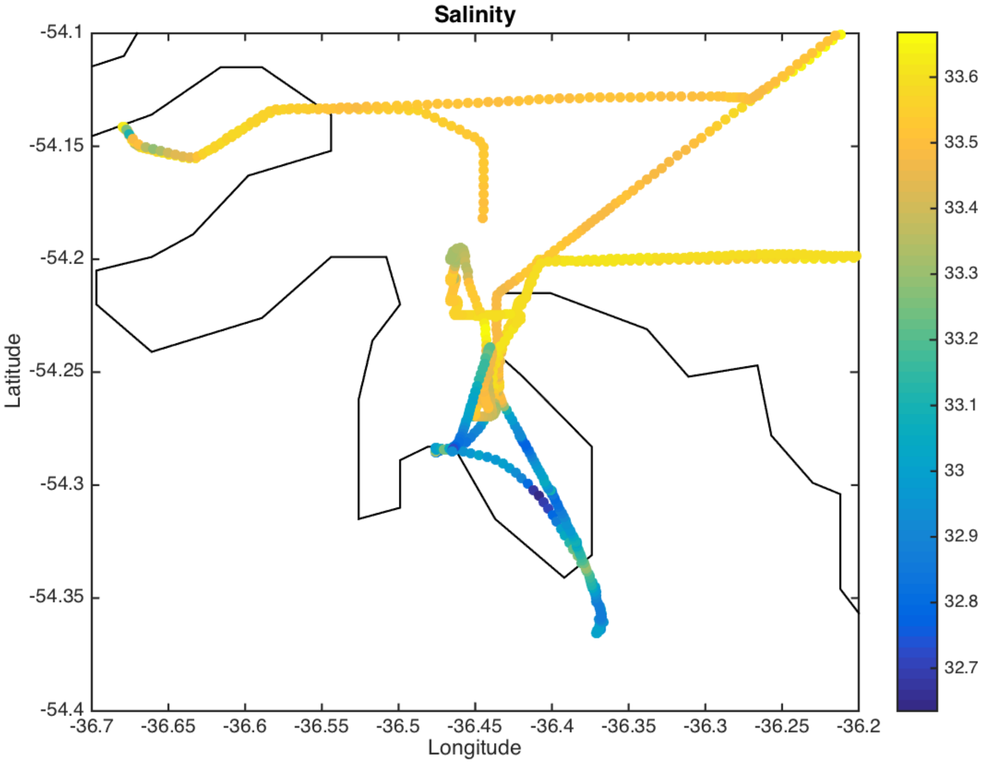


Figure 7.6: Calibrated, minute averaged sea surface salinity around KEP.

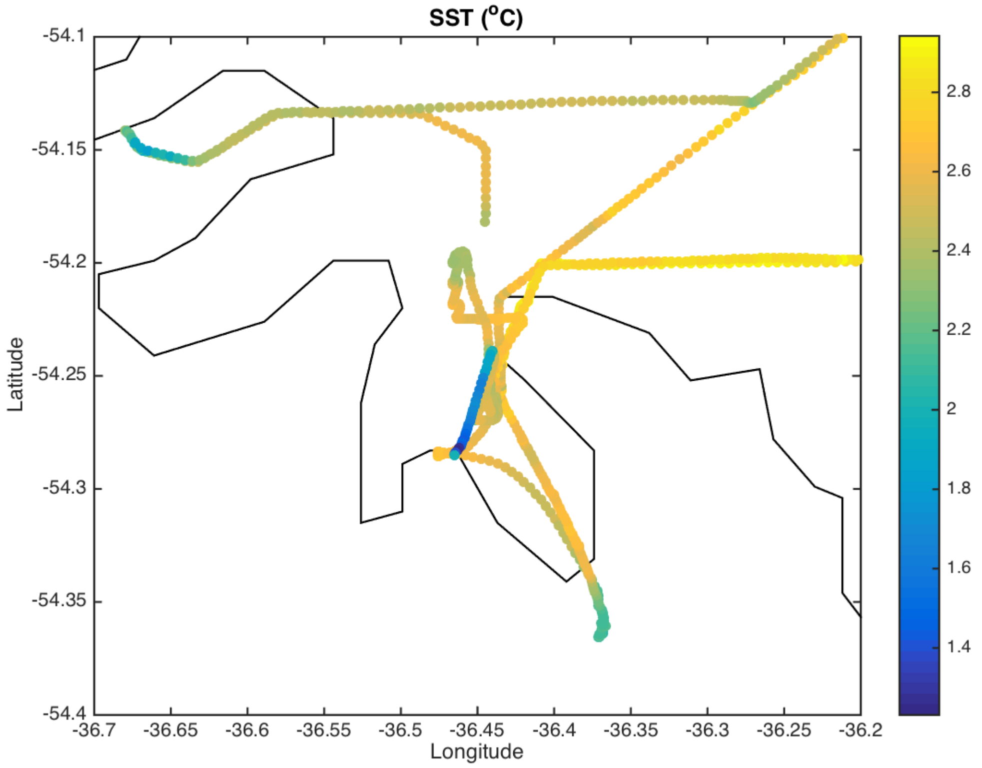


Figure 7.7: Calibrated, minute averaged sea surface temperature around KEP.

8. Underway Water Isotope Analyser

Robert Mulvaney

8.1 Introduction

Oceanographers traditionally take discrete samples of near-surface seawater from underway vessels to distinguish between discrete ocean water masses and mixing water with freshwater sources (river run-off, glacial melt-water, sea-ice melt-water, precipitation etc.) using measurements of salinity and the ratio of the stable oxygen isotopes in water.

Water (H_2O) is molecule that combines the atoms hydrogen and oxygen. There are several stable isotopes of both atoms: ^{1}H (Hydrogen - one proton, no neutrons in the nucleus); ^{2}H (Deuterium - one proton, one neutron); ^{16}O (Oxygen - eight protons, eight neutrons); ^{17}O (Oxygen - eight protons, nine neutrons); ^{18}O (Oxygen - eight protons, ten neutrons). 'Stable isotopes' of hydrogen and oxygen are those that do not undergo radioactive decay, and their abundance on Earth is essentially constant. In comparison other isotopes such as ^{3}H (Tritium – one proton, two neutrons) undergo radioactive decay with a characteristic half-life, and their abundance depends on the balance of decay and creation by radioactive pathways.

Typical abundance of the stable isotopes of water are given in table 8.1

	Hydrogen		Oxygen		
Stable Isotope	^{1}H	^{2}H (D)	^{16}O	^{17}O	^{18}O
Concentration (%)	99.985	0.015	99.759	0.037	0.204

Table 8.1: Typical abundance of the stable isotopes of the water molecule in seawater

Isotopes of an atom are chemically identical, but have differing physical properties: the property of interest to oceanographers is the differing mass of the isotopes (greater number of neutrons implies a greater atomic mass, and greater molecular mass of the water molecule), which impacts the vapour pressure of the water molecules with differing isotope composition. The 'heavier' the isotope, the greater the mass of the water molecule, and the higher the vapour pressure. This translates as implying that a greater energy is required to enable the change of state of the water molecule from water to vapour (evaporation).

Because 'stable isotopes' abundance on earth is essentially constant, the ratio of the stable isotopes in the water molecule can be used as a tracer of the origin of water. Typically, evaporation from the oceans (the largest water body on earth) causes a change in the isotopic composition of the water vapour when compared to the liquid water from which it has originated. The water molecules with the heavier isotopes tend to remain in the liquid phase, and the vapour is said to be depleted in the heavy isotope molecules.

Once in the vapour phase, any subsequent condensation and precipitation tends to favour the heavy isotope molecules preferentially being deposited in the condensed phase, further depleting the vapour of isotopically heavy molecules. This process is referred to as Rayleigh Fractionation, and the result is that precipitation tends to be markedly depleted in heavy isotopes of water compared to the vapour source (figure 8.1 gives a schematic of the depletion of heavy isotopes in a precipitating vapour body moving polewards from the sub-tropics). In contrast, the original water mass becomes enriched in the heavy isotopes. Typical values for end members such as Antarctic precipitation (depleted in heavy isotopes) and evaporating lakes (enriched) are given in table 8.2.

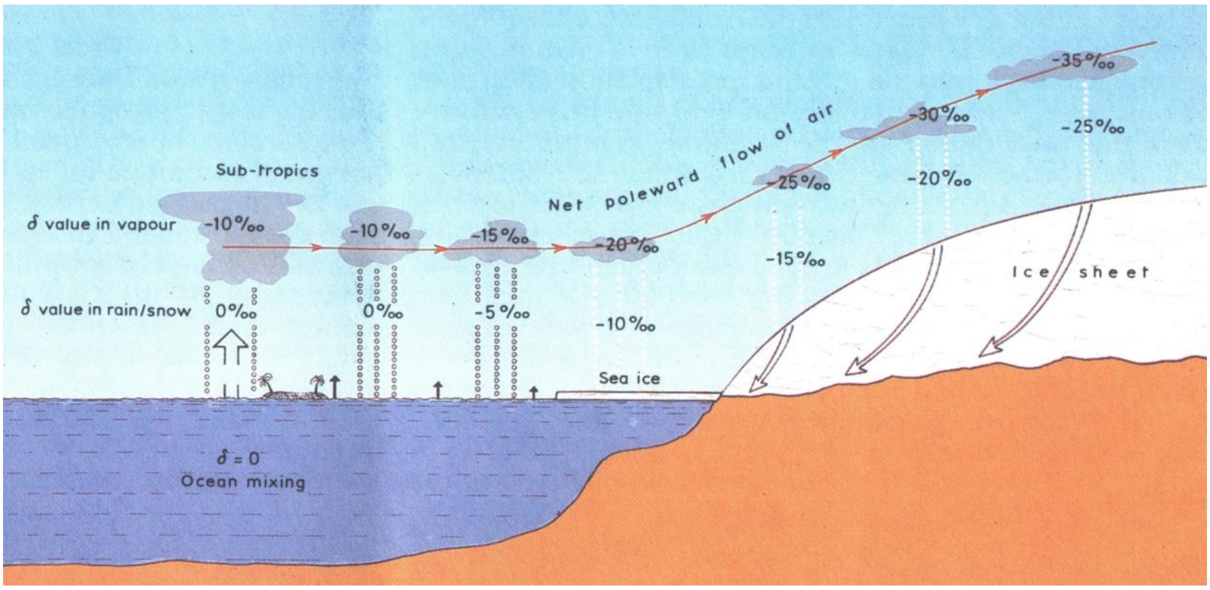


Figure 8.2: depletion of heavy water isotopes from a vapour body moving polewards from the sub-tropics

	Antarctica	Evaporating tropical lakes
$\delta^{18}O$	-60‰	+5‰
δD	-400‰	+40‰

Table 8.2: typical values of Antarctic precipitation and evaporating tropical lakes

8.2 Instrumental measurement of water isotopes

Water isotopes are traditionally measured Isotope Ratio Mass Spectrometers (IRMS). Samples of around 50 mL are collected, and the ratio of $H_2{}^{18}O$/ $H_2{}^{16}O$ measured by equilibrating carbon dioxide (CO_2) gas with an aliquot of the sample in small sealed conical flasks before measurement with the IRMS. The sealed flasks are swirled in a water bath for 24 hours, allowing the oxygen isotopes in the water sample to equilibrate with the oxygen isotopes of CO_2. The headspace gas is then taken into the IRMS and the ratio $H_2{}^{18}O$/ $H_2{}^{16}O$ measured, and compared to the $H_2{}^{18}O$/ $H_2{}^{16}O$ ratio of internal laboratory working standards that have themselves been calibrated against the global reference standards VSMOW (Vienna Standard Mean Ocean Water) and VSLAP (Vienna Standard Light Antarctic Precipitation).

Isotope instruments measure the minor isotopes as concentration ratios against the concentration of the major isotope molecule $H_2{}^{16}O$ (equations 8.1, 8.2, 8.3).

$$^{17}r = \frac{[H_2{}^{17}O]}{[H_2{}^{16}O]} \qquad ^{18}r = \frac{[H_2{}^{18}O]}{[H_2{}^{16}O]} \qquad ^{2}r = \frac{[{}^1H{}^2H{}^{16}O]}{[H_2{}^{16}O]}$$

Equations 8.1, 8.2, 8.3: isotope ratio pairs measured by stable water isotope instruments

Absolute values are difficult to measure accurately in the IRMS, so the ratio measured is normally compared to the measurement of the same ratio in standard mean ocean water (SMOW – the actual standard is known as VSMOW). Equation 8.4 gives the example for the $H_2{}^{18}O$.

$$^{18}R = \frac{^{18}r_{sample}}{^{18}r_{SMOW}}$$

Equation 8.4: example of the ratio of H218O in sample and SMOW

This is generally expressed as a delta value where $\delta^{18}O$ is in parts per thousand (‰) – equation 8.5, and the same for δD (= δ^2H) etc.

$$\boxed{\delta^{18}O = 1000 \text{ x } ({}^{18}R - 1)}$$

Equation 8.5: final value of isotope ratio reported as a delta value

8.3 Alternatives to the Isotope Ratio Mass Spectrometer

Measurement by IRMS is a lengthy and expensive process: the instruments is itself expensive, and requires a skilled operator, and the process is not amenable to ship-board operations. In recent years, a new class of instrument has appeared that passes vapour from water samples into a small cavity, and measures the absorption of laser light by the water molecules, distinguishing between the frequencies of absorption bands of the isotopes of water ($H_2{}^{16}O$, $HD^{16}O$, $H_2{}^{18}O$, and more recently $H_2{}^{17}O$). Mirrors at each end of the laser cavity reflect the light many times, giving a laser path length commonly in the range of kilometres from a cavity only around 0.3 m in length. This increase in the laser path length increases the laser interaction with individual water molecules and thus the instrument sensitivity, allowing detection of the absorption by the minor isotopes.

The advantage of these new laser-based instruments is the comparative ease of use and lower cost than mass spectrometers and, significantly, the portability of the instruments. While most laser-based instruments are sold for laboratory use, the manufacturers are developing instruments for field-based use.

8.4 Laser instruments for seawater analysis

The laser instruments were originally designed for discrete fresh-water sample analysis. They use an evaporator to vaporise a small volume of water (around 0.9 to 2.0 μL) and pass the vapour into the instrument cavity. The pressure (generally a vacuum of around 50 Torr) and temperature (generally around 45°C) of the cavity are held within very tight bounds. A downstream vacuum pump provides the flow of vapour through the cavity from the evaporator, and variable valves on the inlet and outlet ports of the cavity maintain pressure.

For seawater, discrete sampling of the water directly will lead to a rapid build-up of residual salt in the evaporator, and potentially may pass through into the cavity and deposit on the walls and mirrors. Any contamination of the mirrors would rapidly reduce the sensitivity and precision of the instrument, so must be avoided.

However, the concept of the laser-based isotope instrument lends itself to measurement of vapour directly, and the manufacturers have recently marketed vapour instruments in parallel with their discrete water sample instruments. These instruments tend to be used in the field for measurement of atmospheric vapour in real time.

These new real-time vapour instruments offer a solution to the analysis of seawater – if seawater can be vaporised without entraining residual salt, then potentially they can be used for real-time analysis of seawater, and might enable at-sea, under-way, analysis of water body stable water isotopes.

8.5 Choice of instrument

Two manufacturers produce laser-based water isotope instruments: Picarro (www.picarro.com) and Los Gatos Research (www.lgrinc.com) . The author has experience of both manufacturers instruments, with examples of both installed in his laboratory in Cambridge where they are used for measuring discrete water samples from ice cores.

The instrument chosen for the RRS James Clark Ross was a Los Gatos Research Triple-Water Vapor Isotope Analyzer (T-WVIA model 912-0034) together with a Water Vapor Isotope Standard Source (WVISS model 908-004-9002).

The reasons for the choice can be summarised:

1. Availability - at the point that funds became available, the Los Gatos instrument was commercially available, while the Picarro instrument was still in development.
2. Experience with post-purchase support suggested Los Gatos provide the better user support.
3. The mirrors on the Los Gatos instrument can be user-serviced with an optional service kit, potentially allowing the cleaning of the mirrors during a voyage should they become contaminated by a salt ingress incident. In contrast, servicing of the mirrors on the Picarro requires a return to the factory.

8.6 The instrument configuration for the JCR Underway Water Isotope Analysis

At the time of the instrument purchase, neither manufacturer had the capability of measuring seawater samples directly as was required by the JCR Underway Water Isotope Instrument, though both have very recently (in the last few months as this is written) marketed seawater extraction devices.

Following an idea reported by Munksgaard (Environ. Chem. Lett., 2012), I developed a membrane extraction system to pull water vapour across a membrane from a continuously flowing stream of seawater. Essentially seawater is pumped across one side of a ‘contactor’ membrane, normally used in industry to degas fluids, while on the other side of the membrane, dried ambient air is drawn by the inlet side of the instrument. Water molecules pass across the membrane from the wet to the dry side, and are entrained into the dry air forming a continuous vapour stream that passes into the instrument cavity for measurement.

The membrane used is a Membrana Liqui-Cel 0.5 x 1 MicroModule contactor membrane, with a folded polypropylene membrane of typically 100 cm^2 are in a polycarbonate body about 25 x 13mm with four ports (gas inlet and outlet, liquid inlet and outlet). The internal liquid volume is 2.7 mL, and is capable of a liquid flow of up to 30 mL per minute.

The flow of seawater was (originally) provided by a KNF Simdos 02 diaphragm metering pump set to run at a constant flow rate of 2.0 mL per minute.

The instrument diaphragm vacuum pump itself (situated downstream of the cavity) provides the airflow though the cavity, from the inlet port of the instrument. The inlet side is then connected to the downstream air side of the membrane, while the upstream air is supplied from ambient air dried through a Drierite desiccant column.

Recognising that the transfer of water molecules through the membrane is a dynamic process with some fractionation taking place (due to the differing vapour pressures of the water isotopes), I sought to control fractionation by closely controlling the temperature, airflow, and liquid flow through the membrane.

Temperature was controlled by placing the membrane inside a Thermo Heratherm temperature controlled cabinet (capable of both warming via a heater, and cooling via a Peltier plate), with a temperature range from 17° to 40°C. Seawater flow rate was controlled by the Simdos metering pump, while airflow was controlled by an Alicat Scientific Precision MCS-series Gas Mass Flow Controller (MFC).

The liquid flow path was via 1/8” OD PFA tubing, while the gas flow path was in ¼” PFA tube. Connections were rudimentary, and generally used appropriate diameter silicone tubing. Holes were drilled in the side of the Heratherm cabinet to pass through the liquid and gas tubes.

8.7 Testing the instrument prior to installation on the JCR

The instrument and air/liquid flow paths were set up in Cambridge in the spring of 2015 (figure 8.3). The fractionation control side (metering pump and MFC) were both set up inside the Heratherm cabinet for convenience, and to simplify the flow paths when installed on the JCR.

Figure 8.3: test set up of the Underway Water Isotope Analyser in Cambridge

Filters on both air side and fluid side were needed to protect both the membrane from particulates in the fluid side, and on the gas side to protect both the membrane and the instrument from the ingress of dust (either from the air or from the Drierite matrix). The instrument itself does have internal filters, but there is little lost by filtering the air side between the Drierite column and the membrane, and a disposable Whatman 47mm diameter x 0.2 μm PTFE disk filter was used for this purpose. The liquid side was filtered by a 47mm Millipore Omnipore type JMWP 5.0 μm filter in a split housing cassette allowing the filter to be routinely changed while maintaining the liquid connections to the filter housing.

Initial testing of the instrument in Cambridge used tap water as the water source, passing through the Omnipore filter and onto the membrane, and then to waste.

First measurements indicated that the concept of vapour extraction worked well, and the choice of the Liqui-Cel MicroModule was right first time. The Los Gatos Research T-WVIA instrument as a measurement range of between 3,000 and 60,000 ppm water molecule concentration in the vapour, and my earlier experience suggested the range 18,000 to 25,000 ppm water density was an ideal range for optimum precision. Measurements of the water density, once the instrument was stable, were around 20,000 to 28,000 depending on the temperature of the cabinet (ranging from 21 to 25°C). Similarly, the isotopic composition of the vapour appeared to be stable over a matter of days.

Checking the level of dehydration provided by the Drierite column indicated that ambient laboratory air had a water density of around 10,000 ppm, while air passed through the Drierite column dropped to around 2,500 to 3,000 ppm. Calculations suggested that the Drierite column would last more than one month before requiring replacement assuming similar ambient humidity on the ship. (This knowledge was required because the intention was to use non-indicator Drierite which is a non-hazardous material, whereas the indicating Drierite is hazardous due to the carcinogenic indicator.)

Once measurement of tap water was considered stable, water source changed to a seawater standard (IAPSO Seawater standard, batch 146, expires 12/03/2005, K15 0.99979, Salinity 34.992), using a closed loop to return the waste from the membrane back to the seawater standard bottle.

Instrument appears stable over a 7-day period.

8.8 Calibration of the instrument

The manufacturer (LGR) recommends that the instrument is left with its factory calibration – its argument is that the measured fractional absorption of light at a water isotope resonant wavelength is an absolute measurement of the water density in the cell. Instead, they recommend the periodic measurement of known reference gases and post-measurement corrections to calibrate the output of the instrument.

This is helpful to the proposed use of the instrument on the ship. It is intended to run autonomously with little operator intervention, other than changes of filters, tubing and Drierite. To include periodic calibration of the instrument by ships personnel is both tricky, and requires a source of water isotope standards to be carried on the voyage.

However, all laser-instruments tend to drift slightly in operation, so a second module was purchased to allow periodic injection of a 'standard' into the instrument to post-correct for drift characteristics of the T-WVIA instrument.

The calibration unit is known as the Water Vapour Isotope Standard Source (WVISS). It takes a 'standard' (in practice, a 500 mL bottle of Milli-Q water is fine), and periodically pulls water from the standard bottle through a nebuliser held at 75°C and passes the vapour to the input side of the T-WVIA. While the WVISS is passing vapour to the instrument, the normal sample vapour inlet port is closed.

The instrument can be set to automatically run the WVISS periodically throughout a long run. Initially, in Cambridge, the WVISS was set to run every two hours, and long runs over several days suggested the 'calibration' values were reasonably stable, and would form the basis for drift correction of the sample vapour results.

8.9 Installation on the JCR

The instrument was closed down in June 2015, and shipped to Frederikshaven in Denmark to be fitted into the underway water analysis laboratory on the James Clark Ross during its annual refit between Antarctic seasons.

The instrument was housed in a 19" rack system in the starboard/forward corner of the Prep Lab on the Upper Deck, in the scientific laboratories area towards the stern of the ship. Physically, it occupies a space 1.95m (h) x 0.58m (w) x 0.77m (d).

The technicians only built and housed the units, but made no connections between the units, nor connected to the underway seawater supply.

I visited the ship in Immingham in September 2015 to check on the installation – a very neat solution had been found to create a secure sea-going instrument (figures 8.3 and 8.4).

Figure 8.4: rack mounted UWIA in the JCR Prep Lab

Figure 8.5: Rack mounted UWIA

8.10 Joining the JCR cruise JR15006 and setting up the instrument

The original itinerary anticipated the scientists leaving Brize Norton on Sunday 27th march and joining the JCR on Monday 28th March, and sailing later that week (Thursday 31st March). This would have allowed several days to set up the isotope instrument, connect through to the under-way water supply and check the functionality of the instrument.

In practice, due to poor weather in the Falklands and in the UK, we did not depart Brize Norton until Wednesday 30th March, joining the ship at around 1600 on the 31st March at Mare Harbour. Within an hour of joining the ship we had let go the lines and the JCR was underway for Signy.

This meant that no time was available to set up and test the instrument before we were at sea.

8.11 Event log

(Where time is given, it is instrument time, set as GMT, written here as ‘Z’ (zulu) for short. Ship’s local time 3 hours behind GMT.)

Friday 1st April (at sea)

All instrument interconnections (electrical, signal and gas lines) made, requiring each instrument to be removed from the rack to access the rear connection panels. (In practice, and later in the cruise, I removed the left-hand side panel, which gave access to the rear panels without removing the instruments.)

Set up circulating water supply (figure 8.5). From a ½" BSP female port on the ships supply, via a Swagelok ½" male tapered BSP to ¼" OD tube fitting. ¼" OD PFA tube routed around the rear of the lab Super-Q system to a Swagelok ¼" x ¼" x ¼" tubing T-junction and routed by ¼" OD PFA tube back to open drain into the sink. This allowed a circulating supply of seawater to a point close to the instrument. From the T-junction, a ¼" OD stainless steel tube to a Swagelok 40 μm filter unit, and then to a Swagelok 7 μm filter unit. A Swagelok ¼" to 1/8" OD fitting accepted the 1/8" PFA tubing that will carry the seawater to the instrument. These fittings are mounted on a stainless steel flat plate, and screwed to the wooden panel above the Super-Q system, and appropriately marked. At this point, no further liquid line filtration was incorporated into the liquid flow path (i.e. the Omnipore 5.0 μm filter pack used in Cambridge is not used here).

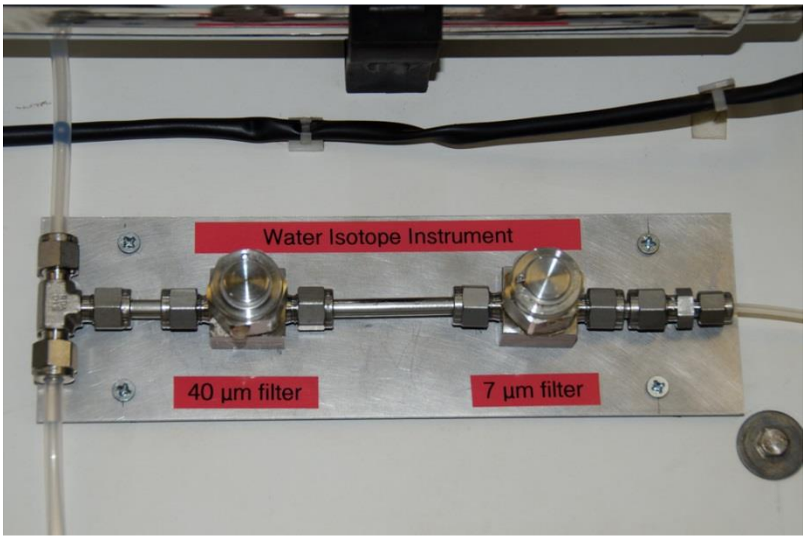


Figure 8.6: filter bank for circulating seawater and take off to isotope instrument

Liquid and airflow paths established. Liquid flow path tested.

Fault:

1. Simdos metering pump pumping erratically; suspect either clogged 5um on pump inlet, or pump head needs servicing (after several months in use in Cambridge).

Instrument started up: normal run-up sequence.

Faults:

2. No measurements taking place, screen shows zeros for all fields (H_2O, $\delta^{18}O$, δD, $\delta^{17}O$)

3. Sample pump does not seem to be drawing air through sample inlet port

Waited for instrument to reach stable cavity pressure and temperature in the expectation that measurements might begin automatically.

Stabilised after several hours to 45.10°C and 39.46 Torr, Laser A 14.84 μs and Laser B 15.42 μs.

Fault:

4. Still not measuring; suspect laser are out of adjustment.

Setup/Laser adjustment tab shows Laser A target lines not-locked to main water absorption peaks. Laser A voltage current set to -1.542 Volts.

Adjustment of Laser A voltage from -1.542 to -1.347 V needed to bring target lines in alignment with absorption peaks.

Laser B appears to need no adjustment at -3.112 V and is already aligned

Fault rectified: instrument now working.

Measuring ambient air through 0.2 μm filter direct to inlet port on WVISS. Total water volume 6000 ppm – seems reasonable; lower than Cambridge indicating lower humidity on JCR (and suggesting lifetime of Drierite might be longer).

Left to run/stabilize overnight.

Saturday 2nd April (at sea)

Ambient air during morning still at around 6000 ppm.

Fault:

5. Despite the fact the instrument is measuring, my feeling is that the instrument sample pump is drawing significantly less well than experienced in Cambridge. (Same fault log as 3. above)

WVIA module removed from rack and moved to Deck Engineer's workshop. Removed lower left side panel to access instrument vacuum pump, assisted by Deck Engineer and Electrician. Pump appears to start up and run normally, though both inlet and exhaust streams are weaker than experienced in Cambridge.

Returned to instrument rack and reconnected. Instrument restarted, continuing to draw ambient air.

Checking on Simdos pump performance (Fault log 1. above). Replaced pump head with new spare head. Not working any better. Checked pump rate at setting 20 mL/minute – achieved 3.6 mL/minute. Checked pump rate at setting 12 mL/minute – achieved less than 1.0 mL/minute. No obvious fault visible on either old or new pump heads, so no way forward.

Swapped out Simdos metering pump for a Cole Palmer Masterflex C/L peristaltic pump brought along as a spare liquid pump. Set flow rate to 2.0 mL/minute (around 6 o'clock on small setting knob).

1940 (clock): Set to pump seawater across membrane for first time.

2000 (clock): Set air source to pass ambient air across membrane and into the inlet port of the WVISS.

2200 (clock): measuring 22,000 ppm water, at around -8 per mil δ18O.

Fault:

6. MFC reads 68.5 sccm (cm^3 per minute at STP), whereas manufacturer suggests flow rate should be around 150 sccm – essentially a ‘value for the Faults 3 and 5 above.

1956 Z: Time set to ships GMT clock by transferring time from time screens in UIC lab. Required adjusting by retarding instrument clock by 1h 08m 30s.
2012 Z: Drierite added to desiccant column, and connected to air inlet of membrane via 0.2 μm filter.

Noted distinct cycle in water density, with similar cycle in isotopes. Assumed cabinet or laboratory temperature cycling. Dropped cabinet set point to 18°C to closer match laboratory. Cycle disappears after next calibration sequence.

2253 Z: Left overnight running seawater, changing sampling frequency to 50s intervals.

Sunday 3rd April (in vicinity of Signy Island)

Overnight seawater looked good, though some marked shifts in isotope values.

Instrument appears stable. Water 20970 ppm, δ^{18}O -8.23 per mil.

Intentions to go ashore to collect glacier samples, but weather prevents small boat operations. Ship stooges around Coronation and Signy Islands.

Instrument left running during morning with no interventions, but by mid-afternoon, the signal in both water density and isotopes looks increasingly poor.

1610 Z: Added 1/8” OD stainless steel coiled loop approximately 2.0m in length between external filter bank and liquid inlet to membrane, mounted outside the Heratherm cabinet.

Reasoning: I anticipated that the length of plastic tube inside the Heratherm cabinet would not be sufficient to warm the near-0°C seawater source to the cabinet temperature of 19°C in the time spent between the filter bank and the membrane, with the result that the membrane performance would not be stable. Installed outside the cabinet to allow the lab temperature to equilibrate the water flow temperature.

1631 Z: sampling rate change to 20s averaging.

1700 Z: replaced old membrane (ex testing in Cambridge) with a new membrane module (model G591, Lot 083133).

2030 Z: set up WVISS calibration sequence to once every 2 hours

Purge	30 s	4.99 V
Stabilise	60 s	0.50 V
Ref flow	540 s	0.50 V
Purge	30 s	4.99 V

Left to run seawater overnight.

Monday 4th April (in vicinity of Signy Island)

Scientists out all day sampling glacier ice, melt ponds and seawater in face of glacier.
2014 Z: Discontinued water sampling to position membrane better, with ‘air pocket’ at the top of the liquid flow direction. Purpose was to allow air bubbles currently trapping in membrane to escape.

Fault:

7. A great deal of air seems to be evolving from the membrane, with one large bubble every minute of so.

Tried setting peristaltic pump to maximum (9 o’clock position). Checked for leaks on membrane and in the feeder tubes and joints. Nothing obvious. Fault traced to the rather obscure factor that the drain syphon pressure was sufficient to pull air across membrane from dry to wet side.

Solved by running drain to a high point above instrument – eventually to an open tube above the level of the membrane. No further air bubbles via this source.

Left overnight running ambient air.

Tuesday 5th April (at sea, towards Weddell Sea sea-ice)

Changed to run ambient air via Drierite column – water density only 2200 ppm. Good drying performance.

1133 Z: closed down instrument to test internal pump again.

Tried external KNF pump (borrowed from Picarro gas analyser in UIC lab). No improvement in gas flow on either the WVISS inlet port, nor the T-WVIA rear panel inlet port.

Tried removing T-WVIA internal pump, disconnecting air tubing, then reconnecting power and turning on instrument. Pump sucks and blows as well as I remember in Cambridge. Conclusion is that the pump itself is fine, but there is some restriction in the gas volume flow somewhere in the instrument.

1248 Z: restarted instrument after rebuilding, switching from ambient air to seawater.

1533 Z: stopped and restarted instrument.

2006 Z: switched to pump ambient air.

Fault:

8. Failing to keep Heratherm cabinet at a stable temperature (see figure 8.6).
9. Strong ripple in water concentration with about 5 minute period.

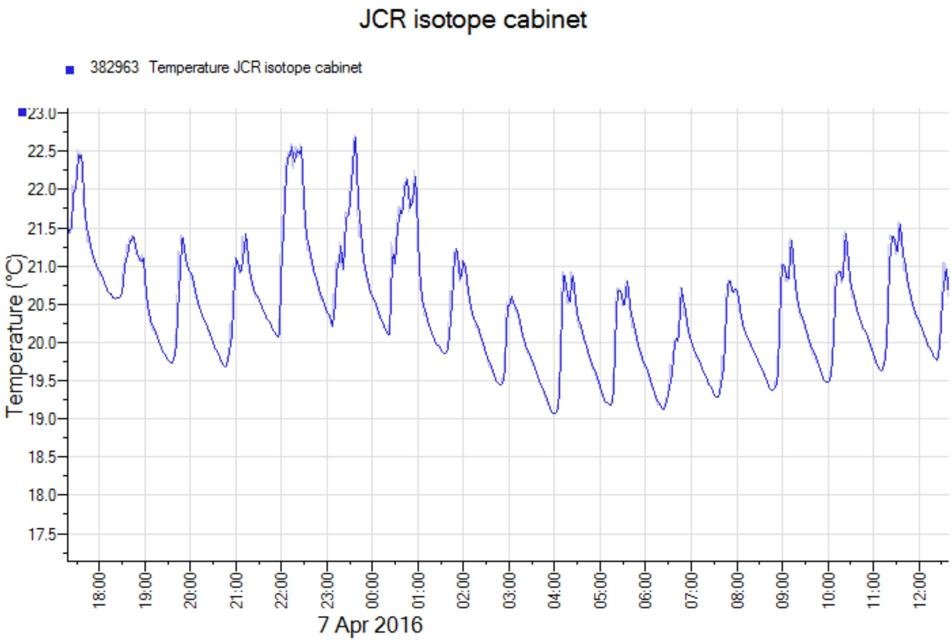


Figure 8.7: Temperature log from Heratherm cabinet overnight 5th to 6th April. Note instability with about a 3 degree cycle in cabinet temperature.

Assumed cabinet failing to hold temperature closely. Noted that MFC is getting very hot, and probably contributing heat to the cabinet. Moved MFC out of cabinet to frame of rack.

Set MFC to monitor rather than control flow mode. Noted that MFC now reading only 58.1 sccm – lower than earlier in the voyage.

Replaced peristaltic pump tube.

Left running seawater overnight.

Wednesday 6th April (at sea)

Signal became significantly less noisy, with temperature cycles now reduced from around 3 degrees, to around 0.1 degrees (figure 8.7) and water concentration ripple much reduced.

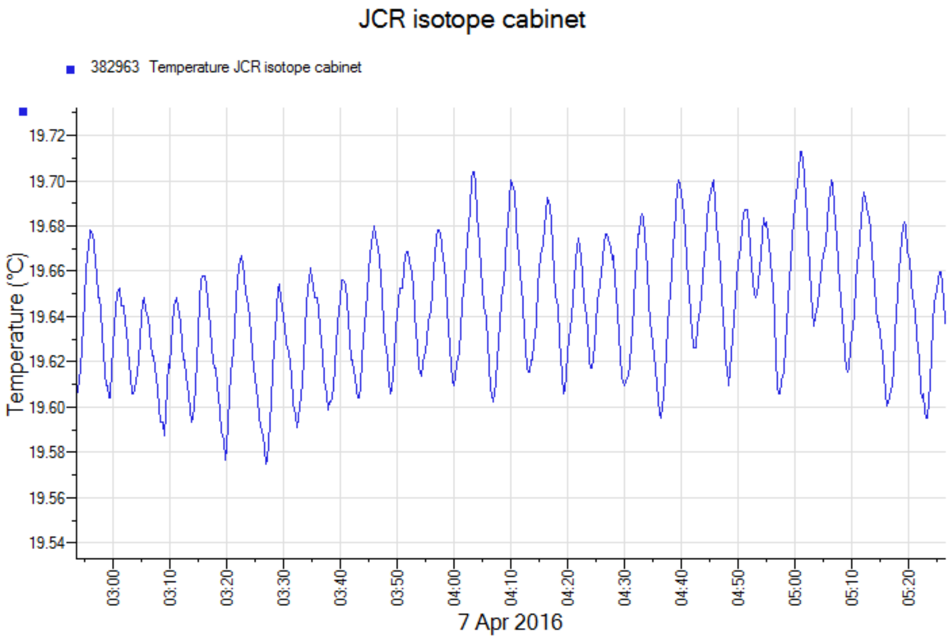


Figure 8.8: Temperature log in Heratherm cabinet 7th April. Temperature cycling now reduced to better than 0.2 degrees.

1700 Z: Turned off instrument. Following advice from Los Gatos Research (engineer Bob Provencal), tried removing the check valve from the line between the internal pump and the cavity in case it was failing to open fully.

Reassembled and restarted instrument – airflow volume back to 68.5 sccm.

Turned off cabinet overnight to see if it settles like this. Running seawater.

Thursday 7th April (at sea)

0035 Z: data very ugly. Water concentration both very high, and very noisy, and δ^{18}O has dropped to around -12 per mil.

0700 Z: data still very ugly.

0707 Z: turned off instrument. Worried that the lack of check valve in the system has not improved things much, decided to put it back into the instrument to avoid any ingress of air from the open exhaust side to the cavity when the system is turned off.

0810 Z: after waiting one hour, removed instrument from rack and replaced check valve.

0824 Z: instrument turned on. MFC stabilized at 68.5 sccm – back to same flow rate despite refitting check valve.

Fault:

10. Substantial amount of water vapour in gas line between membrane and MFC, and between MFC and inlet port on WVISS.

Suspect either leak in membrane or high temperature reached in cabinet overnight (~26°C; cabinet temperature control had been turned off) might be causing too much evaporation across membrane which is then condensing in the air lines in the cooler lab.

Bypassed membrane with dry air lines from desiccant, and ran instrument on ambient (dry) air from Drierite to evaporate all moisture from air lines. Water concentration remained high at ~25300 ppm until 1038 Z when it suddenly dropped as the last of the moisture left the air lines.

1142 Z: instrument stable at ~3000 ppm water. Changed set up to suck ambient lab air directly into instrument. Stabilized at 6800 ppm at 1146 Z.

1205 Z: changed to pull Drierite air into system again, without 0.2 μm filter. Slow ramp down to 2800 ppm water by 1235 Z. No discernible change in MFC flow at 68.4 sccm, implying no loss of airflow from air filter – must always use air filter then since no impact on flow rate. Returned 0.2 μm filter back into air line.

1248 Z: changed membrane in case leaking to new G591/Lot W083133 membrane.

1326 Z: reduced Heratherm cabinet temperature to 19°C to test cabinet temperature control at a lower temperature (recall that fractionation is taking place across membrane, so stability of the isotope signal has a dependence on the temperature control of the membrane cartridge installed in the cabinet).

Figures 8.8 and 8.9 demonstrates the further stability in temperature control of the cabinet at the lower temperature, with the temperature controlled now to better than 0.05°C.

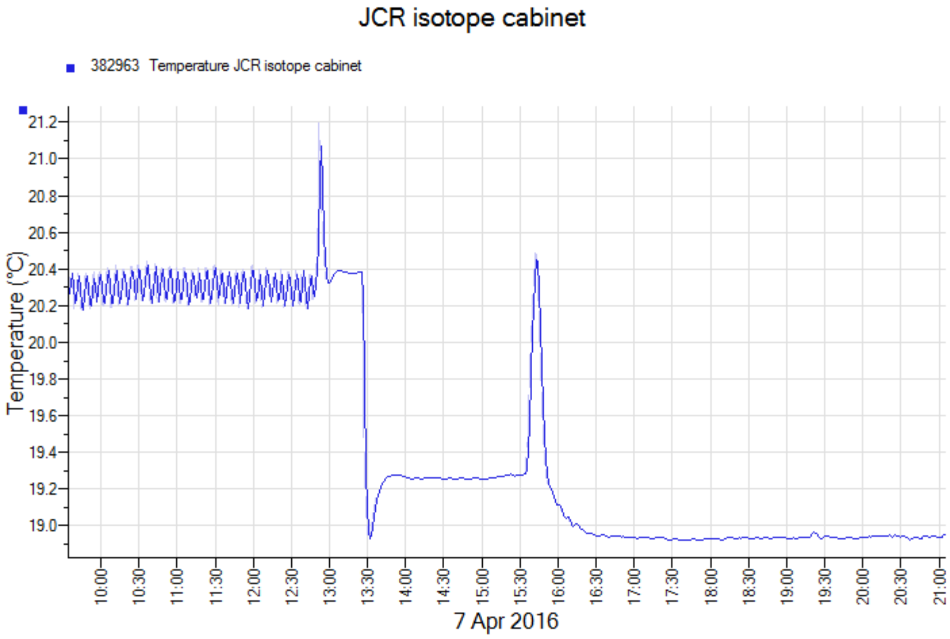


Figure 8.9: Heratherm cabinet temperature 7th April demonstrates the additional stability that came from reducing the cabinet temperature from 21C to 19C.

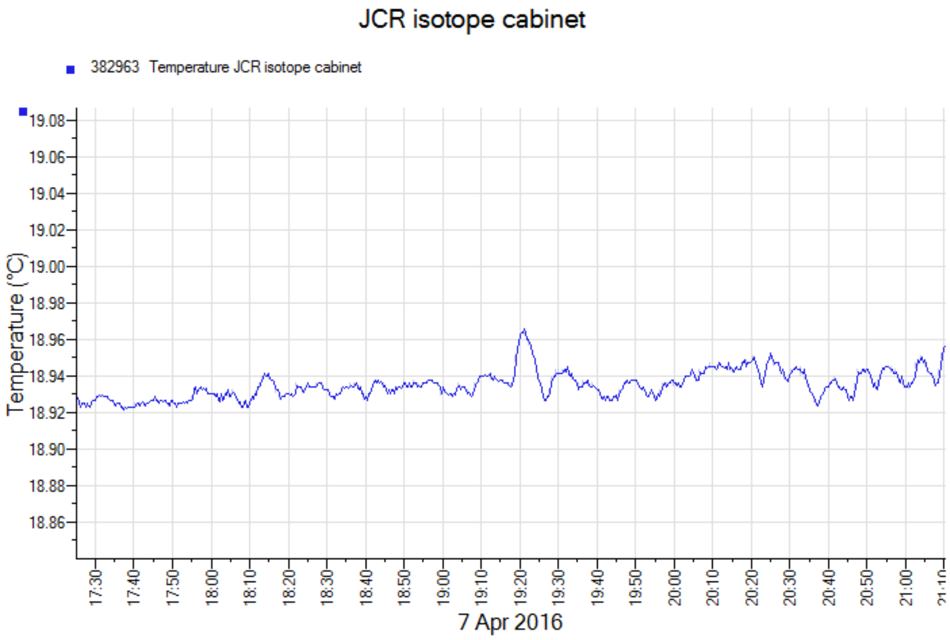


Figure 8.10: Log of Heratherm cabinet temperature when set to maintain 19C. Temperature stability is now better than 0.05 degrees - pretty impressive!

1538 Z: measuring seawater again.

Left measuring seawater overnight.

Friday 8th April (at sea)

1108 Z: changed calibration interval to three hours (losing too much data on a two-hourly schedule).

1158 Z: ***Fault:***

11. Water again visible in outlet of (new) membrane.

Again bypassed membrane and dried lines by pulling fry air through to instrument. New membrane (G591, Lot W083133). Once lines dry, set to run seawater again.

1500 Z: entering scattered patches of sea-ice

1608 Z: underway seawater intake closed off by Deck Engineer (Craig). Peristaltic pump turned off. Set to draw un-dried lab air through instrument.

1925 Z: set up to run from 1L bottle of MQ water as liquid intake, using ship supply tube off filter panel and directly into MQ water bottle.

Observation: is the condensation in the outlet side of the membrane due to the change in temperature between the lab (around 22°C) and the cabinet (set to 19°C)? The water stream passes through 2m long 1/8” stainless steel tube to equilibrate the seawater to the lab temperature. Or could the condensation be building up due to the long calibration time when dry air is not being pulled across the membrane?

Reduced the ‘Ref Flow’ time on the calibration sequence to 240 s (from 540 s). Note: only the ‘Ref Flow’ part of the calibration sequence switches airflow from the membrane inlet side to the WVISS side.

2259 Z: increased cabinet temperature to 21°C (from 19°C) to reduce difference with lab temperature.

0002 Z: water concentration in the cavity has risen to 27,000, higher than my preference. Reduced cabinet temperature to 20°C.

0112 Z: reduced pump speed to 2 o'clock position, topped up MQ bottle and left to run on slow flow of MQ overnight, calibrating every two hours.

Saturday 9th April (in the sea-ice, no underway seawater supply)

0945 Z: ***Fault:***

12. Laser B lost lock on absorption peaks overnight, so no δ^{17}O signal, though δ^{18}O and δD seem OK (measured with laser A).

Tried manually slipping lock voltage to re-align absorption peak with target line, but unable to get it to lock on. Absorption peak seemed to flick from well to the left of the target line to well to the right with only a single press of the manual voltage signal change. Sought advice from Los Gatos Research via email.

0952 Z: increased peristaltic pump to 6 o'clock position. Increased calibration 'Ref Flow' to 300s (from 240s) to be sure of capturing a stable calibration signal.

Intentions for today: find multi-year sea-ice flow, and put team onto it via the Wor Geordie to collect sea-ice cores, then do similar on a flow of first-year ice.

1400 Z: slowed peristaltic pump to 2 o'clock position.

1805 Z: once sea-ice sampling finished, re-plumbed water supply and cabinet to bring the 2m stainless steel tube inside the cabinet so all equilibration of seawater supply takes place inside the cabinet. Simplified some of the silicone tube joints.

Moving the 2 m stainless steel loop into the cabinet means that the seawater is brought up to cabinet temperature inside the cabinet, so is less prone to changes in laboratory room temperature, and relies less on the final liquid lines and membrane providing the 'final tuning' of the liquid stream temperature. Don't know why I didn't make this rather obvious change earlier figure 8.10 shows the laboratory temperature cycles through about 2°C.

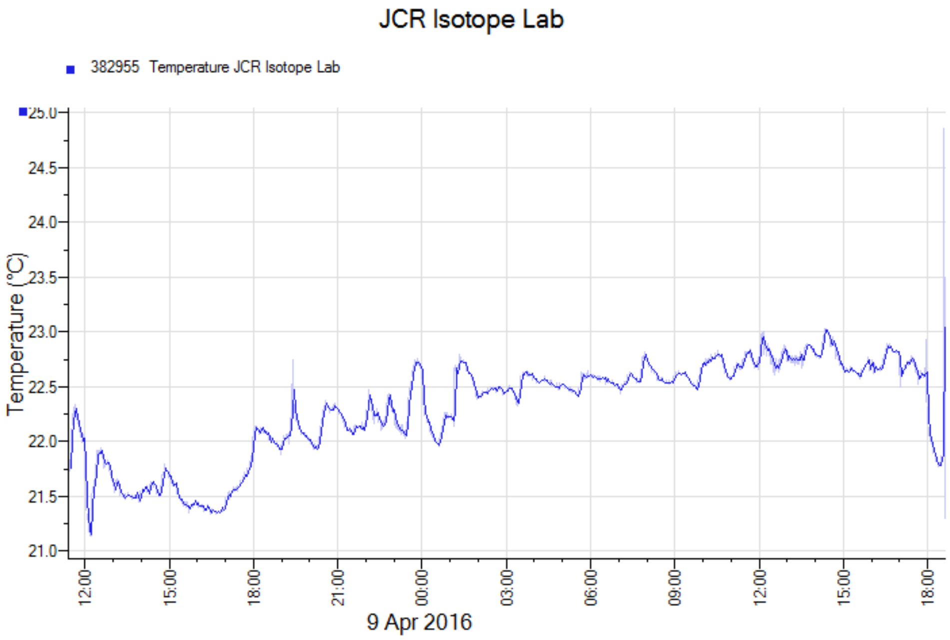


Figure 8.11: Log of laboratory temperature 8th to 9th April.

1934 Z: topped up MQ bottle and set peristaltic pump to 4 o'clock position.

2045 Z: peristaltic pump to 2 o'clock, left overnight running MQ water

<u>Sunday 10th April (leaving sea-ice zone, out to sea towards CTD transect)</u>

1105 Z: seawater running again

1115 Z: set up intake to seawater again, peristaltic pump at 6 o'clock position

2157 Z: initiated calibration sequence in preparation for changing peristaltic pump tube

2211 Z: on advice from Bob Provencal (LGR) who believed the laser lock board had 'got into an odd state' turned off instrument and restarted. Was now able to successfully manually re-tune laser voltage to bring absorption peak onto target line. Re-measuring all isotopes again.

2232 Z: cabinet temperature set to 19°C - this seems to the optimum from experience of the last few days.

2240 Z: check on instrument time – 2 seconds ahead of UIC lab reference time clocks.

<u>Monday 11th April (at sea)</u>

0935 Z: all system appear working OK but there is a strong drift in δ^{18}O signal towards less depleted, evident in both seawater and standards (implying instrument drift)

1300 Z: δ^{18}O drift seems to have leveled out.

1330 Z: δ^{18}O now drifting down to more depleted

Fault?:

13. Is this drift in δ^{18}O a fault, or signal? (Drift less apparent in δD.)

Emailed LGR for advice (did not hear back for another week – LGR guys at EGU).

Tuesday 12th April (at sea, arriving at first CDT location)

1152 Z:

Fault:

14. Air leaking into fluid flow path after the filter bank

Solved by replacing sealing cones on Swaglok to 1/8” PFA tube and tightening sealing nuts on the two filters.

Fault:

15. Noted that filters do not seem to seal well, and persistently leak seawater from a small breather hole on the cap (outside of the seal).

Not solved by end of cruise. No spares available – needs re-design of filter side of seawater intake.

2230 Z: arrived at deep CTD site. Use time to test instrument internal calibration routines.

Wednesday 13th April (at sea)

0120 Z: instrument back on board, underway, just as instrument stabilizes to seawater again.

Thursday 14th April (at sea)

0905 Z:

Fault:

16. Brown tint to water inlet tubes between filters and cabinet; membrane has turned brown; water appears clean at T-junction upstream of filters; very low flow through peristaltic pump. (Instrument itself seems stable.)

Removed and rinsed 40 μm filter, removed and replaced 7 μm filter. Both filters appear to be filled with ‘rust’. Replaced 1/8” PFA tube to cabinet.

Installed 5 μm filter (replaceable Omnipore 47 mm diameter 5 μm filter in split-body cartridge) in order to have a further filtration stage, and the ability to replace filters every day.

Increased sample water flow rate to pump 9 o’clock position to allow for greater dead volume in filtration system.

1847 Z: ***Calibration of system***

Until this point, the system has retained its factory calibration, with the local WVISS providing the ability to drift correct the recorded seawater data.

We now need to calibrate the system using a secondary standard that has been calibrated against NIGL/Keyworth IRMS standards (BAS-HI and BAS-Lo – themselves calibrated directly with Vienna VSMOW-2 and VSLAP-2 primary standards).

Water from a 1-L sealed glass bottle of Cambridge MQ water, calibrated against BAS-Hi and BAS-Lo in late March 2016, and hand-carried to the JCR on the Brize Norton flight, was transferred into three sealed liquid-, light- and air-tight gas sample bags (known as ‘Tedlar bags’) using the now-repaired KNF Simdos 2 liquid pump.

Calibration data from Cambridge for MQ water (no calibration data for $\delta^{17}O$):

$\delta^{18}O$: -8.06 per mille

$\delta^{18}O$: - 49.6 per mille

Connected one Tedlar bag directly to input side of peristaltic pump, set at 9 o'clock pump speed, passing calibration standard directly to the membrane. Signal on the instrument began to change to lower values (than the seawater sample flow that had been the input up until 1847 Z) at 1903 Z. Values stabilized at 1907 Z.

Cambridge MQ water on WVIA:

$\delta^{18}O$: -16.56 (+/- 0.06) per mille

$\delta^{18}O$: - 82.0 (+/- 0.2) per mille

Instrument set to self-calibrate based on the values measured in Cambridge (no calibration possible for $\delta^{17}O$).

Following calibration, and continuing to pump from Tedlar bag of standard MQ water, instrument settled with values of -8.20 $\delta^{18}O$, and -50.6 δD, indicating a small drift between calibration and later measurement of same standard.

Friday 15th April (at sea)

Instrument stable - resisted desire to fiddle with it.

Saturday 16th April (at sea towards South Georgia)

Instrument stable

Sunday 17th April (closing South Georgia/boat sampling in Cumberland Bay/chasing pirates)

0845 Z: all looks fine

1230 Z: water flow through membrane stopped – replaced 7mm filter and peristaltic pump tubing.

1310 Z: instrument running again

Evening – off chasing pirates

Monday 18th April (in Cumberland Bay/CTD casts)

1020 Z: instrument stable – no damage from overnight rough seas/ship motion.

Tuesday 19th April (in Cumberland Bay)

Ship lying to strong winds. No CTDs, boat work etc.

Instrument stable

Wednesday 20th April (moved alongside KEP)

0930 Z: underway seawater supply to lab and instrument turned off to go alongside; peristaltic pump left on and membrane allowed to slowly dehydrate to see what happens.

Scientists ashore for collecting ice core and lake samples on route into Glacier Col, and stream samples from Penguin Creek.

Thursday 21st April (left KEP towards Stanley)

1220 Z: ship slips lines and moves away from quay

1250 Z: underway seawater supply re-established; measurement continues and quickly reaches equilibrium after membrane is wetted.

Three CTD stations occupied and cast.

Friday 22nd April (at sea)

0930 Z: underway seawater supply to lab fails; peristaltic pump turned off at 0950 Z.

1130 Z: underway seawater supply re-established; peristaltic pump on at 1135 Z.

2159 Z: following request from Los Gatos engineer, tested calibration sequences from WVISS at 1s sampling interval (new file for this run).

Saturday 23rd April (at sea)

0040 Z: changed back to 20s interval and normal seawater/calibration sequence for overnight run.

0136 Z: underway seawater supply to lab failed again. Not noticed until 0950 Z; peristaltic pump turned off at 1000 Z.

1108 Z: underway seawater supply to lab re-established; instrument pump turned back on again. Instrument takes 10 minutes to settle to seawater analysis.

Instrument running seawater on passage towards Falklands.

Sunday 24th April (at sea)

Instrument running seawater on passage towards Falklands. Data stable until 2350 Z, when the isotope signal gradually became less depleted until 0240 Z (25th April), before falling back to the more normal seawater character at 0540 Z (25th).

Monday 25th April (at sea to evening, then hold position in Port William, Falkland Islands)

0830 Z: underway seawater failed.

1145 Z: underway seawater re-established.

1221 Z: shut down instrument and restarted

1247 Z: underway seawater failed again.

1338 Z: switched to running laboratory Super-Q water

No further seawater analysis prior to arrival at Falkland Islands.

Tuesday 26th April (moved alongside FIPASS)

Taught Carson McAfee (BAS/AME) to manage the instrument on voyage to the UK. Full written instructions left with Carson, and with Chief Engineer.

Instrument turned on and off several times while demonstrating instrument function.

Running Super-Q water – very stable throughout day.

2213 Z: Set up WVISS to run long (7200 seconds, i.e. 2 hours) calibration sequences, at 1 second recording interval.

0114 Z: Set up instrument to run calibration and Super-Q water overnight at 1 second recording interval.

Wednesday 27th April (alongside FIPASS)

Instrument unstable for majority of today, with odd episodes of rising water volume and linear rise in stable isotopes, unrelated to calibration sequences.

2055 Z: instrument turned off to reset.
Left running overnight with Super-Q water.

Thursday 28th April (alongside FIPASS)

Instrument slow to reach a stable operating conditions; not fully stable until 1420 Z. Cause of instability unknown.

1420 Z to 29th April – instrument stable and measuring well.

Replaced peristaltic pump tube connectors from slip-on to PFA via silicone tube sleeving and cable ties (which avoid the leak) to pukka peri-tube connectors (brought down by Captain of new crew).

Replaced red/red peristaltic pump with purple/purple (higher flow rate) for routine use from Stanley towards UK. Higher flow rate requires lower pump speed, and increases a little the lifetime of the pump tube. A comparison of the liquid flow rate for the two tubes is given in figure 8.11.

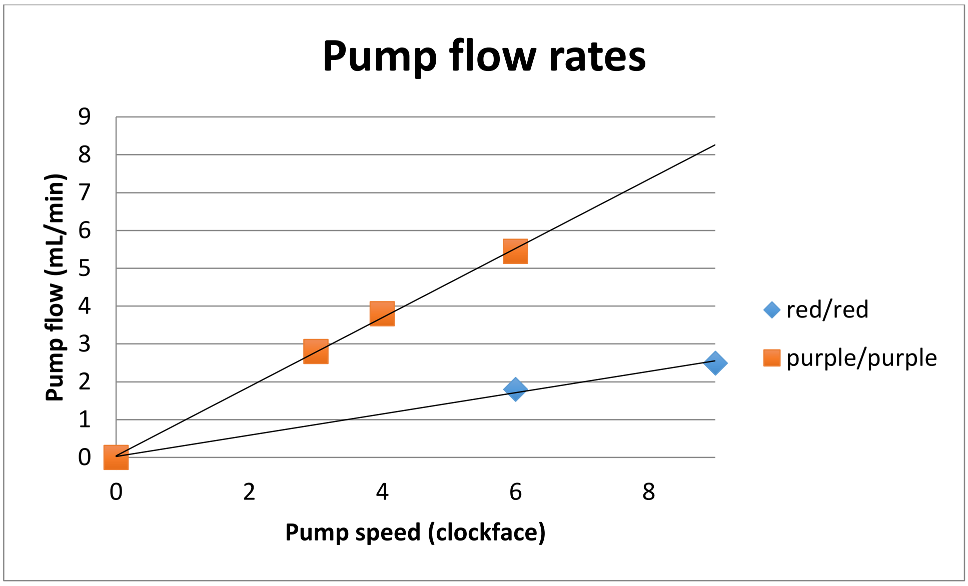


Figure 8.12: pump flow rate with two diameters peristaltic pump tubes

Recommendation for setting for pump on cruise to UK is to set the pump flow knob to the 4 o'clock position (approx. 3.8 mL/min).

1221 Z: Changed calibration parameters to 300 seconds stabilisation and 360 seconds calibration flow.

2230 Z: Topped up WVISS standard bottle with fresh Super-Q water taking it from lowest part of should of glass bottle, to the neck. This will now last the cruise through to the UK.

Friday 29th April (alongside FIPASS / transfer to MPA and flight to UK)

Instrument running well on Super-Q water. Left in hands of Carson McAfee for the run north towards Trinidad and the UK.

8.12 Summary of final operating parameters, 29th April 2016

Parameter	Value	Units
Liquid flow rate	3.8	mL/min
Rough filter	40	µm
Fine filter	7	µm
Final filter	5	µm
Peristaltic pump tube ID	2.06	mm
Peristaltic pump tube OD	3.78	mm
Air flow rate	68.3	sccm
Cabinet temperature	19	°C
Data averaging	20	seconds
Calibration interval	3	hours
Cal sequence - stabilise	300	seconds
Cal. Sequence - flow	360	seconds
WVISS nebulizer pressure	20	psi
WVISS output pressure	36	psi

8.13 Processing/calibration of data files

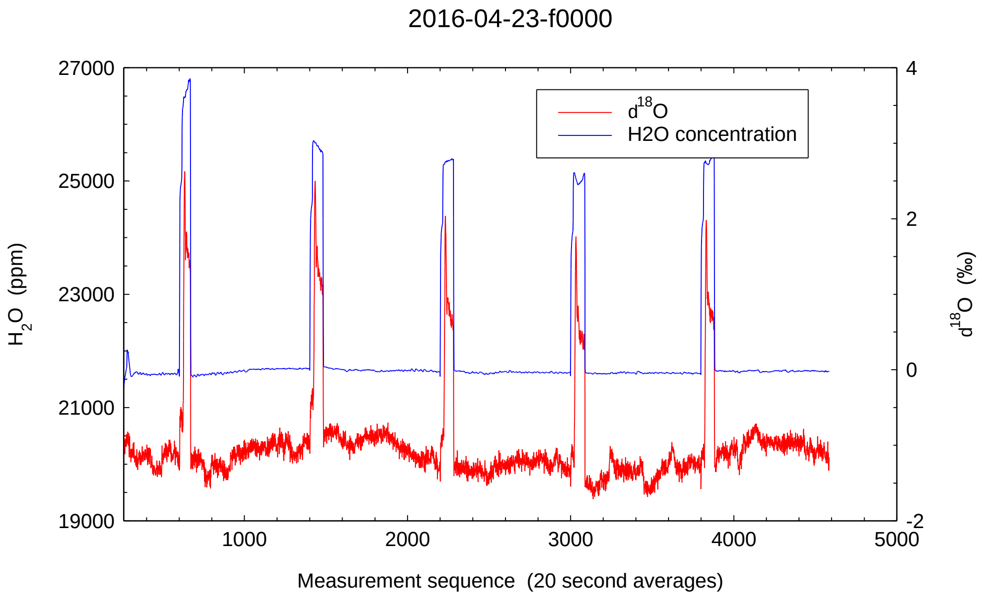
Raw data files from the WVIA are stored daily as zipped files containing the raw data in plain text format with the naming convention twvia yyy-mm-f000x.txt. At the end point of the cruise, the UWIA raw data remains to be fully processed to remove spurious signals, and instrument drift, and calibrated against measured isotope values from coincident samples taken from the underway seawater supply to the laboratory.

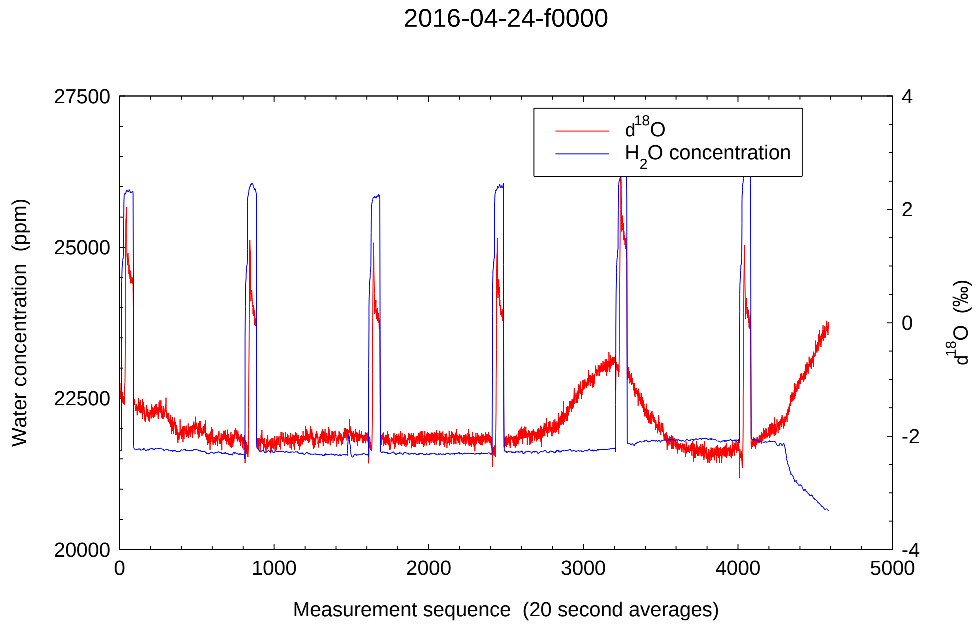
Generally, the discrete samples were taken several time daily, timed to not fall into the periods when the WVISS was drift-calibrating. These samples will be later measured at the NERC Isotopes Geosciences Laboratory in Keyworth.

Once we have the discrete isotopes measurements, we will be in a position to test the performance of the UWIA.

Example 24-hour periods of underway d18O data are shown in Section 8.14.

8.14 Example raw data





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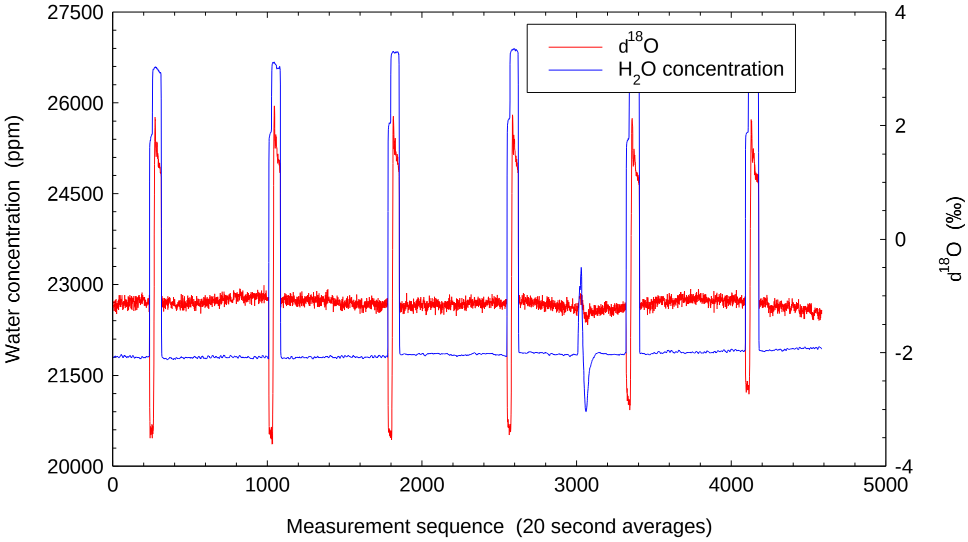

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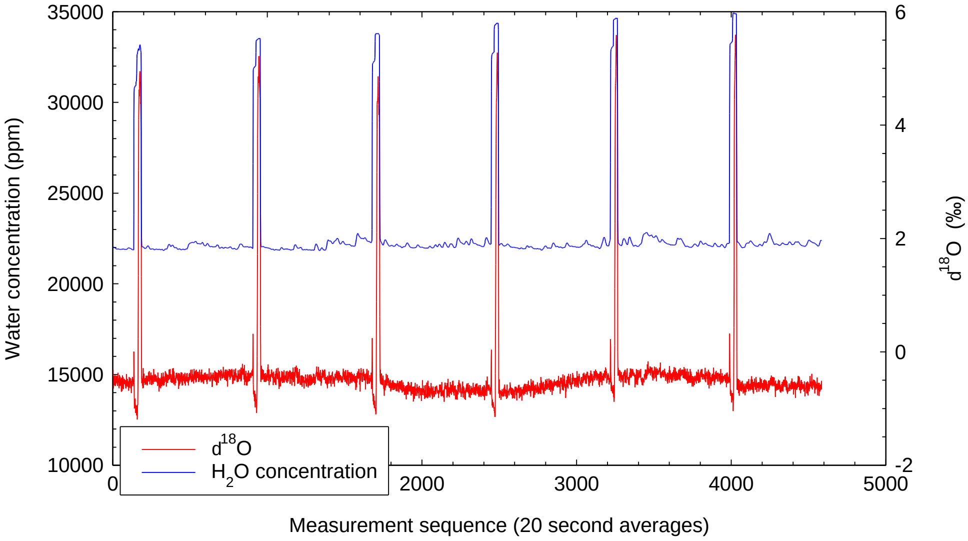


9. Signy Island Fieldwork & Small Boat Work

Erik Mackie

We arrived at Signy Island in the morning of Sunday 3rd April 2016, at around 07:00 local time. The intention was for a fieldparty of 10 people (7 scientists, 2 crew members and the doctor) to go ashore in the Humber inflatable powerboats. The boats were prepared and everyone was kitted out in boatsuits and ready to go by 09:00. However, after lowering the first Humber boat over the edge of the ship it was decided that the sea state was too rough to be able to use the boats safely, and the fieldwork was postponed till the following day.

On our second day at Signy, Monday 4th April 2016, the weather was much improved so the fieldwork plans were able to go ahead. Due to the previous day's work being postponed, we had to condense the plans for both days into one. This meant that a smaller fieldparty of 6 people (4 scientists, 1 crew member and the doctor) went ashore in the Humber boats, setting off at 07:00 local time, while the other scientists stayed on the JCR with the intention of doing the planned small boat work in Clowes Bay to sample the glacial runoff water from McLeod Glacier.

The fieldparty was dropped off at the jetty at Signy research station, which was deserted apart from a few elephant seals as it had been closed for the winter a few days previously. From the base, we walked up Stonechute Gully to get to Moraine Valley and followed that up to Khyber Pass, on the edge of McLeod Glacier. Crampons were used to proceed onto the glacier in a safe manner. Once on the glacier, a sampling line was chosen along the length of the Gourlay Snowfield arm of McLeod Glacier, starting at the top near Garnet Hill and finishing near the glacier terminus. Along this line, 7 ice cores were taken using a handheld ice corer. Each ice core consisted of two sections which were packaged individually in plastic tubing, carefully labelled according to the numbering system used by Robert Mulvaney, and finally stored in the -20°C freezer back on the JCR. The GPS locations and sampling times of the ice cores are shown in Table 9.1, and marked on the map in Figure 9.1.

Ice Core Label	Latitude	Longitude	Time (UTC)	Map ID
15/S1/01-02	S60°43.239'	W45°36.789'	13:19	J15-S1
15/S2/01-02	S60°43.217'	W45°36.838'	13:30	J15-S2
15/S3/01-02	S60°43.188'	W45°36.888'	13:50	J15-S3
15/S4/01-02	S60°43.165'	W45°36.913'	14:15	J15-S4
15/S5/01-02	S60°43.263'	W45°36.735'	14:37	J15-S5
15/S6/01-02	S60°43.314'	W45°36.629'	14:53	J15-S6
15/S7/01-02	S60°43.293'	W45°36.667'	15:02	J15-S7

Table 9.1: Signy Island fieldwork ice core locations and sampling times. Map markers are shown in Figure 9.1

We had a couple of technical issues with the handheld ice corer. Firstly, the metal clips which are supposed to pop out and catch the ice core as it is pulled up were not always deploying properly. This appeared to be due to residue ice and snow from the previous core building up in the mechanism and obstructing the clips. Careful cleaning before drilling the next core ensured that the clips were functioning properly. Secondly, the section of metal tubing that connects the handle to the top of the main shaft of the corer started jamming. This made it almost impossible to add the extender sections onto the shaft. For fear of permanently damaging the tubing and risk not being able to reconnect the handle at all (which would have put a stop to the ice coring completely), we decided to no longer use the extenders and keep the handle attached to the main shaft section. This meant that we could only drill up to a depth of one time the length of the corer (rather than 2 or 3 times with the extender sections), but this was deep enough for our purposes. Once back on the JCR, one of the engineers was able to fix the problem with the metal tubing.

Once the ice cores had been completed, we proceeded to collect water samples from the Khyber

Pools along the edge of the glacier and from a meltwater pool at the foot of the glacier. We were also able to sample the seawater from the beach at the glacier terminus in Clowes Bay. A block of ice was collected from this beach as well and taken back to the JCR where part of it was melted down for sampling (the remaining part was stored in the -20°C freezer). Finally, we sampled the seawater at the beach in Rethval Cove where we were picked up by the Humber boats before returning to the JCR. At all sample locations, 2 or more salinity bottles and δ^{18}O vials were filled following the usual procedure. Salinity bottles were rinsed 3 times, then filled up to the base of the neck, dried with clean paper, and sealed with a stopper. The caps were also rinsed and dried before being screwed onto the bottles. The δ^{18}O vials were also rinsed 3 times, filled and dried before being closed with a stopper and sealed with the crimper. The GPS locations of all samples are marked on the map in Figure 9.1, and listed in Table 9.2 along with the δ^{18}O vial numbers and sample times.

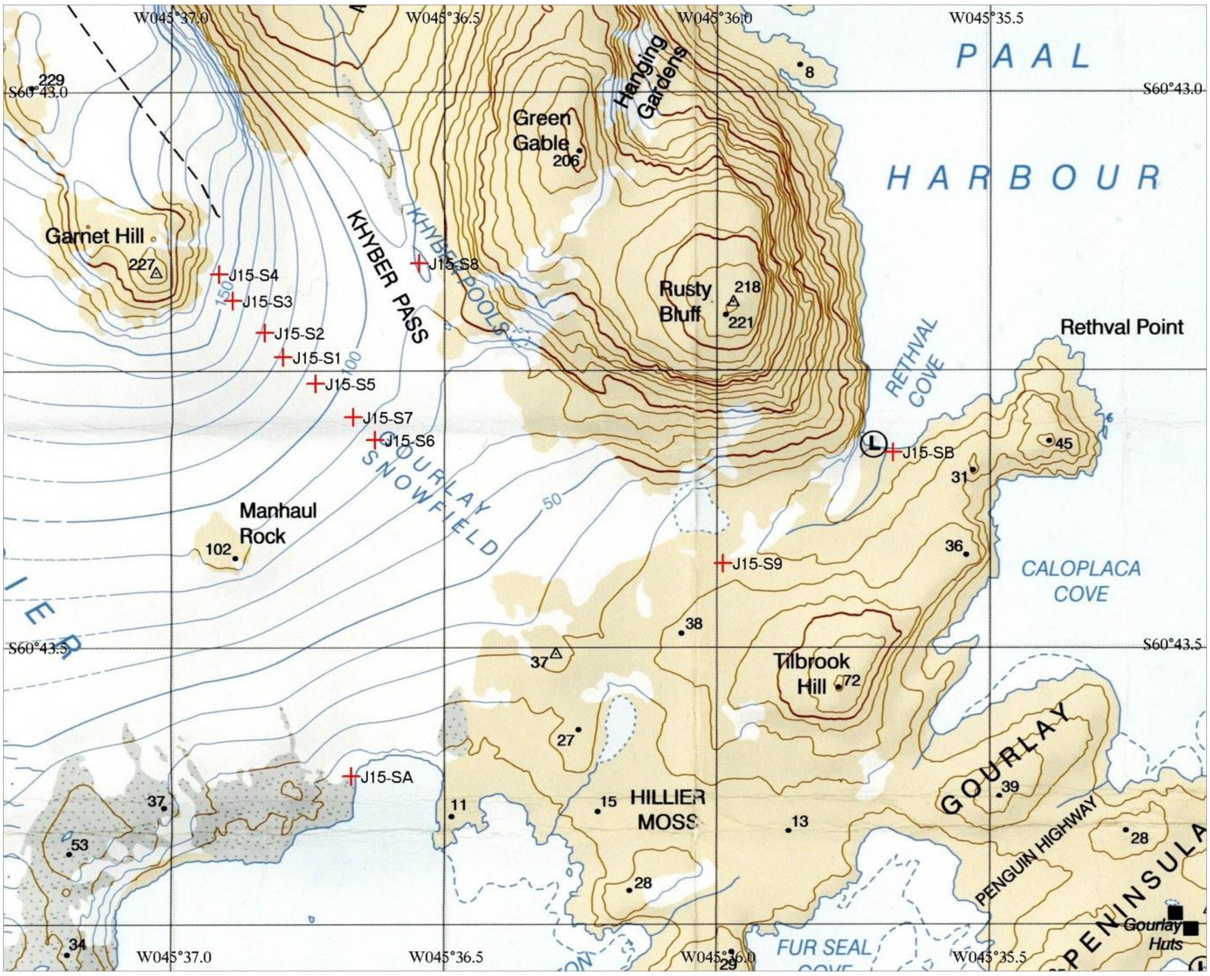


Figure 9.1: Map showing locations of ice cores and water sampling on Signy. For map IDs see Tables 9.1 and 9.2.

Location	Latitude	Longitude	Time	δ^{18}O vial numbers	Map ID
Khyber Pools	S60°43.155’	W45°36.546’	15:44	0001 → 0002	J15-S8
Melt pool at glacier foot	S60°43.425’	W45°35.988’	17:41	0008 → 0010	J15-S9
Clowes Bay beach	S60°43.616’	W45°36.673’	17:12	0003 → 0007	J15-SA
Ice block C. Bay beach	S60°43.616’	W45°36.673’	17:15	0040 → 0042	J15-SA
Rethval Cove beach	S60°43.327’	W45°35.671’	18:01	0012 → 0014	J15-SB

Table 9.2: Signy Island fieldwork water sampling locations and times.

While the fieldparty was ashore on Signy, the plan was for the other scientists remaining on the

JCR to undertake some water sampling from the Humber boats out in Clowes Bay. To this end, the JCR sailed round to Clowes Bay after having dropped off the fieldparty at Signy research station. However, on arrival in the bay, the sea state was once again too rough to be able to deploy the boats safely. Even though the weather had greatly improved from the day before, there was still a strong southerly wind which meant that Clowes Bay was particularly exposed and the water there was quite choppy. The small boat work was therefore postponed until later in the day after the fieldparty had returned, by which time the wind had died down enough to make deploying the boats in Clowes Bay possible. At this point, two Humber boats went out to collect samples in the bay, each with 1 scientist and 2 crew members on board. One boat followed a sampling line in the eastern part of Clowes Bay, the other went to sample the western part. At each sampling location two salinity bottles were filled and sealed following the usual procedure, one of which was carefully decanted into a δ^{18}O vial once back on the JCR. The western boat also collected a block of ice from the bay, part of which was melted down and decanted into salinity bottles and δ^{18}O vials (the remainder was stored in the -20°C freezer). The GPS locations of all samples are shown on the map in Figure 9.2, and listed in Table 9.3 along with sampling times and δ^{18}O vial numbers. Unfortunately, the eastern boat did not record the longitudes of the sampling locations at the time of sampling, so these were added at a later stage based on the location of the JCR during the sampling campaign.

Location	**Latitude**	**Longitude**	**Time**	**δ^{18}O vial number(s)**	**Map ID**
C. Bay West	S60°44.0’	W45°37.327’	20:23	0015	J16-CB01
C. Bay West	S60°44.0’	W45°37.327’	20:23	0035, 0036, 0039 *	J16-CB01
C. Bay West	S60°44.106’	W45°37.206’	20:33	0034	J16-CB02
C. Bay West	S60°44.210’	W45°37.043’	20:37	0023	J16-CB03
C. Bay West	S60°44.320’	W45°36.976’	20:43	0024	J16-CB04
C. Bay East	S60°44.55’	W45°36.82’ **	20:14	0022	J16-CB05
C. Bay East	S60°44.35’	W45°36.82’ **	20:19	0033	J16-CB06
C. Bay East	S60°44.20’	W45°36.82’ **	20:23	0032	J16-CB07
C. Bay East	S60°44.05’	W45°36.82’ **	20:26	0038	J16-CB08
C. Bay East	S60°43.90’	W45°36.82’ **	20:31	0029	J16-CB09
C. Bay East	S60°43.75’	W45°36.82’ **	20:35	0037	J16-CB10

Table 9.2: Sampling locations and times for small boat work in Clowes Bay, Signy.

*Block of ice collected from bay which was later melted down and decanted into bottles.

**Longitude not recorded during original sampling, but added later based on JCR location.

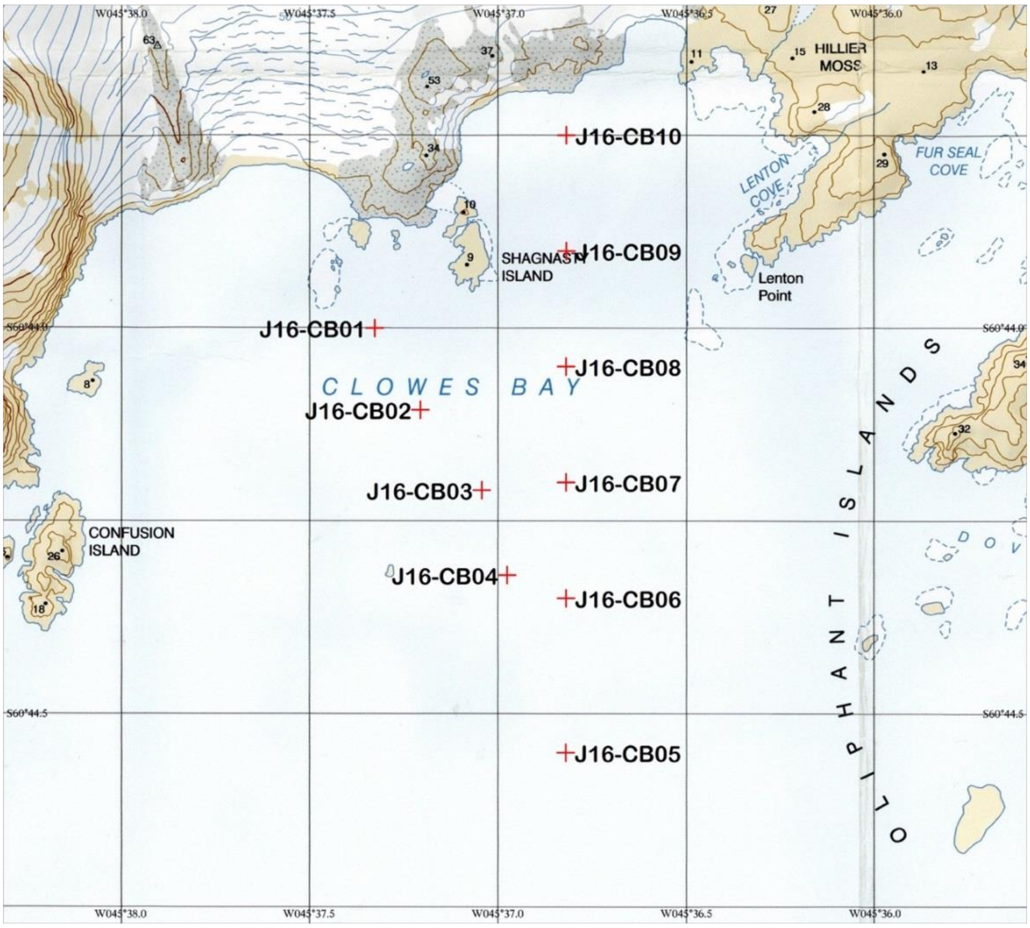


Figure 9.2: Map showing small boat sampling locations in Clowes Bay. For map IDs see Table 9.3.

In addition, a final set of boat samples was taken by Wave, the ship's Second Officer, on his approach to Rethval Cove to pick up the field party. He did not get a chance to record GPS locations for these samples, however based on the start and end points of his route we were able to estimate the 12 sample locations, evenly distributed along a straight line leading towards Rethval Cove. These locations are shown on the map in Figure 9.3, and in Table 9.4 along with the associated sampling times and δ^{18}O vial numbers. Many thanks go to Wave for the collection of these samples.

Latitude	Longitude	Time (UTC)	δ^{18}O vial number	Map ID
S60°42.950'	W45°34.900'	17:15	0016	J16-RC01
S60°42.985'	W45°34.985'	17:22	0017	J16-RC02
S60°43.010'	W45°35.020'	17:27	0018	J16-RC03
S60°43.050'	W45°35.115'	17:31	0019	J16-RC04
S60°43.075'	W45°35.200'	17:35	0020	J16-RC05
S60°43.115'	W45°35.265'	17:40	0021	J16-RC06
S60°43.150'	W45°35.325'	17:45	0025	J16-RC07
S60°43.180'	W45°35.400'	17:49	0026	J16-RC08
S60°43.220'	W45°35.490'	17:53	0027	J16-RC09
S60°43.250'	W45°35.550'	17:57	0028	J16-RC10
S60°43.275'	W45°35.615'	18:01	0030	J16-RC11
S60°43.310'	W45°35.680'	18:08	0031	J16-RC12

Table 9.3: Location and sampling times of samples collected on approach to Rethval Cove.

Figure 9.3: Map showing small boat sampling locations on approach to Rethval Cove. For map IDs see Table 9.4.

Once the small boat sampling work had been completed, we finished off the work at Signy with a line of CTDs leading out from Clowes Bay towards the shelf break. These were CTD casts numbers 2, 3 and 4.

10. Sea Ice Fieldwork

Erik Mackie

The aim on JR15006 was to collect some ice and water samples from the sea ice in the Weddell Sea, ideally by finding some ice that was thick enough to be able to drill an ice core from it. On 8th April 2016, we entered the sea ice at a point just south of the southern end of the A23 hydrographic section. We then proceeded to sail further south into the denser sea ice, on the lookout for some ice that would suit our purposes. It took longer than expected to find some ice of the right thickness, and eventually it was not until the morning of 9th April at a latitude of S68º that we stopped by a thick floe of multi-year sea ice to get some samples. Our exact location was S68º09.066' W30º59.508', and this position was named "Sea Ice Station 1". Once the JCR was positioned directly alongside the ice floe, several parties of scientists and crew members were transported onto the ice using the "Wor Geordie", a rope basket for passengers to stand on and hold onto, which was then hoisted up by the JCR's rear crane and lowered onto the ice. No more than 4 people were allowed on the ice at any one time. Four ice cores were drilled from this multi-year ice floe, using the same handheld ice core drill we used on Signy Island. The ice cores were packaged up individually, labelled, and stored in the -20ºC freezer on the JCR for analysis back in the UK. Two plastic bags full of surface snow were also collected from the same ice floe, and then melted down and decanted into salinity and $\delta^{18}O$ sampling bottles once back on the JCR. We also attempted to get water samples directly through the hole left in the ice by the ice core, but the ice was too thick for this to be possible. Instead, we lowered a bucket over the side of the JCR, next to the sea ice, to collect some water samples that way. Two bucket loads were collected in this fashion, one containing water and ice slush, and a second containing just clear water. The water from both buckets was then decanted into salinity and $\delta^{18}O$ sampling bottles. We also got some samples from a different, thinner, floe of new sea ice, next to the multi-year ice floe. Another 4 ice cores were taken from this floe and water samples were also taken through a hole in the ice. The descriptions, sampling times and $\delta^{18}O$ vial numbers for all ice cores and water samples taken at Sea Ice Station 1 are given in Table 10.1. Finally, we also did one CTD cast at Sea Ice Station 1 (CTD cast number 5), down to a depth of 1000m. The exact location for this CTD was S68º08.507' W31º00.176'.

Description	Time (UTC)	$\delta^{18}O$ vial number(s)
Ice core 1 from multi-year sea ice floe	13:00	N/A
Ice core 2 from multi-year sea ice floe	13:00	N/A
Ice core 3 from multi-year sea ice floe	13:00	N/A
Ice core 4 from multi-year sea ice floe	13:00	N/A
Bag 1 surface snow from multi-year sea ice floe	13:00	0226 & 0227
Bag 2 surface snow from multi-year sea ice floe	13:00	0232 & 0233
Water bucket 1 (water and ice slush)	14:24	0220, 0223, 0224, 0225
Water bucket 2 (clear water)	14:30	0218, 0219, 0221, 0222
Ice core 5 from new sea ice floe	15:00	N/A
Ice core 6 from new sea ice floe	15:00	N/A
Ice core 7 from new sea ice floe	15:00	N/A
Ice core 8 from new sea ice floe	15:00	N/A
Water samples from new sea ice floe	15:00	0214, 0215, 0216, 0217

Table 10.1: All ice cores and water samples taken at Sea Ice Station 1 on 9th April 2016, at position S68º09.066' W30º59.508'.

From Sea Ice Station 1, we sailed north again towards the southern end of the A23 and occupied one more station in the sea ice in the morning of 10th April 2016. This station was appropriately named Sea Ice Station 2, at a location of S66º42.325' W27º02.986'. The sea ice here was in the form of pancake ice, and we were not far off the edge of the sea ice. We did one more CTD cast here (cast number 7), down to a depth of 1000m, and also collected some more water and ice slush samples using the approach of dangling a bucket over the side of the JCR, which were decanted into salinity and $\delta^{18}O$ bottles (numbers 0228 → 0231).

11. South Georgia Fieldwork, Small Boat Work & CTDs

Erik Mackie

We arrived in Cumberland Bay, South Georgia, on the morning of Sunday 17th April 2016, having sailed there from the northern end of the A23 hydrographic section. The first part of our work at South Georgia consisted of water sampling from small boats in the eastern end of Cumberland Bay, at the Nordenskjöld Glacier terminus. The JCR sailed as close to the glacier terminus as possible, which was about 1km away from it, and the small Humber powerboats were launched at this point. Each boat had a team of 2 scientists, 1 JCR officer and 1 crew member on board. The boats sailed together towards the centre of the Nordenskjöld Glacier terminus, and then started taking samples along the glacier front, with one boat working its way towards the eastern end of the front and the other boat going towards the western end. Once at their respective endpoints, the boats then sailed in a straight line back to the JCR, taking samples along the way, thus creating a triangle of sampling points from the JCR's location in the bay to each end of the glacier terminus and right along the glacier front, as shown on the map in Figure 11.1. It is clear from this map that the glacier terminus has retreated since the background map was produced, as the sampling points along the glacier terminus were definitely in open water and not on top of the glacier (as the map would suggest). The closest we got to the glacier front was about 200 m away from it, so as to keep a safe distance. At each sampling location, two salinity bottles were filled and sealed with stoppers. One of each of these sets of bottles was later decanted into a δ^{18}O bottle, once back on the JCR. The numbers of these δ^{18}O bottles are listed in Table 11.1, along with their sampling locations, times and marker IDs for the map in Figure 11.1.

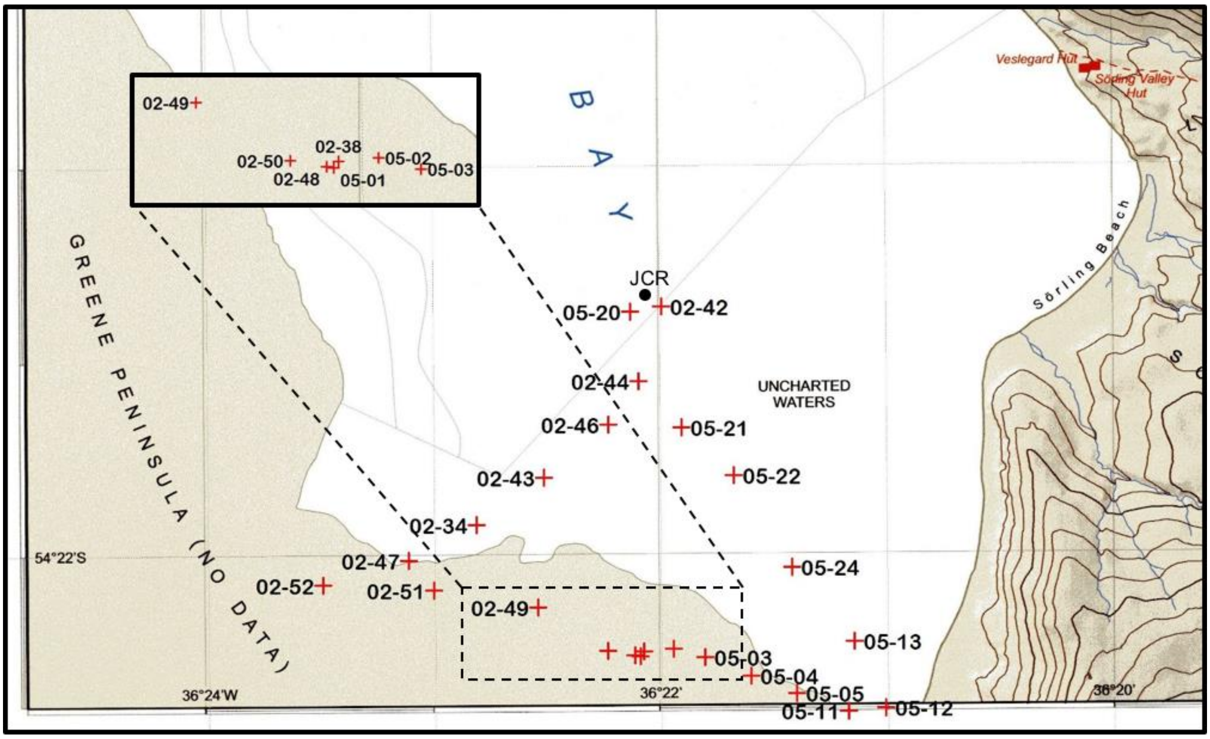


Figure 11.1: Small boat sampling locations in Cumberland Bay, South Georgia, along the Nordenskjöld Glacier front.

Latitude	**Longitude**	**Time (UTC)**	**δ^{18}O bottle number(s)**	**Map ID**
S54º22.251’	W36º22.078’	14:30	0238	02-38
S54º22.261’	W36º22.118’	14:34	0248	02-48
S54º22.249’	W36º22.238’	14:43	0250	02-50
S54º22.136’	W36º22.546’	14:47	0249	02-49
S54º22.090’	W36º23.004’	14:52	0251	02-51
S54º22.076’	W36º23.493’	14:58	0252	02-52
S54º22.013’	W36º23.116’	15:03	0247	02-47
S54º21.923’	W36º22.815’	15:06	0234	02-34
S54º21.802’	W36º22.516’	15:12	0243	02-43
S54º21.666’	W36º22.230’	15:17	0246	02-46
S54º21.363’	W36º21.941’	15:21	0242	02-42
S54º21.555’	W36º22.045’	15:24	0244	02-44
S54º22.264’	W36º22.095’	14:32	0239 & 0240	05-01
S54º22.245’	W36º21.947’	14:37	0236 & 0241	05-02
S54º22.267’	W36º21.808’	14:42	0237 & 0622	05-03
S54º22.316’	W36º21.607’	14:47	0623 & 0634	05-04
S54º22.362’	W36º21.405’	14:52	0245 & 0624	05-05
S54º22.409’	W36º21.177’	14:56	0625 & 0235	05-11
S54º22.228’	W36º21.148’	15:09	0627 & 0629	05-12
S54º22.037’	W36º21.422’	15:16	0621 & 0630	05-24
S54º21.799’	W36º21.677’	15:28	0631 & 0633	05-22
S54º21.675’	W36º21.907’	15:35	0628 & 0636	05-21
S54º21.376’	W36º22.129’	15:42	0632 & 0637	05-20

Table 11.1: Cumberland Bay small boat sampling locations, times, bottle numbers and map IDs for map in Figure 11.1.

Several chunks of ice were also fished out of the water from the small boats, in front of the Nordenskjöld Glacier terminus. These chunks of ice were melted down and decanted into salinity and δ^{18}O bottles once back on the JCR. The locations, sampling times, δ^{18}O bottle numbers, and marker IDs for the map in Figure 11.1 are given below in Table 11.2.

Latitude	**Longitude**	**Time (UTC)**	**δ^{18}O bottle number(s)**	**Map ID**
S54º22.251’	W36º22.078’	14:30	0638 & 0639	02-38
S54º22.245’	W36º21.947’	14:37	0641 & 0643	05-02
S54º22.267’	W36º21.808’	14:42	0646 & 0647	05-03

Table 11.2: locations, sampling times, bottle numbers and map IDs for ice chunks collected from Cumberland Bay.

Once the small boat work was completed, we went on to do a line of CTD stations (cast numbers 35 through to 46) along the length of Cumberland Bay, starting at the eastern end in front of Nordenskjöld Glacier, and across the mouths of the eastern and western arms of Cumberland Bay where they meet, as shown on the map in Figure 11.2. These CTD stations were started on Sunday 17th April after the small boat work and continued on Monday 18th April. This line of CTDs was completed on our departure from South Georgia, on Thursday 21st April, when a final 3 CTD stations (cast numbers 47, 48 and 49) where occupied along a line to the north-east from the mouth of Cumberland Bay out to the shelf break, as shown on the map in Figure 11.3.

On Tuesday 19th April, the weather was too bad to do any fieldwork, so we sat in Cumberland Bay and waited out the weather. The conditions were much improved on Wednesday 20th April, so the fieldwork plans could go ahead. The JCR went alongside at King Edward Point (KEP) research station, where we were greeted by the South Georgia government officials and BAS scientists working on the base. After a bio-security briefing, the fieldwork parties could set off. One party consisting of 4 scientists (Andrew, Rob, Ollie

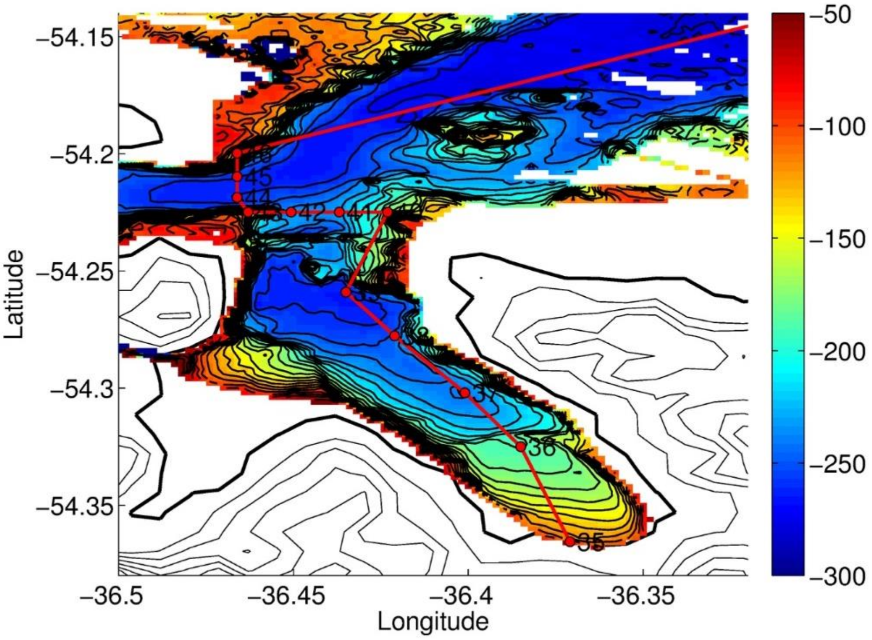


Figure 11.2: Locations of CTD casts 35 through to 46 and bathymetry in Cumberland Bay, South Georgia.

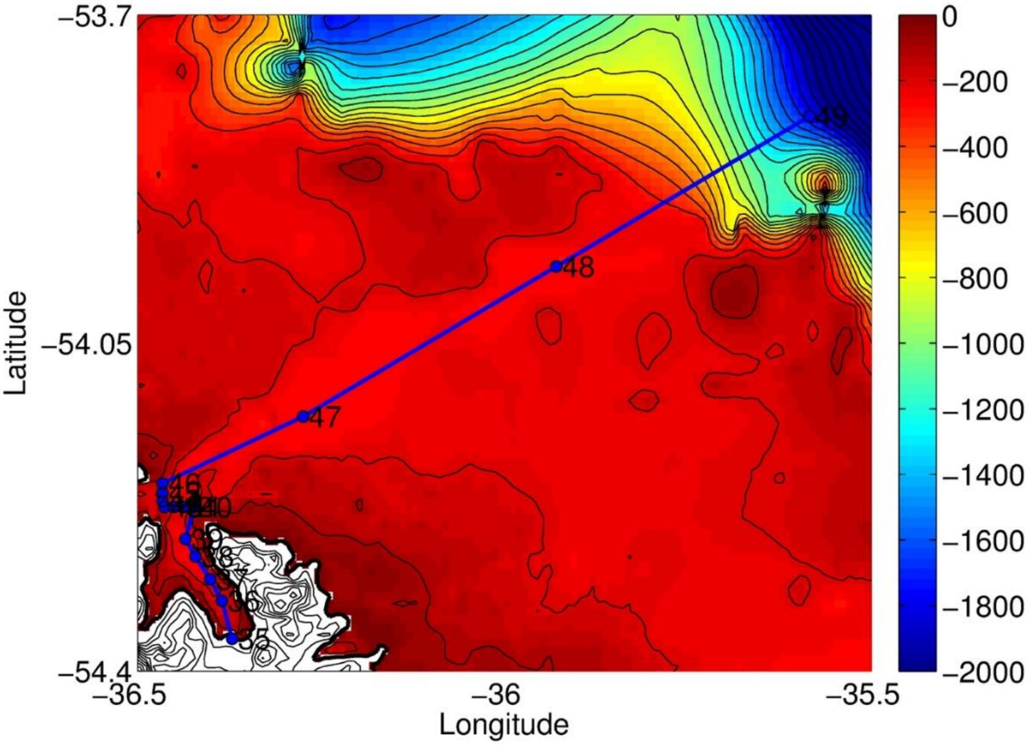


Figure 11.3: Locations of CTD casts 47, 48 and 49 and bathymetry to the North-East of Cumberland Bay, South Georgia.

and Erik), 1 JCR officer (Wave) and a member of the BAS team at KEP (Matt), climbed up to Glacier Col via Gull Lake, to drill an ice core from the glacier and collect water samples from the lake. The second party of 3 scientists (Mike, Dave and Dan), walked round along the shore to Penguin River to collect water samples there. The walking route of the Glacier Col party is shown by the yellow line on the map in Figure 11.4 (a GPS tracker was used to log our route). The outward and return routes varied slightly hence why there appear to be two yellow lines criss-crossing each other. On the return route two short detours were made to visit Shackleton’s Grave and the old whaling station at Grytviken. The map also clearly shows the location where the ice core was drilled on Glacier Col, and the location where water samples were collected from Gull Lake. Gull Lake was substantially bigger than indicated on this map, and the edge of the lake actually came right up to our walking route and the marked sampling location. The second field party, who were aiming for Penguin River, were not able to follow the shoreline due to avalanche risk and had to follow a route further inland across some small ridges. The terrain here proved to be quite challenging with a lot of deep snow on top of boggy ground, which made the going very tough. Therefore, they did not quite reach Penguin River but turned back at a point just before it. Samples of surface snow were collected here as a substitute for the intended river samples from Penguin River (as indicated on the map). These snow samples were later melted down and decanted into δ^{18}O bottles. The sampling locations, times and respective δ^{18}O bottle numbers from all the South Georgia fieldwork samples are listed in Table 11.3.

Description	Latitude	Longitude	Time (UTC)	δ^{18}O bottle num(s)
Glacier Col ice core	S54º18.457’	W36º33.052’	16:19	N/A
Gull Lake sample	S54º17.144	W36º31.085’	17:46	0642, 0645 & 0648
Penguin River sample	~ S54º18’*	~ W36º30’*	16:30	0640 & 0644

*Table 11.3: South Georgia fieldwork sampling locations, times and bottle numbers. *Approximate Location*

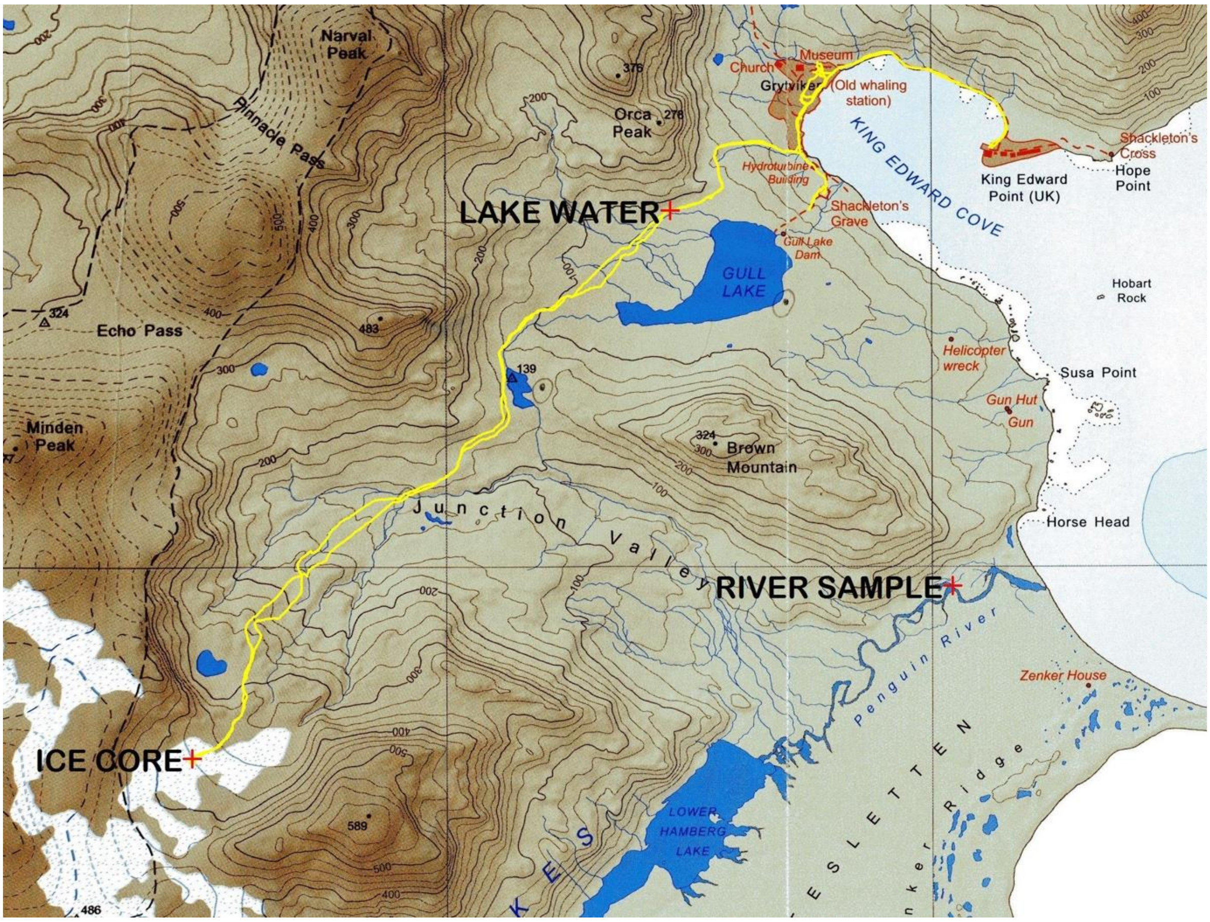


Figure 11.4: South Georgia fieldwork sampling locations and walking route to Glacier Col (yellow line).

12. Associating $\delta^{18}O$ and salinity samples

Erik Mackie

During JR15006, $\delta^{18}O$ samples were taken from every Niskin bottle on each CTD cast, from all the field and small boat sampling locations (Signy, South Georgia, Weddell Sea Ice), and from each underway sample. These samples were taken in small glass vials, which were rinsed 3 times, filled up to the neck, dried with blue roll, stoppered, and finally covered with a metal seal that was closed with a crimping device. Each of these bottles had been labelled in advance with a unique identifier, of the format "xxxx/2000", with "xxxx" ranging from "0001" to "2000". By the end of the cruise, bottle numbers "0001" through to "1001" had been used (some intermediate numbers were not used). The remaining bottles (1002 through to 2000) were not labelled.

To keep track of all these samples and their respective origins, an Excel spreadsheet was set up with the name *jr15006_d18O_master.xlsx* In this spreadsheet, each $\delta^{18}O$ sample is listed with its unique bottle number identifier (between 0001 and 1001), and several other columns of associated information about that sample. These include: the type of sample (C=CTD, B=Boat, F=Field, U=Underway, SI=Sea Ice), the CTD station number (for CTDs only, if not a CTD then the name of the location is given here), the Niskin bottle number (for CTDs only), the depth in metres (for CTDs only), the latitude in degrees and minutes, the longitude in degrees and minutes, the date, the time (UTC) and finally the measured salinity for that sample (PSU). The salinity shown here is the result of running that sample through the salinometer, with the appropriate correction applied (see Chapter 3). Not every $\delta^{18}O$ sample has a salinity sample associated with it, as we did not take a salinity sample from every single Niskin bottle on the CTD casts. On bottles with no salinity sample those $\delta^{18}O$ samples will later be associated with a calibrated CTD salinity from the bottle files. Similarly the ice core samples must be transported back to BAS Cambridge for sectioning, melting and sampling, hence their salinity is not yet available (though can be safely assumed to be practically zero). If there is no salinity sample associated with an $\delta^{18}O$ sample, then this is indicated by a "NaN".

Table 12.1 below is an extract from the *jr15006_d18O_master.xlsx* spreadsheet showing some of the different types of samples. Sample 0001 is a fieldwork (F) sample from Signy and has a very low salinity because it is a freshwater sample. Niskin bottle number and depth are shown as "N/A" here because it is not a CTD sample. Sample 0085 is a typical CTD sample from cast number 4, Niskin 1 (depth 360m), with an associated salinity, whereas sample 0126 from CTD cast 11, Niskin 5 (depth 3836m), does not have a salinity sample associated with it (indicated by "NaN" in the last column). This will later be filled in when calibrated CTD bottle salinities become available.

d18O Bottle Number	Type (C/B/F/U/SI)*	CTD Station Number	Niskin Bottle Number	Depth (metres)	Latitude (degrees S)	Latitude (minutes)	Longitude (degrees W)	Longitude (minutes)	Date	Time (UTC)	Measured Salinity** (PSU)
0001	F	Signy	N/A	N/A	60	43.155	45	36.546	04/04/2016	15:44	0.098938
0085	C	4	1	360	60	50.361	45	32.823	04/04/2016	22:59	34.604393
0126	C	11	5	3836	62	29.496	31	15.594	12/04/2016	08:10	NaN

Table 12.1: Extracts from jr15006_d18O_master.xlsx spreadsheet.

The spreadsheet is sorted numerically according to the $\delta^{18}O$ bottle number identifiers, from smallest to largest (0001 → 1001), but can be sorted by any of the other columns as required. E.g. one could sort the samples by CTD station number if necessary. Care should be taken to select the option "Expand Selection" when sorting by another column so as to retain the correct horizontal alignment of the samples and their associated data.

13. ICT Report

Andy England

13.1 SCS Logging system / Data logging

Newleg & ACQ started at 16:12 30th March 2016 (UTC)

SCS ACQ version : 4.5.1.1063

13.2 Systems

UNIX

No veeam replication of the whole JRLB virtual machine was run during this cruise, but a new job replicating just the JRLB OS disk has been created. Due to either its small size or short run time (~6 mins) it did not cause a disconnect of the samba shares, although there is a long enough delay that the SCS string compression process turns red briefly. This replication of the OS combined with the Amanda backups provide suitable backups in case of a fault. The new job is configured to run automatically every Sunday.

The AMS system experienced several instances where the IO wait increased to 100%. As a single core virtual machine it resulted in the web interface becoming unresponsive. Increased vCPU's to two as a short term fix.

Windows

Warning light on SCS1 indicates a memory module errors. This did not prevent host from working normally. Additional troubleshooting to take place on return to Stanley. Replacement module may need to be purchased and installed at the beginning of JR15007.

Network

No problems reported with the ships network.

UPS

Several UPS's around the ship need their batteries replaced, this includes the ESX UPS. A new UPS has been purchased and will be installed at the beginning of JR15007.

13.3 Event Log

30 March 2016
New leg started.
Swath is being run opportunistically on behalf of Alex Tate by AME.
01 April 2016
Performed runtime calibrations on both ESX and SCS UPS's. Identified fault with ESX UPS battery.
02 April 2016
Performed testing of OS replication of JRLB using veeam. Despite short pause in SCS strings no interruption to data logging or samba connectivity.
03 April 2016
Performed testing of OS replication of JRLB using veeam. Again, despite short pause in SCS strings no interruption to data logging or samba connectivity. These pauses occur during the VM snapshot creation and removal.

06 April 2016

Investigated setup of snapchat connectivity for a PR event approved by Cambridge and the Captain.

Configured UPS with NTP settings, notifications and remote syslog on JRLA. Configured DHCP with MAC address of the two UPS's.

10 April 2016

11:00 UTC Beeping coming from Acoustic cabinet. When listening to the various devices in the rack the beeping appeared to be coming from the ADCP. Powered down the ADCP but beeping continued. Powered on ADCP and started to examine other devices. Beeping then stopped.

15 April 2016

Investigated errors in the ADCP data streams log files with AME:

```
        [2016/04/04, 09:12:57.148]: CX0,0  ERR:  Bad command!
        [2016/04/14, 17:57:18.745]: CScreenNav::ProcessNmea() - Invalid PRDID       data.
```

These have happened on previous cruises, but don't occur everyday or cause any issues with the data logged. Added note to wiki with this information.

17 April 2016

Corrected science log start date to match the cruise leg. This enabled the CTD Bottles event log information to be generated automatically, but only for the current and future CTD casts.

18 April 2016

Noticed there was a hardware alarm on SCS1, identified as a Memory Error for module 1. No impact, to be investigated on return to Stanley.

22 April 2015

Increased number of vCPU's for AMS3 to two due to continuing issues with IO wait and the web interface being unresponsive.

25 April 2016

Swathing now stopped.

Newleg & ACQ started

28 April 2016

Legdata/legwork taken offline

14. AME Report

Carson McAfee

14.1 Instrumentation used/comments

LAB Instruments

Instrument	S/N Used	Comments
AutoSal	Y	Required Maintenance. Needs Service.
Scintillation counter	N	
Magnetometer STCM1	N	
XBT	Y	SVP needed for EM122

ACOUSTIC

Instrument	S/N Used	Comments
ADCP	Y	
PES	N	
EM120	Y	EM122
TOPAS	N	
EK60	N	
EK80	N	
Ksync	Y	
USBL	N	
10kHz IOS pinger	N	
Benthos 12kHz pinger S/N 1316 + bracket	N	
Benthos 12kHz pinger S/N 1317 + bracket	N	
MORS 10kHz transponder	N	

OCEANLOGGER

Instrument	**S/N Used**	**Comments**
Barometer1(UIC)	5002	
Barometer1(UIC)	5003	
Foremast Sensors		
Air humidity & temp1	3898	
Air humidity & temp2	3896	
TIR1 sensor (pyranometer)	2993	Not working
TIR2 sensor (pyranometer)	2992	Not working
PAR1 sensor	0127	
PAR2 sensor	0126	
prep lab		
Thermosalinograph SBE45	0016	
Transmissometer	396DR	
Fluorometer	1100243	
Flow meter	811950	
Seawater temp 1 SBE38	0601	
Seawater temp 2 SBE38	0599	

CTD (all kept in cage/ sci hold when not in use)

Instrument	**S/N Used**	**Comments**
Deck unit 1 SBE11plus	0458	Fan making occasional noise
Underwater unit SBE9plus	0707	
Temp1 sensor SBE3plus	5766	
Temp2 sensor SBE3plus	2705	
Cond1 sensor SBE 4C	2289	
Cond2 sensor SBE 4C	2222	Replaced During Trip. Damaged Unit: 2248
Pump1 SBE5T	1807	
Pump2 SBE5T	7606	
Standards Thermometer SBE35	0024	
Transmissometer C-Star	CST-846DR	
Oxygen sensor SBE43	0676	
PAR sensor	7274	
Fluorometer Aquatracka	008-249	
Altimeter PA200	163162	
LADCP	15060	Used During Cruise
CTD swivel linkage		
Pylon SBE32	0636	
Notes on any other part of CTD e.g. faulty cables, wire drum slip ring, bottles, swivel, frame, tubing etc		Replaced 6 bottles. Replaced Conductivity sensor. CTD touched Sea floor. Small kink in Cable (not mechanically unsound). Small bend in lifting bail.

AME UNSUPPORTED INSTRUMENTS BUT LOGGED

Instrument	**Working ?**	**Comments**
EA600	Y	
Anemometer	Y	
Gyro	Y	
DopplerLog	Y	
EMLog	Y	

End of Cruise Procedure

At the end of the cruise, please ensure that:

- The XBT is left in a suitable state (store in cage if not to be used for a while – do not leave on deck or in UIC as it will get kicked around). Remove all deck cables at end of cruise prior to refit.
- The salinity sample bottles have been washed out and left with deionised water in – please check this otherwise the bottles will build up crud and have to be replaced.
- The CTD is left in a suitable state (washed (including all peripherals), triton + deionised water washed through TC duct, empty syringes put on T duct inlets to keep dust out and stored appropriately). Be careful about freezing before next use – this will damage the C sensors (run through with used standard seawater to reduce the chance of freezing before the next use). Remove all the connector locking sleeves and wash with fresh water. Blank off all unconnected connectors. See the CTD wisdom file for more information. If the CTD is not going to be used for a few weeks, at the end of your cruise please clean all connectors and attach dummy plugs or fit the connectors back after cleaning if they are not corroded.
- The CTD winch slip rings are cleaned if the CTD has been used – this prevents failure through accumulated dirt.
- All manuals have been returned to the designated drawers and cupboards.
- You clean all the fans listed below every cruise or every month, whichever is the longer.

<u>Please clean the intake fans on the following machines:</u>

Instrument	**Cleaned?**
Oceanlogger	Y
EM120, TOPAS, NEPTUNE UPSs	Y
Seatex Seapath	Y
EM120 Tween Deck	Y
TOPAS Tween Deck	Y

14.2 Notes and recommendations for change / future work

14.2.1 Salinometer

On the 6th April salinometer 2 (Serial Number 68959) was tested, and it was found that the unit had a cooling issue. After opening the unit, I found that the fan on the cooling unit (not the extractor fan) was not turning. The wires feeding the motor coil had corroded, and after some very delicate soldering the fan was repaired. Testing on the 7th showed that the unit was fully operational.

On the 7th of April a new heating element bulb was installed on salinometer 1 (Serial Number 63360). Both units are fully operational.

Note: Both units are due for a service at the end of April 2016. This has been reported to Neil French, who is arranging for the service once the ship gets back to the UK in July 2016.

14.2.2 CTD

On the 10th and 11th of April six CTD Niskin Bottles were replaced. The chips and pitting on the bottom of the bottle were preventing an adequate seal, and compromising the sample water. The old bottles will be disposed of in the UK.

Note: A number of the spare CTD Bottles in the cage have been stored in a sealed state, with water inside the bottles. This has resulted in the water going stagnant, and algae to form on the walls of the bottles. This ultimately would compromise the sample water. Each of these bottles will be dried out and cleaned during the next cruise.

On the 11th and 12th the CTD rosette had two misfires, on two casts. Both happened on bottle 17 firing leaver. Paul Morgan (AME) reported a similar issue on cruise JR15001. The rosette firing pin head was removed, cleaned, and reinstalled and the problem stopped.

On the 13th April the secondary conductivity sensor failed. The original sensor (SBE4-2248) was replaced with SBE4-2222. The new sensor calibration constants were entered in the Seasave software.

On the 15th April the CTD landed on the sea floor due to operator error. The CTD cable got a small kink, and the lifting bail has a slight bend. The rest of the CTD and instruments remained unharmed. A full incident report has been included at the end of this document.

14.2.3 AME Storage Cage

The storage cage currently has a number of instruments and equipment being brought back to Cambridge for proper disposal.

The storage shelve guards have been trimmed, and can now be removed easily.

14.2.4 Cargo Tender

A number of days between the 12th and the 18th of April were spent helping the Deck Engineer to build a tool to open the cargo tender engine hatch.

14.2.5 Ship ADCP

A review of the ADCP “*.LOG” files shows the following error:

“CScreenNav::ProcessNmea() – Invalid PRDID data.”

The Pitch, Roll and Direction (PRD) data feed was checked in the “*.N1R” data files, and no fault could be found. A review of the ADCP data also showed no problems. The same problem was reported in the cruise report for JR179 (Feb-April 2008). They assumed that the problem was related to an issue with 360.0 and 000.0 degree crossings in the direction data, however these occurs more often than the number of error messages. The source of this error is currently unclear, however it does not seem to affect the data. No solution has been implemented.

14.2.6 Winch Monitors

New Winch monitors were ordered on the last cruise, however the units do not have the required VGA inputs that they appeared to have when ordered. The proposed solution is to order VGA-

HDMI converters.

14.3 CTD Sea Floor Encounter – Incident Report

14.3.1 General Overview:

On the 15th April 2016 during a CTD deployment (Cast 025), the CTD instrument made contact with the sea floor. During the upcast the Temperature Sensor (Primary), Conductivity Sensor (Primary) and Dissolved Oxygen Sensor all showed problems with their recorded data. After recovery it was found that the problem with these sensors was caused by a blocked water inlet valve. After flushing the inlet valve the instrument returned to normal.

Following the cast the CTD was thoroughly inspected. No instruments sustained any damage. It was noted that the winch cable had a small kink, and the lifting bail had a small bend. It is possible that this happened during previous casts, however it is more likely that both were caused during the bottom contact.

Approximately 5 meters from the CTD the cable has a small kink, however no braids are damaged, and the data signal was not compromised. After discussions with the winch drivers it was decided that mechanically the cable is still in an acceptable state. Therefore the cable was not re-terminated.

Figure 14.1 shows a picture of the lifting bail, and the bend towards the left. As mentioned, this bend may have happened on a previous cast, however it most likely happened during this cast. A review of the LADCP data showed that after landing on the sea floor the CTD frame tilted over by 40°. The current theory is that while sitting at this angle the winch cable must have been reeled in till taught. While taught the ship may have been moved by a swell, and this sharp force must have pulled the lifting bail causing the bend. This is however still a theory, and cannot be proved.

Figure 14.1: Bend in Lifting Bail

14.3.2 Sequence of events

Figure 14.2 shows the altimeter readings from a typical CTD cast (Cast 030) as the frame approaches the sea floor. This figure shows that the altimeter occasionally registers a false bottom. The altimeter incorrectly interprets 200 m from the sea floor as being 100 m, and has a slow ramp to 20 m. At the 20 m mark the altimeter corrects for this false bottom, and returns to the default 100 m reading until it senses the true bottom.

Figure 14.3 shows the altimeter readings from CTD Cast 025. During this cast no false bottom was registered, and the true bottom was incorrectly identified as being the false bottom. This figure has 6 time points identified.

- Before point 1 there was no altimeter readings, not even noise spikes.
- Between point 1 and 2 the altimeter has a slow ramp towards the sea floor. The CTD operator noticed the initial noise in the ramp, and thought that this was an indication of a false bottom.
- At point 2 the CTD has reached a point less than 10 m off of the sea floor. The operator called for a full stop to evaluate the situation. At this point the CTD had not reached the sea floor.
- Between point 2 and 3 the CTD operator monitored the CTD data and the Navigation data. During this time the altimeter continued to produce noisy data, rather than settling (as seen in Figure 14.2). The altimeter values at this point resembled those on the trough on the false bottom of Figure 14.2. During this time the EM122 depth values were also fluctuating by 50 m.
- Between point 3 and 4 the altimeter stabilised at the default 100 m value. In combination with the previous assumptions, and the unstable EM122 depth reading, the CTD operator decided that this was a false bottom altimeter reading.
- At point 4 the CTD was slowly lowered, and shortly afterwards made contact with the sea floor. Given the height of the CTD and the speed of the winch, this would not have been a hard impact.
- Between point 4 and 5 the winch registered a loss in tension/load. The situation was carefully managed, and the CTD was lifted back up to a height of 10 m.
- Between point 5 and 6 the CTD remained at 10 m off the bottom. The winch driver checked the winch for cable slack issues, and then started bringing up the CTD.

14.3.3 Recommendations

During training CTD operators are taught about the false bottom readings of the altimeter. From experience the false bottom does not continue past 20 m. Although this was discussed during training, more emphasis will be made on the fact that if the altimeter trend continues past 20 m, then the reading is true. Additionally not every cast will produce a false bottom.

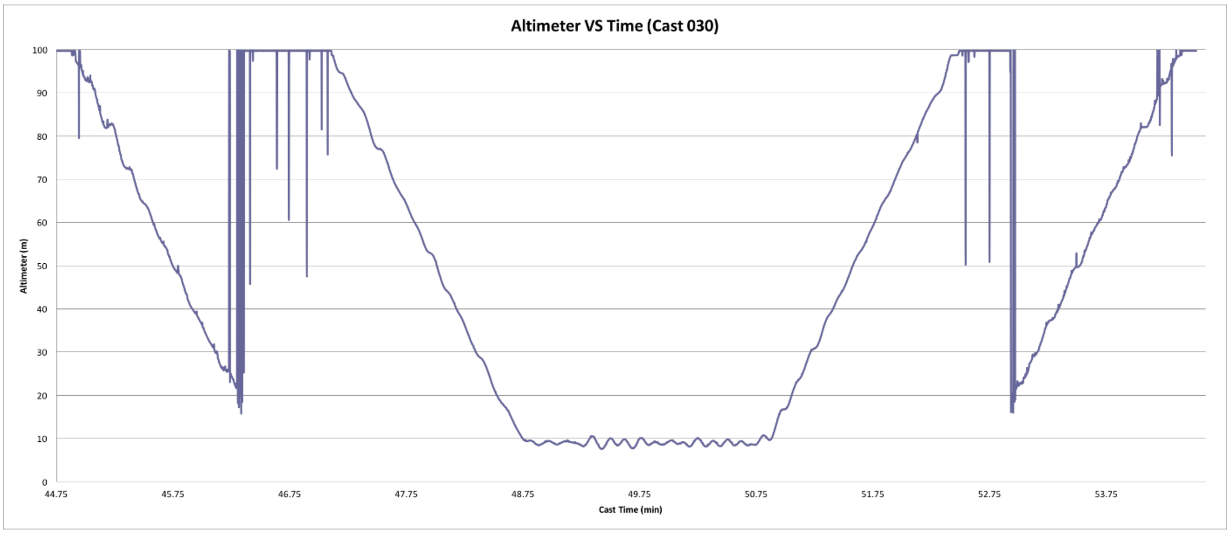


Figure 14.2: Typical altimeter reading at bottom of cast

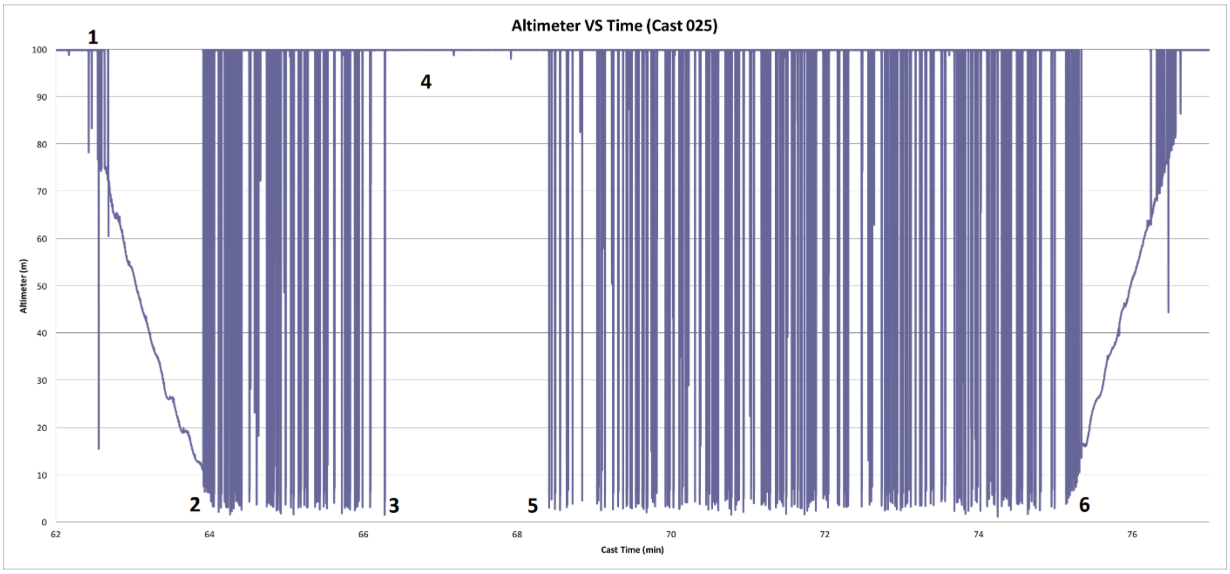
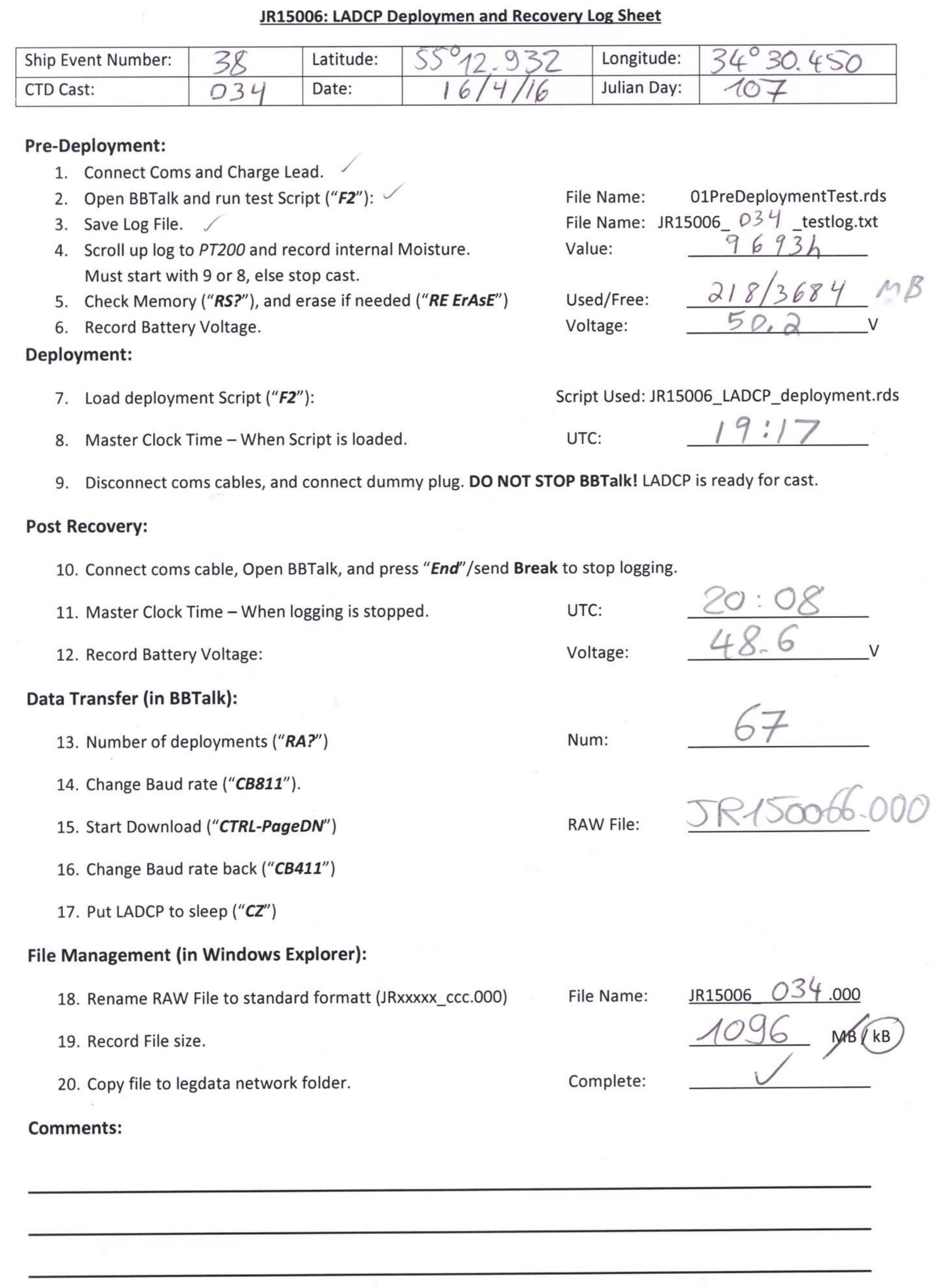


Figure 14.3: Anomalous altimeter reading at bottom of CTD 025

Appendices

A. Sample LADCP logsheet



JR15006: LADCP Deploymen and Recovery Log Sheet

Ship Event Number:	38	Latitude:	55°12.932	Longitude:	34°30.450
CTD Cast:	034	Date:	16/4/16	Julian Day:	107

Pre-Deployment:

1. Connect Coms and Charge Lead. ✓
2. Open BBTalk and run test Script ("***F2***"): ✓ File Name: 01PreDeploymentTest.rds
3. Save Log File. ✓ File Name: JR15006_ 034 _testlog.txt
4. Scroll up log to *PT200* and record internal Moisture. Must start with 9 or 8, else stop cast. Value: 96934
5. Check Memory ("***RS?***"), and erase if needed ("***RE ErAsE***") Used/Free: 218/3684 MB
6. Record Battery Voltage. Voltage: 50.2 V

Deployment:

7. Load deployment Script ("***F2***"): Script Used: JR15006_LADCP_deployment.rds
8. Master Clock Time – When Script is loaded. UTC: 19:17
9. Disconnect coms cables, and connect dummy plug. **DO NOT STOP BBTalk!** LADCP is ready for cast.

Post Recovery:

10. Connect coms cable, Open BBTalk, and press "***End***"/send **Break** to stop logging.
11. Master Clock Time – When logging is stopped. UTC: 20:08
12. Record Battery Voltage: Voltage: 48.6 V

Data Transfer (in BBTalk):

13. Number of deployments ("***RA?***") Num: 67
14. Change Baud rate ("***CB811***").
15. Start Download ("***CTRL-PageDN***") RAW File: JR150066.000
16. Change Baud rate back ("***CB411***")
17. Put LADCP to sleep ("***CZ***")

File Management (in Windows Explorer):

18. Rename RAW File to standard formatt (JRxxxxx_ccc.000) File Name: JR15006_034.000
19. Record File size. 1096 ~~MB~~ / [✓ kB]
20. Copy file to legdata network folder. Complete: ✓

Comments:

B. Bridge Science Log

Time	Event	Latitude	Longitude	Comment
21:54:00 21/04/2016	54	-53.81097	-35.59354	Gantry lashed and vents secure. set course for Stanly
21:48:00 21/04/2016	55	-53.80795	-35.58565	Vessel out of DP
21:40:00 21/04/2016	55	-53.80798	-35.58567	CTD on deck
21:38:00 21/04/2016	55	-53.80797	-35.58567	CTD out of the water
21:00:00 21/04/2016	55	-53.80797	-35.58562	CTD at depth 1641
20:30:00 21/04/2016	55	-53.80799	-35.58568	CTD in the water
20:28:00 21/04/2016	55	-53.80799	-35.58563	CTD in DP
20:20:00 21/04/2016	55	-53.80767	-35.5853	Vessel in DP
19:00:00 21/04/2016	54	-53.96841	-35.92921	Vessel out of DP
18:57:00 21/04/2016	54	-53.96841	-35.92919	CTD on deck
18:55:00 21/04/2016	54	-53.9684	-35.92921	CTD on the surface
18:43:00 21/04/2016	54	-53.9684	-35.92916	CTD at depth
18:36:00 21/04/2016	54	-53.96838	-35.92913	CTD left surface.
18:35:00 21/04/2016	54	-53.9684	-35.92913	CTD off deck.
18:30:00 21/04/2016	54	-53.96865	-35.93035	Vessel on DP.
17:11:00 21/04/2016	53	-54.12861	-36.27433	Vessel off DP
17:10:00 21/04/2016	53	-54.12861	-36.27432	CTD on deck.
17:08:00 21/04/2016	53	-54.12861	-36.27431	CTD on surface.
16:54:00 21/04/2016	53	-54.12864	-36.27428	CTD at depth
16:45:00 21/04/2016	53	-54.12858	-36.27427	CTD left surface.
16:44:00 21/04/2016	53	-54.1286	-36.27426	CTD off deck.
16:35:00 21/04/2016	53	-54.12828	-36.27878	Vessel on DP.
19:00:00 18/04/2016	Comment	-54.26963	-36.44629	Vessel standing by on DP in Cumberland Bay.
18:18:00 18/04/2016	52	-54.19966	-36.4661	Gantry lashed
18:12:00 18/04/2016	52	-54.19966	-36.46609	CTD on deck.
18:09:00 18/04/2016	52	-54.19967	-36.4661	CTD on surface.
18:00:00 18/04/2016	52	-54.19967	-36.46618	CTD at depth
17:55:00 18/04/2016	52	-54.19969	-36.46615	CTD left surface.
17:54:00 18/04/2016	52	-54.19971	-36.46617	CTD off deck.
17:45:00 18/04/2016	52	-54.19956	-36.46535	On DP.
17:26:00 18/04/2016	51	-54.20954	-36.46593	Off DP
17:23:00 18/04/2016	51	-54.20953	-36.46592	CTD on deck.
17:22:00 18/04/2016	51	-54.20953	-36.46594	CTD on surface.
17:08:00 18/04/2016	51	-54.20953	-36.46594	CTD at depth
17:02:00 18/04/2016	51	-54.20954	-36.46594	CTD left surface.

16:58:00 01/04/2016	1	-55.24876	-53.84873	Vessel on DP.

17:00:00 18/04/2016	51	-54.20956	-36.46596	CTD off deck.
16:50:00 18/04/2016	51	-54.20909	-36.4653	Vessel on DP.
16:34:00 18/04/2016	50	-54.21854	-36.46612	Off DP
16:33:00 18/04/2016	50	-54.21854	-36.46613	CTD on deck.
16:31:00 18/04/2016	50	-54.21853	-36.46613	CTD on surface.
16:18:00 18/04/2016	50	-54.21852	-36.46615	CTD at depth
16:12:00 18/04/2016	50	-54.21853	-36.46616	CTD left surface.
16:10:00 18/04/2016	50	-54.21853	-36.46614	CTD off deck.
16:00:00 18/04/2016	50	-54.21856	-36.46466	Vessel on DP.
15:47:00 18/04/2016	49	-54.22477	-36.46302	Off DP
15:45:00 18/04/2016	49	-54.22477	-36.46301	CTD on deck.
15:42:00 18/04/2016	49	-54.22479	-36.46302	CTD on surface.
15:33:00 18/04/2016	49	-54.22476	-36.46302	CTD at depth
15:29:00 18/04/2016	49	-54.22475	-36.46301	CTD left surface.
15:27:00 18/04/2016	49	-54.2248	-36.46304	CTD off deck.
15:22:00 18/04/2016	49	-54.22479	-36.46258	Move complete on DP
14:58:00 18/04/2016	48	-54.22477	-36.4508	C.T.D. on deck vessel moving off position to next C.T.D. position
14:56:00 18/04/2016	48	-54.22478	-36.4508	C.T.D. at surface
14:42:00 18/04/2016	48	-54.22478	-36.45082	C.T.D. at depth 224m
14:35:00 18/04/2016	48	-54.22479	-36.45079	C.T.D. in the water
14:34:00 18/04/2016	48	-54.2248	-36.45078	Commenced deployment C.T.D.
14:23:00 18/04/2016	48	-54.22478	-36.45076	vessel on DP ready to deploy
14:11:00 18/04/2016		-54.2255	-36.43657	off DP
14:10:00 18/04/2016	47	-54.2255	-36.43655	CTD on deck
13:49:00 18/04/2016	47	-54.22553	-36.43659	CTD 219m
13:39:00 18/04/2016	47	-54.22548	-36.43656	CTD in the water
13:22:00 18/04/2016	46	-54.22545	-36.43656	Vessel in D.P. in position to deploy
13:08:00 18/04/2016	45	-54.2245	-36.42304	C.T.D. on deck vessel moving off position
13:05:00 18/04/2016	45	-54.2245	-36.42313	C.T.D at surface
12:55:00 18/04/2016	45	-54.22455	-36.42306	C.T.D. at depth 166m
12:49:00 18/04/2016	45	-54.22455	-36.42307	C.T.D. in the water
12:48:00 18/04/2016	45	-54.22453	-36.42308	Commenced depoyment C.T.D.
12:40:00 18/04/2016	45	-54.22433	-36.42402	Vessel in D.P. for C.T.D.
12:10:00 18/04/2016	Comment	-54.2697	-36.45076	Vessel off D.P. proceeding to C.T.D. station
05:45:00 18/04/2016	Comment	-54.26968	-36.45152	Vessel returned to Cumberland Bay
21:26:00 17/04/2016		-54.25663	-36.43449	2 persons embarked
20:13:00 17/04/2016				on DP
20:06:00 17/04/2016		-54.25919	-36.43495	off DP

20:04:00 17/04/2016	44	-54.25921	-36.43494	CTD on deck
19:46:00 17/04/2016	44	-54.2592	-36.43495	CTD 254m
19:35:00 17/04/2016	44	-54.25923	-36.43494	CTD off the deck
19:26:00 17/04/2016		-54.2586	-36.43541	on DP
19:10:00 17/04/2016		-54.27825	-36.42073	off DP
19:08:00 17/04/2016	43	-54.27825	-36.42073	CTD on deck
18:51:00 17/04/2016	43	-54.27822	-36.42071	CTD at depth
18:43:00 17/04/2016	43	-54.27819	-36.42071	CTD left surface.
18:42:00 17/04/2016	43	-54.27819	-36.42072	CTD off deck.
18:32:00 17/04/2016	43	-54.27844	-36.42052	Vessel on DP.
18:06:00 17/04/2016	42	-54.30239	-36.40083	Off DP
18:05:00 17/04/2016	42	-54.3024	-36.40083	CTD on deck.
18:03:00 17/04/2016	42	-54.3024	-36.40083	CTD on surface.
17:50:00 17/04/2016	42	-54.30241	-36.40082	CTD at depth
17:42:00 17/04/2016	42	-54.3024	-36.40086	CTD left surface.
17:41:00 17/04/2016	42	-54.30242	-36.40088	CTD off deck.
17:32:00 17/04/2016	42	-54.30264	-36.40051	Vessel on DP.
17:07:00 17/04/2016	41	-54.32525	-36.38413	Off DP
17:06:00 17/04/2016	41	-54.32525	-36.38413	CTD on deck.
17:04:00 17/04/2016	41	-54.32525	-36.38416	CTD on surface.
16:46:00 17/04/2016	41	-54.32523	-36.38413	CTD at depth
16:38:00 17/04/2016	41	-54.32523	-36.38417	CTD left surface.
16:36:00 17/04/2016	41	-54.32522	-36.38412	CTD off deck.
16:30:00 17/04/2016	41	-54.32675	-36.38381	Vessel on DP.
15:55:00 17/04/2016	40	-54.35933	-36.36964	Boat ops complete.
13:18:00 17/04/2016	40	-54.36062	-36.36707	Vessel in D.P. for Boat work
13:02:00 17/04/2016	39	-54.36552	-36.37092	C.T.D. on deck
12:58:00 17/04/2016	39	-54.36552	-36.3709	C.T.D. at surface
12:50:00 17/04/2016	39	-54.36554	-36.37092	C.T.D. at depth 45m
12:46:00 17/04/2016	39	-54.36554	-36.37094	C.T.D. in the water
12:45:00 17/04/2016	39	-54.36553	-36.37096	Commenced deployment C.T.D.
12:25:00 17/04/2016	39	-54.36555	-36.37069	Vessel in D.P. in position for C.T.D.
20:16:00 16/04/2016	38	-55.21272	-34.50728	Vents closed vessel on route
20:10:00 16/04/2016	38	-55.21557	-34.50751	Vessel out of DP
20:02:00 16/04/2016	38	-55.21557	-34.50751	CTD on deck
20:00:00 16/04/2016	38	-55.21558	-34.50751	CTD on the surface
19:38:00 16/04/2016	38	-55.21556	-34.50747	CTD at depth. 537m
19:25:00 16/04/2016	38	-55.21556	-34.50745	CTD in the water

19:23:00 16/04/2016	38	-55.21557	-34.50753	CTD off deck
19:22:00 16/04/2016	38	-55.21552	-34.50778	Vessel in DP
19:07:00 16/04/2016	37	-55.21554	-34.50749	Vessle out of DP
19:00:00 16/04/2016	37	-55.23046	-34.48958	CTD on deck
18:58:00 16/04/2016	37	-55.23047	-34.48957	CTD On the surface
18:32:00 16/04/2016	37	-55.23046	-34.48961	CTD at depth
18:11:00 16/04/2016	37	-55.23048	-34.48959	CTD left surface.
18:10:00 16/04/2016	37	-55.23049	-34.48959	CTD off deck.
18:05:00 16/04/2016	37	-55.23121	-34.48922	On DP.
17:36:00 16/04/2016	36	-55.25999	-34.44378	Off DP
17:35:00 16/04/2016	36	-55.25999	-34.4438	CTD on deck.
17:32:00 16/04/2016	36	-55.25998	-34.44357	CTD on surface.
16:55:00 16/04/2016	36	-55.25996	-34.4433	CTD at depth
16:23:00 16/04/2016	36	-55.2599	-34.44336	CTD left surface.
16:22:00 16/04/2016	36	-55.25991	-34.44335	CTD off deck.
16:10:00 16/04/2016	36	-55.26036	-34.44298	On DP. Gantry unlashed.
15:47:00 16/04/2016	35	-55.28875	-34.40265	Gantry lashed
15:39:00 16/04/2016	35	-55.28871	-34.40266	CTD on deck.
15:37:00 16/04/2016	35	-55.28874	-34.40268	CTD on surface.
14:49:00 16/04/2016	35	-55.28875	-34.40265	C.T.D. at depth 2032m
14:10:00 16/04/2016	35	-55.28879	-34.40266	C.T.D. at surface
14:08:00 16/04/2016	35	-55.28879	-34.40269	Vessel in position on D.P.
12:00:00 16/04/2016	34	-55.48443	-34.13456	Gantry secure vessel proceeding to next C.T.D. station
11:48:00 16/04/2016	34	-55.48645	-34.13177	C.T.D on deck
11:46:00 16/04/2016	34	-55.48643	-34.13179	C.T.D. at surface
10:50:00 16/04/2016	34	-55.48645	-34.13176	CTD at Depth. 2457m
10:02:00 16/04/2016	34	-55.48641	-34.13174	CTD in the water
10:00:00 16/04/2016	34	-55.48644	-34.1318	CTD off deck
09:55:00 16/04/2016	34	-55.48646	-34.13174	Vessel in DP
09:05:00 16/04/2016	34	-55.55404	-34.02687	Gantry unlashed
07:21:00 16/04/2016	33	-55.72521	-33.78422	Gantry lashed and vessel out of DP
07:13:00 16/04/2016	33	-55.72519	-33.78422	CTD on deck
07:11:00 16/04/2016	33	-55.72516	-33.78424	CTD on the surface
05:47:00 16/04/2016	33	-55.72519	-33.78421	CTD at depth
04:42:00 16/04/2016	33	-55.72515	-33.78423	CTD left surface.
04:40:00 16/04/2016	33	-55.72518	-33.78419	CTD off deck.
04:30:00 16/04/2016	33	-55.73025	-33.77892	Vessel on DP
02:30:00 16/04/2016	32	-55.99114	-33.42193	Gantry lashed and secure vessel proceeding to next C.T.D. station

02:22:00 16/04/2016	32	-55.99115	-33.42194	C.T.D. on deck
02:20:00 16/04/2016	32	-55.99115	-33.42191	C.T.D. at surface
01:04:00 16/04/2016	32	-55.99118	-33.42188	C.T.D. at depth 3054m
00:06:00 16/04/2016	32	-55.99117	-33.42187	C.T.D. in the water
00:05:00 16/04/2016	32	-55.99117	-33.42185	Commenced deployment C.T.D.
00:00:00 16/04/2016	32	-55.99116	-33.42185	Vessel in D.P. in position to deploy
20:22:00 15/04/2016	31	-56.38153	-32.87272	CTD on deck
20:20:00 15/04/2016	31	-56.38153	-32.87275	CTD on the surface
19:06:00 15/04/2016	31	-56.38153	-32.87271	CTD at depth. 3114m
18:11:00 15/04/2016	31	-56.38184	-32.87304	CTD left surface.
18:10:00 15/04/2016	31	-56.38185	-32.87299	CTD off deck.
17:55:00 15/04/2016	31	-56.39548	-32.85252	Gantry unlashed
15:15:00 15/04/2016	30	-56.77609	-32.30516	Gantry lashed
15:07:00 15/04/2016	30	-56.77641	-32.30347	CTD on deck.
15:04:00 15/04/2016	30	-56.77642	-32.30343	CTD on surface.
13:43:00 15/04/2016	30	-56.7764	-32.30347	C.T.D. at depth 3215m
12:41:00 15/04/2016	30	-56.77644	-32.30343	C.T.D. at surface
12:40:00 15/04/2016	30	-56.77644	-32.3034	Commenced deployment C.T.D.
12:38:00 15/04/2016	30	-56.77643	-32.30344	Vessel in D.P.
09:45:00 15/04/2016	29	-57.11949	-31.81335	Gantry lashed vessel out of DP
09:34:00 15/04/2016	29	-57.11948	-31.81342	CTD on deck
09:32:00 15/04/2016	29	-57.11949	-31.81343	CTD on the surface
07:54:00 15/04/2016	29	-57.1195	-31.81337	CTD at depth. 3405m
06:49:00 15/04/2016	29	-57.11947	-31.81339	CTD in water.
06:47:00 15/04/2016	29	-57.11941	-31.81338	CTD off deck.
06:40:00 15/04/2016	29	-57.11944	-31.81215	On DP
03:50:00 15/04/2016	28	-57.45768	-31.33022	Gantry lashed
03:40:00 15/04/2016	28	-57.45765	-31.33025	CTD on deck.
03:38:00 15/04/2016	28	-57.45767	-31.33025	CTD on surface.
02:12:00 15/04/2016	28	-57.45768	-31.33024	C.T.D. at depth 3710m
01:04:00 15/04/2016	28	-57.45767	-31.33026	C.T.D. at surface
01:02:00 15/04/2016	28	-57.45766	-31.33027	Commenced deployment C.T.D.
00:58:00 15/04/2016	28	-57.45771	-31.33031	Vessel in D.P.
21:08:00 14/04/2016	27	-57.80132	-30.84016	Gantry secured Vessel out off DP
21:00:00 14/04/2016	27	-57.80179	-30.83162	CTD on deck
20:58:00 14/04/2016	27	-57.80177	-30.83165	CTD at the surface
19:32:00 14/04/2016	27	-57.80171	-30.8318	CTD at depth. 3543m
18:27:00 14/04/2016	27	-57.80171	-30.83182	CTD left surface.

18:25:00 14/04/2016	27	-57.80168	-30.83183	CTD off deck.
18:15:00 14/04/2016	27	-57.80253	-30.83149	On DP
15:33:00 14/04/2016	26	-58.21129	-30.81841	Off DP
15:23:00 14/04/2016	26	-58.21123	-30.8184	CTD on deck.
15:20:00 14/04/2016	26	-58.21126	-30.81842	CTD on surface.
13:50:00 14/04/2016	26	-58.2113	-30.81832	C.T.D. at depth 3996m
12:40:00 14/04/2016	26	-58.21133	-30.81835	C.T.D. at surface
12:38:00 14/04/2016	26	-58.21134	-30.81835	Commenced deployment C.T.D.
12:34:00 14/04/2016	26	-58.21129	-30.81826	Vessel in position in D.P.
09:55:00 14/04/2016	25	-58.63424	-30.82409	Gantry secure vessel out of DP
09:43:00 14/04/2016	25	-58.63423	-30.82408	CTD on the surface
09:35:00 14/04/2016	25	-58.63425	-30.82411	CTD on deck
08:13:00 14/04/2016	25	-58.63424	-30.82407	CTD at depth. 3516m
07:08:00 14/04/2016	25	-58.63421	-30.82407	CTD in the water
07:06:00 14/04/2016	25	-58.63422	-30.82402	CTD off deck
06:55:00 14/04/2016	25	-58.63461	-30.82421	Vessel in DP gantry unlashed
04:35:00 14/04/2016	24	-59.05068	-30.833	Gantry lashed
04:26:00 14/04/2016	24	-59.05068	-30.83299	CTD on deck.
04:24:00 14/04/2016	24	-59.05067	-30.83298	CTD on surface.
03:07:00 14/04/2016	24	-59.0507	-30.83297	CTD at depth
02:08:00 14/04/2016	24	-59.05069	-30.83299	C.T.D. in the water
02:06:00 14/04/2016	24	-59.05068	-30.83296	Commenced deploy C.T.D.
02:04:00 14/04/2016	24	-59.05069	-30.83298	Vessel in D.P.
23:55:00 13/04/2016	23	-59.43691	-30.86687	Gantry lashed and secure
23:42:00 13/04/2016	23	-59.43758	-30.86078	C.T.D. on deck
23:38:00 13/04/2016	23	-59.43759	-30.86078	C.T.D. at surface
22:16:00 13/04/2016	23	-59.43763	-30.86079	CTD at depth. 3423m
21:12:00 13/04/2016	23	-59.43759	-30.86078	CTD in the water
21:10:00 13/04/2016	23	-59.4376	-30.86078	CTD off deck
21:08:00 13/04/2016	23	-59.43759	-30.86079	Gantry unlashed
21:05:00 13/04/2016	23	-59.4376	-30.86075	Vessel in DP
19:11:00 13/04/2016	22	-59.76591	-30.90591	Gantry lashed vessel out of DP
19:04:00 13/04/2016	22	-59.76593	-30.90591	CTD on deck
19:02:00 13/04/2016	22	-59.76593	-30.90594	CTD on the surface
17:32:00 13/04/2016	22	-59.76595	-30.90589	CTD at depth
16:21:00 13/04/2016	22	-59.76537	-30.90719	CTD left surface.
16:20:00 13/04/2016	22	-59.76537	-30.9072	CTD off deck.
16:14:00 13/04/2016	22	-59.76547	-30.90719	Vessel on DP

14:50:00 13/04/2016	21	-60.001	-30.93807	Gantry secure vessel moving off D.P. proceeding to next C.T.D station
14:42:00 13/04/2016	21	-60.001	-30.93804	C.T.D. on deck
14:40:00 13/04/2016	21	-60.001	-30.938	C.T.D. at surface
12:46:00 13/04/2016	21	-60.00097	-30.93789	C.T.D. in the water
12:36:00 13/04/2016	21	-60.00098	-30.93787	Commenced deploy C.T.D.
12:34:00 13/04/2016	21	-60.00097	-30.93787	Vessel in position on D.P.
10:42:00 13/04/2016	20	-60.31445	-30.95797	Gantry lashed vessel ot of DP on route to next CTD
10:34:00 13/04/2016	20	-60.31443	-30.95795	CTD on the surface
10:26:00 13/04/2016	20	-60.31441	-30.95793	CTD on deck
09:21:00 13/04/2016	20	-60.31446	-30.95799	CTD at depth 2693m
08:30:00 13/04/2016	20	-60.31448	-30.95799	CTD in the water
08:28:00 13/04/2016	20	-60.31446	-30.95793	CTD off deck
08:22:00 13/04/2016	20	-60.31457	-30.95786	Vessel in DP
08:20:00 13/04/2016	20	-60.31526	-30.95619	Gantry unlashed
06:02:00 13/04/2016	19	-60.70072	-31.00892	Off DP
06:01:00 13/04/2016	19	-60.70073	-31.00894	Gantry lashed.
05:53:00 13/04/2016	19	-60.70072	-31.00887	CTD on deck.
05:50:00 13/04/2016	19	-60.70073	-31.0089	CTD on surface.
05:05:00 13/04/2016	19	-60.70072	-31.00891	CTD at depth
04:31:00 13/04/2016	19	-60.70072	-31.00894	CTD left surface.
04:30:00 13/04/2016	19	-60.70072	-31.00894	CTD off deck.
04:20:00 13/04/2016	19	-60.70026	-31.00796	On DP.
04:05:00 13/04/2016	19	-60.73111	-30.95608	Gantry unlashed.
01:30:00 13/04/2016	18	-61.17272	-31.05762	Gantry lashed and secure vessel proceeding to next C.T.D. station
01:17:00 13/04/2016	18	-61.17144	-31.05142	C.T.D. on deck
01:15:00 13/04/2016	18	-61.17143	-31.05148	C.T.D. at surface
23:44:00 12/04/2016	18	-61.17117	-31.05145	C.T.D. at depth 3436m
22:40:00 12/04/2016	18	-61.17121	-31.0515	CTD in the water
22:38:00 12/04/2016	18	-61.17121	-31.05148	CTD off deck
22:35:00 12/04/2016	18	-61.17119	-31.0515	Gantry unlashed
22:30:00 12/04/2016	18	-61.17185	-31.04905	Vessel on station in DP
19:38:00 12/04/2016	17	-61.66087	-31.11097	Out of DP
19:29:00 12/04/2016	17	-61.66087	-31.11102	CTD on deck
19:17:00 12/04/2016	17	-61.66086	-31.111	CTD on the surface
17:54:00 12/04/2016	17	-61.66091	-31.11105	CTD at depth
16:49:00 12/04/2016	17	-61.66089	-31.11095	CTD left surface.
16:48:00 12/04/2016	17	-61.66088	-31.11098	CTD off deck.
16:42:00 12/04/2016	17	-61.66142	-31.11039	Vessel on station

14:06:00 12/04/2016	16	-62.07655	-31.19288	Gantry lashed vessel proceeding to next C.T.D. station
14:00:00 12/04/2016	16	-62.07655	-31.19288	C.T.D. on deck
13:57:00 12/04/2016	16	-62.07654	-31.19291	C.T.D. at surface
12:08:00 12/04/2016	16	-62.07654	-31.19288	C.T.D. at depth 4682m
10:44:00 12/04/2016	16	-62.07649	-31.19283	CTD in the Water
10:42:00 12/04/2016	16	-62.07652	-31.19286	CTD off deck
10:34:00 12/04/2016	16	-62.07641	-31.19258	Vessel in DP
10:30:00 12/04/2016	16	-62.07736	-31.18618	Gantry unlashed vessel on station
08:17:00 12/04/2016	15	-62.49144	-31.26096	Gantry lashed vessel on route to next CTD
08:09:00 12/04/2016	15	-62.49178	-31.25985	CTD on deck
08:07:00 12/04/2016	15	-62.49179	-31.25984	CTD on the surface
06:05:00 12/04/2016	15	-62.49164	-31.25988	CTD at depth
04:37:00 12/04/2016	15	-62.49157	-31.2599	CTD left surface.
04:36:00 12/04/2016	15	-62.49158	-31.25991	CTD off deck.
04:30:00 12/04/2016	15	-62.4916	-31.25988	Vessel on DP
02:10:00 12/04/2016	14	-62.79035	-30.69555	Gantry secure vessel proceeding to next C.T.D. position
02:00:00 12/04/2016	14	-62.79036	-30.69545	C.T.D. on deck
01:56:00 12/04/2016	14	-62.79038	-30.69547	C.T.D. at surface
00:04:00 12/04/2016	14	-62.79033	-30.69527	C.T.D. stopped at depth 4821m
22:41:00 11/04/2016	14	-62.79037	-30.69519	CTD in the Water
22:34:00 11/04/2016	14	-62.79035	-30.69527	V/L on DP
19:55:00 11/04/2016	13	-63.07228	-30.1162	V/L out of DP set course for next
19:45:00 11/04/2016	13	-63.07226	-30.11643	CTD on deck
19:43:00 11/04/2016	13	-63.07225	-30.11652	CTD on the surface
17:57:00 11/04/2016	13	-63.07231	-30.11663	CTD at depth
16:28:00 11/04/2016	13	-63.07228	-30.11653	CTD left surface.
16:26:00 11/04/2016	13	-63.07228	-30.11656	CTD off deck.
16:20:00 11/04/2016	13	-63.0723	-30.11669	Gantry unlashed.
16:15:00 11/04/2016	13	-63.07304	-30.11513	Vessel on station
13:35:00 11/04/2016	12	-63.35085	-29.56306	Gantry lashed deck secure vessel proceeding to next C.T.D. position
13:26:00 11/04/2016	12	-63.35139	-29.56281	C.T.D. on deck
13:22:00 11/04/2016	12	-63.3514	-29.56293	C.T.D. at surface
11:35:00 11/04/2016	12	-63.35139	-29.56183	C.T.D. at depth 4682m
10:10:00 11/04/2016	12	-63.35138	-29.56233	CTD in the water
09:58:00 11/04/2016	12	-63.35146	-29.56298	V/L in DP
09:55:00 11/04/2016	12	-63.35163	-29.56381	thruster on gantry unlashed
05:25:00 11/04/2016	11	-63.96443	-28.87784	Gantry lashed
05:18:00 11/04/2016	11	-63.96436	-28.87771	CTD on deck.

05:14:00 11/04/2016	11	-63.96432	-28.87765	CTD on surface.
03:14:00 11/04/2016	11	-63.96437	-28.87767	Commencing recovery.
03:10:00 11/04/2016	11	-63.96436	-28.87771	CTD at depth
01:42:00 11/04/2016	11	-63.96414	-28.87734	C.T.D. at surface
01:40:00 11/04/2016	11	-63.96413	-28.87727	Commenced deployment C.T.D.
01:25:00 11/04/2016	11	-63.96445	-28.87732	Vessel in position setting up in D.P.
12:40:00 10/04/2016	10	-66.70718	-27.04767	Gantry lashed and deck secure vessel resuming on passage
12:35:00 10/04/2016	10	-66.70711	-27.047	C.T.D. on deck
12:28:00 10/04/2016	10	-66.70692	-27.04732	C.T.D. at surface
11:52:00 10/04/2016	10	-66.70523	-27.04998	C.T.D. stopped at 1000m
11:30:00 10/04/2016	10	-66.70522	-27.05001	C.T.D. at surface
11:28:00 10/04/2016	10	-66.70523	-27.05002	Vessel in D.P. in position to deploy C.T.D.
17:05:00 09/04/2016	Comment	-68.14316	-31.00906	Commencing passage north.
17:01:00 09/04/2016	9	-68.14343	-31.01056	CTD on deck.
16:59:00 09/04/2016	9	-68.14336	-31.01043	CTD on surface.
16:29:00 09/04/2016	9	-68.1423	-31.00653	CTD at depth
16:07:00 09/04/2016	9	-68.14182	-31.00319	CTD left surface.
16:06:00 09/04/2016	9	-68.1418	-31.00304	CTD off deck.
15:28:00 09/04/2016	8	-68.14185	-31.01618	Sampling team recovered to deck. Relocating vessel for CTD.
15:26:00 09/04/2016	8	-68.14186	-31.01589	Sampling team off ice
14:58:00 09/04/2016	8	-68.14214	-31.0114	Sampling team transferred onto Ice flow.
14:30:00 09/04/2016	7	-68.14428	-31.00351	Sampling team transferred back onboard
12:50:00 09/04/2016	7	-68.1503	-30.99244	Vessel alongside multi-year ice flow
13:24:00 07/04/2016	Comment	-63.817	-29.32074	Vessel proceeding to ICE edge
00:30:00 07/04/2016	Comment	-63.9481	-28.9613	Vessel arrived on location awaiting day shift & weather conditions to improve
12:24:00 06/04/2016	6	-63.11018	-33.57451	X.B.T. deployment complete
12:05:00 06/04/2016	6	-63.09644	-33.62021	Vessel reduced speed for X.P.T. deployment
23:00:00 04/04/2016	Comment	-60.83936	-45.54714	Vessel off DP
22:56:00 04/04/2016	5	-60.83936	-45.54711	CTD on deck
22:41:00 04/04/2016	5	-60.83936	-45.54709	CTD at 316m
22:27:00 04/04/2016	5	-60.83942	-45.54648	CTD off deck
21:30:00 04/04/2016	4	-60.75308	-45.61083	CTD on deck
21:16:00 04/04/2016	4	-60.83936	-45.54709	CTD stooped at 44m
21:10:00 04/04/2016	4	-60.75309	-45.61079	CTD off Deck
20:32:00 04/04/2016	3	-60.74574	-45.61373	CTD on deck
20:23:00 04/04/2016	3	-60.74575	-45.61366	CTD at 35 m
20:18:00 04/04/2016	3	-60.74574	-45.61371	vessel on ctd station 2
11:32:00 04/04/2016	Comment	-60.70164	-45.58212	Boats recovered on deck- vessel manoeuvering to next location for launching boats.

10:26:00 04/04/2016	Comment	-60.70166	-45.58221	Vessel commenced boat logisitics Signy
17:30:00 03/04/2016	Comment	-60.69773	-45.55571	Vessel back on DP off Signy Base following recce of McLeod glacier location.
15:02:00 03/04/2016	2	-60.6524	-45.51286	Boats ops cancelled due to Sea and Swell conditions- vessel moving off D.P.
14:45:00 03/04/2016	2	-60.64883	-45.51154	Vessel in D.P off Sunshine Glacier
12:26:00 03/04/2016	2	-60.69986	-45.57362	Boat ops aborted due to Sea and Swell conditions- vessel moving off position to locate sheltered position
11:00:00 03/04/2016	2	-60.69922	-45.57307	Vessel in D.P off Signy preparing boats for Science Logistics
18:21:00 01/04/2016	1	-55.24994	-53.83449	CTD on deck.
18:21:00 01/04/2016	1	-55.24994	-53.83449	CTD on deck.
18:18:00 01/04/2016	1	-55.24989	-53.83614	CTD on surface.
17:47:00 01/04/2016	1	-55.2484	-53.8482	Commencing recovery.
17:43:00 01/04/2016	1	-55.24842	-53.84818	CTD at depth
17:21:00 01/04/2016	1	-55.2484	-53.84817	CTD left surface.
17:20:00 01/04/2016	1	-55.24839	-53.84823	CTD off deck.
17:05:00 01/04/2016	1	-55.24844	-53.84815	Gantry unlashed.