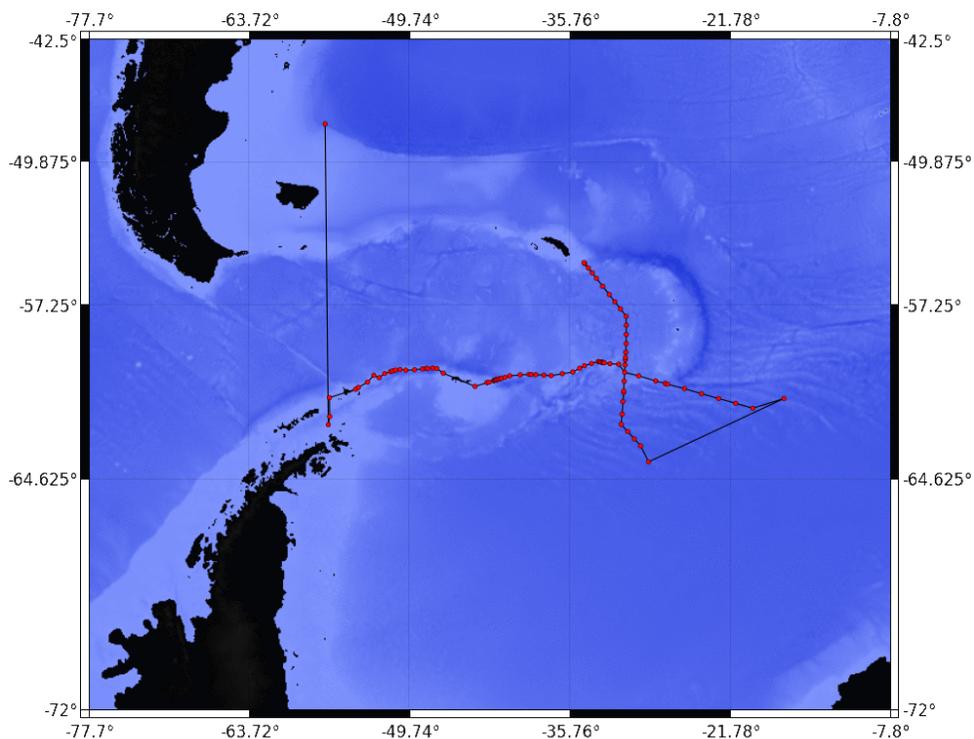


# CRUISE REPORT: ANDREX

(Updated SEP 2013)



## Highlights

### Cruise Summary Information

|                                    |  |
|------------------------------------|--|
| WOCE Section Designation           | ANDREX   |
| Expedition designation (ExpoCodes) | 74JC20100319   |
| Alias                              | JR239, A21, 74JC20100301                             |
| Chief Scientists                   | Michael Meredith / BAS                               |
| Dates                              | 2010 MAR 19 - 2010 APR 24                            |
| Ship                               | <i>JAMES CLARK ROSS</i>                              |
| Ports of call                      | Montevideo, Uruguay - Stanley, Falkland Islands      |
| Geographic Boundaries              | 59° 51' S<br>56° 47' 32" W 17° 4' 29" W<br>62° 30' S |
| Stations                           | 97   |
| Floats and drifters deployed       | 3 Argo floats deployed                               |
| Moorings deployed or recovered     | 0  |

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## Links To Select Topics

Shaded sections are not relevant to this cruise or were not available when this report was compiled.

| <b>Cruise Summary Information</b>   | <b>Hydrographic Measurements</b>                     |
|---|--|
| <a href="#">Description of Scientific Program</a>                               | <b>CTD Data:</b>                                     |
| <a href="#">Geographic Boundaries</a>   | <a href="#">Acquisition</a>                          |
| <a href="#">Cruise Track (Figure):</a> <a href="#">PI</a> <a href="#">CCHDO</a> | <a href="#">Processing</a>                           |
| <a href="#">Description of Stations</a>   | <a href="#">Calibration</a>                          |
| <a href="#">Description of Parameters Sampled</a>                               | <a href="#">Temperature</a> <a href="#">Pressure</a> |
| <a href="#">Bottle Depth Distributions (Figure)</a>                             | <a href="#">Salinities</a> <a href="#">Oxygens</a>   |
|   |  |
| <a href="#">Floats and Drifters Deployed</a>                                    | <b>Bottle Data</b>                                   |
| <a href="#">Moorings Deployed or Recovered</a>                                  | <a href="#">Salinity</a>                             |
|   | <a href="#">Oxygen</a>                               |
| <a href="#">Principal Investigators</a>   | <a href="#">Nutrients</a>                            |
| <a href="#">Cruise Participants</a>   | <a href="#">Carbon System Parameters</a>             |
|   | <a href="#">CFCs</a>                                 |
| <a href="#">Problems and Goals Not Achieved</a>                                 | <a href="#">Helium / Tritium</a>                     |
| <a href="#">Other Incidents of Note</a>   | <a href="#">Radiocarbon</a>                          |
|   |  |
| <b>Underway Data Information</b>  | <b>References</b>                                    |
| <a href="#">Navigation</a> <a href="#">Bathymetry</a>                           | <a href="#">Dissolved Oxygen</a>                     |
| <a href="#">Acoustic Doppler Current Profiler (ADCP) (LADCP)</a>                | <a href="#">Carbonate parameters</a>                 |
| <a href="#">Thermosalinograph</a>   | <a href="#">Noble gases, tritium and carbon-14</a>   |
| <a href="#">XBT and/or XCTD</a>   |  |
| <a href="#">Meteorological Observations</a>                                     |  |
| <a href="#">Atmospheric Chemistry Data</a>                                      |  |
|   |  |
| <b>Data Processing Notes</b>  | <b>Acknowledgments</b>                               |



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Antarctic Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

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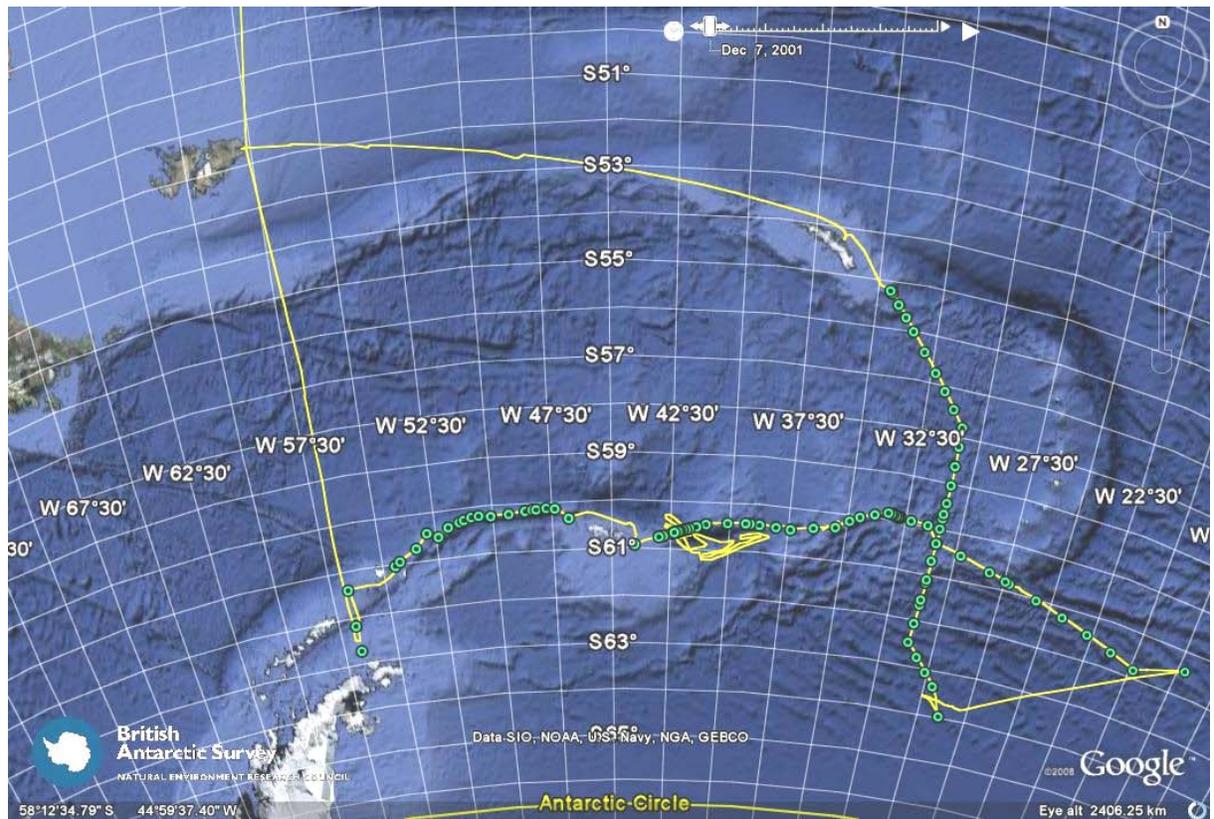
# **CRUISE REPORT, *RRS JAMES CLARK ROSS* JR235/236/239**

**19 March – 24 April 2010**

**Principal Scientist: Dr. Michael Meredith ([mmm@bas.ac.uk](mailto:mmm@bas.ac.uk))**



**Polar  
ceans**



**Frontispiece.** Cruise track of RRS James Clark Ross in the Weddell Sea and Scotia Sea during JR235/236/239. Green dots denote locations of CTD/tracer/CO<sub>2</sub> stations. Science conducted contributed to the Antarctic Deep Water Rates of Export (ANDREX) project, and the BAS Polar Oceans strategic research programme.

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## **2a. Acknowledgements.**

It is a pleasure to thank some of the many people and groups that helped to make JR235/236/239 the great success that it was. Particular thanks are owed to Jerry Burgan and the officers and crew of *JCR*, for keeping us moving in the right direction, keeping us safe, keeping us fed, and keeping our spirits high. Particular thanks also to Brian King, for a remarkable level of assistance from shore with technical and computing matters, despite weekends, bank holidays and travels of his own. Alberto Naveira Garabato is also thanked for help and guidance from shore, and for keeping the science wheels of ANDREX turning. We are also grateful to Tara Deen and Alex Tate for help and advice with the swath bathymetry system, both before and during the cruise. A final vote of thanks is due to the weather gods, who kept the Weddell and Scotia Seas calmer and more ice-free than we had any right to expect in March and April.

Mike Meredith, PSO, May 2010.

## 2b. Overview and Rationale for JR235/236/239

On this cruise of *RRS James Clark Ross*, three discrete elements of work were undertaken. Following the BAS policy of giving each element of work its own unique identifier, so that such units can be moved within or between seasons without needing to renumber the whole schedule, these were designated JR235, JR236 and JR239. However, the scientific goals and *modus operandi* were strongly related across these cruises (especially JR235 and JR239), and each was conducted collaboratively by the same scientific party on board. The elements of work undertaken are outlined below in chronological order of completion.

### (i) JR239

JR239 was the cruise designation given to the “ANDREX recovery cruise”. ANDREX is the Antarctic Deep Water Rates of Export project, supported by NERC via the Antarctic Funding Initiative (PI Dr. Alberto Naveira Garabato, NOC). The stated goals of ANDREX were:-

1. To quantitatively assess the import / export routes of Circumpolar Deep Water and Antarctic Bottom Water (AABW) to / from the Weddell gyre.
2. To obtain an optimal, self-consistent estimate of the rates of ventilation and AABW formation and export in the Weddell gyre.
3. To quantify the nutrient and carbon cycles of the Weddell gyre.
4. To determine the rate of sequestration of anthropogenic carbon into the deep Weddell gyre.
5. To investigate the extent to which ventilation in, and AABW export from, the Weddell gyre have varied on interannual to decadal time scales.
6. To feed the newly-gained quantitative understanding of exchanges across the Weddell gyre’s rim into the design of the emerging Southern Ocean Observing System during the IPY.

For the fieldwork phase of ANDREX, a major hydrographic/tracer/carbon section along the northern edge of the Weddell Sea was conceived. This was planned to connect with the WOCE/CLIVAR section IR6S, which was successfully conducted by US collaborators in season 2007/8 ([Figure 2.1](#)), and which collected measurements of many of the same parameters as was planned for ANDREX. When considered together, the sections would effectively form box around the Weddell gyre, enabling inverse analyses to be used to provide quantifications of the desired fluxes outlined above.

A second (strongly related) project was also linked to the ANDREX cruise, namely “Freshwater Export from the Weddell Gyre: Magnitude, Variability and Impacts” (a.k.a. “ANDREX-Fresh”; PI Dr. Mike Meredith, BAS). This was supported by NERC via the Small Grants scheme, effectively to cover the costs of stable oxygen isotope analyses on ANDREX. These measurements are to be used, in combination with the measured salinity and derived velocity fields from ANDREX, to quantify the freshwater export from the Weddell gyre, to separately deduce how much of this export is from sea ice and meteoric sources, and to better ascertain the climatic relevance of these fluxes.

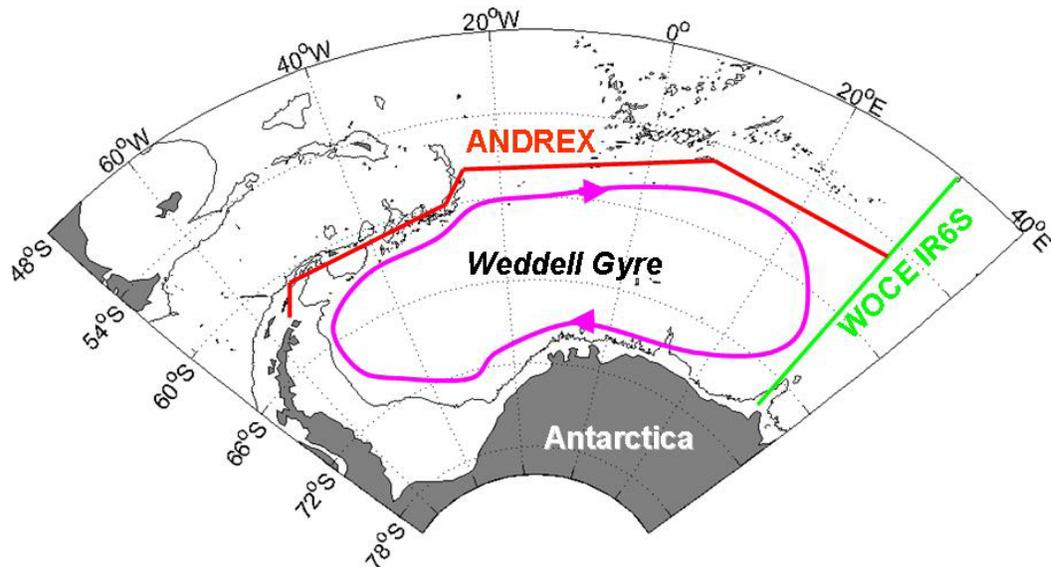


Figure 2.1. Schematic of intended location of ANDREX hydrographic / tracer / carbon section, along the northern edge of the Weddell gyre, and its connection to the WOCE/CLIVAR IR6S section at the eastern boundary of the gyre.

The original ANDREX cruise was conducted from *RRS James Cook*, in season 2008/9. However, this cruise was beset by difficulties and was aborted early due to a medical emergency, with the major part of the hydrographic / tracer / carbon section remaining incomplete. Negotiations were entered into with NERC, and a recovery cruise was scheduled in 2009/10 season, to be conducted from *RRS James Clark Ross*; this is what became JR239.

**(ii) JR236.**

As part of the BAS Polar Oceans programme, funding has been provided to deploy an array of current meter moorings in Orkney Passage. This deep gap, on the South Scotia Ridge, is a key location of outflow of AABW from the Weddell Sea into the Scotia Sea, and the intention is to monitor this outflow over the course of several years, and hopefully longer. Working with Lamont-Doherty Earth Observatory in the US, a small number of moorings have been deployed here already, and the resource needed for a larger array (from which quantifications of flux can be made) was recently obtained. Prior to the deployment of this larger array (scheduled for season 2010/11), we deemed it sensible to better understand the topography of Orkney Passage, so as to increase confidence that the moorings locations chosen were the most effective places, and to help with the interpretation of the moorings data once recovered. Accordingly, 3 days of shiptime was provided in 2009/10 season for mapping of the seabed in the Orkney Passage area using the *James Clark Ross*' multibeam echosounder. These 3 days were designated JR236.

**(iii) JR235.**

In 1995, WOCE section A23 was conducted from *RRS James Clark Ross*, running from Antarctica (Weddell Sea coastline) northward to Brazil. The part of this section in the eastern Scotia Sea has been repeated twice since, in 1999 (also from *JCR*), and in 2005 (by the US CLIVAR repeat hydrography/CO<sub>2</sub> program). Figure 2.2 shows the locations of the stations conducted in each of these years. A number of works have highlighted the usefulness of this section in determining and understanding the changing characteristics and circulation of AABW 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. Accordingly, the BAS Polar Oceans programme secured shiptime to repeat this section, 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. The presence of tracer groups from UEA, NOC, WHOI and Manchester onboard from JR239 also offered the opportunity to work collaboratively to measure a range of other parameters (in addition to standard hydrographic properties) along this line. This section of work was designated JR235.

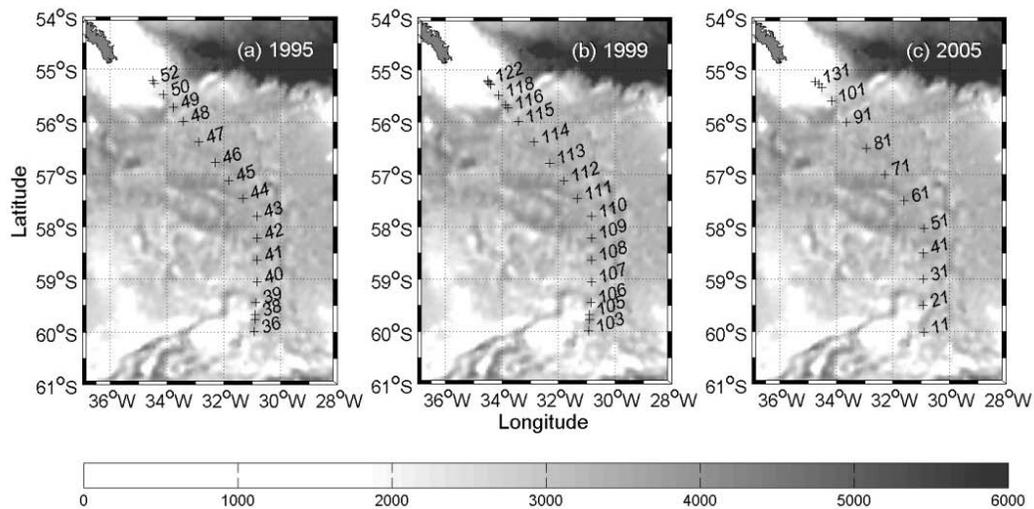


Figure 2.2. Locations of stations in the eastern Scotia Sea (between the South Scotia Ridge and South Georgia) conducted in 1995, 1999 and 2005 along the track of the WOCE A23 cruise.

## 2c. Cruise participants.

### (i) Scientific party:-

| <b>Name</b>          | <b>Institute</b> | <b>Primary Responsibility</b>            |
|----------------------|------------------|--|
| Michael Meredith     | BAS              | Principal Scientist                      |
| Povl Abrahamsen*     | BAS              | Salinometry, swath bathymetry            |
| Dorothee Bakker      | UEA              | Carbonate parameters                     |
| Andrew Brousseau     | UEA              | CFCs, CCl <sub>4</sub> , SF <sub>6</sub> |
| Peter Brown          | UEA              | CFCs, CCl <sub>4</sub> , SF <sub>6</sub> |
| Sophie Chollet       | UEA              | Dissolved oxygen, nutrients              |
| Nathan Cunningham    | BAS              | Data management, CTD ops                 |
| Eleanor Darlington   | NOC              | Dissolved oxygen, nutrients              |
| Allan Davies         | NMF              | CTD support, CTD ops                     |
| Johnnie Edmonston    | BAS              | Computing support                        |
| Elizabeth Jones      | UEA              | Carbonate parameters                     |
| Stephen Jones        | UEA              | Carbonate parameters                     |
| Loic Jullion*        | NOC              | Lowered ADCP                             |
| Vsevolod Afanasyev   | BAS              | Engineering support                      |
| Brice Loose          | WHOI             | Noble gases, tritium, <sup>14</sup> C    |
| Roísín Moriarty      | U. Manchester    | Noble gases, tritium, <sup>14</sup> C    |
| Aurelie Persechino   | NOC              | Reference thermometer                    |
| Angelika Renner      | UEA              | Shipboard ADCP                           |
| Maceij Telszewski    | UEA              | Carbonate parameters                     |
| Sinhue Torres-Valdes | NOC              | Dissolved oxygen, nutrients              |
| Takamasa Tsubouchi   | NOC              | Underway measurements                    |
| Hugh Venables*       | BAS              | CTD processing                           |
| Stephen Woodward     | UEA              | CFCs, CCl <sub>4</sub> , SF <sub>6</sub> |
| John Wynar           | NMF              | CTD support, CTD ops                     |

\* watch leader

BAS = British Antarctic Survey

UEA = University of East Anglia

NOC = National Oceanography Centre

NMF = National Marine Facilities

WHOI = Woods Hole Oceanographic Institution

**(ii) RRS James Clark Ross Officers and Crew:-**

| <b>Name</b>            | <b>Rank or Rating</b>    |
|------------------------|--------------------------|
| Michael (Jerry) Burgan | Master                   |
| Howard Markham         | Chief Officer            |
| Euan Beynon            | 2 <sup>nd</sup> Officer  |
| Spencer Wiles          | 3 <sup>rd</sup> Officer  |
| John Summers           | Do'Sci'Ops               |
| Michael Gloistein      | ETO Comms                |
| Joanna Gregory         | Doctor                   |
| Duncan Anderson        | Chief Engineer           |
| Thomas Elliott         | 2 <sup>nd</sup> Engineer |
| James Stevenson        | 3 <sup>rd</sup> Engineer |
| John Willetts          | 4 <sup>th</sup> Engineer |
| Gareth Wale            | Deck Engineer            |
| John McManmon          | ETO Engineer             |
| Richard Turner         | Purser                   |
| David Peck             | Bosun                    |
| Albert Bowen           | Bosun's Mate             |
| Kelvin Chappell        | SG1A                     |
| George Dale            | SG1A                     |
| Anthony Estibeiro      | SG1A                     |
| David Triggs           | SG1A                     |
| David Phillips         | SG1B                     |
| James Reid             | MG1                      |
| Jeremy Summers         | MG1                      |
| Ashley Huntley         | Chief Cook               |
| Jamie Lee              | 2 <sup>nd</sup> Cook     |
| Lee Jones              | Sr. Steward              |
| Nicholas Greenwood     | Steward                  |
| Graham Raworth         | Steward                  |
| Michael Weirs          | Steward                  |

## 2d. Principal Scientist's narrative

**Tuesday 16<sup>th</sup> March 2010.** Science party arrived in Montevideo after overnight flight from UK, via Sao Paulo. Joined ship straight away, and began with safety briefing and familiarisation for those new to *JCR*. Mobilisation began with science parties locating their cargo in the holds, though some groups were limited in what they could do until the containers from Southampton and *Discovery* arrive. Uruguayan mosquitos a persistent nuisance.

**Wednesday 17<sup>th</sup> March 2010.** Mobilisation continues for those that can; others using the opportunity to explore a little of Montevideo and enjoying the last few days on land before several weeks in the Southern Ocean. Meat market a particular draw, as always. Still awaiting confirmation of arrival time/day of containers.

**Thursday 18<sup>th</sup> March 2010.** Containers have been sighted on quayside, just a few hundred yards from the ship, but are still not cleared by customs and so cannot be accessed. So near, and yet.... Dramatic thunderstorm in evening, with torrential downpour.

**Friday 19<sup>th</sup> March 2010.** Containers arrived at ship in morning. The UEA containerised laboratories were winched into place and secured, and the UEA teams set about mobilising their equipment and getting the labs connected with power, water, gaslines. The Southampton container was unloaded quayside, and gear netted onto the ship. One issue became immediately apparent – none of the WHOI tracer sampling gear was in the container. The cause of this is not immediately clear; the gear was in Southampton, but appears not to have been consigned to *JCR*. Brice set about trying to procure some equipment at very short notice, and (aided by the ship's Purser) managed to secure 120m of copper tubing just before the ship sailed (with literally just seconds to spare). Sailed from Montevideo, 4pm local; heading South.

**Saturday 20<sup>th</sup> March 2010.** Equipment problems within the oxygen/nutrients team were circumvented by Gareth (Deck Engineer), who manufactured a carousel system to replace a missing one, and by the donation of a temperature-controlled bath from the carbon team. Mobilisation continued in sunshine and on calm seas.

**Sunday 21<sup>st</sup> March 2010.** Weather turned cloudy, but seas still beautifully calm. Mobilisation continues, and most things now seem to be in place. Sea ice imagery examined, and suggested that the first part of the JR239 section (close to tip of Antarctic Peninsula) might not be workable. Will begin giving thought to an alternative plan. PSO gave an overview talk after dinner, outlining the rationale for the cruise, and how the work we will be doing will answer some key scientific questions. Not too many people fell asleep.

**Monday 22<sup>nd</sup> March 2010.** Test CTD cast conducted soon after breakfast. In deep water (>5000m) so decision made not to profile full depth (and hence not to test altimeter on frame), but other systems seem to work well, with exception of transmissometer. Upcast was paused at ~1000m to accommodate a crew safety drill. Some Niskins leaked. Fire extinguisher training in the afternoon for science party, including using hoses over aft deck. Amazingly clear night sky, unlike anything seen at home.

**Tuesday 23<sup>rd</sup> March 2010.** Called at Stanley, F.I., to exchange the BAS Antarctic & Marine Engineering staff on board. Clear, sunny and calm, and we were escorted in by sei whales, dolphins and penguins. Ship did not go alongside, but stopped outside the harbour for boat transfer. We bade farewell to Julian Klepacki, and thanked him for his help in mobilising the cruise, and welcomed onboard Vsevolod Afanasyev as his replacement.

**Wednesday 24<sup>th</sup> March 2010.** Traversing northern Drake Passage; still bright and clear, but significantly more lumpy. A planned Argo deployment was delayed; Hugh Venables examined satellite altimeter data, and found that the Polar Front is presently slightly further south than its climatological mean (the intention is for this float to advect across the Scotia Sea and exit in the vicinity of South Georgia, so we are targeting the region just south of the PF). Some of the first few stations of planned section now seem definitely to be covered by sea ice, following examination of various different sea ice products (including via Polarview). Working on a plan to move the planned subsection between the tip of the Peninsula and the South Orkneys to the more northerly ridge crest, including stations along the other edge of Bransfield Strait. Ideally will not involve increasing the number of stations. Decision taken to remove the uplooker LADCP, following discussions with Brian King in Southampton. It has been reporting a weak beam, but might be usefully functional nonetheless - but the failure rate of these units is so high that it is deemed unnecessarily risky to deploy two at once. This also has the advantage of making the package easier to manoeuvre into and out of the water bottle annex, which was only designed to accommodate a 12-bottle frame. Argo float "Molly" deployed at ~1900Z.

**Thursday 25<sup>th</sup> March 2010.** Started grey and overcast but brightened in afternoon. Heading south to start CTD section. Decision is confirmed to move section between Peninsula and South Orkneys to the more northerly ridge crest, to minimise interference from sea ice. Ship encountered lots of bergy bits and a few larger bergs, and then came close to edge of sea ice. Ship entered into a recess in the ice; decision made not to try and reach planned position of first station of section, since it would involve navigating back out of the ice after dark, with a considerable time penalty. First station of JR239 section conducted, in around 450m of water.

**Friday 26<sup>th</sup> March 2010.** CTDs continued overnight, and instruments are operating well with the exception of the transmissometer (which is not a priority for us). Passed very close to Elephant Island around lunchtime, and were treated to some spectacular views in the sunshine. Still doesn't look a good place to be stranded though.

**Saturday 27<sup>th</sup> March 2010.** Three Niskin bottles were lost overnight; presumption is that one closed upon entering the water, and trapped air, and then imploded violently under pressure. Bottles replaced; hoping not for recurrence as we are now short of spares. Problems persist with other Niskins not closing properly; AME and NMF will investigate. Two salinometers were set up in microradio lab at start of cruise, since it is the most thermally stable small lab on the ship. The one used initially has been giving noisy readings and some signs of (unexplained) drift. Decision made to switch to using second unit, which seems to be performing much better.

**Sunday 28<sup>th</sup> March 2010.** A number of Niskin bottles still leaking, especially numbers 1, 20, 24. Plan is for AME and NMF to investigate after station 23, during the longer steam across the South Orkneys shelf. LADCP reporting a broken beam. Decision made

to swap in a new unit after station 20. A NMF unit is now on the frame. A recurring problem with bottom endcaps closing on entering the water was noted. This was addressed by moving the point of connection of the lower lanyard much closer to the carousel, and reducing the freedom to move of the bottom endcap. Plan is also to replace several O-rings and increase the bottles' spring tensions to (hopefully) improve success rate of water sampling.

**Monday 29<sup>th</sup> March 2010.** Steam across shelf close to South Orkney islands. Calm and sunny, and ocean dotted with icebergs. Tensions in bottle closing springs measured; no clear relationship between these and success rate of sampling. Thought is still that increasing the tension might help improve matters though. Will be worked on.

**Tuesday 30<sup>th</sup> March 2010.** Three more CTDs conducted overnight, and we are now surveying Orkney Passage with the ship's multibeam echosounder prior to conducting CTDs here, and prior to deploying moorings next season. Slight hitch with data when the multibeam stopped profiling to the seabed; Alex Tate in Cambridge provided advice on how to solve. A problem with the ship's motor has arisen, which will require ~12 hours maintenance. This will be done tomorrow, starting ~0800L. Ship will heave to for this; multibeam and CTD work will be temporarily halted. Bottles 1 and 11 swapped on the CTD frame; bottle 1 was one of the worst repeat offenders, and (given that it is normally the deepest bottle closed), it was thought prudent to swap in a better-performing unit. Tension upped in some more of the closure springs, since this seems to be having a positive effect.

**Wednesday 31<sup>st</sup> March 2010.** Swath finished at around 0730L; ship hove to for maintenance. This finished around 1800L. Fortuitously, some useful swath data was obtained as the ship drifted backwards for these hours, since it drifted over an area of a gap in swath data coverage.

**Thursday 1<sup>st</sup> April 2010.** Station 30 had a problem with air valves on Niskins not being closed; decision made to accept the time penalty and repeat the cast, since it is one of the key ones on the western side of Orkney Passage. AME tech plans to try chamfering the runnels through which the Niskin lanyards slide, so as to reduce the friction associated with the right-angle and hence increase the tension passed to the endcaps on closure. Should also help reduce risk of lanyard breakages. Efforts were made to detect the BAS OP1 mooring in Orkney Passage, which the *Ernest Shackleton* had failed to recover last season. Although unlikely to succeed, it was thought worth deploying a hydrophone to listen for it, since *JCR* is a quieter ship. Povl Abrahamsen tried making contact from three different locations close to the mooring site, but to no avail. The French contingent on board had much fun with the "Poisson d'Avril", a 1<sup>st</sup> April tradition unknown to most Anglo-Saxons onboard. This spread to the Mexican contingent at one point. An unknown prankster tried convincing the science party that all clocks were going forward 1 hour at midnight, as a move to "Antarctic Winter Time". The number of scientists duped is unknown, but is thought to be significantly greater than zero. Penguin and chips were on the menu for dinner, and photographic evidence obtained of the veracity of this.

**Friday 2<sup>nd</sup> April 2010.** Swath bathymetry to south and southeast of Orkney Passage. Weather getting less favourable, but data still of reasonable quality. People using time to catch up with backlogs of samples, and to catch breath for the rest of the cruise. Plan to deploy one of the ice-capable Argo floats overnight, at a location that might lead to it advecting through Orkney Passage.

**Saturday 3<sup>rd</sup> April 2010.** Swath continuing, in deteriorating weather. Air temperatures down around -9 degC; forward deck completely iced up. Aft deck salted to allow safe access to container labs. Argo float "Jessica" deployed at ~0630L. CTD33 deployed into quite choppy seas; package had to be recovered and one bottle reset due to accidental closure as it hit a wave on deployment. During the cast, we were joined by a pair of southern right whales, who examined the ship at very close quarters (sometimes just a few yards) for an hour or more. These rapidly became amongst the most photographed whales in history. Package was recovered straight into hangar, to avoid freezing problems. Sampling rather cosy.

**Sunday 4<sup>th</sup> April 2010.** Easter Sunday aboard; significantly calmer, but with occasional flurries of snow. CTDs continued overnight, with sampling conducted in the hangar. The noble gas samplers missed one planned cast due to a problem with the compressed air supply, but being on the eastern side of Orkney Passage now, this is less critical. Disappointingly, station 37 showed a recurrence of the bottle closure/leakage problems, but the previous few casts had shown much improvement so we are hoping that this is a random bad cast rather than anything systematic. Time will tell.

**Monday 5<sup>th</sup> April 2010.** CTD work suspended on station 42, due to increasingly rough seas. Decision was made during the upcast, so the downcast and the lower part of the upcast were conducted as per usual, however for the upper part of the upcast the package was not stopped for bottle closures. This means that the target depths were missed in most cases, and whilst the actual depth of bottle closure is logged, the comparison of bottle salts and CTD salinity may be different for this section due to the influence of the package on the water. SBE35 temperatures will certainly be affected, since the package was moving during the reference thermometer's averaging period. Other tracers will need examining closely.

**Tuesday 6<sup>th</sup> April 2010.** Weather got up quite dramatically overnight, and CTD work was suspended again after station 44. This station also suffered from an apparent electrical/data fault on the upcast, with three instances of spikes during which the pumps turned off. AME investigated, but no obvious cause was immediately apparent. The instances seem to be related to times at which there was heavy tension on the wire. Access to container labs was restricted during the bad weather, and we heaved to pending a break. Everyone tired, especially those who had been trying to sleep overnight, but for the most part people retained good humour. Station 45 started in brilliant sunshine but very choppy seas, around 1345L, after a frustrating few hours waiting for calmer weather.

**Wednesday 7<sup>th</sup> April 2010.** Midpoint of the cruise just passed, both chronologically and by CTD number. Very much calmer, to everyone's relief. Now tackling the tightly-packed stations around number 50, so very little steaming time between casts. Sampling on deck has resumed, which offers much more space than sampling in the water bottle annex. CTD electrical/data fault has subsided, but this may be due to the calmer conditions and hence reduced peak tensions on the wire. Visited again by whales; humpbacks this time, during stations 51 and 52. A stunning display - very close to the ship for lengthy periods, with lots of flukes on display.

**Thursday 8<sup>th</sup> April 2010.** CTDs continue, and are now more widely spaced, to everyone's relief. Intensive sampling of tightly-packed stations takes its toll. A few cattle

egrets landed on the aft deck, looking tired and bedraggled. On past evidence, the omens for them are not good.

**Friday 9<sup>th</sup> April 2010.** The planned location of station 62 was occupied by an irksome but rather beautiful iceberg. Accordingly, the station was conducted about 1nm SSW of the planned location, which afforded us some stunning views of the berg during the cast. Now behind schedule by a margin that we are unlikely to be able to make up with a business-as-usual plan, so the decision was made to cut station 69 (the easternmost station of the zonal section). This saves us a long steam in both directions, so represents a double win, time-wise.

**Saturday 10<sup>th</sup> April 2010.** Stations now much more widely spaced, giving some much-needed time in between to catch up with processing of samples and data, and general catching of breath. Station 65 (around 4655m in the Weddell Sea) was adorned with the traditional array of decorated polystyrene cups, to be shrunk under pressure. Some unusual wind velocity readings caused much puzzlement amongst the science party, until it was realised that a bird strike overnight on the anemometer had knocked it over. Fixing it involved crane work to access the mast; this was done by Mike (ETO Comms) with the ship on station, after station 65.

**Sunday 11<sup>th</sup> April 2010.** A long steam out to the last station of our zonal section (JR239; ANDREX recovery); arrived just around dusk. Earlier in the day, we were visited by some more humpback whales, who entertained us magnificently for half an hour or so, before we bade them farewell and left station. Anemometer now working and feeding data to the bridge (hence DP now functional), but not yet feeding data through SCS. ICT is investigating, and restarting data streams to attempt to rectify.

**Monday 12<sup>th</sup> April 2010.** A quieter day, following the completion of the JR239 CTD line. Now steaming south and west into the deeper Weddell Sea, to reach the start position for JR235. Making good speed, currently >14 knots. Dissolved oxygen sensor was removed from frame, and replaced with the corresponding BAS unit, following an apparent shift in readings. In the evening, Nathan composed and compered a pub quiz in the officers' lounge, which was greatly enjoyed by all (even though the result was a travesty of justice).

**Tuesday 13<sup>th</sup> April 2010.** Weather has closed in, and, having made good speed to the start position for JR235, we now have a frustrating wait to start the section. And the PSO became another year older, to make matters worse.

**Wednesday 14<sup>th</sup> April 2010.** Things became progressively calmer overnight, and we headed toward the start point of JR235 in the Weddell Sea to commence the section around 0930L. In total, over a day was lost to weather during this spell, and we don't now have the option of shortening the shiptrack to save time. Difficult decisions concerning which stations to omit are looming. Nonetheless, station 70 was successfully conducted at the southernmost point of the cruise, followed by the deployment of the last of our Argo floats ("Bethany"). Onwards and northwards.

**Thursday 15<sup>th</sup> April 2010.** Cloudy and grey to begin with, but wonderfully calm, and some much-needed sunshine arrived mid-morning. Station 73 was conducted, but a problem became apparent in both primary temperature and conductivity. The problem affected most of the downcast, but then seemed to clear itself, and the most likely initial

diagnosis was some sort of fouling. Powl flushed the system through when back on deck, and the hope was that it was just a temporary blockage that had cleared. However, the problem recurred on the following cast, suggesting a failure of the pump instead, so the decision was taken to replace it. Because of time lost to weather, the decision was made to remove two stations from the schedule, namely 76 and 81. The former of these is the shallower of a pair of closely-spaced stations in the northern Weddell Sea, whilst the latter is in a position that we occupied on our zonal transect, so loss of unique information should be minimised.

**Saturday 17th April 2010.** Beautifully calm, and now into the Scotia Sea and making good progress with the CTDs working northbound. Primary temperature and conductivity now seem much better with the new pump fitted. A southern right whale and a large raft of chinstraps visited us during station 85; sightings were aided by the conditions.

**Monday 19th April 2010.** Now onto CTD 93, and the end is in sight. The timing is good to be finishing the measurements, because the forecast is ominous, and the predicted wave heights around South Georgia are looking very much more lumpy than would be ideal. Everyone concentrating now on just getting to the end before it really sets in. Ash from the Icelandic volcano has shut down British airspace, so there are a few nagging doubts about flights home – the nightmare scenario is having to do an AMT northbound.

**Tuesday 20th April 2010.** CTDs finished overnight, with the successful completion of station 98. Many samples of different flavours remain to be run, but this still marks the last big significant milestone of the cruise. Much relief about how it has gone – given the timing of the cruise, and the potential for disruption by ice and weather, we have been extraordinarily fortunate. Choppy weather precluded working in the containerised laboratories in the morning, but bright sunshine helped the upbeat mood onboard. Entered Cumberland Bay shortly after lunch, for pax collection at KEP. By this time the views were hampered by fog and snow, but the calmer waters were a relief to all. However, the conditions were still not suitable for personnel to go ashore; intention is to hold station here overnight and wait for the bad weather to pass, before commencing the passage to Stanley.

**Wednesday 21st April 2010.** Conditions cleared overnight, and daybreak brought some stunning views of South Georgia in brilliant sunshine. A great shame to leave, but we had to sail out into open waters and commence the passage back to the Falklands. Next stop Stanley, then home.

### 3. Conductivity-Temperature-Depth (CTD) measurements

#### 3a. CTD setup, configuration and operations (John Wynar, Allan Davies)

A total of 96 CTD casts were completed on this cruise, numbered by station ([Appendix 2](#)). The initial sensor configuration was as follows:-

- Sea-Bird *9plus* underwater unit, s/n: 09P-0869
- Frequency 0 - Sea-Bird 3 Premium temperature sensor, s/n: 03P-2919
- Frequency 1 - Sea-Bird 4 conductivity sensor, s/n: 04C-2450
- Frequency 2 - Digiquartz temperature compensated pressure sensor, s/n: 46253
- Frequency 3 - Sea-Bird 3 Premium temperature sensor, s/n: 03P-4782
- Frequency 4 - Sea-Bird 4 conductivity sensor, s/n: 04C-2571
- V0 - Sea-Bird 43 dissolved oxygen sensor, s/n: 43-0619
- V2 - Benthos PSA-916T 7Hz altimeter, s/n: 874
- V3 - Chelsea Aquatracka MKIII fluorometer, s/n: 088195
- V6 - WETLabs Light Scattering sensor, s/n: BBRTD-168
- V7 - Chelsea Alphatracka MKII transmissometer, s/n: 0971007-001

The primary temperature and conductivity sensors were vane-mounted. Ancillary instruments & components were:-

- Sea-Bird *11plus* deck unit, s/n: 11P-0502
- Sea-Bird 24-position Carousel, s/n: 32-0722
- Sonardyne HF Deep Marker Beacon, s/n: 234002-001
- RDI WorkHorse Monitor 300KHz ADCP, s/n: 13191 (downward-looking, casts 1-20)
- RDI WorkHorse Monitor 300KHz ADCP, s/n: 12369 (downward-looking, casts 21-98)
- 24 x Ocean Test Equipment ES-20L water samplers, s/n: 01 to 24 inc.

#### *CTD Analysis & changes to Configuration*

The first CTD cast (number 1) was used as a shakedown cast. Two of the Niskin water samplers' lower end caps failed to close properly. Unfortunately this is not unexpected with this type of bottle (see below for [report on the 20L water samplers](#)). The pressure sensor was located 70cm below the centre of the 20L water sampling bottles. Due to the difference in wire out "depths" (as measured by the winch monitoring system) and the CTD pressure sensor, both values were recorded on the log sheet. (Paper log sheets were kept for all casts, and scanned).

For casts 1 – 32 the configuration file used was `ctd_jr239.con`. After cast 32 the BBRTD and transmissometer were moved to channels V4 and V5 respectively and the config file changed to `ctd_jr239a.con`. After cast 44 the transmissometer was removed and so for casts 45 and 46 config file `ctd_jr239b.con` was used. However, this caused problems with the data processing batch file and so from cast 47 onwards `ctd_jr239a.con` was used again. When the dissolved oxygen sensor was changed after cast 68, the config file used was `ctd_jr239c.con`.

To summarise:-

ctd\_jr239.con was used for casts 1-32;  
ctd\_jr239a.con for casts 33-44;  
ctd\_jr239b.con for casts 45 and 46;  
ctd\_jr239c.con for casts 47-98

(See [Appendix 1](#) for the configuration files themselves)

Due to time constraints cast #69 was cancelled although the original station numbering was kept, hence there is no CTD #69 data file. Similarly cast #76 and #81.

### *Sensor Failures*

After the shakedown cast #1, there was little if any output from the BBRTD and the transmissometer. First the Y-cable and then the cables to the individual instruments were replaced, but the fault persisted. After further investigation it was found that in fact the Y-cable was incorrectly labeled so that the BBRTD output was appearing on the transmissometer channel, and vice versa. However even after this fault was rectified the transmissometer was only observed to function correctly at shallow depths. The unit operated correctly from the surface to between 80 and 100m on every cast before the output saturated. It then remained at 5V/102% for the remainder of the downcast before usually recovering and operating normally at about the same depth on the up-cast. Replacing the cables to the instrument did not help, neither did swapping the unit to a spare analogue channel on the SBE 9plus. Eventually, as no direct replacement was available, both the BBRTD and the transmissometer were removed.

During the upcast of #44, the deck unit alarmed briefly, causing the CTD pumps to turn off. The upcast resumed when the pumps turned on again, after about 1 minute delay. However, the resulting reset of the carousel meant that the water samplers had to be fired from the deck unit, and a miscount meant that only 23 bottles were tripped. A similar situation occurred during cast #46. A further anomaly occurred during cast #62 when the water samplers were fired from the deck unit. This time the firing order ran from 1 – 18, then repeated 17 and 18 before continuing from 19 through to 22. As the firing sequence was not being displayed on screen, this went unnoticed until the CTD was recovered and it was observed that samplers 23 and 24 had not been tripped.

### *Ocean Test Equipment 20L Water Samplers*

Tables providing the statistics and/or frequency of failure of water samplers are included in a separate report by Nathan Cunningham ([Section 3b](#)).

On recovering the CTD after cast 10, water samplers 17, 18 and 19 were found to be irreparably damaged. The most likely scenario is that sampler 18 prematurely closed for some unknown reason as the CTD entered the water, causing it to implode shortly thereafter, and the force of the implosion damaged the samplers on either side. The deployment of cast 10 had been in darkness and relatively large seas. A little later as the CTD was being deployed in daylight, it was noticed that the lower end caps of a few samplers had shut as they entered the water, with potentially damaging results. The resident BAS AME technician put forward the idea to extend the lanyards from the lower

end caps to the point on the upper lanyards where they loop over the carousel hooks. This greatly reduced the amount of slack in the lanyard connected to the lower end cap. The lanyards of all the water samplers were modified and deployments recommenced.

In an attempt to improve the closing and sealing efficiency of the water samplers, when time allowed between casts the spring tensions were measured and increased where necessary. The O-ring seals at the top and bottom of the samplers were also replaced, as were the seals around the spigots of several units.

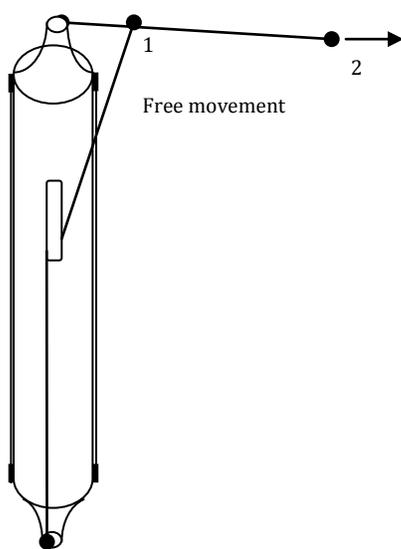
After a spring lanyard broke, it was noticed that the lanyard guides might cause less wear and/or damage if their corners were rounded off. A modification program to this end was initiated and completed without any further scientific downtime.

### 3b. Niskin bottle modifications (report by Nathan Cunningham & Mike Meredith, BAS)

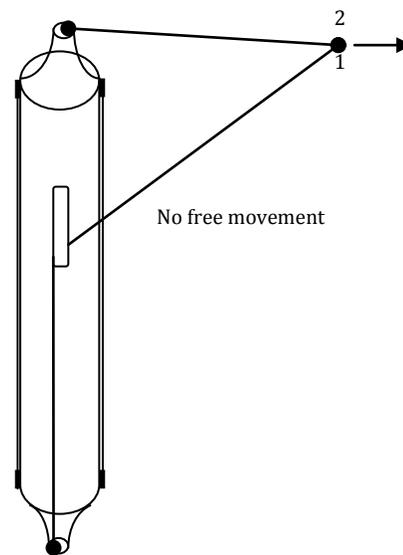
The water sampling system used on JR235/236/239 was a 24-bottle carousel system fitted with externally-sprung 20L Niskin bottles manufactured by Ocean Test Equipment, Florida, and owned by National Marine Facilities (NMF) Southampton. Over the course of the cruise, these bottles had a success rate of 89% (judged by successful closure and non-leakage). This rate was markedly lower toward the start of the cruise (see [Section 3a](#) for further details), and this report summarises the work that was undertaken during the cruise to help improve the success rate. Much of this work was instigated by Vsevolod Afanasyev and assisted by Gareth Wale (Deck Engineer), and their endeavours are gratefully acknowledged by all those involved in running the CTD or sampling from the package.

On CTD event 10, the package suffered three shattered Niskin bottles. It is suspected that the endcaps closed without being fired at the surface, and imploded under pressure at depth. Further instances of closure of the bottle lids at the surface were observed on cast CTD 25, with the package recovered and re-set before redeployment. These observations prompted significant thought and action to try to avert further loss of bottles. (Details of how the package performed up to cast 25 are provided in [Table 3.1](#))

The first measure that was taken was that the configuration of the lanyards was altered. In the original configuration, the top lanyard was attached to the release pin (see [Figure 3.1](#), Label 2), and the bottom lanyard was attached with a free moving loop to the top lanyard (see [Figure 3.1](#), Label 1). With this setup, the bottom endcap had a significant level of free movement when cocked. [Figure 3.2](#) shows the modification made; with this newer configuration, it was harder for the bottom endcap to close from the cocked position without being released by the rosette.



*Figure 3.1: Original setup*



*Figure 3.2: Modified setup*

Further modifications were made to help address the problem of the bottles leaking after recovery of the CTD package. One cause of the leaks is thought to be that the external springs had too little tension to support the weight of the water collected, hence leading to leaks from the bottom endcap. Figures for the recommended minimum spring tension were available on the OTE bottles themselves for different sizes Niskins, but surprisingly not including the 20L version itself. Thus, to estimate the minimum spring tension that would be needed, an empirical relationship was established using the tensions and bottle volumes that were quoted, and an approximate minimum spring tension of 14 kg for a 20L bottle was derived (Figure 3.3).

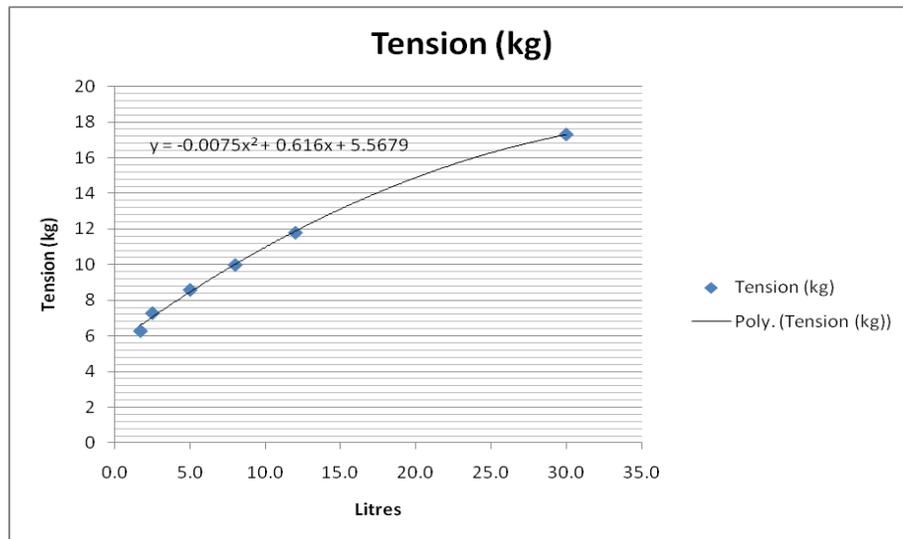


Figure 3.3: Empirical relationship used to derive the minimum spring tension for a 20L Niskin bottle, obtained using the values shown in Table 3.2.

The re-tensioning of the springs was done progressively, with the effort focused initially on the bottles that leaked most frequently, and those with the lowest tension. Success rates for bottle closures improved as the cruise progressed. A number of O-rings were replaced, to help further in preventing leaks. A further modification was also made to some bottles, whereby chamfering of the runnels through which the lanyards slide was undertaken, so that more of the tension from the springs is passed to the endcaps upon closure, and the risk of lanyard breakages is reduced (though only one such breakage occurred during the cruise).

Table 3.3 summarises the alterations and details of the bottles' performance from CTD 26 onwards; the success of the procedures adopted can be judged by comparing the final column in Table 3.3 with that in Table 3.1. An additional factor that must be borne in mind when considering these statistics, however, is that the expertise with which the bottles were cocked undoubtedly improved during the course of the cruise (the bottles are very sensitive to how the endcaps are positioning when being set, and skill in this was gained during the cruise by all those who performed this task).

Table 3.4 contains a summary of the bottle performance over the cruise as a whole.

| Bottle # | O-Ring change | Orig. tension (kg) | Lanyard change (cm) | New tension (kg) | Fired | Worked | W% | Failed | F% |
|----------|---------------|--------------------|---------------------|------------------|-------|--------|----|--------|----|
| 1        | Yes *         | 14                 | -2                  | 15.5             | 25    | 12     | 48 | 13     | 52 |
| 2        | No            | 13                 | -4                  | 15               | 25    | 21     | 84 | 4      | 16 |
| 3        | No            | 12                 | -4                  | 14               | 25    | 20     | 80 | 5      | 20 |
| 4        | No            | 11                 | -3                  | 14               | 25    | 22     | 88 | 3      | 12 |
| 5        | Yes *         | 13                 | -3                  | 14.5             | 25    | 22     | 88 | 3      | 12 |
| 6        | Yes *         | 13.5               | -3                  | 14               | 25    | 23     | 92 | 2      | 8  |
| 7        | Yes *         | 12                 | -5                  | 14               | 25    | 23     | 92 | 2      | 8  |
| 8        | No            | 11.5               | -4                  | 16               | 25    | 22     | 88 | 3      | 12 |
| 9        | Yes *         | 13                 | -5                  | 15               | 25    | 22     | 88 | 3      | 12 |
| 10       | Yes *         | 12                 | -4                  | 15               | 25    | 22     | 88 | 3      | 12 |
| 11       | Yes *         | 12.5               | -5                  | 14               | 25    | 22     | 88 | 3      | 12 |
| 12       | No            | 11                 | -5                  | 14               | 25    | 21     | 84 | 4      | 16 |
| 13       | No            | 11                 | -3                  | 13               | 25    | 17     | 68 | 8      | 32 |
| 14       | No            | 11                 | -5                  | 14.5             | 25    | 24     | 96 | 1      | 4  |
| 15       | No            | 11.5               | -5                  | 14.5             | 25    | 22     | 88 | 3      | 12 |
| 16       | No            | 11                 | -5                  | 16               | 25    | 22     | 88 | 3      | 12 |
| 17       | No            | 11                 | -6                  | 14.5             | 25    | 21     | 84 | 4      | 16 |
| 18       | Yes *         | 12                 | -6                  | 15               | 25    | 22     | 88 | 3      | 12 |
| 19       | No            | 17                 | 0                   | 17               | 25    | 22     | 88 | 3      | 12 |
| 20       | Yes *         | 12.5               | -3                  | 15               | 25    | 14     | 56 | 11     | 44 |
| 21       | Yes *         | 13                 | -1                  | 15               | 25    | 18     | 72 | 7      | 28 |
| 22       | Yes *         | 13                 | -1                  | 14               | 25    | 18     | 72 | 7      | 28 |
| 23       | Yes *         | 13                 | -5                  | 14               | 25    | 19     | 76 | 6      | 24 |
| 24       | Yes *         | 12                 | -2                  | 15               | 25    | 18     | 72 | 7      | 28 |

Table 3.1: Details of water sampling success during casts 1-25, and modifications made.

**OTE manufacturers guidance figures**

| Model | Size (l) | Tension (kg) |
|-------|----------|--------------|
| 110   | 1.7      | 6.3          |
| 110   | 2.5      | 7.3          |
| 110   | 5.0      | 8.6          |
| 110   | 8.0      | 10           |
| 110   | 12.0     | 11.8         |
| 110   | 30.0     | 17.3         |

Tension at for 20 bottle is 14.8879 Kg  
**Approx 14.8 Kg**

Table 3.2: Values used to derive minimum tension for 20L bottles.

| Bottle # | O-ring changed | Orig. tension (kg) | Lanyard change (Cm) | New (kg) | Modification              | Fired | Worked | W%  | Failed | F% |
|----------|----------------|--------------------|---------------------|----------|---------------------------|-------|--------|-----|--------|----|
| 1        | Yes *          | 14                 | -2                  | 15.5     |                           | 71    | 65     | 92  | 6      | 8  |
| 2        | No             | 13                 | -4                  | 15       | Countersunk               | 71    | 62     | 87  | 9      | 13 |
| 3        | No             | 12                 | -4                  | 14       |                           | 71    | 66     | 93  | 5      | 7  |
| 4        | No             | 11                 | -3                  | 14       |                           | 71    | 69     | 97  | 2      | 3  |
| 5        | Yes *          | 13                 | -3                  | 14.5     |                           | 71    | 70     | 99  | 1      | 1  |
| 6        | Yes *          | 13.5               | -3                  | 14       |                           | 71    | 63     | 89  | 8      | 11 |
| 7        | Yes *          | 12                 | -5                  | 14       |                           | 71    | 70     | 99  | 1      | 1  |
| 8        | No             | 11.5               | -4                  | 16       | Countersunk & Retensioned | 71    | 58     | 82  | 13     | 18 |
| 9        | Yes *          | 13                 | -5                  | 15       |                           | 71    | 70     | 99  | 1      | 1  |
| 10       | Yes *          | 12                 | -4                  | 15       | Countersunk & Retensioned | 71    | 68     | 96  | 3      | 4  |
| 11       | Yes *          | 12.5               | -5                  | 14       | Countersunk               | 71    | 61     | 86  | 10     | 14 |
| 12       | No             | 11                 | -5                  | 14       |                           | 71    | 68     | 96  | 3      | 4  |
| 13       | No             | 11                 | -3                  | 13       |                           | 71    | 66     | 93  | 5      | 7  |
| 14       | No             | 11                 | -5                  | 14.5     |                           | 71    | 64     | 90  | 7      | 10 |
| 15       | No             | 11.5               | -5                  | 14.5     |                           | 71    | 71     | 100 | 0      | 0  |
| 16       | No             | 11                 | -5                  | 16       |                           | 71    | 67     | 94  | 4      | 6  |
| 17       | No             | 11                 | -6                  | 14.5     |                           | 71    | 68     | 96  | 3      | 4  |
| 18       | Yes *          | 12                 | -6                  | 15       |                           | 71    | 60     | 85  | 11     | 15 |
| 19       | No             | 17                 | 0                   | 17       | Countersunk               | 71    | 63     | 89  | 8      | 11 |
| 20       | Yes *          | 12.5               | -3                  | 15       | Countersunk               | 71    | 54     | 76  | 17     | 24 |
| 21       | Yes *          | 13                 | -1                  | 15       |                           | 71    | 69     | 97  | 2      | 3  |
| 22       | Yes *          | 13                 | -1                  | 14       | Countersunk               | 71    | 63     | 89  | 8      | 11 |
| 23       | Yes *          | 13                 | -5                  | 14       | Countersunk & Retensioned | 71    | 65     | 92  | 6      | 8  |
| 24       | Yes *          | 12                 | -2                  | 15       |                           | 71    | 64     | 90  | 7      | 10 |

Table 3.3: Details of water sampling success from cast 26 onwards, and modifications made.

As of  
21/04/10

|                            | Number | %   |
|----------------------------|--------|-----|
| <b>Total Bottles Fired</b> | 2304   | 100 |
| <b>Successful</b>          | 2053   | 89  |
| <b>Failure</b>             | 251    | 11  |

All casts

| Bottle # | O-Ring Replaced | Orig. tension (kg) | Lanyard change (Cm) | New tension (kg) | Fired | Worked | W% | Failed | F% |
|----------|-----------------|--------------------|---------------------|------------------|-------|--------|----|--------|----|
| 1        | Yes *           | 14                 | -2                  | 15.5             | 96    | 77     | 80 | 19     | 20 |
| 2        | No              | 13                 | -4                  | 15               | 96    | 83     | 86 | 13     | 14 |
| 3        | No              | 12                 | -4                  | 14               | 96    | 86     | 90 | 10     | 10 |
| 4        | No              | 11                 | -3                  | 14               | 96    | 91     | 95 | 5      | 5  |
| 5        | Yes *           | 13                 | -3                  | 14.5             | 96    | 92     | 96 | 4      | 4  |
| 6        | Yes *           | 13.5               | -3                  | 14               | 96    | 86     | 90 | 10     | 10 |
| 7        | Yes *           | 12                 | -5                  | 14               | 96    | 93     | 97 | 3      | 3  |
| 8        | No              | 11.5               | -4                  | 16               | 96    | 80     | 83 | 16     | 17 |
| 9        | Yes *           | 13                 | -5                  | 15               | 96    | 92     | 96 | 4      | 4  |
| 10       | Yes *           | 12                 | -4                  | 15               | 96    | 90     | 94 | 6      | 6  |
| 11       | Yes *           | 12.5               | -5                  | 14               | 96    | 83     | 86 | 13     | 14 |
| 12       | No              | 11                 | -5                  | 14               | 96    | 89     | 93 | 7      | 7  |
| 13       | No              | 11                 | -3                  | 13               | 96    | 83     | 86 | 13     | 14 |
| 14       | No              | 11                 | -5                  | 14.5             | 96    | 88     | 92 | 8      | 8  |
| 15       | No              | 11.5               | -5                  | 14.5             | 96    | 93     | 97 | 3      | 3  |
| 16       | No              | 11                 | -5                  | 16               | 96    | 89     | 93 | 7      | 7  |
| 17       | No              | 11                 | -6                  | 14.5             | 96    | 89     | 93 | 7      | 7  |
| 18       | Yes *           | 12                 | -6                  | 15               | 96    | 82     | 85 | 14     | 15 |
| 19       | No              | 17                 | 0                   | 17               | 96    | 85     | 89 | 11     | 11 |
| 20       | Yes *           | 12.5               | -3                  | 15               | 96    | 68     | 71 | 28     | 29 |
| 21       | Yes *           | 13                 | -1                  | 15               | 96    | 87     | 91 | 9      | 9  |
| 22       | Yes *           | 13                 | -1                  | 14               | 96    | 81     | 84 | 15     | 16 |
| 23       | Yes *           | 13                 | -5                  | 14               | 96    | 84     | 88 | 12     | 13 |
| 24       | Yes *           | 12                 | -2                  | 15               | 96    | 82     | 85 | 14     | 15 |

\* O-ring replaced with clean ones prepared according to requirements of the CFC Team.

Bottle 1 was swapped with bottle 11 on 29th March 2010 and renamed as 11.

Bottle 11 was swapped with bottle 1 on 29th March 2010 and renamed as 1.

Table 3.4: Overall summary details of bottle performance, for cruise as a whole.

An Access database (andrex\_log.accdb) was created, containing information on bottle samplings, closures etc along with the relevant CTD event parameters. This can be queried to extract information on what was sampled where and when for any Niskin, and also contains information on individual bottle closures/leaks and the presumed/suspected reasons for them.

### *Recommendations*

1. The procedures and modifications made during JR235/236/239 appear to have improved the success rate in sampling from the externally-sprung 20L bottles. Propagating the information learned may benefit other cruises also. The design of the bottles is not ideal though.
2. Bottle 11 (previous bottle 1) and bottle 20 need to be replaced. They continued to leak despite modification, and may be slightly misshapen preventing a good seal forming upon closure.
3. BAS should consider buying a set of externally-sprung 20L Niskins (and spares) for its 24 bottle CTD frame.

### 3c. SBE35 Reference Thermometer (Aurelie Persechino)

SeaBird SBE35 Deep Ocean Standards Thermometer.  
SBE35 V 2.0 Serial No.0005

#### (i) Instrument setup and operation

The SBE35 is a self-recording instrument that logs a temperature measurement to erasable/programmable read-only memory (EPROM) each time a Niskin bottle is closed. The BAS SBE35 high-precision thermometer was fitted to the CTD frame for all stations during JR235/236/239. It was fixed vertically (sensor end up) along an outer upright of the CTD frame, outside the ring of Niskin bottles and approximately 1m above the level of the SBE 911*plus* temperature sensor 1 (primary) and 1.10m above sensor 2 (secondary). The SBE 911*plus* sensor 1 was also outside the ring of Niskin bottles, and was fixed horizontally on the CTD package fin, while sensor 2 was fixed horizontally near the base of the CTD frame. Each time a water sample was taken using the rosette, the SBE35 recorded time, bottle position and temperature in EPROM, allowing comparison of the SBE35 readings with the CTD and bottle data. The temperature recorded was the mean of 8\*1.1 seconds recording cycles (therefore 8.8 seconds) data once the bottle has been fired.

Before programming, the SBE35.CON (configuration file) was checked to ensure the calibration coefficients are current and accurately entered. On JR235/236/239/, the values used were:-

a0 = 5.504409960e-03;  
a1 = -1.565337550e-03;  
a2 = 2.268165470e-04;  
a3 = -1.254557800e-05;  
a4 = 2.650482810e-07;  
slope = 0.999989;  
offset = 0.000101;

with temperature then calculated as:-

$$Temp(ITS-90) = 1 / \{a_0 + a_1[\ln(n)] + a_2[\ln^2(n)] + a_3[\ln^3(n)] + a_4[\ln^4(n)]\} - 273.15,$$

where n = sensor output.

Values for a0-a4, slope and offset were determined by a linearization calibration on 12th October 2007. For JR235/236/239, the SBE35 was set to average 8 cycles per measurement. In a thermally quiet environment, the temperature noise standard deviation is  $0.000029 * \sqrt{8/\text{ncycles}}$ , equal to 0.000029 degC in our case.

When programmed, the SBE35 is connected to the subsea cabling ready for CTD deployment. Bottles were fired on the upcast, where the procedure was to stop the CTD winch, hold the package *in situ* for a few seconds to allow sensors to equilibrate, and then fire a bottle. The CTD was left at the selected depth for about 15 seconds to allow the SBE35 temperature sensor to take reading over 8 data cycles. If duplicate bottles were fired at any depth, at least 20 seconds had to be left between firing to allow the

SBE35 to take readings and recharge. Shorter times between firings led to no SBE35 readings for certain bottles.

### ***(ii) Data acquisition & preliminary processing***

Communication with the SBE35 for programming and data downloading is via an SBE90248 Optobox situated in the winch control room of the UIC. This connects to the CTD via a cable that is run down to the water bottle annex via the cable entry to the main lab, and connects to the CTD PC via an RS232 connector link to the COM1 port of the computer. To process the data, communication was established between the CTD PC and the SBE35 by switching on the deck unit.

The SBE35 can log up to 157 measurements, but in general we downloaded data after every 3-4 casts (72-96 measurements) using the *SeaTerm* program. This is a simple terminal emulator set up to talk to the SBE35. Once the readings had been written to an ascii file (named *jr239\_NNN\_sbe35.asc*), the file was opened and the contents checked to make sure that the correct number of readings had been stored. The memory of the SBE35 was then cleared using the '*samplenum=0*' command. To check that the memory was clear, the command '*ds*' was entered, which displays the number of data points stored in the instrument's memory. This number should be zero. The date and time are also shown by the '*ds*' command and these should be checked and corrected if needed. Once all data had been downloaded and the preliminary processing described above carried out, the directory containing all data for that CTD cast was copied to the Unix system (U:\data\jr239\ drive) for further processing in Matlab.

### ***(iii) Data processing***

For analysis, extraction of sections of SBE911*plus* temperature data was performed according the following protocols:-

- (1) A single temperature point nearest to the time of bottle firing.
- (2) A time segment of 4 seconds, running 2 seconds before to 2 seconds after bottle firing.
- (3) A time segment of 9 seconds, running between the time of bottle firing to 9 seconds afterwards.

The SBE35 data were then compared to the data from both the primary and secondary temperature sensors of the SBE 911*plus* for each method. For this purpose, further processing of SBE35 data was carried out in Matlab using several programs:

- (i) **JR239sbe12\_process\_M1.m** (in *L:\CTD\_bottle\_files\sbe35\method1\...*): this script extracts data needed for method 1 and is from an existing program with few changes made for this cruise. It extracts several variables (station number, Niskin bottle number, pressure, temperatures for SBE35, CTD temperature 1 and 2) from the *sam\_jr239\_NNN.nc* netcdf file obtained from CTD data processing (in *U:\pstar\ctd\...*) to a .csv file saved as *CTDSBE35\_statNNN.csv* (in *L:\CTD\_bottle\_files\sbe35\method1\...*). Then Niskin bottle number, pressure, temperature for sensor 1, 2 and SBE35 are extracted from this latter file and saved as *stationNNN.mat* (in *L:\CTD\_bottle\_files\sbe35\method1\...*).

(ii) **JR239sbe12\_process\_M2.m** and **JR239sbe12\_process\_M3.m** (in *L:\CTD\_bottle\_files\sbe35\method2(3)\...*): these scripts extract data needed for method 2 and 3. It extracts several variables (station number, Niskin bottle number, pressure, temperatures for SBE35, CTD temperature 1 and 2) from the *CTDbottfileLatLonPeriodEffect3.mat* file (in *L:\CTD\_bottle\_files\sbe35\...*, which has been obtained by running the script *JR239bottlefilesavperiodeffect.m* written by Hugh Venables in the same directory). These store the requested variables to a .csv file saved as *CTDSBE35\_statNNN\_4s.csv* for method 2 and *CTDSBE35\_statNNN\_9s.csv* for method 3 (in *L:\CTD\_bottle\_files\method2(3)\...*). These files are then converted to .mat files as *stationNNN\_4s.mat* and *stationNNN\_9s.mat* (in *L:\CTD\_bottle\_files\method2(3)\...*).

Each *stationNNN.mat*, *stationNNN\_4s.mat* and *stationNNN\_9s.mat* files contain in their 1st column Niskin bottle number, the 2nd column contains pressure, the 3rd column contains CTD temperatures for sensor 1, the 4th column contains CTD temperatures for sensor 2 and the 5th column contains SBE35 temperatures.

(iii) **Plot\_sbe35\_vs\_t1t2\_M1.m**, **Plot\_sbe35\_vs\_t1t2\_M2.m**, and **Plot\_sbe35\_vs\_t1t2\_M3.m** (in *L:\CTD\_bottle\_files\sbe35\method1(2)(3)\...*): these scripts load .mat files obtained from the previous scripts (i, ii), and plots SBE35 temperature minus CTD temperature (1 & 2) and CTD temperature 1 minus temperature 2 for each Niskin bottle at each station. Each plot is saved as *SBE35\_vs\_t1t2\_NNN.eps* for method 1, *SBE35\_vs\_t1t2\_NNN\_4s.eps* for method 2 and *SBE35\_vs\_t1t2\_NNN\_9s.eps* for method 3 (in *L:\CTD\_bottle\_files\sbe35\method1(2)(3)\PLOTS\sbe\_vs\_t1t2\...*). The scripts also save in *statistics\_SBE35.mat*, *statistics\_SBE35\_4s.mat*, and *statistics\_SBE35\_9s.mat* two variables for which the standard deviation (*std\_diff*) and mean difference (*mean\_diff*) in temperature between SBE35 and CTD temperatures for both sensor for the 24 bottles are stored. *statistics\_SBE35\_bot.mat*, *statistics\_SBE35\_bot\_4s.mat* and *statistics\_SBE35\_bot\_9s.mat* store the same statistics as above but for bottles 1 to 12 only.

In order to investigate how the difference in temperature between the different sensors responds to temperature gradient in the water column, the following programs have been used to process the data:

(iv) **JR239temp2db\_process.m** (in *L:\CTD\_bottle\_files\sbe35\tempgrad\...*): this script extracts CTD temperature (1 & 2) and pressure at 2 decibar intervals from *ctd\_jr239\_NNN\_2db.nc* files (in *U:\pstar\ctd\filename.nc*) and stores the data as *CTD\_temp2db\_NNN.csv* file (in *L:\CTD\_bottle\_files\sbe35\tempgrad\...*). These .csv files are then saved as *temp2db\_NNN.mat* files (in *L:\CTD\_bottle\_files\sbe35\tempgrad\...*). Finally using these .mat files, CTD temperature (1 & 2) gradients are calculated through the water column and saved as *grad\_NNN.mat* (in *L:\CTD\_bottle\_files\sbe35\tempgrad\...*). These .mat files contain CTD temperature gradient (1 & 2) as functions of pressure.

(v) **Plot\_TempGrad\_M1.m**, **Plot\_TempGrad\_M2.m**, and **Plot\_TempGrad\_M3.m** (in *L:\CTD\_bottle\_files\sbe35\method1(2)(3)\...*): these scripts load both *stationNNN.mat* and *grad\_NNN.mat* obtained from the previous scripts (i,ii,iv). For each CTD temperature sensor, they plot both the temperature gradient and the temperature difference with SBE35 against pressure. Three plots are produced for each station and

each method; one showing the entire water column; one zoomed in at the surface (0-250 dbar) and one zoomed in between 250 and 1000 dbar. The plots are saved as *TempGrad\_NNN.eps*, *TempGrad\_NNN\_zoomSurf.eps* & *TempGrad\_NNN\_zoom250-1000.eps* (in *L:\CTD\_bottle\_files\sbe35\method1(2)(3)\PLOTS\TempGrad\...*).

Data extracted using methods 1, 2 and 3 exhibit the same general pattern in temperature between SBE35 and primary/secondary CTD temperatures (Table 3.5). However method 1 exhibits a greater noise level than method 2 and 3, including significantly larger differences between the primary and secondary CTD temperatures. Method 2 also exhibits greater noise level than method 3, consistent with the fact that method 3 covers the same interval as the SBE35 averaging period. Therefore, results and figures presented in this report are for data extracted using method 3.5.

|                       | <b>Method 1</b><br><i>(single nearest point to time of bottle firing)</i> |                          | <b>Method 2</b><br><i>(2 seconds before firing to 2 seconds afterwards)</i> |                          | <b>Method 3</b><br><i>(0 to 9 seconds after bottle firing)</i> |                          |
|-----------------------|---|--------------------------|---|--------------------------|--|--------------------------|
|                       | <i>1-24</i>   | <i>1-12</i>              | <i>1-24</i>   | <i>1-12</i>              | <i>1-24</i>  | <i>1-12</i>              |
| <i>bottles</i>        |   |                          |   |                          |  |                          |
| SBE35 minus CTD temp1 | -0.0012<br><i>0.0113</i>  | -0.0016<br><i>0.0023</i> | -0.0014<br><i>0.0110</i>  | -0.0016<br><i>0.0022</i> | -0.0015<br><i>0.0092</i>                                       | -0.0016<br><i>0.0018</i> |
| SBE35 minus CTD temp2 | -0.0021<br><i>0.0115</i>  | -0.0021<br><i>0.0022</i> | -0.0020<br><i>0.0110</i>  | -0.0021<br><i>0.0021</i> | -0.0021<br><i>0.0100</i>                                       | -0.0021<br><i>0.0018</i> |
| CTD temp1 minus temp2 | -0.0009<br><i>0.0074</i>  | -0.0005<br><i>0.0014</i> | -0.0006<br><i>0.0067</i>  | -0.0005<br><i>0.0011</i> | -0.0006<br><i>0.0055</i>                                       | -0.0006<br><i>0.0010</i> |

*Table 3.5. Summary statistics of differences between SBE35 and CTD temperatures (1 & 2). The upper number is the mean difference in temperature and the lower number is the standard deviation for all the stations. Individual values for each station are attached in the [Appendix](#).*

The following figures based on the SBE35 statistics show the following:-

**Figure 3.4** (A) summarises the mean difference in temperature between SBE35 and CTD temperature (1 & 2) and (B) the standard deviation at each station.

**Figure 3.5** shows the difference between the SBE35 and primary CTD temperature (blue), the difference between SBE35 and secondary CTD temperature (green), and the difference between primary and secondary CTD temperatures (red) plotted as a function of bottle number, at some selected stations (A) deeper than 1000m and (B) shallower than 1000m. (Bottle 1 is deepest; bottle 24 shallowest).

**Figure 3.6** shows CTD temperature (1 & 2) gradient in black, and temperature difference between SBE35 and CTD temperature (1 & 2) in red plotted against pressure for some selected stations deeper than 1000m. Negative (positive) gradient is associated with

warmer (colder) water above. (A) shows the entire water column and (B) is zoomed in at the surface.

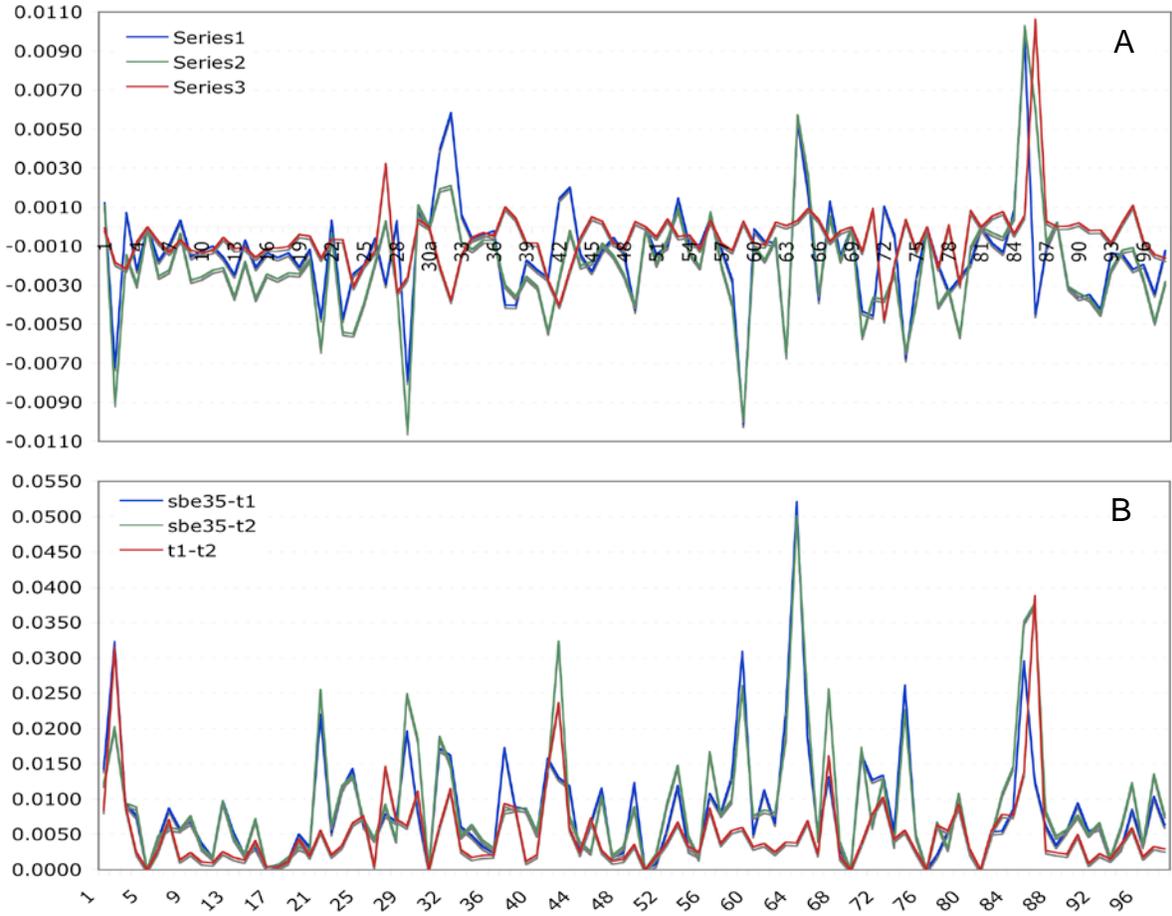
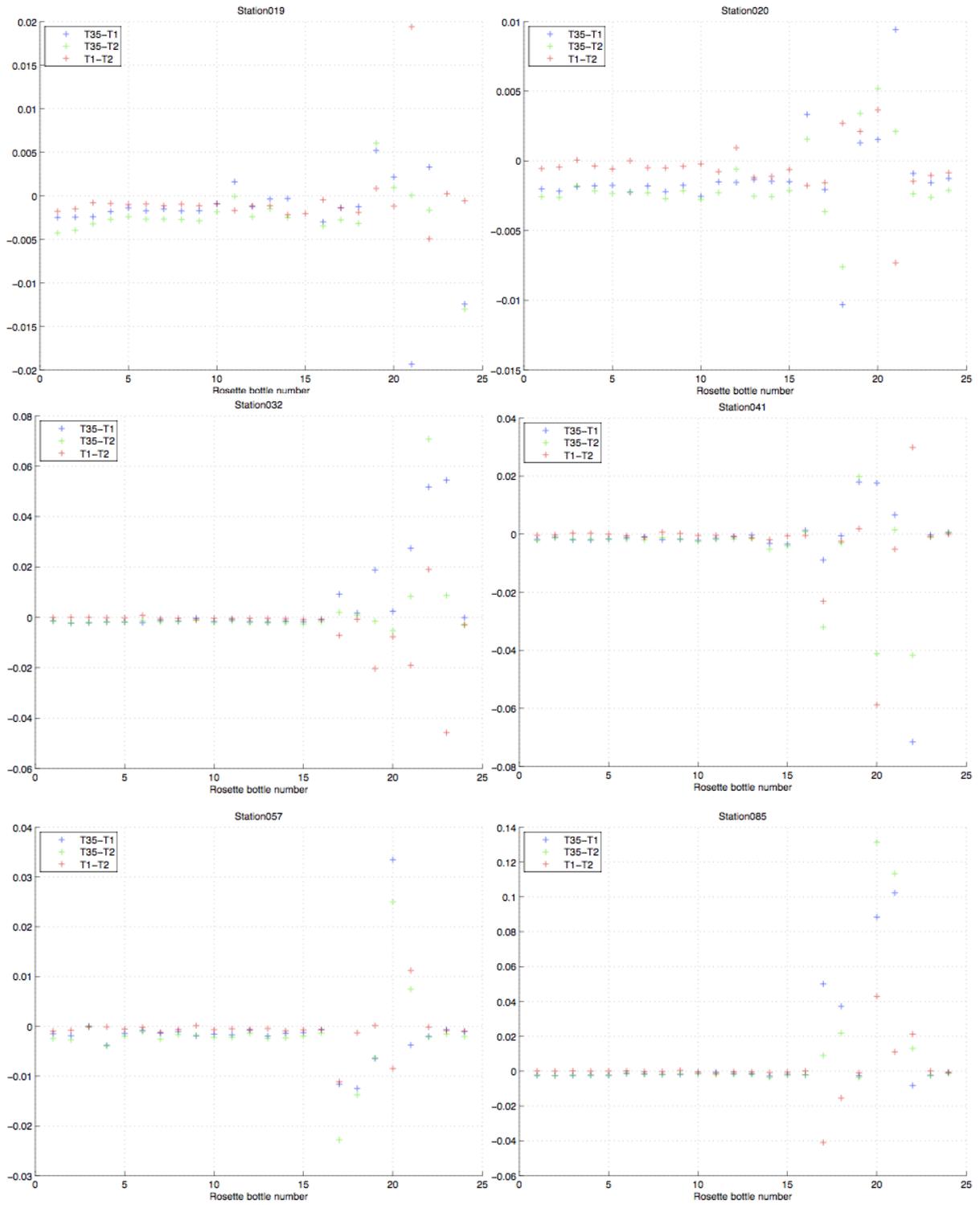


Figure 3.4 (A) Mean difference in temperature between SBE35 and CTD temperature (1 & 2) and (B) standard deviation at each station.

(A)



(B)

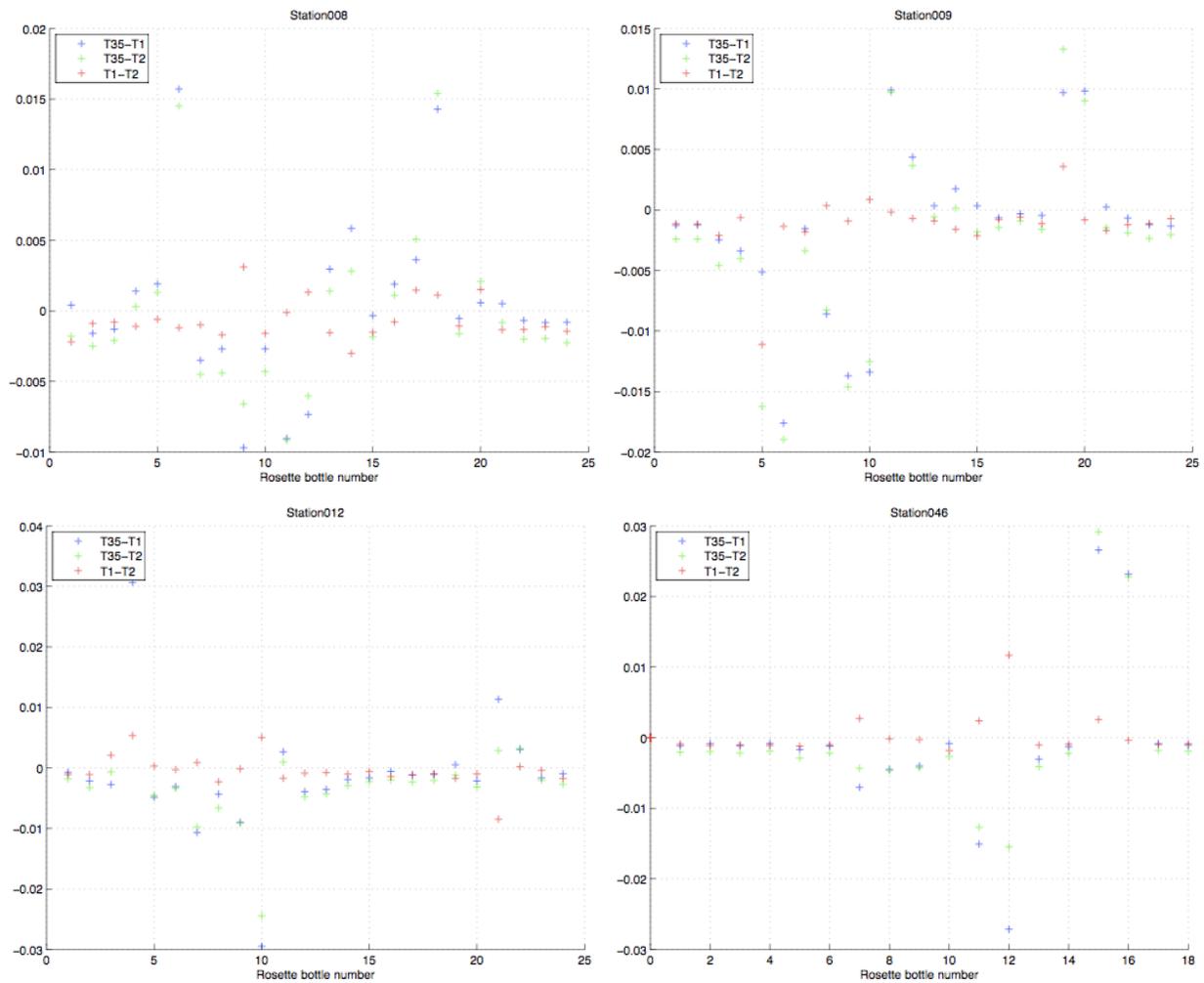
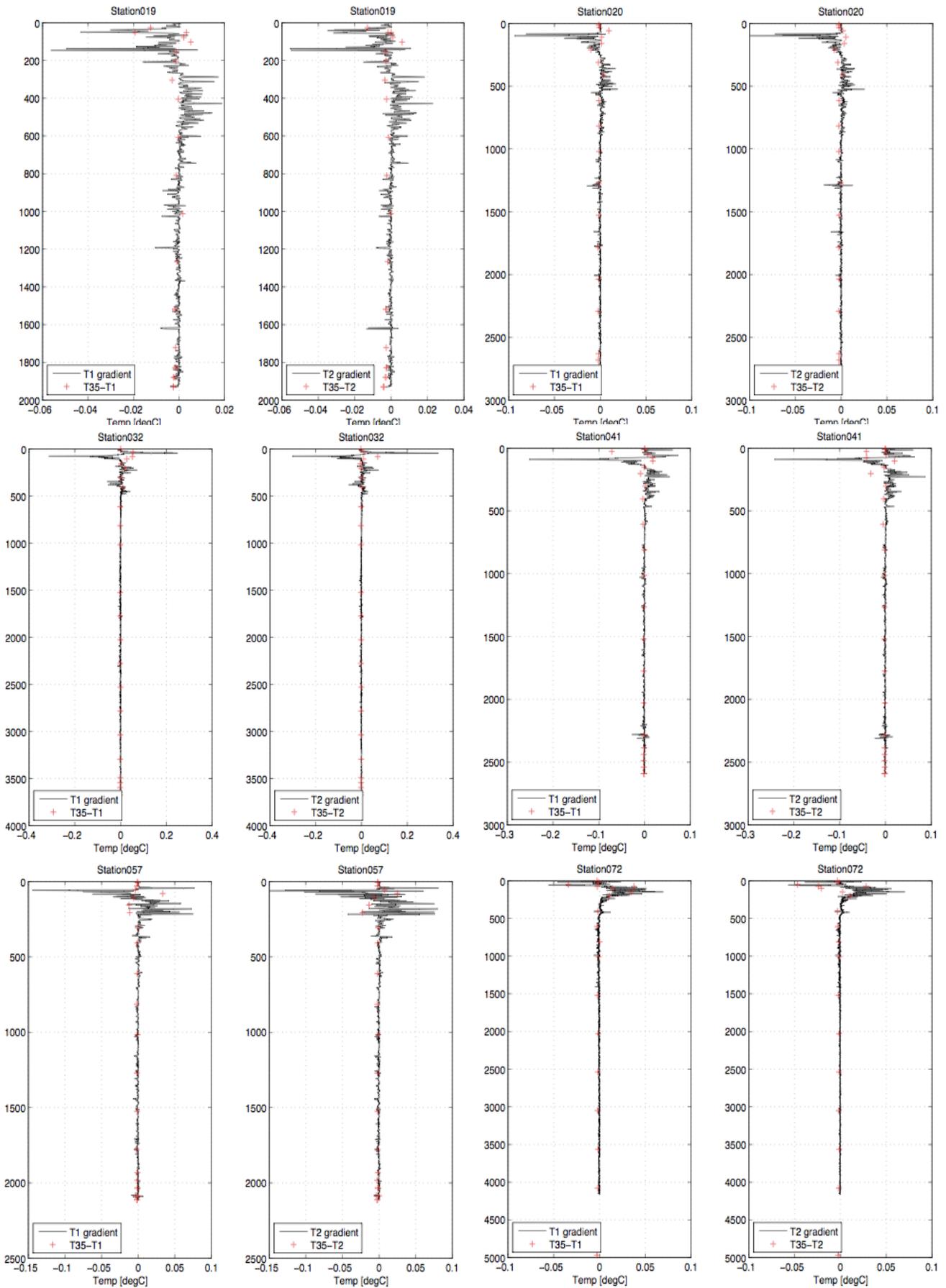


Figure 3.5: Difference between the SBE35 and primary CTD temperature (blue), the difference between SBE35 and secondary CTD temperature (green), and the difference between primary and secondary CTD temperatures (red) plotted as a function of bottle number, at some selected stations (A) deeper than 1000m (B) shallower than 1000m. (Bottle 1 is deepest; bottle 24 shallowest).

(A)



(B)

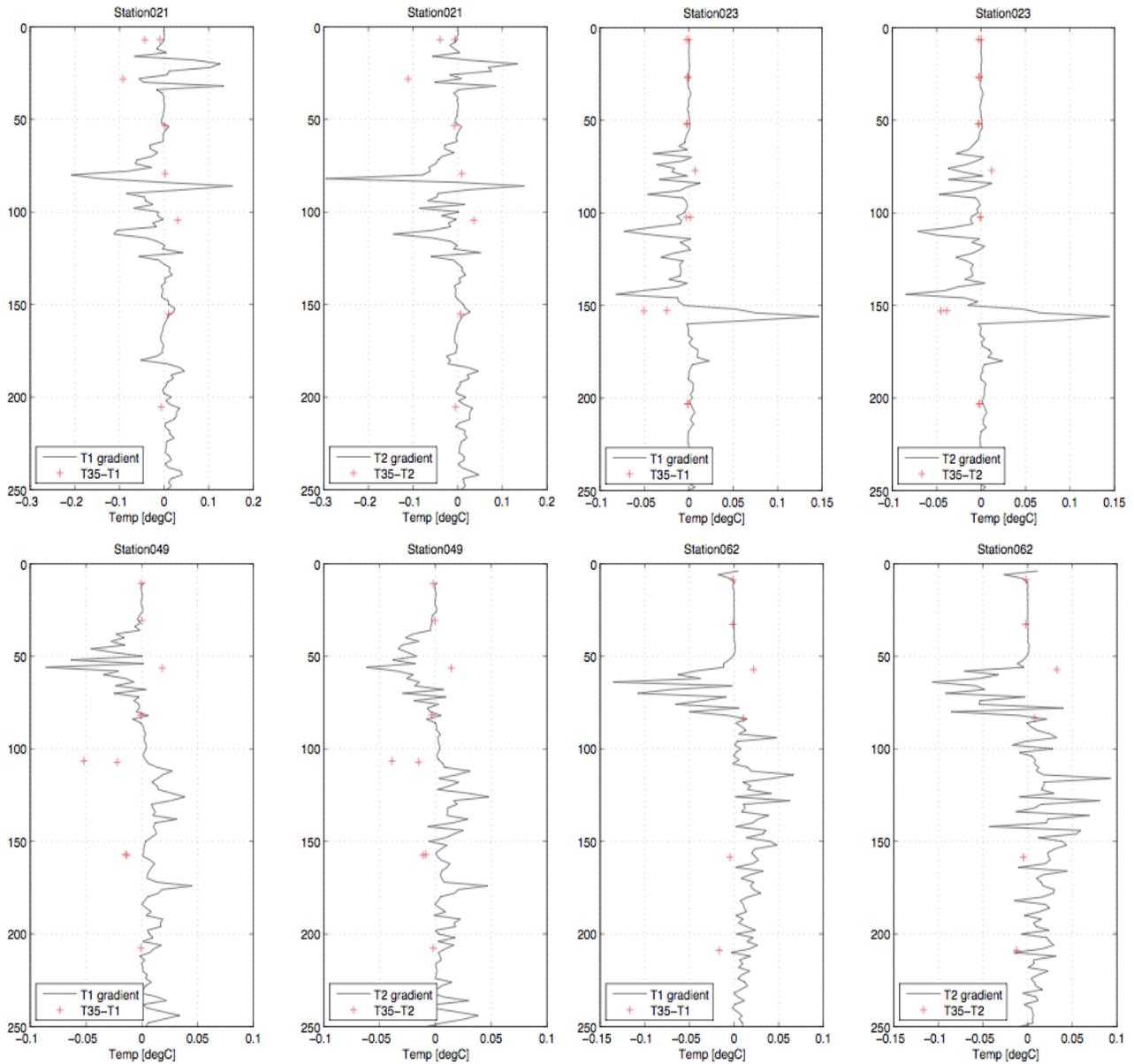


Figure 3.6: CTD temperature (1 & 2) gradient in black, and temperature difference between SBE35 and CTD temperature (1 & 2) in red plotted against pressure for some selected stations deeper than 1000m. Negative (positive) gradient is associated with warmer (colder) water above. (A) shows the entire water column and (B) is zoomed in at the surface.

In these figures, some key features apparent are:-

- (i) There is no obvious trend in mean difference in temperature between SBE35 and CTD temperature (1 & 2) over time/stations (Figure 3.4A).
- (ii) On average, (a) SBE35 is colder than CTD temperature 1 by  $0.0015^{\circ}\text{C}$  with a standard deviation of  $0.0092$ , and (b) SBE35 is colder than CTD temperature 2 by  $0.0021^{\circ}\text{C}$  with a standard deviation of  $0.0100^{\circ}\text{C}$  (Table 3.5). The temperature difference seems to be smaller with sensor 1 than with sensor 2; this is consistent with the fact that both the SBE35 sensor and CTD sensor 1 were fixed outside the ring of Niskin bottles. In most cases, the highest temperature difference between SBE35 and CTD temperature (1 & 2) occurs near the surface (Figure 3.5A). Indeed, if we consider only the first 12 bottles in our calculation, the standard deviation is significantly reduced (to  $0.0018^{\circ}\text{C}$  in both case, Table 3.5).
- (iii) In most cases, the most likely explanation for the large offsets between SBE35 and CTD temperatures is the comparatively large oceanic vertical gradients in temperature at these depths (mainly in the upper ocean), combined with the different positioning on the frame of the instruments (Figure 3.6A). As a result, offsets between SBE35 and CTD temperatures occur in all of the water column for shallow stations (Figure 3.5B). However, the magnitude of the temperature gradient is probably not sufficient to explain the full differences between the SBE35 and CTD temperatures, thus it is likely that wake effects are also being observed.
- (iv) The amplitude of the offsets between SBE35 and CTD temperature sensors does not seem to depend on the sign of the temperature gradient. We observed as many large offsets with positive temperature gradients as with negative temperature gradients. However, in most cases, the SBE35 tends to be warmer (colder) than t1/t2 when the temperature gradient is negative (positive), that is when the water is getting warmer (colder) above (Figure 3.6B). This is consistent with the fact that the SBE35 sensor is situated about 1m above the CTD temperature sensors. Thus, the sense of the difference between SBE35 and CTD temperatures agrees with the sense of the oceanic vertical temperature gradient.
- (v) Some calculations have been carried out to find out whether large offsets between SBE35 and CTD temperature 2 were due to water dragged behind the CTD frame on the way up (vortex effects). It appears that in most cases the offset between the SBE35 and CTD sensor 2 was due to noise rather than such effects, as the same calculation with sensor 1 (situated outside of the ring of Niskin bottles) shows the same order of magnitude.

In summary:-

- (1) The main purpose of the SBE35 is to monitor possible changes in calibration of the CTD within or between cruises. As such, it is important that the CTD data extracted for comparison cover the same time interval as the SBE35 averaging period.
- (2) Large offsets between SBE35 and CTD temperatures sensors are in most cases associated with strong temperature gradients in the upper ocean.
- (3) Shallow stations with moderately large temperature gradients are not ideal for attempting to use the SBE35 to monitor the CTDs performance. Deep stations with smaller gradients in the deep waters are much more suitable.

(4) Using deep stations, the SBE35 provided valuable information on the performance and stability of the CTD primary and secondary temperatures over the duration of the cruise (see also [next section](#), on data processing and calibration).

### 3d. CTD data processing (Hugh Venables)

JR235 and 239 CTD data were processed using mstar scripts written by Brian King, NOC. They were run on the ship's system, with matlab being run from jruj. Some of the navigation pre-processing, written for linux, was not compatible with unix processing so was done on jrlb, a ship linux box. Processing was much slower than running locally on nosea2, the NOCS linux box on the ship, but the advantages of data backup and visibility from other machines was considered to outweigh the slow speed. Hopefully improvements can be made. Creating files seemed to be the bottleneck, rather than the volume of data.

Setup programme to initialise mstar is **m\_setup\_\*\*\*** - this sets roots and global variables (ship, cruise etc.)

#### ***New/adapted mstar programs:-***

**mfallrate** – mstar implementation of Seabird loopedit processing but allowing more control. Important for secondary sensors at base of frame but primary sensors on the fin of the CTD frame show far less package effect when ship roll pulls the CTD up through its wake.

**mpaste2**, in unfinished. Adapted from mpaste but changed to use first matching of control variable. This is because Niskin numbers can appear twice in .bl files if the deck unit resets itself or if the method of firing is changed from using the software to the fire button on the deck unit. In these cases the first occurrence corresponds to the bottle closing, later occurrences are further attempts to close an already closed bottle. Used in mfir\_04 and msbe\_02 (latter usage is redundant as the same process happens earlier in msbe\_01)

**mbottle** – adapted from mmerge but with options to set an averaging period around the merging datacycle. Used to create bottle data that is an average of 24hz CTD data from either the four second period centred on the bottle firing time (for all variables, but only in fir...\_av2.nc files at end of cruise, data in sam files is from pointwise matching of data using mmerge) or from the nine seconds after the bottle firing time (in fir...\_av.nc) to match the SBE35 reference thermometer averaging period.

**msbe\_01, msbe\_02** – read in SBE35 high precision thermometer data, based on other scripts to read in data (\_01) and then paste it to sam file (\_02)

**oxyfiddle** – investigate options for oxygen hysteresis values. Not used extensively, default values used throughout for initial processing.

#### ***Mstar processing route:-***

(Files in ../ctd relative to processing scripts unless stated)

##### **1) ctd\_all\_part0**

Create sam and dcs files in advance, as this was a very slow process (for reasons unknown) so the computer could be left creating empty files while e.g. the CTD was being sampled.

**msam\_01** -> sam\_jr200\_002.nc

Creates empty sam file. The list of variables included is set by

**Mdcs\_01** -> dcs\_jr200\_002.nc + ../templates/dcs\_jr200\_varlist\_out.csv

Creates datacycles file

*(end of ctd\_all\_part0)*

## 2) ctd\_all\_part1 – Includes:-

**msam\_01** and **mdcs\_01** (if ctd\_all\_part0 has not been run for the cast)

**mctd\_01** ctd\_jr200\_002\_ctm -> ctd\_jr200\_002\_raw.nc

Reads in CTD \*ctm.cnv data and gives it a dataname. No need to tell it how CTD is setup – works that out by comparing .cnv file with list of SBE output variables.

Replaces special characters in name such as '/'. Writes list of SBE programs run on data into comments.

**mctd\_02a** ctd\_jr200\_002\_raw.nc (then archived) -> ctd\_jr200\_002\_24hz.nc

Renames variables (from SBE names to usual names, via reference to a .csv file).

Write-protects \*\_raw.nc and copies to \*\_24Hz.nc which is working version.

**mctd\_02b** ctd\_jr200\_002\_24hz.nc -> ctd\_jr200\_002\_24hz.nc

Applies oxygen hysteresis correction

**mctd\_02c** ctd\_jr200\_002\_24hz.nc -> ctd\_jr200\_002\_24hz\_fr.nc

Calls hfallrate, which is a matlab equivalent of loopedit. It creates a NaN/1 flag variable where 1 is good (so variable.\*flag leaves good data). Bad is defined as the initial soak (which it identifies and asks for confirmation), times when the CTD package is above a previously reached depth or when the CTD package speed is <0.25 m/s downwards. It only flags data bad if >=2 consecutive points are considered bad, to allow for noise in the speed calculation at 24Hz. Datacycle for start of downcast is written to dcs\_jr239\_0nn.nc

**mctd\_02d** ctd\_jr200\_002\_24hz\_fr.nc-> ctd\_jr200\_002\_24hz\_fr\_app2.nc

Applies the fallrate flag to appropriate CTD variables

*(end of ctd\_all\_part1)*

## 3) mplxied Interactive editing, ctd\_jr200\_002\_24hz\_fr\_app.nc ->

ctd\_jr200\_002\_24hz\_fr\_app.nc

## 4) ctd\_all\_part2

**mctd\_03\_noave** ctd\_jr200\_002\_24hz\_fr\_app.nc -> ctd\_jr200\_002\_1hz.nc + ctd\_jr200\_002\_psal.nc + ctd\_jr200\_002\_24hz\_psal.nc

Average to 1hz – used for LADCP processing. Also calculates salinity and adds to 24hz which is used for further processing and averaging (rather than going through 1hz data)

**mdcs\_02** ctd\_jr200\_002\_psal.nc -> dcs\_jr200\_002.nc (again)

*Finds bottom of cast and adds it to datacycle file*

**mdcs\_03** user input -> dcs\_jr200\_002.nc (again)

*Mlists end of cast to allow user to select, copy and paste the scan number of end of cast (last good conductivity).*

**mctd\_04** dcs\_jr200\_002.nc+ ctd\_jr200\_002\_psal.nc->ctd\_jr200\_002\_2db.nc

Use start, bottom and stop data cycles to split cast and average to 2dbar. Issues at mcopya – hardwiring of number of variables (1~17) and script fails. Bug with adding '.nc' to end of \_psal filename. Added it at definition of infile1 and script ran.

**mfir\_01** -> fir\_jr200\_002\_bl.nc

Read in .bl file

**mfir\_02** fir\_jr200\_002\_bl.nc + ctd\_jr200\_002\_1hz.nc -> fir\_jr200\_002\_time.nc

Merge times from CTD into fir file

**mfir\_03** fir\_jr200\_002\_time.nc+ ctd\_jr200\_002\_psal.nc -> fir\_jr200\_002\_ctd.nc

Merge upcast data into fir file. ???Warning about NaNs in merging oxygen.

**mfir\_04** fir\_jr200\_002\_ctd.nc-> sam\_jr200\_002.nc

Pastes fir data into sam file

stn = stnlocal; **mwin\_01**; -> win\_jr239\_nnn.nc

stn = stnlocal; **mwin\_03**; -> fir\_jr239\_nnn\_winch.nc

stn = stnlocal; **mwin\_04**; -> sam\_jr239\_nnn.nc

Read winch data, there is no mwin\_02

*(end of ctd\_all\_part2)*

- 5) **ctd\_all\_part3** – to be run once navigation data has been processed for the day of the cast. Written to loop through all CTDs from the day. Includes:-

**Mdcs\_04**

Merge CTD times with navigation file to add positions to dcs\_jr239\_nnn\_pos.nc file.

Changed to merging with bestnav rather than seapos

**Mdcs\_05**

Apply positions to ctd, fir, sal, sam and dcs files

**mctd\_04depth**

**mfir\_04a**

Calculate depth once position known. mfir\_04a actually adds depth to the sam file rather than fir files

*(end of ctd\_all\_part3)*

- 6) **ctd\_all\_part4** – to be run once salinity, oxygen and nutrient data are available.

Written to loop through CTD casts where bottle files are available. Includes:-

**Msal\_01** sal\_jr200\_002.txt->sal\_jr200\_002.nc

Reads in bottle salinities from csv file (format one row per sample; station, bottle, salinity)

**Msal\_02** sal\_jr200\_002.nc-> sam\_jr200\_002.nc

Paste sal into sam

**msbe\_01/02, moxy\_01/02, mnut\_01/02** do same as above for sbe35, oxy and nutrients

**msam\_oxykg** – converts bottle oxygen from umol/l to umol/kg (accidentally in batch file twice but to no consequence)

**msam\_02** sam\_jr200\_002.nc -> sam\_jr200\_002\_resid.nc

Calculate residuals between samples and ctd bottle averages

*(end of ctd\_all\_part4)*

### 3e. CTD calibration (Hugh Venables)

Bottle samples were drawn for salinity and oxygen from each available bottle depth for every CTD cast. Some bottles were leaking badly and were excluded from any sampling. The bottle depths were chosen from the depths: surface, 25, 50, 75, 100, 150, 200, 300, 400, 600, 800, 1000, (1250), 1500, (1750), 2000, (2250), 2500, (2750), 3000, (3250), 3500, (3750), 4000, (4250), 4500, (4750), 5000, bottom-200, bottom-150, bottom-100, bottom-50, bottom with depths in brackets being dropped (shallowest first) where necessary. On some casts some bottles (especially bottle 20) were double fired, at the expense of another depth, as they were deemed likely to leak. On some casts the bottle depths differed from this scheme due to errors: either deeper depths were dropped in favour of shallower or due to transcription errors.

Conductivity will be calibrated rather than salinity as this allows recalculation of salinity, though at the time of writing this has not yet been done. Some initial plots (temperature, salinity and oxygen) to assess the performance of the sensors are included below. Calibration will require back calculating a bottle conductivity, which needs to be done with the corresponding (calibrated) temperature that will be used for any recalculation.

Therefore, the processing steps will be:-

- 1) Calibrate temp1 and temp2 from SBE35 (see [section 3c](#)).
- 2) Back calculate bottle cond1&2
- 3) Find and apply conductivity calibrations
- 4) Recalculate salinity
- 5) Check salinity
- 6) Calibrate oxygen

Overall the sensor performance is assessed to be good, and the precision after calibration is within targeted limits. (Note that changing the method for creating bottle data, from pointwise to 4 second averages does not change calibration functions found and also does not reduce the spread of points noticeably).

### Temperature

Based on the comparison of CTD temperature with SBE35 temperature, the calibration equation for temp1 is:-

```
x=1:6000; %pressure
gr=-0.0025/6000;
intgr=-0.0013-2000*gr;
y=intgr+gr*x; y(1:2000)=-0.0013;
```

and for temp2 is:-

```
x0=1400; x1=250; x2=5000;
y1=-0.0027; y0=-0.00148; y2=-0.00232;
m1=(y0-y1)/(x0-x1); m2=(y2-y0)/(x2-x0);
c1=-m1*x1+y1; c2=-m2*x0+y0;
```

```
y(1:x0)=m1*x(1:x0)+c1;  
y(x0:6000)=m2*x(x0:6000)+c2;
```

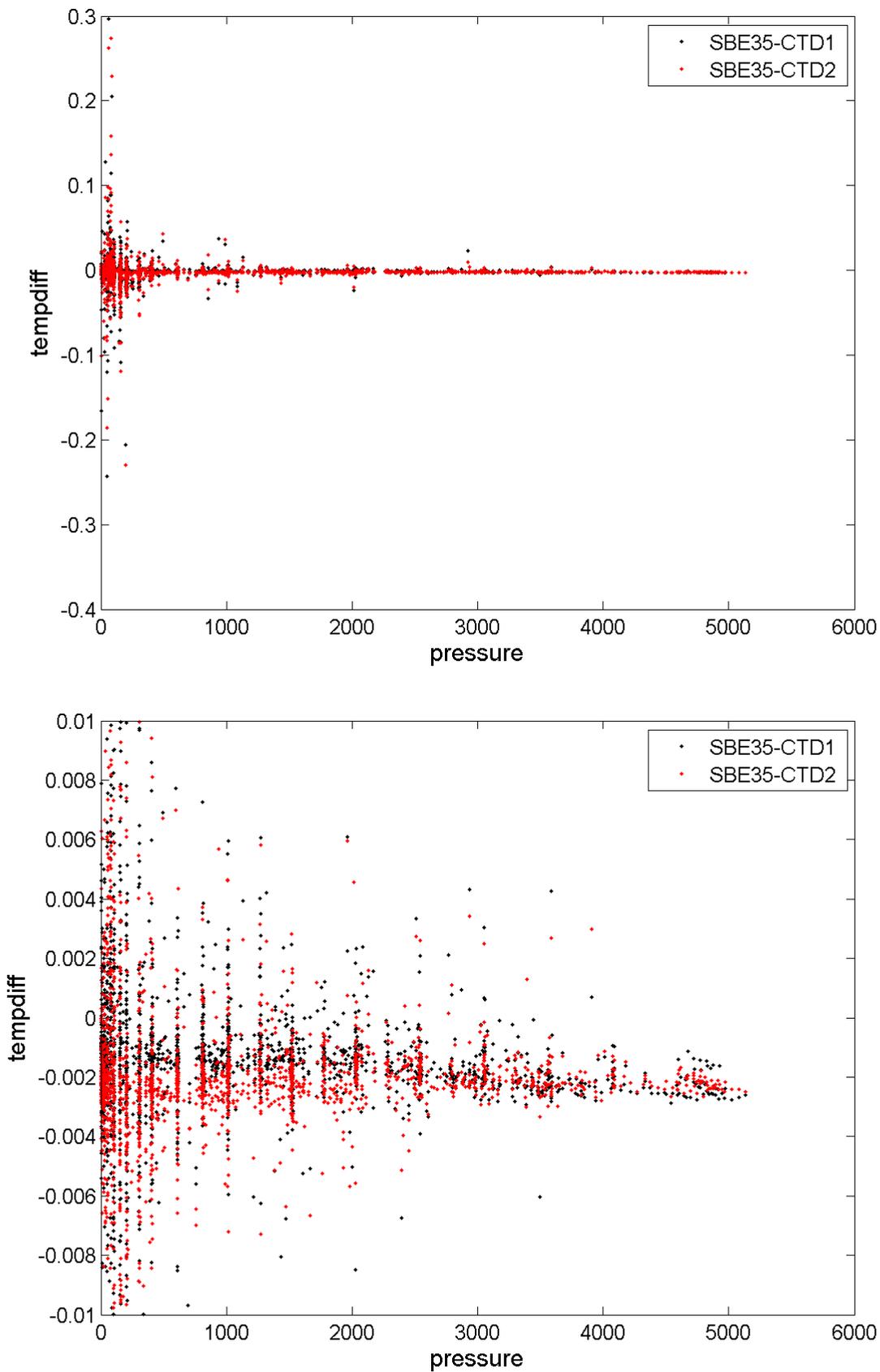


Figure 3.7. SBE35 minus CTD temperature: all (top) and with outliers excluded (bottom).

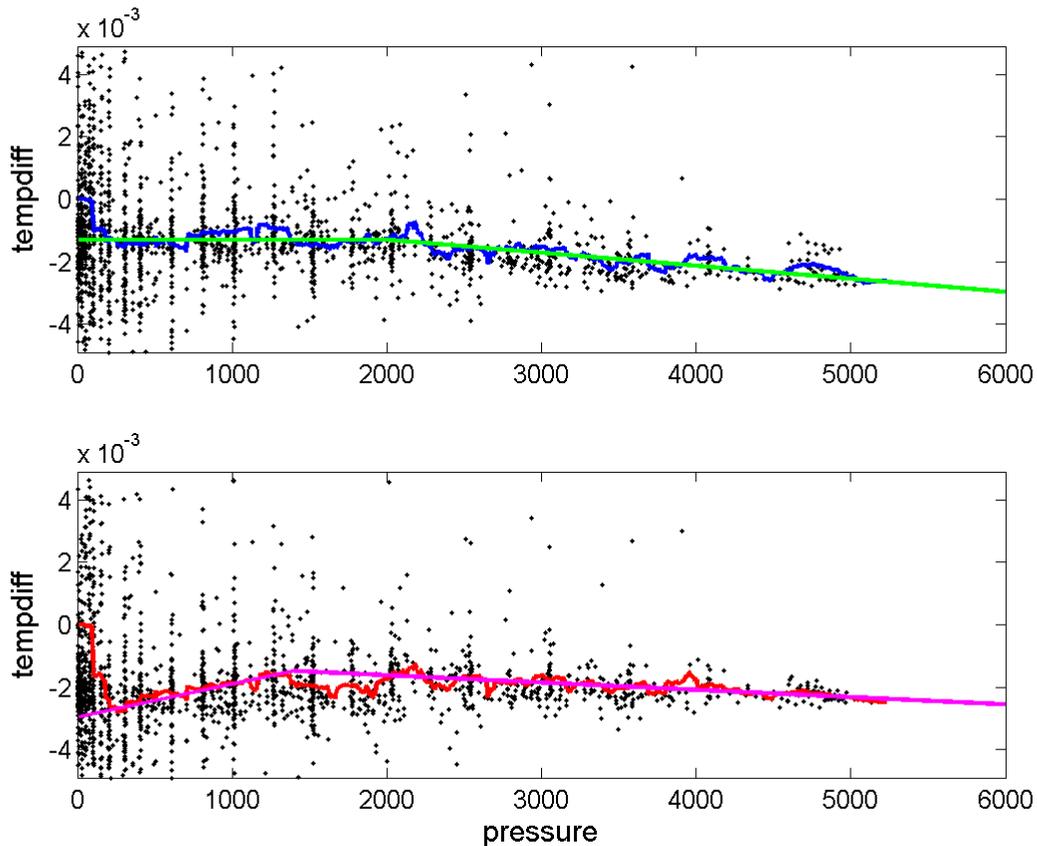


Figure 3.8. Calibration fits to SBE35-CTD temperature offsets (temp1 above, temp2 below).

Figures 3.7 and 3.8 show the differences between the CTD and SBE35 temperatures, and the shapes of the calibration curves. The derived calibrations will be applied before conductivity offsets are found.

## Salinity

As with the temperature sensors, no conductivity sensors were changed during the cruise and no change in behaviour was noted. After comparison with bottle salts, it is concluded that CTD salinity1 does not have an offset, though temp1 does so it is likely that cond1 will need calibrating. Salinity2 has a slight pressure-dependent offset. Figure 3.9 shows bottle sample salinity minus CTD salinity (salinity is shown here to demonstrate behaviour of sensors; it is conductivity, not salinity, that will be calibrated). The blue line is a running average of (bot-sal2), the equation of the green line is  $y=0.0011-(0.0036/4500)*\text{pressure}$ .

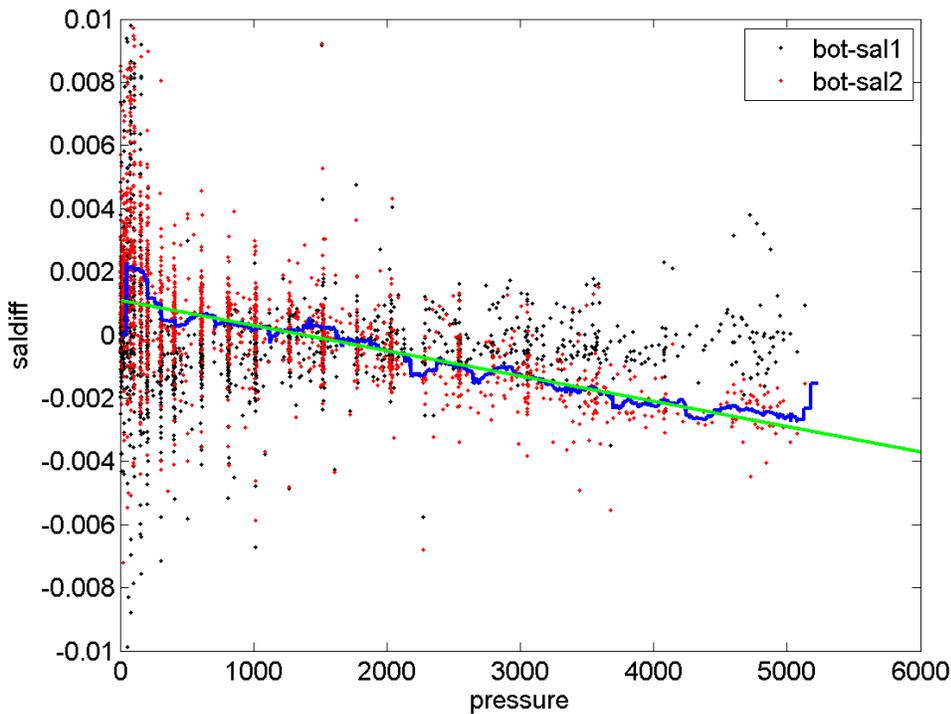


Figure 3.9. Bottle sample salinity minus CTD salinity.

## Oxygen

The behaviour of the CTD oxygen sensor was examined by comparison with discrete bottle measurements made by Sinhue Torres-Valdes et al. (section 5b). Figure 3.10 shows bottle sample oxygen minus CTD oxygen, as a function of pressure. The CTD sensor behaviour was observed to have jumped between casts 23 and 26 (with casts 24 and 25 close to latter behaviour). Section 5b presents full details of this observation. The sensor was changed before cast 70 (there was no cast 69), hence the calibration here is considered in three parts.

The equations for the curves in Figure 3.10 are (with  $x$ =pressure):-

$$y = -2 + \log((x+2)/80) / 1.6 \text{ for stations } 1:23$$

$$y = 19.0 + 1. / ((x+3)/1250) - (x/1250 - 5) * x / 1150; \quad y(1:66) = 38 \text{ for Stations } 26:68$$

$$y = -1 + 1. / ((x+100)/1250) - (x/1025 - 5) * x / 1500; \quad y_3(1:66) = 6.25 \text{ for Stations } 68:98$$

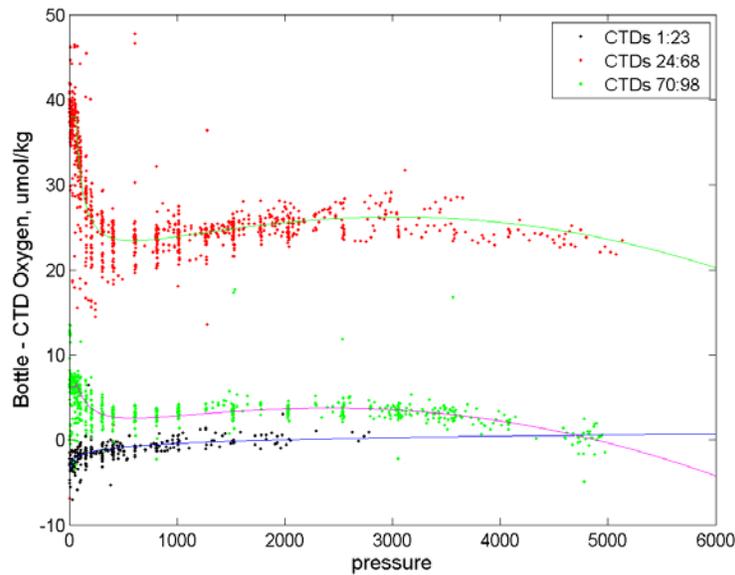


Figure 3.10. Bottle sample minus CTD oxygen.

Figure 3.11 shows residuals from the calibration curves found (casts 24 and 25 excluded, they will need individual calibration curves), as a function of pressure. The precision drops after the jump in sensor behaviour but is still acceptable.

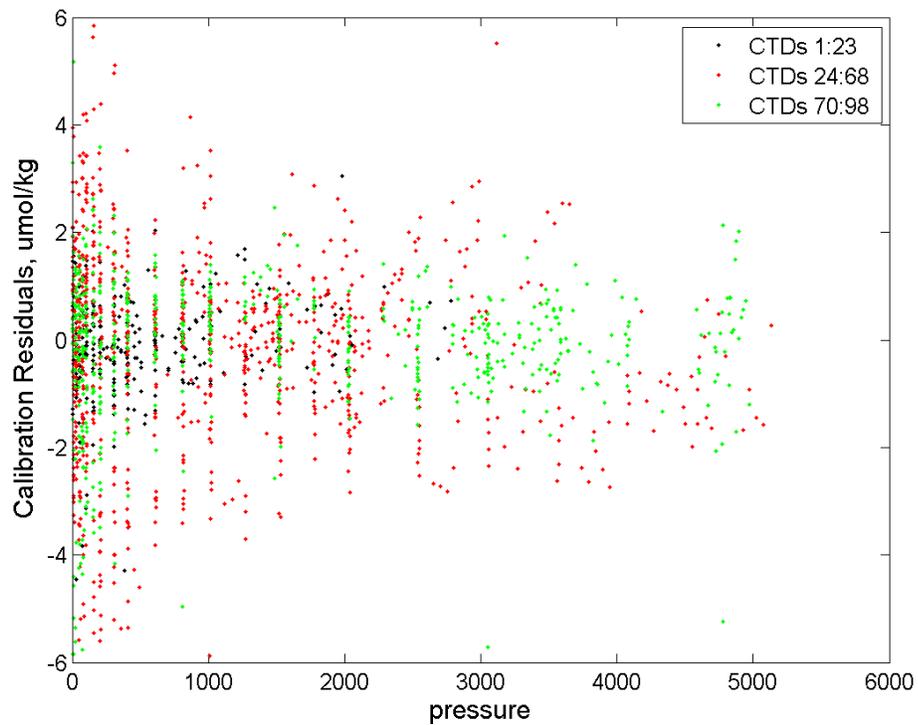


Figure 3.11. Residuals from the calibration curves found (casts 24 and 25 excluded, they will need individual calibration curves).

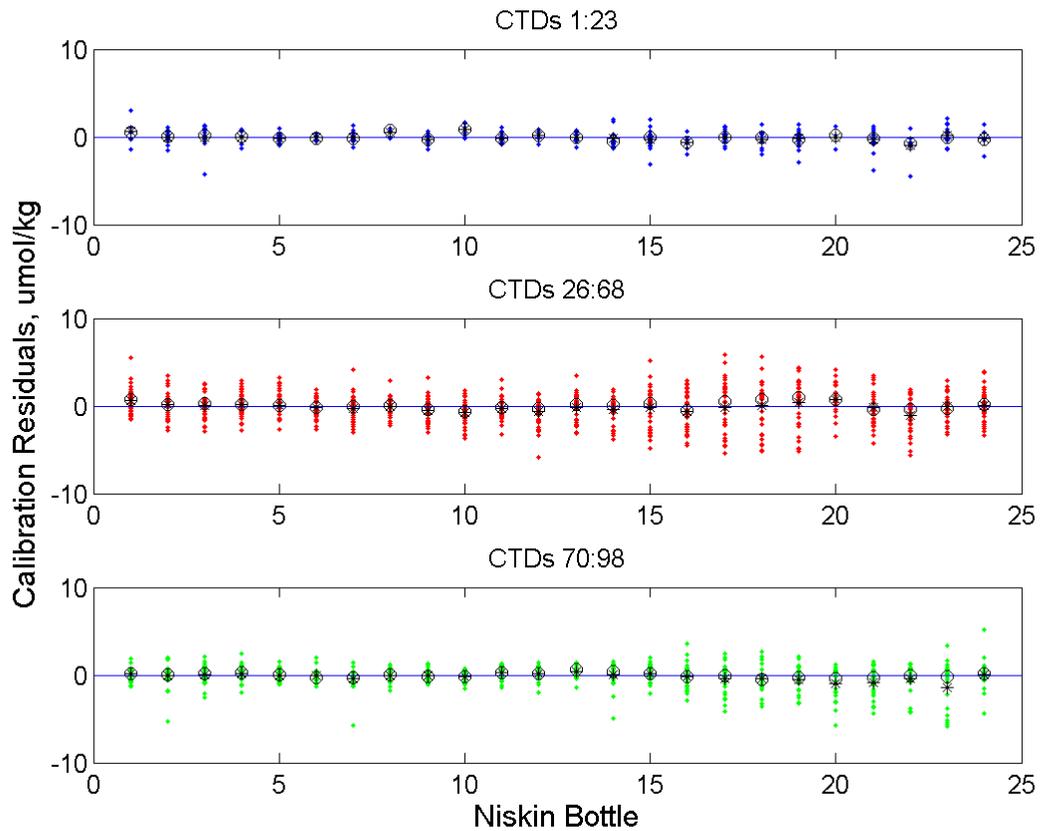


Figure 3.12. Residuals from the calibration curves against Niskin Bottle.

Figure 3.12 shows residuals from the calibration curves, as a function of Niskin bottle number. It is noticeable in the first two plots that bottle 1 difference is biased high (bottle higher than CTD). This could be chance or could be a systematic artefact of sampling two bottles together for the duplicate on bottle 1, leaving one (normally the main sample) open to the air for slightly longer than normal.

## 4. Lowered Acoustic Doppler Current Profiler (LADCP) (Loic Jullion)

### 4.1 Instruments

A total of four RDI 300kHz Workhorse LADCPs were available for JR239 and JR235 (two belonging to BAS and two belonging to NMFD). During the test station, the two BAS LADCPs (one downward-looking and one upward-looking) were deployed simultaneously. However, given the number of stations scheduled and the tendency of LADCPs to fail rather quickly, it was decided to use only a downward-looking instrument for the rest of the cruise (Table 4.1).

|   |                |
|---|----------------|
| RDI Workhorse Monitor 300 kHz ADCP S/N: 13191 | Casts 1 to 20  |
| RDI Workhorse Monitor 300 kHz ADCP S/N: 12369 | Casts 21 to 98 |

Table 4.1: Instruments used during JR239 and JR235

One of the beams of the first LADCP used broke suddenly after station 14, and was detected after station 20 during the processing of the data. The LADCP was then removed, as solutions given by only three working beams tend to be less reliable even if only three beams are necessary to calculate the three velocity components.

### 4.2 Operations

The LADCP was configured to have a standard 10 x 16 m bins, with one water track and one bottom track ping in a two second ensemble. There was also a 5m blank at the surface. Data were collected in beam coordinates and rotated to earth coordinates during post-processing. The instruments were mounted in a downward-looking orientation and positioned near the centre of the CTD frame.

Prior to each station the ADCP was connected to a laptop in the deck lab (via a serial port – USB adapter) for pre-deployment tests and the instrument was programmed (see script below). After each station the instrument was reconnected to the laptop for the retrieval of the data. The battery package was charged between stations. The raw data (.000 files) for each station were downloaded from the instrument and copied into a central data directory.

---

```
PSo
CR1      $ Set to factory defaults
CF11101  $ Record data internally
EA00000  $ Set heading alignment to 0 degrees
EB00000  $ Set heading bias to 0 degrees
ED00000  $ Set transducer depth to zero
ES35     $ Set salinity to 35
EX00000  $ Set system coordinate (EX00000: Beam coordinate)
EZ0011101 $ Set to use a fixed speed of sound
WM15     $ Use the WM15 for firmware update 16.3
LW1      $ Set ADCP to narrow bandwidth
LD111100000 $ Set to output velocity, correlations amplitude and percent good
LF0500   $ Set blank to 500 cm
```

|               |  |
|---------------|--|
| LN016         | \$ Set record to 16 bins   |
| LP00001       | \$ Set one ping per ensemble                                     |
| LS1000        | \$ Set bin size to 1000 cm                                       |
| LV250         | \$ Set max radial (along beam axis) water velocity to 250 cm s-1 |
| SM1           | \$ Set as master LADCP   |
| SA001         | \$ Transmits synchronizing pulse before each water ping          |
| SW05000       | \$ Wait 50 milliseconds  |
| TE00:00:01.00 | \$ Set to one ensemble s-1                                       |
| TP00:00.00    | \$ Set one second between pings                                  |
| CK            | \$ Save set up   |
| CS            | \$ start pinging   |

---

Station 5 was aborted as the CTD was giving bad data and the station was repeated shortly after (and named station 6). Station 5 is therefore ignored as the profile is not complete and no CTD data are available to correct the sound speed. Station 30 was occupied twice (named station 30 and station 30A). The two LADCP profiles were averaged together to give the final velocity profile.

### 4.3 Data processing

The LADCP measures the instantaneous velocity profile of scatterers drifting with the currents. The instrument sends an acoustic ping and listens for the echo return. The velocity of the scatterers relative to the CTD package is then calculated from the Doppler shift of the backscattered sound received by the four beams looking in four different directions. One pair of beams obtains one horizontal and one vertical velocity and the other pair of beams obtains a horizontal velocity orthogonal to the first and a second estimate of the vertical velocity. The second vertical velocity gives an estimate of the data quality.

The data obtained by the instrument needs to be processed to:-

- Remove the velocities of the scatterers relative to the CTD package and relative to the ship.
- Correct the sound velocity using the *in situ* CTD measurements.
- Average the individual ensembles into one vertical velocity shear profile.
- Calculate the depth of the instrument.
- Calculate the barotropic velocity profile from the ship navigation data.
- Combine both the baroclinic and barotropic profiles.

Two independent methods are available to process LADCP data. Both methods are used here in order to compare their performances and because each gives several useful diagnostics:-

- The University of Hawaii (UH) software, developed by Eric Firing, averages the individual velocity shear into one full depth geostrophic shear profile.
- The Lamont-Doherty Earth Observatory (LDEO) software (version 7b), developed by Martin Visbeck, uses inverse techniques to calculate the geostrophic shear, adding extra data such as shipboard ADCP data or bottom-tracking data to constraint the results. It is also used for obtaining bottom track profiles, to monitor the beams of the instrument and to

calculate three-beam solutions for stations 14 to 20, as the UH software is unable to cope with 3-beams only.

#### *Setting the up directory tree:-*

The two software packages were set up to use only one set of directories containing the raw data (LADCP, navigation and CTD data). This avoided redundancy of data and possible mishandling of the raw data. During JR239, the LADCP data processing was done on the linux box "nosea2". The processing always occurred in:

*/pstar/cruise/data/ladcp/*,

where "cruise" was a symbolic link to the cruise directory (jr239 in this case). To setup the ladcp directory, it was copied from the previous cruise where comparable processing was done (in our case, JR195, the last Drake Passage repeat) and cleaned.

#### *Cleaning steps:-*

1) For the UH directory:

In *uh/raw/* renamed the directory *jrYYMM* (jr1003)

In *uh/pro/*: the same

In *uh/*: edited the *LADall* script: changed the cruise directory ID and the year.

In *uh/pro/jr1003/ladcp/*: edited and ran *makelinks* to create the symbolic link for *Rnav, Rctd, Rlad, Pctd, Fctd*.

Cleared the *latlon.asc, stations.asc, proc.dat, mag\_var.tab* files

Cleared the files in *postimes/postime*

Cleared the files in *matprof/h/*

Cleared the files in */casts/*

2) For the Ideo directory:

In Ideo/: renamed the directory *jrYYMM* (jr1003)

In Ideo/jr1003/: edited the symbolic links to *gps/, raw/, ctd/*. To avoid redundancy, the directories containing the raw data used for the processing (LADCP, CTD, navigation) are linked to the UH raw directories:

**ctd -> ../../uh/raw/jr1003/ctd**

**gps -> ../../uh/raw/jr1003/gps**

**ladcp -> ../../uh/raw/jr1003/ladcp**

#### *Processings steps with UH software (/local/users/pstar/sw/ladcp/lad\_uhsoft)*

The UH software is a combination of PERL and MATLAB scripts. The first step in the processing is to copy the raw files into the correct directory and to link the .000 data files to files using the UH nomenclature. We used a down-looking Workhorse LADCP, therefore the files were named: jNNN\_02. The \_02 is used for consistency with previous cruises.

The raw data were copied into the directory:

*/local/users/pstar/cruise/data/ladcp/uh/raw/jr1003/ladcp*

Processing steps followed-:

1. **scan.perl**: script that scans the raw data and creates a station specific directory tree in the  
/local/users/pstar/cruise/data/ladcp/uh/pro/jr1003/ladcp/proc/casts directory. Data printed to the screen should be checked to ensure the details of the cast (i.e. depth, downcast/upcast times) agree approximately with the CTD log sheet.
2. **putpos.m**: gets position of the cast by accessing the SCS datastreams.  
**magvarsm.m**: applies the magnetic correction to the compass on the LADCP.
3. **load.prl**: loads the raw data, correcting for magvar.tab to start processing. It is very important that this step is only carried out once. If it needs to be repeated (for example if a mistake has been found in one of the previous steps, the database files (~ /proc/casts/jNNN\_02/scdb) must be deleted first.

**domerge.prl**: merge the velocity shear profiles from individual pings into full upcast and downcast profiles. The option -c0 refers to the fact that CTD data has not yet been included. Calculates the baroclinic shear profiles and applies corrections and editing options that were kept constant throughout the cruise.

4. **make\_sm.m**: makes a smoothed navigation file for the cast.
5. **do\_abs**: calculates the relative velocity profiles and produces a standard set of profiles. User checks that these plots look sensible, i.e. reasonable agreement between downcast and upcast and that the vertical velocity changes sign between downcast and upcast (it may be necessary to rescale some of the plots).
6. Once the CTD data were calibrated, the data were interactively matched to the ADCP vertical velocities (**fd.m**), and the true depth information for the cast merged into the database together with sound speed data corrected for temperature and salinity. Then, the **domerge.prl** and **do\_abs.m** steps are reapplied to obtain the corrected shear profiles.

Note: It is important to run the UH software before running the LDEO software as the navigation data (**make\_sm.m**) have to be collected after the putpos.m and magvarsm.m scripts have been run.

Next is the list of instruction to process any station *NNN* on nosea2.

- 
- 1) Log on to nosea2 as pstar, password pstar.
  - 2) cd /local/users/pstar/cruise/data/ladcp/uh  
Source LADall (setup paths)
  - 3) cd proc  
cd Rlad  
linkscript\_jr239(NNN); (Create a symbolic link to jNNN\_02)
  - 4) cd proc  
perl -S scan.prl NNN\_02

```
5) matlab -nodesktop
    m_setup
    putpos(NNN,o2)
    magvarsm(NNN.o2) (ignore decimal year warning)
```

```
6) perl -S load.prl NNN_o2
```

Note: It is very important that this step is only done once. If you need to do it again, for example if you discover an error in step 5, then you must delete the database files first. These are found in `proc/casts/jNNN_o2/scdb`. If in doubt delete entire cast processing and start again from step (4). (cd `proc/casts`, then `/bin/rm -r jNNN_o2`)

```
7) perl -S domerge.prl -co NNN_o2
```

```
8) cd Rnav
    matlab
        m_setup
        make_sm
    cd proc
```

```
8) matlab
    plist = NNN.o2
    do_abs;
```

---

*Processing with LDEO software (/local/users/pstar/sw/ladcp/ldeo\_ladcp\_software):-*

The LDEO software is a set of MATLAB scripts. Whereas the University of Hawaii software handled the beam coordinates without any changes to the software, the LDEO software required an updated version of their *loadrdi.m* program. The *loadrdi.m* version used during the Rapid 24°N section in January-February 2010 was used for JR239. The processing was done in:

```
/local/users/pstar/cruise/data/ladcp/ldeo/jr1003/
```

The results are store in directories named: */jr239NNN/*, where *NNN* is the station number.

Processing steps:-

This software is much quicker to run as it is only a set of MATLAB scripts and just two MATLAB files (*sp.m* and *lp.m*) need to be run.

**sp.m**: sets the correct raw directories, using symbolic links to the raw directories used by the UH software.

**lp.m**: sets the software directory and some of the processing options and launches the processing by calling the main routine *laproc.m*.

Like the UH software, the LDEO software corrects for sound speed using the CTD calibrated data. The barotropic velocity is calculated from the ship position at the beginning and end of the cast. The software excludes bad quality data (large tilt of the CTD package, low backscatter *etc*)

#### 4.4 Assessing LADCP performance

It is important to run the basic data processing as soon as possible after the cast in order to monitor the quality of the instrument and in particular the strength of the four beams. A weak beam results in general in noisier and less accurate results. Moreover, the UH software is unable to cope with 3-beams solutions and return segments of null velocity instead of a continuous vertical velocity profile (Figure 4.1). Finally, instruments with a weak or broken beam are more likely to sustain hardware failure such as leaks, therefore the instrument should be removed as soon as one of the beam breaks.

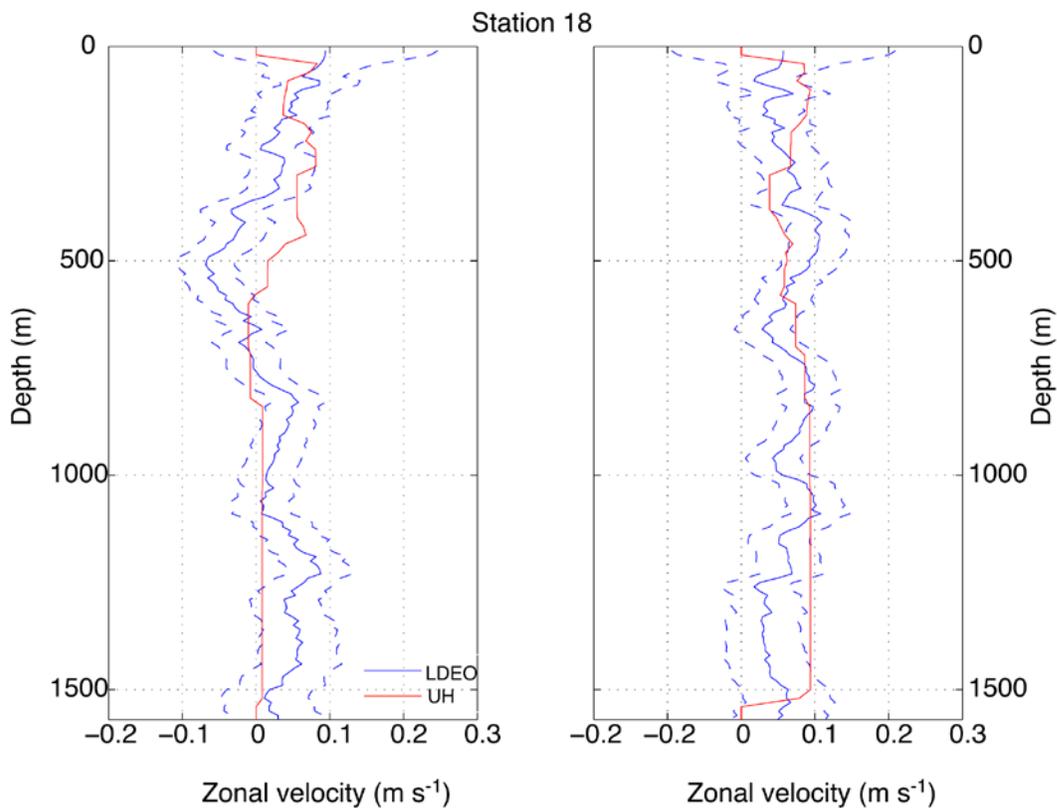


Figure 4.1: Comparison between the LDEO and UH software performances during station 18 with 3 beams only.

The LDEO software provides a useful plot to monitor the beam performances. The two bottom plots of figure Figures 4.2 and 4.3 show the echo amplitude and autocorrelation for each of the four beams. Echo amplitude is a measure of the received signal strength (in dB) as a function of the distance from the beam. The correlation gives an indication of how correlated the beam are. If the four beams are all working well, the correlations and echo amplitude will be similar for the four beams (Figure 4.3) whereas if one of the beams has failed, its echo amplitude and correlation will differ more or less from the others, as it is the case for station 18 (Figure 4.2).

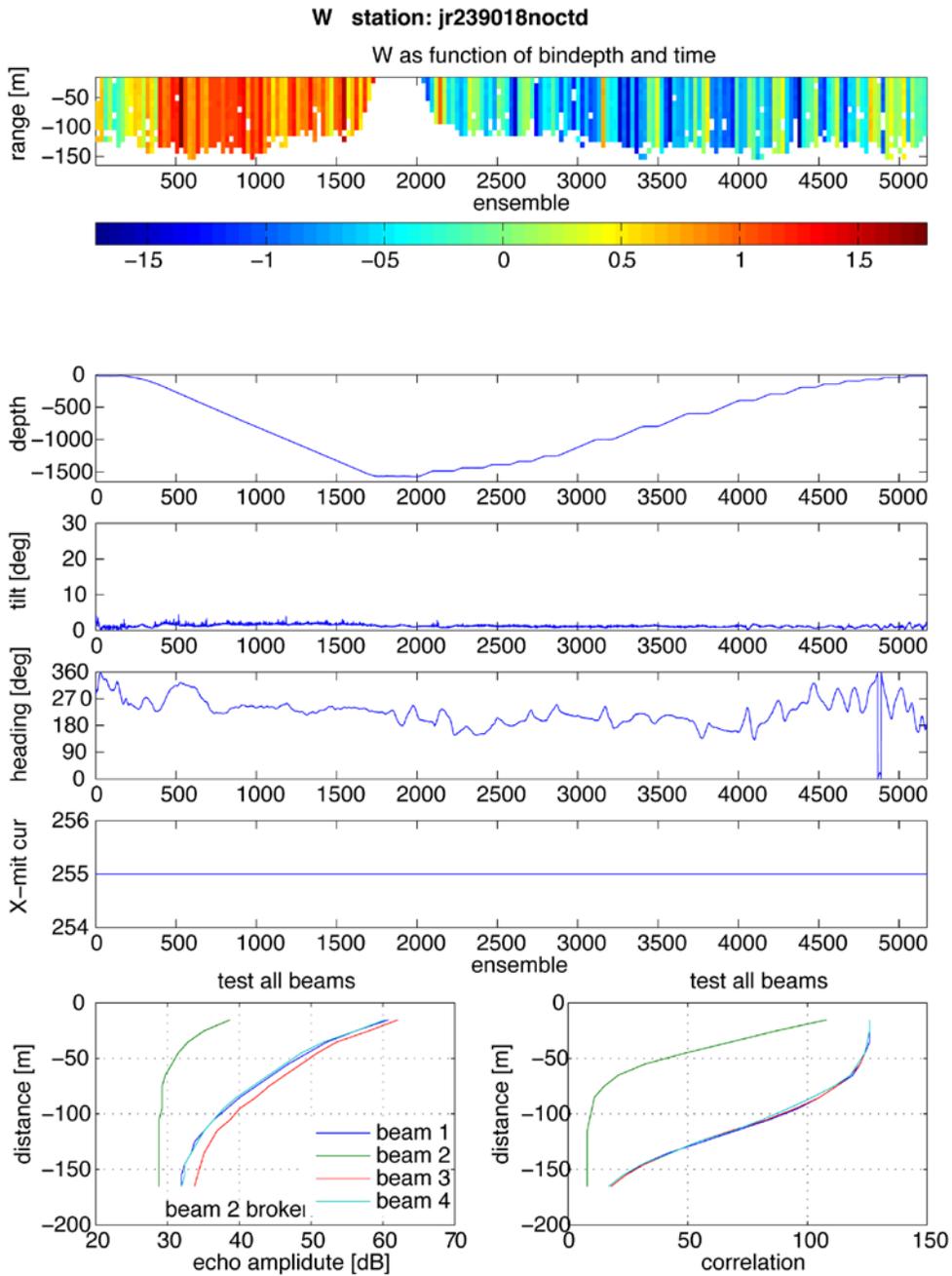


Figure 4.2: Diagnostic plots from the LDEO software showing that beam 2 has failed (station 18).

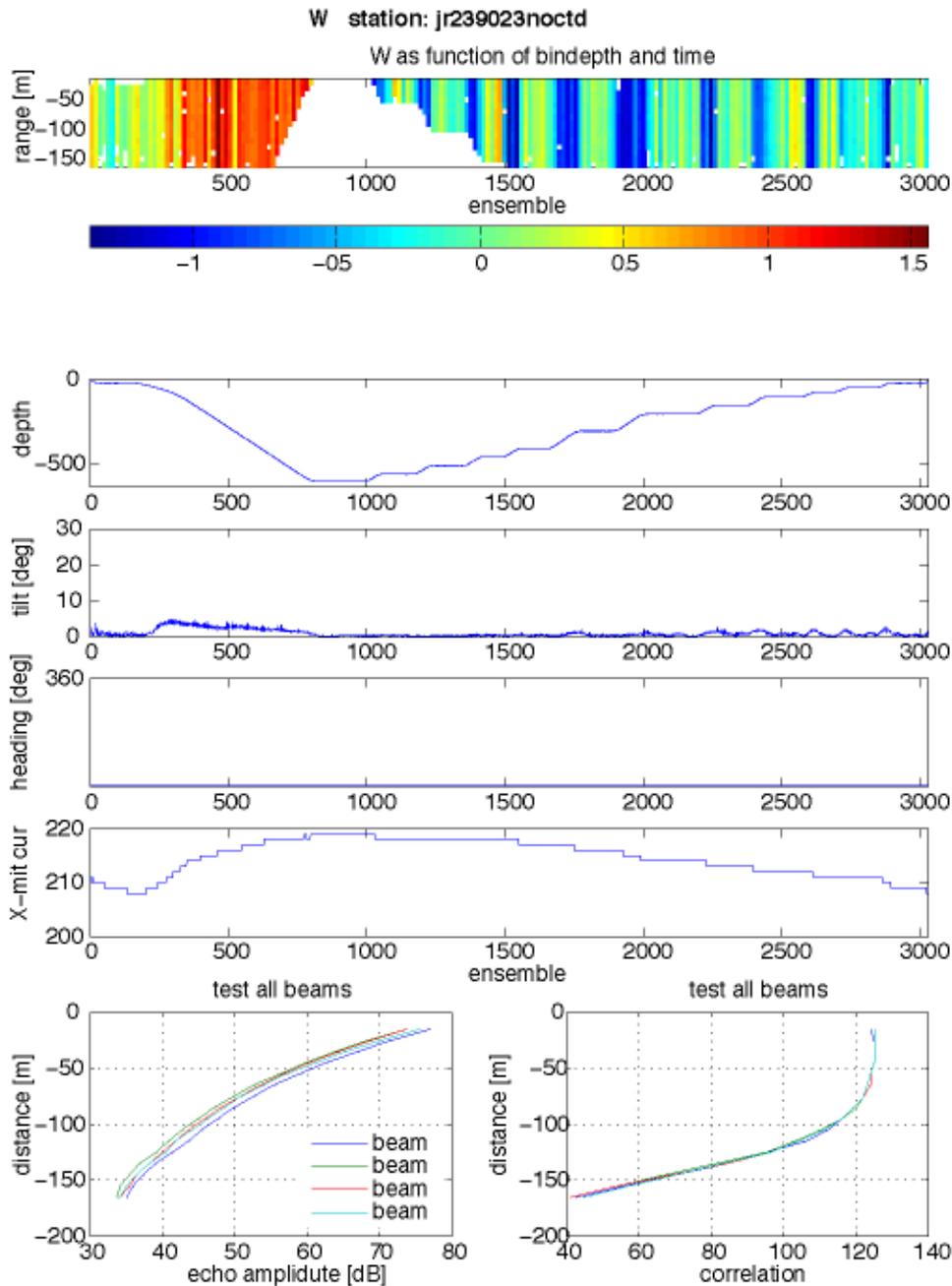


Figure 4.3: LDEO diagnostic plot for station 23 with 4 beams fully working.

During JR239, beam 2 failed suddenly after station 14 and the broken beam was only discovered after station 20 due to some delay in data processing. Therefore between station 14 and 20, the only LADCP data available come from the LDEO software. However, in this shallow part of JR239, Vessel-Mounted ADCP data covered the whole water column and RDI bottom-track velocities should give a good coverage of the velocity field.

## 4.5 Method comparison

We can compare the different processing methods, namely the UH shear method, the LDEO inverse method, and the LDEO implementation of the shear method. The LDEO inverse method allows several options (no constraint, VM-ADCP only, bottom-track velocities only or both) to constrain the inversion. No constraint was used in this comparison and the VM-ADCP and bottom-track data are used as independent data to assess the performance the different software. Bottom-tracking mode is independent from water-profiling mode as it uses longer pings (whereas water-profiling pings are shorter) to detect the bottom and calculate the Doppler shift induced by the displacement of the LADCP relative to the bottom. The echo received from the long ping is then processed in a different way. Thus both VM-ADCP for the upper-ocean and bottom-tracking pings for the near bottom give an independent estimate of the velocity and can be used for comparison with LADCP data.

The LADCP data are interpolated onto the VM-ADCP/bottom-track velocity depth grid and the differences in both the magnitude and direction between the LADCP velocity vectors and the bottom-track/VM-ADCP vectors are calculated (Figures 4.4 to 4.7). Near the bottom, both the LDEO and UH software present a strong positive bias ( $> 0.2 \text{ m s}^{-1}$ ) in the magnitude in the Orkney Passage (stations 30-33) and at stations 62-63: the bottom-track velocities are more negative than the water-profiling velocities (Figure 4.4). The Orkney Passage is a complex flow regime, with bottom-intensified flows. The discrepancies could be caused by an increased concentration of suspended matter near the bottom (due to the strong bottom currents) that could bias the bottom-track mode. Along the South Scotia Ridge west of the South Orkney Islands, the differences in magnitude and direction (Figures 4.4 & 4.5) are low showing a good agreement between the bottom-track velocities and the LADCP profiles.

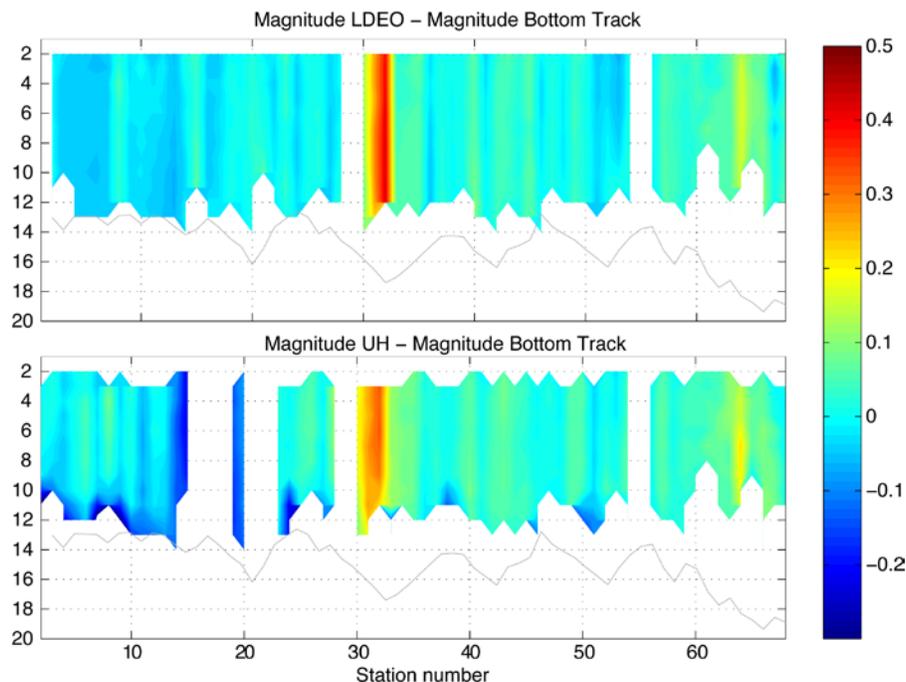


Figure 4.4: Difference in magnitude ( $\text{m s}^{-1}$ ) between the LADCP bottom velocities and the bottom-track velocities for the LDEO software (top) and UH software (bottom).

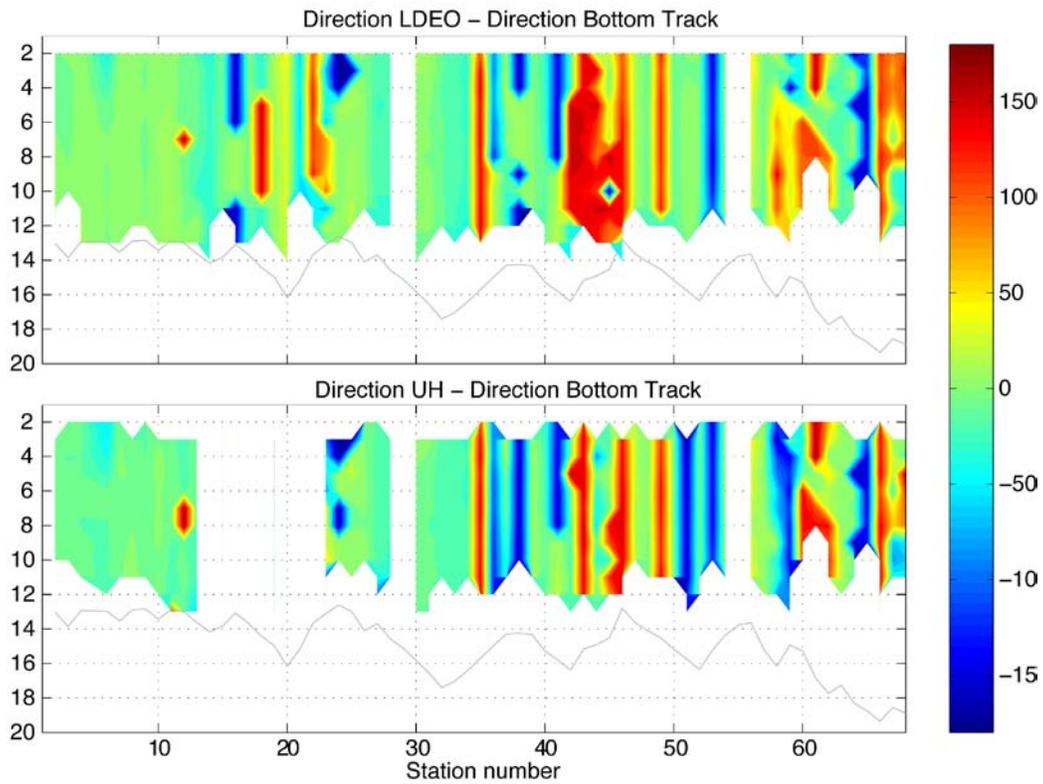


Figure 4.5: Difference in direction (degrees) between the LADCP bottom velocities and the bottom-track velocities for the LDEO software (top) and UH software (bottom).

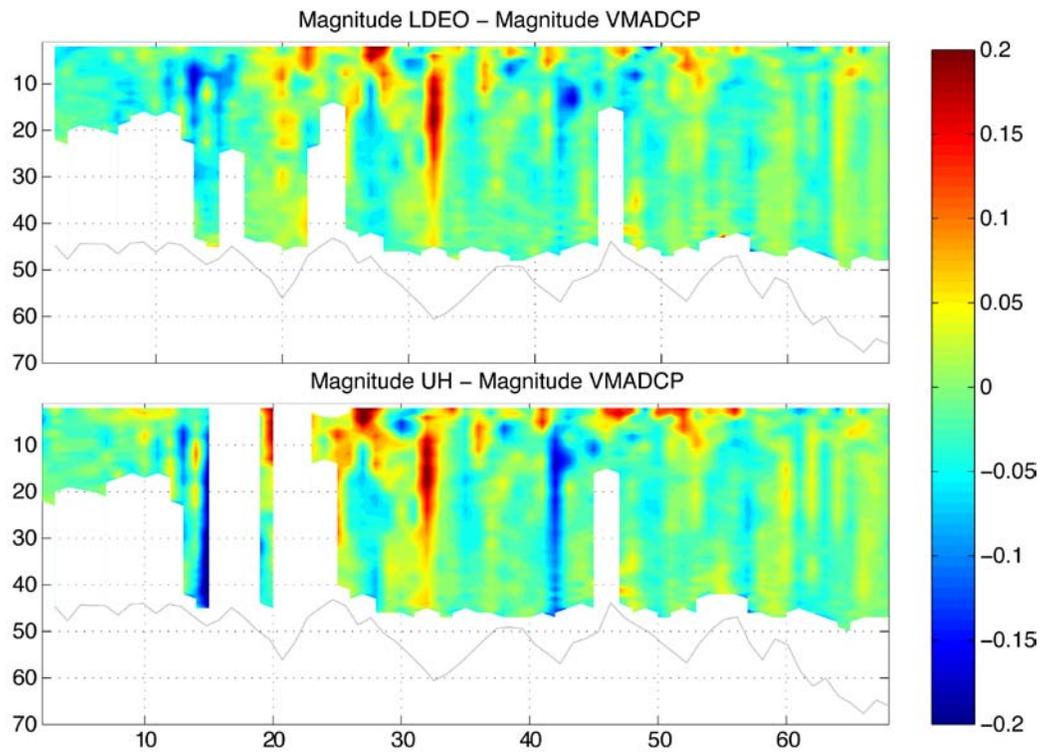


Figure 4.6: Difference in magnitude ( $m s^{-1}$ ) between the LADCP upper-ocean velocities and the shipboard ADCP velocities for the LDEO software (top) and UH software (bottom).

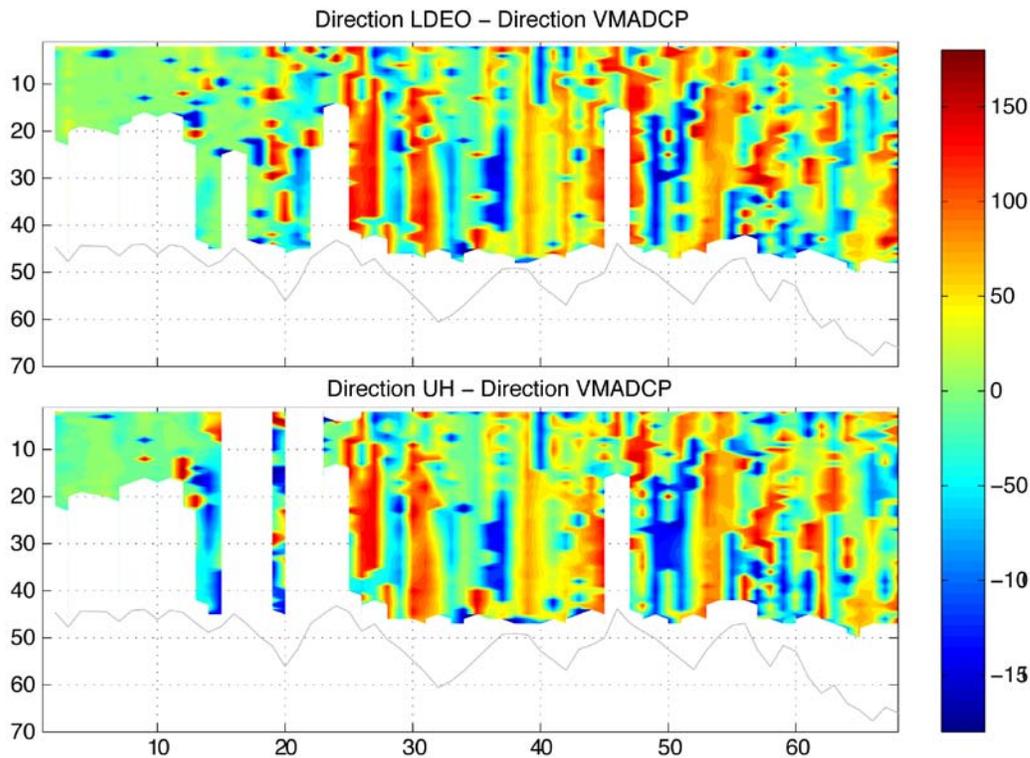


Figure 4.7: Difference in direction (degrees) between the LADCP upper-ocean velocities and the shipboard ADCP velocities for the LDEO software (top) and UH software (bottom).

The same comparison with VM-ADCP data shows good agreement in magnitude in most places (Figure 4.6) but strong discrepancies in direction east of the South Orkneys (Figure 4.7). A closer look at the output diagnostics from both the UH and LDEO software showed that after the replacement of the LADCP unit (station 20), the heading extracted from the LADCP raw data is constant for all the casts done with this instrument (see the 4<sup>th</sup> panel from the top in Figures 4.2 & 4.3). In Figure 4.2, the heading shows some variation during the cast whereas in Figure 4.3, the heading output is a straight line. Following consultation with NMF personnel onboard, it was discovered that a bug in the RDI firmware that should have been corrected before the instrument was sent into the field (but was not) leads to an incorrect heading and therefore causes the data to be unusable, as a correct heading is crucial to determine the directions of the velocity vectors. The two versions of the firmware affected by the bug are V.16.31 (used here) and V.50.31.

#### 4.6 Conclusion

For the stations 2 to 14, the comparison with the VM-ADCP data shows very good agreement for both the UH and LDEO software. Perhaps more surprisingly, for stations 15 to 20, after beam 2 had failed, the 3-beam solutions calculated by the LDEO software still show good agreement with the VM-ADCP data. Unfortunately, due to the late discovery of the bug in the RDI firmware, the LADCP data from station 21 to station 98 are not readily available. It may be possible to recover LADCP profiles by modifying the two LADCP post-processing software. However, this might require considerable experimentation and code writing and will be done once back in the UK.

## 5. Discrete water sample measurements

### 5a. Salinometry (Povl Abrahamsen)

During JR239, salinities of water samples were analyzed using two Guildline Autosal 8400B salinometers. This section will briefly describe the procedures used, and issues encountered with the instrumentation.

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 at 20 degrees, and 1 atm. pressure. The instrument is standardized at the beginning of the cruise, and when the temperature of the water bath is changed; in between, bottles of standard seawater are analyzed at intervals of approx. 24 samples, with corrections applied to the intermediate measurements. Several readings are performed until the value is determined with sufficient certainty:  $\pm 0.00002$  in the readout or  $\pm 0.00001$  in the ratio, equivalent to approx. 0.0003 salinity, which is less than the accuracy of the CTD salinity measurements. The median reading is used. From these conductivity ratios, the practical salinity of the sample can be calculated using the equation of state from UNESCO (1978). The measurements were loaded into an Excel spreadsheet, where salinities were calculated; text files with station number, Niskin bottle number, and salinity were exported for use in the CTD data processing.

A summary of events in the salinometer room follow. At the beginning of the cruise, Autosal no. 68533 was used, with a bath temperature of 24. However, this was reduced to 21, as the samples took too long to equilibrate to the water bath temperature, and measurements were quite noisy when the ambient temperature in the room was below 20 degrees. After running two crates of bottles through the instrument, we determined that the spread in measurements was still unacceptably high, and decided to change to the other instrument, no. 65763. One of the heating lamps in this instrument was not working (the error lamp on the front of the instrument was lit, indicating an open circuit on one of the lamps); however, the instrument was still able to maintain a stable temperature above the ambient temperatures in the room. However, on April 5 the temperature in the lab reached 22.0 degrees, and the instrument was not able to cool sufficiently to maintain a stable temperature in the water bath. This probably indicates that the Peltier cooler in the instrument is not working properly. The cell temperature was increased to 24 degrees, and after re-standardizing the instrument on April 6, no further adjustments were made until the end of the cruise. On the morning of April 9, the power supply for the peristaltic pump was found to be overheating to the point of melting. It was immediately isolated and once it had cooled down, was replaced with a bench power supply, set to 10.8 V, which gave a good speed for loading samples. This was used for the remainder of the cruise.

A total of 1698 CTD samples plus a further 118 underway samples were analyzed during the cruise, excluding standards. During the cruise a total of 50 P-series standards from batch P150 (dated 22/5/2008) were used, in addition to 67 standards from batch P151 (dated 20/5/2009). Two samples from batch P148 (10/10/2006) were analyzed to test the instruments, but were not used for calibration, as they are out of date.

*Summary of suggested repairs:-*

Autosal no. 68533:

- Measurements are noisy and drift considerably; unknown cause of problem, though it may be an issue with cell alignment, a leak in the sample tubing, or a problem with the measurement circuitry. This instrument should be returned for servicing and diagnostics.
- Considerable biological growth in the water bath; the outside of the cell should be cleaned, and care should be taken only to use Milli-Q water in the water bath in the future, possibly with a small amount of bleach to prevent growth.

Autosal no. 65763:

- One heater lamp is not working. It should be replaced, though the instrument appears to work well with only one lamp.
- Cooling is not working correctly; the cooler should be checked and/or replaced.
- The air pump for cell flushing was quite slow to start; it did always turn on after a few attempts, but should start properly the first time; this may be sign of impending failure. The cause could be a mechanical blockage in the air pump itself; the pump should be inspected and the pump seal replaced if worn.
- A small amount of biological growth in the water bath; again, Milli-Q should be used in the bath.

Peristaltic pumps:

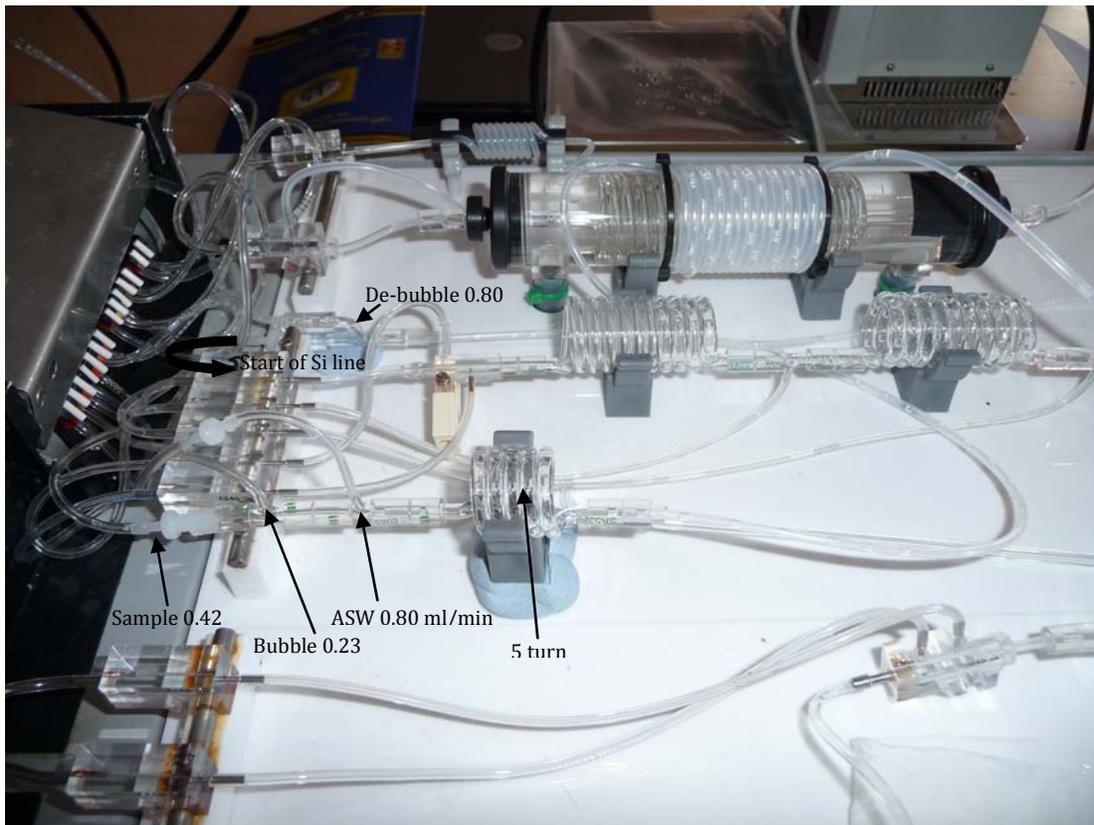
- The pumps themselves are in good working order. However, care must be taken to have a sufficient supply of suitable power supplies on board. The power supply marked "Autosal peristaltic pump" did not output the correct voltage, and another power supply used as a replacement overheated and melted (see above). Finally a bench power supply was used; the pumps worked well at 10.8 V. Rather than a 12-V power supply, 9 V may be preferable to ensure that the speed is kept low, to allow sample temperatures to equilibrate with the water bath.
- The electrical connection from the power supply to the pump was slightly loose; the socket on the pump should probably be cleaned.

**5b Dissolved inorganic nutrients and dissolved oxygen.**  
**(Sinhue Torres-Valdes, Sophie Chollet and Ella Darlington).**

**5b(i). Inorganic and Total Nutrient Analysis**

Seawater was collected for the analysis of micro-molar concentrations of dissolved nutrients; nitrate and nitrite (hereafter nitrate), phosphate and silicate. Samples for inorganic nutrient analysis were collected directly into 30 mL plastic pots. Pots were rinsed with sample water at least three times before drawing the sample. Samples were stored in a fridge at approximately 4°C until sampling for two or three stations was completed; analyses were thus carried out for typically 2-3 stations at a time. This was done in order to avoid excess production of waste, given that waste was to be returned to the UK.

In general, analyses were started within 2-12 hours of sample collection using a segmented continuous-flow Skalar San<sup>plus</sup> autoanalyser set up for analysis and data logging with the Flow Access Software version 1.3.11. This system follows the method described by *Kirkwood* (1996), with the exception that the pump rates through the phosphate line were increased by a factor of 1.5, which improves reproducibility and peak shape. As for the first ANDREX (2008-2009) cruise, a dilution loop for the silicate channel was also installed giving a 2.9 times dilution (Figure 5.1). This was done in anticipation of the high silicate concentrations typical of the Southern Ocean.



*Figure 5.1. Picture showing the set up of the silicate dilution loop.*

For JR239 and JR235, the analysis was calibrated using the set of standards shown in Table 5.1, which shows target and actual standards concentration. Target concentrations are values aimed at when preparing working standards (i.e., every day used standards). Actual concentrations are values corrected by taking into account (i) the weight of the dry chemical used to prepare a given standard (Table 5.2) and (ii) the calibrated volume of the pipettes used for diluting stock standards (i.e., high concentration standards).

~5 mmol L<sup>-1</sup> stock standard solutions prepared in Milli-Q water were used to produce working standards. Working standards were prepared in a saline solution (40 g NaCl in 1 L of Milli-Q water, here after artificial seawater), which was also used as a diluent for the analysis.

|              | <b>Nitrate</b> |      | <b>Phosphate</b> |      | <b>Silicate</b> |       |
|--------------|----------------|------|------------------|------|-----------------|-------|
| <i>Std 1</i> | <b>40</b>      | 38.2 | <b>4.0</b>       | 3.92 | <b>160</b>      | 156.8 |
| <i>Std 2</i> | <b>30</b>      | 29.4 | <b>3.0</b>       | 2.94 | <b>120</b>      | 117.6 |
| <i>Std 3</i> | <b>20</b>      | 19.8 | <b>2.0</b>       | 1.96 | <b>80</b>       | 78.4  |
| <i>Std 4</i> | <b>10</b>      | 9.8  | <b>1.0</b>       | 0.98 | <b>40</b>       | 39.2  |
| <i>Std 5</i> | <b>5</b>       | 4.9  | <b>0.5</b>       | 0.49 | <b>10</b>       | 9.8   |

*Table 5.1. Set of calibration standards (Std) used for dissolved inorganic nutrient analysis. Bold numbers are target concentrations, otherwise actual concentrations. Concentration units are mmol L<sup>-1</sup>.*

| <b>Compound</b>                  | <b>Weight (g)</b> | <b>Molarity 1 L stock solution</b> |
|----------------------------------|-------------------|------------------------------------|
| KH <sub>2</sub> PO <sub>4</sub>  | 0.6812            | <b>5.0057</b>                      |
| Na <sub>2</sub> SiF <sub>6</sub> | 0.9414            | <b>5.0060</b>                      |
| NaNO <sub>3</sub>                | 0.4252            | <b>5.0027</b>                      |
| NaNO <sub>2</sub>                | 0.3429            | <b>4.9699</b>                      |

*Table 5.2. Compounds used to prepare stock standard solutions, weight dissolved in 1 L of Milli-Q water and Molarity of the solution.*

Previous to the cruise, all labware was washed with 10% HCl and rinsed with MQ water and rinsed several times before use once onboard.

Typically, the autoanalyser was washed through with 10% Decon 90 then Milli-Q water for at least 15-30 minutes each after each run when the time between stations allowed, otherwise the autoanalyser was left with the reagent tubing connected ready for the next run. New pump tubing and lamps were fitted at the start of the cruise, along with a new cadmium column. All tubing was turned around on the 8<sup>th</sup> of April and the cadmium column was replaced (from run 25).

New batches of artificial seawater were prepared almost once every 2 weeks. These were analysed prior to being used in order to check for contamination and consistency.

Time series of baseline, instrument sensitivity, calibration curve correlation coefficient and nitrate reduction efficiency were compiled to check the performance of the autoanalyser over the course of the cruise, and are shown in Figures 5.2 to 5.8.

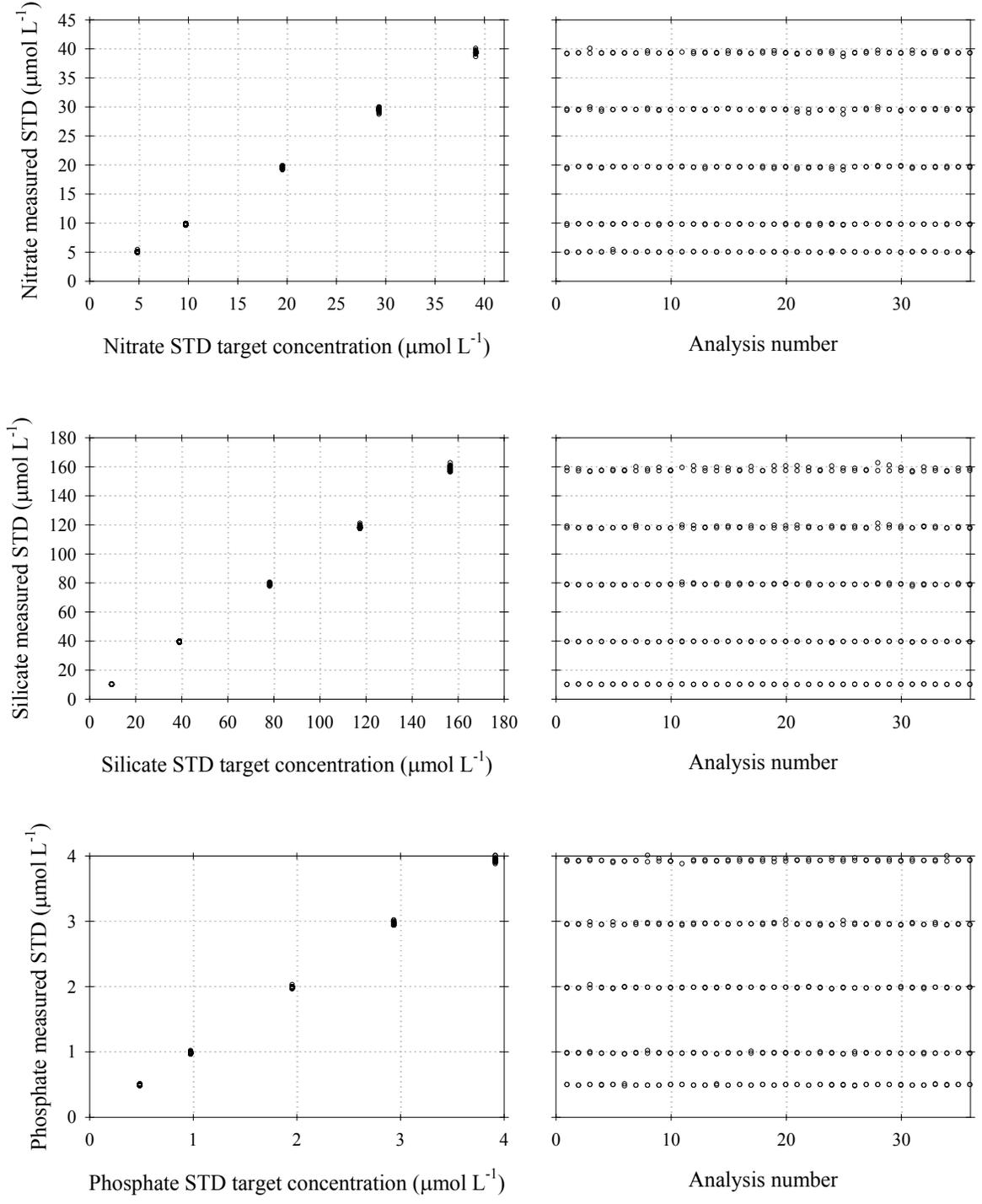
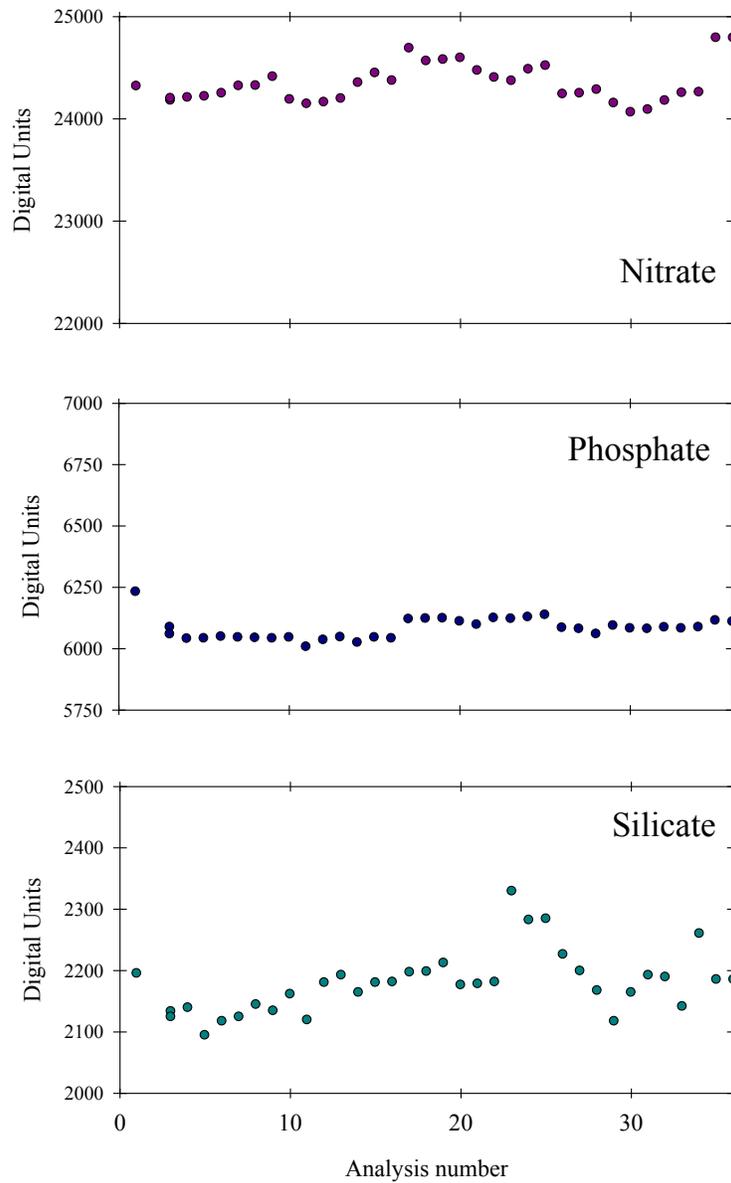
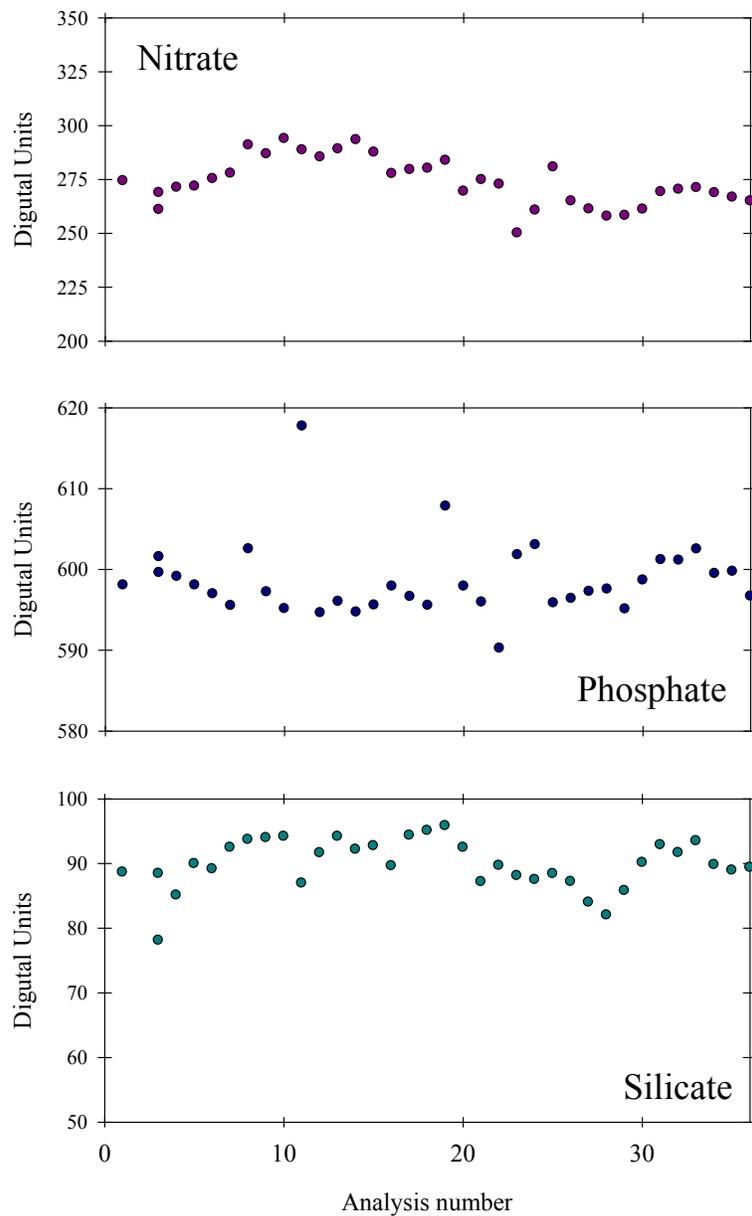


Figure 5.2. Complete set of 'measured' standards plotted against the 'target' concentration (left side panels). 'Measured' standards plotted against respective analysis number (right side panels).



*Figure 5.3. Baselines time series. The baselines for nitrate and phosphate were fairly consistent throughout the cruise, with the silicate baseline being more variable. Although the variability observed does not affect the results, it can be a good indicator of the quality of artificial seawater and reagents used.*



*Figure 5.4. Calibration slopes time series. These show the sensitivity of the three different autoanalyser channels (i.e., nitrate, silicate and phosphate), with increasing values (in digital units) indicating better sensitivity. Though there is variability, the slopes for the three channels do not show dramatic changes, albeit a slight tendency in the nitrate calibration slopes to decrease with time.*

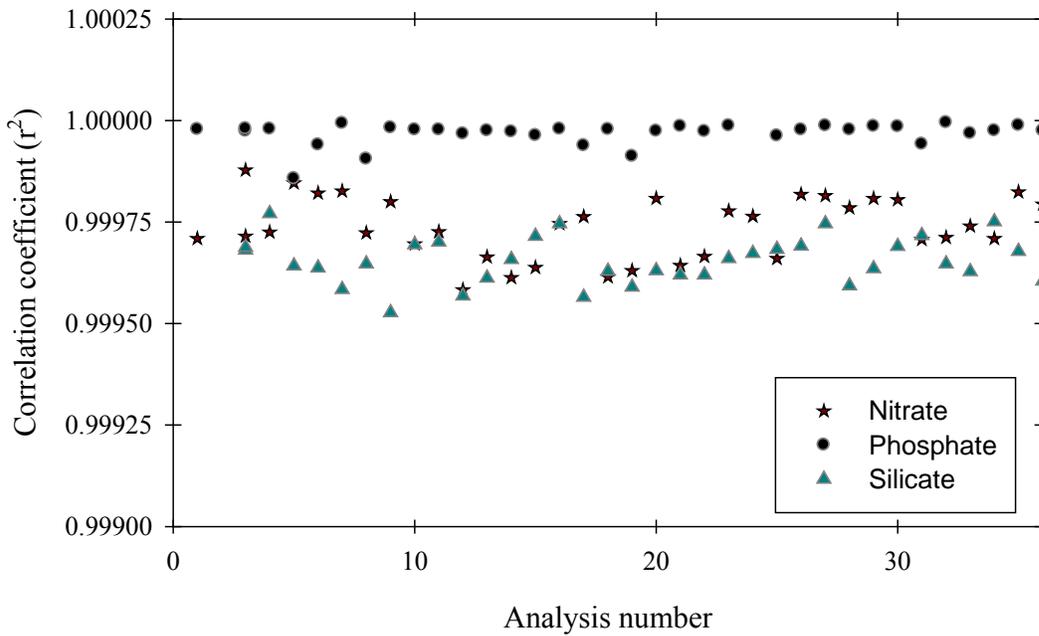


Figure 5.5. Calibration correlation coefficients. All  $r^2$  were better than 0.999.

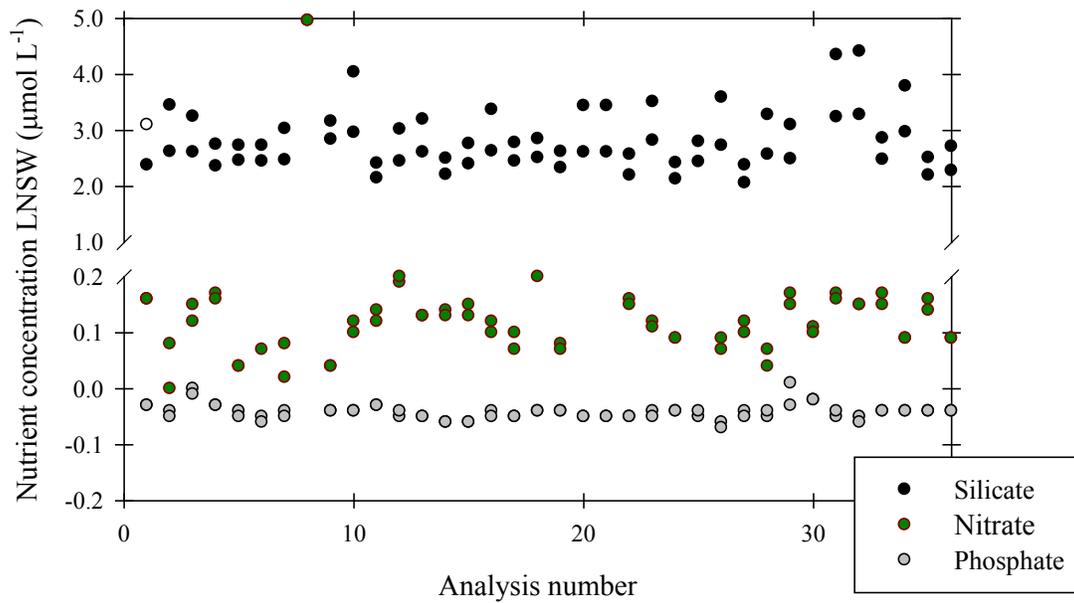


Figure 5.6. Low Nutrient Seawater (LNSW) time series. Black dots represent silicate, green dots represent nitrate and grey dots represent phosphate concentrations.

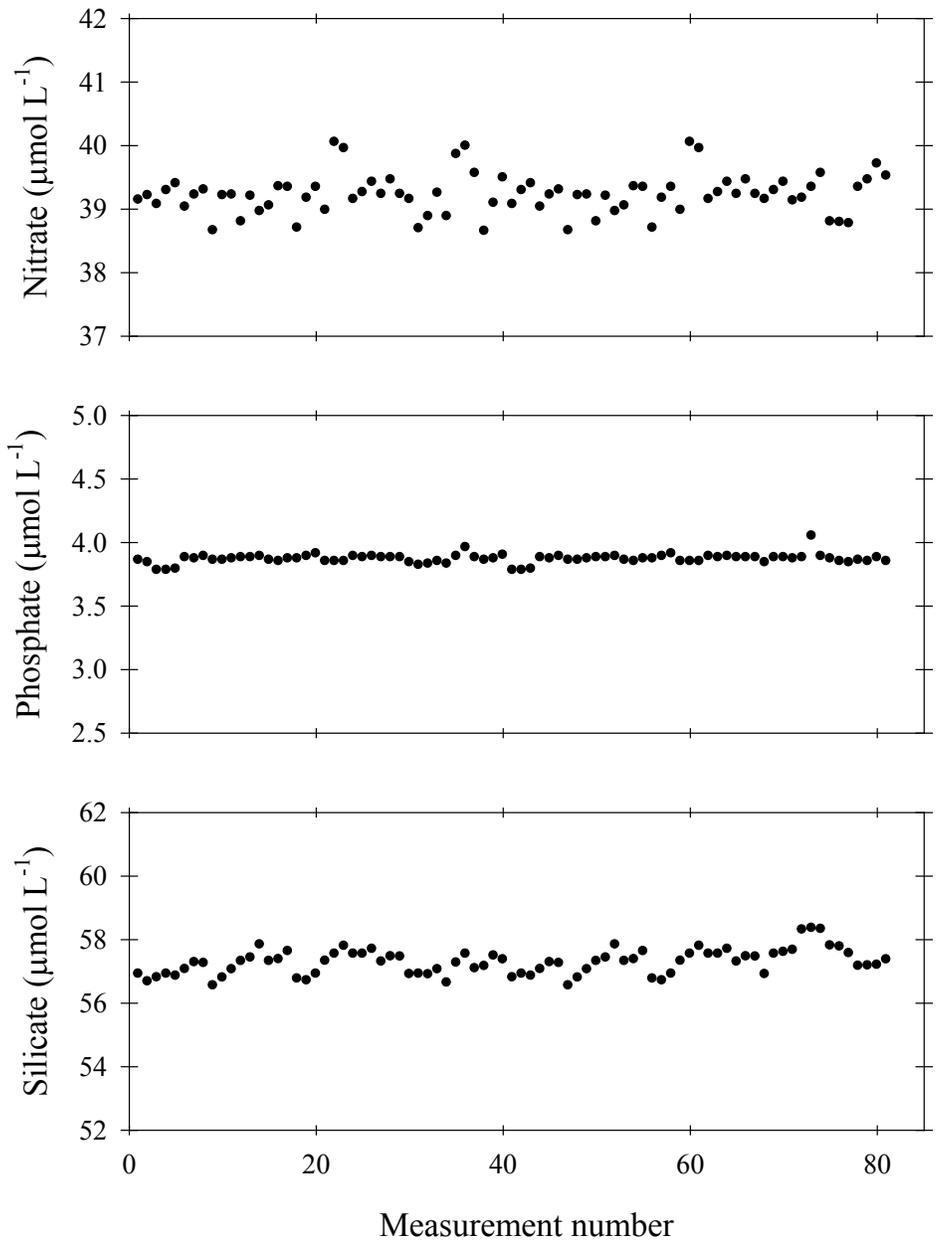


Figure 5.7. Time series of certified standard with average concentrations of  $39.2 \pm 0.3 \mu\text{mol L}^{-1}$  for nitrate,  $3.87 \pm 0.04 \mu\text{mol L}^{-1}$  for phosphate and  $57.3 \pm 0.4 \mu\text{mol L}^{-1}$  for silicate.

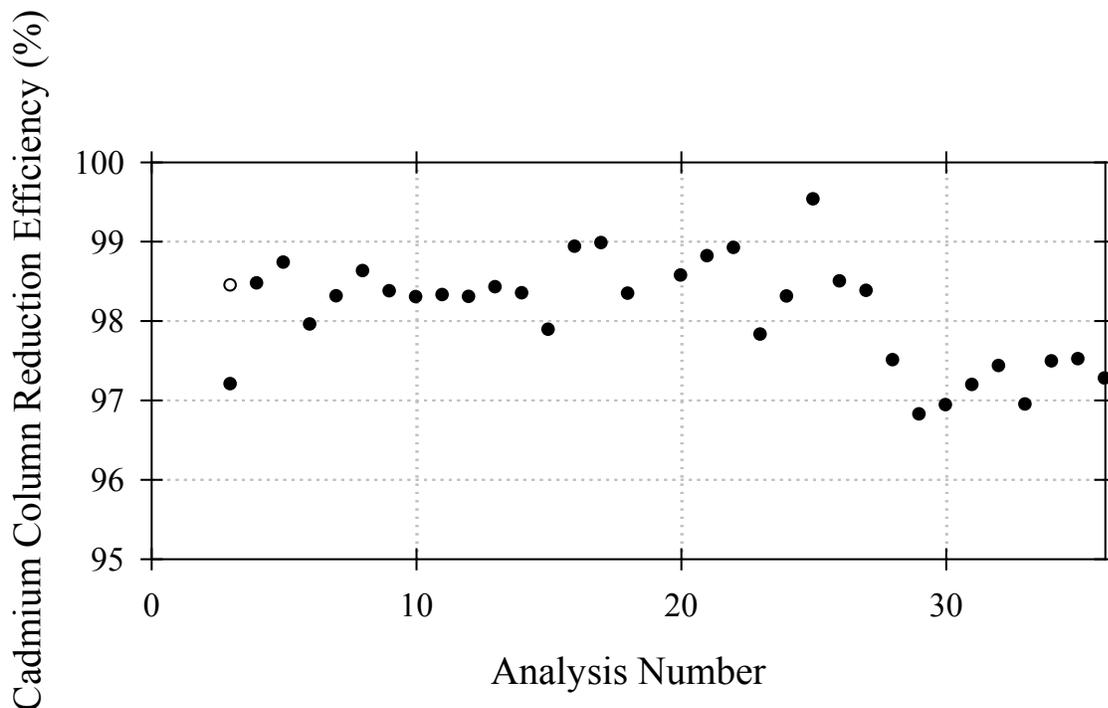


Figure 5.8. The efficiency of the cadmium column in reducing nitrate to nitrite is tested by measuring a nitrite standard of similar concentration to the top nitrate standard (approximately 40 mmol L<sup>-1</sup>). This figure shows the ratio of nitrate to nitrite for all analysis carried out (expressed in %). The nitrite standard prepared however was slightly higher than the nitrate standard, thus resulting in a ratio lower than 1 (or lower than 100%). Knowing this, the nitrate to nitrite ratio is expected to remain relatively constant while the reduction efficiency of the cadmium column is 100%. The ratio changes after run 29 when a new nitrite standard solution was prepared, but remains roughly constant until the last run, indicating the efficiency of the cadmium column was about 100%. A new cadmium column was installed from run 25.

#### Low Nutrient Seawater:-

Certified Ocean Scientific International (OSIL) Low Nutrient Seawater (LNSW) was measured in duplicate in every run in order to test artificial seawater for contamination. LNSW has been also used as a quality control in order to check for the reproducibility of low nutrient concentrations.

#### Performance of the Analyser:-

The performance of the autoanalyser was monitored by producing time series plots of the following parameters: standards concentration, baseline, calibration slope (instrument sensitivity), calibration correlation coefficient, nitrate reduction efficiency, low nutrient seawater and certified standards. These are plotted against run/analysis number rather than date or station number given that runs sometimes included more than 2 stations.

The precision of the method was determined by monitoring the variations of the complete set of standards measured throughout the cruise. Results of the standards

measurements are summarised in Table 5.3 and shown in Figure 5.3. Triplicate analyses were performed on the first and last sample of every station, plus in a randomly selected sample for most station. These showed the sample variability of replicates from a given mean concentration was in general <0.5%, <0.3% and <0.5% for nitrate, silicate and phosphate respectively. The limits of detection of this method were estimated as twice the standard deviation of the concentration of lowest standard of each nutrient. The limits of detection of this method during JR239 and JR235 were 0.01 mmol L<sup>-1</sup> for PO<sub>4</sub><sup>3-</sup>, 0.13 mmol L<sup>-1</sup> for NO<sub>3</sub><sup>-</sup> and 0.15 mmol L<sup>-1</sup> for Si(OH)<sub>4</sub>.

|              | NO <sub>3</sub> <sup>-</sup> | Prec. | PO <sub>4</sub> <sup>3-</sup> | Prec. | Si(OH) <sub>4</sub> | Prec. |
|--------------|------------------------------|-------|-------------------------------|-------|---------------------|-------|
| <i>Std 1</i> | 39.2 ± 0.18                  | 0.5%  | 3.92 ± 0.02                   | 0.5%  | 157.8 ± 1.3         | 0.8%  |
| <i>Std 2</i> | 29.4 ± 0.18                  | 0.6%  | 2.95 ± 0.02                   | 0.5%  | 117.9 ± 0.8         | 0.6%  |
| <i>Std 3</i> | 19.5 ± 0.13                  | 0.7%  | 1.98 ± 0.01                   | 0.4%  | 78.6 ± 0.4          | 0.6%  |
| <i>Std 4</i> | 9.7 ± 0.07                   | 0.7%  | 0.97 ± 0.01                   | 0.9%  | 39.2 ± 0.2          | 0.4%  |
| <i>Std 5</i> | 4.9 ± 0.07                   | 1.3%  | 0.49 ± 0.01                   | 1.3%  | 9.8 ± 0.07          | 0.8%  |

Table 5.3. Mean and variation of all standards measured, and precision of the analysis at each concentration (mmol L<sup>-1</sup>).

## 5b(ii) Dissolved Oxygen

All stations occupied during JR239 and JR235 were sampled for dissolved oxygen (DO). This was done just after CFCs and noble gases were sampled. Seawater was collected directly into pre-calibrated glass bottles using a Tygon® tube. Before the sample was drawn, bottles were flushed with seawater for several seconds (for about 3 times the volume of the bottle) and the temperature of the water was recorded simultaneously using a hand-held thermometer. The fixing reagents (i.e., manganese chloride and sodium hydroxide/sodium iodide solutions) were then added. Care was taken to avoid bubbles inside the sampling tube and sampling bottle, and a water seal was used after the sample was fixed. Samples were thoroughly mixed following the addition of the fixing reagents and were then kept in a dark plastic crate for 30-40 min to allow the precipitate to settle to <50% the volume of the bottle. Once the precipitate had settled all samples were thoroughly mixed for a second time in order to maximize the efficiency of the reaction. Analyses were carried out within 2-10 h of sample collection.

### Methods

DO determinations were made using a Winkler Ω-Metrohm titration unit (794 DMS Titrimo) with an amperometric system to determine the end point of the titration (Culbertson and Huang, 1987). Chemical reagents were previously prepared at NOCS following the procedures described by Dickson (1994). Recommendations given by Dickson (1994) and by Holley and Hydes (1994) were adopted. In general, thiosulphate calibrations were carried out every week using a 1.667 mmol L<sup>-1</sup> certified OSIL iodate standard. Calibration values are summarised in Table 5.4 (see observations section below). Thiosulphate solutions were prepared by dissolving 50 g of sodium thiosulphate in 1 L of Milli-Q water. These solutions were left to stabilise for 24 h and a new calibration was carried out before using it. Calculation of oxygen concentrations were facilitated by the use of an Excel spreadsheet provided by Dr. Richard Sanders (NOCS).

This spreadsheet has been modified/corrected to include pipettes' calibrated dispensing volumes (i.e., reagents and iodate standard additions have been calibrated).

Figure 5.9 shows a time series of replicates

### *Observations*

1) Table 5.4 shows thiosulphate calibrations carried out during the cruise. The blank and standard titre values are used for the calculation of dissolved oxygen concentrations and typically these are updated in the calculation sheets every time a calibration is performed. As can be seen in Table 5.4, not all the calibrations were used for the calculation of results. This was due to the fact that in previous cruises it was found that a change in the third decimal place of the difference between the standard and the blank can modify the results significantly. The blank and titre values can of course change if the thiosulphate solution evaporates or degrades, however, dramatic changes are unlikely to occur. The calibration number 1 was not used because a new solution has to be left to stabilise for at least 24 hours, and though this was the case, a second calibration suggested the solution was not stable enough during the first calibration. The third calibration suggested the second calibration was appropriate relative to the first. Calibrations 4 to 7 however produced inconsistent results and thus it was decided not to use them.

A way to assess whether a calibration is correct is by analysing the difference between the CTD oxygen sensor and the measurements ( $\text{Bot\_oxy} - \text{CTD\_oxy}$ ). Provided the CTD oxygen sensor is reliable, calculation of dissolved oxygen with different thiosulphate calibrations should yield consistent differences. If this is not the case, this may indicate a given calibration needs to be ignored and a new one carried out. When assessing the calibrations though, a significant change was observed in the difference between the CTD and the measurements, which made it difficult to properly assess whether a given calibration produced consistent results. A test was thus carried out, where dissolved oxygen concentrations for stations 23-30 were calculated with calibrations 3-7 (Table 5.4). This test suggests, 1) that there was a problem with the CTD oxygen sensor and 2) given the spread of the differences, that either all calibrations produce similar results or that the spread is larger than the noise incurred by using different calibrations and that we can not assess them properly.

2) A similar problem was encountered after preparing a new solution of thiosulphate (calibration 8, Table 5.4). However, at the time of writing (23/04/2010) we have not been able to assess these calibrations (8-10), by comparing the differences between the CTD oxygen values and the measurements. Given that calibration 10 is rather consistent with calibration 9, dissolved oxygen concentrations for stations 56-68 may need to be recalculated.

3) In general, replicate measurements of selected samples were carried out in order to test for reproducibility. At least one Niskin bottle was always sampled in duplicate, typically the deepest. Any misfires were used to duplicate further Niskin bottles. All repeats are shown and information summarised in Figure 5.10.

| Calibration number | Date       | BLK (mL) | STD (mL) | STD-BLK | Thiosulphate Molarity | Used from CTD No. |
|--------------------|------------|----------|----------|---------|-----------------------|-------------------|
| 1*                 | 21/03/2010 | 0.0010   | 0.4991   | 0.4981  | 0.1959                | ---               |
| 2                  | 22/03/2010 | 0.0006   | 0.5023   | 0.5016  | 0.1945                | 1-20              |
| 3                  | 28/03/2010 | 0.0012   | 0.5030   | 0.5018  | 0.1944                | 21-55             |
| 4                  | 03/04/2010 | 0.0011   | 0.5080   | 0.5069  | 0.1924                |                   |
| 5                  | 03/04/2010 | 0.0010   | 0.4993   | 0.4989  | 0.1958                |                   |
| 6                  | 05/04/2010 | -0.0016  | 0.5054   | 0.5070  | 0.1924                |                   |
| 7                  | 06/04/2010 | 0.0011   | 0.5033   | 0.5022  | 0.1959                |                   |
| 8*                 | 08/04/2010 | 0.0004   | 0.5103   | 0.5099  | 0.1913                | 56-68             |
| 9                  | 12/04/2010 | 0.0000   | 0.5021   | 0.5021  | 0.1943                | 70-98             |
| 10                 | 19/04/2010 | 0.0006   | 0.5033   | 0.5028  | 0.1940                |                   |

Table 5.4. JR239 and JR235 O<sub>2</sub> determinations; number of thiosulphate calibrations, dates on which calibrations were carried out, mean blank titre volume (BLK), standard titre volume (STD), STD minus BLK, molarity of thiosulphate solution and stations affected by each calibration (\*new thiosulphate solution prepared).

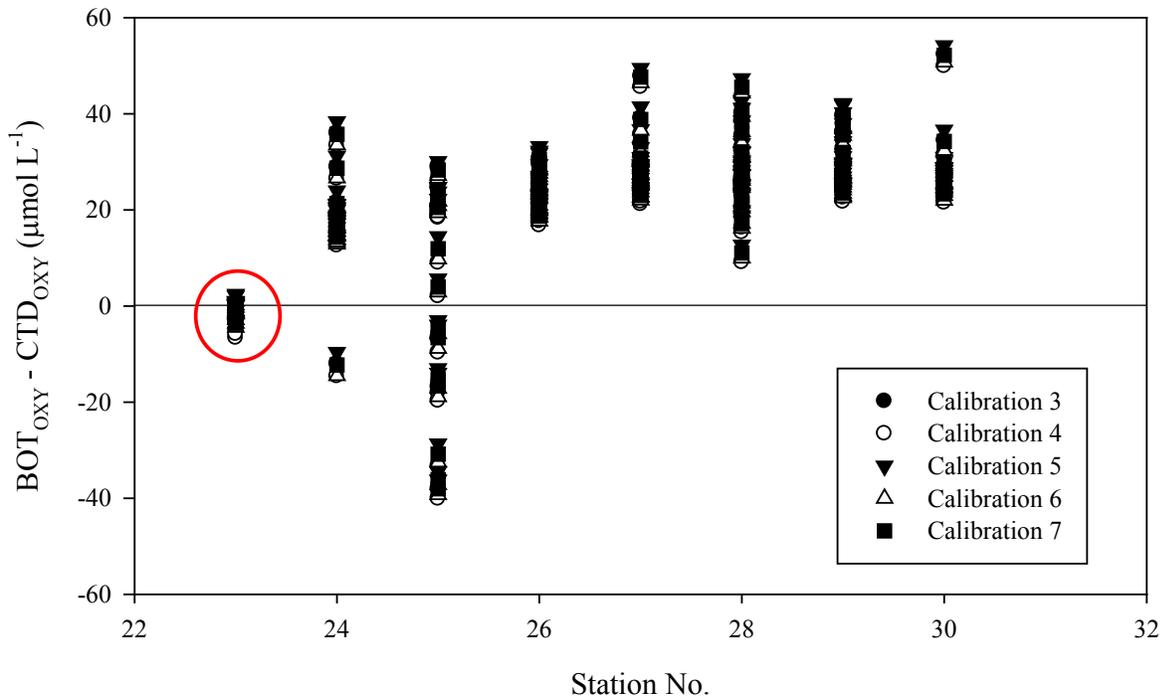


Figure 5.9. Tests carried out in order to assess the reliability of thiosulphate calibrations 4-7. The red circle shows results of calculating dissolved oxygen (DO) values for station 23 with calibrations 3-7. The spread of this station is similar for stations 1-23. However, there is a significant change from station 24 resulting in a larger spread. Given that DO values calculated with the calibrations shown produce similar values, these results suggest there was a problem with the CTD oxygen sensor, which makes it difficult for us to properly assess the calibrations carried out.

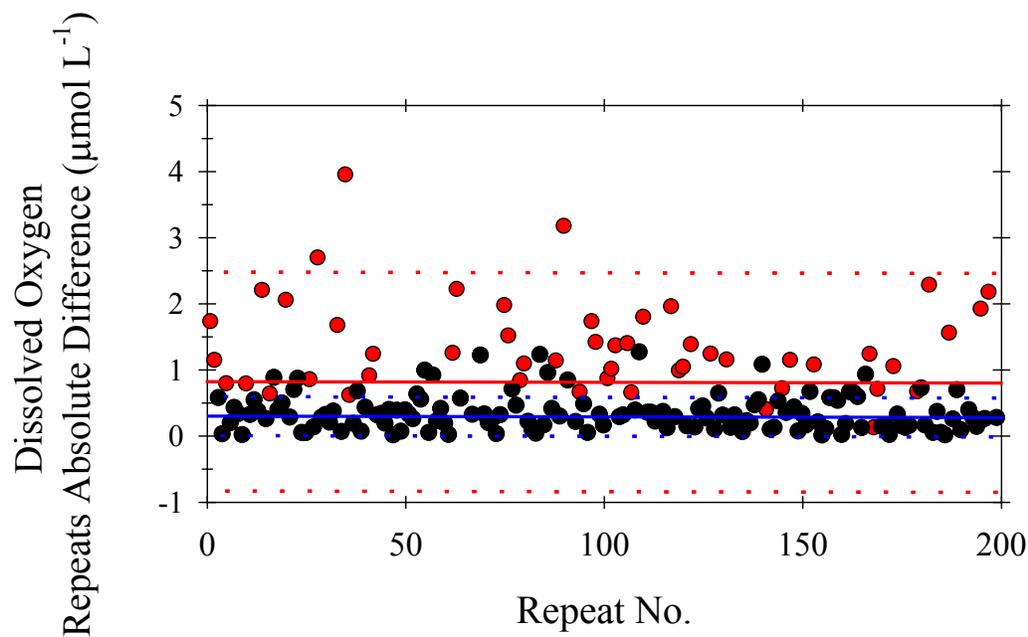


Figure 5.10. The absolute replicate difference for the oxygen bottles in each CTD cast ( $n=199$ ). The mean and the standard deviation are specified with solid and dash lines respectively. Black symbols and blue lines show replicate values flagged as good ( $0.3 \pm 0.3$  mmol L<sup>-1</sup>) and red symbols and lines show all data, included values flagged as dubious or bad ( $0.8 \pm 1.6$  mmol L<sup>-1</sup>).

#### Preliminary results

Figure 5.11 shows sections of nitrate, phosphate and silicate along the JR239 (ANDREX II) transect, with imposed contours of salinity, temperature and dissolved oxygen. All three nutrient sections show a strong signal of high concentration (130 mmol L<sup>-1</sup> silicate, 34 mmol L<sup>-1</sup> nitrate and 2.39 mmol L<sup>-1</sup> phosphate) which decreases and thins westwards at mid depths (1000-3000 m), from 17 °W to 40°W. This signal is in particular noticeable in the silicate and phosphate sections. Another conspicuous feature is a layer of relative high nutrient concentrations (115 mmol L<sup>-1</sup> silicate, 32 mmol L<sup>-1</sup> nitrate and 2.2 mmol L<sup>-1</sup> phosphate) underlying the bottom of the section, associated with Weddell Sea Deep and Bottom Waters. Nutrients and dissolved oxygen distributions closely follow the pattern of the isotherms.

#### References

- Culberson, C.H. and Huang, S. (1987) Automated amperometric oxygen titration. *Deep Sea Research*, 34, 875-880.
- Dickson, A.G. (1994) Determination of dissolved oxygen in seawater by Winkler titration. Technical report, WOCE operations manual, WOCE report 68/91 Revision 1 November 1994.
- Holley, S.E. and Hydes, D.J. (1994) Procedures for the determination of dissolved oxygen in seawater. Technical report, James Rennell Centre for Ocean Circulation.
- Kirkwood, D. (1996) Nutrients: Practical notes on their determinations in seawater. ICES Techniques in marine environmental sciences. 17, 1-25.

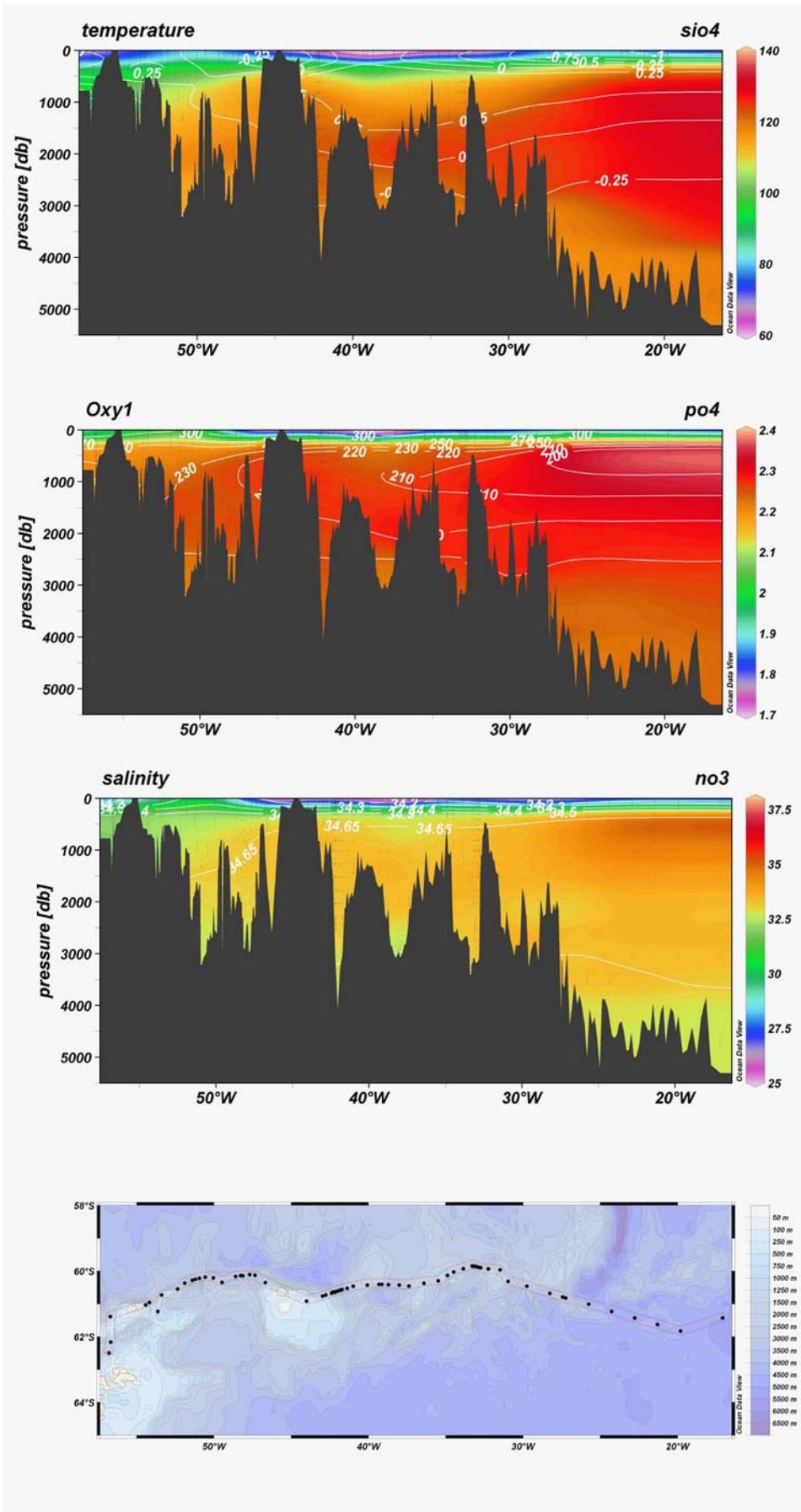


Figure 5.11. Nitrate, silicate and phosphate sections along the JR239 (ANDREX II) transect, with salinity, temperature and dissolved oxygen isolines superimposed.

## 5c. Chlorofluorocarbons (CFCs), carbon tetrachloride (CCl<sub>4</sub>) and sulphur hexafluoride (SF<sub>6</sub>)

(Peter Brown, Stephen Woodward, Andrew Brousseau)

A series of four halocarbons (dichlorodifluoromethane – CFC-12, trichlorofluoromethane - CFC-11, trichlorotrifluoroethane - CFC-113 and carbon tetrachloride - CCl<sub>4</sub>) and sulphur hexafluoride (SF<sub>6</sub>) were measured on board by a purge-and-trap gas chromatographic method. The instrumentation was developed at the University of East Anglia by Marie-Jose Messias following the Lamont Doherty Earth Observatory (LDEO) design (Bill Smethie, 2004, personal communication). The method combines the LDEO CFC method [Smethie et al., 2000] and the Plymouth Marine Laboratory SF<sub>6</sub> method [Law et al. 1994] tied together with a common valve for the introduction of gas and water samples. This system has the advantage of a simultaneous analysis of SF<sub>6</sub> and halocarbons from the same water sample but the running time per sample is long; ~23 minutes when including CCl<sub>4</sub>. The system was set up in a UEA laboratory container on the aft deck of the *RRS James Clark Ross*.

### 1. Sample collection and Analysis technique

Water samples were collected from 20 litre bottles attached to the CTD sampling rosette. As per WOCE protocol, they were the first samples drawn. The Niskin nitrile 'O' rings were first washed in isopropanol and baked in a vacuum oven for 24 hours to remove susceptible contamination before installation in individual Niskin bottles. The trigger system of the bottles was external stainless steel springs. Water samples were collected in 500 ml ground glass stoppered bottles that were filled from the bottom using Tygon tubing and overflowed at least 2 times to expel all water exposed to the air. Immediately after sampling, the glass bottles were immersed in a cool box of clean, cold deep water in the CTD annex until the full complement of Niskins for each station had been sampled. Samples were then moved to cool boxes situated in the cold storage facility, they were stored immersed in clean, cold deep water until removed for analysis. This room was kept at 5°C, although ice packs were added as necessary to maintain a temperature below 5°C and prevent degassing.

For air sampling, ¼" o.d. Dekabon tubing was run from the system to the foremast of the ship. Air was pumped through the line to the instrument using a DA1 SE Charles Austen pump, with the line being flushed for approximately 30 minutes before beginning analysis.

Sample analysis was performed on board as soon as possible after collection using a coupled SF<sub>6</sub> and CFCs system with a common valve for the introduction of gas and water samples. Samples were introduced to the system by applying nitrogen (N<sub>2</sub>) pressure to the top of the sample bottles, forcing the water to flow through and fill a 25 cm<sup>3</sup> calibrated volume for CFCs and a 300 cm<sup>3</sup> volume for SF<sub>6</sub>. The measured volumes of seawater were then transferred to separate purge and trap systems, before being stripped with N<sub>2</sub> and trapped at -100°C on a Unibeads 3S trap (for CFCs) and at -80 °C on a Porapak Q trap (for SF<sub>6</sub>) each immersed in the headspace of liquid nitrogen. Each purge and trap system was interfaced to an Agilent 6890N gas chromatograph with

electron capture detector (GC-ECD). The traps were heated to 100° C for CFCs and 65°C for SF<sub>6</sub> and injected into the respective gas chromatographs. The SF<sub>6</sub> separation was achieved using a molecular sieve packed 2m main column and 1m buffer column. The CFCs separation was achieved using a 1m Porasil B packed pre-column and a 1.5m carbograph AC main column. The carrier gas was pure nitrogen, which was cleaned by a series of purity traps (molecular sieve 13X and charcoal).

Liquid nitrogen was used as the cryogenic cooling material for the sample traps, and was provided by the on-board liquid nitrogen generator located at the back of the CTD annex (See [Appendix 3](#)). An additional quantity of 170L was also acquired in Montevideo prior to leaving port for use whilst the generator was commissioned and still building up reserves - this was stored in four UEA dewars located on the boat deck. Of the 170L obtained, approximately 50L was used in the initial few days of the cruise before small quantities were available to be withdrawn from the generator's dewar. An additional 30L was lost from one of the four storage UEA dewars due to a combination of a poor closure system and warm temperatures.

Once fully active, approximately 8L a day was removed from the generator's dewar for use in sample analysis. Additional quantities were removed to top up the three remaining functional UEA dewars, whose filling was completed after approximately two weeks. Towards the end of the cruise, the generator dewar was typically between ¾-full and full.

## 2. Calibration

The CFCs/SF<sub>6</sub> concentrations in air and water were calculated using an external gaseous standard. The standard supplied by NOAA (Brad Hall, December 2008) corresponds to clean dry air slightly enriched in SF<sub>6</sub>, CFC-11 and CCl<sub>4</sub> in a 29L Aculife-treated aluminum cylinder (Table 5.5). The calibration curves were made by multiple injections of different volumes of standard that span the range of tracers measured in the water. Complete calibration curves were made at the beginning and end of the cruise, with intermediate calibration curves being carried out every ~48 hours. The calibration curves generated during the cruise can be seen for each tracer parameter in [Figure 5.12](#).

| AAL_70510        |              |         |                  |
|------------------|--------------|---------|------------------|
|                  | Mixing ratio | Std Dev | Scale NOAA       |
| SF <sub>6</sub>  | 9.78 ppt     | 0.02    | 2006             |
| CFC-12           | 510.6 ppt    | 0.8     | 2001             |
| CFC-11           | 1010 ppt     | 5       | To be determined |
| CFC-113          | 75.2 ppt     | 0.28    | 2002             |
| CCl <sub>4</sub> | 511 ppt      | 3       | To be determined |

*Table 5.5: Details of calibration standard used*

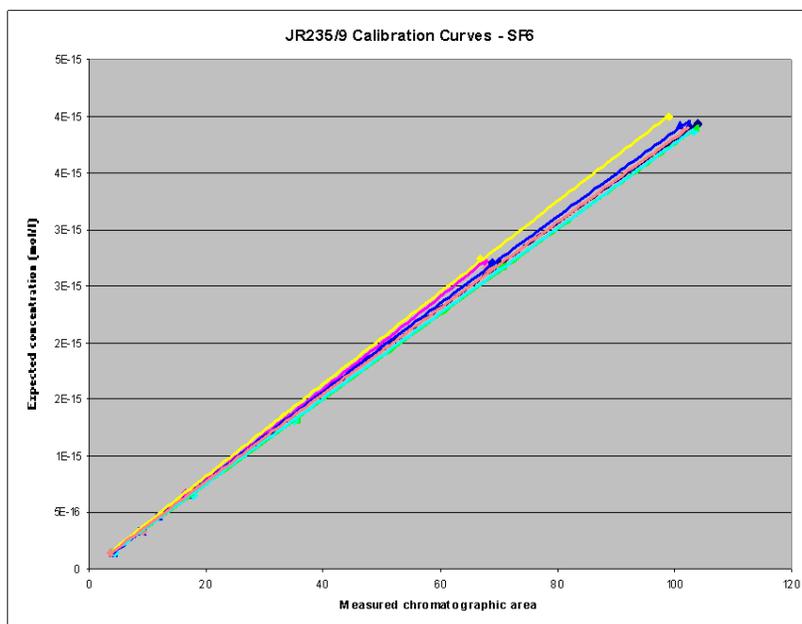


Figure 5.12. Calibration curves generated through the analysis of a gas standard at different injection sizes. Different colours indicate separate calibrations undertaken. Above: SF6 (see also [next page](#)).

Changes in the slope of the curve indicate some change in the response and sensitivity of the instrument. The finer variability of this changing response behavior was monitored throughout the cruise through the analysis of a fixed volume of standard gas every ~6-10 samples (~2.5-4.5 hours). These analyses will be used to fine-tune the calibration of the final data.

Figure 5.13 shows the control charts over the course of the cruise of the instrument response for the standard analyses for each of the five tracers investigated. The thick, solid red lines are the cruise means, with the dashed red lines indicating +/- 3 standard deviations of the mean. All values can be seen to lie within these limits, meaning that the instrumental system and analysis process was in control at all times. An exception to this can be seen for CFC-113 and for CCl<sub>4</sub>; for CFC-113 there are two instances where the standard analysis result falls out of the control limits. Initial investigations failed to identify a cause, but the quick return to within control conditions suggested an unidentified random error being the cause. For CCl<sub>4</sub>, analyses at the start of the cruise gave somewhat higher responses before the instrument settled down to a more uniform and consistent response. A certain wave-like structure is apparent for a number of the tracers – this is thought to be maybe temperature related, with higher laboratory container temperatures often eliciting a higher instrumental response. This is examined by the plotting of temperature (in pink) on a number of the control charts for comparison.

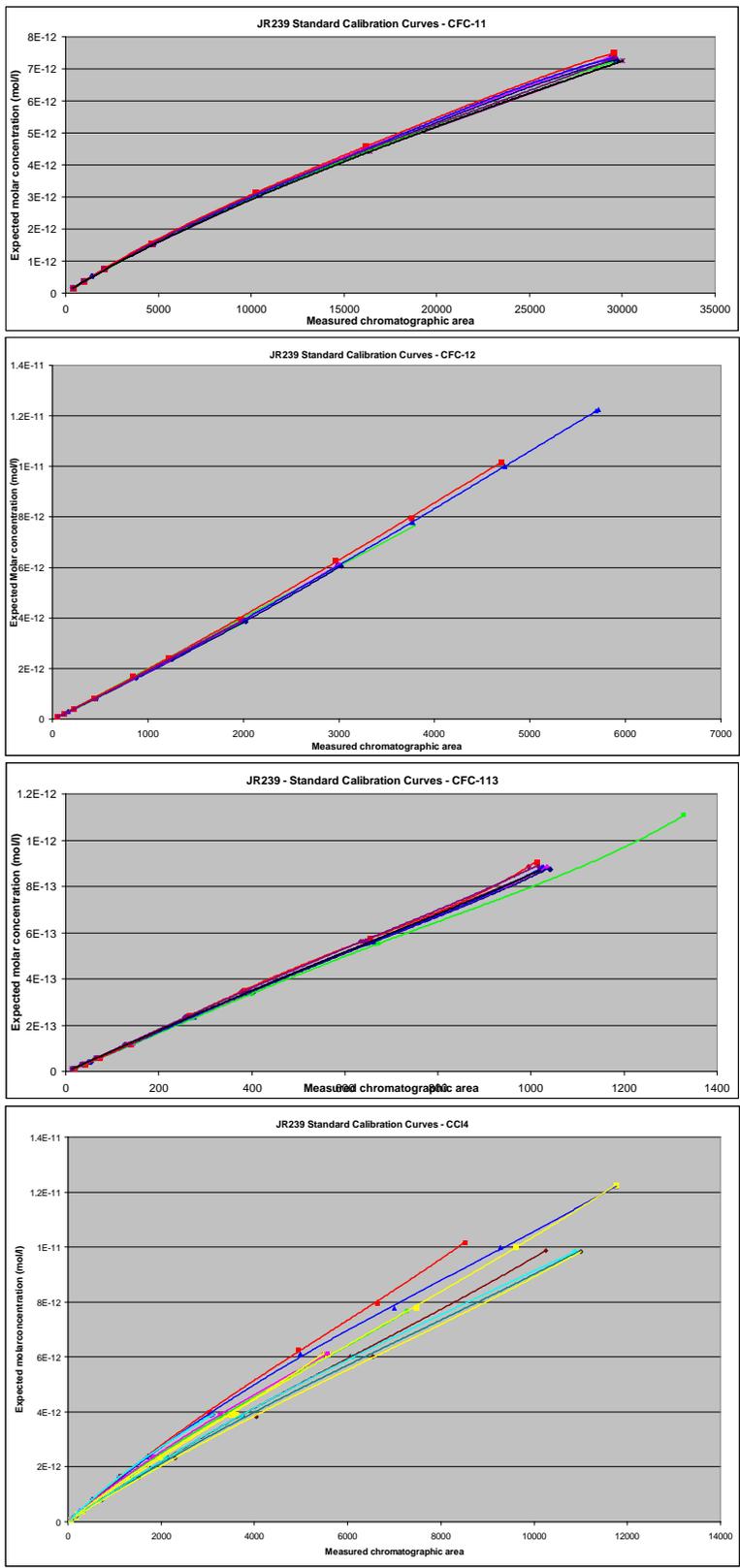


Figure 5.12 (cont). Calibration curves for CFC-12, CFC-11, CFC-113, and CCl<sub>4</sub>.

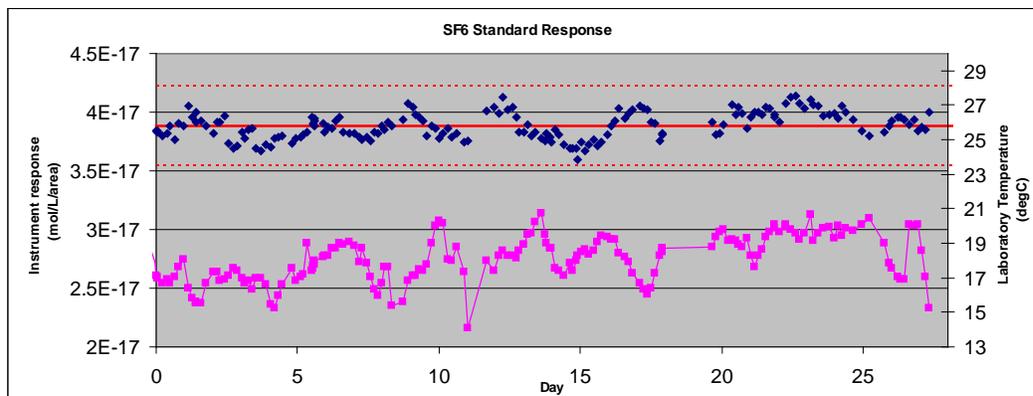


Figure 5.13. Control chart of instrumental response for standard analyses of SF<sub>6</sub> during JR239. Laboratory container temperature also plotted. (Figure continued on next page)

### 3. Precision and accuracy

The precision (or reproducibility) for the water samples measurements can be determined from replicate samples drawn from the same Niskin. 50 duplicate samples were drawn at randomly from the rosette along the cruise when time permitting and additional surface samples were collected during initial transit from Montevideo to Port William, Falkland Islands. Initial estimates of precision were calculated using the average standard deviation for duplicate analyses: results were 0.005 fmol/L for SF<sub>6</sub>, 0.006 pmol/L for CFC-12, 0.009 pmol/L for CFC-11, and 0.002 pmol/L for CFC-113 and 0.02 pmol/L for CCl<sub>4</sub>. It is expected that these values will improve once final calibrations have been performed, they are converted to per kilogram units and any blank corrections have been applied.

The average standard deviation for the underway surface samples with modern concentrations are  $\pm 0.9\%$  for CFC-11,  $\pm 1.1\%$  for CFC-12,  $\pm 1.2\%$  for CFC-113,  $\pm 3.0\%$  for CCl<sub>4</sub> and  $\pm 2.5\%$  for SF<sub>6</sub>. Again, it is expected that these values will improve once final calibrations have been completed and blank corrections have been included.

The blank correction is to compensate for any trace CFCs/SF<sub>6</sub> originating from the sampling bottles, handling and from the measurements procedure. This correction is normally estimated from analysis of either samples collected in water that are free of CFCs or water collected after sparging all the tracers out of a sample. Zero SF<sub>6</sub> and CFC waters were not observed on this cruise. Lowest levels were observed between ~600m and 2000m in the waters of the eastern end of the ANDREX recovery section. System blanks were determined through the analysis of water samples that had been purged of all dissolved gases. This was achieved through the continual respurge of a single sample until uniform and consistent results were obtained. To investigate how the effects of Niskin sampling and sample handling contribute to the system blank, and 20L Niskin was sparged with oxygen-free nitrogen at 440 mL/minute for 19.5 hours in order to purge it of all dissolved CFCs, CCl<sub>4</sub> and SF<sub>6</sub>. Initial analyses appear to suggest that some tracers are introduced into the system during this process. However, additional investigations are required to confirm this.

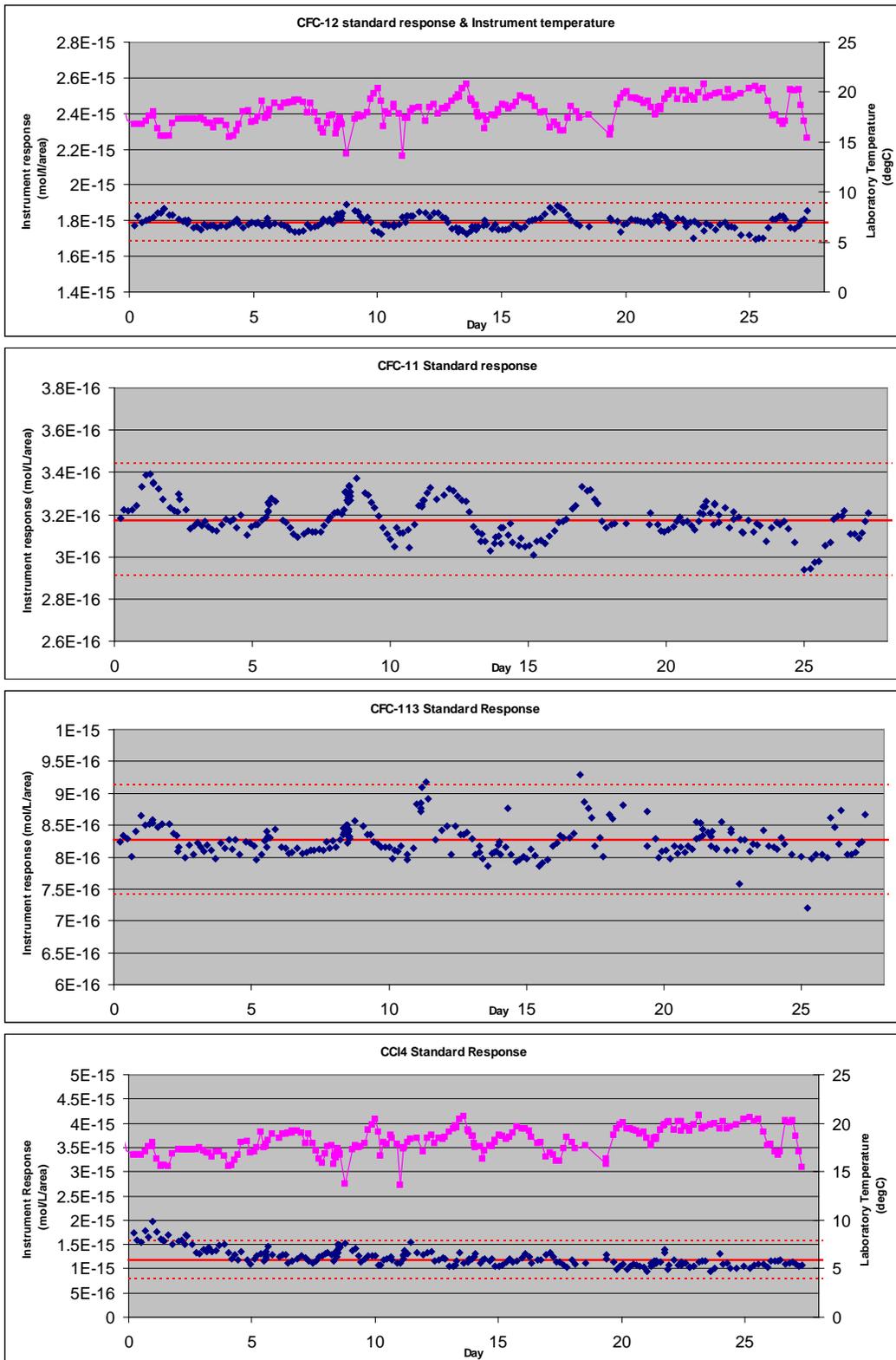


Figure 5.13 cont. Control chart of instrumental response for standard analyses of CFC-12, CFC-11, CFC-113 and  $\text{CCl}_4$  during JR239. Laboratory container temperature also plotted for CFC-12 and  $\text{CCl}_4$ .

The detection limit, expressed as the double peak height of the measured noise, lies within 0.007 pmol kg<sup>-1</sup> for CFC-11, 0.017 pmol kg<sup>-1</sup> for CFC-12, and 0.002 pmol kg<sup>-1</sup> for CFC-113 and CCl<sub>4</sub>.

Additional factors affecting accuracy include trapping efficiency (functions of temperature and flow rate), and chromatographic considerations, such as interferences and baseline variation. Sparge efficiencies were investigated through the continual resparge of a single sample until results did not change (having reached the system blank) at a number of different flow rates. Initial results for general lab conditions for the tracers under investigation were as detailed in Table 5.6.

| Tracer           | Sparge efficiency |
|------------------|-------------------|
| SF <sub>6</sub>  | 97.8 %            |
| CFC-12           | 98.8 %            |
| CFC-11           | 99.3 %            |
| CFC-113          | 96.7 %            |
| CCl <sub>4</sub> | 97.9 %            |

*Table 5.6. Initial sparge efficiencies estimated for the tracers under investigation during JR239.*

These effects will all be assessed in more detail and accounted for in the final data set, but have not yet been addressed. Particular difficulty was noted for CCl<sub>4</sub>, where larger changes in instrument response were noted than for the other tracers.

#### 4. Data

In total, 68 of 98 stations were sampled and analysed for CFCs and SF<sub>6</sub>. Including standards, 2005 analyses were performed for CFCs and 1731 for SF<sub>6</sub>. Initial, uncalibrated results are presented in [Figure 5.14](#). The distributions of the CFCs and SF<sub>6</sub> seen here are largely consistent with previous studies, showing a broad surface maximum, minimum between 400 to 2000m and a measurable signal in the bottom waters.

The final analysis of this data set will involve additional filtering for instrumental problems, outlier identification, correction for standard drift and refined blank and extraction efficiency corrections.

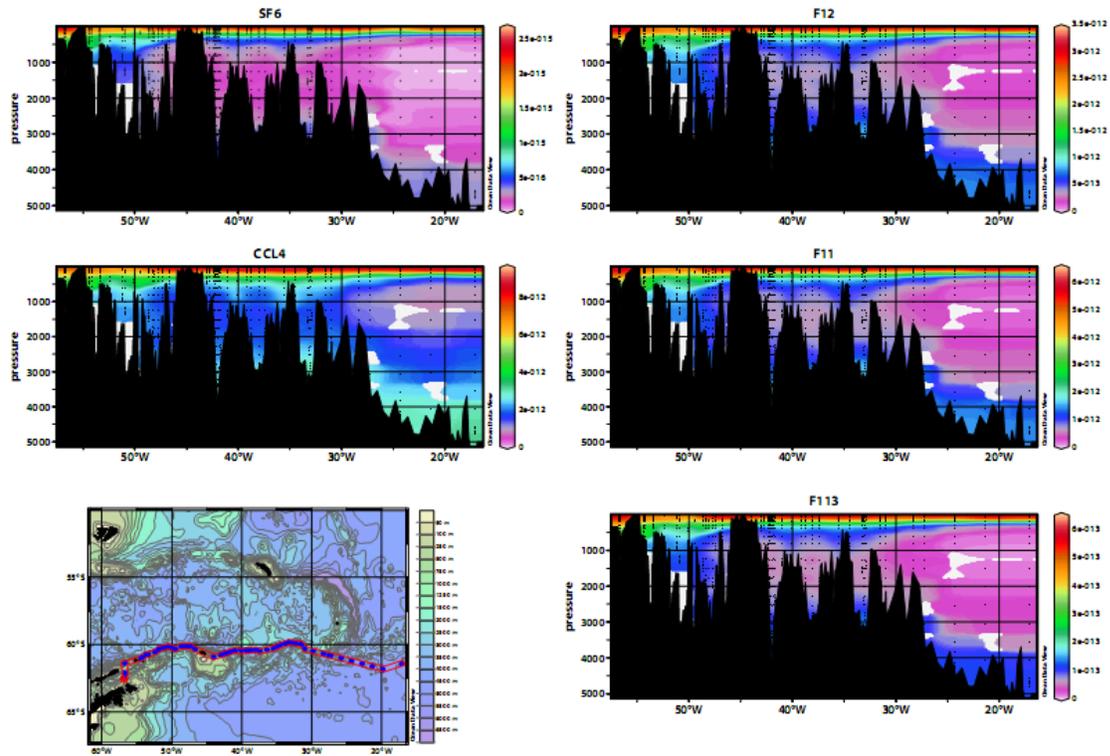


Figure 5.14. Initial section profiles for CFCs and SF<sub>6</sub> along ANDREX recovery section. Data are uncalibrated and so only internally consistent.

## 5d. Carbonate parameters

Dorothee C.E. Bakker, Elizabeth Jones, Maciej Telszewski and Stephen Jones

### 1. Rationale

In the Southern Ocean, ventilation of the deep ocean and uptake of anthropogenic CO<sub>2</sub> take place. Deep water upwelling at the surface leads to exchanges of heat, CO<sub>2</sub>, and other gases with the atmosphere. Estimates of net oceanic CO<sub>2</sub> uptake south of 50°S for ~1995 range from 0.1-0.5 Pg C yr<sup>-1</sup> (Pg = 10<sup>15</sup> g) (Rayner et al., 1999; Takahashi et al., 2002, 2009). The relatively small net sink may reflect a transition from a pre-industrial source for atmospheric CO<sub>2</sub> to a modern day CO<sub>2</sub> sink.

The strongest circulation feature of the Southern Ocean is the Antarctic Circumpolar Current (ACC). The Weddell Gyre is a large elongated clockwise rotating gyre, south of the ACC. Upwelling of Lower Circumpolar Deep Water (with a sizeable component of former North Atlantic Deep Water) occurs in the central Weddell Gyre. In parallel, major quantities of dense deep and bottom water are produced near and on the Antarctic continental shelf. The largest share of dense waters is produced in the southern and western Weddell Gyre. There is discussion to the quantity of anthropogenic carbon taken up by these deep and bottom waters (Sabine et al., 2004; Lo Monaco et al., 2005), in particular as to what extent the near-year round ice cover impedes uptake of anthropogenic CO<sub>2</sub> from the atmosphere (Klatt et al., 2002). Part of the newly-formed deep and bottom waters leaves the Weddell Gyre through deep passages in the South Scotia Ridge, along the northern boundary of the gyre, while another part is transferred to the eastern gyre.

An east-west section with deep carbon and tracer measurements was carried out from 30°E to 17°W along the northern boundary of the Weddell Gyre in early 2009 (ANDREX-1 section on JC30). On JR239, this section was joined by a section from the tip of the Antarctic Peninsula along the South Scotia Ridge to the final ANDREX-1 station. The most westerly station of JC30 was repeated on JR239. In addition we carried out a deep northward section from inside the Weddell Gyre, via the South Scotia Ridge to South Georgia (partly repeating A23 and carbon measurements by US colleagues made in 2005).

### 2. Objectives

- Complete the deep carbon measurements along the northern boundary of the Weddell Gyre (ANDREX-1 section on JC30);
- Assess the export of natural and anthropogenic carbon from the Weddell Gyre, in particular across the deep passages in the South Scotia Ridge.
- Quantify the carbon budget for the Weddell Gyre;
- Carry out a deep northward carbon section from the Weddell Gyre, via the South Scotia Ridge to South Georgia (partly repeating A23).

- Assess the carbonate chemistry of the (upper) water column in these seasonally ice covered waters with abundant ice bergs.

### 3. Methods

#### 3.1. Vertical profiles of Dissolved Inorganic Carbon and Total Alkalinity

##### *Rosette sampling*

Water samples for the determination of DIC and alkalinity were drawn from the 20 l Niskin bottles on the CTD rosette and collected in 500 ml glass bottles with ample rinsing and overflowing to avoid gas exchange with the air. Almost 60% of the CTD stations were sampled, coinciding with sampling for trace gases. All depths were sampled on every CTD, unless the Niskin did not close or was leaking. The failure rate of Niskins was high early in the cruise, decreasing to ~one Niskin per cast afterwards. A total of 40 full depth CTD stations were sampled and analysed on the ANDREX-2 section, equivalent to about 800 samples. Sixteen stations were sampled on the northward section, of which 12 stations have been analysed to date, equivalent to about 220 samples. Two replicate samples were taken per cast. The samples were poisoned with a saturated mercuric chloride solution (100 µl per 500 ml sample) if they could not be analysed within 8 hours of collection. In practice about 90% of samples were poisoned.

##### *Dissolved Inorganic Carbon and Total Alkalinity measurements*

Water samples were analysed for DIC and TA on two VINDTA instruments. The VINDTA combined DIC/alkalinity instruments (#4 and #7, version 3C) operate at 25°C (Mintrop, 2004). Two replicate analyses for TA and DIC were made on each sample bottle. The DIC concentration was determined by coulometry after the method of Johnson et al. (1987). Generally all samples from one station were run using the same coulometer cell. Two to three CRMs (batches 96 and 97) were used per coulometric cell and station. The DIC content of the second replicate was often lower (by ~1 µmol/kg) than the first replicate due to outgassing of the sample during the long combined DIC and TA analysis. In such cases the second DIC replicate of a sample was discarded. This outgassing effect was not apparent for the CRM analyses. Tiny white or transparent particles in the water seemed to coincide with a lower reproducibility of DIC and TA replicates at some depths (both in the upper water column and at depth) on the northward section.

The alkalinity measurements were made by potentiometric titration. The acid consumption up to the second endpoint is equivalent to the titration alkalinity. The systems use a highly precise Metrohm Titrino 719S for adding acid, an ORION-Ross pH electrode and a Metrohm reference electrode. The burette, the pipette (volume approximately 100 ml), and the analysis cell have a water jacket around them. The titrant (0.1 M hydrochloric acid, HCl) was made in the home laboratory. The replicate analyses for TA did not show any systematic offsets and in general the average of both values was used.

The VINDTA instruments performed well for the first three weeks of the cruise. Common problems encountered included a rapidly corroding earth rod on the TA cell (#4), failing level sensors for pipette full and cell full (#4, #7), electrical interference (#4, #7) and rough sea state slowing down TA titrations and reducing the accuracy of TA and DIC analyses. Both VINDTAs had a loss of reproducibility of TA and DIC early on the northward section and two days were spent on troubleshooting and maintenance, which included replacing various

kinds of tubing, cleaning pipettes, the cell and strippers and repairing a faulty cell valve. The instruments regained their initial accuracy and reproducibility after the maintenance period. Downtime was low with the exception of the maintenance period and three evacuations of the laboratory container during bad weather. The DIC and TA data are undergoing quality control.

### *3.2. Underway pCO<sub>2</sub>*

#### *Partial pressure of CO<sub>2</sub> in surface water and marine air*

Continuous measurements of the partial pressure of CO<sub>2</sub>, pCO<sub>2</sub>, in surface water and marine air were made throughout the cruise. The precision and accuracy of the pCO<sub>2</sub> data are highly uncertain as the pCO<sub>2</sub> readings exhibited long-term drift, presumably due to a leak on the reference cell or inside the LI-COR, which we did not manage to locate and repair.

The ship's seawater supply provided a high volume of water for underway sampling from 6.5 m depth at the bow to the laboratory container on the aft deck. Temperature and salinity of the intake water were determined by the ship's sensors. In the laboratory container, which was placed at the aft deck, the seawater passed a strainer with a bypass, and the equilibrator for pCO<sub>2</sub> analysis. The bypass was incidentally used for discrete sampling water for dissolved inorganic carbon (DIC) and alkalinity.

Marine air was pumped through tubing from the deck in front of the bridge at 15 m height. Seawater from the ship's surface water supply was introduced at a rate of 2-3 l min<sup>-1</sup> into the equilibrator. Two Pt-100 probes accurately determined the water temperature in the equilibrator. A long vent kept the headspace of the equilibrator close to atmospheric pressure. The CO<sub>2</sub> content and the moisture content of the headspace were determined by an infrared LI-COR 7000 analyser. The analysis of the CO<sub>2</sub> content in the headspace was interrupted for that of the CO<sub>2</sub> content in marine air (20 minutes per six hours) and in three CO<sub>2</sub> standards (30 minutes per six hours each). Samples from the equilibrator headspace and marine air were partly dried to 10°C below the ambient temperature in an electric cool box. The standards bought from BOC amounting to 2.15 (0B), 248.37 (25-B18), 350.50 (35-B04) and 455.61 (45-B18) μmol CO<sub>2</sub> mol<sup>-1</sup> in a nitrogen and oxygen mixture had been calibrated against certified NOAA standards prior to the cruise and will be recalibrated upon the return of the equipment to UEA. The analyses were carried out for a flow speed of 100 ml min<sup>-1</sup> through the LI-COR at a slight overpressure. A final analysis for each parameter was made at atmospheric pressure with no flow. The flow and overpressure did not have a discernable effect on the CO<sub>2</sub> and moisture measurements, once the pressure had been corrected for. The correction by Takahashi et al. (1993) will be used to correct for warming of the seawater between the ship's water intake and the equilibrator. The pCO<sub>2</sub> measurements will be time stamped by our own GPS positions. The pCO<sub>2</sub> data await data quality control.

### *4. Recommendations*

- Reliable closure of Niskins and an end to leaking or dripping Niskins on the CTD rosette, with a target for overall failure rate of less than 1%.
- A larger and reasonably quiet CTD sampling site would make CTD sampling more efficient and pleasant.

- Docking stations for laboratory containers would make the analyses less dependent on sea state and would provide amenities to the containers, such as fresh water, intranet and intercom.

## 5. Data availability

The final DIC, alkalinity, and pCO<sub>2</sub> data will be stored with other cruise data at the British Oceanographic Data Centre (<http://www.bodc.ac.uk/>). The data will become publically accessible once the results have been published. The carbonate parameters will also be submitted to the international, publically accessible CO<sub>2</sub> databases at the Carbon Dioxide Information Analysis Center (<http://cdiac.esd.ornl.gov/oceans/>).

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and crew of RRS James Clark Ross enthusiastically supported the ANDREX-2 project. Gareth Lee and Ute Schuster (UEA) contributed in many ways to the cruise preparations.

## 5e. Noble gases, tritium and carbon-14.

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### *Introduction*

Noble gases, helium and tritium may be used to identify the origins of a water mass. They help elucidate mixing and dilution rates, circulation patterns, ocean ventilation and the changes that occur in water mass characteristics over time. As part of the ANDREX tracers team our primary role is to collect samples of helium isotopes ( $^3\text{He}$  and  $^4\text{He}$ ) and tritium ( $^3\text{H}$ , an isotope of hydrogen) for analysis in both the UK and the US. We are also interested in the entire suite of dissolved noble gases including isotopes of argon ( $^{40}\text{Ar}$  and  $^{36}\text{Ar}$ ), Ne, Kr, Xe and Ar/Kr/Xe ratios.  $^{14}\text{C}$  samples will also be collected for analysis in the US.

### *Dissolved noble gases*

Noble gases may be used in the detection and quantification of the relative contributions of air-sea exchange, seasonal changes in temperature (Hamme and Severinghaus, 2007), sea-ice formation, sub-glacial melting, and sub-glacial marine ice production and in Ice Shelf Water (ISW). The latter is an important component in Weddell Sea Deep Water (WSDW) and Weddell Sea Bottom Water (WSBW) (Schlosser et al., 1990), which are the water masses from the Weddell Sea that contribute to Antarctic Bottom Water (AABW), found in all of the worlds ocean basins. In this way, it is possible to use noble gas saturation anomalies and ratios to detect WSBW and WSDW that may occur along the topographic perimeter of the Weddell Sea, along which the ANDREX cruise has sampled. The melting of glacial ice produces a trace gas concentration that is unique from seawater in its saturation state and in the ratio between two individual gases. Based on the average air content of glacial ice ( $0.11 \text{ cm}^3 \text{ g}^{-1}$  of ice; Hohmann et al., 2002), pure glacial meltwater (GMW) is oversaturated in atmospheric gases as follows: He = 1050%, Ne = 781%, Ar = 175%, Kr = 85%, Xe = 41% and  $\text{O}_2$  = 195%. At nominally 0.5% analytical precision, the noble gas signal in GMW can be detected at a concentration of 12‰ for Xe and 0.47 ‰ for He. These gas excesses surpass those of air-sea exchange processes, and thus can provide a measure of GMW, even far from the melt source. Further, the ratio of gas concentration in GMW will reflect the atmospheric concentration ratio. Atmospheric gas ratios are unique from aqueous gas ratios because of solubility (e.g.  $[\text{Ne}]/[\text{Kr}]$  (at solubility equilibrium) = 1.74 and  $[\text{Ne}]/[\text{Kr}]$  (in GMW) = 15.95).

### *Helium isotopes*

The concentration of helium in the atmosphere is ~5 ppm. It has very low solubility in seawater (2 nmol/Kg). Helium in the atmosphere is a mixture of two stable isotopes  $^3\text{He}$  and  $^4\text{He}$ . The isotopic ratio of  $^3\text{He}/^4\text{He}$  is  $1.4 \times 10^{-6}$  in air with  $^4\text{He}$  being one million times more prolific than  $^3\text{He}$ . Helium in the surface waters of the world ocean is in solubility equilibrium with the atmosphere. Volcanic and hydrothermal activity on the sea floor are a source of helium to intermediate depth waters in the ocean. The ratio of  $^3\text{He}/^4\text{He}$  in helium that originates from mantle outgassing is between ten and thirty times

greater than the atmospheric  $^3\text{He}/^4\text{He}$  ratio.  $^3\text{He}/^4\text{He}$  ratios are therefore a useful indicator of the origin of intermediate depth waters. Understanding the distribution of  $^3\text{He}$  that originates from mantle outgassing can help in the unraveling of large scale ocean circulation and in elucidating the closure of the Meridional Overturning Circulation (MOC) at intermediate depths.

### *Tritium*

Tritium was first detected in the environment in the late 1940s. As tritium is an isotope of hydrogen it is oxidized to HTO (tritiated water) and so is the perfect tracer for studies of the natural water cycle. The applications of bomb tritium are limited as an aging tool in waters that have been in contact with the surface oceans after the 1970s and 1980s as concentrations decreased below those that allow the age of water mass to be determined. However, if we measure tritium and its radioactive decay product – tritogenic  $^3\text{He}$  – simultaneously we can calculate the tritium/ $^3\text{He}$  age of the water mass (the amount of time the water parcel has been isolated from the surface of the ocean). (Clarke et al., 1976).

### *Radiocarbon*

Radiocarbon is unique among the ocean tracers in that it has a half-life of ca. 5000 years, which coincidentally is of the same order as the water mass ventilation timescale of the ocean  $O(1000)$  years. The next closest tracer of ocean mixing,  $^3\text{H}$  has a half-life near 12.5 years, making it much less suitable to resolve long-period circulation in the ocean.  $^{14}\text{C}$  has been treated as a steady state radioactive tracer in the atmosphere (Jenkins, 2003), but several corrections must be made before the appropriate boundary condition is applied at the ocean surface. These are, (1) the reconstruction of the atmospheric source function of  $^{14}\text{C}$ , which varies with solar flare activity, (2) the dilution of radiocarbon in the atmosphere by fossil-fuel burning (the Suess effect) and (3) the separation of bomb  $^{14}\text{C}$  from natural  $^{14}\text{C}$ . The first two can be reconstructed through time series measurements of atmospheric  $^{14}\text{C}$ , and the separation of bomb radiocarbon is often carried out through linear correlation of water samples with other biologically active tracers, namely silicate or alkalinity (Rubin and Key, 2002).  $^{14}\text{C}$  is an effective tracer for the observation of deep-water upwelling at the ocean surface, because the seawater carbonate system slows the rate of atmospheric equilibration to  $O(10)$  yrs, (Ito et al., 2004). However, this also presents some difficulty in establishing the boundary condition for AABW formation as surface waters in the Southern Ocean can be heavily depleted in radiocarbon.

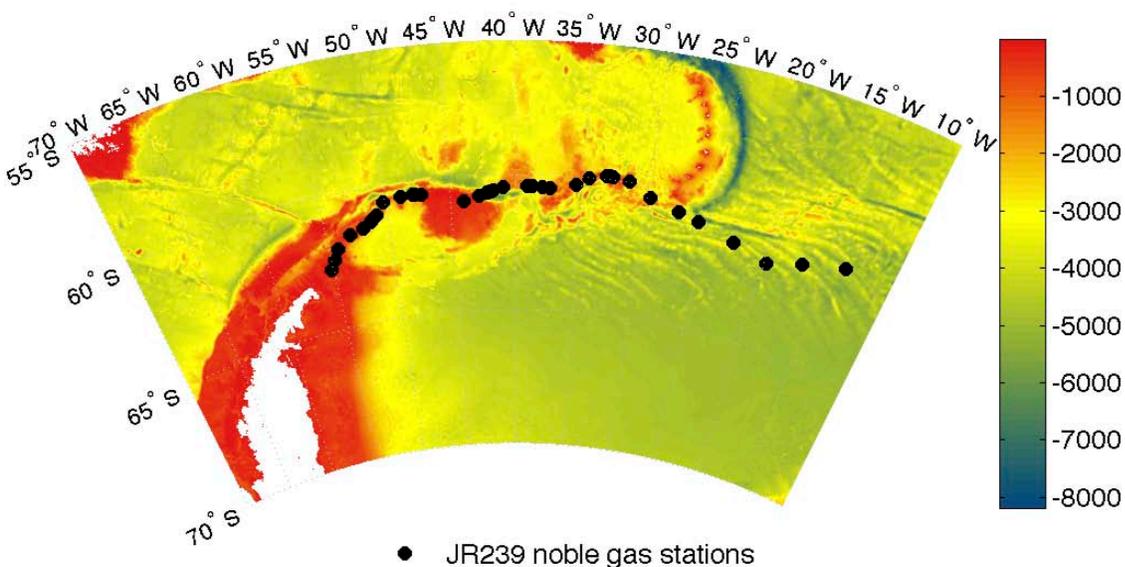
### *Project Background*

The overall objective of the tracer group is provide information that will help in providing an optimal, self-consistent estimate of the rates of ventilation and AABW formation in, and AABW export from, the Weddell gyre. Transient tracers, including tritium, the ignoble gases (CFC-11, CFC-12, CFC-113 and  $\text{SF}_6$ ) and their ratios CFC-11/CFC-12, CFC-11/tritium and  $\text{SF}_6$ /CFC-12 will be used to quantify the ventilation age and transit time distribution of water masses on the Weddell gyre's outer rim and allow a second estimation of dilution times that will compliment the physical data collected. The variety of tracers used will allow estimates of ventilation ages and transit time

distributions to be optimized through constraining the mixing history of the water parcels. The end result of the model investigation of parameter space provided by both the physical and chemical tracer data collected on ANDREX will allow a comprehensive evaluation of ventilation timescales of the water masses flowing into and out of the Weddell gyre.

### *Sampling*

Noble gas samples were collected from the Niskin rosette at 41 of the 68 stations along the ANDREX (JR239) cruise track (Figure 5.15). Noble gases were sampled at three stations (70, 82 and 90) along the JR235 cruise track. In total 629 He, 381 tritium, and 243 radiocarbon samples were collected, with an average of 14.7 noble gas samples per station, resulting in a vertical resolution close to 100 m.



*Figure 5.15: Geochemical tracer stations in the Weddell Sea during JR239.*

Noble gases are collected in copper tubes that are fitted with tygon tubing and clamps at both ends. Once the Noble gas sample has been taken it is brought into the wet lab where the tube is sealed using a crimping device that forms a cold weld at each end of the copper tube containing the sample. The nominal sample volume of a single noble gas samples is ca. 33 ml. Duplicate samples were collected at every station and every depth. These samples have been divided between the WHOI and University of Manchester labs, to facilitate a coordinated analysis effort and permit laboratory inter-calibration.

Typically, tritium is collected in Argon-filled bottles to avoid contamination with the water vapour in air, and indeed tritium samples for analysis at the University of Manchester were collected in 1L amber bottles pre-filled with Ar. However, sample containers from WHOI did not arrive in Montevideo and alternate sample containers were provided that did not permit the use Ar pre-filled bottles on ca. half the tritium samples collected (see details below).

Radiocarbon samples were collected in 250 ml BOD bottles using a short length of tygon tubing. Sample containers were rinsed once with seawater from the Niskin and then overfilled with a volume 1.5 times the sample container. Samples were subsequently poisoned with 50 µl of HgCl<sub>2</sub> saturated solution and glass stoppers were coated with Apiezon grease to avoid exchange across the cap-bottle seal.

The sample containers from WHOI that did not arrive resulted in a shortage of tritium and radiocarbon glass bottles. However, the UEA CFC and CO<sub>2</sub> labs generously provided bottles from their reserves to compensate for those lost in shipment. Several irregularities in the sample collection and storage method have resulted from this ad-hoc adaptation in the sample containers as follows:

- 180 <sup>3</sup>H samples were collected in 500 ml glass bottles that were baked at 100 °C aboard the ship, and filled with UHP N<sub>2</sub> prior to sampling. N<sub>2</sub> being lighter than air and Ar is not as good a buffer for atmospheric contamination.
- 243 radiocarbon samples were collected in 250 ml BOD bottles with ground glass stoppers. These bottles belong to the UEA CO<sub>2</sub> laboratory and were pre-rinsed with organic-free MilliQ water before departure from UEA. Normally radiocarbon samples are collected in 500 ml BOD bottles that have been baked at 500 °C and rinsed with organic-free MilliQ water.

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*Acknowledgement.* Brice Loose and Bill Jenkins would like to gratefully acknowledge the University of East Anglia scientists Dorothee Bakker and Peter Brown.

## 5f. Stable Oxygen Isotopes (Mike Meredith)

Via a NERC Small Grant (“Freshwater Export from the Weddell Gyre: Magnitude, Variability and Impacts”; PI Dr. M. Meredith, BAS), we are funded to collect samples for the determination of stable oxygen isotopes along the ANDREX (JR239) cruise track. Such sampling has already been conducted along last year’s ANDREX cruise (from *RRS James Cook*), and along the US occupation of the CLIVAR IR6S section at the eastern edge of the Weddell gyre. The intention is to use this ensemble of data (in combination with the measured salinity and derived velocity fields from ANDREX and IR6S) to quantify the freshwater export from the Weddell gyre, to separately deduce how much of this export is from sea ice and meteoric sources, and to better ascertain the climatic relevance of these fluxes. It is also anticipated that these data will be of significant use in assessing the factors influencing the distribution of noble gases along the section.

Stable oxygen isotopes are of great utility in tracing the origin of high-latitude freshwater. Salinity on its own can be used to quantify the prevalence of freshwater in a given water sample (relative to some known oceanic endmember for salinity), however it does not provide information on its source. Oxygen isotopes add unique information on this, since the ratio of  $\text{H}_2^{18}\text{O}$  to  $\text{H}_2^{16}\text{O}$  in seawater is strongly affected by the addition of freshwater from high-latitude meteoric sources (snow, glacial melt etc), but (unlike salinity) is much less sensitive to sea ice melt. This decoupling of the two tracers allows for quantitative partitioning of derived freshwater prevalences into separate components of different origin.

Oxygen isotopes were sampled at 60 stations during JR239 (no JR235 stations were sampled). Sampling was intensified toward the start of the cruise, since the region close to the Antarctic Peninsula is the area of our cruise where the meteoric water signal (especially due to glacial melt) is expected to be strongest, and oceanographically most significant. Sampling was spread out toward the eastern end of the section. Water was not collected from every Niskin on those stations that were sampled (the cost of analyses precludes sampling every bottle from every Niskin), but was concentrated in the near-surface layers (where freshwater is most prevalent), and in the deepest layers (where Antarctic Bottom Water of different flavours often resides).

Samples were drawn into 50ml glass bottles, which had been rinsed once with water from the Niskin. These then had a silicon bung inserted and a metal crimp overlaid, which was sealed with a pair of crimping tongs. The bung and crimp are the same as are used for sealing bottles of OSIL standard seawater. Toward the end of the JR239 section, it was realized that we had been over-enthusiastic in our sampling near the start, and that we would run out of 50ml bottles before the eastern end was reached. Accordingly, we re-used standard seawater bottles that had been left over from the salinity analyses; these (although significantly larger, and therefore more troublesome to transport and store) are perfectly adequate for the task. All samples will be transported back to the UK, and will be delivered to the NERC Isotope Geosciences Laboratory, Keyworth, for laboratory analysis.

*A test of the BAS method for collecting oxygen isotope samples*

Previously we have used a number of methods for collecting and sealing oxygen isotope samples, including the use of screw cap bottles and sealed with Parafilm or wax to prevent evaporation (which would compromise the sample). The adoption of the current method was borne of the desire for a quick and easy solution to collect small volumes of water and seal them against interaction with the atmosphere. When the new method was adopted (about 4 years ago), the opportunity was taken to open a bottle of OSIL standard seawater, and reseal it straight away using one of our bungs and crimpers. This bottle of standard seawater was a P146, dated 12 May 2005, with  $K15 = 0.99979$  ( $S = 34.992$ ). It was opened and resealed on 5 May 2006.

This bottle was put to one side, with the intention of being measured for salinity at some point in the future. This would indicate whether significant evaporation had ensued since the sample was re-sealed, since the salinity would be noticeably affected. During JR239, with the Guildline 8400B salinometer working well, the opportunity was taken to re-measure the salinity of this standard (work kindly conducted by Povl Abrahamsen).

The sample was re-measured on 29 March 2010, when it gave a reading of  $K15 = 0.99980$ . This is insignificantly different from the label value of the standard, indicating that the sample had not been compromised by the method used to seal it. Although not statistically significant ( $n=1$ ), this nonetheless provides encouraging evidence that the method we use to collect and store oxygen isotopes is robust.

## 6. Underway measurements

### 6a. Oceanlogger, meteorological data and single-beam echosounder (Takamasa Tsubouchi)

#### 1. Instrumentation and data collection

Surface ocean and meteorological data were logged continuously throughout JR235/236/239. Ocean data were collected from the ship's uncontaminated seawater supply, whilst the meteorological data were measured by instruments on the forward mast. Instruments were as follows:-

##### *Oceanlogger:-*

SeaBird Electronics SBE45 CTD  
Turner Designs 10-AU Fluorometer

##### *Meteorological data:-*

Photosynthetically Active Radiation (PAR) 1, Parlite Quantum Sensor, Kipp & Zonen  
Photosynthetically Active Radiation (PAR) 2, Parlite Quantum Sensor, Kipp & Zonen  
Transmissometer 1, Proto1 SPLite, Kipp & Zonen  
Transmissometer 2, Proto1 SPLite, Kipp & Zonen  
Air temperature/humidity 1, Chilled Mirror Hygrometer MBW, PM-20251/1,  
Temperature Sensor Pt100, PM-20252/1

The anemometer logs wind speed relative to the ship. True wind speed was calculated by merging with navigational data, including gyrocompass data. Surface ocean data was collected at 5 seconds interval and meteorological data was collected at 2 seconds interval. Satellite positioning data from GPS were also included in the analysis, so as to provide the necessary positional data for the oceanlogger and meteorological sensor values.

##### *Satellite positioning data:-*

Seatex SeaPath 200: Primary position data.  
Ashtech ADU5: Including attitude information in 3 dimensions (pitch, roll and yaw) based on 3 dishes positioning data.

#### 2. Data Processing

Initial data processing was carried out with Matlab by logging remotely into the ship's Unix network (jruj). All mscripts used to do this data processing are located under the directory "/local/users/pstar/cruise/data/mexec\_processing\_scripts/."

As a part of SCS data stream, all the original data are stored under the directory “/local/users/pstar/cruise/data/scs\_sed/” as ascii files, named as \*.ACO:-

oceanlogger.ACO  
anemometer.ACO  
ashtech.ACO  
seatex-vtg.ACO  
seatex-zda.ACO  
seatex-gga.ACO  
seatex-gll.ACO  
seatex-hdt.ACO  
gyro.ACO  
seatex-psxn.ACO

Final products were saved as netcdf files and stored under the directory “L:/legdata/pstar/ocl/”, “L:/legdata/pstar/surfmet/”. Final products are:-

ocl/ocl\_jr239\_01.nc: Ocean logger data (SST, SSS, fluor etc) from the first day of the cruise to the latest day including seatex position information. Time interval is 5 seconds.

surfmet/ met\_jr239\_true.nc, met\_jr239\_trueav.nc: Anemometer data (true wind speed, true wind direction) from the first day of the cruise to the latest day including seatex position information. Time interval is 2 seconds (met\_jr239\_true.nc) and 30 seconds (met\_jr239\_trueav.nc).

*Detailed data procedures:-*

*1. mday\_00\_get\_all(day).m*

\* day is a julian day since 01/01/2010 (eg. Mday\_00\_get\_all(95) for 95 julian day)

Input: oceanlogger.ACO, ashtech.ACO, anemometer.ACO etc.

Output: ocl\_jr239\_dYYY\_raw.nc, sim\_jr239\_dYYY\_raw.nc, ash\_jr239\_dYYY\_raw.nc, gyr\_jr239\_dYYY\_raw.nc, pos\_jr239\_dYYY\_raw.nc.

(YYY is a julian day since 01/01/2010)

Call mday\_00(‘variable’,day) and translate original ascii data into netcdf format.

*2. mday\_00\_clean\_all.m (mday\_00\_clean\_all\_temp0413.m)*

Input: ocl\_jr239\_dYYY\_raw.nc, sim\_jr239\_dYYY\_raw.nc, ash\_jr239\_dYYY\_raw.nc, gyr\_jr239\_dYYY\_raw.nc, pos\_jr239\_dYYY\_raw.nc.

Output: ocl\_jr239\_dYYY.nc, sim\_jr239\_dYYY.nc, ash\_jr239\_dYYY.nc, gyr\_jr239\_dYYY.nc, pos\_jr239\_dYYY.nc.

Clean data by applying range check for each parameter in order to eliminate clearly erroneous values. The threshold for temperature is from -50 deg to +50 deg, salinity is from 0.1 psu to 50 psu etc. As outputs, ocl\_jr239\_dYYYY\_edit.nc etc were also created since ocl\_jr239\_dYYYY.nc etc will be replaced from the next step.

### 3. *underwaycheckplots.m (underwaycheckplots\_temp0414.m)*

Input: ocl\_jr239\_dYYYY.nc, sim\_jr239\_dYYYY.nc.  
Output: ocl\_jr239\_dYYYY.nc, sim\_jr239\_dYYYY.nc.

Clean data manually with interactive procedure. Spikes were eliminated mainly from simrad (depth echosounder), fluorescence, and sometimes from SST and SSS data. Spikes tend to appear in the data when the oceanlogger flow rate jumps or dips. The input file was updated once data cleaning was finished.

### 4. *mmerge\_ocl\_nav.m*

Input: ocl\_jr239\_dYYYY.nc.  
Output: ocl\_jr239\_dYYYY.nc.

Oceanlogger data does not initially have position information. By matching time stamps between oceanlogger data and navigation data, this script includes seatex position information into the input data.

### 5. *mmerge\_sim\_nav.m*

Input: sim\_jr239\_dYYYY.nc.  
Output: sim\_jr239\_dYYYY.nc.

Simrad echosounder data also does not initially have position information. By matching the time steps between sim data (depth data) and navigation data, this script includes seatex position information into the input data. After running this script, output netcdf file now includes seatex position information.

### 6. *mday\_02\_run\_all(day).m*

Input: ocl\_jr239\_d\*.nc, sim\_jr239\_d\*.nc, ash\_jr239\_d\*.nc, gyr\_jr239\_d\*.nc,  
pos\_jr239\_d\*.nc.  
Output: ocl\_jr239\_01.nc, sim\_jr239\_01.nc, ash\_jr239\_01.nc, gyr\_jr239\_01.nc,  
pos\_jr239\_01.nc.

This script assembles the input data from the first day of the cruise to the latest day for each parameter. Output file (ocl\_jr239\_01.nc etc) now has information from day 1 to the latest day.

### 7. *mbest\_all.m*

Input: pos\_jr239\_01.nc

Output: bst\_jr239\_01.nc, gyr\_jr239\_ave.nc, pos\_jr239\_spd.nc, pos\_jr239\_ave.nc

This script calls mbest\_01, mbest02, mbest\_03 and mbest\_04. Mbest\_01 creates pos\_jr239\_ave.nc from pos\_jr239\_01.nc by converting 1Hz position data into 30 seconds interval position data. Mbest\_02 creates pos\_jr239\_spd.nc from pos\_jr239\_ave.nc by calculating ships speed, course and running distance. Mbest\_03 creates gyr\_jr239\_ave.nc from gyr\_jr239\_01.nc by converting 1Hz gyro data into 30 seconds ship heading data. Mbest\_04 creates bst\_jr239\_01.nc from pos\_jr239\_spd.nc and gyr\_jr239\_01.nc by merging these data. bst\_jr239\_01.nc is 30 seconds time interval positioning data including ship heading information.

#### *8. mtruw01.m*

Input: bst\_jr239\_01.nc, met\_jr239\_01.nc

Output: met\_jr239\_true.nc, met\_jr239\_trueav.nc

This script calculates true wind speed by adding smoothed navigation data to relative wind. met\_jr239\_true.nc has 2 seconds time interval true wind data and met\_jr239\_trueav.nc has 60 seconds time interval true wind data.

### **3. Problems encountered**

(1) The anemometer was replaced on 09 April noon, following damage caused by a bird strike. After this replacement, data were not streamed into the SCS, marking the end of anemometer data for the cruise. This caused the matlab scripts that were being used to crash. The mscripts mday\_00\_clean\_temp0413.m and underwaycheckplots\_temp0414.m were adapted by commenting out several lines which deal with anemometer data to handle this problem.

(2) Ashtech data showed noise during 25 March and 06 April. Since seatex data is merged with the oceanlogger data, and worked well during whole of the cruise, no secondary problems occurred for the data procedures. No cleaning was applied to the ashtech data, and the cause of the noise is not yet known.

(3) Ashtech data had non-numeric character on 25 March (ashtech.ACO in line 516039), causing failure of a script. The offended line was manually removed.

### **4. Underway salinity samples**

Throughout the cruise, water samples were collected every 6 hours in order to calibrate the underway conductivity sensor. The water samples were collected in 200ml medicine bottles. Standard procedure was to rinse the bottle three times, before filling it to just below the neck to allow room for expansion during warming and to facilitate homogenisation of the bottle's contents prior to analysis. The rim of each bottle was wiped dry with a tissue, then a plastic seal inserted and the screw cap replaced. Ongoing crates of salt samples were kept in salinometer lab and allowed to equilibrate with ambient conditions for at least 24 hours prior to analysis.

The samples were analysed on one of the shipboard Guildline 8400B Autosal salinometers (s/n 65763), which had been standardised at the beginning of the cruise using Ocean Scientific International Ltd (OSIL) P150, P151 standard seawater. Prior to, and following, analysis of each water sample crate, a new bottle of standard seawater was analysed to ensure that the salinometer remained stable and in order to derive a calibration offset.

Standard procedure was to invert each sample bottle a few times in order to mix the contents but avoid the introduction of a large number of air bubbles into the sample. The salinometer cell was then flushed three times with the sample, prior to taking the first reading. The cell was then flushed once between subsequent readings, with at least three readings being taken for each sample.

Once analysed, the conductivity ratios were entered by hand into an Excel spreadsheet, converted to salinities and transferred to the Unix system. They were then used to investigate a conductivity offset for the underway sensor.

### ***5. Conductivity calibration***

Times at which underway salts were collected were entered by hand into the Excel file *underwaySalts.xls*. The Matlab script reads in *Salts underway.xls*, and extracts data corresponding to the times at which underway samples were taken (*SamplesOCL.mat*). These data were compared with salinity values from oceanlogger salinity data, and a plot of oceanlogger salinity minus bottle sample salinity is given in [Figure 6.1](#). It shows an offset of  $\approx -0.069 \pm 0.027$  between the two datasets, which is similar to the offset of  $-0.073 \pm 0.023$  obtained through comparison of the underway salinity and CTD data (from 7m depth during CTD casts). The offset shows time dependency, changing from around  $-0.05$  during 20 March and 04 April to around  $-0.08$  during 04 April to 20 April. This characteristic was observed in both comparisons (against under water bottle sample data and CTD salinity data). No calibration has been applied yet to the underway conductivity sensor.

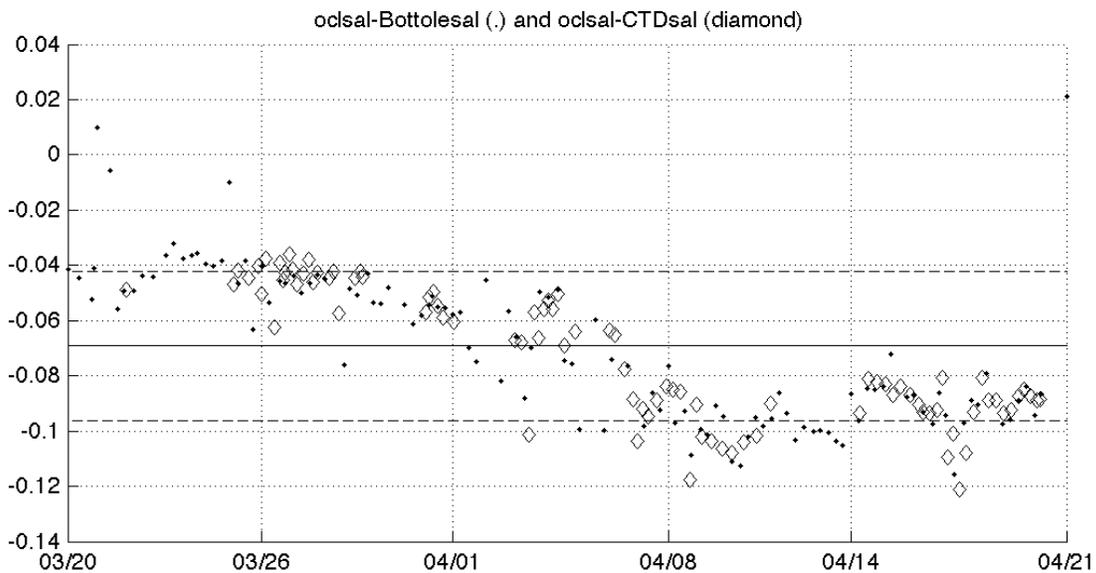


Figure 6.1: Oceanlogger salinity minus bottle sampling salinity (dots), with mean value (-0.069) and standard deviation (0.027). Oceanlogger salinity minus CTD salinity (at 7m) are also plotted (diamonds).

## 6. Temperature calibration

Underway oceanlogger temperatures on *JCR* have previously been observed to be  $\approx 0.3^\circ\text{C}$  too low. This was noted during JR165 (Feb-Apr 2007) and the same problem was encountered on JR171 and JR193 (Nov-Dec 2007). A comparison has been made between CTD data from 7m and oceanlogger temperature data. The plot of underway temperature minus CTD temperature (Figure 6.2) yields a  $-0.0735 \pm 0.0345^\circ\text{C}$  offset. This offset is much smaller than, for example, JR177, where a mean offset of  $0.37^\circ\text{C}$  (oceanlogger reading too cold) was observed, with a standard deviation of  $0.1^\circ\text{C}$ . The offset during our cruise was fairly constant against the time. No calibration has been applied yet to the underway temperature sensor.

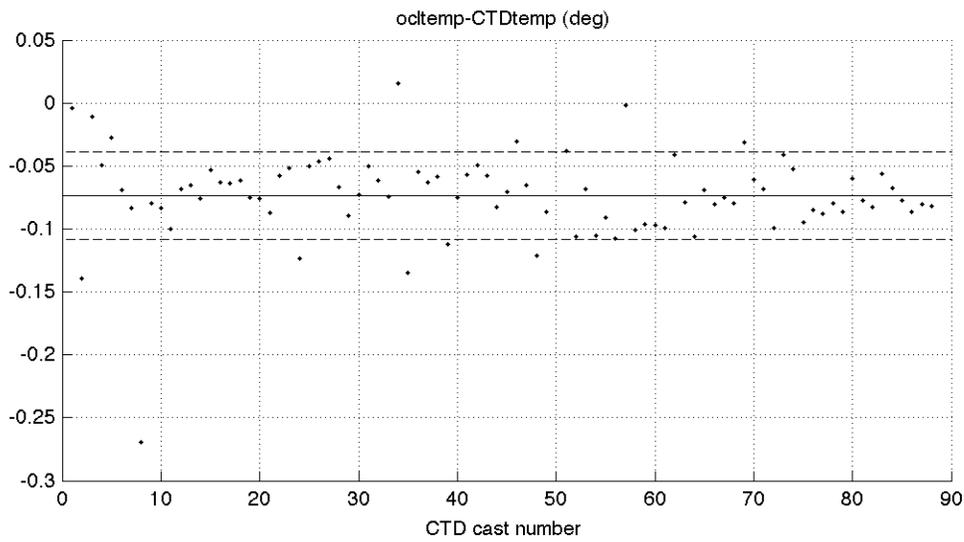


Figure 6.2: Oceanlogger temperature minus CTD temperature at 7m, with mean value (-0.0735) and standard deviation (0.0345).

### 7. Complete series

For completeness, the overall series of meteorological data and oceanlogger data from the cruise JR235/236/239 are shown in [Figure 6.3](#).

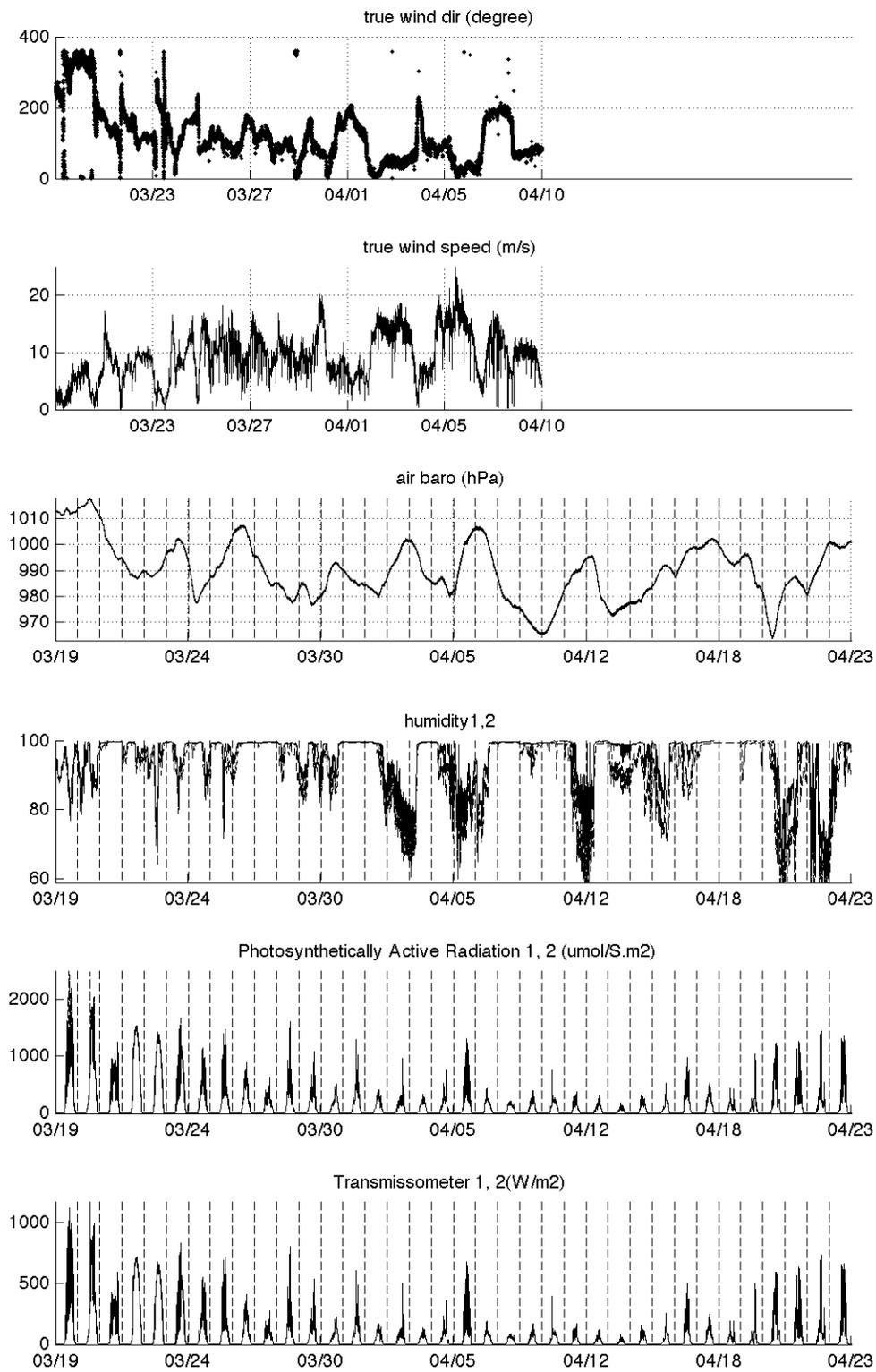


Figure 6.3: Meteorological and Oceanlogger data time series during the cruise.

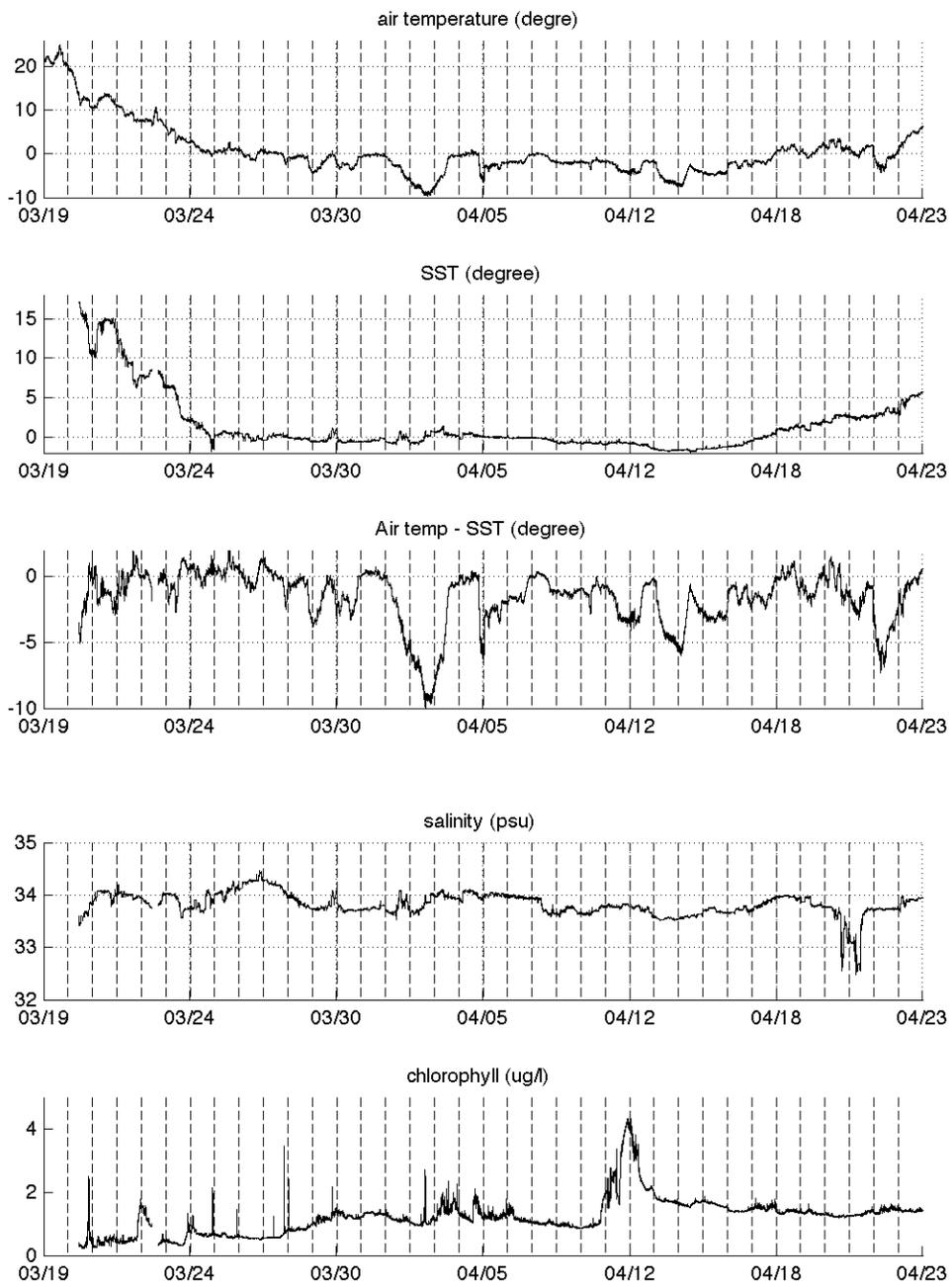


Figure 6.3: Meteorological and Oceanlogger data time series during the cruise (cont.).

## 6b. Vessel-Mounted Acoustic Doppler Current Profiler (Angelika Renner)

### 1 Introduction

The ADCP on the RRS James Clark Ross is a 75 kHz RD Instruments Ocean Surveyor (OS75). Under ideal conditions (calm sea, bubble free water, low noise, good scattering), it should be able to measure water velocity down to approximately 1000 m. More realistically, good and usable water profiles can reach a depth of 800 m while bottom tracking is possible to around 1100 m. The ADCP can be run in narrowband or broadband mode, allowing for either deep or shallow (but higher-resolved) profiling. During JR235/236/239, we mainly used the narrowband mode with and without bottom tracking. The following sections give the details of the data acquisition, processing, and post processing.

### 2 The Instrument: OS75

**Transducer:** The transducer well contains 90% de-ionised water and 10% monopropylene glycol. The transducer depth is 6.3m: the hull depth is 6.47m, the distance of the transducer behind the seachest window is 100-200mm and the window thickness amounts to 50mm. The design draft of the ship is 6.3 m, which is subject to slight changes depending on cargo/fuel/ballast load, and the full load draft is 6.4 m.

**Alignment:** The transducer should have been aligned with beam 3 at 45 degrees from the centre line, however the misalignment angle is actually approximately 60 degrees. The transducer misalignment angle (EA) has been set to 60.08 degrees in the command files. This is a rough estimate of the misalignment, but is acceptable given that we fine-tune it during post-processing.

**Synchronisation:** The ADCP was run independently from the SSU, with an internally set ping rate. The EM120 was turned on after leaving Montevideo and run throughout the cruise with stops on stations. The single-beam echosounder EA600 was set to passive. Checks of the raw ADCP data did not reveal any interference from the EM120.

**Data storage:** The ADCP data is written to a Samba-mounted UNIX-drive. Files can only be modified when accessed from the ADCP PC. In case of a network or UNIX system failure, the data is stored on the local ADCP PC in a directory specified in VmDas.

### 3 Data Acquisition: VmDas

The ADCP is controlled using the proprietary RDI VmDas software, version 1.42. The software is installed on the ADCP PC in the UIC. VmDas can be used for data acquisition, archiving, processing, display, and reporting. During JR235/236/239, the ADCP setup, data logging, preliminary screening, and mapping of beam data onto Earth coordinates was done with VmDas. The final processing was performed after the cruise using a set of Matlab routines.

### 3.1 General settings

Five settings were used for the OS75:-

- Narrowband with Bottom Tracking on, maximum bin depth 500 m
- Narrowband with Bottom Tracking on, maximum bin depth 1000 m
- Narrowband with Bottom Tracking off, maximum bin depth 1000 m
- Broadband with Bottom Tracking on, maximum bin depth set to 200 m
- Broadband with Bottom Tracking on, maximum bin depth set to 500 m.

The bin size was set to 8 m in broadband and 16 m in narrowband mode. Blanking distance at the surface was set to 8 m. An overview over the available commands to set the ADCP operating parameters and the command files for the Narrowband modes to 1000 m used during JR235/6/9 can be found at the end of this section. For more information on the commands, refer to the RDI Ocean Surveyor manuals, in particular the volume 'Commands and Output Data Format'.

Note: To run the ADCPs through the SSU, a line in the command files has to be uncommented or added:-

```
; Set Trigger In/Out [ADCP run through SSU]  
CX1,3
```

### 3.2 What to set and to check

In VmDas, several things have to be set or checked before start acquiring data:-

Open VmDas, click on 'file'→'collect data'.

Then in 'options' →'edit data options':

- Communications tab: (this should be set already)
  - ADCP Input: COM1, 9600, N, 8, 1
  - Navigation Input (NMEA): COM5, 19200, N, 8, 1
  - Enable serial
- ADCP setup tab:
  - ADCP setup from file (enter the required command file)
  - time between ping ensembles: 2 or 3 seconds
- Recording tab:
  - name: jr239\_
  - number: 1 (has to increase everytime the ADCP recording is stopped and restarted, otherwise data loss can occur as VmDas overwrites previously created files. VmDas increases the number automatically but it's worth checking!)
  - max size: 10 (MB; when that size is reached, VmDas starts a new file with automatic numbering)
  - dual output directories:
    - Primary drive: U:\data\
    - Backup Path: C:\ADCP\_Data\_Secondary\_jr239
- Transform tab:

- Heading Source: NMEA/PRDID
- Tilt Source: Fixed Tilts: 0 Fixed Pitch, 0 Fixed Roll
- Heading Corrections: 0 EV: Primary Heading Error, 60.08 EA: hdng align error
- Do not enable tilt correction
- Averaging tab:
  - check Temporal. The STA interval was set to 120 seconds, LTA to 600 seconds. Profile Ping
  - Normalisation Reference Layer was enabled and set to start bin = 3, end bin = 10

No changes made in Data Screening (all disabled), User Exit (all disabled), and Sim Input tabs (set to collect real data for both data streams).

The physical misalignment of the ADCP is set in the command files, not in VmDas.

When the ADCPs are recording, several things should be checked regularly:

- Size of the .LOG-files: If there are any problems (e.g. buffer overload, timeouts and resetting of the ADCP, problems with the navigation data stream), they get recorded here. If the file size suddenly increases or the file becomes bigger than 10 KB, an error might have occurred that needs to be resolved.
- Check regularly that the size of the data files is increasing.
- Create and maintain a list with all files created and the setup used. The lists for JR235/6/9 are shown at the end of this section. For extraction of on/off station data etc it helps to note station times together with the file sequences.
- Check that GPS data is properly logged and written to the N1R-files.
- Check regularly the PC clock deviation from the ship's clock: the last entry in the \$PADCP line in the N1R-files gives the difference in seconds. It should be small and jumps in the PC clock time can be detected by checking this.

### 3.3 Output data format

The filenames of the VmDas data are of the general structure CRUISE\_XXX\_yyyyyy.END where CRUISE is the name set in the data options recording tab of VmDas (see above), XXX is the number set in the same tab and changed before every restart of recording, and yyyyyy is a number automatically set by VmDas starting at 0 and increasing when the file size becomes larger than max size and a new file is created. END is the filename extension, denoting the different files that are created for each recording. The following list shows all the different file types that were created during JR235/236/239 and their content.

- .ENR: binary; raw ADCP data file.
- .STA: binary; average ADCP data, using the short time period specified in VmDas Data Options.
- .LTA: binary; average ADCP data, using the long time period specified in VmDas Data Options.
- .ENS: binary; ADCP data after screening for RSSI and correlation, either by VmDas or adjusted by user, and navigation data from .NMS file.

- .ENX: binary; : ADCP single-ping data and navigation data, after having been bin-mapped, transformed to Earth coordinates and screened for error velocity, vertical velocity and false targets.
- .N1R: ASCII text; raw NMEA data, see [section 4](#).
- .NMS: binary; navigation data after screening and pre-averaging.
- .VMO: ASCII text; option setting used for collection the data.
- .LOG: ASCII text; all logging output and error messages.

More options are available and information about the data files and their format is available in the various OS user guides. Here, a short overview about the structure of the binary data files is given. The structure varies slightly depending on whether only narrowband OR broadband mode are turned on or both are on. During JR235/236/239, the first option was used and only one of the modes was active at any time.

- **Header:** header ID, data source ID, number of data types (i.e. fixed leader, variable leader, etc.) and their offsets;
- **Fixed leader data:** fixed leader ID, ADCP hardware configuration, number of beams, cells, and pings per ensemble, depth cell length, blank after transmit, signal processing mode (narrow- or broadband), output controls, amount of time between ping groups, coordinate transform parameters, heading alignment, heading bias, sensor source, sensors available, distance to middle of first depth bin, length of transmit pulse, distance between pulse repetitions;
- **Variable leader data:** variable leader ID, ping ensemble number, date and time, speed of sound, transducer depth, heading, pitch and roll, salinity and temperature;
- **Variable data:** velocity, correlation magnitude, echo intensity, and status data
- **Bottom track (BT):** BT ID, BT number of pings, correlation magnitude, evaluation amplitude, BT mode, error velocity maximum, BT range, BT velocity, BT correlation magnitude, BT evaluation amplitude, BT maximum depth, receiver signal strength indicator, gain level for shallow water, most significant byte of the vertical range from the ADCP to the sea bottom;
- **Attitude:** fixed and variable attitude data. Fixed attitude data includes the command settings and is the same for all pings. Variable attitude data changes with every ping and consists of heading, pitch and roll;
- **Navigation (ENS, ENX, STA, and LTA-files only):** navigation ID, UTC date and time, PC clock offset, latitude and longitude received after the previous ADCP ping, UTC time of last fix, last latitude and longitude received prior to the current ADCP ping, average navigation speed, true navigational ship track direction and magnetic navigation ship track direction, speed made good, direction made good, flags, ADCP ensemble number, date and time, pitch, roll and heading, number of sampled average since the previous ADCP ping for speed, true track, magnetic track, heading, pitch and roll;
- **Checksum:** modulo 65536 checksum (sum of all bytes in the output buffer excluding the checksum). If data storing by VmDas is interrupted by e.g. a software crash and/or the data files are not closed properly by VmDas, the checksum can be incorrect and the check in the postprocessing can fail.

Note: The date recorded by VmDas is given as Julian day. VmDas takes 1st Jan to be day no. 0, different from the ship clock and the other data logging systems.

#### 4 Navigation data input

##### 4.1 The Seatex SeaPath 200 Instrument and the navigation repeater

The ADCP is fed with navigation and attitude data from the Seatex GPS system. On the ADCP PC desktop is a shortcut called 'Navigation Repeater' which points to a perl script, 'data\_server\_1\_1.pl'. This program has to be started (double click) and run before starting ADCP pinging and logging to get navigation data input for VmDas. The script gets navigation data from the Seatex, extracts the information wanted, and feeds it into VmDas.

##### 4.2 Navigation data in the VmDas output files

The navigation data is saved in two of the VmDas files: in .ENX the data is included in binary format. The .N1R-files contain the information in ASCII format and includes lines for \$INGGA, \$INVTG, \$PRDID, and \$PADCP. The \$INGGA and the \$INVTG lines are of the standard NMEA (National Marine Electronics Association) format and contain:  
\$INGGA, time (UTC), deg latitude, south or north, deg longitude, west or east, quality indicator, number of satellites in view, various other parameters  
\$INVTG, track degrees, true (T), track degrees, magnetic (M), speed in knots, knots (N), speed in km/h, km/h (K)  
\$PRDID, pitch, roll, heading  
\$PADCP, ensemble number, date (yyyymmdd), time from PC clock, PC clock offset.

#### 5 Processing in Matlab

##### 5.1 The Matlab routines

For the post-processing of the VmDas data, we used a set of Matlab routines. They were first obtained from IfM Kiel by Mark Inall and adapted for use on the *RRS James Clark Ross* by Deb Shoosmith. During JR165, Mark Brandon and Angelika Renner cleaned up large parts of the routines and added comments throughout. Since JR165, some further debugging and refinement have been done by Deb Shoosmith, Hugh Venables and Angelika Renner. The structure, general processing, and in- and output formats remain the same. The following description of the routines and the output data files are adapted from the JR165 and JC29 ADCP reports with adjustments for JR235/236/239.

##### 5.2 Remarks and Glossary

Whenever it says 'run a routine/program/function', it means type in the function name in the Matlab command window and hit enter... A few terms should be clear:

- file sequence: all files for which in the filename CRUISE\_xxx\_yyyyyy.END the number at position xxx is the same. These files have been recorded without stopping the ADCP in between and the same setting was used.
- ping and ping ensemble: In case of JR235/236/239, they are the same, as a ping ensemble was set to include one ping only.

- amplitude, scaling factor, A: Throughout the routines the factor by which the ADCP data has to be scaled for calibration is called either amplitude, scaling factor or A.
- misalignment (angle), phi: synonyms for the angle by which the ADCP is misaligned in addition to the physical misalignment set in the command files.

### 5.3 *Quick'n'dirty: How to get processed ADCP data*

There are a few things that have to be set for each cruise in file OS75\_JCR.m. These are:

- Add the path where the routines are stored to the Matlab search path.
- The cruise name: variable 'cruise'. The name is used when reading in raw data and saving processed data, and appears in the plots.
- The file sequences: variable 'files'. This determines which of the file sequences are processed. 'files' can be a single number or a vector containing the numbers of several file sequences.
- Paths to data files: variables 'RAWPATH' and 'PATH'. They contain the directory paths to the directory where the raw data is stored ('RAWPATH'), and where the processed data will be written ('PATH').
- The averaging interval: variable 'superaverage'. 'superaverage' sets the interval over which ping ensembles will be averaged. Unit is seconds.
- The year: variable 'YYYY'.
- A switch for which lat/lon fix to be used (see below, 5.4): variable 'which\_prdid\_fix'. Options are (a) 1 to use the fix directly after the previous ADCP ping, or (b) any other number to use the fix directly before the current ADCP ping. Set it to 1 if you don't want to bother; it works.
- The upper and lower limit of the reference layer: variables 'ref\_uplim' and 'ref\_lowlim'. Those are needed for calculation of a reference velocity that is used when doing calibration by water tracking. Unit is meters.
- The misalignment angle and the scaling factor: variables 'misalignment\_xb' and 'amplitude\_xb' with x=b for broadband and x=n for narrowband. When running OS75\_JCR.m the first time (see below), set the misalignment to 0 and amplitude to 1. After the first run, to correct for the angle and the scaling, set the variables to the mean, median, mode or whichever value is preferred, and run OS75\_JCR.m again. Mean, median, and standard deviation are displayed in the plot adcp\_calib\_calc.ps. To keep track of which values were used, it is a good idea to note down which file sequences require which correction factors. *Deb Shoosmith modified this bit so that only 'misalignment\_nb' and 'amplitude\_nb' are used. On JR235/236/239, almost all data are in narrowband mode so that we just use the changed version. It is possible though to return to the previous version. The description below therefore still includes this option.*

That is all that should be set. All that needs to be done then is:

- Run OS75\_JCR.m.
- Check which values for misalignment angle and scaling factor are derived.
- Set 'misalignment\_xb' and 'amplitude\_xb' (with x=b or n) in OS75\_JCR.m to these values.
- Run OS75\_JCR.m again.

- If you reprocess the raw data, make sure to remove the old .ps-files containing the various plots, otherwise the new plots will simply be added instead of written to a new file.

## 5.4 Detailed description of the processing functions

### 5.4.1 The master function: OS75\_JCR.m

The main function for the processing is OS75\_JCR.m. In there, the environment and variables are set, and the subfunctions are called. [Figure 6.4](#) gives an overview of the processing routines, their order and the output.

In the first part, the work environment is defined: the paths to the processing routines are added to the Matlab search path, the directory with the raw data and the directory for the processed data are declared, the file- and cruise names are defined, and the vector containing the numbers of the file sequences that are to be processed is created. Several choices can be made for the processing: the variable *superaverage* is used to define the interval over which pings will be averaged in time, unit is seconds; which \$PRDID string sets, i.e. the first \$PRDID fix after the previous \$PADCP string or the last one before the current \$PADCP string; this will make sense later, see [5.4.8](#). The values for *ref\_uplim* and *ref\_lowlim* give the upper and lower limits of the reference layer of which a velocity is calculated and used as reference velocity. This is of importance mostly for water track calibration in cases where no bottom track data is available or the bottom track calibration is not satisfactory.

Then, during the first run through OS75\_JCR.m, where no data are processed yet and no calibration data are available, the correction values for the misalignment angle (*misalignment\_xb*) and the scaling factor (*amplitude\_xb*) are set to 0 and 1 respectively (x=n for narrowband mode, x=b for broadband mode). For the second run, when values for *misalignment\_xb* and *amplitude\_xb* have been calculated, they should be set to the median, mean, mode or whichever value works best (i.e. gives the smallest angle and amplitude after the second run). To keep a record of the settings used to process a set of ADCP data, the settings and the text displayed on screen during the processing are written to a diary called *adcp\_proc\_log\_runX.txt*. X will be 1 for the first run (when *misalignment\_xb* and *amplitude\_xb* are equal to 0 and 1, resp.) and 2 for the second run (*misalignment\_xb* and *amplitude\_xb* unequal 0 and 1, resp.).

After this introductory part, the processing starts. Arrays are declared for later use when calling some of the subroutines, and the file containing calibration point data is deleted if it exists in the processed data directory. Then, the loop through all file sequences specified above starts. First, the filename is set. Its general structure is *CRUISE\_xxx\_yyyyyy*. At this point, *xxx* is set to the file sequence number that is the current in the loop and *yyyyyy* is 000000. After the initialisations, the run through the subroutines begins. This includes all routines described in 5.4.2 to 5.4.11. Once all files have been passed through these routines and the loop is finished, the functions described in 5.4.12 to 5.4.16 are called. After that, all data is processed and saved in the specified directory. The last thing in the main function is a plot of velocities: cross

sections of the zonal and meridional velocities against time are produced and the plots are saved in *adcp\_vel\_contours.ps*.

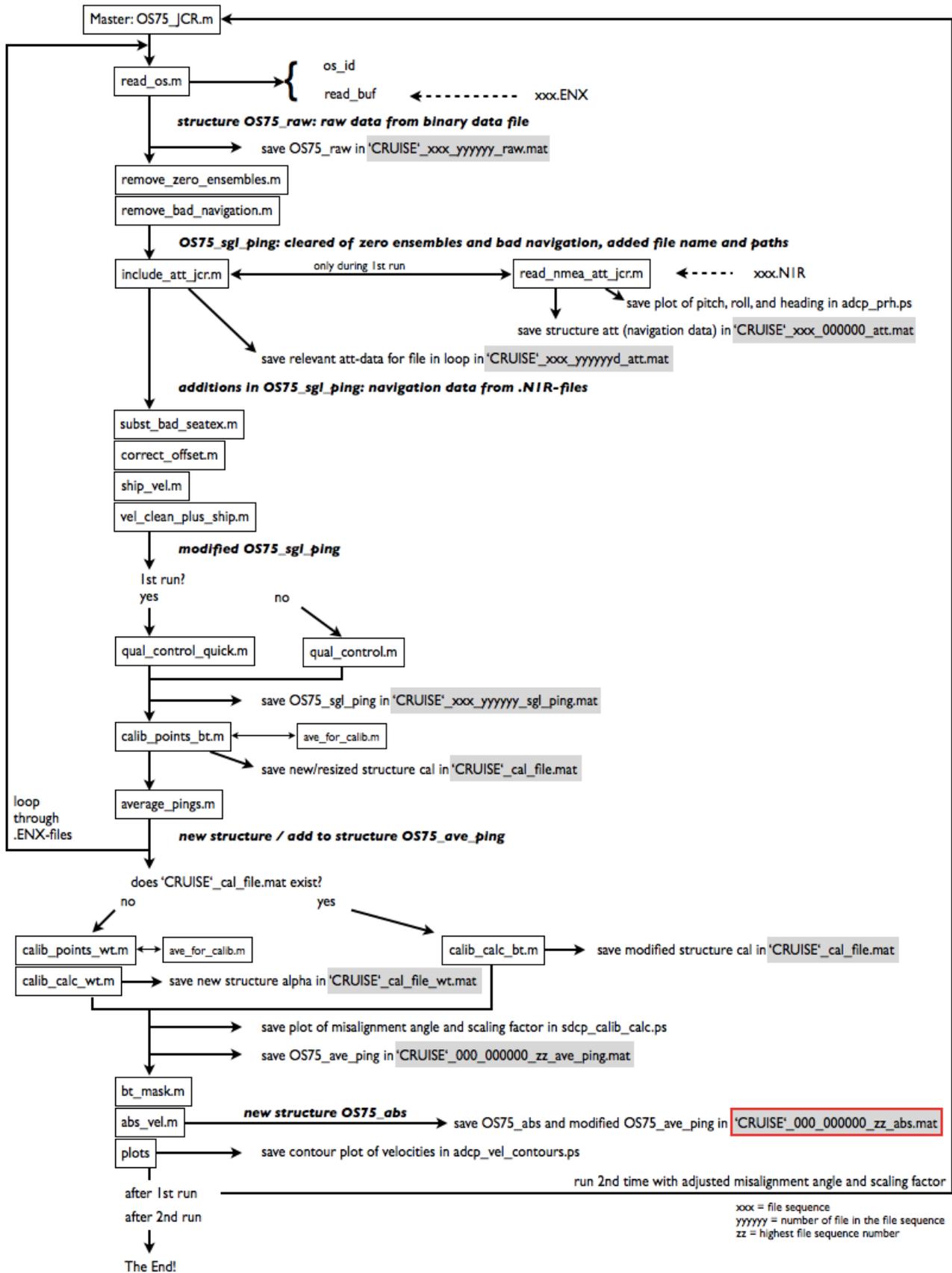


Figure 6.4: Flowchart of the processing path. The master for JR235/6/9 is OS75\_JCR\_jr239.m.

## 5.4.2 `read_os.m`

In this routine, the raw binary data from VmDas are read. In case of JR235/236/239, we used the .ENX files, which contain ADCP single-ping and navigation data. The ADCP single-ping data has already been bin-mapped, transformed to Earth coordinates, and screened for error velocity, vertical velocity and false targets (see VmDas User's Guide). `read_os.m` is called with the file name variable and optional arguments. The latter define which part of the raw data is read:

- 'ends': ?
- 'ens list': list of ensemble numbers
- 'yearbase': start year
- 'second set': read narrow band mode data when both broad and narrow band are collected.
- 'vel': read velocity.
- 'cor': read correlation magnitude.
- 'amp': read echo intensity.
- 'pg': read percent good.
- 'ts': read pitch, roll, and heading.
- 'bt': read bottom track data.
- 'nav': read navigation data
- 'all': includes vel, cor, amp, ts, bt, and pg.

More than one argument can be passed on to `read_os.m`. Arguments can also be numbers. After the switches are set, the subroutine `os_id`, which is within `read_os.m`, is called with the argument `id_arg`. The value of `id_arg` depends on the offset of the positions of the data. If both narrowband and broadband data are collected in broadband mode, this also decides which data are read. If `id_arg=1`, the narrowband data is extracted. `os_id` returns the structure `id` with the positions/identifiers of the data fields in the binary data files. The next step is the first call to the subroutine `read_buf`, also within `read_os.m`.

`read_buf` This is the part where the binary data is read. During the first call with only one argument, the configuration of the OS75 ADCP is extracted from the fixed leader data (see 3.3) and stored in the structure `config`. If one of the checks on number of bytes, header or data source ID or checksum fails, an error message will be returned to `read_os.m`. Otherwise, information about ADCP hardware and setup that remains the same for all pings is read. After that and during the second call (with two arguments), the variable, bottom track, attitude, and navigation data is extracted. After the first call to `read_buf`, the configuration data is used to set up the variables and the reading loop. During the second call, the data requested by using the various switches is stored. Before returning to the main routine, variables are adjusted for negative numbers or NaNs. All raw data read in is stored in the structure `OS75_raw` and returned to the main function and written to the file `CRUISE_xxx_yyyyyy_raw.mat`.

## 5.4.3 `remove_zero_ensembles.m`

The structure *OS75\_raw* is handed over to *remove\_zero\_ensembles.m*. A search for all ensembles whose ensemble number (*OS75\_raw.ens\_num*) is not zero is done and only those are kept and handed back to the main routine as *OS75\_sgl\_ping*.

#### 5.4.4 *remove\_bad\_navigation.m*

Depending on *which\_prdid\_fix*, *OS75\_sgl\_ping.nav.txy1* or *2* is checked for time (first row), longitude (second row) and latitude (third row) duplicates. The number of rejected data cycles is printed on screen and saved as bad and good (=number of data cycles - number of rejected cycles) in the file *CRUISE\_bad\_nav.mat*. The rejected data cycles are then removed from *OS75\_sgl\_ping* and the structure handed back to the main routine.

#### 5.4.5 *include\_att\_jcr.m*

Arguments passed on to this routine are *OS75\_sgl\_ping*, *add\_to\_ensnum* (for the correction of ensemble numbers; see below) and *which\_prdid\_fix*. If no file *CRUISE\_xxx\_000000\_att.mat* exists yet in the processed data directory (i.e. the navigation data in the .N1R-files has not been read yet), *OS75\_sgl\_ping* is passed on to *read\_nmea\_att\_jcr.m* which is called to read the .N1R-files.

*read\_nmea\_att\_jcr.m* The routine goes through all .N1R-files in a file sequence. The number of lines to be read in one go is limited to a maximum of 160000, the loop will go on until all lines are read. The text in the .N1R-file is read into a matrix. Then lines containing the \$PADCP or the \$PRDID string are extracted. If two \$PADCP-lines are consecutive, the first of them is discharged (no attitude data available for this ping ensemble!). From the \$PRDID-lines the one following the \$PADCP-line are extracted, the others discharged. Pitch, roll and heading are read from the remaining \$PRDID-lines and stored. If heading is missing (=999), pitch and roll are set to 999 as well. From \$PADCP-lines, the ping ensemble number, the PC clock offset, and the PC time of the ping ensembles (converted to decimal Julian days) are extracted. After all files are read, the ping ensemble number is checked and corrected for duplicates, which can appear due to the splitting of the files after the maximum number of lines is read. The data is stored in the structure *att* which is written to *CRUISE\_xxx\_000000\_att.mat*. Pitch, roll, heading, and the PC clock offset are plotted and the figures saved to *adcp\_prh.eps*. After that, return to *include\_att\_jcr.m*.

The file *CRUISE\_xxx\_000000\_att.mat* with the *att*-structure is loaded in. If the structure contains data, the following is done: For further processing the ping ensemble number has to be increasing. When the ADCP times out while waiting for a response and resets, the ensemble number goes back to 1. Here, the ensemble numbers are modified so that they increase throughout the file (for *att*) and throughout the files of a file ensemble in *OS75\_sgl\_ping.ens\_num*. (There was a bug here which was corrected during JR235/6/9.) There is already attitude data in the structure *OS75\_sgl\_ping* which comes from the .ENX-file. To extract pitch, roll, heading, and PC clock offset which are relevant for the current .ENX-file, a vector is created for each variable of the length max(highest ensemble number in *att*, highest ensemble number from the .ENX attitude data) and filled with NaNs. Then, the attitude information from *att* is written into the vector and only the data points corresponding to the ensemble numbers from the .ENX-file are stored. If *att* is empty, heading, pitch, roll, and PC clock offset are set to NaN. The

extracted attitude data is written to *OS75\_sgl\_ping.att*. The attitude data relevant to the current .ENX- file is also saved in the new structure *att* in *CRUISE\_xxx\_yyyyyy\_d\_att.mat*. The modified *OS75\_sgl\_ping* is returned to the main routine.

#### 5.4.6 *subst\_bad\_seatex.m*

The arguments *OS75\_sgl\_ping.att*, and *sea\_file* are handed over. In *sea\_file* the number of accepted and rejected (due to bad Seatex data) data points will be stored. A search on *OS75\_sgl\_ping.att* data is done for ensembles where

- heading = 0;
- heading = 999;
- pitch and roll = 0;
- the second differential of heading = 0.

The total number of those ensembles is printed on screen and saved as *bad* in '*CRUISE'\_bad\_heading.mat*.

*OS75\_sgl\_ping* contains two headings: *OS75\_sgl\_ping.heading* which comes from the .ENX-file and *OS75\_sgl\_ping.att.heading* from the .N1R-file. Both are from the same instrument (Seapath Seatex), but may be slightly different due to a (very) small time difference in when they are recorded. Therefore, the velocities in *OS75\_sgl\_ping* are rotated by the difference. To get bottom track velocities in the correct orientation, *OS75\_sgl\_ping.bt.vel* is multiplied by -1. *OS75\_sgl\_ping* with the modified values is returned to the main routine.

#### 5.4.7 *correct\_offset.m*

Using the helper routine *uvrot.m*, this routine scales the water and bottom track velocities and corrects them for misalignment. From the main routine, the arguments *OS75\_sgl\_ping*, *misalignment\_xb* and *amplitude\_xb* are passed on, x=n or b depending on whether the current file ensemble is in narrow- or broadband mode. The horizontal velocities are multiplied by the scaling factor *amplitude\_xb* and rotated by the specified misalignment angle *misalignment\_xb*. The heading is adjusted by subtracting the misalignment angle. The modified structure *OS75\_sgl\_ping* is returned to the main routine.

#### 5.4.8 *ship\_vel.m*

The routine is called with the arguments *OS75\_sgl\_ping* and *which\_prdid\_fix*. The latter decides which navigation fix is used for the calculation of the ship velocity: either *txy1* or *txy2* (see also 5.4.1, 5.5.1). With the help of the routine *sw\_dist.m* from the CSIRO Seawater toolbox, the distance and the direction between the fixes is calculated and then converted to distance in east- and northward direction in meters and time difference in seconds. Dividing distance by time difference results in ship velocity in m/s, which is written to *OS75\_sgl\_ping.ship\_velocity*. If bottom tracking was on, the horizontal bottom track velocities *OS75\_sgl\_ping.bt.vel(1:2,:)* should contain values other than NaN. If that is the case, the ship velocity is set to *OS75\_sgl\_ping.bt.vel(1:2,:)*. The structure *OS75\_sgl\_ping* is then handed back to the main routine.

#### 5.4.9 *vel\_clean\_ship\_vel.m*

This routine was added by Hugh Venables during JR218 to filter out spikes in the GPS data. It is called with the arguments *OS75\_sgl\_ping* and *which\_prdid\_fix* and returns the modified structure *OS75\_sgl\_ping*.

#### 5.4.9 `qual_control.m`

Several criteria are used in this routine for further quality control. Therefore, the arguments *OS75\_sgl\_ping*, *beam*, *heading\_change* and *ship\_velocity\_change* are included in the call. *beam* is the number of beams of the ADCP instrument, *heading\_change* is the maximum change in heading allowed at any one time step, and *ship\_velocity\_change* is the maximum change in ship velocity allowed at any one time step. Large changes lead to less reliable ADCP data. The values used during JR239 are 10° per ping for the heading change and 0.5514 m per ping for the ship velocity change.

The first step of quality control uses the error velocity provided through the fourth beam (`vel(:,4,:)`). A variable `err_vel` is set to 2 times standard deviation of the error velocity, and the velocities of all ping ensembles where the absolute value of this velocity exceeds `err_vel` are set to NaN. Then, if `beam = 0`, a check using percent good is performed: velocities of ping ensembles with percentage of good four beam solutions equal to zero are set to NaN.

The two following steps look at the heading changes. First, a smoothed version of the heading change (`diff(heading)`), created using a Hamming-window based, second order filter (see 5.4.17), is checked for values exceeding heading change, and the velocities of affected ping ensembles (i.e. the two ensembles in between which the change is large) are set to NaN. The same is done for the unfiltered heading change. NOTE: for `mfilter.m` and the therein used Matlab function `filtfilt.m`, the data needs to have a minimum length of 3 times the filter order. This means that *files with less than 5 minutes of data cannot be used*.

Velocities are set to NaN if the change in ship speed exceeds ship velocity change. A last control is done on absolute horizontal velocities in a reference layer: The eastward and northward velocities in the ninth depth bin are chosen and the ship velocity is added to obtain absolute velocities. Then, velocities of ping ensembles between which the change of either of these reference velocities is larger than 2 m/s are set to NaN. The structure with the modified velocity array is returned to the main routine.

Hugh Venables modified the call to the quality control routine such that in the first run, a quicker, less thorough quality check is done using the routine `qual_control_quick.m` to allow faster processing for quick data checks. During the second run, the above quality control is done.

#### 5.4.10 `calib_points_bt.m`

In this routine, calibration points are extracted using 2-minute averages of ADCP data and various criteria these points have to fulfill. It is called with the arguments *OS75\_sgl\_ping*, *cal\_file*, *which\_prdid\_fix*, *ref\_uplim* and *ref\_lowlim*. *cal\_file* specifies where the data for calibration extracted here will be written to, *which\_prdid\_fix* does the same as in `ship_vel.m` (5.4.8). To average the ADCP data over 2 minutes, the routine

`ave_for_calib.m` is called with the arguments `OS75_sgl_ping`, `av_time` (set to 120 seconds), `ref_uplim`, `ref_lowlim`, and `which_prdid_fix`.

`ave_for_calib.m` This routine is a reduced version of `average_pings.m` (see 5.4.11), including only variables required by `calib_points_bt.m`. The possibility of missing out ping ensembles in the averaging process when several `.ENX`-files exist in a file sequence is ignored here (for more about that issue see 5.4.11).

After the averaging, a check is done whether bottom track velocities are available or not. If all bottom velocities are NaNs, the routine stops and returns to the main program. The principle used is based on a comparison of ADCP bottom track data and GPS tracks. The bottom velocity recorded by the ADCP should be the same as the GPS derived ship velocity. Therefore, the value GPS ship speed/ADCP bottom track speed gives the scaling factor to adjust ADCP velocities, and  $-(\text{GPS ship heading} - \text{ADCP bottom track heading})$  is the misalignment angle.

As velocities from bottom tracking are crucial for the calibration, ping ensembles with NaNs in either zonal or meridional bottom velocity are discharged. The ship velocity is derived from navigation data in `OS75_sgl_ping.nav` and `which_prdid_fix` sets which fix is used. Ship velocity is then calculated as in `ship_vel.m` (5.4.8) as distance in east- and northward direction divided by time difference.

The criteria potential calibration points have to fulfill are:-

- the change in ship heading is small;
- the change in ship speed is small;
- the ship speed is within the interval average ship speed  $\pm$  standard deviation;
- the ship heading is within the interval average ship heading  $\pm$  standard deviation;
- the bottom speed is larger than a specified minimum speed;
- there are a minimum number of possible calibration points in a row that fulfill the criteria.

Relevant data at the calibration points are extracted and saved in the structure `cal`. This includes bottom velocity, speed, heading and range, ADCP velocities and heading, ship speed and heading, and the navigation data. The scaling factor at the calibration points is calculated as is the misalignment angle. To enable quality control of the intervals of calibration points (interval=row of successive calibration points) and possible filtering by hand after the processing, some statistics are done and included in the structure: average and standard deviations of ship velocity and heading, bottom velocity and heading, scaling factor and misalignment angle, and the number of 2-minute averages in the interval. If the `cal_file` does not exist yet, it is created, otherwise, the data is added to the existing file.

#### 5.4.11 `average_pings.m`

The routine is called with the arguments `OS75_sgl_ping`, `d_missed`, `OS75_ave_ping`, `superaverage`, `ref_uplim`, `ref_lowlim`, and `which_prdid_fix`. The time in seconds over which the ping ensembles are averaged is given by `superaverage`. As the ping ensembles in a file of a file sequence are not necessarily divisible into the specified time intervals without remainder, the structure `d_missed` is used to carry on the surplus ensembles

and add them to the ping ensembles of the next file in the same file sequence. If there are ping ensembles left at the end of a file sequence, they will not be included in the averaging. At first, a check is done whether any ping ensembles from the previous file were carried forward. If that is the case, and the bin depth is the same in both files, they are added to the current file in the loop. A depth range for the reference layer velocity is set as is the maximum number of depth bins. Pings are averaged in intervals determined by *superaverage* and using the time stamps in *OS75\_sgl\_ping.nav.txyX* where *X* is either 1 or 2 depending on *which\_prdid\_fix*. Throughout the routine, there are various occasions where (usually) three dimensional arrays are split up into several 2d-arrays. This is done using the reshape-command and the size of the velocity fields. To avoid problems when the original velocity field is 2d instead of 3d, a check is introduced and the variable containing the size of the field is adjusted.

Several variables are extracted and derived: the reference layer velocity (zonal and meridional) as mean of the horizontal velocities in the depth range specified by *ref\_uplim* and *ref\_lowlim*; absolute velocities by adding the ship velocity to the horizontal velocities; percent good from the fourth beam; a value for bottom range for each ping ensemble with the condition that it is between 50 and 1200 m depth and using the median of the four beams; the difference between the headings from the .ENX- and from the .N1R-file (set to NaN if the .ENX-heading does not change for two successive ping ensembles); pitch and roll (set to NaN if data is missing, i.e. > 998); the PC clock offset; the echo intensity as mean over all beams. The navigation data is set to NaN for ping ensembles where there is no velocity data in any of the beams and any of the depth bins. For the averaging, the heading is broken up into components (-cos and sin) and reconverted to angles in degrees afterwards.

Of the extracted variables, the ones included in the averaging are: absolute velocity (all three directions), reference velocity, heading, difference in .ENX- and .N1R-heading, PC clock offset, echo intensity, percent good, and bottom range. Additionally, ship velocity and navigation data (time, longitude, latitude) are averaged. For pitch and roll, the standard deviation is calculated.

The data from ping ensembles that were remainders after the averaging is written to *d\_missed* and returned to the main routine. The averaged absolute velocity is converted back to velocity relative to the ship by subtracting the averaged ship velocity. The reference layer velocity is then recalculated from the resulting averaged (relative) velocity. The averaged variables are added to the structure *OS75\_ave\_ping* as are the variables *depth* and *ref.bins* (= numbers of the bins in the reference layer). The structure is then returned to the main routine.

*average\_pings.m* is the last routine called within the loops through all files in a file sequence and through all file sequences specified. At the end of the loops, the structure *OS75\_ave\_ping* contains averaged data for all files included in the processing. Before the loops are left, the array *bindepth* containing bin depths for each of the averaged velocity profiles is created.

Next steps are the final part of the calibration, blanking the bottom, and removing the ship velocity from the ADCP velocity data.

#### 5.4.12 `calib_points_wt.m`

If there is no bottom track data available, the calibration is done using water track. Again, the search for possible calibration points is done using 2 minute averages produced by `ave_for_calib.m`. First differences are calculated from the average data for the reference velocities (i.e. the water velocities in the reference layer specified by `ref_uplim` and `ref_lowlim`)  $du$  and  $dv$ , and the ship velocities  $dsu$  and  $dsv$ . Of those, only differences were considered for when ship speed exceeded 3 m/s between ensembles not more than 5000 m or 3600 s apart. Using the Matlab function `fminsearch.m`, the following function was minimised for  $\phi$  and  $A$ :

$$f(A,\phi)=(A\cdot du\cdot\cos(\phi)-A\cdot dv\cdot\sin(\phi)+dsu)^2+(A\cdot du\cdot\sin(\phi)+A\cdot dv\cdot\cos(\phi)+dsv)^2$$

Values for  $A$  and  $\phi$  are written to the array `alpha` together with relevant heading, navigation, and velocity data, and `alpha` is handed back to the main routine.

#### 5.4.13 `calib_calc_wt.m`

After `alpha` has been created in `calib_points_wt.m`, it is passed on to this subroutine. Here, average, median, and standard deviation for  $\phi$  and  $A$  are calculated and written to `cal_file_wt`. The average or the median should then be used during the second run of `OS75_JCR.m` for misalignment and amplitude correction. Several plots of the misalignment and the scaling are also produced and stored in `adcp_correction_stats.ps`.

#### 5.4.14 `calib_calc_bt.m`

During the first run of `OS75_JCR.m`, the misalignment angle and the scaling factor that are to be used for the second run are calculated here. In the second run, the results for  $\phi$  and  $A$  should be closer to zero and one, respectively, than before. The arguments handed over are `cal_file`, which specifies the file with the calibration point data, `cruise`, `misalignment_xb` and `amplitude_xb`, which are used for the plots created in this routine. After `cal_file` is read in, scaling factors and misalignment angles outside the interval average  $\pm$  standard deviation are sorted out. From the remaining points, the average, the median and the standard deviation for  $A$  and  $\phi$  are calculated and added to the structure `cal`. The median is less affected by outliers that might have survived the screening in `calib_points_bt.m` and `calib_calc_bt.m` and should therefore be used as correction value in the second run. Before returning to the main routine, a plot showing the distribution of the misalignment angles and the scaling factors and their temporal evolution is produced. (After returning to the main program, the plot is written to the file `adcp_calib_calc.ps`.)

#### 5.4.15 `bt_mask.m`

`OS75_ave_ping` and `bindepth` are passed on to this routine. Here, a mask is created using the bottom range `bt.range`. With this mask, velocity data below 86% of the bottom range (= water depth) is set to NaN. The structure containing the modified velocity fields is returned to the main routine.

#### 5.4.16 `abs_vel.m`

`OS75_ave_ping` and `bindepth` are handed over from the main routine. In order to derive absolute water velocities independent of the ship movement, the east- and northward ship velocity is added to the horizontal water velocity (`OS75_ave_ping.vel`). The same is

done for the velocity in the reference layer (*OS75\_ave\_ping.ref.vel*). The resulting absolute velocities, the navigation data and the depth array (set to *bindepth*) are handed back to the main routine within the structure *OS75\_abs*.

5.4.17 Helper routines: *julian.m*, *sw\_dist.m*, *uvrot.m*, *rot\_fun\_1.m*, *mfilter.m*

These routines are called on various occasions during the processing. *sw\_dist.m* is part of the CSIRO Seawater toolbox.

## 5.5 Overview of output files

### 5.5.1 *CRUISE\_xxx\_yyyyyy\_raw.mat*

The structure *OS75\_raw* in this file contains the raw, unedited data from the .ENX-file as read in in *include\_att\_jcr.m* and *read\_nmea\_att\_jcr.m*. For JR235/6/9 the structure consists of:

- *vel*, *cor*, *amp*, *pg* (arrays of size [number of bins x number of beams x number of ensembles]): velocity, correlation magnitude, echo intensity and percent good for the four beams.
- *heading*, *pitch*, *roll* as [1 x number of ensembles]-array.
- *temperature*, *soundspeed*: [1 x number of ensembles]-array. The temperature here is the temperature of the water at the transducer head. It is either set manually or measured. The soundspeed is calculated or set manually.
- *dday*, *ens\_num*, *num pings*: [1 x number of ensembles]-array. *dday* is decimal day, *ens\_num* the ensemble number of the pings, and *num ping* the number of pings in each ensemble.
- *bt*: structure containing the bottom track data:
  - *vel*, *range*, *cor*, *amp*, *rsi* (arrays of size [4 x number of ensembles]): bottom track velocity, range, correlation magnitude, echo intensity and receiver signal strength indicator for the four beams
- *nav*: structure containing navigation data:
  - *sec pc minus utc*: [number of ensembles x 1]-array containing the PC clock offset in seconds;
  - *txy1*, *txy2*: [3 x number of ensembles]-arrays; first row: time in decimal Julian days, second row: longitude, third row: latitude. *txy1* is data from the first \$PRDID-fix after the previous ADCP ping, *txy2* is from the last \$PRDID-fix before the actual ADCP ping.
- *config*: structure containing the setup information about the OS75 and VmDas
- *depth*: [1 x number of bins] array. The array contains the depth of the bins in the configuration used for the actual file sequence.
- *error*: if reading of data fails, an error message will be stored here, otherwise it should be empty.

There is one such file for each .ENX-file in a file sequence.

### 5.5.2 *CRUISE\_xxx\_000000\_att.mat*

In this file, the structure *att* contains the attitude information from all .N1R-files of a file sequence, read

during `read_nmea_att_jcr.m`. This includes the following [1 x number of ensembles]-arrays from the and \$PADCP lines:

- heading, pitch, roll;
- `pc_time`: time from the ADCP PC clock;
- `pc_time_offset`: offset of the ADCP PC clock from UTC in seconds;
- `ens_num`: the ping ensemble number.

Per file sequence, one file `CRUISE_xxx_000000_att.mat` is produced.

### 5.5.3 *CRUISE\_xxx\_yyyyyyd\_att.mat*

For each file in a file sequence, attitude data is extracted and saved in `CRUISE_xxx_yyyyyyd_att.mat`. It contains a structure `att` which consists of the following arrays of size [1 x number of ensembles] per .ENX-file:

- `att_heading`, `att_pitch`, `att_roll`: heading, pitch and roll from the .N1R-files for the ping ensembles in the corresponding .ENX-file;
- `heading_orig`: heading from the .ENX-file;
- `ens_num`: the ping ensemble number;
- `lat`: latitude of the ping ensemble.

The difference between `att_heading` and `heading_orig` should be small and therefore negligible. In the case of JR235/6/9, they both come from the SeaPath Seatex, but there is a small time lapse between the writing of data to the .ENX- and the .N1R-files (see also 4).

### 5.5.4 *CRUISE\_xxx\_yyyyyy\_sgl\_ping.mat*

Again, one file with single ping data is produced for each .ENX-file. In the structure `OS75_sgl_ping`, after several steps of quality control, filtering and correcting for misalignment and scaling (after final processing), data from the four beams, bottom track data, navigation data, configuration data and information about the processing environment are stored:

- all variables that exist in `OS75_raw` in the file `CRUISE_xxx_yyyyyy_raw.mat` are included;
- additional variables:
- `filename`: `CRUISE_xxx_000000`;
- `path`, `rawpath`: paths to the directories where the processed data is written to (`path`) and where the raw data files are stored (`rawpath`);
- `att`: structure containing heading, pitch, roll, and PC clock offset;
- `heading_orig`: [number of ping ensembles x 1]-array, heading from the .ENX-file;
- `ship velocity`: [2 x number of ping ensembles]-array, containing the eastward (first row) and the northward (second row) ship velocity.

### 5.5.5 *CRUISE\_cal\_points.mat*

In this file, all information at bottom track calibration points needed for the calculation of misalignment angle and scaling factor are stored. This includes:

- `bt`: structure with bottom track data: arrays `vel` ([2 x number of calibration points]), `speed`, `heading`, and `range` ([1 x number of calibration points]);
- `vel`: [number of bins x 2 x number of calibration points]-array of east- and northward velocity heading: [1 x number of cal. points]-array; heading from .N1R-data; `nav`: structure containing `txy1` data at the calibration points;
- `ship speed`, `ship heading`: [1 x number of cal points]-arrays;

- scaling, phi: scaling factor and misalignment angle at each calibration point; [1 x number of cal. points]- array;
- intervals: stats for each interval of successive calibration points; see description of routine `calib_points_bt.m` in 5.4.10;
- mode: [1 x number of cal points]-array. 1 or 10 for each calibration point depending on broadband or narrowband mode.
- which file: [number of cal points x 16]-character array with file name of the file the calibration point is from.
- stat: structure with values for the scaling factor (a) and the misalignment angle (phi) as calculated in the routine `calib_calc_bt.m`, see 5.4.14; the values stored here after the first run of the main routine `OS75_JCR.m` are the ones that should be used for the second run.

Only one file for all file sequences processed in a run is created.

#### 5.5.6 *CRUISE\_cal\_points\_wt.mat*

If no bottom track data is available, calibration is done using water track. For this, the array `alpha` is created. From data in `alpha`, the misalignment angle `phi` and the scaling factor `scaling` are derived and `alpha`, `phi`, and `scaling` are stored in this file.

#### 5.5.7 *CRUISE\_000\_000000\_zz\_ave\_ping.mat*

(zz=highest file ensemble number included in the processing)

The structure `OS75_ave_ping` contains data after averaging over a chosen time interval (xyz = number of velocity profiles after averaging):

- vel: [number of bins x 3 x xyz]-array of average velocity (zonal, meridional and vertical);
- amp, pg: [number of bins x xyz]-arrays; echo intensity and percent good;
- ship velocity: [2 x xyz]-array of zonal and meridional ship velocity; if bottom track velocity is available, then the ship velocity equals the bottom track velocity;
- heading: [1 x xyz]-array;
- nav: structure containing `txy1`: [3 x xyz]-array of time (decimal Julian days), longitude and latitude;
- att: structure containing:
  - heading difference: [1 x xyz]-array of the difference between heading from `.ENX` and `.N1R` (hopefully equal to zero);
  - pitch, roll, pc time: [1 x xyz]-arrays;
- ref: structure with velocity ([2 x xyz]-array): average over the reference layer, and bins: vector containing the depth bins that lie within the reference layer;
- bt: structure containing range: [1 x xyz]-array of bottom track range;
- depth: [1 x number of bins]-array (bin depths of the setting of the last file sequence processed).

#### 5.5.8 *CRUISE\_000\_000000\_zz\_abs.mat*

(zz=highest file ensemble number included in the processing) In this file, both `OS75_abs` and `OS75_ave_ping` are saved. The latter contains the same fields as in `CRUISE_000_000000_zz_ave_ping.mat`, where only the values in the velocity field are changed. Additionally, the variable `bindepth` is included as well.

`OS75_abs` includes (xyz = number of velocity profiles after averaging):

- `vel`: [number of bins x 3 x xyz]-array of absolute velocity (zonal, meridional and vertical), i.e. horizontal velocities are corrected for ship velocity;
- `nav`: structure containing `txy1`: [3 x xyz]-array of time (decimal Julian days), longitude and latitude;
- `ref`: structure with velocity ([2 x xyz]-array): average over the reference layer, and `bins`: vector containing the depth bins that lie within the reference layer;
- `depth`: [number of bins x xyz]-array (bin depths corresponding to the settings used for the velocity profiles).

### 5.5.9 Plots

#### **adcp\_prh.ps**

For each .N1R-file a plot of pitch, roll, heading, and PC clock offset is produced in `read_nmea_att_jcr.m` and saved to `adcp_prh.ps`. They need editing to make them really useful.

#### **adcp\_calib\_calc.ps**

After the final filtering of calibration points, misalignment angle and scaling factor are plotted in form of histograms and timeseries (in `calib_calc_bt.m`). There should be two plots after completed processing: the first plot from the first run of `OS75_JCR.m` with amplitude = 1 and misalignment angle = 0, and second plot from the second run using the calculated values for amplitude and misalignment.

#### **adcp\_correction\_stats.ps**

These plots show the results of the water track calibration if no bottom track is available, similar to the ones in `adcp_calib_calc.ps`.

#### **adcp\_vel\_contours.ps**

The final step in `OS75_JCR.m` is to plot meridional and zonal velocity as it is saved in the structure `OS75_abs` in file `CRUISE_000_000000_zz_abs.mat`. Added in the figure are the cruise track, the values used for correction for misalignment and scaling, the cruise name, and numbers of the file sequences processed. As in `adcp_calib_calc.ps` the first plot is from the first run, the second plot from the second run.

## 5.6 Further processing and JR235/6/9 specifics

### **Blanking the bottom**

For sequences recorded in Bottom Track mode we used the bottom range to blank the data below 86% of the detected bottom depth during the above described processing. Additionally, we used the gradient in the return signal strength fields in the postprocessing. The Matlab routine is `jr239_bottom_blank.m`.

### **Filtering bad data**

To filter bad data points (e.g. from interference, bubbles, outliers), we use the routine `jr239_post_proc_filter.m`. Various criteria were applied to sort out bad data:

- velocities greater than 1.5 m/s are discarded;
- data with error velocities outside running average error vel.  $\pm 2 \times$  standard deviation are discarded;

- velocities outside running average velocity  $\pm 2 \times$  std. dev. or running median velocity  $\pm 2 \times$  std. dev. are discarded.

The running averages and medians are calculated with a window size of  $2 \times 15 + 1$ , both rowwise and columnwise.

### Final averaging

To get usable data, we calculated 10 minute averages from the clean, filtered data. This is done in the same way as the 2 minute averages during the processing and takes into account varying bin depths. The Matlab routine is `jr239_ave_after_filtering.m`.

The file containing the data prior to and after the bottom blanking, the filtering, and the 10 minutes averaging is 'jr239\_1to31\_abs\_filt\_ave\_wt.mat'.

### Detiding

Preliminary detiding has been done for the final 10 minute averages using the tide model 'AntPen'. The matlab routine is `jr239_detide.m`; the data is saved in 'jr239\_abs\_filt\_ave\_detide.mat'.

### ADCP profiles for CTD stations

For comparison with the LADCP profiles, shipboard ADCP profiles have been extracted using the file `time_ladcp.mat` created by Loic Jullion from the LADCP times. The profiles are numbered according to Dr. Jullion's station numbering, and are saved in 'jr239\_adcp\_stn\_profiles.mat'.

### JR235/6/9 settings of variables in the Matlab processing routines

in `OS75_JCR.m`:

|  |                      |
|--|----------------------|
| filename   | jr239_               |
| cruise   | JR239                |
| files for calculating misalignment and amplitude | 1-4, 6-15, 18, 20-31 |
| superaverage                                     | 120 seconds          |
| year   | 2010                 |
| which_prdid_fix                                  | 1                    |
| upper limit of reference layer                   | 400 m                |
| lower limit of reference layer                   | 600 m                |

in `read_os.m`:

|                        |     |
|------------------------|-----|
| raw data format        | ENX |
| which raw data to read | all |
| id_arg                 | 0   |
| optional argument      | nav |

in `include_att_jcr.m`

|                            |     |
|----------------------------|-----|
| raw navigation data format | N1R |
|----------------------------|-----|

in `qual_control.m`

|                        |     |
|------------------------|-----|
| no. of beams           | 4   |
| maximum heading change | 10° |

maximum ship velocity change 0.5514 m/s

Criteria for calibration points (in `calib_points_wt.m`):

max. distance in time between ensembles 3600 s  
max. distance along track between ensembles 5000 m  
min. ship velocity 3 m/s

Filtering and smoothing:

bottom blanking below 86% of bottom depth  
maximum velocity 2 m/s  
maximum velocity change  
window size for running means and medians  $2 \times 15 + 1$

## 6 Calibration

The calibration was done for the entire cruise JR235/236/239 using water track calibration. Although bottom track data was collected, most of the cruise took place in deep water, and the available bottom track is not sufficient. Bottom track calibration was not satisfactory.

The water track calibration in the following values:

misalignment angle: -0.0748  
amplitude: 1.015741

## 7 Summary of VmDas Commands

### 7.1 Overview of available commands

|                                  | Command     | * | Description   |
|----------------------------------|-------------|---|---|
| Control                          | CRn         |   | Retrieve Parameters (0=User, 1=Factory)   |
|                                  | CBnnn       | 1 | Serial Port Control (Baud Rate, Parity, Stop Bits)  |
| Narrow Bandwidth Water Profiling | NPnnn       |   | Number of Pings (0 to 999 pings; 0=disable)   |
|                                  | NNnnn       |   | Number of Bins (0 to 128 bins)  |
|                                  | NSnnnn      |   | Bin size (800 to 3200 cm)   |
|                                  | NFnnnn      |   | Blanking Distance (0 to 99999cm)  |
|                                  | NDnnnnn0000 |   | Data out (velocity, power, echo intensity, percent good, status)  |
| Broad Bandwidth Water Profiling  | WPnnn       |   | Number of pings (0 to 999 pings; 0=disable)   |
|                                  | WNnnn       |   | Number of Bins (0 to 128 bins)  |
|                                  | WSnnnn      |   | Bin size (40 to 3200 cm)  |
|                                  | WFnnnn      |   | Blanking Distance (0 to 9999cm)   |
|                                  | WVnnn       | 6 | Ambiguity Velocity (0 to 390 cm/s)  |
|                                  | WDnnnnn0000 |   | Profile data out (velocity, correlation, echo intensity, percent good, status)  |
| Bottom Track                     | BPn         |   | Number of Pings (0 to 999 pings; 0=disable)   |
|                                  | BXnnnn      |   | Maximum Tracking Depth (0 to 9999dm)  |
| Timing                           | TPmmssff    | 2 | Time between pings (mm=mins, ss=secs, ff=hundredths of secs)  |
|                                  | TEhmmssff   | 3 | Time per Ensemble (hours, mins, secs, hundredths of secs)   |
| Environment                      | EZcdhprst   |   | Sensor Source (speed of sound, depth, heading, pitch, roll, salinity, temperature); (0=manual, 1=transducer, 2=synchro) |
|                                  | EXnnnnn     | 4 | Coordinate transformations  |
|                                  | EA±nnnn     | 5 | Heading Alignment (-179.99 to 180.00 degrees) (100ths of degrees)   |
|                                  | EDnnnnn     |   | Depth of Transducer (0 to 65535 decimeters) Salinity (0 to 40 ppt)  |
|                                  | ESnn        |   | Keep parameters as user defaults (i.e. save this setup to non-volatile memory in the ADCP)                              |
| Control                          | CK          |   |   |

**\* Notes:**

1. VmDas sends baud rate change command (CB) after all other commands in this file, so that it is not made permanent by a CK command.

2. TP is the minimum time between pings (independent of the type of ping), used to make sure the previous ping is “dead”, i.e. there is no more echo, before the following ping is sent.
  3. Since VmDas uses manual pinging, TE is ignored by the ADCP. You must set the time between ensembles in the VmDas Communication options.
  4. Output beam data (rotations are done in software).
  5. Set transducer misalignment (EA). Note: contrary to the manual, this is given in hundredths of degrees NOT degrees.
- (iii) Don't touch ambiguity velocity (WV), it is the max speed ADCP can measure.

## 7.2 Command files

### 7.2.1 JR239 OS75 NB BT\_off 1000m 16m bins.txt:-

```

;-----\
; ADCP Command File for use with VmDas software.
;
; ADCP type: 75 Khz Ocean Surveyor
; Setup name: default
; Setup type: low resolution, Long range profile(Narrowband) 1000 m
;
; NOTE: Any line beginning with a semicolon in the first
; column is treated as a comment and is ignored by
; the VmDas software.
;
; NOTE: This file is best viewed with a fixed-point font (e.g. courier).
; Modified Last: 28August2005
;-----/

; Restore factory default settings in the ADCP
cr1

; set the data collection baud rate to 38400 bps,
; no parity, one stop bit, 8 data bits
; NOTE: VmDas sends baud rate change command after all other commands in
; this file, so that it is not made permanent by a CK command.
cb611

; Set for narrowband single-ping profile mode (NP), sixty five (NN) 16 meter bins (NS),
; 8 meter blanking distance (NF), 390 cm/s ambiguity vel (WV)

; Switch Narrowband ON NP1
NP1
nn65
ns1600
nf0800

; Switch Broadband OFF WP0
WP000
WN065
WS800
WF0200
WV390

; Disable single-ping bottom track (BP),
; Set maximum bottom search depth to 1200 meters (BX) (decimeters)
BP00
BX12000

; output velocity, correlation, echo intensity, percent good

```

WD11110000

; One and a half seconds between bottom and water pings  
TP000150

; Two seconds between ensembles  
; Since VmDas uses manual pinging, TE is ignored by the ADCP.  
; You must set the time between ensemble in the VmDas Communication options  
TE0000200

; Set to calculate speed-of-sound, no depth sensor, external synchro heading  
; sensor, no pitch or roll being used, no salinity sensor, use internal transducer  
; temperature sensor  
EZ1020001

; Output beam data (rotations are done in software)  
EX00000

; Set transducer misalignment (hundredths of degrees)  
EA6008

; Set transducer depth (decimeters) [= 6.3 on JCR]  
ED00063

; Set Salinity (ppt) [salinity in transducer well = 0]  
ES0

; Set Trigger In/Out [ADCP run through SSU]  
; CX1,3

; save this setup to non-volatile memory in the ADCP  
CK

### 7.2.2 JR239 OS75 NB BT\_on 1000m 16m bins.txt:-

```
-----\  
; ADCP Command File for use with VmDas software.  
;  
; ADCP type: 75 Khz Ocean Surveyor  
; Setup name: default  
; Setup type: low resolution, Long range profile(Narrowband) 1000 m  
;  
; NOTE: Any line beginning with a semicolon in the first  
; column is treated as a comment and is ignored by  
; the VmDas software.  
;  
; NOTE: This file is best viewed with a fixed-point font (e.g. courier).  
; Modified Last: 28August2005  
-----/  
  
; Restore factory default settings in the ADCP  
cr1  
  
; set the data collection baud rate to 38400 bps,  
; no parity, one stop bit, 8 data bits  
; NOTE: VmDas sends baud rate change command after all other commands in  
; this file, so that it is not made permanent by a CK command.  
cb611  
  
; Set for narrowband single-ping profile mode (NP), sixty five (NN) 16 meter bins (NS),  
; 8 meter blanking distance (NF), 390 cm/s ambiguity vel (WV)  
  
; Switch Narrowband ON NP1  
NP1
```

nn65  
 ns1600  
 nf0800

; Switch Broadband OFF WP0  
 WP000  
 WN065  
 WS800  
 WF0200  
 WV390

; Enable single-ping bottom track (BP),  
 ; Set maximum bottom search depth to 1200 meters (BX) (decimeters)  
 BP01  
 BX12000

; output velocity, correlation, echo intensity, percent good  
 WD111100000

; 1.5 seconds between bottom and water pings  
 TP000150

; Three seconds between ensembles  
 ; Since VmDas uses manual pinging, TE is ignored by the ADCP.  
 ; You must set the time between ensemble in the VmDas Communication options  
 TE00000300

; Set to calculate speed-of-sound, no depth sensor, external synchro heading  
 ; sensor, no pitch or roll being used, no salinity sensor, use internal transducer  
 ; temperature sensor  
 EZ1020001

; Output beam data (rotations are done in software)  
 EX00000

; Set transducer misalignment (hundredths of degrees)  
 EA6008

; Set transducer depth (decimeters) [= 6.3 on JCR]  
 ED000063

; Set Salinity (ppt) [salinity in transducer well = 0]  
 ES0

; Set Trigger In/Out [ADCP run through SSU]  
 ; CX1,3

; save this setup to non-volatile memory in the ADCP  
 CK

### 8 File sequences during ANDREX-2

| Date/time (GMT)   | Jday (1 Jan = Jday 0) | File seq. | First & last \$PADCP line  | Files                    | Config.          | Comments          |
|-------------------|-----------------------|-----------|--|--------------------------|------------------|-------------------|
| 20/03/2010, 21:25 | 78                    | 00 1      | \$PADCP,1,20100320,212210.01,0.52<br>\$PADCP,4615,20100321,004804.67,0.42  | jr239_001_000<br>000.XXX | BB, BT on, 500 m |                   |
| 21/03/2010, 00:48 | 79                    | 00 2      | \$PADCP,1,20100321,004851.00,0.58<br>\$PADCP,52916,20100322,185003.49,0.74 | ...000 -<br>9.ENX/ENS    | NB, BT off       | test CTD          |
| 22/03/2010, 18:50 | 80                    | 00 3      | \$PADCP,1,20100322,185046.00,0.82<br>\$PADCP,3014,20100322,232636.80,1.76  | ...000.XXX               | NB, BT on        | approaching shelf |

| Date/time (GMT)   | Jday (1 Jan = Jday 0) | File seq. | First & last \$PADCP line  | Files                          | Config.             | Comments  |
|-------------------|-----------------------|-----------|--|--------------------------------|---------------------|---|
| 22/03/2010, 23:27 | 80                    | 00 4      | \$PADCP,1,20100322,232703.00,1.79<br>\$PADCP,10905,20100323,083814.25,-0.31  | ...000 -<br>1.ENX/ENS/EN<br>R  | BB, BT<br>on, 500 m | onto shelf approaching Falklands  |
| 23/03/2010, 08:43 | 81                    | 00 5      | \$PADCP,1,20100323,084149.00,-0.25<br>\$PADCP,32,20100323,084322.00,-0.21    | ...000.XXX                     | BB, BT<br>on, 500 m | was meant to be 200 m but didn't edit<br>command file properly<br>(too short for processing)                                |
| 23/03/2010, 08:45 | 81                    | 00 6      | \$PADCP,1,20100323,084414.00,-0.15<br>\$PADCP,11249,20100323,180703.00,1.28  |                                | BB, BT<br>on, 200 m |   |
| 23/03/2010, 18:07 | 81                    | 00 7      | \$PADCP,1,20100323,130726.00,1.21<br>\$PADCP,4009,20100323,213141.43,3.56    | ...000.XXX                     | BB, BT<br>on, 500 m |   |
| 23/03/2010, 21:32 | 81                    | 00 8      | \$PADCP,1,20100323,213214.00,3.63<br>\$PADCP,10475,20100324,120557.49,0.91   | ...000 -<br>1.ENX/ENS/EN<br>R  | NB, BT on           |   |
| 24/03/2010, 12:06 | 82                    | 00 9      | \$PADCP,1,20100324,120621.99,0.75<br>\$PADCP,32803,20100325,152631.07,0.01   | ...000 -<br>5.ENX/ENS/EN<br>R  | NB, BT off          | Drake Passage<br>24/03/2010, 19:00: Argo float<br>deployment  |
| 25/03/2010, 15:26 | 83                    | 01 0      | \$PADCP,1,20100325,152656.00,0.10<br>\$PADCP,38301,20100328,031810.34,0.69   | ...000 -<br>7.ENX/ENS          | NB,BT on            | Bransfield Strait<br>CTD 002-017  |
| 28/03/2010, 03:18 | 86                    | 01 1      | \$PADCP,1,20100328,031838.00,0.58<br>\$PADCP,39074,20100329,115226.72,1.31   | ...000 -<br>6.ENX/ENS/EN<br>R  | NB, BT off          | CTD 018-023   |
| 29/03/2010, 11:55 | 87                    | 01 2      | \$PADCP,1,20100329,120104.38,1.27<br>\$PADCP,5665,20100329,153329.11,1.46    | ...000.XXX                     | NB BT on,<br>500 m  | VmDAS hung while changing<br>command files, restarted. File no. set<br>to 12, so should carry on as before.<br>Screen reset |
| 29/03/2010, 15:34 | 87                    | 01 3      | \$PADCP,1,20100329,153404.00,1.36<br>\$PADCP,9244,20100329,223720.49,4.74    | ...000 -<br>1.ENX/ENS/EN<br>R  | BB, BT<br>on, 500 m | Seq 012 doesn't seem to recognise<br>bottom (wrong max bottom<br>recognition in command file)<br>CTD 024-205                |
| 29/03/2010, 22:37 | 87                    | 01 4      | \$PADCP,1,20100329,223751.99,4.65<br>\$PADCP,74140,20100401,093135.48,-0.00  | ...000 -<br>13.ENX/ENS         | NB, BT off          | CTD 026<br>first period of swathing<br>CTD 027-030  |
| 01/04/2010, 09:30 | 90                    | 01 5      | \$PADCP,1,20100401,043144.00,-0.04<br>\$PADCP,36351,20100402,142439.94,-0.05 | ...000 -<br>6.ENX/ENS/EN<br>R  | NB, BT off          | CTD 031, 030A, 032  |
| 02/04/2010, 14:24 | 91                    | 01 6      |  |                                |                     | could not write to backup file (file<br>existed due to earlier testing and file<br>naming confusion) => restarted           |
| 02/04/2010, 14:25 | 91                    | 01 7      |  |                                | NB, BT off          | didn't start up properly => restart   |
| 02/04/2010, 14:25 | 91                    | 01 8      | \$PADCP,1,20100402,142554.00,0.09<br>\$PADCP,105875,20100406,023322.44,1.22  | ...000 -<br>18.ENX/ENS         | NB, BT off          | CTD 033-044   |
| 06/04/2010, 02:33 | 95                    | 01 9      |  |                                |                     | wrong set up => restart   |
| 06/04/2010, 02:33 | 95                    | 02 0      | \$PADCP,1,20100406,023356.00,1.23<br>\$PADCP,15669,20100407,023110.77,-0.60  | ...000 -<br>2.ENX/ENS/EN<br>R  | NB, BT on           | bad weather<br>CTD 045-047  |
| 07/04/2010, 02:31 | 96                    | 02 1      | \$PADCP,1,20100407,023143.02,-0.66<br>\$PADCP,33660,20100408,051524.38,0.84  | ...000 -<br>5.ENX/ENS/EN<br>R  | NB, BT off          | CTD 048-055   |
| 08/04/2010, 05:15 | 97                    | 02 2      | \$PADCP,1,20100408,051554.00,0.71<br>\$PADCP,5447,20100408,134009.38,0.73    | ...000 -<br>1.ENX/ENS          | NB, BT on           | CTD 056-057   |
| 08/04/2010, 13:40 | 97                    | 02 3      | \$PADCP,1,20100408,134031.00,0.75<br>\$PADCP,100861,20100411,214952.31,0.32  | ...000 -<br>17.ENX/ENS/E<br>NR | NB, BT off          | CTD 058-068   |

| Date/time (GMT)   | Jday (1 Jan = Jday 0) | File seq. | First & last \$PADCP line   | Files                         | Config.    | Comments  |
|-------------------|-----------------------|-----------|---|-------------------------------|------------|---|
| 11/04/2010, 21:50 | 100                   | 02<br>4   | \$PADCP,1,20100411,215012.01,0.31<br>\$PADCP,83515,20100414,161038.63,0.80  | ...000 -<br>14.ENX/ENS/<br>NR | NB, BT off | end of ANDREX, steam to second transect<br>CTD 070  |
| 14/04/2010, 16:10 | 103                   | 02<br>5   | \$PADCP,1,20100414,161055.99,0.72<br>\$PADCP,103241,20100418,021123.58,0.00 | ...000 -<br>18.ENX/ENS        | NB, BT off | CTD 071-086<br>17/04/2010, at around 19:30: jump in GPS data stream<br>CTD 087                                    |
| 18/04/2010, 02:11 | 106                   | 02<br>6   | \$PADCP,1,20100418,021142.00,-0.08<br>\$PADCP,51616,20100419,191202.00,0.10 | ...000 -<br>9.ENX/ENS         | NB, BT off | CTD 088-095<br>PC crashed at 19/04/2010, ~19:15; loose serial port; restarted with Johnnie Edmonston's help       |
| 19/04/2010, 20:30 | 107                   | 02<br>7   | \$PADCP,1,20100419,203013.01,0.18<br>\$PADCP,10389,20100420,044542.04,0.13  | ...000 -<br>1.ENX/ENS/<br>NR  | NB, BT off | first wrong file nameing (jr239027), discarded those files; restart with proper naming (jr239_027)<br>CTD 096-097 |
| 20/04/2010, 04:46 | 108                   | 02<br>8   | \$PADCP,1,20100420,044612.99,0.27<br>\$PADCP,24660,20100421,114057.16,0.36  | ...000 -<br>4.ENX/ENS/<br>NR  | NB, BT on  | South Georgia Shelf<br>CTD 098  |
| 21/04/2010, 11:41 | 109                   | 02<br>9   | \$PADCP,1,20100421,114113.01,0.48<br>\$PADCP,13793,20100422,062041.78,-0.26 | ...000 -<br>2.ENX/ENS/<br>NR  | NB, BT on  | steam from South Georgia to Falklands   |
| 22/04/2010, 06:20 | 110                   | 03<br>0   | \$PADCP,1,20100422,062114.01,-0.36<br>\$PADCP,64046,20100424,091308.17,1.53 | ...000 -<br>11.ENX/ENS        | NB, BT off | steam from South Georgia to Falklands   |
| 24/04/2010, 09:15 | 112                   | 03<br>1   | \$PADCP,1,20100424,091335.00,1.39<br>\$PADCP,2303,20100424,120528.18,1.59   | ...000.XXX                    | NB, BT on  | Falklands<br>stopped recording 24/04/2010, 12:05  |

## 8. Swath bathymetry (Povl Abrahamsen)

The multi-beam sonar on the JCR, a Kongsberg Simrad EM120, was running during most of the cruise, from after leaving the Uruguayan and Argentinean exclusive economic zones, until approaching the Falkland Islands. The data have been split into seven surveys, jr239\_a through jr239\_g, one for each leg of the cruise, with an additional break when entering and leaving the Orkney Passage area, which is jr239\_c. The division into surveys is shown in Figure 6.5.

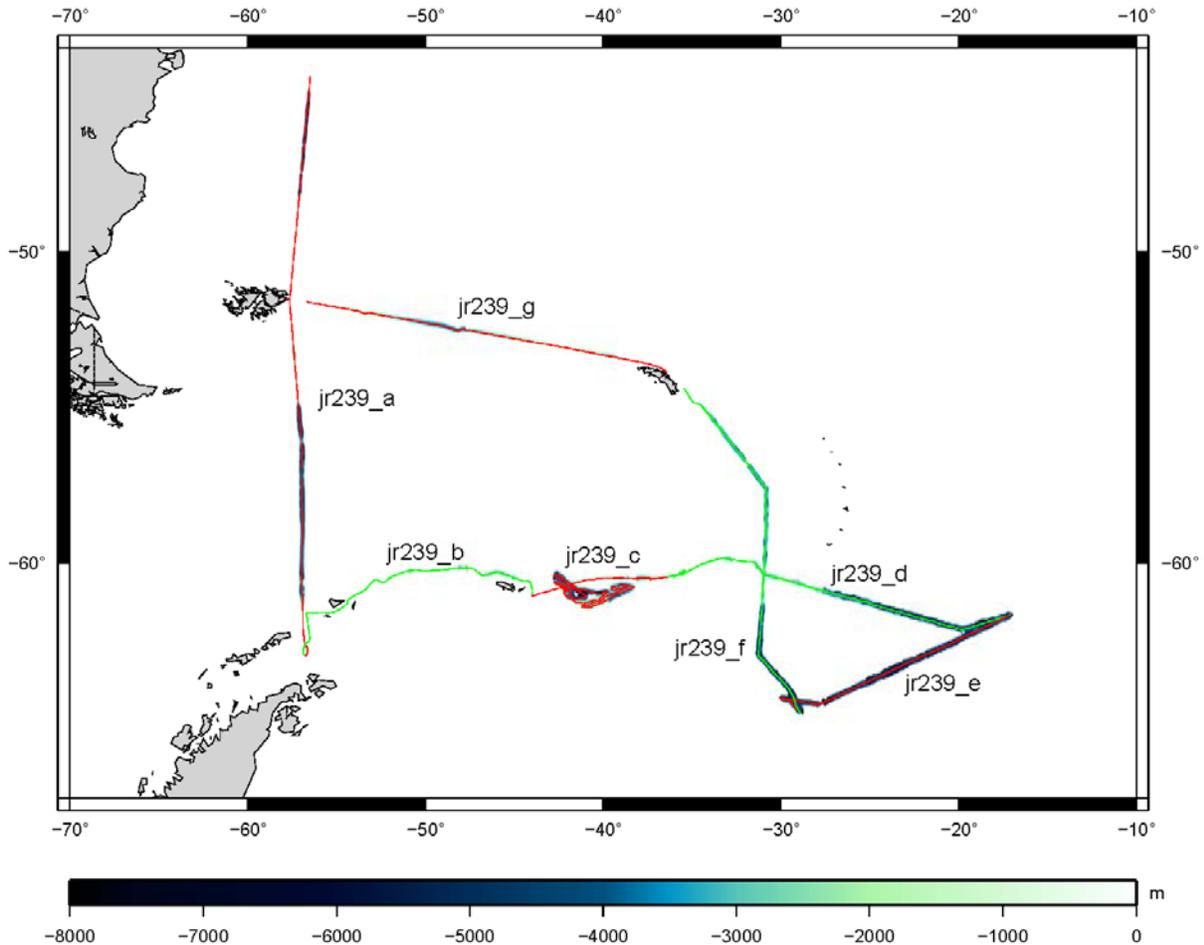


Figure 6.5. Overview of the swath bathymetry data from JR235/236/239, with track colours alternating between red and green.

This report will first give an overview of the data processing for swath data in general, and then discuss the generation of a map of the Orkney Passage region – the main deliverable of cruise JR236, and a valuable aid for placing moorings in this important pathway for deep water export. Finally, a table outlines the speed of sound profiles used and other noteworthy events in the data.

### *Instruments and methods*

Data acquisition was performed on a Sun workstation, em120-101, running Simrad's em120 software, version 6.0r3, on Solaris. The default settings, as described in the notes

“Using multibeam on an opportunistic basis”, by Tara Deen, version dated 10/3/2010, were used – with varying maximum beam angles, depending on the weather conditions, and whether or not a more detailed survey was being undertaken (as in the first part of JR236). The maximum useful beam angle was around 60 degrees, except in shallow water and very calm conditions.

MB-system 5.12 (Caress and Cheyes, updated Dec. 2009) was used to process the data from the cruise. First the raw Simrad data were copied onto a laptop running Ubuntu 9.10 Linux, where they were first converted from Simrad format (MB-system ID 56) to MB-system’s own Simrad sonar editing format (ID 57). Most of the data were not cleaned, because of time constraints, while almost all of the data in jr239\_c have been cleaned, since this is an area of priority.

Some problems were encountered during the cruise, caused by using CTD casts as speed of sound profiles for the swath data. The default behaviour of the software was to use the full casts, with 5 m resolution. This caused the EM120 software to stall once deep water was encountered; it was not apparent until line 66 of JR239\_b. This problem was solved by reducing the number of points in the profiles used; an awk script was written for this purpose. Towards the end of the cruise, this script was e-mailed to Jeremy Robst, who promptly changed one parameter in the CTD upload script, automatically reducing the resolution of the casts. Hopefully this fix will prevent similar problems from reoccurring on future cruises.

### *JR236 swath survey*

The main aim of JR236 was to improve our knowledge of the bathymetry around Orkney Passage, to assist in placing moorings to monitor the outflow of Weddell Sea Deep Water from the Weddell Sea into the Scotia Sea. There are currently three moorings there, as part of a collaborative effort between the BAS Polar Oceans long-term monitoring and survey (LTMS) project and Lamont-Doherty Earth Observatory, Columbia University (LDEO). The deepest of these moorings, OP1, is an extension of a mooring, M4, from the LDEO CORC-ARCHES project.

A number of past cruises have passed through our area of interest, and BAS data holdings include multi-beam data from many BAS cruises as well as data from some American and German cruises in the area. All of these sources were combined into the map shown in [Figure 6.6a](#). With this information, we decided to do a more detailed survey of Orkney Passage itself, as well as filling in some of the gaps in data coverage near the southern sills leading into Orkney Passage. The original plan was based on doing one continuous survey for 72 hours, with 50° beam angles, going at 8 knots for the first half, around Orkney Passage itself, and 10 knots during the second half, near the southern sills. During the cruise this approach was opportunistically changed, as coverage was better than originally envisaged. Therefore, only two lines running northwest/southeast through Orkney Passage were done, and more time was spent in the southern region, trying to maximise coverage using increased beam angles. Rather than using the pre-determined survey lines, the bridge was asked to use the helmsman’s display of swath data coverage to ensure a slight overlap with adjacent lines. The survey was split into two parts, with the northern part done for approximately 32 hours between stations 26 and 27 (excluding the time spent drifting while repairs were done

on the propulsion motor), and the southern part for approximately 40 hours between stations 32 and 33. During JR236, a detailed log was kept, with quarter-hourly notes of the bottom depth, bottom detection depth range, and beam angle range.

For all of jr239\_c, a sound velocity profile from ES031 (CTD station 115 – the deepest station from Orkney Passage) was used to correct the data. Since the edited survey data from JR149\_i (March 2006) were brought on the ship, they were gridded with the data from jr239\_c. The JR149 data were corrected using XBT profiles obtained during that cruise.

The full data coverage from the jr239\_c survey (from both JR236 and the JR239 CTD section) is shown in [Figure 6.6b](#), and our collected swath data from this and past cruises are superimposed on the GEBCO08 bathymetry in [Figure 6.6c](#).

To create a merged grid, the following processing steps are taken, using Matlab:-

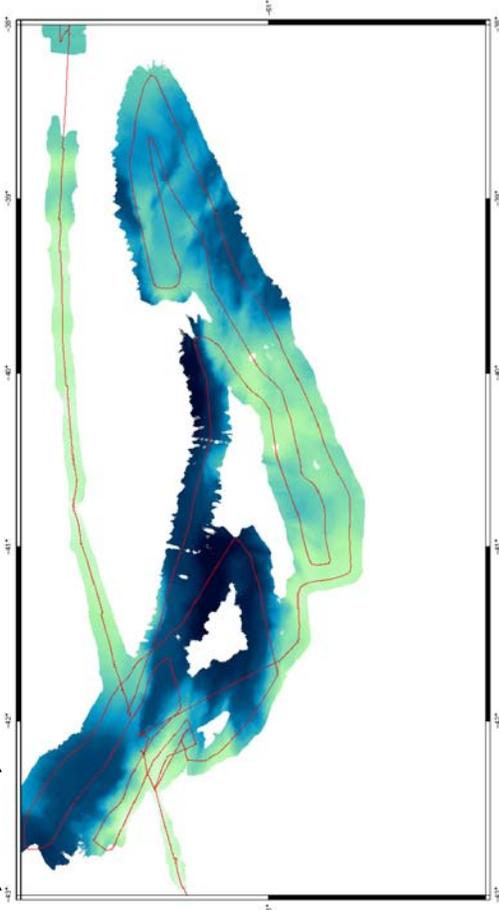
1. Past swath data are loaded, and masked based on a grid generated by hand using GIMP. This removes some outliers in the previous data, though proper editing of the raw swath data would give a better result (and will be done following the end of the cruise).
2. A grid for jr239\_c and jr149\_i is generated using mbgrid; 100-m cell spacing is used (0.111' longitude \* 0.054' latitude), and spline interpolation is used between gaps of up to 7 grid cells. Three pings are averaged, and grid cell weighting is done using a Gaussian weighted average with a spatial scale (1/e) of 2 grid cells. This grid is loaded into Matlab.
3. The previous swath data and GEBCO08 bathymetry are interpolated onto the 100-m grid.
4. The jr239\_c and jr149\_i data are superimposed onto the other swath data; the differences between this combined grid and GEBCO are written to a text file, along with zeros at one grid-cell's spacing outside the boundaries.
5. mbgrid is run to fit a spline through these points, at a reduced grid spacing of 1 km.
6. The difference grid is loaded into Matlab and interpolated back onto the 100-m grid using bi-linear interpolation.
7. The unassigned points in the swath grid are filled with GEBCO08 data, corrected using the difference grid.
8. The final grid is written to a NetCDF grid for use with GMT, as well as to an ASCII file for use with ArcInfo (in this file, the longitudes are interpolated onto a grid with the same spacing as the latitudes).

The final grid is shown in [Figure 6.6d](#). In addition, the GEBCO08 bathymetry and our final grid are shown in [Figure 6.7](#), with contours drawn at 250-m intervals.

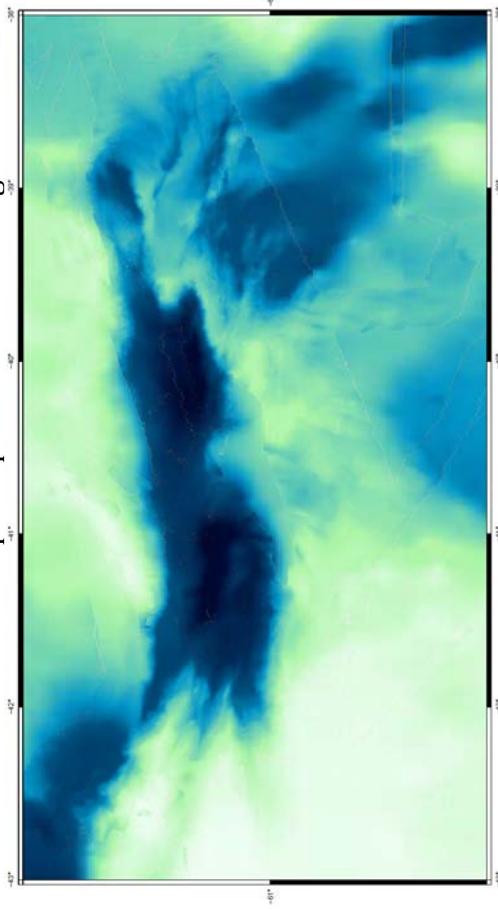
A. Pre-existing swath data (BAS, AWI, and US data)



B. JR236 & JR239 data



C. Combined swath data superimposed on GEBCO08 grid



D. Swath data merged with GEBCO08 data

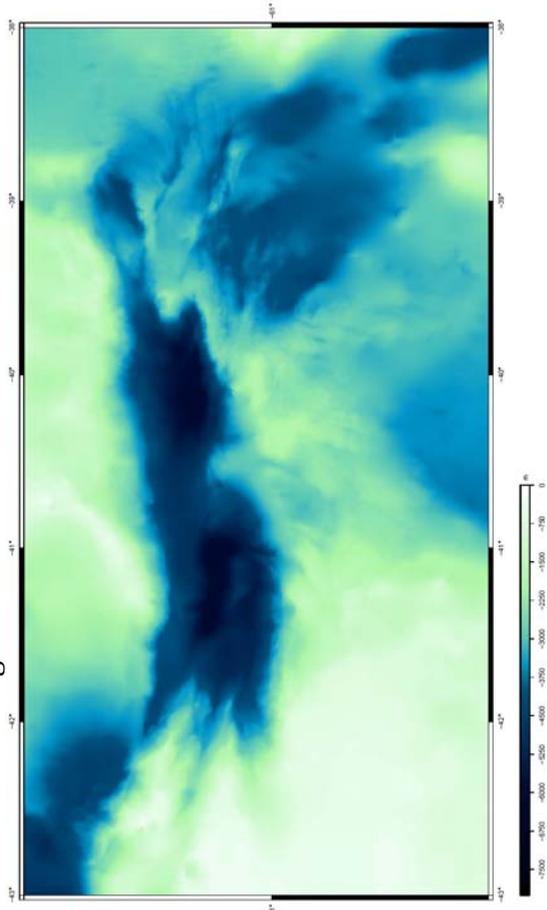


Figure 6.6. Steps in producing the final Orkney Passage grid.

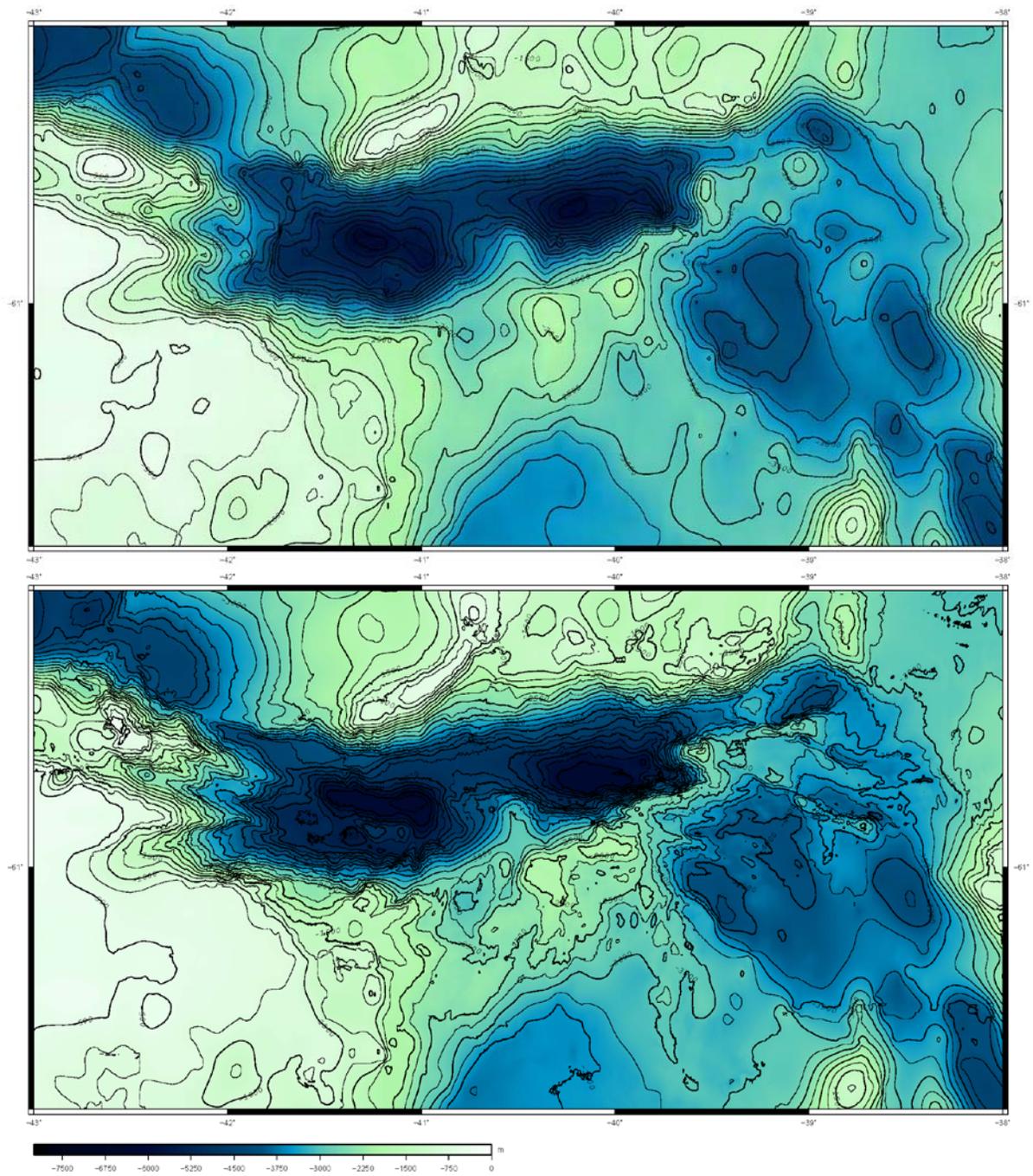


Figure 6.7a. GEBCO08 bathymetry. 6.7b. Map from combining swath bathymetry with GEBCO08 data.

Table 6.1. Summary of swath data and speed of sound profiles used. All times UTC.

| Survey                                      | Note | Lines | Date | Time   | XBT/CTD for SVP | file name | XBT ID no. | JR239 stn. |
|---|------|-------|------|--------|-----------------|-----------|------------|------------|
| JR239_a                                     |      | 1     | 21/3 | 14:01  | Unknown         |           |            |            |
|   |      | 3     | 21/3 | 14:28  | JR206 XBT 18    | T5_00020  | 1576       |            |
|   |      | 4     | 21/3 | 16:00  |                 |           |            |            |
|   |      | 2     | 21/3 | 16:07  | JR206 XBT 18    | T5_00020  | 1576       |            |
|   |      | 6     | 21/3 | 17:02  | JR206 XBT 18    | T5_00020  | 1576       |            |
|   |      | 24    | 22/3 | 11:14  |                 |           |            | 1          |
|   |      | 25    | 22/3 | 15:04  | JR73 XBT 5      | T5_00005  | 421        | 1          |
|   |      |       | 22/3 | 15:32  |                 |           |            |            |
|   |      | 26    | 22/3 | 15:32  | JR239 CTD 1     |           |            |            |
|   |      | 34    | 23/3 | 00:30  |                 |           |            |            |
|   |      | 35    | 23/3 | 00:30  | JR84 event 35   | T7_00001  | 801        |            |
|   |      | 45    | 23/3 | 11:13  |                 |           |            |            |
| Swath stopped while in the Falkland Islands |      |       |      |        |                 |           |            |            |
|   |      | 46    | 23/3 | 17:26  | JR84 event 35   | T7_00001  | 801        |            |
|   |      | 60    | 24/3 | 08:12  |                 |           |            |            |
|   |      | 61    | 24/3 | 08:12  | JR73 27/4/02    | T5_00067  | 481        |            |
|   |      | 72    | 24/3 | 19:41  |                 |           |            |            |
|   |      | 73    | 24/3 | 19:42  | JR71 XBT 63     | T5_00117  | 319        |            |
|   |      | 79    | 25/3 | 02:20  |                 |           |            |            |
|   |      | 80    | 25/3 | 02:21  | JR82 event 16   | T5_00003  | 610        |            |
|   |      | 88    | 25/3 | 11:00  |                 |           |            |            |
|   |      | 89    | 25/3 | 11:00  | JR82 event 22   | T5_00005  | 612        |            |
|   |      | 99    | 25/3 | 21:16  |                 |           |            | 2          |
| JR239_b                                     |      | 1     | 25/3 | 22:35  | JR82 event 22   | T5_00005  | 612        | 2          |
|   |      | 21    | 26/3 | 22:46  |                 |           |            | 8          |
|   | 1    | 22    | 26/3 | 22:46  | JR239 CTD 7     |           |            | 8          |
|   |      | 43    | 28/3 | 00:18  |                 |           |            | 17         |
|   |      | 44    | 28/3 | 03:14  | JR239 CTD 14    |           |            | 17         |
|   |      | 57    | 29/3 | 00:35  |                 |           |            | 22         |
|   | 2    | 58    | 29/3 | 02:14  | JR239 CTD 20    |           |            | 22         |
|   |      | 72    | 29/3 | 16:55  |                 |           |            | 24         |
| JR239_c                                     |      | 73,   | 29/3 | 17:38  | ES031 CTD 115   |           |            | 24         |
|   |      | 2-    | 29/3 | 18:30  |                 |           |            |            |
|   |      | 6     | 29/3 | 23:59  |                 |           |            | 26         |
|   | 3    | 7     | 30/3 | 01:39  | ES031 CTD 115   |           |            | 26         |
|   |      | 46    | 31/3 | 10:32  |                 |           |            |            |
|   | 4    | 47    | 31/3 | 11:15  | ES031 CTD 115   |           |            |            |
|   |      | 57    | 31/3 | 21:52  |                 |           |            | 27         |
|   | 5    | 57*   | 31/3 | 23:04- | ES031 CTD 115   |           |            |            |
|   |      |       | 31/3 | 23:58  |                 |           |            |            |
|   |      | 59    | 1/4  | 02:00  | ES031 CTD 115   |           |            |            |
|   |      | 64    | 1/4  | 10:50  |                 |           |            | 31         |
|   | 6    | 66-   | 1/4  | 23:56  | ES031 CTD 115   |           |            | 32         |
|   |      | 71,   | 2/4  | 08:05  |                 |           |            |            |
|   |      | 74-   | 2/4  | 08:05  |                 |           |            |            |
|   |      | 104   | 3/4  | 16:38  |                 |           |            | 33         |
|   |      | 105   | 3/4  | 20:18  | ES031 CTD 115   |           |            | 33         |
|   |      | 130   | 5/4  | 19:51  |                 |           |            | 44         |
| JR239_d                                     |      | 1     | 5/4  | 22:23  | JR239 CTD 43    |           |            | 44         |
|   |      | 6     | 6/4  | 03:30  |                 |           |            | hove to    |
|   |      | 7     | 6/4  | 11:46  | JR239 CTD 43    |           |            | hove to    |
|   |      | 42    | 8/4  | 11:10  |                 |           |            | 57         |
|   | 7    | 43    | 8/4  | 12:48  | JR239 CTD 52    |           |            | 57         |
|   |      | 61    | 9/4  | 13:27  |                 |           |            | 62         |
|   |      | 63    | 9/4  | 16:28  | JR239 CTD 61    |           |            | 62         |
|   |      | 100   | 11/4 | 18:02  |                 |           |            | 68         |

|                                      |   |          |              |                |                |          |          |
|--------------------------------------|---|----------|--------------|----------------|----------------|----------|----------|
| JR239_e                              |   | 1<br>65  | 11/4<br>14/4 | 21:48<br>13:20 | JR239 CTD 61   |          | 68<br>70 |
| JR239_f                              |   | 1<br>25  | 14/4<br>16/4 | 15:55<br>12:04 | JR239 CTD 61   |          | 70<br>79 |
|                                      | 8 | 26<br>59 | 16/4<br>18/4 | 14:28<br>18:56 | JR239 CTD 78   |          | 79<br>91 |
|                                      |   | 60<br>61 | 18/4<br>19/4 | 22:59<br>00:47 | JR239 CTD 90   |          | 91<br>92 |
|                                      |   | 62<br>68 | 19/4<br>19/4 | 03:18<br>11:12 | JR239 CTD 91   |          | 92       |
|                                      |   | 69<br>76 | 19/4<br>19/4 | 11:12<br>21:29 | JR239 CTD 93   |          | 96       |
|                                      |   | 77<br>86 | 19/4<br>20/4 | 23:50<br>11:07 | JR239 CTD 95   |          | 96       |
| Swath stopped while in South Georgia |   |          |              |                |                |          |          |
| JR239_g                              | 9 | 1<br>9   | 21/4<br>21/4 | 11:28<br>20:05 | JR238 CTD 98   |          |          |
|                                      |   | 10<br>12 | 21/4<br>21/4 | 20:05<br>22:45 | JR100 XBT 57   | T5_00057 | 40       |
|                                      |   | 13<br>22 | 21/4<br>22/4 | 22:45<br>11:08 | JR100 XBT 55   | T5_00055 | 38       |
|                                      | 9 | 23<br>41 | 22/4<br>23/4 | 11:08<br>05:51 | JR57 event 275 | T5_01228 | 1059     |
|                                      |   | 42<br>54 | 23/4<br>23/4 | 05:51<br>18:23 | JR57 event 288 | T5_01242 | 1072     |
|                                      |   | 55<br>67 | 23/4<br>24/4 | 18:23<br>06:40 | JR57 event 294 | T5_01248 | 1078     |

*Notes to Table:-*

The ID numbers given in the table above are from the onboard MySQL database of XBT casts.

1. Lost bottom between lines 28-30 and 40.
2. Problems with ping rate around line 66. Appeared to be OK by line 71. This was probably related to the length of CTD 20.
3. This is the first half of JR236. Problems with the length of sound velocity profiles overnight. Lines 18-22 were done with inappropriate SVPs, but have been updated in post-processing. From line 22 onwards a profile with fewer points was used, solving the problems encountered.
4. Ship drifting slowly towards E while repairs undertaken on fwd propulsion motor. Swath running, since we were drifting through an area of interest.
5. Computer crashed after the first line 57; restarted at 23:04 – so there are two lines 57.
6. Second half of JR236. Numbering is 66-71,74-104; apparently the presence of a previous line 73 caused problems for the software, so line 71 is over three hours long and was stopped manually. Total time spent on JR236: 31:53 + 40:42 = 72:35.
7. Apparently there is no line 62.
8. At 19:29, in line 44, the Seapath GPS that provides position and attitude data to the EM120 received invalid positions, causing a sudden northwestward drift on the otherwise northward track, followed by a jump back to the correct positions. The navigation data have been corrected in post-processing (using mbnavedit).

9. Some starboard beams missing in lines 8, 9, and 32, because the maximum depth range was set too shallow.

## 9. Argo float deployments (Hugh Venables)

Three Argo floats were deployed during the cruise. The first was not capable of surviving in areas with sea ice so was deployed in the central Drake Passage. The latter two were ice capable and so were deployed in the region of the South Orkney Trough and at the most southerly point of the cruise in the Weddell Sea. They were deployed by hand over the back of the ship, being released by pulling a wooden stopper from a strop around the float. The ship was kept at 1 knot to help reduce the risk of the float moving under the ship. All deployments went well.

| ID number | Latitude | Longitude | Date          | Time (GMT) |
|-----------|----------|-----------|---------------|------------|
| 3170      | 57 09.8S | 56 58.5W  | 24 March 2010 | 1900       |
| 4501      | 60 47.7S | 39 51.7W  | 3 April 2010  | 0945       |
| 4502      | 63 57.9S | 28 52.5W  | 14 April 2010 | 1545       |

*Table 7.1 Summary of Argo float deployments on the cruise.*

# Appendix 1 (Sea-Bird JR239 configuration files)

## (i) ctd\_jr239.con

Frequency channels suppressed : 0  
Voltage words suppressed : 0  
Computer interface : RS-232C  
Scans to average : 1  
Surface PAR voltage added : No  
NMEA position data added : No  
Scan time added : No

I : -8.66569830e-005  
J : 9.90786631e-005  
CTcor : 3.2500e-006  
CPcor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

### 1) Frequency 0, Temperature

Serial number : 2919  
Calibrated on : 13-Feb-2010  
G : 4.31691832e-003  
H : 6.44279050e-004  
I : 2.26989097e-005  
J : 2.10901883e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

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

Serial number : 0619  
Calibrated on : 27-Oct-2009  
Equation : Murphy-Larson  
Coefficients for Owens-Millard:  
Soc : 0.0000e+000  
Boc : 0.0000  
Offset : 0.0000  
Tcor : 0.0000  
Pcor : 0.00e+000  
Tau : 0.0  
Coefficients for Murphy-Larson:  
Soc : 5.07300e-001  
Offset : -4.90700e-001  
A : -2.78180e-003  
B : 1.64750e-004  
C : -3.37680e-006  
E : 3.60000e-002  
Tau : 2.24000e+000

### 2) Frequency 1, Conductivity

Serial number : 2450  
Calibrated on : 10-Feb-2010  
G : -1.02041644e+001  
H : 1.62657100e+000  
I : -1.98092825e-003  
J : 2.46199266e-004  
CTcor : 3.2500e-006  
CPcor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

### 7) A/D voltage 1, Free

### 8) A/D voltage 2, Altimeter

Serial number : Unknown  
Calibrated on : Unknown  
Scale factor : 15.000  
Offset : 0.000

### 3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0869-46253  
Calibrated on : 31-Jul-2009  
C1 : -4.405863e+004  
C2 : -6.206030e-002  
C3 : 1.337540e-002  
D1 : 3.669100e-002  
D2 : 0.000000e+000  
T1 : 2.990734e+001  
T2 : -3.493620e-004  
T3 : 4.061200e-006  
T4 : 3.043880e-009  
T5 : 0.000000e+000  
Slope : 0.99994000  
Offset : -1.08250  
AD590M : 1.288520e-002  
AD590B : -8.271930e+000

### 9) A/D voltage 3, Fluorometer, Chelsea Aqua 3

Serial number : 088 195  
Calibrated on : 27-May-2008  
VB : 0.175800  
V1 : 2.072600  
Vacetone : 0.272400  
Scale factor : 1.000000  
Slope : 1.000000  
Offset : 0.000000

### 10) A/D voltage 4, Free

### 11) A/D voltage 5, Free

### 4) Frequency 3, Temperature, 2

Serial number : 4782  
Calibrated on : 12-Feb-2010  
G : 4.34994325e-003  
H : 6.36521273e-004  
I : 2.09171407e-005  
J : 1.77111645e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

### 12) A/D voltage 6, User Polynomial

Serial number : 168  
Calibrated on : 19-Oct-2009  
Sensor name : BBRTD  
A0 : -0.00025770  
A1 : 0.00303560  
A2 : 0.00000000  
A3 : 0.00000000

### 5) Frequency 4, Conductivity, 2

Serial number : 2571  
Calibrated on : 29-Jan-2010  
G : -1.02884084e+001  
H : 1.59651066e+000

### 13) A/D voltage 7, Transmissometer, Chelsea/Seatech/Wetlab CStar

Serial number : 097107-001  
Calibrated on : 09-Jun-2009/22-Mar-2010  
M : 20.4049  
B : -0.2041  
Path length : 0.250

## (ii) ctd\_jr239a.con

Frequency channels suppressed : 0  
Voltage words suppressed : 0  
Computer interface : RS-232C  
Scans to average : 1  
Surface PAR voltage added : No  
NMEA position data added : No  
Scan time added : No

### 1) Frequency 0, Temperature

Serial number : 2919  
Calibrated on : 13-Feb-2010  
G : 4.31691832e-003  
H : 6.44279050e-004  
I : 2.26989097e-005  
J : 2.10901883e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

### 2) Frequency 1, Conductivity

Serial number : 2450  
Calibrated on : 10-Feb-2010  
G : -1.02041644e+001  
H : 1.62657100e+000  
I : -1.98092825e-003  
J : 2.46199266e-004  
CTcor : 3.2500e-006  
PCor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

### 3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0869-46253  
Calibrated on : 31-Jul-2009  
C1 : -4.405863e+004  
C2 : -6.206030e-002  
C3 : 1.337540e-002  
D1 : 3.669100e-002  
D2 : 0.000000e+000  
T1 : 2.990734e+001  
T2 : -3.493620e-004  
T3 : 4.061200e-006  
T4 : 3.043880e-009  
T5 : 0.000000e+000  
Slope : 0.99994000  
Offset : -1.08250  
AD590M : 1.288520e-002  
AD590B : -8.271930e+000

### 4) Frequency 3, Temperature, 2

Serial number : 4782  
Calibrated on : 12-Feb-2010  
G : 4.34994325e-003  
H : 6.36521273e-004  
I : 2.09171407e-005  
J : 1.77111645e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

### 5) Frequency 4, Conductivity, 2

Serial number : 2571  
Calibrated on : 29-Jan-2010  
G : -1.02884084e+001  
H : 1.59651066e+000

I : -8.66569830e-005  
J : 9.90786631e-005  
CTcor : 3.2500e-006  
PCor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

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

Serial number : 0619  
Calibrated on : 27-Oct-2009  
Equation : Murphy-Larson  
Coefficients for Owens-Millard:  
Soc : 0.0000e+000  
Boc : 0.0000  
Offset : 0.0000  
Tcor : 0.0000  
Pcor : 0.00e+000  
Tau : 0.0  
Coefficients for Murphy-Larson:  
Soc : 5.07300e-001  
Offset : -4.90700e-001  
A : -2.78180e-003  
B : 1.64750e-004  
C : -3.37680e-006  
E : 3.60000e-002  
Tau : 2.24000e+000

### 7) A/D voltage 1, Free

### 8) A/D voltage 2, Altimeter

Serial number : Unknown  
Calibrated on : Unknown  
Scale factor : 15.000  
Offset : 0.000

### 9) A/D voltage 3, Fluorometer, Chelsea Aqua 3

Serial number : 088 195  
Calibrated on : 27-May-2008  
VB : 0.175800  
V1 : 2.072600  
Vacetone : 0.272400  
Scale factor : 1.000000  
Slope : 1.000000  
Offset : 0.000000

### 10) A/D voltage 4, User Polynomial

Serial number : 168  
Calibrated on : 19 Oct 2009  
Sensor name : BBRTD  
A0 : -0.00025770  
A1 : 0.00303560  
A2 : 0.00000000  
A3 : 0.00000000

### 11) A/D voltage 5, Transmissometer, Chelsea/Seatech/Wetlab CStar

Serial number : 0971007-001  
Calibrated on : 22 March 2010  
M : 20.4049  
B : -0.2041  
Path length : 0.250

### 12) A/D voltage 6, Free

### 13) A/D voltage 7, Free

### (iii) ctd\_jr239b.con

Frequency channels suppressed : 0  
Voltage words suppressed : 0  
Computer interface : RS-232C  
Scans to average : 1  
Surface PAR voltage added : No  
NMEA position data added : No  
Scan time added : No

#### 1) Frequency 0, Temperature

Serial number : 2919  
Calibrated on : 13-Feb-2010  
G : 4.31691832e-003  
H : 6.44279050e-004  
I : 2.26989097e-005  
J : 2.10901883e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

#### 2) Frequency 1, Conductivity

Serial number : 2450  
Calibrated on : 10-Feb-2010  
G : -1.02041644e+001  
H : 1.62657100e+000  
I : -1.98092825e-003  
J : 2.46199266e-004  
CTcor : 3.2500e-006  
CPcor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

#### 3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0869-46253  
Calibrated on : 31-Jul-2009  
C1 : -4.405863e+004  
C2 : -6.206030e-002  
C3 : 1.337540e-002  
D1 : 3.669100e-002  
D2 : 0.000000e+000  
T1 : 2.990734e+001  
T2 : -3.493620e-004  
T3 : 4.061200e-006  
T4 : 3.043880e-009  
T5 : 0.000000e+000  
Slope : 0.99994000  
Offset : -1.08250  
AD590M : 1.288520e-002  
AD590B : -8.271930e+000

#### 4) Frequency 3, Temperature, 2

Serial number : 4782  
Calibrated on : 12-Feb-2010  
G : 4.34994325e-003  
H : 6.36521273e-004  
I : 2.09171407e-005  
J : 1.77111645e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

#### 5) Frequency 4, Conductivity, 2

Serial number : 2571

Calibrated on : 29-Jan-2010  
G : -1.02884084e+001  
H : 1.59651066e+000  
I : -8.66569830e-005  
J : 9.90786631e-005  
CTcor : 3.2500e-006  
CPcor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

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

Serial number : 0619  
Calibrated on : 27-Oct-2009  
Equation : Murphy-Larson  
Coefficients for Owens-Millard:  
Soc : 0.0000e+000  
Boc : 0.0000  
Offset : 0.0000  
Tcor : 0.0000  
Pcor : 0.00e+000  
Tau : 0.0  
Coefficients for Murphy-Larson:  
Soc : 5.07300e-001  
Offset : -4.90700e-001  
A : -2.78180e-003  
B : 1.64750e-004  
C : -3.37680e-006  
E : 3.60000e-002  
Tau : 2.24000e+000

#### 7) A/D voltage 1, Free

#### 8) A/D voltage 2, Altimeter

Serial number : Unknown  
Calibrated on : Unknown  
Scale factor : 15.000  
Offset : 0.000

#### 9) A/D voltage 3, Fluorometer, Chelsea Aqua 3

Serial number : 088 195  
Calibrated on : 27-May-2008  
VB : 0.175800  
V1 : 2.072600  
Vacetone : 0.272400  
Scale factor : 1.000000  
Slope : 1.000000  
Offset : 0.000000

#### 10) A/D voltage 4, User Polynomial

Serial number : 168  
Calibrated on : 19 Oct 2009  
Sensor name : BBRTD  
A0 : -0.00025770  
A1 : 0.00303560  
A2 : 0.00000000  
A3 : 0.00000000

#### 11) A/D voltage 5, Free

#### 12) A/D voltage 6, Free

#### 13) A/D voltage 7, Free

## (iv) ctd\_jr239c.con

Frequency channels suppressed : 0  
Voltage words suppressed : 0  
Computer interface : RS-232C  
Scans to average : 1  
Surface PAR voltage added : No  
NMEA position data added : No  
Scan time added : No

### 1) Frequency 0, Temperature

Serial number : 2919  
Calibrated on : 13-Feb-2010  
G : 4.31691832e-003  
H : 6.44279050e-004  
I : 2.26989097e-005  
J : 2.10901883e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

### 2) Frequency 1, Conductivity

Serial number : 2450  
Calibrated on : 10-Feb-2010  
G : -1.02041644e+001  
H : 1.62657100e+000  
I : -1.98092825e-003  
J : 2.46199266e-004  
CTcor : 3.2500e-006  
PCor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.0000

### 3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0869-46253  
Calibrated on : 31-Jul-2009  
C1 : -4.405863e+004  
C2 : -6.206030e-002  
C3 : 1.337540e-002  
D1 : 3.669100e-002  
D2 : 0.000000e+000  
T1 : 2.990734e+001  
T2 : -3.493620e-004  
T3 : 4.061200e-006  
T4 : 3.043880e-009  
T5 : 0.000000e+000  
Slope : 0.99994000  
Offset : -1.08250  
AD590M : 1.288520e-002  
AD590B : -8.271930e+000

### 4) Frequency 3, Temperature, 2

Serial number : 4782  
Calibrated on : 12-Feb-2010  
G : 4.34994325e-003  
H : 6.36521273e-004  
I : 2.09171407e-005  
J : 1.77111645e-006  
F0 : 1000.000  
Slope : 1.00000000  
Offset : 0.0000

### 5) Frequency 4, Conductivity, 2

Serial number : 2571  
Calibrated on : 29-Jan-2010  
G : -1.02884084e+001  
H : 1.59651066e+000

I : -8.66569830e-005  
J : 9.90786631e-005  
CTcor : 3.2500e-006  
PCor : -9.57000000e-008  
Slope : 1.00000000  
Offset : 0.00000

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

Serial number : 0242  
Calibrated on : 21-Jan-2009  
Equation : Murphy-Larson  
Coefficients for Owens-Millard:  
Soc : 0.0000e+000  
Boc : 0.0000  
Offset : 0.0000  
Tcor : 0.0000  
Pcor : 0.00e+000  
Tau : 0.0  
Coefficients for Murphy-Larson:  
Soc : 4.16500e-001  
Offset : -4.97900e-001  
A : -9.13570e-004  
B : 1.62030e-004  
C : -2.34710e-006  
E : 3.60000e-002  
Tau : 1.20000e+000

### 7) A/D voltage 1, Free

### 8) A/D voltage 2, Altimeter

Serial number : Unknown  
Calibrated on : Unknown  
Scale factor : 15.000  
Offset : 0.000

### 9) A/D voltage 3, Fluorometer, Chelsea Aqua 3

Serial number : 088 195  
Calibrated on : 27-May-2008  
VB : 0.175800  
V1 : 2.072600  
Vacetone : 0.272400  
Scale factor : 1.000000  
Slope : 1.000000  
Offset : 0.000000

### 10) A/D voltage 4, User Polynomial

Serial number : 168  
Calibrated on : 19 Oct 2009  
Sensor name : BBRTD  
A0 : -0.00025770  
A1 : 0.00303560  
A2 : 0.00000000  
A3 : 0.00000000

### 11) A/D voltage 5, Transmissometer, Chelsea/Seatech/Wetlab CStar

Serial number : 0971007-001  
Calibrated on : 22 March 2010  
M : 20.4049  
B : -0.2041  
Path length : 0.250

### 12) A/D voltage 6, Free

### 13) A/D voltage 7, Free

## Appendix 2 – CTD cast and sampling summary

| Event | Start Time          | Latitude  | Longitude | No. of working bottles | Max. depth | CFCs taken | Noble gases taken | O2 taken | CO2 taken | 14C taken | 3H taken | O18 taken | Nuts taken | Salts taken |
|-------|---------------------|-----------|-----------|------------------------|------------|------------|-------------------|----------|-----------|-----------|----------|-----------|------------|-------------|
| 1     | 22/03/2010 11:14:00 | -47.69135 | -57.06673 | 24                     | 2000       | 23         | 3                 | 24       | 24        | 4         | 0        | 0         | 24         | 24          |
| 2     | 25/03/2010 21:33:00 | -62.50482 | -56.79228 | 24                     | 532        | 14         | 6                 | 12       | 13        | 0         | 0        | 13        | 13         | 13          |
| 3     | 26/03/2010 00:45:00 | -62.17113 | -56.66931 | 20                     | 1119       | 15         | 7                 | 15       | 15        | 7         | 0        | 15        | 15         | 15          |
| 4     | 26/03/2010 08:17:00 | -61.39191 | -56.69496 | 22                     | 472        | 0          | 0                 | 12       | 0         | 0         | 0        | 12        | 13         | 12          |
| 5     | 26/03/2010 15:25:00 | -61.04087 | -54.40498 | 0                      | 100        | 0          | 0                 | 0        | 0         | 0         | 0        | 0         | 0          | 0           |
| 6     | 26/03/2010 16:07:00 | -61.04087 | -54.40538 | 20                     | 500        | 13         | 0                 | 12       | 12        | 0         | 0        | 12        | 12         | 12          |
| 7     | 26/03/2010 18:05:00 | -60.96333 | -54.17012 | 22                     | 891        | 16         | 11                | 14       | 14        | 11        | 11       | 13        | 15         | 14          |
| 8     | 26/03/2010 19:25:00 | -60.95874 | -54.16285 | 22                     | 444        | 0          | 0                 | 12       | 0         | 0         | 0        | 12        | 0          | 12          |
| 9     | 26/03/2010 22:44:00 | -60.729   | -53.36385 | 23                     | 399        | 13         | 4                 | 12       | 12        | 0         | 4        | 12        | 12         | 12          |
| 10    | 27/03/2010 04:20:00 | -60.5491  | -52.35282 | 16                     | 822        | 11         | 8                 | 10       | 10        | 7         | 0        | 10        | 10         | 10          |
| 11    | 27/03/2010 07:52:00 | -60.37049 | -51.88582 | 19                     | 404        | 0          | 0                 | 12       | 0         | 0         | 0        | 12        | 12         | 12          |
| 12    | 27/03/2010 10:18:00 | -60.28706 | -51.38718 | 24                     | 526        | 0          | 0                 | 13       | 0         | 0         | 0        | 12        | 12         | 12          |
| 13    | 27/03/2010 11:22:00 | -60.28849 | -51.38684 | 20                     | 971        | 16         | 10                | 14       | 14        | 0         | 0        | 14        | 14         | 14          |
| 14    | 27/03/2010 15:24:00 | -60.22423 | -50.9318  | 15                     | 1355       | 13         | 10                | 13       | 13        | 10        | 10       | 13        | 13         | 13          |
| 15    | 27/03/2010 17:50:00 | -60.19352 | -50.54458 | 21                     | 1071       | 0          | 0                 | 15       | 0         | 0         | 0        | 15        | 15         | 15          |
| 16    | 27/03/2010 20:40:00 | -60.22494 | -50.04016 | 6                      | 577        | 3          | 0                 | 5        | 0         | 0         | 0        | 6         | 0          | 6           |
| 17    | 28/03/2010 01:00:00 | -60.20693 | -49.27947 | 20                     | 1000       | 4          | 11                | 13       | 0         | 0         | 0        | 13        | 13         | 13          |
| 18    | 28/03/2010 04:26:00 | -60.16506 | -48.58581 | 21                     | 1570       | 17         | 14                | 17       | 17        | 14        | 14       | 17        | 17         | 17          |
| 19    | 28/03/2010 06:33:00 | -60.15846 | -48.55893 | 20                     | 1903       | 16         | 13                | 16       | 16        | 14        | 14       | 15        | 15         | 15          |
| 20    | 28/03/2010 11:49:00 | -60.15182 | -48.35321 | 18                     | 2761       | 17         | 15                | 16       | 16        | 13        | 0        | 15        | 15         | 15          |
| 21    | 28/03/2010 15:49:00 | -60.12538 | -47.69512 | 24                     | 2023       | 18         | 14                | 18       | 17        | 0         | 0        | 18        | 18         | 17          |
| 22    | 28/03/2010 23:39:00 | -60.14759 | -47.33577 | 22                     | 998        | 15         | 0                 | 14       | 0         | 0         | 0        | 14        | 14         | 14          |
| 23    | 29/03/2010 03:20:00 | -60.35485 | -46.7687  | 24                     | 601        | 9          | 5                 | 11       | 0         | 0         | 0        | 11        | 11         | 11          |
| 24    | 29/03/2010 15:55:00 | -60.92008 | -43.99928 | 20                     | 241        | 10         | 0                 | 20       | 9         | 0         | 0        | 9         | 12         | 9           |
| 25    | 29/03/2010 19:25:00 | -60.75901 | -42.96073 | 22                     | 492        | 13         | 0                 | 15       | 0         | 0         | 0        | 12        | 21         | 13          |
| 26    | 29/03/2010 21:05:00 | -60.74007 | -42.79433 | 23                     | 1308       | 18         | 13                | 17       | 17        | 0         | 12       | 17        | 23         | 17          |
| 27    | 31/03/2010 20:32:00 | -60.67915 | -42.39152 | 20                     | 999        | 15         | 0                 | 20       | 0         | 0         | 0        | 14        | 7          | 14          |
| 28    | 31/03/2010 23:00:00 | -60.65977 | -42.30704 | 21                     | 1645       | 18         | 0                 | 21       | 17        | 0         | 0        | 16        | 18         | 16          |
| 29    | 01/04/2010 01:45:00 | -60.64996 | -42.20911 | 21                     | 2022       | 19         | 17                | 21       | 18        | 14        | 14       | 18        | 21         | 18          |
| 30    | 01/04/2010 05:09:00 | -60.65004 | -42.19001 | 16                     | 2514       | 14         | 13                | 16       | 15        | 0         | 13       | 14        | 15         | 15          |
| 31    | 01/04/2010 07:38:00 | -60.64876 | -42.18905 | 23                     | 3066       | 23         | 20                | 23       | 23        | 18        | 18       | 23        | 23         | 23          |
| 30a   | 01/04/2010 12:55:00 | -60.64009 | -42.16998 | 21                     | 2471       | 17         | 16                | 21       | 16        | 0         | 7        | 12        | 21         | 12          |
| 32    | 01/04/2010 17:39:00 | -60.62952 | -42.0894  | 22                     | 3609       | 24         | 19                | 24       | 24        | 0         | 16       | 12        | 24         | 24          |

| Event | Start Time          | Latitude  | Longitude | No. of working bottles | Max. depth | CFCs taken | Noble gases taken | O2 taken | CO2 taken | 14C taken | 3H taken | O18 taken | Nuts taken | Salts taken |
|-------|---------------------|-----------|-----------|------------------------|------------|------------|-------------------|----------|-----------|-----------|----------|-----------|------------|-------------|
| 33    | 03/04/2010 15:38:00 | -60.60933 | -41.97347 | 22                     | 3393       | 22         | 18                | 22       | 21        | 17        | 17       | 12        | 21         | 21          |
| 34    | 03/04/2010 18:19:00 | -60.60975 | -41.9745  | 23                     | 2947       | 22         | 3                 | 23       | 22        | 0         | 0        | 12        | 20         | 20          |
| 35    | 04/04/2010 02:28:00 | -60.56962 | -41.6919  | 23                     | 2430       | 18         | 16                | 21       | 17        | 0         | 16       | 12        | 21         | 17          |
| 36    | 04/04/2010 05:45:00 | -60.53031 | -41.38026 | 22                     | 1922       | 0          | 0                 | 21       | 0         | 0         | 0        | 10        | 24         | 17          |
| 37    | 04/04/2010 08:08:00 | -60.53028 | -41.37997 | 19                     | 1436       | 16         | 15                | 18       | 15        | 13        | 0        | 12        | 18         | 15          |
| 38    | 04/04/2010 11:05:00 | -60.46984 | -40.98007 | 19                     | 1412       | 13         | 0                 | 20       | 0         | 0         | 0        | 12        | 20         | 14          |
| 39    | 04/04/2010 17:13:00 | -60.40963 | -39.30019 | 22                     | 1471       | 0          | 0                 | 21       | 0         | 0         | 0        | 11        | 20         | 20          |
| 40    | 04/04/2010 18:57:00 | -60.40989 | -39.3001  | 22                     | 2158       | 18         | 14                | 22       | 20        | 14        | 14       | 12        | 22         | 20          |
| 41    | 05/04/2010 00:15:00 | -60.4137  | -38.98104 | 23                     | 2552       | 22         | 18                | 23       | 22        | 15        | 15       | 12        | 23         | 22          |
| 42    | 05/04/2010 05:12:00 | -60.43979 | -38.00073 | 21                     | 2926       | 22         | 17                | 21       | 21        | 13        | 16       | 11        | 21         | 22          |
| 43    | 05/04/2010 10:55:00 | -60.42301 | -38.05205 | 23                     | 2055       | 19         | 19                | 23       | 19        | 0         | 0        | 13        | 23         | 18          |
| 44    | 05/04/2010 19:08:00 | -60.39031 | -36.46362 | 22                     | 1860       | 7          | 0                 | 22       | 0         | 0         | 0        | 0         | 14         | 17          |
| 45    | 06/04/2010 15:00:00 | -60.3033  | -35.47554 | 21                     | 1597       | 19         | 15                | 21       | 17        | 0         | 10       | 12        | 21         | 18          |
| 46    | 06/04/2010 19:07:00 | -60.22514 | -35.18445 | 18                     | 363        | 0          | 0                 | 18       | 0         | 0         | 0        | 0         | 12         | 9           |
| 47    | 06/04/2010 22:00:00 | -60.09673 | -34.75259 | 23                     | 973        | 14         | 15                | 23       | 16        | 0         | 0        | 12        | 23         | 15          |
| 48    | 07/04/2010 02:06:00 | -59.92961 | -33.85054 | 19                     | 1257       | 0          | 0                 | 19       | 0         | 0         | 0        | 0         | 19         | 15          |
| 49    | 07/04/2010 05:40:00 | -59.84964 | -33.27959 | 21                     | 1602       | 17         | 16                | 21       | 14        | 0         | 0        | 10        | 21         | 15          |
| 50    | 07/04/2010 07:18:00 | -59.84961 | -33.27958 | 19                     | 2066       | 0          | 17                | 19       | 0         | 0         | 12       | 12        | 19         | 17          |
| 51    | 07/04/2010 11:15:00 | -59.86001 | -33.15983 | 23                     | 2490       | 19         | 19                | 23       | 20        | 15        | 14       | 12        | 23         | 19          |
| 52    | 07/04/2010 14:58:00 | -59.88031 | -32.94954 | 23                     | 2898       | 23         | 16                | 23       | 23        | 15        | 0        | 11        | 23         | 23          |
| 53    | 07/04/2010 18:34:00 | -59.88021 | -32.94991 | 22                     | 2106       | 0          | 0                 | 21       | 0         | 0         | 0        | 0         | 22         | 20          |
| 54    | 07/04/2010 22:30:00 | -59.88996 | -32.85987 | 21                     | 1512       | 15         | 15                | 20       | 15        | 0         | 0        | 12        | 20         | 15          |
| 55    | 08/04/2010 02:58:00 | -59.90059 | -32.73189 | 21                     | 1122       | 0          | 0                 | 21       | 0         | 0         | 0        | 0         | 20         | 15          |
| 56    | 08/04/2010 06:10:00 | -59.94001 | -32.24143 | 21                     | 965        | 0          | 0                 | 21       | 0         | 0         | 0        | 0         | 21         | 14          |
| 57    | 08/04/2010 07:29:00 | -59.94002 | -32.24142 | 23                     | 2081       | 20         | 19                | 21       | 19        | 0         | 15       | 11        | 22         | 19          |
| 58    | 08/04/2010 15:38:00 | -60.31925 | -30.96101 | 22                     | 2783       | 22         | 19                | 22       | 21        | 0         | 0        | 11        | 22         | 22          |
| 59    | 08/04/2010 21:48:00 | -60.4693  | -29.73543 | 20                     | 1885       | 0          | 0                 | 20       | 0         | 0         | 0        | 0         | 0          | 16          |
| 60    | 09/04/2010 04:59:00 | -60.68614 | -28.26311 | 24                     | 2140       | 21         | 16                | 24       | 20        | 0         | 14       | 8         | 24         | 22          |
| 61    | 09/04/2010 09:41:00 | -60.79783 | -27.42591 | 21                     | 3266       | 0          | 0                 | 21       | 0         | 0         | 0        | 0         | 21         | 21          |
| 62    | 09/04/2010 13:30:00 | -60.82673 | -27.22821 | 21                     | 3871       | 20         | 19                | 21       | 20        | 0         | 12       | 14        | 21         | 20          |
| 63    | 09/04/2010 21:02:00 | -61.01484 | -25.74635 | 20                     | 3528       | 0          | 0                 | 20       | 0         | 0         | 0        | 0         | 20         | 20          |
| 64    | 10/04/2010 05:23:00 | -61.23032 | -24.26396 | 24                     | 35110      | 23         | 18                | 24       | 23        | 0         | 0        | 8         | 24         | 24          |
| 65    | 10/04/2010 08:40:00 | -61.23084 | -24.26115 | 22                     | 4570       | 0          | 0                 | 22       | 0         | 0         | 0        | 0         | 22         | 22          |
| 66    | 10/04/2010 21:22:00 | -61.63263 | -21.28116 | 21                     | 5021       | 21         | 18                | 21       | 21        | 0         | 15       | 12        | 21         | 0           |
| 67    | 11/04/2010 06:22:00 | -61.83322 | -19.79848 | 22                     | 4452       | 4          | 0                 | 22       | 0         | 0         | 0        | 8         | 4          | 22          |

| Event | Start Time          | Latitude  | Longitude | No. of working bottles | Max. depth | CFCs taken | Noble gases taken | O2 taken | CO2 taken | 14C taken | 3H taken | O18 taken | Nuts taken | Salts taken |
|-------|---------------------|-----------|-----------|------------------------|------------|------------|-------------------|----------|-----------|-----------|----------|-----------|------------|-------------|
| 68    | 11/04/2010 10:12:00 | -61.8325  | -19.79711 | 22                     | 4700       | 22         | 18                | 22       | 22        | 18        | 18       | 16        | 22         | 22          |
| 70    | 14/04/2010 12:15:00 | -63.96433 | -28.87363 | 23                     | 4792       | 0          | 0                 | 0        | 0         | 0         | 0        | 0         | 24         | 0           |
| 71    | 14/04/2010 19:06:00 | -63.3468  | -29.56781 | 22                     | 4728       | 21         | 0                 | 22       | 21        | 0         | 0        | 0         | 22         | 21          |
| 72    | 15/04/2010 01:30:00 | -63.07286 | -30.11506 | 24                     | 4865       | 0          | 0                 | 24       | 0         | 0         | 0        | 0         | 24         | 24          |
| 73    | 15/04/2010 07:48:00 | -62.78266 | -30.69457 | 22                     | 4824       | 22         | 0                 | 22       | 22        | 0         | 0        | 0         | 22         | 22          |
| 74    | 15/04/2010 13:30:00 | -62.48949 | -31.2594  | 24                     | 4754       | 0          | 0                 | 24       | 0         | 0         | 0        | 0         | 24         | 23          |
| 75    | 15/04/2010 19:24:00 | -62.07192 | -31.18255 | 22                     | 4852       | 21         | 0                 | 22       | 0         | 0         | 0        | 0         | 19         | 20          |
| 77    | 16/04/2010 02:50:00 | -61.55137 | -31.10059 | 22                     | 4060       | 22         | 0                 | 22       | 0         | 0         | 0        | 0         | 14         | 22          |
| 78    | 16/04/2010 08:48:00 | -61.17089 | -31.0454  | 21                     | 3483       | 21         | 0                 | 21       | 0         | 0         | 0        | 0         | 21         | 21          |
| 79    | 16/04/2010 12:05:00 | -61.10935 | -31.04017 | 22                     | 2565       | 0          | 0                 | 22       | 0         | 0         | 0        | 0         | 22         | 20          |
| 80    | 16/04/2010 16:50:00 | -60.69874 | -31.00883 | 21                     | 1630       | 16         | 0                 | 21       | 0         | 0         | 0        | 0         | 21         | 19          |
| 82    | 16/04/2010 22:30:00 | -59.99463 | -30.92959 | 24                     | 2984       | 20         | 18                | 24       | 20        | 0         | 8        | 0         | 24         | 20          |
| 83    | 17/04/2010 02:57:00 | -59.76635 | -30.9054  | 24                     | 3780       | 23         | 0                 | 24       | 23        | 0         | 0        | 0         | 24         | 24          |
| 84    | 17/04/2010 06:54:00 | -59.67304 | -30.89571 | 19                     | 2950       | 0          | 0                 | 19       | 0         | 0         | 0        | 0         | 20         | 20          |
| 85    | 17/04/2010 09:31:00 | -59.67368 | -30.89569 | 21                     | 3451       | 0          | 0                 | 20       | 0         | 0         | 0        | 0         | 20         | 20          |
| 86    | 17/04/2010 15:42:00 | -59.04843 | -30.83072 | 24                     | 3110       | 21         | 0                 | 24       | 22        | 0         | 0        | 0         | 24         | 22          |
| 87    | 17/04/2010 20:15:00 | -58.63543 | -30.82366 | 24                     | 3524       | 0          | 0                 | 23       | 0         | 0         | 0        | 0         | 23         | 18          |
| 88    | 18/04/2010 02:25:00 | -58.21446 | -30.82252 | 24                     | 3985       | 23         | 0                 | 23       | 21        | 0         | 0        | 0         | 23         | 23          |
| 89    | 18/04/2010 08:37:00 | -57.80117 | -30.8319  | 24                     | 3575       | 0          | 0                 | 24       | 0         | 0         | 0        | 0         | 24         | 24          |
| 90    | 18/04/2010 13:50:00 | -57.45867 | -31.32588 | 24                     | 3755       | 22         | 0                 | 24       | 22        | 0         | 0        | 0         | 24         | 22          |
| 91    | 18/04/2010 18:55:00 | -57.11896 | -31.81411 | 24                     | 3424       | 6          | 0                 | 24       | 0         | 0         | 0        | 0         | 24         | 22          |
| 92    | 18/04/2010 21:51:00 | -57.11865 | -31.81451 | 24                     | 3226       | 21         | 16                | 24       | 22        | 0         | 0        | 0         | 24         | 24          |
| 93    | 19/04/2010 06:47:00 | -56.38077 | -32.87068 | 23                     | 3124       | 6          | 0                 | 23       | 0         | 0         | 0        | 0         | 23         | 23          |
| 94    | 19/04/2010 12:05:00 | -55.99113 | -33.41925 | 24                     | 3039       | 20         | 0                 | 24       | 20        | 0         | 0        | 0         | 24         | 21          |
| 95    | 19/04/2010 16:27:00 | -55.72591 | -33.78531 | 24                     | 3524       | 22         | 0                 | 24       | 21        | 0         | 0        | 0         | 24         | 22          |
| 96    | 19/04/2010 21:15:00 | -55.48573 | -34.13263 | 24                     | 2460       | 6          | 0                 | 24       | 0         | 0         | 0        | 0         | 24         | 21          |
| 97    | 20/04/2010 01:50:00 | -55.26031 | -34.44336 | 24                     | 1514       | 16         | 0                 | 24       | 0         | 0         | 0        | 0         | 24         | 17          |
| 98    | 20/04/2010 04:16:00 | -55.21523 | -34.50779 | 24                     | 546        | 16         | 0                 | 23       | 13        | 0         | 0        | 0         | 21         | 13          |

*Notes to Table:-*

CTD1 - test cast

CTD10 - three bottles imploded

CTD16 - top caps not closed

CTD19 - firing problems due to change of procedure during cast

CTD20 - CTD brought up from 2730 to 1700m and then back to 2680

CTD30 – air valves not closed 22:24, 1, 3,4, 2 leaking slightly. Cast repeated as 30a after 31

CTD34 - salinity sample values out due to salinity lab heating above salinometer temperature

CTD42 - weather deteriorated so bottles 13-24 fired without stopping package

CTD44, 46 - CTD package alarmed, resetting firing sequence. (24 not fired on 44; 19:24 not fired on 46).

CTD62 - bottles 23 & 24 not fired

CTD70 - new Oxygen sensor fitted

CTD73, 74 - pump for primary sensors not working properly

### **Appendix 3 – Liquid Nitrogen Generator (Allan Davies)**

The Liquid Nitrogen Generator used on JR235/236/239 is part of the National Marine Equipment Pool and is supplied and maintained by National Oceanography Centre, Empress Dock, Southampton. SO14 3ZH. Tel. +44 (0)23 80 59 66 66 (Inventory No.:250006330)

The unit is a standalone item that, when operating under optimum conditions, can produce approximately 12 litres of liquid nitrogen per 24-hour period. A standard industrial compressor feeds compressed air through a drier to remove excess moisture into a filter bank where the nitrogen gas is stripped off and passed on into an insulated receiver. The remaining gases are vented to atmosphere. The receiver also contains the 'Cold Head' part of a self-contained cryogenic refrigeration unit that circulates liquid helium through the cold head upon which the nitrogen gas condenses to form droplets of liquid nitrogen, which eventually produce a pool of liquid nitrogen in the receiver. The receiver can hold 25 litres when full and will produce around 12 litres per day when fully operational. It takes approximately 48 hours from a dry start before usable quantities of liquid nitrogen are produced and performs best when the receiver is kept at least half full.

#### **Safety Considerations:-**

The unit is designed to operate in a dry and stable environment with a temperature range between +5<sup>0</sup> and +25<sup>0</sup> Celsius. As the unit essentially removes nitrogen from the atmosphere it must be operated in a well-ventilated space to prevent the possibility of an oxygen rich atmosphere developing which could lead to problems with spontaneous combustion. Liquid nitrogen is an extremely dangerous substance, which can cause cryogenic burns (ie frost bite) if allowed to come into contact with skin and can alter the physical properties of metal or plastics. Thus only properly trained staff wearing correct personal protective clothing should operate the equipment. Special procedures should be in place to deal with a fractured receiver as the liquid will displace 267 times its own volume in air when turning back into a gas thus posing a very real danger of asphyxiation to anyone in the vicinity.

#### **Specific use on cruise JR235/236/239:-**

After much discussion the ship's crew decided to locate the unit in the water bottle annex on the starboard side of the main deck. This was not the most ideal location as it is exposed to atmosphere when the annex doors are open (which they are for considerable periods of time) and access is very restricted with plenty of trip hazards present for those having to transport the liquid nitrogen to their work areas (exacerbated by the ships motion) and it also impinges on the working space available for those sampling from the CTD. Also no suitable electricity supply is available in the annex so the ships ETO had to run a supply from another part of the vessel. A more appropriate location would be the scientific workshop, this is immediately adjacent to the work area, has a suitable electricity supply and is a considerably more temperature-stable environment. However access to the overhead travelling crane which would be needed to bring the unit inside the workshop had been blocked by the laboratory containers positioned immediately outside.

Despite the problems highlighted above, the unit performed to specification throughout the cruise. It was noted that the receiving Dewar had reached capacity after about 5 days from start up and since then scientists have been drawing approximately 8 litres per day from the Dewar without problems. However transporting the liquid nitrogen from the unit to the work area (lab. containers on the aft deck) was not easy as it involved either an outside route via an icy rolling deck or inside via many door openings and narrow passage ways.

On this particular cruise the liquid nitrogen was used exclusively as a cooling medium in the CFC / SF<sub>6</sub> instruments where samples of water taken from the bottles attached to the CTD frame were quickly cooled to trap gas content before their temperatures were raised again to various levels thus releasing different gases for analysis. (See [section 5c](#) for a more scientific explanation).

## Appendix 4 - Shipboard computing

Johnnie Edmonston (BAS)

**Netware system:** netware presented no problems during the cruise

**Unix systems:** Unix workstations, including the unit placed on board by Brian King (NOC) for the cruise all presented no problems. At one point navigation processing on the NOC unit had to be restarted after suffering process failure due to the rvs string and scs raw to compressed processes were restarted following a reboot of the SCS..

**Linux systems:** AMS 3 had to be rebooted once during the cruise. Processor and memory utilization having reached 100%, and staying there, the unit was unresponsive to either client or console.

### SCS

18/03/2010 1435 Continuous acquisition started

24/04/2010 1350 Continuous acquisition stopped

On 17th April, between 1752 and 1818, the SCS was rebooted following the anemometer replacement. No anemometer data was being received after the anemometer on the foremast was replaced and the first thing suspected was the SCS failing to receive rather than the anemometer failing to send. It transpired the anemometer was not sending data and has not been configured to send serial data, only digital to the DP desk and wind display on the bridge. The old anemometer will be repaired and reinstated into the scientific systems.

Following the reboot of the SCS, problems were experienced both rebuilding the RVS strings and the compressed data files. The RVS strings were rebuilding but at an alarmingly slow pace, little more than twice real time, and the compressed data was minus the winch. The RVS streaming was solved by moving the streamstates file onto jrub until the streams had caught up the present time. The problem with the winch compress file conversation was found to be that the process was unhappy with a zero byte raw file as its last file to append. Zero byte file deleted and the process restarted happily on all streams.

**EM120:** was rebooted twice during the cruise, both times on station and in deep water. Normal operation was resumed immediately upon restarting the workstations; no action was taken on the transducers on either occasion.

**Topas:** happily stayed switched off during the cruise.

## CCHDO Data Processing Notes

| Date       | Person       | Data Type  | Action         | Summary  |
|------------|--------------|------------|----------------|--|
| 2010-10-27 | Diggs, Steve | CTD        | Submitted      | NonPublic<br>CTD data acquired for Argo DMQC data base, held in NetCDF. Data are proprietary for now. Other cruise contacts are Alberto Naveira Garabato and Loic Jullion (NOC/UK).  |
| 2013-02-19 | Staff, CCHDO | BTL        | Website Update | Available under 'Files as received'<br>The following files are now available online under 'Files as received', unprocessed by the CCHDO.<br><br>74JC20100319.exc.csv<br><br>ANDRX-2 jr235_236_239 cruise report.pdf  |
| 2013-02-19 | Key, Bob     | BTL/CrsRpt | Submitted      | to go online   |
| 2013-07-02 | Shen, Matt   | maps       | Website Update | Map updated<br><br>=====<br>74JC20100319 processing<br>=====<br>2013-07-02<br>M Shen<br>.. contents:: :depth: 2<br>Process<br>=====<br>Changes<br>-----<br>74JC20100319_trk.jpg<br>~~~~~<br>Updated title.<br>74JC20100319_trk.gif<br>~~~~~<br>Updated title.<br>Directories<br>=====<br>:working directory:<br>/data/co2clivar/atlantic/a21/a21_74JC20100319/original/2013.07.02_maps_MYS<br>:cruise directory:<br>/data/co2clivar/atlantic/a21/a21_74JC20100319<br>Updated Files Manifest<br>=====<br>- 74JC20100319_trk.gif<br>- 74JC20100319_trk.jpg |
| 2013-09-05 | Kappa, Jerry | CrsRpt     | Website Update | Final PDF version online<br>I've placed a new PDF version of the cruise report: a21_74JC20100319do.pdf into the directory: co2clivar/atlantic/a21/a21_74JC20100319/.   |

It includes all the reports provided by the cruise PIs, summary pages and CCHDO data processing notes, as well as a linked Table of Contents and links to figures, tables and appendices.