**National Oceanography Centre, Southampton**

# Cruise Report No. 53

## RRS *Discovery* Cruise 332

20 AUG-25 SEP 2008

Arctic Gateway (WOCE AR7)

*Principal Scientist*

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2010

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*ABSTRACT*

This report describes scientific activities on RRS *Discovery* cruise 332, “Arctic Gateway”, in the vicinity of WOCE hydrographic section AR7 between Canada, Greenland and Scotland during late summer 2008. Hydrographic work comprised 74 CTD/LADCP stations and one tow of the Moving Vessel Profiler. Water samples were captured for on-board measurement of salinity, dissolved oxygen, inorganic nutrients, calcite, particulate organic carbon and chlorophyll. Samples were also captured for storage for later on-shore analysis of oxygen isotope fraction, chlorofluorocarbons, sulphur hexafluoride and alkalinity / total carbon dioxide. Continuous underway measurements comprised: navigation; currents, using vessel-mounted ADCPs (75 and 150 kHz); meteorology; sea surface temperature and salinity; and bathymetry. Mooring operations comprised the recovery of two current meter moorings off Cape Farewell; two other moorings were deemed lost; an instrument from a fifth mooring, not recovered at the time, was later found intact in west Scotland. Additionally, a party from the Royal NIOZ were engaged in a programme of recovery and redeployment of Dutch moorings. UK funding for D332 was provided by the Natural Environment Research Council under its *Oceans2025* programme.

*KEYWORDS*

ADCP, AR7, North Atlantic, CO2, CFC, CTD, *Discovery*, Irminger Basin, Labrador Sea, LADCP, Nutrients, Oxygen, Oxygen Isotope, Moorings, Moored Vessel Profiler, SF6, Meteorology

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**ACKNOWLEDGEMENTS**

Thanks are due to the Master, Officers, Engineers and Crew, and to all scientific staff. This was a difficult cruise, hard hit by foul weather and mechanical problems.

Unusually, I also offer my sincere thanks to two Scottish fishermen – Kenneth MacIntyre and John McCann. Passing the Hebridean island of Coll in summer 2009, they noticed what appeared to be an item of oceanographic equipment washed up on one of the island's beaches. It proved to be our East Greenland Current (formerly-) moored ADCP, believed lost. They saw to its recovery and subsequent delivery to SAMS, Oban, where Colin Griffiths was quickly able to determine that its watertight integrity had not been compromised, and that it was full of data! An extraordinary coincidence in many ways, and a valuable 2-year data set (plus about a year of drifting in the North Atlantic) recovered.

Thanks to Dave Berry back at base for putting up the (near-) daily web diary.

This research was funded by the UK Natural Environment Research Council under the *Oceans2025* programme.

# 1 INTRODUCTION

Sheldon Bacon

This cruise was planned as (i) an enhanced occupation of the whole WOCE AR7 hydrographic section, and (ii) recovery / servicing of several NOCS and NIOZ moorings in the same region. WOCE AR7 – Canada to Greenland to Ireland/Scotland – seemed worth doing in this way because in the now quite long history of this section, I can't find any occurrence of its having been occupied in its entirety in one go. It has usually been split into its western part, the Labrador Sea (AR7W), and its eastern part (AR7E), crossing the Irminger Basin, the Iceland Basin, the Rockall-Hatton Plateau and the Rockall Trough. Also these sections have typically been occupied at different times of year – Spring for AR7W and Summer for AR7E. This means that ambiguities in the measured circulation and issues of supposed continuity of the boundary currents around Cape Farewell have been obscured by asynopticity. By reason of guarding against the possibility that a time-delay might be to blame for any such observed discontinuity, we added a "box" section around Cape Farewell so that the fate of any waters entering or leaving the boundary current system could be determined.

As it proved, this was an extremely difficult cruise by reason of time lost due to mechanical problems, but much more severe was the loss of time due to extraordinarily foul weather. The cruise can be seen as a game of three halves. The first 10 days or so were conducted in quite fine weather and we completed the Labrador Sea section and part of the "box". The next 10 days were spent partly engaged in mooring operations, finishing the "box" and beginning AR7E while spending a lot of time hove to awaiting the passage of weather systems. The final 10 days were a near-total washout, including the need to flee (!) from the fast-approaching remains of Hurricane Ike (!). My estimate of total time lost, based on 32 work days (not including three days' passage to and from the work area), was (for me) an unheard-of 52%. As can be seen in figure 1, this meant that while we conducted all mooring operations and completed all western stations important for measuring the outflow of fresh Arctic waters, we made no measurements at all in the Iceland Basin or over the Rockall-Hatton Plateau, and only a few stations in the Rockall Trough right at the end of the cruise. A summary of the downtime follows. However, an important aim of the cruise *was* achieved: the synoptic measurement of the magnitude and fate of Arctic outflows. Publications in refereed journals will follow.

<u>Mechanical problems</u>

Early in the cruise (straight after station 13), the main hydro winch was taken out of commission. Without going into the technical issues, it was decided that the main hydro winch posed an unreasonable risk to the CTD package, with possible safety issues for personnel in the event of further such events. The spare (Lebus) winch was commissioned to serve in its stead. It worked quite steadily but suffered scrolling problems on one of the final casts. There was also a late CTD cable retermination needed (final 2 days), the CTD oxygen sensor failed during cast 71, which cross-talked into spoiling the conductivity sensor output, so the fault had to be diagnosed and the station repeated. The ship's engine problems (loss of power) in the final work day caused loss of time for repair.

Foul weather

For several weeks there was a well-established blocking high over Scandinavia. In conjunction with the Azores High (in its usual position), North Atlantic depressions were being channelled away from the usual storm track (roughly Maine to Scotland/Norway) and onto a displaced and rotated storm track, such that depressions were running east of north from Maine up the Irminger Basin and through Denmark Strait. Also they were moving and developing slowly. The depressions were bypassing the Labrador Sea during the beginning of D332, so we were able to make quite steady progress through the western part of the cruise, although we were slowed by reduced overnight vessel speeds as a precaution against the possibility of encountering sea ice, and also by fog. Unrelenting foul weather in the final 10 days of the work time caused loss of all measurements in the Iceland Basin and over the Rockall-Hatton Bank.

Miscellaneous

The incorrect cruise dates on the Irish Diplomatic Clearance note cost half a day in reorienting the final work days. The Naval gunfire exercise in the region of the eastern Rockall Trough, of which we were notified the evening before it was due to start, caused redesign of the cruise track and cost half a day (inclusion of a long dog-leg); also we were subsequently informed that the exercise had been cancelled.

Lost time

The mechanical problems caused 2 lost days, due to cast 13 recovery, problem solving, Lebus commissioning (electrical connections, mechanical and electrical termination, load testing) and associated issues. Foul weather (strong winds), due to unusual conditions outlined above (including the tail-end of Hurricane Ike), caused the loss of 12.5 days in total. Fog in the Labrador Sea west of Greenland necessitated slow steaming day and night, and cost another day. Also the Lebus winch is more susceptible to wind and sea state than the main hydro winch. It can be difficult to use it even in low winds if a contrary swell is running, causing the vessel to roll on station, which in turn adversely affects wire tension. The average veer and haul rates of the Lebus winch are lower over an entire cast than the standard 60 metres per minute of the main winch: typically lower by 25%. I estimate that a day was lost due to reduced winch speed, therefore.

Timing summary

The total of lost work time stands at 16.5 days. This cruise was of 35 days' duration, of which 32 were work days and 3 passage (2 out of Canada, one into Glasgow). Therefore 16.5 days lost out of 32 is equal to 52% of total work time.

I do not attempt to subdivide the downtime into categories because there were so many difficulties experienced during the cruise that issues often overlapped: eg, Irish permission to work, Naval gunfire exercise, ship's engine problems, Lebus scrolling, CTD sensor failure, heavy swell over Rockall Bank, all influenced the last few scheduled work days.

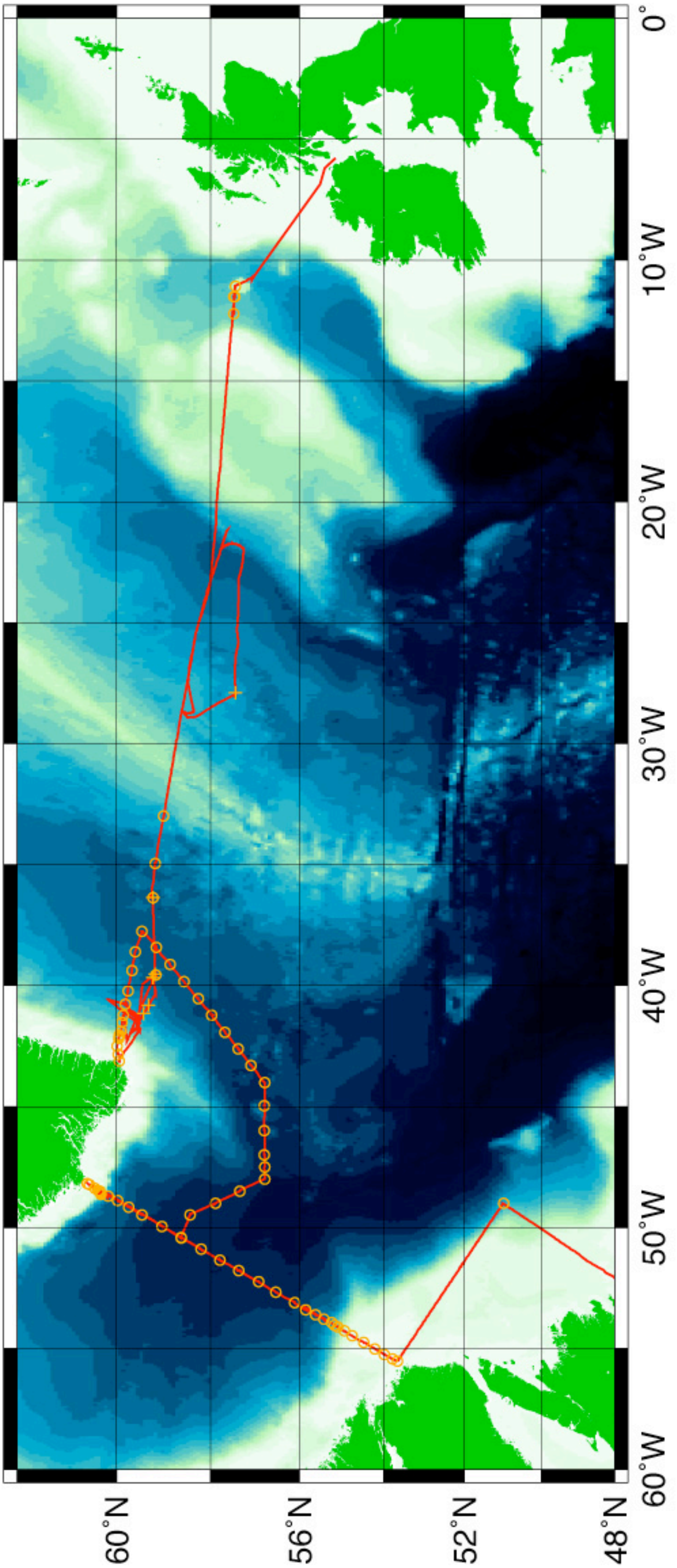



**Figure 1:**
Track of RRS *Discovery* cruise 332 (red); CTD station positions (orange circles); moorings (orange plus symbols). The first station, right outside St. John's, is off the chart to the south-west. The cruise began in St. John's, Newfoundland, and ended in Glasfgow.

## 2 MOORING OPERATIONS

Dave Childs, Ben Poole, Steve Whittle

The objectives of the Mooring Team were to recover the Cape Farewell mooring array that was deployed in 2006; the array was started in 2005 then recovered and redeployed in 2006. This was the final year for this array; all moorings that will be recovered will have been deployed for a period of two years.

For all mooring recovery work Steve Whittle handled all the back deck work, whilst Ben Poole operated the double barrel winch, with Dave Childs operating the reeling winch. Additional support on deck was supplied by Leighton Rolley who provided assistance as and when needed.

All mooring recovery work was started at the earliest opportunity in daylight hours to provide as much daylight working as possible, to assist in the sighting of moorings once on the surface. Both Ben Poole and Dave Childs worked full CTD shifts whilst CTD watches were being maintained, these were however stopped as mooring operations were under way, giving the scientists a break from sampling.

All recovered instrumentation will be downloaded and serviced on board then it is intended to return all instruments to NOCS for post deployment calibration.

These are the proposed moorings for recovering on D332, with their corresponding NMF ID numbers. These moorings were deployed during August 2006 on board Discovery, for cruise D309:

| | |
|---|---|
| MOORING F | 2006/31 |
| MOORING B | 2006/32 |
| MOORING C | 2006/33 |
| MOORING A | 2006/34 |
| MOORING H | 2006/35 |

Instrumentation used throughout the mooring array consisted of Aanderaa RCM 7 and 8 current meters, and Aanderaa RCM 11 current meters. As the RCM 11 instruments were all supplied new for the D309 no pre-cruise calibrations had been undertaken, thus calibration casts were carried out on CTD stations during D309.

For each attempted recovery the IXSEA deck unit TT801 and transducer were taken to the hanger and set-up so that the transducer could be deployed overboard by the starboard CTD gantry. All releases used throughout this mooring array were IXSEA AR861's.

Once we were informed by the bridge that we were on station we placed the transducer overboard and started to interrogate the release, using the telemetry mode. This established communication with the release and also provided additional information such as release range, battery condition and the release position, this being either vertical or horizontal.

Upon successful communication with the release, and permission with the bridge, the release command was sent. Once received, the release operated, releasing itself from the anchor weight.

Periodically, a check on the release's depth was made to track the ascent rate, which was then used to calculate a rough time that the mooring might be on the surface; this information was then passed to the bridge.

Unfortunately, not all moorings responded when interrogated, and weather and time constraints prohibited dragging operations, therefore we were unable to recover three moorings. This obviously resulted in the loss of instruments, releases and data.

Notes were made at each mooring site of all the events that took place with times being recorded in GMT. This was then used to produce a log of events, which follows in this report.

## 2.1 Diary of NOCS Mooring Operations

Mooring operations began on Tuesday the 9th of September 2008 and continued until the following Sunday. Additional mooring operations were carried out in the recovery and deployment of several moorings for NIOZ, these are not detailed in this report, except to say that all of the Mooring Team were on deck throughout all of the NIOZ mooring operations to assist, again with Steve Whittle working on the back deck, Ben Poole operating the double barrel winch and Dave Childs operating the scrolling winch.

<u>Tuesday 9 September</u>

*Mooring F – Recovery*

The ship arrived on station 16:55 GMT then when the ship was hove-to, the transducer was placed overboard, with the first attempt of establishing communication with the release sent at 16:56 GMT.

Straight away we received a reply from release, giving a range of 1072m. A release command was sent at 16:57 GMT, and the release responded with release OK. Further commands were sent to the release to check on its ascent rate. By 17:00 GMT the release was at a depth of 970m, indicating that the mooring was on its way up to the surface. However, additional ranges received indicated that the mooring had stopped surfacing and for some reason had stopped at a depth of approximately 960m.

Over a period of several hours the range of the release was checked, but its depth remained fairly constant, allowing for the drift of the ship. At 21:00 GMT it was decided to abandon the attempted recovery of this mooring, due to the fact that it appeared that something was stopping the mooring surfacing. We then steamed overnight to the next NIOZ site, with the intention of returning to the mooring site for dragging operations, however time, weather and ship restraints prohibited this. It is thought that maybe the ADCP Buoy had broken away from the mooring with the Argos beacon failing causing the remaining rope to fall to the sea bed and possibly getting tangled in the anchor.

Wednesday 10th September

*Mooring C – Recovery*

Today we arrived on station at the NIOZ mooring site at 10:00 GMT where we assisted in their mooring operations. After the first NIOZ mooring was successfully recovered, we moved off to the second NIOZ mooring site, and again their mooring was successfully recovered without any problems.

For the NOCS mooring recovery we steamed to the NOCS Mooring Site C arriving on station at 19:00 GMT. Communication with the release was first attempted at 19:05 GMT but no reply was received. Further commands were sent to interrogate the release, however no reply was received. At 20:24 GMT the decision was made to move off from the current station and head off towards the next mooring site, with the option of returning at a later point in the cruise for possible dragging operations, again this did not happen due to time and weather constraints.

We arrived at Mooring Site B overnight, and then interrogated the release to see if we could get a reply. The release responded with a range of 2807m, 11.2 battery voltage, and the release was in the vertical position. The decision was then made to hold off until first light on Thursday, so that the mooring could be released and recovered in daylight.

Thursday 11th September

*Mooring B – Recovery*

*Mooring H – Recovery*

At 07:48 GMT permission was given by the bridge to attempt the recovery of Mooring B. With the transducer over the side at 07:49 GMT the first release command was sent with a reply received, giving a release depth of 2754m, and a release OK confirmation. At 07:51 GMT the release was ranged again, this time giving a depth of 2697m confirming that the mooring was on its way up. By 07:52 GMT the range was 2635m, and by 08:21 GMT the mooring was in sight and on the surface. By 09:10 GMT the mooring was completely recovered and inboard.

Throughout the day the weather and sea conditions continued to deteriorate, however the recovery of mooring H went ahead. We arrived on station at 10:36 GMT with the ship hove-to an initial attempt to communicate with the release gave us a range of 2438m, with additional ranges of 2390m, 2293m, 2101m confirming the mooring was on its way to the surface. Additional ranges showed the mooring continuing to surface. By 11:48 GMT the mooring had been fully recovered without incident.

After the successful recovery of mooring H we steamed to Mooring Site A, once on station and hove too we attempted to communicate with the release, however the transducer was pulled aft reducing the deployed depth of the transducer. After several attempts at trying to communicate with the release we were unable to do so, and decided to wait until weather and sea state conditions improved.

Friday 12th September

*No science due to bad weather*

Ship hove-to in rough weather. All on-deck science off until further notice. Due to the bad weather mooring recovery operations were unable to continue so the day was spent cleaning and servicing all recovered instruments.

Saturday 13th September

*Mooring A – Recovery*

Bad weather overnight and into the first part of Saturday stopped mooring recovery again. However at 11:30 GMT the ship was on station at Mooring Site A. Attempted communication with the release started at 11:33 GMT with no reply from the release being received. Further attempts were made at 11:34 GMT, again with no response being received.

It was then decided to send a blind release command at 11:35 GMT; however we still had no response from the release.

In order to allow time for the release to operate and for the mooring to rise to the surface on the assumption that the release could have operated but failed to send a confirmation we held station for a period of an hour, during which time lookouts were in position on the bridge and around the ship. Additional commands were sent to the release to see if it was rising; however we received no reply from the release. A decision was then made made to abandon the attempted recovery of Mooring A and to start to steam towards the next NIOZ mooring site. No dragging operations were undertaken again due to weather and time restrictions.

Whilst steaming to the next mooring site all data was downloaded from the RCM DSU units, and saved for later use. All data recorded by the instruments will remain on the DSU's as an additional backup. After the end of the cruise all the recovered instruments will be returned NOC for post deployment calibration at the National Marine Facilities Sea Systems Calibration Laboratory.

The table below summarises the data obtained from the recovered instrumentation used on the mooring array.

| Instrument | Serial Number | Detected Sampling Interval | Number of Records |
|---|---|---|---|
| RCM | 522 | 60 Minutes | 19009 |
| RCM | 524 | 60 Minutes | 19009 |
| RCM | 525 | 60 Minutes | 19009 |
| RCM | 527 | 60 Minutes | 19010 |
| RCM | 9589 | 120 Minutes | 9746 |
| RCM | 10280 | 120 Minutes | 51 |
| RCM | 12293 | 120 Minutes | 8965 |

For the final mooring operation of the day we assisted in the NIOZ mooring deployment which commenced 00:54 GMT. All of the mooring was deployed without any problems; the anchor was released from the ship at 03:25 GMT.

Sunday 14th September

*NIOZ Mooring Recovery*

For the NIOZ mooring recovery we were on deck for 10:00 GMT to prepare the deck. The ship was on station at 12:00 GMT. All communication with the release was handled by the NIOZ mooring team. Upon successful release the mooring was on surface and insight by around 12:40 GMT. All of the mooring was successfully recovered without incident.

## 2.2 Recovered Equipment

With the successful recovery of Mooring B and Mooring H the following items were recovered:

**Mooring B [59° 20.005N, 40° 49.151W]**

| Equipment Recovered | Serial Number |
|---|---|
| RCM 8 | 9598 |
| RCM 8 | 10280 |
| RCM 11 | 524 |
| RCM 11 | 525 |
| Acoustic Release AR861 | 311 |
| 15 Glass | N/A |

**Mooring H [59° 26.333N, 41° 09.347W]**

| Equipment Recovered | Serial Number |
|---|---|
| RCM 8 | 12293 |
| RCM 11 | 522 |
| RCM 11 | 527 |
| Acoustic Release AR861 | 360 |
| 15 Glass | N/A |

### 2.3 Unrecoverable Moorings

However, with the unsuccessful recovery of Mooring A, Mooring C and Mooring F the following instrumentation and hardware was not recovered. All wire, links, shackles and recovery lines were also lost.

**Mooring A [59° 33.169N, 33° 54.050W]**

| Equipment Lost | Serial Number |
|---|---|
| RCM 8 | 8248 |
| RCM 11 | 514 |
| RCM 11 | 528 |
| Acoustic Release AR861 | 355 |
| 13 Glass | N/A |

**Mooring C [59° 11.104N, 40° 21.205W]**

| Equipment Lost | Serial Number |
|---|---|
| RCM 8 | 6750 |
| RCM 8 | 9681 |
| RCM 11 | 524 |
| RCM 11 | 526 |
| Acoustic Release AR861 | 310 |
| 13 Glass | N/A |

**Mooring F [59° 47.075N, 42° 17.308W]**

| Equipment Lost | Serial Number |
|---|---|
| 45 inch ADCP Buoy | N/A |
| 75 kHz ADCP | 1767 |
| Argos Beacon | 59619 / 733435 |
| RCM 8 | 12356 |
| RCM 8 | 12363 |
| Acoustic Release AR861 | 257 |
| 5 Glass | N/A |

Both available time and weather conditions prevented dragging operations and the decision was made to abandon the moorings and to move on to the next station for either other mooring recoveries or CTD stations.

*Note added by SB at time of writing:* as mentioned in the Acknowledgements, by great good fortune and the considerable goodwill of two Scottish fishermen, the ADCP from Mooring F was recovered from Coll in 2009 and returned to NOCS.

### 2.4 Instrument Problems

Aanderaa RCM 8 SN 10280 only had 51 records, indicating a fault with the instrument. A new battery was fitted to this instrument prior to it's deployment, however the instrument had stopped logging, so an initial conclusion was that a fault with the instrument had caused the battery to drain much faster than normal. Tests will be carried out back at NOC to try and identify a fault.

Aanderaa RCM 8 SN 12293 was recovered with a missing rotor, upon looking at the instruments recorded data it was found the rotor had come off during recovery, so no data was lost.

### 2.5 NIOZ MMP Mooring Operations and Observations

On recovery of the two MMP moorings, when the MMP instrument was downloaded it was seen that several hundred successful up and down profiles had been completed throughout the period of deployment, which was one year. Whilst this instrument has not proved too successful on NOC moorings, it is thought that this could be due to the diameter of the mooring wire used. On inspection of the NIOZ mooring they have used a wire with a diameter of 7mm with a plastic covering of 2mm thickness, brining the total diameter of the wire to 9mm mm and this seems to have given them excellent results with all deployments. See below for further information.

### 2.6 NIOZ mooring activities

Femke de Jong, Sven Ober

The three moorings that were deployed by the R.V. Pelagia in September last year were successfully recovered during this cruise; positions are given in Table 2.1. One of the moorings, Loco 2-5, has been redeployed as mooring Loco 2-6. The mooring operations were carried out smoothly and safely by Lorendz Boom, the ship’s crew and the technicians of NOCS.

| Mooring | Action | Date | Lat | Lon | Echo Depth |
|---|---|---|---|---|---|
| Loco 2-5 | Recovery | 10 Sept '08 | 59° 11.91' N | 39° 31.87' W | 3045 m |
| Irm 5 | Recovery | 10 Sept '08 | 59° 14.75' N | 39° 39.79' W | 3036 m |
| Loco 2-6 | Deployment | 14 Sept '08 | 59° 11.91' N | 39° 31.91' W | 3053 m |
| Loco 3-5 | Recovery | 14 Sept '08 | 59° 14.67' N | 36° 22.20' W | 3036 m |

**Table 2.1:** Positions of the moorings serviced during RRS *Discovery* Cruise 332.

The two Loco moorings are part of the "Long-term OCean Observations" project and have gathered hydrographic data from the Irminger Basin for the fifth consecutive year. The following instruments were contained in the moorings. A downlooking RDI Long Ranger Acoustic Doppler Current Profiler (ADCP) fitted in the upper float (at ~120 m depth) measuring at 20 min intervals. A McLane Moored Profiler (MMP) fitted with a FSI CTD, which measures daily profiles between 200 and 2400m depth. A second RDI Long Ranger ADCP at 2500 m depth, also measuring at 20 min intervals. And a SBE Microcat CTD, recording every 5 min, was fitted to the cable near the bottom weight at 3050 m depth. Almost all the instruments in both moorings worked properly during the full deployment period. The McLane Moored Profilers apparently experienced only slight troubles with bio-fouling on the cable this year and recorded full depth profiles for most of the deployment.

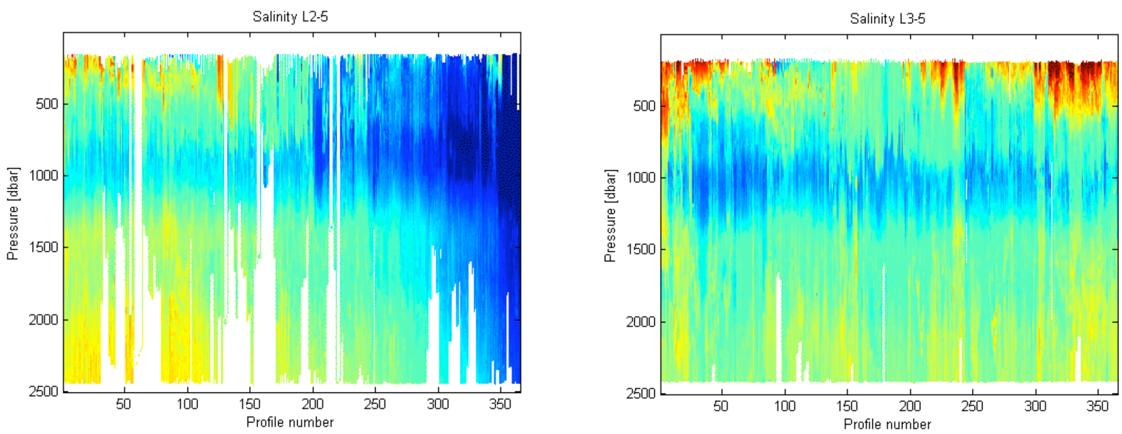
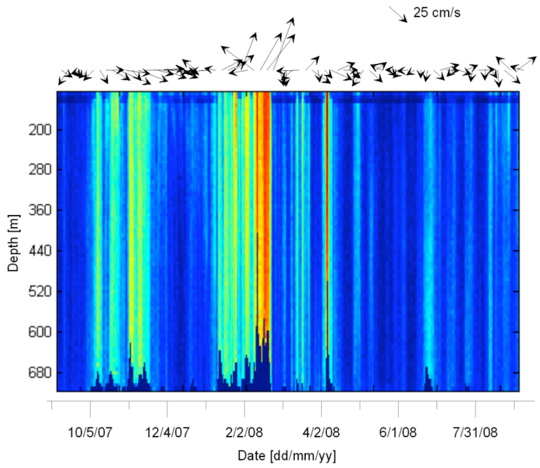



**Figure 2.1:** One year of vertical salinity profiles for the moorings Loco 2-5 (left) and Loco 3-5 (right). The colour scale ranges from 34.75 psu (dark blue) to 35.1 psu (dark red).

The conductivity sensor on the Loco 2-5 MMP started to drift significantly during the second half of the deployment (Fig. 2.1), but this will be corrected with the help of the calibration CTDs taken by the Discovery. The sensor itself will be sent to the manufacturer for check, maintenance and calibration.

Only one recovered instrument seemed to have has a serious problem during the deployment. The topmost ADCP in Loco 3-5 contained data with dates and settings that were inconsistent with its programming for this particular mooring. The cause of this problem is as yet unclear and will be




subject of analysis at NIOZ as soon as possible.

**Figure 2.2:** Velocity vectors at 120 m depth from Loco 2-5 (top) and vertical profiles of the magnitude of velocity from Loco 2-5 (bottom, red colours are high velocities, blue colours are low velocities.).

The remaining three ADCPs functioned properly. Their data records show mainly barotropic velocity profiles (Fig. 2.2) with tidal currents on short time scales. Several storms passed during winter forcing currents with velocities up to 45 cm/s (red areas Fig. 2.2).

## 2.7 Sediment traps and BOBO-lander

Santiago R. Gonzalez

The sediment traps in the Irminger Sea and the BOBO lander on Gardar Drift were deployed within the VAMOC (Variability of Atlantic Meridional Overturning Circulation) programme; a Netherlands, Norway, UK collaboration within RAPID. The main research questions are: How did the Atlantic Meridional Overturning Circulation change on glacial-interglacial timescales, and did changes take place in the same way every time? These changes can be derived from the bottom sediments. Within this project the Royal NIOZ is mainly studying the present on-going sedimentation in relation to the present water circulation. For this purpose moored sediment traps were deployed alongside the moored LOCO 2 CTD-profiler in the Irminger Sea. These enable approximately biweekly observations of particle flux, both pelagic and resuspended. With the successful recovery of the IRM-5 sediment trap mooring on 10 September 2008, the mooring programme within VAMOC has, after 5 successive years, come to an end. Laboratory analyses of the samples at the NIOZ are ongoing and will include the new samples.

An important aspect of the VAMOC project is the study of drift deposits. These are deposits with extremely high sedimentation rates of sediments that arrive more or less horizontally. A modified BOBO-lander was deployed on Gardar Drift, in September 2007. At the specific site present sedimentation rates amount up to 2.3 mm/yr (Boessenkool et al., GRL, 2007). Sediments consist dominantly of resuspended lithogenous matter that is transported within the Iceland-Scotland Overflow waters. The lander was fitted with three sediment traps and sensors to measure current velocity above the lander, temperature, salinity, turbidity and with a passive sampler for organic contaminants. Its successful recovery from the very soft seafloor at 19 september 2008 and its functioning well during the very long deployment provide a tremendous boost to the VAMOC project. The collected sediments and measured data will be analysed at the NIOZ and are expected to provide new insights into the development of drift deposits and will be used for proxy calibration.

# 3 CTD

## 3.1 CTD Operations

Dougal Mountifield

A total of 74 CTD casts excluding aborted casts were completed during the cruise. These included 3 casts for calibration of the NIOZ MMP moorings. All casts used the 24-way stainless steel frame. There were no major operational issues with the CTD suite during the cruise. However one RDI WH300 LADCP (s/n 4908) failed due to flooding during cast 36 and a SBE43 dissolved oxygen sensor (s/n 43-0619) failed during cast 71. Failed instruments were replaced with spares prior to the subsequent cast. The deepest cast was to 3590m.

### *3.1.1 CTD frame configuration*

The 24-way stainless steel frame configuration was as follows:

• Sea-Bird 9/11 plus CTD System
• Sea-Bird SBE-32 24 way rosette pylon on NMF 24 way frame
• 24 by 20L custom OTE external spring water samplers
• Sea-Bird SBE-43 Oxygen Sensor
• Chelsea MKIII Aquatracka Fluorometer
• Chelsea MKII Alphatracka 25cm path Transmissometer
• Wetlabs BBRTD 660nm Backscatter Sensor
• NMF LADCP Pressure Case Battery Pack
• RD Instruments Workhorse 300 KHz Lowered ADCP (Downward-looking configuration)
• RD Instruments Workhorse 300 KHz Lowered ADCP (Upward-looking configuration)
• Benthos Altimeter
• NMF 10kHz Pinger

The pressure sensor was located 13cm below the bottom of the water samplers, and 120 cm below the top of the water samplers.

### *3.1.2 Sea-Bird CTD configuration*

The Sea-Bird CTD configuration for the stainless steel frame was as follows:

• SBE 9 plus Underwater unit s/n 09P-19817-0528
• Frequency 0—SBE 3P Temperature Sensor s/n 03P-4381 (primary)
• Frequency 1—SBE 4C Conductivity Sensor s/n 04C-3160 (primary)

• Frequency 2—Digiquartz Temperature Compensated Pressure Sensor s/n 73299
• Frequency 3—SBE 3P Temperature Sensor s/n 03P-4380 (secondary)
• Frequency 4—SBE 4C Conductivity Sensor s/n 04C-3153 (secondary)
• SBE 5T Submersible Pump s/n 05T-3609
• SBE 5T Submersible Pump s/n 05T-3607
• SBE 32 Carousel 24 Position Pylon s/n 32-31240-0423
• SBE 11 plus Deck Unit s/n 11P-24680-0587

The auxiliary A/D output channels were configured as below:

• V0 --- SBE 43 Oxygen s/n 43-0619 (43-0709 from cast 72 onwards)
• V1 --- Unused – obsolete oxygen temperature
• V2 --- Benthos Altimeter s/n 874
• V3 --- Chelsea MKIII Aquatracka Fluorometer s/n 88163
• V4 --- Unused – usually used for 2PI PAR
• V5 --- Unused – usually used for 2PI PAR
• V6 --- Wetlabs BBRTD backscatter s/n 168
• V7 --- Chelsea MKII Alphatracka 25cm path Transmissometer s/n 2642-002

The additional self-logging instruments were configured as follows:

• RDI Workhorse 300 KHz Lowered ADCP (downward-looking master configuration) s/n 4275
• RDI Workhorse 300 KHz Lowered ADCP (upward-looking slave configuration) s/n 4908
• RDI Workhorse 300 KHz Lowered ADCP (spare) s/n 1855 used as upward-looking slave from cast 37 onwards.

The LADCPs were powered by the NMF battery pack s/n WH001. Battery pack WH005 was available as a spare, but was not used.

### *3.1.3 Wetplug Y-cables*

NMF Seabird 9+ CTD systems are in the process of being converted to 'wet-pluggable' style underwater connectors. This should improve the reliability of the systems, most notably in cold water. A reduction in the frequency of sensor spiking events is expected. The conversion to wet-pluggables also makes the Break-Out Box (BOB) pressure case redundant using Y-cables instead. During the first CTD cast it became obvious that the labelling of the Y-cable pairs was transposed. This transposes the even and odd analogue channels. The CON file was edited to swap V2 with V3 and V6 with V7. Hence the altimeter, fluorimeter, BBRTD and transmissometer are not on the historically used channels. Please see the con file for clarification. The old con file was deleted and the new one copied over the existing CTD001.con. Hence there is only one con file is the same for all casts. The wetplug connectors proved to be very reliable with no major spiking events. No connectors required pulling for servicing during the cruise.

### *3.1.4 Discovery CTD Winch Wire Jump*

During the early part of the upcast on cast CTD013 whilst hauling at constant speed, a rumbling noise was heard coming from the winch room. The winch operator stopped the winch at 2289m and went to investigate. The wire had jumped out of the traction winch groove on the bottom sheave of the outboard load side and was running on the bolt heads alongside the traction sheave. The wire has been deformed by running on the bolt heads and some wear had occurred to the bolt heads. Once the CTD was eventually recovered, the CTD winch was no longer used. Notably the wire jumped on the outboard side of the winch whilst hauling. The outboard load was 1.5T and the sea-state was very calm. The Chief Engineer and the E.T.O completed some static deck load tests and confirmed the correct operation and calibration of the CTD load cell. Following instruction from NOC, no further tests were attempted.

### *3.1.5 Commissioning of Portable Hydrographic Winch (PHW)*

The hangar top PHW was commissioned after the failure of the ship's CTD winch. Most of this was straightforward, but the deck cable run for CTD telemetry between the winch and the main lab could not be located. There is a junction box in the main lab and a fixed cable run terminating in another junction box in the funnel. No documentation could be located on board. It was only after receiving a detailed description from NOC of the location of the funnel junction box that it could be found. By this time a coax cable had been run from the main lab along the hangar top to the winch. After a few casts this cable was damaged in the slip ring junction box by strain causing the braid to cut into the core insulation. The coax was re-terminated in the junction box with a better arrangement for strain relief. No further problems were experienced with the deck cable.

After a few casts a birds cage occurred during haul. The scrolling was reset and no further problems occurred until one of the last casts were the scrolling stopped completely, it was found that the clutch had disengaged due to missing springs. Once again the scrolling was reset and no further problems occurred. The springs are to be fitted during the port-call at Govan.

Use of the winch started by limiting haul and veer speeds and limiting the number of bottles fired. Records of outboard loads were recorded on the CTD rough log sheets. As confidence was gained in the winch, speeds were increased until 60m/min became the norm. Also the number of bottles fired was increased until all 24 were used. The main operational limitation of the PHW is the long wire run from the winch through the goal posts to the first 90 degree sheave. In swell this run can become very slack whilst veering in the first few hundred metres of water. Hence speeds were limited to 20m/min until a sufficient weight of wire had been deployed to reduce the slack generation. Because of this it is estimated that CTD casts took approximately a half-hour longer than using the ship's CTD winch.

### *3.1.6 Removal of CTD Stabilising Fin*

Following stored torque in the PHW cable causing a cat's-paw to foul a sheave after cast CTD014, the wire had to be cropped and re-terminated. The fin on the CTD was subsequently removed to assess whether this would improve package rotation. The secondary T&C sensors and the associated pump were refitted on the 9+ underwater unit. Hence prior to cast CTD015 secondary sensors were fin mounted, but 9+ mounted from CTD015 onwards.

An initial look at LADCP compass data from several casts indicates the following:

With the fin fitted, the CTD rotates steadily and slowly on the downcast, and likewise on the up-cast. It is likely that there are no net rotations. However just below and most obviously above the surface, several rotations occur that are not subsequently taken out. Notably these rotations occur in a very short unconstrained length of wire.

Without the fin fitted, the CTD rotates steadily and quickly on the downcast, and rather sporadically on the upcast. It is difficult to determine visually whether there are net stored turns by the time the CTD is held at 5-10m prior to recovery. However the rotations just below and just above the surface are notably less than with the fin on.

One explanation could be that near surface swell, and or wind could be affecting the finned CTD frame more than the finless. Another point to note is that due to the location of instruments on the CTD frame, the frame was not well balanced. It had a cant of perhaps 10-15 degrees. This may have created a windmill effect with the fin fitted.

Regardless, it was found that as far as net torque in the CTD wire goes, the situation was better without the fin on.

Further detailed analysis of LADCP compass data will be undertaken.

### *3.1.7 CTD Wire Terminations*

An existing recent load-tested mechanical termination was used at the start of the cruise, but with a new wet-pluggable electrical splice. When the PHW was commissioned for the repeat of station 13, the 8mm wire had a new termination fitted, and a new electrical splice. Following the cat's-paw after station 14, a new mechanical termination and electrical splice was made. The PHW wire had to be unrigged to allow the deck pull testing of the CTD winch for load cell assessment. To allow the wire to be pulled up, the mechanical termination had to be removed. However, the electrical pig-tail fouled and the electrical splice was damaged. A new electrical splice was made once the mechanical termination had been refitted. During recovery of the CTD package at the end of cast 72 damage was seen to the outer armour on the CTD wire. About 8m of wire was removed and a new mechanical termination and electric splice was made.

Hence during the cruise four mechanical terminations and associated load-tests were completed. Four electrical splices were also made. No electrical splice failures occurred in the water, and no CTD telemetry errors occurred.

### *3.1.8 Sensor Failures*

The only CTD sensor failure during the cruise was the dissolved oxygen sensor SBE43-0619. This failed very early during the downcast of CTD071. Unusually this also had an effect on both conductivity channels, but none on either temperature or pressure. The DO sensor is an analogue 0-5V sensor, whereas the T, C and P sensors are frequency devices, hence the failed sensor was probably pulling down the instrument power supply and the conductivity cells may be particularly sensitive to supply voltage. A repeat of this station was made as CTD073. A new con file was created for the new DO sensor (s/n 43-0709) with suffix '_spareDO'. Details of both oxygen sensors used are contained in the configuration file, see Appendix 1 to Section 3.

### *3.1.9 Altimetry*

The Benthos altimeter worked very reliably, obtaining a good bottom return within 80m of the bottom in low sediment areas and 35m from the bottom when a lot of sediment was present. The NMF pinger was also used both as a backup and as a double check on proximity to the bottom. The pinger was visualised using the EA500 PES display. In calm seas the CTD was worked to around 10m from the bottom. This was increased to approximately 15m from the bottom in swell. During shelf stations in large currents, it was not possible to work the CTD close to the bottom. Rapid shallowing of 200-800 m was observed in the matter of minutes on occasion.

### *3.1.10 Further Documentation*

A sensor information sheet 'D332 Sensor Information.doc' and calibration & instrument history sheets were included in the main cruise archive in electronic format (Adobe Acrobat & Microsoft Word). Original copies of all log sheets were supplied to the PSO in addition to the copies that NMF will retain and also supply to BODC. Electronic copies of all instrument work histories and calibration sheets were also supplied. See also Appendix 3 to Section 3.

### 3.2 CTD Data Processing

Elizabeth Kent, Katherine Gowers, Rosalind Pidcock

As far as possible, the processing route for CTD data followed that used on RRS *Discovery* 309 in August/September 2006 (see D309 cruise report: Bacon, 2006).

The CTD package comprised the following instruments: Seabird 911+ CTD with dual temperature and conductivity sensors; Seabird carousel type SBE 32; RDI 300kHz workhorse ADCPs, one upward looking and one downward looking; Chelsea instruments Alphatracka (transmissometer) and Aquatracka (fluorometer); Wetlabs light back sensor type BBRTD; Benthos altimeter type 915T; twenty four 20 litre Ocean Test Equipment water bottles. The Seabird primary T/C duct had an inline seabird oxygen sensor type SBE 43 fitted and was mounted on the stabilising vane for casts 1-14. The first cast (14) with the Lebus Portable Hydrographic Winch showed excessive rotation of the package and subsequently the vane was removed, necessitating attaching of the primary sensors to the main body of the CTD. 74 full casts were completed (see Station List below).

*Station List:*

| Station number | Code | Date 2008 JDAY HHMMSS | Latitude | Longitude |
|---|---|---|---|---|
| 001 | S | 233 175411 | 052 35.629 °W | 047 30.895 °N |
| 001 | B | 233 180237 | 052 35.669 °W | 047 30.875 °N |
| 001 | E | 233 181937 | 052 35.734 °W | 047 30.894 °N |
| 002 | S | 234 164703 | 049 00.068 °W | 051 00.038 °N |
| 002 | B | 234 173025 | 048 59.762 °W | 050 59.536 °N |
| 002 | E | 234 181543 | 048 59.353 °W | 050 59.069 °N |
| 003 | S | 235 233937 | 055 32.270 °W | 053 40.544 °N |
| 003 | B | 235 234506 | 055 32.179 °W | 053 40.542 °N |
| 003 | E | 236 000415 | 055 31.898 °W | 053 40.570 °N |
| 004 | S | 236 014533 | 055 26.317 °W | 053 47.752 °N |
| 004 | B | 236 015659 | 055 26.341 °W | 053 47.809 °N |
| 004 | E | 236 021709 | 055 26.321 °W | 053 47.840 °N |
| 005 | S | 236 045850 | 055 14.738 °W | 053 59.220 °N |
| 005 | B | 236 050543 | 055 14.674 °W | 053 59.232 °N |
| 005 | E | 236 052205 | 055 14.540 °W | 053 59.267 °N |
| 006 | S | 236 084525 | 055 00.960 °W | 054 13.022 °N |
| 006 | B | 236 085149 | 055 00.953 °W | 054 12.953 °N |
| 006 | E | 236 091141 | 055 00.940 °W | 054 12.730 °N |
| 007 | S | 236 113814 | 054 45.263 °W | 054 29.304 °N |
| 007 | B | 236 114727 | 054 45.210 °W | 054 29.254 °N |
| 007 | E | 236 120641 | 054 45.391 °W | 054 29.149 °N |

| Station number | Code | Date 2008 JDAY HHMMSS | Latitude | Longitude |
|---|---|---|---|---|
| 008 | S | 236 142545 | 054 29.281 °W | 054 45.809 °N |
| 008 | B | 236 143554 | 054 29.239 °W | 054 45.877 °N |
| 008 | E | 236 145733 | 054 29.078 °W | 054 46.051 °N |
| 009 | S | 236 163619 | 054 17.048 °W | 054 56.718 °N |
| 009 | B | 236 164745 | 054 16.926 °W | 054 56.723 °N |
| 009 | E | 236 171822 | 054 16.638 °W | 054 56.761 °N |
| 010 | S | 236 184118 | 054 07.637 °W | 055 06.092 °N |
| 010 | B | 236 190152 | 054 07.177 °W | 055 06.089 °N |
| 010 | E | 236 194307 | 054 06.497 °W | 055 06.116 °N |
| 011 | S | 236 204524 | 054 03.032 °W | 055 11.148 °N |
| 011 | B | 236 211334 | 054 02.491 °W | 055 11.088 °N |
| 011 | E | 236 221047 | 054 01.817 °W | 055 10.782 °N |
| 012 | S | 237 000709 | 053 56.790 °W | 055 15.364 °N |
| 012 | B | 237 005447 | 053 56.358 °W | 055 15.114 °N |
| 012 | E | 237 022148 | 053 56.124 °W | 055 14.582 °N |
| 013 | S | 238 083241 | 053 48.278 °W | 055 25.349 °N |
| 013 | B | 238 094255 | 053 47.326 °W | 055 25.633 °N |
| 013 | E | 238 113349 | 053 45.689 °W | 055 25.649 °N |
| 014 | S | 238 133336 | 053 36.618 °W | 055 37.117 °N |
| 014 | B | 238 150105 | 053 36.145 °W | 055 37.388 °N |
| 014 | E | 238 165401 | 053 35.989 °W | 055 37.938 °N |
| 015 | S | 239 041658 | 053 24.278 °W | 055 51.101 °N |
| 015 | B | 239 053120 | 053 24.451 °W | 055 51.408 °N |
| 015 | E | 239 071037 | 053 24.787 °W | 055 51.753 °N |
| 016 | S | 239 094228 | 053 07.202 °W | 056 07.152 °N |
| 016 | B | 239 110732 | 053 06.426 °W | 056 07.063 °N |
| 016 | E | 239 130629 | 053 05.798 °W | 056 07.235 °N |
| 017 | S | 239 162924 | 052 40.561 °W | 056 32.458 °N |
| 017 | B | 239 175005 | 052 40.338 °W | 056 32.588 °N |
| 017 | E | 239 194049 | 052 40.474 °W | 056 32.597 °N |
| 018 | S | 239 230154 | 052 14.160 °W | 056 56.869 °N |
| 018 | B | 240 003204 | 052 13.847 °W | 056 56.387 °N |
| 018 | E | 240 025725 | 052 13.782 °W | 056 56.111 °N |
| 019 | S | 240 083835 | 051 47.501 °W | 057 22.625 °N |
| 019 | B | 240 095817 | 051 47.279 °W | 057 22.792 °N |
| 019 | E | 240 120717 | 051 46.453 °W | 057 22.484 °N |
| 020 | S | 240 151900 | 051 19.897 °W | 057 47.932 °N |
| 020 | B | 240 164414 | 051 20.567 °W | 057 47.740 °N |
| 020 | E | 240 200111 | 051 22.476 °W | 057 47.084 °N |
| 021 | S | 240 231619 | 050 54.011 °W | 058 12.784 °N |

| Station number | Code | Date 2008 JDAY HHMMSS | Latitude | Longitude |
|---|---|---|---|---|
| 021 | B | 241 005259 | 050 54.048 °W | 058 12.436 °N |
| 021 | E | 241 033455 | 050 54.968 °W | 058 12.336 °N |
| 022 | S | 241 090922 | 050 25.078 °W | 058 38.386 °N |
| 022 | B | 241 102617 | 050 25.751 °W | 058 38.156 °N |
| 022 | E | 241 123843 | 050 26.855 °W | 058 37.982 °N |
| 023 | S | 241 161756 | 049 56.125 °W | 059 03.446 °N |
| 023 | B | 241 174649 | 049 56.972 °W | 059 03.299 °N |
| 023 | E | 241 200317 | 049 57.635 °W | 059 02.983 °N |
| 024 | S | 241 230933 | 049 28.859 °W | 059 28.622 °N |
| 024 | B | 242 005743 | 049 28.769 °W | 059 28.256 °N |
| 024 | E | 242 033059 | 049 28.906 °W | 059 27.946 °N |
| 025 | S | 242 074857 | 049 09.086 °W | 059 44.574 °N |
| 025 | B | 242 090053 | 049 09.074 °W | 059 44.888 °N |
| 025 | E | 242 105713 | 049 08.831 °W | 059 45.343 °N |
| 026 | S | 242 130616 | 048 53.436 °W | 059 58.831 °N |
| 026 | B | 242 143017 | 048 53.774 °W | 059 58.662 °N |
| 026 | E | 242 161301 | 048 53.772 °W | 059 58.349 °N |
| 027 | S | 242 180838 | 048 40.973 °W | 060 10.261 °N |
| 027 | B | 242 191132 | 048 42.564 °W | 060 10.540 °N |
| 027 | E | 242 205542 | 048 46.204 °W | 060 11.335 °N |
| 028 | S | 242 224142 | 048 35.268 °W | 060 18.580 °N |
| 028 | B | 243 001132 | 048 38.473 °W | 060 19.278 °N |
| 028 | E | 243 022134 | 048 42.258 °W | 060 20.029 °N |
| 029 | S | 243 044645 | 048 32.014 °W | 060 19.951 °N |
| 029 | B | 243 053929 | 048 34.021 °W | 060 20.245 °N |
| 029 | E | 243 071121 | 048 37.139 °W | 060 21.661 °N |
| 030 | S | 243 092543 | 048 28.901 °W | 060 20.558 °N |
| 030 | B | 243 094756 | 048 29.775 °W | 060 20.969 °N |
| 030 | E | 243 103533 | 048 31.579 °W | 060 21.554 °N |
| 031 | S | 243 113408 | 048 27.578 °W | 060 22.100 °N |
| 031 | B | 243 115737 | 048 28.374 °W | 060 22.458 °N |
| 031 | E | 243 123213 | 048 29.357 °W | 060 22.808 °N |
| 032 | S | 243 141247 | 048 22.459 °W | 060 26.537 °N |
| 032 | B | 243 141955 | 048 22.484 °W | 060 26.580 °N |
| 032 | E | 243 143545 | 048 22.585 °W | 060 26.672 °N |
| 033 | S | 243 174343 | 048 13.361 °W | 060 33.859 °N |
| 033 | B | 243 174849 | 048 13.381 °W | 060 33.875 °N |
| 033 | E | 243 175829 | 048 13.423 °W | 060 33.960 °N |
| 034 | S | 243 185448 | 048 10.327 °W | 060 36.366 °N |
| 034 | B | 243 190025 | 048 10.440 °W | 060 36.415 °N |

| Station number | Code | Date 2008 JDAY HHMMSS | Latitude | Longitude |
|---|---|---|---|---|
| 034 | E | 243 190931 | 048 10.800 °W | 060 36.464 °N |
| 035 | S | 244 192515 | 050 24.882 °W | 058 38.536 °N |
| 035 | B | 244 204520 | 050 24.578 °W | 058 38.712 °N |
| 035 | E | 244 231411 | 050 24.206 °W | 058 38.669 °N |
| 036 | S | 245 022646 | 049 29.574 °W | 058 27.082 °N |
| 036 | B | 245 034455 | 049 28.402 °W | 058 27.032 °N |
| 036 | E | 245 055515 | 049 26.748 °W | 058 26.760 °N |
| 037 | S | 245 103648 | 048 59.812 °W | 057 53.868 °N |
| 037 | B | 245 121336 | 048 59.917 °W | 057 53.891 °N |
| 037 | E | 245 143508 | 049 1.175 °W | 057 54.167 °N |
| 038 | S | 245 184050 | 048 29.993 °W | 057 21.064 °N |
| 038 | B | 245 195041 | 048 29.581 °W | 057 21.109 °N |
| 038 | E | 245 214951 | 048 29.131 °W | 057 21.624 °N |
| 039 | S | 246 015819 | 047 59.726 °W | 056 47.933 °N |
| 039 | B | 246 031940 | 047 59.624 °W | 056 47.844 °N |
| 039 | E | 246 051411 | 047 59.170 °W | 056 47.664 °N |
| 040 | S | 246 065919 | 047 29.946 °W | 056 48.028 °N |
| 040 | B | 246 081526 | 047 29.878 °W | 056 47.927 °N |
| 040 | E | 246 100212 | 047 29.893 °W | 056 47.910 °N |
| 041 | S | 246 120152 | 046 59.861 °W | 056 47.941 °N |
| 041 | B | 246 133035 | 047 00.016 °W | 056 48.348 °N |
| 041 | E | 246 152353 | 047 00.085 °W | 056 48.570 °N |
| 042 | S | 246 183309 | 046 00.031 °W | 056 48.017 °N |
| 042 | B | 246 193909 | 045 59.976 °W | 056 48.185 °N |
| 042 | E | 246 212950 | 046 00.229 °W | 056 48.604 °N |
| 043 | S | 247 005907 | 044 59.534 °W | 056 48.066 °N |
| 043 | B | 247 022627 | 044 58.240 °W | 056 48.228 °N |
| 043 | E | 247 041810 | 044 57.313 °W | 056 48.538 °N |
| 044 | S | 247 071822 | 044 0.173 °W | 056 48.066 °N |
| 044 | B | 247 082451 | 044 0.577 °W | 056 48.080 °N |
| 044 | E | 247 100706 | 044 0.826 °W | 056 48.286 °N |
| 045 | S | 247 131209 | 043 18.280 °W | 057 06.080 °N |
| 045 | B | 247 142307 | 043 18.371 °W | 057 06.278 °N |
| 045 | E | 247 155014 | 043 18.236 °W | 057 06.257 °N |
| 046 | S | 247 184143 | 042 37.081 °W | 057 23.693 °N |
| 046 | B | 247 194220 | 042 37.279 °W | 057 23.540 °N |
| 046 | E | 247 212547 | 042 37.302 °W | 057 22.815 °N |
| 047 | S | 248 003703 | 041 55.375 °W | 057 41.474 °N |
| 047 | B | 248 015657 | 041 55.187 °W | 057 41.338 °N |
| 047 | E | 248 034025 | 041 54.134 °W | 057 41.249 °N |

| Station number | Code | Date 2008 JDAY HHMMSS | Latitude | Longitude |
|---|---|---|---|---|
| 048 | S | 248 063102 | 041 13.291 °W | 057 59.227 °N |
| 048 | B | 248 073103 | 041 13.124 °W | 057 58.909 °N |
| 048 | E | 248 091134 | 041 12.270 °W | 057 58.404 °N |
| 049 | S | 248 121609 | 040 32.076 °W | 058 16.951 °N |
| 049 | B | 248 132949 | 040 32.121 °W | 058 16.356 °N |
| 049 | E | 248 150723 | 040 31.755 °W | 058 15.919 °N |
| 050 | S | 248 175529 | 039 49.950 °W | 058 35.012 °N |
| 050 | B | 248 185359 | 039 49.883 °W | 058 34.842 °N |
| 050 | E | 248 202959 | 039 49.847 °W | 058 34.744 °N |
| 051 | S | 248 232821 | 039 08.789 °W | 058 52.676 °N |
| 051 | B | 249 005838 | 039 07.705 °W | 058 52.547 °N |
| 051 | E | 249 025501 | 039 05.857 °W | 058 52.390 °N |
| 052 | S | 249 053453 | 038 26.713 °W | 059 10.520 °N |
| 052 | B | 249 063452 | 038 25.470 °W | 059 10.386 °N |
| 052 | E | 249 081545 | 038 23.897 °W | 059 10.032 °N |
| 053 | S | 249 110844 | 037 45.550 °W | 059 28.356 °N |
| 053 | B | 249 122614 | 037 44.922 °W | 059 28.150 °N |
| 053 | E | 249 142325 | 037 44.876 °W | 059 28.163 °N |
| 054 | S | 249 171715 | 038 35.759 °W | 059 36.563 °N |
| 054 | B | 249 181411 | 038 35.236 °W | 059 36.481 °N |
| 054 | E | 249 194831 | 038 35.197 °W | 059 37.085 °N |
| 055 | S | 249 223425 | 039 23.246 °W | 059 41.174 °N |
| 055 | B | 249 235005 | 039 22.435 °W | 059 40.939 °N |
| 055 | E | 250 020138 | 039 21.623 °W | 059 40.799 °N |
| 056 | S | 250 044002 | 040 13.051 °W | 059 46.079 °N |
| 056 | B | 250 053049 | 040 13.030 °W | 059 46.057 °N |
| 056 | E | 250 071325 | 040 12.834 °W | 059 45.781 °N |
| 057 | S | 250 164805 | 040 46.016 °W | 059 49.188 °N |
| 057 | B | 250 180333 | 040 45.766 °W | 059 49.278 °N |
| 057 | E | 250 194314 | 040 45.711 °W | 059 48.934 °N |
| 066 | S | 252 134007 | 043 07.118 °W | 059 57.099 °N |
| 066 | B | 252 135308 | 043 07.450 °W | 059 56.804 °N |
| 066 | E | 252 141015 | 043 08.072 °W | 059 56.480 °N |
| 065 | S | 252 152258 | 042 50.345 °W | 059 58.044 °N |
| 065 | B | 252 152656 | 042 50.363 °W | 059 57.995 °N |
| 065 | E | 252 154020 | 042 50.507 °W | 059 57.907 °N |
| 064 | S | 252 171500 | 042 30.299 °W | 059 59.719 °N |
| 064 | B | 252 171938 | 042 30.294 °W | 059 59.719 °N |
| 064 | E | 252 173612 | 042 30.316 °W | 059 59.633 °N |
| 063 | S | 252 184647 | 042 11.189 °W | 059 57.722 °N |

| Station number | Code | Date 2008 JDAY HHMMSS | Latitude | Longitude |
|---|---|---|---|---|
| 063 | B | 252 185817 | 042 11.270 °W | 059 57.631 °N |
| 063 | E | 252 192847 | 042 11.341 °W | 059 57.460 °N |
| 062 | S | 252 201939 | 042 06.325 °W | 059 57.187 °N |
| 062 | B | 252 205024 | 042 06.419 °W | 059 57.157 °N |
| 062 | E | 252 214200 | 042 06.318 °W | 059 56.780 °N |
| 061 | S | 252 225246 | 042 02.504 °W | 059 56.688 °N |
| 061 | B | 252 234416 | 042 02.524 °W | 059 56.531 °N |
| 061 | E | 253 012601 | 042 03.294 °W | 059 56.124 °N |
| 060 | S | 253 031304 | 041 51.938 °W | 059 55.535 °N |
| 060 | B | 253 035039 | 041 52.669 °W | 059 55.016 °N |
| 060 | E | 253 050404 | 041 53.375 °W | 059 54.056 °N |
| 059 | S | 253 074551 | 041 31.500 °W | 059 53.684 °N |
| 059 | B | 253 082546 | 041 31.757 °W | 059 53.593 °N |
| 059 | E | 253 094441 | 041 31.919 °W | 059 53.346 °N |
| 058 | S | 253 111235 | 041 12.798 °W | 059 51.910 °N |
| 058 | B | 253 121107 | 041 13.456 °W | 059 51.742 °N |
| 058 | E | 253 133601 | 041 13.638 °W | 059 51.276 °N |
| 067 | S | 257 204433 | 039 32.125 °W | 059 11.233 °N |
| 067 | B | 257 215414 | 039 33.185 °W | 059 10.891 °N |
| 067 | E | 257 233117 | 039 34.006 °W | 059 10.549 °N |
| 068 | S | 258 151523 | 036 22.465 °W | 059 14.703 °N |
| 068 | B | 258 160940 | 036 22.223 °W | 059 14.610 °N |
| 068 | E | 258 172146 | 036 22.302 °W | 059 14.952 °N |
| 069 | S | 258 215217 | 034 56.105 °W | 059 11.999 °N |
| 069 | B | 258 230622 | 034 56.417 °W | 059 11.386 °N |
| 069 | E | 259 010014 | 034 56.573 °W | 059 10.805 °N |
| 070 | S | 259 063612 | 032 59.820 °W | 059 01.086 °N |
| 070 | B | 259 072202 | 032 59.380 °W | 059 00.964 °N |
| 070 | E | 259 084912 | 032 58.871 °W | 059 00.475 °N |
| 071 | S | 266 100755 | 011 31.958 °W | 057 28.186 °N |
| 071 | B | 266 112059 | 011 31.344 °W | 057 27.930 °N |
| 071 | E | 266 121346 | 011 30.970 °W | 057 28.146 °N |
| 072 | S | 266 192333 | 012 14.095 °W | 057 30.498 °N |
| 072 | B | 266 202513 | 012 13.739 °W | 057 29.821 °N |
| 072 | E | 266 214327 | 012 13.864 °W | 057 28.991 °N |
| 073 | S | 267 032148 | 011 32.011 °W | 057 29.070 °N |
| 073 | B | 267 042542 | 011 31.447 °W | 057 29.165 °N |
| 073 | E | 267 052714 | 011 30.935 °W | 057 29.230 °N |
| 074 | S | 267 071735 | 011 5.094 °W | 057 27.265 °N |
| 074 | B | 267 080006 | 011 5.478 °W | 057 27.510 °N |

| Station number | Code | Date 2008 JDAY HHMMSS | Latitude | Longitude |
|---|---|---|---|---|
| 074 | E | 267 084246 | 011 5.575 °W | 057 27.797 °N |

Note: S, B and E denote the start, bottom and end of the cast respectively.

Our first CTD station was an occupation of the Canadian "Station 27" just outside St. John's; station 2 was a deep test; stations 3 to 34 were AR7W; stations 35 to 52 were the outside of the "box"; AR7E began with station 53 off Cape Farewell.

### *3.2.1 Data Processing using the SeaBird Software on the data-logging PC*

Following each cast the logging was stopped and the data saved to the deck unit PC. The logging software produces four files per CTD cast in the form D332nnn with the following extensions: .hex (raw data file), .con (data configuration file), .bl (contained record of bottle firing locations), and .hdr (a header file).

These files were manually backed up onto the UNIX network by copy and paste to the file location /data32/d332/ctd/raw. The raw data files were then processed using SeaBird's own CTD data processing software, SBE.DataProcessing-Win32: v.7.18. SeaBird CTD processing routines were used as follows.

DatCnv: The Data Conversion routine, DatCnv, read in the raw CTD data file (D332nnn.hex). This contained the raw CTD data in engineering units output by the SeaBird hardware on the CTD rosette. DatCnv requires a configuration file that defines the calibrated CTD data output so that it is in the correct form to be read into the pstar format on the UNIX system. The output file (D332nnn.cnv) format was set to binary and to include both up and down casts. A second output file (D309nnn.ros) contained bottle firing information, taking the output data at the instant of bottle firing. The numbers of bottles fired is recorded in the

AlignCTD: This program read in D332nnn.cnv and was set to shift the Oxygen sensor relative to the pressure data by 5 seconds compensating for lags in the sensor response time. Input and output files are the same.

WildEdit: A de-spiking routine, the input and output files again were D332nnn.cnv. The data was scanned twice calculating the standard deviation of a set number of scans, setting values that are outside a set number of standard deviations (sd) of the mean to bad data values. On this cruise, the scan range was set to 500, with 2 sd's on the first pass and 10 sd's on the second.

CellTM: The effect of thermal 'inertia' on the conductivity cells was removed using the routine CellTM. It should be noted that this routine must only be run after WildEdit or any other editing of bad data values as this routine uses the temperature variable to adjust the conductivity values, and if spikes exist in the former they are amplified in the latter. The algorithm used was:

$$dt = t_i - t_{i-7}$$
$$ctm_i = -b * ctm_{i-7} + a * \partial c \partial t * dt$$
$$c_{cor,i} = c_{meas,i} + ctm_i$$
$$a = \frac{2\alpha}{7\Delta * \beta + 2}$$
$$b = 1 - {}^{2a}\!/_{\alpha}$$
$$\partial c \partial t = 0.8 * (1 + 0.006 * (t_i - 20))$$

where α, the thermal anomaly amplitude was set at 0.03 and β, the thermal anomaly time constant was set at 1/7 (the SeaBird recommended values for SBE911+ pumped system). Δ is the sample interval (1/24 second), dt is the temperature (t) difference taken at a lag of 7 sample intervals. $c_{cor,i}$ is the corrected conductivity at the current data cycle (i), $c_{meas,i}$ the raw value as logged and $ctm_i$ is the correction required at the current data cycle, ∂c∂t is a correction factor that is a slowly varying function of temperature deviation from 20 °C.

Translate: Finally, the D332nnn.cnv file was converted from binary into ASCII format so that it could be read into pstar format.

The .cnv and .ros files were then copied to /data32/cd332/ctd/raw so that data processing could be continued using PEXEC routines.

### *3.2.2 Data Processing on the UNIX system*

The following c-shell UNIX scripts were used to process the data. Scripts were modified from versions used on D309 to allow for 3 digit cast numbers, although this eventually proved to be unnecessary. Latitude and longitude are now available as part of the CTD data stream.

ctd0: This script read in the SeaBird processed ascii file (.cnv) and converted it into pstar format, also setting header information. Information from the header was extracted from the SeaBird ascii file where possible. The latitude and longitude of the ship when the CTD was at the bottom were typed in manually and added to the header, although later in the cruise this information was omitted and the position read in from latitude and longitude values in the data stream. The output file contained the data averaged to 24hz. The output file was ctd332nn.24hz.

ctd1: This script operated on the .24hz file and used the PEXEC program *pmdian* to remove residual spikes from all of the variables. The data were then averaged into a 1hz file using *pavrge*. Absent data values in the pressure data were interpolated across using *pintrp*. Salinity, potential temperature, sigma0 and sigma2 (referenced to 2000 db) were calculated using *peos83* and finally a 10 second averaged file was also created. The output files were ctd332nn.1hz and ctd332nn.10s respectively.

ctd2: This script carried out a head and tail crop of the .1hz file to select the relevant data cycles for just the up and down casts of the CTD. Before running ctd2, the .1hz files were examined in *mlist* to determine the data cycles for i.) the shallowest depth of the CTD rosette after the initial soaking at 10m, ii.) the greatest depth, and iii.) the last good point before the CTD is removed from the water. These values were then manually entered at the correct screen prompts in ctd2. The data were then cut out with *pcopya* and the files ctd332nn.ctu created. Finally, the data were averaged into two decibar pressure bins creating the files ctd332nn.2db. Position information was extracted for the start data cycle of the downcast file and written to the header.

ctd3: The script ctd3 was used to produce plots from the .ctu files.

fir0: This script converted the .ros file into pstar format. It then took the relevant data cycles from the .10s averaged file (secondary output from ctd1) and pasted it into a new file fir332nn containing the mean values of all variables at the bottle firing locations.

samfir: This script created the file, sam332nn containing selected variables from fir332nn so that the results from the bottle sampling analysis could be added. Modification to the standard processing was needed to convert the oxygen variable from ml/l output from the SeaBird system to μmol/kg. Further modifications were required on D332 as not all bottles were fired on all casts due to the problems encountered with the winch. The changes involved inserting a bottle number variable into the file, reading in the number of each bottle fired from the .bl file (this information isn't in the .ros file) then using ppaste with a control variable rather than assuming that the record numbers in the donor and recipient files match.

Once salinity bottle data had been processed and excel files were created for each ctd. The following scripts were then run:

sal0: Read in the sample bottle excel files, that had been saved as tab delimited text only files, and converted some PC unique characters into UNIX friendly characters. Then sal0 created pstar format files with *pascin*: output file sal332nn.bot

sal1: (previously passal). Pasted bottle file (sal332nn.bot) values into sam332nn files.

sal2: (previously botcond). Calculated conductivity for bottle salinities using *peos83* and primary temperature.

SeaBird claim that the correct in-situ calibration for their conductivity sensors is a linear function of conductivity with no offset. Plots of conductivity difference against conductivity added support to this and therefore *parith* and *allav* were used to calculate the mean square of the conductivity values and the mean product of the bottle and CTD conductivity values; to solve thus,

$$conductivity = A * (primary\ conductivity)$$
$$conductivity = B * (secondary\ conductivity)$$

where

$$A = \frac{\sum Cond_{bot} Cond_{ctd}}{\sum (Cond_{ctd})^2} = \frac{\overline{Cond_{bot} Cond_{ctd}}}{\overline{(Cond_{ctd})^2}}$$

and

$$B = \frac{\sum Cond2_{bot} Cond2_{ctd}}{\sum (Cond2_{ctd})^2} = \frac{\overline{Cond2_{bot} Cond2_{ctd}}}{\overline{(Cond2_{ctd})^2}}$$

and $cond2_{bot}$ is the sample bottle conductivity determined with the secondary temperature variable.

ctdcondcal: This script was used to calibrate the .ctu and .2db files and re-calculate salinity, potential temperature and sigma0/sigma2. A and B were set to 1.00004361 and 0.99998671 respectively.

Residual conductivity differences were -0.0001 for both sensors with standard deviations of 0.0010 for the primary (cond2) and 0.0011 for the secondary (cond) conductivity sensor (see figure 3.1). Statistics quoted are for samples at 250db or deeper and following removal of all differences greater than abs(0.004) to remove outliers.

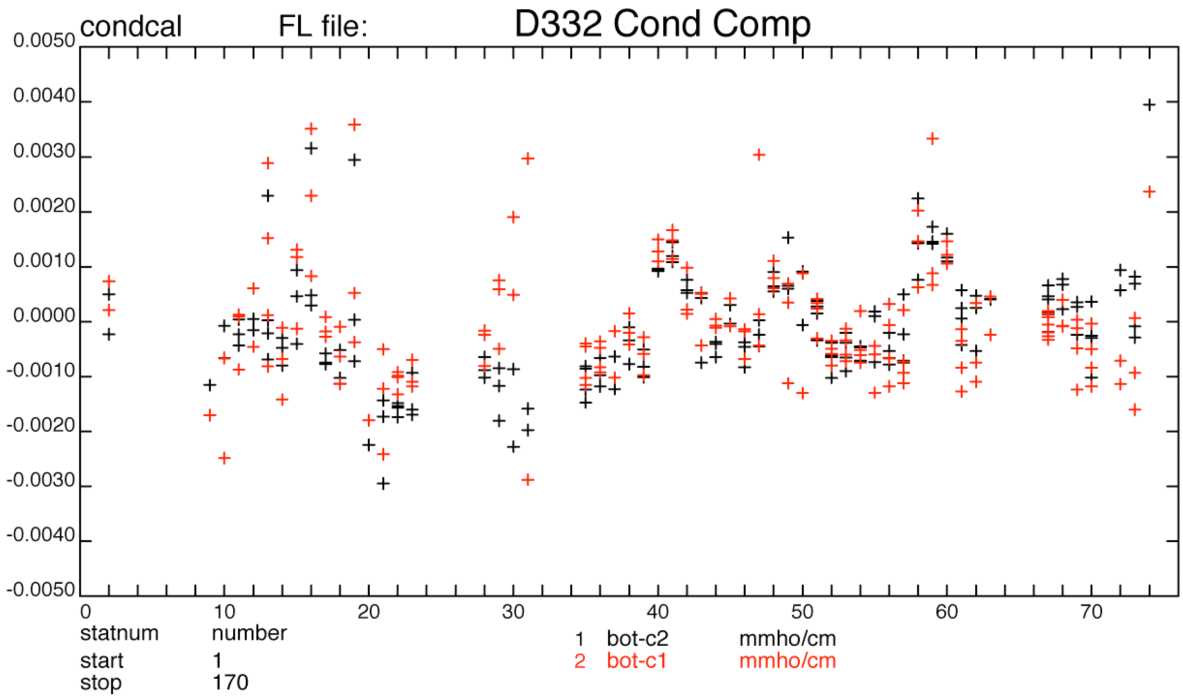



**Figure 3.1:** CTD primary (black, cond2) and secondary (red, cond) post-calibration conductivity differences (bottle minus CTD).

### 3.3 Salinometry

Dougal Mountifield

One Guildline Autosal 8400A and one 8400B salinometer were available for use having serial numbers 56747 and 65764. Unit s/n 65764 was used for all samples with unit s/n 56747 being reserved as a spare.

Both salinometers were located in the Constant Temperature (C.T.) lab and operated at 24°C bath temperature in 24°C ambient lab temperature. The CTD and underway samples were taken and run using the Softsal PC by the science party.

### 3.4 CTD Oxygen Sensor Calibration

Elizabeth Kent

Stage 1: to complete the station sample files (`sam332nnn`) containing the upcast CTD sensor data collected as each bottle was fired, by adding to the file the measured bottle oxygen concentration determined by chemical analysis from the separate data files. Bottle oxygen text files are converted to pstar files using exec *oxy0*. Fixing temperatures and oxygen concentrations for primary samples and duplicate samples (`tfixa, botoxya, tfixb, botoxyb`) are pasted into the station sample files using exec *oxy1* (previously pasoxy). Sample oxygen concentrations in µmol/l are converted to concentrations in μmol/kg by calculating sample seawater density at the time of fixing using the relevant `tfix` temperature variable and CTD salinity in exec *oxy2* (previously botoxy).

Stage 2: replacing the upcast CTD oxygen data with the "good" downcast values. The oxygen sensor suffers from a hysteresis effect that offsets upcast oxygen concentration from downcast (clear water) oxygen concentration. This was done by tracing water masses between the up and down casts along density, potential temperature (and/or pressure) surfaces using Pexec program *pbotle* within script *pbotle.exec*, which also calculates the (bottle minus downcast CTD) oxygen differences described below. Figure 3.2 shows the bottle minus sensor differences for both the pbotle-derived values and the upcast measured values as a function of station number.

Stage 3: the differences between bottle oxygen concentration ($O_{bot}$) and equivalent downcast CTD oxygen concentration ($O_{dCTD}$) were calculated and, after the removal of outliers, regressed as a linear function of pressure (equation O1). Taking $O_{bot}$ to represent the true value of seawater oxygen concentration and assuming this fit adequately explains the remainder of the data points, equation O1 can be employed to calibrate the downcast CTD oxygen profiles to "true" oxygen concentrations.

$$O_{bot} - O_{dCTD} = a + bP \qquad \text{(O1)}$$

where *a* and *b* are offset and slope parameters of the linear fit. Various other functional forms were investigated on D298, including (e.g.) higher-order pressure polynomials, and the incorporation of oxygen concentration as a parameter, but the simple form shown above proved to be the most efficient form of calibration.

For stations 1-70 parameters were: a = 16.662 ; b = 0.001558. The fit was performed after selection to include only (bottle-sensor) values between 10 and 30 μm/kg and for differences between the upcast and the pbotle-derived values to be less than 10.

For stations 72-74 there was not enough data to perform a separate calibration of the new oxygen sensor, however there was no evidence of significantly different behaviour to the previous sensor. The same calibration parameters were applied to these final 3 stations as to the previous stations. Figure 3.3.

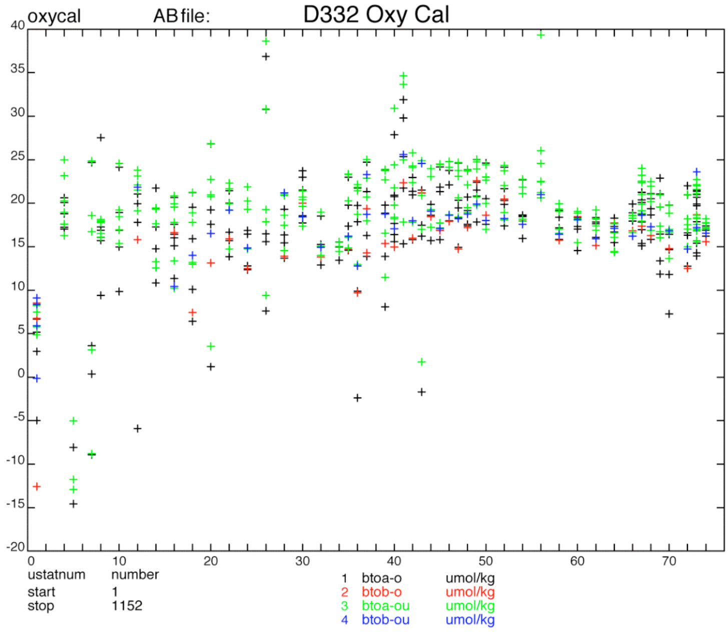



**Figure 3.2:** Bottle - sensor oxygen differences (μmol/kg) as a function of D332 station number. Black & red: downcast sensor values interpolated to upcast using pbotle; Green and blue: upcast sensor values. Black and green are for the main bottle oxygens, red and blue are the duplicates. Note the change of sensor after failure on station 71.

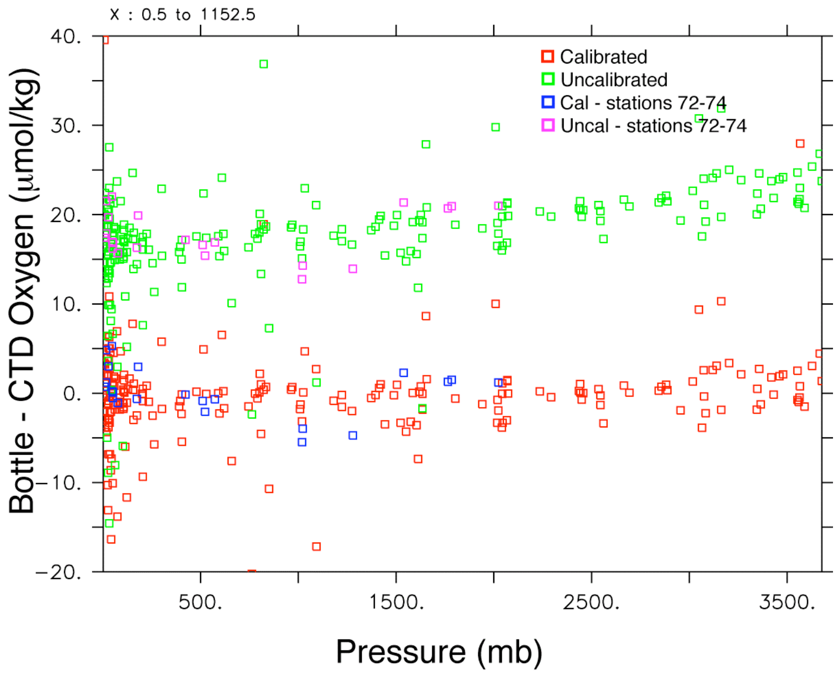



**Figure 3.3:** Bottle - sensor oxygen differences (μmol/kg) as a function of pressure. Green points are uncalibrated data for stations 1-70, pink for stations 72-74. Red shows the differences after application of the calibration for stations 1-70, blue shows differences for stations 72-74.

## Appendix 1 to Section 3: SeaBird sensor types, serial numbers and calibration dates

```
Date: 08/20/2008

Instrument configuration file: NO_PAR_0528.con

Configuration report for SBE 911plus/917plus CTD
------------------------------------------------

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

1) Frequency 0, Temperature

   Serial number : 03P-4381
   Calibrated on : 28 May 2008
   G             : 4.42348689e-003
   H             : 6.44714876e-004
   I             : 2.25407335e-005
   J             : 1.94949471e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 04C-3160
   Calibrated on : 11 April 2008
   G             : -1.04273433e+001
   H             : 1.43276583e+000
   I             : -1.40115694e-003
   J             : 1.85833637e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0528
   Calibrated on : 8 April 2008
   C1            : -5.087539e+004
   C2            : 2.199664e-002
   C3            : 1.589010e-002
   D1            : 3.721700e-002
   D2            : 0.000000e+000
   T1            : 3.011152e+001
   T2            : -2.857091e-004
   T3            : 4.528990e-006
   T4            : -5.484500e-011
   T5            : 0.000000e+000
   Slope         : 0.99983000
   Offset        : -1.48410
   AD590M        : 1.282870e-002
   AD590B        : -9.075590e+000
```

```
4) Frequency 3, Temperature, 2

   Serial number : 03P-4380
   Calibrated on : 28 May 2008
   G             : 4.37168057e-003
   H             : 6.54126629e-004
   I             : 2.31636698e-005
   J             : 1.73538404e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Conductivity, 2

   Serial number : 04C-3153
   Calibrated on : 11 April 2008
   G             : -1.03236967e+001
   H             : 1.32204184e+000
   I             : -3.64745984e-004
   J             : 9.69340165e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

6) A/D voltage 0, Oxygen, SBE 43 [casts 1-71]

   Serial number : 43-0619
   Calibrated on : 13 June 2008
   Equation      : Murphy-Larson
   Coefficients for Owens-Millard:
   Soc           : 3.6760e-001
   Boc           : 0.0000
   Offset        : -0.5025
   Tcor          : 0.0010
   Pcor          : 1.35e-004
   Tau           : 0.0
   Coefficients for Murphy-Larson:
   Soc           : 3.67600e-001
   Offset        : -5.02500e-001
   A             : -2.54820e-003
   B             : 2.17030e-004
   C             : -4.06960e-006
   E             : 3.60000e-002
   Tau           : 2.07000e+000

6) A/D voltage 0, Oxygen, SBE 43 [casts 72-74]

   Serial number : 43-0709
   Calibrated on : 28 May 2008
   Equation      : Murphy-Larson
   Coefficients for Owens-Millard:
   Soc           : 3.6760e-001
   Boc           : 0.0000
   Offset        : -0.5025
   Tcor          : 0.0010
   Pcor          : 1.35e-004
   Tau           : 0.0
   Coefficients for Murphy-Larson:
   Soc           : 4.29400e-001
   Offset        : -4.95700e-001
   A             : -1.33110e-003
```

```
   B              : 1.51160e-004
   C              : -3.22560e-006
   E              : 3.60000e-002
   Tau            : 1.58000e+000

7) A/D voltage 1, Free

8) A/D voltage 2, Fluorometer, Chelsea Aqua 3

   Serial number : 088163
   Calibrated on : 20 March 2008
   VB            : 0.076200
   V1            : 1.972200
   Vacetone      : 0.125600
   Scale factor  : 1.000000
   Slope         : 1.000000
   Offset        : 0.000000

9) A/D voltage 3, Altimeter

   Serial number : 874
   Calibrated on : September 2000
   Scale factor  : 15.000
   Offset        : 0.000

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Transmissometer, Chelsea/Seatech/Wetlab CStar

    Serial number : 161-2642-002
    Calibrated on : 4 September 1996
    M             : 22.9952
    B             : -0.5749
    Path length   : 0.250

13) A/D voltage 7, User Polynomial

    Serial number : BBRTD-168
    Calibrated on : 10 October 2006
    Sensor name   : WETLabs Backscatter
    A0            : -0.00023613
    A1            : 0.00298900
    A2            : 0.00000000
    A3            : 0.00000000
```

**Appendix 2 to Section 3: CTD processing summary**

| Script | Input | Output | Notes |
|---|---|---|---|
| SeaBird processing | D332nnn.hex<br>D332nnn.hdr<br>D332nnn.bl<br>D332nnn.ros | D332nnn.cnv | Processing would have been much easier if oxygen was output directly in μmol/kg in addition to the ml/l chosen on D332. |

| Script | Input | Output | Notes |
|---|---|---|---|
| ctd0 | ctd332nnn.cnv | ctd332nnn.24hz | Reads in raw data from SeaBird file, converts to Pstar and sets some header information. Asks for position information but on D332 this was available in the raw files from the NMEA stream and was inserted automatically as part of script ctd2. |
| ctd1 | ctd332nnn.24hz | ctd332nnn.1hz<br>ctd332nnn.10s | Some automatic QC then averages to 1hz and 10s. |
| ctd2 | ctd332nnn.1hz | ctd332nnn.ctu<br>ctd332nnn.2db | Requests datacycle numbers for start, bottom and end of cast, .ctu file is full cast, .2db file is downcast only (binned on pressure after sorting). |
| fir0 | D332nnn.ros<br>D332nnn.cnv<br>ctd332nnn.10s | fir332nnn | Reads in ctd information at the bottle firing times from the .ros file. The .cnv file is used to set some header information. Times only are taken from the .ros file and the ctd sensor data is merged on from the .10s file. |
| samfir | d332sam.master<br>fir332nnn<br>D332nnn.bl<br>twentyfour<br>ctd332nnn.24hz | sam332nnn | Generates a sample file for a cast by copying the blank sam.master file. On D332 some casts did not fire all bottles so modifications were required to ensure that the samples were assigned to the correct positions. This required the pasting of the numbers 1-24 from a pstar file (twentyfour) containing 1 variable called Botnum. This then allowed ppaste to be used with a control variable of bottle number (available only in the .bl file not in the .ros file used to generate the firing file). The .24hz file is used for header information. ctd sensor information comes from the .10s file via fir332nnn. ctd oxygen was converted from ml/l to μmol/kg (better to output these units directly from the SeaBird processing. |
| sal0 | sal332nnn.txt | sal332nnn.bot | Reads bottle salinities in from text file (converted from excel spreadsheet). |
| sal1 | sal332nnn.bot<br>sam332nnn | sam332nnn | Pastes bottle salinities into cast sample file. |
| sal2 | sam332nnn | sam332nnn.ccal | Calculates conductivities from bottle salts using ctd temperatures. |
| oxy0 | oxy332nnn.txt | oxy332nnn.bot | Reads bottle oxygens in from text file (converted from excel spreadsheet). Oxygens in μmol/l. |
| oxy1 | oxy332nnn.bot<br>sam332nnn | sam332nnn | Pastes bottle oxygens into cast sample file. |
| oxy2 | sam332nnn | sam332nnn.oxy2 | Converts bottle oxygens from μmol/l to μmol/kg. To do this need density at oxygen fixing temperature. |

| Script | Input | Output | Notes |
|---|---|---|---|
| oxy3 | sam332nnn.oxy2<br>ctd332nnn.2db | sam332nnn.ocal | Runs pexec program pbotle to associate upcast oxygen values affected by hysteresis to the less-affected downcast values. Various issues with this on D332. Oxygens from the .2db file were converted to μmol/kg in a temporary file. pbotle will not work with absent data so the sample file was "datpiked" to remove absent data, then required padding back to 24 datacycles after pbotle had been run. This was done using a script padfile which repeatedly appends a blank file with the same variables as the sample file until the file has 24 data cycles. |
| nut0 | nut332nnn.txt | nut332nnn.bot | Reads bottle nutrients in from text file (converted from excel spreadsheet). |
| nut1 | nut332nnn.bot<br>sam332nnn | sam332nnn | Pastes bottle nutrients into cast sample file. |

On D332 calibrations were performed on the files ctd332nnn.2db. This resulted in the .2db files having different numbers of variable and variable names prior to, and subsequent to, calibration. This procedure is not recommended. In future it would be better to produce calibrated files with a unique file suffix, indicating that calibration had taken place.

## Appendix 3 to Section 3: Sensor Information

RRS *Discovery* cruise 332. Updated on board at end of D332. Checked by Dougal Mountifield, 24/09/2008.

| SENSOR / SYSTEM TYPE | SERIAL No | Service / Cal | Cruise Notes |
|---|---|---|---|
| WH-LADCP | 1855 | | Spare Used as uplooker after failure of 4908 |
| WH-LADCP | 4275 | | Master (upwelling) |
| WH-LADCP | 4908 | | Slave (downwelling) Failed returned to NOC |
| SBE3 Temperature | 4381 | 28/05/08 + 6mths | Primary (frame) |
| SBE3 Temperature | 4380 | 28/05/08 + 6mths | Secondary (fin mounted) |
| SBE3 Temperature | 4592 | 28/05/08 + 6mths | Spare (Ti) |
| SBE4 Conductivity | 3160 | 11/04/08 + 6mths | Primary (frame) returned for cal post cruise |
| SBE4 Conductivity | 3153 | 11/04/08 + 6mths | Secondary (fin mounted) returned for cal post cruise |
| SBE4 Conductivity | 3272 | 13/06/08 + 6mths | Spare (Ti) |
| SBE43 Oxygen | 0619 | 13/06/08 | Primary (frame), A/D voltage 0 Failed, returned NOC |
| SBE43 Oxygen | 0709 | 28//05/08 | Spare Fitted to CTD after failure of 0619 |
| SBE5 Pump | 3609 | | Primary (frame) |
| SBE5 Pump | 3607 | | Secondary (fin mounted) |
| SBE5 Pump | 2279 | | Spare |
| SBE9+ | 19817-0528 | | Main (frame) |
| Digiquartz pressure sensor | 0528 | 08/04/08+ 3 yrs | Main (frame) |
| SBE9+ (Ti) | 39607-0803 | | Spare (Ti) |
| Digiquartz pressure sensor | 0803 | 27/05/08 + 3 yrs | Spare |
| SBE11+ deck unit | 29817-0495 | | Spare |
| SBE11+ deck unit | 24680-0587 | | Main |
| SBE32 carosel | 32-31240-0423 | | Main |
| SBE32 carosel (Ti) | 32-34173-0493 | | spare (Ti) |
| Salinometer | 65764 | 25/09/07 + 1 yrs | Main – returned NOC at end of cruise |
| Salinometer | 56747 | 18/03/08 + 1 yrs | Spare – returned NOC at end of cruise |
| Altimeter - Benthos PSA/916T | 874 | | Main, A/D voltage 2 |
| Altimeter - Tritech PA200 | 6196 112522 | | Spare |
| Altimeter - Tritech PA200 | 6198 118171 | | Spare |
| Sonardyne beacon | 234002 001 | 16/05/08 | Spare |
| Sonardyne beacon | 234002 002 | 06/03/08 | Main |
| Pinger 10kHz | B7 | | Main |

| | | | |
|---|---|---|---|
| Pinger 10kHz | B8 | | Spare |
| Transmissometer, Chelsea Alpha Mk2 | 2642-002 | | Main, A/D voltage 7 |
| Transmissometer, Chelsea Alpha Mk2 | 161048 | 28/05/08 | Spare |
| Fluorometer, Chelsea Aqua 3 | 88195 | | Spare |
| Fluorometer, Chelsea Aqua 3 | 88163 | 20/03/08 | Main, A/D voltage 3 |
| 24x 10l OTE water bottles | 1A-24A | | |
| 24x 10l OTE water bottles | 1B-24B | | |
| 24x 20l OTE water bottles | | | |
| 24x 20l OTE water bottles | | | |
| WetLabs BBRTD | 167 | 13/05/08 + 2yrs | Spare |
| WetLabs BBRTD | 168 | 10/10/06 + 2yrs | Main, A/D voltage 6 |

# 4 LOWERED ADCP

Dougal Mountifield and Sheldon Bacon

As noted in section 3.1, the following three LADCPs were used during D332:

• RDI Workhorse 300 KHz Lowered ADCP (downward-looking master configuration) s/n 4275
• RDI Workhorse 300 KHz Lowered ADCP (upward-looking slave configuration) s/n 4908
• RDI Workhorse 300 KHz Lowered ADCP (spare) s/n 1855 used as upward-looking slave from cast 37 onwards.

The LADCPs were powered by the NMF battery pack s/n WH001. Battery pack WH005 was available as a spare, but was not used.

The LADCP data were processed after the cruise at NOCS.

## 4.1 Set-up

Prior to each deployment the BBtalk terminal session was logged to a file named with the format CTDxxxm.txt for the down-looking master and CTDxxxs.txt for the up-looking slave, where xxx was the CTD cast number.

Then the following commands were sent:

PS0 – to check that the deck cables were connected to the correct unit
TS? – time set, offset from GPS clock noted and time reset if greater than a few seconds.
RS? – to check flashcard space and re ErAse if necessary
PA and PT200 – pre-deployment and built in self tests

A few minutes before the CTD was deployed the command files (see below) were sent and BBtalk file logging stopped. Deployment and end of pinging times were recorded on the rough log sheets.

After pinging was stopped, the number of deployments in the recorder was queried with RA? And the most recent file downloaded in the default RDI-xxx.000 name format. The file was then renamed to the form CTDxxxm.000 for the master and CTDxxxs.000 for the slave. All filenames were noted on the rough log sheets.

The battery was fully charged at 58V until it was drawing 100mA between each cast. Every few casts the battery was vented.

For casts 8, 9, 14, 33 and 54 there is no slave data due to the command file being sent with the unit at 115,200 baud rate causing a communications buffer overflow in workhorse unit.

During CTD036 the up-ward looking slave LADCP s/n 4908 failed. The unit was dismantled and evidence of a low pressure leak via the transducer potting was found. The receiver board had salt water on it and severe corrosion. The unit was replaced with s/n 1855 from CTD037 onwards.

*Down-looking Master Command File:*

```
PS0
CR1
CF11101
EA00000
EB00000
ED00000
ES35
EX11111
EZ0011111
TE00:00:01.00
TP00:01.00
LD111100000
LF0500
LN016
LP00001
LS1000
LV250
LJ1
LW1
LZ30,220
SM1
SA001
SW05000
CK
CS
```

*Up-looking Slave Command File:*

```
PS0
CR1
CF11101
EA00000
EB00000
ED00000
ES35
EX11111
EZ0011111
TE00:00:01.00
TP00:01.00
LD111100000
LF0500
LN016
LP00001
LS1000
LV250
LJ1
LW1
LZ30,220
SM2
```

SA001
ST0
CK
CS

## 4.2 LADCP Processing

LADCP data were processed using the Lamont-Doherty Earth Observatory software (version 7b, 2002; Visbeck, 2002). At the time of writing, all D332 LADCP data reside in this NOCS Unix directory:

/noc/ooc/cfer/d332_sea/ladcp/proc

in folders for each station, named D332nnn (nnn = station number). The data live in Matlab files called D332nnn{run_letter}.save.mat. The variable {run_letter} labels the six passes made through the data, the labels for which are p1 to p6. Plot files (postscript) corresponding to the printed figures in the paper folders are called D332nnn{run_letter}.ps. A description of the six passes follows. The CTD data were the .1hz station files, and navigation information was from bestnav – the abnv3321 file with 10 s timebase.

*Pass 1 (p1):* Not for use. QC only, inspecting both uplooker (Slave) and downlooker (Master), with no CTD, no navigation, no VM-ADCP, no bottom-track. Determined that uplooker was either on 3 beams, or broken, or (after replacement) still of questionable quality. All subsequent passes use the downlooker only.

*Pass 2 (p2):* Not for use. Run includes CTD and navigation but with barotropic calculation disabled.

*Pass 3 (p3):* For use. Run includes CTD, navigation and bottom-track, with barotropic calculation enabled. All stations (1-74) good, but warnings for 31 (increased error due to shear / inversion difference), and 56 (7 minute bottom time difference between CTD and LADCP).

*Pass 4 (p4):* For use. Repeat of p2 but with barotropic calculation enabled (run includes CTD and navigation). All stations good, time warning on 56 repeated.

*Pass 5 (p5):* Possibly for use (although probably no good). Run includes CTD, navigation, bottom-track and VM-ADCP, but with barotropic calculation from navigation disabled (obeying instructions in script). Station 1, no VM-ADCP data; repeat of station 56 time warning; no warnings issued for 29 and 30 but profiles poor. All others good.

*Pass 6 (p6):* For use. Repeat of p5 but with barotropic calculation enabled. Run includes CTD, navigation, bottom-track and VM-ADCP. All stations good (but repeat of time warning on 56).

Summary:

The processing method for inclusion of VM-ADCP creates one mean station VM-ADCP profile. The LADCP is only near the surface for a relatively short period at the start and end of most casts, so there is a potential mismatch between the two data sources, therefore I don’t much trust the runs including VM-ADCP (p5, p6). My personal preference is therefore:

| | |
|---|---|
| Probable best: | p3 (CTD, nav, bottom-track) |
| Second best: | p4 (CTD, nav) |
| Third best: | p6 (CTD, nav, bottom-track, VM-ADCP) |

Of the others, p1 and p2 are QC only and of no scientific use. p5 does not include explicit barotropic calculation from navigation and is probably not useful. The advantage of withholding the VM-ADCP data is that it provides an independent check of the LADCP data.

Subsequently, tidal velocities were removed from the p3 version of the D332 LADCP data using predictions from the Oregon State University's TOPEX/Poseidon Global Inverse Solution TPXO7.1 (Egbert, 1994, 2002). Consult Dr. N. P. Holliday (NOCS) for further information.

# 5 MOVING VESSEL PROFILER

Roz Pidcock, John Allen, Dougal Mountifield

## 5.1 Overview

The ODIM Brooke Ocean MVP300-1700 Moving Vessel Profiler (MVP) system has recently been completed overhauled and updated. The bearings, sheaves, brake actuator, hydraulic pump and boom rotator motor have been replaced. New control limit switches and control cables have been fitted. The powerpack motor and winch hydraulic motor have been overhauled and new brake linings fitted. The system features a new hydraulic control system and new control box and topside interface unit and all firmware and software has been updated and installed on new industrial PCs. Also a new design of tow-rope has been fitted that should have a longer lifetime than previously experienced.

One 8.5 hour tow was completed. The tow was conducted at 4kts. Profiling started on the East Greenland shelf off Cape Farewell heading eastwards, and ended in deep off-shelf water profiling to 300 m. Until off the shelf, the maximum depth was set manually every few casts to work 30-50m from the bottom. There were no problems, but spiking from the cable counter during haul was observed. Also there was one cast which automatically aborted with an emergency stop. It is thought that this may also be a cable counter issue. A spare cable counter is carried in the spares kit for the MVP and will be fitted before the next use. A full suite of instruments including the fish multiplexer is also now carried in the spares kit along with 2 complete spare sets of tow-fish instrument cables.

The small Multi Sensor Free Fall Fish (MSFFF-I) was used with the following instrumentation:

AML Micro CTD s/n: 7027
AML Micro DO s/n: 7517
Chelsea Minitracka II Flurorimeter s/n: 175222
Satlantic OCR-507 ICSW Irradiance s/n: 136
Satlantic OCR-507 R10W Radiance s/n: 074
PML Tilt/Roll s/n: PMLTR02 (P01)
All these sensors were interfaced using the underwater Data Telemetry Modem (DTM) multiplexer s/n: 10113.

Most of the tow was conducted at night, so it is unlikely that there will be any useful light data. However the Satlantic serial messages are logged into the raw file mixed with the multiplexer data and a separate data extractor program is required before it can be used with Satlantic software. Please contact NMF-SS for this software if required.

**Table 5.1:** Summary of MVP tow.

| Tow no. | start date | start time GMT | stop date | stop time GMT | duration | distance run start (km) | end (km) | total (km) |
|---|---|---|---|---|---|---|---|---|
| Tow 1 | 30/08/08 | 21:38 | 31/08/08 | 06:14 | 0 d 8 h 36 m | 2235 | 2282 | 47 |

## 5.2 Data

The MVP carried an AML micro CTD (Conductivity, Temperature, Depth) instrument, a Chelsea TG MiniTracka II fluorimeter, an AML micro DO oxygen sensor with an Idronaut sensing head (does not include temperature sensor) and two Satlantic (OCR507) light sensors (one PAR and one TIR). See above for further details.

The data were recovered, in near real time, through the Brooke Ocean Technology (BOT) software on a PC in the main lab. A series of files are created after each down/up cycle. The principal file containing most of the data had the suffix '.m1'. Eight other files were written, most duplicating some of the data streams in the '.m1' file but in a specific format for feeding into other instruments. The PAR and TIR data were not in the '.m1' file and only seem to be present in a raw counts instrument file. No attempt was made to read the PAR or TIR data in during the cruise, but the raw files were archived with all the other cruise data for later reference if required.

With the exception of the 'user variables' channels, the data in the '.m1' files are in engineering units 'calibrated' using pre-set coefficients stored in the BOT software. The fluorimeter and the oxygen sensor were connected to the 'user variables' channels, ANLG1 and ANLG2 respectively. The sensors sample at 25 Hz, and each data file (.m1) is time stamped with GPS time in the header only.

Owing to the short duration of this cruise, no attempt was made at in-situ calibration of either fluorescence or oxygen on board; however an initial calibration was made for salinity, this is described later.

## 5.3 Processing Steps

The processing followed that developed by JTA on D306 and D309 in the summer of 2006. The PC files were transferred to the ship's UNIX computer system by ftp over the ship's ethernet.

***mvpexec0***

This read the '.m1' data files, 59 files in total, e.g D332_0000.m1 – D332_0059.m1, into PSTAR format files. Having a file number '0000' caused mvpexec0 to fall over and it was easier to rename this file number '0100' rather than effect a rather tortuous fix to the script. The start time was extracted from the header information and placed in the PSTAR headers, then a relative 25Hz time variable for each PSTAR file was created. Variables were calibrated as appropriate, and a temperature difference variable was created. The data were despiked and 1Hz averaged files were created. Finally the script appended the 1Hz files into a 1Hz survey file, e.g. mvp33201.raw.

***mvpexec1***

The main steps to mvpexec1 were firstly *pcalc* to apply a temperature lag correction (see below) which, having experimented with a number of corrections, turned out to be 0.28. Secondly *peos83* was run to calculate potential temperature, salinity and density.

No editing of surface spiking was required as the MVP controls had been set such that the vehicle never got closer than 2-3 metres from the surface even allowing for the overshoot in the profile, and the tow was made in very calm water conditions. Further editing for spikes, and salinity offsets due to fouling of the conductivity cell was carried out by inspection with *plpred*, none appeared necessary at this stage.

### 5.4 Temperature Correction

It is necessary to make a correction for the small delay in the response of the CTD temperature sensor for two reasons. Firstly, to obtain a more accurate determination of temperature for points in space and time. But, more importantly to obtain the correct temperature corresponding to conductivity measurements, so that a sensible calculation of salinity can be made.

A lag in temperature is apparent in the data in two ways. There is a difference between up and down profiles of temperature (and hence salinity) because the time rate of change of temperature has opposite signs on the up and down casts. The second manifestation is the "spiking" of salinity as the sensors traverse maxima in the gradients of temperature and salinity. The rate of ascent and descent of the MVP is greater (up to ~ 6 $ms^{-1}$ during descent and at the beginning of ascent) than that of a lowered CTD package, thus the effects of the temperature lag are more pronounced. Thus, the following correction was applied to the temperature during ***mvpexec1*** before evaluating the salinity

$$T_{corr} = T_{raw} + \tau.\Delta T$$

where $\Delta T$ is defined above and $\tau$ is constant.

The best value of $\tau$ was chosen so as to minimise the difference between up and down casts and noise in the salinity profile. The best value was found to be $\tau = 0.28$ second, rather larger than the values of 0.15 and 0.12 used on D309 and D306 respectively.

## 5.5 Salinity calibration

During the MVP tow, 13 surface salinity samples were taken from the ship's non-toxic water supply at the tap on the thermosalinograph house in the water bottle annex. Comparison of salinities from these surface samples and the MVP salinity over the 4-6 dbar pressure range for the duration of the tow indicated that the MVP salinity was ~ 0.1 low.

The next stage in verifying/determining the temperature and salinity calibration for the MVP involved creating a scatter T/S (temperature vs. salinity) plot for the CTDs completed on the reverse section into the Greenland coast (end of WOCE line AR7W) immediately prior to the MVP section – i.e. CTDs 027-034: and comparing this with a similar scatter plot for the MVP data. Matching up distinct water mass points in these plots showed a good calibration for temperature but again an offset of +0.1 in salinity (**Figure 5.1**).

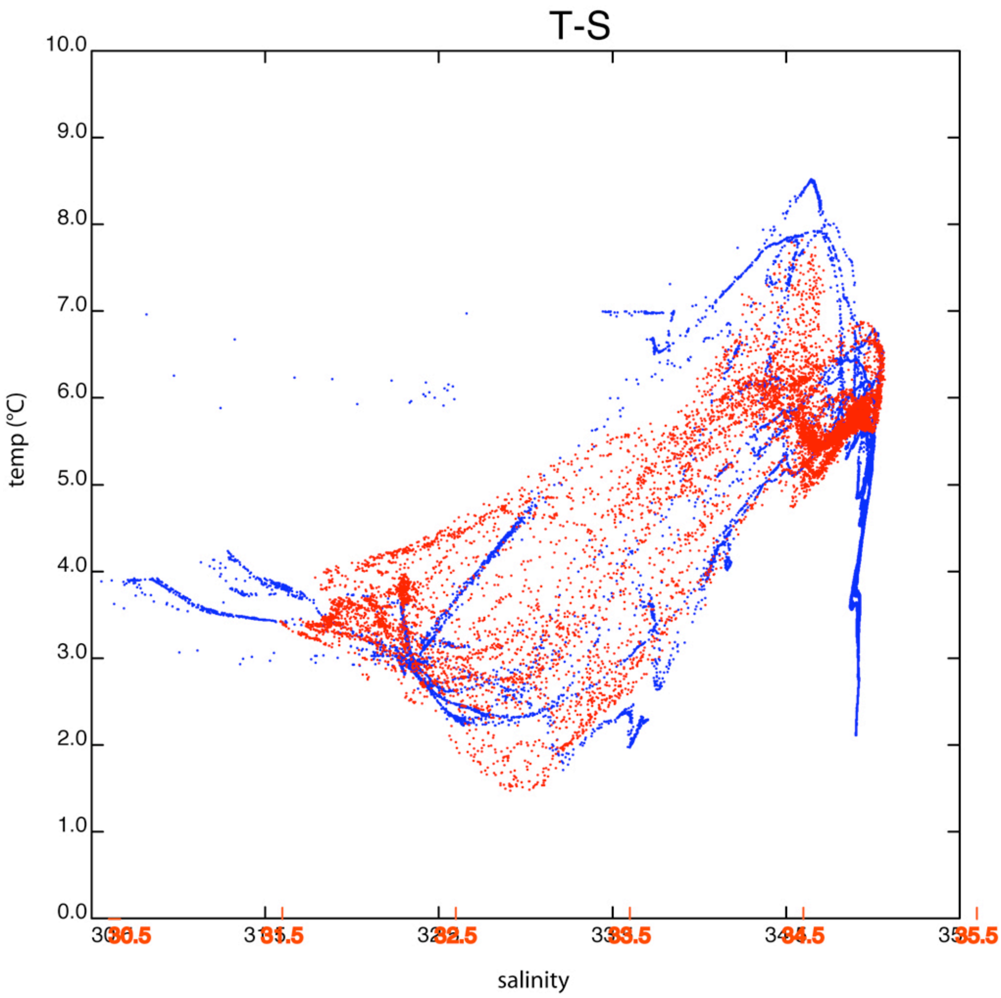



**Figure 5.1:** T/S scatter plots, MVP data (red dots and x-axis notation) offset +0.1 and plotted over CTD data (blue dots).

Finally the thermosalinograph (TSG) was calibrated for this 9 hour period to the salinity bottle samples ($TSG = TSG + 2.933$) and then these data were compared to the MVP salinity over the 4-6 dbar pressure range. This also supported the MVP salinity being low by 0.1, however this maybe little better than the accuracy of this short term calibration of the TSG.

Therefore a calibration of the MVP was made for salinity such that:

$$S = S(MVP) + 0.1$$

however, over this short tow, with few inter-calibration points available, the error in this calibration should be considered to be around the 0.02-0.03 level.

### 5.6 Early results

The MVP tow was made at high spatial resolution (~ 1 km per up/down cast) at a vessel speed of ~ 4 knots. The contoured parameters, created after gridding the MVP data in 8 metre by 1 km bins (*pgrids)*, are presented in **figure 5.2**. The dominant feature is the tongue of high temperature water at 80-100 m water depth. The fluorescence and oxygen signals suggest this water has been subducted from the surface, probably further south, which may indicate significant instability of the strong west Greenland current.

The oxygen data indicates that there may be problems with this kind of oxygen sensor on such a tow vehicle or with its position in the tow vehicle. Although generally matching the fluorescence signal, the vertical streaking suggests a large effective time lag. The position of the oxygen sensor, hidden away in the rear of the tow vehicle, may entirely account for this. The strange looking increase in implied oxygen concentration over the whole water depth towards the end of the tow (deeper water) also looks suspiciously like an impending instrument failure, possibly membrane failure.

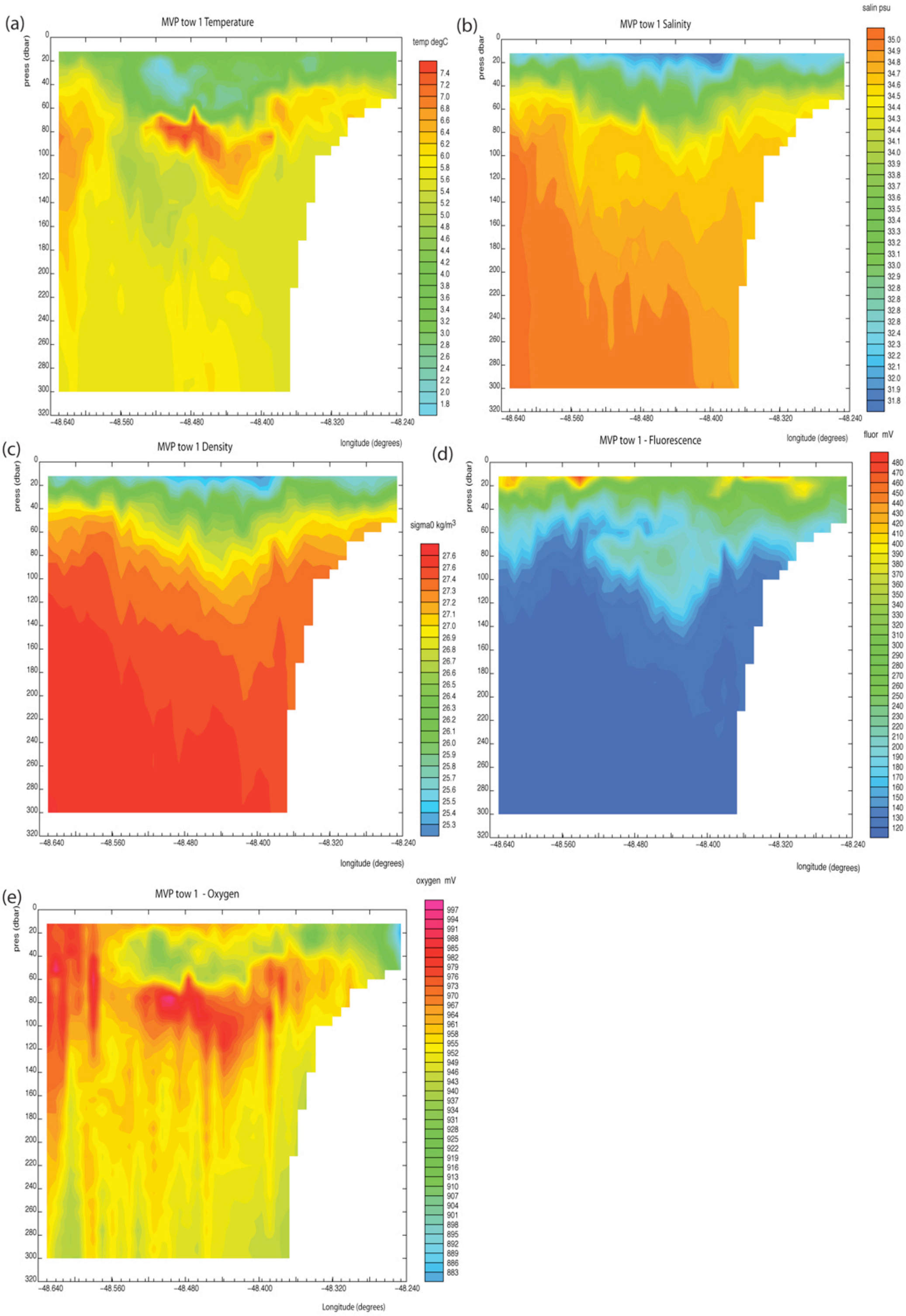



**Figure 5.2**: Contour plots of temperature (a), salinity (b), density (c), fluorescence (d) and oxygen (e) for the MVP tow across the Greenland shelf towards the Labrador Basin. Salinity has had the initial calibration described in the text applied. Fluorescence and oxygen remain, however, in raw instrument units.

# 6 NAVIGATION

Roz Pidcock, Leighton Rolley, John Allen

With the gradual replacement of the old RVS Level ABC system complete, all navigation streams were logged on D332 by the Ifremer TECHSAS system. Position, gyro-heading and ship's attitude information were transferred from the National Marine Facilities (NMF) TECHSAS data stream to PSTAR files daily and processed as described below. These data provide not only important information about the ship's movements but are also required to correct initial estimates of water velocity made by the vessel-mounted Acoustic Doppler Current Profiler (ADCP) for the ship's direction, speed and attitude. This, in effect, removes the ship's motion from the measurements, allowing accurate water velocities to be obtained.

The extensive NMFSS scripts to read the netcdf format TECHSAS file streams have been developed alongside the implementation of the system and most errors and wrinkles have been worked out. However, a residual problem with the reading precision of position data (nclistit) was noticed on D328 and still persisted on D332. It is recommended that this be addressed as soon as practical, an extra 2 characters should be sufficient. The number of characters for position is constant, and currently if degrees of latitude or longitude are less than ten then the precision is $10^{-6}$ (i.e. ~ 10 cm resolution – and indeed this appears to be the limit of the netcdf data), however where degrees of latitude or longitude exceed 10 then the precision read reduces to $10^{-5}$ (i.e. only ~ 1 m resolution), and should the longitude exceed 100 degrees then the precision read would decrease to $10^{-4}$ (i.e. ~ 10 m resolution !!).

## 6.1 Ship's position and navigation data

The ship's primary navigational systems were the GPS Trimble 4000 and the Ashtec GPS G12. The former provides the most accurate position, determined on previous cruises to be ~1.0 m. Figure 6.1 shows the positional accuracy of the GPS 4000 system whilst in port. As a result of the nclistit issue, as described above, the resolution in both latitude and longitude is 1m. Despite being less than ideal, this was sufficient to enable a calculation of ship's velocities to better than 1 $cms^{-1}$, and therefore below the instrumental limits of the RDI ADCP systems.

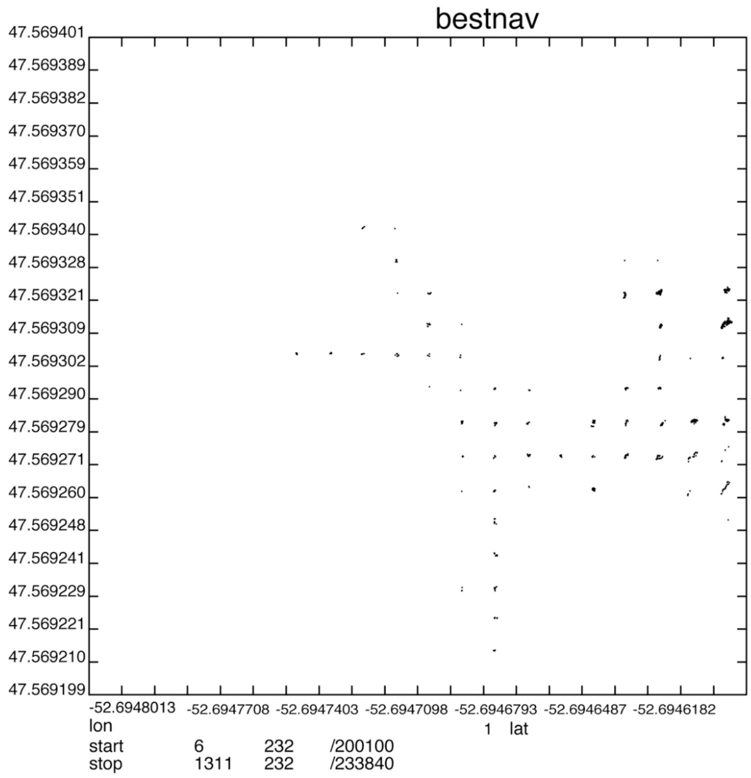



**Figure 6.1**. Positional data in port at the beginning of the cruise for the gps4000 system

Trimble GPS 4000 and Ashtec GPS G12 data (converted to RVS format as *gps_4000* and *gps_g12*) were transferred and processed daily using the steps detailed below. The NMFSS *bestnav* combined (10 second) clean navigation process was operational on D332, using the GPS 4000 system as its primary navigation source. Data were transferred daily from the NMF *bestnav* file to the PSTAR absolute navigation file *abnv3321* for use in PSTAR processing.

The ship's gyro instrument is the most reliable direction indicator on the ship and provides essential information for referencing the ADCP velocities to earth coordinates. Gyro data were transferred daily using the script *gyroexec0*.

The PSTAR execs used for processing navigation data streams were:

*navexec0*: transferred the NMF *bestnav* data stream to PSTAR format daily. Ship's velocities and distance run were calculated from position calculated after appending to the master file abnv3321

*gps4exec0*: transferred the NMF TECHSAS *gps_4000* data stream to PSTAR format.

Data with pdop (position dilution of position) outside the range 0-7 should have been removed. However, these data are not transferred through TECHSAS. This needs to be fixed. Further edits were made to remove outliers and gaps interpolated before the file was appended to the master file gp433201 and distance run calculated. A 30 second average file gp433201.30sec was also created.

*gpsg12exec0*: identical to gps4exec0 but transferred the NMF *gps_g12* data stream to PSTAR format and no 30 second file is created.

*gyroexec0*: transferred data from the NMF *gyronmea* stream to PSTAR format. Headings outside the range 0-360° were deleted and the file appended to the master gyr33201 file.

It was discovered that an *fdiff and pedita* sequence in the gp4exec0 script to remove duplicate times was being immediately reversed by a subsequent *pintrp* command. Duplicate times tend not to be too problematic. However, should it be decided in the future that duplicate times should be taken out completely, they can be removed by applying the *datpik* command to remove data where the outcome of *fdiff* (deltat) is between -0.5 and 0.5. *Pintrp* can then be run to interpolate over any real time gaps.

## 6.2 TECHSAS Logging Problems

During the cruise, problems were experienced with the TECHSAS primary logging system that caused it to hang for periods of a few seconds to up to a few hours. Large dropouts of 3.6 hrs, 2.2 hrs, 3.3 hrs and 1.6 hrs occurred whilst we were still alongside or just leaving port in St Johns, (see computing and instrumentation section of this report for details). During such dropouts, gaps were experienced in the gps_4000, gps_g12 and adu2 (3-D Ashtech) data streams.

This was solved by stitching data from the secondary TECHSAS system (TECHSAS II) into the gaps in the original gps_4000, gps_g12 and adu2 streams. Again, for more information refer computing and instrumentation section of this report. The new streams were named gps40003, gpsg123 and adu3.

The gps_4000 stream with data substituted into the gaps was read in daily alongside the original stream. This meant it was available should we choose to reprocess any of the other datasets with the more complete navigation. This would be most applicable to the ADCP data. However, we were fortunate that the biggest time gap (2.5 hrs) after the ones early in the cruise whilst still in port occurred whilst we were hove-to in bad weather and therefore it was not crucial to reprocess ADCP data for this period.

## 6.3 Ships heading and attitude

The ship's attitude was measured every second by the 3D GPS Ashtech navigation System, or ADU2. Four antenna, two on the boat deck, two on the bridge top, measured the phase difference between incoming satellite signals from which the ship's position, heading, pitch and roll were determined. The data is logged in two streams; ADU2 GPPAT containing position, heading and diagnostics and ADU2 PASHR containing pitch and roll information. Ashtech data were read from the NMF TECHSAS stream into PSTAR and used to calibrate the gyro heading information as follows:

**ashexec0**: transferred data from the RVS gps_ash stream to pstar.

**ashexec1**: merged the ashtech data from ashexec0 with the gyro data from gyroexec0 and calculated the difference in headings (hdg and gyroHdg); ashtech-gyro (a-ghdg).

**ashexec2**: edited the data from ashexec1 using the following criteria:

| | |
|---|---|
| heading | 0 < hdg < 360 (degrees) |
| pitch | -5 < pitch < 5 (degrees) |
| roll | -7 < roll < 7 (degrees) |
| attitude flag | -0.5 < attf < 0.5 |
| measurement RMS error | 0.00001 < mrms < 0.01 |
| baseline RMS error | 0.00001 < brms < 0.1 |
| ashtech-gyro heading | -7 < a-ghdg < 7 (degrees) |

The heading difference (a-ghdg) was then filtered with a running mean based on 5 data cycles and a maximum difference between median and data of 1 degree. The data were then averaged to 2 minutes and further edited for

-2 < pitch <2
0 < mrms < 0.004

The 2 minute averages were merged with the gyro data files to obtain spot gyro values. The ships velocity was calculated from position and time, and converted to speed and direction. The resulting a-ghdg should be a smoothly varying trace that can be merged with ADCP data to correct the gyro heading. Diagnostic plots were produced to check this. During ship manoeuvres, bad weather or around data gaps, there were spikes which were edited out manually (plxyed).

During the cruise, a number of gaps occurred in the Ashtech data stream. The largest of these gaps occurred as a result of the TECHSAS logging system dropouts, as described earlier in the report. In the same way as for the gps_4000 and gps_g12 data streams, gaps were filled by stitching data in from the TECHSAS II system (refer to computing and instrumentation section).

A number of smaller gaps occurred in the Ashtech data stream. Those greater than 60 seconds are listed below.

time gap : 08 230 13:00:07 to 08 230 13:47:49 (47.7 mins)
time gap : 08 230 17:56:12 to 08 230 17:57:15 (63 s)
time gap : 08 231 17:19:35 to 08 231 17:27:54 (8.3 mins)
time gap : 08 231 17:30:55 to 08 231 17:51:07 (20.2 mins)

time gap : 08 234 23:10:24 to 08 234 23:12:50 (2.4 mins)

time gap : 08 236 08:51:48 to 08 236 08:55:54 (4.1 mins)

time gap : 08 236 11:04:24 to 08 236 11:07:19 (2.9 mins)

time gap : 08 236 12:45:21 to 08 236 12:46:56 (95 s)

time gap : 08 236 21:47:57 to 08 236 21:49:09 (72 s)

time gap : 08 237 18:35:10 to 08 237 18:36:13 (63 s)

time gap : 08 237 20:47:09 to 08 237 21:09:49 (22.7 mins)

time gap : 08 238 18:30:30 to 08 238 18:31:33 (63 s)

time gap : 08 239 19:50:15 to 08 239 19:51:19 (64 s)

time gap : 08 239 20:58:40 to 08 239 20:59:58 (78 s)

time gap : 08 241 21:42:50 to 08 241 21:43:58 (68 s)

time gap : 08 241 23:28:15 to 08 241 23:35:28 (7.2 mins)

time gap : 08 244 17:26:50 to 08 244 17:27:52 (62 s)

time gap : 08 244 21:20:20 to 08 244 21:21:52 (92 s)

time gap : 08 245 18:03:51 to 08 245 18:20:54 (17.1 mins)

time gap : 08 245 20:26:07 to 08 245 20:27:23 (76 s)

time gap : 08 245 21:25:45 to 08 245 21:26:48 (63 s)

time gap : 08 247 20:36:58 to 08 247 20:38:01 (63 s)

time gap : 08 248 00:18:45 to 08 248 00:22:31 (3.8 mins)

time gap : 08 249 07:02:03 to 08 249 07:03:06 (63 s)

time gap : 08 249 21:23:45 to 08 249 21:25:25 (100 s)

time gap : 08 250 07:37:54 to 08 250 07:38:56 (62 s)

time gap : 08 251 07:58:27 to 08 251 07:59:33 (66 s)

time gap : 08 253 00:07:44 to 08 253 00:09:17 (93 s)

time gap : 08 253 15:21:25 to 08 253 15:22:30 (65 s)

time gap : 08 253 20:15:08 to 08 253 21:41:49 (86.7 mins)

time gap : 08 254 17:01:13 to 08 254 17:02:16 (63 s)

time gap : 08 254 20:17:43 to 08 254 20:50:54 (33.2 mins)

time gap : 08 254 20:51:39 to 08 254 20:52:54 (75 s)

time gap : 08 255 12:32:45 to 08 255 12:33:52 (67 s)

time gap : 08 256 19:48:30 to 08 256 19:49:32 (62 s)

time gap : 08 259 20:04:38 to 08 259 20:05:41 (63 s)

With considerable frequency during the cruise, the ADU2 PASHR (pitch and roll) stream would drop out as the ADU2 lost satellite mapping. At these times, the TECHSAS logging of ADU2 would frequently stop as though there were a time-out set too short in the logging routine. Frequent watch checks were necessary to limit data loss this problem needs to be rectified however.

# 7 SHIPBOARD ADCP

John Allen, Leighton Rolley

## 7.1 Introduction

During the refit for RRS *Discovery* in March 2008, the original narrow band RDI 150 kHz Vessel-Mounted Acoustic Doppler Current Profiler (VM-ADCP) was replaced with an RDI broad band 150 kHz (Ocean Surveyor) phased array style VM-ADCP. This was in addition to the similar 75 kHz Ocean Surveyor instrument that had been in use in the forward ADCP housing since 2001.

The 150 kHz ADCP is mounted in the hull 1.75 m to port of the keel, 33 m aft of the bow at the waterline and at an approximate depth of 5 m. The 75 kHz ADCP is also mounted in the hull, but in a second water chest 4.15 m forward and 2.5 m to starboard of the 150 kHz well.

This section describes the operation and data processing paths for both ADCPs.

## 7.2 75 kHz and 150 kHz VM-ADCP data processing

The RDI Ocean Surveyor 150 kHz Phased Array VM-ADCP was configured to sample over 120 second intervals with 100 bins of 4m depth and a blank beyond transmit of distance of 4m. The instrument is a broad band phased array ADCP with 153.6 kHz frequency and a 30° beam angle.

The RDI Ocean Surveyor 75 kHz Phased Array VM-ADCP was configured to sample over 120 second intervals with 100 bins of 8m depth and a blank beyond transmit of distance of 8m. The instrument is a broad band phased array ADCP with 76.8 kHz frequency and a 30° beam angle.

Both deck units had firmware upgrades to VMDAS 23.17 after the March 2008 refit. Both PCs ran RDI software VmDAS v1.44. Gyro heading, and GPS Ashtech heading, location and time were fed as NMEA messages into the serial ports of the both PCs and VmDAS was configured to use the Gyro heading for co-ordinate transformation. VmDAS logs the PC clock time, stamps the data (start of each ensemble) with that time, and records the offset of the PC clock from GPS time. This offset was applied to the data in the processing path before merging with navigation.

The 2 minute averaged data were written to the PC hard disk in files with a .STA extension, eg D332001_000000.STA, D332002_000000.STA etc. for the 150kHz data and D332_75001_000000.STA, D332_75002_000000.STA etc. for the 75 kHz data. Sequentially numbered files were created whenever data logging was stopped and re-started. The software was set to close the file once it reached 100MB in size, though on D332 files were closed and data collection restarted daily such that the files never became that large. All files were transferred to the unix directories /data32/d332/os150/raw and /data32/d332/os75/raw as appropriate. This transfer included the plethora of much larger ping by ping data files, these can be useful in the event of major failure of the ship's data handling systems as they record all the basic navigation and ships heading/attitude data supplied by NMEA message.

Both instruments were configured to run in 'Narrowband' range over resolution mode after leaving Greenland for the first time (files 012 – onwards). Before this the 150kHz instrument had been configured to run in 'Broadband' resolution over range mode (files 001-011); in this mode the 150 kHz VM-ADCP had an effective depth range of only 200-250 metre even in the calm weather that we experienced across the Labrador Sea. Bottom tracking was used leaving St John's and on our first approach to Greenland where we had shallow shelf waters; files 001, 002, 003, 012 and 013 for both instruments.

The VM-ADCP processing path followed an identical route to that developed in 2001 for the 75 kHz ADCP (RRS *Discovery* cruise 253). In the following script descriptions, "##" indicates the daily file number.

**S75exec0 and S150exec0:** data read into Pstar format from RDI binary file (psurvey2). Water track velocities written into "sur" (75kHz) or "adp" (150kHz) files, bottom track into "sbt" (75kHz) or "sur" (150kHz) files if in bottom track mode. Velocities were scaled to cm/s and amplitude by 0.45 to db. The time variable was corrected to GPS time by combining the PC clock time and the PC-GPS offset. An offset depth for the depth bins was provided in the user supplied information (13 m for the 75kHz and 9 m for the 150 kHz instruments), this equated to the sum of the water depth of the transducer in the ship's hull (~5 m in RRS *Discovery*) and the blank beyond transmit distance used in the instrument setup (see earlier). Output Files: 75kHz (sur332##.raw, sbt332##.raw), 150 kHz (adp332##.raw, bot332##.raw).

**S75exec1 and s150exec1**: data edited according to status flags (flag of 1 indicated bad data). Velocity data replaced with absent data if variable "2+bmbad" was greater than 25% (% of pings where >1 beam bad therefore no velocity computed). Time of ensemble moved to the end of the ensemble period (120 secs added with pcalib). Output files: 75kHz (sur332##, sbt332##), 150 kHz (adp332##, bot332##).

**S75exec2 and s150exec2**: this merged the adcp data (both files) with the ashtech a-ghdg created by ashexec2. The adcp velocities were converted to speed and direction so that the heading correction could be applied and then returned to east and north. Note the renaming and ordering of variables. Output files: 75kHz (sur332##.true, sbt332##.true), 150 kHz (adp332##.true, bot332##.true).

**S75exec3 and s150exec3**: applied the misalignment angle, ø, and scaling factor, A, to both files. Variables were renamed and re-ordered to preserve the original raw data. Output Files: 75kHz (sur332##.cal, sbt332##.cal), 150 kHz (adp332##.cal, bot332##.cal).

**S75exec4 and s150exec4**: merged the adcp data (both files) with the bestnav (10 sec) NMFSS combined navigation imported to pstar through navexec0 (abnv3321). Ship's velocity was calculated from spot positions taken from the abnv3321 file and applied to the adcp velocities. The end product is the absolute velocity of the water. The time base of the ADCP profiles was then shifted to the centre of the 2 minute ensemble by subtracting 60 seconds and new positions were taken from abnv3321. Output Files: 75kHz (sur332##.abs, sbt332##.abs), 150 kHz (adp332##.abs, bot332##.abs).

### 7.3 75 kHz and 150 kHz VM-ADCP calibration

A calibration of both VM-ADCPs was achieved using bottom tracking data available from our departure from St. John's across the continental shelf. No further calibration was deemed necessary from inspection of the processed data during the cruise. Using long, straight, steady speed sections of standard two minute ensemble profiles the following calibrations for mis-alignment angle, $\phi$, and necessary amplification (tilt), A, by comparing GPS derived component vectors of the vessel speed and direction with processed VM-ADCP bottom track determined component vectors of the vessel speed and direction:

***150 kHz:***

| | $\phi$ | A |
|---|---|---|
| | -0.018512871 | 1.000441046 |
| | -0.016868291 | 1.000713913 |
| | -0.073552092 | 1.001649237 |
| | -0.069557015 | 1.001224268 |
| | -0.071581693 | 1.001931542 |
| | -0.244478970 | 1.013804604 |
| | -0.079962566 | 1.001662313 |
| | -0.041468116 | 1.001246205 |
| mean | -0.076997702 | 1.002834141 |
| s.d | 0.072164205 | 0.004460596 |

Therefore $\phi$ = -0.0770 and A = 1.0028 were used to calibrate the 150 kHz VM-ADCP.

*75 kHz:*

| | $\phi$ | A |
|---|---|---|
| | -61.56854572 | 1.000847964 |
| | -61.59553717 | 0.999593243 |
| | -61.61658854 | 1.002341076 |
| | -61.48439489 | 1.009464745 |
| | -61.52071430 | 1.002429133 |
| | -61.60229483 | 1.000229935 |
| | -61.47084647 | 0.999899017 |
| | -61.58901336 | 1.003569632 |
| mean | -61.55599191 | 1.002296843 |
| s.d. | 0.056376467 | 0.003217112 |

Therefore $\phi$ = -61.5560 and A = 1.0023 were used to calibrate the 75 kHz VM-ADCP.

### 7.4 Initial data inspection

In good weather and calm seas both VM-ADCPs behaved well and agreed very closely (**Figure 7.1**). During the latter part of the cruise, severe weather significantly degraded the VM-ADCP data. The 75 kHz data were affected worst probably due to its position in the forward ADCP water chest. In most cases, both ADCP datasets still retained some good data in bad weather, but at deeper depths (e.g. 100m), although this was most apparent for the 150 kHz data.

The 150 kHz VM-ADCP was in 'Broadband' mode during the transect across the Labrador Sea. However it became apparent that having the VM-ADCPs in 'Broadband' high resolution mode significantly reduces their range penetration in the water column as can clearly be seen in **Figure 7.1**, whilst any increase in resolution was not obvious in the mixed underway and on-station use that we were making of the data.

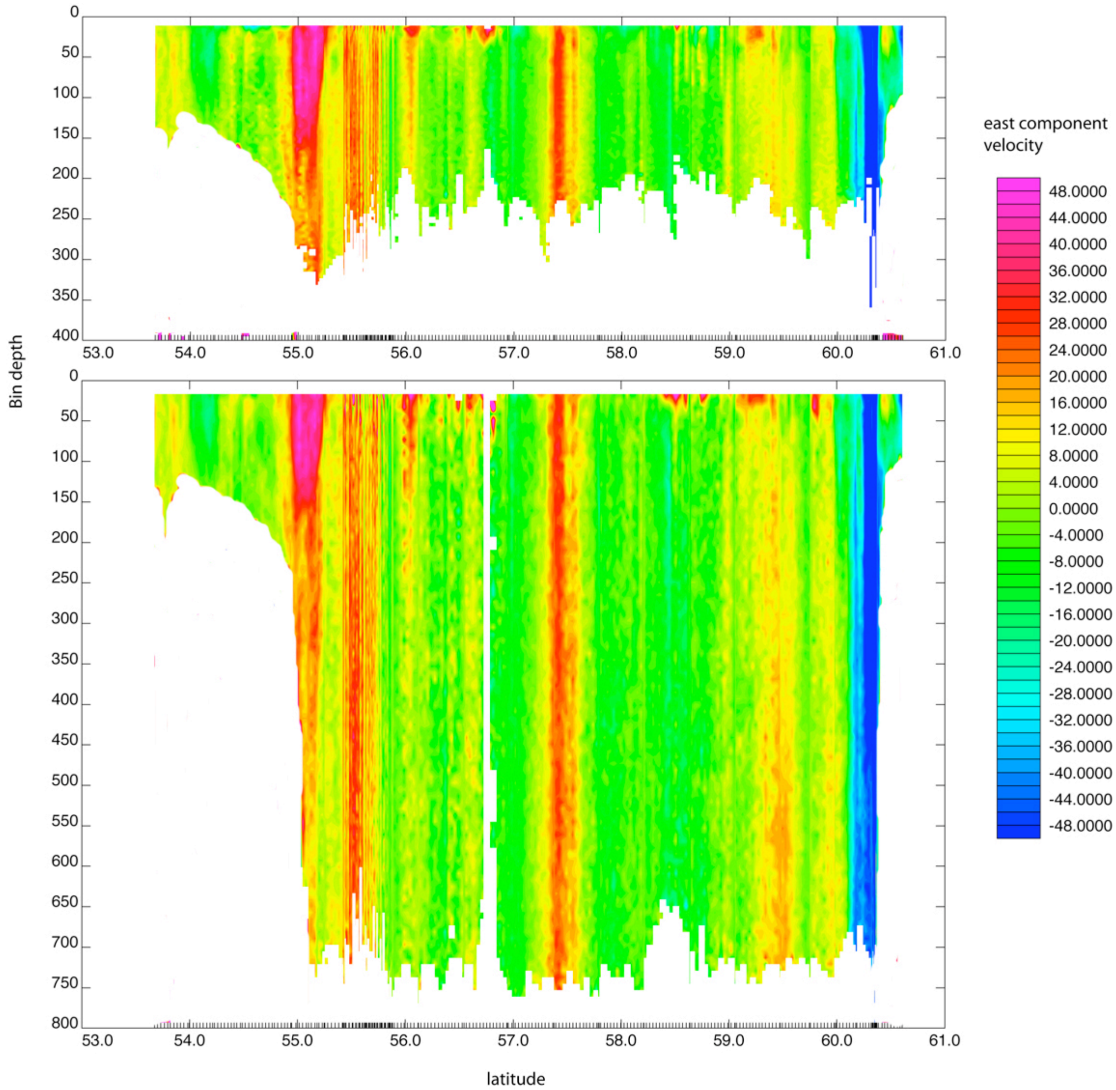



**Figure 7.1:** East component velocity for the 150 kHz VM-ADCP (top) and the 75 kHz VM-ADCP bottom, across the Labrador sea (section AR7W).

# 8 WATER SAMPLES

## 8.1 Inorganic nutrient analysis

Ian Salter

My objective during cruise D332 was to measure micro-molar levels of the inorganic nutrients: nitrate, silicate and phosphate from CTD samples using segmented flow analysis. The analysis of micro-molar concentrations of nitrate+nitrite (hereinafter nitrate), phosphate and silicate was undertaken using a Scalar Sanplus Autoanalyser following the methods described below.

### *8.1.1 Colorimetry*

At the correct pH and concentration, the chemical reaction of nutrients with certain metals forms coloured solutions of reduced metal complexes. Over a certain range, the intensity of the colour produced is proportional to the concentration of the reacted nutrient. The concentration of nutrient present can therefore be determined by measuring the absorbance of light at the wavelength corresponding to the colour of the solution, according to the Beer-Lambert law:

$$I_a = I_o\,(1 - e^{-cx})$$

Where $I_a$ is the light absorbed, $I_o$ is incident light, $c$ is the concentration of the nutrient, and $x$ is a constant (constant for each system). In general, this law holds for reactions where $I_a < 0.85\ I_o$. The light absorbed by the solution is measured using a photometer to which filters have been fitted so that the wavelength of light passing through is equal to that of the colour of the nutrient-metal solution. Using a series of inorganic nutrient standard solutions of concentrations within the linear range of the Beer-Lambert Law, the absorbance of the solution is calibrated to the nutrient concentration of the solution. This linear calibration may then be used to obtain nutrient concentrations in unknown samples.

### *8.1.2 Automated segmented flow analysis*

The advantages of automated rather than manual techniques in nutrient analysis are that constant reaction conditions are maintained for all samples, ensuring greater reproducibility and comparability of results, and that the speed of analysis and therefore sample throughput can be greatly increased. A precision of better than 1% of the full-scale value of the calibration should be achieved by this system. The concept can be briefly described as follows: A seawater sample is pumped into the system and the colorimetric reagents are introduced into the sample line in the appropriate sequence. The constant flow of reagents and samples is segmented by air bubbles, which serves the dual purpose encouraging the turbulent mixing of the sample with reagents in the glass coils, and preventing cross-contamination between samples. The quantity of reagent added to each sample segment is controlled by the concentration of the initial reagent solution and the flow rate of the tubing transporting the reagent to the sample line. Glass coils inserted into the line enhance mixing and determine the time allowed for colour development. The differential speed of movement of the solution on the inner side of the coil relative to that on the outer side creates circulation within the segment and thus increases mixing. After mixing, the segments are de-bubbled and transferred to a photometer cell where absorbance of the sample is measured. After analysis, the waste sample is drained away.

The size and frequency of the bubbles in the line is important in improving the resolution of the sample signals. The size of the bubble is controlled by the geometry of the air injector and the surface tension of the sample/reagent mixture, whilst the frequency of the bubbles is determined by the rate of air input. The optimal length of bubble is about twice the tube diameter. The frequency of bubbles should be such that the mixing coils have two and a half to three bubbles per turn of the coil, in order to maximise the mixing of the sample and to ensure sufficient scrubbing of the sample line between segments, thus reducing carry over between samples.

The resolution of sample signals is also influenced by the length of sampling and wash times. The segments are de-bubbled prior to entering the photometer cell, and thus are potentially subject to mixing. The rate at which one sample is washed out of the cell depends on the geometry of the cell and the viscosity of the solutions and the length of time where the sample may be exposed to mixing may result in overlapping of sample peaks. . The best resolution of peaks is obtained where the sampling time is sufficiently long for the peak to reach a plateau, and the wash time is sufficient for separation of the peaks so the can be identified. However, excessively long wash times may degrade peak quality by moving the mixing process within the cell away from equilibrium. When deciding on the length of sampling and wash times, the need for good peak resolution (long sampling time) and separation (long wash time) must be balanced with the availability of sample and the overall time required for the analytical run.

### *8.1.3 Nitrate+Nitrite*

The method presented here is that of Kirkwood (1984), which is in turn based on Bendschneider and Robinson (1952). It relies on the quantitative reduction of nitrate, which cannot be determined directly by colorimetric methods, to nitrite, by heterogeneous reaction with activated copper cadmium under alkaline (pH 8-9) conditions. Nitrate is then reacted with an aromatic amine (sulphanilamide) to form a diazonium compound. Reaction of this compound with a second aromatic amine (n-(1-napthyl)-ethylenediamine dihydrochloride, or NEDD) forms an azo dye with extinction at 543 nm. Measurement of nitrite only is achieved by removal of the cadmium column step.

Reagents

| | | | | |
|---|---|---|---|---|
| *Reagent 1* | Buffer solution | Ammonium chloride | 6 g | } in 2 litres of $d.H_2O$ |
| *Reagent 2* | Combined reagent | Sulfanilamide | 1 g | } |
| | | 4 M HCl | 30 ml | } in 2 litres of $d.H_2O$ |
| | | NEDD | 0.1 g | } |
| | | 20% BRIJ-35 | 0.5 ml | } |

The combined reagent should ideally be kept in a dark bottle and must be monitored closely for signs of colouration – once the reagent begins to turn pink it should be discarded.

### *8.1.4 Phosphate*

The standard method of phosphate analysis is that of Murphy and Riley (1962), in which phosphate is reacted with acidified ammonium molybdate and potassium antimonyl tartrate, then reduced using ascorbic acid to form a blue phosphoantimonyl molybdate complex, with extinction measured at 880 nm. The method reported here uses the split reagent of Grasshoff (1983, as reproduced in Kirkwood, 1984), which separates the ascorbic acid from the other components, thus increasing the stability of the reagents.

Reagents

| | | | |
|---|---|---|---|
| *Reagent 1* | 5 M (280 ml conc./l) sulphuric acid | 800 ml | } |
| | Ammonium molybdate | 20 g | } in 2 litres of $d.H_2O$ |
| | Potassium antimonyl tartrate | 0.4 g | } |
| *Reagent 2* | Ascorbic acid | 16 g | } |
| | Sodium dodecyl sulphate | 2 g | } in 2 litres of $d.H_2O$ |

In standard colorimetric methods, it is generally advised to allow ten minutes after addition of the reagents to allow for full colour development. To ensure completion of the reaction in the automated system, the sample/reagent mixture is passed through a water bath with a temperature of about 40 °C.

### *8.1.5 Silicate*

The method presented here is based on that of Koroleff (1971), modified by Grasshoff (1983) and reported in Kirkwood (1984). Silicate is reacted with ammonium molybdate, forming a yellow silicomolybdate complex. Acidic conditions are maintained in order to ensure the reaction product is the more rapidly-formed beta isomer of the silicomolybdate. Oxalic acid is then added to the system to removed any excess molybdate and prevent interference from phosphate. Finally, ascorbic acid is added to reduce the silicomolybdate complex to a strongly-coloured blue complex, with extinction at 810 nm.

<u>Reagents</u>

| | | | |
|---|---|---|---|
| *Reagent 1* | 5 M Sulphuric acid | 40 ml | } |
| | Ammonium molybdate | 14 g | } in 2 litres of d.$H_2O$ |
| | Sodium dodecyl sulphate | 2 g | } |
| *Reagent 2* | Oxalic acid 12 g | | } in 2 litres of d.$H_2O$ |
| *Reagent 3* | Ascorbic acid 32 g in 2 l d.$H_2O$ | | } in 2 litres of d.$H_2O$ |

The silicate method works well only within a limited temperature range of 20-40 °C, and a water bath with temperature around 30 °C is used after addition of the reagents.

### *8.1.6 Sampling*

All samples were drawn directly from the CTD Niskins into brand new 25ml Sterilin coulter counter vials. Each vial was rinsed three times with sample water before the sample was finally taken. All samples were stored in refrigerated conditions ($4^{o}$C, dark) and analysed within 24 hours of collection. The only exception to this was for the samples originating from CTD casts 045, 046, 047, and 048, which were frozen at $-20^{0}$C. Prior to analysis these samples were allowed to thaw under the refrigerated conditions described above. During D332 1394 samples were analysed for nitrate, phosphate, and silicate, of which, 176 were duplicates. Duplicates were taken either from 1) different Sterilin vials drawn from different Niskin bottles fired at the same depth, or from 2) the same Sterilin Vial. 16.9% of the samples were analysed in duplicate.

**Table 8.1:** Summary of the number of rosette bottles sampled from the CTD for inorganic nutrient analysis. Also included is the number of duplicate samples analysed from each cast, and for reference the number of discrete depths sampled during each cast.

| Cast Number | Number of rosettes sampled from | Number of duplicate samples | Number of depths sampled |
|---|---|---|---|
| 33200003 | 8 | 2 | 6 |
| 33200004 | 8 | 2 | 6 |
| 33200005 | 7 | 2 | 5 |
| 33200006 | 8 | 1 | 7 |
| 33200007 | 8 | 2 | 6 |
| 33200008 | 7 | 0 | 7 |
| 33200009 | 9 | 0 | 9 |
| 33200010 | 12 | 0 | 12 |
| 33200011 | 12 | 2 | 12 |
| 33200012 | 18 | 5 | 18 |
| 33200013 | 12 | 2 | 12 |
| 33200014 | 12 | 2 | 12 |
| 33200015 | 12 | 3 | 11 |
| 33200016 | 12 | 2 | 13 |
| 33200017 | 14 | 2 | 14 |
| 33200018 | 18 | 3 | 19 |
| 33200019 | 20 | 1 | 23 |
| 33200020 | 24 | 2 | 24 |
| 33200021 | 24 | 5 | 24 |
| 33200022 | 24 | 6 | 24 |
| 33200023 | 22 | 2 | 24 |
| 33200024 | 20 | 4 | 24 |
| 33200025 | 24 | 1 | 24 |
| 33200026 | 22 | 3 | 22 |
| 33200027 | 22 | 3 | 23 |
| 33200028 | 23 | 3 | 23 |
| 33200029 | 23 | 2 | 23 |
| 33200030 | 17 | 3 | 18 |
| 33200031 | 9 | 1 | 10 |
| 33200032 | 6 | 2 | 6 |
| 33200033 | 6 | 2 | 6 |
| 33200034 | 5 | 1 | 6 |
| 33200035 | 22 | 2 | 24 |
| 33200036 | 24 | 14 | 24 |
| 33200037 | 19 | 2 | 23 |
| 33200038 | 22 | 2 | 24 |
| 33200039 | 24 | 2 | 24 |
| 33200040 | 18 | 1 | 24 |
| 33200041 | 15 | 2 | 24 |
| 33200042 | 23 | 3 | 24 |

**Table 8.1:** *continued*

| Cast Number | Number of rosettes sampled from | Number of duplicate samples | Number of depths sampled |
|---|---|---|---|
| 33200043 | 23 | 2 | 24 |
| 33200044 | 23 | 6 | 23 |
| 33200045 | 22 | 2 | 24 |
| 33200046 | 21 | 2 | 24 |
| 33200047 | 21 | 2 | 24 |
| 33200048 | 23 | 2 | 24 |
| 33200049 | 24 | 3 | 23 |
| 33200050 | 24 | 3 | 23 |
| 33200051 | 24 | 3 | 23 |
| 33200052 | 22 | 2 | 23 |
| 33200053 | 23 | 2 | 23 |
| 33200054 | 23 | 2 | 23 |
| 33200055 | 22 | 3 | 23 |
| 33200056 | 22 | 2 | 24 |
| 33200057 | 21 | 1 | 22 |
| 33200058 | 23 | 2 | 22 |
| 33200059 | 23 | 2 | 22 |
| 33200060 | 24 | 3 | 23 |
| 33200061 | 24 | 3 | 23 |
| 33200062 | 12 | 2 | 12 |
| 33200063 | 12 | 2 | 12 |
| 33200064 | 9 | 2 | 9 |
| 33200065 | 9 | 0 | 9 |
| 33200066 | 8 | 1 | 8 |
| 33200067 | | | |
| 33200068 | 22 | 2 | 24 |
| 33200069 | 23 | 3 | 23 |
| 33200070 | 22 | 2 | 23 |
| 33200071 | 12 | 12 | 12 |
| 33200072 | 12 | 2 | 12 |
| 33200074 | 10 | 2 | 10 |
| Total | 1218 | 176 | |

### 8.1.7 *Preparation of analytical standards*

Separate analytical standard stock solutions of nitrate ($NaNO_3$), nitrite ($NaNO_2$), phosphate ($KH_2PO_4$), and silicate ($Na_2SiF_6$) were prepared by dissolving pre-weighed salts in 1 l of deionised water (18.2Ω $cm^{-1}$) to a concentration of approximately 5mM and stored in a refrigerator (4°C). The exact mass of the nutrient salts and resulting concentration of the analytical stock solutions after dissolution in 1 l of deionised water is summarised in Table 8.2. The stock solutions were used to making a set of analytical working standards in a matrix of artificial seawater (ASW: 40g NaCl / litre). For nitrate and silicate the working standards were made at concentrations of 0.5, 2.5, 5, 10, and 20µM. For phosphate the working standards were made at concentrations of 0.1, 0.5, 1, 2.5, and 5µM. The nitrate, phosphate, and silicate working standards were made as a mixed standard. For nitrite the working standard was made at a concentration of 10µM. The exact concentrations of the working standards nitrate, phosphate, and silicate is summarised in tables 8.3-8.5. All standards were made up in plastic volumetric flasks that had been soaked in 1.2M HCl and rinsed thoroughly with de-ionised water.

**Table 8.2:** Shows the exact concentration of analytical stock solutions after dissolution in 1 litre of de-ionised water. The concentrations reported in this table are used to calculate the exact concentrations of the analytical working standards presented in tables 8.3-5.

| Nutrient | Mass (g) | Concentration (mM) |
|---|---|---|
| $NaNO_3$ | 0.4342 | 5.11 |
| $KH_2PO_4$ | 0.6787 | 4.99 |
| $Na_2SiF_6$ | 0.9432 | 5.02 |
| $NaNO_2$ | 0.3469 | 5.03 |

**Table 8.3:** Nitrate: Concentration range of the analytical working standards used for daily calibrations.

| Std # | Voume of 5.11mM standard (mL) in 1 l of d.H2O | Concentration of working standard (_M) |
|---|---|---|
| 1 | 0.1 | 0.503 |
| 2 | 0.5 | 2.515 |
| 3 | 1.0 | 5.030 |
| 4 | 2.0 | 10.060 |
| 5 | 4.0 | 20.120 |

**Table 8.4:** Silicate: Concentration range of the analytical working standards used for daily calibrations.

| Std # | Voume of 5.02mM standard (mL) in 1 l of d.H2O | Concentration of working standard (_M) |
|---|---|---|
| 1 | 0.1 | 0.502 |
| 2 | 0.5 | 2.510 |
| 3 | 1.0 | 5.020 |
| 4 | 2.0 | 10.040 |
| 5 | 4.0 | 20.080 |

**Table 8.5:** Phosphate: Concentration range of the analytical working standards used for daily calibrations.

| Std # | Voume of 4.99mM standard (mL) in 1 l of d.H2O | Concentration of working standard (_M) |
|---|---|---|
| 1 | 0.02 | 0.0998 |
| 2 | 0.10 | 0.4990 |
| 3 | 0.20 | 0.9980 |
| 4 | 0.50 | 2.4950 |
| 5 | 1.00 | 4.9900 |

### *8.1.8 Blanks*

An artificial seawater (ASW) solution (40g NaCl / l) was used as the inter-sample wash and for baseline determinations, in addition to its use as a matrix for the working standards as described above. Several batches of ASW were made up during the cruise by dissolving 1kg of NaCl in 12.5 l of deionised water. 2.5 l of this solution were quantitatively removed from the carboy to give 10 l of 80g / l NaCl solution. 10 l of deionised water was added to this to provide a 20 l solution of 40 g NaCl / l. All aqueous NaCl solutions were made from the same batch of analytical dried reagent (Sigma Aldrich, Batch number: 106K0082). In order to test the contamination associated with this batch of NaCl a blanking run was performed as follows:

1. Analyser was started with all reagent tubes in 10% Decon until a steady baseline was attained.

2. Reagent sampling tubes were transferred to corresponding reagent flasks and ASW sample tube placed in ASW reservoir until a steady baseline was achieved.

3. Nitrate column was connected and system left until a steady baseline was attained.

4. A sample table was set up which consisted of 2 samples of standard #2 (N = 2.51μM, Si = 2.52μM, P = 0.49μM) and 100 washes to produce a continuous base line.

5. Once the standards had appeared on the real-time trace and the baseline had settled to a steady value the reagent tubes were removed from silicate reagent 1 and phosphate reagent 1 (see sections 2.4 and 2.5) and placed in deionised water and the cadmium reduction column on the nitrate line was disconnected. This removes all of the colour-forming capabilities of the autoanalyser.

6. The baselines for each chemistry drop to a lower value. The difference between the baseline values with the colour-forming chemicals connected and the baseline values with them disconnected is recorded. This difference is caused by contamination in the ASW matrix that is being rinsed through. The difference in baseline values can be equated to a concentration by comparing with the height of the standard #2 peaks. The data is summarised in Table 8.6.

**Table 8.6:** Details of the ASW blank corrections performed for each nutrient chemistry

| I.D | Nitrate | Phosphate | Silicate |
|---|---|---|---|
| Baseline (DU) | 18870 | 12635 | 2508 |
| Std 2 Concentration (uM) | 2.5 | 0.5 | 2.5 |
| Std 2 Height (DU) | 19476 | 12946 | 2992 |
| Baseline minus colour forming (DU) | 18816 | 12562 | 2462 |
| Standard #2 Height (DU) | 606.0 | 311.0 | 484.0 |
| Signal (DU/uM) | 0.0 | 0.0 | 0.0 |
| Baseline difference (DU) | 54.0 | 73.0 | 46.0 |
| ASW Blank (uM) | 0.22 | 0.12 | 0.24 |

The blank values reported in table 8.6 were added to each sample value to provide ASW blank-corrected data.

*8.1.9 Quality of the analytical calibration.*

An analytical calibration was performed separately for each run in order to account for the degradation and/or contamination of the analytical reagents and ASW, and changes in the intensity of the lamps as a function of time. In order to ensure high quality calibration data several measures were taken: 1) analytical standards were kept refrigerated at all times. The standards were removed from the fridge 1 hour before analysis in order to allow them to warm up to room temperature. 2) The samples were decanted into small 100mL Nalgene flasks after thoroughly shaking the 1L volumetric flasks. Once in the small flasks it was easier to decant the standards into the autosampler vials minimising spillage and cross-contamination between standards. The 100ml Nalgene bottles were shaken thoroughly prior to decanting into the autosampler vials. The $r^2$ values from the linear regressions were recorded for each nutrient as a function of time and are presented in Figure 8.1. For nitrate the $R^2$ values range from 0.99324 – 0.99999 with a mean of 0.99949 ± 0.00173. With the exception of one data-point (0.993) all calibrations are >0.999. For phosphate the $R^2$ values range from 0.99950 – 0.99999 with a mean of 0.99994 ± 0.00012, all calibrations are >0.999. For silicate the $R^2$ values range from 0.99977

– 1.00000 with a mean of 0.99990 ± 0.00007, all calibrations are > 0.999. The quality of calibrations showed no relationship with time for any of the three nutrients.

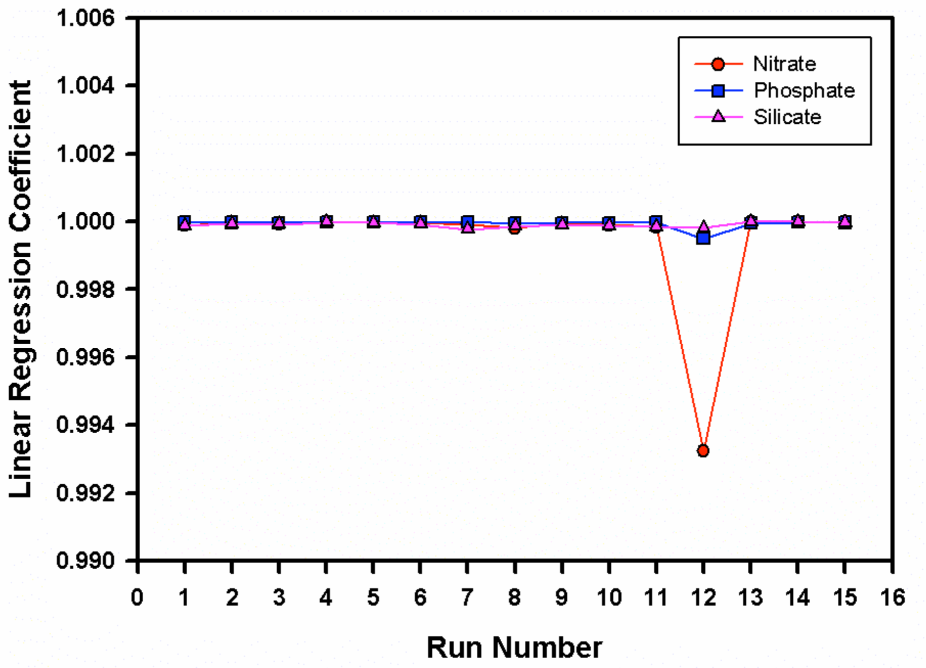



**Figure 8.1:** Linear regression coefficients for the standard calibrations for the inorganic nutrients nitrate, phosphate, and silicate.

<u>Nitrate reduction efficiency</u>

As discussed in section 2.4 the measurement of nitrate relies on the quantitative reduction of nitrate, which cannot be determined directly by colorimetric methods, to nitrite, by heterogeneous reaction with activated copper cadmium under alkaline (pH 8-9) conditions. In order to monitor the reduction efficiency of nitrate to nitrite by the cadmium column was checked at the start of each run. This is achieved by running a nitrite standard of a known concentration (10µM ) through the system. Subsequently a analytical nitrate standard with an identical concentration is also analysed. If the column is operating with 100% efficiency the nitrate and nitrite peak heights should be identical. Comparing the relative peak height of nitrate against nitrite allows the column's reduction efficiency to be calculated, this data is shown in Figure 8.2. In order to ensure that column efficiency remained high, great care was taken to ensure that no bubbles entered the column when connecting and disconnecting. The column efficiency ranged from 99.65 to 100.40 with a mean of 100.03 ± 0.20.

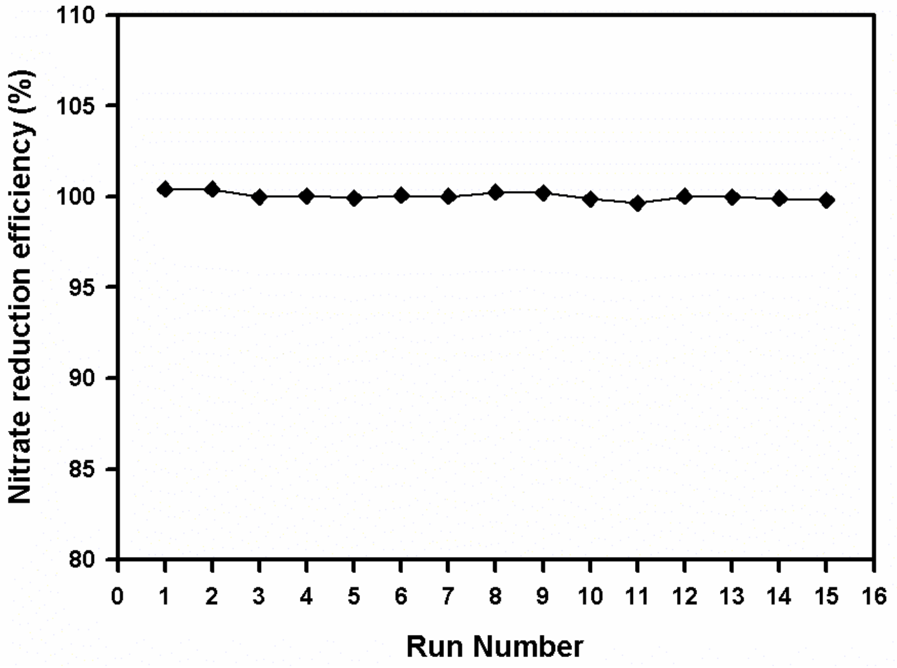



**Figure 8.2:** Shows the quantitative reduction efficiency of nitrate to nitrite by the cadmium column as a function of time.

<u>Baselines</u>

The baseline values were recorded during each analytical run to monitor any changes in the intensity of the lamps and the condition of the flow cells. The data is shown in Figure 8.3. The baseline values were practically constant for each nutrient varying by 1.9% for nitrate, 3.1% for phosphate, and 2.3% for silicate. If any trends are discernible it is that there was a slight increase in the nitrate baseline and a slight drop in the phosphate baseline with time, possibly due to the aging of reagents and or deterioration of the lamp. However, these changes are insignificant and the sensitivity of the instrument (see section 4.3.4) was very stable over the course of the cruise.

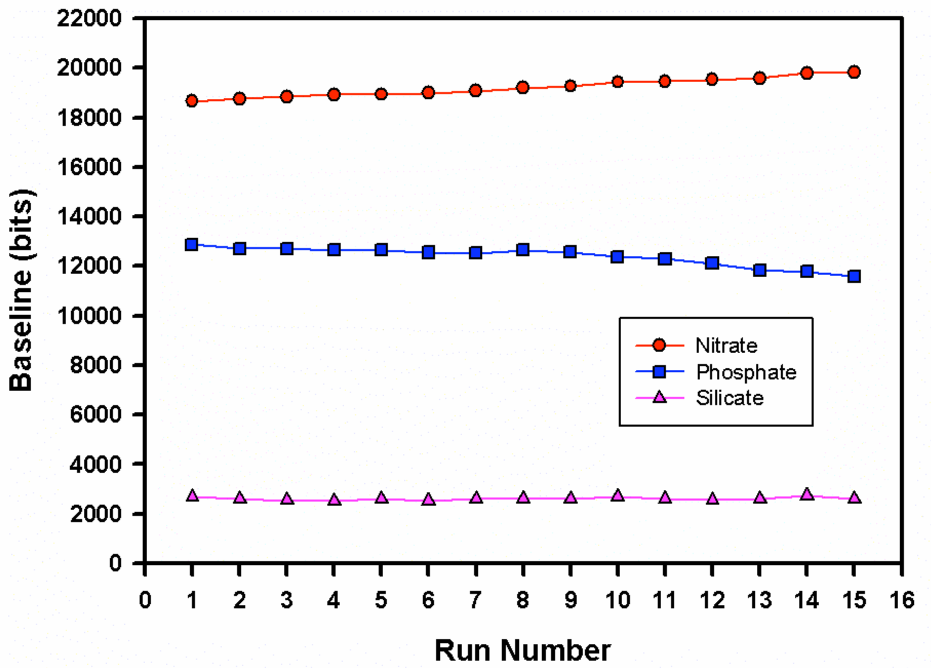



**Figure 8.3:** Baseline values for the three inorganic nutrients nitrate, phosphate and silicate.

<u>Sensitivity</u>

The sensitivity of the analyser was computed for all three chemistries to document any changes over the course of the cruise. Sensitivity is calculated as bits / µM. This parameter is calculated by subtracting the height of an analytical standard (of known concentration) from the "height" of the baseline for each nutrient. The nature of this calculation normalises for any slight baseline drifts (as discussed in section 4.3.3) and provides an absolute measure of instrument sensitivity. The purpose of this is to keep a track on reagent contamination/degradation, the flow cells, and deterioration of the peristaltic pump tubing. The data is presented in Figure 8.4. For nitrate the sensitivity ranged from 226.34 – 281.66 with a mean of 258.50 ± 12.2, varying by <4.7%. For phosphate the sensitivity ranged from 596.98 – 47.90, with a mean of 618.16 ± 13.22, varying by <2.2%. For silicate the sensitivity ranged from 194.37 – 208.52, with a mean of 200.95 ± 4.39, varying by <2.2%. Overall the sensitivity of the instrument was very high and very stable for all three nutrients during the cruise.

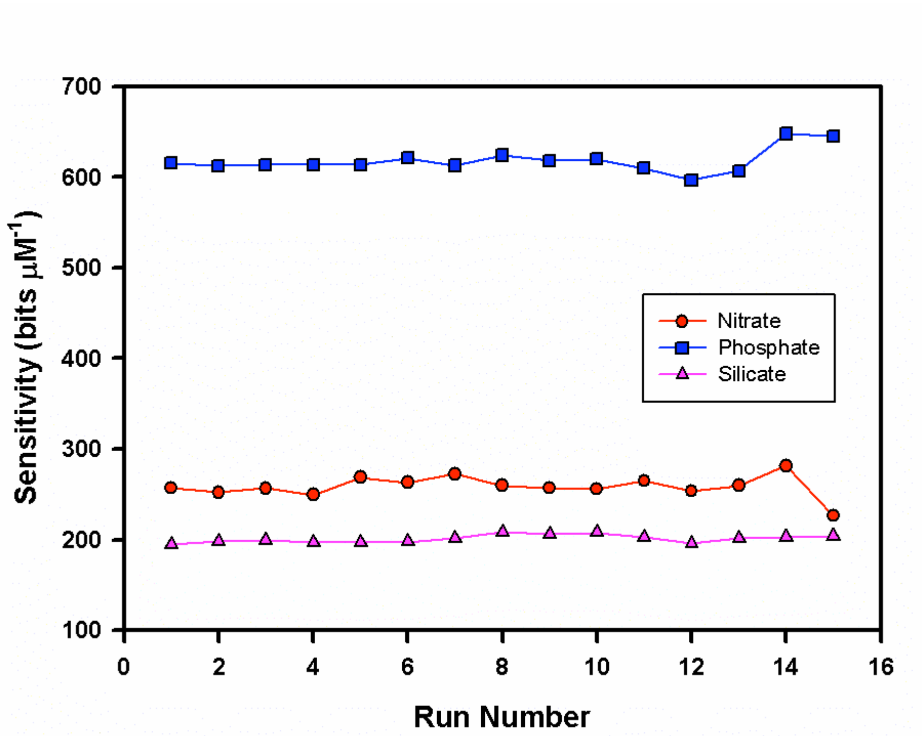



**Figure 8.4:** Instrument sensitivity of nitrate, phosphate, and silicate over the course of the cruise.

Precision

The analytical precision was determined separately on analytical standards (Figure 8.5) and samples (Figures 8.6 – 8.9). The "*standard precision*" is calculated from duplicate standard measurements (Figure 8.5) and is viewed as the instrument precision, including any handling errors incurred in the laboratory. The *standard precision* was always <0.5% for all three nutrients. Nitrate has a mean of 0.06%, phosphate has a mean of 0.03%, and silicate has a mean of 0.12%. For comparison, on a previous cruise (D326), the "*standard precision*" for nitrate had a mean 1.2%, phosphate had a mean of 1.79% and silicate had a mean of 1.48%.

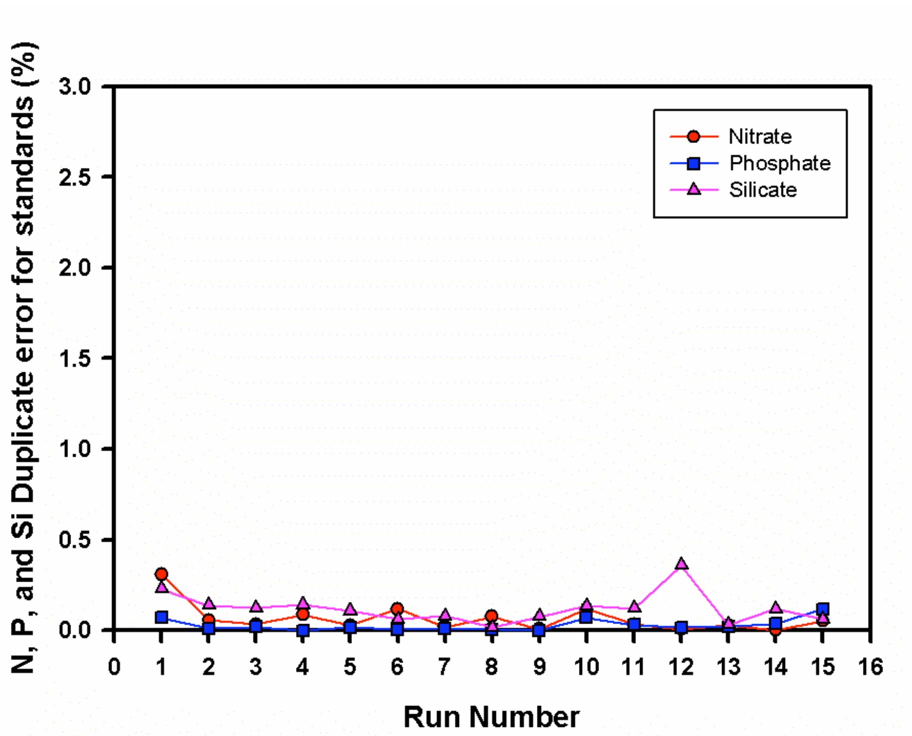



**Figure 8.5:** Instrument precision calculated from duplicate measurements of the analytical standards (10µM). Errors are of the same order (<0.5%) for all standard concentrations (data not shown.)

The precision of the measurements was also calculated from duplicate samples, taken both as replicates from the same coulter counter vial and as replicates from different CTD Niskins fired at the same depth. The "*sample precision*" integrates the instrument precision with the sampling errors from handling incurred at the CTD. Figure 8.6 shows the *sample precision* as a function of sample concentration for nitrate. 80% of the samples analysed in duplicate have a *sample precision* of better than 3%. However, the *sample precision* at concentrations <1µM is variable and can reach as high as 40%. It appears that the *sample precision* of the method for nitrate is only desirable at concentrations >1µM. Figure 8.7 shows the *sample precision* for nitrate with the data points removed at sample concentrations <1µM. Treating the data in this way results in 91% of the duplicate samples analysed having a sample precision of better than 3%. The inlay in Figure 8.7 shows that 66% of the samples have a precision of better than 1%. Figure 8.8 shows the *sample precision* as a function of sample concentration for phosphate. 91% of the samples analysed in duplicate have a *sample precision* of better than 3%. The inlay in Figure 8.8 shows that 68% of the samples have a precision of better than 1%. Figure 8.9 shows the *sample precision* as a function of sample concentration for silicate. 91% of the samples analysed in duplicate have a *sample precision* of better than 3%. The inlay in Figure 8.9 shows that 75% of the samples have a precision of better than 1%. The data presented in the inlays of Figures 8.6-9 is summarised in Table 8.7.

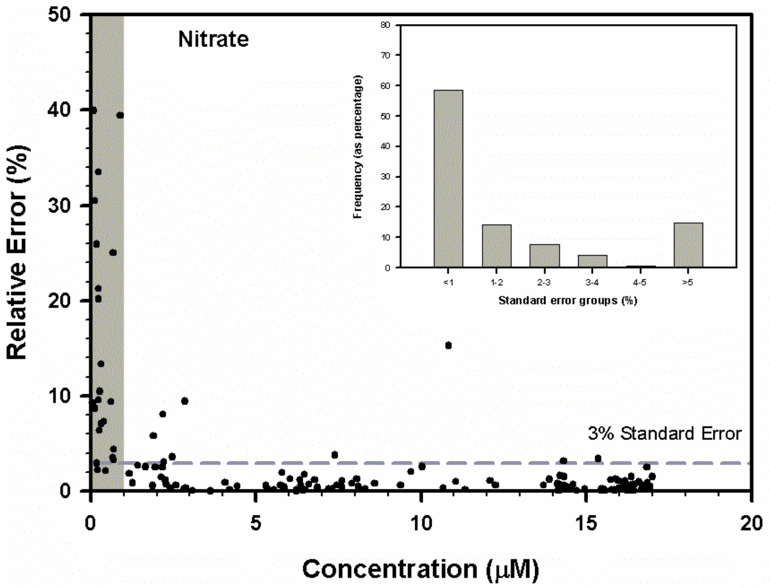



**Figure 8.6:** Shows sample precision for nitrate as a function of sample concentration. Grey shaded area marks the region where the sample concentration is less than 1μM. The inlay shows, as a percentage, the distribution of data over the discrete precision intervals <1, 1-2, 2-3, 3-4, 4-5, and >5%.

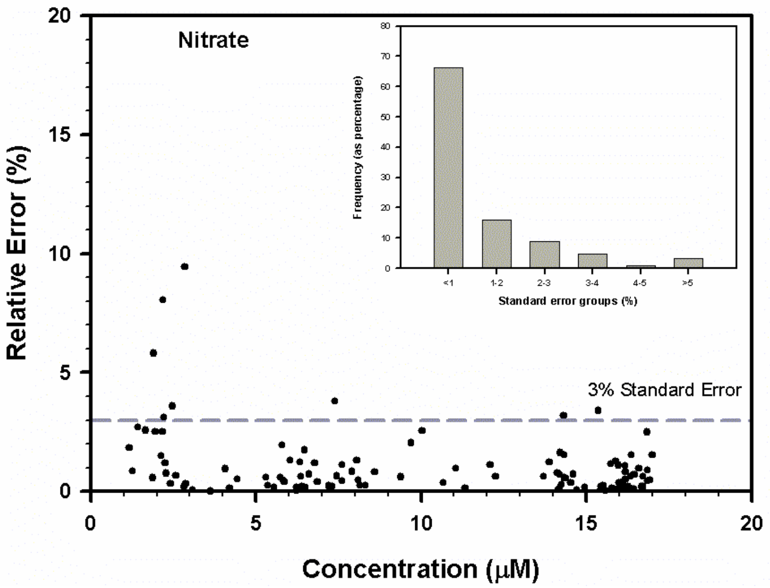



**Figure 8.7:** Shows sample precision for nitrate as a function of sample concentration with <1μM data removed. The inlay shows, as a percentage, the distribution of data over the discrete precision intervals <1, 1-2, 2-3, 3-4, 4-5, and >5% excluding the <1μM data.

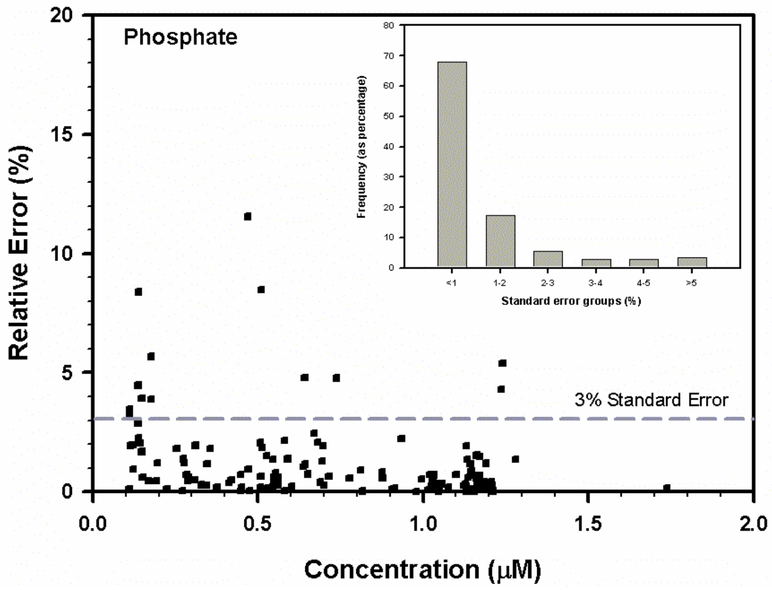



**Figure 8.8:** Shows sample precision for phosphate as a function of sample concentration. The inlay shows, as a percentage, the distribution of data over the discrete precision intervals <1, 1-2, 2-3, 3-4, 4-5, and >5%.

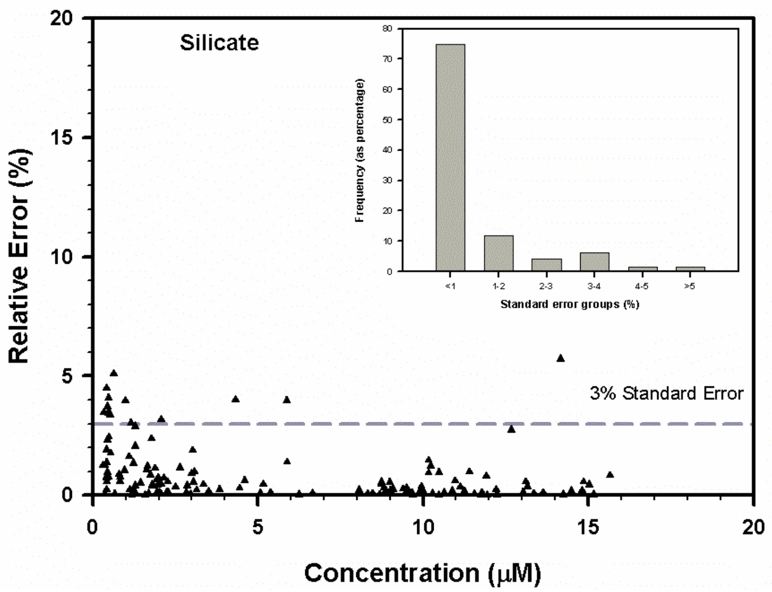



**Figure 8.9:** Shows sample precision for phosphate as a function of sample concentration. The inlay shows, as a percentage, the distribution of data over the discrete precision intervals <1, 1-2, 2-3, 3-4, 4-5, and >5%.

**Table 8.7:** A summary of the distribution (as percentage) of data over the discrete precision intervals <1, 1-2, 2-3, 3-4, 4-5, and >5%, for nitrate, phosphate and silicate. Nitrate values are excluding the <1 µM data.

| Precision Interval | Nitrate % | Phosphate % | Silicate % |
|---|---|---|---|
| **<1%** | 66.4 | 67.8 | 74.8 |
| **1-2%** | 16.0 | 17.5 | 11.9 |
| **2-3%** | 8.8 | 5.6 | 4.2 |
| **3-4%** | 4.8 | 2.8 | 6.3 |
| **4-5%** | 0.8 | 2.8 | 1.4 |
| **>5%** | 3.2 | 3.5 | 1.4 |

### *8.1.10 Data Processing*

Data processing was undertaken using Skalar proprietary software and was performed within a few days of the run completion. Within an analytical run, batches of samples consisted of between 12-20 samples, capped at both ends by drift standards (Standard #4) and baseline standards (ASW). The software uses this data to account for drifts in the baseline and peak heights and applies a linear drift correction if necessary. Some samples with expected high concentrations were diluted by 50%. However, comparison of non-diluted samples with diluted samples yielded similar results and this precaution was abandoned after the first few runs. All samples analysed fell within the calibration range of 0-20µM (nitrate and silicate) and 0-5µM (phosphate).

Some issues were encountered with the software incorrectly assigning the peak cross hairs with the correct peaks. Consequently the peak cross hairs were assigned manually for each run. This process required 5-8 hours depending on the length of the run. It was apparent that the software was getting progressively worse at correctly assigning the peaks within the duration of a run after each set of wash samples. In order to try and resolve this issue, for the later runs the wash samples were set as unknowns in the sample table. This resulted in the software trying to assign peaks rather than troughs for the washes. After the run the sample table was edited to turn the wash samples I.D. back to washes and then the peaks were re-picked and saved and the date re-calculated. This technique significantly reduced the problem for all three nutrients.

### *8.1.11 Results*

The following plots (figures 8.10–8.12) show the spatial sample distribution for the inorganic nutrients.

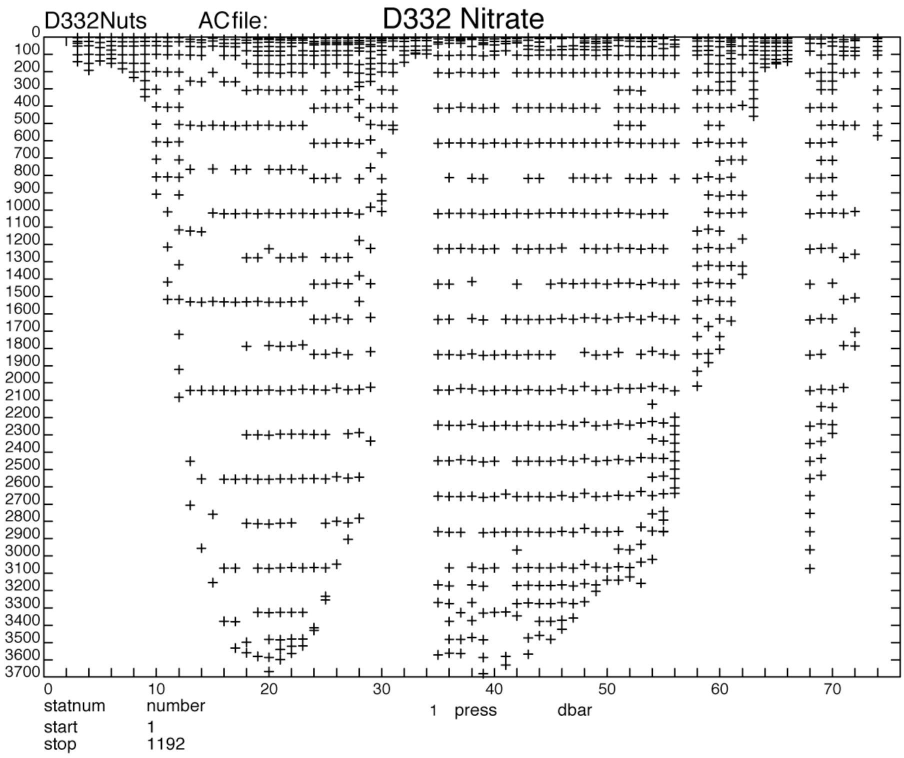



**Figure 8.10:** Spatial distribution of nitrate samples.

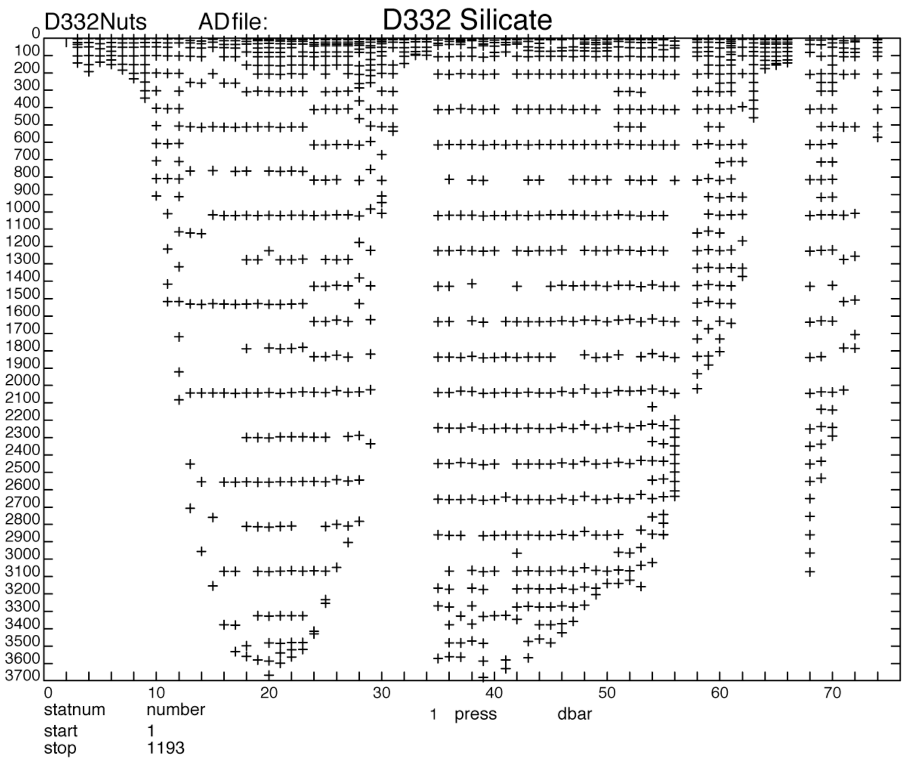



**Figure 8.11:** Spatial distribution of silicate samples.

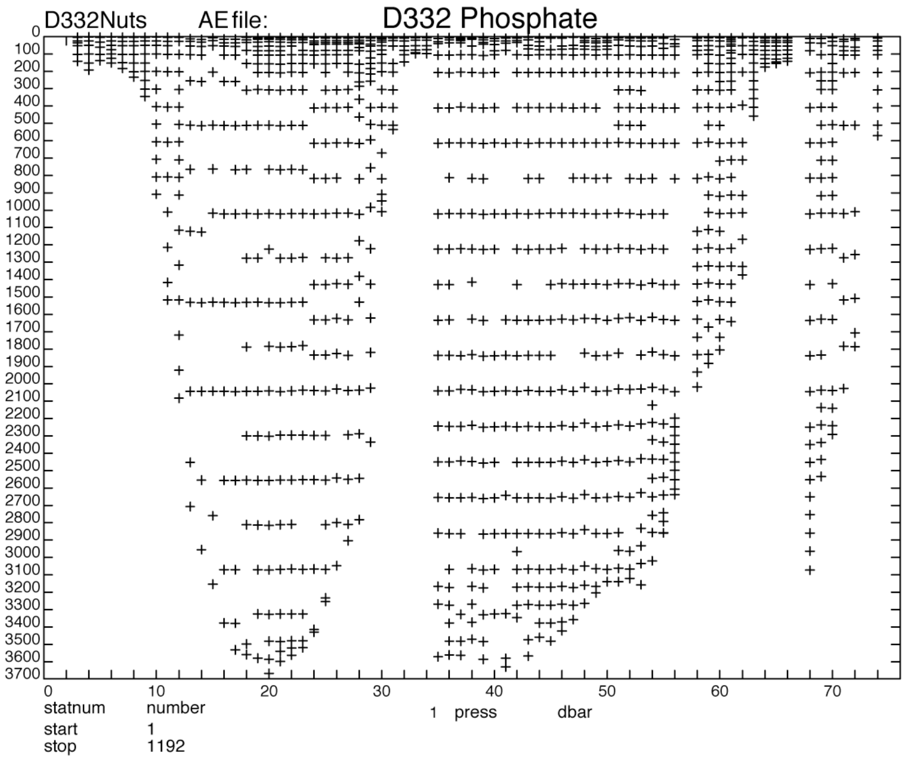



**Figure 8.12:** Spatial distribution of phosphate samples.

## 8.2 Calcite, POC, Chl

Emma Rathbone, Ian Salter, Esben Madsen

### *8.2.1 Objectives*

As part of my Undergraduate Masters of Oceanography research project, biological data was collected in order to investigate the effect of stratification, nutrients and $CO_2$ on coccolithophore dominance in the northern North Atlantic. Water samples were taken and filtered for particulate calcite; a proxy for coccolithophores. Furthermore, water samples were filtered for S.E.M. in order to distinguish individual species of coccolithophores. Two other biological parameters were measured: particulate organic carbon (POC) and chlorophyll (Chl). Three areas in the northern North Atlantic were investigated; 1. Labrador Basin, 2. The box around the tip of Greenland, and 3. The Irminger Basin. 239 samples were taken from 72 stations.

### *8.2.2 Methods*

Sampling

1.5 litre water bottles covered with black tape were used to collect water samples from the niskin bottles on the CTD. One was labelled 'surface' and the other 'Chlorophyll maximum', and samples were taken from these depths at all stations with the exception of stations which showed a well mixed upper water column, where only one sample was taken. Each bottle was flushed with the water sample three times and then filled. After sampling from the CTD, the samples were stored in a cold (4°c), dark environment to minimise biological activity. The samples were collected immediately after the CFC, $CO_2$, dissolved $O_2$, $\delta^{18}0$, salinity and nutrients.

Filtering

The water samples were filtered to measure four biological parameters:

*1* *Particulate calcite*: 250 ml of the water sample was filtered through a 0.2 µm polycarbonate filter and the filter funnel was rinsed with Milli-Q with a trace of ammonia to ensure that all the calcium in the salt residue was filtered. The filter was placed into a 50 ml falcon tube and labelled.

*2* *Particulate calcite for S.E.M.*: 10 ml of the water sample was filtered through a 0.2 µm polycarbonate filter and the filter funnel was rinsed with Milli-Q with a trace of ammonia which was filtered. The filter was placed into a plastic petri-dish, sealed with tape and labelled.

3 *Particulate organic carbon*: 250 ml of the water sample was filtered through a glass microfibre filter with a nominal pore size of 0.7 µm. The filter funnel was rinsed with artificial seawater (40 g per litre) to ensure that all organic material was filtered. The filter was placed into a plastic petri-dish, sealed with tape and labelled.

4 *Chlorophyll*: 250 ml of the water sample was filtered through a glass microfibre filter with a nominal pore size of 0.7 µm, and the filter funnel was rinsed with artificial seawater and filtered. The filter was placed into a plastic petri-dish, sealed, labelled and stored in a freezer set at –20 °C.

After each water sample was filtered, the equipment used; filter funnel, measuring cylinder and the plastic forceps, were rinsed with a 10% HCL wash and then rinsed with Milli-Q three times. In addition, the measuring cylinder was rinsed with 250ml of the water sample before use. This is to ensure that the water sample filtered was not contaminated with a previous sample. Furthermore, before the cruise the falcon tubes had been soaked in 10% HCL wash and then rinsed three times with Milli-Q. Plastic forceps were used to handle the filter to eliminate contamination.

Storage

The particulate calcite filters were stored in the onboard cold store to minimise biological activity. The glass microfibre filters were stored in a freezer set at -20°c to eliminate biological activity and to preserve the samples.

Duplicates and blanks

At some of the stations, duplicates filters were measured for particulate calcite. Filters were taken from both the polycarbonate filters and glass microfibre filters to measure as blanks. However, the glass microfibre filters were not combusted before the cruise so high particulate organic carbon blanks are expected.

Sample nomenclature

1. Particulate calcite filters: PCa - station number – niskin number - duplicate number e.g. PCa-001-24-1
2. S.E.M. filters: Mic - station number - niskin number e.g. Mic-001-24
3. Particulate organic carbon: POC – station number - niskin number e.g. POC-001-24
4. Chlorophyll: Chl - station number – niskin number e.g. Chl-001-24

### *8.2.3 Problems*

After the first pack of polycarbonate filters had been used (*Millipore Isopore* membrane filters; cat no. GTTP02500, lot no. R8CN54470), the filtration rate using the second pack (*Sterlitech* polycarbonate membrane filters; batch no. PCT0225100) was very low to the extent that the extraction of the desired solids was impractical in the time available (taking 4-8 hours to filter 250ml of water sample). After deciding that the filters were possibly hydrophobic, the method for measuring particulate calcite was altered to include filtering 2ml of propan-2-ol prior to the water sample, this effected a satisfactory filtration rate for the seawater sample. Furthermore, a pump with more suction was used to filter when using the *Sterlitech* polycarbonate membrane filters; this did increase the filtration rate. However, it is important to note that this pump overheated after being switched on for more than a few minutes. Nevertheless, it was discovered that the pump only had to be switched on for the time required to create a vacuum, which was still faster than the original pump.

### *8.2.4 Stations sampled*

Biological samples were only taken at stations where $CO_2$ was measured by the University of East Anglia, with the exception of stations in the box around the tip of Greenland, as no $CO_2$ samples were taken in this region. This was due to the fact that the effects of $CO_2$ on coccolithophore dominance were being determined and also time limitations. A maximum of two niskin bottles were sampled from each station due to the fact that the filtration apparatus only allowed one sample to be filtered at one time and because time was limited between stations.

| Station | Depth (m) | PCa-1 | PCa-2 | MIC | POC | Chl |
|---|---|---|---|---|---|---|
| 003 | | | | | | |
| | 35 | ✓ | | | | |
| 006 | 3 | ✓ | | | | |
| | | | | | | |
| 009 | 3 | ✓ | | | | |
| | | | | | | |
| 011 | 3 | ✓ | | | | |
| | | | | | | |
| 013 | | | | | | |
| | 25 | ✓ | | | | |
| 015 | 5 | ✓ | | | | |
| | | | | | | |
| 017 | 10 | ✓ | | | | |
| | | | | | | |
| 019 | 3 | ✓ | | | | |
| | | | | | | |
| 021 | 3 | ✓ | | | | |
| | 30 | ✓ | | | | |
| 023 | 5 | ✓ | | | | |
| | | | | | | |
| 025 | 5 | ✓ | ✓ | | ✓ | ✓ |
| | 30 | ✓ | ✓ | | ✓ | ✓ |
| 027 | 5 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 20 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 029 | 5 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 20 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 031 | 20 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 033 | 5 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 20 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 035 | 5 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 35 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 036 | 5 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 36 | ✓ | ✓ | ✓ | | |
| 037 | 5 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 32 | ✓ | ✓ | ✓ | ✓ | ✓ |
| 038 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | 50 | ✓ | | ✓ | ✓ | ✓ |
| 039 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | 35 | ✓ | | ✓ | ✓ | ✓ |
| 041 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | 30 | ✓ | | ✓ | ✓ | ✓ |
| 042 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | 30 | ✓ | | ✓ | ✓ | ✓ |
| 043 | 20 | ✓ | | ✓ | ✓ | ✓ |
| | | | | | | |
| 044 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | 25 | ✓ | | ✓ | ✓ | ✓ |
| 045 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | | ✓ | | ✓ | ✓ | ✓ |
| 046 | 5 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 50 | ✓ | | ✓ | ✓ | ✓ |
| 047 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | | | | | | |
| 051 | 5 | | | ✓ | ✓ | ✓ |
| | 20 | | | ✓ | ✓ | ✓ |
| 053 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | | | | | | |
| 055 | 10 | ✓ | | ✓ | ✓ | ✓ |
| | | | | | | |
| 065 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | 30 | ✓ | | ✓ | ✓ | ✓ |
| 061 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | 20 | ✓ | | ✓ | ✓ | ✓ |
| 059 | 5 | ✓ | | | | |
| | | | | | | |
| 068 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | 30 | ✓ | | ✓ | ✓ | ✓ |
| 069 | 10 | ✓ | | ✓ | ✓ | ✓ |
| | 35 | ✓ | | ✓ | ✓ | ✓ |
| 070 | 5 | ✓ | | ✓ | ✓ | ✓ |
| | | | | | | |
| 071 | 10 | ✓ | | ✓ | ✓ | ✓ |
| | 50 | ✓ | | ✓ | ✓ | ✓ |
| 072 | 20 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | | | | | |

**Table 8.2.1** Biological parameters filtered: 1, PCa-1 – Particulate calcite; 2, PCa-2 – Duplicate particulate calcite filter; 3, Mic Particulate calcite for S.E.M.; 4, POC – particulate organic carbon; 5, Chl – Chlorophyll, at each station and depth in the northern North Atlantic. Highlighted areas indicate the estimated chlorophyll maximum.

## 8.3 CFC and $SF_6$ Sampling

Katie Gowers, Ian Salter, Liz Kent, Joerg Frommlet, Roz Pidcock, Esben Madsen, John Allen, Katherine Cox and Emma Rathbone

### *8.3.1 Objectives*

The objective was to take CFC and $SF_6$ samples from CTD casts into glass ampoules and seal them under nitrogen for subsequent analysis at the University of East Anglia.

### *8.3.2 Materials*

Nitrogen bottle and regulator
Board with scrubbers
Ampoules
Stainless-steel tees
Butane blow lamp
Face guard, safety gloves and laboratory coat.

### *8.3.3 Set-up*

1 The purity line was removed from aluminium trunk and the indicator purity traps were checked to confirm the difference in colour between spent indicator and unspent.

2 The OFN cylinder + regulator were set-up in the hanger. The gas cylinder was securely clamped to the bench.

3 The Secure purity line was bolted to the bench close to gas cylinder to prevent movement in high seas.

4 The purity line was connected to gas cylinder. The 1/8" stainless steel tube was connected to the regulator.

5 The gas cylinder was opened and the regulator set to approximately 1Bar. All connections were tested with snoop to confirm that all connections were completely leak free.

6 The needle gauge was used to set flow rate to about 10ml $min^{-1}$, confirmed with the bubble flow meter.

7 A retort stand was secured adjacent to the purity board.

### *8.3.4 Problems encountered during set-up*

Several hours after connecting the purity lines it became clear that the oxygen scrubber/indicator had developed a leak (shown by the indicator darkening to 2/3 of the tube where it had been only 1/3 previously). It transpired that fragile glass connectors inside the oxygen scrubber had cracked. A replacement oxygen scrubber was fitted to the purity line. No further problems were experienced during the cruise.

### *8.3.5 Sampling*

$SF_6$ and CFC samples were taken first from the CTD:

1 Prior to the CTD arriving on deck ampoules were labelled with both the station number and the Niskin bottle to be sampled.

2 Labelled ampoules were then connected to the bottom of the tee by hand tightening the 3/8" ultra-torr fitting ensuring that the o-rings had created a secure fit

3 Next the moveable tube was moved to the bottom of the ampoule and the 1/8" ultra-torr tightened.

4 Stages 1 and 2 were repeated for the remaining ampoules (see Fig 8.3.1).

5 Sampling from the Niskin bottles was done using very short tubing and an adaptor connected to the moveable tube of the tee and the petcock of the Niskin.

6 The time taken to fill the bottle was counted and three rinse volumes were allowed to flow through the ampoule.

7 Once flushed but whilst the water was still running through the tee the moveable tube was raised to just below the 3/8" ultra-torr fitting and the 1/8" ultra-torr nut was tightened to secure the moveable tube in place. The cap was then hand-tightened on to the stationary tube.

8 The moveable tube was then removed from the Petcock of the Niskin and a cap hand-tightened on the end.

9 The ampoules (with tees still attached and capped) were then stored in the provided cool boxes on deck until all the ampoules were sampled for that station had been filled.

See Figures 8.3.1-2 for reference.

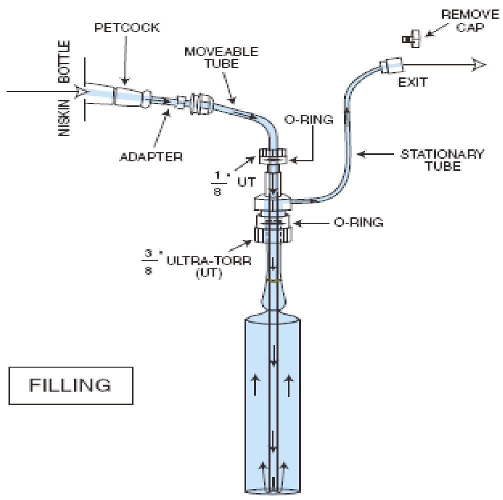



**Figure 8.3.1**: Schematic of the glass ampoule and tee during sampling.

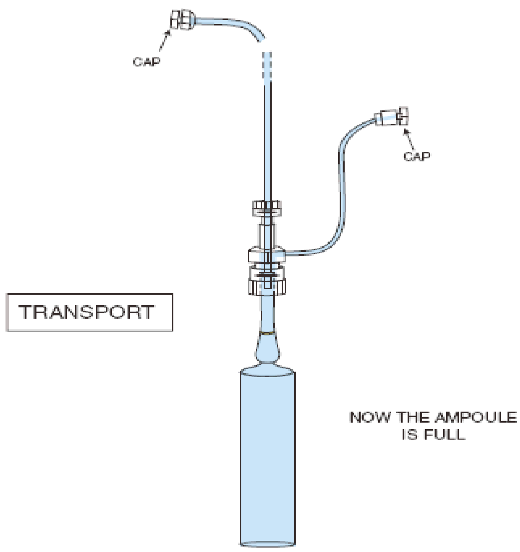



**Figure 8.3.2**: Schematic of the glass ampoule and tee during transport from the CTD to the sealing station.

*8.3.6 Problems encountered during sampling*

The sampling for CFCs and $SF_6$ was very time consuming, a problem augmented by not having enough metal tees in our possession. Due to the movement of the ship and the equipment provided it was necessary to support the ampoules by hand during the filling procedure. It became clear that this problem needed resolving. Accordingly, advice was sought from Sven Ober and Steve Whittle. Steve went off on a rummage and found PVC bars which could be machined and bored into new adaptors which screwed on to the moveable tube of the tees as well as fitting in the larger tap of the Niskin bottles creating a secure connection. After trialling, enough were produced to service a full cast. This eliminated the problem of not being able to leave the bottles unattended whilst sampling, as previously the adaptors did not secure well to either the tees or the Niskin bottles. The new adaptors, being made of rigid PVC, meant that sampling became much quicker without contamination of the CFC samples.

### *8.3.7 Flame Sealing*

1. The nitrogen regulator was set up to approximately 1.3-1.5 psi and the nitrogen turned on to flush the system.

2. A flow meter was then used to adjust the flow out of a needle valve to around 10ml/min.

3. The cap was then removed from the stationary tube and connected to the needle valve whilst nitrogen was flowing followed by the removal of the cap on the moveable tube. This allowed water in the tee to be replaced by nitrogen.

4. The 1/8" ultra-torr nut was loosened and the moveable tube pushed down to just above the bottom of the neck of the ampoule allowing the water in the neck to be displaced by nitrogen.

5. With the nitrogen still flowing the moveable tube was pulled up to just below the 3/8" ultra-torr fitting and tightened with the 1/8" ultra-torr fitting to secure it for the sealing process.

6. A butane blow lamp was used to warm and then melt the neck of the ampoule at about 2cm above the water level. Once the glass started to melt the neck was pulled gently upwards from the tee and was melted to create a seal.

7. Ampoules were then allowed to cool before the seal was tested by inverting the ampoule, any ampoules that did not seal were noted on the log sheets.

See Figure 8.3.3 for reference.

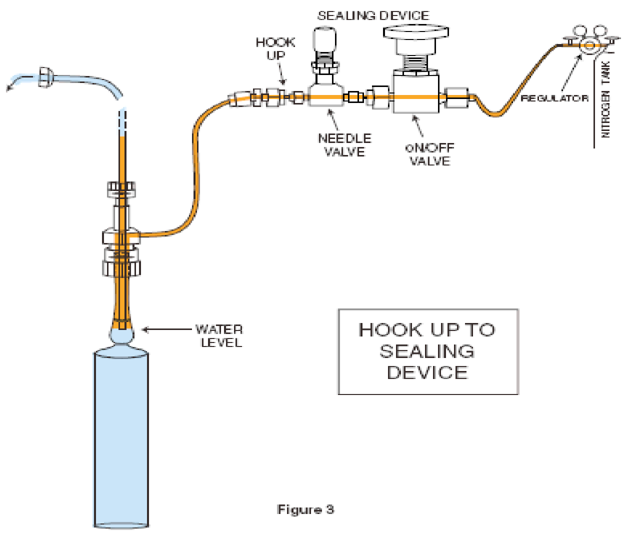



**Figure 8.3.3:** Schematic of the glass ampoule and tees during flame sealing

### *8.3.8 Problems encountered during sealing*

Sealing of the ampoules began as soon as the last ampoule was sampled, however due to the time involved in both sampling and sealing the ampoules there was occasionally as much as a couple of hours between the sampling and sealing of the ampoules. This exceeds the prescribed 1 hour recommended by UEA. On a number of occasions the glass ampoules did not seal properly. This resulted in the loss of samples.

### *8.3.9 Storage*

Once it was determined whether the ampoules had sealed they were securely wrapped in bubble wrap and placed in the cool boxes provided ready for transport home.

### *8.3.10 Stations sampled*

| Stn | No. of samples | Stn | No. of samples | Stn | No. of samples | Stn | No. of samples |
|---|---|---|---|---|---|---|---|
| 2 | 6 | 17 | 10 | 33 | 4 | 59 | 8 |
| 3 | 3 | 19 | 9 | 53 | 9 | 58 | 8 |
| 6 | 2 | 21 | 9 | 55 | 9 | 68 | 7 |
| 9 | 4 | 23 | 11 | 57 | 9 | 69 | 9 |
| 11 | 6 | 25 | 9 | 65 | 4 | 70 | 8 |
| 13 | 8 | 29 | 6 | 63 | 3 | 59 | 8 |
| 15 | 10 | 31 | 6 | 61 | 7 | | |

## 8.4 Alkalinity and $TCO_2$ Sampling

Esben Madsen and Emma Rathbone

*Additional operators*: Ian Salter, John Allen, Roz Pidcock, Jörg Frommolet, Katherine Cox.

Water samples were collected during D332 for subsequent analysis of alkalinity and $TCO_2$ by the University of East Anglia.

### *8.4.1 Materials: Preparation of a saturated $HgCl_2$ solution*

<u>Materials and ingredients</u>

Plastic container with screw lid
MilliQ water
Mercuric chloride ($HgCl_2$) (solid)
Marker pen and marking tape
Spoon (clean)
Safety glove, safety glasses, laboratory coat

The plastic container was labelled '$HgCl_2$ saturated solution, (date), UEA'. Then:

- A spoonful of $HgCl_2$ powder was added to the plastic container;
- MilliQ was added to the container and the $HgCl_2$ powder allowed to dissolve;
- More $HgCl_2$ powder was added to the solution in the container until solid $HgCl_2$ powder remained at the bottom of the container. The presence of $HgCl_2$ powder at the bottom of the container was checked regularly.

### *8.4.2 Alkalinity/$TCO_2$ methods*

Joint alkalinity and $TCO_2$ bottles were labelled prior to water sampling, ensuring that each bottle had a unique number (cast number and Niskin number). White tape and permanent black marker pens were used for labelling purposes. Prior to water sampling, a sampling sheet was completed, indicating station/cast number, and the Niskins from which samples with their unique number were taken. Work was carried out in GMT.

<u>Sampling</u>

Sampling procedures described in the SOP1 by Dickson and Goyet were followed. Samples were drawn from 20L Niskin bottles from 28 stations. The 250 ml glass bottle for the joint alkalinity and $TCO_2$ sample was rinsed with 30-50 ml of sample water. The tygon tubing was placed in the bottom of the bottle, and the bottle was filled from the bottom to the top. Bubbles were removed from the tubing by squeezing the tube, and removed from the bottle by moving the tubing around as well as gently tapping with against the deck or CTD rack. The bottle was allowed to overflow for ten slowly counted seconds. After sufficient overflow, the tygon tube was slowly pulled to the surface of the bottle. While maintaining the flow, to prevent bubbling when removing the tubing, the tube mouth was manoeuvred laterally across the surface of the overflowing sample water and out of the bottle. The bottle was then secured with a stopper, placed in a temporary storage box. The full set of samples were then taken to the wet lab.

Fixing

Fixing of samples was carried out in the wet lab shortly after sampling. The stopper was removed from the bottle and a small headspace created by removing 2.5 ml of the sample with a pipette. The stopper was dried with blue paper towel. The stopper was greased with 4 strips of grease, each extending 2/3 of the way from the top towards the bottom ground portion of the stopper. The 250 ml sample was poisoned with 50 µl of the prepared saturated mercuric chloride solution. The stopper was inserted into the bottle twisted to squeeze air out of the grease and create a good seal. A rubber band was placed around the bottle and stopper. The bottle was shaken, while keeping the stopper in place. Gloves, safety glasses and laboratory coats were used for this method due to the hazardous chemical handled. The used gloves and pipette tips were stored in a tight glass jar for subsequent disposal.

Storage

The bottle was packed in its cardboard box and packed into a storage crate along with samples from the same station/cast. After the samples were packed into crates, a note was made of the samples contained within each individual storage crate. The crates had room for 48 samples. Sampling constraints did not always allow for a full set of 24 samples to be taken from each CTD cast, and therefore samples from one individual cast were in some cases spread over two storage crates.

Stations sampled

No water samples were taken for $CO_2$ to the east of Greenland from stations 35 to 51. The majority of the remaining stations were sampled. Three duplicate samples were taken at all stations. A duplicate was taken at the deepest depth, and the remaining two were taken at intermediate or shallow depths. The total number of samples taken on this cruise was 500. See Table 8.4.1.

| Station number | No. of $CO_2$ samples | Duplicate samples | Station number | No. of $CO_2$ samples | Duplicate samples |
|---|---|---|---|---|---|
| 002 | 6 | 3 | 031 | 10 | 3 |
| 003 | 4 | 3 | 033 | 6 | 3 |
| 006 | 4 | 3 | 053 | 23 | 3 |
| 009 | 4 | 3 | 055 | 22 | 3 |
| 011 | 12 | 3 | 057 | 24 | 3 |
| 013 | 12 | 3 | 058 | 21 | 3 |
| 015 | 12 | 3 | 059 | 24 | 3 |
| 017 | 14 | 3 | 065 | 9 | 3 |
| 019 | 22 | 3 | 063 | 12 | 3 |
| 021 | 24 | 3 | 061 | 23 | 3 |
| 023 | 22 | 3 | 068 | 24 | 3 |
| 025 | 24 | 3 | 069 | 24 | 3 |
| 027 | 24 | 3 | 070 | 24 | 3 |
| 029 | 24 | 3 | 071 | 12 | 3 |

**Table 8.4.1:** CO2 / alkalinity samples and duplicates.

## 8.5 Dissolved Oxygen

Jörg Frommlet

Additional analysts: Emma Rathbone, Esben Madsen, Ian Salter and Katie Gowers

### *8.5.1 Introduction*

Dissolved oxygen profiles during cruise D332 were measured using a SBE 43 membrane polarographic oxygen detector (Sea-Bird electronics, Inc.). At the working electrode (cathode) of this type of sensor, oxygen gas molecules are converted to hydroxyl ions ($OH^-$). The electrode supplies four electrons per molecule oxygen to complete the reaction. The sensor counts oxygen molecules by measuring the electrons per second (amperes) delivered to the reaction. At the anode, silver chloride is formed and silver ions ($Ag^+$) are dissolved in solution. Consequently, the chemistry of the sensor electrolyte changes continuously as oxygen is measured and this produces a slow but continuous change of the sensor calibration over time.

To correct for this change of the sensor calibration, reference measurements of dissolved oxygen in discrete water samples were performed, using Winkler titration. The Winkler titration is based on the quantitative oxidization of iodide ions to iodine by the oxygen in a sea water sample. The amount of iodine generated in this fashion is determined by titration with a standard thiosulfate solution. Water samples from various depths were analysed regularly with this method, the depths being chosen based on observed minima and maxima in the oxygen profile.

### *8.5.2 Material and Method*

<u>Calibration of Dissolved Oxygen Analyser</u>

*Determination of the blank* – Blank measurements were performed every fourth day (see also table 8.5.1), unless sampling had been interrupted for longer periods of time due to e.g. bad weather. Thoroughly rinsed bottles were filled to around 4/5 with Milli-Q water, 1mL of iodide standard (1.667 mM, Osil) and 1 mL of $H_2SO_4$ (5 M) were added and blanks were mixed on the stirring plate of the oxygen unit. Then 1 mL of alkaline iodide (320 g/L sodium hydroxide, 600 g/L sodium iodide) was added, blanks were stirred, 1 mL of $MnCl_2$ was added and blanks were stirred again. The titration was started and, once complete, the titre volume ($V_1$; Addition 1) was recorded. This was followed by a second addition of 1 mL of alkaline iodide to the blank and the titration was repeated ($V_2$; Addition 2). According to another protocol, a total of four additions of alkaline iodide were made. Depending on the protocol the blank value was calculated as follows:

$$V_{blank} = V_1 – V_2, \text{ or alternatively:}$$

$$V_{blank} = V_1-((V_2 + V_3 + V_4)/3)$$

Typically, five blanks ($V_{blank}$) were measured and the average value was used in calculating the oxygen concentrations of samples until new blank measurements were performed.

*Standardization of sodium thiosulfate titrant* – Regular standardization is important to correct for the time related degradation of the sodium thiosulfate reagent. The standardization was usually performed every fourth day (see also table 8.5.2), directly following the measurement of blanks. Thoroughly rinsed bottles were filled to around 4/5 with Milli-Q water, 5 mL of iodide standard and 1 mL of $H_2SO_4$ were added and standards were mixed on the stirring plate of the oxygen unit. Then 1mL of alkaline iodide was added, blanks were stirred, 1 mL of $MnCl_2$ was added and blanks were stirred again. The titration was started and, once complete, the titre volume was recorded. Typically, five standard measurements were performed and the average titre volume was used in calculating the oxygen concentrations of samples until new standard measurements were performed.

*Sampling* – Water samples for the measurement of dissolved oxygen were drawn off first from the CTD Niskin bottles to minimize gas exchange between the atmosphere and the sample. To sample, a piece of rubber tubing, approximately 20 cm long, was attached to the Niskin bottle nozzle. Before the samples were drawn, any air in the tube was displaced. The tube was then lowered to the bottom of the sampling bottles and the samples were taken without creating bubbles. The water was allowed to overflow until the bottles had been flushed with approximately 3 times their volume. The temperature of water samples was measured during the filling of bottles using a handheld electronic thermometer.

*Sample processing* – Samples were fixed directly after collection by adding 1 mL of a manganese chloride solution (600 g/L) followed by 1mL of alkaline iodide solution (320 g/L sodium hydroxide, 600 g/L sodium iodide). Both solutions were added using automatic dispensers (1-5 mL, Ceramus classic, Hirschmann Laborgeräte) the tip of the dispenser being inserted about 10 mm below the water level to prevent bubbles being introduced into the sample. The lids were placed on the bottles making sure no bubbles were trapped and the bottles were thoroughly shaken. A precipitate of manganese (II) and (III) hydroxides formed. The precipitate was given 30-60 min to settle before the samples were shaken again. After the precipitate had settled for another 30-60 min the samples were analysed.

*Winkler titration* – The sampling bottles were opened carefully to avoid spillage and 1 mL of sulphuric acid (5 molar) was added. The samples were stirred on the Dissolved oxygen Analyser (E649, Metrohm) using a magnetic stirring bar until the precipitate had dissolved and a clear yellow iodine solution had formed. The pipette from the automated burette (665 Dosimat, Metrohm) was lowered into the solution and the titration was started. The burette slowly added a sodium thiosulphate solution (25 g/L) until the iodine solution had been reduced to a colourless iodide and tetrathionate solution. The amount of dissolved oxygen (µmoles $O_2$/L) was calculated using the following equations with V = Titre volume (mL), Vol = Volume (mL) and M = molarity:

$$O_2 \text{ (moles)} = 1.5 * (V_{Sample} - V_{Blank}) * (Vol_{Standard} / 1000) * \text{Iodate (M)} / (V_{Standard} - V_{Blank})$$

$$O_2 \text{ (µmoles/L)} = (O_2 \text{ (moles)} - 0.000000075) / (Vol_{Bottle} / 1000) * 1000000$$

*Data analysis* – Average dissolved oxygen concentrations, the mean difference and the standard deviation were calculated based on duplicate measurements. The actual oxygen sensor calibration is described in section 3 by Liz Kent.

### *8.5.3 Results and Discussion*

*Blank and standard measurements* – Blank measurements were comparable to those of previous cruises and ranged from 0.0199 to 0.0377 (Table 8.5.1). For the determination of $V_{blank}$ two protocols were used previously - One in which only a second addition of alkaline iodide is made and another protocol in which also a third and a fourth addition of alkaline iodide is made (see difference in calculating $V_{blank}$ in materials and methods). As shown by a comparison of blank values determined with the two protocols (compare value for 01.09.2008 with other values in Table 8.5.1), multiple additions did not result in significantly different values for $V_{blank}$ and hence the quicker protocol of only adding alkaline iodide twice was adopted for all other blank measurements.

**Table 8.5.1:** Blank measurements.

| Date | | Blank 1 | Blank 2 | Blank 3 | Blank 4 | Blank 5 | Average |
|---|---|---|---|---|---|---|---|
| 20.08.2008 | Addition 1 | 0.0890 | 0.0952 | | | | |
| | Addition 2 | 0.0780 | 0.0702 | | | | |
| | $V_{blank}$ | 0.0110 | 0.0250 | | | | 0.0180 |
| 21.08.2008 | Addition 1 | 0.0994 | 0.0961 | 0.1014 | 0.0952 | 0.1007 | |
| | Addition 2 | 0.0701 | 0.0412 | 0.0532 | 0.0687 | 0.0709 | |
| | $V_{blank}$ | 0.0293 | 0.0549 | 0.0482 | 0.0265 | 0.0298 | 0.0377 |
| 24.08.2008 | Addition 1 | 0.0929 | 0.0939 | 0.0949 | 0.0931 | 0.1002 | |
| | Addition 2 | 0.0758 | 0.0742 | 0.0658 | 0.0723 | 0.0713 | |
| | $V_{blank}$ | 0.0171 | 0.0197 | 0.0291 | 0.0208 | 0.0280 | 0.0231 |
| 28.08.2008 | Addition 1 | 0.0937 | 0.0941 | 0.0929 | 0.0941 | 0.0955 | |
| | Addition 2 | 0.0710 | 0.0751 | 0.0734 | 0.0732 | 0.0781 | |
| | $V_{blank}$ | 0.0227 | 0.019 | 0.0195 | 0.0209 | 0.0174 | 0.0199 |
| 01.09.2008 | Addition 1 | 0.0981 | 0.0964 | 0.0961 | 0.0946 | 0.0958 | |
| | Addition 2 | 0.0612 | 0.0738 | 0.0746 | 0.0737 | 0.0748 | |
| | Addition 3 | 0.0687 | 0.0753 | 0.0693 | 0.0733 | 0.0719 | |
| | Addition 4 | 0.0716 | 0.065 | 0.0721 | 0.0716 | 0.0744 | |
| | Average (2-4 ) [a] | 0.0672 | 0.0714 | 0.0720 | 0.0729 | 0.0737 | |
| | $V_{blank}$ | 0.0309 | 0.0250 | 0.0241 | 0.0217 | 0.0221 | 0.0248 |
| 05.09.2008 | Addition 1 | 0.1001 | 0.0901 | 0.0952 | 0.0959 | 0.0967 | |
| | Addition 2 | 0.0674 | 0.0724 | 0.0721 | 0.0735 | 0.0731 | |
| | $V_{blank}$ | 0.0327 | 0.0177 | 0.0231 | 0.0224 | 0.0236 | 0.0239 |
| 13.09.2008 | Addition 1 | 0.0956 | 0.1018 | 0.1022 | 0.0934 | 0.0979 | |
| | Addition 2 | 0.0774 | 0.079 | 0.0696 | 0.0705 | 0.0741 | |
| | $V_{blank}$ | 0.0182 | 0.0228 | 0.0326 | 0.0229 | 0.0238 | 0.0241 |
| 21.09.2008 | Addition 1 | 0.1010 | 0.0965 | 0.1031 | 0.0929 | 0.1029 | |
| | Addition 2 | 0.0769 | 0.0749 | 0.0785 | 0.0741 | 0.0764 | |
| | Difference | 0.0241 | 0.0216 | 0.0246 | 0.0188 | 0.0265 | 0.0231 |

Note a: A total of four additions was made and the average of additions 2-4 was used in the blank calculation. Values are shown in mL.

Values for the titre volume of sodium thiosulfate standards are shown in Table 8.5.2. The values were comparable to those of previous cruises and ranged from 0.4978 to 0.5033. As a result of the slow degradation of the *sodium thiosulfate* solution, the titre volume increased slightly over time. This did however not affect the analysis of samples since the standardization process takes this aging of the titrant into account.

**Table 8.5.2**: Standardization of sodium thiosulfate titrant. Values are shown in mL.

| Date | STD 1 | STD 2 | STD 3 | STD 4 | STD5 | Average |
|---|---|---|---|---|---|---|
| 20.08.2008 | 0.4984 | 0.4985 | 0.4977 | 0.4966 | 0.4976 | 0.4978 |
| 24.08.2008 | 0.4983 | 0.5015 | 0.5012 | 0.4999 | 0.5021 | 0.5006 |
| 28.08.2008 | 0.4998 | 0.4995 | 0.4989 | 0.4993 | 0.5 | 0.4995 |
| 01.09.2008 | 0.4992 | 0.4973 | 0.4995 | 0.4983 | 0.4966 | 0.4982 |
| 05.09.2008 | 0.5002 | 0.5005 | 0.5009 | 0.5008 | 0.5005 | 0.5006 |
| 13.09.2008 | 0.5000 | 0.5003 | 0.5014 | 0.5007 | 0.5010 | 0.5007 |
| 21.09.2008 | 0.5035 | 0.5043 | 0.5034 | 0.5033 | 0.5020 | 0.5033 |

*Sampling statistics*- During D332 a total of 51 CTD casts were sampled. From each of the sampled CTD casts between 3 and 12 (predominantly 5) Niskin bottles were sampled, of which generally 1 or 2 were sampled in duplicate. This resulted in a total of 314 analysed samples. CTD casts that were sampled for dissolved oxygen were: 001, 004, 005, 007, 008, 010, 012, 014, 016, 018, 020, 022, 024, 026, 028, 030, 032, 034, 035, 036, 037, 038, 039, 040, 041, 042, 043, 044, 045, 046, 047, 048, 049, 050, 051, 052, 054, 056, 058, 060, 062, 064, 066, 067, 068, 069, 070, 071 (oxygen sensor failed), 072, 073, 074. See figure 8.5.1 for sampled depths.

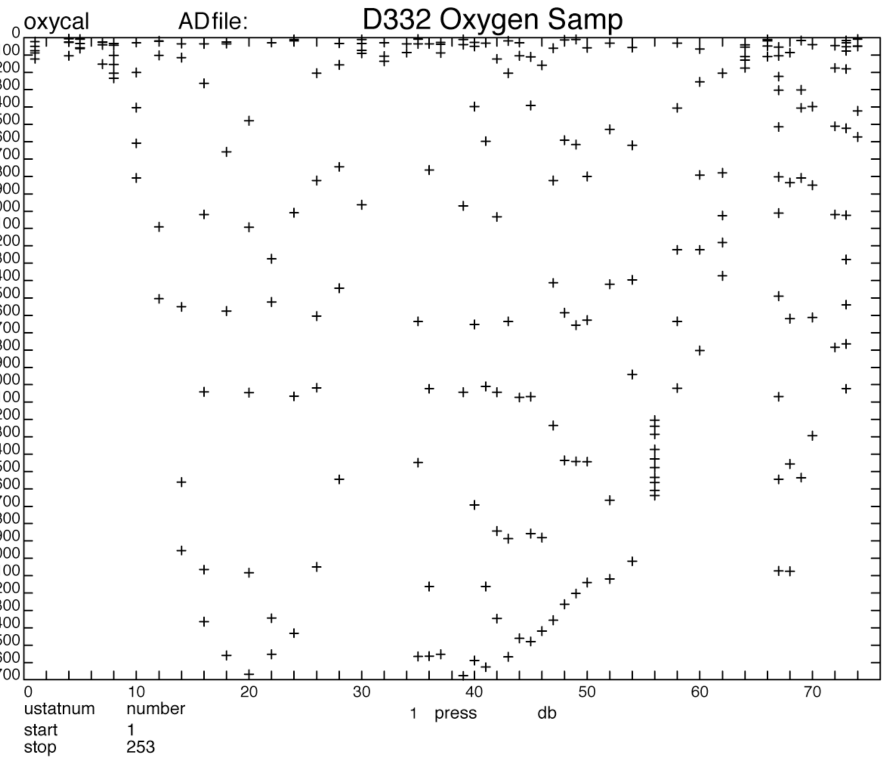



**Figure 8.5.1:** Sampling depths of the 51 casts of which dissolved oxygen measurements were conducted.

*Instrument performance and reproducibility of Winkler titration* – Throughout cruise D332, the dissolved oxygen analyser worked consistently well and no significant errors or problems were encountered with the instrument. Based on 39 duplicate measurements the calculated overall mean difference between duplicates was 0.4325 µmoles $O_2$/L (< 0.2 %) and the standard deviation was 2.35 µmoles $O_2$/L, showing good reproducibility.

*Replacement* of *SBE 43 oxygen sensor* – On the 22.09.2008 (cast 71) the oxygen sensor with the serial number 430619 (hereafter referred to as 'old oxygen sensor') failed and had to be replaced by a new oxygen sensor with the serial number 430709 (hereafter referred to as 'new oxygen sensor'). Measurements of dissolved oxygen using the Winkler titration up to, and including, cast 70 are therefore to be used to calibrate the old oxygen sensor and measurements of casts thereafter are to be used to calibrate the new oxygen sensor.

*Sensor calibration* - The Winkler titration data provides the necessary references to calibrate the oxygen sensor 430619 and will gives a first indication for the performance of the oxygen sensor 430709. For details regarding the actual calibration of sensors see section 3 by Liz Kent.

## 8.6 Oxygen Isotope Samples

Katharine Cox

Water samples for $\delta^{18}O$ analysis were collected from all 74 CTD stations (excluding test station 1) and each depth level that was sampled, 1220 samples were collected in total. The samples were collected immediately after CFC, $CO_2$ and $O_2$ samples. They were collected in 28 ml McCartney glass bottles. These were labeled [D332- 'station number'-'niskin number'].

The bottles and caps were flushed three times with the sample, and then filled leaving a 5-10 mm head space to accommodate thermal expansion of the water. After filling, the bottles were sealed using an aluminium screw cap with a high density rubber seal insert; to prevent the aluminium caps from loosening, the bottles were then further sealed with insulation tape. The samples were then stored in the onboard cold store, set to 4 °C, to reduce the risk of evaporation of the samples and minimise thermal expansion.

The water samples were freighted back to NOCS for analysis. They will be analysed for $\delta^{18}O$ using a GV Instruments Multiprep Isoprime dual inlet mass spectrometer. These data will then be used in conjunction with $\delta^{18}O$ data from the water samples collected on D298 in order to determine the freshwater sources to North Atlantic via the East Greenland Current, the West Greenland Current and the Labrador Current.

## 8.7 Salinometry

Katharine Cox and Esbsen Madsen

Additional operators: Roz Pidcock, John Allen, Katie Gowers, Emma Rathbone.

Salinity samples were drawn from the Niskin bottles mounted on the CTD rosette that sampled the surface and bottom waters and several depth levels in between where a constant salinity was observed from the CTD. Four to five samples were taken per CTD cast. A duplicate sample was taken from an intermediate depth at most stations. Samples were taken using 200ml glass bottles; these were flushed three times with the sample and then filled to the shoulder. The bottleneck, plastic insert and bottle screw cap were wiped dry to prevent salt crystallisation before sealing the bottles.

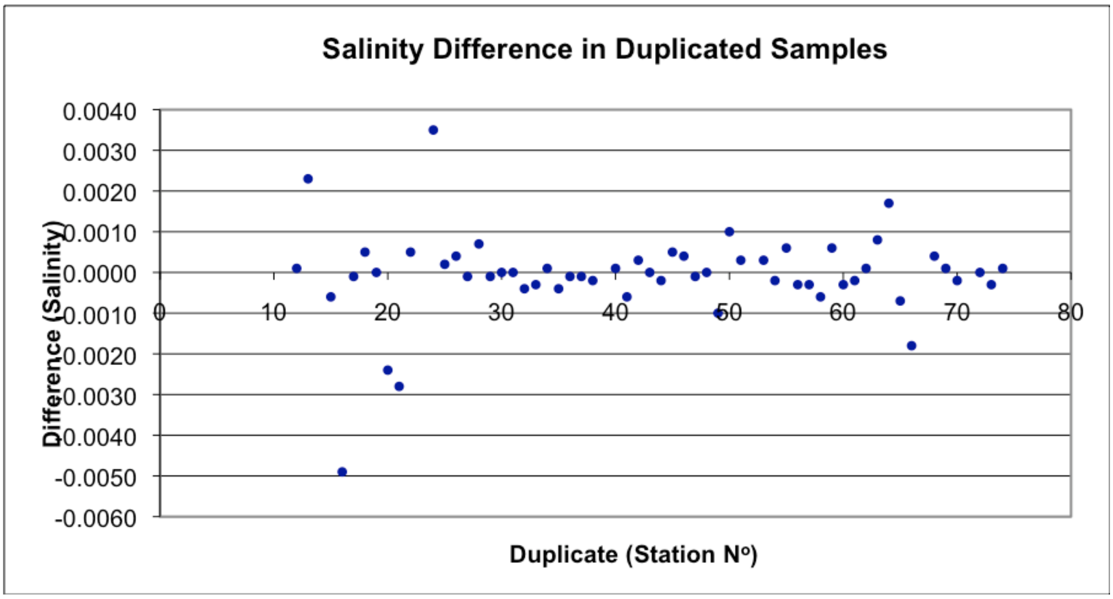
Salinity analyses were performed using a Guildline Autosal salinometer (model 8400B, serial no. 65764), fitted with a peristaltic pump, installed in the controlled temperature laboratory (maintained at 24$^{o}$C). According to the manual, the 8400B can operate successfully at lab temperatures between 4°C below and 2°C above the bath temperature, the preferred temperature being in the middle of this range. The bath temperature was set at 24°C. A thermometer was used to measure the temperature of the CT lab, which has not varied throughout the cruise. Salinity samples were stored in the CT lab for a minimum of 24 hours prior to analysis to allow equilibration to the lab conditions. The salinometer was calibrated using the IAPSO standard seawater (batch number P148, 10$^{th}$ October 2006), which has a salinity of 34.993 ($K_{15}$ = 0.99982). OSIL's Autosal software, SoftSal, was used throughout. On multidisciplinary cruises this expedites the entry of determined salinities into excel spreadsheets for merging with instrument data files. The software and the Autosal worked well.

Salinity values were copied in to an Excel spreadsheet, and then transferred to the Unix system in the form of a tab-delimited ASCII file. Data from the ASCII files were then incorporated into the sam files using the Pstar script passal. Initial calibrations of both the thermosalinograph and the SeaBird CTD were made successfully at the end of the cruise.

The stability of measurements, determined by monitoring the standard deviation of the salinity measurements, was good. With few exceptions, the bottle samples were determined to a precision greater than 0.001. Additionally, over the period of the cruise 74 duplicates were taken, the differences between these duplicate samples are shown in figure 8.7.1. The mean difference is 0.0001 with a standard deviation of these differences of 0.001, this indicates consistent sampling and stability in the measurements.

As mentioned on a number of previous cruises, there are a couple of points worth noting about using this software however; firstly the software encourages the operator to re-trim the salinometer after each standardisation to the IAPSO standard seawater. This is almost certainly because the measured salinity standard is not recorded in the output file (the second point to note), so no post measurement offset can be made. OSIL's latest software (advertised in the IAPSO standard seawater boxes), looks as though it overcomes this limitation, furthermore it is designed to be directly compatible with spreadsheet software like MS Excel. Standard seawater samples were analysed after every crate as a quality check.

**Figure 8.7.1:** Plot of the differences between salinity measurements of duplicate samples.




## 8.8 Secondary production and biomass

Santiago R. Gonzalez

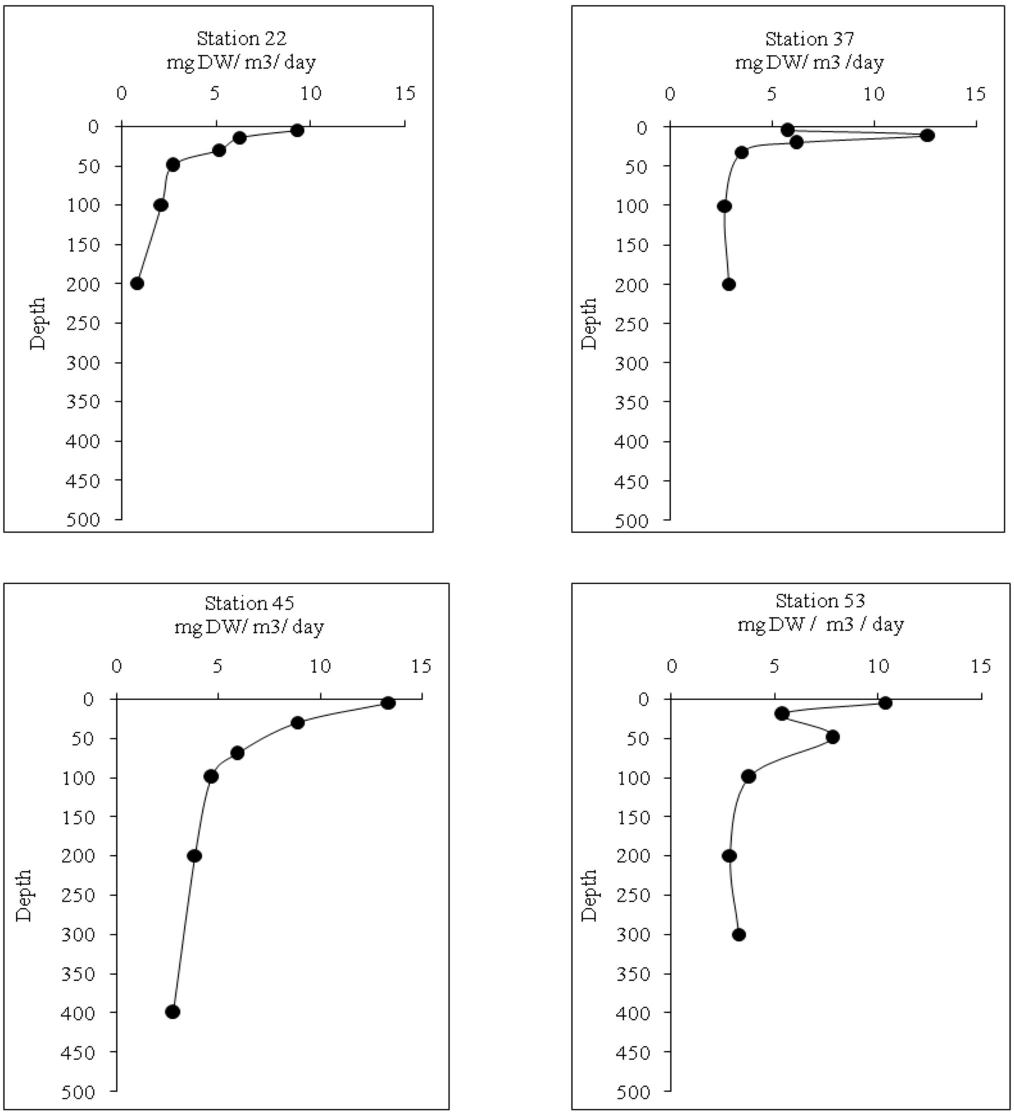
In the process of moulting, crustaceans use an enzyme, chitobiase, that plays a role in the degradation of the old exoskeleton into mono aminosugars. These are in turn used for building the new exoskeleton underneath the old skeleton. Once the old exuvium is shed, the enzyme is released freely into the ambient water. A relation between the released enzyme activity and the increase in biomass (secondary production) was found by Oosterhuis et. al. (MEPS, 2000)

During the DISCOVERY cruise D-332, August 19$^{th}$ until September 25$^{th}$, the secondary (crustacean) production through the water column was measured at 9 stations. 0.5 liter water samples were taken from the rosette sampler at discrete depths. 5 ml samples from these 0.5 liter bottles were used for the chitobiase assay. The water bottles were stored in a climate room at approximately 4 degrees Celcius. The assay was done by adding 200 ul Tris/HCl buffer (final pH=7.5) and 100 ul of the substrate Methylumbelliferyll N-acetyl b-D glucosaminide (final concentration 150 mM). The enzyme activity was measured after a 2 hours incubation period at $25^{0}$ C using a spectrofluorometer, exitation 366 nm, emission 450 nm. The activity of the enzyme was also measured in the different bottles during a period of 24 hours. This gives the degradation rate of the enzyme by mainly bacteria. From the degradation rate and the initial enzyme activity, the total release of chitobiase per day can be calculated. From here, the increase in biomass expressed as mg dry weight per m3 per day (secondary production) can be estimated using the relation found by Oosterhuis et. al. (MEPS, 2000).

To estimate zooplankton biomass, vertical net hauls were done at the 9 stations prior to the water sampling for the chitobiase assays. The water column was sampled from 100 meter depth to surface. The catches were preserved in 4% formalin and stored for later analysis.

Preliminary results

**Figure 8.8.1:** Examples of the production profiles as measured at selected stations.



# 9 UNDERWAY SURFACE METEOROLOGY

Elizabeth Kent

## 9.1 Surfmet processing

The Ships' *surfmet* system logs data from a range of meteorological and underway sensors. The meteorological system comprises pressure, air temperature, humidity, wind speed and direction (all on the port foremast) and pairs of shortwave sensors for each of total incident radiation (TIR) and photosynthetically active radiation (PAR). The underway pumped system measures sea surface temperature (SST), conductivity (along with the temperature at the which the conductivity is measured, required for salinity calculation), fluorescence and the transmissivity of the seawater.

| Variable | Instrument type | Instrument number | Calibration $a + bx + cx^2 + dx^3$ |
|---|---|---|---|
| Port PAR | Skye Instruments Energy Sensor (400nm-700nm) | SKE 510 1204 28561 | b = 1.020 mV per 100 $Wm^{-2}$ |
| Starboard PAR | Skye Instruments Energy Sensor (400nm-700nm) | SKE 510 1204 28562 | b = 1.020 mV per 100 $Wm^{-2}$ |
| Port TIR | Kipp and Zonen Pyranometer, Model CM6B | 973135 | b = 11.66 $\mu V/(Wm^{-2})$ |
| Starboard TIR | Kipp and Zonen Pyranometer, Model CM6B | 973134 | b = 10.84 $\mu V/(Wm^{-2})$ |
| Air Temperature/Humidity | Vaisala HMP45 | C1320001 | output meets specification |
| Air Pressure | Vaisala, PTB100A | U1420016 | a = 3.51188e-1 b=9.99218e-1 |
| SST | FSI Temperature Module, OTM | 1401 | a = -8.86735e-3 b=1.00053e0 c=-8.88572e-5 d=1.95377e-6 |
| Conductivity (uncalibrated, coefficients from CTD comparison) | OCM Conductivity | 1339 | a = 0.65567 b= 1.1108 |
| Thermosalinograph temperature | FSI Temperature Module, OTM | 1339 | a = -1.36685e-2 b=1.00070e0 c=-4.31229e-5 d=8.84556e-7 |
| Wind speed & direction | Gill Windsonic | 071123 | none |
| Fluorescence | Wetlabs | WS3S-247 | a = 0.055V b=12.4/µg/l/V |

| Variable | Instrument type | Instrument number | Calibration $a + bx + cx^2 + dx^3$ |
|---|---|---|---|
| Transmission | Wet Labs | CST-114R | a= 0.013063<br>b= 0.217723 |

A new version of the *surfmet* logging software had been installed on a previous cruise, however there were bugs in the software which meant that the contents of the "airtemp" stream and the "temp_m" stream were identical and that air temperature was not being logged, although it was being displayed on the screen. It later became clear that the "temp_m" stream which was supposed to contain SST actually contained the thermosalinograph (TSG) temperature "temp_h". The *surfmet* code was not available on board to correct these problems and there were delays before a new version of the code was made available. The temp_m and temp_h streams were not swapped however as it was thought easier to have them logging in the same way for the whole cruise. Air temperature data were logged from 10:17 on day 250. Prior to this the air temperature values noted on the nominally hourly watch-keeping log were typed in and added to the file.

Throughout the cruise the TSG system had suffered from periodic data losses with bad data recorded for the two temperature variables and for conductivity. This problem became worse over time, and eventually the system failed. The problem was traced to the Ethernet connection and there was a major loss of *surfmet* data between 14:40 on day 249 and 08:35 on day 250 whilst a replacement Ethernet box was built.

Data from the *surfmet* system was transferred daily from the ship's computer system and processed to give along track surface properties such as sea surface temperature, air pressure and true wind speed.

Data were logged from the Shipborne Wave Recorder (SBWR) for processing ashore. On the following cruise (D333) however, Robin Pascal checked the SWBR system and found that the pressure sensors which provide the high frequency component of the wave record were not switched on. The measurements taken on D332 therefore constitute only the low frequency part of the wave signal and are therefore only indicative of the amount of swell present, excluding any wind-wave component.

Four scripts were used in the processing:

*surfmet0* convert data into PSTAR format; add in header information such as the name of the ship and variable names

*surfmet1* selected only data with non-zero time difference and pressure, removes 1.2% and 0.3% of the data respectively. When pressure is zero, all other variables apart from time are zero. A variable equal to zero was inserted for later use in salinity calculation. Conductivity is calibrated (see below). Editing specific to D332 based on data cycle numbers was carried out to 1) remove erroneous air temperatures 2) remove TSG variables when Ethernet connections caused bad data. Further general editing was carried out to range data and to remove spikes (see table). As the tsg_temp value required to calculate salinity was absent at times when there was valid SST, any gaps in tsg_temp for which SST was valid were replaced with SST+0.28˚C. Applying a time shift to allow for the lag in measurement was investigated but made little difference so was not applied. The *surfmet* system outputs calibrated (or nominally-calibrated) data. The conductivity was calibrated from the nominal output using surface data from the CTD (see below).

*surfmet2* merges on bestnav navigation (30 second data) to give ship speed and direction, calculate components for all speeds and directions, then average to 2 minutes. Merge on Ashtech heading information (2 minute file).

*surfmet3* applies some qc to the ship speed and then calculates true wind speed and direction.

| Variable | Valid range for pedita | Criteria for peditc | Spike limit for pmdian |
|---|---|---|---|
| ppar | -10 - 1500 | - | - |
| spar | -10 - 1500 | - | - |
| ptir | -10 - 1500 | - | - |
| stir | -10 - 1500 | - | - |
| humidity | 0 - 100 | - | - |
| airtemp | -50 85 | - | - |
| press | 900 - 1100 | - | - |
| SST | 1 - 30 | 25 < cond < 47; \|SST-tsg_temp\| < 0.7 | 0.05 |
| cond | -1 100 | 25 < cond < 47; \|SST-tsg_temp\| < 0.7 | 0.05 |
| tsg_temp | 1 - 30 | 25 < cond < 47; \|SST-tsg_temp\| < 0.7 | 0.05 |
| wind speed | 0 100 | - | - |
| wind dirn, | -361 361 | - | - |
| fluor | -1 100 | - | - |
| trans | -1 100 | - | - |

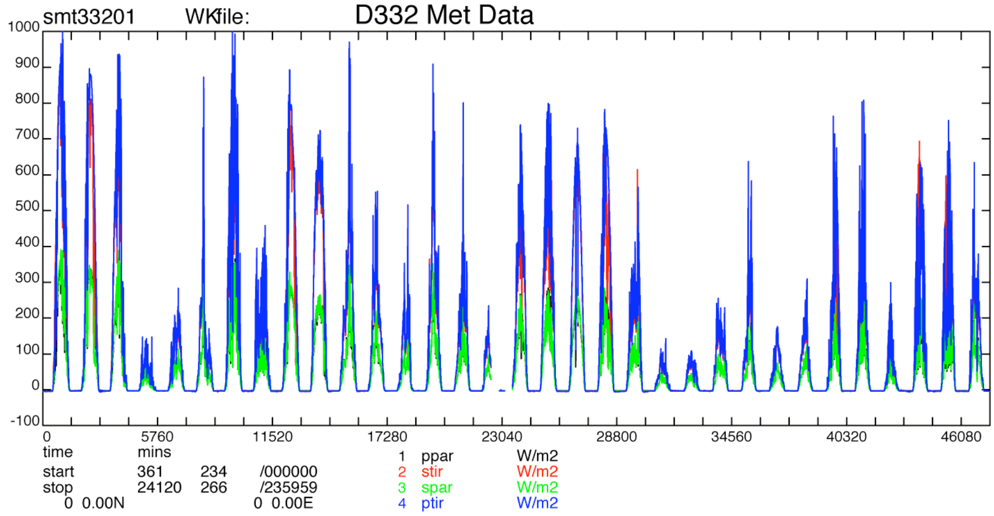



**Figure 9.1** Full cruise time series of light sensor data.

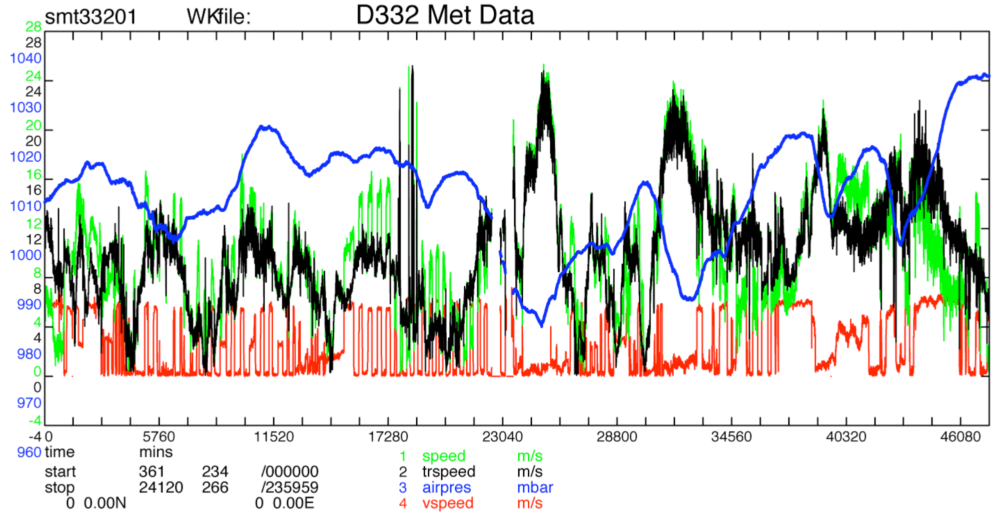



**Figure 9.2** Full cruise time series of relative wind speed (speed), true wind speed (trspeed), atmospheric pressure (airpres) and ship speed (vspeed).

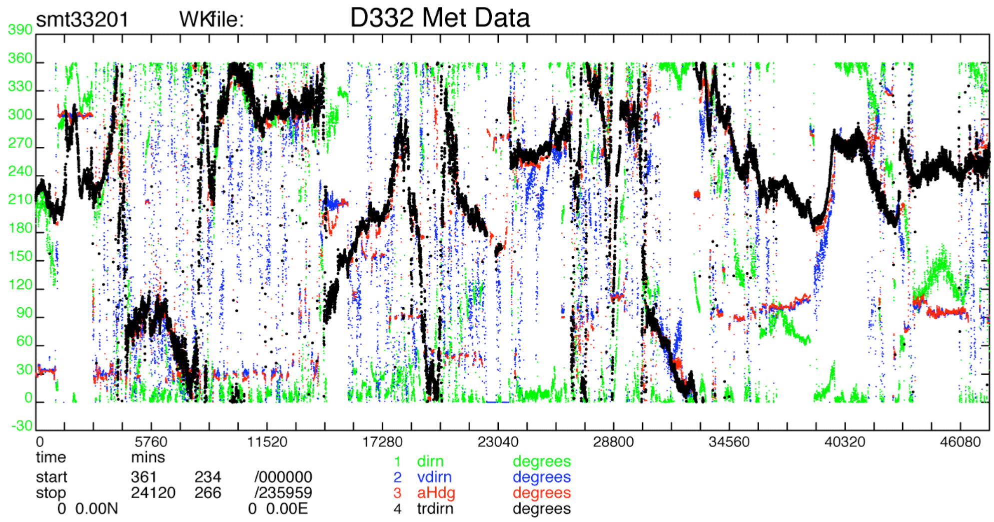



**Figure 9.3** Full cruise time series of relative wind direction (dirn), true wind speed (trdirn), Ashtech heading (aHdg) and ship direction (vdirn).

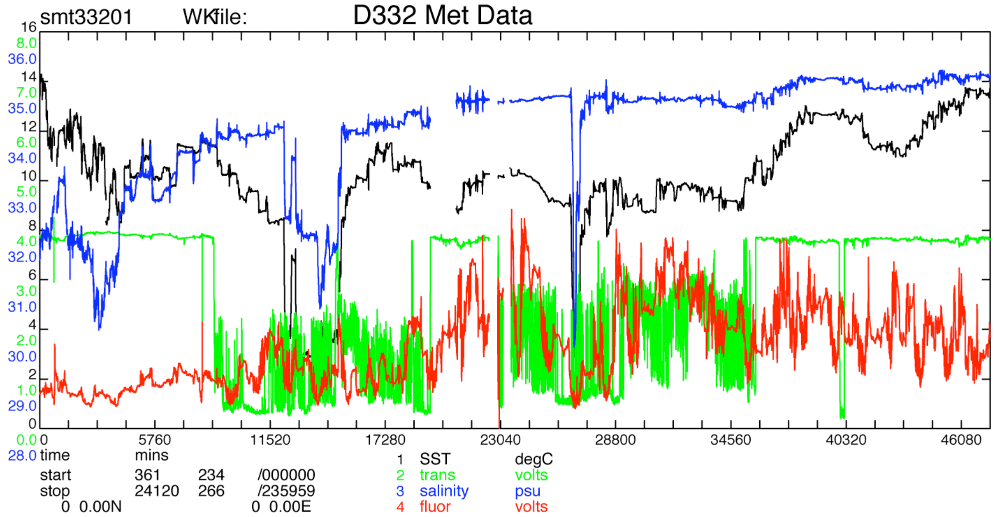



**Figure 9.4** Full cruise time series of SST, transmissivity, salinity and fluorescence.

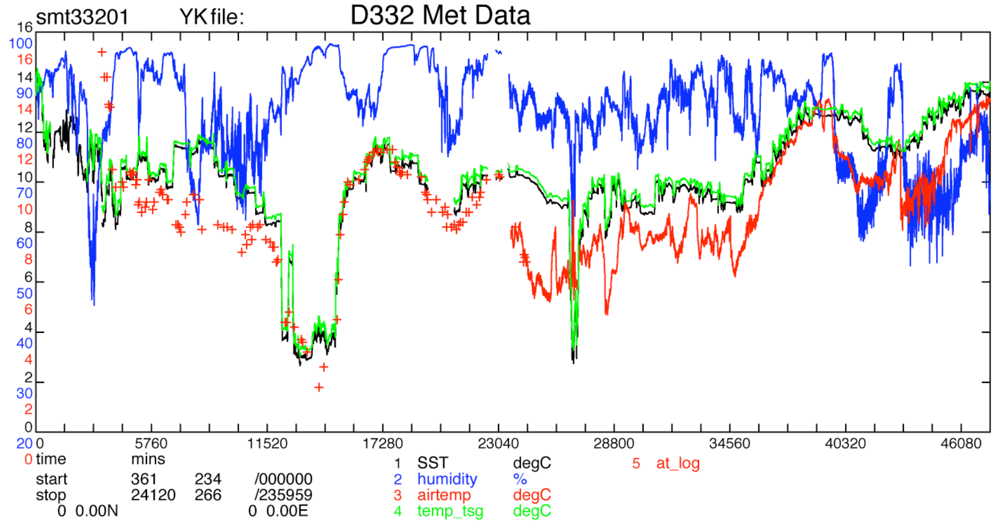



**Figure 9.5** Full cruise time series of SST, humidity, air temperature (airtemp) and TSG temperature (temp_tsg).

## 9.2 TSG Calibration

The TSG conductivity was calibrated using the 8 m depth CTD conductivity from the gridded CTD file. Obvious erroneous data were removed from the comparison and a regression performed on the resulting 68 conductivity data pairs using plreg2. The resulting calibration was:

$$cond\_tsg_{cal} = -0.682 + 1.112 *cond\_tsg$$

the $r^2$ value was 0.99936. Figure 9.6 shows the CTD and TSG conductivity data pairs before and after calibration.

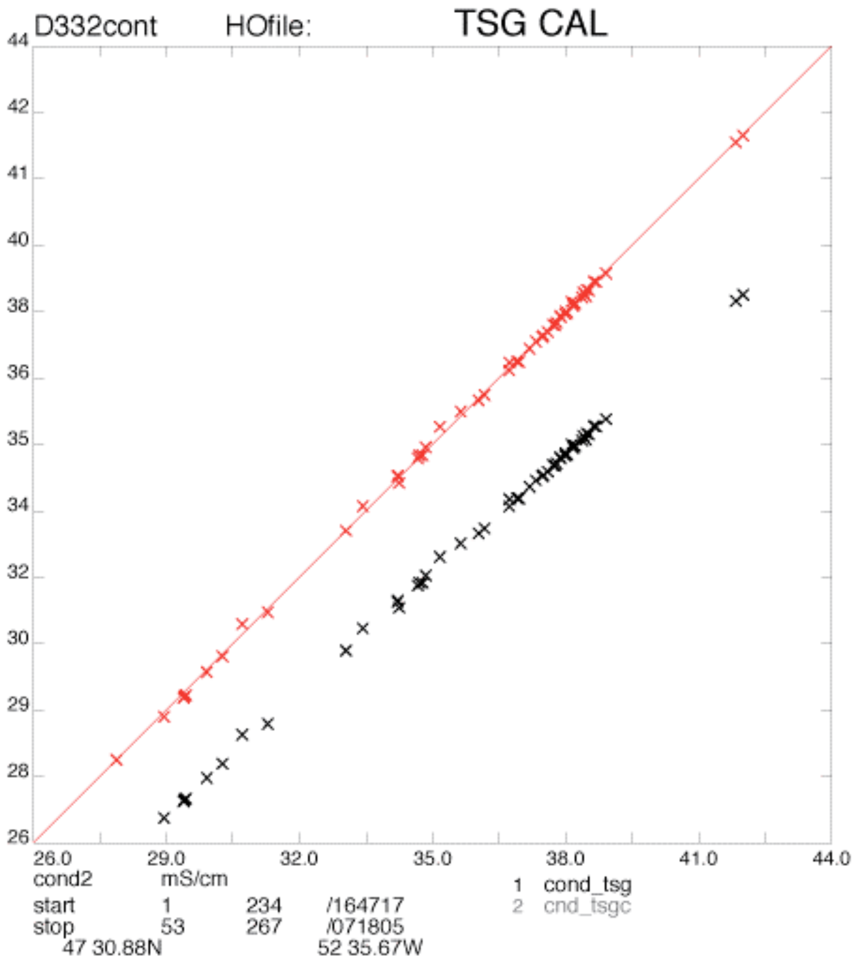



**Figure 9.6** Scatter plot of CTD primary conductivity against TSG conductivity as measured (black) and following calibration (red). The red line indicates a 1:1 relationship.

# 10 SHIP'S FITTED SYSTEMS

Leighton Rolley

## 10.1 General Issues Raised

### *10.1.1 Navigation Precision*

An issue that was raised during the cruise was the accuracy of the GPS positions in NetCDF files created by TECHSAS. The number of characters for position is constant i.e 8, currently if degrees of latitude or longitude are less than ten then the precision is 10-6 (i.e. ~10 cm resolution – and indeed this appears to be the limit of the netcdf data), however where degrees of latitude or longitude exceed 10 then the precision read reduces to 10-5 (i.e. only ~ 1 m resolution), and should the longitude exceed 100 degrees then the precision read would decrease to 10-4 (i.e ~ 10 m resolution). Whilst this has not been a major problem on this cruise – this should be addressed as a matter of urgency.

*Update: This has been investigated and found to be an issue with the listit script. Using anylist produces full gps positions. Investigations are ongoing at base to remove the two levels of precision that are caused by using the listit script.*

### *10.1.2 TECHSAS Issues*

The TECHSAS data logger caused concern throughout D332. The problems that we encountered with TECHSAS operation this cruise were entirely new and had not been experienced or identified by technicians on previous cruises. Each of these problems was identified and handled to the best of our ability with the PSO getting regular updates on the progress. Below is a list of identified issues with the TECHSAS systems:

<u>Audible Alarm</u>

TECHSAS would benefit from the inclusion of an audible alarm that should sound in the event that data streams freeze or the entire logging process dies. A program or "mod" should be written/requested from Ifremer that detects the increase in file sizes of the latest file generated by TECHSAS. If any file does not increase in size for a specified period of time (i.e 30seconds) an audible alarm should sound drawing the attention of the Technician to the problem.

<u>TECHSAS Crashes Due To Mounted Drives</u>

A problem that occurred on a number of occasions during the cruise was TECHSAS 1 "falling-over" when unable to write to its mounted drive (See investigation below). Data from TECHSAS was written to a mounted folder on TECHSAS 2 to ensure data integrity. However, on a number of occasions this folder became unavailable to TECHSAS 1 due to high disk activity on TECHSAS 2 or the Linux operating system on TECHSAS 2 crashing and not being able to manage the drive. When TECHSAS 1 tried to write to this folder it could not access it and TECHSAS 1 did not appear to be able to handle a non-existent location. This caused TECHSAS 1 to hang. This is a problem with the software and the OS. Once again safeguarding should be in place that would raise a visual and/or audible error if TECHSAS is unable to write the logged data to its primary or secondary locations. *This should not crash the application and result in data loss.* In addition, new methods should be investigated to determine the best destination for a secondary storage location for data from TECHSAS 1. It is critical that data is stored of system in the event of a major failure which results in total loss of TECHSAS 1.

During this cruise I retained the NFS mount on Techsas 2 although there were a few crashes triggered by this with a total loss of data. I retained this mount because of a lack of suitable other storage medium and because TECHSAS 1 was operating without its UPS due to a fault or a supply conditioner. If TECHSAS had not been writing to an additional drive and had catastrophically died during this cruise (i.e through a power spike which we know can occur) the data loss would have been much more significant and could have resulted in up to 24hrs data loss. In the event of this I choose to play it safe and retain the T1 backup on Techsas 2.

TECHSAS Module Errors

During the cruise logical problems were identified with two TECHSAS modules that mishandled data thus resulting in the loss of data.

The Trimble did not handle VDOP (vertical dilution of precision) correctly. This variable was populated with the ID of a space vehicle (Satellite). This error was not addressed during this cruise as the scientific party were primarily concerned with Horizontal Dilution of Precision (HDOP) and Precision Dilution of Precision (PDOP) which were logged correctly. This problem is traced to an Ifremer module.

Also the Surfmet module did not correctly store r_temp and h_temp and the values were storing in the wrong filed. i.e r_temp was being stored in h_temp and vice versa. In addition airtemp was being populated with x_temp. This resulted in a loss of airtemp recordings. Subsequent investigation of these problems revealed that they had been present for a number of cruises. The respective authorities for data handling have been informed.

Live Data

During the cruise the scientific party commented on the fact that they did not have access to the "live-data" from TECHSAS. This issue has been addressed and a new script has been written that will be installed in the coming months that populates the streams in "real-time".

## 10.2 Streams logged During the Cruise

We have used three sets of data streams during this cruise: one for data from TECHSAS 1; one for data from TECHSAS 2; the third set of streams is used as a composite – using data from both TECHSAS 1 and TECHSAS 2 to produce the most complete data streams.

| TECHSAS 1 DATA STREAMS | TECHSAS 2 DATA STREAMS | FULL STREAM |
|---|---|---|
| adu2 | adu22 | adu23 |
| ea500d1 | ea500d2 | ea500d3 |
| gps_4000 | gps4000 | gps4000 |
| gps_g12 | gps_g122 | gps_g123 |
| gyronmea | gyro2 | Gyro3 |
| lighttmp | light2 | Light3 |
| log_chf | log_chf2 | log_chf3 |
| mettmp | mettmp2 | Mettmp3 |
| winch | winch2 | Winch3 |

## 10.3 Processed Data Streams

### *10.3.1 Relmov*

Calculate the relative motion of the ship from gyro and log data

Input File Gyro – gyronmea
Input File Log – log_chf
Outpur File Relative Motion- relmov
Vn
Ve
Pfa
Pps

### *10.3.2 Bestnav*

Calculates continuous navigation from a series of fix files and relative motion.

| | |
|---|---|
| Primary input File – Fixes | gps_4000 |
| Secondary Input File – Fixes | gps_g12 |
| Third Input File – Fixes | adu2 |
| Input File – Relative Motion | relmov |
| Output file – navigation | bestnav |
| Output file – drifts | bestdrf |

OUTPUT VARIABLES BESTNAV
Lat
Lon
Vn
Ve
Cmg

Smg
Dist_run
Heading

OUTPUT VARIABLES BESTDRF

Vn
Ve
Kvn
Kve

The program bestnav reads position fixes from up to three RVS data files along with the ship's motion as calculated by relmov and generates a series of positions at time intervals of the navigation window. The names of the data files and the start and end times for processing are given on the menu; the size of the navigation window is taken from the environment variable NAVWINDOW. The menu also allows the maximum acceptable drift speed and a known drift speed to be input. The use of these values is described below.

The basis for the program's calculations is a series of position fixes. The input fix files are given in order and a timeout given for each file. Fixes will be taken from the first file until a data gap longer than that file's timeout is encountered. Fixes will then be taken from the second file until either the first file resumes or the second file also times out. In the latter case the third file will be used.

The gaps in the series of fixes are next filled using dead-reckoning based on the ship's motion relative to the water. When the end of each gap is reached the position obtained by dead-reckoning is compared with the fix position and the difference between the positions attributed to drift, caused either by wind or water currents. The drift in position is used to calculate an average drift velocity during the fix gap whose magnitude is compared with the known drift and maximum allowable drift entered on the menu. If the drift is greater than the limit then the fix is assumed to be in error and processing is halted. If this occurs the user should either correct (or delete) the fix or increase the allowed drift and re-run the program.

If an acceptable drift velocity is found this is added to the dead reckoned positions. This completes the calculation of the ship's track. For each navigation window a position is interpolated from the calculated track and a record written to the output fixes file. Each record also contains the calculated velocity represented as north and east components and as speed made good and course made good. The average heading of the ship is calculated along with a cumulative distance since the start of the file. If the output file contains a variable stream this will be set to 1, 2 or 3 to indicate which of the fix files the current fix was taken from. The status of the calculated values will either be good, if there was a fix at the time of the output record, or interp otherwise. The calculated drift velocities are also written to an output data file. This contains either one record per navigation window (if there is more than one fix in the window) or one record per fix. The file contains the north and east calculated drift velocities as well as the known and limitdrift speeds entered on the menu.

### *10.3.3 Protsg*

Calibrate temperature/conductivity data

| | |
|---|---|
| Raw Input File: | Surfmet |
| Processed Output File: | Protsg |
| Calibration File | surftsg.cal |

Protsg is used to apply quadratic calibrations to values from the flow-through thermosalinograph. Output variables for salinity and, optionally, density are calculated from the calibrated values using standard algorithms. This program can also be used when calibrated temperature and conductivity data are available, but salinity and/or density must be calculated. This is achieved by using the program with the alternate calibration file surftsg.cal.

Temp_m
Temp_h
Cond
Salin
Sigmat

### *10.3.4 Prodep*

The program corrects the raw depths recorded by the EA500 echo sounder for local variations in sound velocity using values from Carter's tables published by the Hydrographic Office. These tables divide the world's oceans into areas of similar water masses and provide depth corrections for each of these areas. The prodep program uses a navigation file (bestnav) to find the position of each depth record and applies the relevant correction. Each record in the output file contains the raw and processed depths together with the number of the Carter area used.

Input File Ea500d1
Output File prodep
Corrected Navigation in File bestnav
Uncdepth
Cordepth
Cartarea

### *10.3.5 Pro_wind*

WINDCALC inputs: bestnav, surftmp*
Outputs:
pro_wind
Abswspd (knots)
Abswdir

### *10.3.6 Gps_4000 - Trimble 4000*

Streams:
Gps_4000
Gps4000
Gps40003
NetCDF Files:

YYYYMMDD-HHMMSS-satelliteinfo-4000.gps
YYYYMMDD-HHMMSS-position-4000.gps

All three streams used the same variables:

lat
lon
hdg
hvel
pdop
s
s1
s1
s3
s4
s5
s6

### *10.3.7 gps_ g12 - Fugro GPS_G12*

Streams

| | |
|---|---|
| Gps_g12 | - Techsas 1 |
| Gps_g122 | - Techsas 2 |
| Gps_g123 | - Techsas 1 & 2 Consolidated |

NetCDF Files

YYYYMMDD-HHMMSS-ADUPOS-G12PAT.gps

All three streams used the same variables:

| | |
|---|---|
| Type | |
| Svc | |
| Utc | Universal Time Coordinated |
| Lat | Latitude |
| Lon | Longitude |
| Alt | Altitude |
| Cmg | Course Made Good |
| Smg | Speed Made Good |
| VVel | |
| Pdop | Position Dilution of Precision |
| Hdop | Horizontal Dilution of Precision |
| Vdop | Vertical Dilution of Precision |
| Tdop | Time Dilution of Precision |

### *10.3.8 ADU2 - Ashtec Attitude Detection Unit 2*

Streams

| | |
|---|---|
| Adu2 | - Techsas 1 |
| Adu22 | - Techsas 2 |
| Adu3 | - Techsas 1 & 2 Consolidated |

NetCDF Files

YYYYMMDD-HHMMSS-ADUPOS-PAPOS.gps

All three streams used the same variables:

| | |
|---|---|
| Sec | |
| Lat | Latitude |
| Lon | Longitude |
| Hdg | Heading |
| Pitch | Pitch |
| Roll | Roll |
| Mrms | Measurement (rms) error in meters |
| Brms | Baseline error in meters |

Attf Attitude

*10.3.9 Winch - CLAM*

Streams

Winch1 - Techsas 1
Winch2 - Techsas 2
Winch3 - Techsas 1 & 2 Consolidated

NetCDF Files

YYYYMMDD-HHMMSS-DWINCH-CLAM.DWINCH

All three streams used the same variables:

Cabltype
Cablout
Rate
Tension
Btension
Comp
Angle

*10.3.10 EA500d1 – Simrad EA500 Echosounder*

Streams

Ea500d1 - Techsas 1
Ea500d2 - Techsas 2
Ea500d3 - Techsas 1 & 2 Consolidated

All three streams used the same variables:

Depth
Rpow
Angfa
Angps

*10.3.11 Gyronmea – Ships Gyro*

Streams

gyronmea - Techsas 1
gyro2 - Techsas 2
gyro3 - Techsas 1 & 2 Consolidated

NetCDF Files

YYYYMMDD-HHMMSS-gyro-GYRO.gyr

All three streams used the same variables:

Heading

*10.3.12 Log_chf – Chernikeef Log (EM LOG)*

Streams

Log_chf - Techsas 1
Log_chf2 - Techsas 2
Log_chf3 - Techsas 1 & 2 Consolidated

NetCDF Files

YYYYMMDD-HHMMSS-DYLog-LOGCHF.DYLog

All three streams used the same variables:

Speedfa
speedps

### *10.3.13 Surfmet – Surfmet Met System*

Streams

| | |
|---|---|
| Surfmet1 | - Techsas 1 |
| Surfmet2 | - Techsas 2 |
| Surfmet3 | - Techsas 1 & 2 Consolidated |

NetCDF Files
YYYYMMDD - HHMMSS-MET-SURFMET.SURFMETv2
YYYYMMDD - HHMMSS -Light-SURFMET.SURFMETv2
YYYYMMDD - HHMMSS -Surf-SURFMET.SURFMETv2
All three streams used the same variables:

Temp_h
Temp_m
Cond
Fluo
Trans
Press
Ppar
Spar
Speed
Direct
Airtemp
Humid
Ptir
stir

## 10.4 Downtime

### *10.4.1 Surfmet – Met System Downtime*

| Date | Time Start | Time End | Duration | Culm | |
|---|---|---|---|---|---|
| 233 | 20:52:30 | 21:07:31 | 00:15:01 | 00:15:01 | Surfmet Crash – Application Error |
| 238 | 08:13:14 | 08:15:18 | 00:02:04 | 00:17:05 | Spiking Data reset and reboot of Surfmet system |
| 241 | 18:18:53 | 18:30:20 | 00:11:27 | 00:28:32 | Data capture for investigation of message problems. The system was taken offline for 10 minutes with approval from the PSO for investigation of airtemp issue discussed below |
| 249 | 14:48:38 | 21:46:04 | 06:57:26 | 07:25:58 | Major issue with TECHSAS. Failed Devicemaster. See additional notes |
| 249 | 22:49:57 | 23:37:57 | 00:48:00 | 08:13:58 | |
| 250 | 02:23:28 | 08:43:17 | 06:19:49 | 14:33:47 | |

| | |
|---|---|
| Total Downtime | 873 Minutes |
| Total Time At Sea | 10:00 (233) till 10:00 (267)1512hrs – 51840 |
| Total Downtime | 1.68% Downtime – 98.32 Uptime |

Airtemp Message Problems

The Surfmet system had a number of issues that affected its operation and data logging capabilities throughout D332. The first main problem that we encountered was that SURFMET was outputting the wrong value for airtemp in the $GPXSM message sent from Surfmet to TECHSAS. It was actually outputting the temp_h value in the airtemp field. This was a major issue as the meteorological team specifically required the air temperature for study of the air-sea interface. The information regarding this problem was emailed to base and the problem was observed on the RRS James Cook (25th August) as well. The individual responsible for this system was currently available on leave. A fix for the air temp was received on 03/09/2008 (247) and air temperature logging commence from 03/09/2008 onwards. This meant the scientific party were without accurate air temperature for 15 days of the cruise. Since identifying this as a problem it took 10 days to fix this issue.

Surfmet Device master Failure Friday September 5$^{th}$ 2008 (249)

Most notable was the loss of the system on day 249 for six hours followed by data logging for roughly one hour and then another fall over followed by nearly 3 hours of logging before another gap of roughly six hours. On Friday 5$^{th}$ September (249) it was decided that the Surfmet system should get a thorough clean pending some of the strange readings (See spike information) we have been getting. The system was taken offline for cleaning at 14:40:17 and the Transmissometer, Flurometer and Conductivity sensor were inspected and thoroughly cleaned with NOC's calibration technician present. When the system was restarted the Surfmet graphical displays showed values of 0 for all instruments in the Surfmet system. The voltages display within the Surfmet application indicated that no voltages were being received from any instruments. The lack of input voltages suggested a potential problem with the 12v power supply. The junction Box was opened and the 12v power supply inspected for faults. One of the 12v power supply looked as though it had been shorted and the casing was considerably warped and had been apparently subjected to quite a bit of heat. However, test revealed that the 12v supply was actually for the fans and the 12v supply below was for the actual Surfmet system which was functioning correctly. The 12v supply for the fans also appeared not be working correctly and is not required by the Surfmet system. However, spares should be sourced in the event that this component of the system failed.

As the system was receiving power the next line of inquiry was to analyze each individual instruments and component of the Surfmet system. The usual system reboots of the Surfmet, device master and 12v supply were conducted. When the system was brought back online it still showed 0's in the main display. However, the raw values (voltages) now showed values for the majority of instruments with the exception of the conductivity and housing temperatures. These two instruments are on the same instrument bus of the surfmet system so it was decided that one of these had potentially become problematic. Inspection of the instruments showed that the transmissometer casing was loose and potentially susceptible to moisture ingress. However, analysis of the internal workings showed that no shorts or visible problems could be seen. A spare conductivity sensor was sourced and this was replaced with the existing one with no results or improvements - the system still registered 0 voltages form the conductivity and housing temperature sensors.

As the spare conductivity sensor had no calibration sticker and attempts to communicate with it had failed the old sensor was reinstalled. During another subsequent reboot, communication with the conductivity sensor was restored but the raw voltage value was populated with either gibberish or "bad command" – which would have indicated a problem with the instrument and/or its settings. Inspections of the cabling yielded no problems. Subsequent reboots sorted out the "Bad command" problem and eventually we were receiving all raw values but the system was not displaying any real units within the application. As the application was receiving data from all instruments but not outputting them it was decided that the program was not applying its calibrations or had become corrupted. During this it was also noticed that the Ethernet connection was dropping in and out, although this was sporadic. A Windows XP restore was conducted which restored the system files to the 23rd of August – just before we sailed. Once restored the whole system started working again with the September version of the Surfmet program. However, the system promptly fell over 4 hours later and was once again displaying all voltages but no real data again. Once again the network connection was flaky. For test purposes the surfmet system was plugged temporarily into the ship's network and the port on the surfmet system was found to be working correctly. Plugging this back into the device master the system almost instantly got network dropouts. It would appear that device master had developed a hardware fault. The device master was possibly another victim of the power spike phenomenon that has plagued operations during this cruise. The device master was replaced with an edgeport USB expansion module. New cables were made from the junction box to the module following the pin configurations (Half Duplex) etc. Using this device we were able to remove the potential for power spikes in the future. Port assignment was copied from the device master to the Edgeport. The system then began responding correctly on the morning of 250 at 10:25.

During the early days (233-249) of the cruise the system was also plagued by spiking data – this was attributed to runaway processes in the application. However, in hindsight this was likely due to corrupted data from the failed device master which was corrected by the restart (start/stop) of communications to the instruments when the application was restarted. When the system fell over on a total inspection of the system resulted and every aspect of the system was checked from the instruments to the cabling. The original prognosis although wrong (we thought surfmet had lost its calibrations) helped us identify an intermittent hardware failure with surfmet's device manager (a hub which controls instrument input) which was changed during the night/morning of 250 and resulted in a fully functioning system free of spiking data.

<u>Air in System</u>

Further issues were caused by the build up of air in the Transmissometer which resulted in “bad data”. This was attributed to the low flow rate through the surfmet system. The pipe work into Surfmet was checked for blockages but none were identified.

### *10.4.2 SIMRAD EA500*

During the first test deployment of the CTD a fault was detected with the EA500 which would not ping. The system was thoroughly examined and the in-built system check indicated a possible fault on one of the signal processing boards. Spares were sourced and although we had several spare signal processing boards, all boards differed and no documentation was available to indicate which board should be used as a replacement. Eventually a hardware reset solved the problem and the system was restored to fully working condition.

Additional downtime was incurred during days 261 and 262. During this period the TLO altered a number of settings to try and obtain optimum data quality from the EA500 which resulted in no depth readings. This was attributed to bad sea state. However, during lowered sea state no additional readings were received from the EA500 and a hardware reset was undertaken. This resulted in the need to re-enter all default values. Once the system was brought online it recommenced pinging and returning a depth.

### *10.4.3 SBWR*

There were two occasions during the cruise when the wave recorder stopped logging. The first occurred on 06/09/2008 (250) when the system froze. Watch checks by scientific personnel failed to detect that the system had fallen over despite the values not increasing for a number of hours, the clock frozen (10:29) and the display not scrolling. The system was eventually restored at 16:10. The second occurrence of data logging failure appears to be caused by operator error or ship motion. The technician noticed that someone had been using the system as the SBWR screen showed the calibration setup. The technician closed the calibration screen, although failed to check that the system was still logging. Later that day it was noticed that logging had been stopped on the system. The system was subsequently restarted and continued logging.

*Note added by SB: After the cruise, it was found that the SBWR pressure sensor had been off for the entire cruise. See section 9.1.*

### *10.4.4 ADU – Ashtec Attitude Detection Unit*

There were times during the cruise when Surfmet was receiving no data from the ADU2 and warranted a reset. However, the effect of resetting the system was unknown as it still took a number of minutes before any positional information was received. The ADU was also the least reliable of the onboard GPS systems and dropouts of 30 seconds occurred quite frequently throughout the cruise especially when quite far north. Returning much further south the fixes became much stronger and the drop-outs less frequent.

During the cruise the system was fully checked in accordance with the system documentation. Antennae and cables were inspected for damage and the hardware was checked for any errors. No damage to the coaxial cabling was found or damage to connectors. The system appeared to be performing normal and the only conclusion is that the frequent 30 second drop-out occurred when the system lost track of one satellite, reducing the number of space vehicles it is tracking to below the minimum required for a hard fix. It then took an average of 30 seconds to locate another satellite. It is worth noting that there is minimum requirement of 4 satellites for the system to compute Pitch Heave and Roll data.