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Aurora Australis Marine Science Cruise AU1602, Dalton, Mertz and Ninnis CTDs - Oceanographic Field Measurements and Analysis

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ABSTRACT

Oceanographic measurements were collected aboard Aurora Australis cruise au1602, voyage 2 2016/2017, from 8th December 2016 to 21st January 2017. The cruise commenced with a Casey resupply, followed by work around the Dalton Polynya/Moscow University Iceshelf, then the Mertz Glacier region, and then around the Ninnis Polynya. 14 stations at the southern end of the SR3 transect were also completed. Ice conditions prevented access to the front of the Totten Glacier. A total of 73 CTD vertical profile stations were taken on the cruise, most to within 12 metres of the bottom (Table 1). Over 800 Niskin bottle water samples were collected for the measurement of salinity, dissolved oxygen, nutrients (phosphate, nitrate+nitrite, silicate, ammonia and nitrite), dissolved inorganic carbon (i.e. TCO_2), alkalinity, Th-234, POC, Chla, PAM, HPLC, Nd, Po-210/Pb-210, bacteria, O-18, caesium, and Teflon pollutants, using a 24 bottle rosette sampler. Full depth current profiles were collected by an LADCP attached to the CTD package. Upper water column current profile data were collected by a ship mounted ADCP. Meteorological and water property data were collected by the array of ship's underway sensors. 8 Argo floats were also deployed (Table 13) on the transit from Hobart to Casey.

This report describes the processing/calibration of the CTD data, and gives data quality details. Underway sea surface temperature and salinity data are compared to near surface CTD data. CTD station positions are shown in Figures 1a to d, while CTD station information is summarised in Table 1. Data from the LADCP and ADCP are not discussed further.

CRUISE NARRATIVE

(all times are local; the ship remained on Hobart time for the entire voyage)

During the V1/V2 port call the original departure time of Wednesday 7th December afternoon was delayed to the following morning, due to a late fuel delivery to Hobart. The ship departed Selfs Point at 1000 on the 8th, headed for the SOTS mooring location. Transit time to the frequently visited (by both the Aurora Australis and CSIRO vessels) SOTS location is 30 to 36 hours, so a morning departure from Hobart is never ideal as this typically places the ship onsite too late to commence deck operations. As it happened, on approach to SOTS the weather forecast was unfavourable, with no suitable weather window available for several days, so the decision was made to skip the site and save the job for the transit home.

The ship was instructed not to arrive at Casey before the 17th December, so time was available for some marine science, including krill fishing, and a CTD test cast to 3000 m. The latter took place in the vicinity of the W Casey whale mooring (following the scheduled recovery and redeployment of the mooring).

The ship arrived at Casey ~0700 on the 17th, and resupply continued steadily over the ensuing days. During this time there was a cold water acoustic calibration and a test deployment of the CTD. Refuelling of the station was completed the morning of the 21st, and with the wind increasing the ship upped anchor and put back out to sea. During this time there was some opportunistic marine science, including more krill fishing, and a test deployment of the in situ pumps from the trawl deck. The ship returned to Casey early on the 23rd, and cargo ops recommenced, with full 24 hour rolling shifts of 8 hours on/8 hours off. At 0400 on the 24th cargo ops paused for 4 hours for a second go at the cold water acoustic calibration (required to address a problem with the 200 kHz transducer). Final departure from Casey was at 0100 on Monday 26th December, 2 days ahead of schedule, and the ship re-entered the pack ice at ~0530 the same morning.

Ice conditions over the next ~1.5 weeks were unfavourable, and the general theme was long transits, slow passages through the ice, and a lack of timely ice images arriving to the ship. Nevertheless, all on board remained admirably flexible in the face of the frequently changing marine science plan. After departing Casey 2 days ahead of schedule this advantage was immediately lost in the pack ice. Progress was slow on the transit back to open water, and the ship spent 23 hours shutdown in the pack to await more favourable conditions, saving on fuel. During this shutdown an opportunistic sea ice station took place. The north end of the pack was finally reached at 1730 on the 28th December.

En route east to the Totten region, two options were considered for access to the Totten Glacier front – entry from the northwest via a crack, and entry from the east via a “shore” lead from the Dalton Polynya (as per Voyage 2 2014/15). With the ice images available at the time, the northwest entry option (~116°E) was rejected as too risky and the ship continued eastward. Six hours later an ice image was received, showing a possible entry from the northwest was in fact available, but the return travel time (along with uncertainty of success) was considered too costly. So the ship continued on to the Dalton Polynya, taking ~21 hours to break through the pack ice into the polynya (entering the north end of the polynya at 1720 on the 30th December).

With both a favourable ice image and weather window, an immediate attempt was made to access the Totten from the south end of the polynya. Six hours were spent following leads and breaking ice on a westward heading, before an impassable choke point in the ice was reached. So the attempt was abandoned, and the ship retraced its course back to the Dalton Polynya. The first science CTD was taken near an iceberg on the way back to the polynya, followed by a sea ice station. Two days were then spent doing a lap of 19 CTD’s around the perimeter of the polynya, including 4 in situ pump deployments and a dedicated CTD cast to gather large volumes for radium sampling.

For access to the Totten from the Dalton Polynya, no weather windows or suitable ice conditions were forthcoming. There was however a tantalising possibility for access from the northwest. So on 2nd January 2017 it was decided to leave the polynya, the plan being to reassess any attempt on northwest access after exiting the pack north of the polynya. The north end of the pack was reached after 23 hours of icebreaking, but the updated forecast no longer showed a favourable weather window for the northwest Totten access. So the Totten case was closed, and the ship began the transit east towards the Mertz region (with a couple of failed sea ice station attempts prior to exiting the pack).

Krill fishing took place during the transit, and as the ship continued eastward some deviation to the north was required, to avoid the ice edge. This turned out to be sufficiently northward to resume CTD’s with the planned SR3 stations, starting at the north end (SR3-11). All went well for the line of 11 CTD’s, and some successful krill hits were made between stations.

At the south end of SR3 the initial decision was to head for the Mertz outflow sill stations at the northwest end of the Mertz work region. Heavy ice was encountered on the way, quite different from anything shown by the modis images. When a new modis image was received it confirmed that access to the sill stations and indeed the Mertz Depression stations was too difficult, so after completing a sea ice station the ship headed northeast through the pack to transit around to the Mertz Glacier front.

A subplot to the ice saga in the sill region was the Polynya West mooring, and the iceberg C-29 that had covered it for most of the previous 6 years. In the days just prior to arriving near the sill, a series of modis images showed little movement of the iceberg, but a chance SAR image at just the right time captured a southward shift of the iceberg on the 2nd January, enough to expose the mooring. The event however only lasted a few hours, with the berg rapidly shifting back over the mooring. In any case, access to the site through the heavy ex fast ice and numerous grounded bergs would not have been possible.

A line of 6 CTD's were done on the southward approach to the Mertz Glacier, with another sea ice station in the pack to the north. The ice thickened at the southern end of this line, and it was apparent that westward access to any of the Mertz Depression stations would not be possible. So the ship continued south, breaking into open water at the northwest corner of the glacier front, on the way into Buchanan Bay. Conditions in Buchanan Bay were benign, quite different from the steady 70 knots experienced there on some previous occasions. The "sea ice factory" was evidently not in operation. Nine CTD's were completed along the western flank and most of the northern flank of the glacier, with 3 in situ pump casts and another dedicated radium CTD cast on the way. Transit through the ice along the northern flank was slow, until further east a lead at the glacier front was entered. Two final glacier front CTD's were completed in this lead, until passage was blocked ~6 miles short of the northeast corner of the glacier.

Time was short by this stage of the cruise, but a lifeline came from Kingston with the offer of extra time (2 days max). With this easing of time pressure a plan was hatched to enter the Ninnis Polynya. A favourable weather window together with fairly easy passage through the ice allowed a full 24 hours of CTD work in the polynya. The first station was taken in the cul de sac at the very western end of the polynya, a spectacular location with fast ice to the north and west and nearby exposed rock cliffs amongst the ice walls to the south. Bathymetry transects in this uncharted region were taken across the polynya, with many of the CTD stations called on the fly according to bathymetry. A final CTD had been planned at the exit point from the polynya, to close the box of CTD's, however the ship had to leave the area before doing this final CTD, to ensure safe passage back out through the ice. As it happened the transit north was fast, and there was time for more science: a final sea ice station, and a line of 8 CTD's along then across the Mertz Trough (north of the Ninnis).

At this stage, time remained (in theory) for more of the priority work in the Mertz region. In reality, ice conditions meant that none of the priority sites were accessible, so the ship left the region. Passage through the pack to the north was rapid, and on exiting the ice krill fishing commenced. Successful krill hits were again made near the SR3 transect. And for the last of the CTD's an additional three SR3 stations were occupied, resulting in a tally of 14 SR3 stations, with the northernmost at 61^{o} 51'S.

Following exit from the pack ice most of the transit was done at 13 knots, putting the ship well ahead of any transit planned at 10 knots. The SOTS mooring location was reached at 0100 on 19^{th} January, and a total of seven trawl attempts were made to recover the mooring, with no success. The ship left the site at ~1400 on the 20^{th} January for the return to Hobart. Full details of the attempted SOTS mooring recovery operation are in Appendix 3.

Summary of cruise itinerary:

Expedition Designation	AU1602, voyage 2 2016/2017
Projects	Totten and Mertz Glacier projects
Chief Scientist	Mark Rosenberg (ACECRC)
Ship	RSV Aurora Australis
Ports of Call	Hobart Casey
Cruise Dates	Dec 8th 2016 – Jan 21st 2017

1 INTRODUCTION

A total of 73 CTD's were completed on the cruise (Table 1, Figures 1a to d), as follows:

CTD number	location
1	test cast to 3000 dbar, near W Casey whale mooring
2	near iceberg to the southeast of south end of Dalton Polynya; intended for mini trough nearby, but ice prevented access to trough
3 to 21	Dalton Polynya, and including a radium cast
22 to 32	SR3 (running north to south)
33 to 38	running southward towards the Mertz Glacier, along what used to be the western flank of the former glacier tongue prior to breaking off in 2010
39 to 48	front of Mertz Glacier (including Buchanan Bay, and including a radium cast)
49 to 62	Ninnis Polynya
63 to 70	Mertz Trough
71 to 73	SR3 (northern stations)

2 CTD INSTRUMENTATION

SeaBird SBE9plus CTD serial 704, with dual temperature (SBE3Plus) and conductivity (SBE4C) sensors and a single SBE43 dissolved oxygen sensor (serial 0178, on the primary sensor pump line), was used, mounted on a SeaBird 24 bottle rosette frame, together with a SBE32 24 position pylon and up to 24 x 10 litre General Oceanics Niskin bottles. The following additional sensors/instruments were mounted:

* Wetlabs ECO-AFL/FL fluorometer serial 756
* Biospherical Instruments PAR sensor QCP2300HP, serial 70110
* Wetlabs C-star transmissometer serial 1421DR
* Teledyne RDI lowered ADCP (i.e. LADCP) workhorse monitor – 300 kHz head only, mounted as the downward looking head (150 kHz head, in US for repairs, didn’t make it back in time); battery housing
* Tritech 200 kHz altimeter serial 237622
* Tritech 500 kHz altimeter serial 126288

CTD data were transmitted up a 8 mm seacable to a SBE11plusV2 deck unit, at a rate of 24 Hz, and data were logged simultaneously on 2 PC's using SeaBird data acquisition software "Seasave" (version unknown).

The CTD deployment method was as follows:

* CTD initially deployed down to ~10 to 20 m
* after confirmation of pump operation, CTD returned up to just below the surface (depth dependent on sea state)
* after returning to just below the surface, downcast proper commenced

Pre cruise temperature, conductivity and pressure calibrations were performed by SeaBird (Table 2) (July 2016). The SeaBird calibration for the SBE43 oxygen sensor was used for initial data display only. Manufacturer supplied calibrations were used for the fluorometer, transmissometer, PAR and altimeter. Final conductivity and dissolved oxygen calibrations derived from in situ Niskin bottle samples are listed later in the report. Final transmissometer data are referenced to a clean water value.

3 PROBLEMS ENCOUNTERED

The main problem on the cruise was the ice, as described in the cruise narrative above. Much time was lost due to heavy ice conditions, and many areas were inaccessible (Totten, Mertz Sill and Mertz Depression).

Recovery of the CTD at the first station (the test cast) was rough, with difficulty setting the correct winch tension. The package bounced up and down a few times between the sheaf and the water, with alarming shock loading of the wire. Correct tensions were determined during a test deployment at Casey.

The LADCP failed to log data at station 3, due to operator error in pre deployment setup.

At station 6, a drifting floe threatened the CTD wire when stopped at 8 m at the top of the upcast. The last 8 bottles were fired rapidly.

The keyboard and mouse on the main CTD PC failed on several occasions. The problem was finally fixed at station 22 by a permanent hard-wired reroute of the cabling.

The CTD primary sensor data at station 22 were very spikey, due to a problem with the primary sensor plumbing. The short 1 cm tube near the plumbing inlet had slipped off, due to incorrect handling of the on-deck fill tubing.

At station 23, oil was found over the deck in the CTD room – the chief engineer traced this back to overflowing forecastle scuppers. At the same station the problem with the primary sensor plumbing became more serious – a small nylon screw holding the primary temperature sensor guard in place had sheared, again due to incorrect handling of the on-deck fill tubing. At station 24 after the repairs, there was initially a secondary-primary temperature difference of ~-0.0005 to -0.001^{o}C. This eventually cleared by 3000 m on the downcast. Primary temperature sensor data should not be used for the downcast of station 24.

There was a problem with the NMEA data feed at station 32, and NMEA had to be temporarily deselected to allow commencement of CTD logging.

The pumps remained on after recovery of the CTD at station 40, probably due to some ice in the plumbing (immediately cured by flushing).

SOTS mooring recovery attempts by dragging were unsuccessful, as described in Appendix 3.

4 CTD DATA PROCESSING AND CALIBRATION

Preliminary CTD data processing was done at sea, to confirm correct functioning of instrumentation. Final processing of the data was done in Hobart. The first processing step is application of a suite of the SeaBird "Seasoft" processing programs to the raw data, in order to:
* convert raw data signals to engineering units
* remove the surface pressure offset for each station
* realign the oxygen sensor with respect to time (note that conductivity sensor alignment is done by the deck unit at the time of data logging)
* remove conductivity cell thermal mass effects
* apply a low pass filter to the pressure data
* flag pressure reversals
* search for bad data (e.g. due to sensor fouling etc)

Further processing and data calibration were done in a UNIX environment, using a suite of fortran and matlab programs. Processing steps here include:
* forming upcast burst CTD data for calibration against bottle data, where each upcast burst is the average of 10 seconds of data centered on each Niskin bottle firing
* merging bottle and CTD data, and deriving CTD conductivity calibration coefficients by comparing upcast CTD burst average conductivity data with calculated equivalent bottle sample conductivities
* forming pressure monotonically increasing data, and from there calculating 2 dbar averaged downcast CTD data
* calculating calibrated 2 dbar averaged salinity from the 2 dbar pressure, temperature and conductivity values
* deriving CTD dissolved oxygen calibration coefficients by comparing bottle sample dissolved oxygen values (collected on the upcast) with CTD dissolved oxygen values from the equivalent 2 dbar downcast pressures

Full details of the data calibration and processing methods are given in Rosenberg et al. (unpublished), referred to hereafter as the *CTD methodology*. Additional processing steps are discussed below in the results section. For calibration of the CTD oxygen data, whole profile fits were used for shallower stations (stations 2-21, 30-57, 59-60, 62-70), while split profile fits were used for deeper stations (stations 1, 22-29, 58, 61, 71-73).

Final station header information, including station positions at the start, bottom and end of each CTD cast, were obtained from underway data for the cruise (see section 6 below). Note the following for the station header information:
* All times are UTC.
* "Start of cast" information is at the commencement of the downcast proper, as described above.
* "Bottom of cast" information is at the maximum pressure value.
* "End of cast" information is when the CTD leaves the water at the end of the cast, as indicated by a drop in salinity values.
* All start and end of cast bottom depth values are corrected for local sound speed, where sound speed values are calculated from the CTD data at each station.
* "Bottom of cast" depths are calculated from CTD maximum pressure (converted to depth) and altimeter values at the bottom of the casts.

Lastly, data were converted to MATLAB format, and final data quality checking was done within MATLAB.

5 CTD AND BOTTLE DATA RESULTS AND DATA QUALITY

Data from the secondary CTD sensor pair (temperature and conductivity) were used for the whole cruise. Suspect CTD 2 dbar averages are listed in Table 8, while suspect nutrient samples are listed in Table 11. Nutrient and dissolved oxygen comparisons to previous cruises are made in section 7. Appendices 1 and 2 contain the hydrochemistry lab reports.

5.1 Conductivity/salinity

The conductivity calibration and equivalent salinity results for the cruise are plotted in Figures 2 and 3, and the derived conductivity calibration coefficients are listed in Tables 3 and 4. Station groupings used for the calibration are included in Table 3. International standard seawater batch number P158 (expiry March 15th 2018) was used for salinometer standardisations. Lab temperature for salinity analyses mostly ranged between 22 and 24^{o}C over the course of the cruise.

Guildline Autosal serial 72088 was used for the whole cruise, with analyses taking place in lab 3 (alongside the carbon group). Salinometer performance overall was mostly good, without the serious bubble troubles encountered on the previous cruise au1402 (Rosenberg and Rintoul, unpublished-2) (see Appendix 1 for more details). Overall CTD salinity accuracy for the cruise is within 0.002 (PSS78).

For salinometer runs 11, 12 and 19, P158 standard readings at the end of the run were higher than at the start of the run, by 0.0017, 0.0007 and 0.0012 (PSS78) respectively. No drift corrections were applied to the salinity data, and any potential error would still be less than 0.002 (PSS78).

Pressure dependent salinity residuals are evident for most cruises (Rosenberg and Rintoul, unpublished-1). These residuals can only be assessed for deep stations, and where they occurred they were of the order 0.0025 (PSS78) over the whole vertical profile. These residuals have finally been identified as due to the compressibility of the borosilicate glass, individual to each conductivity sensor (SeaBird, pers. comm.). For processing of the secondary conductivity data (sensor serial no. 2821), the default factory value of -9.57e-8 used for the conductivity calibration coefficient CPCOR was changed to -8.0e-8, thereby minimizing the pressure dependent salinity residual. Any remaining pressure dependency was insignificant.

Very low near surface salinity values (down to 32.75 PSS78 for this cruise) are often encountered on Antarctic cruises, and the collection of useful conductivity calibration data in the associated steep vertical gradients can be difficult. This can result in a lack of usable samples at the lower end of the conductivity calibration range. The edit factor used in the conductivity calibration (see *CTD Methodology*) was varied for two of the calibration station groupings, to ensure some low conductivity calibration points were retained within each group. Specifically, an edit factor of 3.8 was used for group 1 (stations 1-26), and 2.7 for group 2 (stations 27-49). The usual default value of 2.8 was used for the remaining calibration groups (stations 50-58 and 59-73).

Close inspection of the vertical profiles of the bottle-CTD salinity difference values reveals a slight biasing for a few stations, of the order 0.001 (PSS78) or less, as follows:

station	bottle-CTD bias (PSS78)
9	-0.0005
10	-0.0005
30	-0.0005
42	-0.001
43	-0.0005
44	-0.001
45	-0.0005
46	-0.001
73	+0.0005

This is most likely due to a combination of factors, including salinometer performance. There is no significant diminishing of overall CTD salinity accuracy from this apparent biasing.

Bad salinity bottle samples (not deleted from the data files) are listed in Table 9.

5.2 Temperature

Temperature differences between the primary and secondary CTD temperature sensors (T_p and T_s respectively), from data at Niskin bottle stops, are shown in Figure 4. Temperature ranges for this Antarctic cruise are relatively small, and the difference $T_s - T_p$ is well within the manufacturer quoted sensor accuracy of 0.001^{o}C. Specifically, the difference between sensors is less than 0.0005^{o}C over all depths, with no obvious pressure dependence (Figure 4a); and there is no obvious temperature dependence (Figure 4b).

* Note that primary sensor data for the downcast of station 24 are suspect, as described in section 3 above. These data aren't used anyway, as secondary sensor data have been used for the whole cruise.

5.3 Pressure

Surface pressure offsets for each cast (Table 5) were obtained from inspection of the data before the package entered the water. Pressure spiking, a problem on some previous cruises, did not occur.

5.4 Dissolved oxygen

CTD oxygen data were calibrated as per the *CTD methodology*, with profiles deeper than 1400 dbar (i.e. stations 1, 22-29, 58, 61, 71-73) calibrated as split profile fits, and profiles shallower than 1400 dbar (i.e. stations 2-21, 30-57, 59-60, 62-70) calibrated as whole profile fits. For most stations a duplicate sample was drawn from one of the Niskins, as a quality check on the analyses. For stations 11 and 40 (radium casts), no bottle samples were collected, therefore CTD oxygen data were not calibrated.

Calibration results are plotted in Figure 5, and the derived calibration coefficients are listed in Table 6. Overall the calibrated CTD oxygen agrees with the bottle data to within 1% of full scale (where full scale is ~450 µmol/l above 1600 dbar, and ~260 µmol/l below 1600 dbar) i.e. from the standard deviation values in Figure 5. Note that for parts of the cruise in Antarctic shelf waters, there was significant variability between down and upcast data, and as a result more than the usual number of samples were rejected (Figure 5) during the calibration procedure i.e. when comparing downcast CTD data with bottle samples collected on the upcast, as per the *CTD methodology*. Nevertheless, sufficient samples remained for reliable calibration of the CTD data.

* Sample draw temperature estimated for stn 4 btl 19, stn 25 btl15, and stn 59 btl 17.

* For many stations, the top of the upcast and downcast differ due to ocean variability. For stations 3 and 5, the shallowest bottle sample is at 20 dbar, meaning the top part of profile is suspect (i.e. calibration unreliable). For station 5, this top part is unusable.

* For station 39, the top part of the profile was hard to fit, and is therefore suspect.

* For station 47, top part of profile is suspect or unusable, as insufficient data bins are present for calibration (bins missing as downcast proper started below 10 dbar).

* A small section of data near the top of station 49 is suspect.

* For station 53, there's a large section of unusable data (couldn't be calibrated, due to numerous bad oxygen samples).

5.5 Fluorescence, PAR, transmittance, altimeter

All fluorescence, PAR and transmittance data have a manufacturer supplied calibration (Table 2) applied to the data, with transmittance values referenced to clean water. In the CTD 2dbar averaged data files, both downcast and upcast data are supplied for these sensors; and the data are strictly 2 dbar averages (as distinct from other calculations used in previous cruises i.e. au0703, au0803 and au0806).

For fluorescence and transmittance, the 2 dbar averaged upcast data (in the CTD 2 dbar files) do not always match the upcast 10 second burst average data (in the bottle data file). This is due to the difference between 2 dbar and 10 second averaging on data with frequent significant vertical structure.

The PAR calibration coefficients in Table 2 were calculated from the manufacturer supplied calibration sheet, using the method described in the following SeaBird documents: page 53 of SeaSave Version 7.2 manual; Application Note No. 11 General; and Application Note No. 11 QSP-L.

The usual altimeter "artefacts", as seen on previous cruises (described in Rosenberg and Rintoul, unpublished-1), were observed on both the 200 and 500 kHz Tritech sensors, with false bottom readings often observed before coming within nominal altimeter range. While doing a cast at sea, these artefacts are easily identifiable by simultaneously plotting the 200 and 500 kHz data during logging – artefacts are identifiable by a mismatch between data from the two altimeters.

* Near bottom transmittance spikes (real features) are evident in the full 24 Hz data for some stations (e.g. stations 46 and 47 in front of the Mertz Glacier). These features may be lost in the 2 dbar averaging.

* Deeper fluorescence data are slightly negative in value, due to the calibration coefficients supplied.

* Maximum transmittance values are slightly less than the expected 100%, due to a small calibration error (possibly by referencing to clean water).

5.6 Nutrients

No nutrient analyser was available for the cruise, so nutrients were taken home for analysis – both frozen, and refrigerated (i.e. not frozen). Analyses were done by Stephen Tibben, Kendall Sherrin and

Christine Rees at CSIRO in Hobart, from May to June 2017. Nutrients measured were phosphate, total nitrate (i.e. nitrate+nitrite), silicate, ammonia and nitrite, using a SEAL Autoanalyzer 3 HR (AA3) (a continuous segmented flower analyser). Silicates were run using the refrigerated samples, while all other nutrients were run using the frozen samples.

Suspect data are listed in Table 11, and nitrate+nitrite versus phosphate data are shown in Figure 6. The following full scale values apply to the analyses: 3.0 µmol/l for phosphate; 36.4 µmol/l for nitrate+nitrite; 140 µmol/l for silicate; 2.0 µmol/l for ammonia; 1.4 µmol/l for nitrite. In Figure 6, the differing trend for the Mertz data appears to be a real feature, also evident in data from previous cruises (e.g. au1203 and au1402, in Rosenberg and Rintoul, unpublished-2 and unpublished-3). Phosphate depletion for shallow samples can also be seen in the figure, again consistent with previous cruises. Further assessment of nutrient data quality is given in section 7 below, comparing the data to previous cruises.

To summarize the data quality, the silicate and nitrate+nitrite data are considered reasonable. For phosphate, au1602 and au1402 data are consistent, though both cruises are lower than the other cruises (with the exception of au0103 and au9601, as discussed in section 7 below). Significantly, the phosphate spread is much tighter for au1602 than for au1402, and for this reason the au1602 data are considered reasonable. Note that the same autoanalyser and analysis methodology were used for au1402 and au1602, different to the previous cruises, but it is unknown whether this accounts for the quantitative difference between cruises.

5.7 Additional CTD data processing/quality notes

For Antarctic shelf data, when lowering or raising of the CTD slowed down in regions of significant vertical structure, high variability is at times evident in the profile data. Examples of this are oxygen sensor spikes (seen in the full 24 Hz data) near the bottom of Dalton Polynya stations. This variability is also evident as sensor drift during bottle stops. In all these cases, similar profile features can be seen in both the primary and secondary data, however primary/secondary sensor data mismatch is more than usual. Possible reasons are highly variable ocean structure (most likely) and sensor time constants (possible contributor). These data are not flagged as suspect, but are perhaps at the limit of what the CTD can accurately measure in a highly variable environment.

6 UNDERWAY MEASUREMENTS

Underway data were logged to an Oracle database on the ship. For most sensors there has been no quality control, so there may be a few suspect data points (in particular for underway sea surface conductivity and salinity). 12 kHz bathymetry data were quality controlled on the cruise (all depths are from the water surface, and calculated using sound speed 1445 m/s), by manually line-picking the bottom in bathymetry data processing software.

1 minute instantaneous underway data are contained in the file au16021min.ora as column formatted text; and in the file au1602ora1min.mat as matlab format. Data from the hull mounted underway temperature sensor (T_{dls}) and the underway thermosalinograph salinity (S_{dls}) are compared to CTD temperature and salinity data at 8 dbar (Figures 7 and 8). In both cases a simple offset correction appears best (Figures 8a and b), with the S_{dls}-S_{CTD} difference for the cruise approximately equal to -0.030 (PSS78), and the T_{dls}-T_{CTD} difference for the cruise approximately equal to +0.016 (^{o}C). Note that these comparisons have not been applied to the underway data.

7 INTERCRUISE COMPARISONS

Intercruise comparisons of nitrate vs phosphate, silicate and dissolved oxygen bottle data compare data from cruise au1602 with previous cruises. At the south end of SR3, comparisons are made to Aurora Australis cruises au9407, au9404, au0103, au0806, au1121 and au1402, ranging over the years 1994 to 2015 (Figures 9a, 10a and 11a). For shelf data in the Mertz region, comparisons are made to Aurora Australis cruises au0803, au1121, au1203 and au1402 (Figures 9b, 10b and 11b).

Note that the au1602 Ninnis data are included on the Mertz region plots. For shelf data in the Dalton Polynya, comparisons are made to Aurora Australis cruise au1402 (Figures 9c, 10c and 11c).

For nitrate+nitrite vs phosphate, at the south end of SR3 the au1602 phosphates approximately overlay the au1402 data, and are lower than the other cruises (except for au0103) by ~0.05 to 0.1 µmol/l (Figure 9a). The spread of phosphate values is fairly tight, much improved over the scatter found on au1402. From the bulk plot of shelf stations in the Mertz/Ninnis region (Figure 9b), au1602 phosphates agree well with other cruises at higher concentrations (i.e. deeper samples). For lower concentrations (i.e. shallower samples), the trends followed by au1602, au1402 and au1203 are in approximate agreement, but they diverge from the au1121 and au0803 data. For the Dalton Polynya data (Figure 9c), quantitative agreement between au1602 and au1402 is fairly good. Note that from all 3 of the above plots, phosphate scatter for au1602 is much improved over the suspect scatter in the au1402 data. Au0103 data, seen as an apparent outlier in Figure 9a, have been discussed in previous data reports (with au0103 phosphates in general agreement with the 1996 cruise au9601). For phosphates in general. intercruise variability is most likely due to variation in autoanalyser performance (specific reasons unknown), and due to the freezing of samples for au1402. Phosphate results have previously shown significant intercruise offsets (Rosenberg and Rintoul, unpublished-1).

For silicate, at the south end of SR3 the au1602 data lie favourably within the intercruise scatter (Figure 10a). The same is true for shelf stations in the Mertz/Ninnis region (Figure 10b). For the Dalton Polynya data (Figure 10c), au1602 and au1402 are reasonably consistent.

For dissolved oxygen, at the south end of SR3 the au1602 data lie mostly within the intercruise scatter (Figure 11a). From the bulk plot of shelf stations in the Mertz region (Figure 11b), au1602 data are mostly at the lower end of the intercruise scatter (intercruise scatter is of the order 10 µmol/l), though surface values tend to be higher, and oxygen minima aren't as low as seen on au0803 and au1121. For the Dalton Polynya data (Figure 11c), au1602 and au1402 are reasonably consistent.

Overall, nutrient data quality appears improved over au1402 data, in particular for phosphates.

8 FILE FORMATS

Data are supplied as column formatted text files, or as matlab files, with all details fully described in the README file included with the data set. Note that all dissolved oxygen and nutrient data in these file versions are in units of µmol/l.

The data are also available in WOCE "Exchange" format files. In these file versions, dissolved oxygen and nutrient data are in units of µmol/kg. For density calculation in the volumetric to gravimetric units conversion, the following were used:

dissolved oxygen – in situ temperature and CTD salinity at which each Niskin bottle was fired; zero pressure

nutrients – laboratory temperature, and in situ CTD salinity at which each Niskin bottle was fired; zero pressure. Note that laboratory temperature for all the nutrient runs, run over several weeks, ranged from 21.1 to 21.95^{o}C; a mean value of 21.5^{o}C (over all the runs) was used.

Table 1: Summary of station information for cruise au1602. All times are UTC; "alt" = minimum altimeter value (m), "maxp" = maximum pressure (dbar). Note: “Dalton” refers to Dalton Polynya/Moscow University Iceshelf region.

	start of CTD					bottom of CTD				end of CTD					
CTD station	date	time	latitude	longitude	depth	time	latitude	longitude	depth	time	latitude	longitude	depth	alt	maxp
001 test	15 Dec 2016	041009	63 48.80 S	111 42.80 E	2958	052635	63 48.78 S	111 42.20 E	2966	064921	63 49.16 S	111 42.05 E	2972	39.9	2976
002 Dalton	30 Dec 2016	193251	66 50.62 S	119 32.57 E	642	194939	66 50.60 S	119 32.36 E	771	202612	66 50.62 S	119 32.45 E	669	13.1	767
003 Dalton	31 Dec 2016	080745	66 47.90 S	120 05.78 E	227	081631	66 47.90 S	120 05.78 E	242	083731	66 47.86 S	120 05.71 E	220	13.8	230
004 Dalton	31 Dec 2016	115416	66 48.79 S	120 19.46 E	539	120534	66 48.80 S	120 19.40 E	569	123124	66 48.89 S	120 19.44 E	568	9.6	566
005 Dalton	31 Dec 2016	135141	66 49.36 S	120 33.60 E	263	135829	66 49.36 S	120 33.67 E	263	141513	66 49.39 S	120 33.54 E	247	10.0	256
006 Dalton	31 Dec 2016	154302	66 44.45 S	120 40.76 E	384	155133	66 44.52 S	120 40.76 E	398	160744	66 44.69 S	120 40.76 E	304	10.5	392
007 Dalton	31 Dec 2016	171814	66 39.58 S	120 50.71 E	232	172136	66 39.59 S	120 50.74 E	239	173449	66 39.59 S	120 50.38 E	232	5.3	236
008 Dalton	31 Dec 2016	210511	66 37.63 S	121 05.27 E	296	211122	66 37.61 S	121 05.15 E	294	212735	66 37.58 S	121 05.30 E	286	7.0	290
009 Dalton	01 Jan 2017	043309	66 30.72 S	121 26.38 E	206	044036	66 30.72 S	121 26.30 E	207	050024	66 30.77 S	121 26.00 E	211	13.3	195
010 Dalton	01 Jan 2017	061711	66 36.65 S	121 32.92 E	242	062602	66 36.61 S	121 32.86 E	242	065000	66 36.55 S	121 32.69 E	243	13.8	231
011 Dalton	01 Jan 2017	092140	66 36.52 S	121 33.37 E	233	092810	66 36.55 S	121 33.34 E	235	093804	66 36.58 S	121 33.35 E	236	7.3	231
012 Dalton	01 Jan 2017	103942	66 36.11 S	121 21.16 E	260	104657	66 36.08 S	121 21.18 E	260	110656	66 36.04 S	121 21.10 E	259	4.6	258
013 Dalton	01 Jan 2017	122924	66 25.79 S	121 13.67 E	275	123630	66 25.76 S	121 13.61 E	280	125124	66 25.71 S	121 13.48 E	277	11.2	271
014 Dalton	01 Jan 2017	140434	66 21.82 S	120 56.07 E	260	141051	66 21.83 S	120 55.98 E	261	142327	66 21.86 S	120 55.78 E	263	7.7	256
015 Dalton	01 Jan 2017	153344	66 15.11 S	120 47.85 E	325	154039	66 15.10 S	120 47.76 E	329	155619	66 15.09 S	120 47.51 E	335	10.4	322
016 Dalton	01 Jan 2017	170641	66 08.05 S	120 51.43 E	308	171235	66 08.00 S	120 51.40 E	307	172830	66 07.96 S	120 51.54 E	306	9.3	301
017 Dalton	01 Jan 2017	184002	66 07.78 S	120 34.75 E	524	184939	66 07.77 S	120 34.88 E	522	190930	66 07.73 S	120 34.99 E	524	9.7	518
018 Dalton	01 Jan 2017	202828	66 09.84 S	120 15.59 E	526	203831	66 09.80 S	120 15.50 E	520	205908	66 09.77 S	120 15.45 E	518	6.6	519
019 Dalton	01 Jan 2017	221849	66 16.27 S	119 57.56 E	542	222956	66 16.26 S	119 57.49 E	542	225243	66 16.24 S	119 57.45 E	542	10.0	538
020 Dalton	02 Jan 2017	001104	66 26.60 S	119 57.59 E	713	002351	66 26.59 S	119 57.56 E	712	004914	66 26.59 S	119 57.46 E	712	9.7	711
021 Dalton	02 Jan 2017	025644	66 37.78 S	120 01.46 E	397	030706	66 37.81 S	120 01.39 E	412	032824	66 37.87 S	120 01.26 E	409	10.5	406
022 SR3	05 Jan 2017	202133	63 20.95 S	139 50.02 E	3777	212426	63 20.65 S	139 50.32 E	3774	224827	63 20.42 S	139 50.83 E	3778	7.8	3837
023 SR3	06 Jan 2017	015644	63 52.04 S	139 50.58 E	3701	030514	63 52.07 S	139 51.62 E	3696	042351	63 52.10 S	139 52.76 E	3705	7.9	3757
024 SR3	06 Jan 2017	081748	64 12.53 S	139 50.70 E	3502	092039	64 12.50 S	139 51.65 E	3499	103252	64 12.53 S	139 53.71 E	3505	9.2	3553
025 SR3	06 Jan 2017	124353	64 32.95 S	139 50.05 E	3062	133640	64 33.09 S	139 49.43 E	3066	144134	64 33.29 S	139 48.22 E	3089	10.4	3109
026 SR3	06 Jan 2017	163727	64 48.97 S	139 51.10 E	2556	172023	64 49.12 S	139 50.61 E	2549	182234	64 49.23 S	139 49.65 E	2541	10.3	2580
027 SR3	06 Jan 2017	210050	65 03.88 S	139 49.75 E	2429	214424	65 03.97 S	139 50.00 E	2506	224251	65 03.98 S	139 50.22 E	2439	10.0	2536
028 SR3	07 Jan 2017	034054	65 23.05 S	139 49.15 E	2364	042141	65 23.08 S	139 48.89 E	2373	052002	65 23.35 S	139 48.67 E	2363	8.9	2401
029 SR3	07 Jan 2017	082238	65 26.41 S	139 51.77 E	1669	085228	65 26.47 S	139 52.46 E	1658	093755	65 26.50 S	139 53.77 E	1774	9.8	1671
030 SR3	07 Jan 2017	113555	65 31.82 S	139 52.48 E	1199	115835	65 31.77 S	139 52.90 E	1245	123738	65 31.49 S	139 53.50 E	1215	12.1	1249
031 SR3	07 Jan 2017	135953	65 33.76 S	139 51.05 E	949	141916	65 33.65 S	139 51.14 E	987	145023	65 33.44 S	139 51.20 E	1051	12.8	987
032 SR3	07 Jan 2017	162246	65 42.18 S	139 51.29 E	301	162829	65 42.25 S	139 50.54 E	304	164403	65 42.20 S	139 50.50 E	311	6.3	301
033towardsMertz	09 Jan 2017	090827	66 42.91 S	145 57.88 E	348	091633	66 42.91 S	145 57.76 E	348	093227	66 43.03 S	145 57.75 E	350	11.9	340
034towardsMertz	09 Jan 2017	105443	66 46.44 S	145 48.84 E	435	110405	66 46.43 S	145 48.67 E	435	111927	66 46.40 S	145 48.55 E	435	10.6	429
035towardsMertz	09 Jan 2017	121619	66 50.51 S	145 40.61 E	507	122654	66 50.47 S	145 40.61 E	505	124516	66 50.40 S	145 40.42 E	509	11.3	499
036towardsMertz	09 Jan 2017	135505	66 54.56 S	145 30.68 E	643	140818	66 54.53 S	145 30.49 E	644	143442	66 54.49 S	145 29.81 E	645	11.7	639
037towardsMertz	09 Jan 2017	180739	66 58.11 S	145 23.64 E	819	182236	66 58.19 S	145 23.50 E	826	184637	66 58.28 S	145 23.32 E	828	11.2	824
038towardsMertz	09 Jan 2017	204332	67 01.75 S	145 10.78 E	1261	210732	67 01.73 S	145 10.28 E	1265	213838	67 01.70 S	145 09.55 E	1291	10.7	1271

Table 1: (continued)

CTD station	start of CTD date	time	latitude	longitude	depth	bottom of CTD time	latitude	longitude	depth	end of CTD time	latitude	longitude	depth	alt	maxp
039 MertzGlacier	09 Jan 2017	235008	67 12.04 S	144 42.68 E	354	235741	67 12.07 S	144 42.59 E	377	001722	67 12.08 S	144 42.43 E	372	7.8	373
040 MertzGlacier	10 Jan 2017	031211	67 11.92 S	144 42.87 E	342	031703	67 11.92 S	144 42.83 E	343	032258	67 11.95 S	144 42.76 E	343	-	204
041 MertzGlacier	10 Jan 2017	042507	67 09.08 S	144 53.79 E	583	043632	67 09.08 S	144 53.75 E	585	050059	67 09.09 S	144 53.62 E	582	10.6	581
042 MertzGlacier	10 Jan 2017	055453	67 04.37 S	145 01.20 E	1041	061727	67 04.37 S	145 01.44 E	1115	064949	67 04.32 S	145 01.25 E	1044	11.1	1118
043 MertzGlacier	10 Jan 2017	115233	67 04.16 S	145 11.09 E	1318	121824	67 04.07 S	145 10.94 E	1317	125055	67 04.04 S	145 11.08 E	1319	9.5	1325
044 MertzGlacier	10 Jan 2017	151920	67 05.05 S	145 19.29 E	1151	154002	67 04.96 S	145 18.85 E	1149	161039	67 04.78 S	145 18.22 E	1148	10.2	1154
045 MertzGlacier	10 Jan 2017	230113	67 08.29 S	145 28.53 E	1116	232108	67 08.28 S	145 28.44 E	1115	235128	67 08.24 S	145 28.28 E	1113	10.4	1118
046 MertzGlacier	11 Jan 2017	020211	67 10.77 S	145 31.39 E	1055	022032	67 10.73 S	145 31.40 E	1054	024902	67 10.72 S	145 31.45 E	1052	11.9	1055
047 MertzGlacier	11 Jan 2017	042045	67 12.53 S	145 41.21 E	802	043632	67 12.49 S	145 41.21 E	801	045916	67 12.50 S	145 41.26 E	800	9.7	800
048 MertzGlacier	11 Jan 2017	060900	67 13.16 S	145 53.03 E	674	062250	67 13.16 S	145 53.08 E	674	064902	67 13.18 S	145 53.09 E	669	10.2	671
049 Ninnis	11 Jan 2017	184733	67 39.24 S	146 50.39 E	906	190409	67 39.27 S	146 50.62 E	906	192654	67 39.23 S	146 50.96 E	893	10.3	906
050 Ninnis	11 Jan 2017	203311	67 37.71 S	146 28.04 E	932	204933	67 37.75 S	146 28.05 E	927	211521	67 37.82 S	146 28.15 E	939	10.7	927
051 Ninnis	11 Jan 2017	223540	67 36.40 S	146 11.06 E	384	224319	67 36.41 S	146 11.09 E	395	230122	67 36.43 S	146 11.14 E	391	8.9	390
052 Ninnis	12 Jan 2017	002708	67 40.78 S	146 38.55 E	1107	004707	67 40.75 S	146 38.59 E	1103	011446	67 40.67 S	146 38.56 E	1105	10.0	1107
053 Ninnis	12 Jan 2017	022739	67 43.30 S	146 48.06 E	1063	024620	67 43.33 S	146 48.05 E	1062	031149	67 43.37 S	146 48.07 E	1049	9.8	1066
054 Ninnis	12 Jan 2017	040207	67 45.17 S	146 32.74 E	485	041030	67 45.17 S	146 32.70 E	496	042908	67 45.16 S	146 32.67 E	480	10.2	491
055 Ninnis	12 Jan 2017	053446	67 51.05 S	146 41.26 E	870	055057	67 51.03 S	146 41.18 E	889	061836	67 50.81 S	146 40.66 E	906	10.1	890
056 Ninnis	12 Jan 2017	071637	67 45.46 S	146 56.24 E	1109	073607	67 45.41 S	146 56.08 E	1137	080222	67 45.46 S	146 56.17 E	1110	9.4	1142
057 Ninnis	12 Jan 2017	085256	67 42.36 S	147 04.49 E	843	090734	67 42.40 S	147 04.51 E	844	093047	67 42.43 S	147 04.71 E	841	8.9	845
058 Ninnis	12 Jan 2017	102113	67 45.20 S	147 05.41 E	1578	105051	67 45.11 S	147 05.59 E	1577	112452	67 45.06 S	147 05.70 E	1479	9.0	1590
059 Ninnis	12 Jan 2017	132935	67 55.19 S	146 59.57 E	966	134744	67 55.15 S	146 59.44 E	967	141151	67 55.03 S	146 59.40 E	924	5.3	973
060 Ninnis	12 Jan 2017	150729	67 56.77 S	147 16.57 E	985	152722	67 56.73 S	147 16.46 E	1152	155541	67 56.72 S	147 16.24 E	1078	10.8	1156
061 Ninnis	12 Jan 2017	170051	67 52.51 S	147 28.70 E	1413	172541	67 52.57 S	147 28.69 E	1421	175633	67 52.55 S	147 28.65 E	1409	10.3	1430
062 Ninnis	12 Jan 2017	185559	67 47.28 S	147 37.29 E	632	190822	67 47.22 S	147 37.27 E	641	192921	67 47.17 S	147 37.33 E	629	5.9	643
063 MertzTrough	13 Jan 2017	060403	66 53.40 S	147 42.08 E	596	061654	66 53.47 S	147 41.99 E	598	063704	66 53.47 S	147 42.37 E	595	8.9	595
064 MertzTrough	13 Jan 2017	081217	66 41.50 S	147 38.81 E	612	082455	66 41.51 S	147 38.98 E	611	084322	66 41.48 S	147 39.17 E	611	11.0	607
065 MertzTrough	13 Jan 2017	095412	66 33.92 S	147 39.95 E	606	100629	66 33.90 S	147 39.90 E	607	102422	66 33.91 S	147 39.81 E	608	7.0	607
066 MertzTrough	13 Jan 2017	121435	66 26.74 S	147 48.71 E	587	122657	66 26.75 S	147 48.56 E	586	124446	66 26.78 S	147 48.29 E	584	9.7	583
067 MertzTrough	13 Jan 2017	135725	66 19.56 S	147 54.88 E	573	141020	66 19.57 S	147 54.83 E	574	142841	66 19.60 S	147 54.77 E	574	8.6	572
068 MertzTrough	13 Jan 2017	160016	66 17.02 S	147 37.96 E	545	161036	66 16.99 S	147 37.84 E	545	162817	66 16.96 S	147 37.55 E	546	11.1	540
069 MertzTrough	13 Jan 2017	174414	66 14.50 S	147 21.10 E	561	175506	66 14.50 S	147 20.98 E	560	181240	66 14.50 S	147 20.68 E	557	9.3	557
070 MertzTrough	13 Jan 2017	192409	66 11.93 S	147 03.64 E	411	193247	66 11.92 S	147 03.62 E	408	194730	66 11.90 S	147 03.50 E	409	9.4	403
071 SR3	15 Jan 2017	005311	62 51.13 S	139 49.10 E	3160	014204	62 51.27 S	139 48.87 E	3154	024944	62 51.43 S	139 48.54 E	3150	9.8	3199
072 SR3	15 Jan 2017	061803	62 21.53 S	139 50.41 E	3925	072109	62 21.10 S	139 50.63 E	3924	083847	62 20.64 S	139 50.98 E	3932	8.6	3990
073 SR3	15 Jan 2017	122544	61 50.92 S	139 50.04 E	4272	133713	61 50.72 S	139 50.06 E	4268	145539	61 50.67 S	139 49.85 E	4274	9.9	4343

Table 2: CTD calibration coefficients and calibration dates for cruise au1602. Note that platinum temperature calibrations are for the ITS-90 scale. Pressure slope/offset, temperature, conductivity and oxygen values are from SeaBird calibrations. Fluorometer and PAR values are manufacturer supplied. Transmissometer values are a rescaling of the manufacturer supplied coefficients to give transmittance as a %, referenced to clean water. For oxygen, the final calibration uses in situ bottle measurements (the manufacturer supplied coefficients are not used). Note the revised CPcor value used for secondary conductivity, which reduces the depth dependent calibration error due to compressibility of the borosilicate glass cell.

Primary Temperature, serial 4245, 12/07/2016

G	: 4.38208846e-003
H	: 6.45695609e-004
I	: 2.25815632e-005
J	: 1.86526780e-006
F0	: 1000.000
Slope	: 1.0000000
Offset	: 0.0000

Secondary Temperature, serial 4248, 12/07/2016

G	: 4.38734976e-003
H	: 6.51083165e-004
I	: 2.33485084e-005
J	: 1.87674066e-006
F0	: 1000.000
Slope	: 1.0000000
Offset	: 0.0000

Primary Conductivity, serial 2788, 13/07/2016

G	: -9.73619110e+000
H	: 1.42990388e+000
I	: -8.38908400e-004
J	: 1.45191225e-004
CTcor	: 3.2500e-006
CPcor	: -9.5700000e-008
Slope	: 1.00000000
Offset	: 0.00000

Secondary Conductivity, serial 2821, 13/07/2016

G	: -1.05913976e+001
H	: 1.43438160e+000
I	: 1.14355003e-003
J	: -5.01227107e-006
CTcor	: 3.2500e-006
CPcor	: -8.0000000e-008
Slope	: 1.00000000
Offset	: 0.00000

CTD704 Pressure, serial 89084, 12/09/2016
(for slope, offset only)

C1	: -5.337692e+004
C2	: -5.768735e-001
C3	: 1.541700e-002
D1	: 3.853800e-002
D2	: 0.000000e+000
T1	: 2.984003e+001
T2	: -4.090591e-004
T3	: 3.693030e-006
T4	: 3.386020e-009
T5	: 0.000000e+000
Slope	: 0.9999500
Offset	: 0.04090 (dbar)
AD590M	: 1.283280e-002
AD590B	: -9.705660e+000

Oxygen, serial 0178, 16/07/2016
(for display at time of logging only)

Soc	: 4.86100e-001
Voffset	: -4.99700e-001
A	: -5.35410e-003
B	: 2.95440e-004
C	: -4.09250e-006
E	: 3.60000e-002
Tau20	: 1.65000e+000
D1	: 1.92634e-004
D2	: -4.64803e-002
H1	: -3.30000e-002
H2	: 5.00000e+003
H3	: 1.45000e+003

Transmissometer, serial 1421DR, 21/09/2016
(referenced to clean water)

M	: 21.3128
B	: -0.1492

Path length: 0.25 (m)

Fluorometer, serial 756, 08/05/2014
(analog range 2)

Dark output	: 0.0460
Scale factor	: 1.000e+001

PAR, serial 70110, QCP2300HP, 14/08/2014

M	: 1.000
B	: 0.000
Cal. Constant	: 1.618123e+010
Multiplier	: 1.0
Offset	: -6.214e-002

(note: offset value derived using earlier cruise au15vt dark voltage data)

Table 3: **CTD conductivity calibration coefficients for cruise au1602. F_1 , F_2 and F_3 are respectively conductivity bias, slope and station-dependent correction calibration terms. n is the number of samples retained for calibration in each station grouping; σ is the standard deviation of the conductivity residual for the n samples in the station grouping.**

stn grouping	F_1	F_2	F_3	n	σ
001 to 026	0.11121349E-01	0.99967663E-03	-0.60381258E-09	242	0.000606
027 to 049	0.30665223E-01	0.99903435E-03	-0.18880979E-08	183	0.000989
050 to 058	0.42766811E-01	0.99844935E-03	0.83917385E-09	62	0.000989
059 to 073	0.11332802E-01	0.99961526E-03	0.60560064E-09	146	0.000766

Table 4: **Station-dependent-corrected conductivity slope term ($F_2 + F_3 . N$), for station number N, and F_2 and F_3 the conductivity slope and station-dependent correction calibration terms respectively, for cruise au1602.**

station number	($F_2 + F_3 . N$)	station number	($F_2 + F_3 . N$)
1	0.99967603E-03	38	0.99896260E-03
2	0.99967542E-03	39	0.99896071E-03
3	0.99967482E-03	40	0.99895883E-03
4	0.99967421E-03	41	0.99895694E-03
5	0.99967361E-03	42	0.99895505E-03
6	0.99967301E-03	43	0.99895316E-03
7	0.99967240E-03	44	0.99895127E-03
8	0.99967180E-03	45	0.99894939E-03
9	0.99967120E-03	46	0.99894750E-03
10	0.99967059E-03	47	0.99894561E-03
11	0.99966999E-03	48	0.99894372E-03
12	0.99966938E-03	49	0.99894183E-03
13	0.99966878E-03	50	0.99849130E-03
14	0.99966818E-03	51	0.99849214E-03
15	0.99966757E-03	52	0.99849298E-03
16	0.99966697E-03	53	0.99849382E-03
17	0.99966636E-03	54	0.99849466E-03
18	0.99966576E-03	55	0.99849550E-03
19	0.99966516E-03	56	0.99849634E-03
20	0.99966455E-03	57	0.99849718E-03
21	0.99966395E-03	58	0.99849802E-03
22	0.99966335E-03	59	0.99965099E-03
23	0.99966274E-03	60	0.99965159E-03
24	0.99966214E-03	61	0.99965220E-03
25	0.99966153E-03	62	0.99965281E-03
26	0.99966093E-03	63	0.99965341E-03
27	0.99898337E-03	64	0.99965402E-03
28	0.99898148E-03	65	0.99965462E-03
29	0.99897959E-03	66	0.99965523E-03
30	0.99897771E-03	67	0.99965583E-03
31	0.99897582E-03	68	0.99965644E-03
32	0.99897393E-03	69	0.99965704E-03
33	0.99897204E-03	70	0.99965765E-03
34	0.99897015E-03	71	0.99965826E-03
35	0.99896827E-03	72	0.99965886E-03
36	0.99896638E-03	73	0.99965947E-03
37	0.99896449E-03		

Table 5: **Surface pressure offsets (i.e. poff in dbar) for cruise au1602. For each station, these values are subtracted from the pressure calibration "offset" value in Table 2.**

stn	poff	stn	poff	stn	poff	stn	poff	stn	poff	stn	poff
1	-0.29	14	-0.41	27	-0.24	40	-0.26	53	-0.33	66	-0.41
2	-0.23	15	-0.37	28	-0.19	41	-0.24	54	-0.27	67	-0.30
3	-0.19	16	-0.37	29	-0.29	42	-0.26	55	-0.20	68	-0.33
4	-0.32	17	-0.33	30	-0.24	43	-0.23	56	-0.29	69	-0.32
5	-0.34	18	-0.31	31	-0.32	44	-0.34	57	-0.25	70	-0.30
6	-0.38	19	-0.32	32	-0.33	45	-0.27	58	-0.32	71	-0.20
7	-0.44	20	-0.35	33	-0.22	46	-0.31	59	-0.39	72	-0.25
8	-0.45	21	-0.33	34	-0.05	47	-0.35	60	-0.15	73	-0.25
9	-0.36	22	-0.30	35	-0.20	48	-0.22	61	-0.29		
10	-0.33	23	-0.27	36	-0.32	49	-0.17	62	-0.34		
11	-0.47	24	-0.36	37	-0.33	50	-0.13	63	-0.27		
12	-0.32	25	-0.37	38	-0.34	51	-0.28	64	-0.28		
13	-0.41	26	-0.35	39	-0.34	52	-0.28	65	-0.31		

Table 6: **CTD dissolved oxygen calibration coefficients for cruise au1602: slope, bias, tcor (= temperature correction term), and pcor (= pressure correction term). dox is equal to 2.8σ , for σ as defined in the *CTD Methodology*. For deep stations, coefficients are given for both the shallow and deep part of the profile, according to the profile split used for calibration (see section 5.4 in the text); whole profile fit used for stations shallower than 1400 dbar (i.e. stations with only "shallow" set of coefficients in the table).**

	shallow					deep				
stn	slope	bias	tcor	pcor	dox	slope	bias	tcor	pcor	dox
1	0.554965	-0.399058	0.049227	0.000209	0.058998	0.401159	-0.099654	0.011223	0.000127	0.013784
2	0.492788	-0.312205	-0.039053	0.000188	0.052934					
3	0.312286	0.215165	0.034605	0.000079	0.019711					
4	0.301895	0.199977	0.013521	0.000096	0.022767					
5	0.515128	-0.166593	0.063486	0.000033	0.058017					
6	0.132156	0.737903	0.100227	0.000033	0.093643					
7	0.774745	-1.053037	-0.085117	0.000620	0.072330					
8	0.316840	0.226796	0.045406	0.000054	0.053517					
9	0.300386	0.201453	0.005521	0.000040	0.048344					
10	0.300964	0.202318	0.008667	0.000052	0.046547					
11	-	-	-	-	-					
12	0.486277	-0.226828	0.006573	0.000164	0.028978					
13	0.443877	-0.007684	0.077740	0.000150	0.026079					
14	0.415630	-0.069976	-0.002776	0.000084	0.082815					
15	0.505414	-0.237414	0.029695	0.000092	0.040365					
16	0.410881	-0.028577	0.014386	0.000007	0.090096					
17	0.486421	-0.225890	0.005031	0.000155	0.069954					
18	0.602224	-0.477798	0.022565	0.000266	0.054763					
19	0.463534	-0.194955	-0.008836	0.000144	0.026977					
20	0.483568	-0.234019	-0.005558	0.000147	0.027287					
21	0.436420	-0.097949	0.013657	0.000136	0.021210					
22	0.479948	-0.246111	0.019872	0.000153	0.095686	0.396851	-0.109421	0.021674	0.000135	0.050259
23	0.475873	-0.194975	-0.018280	0.000118	0.122649	0.396450	-0.106750	0.013971	0.000135	0.026758
24	0.473300	-0.254279	0.036157	0.000173	0.139067	0.484548	-0.155352	-0.087959	0.000082	0.055072
25	0.488417	-0.244767	0.007457	0.000143	0.090625	0.403248	-0.099215	0.000783	0.000125	0.034749
26	0.509401	-0.303050	0.024129	0.000180	0.063759	0.402562	-0.097852	-0.002314	0.000127	0.020727
27	0.409620	-0.085044	-0.027069	0.000101	0.064478	0.600093	-0.397420	-0.021148	0.000130	0.029378
28	0.510933	-0.273055	0.016006	0.000140	0.127465	0.497138	-0.239322	-0.024154	0.000126	0.018849
29	0.509312	-0.282049	0.007323	0.000163	0.078565	0.406638	-0.094610	-0.020995	0.000125	0.020869
30	0.465539	-0.207362	-0.013891	0.000150	0.109285					
31	0.520806	-0.303658	0.003106	0.000157	0.081669					
32	0.886054	-1.239064	-0.013053	0.001592	0.087905					
33	0.366022	0.059563	0.037866	0.000208	0.045522					
34	0.482534	-0.223979	0.005571	0.000172	0.036079					
35	0.486696	-0.225012	0.006441	0.000151	0.056459					
36	0.485232	-0.226433	0.000748	0.000141	0.013079					
37	0.462173	-0.146448	0.027257	0.000149	0.060047					
38	0.506401	-0.289145	-0.009518	0.000154	0.074521					

Table 6: (continued)

	shallow					deep				
stn	slope	bias	tcor	pcor	dox	slope	bias	tcor	pcor	dox
39	0.505423	-0.290357	-0.008425	0.000170	0.033785					
40	-	-	-	-	-					
41	0.484408	-0.225171	0.003673	0.000154	0.060095					
42	0.446202	-0.133307	0.007293	0.000130	0.027290					
43	0.488316	-0.265590	-0.019011	0.000151	0.104300					
44	0.484573	-0.225095	0.001757	0.000143	0.065825					
45	0.491444	-0.238089	0.008734	0.000156	0.088336					
46	0.487765	-0.223550	0.007756	0.000144	0.055918					
47	0.428295	-0.184225	-0.053964	0.000139	0.032529					
48	0.488602	-0.220406	0.014207	0.000162	0.075986					
49	0.471878	-0.186783	0.008648	0.000137	0.014657					
50	0.481565	-0.227078	-0.001610	0.000148	0.044115					
51	0.412296	-0.002142	0.047451	0.000146	0.035251					
52	0.586248	-0.506594	-0.039288	0.000193	0.030018					
53	0.355833	0.174294	0.077937	0.000099	0.057788					
54	0.385633	0.035321	0.037500	0.000148	0.030791					
55	0.415733	-0.077498	0.001966	0.000125	0.022748					
56	0.415987	-0.078571	0.001945	0.000125	0.037465					
57	0.546068	-0.391178	-0.017182	0.000179	0.044860					
58	0.388082	0.055155	0.047410	0.000108	0.061083	1.427205	-0.848085	0.514921	0.000123	0.011619
59	0.456342	-0.238974	-0.047553	0.000150	0.086257					
60	0.385227	-0.110376	-0.065964	0.000131	0.017589					
61	0.514501	-0.279091	0.008907	0.000150	0.019576	1.266064	-0.831761	0.435600	0.000139	0.014255
62	0.483308	-0.226603	0.002229	0.000156	0.035259					
63	0.426447	-0.098218	0.013344	0.000159	0.047134					
64	0.440477	-0.137456	0.003533	0.000152	0.041991					
65	0.420397	0.007007	0.072712	0.000153	0.072000					
66	0.521442	-0.330802	-0.009785	0.000184	0.047087					
67	0.493713	-0.245746	0.007999	0.000172	0.074653					
68	0.494732	-0.284821	-0.023097	0.000159	0.099032					
69	0.579314	-0.431139	-0.001052	0.000175	0.067913					
70	0.484113	-0.226605	0.007566	0.000181	0.045542					
71	0.424109	-0.123815	-0.015440	0.000124	0.062051	0.602780	-0.396094	-0.030286	0.000139	0.021366
72	0.481348	-0.244239	0.009465	0.000156	0.021627	0.602613	-0.394734	-0.029255	0.000141	0.025137
73	0.481918	-0.234075	0.002060	0.000145	0.044442	0.398008	-0.104975	0.016758	0.000127	0.033651

Table 7: Missing data points in 2 dbar-averaged files for cruise au1602. "x" indicates missing data for the indicated parameters: T=temperature; S/C=salinity and conductivity; O=oxygen; F=fluorescence downcast; PAR=photosynthetically active radiation downcast; TR=transmittance downcast; F_up=fluorescence upcast; PAR_up=photosynthetically active radiation upcast; TR_up=transmittance upcast. Note: 2 and 4 dbar values (i.e. first two bins) not included here as they're missing for most casts.

station	pressure (dbar) where data missing	T	S/C	O	F	PAR	TR	F_up	PAR_up	TR_up
5	6-28			x						
11	6-230			x						
22	3838	x	x	x	x	x	x	x	x	x
40	6-204			x						
47	6-10	x	x	x	x	x	x			
47	12-36			x						
53	152-700			x						
72	6-8	x	x	x	x	x	x			
73	6-8	x	x	x	x	x	x			

Table 8: Suspect CTD 2 dbar averages (not deleted from the CTD 2 dbar average files) for the indicated parameters, for cruise au1602.

station	suspect 2 dbar value (dbar)	parameters	comment
3	6-18	ox	no shallow sample for calibration
5	30-90	ox	suspect sample (and no shallow samples) for calibration
39	4-30	ox	possibly low by ~4 µmol/l
49	16-28	ox	possibly high by ~4 µmol/l

Table 9: Obvious bad salinity bottle samples (not deleted from bottle data file) for cruise au1602 (note: there may be other less obvious ones).

station	rosette position	station	rosette position
1	5	29	4, 9
2	5	32	1
3	15	36	12
5	13	43	9, 10
8	23	45	5
13	23	52	3
20	23	56	3, 5
21	11		
27	3, 10		

Table 10: Suspect dissolved oxygen bottle values (not deleted from bottle data file) for cruise au1602.

station	rosette position
5	7, 11, 13
6	5
15	5
53	7, 11

Table 11: Suspect nutrient sample values for cruise au1602. For the nutrients, P=phosphate, N=nitrate+nitrite, S=silicate, Ni=nitrite, A=ammonia. In the comments, % refers to % of full scale (as listed in section 5.6).

station	rosette position	nutrient	comment	flag
3	12	P,N	possibly a bit low	3
18	1	P,N,S	low by ~5-10%	3
18	1	Ni	bit high	3
20	1	P,N,S	low by ~5-10%	3
20	1	Ni	bit high	3
24	22	P	high by ~3%	3
26	4	A	bit high	3
28	15	A	bit high	3
30	7	A	bit high	3
34	1	A	bit high	3
37	8	P	low by ~6%	3
37	8	A	bit high	3
41	1	P	low by ~4%	3
63	23	P,N	either P high or N low, by ~5%	3
64	17	P	high by ~6%	3
66	5	A	bit high	3
73	17,23	P	high by ~6%	3
73	13	P,N	low by over 10%	4
73	13	A, Ni	bit high	3
73	10	A	bit high	3

Table 12: Scientific personnel (cruise participants) for cruise au1602, post Casey resupply.

Will Hobbs	CTD
Mana Inoue	CTD
Benoit Legresy	CTD, sea ice image magician
Mark Rosenberg	CTD, SOTS mooring attempt
Alessandro Silvano	CTD
Katherine Tattersall	CTD
Eva Cougnon	hydrochemistry (salinity)
Stephen Tibben	hydrochemistry (oxygen)
Mar Arroyo	carbon
Kate Berry	carbon
Ella Clausius	carbon
Madi Green	carbon
Jemina Stuart-Smith	carbon
Matt Corkill	trace elements/carbon cycle
Cristina Genovese	trace elements/carbon cycle
Julie Janssens	trace elements/carbon cycle
Delphine Lannuzel	trace elements/carbon cycle
Sebastien Moreau	trace elements/carbon cycle
Lavy Ratnarajah	trace elements/carbon cycle, lugols
Viena Puigcorbe Lacueva	trace elements/isotopes/bacteria
Muntsa Roca	trace elements/isotopes/bacteria
Rob King	krill
Sarah McCulloch	krill
Jess Melvin	krill
Blair Smith	krill
Sven Gastauer	hydroacoustics
Amanda Dawson	plastics pollution
Andrew Cawthorn	gear officer
Matt Wright	gear officer
Jay McGlashan	electronics, programmer
Jim Williams	electronics
Jeff Teda	comms
Andy Cianchi	voyage leader
Mike Woolridge	deputy voyage leader
Malcolm Vernon	doctor
Cassie Brown	medical trainee
Helen Achurch	small boat ops, phytoplankton
Paul Baker	small boat ops
Tom Clarke	small boat ops, phytoplankton
Simon Cross	FTO, small boat ops
Rupert Davies	small boat ops
Zane Hacker	small boat ops, phytoplankton
Ollie Hentschel	small boat ops leader
Andrew Hodgkins	small boat ops
Tim McNamara	small boat ops, phytoplankton
Penny Purdie	small boat ops
Mick Stapleton	FTO, small boat ops
Noel Tennant	small boat ops
Ben Tucker	small boat ops
Brad Collins	Casey refuelling, small boat ops
Mike Sparg	Casey refuelling, small boat ops

<u>Table 13:</u> Summary of 'Argo' float deployments on cruise au1602 (depths are from underway data file: depth from surface, sound speed 1445 m/s). Deployments were from the trawl deck on the transit south to Casey.

Argo serial	latitude	longitude	UTC time	depth (m)
7608	45° 01.46'S	144° 57.64'E	2040, 08/12/2016	4515
7798	55° 16.38'S	140° 32.41'E	0900, 11/12/2016	4020
7799	58° 44.81'S	138° 10.58'E	0315, 12/12/2016	4590
7794	59° 59.90'S	135° 46.20'E	1143, 12/12/2016	4580
7737	60° 59.64'S	133° 33.13'E	1857, 12/12/2016	4571
7736	62° 00.00'S	126° 13.87'E	1145, 13/12/2016	4374
7735	62° 30.02'S	122° 15.67'E	2313, 13/12/2016	4130
7734	64° 00.20'S	111° 44.50'E	0757, 15/12/2016	2732

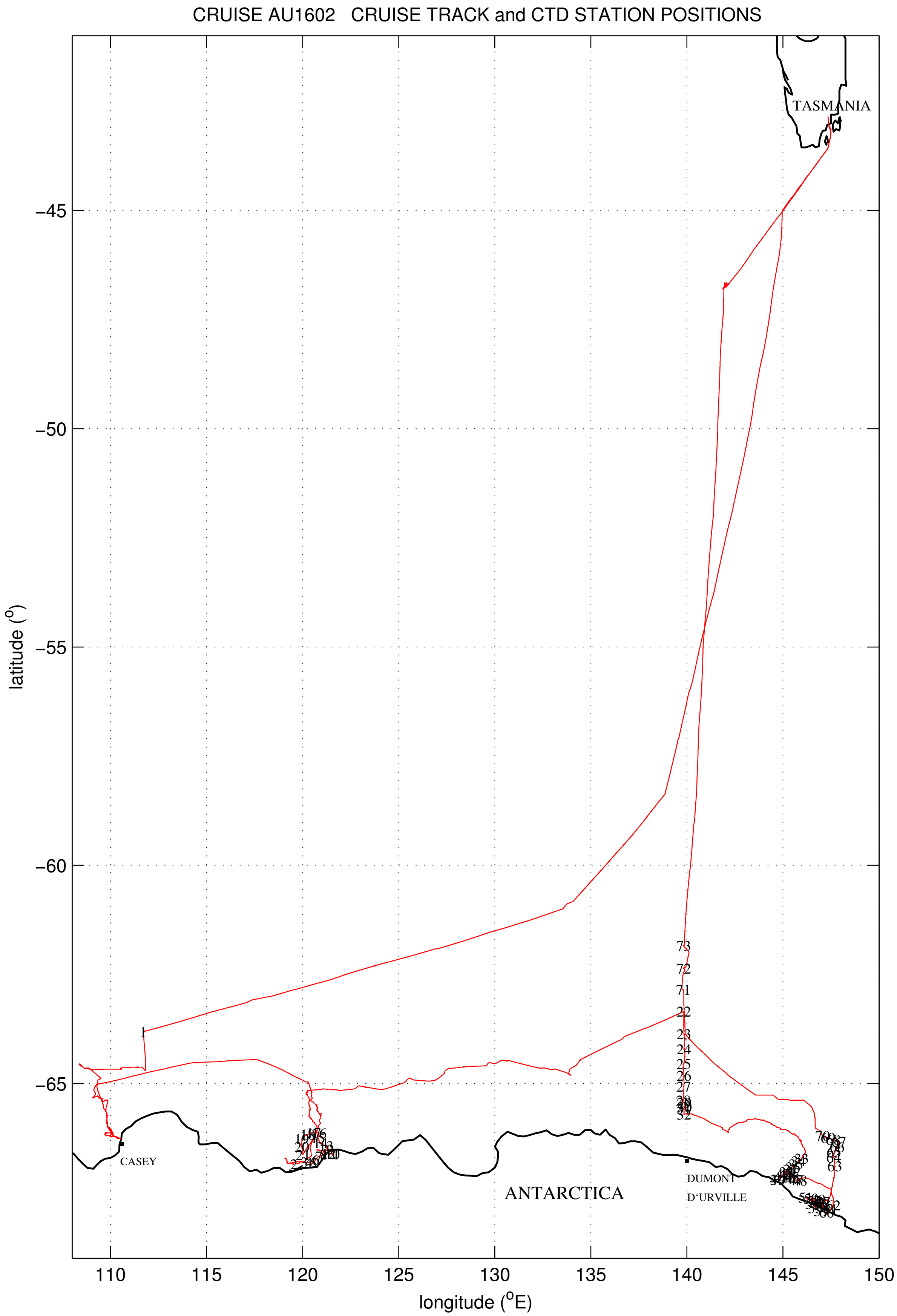
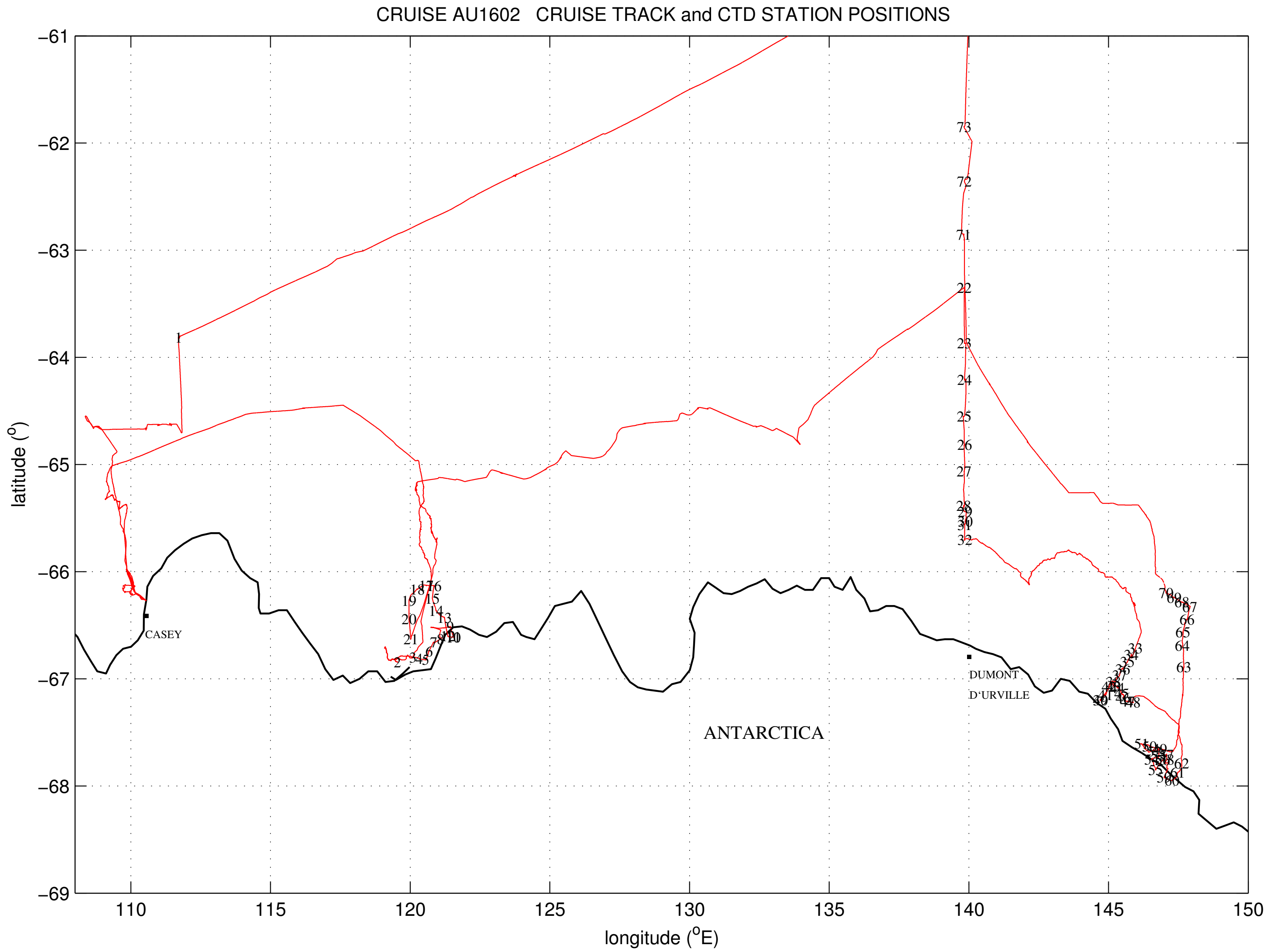
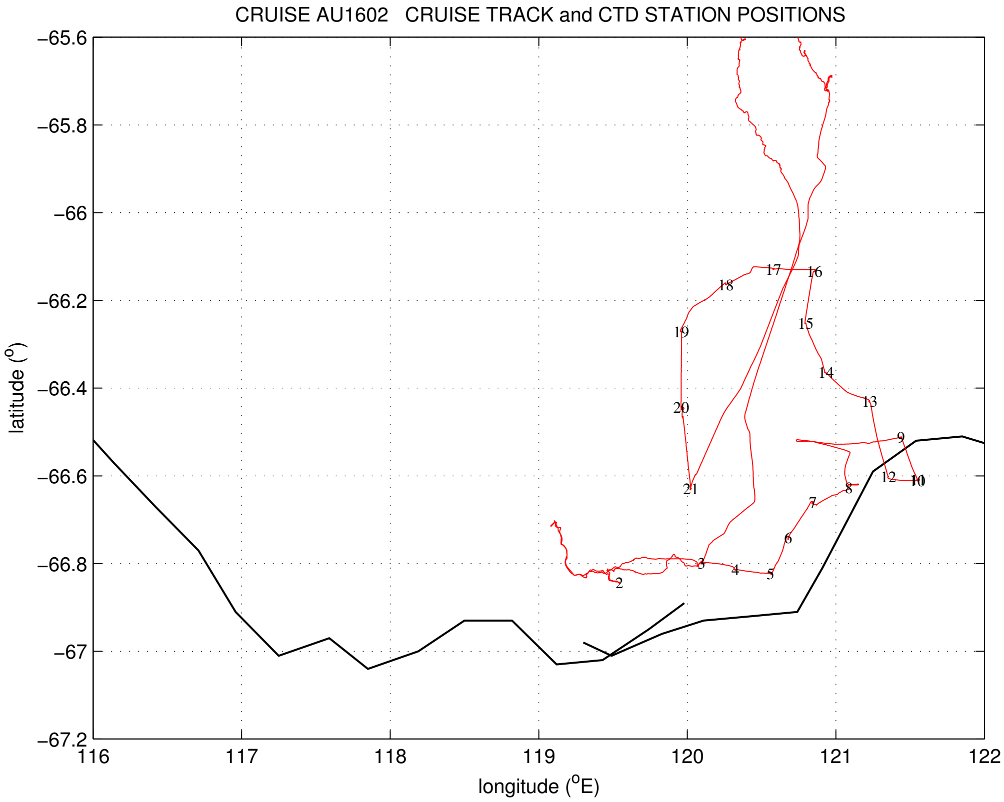


Figure 1a: CTD station positions and ship's track for cruise au1602.

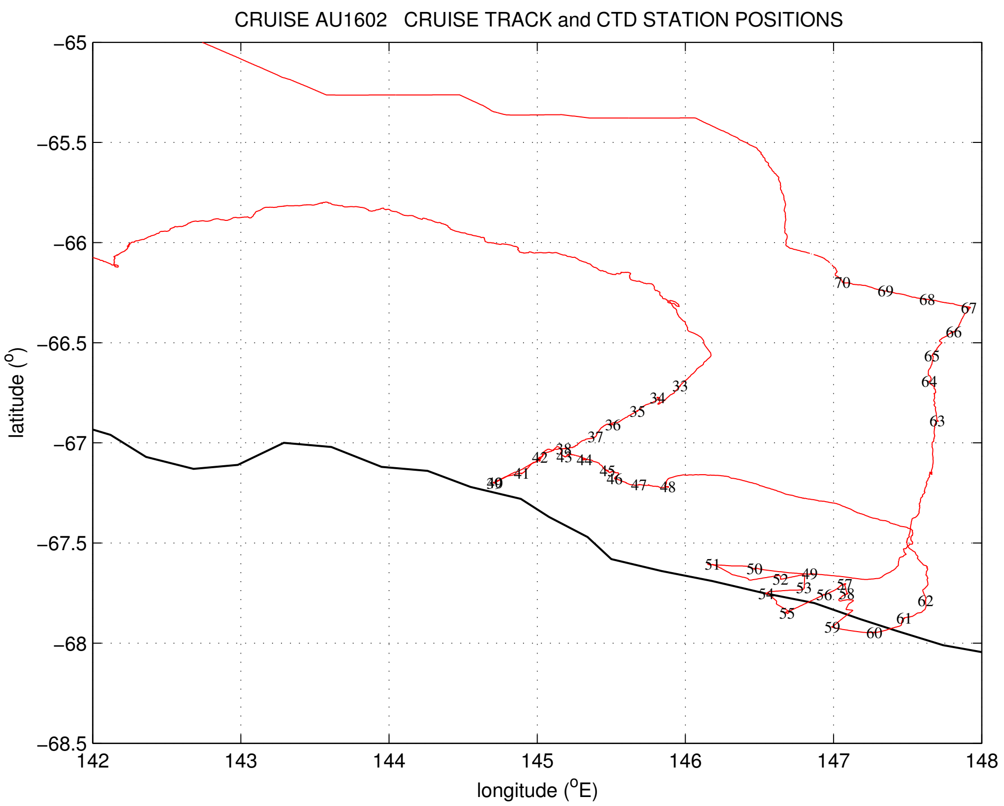


<u>Figure 1b:</u> CTD station positions and ship's track for cruise au1602 – all southern work.

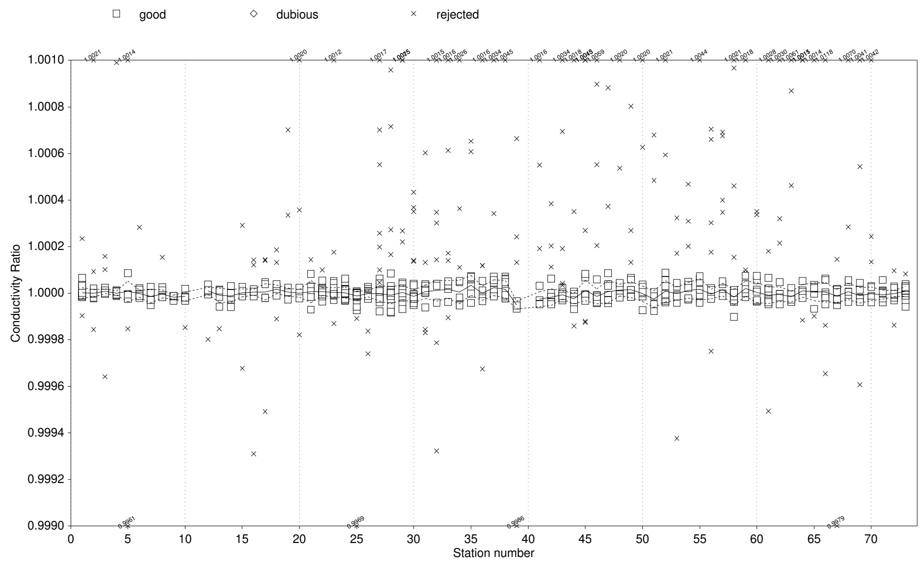
(c)



(d)



<u>Figure 1c and d:</u> CTD station positions and ship's track for cruise au1602, for (c) Dalton Polynya region, and (d) Mertz Glacier region.



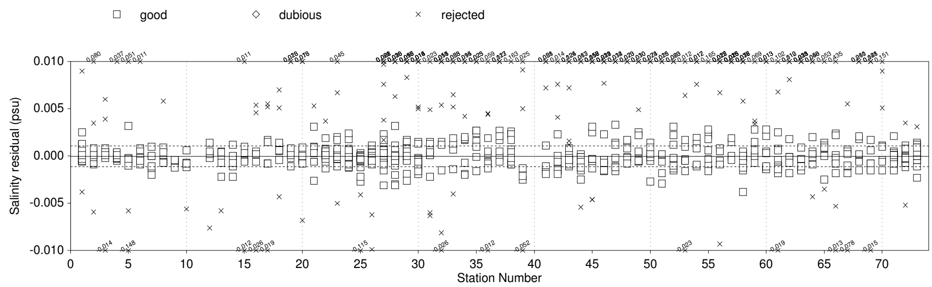
Calibration data for cruise : au1602

Calibration file : a1602.bot

Conductivity s.d. = 0.00003

Number of bottles used = 633 out of 817 Mean ratio for all bottles = 1.00000

<u>Figure 2:</u> Conductivity ratio c_{btl}/c_{cal} versus station number for cruise au1602. The solid line follows the mean of the residuals for each station; the broken lines are ± the standard deviation of the residuals for each station. c_{cal} = calibrated CTD conductivity from the CTD upcast burst data; c_{btl} = 'in situ' Niskin bottle conductivity, found by using CTD pressure and temperature from the CTD upcast burst data in the conversion of Niskin bottle salinity to conductivity.



Calibration data for cruise : au1602

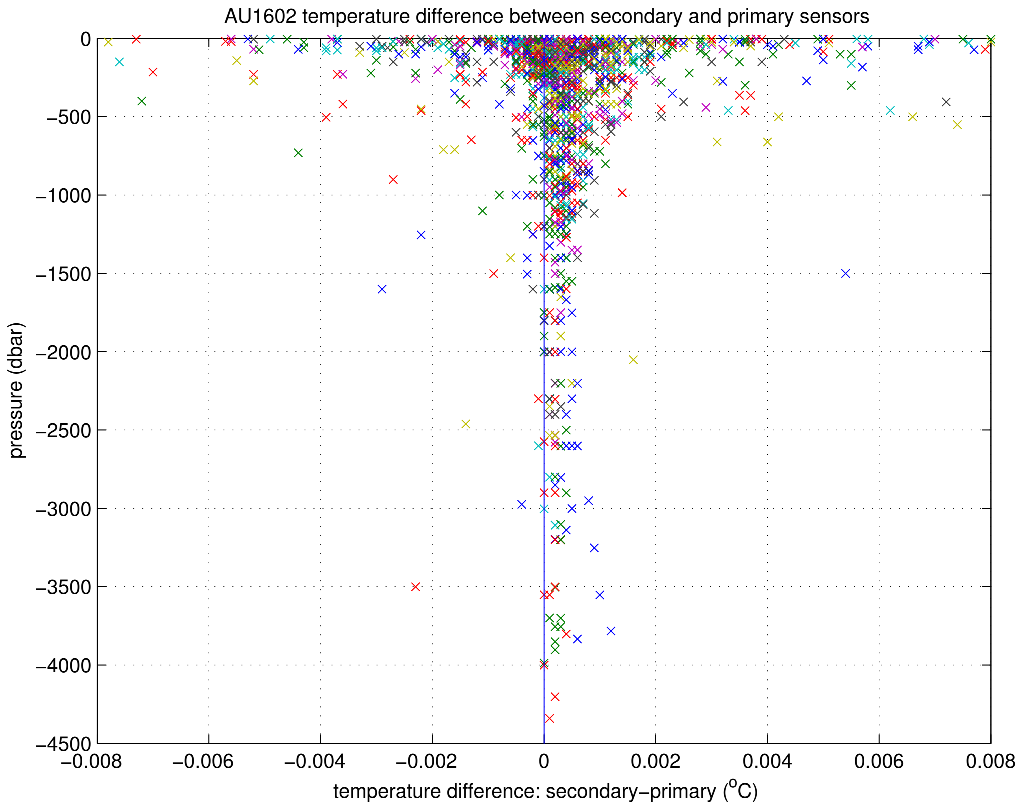
Calibration file : a1602.bot

Mean offset salinity = 0.0000psu (s.d. = 0.0011 psu)

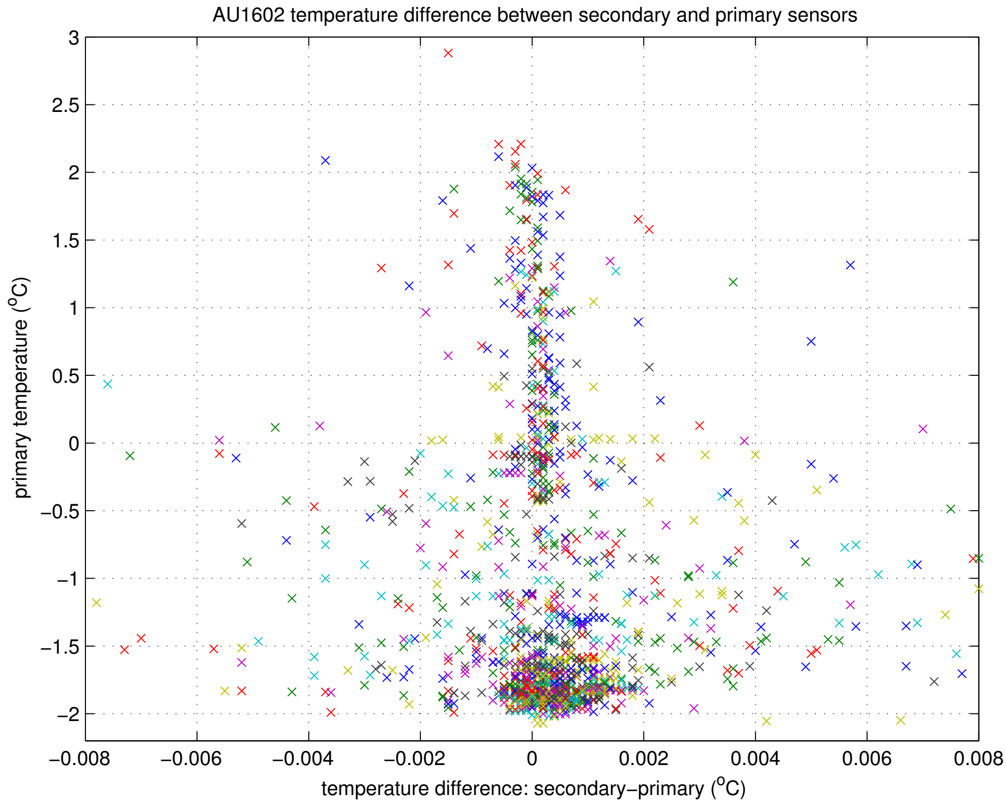
Number of bottles used = 633 out of 817

<u>Figure 3:</u> Salinity residual (s_{btl} - s_{cal}) versus station number for cruise au1602. The solid line is the mean of all the residuals; the broken lines are ± the standard deviation of all the residuals. s_{cal} = calibrated CTD salinity; s_{btl} = Niskin bottle salinity value.

(a)



(b)



<u>Figure 4:</u> Difference between secondary and primary temperature sensors with (a) pressure, and (b) temperature. Data are from the upcast CTD data bursts at Niskin bottle stops.

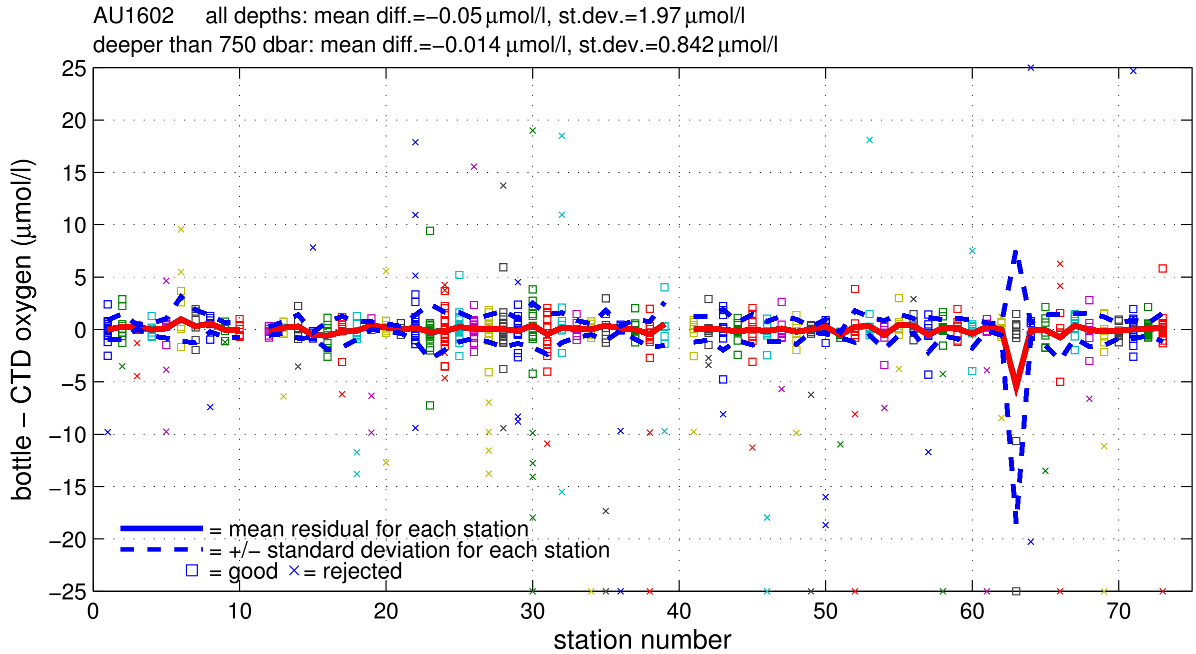


Figure 5: **Dissolved oxygen residual (o_{btl} - o_{cal}) versus station number for cruise au1602. The solid line follows the mean residual for each station; the broken lines are ± the standard deviation of the residuals for each station. o_{cal}=calibrated downcast CTD dissolved oxygen; o_{btl}=Niskin bottle dissolved oxygen value.**

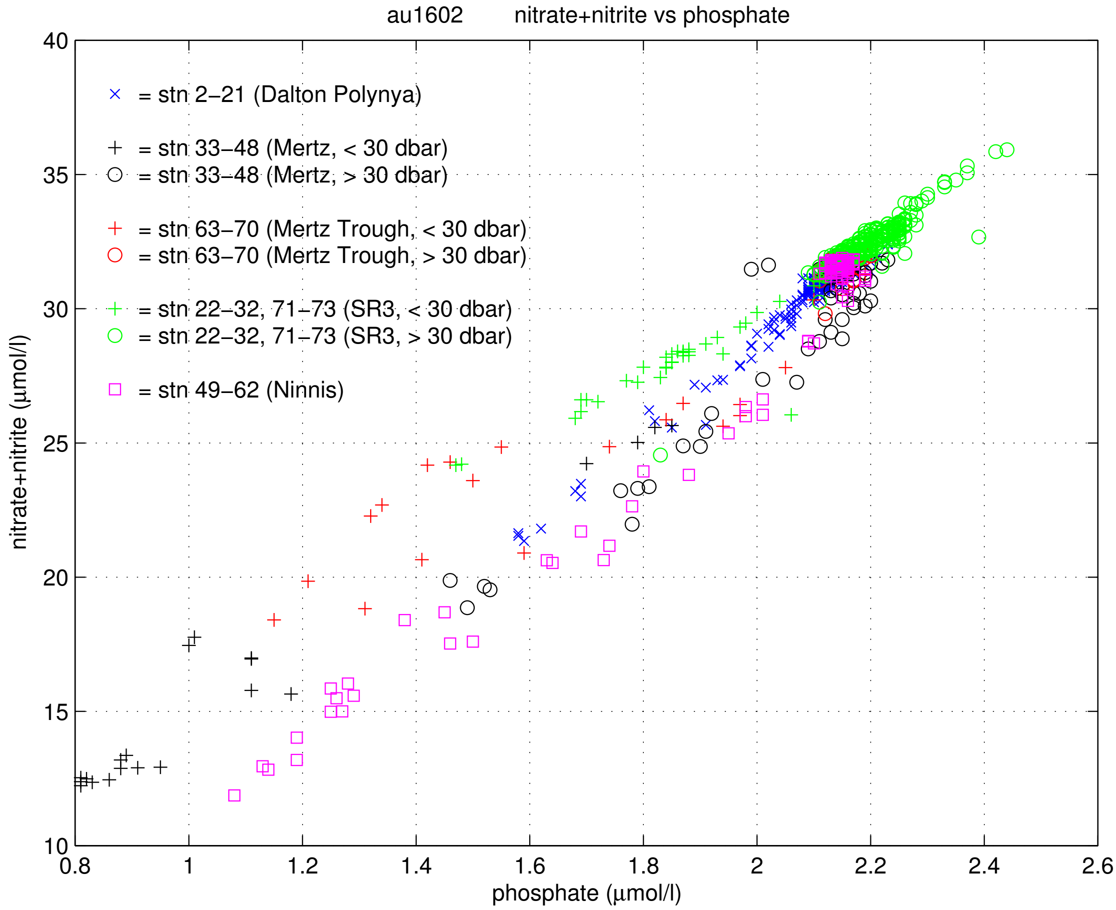


Figure 6: **Nitrate+nitrite versus phosphate data for cruise au1602.**

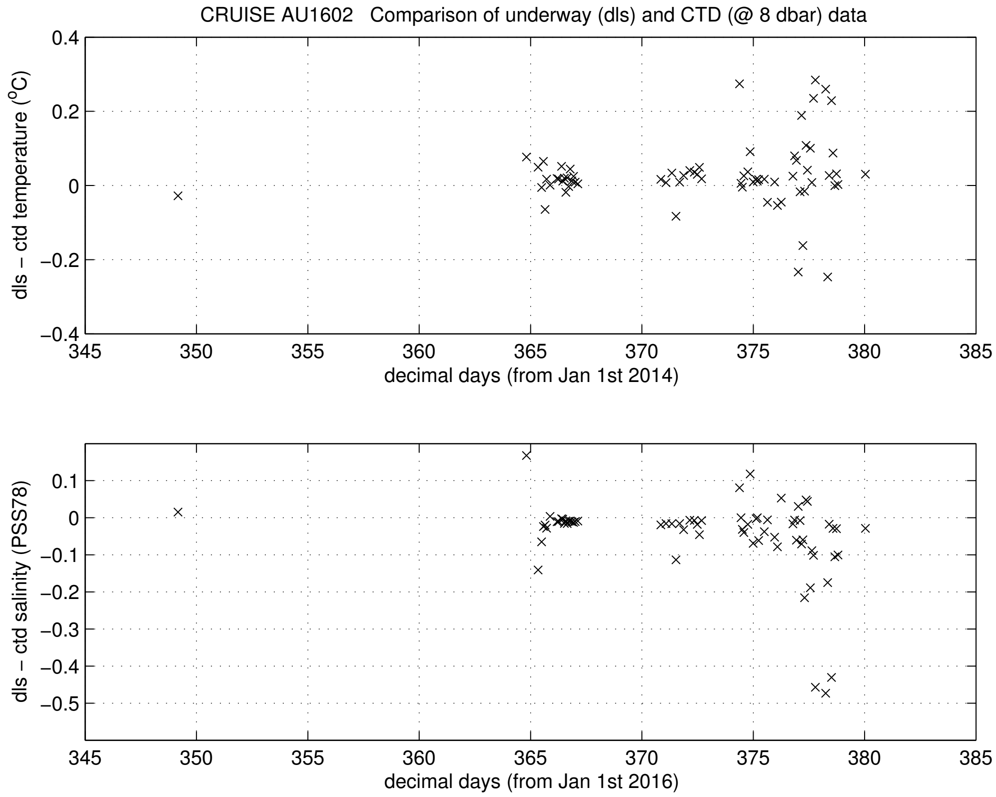
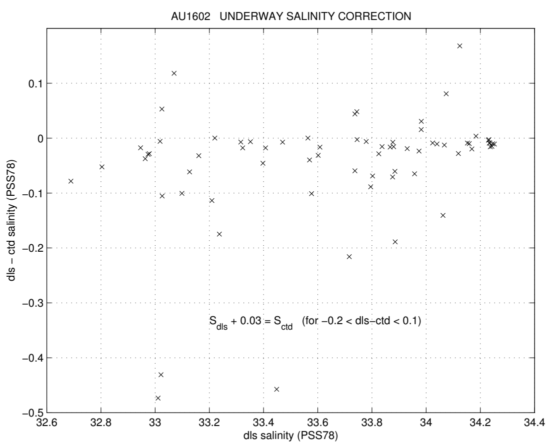


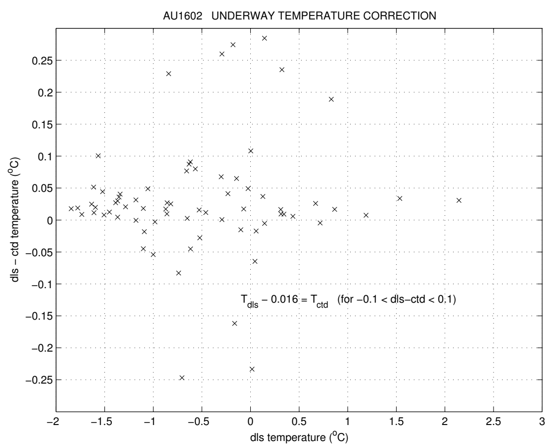
Figure 7: au1602 comparison of underway temperature and salinity data to CTD data, with time.

Figure 8a and b: au1602 comparison between (a) CTD and underway salinity data and (b) CTD and underway temperature data (i.e. hull mounted temperature sensor). Note: dls refers to underway data. Note that these corrections have not been applied to the underway data.

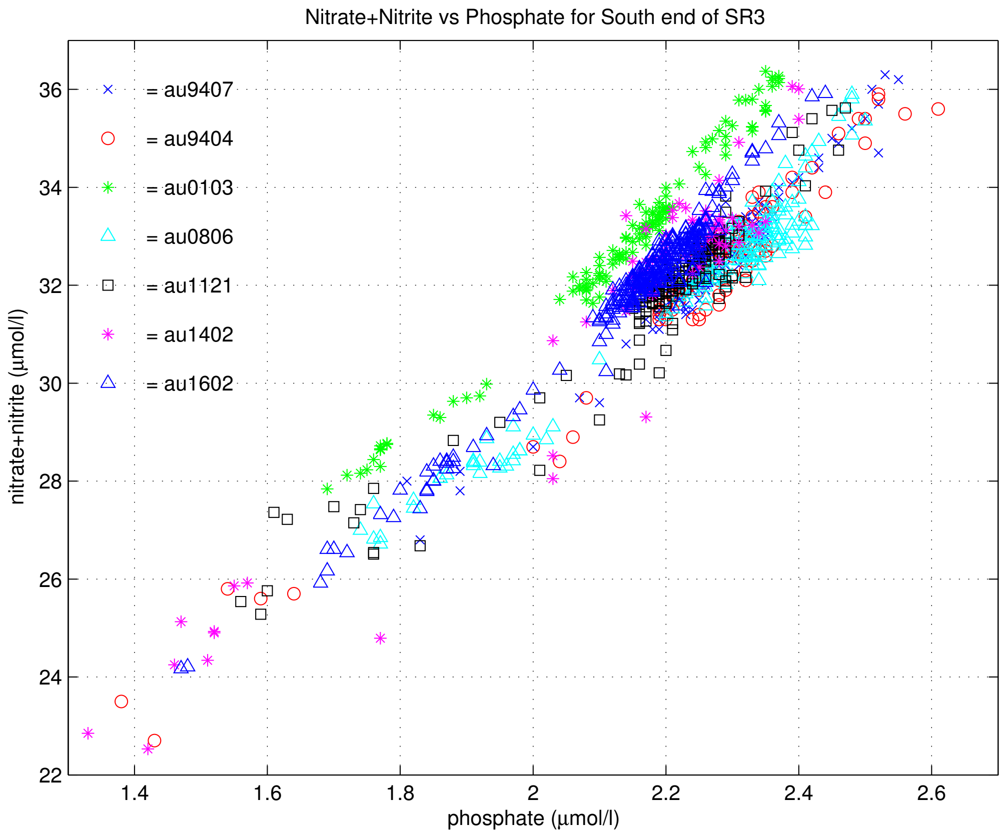
(a)



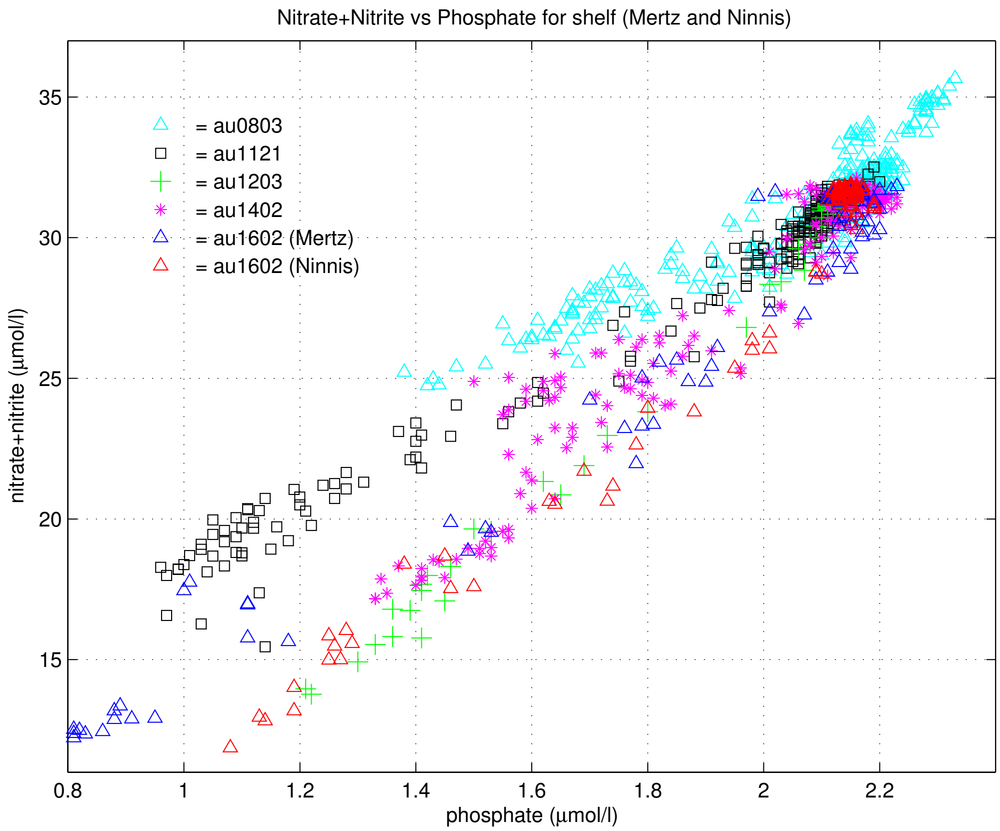
(b)



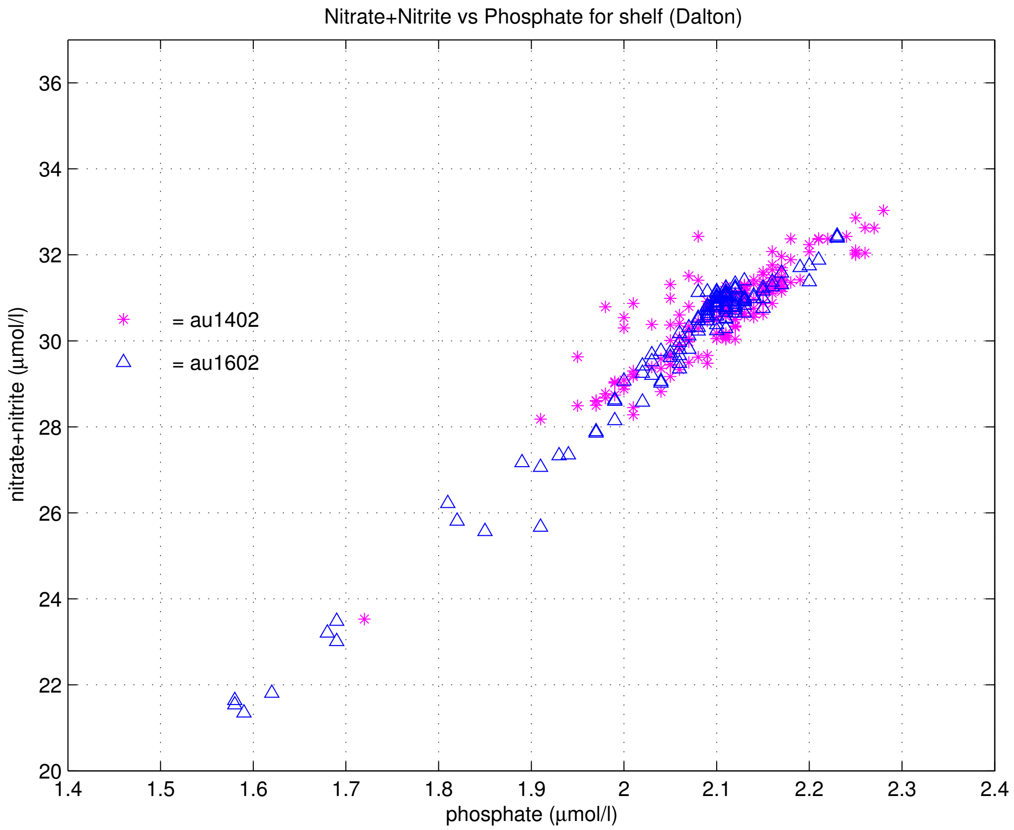
(a)



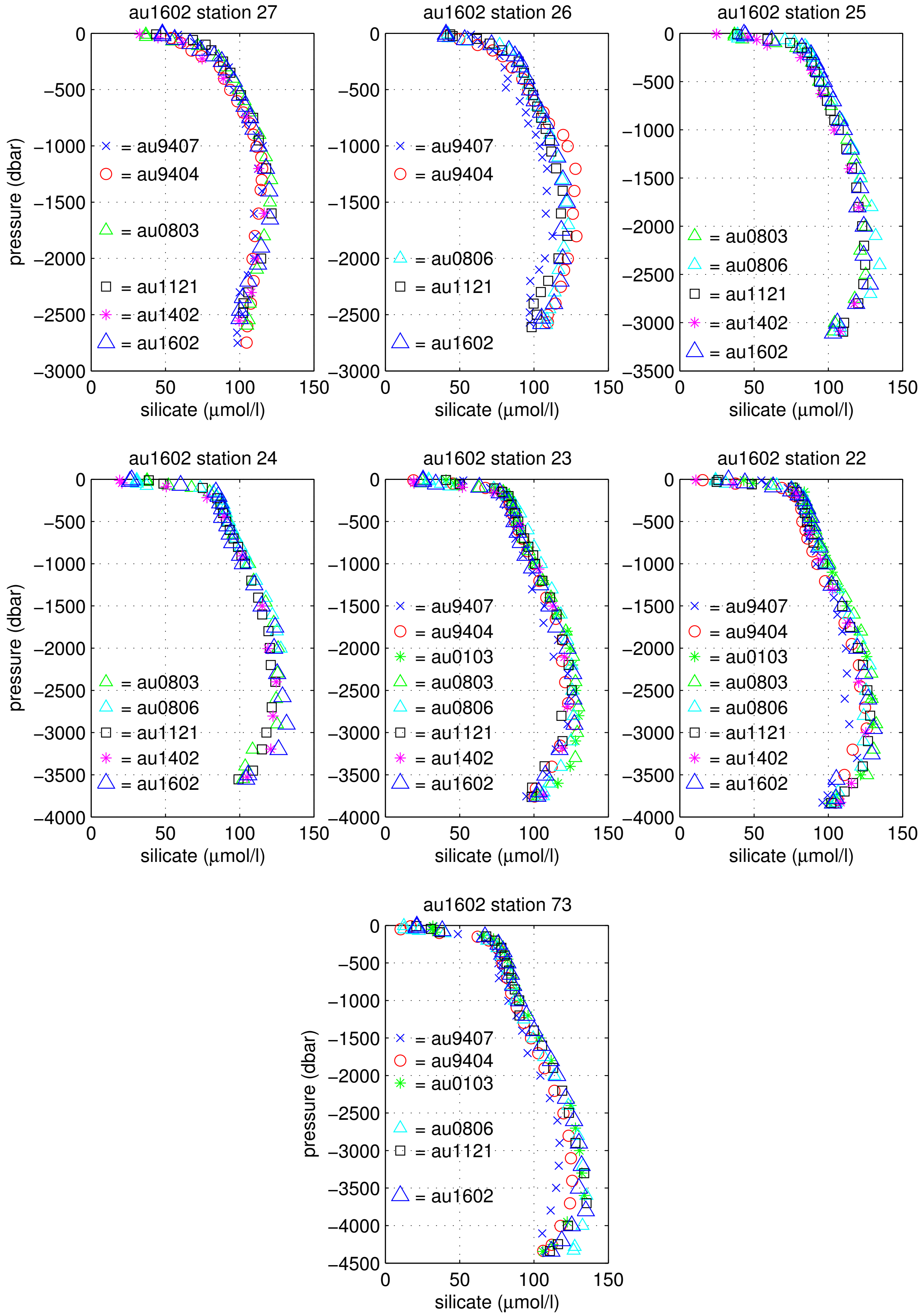
(b)



<u>Figure 9a and b:</u> Bulk plots showing intercruise comparisons of nitrate vs phosphate data for (a) south end of SR3, and (b) shelf stations in the Mertz region (Ninnis included for au1602).

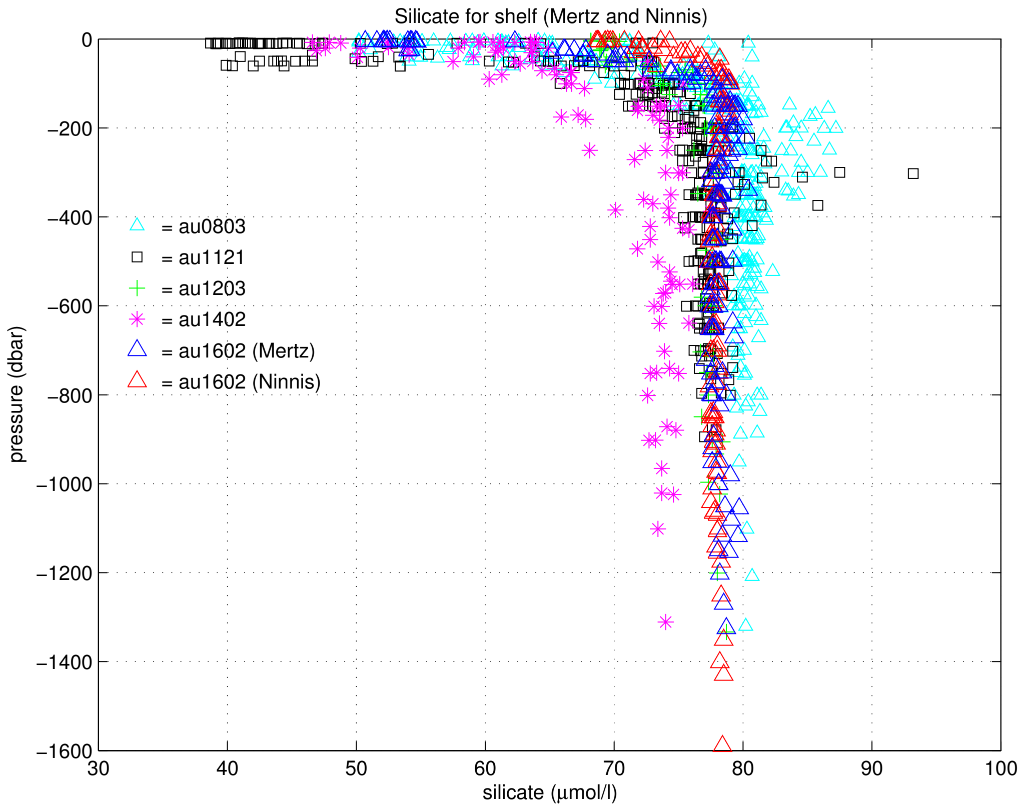


<u>Figure 9c:</u> Bulk plots showing intercruise comparisons of nitrate vs phosphate data for Dalton Polynya.

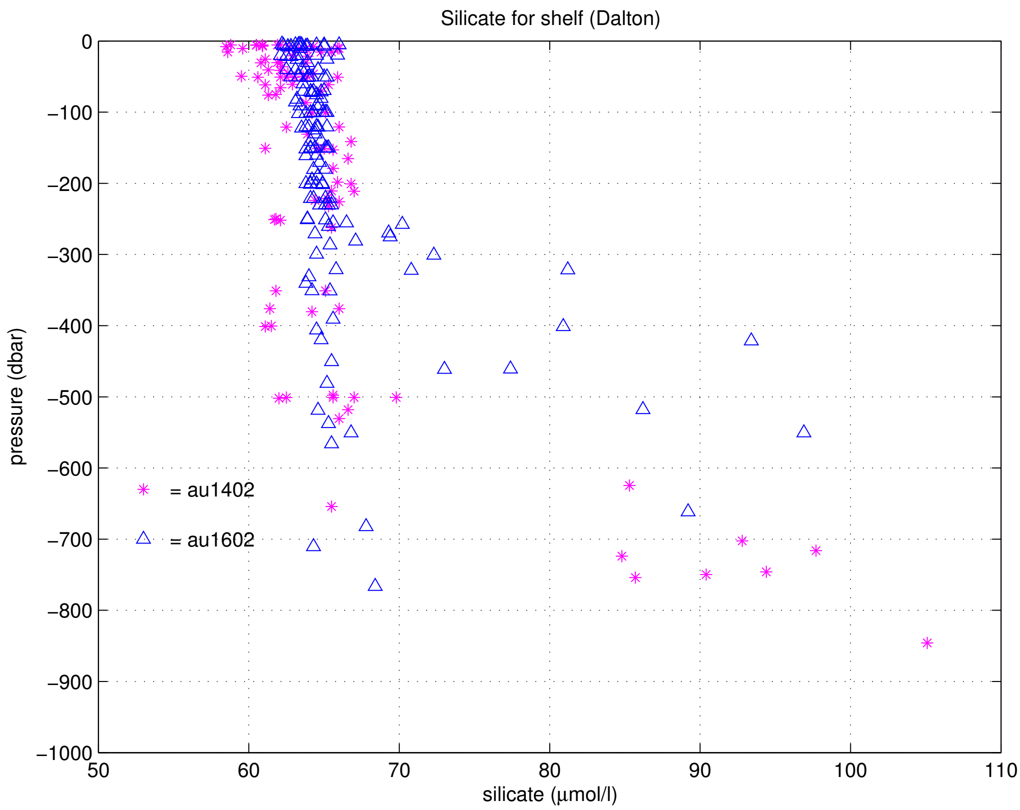


<u>Figure 10a:</u> Intercruise comparisons of silicate data for south end of SR3.

(b)



(c)



<u>Figure 10b and c:</u> Intercruise comparisons of silicate data for shelf stations (a) in the Mertz region (Ninnis included for au1602), and (b) in the Dalton Polynya.

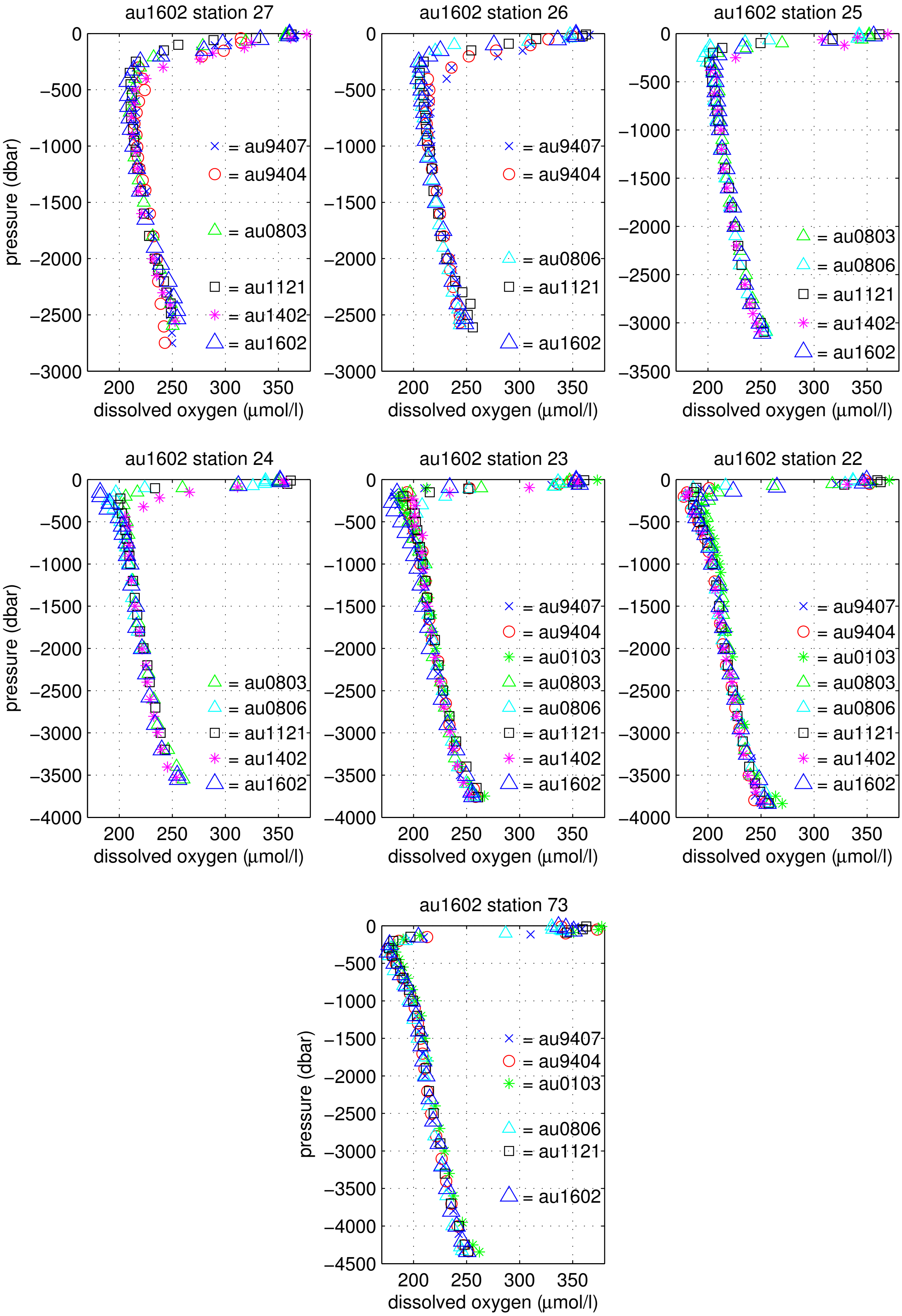
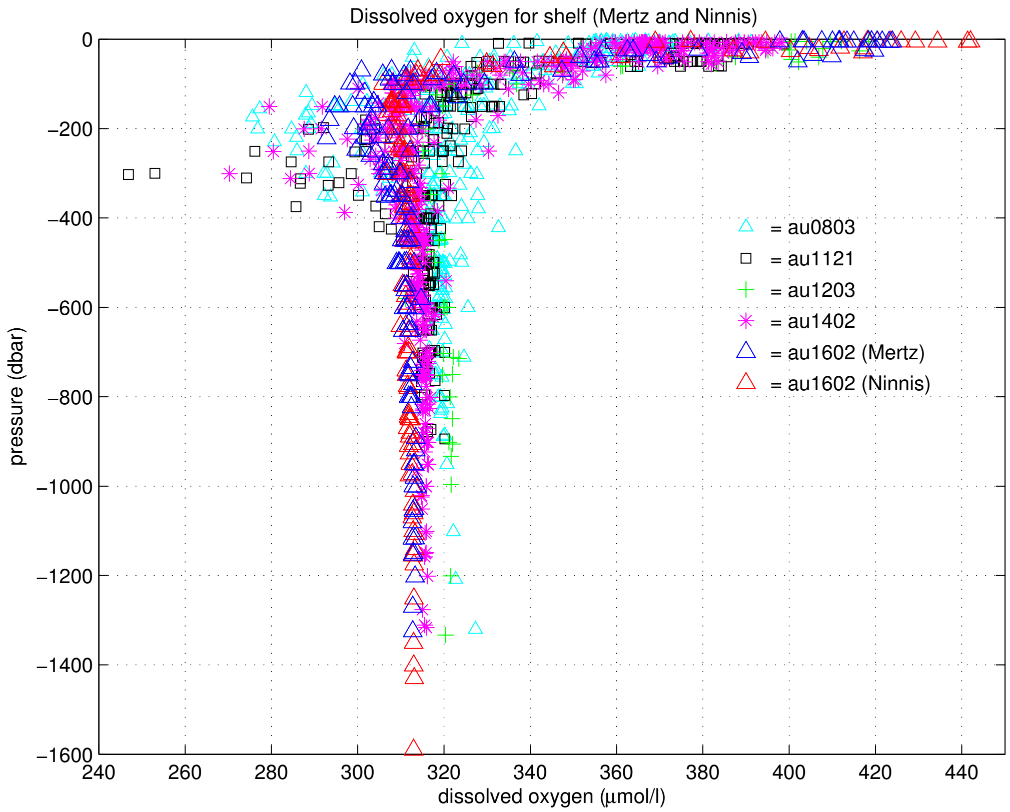
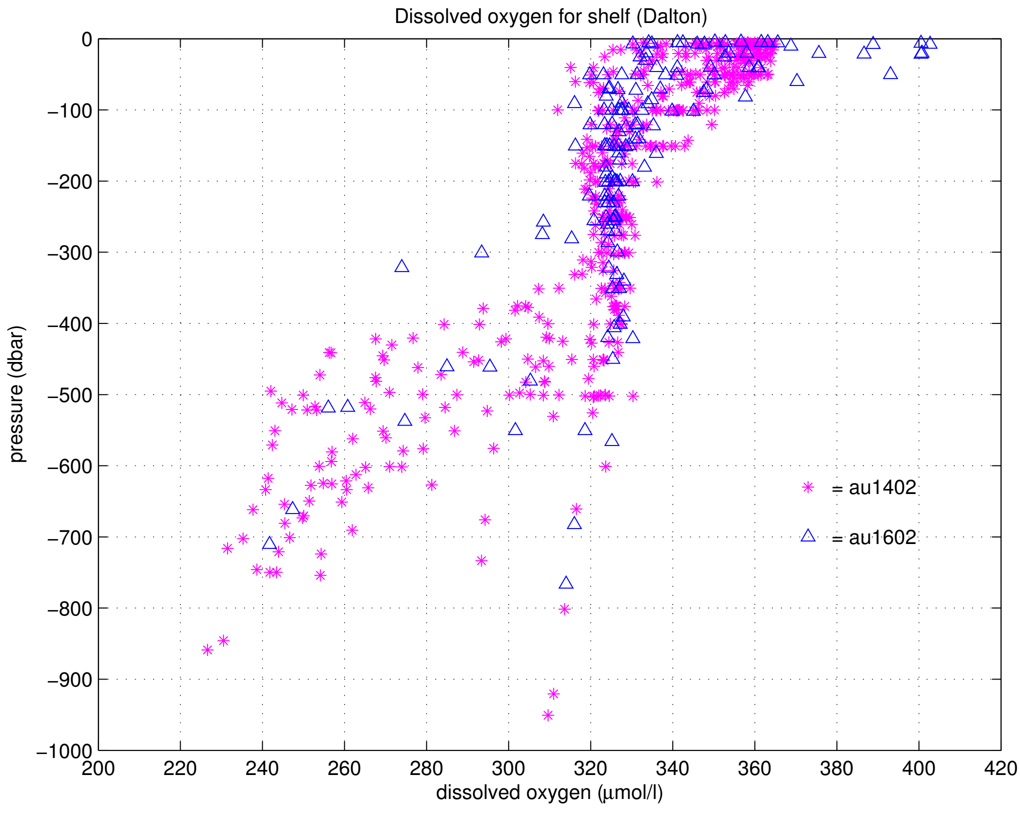


Figure 11a: Intercruise comparisons of dissolved oxygen bottle data for south end of SR3.

(b)



(c)



<u>Figure 11b and c:</u> Intercruise comparisons of dissolved oxygen bottle data for shelf stations (b) in the Mertz region (Ninnis included for au1602), and (c) in the Dalton Polynya.

APPENDIX 1 SALINITY LABORATORY ANALYSES

Cruise report by EVA COUGNON (*ACECRC, Hobart)*

Salinometers

Two Guildline Autosal salinometers were available during the voyage and located in the carbon lab (lab 2/3, E deck). Only the Autosal serial 72088 was used during the voyage (Guildline Autosal serial MNF72151 was the spare). Both had a stable standby number throughout the voyage. No thermometer was available for ongoing recording of lab temperature, however the bath temperature and standby number for the main salinometer were constant for the entire voyage. In the future it would be very useful to have a thermometer where the samples are stored, even if the salinometer seems stable. Occasional lab temperature checks where done when it started to feel too warm (see below for more details). Most of the time, the lab temperature stayed above 22 ˚C and below 24 ˚C. International standard seawater batch number P158 (15th March 2018) was used for salinometer standardisations.

Sampling

Niskin bottle sampling was done after oxygen and carbon. Sample bottles were rinsed 3 times then filled to the shoulder. Note that by not filling the bottles to the neck, the extra air space in the bottles allowed some gas realise before sample analysis, minimizing bubble troubles with the salinometer. This space left in the bottles was estimated as being small enough to avoid evaporation issues within the sample. Lastly for each sample, someone with dry hands sealed the bottle with a clean insert, rinsed the top with milli Q, and closed the bottle with a clean lid.

Processing the samples

The lab space for the main salinometer was on the corridor side of lab 3 using a third of the length of the bench, with the other two thirds used for the carbon team. The partition between lab 2 and 3 was not used. The air conditioning system was on the lab 3 bulkhead above the carbon water bath (on the right of the salinometer). The computer linked to the salinometer was on the right of the instrument, leaving a corner for one crate. However, this corner next to the computer became too warm during long runs. From salinity run sal013 the samples were placed on top of 3 blue boxes, away from the computer fan.

A new Standard Sea Water (SSW) was used for standardisation at the start of each run. During a long run another SSW was used after about 36 samples, to check for any possible salinometer drift. Table A1.2 summarises the SSW readings for each salinometer run.

After the normal shaking of a sample bottle for homegenisation, the bottle was given a "bang" on a soft surface prior to running on the salinometer. This further helped minimize bubble formation within the cell (in addition to only filling sample bottles to the shoulder). Only a few samples with tiny bubbles and unstable readings were encountered, but in these cases two good readings were still achieved. More common was the formation of a bigger bubble in the bottom right corner of the cell, resulting in an unstable reading. This issue was easily solved with one or two more flushes of the cell. When banging the bottle, it would be good to have a keyboard protection/cover next time, as some drops coming from water within the blue cap sprayed onto the keyboard.

The cell was clean with bleach only 3 times during the voyage, mainly after a sea ice sample run. When cleaning with bleach (sodium hypochlorite 2-3%), the cell was flushed 3 times, left full of bleach for about 10 minutes, then rinsed with milliQ and left to rest with milliQ until the next run.

Underway samples

Underway samples were taken during the transit south. A triplicate was taken every 6 hours, with a total of 56 bottles analysed in 2 salinometer runs. This was also a way to test the salinometer and the set up of the lab., prior to commencement of CTDs. These samples were used by the carbon group for calibration of the ship's underway thermosalinograph.

Sea ice samples

Salinity samples from salinity were also analysed during the voyage. Some of the samples had a lot of particles, and in this cases the bottle was shaken only once at the start of the run and the particles allowed to settle. Then during analysis the tube to the pump was held only within the top half of the sample. In the future, if sea ice samples need to be analysed it would be better to pre filter them. After each sea ice run the cell was cleaned with bleach (due to the high level of biology in the samples).

Temperature control

From the start of the cruise, the bath temperature was constant between 24.016°C and 24.018°C. The temperature was checked before and at the end of each run. Note that during each run the power line had to be swapped from the bath to the communication box between the salinometer and the software. The standby number was also relatively constant, varying between 5903 and 5920 during the entire voyage. The changes were due to adjustment during the standardisation, rather than instrument drift during a run or between two runs.

Stability of the lab temperature was not very good in the middle of the voyage, in particular for runs sal011 to sal013. However, as the bath temperature, the analysis readings and the standby number were all stable there were no specific reasons to check the lab temperature. Also we did not have a second thermometer available. The lab temperature was first recorded on 4/01/2017 at 5am UTC using a thermometer from the sea ice team. The recorded temperature was 23.4°C. At the end of the day, I checked the temperature to make sure it hadn't changed, and was above 27°C. I was not running any samples at the time, but the carbon team were, and they manage to decrease and get a stable temperature by the following morning. When I started sal014, the temperature was below 24°C and the following day was even better (21-23°C). More details is given in Table A1.1.

Other notes

To summarise, 1033 samples were analysed, including:

- 818 from the 73 CTDs;
- 56 from the underway system;
- 159 from the sea ice samples

46 standard seawaters were used for these analyses.

<u>Table A1.1:</u> List of each salinity run, with corresponding station and specific comments

Salinity run	Stations	Comments
Sal001	Underway system	C01-C24+G01-G09
Sal002	Underway system	G10-G24+G01-G09
Sal003	CTD 001	CTD test
Sal004	Sea ice	Casey 1-2 + Pack 1 Finished the run with cleaning the cell with **bleach**
Sal005	CTD 002 to 006	
Sal006	CTD 007 to 010 + 012+ 013	CTD 011 radium cast
Sal007	CTD 013 to 017	
Sal008	CTD 018 to 021	2 days after the run, first note of warm lab temperature (nothing changed at this stage as the salinometer was working well and maintain the bath temperature)
Sal009	CTD 022	
Sal010	CTD 23 to 26	
Sal011	CTD 027 to 32	Overnight (before the run) the temperature of the lab was changed (decreased) due to weird light flashing for the spare salinometer and increased again due to issue with the carbon system Readings of the standard seawater (SSW) 34.9880 (start), 34.9884 (middle 1), 34.9884 (middle 2), 34.9897 (end)
Sal012	CTD 033 to 038	Readings of the SSW 34.9882 (start), 34.9885 (middle), 34.9892 (end) and 34.9889 (end duplicate)
Sal013	CTD 039 + 041 to 044 **(**	Cleaned the cell with **bleach** before the start Decreased the temperature of the lab Light was working when the flow was fast (rinsing) but working with slow flow (reading fill _ reading) – samples likely too warm due to computer fan (moved them under the bench) CTD 040 radium cast
Sal014	CTD 044 to 048	Better control of the lab temperature, between 23.6 and 24˚C
Sal015	CTD 049 to 056	Again improvement of the lab temperature control, between 21 and 23˚C
Sal016	CTD 056 to 062	Ran on the same day than sal015 – preferred to start another run to follow the stability of the SSW as the temperature of the lab felt warmer than in the morning but managed to get back to how it felt in the morning (no thermometer in the afternoon – sea ice station)
Sal017	CTD 063 to 070	
Sal018	Sea ice pack 2 to 5	Long standardization, had to pass a second SSW at the start. The readings were low but not to affect the precision required for the sea ice samples. The second SSW was fine. At the end of the run, cleaned the cell with **bleach**.
Sal019	CTD 071, 072, 073	Note of a drift in the SSW values along the run
Sal020	Sea ice station pack 6, 5 + brines	Brines can have a salinity of >40, however we were in the sea ice melting season and the sea ice team expected the brines to be at around 20 and certainly below 40. The highest brine was measured at 29.8 and the fresher at 21.1

Table A1.2: readings of the standard sea water (SSW) for each salinity run at the start of the standardization, and after a certain number of sea water samples

Run	first standard seawater (SSW)	number of samples	mid SSW reading	number of samples	last SSW reading
au1602sal001	34.9882	33			
au1602sal002	34.9883	23			
au1602sal003	34.9883	24			
au1602sal004	34.9879	42			
au1602sal005	34.9886	28	34.9883	16	
au1602sal006	34.9883	37			
au1602sal007	34.9882	30			
au1602sal008	34.9880	34			
au1602sal009	34.9882	23			
au1602sal010	34.9885	35	34.9885	23	
		35	34.9883		
au1602sal011	34.9880	36	34.9884	33	34.9897
		36	34.9884		
au1602sal012	34.9882	30	34.9885	28	34.9892
				duplicate	34.9889
au1602sal013	34.9886	24	34.9883	24	34.9880
		same sample	34.9880		
au1602sal014	34.9878	24	34.9882	19	34.9884
au1602sal015	34.9880	36	34.9881	35	34.9880
au1602sal016	34.9882	33	34.9881	34	34.9882
au1602sal017	34.9882	34	34.9889	35	34.9882
au1602sal018	34.9876	51	34.9874	19	
au1602sal019	34.9881	36	34.9881	36	34.9893
au1602sal020	34.9883			47	34.9882

APPENDIX 2 DISSOLVED OXYGEN LABORATORY ANALYSES (SKY LAB)

Cruise report by STEPHEN TIBBEN (*CSIRO CMAR)*

The sky lab was used for analysis of dissolved oxygen samples by sodium thiosulfate titration from the CTD and underway samples from labs 2/3. Stephen Tibben was the analyst for the entire voyage.

Workspace

The workspace was mostly pleasant with ample natural light and comfortable room temperature.
Benches vibrate a lot when breaking ice, but this did not seem to negatively affect dissolved oxygen anaylsis.
Air quality was not always good, with the lab vent opening near a smoking area and cigarette smoke could often be smelled inside at the main workbench.
The two computer screens mounted on the starboard and aft walls were great for monitoring DiRT (i.e. the underway data display).
There were ample power outlets for the required analysis.
Oxygen reagents were transported between the CTD room and sky lab for sampling and analysis. This was not dangerous.
Samples were delivered from CTD room and labs 2/3. This was not dangerous.

Sample storage

Loading through side doors from trawl deck was convenient.
18 x 32 L blue hinged crates fit comfortably under the aft side of the main bench.
15 X 32 L blue hinged crates fit comfortably under the fore side of the main bench.
Acids stored in the fume cupboard.
Other chemicals stowed under fume cupboard.
8 x boxes of 500 nutrient tubes (30 mL) we stored under the aft bench, along with 10 x 20 L carboys (for chemical waste).
290 L -18 degrees C chest freezer was secured just aft of the loading doors, under a power outlet. This was adequate for freezing and storing 1700 nutrient samples and could likely store up to 2000.

Sink

Hot and cold water both provided. Water pressure not ideal for high flow but adequate for washing dissolved oxygen flasks.
Underway water outlet works. Not required on this voyage.
Drain tended to accept ~15 L of water before outflow diminishes to nearly a stop. Does eventually drain though.

Temperature control

Temperature control was good throughout the voyage (see **Table 1**). No changes were made.

Number of samples analysed

CTD: 826
UWY: 90
TOTAL: 916

Overview

Table A2.1: Analysis overview. Note: Thio normality should not change by more than 0.0005

Date	Files	Samples	Thio temp	Thio normality	Δ Thio normality	Comments
11/12/16	oxy001	uwy001-013	21.31	0.21955	N/A	
16/12/16	oxy002 oxy003	uwy014-031 ctd001	20.94	0.21969	0.00014	
01/01/17	oxy004 oxy005	uwy032-037 ctd002-008	21.02	0.21973	0.00004	
02/01/17	oxy006 oxy007	ctd009-021 uwy042-044	20.66	0.21993	0.00020	
06/01/17	oxy008 oxy009	uwy045-055 ctd022-023	21.05	0.21985	0.00008	
07/01/17	oxy010 oxy011 oxy012	uwy056-059 ctd024-026 ctd027-028	21.21	0.21968	0.00017	
08/01/17	oxy013 oxy014	ctd029-032 uwy060-064	20.17	0.21976	0.00008	New KIO_3
10/01/17	oxy015 oxy016	uwy065-072 ctd033-039	21.63	0.21968 0.22296	0.00008 N/A	Old Thio New Thio
11/01/17	oxy017 oxy018	uwy073-074 ctd041-048	20.71	0.22317	0.00021	
12/01/17	oxy019 oxy020	uwy075-077 ctd049-057	20.79	0.22324	0.00007	
13/01/17	oxy021	ctd058-064	19.46	0.22308	0.00016	
15/01/17	oxy022 oxy023	ctd064-070 uwy078-085	21.18	0.22318	0.00010	
17/01/17	oxy024 oxy025	ctd071-073	21.28	0.22299 0.22223	0.00019 N/A	Old Thio New Thio

APPENDIX 3 FLUX-PULSE (i.e. SOTS) MOORING RECOVERY ATTEMPT

Mark Rosenberg (*ACECRC, Hobart)*

All times in the following report are local.

Aurora Australis Voyage 2 2016/17 (cruise au1602) departed Hobart on December 8th 2016. The SOTS site was bypassed on the transit south, due to bad weather. The mooring location was reached at 01:00 on 19th January, on the transit back north near the end of the voyage. Voyage 1 had released the mooring a few weeks previous (see Lloyd Symons "Flux Pulse 1: Report on Mooring Recovery Attempt" document), leaving the floats at ~920 m below the surface at position 46° 43.29'S 141° 57.32'E i.e. ~900 m west of the assumed crash site of the instruments on the bottom. Communication with the releases was established on the first attempt, and the new location (from minimum ranges) was 46° 43.291'S, 141° 57.812'E, at a depth of 851 m below the surface i.e. ~300 m west of the assumed crash site. This position was reconfirmed at ~06:00 prior to commencement of trawling operations on 19/01/2017. Five trawls were done over the course of the day, with no success. Extra time for another attempt was granted by Kingston, for the following morning. Again there was no success, after two shots.

At first the configuration of the mooring was assumed to be at a diagonal, with the group of 40 glass floats on a new watch circle and hanging 300 m west of the assumed crash site. After rechecking the minimum ranges to the releases at the start and end of trawl ops on the first day, and seeing the position unchanged, it was obvious that the mooring configuration was as follows: stable float location, with rope to the floats straight up and down, coming from a heavy object on the bottom (e.g. the ADCP, or a large snag of wire). In this configuration the initial trawl attempts were not likely to succeed. What's required is a bottom drag across the line of wire between the float anchor point and the RAS (300 m or less further east). Sufficient wire was not available on board to reach the bottom for such an attempt.

Trawl gear and deployment

Three large CSIRO inline trawl grapples were used, spaced by 30 m shots of 12 mm wire (these shots were made up by AAD [thanks to Pud and Matt] just prior to sailing). 60 kg of dumb-bell weights were joined to the bottom grapple by a 5 m shot of gal chain. The top grapple was joined to the trawl wire by another 5 m shot of gal chain. The intial line of grapples and wire was deployed from the netdrum via the stern gantry, as per a short mooring (i.e. stoppering off to insert the second and third grapples). After all grapples had been deployed, the trawl wire from the starboard trawl winch was passed through the large block on the starboard trawl gallows, and back up the stern ramp. This was then joined to the top of the grapple run (i.e. at the temporary join between the chain from the top grapple and the wire from the netdrum, and the load was then transferred to the trawl wire. The wire from the netdrum was disconnected with the join now at the starboard gallows. The operation up to this point took ~30 minutes (10 minutes deck prep time, followed by 20 minutes to deploy the run of grapples). With all grapples in the water the trawl wire was run out to the maximum usable length (~3500 to 3700 m), with the ship speed around 2-3 knots. After deployment of all trawl wire, ship speed was lowered to ~1-1.5 knots for the trawl run past the mooring. All wire lengths/targets etc were calculated with an assumption of trawl wire angle 30° (from the vertical).

On day two the grapple rig was modified as follows: ~800 m of old 7 mm mooring wire (from recovered CSIRO EAC moorings) was inserted above the grapples (and therefore required prespooling onto the netdrum), to give more length. The 60 kg weight from the bottom of the grapples was moved to the join between the trawl wire and the 800 m of old mooring wire, to try and get the run of grapples run to "fly" more horizontally.

On day one, the first 4 trawls were deep shots, along a N-S line, varying the longitude of the run each time. The 5th attempt on day one was a shallow shot, dangling the grapples at ~1200 m and running a "spirograph" pattern around the location of the releases. On day two, the 2 attempts (both deep shots) were staged to try and catch the mooring line by turning the ship. The digital display of trawl wire tension was monitored over the course of all trawl attempts, but there were no obvious “hits” from the readout.

First trawl attempt

Target chosen: halfway between position of releases and assumed crash site of RAS;
started deploying grapples ~3-3.5 miles from the target;
approaching from the N, running N to S;
first grapple in water at 07:20 on 19/01/2017 (10 min of prep before that);
3500 m of trawl wire deployed by 08:20, which included some stops to test trawl wire tension;
going for a straight through trawl, deep shot;
ship speed just over 2 knots;
started retrieving trawl wire ~1.3 nm past the line (i.e. E-W line between floats and the assumed crash site of RAS on the bottom);
crossed the line at ~2.2 knots (wire angle at block ~40^{o} from vertical; want ship speed slower next time);
after recovery of trawl wire, no obvious change in trawl wire tension, so grapple run left in the water for next attempt.

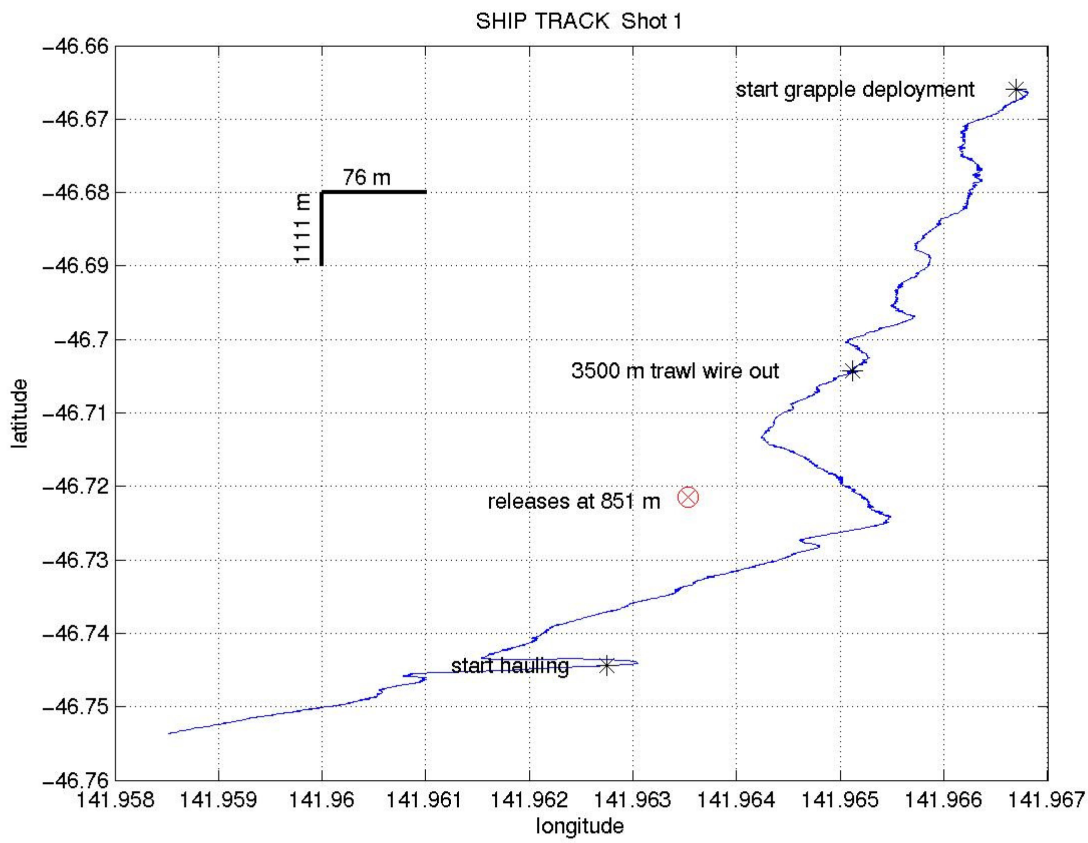


Figure A3.1: First trawl attempt on mooring

Second trawl attempt

Started paying out trawl wire at 10:29 on 19/01/2017, 1.5 nm S of the target;
10:57 - 3630 m of trawl wire out; trawl run S to N;
12:45 - second attempt finished;
grapple run left in the water for next attempt;
went back S to confirm position of releases – position unchanged.

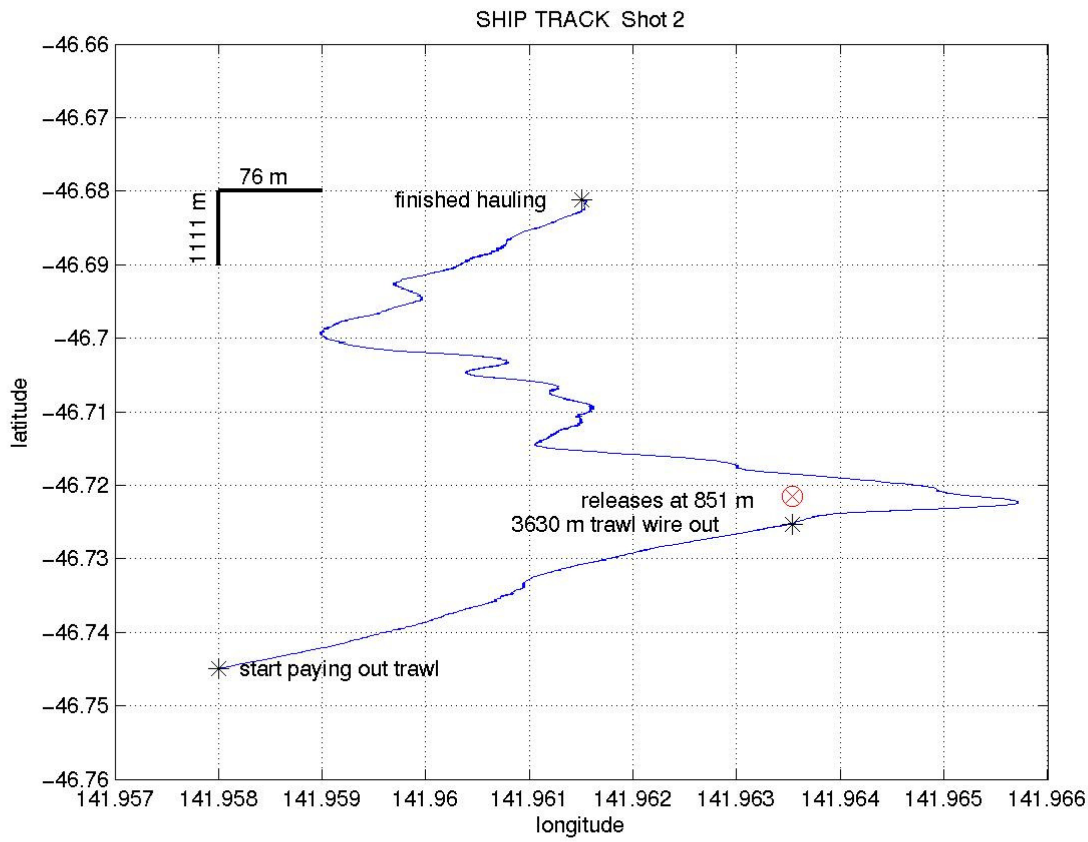
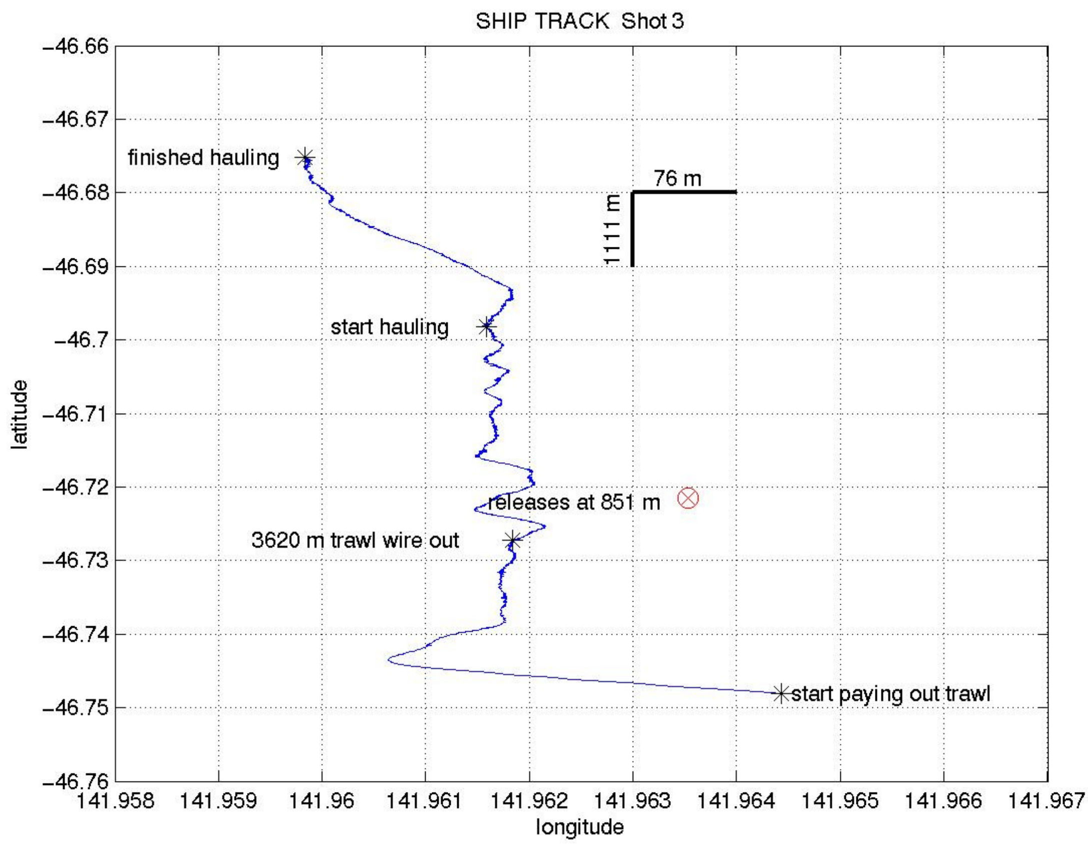


Figure A3.2: Second trawl attempt on mooring

Third trawl attempt

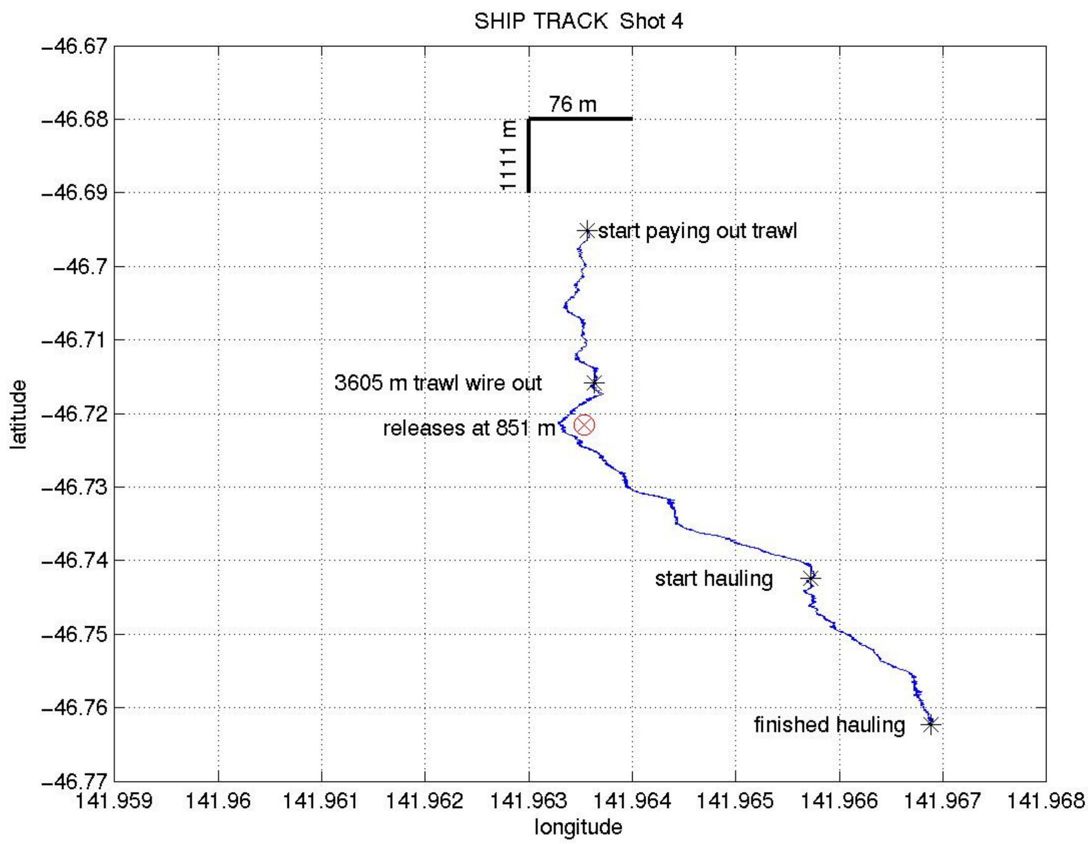
From the S, running N up longitude 147^o 57.7'E;
started paying out trawl wire at 13:55 on 19/01/2017, ~1.3 nm south of the line;
14:25 - 3620 m of trawl wire out;
15:30 - started hauling in trawl wire, 1.5 nm N of the line;
16:15 - all trawl wire at surface;
grapple run left in the water for next attempt.



<u>**Figure A3.3:**</u> **Third trawl attempt on mooring**

Fourth trawl attempt

From the N, running down longitude 141° 58.81'E (i.e. right over the floats/releases);
16:40 on 19/01/2017 - started paying out trawl wire, ~1.3 nm N of the target;
17:08 - 3605 m of trawl wire out;
18:20 - started hauling in trawl wire 1.4 nm past the target, ship speed 1.5 knots;
19:05 - all trawl wire at surface;
grapple run left in the water for next attempt.

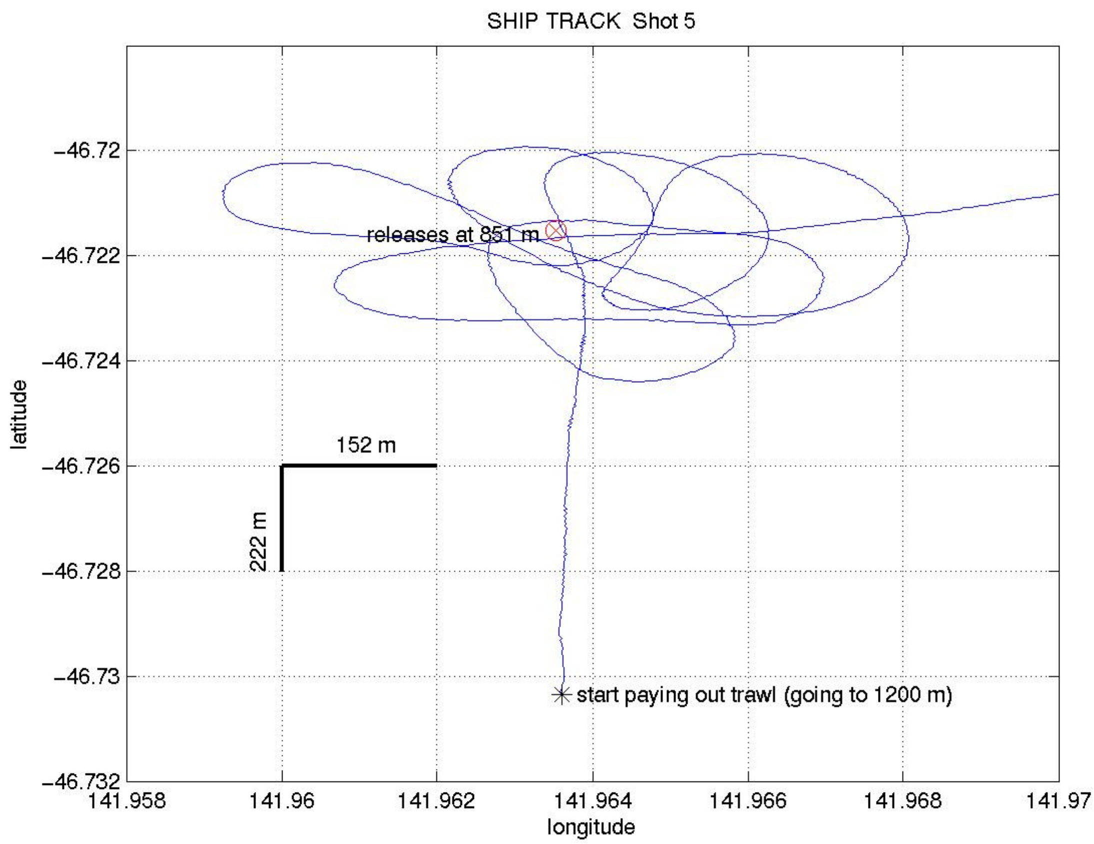


<u>Figure A3.4:</u> Fourth trawl attempt on mooring

Fifth trawl attempt

Running a “spirograph” pattern around the location of the releases, with the grapples much shallower; 19:33 on 19/01/2017 - start deploying trawl wire; going to 1200 m wire out; final attempt for the day, so all grapples recovered at the end.

Float/releases position confirmed at 46° 43.297’S, 141° 57.765’E, range 851 m.



<u>Figure A3.5:</u> Fifth trawl attempt on mooring

Sixth trawl attempt

Day two: rechecking location of releases prior to commencing trawl ops; releases at 46° 43.291'S, 141° 57.730'E range 852 m (i.e. position effectively unchanged);
~800 m of old 7 mm mooring wire (intended for Polynya West recovery) spooled onto netdrum, before grapple spacing 30 m wires;
60 kg weight at bottom of trawl wire (no weight at bottom of grapples);
trying to "fly" grapples in a noose around mooring rope;

started deploying grapples at ~07:00 on 20/01/2017;
08:15 - 3600 m of trawl wire out;
08:41 - trawl wire out extended to 3710 m;
pattern completed, and standing 0.5 nm off to the S for hauling;
during hauling, obvious from trawl wire tension that nothing there, so trawl wire not hauled all the way in prior to next attempt.

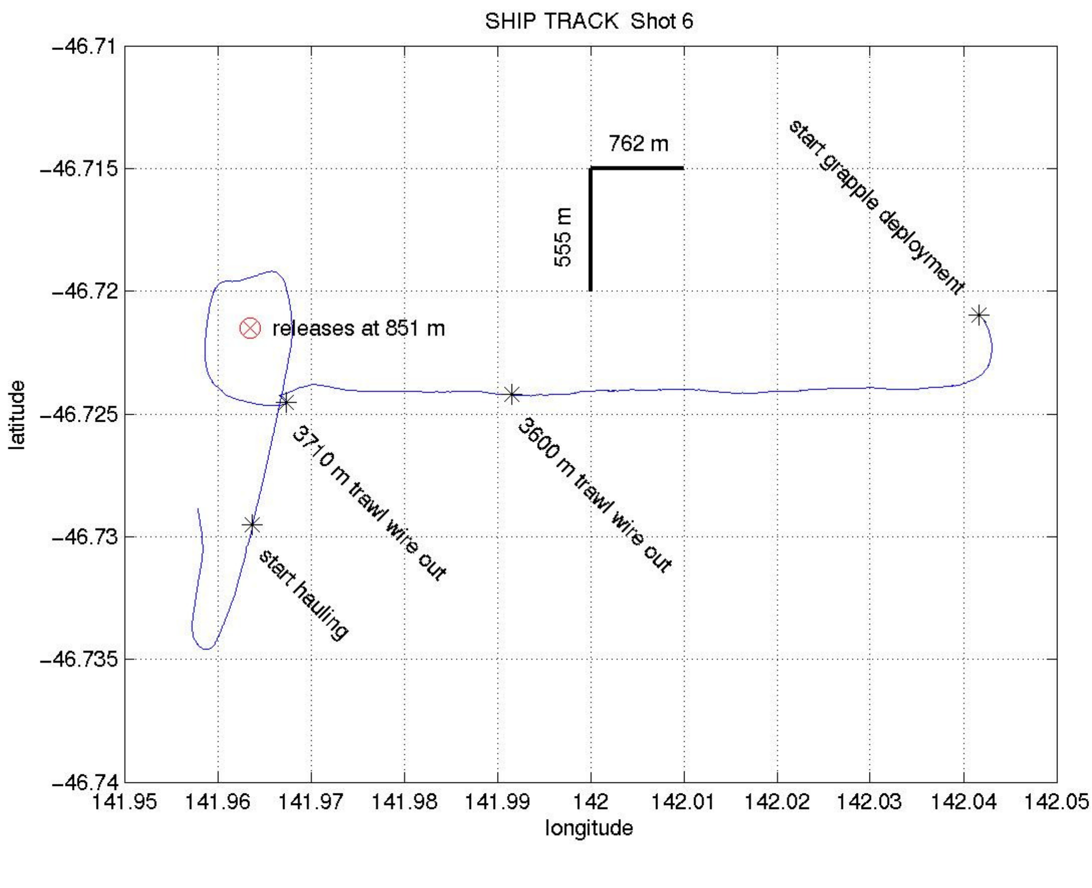
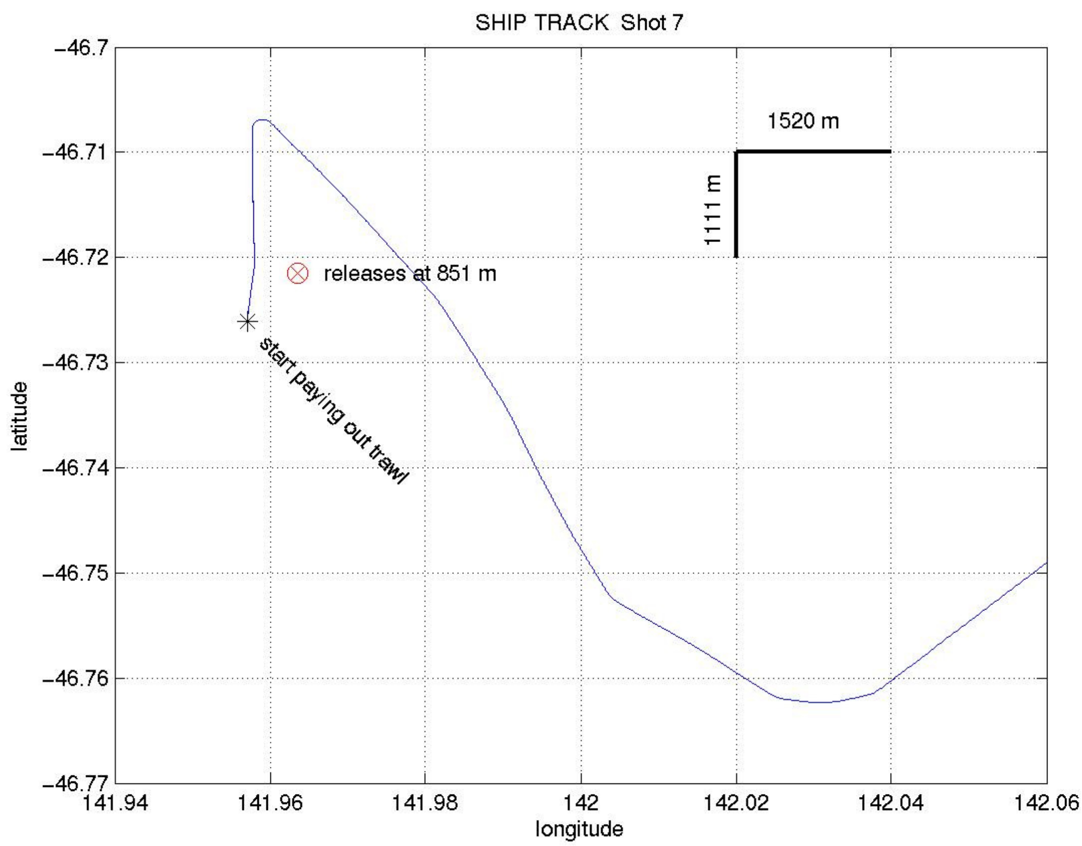


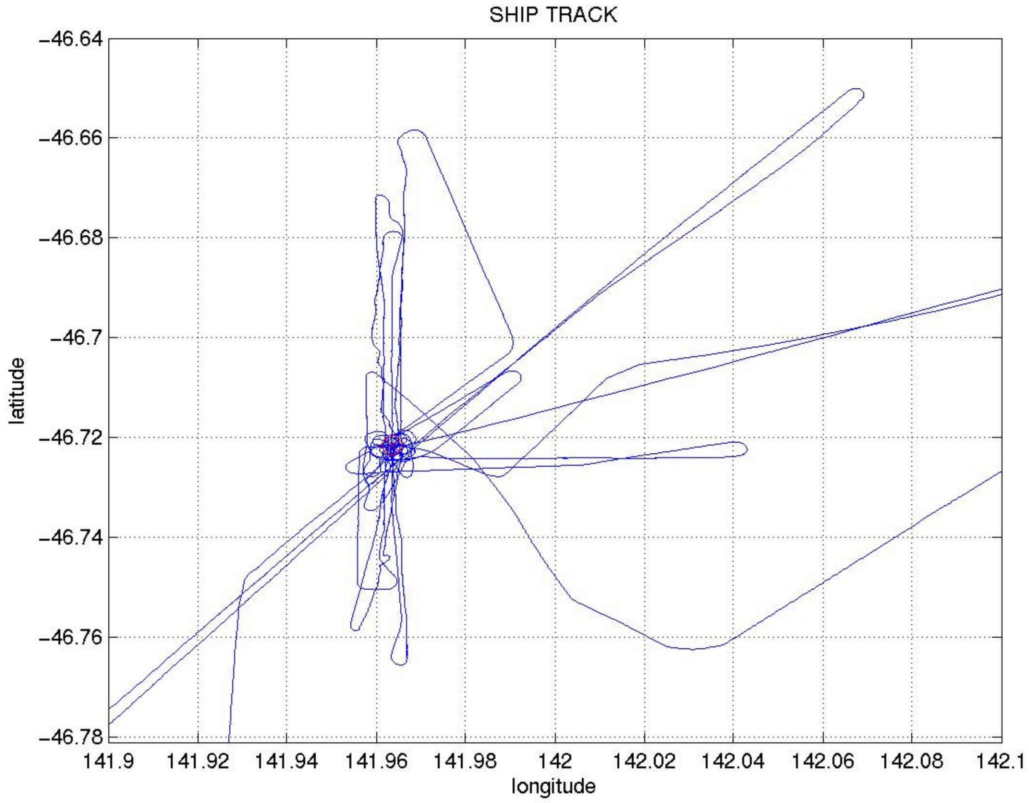
Figure A3.6: Sixth trawl attempt on mooring

Seventh trawl attempt

Final attempt. Recommenced paying out trawl wire at 09:55, from the hauling location of the previous attempt;
all grapple gear recovered at the end;
wire spooled off netdrum and all gear packed away after ship resumed transit back to Hobart.



<u>Figure A3.7:</u> Seventh trawl attempt on mooring



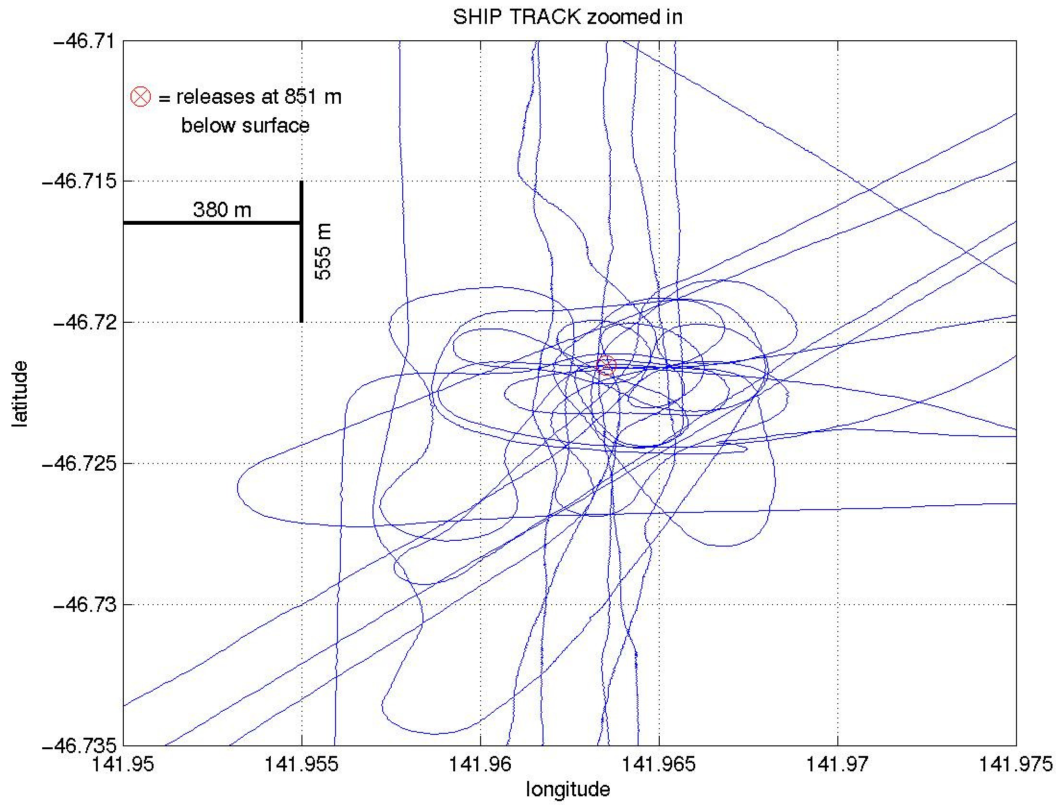


Figure A3.8: Plots of ship track over the two days at the SOTS location

Recommendations for any future attempts

Plan A - bottom trawl i.e. take enough extra old mooring wire to drag grapples along bottom, running N-S lines to cross over the E-W line that runs between the float/releases and the assumed crash site of the RAS on the bottom.

Plan B – further trawl attempts as above, refining the ship's course with better prediction of behaviour/location of grapples at the bottom of the trawl. Useful information for this prediction were obtained from rigorous scale model pool tests done by Gerry O'Doherty, in his swimming pool:

From Gerry O':

I used a float, a length of string and a weight at the deep end of my pool (about 1.6m deep) to simulate the mooring. A length of fine stainless rigging wire to simulate the trawl wire.
I had to scale up the speed to get the wire to behave the same way (30 to 40 degree inclination out the back) and had a difficult time trying to make the wire connect with the mooring.

After some experimenting I found the most effective way to get it to collect the mooring was to approach as fast as possible, trailing the wire behind as close to the horizontal as possible. Then, once a significant distance (approximately 1/4 the wire length) turn sharply through 130 to 160 degrees and steam away fast until there is some sign of having collected the mooring or until you have achieved a distance of about 1.5 x the length of the wire, after which you haul back and/or try again.

Speeding along quickly induces the horizontal characteristic the wire needs to intersect the mooring. Turning sharply and doubling back somewhat allows the lower half of the wire to fall through the water column maintaining its (close to) horizontal orientation. Then when the wire is pulled away it crosses the mooring rope at a good 'angle of cut'.

Locating gear (pingers etc) near the end of the trawl are also recommended, to monitor live the position of the grapples.

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