Aurora Australis Marine Science Cruise AU1603 - Oceanographic Field Measurements and Analysis

MARK ROSENBERG (*ACE CRC) – data processor (stayed at home)*
RUTH ERIKSEN (IMAS and CSIRO CMAR) – hydrochemistry (on the cruise)
CTD team *(ACR CRC, IMAS and CSIRO) – data collection (on the cruise)*

August, 2016 (with September 2017 updates)

1 INTRODUCTION

Oceanographic measurements were collected aboard Aurora Australis cruise au1603, voyage 3 2015/2016, from 11th January to ~24th February 2016. The cruise commenced with the K-AXIS project, the major marine science component of the cruise. This was the Australian component (P.I.'s Andrew Constable, Steve Rintoul and others) of a combined biological and oceanographic study in the vicinity of the Kerguelen Axis. After conclusion of marine science work the ship went to Mawson for a resupply. During a storm on 24th February the ship broke free of its mooring lines and ran aground on the rocks at West Arm in Horseshoe Harbour, thus ending the cruise. Expeditioners were eventually taken to Casey on the Shirase, then flown home. Meanwhile the Aurora Australis was refloated and sailed to Fremantle, then on to Singapore for repairs.

This report discusses the oceanographic data from CTD operations on the cruise. A total of 47 CTD vertical profile stations were taken on the cruise (Table 1). Over 850 Niskin bottle water samples were collected for the measurement of salinity, dissolved oxygen, nutrients (phosphate, nitrate+nitrite and silicate), dissolved inorganic carbon (i.e. TCO_2), alkalinity, POC and PN, and biological parameters, using a 24 bottle rosette sampler. A UVP particle counter/camera system was attached to the CTD package (P.I. Emmanuel Laurenceau). A separate trace metal rosette system was deployed from the trawl deck (P.I. Andrew Bowie). Upper water column current profile data were collected by a ship mounted ADCP, and meteorological and water property data were collected by the array of ship's underway sensors. Eight drifting floats were deployed over the course of the cruise.

Processing/calibration and data quality for the main CTD data are described in this report. Underway sea surface temperature and salinity data are compared to near surface CTD data. CTD station positions are shown in Figure 1, while CTD station information is summarised in Table 1. Float deployments (5 x Argo/Apex, 2 x SOCCOM and 1 x Provor) are summarised in Table 10. Further cruise itinerary/summary details can be found in the voyage leader report (Australian Antarctic Division unpublished report: Voyage 3 2015-2016, RSV Aurora Australis, Voyage Leader's report).

2 CTD INSTRUMENTATION

SeaBird SBE9plus CTD serial 704, with dual temperature and conductivity 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 24 x 10 litre General Oceanics Niskin bottles. The following additional sensors/instruments were mounted:

* Wetlabs ECO-AFL/FL fluorometer serial 756 (analog range 2)
* Biospherical Instruments PAR sensor QCP2300HP, serial 70110
* Wetlabs C-star transmissometer serial 899DR
* Tritech 200 kHz altimeter serial 237622
* Tritech 500 kHz altimeter serial 76031
* UVP/camera system and lighting (a few stations only)

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 2015). 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. UVP data are not discussed.

3 PROBLEMS ENCOUNTERED

Running aground of the ship at Mawson was obviously the most serious incident on the cruise. On the equipment side, CTD operations went relatively smoothly, with few significant equipment problems. Notable problems (on a lesser scale of drama than grounding of the ship) were as follows:

* Grease contamination of the rosette was a problem over several days (first noted on station 23). The grease, from a winch on the trawldeck, was inadvertently being brought into the CTD room and daubed over the Niskins and rosette frame. Grease was removed with paper towel prior to station 24. After station 24 the Niskins and frame were thoroughly cleaned with isopropyl alcohol, and during station 25 (while CTD was in the water) the CTD room was thoroughly cleaned with hot water.

* There was difficulty interpreting altimeter readings for station 1, and bottom of cast was at ~79 m above the bottom.

* At station 12, the CTD was initially deployed with the fluorometer cap left on. The package was recovered then redeployed with the cap removed.

* Niskin 5 leaked for many stations, and was eventually replaced prior to station 17.

* Station 18 was moved by ~3miles due to heavy ice. Station 20 was also moved, due to ice.

* Station 30: some delay due to problems with gantry. Grease cleaned from rosette and CTD room deck while gantry was being repaired.

* Station 33: the trolley broke after retrieval, so the CTD couldn't be shifted inboard. Sampling was done with the CTD hard up against the CTD door.

* For station 35 onwards, in many cases the CTD was taken to near bottom but samples were only collected in the upper water column. It will therefore not be possible to reliably calibrate much of the CTD oxygen data for these stations, in particular for stations 38-40 and 42-43.

* Station 44: pump took a long time to come on, and reboots were required (PC's and deck unit). As a result the CTD was already in the water by the time logging was successfully started.

* Station 47: when CTD at 55 dbar on upcast, returned back down to 200 dbar to fire a bottle.

4 CTD DATA PROCESSING AND CALIBRATION

Final processing of the CTD data was done in Hobart (only limited processing was possible at sea). 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, while split profile fits were used for deeper stations.

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 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. Data from the test cast (station 0) were not processed.

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 25th March 2018) was used for salinometer standardisations.

Guildline Autosal serial 62549 was used for the whole cruise, with analyses taking place in the skylab. Salinometer performance was stable, with lab temperature averaging 20.5 ±0.8 ^{o}C during analyses.

Overall salinity accuracy for the cruise is within 0.002 (PSS78). Note that very low near surface salinities occurred for some stations (most notably station 2 to 4, 12, and 17 to 22). These features are typically accompanied by steep vertical gradients (often with little, if any, surface mixed layer), and for such cases it's difficult to obtain salinity samples suitable for calibration of the CTD data. As a result, very few low salinity sample values were included in the calibrations. The manufacturer claims little significant non-linearity in the conductivity cell response, so any additional inaccuracy for the lowest salinity values, i.e. salinity < 33.2 (PSS78), is assumed to be small (of the order 0.001 at most over the implied calibration extrapolation range).

Pressure dependent salinity residuals are evident for most cruises, due to pressure effects on the glass conductivity cells (SeaBird tech, personal communication). For this cruise the residuals were small, and where they occurred they were of the order 0.002 (PSS78) or less over the whole vertical profile.

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

station	bottle-CTD bias (PSS78)
13	-0.001
17	-0.001
18	-0.0005
19	-0.0015 below 1000 dbar
27	-0.001
34	-0.001
60	+0.001

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.

* Salinity samples for station 44 to 47 were unreliable, and conductivity calibrations for these stations were extrapolated from previous stations. For station 44, samples do not compare well with CTD data. For stations 45 to 47, samples do not seem to correspond with bottle firings (there may have been a mixing up of crates, or some error in data entry).

* For stations 46 and 47, secondary conductivity data were suspect on the upcast over the following intervals: 315 to 91 dbar (station 46), and 268 to 70 dbar (station 47). There may have been something on the frame interfering with flow past the sensors, but this is inconclusive.

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. The difference $T_s - T_p$, at an average of 0.0005°C over the whole profile (Figure 4a), is within the manufacturer quoted sensor accuracy of 0.001°C.

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. For station 44, the CTD was already in the water by the time logging was successfully started, so the surface pressure offset value from station 45 was used.

5.4 Dissolved oxygen

CTD oxygen data were calibrated as per the *CTD methodology*, with profiles deeper than 1400 dbar calibrated as split profile fits, and profiles shallower than 1400 dbar (i.e. stations 7 to 9, 21, 24, 26, 35-37, 40 and 45-47) calibrated as whole profile fits. Additional stations also calibrated as whole profile fits were: stations 31 and 41 (with a maximum pressures of 1561 and 1738 dbar respectively); and stations 38, 39, 42 and 43 (no bottle samples for calibration of deep part of profile).

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 ~400 μmol/l above 1500 dbar, and ~250 μmol/l below 1500 dbar).

* For stations 1 to 5, there's a small error in the temperature of the iodate reagent used to calculate the amount of reagent dispensed. Any resulting error in the bottle analyses is assumed to be small (less than 1% full scale).

* For station 13, reagent 2 was added using a hand pipette.

* For station 26 oxygen sampling, reagents were accidentally dispensed in reverse order (i.e. reagent 2 followed by reagent 1). Samples were not analysed (therefore no CTD oxygen data).

* Stations 30-34: CTD oxygen spikes around ~200 dbar on the downcast each time.

* For station 35 onwards, in many cases the CTD was taken to near bottom but samples were only collected in the upper water column. It was therefore not be possible to reliably calibrate much of the CTD oxygen data for these stations, in particular for the full depth stations 38-40 and 42-43.

* For station 47, CTD oxygen data for 2 to 50 dbar are suspect.

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).

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 PAR calibration "offset" value (Table 2) was derived from deep water voltage values from the trials cruise in December 2015.

Maximum transmittance values are slightly less than the expected 100%, and the station means drift downward over the cruise by ~4%. The former is most likely a small calibration error, while the later is most likely due to a lack of cleaning of the sensor windows. For stations 1 and 2, values are slightly higher than 100% - most likely a small calibration error again. Station 28 downcast transmittance data were very low (and these data have been removed), most likely due to contamination of sensor windows.

The usual altimeter "artefacts" (as seen on previous cruises) were observed on occasion, with false bottom readings often observed before coming within nominal altimeter range. For station 1, minimum altimeter height above the bottom was ~79 m. due to uncertainty in interpretation of altimeter readings.

5.6 Nutrients

All nutrients were frozen and returned to Hobart, with analysis taking place at CSIRO between November 2016 and March 2017. As a result of this long delay the data were approached with great caution. Data from the Roger Revelle 2016 cruise along CLIVAR I8S transect (expocode 33RR20160208) (Figure 8) were extremely valuable for verification and quality control of the K-AXIS data. Note that K-AXIS nutrients were first converted to gravimetric units (µmol/kg) to allow direct comparison to the Revelle data. Laboratory temperature used for this conversion was 20^{o}C. Overall, K-AXIS silicate and nitrate+nitrite data comparisons to the Revelle data are reasonable (Figures 10 and 9 respectively). K-AXIS phosphates however are noisier, and are consistently offset from the Revelle data by ~0.05 µmol/kg (Figure 7). From profile comparisons and inspection of nitrate+nitrite versus phosphate data (Figure 6), a significant number of phosphate values were initially flagged as either suspect or bad. Taking into account the offset from the Revelle data, all K-AXIS phosphates are considered suspect, and have been flagged accordingly. Note that the bottle data files include nutrient flags, with the following flag values:

1 = below detection threshold (applies to some ammonia & nitrite data from station 3 and 44)
2 = good
3 = suspect
4 = bad
9 = no data

Quality control decisions were sometimes difficult, in particular for isolated southern stations following a frontal feature (e.g. stations 21 and 22). In general, values are only flagged as bad (flag value 4) if they are out by at least ~10% of full scale (where full scale ≈ 3.0, 40 and 150 µmol/l respectively for phosphate, nitrate+nitrite and silicate), or if they are obvious outliers. However for this data set, many nitrate and phosphate data points that would usually be flagged as bad were left with a suspect flag only – again, due to the difficulty of QC decisions for this cruise. Data flagged as suspect were values deemed to be out by at least ~3% (in most cases) of full scale. In some cases (e.g. phosphate and nitrate for station 21 bottles 1, 4-6 and 10, and station 22 bottles 7 and 9) it is unknown whether apparent spikes in the profile are real features or not – flag values were left as 2 for these.

Note that nutrient samples assigned a flag value of 3 or 4 are listed in the series of text files bad* (e.g. badphos) and suss* (e.g. sussphos) included with the data set. The phosphate samples listed in the file sussphos are judged as outliers within the vertical profiles – this information may be of use, and is additional to the overall suspect label for all the phosphate data.

For stations 3 and 44, nutrients were analysed by hydrochemistry groups from both CSIRO and SCRIPPS (results not discussed here). The CSIRO silicate data for these 2 stations are all bad, so the SCRIPPS data (converted back to µmol/l units from the original µmol/kg, using an assumed lab temperature of 20^{o}C) have been used instead.

6 UNDERWAY MEASUREMENTS

Underway data were logged to an Oracle database on the ship. Quality control for the cruise was largely automated. 12 kHz bathymetry data were not quality controlled, and these data in the underway file are from the sounder's automatic bottom detection – as a result, the data are scattered and often incorrect. Bottom depths at CTD stations were carefully extracted (i.e. good values only were used), and corrected for the local sound speed at each station.

10 second instantaneous underway data are contained in the file au1603.ora as column formatted text; and in the file au1603ora.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 11 and 12). Offset corrections are sufficient in both cases (Figure 12). Note that for salinity, underway salinity values are too low for decimal days 30 to 38 (Figure 11) i.e. CTD stations 18 to 31, possibly due to fouling of the sensor or the flow inlet. These data have been excluded from the offset calculation. Also note that the offset corrections have not been applied to the underway data files.

7 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 (20°C), and in situ CTD salinity at which each Niskin bottle was fired; zero pressure

REFERENCES

Rosenberg, M., Fukamachi, Y., Rintoul, S., Church, J., Curran, C., Helmond, I., Miller, K., McLaughlan, D., Berry, K., Johnston, N. and Richman, J., unpublished. *Kerguelen Deep Western Boundary Current Experiment and CLIVAR I9 transect, marine science cruises AU0304 and AU0403 - oceanographic field measurements and analysis.* ACE Cooperative Research Centre, unpublished report. 78 pp.

ACKNOWLEDGEMENTS

Thanks to all scientific personnel who participated in the cruise, and to the crew of the RSV Aurora Australis. Special thanks to the oceanography team for a great job collecting the data.

<u>Table 1:</u> Summary of station information for cruise au1603. All times are UTC; "alt" = minimum altimeter value (m), "maxp" = maximum pressure (dbar).

	------------------------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 LEG2	22 Jan 2016	130130	64 38.63 S	093 33.64 E	2584	135523	64 38.81 S	093 33.13 E	2573	150631	64 39.06 S	093 32.92 E	2563	78.5	2534
002 LEG2	22 Jan 2016	190623	64 18.13 S	093 31.73 E	2843	200611	64 18.11 S	093 32.16 E	2850	210609	64 17.90 S	093 32.54 E	2870	9.8	2888
003 LEG2	23 Jan 2016	003638	64 00.02 S	093 33.08 E	-	013750	64 00.05 S	093 33.08 E	3213	025430	64 00.41 S	093 33.02 E	3152	5.2	3264
004 LEG2	23 Jan 2016	062423	63 28.19 S	093 32.69 E	3134	072057	63 28.36 S	093 32.86 E	3133	083427	63 28.49 S	093 32.96 E	3136	19.8	3167
005 LEG2	23 Jan 2016	141638	62 59.88 S	093 33.70 E	3277	152055	62 59.95 S	093 34.09 E	3279	164037	62 59.67 S	093 35.14 E	3287	14.9	3322
006 LEG2	23 Jan 2016	222949	62 17.08 S	093 09.24 E	-	233939	62 17.50 S	093 09.50 E	3917	005224	62 17.92 S	093 09.68 E	3919	10.6	3981
007 LEG2	24 Jan 2016	052837	61 42.49 S	093 22.16 E	4137	053554	61 42.51 S	093 22.01 E	-	055334	61 42.67 S	093 21.86 E	-	-	305
008 LEG2	24 Jan 2016	155933	61 09.01 S	093 32.95 E	4221	160846	61 09.05 S	093 32.96 E	-	164342	61 09.16 S	093 33.00 E	-	-	304
009 LEG2	25 Jan 2016	054719	61 58.39 S	092 33.05 E	4456	055409	61 58.40 S	092 32.88 E	-	061147	61 58.37 S	092 32.60 E	-	-	305
010 LEG3	25 Jan 2016	213831	62 19.38 S	091 32.06 E	-	225928	62 18.80 S	091 31.72 E	4013	001116	62 18.38 S	091 31.51 E	4037	9.9	4081
011 LEG3	26 Jan 2016	131007	62 23.49 S	089 40.00 E	4112	142140	62 23.53 S	089 39.82 E	4110	155328	62 23.81 S	089 39.07 E	-	20.4	4170
012 LEG3	27 Jan 2016	010410	62 28.25 S	087 47.06 E	3756	021100	62 28.19 S	087 47.40 E	3761	032011	62 28.21 S	087 48.47 E	3767	8.1	3823
013 LEG3	27 Jan 2016	144215	62 30.85 S	086 06.99 E	3713	154630	62 30.78 S	086 06.47 E	3710	172050	62 30.28 S	086 06.69 E	3705	11.1	3768
014 LEG3	28 Jan 2016	024342	62 32.25 S	083 52.03 E	2603	032834	62 32.09 S	083 52.15 E	2603	042044	62 31.94 S	083 52.24 E	2603	8.6	2636
015 LEG3	28 Jan 2016	185807	62 31.27 S	082 01.49 E	1969	193324	62 31.19 S	082 01.51 E	1969	202033	62 31.04 S	082 01.48 E	1937	7.7	1990
016 LEG4	29 Jan 2016	151059	63 16.20 S	082 01.02 E	2951	160638	63 16.41 S	082 01.46 E	2950	173306	63 16.90 S	082 01.96 E	2950	12.6	2988
017 LEG4	30 Jan 2016	052216	63 57.05 S	083 07.99 E	3651	063253	63 57.11 S	083 08.49 E	3650	075226	63 57.23 S	083 08.91 E	3651	8.7	3709
018 LEG4	31 Jan 2016	043719	64 22.02 S	083 28.64 E	3579	054626	64 21.58 S	083 30.03 E	3577	070801	64 21.34 S	083 31.69 E	3585	7.2	3636
019 LEG4	31 Jan 2016	220430	64 38.24 S	084 19.58 E	3525	231428	64 38.53 S	084 19.55 E	3526	002222	64 38.71 S	084 19.81 E	3528	3.6	3587
020 LEG4	01 Feb 2016	173055	65 11.29 S	085 13.90 E	3192	182748	65 11.17 S	085 13.94 E	3193	193006	65 10.95 S	085 13.94 E	3213	7.7	3241
021 LEG6	02 Feb 2016	173050	65 09.39 S	091 36.95 E	1188	175542	65 09.44 S	091 37.11 E	1224	183249	65 09.54 S	091 37.13 E	1186	12.9	1227
022 LEG6	02 Feb 2016	230739	65 00.27 S	091 23.15 E	2308	235727	65 00.40 S	091 22.99 E	2320	004802	65 00.46 S	091 22.48 E	2258	6.0	2350
023 LEG6	03 Feb 2016	094256	64 18.97 S	089 47.87 E	3575	104455	64 18.97 S	089 47.83 E	3571	115836	64 18.71 S	089 47.54 E	3568	8.3	3629
024 LEG6	04 Feb 2016	023051	63 35.78 S	088 12.43 E	3761	023745	63 35.82 S	088 12.38 E	3762	025445	63 35.69 S	088 12.26 E	3760	-	305
025 LEG6	04 Feb 2016	100915	63 06.72 S	087 15.59 E	3780	111140	63 06.90 S	087 15.37 E	3781	122903	63 07.33 S	087 15.19 E	3813	9.1	3844
026 LEG6	04 Feb 2016	212630	62 30.46 S	086 07.66 E	3712	213351	62 30.43 S	086 07.72 E	3711	214929	62 30.39 S	086 07.90 E	3710	-	305
027 LEG6	05 Feb 2016	063518	61 55.07 S	085 03.83 E	3156	073620	61 54.89 S	085 03.86 E	3156	084240	61 54.76 S	085 03.58 E	3141	7.6	3203
028 LEG6	05 Feb 2016	201336	61 11.87 S	083 51.58 E	2350	205848	61 11.63 S	083 51.67 E	2337	215310	61 11.41 S	083 51.86 E	2303	6.0	2367
029 LEG6	06 Feb 2016	100106	60 21.50 S	082 32.91 E	1716	103158	60 21.38 S	082 32.84 E	1714	112221	60 21.34 S	082 32.56 E	1710	2.7	1733
030 LEG6	07 Feb 2016	071651	59 20.70 S	081 04.49 E	1932	075645	59 20.56 S	081 04.37 E	1927	085031	59 20.53 S	081 04.61 E	1929	8.2	1946
031 LEG6	07 Feb 2016	174413	58 39.51 S	080 09.01 E	1545	181540	58 39.44 S	080 08.92 E	1547	185643	58 39.32 S	080 08.84 E	1546	6.3	1561
032 LEG7	08 Feb 2016	070817	58 14.11 S	082 00.37 E	1793	073931	58 13.94 S	082 00.49 E	1797	083203	58 13.55 S	082 00.43 E	1800	8.1	1814
033 LEG7	08 Feb 2016	190227	57 55.17 S	083 19.73 E	3164	200451	57 55.51 S	083 20.45 E	3169	210921	57 55.78 S	083 21.43 E	3171	5.4	3217
034 LEG7	09 Feb 2016	061602	57 35.16 S	084 36.32 E	4548	074336	57 35.59 S	084 37.20 E	4543	091902	57 36.04 S	084 37.80 E	4546	7.0	4628
035 LEG8	09 Feb 2016	174602	57 49.37 S	085 16.92 E	4619	175431	57 49.42 S	085 16.99 E	4624	182005	57 49.70 S	085 17.60 E	4624	-	504
036 LEG8	10 Feb 2016	062631	58 52.04 S	085 08.04 E	3913	063709	58 52.09 S	085 08.17 E	3910	070724	58 52.24 S	085 08.50 E	3916	-	503
037 LEG8	10 Feb 2016	145708	59 05.76 S	084 26.77 E	2500	150514	59 05.65 S	084 26.69 E	2508	153018	59 05.51 S	084 26.89 E	2523	-	503

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
038 LEG8	11 Feb 2016	043157	59 56.81 S	086 41.93 E	4385	055708	59 57.77 S	086 44.09 E	4391	072538	59 58.69 S	086 45.75 E	4417	6.3	4473
039 LEG9	11 Feb 2016	173729	60 04.55 S	085 50.83 E	4072	185624	60 04.31 S	085 51.13 E	4126	201522	60 04.10 S	085 51.32 E	-	8.3	4198
040 LEG9	12 Feb 2016	151956	60 18.97 S	083 35.38 E	1346	154227	60 18.94 S	083 35.44 E	1348	162340	60 18.97 S	083 35.92 E	1350	9.6	1356
041 LEG9	12 Feb 2016	214943	60 21.61 S	082 33.83 E	1728	222457	60 21.59 S	082 34.08 E	1720	230215	60 21.77 S	082 34.03 E	1728	5.2	1738
042 LEG9	13 Feb 2016	105346	60 53.83 S	079 55.61 E	2628	113615	60 53.75 S	079 56.08 E	2624	123339	60 53.60 S	079 56.62 E	2615	7.7	2658
043 LEG9	14 Feb 2016	020618	61 19.39 S	077 34.72 E	-	031613	61 19.45 S	077 35.00 E	3268	041811	61 19.54 S	077 34.84 E	-	3.5	3322
044 LEG9	14 Feb 2016	201507	61 49.78 S	074 06.35 E	3972	212636	61 49.46 S	074 06.97 E	3967	224844	61 49.04 S	074 07.62 E	3970	5.9	4038
045 LEG10	15 Feb 2016	091246	62 40.75 S	073 21.20 E	3946	092355	62 40.70 S	073 21.28 E	3945	095301	62 40.54 S	073 21.10 E	3948	-	502
046 LEG10	15 Feb 2016	212056	63 57.55 S	072 08.23 E	3586	213145	63 57.54 S	072 08.29 E	3585	215030	63 57.47 S	072 08.43 E	3584	-	503
047 LEG10	16 Feb 2016	064816	64 52.54 S	071 10.15 E	-	065737	64 52.55 S	071 10.29 E	-	073351	64 52.45 S	071 10.84 E	3277	-	502

Table 2: CTD calibration coefficients and calibration dates for cruise au1603. 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 (with the PAR offset value updated from dark voltage values observed on the trials cruise in December 2015). 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).

Primary Temperature, serial 4245, 10/07/2015

G	: 4.38205200e-003
H	: 6.45616924e-004
I	: 2.25352083e-005
J	: 1.85685549e-006
F0	: 1000.000
Slope	: 1.0000000
Offset	: 0.0000

Secondary Temperature, serial 4248, 10/07/2015

G	: 4.38741354e-003
H	: 6.51228721e-004
I	: 2.34575055e-005
J	: 1.90277536e-006
F0	: 1000.000
Slope	: 1.0000000
Offset	: 0.0000

Primary Conductivity, serial 2788, 10/07/2015

G	: -9.73705679e+000
H	: 1.43010808e+000
I	: -8.81924754e-004
J	: 1.49912247e-004
CTcor	: 3.2500e-006
CPcor	: -9.5700000e-008
Slope	: 1.00000000
Offset	: 0.00000

Secondary Conductivity, serial 2821, 10/07/2015

G	: -1.05917079e+001
H	: 1.43436015e+000
I	: 1.16265900e-003
J	: -4.16396285e-006
CTcor	: 3.2500e-006
CPcor	: -9.5700000e-008
Slope	: 1.00000000
Offset	: 0.00000

CTD704 Pressure, serial 89084, 13/07/2015
(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	: 0.99999000
Offset	: 0.10750 (dbar)
AD590M	: 1.283280e-002
AD590B	: -9.705660e+000

Oxygen, serial 0178, 11/07/2015
(for display at time of logging only)

Soc	: 4.85400e-001
Voffset	: -4.96000e-001
A	: -4.06910e-003
B	: 2.17910e-004
C	: -2.98160e-006
E	: 3.60000e-002
Tau20	: 1.70000e+000
D1	: 1.92634e-004
D2	: -4.64803e-002
H1	: -3.30000e-002
H2	: 5.00000e+003
H3	: 1.45000e+003

Transmissometer, serial 899DR, 12/11/2010
+cal drift (referenced to clean water)

M	: 22.2036
B	: -1.3322

Path length: 0.25 (m)

Fluorometer, serial 756, 08/05/2014
analogue range 2

Vblank	: 0.046
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 dark voltage data from trials cruise in December 2015)

Table 3: **CTD conductivity calibration coefficients for cruise au1603. 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 022	0.26439907E-01	0.99910781E-03	-0.79487368E-09	353	0.001253
023 to 047	0.10092528E-01	0.99964156E-03	-0.53308139E-09	281	0.000996

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 au1603.**

station number	($F_2 + F_3 . N$)	station number	($F_2 + F_3 . N$)	station number	($F_2 + F_3 . N$)
1	0.99910701E-03	17	0.99909430E-03	33	0.99962397E-03
2	0.99910622E-03	18	0.99909350E-03	34	0.99962344E-03
3	0.99910542E-03	19	0.99909271E-03	35	0.99962290E-03
4	0.99910463E-03	20	0.99909191E-03	36	0.99962237E-03
5	0.99910383E-03	21	0.99909112E-03	37	0.99962184E-03
6	0.99910304E-03	22	0.99909032E-03	38	0.99962131E-03
7	0.99910225E-03	23	0.99962930E-03	39	0.99962077E-03
8	0.99910145E-03	24	0.99962877E-03	40	0.99962024E-03
9	0.99910066E-03	25	0.99962824E-03	41	0.99961971E-03
10	0.99909986E-03	26	0.99962770E-03	42	0.99961917E-03
11	0.99909907E-03	27	0.99962717E-03	43	0.99961864E-03
12	0.99909827E-03	28	0.99962664E-03	44	0.99961811E-03
13	0.99909748E-03	29	0.99962610E-03	45	0.99961757E-03
14	0.99909668E-03	30	0.99962557E-03	46	0.99961704E-03
15	0.99909589E-03	31	0.99962504E-03	47	0.99961651E-03
16	0.99909509E-03	32	0.99962450E-03		

Table 5: **Surface pressure offsets (i.e. poff, in dbar) for cruise au1603. For each station, these values are subtracted from the pressure calibration "offset" value in Table 2. Note: for station 44, pressure offset from station 45 used.**

stn	poff	stn	poff	stn	poff
1	-0.25	17	-0.34	33	-0.29
2	-0.47	18	-0.33	34	-0.43
3	-0.47	19	-0.52	35	-0.41
4	-0.60	20	-0.53	36	-0.45
5	-0.50	21	-0.48	37	-0.42
6	-0.41	22	-0.40	38	-0.40
7	-0.37	23	-0.42	39	-0.39
8	-0.44	24	-0.30	40	-0.35
9	-0.58	25	-0.51	41	-0.38
10	-0.56	26	-0.32	42	-0.40
11	-0.50	27	-0.46	43	-0.31
12	-0.44	28	-0.28	44	-0.34
13	-0.61	29	-0.34	45	-0.34
14	-0.49	30	-0.39	46	-0.34
15	-0.34	31	-0.37	47	-0.51
16	-0.28	32	-0.50		

<u>Table 6:</u> CTD dissolved oxygen calibration coefficients for cruise au1603: 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), plus stations 31, 38-39 and 41-43.

	shallow					deep				
stn	slope	bias	tcor	pcor	dox	slope	bias	tcor	pcor	dox
1	0.388356	-0.045690	-0.029050	0.000106	0.165123	0.207086	0.206708	0.120414	0.000116	0.087826
2	0.482792	-0.226288	-0.007240	0.000143	0.166876	0.597157	-0.400283	-0.041151	0.000148	0.022022
3	0.486739	-0.232112	0.000487	0.000139	0.059267	0.593180	-0.401522	-0.015897	0.000157	0.019853
4	0.494280	-0.255714	0.008416	0.000157	0.128833	0.592261	-0.402028	-0.006076	0.000158	0.034521
5	0.492139	-0.251150	0.006422	0.000152	0.136572	0.406833	-0.096700	0.001078	0.000119	0.022936
6	0.493549	-0.265937	0.018693	0.000162	0.081381	0.434711	-0.131501	-0.017675	0.000115	0.022725
7	0.526078	-0.330577	0.002792	0.000354	0.109246					
8	0.507782	-0.289804	0.003103	0.000261	0.146412					
9	0.501453	-0.272105	0.004097	0.000214	0.132563					
10	0.492629	-0.254325	0.008258	0.000150	0.105904	0.430245	-0.116398	-0.032347	0.000109	0.024933
11	0.491611	-0.221691	-0.021322	0.000126	0.137518	0.535293	-0.305213	-0.007212	0.000144	0.022677
12	0.500686	-0.263098	0.001532	0.000151	0.078667	0.603937	-0.443922	0.025164	0.000181	0.020676
13	0.503381	-0.276253	0.006982	0.000162	0.125562	0.576627	-0.380290	-0.002789	0.000159	0.028065
14	0.486375	-0.312293	0.074547	0.000203	0.100862	0.600449	-0.396796	-0.025342	0.000151	0.011666
15	0.491183	-0.265617	0.017966	0.000163	0.123867	0.400858	-0.100592	0.005628	0.000128	0.013735
16	0.482703	-0.252696	0.025647	0.000155	0.112827	0.400587	-0.100774	0.013466	0.000123	0.016032
17	0.481533	-0.229478	0.007763	0.000139	0.124096	0.398576	-0.103466	0.023213	0.000128	0.027702
18	0.564455	-0.374048	0.012014	0.000157	0.161058	0.443185	-0.147299	-0.011959	0.000118	0.023509
19	0.412967	-0.103141	-0.017193	0.000121	0.178584	0.473021	-0.176925	-0.049178	0.000110	0.033660
20	0.485248	-0.227775	-0.003977	0.000138	0.219907	0.526609	-0.297883	0.006417	0.000146	0.010659
21	0.538476	-0.413876	0.092529	0.000276	2.190787					
22	0.508880	-0.277388	0.002787	0.000158	0.149113	0.593503	-0.404572	-0.037456	0.000153	0.018273
23	0.507141	-0.292931	0.022747	0.000172	0.106449	0.433430	-0.117644	-0.043376	0.000107	0.024926
24	0.495213	-0.266783	0.019773	0.000188	0.109770					
25	0.487261	-0.239941	0.003481	0.000147	0.103812	0.444689	-0.141647	-0.028285	0.000113	0.024498
26	-	-	-	-	-					
27	0.481298	-0.233062	0.005467	0.000148	0.118975	0.398026	-0.104359	0.024457	0.000131	0.021862
28	0.490229	-0.243295	0.001588	0.000145	0.033307	0.399881	-0.101191	0.014811	0.000125	0.009476
29	0.481292	-0.242777	0.018375	0.000151	0.090045	0.398711	-0.102647	0.014533	0.000131	0.041872
30	0.501337	-0.271356	0.003985	0.000162	0.140744	0.343651	0.062078	-0.040492	0.000057	0.003905
31	0.495249	-0.249600	-0.000611	0.000147	0.099414					
32	0.465832	-0.268397	0.060939	0.000206	0.142076	0.399074	-0.102212	0.018732	0.000127	0.004468
33	0.470704	-0.236134	0.028606	0.000158	0.055313	0.597385	-0.399862	-0.020633	0.000153	0.012946
34	0.461480	-0.236454	0.025081	0.000176	0.178596	0.464950	-0.175799	-0.017329	0.000117	0.019650
35	0.528001	-0.442046	0.025338	0.000871	0.118292					
36	0.477915	-0.224282	0.010985	0.000124	0.042564					
37	0.508747	-0.300095	0.027583	0.000193	0.134298					
38	0.442391	-0.188432	0.033818	0.000067	0.160640					
39	0.462591	-0.202230	0.044338	0.000102	0.111759					
40	0.487391	-0.278414	0.032561	0.000224	0.081123					
41	0.490933	-0.258296	0.016496	0.000158	0.118800					
42	0.503229	-0.284947	0.009298	0.000274	0.041613					
43	0.503291	-0.280349	0.002989	0.000261	0.067665					
44	0.493095	-0.236508	-0.007652	0.000136	0.080532	0.602672	-0.393654	-0.032327	0.000146	0.024525
45	0.494540	-0.287093	0.032102	0.000228	0.090405					
46	0.511532	-0.297017	-0.001755	0.000358	0.057352					
47	0.527317	-0.335312	-0.002883	0.000378	0.120421					

Table 7: **Missing data points in 2 dbar-averaged files for cruise au1203. "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 not included here - 2 dbar value missing for most casts, 4 dbar value missing for many casts.

station	pressure (dbar) where data missing	T	S/C	O	F	PAR	TR	F_up	PAR_up	TR_up
10	4082	x	x	x	x	x	x	x	x	x
12	3824	x	x	x	x	x	x			
26	6-306			x						
28	6-2366						x			
31	190, 206-214			x						
32	178-180, 198-204			x						
33	214			x						
34	194-196			x						
35	400-504			x						
37	400-502			x						
38	400-4474			x						
39	350-4198			x						
40	400-1356			x						
42	400-2658			x						
43	400-3322			x						
45	400-502			x						
46	250-504			x						
47	400-502			x						

Table 8: **Suspect CTD 2 dbar averages (not deleted from the CTD 2 dbar average files) for the indicated parameters, for cruise au1603.**

station	suspect 2 dbar value (dbar)	parameters	comment
47	2-50	oxygen	sensor data not calibrating well

Table 9: **Bad salinity bottle samples (not deleted from bottle data file) for cruise au1603.**

station	rosette position
10	3, 8
11	2
16	7, 14
18	1
21	1, 13
24	4
25	12, 13
27	5
32	2
33	4, 6
42	8, 9
44	whole station
45	whole station
46	whole station
47	whole station

Table 10: Summary of APEX Argo, SOCCOM and Provor float deployments on cruise au1603.

hull ID	position		time	depth (m)	CTD stn
APEX 7383	57° 36.291' S	84° 38.024' E	0937, 09/02/2016	4560	34
APEX 7384	59° 06.033' S	84° 26.805' E	1542, 10/02/2016	2494	37
APEX 7385	61° 12.3' S	83° 51.7' E	0000, 06/02/2016	2406	28
APEX 7416	60° 59' S	102° 42' E	0336, 20/01/2016	4487	-
APEX 7418	61° 55.7' S	85° 02.2' E	1107, 05/02/2016	3219	27
SOCCOM Navis 0506	62° 59.9' S	93° 36.3' E	1700, 23/01/2016		5
SOCCOM Navis 0507	61° 49.7' S	74° 07.2' E	0059, 15/02/2016		44
Provor	57° 36.291' S	84° 38.024' E	0950, 09/02/2016	4560	34

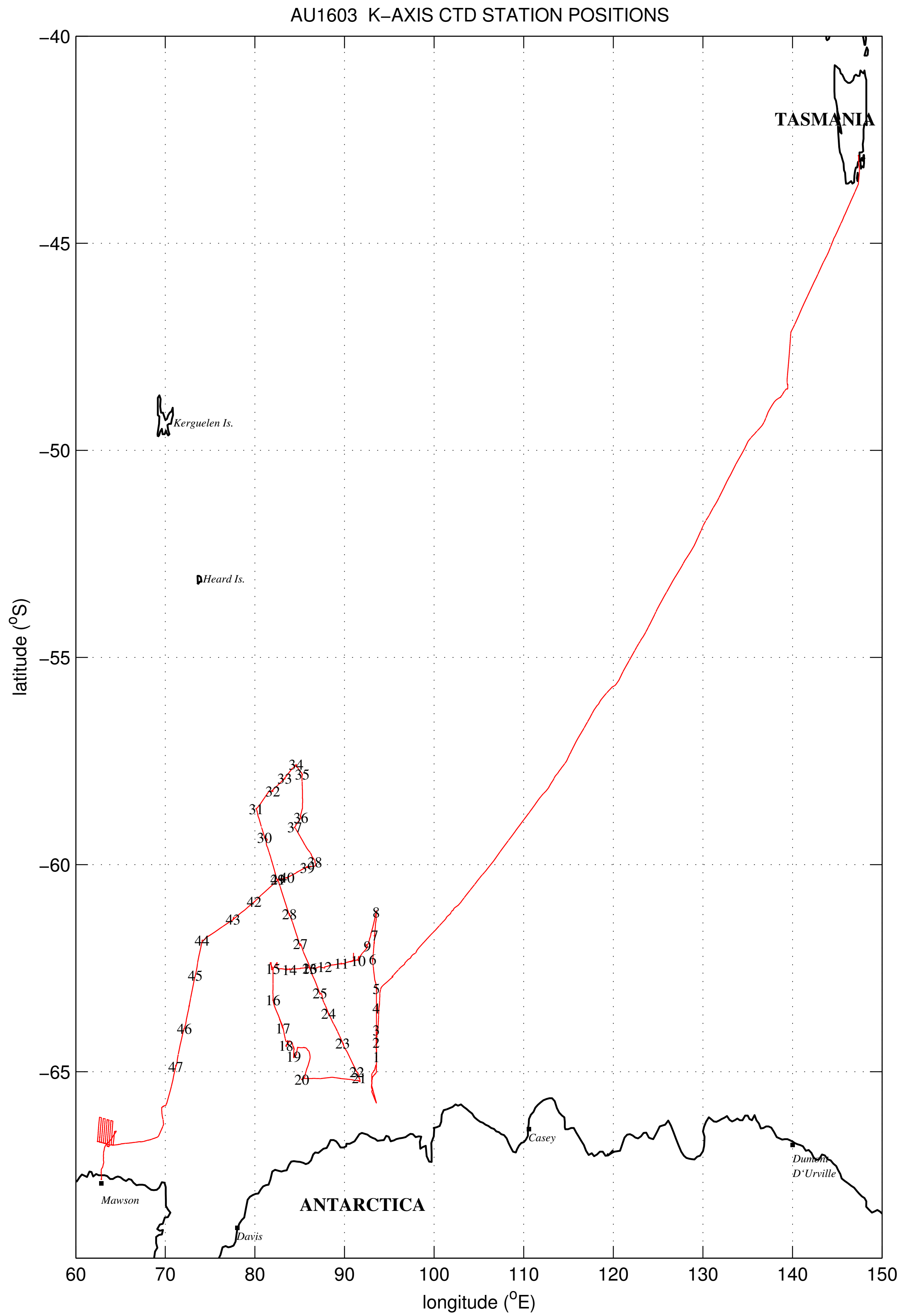
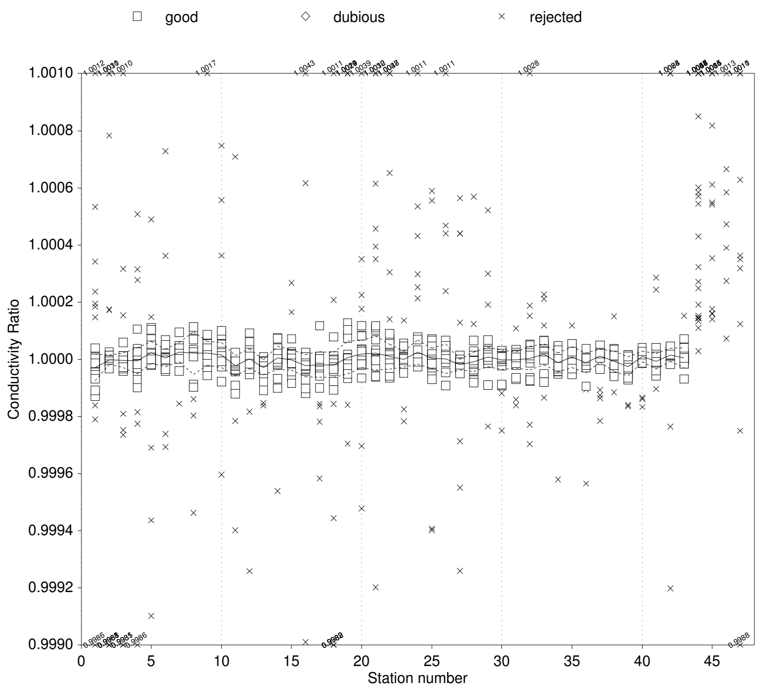


Figure 1: CTD station positions and ship's track for cruise au1603.



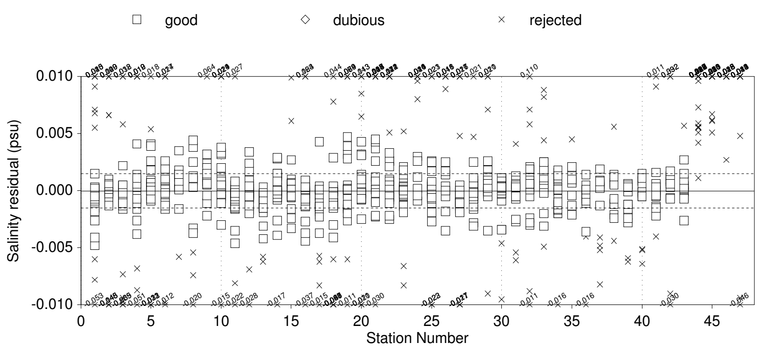
Calibration data for cruise : au1603

Calibration file : a1603.bot

Conductivity s.d. = 0.00004

Number of bottles used = 634 out of 847 Mean ratio for all bottles = 1.00000

<u>Figure 2:</u> Conductivity ratio c_{btl}/c_{cal} versus station number for cruise au1603. 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 : au1603

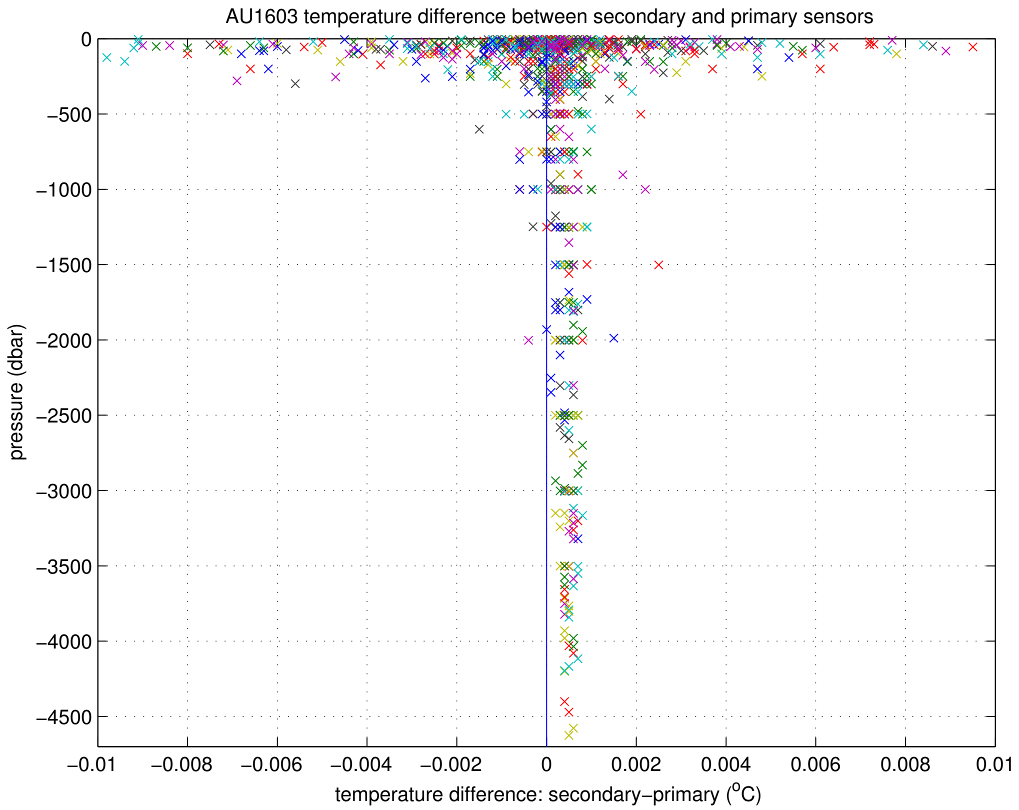
Calibration file : a1603.bot

Mean offset salinity = 0.0000psu (s.d. = 0.0015 psu)

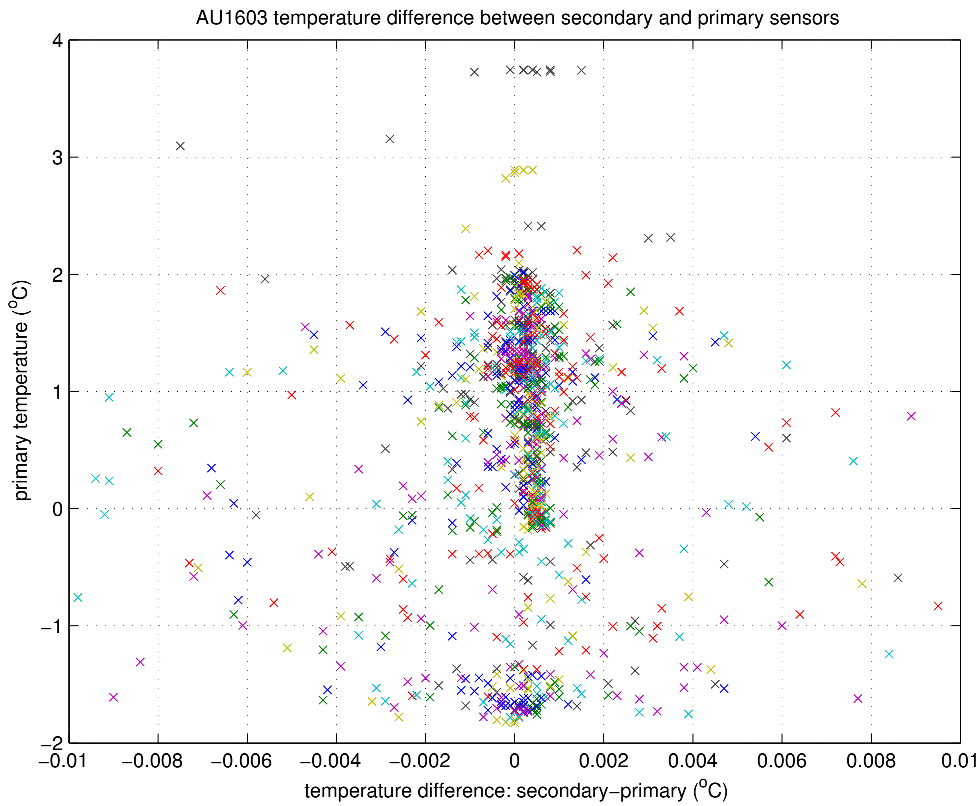
Number of bottles used = 634 out of 847

<u>Figure 3:</u> Salinity residual (s_{btl} - s_{cal}) versus station number for cruise au1603. 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.

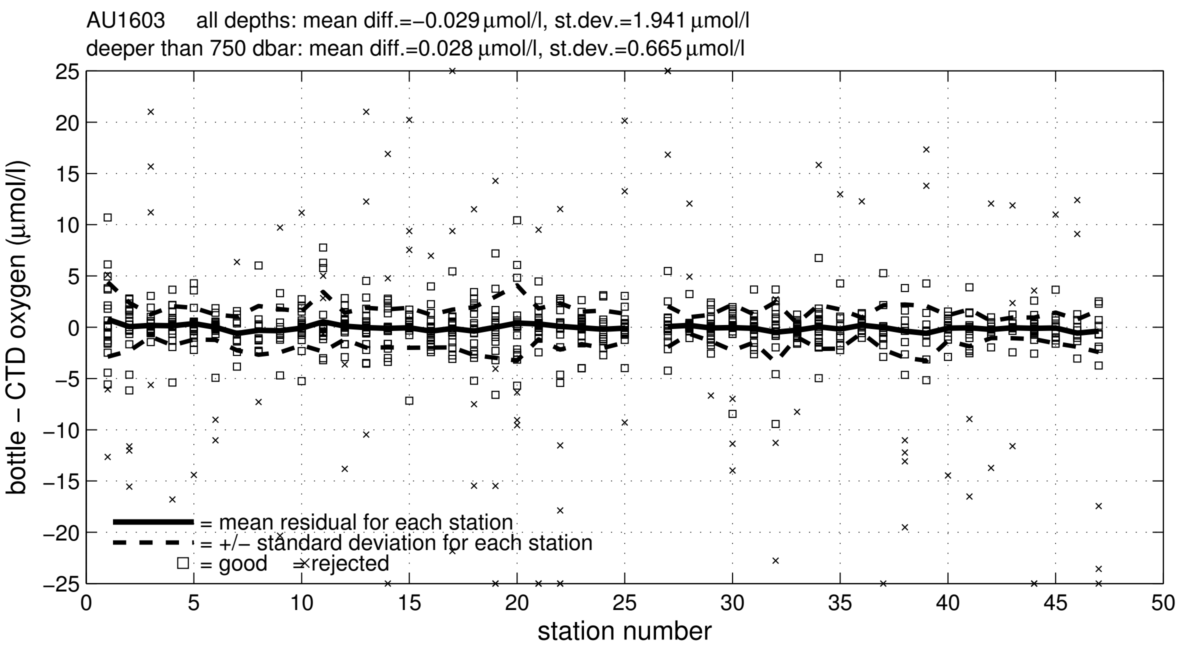


Figure 5: **Dissolved oxygen residual (o_{btl} - o_{cal}) versus station number for cruise au1603. The solid line follows the mean residual for each station; the broken lines are ± the standard deviation of the residuals for each station. o_{cal}=calibrated downcast CTD dissolved oxygen; o_{btl}=Niskin bottle dissolved oxygen value. Note: values outside vertical axes are plotted on axes limits.**

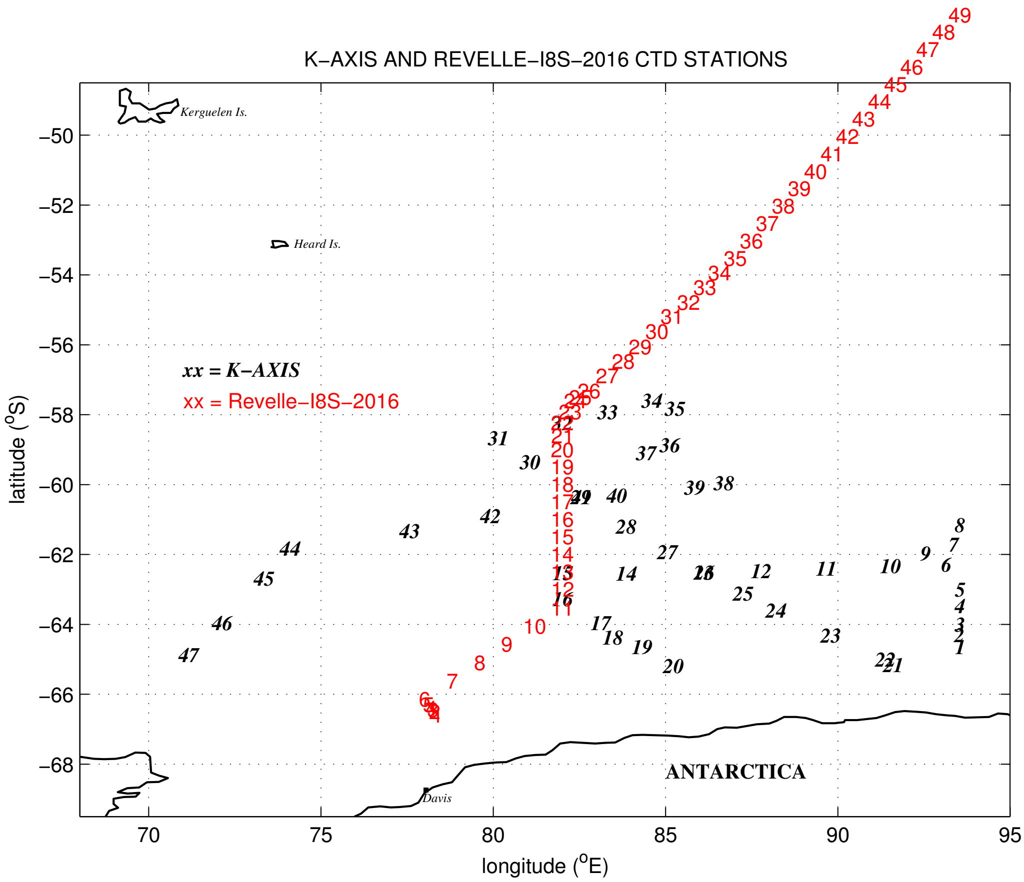


Figure 6: **CTD Station positions for au1603 (K-AXIS) and Roger Revelle I8s 2016 cruise.**

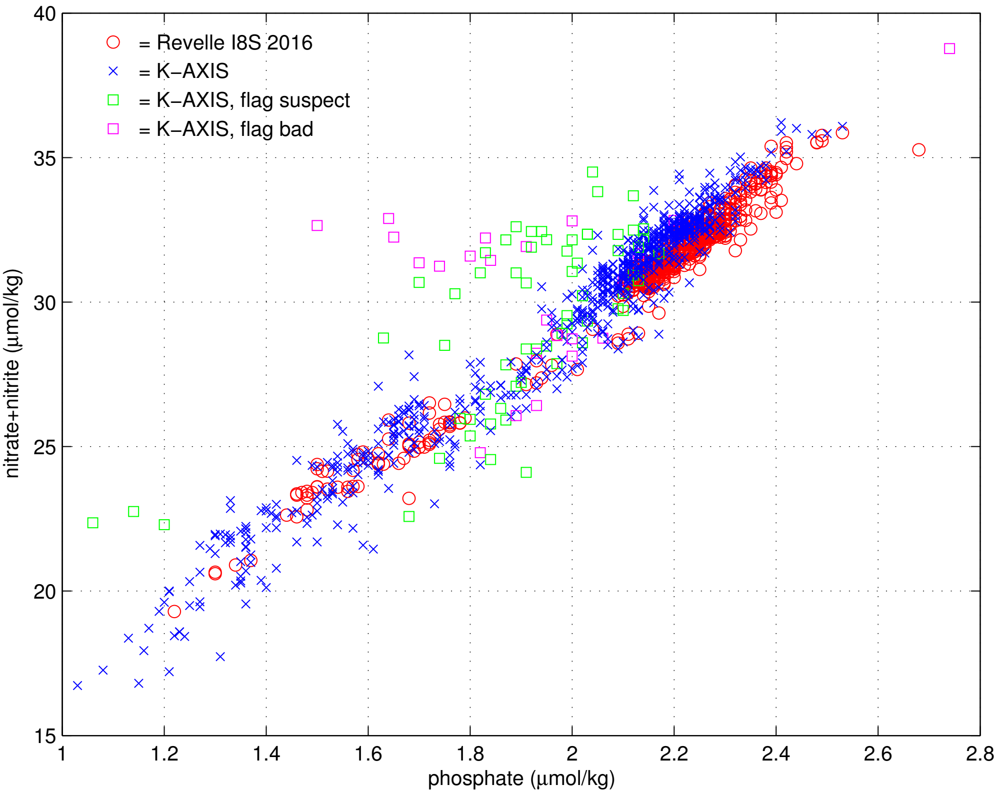
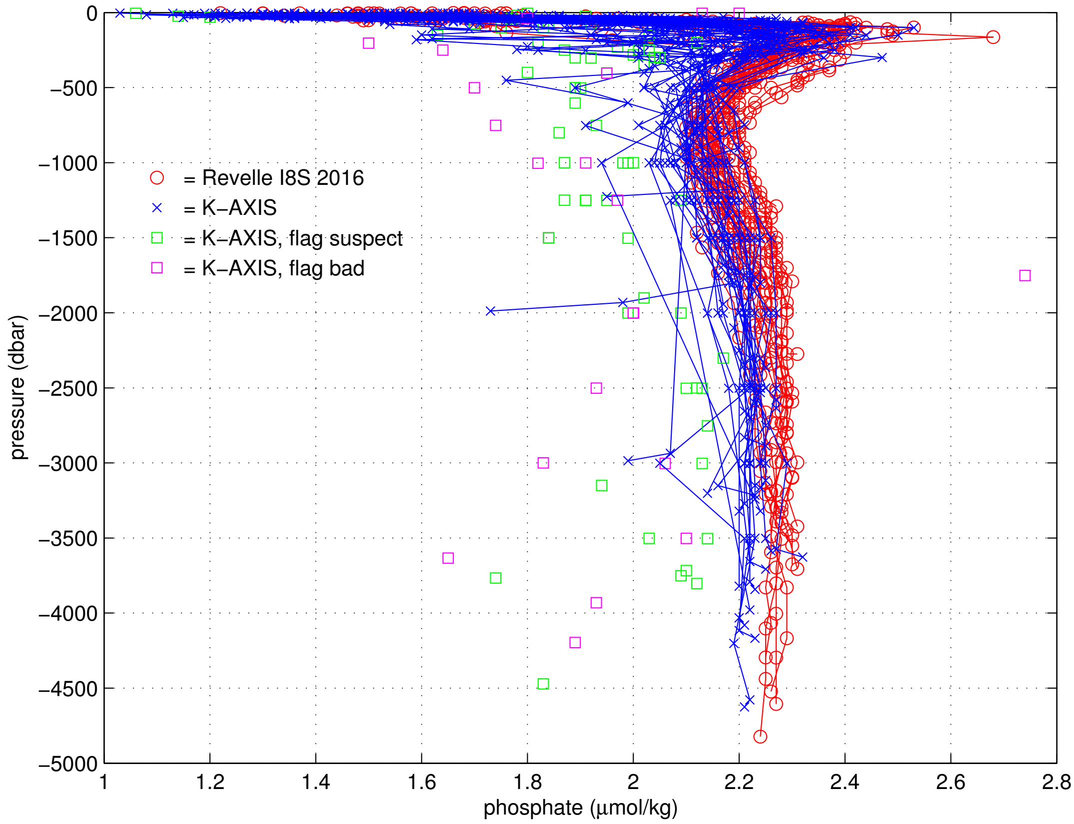
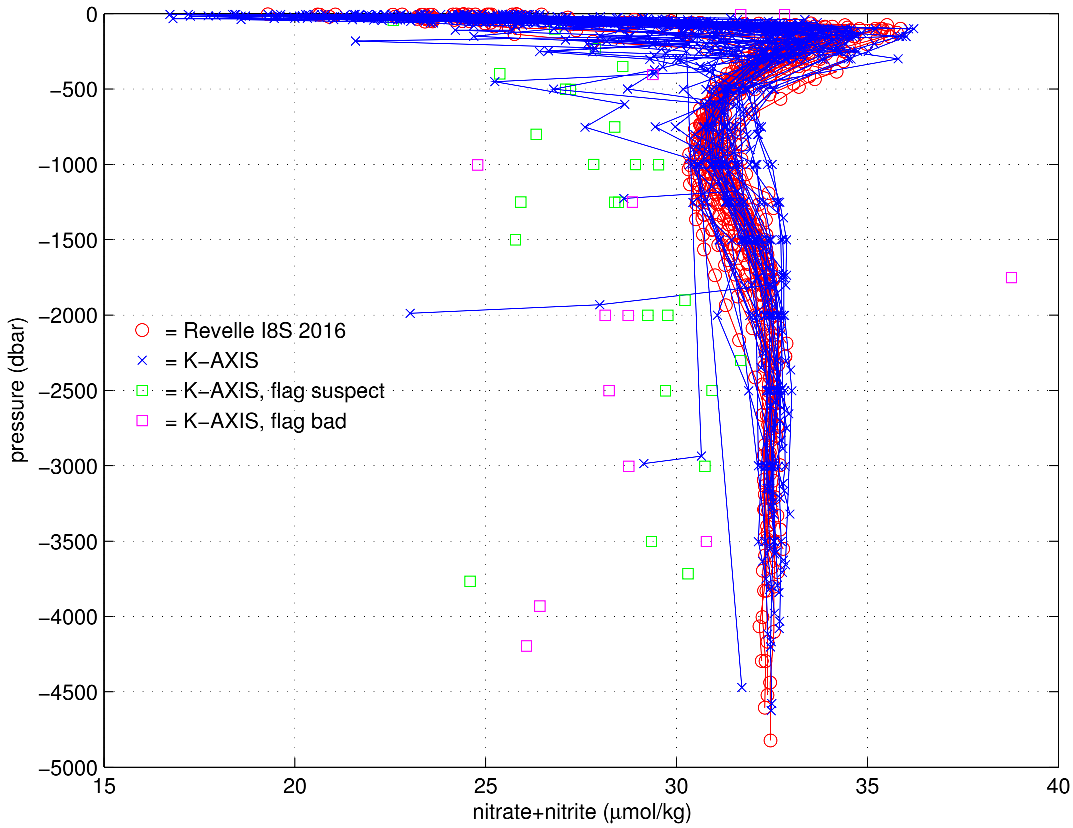


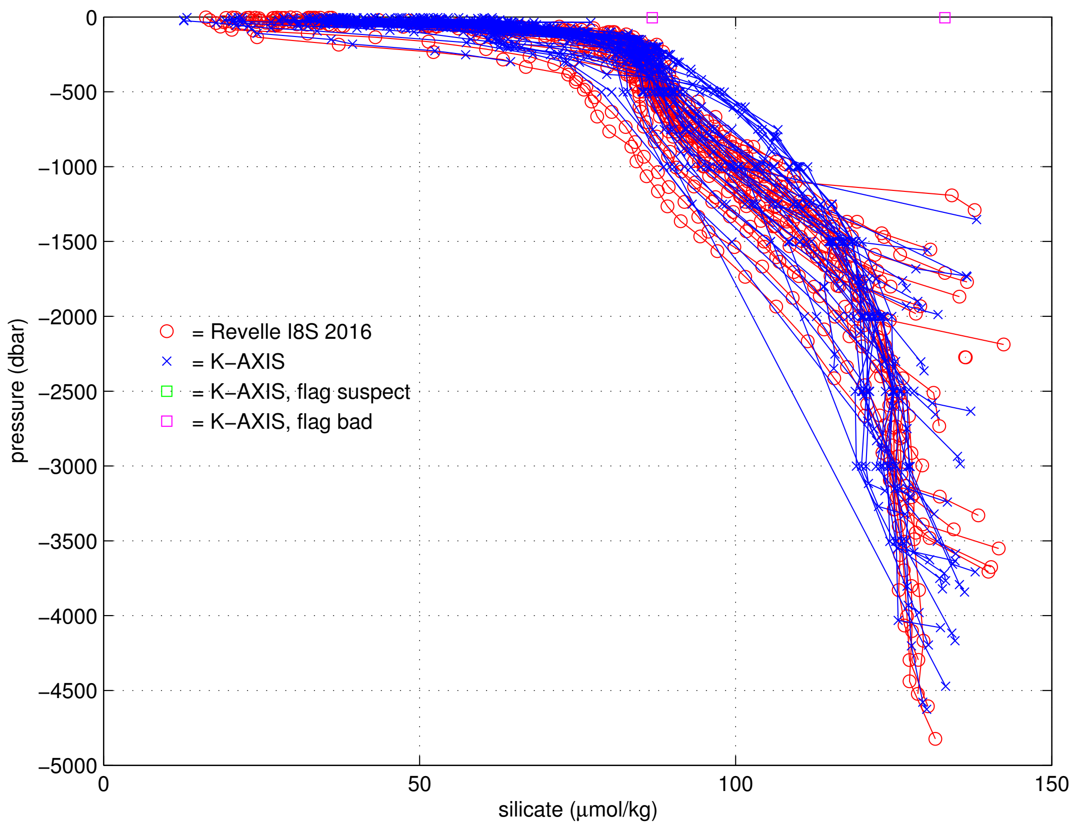
Figure 7: **Nitrate+nitrite versus phosphate data, for au1603 (K-AXIS, whole cruise) and Roger Revelle I8S 2016 (stations 7 to 28). Note that K-AXIS data in the plot have been converted to units µmol/kg. Also note that K-AXIS phosphate shown as suspect are prior to flagging the entire phosphate data set as suspect.**



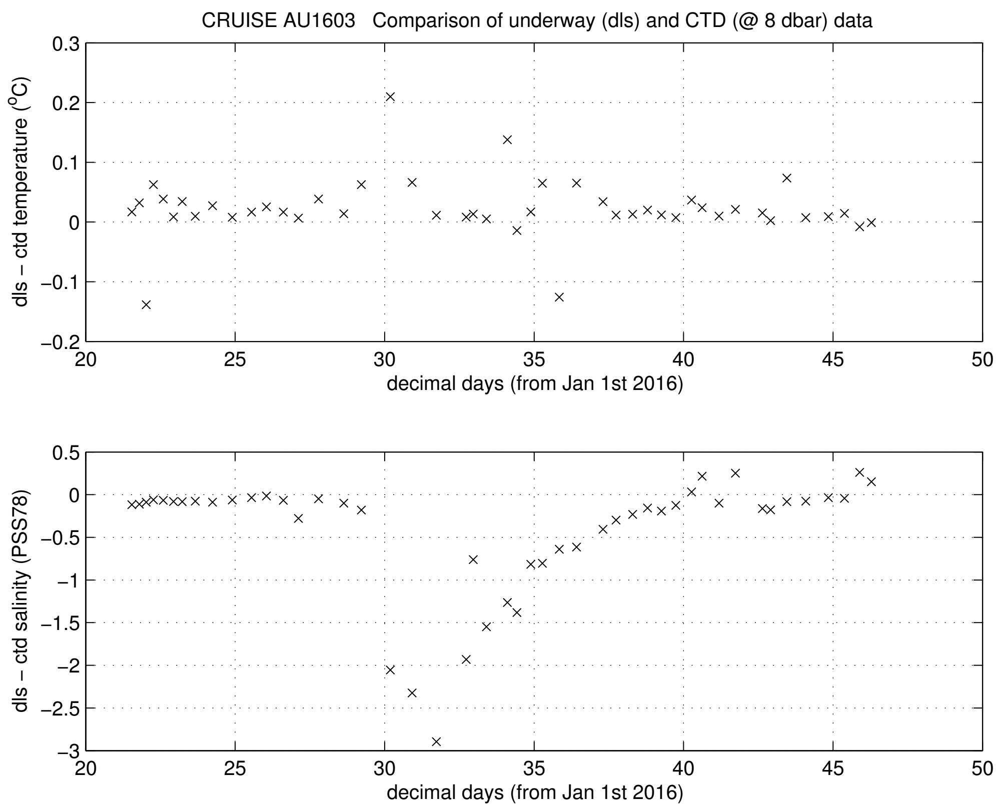
<u>Figure 8:</u> Phosphate profiles for au1603 (K-AXIS, whole cruise), and Roger Revelle I8S 2016 (stations 7 to 28). Note that K-AXIS phosphate shown as suspect are prior to flagging the entire phosphate data set as suspect.



<u>Figure 9:</u> Nitrate+nitrite profiles for au1603 (K-AXIS, whole cruise), and Roger Revelle I8S 2016 (stations 7 to 28). Note that K-AXIS data in the plot have been converted to units µmol/kg.

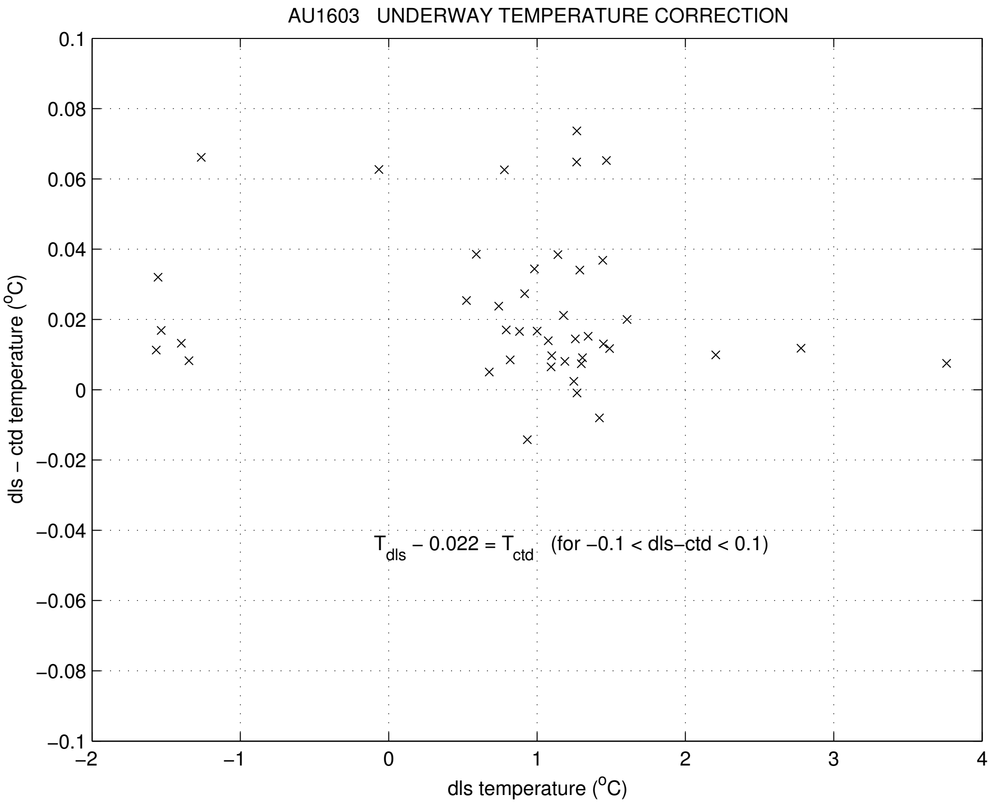


<u>Figure 10:</u> Silicate profiles for au1603 (K-AXIS, whole cruise), and Roger Revelle I8S 2016 (stations 7 to 28). Note that K-AXIS data in the plot have been converted to units µmol/kg.

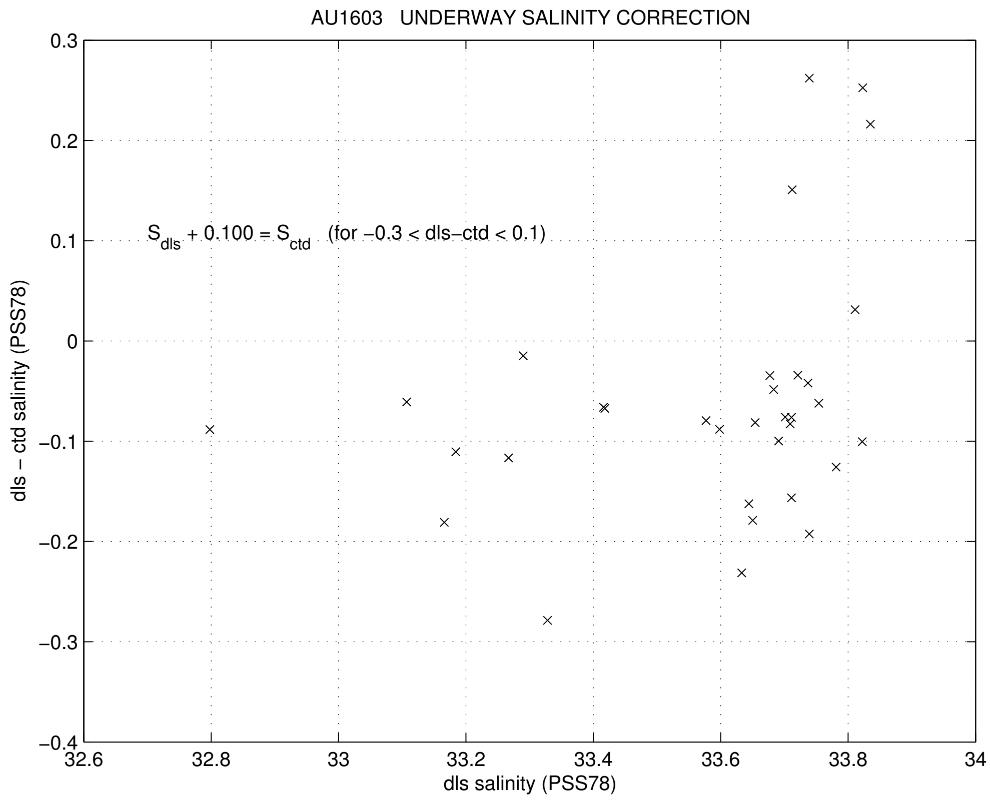


<u>Figure 11:</u> au1603 comparison of underway temperature and salinity data to CTD data, with time.

(a)



(b)



<u>Figure 12a and b:</u> au1603 comparison between (a) CTD and underway temperature data (i.e. hull mounted temperature sensor), and (b) CTD and underway salinity data. Note: dls refers to underway data. Note that due to the large scatter these corrections have not been applied to the underway data.

APPENDIX 1 KAXIS HYDROCHEMISTRY REPORT

(at the time of writing: this appendix is for salinity analyses only)

Personnel
Analysis-Ruth Eriksen
Sampling- Katherine Tattersall, Delphi Ward, Stuart Corney, Christine Weldrick, plus volunteers Justin Phebey and Tom Clarke

Key questions/outputs (from voyage plan)

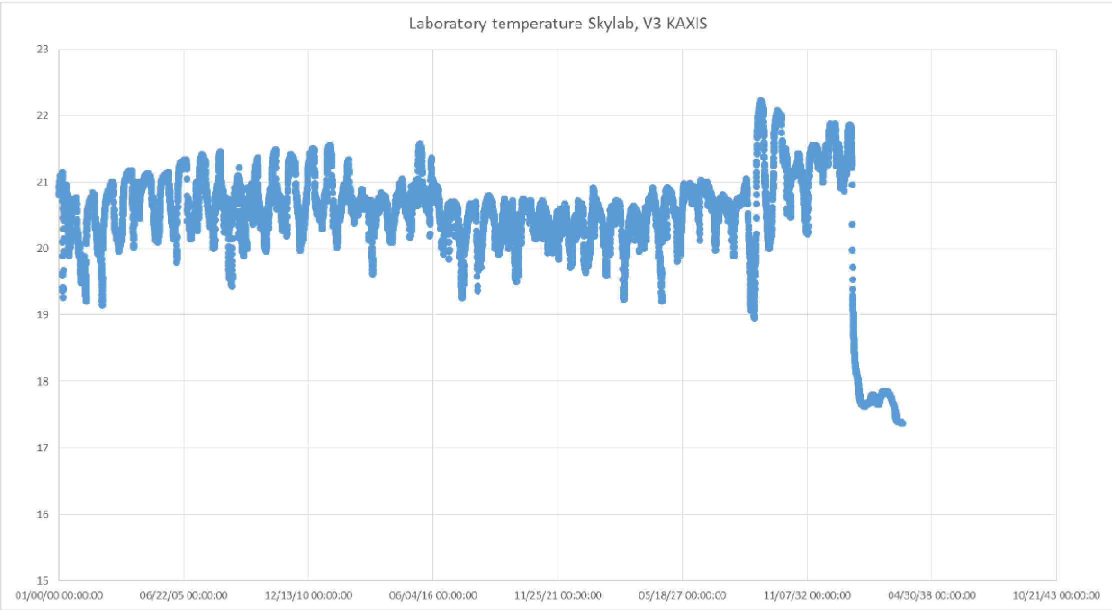
- Calibration of dissolved oxygen and salinity sensors for 47 CTD casts through on-board analysis of samples drawn from Niskins (Rintoul/Rosenberg)
- Collection and preservation of nutrient samples for analysis in Hobart (Rintoul/Rosenberg)
- Measurement of dissolved oxygen concentrations in CO_2 manipulation experiments (King/Kawaguchi)

Strategy behind sampling design

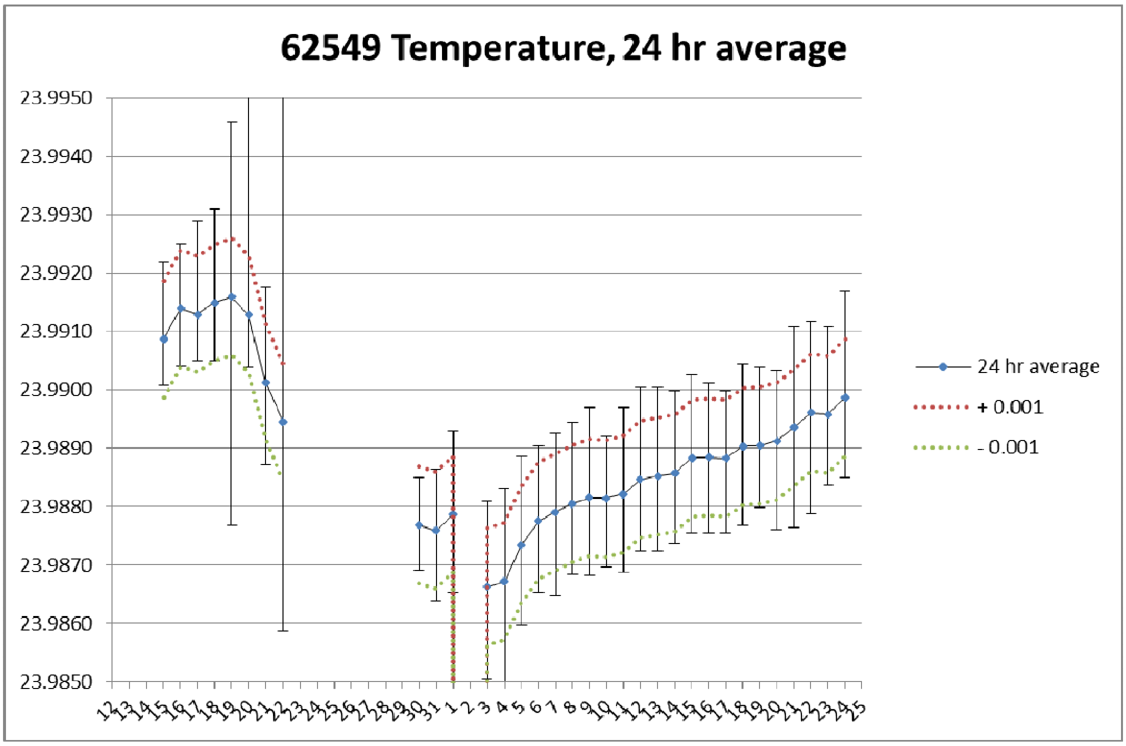
- Sampling was conducted in accordance with standard practice for chemical oceanography. Depths for sampling were based on examination of the down-cast by the CTD watch, with input from groups requiring water as per the water budget. Detailed notes provided by Mark Rosenberg and Steve Rintoul guided decision making about cast deployments and subsequent water masses sampled.

Methods
Salinity

- Salinity samples were collected according to the CSIRO Procedure S2 V01, using new “square” clear glass bottles that had been conditioned with surface seawater collected on earlier voyages onboard Investigator.
- Samples were analysed using a Guildline Model 8400B “Autosal” salinometer (Units 62548 and 62549)
- Analysis protocols were drawn from CSIRO procedures (G3 V01), and the Guildline manual
- Additional information on analysis was drawn from Kawano GO-SHIP (IOCCP Report No 14, 2010) and the original CSIRO Hydrochemistry Manual (Cowley et al 1999)
- Instrument standardisation was undertaken using IAPSO Standard Seawater, Batch P158 (Expiry 25.3.2018)
- Laboratory temperature was set to 20 ^{o}C by the ships engineer, as per hydrochem report by Craig Neill on the previous year’s Totten Glacier voyage.
- Laboratory temperature was logged using a HOBO data logger, at 5 min intervals for the duration of the voyage (Figure 1). Lab temperature averaged 20.5 ±0.8 ^{o}C during the marine science period of the voyage. Temperature dropped immediately after the grounding to 17.8 ^{o}C.
- Water bath temperature in the salinometers was logged using a high precision temperature probe constructed by CSIRO for the voyage (Figure 2). Data was logged at 2 min intervals using the HYDRO1 software developed by CSIRO. The temperature probe was calibrated prior to the voyage by the O&A Oceanographic Calibration Facility on 21/12/2015 over the range -1.458 to 32.042 ^{o}C.
- Duplicates were not routinely analysed, on advice from Mark Rosenberg. An initial set of duplicates was collected on CTD 000 and 001 for the purposes of training the CTD watch in sampling technique.



<u>Figure 1:</u> Laboratory temperature log, Skylab V3 from January 13 – February 29 2016



<u>Figure 2:</u> 24 hr average temperature± 0.001 °C (dotted lines) for Guildline salinometer 62549, KAXIS -V3. Bars represent 24 hour range. Temperature logger in Guildline 62548 23rd January to 27th January. Logger removed 2nd Feb to calibrate DO sensors.

Sample processing

- All samples were processed on-board, as the salinometer appeared stable and reproducible, compared to previous recent voyages (see report by Craig Neill).
- Samples were left to equilibrate for 24 hours in the Skylab before analysis.
- At the start of each run, the instrument was first flushed with surface seawater stored in a 20L carboy, until a stable reading was achieved. Next the flow-cell was flushed with open IAPSO seawater (i.e the previous days IAPSO bottle/s).
- The instrument was then calibrated using 1 or 2 (occasionally 3) new bottles of IAPSO Standard (batch P158) until 3 repeat reads were within acceptable limits. Water bath temp, instrument drift, zero and standby values were checked repeatedly during each run.
- The cell was flushed at least 3 times with a new sample before taking duplicate reads.
- Data was manually processed using the Excel spreadsheet “Saltsheet.xlsm” provided by the Hydrochemistry group, as no Guildline data logger was available for the voyage.
- Preliminary data analysis onboard included plotting lab salinity against scan salinity during the upcast, as a first pass to check for outliers, typos, or sampling mix-ups.
- Data was then passed to Stuart Corney for first stage processing according to Mark Rosenbergs protocols.

Sample summary (how many samples for each method, location, time)

- A sample summary table for all hydrochemistry samples (salinity, dissolved oxygen and nutrients) is presented as Table 1. Note that nutrient samples were collected in triplicate.
- Salinity samples were also collected from the TMR, however the majority of these were analysed in Hobart due to the grounding (see report by C. Schallenberg for more details).
- A summary of analysis and preliminary data checks conducted on –board is included in

Lab set-up (instrumentation, bench configuration, filtration racks, storage)\

Salinity analysis was set up on the central bench in the Skylab, with one salinometer at either end. This allowed standards, samples and the data logging gear to be positioned centrally and accessed from either instrument.

Sample bottles (outgoing) were stacked by the Skylab door, and sample bottles (incoming) were stacked by the salinometers, rotating up onto the benches for 24 hours prior to analysis.

A sample entry/exit log was maintained so that the CTD watch could check crates of bottles in and out. This was useful for analysis, as it allowed easy identification of how long samples had been equilibrating in the Sky lab.

Temperature loggers were placed beside the salinometer (Figure 1), in the water bath (
Figure ***2***) and near the DO system.

Recommendations (what would you do differently)

- Sufficient salinity sample bottles were taken on V3 so that it would be possible to bring all samples back to Hobart for analysis in the event of instrument failure. The sample bottles supplied for this purposed were the type used to supply the IAPSO Standard seawater, as they have crimpable lids which should provide a robust seal to deal with delayed analysis.
- This type of bottle has a narrow neck, and is time-consuming to sample (draining is slow through the small neck) compared to standard bottles.
- All the bottles (~1000) in total were pre-conditioned with surface seawater prior to the voyage.
- There was some questions from Customs officials during the quarantine process conducted in Freemantle as to the necessity to declare these “samples”. I had confirmed with the DVL earlier in the voyage that the bottles were filled with coastal water (Maria Is water collected by the Hydrochemistry group during routine IMOS sampling), and it was decided that it was not necessary to include these in the Quarantine declaration. It would be useful to confirm this before the next voyage, and label the boxes accordingly.

<u>Table 1</u>: Summary of analytical conditions and preliminary data checks for salinity analyses.
Note all calibrations using OSIL batch P158 (K15 =0.99970)

CTD	Date sampled	Date processed	Comments	Instrument	24 hr average bath temp (°C)
00	21.1.2016	21.1.2016	Test cast. 4 replicate samples from 6 depths (0-300m)	62549	No data[1]
01	22.1.2016	21.1.2016	Full depth.	62549	No data[1]
02	22.1.2016	23.1.2016	Full depth.	62549	No data[1]
03	23.1.2016	23.1.2016	Full depth.	62549	No data[1]
04	23.1.2016	24.1.2016	Full depth.	62549	No data[1]
05	23.1.2016	25.1.2016	Full depth.	62549	No data[1]
06	23.1.2016	25.1.2016	Full depth.	62549	No data[1]
07	24.1.2016	26.1.2016	300 m cast.	62549	No data[1]
08	24.1.206	26.1.2016	300 m cast.	62549	No data[1]
09	25.1.2016	26.1.2016	300 m cast.	62549	No data[1]
10	25.1.2016	27.1.2016	Full depth.	62549	No data[1]
11	26.1.2016	27.1.2016	Full depth.	62549	No data[1]
12	27.1.2016	30.1.2016	Full depth.	62549	No data[1]
13	27.1.2016	28.1.2016	Full depth.	62549	No data[1]
14	28.1.2016	30.1.2016	Full depth.	62549	23.9877
15	28.1.2016	31.1.2016	Full depth.	62549	No data[2]
16	29.1.2016	1.2.2016	Full depth. Difficult to get stable reading for D14 (100m) due to trawling activity.	62549	No data[2]
17	30.1.2016	1.2.2016	Full depth.	62549	23.9870
18	31.1.2016	2.2.2016	Full depth.	62549	23.9882
19	31.1.2016	2.2.2016	Full depth.	62549	23.9882
20	1.2.2016	4.2.2016	Full depth.	62549	23.9867
21	2.2.2016	4.2.2016	Full depth.	62549	23.9867
22	2.2.2016	4.2.2016	Full depth.	62549	23.9867
23	3.2.2016	5.2.2016	Full depth.	62549	23.9873
24	4.2.2016	5.2.2016	300 m cast.	62549	23.9873
25	4.2.2016	6.2.2016	Full depth. Suspect G13 (360m) and G12 (500m) sampled wrong way round.	62549	23.9878
26	4.2.2016	5.2.2016	300 m cast.	62549	23.9878
27	5.2.2016	6.2.2016	Full depth. Suspect CTD scan data for 100m is 34.452?	62549	23.9878
28	5.2.2016	7.2.2016	Full depth.	62549	23.9879
29	6.2.2016	8.2.2016	Full depth.	62549	23.9882
30	7.2.2016	9.2.2016	Full depth.	62549	23.9882
31	7.2.2016	9.2.2016	Full depth.	62549	23.9882
32	8.2.2016	10.2.2016	Full depth. Bottle data from G02 (1760m) suspect.	62549	23.9881
33	8.2.2016	11.2.2016	Full depth.	62549	23.9882
34	9.2.2016	15.2.2016	Full depth. Heavy salt crusts under lid on most bottles. MQ rinse and wipe to remove.	62549	23.9888
35	9.2.2016	10.2.2016	300 m cast. Heavy salt crusts under lid on most bottles. MQ rinse and wipe to remove.	62549	23.9881
36	10.2.2016	10.2.2016	300 m cast. Heavy salt crusts under lid on most bottles. MQ rinse and wipe to remove.	62549	23.9881
37	10.2.2016	11.2.2016	300 m cast.	62549	23.9882
38	11.2.2016	13.2.2016	1000m cast[3]	62549	23.9885
39	11.2.2016	13.2.2016	1000m cast[3]	62549	23.9885
40	12.2.2016	13.2.2016	1000m cast[3]	62549	23.9885
41	12.2.2016	13.2.2016	1000m cast[3]	62549	23.9885
42	13.2.2016	15.2.2016	1000m cast[3]	62549	23.9888
43	14.2.2016	15.2.2016	1000m cast[3]	62549	23.9888
44[4]	14.2.2016	25.2.2016	Full depth. Bottle data suspect for F06 (2000 m) and F12 (198.9m). CTD scan data suspect for 3500m and 2000m.	62549	23.9899
45	15.2.2016	25.2.2016	500 m cast. Bottle data suspect for B24 (5 m) and B04 (199.34m).	62549	23.9899
46	15.2.2016		500 m cast.	62549	23.9899
47	16.2.2016	25.2.2016	300 m cast Lost UPS at bottle G10. Spike in bath temp to 24.0043. Wait until bath temp stabilised before continuing. 200m fired out of order?	62549	23.9899

[1] Logger installed on 62548.
[2] Logger removed to trouble shoot DO rig
[3] Plus bottom for genetics
[4] Calibration good and no drift observed for Stations 44- 47, but overall decrease in level of agreement between CTD scan data and bottle data. Analysed post- grounding, on a slight angle

<u>Table 2</u>: Summary of equipment and consumables used for MS Trials and V3-KAXIS

Equipment	Quantity
Guildline salinometers	2
Pump for salinometer (Watson Marlow)	1
Tubing for Watson Marlow pump	2 m
Laptop for data entry	1
Thermometer for Niskin sampling	1
Thermometer & data logger for salinometer water bath	1
IAPSO calibration standards	90
Tool for opening IAPSO standards	1
Salinity bottles (new)	144
Salinity crates (new)	6
Seals for new salinity bottles (re-usable)	400
Empty IAPSO bottles (back-up contingency)	560
Crates for empty IAPSO bottles (back-up contingency)	22
Lids and seals for empty IAPSOs	1000
Crimping tool for lids/seals	1
Data sheets for sample analysis	50
Methods manuals (CSIRO, Guildline, Kawano)	1
Sample waste container (20L)	2
Tubing for waste container	2 m
Spare fuses	6
Powercord for Guildline	2
DI water container	1 x 5L
DI water supply	100L
DI wash bottle	2
Funnel to fit tubing for fill/drain salinometer	1
Overflow drain plug	2
Plastic tube, assorted sizes	2 m
Kimwipes	10
Non-slip matting	many
Container for clean inserts	2
Container for dirty inserts	2
Assorted taps and tubing	various
Tie-down straps and brackets for salinometer	20
Chux wipes	1 roll
Sampling tubes for Niskins	4
Hose clamps for sample tubes, t-pieces	various
70% ethanol for cleaning flow cell	1L
TritonX-100 for cleaning flow cell	

- The results of storage trials conducted by the Hydrochemistry group suggested that the results obtained from the “IAPSO” style bottles were slightly lower than results obtained from the regular salinity bottles, so there was some concern that bringing (some) samples back to Hobart for analysis might result in an offset in the data set. The offset is presumably due to the IAPSO bottles providing a superior seal, but this should be investigated further/confirmed. There was no capacity for me to pursue sample bottle comparisons during V3, although we did trial duplicate sampling so that the CTD watch were familiar and comfortable with the crimping process.
- For this reason, all samples were analysed on-board, with the caveat that analysis would stop if instrument performance deteriorated. This resulted in an intense workload for the sole hydrochemist at times.
- The instrument calibration appeared good after the grounding, so the remaining samples (CTDs 45-47) were analysed post-grounding. There was a great deal of uncertainty during those few days about the likelihood of the samples returning to Hobart, and the time that may take, so I elected to analyse all outstanding samples. It should be noted that the lab temp dropped, but that the salinonometer bath temp was stable.
- Some electrical noise from winches during trawls was observed on both trials and V3. Work flow was organised so that generally, Dos were analysed during trawling operations, and Salinities were analysed whilst we were on station doing CTD casts, or transiting

REFERENCES

Cowley, R. (editor) (1999) *Hydrochemistry Operations ManualA practical manual for the determination of salinity, dissolved oxygen, and nutrients in seawater.* CSIRO Marine Laboratories Report 236. 113 pp.

Guildine Autosal Technical Manual.

Kawano, T. (2010). Method *for Salinity (Conductivity Ratio) Measurement.* In The GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines. Hood, E.M., C.L. Sabine, and B.M. Sloyan, eds. IOCCP Report Number 14, ICPO Publication Series Number 134. Available online at: http://www.go-ship.org/HydroMan.html

<u>Table 3:</u> Summary of hydrochemistry samples collected (salinity, dissolved oxygen, nutrients) from V3 KAXIS CTDs 1-47. Note that nutrients were collected in triplicate.

	CTD001 wp0205					CTD002 wp0206					CTD003 wp0207					CTD004 wp0208					CTD005 wp0209				
Bottle	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients
24	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface				5	Surface	1	1	1	5	Surface	1	1	1
23	5	Surface	1	1	1	5	Surface				5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1
22	15	DCM	1	1	1	10	DCM	1	1	1	15	DCM				15	DCM	1	1	1	15	DCM	1	1	1
21	15	DCM	1	1	1	10	DCM				15	DCM				15	DCM	1	1	1	15	DCM	1	1	1
20	15	DCM				20		1	1	1	15	DCM	1	1	1	15	DCM				15	DCM			
19	20	MLD	1	1	1	30		1	1	1	20	MLD	1	1	1	20	MLD	1	1	1	25		1	1	1
18	30		1	1	1	35		1	1	1	30		1	1	1	35		1	1	1	35	MLD	1	1	1
17	40		1	1	1	40	MLD	1	1	1	40		1	1	1	50	Tmin	1	1	1	45		1	1	1
16	50	CHL0	1	1	1	75		1	1	1	60		1	1	1	75		1	1	1	60	Tmin	1	1	1
15	75	Tmin	1	1	1	100		1	1	1	75		1	1	1	100		1	1	1	80		1	1	1
14	100		1	1	1	150	O2, Tmax	1	1	1	100		1	1	1	150		1	1	1	125		1	1	1
13	150		1	1	1	200		1	1	1						250		1	1	1	200		1	1	1
12	180		1	1	1	250		1	1	1	200		1	1	1	350	O2, Tmax	1	1	1	250		1	1	1
11	200		1	1	1	450		1	1	1	250	O2, Tmax	1	1	1	500	Salmax	1	1	1	300	O2, Tmax, Salmax	1	1	1
10	250		1	1	1	750		1	1	1	350	Salmax	1	1	1	800		1	1	1	500		1	1	1
9	420	O2 min	1	1	1	1000		1	1	1	500		1	1	1	1000		1	1	1	800		1	1	1
8	800		1	1	1	1250		1	1	1	750		1	1	1	1250		1	1	1	1000		1	1	1
7	1000		1	1	1	1500		1	1	1	1000		1	1	1	1500		1	1	1	1250		1	1	1
6	1250		1	1	1	1750		1	1	1	1500		1	1	1	1800		1	1	1	1500		1	1	1
5	1500		1	1	1	2000		1	1	1	2000		1	1	1	2000		1	1	1	2000		1	1	1
4	1750		1	1	1	2500		1	1	1	2500		1	1	1	2500		1	1	1	2500		1	1	1
3	2100		1	1	1	2700		1	1	1	3000		1	1	1	3000		1	1	1	3000		1	1	1
2	2480		1	1	1	2830		1	1	1	3200		1	1	1	3115		1	1	1	3270		1	1	1
1	2530		1	1	1	2885		1	1	1	3260		1	1	1	3165		1	1	1	3320		1	1	1

	CTD006 wp0210					CTD007 wp0211					CTD008 wp0212					CTD009 wp0301					CTD010 wp0302				
Bottle	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients
24	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface			
23	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface				5	Surface				5	Surface	1	1	1
22	20	DCM	1	1	1	15		1	1	1	15		1	1	1	15		1	1	1	15		1	1	1
21	20	DCM	1	1	1	30	DCM				25		1	1	1	30	DCM/MLD	1	1	1	25	DCM	1	1	1
20	30		1	1	1	30	DCM	1	1	1	35	DCM/MLD				30	DCM/MLD				25	DCM			
19	45	MLD	1	1	1	30	DCM	1	1	1	35	DCM/MLD	1	1	1	30	DCM/MLD				40	MLD	1	1	1
18	55	Tmin	1	1	1	40		1	1	1	35	DCM/MLD	1	1	1	40		1	1	1	50		1	1	1
17	60		1	1	1	50		1	1	1	45		1	1	1	50		1	1	1	60	Tmin	1	1	1
16	100		1	1	1	60	Tmin	1	1	1	60	Tmin	1	1	1	60		1	1	1	150		1	1	1
15	150		1	1	1	90		1	1	1	80		1	1	1	80		1	1	1	200	O2, Tmax	1	1	1
14	200	O2	1	1	1	140		1	1	1	100		1	1	1	100		1	1	1	250		1	1	1
13	250		1	1	1	250		1	1	1	150		1	1	1	150		1	1	1	300		1	1	1
12	300	Tmax	1	1	1	300	Tmax	1	1	1	200		1	1	1	200		1	1	1	400		1	1	1
11	500	Salmax	1	1	1						250		1	1	1	250		1	1	1	500		1	1	1
10	750		1	1	1						300		1	1	1	300		1	1	1	750		1	1	1
9	1000		1	1	1																1000		1	1	1
8	1250		1	1	1																1250		1	1	1
7	1500		1	1	1																1500		1	1	1
6	2000		1	1	1																2000		1	1	1
5	2500		1	1	1																2500		1	1	1
4	3000		1	1	1																3000		1	1	1
3	3500		1	1	1																3500		1	1	1
2	3930		1	1	1																4030		1	1	1
1	3970		1	1	1																4080		1	1	1

Table3: (continued)

	CTD011 wp0303					CTD012 wp0304					CTD013 wp0305					CTD014 wp0306					CTD015 wp0307				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1
23	5	Surface				5	Surface				5	Surface				5	Surface				5	Surface			
22	20		1	1	1	20	MLD	1	1	1	15		1	1	1	20		1	1	1	15	DCM	1	1	1
21	30	DCM/MLD	1	1	1	30		1	1	1	25	MLD	1	1	1	35		1	1	1	15	DCM			
20	30	DCM/MLD				40	DCM	1	1	1	40	DCM	1	1	1	45	DCM/MLD				15	DCM			
19	40		1	1	1	40	DCM				40	DCM				45	DCM/MLD				30	MLD	1	1	1
18	50	Tmin	1	1	1	55	Tmin	1	1	1	55	Tmin	1	1	1	45	DCM/MLD	1	1	1	40		1	1	1
17	60		1	1	1	65		1	1	1	75		1	1	1	55	Tmin	1	1	1	50		1	1	1
16	75		1	1	1	80		1	1	1	100		1	1	1	65		1	1	1	60	Tmin	1	1	1
15	100		1	1	1	150		1	1	1	150		1	1	1	100		1	1	1	75		1	1	1
14	150		1	1	1	200		1	1	1	230	O2	1	1	1	150		1	1	1	100		1	1	1
13	200		1	1	1	250		1	1	1	280		1	1	1	200	O2	1	1	1	125		1	1	1
12	300	O2, Tmax	1	1	1	350	O2,Tmax	1	1	1	400	Tmax	1	1	1	250	Tmax	1	1	1	150		1	1	1
11	500		1	1	1	500	Salmax	1	1	1	500		1	1	1	350		1	1	1	180	O2	1	1	1
10	800	Salmax	1	1	1	750		1	1	1	750		1	1	1	500		1	1	1	250	Tmax	1	1	1
9	1000		1	1	1	1000		1	1	1	1000		1	1	1	900	Salmax	1	1	1	350		1	1	1
8	1250		1	1	1	1250		1	1	1	1250		1	1	1	1000		1	1	1	500		1	1	1
7	1500		1	1	1	1500		1	1	1	1500		1	1	1	1250		1	1	1	800	Salmax	1	1	1
6	2000		1	1	1	2000		1	1	1	2000		1	1	1	1500		1	1	1	1000		1	1	1
5	2500		1	1	1	2500		1	1	1	2500		1	1	1	1800		1	1	1	1250		1	1	1
4	3000		1	1	1	3000		1	1	1	3000		1	1	1	2000		1	1	1	1500		1	1	1
3	3500		1	1	1	3500		1	1	1	3500		1	1	1	2500		1	1	1	1800		1	1	1
2	4115		1	1	1	3750		1	1	1	3715		1	1	1	2580		1	1	1	1930		1	1	1
1	4165		1	1	1	3820		1	1	1	3765		1	1	1	2630		1	1	1	1987		1	1	1

	CTD016 wp0401					CTD017 wp0402					CTD018 wp0403					CTD019 wp0404					CTD020 wp0405				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface				5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1
23	5	Surface	1	1	1	5	Surface				5	Surface				5	Surface				5	Surface			
22	15	DCM	1	1	1	15		1	1	1	15		1	1	1	10	DCM	1	1	1	15	DCM	1	1	1
21	15	DCM				25		1	1	1	20		1	1	1	10	DCM				15	DCM			
20	15	DCM				35	DCM/MLD				25	DCM/MLD				20	MLD	1	1	1	15	DCM			
19	30	MLD	1	1	1	35	DCM/MLD				25	DCM/MLD				30		1	1	1	20	MLD	1	1	1
18	45		1	1	1	35	DCM/MLD	1	1	1	25	DCM/MLD	1	1	1	40		1	1	1	30		1	1	1
17	55		1	1	1	45		1	1	1	30		1	1	1	50		1	1	1	40		1	1	1
16	65	Tmin	1	1	1	55		1	1	1	40		1	1	1	75		1	1	1	50		1	1	1
15	75		1	1	1	70	Tmin	1	1	1	50	Tmin	1	1	1	100		1	1	1	65		1	1	1
14	100		1	1	1	80		1	1	1	75		1	1	1	125		1	1	1	75	Tmin	1	1	1
13	150		1	1	1	100		1	1	1	100		1	1	1	200	O2, Tmax	1	1	1	100		1	1	1
12	200	O2,Tmax	1	1	1	125	O2	1	1	1	150	O2	1	1	1	250		1	1	1	150		1	1	1
11	250		1	1	1	200	Tmax	1	1	1	250		1	1	1	350		1	1	1	200		1	1	1
10	350		1	1	1	300		1	1	1	300	Tmax	1	1	1	500		1	1	1	250		1	1	1
9	500		1	1	1	500		1	1	1	500		1	1	1	650	Salmax	1	1	1	500		1	1	1
8	750	Salmax	1	1	1	650	Salmax	1	1	1	750		1	1	1	800		1	1	1	650	Salmax, Tmax	1	1	1
7	1000		1	1	1	1000		1	1	1	1000		1	1	1	1000		1	1	1	900		1	1	1
6	1250		1	1	1	1500		1	1	1	1500		1	1	1	1500		1	1	1	1000	O2	1	1	1
5	1500		1	1	1	2000		1	1	1	2000		1	1	1	2000		1	1	1	1500		1	1	1
4	2000		1	1	1	2500		1	1	1	2500		1	1	1	2500		1	1	1	2000		1	1	1
3	2500		1	1	1	3000		1	1	1	3000		1	1	1	3000		1	1	1	2500		1	1	1
2	2935		1	1	1	3655		1	1	1	3550		1	1	1	3500		1	1	1	3150		1	1	1
1	2985		1	1	1	3705		1	1	1	3632		1	1	1	3585		1	1	1	3241		1	1	1

Table3: (continued)

	CTD021 wp0600.1				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	5	Surface			
22	10	MLD	1	1	1
21	15	DCM	1	1	1
20	15	DCM			
19	15	DCM			
18	30		1	1	1
17	40		1	1	1
16	50		1	1	1
15	60		1	1	1
14	100		1	1	1
13	125	Tmin	1	1	1
12	150		1	1	1
11	200		1	1	1
10	250		1	1	1
9	300		1	1	1
8	385		1	1	1
7	400		1	1	1
6	450		1	1	1
5	600	O2, Tmax	1	1	1
4	750		1	1	1
3	960		1	1	1
2	1175		1	1	1
1	1225		1	1	1

	CTD022 wp0600.2				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	15		1	1	1
22	20	MLD	1	1	1
21	25	DCM	1	1	1
20	25	DCM			
19	30		1	1	1
18	40		1	1	1
17	60		1	1	1
16	80		1	1	1
15	120	Tmin	1	1	1
14	150		1	1	1
13	180		1	1	1
12	200		1	1	1
11	260		1	1	1
10	350		1	1	1
9	500	O2, Tmax	1	1	1
8	600		1	1	1
7	800		1	1	1
6	1000		1	1	1
5	1250		1	1	1
4	1500		1	1	1
3	1800		1	1	1
2	2250		1	1	1
1	2348		1	1	1

	CTD023 wp0600.3				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	5	Surface			
22	15	MLD	1	1	1
21	30		1	1	1
20	45	DCM			
19	45	DCM			
18	45	DCM	1	1	1
17	55	Tmin	1	1	1
16	75		1	1	1
15	100		1	1	1
14	150		1	1	1
13	200		1	1	1
12	250		1	1	1
11	375	O2, Tmax	1	1	1
10	500		1	1	1
9	600	Salmax	1	1	1
8	750		1	1	1
7	1000		1	1	1
6	1500		1	1	1
5	2000		1	1	1
4	2500		1	1	1
3	3000		1	1	1
2	3575		1	1	1
1	3625		1	1	1

	CTD024 wp0601				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	5	Surface			
22	20		1	1	1
21	20				
20	40	MLD	1	1	1
19	40	MLD			
18	55	DCM			
17	55	DCM			
16	55	DCM	1	1	1
15	65	Tmin			
14	65	Tmin	1	1	1
13	75				
12	75		1	1	1
11	100				
10	100		1	1	1
9	125				
8	125		1	1	1
7	150				
6	150		1	1	1
5	200				
4	200		1	1	1
3	250				
2	250		1	1	1
1	300		1	1	1

	CTD025 wp0602				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	5	Surface			
22	15	MLD	1	1	1
21	30	DCM	1	1	1
20	30	DCM			
19	40		1	1	1
18	50		1	1	1
17	65	Tmin	1	1	1
16	80		1	1	1
15	150		1	1	1
14	250		1	1	1
13	360	O2, Tmax	1	1	1
12	500		1	1	1
11	600	Salmax	1	1	1
10	1000		1	1	1
9	1250		1	1	1
8	1500		1	1	1
7	1750		1	1	1
6	2000		1	1	1
5	2300		1	1	1
4	2600		1	1	1
3	3000		1	1	1
2	3790		1	1	1
1	3840		1	1	1

	CTD026 wp0603				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	5	Surface			
22	15		1	1	1
21	15				
20	20	MLD	1	1	1
19	20	MLD			
18	25	DCM			
17	25	DCM			
16	25	DCM	1	1	1
15	35				
14	35		1	1	1
13	45				
12	45		1	1	1
11	60				
10	60		1	1	1
9	70	Tmin			
8	70		1	1	1
7	110				
6	110		1	1	1
5	200				
4	200		1	1	1
3	280				
2	280		1	1	1
1	300		1	1	1

	CTD027 wp0604				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	5	Surface			
22	10	MLD	1	1	1
21	20	DCM	1	1	1
20	20	DCM			
19	20	DCM			
18	25		1	1	1
17	30		1	1	1
16	40		1	1	1
15	60	Tmin	1	1	1
14	70		1	1	1
13	100		1	1	1
12	150		1	1	1
11	225	O2,Tmax	1	1	1
10	300		1	1	1
9	500		1	1	1
8	750	Salmax	1	1	1
7	1000		1	1	1
6	1250		1	1	1
5	1500		1	1	1
4	2000		1	1	1
3	2500		1	1	1
2	3150		1	1	1
1	3200		1	1	1

	CTD028 wp0605				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	5	Surface			
22	15		1	1	1
21	30		1	1	1
20	40	DCM/MLD	1	1	1
19	40	DCM/MLD			
18	40	DCM/MLD			
17	45		1	1	1
16	55	Tmin	1	1	1
15	75		1	1	1
14	120		1	1	1
13	150		1	1	1
12	225	O2	1	1	1
11	250		1	1	1
10	275	Tmax	1	1	1
9	500		1	1	1
8	750	Salmax	1	1	1
7	1000		1	1	1
6	1250		1	1	1
5	1500		1	1	1
4	1750		1	1	1
3	2000		1	1	1
2	2300		1	1	1
1	2364		1	1	1

	CTD029 wp0606				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	5	Surface			
22	15		1	1	1
21	30		1	1	1
20	40	DCM	1	1	1
19	40	DCM			
18	40	DCM			
17	55		1	1	1
16	60	MLD	1	1	1
15	70		1	1	1
14	80	Tmin	1	1	1
13	100		1	1	1
12	125		1	1	1
11	150		1	1	1
10	200	O2,Tmax	1	1	1
9	250		1	1	1
8	350		1	1	1
7	500		1	1	1
6	750	Salmax	1	1	1
5	1000		1	1	1
4	1250		1	1	1
3	1500		1	1	1
2	1680		1	1	1
1	1730		1	1	1

	CTD030 wp0607				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1
23	5	Surface			
22	20		1	1	1
21	30		1	1	1
20	45	DCM			
19	45	DCM			
18	45	DCM	1	1	1
17	60	MLD	1	1	1
16	75		1	1	1
15	90	Tmin	1	1	1
14	100		1	1	1
13	150		1	1	1
12	200	O2,Tmax	1	1	1
11	250		1	1	1
10	300		1	1	1
9	350		1	1	1
8	500		1	1	1
7	750		1	1	1
6	1000		1	1	1
5	1250		1	1	1
4	1500		1	1	1
3	1750		1	1	1
2	1900		1	1	1
1	1945		1	1	1

Table3: (continued)

	CTD031 wp0608					CTD032 wp0701					CTD033 wp0702					CTD034 wp0703					CTD035 wp0800				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface			
23	5	Surface				5	Surface				20		1	1	1	5	Surface				5	Surface			
22	20		1	1	1	20		1	1	1	40	MLD	1	1	1	20		1	1	1	5	Surface			
21	40		1	1	1	35		1	1	1	60	DCM				40		1	1	1	5	Surface			
20	55	MLD	1	1	1	50	DCM/MLD	1	1	1	60	DCM	1	1	1	55	MLD	1	1	1	5	Surface	1	1	1
19	60	DCM				50	DCM/MLD				80		1	1	1	75	DCM				20		1	1	1
18	60	DCM				50	DCM/MLD				105	Tmin	1	1	1	75	DCM	1	1	1	20				
17	60	DCM	1	1	1	60		1	1	1	135		1	1	1	95		1	1	1	25	MLD	1	1	1
16	65	Tmin	1	1	1	65	Tmin	1	1	1	150		1	1	1	170	Tmin	1	1	1	25	MLD			
15	80		1	1	1	75		1	1	1	250	O2	1	1	1	250		1	1	1	40	DCM			
14	100		1	1	1	100		1	1	1	300		1	1	1	300		1	1	1	40	DCM			
13	150		1	1	1	125		1	1	1	400		1	1	1	500	O2,Tmax	1	1	1	40	DCM			
12	200	O2	1	1	1	170	O2	1	1	1	500		1	1	1	1000		1	1	1	40	DCM	1	1	1
11	250		1	1	1	200		1	1	1	600	Tmax,Salmax	1	1	1	1250	Salmax	1	1	1	60				
10	300	Tmax	1	1	1	250		1	1	1	900		1	1	1	1500		1	1	1	60		1	1	1
9	350		1	1	1	300	Tmax	1	1	1	1000		1	1	1	2000		1	1	1	80				
8	500		1	1	1	350		1	1	1	1250		1	1	1	2500		1	1	1	80		1	1	1
7	500					500	Salmax	1	1	1	1500		1	1	1	2750		1	1	1	110				
6	750		1	1	1	750		1	1	1	1800		1	1	1	3000		1	1	1	110		1	1	1
5	900	Salmax	1	1	1	1000		1	1	1	2000		1	1	1	3500		1	1	1	150		1	1	1
4	1000		1	1	1	1250		1	1	1	2300		1	1	1	3800		1	1	1	180		1	1	1
3	1250		1	1	1	1500		1	1	1	2750		1	1	1	4200		1	1	1	225		1	1	1
2	1500		1	1	1	1760		1	1	1	3150		1	1	1	4575		1	1	1	250		1	1	1
1	1559		1	1	1	1810		1	1	1	3215		1	1	1	4625		1	1	1	300		1	1	1

	CTD036 wp0801					CTD037 wp0802					CTD038 wp0803					CTD039 wp0901					CTD040 wp0902				
Bottle	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**	**Depth**	**Feature**	**Oxygen**	**Salinity**	**Nutrients**
24	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1
23	5	Surface				5	Surface				5	Surface				5	Surface				5	Surface			
22	5	Surface				5	Surface				20		1	1	1	15		1	1	1	5	Surface			
21	15		1	1	1	15	DCM/MLD	1	1	1	20					15					15		1	1	1
20	15					15	DCM/MLD				40		1	1	1	20	MLD	1	1	1	15				
19	25					15	DCM/MLD				40					20	MLD				30	DCM			
18	25		1	1	1	15	DCM/MLD				60	MLD	1	1	1	30	DCM	1	1	1	30	DCM	1	1	1
17	40	DCM/MLD	1	1	1	30		1	1	1	60	MLD				30	DCM				30	DCM			
16	40	DCM/MLD				30					75	DCM	1	1	1	30	DCM				40	MLD	1	1	1
15	40	DCM/MLD				30					75	DCM				40		1	1	1	40	MLD			
14	40	DCM/MLD				40		1	1	1	75	DCM				40					50		1	1	1
13	65		1	1	1	40					90		1	1	1	50		1	1	1	50				
12	65					50		1	1	1	90					50					60		1	1	1
11	80	Tmin	1	1	1	50					100		1	1	1	65		1	1	1	60				
10	80	Tmin				60		1	1	1	100					65					70	Tmin	1	1	1
9	100					60					150		1	1	1	100		1	1	1	70	Tmin			
8	100					80		1	1	1	175		1	1	1	100		1	1	1	100		1	1	1
7	120		1	1	1	80					200		1	1	1	150		1	1	1	150		1	1	1
6	120					110	O2	1	1	1	250	O2,Tmax	1	1	1	200		1	1	1	200	O2	1	1	1
5	160		1	1	1	150		1	1	1	300		1	1	1	250		1	1	1	250	Tmax	1	1	1
4	200		1	1	1	200		1	1	1	500		1	1	1	300		1	1	1	300		1	1	1
3	240		1	1	1	250		1	1	1	1000	Salmax			1	500				1	500				1
2	280		1	1	1	300		1	1	1	4400					1000				1	1000				1
1	300		1	1	1	300					4470				1	4196				1	1354				1

Table3: (continued)

	CTD041 wp0903					CTD042 wp0904					CTD043 wp0905					CTD044 wp0906					CTD045 wp1001				
Bottle	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients
24	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1	5	Surface	1	1	1
23	5	Surface				5	Surface				5	Surface				5	Surface				5	Surface			
22	15					5	Surface				15		1	1	1	15		1	1	1	5	Surface			
21	15		1	1	1	15		1	1	1	15					30		1	1	1	20		1	1	1
20	30	DCM				15					25		1	1	1	45	MLD	1	1	1	20				
19	30	DCM				30					25					50	DCM				35				
18	30	DCM	1	1	1	30		1	1	1	40		1	1	1	50	DCM				35		1	1	1
17	50	MLD				35		1	1	1	40					50	DCM	1	1	1	40	MLD			
16	50	MLD	1	1	1	35					50	MLD	1	1	1	60	Tmin	1	1	1	40	MLD	1	1	1
15	65					50	DCM/MLD	1	1	1	50	MLD				75		1	1	1	45	DCM			
14	65		1	1	1	50	DCM/MLD				63	DCM				100		1	1	1	45	DCm			
13	75	Tmin				50	DCM/MLD				63	DCM				150		1	1	1	45	DCM			
12	75	Tmin	1	1	1	60	Tmin	1	1	1	63	DCM	1	1	1	200	O2	2	1	1	45	DCM	1	1	1
11	100					60	Tmin				70					250	Tmax	1	1	1	55				
10	100		1	1	1	70		1	1	1	70		1	1	1	500		1	1	1	55		1	1	1
9	150		1	1	1	70					80	Tmin				750		1	1	1	60	Tmin			
8	180		1	1	1	100		1	1	1	80	Tmin	1	1	1	1000	Salmax	1	1	1	60	Tmin	1	1	1
7	200	O2				150		1	1	1	100		1	1	1	1500		1	1	1	100		1	1	1
6	200	O2	1	1	1	200	O2	1	1	1	150		1	1	1	2000		1	1	1	100		1	1	1
5	250	Tmax	1	1	1	250	Tmax	1	1	1	250		1	1	1	2500		1	1	1	150		1	1	1
4	300		1	1	1	300		1	1	1	300		1	1	1	3000		2	1	1	200	O2	1	1	1
3	500		1	1	1	500				1	500				1	3500		1	1	1	250		1	1	1
2	1000		1	1	1	1000				1	1000				1	3980		1	1	1	300		1	1	2
1	1735		1	1	1	2655				1	3818				1	4036		1	1	1	500				1

	CTD046 wp1002					CTD047 wp1003				
Bottle	Depth	Feature	Oxygen	Salinity	Nutrients	Depth	Feature	Oxygen	Salinity	Nutrients
24	5	Surface	1	1	1	5	Surface	1	1	1
23	5	Surface				5	Surface			
22	20		2	1	1	5	Surface			
21	20					20	MLD	1	1	1
20	30	DCM/MLD	1	1	1	20	MLD			
19	30	DCM/MLD				20	MLD			
18	30	DCM/MLD				35	DCM	1	1	1
17	35					35	DCM			
16	35		1	1	1	35	DCM			
15	40					35	DCM			
14	40		1	1	1	40		1	1	1
13	50					40				
12	50		1	1	1	45		1	1	1
11	75	Tmin				45				
10	75	Tmin	1	1	1	200		1	1	1
9	100					55				
8	100		1	1	1	55		1	1	1
7	125					65	Tmin			
6	125		1	1	1	65	Tmin	1	1	1
5	150					100				
4	150		1	1	1	100		1	1	1
3	250		1	1	1	135	Zoopl	1	1	1
2	300		1	1	1	250	O2	1	1	1
1						300		1	1	1