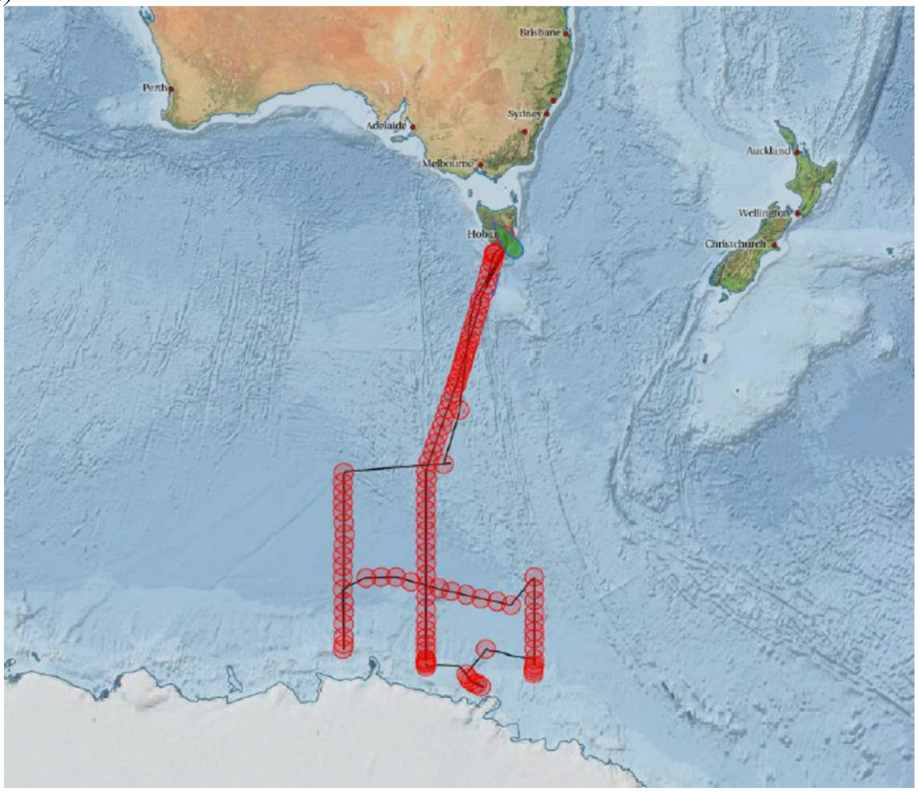
CRUISE REPORT: SR03

(Updated OCT 2018)



Highlights

Cruise Summary Information

Section Designation	**SR03** (IN1801, IN2018_V01, P11S, S04)
Expedition designation (ExpoCodes)	**096U20180111**
Chief Scientists	**Steve Rintoul / CSIRO**
Dates	2018 JAN 11 - 2018 FEB 22
Ship	*R/V Investigator*
Ports of call	Hobart
Geographic Boundaries	44° 0' 5.4" S 131° 59' 59" E 150° 0' 54.7" E 66° 25' 36" S
Stations	108 CTD vertical profile stations
Floats and drifters deployed	29 floats deployed
Moorings deployed or recovered	0

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Links to Select Topics

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

RV Investigator Marine Science Cruise IN1801 (CSIRO Voyage Designation IN2018_V01), SR3 Plus Additional Southern Transects - Oceanographic Field Measurements and Analysis

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RV Investigator Marine Science Cruise IN1801 (CSIRO Voyage Designation IN2018_V01), SR3 Plus Additional Southern Transects - Oceanographic Field Measurements and Analysis

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September, 2018

ABSTRACT

Oceanographic measurements were collected aboard RV Investigator cruise in1801 (CSIRO voyage designation in2018_v01) from 11th January to 22nd February 2018, along CLIVAR Southern Ocean repeat meridional section SR3, followed by Adelie land shelf stations, small meridional sections along 150E (the south end of CLIVAR section P11S) and 132E, and several stations along CLIVAR zonal section S4. A total of 108 CTD vertical profile stations were taken on the cruise, most to within 14 metres of the bottom. Over 2800 Niskin bottle water samples were collected for the measurement of salinity, dissolved oxygen, nutrients (phosphate, nitrate+nitrite, silicate, ammonia and nitrite), CFC's plus tracers (CFC-11, CFC-12, SF6 and N2O), dissolved inorganic carbon (i.e. TCO_2), alkalinity, pH, C13/C14, genomics, HPLC, POC, chlorophyll, radiogenic isotopes, helium, ice nucleation, and Ca/Mg, using a 36 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 (75 kHz). Trace metal rosette and in situ pump deployments were done at some of the CTD stations. Meteorological and water property data were collected by the array of ship's underway sensors. A large assortment of 29 drifting floats was deployed throughout the cruise. A summary of all CTD data and data quality is presented in this report.

1 INTRODUCTION

Marine science cruise in1801 (CSIRO voyage designation in2018_v01) was conducted aboard the RV Investigator from January to February 2018. The major constituent of the cruise was the tenth complete occupation of the CLIVAR SR3 CTD section south of Tasmania, completed from north to south, followed by CTD's at (in order):

* 6 Adelie Land shelf stations
* a Ninja float deployment site
* 11 stations south to north along 150E (the southern end of CLIVAR P11S section)
* 10 stations east to west along CLIVAR S4 section
* 18 stations north to south along 132E (including a station occupied by the Eltanin in the 1970's)
* 2 northern stations (part of the CAPRICORN meteorology project on the cruise)

giving a total of 108 CTD stations (Figure 1, Table 1).

The primary scientific objectives for the oceanography were:

1. to measure changes in water mass properties and inventories throughout the full ocean depth between Australia and Antarctica along SR3;

2. to estimate the transport of mass, heat and other properties south of Australia, and to compare the results to previous occupations of the SR3 line and other sections in the Australian sector;

3. to quantify changes in Antarctic Bottom Water in the Australian Antarctic Basin;

4. to quantify the evolving inventory of heat, freshwater, oxygen, CFCs, and carbon dioxide in the upper 2000 m and to infer changes in the ventilation rate of intermediate waters and ocean acidification;

5. to determine the distributions of trace metals and isotopes, their change with time, and the physical, chemical and biological processes controlling those evolving distributions.

(the last of these was part of the trace metal project, not discussed further).

This report describes the CTD and Niskin bottle data and data quality for this cruise. All information required for use of the data set is presented in tabular and graphical form. CTD station positions are shown in Figure 1, while CTD station information is summarised in Table 1. Float deployments are summarised in Table 13. The hydrochemistry lab report and detailed data processing report (by the cruise hydrochemists Christine Rees, Kendall Sherrin, Stephen Tibben and Kristina Paterson) are in Appendix 1 and 2 respectively. The CFC lab report (by Mark Warner) is in Appendix 3. Data from the LADCP and ADCP are not discussed further.

Summary of cruise itinerary:

Voyage Designation	in1801 (CSIRO voyage in2018_v01)
Chief Scientist	Steve Rintoul (CSIRO CMAR)
Ship	RV Investigator
Main projects	*Physical Oceanography, Trace Metal, CAPRICORN (meteorology)*
Ports of Call	Hobart
Cruise Dates	Jan 11th – Feb 22nd 2018

2 CTD INSTRUMENTATION

SeaBird SBE9plus CTD (CSIRO serial #24) was used, with dual temperature (SBE3Plus), conductivity (SBE4C) and dissolved oxygen (SBE43) sensors, mounted on a SeaBird 36 bottle rosette frame, together with a SBE32 36 position pylon and 36 x 12 litre Ocean Test Equipment Niskin bottles. A fin was mounted on the frame, to help minimize package spin. The following additional sensors/instruments were mounted:

* Wetlabs FLBBRTD (scattering meter and fluorometer) serial 4799
* Biospherical Instruments PAR sensor QCP2300HP, serial 70111
* Wetlabs C-star transmissometer serial 1421DR
* Teledyne RDI lowered ADCP (i.e. LADCP) workhorse monitor – 300 kHz head looking upward, 150 kHz head looking
* Tritech 200 kHz altimeter serial 05300.313642
* Tritech 500 kHz altimeter serial 05301.228403
* CSIRO Intertial Motion Unit (data coming up serial line)

15 seal tags (from Clive McMahon, IMAS) were secured to the frame on stations 1 to 4 and 57 to 66, for calibration of the tags against CTD data.

CTD data were transmitted up a 8 mm seacable to a SBE11plusV2 deck unit, at a rate of 24 Hz, and logged 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, though in most cases it was on the conservative side)
* after returning to just below the surface, downcast proper commenced

Pre cruise temperature, conductivity and pressure calibrations (Table 2, including calibration dates) were performed by CSIRO and SeaBird. For the SBE43 oxygen sensors, these calibrations were used for initial data display only. Manufacturer supplied calibrations were used for the transmissometer, PAR, altimeters and FLBB. “Dark” profiles for the FLBB were measured on stations 25 and 106 by taping over the FLBB sensors, and these dark values were used to correct backscatter and fluorescence data. Deck measurements of path open and path blocked voltages were used to correct transmissometer data. 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 a medivac early on. After completing CTD 8 on day 3, all work was paused for a return to Hobart with a sick crewman. Back in the Derwent River the ship parked for a short time off Wrest Point while the crewman was taken ashore by FRC. The ship then returned south to resume work at CTD 9, with a total of 39 hours lost in the roundtrip. An extra day of ship time was granted to compensate.

CTD winch spooling problems were a constant throughout the cruise. A small mismatch of the spooler with the wire feed occurs as the winch drum rapidly spins during heave compensation events. This mismatch cumulates throughout a cast, requiring several stops for spooler realignment. Over the whole cruise this added up to several hours lost.

Heave compensation was engaged for most of the cruise, however it did not accurately match ship’s motion. There was clearly a lag between ship motion and response of the heave compensation, evident in the jagged CTD profile features in steep gradients in the upper water column. Heave compensation was briefly turned off during station 104 in an attempt to reduce tension spiking during a period of large ship rolls, but it became clear that the situation was better with heave compensation on – some evidence that at least heave compensation was having an effect in the right direction. Any errant profile features should mostly be removed during 2 dbar averaging.

The dreaded winch software “e-stops” occurred on several stations – software error messages with an unknown cause, and requiring winch software reset. Additional winch software problems came and went throughout the cruise, including no tension display, and inability to enter wire speed.

A spooling problem on the upcast of station 83 (possibly as deep as 3000 dbar) was not noticed in time, and as a result the spooling was a bit of a mess for the remainder of the upcast, with numerous bad wraps, particularly near the cheeks. This was fixed during the downcast of station 84 with a slow and cautious descent, making numerous stops for manual spooler repositioning.

During periods of higher well with more rolling of the ship, wire tension problems often occurred when the rosette was near surface at the start and end of the cast. This appears to be a problem with the 36 bottle package, which has lots of drag through the water. The result is slackening and shock loading of the CTD wire, causing wire kinks. 65 kg of weight was added to the bottom of the frame prior to station 26 to try and improve things. Overall, this “snapping” of the wire with the rosette near surface meant caution was needed when returning the rosette close to the surface for commencement of the downcast proper. In general this near surface value was conservative, and as a result numerous casts are missing the top 8 to 10 dbar of data. In addition, on several occasions the shallowest Niskin had to be fired fast, without the usual wait for equilibration (e.g. stations 24 and 48). The following CTD wire reterminations were required, due to various degrees of wire kinking: mechanical only prior to station 20; mechanical and electrical prior to station 21.

The trace metal rosette deployment method designed in port, using the coring winch below deck, failed early on in the cruise. The whole deployment method required changing, and the CTD winch used initially for CTD 1 to 5 was now needed for trace metal rosette deployments. CTD ops were changed to the second CTD winch for stations 6 onwards.

The CTD door was often very slow moving during opening and closing. This sluggish behaviour was attributed to the effect of cold on the door hydraulics. Heaters were left on in the CTD room at agreed times, to try and improve things.

For the hull mounted ADCP, the 150 kHz head was not working - only 75 kHz data were available.

Niskin bottle leakage was a significant problem on the cruise. The main offender was top cap leakage, occurring frequently and for many bottles. The problem was traced to the non-standard large cylindrical floats on the top Niskin lanyards, combined with the tight long lanyard to the bottom cap – together these placed stress on the top caps during recovery of the rosette, causing frequent top cap leaks. Half the Niskins (the most common leakers) were relanyarded, using the standard small white balls for floats, and joining the long lanyard to the top lanyard at a more central position (thus avoiding the tight lanyard to the bottom cap after bottle closure). There were insufficient small white balls on board to relanyard all the Niskins. Top cap leakage was dramatically reduced after the relanyarding, with only the occasional leak occurring. Note that top cap leakers were still sampled, and in almost all cases the salinity, oxygen and CFC samples were good – showing that leakage occurred after the rosette left the water. Fortunately for the gas samples this premature top cap "opening" was insufficient to contaminate water drawn from the bottom of a Niskin; assisted also by CFC and oxygen sampling being at the start of the sampling order.

Mobile pack ice was reasonably close to the ship during stations 69 and 70, so the ship was allowed to drift north with the pack at ~1 knot during these CTD's, rather than holding station.

Temperature sensor changes were required at stations 11 and 13, to first identify and then replace the sensor with calibration issues (serial 6189).

A small amount of bad oxygen data (both primary and secondary) were first observed at station 86, an indicator of a developing fault. At station 88 both oxygen sensors went bad near the start of the downcast. The package was retrieved and the y-cable to the oxygen sensors replaced, fixing the problem.

Primary salinity was fouled at ~307 dbar on the upcast of station 41, with values shifting and never coming good. Sea snot was removed from around the sensor inlet after the cast, however a small S2-S1 difference remained for station 42. After the cast the primary line was backflushed from the outlet end, fixing the problem.

Secondary conductivity was fouled at ~3200 dbar on the upcast of station 92. The fouling mostly disappeared at ~3050 dbar on the upcast, however a subtle sensor difference remained, and it is unclear whether the tiny remnant fouling was ever fully removed.

A small number of Niskins pre-tripped, the most obvious occasions being for Niskin 24 on stations 21 and 23, and Niskins 25 and 29 on stations 25 and 26.

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 MS-Windows 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, split profile fits were used for most stations deeper than 1400 dbar, with the exception of stations 7, 13, 57 and 93, where whole profile fits were used (better results than the split profile fits). Whole profile fits were used for stations shallower than 1400 dbar (stations 1-3, 41, 58-66, 94-95, 107-108).

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 sensors (temperature, conductivity and dissolved oxygen) were used for the whole cruise. Suspect CTD 2 dbar averages are listed in Table 8, while suspect and bad nutrient data are listed in Table 11. Nutrient and dissolved oxygen comparisons to previous cruises are made in section 7. Hydrochemistry lab and data processing reports are in Appendices 1 and 2. The CFC lab report is in Appendix 3.

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. A single duplicate salinity sample was taken for most stations, usually from Niskin 2, as a quality check. International standard seawater batch numbers P161 (expiry date 03/05/2020) and P158 (expiry date 25/03/2018) were used for salinometer standardisations. Lab temperature for salinity analyses mostly ranged between 20 and 24^{o}C over the course of the cruise (see lab temperature figure at the end of Appendix 1).

Two Guildline Autosals serials 71613 and 72151 were used over the course of the cruise, with analyses taking place in the salinity lab. Salinometer performance overall was mostly good, though a few problems were encountered during the cruise, including:

- bubble trouble when running the station 47 samples;
- unstable performance of salinometer 71613 when analysing station 47 or 48 (unclear which from lab notes); anaylsis shifted to salinometer 72151 for remainder of the day;
- cell flush/rinse problems for salinometer 72151 during analysis of station 99, due to build up of contamination at the end of the flow path.

Full details can be found in the hydrochemistry reports (Appendices 1 and 2). Overall CTD salinity accuracy for the cruise is well within 0.002 (PSS78) (Figure 3).

The following station groupings were used for CTD conductivity calibration:

Group 1 = station 1-11
Group 2 = station 12-80
Group 3 = station 81-108

The initial group change after station 11 was due to temperature sensor changes. The large group sizes after that are an indication of reasonably stable CTD conductivity cell performance for the cruise. Subtle outlier stations in the post calibration salinity residuals (of the order 0.001 PSS78 e.g. stations 7 and 8) are more likely due to salinometer performance.

For initial calibration of the CTD conductivity against bottle data, the CPCOR conductivity coefficient was set to the factory recommended value of -9.57e-8. Significant pressure dependence of the CTD-bottle residuals remained, with a maximum range of ~0.004 PSS78 over the deep profiles. Compressibility of the borosilicate glass in a CTD conductivity cell is individual to each cell (SeaBird, pers. comm.), meaning the recommended value is not suitable as a blanket application for all sensors. CPCOR for the secondary conductivity cell was changed to -8.45e-8 and the data recalibrated/reprocessed, thereby minimizing the pressure dependent salinity residual. Any remaining pressure dependency was insignificant.

The 36 bottle package drags more water than the 24 bottle system, and as a result more sample equilibration time is required in steeper vertical gradients in the upper water column. The standard 30 second bottle stop (prior to firing) was adhered to for most of the cruise, but salinity residuals (i.e. bottle-CTD) were still high in the steep gradients, rendering those samples unusable for CTD conductivity calibration. For station 85 onwards 60 second bottle stops were adopted in the upper profile where a steep gradient was present. This dramatically improved the bottle-CTD salinity comparisons in those parts of the water column.

Several inserts for the salinity sample bottles were damaged, going unnoticed and remaining in circulation until station 83, and resulting in several bad samples.

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)
7	+0.001
8	+0.001
11	-0.001 below ~1100 dbar
13	-0.001 below ~1000 dbar
15	+0.0005 below ~1100 dbar
17	+0.0005
19	-0.001 below ~1100 dbar
21	-0.0005 below ~1100 dbar
25	-0.0005
26	-0.0005
28	+0.0005 below ~1100 dbar
39	-0.0005
47	-0.001 below 2000 dbar

station	bottle-CTD bias (PSS78)
48	+0.0005 above 2000 dbar
57	-0.0005
58	-0.001
61	-0.0015
68	-0.0005
71	-0.0005
81	+0.0005
82	-0.001
83	+0.0005
84	+0.0005
90	small p dependence remains, +0.001 at top, -0.001 at bottom
98	-0.0005
102	-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 sensor changes were required at stations 11 and 13, to first identify and then replace the sensor with a calibration problem (serial 6189) (evident in Figure 4). For station 14 onwards, with 2 well calibrated temperature sensors in place, sensor difference is less than 0.0005^{o}C over all depths, with no obvious pressure dependence (Figure 4a), and no obvious temperature dependence (Figure 4b). Despite these sensor changes, a good temperature sensor always remained in the secondary sensor position (serial 6180 for stations 1-11 and 14-108; serial 4522 for stations 12-13).

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 calibrated as split profile fits, and profiles shallower than 1400 dbar calibrated as whole profile fits – with the exception of stations 7, 13, 57 and 93, all deeper than 1400 dbar and for which whole profile fits were used (better results than the split profile fits). To summarise:

whole profile fits used for stations 1-3, 7, 13, 41, 57-66, 93-95, 107-108
split profile fits used for stations 2-6,8-12, 14-40, 42-56, 67-92, 96-106

Calibration results are plotted in Figure 5, and the derived calibration coefficients are listed in Table 6. Oxygen bottle data were high quality, with only a minimum number of bad and suspect samples (Table 10) (many of the bad samples were due to pre-tripping Niskins, discussed in section 3). Overall, the calibrated CTD oxygen agrees with the bottle data to within 1% of full scale (where full scale is ~370 µmol/l above 750 dbar, and ~260 µmol/l below 750 dbar) i.e. from the standard deviation values in Figure 5. Cruise lab and data processing notes, including sample analysis method, are in the hydrochemistry reports (Appendices 1 and 2).

* For some stations, the top of the upcast and downcast differ due to ocean variability, stations 4 and 5 in particular. Numerous bottle rejections were required to calibrate these two stations, and a meld point (between shallow and deep calibrations in the split profile fit) of 2000 dbar was used (usually 1500 dbar for stations of this depth, as per *CTD methodology*).

* For station 21, the bottom 2 oxygen samples were not available for calibration (bottle 1 titration bad, and bottle 2 suspect); as a result, CTD oxygen is possibly low by ~2 µmol/l for 3600 to 3854 dbar i.e. the bottom part of the profile.

* For station 107, the bottom oxygen sample was bad, so the bottom part of the CTD oxygen profile (850 to 1002 dbar) is suspect.

* The small number of missing deep CTD oxygen data bins for stations 10, 12, 46 and 100 (Table 7) are due to sensor fouling.

* Close comparison of CTD oxygen profiles with bottle data reveal a number of near surface CTD profile segments which are slightly low. The magnitude is ~1% or less of the expected CTD oxygen

accuracy, and the data are therefore not flagged as suspect. Specifically:

station	pressure(dbar)	CTD oxygen
1	6-14	low by up to ~5 µmol/l
20	8-12	low by up to ~4 µmol/l
25	10-12	low by ~3 µmol/l
59	6-18	low by up to ~4 µmol/l
63	6-12	low by up to ~4 µmol/l
67	8-16	low by up to ~3 µmol/l
68	6-20	low by up to ~4 µmol/l
73	8-12	low by up to ~4 µmol/l
82	6-20	low by up to ~4 µmol/l
83	8-22	low by up to ~4 µmol/l
100	4-18	low by up to ~4 µmol/l
105	10-28	low by up to ~4 µmol/l

5.5 Fluorescence, backscatter, PAR, transmittance/beam attenuation, altimeter

Note that fluorescence and backscatter data come from the FLBB sensor; and transmittance and beam attenuation are different data calculations derived from the same transmissometer sensor voltage. All fluorescence, backscatter, PAR and transmittance/beam attenuation data have a manufacturer supplied calibration (Table 2) applied to the data, with transmittance/beam attenuation values referenced to clean water. For fluorescence and backscatter, “dark profiles” were collected on stations 25 and 106 by taping over the FLBB sensors. Fluorescence and backscatter data were recalculated using these field dark voltage values (and note that these are the dark voltages listed in Table 2). For transmittance/beam attenuation, an additional field correction was made to the calibration by measuring the on deck path open and path blocked voltage values.

In the CTD 2dbar averaged data files, both downcast and upcast data are supplied for fluorescence, PAR and transmittance. Note that upcast 2 dbar backscatter data, with the sensor in the wake of the rosette package, are considered suspect, as particles are potentially broken up by the rosette (Emmanuel Boss, pers. com.). Backscatter CTD upcast burst average data in the bottle data files are on the other hand considered okay, as the package is in theory stationary (other than the obvious motion with the swell). Note that all 2 dbar data for these sensors are strictly 2 dbar averages (as distinct from other calculations used in previous cruises i.e. au0703, au0803 and au0806).

For fluorescence and transmittance/beam attenuation, 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 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 plots for the two altimeters.

Maximum transmittance values are slightly more than the expected 100%, and beam attenuation values are equivalently slightly less than the expected 0 value, due to a small calibration error (possibly by referencing to clean water).

* For stations 1, 3, 4, 5 and 6, suspect small segments of downcast transmittance/beam attenuation CTD 2 dbar data are listed in Table 8.

* Fluorescence and backscatter data for stations 25 and 106 are not included in the files, as the FLBB sensors were taped over to collect dark profiles.

5.6 Nutrients

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). Samples were run within 12 hours of collection, either kept in the dark or refrigerated prior to analysis. Full lab and data processing details are in the hydrochemistry reports (Appendices 1 and 2). Laboratory temperatures for nutrient analyses ranged between 19 and 22°C over the course of the cruise, except for station 108 where the temperature was slightly higher at ~22.7°C.

Suspect and bad nutrient 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; 42.0 µmol/l for nitrate+nitrite; 140 µmol/l for silicate; 2.0 µmol/l for ammonia; 1.4 µmol/l for nitrite. Phosphate depletion for shallow samples, consistent with previous cruises (Rosenberg et al., unpublished-1, 2 and 3), can be seen in Figure 6 as a tail of lower phosphate values around the 25 µmol/l nitrate+nitrite level. For cruise in1801, these lower phosphates all come from the top 100 dbar and south of 54°S. Further assessment of nutrient data quality is given in section 7 below, comparing the data to previous cruises.

Overall nutrient data quality is considered very good, and possibly the best to date measured on the SR3 transect. Measurements within the cruise are consistent, profile shapes look good, and scatter is low. Note that flagging of ammonia and nitrite data may not be complete - at the low levels at which these nutrients are measured, suspect data can sometimes be hard to pick. Flag values have all been left at 2 for these two nutrients.

5.7 Additional CTD data processing/quality notes

For some stations, heave compensation error of the CTD winch, discussed above in section 3, resulted in jagged features in the 24 Hz CTD profile data in steep gradients in the upper water column. Any errant profile features should mostly be removed during 2 dbar averaging.

At station 71, the CTD was initially taken down to ~200 dbar then returned to near surface to check sensor performance. This initial yoyo down to 200 dbar was removed from the 24 Hz data prior to processing.

6 UNDERWAY MEASUREMENTS

Underway data, logged by the full suite of Marine National Facility (MNF) underway water and meteorological sensors, are available on request. The MNF data file in2018_v01uwy.nc contains 5 sec instantaneous data in netcdf format, with data from all sensors merged and synchronised. 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). Along track bathymetry data from the 18 kHz sounder (multibeam was not run on this voyage) are also available on request, as 5 sec instantaneous data in the files in1801bath.alf (text format) and in1801bathalf.mat (matlab format). Bottom depths in these files are from the water surface, and calculated using sound speed 1500 m/s. (Note that bottom depths in all CTD data files are corrected for local sound speed). At the time of writing, the 18 kHz data have not yet been quality controlled (i.e. by manually line-picking the bottom in bathymetry data processing software).

7 INTERCRUISE COMPARISONS

Intercruise comparisons of nitrate+nitrite vs phosphate, silicate and dissolved oxygen bottle data compare data from cruise in1801 with previous cruises. For the whole SR3 line, comparisons are made to Aurora Australis cruises au9407, au9404, au9501, au9601, au0103, au0806 and au1121, ranging over the years 1994 to 2011 (i.e. former occupations of the entire SR3 line, with the omission of au9101 and au9309) (Figures 7a, 8 and 9). At the south end of SR3, comparisons are made to Aurora Australis cruises au9407, au9404, au0103, au0806, au1121, au1402 and au1602, ranging over the years 1994 to 2015 (Figure 7b). For au1402 and au1602, note that nutrients were frozen and returned home for analysis.

For nitrate+nitrite vs phosphate, cruises au9407, au9404, au9501, au0806 and au1121 all approximately overlay in1801 (Figure 7a), with in1801 clearly showing the tightest spread of values. For au9501 and au0806, the spread is biased towards higher phosphate values; similarly for au9407, but to a lesser degree. Note that the axes in Figure 7a are curtailed at 1.3 µmol/l phosphate and 22 µmol/l nitrate+nitrite, to make comparisons easier to see (the trends continue in a similar fashion towards low nutrient values beyond the axes). Au0103 and au9601 are apparent outliers in Figure 7a, discussed in previous data reports. The same intercruise trends can be seen at the south end of SR3 (Figure 7b). Phosphates for au1402 and au1602 clearly lie between in1801 and au0103 values. For phosphates in general. intercruise variability is most likely due to variation in autoanalyser performance (specific reasons unknown); and for au1402 and au1602, due freezing of samples for later analysis back in Hobart. From this initial comparison, data quality for in1801 looks better than for previous cruises, though confirmation would require a future occupation of SR3, with nutrient analyses via the SEAL autoanalyser.

Figure 8 shows intercruise comparisons of silicate, plotted against bottle salinity. Note that silicate values below 50 µmol/l are not shown in the plots. Good agreement is seen between in1801 au1121 (the latest SR3 occupation previous to in1801 with on board nutrient analysis). Au0103 also compares favourably with in1801, but there is increased scatter for the remaining cruises, with slightly lower silicates evident for au9404, au9501 and au9601 (the lower au9407 values are a small number of outliers).

Figure 9 shows intercruise comparisons of bottle dissolved oxygen, plotted against bottle salinity. Note that only data deeper than 500 dbar are plotted. In1801 data are mostly tighter (i.e. less scattered) than for the other cruises (with the exception of au9407). There's reasonable agreement between in1801 and au9407. Au9501 and au0806 also have reasonable agreement with in1801, though values for au9501 and au0806 are slightly biased on the high side, and there's significantly more scatter for au0806 data. Au9404 and au1121 values are often higher than in1801, while au9601 and au0103 show the highest offset.

Overall, nutrient data quality appears much improved for in1801, though confirmation requires a repeat SR3 occupation.

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, mostly ranged from ~19 to 22°C; a mean value of 21°C (over all the runs) was used.

<u>Table 1:</u> Summary of station information for cruise in1801. 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 SR3	11 Jan 2018	081635	44 00.09 S	146 19.24 E	251	082356	44 00.09 S	146 19.24 E	253	085350	44 00.12 S	146 19.26 E	253	10.4	244
002 SR3	11 Jan 2018	113033	44 02.98 S	146 17.41 E	561	115907	44 02.98 S	146 17.41 E	568	123535	44 02.93 S	146 17.33 E	558	7.6	566
003 SR3	11 Jan 2018	135925	44 07.19 S	146 13.21 E	1019	142150	44 07.19 S	146 13.22 E	1028	151438	44 07.14 S	146 13.16 E	1014	9.7	1029
004 SR3	11 Jan 2018	184121	44 22.81 S	146 11.36 E	2321	192501	44 22.79 S	146 11.27 E	2327	204427	44 22.77 S	146 11.23 E	2321	9.7	2349
005 SR3	11 Jan 2018	231414	44 43.20 S	146 02.57 E	3205	001257	44 43.13 S	146 02.43 E	3219	014740	44 43.24 S	146 02.60 E	3205	9.3	3261
006 SR3	12 Jan 2018	123729	45 13.31 S	145 51.14 E	2847	132826	45 13.56 S	145 51.13 E	2853	151100	45 13.73 S	145 51.08 E	2837	7.5	2888
007 SR3	12 Jan 2018	181943	45 42.24 S	145 39.38 E	2043	190524	45 42.64 S	145 38.93 E	2146	201538	45 43.00 S	145 38.29 E	2403	13.7	2161
008 SR3	13 Jan 2018	010739	46 10.16 S	145 28.33 E	2713	015928	46 10.18 S	145 28.34 E	2724	032642	46 10.13 S	145 28.30 E	2714	8.3	2756
009 SR3	14 Jan 2018	233315	46 39.04 S	145 15.22 E	3312	003543	46 39.03 S	145 15.23 E	3327	022900	46 38.96 S	145 15.13 E	3319	8.6	3373
010 SR3	15 Jan 2018	143119	47 08.95 S	144 54.64 E	4796	160720	47 09.03 S	144 54.64 E	4810	181412	47 08.95 S	144 54.67 E	4798	11.4	4895
011 SR3	15 Jan 2018	202031	47 28.19 S	144 53.96 E	4389	214043	47 28.12 S	144 53.98 E	4401	234008	47 28.23 S	144 53.98 E	4391	11.3	4473
012 SR3	16 Jan 2018	044621	48 00.00 S	144 40.21 E	4338	061545	48 00.06 S	144 40.19 E	4378	082621	48 00.02 S	144 40.22 E	4268	3.9	4457
013 SR3	16 Jan 2018	104619	48 19.24 S	144 31.79 E	4022	120957	48 19.31 S	144 31.78 E	4081	142253	48 19.51 S	144 31.70 E	4076	7.1	4149
014 SR3	16 Jan 2018	210918	48 46.87 S	144 19.13 E	4130	222642	48 47.11 S	144 19.18 E	4122	002923	48 47.29 S	144 19.22 E	4095	9.4	4189
015 SR3	17 Jan 2018	053900	49 16.23 S	144 05.48 E	4227	065922	49 16.34 S	144 06.26 E	4375	091224	49 16.70 S	144 07.36 E	4381	6.7	4452
016 SR3	17 Jan 2018	202448	49 36.51 S	143 55.84 E	3654	213616	49 36.56 S	143 55.76 E	3697	232537	49 36.59 S	143 55.73 E	3667	12.0	3749
017 SR3	18 Jan 2018	012437	49 53.47 S	143 47.90 E	3668	023643	49 53.41 S	143 48.02 E	3725	044018	49 53.41 S	143 48.02 E	3663	7.5	3783
018 SR3	18 Jan 2018	082601	50 09.56 S	143 39.46 E	3657	093912	50 09.50 S	143 38.98 E	3816	114527	50 09.57 S	143 38.52 E	3706	9.6	3874
019 SR3	18 Jan 2018	134525	50 24.05 S	143 31.69 E	3542	145136	50 23.97 S	143 31.81 E	3509	163629	50 23.92 S	143 31.88 E	3493	9.7	3559
020 SR3	19 Jan 2018	033735	50 40.69 S	143 25.04 E	3471	044121	50 40.72 S	143 25.03 E	3483	063943	50 40.68 S	143 25.07 E	3470	11.9	3530
021 SR3	19 Jan 2018	112246	51 00.56 S	143 16.31 E	3787	124426	51 00.72 S	143 16.19 E	3801	144955	51 01.04 S	143 15.92 E	3772	13.7	3855
022 SR3	19 Jan 2018	172020	51 15.67 S	143 07.95 E	3740	183408	51 15.94 S	143 07.88 E	3789	202715	51 16.30 S	143 07.78 E	3620	6.4	3850
023 SR3	20 Jan 2018	003340	51 33.12 S	143 00.03 E	3632	014720	51 33.29 S	142 59.96 E	3609	032550	51 33.42 S	142 59.92 E	3594	9.2	3663
024 SR3	20 Jan 2018	141346	51 48.63 S	142 50.42 E	3688	153022	51 48.88 S	142 50.18 E	3690	172323	51 49.38 S	142 49.89 E	3654	11.3	3744
025 SR3	20 Jan 2018	191829	52 04.86 S	142 42.68 E	3472	202848	52 05.30 S	142 43.01 E	3461	221808	52 05.90 S	142 43.05 E	3521	11.8	3509
026 SR3	21 Jan 2018	004030	52 22.30 S	142 31.95 E	3368	020556	52 22.55 S	142 31.82 E	3427	040740	52 22.47 S	142 31.88 E	3344	11.3	3475
027 SR3	21 Jan 2018	082028	52 40.10 S	142 23.42 E	3353	093524	52 40.29 S	142 23.20 E	3388	112909	52 40.89 S	142 22.13 E	3396	10.8	3435
028 SR3	21 Jan 2018	142201	53 07.76 S	142 08.42 E	3082	152141	53 07.77 S	142 08.46 E	3104	165209	53 07.78 S	142 08.68 E	3102	12.8	3142
029 SR3	21 Jan 2018	233115	53 34.75 S	141 51.73 E	2495	002036	53 34.63 S	141 51.84 E	2488	014159	53 34.53 S	141 51.92 E	2419	11.7	2514
030 SR3	22 Jan 2018	064756	54 04.26 S	141 35.87 E	2496	073725	54 04.25 S	141 35.88 E	2531	091042	54 04.24 S	141 35.93 E	2510	8.7	2561
031 SR3	22 Jan 2018	193751	54 31.67 S	141 19.76 E	2769	203800	54 31.54 S	141 19.96 E	2823	220202	54 31.50 S	141 20.04 E	2782	11.1	2857
032 SR3	23 Jan 2018	041538	55 01.28 S	141 01.27 E	3139	052407	55 01.24 S	141 01.30 E	3318	070603	55 01.24 S	141 01.31 E	3162	12.4	3362
033 SR3	23 Jan 2018	134700	55 29.97 S	140 43.81 E	4048	150956	55 29.95 S	140 43.79 E	4176	170630	55 29.98 S	140 43.89 E	4062	11.4	4245
034 SR3	23 Jan 2018	200321	55 55.81 S	140 24.56 E	3569	211700	55 55.80 S	140 24.56 E	3656	225829	55 55.80 S	140 24.59 E	3600	11.6	3710
035 SR3	24 Jan 2018	050932	56 25.82 S	140 06.05 E	3843	062639	56 25.80 S	140 06.01 E	3927	082435	56 25.81 S	140 06.05 E	3843	11.7	3989
036 SR3	24 Jan 2018	112749	56 55.78 S	139 50.93 E	4097	124741	56 55.76 S	139 50.93 E	4127	144014	56 55.76 S	139 51.09 E	4102	12.2	4194
037 SR3	24 Jan 2018	205021	57 21.04 S	139 53.08 E	4090	220630	57 20.94 S	139 53.45 E	4095	235059	57 21.06 S	139 53.06 E	4087	10.6	4163
038 SR3	25 Jan 2018	024825	57 50.99 S	139 51.02 E	3971	040124	57 50.99 S	139 50.98 E	3992	060143	57 51.01 S	139 51.01 E	3971	11.8	4055

Table 1: (continued)

CTD station	date	start of CTD time	latitude	longitude	depth	bottom of CTD time	latitude	longitude	depth	end of CTD time	latitude	longitude	depth	alt	maxp
039 SR3	25 Jan 2018	103255	58 21.11 S	139 51.14 E	3953	114544	58 21.06 S	139 51.04 E	3994	135330	58 21.07 S	139 51.01 E	3944	9.7	4060
040 SR3	25 Jan 2018	184621	58 51.00 S	139 50.33 E	3879	200048	58 51.00 S	139 50.31 E	3893	213622	58 51.04 S	139 50.30 E	3880	9.3	3957
041 SR3	26 Jan 2018	023630	58 50.74 S	139 50.38 E	3860	030030	58 50.72 S	139 50.41 E	3860	034147	58 50.72 S	139 50.38 E	3859	-	1004
042 SR3	26 Jan 2018	101856	59 21.02 S	139 51.02 E	4125	113947	59 21.02 S	139 51.10 E	4166	133951	59 21.02 S	139 50.90 E	4121	11.4	4236
043 SR3	26 Jan 2018	164740	59 50.96 S	139 51.59 E	4441	180955	59 50.99 S	139 51.53 E	4455	200536	59 51.02 S	139 51.51 E	4441	11.0	4534
044 SR3	27 Jan 2018	010338	60 21.05 S	139 51.13 E	4404	022650	60 20.99 S	139 50.99 E	4416	044020	60 20.94 S	139 50.84 E	4403	11.5	4494
045 SR3	27 Jan 2018	092040	60 50.98 S	139 50.94 E	4366	104255	60 51.05 S	139 51.10 E	4379	124440	60 51.11 S	139 51.34 E	4367	12.4	4454
046 SR3	28 Jan 2018	002523	61 21.01 S	139 50.44 E	4305	014550	61 21.09 S	139 50.42 E	4317	034344	61 21.11 S	139 50.45 E	4304	12.4	4391
047 SR3	28 Jan 2018	063729	61 51.05 S	139 50.31 E	4253	075541	61 51.05 S	139 50.38 E	4266	101333	61 51.04 S	139 50.36 E	4254	12.5	4338
048 SR3	28 Jan 2018	203525	62 21.61 S	139 50.38 E	3908	215759	62 21.74 S	139 50.75 E	3920	235140	62 21.89 S	139 51.27 E	3914	7.0	3988
049 SR3	29 Jan 2018	031655	62 51.01 S	139 51.11 E	3168	042236	62 50.99 S	139 51.05 E	3179	060556	62 50.98 S	139 51.02 E	3169	11.1	3223
050 SR3	29 Jan 2018	130506	63 20.99 S	139 49.67 E	3759	141715	63 20.99 S	139 49.72 E	3774	160431	63 20.97 S	139 49.93 E	3763	8.6	3837
051 SR3	29 Jan 2018	211350	63 51.88 S	139 51.94 E	3686	222301	63 51.58 S	139 52.31 E	3703	235442	63 51.17 S	139 52.92 E	3694	11.4	3761
052 SR3	30 Jan 2018	115914	64 12.81 S	139 50.19 E	3482	130355	64 12.86 S	139 49.96 E	3495	144638	64 12.86 S	139 49.84 E	3481	10.2	3549
053 SR3	30 Jan 2018	172842	64 33.08 S	139 51.01 E	3039	182547	64 33.05 S	139 50.83 E	3052	194414	64 32.99 S	139 50.65 E	3044	11.4	3093
054 SR3	30 Jan 2018	213823	64 48.66 S	139 51.62 E	2556	223009	64 48.61 S	139 51.56 E	2566	234242	64 48.65 S	139 51.57 E	2557	11.7	2596
055 SR3	31 Jan 2018	041844	65 04.19 S	139 51.56 E	2458	050332	65 04.16 S	139 51.56 E	2475	063220	65 04.19 S	139 51.52 E	2459	11.6	2503
056 SR3	31 Jan 2018	100512	65 23.95 S	139 51.17 E	2390	105444	65 23.93 S	139 51.19 E	2399	122432	65 23.89 S	139 51.24 E	2394	10.2	2426
057 SR3	31 Jan 2018	212221	65 25.78 S	139 51.06 E	1797	220253	65 25.79 S	139 51.01 E	1939	230701	65 25.76 S	139 51.07 E	1794	13.5	1953
058 SR3	01 Feb 2018	015231	65 31.81 S	139 51.03 E	1289	021748	65 31.85 S	139 51.00 E	1317	030122	65 31.78 S	139 50.94 E	1296	10.3	1324
059 SR3	01 Feb 2018	051552	65 34.19 S	139 51.18 E	800	053427	65 34.21 S	139 51.19 E	819	061919	65 34.24 S	139 51.17 E	782	10.0	818
060 SR3	01 Feb 2018	073939	65 42.70 S	139 51.69 E	283	074720	65 42.70 S	139 51.69 E	283	081821	65 42.67 S	139 51.67 E	285	7.8	278
061 shelf	01 Feb 2018	234040	66 25.60 S	145 04.19 E	423	235012	66 25.59 S	145 04.22 E	424	001752	66 25.58 S	145 04.24 E	421	10.0	418
062 shelf	02 Feb 2018	063107	66 20.84 S	144 39.53 E	414	064119	66 20.85 S	144 39.55 E	419	070940	66 20.83 S	144 39.50 E	414	12.0	411
063 shelf	02 Feb 2018	081037	66 19.25 S	144 23.46 E	432	082147	66 19.17 S	144 23.29 E	434	085305	66 19.11 S	144 23.02 E	433	8.3	431
064 shelf	02 Feb 2018	110336	66 14.50 S	144 01.33 E	439	111409	66 14.47 S	144 01.36 E	442	114758	66 14.44 S	144 01.42 E	435	10.0	437
065 shelf	02 Feb 2018	130425	66 07.24 S	143 49.78 E	432	131522	66 07.22 S	143 49.84 E	437	134740	66 07.20 S	143 49.88 E	432	9.7	432
066 shelf	02 Feb 2018	145858	65 59.99 S	143 38.44 E	424	150745	66 00.00 S	143 38.41 E	423	153126	66 00.01 S	143 38.39 E	422	9.4	418
067 Ninja	02 Feb 2018	231547	64 59.90 S	145 29.73 E	3301	001613	64 59.90 S	145 29.86 E	3312	014615	64 59.89 S	145 30.16 E	3307	12.1	3359
068 P11S	03 Feb 2018	122048	65 23.99 S	150 00.05 E	2853	131345	65 23.99 S	150 00.01 E	2866	145327	65 23.98 S	149 59.98 E	2854	6.6	2908
069 P11S	03 Feb 2018	171310	65 35.49 S	149 59.87 E	2478	180138	65 35.12 S	149 59.42 E	2494	191305	65 34.72 S	149 58.24 E	2522	11.3	2522
070 P11S	04 Feb 2018	034754	65 38.32 S	150 00.91 E	2328	043552	65 38.10 S	150 00.83 E	2345	055216	65 37.22 S	149 59.36 E	2401	10.2	2371
071 P11S	04 Feb 2018	093618	64 59.96 S	149 59.75 E	3254	104434	64 59.97 S	149 59.90 E	3274	121901	65 00.00 S	150 00.31 E	3264	10.0	3322
072 P11S	04 Feb 2018	144722	64 35.99 S	150 00.01 E	3423	155018	64 36.00 S	150 00.04 E	3434	172606	64 36.01 S	150 00.09 E	3425	11.9	3484
073 P11S	04 Feb 2018	223939	64 17.97 S	149 59.98 E	3525	234608	64 18.04 S	150 00.13 E	3549	012105	64 18.10 S	150 00.26 E	3527	14.1	3600
074 P11S	05 Feb 2018	034355	63 54.01 S	150 00.03 E	3628	044945	63 54.02 S	150 00.08 E	3639	064111	63 54.04 S	150 00.17 E	3629	11.8	3695
075 P11S	05 Feb 2018	091006	63 29.96 S	150 00.00 E	3690	102716	63 29.96 S	150 00.02 E	3703	122502	63 30.09 S	150 00.18 E	3692	11.2	3761
076 P11S	05 Feb 2018	184038	62 59.99 S	150 00.02 E	3807	195028	63 00.02 S	150 00.05 E	3817	213250	63 00.04 S	150 00.08 E	3805	11.5	3878
077 P11S	06 Feb 2018	002818	62 30.01 S	150 00.01 E	3834	013737	62 30.01 S	150 00.01 E	3851	034006	62 30.13 S	150 00.07 E	3846	11.6	3912

<u>Table 1:</u> (continued)

	-----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
078 P11S	06 Feb 2018	064253	62 00.02 S	149 59.98 E	3707	074933	62 00.02 S	149 59.98 E	3722	100259	62 00.08 S	149 59.95 E	3705	11.3	3780
079 S4	06 Feb 2018	215412	63 11.37 S	147 49.91 E	3871	230552	63 11.44 S	147 49.88 E	3881	004815	63 11.43 S	147 49.90 E	3869	11.1	3944
080 S4	07 Feb 2018	042848	63 03.01 S	146 26.86 E	3910	054114	63 03.00 S	146 26.97 E	3920	073445	63 02.99 S	146 27.00 E	3909	11.5	3984
081 S4	07 Feb 2018	150634	62 54.00 S	145 01.79 E	3982	162157	62 54.03 S	145 01.76 E	3995	180351	62 54.55 S	145 01.20 E	3979	11.0	4061
082 S4	07 Feb 2018	220108	62 45.02 S	143 37.18 E	4074	231737	62 45.05 S	143 37.15 E	4086	010148	62 45.05 S	143 37.16 E	4076	11.4	4155
083 S4	08 Feb 2018	092211	62 36.01 S	142 12.03 E	4090	103906	62 36.02 S	142 12.01 E	4101	125444	62 36.07 S	142 11.89 E	4088	11.3	4170
084 S4	08 Feb 2018	161921	62 28.81 S	141 01.76 E	4124	174701	62 28.80 S	141 01.80 E	4138	192836	62 28.82 S	141 01.73 E	4123	11.4	4207
085 S4	09 Feb 2018	141146	62 10.31 S	138 24.57 E	3948	153325	62 10.19 S	138 24.61 E	3959	171818	62 10.15 S	138 24.73 E	3947	11.5	4024
086 S4	09 Feb 2018	215510	61 59.93 S	137 00.04 E	3846	231118	61 59.61 S	137 00.56 E	3863	005334	61 59.51 S	137 00.82 E	3851	9.4	3927
087 S4	10 Feb 2018	053917	62 00.00 S	135 34.87 E	4286	065731	62 00.02 S	135 34.84 E	4300	091225	62 00.02 S	135 34.87 E	4285	13.5	4373
088 S4	10 Feb 2018	163024	62 01.19 S	134 10.27 E	4327	174953	62 01.21 S	134 10.02 E	4340	194449	62 01.22 S	134 10.11 E	4327	11.2	4416
089 132E	11 Feb 2018	013846	62 29.98 S	132 02.98 E	4427	030145	62 29.99 S	132 02.98 E	4441	050218	62 30.01 S	132 02.99 E	4430	11.1	4521
090 132E	11 Feb 2018	093151	63 05.05 S	132 06.08 E	4242	105032	63 05.06 S	132 06.10 E	4254	125942	63 05.04 S	132 05.97 E	4243	9.4	4330
091 132E	11 Feb 2018	173525	63 29.99 S	132 04.81 E	4015	185032	63 30.01 S	132 04.77 E	4028	202850	63 30.04 S	132 04.75 E	4017	11.3	4095
092 132E	11 Feb 2018	231824	63 58.48 S	132 06.38 E	3204	001745	63 58.52 S	132 06.33 E	3218	014423	63 58.63 S	132 06.50 E	3206	11.1	3264
093 132E	12 Feb 2018	063708	64 26.93 S	132 04.60 E	1465	071342	64 26.90 S	132 04.57 E	1471	082303	64 26.87 S	132 04.55 E	1469	11.3	1479
094 132E	12 Feb 2018	182930	64 50.27 S	132 05.41 E	862	184812	64 50.27 S	132 05.53 E	863	191509	64 50.24 S	132 05.70 E	855	7.4	866
095 132E	12 Feb 2018	202939	64 58.76 S	132 03.87 E	292	203654	64 58.74 S	132 03.85 E	293	205514	64 58.76 S	132 03.86 E	292	8.3	288
096 132E	13 Feb 2018	180521	61 59.70 S	132 00.20 E	4466	192615	61 59.71 S	132 00.02 E	4479	212239	61 59.69 S	131 59.60 E	4465	10.8	4559
097 132E	14 Feb 2018	020013	61 29.99 S	131 59.99 E	4521	032137	61 30.00 S	131 59.96 E	4533	055647	61 30.01 S	132 00.25 E	4520	8.4	4618
098 132E	14 Feb 2018	091032	60 59.94 S	132 00.17 E	4572	103444	60 59.98 S	132 00.52 E	4582	125306	61 00.17 S	132 00.50 E	4570	11.2	4665
099 132E	14 Feb 2018	160416	60 31.54 S	132 07.75 E	4612	173012	60 31.50 S	132 07.82 E	4626	192526	60 31.49 S	132 07.82 E	4611	11.2	4710
100 132E	14 Feb 2018	222318	60 01.94 S	132 13.00 E	4648	235057	60 01.91 S	132 13.06 E	4662	014809	60 01.89 S	132 13.01 E	4649	10.7	4748
101 132E	15 Feb 2018	045852	59 30.00 S	132 06.01 E	4672	062431	59 30.01 S	132 06.06 E	4684	082534	59 29.98 S	132 05.99 E	4671	11.5	4770
102 132E	15 Feb 2018	112236	58 58.27 S	132 01.51 E	4663	124949	58 58.32 S	132 01.69 E	4676	150026	58 58.31 S	132 01.75 E	4663	10.0	4763
103 132E	15 Feb 2018	174716	58 29.97 S	132 00.47 E	4655	192152	58 30.01 S	132 00.65 E	4667	212621	58 30.05 S	132 00.70 E	4653	9.9	4753
104 132E	16 Feb 2018	002512	58 00.00 S	131 59.98 E	4656	015126	58 00.00 S	131 59.94 E	4670	042149	58 00.04 S	131 58.73 E	4656	11.4	4754
105 132E	16 Feb 2018	071142	57 31.03 S	132 00.15 E	4656	083549	57 31.00 S	132 00.20 E	4672	110506	57 30.95 S	132 00.20 E	4658	10.9	4757
106 132E	16 Feb 2018	141327	56 57.92 S	132 09.18 E	4529	153627	56 57.92 S	132 09.21 E	4553	173819	56 57.91 S	132 09.22 E	4533	10.5	4634
107 eddy	18 Feb 2018	085930	56 32.99 S	141 29.63 E	3592	092143	56 32.99 S	141 29.63 E	3609	100328	56 33.00 S	141 29.66 E	3664	-	1003
108 eddy	19 Feb 2018	045536	53 37.73 S	142 58.78 E	2999	051737	53 37.75 S	142 58.79 E	3003	060631	53 37.75 S	142 58.79 E	3003	-	1003

Table 2: CTD calibration coefficients and calibration dates for cruise in1801. Note that platinum temperature calibrations are for the ITS-90 scale. Pressure slope/offset, temperature, conductivity and oxygen values are from CSIRO and SeaBird pre cruise 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 primary and secondary conductivity, which reduces the depth dependent calibration error due to compressibility of the borosilicate glass cell. For FLBB fluorometer and backscatter, dark value derived from "dark profiles" at stations 25 and 106.

Primary Temperature, serial 6189, 04/04/2017
(station 1 to 13)

G	: 4.38623631e-003
H	: 6.41207874e-004
I	: 2.30415384e-005
J	: 2.14398355e-006
F0	: 1000.000
Slope	: 1.0000000
Offset	: 0.0000

Secondary Temperature, serial 6180, 19/04/2017
(station 1 to 11, 14 to 108)

G	: 4.33710187e-003
H	: 6.34603081e-004
I	: 2.17586153e-005
J	: 1.99921954e-006
F0	: 1000.000
Slope	: 1.0000000
Offset	: 0.0000

Primary Temperature, serial 4522, 15/12/2017
(station 14 to 108)

G	: 4.33235720e-003
H	: 6.34643520e-004
I	: 1.98678350e-005
J	: 1.55527340e-006
F0	: 1000.000
Slope	: 1.0000000
Offset	: 0.0000

Secondary Temperature, serial 4522, 15/12/2017
(station 12 to 13)

G	: 4.33235720e-003
H	: 6.34643520e-004
I	: 1.98678350e-005
J	: 1.55527340e-006
F0	: 1000.000
Slope	: 1.0000000
Offset	: 0.0000

Primary Conductivity, serial 4685, 02/05/2017

G	: -9.99847835e+000
H	: 1.34567880e+000
I	: 2.26080131e-004
J	: 3.94289636e-005
CTcor	: 3.2500e-006
CPcor	: -8.4500000e-008
Slope	: 1.00000000
Offset	: 0.00000

Secondary Conductivity, serial 4664, 02/05/2017

G	: -9.89576006e+000
H	: 1.34531130e+000
I	: -2.43201518e-004
J	: 7.66668505e-005
CTcor	: 3.2500e-006
CPcor	: -8.4500000e-008
Slope	: 1.00000000
Offset	: 0.00000

CTD704 Pressure, serial 1332, 21/08/2017

C1	: -4.143143e+004
C2	: -3.307590e-001
C3	: 1.332300e-002
D1	: 3.552400e-002
D2	: 0.000000e+000
T1	: 3.046230e+001
T2	: -4.100470e-004
T3	: 3.894920e-006
T4	: 4.633350e-009
T5	: 0.000000e+000
Slope	: 1.000000
Offset	: 0.5800 (dbar)
AD590M	: 1.279750e-002
AD590B	: -9.342582e+000

Table 2: **(continued)**

Primary Oxygen, serial 3534, 26/04/2017 (for display at time of logging only)		*Secondary Oxygen, serial 3542, 26/04/2017* (for display at time of logging only)	
Soc	: 4.75400e-001	Soc	: 5.01200e-001
Voffset	: -4.97900e-001	Voffset	: -5.22300e-001
A	: -4.35090e-003	A	: -3.60190e-003
B	: 2.23240e-004	B	: 1.95170e-004
C	: -3.44950e-006	C	: -3.06820e-006
E	: 3.60000e-002	E	: 3.60000e-002
Tau20	: 1.34000e+000	Tau20	: 1.97000e+000
D1	: 1.92634e-004	D1	: 1.92634e-004
D2	: -4.64803e-002	D2	: -4.64803e-002
H1	: -3.30000e-002	H1	: -3.30000e-002
H2	: 5.00000e+003	H2	: 5.00000e+003
H3	: 1.45000e+003	H3	: 1.45000e+003

Transmissometer, serial 1421DR, 07/08/2017
(referenced to clean water)
M : 21.2815
B : -0.1277
Path length: 0.25 (m)

PAR, serial 70111, QCP2300HP, 26/06/2017
M : 1.000
B : 0.000
Cal. Constant : 2.1834061e+010
Multiplier : 1.0
Offset : -4.6362e-002

FLBBRTD, serial 4799, 09/08/2017

Fluorometer
Dark output : 0.0500
Scale factor : 6.000e+000

Backscatter
Dark output : 0.0615
Scale factor : 1.429e-003
Wavelength : 700

Table 3: **CTD conductivity calibration coefficients for cruise in1801. 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 011	-0.34912601E-02	0.10002407E-02	-0.25260120E-08	216	0.000675
012 to 080	-0.19948864E-03	0.10001028E-02	0.43004868E-09	1499	0.000623
081 to 108	0.10274673E-01	0.99966219E-03	0.13331931E-08	638	0.000702

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 in1801.**

station number	($F_2 + F_3 . N$)	station number	($F_2 + F_3 . N$)	station number	($F_2 + F_3 . N$)
1	0.10002382E-02	37	0.10001187E-02	73	0.10001342E-02
2	0.10002357E-02	38	0.10001191E-02	74	0.10001346E-02
3	0.10002332E-02	39	0.10001196E-02	75	0.10001351E-02
4	0.10002306E-02	40	0.10001200E-02	76	0.10001355E-02
5	0.10002281E-02	41	0.10001204E-02	77	0.10001359E-02
6	0.10002256E-02	42	0.10001209E-02	78	0.10001363E-02
7	0.10002230E-02	43	0.10001213E-02	79	0.10001368E-02
8	0.10002205E-02	44	0.10001217E-02	80	0.10001372E-02
9	0.10002180E-02	45	0.10001222E-02	81	0.99977018E-03
10	0.10002155E-02	46	0.10001226E-02	82	0.99977151E-03
11	0.10002129E-02	47	0.10001230E-02	83	0.99977284E-03
12	0.10001080E-02	48	0.10001234E-02	84	0.99977418E-03
13	0.10001084E-02	49	0.10001239E-02	85	0.99977551E-03
14	0.10001088E-02	50	0.10001243E-02	86	0.99977684E-03
15	0.10001093E-02	51	0.10001247E-02	87	0.99977818E-03
16	0.10001097E-02	52	0.10001252E-02	88	0.99977951E-03
17	0.10001101E-02	53	0.10001256E-02	89	0.99978084E-03
18	0.10001105E-02	54	0.10001260E-02	90	0.99978218E-03
19	0.10001110E-02	55	0.10001265E-02	91	0.99978351E-03
20	0.10001114E-02	56	0.10001269E-02	92	0.99978484E-03
21	0.10001118E-02	57	0.10001273E-02	93	0.99978618E-03
22	0.10001123E-02	58	0.10001277E-02	94	0.99978751E-03
23	0.10001127E-02	59	0.10001282E-02	95	0.99978884E-03
24	0.10001131E-02	60	0.10001286E-02	96	0.99979017E-03
25	0.10001136E-02	61	0.10001290E-02	97	0.99979151E-03
26	0.10001140E-02	62	0.10001295E-02	98	0.99979284E-03
27	0.10001144E-02	63	0.10001299E-02	99	0.99979417E-03
28	0.10001148E-02	64	0.10001303E-02	100	0.99979551E-03
29	0.10001153E-02	65	0.10001308E-02	101	0.99979684E-03
30	0.10001157E-02	66	0.10001312E-02	102	0.99979817E-03
31	0.10001161E-02	67	0.10001316E-02	103	0.99979951E-03
32	0.10001166E-02	68	0.10001320E-02	104	0.99980084E-03
33	0.10001170E-02	69	0.10001325E-02	105	0.99980217E-03
34	0.10001174E-02	70	0.10001329E-02	106	0.99980351E-03
35	0.10001179E-02	71	0.10001333E-02	107	0.99980484E-03
36	0.10001183E-02	72	0.10001338E-02	108	0.99980617E-03

Table 5: **Surface pressure offsets (i.e. poff in dbar) for cruise in1801. 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
001	-0.24	019	-0.55	037	-0.35	055	-0.51	073	-0.47	091	-0.67
002	-0.23	020	-0.33	038	-0.35	056	-0.49	074	-0.48	092	-0.70
003	-0.24	021	-0.36	039	-0.39	057	-0.40	075	-0.44	093	-0.65
004	-0.35	022	-0.36	040	-0.48	058	-0.39	076	-0.45	094	-0.52
005	-0.37	023	-0.30	041	-0.56	059	-0.37	077	-0.45	095	-0.53
006	-0.36	024	-0.27	042	-0.45	060	-0.39	078	-0.42	096	-0.59
007	-0.41	025	-0.29	043	-0.45	061	-0.38	079	-0.49	097	-0.60
008	-0.38	026	-0.32	044	-0.41	062	-0.45	080	-0.53	098	-0.54
009	-0.13	027	-0.32	045	-0.43	063	-0.38	081	-0.48	099	-0.52
010	-0.10	028	-0.43	046	-0.73	064	-0.44	082	-0.50	100	-0.47
011	-0.12	029	-0.55	047	-0.86	065	-0.47	083	-0.47	101	-0.46
012	-0.16	030	-0.58	048	-0.65	066	-0.49	084	-0.52	102	-0.48
013	-0.18	031	-0.59	049	-0.59	067	-0.46	085	-0.59	103	-0.50
014	-0.21	032	-0.66	050	-0.48	068	-0.51	086	-0.61	104	-0.55
015	-0.23	033	-0.54	051	-0.43	069	-0.55	087	-0.61	105	-0.65
016	-0.28	034	-0.53	052	-0.42	070	-0.41	088	-0.52	106	-0.65
017	-0.33	035	-0.45	053	-0.50	071	-0.47	089	-0.60	107	-0.20
018	-0.40	036	-0.41	054	-0.49	072	-0.47	090	-0.62	108	-0.05

<u>Table 6:</u> CTD dissolved oxygen calibration coefficients for cruise in1801: 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) (see section 5.4 for exceptions).

	---------------------shallow----------------------------					---------------------deep---------------------------------				
stn	slope	bias	tcor	pcor	dox	slope	bias	tcor	pcor	dox
1	0.709093	-0.627685	-0.007671	0.000116	0.074810					
2	1.134027	-1.205114	-0.030850	0.000017	0.125380					
3	0.499810	-0.296171	0.004628	0.000227	0.084345					
4	0.495413	-0.227123	0.000071	0.000123	0.089076	0.606878	-0.384455	-0.005512	0.000148	0.032341
5	0.551999	-0.319929	-0.001389	0.000147	0.133773	0.396292	-0.105922	0.005163	0.000124	0.014800
6	0.490131	-0.226701	0.002200	0.000126	0.103328	0.483104	-0.249410	0.016116	0.000153	0.029972
7	0.501120	-0.226831	0.000235	0.000110	0.140051					
8	0.494991	-0.226034	0.001354	0.000116	0.115084	0.345230	-0.086060	0.028373	0.000156	0.019862
9	0.514558	-0.265847	-0.000201	0.000142	0.098784	0.721823	-0.452590	-0.048065	0.000108	0.026115
10	0.511081	-0.261538	0.000322	0.000140	0.087704	0.492506	-0.186540	-0.021769	0.000108	0.022974
11	0.497222	-0.240383	0.002468	0.000138	0.129674	0.450343	-0.107375	-0.029335	0.000093	0.045070
12	0.550091	-0.336700	-0.001891	0.000179	0.080386	0.502941	-0.175235	-0.032700	0.000098	0.044229
13	0.554933	-0.296494	-0.006077	0.000123	0.080305					
14	0.489782	-0.232446	0.003770	0.000137	0.109942	0.485390	-0.244160	0.017125	0.000145	0.046903
15	0.543642	-0.281502	-0.005000	0.000123	0.102582	0.523869	-0.233119	-0.020946	0.000115	0.058348
16	0.492830	-0.216458	0.000921	0.000117	0.121193	0.550769	-0.314064	0.001429	0.000144	0.038747
17	0.492498	-0.215635	0.000668	0.000117	0.110306	0.538958	-0.269344	-0.013742	0.000125	0.032062
18	0.497023	-0.219673	0.000761	0.000110	0.088014	0.562819	-0.311112	-0.010519	0.000134	0.027950
19	0.512231	-0.252161	-0.000334	0.000132	0.078896	0.506831	-0.261339	0.007677	0.000143	0.029020
20	0.495379	-0.261468	0.005875	0.000170	0.109040	0.608817	-0.380791	-0.006316	0.000142	0.029399
21	0.511507	-0.309571	0.006602	0.000210	0.085618	0.743902	-0.452456	-0.060886	0.000094	0.052206
22	0.509788	-0.289455	0.004832	0.000188	0.087803	0.608924	-0.377428	-0.008765	0.000141	0.043013
23	0.406392	-0.087341	0.011126	0.000077	0.094383	0.605107	-0.382466	-0.005476	0.000147	0.037306
24	0.510442	-0.291727	0.004672	0.000192	0.131895	0.604461	-0.386859	-0.000790	0.000150	0.056012
25	0.524595	-0.281221	-0.001065	0.000151	0.095463	0.490138	-0.222256	0.002764	0.000131	0.049667
26	0.545832	-0.294204	-0.005917	0.000134	0.111469	0.560066	-0.339158	0.010721	0.000151	0.050995
27	0.461197	-0.190630	0.010510	0.000125	0.118564	0.605434	-0.389465	-0.002973	0.000151	0.048830
28	0.510490	-0.253664	0.001005	0.000140	0.080402	0.405757	-0.098418	0.010210	0.000117	0.031034
29	0.517210	-0.268364	0.000640	0.000148	0.042756	0.698103	-0.500655	-0.021813	0.000143	0.015449
30	0.536610	-0.290428	-0.004525	0.000144	0.044117	0.699202	-0.499638	-0.028841	0.000142	0.011877
31	0.521820	-0.277616	0.000277	0.000155	0.093576	0.481750	-0.156752	-0.024899	0.000097	0.016571
32	0.500655	-0.246255	0.005958	0.000139	0.105586	0.451270	-0.112710	-0.021395	0.000093	0.025011
33	0.499849	-0.244736	0.005105	0.000142	0.096232	0.600174	-0.403236	0.008915	0.000165	0.019475
34	0.529495	-0.279120	-0.000804	0.000143	0.091344	0.697589	-0.496648	-0.025959	0.000147	0.037855
35	0.516209	-0.262705	0.002562	0.000139	0.056744	0.583164	-0.354774	-0.001974	0.000144	0.023805
36	0.510957	-0.253334	0.003322	0.000137	0.080036	0.433891	-0.096910	-0.017232	0.000098	0.023800
37	0.511298	-0.255871	0.003755	0.000139	0.076315	0.404480	-0.099555	0.016318	0.000120	0.029387
38	0.522191	-0.268248	0.000088	0.000139	0.042243	0.698042	-0.497542	-0.028990	0.000148	0.025218
39	0.521381	-0.267445	-0.001037	0.000140	0.090227	0.403721	-0.100009	0.016545	0.000120	0.029864
40	0.525332	-0.279482	0.000372	0.000151	0.105738	0.405162	-0.098055	0.015692	0.000119	0.028572
41	0.516446	-0.251790	0.000069	0.000119	0.114305					
42	0.520233	-0.275634	0.006966	0.000146	0.077000	0.402748	-0.099707	0.020339	0.000122	0.027079
43	0.518161	-0.274096	0.008219	0.000150	0.088765	0.404546	-0.098322	0.019864	0.000121	0.029332
44	0.523618	-0.279798	0.005875	0.000148	0.110171	0.695168	-0.499442	-0.032451	0.000150	0.029923
45	0.533589	-0.292723	0.004394	0.000148	0.114991	0.348560	0.012168	-0.004547	0.000098	0.026705
46	0.515282	-0.262933	0.006766	0.000140	0.104404	0.401612	-0.100556	0.025607	0.000125	0.023061
47	0.523353	-0.275468	0.004088	0.000145	0.053110	0.403183	-0.099727	0.022251	0.000124	0.029287
48	0.528013	-0.280755	0.002163	0.000147	0.041316	0.696122	-0.501946	-0.028695	0.000146	0.019713
49	0.529768	-0.275554	-0.003294	0.000142	0.071005	0.401867	-0.098909	0.023840	0.000134	0.015471
50	0.541600	-0.321111	0.020951	0.000163	0.065903	0.401767	-0.101060	0.024397	0.000134	0.024396
51	0.548028	-0.315427	-0.005411	0.000163	0.119708	0.491148	-0.211795	0.002606	0.000129	0.029108
52	0.473284	-0.154562	-0.030278	0.000105	0.090771	0.404037	-0.096492	0.024391	0.000132	0.028694
53	0.558745	-0.357213	0.035685	0.000179	0.065744	0.408498	-0.089334	0.009972	0.000124	0.034577
54	0.522752	-0.264220	0.002730	0.000139	0.096748	0.493406	-0.209440	-0.007390	0.000127	0.015079
55	0.543285	-0.307222	0.008888	0.000156	0.108826	0.339152	0.078220	-0.088387	0.000066	0.017838
56	0.532706	-0.283737	0.002375	0.000148	0.102698	0.464079	-0.156548	-0.018589	0.000116	0.019528
57	0.583623	-0.385123	0.026551	0.000183	0.090631					
58	0.527170	-0.269540	0.003479	0.000141	0.094280					
59	0.537021	-0.290998	0.014607	0.000171	0.155403					
60	0.498319	-0.192782	0.012196	0.000117	0.043574					
61	0.523013	-0.267371	0.001429	0.000179	0.132414					
62	0.501716	-0.218162	-0.003458	0.000109	0.112257					
63	0.509702	-0.215402	0.015172	0.000152	0.108634					

Table 6: (continued)

stn	shallow slope	bias	tcor	pcor	dox	deep slope	bias	tcor	pcor	dox
64	0.601828	-0.414234	0.028989	0.000272	0.091321					
65	0.486093	-0.198652	-0.016456	0.000107	0.095527					
66	0.523323	-0.262507	-0.000540	0.000148	0.085874					
67	0.515332	-0.237537	-0.008401	0.000117	0.110292	0.405806	-0.093689	0.023275	0.000128	0.024162
68	0.547669	-0.314049	0.003841	0.000156	0.122370	0.606365	-0.390516	-0.009269	0.000145	0.021951
69	0.517301	-0.248839	-0.001490	0.000128	0.093823	0.424794	-0.041734	-0.124109	0.000061	0.018162
70	0.533134	-0.284080	-0.004472	0.000146	0.099304	0.376946	0.004715	-0.068832	0.000081	0.019936
71	0.534375	-0.297227	0.005665	0.000157	0.059422	0.696757	-0.503283	-0.037048	0.000139	0.018771
72	0.527723	-0.304915	0.028685	0.000166	0.075009	0.697499	-0.502310	-0.037131	0.000139	0.015100
73	0.532210	-0.304946	0.018856	0.000163	0.029445	0.695664	-0.503527	-0.032484	0.000144	0.020585
74	0.532710	-0.324635	0.041288	0.000173	0.044780	0.404988	-0.095442	0.020255	0.000124	0.018318
75	0.507196	-0.196693	-0.037312	0.000103	0.081028	0.697840	-0.501484	-0.035911	0.000141	0.015552
76	0.525201	-0.356876	0.081402	0.000206	0.094769	0.695334	-0.502524	-0.029458	0.000147	0.019828
77	0.529672	-0.288294	0.006728	0.000151	0.047482	0.406140	-0.095017	0.015367	0.000120	0.024758
78	0.528670	-0.316181	0.031071	0.000170	0.046321	0.694208	-0.503084	-0.028745	0.000149	0.020427
79	0.510261	-0.299300	0.044864	0.000175	0.062647	0.403564	-0.097571	0.021391	0.000126	0.019131
80	0.533949	-0.303146	0.013213	0.000155	0.086478	0.546219	-0.278738	-0.018208	0.000124	0.017746
81	0.515015	-0.308336	0.050301	0.000177	0.067253	0.610754	-0.383798	-0.012959	0.000139	0.032684
82	0.529629	-0.285982	0.006538	0.000147	0.067988	0.539262	-0.268001	-0.011846	0.000124	0.039949
83	0.527093	-0.314831	0.033276	0.000174	0.074984	0.508246	-0.230029	-0.011202	0.000124	0.020360
84	0.511384	-0.305312	0.047343	0.000188	0.096424	0.401982	-0.101189	0.033118	0.000130	0.031398
85	0.525139	-0.261187	-0.005724	0.000132	0.036417	0.402024	-0.099964	0.027658	0.000128	0.023893
86	0.524287	-0.264370	-0.005172	0.000138	0.048846	0.696135	-0.501323	-0.029260	0.000147	0.020725
87	0.520158	-0.280838	0.015097	0.000150	0.088778	0.699553	-0.497109	-0.040580	0.000141	0.029837
88	0.510239	-0.246543	0.002648	0.000135	0.117525	0.492521	-0.211418	-0.000154	0.000126	0.041384
89	0.525248	-0.276246	0.001478	0.000145	0.094025	0.490557	-0.200943	-0.005772	0.000119	0.016534
90	0.526587	-0.277618	0.001493	0.000146	0.061147	0.505303	-0.231421	0.002853	0.000127	0.020581
91	0.531627	-0.287823	0.004230	0.000150	0.111040	0.699135	-0.497025	-0.040304	0.000139	0.033962
92	0.523437	-0.282810	0.014655	0.000154	0.109164	0.609480	-0.451085	0.065802	0.000197	0.091676
93	0.506874	-0.222908	0.004907	0.000107	0.111116					
94	0.520519	-0.259221	-0.000479	0.000137	0.081166					
95	0.501916	-0.194606	0.018539	0.000138	0.088159					
96	0.522640	-0.272849	0.003129	0.000145	0.060961	0.492670	-0.208094	-0.007246	0.000123	0.025981
97	0.519180	-0.283234	0.014917	0.000154	0.082959	0.698237	-0.499422	-0.035920	0.000147	0.042723
98	0.534042	-0.275915	-0.006591	0.000135	0.083320	0.446371	-0.128621	-0.007465	0.000109	0.013784
99	0.522605	-0.270201	0.000893	0.000144	0.067569	0.406044	-0.100526	0.020403	0.000121	0.042262
100	0.522584	-0.266143	0.001110	0.000139	0.066456	0.405076	-0.098248	0.020449	0.000120	0.038391
101	0.520815	-0.270435	0.001967	0.000145	0.087136	0.693192	-0.498866	-0.027377	0.000154	0.031291
102	0.525651	-0.270329	-0.000469	0.000141	0.098838	0.469901	-0.160608	-0.011017	0.000110	0.035693
103	0.524404	-0.263961	-0.001334	0.000136	0.075948	0.406946	-0.096948	0.016400	0.000117	0.031326
104	0.518365	-0.266535	0.003285	0.000142	0.069254	0.428853	-0.095954	-0.010602	0.000102	0.028232
105	0.528976	-0.269413	-0.002078	0.000134	0.104911	0.691892	-0.499306	-0.021879	0.000156	0.031926
106	0.518852	-0.255249	-0.000274	0.000134	0.052223	0.430564	-0.098886	-0.010768	0.000102	0.025899
107	0.542638	-0.286916	-0.005663	0.000133	0.142384					
108	0.527812	-0.279738	-0.000353	0.000154	0.046445					

Table 7: **Missing data points in 2 dbar-averaged files for cruise in1801. "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/beam attenuation downcast; BS=backscatter downcast; F_up=fluorescence upcast; PAR_up=photosynthetically active radiation upcast; TR_up=transmittance/beam attenuation upcast. Note: 2 to 8 dbar values (i.e. first four bins) not included here as they're missing for many casts.**

station	pressure (dbar) where data missing	T	S/C	O	F	PAR	TR	BS	F_up	PAR_up	TR_up
6	10	x	x	x	x	x	x	x			
10	4520			x							
10	4682-4698			x							
12	4458	x	x	x	x	x	x	x	x	x	x
13	10	x	x	x	x	x	x	x			
21	10-14	x	x	x	x	x	x	x			
25	whole profile				x			x	x		
35	10	x	x	x	x	x	x	x			
41	10-12	x	x	x	x	x	x	x			
46	4392	x	x	x	x	x	x	x	x	x	x
48	10	x	x	x	x	x	x	x			
85	10-14	x	x	x	x	x	x	x			
100	2428-2430		x	x							
106	whole profile				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 in1801.**

station	suspect 2 dbar value (dbar)	parameters	comment
1	66-104	downcast trans/beam atten.	suspect profile shape, does not match upcast
3	26-90	downcast trans/beam atten.	suspect profile shape, does not match upcast
4	168-678	oxygen	bottles flagged out for calibration due to significant downcast to upcast profile difference
4	2-114	downcast trans/beam atten.	suspect profile shape, does not match upcast
5	80-690	oxygen	bottles flagged out for calibration due to significant downcast to upcast profile difference
5	50-70, 80-120	downcast trans/beam atten.	suspect profile shape, does not match upcast
6	46-64	downcast trans/beam atten.	suspect profile shape, does not match upcast
21	3600-3854	oxygen	may be low by ~2µmol/l as bottom 2 bottles flagged out for calibration
107	850-1002	oxygen	suspect as bottom bottle flagged out for calibration

<u>Table 9:</u> Obvious bad salinity bottle samples (not deleted from bottle data file) for cruise in1801 (note: there may be other less obvious ones).

station	rosette position	station	rosette position	station	rosette position
8	12	42	22	78	23
13	32	42	5	78	19
14	25	43	22	78	18
14	24	43	21	79	23
14	8	43	17	79	9
15	1	43	10	79	8
19	29	43	1	79	7
20	11	44	18	79	5
21	24	44	10	79	3
22	13	44	7	80	11
23	24	45	6	83	22
24	11	47	29	83	17
24	10	47	26	84	14
25	29	49	25	84	9
25	25	49	2	84	3
25	11	50	27	86	12
26	29	50	3	87	14
26	25	51	23	88	10
26	18	51	14	89	21
27	11	52	25	90	9
28	15	53	14	90	4
29	19	54	15	91	7
29	3	55	17	96	7
31	5	55	15	97	20
33	36	56	9	98	14
33	10	58	13	98	10
34	34	62	23	98	7
34	20	62	13	99	18
34	13	67	14	99	13
34	8	69	1	99	10
35	3	72	13	100	16
36	4	73	11	102	20
37	7	74	14	104	26
40	21	74	12	106	18
40	6	75	11	107	3
41	12	77	15		

<u>Table 10:</u> Suspect (qc flag=3) and bad (qc flag=4) dissolved oxygen bottle values for cruise in1801.

suspect samples (qc flag=3)

station	rosette position
1	33
21	2
92	28
107	2

bad samples (qc flag = 4)

station	rosette position
13	32
19	24
21	24
23	24
25	25, 29
26	25, 29
97	6
102	20

<u>Table 11:</u> Suspect (qc flag=3) and bad (qc flag=4) nutrient sample values for cruise in1801. For the nutrients, P=phosphate, N=nitrate+nitrite, S=silicate. In the comments, % refers to % of full scale (as listed in section 5.6). Note that nitrite and ammonia are difficult to QC, due to the low concentrations (approaching precision levels)

station	rosette position	nutrient	comment	flag
9	18	P,N,S	high by at least ~10%	4
36	31	P	possibly high by ~4%	3
56	31	N	possibly low by ~6%	3
81	7	S	possibly low by ~3%	3
102	32	P	possibly high by ~4%	3

<u>Table 12:</u> Scientific personnel (cruise participants) for cruise in1801.

Sophie Bestley	CTD
Benoit Legresy	CTD
Steve Rintoul	chief scientist, CTD
Mark Rosenberg	CTD, float deployments
Katherine Tattersall	CTD
Esmee van Wijk	CTD, float deployments
Dan Anderson	CFC
Mark Warner	CFC
Kate Berry	carbon
Joshua Denholm	carbon
Leo Mahieu	carbon
Craig Neill	carbon
Paula Conde Pardo	carbon
Abe Passmore	carbon
Andrew Bowie	GEOTRACES
Matt Corkill	GEOTRACES, most of everything and then some
Melanie East	GEOTRACES
Tom Holmes	GEOTRACES
Pauline Latour	GEOTRACES
Pier van der Merwe	GEOTRACES
Morgane Perron	GEOTRACES
Christine Weldrick	GEOTRACES
Swan Li San Sow	genomics
Kristina Paterson	hydrochemistry
Christine Rees	hydrochemistry
Kendall Sherrin	hydrochemistry
Stephen Tibben	hydrochemistry
Dan Buonome	CAPRICORN, radiosondes
Ruhi Humphries	CAPRICORN, co-chief scientist
Jay Mace	CAPRICORN, co-chief scientist
Kathryn Moore	CAPRICORN, monumental endeavour in aerosol lab
Alexander Norton	CAPRICORN
Chiemeriwo Godday Osuagwu	CAPRICORN
Isabel Suhr	CAPRICORN, radiosondes
Francis Chui	programmer
Matt Eckersley	doctor, CTD sampling
Ian McRobert	electronics
Peter Shanks	programmer
Tegan Sime	voyage manager
Aaron Tyndall	electronics

Table 13: Summary of float deployments on cruise in1801.

float type	serial	latitude	longitude	UTC time	depth (m)	CTD
APEX APF-11	8156	45° 13.787' S	145° 50.734' E	1525, 12/01/2018	2850	6
APEX APF-11	8155	49° 36.726' S	143° 55.663' E	2338, 17/01/2018	3683	16
NAVIS	0688	48° 19.229' S	144° 30.747' E	1824, 16/01/2018	4076	13
SOCCOM	12736	53° 35.285' S	141° 51.457' E	0200, 22/01/2018	2690	29
SOCCOM	12779	55° 30.261' S	140° 43.212' E	1722, 23/01/2018	4180	33
SOCCOM	12784	58° 21.637' S	139° 51.055' E	1413, 25/01/2018	3996	39
SOCCOM	12769	60° 21.810' S	139° 51.251' E	0503, 27/01/2018	4420	44
SOCCOM	12782	62° 51.266' S	139° 50.917' E	0946, 29/01/2018	3200	49
SOCCOM	12709	64° 48.6 ' S	139° 51.6 ' E	0243, 31/01/2018	2590	54
SOCCOM	12702	65° 24.617' S	149° 59.995' E	2018, 03/02/2018	2890	68
SOCCOM	12741	62° 00.410' S	149° 59.260' E	1342, 06/02/2018	3769	78
SOCCOM	12748	63° 30.140' S	132° 05.520' E	2044, 11/02/2018	4047	91
SOCCOM	12370	58° 29.60 ' S	132° 00.58 ' E	2142, 15/02/2018	4664	103
BIO FLOAT	??	60° 50.674' S	139° 51.088' E	2120, 27/01/2018	4389	45
pCO2 float	16003	60° 21.810' S	139° 51.251' E	0504, 27/01/2018	4420	44
pCO2 float	16011	63° 54.18 ' S	149° 59.83 ' E	0656, 05/02/2018	3660	74
pCO2 float	16001	60° 01.53 ' S	132° 12.93 ' E	0201, 15/02/2018	4660	100
pCO2 float	16009	56° 58.036' S	132° 09.574' E	1752, 16/02/2018	4532	106
deep SOLO	6042	60° 50.660' S	139° 51.968' E	2136, 27/01/2018	4388	45
deep SOLO	6041	61° 29.83 ' S	132° 00.12 ' E	0616, 14/02/2018	4538	97
deep SOLO	6040	60° 01.70 ' S	132° 12.94 ' E	0159, 15/02/2018	4660	100
deep SOLO	6039	58° 29.84 ' S	132° 00.58 ' E	2140, 15/02/2018	4664	103
deep SOLO	6038	56° 57.98 ' S	132° 09.50 ' E	1750, 16/02/2018	4532	106
Ninja (with O_2)	24	63° 21.31 ' S	139° 49.83 ' E	1642, 29/01/2018	3792	50
Ninja	22	65° 00.039' S	145° 30.106' E	0212, 03/02/2018	3340	67
Ninja	25	63° 30.157' S	149° 59.839' E	1556, 05/02/2018	3724	75
ARVOR	005	64° 13.274' S	139° 49.899' E	1524, 30/01/2018	3508	52
ARVOR	104	64° 36.226' S	149° 59.631' E	2042, 04/02/2018	3453	72
ARVOR	004	63° 05.287' S	132° 05.893' E	1510, 11/02/2018	4267	90

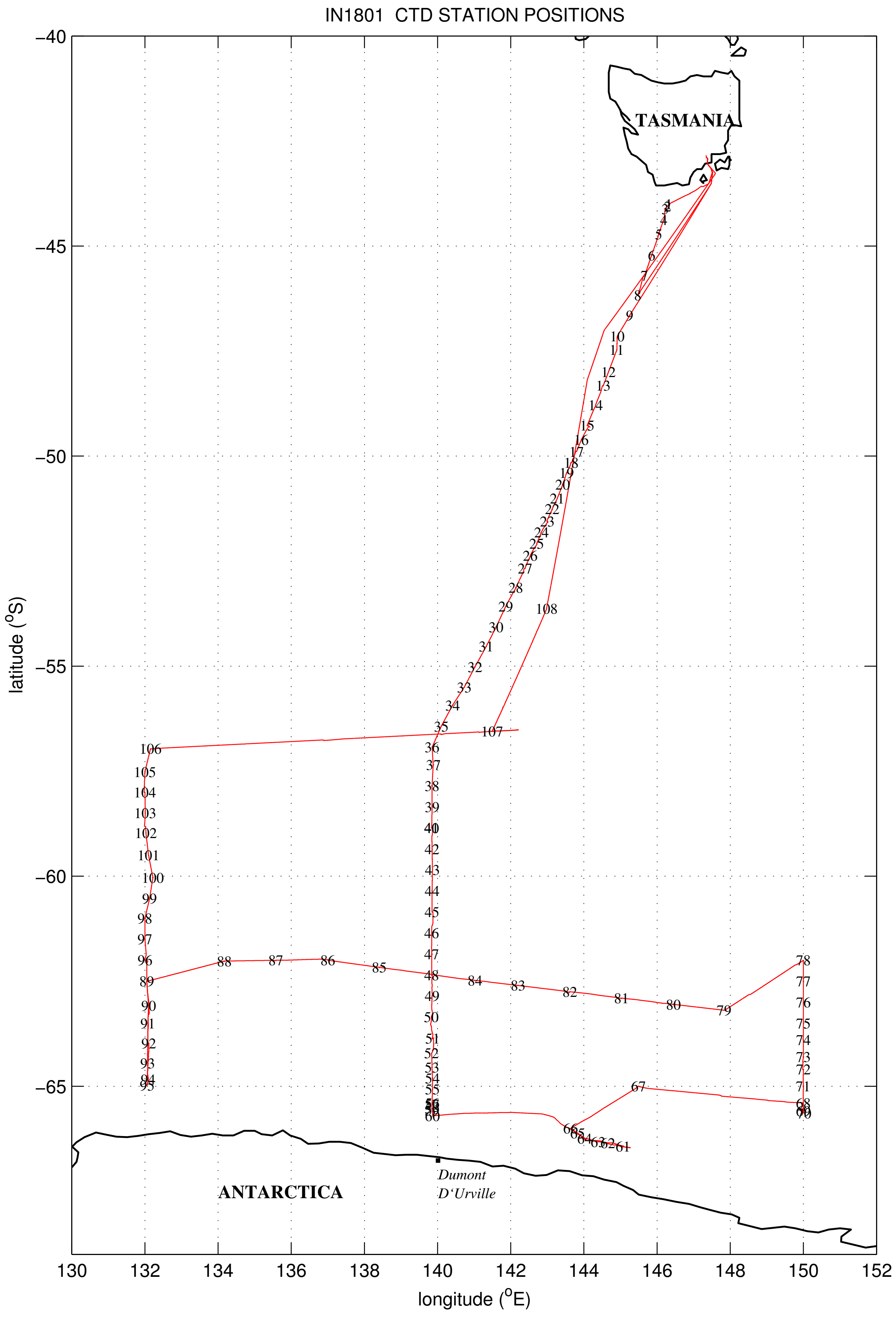
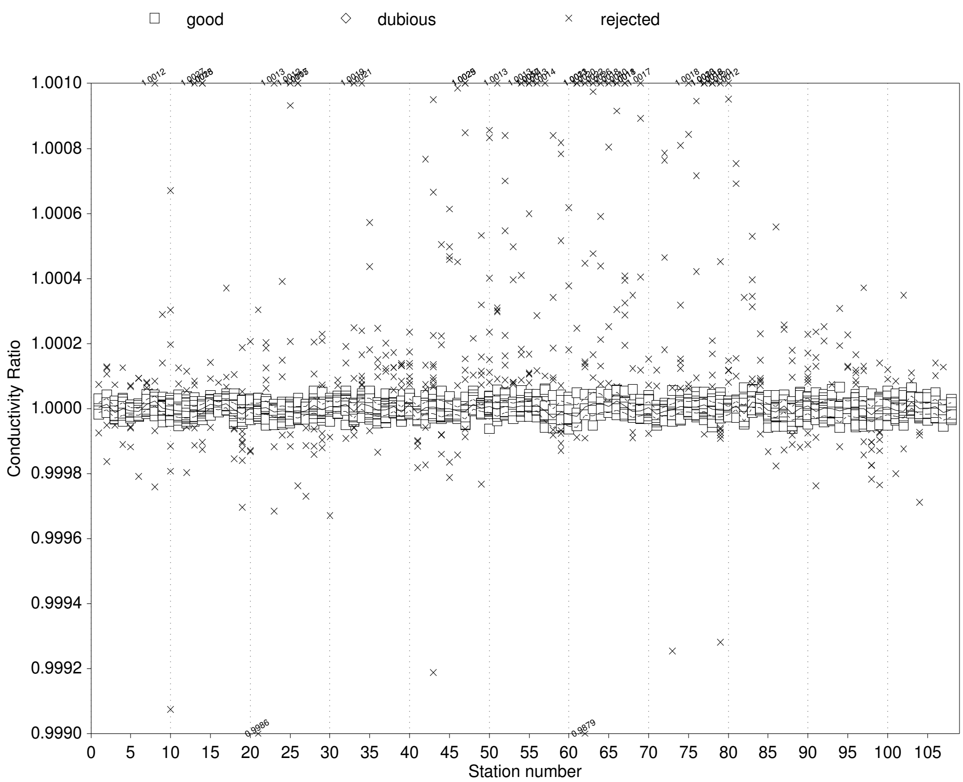


Figure 1: **CTD station positions and ship's track for cruise in1801.**



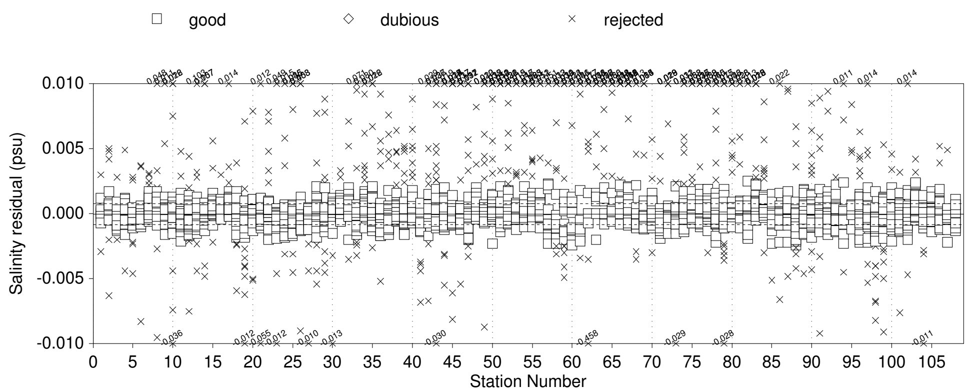
Calibration data for cruise : in1801

Calibration file : in1801.bot

Conductivity s.d. = 0.00002

Number of bottles used = 2353 out of 2815 Mean ratio for all bottles = 1.00000

Figure 2: Conductivity ratio c_{btl}/c_{cal} versus station number for cruise in1801. 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 : in1801

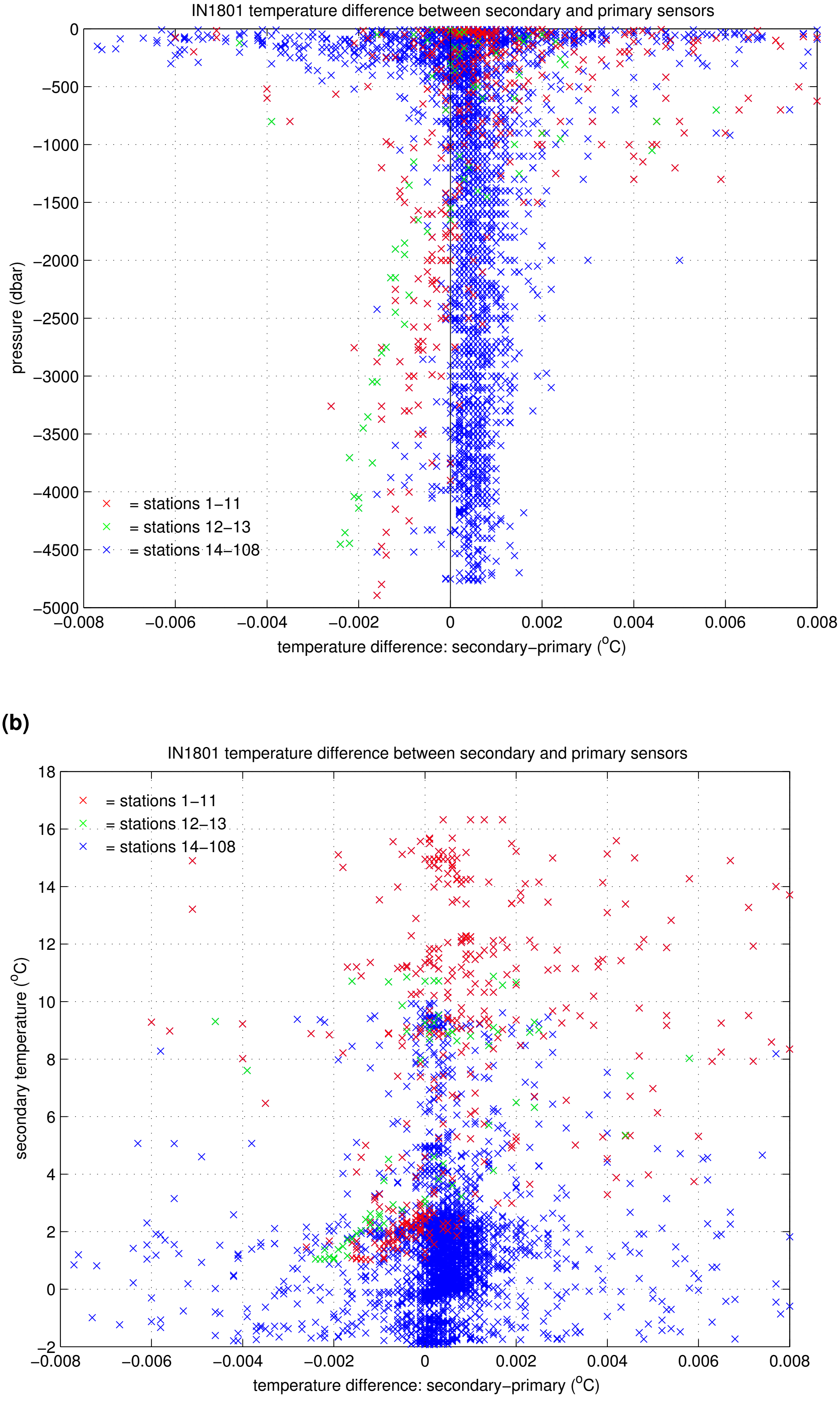
Calibration file : in1801.bot

Mean offset salinity = 0.0000psu (s.d. = 0.0008 psu)

Number of bottles used = 2353 out of 2815

Figure 3: Salinity residual (s_{btl} - s_{cal}) versus station number for cruise in1801. 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.

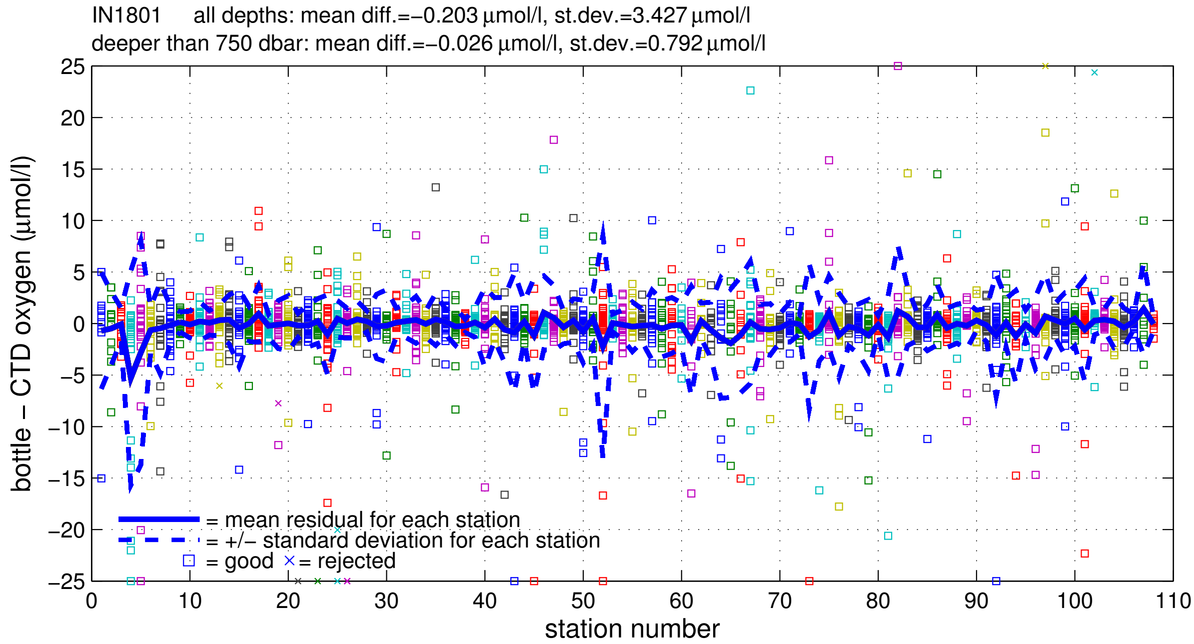


Figure 5: Dissolved oxygen residual (o_{btl} - o_{cal}) versus station number for cruise in1801. The solid line follows the mean residual for each station; the broken lines are ± the standard deviation of the residuals for each station. o_{cal}=calibrated downcast CTD dissolved oxygen; o_{btl}=Niskin bottle dissolved oxygen value.

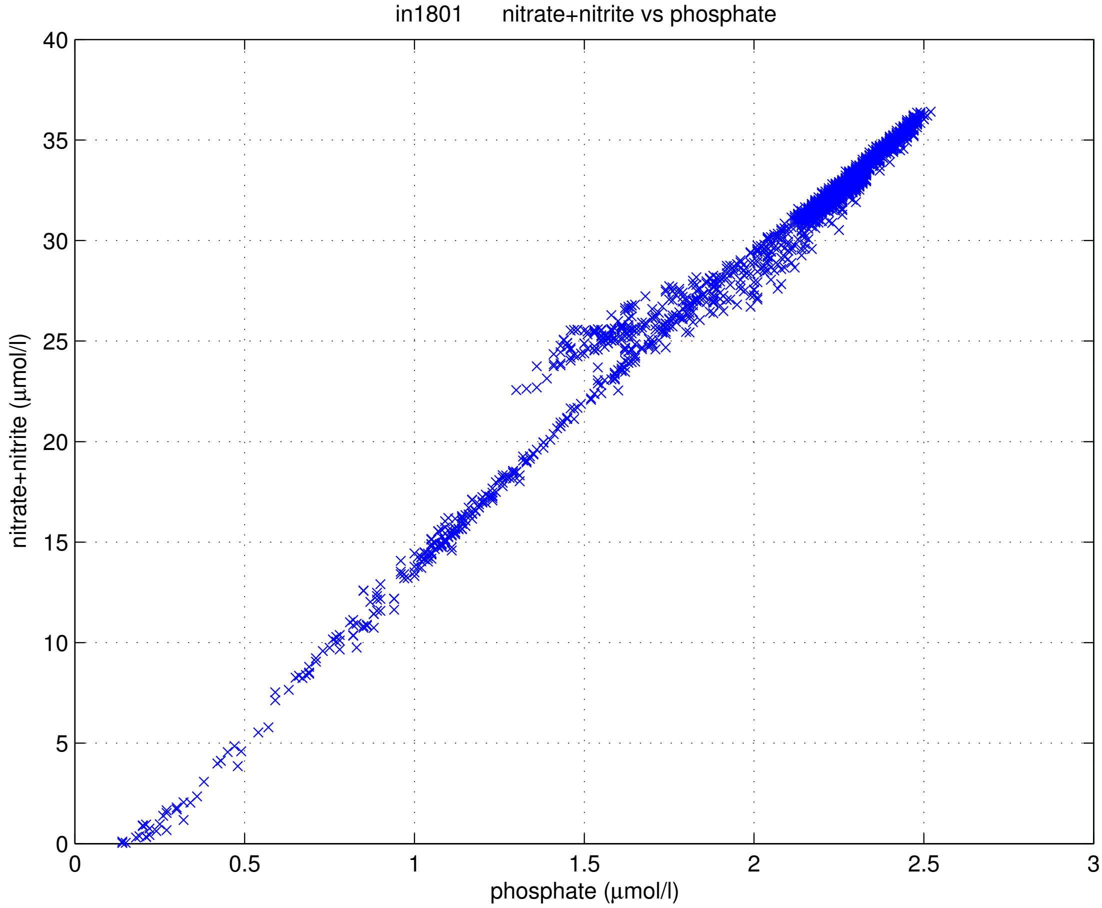


Figure 6: Nitrate+nitrite versus phosphate data for cruise in1801.

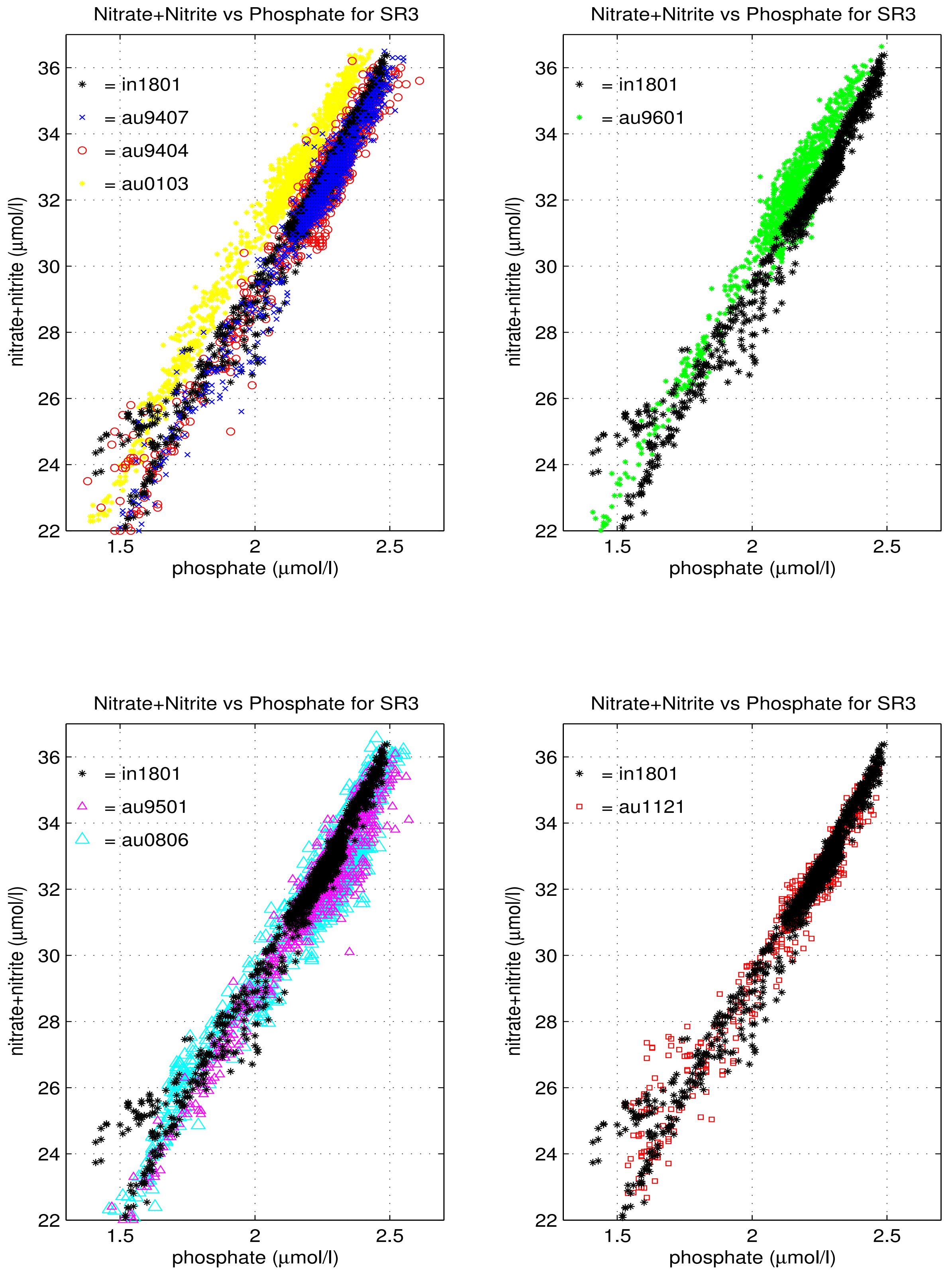
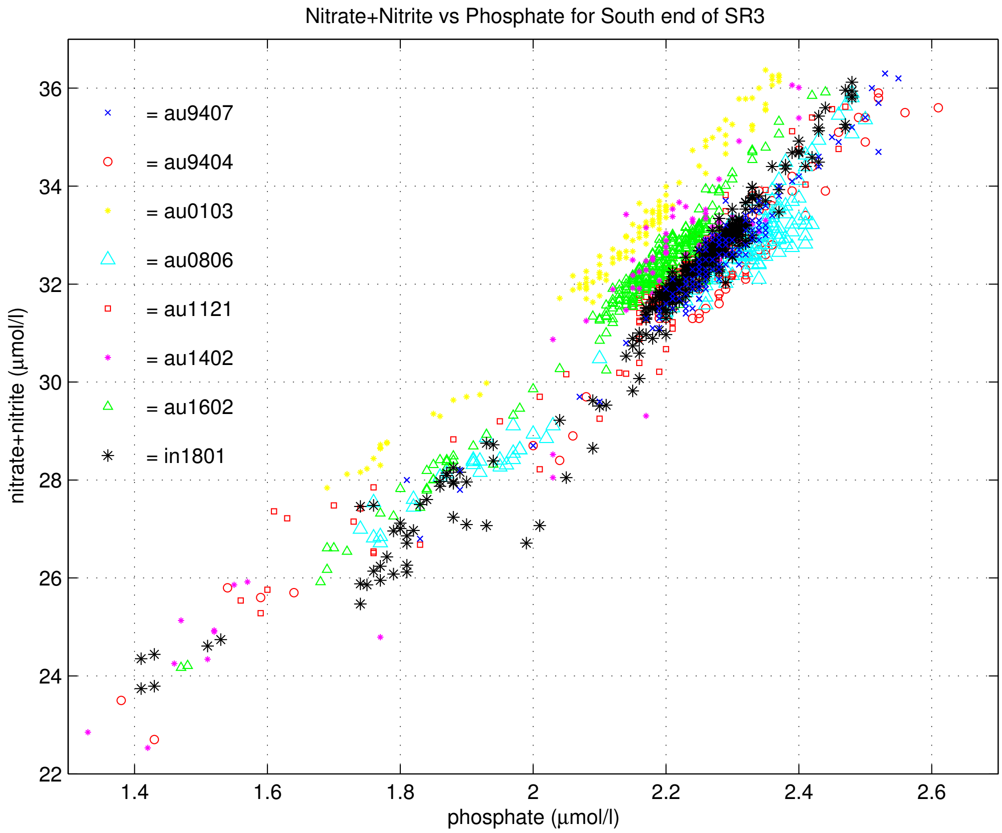
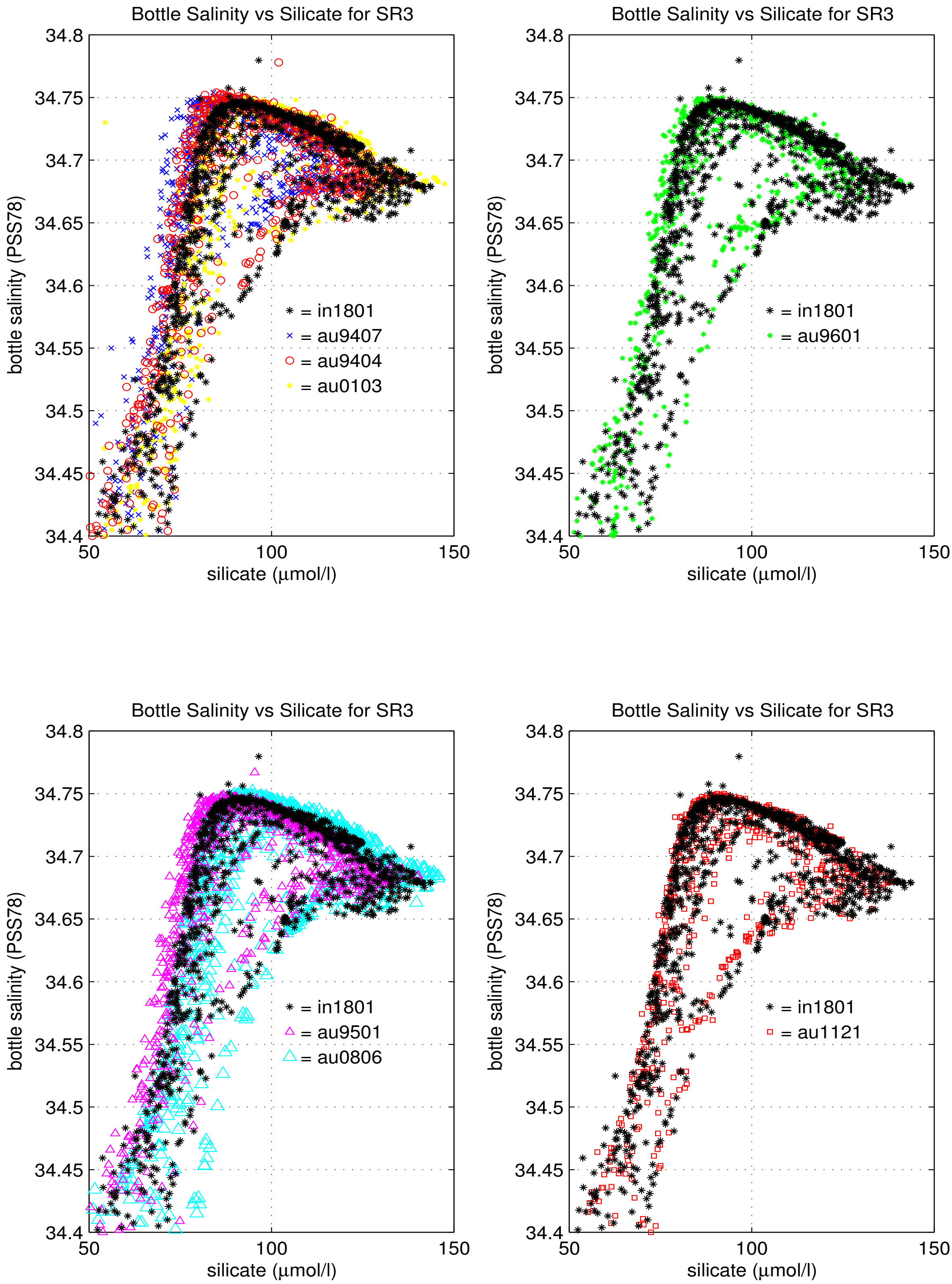


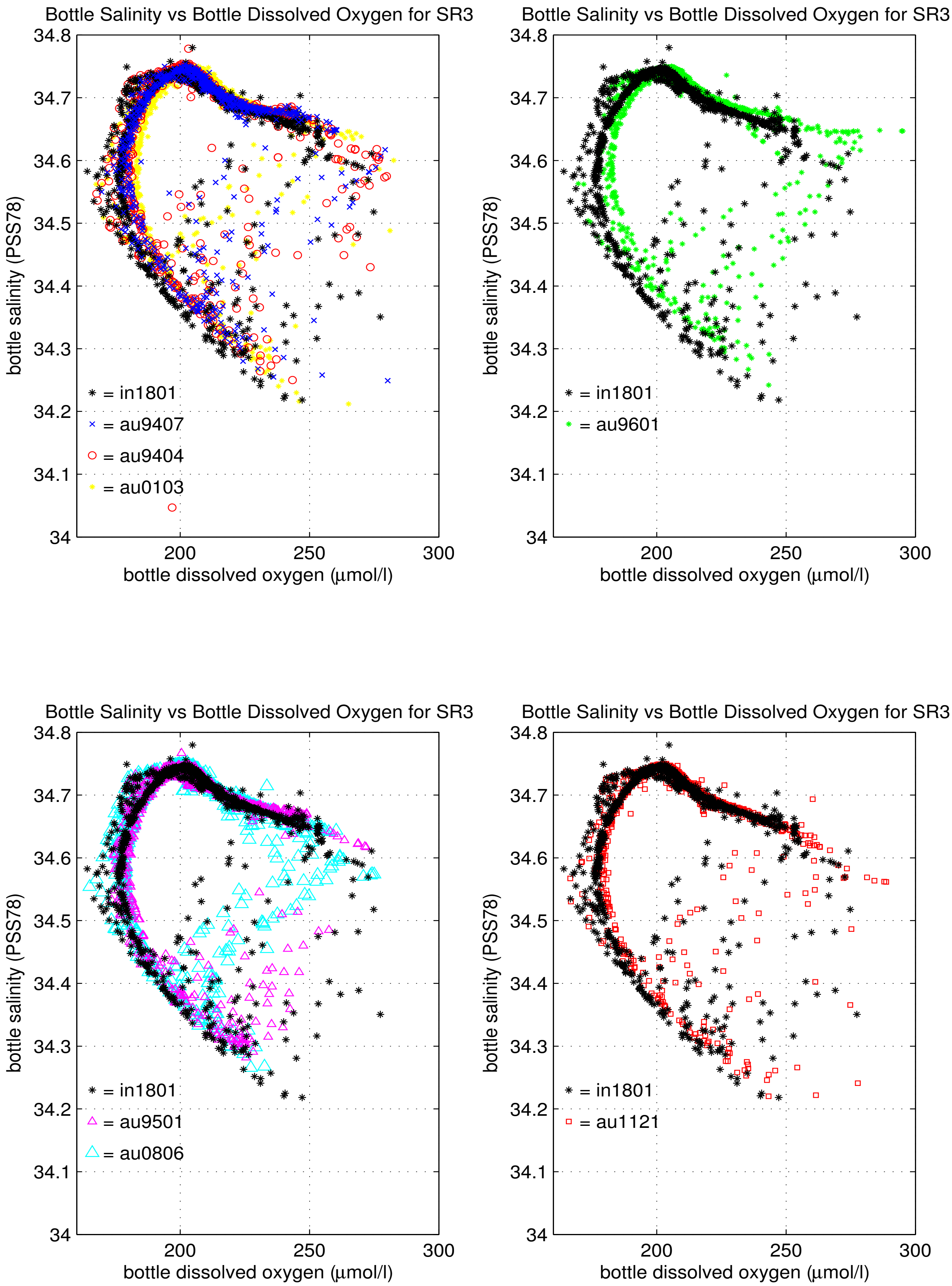
Figure 7a: Bulk plots showing intercruise comparisons of nitrate+nitrite vs phosphate data for SR3 (low end of nutrient values not included in plot).



<u>Figure 7b:</u> Bulk plots showing intercruise comparisons of nitrate+nitrite vs phosphate data for south end of SR3 (including cruises au1402 and au1602).



<u>Figure 8:</u> Bulk plots showing intercruise comparisons of silicate data for SR3, shown as bottle salinity vs silicate (low end of silicate values not included in plot).



<u>Figure 9:</u> Bulk plots showing intercruise comparisons of dissolved oxygen data for SR3, shown as bottle salinity vs bottle dissolved oxygen (and only plotting data below 500 dbar).

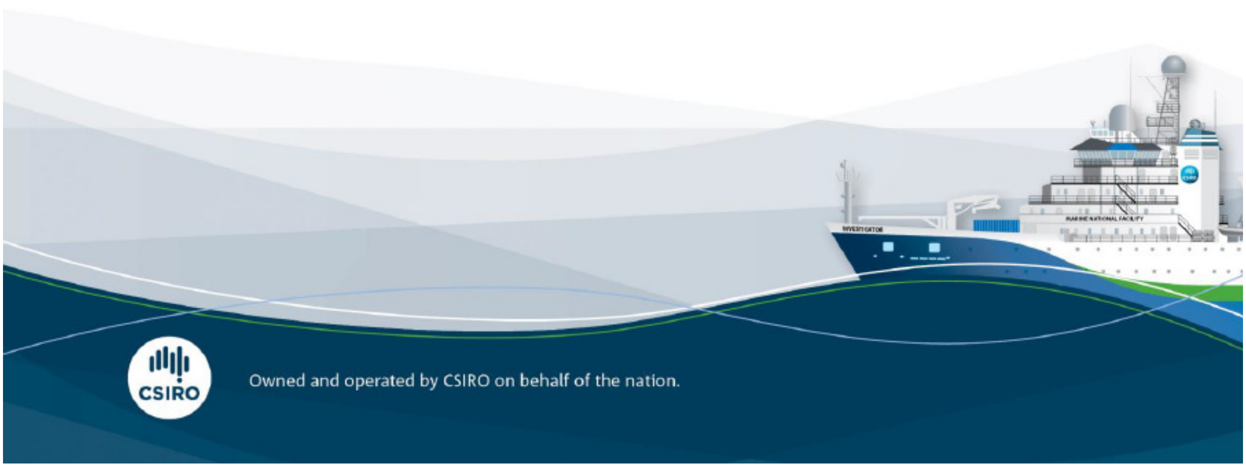
APPENDIX 1 – HYDROCHEMISTRY LAB/VOYAGE REPORT

Marine National Facility

RV *INVESTIGATOR*

HYDROCHEMISTRY VOYAGE REPORT

Voyage:	in2018_v01
Chief Scientist:	Steve Rintoul
Voyage title:	Detecting Southern Ocean change from repeat hydrography, deep Argo and trace element biogeochemistry & CAPRICORN
Report compiled by:	Christine Rees, Kendall Sherrin, Stephen Tibben, Kristina Paterson



Contents

MNF – Highlights, issues, incidents & near misses

The main objective of the voyage was to quantify changes in Antarctic Bottom Water in the Australian Antarctic Basin by analysing nutrients, salinity and dissolved oxygen samples. The samples were collected along the GO-SHIP hydrographic reference sections SR3 and S4, on the Antarctic shelf near the Mertz glacier and along two transect lines at 150°E and 132°E. Five nutrients were analysed; silicate, phosphate, nitrate + nitrite, nitrite and ammonium. This was the first time ammonium has been measured successfully on every station for a hydrographic voyage.

High quality data was produced for the three measured parameters. Certified reference materials for nutrients in seawater were within the specified limits of the certified value. The chief scientist highlighted to all participants that it is the best quality data ever collected along the SR3 transect and congratulated the hydrochemistry team on their efforts.

A large amount of time was spent during the voyage trouble shooting the Niskin bottles for leaks.

The Guildline salinometers were also problematic during the voyage, with one instrument needing a fan replaced which made the instrument unstable for the remainder of the voyage. The other instrument had a blockage on the inlet tubing within the water bath requiring a small amount of tubing to be removed where the blockage occurred.

There was one incident within the lab where the drain pipe leading from the Auto-Analyser-3 was knocked out of the scupper and the waste spilled over the laboratory floor. This caused slightly lower quality ammonium data for the samples being analysed at the time due to the Milli-Q water container becoming contaminated from ammonia fumes. The pipe was fixed and the lab floor was washed with a mop.

A freezing experiment for nutrient samples to determine how freezing affects nutrient concentrations over time was conducted on board during the voyage, the experiment is continuing on shore in Hobart.

Itinerary

Depart	Date	Time
Hobart	11/01/2018	0900
Arrive	**Date**	**Time**
Hobart	22/02/2018	1000

Key personnel list

Name	Role	Organisation
Tegan Sime	Voyage Manager	CSIRO
Steve Rintoul	Chief Scientist	CSIRO

Christine Rees	Hydrochemist	CSIRO
Kendall Sherrin	Hydrochemist	CSIRO
Stephen Tibben	Hydrochemist	CSIRO
Kristina Paterson	Hydrochemist	CSIRO

Hydrochemistry

Analysis parameter	Total Samples taken	Processing Status at voyage end
Nutrients (Seal AA3)	2825 CTD 63 UWY 108 EXP	Completed Completed Completed
Salinity (Guildline salinometer)	2819 CTD 30 TSG	Completed Completed
Dissolved Oxygen (automated titration)	2824 CTD 38 UWY 1 EXP	Completed Completed Completed

Analysis	Data files
AA3 Files	in2018_v01nut001 to nut103
DO files	in2018_v01oxy001 to oxy103
Salinometer Files	In2018_v01sal001 to sal108

CTD stations

Total No. of CTD Stations	108

Water sample bottles

- 36 bottle rosette used, 12 L Niskin bottles.
- Bottles were labelled next to the spigots to minimise confusion for samplers.
- Many issues were reported with the bottle end caps seating incorrectly. Members of the science personnel attributed this to the tightness of the tripped lanyards, and presence of large, heavy floats which could be pulled around in turbulent water or being brought on deck. In most cases this was a superficial issue, with bottles failing a leak test but their samples remaining unaffected. Large floats were removed and the lanyards were altered to better reflect the stock OTE configuration.
- Mark Rosenberg will provide a copy of the Log book as to what repairs were done to each niskin bottle, as the sampling teams took on the majority of this responsibility.

Nutrient analysis

Nutrient seawater samples assayed using a Seal AA3HR segmented flow instrument.

- Standards prepared were for Antarctic concentrations, Calibrant 6 used for NOx and Silicate. Two sets of stock standards were prepared and compared to the old set of stocks on board the ship (see appendix for results). The 2 sets were deemed good to use. Only stock set 1 were used during the voyage.
- Working standards were prepared one at a time and decanted immediately into the 30 ml polypropylene tubes, this was to minimize silicate contamination.
- Intermediate standards were prepared approximately every 3 days.
- CTD Samples were collected in 50 ml HDPE bottles with screw cap, underway samples were collected in 10 ml polypropylene tubes with screw cap and experimental samples were collected in 30 ml polypropylene tubes with screw caps.
- A Reference Material Nutrient Seawater (RMNS CC, CB & CD) was analysed initially on first run. Thereafter CC was run in every analytical run and CB and CD ran intermittently.
- All samples assayed within 12 hours of collection, samples were kept in the dark or refrigerated until analysis. Samples were taken out of fridge at least 2 hours before analysis.
- Tray protocol consisted of after each Drift, a Null (LNSW), Null (wash), Baseline (MQ) –this improves the ammonium analysis and helps stop the low ammonium samples from going negative.
- The concentrated sulphuric acid (H_2SO_4) trap for ammonium (NH_4) analysis was changed to 10% H_2SO_4, as the pH is still low enough to trap NH_4 and it is safer.
- The standard cleaning protocol after each run was performed. This consisted of MQ water for 10 minutes and then 10% Hypochlorite for each channel except NH4 and 10% HCl through the NH4 channel for 10 minutes followed by MQ for 10 minutes.
- If there was noise seen in the phosphate or silicate channel then they were given an extra clean with NaOH and EDTA.
- The MQ containers and wash pot were also cleaned regularly with 10% Hypochlorite.
- The pump tubes were changed approximately every 70 hours, pharmed air tubing was changed twice during the voyage.
- The Cd column was changed when the conversion efficiency dropped to 98%.
- The CTD samples were warmed in the sink in 16-20°C water.
- The lids were kept on the samples until all the standards and QC's had been analysed. Then they were removed and covered individually with foil.
- All data files on Nutrient PC – AACE software saved in voyage folder (in2018_v01)
- For run nut021, the ammonia results are slightly lower than expected due to a higher than usual background. The cause of the higher background was identified after the run, the culprit being the drainage pipe had become misaligned with the scupper.

This caused the AA3 waste, containing high concentrations of ammonium, to be spilt across the lab and under the benches. This was immediately cleaned up, with the floors being completely cleaned before the next analysis. The background was significantly lower for the next analysis. The drain pipe was fixed before the end of the day to ensure this same issue could not happen again. It was likely caused by the rough sea conditions and a tote box sliding into the pipe and knocking it from the scupper.

- Nitrite analysis was repeated on CTD25 and 26 due to the RMNS, internal QC and BQC all stepping up, the waterfall profiles also showed the samples were offset from previous CTD's. The repeated results were better, the cause may have been the NEDD colour reagent.
- On CTD 56 run Nut056 the nitrite baseline stepped up on sample 5627 and 5625, then stepped back down on 5624 and 5623 but then stepped back up on 5622 and stayed elevated. Drifts are also elevated and end baselines. Flagged all data for NO2 as bad.
- Communication was a problem to the auto-sampler, however once the serial/usb cable was changed to a different type this problem no longer occurred.

Salinity analysis

- Guildline 71613 was calibrated with OSIL P161.
- 21/1/2018. The salinometer started up as usual and a new file was created. Before a sample could be run the software displayed the error message that comms had been lost. Reconnecting the software using the connect button on the top right resulted in a 'run time error 5' message and the software shutting down. This was resolved by restarting the computer twice and did not recur on the 21/1. The salinometer had previously lost comms twice during the same run (a few days prior), each time it was thought to be due to flushing the cell while still in the read position. The two errors may or may not be related
- 24/1/2018 06:30 UTC prior to new run (during the setup phase) the fan of salinometer 71613 failed (partial failure) characterized by very loud buzzing noise and vibrations as it rattled the external case. Possibly bearings? It was replaced and sampling resumed.
- 30/01/2018 salinometer 71613 began 'wandering' throughout analyses. Sample conductivity measurements would drift to lower values during each reading. Samples were analysed on the backup instrument, 72151, with on issues.
- 31/01/2018 salinometer 71613 bath was drained and conductivity cell removed from inside. Cell removed from electronics and cleaned with a mixture of 85% ethanol (methanol suggested but not available), 15% Milli-Q water, and 5% Decon-90. The cell was left to soak in this solution for 24 hours before being flushed with Milli-Q

and reassembled inside the instrument. The lamp globes were replaced and the bath was refilled with new Milli-Q water before the instrument was powered back on.

- 08/02/18 – after a few runs of sporadic bad readings that were not also reflected in sensor or oxygen/nutrient their cause was investigated. It was noted that some inserts were split very close to the cap-side edge and thus likely not sealing the sample correctly. The clean inserts were then inspected between analysis and being handed to the samplers and any compromised pieces removed. In addition, the container for the clean inserts was also rinsed clean and wiped dry to remove any salt that may have accumulated during the voyage.
- Cast 103 sampled without using sampling tube.
- 15/2/2018 During analysis of CTD 099 salinometer 72151 began to struggle with flushing/rinsing the cell. More speed on the pump was needed to push the sample through the cell and noticeable back pressure built up on occasions leading to leaks after the peristaltic pump and the tubing popping off at that location. Cleaning with ethanol helped for a short time. The next day the salinometer was opened, tubing relating to the air flush of the cell and sample water flow path was cleaned with fine copper wire. This did not resolve the problem and SITS (Ian McRoberts) attended, found there was a build-up of material at the end of the inlet flow path where it connects to a stainless steel through to the temperature controlled bath. Cutting out the affected part of tubing and reattaching was enough to solve the problem.
- The second (and final) TSG calibration samples run on 21 Feb 2018 ran under filename in2018_v01SalTSGcalibrationfilebatch2. This file name was too long for the export .csv excel file function of the software and caused an error. A print screen of the results is located with the other TSG calibration data in V:\current\hydrochem\hypro\Salinity\TSG Cal Results.

Oxygen analysis

- Water bath started leaking quite severely out the front, where the clear acrylic joins to rest of the water bath. The brown adhesive used to seal the join had become brittle and cracked under slight pressure from a flask. This was fixed by using some *Aquafix*, a waterproof epoxy. It is flexible and should resist cracking and forming leaks.
- DO instrument lost connection to computer, the standardisation information was lost from the day, reverting to the previous day's standardisation. Standardisation information was written down in log book however, so samples were analysed using old standardisation. The results were then recalculated using the macro and results copied back into the .LST for HyPro to read in. This affected files oxy008-009.
- 31/01/2018 UV lamp would not power on before analysis of CTD 54, so it was replaced. CTD 54 was analysed the following day. Detector voltages were more stable after the installation of a new lamp.
- 14/02/2018 sample line from bottle to burette split. Air was dispensed into one sample (CTD97 RP06) which gave a bad result. This was apparently due to over-

tightening of the connection which had damaged the sample line. The damaged piece of sample line was removed and the new opening flanged to provide a functional seal.

HyPro 5.3

- Version of HyPro 5.3 was used for the voyage.
- Initially Log editor was not functioning due to scripts between seasave and CAPPro not working. However Dap fixed this issue on the 12/01/2018.
- Issue arose where nutrient run nut011, did not have a CC for NOx due to restart of analysis. HyPro did not have the capability to deal with this scenario, Francis however fixed this issue by checking if a CC exists, if not it proceeds without producing a plot for column efficiency. See AA3Analysis.m line 2494.
- Occasionally for NOx placing the # at the beginning of the peak start column did not flag the data as BAD, and a # would need to be placed in front of the AD value column for the data to be flagged as BAD.
- Salinity and the CTD salinity was incorrectly plotted at times within the waterfall plots. It looked like there was an offset when there wasn't one.
- Suggestions for HyPro updates:
    - HyPro to have same flagging system as "WOCE"
    - Option to export BAD data within the deployment data to csv
    - Option to not export BAD data to netcdf file

Milli-Q Systems

- No issues, routine maintenance was performed during mobilisation for in2018_v01. See maintenance log for more information.

General Labs

- 12/02/18 Lime boxes were low on limestone. Refilled by Kendall with new limestone. This new limestone seemed to be a higher purity than the previous batch. New batch is completely white. Old batch was mottled and left undissolved gravel pieces which were cleared out of the boxes in the Hydrochemistry lab.
- HyPro matlab processing computer is suspected to have a Trojan/adware and kept on downloading, processing data and sending data back to unknown IP addresses. It was using the majority of the ships bandwidth so was switched off from the internet.
- The folder in2018_v01_AA3_files for storing a backup copy of the AACE run files also had the master.anl and a few other files copied and placed into it. These do not automatically get copied to this folder. The master .anl file is required if you want to process the run files through AACE.
- The master .anl file was accidently deleted twice from the AACE folder in2018_v01, which meant the run files would not work. The file was restored the first time from

the bin on the desktop and the second time from the backup copy in the in2018_v01_AA3_files folder.

Consumables given

- Order more tubing for the AA3: 116-0536-18c
- Order more of inlet tubing on guildlines
- Order 100 ml plastic measuring cylinder
- Order 1 litre plastic conical flask with screw lid for nutrients
- 2 litre amber coloured bottle for OPA reagent

Freight to ship

- N/A

Freight from ship

- N/A

Recommendations for next voyage

Chemistry inventory

Available to view in Hydrochemistry confluence:

https://confluence.csiro.au/display/HYD/Hydrochemistry

Temperature Plot

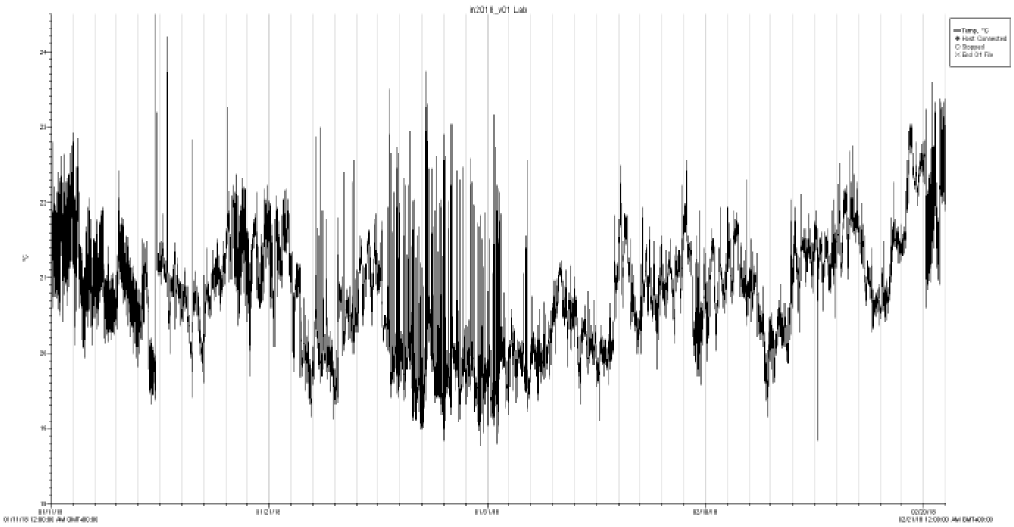
The AC in the nutrient lab was set to cool at 21°C and the salinity lab cool at 24°C on leaving Hobart.

AC in salinity lab was set on heat 24°C while the main laboratory AC was set to cool 21°C. The salt lab was still being cooled however, indicating that the slave control unit is the one in the salt lab. Once the main laboratory AC was switched to heat 20°C, the salt lab was heated. This change occurred on the 16/01 at approximately 0630 local time. The main lab was changed to heat at 19°C a couple hours after the initial change and the fan was set at 2.

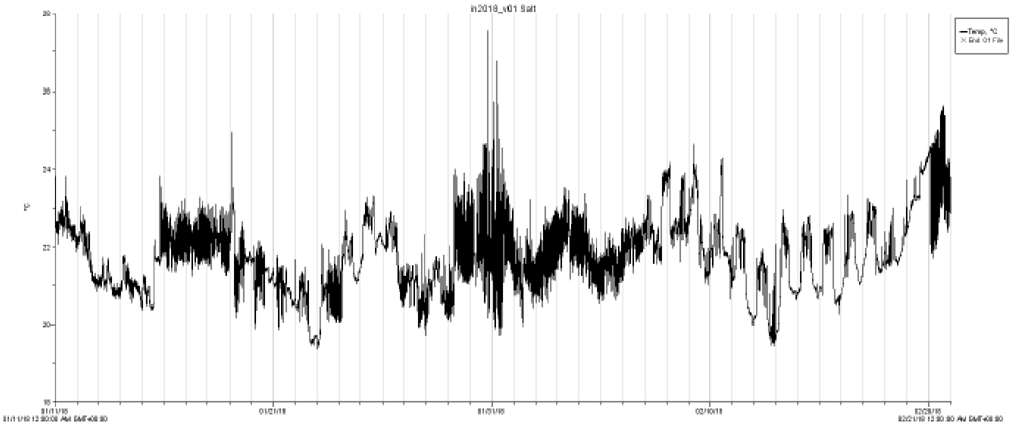
On the 19/01/2018 the temperature in the salt lab was too hot and the AC's were switched to cool again. Main lab was cool at 22°C initially and then later 21°C as it was still over 22°C. The salt lab was set to cool at 24°C. On the 31/01/2018 the AC in main lab was set back to heat at 18°C as the room was still too warm.

Along with the Hobo temperature profiles, laboratory temperature was logged into Grafana.

Hydrochemistry Lab (file located in voyage folder): Scale is 18°C to 24.5°C



Salinity Lab (located in salinity folder): Scale is 18°C to 27°C



Miscellaneous

Appendix

Table 1. Mean concentrations after 10 measurements of a Cal 3 produced from each stock standard. The percentage difference between the new stock standard mean and the old stock standards means is shown.

	Old Stock (A/D)	New Stock 1 (A/D)	New Stock 2 (A/D)
NOx	36958.7	36978.5	37018.59
Difference to Old		0.054%	0.162%
Phosphate	37653.2	37698.2	37665.6
Difference to Old		0.119%	0.033%
Silicate	16459.1	16466.1	16432.5
Difference to Old		0.042%	-0.162%
Nitrite	19550.5	19506.2	19468.8
Difference to Old		-0.227%	-0.420%
Ammonia	33390.8	32840.8	32642.0
Difference to Old		-1.67%	-2.29%

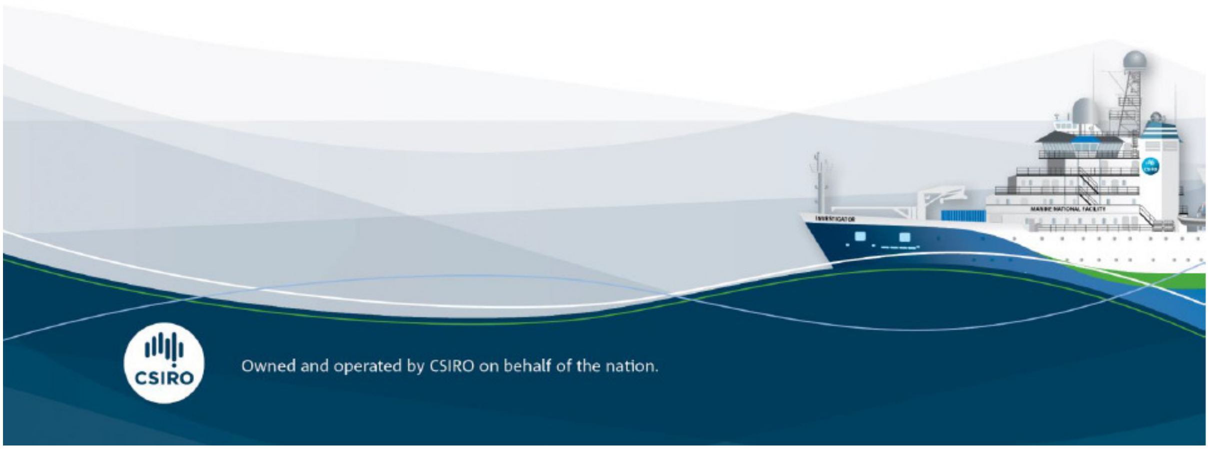
APPENDIX 2 – HYDROCHEMISTRY DATA PROCESSING REPORT

Marine National Facility

RV *INVESTIGATOR*

HYDROCHEMISTRY DATA PROCESS REPORT

Voyage:	IN2018_v01
Chief Scientist:	Dr. Steve Rintoul
Voyage title:	Detecting Southern Ocean change from repeat hydrography, deep Argo and trace element biogeochemistry & CAPRICORN
Report compiled by:	Christine Rees, Kendall Sherrin, Stephen Tibben & Kristina Paterson



Contents

1 Executive Summary

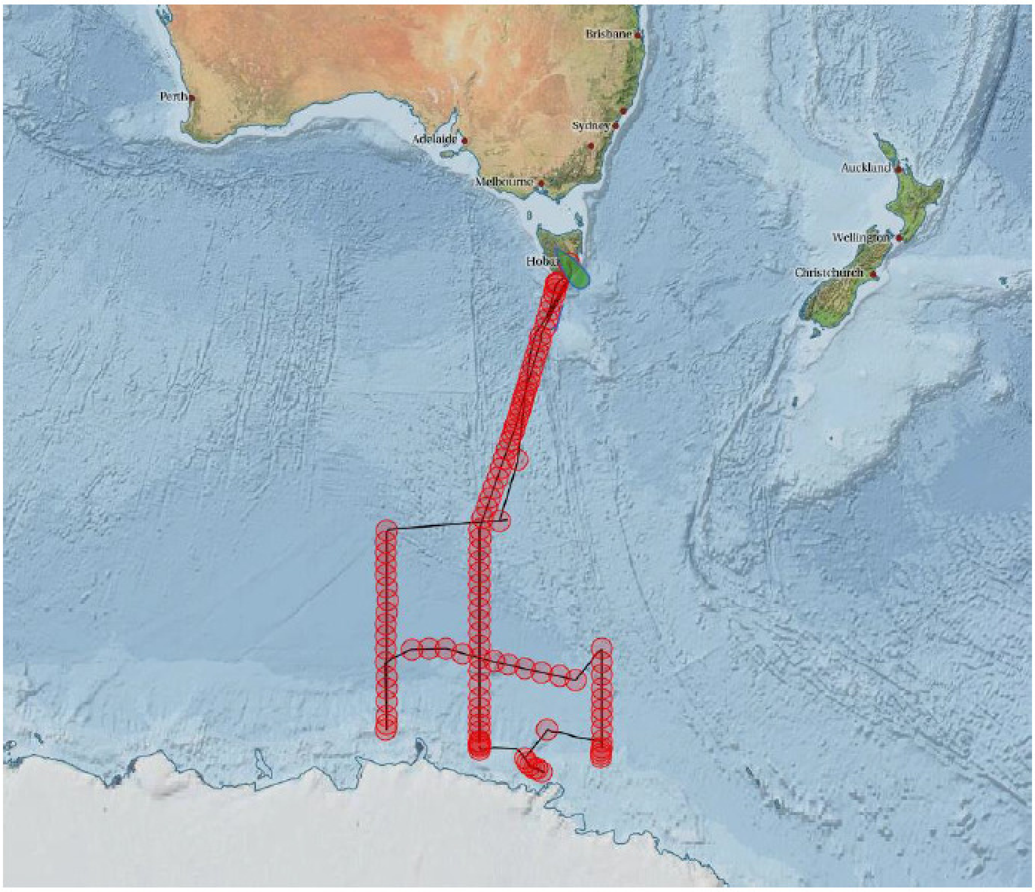
Nutrients, dissolved oxygen and salinity samples were collected and analysed through the full depth for climate studies and to quantify changes in the Antarctic Bottom Water in the Australian Antarctic Basin. The samples were collected along the GO-SHIP hydrographic reference sections SR3 and S4, on the Antarctic shelf near the Mertz glacier and along two transect lines at 150°E and 132°E. Five nutrients were analysed; silicate, phosphate, nitrate + nitrite, nitrite and ammonium. This was the first time ammonium has been measured successfully on every station for a hydrographic voyage.

High quality data was produced for the three measured parameters. Certified reference materials for nutrients in seawater were within the specified limits of the certified value.

All finalized data can be obtained from the CSIRO data centre Contact: DataLibrariansOAMNF@csiro.au.

2 Itinerary

Hobart to Hobart 11 January 2018 to 22 February 2018



3 Key personnel list

Name	Role	Organisation
Steve Rintoul	Chief Scientist	CSIRO & ACE CRC
Tegan Sime	Voyage Manager	CSIRO
Alain Protat	Principal Investigator	Bureau of Meteorology
Andrew Bowie	Principal Investigator	IMAS-UTAS/ACE CRC
Bronte Tilbrook	Principal Investigator	CSIRO & ACE CRC
Lev Bodrossy	Principal Investigator	CSIRO
Christine Rees	Hydrochemist	CSIRO
Kendall Sherrin	Hydrochemist	CSIRO
Stephen Tibben	Hydrochemist	CSIRO
Kristina Paterson	Hydrochemist	CSIRO

4 Summary

4.1 Hydrochemistry Samples Analysed

Analysis	Number of Samples
Salinity (Guildline Salinometer)	2819 CTD 30 TSG
Dissolved Oxygen (automated titration)	2824 CTD 38 UWY 1 EXP
Nutrients (AA3)	2825 CTD 63 UWY 108 EXP

Note:

- Conductivity Temperature Density (CTD); samples collected from NISKIN bottles on the CTD rosette.
- Underway (UWY); samples collected from underway clean instrument seawater supply in the PCO2 lab.

- Experimental (EXP): sample from microcosm experiments
- For sample information on UWY and EXP samples refer to the Hydrochemistry ELog from the voyage.

4.2 Rosette and CTD

- 108 CTD stations were sampled with a 36 bottle rosette (12 L).
- See in2018_v01_HYD_VoyageReport.pdf (voyage report) for more details on sample collection.

4.3 Data Procedure Summary

The procedure for data processing is outlined below.

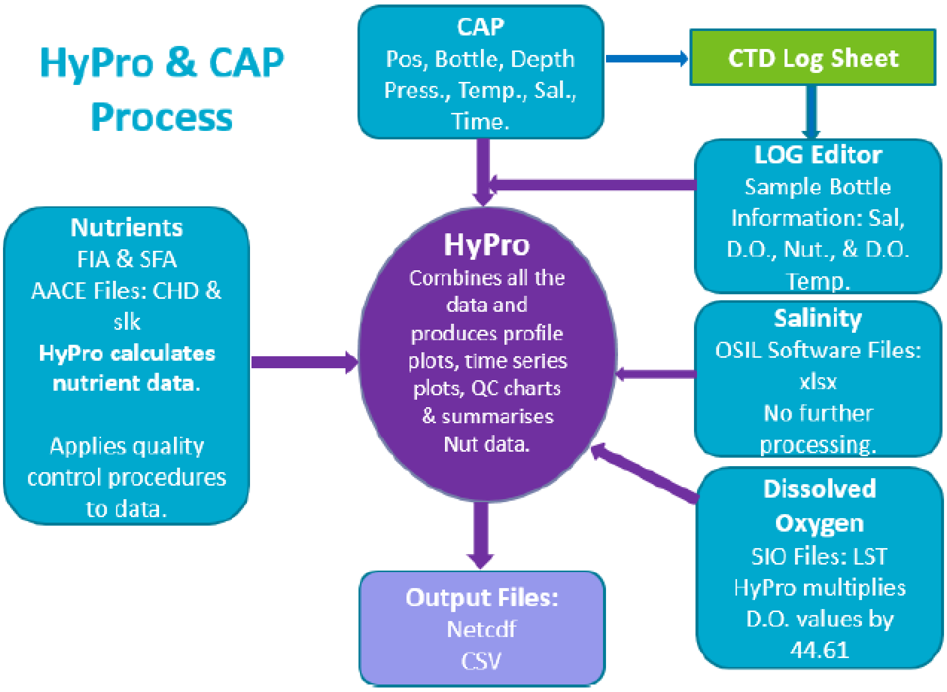


Figure 1: The processing steps for hydrology data following sample assay.

5 Salinity Data Processing

5.1 Salinity Parameter Summary

Details	
HyPro Version	5.3
Instrument	Guildline Autosal Laboratory Salinometer 8400(B) – SN 72151 and SN 71613
Software	OSIL Data Logger ver 1.2
Methods	Hydrochemistry Operations Manual + Quick Reference Manual
Accuracy	± 0.001 practical salinity units
Analyst(s)	Kristina Paterson
Lab Temperature (±0.5°C)	21.5 -23.5°C during analysis.
Bath Temperature	24.01°C
Reference Material	Osil IAPSO - Batch P161 and P158 (see appendix 8.1)
Sampling Container type	200 ml volume OSIL bottles made of type II glass (clear) with disposable plastic insert and plastic screw cap.
Sample Storage	Samples held in Salt Room for 6 -12 hrs to reach 22°C before analysis
Comments	Both instruments were used interchangeably

5.2 Salinity Method

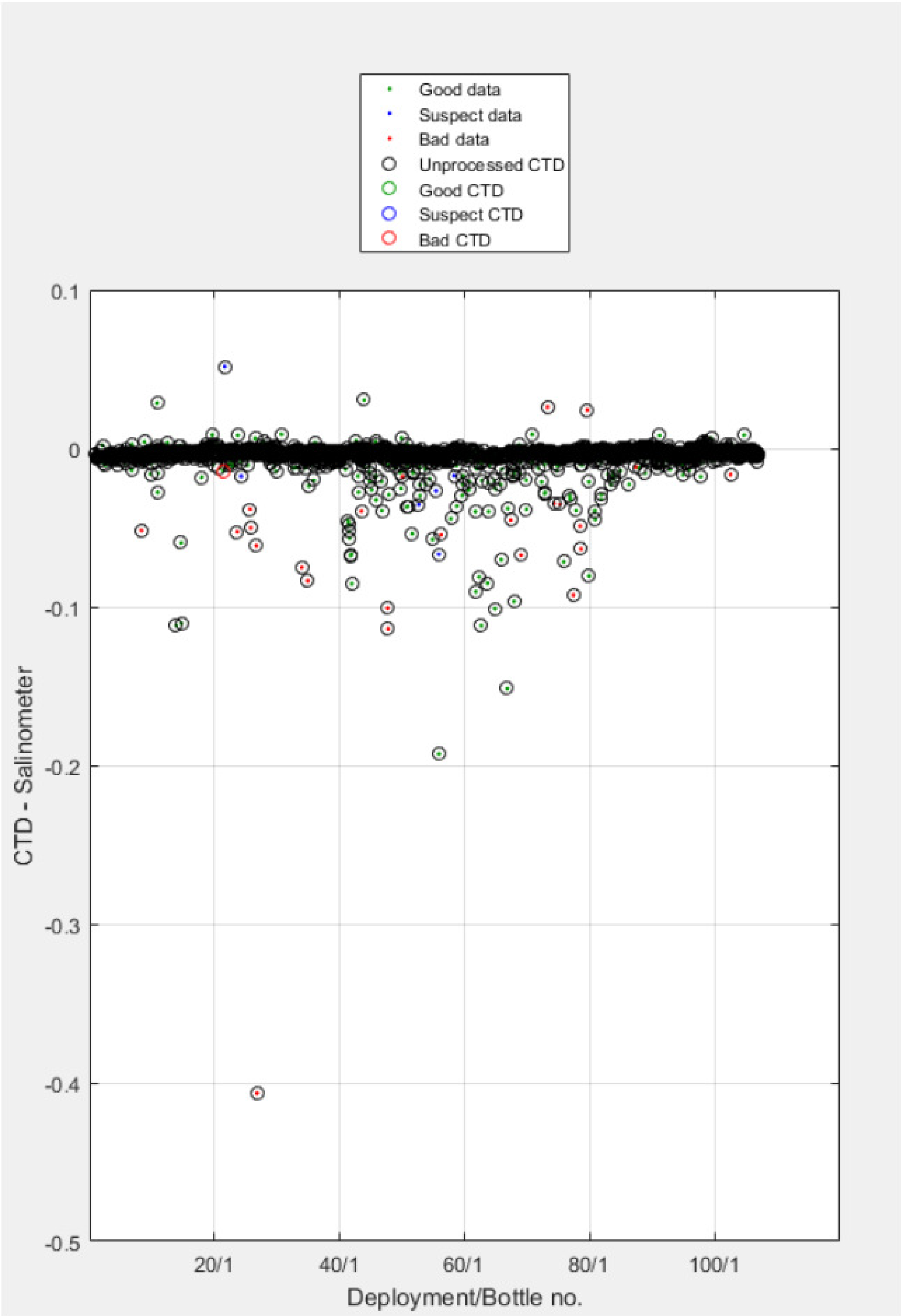
The method uses a high precision laboratory salinometer (Guildline Autosal 8400B) which is operated in accordance with its technical manual.

Practical salinity (S), is defined in terms of the ratio (K_{15}) of the electrical conductivity measured at 15°C 1atm of seawater to that of a potassium chloride (KCl) solution of mass fraction 32.4356 x 10^{-3}.

The Autosal is calibrated with standard seawater (OSIL, IAPSO) of known conductivity ratio against which the samples are measured. The Autosal is calibrated before each batch run of samples.

Salinity samples are collected into 200ml OSIL bottles –from the bottom via a PTFE straw filled till overflowing. The sample is decanted to allow a headspace of approximately 25cm^3. A plastic insert is fitted, the bottle inverted and rinsed then capped and stored cap-down until measured. To measure, the salinometer cell is flushed three times with the sample and then measured after the fourth and fifth flush. Further flush-measurement cycles are done where the initial values are more than 3 digits different. The conductivity ratio data is captured by the Osil data logger v1.2 program which then calculates the practical salinity.

5.3 CTD Salinities vs Hydrochemistry Salinities Plot



5.4 Missing or Flagged Salinity Data and Actions taken

Data is flagged based on notes from CTD sampling log sheet, observations during analysis, and examination of depth profile and waterfall plots.

CTD	RP	Run	Flag	Reason for Flag or Action
008	D12	8	133	Salinometer measurement was good, potentially sampled from the wrong niskin (niskin 11).
021	K16	021	133	Bottle was dropped/some sample spilled. The subsequent reading was at first unstable (poor agreement between readings) then stable but comparatively low salinity/out of profile.
021	K24	021	133	Salinometer measurement was good. Comparatively low salinity/out of profile.
023	E24	023	133	Comparatively high Salinity/out of profile, unusual nutrient and cfc data points suggests bottle fired at wrong depth
024	K10	024	69	First effort to sample was unstable, second effort was comparatively stable across 3 readings but high compared to CTD/out of profile.
025	C25	025	133	Out of profile (as is nuts and possibly other measurements) likely fired at wrong depth
025	C29	025	133	Out of profile (as is nuts and possibly other measurements) likely fired at wrong depth
026	E29	026	69	Sample was unstable during analysis (three attempts to make a stable measurement), cause unknown
026	E25	026	133	Sample was analysed ok, result out of profile cause unknown
033	C10	033	133	Salinometer measurement was good, high/out of profile.
033	C36	033	133	The first sample attempt was variable with a large difference between the two readings, the second sample was comparatively stable between the two readings but in comparison to the rest of the cast is out of profile/high
034	M34	034	133	Result is out of profile and comparatively high.
035	G03	035	133	Analysis was good and agreement good, sample is out of profile (high) cause unknown
043	E17	043	133	The sample was unstable and the result constantly increasing during analysis. The sample is high and out of profile
043	E10	043	133	Salinometer measurement was good. Result is high/out of profile.
043	E01	043	133	Salinometer measurement was good. Result is high/out of profile.

047	C26	046	133	Salinometer measurement was good. The result is out of profile, cause unknown, The measurement over the entire CTD was the most problematic to date, small bubbles forming on the electrodes and other unknown problems causing jumps of up to .003 units
047	C29	046	133	Salinometer measurement was good. The result is out of profile, cause unknown, The measurement over the entire CTD was the most problematic to date, small bubbles forming on the electrodes and other unknown problems causing jumps of up to .003 units
050	A03	050	133	High salinity/out of profile, measurement was erratic and difficult to obtain two readings within QC accepted range of each other.
052	E25	052	69	Salinity is comparatively high for the profile, but mimics/exaggerates a feature (spike/increase) seen in the CTD data. The sample needed two measurements, the first was low with poor agreement over two readings, the second reading was ok
055	M31	055	133	The sample ran poorly 2 times (significant difference between the two readings, internally stable for each of the 5 sub-readings within a reading), third try was stable but the value is high
055	M15	055	133	The sample ran poorly on the first attempt stepping up from 34.7044 to 34.7080, and remaining stable at the higher reading on the second attempt. Both results were significantly higher than the CTD.
056	G09	056	133	The sample analysed poorly on four attempts - one was within or close to acceptable limits but the final result is high/ out of profile. Could be related to salt inserts (conclusion post discovery of the lid holes on CTD 083). It was APPROXIMATELY at this point that inserts from the reserve bag of good/new inserts were introduced into circulation and which were later found to have approximately 50 with punctures near the top lip due to the insertion of a screwdriver to remove the inserts from the sample bottle. Some inserts with this problem may have been in circulation for the entire voyage, and may be the reason for anomalous high salinity readings.
058	C13	058	69	The sample had poor agreement during the first analysis attempt, and was low/out of profile.
067	E14	067	133	Salinometer measurement was good, high salinity/out of profile cause unknown. Could be

				related to salt inserts (conclusion post discovery of the lid holes after CTD 083)
069	C01	069	133	High salinity, cause unknown. Sample was run twice due to instability second reading was stable (but high compared to the rest of the profile and CTD salinity). Could be related to salt inserts (conclusion post discovery of the lid holes on CTD 083)
073	E11	073	133	Salinometer measurement was good. Results is low/out of profile. Could be related to salt inserts (conclusion post discovery of the lid holes on CTD 083)
074	M12	074	133	The sample analysed poorly on the first attempt and well on the second attempt, but the value is high/out of profile. Could be related to salt inserts (conclusion post discovery of the lid holes on CTD 083)
077	G15	077	133	Salinometer measurement was good. Results is low/out of profile. Could be related to salt inserts (conclusion post discovery of the lid holes on CTD 083)
078	M23	078	69	The sample analysed poorly and took 4 tries. Consensus was reached finally but there were significant differences between readings.
078	M18	078	133	The sample analysed poorly and took 3 tries. Consensus was reached but high compared to the CTD profile. Could be related to salt inserts (conclusion post discovery of the lid holes on CTD 083)
079	A23	079	133	Low/out of profile, sample ran poorly (three attempts). Could be related to salt inserts (conclusion post discovery of the lid holes on CTD 083)
083	M17	083	133	Analysed poorly. A hole was found in one insert from this CTD, not confirmed to be from this sample, but likely was from this sample based on the cluster of recent 'off' samples
086	C12	086	113	High salinity caused by small slit in insert.
087	J14	087	133	High salinity caused by small slit in insert.
101	M16	101	69	Sample analysed poorly on 1st attempt. High/ out of profile (not caused by hole in insert)
102	B20	201	133	High/ out of profile, potentially a misfire, suspect nutrient results also

6 Dissolved Oxygen Data Processing

6.1 Dissolved Oxygen Parameter Summary

Details	
HyPro Version	5.3
Instrument	Automated Photometric Oxygen system
Software	SCRIPPS
Methods	SCRIPPS
Accuracy	0.01 ml/L + 0.5%
Analyst(s)	Stephen Tibben & Kendall Sherrin
Lab Temperature (±1°C)	Variable, 20.0 - 23.0°C
Sample Container type	Pre-numbered glass 140 mL glass vial w/stopper, sorted into 18 per box and boxes labelled A to S.
Sample Storage	Samples were stored within Hydrochemistry lab under the forward starboard side bench until analysis. All samples were analysed within ~48 hrs
Comments	8 – 34 samples were collected from each deployment

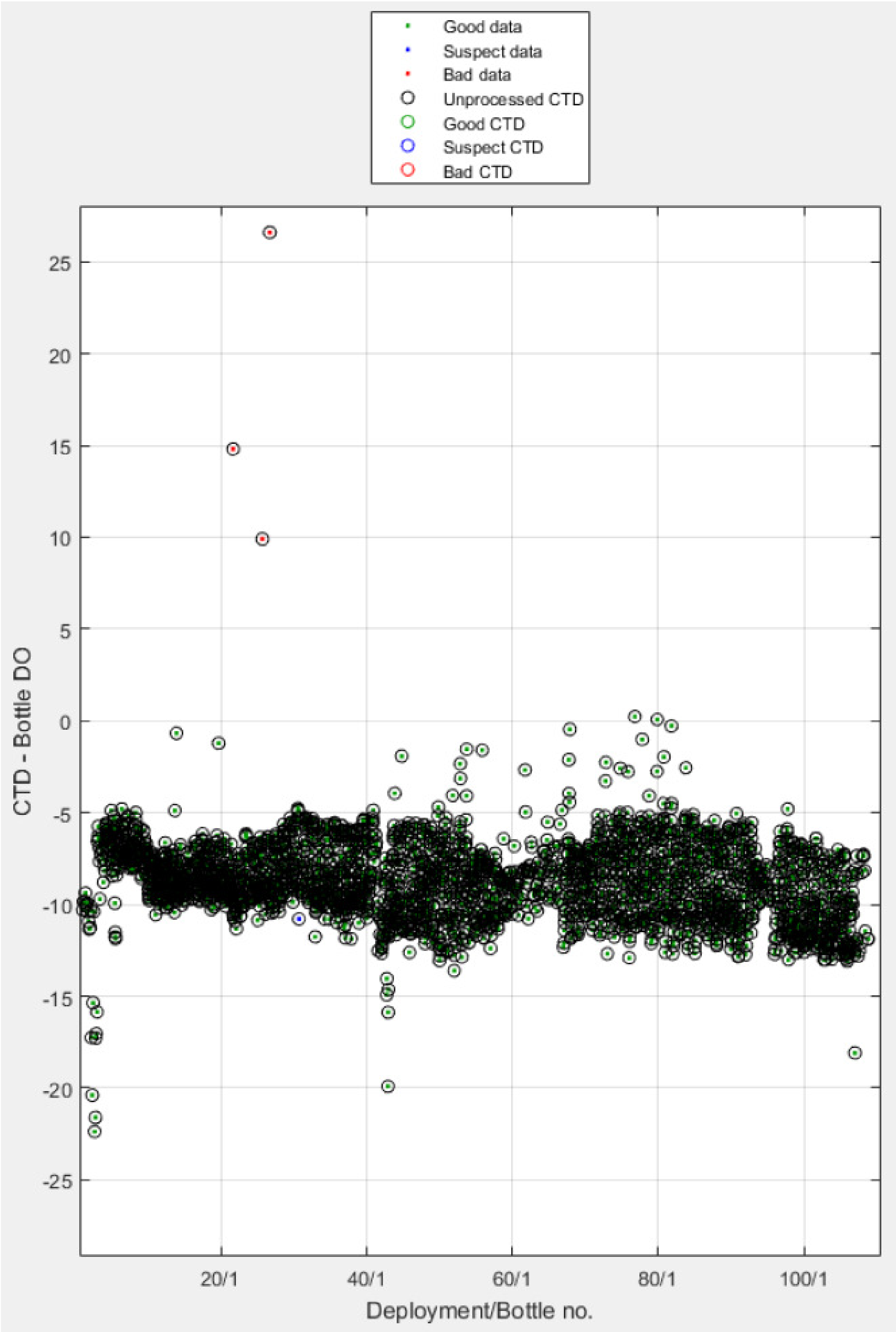
6.2 Dissolved Oxygen Method

SCRIPPS method used. The method is based on the whole-bottle modified Winkler titration of Carpenter (1965) plus modifications by Culberson *et al* (1991).

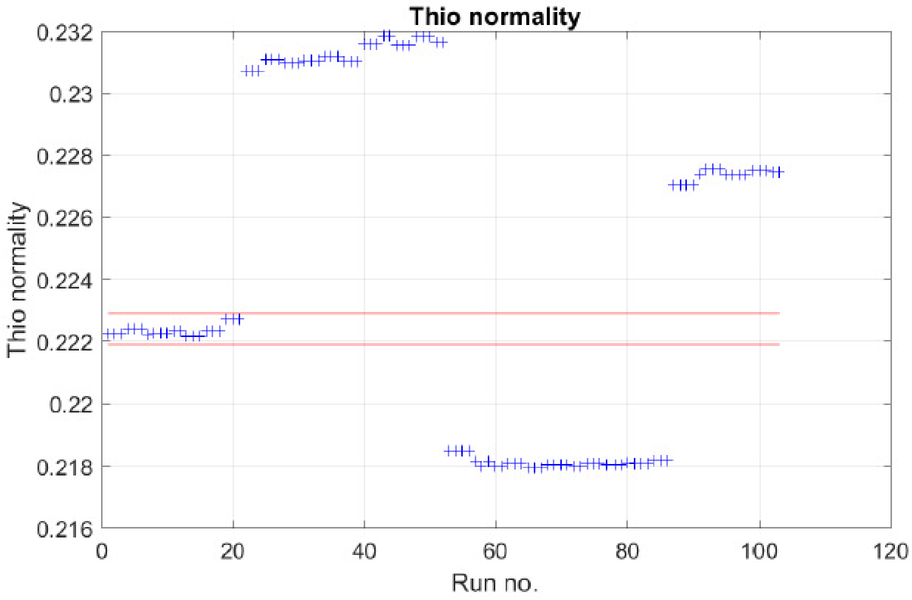
Manganese chloride followed by alkaline iodide, is added to the sample, and the precipitated manganous hydroxide is distributed evenly throughout the bottle by shaking. At this stage, the dissolved oxygen oxidizes an equivalent amount of Mn (II) to Mn (IV). Just before titration, the sample is acidified, converting the Mn (IV) back to the divalent state liberating an amount of Iodine equivalent to the original dissolved oxygen content of the water. The Iodine is auto-titrated with a standardised thiosulphate solution using a Met Rohm 665 Dosimat with a 1ml burette. The endpoint is determined by measuring changes in the UV absorption of the tri-iodide ion at 365 nm. The point at which there is no change in absorbance is the endpoint.

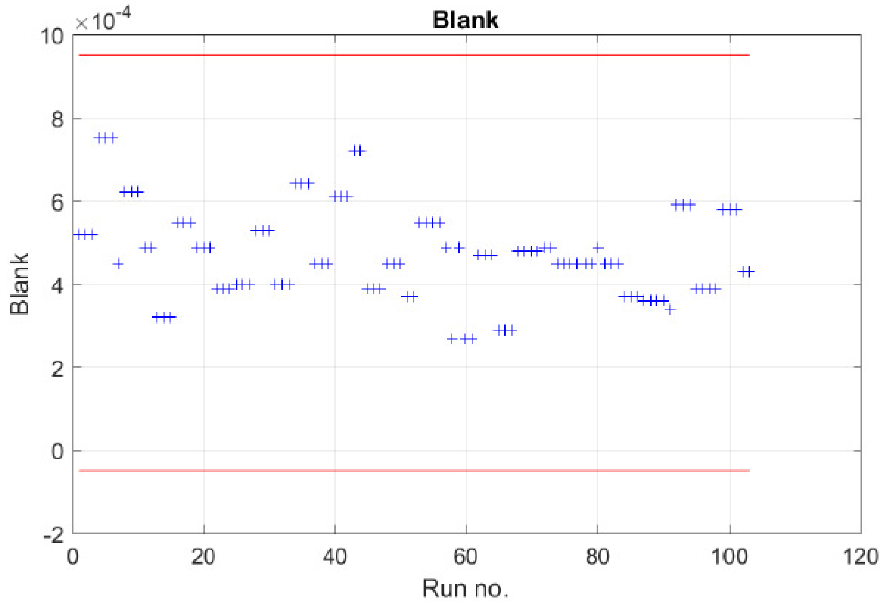
The thiosulphate solution is standardised by titrating a 10ml aliquot of potassium iodate primary standard. The blank correction is determined from the difference between two consecutive titres for 1 ml aliquots of the same potassium iodate solution.

6.3 CTD Dissolved Oxygen vs Hydrochemistry Dissolved Oxygen Plot



6.4 Dissolved Oxygen thiosulphate normality and blanks across voyage





6.5 Missing or Flagged Dissolved Oxygen Data and Actions taken

Data is flagged as Good, Suspect or Bad in HyPro based on notes from CTD sampling log sheet, observations during analysis, and examination of depth profile and waterfall plots.

CTD	RP	Run	Flag	Reason for Flag or Action
21	01	oxy020	141	Titrated sample with lamp off
21	24	oxy020	133	Outlier in vertical profile plot
23	24	oxy022	133	Outlier in vertical profile plot
25	25	oxy024	133	Outlier in vertical profile plot
25	29	oxy024	133	Outlier in vertical profile plot
97	4	oxy092	133	Titration end point bad, outlier in vertical profile plot
97	6	oxy092	133	Instrument failure. Burette dispensed air.
102	20	oxy097	133	Outlier in vertical profile plot

7 Nutrient Data Processing

7.1 Nutrient Parameter Summary

Details					
HyPro Version	5.3				
Instrument	AA3				
Software	Seal AACE 6.10				
Methods	AA3 Analysis Methods internal manual				
Nutrients analysed	☒ Silicate	☒ Phosphate	☒ Nitrate + Nitrite	☒ Nitrite	☒ Ammonia
Concentration range	140 µmol l^{-1}	3 µmol l^{-1}	42.0 µmol l^{-1}	1.4 µmol l^{-1}	2.0 µmol l^{-1}
Method Detection Limit* (MDL)	0.2 µmol l^{-1}	0.02 µmol l^{-1}	0.02 µmol l^{-1}	0.02 µmol l^{-1}	0.02 µmol l^{-1}
Matrix Corrections	N	N	N	N	N
Analyst(s)	Christine Rees, Kendall Sherrin, Stephen Tibben				
Lab Temperature (±1°C)	Variable, 19.0 – 22.0°C				
Reference Material	RMNS – CC, CB, CD				
Sampling Container type	50 ml HDPE screw cap lids for CTD samples 30 ml polypropylene sample tubes for experimental samples 10 ml polypropylene sample tubes for underway samples				
Sample Storage	< 2 hrs at room temperature or ≤ 12 hrs @ 4°C				
Pre-processing of Samples	None				
Comments					

7.2 Nutrient Methods

CSIRO Oceans and Atmosphere Hydrochemistry nutrient analysis is performed with a segmented flow auto-analyser – Seal AA3 HR – to measure silicate, phosphate, nitrite, nitrate plus nitrite (NOx), and ammonium

Silicate: colourimetric, molybdenum blue method. Based on Armstrong et al. (1967). Silicate in seawater is reacted with acidified ammonium molybdate to produce silicomolybdic acid. Tartaric acid is added to remove the phosphate molybdic acid interference. Tin (II) chloride is then added to reduce the silicomolybdic acid to silicomolybdous acid and its absorbance is measured at 660nm.

Phosphate: colourimetric, molybdenum blue method. Based on Murphy and Riley (1962) with modifications from the NIOZ-SGNOS Practical Workshop 2012 optimizing the antimony catalyst/phosphate ratio and the reduction of silicate interferences by pH. Phosphate in seawater forms a phosphomolybdenum complex with acidified ammonium molybate. It is then reduced by ascorbic acid and its absorbance is measured at 880nm.

Nitrate: colourimetric analysis, Cu-Cd reduction – Naphthylenediamine photometric method. Based on Wood et.al (1967). Nitrate is reduced to nitrite by first adding an ammonium chloride buffer then sending it through a copper - cadmium column. Sulphanilamide is added under acidic conditions to form a diazo compound. This compound is coupled with 1-N-naphthly-ethylenediamine di-hydrochloride to produce a reddish purple azo complex and its absorbance is measured at 520 nm.

Nitrite: colourimetric analysis, Naphthylenediamine photometric method. As per nitrate method without the copper cadmium reduction column and buffer.

Ammonium: fluorescence analysis, ortho-phtaldiadehyde method. Based on Roger Kérouel and Alain Aminot, IFREMER (1997 Mar.Chem.57). Ammonium reacted with ortho-phtaldialdehyde and sulphite at a pH of 9.0-9.5 to produce an intensely fluorescent product. Its emission is measured at 460nm after excitation at 370nm.

Detailed SOPs can be obtained from the CSIRO Oceans and Atmosphere Hydrochemistry Group on request.

7.3 Instrument Calibration and Data Parameter Summary

All instrument parameters and reagent batch compositions are logged for each analysis run. This information is available on request.

The raw data from each analysis run on the Seal AA3HR is imported into HyPro for peak height determination, constructing the calibration curve, deriving the sample results and applying drift and carry-over corrections.

Following standard procedures, the operator may choose to not include bad calibration points (see section 7.8 for edited data). Below are the corrections and settings that HyPro applied to the raw data.

All runs have a corresponding "AA3_Run_Analysis_sheet" to record the following: sample details, LNSW batch, cadmium column, working standards, reagent information, instrumentation settings, and pump tube hours. The NUT### file numbers that correspond to each analytical run and the CTD samples analysed are in table 8.4. The NUT### file numbers for underway and experimental samples are available upon request. Calibration summary data for each analysis run are in the voyage documentation and available upon request.

Result Details	Silicate	Phosphate	Nitrate + Nitrite	Nitrite	Ammonia
Data Reported as	µmol l^{-1}	µmol l^{-1}	µmol l^{-1}	µmol l^{-1}	µmol l^{-1}
Calibration Curve degree	Linear	Linear	Quadratic	Quadratic	Quadratic
Forced through zero?	N	N	N	N	N
# of points in Calibration	7	6	7	6	6
Matrix Correction	N	N	N	N	N
Blank Correction	N	N	N	N	N
Carryover Correction (HyPro)	Y	Y	Y	Y	Y
Baseline Correction (HyPro)	Y	Y	Y	Y	Y
Drift Correction (HyPro)	Y	Y	Y	Y	Y
Data Adj for RMNS	N	N	N	N	N
Window Defined*	HyPro	HyPro	HyPro	HyPro	HyPro
Medium of Standards	LNSW (bulk on deck of Investigator) collected on 28/9/2016. Sub-lot passed through a 10 micron filter and stored in 20 L carboys in the clean dry laboratory at 22°C.				
Medium of Baseline	18.2 Ω MQ				
Proportion of samples in duplicate?	Samples were collected in duplicate at the greatest depth either RP01 or RP02 on the CTD rosette.				
Comments	Calibration and QC data that was edited or removed is located in the table within section 7.8. The reported data is not corrected to the RMNS. Per deployment RMNS data can be found in appendix 8.4.				

7.4 Accuracy - Reference Material for Nutrient in Seawater (RMNS) Plots

Japanese KANSO certified reference materials (RMNS) for silicate, phosphate, nitrate and nitrite in seawater was used in each nutrient analysis run to determine the accuracy. For each analysis run, a new RMNS bottle was opened and used. The RMNS was assayed in quadruplicate after the calibration standards.

RMNS lots CB, CC and CD were used. Their stated values in µ mol/kg are converted to µ mol l^{-1} at 21°C and are listed below. RMNS do not have certified ammonium values.

Table 1: RMNS CB, CC and CD concentrations with expanded uncertainty (µmol/L) at 21°C

RMNS	NO_3	NO_X	NO_2	PO_4	SiO_4
CB	36.65 ±0.28	36.77 ±0.28	0.119 ±0.006	2.58 ±0.02	111.82 ±0.64
CC	31.62 ± 0.25	31.74 ± 0.25	0.119 ± 0.006	2.13 ± 0.02	88.23 ± 0.49
CD	5.63 ± 0.05	5.65 ± 0.06	0.018 ± 0.005	0.46 ± 0.008	14.26 ± 0.10

The submitted nutrient results do NOT have RMNS corrections applied.

RMNS Correction

Ratio = Certified RMNS Concentration/Measured RMNS Concentration in each run
Corrected Concentration = Ratio x Measured Nutrient Concentration

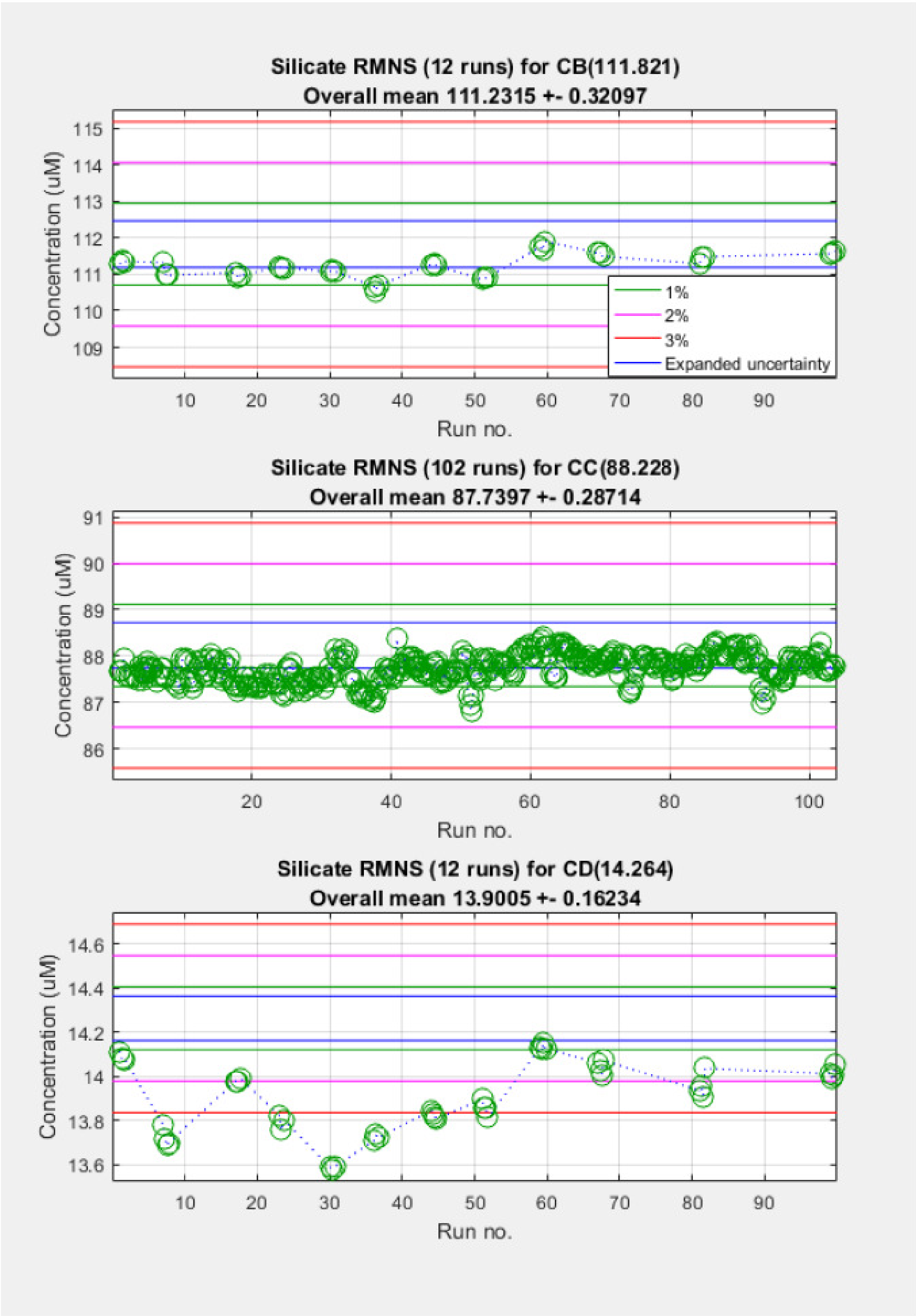
Or for smoothing data

Ratio = Average RMNS Concentration across voyage/Measured RMNS Conc. in each run
Corrected Concentration = Ratio x Measured Nutrient Concentration

The following plots show RMNS values within 1% (green lines), 2% (pink lines) and 3% (red lines) of the published RMNS value except for nitrite. The nitrite limit is set to ±0.020 µM (MDL) as 1% is below the method MDL. The GO-SHIP criteria (Hyde *et al*., 2010), appendix 8.3, specifies using 1-3 % of full scale (depending on the nutrient) as acceptable limits of accuracy. The assayed RMNS values per CTD deployment are reported in the table in appendix 8.4.

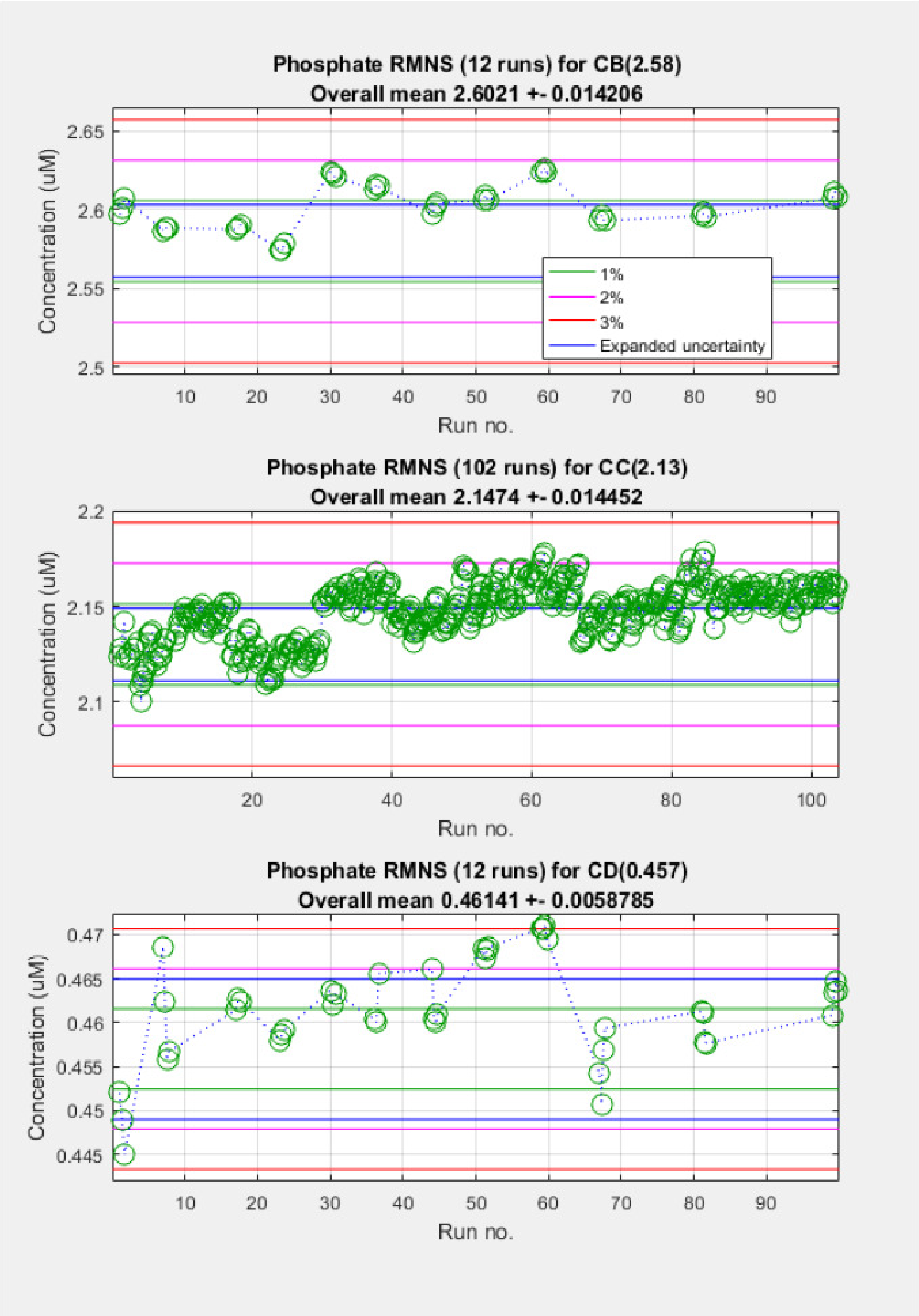
7.4.1 Silicate RMNS Plot

1% of RMNS value 2% of RMNS value 3% of RMNS value



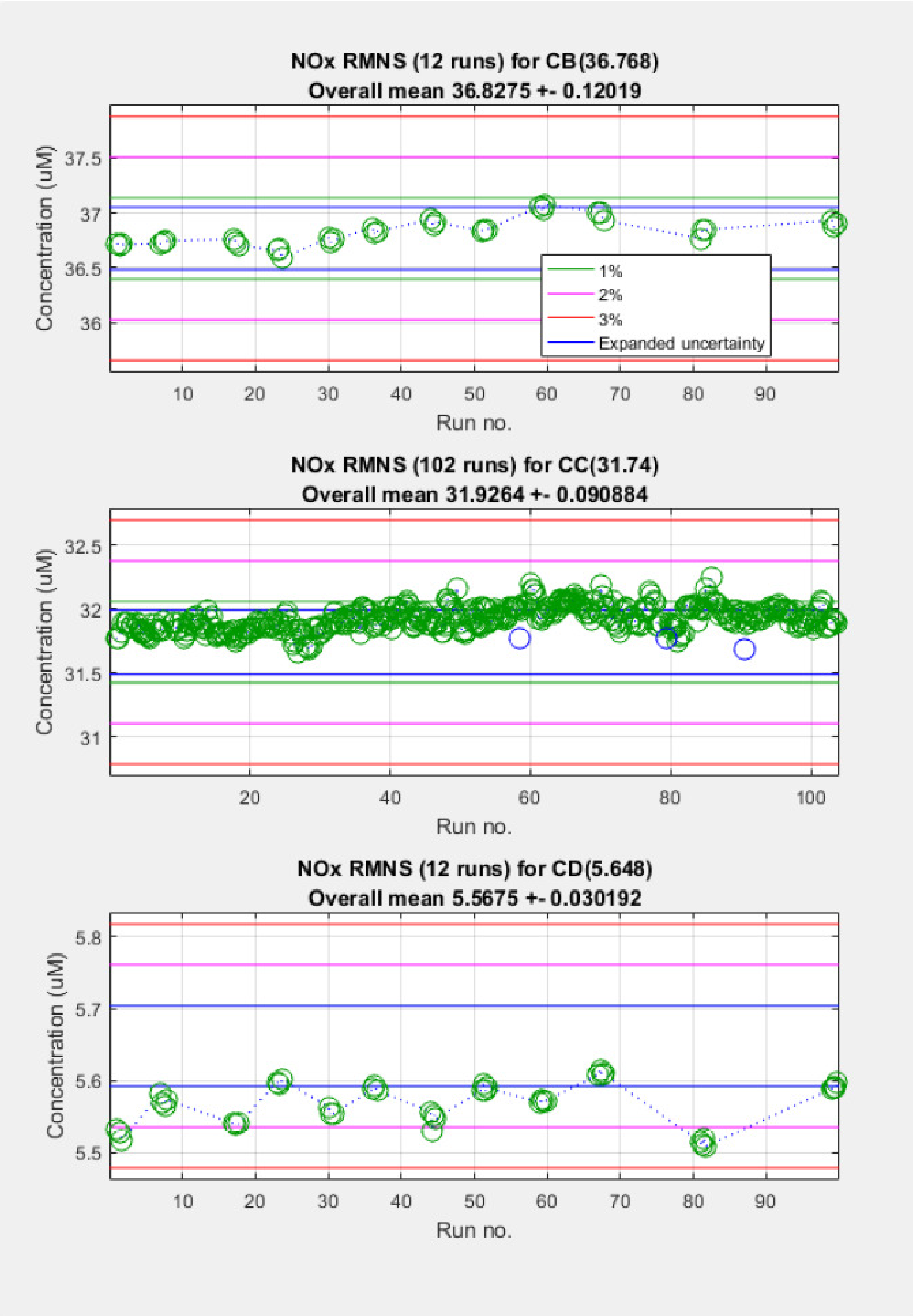
7.4.2 Phosphate RMNS Plot

1% of RMNS value 2% of RMNS value 3% of RMNS value

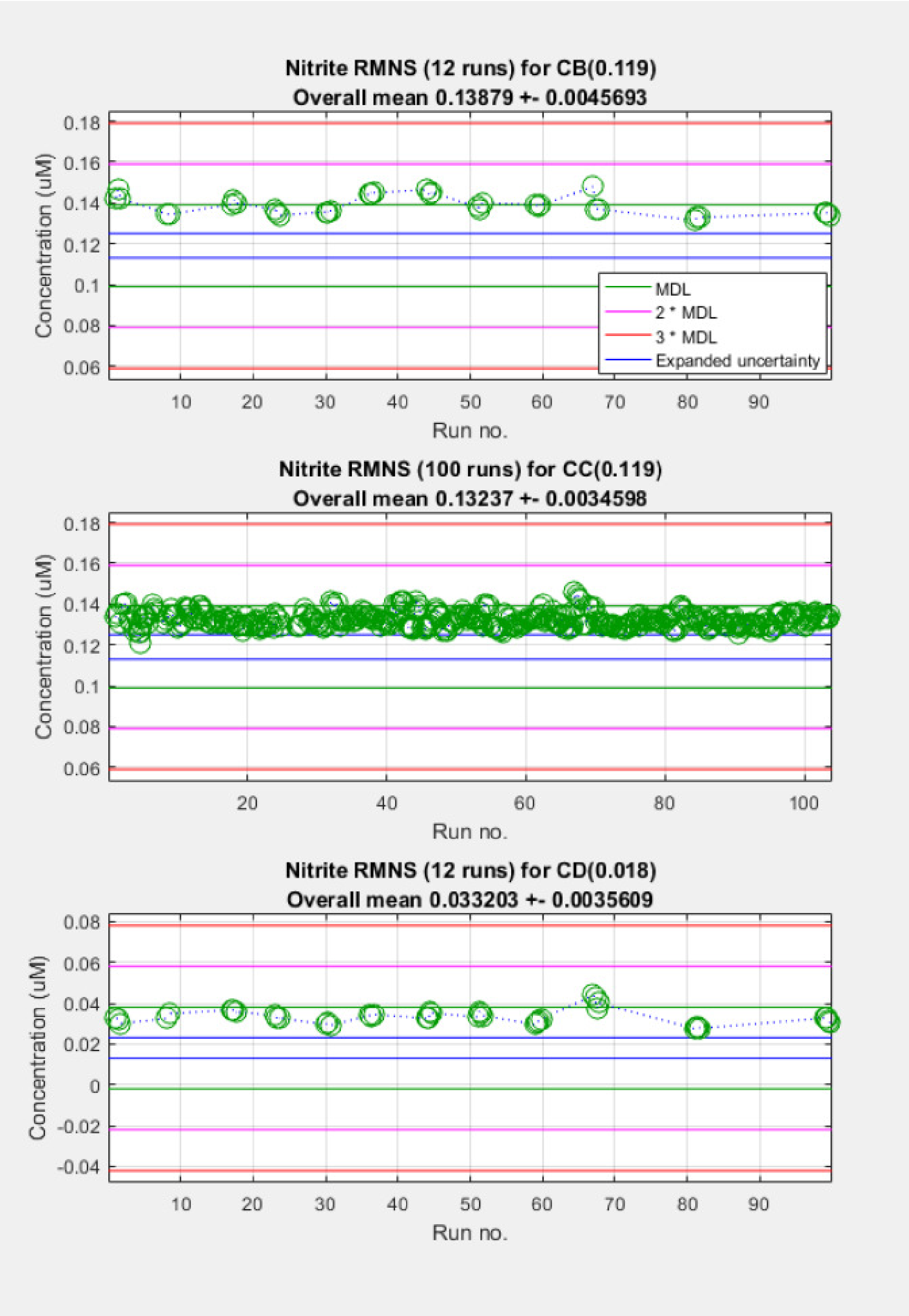


7.4.3 Nitrate + Nitrite (NOx) RMNS Plot

1% of RMNS value 2% of RMNS value 3% of RMNS value



7.4.4 Nitrite RMNS Plot



7.5 Internal Quality Control

The internal quality control samples were prepared on the 28/9/2017 by filtering more than 2 litres of low nutrients seawater (LNSW) from a carboy through a 0.2 µM Acropak filter into HDPE square 1L bottles and then autoclaving.

A LNSW control was prepared to account for any nutrients already in the LNSW and also any nutrients picked up in the autoclaving. The autoclaved LNSW was well mixed and poured into an acid cleaned and dry HDPE square 1L bottle and lid screwed shut and wrapped with parafilm around the lid and stored at 4°C.

The Spiked internal quality control was prepared by spiking nutrients into the autoclaved LNSW from an OSIL kit containing 5 nutrients each in separate bottles containing 50 ml. The concentrations of the each bottle were as follows: Silicate 1000 µmol/L, Phosphate 100 µmol/L, Nitrate 1000 µmol/L, Nitrite 100 µmol/L and Ammonia 10,000 µmol/L.

The following amounts were pipetted into a calibrated 1 L volumetric flask.

10 ml of phosphate 100 µmol/L = 1 uM

5 ml of Nitrate 1000 µmol/L = 5 µM

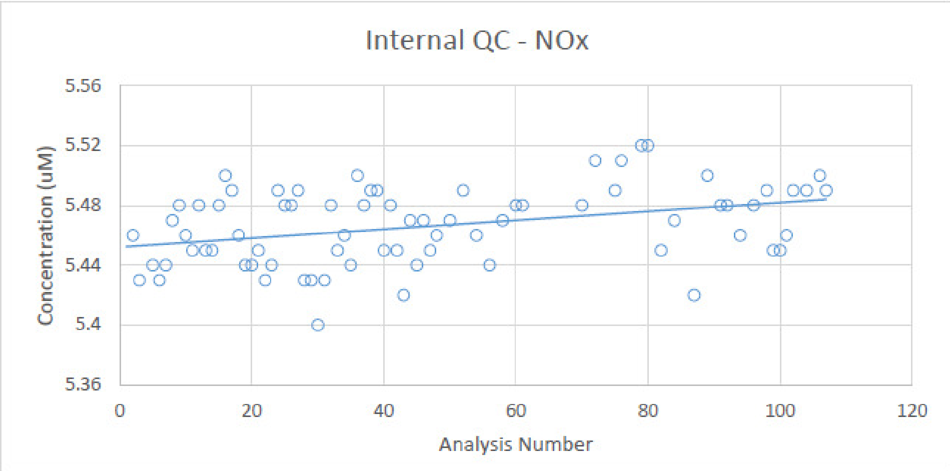
10 ml of silicate 1000 µmol/L = 10 µM

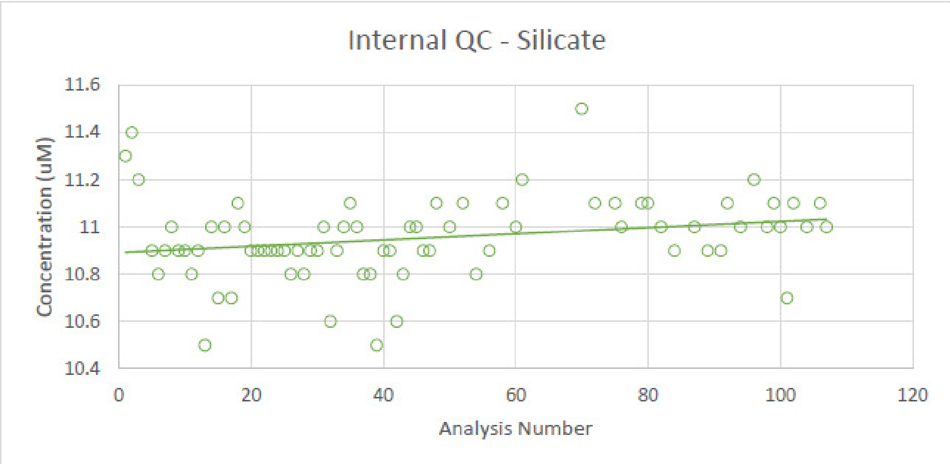
5 ml of nitrite 100 µmol/L = 0.5 µM

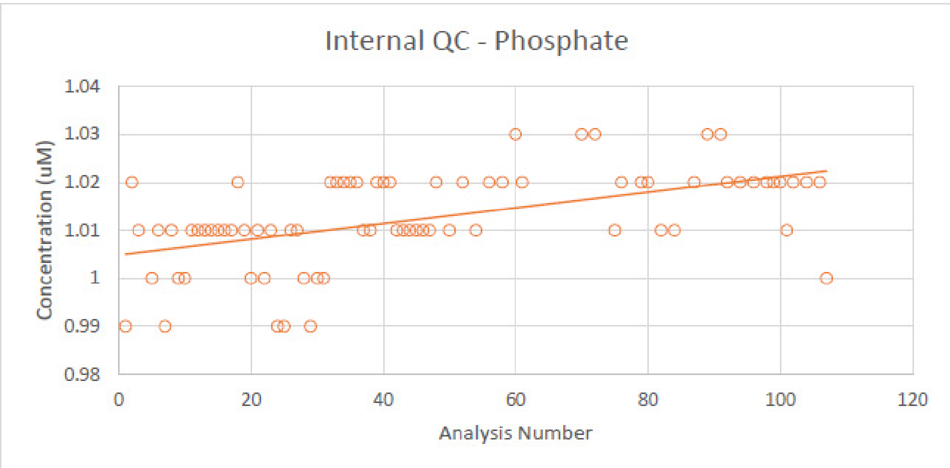
0.1 ml of ammonium 10,000 = 1µM

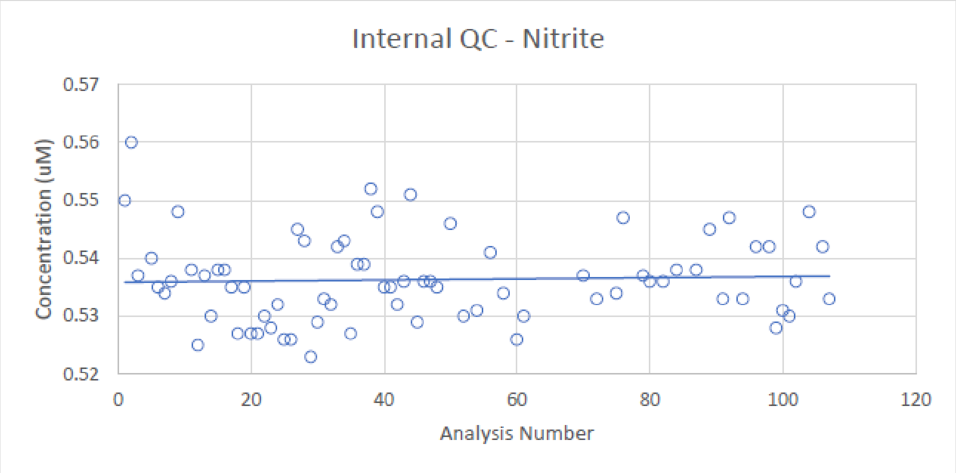
The flask was then made to volume with the autoclaved LNSW. It was mixed well and poured into an acid-cleaned and dry HDPE square 1L bottle with the lid screwed shut and parafilm wrapped around the lid and stored at 4°C.

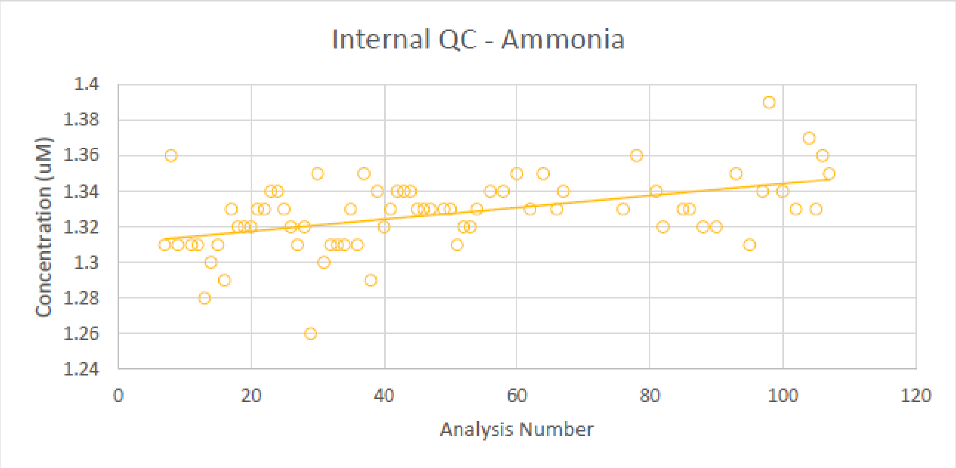
An initial measurement was made in October 2017 and another measurement was made in December 2017. It was determined that the standards were stable to be used on the voyage. The internal QC's were decanted into a number of 10 ml polypropylene screw lid sample tubes on three separate occasions and stored at 4°C. A sample tube of the control and the spike were analysed with the CTD samples, due to limited volume not all analytical runs contained an internal quality control.


Internal QC - NOx
Concentration (uM)
5.56
5.52
5.48
5.44
5.4
5.36
0
20
40
60
80
100
120
Analysis Number


Internal QC - Silicate
Concentration (uM)
11.6
11.4
11.2
11
10.8
10.6
10.4
0
20
40
60
80
100
120
Analysis Number


Internal QC - Phosphate
Concentration (uM)
1.04
1.03
1.02
1.01
1
0.99
0.98
0
20
40
60
80
100
120
Analysis Number





7.6 Analytical Precision

The CSIRO Hydrochemistry method measurement uncertainty (MU) has been calculated for each nutrient based on variation in the calibration curve, calibration standards, pipette and glassware calibration, and precision of the RMNS over time (Armishaw 2003).

	Silicate	Phosphate	Nitrate + Nitrite (NOx)	Nitrite	Ammonia
Calculated MU* @ 1 µmol l^{-1}	±0.017	±0.024	±0.019	±0.137	±0.296[¥]

*The reported uncertainty is an expanded uncertainty using a coverage factor of 2 giving a 95% level of confidence.

*The ammonia MU precision component does not include data on the RMNS.

Method detection limits (MDL) achieved during the voyage were much lower than the nominal detection limits, indicating high analytical precision at lower concentrations. RMNS and MDL precision data listed below. Results are µmol l^{-1}.

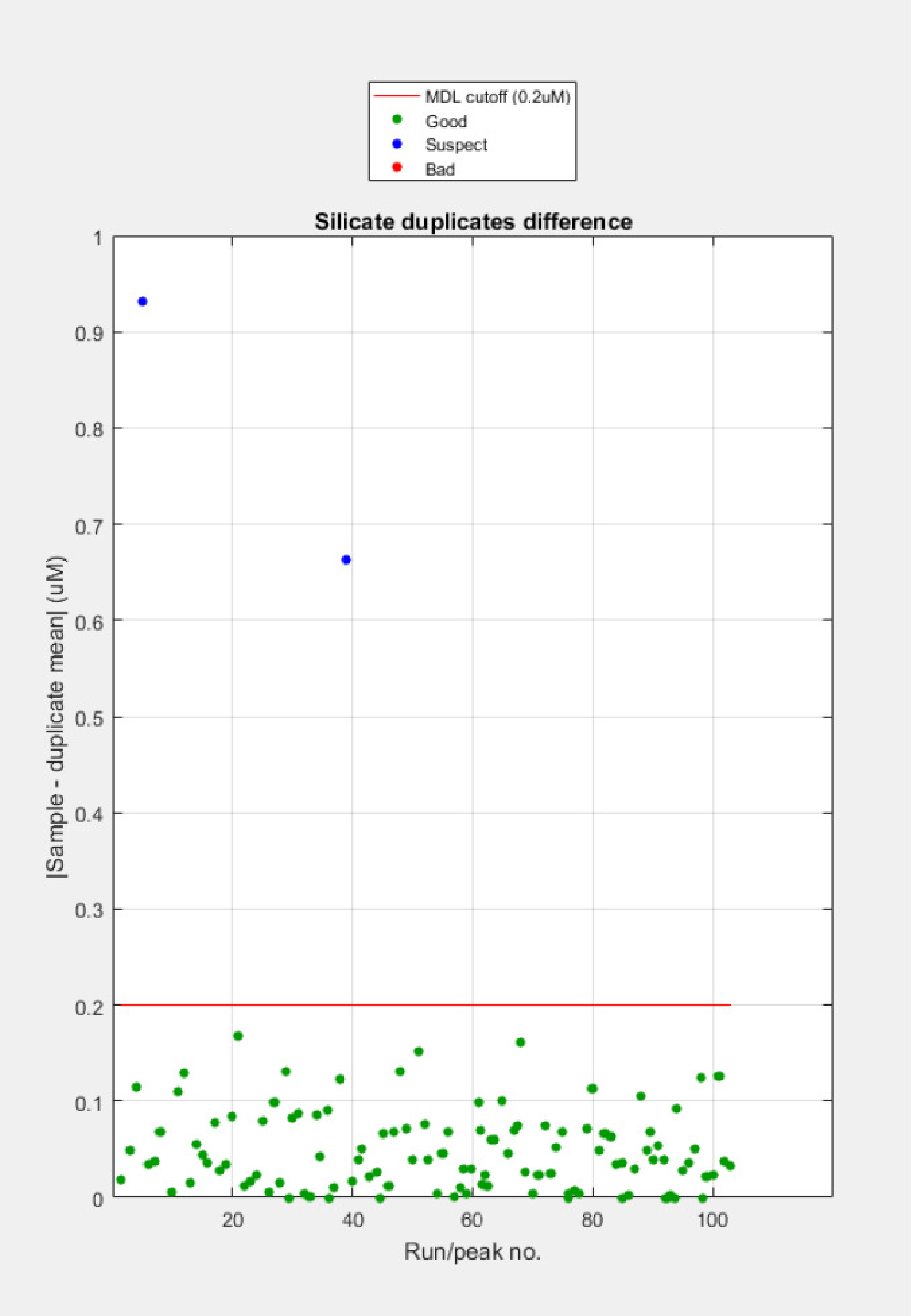
MDL	Silicate	Phosphate	Nitrate + Nitrite (NOx)	Nitrite	Ammonia
Nominal MDL*	0.20	0.02	0.02	0.02	0.02
Standard Dev. Min	0.00	0.00	0.00	0.000	0.00
Standard Dev. Max	0.057	0.010	0.0057	0.0040	0.0057
Standard Dev. Mean	**0.023**	**0.003**	**0.0053**	**0.0010**	**0.0007**
Standard Dev. Median	0.00	0.005	0.00	0.0005	0.00
Precision of MDL (stdev)	0.186	0.012	0.012	0.004	0.030
*MDL is based on 3 times the standard deviation of Low Nutrient Seawater (LNSW) analysed in each nutrient run.					
Published RMNS CD (µmol l^{-1})	14.26	0.46	5.65	0.018	-
w/std deviation	± 0.009	± 0.001	± 0.004	± 0.001	-
RMNS Min	13.6	0.44	5.51	0.028	1.43
RMNS Max	14.2	0.47	5.61	0.044	1.91
RMNS Mean	13.90	0.46	5.56	0.033	1.61
RMNS Median	13.90	0.46	5.57	0.033	1.56
RMNS Std Dev	0.16	0.006	0.03	0.003	0.14
Published RMNS CC (µmol l^{-1})	88.23	2.13	31.74	0.119	-
w/std deviation	± 0.053	± 0.005	± 0.029	± 0.002	-
RMNS Min	86.8	2.10	31.67	0.121	1.22
RMNS Max	88.5	2.18	32.45	0.141	2.35
RMNS Mean	87.74	2.14	31.92	0.132	1.60
RMNS Median	87.8	2.15	31.92	0.130	1.60
RMNS Std Dev	0.29	0.01	0.095	0.003	0.19

Published RMNS CB (µmol l^{-1})	111.82	2.58	36.768	0.119	-
w/std deviation	± 0.053	± 0.004	± 0.020	± 0.002	-
RMNS Min	110.5	2.57	36.59	0.131	1.16
RMNS Max	111.9	2.63	37.08	0.147	1.66
RMNS Mean	111.24	2.60	36.82	0.138	1.39
RMNS Median	111.25	2.60	36.83	0.138	1.38
RMNS Std Dev	0.32	0.01	0.12	0.004	0.13

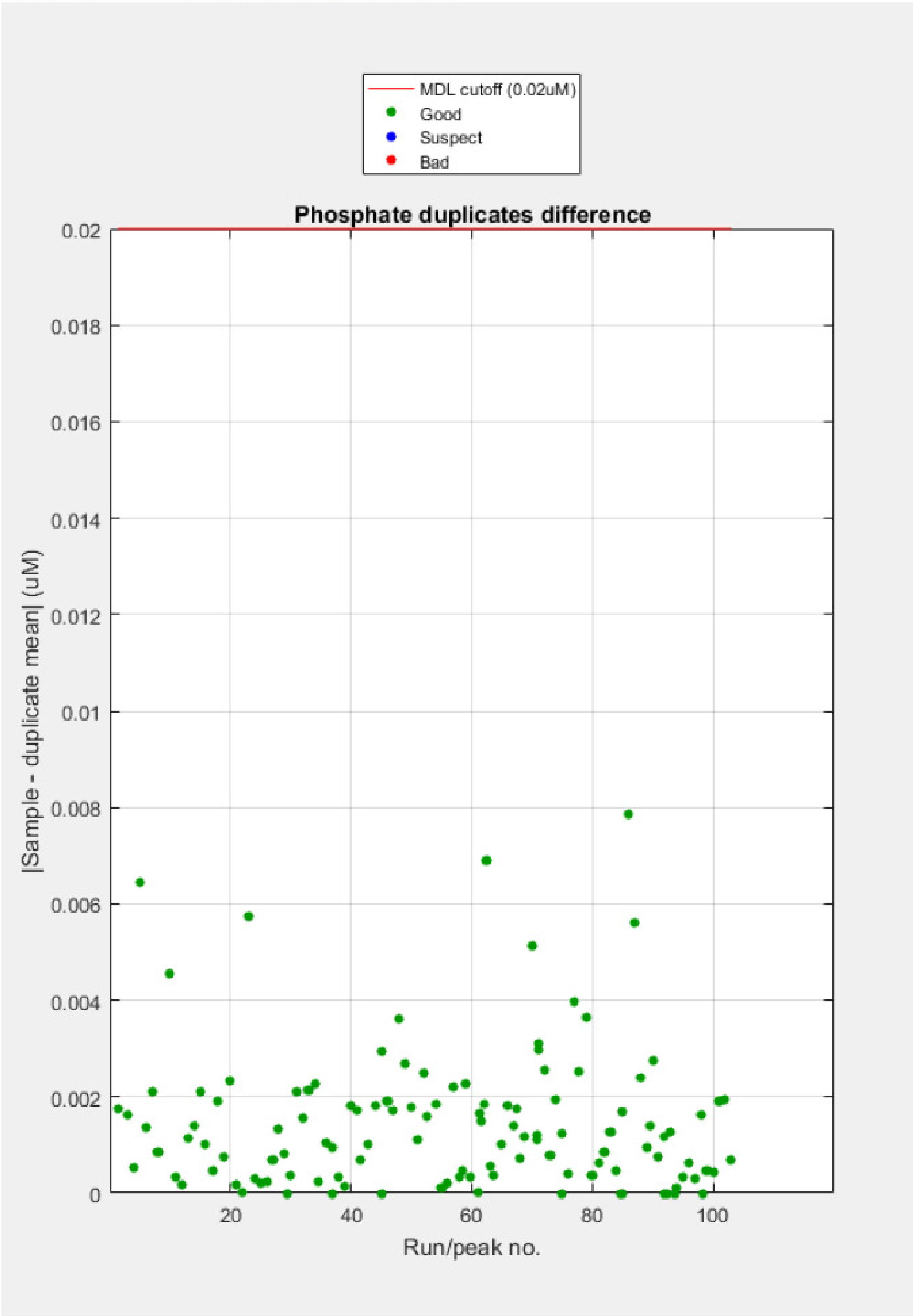
7.7 Sampling Precision

Duplicate samples were collected during CTD deployments from the NISKIN bottle in rosette position 01 or 02 to measure the sample precision. The multiple measurements are reported in the data as an average, when all measurements are flagged GOOD. The sampling precision is deemed good if the difference between the concentrations is below the MDL for silicate, phosphate and nitrite and within 0.06 µM for nitrate.

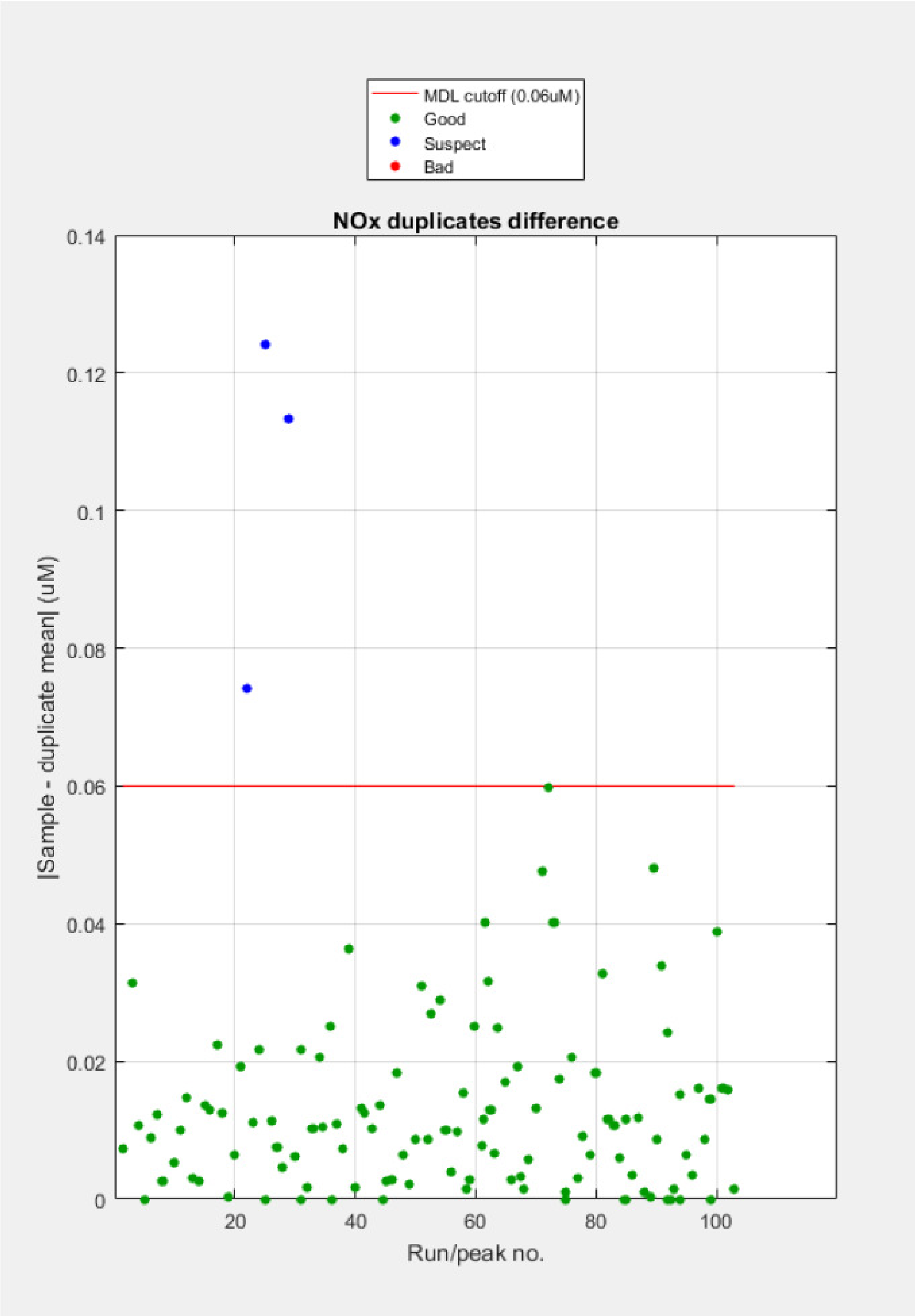
7.7.1 Silicate Duplicate/Replicates Plot



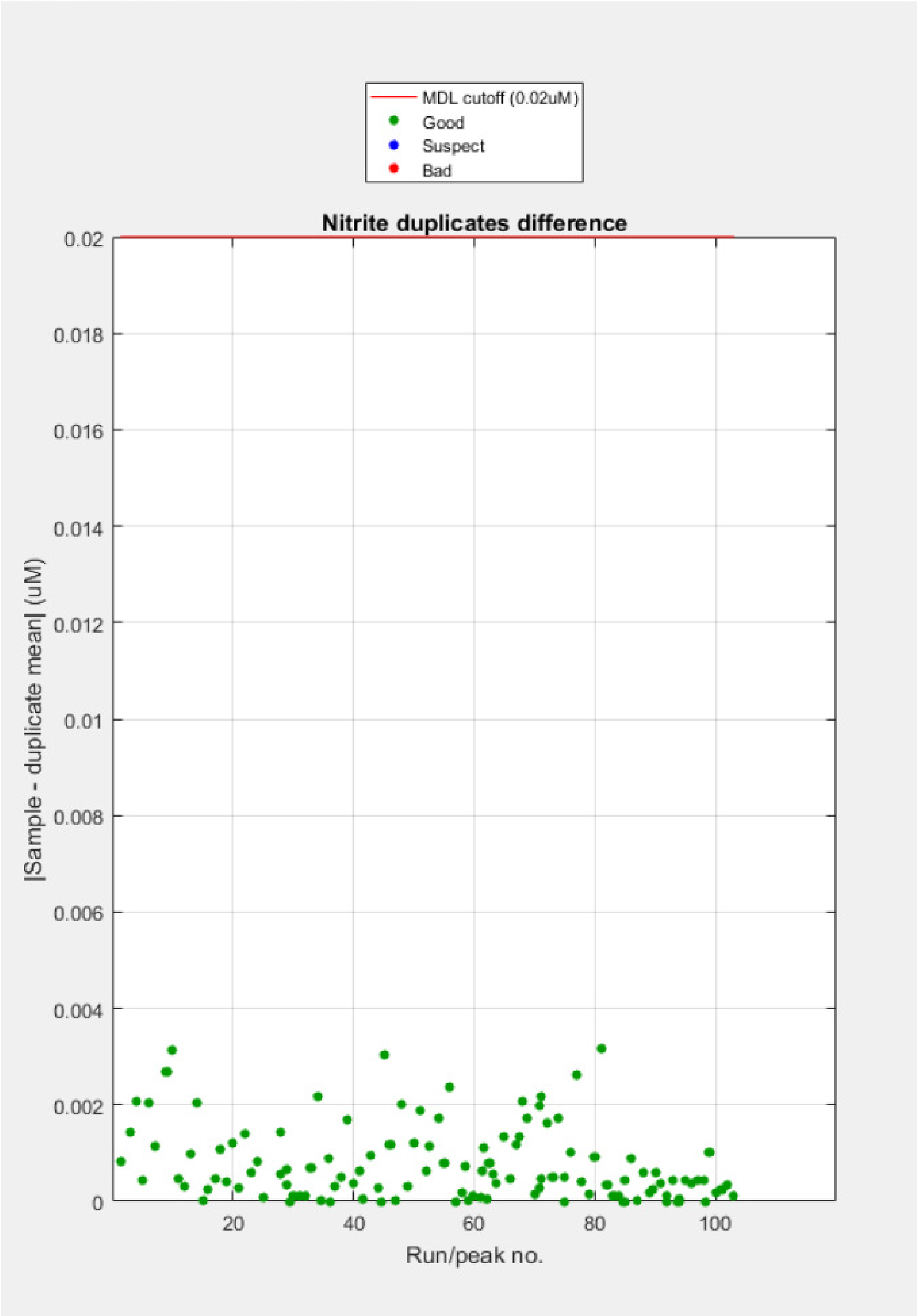
7.7.2 Phosphate Duplicate/Replicates Plot



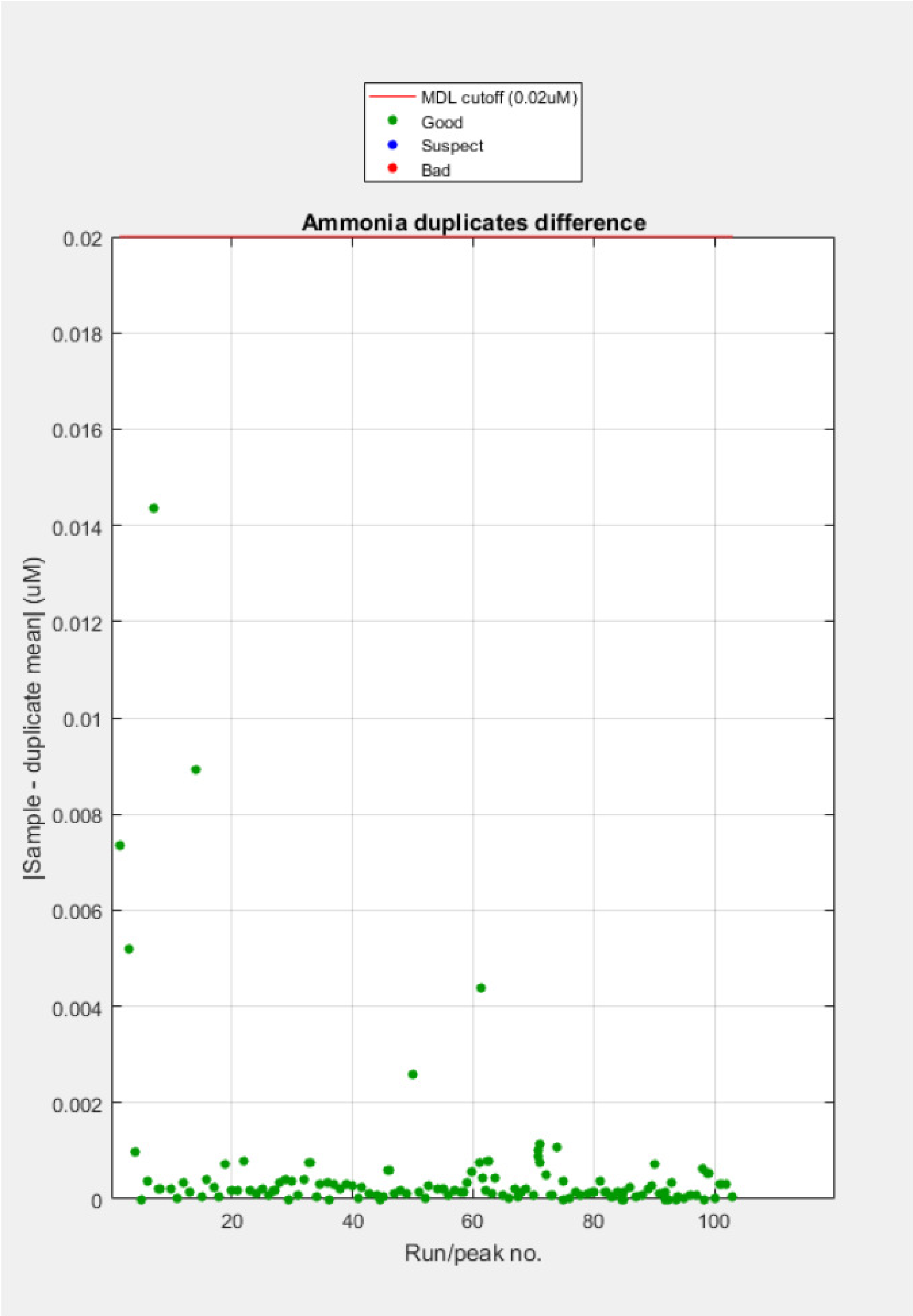
7.7.3 Nitrate + Nitrite (NOx) Duplicate/Replicates Plot



7.7.4 Nitrite Duplicate/Replicates Plot

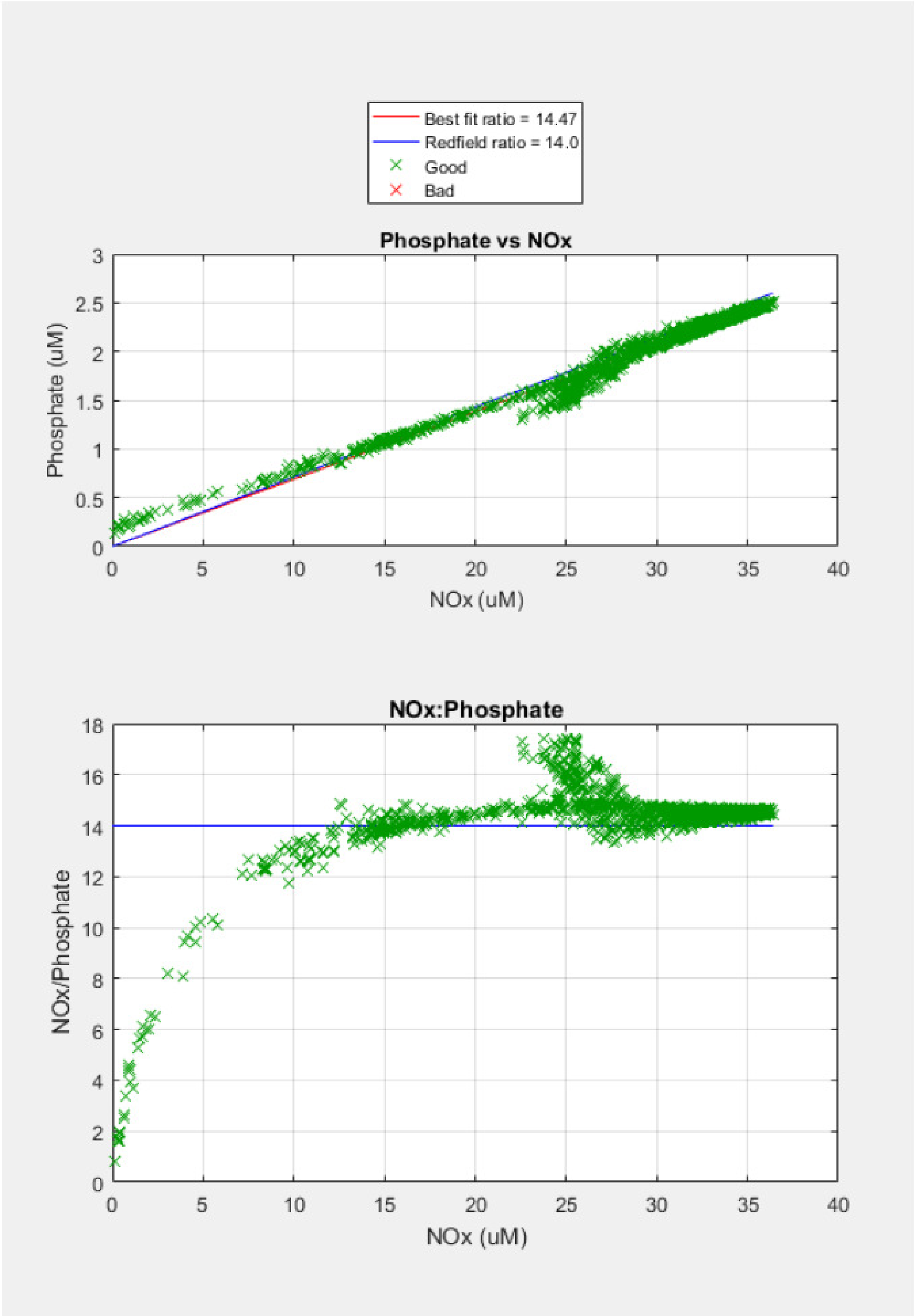


7.7.5 Ammonia Duplicate/Replicates Plot



7.7.6 Redfield Ratio Plot (14.0)

Plots consists of phosphate versus NOx, best fit ratio = 14.47.



7.8 Flagged Nutrient Calibration and Quality Control Data

The table below identifies all flagged data by HyPro. The calibration curve is fitted to the standards by performing several passes over each standard point and weighting its contribution to the curve depending on the magnitude of the difference between its measured and calculated value. The larger the difference, the less weighting is given to the standard's contribution towards the curve construction. The cut-off limits for good calibration data are

- ±0.5% of the concentration of the top standard for silicate and nitrate+nitrite (as per WOCE).
- 0.02uM for phosphate, nitrite and ammonium.

CTD	Peak	Run	Analysis	Reason for Flag or Action
1	Cal 4	Nut001	NH4	Both points BAD as greater than calibration error, not used in calibration.
1	BQC	Nut001	All	Suspect (MAD) peak shape, placed test in front so not to be used in calculations.
3	Cal 4	Nut002	NH4	Both points BAD as greater than calibration error, not used in calibration.
4	BQC	Nut003	SiO2	3rd point flagged BAD (soft), large error compared to other 2 points.
5	Cal 2	Nut004	PO4	2nd Point suspect less weighting in calibration curve.
5	Cal 2&4	Nut004	NH4	<70% of calibration peaks are within calibration limits. Cal 2 & 4 suspect less weighting in calibration curve.
5	Duplicate RP02	Nut004	SiO2	Suspect, duplicate difference >0.2 µM. [First peak (lower concentration) is noisier than second].
5	Duplicate	Nut004	NOx	Second sample flagged as BAD (mad) peak shape. Duplicates much greater than 0.06 µM, due to bad peak shape exceed A/D value, peak window on side of peak.
5	Duplicate	Nut004	NH4	First sample flagged as BAD (op) peak window slipped down side of peak.
6	Cal 3&4	Nut005	NH4	<70% of calibration peaks are within calibration limits. Cal 3 & 4 suspect less weighting in calibration curve.
7	Cal 4	Nut006	NH4	Cal 4 both points suspect, less weighting in calibration curve.
8		Nut007	NO2	Base off set was higher than normal all results looked too high. Re-run samples for NO2 only in Nut008, results good. Also No High low sample for analysis Nut008 due to running out of volume. Hypro used previous high low measurement.
8	CC RMNS	Nut007	PO4	1st point suspect, greater than 2%
8	CD RMNS	Nut007	SiO2	All points greater than 3%
9	Cal 3	Nut009	NH4	Both points BAD as greater than calibration error, not used in calibration.
10	Cal 2 & 3	Nut010	NH4	Cal 2 1st point and cal 3 both points suspect less weighting in calibration curve.
11	Cal 3	Nut011	NH4	Both points BAD as greater than calibration error, not used in calibration.
12	Cal 3	Nut012	NH4	Both points BAD as greater than calibration error, not used in calibration.
16	Cal 5&6	Nut016	NOx	2nd points suspect, less weighting in calibration curve.
19	Cal 5	Nut019	NH4	Both points BAD greater than calibration error, not used in calibration.
21	Duplicate RP01	Nut021	NOx	Suspect, duplicate difference greater than 0.06 µM
22	CD RMNS	Nut022	SiO2	All points greater than 3%

24	Duplicate RP01	Nut024	NOx	First duplicate Suspect (MAD) peak shape.
25	All	Nut025	NO2	Bad data, hashed out of file, re-run in nut027, processed as nut027b
26	All	Nut026	NO2	Bad data, hashed out of file, re-run in nut028, processed as nut028b
26	Cal 4	Nut026	NH4	1st point suspect, less weighting in calibration curve.
28	Duplicates RP01	Nut028	NOx	Suspect, duplicate difference greater than 0.06 µM.
30	Cal 2,3 & 4	Nut030	NH4	Cal 2 suspect (both points), Cal 3 suspect (2nd point)- less weighting in calibration curve. Cal 4 BAD both points – not used in calibration.
30	CD RMNS	Nut030	SiO2	All points greater than 3%.
32	Cal 3	Nut032	NH4	Cal 3 suspect, less weighting in calibration curve.
35	Cal 2	Nut035	NOx	Cal 2, 1st point suspect, less weighting in calibration curve.
38	Duplicates RP01	Nut038	SiO2	Suspect duplicate difference greater than 0.2 µM.
42	Cal 2	Nut042	NOx	Cal 2 suspect, less weighting in calibration curve.
43	Cal 2	Nut043	NOx	Cal 2 suspect, less weighting in calibration curve.
44	Cal 2	Nut044	NOx	Cal 2 suspect, less weighting in calibration curve.
45	Cal 2	Nut045	NOx	Cal 2 suspect, less weighting in calibration curve.
45	Cal 6	Nut045	SiO2	Cal 6 2nd point greater than calibration error.
48	Cal 3	Nut048	NH4	Cal 3 2nd point suspect, less weighting in calibration curve.
51	Cal 2	Nut051	PO4	Cal 2 1st point suspect, less weighting in calibration curve.
52	Cal 2	Nut052	PO4	Cal 2 1st point suspect, less weighting in calibration curve.
54	Cal 5	Nut054	PO4	Cal 5 2st point suspect, less weighting in calibration curve.
54	BQC	Nut054	SiO2	1st point Suspect (MAD) peak shape.
54	Cal 4	Nut054	NH4	Cal 4 both points suspect, less weighting in calibration curve.
54	Drift	Nut052	NO2	Last drift has large spike in plateau, swapped the drift and drift sample check peaks around.
55	Cal 4	Nut055	NH4	Cal 4 both points suspect, less weighting in calibration curve.
56	Cal 4	Nut056	NH4	Cal 4 1st point suspect, less weighting in calibration curve.
58	RMNS	Nut058	NOx	2nd last RMNS peak is suspect (mad) peak shape.

61	Drift	Nut060	NOx	Last drift has large spike in plateau, swapped the drift and drift sample check peaks around.
70	Baseline	Nut066	NO2	Baseline stepped up on the Null before the BQC samples and then stepped down again on the uwy sample. # out all of those samples and stds etc. #peak start of No2 and it didn't work, had to # the AD value column.
70	Drift	Nut066	NO2	2nd Drift is BAD. Baseline stepped up on the Null before the BQC samples and then stepped down again on the uwy and ctd samples. # out all of the BQC and drift stds. All samples good.
71, 72	Cal 3	Nut067	NH4	Cal 3 both points suspect (MAD), less weighting in calibration curve.
75	Duplicates RP01	Nut070	NOx & SiO2	Bad peak shapes, re-ran samples at end of the run and they were OK.
76	Cal 6	Nut071	NOx	Cal 6 2nd point was flagged Bad (MAD) peak shape, not used in calibration.
78	Cal 2	Nut073	NO2	Cal 2 2nd point BAD greater than calibration error.
80	Cal 1	Nut075	NH4	Cal 1 2nd point suspect, less weighting in calibration curve.
81	Cal 1 & Cal 3	Nut076	NH4	Cal 1 both points suspect and Cal 3 1st point suspect, greater than calibration error.
82	Cal 1 & Cal 3	Nut077	NH4	Cal 1 both points suspect and Cal 3 1st point suspect, less weighting in calibration curve.
83	Cal 3	Nut078	NH4	Cal 3 both points suspect, less weighting in calibration curve.
84	Cal4 & 5	Nut079	NOx	Blockage occurred during the cals (cal 4-2 and 5-1 bad, rest perfect), this offset the timing, meaning the peaks were shifted. This only really affected the carryover (use from last run) and the first two RMNS (hashed out).... RMNS values good on peaks that are good. Magical. Second MDL also hashed out - the rest are good.
85	Cal 3	Nut080	NH4	Cal 3 both points Bad greater than calibration error.
86	RMNS	Nut081	SiO2	RMNS CD, 1 point flagged suspect outside of 3% line
87	Cal 3 & Cal 4	Nut082	NH4	Cal 3 2nd point and Cal 4 both points suspect greater than calibration error.
87	Cal 2	Nut082	NOx	Cal 2 both points suspect, less weighting in calibration curve.
88	Cal 4	Nut083	NH4	Cal 4 both points suspect, less weighting in calibration curve.
88	Cal 2	Nut083	NOx	Cal 2 both points suspect, less weighting in calibration curve.
89	Cal 2	Nut084	NOx	Cal 2 both points suspect, less weighting in calibration curve.

89	Cal 5	Nut084	NOx	Cal 5 2nd point suspect, less weighting in calibration curve.
89	Cal 3	Nut084	NH4	Cal 3 both points suspect, less weighting in calibration curve.
89	Cal 4	Nut084	NH4	Cal 4 both points suspect, less weighting in calibration curve.
90	Cal 2	Nut085	NOx	Cal 2 both points suspect, less weighting in calibration curve.
90	Cal 3	Nut085	NH4	Cal 3 both points suspect, less weighting in calibration curve.
91	Cal 3	Nut086	NH4	Cal 3 first point suspect, less weighting in calibration curve.
93	Cal 3	Nut088	NH4	Cal 3 both points are suspect, less weighting in calibration curve.
93	Cal 5	Nut088	NOx	Cal 5 2nd point suspect, less weighting in calibration curve.
94, 95	Cal 3	Nut089	NH4	Cal 3 first point suspect, less weighting in calibration curve.
96	Cal 3	Nut090	NOx	Cal 3 both points suspect greater than calibration error.
96	RMNS	Nut090	NOx	Fourth peak is suspect (mad) peak shape.
99	Cal 5	Nut093	NOx	Cal 5 2nd point suspect, less weighting in calibration curve.
100	Cal 2	Nut094	PO4	Cal 2 1st point suspect greater than calibration error.
101	Cal 5	nut095	NOx	Cal 5 1st point bad shape, 2nd point greater than calibration error.
102	Cal 6	Nut096	PO4	Cal 5 2nd point is suspect, less weighting in calibration curve.
uwy	Cal 1	Nut103	NH4	Cal 1 both points suspect, less weighting in calibration curve.

7.9 Missing or Flagged Nutrient Data and Actions taken.

The table below identifies all flagged data and any samples that had repeated analyses performed to obtain GOOD data. Data that falls below the detection limit, Flag 63, is not captured in this table. All GOOD data is flagged 0 in the .csv and .netcdf files. Data that is flagged BAD is not exported within the .csv files. Suspect data (Flag 69) is exported in the .csv file. Refer to Appendix 8.2 for flag explanations.

CTD	RP	Run	Analysis	Flag	Reason for Flag or Action
4	18	Nut003	All	133	Outliers on profiles, sampled from wrong Niskin.
5	02	Nut004	SiO2	69	Duplicates greater than MDL 0.2 [First peak (lower concentration) is noisier than second].
5	02	Nut004	NOx	129	Duplicates much greater than 0.06 µM, due to bad peak shape exceed A/D value, peak window on side of peak.
5	02	Nut004	PO4	133	BAD air spikes.
5	02	Nut004	NH4	133	First sample flagged as BAD peak window slipped down side of peak.
9	18	Nut009	NOx, PO4, SiO2	69	Outlier on profile [not seen on salinity or dissolved oxygen – same value as RP16, possible duplicate or sampled from wrong Niskin)
15	12	Nut012	SiO2, NO2	133	Outliers on profiles.
16	25	Nut016	All	141	Sample missing accidently not collected.
21	All	Nut021	NH4	N/A	Higher than usual background caused these samples to be slightly lower than expected, resulting in slightly negative values instead of 0. However results are good.
21	01	Nut021	NOx	69	Duplicates greater than 0.06 µM
21	24	Nut021	All	133	Outliers on profiles, Niskin misfire. Also seen in salinity data.
23	24	Nut023	All	133	Outliers on profiles, Niskin misfire. Also seen in salinity data.
24	01	Nut024	NOx	69	1st duplicate suspect peak shape.
25	All	Nut025	NO2	133	Bad data # out of file and re-run in nut027, processed as nut027b, this data is good.
25	25, 29	Nut025	All	133	Outliers on profiles, Niskin misfire. Also seen in salinity data.
26	29	Nut026	All	133	Outliers on profiles, Niskin misfire. Also seen in salinity data.
26	All	Nut026	NO2	N/A	The rmns, BQC and intQC all stepped up. The sample profiles were also offset from

					previous ctd profiles. CTD 25 & 26 were re-run for NO2 in the nut027b & nut028b. The initial NO2 results were # out of original files and second results used as they were good.
28	01	Nut028	NOx	69	Duplicates greater than 0.06 µM
28	29	Nut028	NOx	141	It's marked as Bad (soft) in trace. However error given in HyPro is exceeds A/D value 129, we do not have value for this one.
28	26, 27	Nut028	NOx	N/A	BAD peak shapes but were re-run at end of analysis and results OK.
29	21	Nut029	NOx	133	Bad peak shape, repeated in nut030 and result good. The repeated measurement for other nutrient data was # out of file as original results were good.
36	33	Nut036	PO4	133	Bad peak shape repeated in nut037 and result is good. The repeated measurement for other nutrient data was # out of file as original results were good.
38	01	Nut038	SiO2	69	Duplicates greater than 0.2 µM
44	23	Nut044	PO4	133	Bad peak shape repeated in nut045, and result is good. The repeated measurement for other nutrient data was # out of file as original results were good.
49	17	Nut49	NO2	69	Outlier on profile, bump on peak plateau.
56	All	Nut056	NO2	133/141	Nitrite baseline stepped up on sample 5627 and 5625, then stepped back down on 5624 and 5623 but then stepped back up on 5622 and stayed elevated. Drifts are also elevated and end baselines. Flagged all data for NO2 as bad.
75	02	Nut070	SiO4	133	Bad peak shape, repeated during run and result is OK, # out bad results.
75	02	Nut070	NOx	133	Bad peak shape, repeated during run and result is OK, # out bad results.
79	08	Nut074	SiO2	133	Bad peak shape, repeated in Nut075 and result is good. The repeated measurement for other nutrients data was # out of file as original results were good.
81	07	Nut076	SiO4, NOx, PO4	69	Outlier on profile, peak shapes good – not seen in salinity or dissolved oxygen.

89	09	nut084	SiO4	133	Bad peak shape. Outlier on profile. Re-run and replaced as new result is good. The repeated measurement for other nutrient data was # out of file as original results were good.
89	04	nut084	SiO4	133	Bad peak shape. Outlier on profile. Re-run and replaced. The repeated measurement for other nutrient data was # out of file as original results were good.
96	23	Nut090	NOx	69	Suspect peak shape was re-run later in the run and result was OK used that result for all nutrients and "tested" first one out.
97	06	Nut091	SiO4	133	Bad peak shape, re-run at end of the run and this result was OK and used. The repeated measurement for other data was # out of file as original results were good.
98	18 & 19	Nut092	NO2	133	Outliers on profile, re-run in nut094 results ok in nut094. The repeated measurement for other data was # out of file as original results were good.
98	34 & 35	Nut092	All	141	Samples missing accidently not collected.
99	14	Nut093	NOx	133	Bad outlier on profile, repeated in Nut94 this result good. The repeated measurement for other data was # out of file as original results were good.
102	20	Nut096	All	133	Bad, outlier in vertical profile plot (also when repeated in following run). Also seen as outlier in salinity and D.O. data.
104	29	Nut098	NOx	133	Bad peak shape, repeated and measurement OK. The repeated measurement for other nutrient data was # out of file as original results were good.
104	36	Nut098	All	141	Sample missing accidently not collected.
Uwy	08	Nut026	NO2	133	The rmns, BQC and intQC all stepped up. The sample profiles were also offset from previous ctd profiles. CTD 25, 26 and uwy were re-run and for NO2 in the nut027b & nut028b. The initial NO2 results were # out of original files and second results used as they were good.

7.10 Temperature & Humidity Change over Nutrient Analyses

The temperature and humidity within the AA3 chemistry module was logged using a temperature/humidity logger QP6013 (Jaycar) placed on the deck of the chemistry module.

Refer to "in2018_v01_hyd_voyagereport.docx" for room temperature graphs, nutrient samples were placed on XY3 auto sampler at the average room temperature of 21.7°C.

8 Appendix

8.1 Salinity Reference Material

Osil IAPSO Standard Seawater		
Batch	P161	P158
Use by date	03/05/2020	25/03/2018
K_{15}	0.99987	0.99970

8.2 HyPro Flag Key for CSV & NetCDF file

Flag	Meaning
0	Data is GOOD – nothing detected.
192	Data not processed.
63	Below nominal detection limit.
69	Data flagged suspect by operator. Set suspect by software if Calibration or Duplicate data is outside of set limits but not so far out as to be flagged bad.
65	Peak shape is suspect.
133	Error flagged by operator. Data is bad – operator identified by # in slk file or by clicking on point.
129	Peak exceeds maximum A/D value. Data is bad.
134	Error flagged by software. Peak shape is bad - Median Absolute Deviation (MAD) analysis used. Standards, MDL's and Duplicates deviate from the median, Calibration data falls outside set limits.
141	Missing data, no result for sample ID. Used in netcdf file as an array compiles results. Not used in csv file.
79	Method Detection Limit (MDL) during run was equal to or greater than nominal MDL. Data flagged as suspect.

8.3 GO-SHIP Specifications

Salinity — Accuracy of 0.001 is possible with Autosal™ salinometers and concomitant attention to methodology, e.g., monitoring Standard Sea Water. Accuracy with respect to one particular batch of Standard Sea Water can be achieved at better than 0.001 PSS-78. Autosal precision is better than 0.001 PSS-78. High precision of approximately 0.0002 PSS-78 is possible following the methods of Kawano (this manual) with great care and experience. Air temperature stability of ± 1°C is very important and should be recorded.[1]

O_2 — Target accuracy is that 2 sigma should be less than 0.5% of the highest concentration found in the ocean. Precision or reproducibility (2 sigma) is 0.08% of the highest concentration found in the ocean.

SiO_2 — Approximately 1-3% accuracy†, 2 and 0.2% precision, full-scale.

PO_4 — Approximately 1-2% accuracy†, 2 and 0.4% precision, full scale.

NO_3 — Approximately 1% accuracy†, 2 and 0.2% precision, full scale.

Notes: † If no absolute standards are available for a measurement then *accuracy* should be taken to mean the *reproducibility* presently obtainable in the better laboratories.

1 Keeping constant temperature in the room where salinities are determined greatly increases their quality. Also, room temperature during the salinity measurement should be noted for later interpretation, if queries occur. Additionally, monitoring and recording the bath temperature is also recommended. The frequent use of IAPSO Standard Seawater is endorsed. To avoid the changes that occur in Standard Seawater, the use of the most recent batches is recommended. The bottles should also be used in an interleaving fashion as a consistency check within a batch and between batches.

2 Developments of reference materials for nutrients are underway that will enable improvements in the relative accuracy of measurements and clearer definition of the performance of laboratories when used appropriately and the results are reported with the appropriate meta data.

8.4 RMNS Values for each CTD Deployment

Analysis Run	CTD #	SiO4 measured	PO4 measured	NO2 measured	NOx measured
CB reported		**111.821**	**2.580**	**0.199**	**36.649**
1	1,2	111.367	2.603	0.144	36.713
7	8	111.100	2.590	-	36.730
8	8	-	-	0.135	-
17	17	110.967	2.590	0.140	36.737
23	23	111.200	2.573	0.135	36.640
30	30	111.100	2.620	0.136	36.753
36	36	110.633	2.613	0.145	36.833
44	44	111.267	2.600	0.145	36.917
51	51	110.900	2.610	0.138	36.843
59	60	111.767	2.623	0.139	37.057
67	71	111.567	2.593	0.141	36.983
81	86	111.433	2.600	0.132	36.823
99	105	111.600	2.610	0.135	36.900
CC reported		**88.228**	**2.130**	**0.119**	**31.740**
1	1,2	87.767	2.130	0.133	31.787
2	3	87.600	2.120	0.140	31.893
3	4	87.533	2.130	0.130	31.857
4	5	87.663	2.114	0.129	31.836
5	6	87.775	2.138	0.133	31.788
6	7	87.600	2.123	0.137	31.860
7	8	87.600	2.128	-	31.858
8	8	-	-	0.133	-
9	9	87.400	2.138	0.135	31.863
10	10	87.925	2.145	0.130	31.828
11	11	87.425	2.143	0.138	31.868
12	12	87.850	2.150	0.133	31.908
13	13	87.625	2.140	0.138	31.848
14	14	87.925	2.145	0.131	31.925
15	15	87.625	2.140	0.132	31.798
16	16	87.875	2.150	0.131	31.810
17	17	87.400	2.125	0.133	31.815
18	18	87.325	2.118	0.131	31.778

19	19	87.375	2.135	0.130	31.825
20	20	87.375	2.125	0.130	31.845
21	21	87.425	2.120	0.130	31.883
22	22	87.525	2.110	0.130	31.868
23	23	87.450	2.118	0.131	31.878
24	24	87.225	2.128	0.133	31.875
25	25	87.750	2.128	-	31.923
26	26	87.375	2.130	-	31.738
27	27	87.375	2.120	0.130	31.820
28	28	87.425	2.130	0.134	31.700
29	29	87.475	2.128	0.133	31.835
30	30	87.450	2.153	0.130	31.835
31	31	87.667	2.160	0.130	31.877
32	32	87.975	2.160	0.140	31.930
33	33	88.025	2.155	0.131	31.898
34	34	87.500	2.155	0.133	31.925
35	35	87.225	2.160	0.132	31.905
36	36	87.175	2.153	0.136	32.005
37	37	87.050	2.163	0.134	31.915
38	38	87.475	2.155	0.133	31.885
39	39	87.675	2.160	0.131	31.943
40	40	87.775	2.146	0.131	31.966
41	41	87.800	2.143	0.138	31.970
42	42	87.925	2.150	0.141	32.038
43	43	87.857	2.139	0.129	31.904
44	44	87.675	2.140	0.139	31.953
45	45	87.625	2.140	0.129	31.895
46	46	87.850	2.150	0.131	31.880
47	47	87.517	2.140	0.136	31.882
48	48	87.625	2.143	0.128	32.060
49	49	87.650	2.150	0.131	32.013
50	50	87.960	2.168	0.135	31.836
51	51	86.975	2.145	0.135	31.963
52	52	87.586	2.156	0.133	31.897
53	53	87.925	2.145	0.132	32.005
54	54	87.775	2.160	0.139	31.908

55	55	87.775	2.165	0.129	31.960
56	56	87.825	2.150	0.128	31.933
57	57	87.650	2.150	0.133	32.013
58	58, 59	88.025	2.168	0.130	32.000
59	60	88.175	2.168	0.131	32.035
60	61	88.050	2.163	0.133	32.153
61	62, 63, 64	88.250	2.175	0.133	31.935
62	65, 66	88.175	2.158	0.136	31.993
63	67	87.575	2.155	0.134	31.988
64	68	88.233	2.165	0.131	32.048
65	69	88.167	2.152	0.133	32.057
66	70	88.000	2.168	0.129	32.082
67	71, 72	87.880	2.132	0.143	32.022
68	73	87.925	2.140	0.130	31.960
69	74	87.825	2.148	0.138	32.020
70	75	87.900	2.148	0.132	32.058
71	76	88.025	2.135	0.130	32.008
72	77	87.775	2.150	0.129	31.868
73	78	87.975	2.153	0.129	31.993
74	79	87.275	2.138	0.128	31.915
75	80	87.750	2.150	0.131	31.875
76	81	88.000	2.150	0.133	31.995
77	82	87.800	2.150	0.132	32.090
78	83	87.900	2.158	0.133	31.880
79	84	87.800	2.145	0.131	31.890
80	85	87.667	2.155	0.134	31.863
81	86	87.800	2.140	0.128	31.780
82	87	87.875	2.168	0.138	32.018
83	88	87.825	2.163	0.134	31.995
84	89	87.800	2.173	0.134	32.000
85	90	88.000	2.160	0.132	32.140
86	91	88.250	2.148	0.128	32.050
87	92	88.000	2.158	0.133	31.973
88	93	88.100	2.158	0.131	31.938
89	94, 95	88.200	2.158	0.134	31.945

90	96	87.950	2.157	0.129	31.938
91	97	88.150	2.160	0.130	31.933
92	98	87.950	2.160	0.130	31.930
93	99	87.175	2.155	0.130	31.963
94	100	87.675	2.155	0.132	31.998
95	101	87.600	2.150	0.128	32.010
96	102	87.500	2.160	0.135	31.990
97	103	87.950	2.148	0.132	31.953
98	104	87.850	2.158	0.135	31.875
99	105	87.925	2.150	0.134	31.910
100	106	87.875	2.160	0.131	31.888
101	107	88.125	2.158	0.135	32.030
102	108	87.700	2.160	0.133	31.860
103	uwy	87.775	2.158	0.134	31.910
CD reported		**14.264**	**0.457**	**0.018**	**5.648**
1	1, 2	14.100	0.447	0.447	5.527
7	8	13.725	0.463	0.463	5.573
17	17	14.000	0.460	0.460	5.540
23	23	13.800	0.460	0.460	5.597
30	30	13.600	0.460	0.460	5.553
36	36	13.700	0.463	0.463	5.590
44	44	13.800	0.463	0.463	5.547
51	51	13.875	0.470	0.470	5.590
59	60	14.125	0.470	0.470	5.570
67	71	14.050	0.455	0.455	5.610
81	86	13.950	0.460	0.460	5.512
99	105	14.025	0.460	0.460	5.592

8.5 Internal Quality Control Values for each CTD Deployment

Measured concentrations (µM) of the internal quality control and the low nutrient seawater that were produced in the shore laboratory.

CTD/Date	LNSW	Spike	LNSW	Spike	LNSW	Spike	LNSW	Spike	LNSW	Spike
	NOx	NOx	PO4	PO4	SiO2	SiO2	NO2	NO2	NH4	NH4
Prepared Concentration	NA	5.5	NA	1.0	NA	10	NA	0.5	NA	1.0
	Measured Concentrations (µM)									
Oct-17	0.07	5.59	-0.001	0.99	0.9	11.3	0.06	0.55	0.34	1.31
Dec-17	0.1	5.46	0.017	1.02	1.0	11.4	0.041	0.56	0.39	1.36
CTD 1 & 2	0.09	5.43	0.01	1.01	0.7	11.2	0.037	0.537	0.35	1.31
CTD 3	0.09	5.44	0.01	1	0.5	10.9	0.04	0.54	0.36	1.31
CTD 4	0.09	5.43	0.02	1.01	0.4	10.8	0.037	0.535	0.37	1.31
CTD 5	0.09	5.44	0.01	0.99	0.5	10.9	0.037	0.534	0.34	1.28
CTD 6	0.1	5.47	0.02	1.01	0.5	11	0.043	0.536	0.34	1.3
CTD 7	0.09	5.48	0.01	1	0.4	10.9	0.046	0.548	0.36	1.31
CTD 8	0.09	5.46	0.01	1	0.4	10.9			0.34	1.29
CTD 9	0.1	5.45	0.02	1.01	0.4	10.8	0.038	0.538	0.39	1.33
CTD 10	0.1	5.48	0.01	1.01	0.5	10.9	0.038	0.525	0.39	1.32
CTD 11	0.11	5.45	0.01	1.01	0	10.5	0.043	0.537	0.36	1.32
CTD 12	0.1	5.45	0.02	1.01	0.5	11	0.035	0.53	0.36	1.32
CTD 13	0.11	5.48	0.02	1.01	0.2	10.7	0.042	0.538	0.37	1.33
CTD 14	0.1	5.5	0.01	1.01	0.5	11	0.034	0.538	0.36	1.33
CTD 15	0.11	5.49	0.01	1.01	0.2	10.7	0.0.36	0.535	0.37	1.34
CTD 16	0.11	5.46	0.03	1.02	0.7	11.1	0.033	0.527	0.38	1.34
CTD 17	0.09	5.44	0.02	1.01	0.6	11	0.038	0.535	0.37	1.33
CTD 18	0.1	5.44	0.02	1	0.5	10.9	0.04	0.527	0.37	1.32
CTD 19	0.1	5.45	0.02	1.01	0.5	10.9	0.041	0.527	0.37	1.31
CTD 20	0.1	5.43	0.01	1	0.4	10.9	0.032	0.53	0.36	1.32
CTD 21	0.1	5.44	0.02	1.01	0.5	10.9	0.037	0.528	0.32	1.26
CTD 22	0.09	5.49	0.02	0.99	0.5	10.9	0.039	0.532	0.38	1.35
CTD 23	0.09	5.48	0.02	0.99	0.4	10.9	0.038	0.526	0.36	1.3
CTD 24	0.09	5.48	0.02	1.01	0.4	10.8	0.039	0.526	0.36	1.31
CTD 25	0.09	5.49	0.02	1.01	0.4	10.9	0.048	0.545	0.36	1.31
CTD 26	0.1	5.43	0.01	1	0.1	10.8	0.046	0.543	0.36	1.31
CTD 27	0.09	5.43	0.01	0.99	0.4	10.9	0.034	0.523	0.37	1.33
CTD 28	0.11	5.4	0.02	1	0.5	10.9	0.038	0.529	0.37	1.31
CTD 29	0.1	5.43	0.02	1	0.6	11	0.04	0.533	0.38	1.35
CTD 30	0.1	5.48	0.01	1.02	0.1	10.6	0.033	0.532	0.36	1.29
CTD 31	0.09	5.45	0.02	1.02	0.5	10.9	0.041	0.542	0.38	1.34
CTD 32	0.09	5.46	0.02	1.02	0.5	11	0.044	0.543	0.35	1.32

CTD 33	0.09	5.44	0.03	1.02	0.6	11.1	0.033	0.527	0.37	1.33
CTD 34	0.12	5.5	0.02	1.02	0.6	11	0.043	0.539	0.36	1.34
CTD 35	0.13	5.48	0.02	1.01	0.4	10.8	0.039	0.539	0.37	1.34
CTD 36	0.12	5.49	0.01	1.01	0.4	10.8	0.044	0.552	0.38	1.34
CTD 37	0.12	5.49	0.02	1.02	0.1	10.5	0.045	0.548	0.37	1.33
CTD 38	0.11	5.45	0.02	1.02	0.5	10.9	0.04	0.535	0.37	1.33
CTD 39	0.12	5.48	0.01	1.02	0.4	10.9	0.038	0.535	0.37	1.33
CTD 40	0.11	5.45	0.01	1.01	0.3	10.6	0.038	0.532		
CTD 41	0.1	5.42	0.01	1.01	0.3	10.8	0.045	0.536	0.36	1.33
CTD 42	0.12	5.47	0.01	1.01	0.5	11	0.048	0.551	0.36	1.33
CTD 43	0.12	5.44	0.01	1.01	0.5	11	0.034	0.529	0.36	1.31
CTD 44	0.12	5.47	0.01	1.01	0.4	10.9	0.04	0.536	0.37	1.32
CTD 45	0.12	5.45	0.01	1.01	0.3	10.9	0.034	0.536	0.38	1.32
CTD 46	0.11	5.46	0.01	1.02	0.6	11.1	0.041	0.535	0.36	1.33
CTD 48	0.14	5.47	0.01	1.01	0.6	11	0.045	0.546	0.39	1.34
CTD 50	0.11	5.49	0.02	1.02	0.7	11.1	0.038	0.53	0.37	1.34
CTD 52	0.12	5.46	0.02	1.01	0.4	10.8	0.04	0.531	0.38	1.35
CTD 54	0.12	5.44	0.02	1.02	0.5	10.9	0.048	0.541	0.36	1.33
CTD 56	0.11	5.47	0.02	1.02	0.6	11.1	0.039	0.534	0.37	1.35
CTD 58	0.12	5.48	0.02	1.03	0.5	11	0.036	0.526	0.36	1.33
CTD 59	0.11	5.48	0.02	1.02	0.6	11.2	0.037	0.53	0.37	1.34
CTD 68	0.13	5.48	0.02	1.03	1	11.5	0.036	0.537	0.37	1.33
CTD 70	0.11	5.51	0.02	1.03	0.6	11.1	0.035	0.533	0.39	1.36
CTD 73	0.1	5.49	0.01	1.01	0.6	11.1	0.039	0.534	0.38	1.34
CTD 74	0.1	5.51	0.02	1.02	0.6	11	0.056	0.547	0.36	1.32
CTD 77	0.12	5.52	0.02	1.02	0.6	11.1	0.041	0.537	0.37	1.33
CTD 78	0.12	5.52	0.03	1.02	0.6	11.1	0.043	0.536	0.37	1.33
CTD 80	0.12	5.45	0.01	1.01	0.5	11	0.04	0.536	0.36	1.32
CTD 82	0.12	5.47	0.02	1.01	0.5	10.9	0.043	0.538	0.36	1.32
CTD 85	0.12	5.42	0.02	1.02	0.5	11	0.05	0.538	0.39	1.35
CTD 87	0.14	5.5	0.02	1.03	0.4	10.9	0.052	0.545	0.36	1.31
CTD 89	0.14	5.48	0.02	1.03	0.5	10.9	0.042	0.533	0.37	1.34
CTD 90	0.14	5.48	0.01	1.02	0.6	11.1	0.046	0.547	0.38	1.39
CTD 92	0.12	5.46	0.02	1.02	0.5	11	0.038	0.533	0.38	1.34
CTD 94	0.1	5.48	0.02	1.02	0.7	11.2	0.042	0.542	0.37	1.33
CTD 96	0.13	5.49	0.02	1.02	0.5	11	0.052	0.542	0.4	1.37
CTD 97	0.11	5.45	0.02	1.02	0.7	11.1	0.039	0.528	0.37	1.33
CTD 98	0.1	5.45	0.02	1.02	0.6	11	0.044	0.531	0.4	1.36

CTD 99	0.12	5.46	0.01	1.01	0.4	10.7	0.039	0.53	0.39	1.35
CTD 100	0.11	5.49	0.02	1.02	0.7	11.1	0.041	0.536	0.39	1.36
CTD 101	0.11		0.01		0.6		0.037		0.39	
CTD 102	0.16	5.49	0.02	1.02	0.5	11	0.048	0.548	0.39	1.33
CTD 103	0.12		0.02		0.6		0.045		0.41	
CTD 104	0.12	5.5	0.02	1.02	0.6	11.1	0.042	0.542	0.39	1.34
CTD 105	0.12	5.49	0.02	1	0.6	11	0.041	0.533	0.39	1.36

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APPENDIX 3 – CFC LAB REPORT

2018 SR3 Chlorofluorocarbon (CFC), Sulfur Hexafluoride (SF_6), and Nitrous Oxide (N_2O)* Measurements

- Note that N_2O measurements are a Level 3 measurement. The concentrations were measured on the same water samples collected for the Level 1 CFC/SF_6 measurements. The N_2O analysis is still under development. Please contact the PI for any use of these data

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Samplers and Analysts: Mark J. Warner, University of Washington
Daniel Anderson, University of Washington

Samples for the analysis of dissolved CFC-11, CFC-12, SF_6, and N_2O were collected from approximately 1720 of the Niskin water samples during the expedition. When taken, water samples for CFC analysis were the first samples drawn from the 12-liter bottles. Care was taken to co-ordinate the sampling of CFCs with other samples to minimize the time between the initial opening of each bottle and the completion of sample drawing. In most cases, dissolved oxygen and dissolved inorganic carbon were collected within several minutes of the initial opening of each bottle. To minimize contact with air, the CFC samples were collected from the Niskin bottle petcock into 250-cc ground glass syringes through plastic 3-way stopcocks. The syringes were stored in large ice chest in the laboratory at 3.5° - 6° C until 30-45 minutes before analysis to reduce the degassing and bubble formation in the sample. At that time, they were transferred to a water bath at approximately 29° C in order to increase the stripping efficiency during analysis.

Concentrations of CFC-11, CFC-12, SF_6, and N_2O in air samples, seawater and gas standards were measured by shipboard electron capture gas chromatography (EC-GC). This system from the University of Washington was located in a portable laboratory on the heli-deck. Samples were introduced into the GC-EC via a purge and trap system. Approximately 200-ml water samples were purged with nitrogen and the compounds of interest were trapped on a Porapak Q/Carboxen 1000/Molecular Sieve 5A trap cooled by an immersion bath to -60^{o}C. During the purging of the sample (6 minutes at 220 ml min^{-1} flow), the gas stream was stripped of any water vapor via a Nafion trap in line with an ascarite/magnesium perchlorate dessicant tube prior to transfer to the trap. The trap was isolated and heated by direct resistance to 175^{o}C. The desorbed contents of the trap were back-flushed and transferred onto the analytical pre-columns. The first precolumn was a 40-cm length of 1/8-in tubing packed with 80/100 mesh Porasil B. This precolumn was used to separate the CFC-11 from the other gases. The second pre-column was 13 cm of 1/8-in tubing packed with 80/100 mesh molecular sieve 5A. This pre-column separated the N_2O from CFC-12 and SF_6. Three analytical columns in three gas chromatographs with electron capture detectors were used in the analysis. CFC-11 was separated from other compounds by a long column consisting of 36 cm of Porasil B and 150 cm of Carbograph 1AC maintained at 90°C. CFC-12 and SF_6 were analyzed using a column consisting of 2.33 m of molecular sieve 5A and 1.5 m of Carbograph 1AC maintained at 80°C. The analytical column for N_2O was 30 cm of molecular sieve 5A in a 120°C oven. The carrier gas for this column was instrumental grade

P-5 gas (95% Ar / 5% CH_4) that was directed onto the second precolumn and into the third column for the N_2O analyses. All three detectors were run at 300°C.

The analytical system was calibrated frequently using a standard gas of known gas composition. Gas sample loops of known volume were thoroughly flushed with standard gas and injected into the system. The temperature and pressure was recorded so that the amount of gas injected could be calculated. The procedures used to transfer the standard gas to the trap, precolumns, main chromatographic columns and EC detectors were similar to those used for analyzing water samples. Three sizes of gas sample loops were used. Multiple injections of these loop volumes could be made to allow the system to be calibrated over a relatively wide range of concentrations. Air samples and system blanks (injections of loops of CFC-free gas) were injected and analyzed in a similar manner. The typical analysis time for samples was 750 sec.

For atmospheric sampling, an ~100 meter length of 3/8-in OD Dekaron tubing was run from the portable laboratory to the bow of the ship. A flow of air was drawn through this line to the main laboratory using an Air Cadet pump. The air was compressed in the pump, with the downstream pressure held at ~1.5 atm. using a back-pressure regulator. A tee allowed a flow (100 ml min^{-1}) of the compressed air to be directed to the gas sample valves of the CFC/SF_6/N_2O analytical system, while the bulk flow of the air (>7 l min^{-1}) was vented through the back-pressure regulator. Air samples were generally analyzed when the relative wind direction was within 50 degrees of the bow of the ship to reduce the possibility of shipboard contamination. The pump was run for approximately 30 minutes prior to analysis to insure that the air inlet lines and pump were thoroughly flushed. The average atmospheric concentrations determined during the cruise (from a sets of 4 or 5 measurements analyzed when possible) were 241.7 +/- 8.7 parts per trillion (ppt) for CFC-11 (n=21), 518.6 +/- 10.9 ppt for CFC-12 (N=21), 9.3 +/- 0.5 ppt for SF_6 (N=20), and 336.2 +/- 5.5 parts per billion for N_2O (N=5). Note that a larger aliquot was required for higher precision N_2O analysis, and this higher aliquot resulted in SF_6 peak areas outside the range of the calibration curve used for seawater samples.

Concentrations of the CFCs in air, seawater samples and gas standards are reported relative to the SIO98 calibration scale (Prinn et al., 2000). Concentrations in air and standard gas are reported in units of mole fraction in dry gas, and are typically in the parts per trillion (ppt) range for CFCs and SF_6 and parts per billion (ppb) for N_2O. Dissolved CFC concentrations are given in units of picomoles per kilogram seawater (pmol kg^{-1}), SF_6 in femtomoles per kilogram seawater (fmol kg^{-1}), and N_2O in nanomoles per kilogram seawater (nmol kg^{-1}). CFC concentrations in air and seawater samples were determined by fitting their chromatographic peak areas to multi-point calibration curves, generated by injecting multiple sample loops of gas from a working standard (UW WRS 32399) into the analytical instrument. Full-range calibration curves were run at the beginning and end of the cruise, as well as during long transits/weather delays when possible. Single injections of a fixed volume of standard gas at one atmosphere were run much more frequently (at intervals of 2 hours) to monitor short-term changes in detector sensitivity. The SF_6 peak was often on a small bump on the baseline, resulting in a large dependence of the peak area on the choice of endpoints for integration. Estimated accuracy is +/- 3%. Estimated limit of detection is 1 fmol kg^{-1} for CFC-11, 2 fmol kg^{-1} for CFC-12, 0.05 fmol kg^{-1} for SF_6, and 0.5 nmol kg^{-1} for N_2O.

The efficiency of the purging process was evaluated at every other station by re-stripping water samples and comparing the residual concentrations to initial values. These re-strip values were less than 1% for CFC-11 and essentially zero for CFC-12 and SF_6. For N_2O, the re-strip values were complicated by the apparent production of N_2O within the re-stripped sample within the sparging chamber for a subset of the samples. See the discussion below. Based on the re-strips of numerous samples from the deep ocean, the mean values were approximately 4%.

On this expedition, based on the analysis of 45 duplicate samples, we estimate precisions (1 standard deviation) of 0.3% or 0.002 pmol kg^{-1} (whichever is greater) for dissolved CFC-11, 0.8% or 0.004 pmol kg^{-1} for CFC-12 measurements, 0.036 fmol kg^{-1} or 4.1% for SF_6, and 0.18 nmol kg^{-1} or 1.2% for N_2O.

Analytical Difficulties

The major analytical challenge for this voyage was the sensitivity of the electron capture detector used for the measurement of SF_6 and CFC-12 to changes in atmospheric pressure. The peak area of an injection of one large sample loop of the increased by approximately 4% per decrease of 1 mb in atmospheric pressure. In addition the baseline shifted upwards and was very sensitive to the motion of the ship. At atmospheric pressures below 970 mb, the broad plateau on which the SF6 peak eluted became a broad peak with the SF_6 peak on the downslope. In rough seas, it was difficult to separate the smaller SF_6 peaks from the broader peaks associated with the ship roll. For most of the analyses during these periods, any peak within a time window (74 to 80 sec) was identified as SF_6 with endpoints manually chosen. In most of these instances, the reported low-level SF_6 concentrations are flagged as questionable (flag 3).

One CTD (#32) was not sampled due to analytical difficulties with this same ECD. Unknown contamination caused the detector voltage to be pegged at its maximum response. After 6 hours or so, it returned to normal.

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CCHDO Data Processing Notes

Data History

- **File Online** **Carolina Berys**

in1801.pdf (download) #93736
Date: 2018-10-03
Current Status: unprocessed

- **File Online** **Carolina Berys**

in1801.sea (download) #d4203
Date: 2018-10-03
Current Status: unprocessed

- **File Online** **Carolina Berys**

in1801.sum (download) #dc7de
Date: 2018-10-03
Current Status: unprocessed

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Date: 2018-10-03
Current Status: unprocessed

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Date: 2018-10-03
Current Status: unprocessed

- **File Online** Carolina Berys

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Date: 2018-10-03
Current Status: unprocessed

- **File Submission** Carolina for Mark Rosenberg

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Current Status: unprocessed
Notes

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RV Investigator cruise 096U20180111 (aliases in2018_v01, in1801) includes CTD data
and bottle data with CFC update.
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and bottle data with CFC update.
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and bottle data with CFC update.
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- **File Submission Carolina for Mark Rosenberg**

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- **File Submission Carolina for Mark Rosenberg**

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Notes
096U20180111_woceexchange_version01oct2018.zip contains data and cruise report for RV Investigator cruise 096U20180111 (aliases in2018_v01, in1801) includes CTD data and bottle data with CFC update.

- **File Submission Carolina for Mark Rosenberg**

in1801.pdf (download) #93736
Date: 2018-10-03
Current Status: unprocessed
Notes
096U20180111_woceexchange_version01oct2018.zip contains data and cruise report for RV Investigator cruise 096U20180111 (aliases in2018_v01, in1801) includes CTD data and bottle data with CFC update.