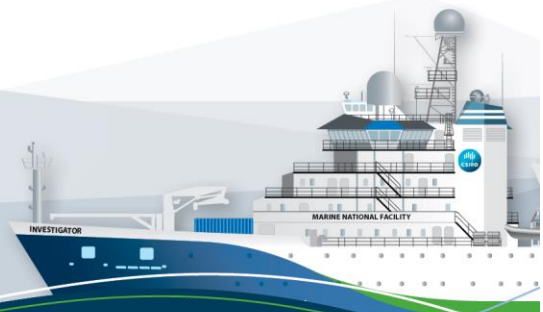
RV *Investigator*

CTD Processing Report

Voyage #:	in2015_c01
Voyage title:	GAB deep water geological and benthic ecology program
Depart:	Hobart, Tuesday 25 October 2015
Return:	Port Lincoln, Friday, 28 November 2015
Report compiled by:	Steven Van Graas, Pamela Brodie, Stewart Wilde and Peter Shanks



Contents

1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2015_c01, from 25 Oct 2015 to 28 Nov 2015.

Data for 16 deployments were acquired using the Sea-Bird SBE911 CTD 20, fitted with 36 twelve litre bottles on the rosette sampler. CSIRO-supplied calibration factors were used to compute the pressures and preliminary conductivity values. CSIRO-supplied calibrations were applied to the temperature data. The data were subjected to automated QC to remove spikes and out-of-range values.

Cast 1 was a test down to 100m. Deployment 4 was aborted early due to winch issues. Deployment 7 was a test cast to examine winch issues. Data Spikes in casts 8 and 9 were likely due to the LISST particle size sensor which was attached to the CTD serial port for casts 7-9. A Rinko Oxygen sensor was used for casts 1-7, 10-15.

The final conductivity calibration was based on a single deployment grouping. The final calibration from the primary sensor had a standard deviation (SD) of 0.0014 PSU, within our target of 'better than 0.002 PSU'. The standard product of 1 decibar binned averaged files were produced using data from the primary sensors.

The dissolved oxygen data calibration fit had a SD of 0.78µM. The agreement between the CTD and bottle data was good.

A Chelsea turbidity, PAH, chlorophyll, and CDOM sensors, the Biospherical PAR sensor, Rinko III oxygen sensor, Franatech methane sensor, and a Tritech altimeter were also fitted on the auxiliary A/D channels of the CTD.

2 Voyage Details

2.1 Title

GAB deep water geological and benthic ecology program

2.2 Principal Investigators

Andy Ross, CSIRO Energy

2.3 Voyage Objectives

The scientific objectives for in2015_c01 were outlined in the Voyage Plan.

For further details, refer to the Voyage Plan and/or summary which can be viewed on the Marine National Facility web site.

2.4 Area of operation

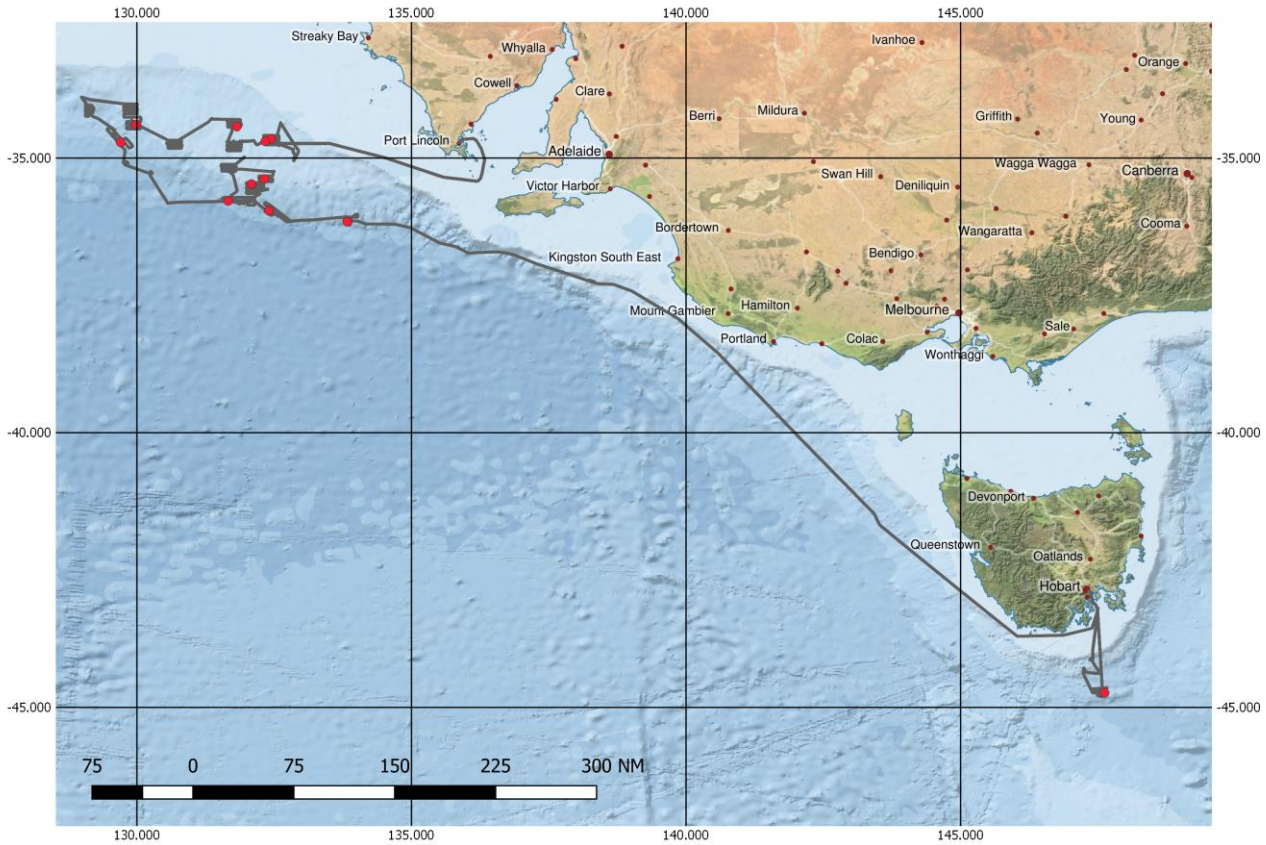


Figure 1. Area of Operation for in2015_c01 CTDs

3 Processing Notes

3.1 Background Information

The data for this voyage were acquired with CTD SBE9+ unit 20 with dual conductivity and temperature sensors. There were 16 CTD deployments, as shown in Figure 1.

A Biospherical photosynthetically active radiation (PAR), Chelsea Nephelometer, Chlorophyll, CDOM sensors were also installed on the auxiliary A/D channels of the CTD. These sensors are described in Table 1 below.

Description	Sensor	Serial No.	A/D	Calibration Date	Calibration Source
Pressure	Digiquartz 410K-134	#20- 552	P	08 Apr 2015	CSIRO
Primary Temperature	Sea-Bird SBE3*plus*	4722	T0	27 Feb 2015	CSIRO
Secondary Temperature	Sea-Bird SBE3*plus*	4522	T1	27 Feb 2015	CSIRO

Primary Conductivity	Sea-Bird SBE4C	3868	C0	26 Feb 2015	CSIRO
Secondary Conductivity	Sea-Bird SBE4C	3168	C1	26 Feb 2015	CSIRO
Nephelometer	Chelsea	11-8199-001	A0	22 Oct 2015	CSIRO Energy
UV Aquatracka	Chelsea	15-0267-001	A1	10 Sep 2015	CSIRO Energy
Chlorophyll	Chelsea	11-8141-001	A2	10 Sep 2015	CSIRO Energy
CDOM	Chelsea	10-7776-001	A3	10 Sep 2015	CSIRO Energy
PAR	QCP-2300HP	70111	A4	25 Aug 2015	Manufacturer
Altimeter	Tritech PA200	313624	A5	22 May 2015	Manufacturer
Dissolved Oxygen	Rinko	0163	A6	23 Jan 2015	CSIRO Energy
Methane	Franatech	1554*/1549	A7	22 Aug 2015	CSIRO Energy

*Sensor used for casts 1-3 inclusive; following casts used Serial Number 1549

Table 1. CTD Sensor configuration on in2015_c01

There were 16 CTD casts.

The raw CTD data were acquired using CAP acquisition software. A conductivity advance of 0.073 seconds was applied in the deck box to both the primary and secondary conductivity.

The netCDF files were processed using CapPro v2.11. This Matlab software was used to apply automated QC and preliminary processing to the data. This included spike removal, identification of water entry and exit times, conductivity sensor lag corrections and the determination of the pressure offsets. The automatically determined pressure offsets and in-water points were inspected and adjusted where necessary. The hydrology data were loaded and CapPro computed the matching CTD sample burst data.

The bottle sample data were used to compute final conductivity and dissolved oxygen calibrations. These were applied to the data and binned 1dB averaged data files were produced.

3.2 Pressure reference

The surface pressure offsets are plotted in Figure 2 below. The blue circles refer to initial out-of-water values and the red circles the final out-of-water values.

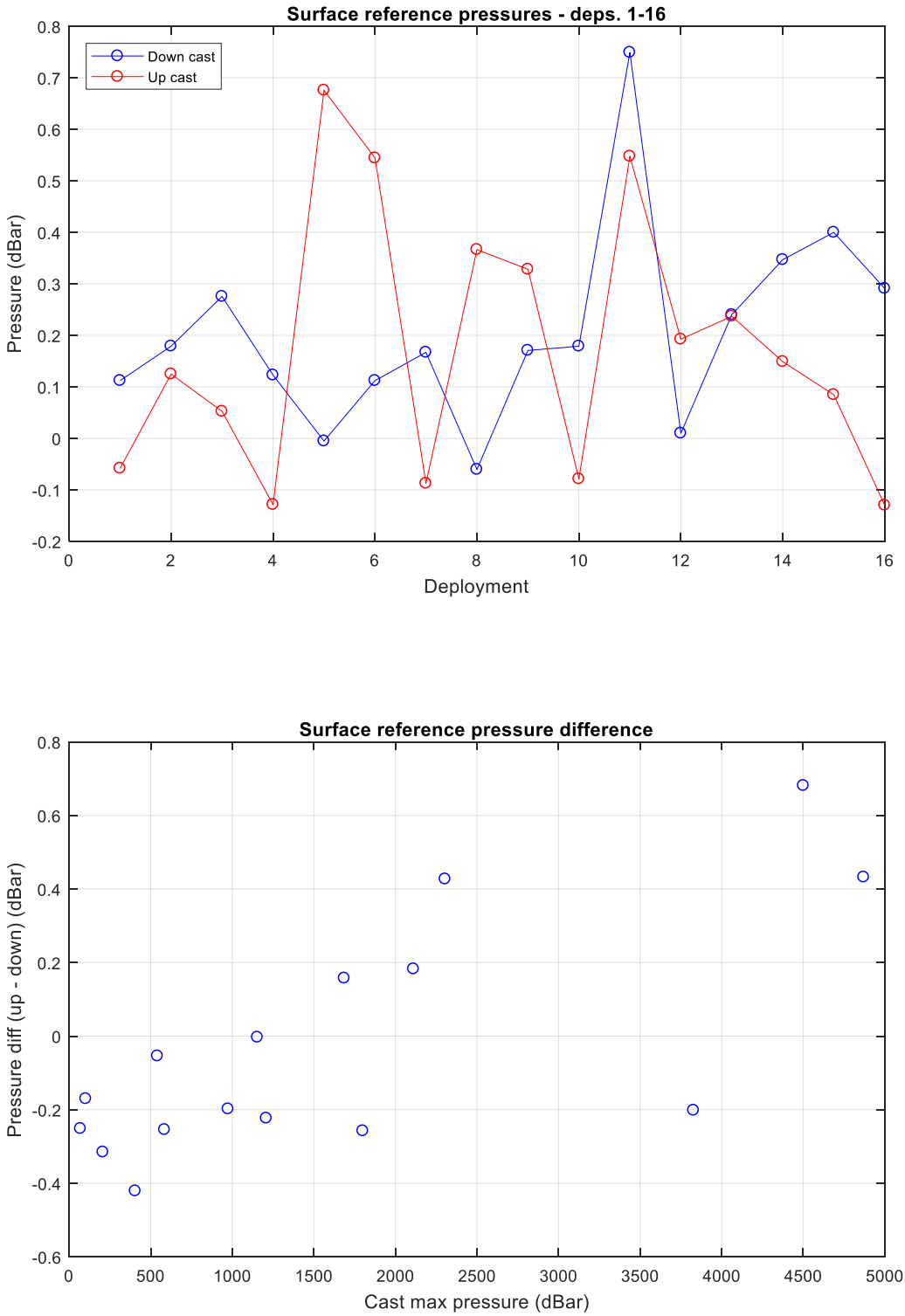


Figure 2. CTD pressure reference

The mean difference between the primary and secondary temperature sensors is plotted below. Most deployments should plot within ±1 m°C. Figure 3 indicates neither sensor has drifted significantly from its calibration, however there is greater than usual noise on the secondary temperature sensor.

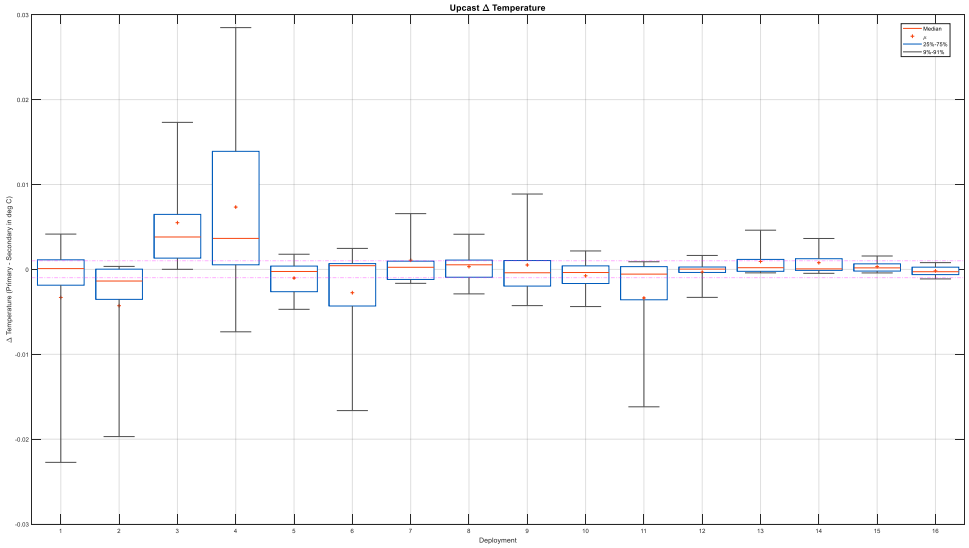


Figure 3. Temperature sensor difference

3.3 Conductivity Calibration

Discrepancies and possible sampling problems between bottle and CTD salinities for the primary conductivity sensor would show in Figure 4, the plot of calibrated (CTD - Bottle) salinity below.

The final calibration used the primary conductivity sensor and was based upon the sample data for 59 of the 75 samples taken during deployments, using both the ‘good’ and ‘suspect’ hydrochemistry results, with the ‘suspect’ values weighted at 10%. These were all within our target of including no less than 75% of samples. The outliers marked in the figures below with magenta dots are excluded from the calibration, the outliers marked with blue dots are used in the calibration but are weighted based on their distance from the mean. Any outliers marked with red crosses or dots are also excluded from the calibration.

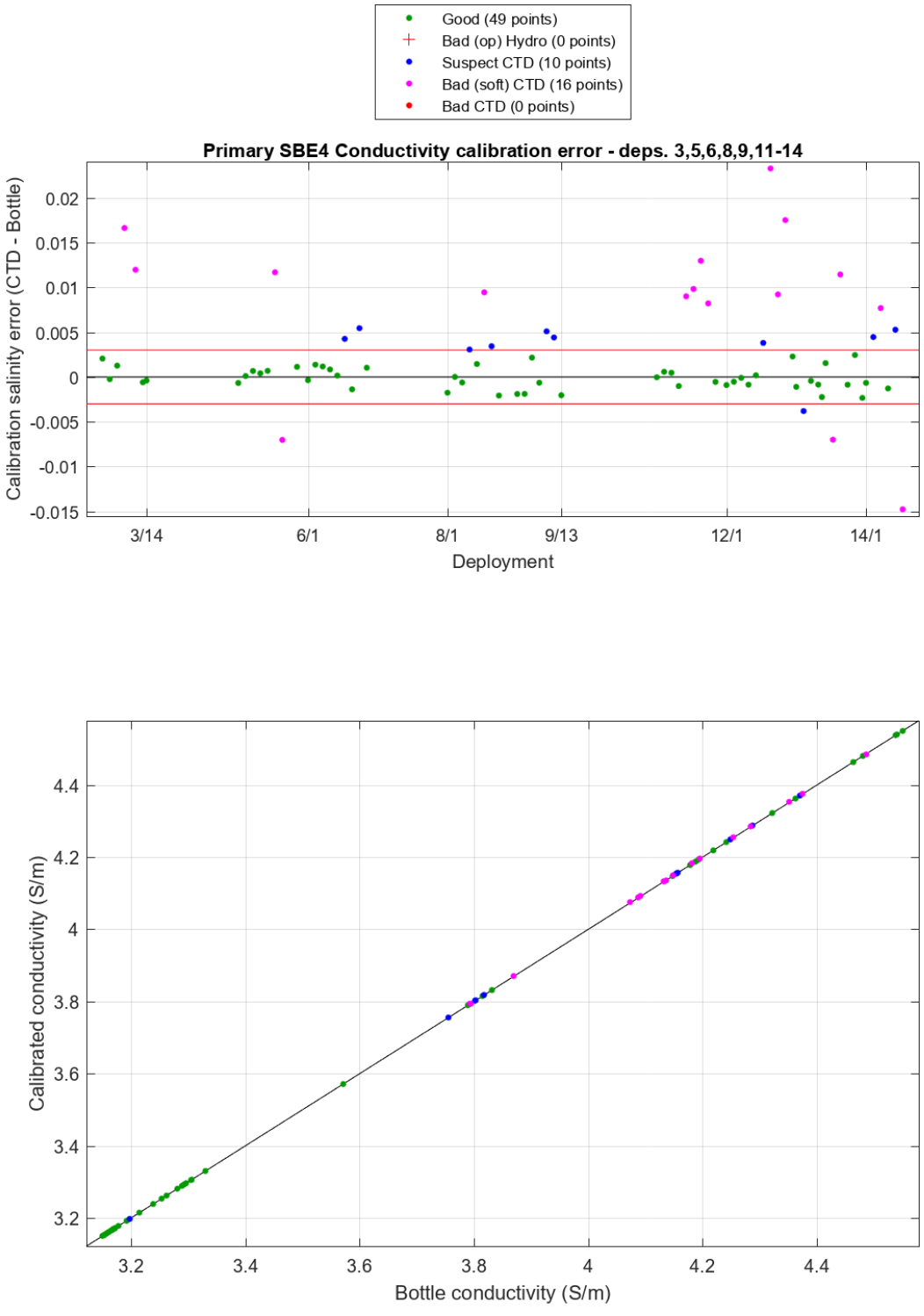


Figure 4. Primary conductivity calibrations

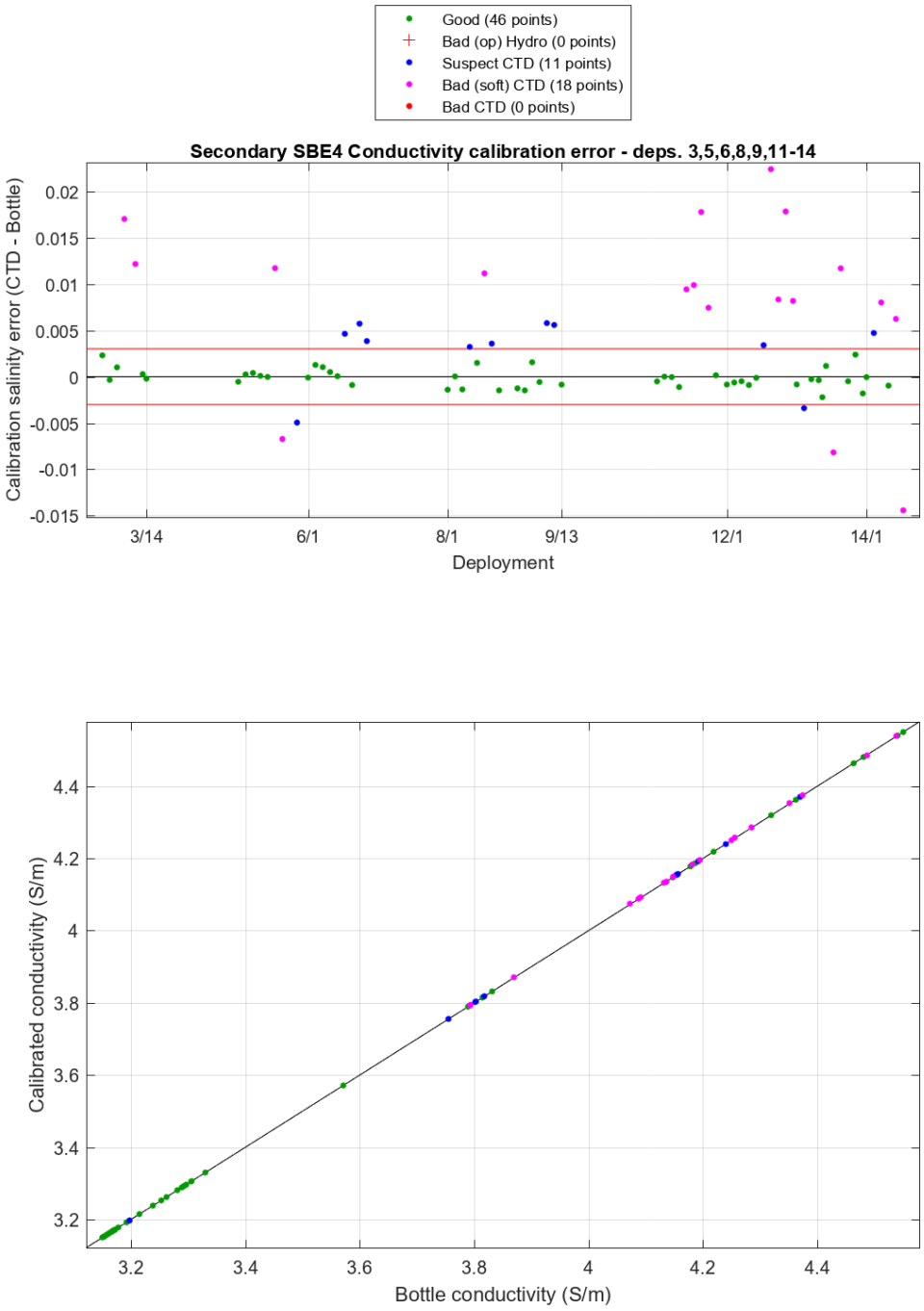


Figure 5. Secondary conductivity calibrations

The final result for the primary and secondary conductivity sensors with respect to their original calibrations are shown in Tables 2 and 3.

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Sensor Group	Deployments	Scale Factor		Offset		Salinity (PSU)	
		a1	±	a0	±	Residual SD	M.A.D.
Primary	1-16	0.99973	0.0013031	0.0013874	0.0052648	0.0014272	0.0011047
Secondary	1–16	0.99937	0.0012678	0.0010385	0.0050883	0.0016173	0.00090671

Table 2 Conductivity calibration with respect to manufacturer calibration and post-calibration results

Conductivity Sensor	Deployments	CPcor	±
Primary	1-16	-8.4179e-08	1.6878e-07
Secondary	1-16	-9.4386e-08	1.5995e-07

Table 3 Calculated CPcor compared with the manufacturer nominal value of -9.5700e-08

This is a good calibration. We normally aim for a S.D. of 0.002 PSU for typical oceanographic voyages. The above calibration factors were applied to all deployments. Full plots of residuals before and after calibration are available in Appendix A.
Data from the primary conductivity and temperature sensors were used to produce the averaged salinities with secondary sensors included with a suffix '_2'.

The cut-off of 0.003 was used in all cases. Calibration standard deviation is the standard deviation of the difference between the calibrated values and the bottle values. This calibration was well within the range we normally aim for, an S.D. of 0.002 PSU or lower for 'typical' oceanographic voyages.

Data from the primary conductivity and temperature sensors were used to produce the averaged salinities.

3.4 Dissolved Oxygen Sensor Calibration

3.4.1 Rinko III calibration procedure

The Rinko III is a fast-response, high-accuracy and high-resolution Dissolved Oxygen sensor. The Rinko III is an optical sensor, based on phosphorescence principle. According to the manufacturer – JFE Advantech- The DO sensor is coated with photostimulable phosphor (PSP) on the outside of the pressure-resistant acrylic optical window, measuring phosphorescence quenching phase shift. The excitation blue LED pulse generates a red phosphorescence pulse, which in turn has an inverse correlation with the oxygen partial pressure in the water.

Calibration involves performing a linear regression, to produce new estimates of the calibration coefficients *Scale* and *Offset*. These new coefficients are used, along with the other manufacturer-supplied coefficients, to derive oxygen concentrations from the sensor voltages.

3.4.2 Results

The plot below in Figure 6 is of CTD - bottle oxygen differences for both upcast and downcast data (red indicates 'bad' data).

Typically on RV Investigator voyages we install primary and secondary SBE43 Oxygen sensors, however for in2015_c01 a single Rinko III sensor was used.

A single calibration group for the DO sensor was used with the associated Rinko III up-cast data to compute the new *Scale* and *Offset* coefficients.

The old and new *Scale* and *Offset* values for the DO sensor is listed in Table 2 below. The *Scale* value is a linear slope scaling coefficient; *Offset* is the fixed sensor voltage at zero oxygen.

The calibrations below were applied for deployments 1 to 16 for the Rinko III DO sensor.

Sensor	Calibration Source	Deployments	Calibration Coefficients				Dissolved Oxygen (µM)	
			Voffset	±	*Soc*	±	Residual SD	M.A.D.
Primary	Hydrochemistry	1-16	-3.7907	7.2142	1.0021	0.0573	0.77782	1.052

Table 4. Dissolved Oxygen calibration

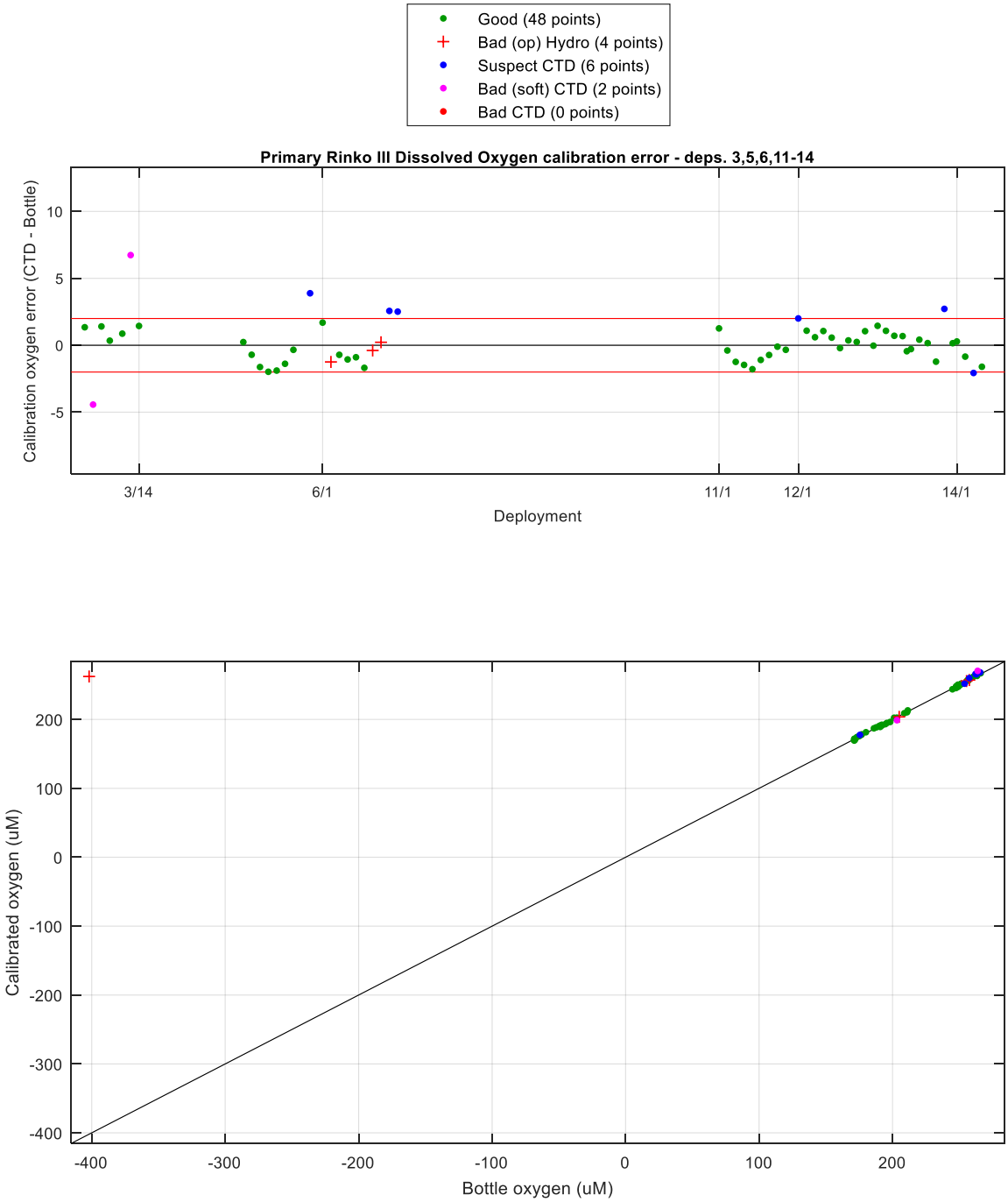


Figure 6. Dissolved Oxygen calibration, all deployments – primary sensor

3.5 Other sensors

The Chelsea fluorometer was used for all deployments. These were calibrated to give nominal outputs of 0-100 fsd (full scale deflection).

The Biospherical PAR sensor was used for all deployments. The output is in umol photons/m^2/s. This data channel has been included in the output files for all deployments. Clearly, time of day and environmental factors such as sea state and cloud cover impact on these readings. If most or all of the values for a deployment are near zero it indicates a night-time cast. In deployments where the PAR profiles have sub-surface maxima the CTD may have been shaded by the ship.

The WET Labs ECO-AFL/FL Fluorometer, and WET Labs ECO-BB Optical Backscatter were used for all deployments. The calibration coefficients are listed below.

Sensor	Deployments	Cal Date	Calibration Coefficients
Chelsea Chlorophyll	1-16	July 2015	Scale: 0.008294
			Offset: -0.01132
Chelsea Nephelometer	1-16	July 2015	Scale: 0.015984
			Offset: -0.05391
Chelsea CDOM	1-16	July 2015	Scale Factor: 0.017854
			Offset: -0.33654
Chelsea UV Aquatraka	1-16	May 2015	Scale Factor: 0.001007
			offset: -0.026336
Methane	1-16	July 2015	Scale Factor: 2.5
			Offset: 100

Table 5. Auxiliary Sensor Calibration Coefficients

3.6 Bad data detection

The limits for each sensor are configured in CapPro and are written to the netCDF scan file. Typical limits used for the sensor range and maximum second difference are in Table 6 below. The rejection rate is recorded in the CapPro processing log file.

Sensor	Range minimum	Range maximum	Maximum Second Difference
Pressure	-7	6500	0.5
Temperature	-2	40	0.05
Conductivity	-0.01	7	0.01
Oxygen	-1	500	0.5
Fluorometer	0	5	0.5
PAR	-5	2000	0.5
Transmissometer	0	105	0.5

Table 6 Sensor limits for bad data detection

3.7 Averaging

The calibrated data were filtered to remove pressure reversals and binned into the standard product of 1dbar averaged netCDF files. The binned values were calculated by applying a linear, least-squares fit as a function of pressure to the sensor data for each bin, using this to interpolate the value for the bin mid-point. This method is used to avoid possible biases which would result from averaging with respect to time.

Each binned parameter is assigned a QC flag. Our quality control flagging scheme is described in Pender (2000).

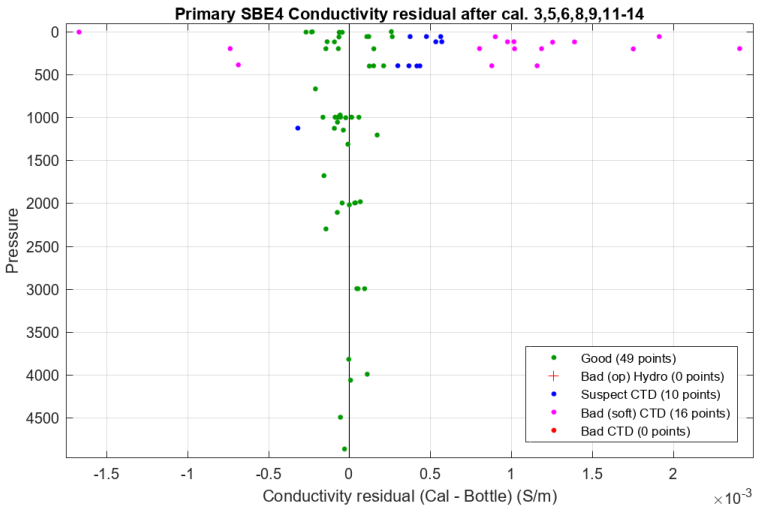
The QC Flag for each bin is estimated from the values for the bin components. The QC Flag for derived quantities, such as Salinity and Dissolved Oxygen are taken to be the worst of the estimates for the parameters from which they are derived.

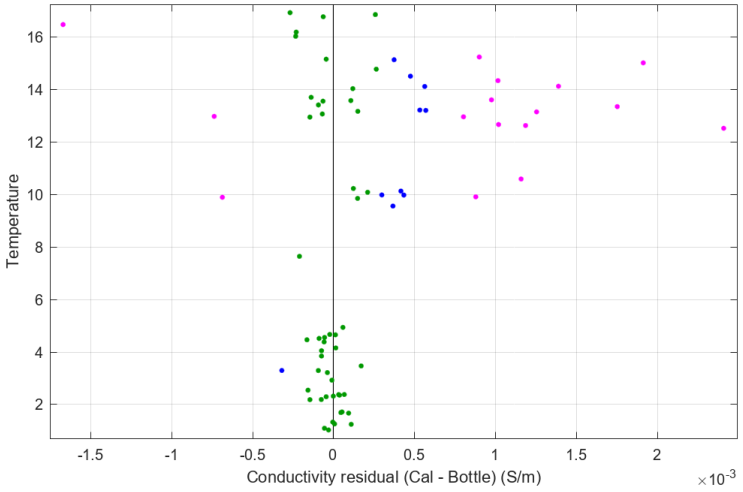
4 References

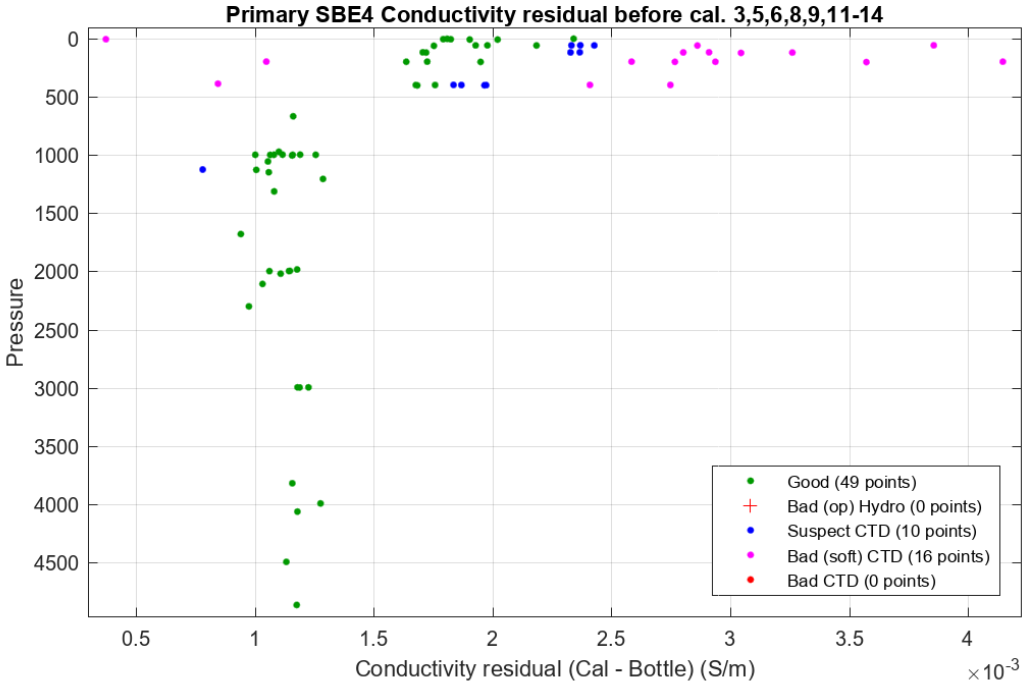
in2015_c01 voyage plan.
https://www.cmar.csiro.au/data/reporting/get_file.cfm?eov_pub_id=77

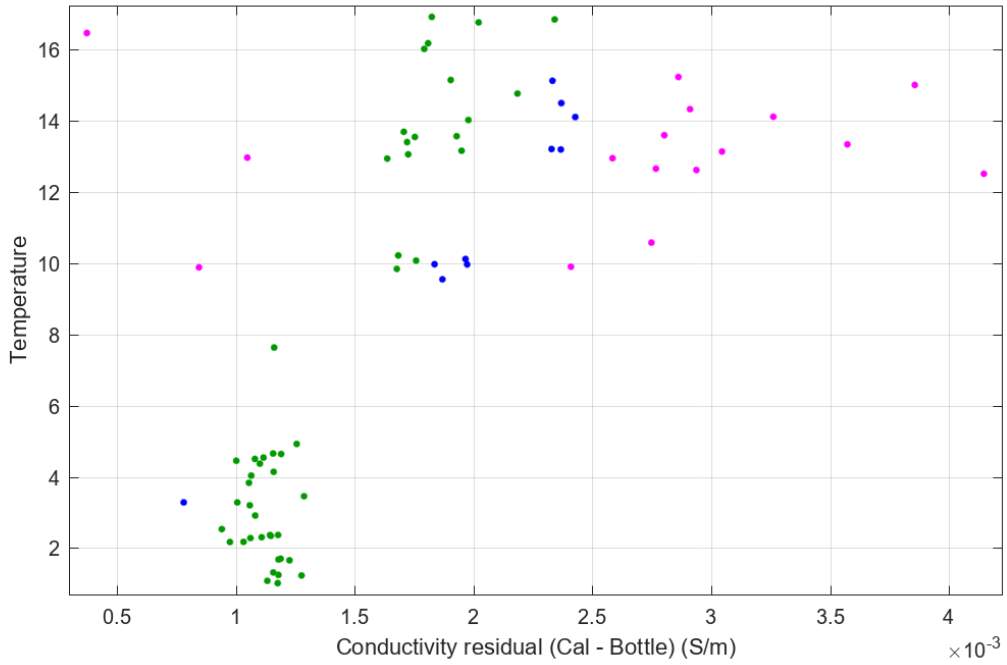
Pender, L., 2000: Data Quality Control Flags.
http://www.cmar.csiro.au/datacentre/ext_docs/DataQualityControlFlags.pdf

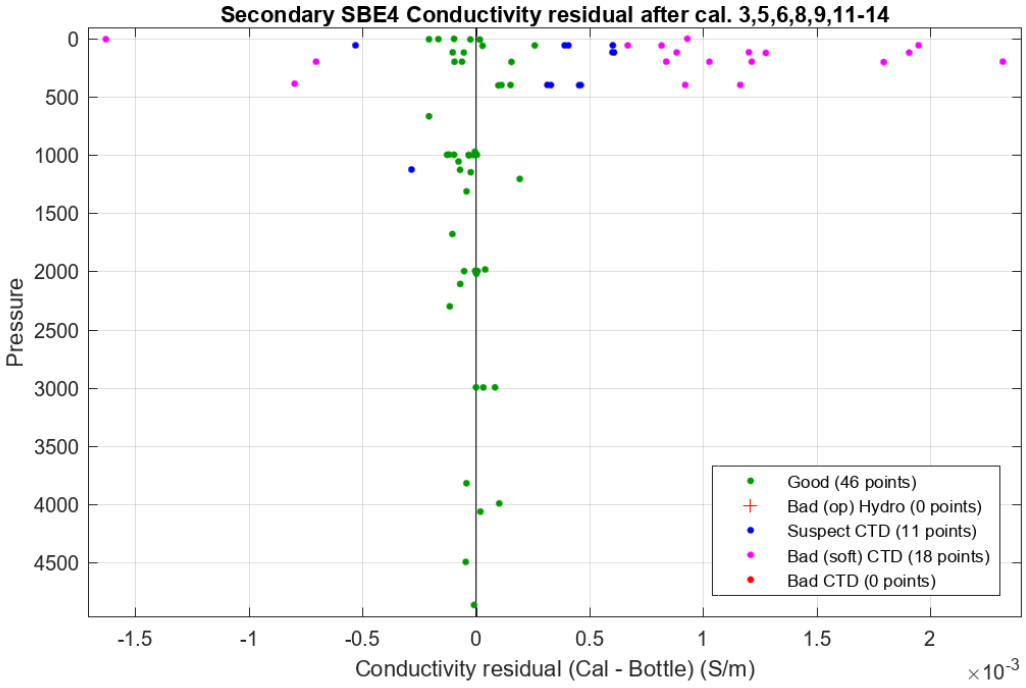
5 Appendix A – Residuals for primary and secondary sensors

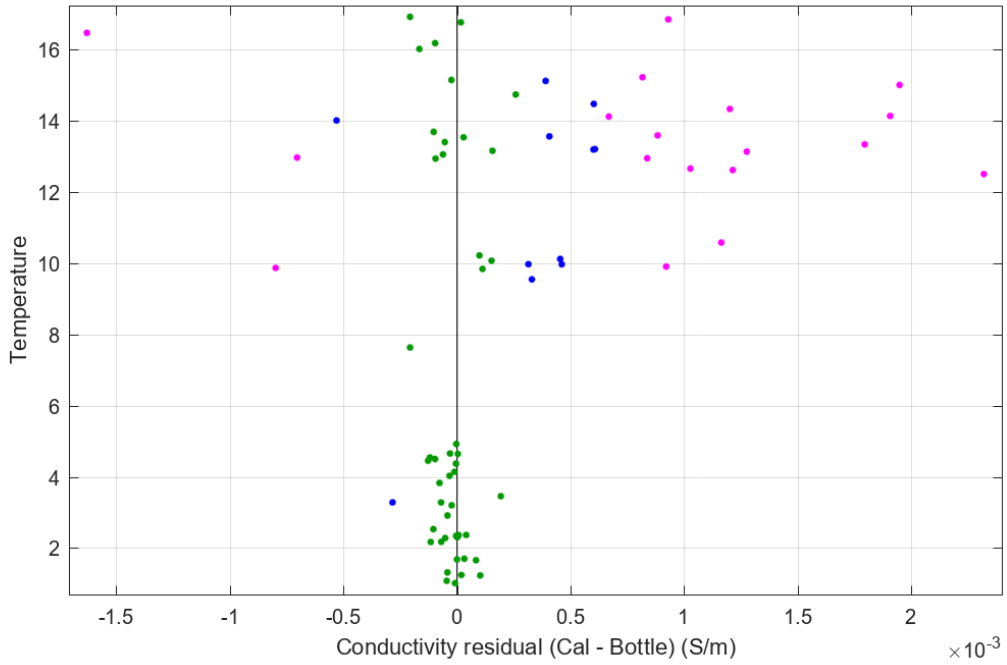


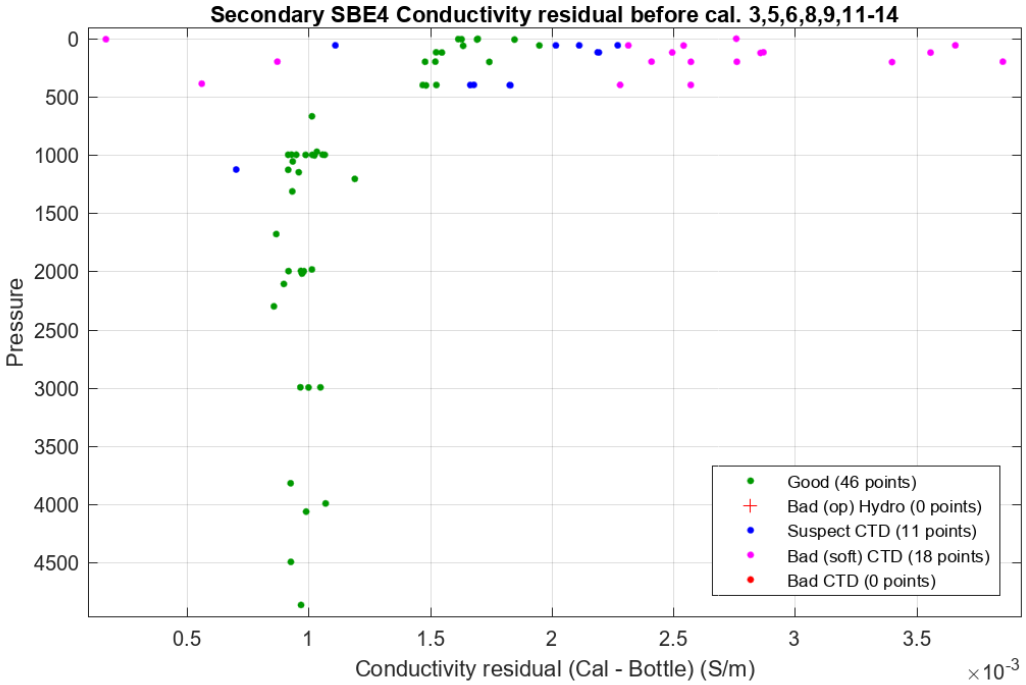


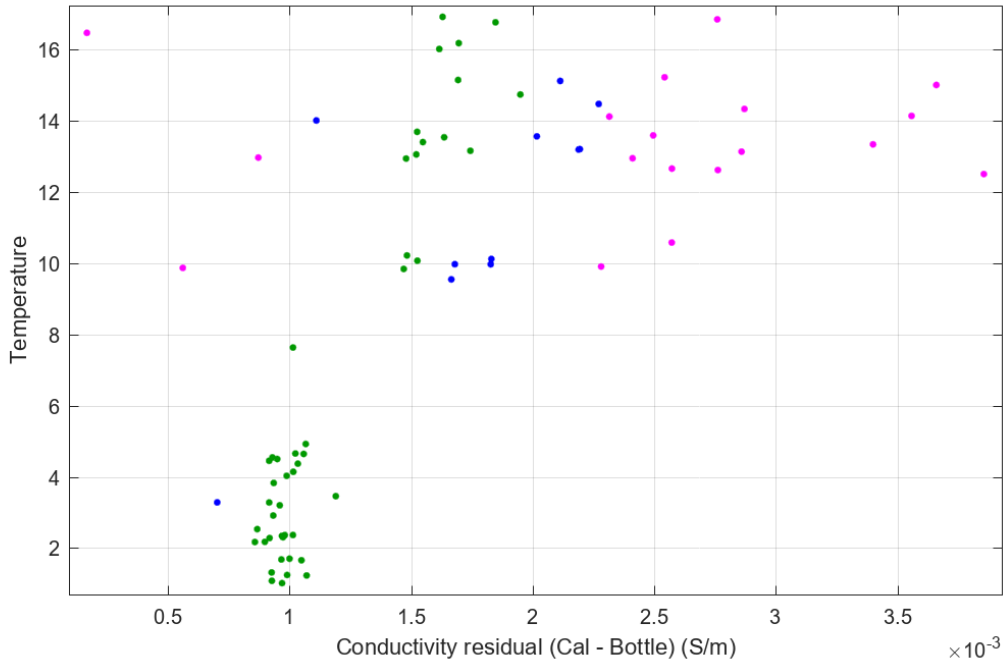

Primary SBE4 Conductivity residual before cal. 3,5,6,8,9,11-14
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0.5
1
1.5
2
2.5
3
3.5
4
Conductivity residual (Cal - Bottle) (S/m)
×10-3
Good (49 points)
Bad (op) Hydro (0 points)
Suspect CTD (10 points)
Bad (soft) CTD (16 points)
Bad CTD (0 points)

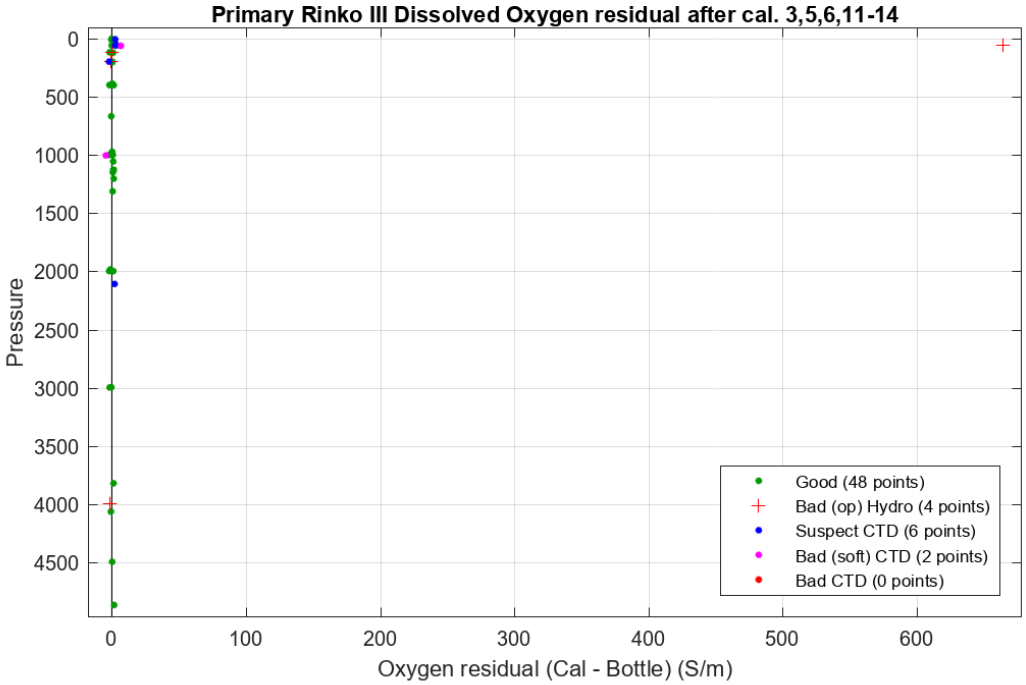

Temperature
16
14
12
10
8
6
4
2
0.5
1
1.5
2
2.5
3
3.5
4
Conductivity residual (Cal - Bottle) (S/m)
×10-3

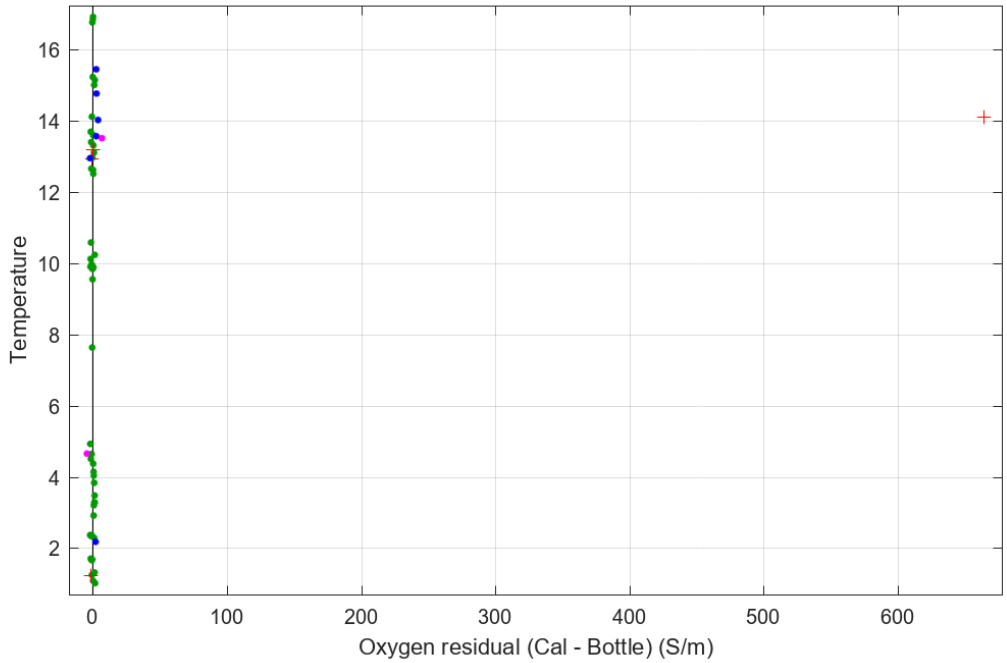

Secondary SBE4 Conductivity residual after cal. 3,5,6,8,9,11-14
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
4500
-1.5
-1
-0.5
0
0.5
1
1.5
2
Conductivity residual (Cal - Bottle) (S/m)
×10-3
Good (46 points)
Bad (op) Hydro (0 points)
Suspect CTD (11 points)
Bad (soft) CTD (18 points)
Bad CTD (0 points)


Temperature
16
14
12
10
8
6
4
2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Conductivity residual (Cal - Bottle) (S/m)
×10-3


Secondary SBE4 Conductivity residual before cal. 3,5,6,8,9,11-14
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0.5
1
1.5
2
2.5
3
3.5
Conductivity residual (Cal - Bottle) (S/m)
×10-3
Good (46 points)
Bad (op) Hydro (0 points)
Suspect CTD (11 points)
Bad (soft) CTD (18 points)
Bad CTD (0 points)


Temperature
16
14
12
10
8
6
4
2
0.5
1
1.5
2
2.5
3
3.5
Conductivity residual (Cal - Bottle) (S/m)
×10-3


Primary Rinko III Dissolved Oxygen residual after cal. 3,5,6,11-14
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
100
200
300
400
500
600
Oxygen residual (Cal - Bottle) (S/m)
Good (48 points)
Bad (op) Hydro (4 points)
Suspect CTD (6 points)
Bad (soft) CTD (2 points)
Bad CTD (0 points)


Temperature
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14
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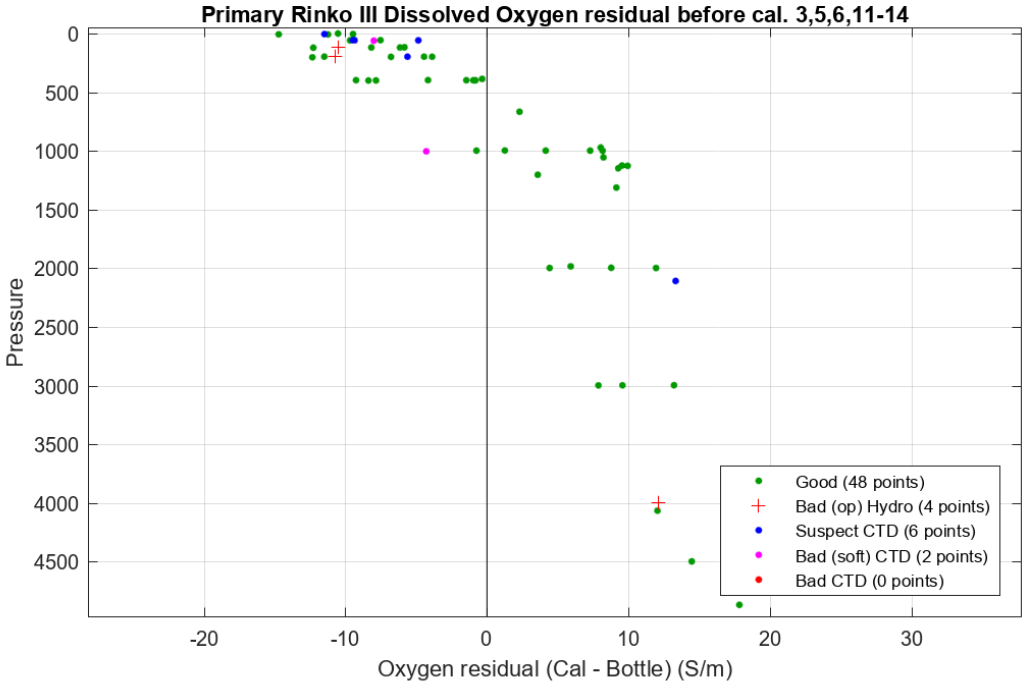
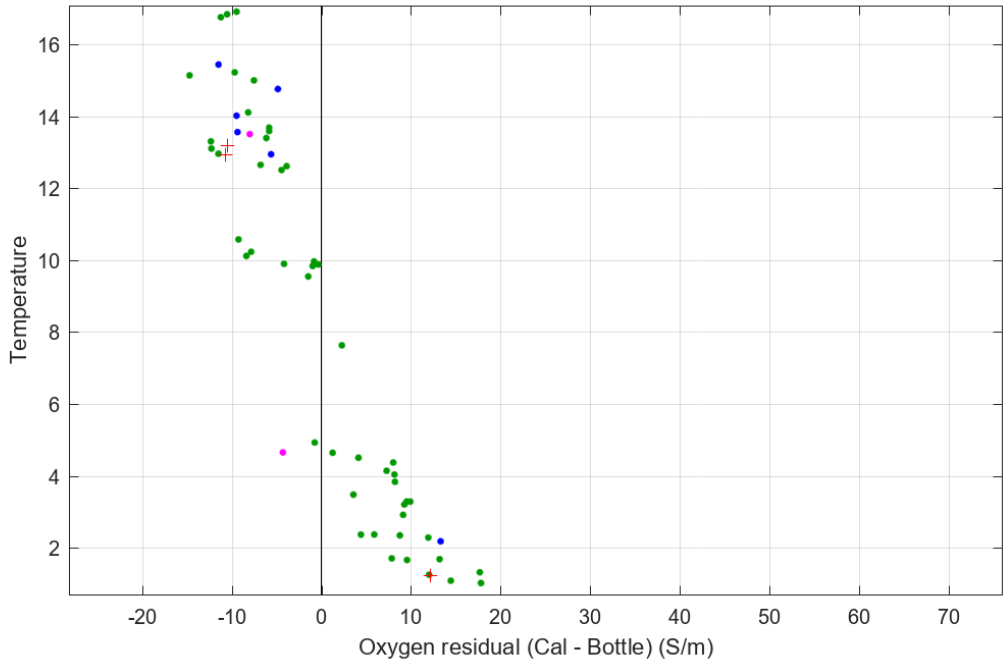
10
8
6
4
2
0
100
200
300
400
500
600
Oxygen residual (Cal - Bottle) (S/m)


Primary Rinko III Dissolved Oxygen residual before cal. 3,5,6,11-14
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
4500
-20
-10
0
10
20
30
Oxygen residual (Cal - Bottle) (S/m)
Good (48 points)
Bad (op) Hydro (4 points)
Suspect CTD (6 points)
Bad (soft) CTD (2 points)
Bad CTD (0 points)


Temperature
16
14
12
10
8
6
4
2
-20
-10
0
10
20
30
40
50
60
70
Oxygen residual (Cal - Bottle) (S/m)