RV *Investigator*

CTD Processing Report

Voyage ID:	in2018_v04
Voyage title:	Constraining external iron inputs and cycling in the southern extension of the East Australian Current
Depart:	Hobart, 0000 Tuesday, 11 September 2018
Return:	Hobart, 0000 Monday, 8 October 2018
Report compiled by:	Steven Van Graas

Contents

1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2018_v04, from 11 Sep 2018 – 08 Oct 2018.

Data for 25 deployments were acquired using the Sea-Bird SBE911 CTD 24, fitted with 36 twelve litre bottles on the rosette sampler. Sea-Bird-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.

Deployment 6 was performed with tubing still attached to the T/C inlets, and as such needed to be discarded. Deployment 20 had a blockage in the primary water line caused by what appears to be a red jellyfish. This can be seen in the bad CTD data for the primary channels.

The final conductivity calibration was based on a single deployment grouping. The final calibration from the primary sensor had a standard deviation (SD) of 0.0012361 PSU, well within our target of 'better than 0.002 PSU'. The standard product of 1 decibar binned averaged were produced using data from the primary sensors.

The dissolved oxygen data calibration fit had a SD of 0.7997µM. The agreement between the CTD and bottle data was good.

A Wetlabs CSTAR Transmissometer, Chelsea Aquatracka III Fluorometer, Wetlabs CDOM Fluorometer, and PAR sensor were also installed on the auxiliary A/D channels of the CTD.

2 Voyage Details

2.1 Title

Constraining external iron inputs and cycling in the southern extension of the East Australian Current

2.2 Principal Investigators

[Click here to enter PIs]

2.3 Voyage Objectives

The scientific objectives for in2018_v04 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 in2018_v04

3 Processing Notes

3.1 Background Information

The data for this voyage were acquired with the CSIRO CTD unit 24, a Sea-Bird SBE911 with dual conductivity and temperature sensors.

The CTD was additionally fitted with SBE43 dissolved oxygen sensors [Click here to list additional sensor]. These sensors are described in Table 1 below.

Description	Sensor	Serial No.	A/D	Calibration Date	Calibration Source
Pressure	Digiquartz 410K-134	[Serial#]	P	[Cal. Date]	CSIRO
Primary Temperature	Sea-Bird SBE3*plus*	4522	T0	3-Jul-2018	CSIRO
Secondary Temperature	Sea-Bird SBE3*plus*	4722	T1	26-Jun-2018	CSIRO
Primary Conductivity	Sea-Bird SBE4C	2312	C0	3-Jul-2018	CSIRO
Secondary Conductivity	Sea-Bird SBE4C	3168	C1	26-Jun-2018	CSIRO
Primary Dissolved Oxygen	SBE43	3534	A0	26-Feb-2018	CSIRO
Secondary Dissolved Oxygen	SBE43	3155	A1	29-Nov-2017	CSIRO
Transmissometer	WET Labs C-STAR	1735DR	A2	27 Feb 2018	Manufacturer
PAR	QCP2300-HP	70677	A3	07 Feb 2018	Manufacturer
Fluorometer (chlorophyll-a)	WET Labs ECO-AFL/FL	5169	A4	24 Aug 2018	Manufacturer
OBS	Wetlabs ECO-BB	5169	A5	24 Aug 2018	Manufacturer
Altimeter 1	PA200	313642	A6	N/A	
Altimeter 2	PA500	310747	A7	N/A	

Table 1 CTD Sensor configuration on in2018_v04

Water samples were collected using a Sea-Bird SBE32, 36-bottle rosette sampler. Sampling was from [NN] twelve litre bottles which were fitted to the frame.

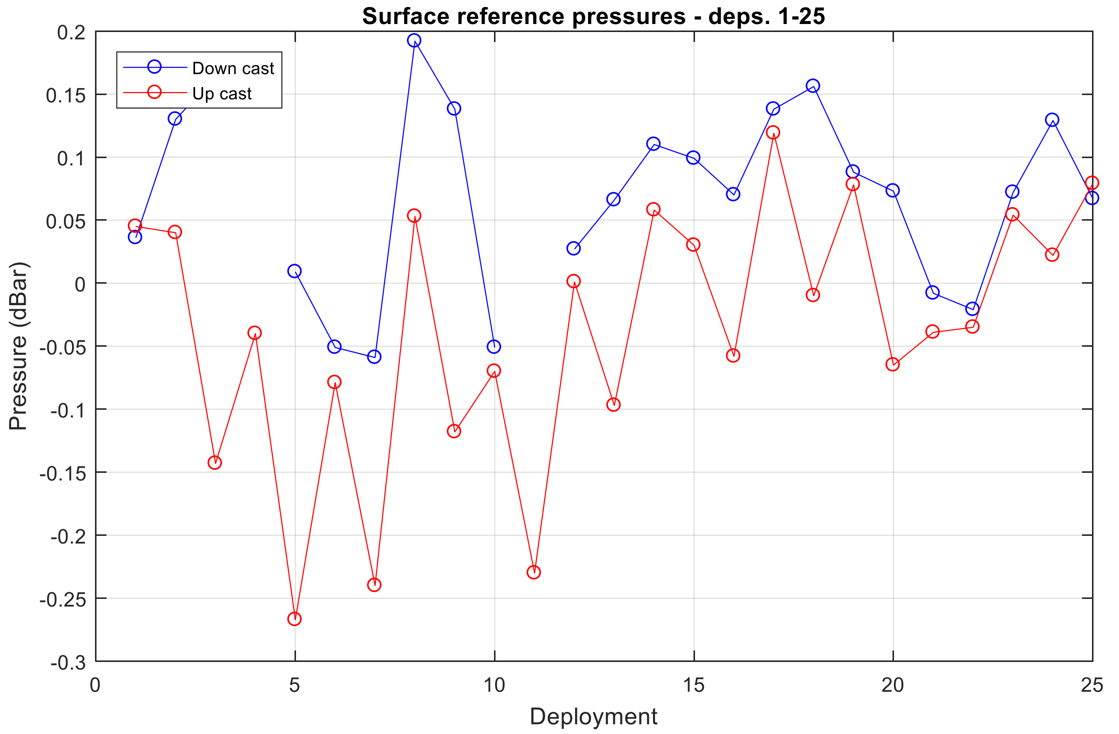
The raw CTD data were collected in SBE SeaSave version 7.26.6.26, converted to scientific units using SBE Data Processing version 7.26.7.114 and written to NetCDF format files with CNV_to_Scan for processing using the Matlab-base, CapPro package version 2.9.

The CapPro 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. It also loaded the hydrology data and computed the matching CTD sample burst data. The automatically determined pressure offsets and in-water points were inspected.

The bottle sample data were used to compute final conductivity and dissolved oxygen calibrations. These were applied to the data, after which files of binned 1 decibar averaged data were produced.

3.2 Pressure and temperature calibration

The 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.



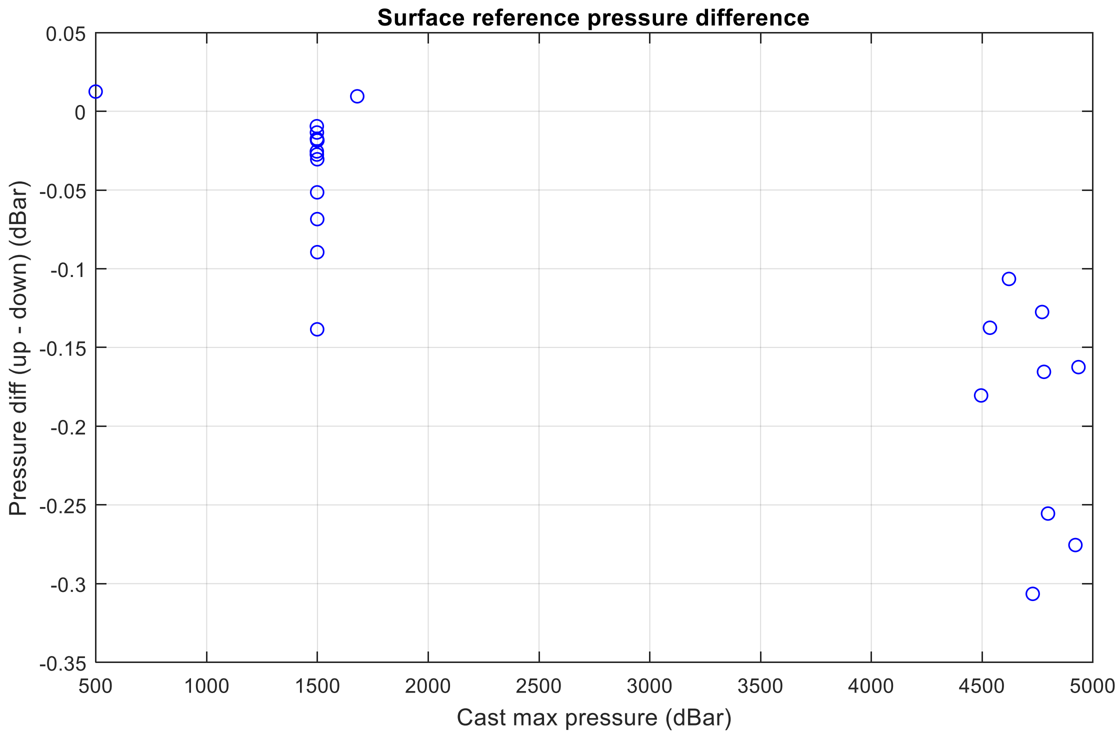


Figure 2 CTD pressure offsets

The difference between the primary and secondary temperature sensors at the bottle sampling depths is plotted below. Most deployments plot within ±0.001°C of zero – outliers result from sampling in regions of high vertical temperature gradient as supported by the similarity between the temperature and conductivity difference shown in Figure 3. This indicates [neither/a] sensor has drifted significantly from its calibration.

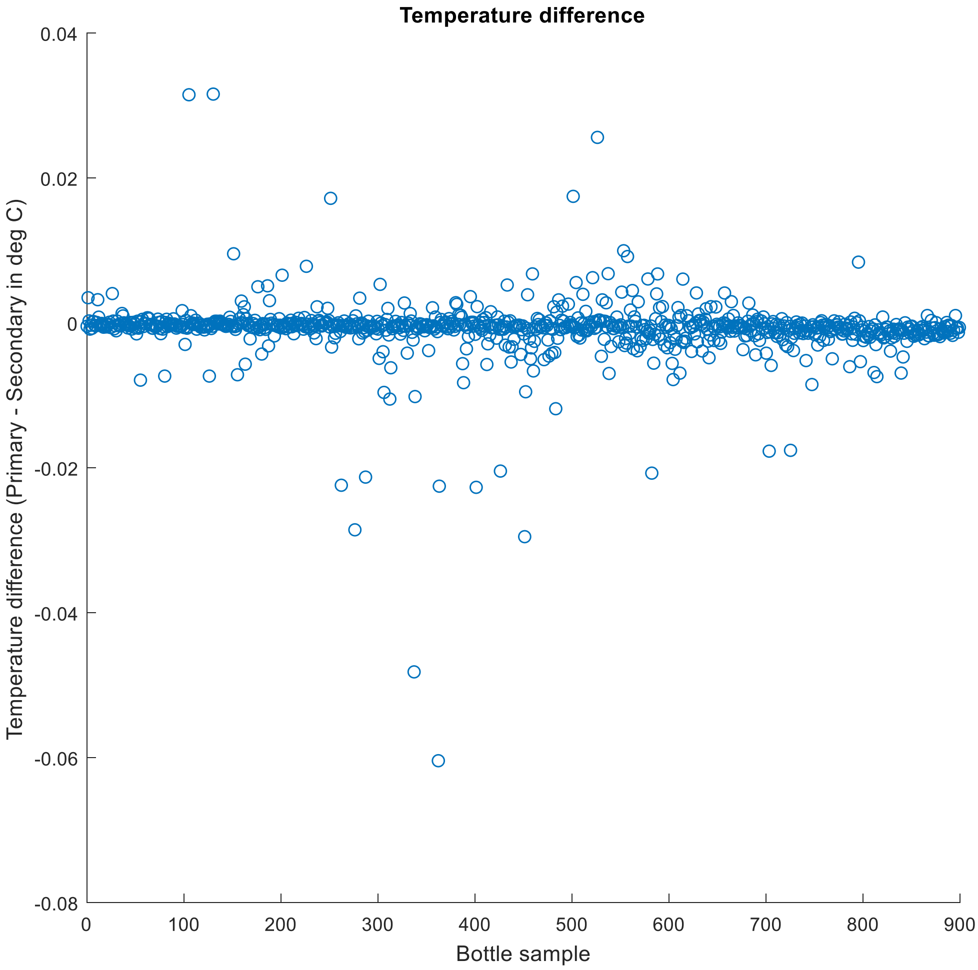


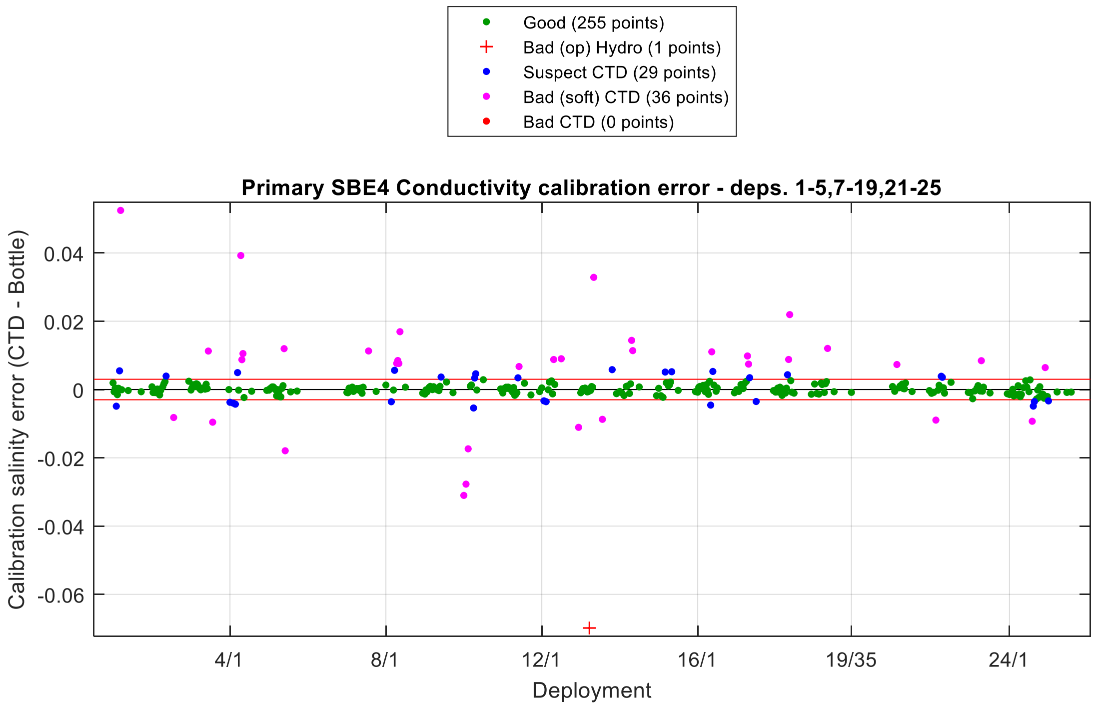
Figure 3 Difference between primary and secondary temperature sensors

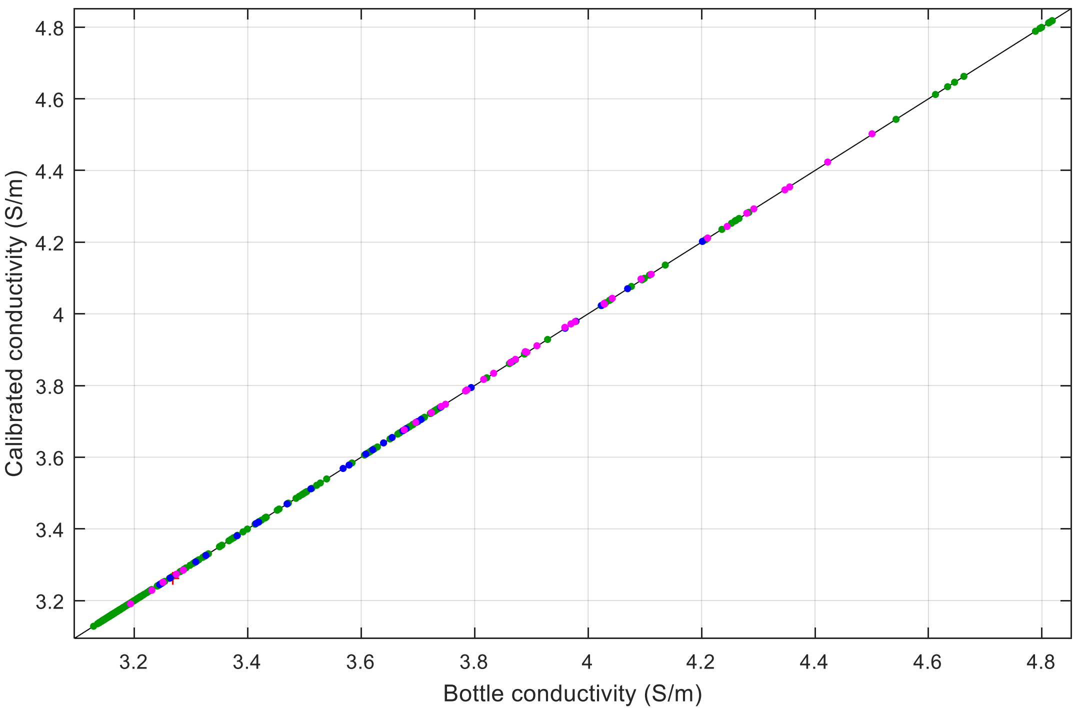
3.3 Conductivity Calibration

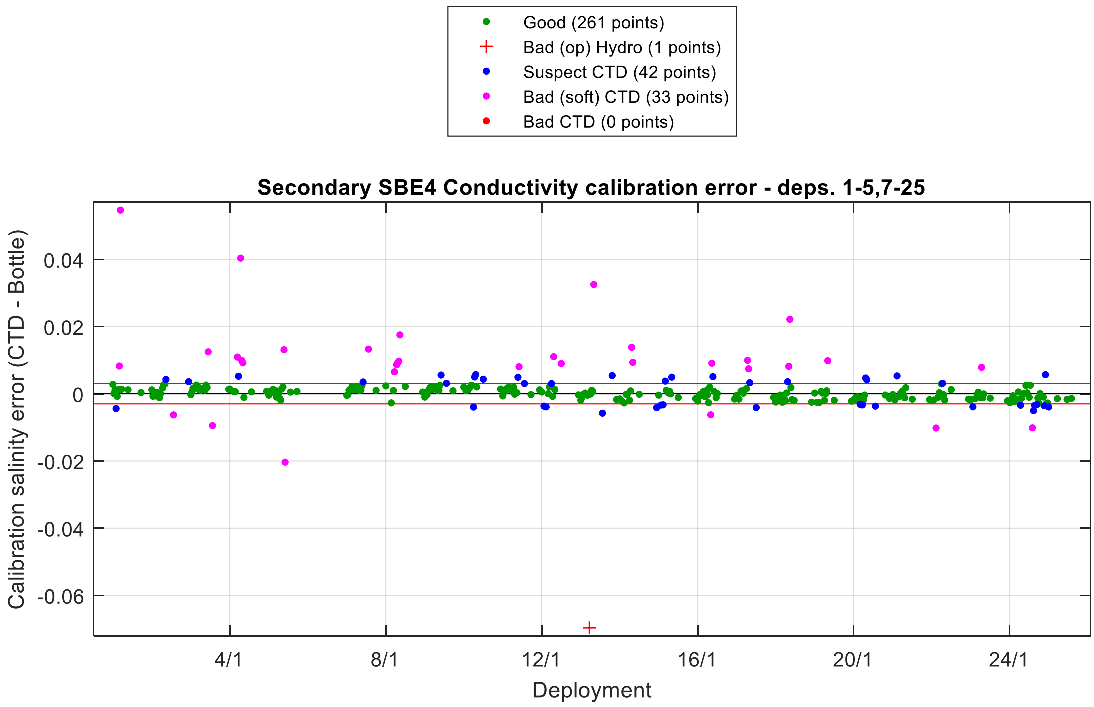
Discrepancies and possible sampling problems between bottle and CTD salinities for the primary conductivity sensor would show in Figure 4; the plot of calibrated (CTD - Bottle) salinity below. The calibration was based upon the sample data (primary/secondary) for 261 of the total of 332 samples taken during deployments which are above our target of 75%.

Data from cast 6 was excluded due to tubes on the intake being present during the cast. Data for the primary sensors was excluded from the calibration for cast 20 due to the jellyfish that was caught in the intake.

The outliers marked in Figure 4 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.


Good (255 points)
Bad (op) Hydro (1 points)
Suspect CTD (29 points)
Bad (soft) CTD (36 points)
Bad CTD (0 points)
Primary SBE4 Conductivity calibration error - deps. 1-5,7-19,21-25
Calibration salinity error (CTD - Bottle)
0.04
0.02
0
-0.02
-0.04
-0.06
4/1
8/1
12/1
16/1
19/35
24/1
Deployment


Calibrated conductivity (S/m)
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
Bottle conductivity (S/m)


Good (261 points)
Bad (op) Hydro (1 points)
Suspect CTD (42 points)
Bad (soft) CTD (33 points)
Bad CTD (0 points)
Secondary SBE4 Conductivity calibration error - deps. 1-5,7-25
Calibration salinity error (CTD - Bottle)
0.04
0.02
0
-0.02
-0.04
-0.06
4/1
8/1
12/1
16/1
20/1
24/1
Deployment

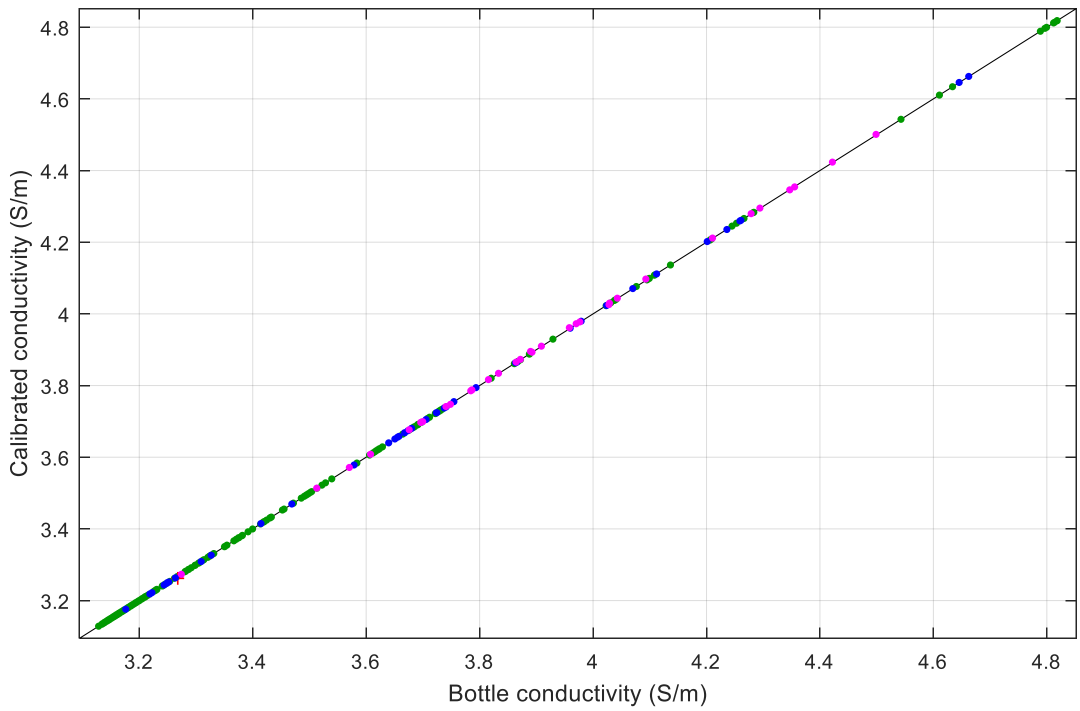

Calibrated conductivity (S/m)
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
Bottle conductivity (S/m)

Figure 4 CTD - bottle salinity plot

The box plot of calibrated downcast conductivities (primary - secondary) at the bottle sampling depths for all deployments in Figure 5 shows that the calibrated conductivity cell responses corresponded very well.

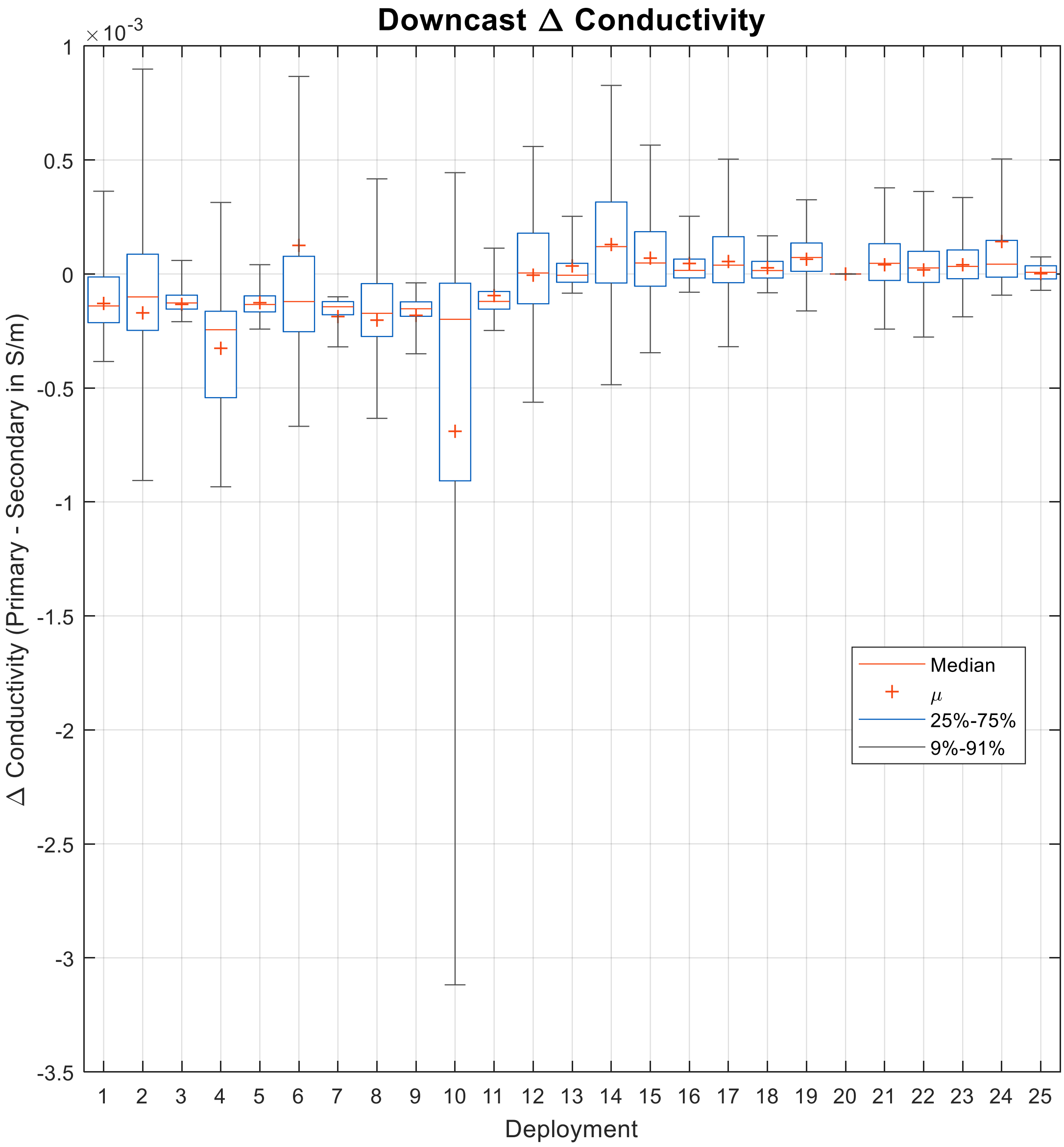


Figure 5 Difference between primary and secondary conductivity sensors

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

Primary	**1-5,7-19,21-25**	**0.99959**	**0.00052231**	**0.0011793**	**0.0020045**	**0.0012361**	**0.00086792**
Secondary	1-5,7-25	0.99965	0.00065497	0.00098159	0.0025101	0.0012703	0.001354

Table 2 and

Secondary	**1-5,7-25**	**-8.2122e-08**	**6.4025e-08**

Table 3.

Sensor Group	Deployments	Scale Factor		Offset		Salinity (PSU)	
		a1	±	a0	±	Residual SD	M.A.D.
Primary	1-5,7-19,21-25	0.99959	0.00052231	0.0011793	0.0020045	0.0012361	0.00086792
Secondary	1-5,7-25	0.99965	0.00065497	0.00098159	0.0025101	0.0012703	0.001354

Table 2 Conductivity calibration with respect to manufacturers' calibration coefficients and post-calibration results

Conductivity Sensor	Deployments	CPcor	±
Primary	1-5,7-19,21-25	-7.9159e-08	5.1462e-08
Secondary	1-5,7-25	-8.2122e-08	6.4025e-08

Table 3 Calculated CPcor for primary and secondary compared to 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 Conductivity Calibration Residual Plots.
Data from the primary conductivity and temperature sensors were used to produce the averaged salinities with secondary sensors included with a suffix '_2'.

3.4 Dissolved Oxygen Sensor Calibration

3.4.1 SBE calibration procedure

AN64: SBE 43 Dissolved Oxygen Sensor - Background Information, Deployment Recommendations, and Cleaning and Storage (Sea-Bird, 2013) describes the SBE43 as "a polarographic membrane oxygen sensor having a single output signal of 0 to +5 volts, which is proportional to the temperature-compensated current flow occurring when oxygen is reacted inside the membrane. A Sea-Bird CTD that is equipped with an SBE43 oxygen sensor records this voltage for later conversion to oxygen concentration, using a modified version of the algorithm by Owens and Millard (1985)".

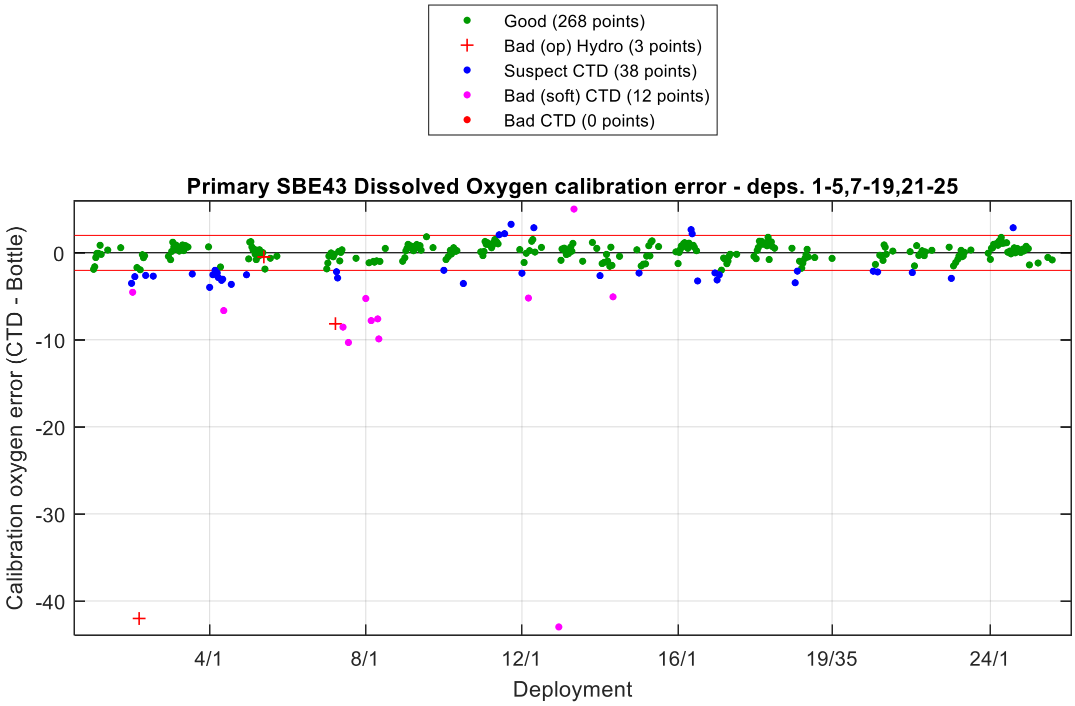
Calibration involves performing a linear regression, as per *AN64-2: SBE 43 Dissolved Oxygen Sensor Calibration and Data Corrections* (Sea-Bird, 2012) to produce new estimates of the calibration coefficients *Soc* and *Voffset*. These new coefficients are used, along with the other, manufacturer-supplied coefficients, to derive oxygen concentrations from the sensor voltages.

3.4.2 Results

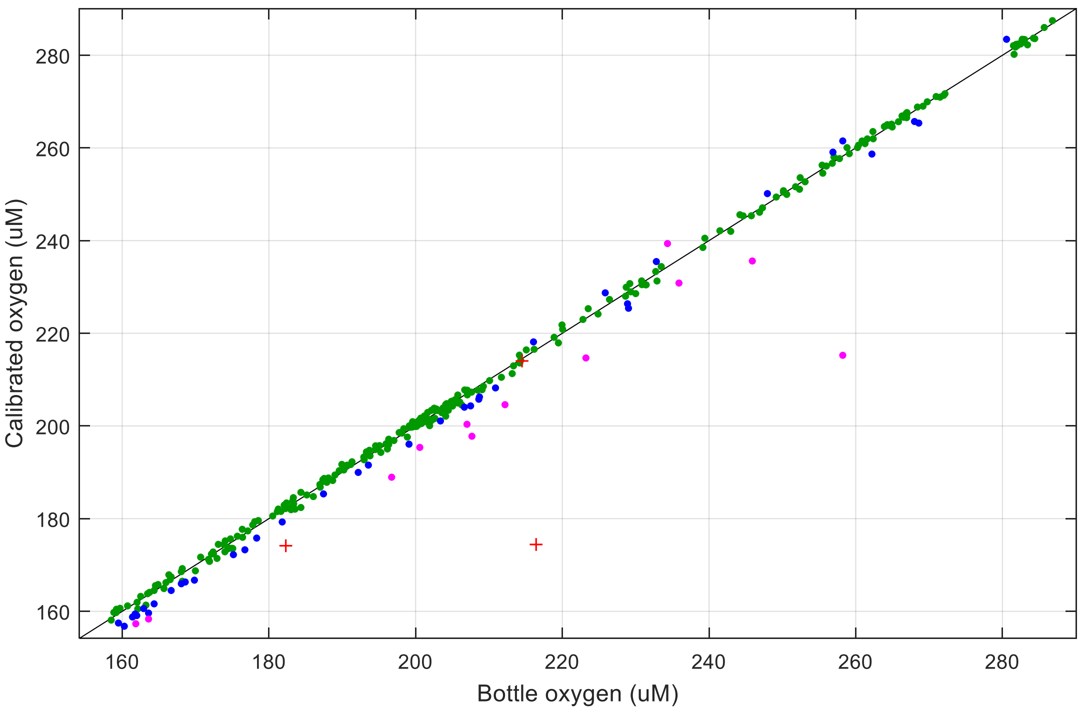
Deeper casts (>1000m) are known to be affected by pressure-induced hysteresis with this sensor. This is corrected automatically within CapPro using the method discussed in *AN64-3: SBE 43 Dissolved Oxygen (DO) Sensor - Hysteresis Corrections* (Sea-Bird, 2014).

There is a small mismatch between downcast and upcast dissolved oxygen due to the response time of the sensor. No correction for the sensor lag effect has been applied.

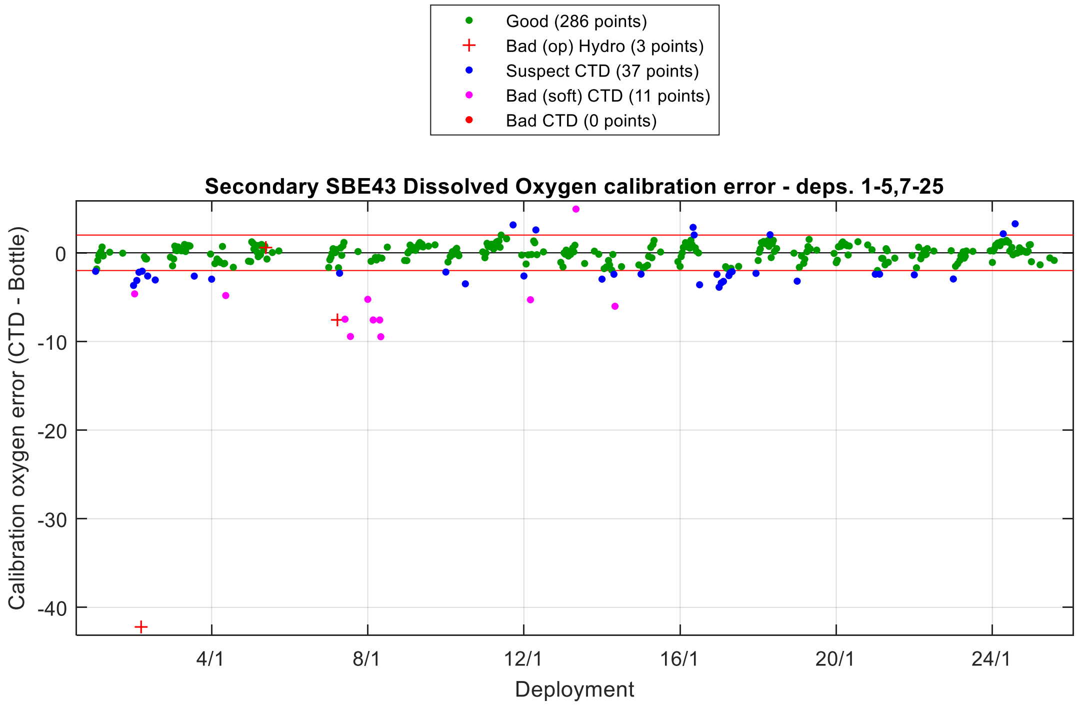
A single calibration group was used with the associated SBE43 up-cast data to compute the new *Soc* and *Voffset* coefficients. The plot below is of CTD - bottle oxygen differences for both upcast and downcast data (red indicates 'bad' data; + for upcast and square for downcast).



Good (268 points)
Bad (op) Hydro (3 points)
Suspect CTD (38 points)
Bad (soft) CTD (12 points)
Bad CTD (0 points)
Primary SBE43 Dissolved Oxygen calibration error - deps. 1-5,7-19,21-25
Calibration oxygen error (CTD - Bottle)
0
-10
-20
-30
-40
4/1
8/1
12/1
16/1
19/35
24/1
Deployment



Calibrated oxygen (uM)
280
260
240
220
200
180
160
Bottle oxygen (uM)



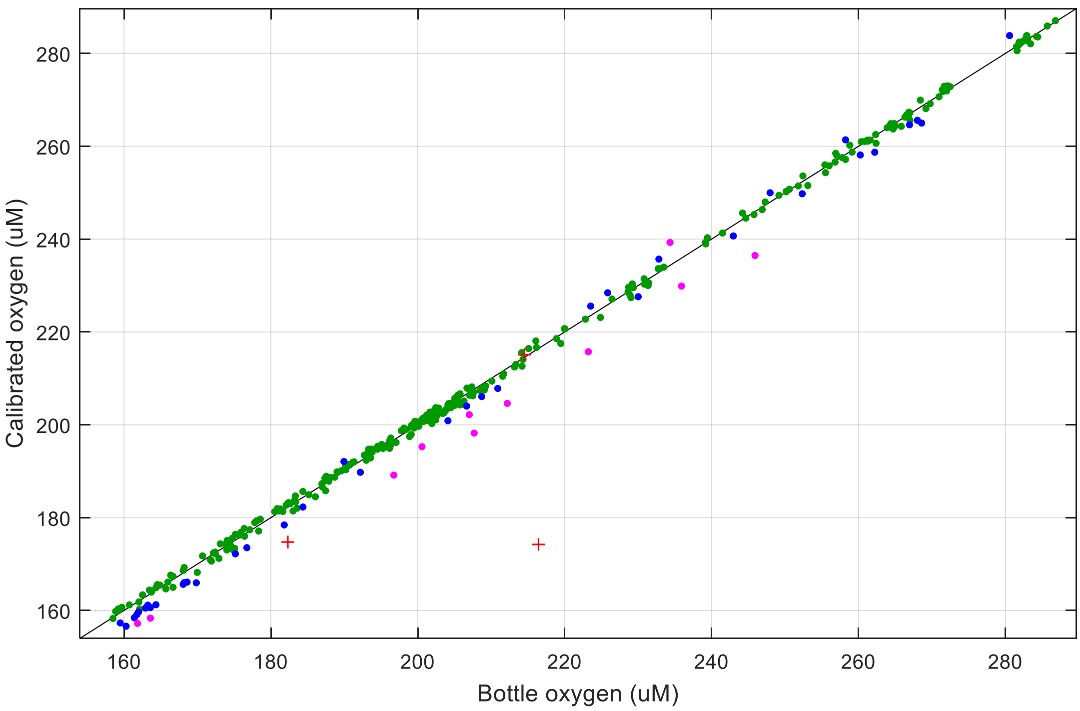


Figure 6 Dissolved Oxygen Difference with upcast CTD data (SBE43 - Bottle)

The old and new *Soc* and *Voffset* values for DO sensors are listed in Table 2 below. The Soc value is a linear slope scaling coefficient; *Voffset* is the fixed sensor voltage at zero oxygen. As expected, over time, the increasing *Soc* scale factors show the SBE43 sensor is losing sensitivity. Full plots of residuals before and after calibration are available in Dissolved Oxygen Calibration Residual Plots.

The calibrations were applied for each sensor and the averaged files were created using the result from the secondary sensor. The primary sensor values are included in the averaged data product with the suffix '_1'.

Sensor	Calibration Source	Deployments	Calibration Coefficients				Dissolved Oxygen (µM)	
			Voffset	±	*Soc*	±	Residual SD	M.A.D.
Primary DO	Hydrochemistry	1-5,7-19,21-25	-0.49553	0.0013383	0.49735	0.00061111	0.80788	0.70737
	Sea-Bird	all	-0.53080		0.532840			
Secondary DO	Hydrochemistry	1-5,7-25	-0.50177	0.0012061	0.53464	0.00063959	0.79968	0.73861
	Sea-Bird	all	-0.51340		5.38530			

Figure 7 Dissolved oxygen calibrations

3.5 Other sensors

The Chelsea fluorometer was used for all deployments. The fluorometer has been calibrated with manufacturer supplied formula derived from various concentrations of Chlorophyll-a dissolved in acetone in addition to pure water and pure acetone. The coefficients in the formula are used in the SBE Data Processing software to convert the raw counts to fluorophore concentration in µg/L with a range of 0 – 100 micrograms per litre with an uncertainty of 0.02 micrograms per litre plus 3% of value. Please refer to the calibration certificate for more details.

The C-Star transmissometer was used on all deployments. It was calibrated by the manufacturer with meter outputs with the beam blocked, in air with a clear beam path and with clean water in the path. These values are used to determine a scale and offset for use in SBE Data Processing software to convert the raw counts to a beam transmittance output of 0-100 percent.

The WET labs ECO Fluorometer-Scattering sensor was used for all deployments. The fluorometer has been calibrated with manufacturer supplied coefficients to give outputs in mg/m3. The scattering (OBS) has been calibrated with manufacturer supplied coefficients to give outputs in m-1/sr.

The Biospherical PAR sensor was also used for all deployments. The output is a nominal 0-5 volts which is converted to the unit µEinsteins/m2/second using manufacturer supplied wet calibration factor and the dark voltage determined at calibration. 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.

3.6 Bad data detection

The limits for each sensor are configured in CNV_to_Scan conversion software and are written to the netCDF scan file. Typical limits used for the sensor range and maximum second difference are in Table 4 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	100	0.5
PAR	-5	2000	0.5
Transmissometer	0	100	0.5

Table 4 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 1 decibar 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 *Data Quality Control Flags* (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

Ellwood. (2018). *The RV Investigator. Voyage Plan* in2018_v04. Retrieved from Marine National Facility: Voyage Plans and summaries: http://mnf.csiro.au/Voyages/Investigator-schedules/Plans-and-summaries/

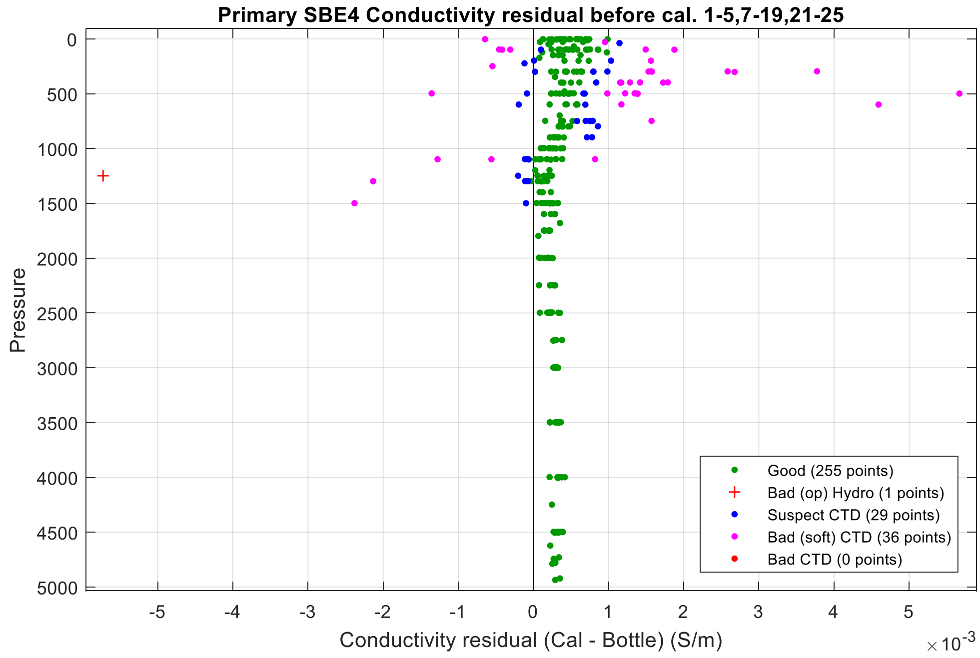
Pender, L. (2000). *Data Quality Control Flags.* Retrieved from Oceans & Atmosphere Information and Data Centre: http://www.cmar.csiro.au/datacentre/ext_docs/DataQualityControlFlags.pdf

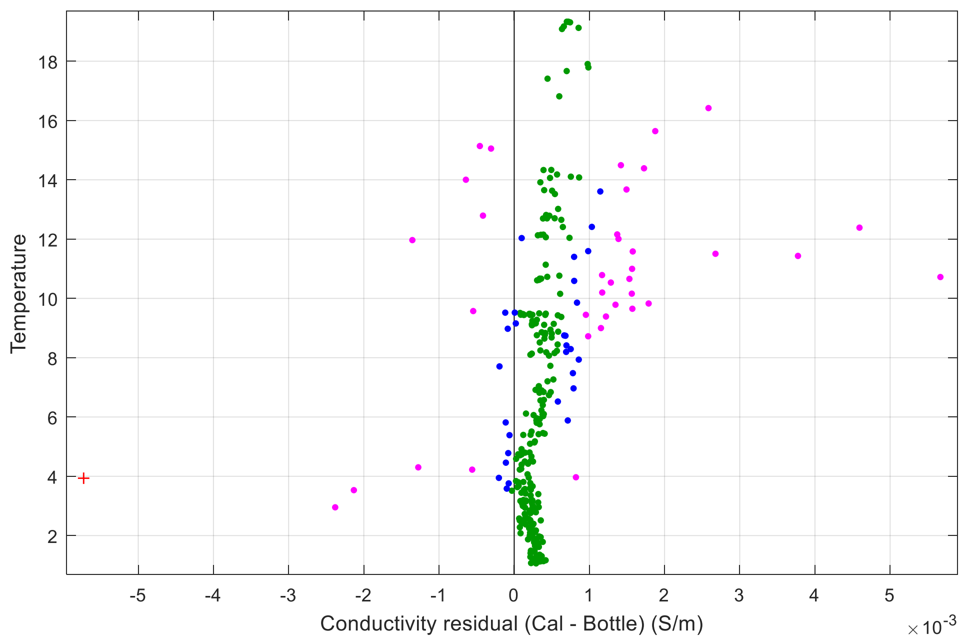
Sea-Bird. (2012). *AN64-2: SBE 43 Dissolved Oxygen Sensor Calibration and Data Corrections.* Retrieved from Sea-Bird Electronics: http://www.seabird.com/document/an64-2-sbe-43-dissolved-oxygen-sensor-calibration-and-data-corrections

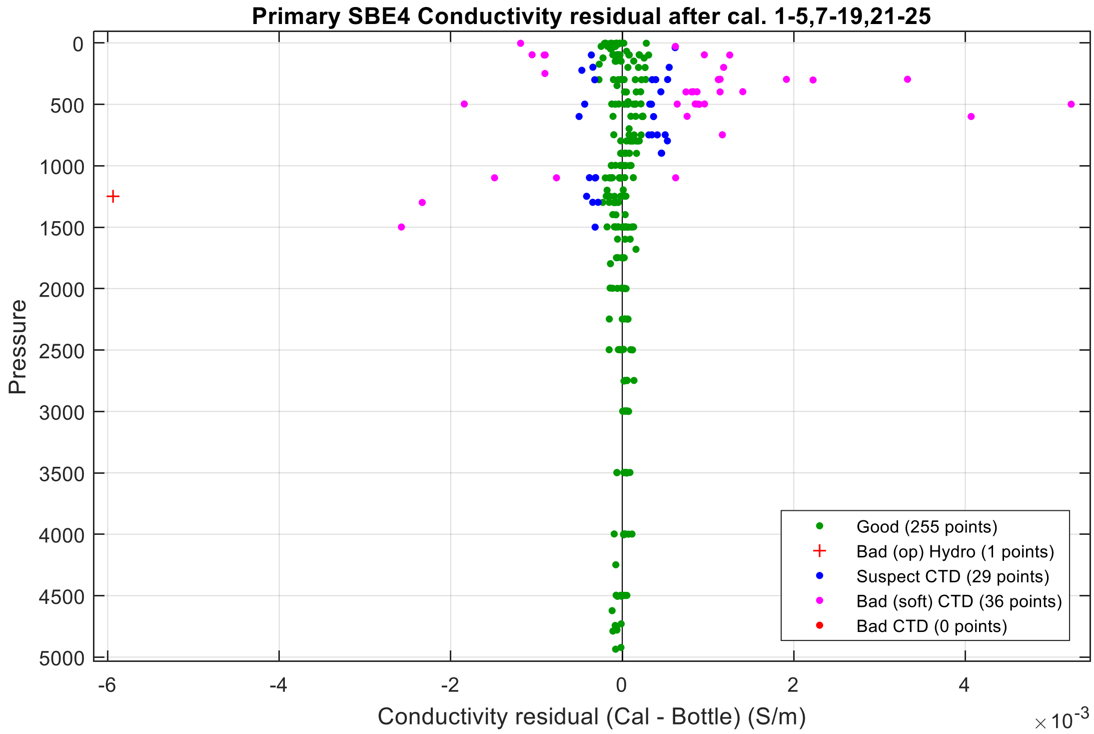
Sea-Bird. (2013). *AN64: SBE 43 Dissolved Oxygen Sensor - Background Information, Deployment Recommendations, and Cleaning and Storage.* Retrieved from Sea-Bird Electronics: http://www.seabird.com/document/an64-sbe-43-dissolved-oxygen-sensor-background-information-deployment-recommendations

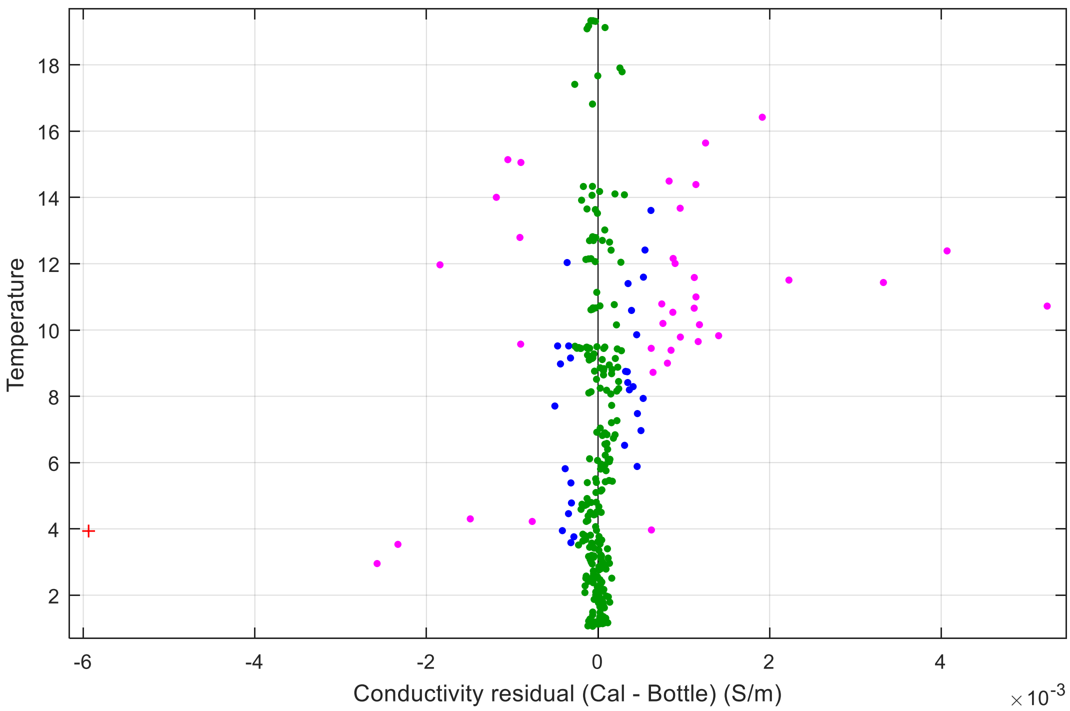
Sea-Bird. (2014). *AN64-3: SBE 43 Dissolved Oxygen (DO) Sensor - Hysteresis Corrections.* Retrieved from Sea-Bird Electronics: http://www.seabird.com/document/an64-3-sbe-43-dissolved-oxygen-do-sensor-hysteresis-corrections

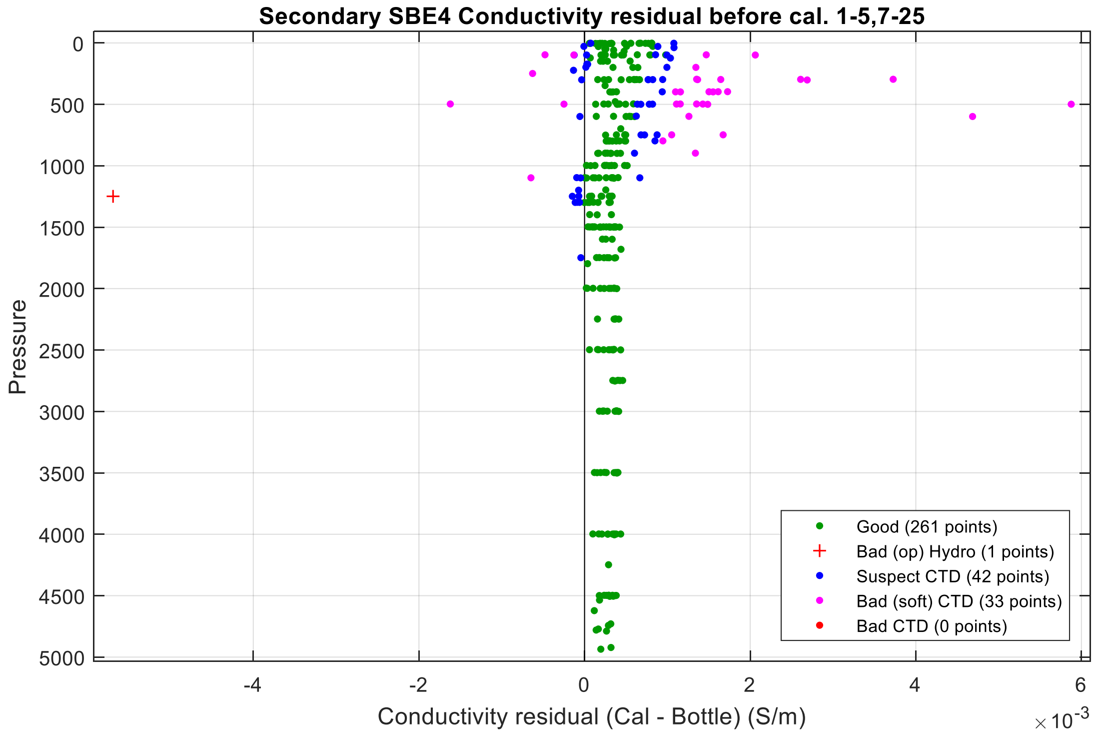
Appendix I: Conductivity Calibration Residual Plots



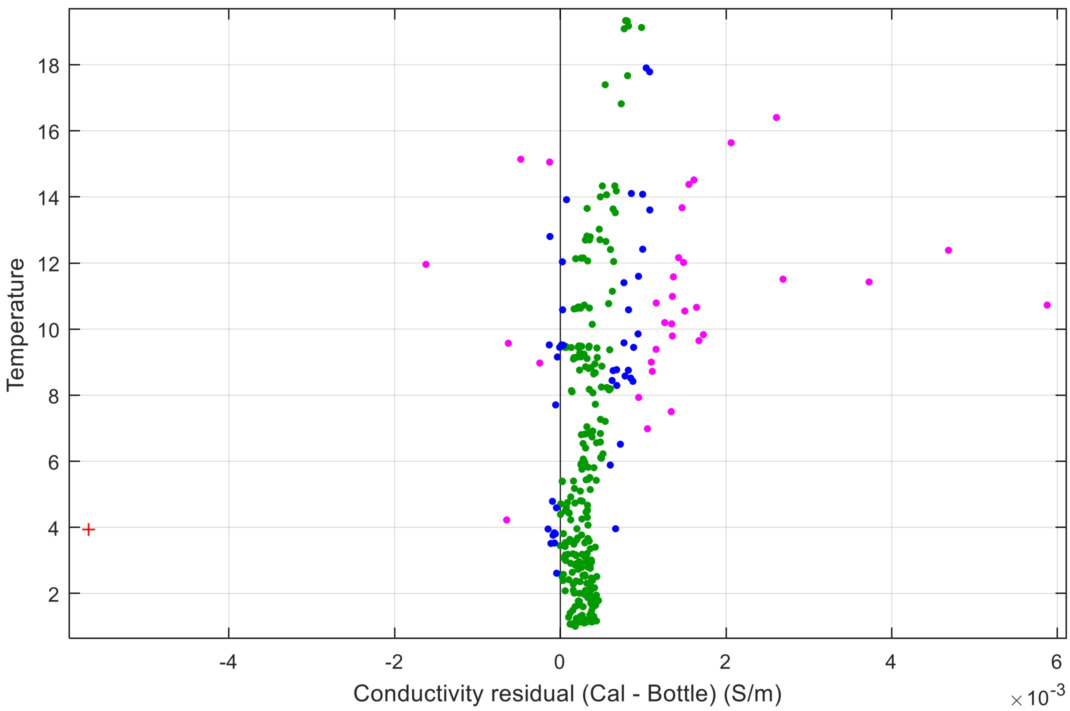



Primary SBE4 Conductivity residual after cal. 1-5,7-19,21-25
Pressure
Conductivity residual (Cal - Bottle) (S/m)
× 10^-3
Good (255 points)
Bad (op) Hydro (1 points)
Suspect CTD (29 points)
Bad (soft) CTD (36 points)
Bad CTD (0 points)

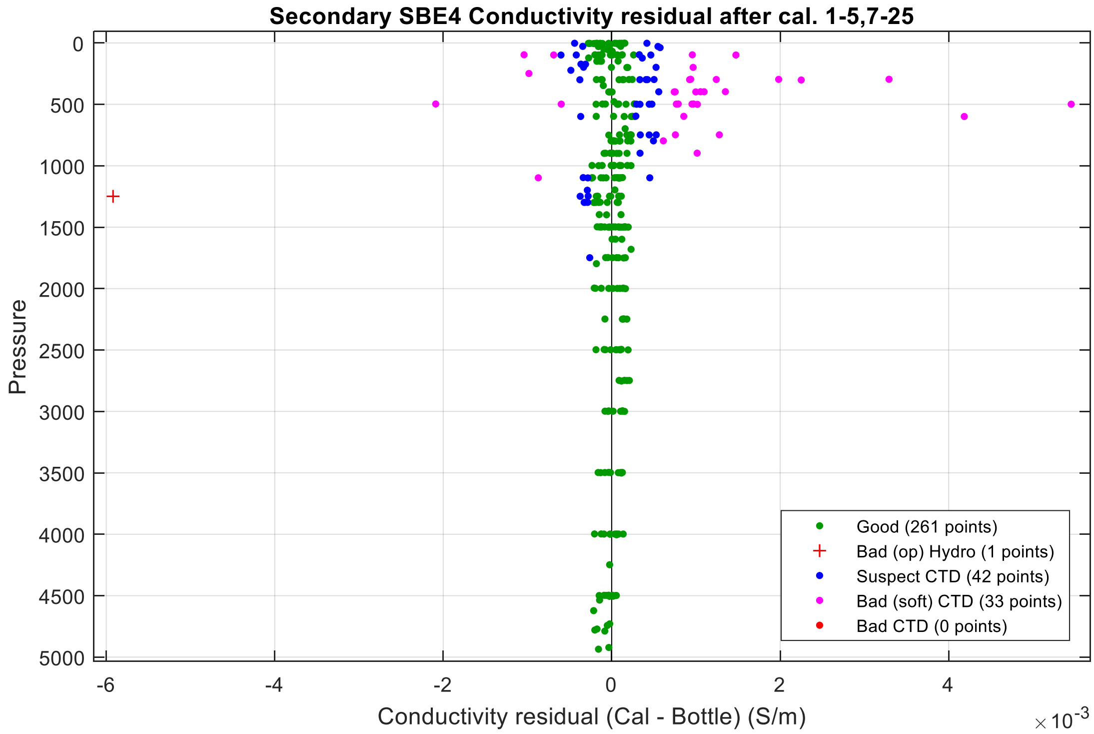

Temperature
Conductivity residual (Cal - Bottle) (S/m)
× 10^-3

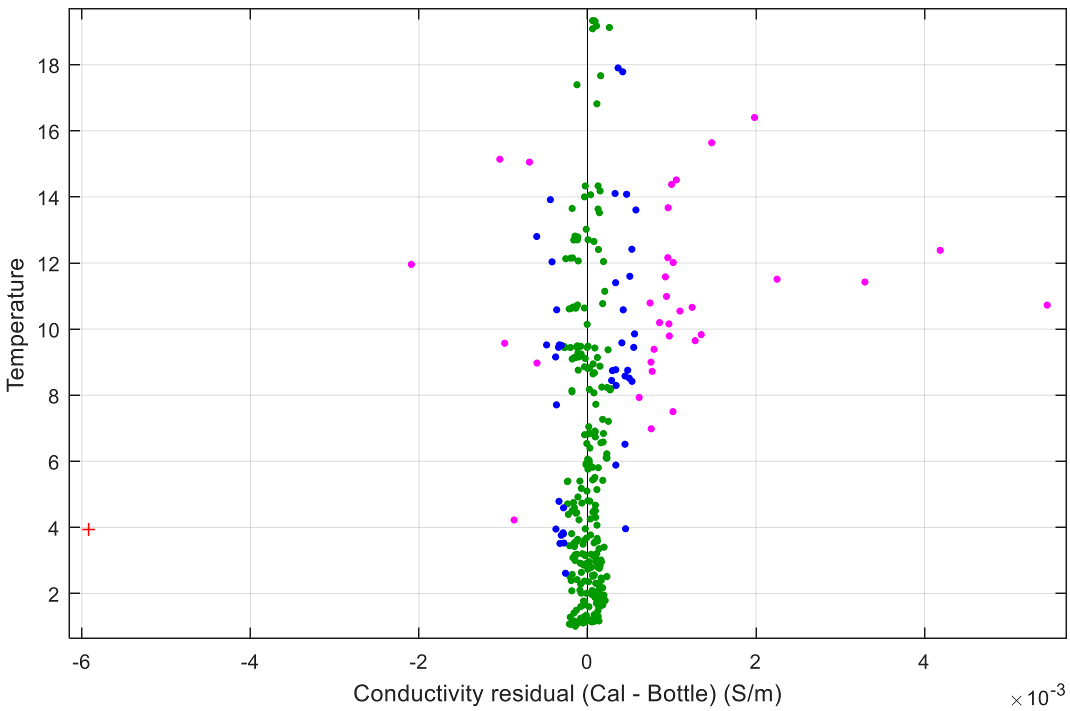


Secondary SBE4 Conductivity residual before cal. 1-5,7-25
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
-4
-2
0
2
4
6
Conductivity residual (Cal - Bottle) (S/m)
× 10^-3
Good (261 points)
Bad (op) Hydro (1 points)
Suspect CTD (42 points)
Bad (soft) CTD (33 points)
Bad CTD (0 points)

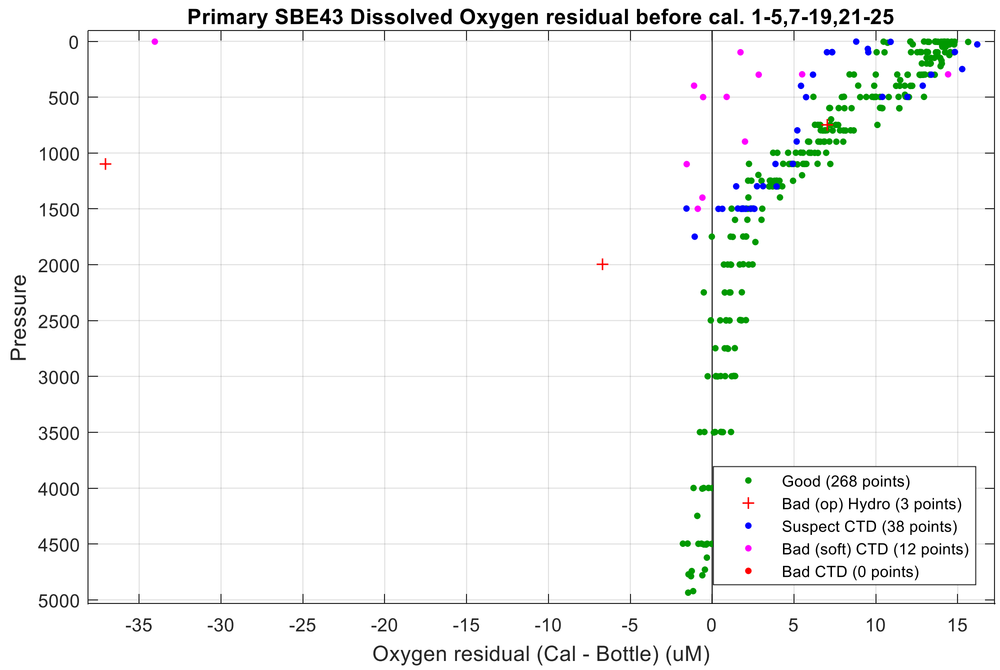


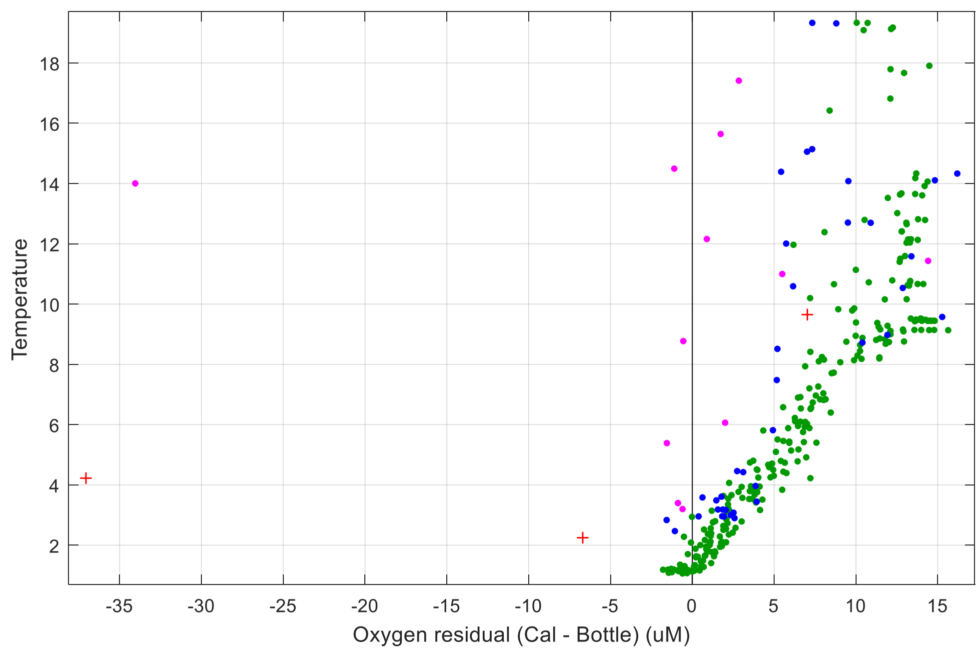
Temperature
18
16
14
12
10
8
6
4
2
-4
-2
0
2
4
6
Conductivity residual (Cal - Bottle) (S/m)
× 10^-3

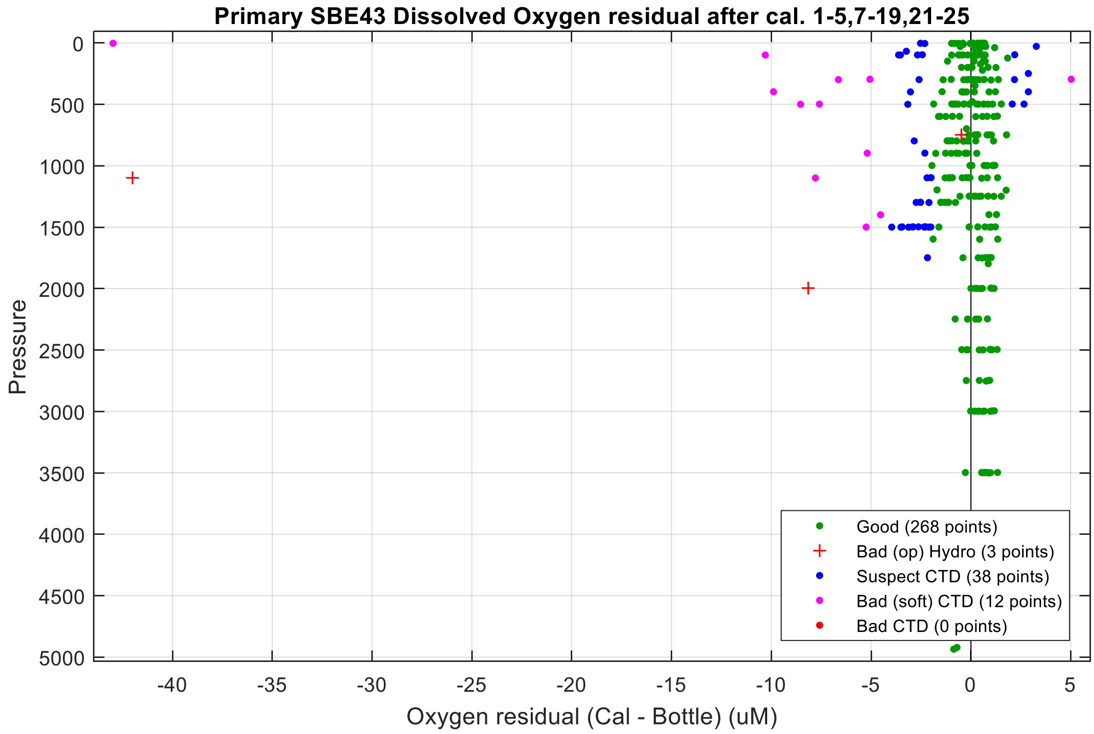

Secondary SBE4 Conductivity residual after cal. 1-5,7-25
Pressure
Conductivity residual (Cal - Bottle) (S/m)
×10-3
Good (261 points)
Bad (op) Hydro (1 points)
Suspect CTD (42 points)
Bad (soft) CTD (33 points)
Bad CTD (0 points)

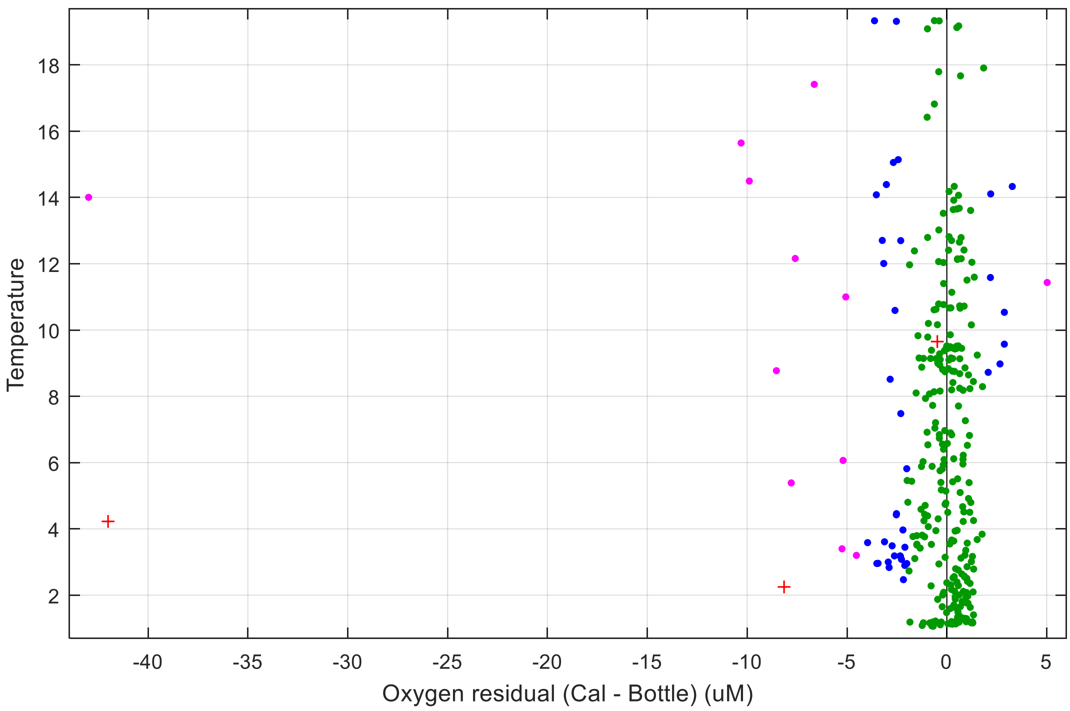

Temperature
Conductivity residual (Cal - Bottle) (S/m)
×10-3

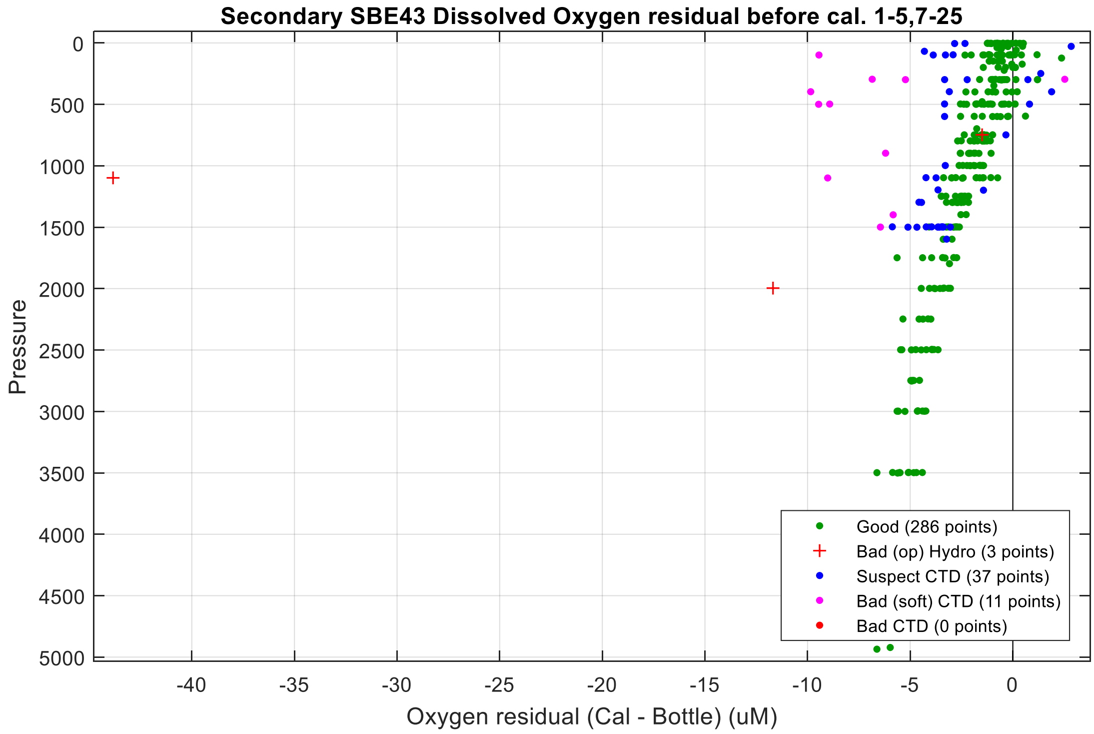
Appendix II: Dissolved Oxygen Calibration Residual Plots

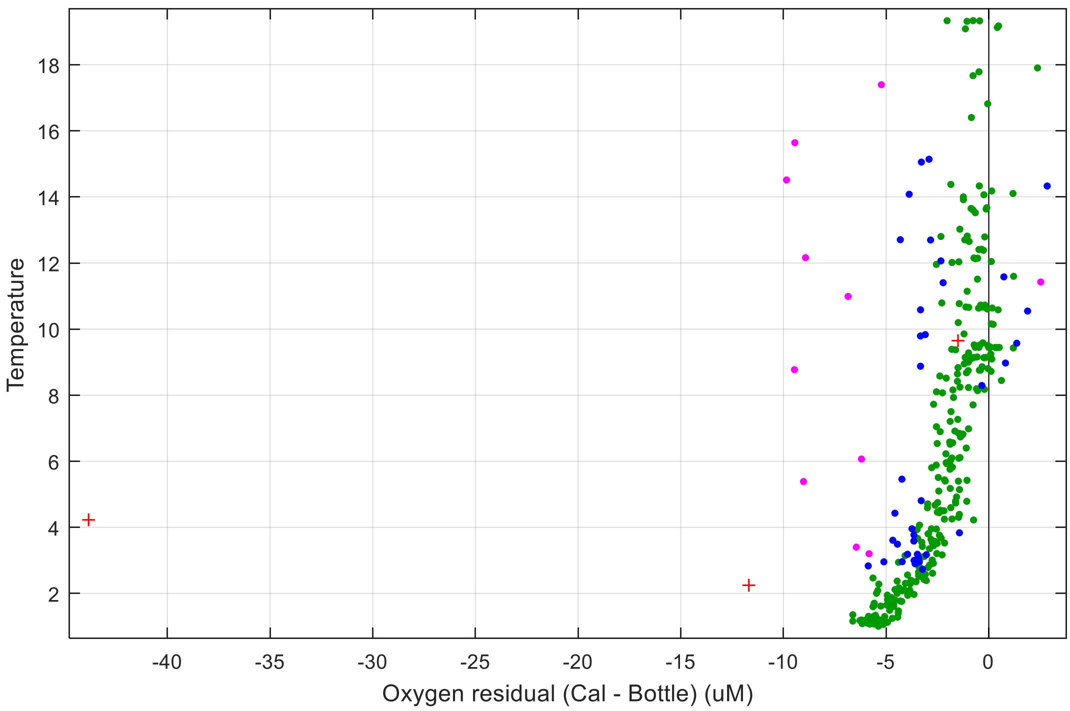


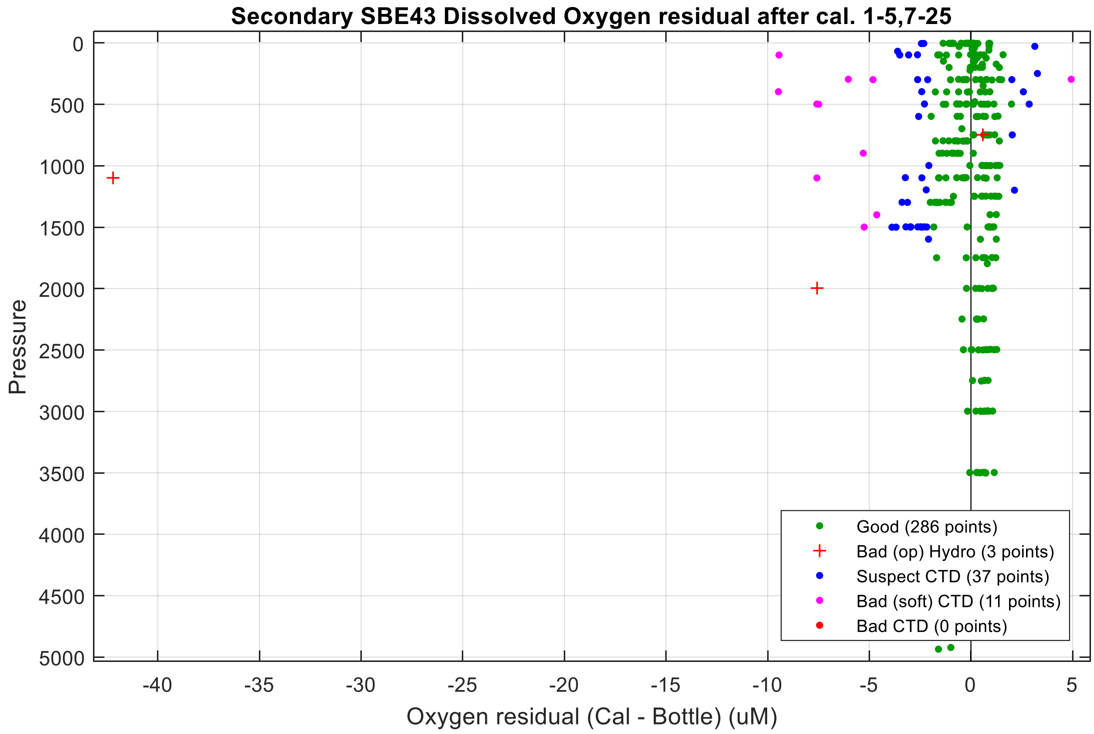


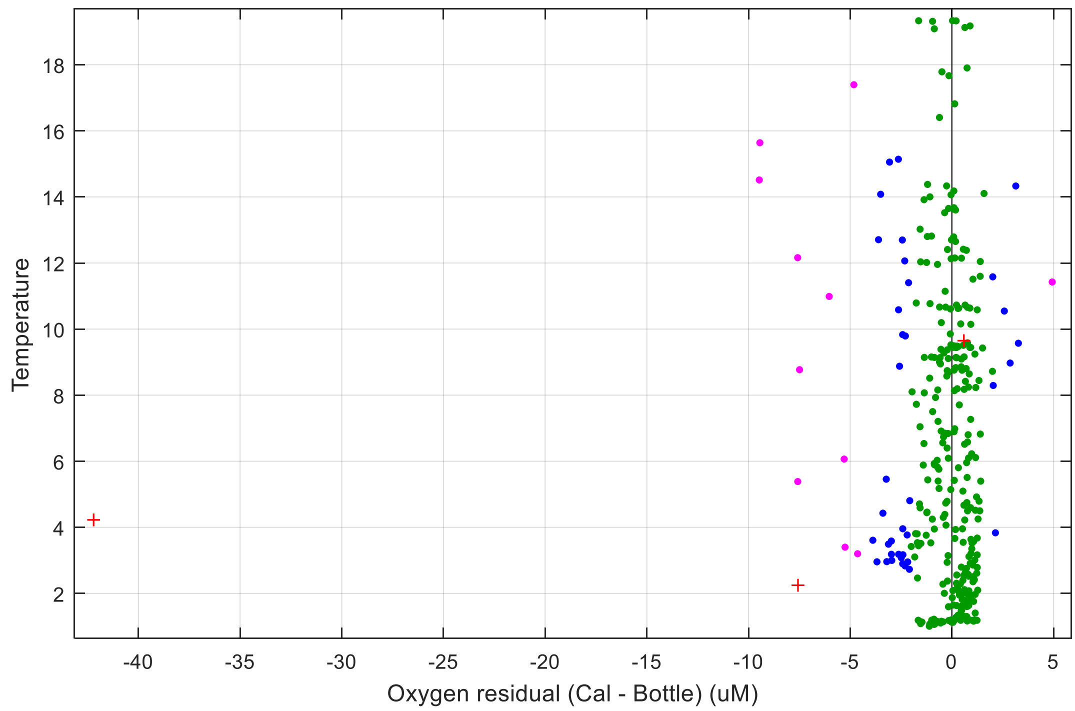

Primary SBE43 Dissolved Oxygen residual after cal. 1-5,7-19,21-25
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
-40
-35
-30
-25
-20
-15
-10
-5
0
5
Oxygen residual (Cal - Bottle) (uM)
Good (268 points)
Bad (op) Hydro (3 points)
Suspect CTD (38 points)
Bad (soft) CTD (12 points)
Bad CTD (0 points)


Temperature
2
4
6
8
10
12
14
16
18
-40
-35
-30
-25
-20
-15
-10
-5
0
5
Oxygen residual (Cal - Bottle) (uM)


Secondary SBE43 Dissolved Oxygen residual before cal. 1-5,7-25
Pressure
Oxygen residual (Cal - Bottle) (uM)
Good (286 points)
Bad (op) Hydro (3 points)
Suspect CTD (37 points)
Bad (soft) CTD (11 points)
Bad CTD (0 points)


Temperature
Oxygen residual (Cal - Bottle) (uM)


Secondary SBE43 Dissolved Oxygen residual after cal. 1-5,7-25
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
-40
-35
-30
-25
-20
-15
-10
-5
0
5
Oxygen residual (Cal - Bottle) (uM)
Good (286 points)
Bad (op) Hydro (3 points)
Suspect CTD (37 points)
Bad (soft) CTD (11 points)
Bad CTD (0 points)


Temperature
18
16
14
12
10
8
6
4
2
-40
-35
-30
-25
-20
-15
-10
-5
0
5
Oxygen residual (Cal - Bottle) (uM)