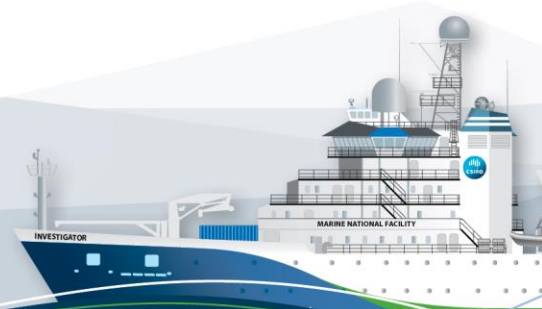


## *RV Investigator*

### CTD Processing Report

<b>Voyage ID:</b>	in2019_v05
<b>Voyage title:</b>	Integrated Marine Observing System: monitoring of East Australian Current property transports at 27 degrees south
<b>Depart:</b>	Brisbane, Monday, 9 September 2019
<b>Return:</b>	Brisbane, Monday, 30 September 2019
<b>Report compiled by:</b>	Steven Van Graas



## Contents

1	Summary.....	3
2	Voyage Details .....	3
2.1	Title .....	3
2.2	Principal Investigators.....	3
2.3	Voyage Objectives.....	3
2.4	Area of operation .....	4
3	Processing Notes .....	5
3.1	Background Information .....	5
3.2	Pressure and temperature calibration.....	6
3.3	Conductivity Calibration.....	8
3.4	Dissolved Oxygen Sensor Calibration.....	12
3.4.1	SBE calibration procedure.....	12
3.4.2	Results.....	12
3.5	Other sensors .....	16
3.6	Bad data detection.....	17
3.7	Averaging .....	17
4	References .....	17
	Appendix I: Conductivity Calibration Residual Plots.....	19
	Appendix II: Dissolved Oxygen Calibration Residuals .....	24

## 1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2019\_v05, from 09 Sep 2019 – 30 Sep 2019.

Data for 28 deployments were acquired using the Sea-Bird SBE911 CTD #25, fitted with 24 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.

Cast 1 was a test cast, and at approximately 920 decibar there was a pump failure, caused by a leaking connector, rendering the data unusable and has been omitted from the result set. Cast 2 had no water samples taken and was a sensor comparison cast. The primary SBE43 Oxygen sensor was swapped after cast 8 due to showing excessive noise.

The final conductivity calibration was based on a single deployment grouping. The final calibration from the secondary sensor had a standard deviation (SD) of 0.0015643 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 secondary sensors.

The dissolved oxygen data calibration fit had a SD of 0. 78299  $\mu$ M. The agreement between the CTD and bottle data was good.

A Biospherical PAR, Tritech Altimeter, C-Star Transmissometer, WET Labs CDOM, WET Labs ECO Scattering, and WET Labs ECO Chlorophyll sensor, were also installed on the auxiliary A/D channels of the CTD.

## 2 Voyage Details

### 2.1 Title

Integrated Marine Observing System: monitoring of East Australian Current property transports at 27 degrees south

### 2.2 Principal Investigators

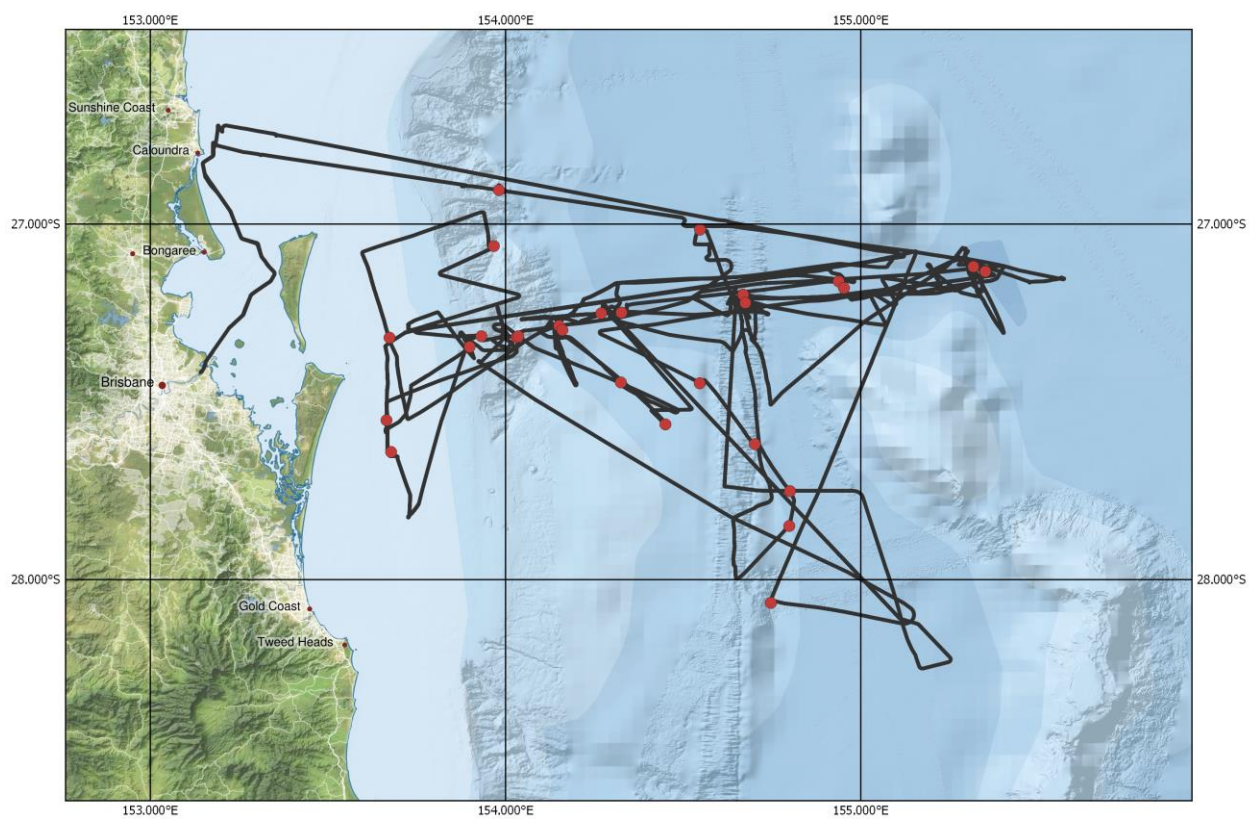
Dr. Bernadette Sloyan

### 2.3 Voyage Objectives

The scientific objectives for in2019\_v05 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 in2019\_v05**

## 3 Processing Notes

### 3.1 Background Information

The data for this voyage were acquired with the CSIRO CTD unit #25, a Sea-Bird SBE911 with dual conductivity and temperature sensors.

The CTD was additionally fitted with SBE43 dissolved oxygen sensors A Biospherical PAR, Trittech Altimeter, C-Star Transmissometer, WET Labs CDOM, WET Labs ECO Scattering, and WET Labs ECO Chlorophyll sensor. These sensors are described in

Altimeter	Trittech PA 500	05301	A2	N/A	Manufacturer
PAR	QCP2300HP	70111	A3	1-Aug-2018	Manufacturer
Transmissometer	C-Star	1421-DR	A4	17-Aug-2018	Manufacturer
WET Labs CDOM	FLCDRTD	4367	A5	23-Apr-2019	Manufacturer
WET Labs ECO-Chlorophyll	FLBB	5169	A6	24-Aug-2018	Manufacturer
WET Labs ECO-Scattering	FLBB	5169	A7	24-Aug-2018	Manufacturer

Table 1 below.

Description	Sensor	Serial No.	A/D	Calibration Date	Calibration Source
Pressure	Digiquartz 410K-134	1354	P	22-Jan-2019	CSIRO
Primary Temperature	Sea-Bird SBE3 <sup>plus</sup>	6180	T0	12-Jan-2019	CSIRO
Secondary Temperature	Sea-Bird SBE3 <sup>plus</sup>	6130	T1	12-Jan-2019	CSIRO
Primary Conductivity	Sea-Bird SBE4C	4685	C0	14-Jan-2019	CSIRO
Secondary Conductivity	Sea-Bird SBE4C	4662	C1	14-Jan-2019	CSIRO
Primary Dissolved Oxygen (1-8)	SBE43	3155	A0	6-Jun-2019	CSIRO
Primary Dissolved Oxygen (9-28)	SBE43	3198	A0	12-Aug-2019	CSIRO
Secondary Dissolved Oxygen	SBE43	3159	A1	14-Jun-2019	CSIRO
Altimeter	Trittech PA 500	05301	A2	N/A	Manufacturer
PAR	QCP2300HP	70111	A3	1-Aug-2018	Manufacturer
Transmissometer	C-Star	1421-DR	A4	17-Aug-2018	Manufacturer
WET Labs CDOM	FLCDRTD	4367	A5	23-Apr-2019	Manufacturer
WET Labs ECO-Chlorophyll	FLBB	5169	A6	24-Aug-2018	Manufacturer
WET Labs ECO-Scattering	FLBB	5169	A7	24-Aug-2018	Manufacturer

**Table 1 CTD Sensor configuration on in2019\_v05**

Water samples were collected using a Sea-Bird SBE32, 24-bottle rosette sampler. Sampling was from 24 twelve litre bottles which were fitted to the frame.

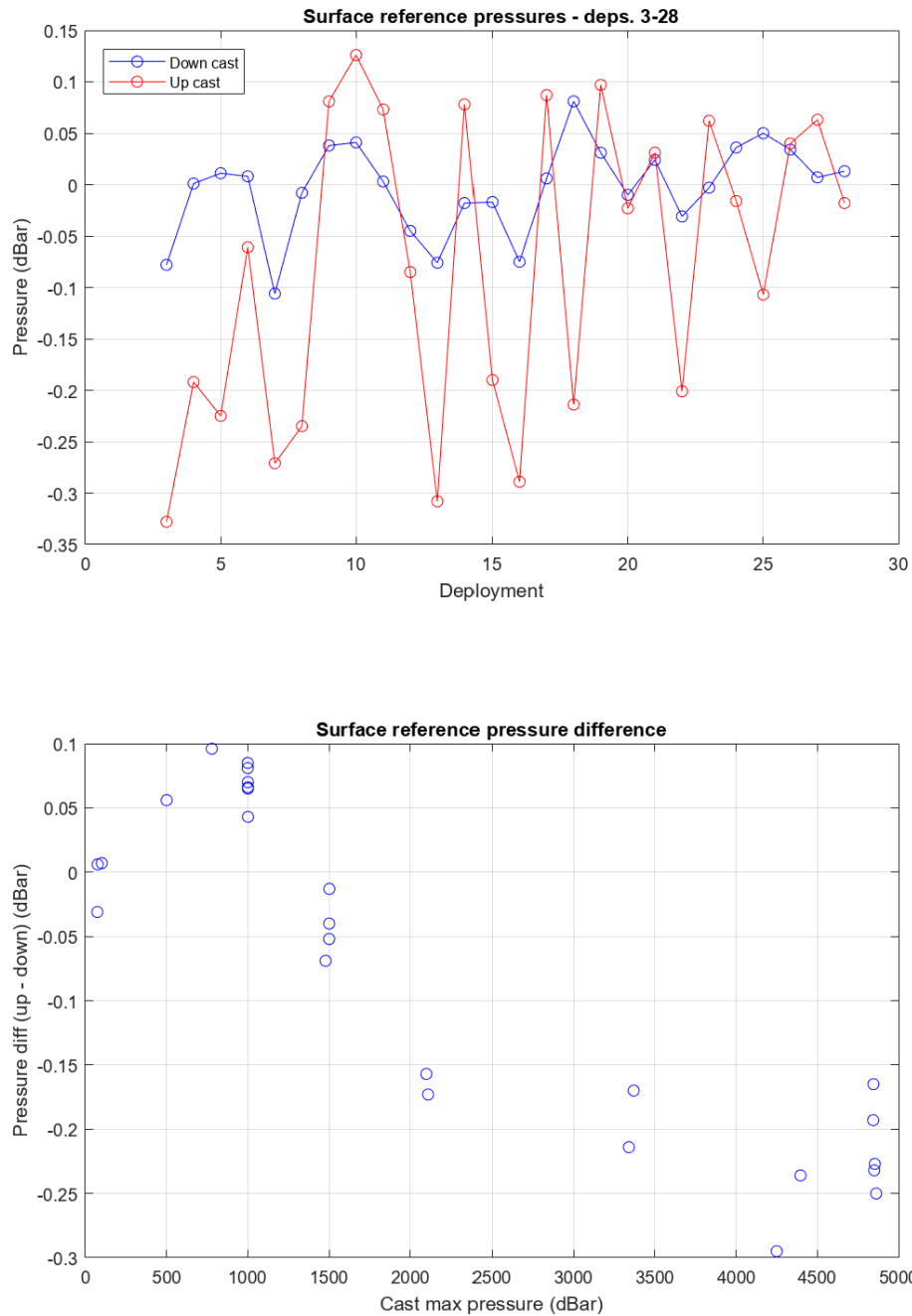
The raw CTD data were collected in SBE SeaSave version 7.26.7, converted to scientific units using SBE Data Processing version 7.26.7 and written to NetCDF format files with CNV\_to\_Scan for processing using the Matlab-base, CapPro package version 2.11.

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.

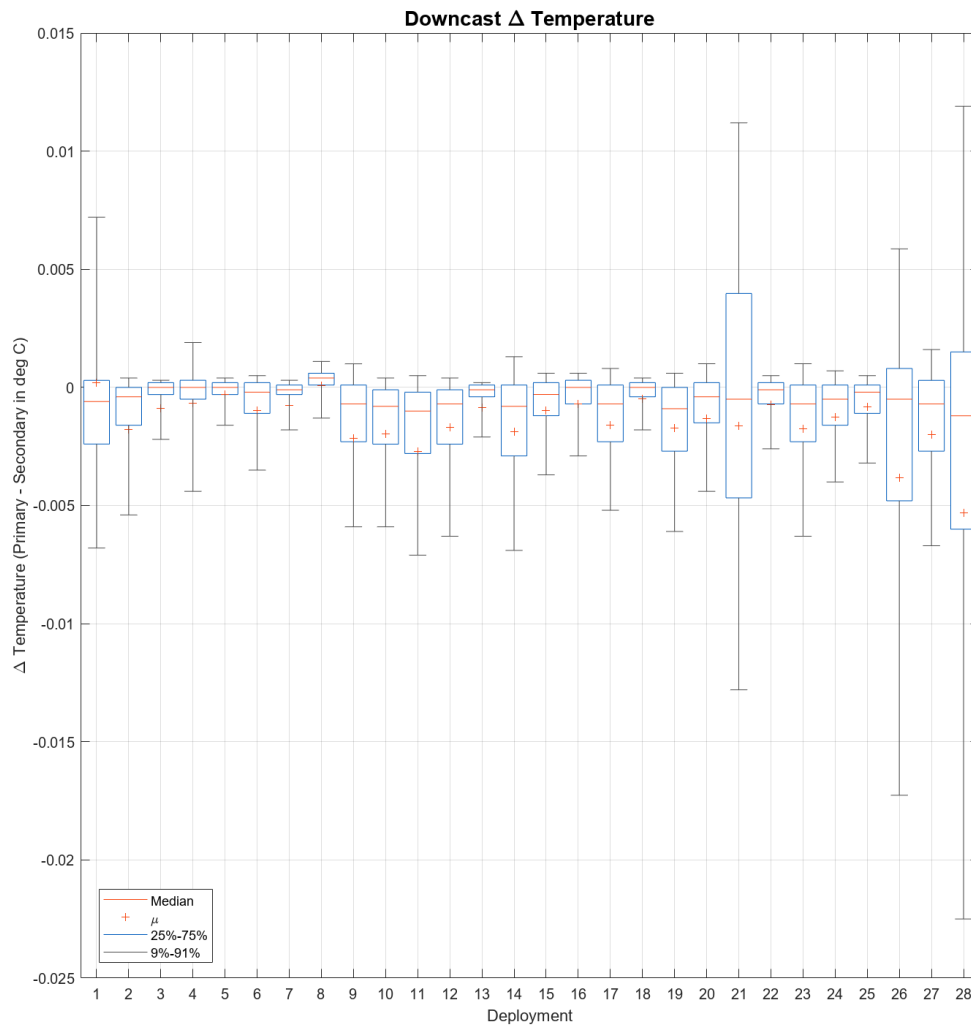
### **3.2 Pressure and temperature calibration**

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  $\pm 0.001^{\circ}\text{C}$  of zero – outliers result from sampling in regions of high vertical temperature gradient as supported by the similarity between the temperature difference shown in Figure 3. There is a trend developing towards the end of the deployments of an increase in temperature difference, indicating a possible growing sensor issue. Both temperature sensors performed within accepted limits.



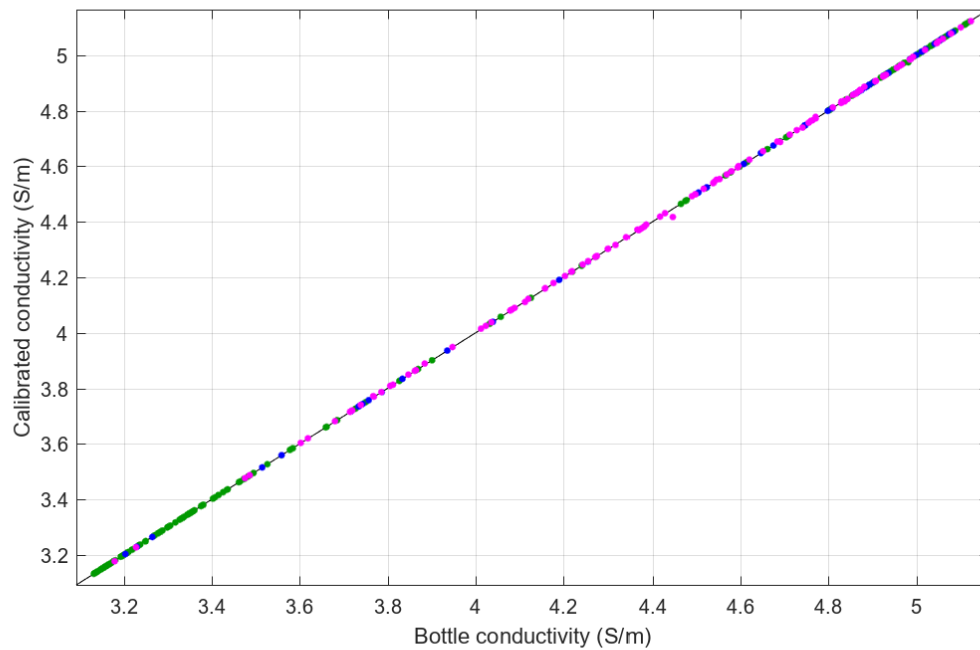
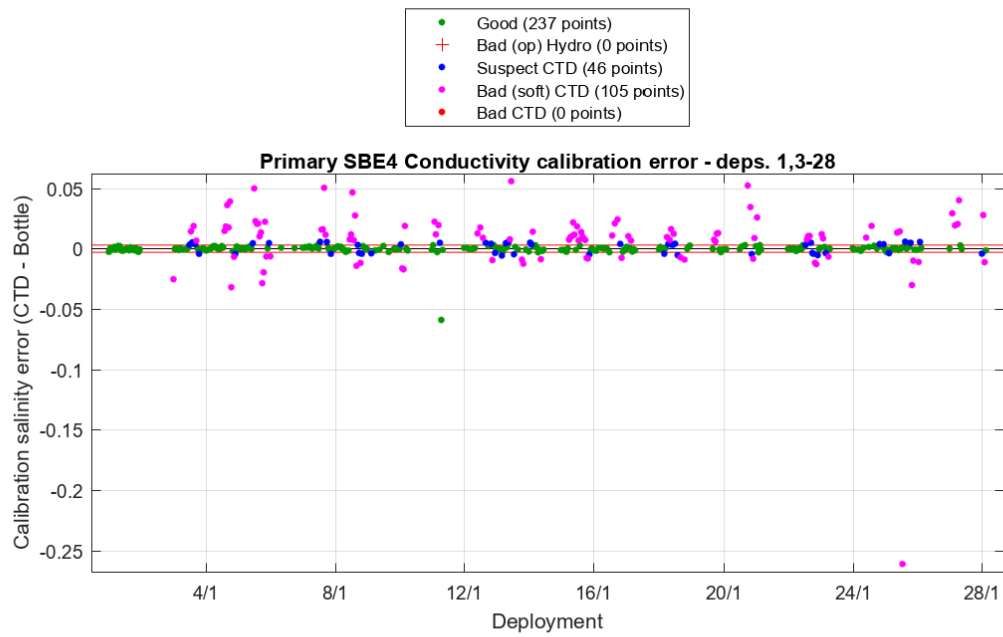
**Figure 3** Difference between primary and secondary temperature sensors

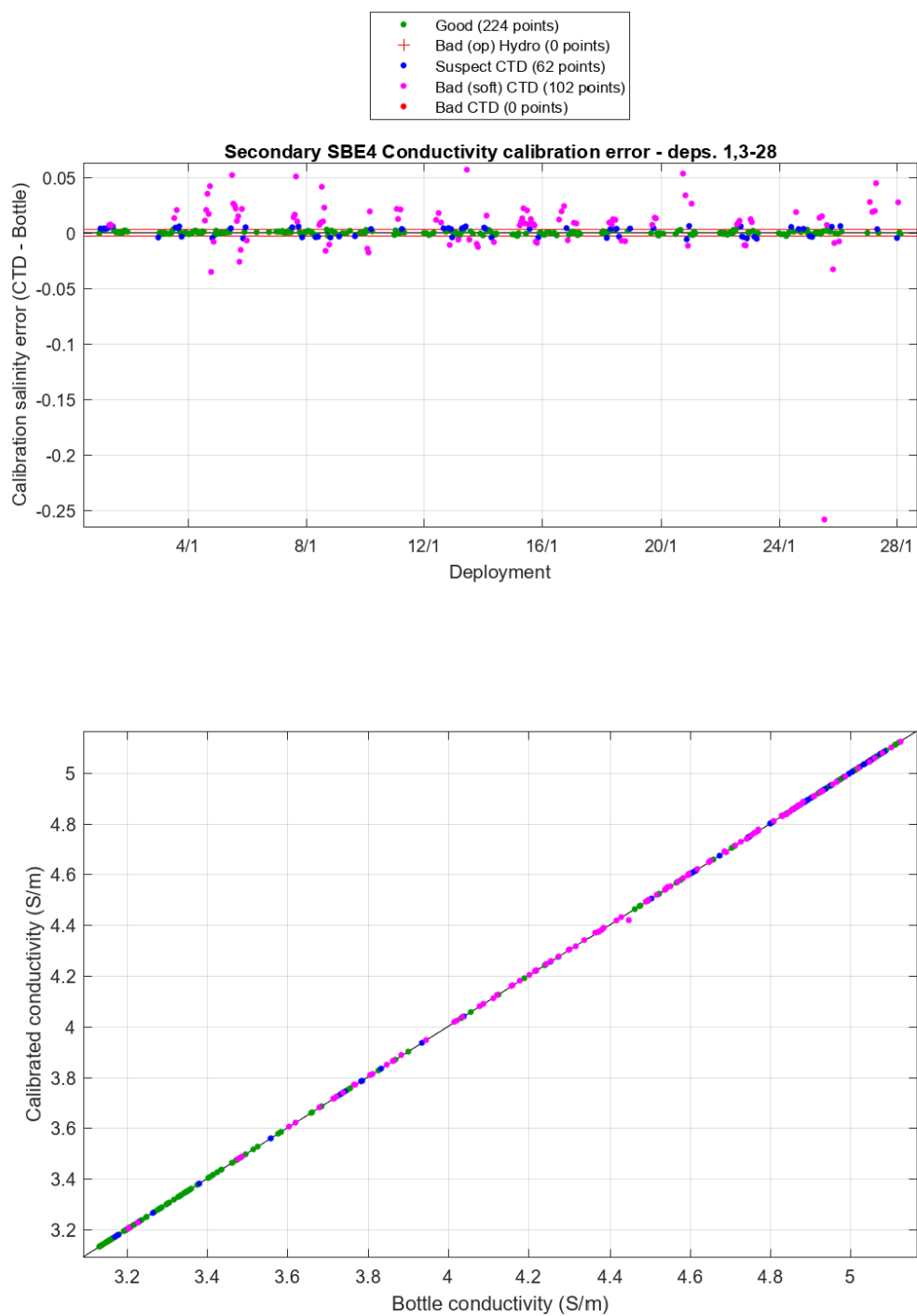
### 3.3 Conductivity Calibration

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 283/286 of the total of 388 samples taken during deployments which are above our target of 70%.

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.

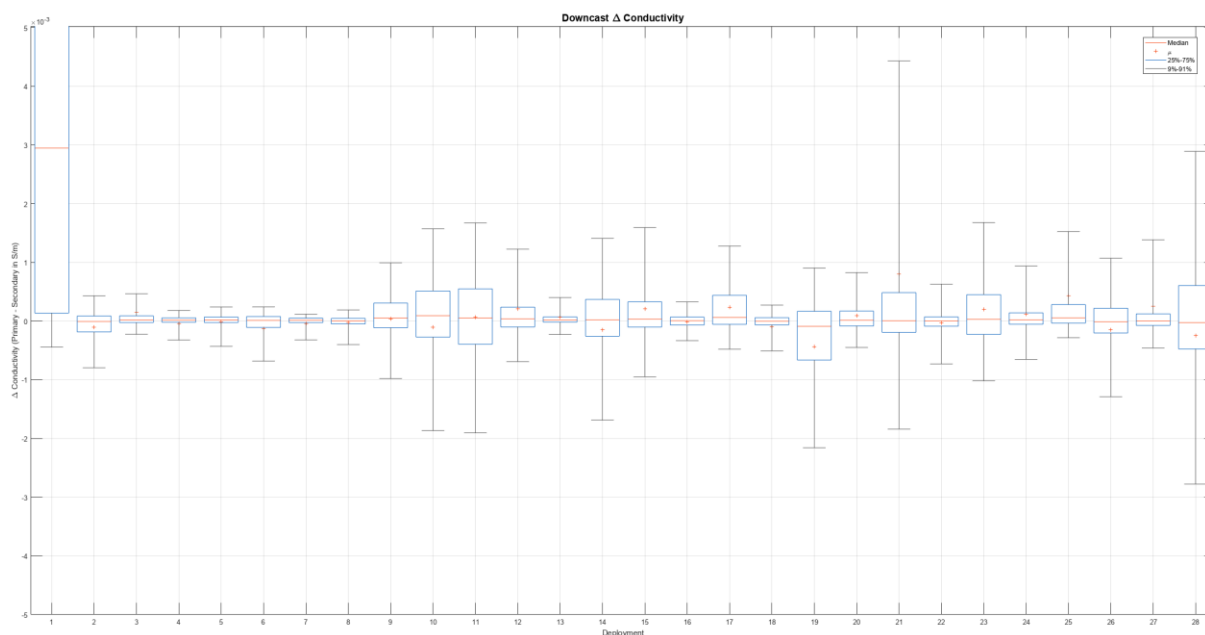






**Figure 4 CTD - bottle salinity plot**

The box plot of calibrated downcast conductivities (primary - secondary) for all deployments in Figure 5 shows that the calibrated conductivity cell responses corresponded well, apart from cast 1, where the excessive difference was caused by a pump failure.



**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	1-28	0.99976	0.00041244	0.00080746	0.0018981	0.0015338	0.0010864
Secondary	1-28	0.99996	0.00041618	0.00040631	0.0019176	0.0015643	0.0010982

Table 2 and

Secondary	1-28	-8.7145e-08	8.4655e-08
-----------	------	-------------	------------

Table 3.

Sensor Group	Deployments	Scale Factor		Offset		Salinity (PSU)	
		a1	±	a0	±	Residual SD	M.A.D.
Primary	1-28	0.99976	0.00041244	0.00080746	0.0018981	0.0015338	0.0010864
Secondary	1-28	0.99996	0.00041618	0.00040631	0.0019176	0.0015643	0.0010982

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

Conductivity Sensor	Deployments	CPcor	±
Primary	1-28	-8.2033e-08	8.4785e-08
Secondary	1-28	-8.7145e-08	8.4655e-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 **Error! Reference source not found.**

Data from the secondary conductivity and temperature sensors were used to produce the averaged salinities with primary sensors included with a suffix '\_1'.

### 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)".

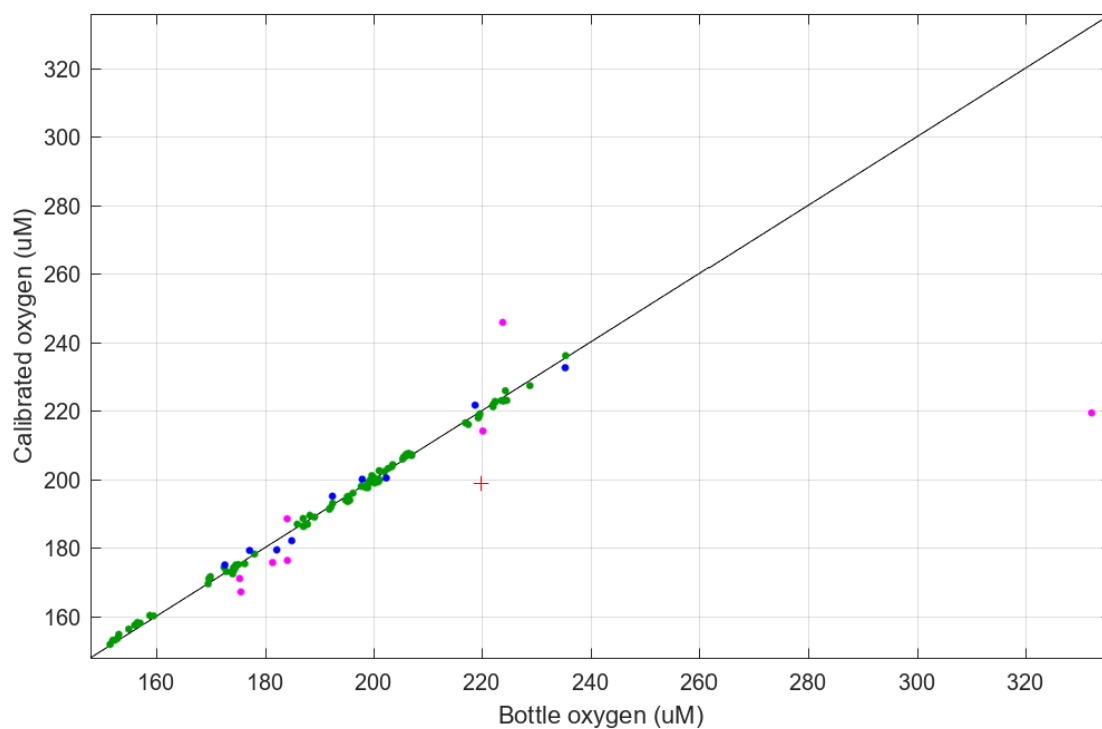
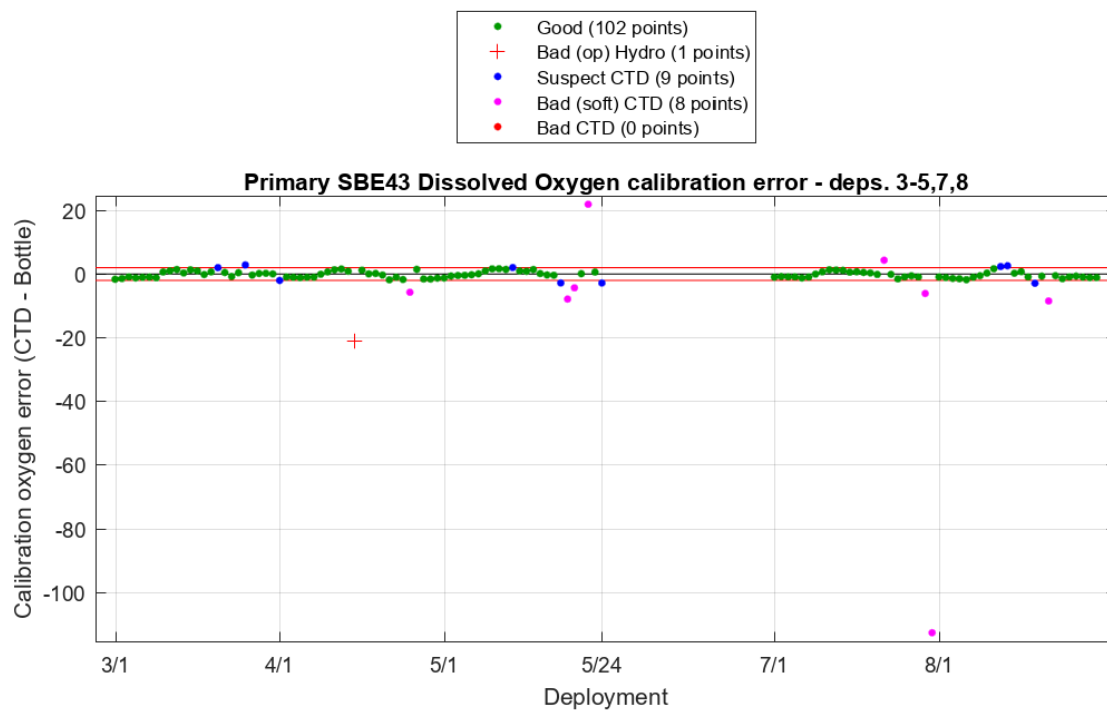
Calibration involves performing a linear regression, as per *AN64-2: SBE 43 Dissolved Oxygen Sensor Calibration and Data Corrections* (Sea-Bird, 2012) to produce new estimates of the calibration coefficients *Soc* and *Voffset*. These new coefficients are used, along with the other, manufacturer-supplied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

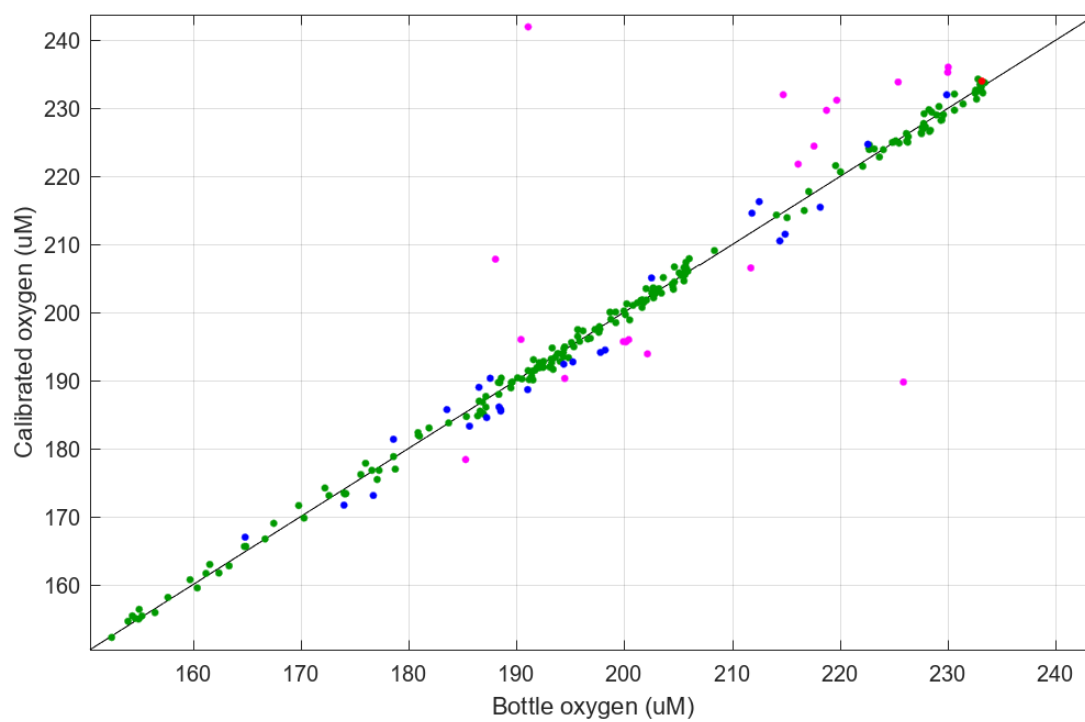
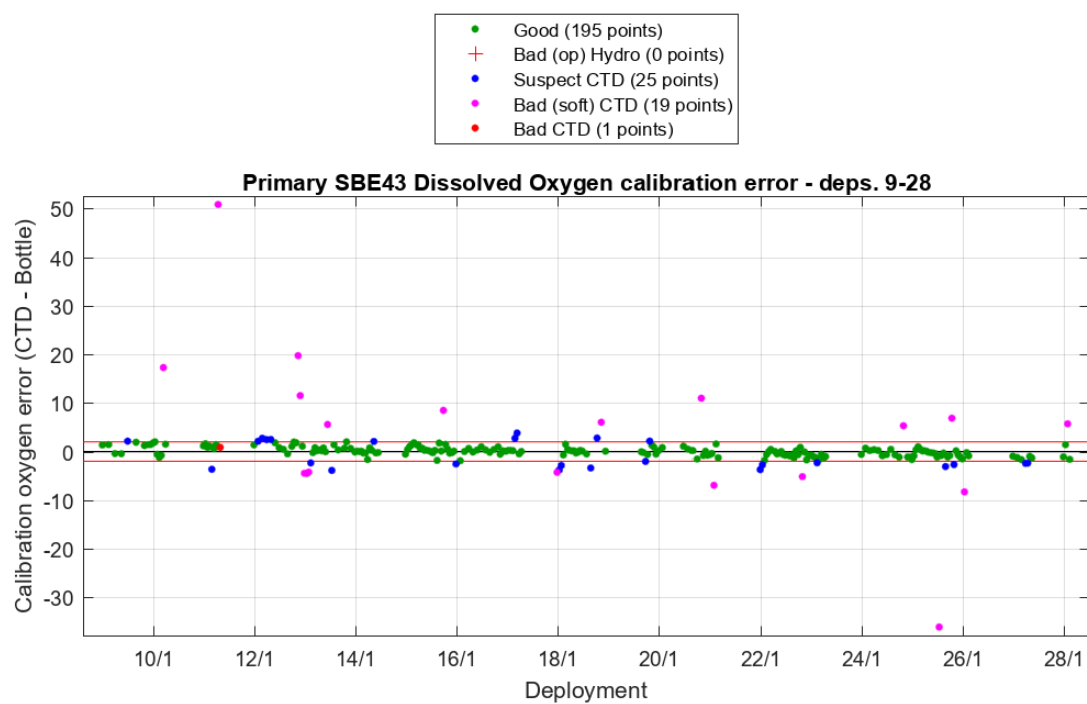
#### 3.4.2 Results

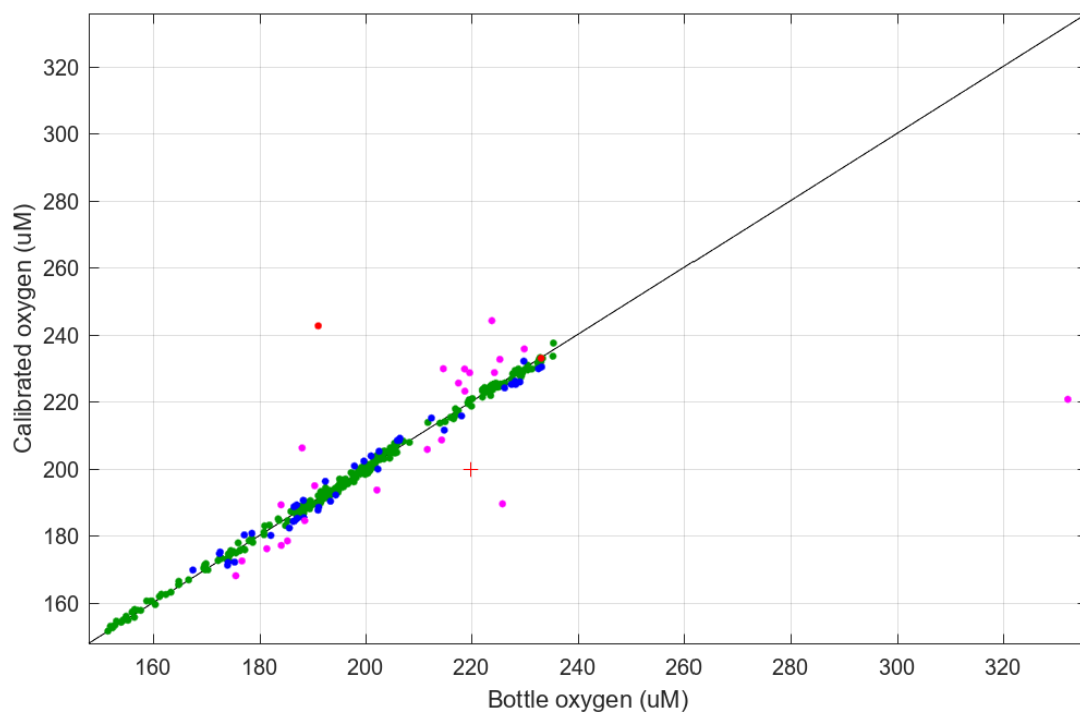
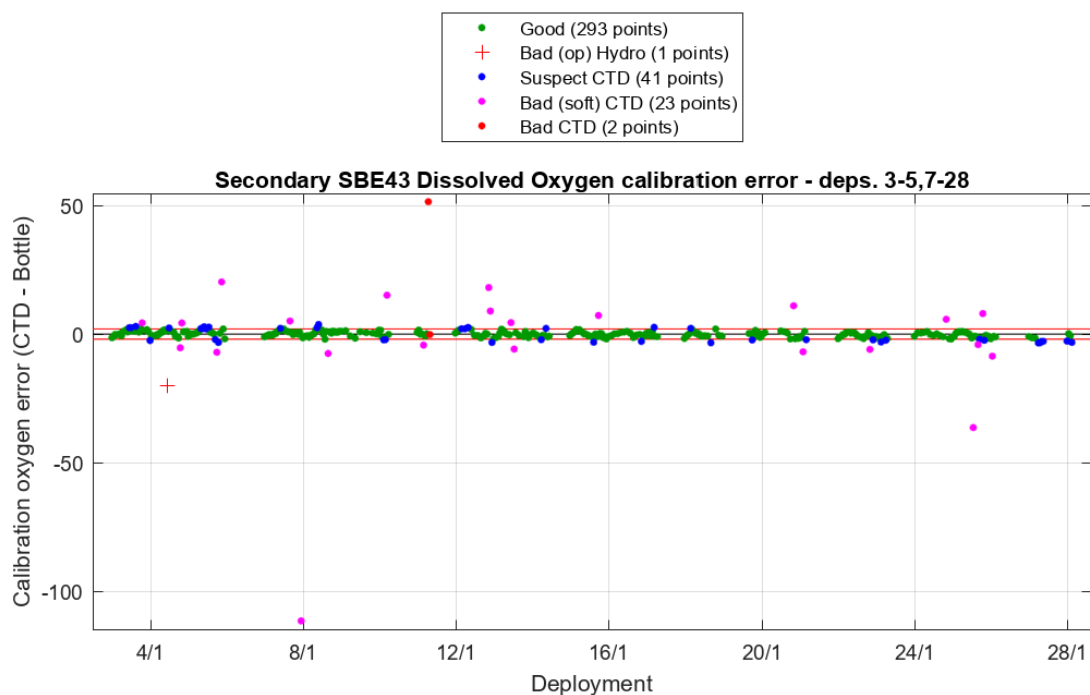
Deeper casts (>1000m) are known to be affected by pressure-induced hysteresis with this sensor. This is corrected automatically within CapPro using the method discussed in *AN64-3: SBE 43 Dissolved Oxygen (DO) Sensor - Hysteresis Corrections* (Sea-Bird, 2014).

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).







**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 Appendix II.

The calibrations were applied for each sensor and the averaged files were created using the result from the secondary sensor.

Sensor	Calibration Source	Deployments	Calibration Coefficients				Dissolved Oxygen ( $\mu\text{M}$ )	
			<i>Voffset</i>	$\pm$	<i>Soc</i>	$\pm$	Residual SD	M.A.D.
Primary DO	Hydrochemistry	1-8	-0.48881	0.0022655	0.52918	0.0013064	0.65364	0.95918
	Sea-Bird	1-8	-0.49910		0.51660			
Primary DO	Hydrochemistry	9-28	-0.45934	0.0035261	0.4012	0.00086934	0.8838	0.83649
	Sea-Bird	9-28	-0.50190		0.40445			
Secondary DO	Hydrochemistry	1-28	-0.50719	0.0017839	0.48717	0.00072316	0.78299	0.92333
	Sea-Bird	1-28	-0.49460		0.46210			

**Figure 7 Dissolved oxygen calibrations**

### 3.5 Other sensors

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 to convert the raw counts to a concentration in  $\text{mg}/\text{m}^3$  with a range of 0 – 30 milligrams per cubic meter of seawater. The scattering (OBS) has been calibrated with manufacturer supplied coefficients to give outputs in  $\text{m}^{-1}/\text{sr}$ , with a range of 0 – 3  $\text{m}^{-1}$ .

The Biospherical PAR sensor was also used for all deployments. The output is a nominal 0-5 volts which is converted to the unit  $\mu\text{Einsteins}/\text{m}^2/\text{second}$  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	5000	0.5
Transmissometer	0	105	0.5
Turbidity, OBS	-5	5000	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).

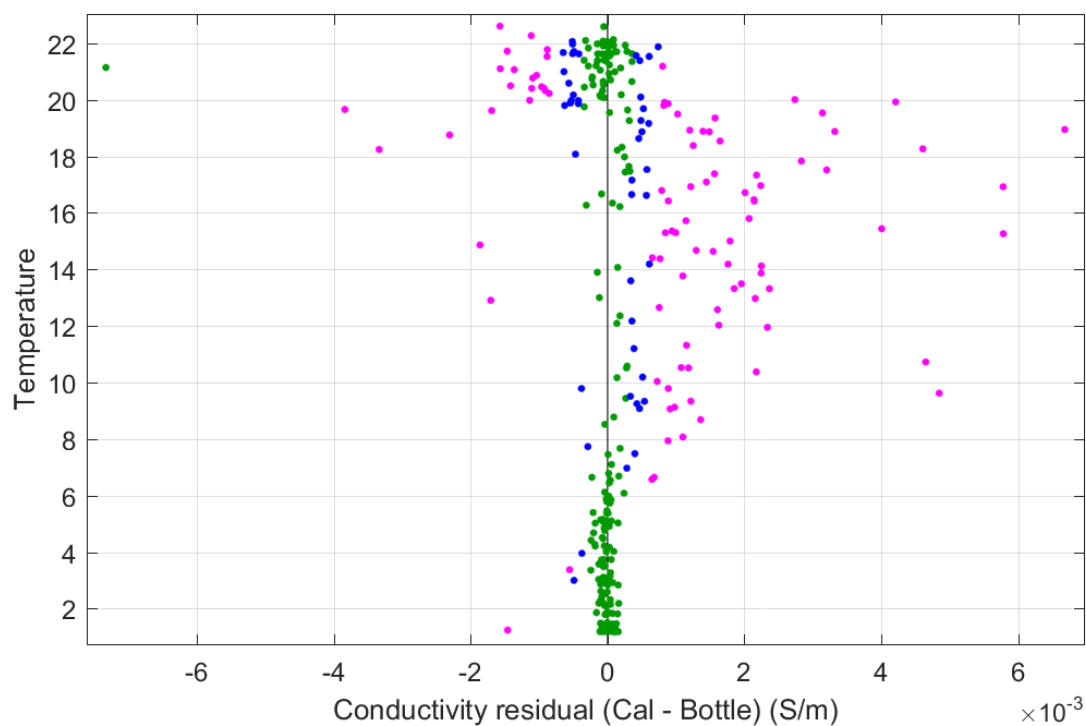
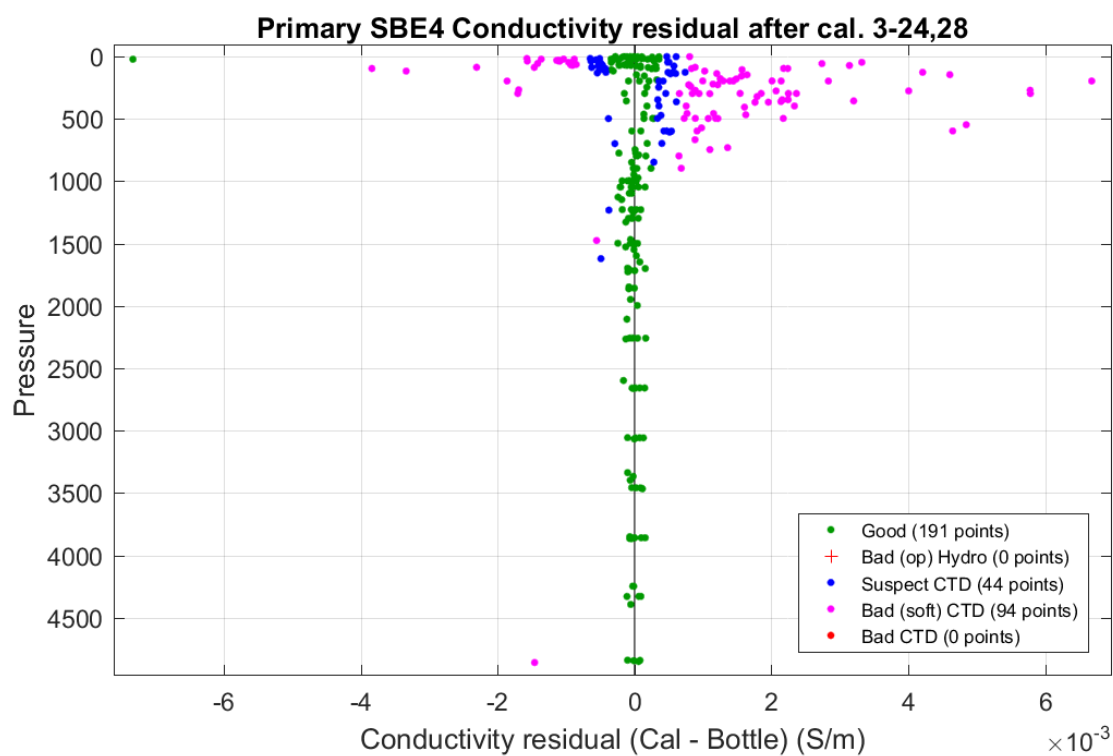
The QC Flag for each bin is estimated from the values for the bin components. The QC Flag for derived quantities, such as Salinity and Dissolved Oxygen are taken to be the worst of the estimates for the parameters from which they are derived.

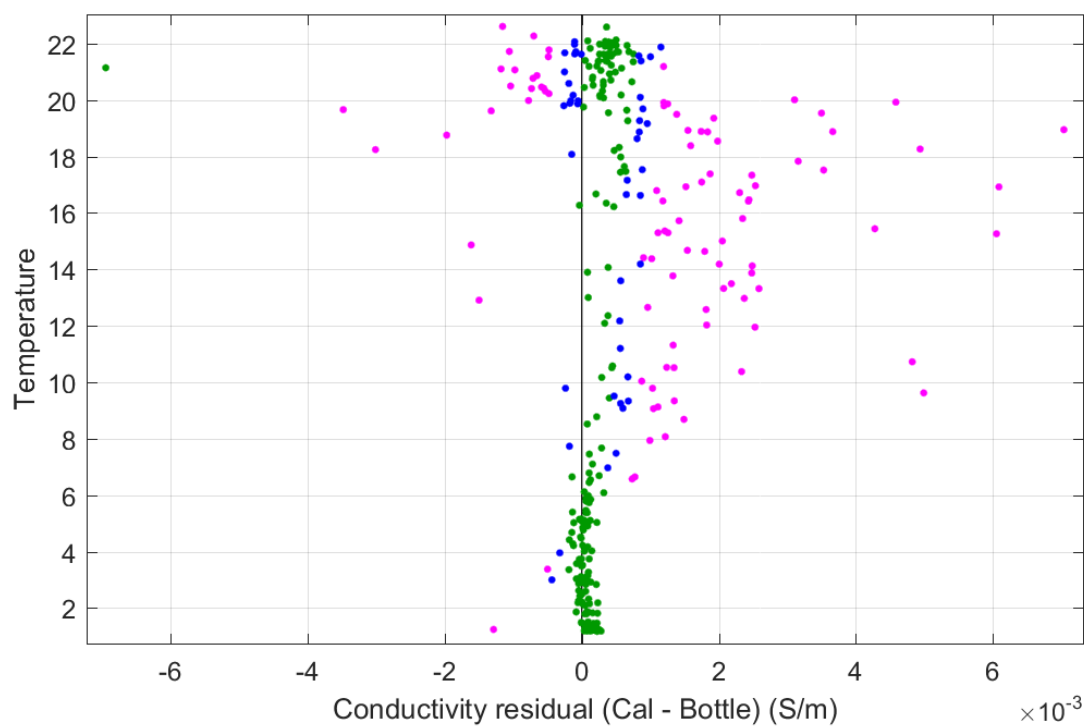
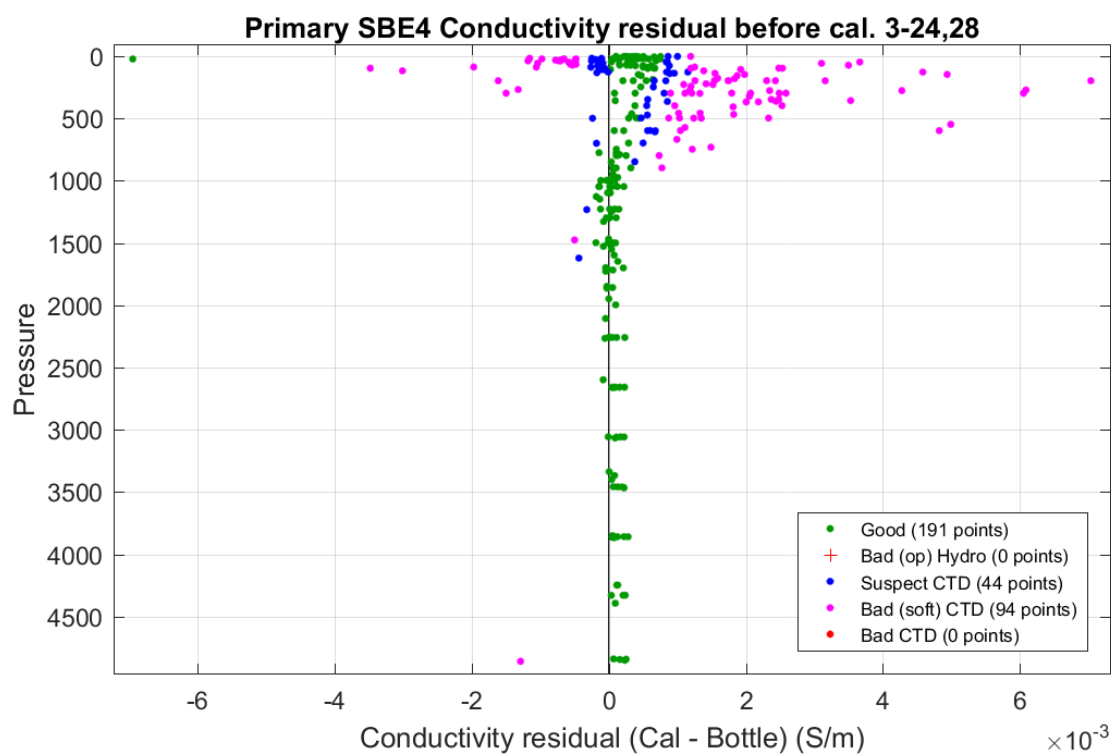
## 4 References

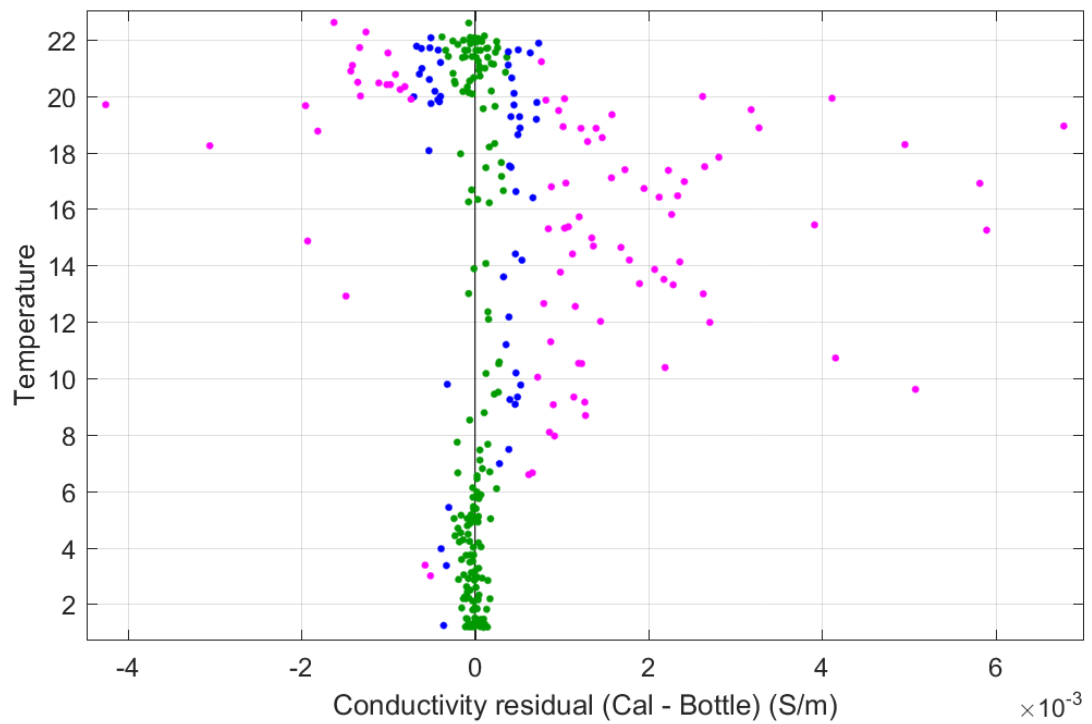
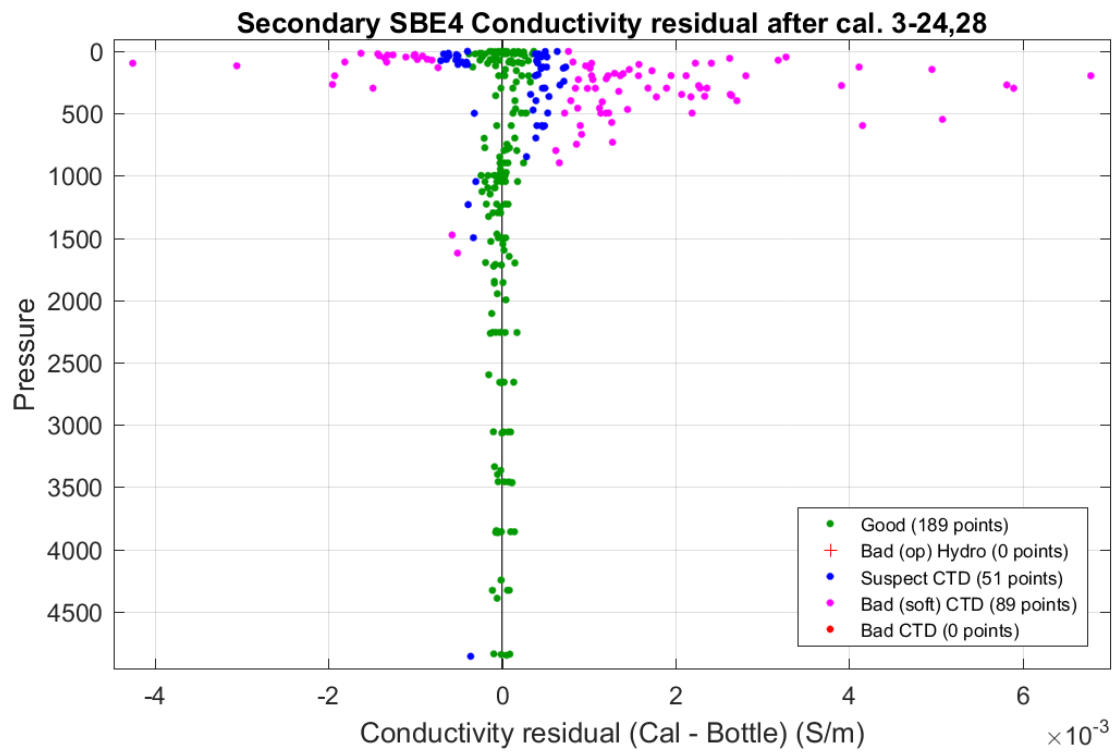
- Sloyan, B. (2019). *The RV Investigator. Voyage Plan in2019\_v05*. Retrieved from Marine National Facility: Voyage Plans and summaries: [https://www.cmar.csiro.au/data/reporting/get\\_file.cfm?eov\\_pub\\_id=1165](https://www.cmar.csiro.au/data/reporting/get_file.cfm?eov_pub_id=1165)
- Pender, L. (2000). *Data Quality Control Flags*. Retrieved from Oceans & Atmosphere Information and Data Centre: [http://www.cmar.csiro.au/datacentre/ext\\_docs/DataQualityControlFlags.pdf](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: <https://www.seabird.com/asset-get.download.jsa?id=54627861704>
- Sea-Bird. (2013). *AN64: SBE 43 Dissolved Oxygen Sensor - Background Information, Deployment Recommendations, and Cleaning and Storage*. Retrieved from Sea-Bird Electronics: <https://www.seabird.com/asset-get.download.jsa?id=54627861706>

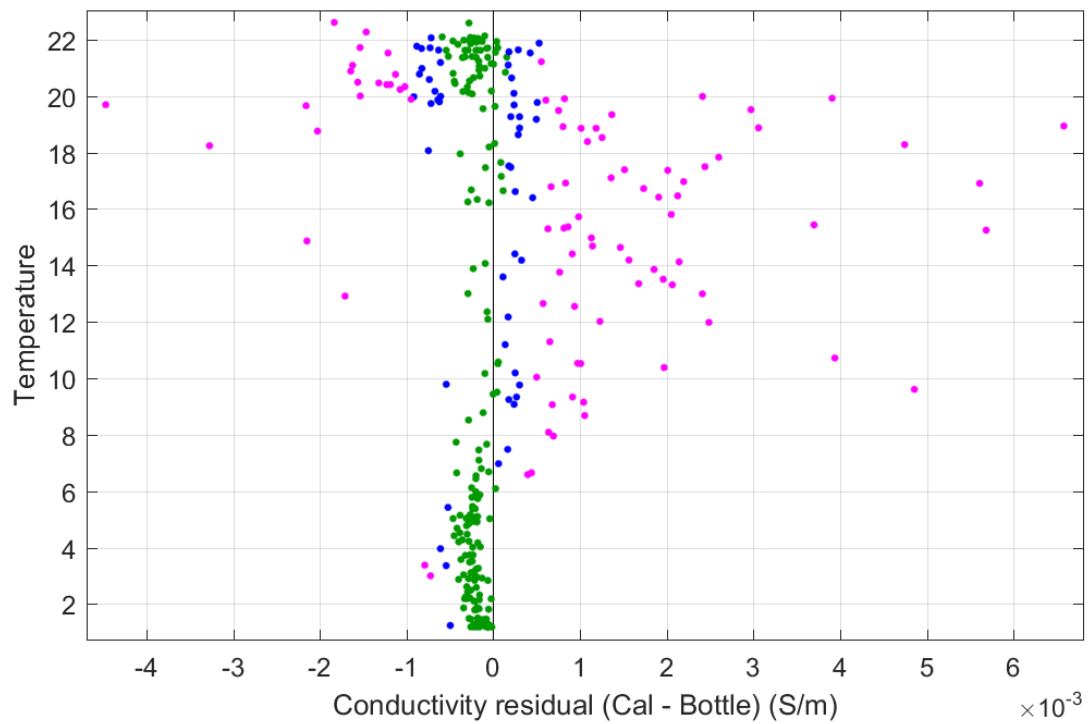
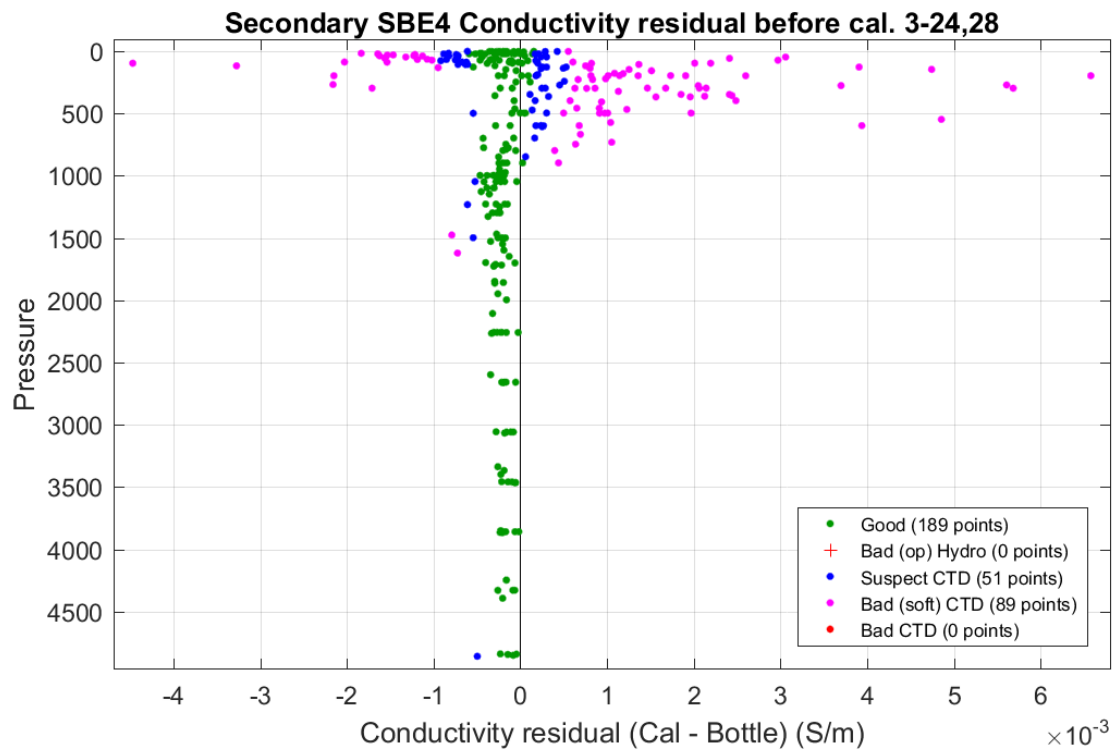
Sea-Bird. (2014). *AN64-3: SBE 43 Dissolved Oxygen (DO) Sensor - Hysteresis Corrections*. Retrieved from Sea-Bird Electronics: <https://www.seabird.com/asset-get.download.jsa?id=54627861705>

## **Appendix I: Conductivity Calibration Residual Plots**









## **Appendix II: Dissolved Oxygen Calibration Residuals**



