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## RV *Investigator* CTD Data Processing Report

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<b>Voyage ID</b>	<b>IN2025_V06</b>
<b>Voyage Title</b>	The Coral Sea frontier: Deep-sea biodiversity of the Coral Sea Marine Park
<b>Depart</b>	Brisbane, 10 October 2025, 08:00 UTC
<b>Return</b>	Brisbane, 14 November 2025, 00:00 UTC
<b>Chief Scientist</b>	Will White (CSIRO)
<b>Data Processor</b>	Mark Brunton (CSIRO – E&T Data Acquisition & Processing)

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## Document History

Date	Version	Author	Comments
13 November 2025	1.0	Mark Brunton	Initial version
17 April 2026	1.1	Mark Brunton	Final revision

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# 1 Summary

This voyage investigated benthic marine life in the southern and eastern Coral Sea Marine Park, focusing on two key ecological features: the reefs of the Marion Plateau and the Tasmantid Seamount Chain (200–3600 m). This was the first modern deep-water exploration of the extinct volcanic peaks of the northern Tasmantid Seamount Chain, which rise over 3000 m from the seabed, as well as of the offshore Kenn Plateau. These investigations were critical for improving understanding of regional biodiversity. A range of sampling tools—including towed cameras, eDNA samplers, CTDs, trawls, and sleds—were used to survey benthic communities. The biodiversity data collected enabled assessments of variation across ecological features and bioregions, levels of endemism among fishes and key invertebrates, and whether seamounts and atolls supported higher local endemism than the continental slope or offshore plateaus. Comparisons between extractive and non-extractive sampling methods were undertaken to evaluate their effectiveness in representing faunal composition. The voyage also produced new high-resolution seabed mapping, particularly for the Marion Plateau where existing data were limited.

This report describes the production of quality controlled, calibrated CTD data from RV *Investigator* voyage IN2025\_V06.

Data for 41 CTD deployments were acquired using the Sea-Bird SBE911 CTD unit #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 3 - Communications were lost at the beginning of the upcast and the Deck box alarmed. Deployment was aborted. Bottle samples were collected at the bottom and the downcast was processed in CapPro.
- Bottles 9 and 31 did not fire on casts 24, 30, 35 and 36 due to a fault with the CTD bottle release mechanism. Release Mechanism 1284 was replaced by Release Mechanism 0964 after cast 36 to address the issue.
- CTD winch experienced spooling issues during several casts, notably 13, 16, 29 and 32, resulting in delayed upcast and retrieval for respooling.
- No bottle samples were collected on cast 33 as the cast was for the purpose of respooling and winch spooling tests. As a result, CTD calibrations exclude cast 33. No further spooling issues were observed following this deployment.
- Altimeter data was observed as noisy during early deployments, particularly in shallow water (less than ~200m). The sensor channel for the PAR and altimeter were swapped after cast 5. Minimal impacts on the PAR sensor and minor improvements to the quality of the altimeter data was observed following the change.

The final conductivity calibration was based on a single deployment grouping. The final calibration from the primary sensor had a standard deviation (SD) of 0.0025203 PSU, marginally outside our

target of 'better than 0.002 PSU'. The standard product of 1-decibar binned averages were produced using data from the primary sensors.

The dissolved oxygen data calibration fit had a SD of 0.88132  $\mu\text{M}$ . The agreement between the CTD and bottle data was good.

PAR, altimeter, g\fluorescence, transmissometer, chlorophyll and turbidity sensors were also installed on the auxiliary A/D channels of the CTD.

To access the full voyage plan and other reports and data associated with this voyage, please see the contact information at the end of this report.

## 1.1 Voyage Track

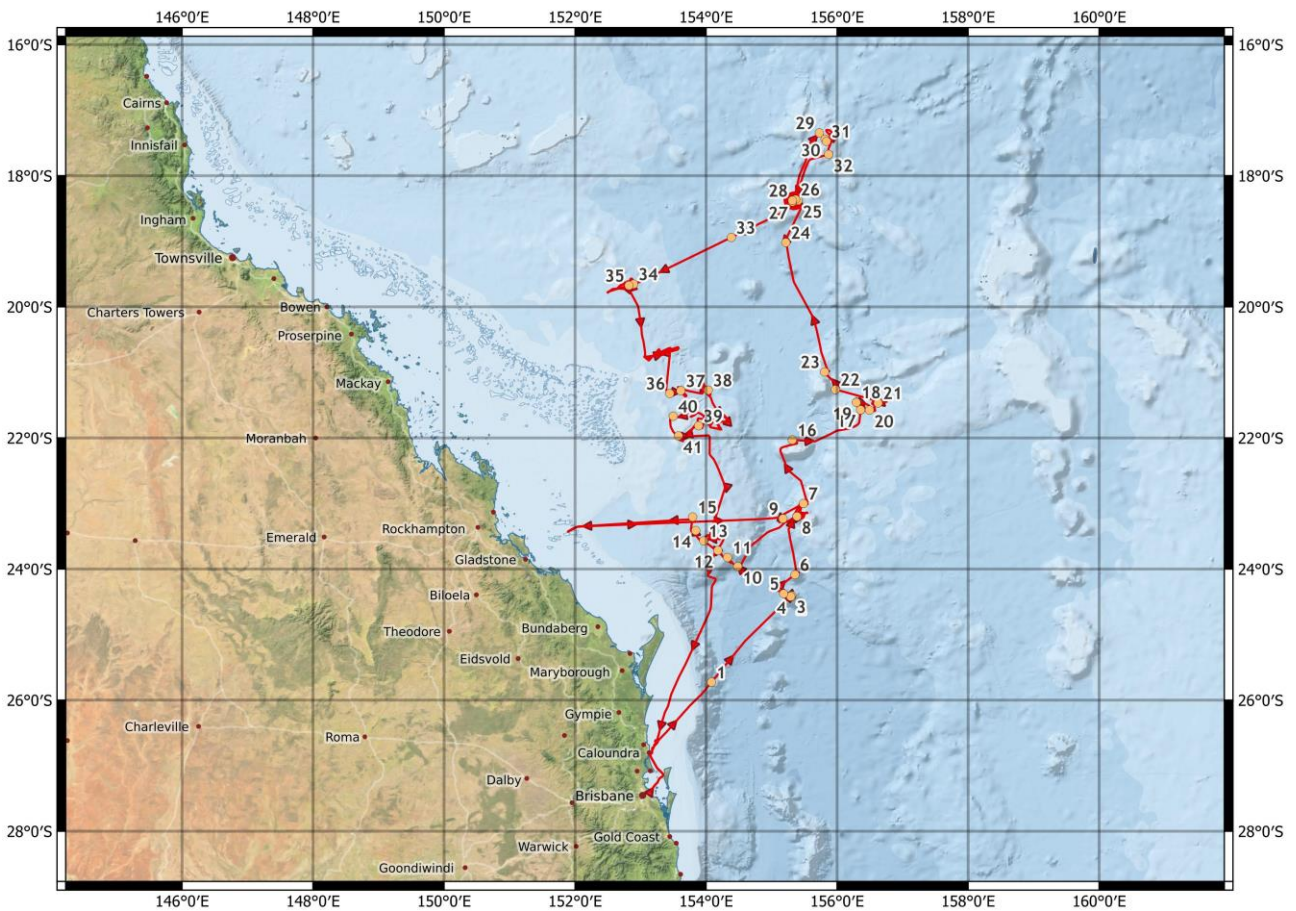


Figure 1: Voyage track with CTD cast locations

## 2 Data Processing

### 2.1 Background Information

41 CTD deployments were conducted on this voyage. The data 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 and PAR, altimeter, fluorescence, transmissometer, chlorophyll and turbidity sensors. These sensors are described in Table 1.

Sensor Description	Model	Serial No.	A/D Channel	Calibration Date	Calibration Source
Pressure	Digiquartz 410K-134	1332	P	25-Mar-2025	CSIRO
Primary Temperature	Sea-Bird SBE3 <i>plus</i>	6024	T0	4-Nov-2024	CSIRO
Secondary Temperature	Sea-Bird SBE3 <i>plus</i>	6189	T1	4-Nov-2024	CSIRO
Primary Conductivity	Sea-Bird SBE4C	3168	C0	17-Apr-2025	Sea-Bird Scientific
Secondary Conductivity	Sea-Bird SBE4C	2235	C1	24-Apr-2025	Sea-Bird Scientific
Primary Dissolved Oxygen	SBE43	4188	A0	16-Apr-2025	Sea-Bird Scientific
Secondary Dissolved Oxygen	SBE43	4187	A1	16-Apr-2025	Sea-Bird Scientific
PAR	Biospherical QCP2300HP	70111	CTD 1-5: A3 CTD 6-39: A2	1-Mar-2025	Biospherical Instruments
Altimeter	Tritech PA500	310747	CTD 1-5: A2 CTD 6-39: A3	11-Sep-2025	Tritech
CDOM Fluorescence	Wetlabs FLCDRTD	7138	A4	16-Apr-2025	Sea-Bird Scientific
Transmissometer	Wetlabs C-Star (DR)	1735	A5	2-Oct-2025	Sea-Bird Scientific
Chlorophyll-a	Wetlabs ECO FLBBRTD	6765	A6	18-Apr-2025	Sea-Bird Scientific
Turbidity	Wetlabs ECO FLBBRTD	6765	A7	18-Apr-2025	Sea-Bird Scientific
<b>Additional Payloads:</b>					
LADCP Slave (Up)	Teledyne 300 kHz	27103			
LADCP Master (Down)	Teledyne 150 kHz	24638			
LADCP Battery	OceanDeep	3122			
Speed of Sound	SVX	73429			

Table 1: CTD Sensor configuration on IN2025\_V06

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

The raw CTD data were collected in SBE Seasave version 7.26.7.121, converted to scientific units using SBE Data Processing version 7.23.2 and written to NetCDF files with `cnv_to_scan` (`cnv_to_scan_ui2.py`, from the CSIRO MNF Data Acquisition and Processing “marinetech” git repository) for processing using the MATLAB-based CapPro software.

The CapPro software version 2.13 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, conductivity cell thermal inertia corrections, and the determination of the pressure offsets. It also loaded the hydrology data and computed the matching CTD sample burst data (i.e., averaged sensor data) for water-sample-to-sensor data comparisons. The automatically-determined pressure offsets and in-water points were inspected and verified during data processing.

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.

## 2.2 Pressure and Temperature Calibration

The pressure offsets for each deployment are plotted in Figure 2. The blue circles refer to initial out-of-water values (beginning of downcast) and the red circles the final out-of-water values (end of upcast).

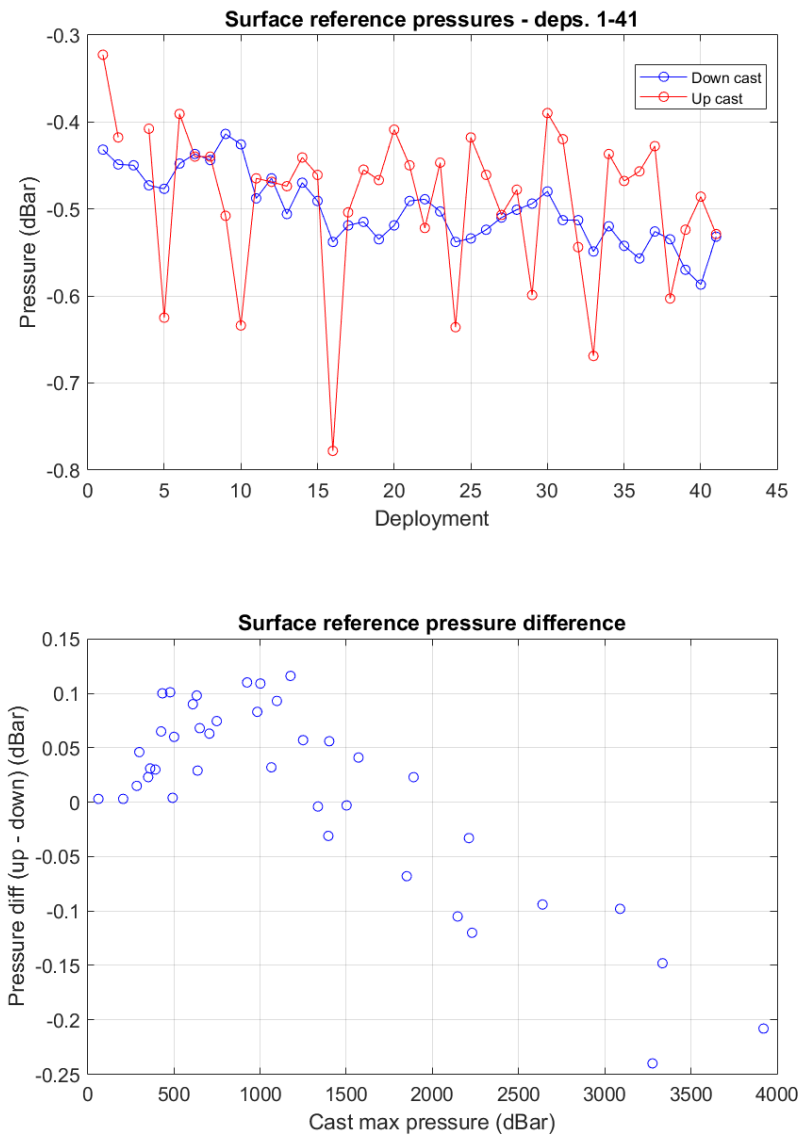


Figure 2: CTD pressure offsets

The difference between the primary and secondary temperature sensors at the bottle sampling depths is plotted in Figure 3. Most deployments plot within  $\pm 0.001$  °C of zero – outliers result from sampling in regions of high vertical temperature gradient. The consistent mean difference

(red + markers) between the primary and secondary temperature from deployment to deployment indicates neither sensor has drifted significantly from its calibration.

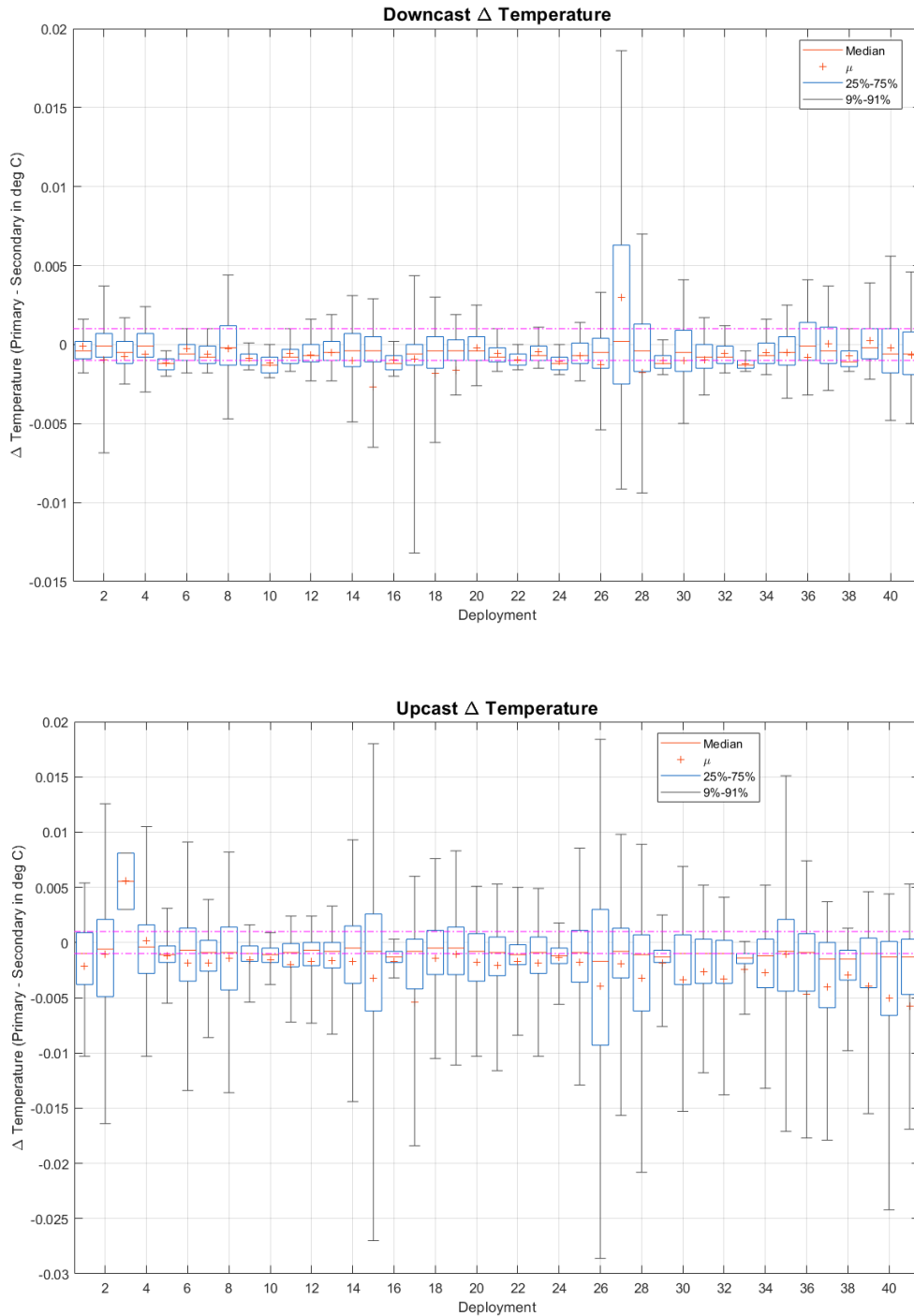


Figure 3: Difference (primary - secondary) between temperature sensor values on downcast (left) and upcast (right)

### 2.3 Conductivity Calibration

If any discrepancies or sampling problems occurred during bottle salinity sampling or between primary and secondary CTD conductivity measurements, these would show in the conductivity calibration plots in Figure 4. We did not observe any sampling problems based on these calibration results. The profile plots showing the thermocline and halocline ranges are in Figure 5.

The calibrations were based upon the percent of 'good' sample data (210 good samples + 47 suspect samples (70%) from the primary unit and 208 good samples + 53 suspect samples (71%) from the secondary unit), out of a total of 369 samples taken during deployments. To perform the calibration with the preferred (default) CapPro calibration settings, a minimum of 70% of the samples need to be in the 'good' range. If there is an insufficient number of good samples for a unit, the conductivity difference 'cutoff' value must be increased to continue with the calibration process in CapPro. For this set of conductivity calibrations, the cutoff values used were 0.05 (primary) and 0.05 (secondary) increased from the preferred default of 0.02.

Figure 4 plots CTD - bottle salinity differences for both upcast (Hydro bottle) and downcast (CTD SBE43) data. The 'bad' outliers (magenta dots, red dots and red + markers) are excluded from the calibration, the 'suspect' outliers (blue dots) are used in the calibration but are weighted based on their distance from the mean. All green dots are considered 'good' data points and are not weighted based on distance from the mean.

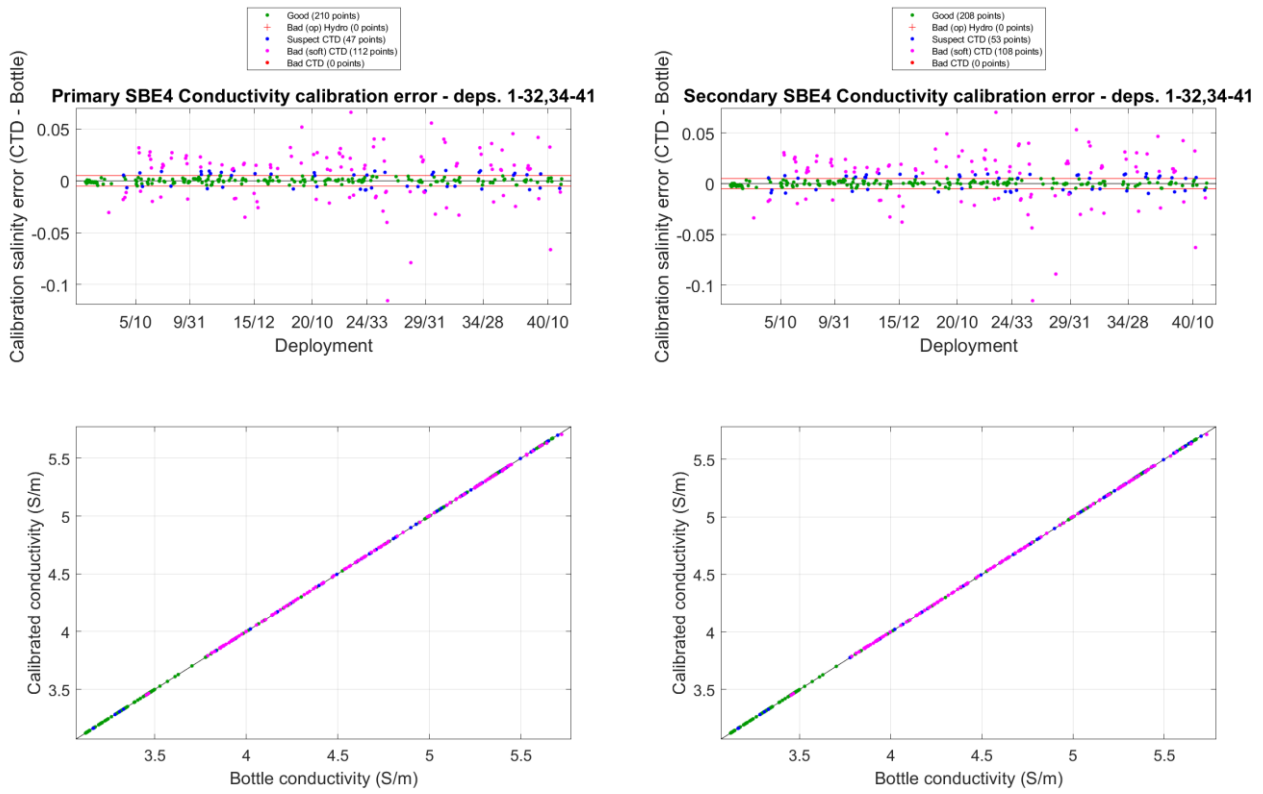


Figure 4: CTD - bottle conductivity difference and salinity calibration error (left: primary, right: secondary)

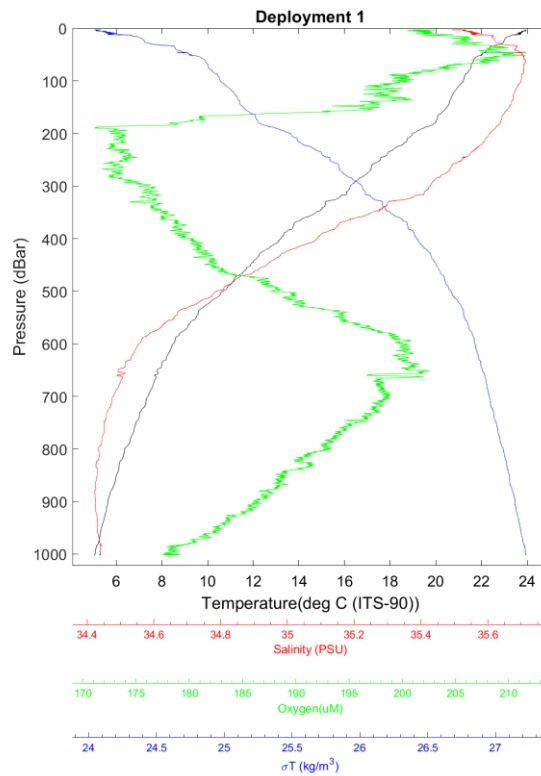


Figure 5: Temperature, salinity, dissolved oxygen and  $\sigma_T$  profiles

The box plot (Figure 6) of calibrated downcast conductivities (primary - secondary) at the bottle sampling depths for all deployments shows that the calibrated primary and secondary conductivity cell responses corresponded reasonably well to each other.

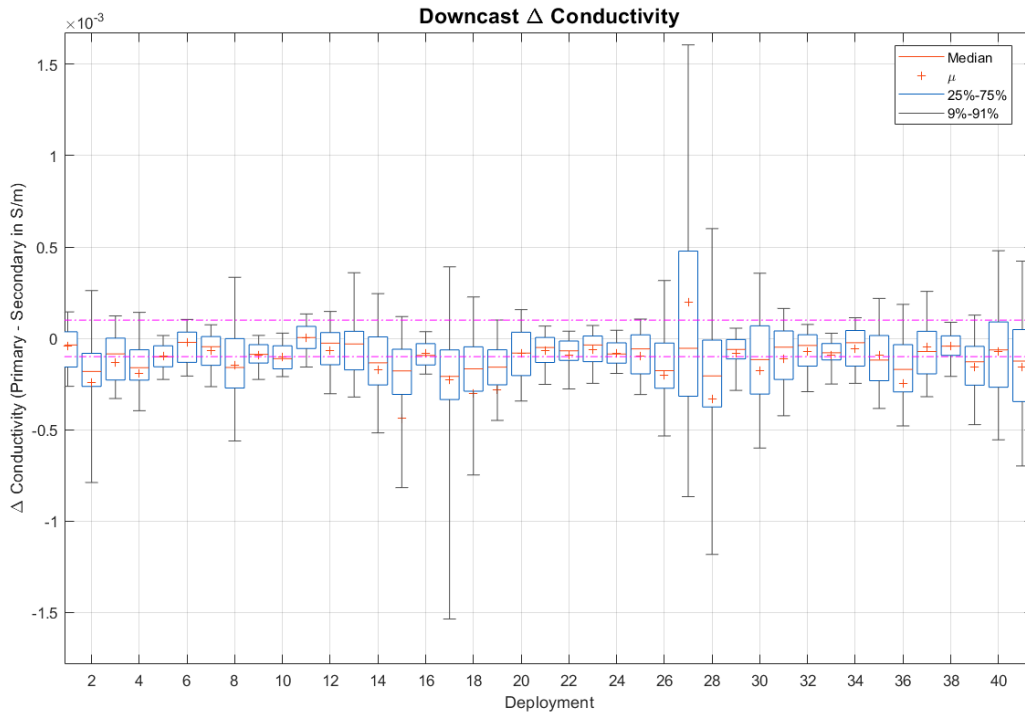


Figure 6: Difference (primary - secondary) between conductivity sensor values on downcast

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

Sensor Group	Deployments	Scale Factor		Offset		Salinity (PSU)	
		a1	±	a0	±	Residual SD	M.A.D.
Primary	1-41	0.99959	0.00060479	0.0012616	0.0030354	0.0025203	0.0016062
Secondary	1-41	0.99951	0.00065804	0.0016225	0.0033107	0.0026337	0.002064

Table 1: Conductivity calibration with respect to manufacturer’s calibration coefficients and post-calibration results

Conductivity Sensor	Deployments	CPcor	±
Primary	1-41	-1.0024e-07	2.4371e-07
Secondary	1-41	-1.0859e-07	2.6698e-07

Table 2: Calculated CPcor (the correction for pressure effects on the conductivity cell) for primary and secondary conductivity units compared to the manufacturer’s nominal value of -9.5700e-08 (for pressure in decibars) (Sea-Bird, 2017)

This is a marginal calibration. We normally aim for a SD of 0.002 PSU for ‘typical’ oceanographic voyages. The above calibration factors were applied to the indicated deployments. Full plots of residuals before and after calibration are available in A.1.

Data from the primary conductivity and temperature sensors were used to produce the averaged salinities (these data variables have no suffix) with secondary sensors included with a suffix ‘\_2’.

## 2.4 Dissolved Oxygen Sensor Calibration

### 2.4.1 SBE Calibration Procedure

(Sea-Bird, 2013) describes the SBE43 dissolved oxygen sensor 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 (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.

### 2.4.2 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 (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 upcast data to compute the new  $Soc$  and  $Voffset$  coefficients. Figure 7 plots CTD SBE43 - bottle oxygen differences for both upcast (Hydro bottle) and downcast (CTD SBE43) data. The ‘bad’ outliers (magenta dots, red dots and red + markers) are excluded from the calibration, the ‘suspect’ outliers (blue dots) are used in the calibration but are weighted based on their distance from the mean. All green dots are considered ‘good’ data points and are not weighted based on distance from the mean.

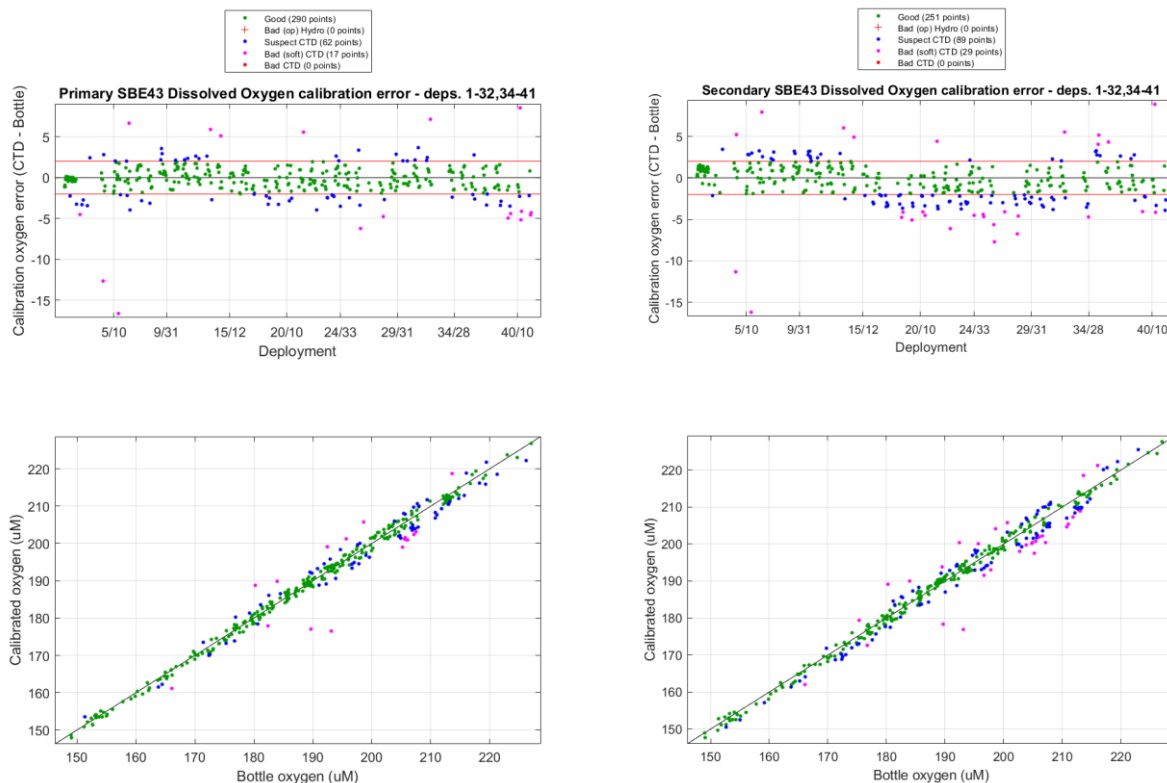


Figure 7: CTD SBE43 - bottle dissolved oxygen difference and calibration error (left: primary, right: secondary)

The box plot (Figure 8) of calibrated downcast dissolved oxygen readings (primary - secondary) at the bottle sampling depths for all deployments shows that the calibrated primary and secondary dissolved oxygen sensor responses corresponded reasonably well to each other.

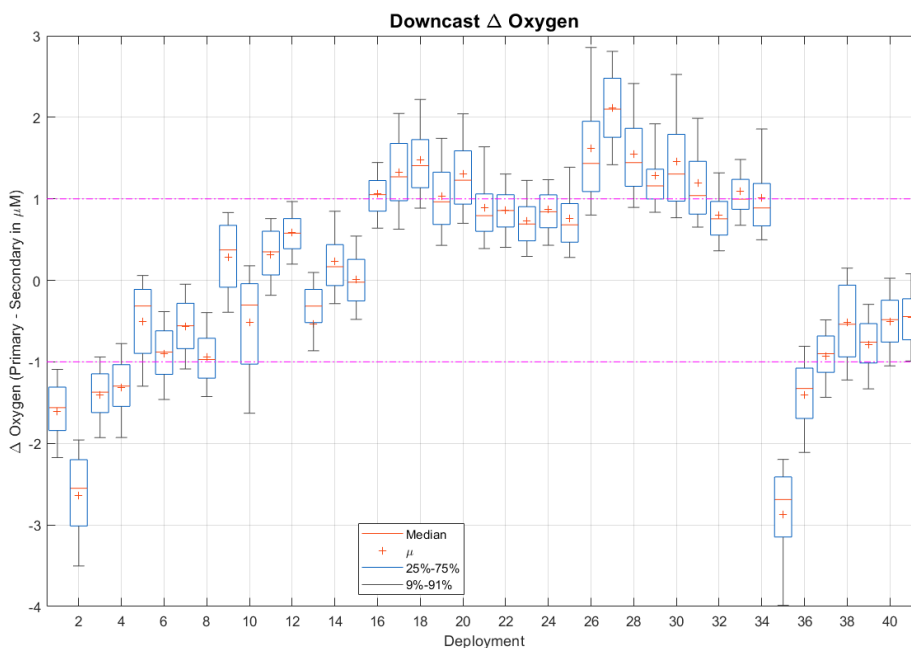


Figure 8: Difference (primary - secondary) between dissolved oxygen sensor values on downcast

The old and new  $Soc$  and  $Voffset$  values for DO sensors are listed in Table 4. 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 A.2.

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

Sensor	Calibration Source	Deployments	Calibration Coefficients				Dissolved Oxygen ( $\mu\text{M}$ )	
			$Voffset$	$\pm$	$Soc$	$\pm$	Residual SD	M.A.D.
Primary DO	CapPro	1-41	-0.50881	0.0023139	0.56913	0.0011759	0.88132	0.99269
	Sea-Bird	1-41	-0.5192		0.54310			
Secondary DO	CapPro	1-41	-0.50022	0.0028253	0.59864	0.001603	0.9472	1.3248
	Sea-Bird	1-41	-0.5014		0.56330			

Table 3: Dissolved oxygen calibrations

## 2.5 Other Sensors

### 2.5.1 C-Star Transmissometer

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.

This sensor worked as expected during this voyage.

### 2.5.2 WET Labs ECO CDOM Sensor

The WET Labs ECO CDOM (coloured dissolved organic matter) sensor was used for all deployments. The CDOM has been calibrated with manufacturer supplied coefficients.

This sensor worked as expected during this voyage. WET Labs ECO Fluorometer-Scattering Sensor

### 2.5.3 WET Labs ECO Fluorometer-Scattering

The WET Labs ECO Fluorometer-Scattering sensor was used for all deployments. The fluorometer (Chlorophyll- $a$ ) has been calibrated with manufacturer supplied coefficients to give outputs in  $\text{mg}/\text{m}^3$  (=  $\mu\text{g}/\text{L}$ ). The scattering (optical backscatter, OBS) has been calibrated with manufacturer supplied coefficients to give volume scattering outputs in  $\text{m}^{-1}\text{sr}^{-1}$ .

This sensor worked as expected during this voyage.

#### 2.5.4 Biospherical PAR Sensor

The Biospherical PAR (photosynthetically active radiation) sensor was used for all deployments. The output is a nominal 0 - 5 volts which is converted to the unit  $\mu\text{Einstein}/\text{m}^2/\text{second}$  using a 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. Time of day and environmental factors such as sea state and cloud cover impact 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.

This sensor worked as expected during this voyage.

## 2.6 Bad-Data Detection

The value 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 5. 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	-10	40	0.05
Conductivity	-0.01	7	0.01
Dissolved Oxygen	-0.1	500	0.5
Fluorometer	0	30	0.5
PAR	-5	5000	0.5
Transmissometer	0	100	0.5
CDOM	-5	515	0.5
Turbidity	0	0.008	0.5

Table 4: Sensor limits for bad-data detection

## 2.7 Heave Filtering

Sensor data impacted by ship heave impeding the CTD deployment is filtered out in three stages and applied during data binning. The first stage detects negative acceleration of the CTD which can cause trailing mixed water to be pumped through the sensors. The second stage looks at all negative density gradients and flags readings which are above 10 times the standard deviation of all negative gradients, for 2 seconds. The third stage flags any pressure reversals which are greater than the height of the CTD sensor pump inlet above the frame.

## 2.8 Temperature-Conductivity Lag

To precisely align the temperature and conductivity measurements for a sample of water a temporal offset can be applied. A manufacturer-recommended nominal offset ( $\Delta t_{c\_SBE9+}$ ) of -0.073 seconds is initially applied at time of acquisition by the SBE9+ deck unit on both primary and secondary conductivity channels. This offset advances the conductivity sensor readings in time to compensate for the amount of time it takes for the measured water sample to move from the temperature sensor through into the conductivity sensor cell.

Post-voyage inspection of the temperature and conductivity data in CapPro can determine fine-tuning adjustments to the conductivity sample time (seconds) offset ( $\Delta t_{c\_CP}$ ) that will optimally align the data. The final adjustments applied to the conductivity sample time can be found in Table 6 and Table 7. Note that although CapPro can set an offset ('lag', in number of scans, with a scan frequency of 24 Hz) for both temperature and conductivity samples, DAP only sets a lag for the conductivity sample to maintain consistency with the nominal offset applied by the SBE9+ to the conductivity data. The equation governing this conductivity sample time adjustment is given below, where  $t_{c\_aligned}$  is the best-estimate of the conductivity measurement time (seconds) to align it with the temperature measurement from the same sample of water on the downcast, and  $t_{c\_meas}$  is the original, uncorrected conductivity measurement time (seconds).

$$t_{c\_aligned} = t_{c\_meas} + \Delta t_{c\_SBE9+} + \Delta t_{c\_CP}$$

Cast #	Nominal Offset Time Applied by SBE9+, $\Delta t_{c\_SBE9+}$ (sec)	Offset ('Cond lag') Set in CapPro (scans)	Calculated Offset Time from CapPro 'Cond lag', $\Delta t_{c\_CP}$ (sec = scans/24 Hz)
01-41	-0.073	1	0.04167

Table 5: Primary conductivity sensor offset adjustments

Cast #	Nominal Offset Time Applied by SBE9+, $\Delta t_{c\_SBE9+}$ (sec)	Offset ('Cond lag') Set in CapPro (scans)	Calculated Offset Time from CapPro 'Cond lag', $\Delta t_{c\_CP}$ (sec = scans/24 Hz)
01-41	-0.073	0.09	0.00375

Table 6: Secondary conductivity sensor offset adjustments

## 2.9 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 quality control (QC) flag (also in the NetCDF files). Our QC flagging scheme is described in (Pender & NCM Information & Data Centre, 2022).

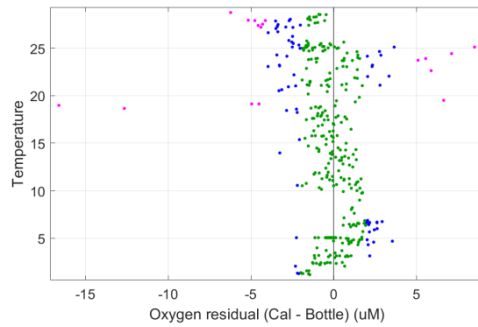
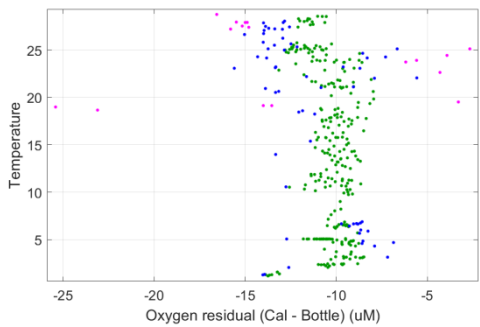
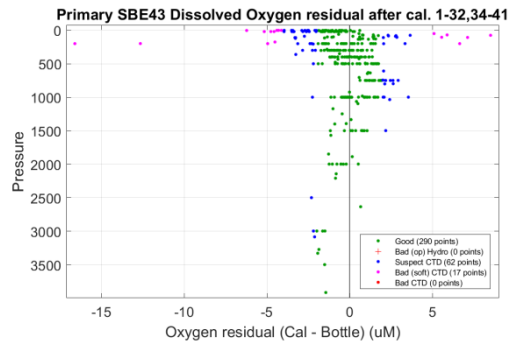
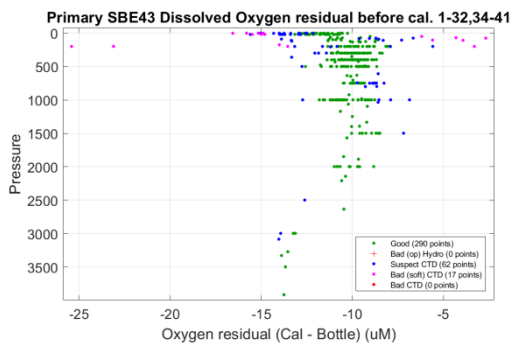
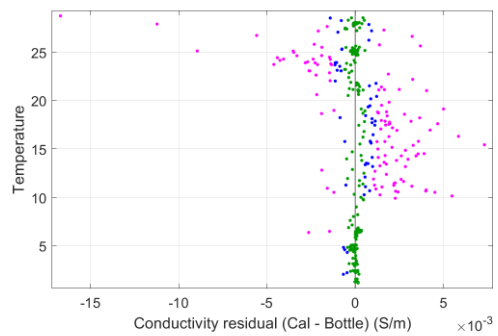
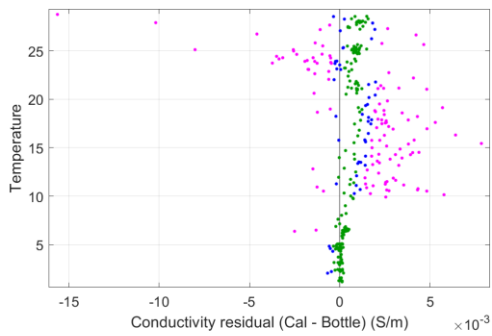
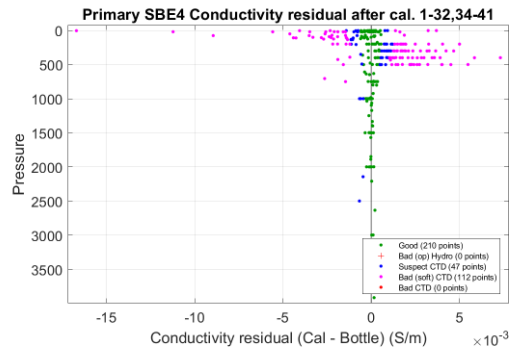
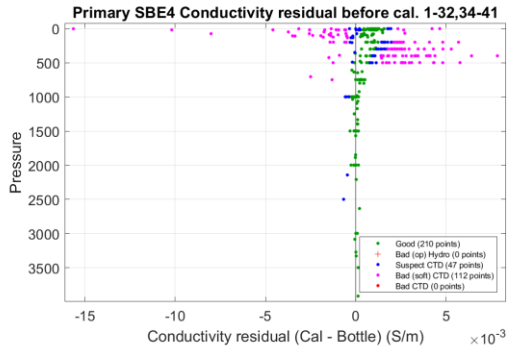
The QC Flag for each bin is estimated from the values for the bin components. The QC Flag for derived quantities, such as salinity and dissolved oxygen, is taken to be the worst of the estimates for the parameters from which they are derived.

### 3 References

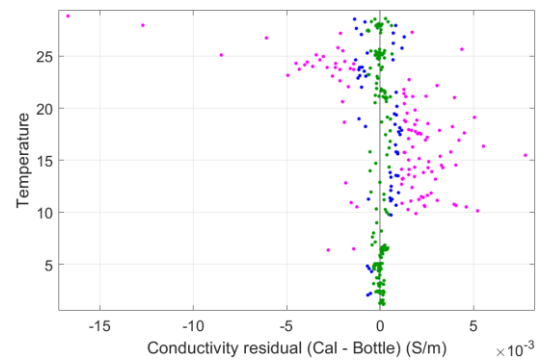
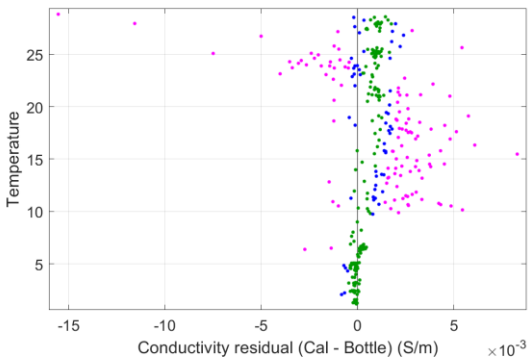
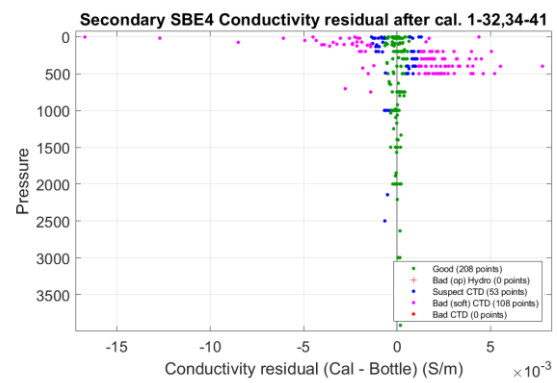
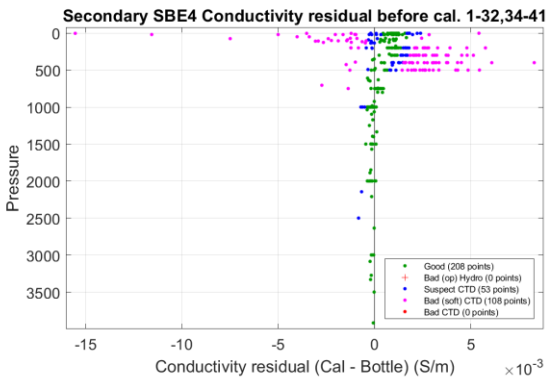
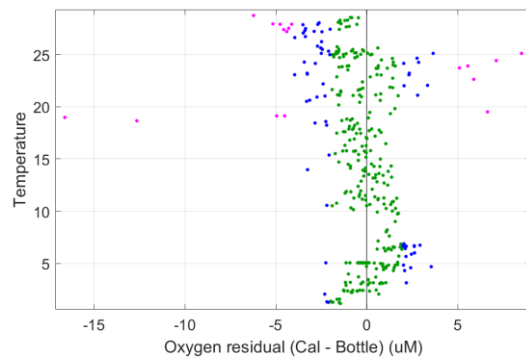
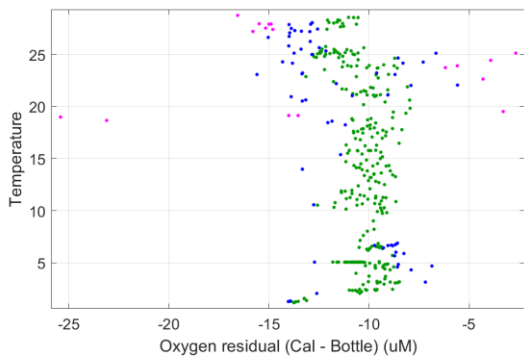
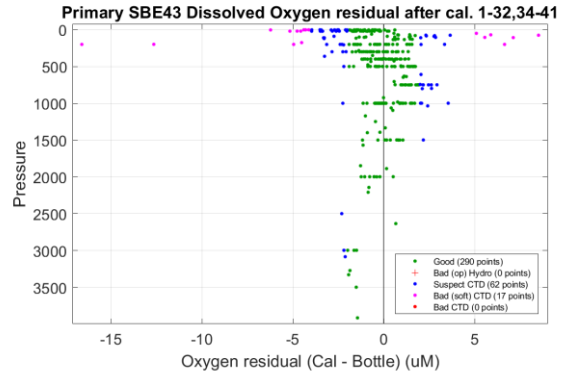
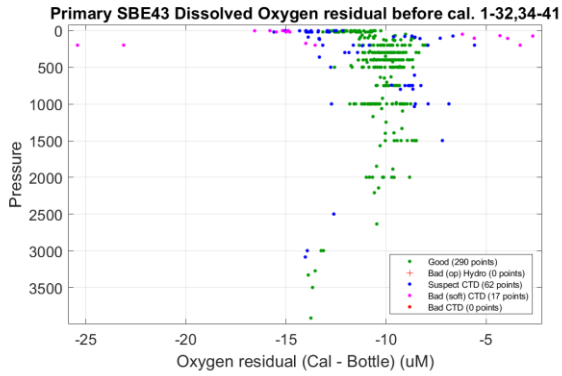
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# 4 Appendices

## A.1 Conductivity Calibration Residual Plots



## A.2 Dissolved Oxygen Calibration Residual Plots



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