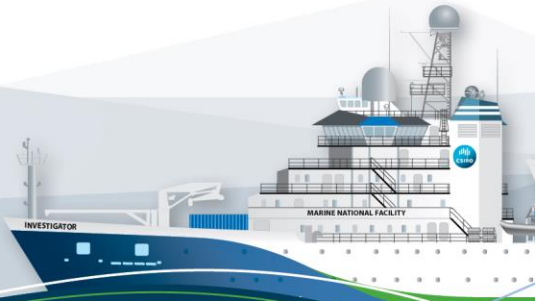
Marine National Facility

RV *Investigator*

CTD Processing Report

Voyage ID:	IN2018_T01
Voyage title:	Physical and biogeochemical gradients in the East Australian Current
Depart:	Hobart, 1700 Thursday, 5 April 2018
Return:	Brisbane, 0800 Saturday, 14 April 2018
Report compiled by:	Francis Chui



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1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage IN2018_T01, from 05 Apr 2018 – 14 Apr 2018.

Data for 21 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.

The Salinometer was found to have been malfunctioning and not reliably reporting results on IN2018_T01. The final conductivity calibration was based on calibrations derived on the subsequent voyage: IN2018_V03. The final calibration from the primary sensor had a standard deviation (SD) of 0.0013986 PSU for the primary and 0.0014150 PSU for the secondary, 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 with secondary sensors included with the suffix '_2'.

The dissolved oxygen data calibration fit had a SD of 0. 79925 uM for the primary and 0.77577 uM for the secondary. The agreement between the CTD and bottle data was good.

Fluorometer, Altimeter, Transmissometer and PAR sensors were also installed on the auxiliary A/D channels of the CTD.

2 Voyage Details

2.1 Title

Physical and biogeochemical gradients in the East Australian Current

2.2 Principal Investigators

Assoc. Prof. Zanna Chase, IMAS., Dr Helen Philips, IMAS., Assoc.Prof. Patti Virtue, IMAS. & Dr Christina Schallenberg, IMAS.

2.3 Voyage Objectives

The scientific objectives for IN2018_T01 were outlined in the Voyage Plan.

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

2.4 Area of operation

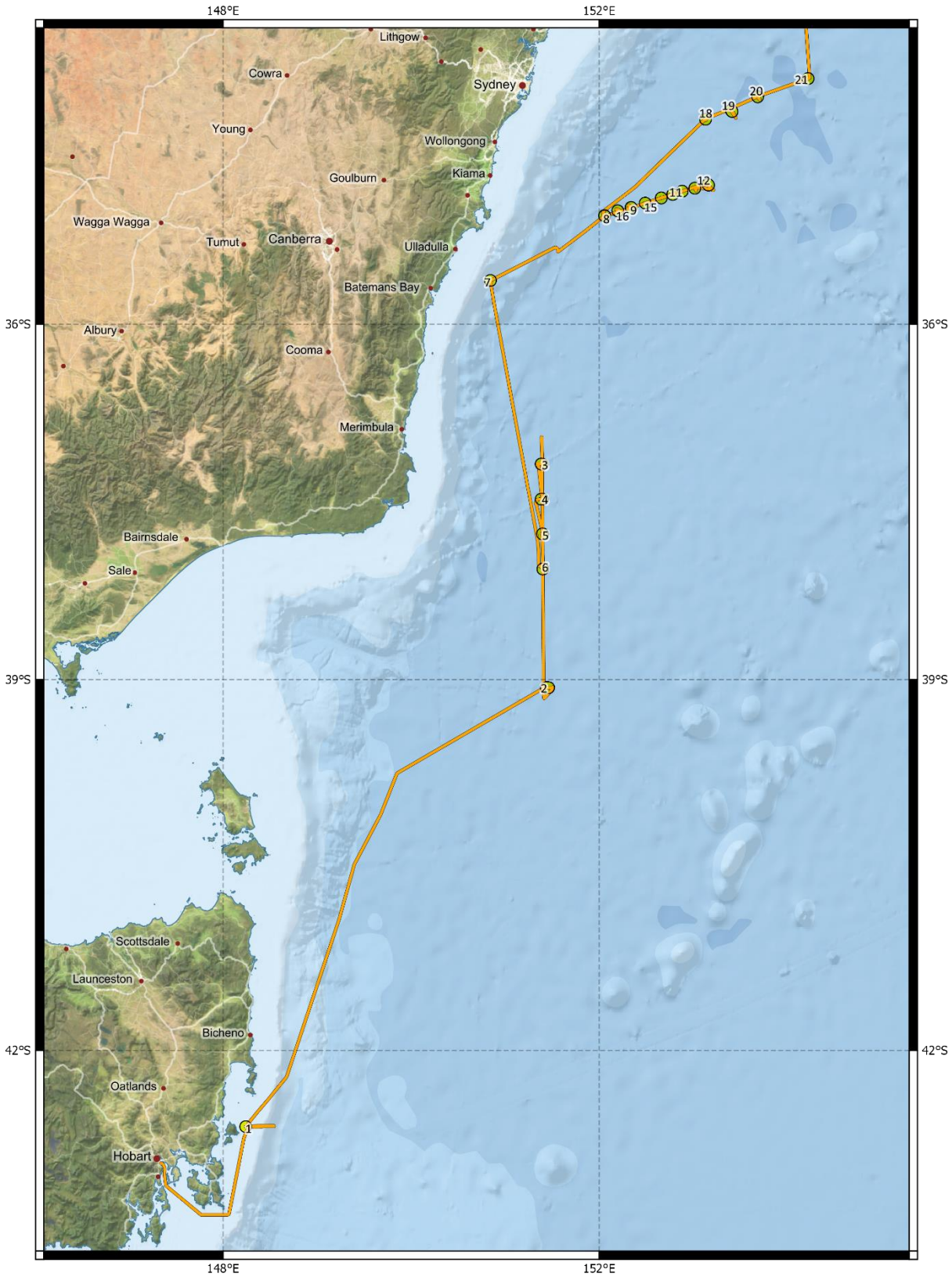

Figure 1 Area of operation for IN2018_T01

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, altimeter, transmissometer, PAR and fluorometer. These sensors are described in Table 1.

Description	Sensor	Serial No.	A/D	Calibration Date	Calibration Source
Pressure	Digiquartz SBE9+ V2	1332	P	21-Aug-2017	Sea-Bird
Primary Temperature	Sea-Bird SBE3T	4522	T0	15-Dec-2017	CSIRO Cal. Lab.
Secondary Temperature	Sea-Bird SBE3T	4722	T1	15-Dec-2017	CSIRO Cal. Lab.
Primary Conductivity	Sea-Bird SBE4C	2312	C0	11-Jul-2017	CSIRO Cal. Lab.
Secondary Conductivity	Sea-Bird SBE4C	3168	C1	11-Jul-2017	CSIRO Cal. Lab.
Primary Dissolved Oxygen	Sea-Bird SBE43	3534	A0	26-Feb-2018	CSIRO Cal. Lab.
Secondary Dissolved Oxygen	Sea-Bird SBE43	3155	A1	29-Nov-2017	CSIRO Cal. Lab.
Fluorometer	Chelsea AquaTracker MKIII	11-8206-001	A2	21-Nov-2016	Chelsea Tech.
Altimeter	Tritech PA 500	05301.228403	A3	02-Sep-2016	Tritech
Transmissometer	Wetlabs CSTAR 25cm	CST-1421DR	A4	7-Aug-2017	WET Labs
PAR	Biospherical QCP2300 – HP	70111	A5	26-Jun-2017	Biospherical

Table 1 CTD Sensor configuration on IN2018_T01

Water samples were collected using a Sea-Bird SBE32, 36-bottle rosette sampler. Sampling was from 36 twelve litre bottles which were fitted to the frame. There were 21 deployments.

The raw CTD data were collected in SeaSave version 7.26, converted to scientific units using SBE Data Processing version 7.26 and written to netCDF format files with CNV_to_Scan for processing using the Matlab-based, CapPro package.

The CapPro 2.9 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.

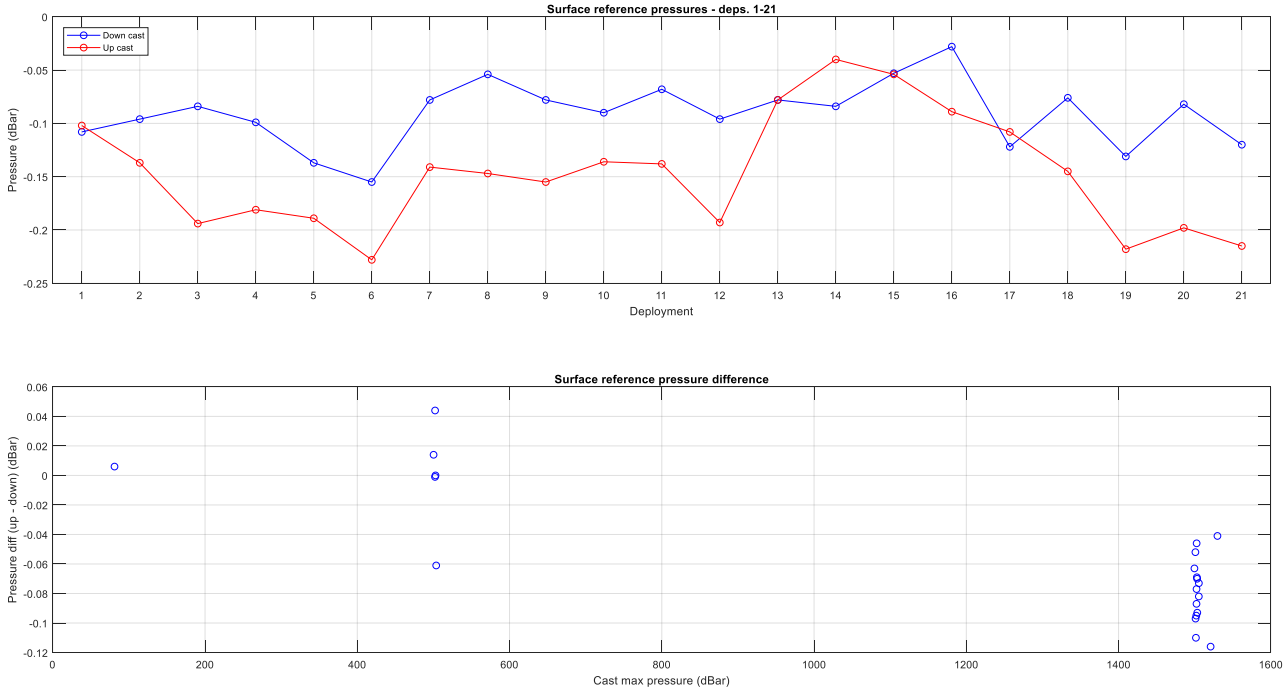

Figure 2 CTD pressure offsets

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 sensor has drifted significantly from its calibration.

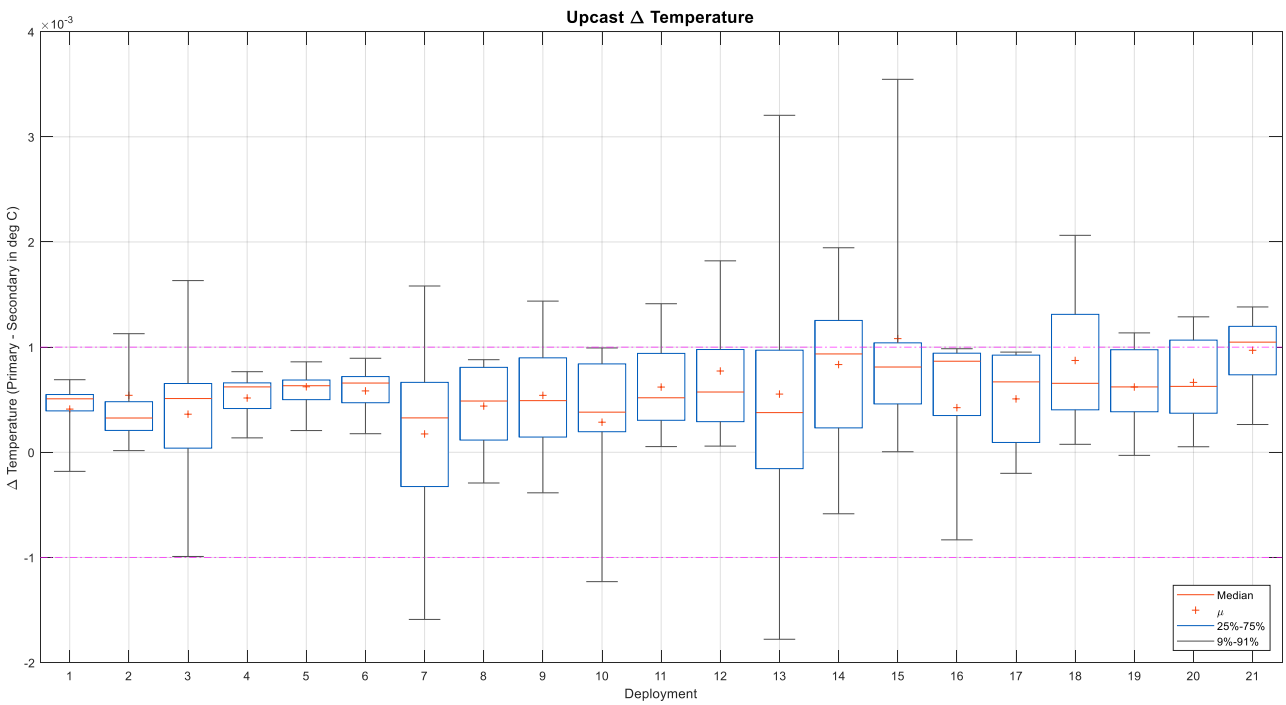

Figure 3 Difference between primary and secondary temperature sensors

3.3 Conductivity Calibration

On a subsequent voyage, it was found that the Salinometers used on board during IN2018_T01 were malfunctioning and not producing reliable measurements; meaning the samples taken during the transit could not be used to calibrate the sensors. This issue was identified at the beginning of the following voyage, IN2018_V03, and the CTD water samples were bottled and processed on shore to calibrate the conductivity sensor.

Calibrations derived from IN2018_V03 samples analysed on shore were then subsequently applied to CTD conductivity sensor data for IN2018_T01. The primary conductivity calibration from IN2018_V03 was based upon the sample data for 181 of the total of 250 samples, which is slightly less than our target of 75%. The secondary conductivity calibration was based upon sample data for 181 of the 250 samples also slightly less than our target of 75%.

The box plot of calibrated downcast conductivities (primary - secondary) for all deployments in shows that the calibrated conductivity cell responses corresponded well.

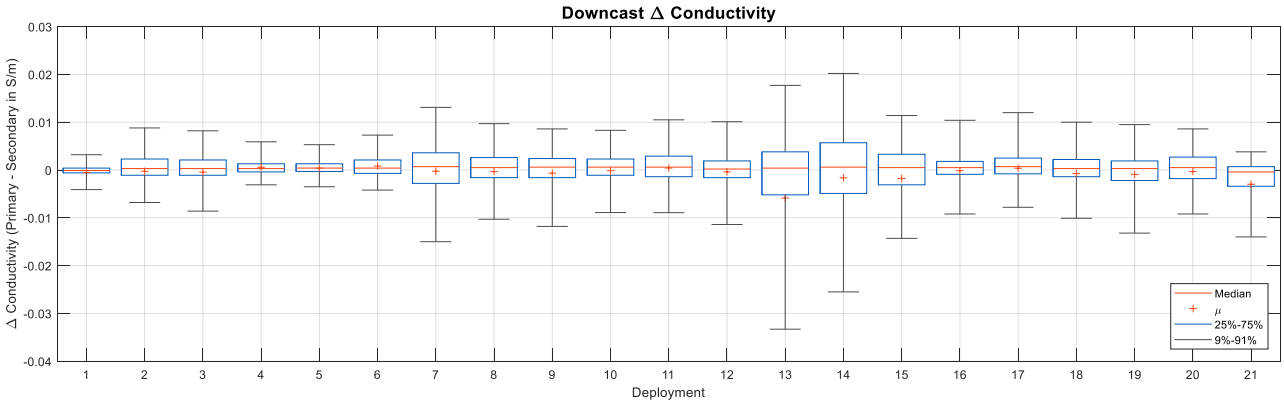

Figure 4 Difference between primary and secondary conductivity sensors

The calibration results from IN2018_V03 for the primary and secondary conductivity sensors with respect to their original calibrations are shown in Table 2 and Table 3.

Sensor Group	Scale Factor		Offset		Salinity (PSU)	
	a1	±	a0	±	Residual SD	M.A.D.
Primary	0.99928	0.00042329	0.00081757	0.0018567	0.0013986	0.0010376
Secondary	0.99970	0.00041053	0.00019174	0.0018054	0.0014150	0.0010168

Table 2 Conductivity calibration from with respect to manufacturers' calibration coefficients and post-calibration results from IN2018_V03

Sensors	CPcor	±
Primary Conductivity	-8.5801e-08	7.5213e-08
Secondary Conductivity	-8.9611e-08	7.3484e-08

Table 3 Calculated CPcor for primary and secondary compared to the manufacturer nominal value of -9.5700e-08 from IN2018_V03

This is a good calibration. We normally aim for a SD of 0.002 psu for 'typical' oceanographic voyages. The above calibration factors were applied to all deployments.

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

Sea-Bird (2013a) 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 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 by Sea-Bird (2013b).

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 are of CTD - bottle oxygen differences for both upcast and downcast data (red indicates 'bad' data).

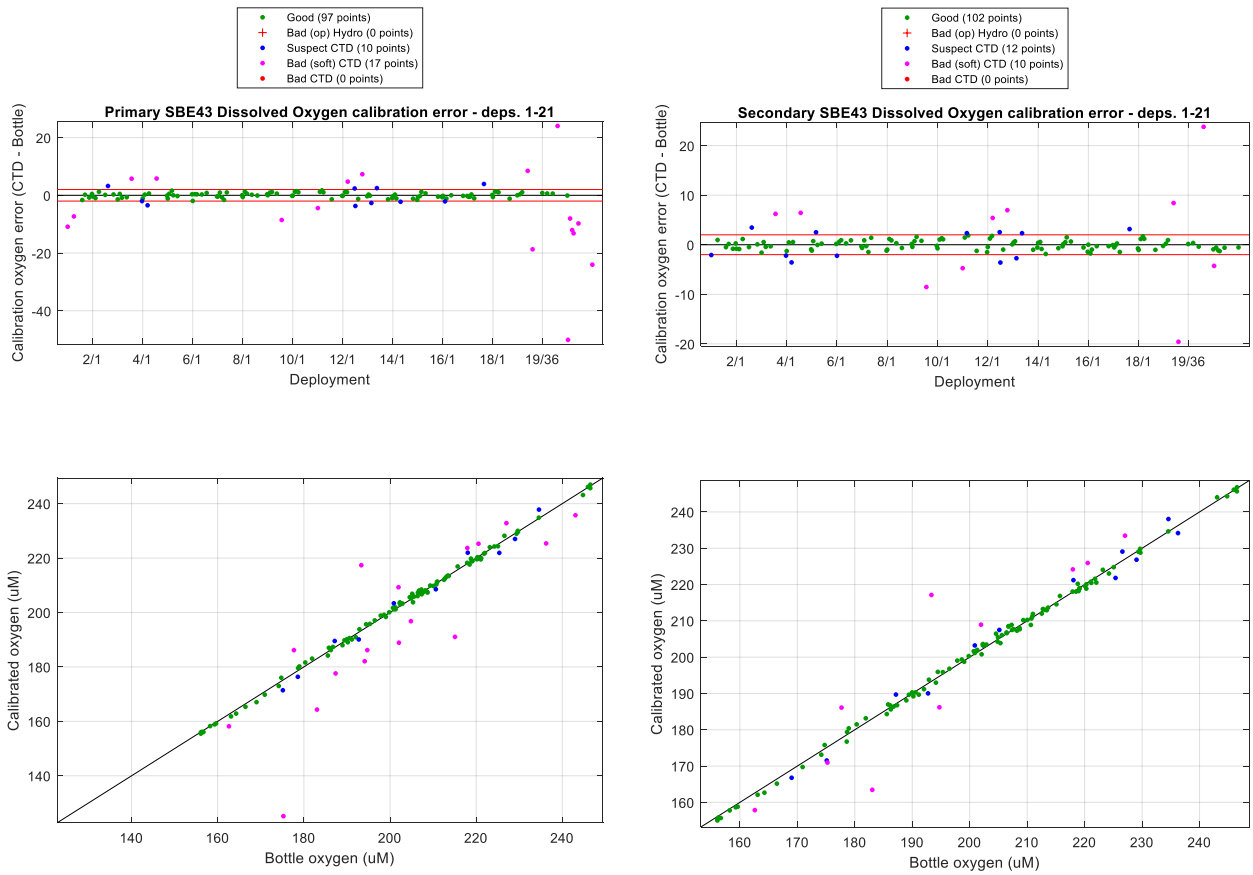

Figure 5 (SBE43 - Bottle) Oxygen Difference with upcast CTD data

The old and new *Soc* and *Voffset* values for DO sensors are listed in Table 4 Dissolved oxygen calibrations 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 I: Dissolved Oxygen Calibration Residual Plots.

The calibrations were applied for each sensor and the averaged files were created using the result from the primary sensor with the secondary DO sensor data appended with the suffix '_2'.

Sensor	Calibration Source	Calibration Coefficients				Dissolved Oxygen (µM)	
		Voffset	±	*Soc*	±	Residual SD	M.A.D.
Primary DO	Hydrochemistry	-0.48636	0.0043830	0.49014	0.0014678	0.79925	0.66403
	Sea-Bird	-0.5308		0.53284			
Secondary DO	Hydrochemistry	-0.49726	0.0042235	0.53671	0.0016839	0.77577	0.81022
	Sea-Bird	-0.5134		0.53853			

Table 4 Dissolved oxygen calibrations

3.5 Other sensors

The Chelsea fluorometer was used for all deployments. The fluorometer has been calibrated to give a manufactuer calibrated value in µg/L.

The Biospherical PAR sensor was also used for all deployments. The output is a nominal 0-5 volts is converted to µEinsteins/m^2/second using manufacturer supplied calibrations. 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 5 below. The rejection rate is recorded in the CapPro processing log file. Note that ranges and maximum second difference for the PAR sensor were kept at a default of -5 to 5000 and 0.5 respectively.

Sensor	Range min	Range max	Max Second Diff
Pressure	-7	6500	0.5
Temperature	-10	40	0.05
Conductivity	-0.01	7	0.01
Oxygen	-0.1	500	0.5
Fluorometer	-5	100	0.5
Altimeter	0	50	0.5
Transmissometer	0	100	0.5
PAR	-5	5000	0.5

Table 5 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 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

Chase, Z., 2018: The RV Investigator. Voyage Plan IN2018_V01 - http://mnf.csiro.au/~/media/Files/Voyage-plans-and-summaries/Investigator/Voyage%20Plans%20summaries/2018/IN2018_T01%20Voyage%20Plan%20201803 15-web.ashx

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Sea-Bird Electronics Inc., 2013b: Application Note No 64-3: SBE 43 Dissolved Oxygen (DO) Sensor - Hysteresis Corrections. http://www.seabird.com/document/an64-sbe-43-dissolved-oxygen-sensor-background-information-deployment-recommendations

5 Appendix I: Dissolved Oxygen Calibration Residual Plots