RV *Investigator*

CTD Processing Report

Voyage #:	IN2018_V03
Voyage title:	Integrated Marine Observing System: monitoring of East Australian Current property transports at 27°S
Depart:	Brisbane, 0800 Thursday 19 April, 2018
Return:	Brisbane, 1200 Thursday, 10 May 2018
Report compiled by:	Karl Malakoff

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1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2018_v03, from 19 Apr 2018 – 10 May 2019.

Data for 14 deployments were acquired using the Seabird SBE911 CTD unit 24 fitted with 24 twelve litre bottles on the 32 bottle rosette sampler. Samples were collected on all casts. Sea-Bird-supplied and CSIRO calibration factors were used to compute the pressures, preliminary conductivity oxygen and temperature data. The data were subjected to automated QC to remove spikes and out-of-range values.

The final conductivity calibration for each deployment was calculated using the sensors with the lowest residuals when compared with the values measured by the hydrochemistry team. The final calibration from chosen sensors all had a standard deviation (SD) less than our target of 'better than 0.002 PSU'.

The dissolved oxygen data calibration generally showed a good agreement between the CTD and bottle data.

Biospherical photosynthetically active radiation (PAR), Wetlabs transmissometer and Chelsea fluorometer sensors were also installed on the auxiliary A/D channels of the CTD.

2 Voyage Details

2.1 Voyage Title

Integrated Marine Observing System: monitoring of East Australian Current property transports at 27^{o}S.

2.2 Principal Investigators

The Chief Scientist on board was Bernadette Sloyan from the CSIRO.

2.3 Voyage Objectives

For details on the objectives of the voyage, refer to the Voyage Plan and/or summary which can be viewed on the CSIRO MNF web site.

2.4 Area of operation

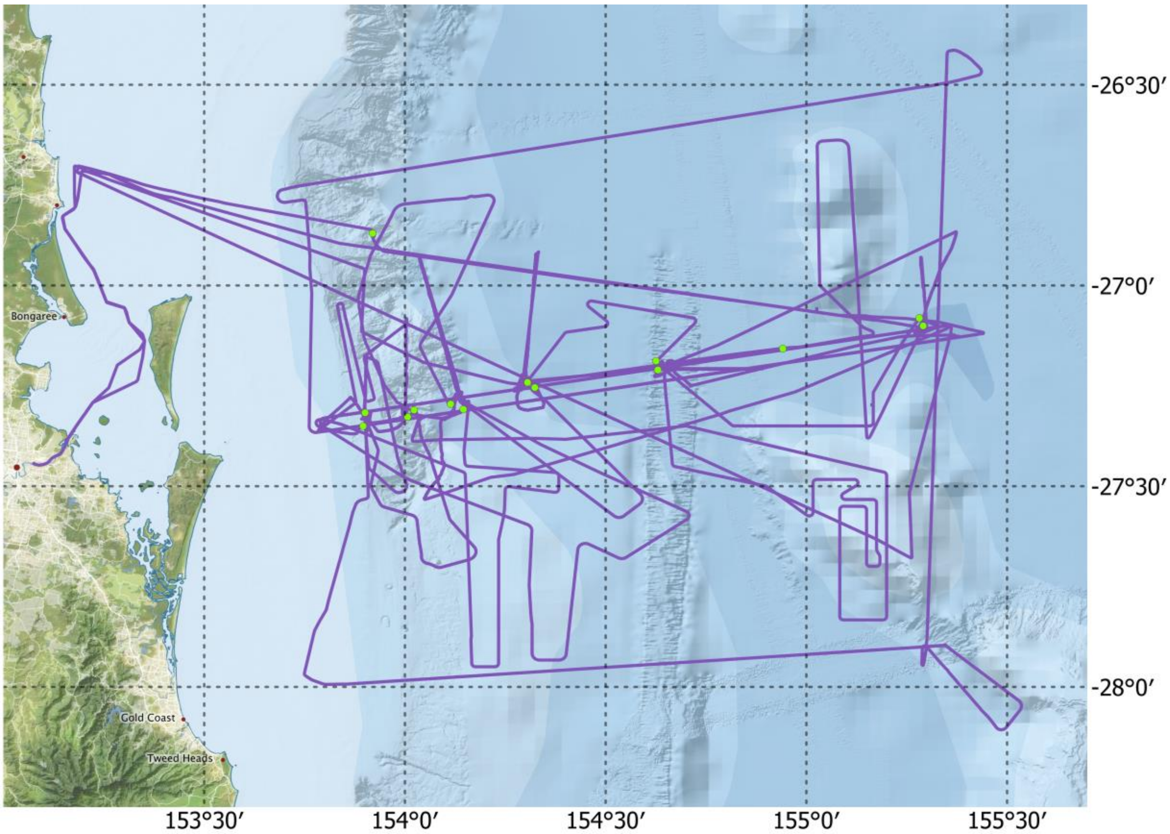


Figure 1. Area of Operation for in2018_v03 CTDs

3 Processing Notes

3.1 Background Information

The data for this voyage were acquired with CTD SBE9+ unit 24 with dual conductivity and temperature sensors.

There were 14 deployments for this voyage as shown on Figure 1. Green dots indicate a CTD cast.

Rapp Hydema heave compensation was used on the CTD winch for all casts.

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

Unit	Data Channel	SBE9 Connector	Model	Serial Number
CTD 24			SBE9+ V_2	13332
Deck Unit			SBE11 V_2	0513
Primary Temperature		JB1	SBE3T	4522

Primary Conductivity		JB2	SBE4C	2312
Secondary Temperature		JB4	SBE3T	4722
Secondary Conductivity		JB5	SBE4C	3168
Primary Pump		JB3	SBE5	8344
Secondary Pump		JB3	SBE5	8345
Primary Oxygen	A0	JT2	SBE43	3534
Secondary Oxygen	A1	JT2	SBE43	3155
Fluorometer Chelsea UV Aquatracker	A2	JT3	Chlorophyll –a Aquatracka III – 430/685nm	11-8206-001
Altimeter	A3	JT3	PA 500	05301.228403
Transmissometer	A4	JT5	Wetlabs CSTAR 25cm	1421DRT
PAR	A5	JT5	QCP-2300-HP	70111
Spare	A6	JT6		
Spare	A7	JT6		
MNF IMU	Serial	JT4	SITIMU007	#01

Table 1. CTD Sensor configuration for in2017_v04 CTDs

Water samples were collected using a Seabird SBE9+ 36-bottle rosette sampler with 24 twelve litre bottles fitted to the frame. Salinity samples for casts 1 and 7 were discarded due to issues with the Guildline Salinometers.

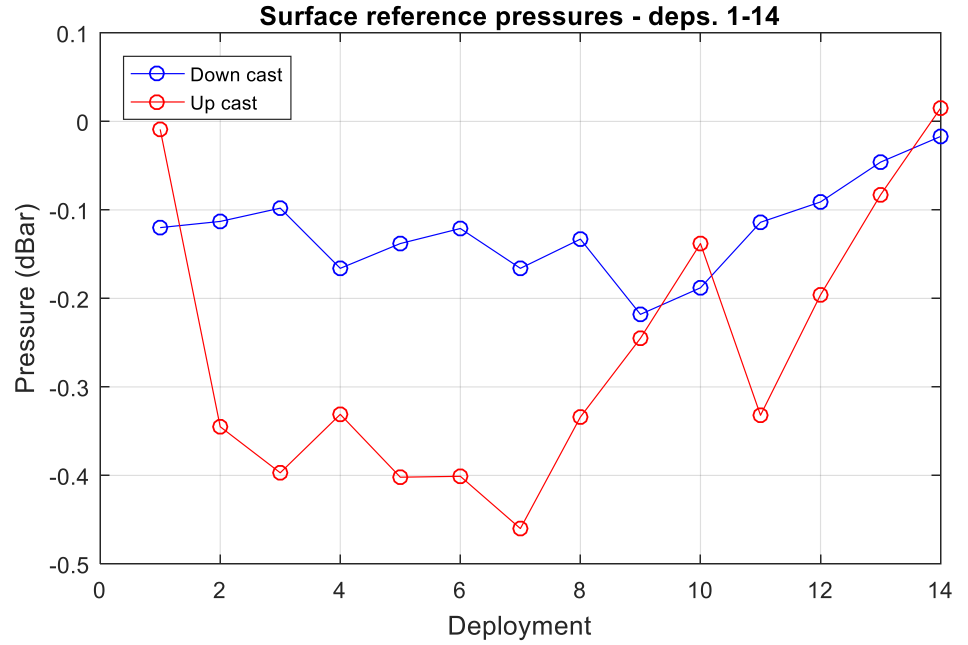
The raw CTD data was acquired using an SBE9/11+ and the SeaSave software. A conductivity advance of 0.073 seconds was applied in the deck box to both the primary and secondary conductivity. The SeaBird hex files were converted to scientific units using SeaSave data processing. NetCDF files were created from the resultant CNV files with cnv_to_scan, an in-house python script.

The netCDF files were processed using CapPro v2.9. 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 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 1decibar 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.



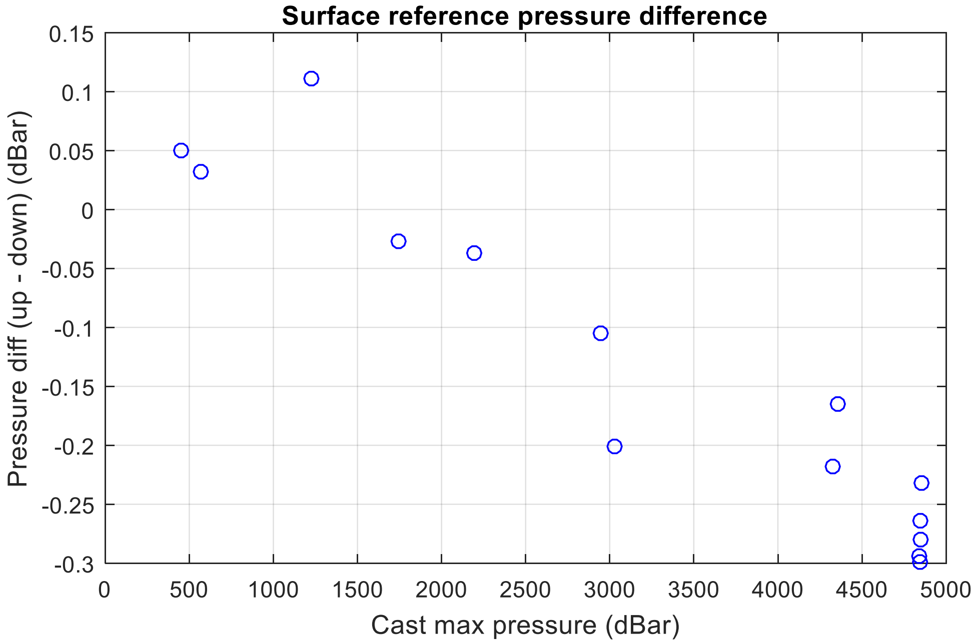


Figure 2. CTD pressure reference

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.

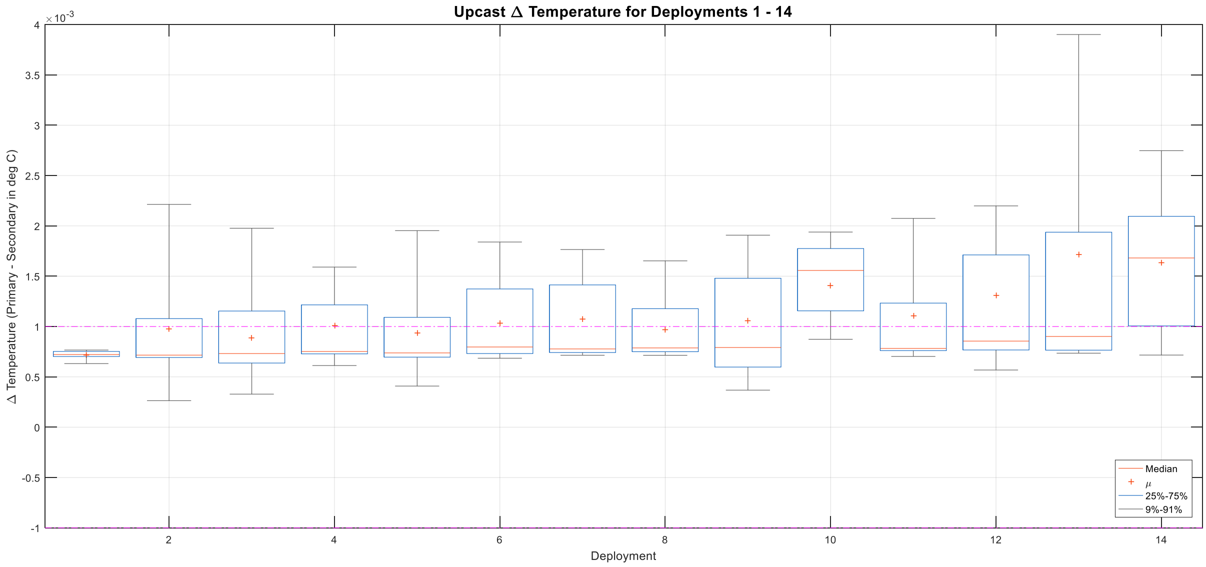
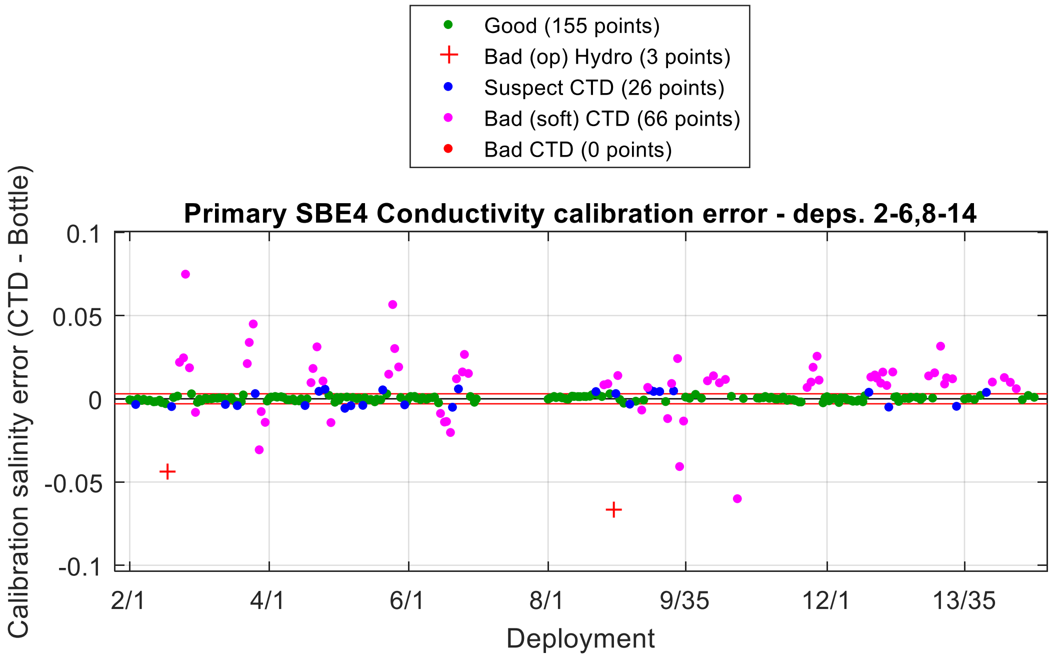


Figure 3. Temperature sensor difference

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 primary conductivity calibration 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 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.



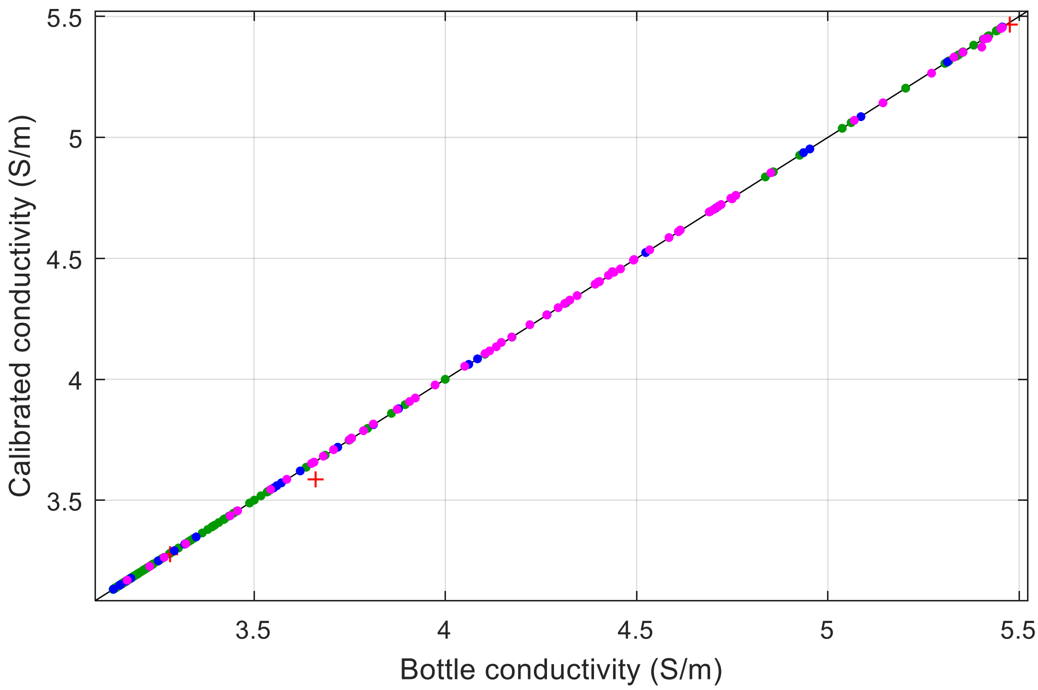
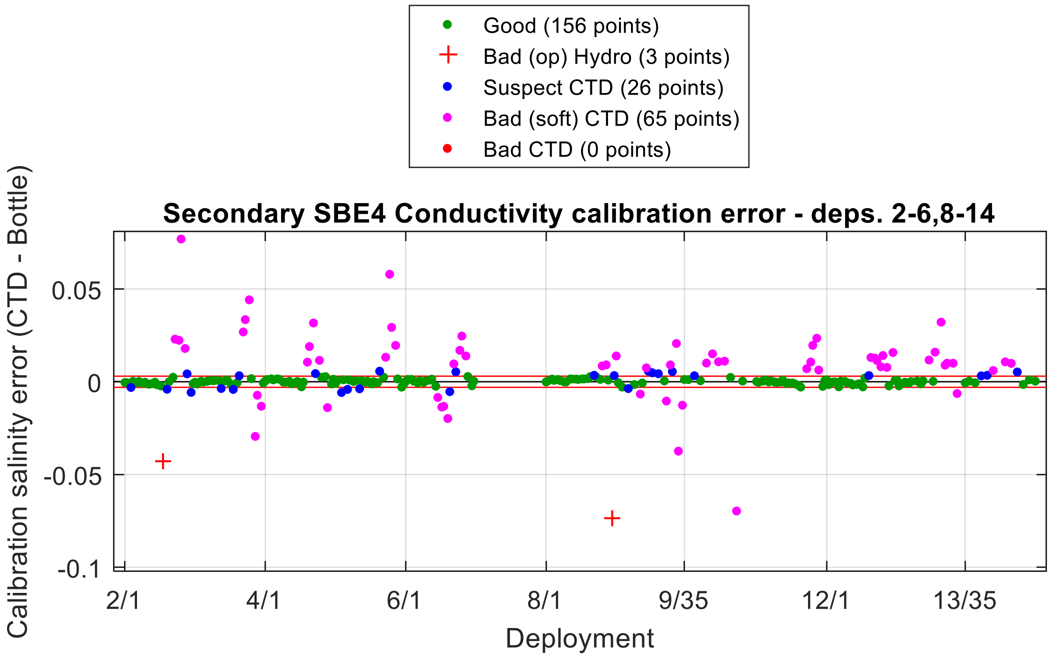


Figure 4. Primary conductivity calibrations



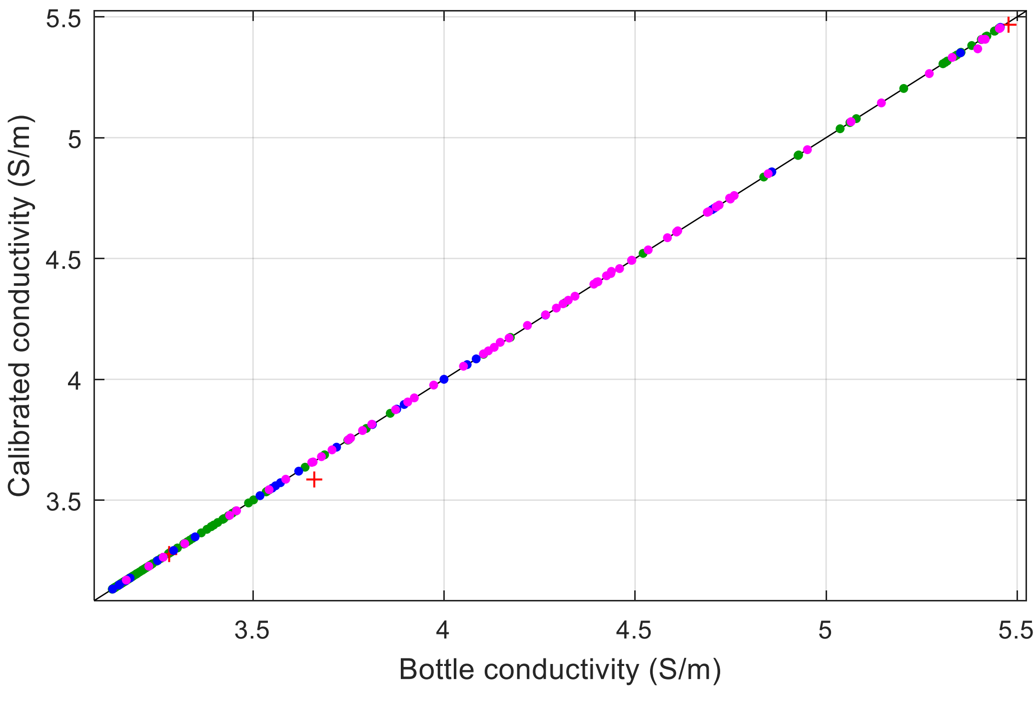


Figure 5. Secondary conductivity calibrations

The box plot of calibrated downcast conductivities (primary - secondary) for all deployments in figure 6 shows that the calibrated conductivity cell responses corresponded well.

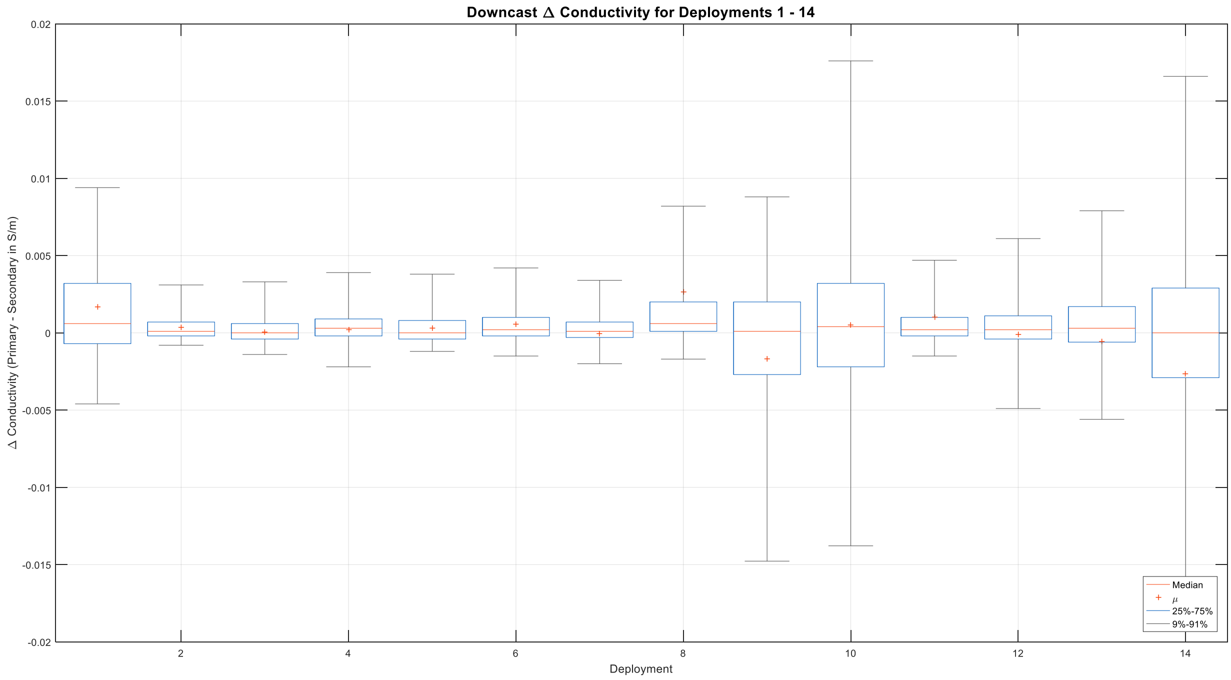


Figure 6 Difference betweem primary and seconday conductivity sensors

The final result for the primary conductivity sensor was –

Cutoff 0.003

Scale Factor (a1)	0.99928	wrt. Manufacturer's calibration
Offset (a0)	0.00081757	ditto
Calibration SD (Sal)	0.0013986 PSU	

The calibration using the secondary conductivity sensor was –

Scale Factor (a1)	0.9997	wrt. Manufacturer's calibration
Offset (a0)	0.00019174	ditto
Calibration SD (Sal)	0.001415	PSU

Calibration standard deviation is the standard deviation of the difference between the calibrated values and the bottle values. This calibration is within the range we normally aim for, an SD of 0.002 psu or lower for 'typical' oceanographic voyages. The above calibration factors were applied to deployments 1 to 14.

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

3.4 Dissolved Oxygen Sensor Calibration

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 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.

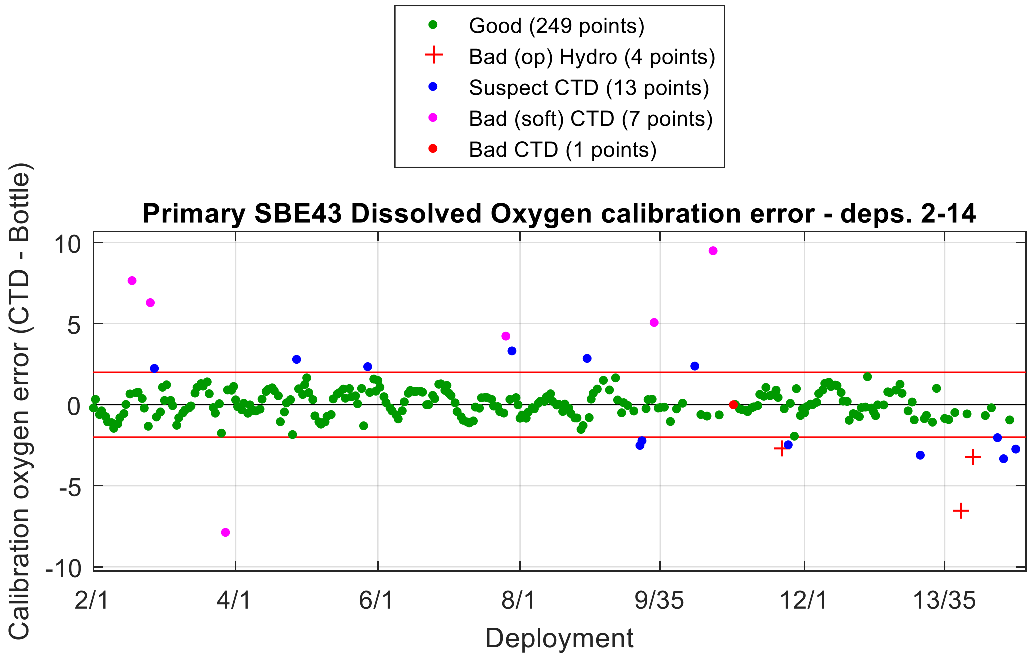
3.4.1 Results

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 (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.

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

A single calibration group for both the primary and secondary sensor was used with the associated SBE43 up-cast data to compute the new Soc and Voffset coefficients. This is shown in Figures 6 and 7.



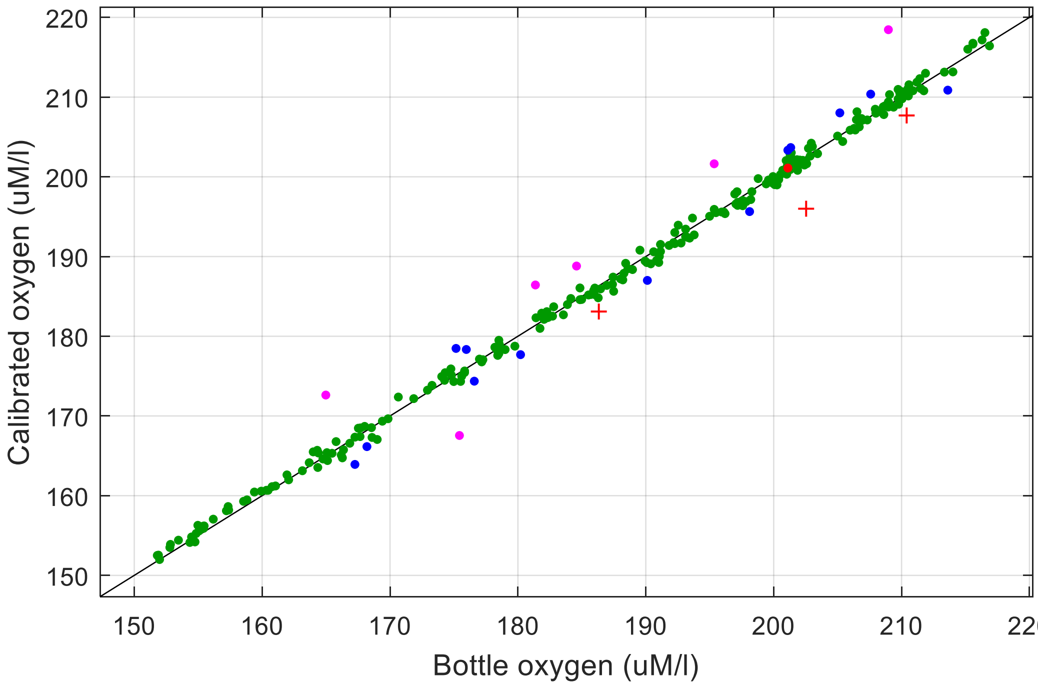


Figure 7. Dissolved Oxygen calibration, deployments 2-14 – primary sensor

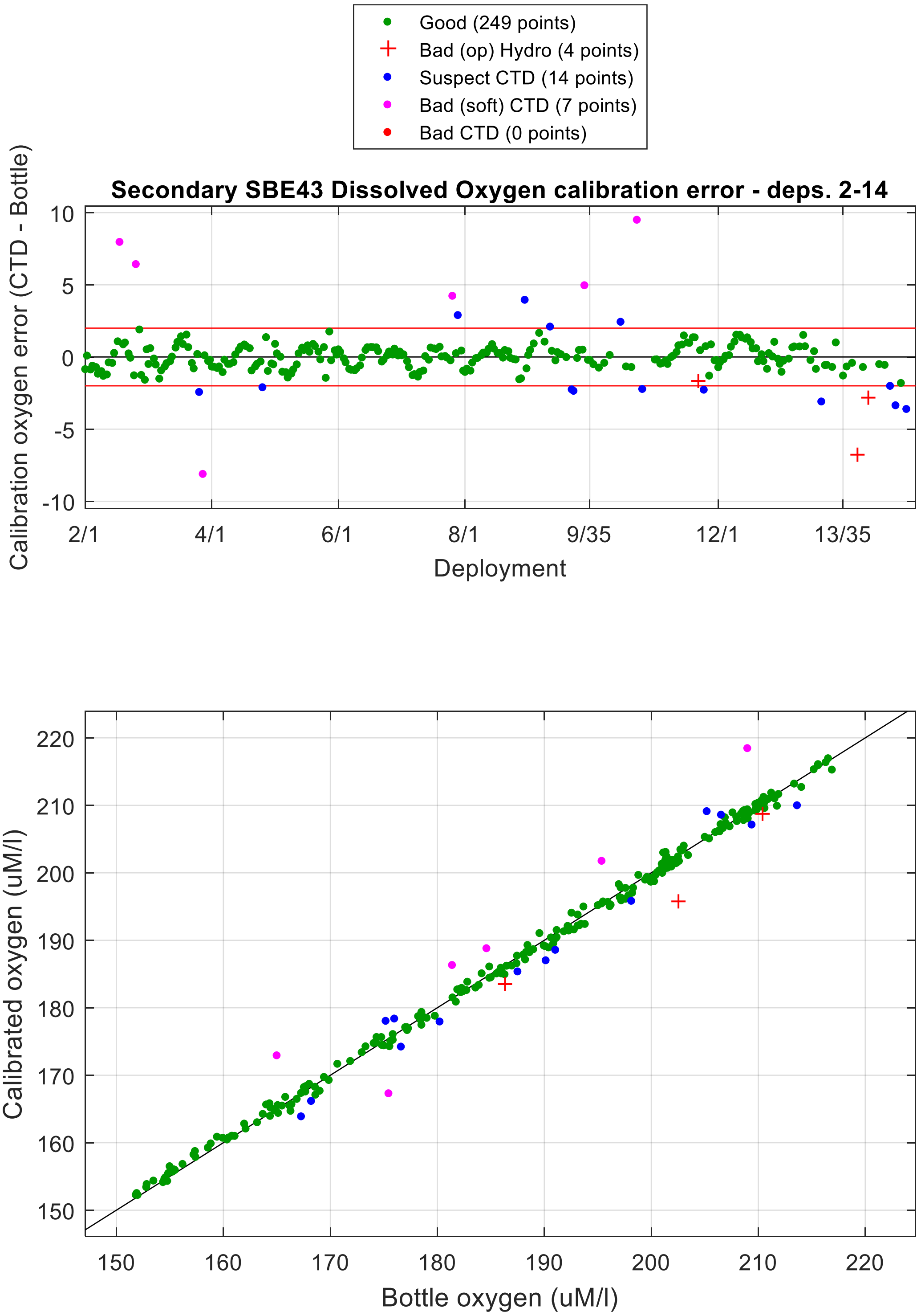


Figure 8. Dissolved Oxygen calibration, deployments 2-14 – secondary sensor

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. The calibration was applied for all deployments for the primary and secondary sensor.

Calibration	February 2018 CSIRO	primary sensor	November 2017 CSIRO	secondary
Voffset	-5.3082e-01	-4.7824e-01	-5.1339e-01	-4.8441e-01
Soc	5.3283e-01	4.8843-01	5.3853e-01	5.3127e-01
Fit SD (uM)		0.63959		0.64478

Table 2. Dissolved Oxygen calibration

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 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 Biospherical PAR sensor was also used for all deployments. The output is calibrated to give umol photons/m^2/sec. 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 the 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 3 below. The rejection rate is recorded in the CapPro processing log file.

SENSOR	RANGE MIN	RANGE MAX	MAX SECOND DIFF
PRESSURE	-7	6500	0.5
TEMPERATURE	-2	40	0.05
CONDUCTIVITY	-0.01	7	0.01
OXYGEN	-0.1	500	0.5
FLUOROMETER	0	100	0.5
TRANSMISSOMETER	0	100	0.5
PAR	-5	5000	0.5

Table 3. 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

Beattie, R.D., 2010: procCTD CTD Processing Procedures Manual. http://www.marine.csiro.au/~dpg/opsDocs/procCTD.pdf.

Sloane, B., 2018: The RV Investigator. Voyage Plan in2018_v03 - http://mnf.csiro.au/~/media/Files/Voyage-plans-and-summaries/Investigator/Voyage%20Plans%20summaries/2018/IN2018_V03_%20Voyage%20Plan_SIGNED.ashx

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

Sea-Bird Electronics Inc., 2013: Application Note No 64: SBE 43 Dissolved Oxygen Sensor -- Background Information, Deployment Recommendations, and Cleaning and Storage. http://www.seabird.com/document/an64-sbe-43-dissolved-oxygen-sensor-background-information-deployment-recommendations

Sea-Bird Electronics Inc., 2012: Application Note No 64-2: SBE 43 Dissolved Oxygen Sensor Calibration and data Corrections. http://www.seabird.com/document/an64-2-sbe-43-dissolved-oxygen-sensor-calibration-and-data-corrections

Sea-Bird Electronics Inc., 2014: Application Note No 64-3: SBE 43 Dissolved Oxygen (DO) Sensor - Hysteresis Corrections.

http://www.seabird.com/document/an64-3-sbe-43-dissolved-oxygen-do-sensor-hysteresis-corrections