RV *Investigator*

CTD Processing Report

Voyage #:	**IN2018_V07**
Voyage title:	SOTS: Southern Ocean Time Series automated moorings for climate and carbon cycle studies southwest of Tasmania;
Depart:	Hobart, Monday, 21 August 2018, 1100
Return:	Hobart, Friday, 24 August 2018, 0800
Report compiled by:	Peter Shanks

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1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2018_v07, from 21 Aug 2018 – 25 Aug 2018.

Data for 1 deployment was acquired using the Seabird 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.

The final conductivity calibration was based on a single deployment grouping. The final calibration from the primary sensor had a standard deviation (S.D) of 0.0011658 PSU, within our target of ‘better than 0.002 PSU’. The standard product of 1dbar binned averaged were produced using data from the primary conductivity and secondary oxygen sensors.

The dissolved oxygen data calibration fit had a S.D. of 0.33778 uM. The agreement between the CTD and bottle data was good.

A Biospherical photosynthetically active radiation (PAR) meter, Seapoint Turbidity Meter (Nephelometer) and a Chelsea Fluorometer were also installed on the auxiliary A/D channels of the CTD.

Voyage Details

1.1 Voyage Title

SOTS: Southern Ocean Time Series automated moorings for climate and carbon cycle studies southwest of Tasmania.

1.2 Principal Investigators

The PI was Eric Schulz (CSIRO O&A)

1.3 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.

1.4 Area of operation

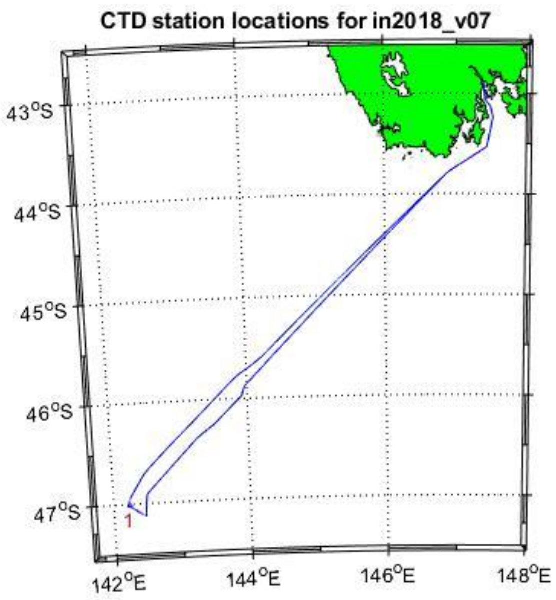


Figure 1. Area of Operation for in2018_v07

2 Processing Notes

2.1 Background Information

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

There was 1 deployment for this voyage as shown on Figure 1.

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

Unit	Data Channel	SBE9 Connector	Model	Serial Number
CTD			SBE9+ V_2	#24 – 1332
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
Transmissometer	A2	JT3	Wetlabs CSTAR 25cm	1735DR
Chelsea Fluorometer - Aquatracka	A3	JT3	Aquatracka III 430-685nm	06-5941-001
Nephelometer	A4	JT5	Seapoint Turbitidty Meter	13142
PAR	A5	JT5	QCP2300-HP	70677
Spare	A6	JT6		
Spare	A7	JT6		
MNF IMU		JT4	CSIRO	na

Table 1. CTD Sensor configuration for in2018_v07 CTD

Water samples were collected using a Seabird SBE9+, 24-bottle rosette sampler with twelve litre bottles fitted to the frame.

There was 1 cast, Sampling was as required from the twelve litre bottles which were fitted to the frame.

The raw CTD data were acquired and converted to scientific units and written to netCDF format files for processing using the CAP package.

Processing was performed with the CapPro application: 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, conductivity sensor lag corrections and the determination of the pressure offsets. The automatically determined pressure offsets and in-water points were inspected and adjusted where necessary. It also loaded the hydrology data and 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, after which files of binned 1dB averaged data were produced.

2.2 Sensor 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.

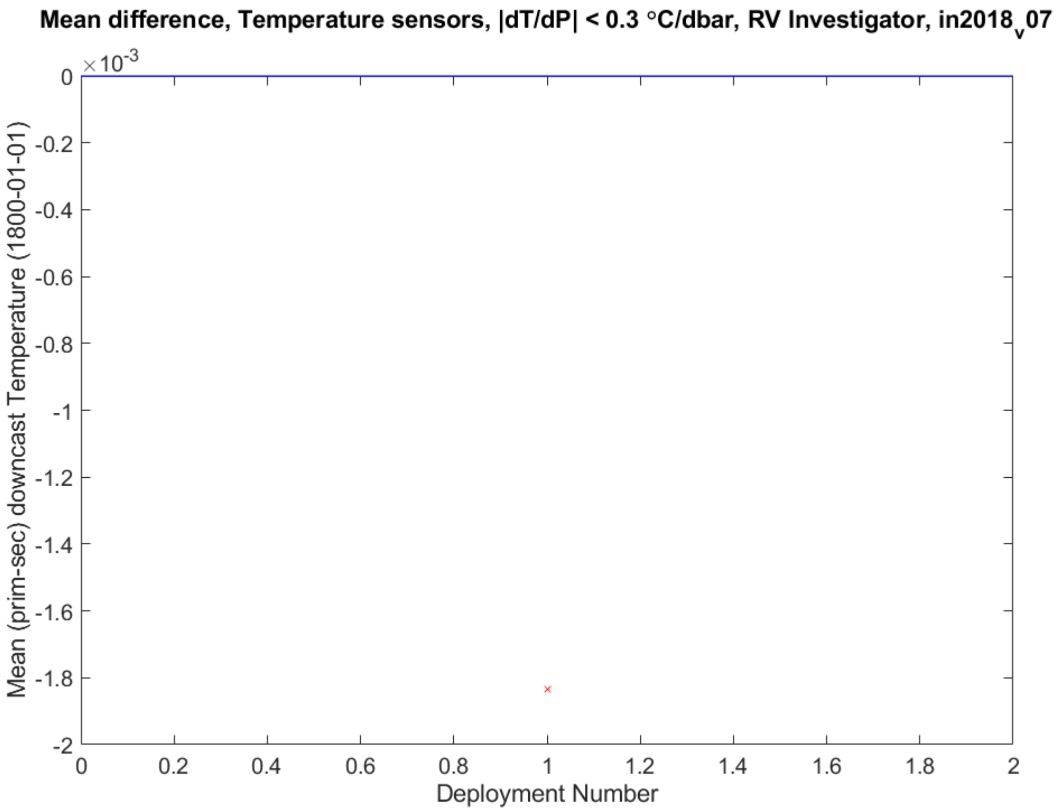
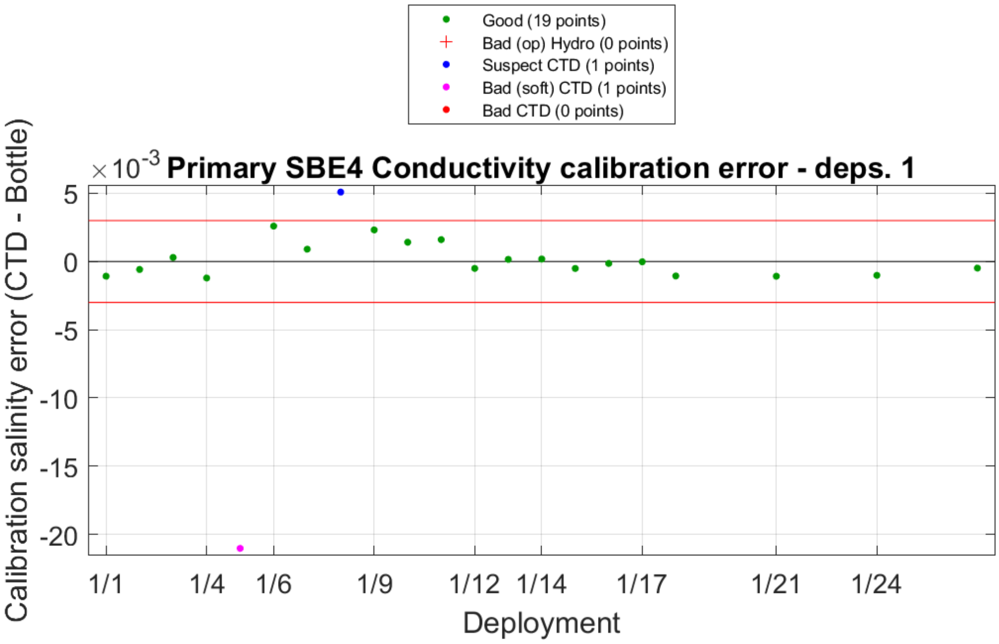


Figure 3. Temperature sensor difference

2.3 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 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.



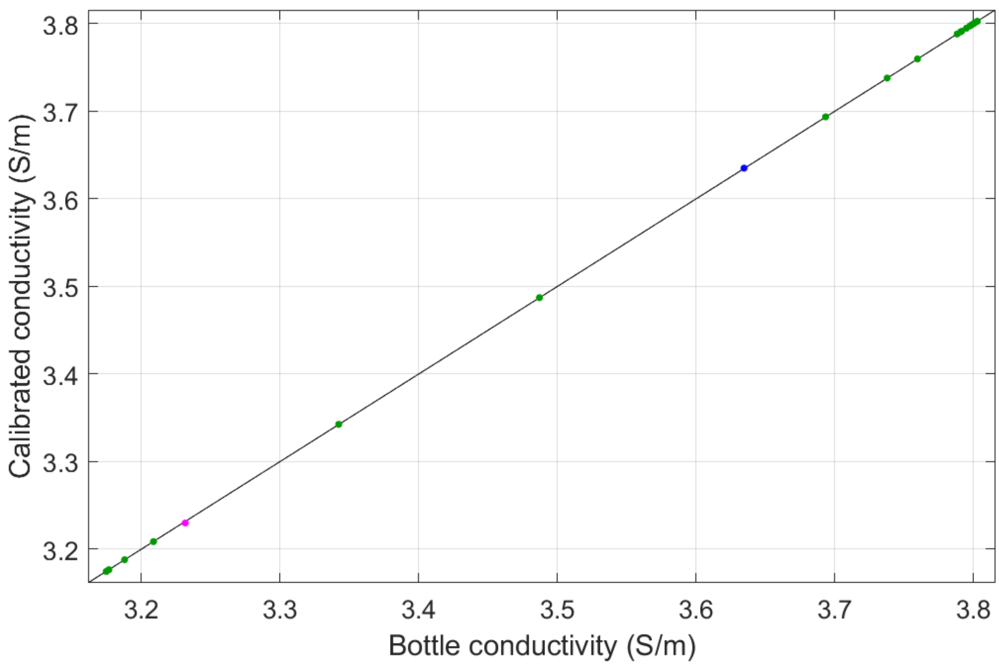


Figure 4. Primary conductivity calibrations

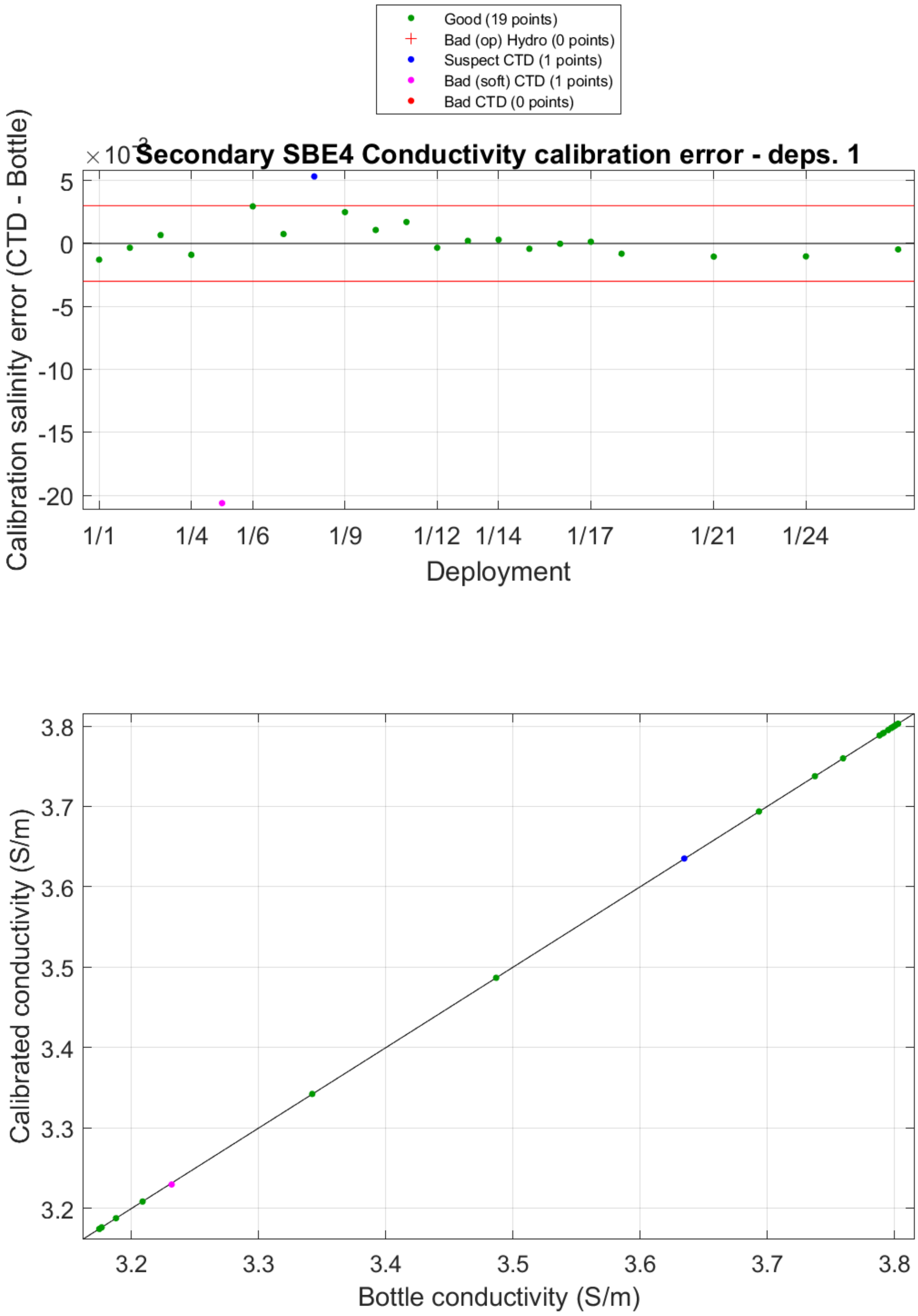


Figure 5. Secondary conductivity calibrations

The final result for the primary conductivity sensor was –

Scale Factor (a1)	1.0001 +- 0.01079	wrt. Manufacturer's calibration
Offset (a0)	-0.00094388 +- 0.041639	ditto
Calibration S.D. (Sal)	0.0011658 PSU	

The calibration using the secondary conductivity sensor was –

Scale Factor (a1)	0.99986 +- 0.010788	wrt. Manufacturer's calibration
Offset (a0)	-0.00019953 +- 0.041634	ditto
Calibration S.D. (Sal)	0.0012468 PSU	

Calibration standard deviation is the standard deviation of the difference between the calibrated values and the bottle values. This calibration is well within the range we normally aim for, an S.D. of 0.002 psu or lower 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.

2.4 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.

2.5 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.

A single calibration group from each sensor was used with the associated SBE43 up-cast data to compute the new Soc and Voffset coefficients. The plots below are of CTD - bottle oxygen differences for both upcast and downcast data (red indicates 'bad' data). It can be seen from these Figures 6 and 7 that there was greater correspondence between bottle and CTD dissolved oxygen values from the primary sensor.

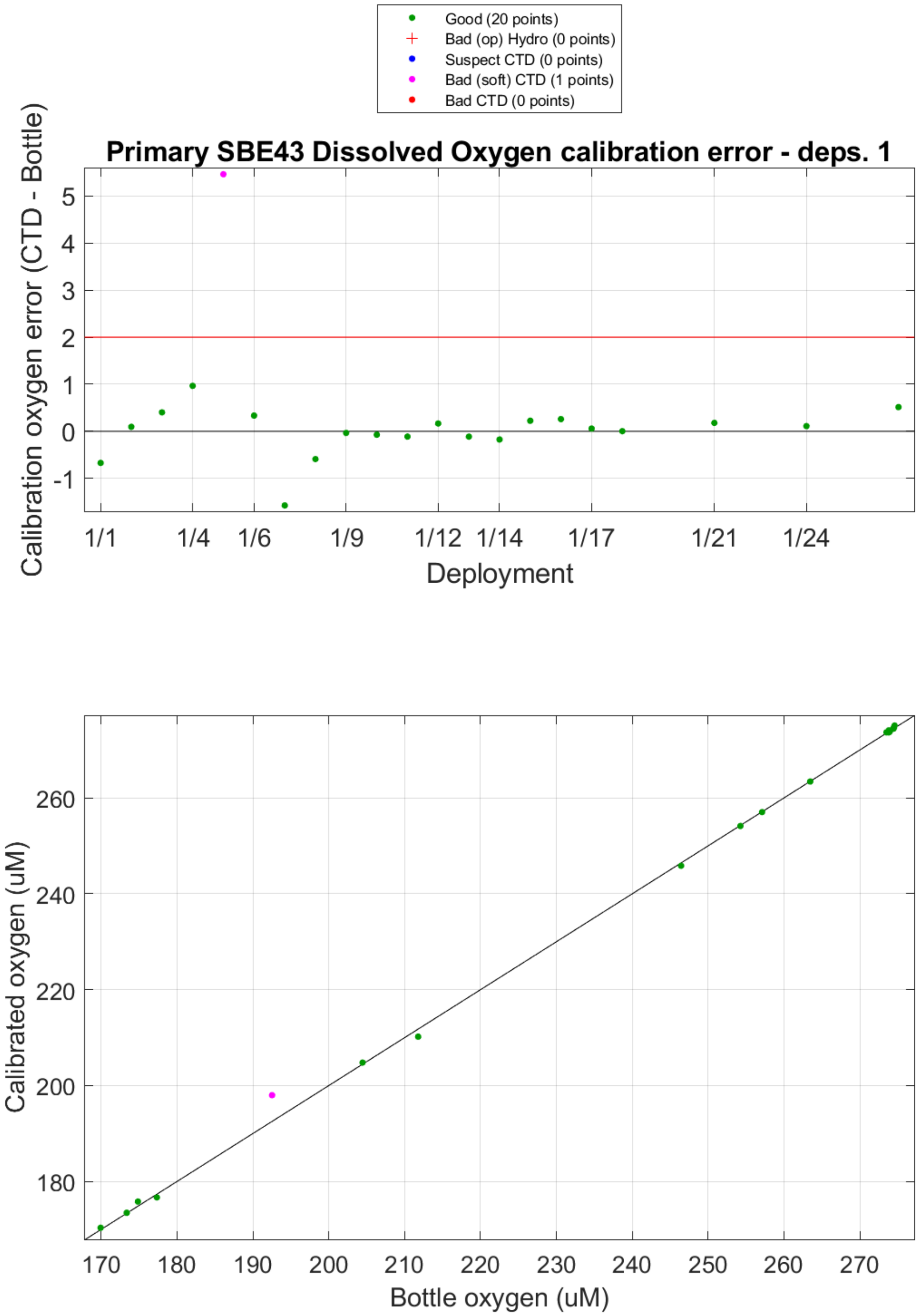


Figure 6. Dissolved Oxygen calibration, all deployments – primary sensor

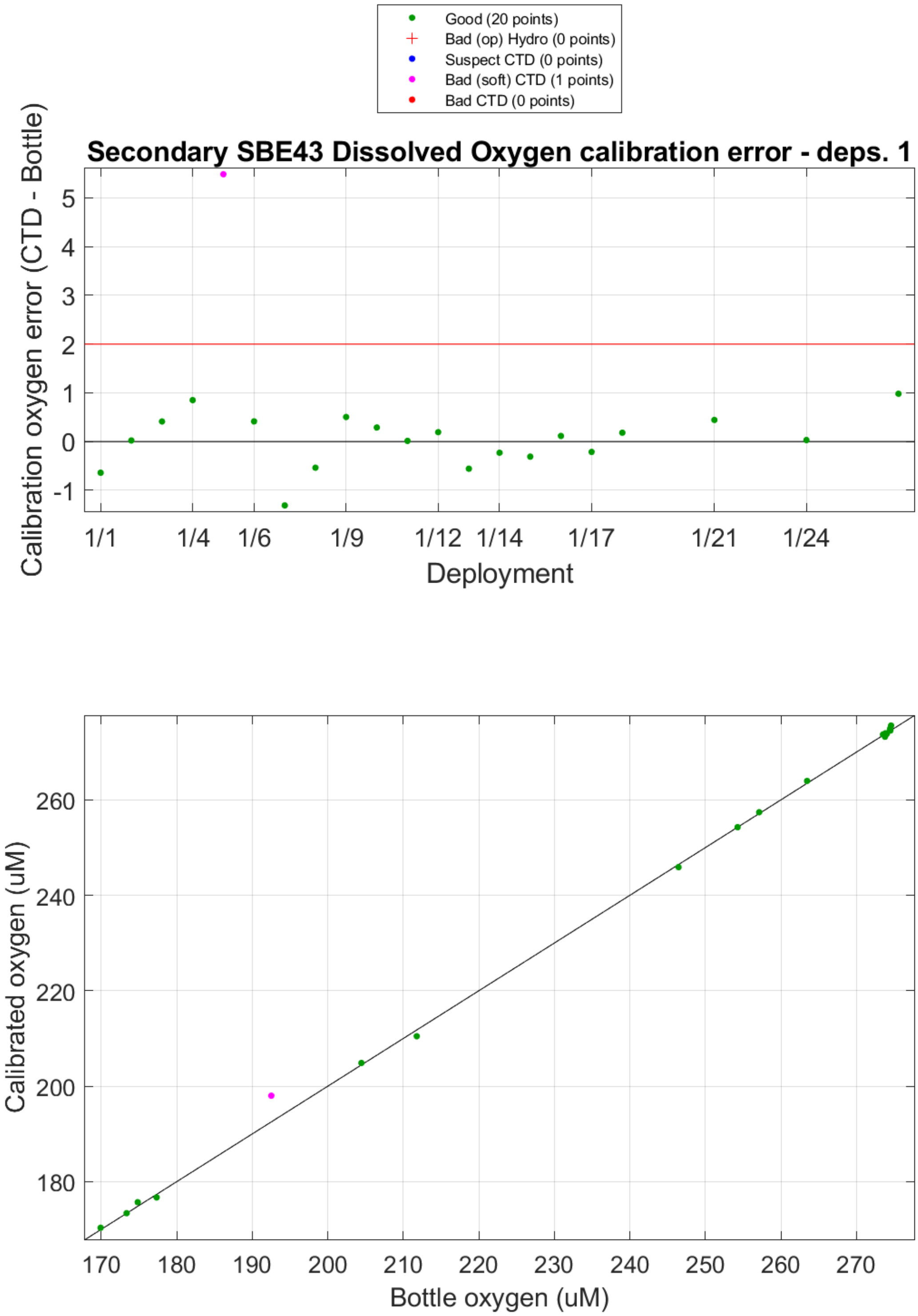


Figure 7. Dissolved Oxygen calibration, all deployments – secondary sensor

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

Calibration	**28-02-2018 CSIRO**	**primary sensor**	**01-12-2017 CSIRO**	**secondary sensor**
Voffset	-5.3082115E-01	-0.47749 +- 0.0032388	-5.1339957E-01	-0.48271 +- 0.003728
Soc	5.3283593E-01	0.48898 +- 0.0010157	5.3853123E-01	0.52546 +- 0.0013546
Fit SD (uM)		0.38391		0.33778

Table 2. Dissolved Oxygen calibration

2.6 Other sensors

The Seapoint Turbidity Nephelometer and Chelsea Fluorometer were calibrated to give nominal outputs of 0-100 fsd (full scale deflection).

The Biospherical PAR output is a nominal 0-5 volts. This data channel has been included in the output files.

2.7 Bad data detection

The limits for each sensor are configured in the CAP CTD acquisition 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**
temperature	-2	40	0.05
conductivity	-0.01	7	0.01
oxygen	-0.1	500	0.5
fluorometer	0	100	0.5

Table 3. Sensor limits for bad data detection

2.8 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.

3 References

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

Sloyan, B., 2016: The RV Investigator. Voyage Plan in2016_v06 - http://www.mnf.csiro.au/~/media/Files/Voyage-plans-and-summaries/Investigator/Voyage%20Plans%20summaries/2016/IN2016_V06_Voyage%20Plan%2020161004%20Final.ashx

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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