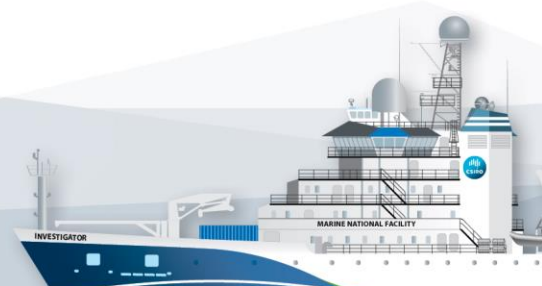


RV Investigator

CTD Processing Report

Voyage #:	IN2017_V01
Voyage title:	Interactions of the Totten Glacier with the Southern Ocean through multiple glacial cycles
Depart:	Hobart, 1800, Saturday 14th January 2017
Return:	Hobart, 0900, Sunday 5th March 2017
Processing completed:	10 April, 2018
Report completed:	10 April, 2018
Report compiled by:	Steven Van Graas



Contents

1	Summary.....	3
1.1	Voyage Title.....	3
1.2	Principal Investigator	3
1.3	Voyage Objectives.....	3
1.4	Area of operation.....	4
2	Processing Notes	4
2.1	Background Information.....	4
2.2	Pressure reference.....	5
2.3	Conductivity Calibration.....	6
2.4	Dissolved Oxygen Sensor Calibration.....	11
2.5	Results.....	11
2.6	Other sensors.....	14
2.7	Bad data detection.....	14
2.8	Averaging	15
3	References.....	17

1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2017_v01, from 14 Jan 2017 – 05 Mar 2017.

Data for 33 deployments were acquired during this voyage using a Seabird SBE911 CTD, fitted with 36 twelve litre bottles on the rosette sampler. Casts 1-10, 13 – 33 were acquired using the Seabird SBE911 CTD unit 20, and casts 11 and 12 were acquired using the Seabird SBE911 CTD unit 22. CTD and sensors were changed in efforts to remediate sensor issues. CSIRO -supplied calibration factors were used to compute the pressures, and preliminary temperature and conductivity values. The data were subjected to automated QC to remove spikes and out-of-range values.

Processing was completed using CapPro processing software, version 2.9.

For the duration of the voyage significant spikes were observed across all recorded sensor channels. Investigation strongly suggests electrical interference was the cause of the data spikes, as mitigation measures have alleviated the issue. Care was taken in post processing to remove the spikes while maintaining true data features. The nature of the spiking was primarily extreme values persisting for a single scan, which were suitably detected and flagged by evaluating the second-difference of the data. An additional filter was also applied to the data which evaluated the median and standard deviation of the conductivity over a moving window, which was used to detect extreme changes in the sensor values characteristic of the noise induced spikes.

The final conductivity calibration was based on two deployment groupings, due to sensor changes during the voyage. The final calibration for casts 1-13 from the secondary sensor had a standard deviation (S.D) of 0.0010393 PSU, within our target of 'better than 0.002 PSU'. The final calibration for casts 14-33 from the secondary sensor had a standard deviation (S.D) of 0.0020084 PSU. The standard product of 1dbar binned averaged were produced using data from the secondary sensors.

The final Oxygen calibration from the primary sensor had a S.D of 0.85991 μM . The agreement between the sensor and bottle data was good. Both Oxygen sensors calibrated closely.

The Biospherical photosynthetically active radiation (PAR), Wetlabs Transmissometer, the Wetlabs ECO chlorophyll, and O&A IMU sensors were also installed on the auxiliary A/D channels of the CTD.

Voyage Details

1.1 Voyage Title

Interactions of the Totten Glacier with the Southern Ocean through multiple glacial cycles.

1.2 Principal Investigator

Leanne Armand

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

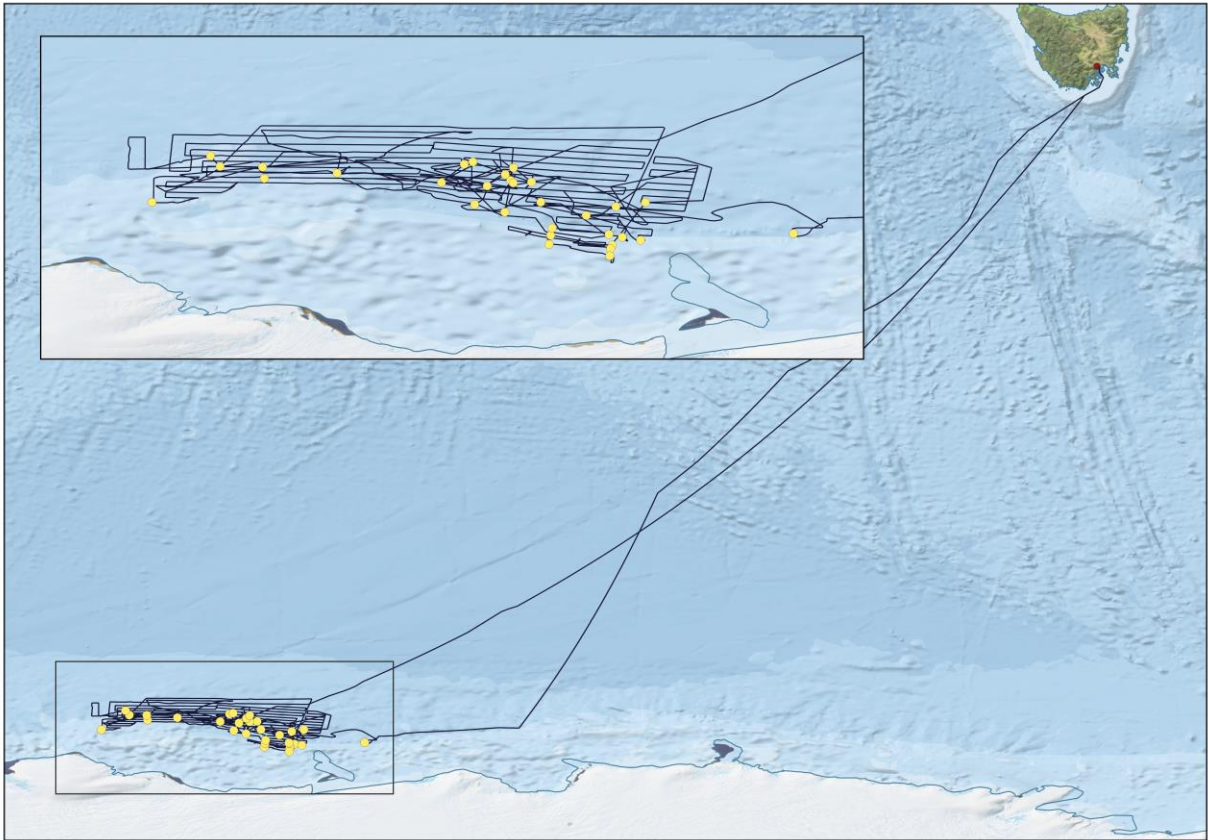


Figure 1. Area of Operation for in2017_v01 CTDs

2 Processing Notes

2.1 Background Information

The data for this voyage were acquired with CTD SBE9+ unit 20 and unit 22 with dual conductivity and temperature sensors.

There were 33 deployments for this voyage as shown on Figure 1.

Heave compensation was used on the CTD winch for all casts.

The Biospherical photosynthetically active radiation (PAR), C-Star transmissometer, Aquatraker Fluorometer and Seapoint turbidity sensors were also installed on the auxiliary A/D channels of the CTD. These sensors are described in Table 1 below.

Description	Sensor	Serial No.	A/D	Calibration Date	Calibration Source	Casts
Pressure	SBE9 <i>plus</i> V2	552	P		SBE Cal	1 – 10, 13 – 33
Pressure	SBE9 <i>plus</i> V2	1243	P		SBE Cal	11, 12

Primary Temperature	Seabird SBE3T	4718	T0		CSIRO	1 – 13
Primary Temperature	Seabird SBE3T	6022	T0		CSIRO	14 – 33
Secondary Temperature	Seabird SBE3T	4722	T1		CSIRO	1 – 13
Secondary Temperature	Seabird SBE3T	6024	T1		CSIRO	14 – 33
Primary Conductivity	Seabird SBE4C	2312	C0		CSIRO	1 – 13
Primary Conductivity	Seabird SBE4C	4425	C0		CSIRO	14 – 33
Secondary Conductivity	Seabird SBE4C	2235	C1		CSIRO	1 – 13
Secondary Conductivity	Seabird SBE4C	4426	C1		CSIRO	14 – 33
Primary Oxygen	Seabird SBE43	3154	A0		CSIRO	1 – 12, 16 – 33
Secondary Oxygen	Seabird SBE43	3159	A1		CSIRO	1 – 12, 16 – 33
Biospherical Instr.PAR	QCP2300	70111	A2	01/8/2016	R12719	1 – 12, 16 – 33
Fluorometer	Aquatrack III	11-8206-01	A3	8/4/2016	Chelsea	1 – 12, 16 – 33
Altimeter	PA500	5301	A4	7/9/2016	Tritech	1 – 12, 16 – 33
Nephelometer	Seapoint	13142	A5		Seapoint	1 – 12, 16 – 33

Table 1. CTD Sensor configuration for in2017_v01 CTD

Water samples were collected using a Seabird SBE9+, 36-bottle rosette sampler with twelve litre bottles fitted to the frame.

There were 33 casts, 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 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.

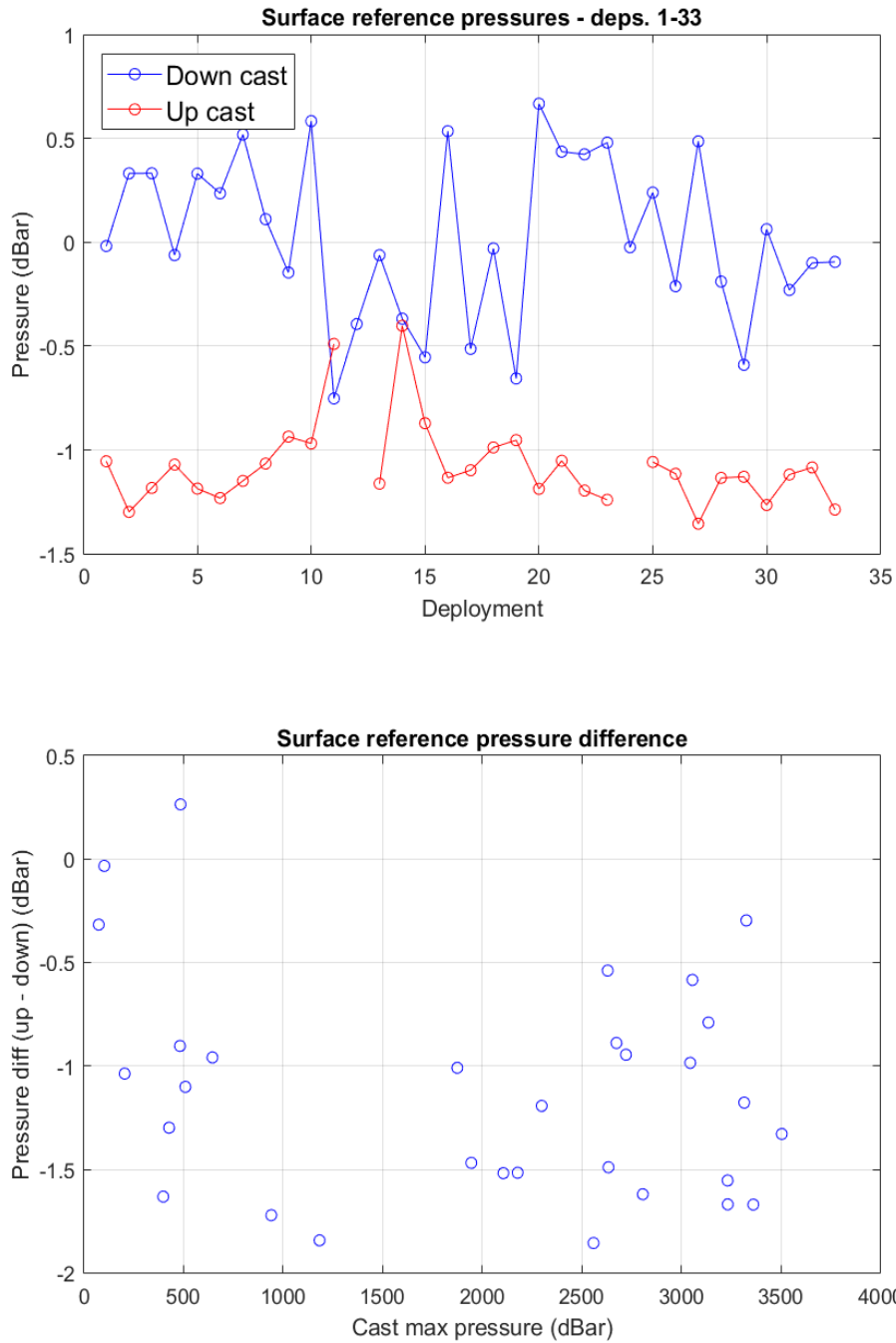


Figure 2. CTD pressure reference

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

calibration was based upon the sample data for 104 of the total of 151 samples taken during deployments. 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.

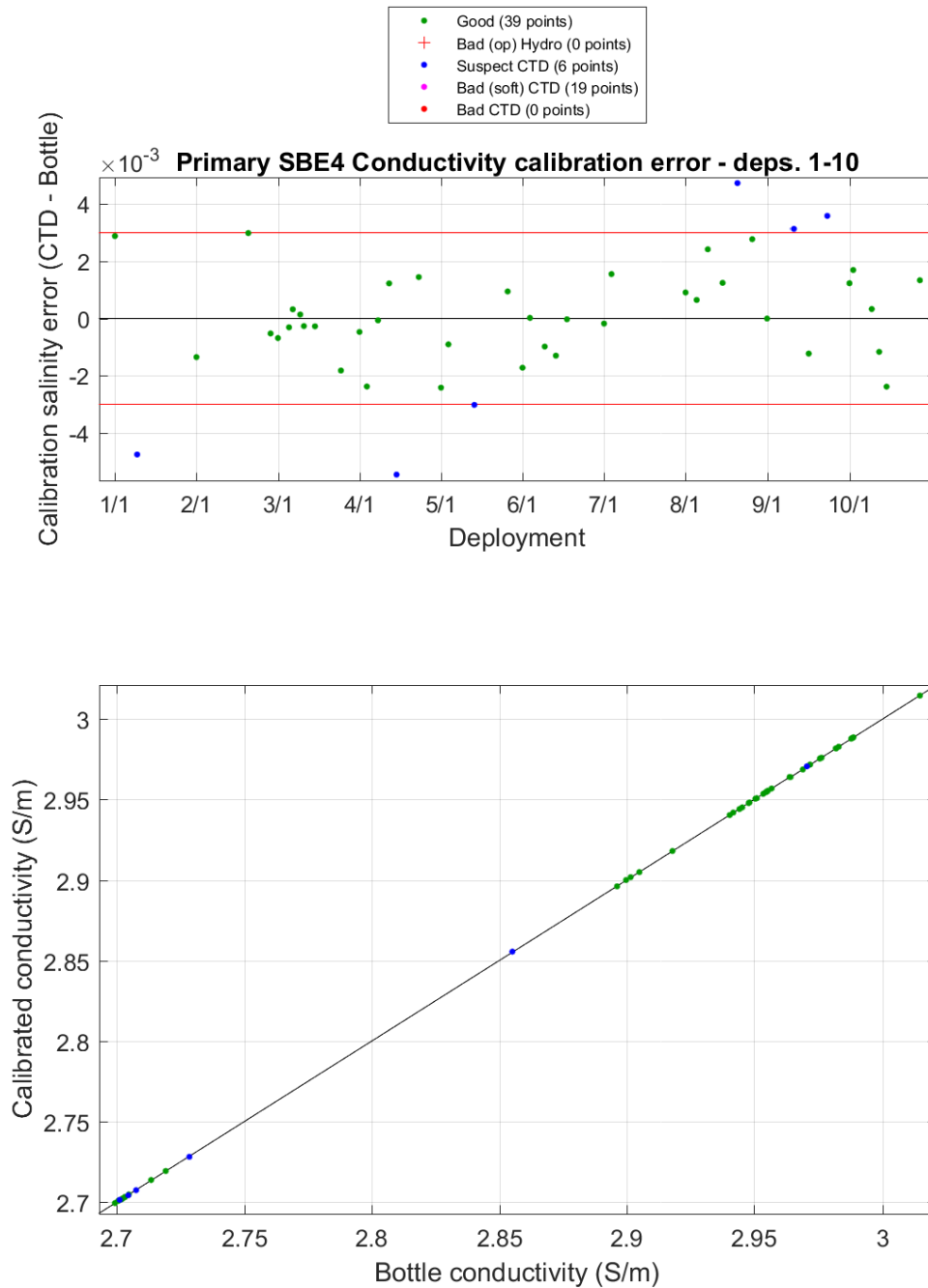


Figure 3: Primary SBE4 Conductivity calibrations, casts 1 - 10

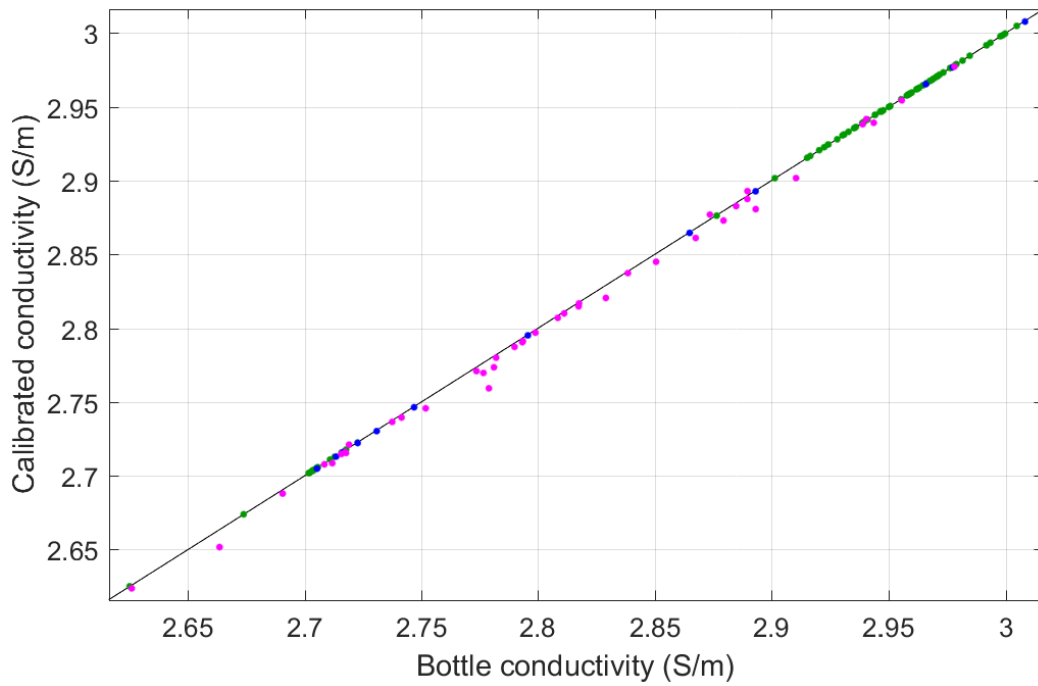
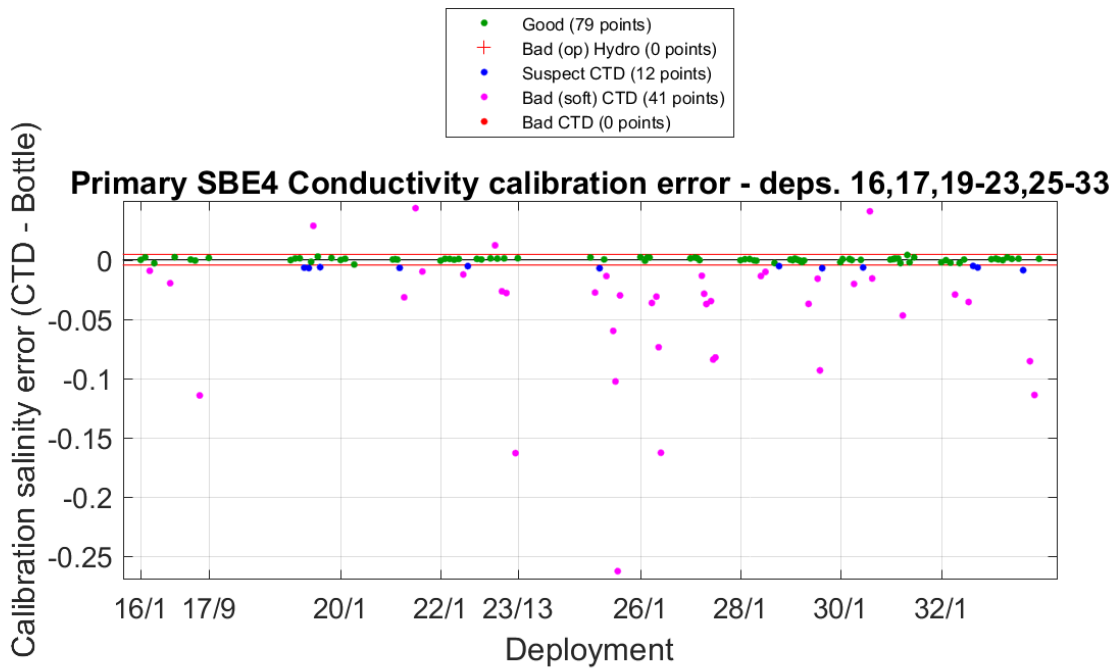


Figure 4: Primary SBE4 Conductivity Calibration, casts 16 - 33

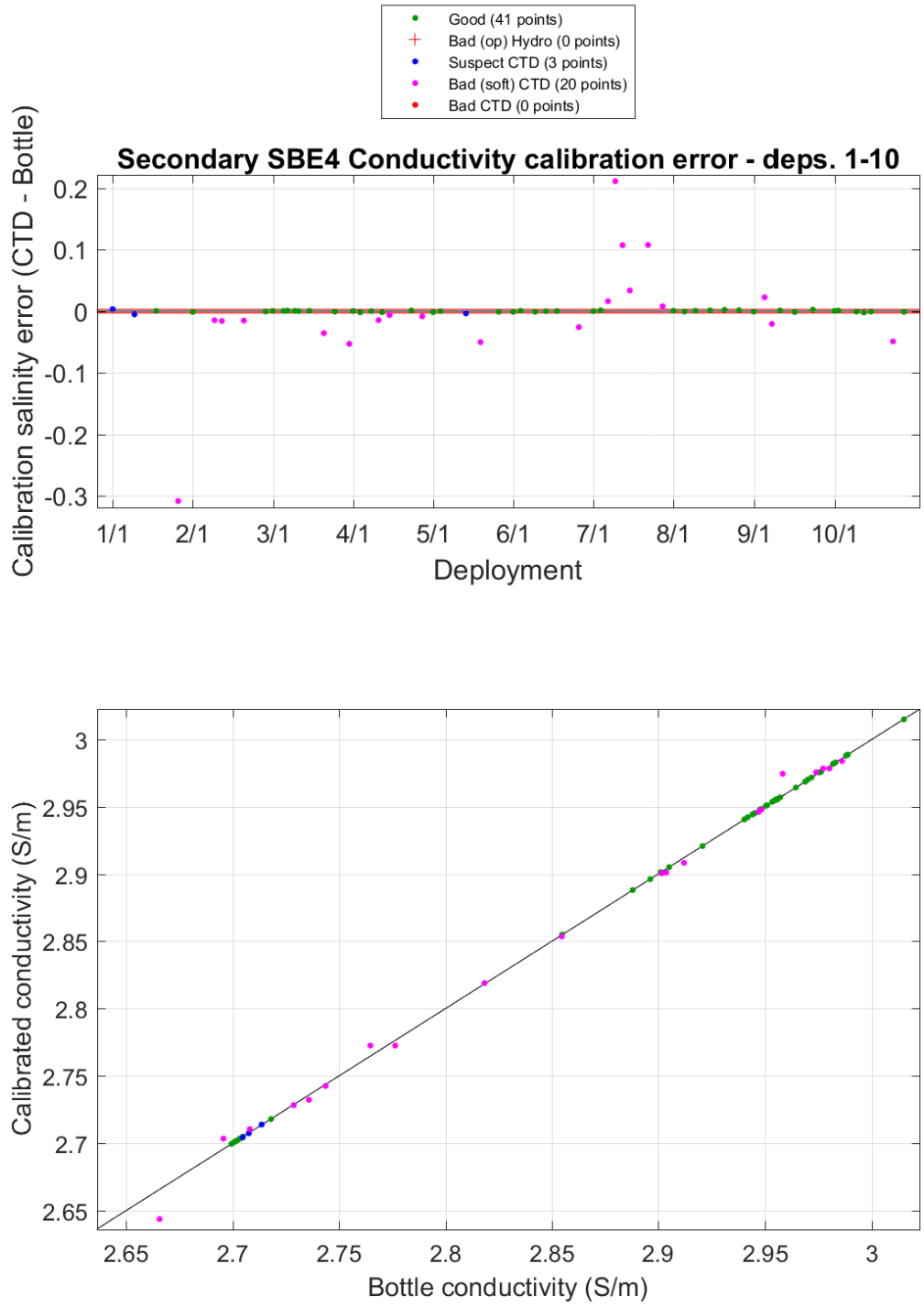


Figure 5: Secondary SBE4 Conductivity Calibration, casts 1-10

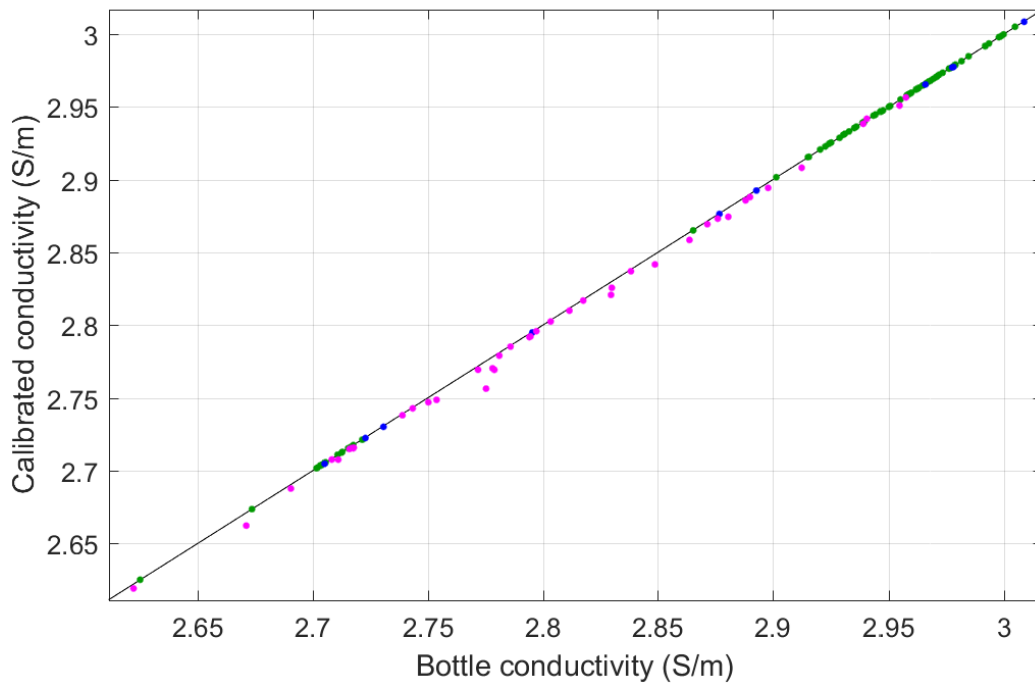
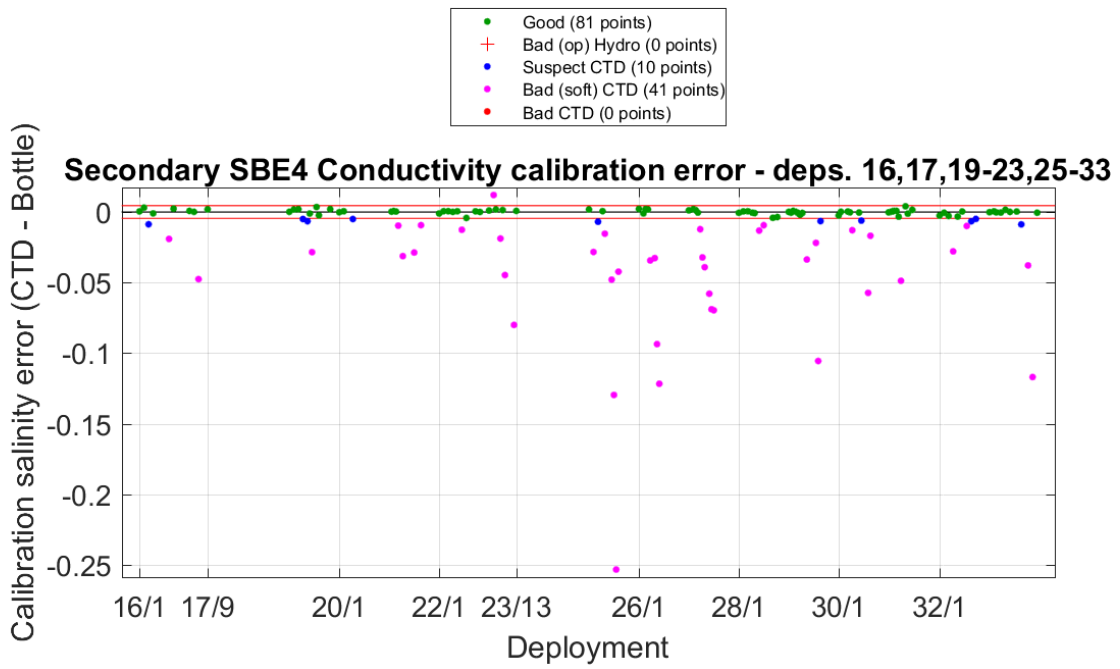


Figure 6: Secondary Conductivity Calibration, casts 16-33

The final result for the primary conductivity sensor was –

Cast 1-10	Scale Factor (a1)	0. 99893	wrt. Manufacturer’s calibration
Cast 16-33	Scale Factor (a1)	0. 99880	wrt. Manufacturer’s calibration
Cast 1-10	Offset (a0)	0. 0033093	wrt. Manufacturer’s calibration
Cast 16-33	Offset (a0)	0. 0031893	wrt. Manufacturer’s calibration
Cast 1-10	Calibration S.D. (Sal)	0. 0013467 PSU	
Cast 16-33	Calibration S.D. (Sal)	0. 002102 PSU	

The calibration using the secondary conductivity sensor was –

Cast 1-10	Scale Factor (a1)	0. 99899	wrt. Manufacturer’s calibration
Cast 16-33	Scale Factor (a1)	0. 99860	wrt. Manufacturer’s calibration
Cast 1-10	Offset (a0)	0. 0037823	wrt. Manufacturer’s calibration
Cast 16-33	Offset (a0)	0. 0035493	wrt. Manufacturer’s calibration
Cast 1-10	Calibration S.D. (Sal)	0. 0010393 PSU	
Cast 16-33	Calibration S.D. (Sal)	0. 0020084 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 secondary sensor.

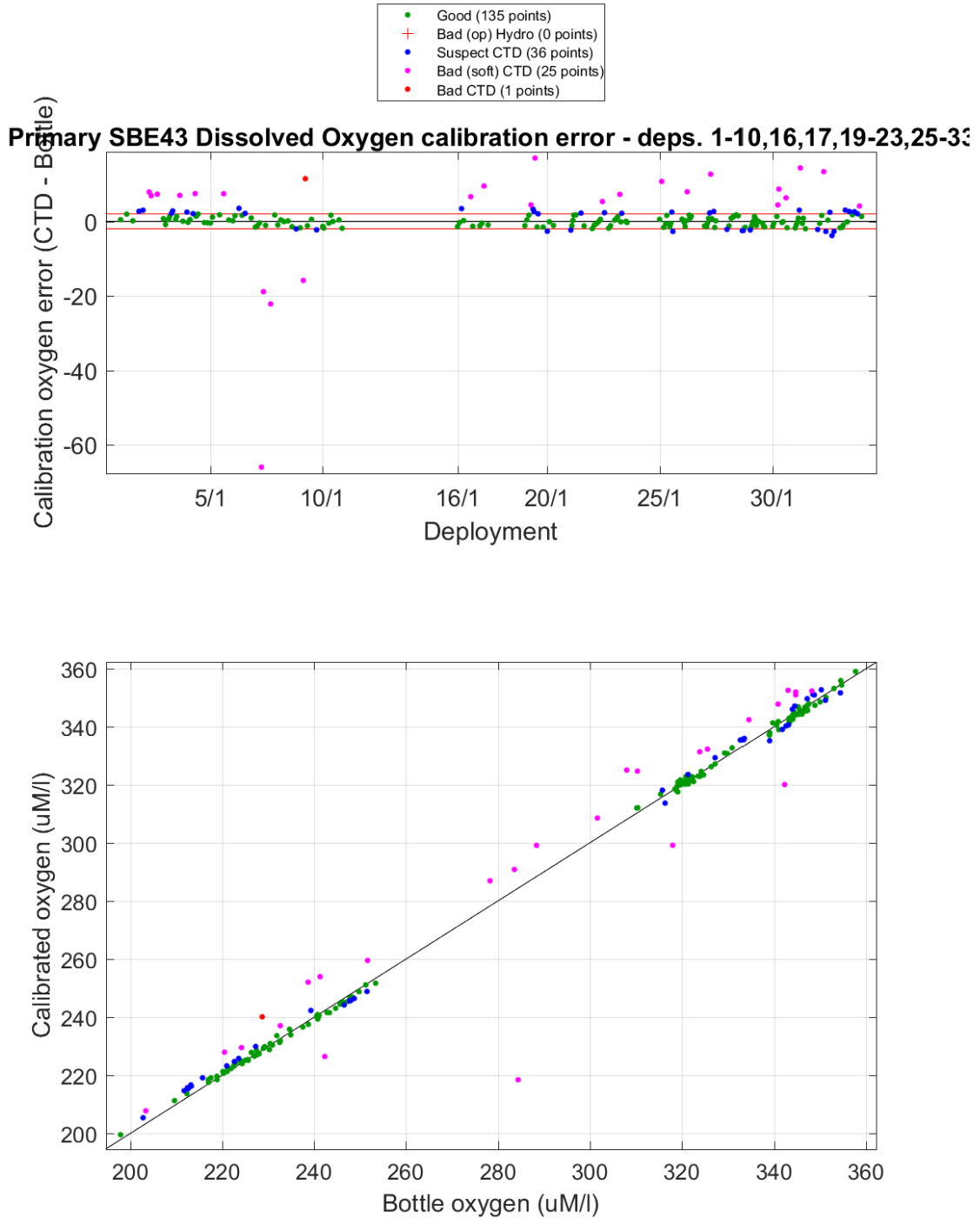


Figure 7. Dissolved Oxygen calibration, all deployments – primary sensor

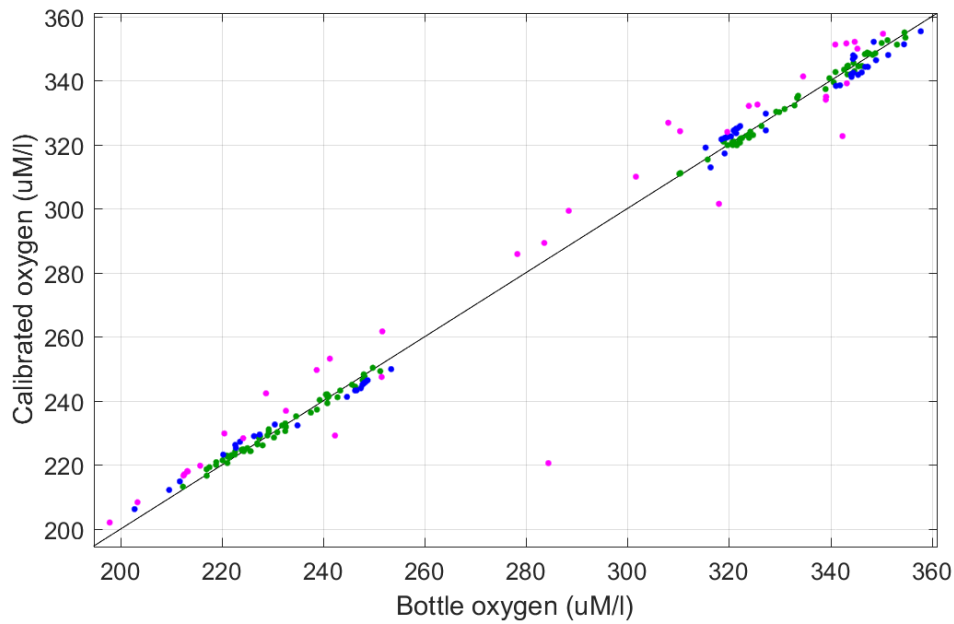
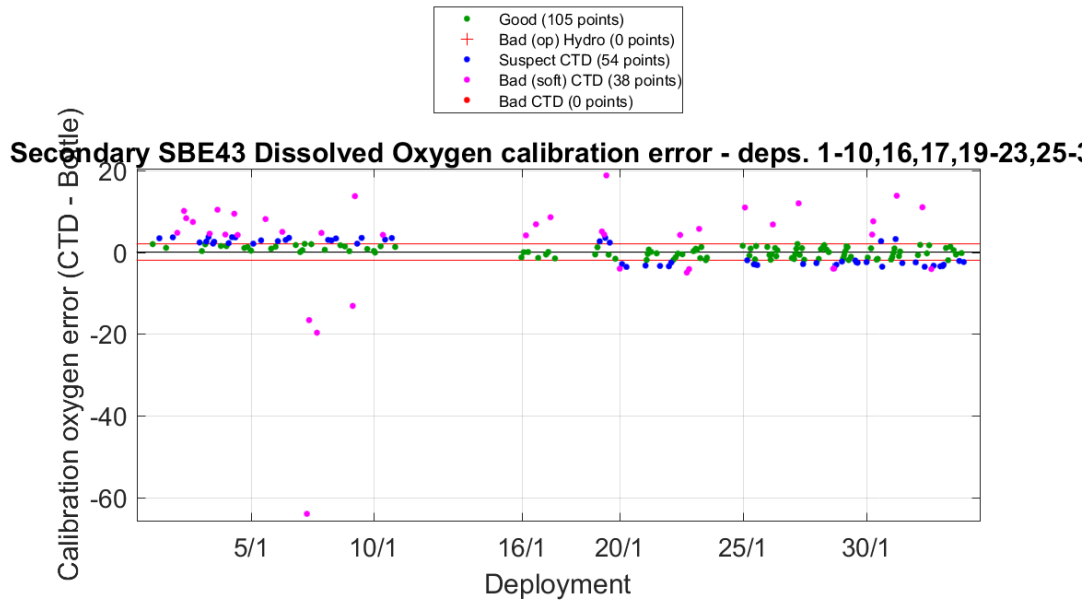


Figure 8. Dissolved Oxygen calibration, all deployments – secondary sensor

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	Mar 2016 CSIRO	primary sensor	Mar 2016 CSIRO	secondary sensor
Voffset	-0.50133997	-0.44561	-0.505678	-0.44796
Soc	0.47520554	0.48145	0.545733	0.55874
Fit SD (uM)		0.87213		1.0681

Table 2. Dissolved Oxygen calibration

2.6 Other sensors

The Seapoint Nephelometer and Chelsea fluorometer were both used for all deployments except casts 13, 14, 15. They were calibrated to give nominal outputs of 0-100 fsd (full scale deflection).

The Biospherical PAR sensor was also used for all deployments except casts 13, 14, 15. The output is a nominal 0-5 volts. 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 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.

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
pressure	-7	6500	1
temperature	-2	40	0.05
conductivity	-0.01	7	0.01
oxygen	-0.1	500	1
fluorometer	0	100	0.5

Table 3. Sensor limits for bad data detection

An additional bad data detection method was applied for this voyage. A moving window filter which flags data when it fluctuates in excess of a configured multiple of the standard deviation about the median. A minimum limit is applied to the standard deviation bound to prevent the sensor noise floor being flagged when the sensor values are constant (e.g. at bottle stops). This minimum parameter is different for each sensor and was determined by manually inspecting the data for each sensor. The filter was applied to the data in engineering units, after the second difference test has been applied. This filter was applied to the pressure, conductivity, and oxygen sensors, which exhibited the spiking due to noise on the CTD cable. The window parameters used are as follows:

Median Window (scans)	Standard Deviation window (scans)	Std. Dev. factor
6	24	2.0

Table 2: Filter parameters

Sensor	Bound minimum
pressure	0.5
conductivity	0.0001
oxygen	0.75

Table 3: Minimum height for the bounds used for spike 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.

A ship heave compensation filter was also applied to the data in order to detect when entraining water from the CTD rosette movement contaminates the sampling due to ship heave altering the descent/ascent rate. The heave filter takes into account the package acceleration, the height of the rosette base above the sensor intake, the fraction of the rosette height distance before the water is considered contaminated, and the fluid drag. The heave correction parameters used for the filter are as follows:

Parameter	Value
Rosette base height	0.5m
Height fraction	0.8
Fluid drag	0.25

Table 6. Heave compensation parameters

Correction for the thermal inertia of the conductivity sensor is also applied. The correction to the temperature is applied in the form of a digital low-pass filter, where Tau is the time constant in seconds, and Beta is the weighting for the unfiltered data. The filter is applied twice.

Parameter	First Pass value	Second Pass value
Tau	7	1
Beta	0.013	0.007

Table 7. Thermal inertia correction parameters

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>.

Trull, T., 2017: The RV Investigator. Voyage Plan in2017_v01 -

http://www.mnf.csiro.au/~media/Files/Voyage-plans-and-summaries/Investigator/Voyage%20Plans%20summaries/2017/IN2017_V01%20Voyage%20plan%2020170316.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>