RV *Investigator*

CTD Processing Report

Voyage #:	in2017_v05
Voyage title:	Long-term recovery of trawled marine communities
Depart:	0800z, Wednesday 11 October 2017, Broome, WA.
Return:	0800, Friday November 10, 2017, Henderson (Fremantle), WA.
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 in2017_v05 CTDs, from 11 Oct 2017 – 10 Nov 2017.

Data for 72 deployments were acquired using the Seabird SBE911 CTD unit 23, 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 0.0012983 PSU, within our target of 'better than 0.002 PSU'. The standard product of 1dbar binned averaged were produced using data from the primary sensors.

The dissolved oxygen data calibration fit had a S.D. of 0.6416uM. The agreement between the CTD and bottle data was good.

The Biospherical photosynthetically active radiation (PAR), C-Star transmissometer, Aqua tracker Flurometer, ISUS Nitrate sensors were also installed on the auxiliary A/D channels of the CTD. Along with a Wetlabs Eco-triplet and a particle size analyser.

Voyage Details

1.1 Voyage Title

Long-term recovery of trawled marine communities.

1.2 Principal Investigators

The PI was John Keesing (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

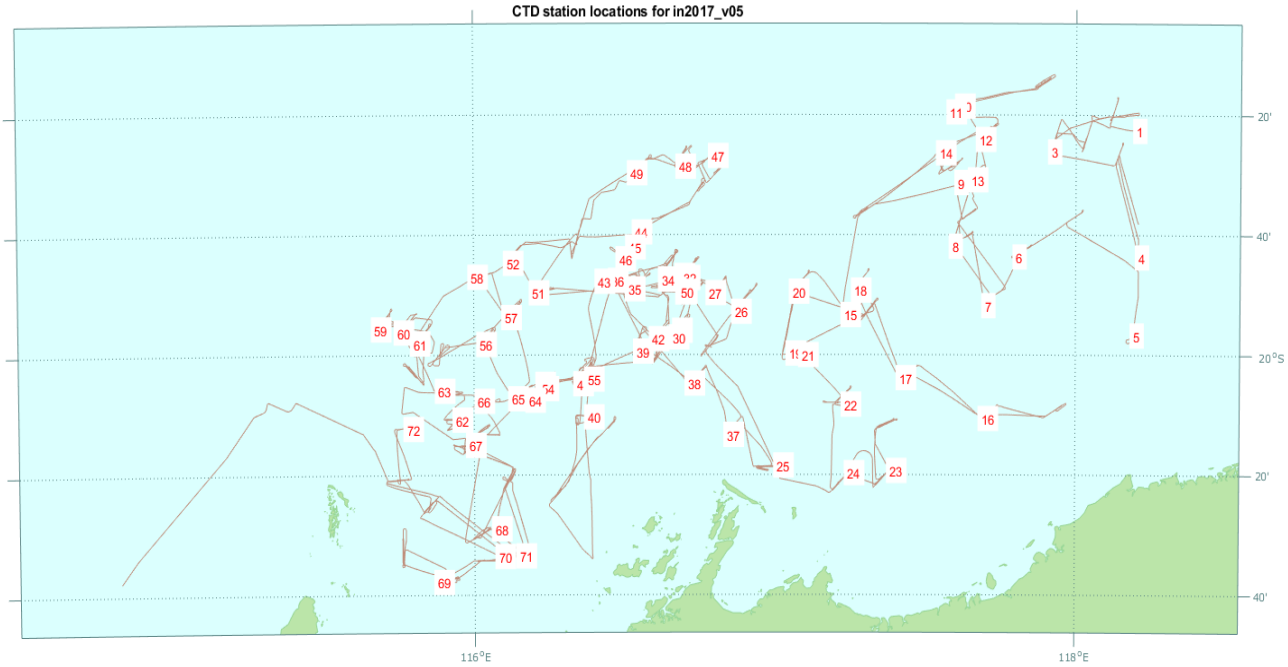

Figure 1. Area of Operation for in2017_v05 CTDs

2 Processing Notes

2.1 Background Information

The data for this voyage were acquired with CTD SBE9+ unit 23 with dual conductivity and temperature sensors.

There were 72 deployments for this voyage as shown on Figure 1.

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

The Biospherical photosynthetically active radiation (PAR), C-Star transmissometer, Aquatracker Flurometer, ISUS Nitrate sensors were also installed on the auxiliary A/D channels of the CTD. Along with the Wetlabs Eco-triplet and a particle size analyser. These sensors are described in Table 1 below.

UNIT	Channel	MODEL	SERIAL NUMBER	Calibration Date
CTD#23		SBE9+	1312	
Primary Temperature		SBE 3T	6189	17/04/2017
Primary Conductivity		SBE4C	4685	2/05/2017
Secondary Temperature		SBE3T	4722	11/01/2017
Secondary Conductivity		SBE4C	4664	2/03/2017
Primary Pump		SBE5	8344	
Secondary Pump		SBE5	8345	
Primary Oxygen	A0	SBE43	3534	26/04/2017
Secondary Oxygen	A1	SBE43	3159	15/03/2017
Altimeter	A2	PA500	05301.228403	7/09/2016
PAR	A3	QCP2300-HP	70111	26/06/2017
Transmissometer	A4	C-Star	CST-1735DR	3/01/2017
Flurometer	A5	Aquatracker	06-5941-001	8/04/2016
Nitrate	A6	ISUS Nitrate Sensor	236	11/08/2016
Nitrate uncertainty	A7	ISUS Nitrate Sensor	236	11/10/2016
Eco-Triplet	Serial	Wetlabs	BBFL2B-754	
Particle size analyser	External	LISST-200X		

Table 1. CTD Sensor configuration for in2017_v05 CTDs

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

There were 72 casts, Sampling was as required from the twelve litre bottles which were fitted to the frame. Cast #57 was aborted before any valid data was collected due to a winch failure.

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 (version 2.3). This Matlab software was used to apply automated QC and preliminary processing to the data, including 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. CapPro 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.

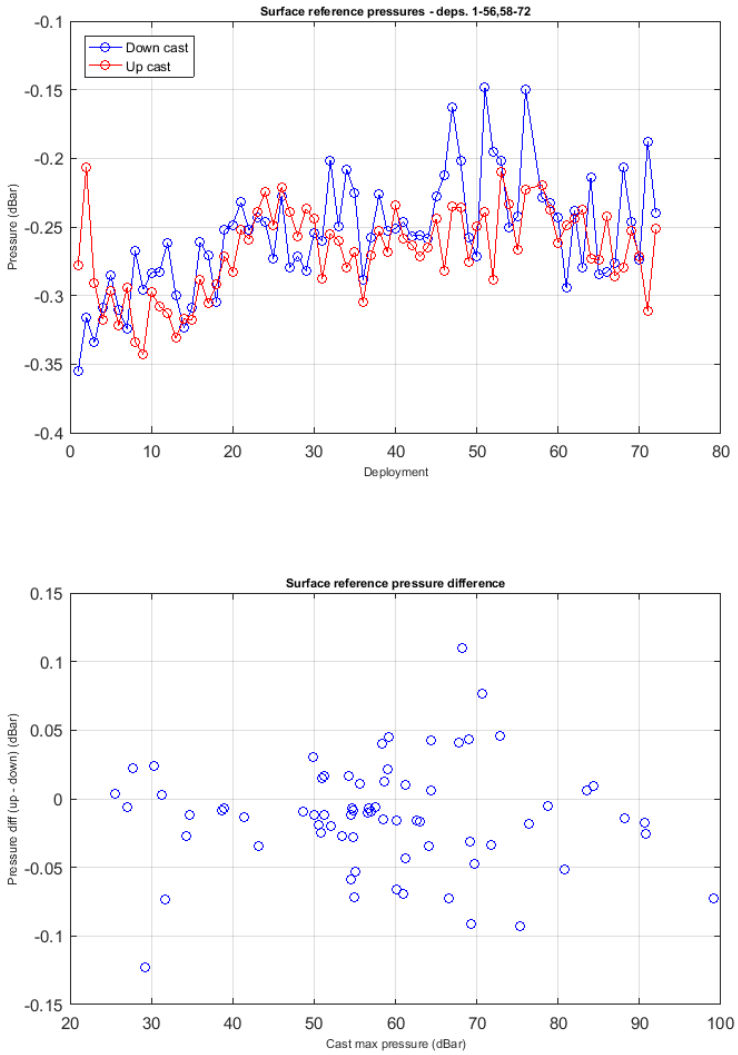

Figure 2. CTD pressure reference

The mean difference between the primary and secondary temperature sensors is plotted below. Most deployments should plot within ±1 m°C. Figure 3 shows that most casts remained within this limit, with the others showing a discrepancy of up to ±5 m°C, possibly due to turbidity in the shallow tropical waters being tested.

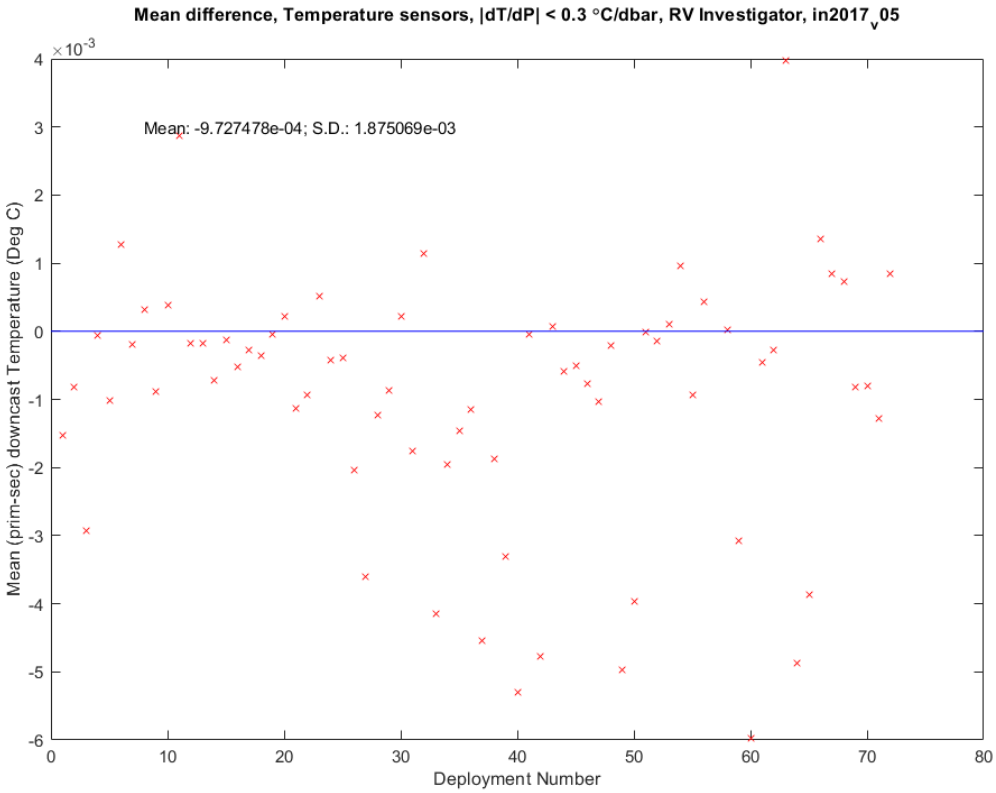

Figure 3. Temperature sensor difference

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 calibration was based upon the sample data for 68 of the total of 88 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.

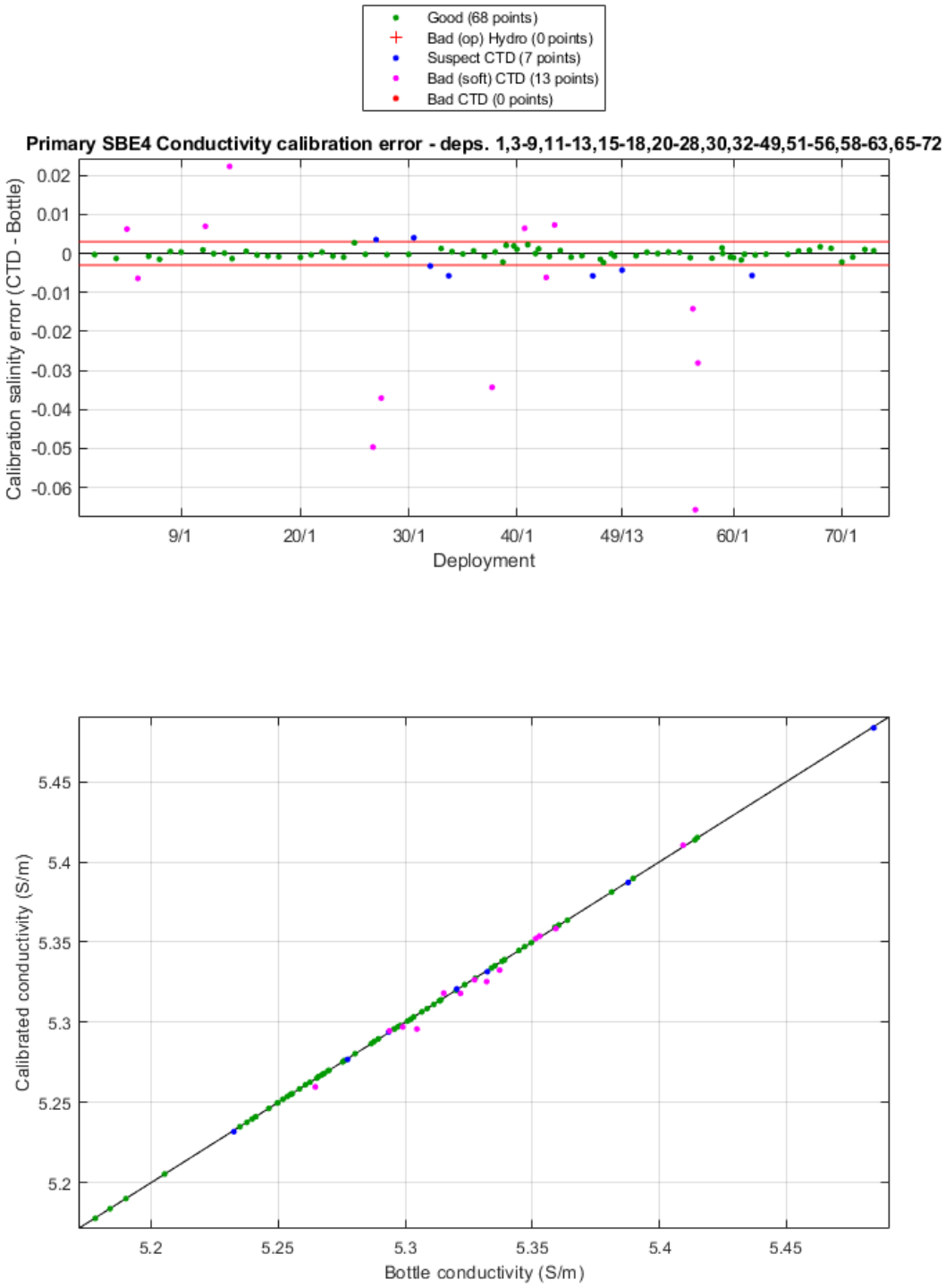

Figure 4. Primary conductivity calibrations

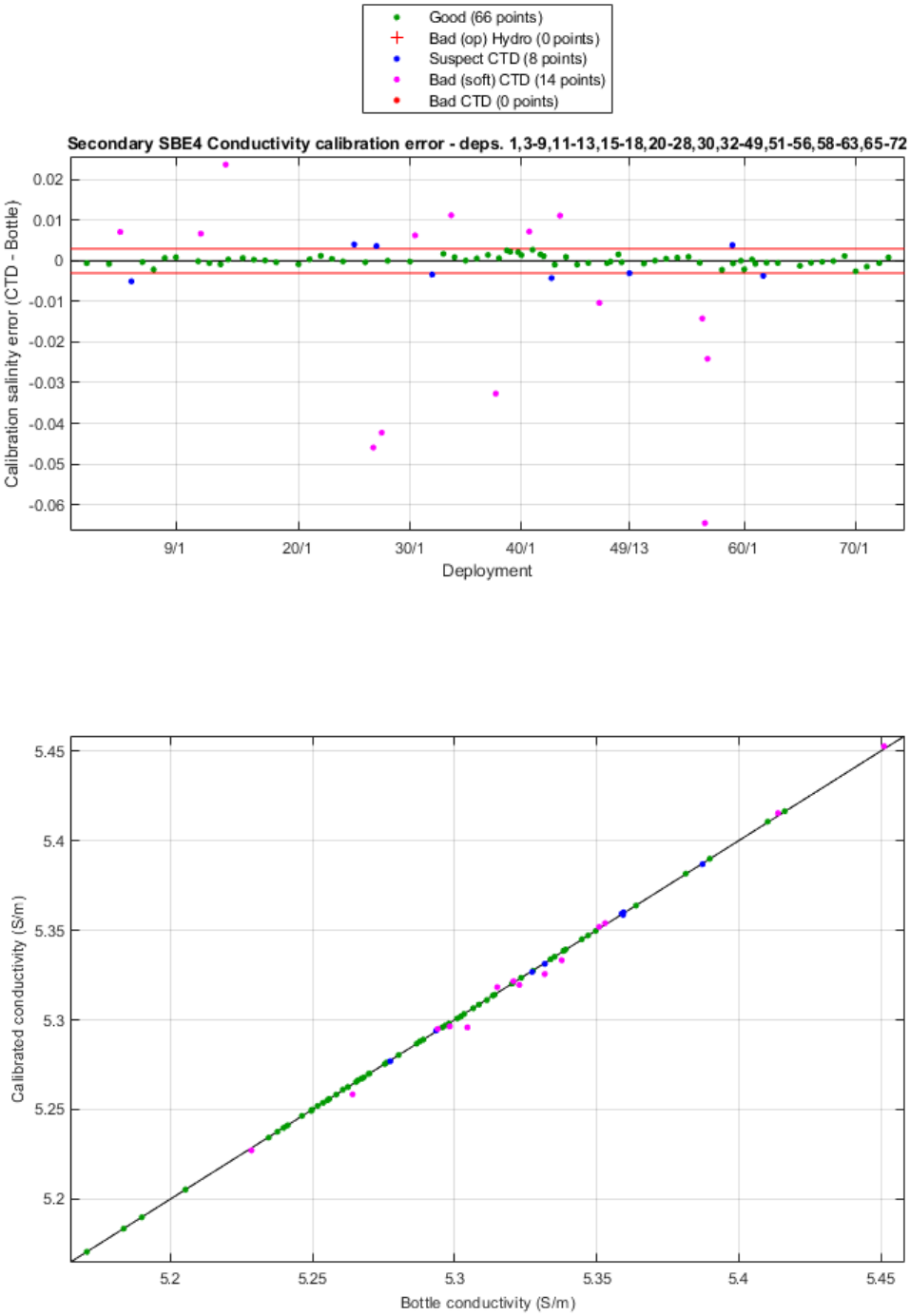

Figure 5. Secondary conductivity calibrations

The final result for the primary conductivity sensor was –

Scale Factor (a1)	0.99948	wrt. Manufacturer's calibration
Offset (a0)	0.0032821	ditto
Calibration S.D. (Sal)	0.0012983 PSU	

The calibration using the secondary conductivity sensor was –

Scale Factor (a1)	0.99921	wrt. Manufacturer's calibration
Offset (a0)	0.0050978	ditto
Calibration S.D. (Sal)	0.0011609 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). Due to the shallow water this voyage was conducted in, this did not affect any of the casts made during this voyage.

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).

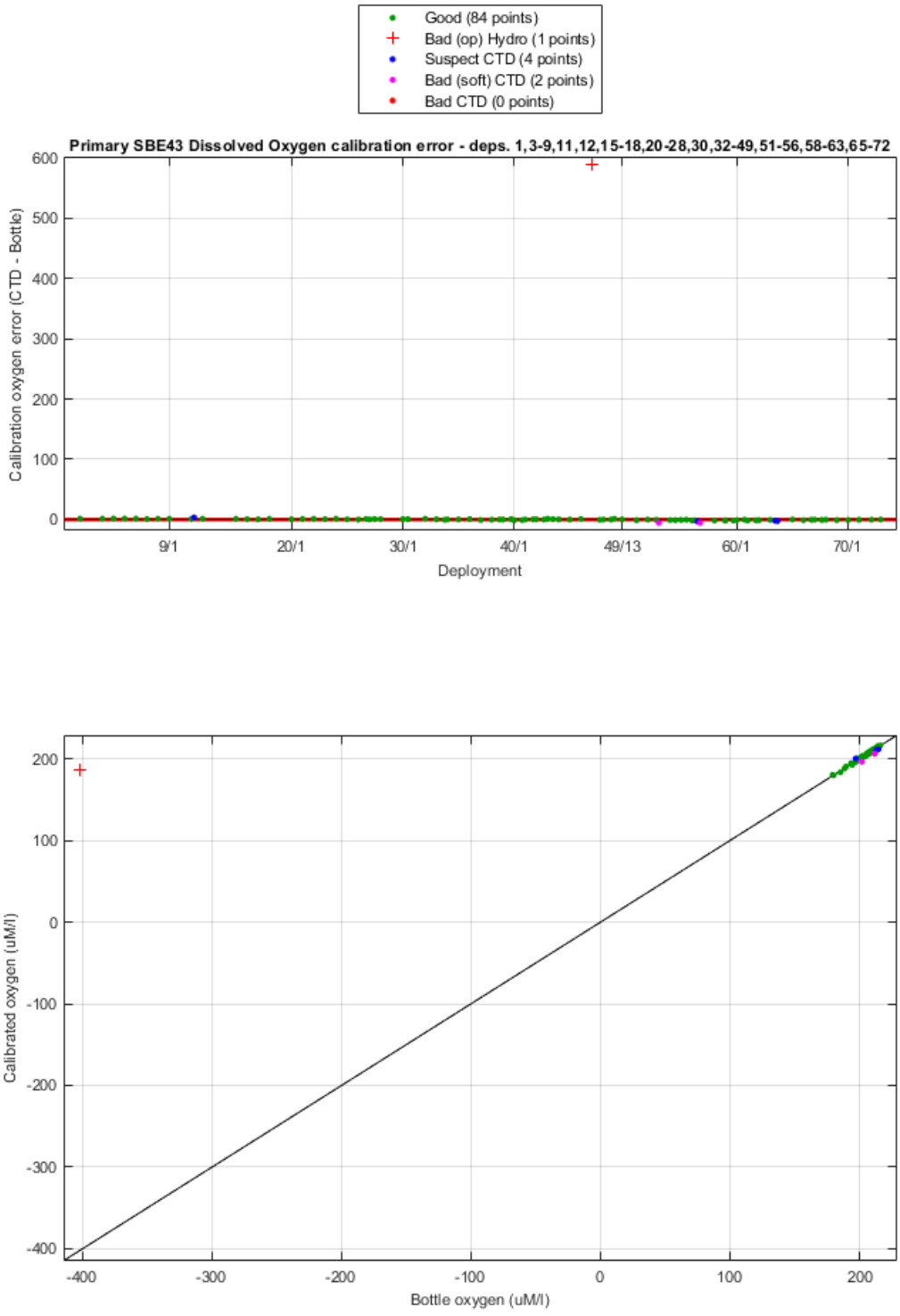

Figure 6. Dissolved Oxygen calibration, all deployments – primary sensor

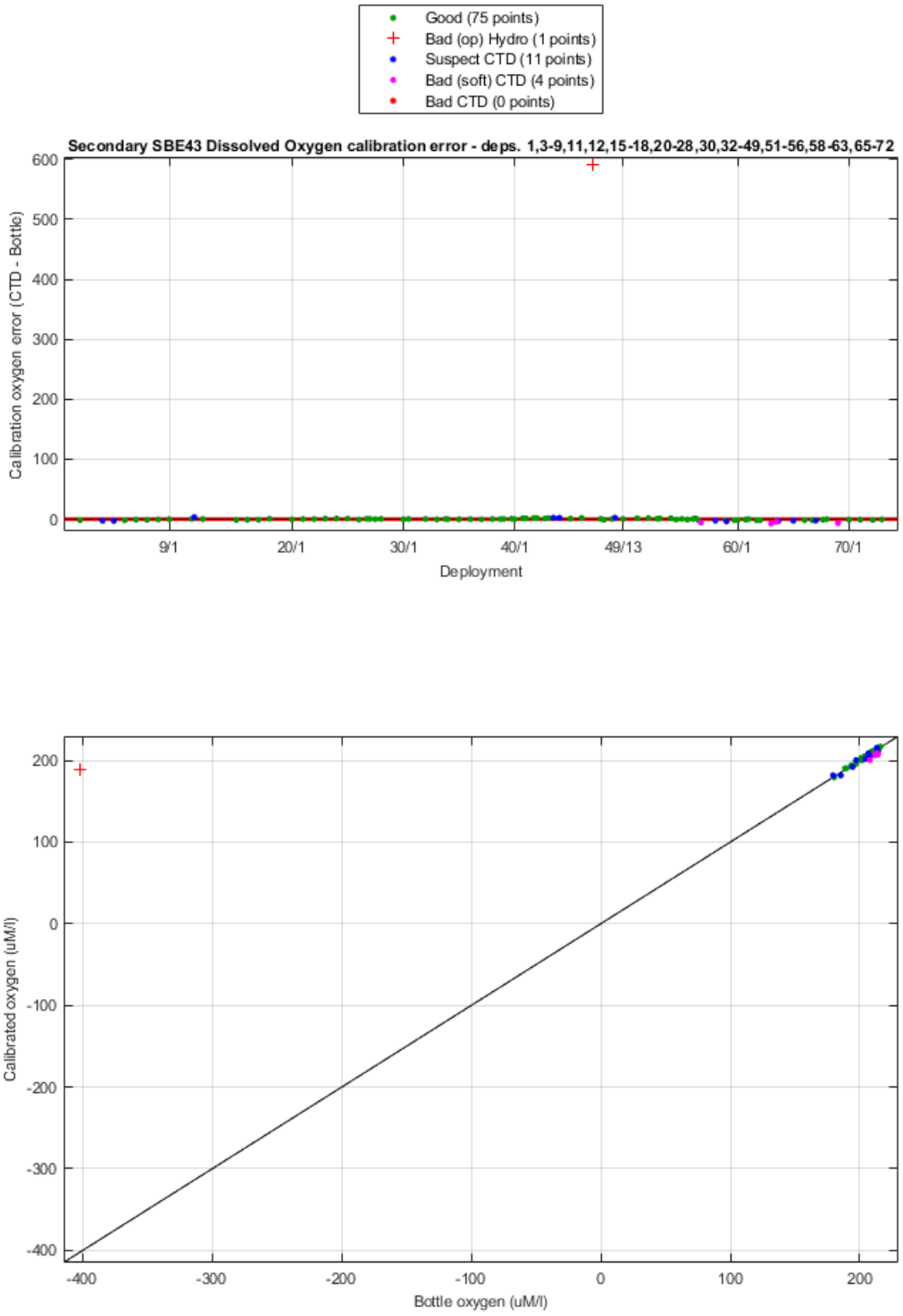

Figure 7. Dissolved Oxygen calibration, all deployments – secondary sensor

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 primary sensor.

Calibration	Apr2017 CSIRO	primary sensor	Mar2017 CSIRO	secondary sensor
Voffset	-0.4979	-0.44632 +- 0.038286	-5.0567800	-0.51796 +- 0.058551
Soc	0.4754	0.48338 +- 0.0089749	0.54573320	0.62113 +- 0.022804
Fit SD (uM)		0.6416		0.88316

Table 2. Dissolved Oxygen calibration

2.6 Other sensors

The C-Star transmissometer and Aquatracker Fluorometer were both used for all deployments. They were calibrated to give nominal outputs of 0-100 fsd (full scale deflection).

The Biospherical PAR sensor was also used for all deployments. The output is a nominal 0-5 volts. 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. There were no night-time casts. 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
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.

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