RV *Investigator*

# CTD Processing Report

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|---|---|
| **Voyage #:** | IN2016_V06 |
| **Voyage title:** | Sustained monitoring of the EAC: mass, heat and freshwater |
| **Depart:** | Brisbane, 08:00 Saturday 29th October 2016 |
| **Return:** | Brisbane, 13:00 Sunday 13th November 2016 |
| **Report compiled by:** | Pamela Brodie, Steve Van Graas, Peter Shanks |

# Contents

# 1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2016_v06 CTDs, from 29 Oct 2016 – 13 Nov 2016.

Data for 12 deployments were acquired using the Seabird SBE911 CTD unit 20, fitted with 24 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. 0013601 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. 84677 uM. The agreement between the CTD and bottle data was good.

The Biospherical photosynthetically active radiation (PAR), C-Star transmissometer and the Wetlabs ECO chlorophyll and CDOM sensors were also installed on the auxiliary A/D channels of the CTD.

# Voyage Details

## 1.1 Voyage Title

Sustained monitoring of the East Australian Current: mass, heat and freshwater transports.

## 1.2 Principal Investigators

The PI was Bernadette Sloyan (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

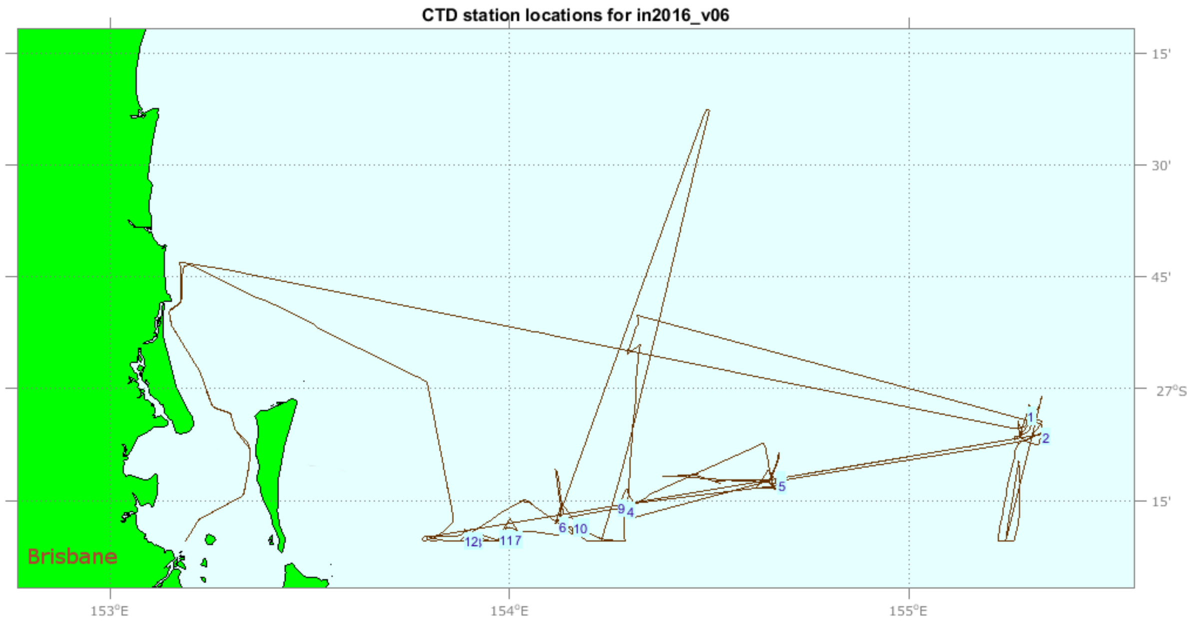



*Figure 1. Area of Operation for in2016_v01 CTDs*

# 2 Processing Notes

## 2.1 Background Information

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

There were 12 deployments for this voyage as shown on Figure 1.

Rapp Hydema heave compensation was used on the CTD winch for all casts, except for an instance when overheating of the winch occurred; heave compensation was off for the last half of the downcast of deployment 3.

The Biospherical photosynthetically active radiation (PAR), C-Star transmissometer, Chelsea 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 |
|---|---|---|---|---|---|
| Pressure | SBE9 *plus* V2 | 552 | P | 27/7/2016 | SBE Cal |
| Primary Temperature | Seabird SBE3T | 5450 | T0 | 1/3/2016 | CSIRO 3831T |
| Secondary Temperature | Seabird SBE3T | 5422 | T1 | 1/3/2016 | CSIRO 3830T |
| Primary Conductivity | Seabird SBE4C | 3309 | C0 | 2/3/2016 | CSIRO 3835C |
| Secondary Conductivity | Seabird SBE4C | 3169 | C1 | 2/3/2016 | CSIRO 3832C |
| Primary Oxygen | Seabird SBE43 | 3154 | A0 | 10/3/2016 | CSIRO 3837DO |

| | | | | | |
|---|---|---|---|---|---|
| Secondary Oxygen | Seabird SBE43 | 3159 | A1 | 10/3/2016 | CSIRO 3839DO |
| Biospherical Instr.PAR | QCP2300 | 70111 | A3 | 01/8/2016 | R12719 |
| Altimeter | PA500 | 5301 | A2 | 7/9/2016 | Tritech |
| Transmissometer | C-Star | CST-1421DR | A4 | 21/9/2016 | Wetlabs |
| Nephelometer | Seapoint Turbidity | 13142 | A5 | 3/5/2012 | Seapoint |
| Fluorometer | Aquatrack III | 06-5941-001 | A6 | 8/4/2016 | Chelsea |

*Table 1. CTD Sensor configuration for in2016_v06 CTDs*

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

There were 12 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.

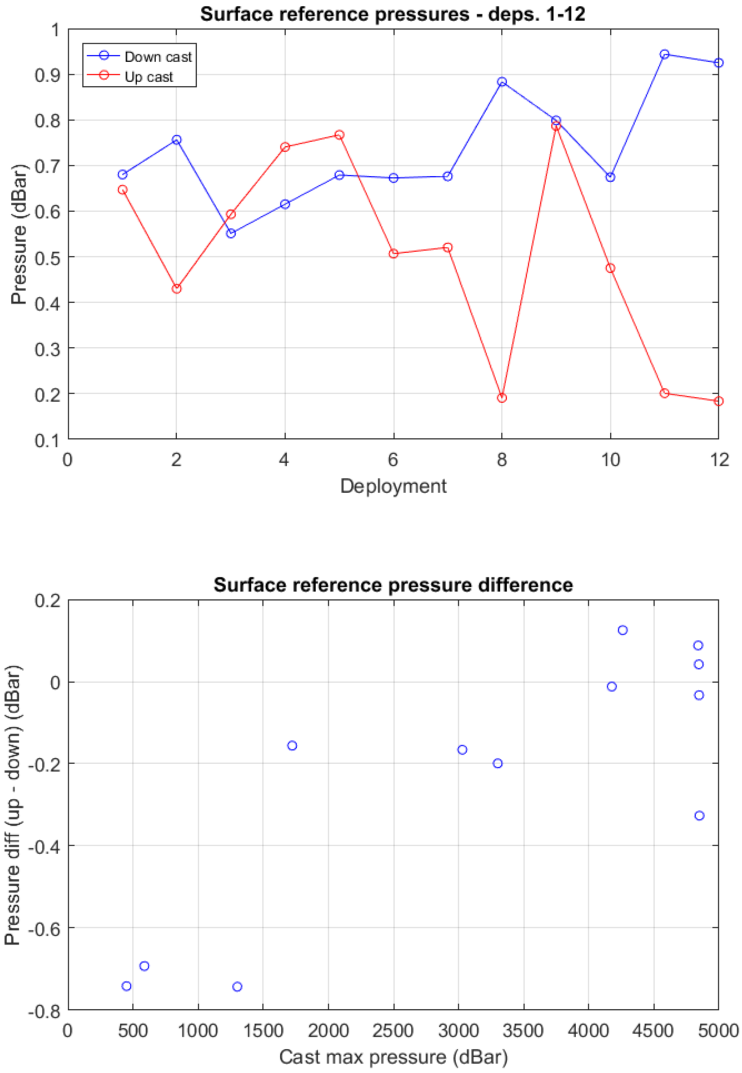



*Figure 2. CTD pressure reference*

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, the obvious exceptions being the 8th and 12th deployments.

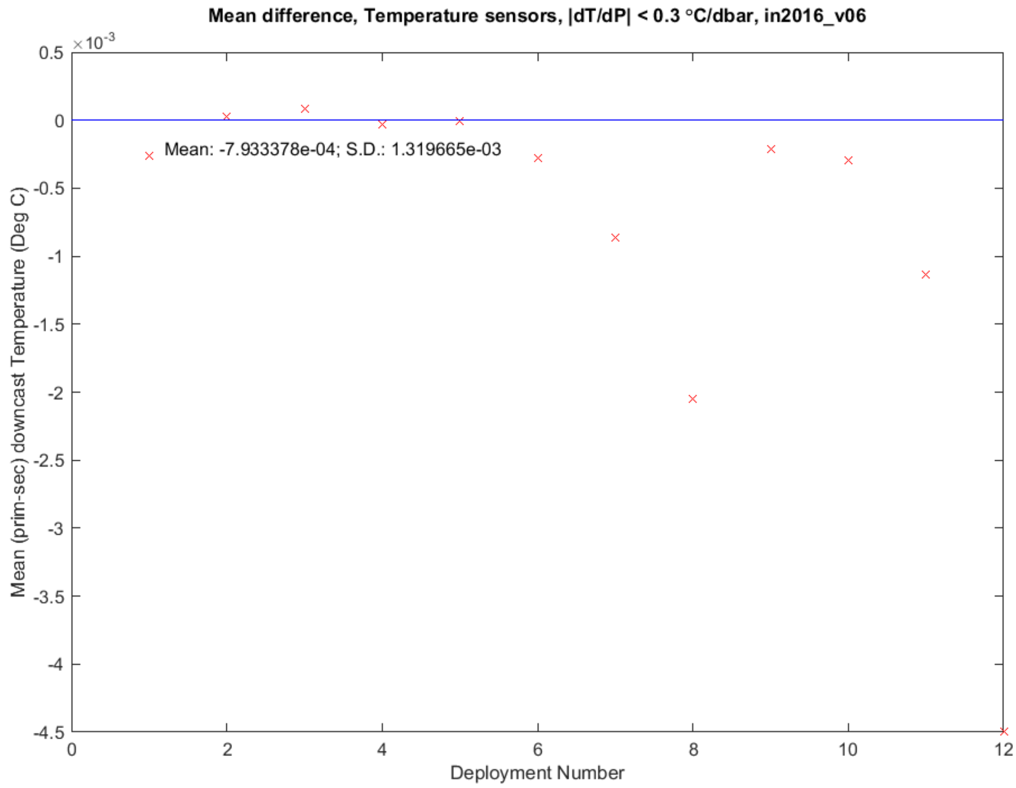
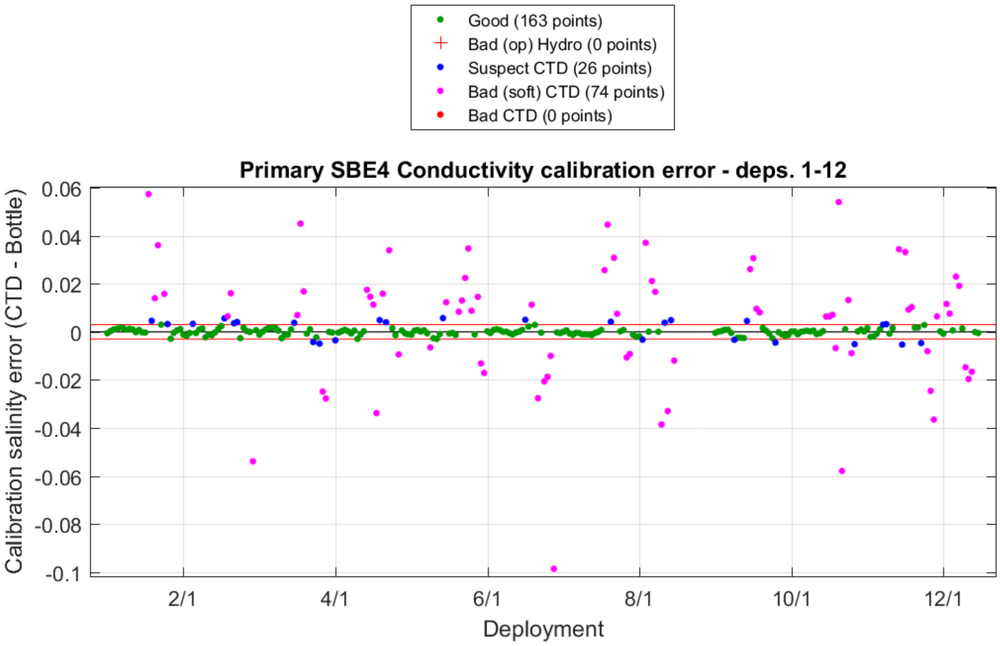



*Figure 3. Temperature sensor difference*

## 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 189 of the total of 263 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.



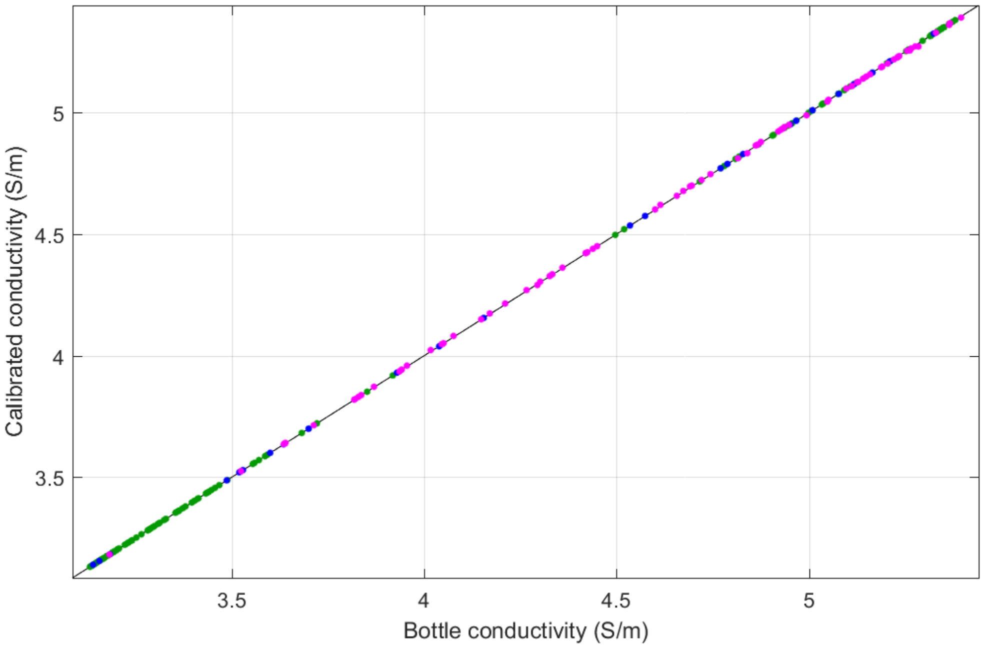




*Figure 4. Primary conductivity calibrations*

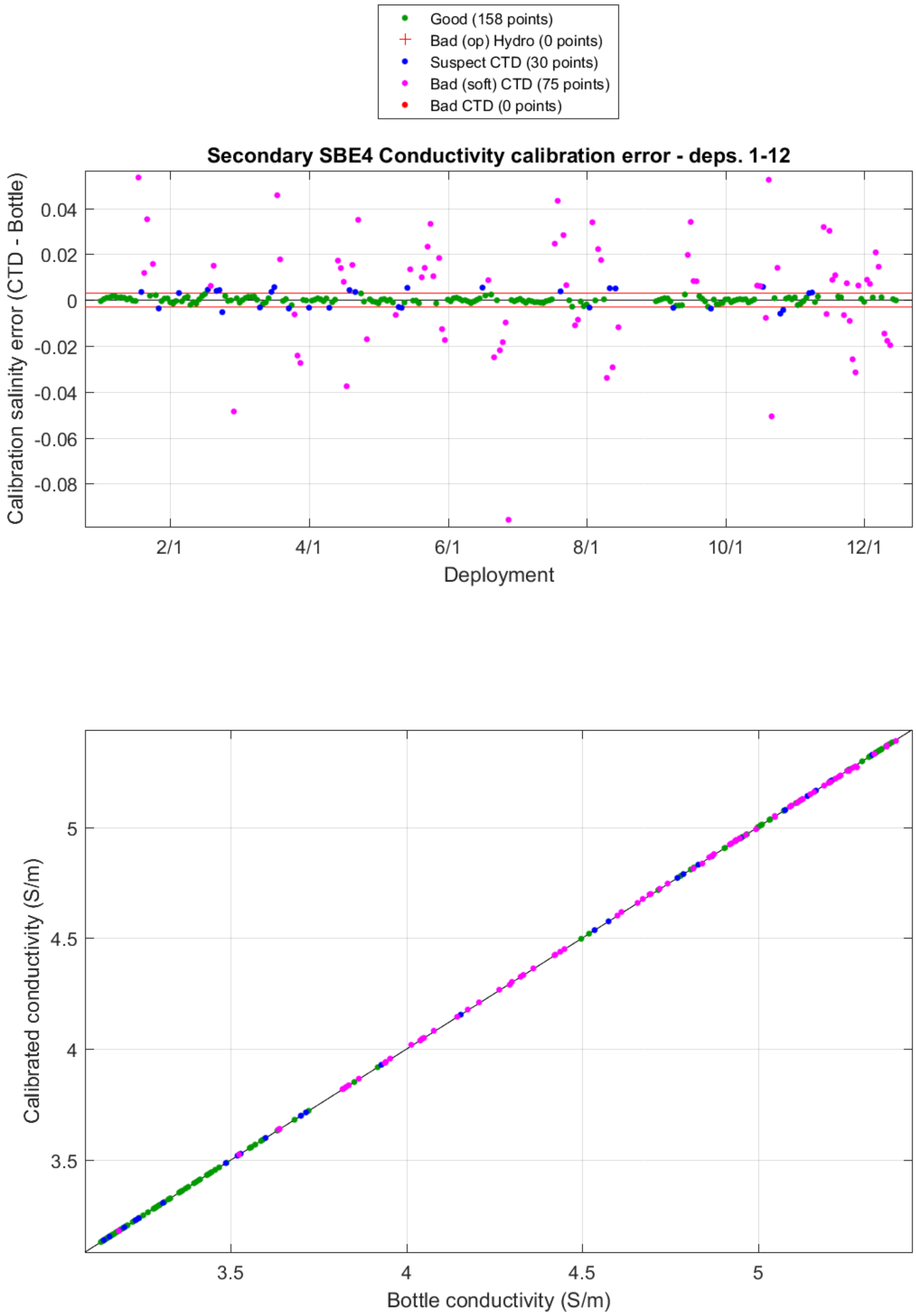



*Figure 5. Secondary conductivity calibrations*

The final result for the primary conductivity sensor was –

| | | |
|---|---|---|
| Scale Factor (a1) | 0.99965 | wrt. Manufacturer's calibration |
| Offset (a0) | 0.000069291 | ditto |
| Calibration S.D. (Sal) | 0.0013601 PSU | |

The calibration using the secondary conductivity sensor was –

| | | |
|---|---|---|
| Scale Factor (a1) | 0.99935 | wrt. Manufacturer's calibration |
| Offset (a0) | 0.00043789 | ditto |
| Calibration S.D. (Sal) | 0.0013906 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.

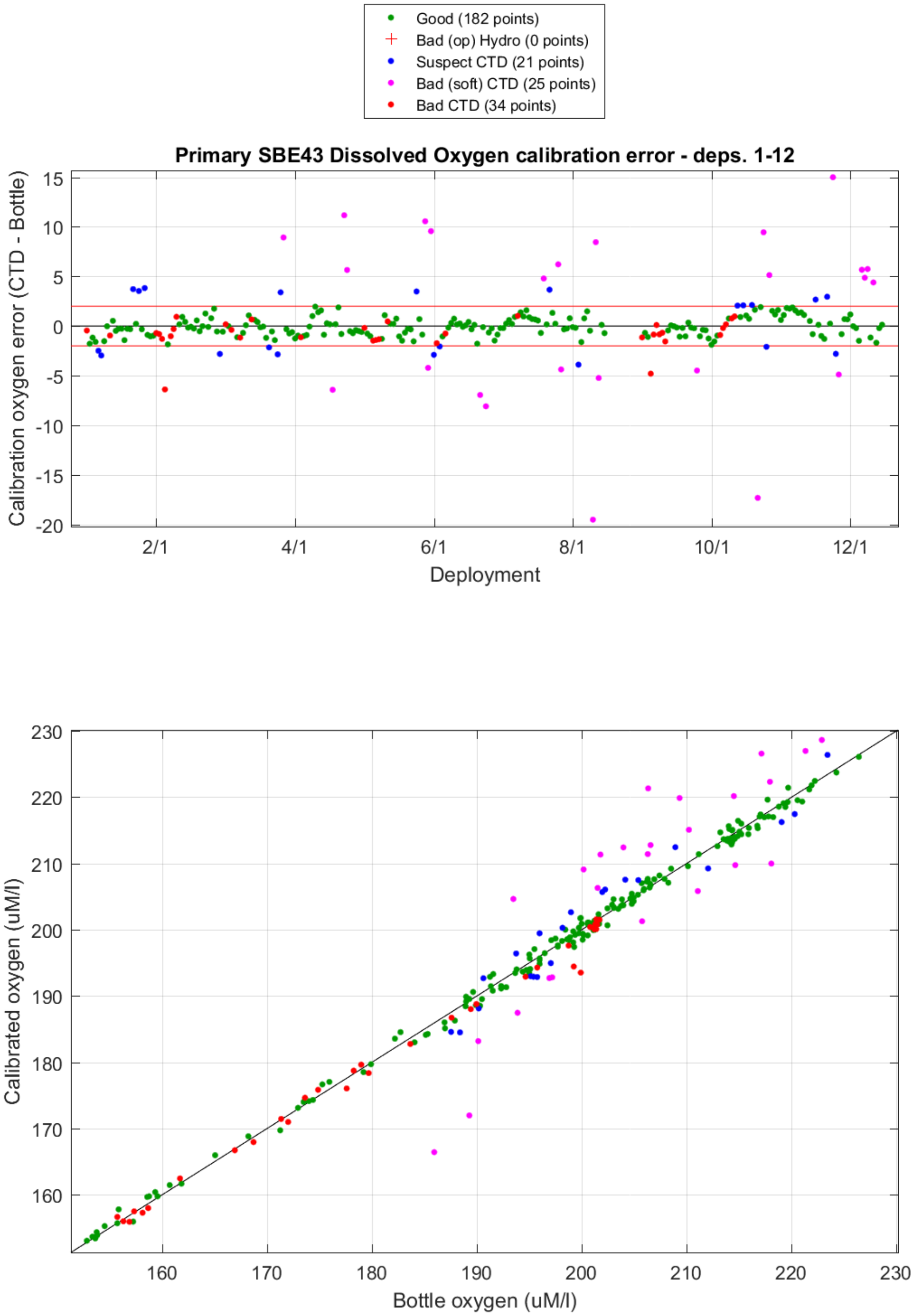
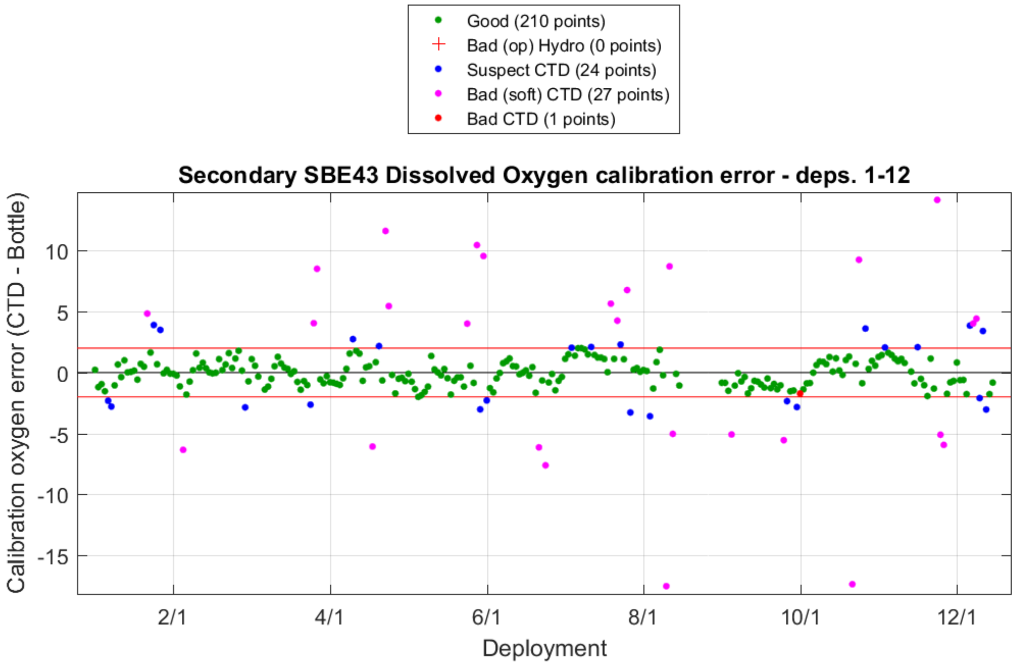



*Figure 6. Dissolved Oxygen calibration, all deployments – primary sensor*



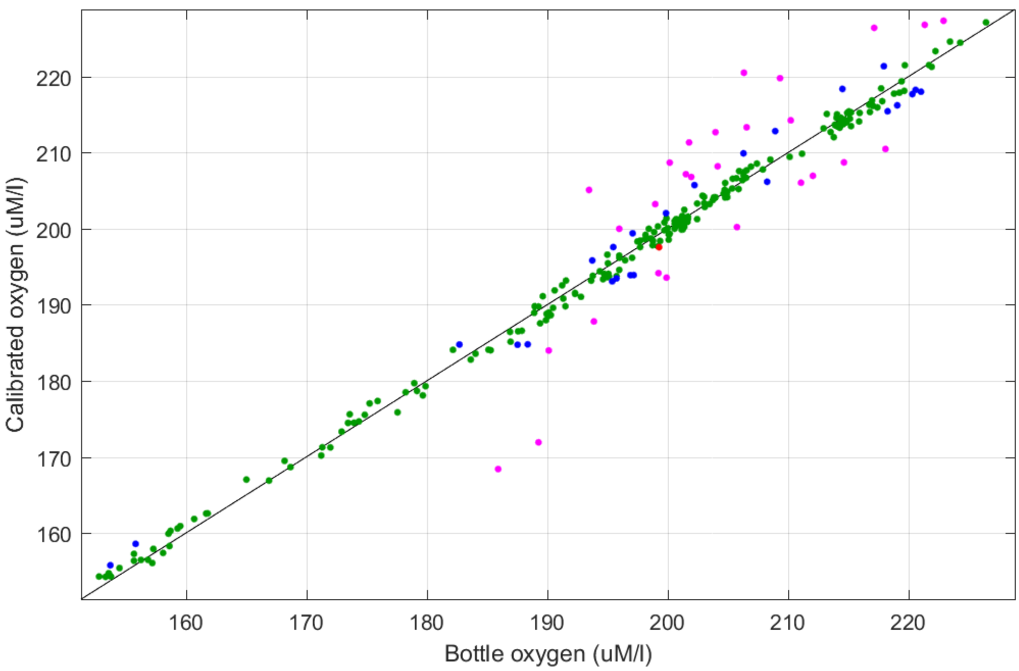




*Figure 7. Dissolved Oxygen calibration, all deployments – secondary sensor*

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 | Mar2016 CSIRO | primary sensor | Mar2016 CSIRO | secondary sensor |
|---|---|---|---|---|
| Voffset | -5.0133997e-01 | -4.7118e-01 | -5.05678e-01 | -4.6686e-01 |
| Soc | 4.7520554e-01 | 4.8983e-01 | 5.457332e-01 | 5.6907e-01 |
| Fit SD (uM) | | 0.7926161 | | 0.84677 |

*Table 2. Dissolved Oxygen calibration*

## 2.6 Other sensors

The C-Star transmissometer and Chelsea 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. 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 |
|---|---:|---:|---:|
| 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.

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