

RV Investigator

CTD Processing Report

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| Voyage #: | IN2016_V03 |
| Voyage title: | Monitoring Ocean Change and Variability along 170° W from the ice edge to the equator. |
| Depart: | Hobart, 0900 Tuesday, 26 April 2016 |
| Return: | Hobart, 0800 Thursday, 30 June 2016 |
| Report compiled by: | Steven Van Graas |



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1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2016_v03, from 26 Apr 2016 – 30 Jun 2016.

Data for 141 deployments were acquired using the Seabird SBE911 CTD 20, fitted with 36 ten litre bottles on the rosette sampler. CSIRO supplied calibrations were applied to the temperature, conductivity, oxygen, and pressure data. The data were subjected to automated QC to remove spikes and out-of-range values.

The final conductivity calibration is based on multiple deployment groupings, due to sensor and deck box changes. Processing was performed on each unique sensor configuration in order to best account for the individual characteristics of each sensor. The final calibration from the primary sensor for casts 1-7 had a standard deviation (S.D) of 0.00088 PSU, a S.D of 0.00117 for casts 8-46, and S.D of 0.00114 for casts 47-141, well within our target of 'better than 0.002 PSU'. The standard product of 1 dbar binned averaged were produced using data from the primary temperature and conductivity sensors, and the secondary Oxygen sensor.

Similarly, the dissolved oxygen data were calibrated in groups of deployments due to sensor changes. The dissolved oxygen data calibration fit had a S.D. of 0.865uM for casts 1-7, S.D. of 0.906uM for casts 8-46, S.D. of 1.05uM for casts 47-63, 0.739uM for casts 64-83, S.D. of 0.874uM for casts 84-110, and a S.D. of 1.0479 for casts 111-141. The agreement between the CTD and bottle data was good.

A Fluorometer, Transmissometer, and altimeter were also installed and logged on the auxiliary A/D channels of the CTD.

2 Voyage Details

2.1 Title

Monitoring Ocean Change and Variability along 170° W from the ice edge to the equator.

2.2 Principal Investigators

Bernadette Sloyan – Leg 1, Susan Wijffels – Leg 2

2.3 Voyage Objectives

The scientific objectives for in2016_v03 were outlined in the Voyage Plan.

For further details, refer to the Voyage Plan and/or summary which can be viewed on the CSIRO Marine and Atmospheric Research web site.

2.4 Area of operation

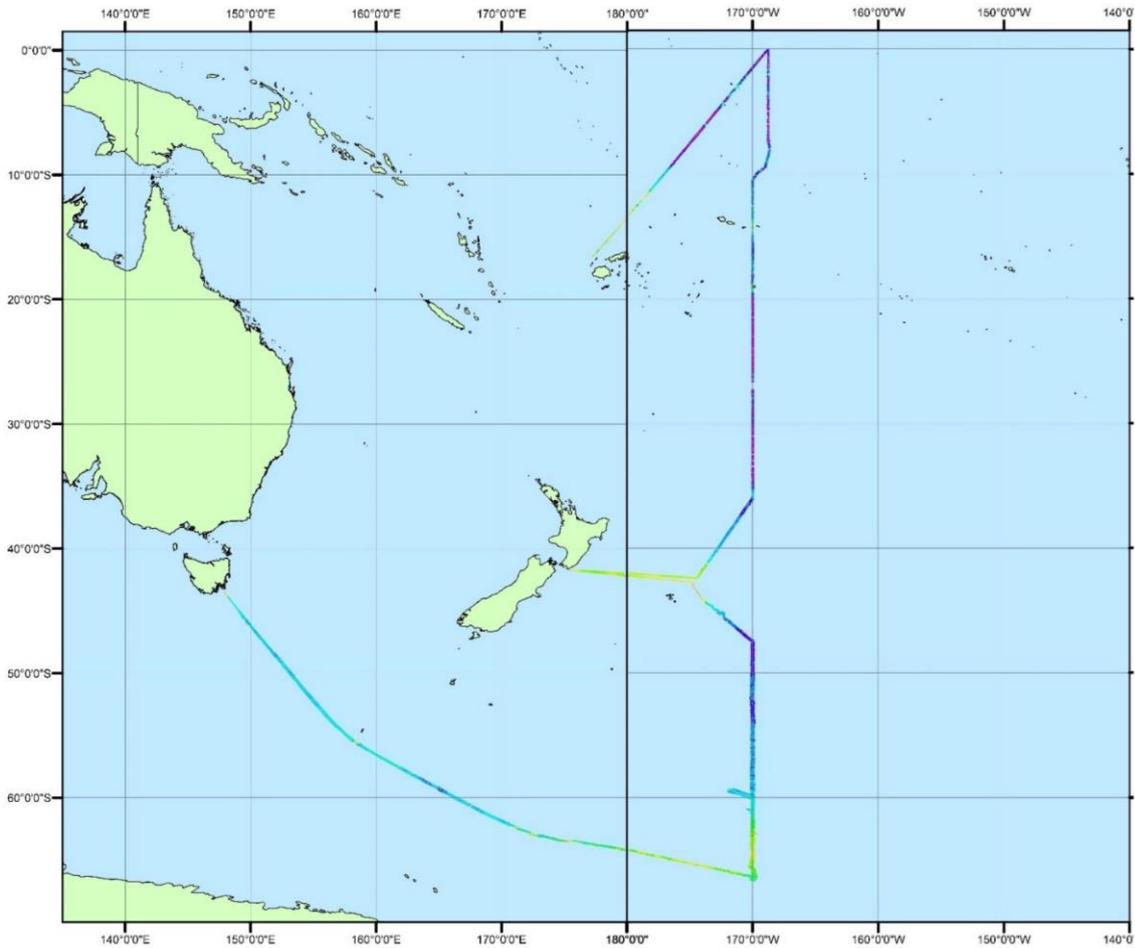


FIGURE 1. Area of operation for in2016_v03

3 Processing Notes

3.1 Background Information

The data for this voyage were acquired with the CSIRO CTD unit #20 and #22, Seabird SBE911 with dual conductivity and temperature sensors.

The CTD was additionally fitted with SBE43 dissolved oxygen sensors, an altimeter, Transmissometer and Fluorometer. Additionally the CTD unit provided power only for two SBE61 units. The sensors that were equipped are described in Table 1 below.

| Description | Sensor | Casts | Serial No. | A/D | Calibration Date | Calibration Source |
|---------------------|------------------|-------------|------------|-----|------------------|--------------------|
| Pressure | Digiquartz SBE9+ | 1-7, 47-141 | 552 | P | 2016-03-09 | CSIRO Cal Lab |
| Pressure | Digiquartz SBE9+ | 8-46 | 1243 | P | 2016-03-09 | CSIRO Cal Lab |
| Primary Temperature | Seabird SBE3plus | 1-46 | 4722 | T0 | 2016-03-01 | CSIRO Cal Lab |

| | | | | | | |
|----------------------------|--------------------------|---------------|-------------|----|------------|---------------|
| Primary Temperature | Seabird SBE3 <i>plus</i> | 47-141 | 6022 | T0 | 2015-07-15 | CSIRO Cal Lab |
| Secondary Temperature | Seabird SBE3 <i>plus</i> | 1-46 | 4522 | T1 | 2016-03-01 | CSIRO Cal Lab |
| Secondary Temperature | Seabird SBE3 <i>plus</i> | 47-93 | 6024 | T1 | 2015-07-24 | CSIRO Cal Lab |
| Secondary Temperature | Seabird SBE3 <i>plus</i> | 94-141 | 4718 | T1 | 2015-10-29 | CSIRO Cal Lab |
| Primary Conductivity | Seabird SBE4C | 1-46 | 3868 | C0 | 2016-03-02 | CSIRO Cal Lab |
| Primary Conductivity | Seabird SBE4C | 47-141 | 4425 | C0 | 2015-07-08 | CSIRO Cal Lab |
| Secondary Conductivity | Seabird SBE4C | 1-46, 114-141 | 4426 | C1 | 2015-07-08 | CSIRO Cal Lab |
| Secondary Conductivity | Seabird SBE4C | 47-88 | 2312 | C1 | 2015-11-24 | CSIRO Cal Lab |
| Secondary Conductivity | Seabird SBE4C | 89-113 | 2235 | C1 | 2015-11-24 | CSIRO Cal Lab |
| Primary Dissolved Oxygen | SBE43 | 1-46 | 3154 | A0 | 2016-03-10 | CSIRO Cal Lab |
| Primary Dissolved Oxygen | SBE43 | 47-141 | 1794 | A0 | 2016-03-10 | CSIRO Cal Lab |
| Secondary Dissolved Oxygen | SBE43 | 1-46, 111-141 | 3198 | A1 | 2015-08-12 | CSIRO Cal Lab |
| Secondary Dissolved Oxygen | SBE43 | 47-111 | 3199 | A1 | 2015-08-12 | CSIRO Cal Lab |
| Transmissometer | C-Star | 1-141 | CST-1421DR | A2 | 2015-08-14 | Manufacturer |
| Altimeter | PA500 | 1-141 | 5301.228403 | A3 | 2015-05-22 | Manufacturer |
| Fluorometer | Chelsea Aquatracka III | 57-141 | 0088-3598C | A6 | 2014-02-06 | Manufacturer |

TABLE 1. CTD Sensor configuration on in2016_v03

Water samples were collected using a Seabird SBE32, 24-bottle rosette sampler. Sampling was from 36 ten litre bottles which were fitted to the frame. There were 141 deployments.

The raw CTD data were converted to scientific units and written to netCDF format files for processing using the Matlab-based, CapPro package.

The CapPro 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. Filtering for bad data caused by ship heave affecting the velocity of the package was also applied to the binned average 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.

3.2 Pressure and temperature calibration

The 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. The jump in the plot that is evident at cast 47 is due to changing the pressure sensor.

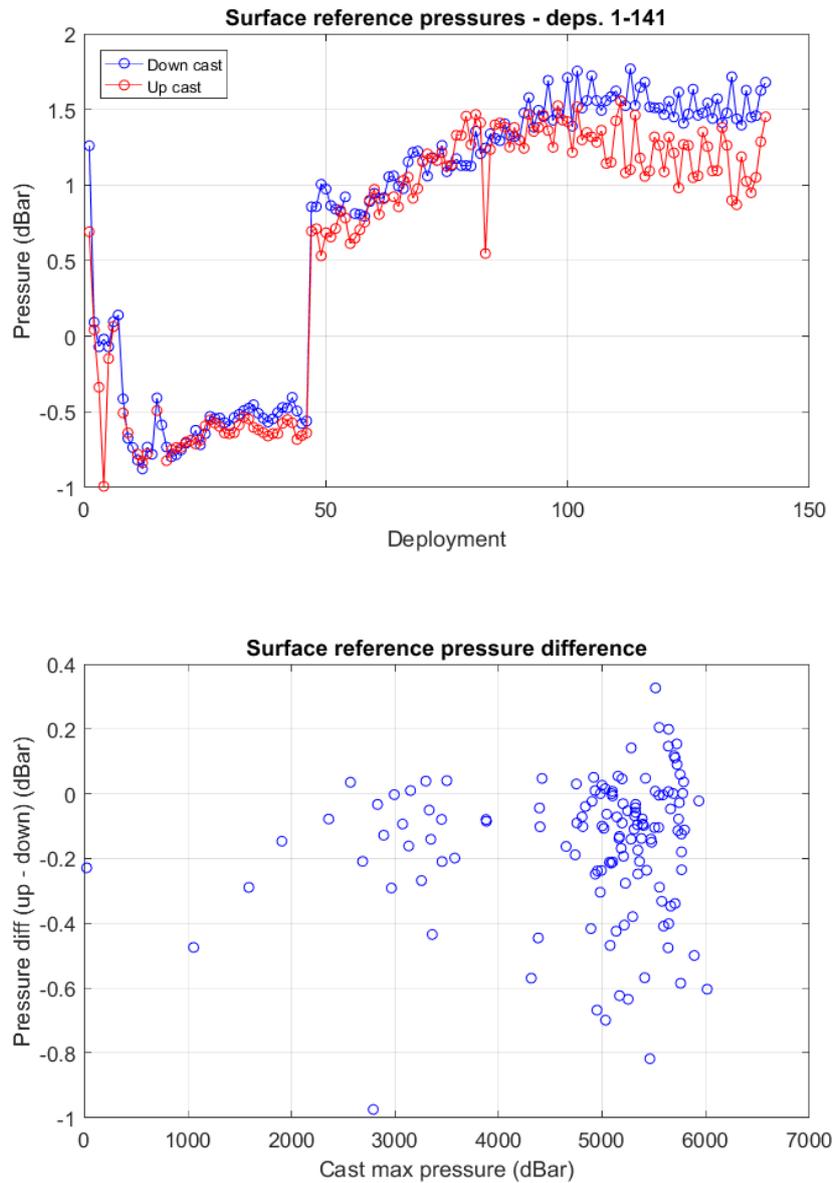
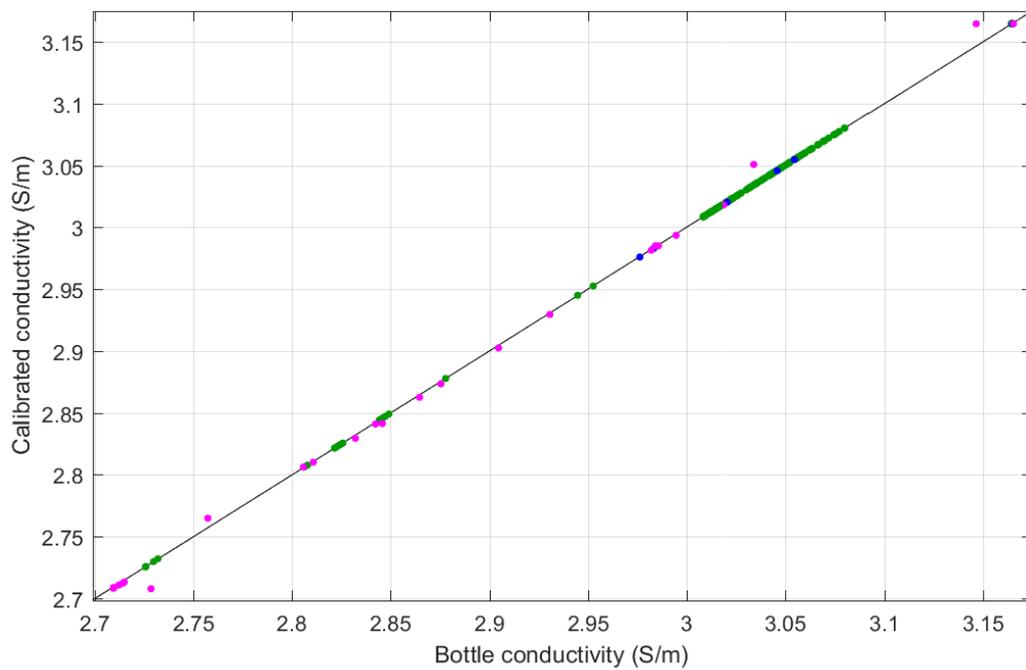
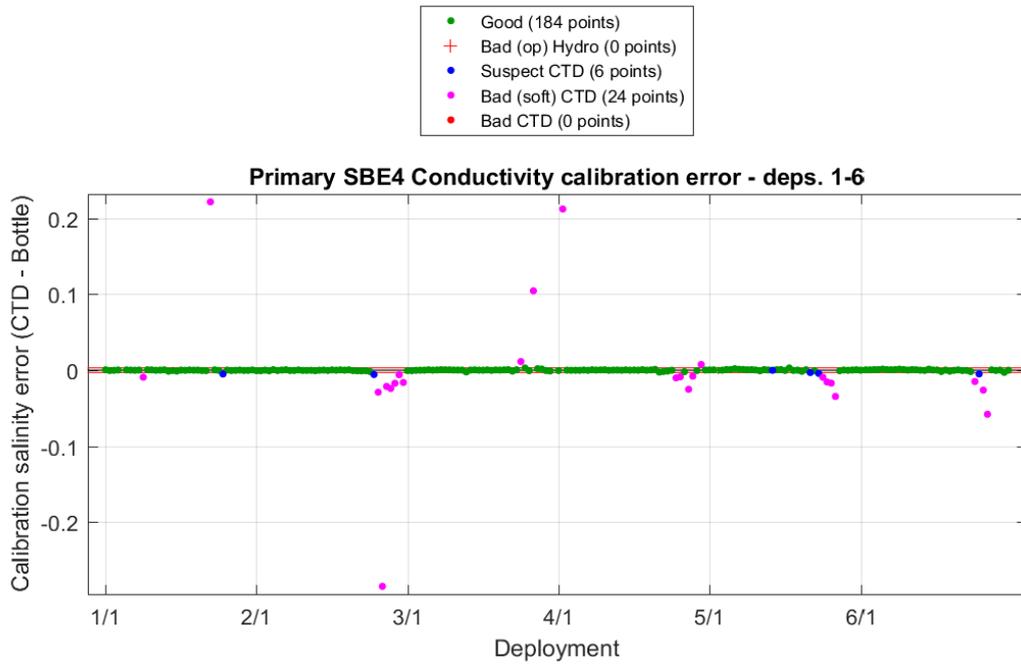
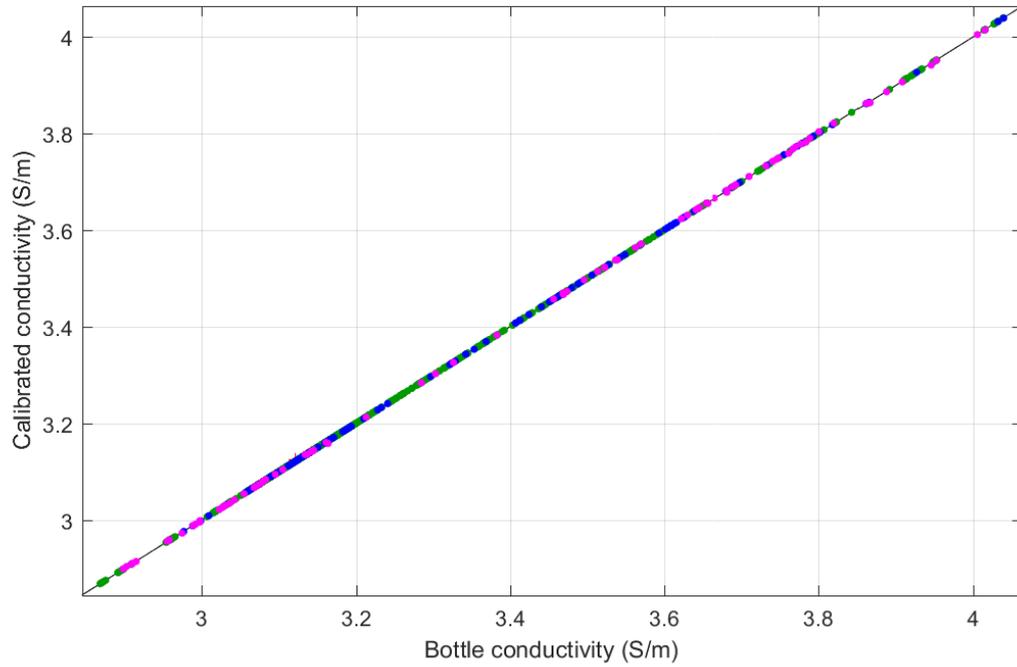
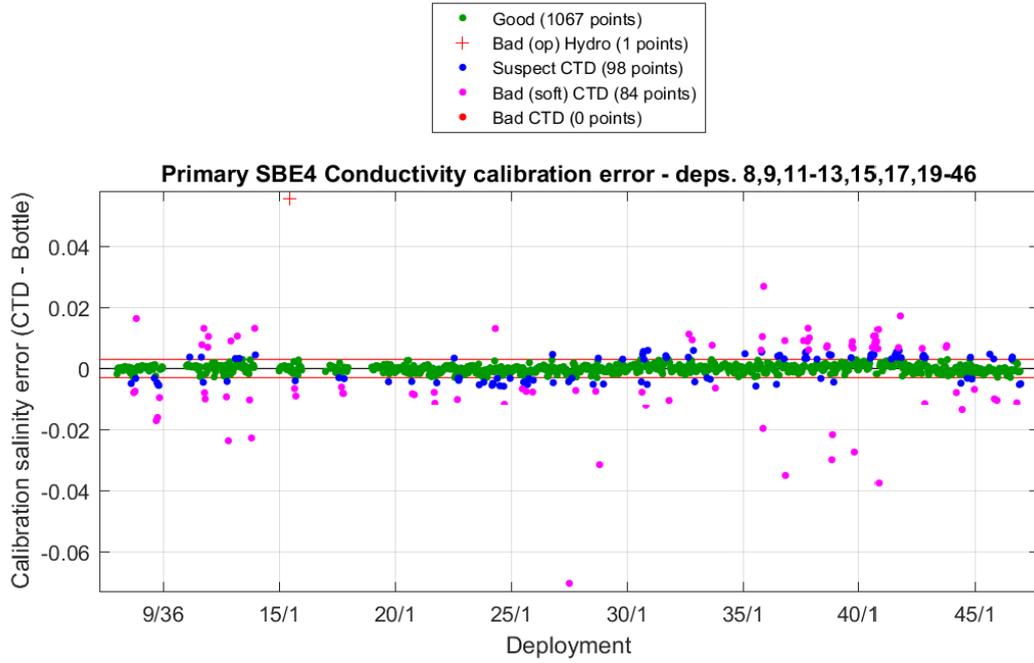


FIGURE 2. CTD pressure offsets

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, for all groups of deployments processed. The calibration was based upon the sample data for an overall total of 3654 of the total of 4720 samples taken during deployments (the outliers marked in Figure 4 below with the magenta diamonds are excluded from the calibration).





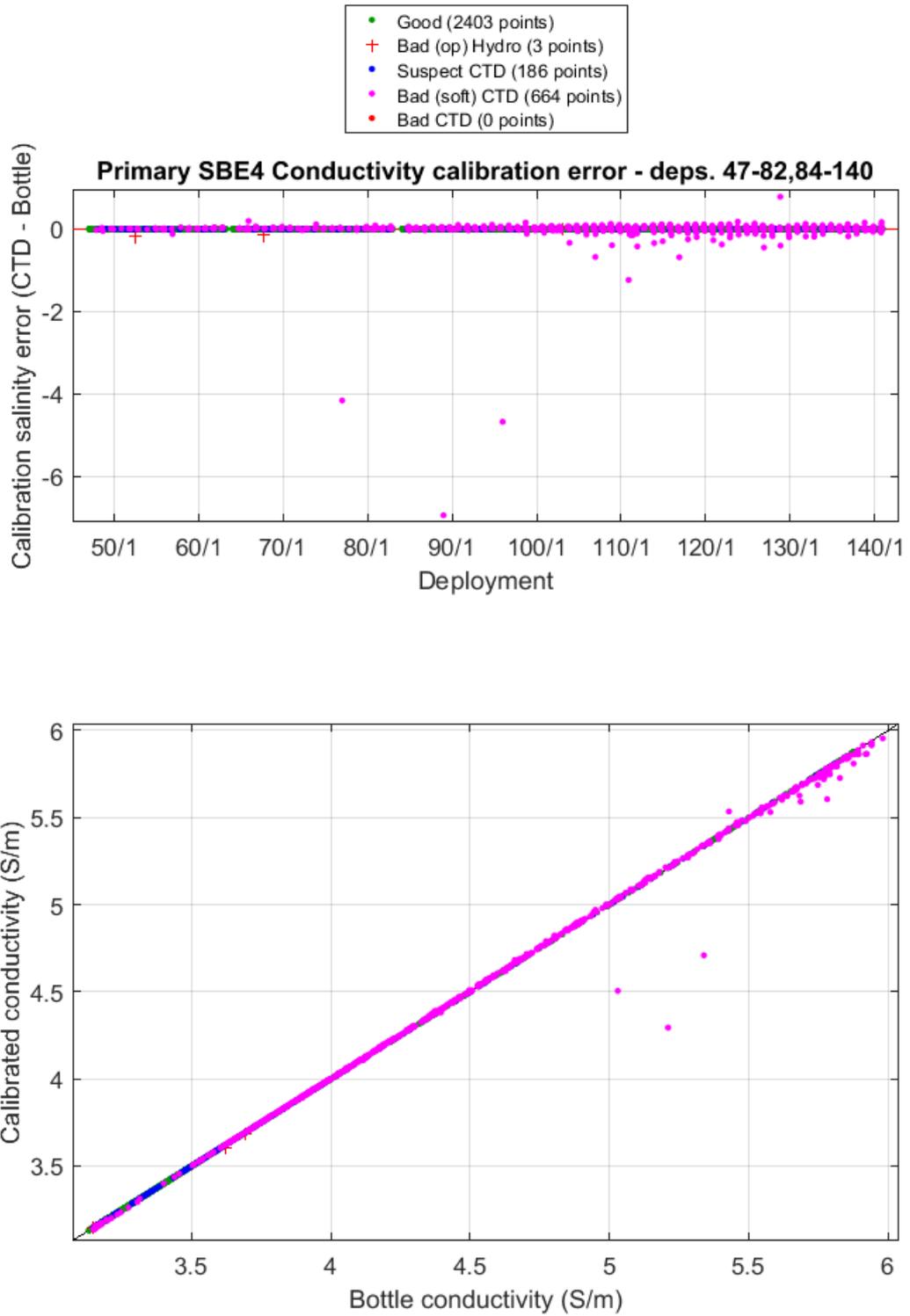


FIGURE 4. CTD - bottle salinity plot.

The final result for the primary conductivity sensor for casts 1 - 7 was –

| | | |
|------------------------|----------------|------------------------|
| Scale Factor (a1) | 0.99943 | wrt. CSIRO calibration |
| Offset (a0) | -8.6338e-05 | ditto |
| Calibration S.D. (Sal) | 0.00087776 PSU | |

The final result for the primary conductivity sensor for casts 8 - 46 was –

| | | |
|------------------------|---------------|------------------------|
| Scale Factor (a1) | 0.99941 | wrt. CSIRO calibration |
| Offset (a0) | -2.4759e-05 | ditto |
| Calibration S.D. (Sal) | 0.0011708 PSU | |

The final result for the primary conductivity sensor for casts 47 - 141 was –

| | | |
|------------------------|---------------|------------------------|
| Scale Factor (a1) | 1.0005 | wrt. CSIRO calibration |
| Offset (a0) | -0.00069281 | ditto |
| Calibration S.D. (Sal) | 0.0011492 PSU | |

This is a good calibration. We normally aim for a S.D. of 0.002 psu for ‘typical’ oceanographic voyages. The above calibration factors were applied to all deployments in their respective calibration groups.

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

The calibration using the secondary conductivity sensor was well beyond our acceptable standard deviation range, and as such was not applied.

3.4 Dissolved Oxygen Sensor Calibration

3.4.1 SBE calibration procedure

Sea-Bird (2010a) 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 (2010b) 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.

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 (2010c).

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.

Multiple deployment calibration groups were used with the associated SBE43 up-cast data to compute the new Soc and Voffset coefficients, due to changes of sensors throughout the voyage.

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. As expected, over time, the increasing Soc scale factors show the SBE43 sensor is losing sensitivity.

The calibrations were applied for each sensor and the averaged files were created using the result from the primary sensor for casts 1-7, and the secondary sensor for casts 8 – 141. These groups were divided further due to changing the CTD unit. The primary oxygen sensor for casts 47-141 calibrated extremely poorly.

| Casts | | CSIRO calibration of sensor | sensor calibration | Primary/Secondary |
|---------|-------------|-----------------------------|--------------------|-------------------|
| 1-7 | Voffset | -0.50133997 | -0.47032 | Primary |
| | Soc | 0.47520554 | 0.49124 | |
| | Fit SD (uM) | | 0.86539 | |
| 8-46 | Voffset | -0.4982 | -0.45105 | Secondary |
| | Soc | 0.4241 | 0.42153 | |
| | Fit SD (uM) | -- | 0.9063 | |
| 47-63 | Voffset | -0.4873 | -0.45033 | Secondary |
| | Soc | 0.5318 | 0.53553 | |
| | Fit SD (uM) | -- | 1.0502 | |
| 64-83 | Voffset | -0.4873 | -0.45744 | Secondary |
| | Soc | 0.5318 | 0.5505 | |
| | Fit SD (uM) | -- | 0.7398 | |
| 84-110 | Voffset | -0.4873 | -0.44407 | Secondary |
| | Soc | 0.5318 | 0.54158 | |
| | Fit SD (uM) | -- | 0.87393 | |
| 111-141 | Voffset | -0.4982 | -0.41699 | Secondary |
| | Soc | 0.4241 | 0.40081 | |
| | Fit SD (uM) | -- | 1.0479 | |

TABLE 2. Dissolved oxygen calibrations

3.5 Other sensors

The Chelsea fluorometer was used for deployments 57 onwards. The fluorometer has been calibrated to give nominal outputs of 0-100 fsd (full scale deflection).

3.6 Bad data detection

The limits for each sensor are configured in the CAP the 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 | -1 | 500 | 0.5 |
| fluorometer | 0 | 100 | 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

Sloyan, Wijffels., 2016: The RV Investigator. Voyage Plan IN2016_V03 -
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