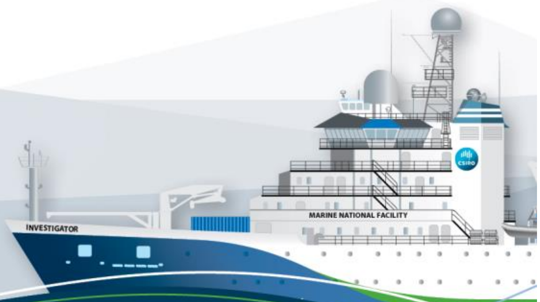
Marine National Facility

RV *Investigator*

CTD Processing Report

Voyage #:	IN2016_V01
Voyage title:	Heard Earth-Ocean Biosphere Interactions
Depart:	Fremantle, 1400z, 8 January 2016
Return:	Hobart, 0800z, 26 February 2016
Report compiled by:	Peter Shanks, Hugh Barker



Contents

1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2016_v01 CTDs, from 08 Jan 2016 – 26 Feb 2016.

Data for 55 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 0.0013449 PSU, within our target of 'better than 0.002 PSU'. The standard product of 1dbar binned averaged were produced using data from the secondary oxygen and primary temperature and conductivity sensors.
The dissolved oxygen data calibration fit had a S.D. of 0.91455uM. The agreement between the CTD and bottle data was good.

A dual channel Fluorometer and an oxidation-reduction potential (ORP) sensor were also installed on the auxiliary A/D channels of the CTD .

NOTE: The netCDF variable in the binned file has the incorrect instrument data for the fluorometer.

In the published data it is as follows:
fluorometer:manufacturer = "Chelsea" ;
fluorometer:model = "Aquatracka" ;
fluorometer:serialNo = "065941001" ;
fluorometer:unitNo = 2. ;

The data should read:
fluorometer:manufacturer = "Wetlabs" ;
fluorometer:model = " FLBBRTD" ;
fluorometer:serialNo = "3698" ;
fluorometer:unitNo = 2. ;

The actual data is unaffected.

2 Voyage Details

2.1 Title

HEOBI: Heard Earth-Ocean-Biosphere Interactions.

2.2 Principal Investigators

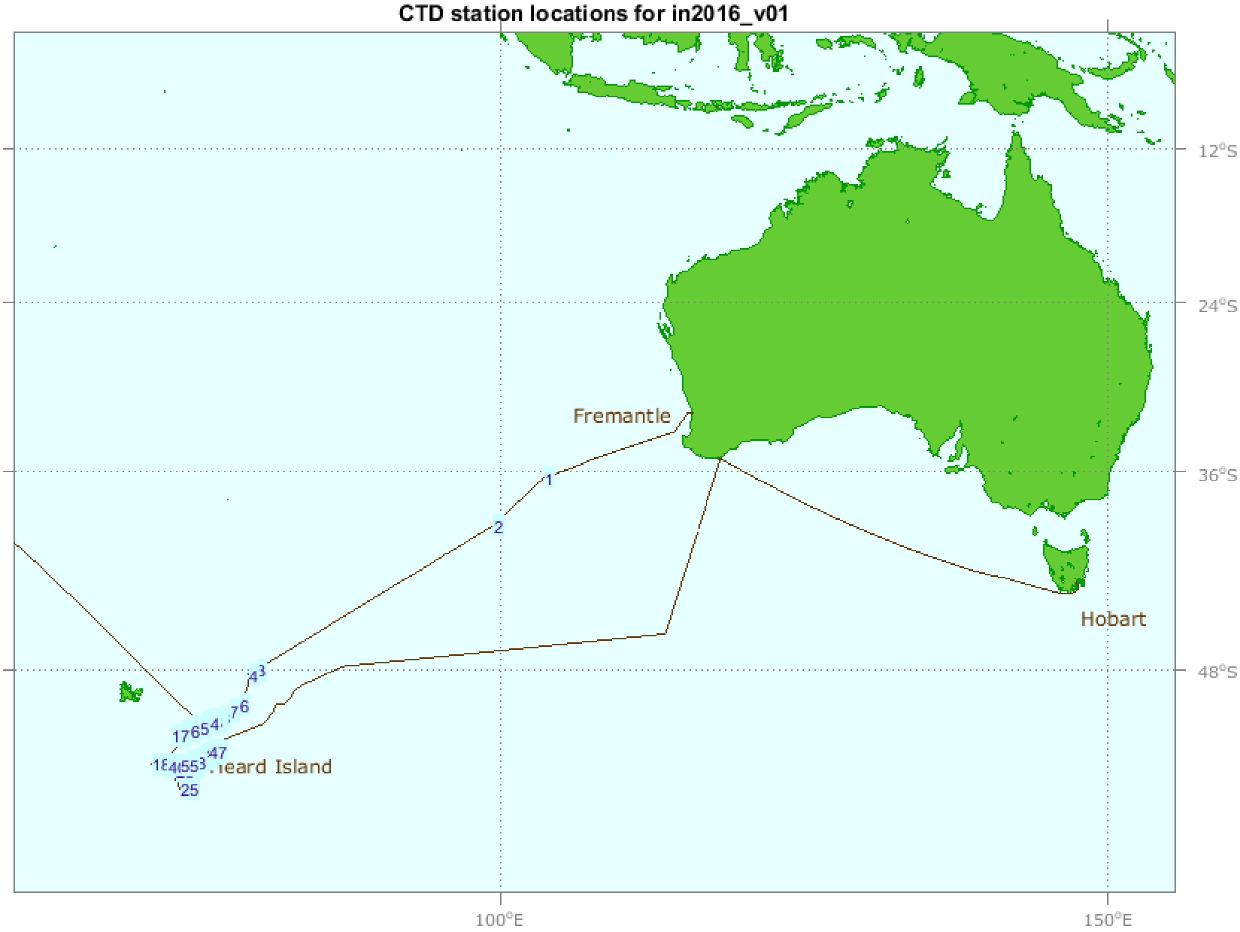
The PI was Professor Millard (Mike) Coffin (Institute for Marine & Antarctic Studies, University of Tasmania).

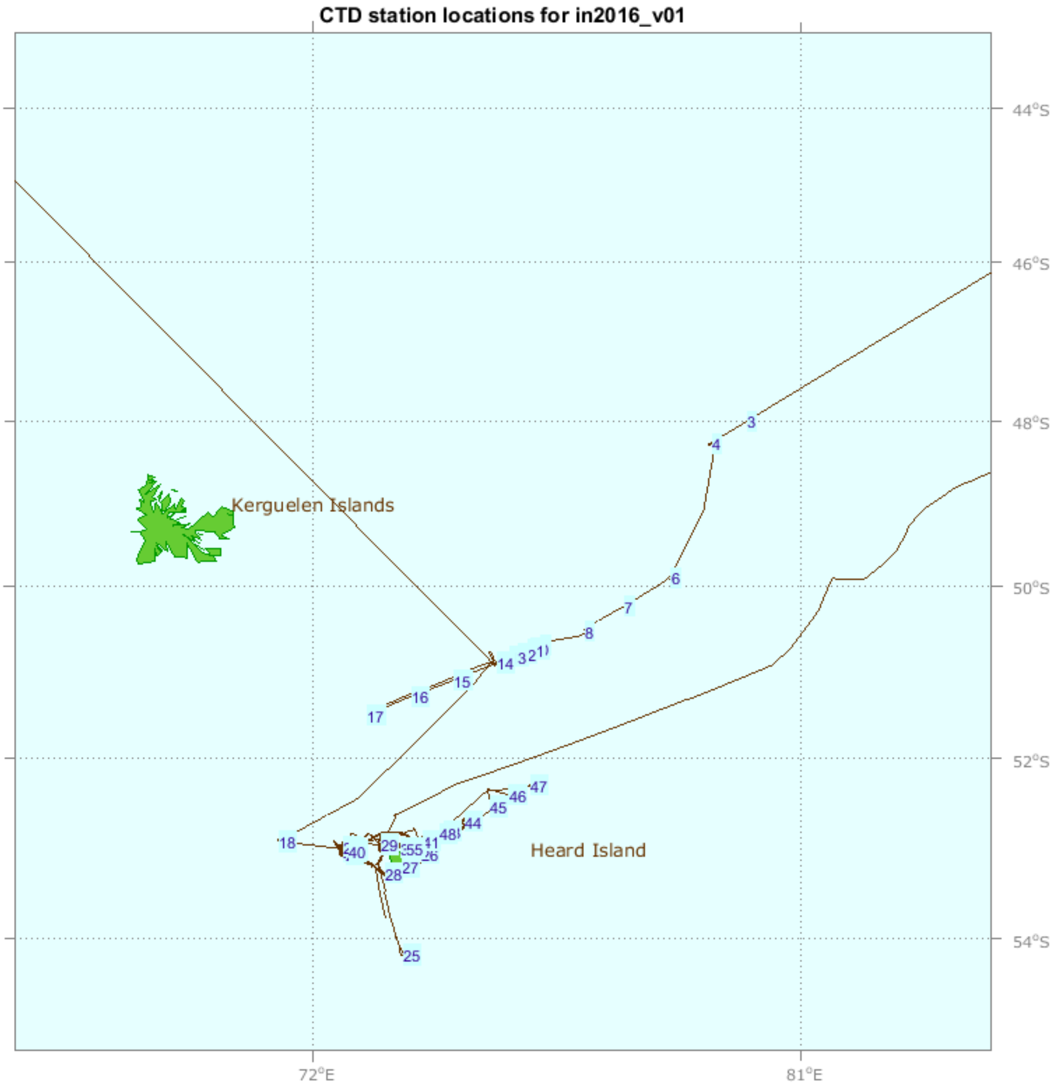
2.3 Voyage Objectives

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.

2.4 Area of operation

CTD station locations for in2016_v01





3 Processing Notes

3.1 Background Information

The data for this voyage were acquired with CTD SBE9+ unit 20 with dual conductivity and temperature sensors. The secondary conductivity sensor developed problems between casts 18 and 19 and was replaced with the spare for all subsequent casts.
There were 55 deployments for this voyage as shown on Figure 1.

The CTD was additionally fitted with SBE43 dissolved oxygen sensors, a Biospherical photosynthetically active radiation (PAR), C-Star transmissometer, ORP4CTD ORP and a Fluorometer. These sensors are described in Table 1 below.

Description	Sensor	Serial No.	Calibration Date
Primary Temperature	Sea-Bird Electronics Inc SBE3T	4722	27-Feb-15
Primary Conductivity	Sea-Bird Electronics Inc SBE4C	3868	26-Feb-15
DigiQuartz Pressure	SEABIRD SBE9plus	552	8-Apr-15
Secondary Temperature	Sea-Bird Electronics Inc SBE3T	4522	27-Feb-15
Secondary Conductivity	Sea-Bird Electronics Inc SBE4C	3168/ 2312 (cast 19 onwards)	26-Feb-15/ 24-Nov-2015
(A0) Primary SBE43 Oxygen	Sea-Bird Electronics Inc SBE43	1794	11-Feb-15
(A1) Secondary SBE43 Oxygen	Sea-Bird Electronics Inc	3159	6-Jun-15
(A3) Altimeter	Tritech PSA500/6	5301.228403	22-May-15
(A2) PAR	Biospherical Instruments Inc. QCP-2300HP	70111	25-Aug-15
(A4) Transmissometer	Wet Labs C-Star	CST-1421DR	14-Aug-15
(A5) ORP	NOAA ORP4CTD	ORP4CTD-09/ ORP4CTD-03	10-Jan-16
(A6) Fluorometer – Chlorophyll	WETLABS FLBBRTD	3698	23-Sep-14
(A7) fluorometer - Scattering	WETLABS FLBBRTD	3698	23-Sep-14
Pressure Temperature	Paroscientific Inc		8-Apr-15

Table 1 CTD Sensor configuration for deployment 1 of IN2016_V01

Water samples were collected using a Seabird SBE9+, 24-bottle rosette sampler with twelve litre bottles fitted to the frame.
There were 55 casts, with deployments 1 and 2 being tests before arriving on station.

- Cast #3 was aborted soon after deployment.
- There is no hydrochemical analysis available for cast 5.
- Cast 19 was stopped and repeated (as cast 20) due to a software problem.
- Cast 37 was aborted due to a bow thruster malfunction.
- Cast 42 was aborted due to high winds.
- Cast 50 was aborted due to software problems (cast #51 was subsequently successfully deployed in this position).

Casts 31, 32 and 33 were deployed as ‘low tow’ casts, drawing the CTD through the water in an attempt to detect volcanic plumes. During the tow, Cast 31 made contact with the bottom. Note: the horizontal component of these casts will not be found in the averaged netCDF files as they were binned on pressure.

Cast 54 was deployed through a volcanic plume.

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.

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.

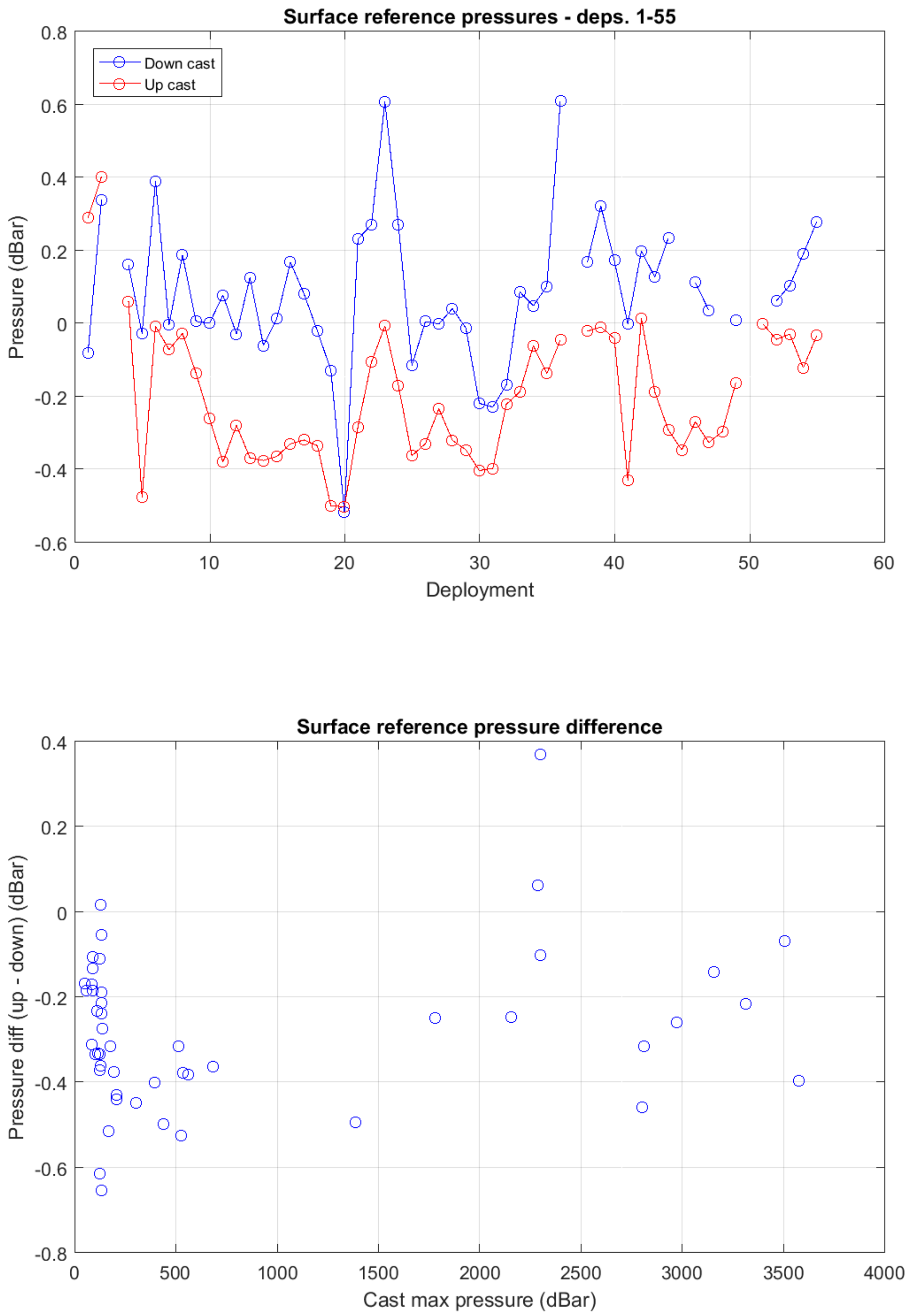


Figure 1 CTD pressure offsets

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.

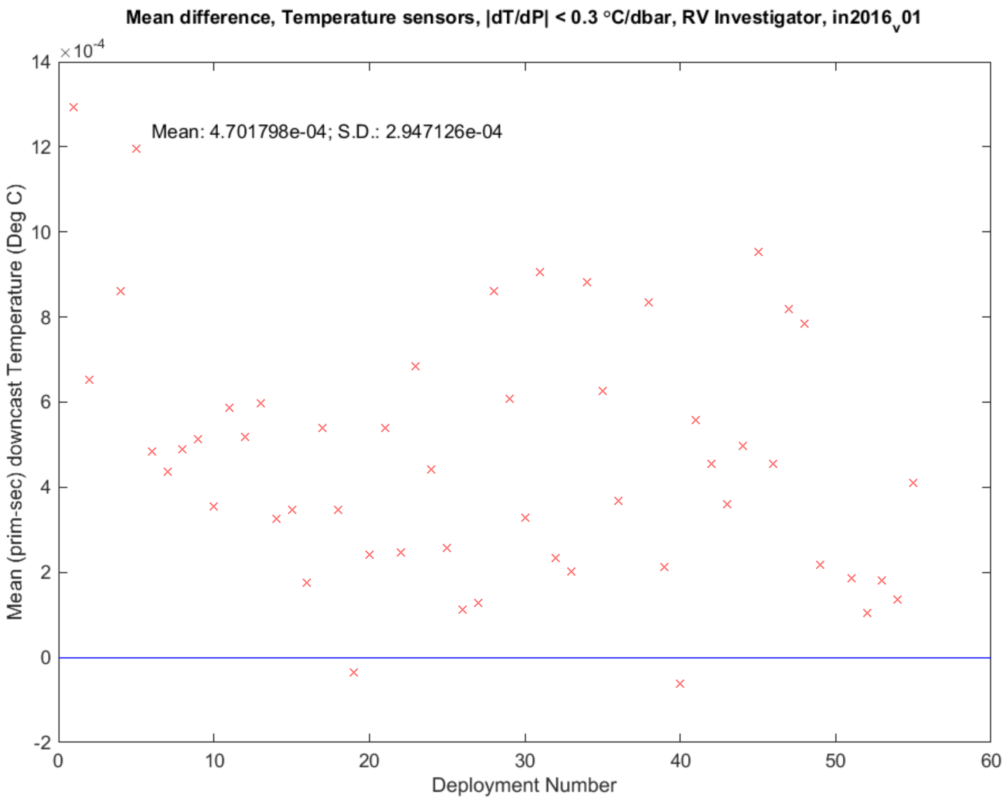


Figure 3. Temperature sensor difference

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. The calibration was based upon the sample data for 512 of the total of 595 samples taken during deployments. The outliers marked in Figure 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. Outliers marked with red crosses or dots are also excluded from the calibration.

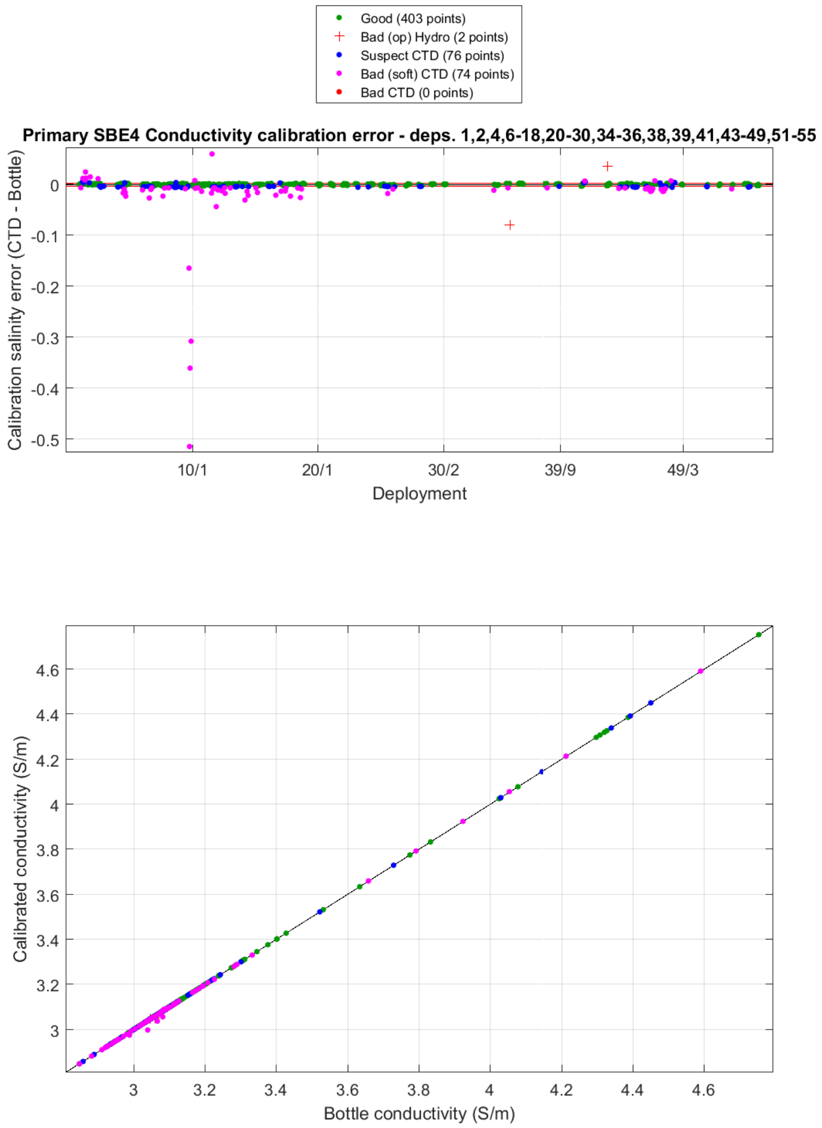
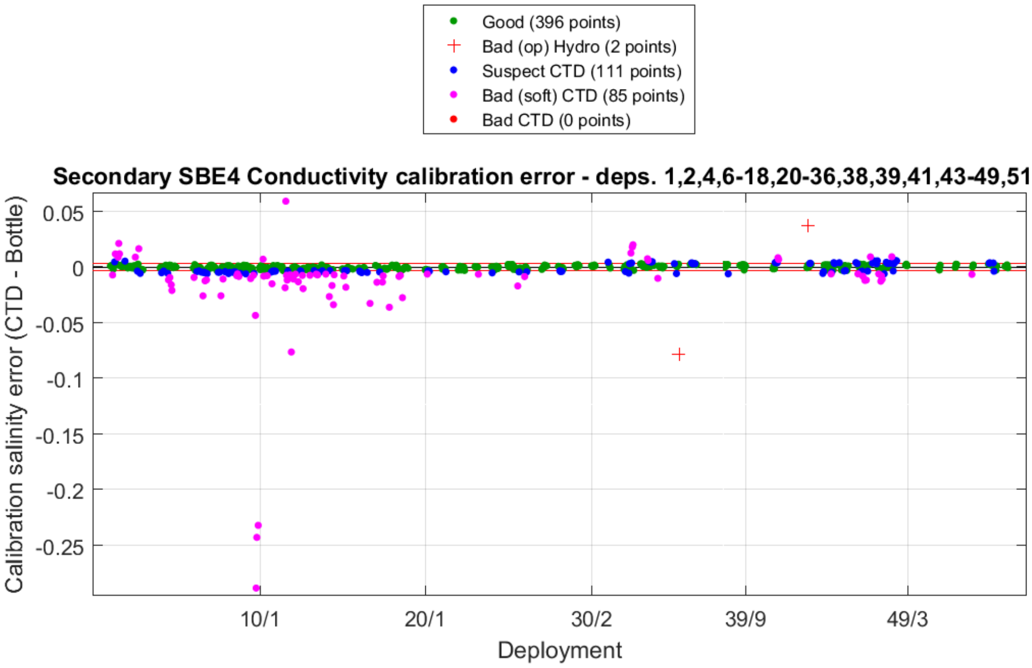


Figure 4. Primary conductivity calibrations



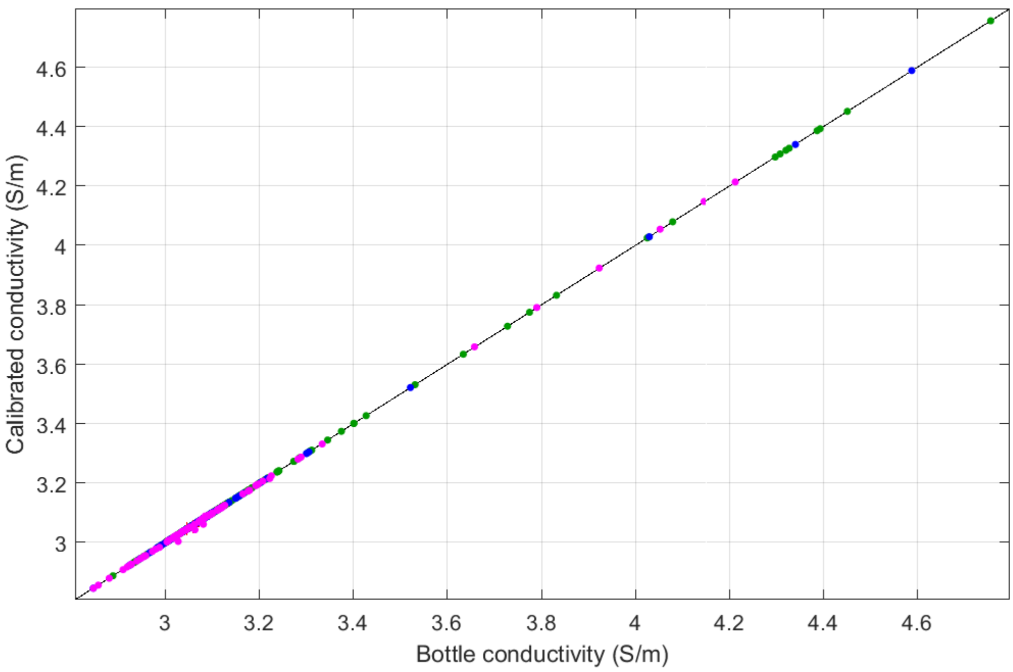


Figure 5. Secondary conductivity calibrations

The final result for the primary conductivity sensor was:

Scale Factor (a1)	0.99904	wrt. Manufacturer's calibration
Offset (a0)	0.0022985	ditto
Calibration S.D. (Sal)	0.0013449 PSU	

The calibration using the secondary conductivity sensor was:

Scale Factor (a1)	0.99926	wrt. Manufacturer's calibration
Offset (a0)	0.0014039	ditto
Calibration S.D. (Sal)	0.0014906 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.

3.4 Dissolved Oxygen Sensor Calibration

3.4.1 SBE calibration procedure

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 .

3.4.2 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.

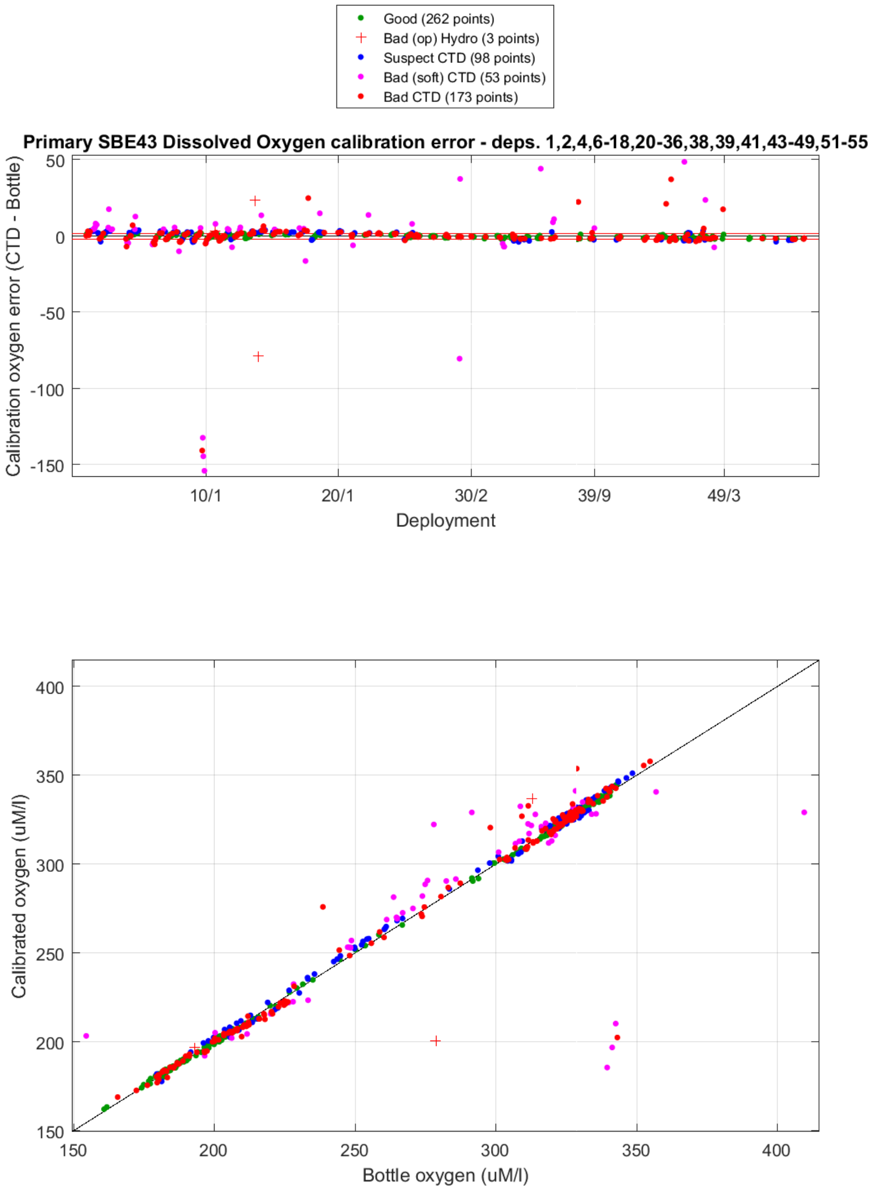
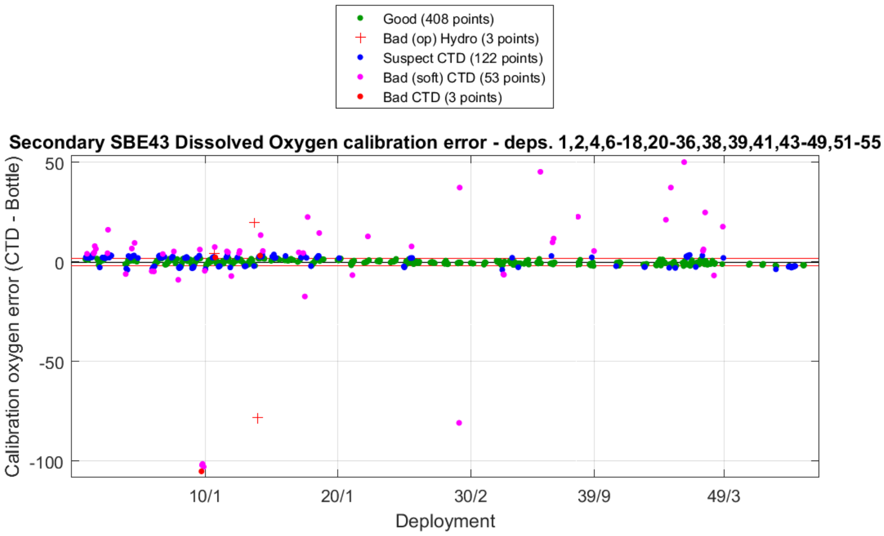


Figure 6. Dissolved Oxygen calibration, all deployments – primary sensor



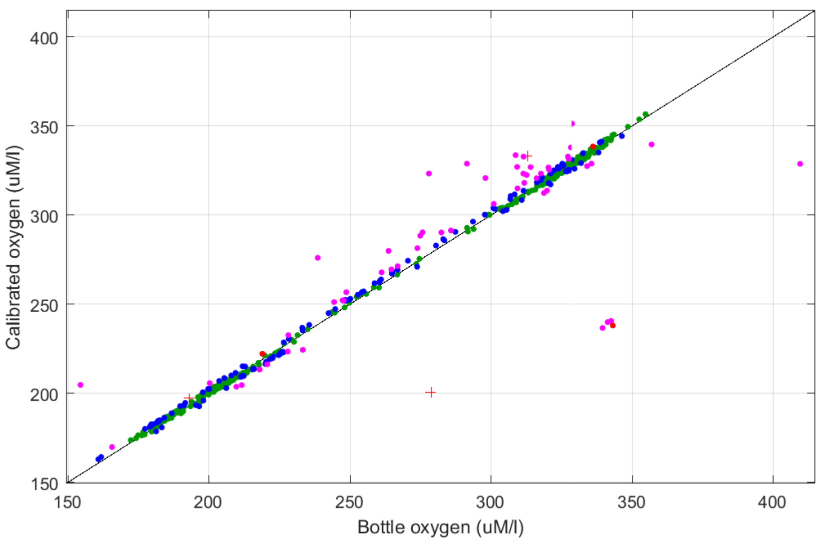


Figure 7. Dissolved Oxygen calibration, all deployments – secondary sensor

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	**Feb 2015 CSIRO**	**primary sensor**	**June 2015 CSIRO**	**secondary sensor**
Voffset	-0.49151738	-0.46096	-0.5016	-0.46151
Soc	0.50939087	0.50236	0.5521	0.55612
Fit SD (uM)		0.97686		0.91455

Table 2. Dissolved Oxygen calibration

3.5 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.

Two user supplied sensors were connected to the 9plus, a dual channel Fluorometer and an oxidation-reduction potential (ORP), supplied by NOAA .

3.6 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

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

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