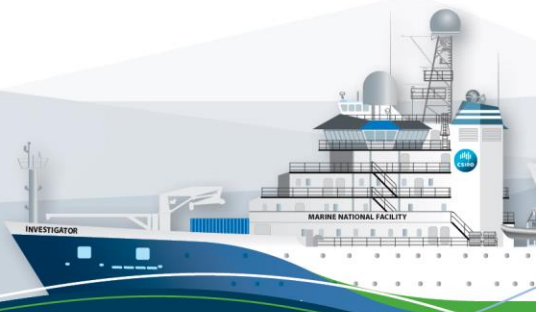
RV *Investigator*

CTD Processing Report

Voyage #:	IN2016_T01
Voyage title:	Continuity of Australian terranes into Zealandia: towards a geological map of the east Gondwana margin.
Depart:	Lautoka, 18:30, Thursday, 30 June 2016
Return:	Hobart, 0800, Thursday 14 July 2016
Processing completed:	28 August, 2017
Report completed:	28 August, 2017
Data Revision:	Version 2.0
Report compiled by:	Steven Van Graas



Contents

1 Revision History

- 3 August 2017: version 1.0
- 28 August 2017: version 2.0 – correction to thermal inertia correction coefficients for conductivity cells

2 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2016_t01, from 30 Jun 2016 – 14 Jul 2016. This data set has been re-released due to an identified issue where incorrect parameters for the thermal inertia corrections to the conductivity cell were applied.

Data for 13 deployments were acquired using the Seabird SBE911 CTD 20, fitted with 36 twelve 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.

During cast 1, a communications error occurred at a depth of 250m (alarm on the deck unit) and the CTD was recovered. All other casts proceeded without issue. The calibrations derived from bottle samples from subsequent casts were applied to cast 1.

There were no changes to the sensor package for the duration of the voyage. The final calibration from the secondary sensor for casts 2-13 had a standard deviation (S.D) of 0.0012559 PSU, well within our target of 'better than 0.002 PSU'.

The final calibration from the secondary dissolved Oxygen sensor for casts 2-13 had a standard deviation (S.D) 0.65093 uM/l. The agreement between the CTD and bottle data was good.

The standard product of 1 dbar binned averaged were produced using data from the secondary temperature and conductivity sensors, and the secondary Oxygen sensor.

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

3 Voyage Details

3.1 Title

Continuity of Australian terranes into Zealandia: towards a geological map of the east Gondwana margin.

3.2 Principal Investigator

Simon Williams

3.3 Voyage Objectives

The scientific objectives for in2016_t01 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.

3.4 Area of operation

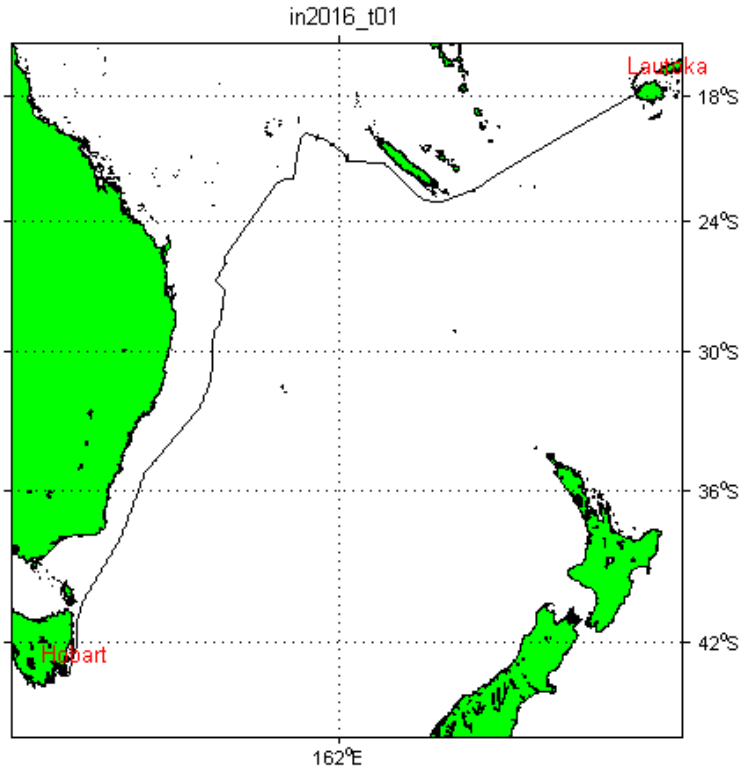


FIGURE 1. Area of operation for in2016_t01

4 Processing Notes

4.1 Background Information

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

The CTD was additionally fitted with SBE43 dissolved oxygen sensors, an altimeter, PAR, Transmissometer and Fluorometer. 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+	1-13	552	P	2016-03-09	CSIRO Cal Lab
Primary Temperature	Seabird SBE3*plus*	1-13	6022	T0	2015-07-15	CSIRO Cal Lab
Secondary Temperature	Seabird SBE3*plus*	1-13	4718	T1	2015-10-29	CSIRO Cal Lab
Primary Conductivity	Seabird SBE4C	1-13	4425	C0	2015-07-08	CSIRO Cal Lab
Secondary Conductivity	Seabird SBE4C	1-13	4426	C1	2015-07-08	CSIRO Cal Lab
Primary Dissolved Oxygen	SBE43	1-13	1794	A0	2016-03-10	CSIRO Cal Lab
Secondary Dissolved Oxygen	SBE43	1-13	3198	A1	2015-08-12	CSIRO Cal Lab

Transmissometer	C-Star	1-13	CST-1421DR	A2	2015-08-14	Manufacturer
Altimeter	PA500	1-13	5301. 228403	A3	2015-05-22	Manufacturer
Fluorometer	Chelsea Aquatracka III	1-13	118206001	A6	2014-02-06	Manufacturer
PAR	BioSpherical QCP2300-HP	1-13	70111	A7	2015-08-25	Manufacturers

TABLE 1. CTD Sensor configuration on in2016_t01

Water samples were collected using a Seabird SBE32, 36-bottle rosette sampler. Sampling was from 36 twelve litre bottles which were fitted to the frame. There were 13 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.

4.2 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.

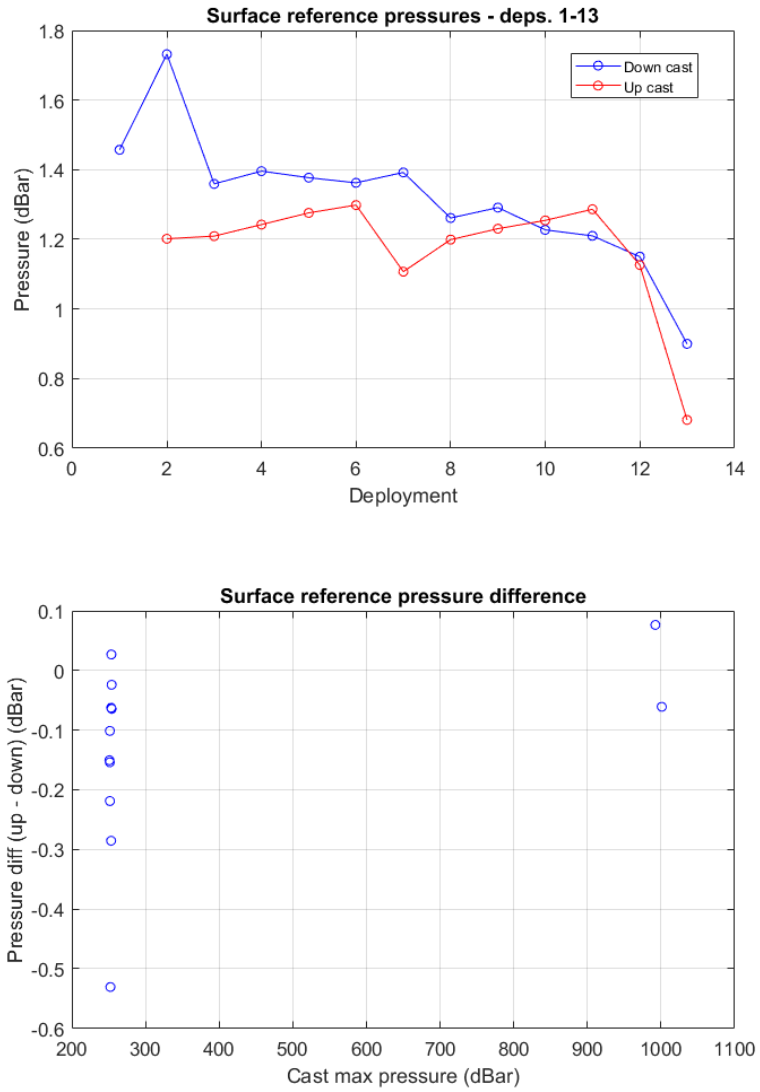


FIGURE 2. CTD pressure offsets

4.3 Conductivity Calibration

Discrepancies and possible sampling problems between bottle and CTD salinities for the secondary conductivity sensor would show in Figure 4, the plot of calibrated (CTD - Bottle) salinity below, for all deployments processed. The calibration was based upon the sample data for an overall total of 33 of the 48 samples taken during deployments (the outliers marked in Figure 4 below with the magenta diamonds are excluded from the calibration).

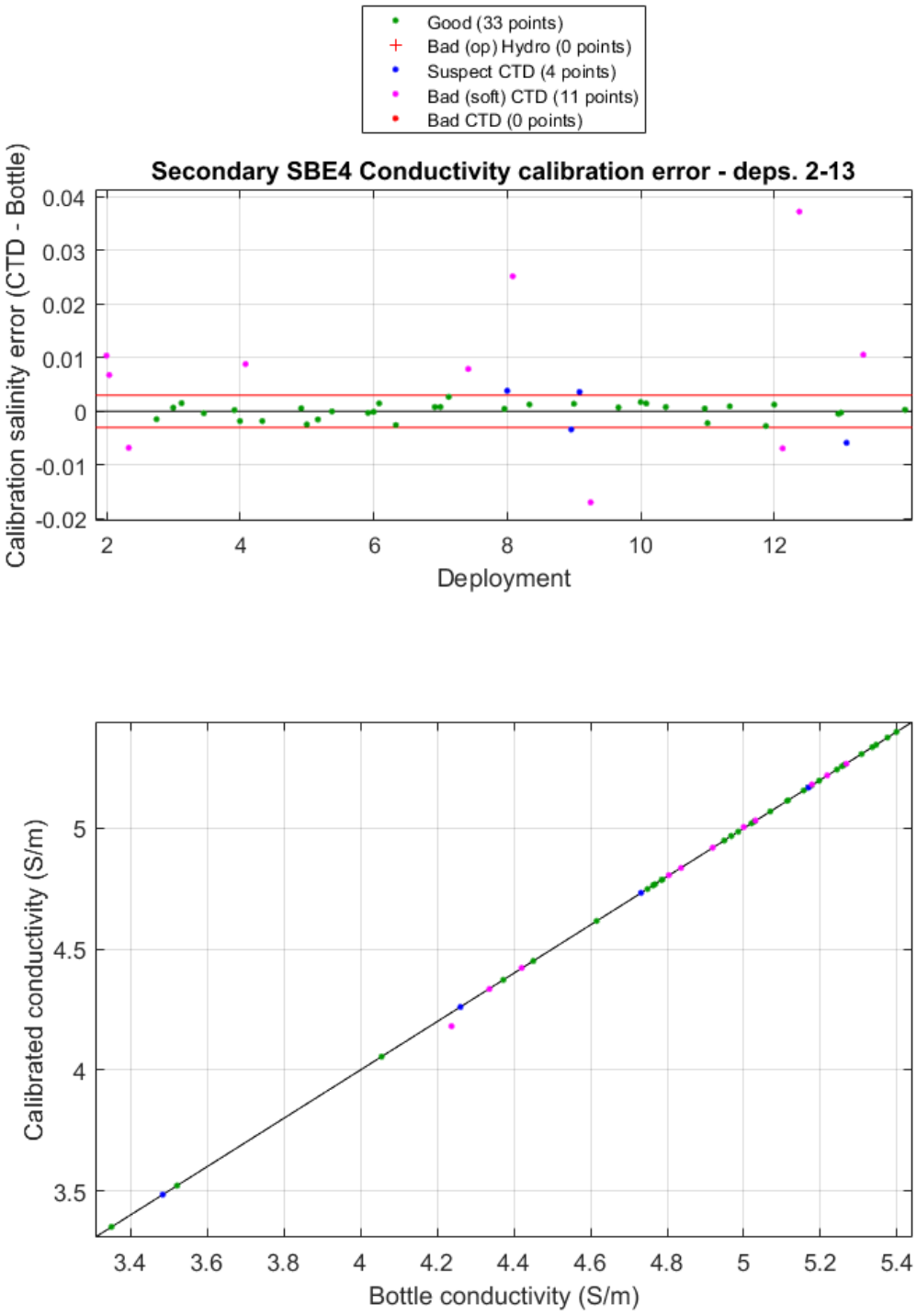


FIGURE 3. CTD - bottle salinity plot.

The final result for the secondary conductivity sensor for casts 2 - 13 was –

Scale Factor (a1)	1.0004	
Offset (a0)	-0.00030194	wrt. CSIRO calibration
Calibration S.D. (Sal)	0.0012559 PSU	

This is a good calibration. We aim for a S.D. of 0.002 psu for 'typical' oceanographic voyages. The above calibration factors were applied to all deployments.

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

The calibration using the primary conductivity sensor was well also within our acceptable standard deviation range, and was applied, however not used for the delivered averaged salinity values.

4.4 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 secondary sensor for casts 1-13.

The final result for the secondary conductivity sensor for casts 1 - 13 was –

Voffset	-0.43373	
Soc	0.41884	wrt. CSIRO calibration
Calibration S.D. (uM)	0.65093	

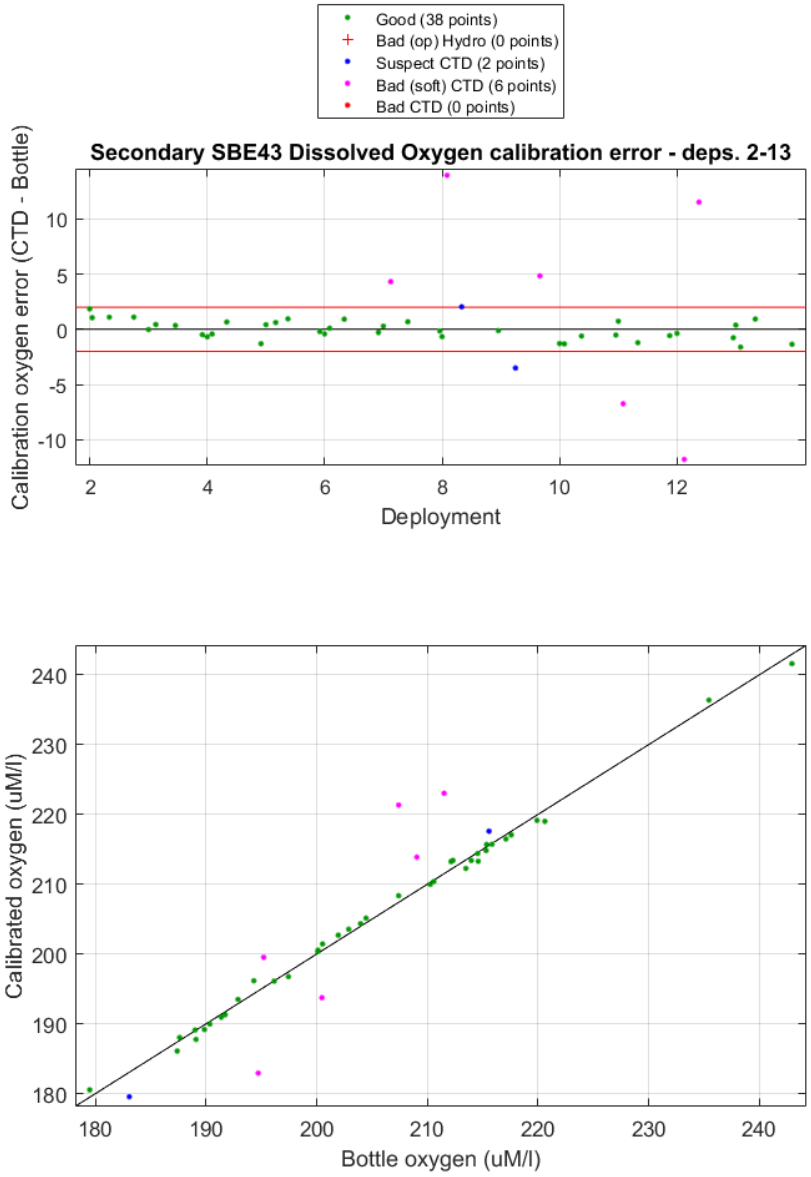


FIGURE 4. CTD - bottle dissolved Oxygen plot.

4.5 Other sensors

The Chelsea Fluorometer, C-Star Transmissometer, and BioSpherical PAR were used for all deployments. These ancillary sensors have been calibrated to give nominal outputs of 0-100 fsd (full scale deflection).

4.6 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
Pressure	-7	6500	0.5
Temperature	-2	40	0.05
Conductivity	-0.01	7	0.01
Oxygen	-0.1	500	0.5
Fluorometer	0	100	0.5

TABLE 2. Sensor limits for bad data detection

4.7 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.

A heave compensation filter is applied to the data during the averaging process, which detects and flags data which has been contaminated by the trailing mixed water parcel, sampled due to deceleration of the CTD package due to ship heave.

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.

5 References

Williams, 2016: The RV Investigator. Voyage Plan IN2016_T01 - http://mnf.csiro.au/~/media/Files/Voyage-plans-and-summaries/Investigator/Voyage%20Plans%20summaries/2016/IN2016_T01%20Voyage%20Plan.ashx

Pender, L., 2000: Data Quality Control Flags. http://www.cmar.csiro.au/datacentre/ext_docs/DataQualityControlFlags.pdf

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Sea-Bird Electronics Inc., 2010c: Application Note No 64-3: SBE 43 Dissolved Oxygen (DO) Sensor - Hysteresis Corrections. http://www.seabird.com/pdf_documents/ApplicationNotes/Appnote64-3Feb10.pdf