RV *Investigator*

CTD Processing Report

Voyage #:	IN2015_V01
Voyage title:	IMOS Moorings
Depart:	Hobart, 0910 Saturday, 21 March 2015
Return:	Hobart, 0900 Tuesday, 30 March 2015
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Contents

1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage IN2015_V01, from 21 Mar 2015 – 30 Mar 2015.

Data for 3 deployments were acquired using the Seabird SBE911 CTD 21, fitted with 24 ten 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 0.0015 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 0.45uM. The agreement between the CTD and bottle data was good.

The Fluorometer, the Wet Labs Transmissometer, and the Biospherical Photosynthetically Active Radiation (PAR) sensor were also installed on the auxiliary A/D channels of the CTD.

Complications regarding the acquisition software caused the deployment numbers recorded with the casts to be different to the actual cast being recorded. Cast 1 was recorded as deployment 5, cast 2 recorded as deployment 7, and cast 3 recorded as deployment 9. To avoid ambiguity the deployment numbers recorded by the acquisition software, not the actual cast, will be referred to throughout the report.

2 Voyage Details

2.1 Title

IMOS Southern Ocean time series automated moorings for climate and carbon cycle studies southwest of Tasmania.

2.2 Principal Investigators

Dr Tom Trull and Dr Eric Schulz.

2.3 Voyage Objectives

The scientific objectives for IN2015_V01 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

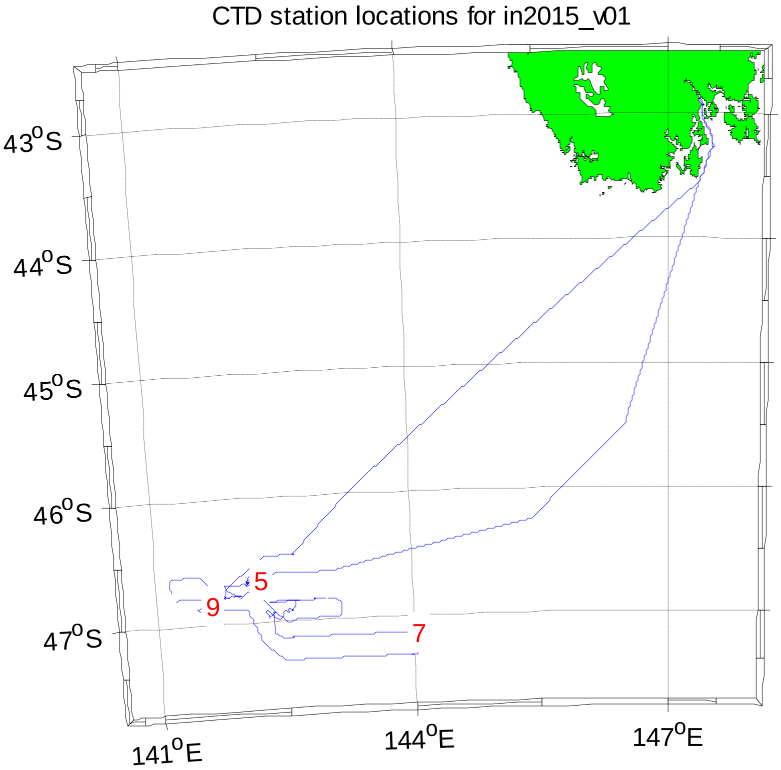

FIGURE 1. Area of operation for IN2015_V01

3 Processing Notes

3.1 Background Information

The data for this voyage were acquired with the CSIRO CTD unit 21, a Seabird SBE911 with dual conductivity and temperature sensors.

The CTD was additionally fitted with SBE43 dissolved oxygen sensors, Fluorometer, Transmissometer and PAR sensors. These sensors are described in Table 1 below.

Description	Sensor	Serial No.	A/D	Calibration Date	Calibration Source
Pressure	Digiquartz 410K-134	858/P380	P	17/3/2015	CSIRO 3153 P – dbar
Primary Temperature	Seabird SBE3*plus*	4722	T0	27/2/2015	CSIRO 3109T
Secondary Temperature	Seabird SBE3*plus*	4522	T1	27/2/2015	CSIRO 3106T
Primary Conductivity	Seabird SBE4C	3868	C0	26/2/2015	CSIRO 3102C
Secondary Conductivity	Seabird SBE4C	3168	C1	26/2/2015	CSIRO 3098C
Primary Dissolved Oxygen	SBE43	1794	A0	11/2/2015	CSIRO 3055DO
Transmissometer	C-Star25cm	CST1421	A1	18/6/2014	Wet Labs
PAR	QCP2300	70111	A2	23/8/2013	Manuf. Cal.

Fluorometer	FLBBRTD	3698	A4	23/9/2014	
Scattering	FLBBRTD	3698	A5	23/9/2014	

TABLE 1. CTD Sensor configuration on IN2015_V01

Water samples were collected using a Seabird SBE32, 24-bottle rosette sampler. Sampling was from 24 ten litre bottles which were fitted to the frame. There were 3 deployments.

The raw CTD data were converted to scientific units and written to netCDF format files for processing using the Matlab-based, procCTD package. This procCTD application is described in the *procCTD Procedures Manual* (Beattie, 2010).

The procCTD 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. It also loaded the hydrology data and computed the matching CTD sample burst data. The automatically determined pressure offsets and in-water points were inspected.

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 ‘crosses’ refer to initial out-of-water values and the ‘diamonds’ the final out-of-water values. Due to software issues there were no out-of-water values captured for the start of deployment 5.

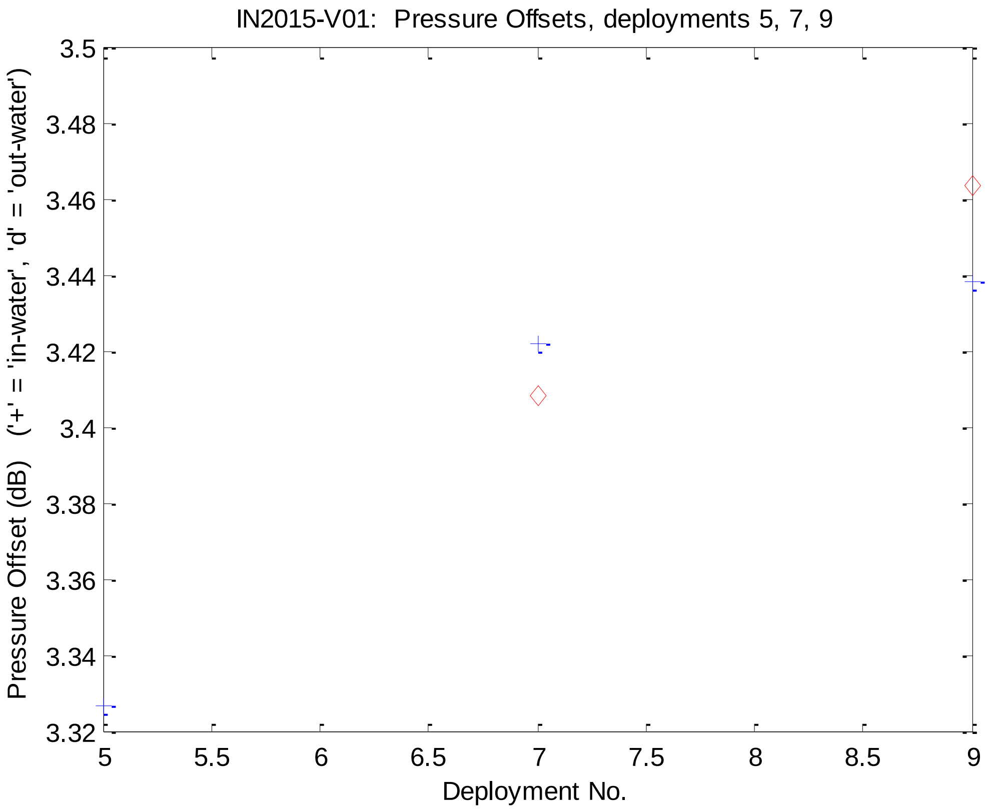

FIGURE 2. CTD pressure offsets

The difference between the primary and secondary temperature sensors at the bottle sampling depths is plotted below. Most deployments plot within ±1 m°C of zero – outliers result from sampling in regions of high vertical temperature gradient as supported by the similarity between the temperature and conductivity difference shown in figure 5. This indicates neither sensor has drifted significantly from its calibration.

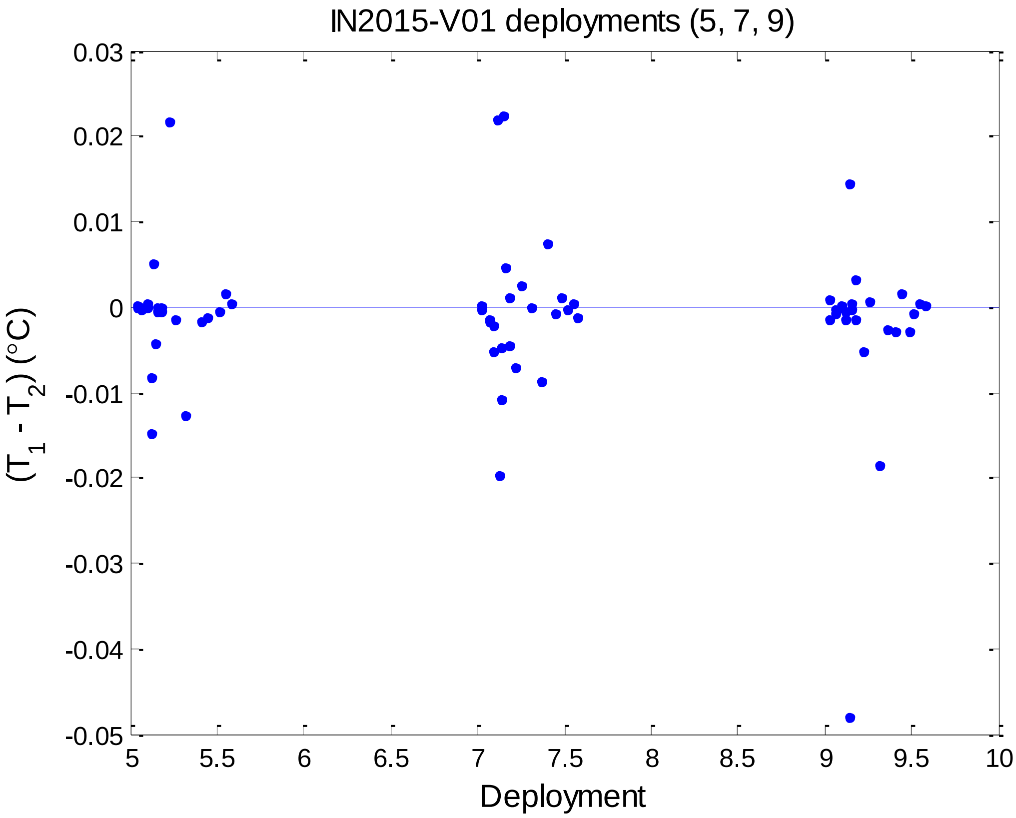

FIGURE 3. .Mean difference between primary and secondary temperature sensors

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 59 of the total of 70 samples taken during deployments (the outliers marked in Figure 4 below with the red ‘+’ and magenta diamonds are excluded from the calibration).

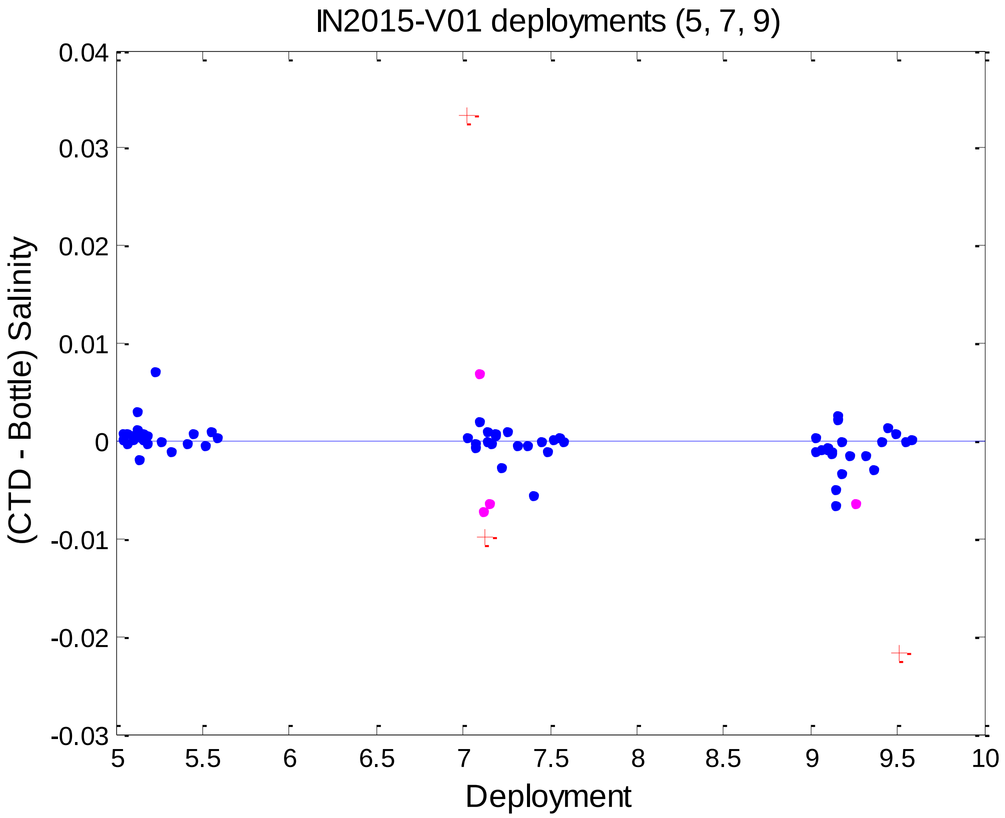

FIGURE 4. CTD - bottle salinity plot.

The plot of calibrated mean (primary - secondary) downcast conductivities at the bottle sampling depths for all deployments in Figure 5 shows that the calibrated conductivity cell responses corresponded well.

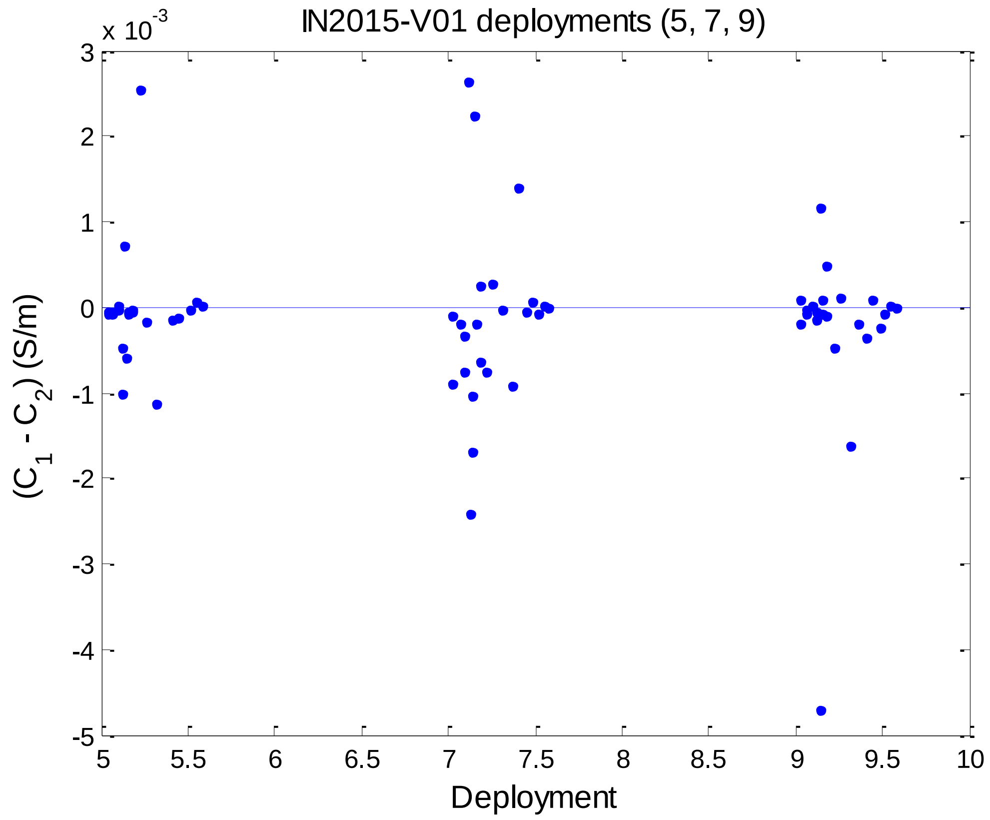

FIGURE 5. Mean difference between primary and secondary conductivity sensors

The final result for the primary conductivity sensor was –

Scale Factor (a1)	0.99939667	wrt. Manufacturer's calibration
Offset (a0)	0.0010603624	ditto
Calibration S.D. (Sal)	0.001494 PSU	

The calibration using the secondary conductivity sensor was –

Scale Factor (a1)	0.99950285	wrt. Manufacturer's calibration
Offset (a0)	0.0010507233	ditto
Calibration S.D. (Sal)	0.0021734 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.

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 (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 procCTD 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.

A single calibration group was used with the associated SBE43 up-cast data to compute the new Soc and Voffset coefficients. The plot below is of CTD - bottle oxygen differences for both upcast and downcast data (red indicates 'bad' data; + for upcast and square for downcast).

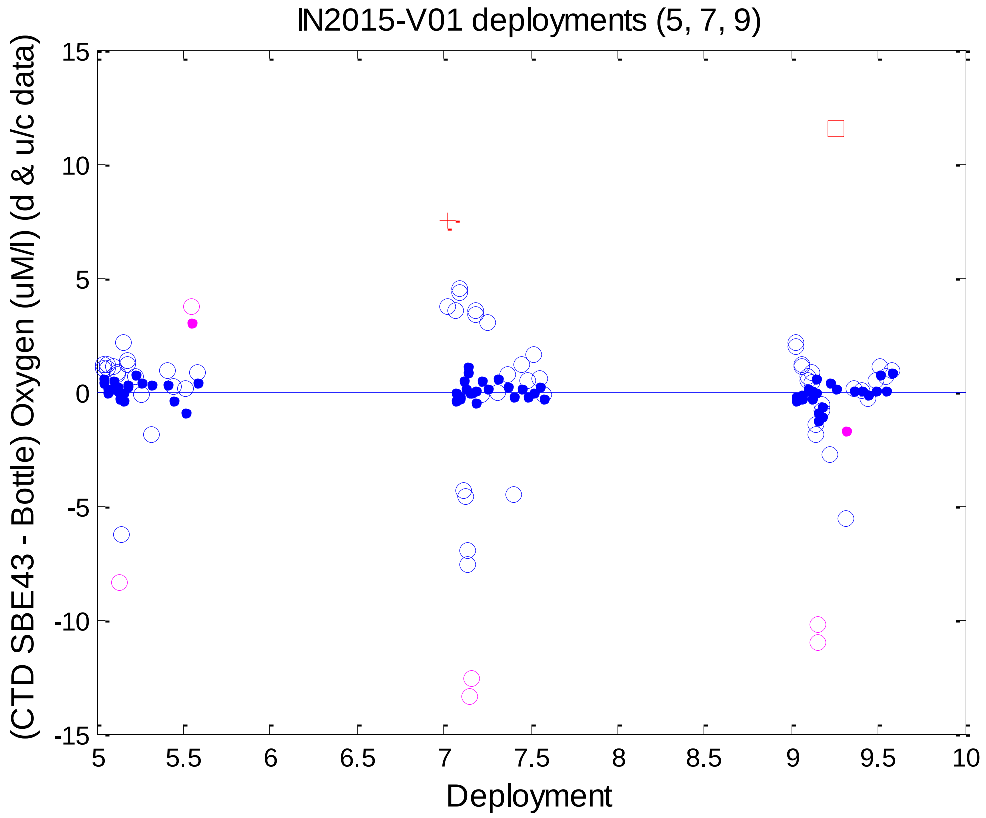

FIGURE 7. (SBE43 - Bottle) Oxygen Difference with upcast CTD data

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, as there was no secondary Oxygen sensor present.

	Manufacturer's calibration of primary sensor	**primary sensor calibration**	**Manufacturer's calibration of secondary sensor**	**secondary sensor calibration**
Voffset	-0.49151738	-0.46500549	N/A	N/A
Soc	0.50939087	0.51282073	N/A	N/A
Fit SD (uM)		0.4474	N/A	N/A

TABLE 2. Dissolved oxygen calibrations

3.5 Other sensors

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.

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 procCTD 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

Beattie, R.D., 2010: procCTD CTD Processing Procedures Manual. http://www.marine.csiro.au/~dpg/opsDocs/procCTD.pdf.

Trull, T., 2015: The RV Investigator. Voyage Plan IN2015_V01 http://www.cmar.csiro.au/datacentre/process/data_files/cruise_docs/Investigator/in2015_v01_plan.pdf

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Sea-Bird Electronics Inc., 2010a: Application Note No 64: SBE 43 Dissolved Oxygen Sensor -- Background Information, Deployment Recommendations, and Cleaning and Storage. http://www.seabird.com/pdf_documents/ApplicationNotes/appnote64Feb10.pdf

Sea-Bird Electronics Inc., 2010b: Application Note No 64-2: SBE 43 Dissolved Oxygen Sensor Calibration and data Corrections using Winkler Titrations. http://www.seabird.com/pdf_documents/ApplicationNotes/Appnote64-2Feb10.pdf

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