RV *Investigator*

CTD Processing Report

Voyage #:	IN2016_v04
Voyage title:	Influence of temperature and nutrient supply on the biogeochemical function and diversity if oceans microbes
Depart:	Sydney, 31 August 2016 14:00
Return:	Brisbane, 22 September 2016 16:00
Report compiled by:	Pamela Brodie, Karl Malakoff

Contents

1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2016_v04 CTDs, between 31 August and 22 September 2016.

Data for 56 deployments were acquired using the Seabird SBE911 borrowed from the Australian Antarctic Division (AAD), fitted with 24 ten litre bottles on the rosette sampler. Sea-Bird-supplied calibration factors were used to compute the pressures and preliminary conductivity and temperature values. 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 0.0012 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 calibration was based on two deployment groups due to a trend in the dissolved oxygen residuals. The data calibration fit had a S.D. of 1.0345uM for casts 1 – 15 and 0.80641uM for casts 16 – 56. 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.

2 Voyage Details

2.1 Title

The voyage was called *The Influence of temperature and nutrient supply on the biogeochemical function and diversity if oceans microbes.*

2.2 Principal Investigators

On board were Martina Doblin (CS, University of Technology, Sydney), Mark Brown (PI. Macquarie University), Iain Suthers (PI, UNSW and SIMS).

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

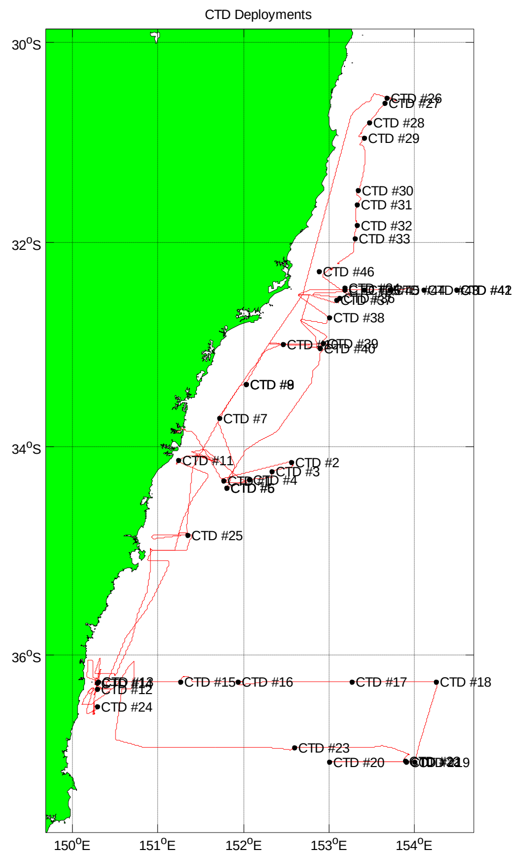


Figure 1. Area of Operation for in2016_v04 CTDs

3 Processing Notes

3.1 Background Information

The data for this voyage were acquired with the borrowed AAD CTD, a Seabird SBE911 with dual conductivity and temperature sensors. One MNF CTD was unavailable, at Seabird for repair. The other two were used for the Trace Metal rosette and the triaxus.

There were 56 deployments for this voyage shown on Figure 1. The first, a test cast, was conducted south of Sydney shortly after departure. All bottles were fired at 1000m and samples taken only for training purposes. Samples were analysed from the subsequent casts.

Rapp Hydema heave compensation was used on the CTD winch for all casts.

The Biospherical photosynthetically active radiation (PAR), C-Star transmissometer and the Wetlabs ECO CDOM and chlorophyll sensors were also installed on the auxiliary A/D channels of the CTD. These sensors are described for the borrowed AAD CTD in Table 1 below.

Description	Sensor	Serial No.	A/D	Calibration Date	Calibration Source
Pressure	SBE9 *plus*	703	P	15/7/2016	SBE Cal
Primary Temperature	Seabird SBE3T	4208	T0	12/7/2016	SBE Cal
Secondary Temperature	Seabird SBE3T	4246	T1	12/7/2016	SBE Cal
Primary Conductivity	Seabird SBE4C	2808	C0	13/7/2016	SBE Cal
Secondary Conductivity	Seabird SBE4C	2977	C1	13/7/2016	SBE Cal
Primary Oxygen	Seabird SBE43	3154	A0	10/3/2016	CSIRO 3836DO
Secondary Oxygen	Seabird SBE43	3159	A1	10/3/2016	CSIRO 3389DO
Biospherical PAR	QCP2300	70111	A3	01/8/2016	R12719
Altimeter	PA916	52306	A2	22/5/2015	Teledyne
Transmissometer*	C-Star	CST-1735DR	A6	16/7/2015	Wetlabs
Wetlabs CDOM	FLCDRTD	4367	A6	02/5/2014	Wetlabs
Chlorophyll	Aquatrack III	06-5941-001	A7	02/6/2014	

Table 1. CTD Sensor configuration for borrowed AAD CTD on in2016_v04 CTDs

*sensor not available for cast 46.

Water samples were collected using a Seabird SBE32, 24-bottle rosette sampler. Sampling was as required from the ten litre bottles which were fitted to the frame. There were 56 deployments.

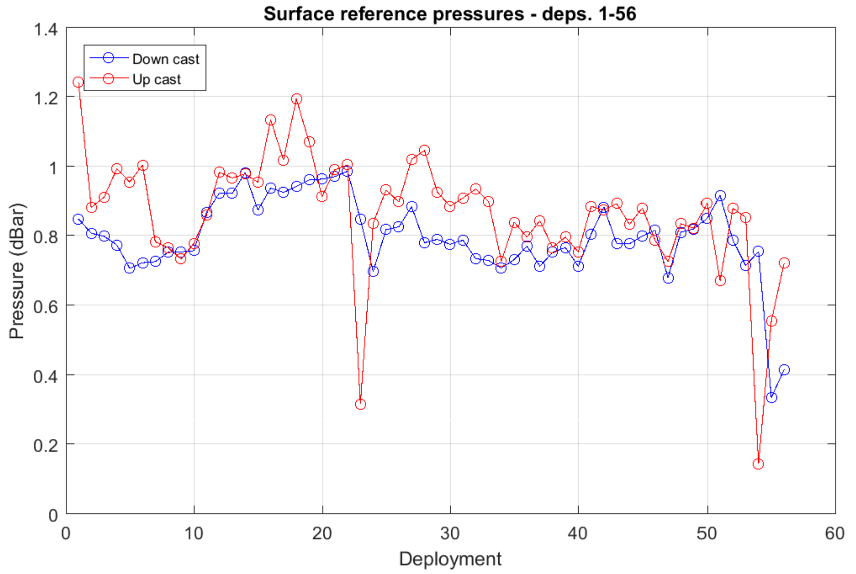
The raw CTD data was acquired and converted converted to scientific units and written to netCDF format files for processing using the CAP java package.

The CapPro 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. 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 reference

The surface pressure offsets are plotted in *Figure* 2~~Figure 22~~ below. The blue circles refer to initial out-of-water values and the red circles the final out-of-water values. Pressure data within a deployment is offset by the pressure offset by interpolating between the two values throughout the cast. If there is no pressure value for the beginning or end of a cast the previous or next value is used.



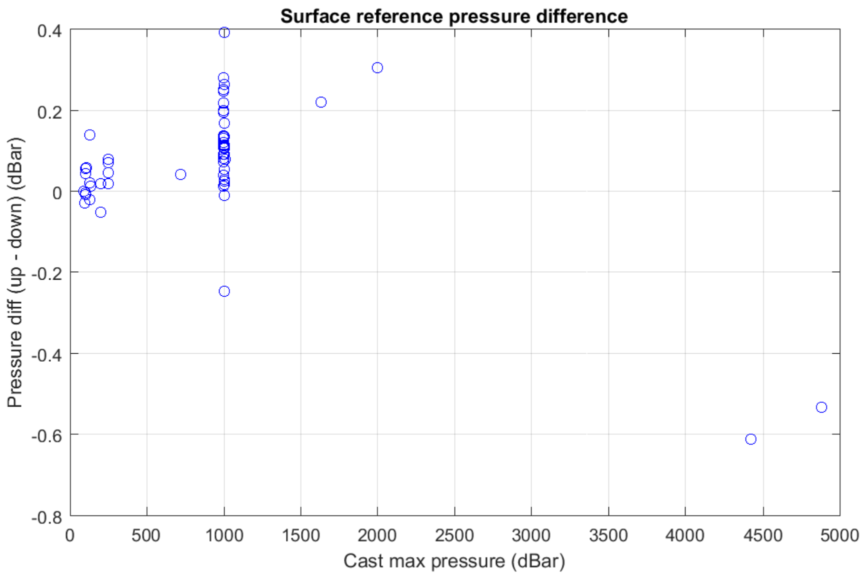
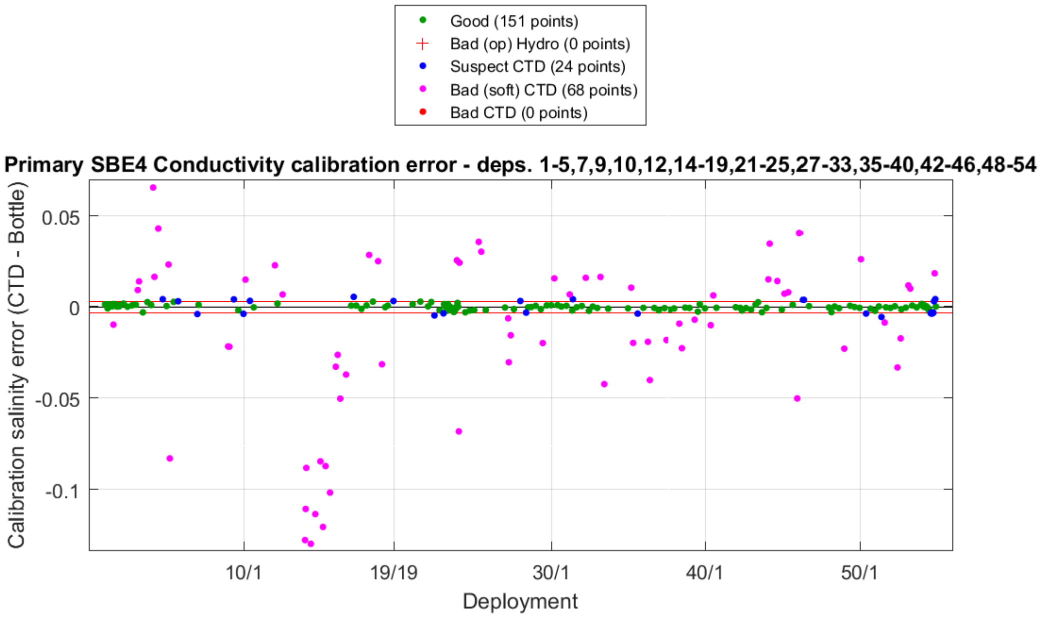


Figure 2. CTD pressure reference

3.3 Conductivity Calibration

Discrepancies and possible sampling problems between bottle and CTD salinities for the primary conductivity sensor would show in Figure 3, the plot of calibrated (CTD - Bottle) salinity below. The calibration was based upon the sample data for 1080 of the total of 1152 samples taken during deployments. The outliers marked in Figure 3 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. Additional plots of residuals can be found on page 15 .



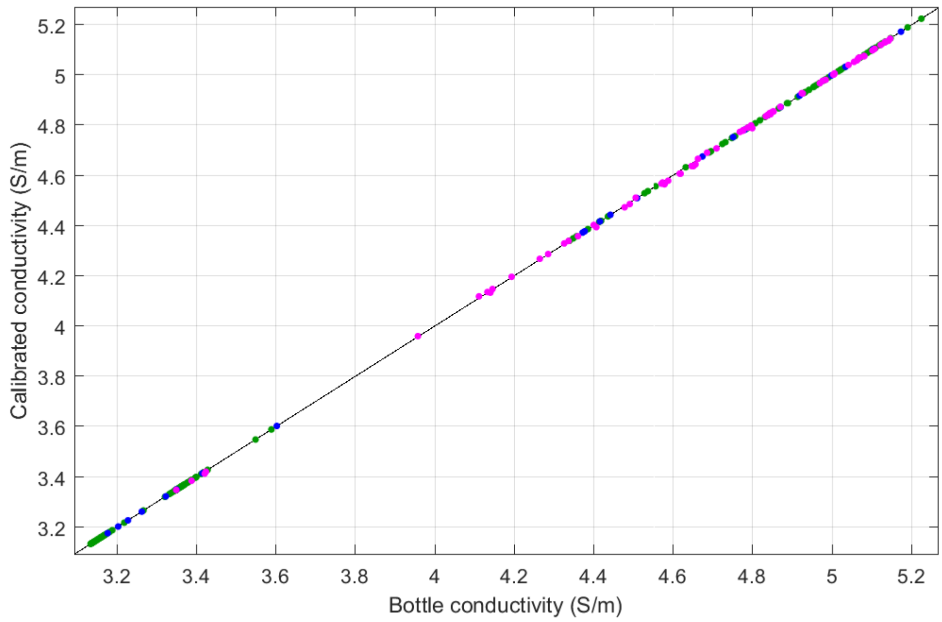


Figure 3. Primary conductivity calibrations

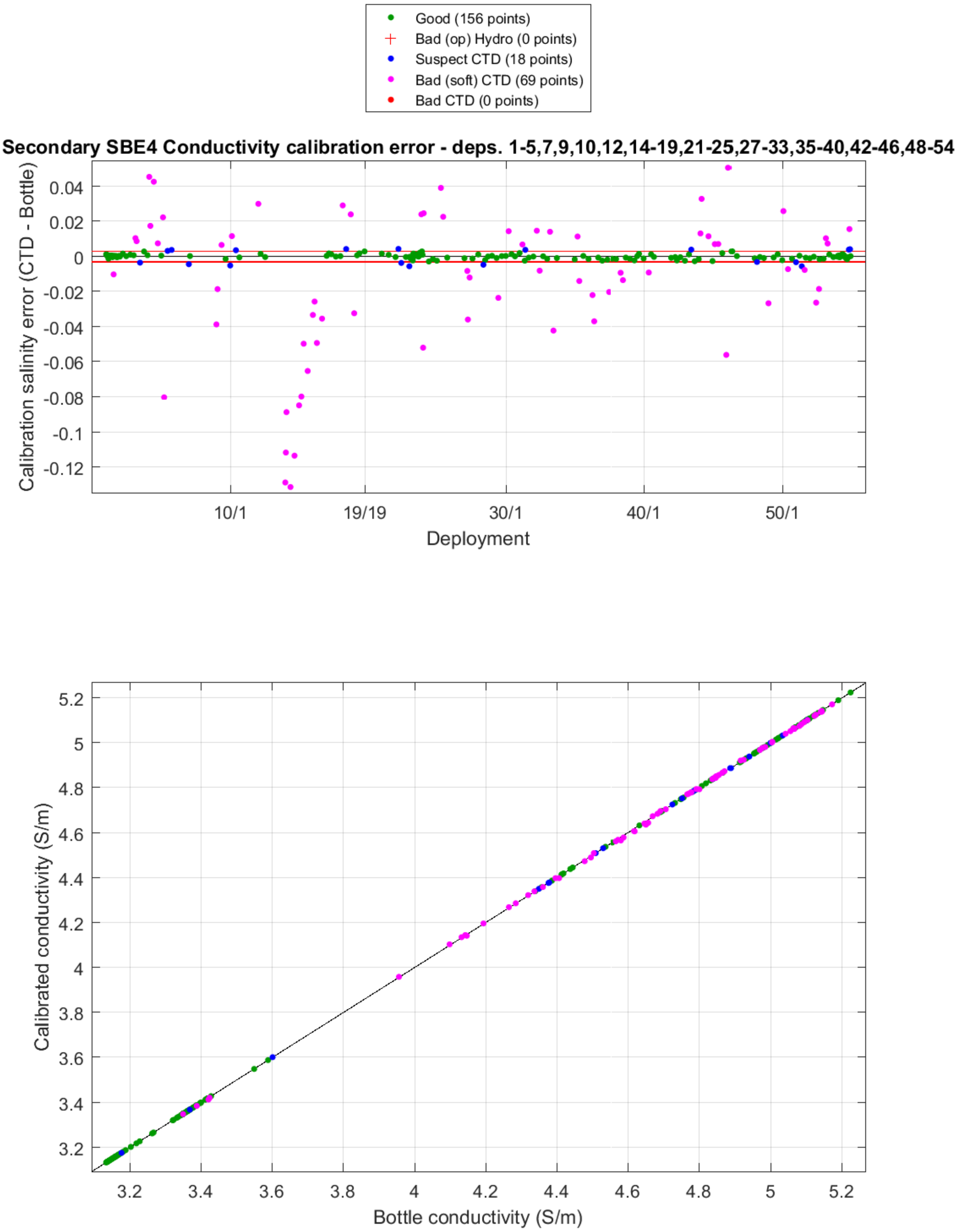


Figure 4. Secondary conductivity calibrations

The final result for the primary conductivity sensor was –

Scale Factor (a1)	1.0003	wrt. Manufacturer's calibration
Offset (a0)	-0.0010908	ditto
Calibration S.D. (Sal)	0.0012034 PSU	

The final result for the secondary conductivity sensor was –

Scale Factor (a1)	1.0001	wrt. Manufacturer's calibration
Offset (a0)	-8.659e-06	ditto
Calibration S.D. (Sal)	0.0012137 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

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)".

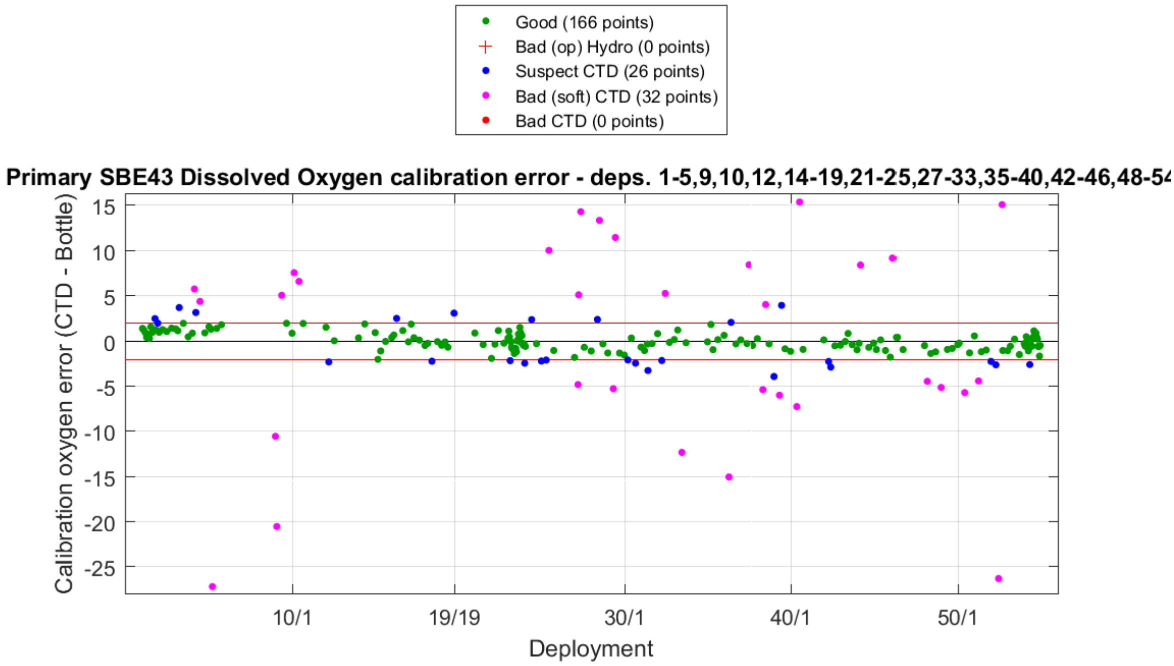
Calibration involves performing a linear regression, as per Sea-Bird (2010b) to produce new estimates of the calibration coefficients Soc and Voffset. These new coefficients are used, along with the other, manufacturer-supplied coefficients, to derive oxygen concentrations from the sensor voltages.

3.4.1 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.

Only one dissolved oxygen sensor was on the CTD, and a two calibration groups were used with the associated SBE43 up-cast data to compute the new Soc and Voffset coefficients. The plot below is of the initial calibration using all deployments. As a trend could be observed in the residuals it was decided to split the calibration into two deployment groups, the first containing deployments 1-15 and the second deployments 16-56. Further plots of residuals can be found on page 19~~19~~.



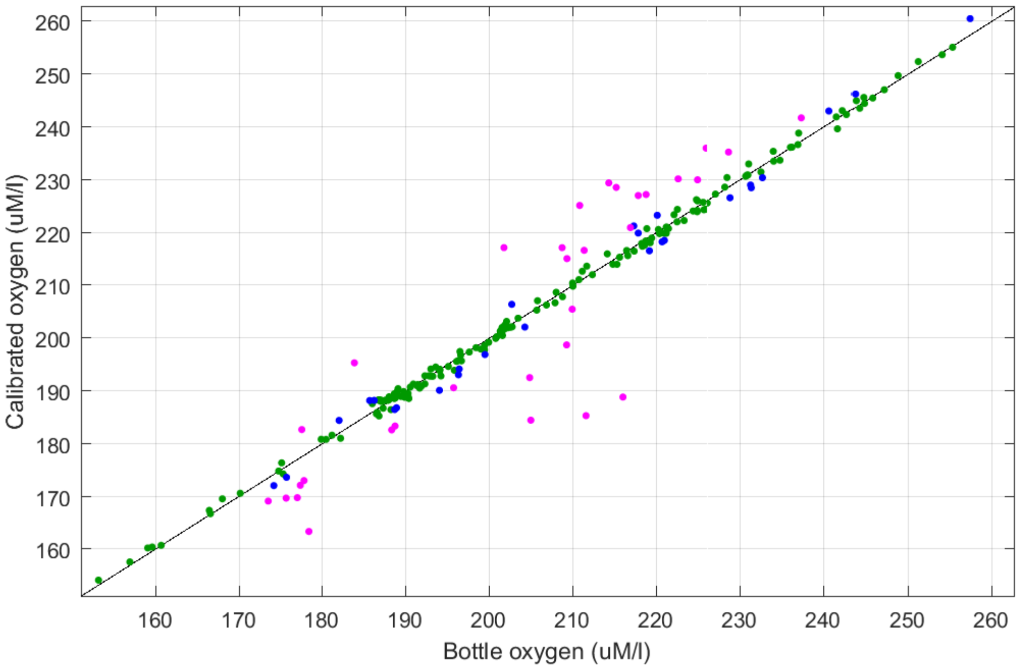


Figure 5. Dissolved Oxygen calibration, all deployments

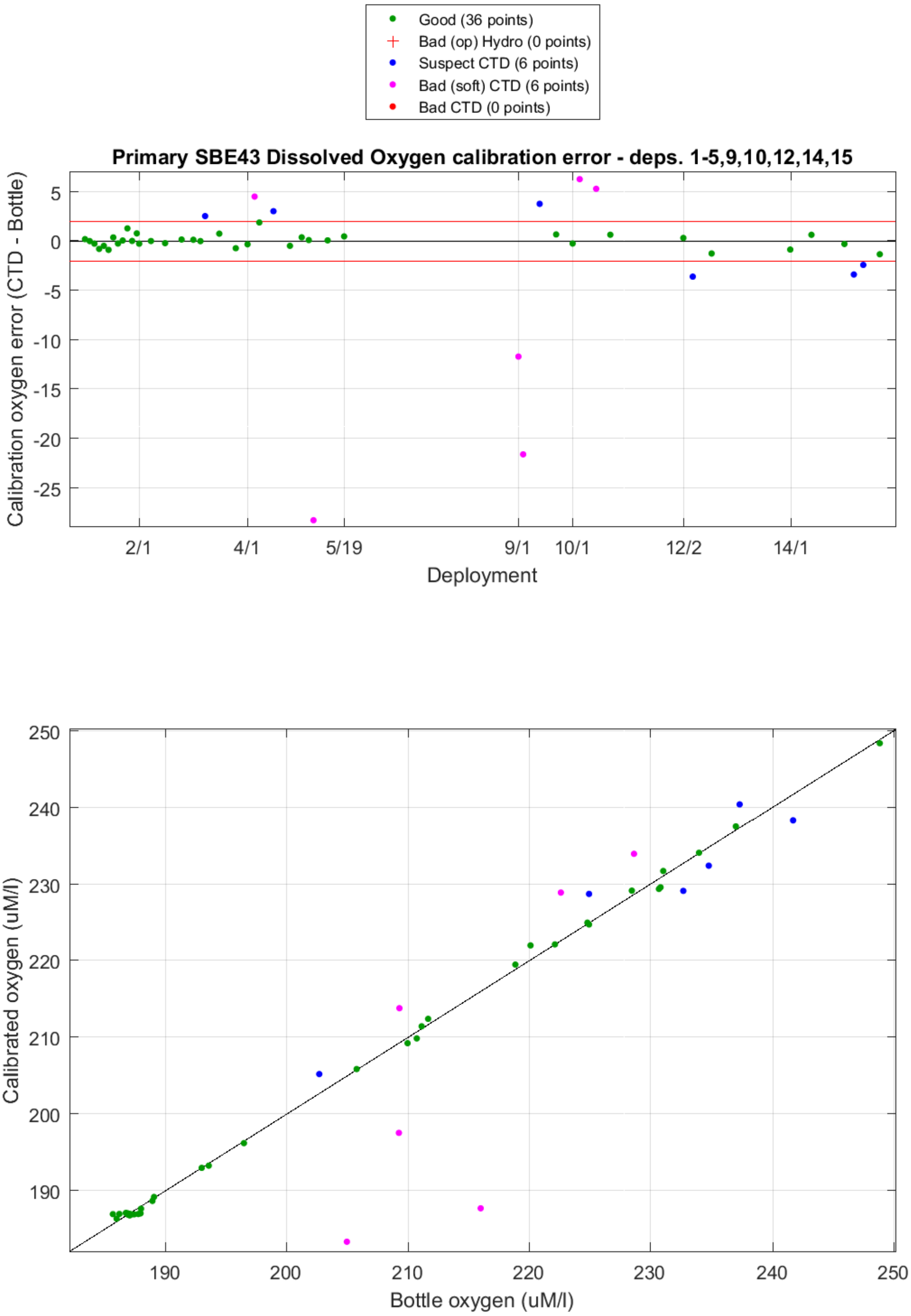


Figure 6. Dissolved oxygen calibration deployments 1 – 15

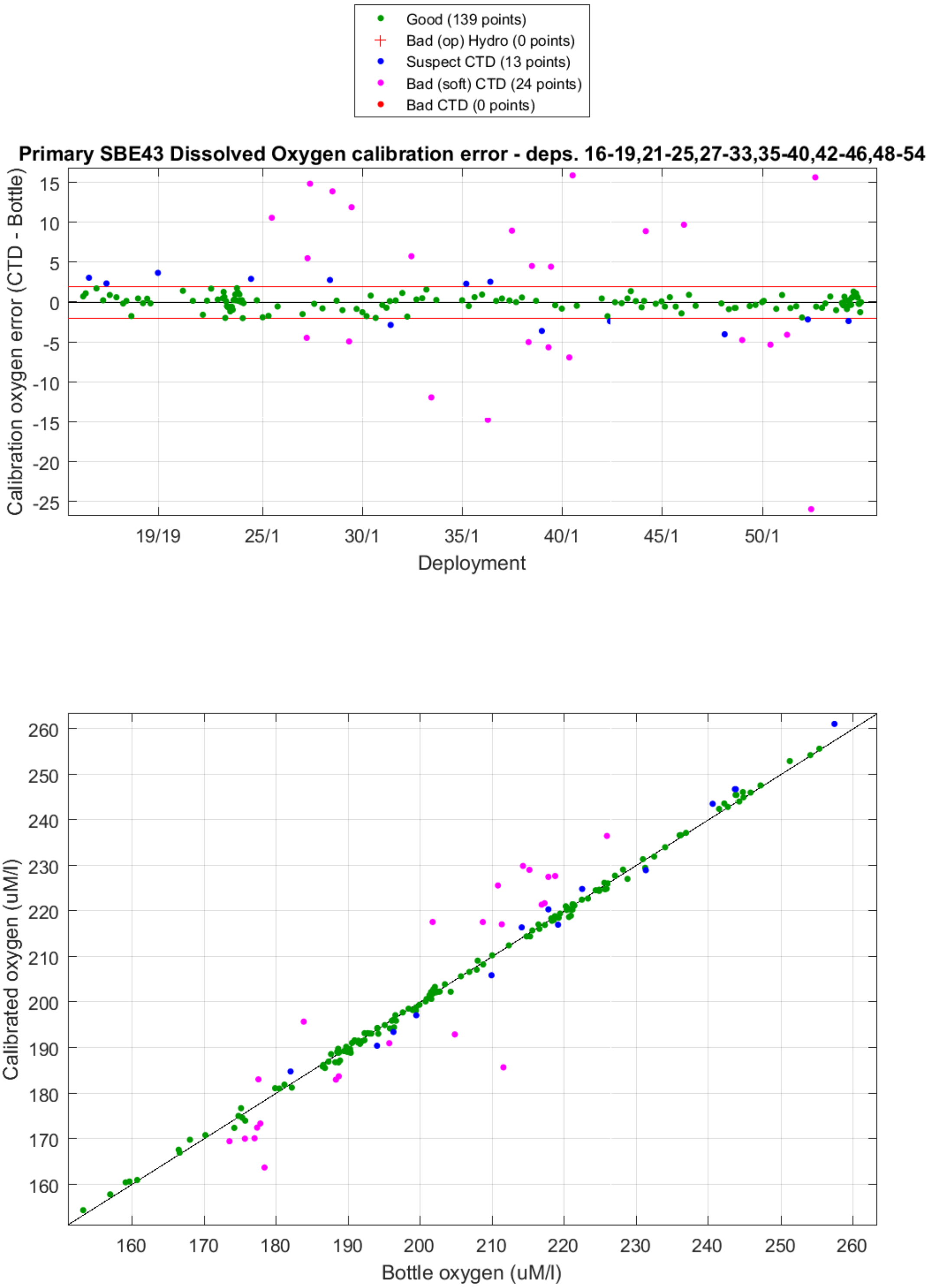


Figure 7. Dissolved oxygen calibration deployments 16 - 56

The old and new Soc and Voffset values for DO sensors are listed in Table 3 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 sensor.

	Feb2015 CSIRO calibration	**primary sensor calibration**
Voffset	-4.9151738e-01	- 4.7575e-01
Soc	5.0939087e-01	4.9531e-01
Fit SD (uM)		1.0348

Table 2 Dissolved oxygen calibration, group 1 deployments 1 – 15

	Feb2015 CSIRO calibration	**primary sensor calibration**
Voffset	-4.9151738e-01	- 4.75109e-01
Soc	5.0939087e-01	4.9907e-01
Fit SD (uM)		0.80641

Table 3. Dissolved oxygen calibration, group 2 deployments 16 – 56

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.

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	-1	500	0.5
fluorometer	0	100	0.5

Table 4. 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

Doblin, M., 2016: The RV Investigator. Voyage Plan in2016_V04 - http://mnf.csiro.au/~/media/Files/Voyage-plans-and-summaries/Investigator/Voyage%20Plans%20summaries/2016/IN2016_V04%20voyage%20plan%2020160829-FINAL.ashx

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

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/sites/default/files/documents/appnote64Jun13.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/document/an64-2-sbe-43-dissolved-oxygen-sensor-calibration-and-data-corrections

Sea-Bird Electronics Inc., 2010c: Application Note No 64-3: SBE 43 Dissolved Oxygen (DO) Sensor - Hysteresis Corrections. http://www.seabird.com/sites/default/files/documents/appnote64-3Aug14.pdf

Appendix I: Conductivity residuals

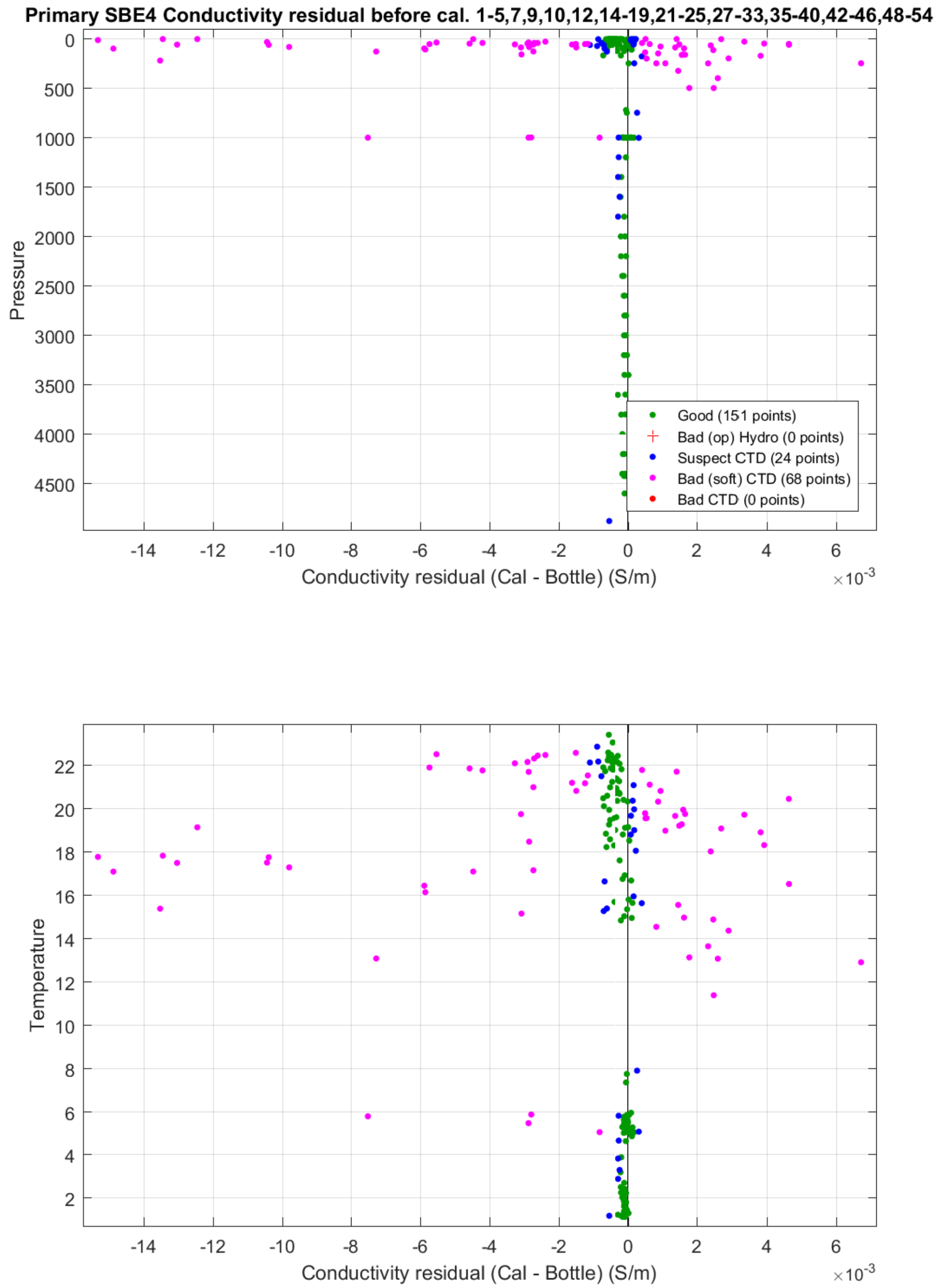


Figure 8. Primary conductivity residuals before calibration

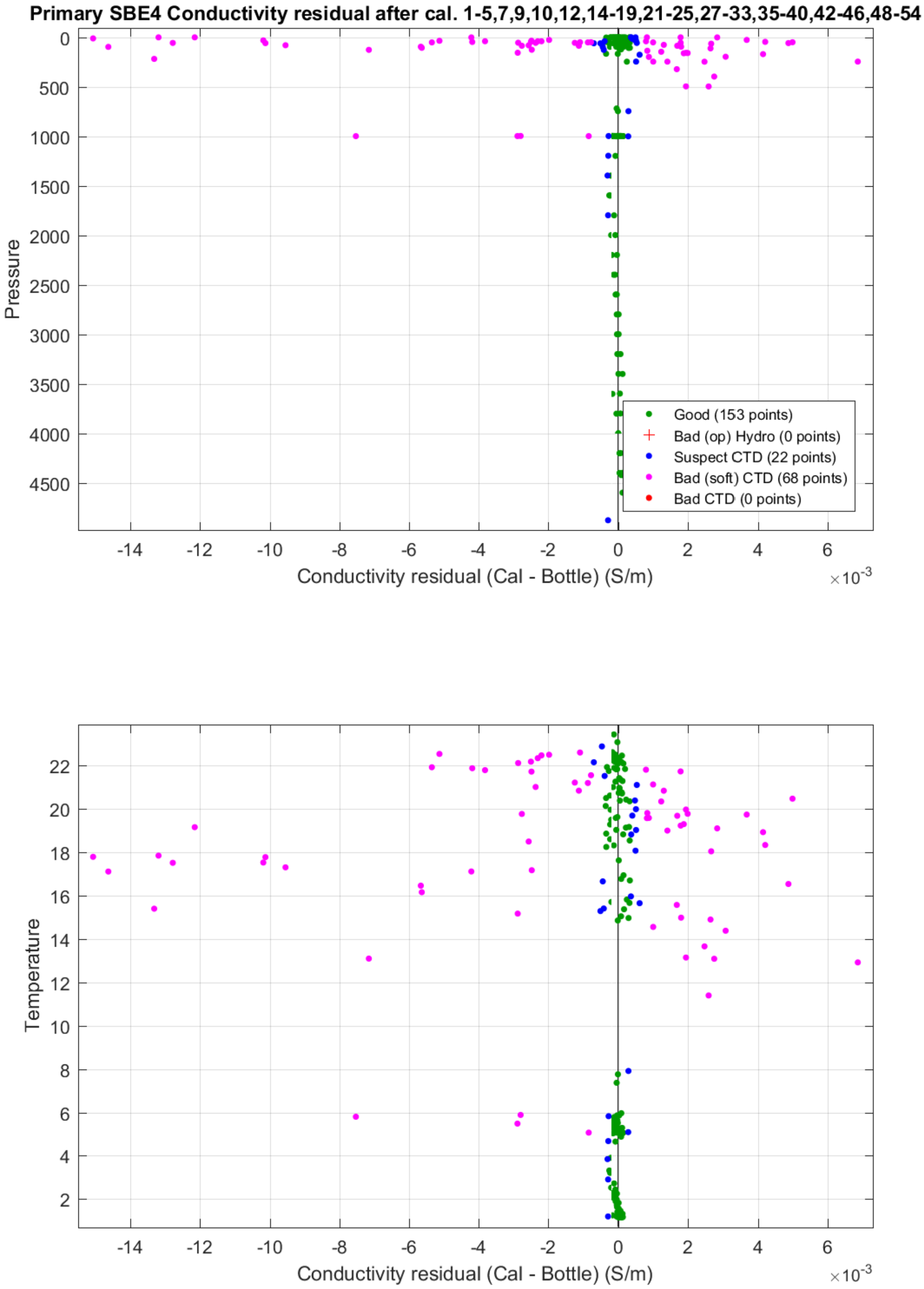


Figure 9. Primary conductivity residuals after calibration

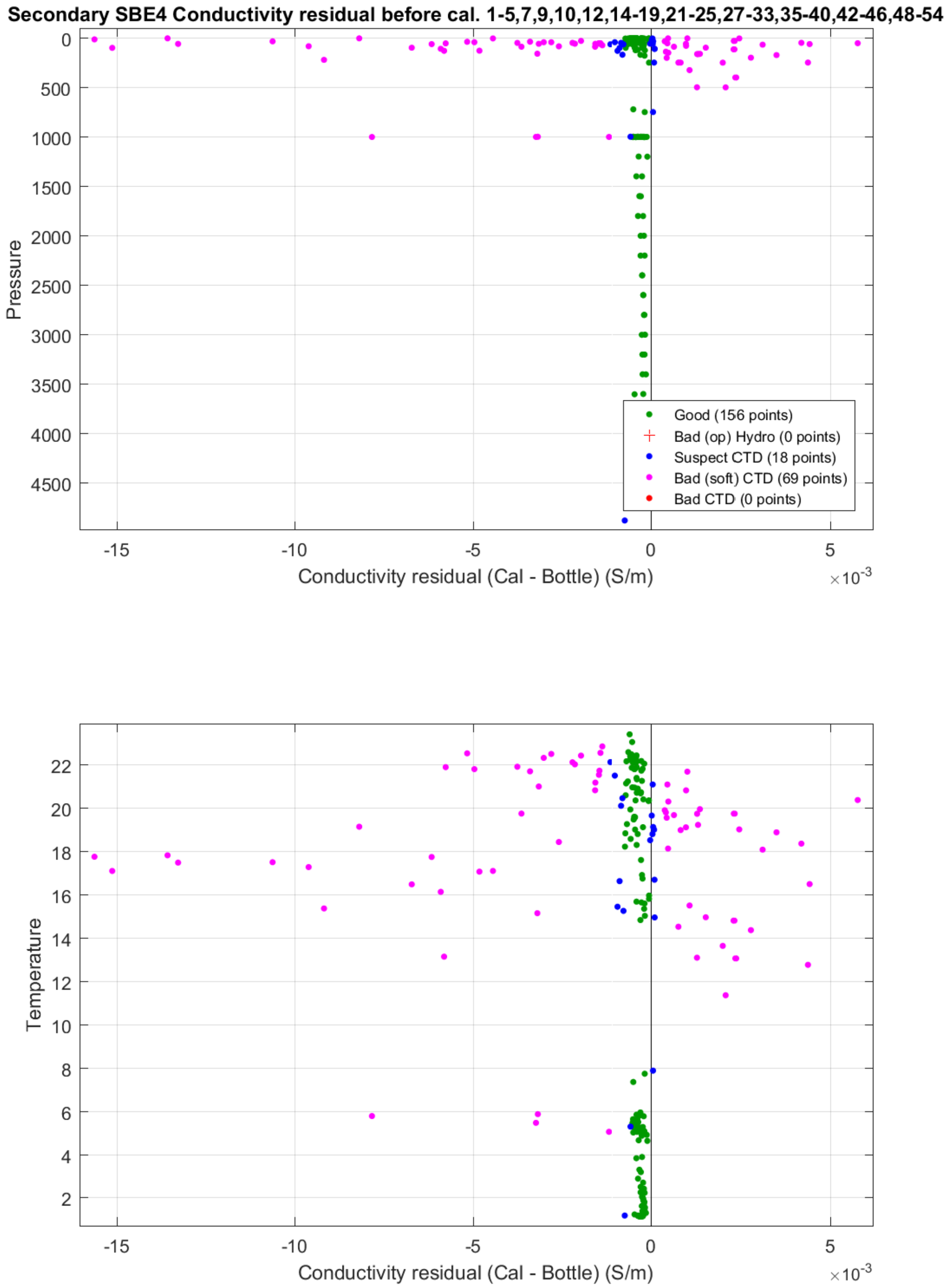


Figure 10. Secondary conductivity residuals before calibration

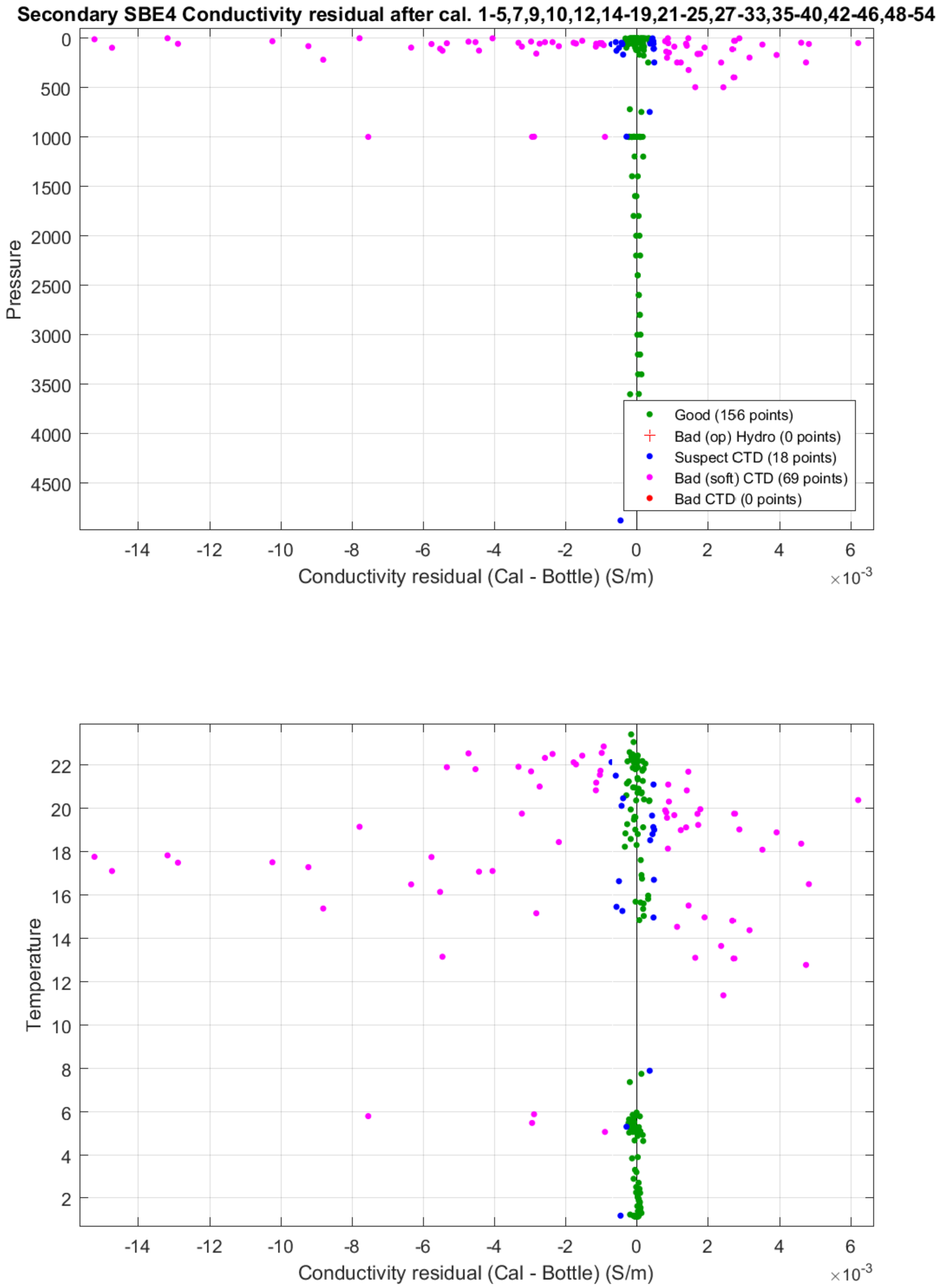


Figure 11. Secondary conductivity residuals after calibration

Appendix II: Dissolved Oxygen Residuals

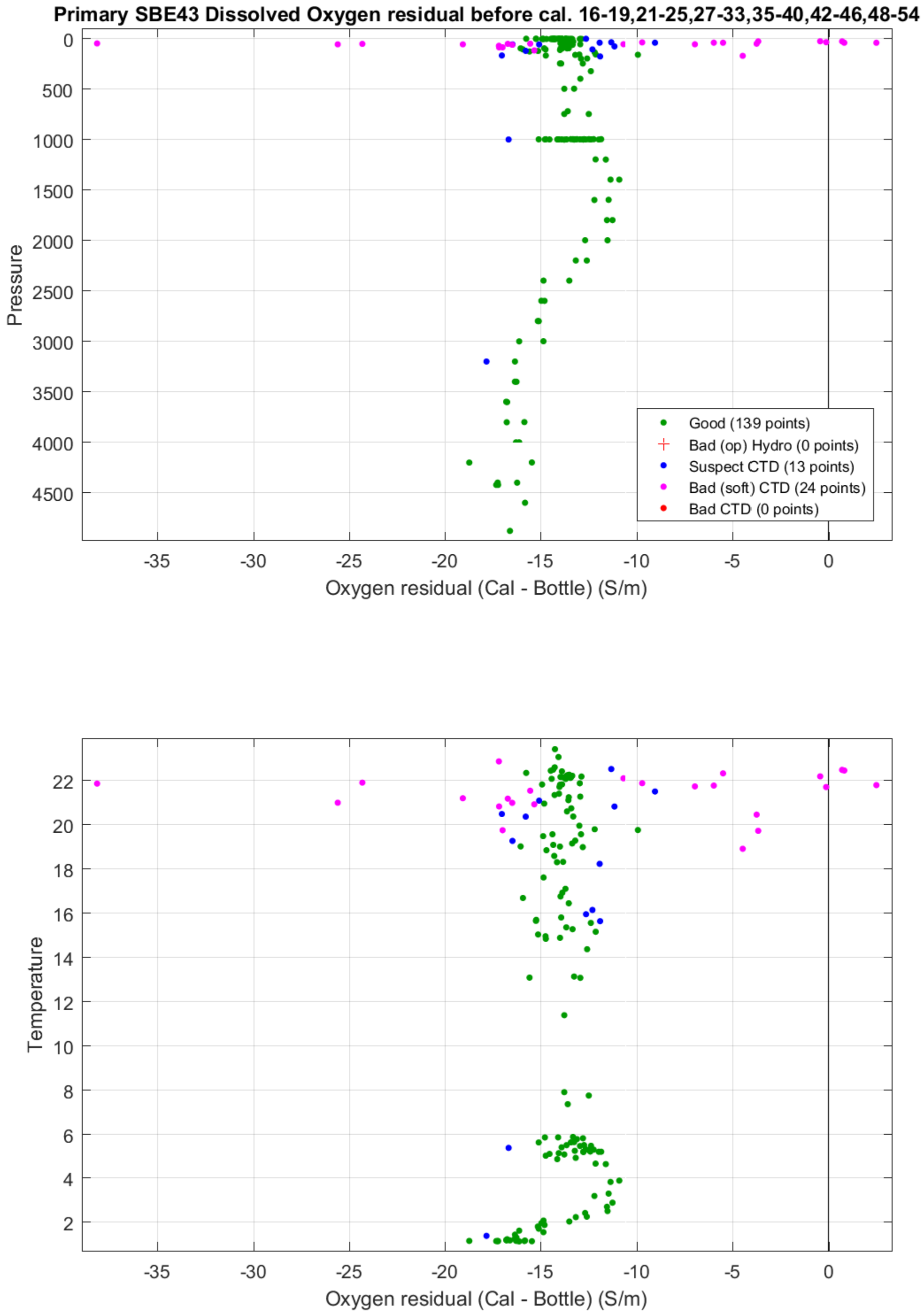


Figure 12. Oxygen Residuals before calibration, deployments

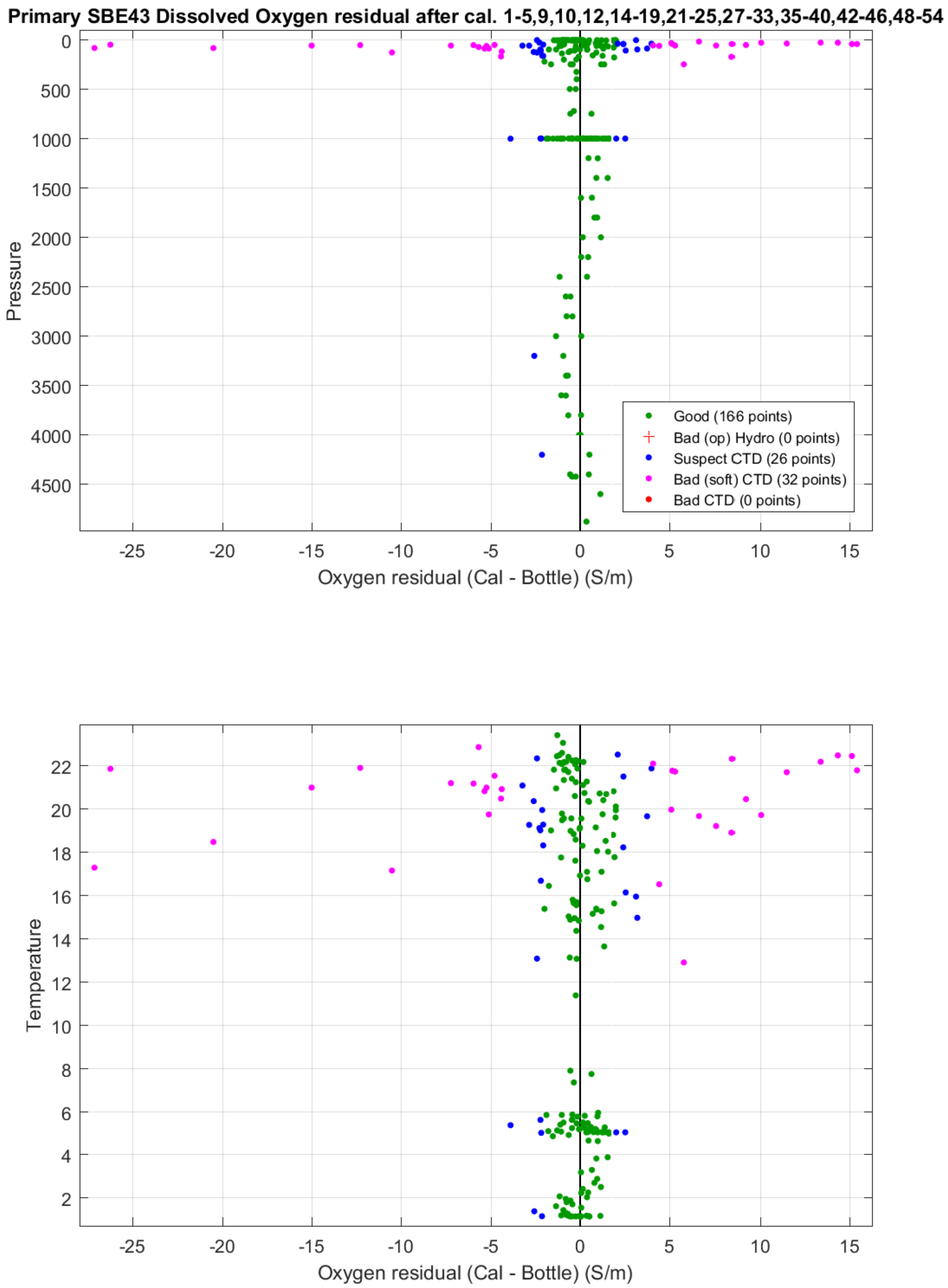


Figure 13. Oxygen residuals after calibration, all deployments

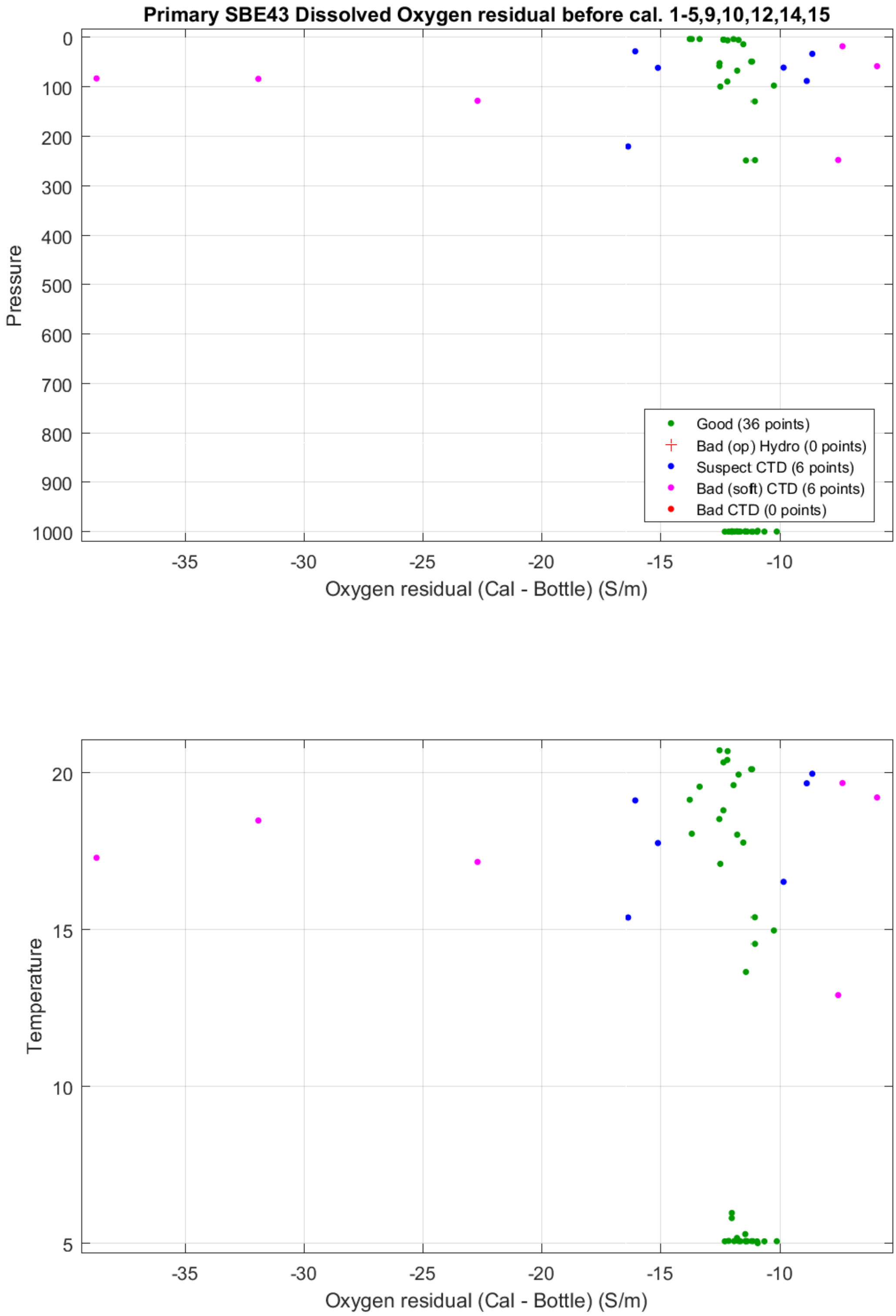


Figure 14. Oxygen Residuals before calibration, deployments 1 – 15 only

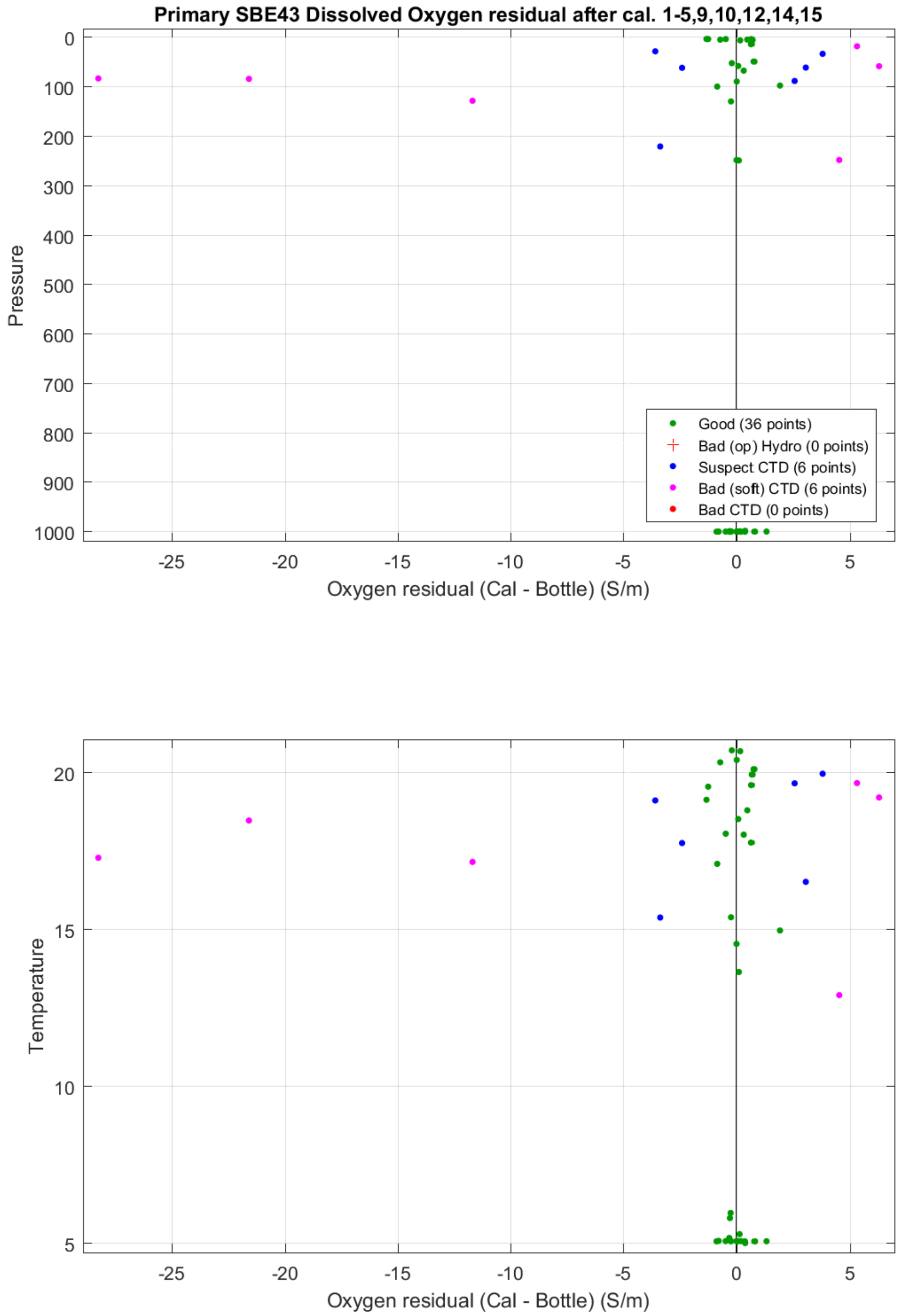


Figure 15. Oxygen residuals after calibration, deployments 1 – 15 only

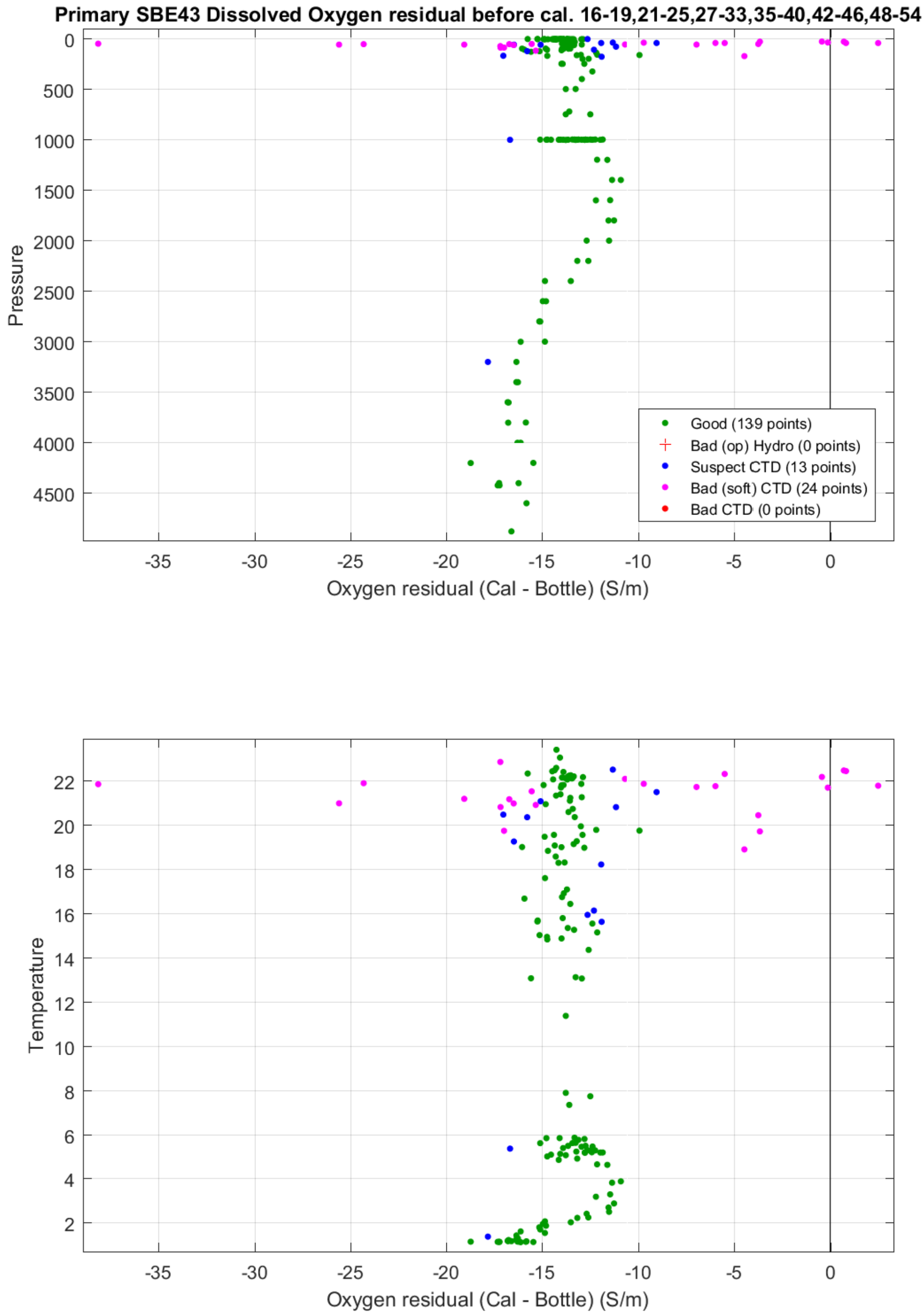
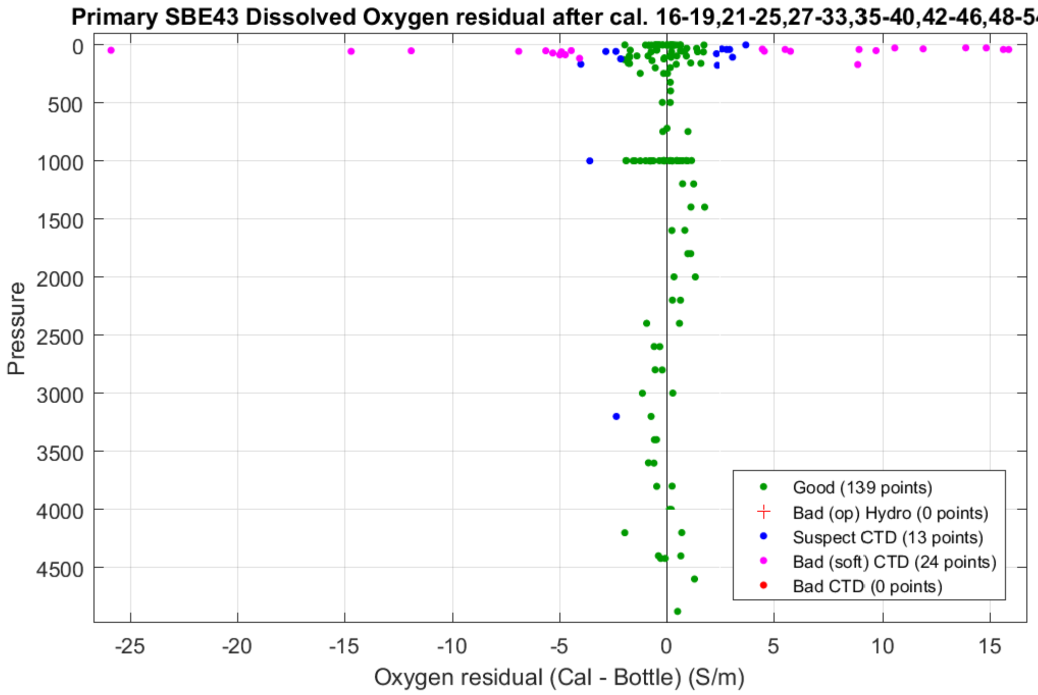


Figure 16. Oxygen residuals before calibration, deployments 16 – 54 only



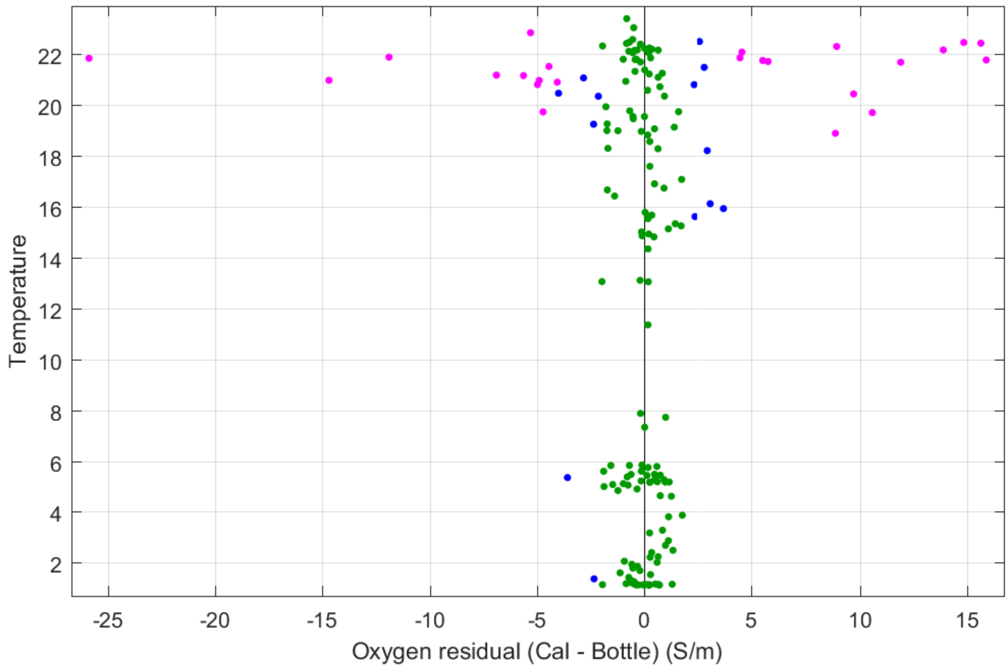


Figure 17. Oxygen residuals after calibration, deployments 16 – 54 only