CSIRO
MARINE RESEARCH

CTD Processing Notes

R V Southern Surveyor Voyage SS2006/04

12 April - 1 May 2006

Data processing completed by Pamela Brodie
February 2008

1. Summary

These notes relate to the production of QC'ed, calibrated CTD data from RV Southern Surveyor voyage SS 2006/04, from 12 April to 1 May, 2006.

On this voyage there were 205 CTD stations. The use of the CTD was not without incident. Data for 92 deployment were acquired using a Seabird SBE911 CTD 20, fitted with 21 ten litre bottles on the rosette sampler. After the failure of this underwater unit a major change over to the similar model CTD unit 19 was necessary. A further 113 deployments were made using this. Pressures and preliminary conductivity values were computed using the Seabird-supplied calibration factors and calibrations provided by the CSIRO Marine and Atmospheric Research Calibration Facility were used to compute the water temperatures. The data were subjected to automated QC to remove spikes

The final conductivity calibration was based on two deployment groupings using the primary sensor. The first calibration is from stations 1-92 and the second from stations 93-205. The calibrations have standard deviations around 0.0023 psu. This is a satisfactory result, but not quite within our target of 'better than 0.002 psu'.

The dissolved oxygen data measured by the Beckman sensor shows a particularly slow response. Oxygen was calibrated by fitting the data to an Owens and Millard (1985) model of the Beckman-style oxygen sensor. It is apparent that this model does not quantify all factors affecting the sensor output, which means that the CTD oxygen values should only be used for qualitative and semi-quantitative interpretation. An AAnderraa optode was installed on an auxiliary A/D channel from cast 89, also measuring oxygen. The optode phase data were processed using the foil constants and these dissolved oxygen (optodeDO) values appear in a second set of averaged files.

A Chelsea fluorometer, the Wet Labs transmissometer and a Photosynthetically Active Radiation (PAR) sensor borrowed from the Antarctic Division were also installed on the CTD's auxiliary A/D channels. Please note, the PAR channel has not been excluded from the averaged files for night-time casts. This auxiliary channel data has been subjected to the same de-spiking as the standard CTD data, but it is essentially, uncalibrated. The fluorometer has been calibrated to output 0-100 fsd.

2. Voyage details

2.1 Title

The title of the Voyage Plan was ‘Continental Shelf processes between Cape Leeuwin and the Great Australian Bight during the summer’.

2.2 Principal Investigators

Charitha Pattiaratchi was the Chief Scientist from the School of Environmental Systems Engineering of the University of Western Australia was the Principle Investigator.

2.3 Voyage objectives

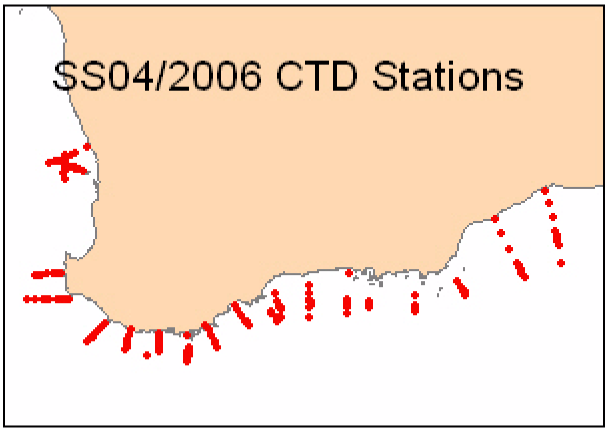
The scientific objectives for SS04/2006 were outlined in the Voyage Plan -

- To determine the summer circulation pattern along the continental shelf between Cape Leeuwin and the Great Australian Bight;
- To determine the connectivity between the Flinders Current (FC) and the Leeuwin Under Current (LUC);
- To determine the interaction of coastal currents, phytoplankton dynamics and trophic transfer in the coastal waters of southern Australia.

For further details, refer to the Voyage Plan (Pattiaratchi, 2006) which can be viewed on the CSIRO Marine and Atmospheric Research web site (http://www.marine.csiro.au/nationalfacility/voyagedocs/2006/PLAN_SS04-2006.pdf). The Voyage Summary report will also be published on this site, in due course.

2.4 Area of operation

FIGURE 1. Area of operation on SS04/2006



3. Processing Notes

Data for 205 CTD deployments were processed.

3.1 Background Information

This voyage was eventful for the CTD. There were not only sensor changes but a replacement underwater unit was also required. The data were initially acquired with CSIRO's CTD unit 20, a Seabird SBE911 with dual conductivity and temperature sensors, and an SBE13B, 'Beckman' dissolved oxygen sensor. It was evident in some casts that there was a problem developing with the instrument. Occasional noise in data from all channels had been noted. After operation 92, when water intrusion occurred, it was determined that the underwater unit of the CTD had been affected and the CTD was changed to unit 19.

The oxygen cell failed on station 58. It was replaced. A new Aanderraa 3975 Optode was used on an auxiliary channel after cast 88. The secondary temperature and conductivity sensors already installed on CTD 19 were used for casts 93 to 122. The conductivity signal appeared less than satisfactory and both sensors were replaced. Table 1 details these changes.

TABLE 1. SS04/2006 CTD units and sensors

Casts	**1 -58**	**59-88**	**89-92**	**93-122**	**123-205**
CTD unit	20	20	20	19	19
Primary temperature	2466	2466	2466	2334	2334
Primary conductivity	2594	2594	2594	2594	2594
Secondary temperature	2443	2443	2443	2751	2466
Secondary conductivity	2598	2598	2598	2312	2598
Dissolved oxygen	130527	130526	130526	130526	130526
Optode phase	no	no	yes	yes	yes

A deep water PAR sensor borrowed from the Antarctic Division and the Chelsea AquaTracka Fluorometer were also connected to the SBE911 auxiliary A/D channels. Water samples were collected using a Seabird SBE32, 24-bottle rosette sampler. Only 21 bottles could be fitted to the frame as externally fitted A/D instruments used the remaining locations.

The raw CTD data was 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, 2007).

procCTD applied 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 and manually adjusted to the correct values, where necessary.

CTD Processing Notes

The bottle sample data was used to compute final conductivity and dissolved oxygen calibrations. These were applied to the data, after which, files of binned, averaged data were produced.

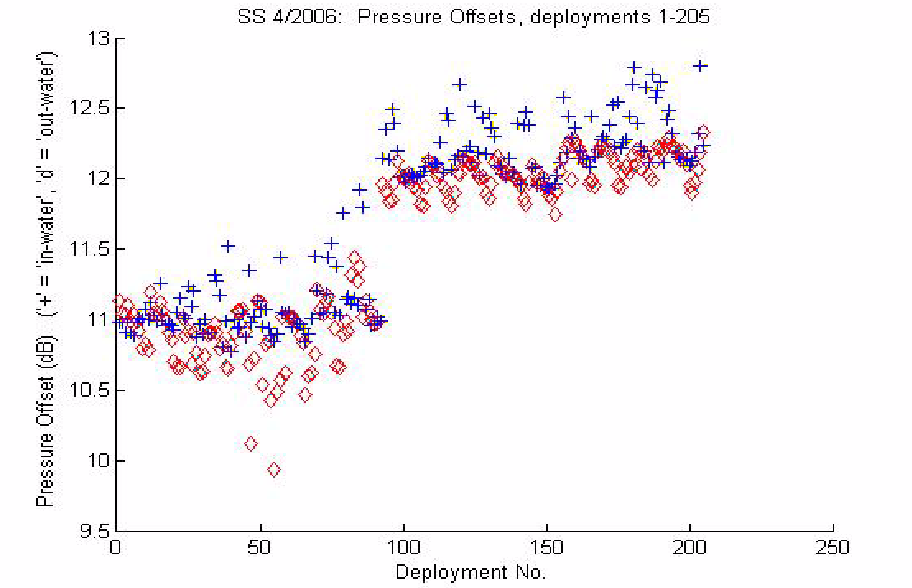
3.2 Pressure and temperature calibration

Pressures were computed using the Seabird-supplied calibrations. The temperature sensors used for the start of the voyage were calibrated on 16th March 2004 at the CSIRO Marine Research Calibration Facility (Calibration reports 265T and 179T for primary and secondary sensors respectively).

An additional pressure offset correction was computed for each deployment by assuming a linear drift between the pre and post-deployment, out-of-water pressures. These offsets are plotted in Figure 2 below. Different pressure sensors used with each CTD (initially 638 for CTD 20 and 637 for CTD 19). The change can be noted after deployment 92.

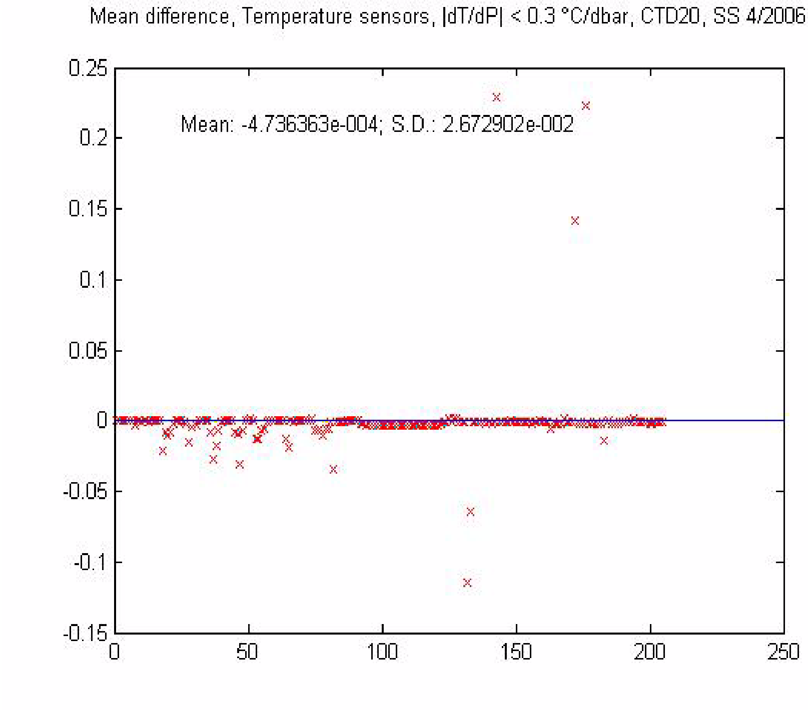
The pressure sensors show slight hysteresis in their response, with the out-of-water offsets being typically 0-0.5 dB less than the in-water offsets. However, there were no major changes in offset, which implies that the sensors had a consistent calibration throughout the voyage

FIGURE 2. CTD pressure offsets



The mean difference between the primary and secondary temperature sensors is plotted below.

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

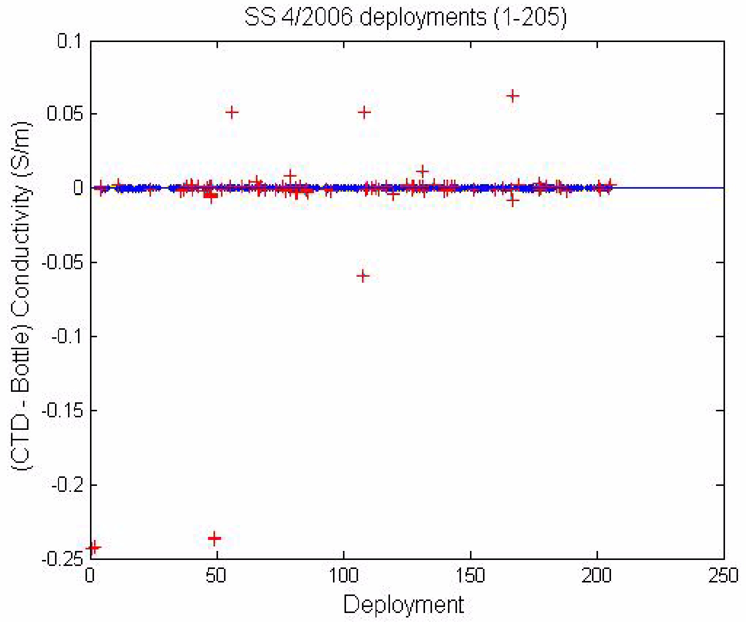


Most deployments plot well within ±1.5 mDeg C of the mean. However this is a larger range than normal (e.g. ±0.2 mDeg C for Fr2001/05). The sensor differences show the changes between the three sets of sensors which were used as detailed in Table 1. For the first pair there was more divergence between sensors (to cast 92) than was the case subsequently, when CTD unit 19 was first used. As shown later in Section 3.3 there is also a conductivity difference for these deployments. This could suggest the effect of problems with the underwater unit. Occasional spikes were noted in all data streams.

3.3 Conductivity calibration

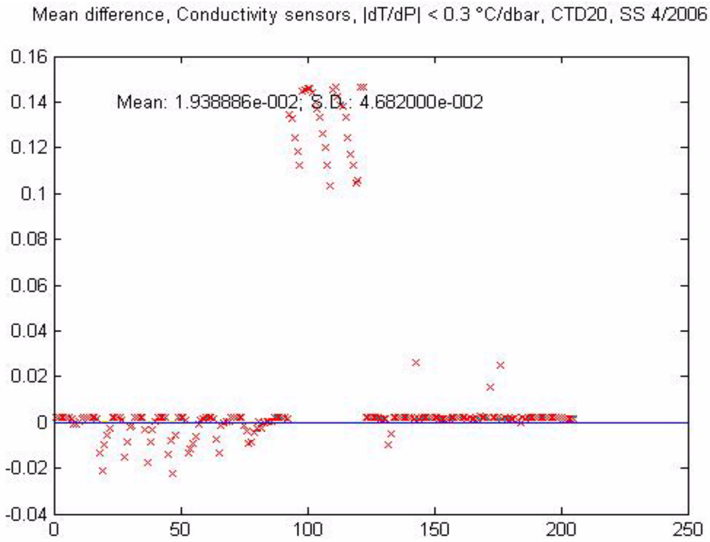
For this voyage two calibrations were produced. The calibrations was based upon the sample data for deployments 1-92 and 93-205. There were considerable discrepancies, probably sampling problems, between bottle and CTD salinities for a few stations as shown in the plots of calibrated (CTD - Bottle) conductivity below.

FIGURE 4. CTD - bottle conductivity plot.



The plot of uncalibrated (Primary - Secondary) conductivity for pressures > 20 dB (Figure 5) shows that the conductivity cell responses diverged markedly before the CTD underwater unit failed at cast 92. A difference was also noted in the temperature sensors for these deployments. The faulty secondary conductivity sensor was initially used with CTD 19, and changed at cast 123. After this the sensors corresponded well. A single primary conductivity sensor was used throughout the voyage and good calibrations were achieved for this. Calibrations were not applied to the secondary conductivity data for deployments 93-122 where the data was bad.

FIGURE 5. Mean difference between primary and secondary conductivity sensors



Samples from several stations were manually flagged as ‘bad’ to exclude them from the calculation. For deployments 1-92 there was a resulting calibration of

Scale Factor (a1)	1.000131	w.r.t. M/facturer’s calibration
Offset (a0)	6.8129246E-04	ditto
Calibration S.D. (Sal)	0.0023083 psu	

for the primary conductivity sensor and, for deployments 93-205

Scale Factor (a1)	1.0009798	w.r.t. M/facturer’s calibration
Offset (a0)	-2.1297248E-02	ditto
Calibration S.D. (Sal)	0.0022374 psu	

also for the primary sensor. This is a good calibration although we normally aim for a S.D. of 0.002 p.s.u. for ‘typical’ voyages. The above calibration factors were applied to all deployments. The secondary sensor was bad between stations 93 and 122. The following calibration was applied for deployments 1-92 and 123-205.

Scale Factor (a1)	1.0004865	w.r.t. M/facturer’s calibration
Offset (a0)	-1.71477E-04	ditto
Calibration S.D. (Sal)	0.0035835 psu	

Data from the primary conductivity sensor were used to produce the averaged files.

3.4 Dissolved Oxygen Sensor Calibration

3.4.1 Calibration procedure for the Beckman sensor

Our model for the response of the Beckman Dissolved Oxygen sensor is based on Owens and Millard (1985). It uses an iterated, 6-parameter fit for the parameters:

Oxygen Current Slope (gain)
Oxygen Current Bias
Sensor Lag
Activation Energy
Reaction Volume
Temperature weight

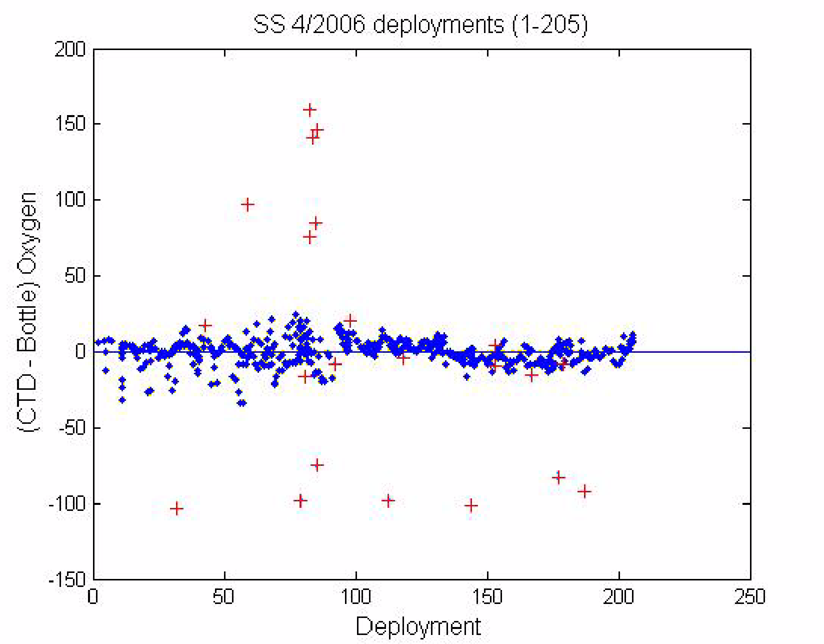
In principle, the last 4 factors should be constant for the sensor type and geometry, with only the Slope and Bias changing, as the sensor becomes depleted. In practice, we iterate some or all of the other components, as we have not yet determined the ideal default values.

In addition, there seems to be a hysteresis effect that is not included in the sensor model. This means that it is not possible to produce a good fit of both the downcast and upcast sensor outputs to the bottle data. (The ‘downcast samples’ are the downcast values for the same pressures as the ‘Upcast’ sample bursts.)

CTD Processing Notes

The Beckman oxygen data was calibrated in three deployment groups based on the Upcast CTD - bottle oxygen plot below.

FIGURE 6. CTD - bottle oxygen plot.



The following calibration procedure was used.

1. All parameters were fitted, using the downcast and upcast CTD and bottle data.
2. All parameters, apart from Slope & Bias, were fixed and the bottle data was iterated against the downcast CTD oxygen (matched to the pressures of the upcast 'sample bursts').

   The aim is to get the best agreement between the bottle data and the CTD downcast.

Deployment grouping	**1-58**	**59-92**	**93-132**	**133-205**
Current Slope	0.0003866	0.0010376	0.00088598	0.0013148
Current Bias	-0.0093913	-0.47755	-0.021572	-0.0018864
Sensor Lag	10	10	10	10
Activation Energy	4399.7	4070.1	4362.1	4123.2
Reaction Volume	74.896	142.27	-14.465	-36.5
Temperature Weight	0.43942	0.7	0.712	0.781
Oxy Stnd. Dev (uM/l)	7.771	14.509	5.557	3.906

TABLE 2: SS04/2006 Beckman sensor oxygen calibration groupings

CTD Processing Notes

The oxygen data were processed in four calibration groups. The first grouping was associated with a different sensor from the later groupings. The second group included data acquired with CTD unit 20. In the last two groups acquisition problems had settled down and the data quality improved. The first results in all cases showed a high sensor lag, from 40 to over 100. This was very much higher than Seabird's suggested normal value of around 7.0. Although on some past voyages we have obtained values of up to 40, which is in the order of the value from the third deployment grouping, the sensor lag was fixed in all cases to a value of 10.

There are deployments with steep oxygen gradients in the near surface section, and occasionally at the bottom of the downcast plots. At the surface this would relate to the following two operational factors about which those conducting the CTD cast are warned. The effect can be due to not allowing the sensor sufficient time to 'warm up' if the power to the CTD is turned on just before a station. When the CTD is placed in the water, it is necessary for the oxygen readings to stabilise before the downcast is commenced. Where steep gradients are evident near surface oxygen data should be ignored. Surface optode values (see the following Section) are helpful in determining how far into the profile the Beckman sensor response was compromised at the surface. The possible pressure effect evident at the bottom of the downcast can also benefit from comparison with the optode trace.

As noted for the conductivity calibration, the developing problem with the CTD underwater unit during the first part of the voyage may have caused the problems which are evident in the datasets. The oxygen data quality ranges from less than satisfactory while CTD unit 20 was in use, to good, for data acquired using CTD unit 19. The fits for the final grouping are as good as could be expected, given the limitations of our current understanding of the oxygen sensor model. The calibrated oxygen data should only be used for qualitative and semi-quantitative work.

3.4.2 The Aanderaa Optode

This was the first time the optode was used on the National Facility CTD. It was the Aanderaa series 3975 optode, serial number 583 with foil 4104. The Aanderaa web site (see References) contains a pdf on the optode specifications. Several advantages are claimed compared with electro-chemical sensors including better stability, the optode is less affected by pressure, has a faster response time and it consumes no oxygen.

The sensor functions on the principle of dynamic fluorescence quenchers, using a platinum porphyrin complex embedded in a gas permeable foil which is exposed to the seawater. The foil is excited through a sapphire window by modulated blue light. The phase of a returned red light is measured. Temperature-compensated phase data is used with the calibration coefficients for the foil to determine the absolute O_2 concentration (uM/l) in the water.

The optode data gathered from casts 194 to 204 is bad, reading off scale between 700 and 1200uM/l. This may be due to a processing anomaly or configuration issue.

The CTD data for this voyage was re-processed when optode phase processing was integrated into the procCTD software. This is the first opportunity we have to directly compare the sensors and further work is to be done in this regard. The optode was noted to have a slower response than the Beckman sensor.

3.5 Other sensors

The Chelsea fluorometer was used for all deployments. The fluorometer has been calibrated to give nominal outputs of 0-100 fsd.

The borrowed deep water PAR sensor was also used for all deployments. The output was in volts. This data channel has been included in the output files for all deployments. If most or all of the values for a deployment are near zero, it implies that it was a night-time cast. The deployments where PAR profiles have sub-surface maxima may have been shaded by the ship.

3.6 Binned data files

The calibrated data was 'filtered' to remove pressure reversals and binned into 2dB averaged netCDF files. The binned values were calculated by applying a linear, least-squares fit to the bin data and using this to interpolate the value for the bin mid-point. This is more accurate than simply taking the mean of the data.

Each binned parameter in each bin is assigned a QC flag. Our flagging scheme is described in **http://www.marine.csiro.au/datacentre/ext_docs/DataQualityControlFlags.pdf**.

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 is taken to be the worst of the estimates for the parameters from which they are derived.

4. References

Aanderaa Data instruments Optode Specifications -

http://www.aanderaa.com/docs/Oxygen_Optode_3830_3930_3975_D335.pdf

Beattie, R.D., 2007: procCTD CTD Processing Procedures Manual. http://www.marine.csiro.au/datacentre/ext_docs/procCTD.pdf. FrameMaker 7.0 source document: /net/fdcs/opt/fdcs/src/ctd/doc/procCTD.fm

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