

DELPHINUS 2009 McArthur II CTD PROCESSING

DELPHINUS 2009 CTD data files were collected using a Sea-Bird 911*plus* profiling instrument aboard the NOAA Ship McArthur II (MACII). The 911*plus* consists of the 9*plus* underwater CTD and 11*plus* V2 Deck Unit, which has high resolution sampling (24Hz) and pump-controlled conductivity and temperature flow-through sensors. Data were collected using Sea-Bird's SeaSave Win32 Version 7.18 and have been processed using Sea-Bird's SBE Data Processing v. 7.26.7. More information regarding the SBE software and recommended data processing procedures can be found online at www.seabird.com.

Each CTD directory on the data server contains two folders named Raw and Data. CTD set-up information, pressure test results, and data collected at sea are stored in the Raw folder. All information and files used in processing are saved in the Data folder, including documentation, configuration files, calibration sheets, intermediate processing steps and final data.

Sensor use on the McArthur II CTD during the DELPHINUS 2009 cruise went through several changes during Leg 3. The table below describes the period for which each sensor was used. The owners of the sensors are responsible for their maintenance.

	Casts	Temp 1, 2	Cond 1, 2	DO	Pressure
Leg 1	001	T4677, T4803	C1725, C3353	O1295	P3001
Leg 1-3	002-050	T4677, T4803	C1725, C3353	O1295	P0405
Leg 3	051-056, 058-059	T4677, T4803	C1725, C3353	O1295	P0311
Leg 3	057	T4803	C3353		P0311
Leg 3	060	T4677, T4803	C1725, C3353	O1294	P0311
Leg 3	061, 067-068, 071	T4677, T4803	C3201, C3353	O1295	P0311
Leg 3	062-065	T2109	C3201	O1295	P0311
Leg 3	066	T2109	C3201		P0311
Leg 3	069-070, 072	T2109, T4803	C3201, C3353		P0311
Leg 3	073-074	T2109, T4803	C3201, C3353		P0311
Leg 3	075-076	T2109, T4803	C3201, C3353	O1294	P0311
Leg 3	077-080	T2109, T4803	C3201, C3353	O1295	P0311

PMC-owned, MMTD-owned

DELPHINUS 2009 MACII CTD SENSOR CALIBRATION

SWFSC MMTD uses Sea-Bird Electronics conductivity, temperature and pressure sensors. Sea-Bird Electronics conductivity sensors drift with usage and time, while temperature and pressure sensors drift primarily over time. Annual calibrations of the conductivity and temperature sensors are necessary to estimate and correct for this drift during data processing. Pre and post-

cruise calibration certificates for the sensors used during DELPHINUS 2009 are in the \CON_Files\Calibrations folder.

Conductivity, temperature, and pressure are computed as polynomial functions of the sensor frequencies stored in the raw data file. We follow Sea-Bird recommended procedures for adjusting calibration coefficients for drift between calibrations (Sea-Bird App. Note # 31). Details can be found in the internal document "CTD Calibration Adjustments MMTD.pdf".

The Excel spreadsheet, CTDcalibrations DELPHINUS 2009_MACII.xlsx, in the \Documentation folder, contains the pre- and post-cruise calibration information for the conductivity, temperature, pressure, and dissolved oxygen sensors. It then derives slope or offset values used to correct the calibration coefficients used in the Data Conversion and Derive modules of Sea-Bird's SBE Data Processing procedure. The adjusted configuration files used to process the DELPHINUS 2009 MacII data (Appendix 1) are in the \CON_Files folder.

Conductivity Sensor Correction:

The SBE 4C series conductivity sensor has a measurement range of 0.0 to 7.0 Siemens/meter (S/m), which spans the conductivity range of SWFSC MMTD's study areas. The SBE 4C sensor is rated to have an initial accuracy of 0.0003 S/m; with a resolution (at 24Hz) of 0.00004 S/m.

The primary conductivity sensor, C1725, was calibrated on 23 December 2008 and 19 February 2010. The difference between the iSlope values at the start and end of the cruise was less than 0.0003, and the iSlope at the end of the cruise was <0.00015 from 1; consequently, no slope calibration adjustment was needed. Pre-cruise calibration coefficients were used to process the data.

The primary conductivity sensor for casts 061-080, C3201, was also calibrated on 23 December 2008 and 19 February 2010. The difference between the iSlope values at the start and end of the cruise was less than 0.0003, and the iSlope at the end of the cruise was <0.00015 from 1; consequently, no slope calibration adjustment was needed. Pre-cruise calibration coefficients were used to process the data.

The secondary conductivity sensor, C3353, was calibrated on 8 January 2009 and 31 March 2010. The difference between the iSlope values at the start and end of the cruise was less than 0.0003, and the iSlope at the end of the cruise was <0.00015 from 1; consequently, no slope calibration adjustment was needed. Pre-cruise calibration coefficients were used to process the data.

Temperature Sensor Correction:

The SBE 3*plus* series temperature sensor has a measurement range of -5.0 to 35 °C, which spans the range of temperatures in SWFSC MMTD's study areas. The SBE 3*plus* sensor is rated to have an initial accuracy of ± 0.001 °C and a resolution (at 24 samples per second) of 0.0003 °C.

The primary temperature sensor, T4667, was calibrated on 14 January 2009 and 19 February 2010. The iOffset at the end of the cruise was less than 2mdeg C; consequently, no offset calibration adjustment was needed.

The alternate temperature sensor, T2109, was calibrated on 18 December 2008 and 18 February 2010. The iOffset at the end of the cruise was less than 2mdeg C; consequently, no offset calibration adjustment was needed.

The secondary temperature sensor, T4803, was calibrated on 29 January 2009 and 31 March 2010. The iOffset at the end of the cruise was also less than 2mdeg C; consequently, no offset calibration adjustment was needed.

Pressure Sensor Correction:

The SBE Paroscientific Digiquartz pressure sensor is rated to have an initial accuracy of 1.02m (i.e., 0.015% of the full scale range, which is 0 – 6800m). We do not exceed a maximum vertical depth of 1100m. Initial resolution (at 24Hz) is 0.068m (i.e., 0.001% of the full scale range).

One deck test was conducted on the CTD pressure sensor P3001, which was used on only one cast, resulting in an offset of 10.659 db; this result was consistent with Sea-Bird calibrations from 7 January 2009 and 26 February 2010 (average iOffset=10.548). Therefore, the average of the deck test offset and iOffset, equal to 10.604, was used in the *.con file.

Two deck tests were conducted on the CTD pressure sensor P0405, which was used during Legs 1 to 3, resulting in offsets of -0.817 and -0.405 db; the first result was consistent with Sea-Bird calibrations from 8 January 2009 and 9 March 2010 (average iOffset=-0.812). Therefore, the average of the first deck test offset and iOffset, equal to -0.814, was used in the *.con file.

One deck test was conducted on the CTD pressure sensor P0311, which was used during the end of Leg 3, resulting in an offset of -6.773 db; this result was nearly consistent with Sea-Bird calibrations from 12 Apr 2007 and 13 April 2010 (average iOffset=-5.814). Therefore, the average of the deck test offset and iOffset, equal to -6.294, was used in the *.con file. Since the pre-cruise calibration was more than 2 years prior to the cruise (12 April 2007), the post-cruise calibration coefficients were used in the *.con file.

Oxygen Sensor Correction:

The SBE 43 oxygen sensors has a measurement range of 0 to 120% of surface saturation (approximately 200 $\mu\text{mol/Kg}$). The SBE 43 sensor is rated to have an initial accuracy of 2% of surface saturation (approximately 4 $\mu\text{mol/Kg}$).

The sensor outputs a voltage that is linearly related to dissolved oxygen concentration by a slope (Soc) and offset (Voffset). The sensor is expected to drift over time due to a decrease in sensitivity. Drift is expected to occur only at sea because the sensor membrane is sealed against exposure to air between cruises. Sea-Bird recommends a simple interpolation based on usage

time between the pre- and post-cruise calibration values of Soc. On the advice of Dave Griffiths (SWFSC Fisheries Resources Division), both Soc and Voffset are normally interpolated.

The dissolved oxygen sensor O1294 was calibrated on 5 January 2009 and 12 April 2010 and was used on three casts during Leg 3. Sensor O1295 was calibrated on 5 January 2009 and 12 April 2010 and was used on Legs 1-3. Pre-cruise calibration values were used for both oxygen sensors. However, both sensors were found to be damaged at the post-cruise calibration. We do not know whether the damage happened during the cruise or on shipment for the post-cruise calibration.

Comparison of the Primary and Secondary Sensors

Differences between primary and secondary sensors by cast are summarized in Figure 1. Fortran program COMSENS.EXE (Author: Paul Fiedler) calculates the mean difference between the primary and secondary sensors for each profile. The output file, compsens07m.dat, is in the \Documents folder. Figure 1 shows that the temperature and conductivity values measured by and salinity values derived from the primary and secondary sensors did not differ by more than the desired accuracy of the sensors, except for salinity and conductivity starting on Leg 2. Bottle salinity analyses (Appendix 2) indicate that the primary conductivity sensor was more accurate than the secondary sensor and should be used for the final CTD data from all legs. These analyses also indicate drift in the secondary conductivity sensor that may be the cause of the excessive conductivity and salinity differences. On Leg 3, when CTD problems were being diagnosed, several casts had only one pair of sensors or were rejected because of errors in secondary sensor salinity data.

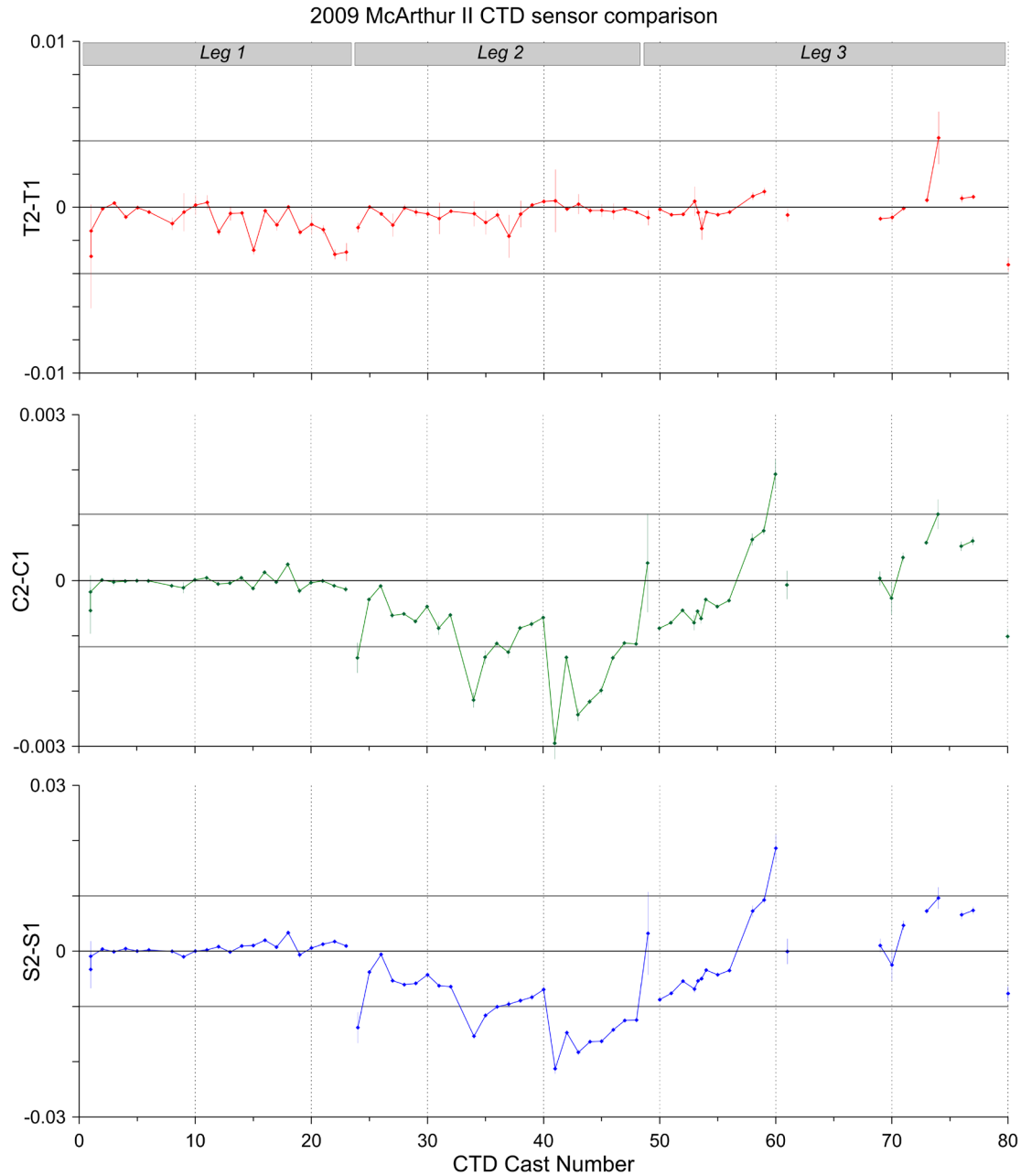


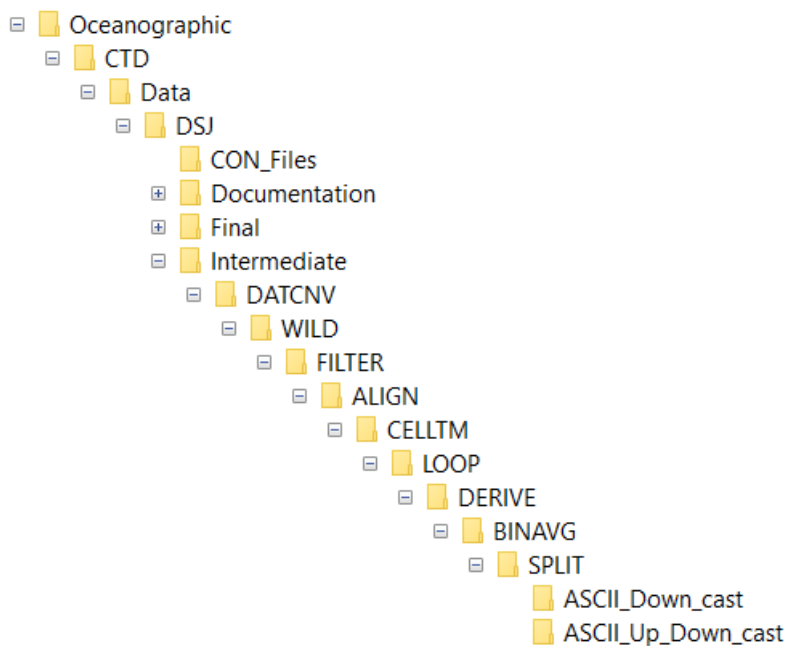
Figure 1. Time series of differences between primary and secondary temperature and conductivity sensors for DELPHINUS 2009 McArthur II CTD casts (062-066 did not use dual sensors). Each temperature (T2-T1), conductivity (C2-C1), and salinity (S2-S1) difference is a mean of 1m bin-averaged downcast values (excluding the upper 10m and bins with density changes $>0.003 \sigma_t$). Gray lines represent desired accuracy ($\pm 0.004^\circ\text{C}$, $\pm 0.0012 \text{ S/m}$, $\pm 0.010 \text{ psu}$, which are 4x the specified initial accuracies of the Sea-Bird temperature and conductivity sensors).

SWFSC MMTD uses pre-cruise calibration coefficients for each sensor when available. Before running the processing modules, it is essential to ensure that the correct sensor configuration coefficients and corrections are loaded into the *.con files used by the SBE Data Processing program. Offset and slope adjustments are obtained from CTDcalibrations DELPHINUS 2009 MACII.xlsx in the \Documentation folder. Configuration files for the sensors used on the McArthur II during DELPHINUS 2009 are listed in Appendix 1. Configuration files DEL2009_069-070_072.con and DEL2009_073-074.con are different because of the number of voltage words suppressed (Appendix 2).

DELPHINUS 2009 CTD SBE MODULE PROCESSING

The SBE Data processing modules that were applied to the raw DELPHINUS 2009 MacII data are listed below. Each SBE module creates a program setup file, named *.psa. The *.psa files are located in the folder preceding their output, i.e. the 'Derive.psa' file is found in the 'LOOP' folder. Output .cnv files are kept in binary format to speed processing and reduce file sizes. The final module – ASCII Out – converts the binary data to ASCII format; if examination of the data is needed during earlier processing steps, the Translate module can be used to convert to the binary data to ASCII.

Modules are run in the following order: Data Conversion, Wild Edit, Filter, Align CTD (as needed), Cell Thermal Mass, Loop Edit, Derive, Bin Average, Split, ASCII Out. The processed data in various stages are in the \Intermediate folder:



1. Data Conversion Module:

Data Conversion converts raw SBE 911plus data, which are typically stored as frequencies and voltages in the *.dat file, to engineering units and stores the converted data in a *.cnv file.

The options selected for processing in Data Conversion for casts with all sensors were as follows:

```
# name 0 = prDM: Pressure, Digiquartz [db]
# name 1 = c0S/m: Conductivity [S/m]
# name 2 = t090C: Temperature [ITS-90, deg C]
# name 3 = c1S/m: Conductivity, 2 [S/m]
# name 4 = t190C: Temperature, 2 [ITS-90, deg C]
# name 5 = sbx0Mm/Kg: Oxygen, SBE 43 [umol/kg]
# name 6 = flag: 0.000e+00
```

Fortran program ScrData (programmer: Paul Fiedler) was used to flag values outside of these broad ranges: pressure -5 to 1200 db, temperature -1 to 33 deg C, conductivity 2.5 to 7.0, and dissolved oxygen 0 to 350 $\mu\text{mol kg}^{-1}$. The program first checks the range of values (primary and secondary, if present) in the header file. If any span exceeds the above limits, the program writes a new file in which each bad value, and the values in the two scans preceding and the two scans succeeding the bad value, are flagged. The original file is renamed with an “x” prefix. For each edited file, the total number of scans, the number of values that were outside limits, and the number of values flagged is summarized in the file *ScrData.dat* in the \Intermediate\DATCNV\ folder. Of 92 CTD files, 66 had no outliers, 16 had primary conductivity outliers, 19 had secondary conductivity outliers, 9 had primary temperature outliers, 20 had secondary temperature outliers, 14 had pressure outliers, and 22 had dissolved oxygen outliers. Flagged values are ignored in subsequent processing.

2. Wild Edit Module:

Wild Edit flags outliers in temperature, conductivity, and oxygen data so that they are not used in further processing. Wild Edit’s algorithm requires two passes through the data in blocks of *npoint* scans. The first pass computes the mean and standard deviation and temporarily flags values that differ from the mean by more than *pass1_nstd* standard deviations. The second pass recalculates the mean and standard deviation, excluding values flagged in the first pass. Scans that differ from the mean by more than *pass2_nstd* standard deviations are replaced with a bad data flag. The criteria established by *pass2_nstd* can be overridden using *pass2_mindelta*; specifically, if data are within *pass2_mindelta* of the mean, they are not flagged.

The options selected for processing in Wild Edit were as follows for all casts:

```
# wildedit_pass1_nstd = 2.0
# wildedit_pass2_nstd = 15.0
# wildedit_pass2_mindelta = 0.000e+000
# wildedit_npoint = 100
```

These options are Sea-Bird defaults, except that *pass2_nstd* was changed from 20.0 to 15.0 to identify more outliers.

3. Filter Module:

The Filter module is run to reduce high-frequency noise in the pressure data, which is caused by counting jitter or other unknown sources. It is important to remove this noise before running the Loop Edit module. Loop Edit flags data that exhibit a change in the CTD velocity. Velocity is calculated using only three successive scans; consequently, noisy pressure data can result in erroneously flagged scans. Filter runs a low-pass filter on the data, which smoothes high frequency (rapidly changing) data. To produce zero phase (i.e., no time shift), the filter is first run forward through the data and then run backward through the data. Pressure data is typically filtered with a time constant equal to four times the CTD scan rate. We run a low-pass filter on the pressure data with time constant = 0.15 seconds, as recommended by Sea-Bird Electronics Inc.

The options selected for processing in Filter were as follows for all CTD casts:

```
# filter_low_pass_tc_A = 0.030
# filter_low_pass_tc_B = 0.150
# filter_low_pass_A_vars =
# filter_low_pass_B_vars = prDM
```

4. Align CTD Module:

It is essential that all variables derived from the data, such as salinity, density, and sound speed, use measurements of temperature and conductivity from same parcel of water. Logistically, it is practically impossible to instantaneously measure the same parcel of water with all sensors due to the physical location of the sensors on the unit and the different time delays of the sensors. The typical time delay of conductivity relative to temperature, 0.073 seconds, is automatically corrected by the SBE 11plus Deck Unit during data collection. If spikes are observed in the processed salinity profiles, further alignment of conductivity may be necessary. The Align CTD module can be used to align the conductivity data relative to pressure.

Fortran program TRIALIGN (programmer: Paul Fiedler) was run to find the optimum alignment value for conductivity (i.e., the number of scans by which to shift conductivity relative to temperature). TRIALIGN finds the maximum temperature gradient within a 240-scan window using linear regression; TRIALIGN tests for the gradient using only the first 10,000 scans to ensure data are from the downcast and imposes the criteria that depth must change by at least 5m in the 240-scan window. Conductivity alignments are tested within the region of maximum temperature gradient because misalignment of temperature and conductivity often results in excessive salinity spikes when temperature is changing rapidly. Within the window, conductivity is shifted by -24 to +24 scans. For each shift, salinity is derived from the temperature and conductivity data in each scan and a linear regression is fit to the salinity values. The shift that results in the minimum standard deviation of the regression residuals is selected as the optimal value for that cast. Optimal values for all casts are averaged to obtain a single alignment value for the cruise (one scan is 0.042 seconds).

TRIALIGN gave a mean optimum advances of -0.003 sec (SE=0.0024) and -0.067 (SE=0.0097) for primary sensors, C1725 and C3201, and +0.059 sec (SE=0.0029) for secondary sensor, C3353, (see Trialalign0_1-60.dat, Trialalign0_61-80 and Trialalign1.dat in \FILTER, which have the following columns: CTD file name, pressure (db) at the maximum temperature gradient, maximum temperature gradient (deg C/db), optimal advance (scans), and relative standard deviation of residuals). The advance for C1725 (C0 on casts 001-060) was set to 0 because the mean optimum advance was only a small fraction of a scan length.

Oxygen data are also systematically delayed with respect to pressure due to the long time delay of the oxygen sensor (the SBE 43 ranges from 2 seconds at 25 °C to approximately 5 seconds at 0 °C) and the time required for the water to transit through the pumped line. The Sea-Bird recommended advance of +2 sec was used for the dissolved oxygen sensors.

The options selected for processing in Align CTD were as follows for casts 001-060:

```
# alignctd_adv = c1S/m 0.059, sbox0Mm/Kg 2.000
```

and for casts 061-080 (for the sensors present):

```
# alignctd_adv = c0S/m -0.067, c1S/m 0.059, sbox0Mm/Kg 2.000
```

5. Cell Thermal Mass Module:

Cell Thermal Mass uses a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. In areas with large temperature gradients, the thermal mass correction is on the order of 0.005 psu. In areas with small temperature gradients, the correction is negligible.

The following Sea-Bird Electronics Inc. recommendations for Cell Thermal Mass when processing SBE 9plus data, with TC duct, were used:

```
# celltm_alpha = 0.0300, 0.0300
```

```
# celltm_tau = 7.0000, 7.0000
```

```
# celltm_temp_sensor_use_for_cond = primary, secondary
```

6. Loop Edit Module:

Loop Edit flags data that exhibit a change in the mean CTD ascent or descent rate (e.g., pressure reversals or slowdowns). Such changes in ascent or descent rates are usually created by ship heave as the CTD unit is lowered or raised, and indicate unreliable data. Data that have been flagged are documented in the *.cnv header. In this module, we remove any scans that were flagged as bad during data collection. Surface soak was removed in case data collection was started before the CTD had been returned to near the surface after the 10m surface soak.

The options selected for processing in Loop Edit follow the recommendations of Sea-Bird Electronics Inc. for all casts:

```
# loopedit_minVelocity = 0.250
```

```
# loopedit_surfaceSoak: minDepth = 5.0, maxDepth = 20, useDeckPress = 0
```

7. Derive Module:

Derive uses pressure, temperature, and conductivity from the input *.cnv file to compute the following oceanographic variables, which are routinely used in the assessment of protected species (other variables are available upon request):

- Salinity
- Density (density, sigma-theta, sigma-t, sigma-1, sigma-2, sigma-4)
- Depth (salt water, fresh water)
- Sound velocity (which can be calculated using the Chen-Millero, DelGrosso or Wilson equation)
- Average sound velocity (the harmonic mean from the surface to the current CTD depth, which is calculated on the downcast only)

The following processing options were selected in this module for casts with dual sensors:

```
# name 6 = depSM: Depth [salt water, m], lat = 26.7172
# name 7 = potemp090C: Potential Temperature [ITS-90, deg C]
# name 8 = sal00: Salinity, Practical [PSU]
# name 9 = sigma-é00: Density [sigma-theta, kg/m^3]
# name 10 = svCM: Sound Velocity [Chen-Millero, m/s]
# name 11 = avgsvCM: Average Sound Velocity [Chen-Millero, m/s], minP = 2, minS = 20
# name 12 = svCM1: Sound Velocity, 2 [Chen-Millero, m/s]
# name 13 = potemp190C: Potential Temperature, 2 [ITS-90, deg C]
# name 14 = sal11: Salinity, Practical, 2 [PSU]
# name 15 = sigma-é11: Density, 2 [sigma-theta, kg/m^3]
```

And for casts with only one temperature and conductivity sensor:

```
# name 4 = depSM: Depth [salt water, m], lat = 33.887
# name 5 = potemp090C: Potential Temperature [ITS-90, deg C]
# name 6 = sal00: Salinity, Practical [PSU]
# name 7 = sigma-é00: Density [sigma-theta, kg/m^3]
# name 8 = svCM: Sound Velocity [Chen-Millero, m/s]
# name 9 = avgsvCM: Average Sound Velocity [Chen-Millero, m/s], minP = 2, minS = 20
# name 10 = svCM1: Sound Velocity, 2 [Chen-Millero, m/s]
```

Note that there is no option in Sea-Bird's SBE Data Processing SEASOFT-Win32 to calculate Average Sound Velocity from secondary sensor data.

To calculate average sound velocity, the following values were used:

```
# minimum pressure = 2 db      [average depth of the acoustic array]
# minimum salinity = 20 psu    [recommended by Sea-Bird Electronics Inc.]
# Latitude = 10                [this value is used only if NMEA latitude is not available in
                                the header]
```

The profiles output by the Derive module were inspected by the Senior Oceanographer for bad data caused by sensor failure, temperature inversions, low surface salinity measurements (likely the result of rain), and spikes in salinity. Comments about each cast are in \Documentation\DELPHINUS 2009 MACII CTD Cast info.xlsx. Comment codes are:

A – acceptable
 N – acceptable for MMTD derived variables but not for NODC archiving
 inv – temperature inversion
 R – reject cast

8. Bin Average Module:

The Bin Average module averages temperature, conductivity, pressure, and oceanographic variables in user-selected intervals; the intervals may be defined using pressure, depth, scan number, or time range. SWFSC MMTD uses 1m bins, with no surface bin. In this module, we exclude scans that were flagged as bad during the Loop Edit module.

The following processing options were selected in this module for all casts:

```
# binavg_bintype = meters
# binavg_binsize = 1
# binavg_excl_bad_scans = yes
# binavg_skipover = 0
# binavg_surface_bin = no, min = 0.000, max = 5.000, value = 0.000
```

9. Split Module:

Split separates the data from an input *.cnv file into upcast (pressure decreasing) and downcast (pressure increasing) *.cnv files. Downcast only files are output because they do not contain the data collected when the bottles are fired (e.g., repetitive sampling at the same pressure). Consequently, they are used to derive variables such as thermocline depth and strength.

The following options were selected in this module for all casts:

```
# split_excl_bad_scans = no
# output the downcast only (into the \Split folder). This command adds a 'd' at the
beginning of the filenames.
```

10. ASCII Out Module:

ASCII Out outputs the header and/or the data from a binary data file (*.cnv). Data are written to an ASCII file (*.asc), while the header information, which lists each processing module and the variables applied, is written to a separate ASCII file (*.hdr).

This module was run twice. First, to convert the complete cast; second, to convert the downcast-only files created with the SPLIT module.

The following options were selected in this module for all casts:

- # Output Header and Data files
- # Label Column at top of the file
- # Column separator = space

FINAL PRODUCT

ASCII Out outputs the header and/or the data from a binary data file (*.cnv). Data are written to an ASCII file (*.asc), while the header information, which lists each processing module and the variables applied, is written to a separate ASCII file (*.hdr).

ASCII down-cast output files, containing only data recorded by the secondary sensors and no error flags, can be found in the \Final\ASCII_Down_cast folder.

The file headers have been saved separately from the final ASCII data files in both directories. The header files contain time in two separate fields: “System UpLoad Time” and “NMEA UTC (Time)”. The time in the “System UpLoad Time” field is taken from the PC used to collect the data and may not be accurate (e.g., this field may be recorded in local time, rather than Coordinated Universal Time, and may not have been adjusted for local time zone changes). The Coordinated Universal Time in the “NMEA UTC (Time)” field is taken from the GPS unit and is accurate as long as the GPS functioned properly.

The downcast profile is used to derive variables commonly used in protected species assessments, such as thermocline depth and strength. Plots of complete casts show hysteresis, or depth offsets, of a few m. The error in the depth, as indicated by the offsets, are expected to occur primarily in the upcasts due to “package wake” (i.e., the “shadowing” of the sensors by the rosette and frame as the CTD is pulled up through the water column). Additionally, the upcasts include repetitive sampling of the same depth when bottles are fired to collect water samples.

In total, 77 acceptable CTD casts were conducted during DELPHINUS 2009 on the McArthur II. The data set is comprised of 76 normal station casts and 1 test cast in which all bottles are tripped at 500m. The test cast typically precedes the first regular cast of each leg of the cruise. Several data files, in which the cast number in the file name has a letter suffix, appear to be repeat casts or sections of a cast that were used to reconstruct the profile. Some data collection failures are noted on the CTD log sheets in the \Raw folder, but we don’t have notes to explain these partial files; they are not included in the Final data folder. The output format for the combined up and down casts is shown below.

PrDM	COS/m	T090C	C1S/m	T190C	Sbox0Mm/Kg	DepSM	Potemp090C	Sal00
Sigma-é00	SvCM	AvgsvCM	SvCM1	Potemp190C	Sal11	Sigma-é11	Nbin	Flag
5.032	5.657591	28.9680	5.654303	28.9673	171.997	5.000	28.9668	34.5304
21.7226	1543.03	1542.98	1543.00	28.9661	34.5084	21.7063	24	0.0000e+00
6.038	5.657895	28.9701	5.654600	28.9697	172.396	6.000	28.9686	34.5308
21.7223	1543.05	1542.99	1543.02	28.9682	34.5084	21.7056	56	0.0000e+00

The dissolved oxygen data are not included in files for which the sensor was not used. Dissolved oxygen data are not included in the Final downcast files because of the extreme hysteresis observed in all casts.

The output format for the down casts only is shown below.

PrDM	C0S/m	T090C	DepSM	Potemp090C	Sal00	Sigma-é00	SvCM	AvgsvCM	Sigma-é11	Nbin
5.036	4.286722	16.7888	5.000	16.7880	33.4066	24.3412	1510.45	1510.43	24.3378	40
6.043	4.286092	16.7815	6.000	16.7806	33.4068	24.3431	1510.45	1510.44	24.3393	58

Column descriptions are as follows (only the bolded variables are included in the final downcast files):

- a) **PrDM = Digiquartz pressure in decibars (db)**
- b) **C0S/m = Primary conductivity in Siemens per meter (S/m)**
- c) **T090C = Primary temperature, in degrees Celsius (°C), calculated using the ITS-90 standard**
- d) C1S/m = Secondary conductivity in Siemens per meter (S/m)
- e) T190C = Secondary temperature, in degrees Celsius (°C), calculated using the ITS-90 standard
- f) Sbox0Mm/Kg = Oxygen, SBE 43 ($\mu\text{mol/Kg}$)
- g) **DepSM = Salt water depth in meters (m)**
- h) **Potemp090C = Potential Temperature (ITS-90, deg C), derived from the primary temperature and conductivity sensors**
- i) **Sal00 = Salinity, in practical salinity units (psu), derived from the primary temperature and conductivity sensors**
- j) **Sigma-é00 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the primary temperature sensor and the salinity data derived from the primary conductivity sensor**
- k) **SvCM = Chen-Millero's sound velocity in meters per second (m/s) calculated from the primary temperature sensor and the salinity data derived from the primary conductivity sensor**
- l) **AvgsvCM = Chen-Millero's average sound velocity in meters per second (m/s) calculated from the primary temperature sensor and the salinity data derived from the primary conductivity sensor**
- m) SvCM1 = Chen-Millero's sound velocity in meters per second (m/s) calculated from the secondary temperature sensor and the salinity data derived from the secondary conductivity sensor
- n) Sal11 = Salinity, in practical salinity units (psu), derived from the secondary temperature and conductivity sensors
- o) Potemp190C = Potential Temperature (ITS-90, deg C), derived from the secondary temperature and conductivity sensors
- p) Sal11 = Salinity, in practical salinity units (psu), derived from the secondary temperature and conductivity sensors
- q) Sigma-é11 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the secondary temperature sensor and the salinity data derived from the secondary conductivity sensor
- r) **Nbin = number of scans included in the bin average**
- s) Flag = bad scan flag

Perl program CTDPositionCheck (programmer: Dan Prosperi) was used to check the CTD cast date/times and positions recorded in the header files against the edited TSG file for the survey. All 77 files had matching TSG records; two files needed date/time corrections.

Paul Fiedler, 16 June 2021

Appendix 1. DELPHINUS 2009 MACII Sea-Bird Data Processing Configuration Files

DEL2009_001.con

Configuration report for SBE 911plus/917plus
CTD

```
-----
Frequency channels suppressed : 0
Voltage words suppressed     : 0
Computer interface           : RS-232C
Deck unit                    : SBE11plus
    Firmware Version >= 5.0
Scans to average             : 1
NMEA position data added     : Yes
NMEA depth data added        : No
NMEA time added              : No
NMEA device connected to    : deck unit
Surface PAR voltage added    : No
Scan time added              : Yes
```

1) Frequency 0, Temperature

```
Serial number : 4667
Calibrated on : 14 Jan 09
G              : 4.39730384e-003
H              : 6.46197553e-004
I              : 2.23235075e-005
J              : 1.85902391e-006
F0             : 1000.000
Slope          : 1.00000000
Offset         : 0.0000
```

2) Frequency 1, Conductivity

```
Serial number : 1725
Calibrated on : 23-Dec-08
G              : -4.08987413e+000
H              : 4.95128741e-001
I              : -9.06906601e-004
J              : 6.94020989e-005
CTcor          : 3.2500e-006
CPcor          : -9.57000000e-008
Slope          : 1.00000000
Offset         : 0.00000
```

3) Frequency 2, Pressure, Digiquartz with TC

```
Serial number : 3001
Calibrated on : 07-Jan-09
C1             : -3.911989e+004
C2             : -1.960405e+000
C3             : 9.871570e-003
D1             : 3.178100e-002
D2             : 0.000000e+000
T1             : 2.933918e+001
T2             : -9.729668e-004
T3             : 3.817570e-006
T4             : 0.000000e+000
T5             : 0.000000e+000
Slope          : 0.99999000
Offset         : 10.60400
AD590M         : 1.135000e-002
AD590B         : -8.643200e+000
```

4) Frequency 3, Temperature, 2

```
Serial number : 4803
Calibrated on : 29-Jan-09
G              : 4.33042098e-003
H              : 6.36538776e-004
I              : 2.06253520e-005
J              : 1.70545580e-006
F0             : 1000.000
Slope          : 1.00000000
Offset         : 0.0000
```

5) Frequency 4, Conductivity, 2

```
Serial number : 3353
Calibrated on : 08-Jan-09
G              : -9.73210586e+000
H              : 1.49194538e+000
I              : -2.12278818e-003
J              : 2.47366110e-004
CTcor          : 3.2500e-006
CPcor          : -9.57000000e-008
Slope          : 1.00000000
Offset         : 0.00000
```

6) A/D voltage 0, Oxygen, SBE 43

```
Serial number : 1295
Calibrated on : 05-Jan-09
Equation       : Sea-Bird
Soc            : 4.11600e-001
Offset         : -5.12500e-001
A              : -1.63200e-003
B              : 2.36240e-004
C              : -3.93140e-006
E              : 3.60000e-002
Tau20          : 1.19000e+000
D1             : 1.92634e-004
D2             : -4.64803e-002
H1             : -3.30000e-002
H2             : 5.00000e+003
H3             : 1.45000e+003
```

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

```
Serial number : 42648
Calibrated on :
Scale factor   : 15.000
Offset         : 0.000
```

11) A/D voltage 5, Free

12) A/D voltage 6, Free

13) A/D voltage 7, Free

Scan length : 41

DEL2009_001T-050.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 4667
Calibrated on : 14 Jan 09
G : 4.39730384e-003
H : 6.46197553e-004
I : 2.23235075e-005
J : 1.85902391e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 1725
Calibrated on : 23-Dec-08
G : -4.08987413e+000
H : 4.95128741e-001
I : -9.06906601e-004
J : 6.94020989e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0405
Calibrated on : 08-Jan-09
C1 : -4.505278e+004
C2 : -9.372496e-001
C3 : 1.416440e-002
D1 : 3.852400e-002
D2 : 0.000000e+000
T1 : 3.024204e+001
T2 : -5.890827e-004
T3 : 4.036660e-006
T4 : 2.914400e-009
T5 : 0.000000e+000
Slope : 0.99988000
Offset : -0.81400
AD590M : 1.111000e-002
AD590B : -8.834520e+000

4) Frequency 3, Temperature, 2

Serial number : 4803
Calibrated on : 29-Jan-09
G : 4.33042098e-003
H : 6.36538776e-004
I : 2.06253520e-005
J : 1.70545580e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3353
Calibrated on : 08-Jan-09
G : -9.73210586e+000
H : 1.49194538e+000
I : -2.12278818e-003
J : 2.47366117e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 1295
Calibrated on : 05-Jan-09
Equation : Sea-Bird
Soc : 4.11600e-001
Offset : -5.12500e-001
A : -1.63200e-003
B : 2.36240e-004
C : -3.93140e-006
E : 3.60000e-002
Tau20 : 1.19000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

Serial number : 42648
Calibrated on :
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Free

12) A/D voltage 6, Free

13) A/D voltage 7, Free

Scan length : 41

DEL2009_051-056_058-059.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 4667
Calibrated on : 14 Jan 09
G : 4.39730384e-003
H : 6.46197553e-004
I : 2.23235075e-005
J : 1.85902391e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 1725
Calibrated on : 23-Dec-08
G : -4.08987413e+000
H : 4.95128741e-001
I : -9.06906601e-004
J : 6.94020989e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

4) Frequency 3, Temperature, 2

Serial number : 4803
Calibrated on : 29-Jan-09
G : 4.33042098e-003
H : 6.36538776e-004
I : 2.06253520e-005
J : 1.70545580e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3353
Calibrated on : 08-Jan-09
G : -9.73210586e+000
H : 1.49194538e+000
I : -2.12278818e-003
J : 2.47366117e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 1295
Calibrated on : 05-Jan-09
Equation : Sea-Bird
Soc : 4.11600e-001
Offset : -5.12500e-001
A : -1.63200e-003
B : 2.36240e-004
C : -3.93140e-006
E : 3.60000e-002
Tau20 : 1.19000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

Serial number : 42648
Calibrated on :
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Free

12) A/D voltage 6, Free

13) A/D voltage 7, Free

Scan length : 41

DEL2009_057.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 4803
Calibrated on : 29-Jan-09
G : 4.33042098e-003
H : 6.36538776e-004
I : 2.06253520e-005
J : 1.70545580e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 3353
Calibrated on : 08 Jan 09
G : -9.73210586e+000
H : 1.49194538e+000
I : -2.12278818e-003
J : 2.47366117e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

4) Frequency 3, Free

5) Frequency 4, Free

6) A/D voltage 0, Free

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

Serial number : 42648
Calibrated on :
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Free

12) A/D voltage 6, Free

13) A/D voltage 7, Free

Scan length : 41

DEL2009_060.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 4667
Calibrated on : 14 Jan 09
G : 4.39730384e-003
H : 6.46197553e-004
I : 2.23235075e-005
J : 1.85902391e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 1725
Calibrated on : 23-Dec-08
G : -4.08987413e+000
H : 4.95128741e-001
I : -9.06906601e-004
J : 6.94020989e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

4) Frequency 3, Temperature, 2

Serial number : 4803
Calibrated on : 29-Jan-09
G : 4.33042098e-003
H : 6.36538776e-004
I : 2.06253520e-005
J : 1.70545580e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3353
Calibrated on : 08-Jan-09
G : -9.73210586e+000
H : 1.49194538e+000
I : -2.12278818e-003
J : 2.47366117e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 1294
Calibrated on : 05-Jan-09
Equation : Sea-Bird
Soc : 4.46700e-001
Offset : -4.81900e-001
A : 1.67270e-004
B : 1.30630e-004
C : -2.44360e-006
E : 3.60000e-002
Tau20 : 1.01000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

Serial number : 42648
Calibrated on :
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Free

12) A/D voltage 6, Free

13) A/D voltage 7, Free

Scan length : 41

DEL2009_061_067-068_071.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 2109
Calibrated on : 18-Dec-08
G : 4.10640917e-003
H : 6.24696189e-004
I : 2.00568756e-005
J : 2.08680965e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 3201
Calibrated on : 23-Dec-08
G : -1.01955922e+001
H : 1.44793479e+000
I : -2.74526571e-005
J : 7.79778169e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

4) Frequency 3, Temperature, 2

Serial number : 4803
Calibrated on : 29-Jan-09
G : 4.33042098e-003
H : 6.36538776e-004
I : 2.06253520e-005
J : 1.70545580e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3353
Calibrated on : 08-Jan-09
G : -9.73210586e+000
H : 1.49194538e+000
I : -2.12278818e-003
J : 2.47366117e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 1295
Calibrated on : 05-Jan-09
Equation : Sea-Bird
Soc : 4.11600e-001
Offset : -5.12500e-001
A : -1.63200e-003
B : 2.36240e-004
C : -3.93140e-006
E : 3.60000e-002
Tau20 : 1.19000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

Serial number : 42648
Calibrated on :
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Free

12) A/D voltage 6, Free

13) A/D voltage 7, Free

Scan length : 41

DEL2009_062-065.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 2
Voltage words suppressed : 3
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 2109
Calibrated on : 18-Dec-08
G : 4.10640917e-003
H : 6.24696189e-004
I : 2.00568756e-005
J : 2.08680965e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 3201
Calibrated on : 23-Dec-08
G : -1.01955922e+001
H : 1.44793479e+000
I : -2.74526571e-005
J : 7.79778169e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

4) A/D voltage 0, Oxygen, SBE 43

Serial number : 1295
Calibrated on : 05-Jan-09
Equation : Sea-Bird
Soc : 4.11600e-001
Offset : -5.12500e-001
A : -1.63200e-003
B : 2.36240e-004
C : -3.93140e-006
E : 3.60000e-002
Tau20 : 1.19000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

5) A/D voltage 1, Free

Scan length : 2

DEL2009_066.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 2
Voltage words suppressed : 4
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 2109
Calibrated on : 18-Dec-08
G : 4.10640917e-003
H : 6.24696189e-004
I : 2.00568756e-005
J : 2.08680965e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 3201
Calibrated on : 23-Dec-08
G : -1.01955922e+001
H : 1.44793479e+000
I : -2.74526571e-005
J : 7.79778169e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

Scan length : 23

DEL2009_069-070_072.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 0
Voltage words suppressed : 4
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 2109
Calibrated on : 18-Dec-08
G : 4.10640917e-003
H : 6.24696189e-004
I : 2.00568756e-005
J : 2.08680965e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 3201
Calibrated on : 23-Dec-08
G : -1.01955922e+001
H : 1.44793479e+000
I : -2.74526571e-005
J : 7.79778169e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

4) Frequency 3, Temperature, 2

Serial number : 4803
Calibrated on : 29-Jan-09
G : 4.33042098e-003
H : 6.36538776e-004
I : 2.06253520e-005
J : 1.70545580e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3353
Calibrated on : 08-Jan-09
G : -9.73210586e+000
H : 1.49194538e+000
I : -2.12278818e-003
J : 2.47366117e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

Scan length : 29

DEL2009_073-074.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 0
Voltage words suppressed : 1
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 2109
Calibrated on : 18-Dec-08
G : 4.10640917e-003
H : 6.24696189e-004
I : 2.00568756e-005
J : 2.08680965e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 3201
Calibrated on : 23-Dec-08
G : -1.01955922e+001
H : 1.44793479e+000
I : -2.74526571e-005
J : 7.79778169e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

4) Frequency 3, Temperature, 2

Serial number : 4803
Calibrated on : 29-Jan-09
G : 4.33042098e-003
H : 6.36538776e-004
I : 2.06253520e-005
J : 1.70545580e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3353
Calibrated on : 08-Jan-09
G : -9.73210586e+000
H : 1.49194538e+000
I : -2.12278818e-003
J : 2.47366117e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

6) A/D voltage 0, Free

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

Serial number : 42648
Calibrated on :
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Free

Scan length : 38

DEL2009_075-076.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 0
Voltage words suppressed : 1
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 2109
Calibrated on : 18-Dec-08
G : 4.10640917e-003
H : 6.24696189e-004
I : 2.00568756e-005
J : 2.08680965e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 3201
Calibrated on : 23-Dec-08
G : -1.01955922e+001
H : 1.44793479e+000
I : -2.74526571e-005
J : 7.79778169e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

4) Frequency 3, Temperature, 2

Serial number : 4803
Calibrated on : 29-Jan-09
G : 4.33042098e-003
H : 6.36538776e-004
I : 2.06253520e-005
J : 1.70545580e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3353
Calibrated on : 08-Jan-09
G : -9.73210586e+000
H : 1.49194538e+000
I : -2.12278818e-003
J : 2.47366117e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 1294
Calibrated on : 05-Jan-09
Equation : Sea-Bird
Soc : 4.46700e-001
Offset : -4.81900e-001
A : 1.67270e-004
B : 1.30630e-004
C : -2.44360e-006
E : 3.60000e-002
Tau20 : 1.01000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

Serial number : 42648
Calibrated on :
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Free

Scan length : 38

DEL2009_077-080.con

Configuration report for SBE 911plus/917plus
CTD

Frequency channels suppressed : 0
Voltage words suppressed : 1
Computer interface : RS-232C
Deck unit : SBE11plus
Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 2109
Calibrated on : 18-Dec-08
G : 4.10640917e-003
H : 6.24696189e-004
I : 2.00568756e-005
J : 2.08680965e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 3201
Calibrated on : 23-Dec-08
G : -1.01955922e+001
H : 1.44793479e+000
I : -2.74526571e-005
J : 7.79778169e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0311
Calibrated on : 13-Apr-10
C1 : -4.123560e+004
C2 : 1.043267e+000
C3 : 1.330030e-002
D1 : 4.018400e-002
D2 : 0.000000e+000
T1 : 3.020637e+001
T2 : 4.924132e-005
T3 : 3.833950e-006
T4 : 6.451910e-009
T5 : 0.000000e+000
Slope : 0.99991000
Offset : -6.29400
AD590M : 1.167000e-002
AD590B : -8.165620e+000

4) Frequency 3, Temperature, 2

Serial number : 4803
Calibrated on : 29-Jan-09
G : 4.33042098e-003
H : 6.36538776e-004
I : 2.06253520e-005
J : 1.70545580e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3353
Calibrated on : 08-Jan-09
G : -9.73210586e+000
H : 1.49194538e+000
I : -2.12278818e-003
J : 2.47366117e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.0000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 1295
Calibrated on : 05-Jan-09
Equation : Sea-Bird
Soc : 4.11600e-001
Offset : -5.12500e-001
A : 1.63200e-004
B : 2.36240e-004
C : -3.93140e-006
E : 3.60000e-002
Tau20 : 1.19000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Altimeter

Serial number : 42648
Calibrated on :
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Free

Scan length : 38

Appendix 2. Bottle Salinity Analyses

Bottle salinity samples were analyzed to validate CTD sensor calibration and to detect evidence of Niskin bottle leakage. Samples were collected from bottles tripped at depth and analyzed with a Guildline Portasal 8410A salinometer using standard methods (Guildline Technical Manual TM 8410A-F-00). The salinity data from the Portasal and CTD can be found in \\Stenella\Ecology\WestCoast\2009_DELPHINUS\Oceanographic\Salinity. The results summarized below can also be found in DELPHINUS 2009 Salts.xls.

Portasal data were collected during salts runs at sea by the program PSAL9709 (Oceanographic Data Facility, Scripps Institution of Oceanography). The raw data files, which are the files without a filename extension in each of the leg subfolders in \\Stenella\Ecology\WestCoast\2009_DELPHINUS\Oceanographic\Salinity\Raw\MACII, were copied with a text editor into a single file named *salts09m.raw*.

Fortran program CR2SAL.EXE (programmer: Fiedler) calculated salinities from the recorded conductivity ratios and bath temperatures in *salts09m.raw* using the Sea-Bird salinity algorithm. The two output files, \\Stenella\Ecology\WestCoast\2009_DELPHINUS\Oceanographic\Salinity\Intermediate\salts09m.sal and *salts09m.sta*, are identical except that the sample records in the *.sta* file are truncated. Output file *salts09m.sal* lists four salinity values for each sample, calculated from the listed value and three adjusted values of the sample conductivity ratio, as discussed below.

File *salts09m.sta* was edited to list the raw CTD file and Niskin bottle number corresponding to each sample. FORTRAN program SALTS.EXE (programmer: Fiedler) called Sea-Bird program SBEBATCH to process each raw CTD file. Specifically, the batch program creates a temporary water bottle *.ros* file from the Data Conversion module and outputs a bottle data summary *.btl* file from the Bottle Summary module. The *.ros* file contains data for each scan associated with a bottle firing, which by default are all scans within a 1.5-second duration after a bottle firing confirmation is received from the water sampler. The *.btl* file contains means and standard deviations of the CTD data for each bottle. SALTS then reads the *.btl* file to find CTD salinity values corresponding to the bottle samples in *salts09m.sal*. Two files are output for each pair of temperature/conductivity sensors (1 = primary, 2 = secondary): *salts09m1.dat* and *salts09m2.dat* contain the CTD salinity and depth for each bottle sample and the differences between each of the four alternative bottle salinity values and the CTD salinity; *salts09m1.sum* and *salts09m2.sum* contain means and standard deviations of the differences within each salts run.

Conductivity Ratio Adjustment for Bottle Salinities

When analyzing samples on the Portasal, the initial salinity standard reading should be equal to 2x the actual conductivity ratio of the standard (K₁₅ on the ampule label) after correct initialization of the instrument. Referencing sample conductivity ratios to the initial standard reading may not give the best results for several reasons; for example, the initial standard reading may be erroneous (e.g., the Portasal was not sufficiently warmed up with standard water before samples are read) or the sensitivity of the Portasal may drift during the run. If the initial and final standard readings differ, then adjusting the reference for sample conductivity ratios will change

both the mean and the standard deviation of Bottle - CTD salinity differences. Selection of an adjustment alternative should be based on minimizing the mean and standard deviation.

CR2SAL calculates four alternative salinity values from sample conductivity ratios adjusted relative to:

- (0) the initial standard reading (no adjustment),
- (1) the final standard reading,
- (2) the average of the initial and final readings, and
- (3) a standard reading interpolated between the initial and final readings.

Salinities calculated from sample conductivity ratios adjusted by method (2) resulted in bottle-CTD differences with the smallest means (biases) and standard deviations (RMSE) overall:

<u>Adjustment</u>	Mean (Bottle – CTD)		St. dev. (Bottle – CTD)	
	<u>primary</u>	<u>secondary</u>	<u>primary</u>	<u>secondary</u>
None:	+0.002021	+0.007266	0.008767	0.010440
(1):	+0.003632	+0.008626	0.005870	0.010319
(2):	+0.002826	+0.007945	0.004270	0.008717
(3):	+0.003315	+0.008274	0.005458	0.008300

Therefore, *bottle salinities calculated from sample conductivity ratios adjusted by method (2) were used in subsequent analyses.*

Precision of Replicates

Three replicate samples collected from 9 deep bottles on selected CTD casts allow an assessment of the precision of our bottle salinity sampling and analysis methods (see Replicates worksheet in DELPHINUS 2009 Salts.xls). An ANOVA gives a “mean squares within” of 2.352e-06, which is equivalent to the variance of replicate salinity values within bottles. The square root of this value gives a *precision of ± 0.0015 psu, better than the accuracy of ± 0.003 specified by Guildline, and close to the ± 0.001 precision that can be achieved under ideal laboratory conditions* (Sea-Bird, personal communication).

The standard deviation of Bottle - CTD salinity differences for all samples was 0.0067 (above table, Adjustment 2), about four times greater than the precision of bottle salinity replicates. A larger error is expected because of the additional errors of the CTD sensors and the mismatch of waters pumped through CTD sensors and sampled by Niskin bottles.

Bottle – CTD Salinity Differences

Figure 4 shows Bottle – CTD salinity differences for all samples. CTD values are from primary (S1) and secondary (S2) sensors. For this cruise, the post-cruise calibration indicated that no calibration adjustments were required for any temperature or conductivity sensor (\\Stenella\Ecology\WestCoast\2009_DELPHINUS\Oceanographic\CTD\Data\MACII\Documents\CTDcalibrations DELPHINUS 2009_MACII.xls). Note the drift indicated by the trend line for the secondary sensors.

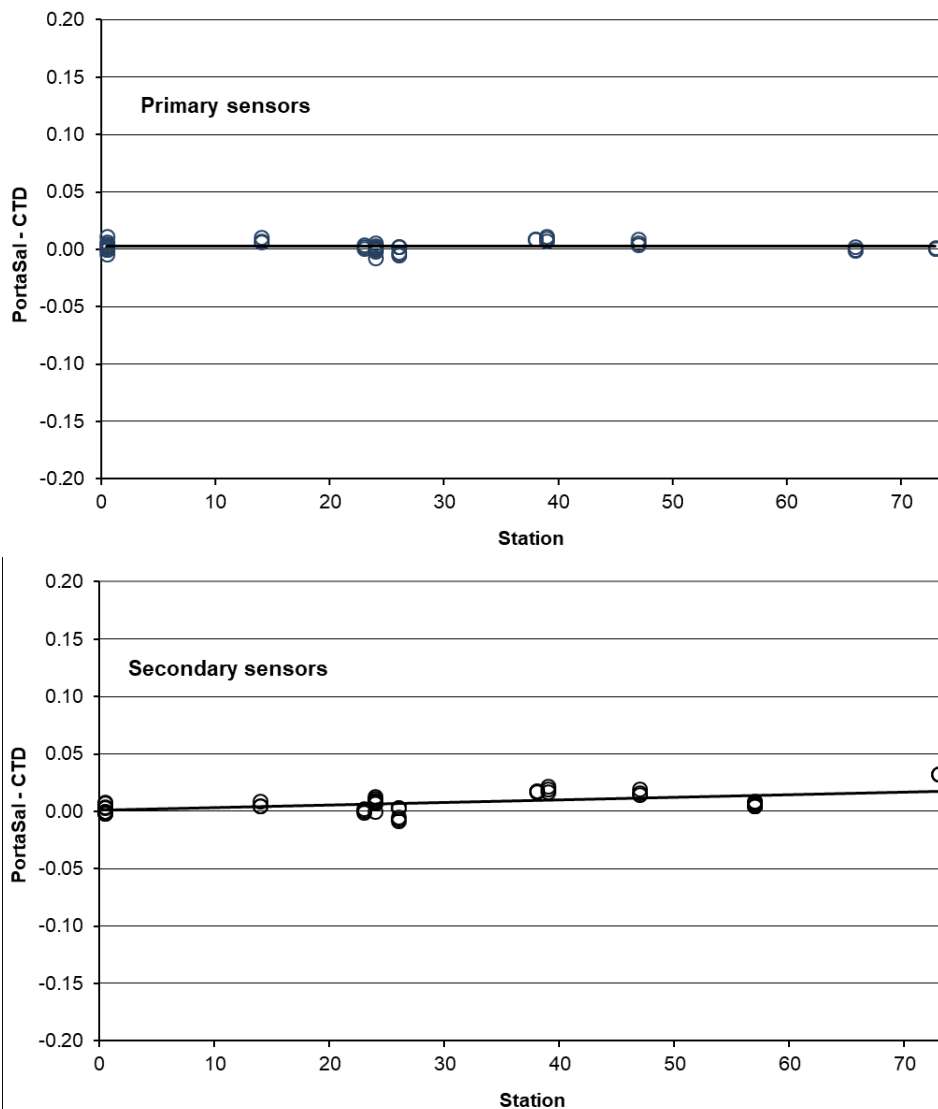


Figure 4. Bottle – CTD salinity differences for DELPHINUS, McArthur II.

Overall, the Bottle – CTD salinity differences indicate that the CTD primary sensors were more accurate than the secondary sensors. Consequently, *temperature and salinity values from the primary sensors should be included in the final CTD data files.*

Test Cast Bottle vs. CTD Salinities

The following table summarizes bottle salinities and corresponding CTD salinities (mean $\pm$ sd) from the three test casts, when all 12 bottles were tripped sequentially at 500m. Although values are listed to four decimal places, the precision of the salinometer is ± 0.003 and the precision of the CTD sensors is ± 0.0004 psu.

	CTD S1	CTD S2	Bottle
Leg 1	34.2582 $\pm$ 0.0034	34.2599 $\pm$ 0.0004	34.2609 $\pm$ 0.0040
Leg 2	34.3230 $\pm$ 0.0005	34.3153 $\pm$ 0.0002	34.3236 $\pm$ 0.0032
Leg 3	No sensor	34.3102 $\pm$ 0.0001	34.3165 $\pm$ 0.0014

The salinity of the bottle samples collected at the same depth (column labeled “Bottle” above) vary by slightly more than the precision of replicates (i.e., ± 0.0015 psu) and the precision of the salinometer; consequently, the measured bottle salinity values are essentially identical.

Salinities derived from the primary CTD sensors, after temperature and conductivity calibration adjustments, are plotted as deviations from the Portasal bottle salinities in Figure 5.

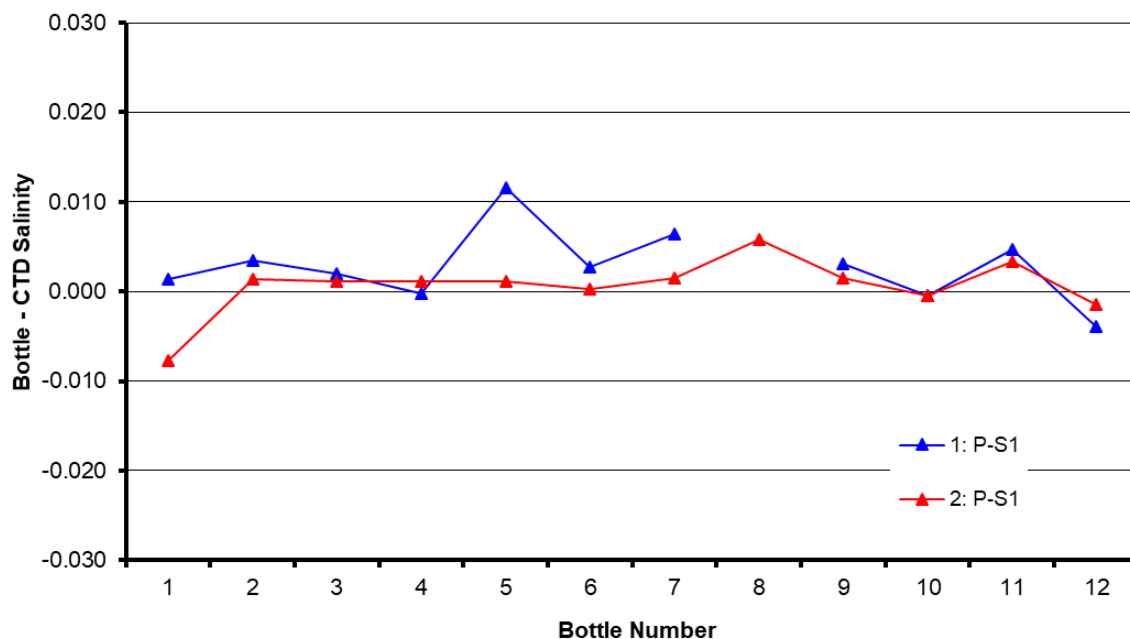


Figure 5. Bottle - CTD salinity differences, derived from primary sensor data, for test casts on DELPHINUS 2009, McArthur II, Legs 1-2. The Leg 3 test cast used secondary sensors only and bottles were tripped just below the surface.

There are no bottles with consistently large negative differences that might indicate leakage of a Niskin bottle as it is brought up from depth to the surface through lower-salinity waters.