STAR 2006 McArthur II CTD PROCESSING

STAR 2006 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 v. 5.28a and have been processed using Sea-Bird's SBE Data Processing SEASOFT-Win32 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 STAR 2006 cruise was complicated by a loading accident the day before departure and then the loss of the CTD unit in October 2006. The table below describes for which period each sensor was used. Secondary sensors were not available for Leg 1 (casts 2-49). The CTD was lost during cast 139 on 10/28. The ship's SEACAT (an unpumped Sea-Bird 19) was used to complete Leg 3 and start Leg 4 (SEACAT casts 1-20). A replacement CTD, with one set of sensors, was used to complete Leg 4 (casts 140-170). Due to the loss of the CTD unit, there are no post-cruise calibrations for SBE3 T2026 and T0885 temperature sensors, SBE4 C0591 and C0528 conductivity sensors, and the SBE9*plus* P2110_92765 pressure sensor.

	Casts	**Temp** 1,2	**Cond 1,2**	**Pressure - CTD Fish**
Leg 1	002-049	T2026[1],	C0591[2],	P2110[1] - 92765
Leg 2	050-092	T2026[1], T0885[3]	C0591[2], C0528[3]	P2110[1] - 92765
Leg 3	093-139	T2026[1], T0885[3]	C0591[2], C0528[3]	P2110[1] - 92765
Leg 3-4	SEACAT 1-20	T0579[1],	C0579[1],	P0579[1]
Leg 4	140-170	T4667[3],	C1725[3],	P3001[1] - 39443

Sensor owners: [1]MacII, [2]FRD, [3]PMC

The owners of the sensors were responsible for their maintenance.

STAR 2006 MACII CTD SENSOR CALIBRATION

SWFSC PRD 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 MACII sensors used during STAR 2006 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 STAR 2006_MACII.xls, in the \Documentation folder contains the pre and post-cruise calibration information for the conductivity, temperature and pressure sensors. It then derives slope or offset values used to correct the calibration coefficients used in both the Data Conversion and Derive modules of Sea-Bird's SBE Data Processing software. The adjusted configuration files used to process the STAR 2006 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 SEACAT SBE 4 series conductivity sensor has a measurement range of 0.0 to 7.0 Siemens/meter (S/m) and is rated to have an accuracy of 0.001 S/m and a resolution of 0.0001 S/m.

The primary conductivity sensor for Legs 1-3, C0591, was calibrated on 17 May 2005. The secondary conductivity sensor for Legs 2-3, C0528, was calibrated on 11 April 2006. No post-cruise calibrations are available, since these sensors were lost at sea. Therefore, pre-cruise calibration coefficients were used to process the data with no slope adjustment.

The primary and secondary conductivity sensors gave conductivity values with a difference of -0.002900 S/m (C2-C1) and salinity values with a difference of -0.031873 psu (S2-S1). These differences were consistent during Legs 2-3 when both sensors were installed (casts 50-139, Fig. 1).

The SEACAT conductivity sensor for Legs 3-4, C0579, was calibrated on 21 December 2005 and 3 February 2007. The average iSlope was 1.000163; this value was used as the configuration file slope adjustment.

The conductivity sensor for Leg 4, C1725, was calibrated on 10 August 2006 and 1 February 2007. The average iSlope was 0.999962; consequently, no slope adjustment was needed.

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 SEACAT SBE 3 series temperature sensor has a measurement range of -5.0 to 35 °C and is rated to have an accuracy of ± 0.01 °C and a resolution of 0.001 °C.

The primary temperature sensor for Legs 1-3, T2026, was calibrated on 20 December 2005. The secondary temperature sensor for Legs 2-3, T0885, was calibrated on 14 April 2006. No post-cruise calibrations are available, since these sensors were lost at sea. Therefore, pre-cruise calibration coefficients were used to process the data with no offset adjustment.

The SEACAT temperature sensor for Legs 3-4, C0579, was calibrated on 21 December 2005 and 3 February 2007. The average iOffset was 0.001005°C; consequently, no offset adjustment was needed.

The temperature sensor for Leg 4, T4667, was calibrated on 27 July 2006 and 7 February 2007. The average iOffset was -0.001053°C; consequently, no offset adjustment was needed.

Pressure Sensor Correction:

The SBE Digiquartz pressure sensor is rated to have an initial accuracy of ±1.04 db (i.e., 0.015% of the full scale range, which is 0 – 6900 db). We do not exceed a maximum vertical depth of 1100 m. Initial resolution (at 24Hz) is 0.069 db (i.e., 0.001% of the full scale range). The SBE SEACAT Strain Gauge pressure sensor is rated to have an accuracy of ±3.75 db (i.e., 0.25% of the full scale range, which is 0 – 1500 db) and a resolution of 0.225 db.

CTD pressure deck tests are stored in the \Raw\MACII\Leg_n\Pressure_tests folders.

The Leg 3 pressure sensor P2110 was calibrated on 1 February 2006 (Offset=-6.0843). Three deck tests were conducted on the Leg 1-3 CTD, resulting in offsets of -6.6050, -6.4605, and -6.5018 db; these results were consistent with the pre-cruise calibration offset. Therefore, the average deck test offset of -6.5224 db was used as the offset in the *.con file.

The SEACAT strain-gauge pressure sensor, P0579, was calibrated on 9 January 2006 and 6 February 2007. No deck tests were conducted on the ship. An Offset of -0.449 db was calculated for the post-cruise calibration coefficients applied to the pre-cruise calibration data. This value gave an average iOffset=-0.36 db; this value was used in the *.con file.

The Leg 4 pressure sensor P3001 was calibrated on 10 February 2006 and 12 February 2007. Two valid deck tests were conducted on the ship, resulting in offsets of +10.7454 and +10.5624 db. The average iOffset=+10.860 was consistent with the deck test results. Therefore, the average deck test offset of +10.6539 was used as the offset in the *.con file. This large positive offset is unusual, but is consistent with the data.

Comparison of the Primary and Secondary Sensors

Differences between primary and secondary sensors by cast are summarized in Figure 1. Dual sensors were used only on Legs 2 and 3. Fortran program COMPSENS.EXE (programmer: Paul Fiedler) calculates the mean difference between the primary and secondary sensors for each profile. Figure 1 shows that the conductivity values measured by and salinity values derived from the primary and secondary sensors differed by more than the desired accuracy of the sensors. Bottle salinities were measured but the data have not been processed. The primary sensor data should be used in the final CTD data file, since these sensors were also used on Leg 1.

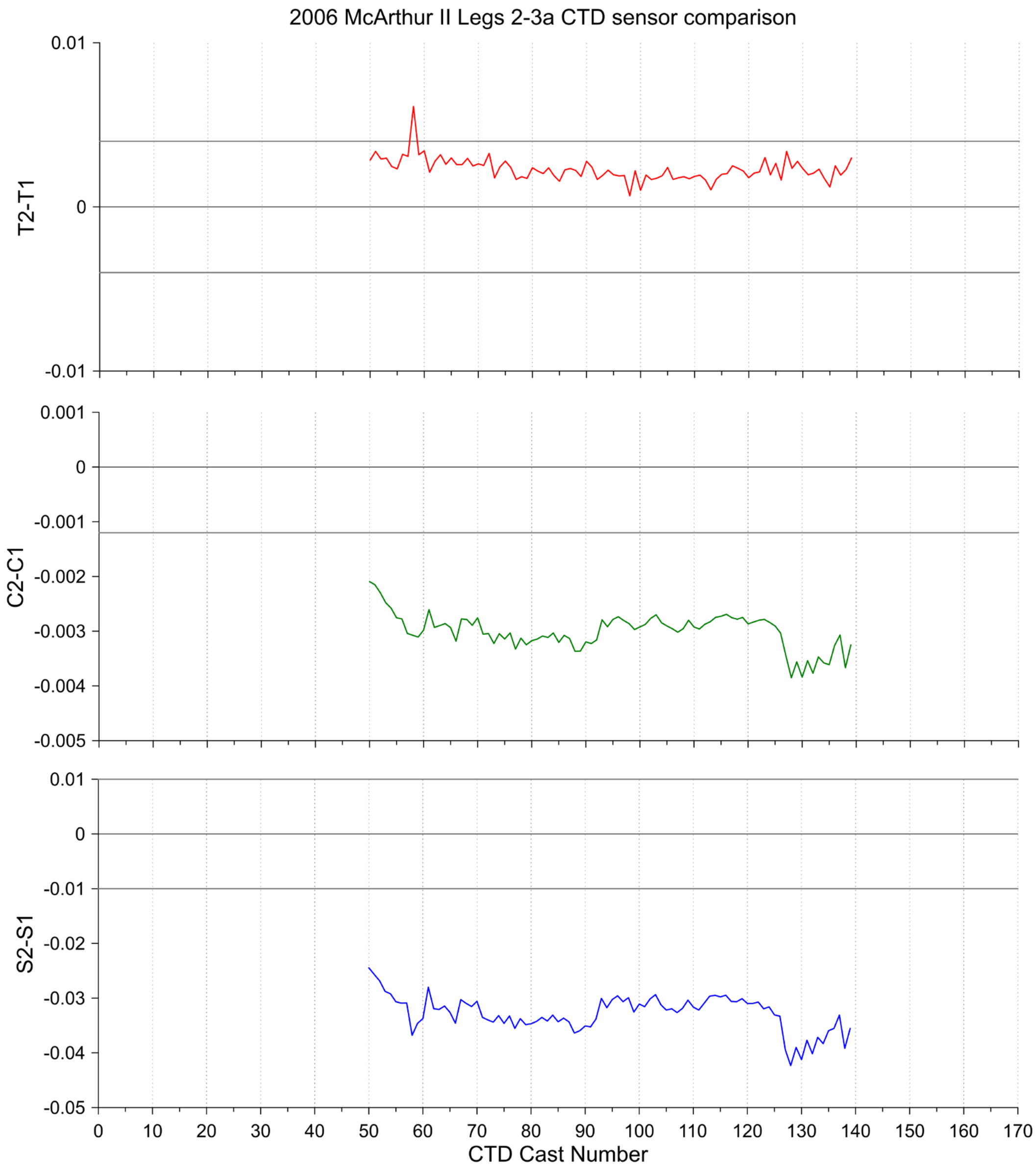


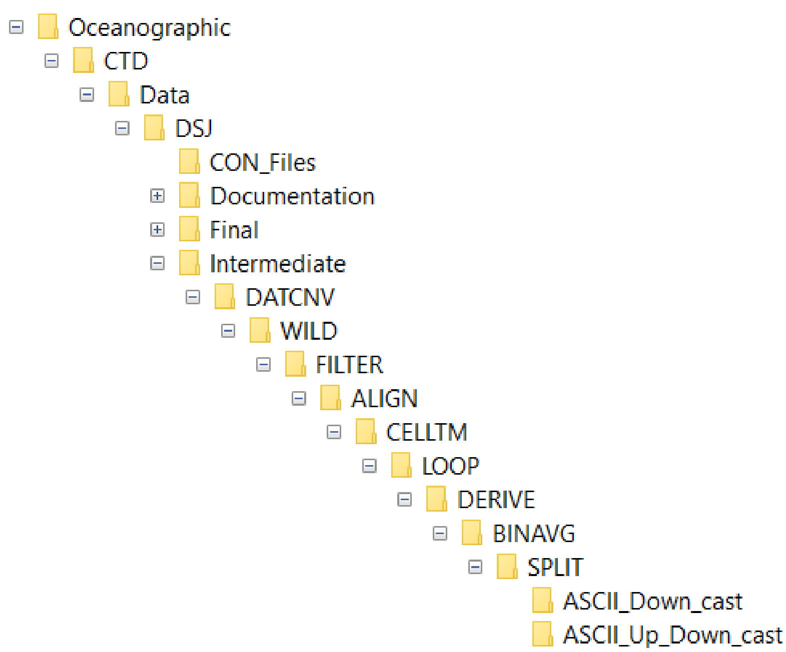
Fig. 1. Time series of differences between primary and secondary temperature and conductivity sensors for STAR 2006 McArthur II CTD casts. Each temperature (T2-T1), conductivity (C2-C1), and salinity (S2-S1) difference is a mean of 1m bin-averaged downcast values (excluding the upper 10m and bins with density changes >0.003 σ_t). Gray lines represent desired accuracy (±0.002 ºC and ±0.0006 S/m, equivalent to ±0.006 psu, which are 2x the specified initial accuracies of the Sea-Bird temperature and conductivity sensors, per SIO/ODF recommendations).

We use 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 STAR 2006_MACII.xlsx in the \Documentation folder. Configuration files for the sensors used on the McArthur II during STAR 2006 are listed in Appendix 1.

STAR 2006 MACII CTD SBE MODULE PROCESSING

The SBE Data processing modules that were applied to the raw STAR 2006 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 were as follows for single-sensor casts 2-49 and 140-170 and SEACAT:

name 0 = prDM: Pressure, Digiquartz [db]
name 1 = c0S/m: Conductivity [S/m]
name 2 = t090C: Temperature [ITS-90, deg C]
name 3 = flag: 0.000e+00

And for dual-sensor casts 50-139:

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 = flag: 0.000e+00

Cast 58 data were collected in two separate files, *AR06058* for the downcast and *AR06058up* for the upcast, because the upcast was done entirely at 30 m/min in order to grease the wire. The downcast and upcast files were combined after Data Conversion using a text editor, then translating back to binary file *AR06058.cnv* for subsequent processing.

Fortran program SCRDATA was used to exclude pressure values <-5.0 or >1200, temperature values <-1.0 or >33, and conductivity values <2.5 or >7.0. The program first checks the range or span of values from the primary and secondary sensors 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 replaced with a missing value of -9.990e-29. The original file is renamed with an “x” prefix. For each edited file, the total number of scans, and for each sensor, the number of values that exceeded the limits and the number of entries replaced with a missing value are summarized in the *ScrData.dat* files in the \\Intermediate\DATCNV folder. Of 170 CTD files, 128 had no outliers, 6 had primary conductivity outliers, 1 had secondary conductivity outliers, and 6 had primary temperature outliers. Flagged values are ignored in subsequent processing.

SEACAT profiles were purged of data collected on deck or not completely in water by excluding scans at <2db or at <10db with conductivity <5.0. Of 22 SEACAT files, there were no outliers after the not-in-water purge.

2. Wild Edit Module:

Wild Edit flags outliers in temperature and conductivity 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 temporarily flagged values. Scans that differ from the mean by more than *pass2_nstd* standard deviations are replaced with a flag signaling that they are bad data. 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 smooths 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

For the SBE19 SEACAT, Sea-Bird recommends Filter time constants of 0.5 sec for the temperature and conductivity sensors and 2.0 sec for the pressure sensor (sampling rate is only 2 Hz, compared to 24 Hz for CTD).

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

filter_low_pass_tc_A = 0.500
filter_low_pass_tc_B = 2.000
filter_low_pass_A_vars = c0S/m t090C
filter_low_pass_B_vars = prSM

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 -0.033 sec (SE=0.0013) for C0591 and +0.021 sec (SE=0.0028) for C0528 (see Trialign0_2-139.dat and Trialign1_50-139.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). No alignment was necessary for the replacement sensor C3201 on Leg 4; TRIALIGN gave a mean optimum advance of -0.004 sec (SE=0.0060, see Trialign0_140-170.dat). This value is equivalent <0.1 scans and is not statistically different from zero.

The options selected for processing in Align CTD were as follows for single-sensor casts 2-49:

    # alignctd_adv = c0S/m -0.033

and for dual-sensor casts 50-139:

    # alignctd_adv = c0S/m -0.033, c1S/m 0.021

For the SBE 19 SEACAT, Sea-Bird recommends an advance of +0.5 sec for temperature, because of the relatively slow time response of the sensor. TRIALIGN gave a mean optimum advance (conductivity relative to temperature) of -0.500 sec (SE=0.0590).

The options selected for processing in Align CTD were as follows for SEACAT casts:

    # alignctd_adv = t090C 0.500

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, with TC duct, data were used for single-sensor casts 2-49 and 140-170:

    # celltm_alpha = 0.0300
    # celltm_tau = 7.0000
    # celltm_temp_sensor_use_for_cond = primary

and for dual-sensor casts 50-139:

    # celltm_alpha = 0.0300, 0.0300
    # celltm_tau = 7.0000, 7.0000
    # celltm_temp_sensor_use_for_cond = primary, secondary

The following Sea-Bird Electronics Inc. recommendations for Cell Thermal Mass when processing SBE 19 data were used for all SEACAT casts:

    # celltm_alpha = 0.0400, 0.0000
    # celltm_tau = 8.0000, 0.0000
    # celltm_temp_sensor_use_for_cond = primary

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 the 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.

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   #
    loopedit_excl_bad_scans = yes

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 single-sensor CTD casts and all SEACAT casts:

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

And for CTD casts with dual sensors (50-139):

name 3 = c1S/m: Conductivity, 2 [S/m]
name 4 = t190C: Temperature, 2 [ITS-90, deg C]
name 5 = depSM: Depth [salt water, m], lat =
name 6 = potemp090C: Potential Temperature [ITS-90, deg C]
name 7 = potemp190C: Potential Temperature, 2 [ITS-90, deg C]
name 8 = T2-T190C: Temperature Difference, 2 - 1 [ITS-90, deg C]
name 9 = C2-C1S/m: Conductivity Difference, 2 - 1 [S/m]
name 10 = sal00: Salinity, Practical [PSU]
name 11 = sal11: Salinity, Practical, 2 [PSU]
name 12 = secS-priS: Salinity, Practical, Difference, 2 - 1 [PSU]
name 13 = sigma-é00: Density [sigma-theta, kg/m^3]
name 14 = sigma-é11: Density, 2 [sigma-theta, kg/m^3]
name 15 = svCM: Sound Velocity [Chen-Millero, m/s]
name 16 = avgsvCM: Average Sound Velocity [Chen-Millero, m/s]

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 °N	[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 questionable 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 "STAR2006 Mac CTD Cast info.xlsx" in the \Documentation folder. Comment codes are:

A – acceptable
N - acceptable for derived variables but not for public data archive

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. We use 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 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 the 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 5-8 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, 169 valid CTD casts were conducted during STAR 2006 on the McArthur II. The format of the output files for CTD casts with one set of sensors is shown below.

```
  PrDM     C0S/m    T090C  DepSM Potemp090C    Sal00  Sigma-é00   SvCM AvgsvCM Nbin
 2.012  5.313620  27.2761  2.000    27.2757  33.3526  21.3897  1538.00  740.56   40
 3.018  5.313544  27.2769  3.000    27.2762  33.3512  21.3885  1538.02 1597.61   36
 4.023  5.313934  27.2805  4.000    27.2796  33.3511  21.3873  1538.04 1538.01   39
 5.029  5.313844  27.2791  5.000    27.2779  33.3512  21.3880  1538.06 1538.02   35
```

The columns are:
- PrDM = Digiquartz pressure in decibars (db)
- C0S/m = conductivity, from the primary conductivity sensor, in Siemens per meter (S/m)
- T090C = temperature, from the primary temperature sensor, in degrees Celsius (ºC), calculated using the ITS-90 standard
- DepSM = salt water depth in meters (m)
- Potemp090C = potential temperature, from the primary temperature sensor (reference pressure = 0.0 decibars)
- Sal00 = salinity, in practical salinity units (psu), derived from the primary temperature and conductivity sensors
- Sigma-é00 = density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the primary temperature sensor and derived salinity
- SvCM = Chen-Millero's sound velocity in meters per second (m/s) calculated from the primary temperature sensor and derived salinity

AvgsvCM = Chen-Millero's average sound velocity in meters per second (m/s) calculated from the primary temperature sensor and derived salinity
Nbin = number of scans used to calculate the bin average

22 SEACAT casts were conducted during STAR 2006 on the McArthur II. The format of the downcast output files is the same as above, except that the first column is `PrSM = Strain gauge pressure in decibars (db).`

The format of the output files for casts with dual sensors (50-139), with the lines split for clarity:

```
  PrDM     C0S/m    T090C    C1S/m    T190C   DepSM Potemp090C Potemp190C  T2-T190C …
 2.011  5.473904  27.1526  5.469140  27.1525  2.000    27.1522    27.1520  -0.0001  …
 3.017  5.474242  27.1547  5.469276  27.1534  3.000    27.1540    27.1527  -0.0013  …
 4.022  5.473897  27.1509  5.468956  27.1501  4.000    27.1500    27.1492  -0.0008  …
 5.028  5.474011  27.1517  5.469112  27.1509  5.000    27.1506    27.1498  -0.0008  …

…    C2-C1S/m    Sal00    Sal11  SecS-priS  Sigma-é00  Sigma-é11   SvCM  AvgsvCM  Nbin
…   -0.004765  34.5777  34.5439  -0.0338  22.3511  22.3257  1539.02  1539.03    25
…   -0.004966  34.5782  34.5439  -0.0343  22.3509  22.3255  1539.04  1539.03    57
…   -0.004940  34.5783  34.5438  -0.0345  22.3523  22.3265  1539.05  1539.04    41
…   -0.004899  34.5782  34.5440  -0.0343  22.3520  22.3265  1539.07  1539.04    27
```

The additional columns are:
C1S/m = secondary conductivity in Siemens per meter (S/m)
T190C = secondary temperature, in degrees Celsius (ºC), calculated using the ITS-90 standard
Potemp190C = potential temperature, from the secondary temperature sensor (reference pressure = 0.0 decibars)
T2-T190C = Difference in temperatures (ºC) from secondary and primary sensors
C2-C1S/m = Difference in conductivities (S/m) from secondary and primary sensors
Sal11 = Salinity, in practical salinity units (psu), derived from the secondary temperature and conductivity sensors
SecS-priS = Difference in salinities (psu) calculated from secondary and primary sensors
Sigma-é11 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the secondary temperature sensor and derived salinity

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. 168 of 169 CTD files and all 22 SEACAT files had matching TSG records; no corrections were necessary.

SEACAT-CTD Comparison

Three SEACAT casts were made just prior to CTD casts at the end of Leg 4. In Fig. 4, plots of SEACAT vs. CTD values show excellent agreement deeper than the mixed layer/thermocline. Therefore, the SEACAT data collected when no CTD was available are valid.

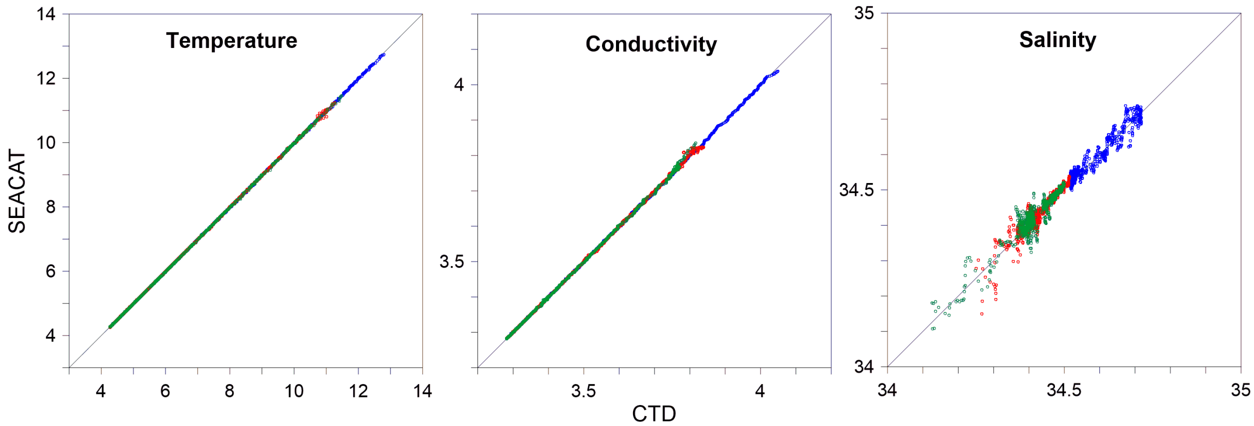


Figure 3. Comparison of SEACAT and CTD temperature, conductivity, and salinity values (150-1000m) for SEACAT A vs. CTD 164 (blue), SEACAT B vs. CTD 169 (red) and SEACAT C vs. CTD 170 (green).

Paul Fiedler, 17 June 2021

Appendix 1. STAR 2006 MacII Sea-Bird CTD Data Processing Configuration Files

STAR 2006 Mac 002_049.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      : No
NMEA depth data added         : No
NMEA time added               : No
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 2026
   Calibrated on : 20-Dec-05
   G             : 4.06929077e-003
   H             : 6.23857739e-004
   I             : 1.96780063e-005
   J             : 2.01509015e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 0591
   Calibrated on : 17-May-05
   G             : -4.03242983e+000
   H             : 5.16826765e-001
   I             : -1.98245253e-004
   J             : 3.97868193e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 2110
   Calibrated on : 01-Feb-06
   C1            : -4.227189e+004
   C2            : 1.322321e+000
   C3            : 1.465956e-002
   D1            : 3.505352e-002
   D2            : 0.000000e+000
   T1            : 2.887341e+001
   T2            : 1.284070e-004
   T3            : 4.585785e-006
   T4            : 0.000000e+000
   T5            : 0.000000e+000
   Slope         : 0.99983000
   Offset        : -6.52240
   AD590M        : 1.147000e-002
   AD590B        : -8.288670e+000
```

STAR 2006 Mac 050_139.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               : No

1) Frequency 0, Temperature

   Serial number : 2026
   Calibrated on : 20-Dec-05
   G             : 4.06929077e-003
   H             : 6.23857739e-004
   I             : 1.96780063e-005
   J             : 2.01509015e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 0591
   Calibrated on : 17-May-05
   G             : -4.03242983e+000
   H             : 5.16826765e-001
   I             : -1.98245253e-004
   J             : 3.97868193e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 2110
   Calibrated on : 01-Feb-06
   C1            : -4.227189e+004
   C2            : 1.322321e+000
   C3            : 1.465956e-002
   D1            : 3.505352e-002
   D2            : 0.000000e+000
   T1            : 2.887341e+001
   T2            : 1.284070e-004
   T3            : 4.585785e-006
   T4            : 0.000000e+000
   T5            : 0.000000e+000
   Slope         : 0.99983000
   Offset        : -6.52240
   AD590M        : 1.147000e-002
   AD590B        : -8.288670e+000

4) Frequency 3, Temperature, 2

   Serial number : 0885
   Calibrated on : 4/14/2006
   G             : 4.79999489e-003
   H             : 6.74136023e-004
   I             : 2.60319693e-005
   J             : 2.05715873e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Conductivity, 2

   Serial number : 0528
   Calibrated on : 11-Apr-06
   G             : -4.13209779e+000
   H             : 4.35513004e-001
   I             : -3.01294821e-004
   J             : 3.37554217e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000
```

STAR 2006 Mac SEACAT.con

```
Configuration report for SBE 19 Seacat CTD
------------------------------------------

Pressure sensor type      : Strain Gauge
External voltage channels : 0
Firmware version          : Version >= 3.0
0.5 second intervals      : 1
NMEA position data added  : No
NMEA depth data added     : No
NMEA time added           : No
Surface PAR voltage added : No
Scan time added           : No

1) Frequency 0, Temperature

   Serial number : 579
   Calibrated on : 21-Dec-05
   G             : 4.15383771e-003
   H             : 5.95207362e-004
   I             : 3.36431142e-006
   J             : -1.41880346e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 579
   Calibrated on : 21-Dec-05
   G             : -3.94534323e+000
   H             : 4.70604009e-001
   I             : 1.19422843e-003
   J             : -2.36482214e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00016300
   Offset        : 0.00000

3) Pressure voltage, Pressure, Strain Gauge

   Serial number : 0579
   Calibrated on : 09-Jan-06
   A0            : 2.491156e+003
   A1            : -6.502470e-001
   A2            : -4.145834e-009
   Offset        : -0.36000
```

STAR 2006 Mac 140_179.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               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 27-Jul-2006
   G             : 4.39695814e-003
   H             : 6.45494230e-004
   I             : 2.18845013e-005
   J             : 1.76685492e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 1725
   Calibrated on : 10-Aug-06
   G             : -4.09198140e+000
   H             : 4.95451859e-001
   I             : -9.60425175e-004
   J             : 7.18076643e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 3001/39443
   Calibrated on : 10-Feb-2006
   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         : 1.00009000
   Offset        : 10.65390
   AD590M        : 1.135000e-002
   AD590B        : -8.643200e+000
```