LUTH 2008 David Starr Jordan CTD PROCESSING

LUTH 2008 CTD data files were collected using a Sea-Bird 911*plus* profiling instrument aboard the NOAA Ship David Starr Jordan (DSJ). 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. 5.39c 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.

No changes in sensor use on the DSJ CTD during the LUTH 2008 were necessary. The table below lists the sensors used. The owners of the sensors were responsible for their maintenance.

	Casts	Temp	Cond	DO	Pressure
Leg 1	001-067	T0536	C0365	O0227	P00291

Owners unknown

LUTH 2008 DSJ CTD SENSOR CALIBRATION

We have no calibration certificates for the sensors used on LUTH 2008. Data were processed with the CON file used for data collection, with no calibration adjustments. No pressure sensor deck tests were conducted, although the CON file has a pressure offset value.

The CON file includes secondary temperature and conductivity sensors, although the secondary conductivity sensor is the same as the primary sensor. In the first data processing step, Data Conversion, the secondary temperature and conductivity data were all assigned missing values.

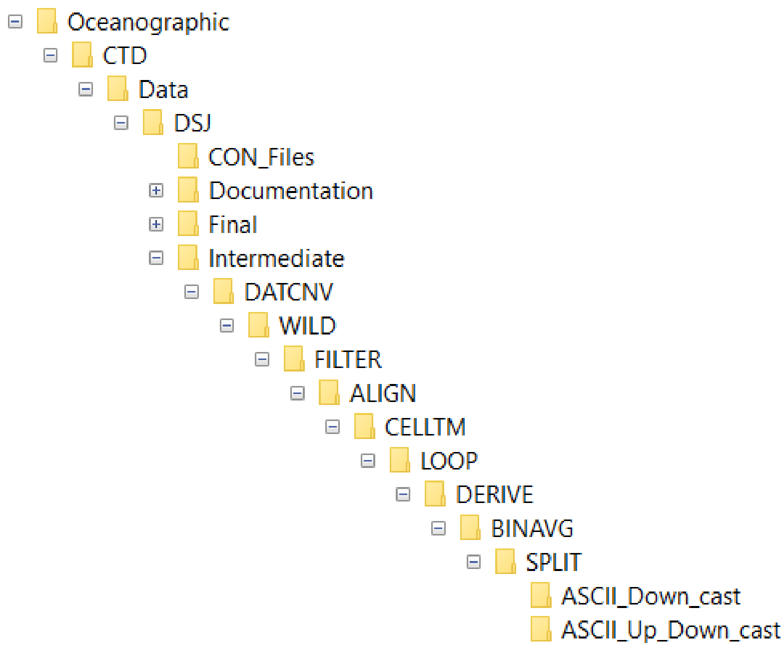
We use pre-cruise calibration coefficients for each sensor when available. Before running the processing modules, it is essential to ensure that the correct sensor configuration coefficients and corrections are loaded into the *.con files used by the SBE Data Processing program. Configuration files for the sensors used on the DSJ during LUTH 2008 are listed in Appendix 1.

LUTH 2008 CTD SBE MODULE PROCESSING

SWFSC MMTD uses Sea-Bird Electronics conductivity, temperature, oxygen, 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 LUTH 2008 are in the \CON_Files\Calibrations folder.

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:

```
# 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 = sbeox0Mm/Kg: Oxygen, SBE 43 [umol/Kg]
# name 6 = flag:  0.000e+00
# file_type = binary
```

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, and conductivity 2.5 to 7.0. 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 179 CTD files, 178 had no outliers, and 1 had secondary conductivity 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. 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.EXE (programmer: Paul Fiedler) was run to find the optimum alignment value for conductivity (i.e., the number of scans by which to advance conductivity). 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, scans are shifted by -24 to +24. For each shift, salinity is derived for 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).

This was confirmed when TRIALIGN gave a mean optimum advance of +0.006 sec (SE=0.0035, see Trialign0.dat in \FILTER, which has 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). This value is equivalent to 0.14 scans and is not statistically different from zero. Slight alignment of C1145 was needed; TRIALIGN cave a mean optimum advance of +0.061 sec (SE=0.0025).

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 ºC to approximately 5 seconds at 0 ºC) 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 all casts:
    # alignctd_adv = c0S/m -0.010, 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.

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 = 1.0, maxDepth = 5, 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 all CTD and SEACAT casts:

name 4 = depSM: Depth [salt water, m], lat = 10
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

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 Sea-Bird Electronics Inc.]
Latitude = 10 °N

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\ LUTH2008 DSJ CTD Cast info.xlsx. Comment codes are:

A – acceptable
IV – 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 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, 173 valid CTD casts were conducted during LUTH 2008 on the DSJ. The format of the downcast output files, containing only primary sensor data, are shown below.

```
  PrDM     C0S/m    T090C  DepSM Potemp090C   Sal00 Sigma-é00    SvCM  AvgsvCM Nbin
 2.011  5.364927  27.6538  2.000   27.6533  33.4438  21.3371  1538.95  1538.95  11
 3.017  5.365673  27.6570  3.000   27.6563  33.4465  21.3381  1538.98  1538.95  24
 4.023  5.365637  27.6561  4.000   27.6551  33.4466  21.3386  1538.99  1538.96  47
 5.028  5.365699  27.6565  5.000   27.6553  33.4465  21.3385  1539.01  1538.97  50
```

The columns are:

PrDM = Digiquartz pressure in decibars (db)
C0S/m = Primary conductivity in Siemens per meter (S/m)
T090C = Primary temperature, in degrees Celsius (ºC), calculated using the ITS-90 standard
Sal00 = Salinity, in practical salinity units (psu), derived from the primary temperature and conductivity sensors

DepSM = Salt water depth in meters (m)
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

Perl program CTDPositionCheck 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 header files were edited to add a N after Latitude and a W after Longitude. Other corrections were made in 3 files as described in \Final\ASCII_Down_cast\Files_With_Errors_ReadMe.txt.

Paul Fiedler, 15 June 2021

Appendix 1. LUTH 2008 DSJ Sea-Bird CTD Data Processing Configuration File

LUTH 2008 DSJ.con

```
Frequency channels suppressed : 0
Voltage words suppressed      : 4
Computer interface            : RS-232C
Scans to average              : 1
Surface PAR voltage added     : No
NMEA position data added      : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 1448
   Calibrated on : 22-Mar-07
   G             : 4.82393572e-003
   H             : 6.72237137e-004
   I             : 2.59500268e-005
   J             : 2.07179761e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 1165
   Calibrated on : 09-Mar-07
   G             : -3.96752349e+000
   H             : 5.47689293e-001
   I             : 1.90561733e-004
   J             : 1.98409688e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 53561/0311
   Calibrated on : 21-Oct-2005
   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         : 0.99998000
   Offset        : -4.27000
   AD590M        : 1.167000e-002
   AD590B        : -8.165620e+000

4) Frequency 3, Temperature, 2

   Serial number : 1352
   Calibrated on : 08-Mar-07
   G             : 4.85510300e-003
   H             : 6.78090622e-004
   I             : 2.63647229e-005
   J             : 2.06701743e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Conductivity, 2

   Serial number : 1145
   Calibrated on : 08-Mar-07
   G             : -4.20264711e+000
   H             : 4.64198294e-001
   I             : -6.47373037e-005
   J             : 2.67875408e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000
```