ORCAWALE 2001 Jordan CTD PROCESSING

ORCAWALE 2001 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 Version 5.26 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 sensor changes were made on the DSJ during the ORCAWALE 2001 cruise. The table below describes the period for which each sensor was used; no secondary sensors were used. The owners of the sensors were responsible for their maintenance.

	Casts	Temp	Cond	Pressure
Legs 1-5	001-051	T1448	C1165	P0311

MMTD-owned

ORCAWALE 2001 DSJ CTD SENSOR CALIBRATION

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 ORCAWALE 2008 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 ORCAWALE 2001_DSJ.xlsx, 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 procedure. The adjusted configuration files used to process the ORCAWALE 2001 DSJ data 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 conductivity sensor, C1165, was calibrated on 21 February 2001 and 4 June 2002. The difference between the iSlope values at the start and end of the cruise was less than 0.0003 but the end iSlope was more than 0.00015 less than 1; consequently, the average iSlope was used for calibration adjustment (slope = 0.999780).

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 temperature sensor, T1448, was calibrated on 21 February 2001 and 5 June 2002. The iOffset at the end of the cruise was less than 2 mdeg C; consequently, no calibration adjustment was necessary (offset = 0).

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).

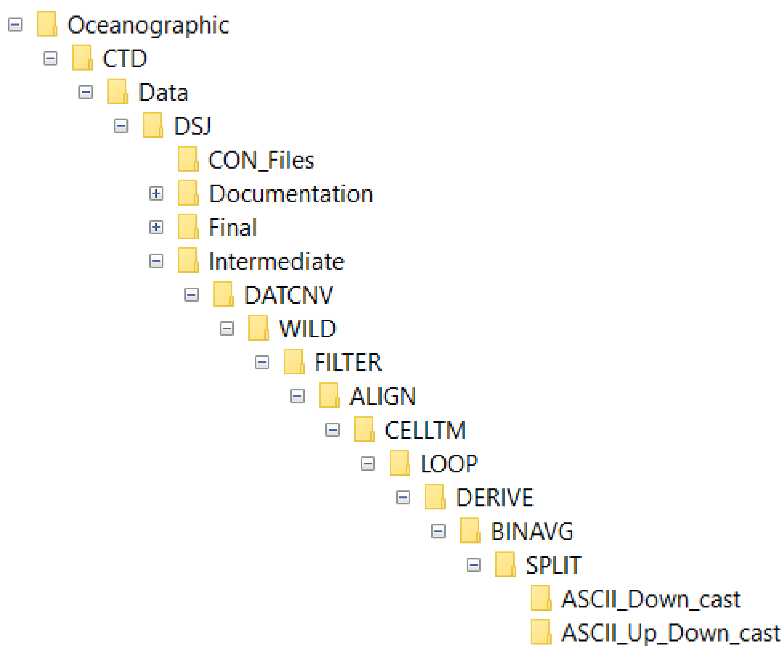
The pressure sensor, P0311 (the manufacturer's serial number 53561 was used during data collection), was calibrated on 17 June 1993 and 21 October 2005, 8 years before and 4 years after the cruise. The average iOffset was -1.971 db. Two deck tests of this pressure sensor were conducted on the DSJ during ORCAWALE 2001, resulting in an offsets of -2.832 and -3.211 db; the average deck test offset was used for calibration adjustment (offset = -3.02).

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 ORCAWALE 2001_DSJ.xls in the \Documentation folder. The configuration files for processing data from the sensors used on the McArthur during ORCAWALE 2001 are listed in Appendix 1.

ORCAWALE 2001 CTD SBE MODULE PROCESSING

The SBE Data processing modules that were applied to the raw ORCAWALE 2001 DSJ 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:

> # 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
> # file_type = ascii

Fortran program ScrData (programmer: Paul Fiedler) 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 51 CTD files, 43 had no outliers and 5 had C0 outliers, 5 had T0 outliers, and 4 had P outliers.

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 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
wildedit_vars = c0S/m t090C

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 mean optimum advances of -0.008 sec (SE=0.0033) for conductivity sensor C1165, (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 not statistically different from zero. The processed data showed no salinity spikes due to sensor misalignment.

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

alignctd_adv = c0S/m -0.008

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, 0.0000
celltm_tau = 7.0000, 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 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.

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 = no

7. Derive Module:

Derive uses pressure, temperature, and conductivity from the input *.cnv file to compute the following oceanographic variables, some of 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 derived variables were calculated in this module for all CTD casts:

name 3 = depSM: Depth [salt water, m], lat = 24.3275
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], 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 by Sea-Bird Electronics Inc.]
# Latitude = 38 °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 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 "ORCAWALE 2001 DSJ CTD Cast info.xlsx" in the \Documentation folder. Comment codes are:

A – acceptable
N – acceptable for assessments of protected species but not for a national archive
R – reject cast

8. Bin Average Module:

The Bin Average module averages temperature, conductivity, pressure, and derived 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 in previous modules.

The following processing options were selected in this module for all casts:
binavg_bintype = meters
binavg_binsize = 1
binavg_excl_bad_scans = yes
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 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 errors 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, 51 CTD casts were conducted during ORCAWALE 2001 on the Jordan. The format of the output files is shown below.

PrDM	C0S/m	T090C	DepSM	Potemp090C	Sal00	Sigma-é00	SvCM	AvgsvCM	Nbin
5.031	5.494556	26.6258	5.000	26.6247	35.1204	22.9278	538.45	538.41	27
6.037	5.494744	26.6266	6.000	26.6253	35.1208	22.9279	1538.47	1538.42	31
7.044	5.494967	26.6283	7.000	26.6267	35.1209	22.9276	1538.49	1538.43	20

The columns are:

PrDM = Digiquartz pressure in decibars (db)
C0S/m = Conductivity in Siemens per meter (S/m)
T090C = Temperature, in degrees Celsius (ºC), calculated using the ITS-90 standard
DepSM = Salt water depth in meters (m)
Potemp090C = Potential temperature (ºC), calculated using the ITS-90 standard

Sal00 = Salinity, in practical salinity units (psu), derived from the temperature and conductivity sensors
Sigma-t00 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the temperature sensor and the derived salinity data
SvCM = Chen-Millero's sound velocity in meters per second (m/s)
AvgsvCM = Chen-Millero's average sound velocity in meters per second (m/s)
Nbin = number of scans used to calculate the bin average

No bottle salinity samples were analyzed to validate CTD sensor calibration.

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 51 files had matching TSG records; no corrections were necessary.

Paul Fiedler, 18 June 2021

Appendix 1. ORCAWALE 2001 DSJ Sea-Bird Data Processing Configuration Files

ORCAWALE 2001 DSJ.con

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Configuration report for SBE 911plus/917plus CTD
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Frequency channels suppressed : 2
Voltage words suppressed      : 4
Computer interface            : IEEE-488 (GPIB)
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 : 1448
   Calibrated on : 21-Feb-01
   G             : 4.82317030e-003
   H             : 6.71427830e-004
   I             : 2.55908185e-005
   J             : 2.01916901e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 1165
   Calibrated on : 21-Feb-01
   G             : -4.16409451e+000
   H             : 5.75529932e-001
   I             : 2.09263211e-004
   J             : 2.68310397e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99978000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 53561
   Calibrated on : 06-17-1993
   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         : 1.00000000
   Offset        : -3.02000
   AD590M        : 1.167000e-002
   AD590B        : -8.165620e+000

Scan length                   : 12
```