HICEAS 2002 McArthur CTD PROCESSING

HICEAS 2002 CTD data files were collected using a Sea-Bird 911*plus* profiling instrument aboard the NOAA Ship McArthur (MAC). 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 5.21 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.

Two different CTD packages (fish plus sensors) were used on the Mac during the HICEAS 2002 cruise. Notes in the ODL suggest that the CTD failed during cast AR02007 and was replaced for cast AR02008, although no explanation was recorded. 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
Leg 1	001-007	*T2126*	*C1697*	*P0414*
Legs 1-3	008-035	*T0875*	*C0524*	*P0281*

PMC-owned

HICEAS 2002 Mac 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 HICEAS 2002 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 HICEAS 2002_MAC.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 the Data Conversion and Derive modules of Sea-Bird's SBE Data Processing software.

The adjusted configuration files used to process the HICEAS 2002 Mac 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 conductivity sensor, C1697, was calibrated on 3 January 2002 and 7 January 2003. The difference between the iSlope values at the start and end of the cruise was less than 0.0003 and the end iSlope was less than 1.00015; consequently, no calibration adjustment was necessary (slope = 1).

The conductivity sensor, C0524, was calibrated on 3 January 2002 and 7 January 2003. The difference between the iSlope values at the start and end of the cruise was less than 0.0003, but the end iSlope was greater than 1.00015; consequently, the average iSlope was used for calibration adjustment (slope = 1.000307).

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, T2126, was calibrated on 3 January 2002 and 6 January 2003. The iOffset at the end of the cruise was less than 2mdeg C; consequently, no calibration adjustment was necessary (offset = 0).

The temperature sensor, T0875, was calibrated on 3 January 2002 and 6 January 2003. The iOffset at the end of the cruise was less than 2mdeg C; consequently, no calibration adjustment was necessary (offset = 0).

Pressure Sensor Correction:

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, P0414, was calibrated on 27 December 2001 and 16 January 2003. The average iOffset was +0.130 db. Because only one deck test of this pressure sensor was conducted on the MAC during HICEAS 2002, resulting in an offset of -0.039 db, the average iOffset was used for calibration adjustment (offset = +0.130).

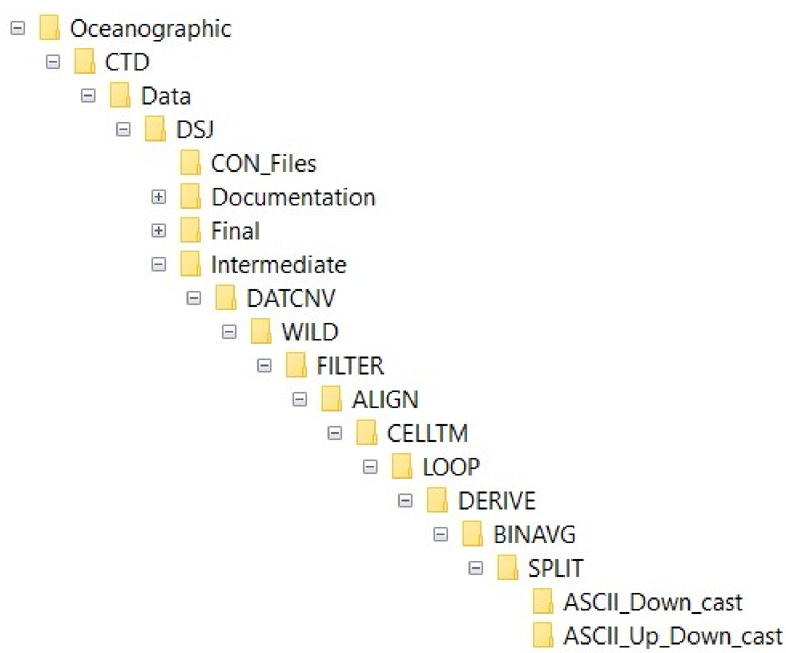
The pressure sensor, P0281, was calibrated on 26 December 2001 and 24 June 2003. The average iOffset was -2.644 db, consistent with one deck test of this pressure sensor conducted on the Mac during HICEAS 2002 that resulted in an offset of -2.830 db. The average of the iOffset and the deck test offset was used for calibration adjustment (offset = -2.74).

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 HICEAS 2002_Mac.xls in the \Documentation folder. The configuration files for processing data from the sensors used on the McArthur during HICEAS 2002 is listed in Appendix 1.

HICEAS 2002 CTD SBE MODULE PROCESSING

The SBE Data processing modules that were applied to the raw HICEAS 2002 Mac 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 = 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, conductivity 2.5 to 7.0, and dissolved oxygen 0 to 350 µmol 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 35 CTD files, 32 had no outliers and 3 had a few T0 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 -0.014 sec (SE=0.0000) for conductivity sensor C1697 on casts 001-007 and -0.059 sec (SE=0.0078) for conductivity sensor C0524 on casts

008-029, (see Trialign0_001-007.dat and Trialign0_008-029.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). Figure 1 illustrates that salinity spiking at extreme temperature gradients was reduced by alignment. However, casts 030-035 had both salinity spikes and lower frequency noise that was not reduced by alignment. We do not know the cause of this noise.

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

# alignctd_adv = c0S/m -0.014	casts 001-007
# alignctd_adv = c0S/m -0.059	casts 008-029
# alignctd_adv = c0S/m 0.021	casts 030-035

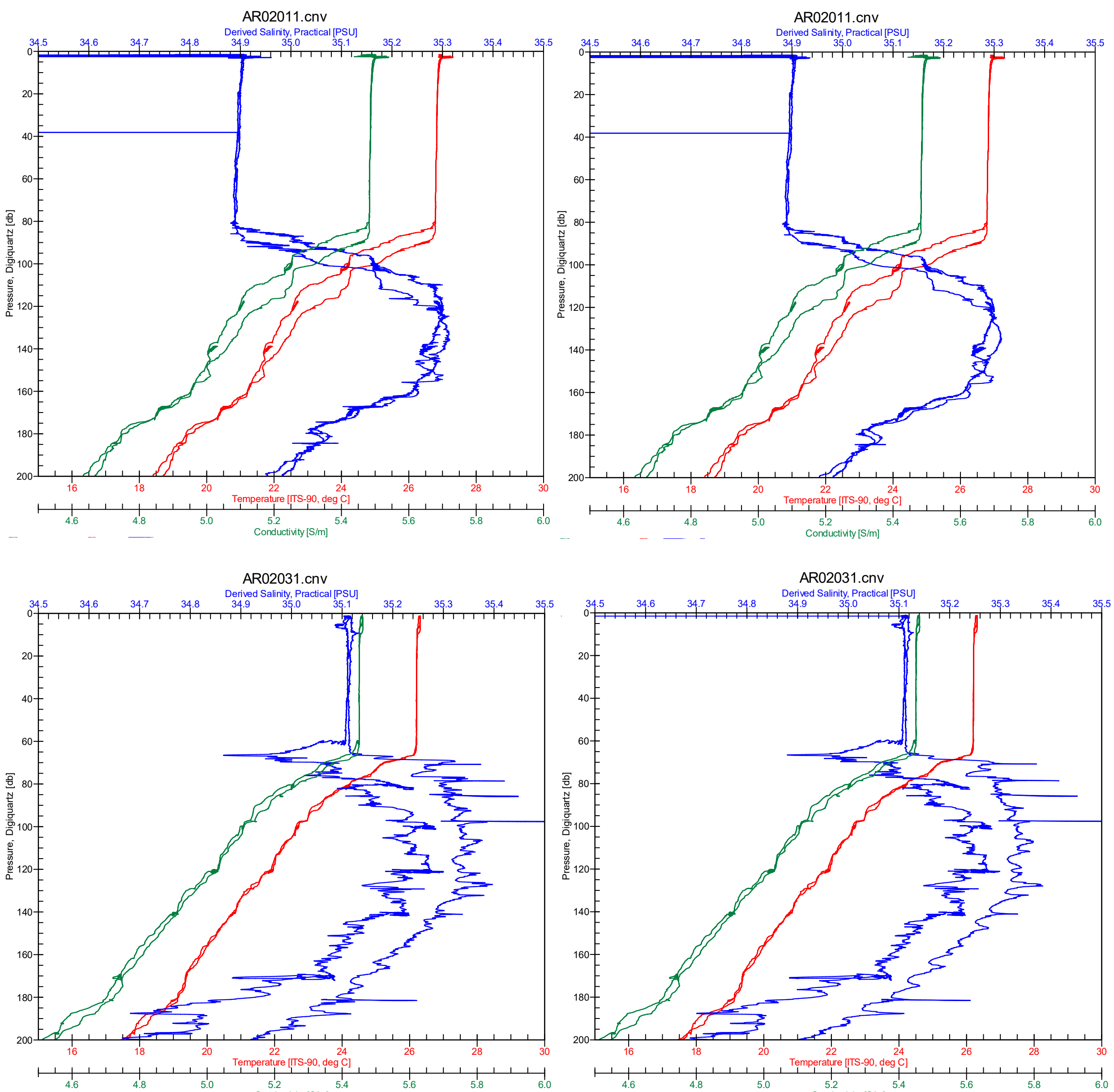


Figure 1. Surface section of CTD casts 011 and 031 before (left) and after (right) alignment. Alignment reduces salinity spikes in the thermocline for cast 011, but has little effect on spikes and other lower frequency noise in cast 031.

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

Data collection for only one cast (031) was started before the CTD had been returned to near the surface after the 10m surface soak (i.e., data collected began either on deck or during the soak).

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 = 25 °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 Mac02_castinfo.txt 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_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 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, 36 CTD casts were conducted during HICEAS 2002 on the McArthur. Cast AR02027a was conducted one hour after cast AR02027 was aborted near the end of the downcast due to engine trouble. 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
```

Column descriptions are as follows:

a) PrDM = Digiquartz pressure in decibars (db)
b) C0S/m = Conductivity in Siemens per meter (S/m)
c) T090C = Temperature, in degrees Celsius (ºC), calculated using the ITS-90 standard
d) DepSM = Salt water depth in meters (m)
e) Potemp090C = Potential temperature (ºC), calculated using the ITS-90 standard
f) Sal00 = Salinity, in practical salinity units (psu), derived from the temperature and conductivity sensors
g) Sigma-t00 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the temperature sensor and the derived salinity data
h) SvCM = Chen-Millero's sound velocity in meters per second (m/s)
i) AvgsvCM = Chen-Millero's average sound velocity in meters per second (m/s)
j) Nbin = number of scans per bin

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 36 files had matching TSG records; times were corrected by 1 or 2 hours in 17 files.

Low-frequency noise, casts 30-35

Low-frequency noise has been observed with MMTD sensors on the McArthur II in 2003 and 2005 (see STAR 2003 MAC CTD Processing Final.pdf). In these cases, the noise occurred during the entire cruise, was obvious as regular bulges in the temperature and conductivity profiles, and was more pronounced on the upcast than on the downcast. The problem appeared to be due either to pump malfunction or to partial or complete loss of the air-release valve that was found to be missing in 2005. The noise observed on casts 30-35 in the HICEAS 2002 McArthur CTD data looks different that that observed on the McArthur II. The sharp salinity spikes are not obviously related to noise in the temperature or conductivity profiles, and are more pronounced on the downcast than on the upcast (see Figure 1). They may be caused by a flow problem in the TC duct. These profiles will be used to derive mixed layer depth and thermocline depth and strength, but the data will not be submitted to NODC.

Paul Fiedler, 18 June 2021

Appendix 1. HICEAS 2002 Mac Sea-Bird Data Processing Configuration Files

HICEAS_2002 Mac Casts 001_007.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 : 2126
   Calibrated on : 03-Jan-02
   G             : 4.07353051e-003
   H             : 6.21229926e-004
   I             : 2.00368555e-005
   J             : 2.19831881e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0042

2) Frequency 1, Conductivity

   Serial number : 1697
   Calibrated on : 03-Jan-02
   G             : -4.14538452e+000
   H             : 4.79022204e-001
   I             : -8.22198179e-004
   J             : 6.42776124e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0414
   Calibrated on : 27-Dec-01
   C1            : -4.285245e+004
   C2            : -1.357147e-001
   C3            : 1.419860e-002
   D1            : 3.730900e-002
   D2            : 0.000000e+000
   T1            : 3.047956e+001
   T2            : -3.872276e-004
   T3            : 4.571210e-006
   T4            : 2.126270e-009
   T5            : 0.000000e+000
   Slope         : 0.99994000
   Offset        : 0.13000
   AD590M        : 1.130000e-002
   AD590B        : -8.801900e+000

Scan length                   : 12
```

HICEAS_2002 Mac Casts 008_035.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 : 875
   Calibrated on : 03-Jan-02
   G             : 4.79634208e-003
   H             : 6.79282329e-004
   I             : 3.00931269e-005
   J             : 2.76148476e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 524
   Calibrated on : 03-Jan-02
   G             : -4.12926967e+000
   H             : 4.31198399e-001
   I             : -6.05690412e-006
   J             : 2.17900899e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00030700
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 281
   Calibrated on : 26-Dec-01
   C1            : -3.954828e+004
   C2            : 4.436600e-001
   C3            : 1.366730e-002
   D1            : 3.909300e-002
   D2            : 0.000000e+000
   T1            : 3.044704e+001
   T2            : -1.544040e-004
   T3            : 4.447890e-006
   T4            : 3.337730e-009
   T5            : 0.000000e+000
   Slope         : 0.99990000
   Offset        : -2.74000
   AD590M        : 1.157000e-002
   AD590B        : -8.476340e+000

Scan length                   : 19
```

Appendix 2. Bottle Salinity Analyses

Bottle salinity samples were analyzed to validate CTD sensor calibration. Samples were collected from bottles tripped at depth and analyzed with a Guildline Autosal 8400B salinometer using standard methods (Guildline Technical Manual TM 8400B). The salinity data from the Autosal and CTD can be found in \\Stenella \Ecology\Survey_Data\PacificIslands \2002_HICEAS\Oceanographic\Salinity. The McArthur bottle salinity samples were analyzed ashore on February 1-4, 2003, almost two months after the cruise ended. The results summarized below can also be found in \\Stenella\Ecology\Survey_Data\PacificIslands\2002_HICEAS\ Oceanographic\Salinity \Documentation\Mac\HICEAS 2002 Mac Salts.xls.

Autosal data were collected during salts runs by the program ASAL v? (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 \Survey_Data\ PacificIslands\2002_HICEAS\Oceanographic\Salinity\Raw\Mac, were copied with a text editor into a single file named *salts02m.raw*.

Fortran program CR2SAL.EXE (programmer: Fiedler) calculated salinities from the recorded conductivity ratios and bath temperatures in *salts02m.raw* using the Sea-Bird salinity algorithm. The two output files, \\Stenella\Ecology\Survey_Data\PacificIslands\2002_HICEAS\ Oceanographic\Salinity\Intermediate\Mac*salts02m.sal* and *salts02m.sta* are identical except that the sample records in the *.sta* file are truncated. Output file *salts02m.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 *salts02m.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 *salts02m.sal*. Two files are output: \\Stenella\Ecology\Survey_Data\PacificIslands\2002_HICEAS\Oceanographic\Salinity \Intermediate\DSJ*salts02m.dat* contains 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; *salts02m.sum* contains means and standard deviations of the differences within each salts run. Two Niskin bottle numbers were changed to obtain reasonable Bottle – CTD salinity differences and two samples were marked for deletion because they were logged as leaking (see *salts05m.sta* for details).

Conductivity Ratio Adjustment for Bottle Salinities

When analyzing samples on the Autosal, the initial salinity standard reading should be equal to 2x the actual conductivity ratio of the standard (K_{15} 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 Autosal was not sufficiently warmed up with standard water before samples are read) or the sensitivity of the Autosal may drift during the run. Adjusting the reference for sample conductivity ratios will change both the mean and the standard deviation of Bottle - CTD salinity differences if the initial and final standard readings differ. Selection of an adjustment alternative should be based on minimizing the 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 with no adjustment resulted in Bottle – CTD differences with means (biases) and standard deviations (RMSE) that were not significantly different than when conductivity ratios were adjusted:

Adjustment	Mean (Bottle – CTD)	St. dev. (Bottle – CTD)
None:	+0.00910	0.02283
(1):	**+0.00903**	0.02284
(2):	+0.00907	0.02283
(3):	+0.00907	**0.02281**

Therefore, bottle salinities calculated from sample conductivity ratios with no adjustment were used in subsequent analyses.

Precision of Bottle Salinity Measurements

No replicate samples were collected to allow an assessment of the precision of our bottle salinity sampling and analysis methods. Guildline specifies a Autosal accuracy of ±0.002 and resolution of 0.0002 psu (although precision might not be equal to resolution). Autosal accuracies of ±0.001 are possible when special care is taken in handling the samples and when the measurements are made with room temperature maintained 1-2°C below the bath temperature (Sea-Bird, personal communication).

The standard deviation of Bottle - CTD salinity differences for all samples was ~0.023 (above table). This value has been about two times the standard deviation of bottle salinity replicates when we run replicate samples, because of the additional errors of the CTD sensors and the mismatch of waters pumped through CTD sensors and sampled by Niskin bottles. The observed standard deviation of Bottle - CTD salinity differences suggests that the Autosal salinity values were not as precise (about ±0.012) as they could be, but are acceptable for our purposes.

Bottle – CTD Salinity Differences

Figure 3 shows Bottle – CTD salinity differences for all samples. CTD values are shown both before and after sensor calibration adjustments based on post-cruise calibrations. The samples show positive Bottle – CTD differences even after CTD calibration adjustment. This mean positive bias is due to a fraction of the samples with large positive salinity differences, suggesting evaporation from these bottles before analysis. The trend line without calibration adjustment shows the negative bias of the CTD sensors (positive Bottle – CTD differences), consistent with the <1 postslopes in the calibration spreadsheet, \\Stenella\Ecology\Survey_Data \PacificIslands\2002_HICEAS \Oceanographic\CTD \Data\Mac\Documents\CTDcalibrations HICEAS 2002_Mac.xls. The slope of the trend line was reduced after adjustment because the conductivity sensors were adjusted by leg. The adjustment of sensor calibrations for drift, based on the post-cruise calibration, reduced the apparent bias of the CTD sensors.

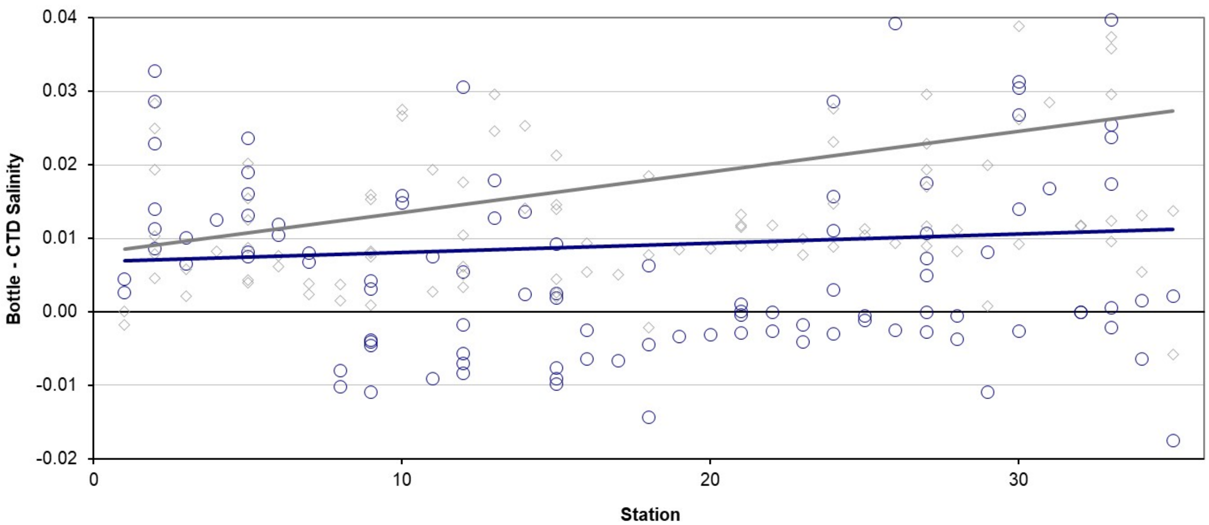


Figure 3. Bottle – CTD salinity differences for HICEAS 2002, McArthur, using pre-cruise sensor calibrations (gray diamonds) and post-cruise adjustments (dark blue circles).

Overall, the Bottle – CTD salinity differences indicate that *the CTD sensors were more accurate after calibration adjustment*.