HICEAS 2010 Sette CTD PROCESSING

HICEAS 2010 CTD data files were collected using a Sea-Bird 911*plus* profiling instrument aboard the NOAA Ship Oscar Elton Sette (Sette). The 911*plus* consists of the 9*plus* underwater CTD and 11*plus* V2 Deck Unit, which has high resolution sampling (24Hz) and pump-controlled conductivity and temperature flow-through sensors. Data were collected using Sea-Bird's SeaSave Win32 Version 7.20c and have been processed using Sea-Bird's SBE Data Processing v. 7.26.7. More information regarding the SBE software and recommended data processing procedures can be found online at www.seabird.com.

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

Sensor use on the Sette CTD during the HICEAS 2010 cruise underwent two minor changes. The table below describes the period for which each sensor was used. The owners of the sensors are responsible for their maintenance.

	Casts	Temp 1, 2	Cond 1, 2	O 1,2	Fl	Pressure
Leg 1	001	T0975, T2779	C0652	O0715, O0593	FLS-912	P0281
Leg 1-2	002-064	T0975, T2779	C0652, C2326	O0715, O0593	FLS-912	P0281
Leg 2	065-090	T0975, T2779	C0652, C2326	O0715, O0593	FLS-1366	P0281

MOCPI-owned

Fluorescence sensor data (Fl) were not processed.

HICEAS 2010 SETTE 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 2010 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 2010.xlsx, in the \Documentation folder, contains the pre and post-cruise calibration information for the conductivity, temperature, pressure, and dissolved oxygen sensors. It then derives slope or offset values used to correct the calibration coefficients used in the Data Conversion and Derive modules of Sea-Bird's SBE Data Processing procedure. The adjusted configuration files used to process the HICEAS 2010 Sette data (Appendix 1) are in the \CON_Files folder.

Conductivity Sensor Correction:

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

The primary conductivity sensor, C0652, was calibrated on 29 July 2010 and 3 August 2011. The difference between the iSlope values at the start and end of the cruise was less than 0.0003, and the iSlope at the end of the cruise was <0.00015 from 1; consequently, no slope calibration adjustment was needed.

The secondary conductivity sensor, C2326, was also calibrated on 25 November 2009 and 30 November 2010. The difference between the iSlope values at the start and end of the cruise was less than 0.0003, and the iSlope at the end of the cruise was <0.00015 from 1; consequently, no slope calibration adjustment was needed.

Temperature Sensor Correction:

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

The primary temperature sensor, T0975, was calibrated on 13 August 2010 and 3 August 2011. The iOffset at the end of the cruise was less than 2mdeg C; consequently, no offset calibration adjustment was needed.

The secondary temperature sensor, T2109, was calibrated on 18 February 2010 and 3 February 2011. The iOffset at the end of the cruise was less than 2mdeg C; consequently, no offset calibration adjustment was needed.

Pressure Sensor Correction:

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

Two deck tests were conducted on the pressure sensor-CTD fish, P0281-51195, resulting in offsets of -5.2404 and -5.1261 db; these results were not consistent with Sea-Bird calibrations from 30 April 2009 and 23 March 2011 (average iOffset=-4.1955). Therefore, the average of the deck test offsets, equal to -5.1832, was used in the *.con file.

Oxygen Sensor Correction:

The SBE 43 oxygen sensor has a measurement range of 0 to 120% of surface saturation (approximately 200 µmol/Kg). The SBE 43 sensor is rated to have an initial accuracy of 2% of surface saturation (approximately 4 µmol/Kg).

The sensor outputs a voltage that is linearly related to dissolved oxygen concentration by a slope (Soc) and offset (Voffset). The sensor is expected to drift over time due to a decrease in sensitivity. Drift is expected to occur only at sea because the sensor membrane is sealed against exposure to air between cruises. Sea-Bird recommends a simple interpolation based on usage time between the pre- and post-cruise calibration values of Soc. On the advice of Dave Griffiths (SWFSC Fisheries Resources Division), both Soc and Voffset are normally interpolated.

The dissolved oxygen sensor, O-0715, was calibrated on 27 July 2010 and 6 June 2012. The iSoc values changed by less than 4% but more than 2% between the start and end of the cruise, therefore the average separate iSoc and iVoffset values were used in the *.con file.

The secondary dissolved oxygen sensor, O-0593, was calibrated on 30 December 2009 and 4 December 2010. The iSoc values changed by less than 4% but more than 2% between the start and end of the cruise, therefore the average iSoc and iVoffset values were used in the *.con file.

Comparison of the Primary and Secondary Sensors

Differences between primary and secondary sensors by cast are summarized in Figure 1. Fortran program COMPSENS.EXE (Author: Paul Fiedler) calculates the mean difference between the primary and secondary sensors for each profile. The output file, compsens2010s.dat, is in the \Documents folder. Figure 1 shows that the temperature and conductivity values measured by and salinity values derived from the primary and secondary sensors did not differ by more than the desired accuracy of the sensors. Bottle salinity analyses (Appendix 2) indicate that the secondary sensors were more accurate than the primary sensors and should be used in the final CTD data file.

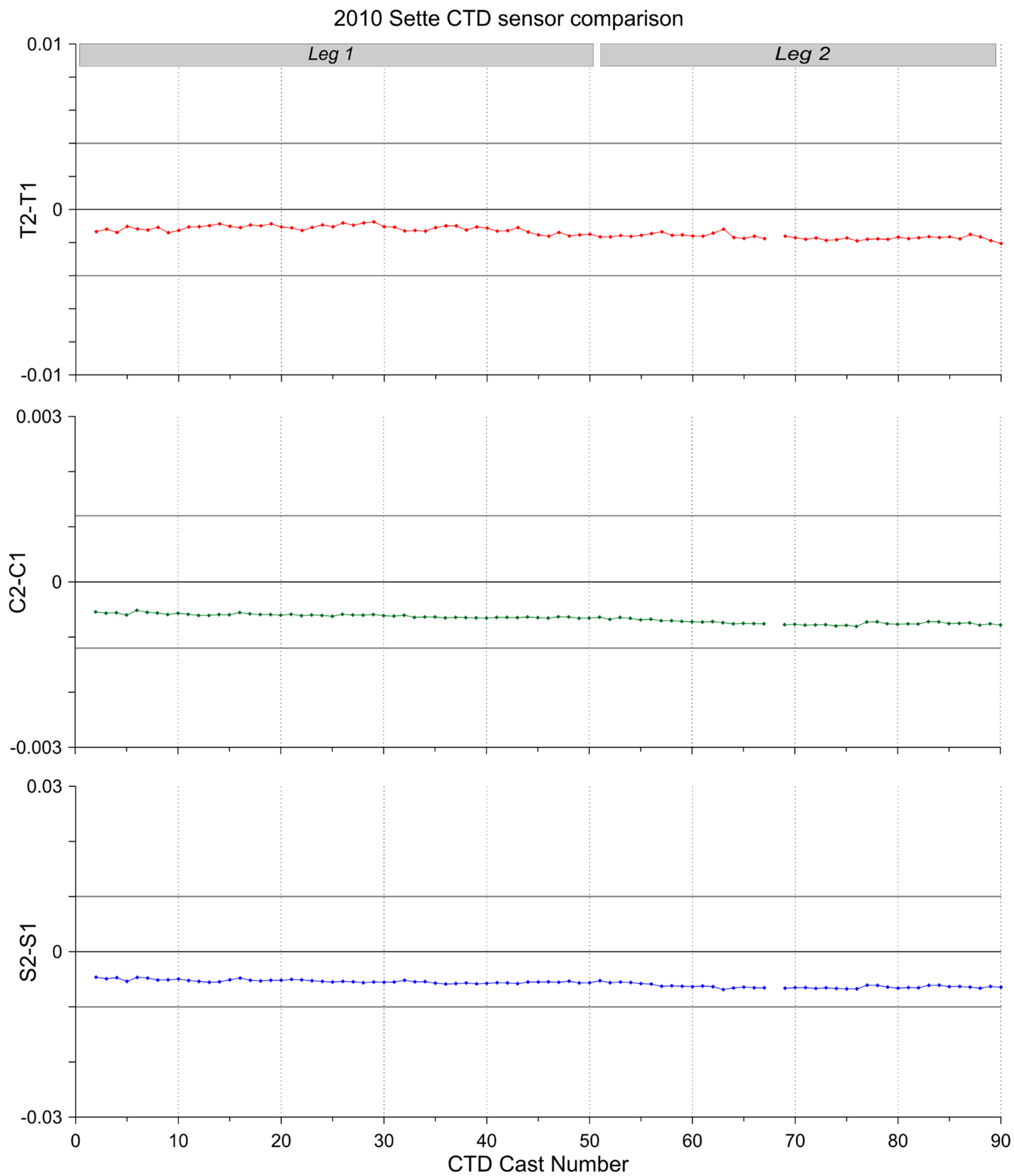


Figure 1. Time series of differences between primary and secondary temperature and conductivity sensors for HICEAS 2010 Sette CTD casts (001 did not use dual sensors). Each temperature (T2-T1), conductivity (C2-C1), and salinity (S2-S1) difference is a mean of 1m bin-averaged downcast values (excluding the upper 10m and bins with density changes >0.003 σ_t). Gray lines represent desired accuracy (±0.004 ºC, ±0.0012 S/m, ±0.010 psu, which are 4x the specified initial accuracies of the Sea-Bird temperature and conductivity sensors).

Oxygen sensor data were checked by Fortran program XO2SAT.EXE (programmer: Paul Fiedler), which extracts near-surface (to 10m) CTD data from the downcast ASCII data files. Surface waters are normally close to saturated with dissolved oxygen. Air-sea exchange due to wind-driven turbulence will saturate surface waters. Observed near-surface dissolved oxygen concentration was compared to an oxygen saturation value calculated from observed temperature and salinity using a Sea-Bird equation (Derived Parameter Formulas in SBE Data Processing).

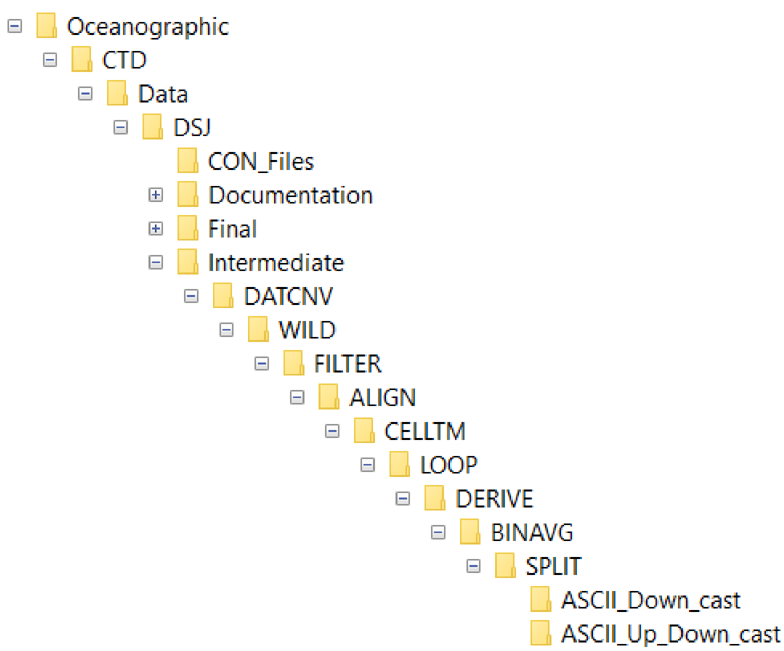
Mean oxygen saturation values were 98.0% and 96.6% for sensors O0715 and O0593, respectively. Therefore, dissolved oxygen values from the first sensor will be included in the final CTD data file.

SWFSC MMTD uses pre-cruise calibration coefficients for each sensor when available. Before running the processing modules, it is essential to ensure that the correct sensor configuration coefficients and corrections are loaded into the *.con files used by the SBE Data Processing program. Offset and slope adjustments are obtained from CTDcalibrations HICEAS 2010 SETTE.xlsx in the \Documentation folder. Configuration files for the sensors used on the Sette during HICEAS 2010 are listed in Appendix 1.

HICEAS 2010 CTD SBE MODULE PROCESSING

The SBE Data processing modules that were applied to the raw HICEAS 2010 Sette data are listed below. Each SBE module creates a program setup file, named *.psa. The *.psa files are located in the folder preceding their output, i.e. the ‘Derive.psa’ file is found in the ‘LOOP’ folder. Output .cnv files are kept in binary format to speed processing and reduce file sizes. The final module – ASCII Out – converts the binary data to ASCII format; if examination of the data is needed during earlier processing steps, the Translate module can be used to convert to the binary data to ASCII.

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



1. **Data Conversion Module:**

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

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

name 0 = prDM: Pressure, Digiquartz [db]
name 1 = c0S/m: Conductivity [S/m]
name 2 = t090C: Temperature [ITS-90, deg C]
name 3 = c1S/m: Conductivity, 2 [S/m]
name 4 = t190C: Temperature, 2 [ITS-90, deg C]
name 5 = sbox0Mm/Kg: Oxygen, SBE 43 [umol/kg]
name 6 = sbox1Mm/Kg: Oxygen, SBE 43, 2 [umol/kg]
name 7 = flag: 0.000e+00

Fortran program ScrData (programmer: Paul Fiedler) was used to flag values outside of these broad ranges: pressure -5 to 1200 db, temperature -1 to 33 deg C, conductivity 2.5 to 7.0, and dissolved oxygen 0 to 350 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 90 CTD files, all had no outliers.

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 derivations, 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 -0.030 sec (SE=0.0022) for primary sensor, C0652, and +0.013 sec (SE=0.0031) for secondary sensor, C2326, (see Trialign0 and Trialign1.dat in \FILTER, which have the following columns: CTD file name, pressure (db) at the maximum temperature gradient, maximum temperature gradient (deg C/db), optimal advance (scans), and relative standard deviation of residuals).

The options selected for processing in Align CTD were as follows cast 001:

    # alignctd_adv = c0S/m -0.030, sbox0Mm/Kg 2.000, sbox1Mm/Kg 2.000

and for casts 002-090:

    # alignctd_adv = c0S/m -0.030, c1S/m 0.013, sbox0Mm/Kg 2.000, sbox1Mm/Kg 2.000

5. Cell Thermal Mass Module:

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

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

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

6. Loop Edit Module:

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

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

    # loopedit_minVelocity = 0.250
    # loopedit_surfaceSoak: minDepth = 5.0, maxDepth = 20, useDeckPress = 0

7. Derive Module:

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

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

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

name 7 = depSM: Depth [salt water, m], lat = 16.485
name 8 = potemp090C: Potential Temperature [ITS-90, deg C]
name 9 = sal00: Salinity, Practical [PSU]
name 10 = sigma-é00: Density [sigma-theta, kg/m^3]
name 11 = svCM: Sound Velocity [Chen-Millero, m/s]
name 12 = avgsvCM: Average Sound Velocity [Chen-Millero, m/s], minP = 2, minS = 20
name 13 = svCM1: Sound Velocity, 2 [Chen-Millero, m/s]
name 14 = potemp190C: Potential Temperature, 2 [ITS-90, deg C]
name 15 = sal11: Salinity, Practical, 2 [PSU]
name 16 = sigma-é11: Density, 2 [sigma-theta, kg/m^3]

And for cast 001 with only one conductivity sensor:

name 6 = depSM: Depth [salt water, m], lat = 21.5747
name 7 = potemp090C: Potential Temperature [ITS-90, deg C]
name 8 = sal00: Salinity, Practical [PSU]
name 9 = sigma-é00: Density [sigma-theta, kg/m^3]
name 10 = svCM: Sound Velocity [Chen-Millero, m/s]
name 11 = avgsvCM: Average Sound Velocity [Chen-Millero, m/s], minP = 2, minS = 20
name 12 = svCM1: Sound Velocity, 2 [Chen-Millero, m/s]
name 13 = potemp190C: Potential Temperature, 2 [ITS-90, deg C]

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

** To calculate average sound velocity, the following values were used for the DELPHINUS study area:

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

The profiles output by the Derive module were inspected by the Senior Oceanographer for bad data caused by sensor failure, temperature inversions, low surface salinity measurements (likely the result of rain), and spikes in salinity. Comments about each cast are in \Documentation\ HICEAS_2010_SETTE_CTD Cast info.xlsx. Comment codes are:

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

8. Bin Average Module:

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

The following processing options were selected in this module for all casts:
binavg_bintype = meters
binavg_binsize = 1
binavg_excl_bad_scans = yes
binavg_skipover = 0
binavg_surface_bin = no, min = 0.000, max = 5.000, value = 0.000

9. Split Module:

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

The following options were selected in this module for all casts:
split_excl_bad_scans = no
output the downcast only (into the \Split folder). This command adds a 'd' at the beginning of the filenames.

10. ASCII Out Module:

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

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

The following options were selected in this module for all casts:
Output Header and Data files

Label Column at top of the file
Column separator = space

FINAL PRODUCT

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

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

The file headers have been saved separately from the final ASCII data files in both directories. The header files contain time in two separate fields: "System UpLoad Time" and "NMEA UTC (Time)". The time in the "System UpLoad Time" field is taken from the PC used to 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 a few m. The error in the depth, as indicated by the offsets, are expected to occur primarily in the upcasts due to "package wake" (i.e., the "shadowing" of the sensors by the rosette and frame as the CTD is pulled up through the water column). Additionally, the upcasts include repetitive sampling of the same depth when bottles are fired to collect water samples.

In total, 90 acceptable CTD casts were conducted during HICEAS 2010 on the Sette. The data set is comprised of 83 normal station casts and 6 test casts in which all bottles are tripped at 500m. The test cast typically precedes the first regular cast of each leg of the cruise. The output format for the combined up and down casts is shown below.

```
   PrDM     C0S/m     C1S/m     T090C     T190C Sbox0Mm/Kg Sbox1Mm/Kg   DepSM Potemp090C…
  Sal00 Sigma-é00      SvCM   AvgsvCM     SvCM1 Potemp190C     Sal11 Sigma-é11      Nbin

  5.032  5.486733  5.486336   25.9355   25.9366   202.770   198.000     5.000   25.9344…
35.5946   23.5025   1537.35   1537.33   1537.35   25.9355   35.5909   23.4994        13

  6.038  5.486400  5.485675   25.9326   25.9303   202.880   198.260     6.000    5.9312…
35.5941   23.5031   1537.36   1537.33   1537.35   25.9290   35.5906   23.5012        19
```

The C1 and Sal11 data are not included in the cast 001 files The output format for the down casts only is shown below.

```
   PrDM     C1S/m     T190C Sbox0Mm/Kg    DepSM      SvCM   AvgsvCM     SvCM1 Potemp190C…
  Sal11 Sigma-é11      Nbin
  5.032  5.486336   25.9366   202.770     5.000   1537.35   1537.33   1537.35   25.9355…
35.5909   23.4994        13
  6.038  5.485675   25.9303   202.880     6.000   1537.36   1537.33   1537.35   25.9290…
35.5906   23.5012        19
```

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

- **a) PrDM = Digiquartz pressure in decibars (db)**
- b) C0S/m = Primary conductivity in Siemens per meter (S/m)
- c) T090C = Primary temperature, in degrees Celsius (ºC), calculated using the ITS-90 standard
- **d) C1S/m = Primary conductivity in Siemens per meter (S/m)**
- **e) T190C = Secondary temperature, in degrees Celsius (ºC), calculated using the ITS-90 standard**
- **f) Sbox0Mm/Kg = Oxygen, SBE 43 (µmol/Kg)**
- g) Sbox1Mm/Kg = Oxygen, SBE 43 (µmol/Kg)
- **g) DepSM = Salt water depth in meters (m)**
- h) Potemp090C = Potential Temperature (ITS-90, deg C), derived from the primary temperature and conductivity sensors
- i) Sal00 = Salinity, in practical salinity units (psu), derived from the primary temperature and conductivity sensors
- j) Sigma-é00 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the primary temperature sensor and the salinity data derived from the primary conductivity sensor
- **k) SvCM = Chen-Millero's sound velocity in meters per second (m/s) calculated from the primary temperature sensor and the salinity data derived from the primary conductivity sensor**
- **l) AvgsvCM = Chen-Millero's average sound velocity in meters per second (m/s) calculated from the primary temperature sensor and the salinity data derived from the primary conductivity sensor**
- **m) SvCM1 = Chen-Millero's sound velocity in meters per second (m/s) calculated from the secondary temperature sensor and the salinity data derived from the secondary conductivity sensor**
- **n) Potemp190C = Potential Temperature (ITS-90, deg C), derived from the secondary temperature and conductivity sensors**
- **o) Sal11 = Salinity, in practical salinity units (psu), derived from the secondary temperature and conductivity sensors**
- **p) Sigma-é11 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the secondary temperature sensor and the salinity data derived from the secondary conductivity sensor**
- **q) Nbin = number of scans included in the bin average**
- r) Flag = bad scan flag

Perl program CTDPositionCheck (programmer: Dan Prosperi) was used to confirm the CTD cast date/times and positions recorded in the header files against the edited TSG file for the survey. 74 out of 90 files had matching TSG records; no corrections were necessary.

Paul Fiedler, 16 June 2021

Appendix 1. HICEAS 2010 MACII Sea-Bird Data Processing Configuration Files

2010_HICEAS_SETTE_001.CON

```
Configuration report for SBE 911plus/917plus CTD
-------------------------------------------

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

1) Frequency 0, Temperature

   Serial number : 0975
   Calibrated on : 13-Aug-10
   G             : 4.84882841e-003
   H             : 6.82933922e-004
   I             : 2.78280402e-005
   J             : 2.27680161e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 0652
   Calibrated on : 29-Jul-10
   G             : -4.17672337e+000
   H             : 4.52215756e-001
   I             : 2.20807621e-004
   J             : 9.26686621e-006
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0281
   Calibrated on : 30-Apr-09
   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         : 0.99986000
   Offset        : -5.24040
   AD590M        : 1.157000e-002
   AD590B        : -8.476340e+000

4) Frequency 3, Temperature, 2

   Serial number : 2779
   Calibrated on : 25-Nov-09
   G             : 4.37517282e-003
   H             : 6.49254014e-004
   I             : 2.40146275e-005
   J             : 2.29194583e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Free

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

   Serial number : 715
   Calibrated on : 27-Jul-10
   Equation      : Sea-Bird
   Soc           : 4.09600e-001
   Offset        : -5.07400e-001
   A             : -1.98840e-003
   B             : 1.98670e-004
   C             : -3.79110e-006
   E             : 3.60000e-002
   Tau20         : 1.24000e+000
   D1            : 1.92634e-004
   D2            : -4.64803e-002
   H1            : -3.30000e-002
   H2            : 5.00000e+003
   H3            : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Oxygen, SBE 43, 2

   Serial number : 0593
   Calibrated on : 30-Dec-09
   Equation      : Sea-Bird
   Soc           : 3.80900e-001
   Offset        : -4.99700e-001
   A             : -7.85740e-004
   B             : 1.54310e-004
   C             : -2.59810e-006
   E             : 3.60000e-002
   Tau20         : 1.20000e+000
   D1            : 1.92634e-004
   D2            : -4.64803e-002
   H1            : -3.30000e-002
   H2            : 5.00000e+003
   H3            : 1.45000e+003

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Fluorometer, WET Labs
        ECO-AFL/FL

    Serial number : FLS-912
    Calibrated on : 1/7/2010
    Dark output   : 0.0750
    Scale factor  : 5.00000000e+000

13) A/D voltage 7, Free

Scan length                   : 41
```

2010_HICEAS_SETTE_002-064.CON

```
Configuration report for SBE 911plus/917plus CTD
-----------------------------------------------

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

1) Frequency 0, Temperature

   Serial number : 0975
   Calibrated on : 13-Aug-10
   G             : 4.84882841e-003
   H             : 6.82933922e-004
   I             : 2.78280402e-005
   J             : 2.27680161e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 0652
   Calibrated on : 29-Jul-10
   G             : -4.17672337e+000
   H             : 4.52215756e-001
   I             : 2.20807621e-004
   J             : 9.26686621e-006
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0281
   Calibrated on : 30-Apr-09
   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         : 0.99986000
   Offset        : -5.24040
   AD590M        : 1.157000e-002
   AD590B        : -8.476340e+000

4) Frequency 3, Temperature, 2

   Serial number : 2779
   Calibrated on : 25-Nov-09
   G             : 4.37517282e-003
   H             : 6.49254014e-004
   I             : 2.40146275e-005
   J             : 2.29194583e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Conductivity, 2

   Serial number : 2326
   Calibrated on : 25-Nov-09
   G             : -1.01690537e+001
   H             : 1.48385147e+000
   I             : -1.89810003e-005
   J             : 7.89981309e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

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

   Serial number : 715
   Calibrated on : 27-Jul-10
   Equation      : Sea-Bird
   Soc           : 4.09600e-001
   Offset        : -5.07400e-001
   A             : -1.98840e-003
   B             : 1.98670e-004
   C             : -3.79110e-006
   E             : 3.60000e-002
   Tau20         : 1.24000e+000
   D1            : 1.92634e-004
   D2            : -4.64803e-002
   H1            : -3.30000e-002
   H2            : 5.00000e+003
   H3            : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Oxygen, SBE 43, 2

   Serial number : 0593
   Calibrated on : 30-Dec-09
   Equation      : Sea-Bird
   Soc           : 3.80900e-001
   Offset        : -4.99700e-001
   A             : -7.85740e-004
   B             : 1.54310e-004
   C             : -2.59810e-006
   E             : 3.60000e-002
   Tau20         : 1.20000e+000
   D1            : 1.92634e-004
   D2            : -4.64803e-002
   H1            : -3.30000e-002
   H2            : 5.00000e+003
   H3            : 1.45000e+003

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Fluorometer, WET Labs ECO-
        AFL/FL

    Serial number : FLS-912
    Calibrated on : 1/7/2010
    Dark output   : 0.0750
    Scale factor  : 5.00000000e+000

13) A/D voltage 7, Free

Scan length                   : 41
```

HICEAS_SETTE_065-090.CON

```
Configuration report for SBE 911plus/917plus CTD
------------------------------------------------

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

1) Frequency 0, Temperature

   Serial number : 0975
   Calibrated on : 13-Aug-10
   G             : 4.84882841e-003
   H             : 6.82933922e-004
   I             : 2.78280402e-005
   J             : 2.27680161e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 0652
   Calibrated on : 29-Jul-10
   G             : -4.17672337e+000
   H             : 4.52215756e-001
   I             : 2.20807621e-004
   J             : 9.26686621e-006
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0281
   Calibrated on : 30apr09
   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         : 0.99986000
   Offset        : -5.24040
   AD590M        : 1.157000e-002
   AD590B        : -8.476340e+000

4) Frequency 3, Temperature, 2

   Serial number : 2779
   Calibrated on : 25-Nov-09
   G             : 4.37517282e-003
   H             : 6.49254014e-004
   I             : 2.40146275e-005
   J             : 2.29194583e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Conductivity, 2

   Serial number : 2326
   Calibrated on : 25-Nov-09
   G             : -1.01690537e+001
   H             : 1.48385147e+000
   I             : 1.89810003e-005
   J             : 7.89981309e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

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

   Serial number : 715
   Calibrated on : 27-Jul-10
   Equation      : Sea-Bird
   Soc           : 4.09600e-001
   Offset        : -5.07400e-001
   A             : -1.98840e-003
   B             : 1.98670e-004
   C             : -3.79110e-006
   E             : 3.60000e-002
   Tau20         : 1.06000e+000
   D1            : 1.92630e-004
   D2            : -4.64800e-002
   H1            : -3.30000e-002
   H2            : 5.00000e+003
   H3            : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Oxygen, SBE 43, 2

   Serial number : 0593
   Calibrated on : 30Dec09
   Equation      : Sea-Bird
   Soc           : 3.80900e-001
   Offset        : -4.99700e-001
   A             : -7.85740e-004
   B             : 1.54310e-004
   C             : -2.59810e-006
   E             : 3.60000e-002
   Tau20         : 1.19000e+000
   D1            : 1.92630e-004
   D2            : -4.64800e-002
   H1            : -3.30000e-002
   H2            : 5.00000e+003
   H3            : 1.45000e+003

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Fluorometer, WET Labs ECO-
        AFL/FL

    Serial number : FLS-1366
    Calibrated on : 8/16/2010
    Dark output   : 0.0790
    Scale factor  : 5.00000000e+000

13) A/D voltage 7, Free

Scan length                   : 41
```

Appendix 2. Bottle Salinity Analyses

Bottle salinity samples were analyzed to validate CTD sensor calibration and to detect evidence of Niskin bottle leakage. Samples were collected from bottles tripped at depth and analyzed with a Guildline Portasal 8410A salinometer using standard methods (Guildline Technical Manual TM 8410A-F-00). The salinity data from the Portasal and CTD can be found in \\Stenella\Ecology\PacificIslands\2010_HICEAS\Oceanographic\Salinometer. The results summarized below can also be found in HICEAS 2010 Salts.xls.

Portasal data were collected during salts runs at sea by the program PSAL9709 (Oceanographic Data Facility, Scripps Institution of Oceanography). The raw data files, which are the files without a filename extension in each of the leg subfolders in \\Stenella\Ecology\PacificIslands \2010_HICEAS\Oceanographic\Salinometer\Raw\SETTE, were copied with a text editor into a single file named *salts10S.raw*.

Fortran program CR2SAL.EXE (programmer: Fiedler) calculated salinities from the recorded conductivity ratios and bath temperatures in *salts10M.raw* using the Sea-Bird salinity algorithm. The two output files, \\Stenella\Ecology\WestCoast\2010_HICEAS\Oceanographic\Salinometer \Intermediate*salts10S.sal* and *salts10S.sta*, are identical except that the sample records in the *.sta* file are truncated. Output file *salts10S.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 *salts10S.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 *salts08S.sal*. Two files are output for each pair of temperature/conductivity sensors (1 = primary, 2 = secondary): *salts10S1.dat* and *salts10S2.dat* contain the CTD salinity and depth for each bottle sample and the differences between each of the four alternative bottle salinity values and the CTD salinity; *salts10S1.sum* and *salts10S2.sum* contain means and standard deviations of the differences within each salts run.

Conductivity Ratio Adjustment for Bottle Salinities

When analyzing samples on the Portasal, the initial salinity standard reading should be equal to 2x the actual conductivity ratio of the standard (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 Portasal was not sufficiently warmed up with standard water before samples are read) or the sensitivity of the Portasal may drift during the run. If the initial and final standard readings differ, then adjusting the reference for sample conductivity ratios will change both the mean and the standard deviation of Bottle - CTD salinity differences. Selection of an adjustment alternative should be based on minimizing the mean and standard deviation.

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

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

Salinities calculated from sample conductivity ratios adjusted by method (1) resulted in bottle–CTD differences overall with the smallest means (biases) and standard deviations (RMSE):

	Mean (Bottle – CTD)		St. dev. (Bottle – CTD)	
Adjustment	primary	secondary	primary	secondary
None:	-0.007588	-0.001405	0.013690	0.014271
(1):	**-0.004875**	0.001307	**0.012587**	**0.013161**
(2):	-0.006232	-0.000049	0.013077	0.013657
(3):	-0.006209	**-0.000027**	0.013046	0.013628

Therefore, *bottle salinities calculated from sample conductivity ratios adjusted by method (1) were used in subsequent analyses.*

Precision of Replicates

Three replicate samples collected from 7 deep bottles on selected CTD casts allow an assessment of the precision of our bottle salinity sampling and analysis methods (see SETTE Replicates worksheet in HICEAS 2010 Salts.xls). An ANOVA gives a "mean squares within" of 1.637e-05, which is equivalent to the variance of replicate salinity values within bottles. The square root of this value gives *a precision of ±0.0040 psu, which is comparable to the accuracy of ±0.003 specified by Guildline, or the ±0.001 precision that can be achieved under ideal laboratory conditions* (Sea-Bird, personal communication).

The standard deviation of Bottle - CTD salinity differences for all samples was 0.0126 (above table, Adjustment 1). A larger error is expected because of the additional errors of the CTD sensors and the mismatch of waters pumped through CTD sensors and sampled by Niskin bottles.

Bottle – CTD Salinity Differences

Figure 4 shows Bottle – CTD salinity differences for all samples. CTD values are from primary (S1) and secondary (S2) sensors. For this cruise, the post-cruise calibration indicated that no calibration adjustments were required for any temperature or conductivity sensor (\\Stenella\Ecology\WestCoast\2009_DELPHINUS\Oceanographic\CTD\Data\MACII\Documents\ CTDcalibrations_HICEAS_2010_SETTE.xlsx). The drift indicated by the trend line for the secondary sensors is negligible.

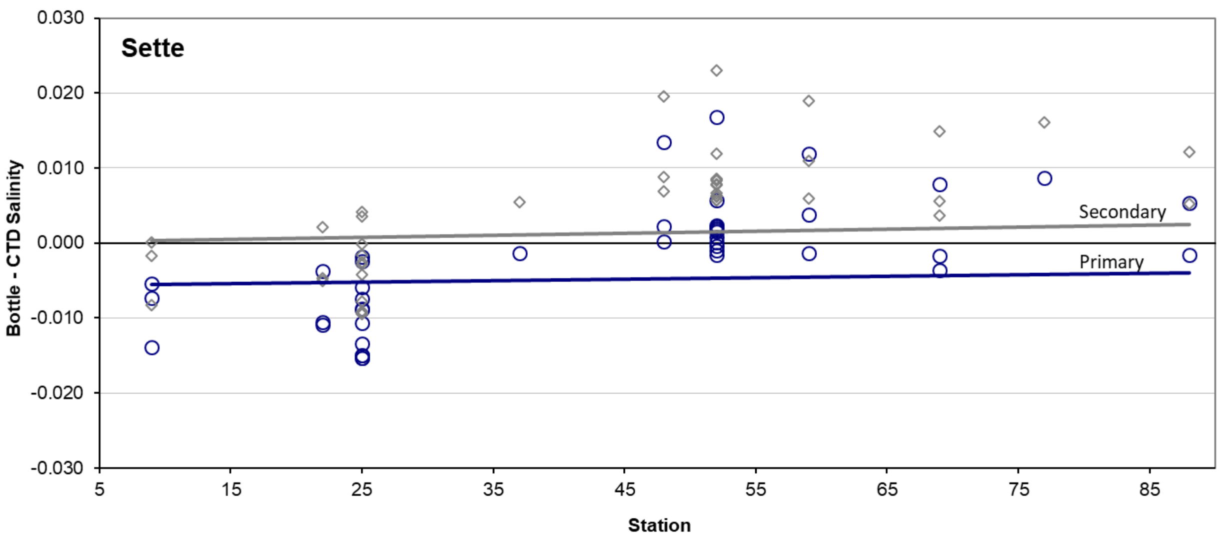


Figure 4. Bottle – CTD salinity differences for 2010 HICEAS, Sette.

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

Test Cast Bottle vs. CTD Salinities

The following table summarizes bottle salinities and corresponding CTD salinities (mean ±sd) from the test casts, when all 12 bottles were tripped sequentially at 700m. Although values are listed to four decimal places, the precision of the salinometer is ±0.003 and the precision of the CTD sensors is ±0.0004 psu.

	CTD S1	CTD S2	Bottle
Leg 2	34.0801 ±0.0002	34.0742 ±0.0003	34.0701 ±0.0049
Leg 3	34.4337 ±0.0002	34.4275 ±0.0003	34.4379 ±0.0058

The salinity of the bottle samples collected at the same depth (column labeled "Bottle" above) vary by just slightly more than the precision of replicates (i.e., ±0.0040 psu) and the precision of the salinometer; consequently, the measured bottle salinity values are identical.

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

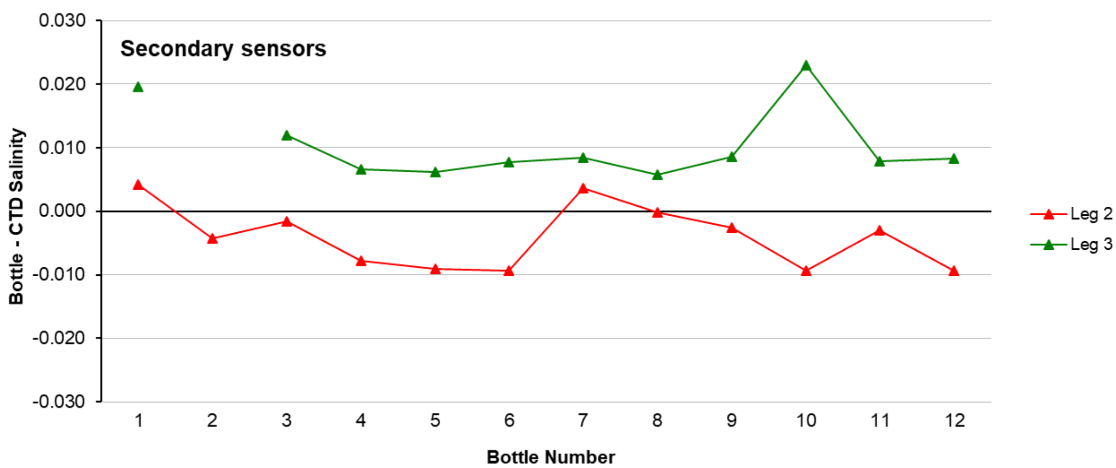


Figure 5. Bottle - CTD salinity differences, derived from secondary sensor data, for test casts on HICEAS 2010, Sette, Legs 2 and 3. The plot using primary sensor data is essentially the same. The PortaSal salinity for bottle 2 on Leg 3 was not valid.

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