Optimizing Data Quality with the SBE 911 System: Best Practices for Setup, Collection, and Data Processing

Marialena Christopoulou
Customer Support Scientist-Oceanographer

SEA-BIRD SCIENTIFIC

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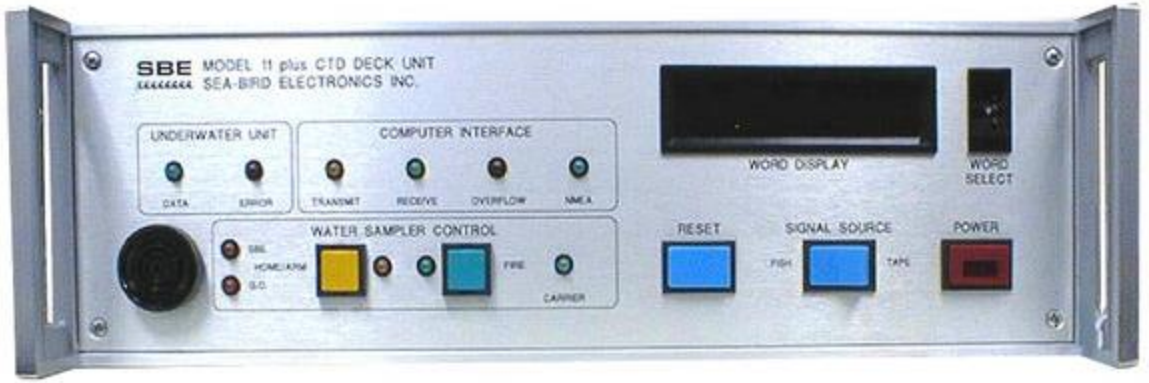
We will cover the following:

- Overview of the SBE911*plus* system and its components
- When Profiling (tips, configurations, sampling and more…)
- Post deployment (data processing, caring for your sensors)

SBE 911*plus* V2 profiling system

SBE 9*plus*



SBE 11*plus* Deck Unit

Components of the SBE 9*plus* profiling system

- Modular sensors that can be separately calibrated
- A thermistor-based temperature sensor (optional secondary)
- A conductivity sensor with an internal field that is immune to proximity effects (optional secondary)
- A pump that controls the flow, matching T and C response times
- A TC Duct to ensure that the temperature and conductivity sensors measure the same water parcel
- A high accuracy and stable quartz pressure sensor inside the housing

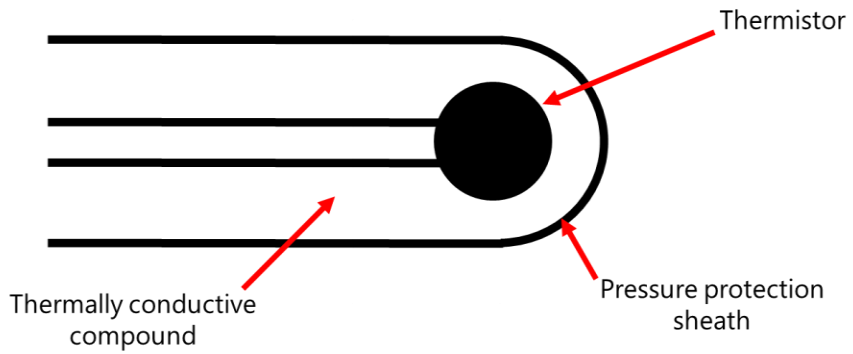
Modular Sensors: Conductivity, Temperature, and Depth (CTD)

- Depth is derived from a pressure sensor
  - Pressure sensor is typically internal to the main pressure housing of the CTD
- Conductivity and temperature sensors may be mounted internally or externally

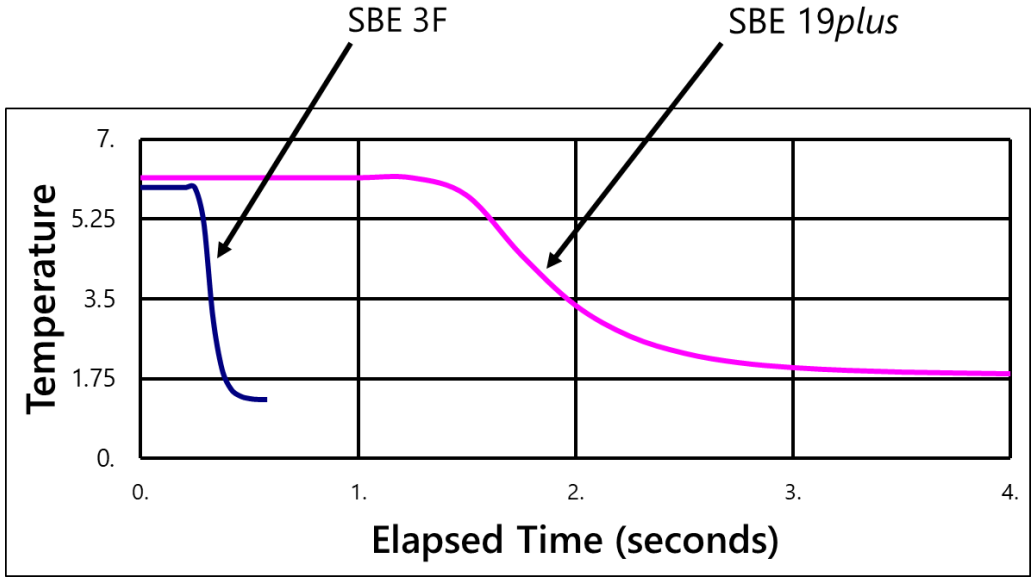
SBE 4 Conductivity sensor

SBE 3 Temperature sensor

SBE 3 Temperature Sensor



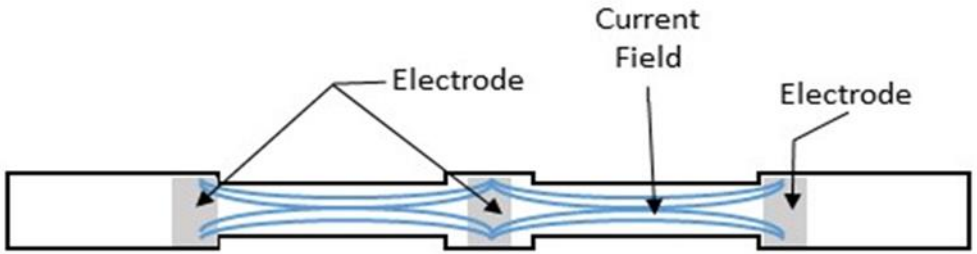
- Active element is a thermistor, a semiconductor that changes resistance when its temperature changes
- Conditioning circuit is an oscillator that changes frequency depending on resistance of thermistor
- Signal is a frequency that is measured with a frequency counter



Time response = 70 milliseconds

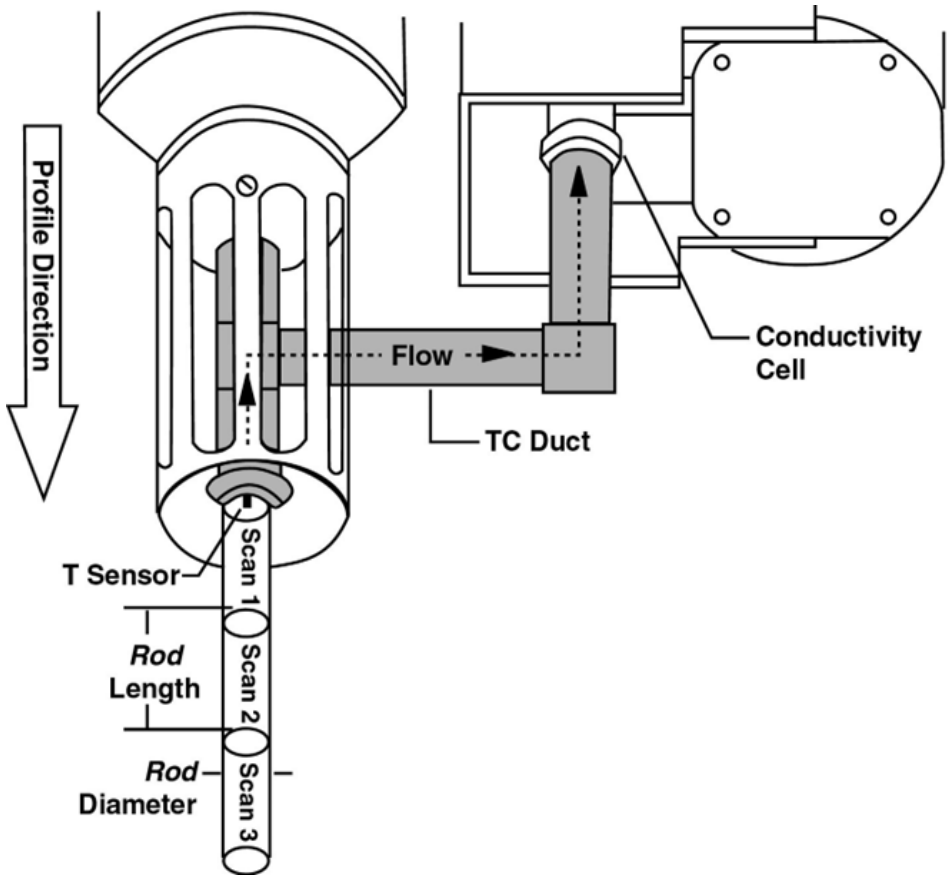
Conductivity Sensors: The borosilicate glass cell

- Internal electric field immune to proximity errors
- Length/Area = constant
- Measure conductivity directly between wet electrodes
- Need to keep **volume of cell constant**

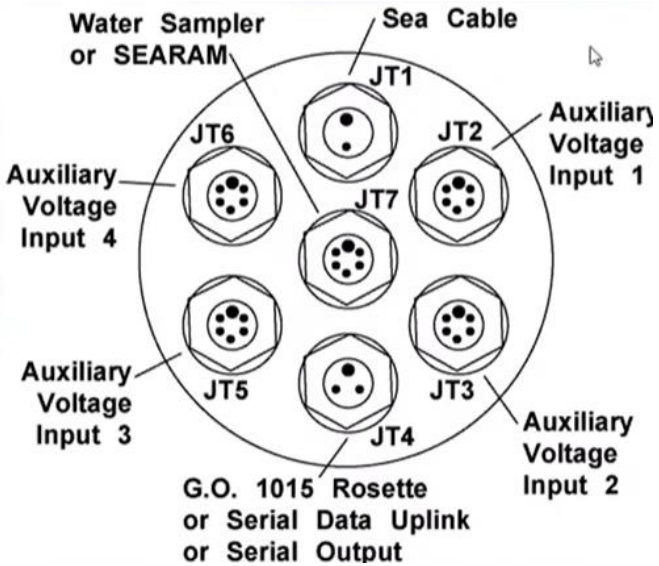


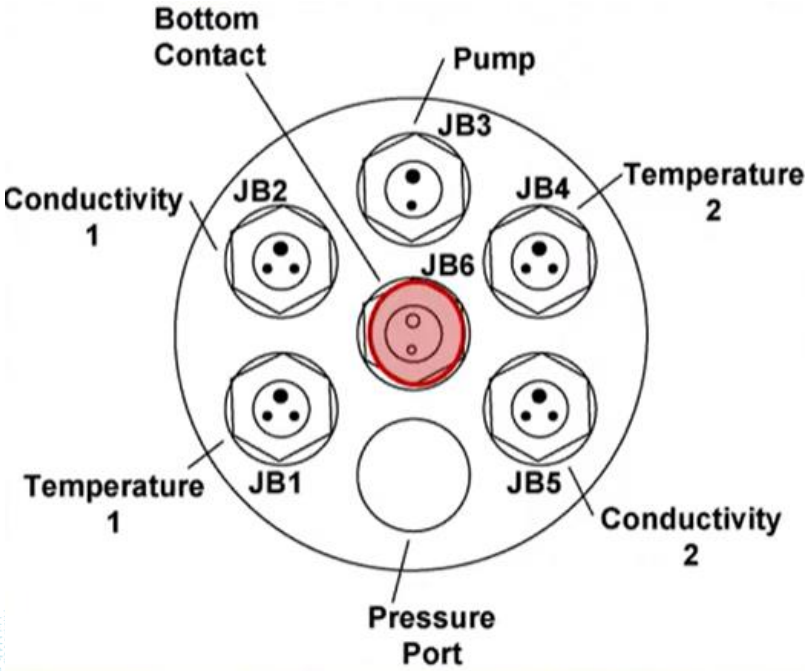
Coupling T and C: The TC duct

- Water is pumped past active element of temperature sensor and into conductivity cell at a fixed, constant rate
- Plumbing setup greatly lessens effects of ship heave
- Filtering and other data manipulation is much more successful because flow rate is constant



SBE 9*plus* End Caps

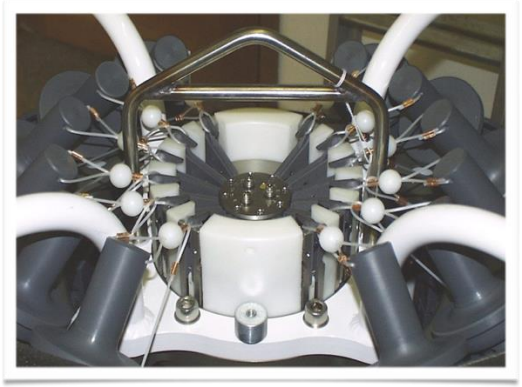




Water Samplers

SBE 11*plus* Unit

SBE 32 Carousel Water Sampler



Water sampling system

SBE 11plus V2 Deck Unit

- The SBE 11*plus* V2 Deck Unit provides power and telemetry to the SBE 9*plus* V2 CTD.
- Connects directly to a shipboard computer where real-time data is archived using Seasave software. In the process of updating Fathom to data collection and post processing.
- GPS can be connected to the deck box for integration into the CTD data stream.
- The SBE11*plus* can be modified to communicate with both “Uplink” and “Non-Uplink” SBE 9*plus.*

Do you know if you have an Uplink or Non-uplink CTD?

SBE 11plus Uplink vs Non-Uplink

How can you tell?

JT4 (3pin vs 4pin)

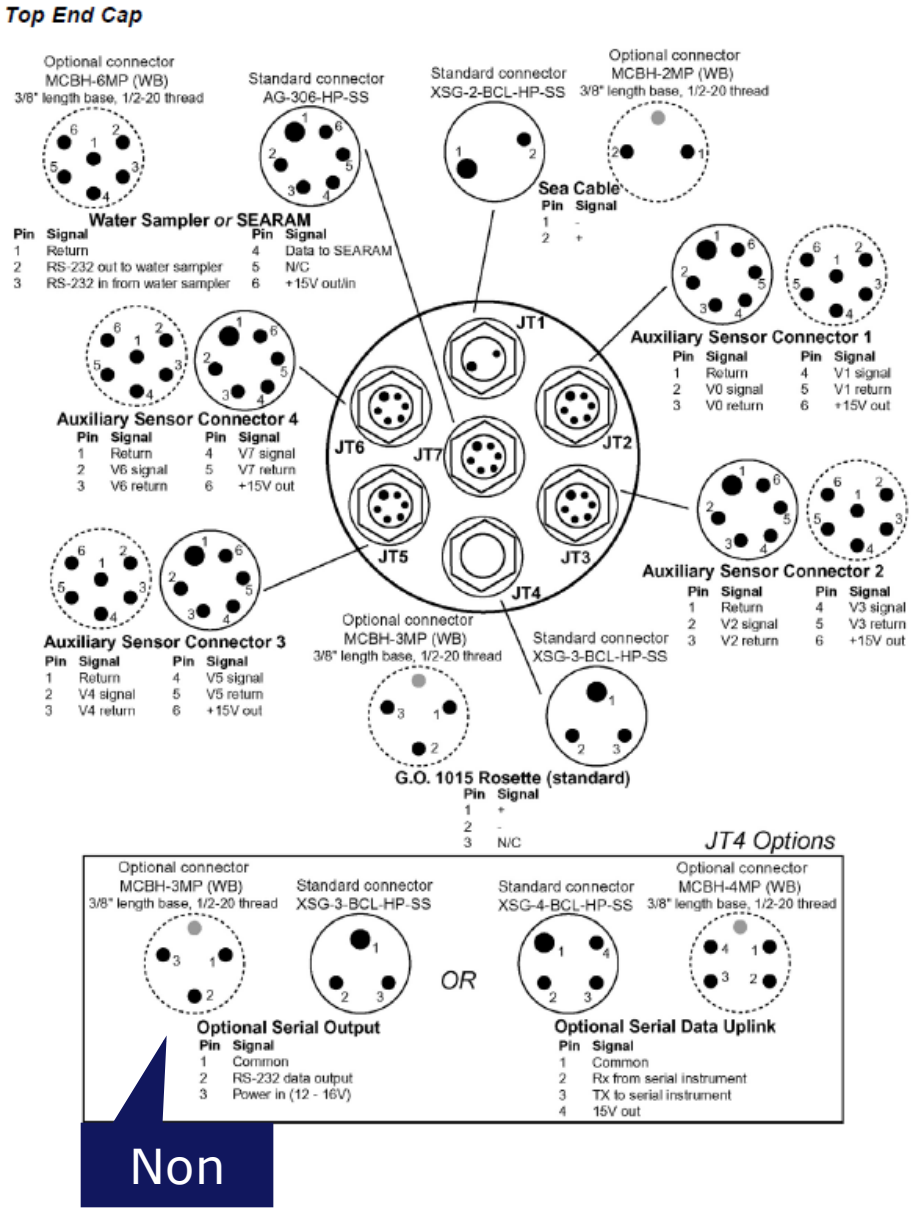
Deck Unit Jumper Positions

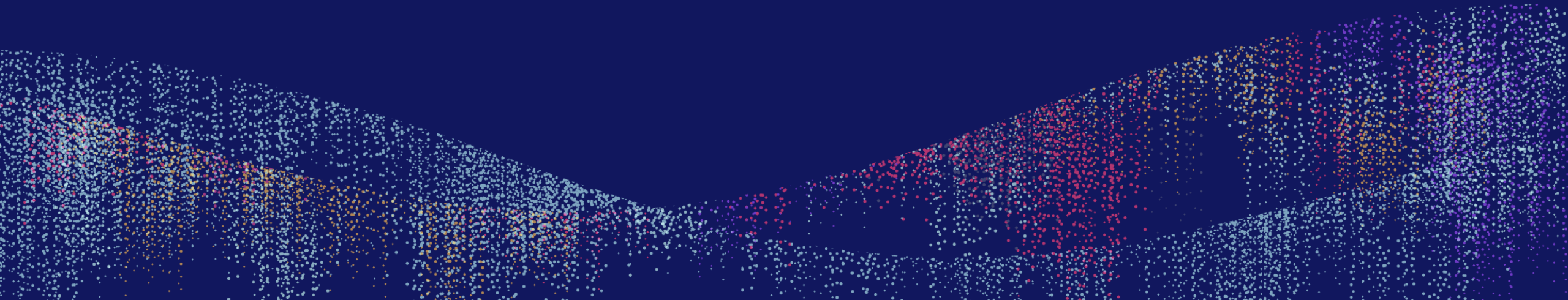
Communication: error code “0.0.0.0.0.0.0.0”

Non

8640 BPS UPLINK	
J1	SHORT 1–2 (L)
J2	SHORT 1–2 (L)
J3	SHORT 3–2 (L)
J4	SHORT 3–2 (L)
J5	OPEN
J6	SHORT 1–2 (L)

17280 BPS UPLINK	
J1	SHORT 3–2 (H)
J2	SHORT 3–2 (H)
J3	SHORT 1–2 (H)
J4	SHORT 1–2 (H)
J5	SHORT
J6	SHORT 3–2 (H)

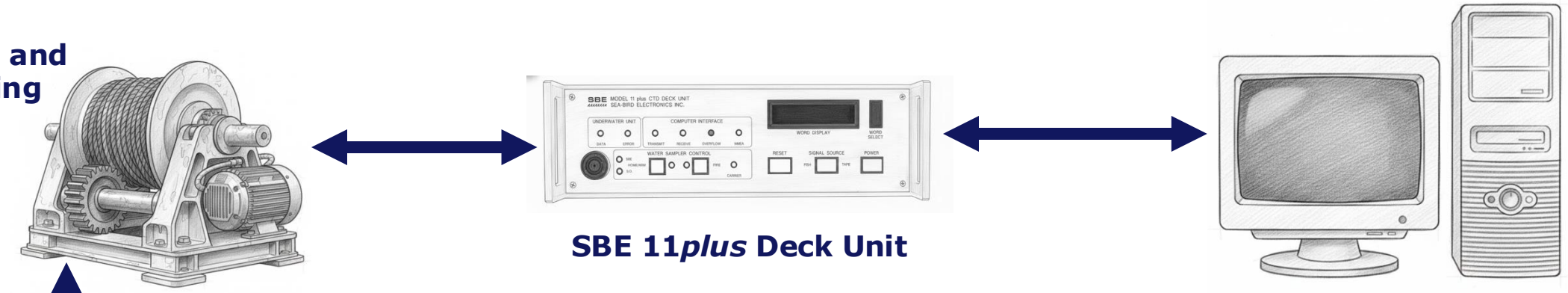




When profiling

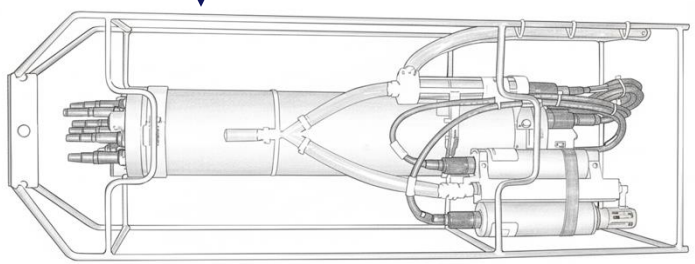
Configuration, orientation, sampling, and more…

System Diagram for Real-Time Profiling



Single
Conductor
Sea Cable

T
P
C



SBE 9*plus* (No Memory)

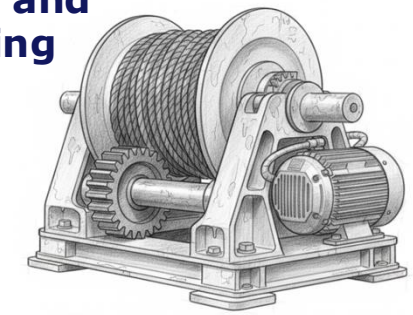
***Real-Time* means:**

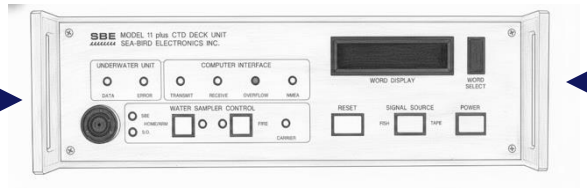
The data is viewed…

as it is collected

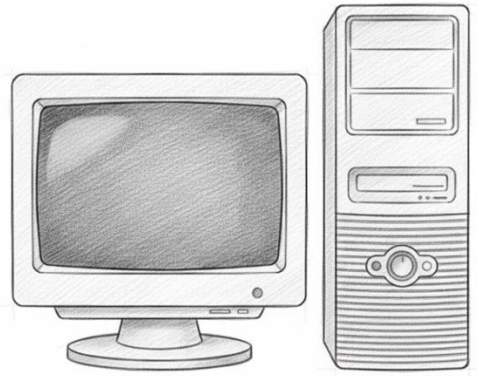
System Diagram for Real-Time Profiling & Real-Time Water Sampling

Winch and Slip Ring





SBE 11*plus* Deck Unit

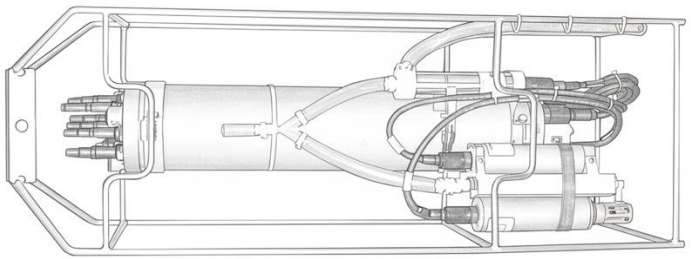


Single Conductor Sea Cable

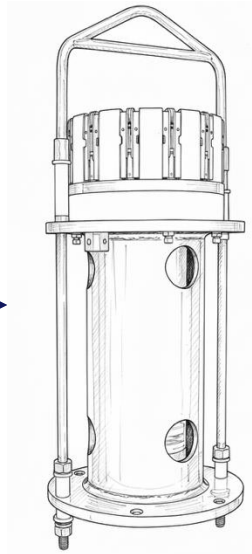
T

P

C

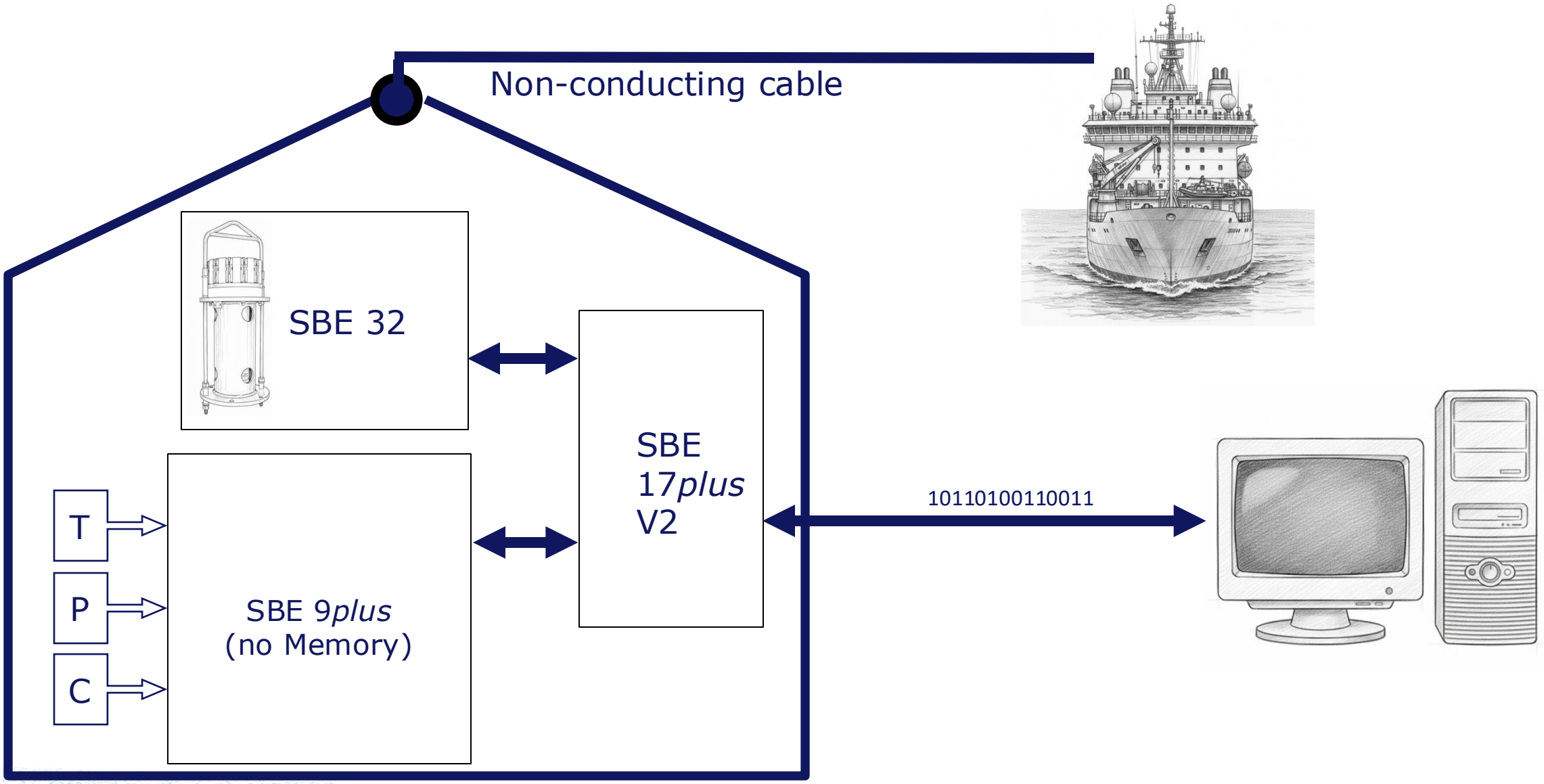


SBE 9*plus* (No Memory)



SBE 32 Carousel with serial data integration option

Recording internally with Real-Time Instruments



SBE 17plus V2 Searam Recorder & Auto Fire Module

- SBE 17*plus* V2 provides memory and power for SBE 9*plus*, has 16 Mb of nonvolatile memory, supports conductivity advance and suppression of channels

- Also features Carousel auto-fire capability to close water samplers.

- Closes Carousel water sampler on pressure, upcast only

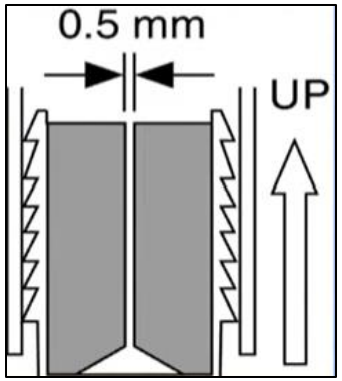
Plumbing for successful CTD measurements

- The pump is magnetically coupled impeller type
  - Not self priming
  - Trapped air will cause non-steady flow
- Be sure to arrange the tubing on the CTD package to allow all air to escape from plumbing

Plumbing for successful Air Removal in Vertical Orientation

Y Fitting Detail

Air release valve

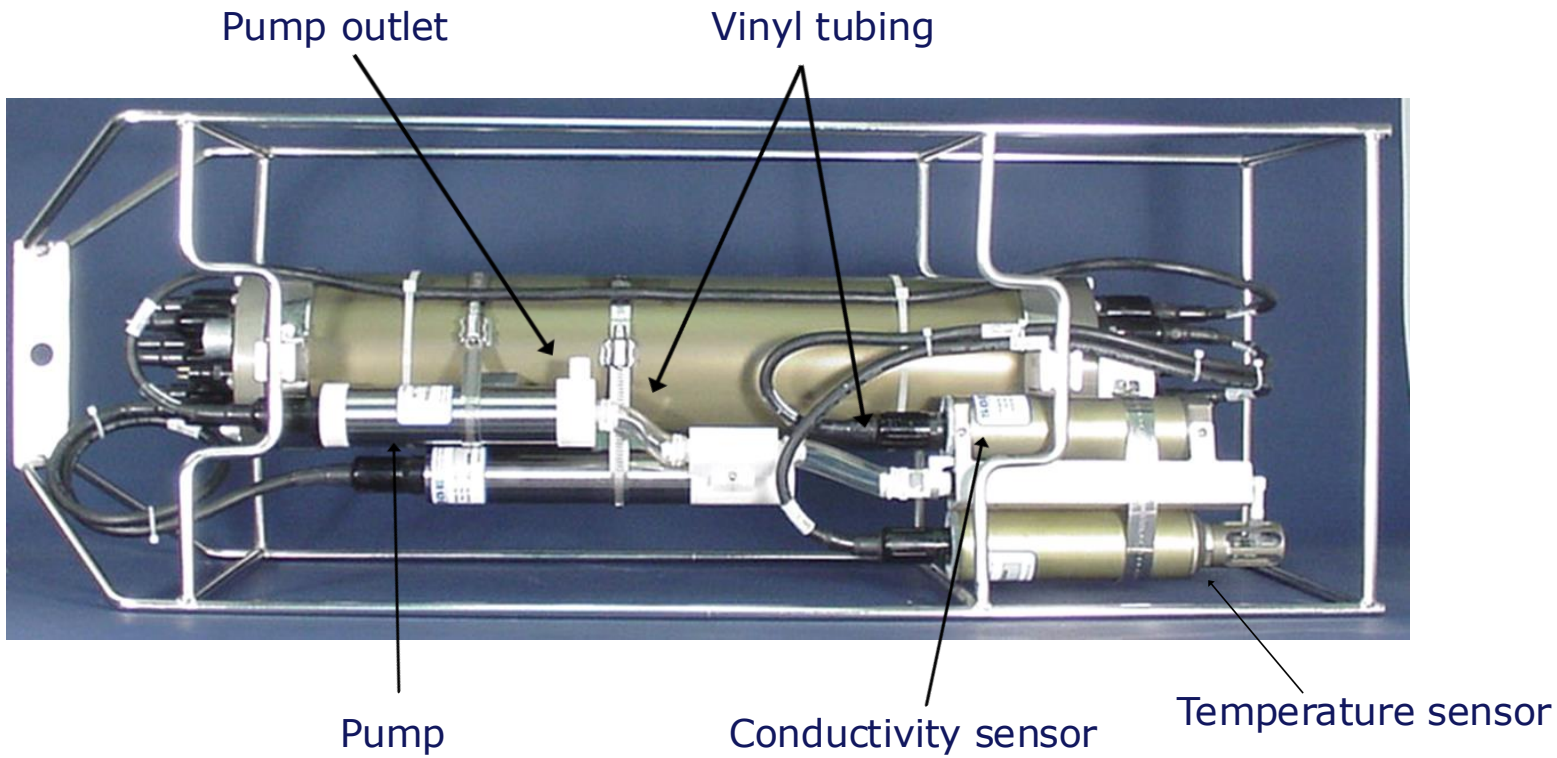


Vinyl tubing

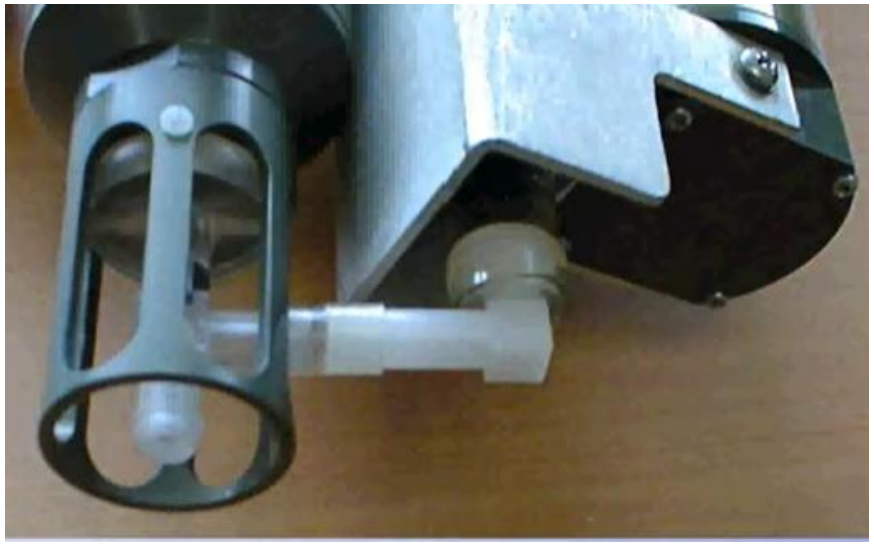
- When deployed without a rosette, mounted vertically because the naturally downward flow keeps bubbles outside of the system and ensures proper flushing.

Plumbing for horizontal deployment

- When deployed with a rosette must be horizontal because the sensor plumbing and pump are integrated within the frame, and the hydrodynamics of the rosette create a cleaner flow horizontally.



Connecting the TC Duct



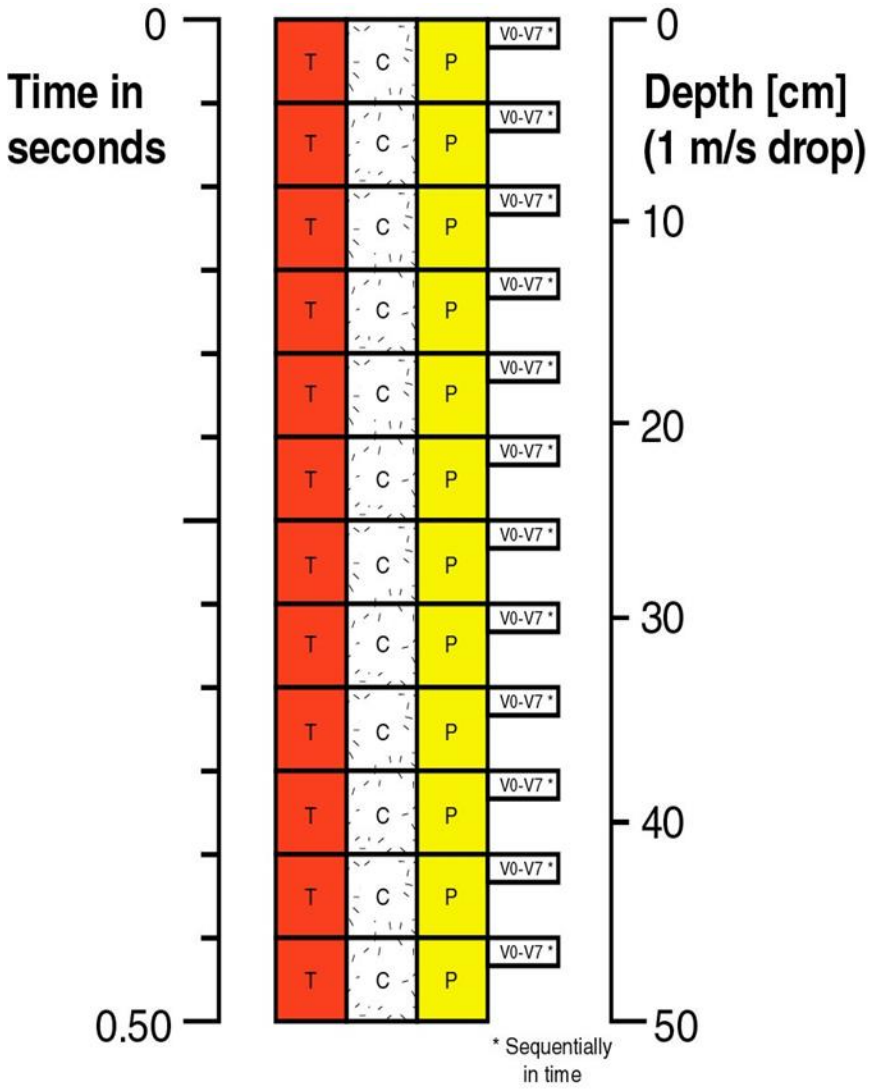
Soak the Instrument

Soaking means putting the instrument package over the side and into water at a shallow depth ~10 m for ~ 5 min

- The package comes to water temperature
- The conductivity cell wets with seawater
- Quick check of instrument operation
- Flush out any bubbles in the system before start profiling

SBE 9*plus* sampling

- SBE 9*plus* measures C, T, and P simultaneously
- It samples as fast as 24 Hz
- For a profiling rate of 1m/s a **sample** is taken every 4.2 cm.
- Always recommend to sample at maximum rate
- Average data during post processing



Matching C and T measurements

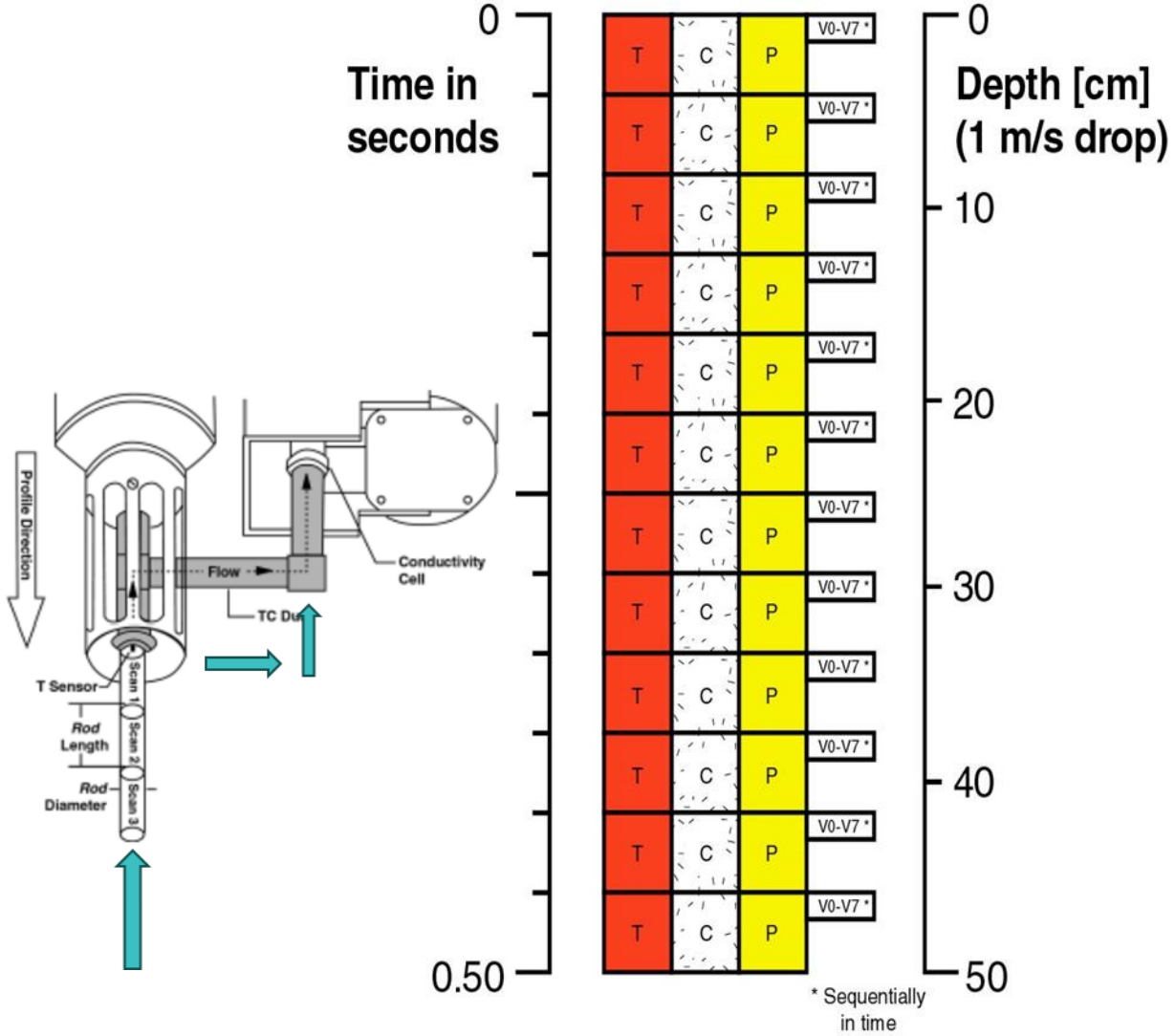
SBE 9plus measures C,T and P simultaneously

A water parcel first encounters the thermistor and then transits into the conductivity cell (different parcel of water)

The water that the T sample is taken at time 0 is the same water that the C sample is taken at time 2.

Because of the pump (constant flow rate)
C and T measurements can be adjusted relative to time or P to match a T and C measurement from the same parcel of water.

This *alignment* is done in SBE 11*plus* and may be fine tuned in data processing



Schematic of Real-Time Data Manipulation

Calculations of flow rates, plumbing distances and sample rates yielded an adjustment of 1.75 data scans (=0.073 sec since 24 Hz)
The conductivity measurement needs to be advanced relative to temperature and pressure measurements.

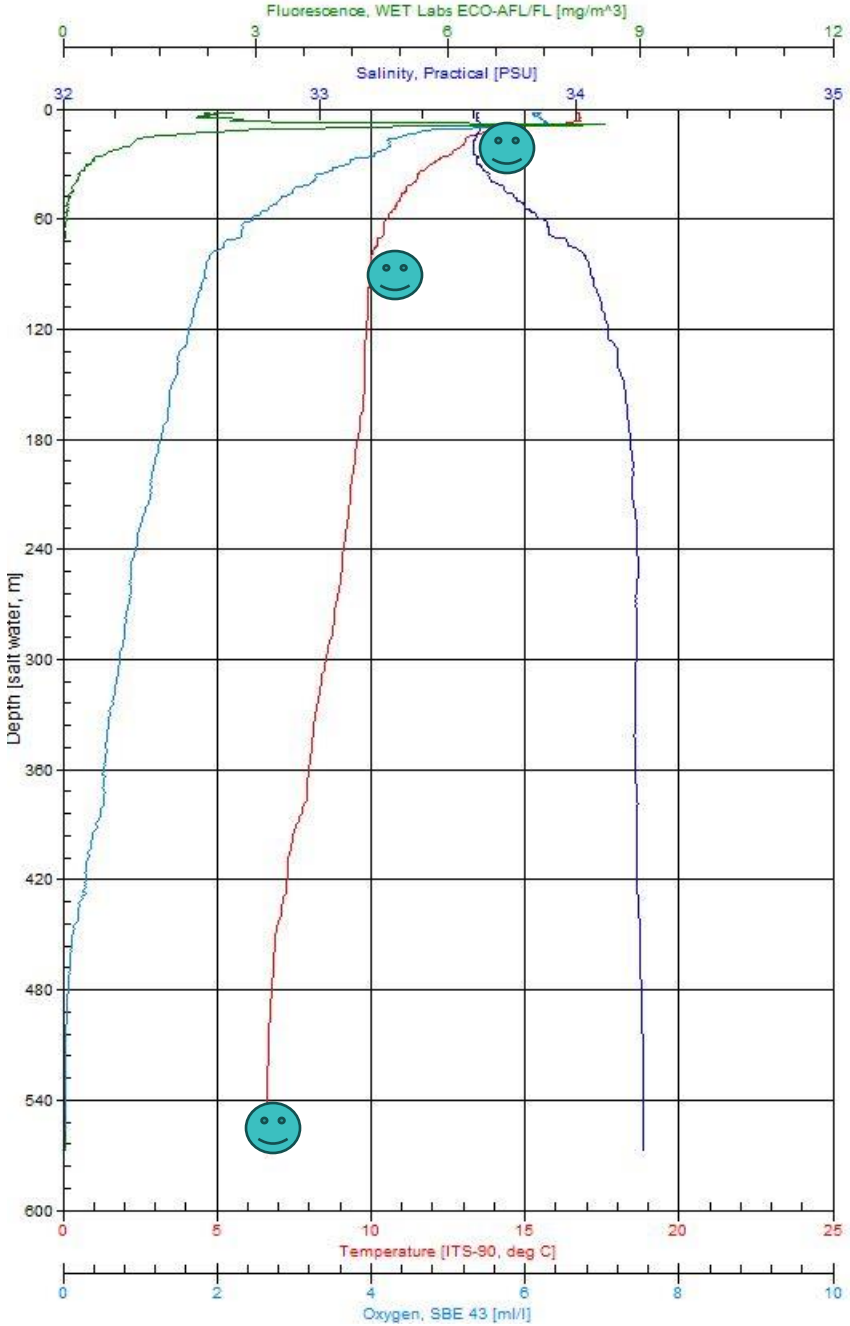
Scan	Pressure	Temperature	Conductivity
0	P0	T0	$C_{1.75}$
1	P1	T1	$C_{2.75}$
2	P2	T2	$C_{3.75}$
3	P3	T3	$C_{4.75}$

Interpolate between C_1 and C_2
Set $C_{1.75}$ as C_0, then C_1 is the interpolated value between C_2 and C_3 …

The 1.75-scan advancement is a nominal value; changes in flow rate caused by plumbing changes will necessitate changes in advancement. Similarly, you should consider any advancement that the 11plus makes to your other sensors a nominal value and make your final decision based on observing the data.

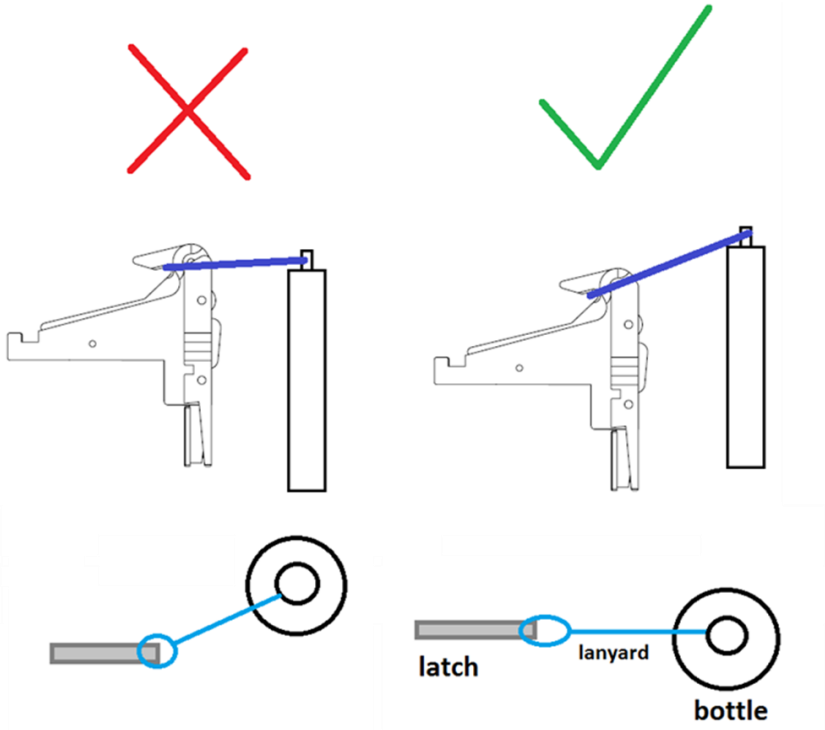
Bottle Closure Events

- Best practice is to stop the package for **5 minutes** prior to bottle closure to reduce spatial and timing uncertainties
- If time restrictions it is better to take less water samples

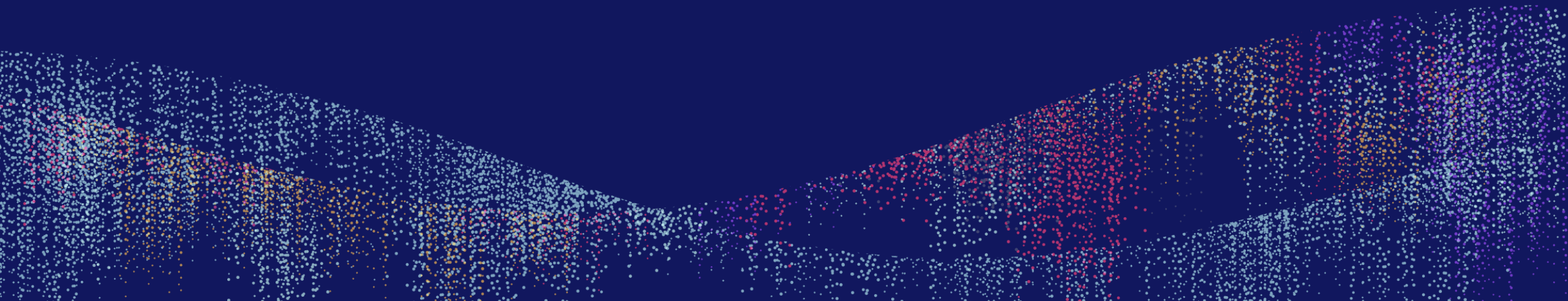


Water Sample Lanyards

- Lanyard must run straight from the trigger assembly to the water sampler

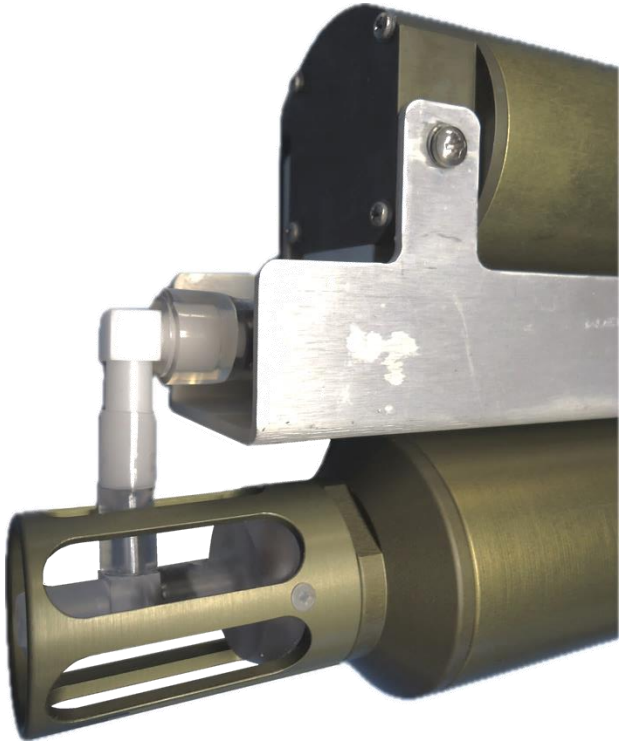


Data Processing



Data Processing Recommendations:
SBE 911plus

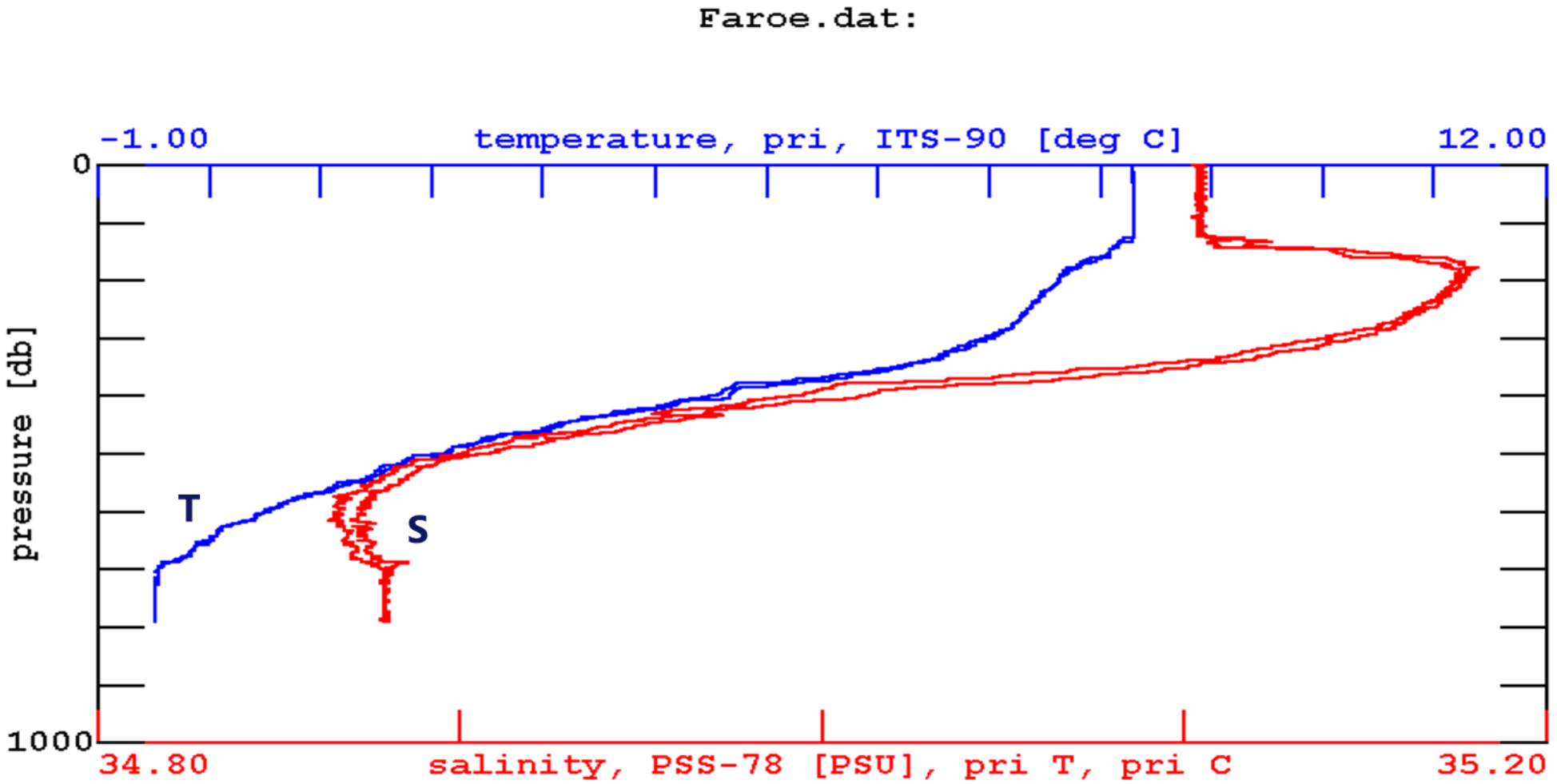
1) **Data Conversion:**
   - Output up and down casts of all parameters
   - Only process on independent parameters (T, C, P, OXVOLTS, Modulo Errors etc.)
   - Output converted variables (salinity, DO conversion) if comparing to water samples
2) **Filter *(optional):* pressure +0.15s**
3) **Align CTD**
   - Temperature ***(none)***
   - Conductivity ***(none)*advanced by SBE11plus +0.073s***
   - Oxygen volts **2-3** seconds
4) **Cell Thermal Mass**: Alpha = **0.03** and Tau = **7s**
5) **Loop Edit** *(optional):* select minimum fall speed by CTD descent rate
6) **Derive**: dependent variables (salinity, dissolved oxygen, density, etc.)
7) **Bin Average**: into depth, time, or pressure bins



Cell Thermal Mass

- Glass conductivity cells store heat
- A warm cell warms water moving through it
  - Will read warm of correct (higher conductivity)
- A cold cell cools water moving through it
  - Will read cold of correct (lower conductivity)
- Water in cell is a different temperature than the thermometer measured a moment earlier
- When salinity is computed, it will be in error
- Applied in saltwater applications only (do not apply in freshwater profiling)

Example

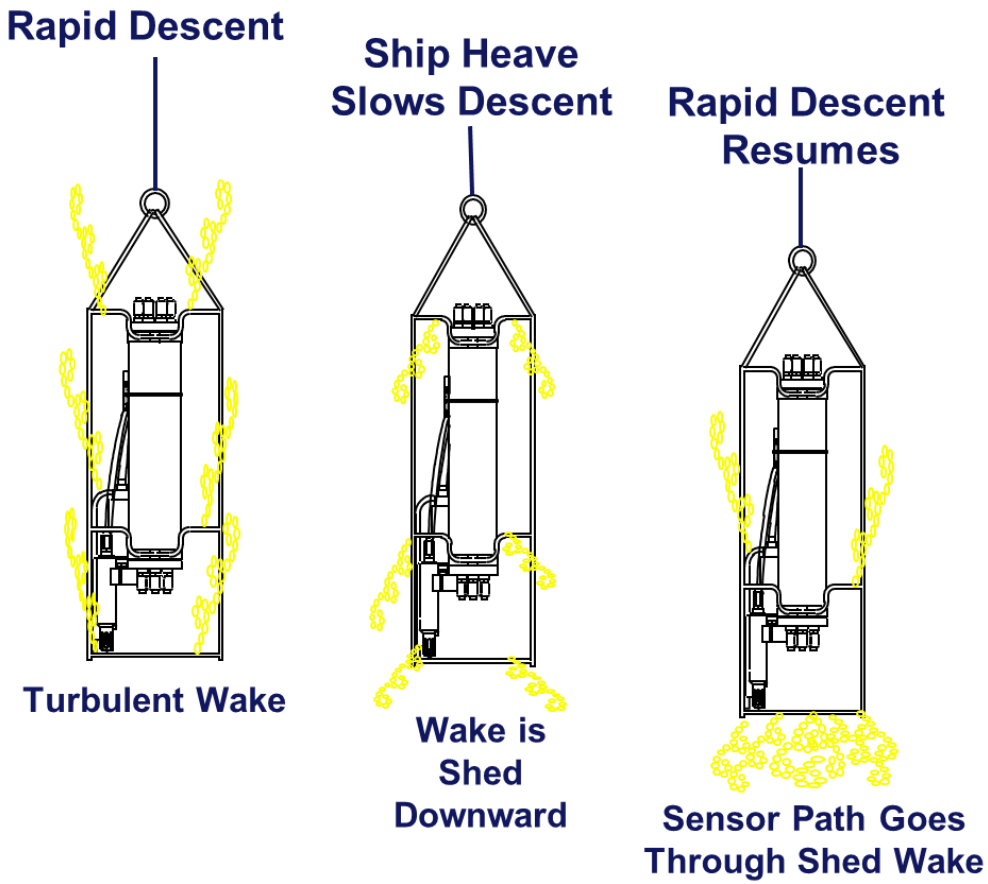


Loop Edit

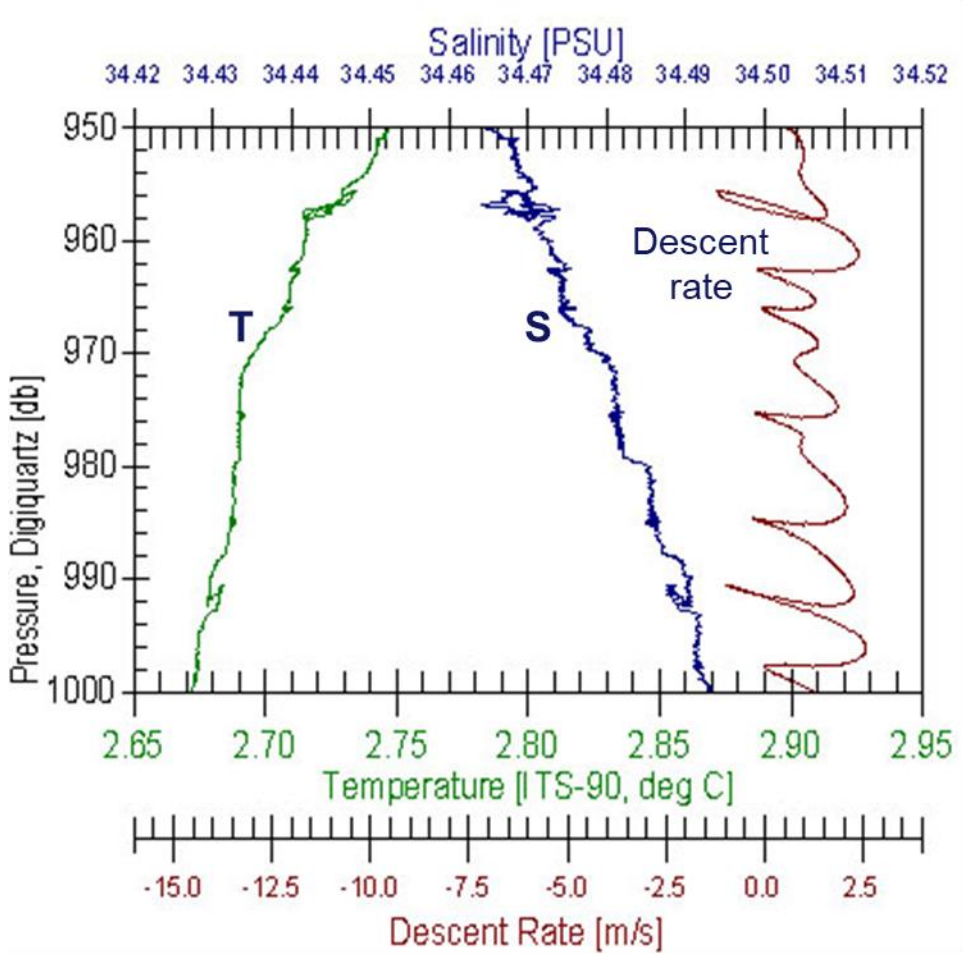
- Data errors caused by CTD profiling reversals are flagged by scan line
- We can choose to omit these “flagged” data from averaging and plots

Data Artifacts Caused by the Underwater Package

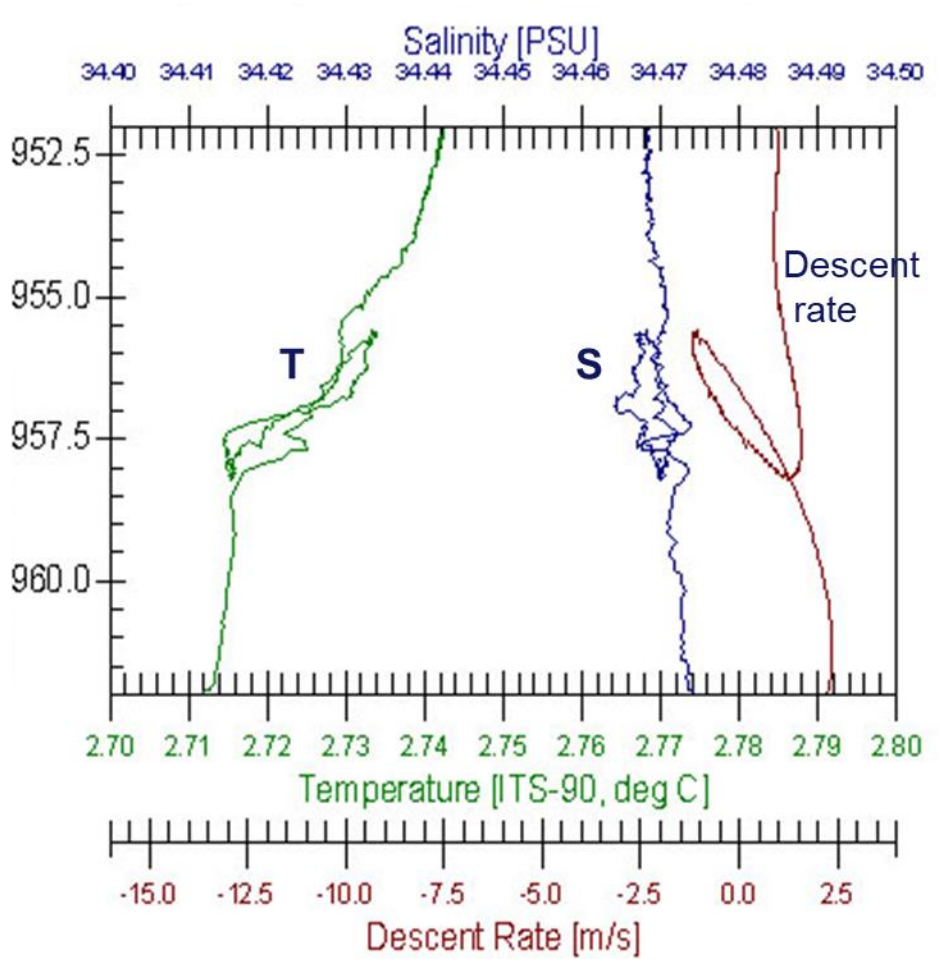
- Ship heave causes underwater package to *loop* through water
- Accelerations and decelerations caused by ship heave cause water entrained within package to blow by sensors



Ship Heave Effects



(Enlargement of plot at left)

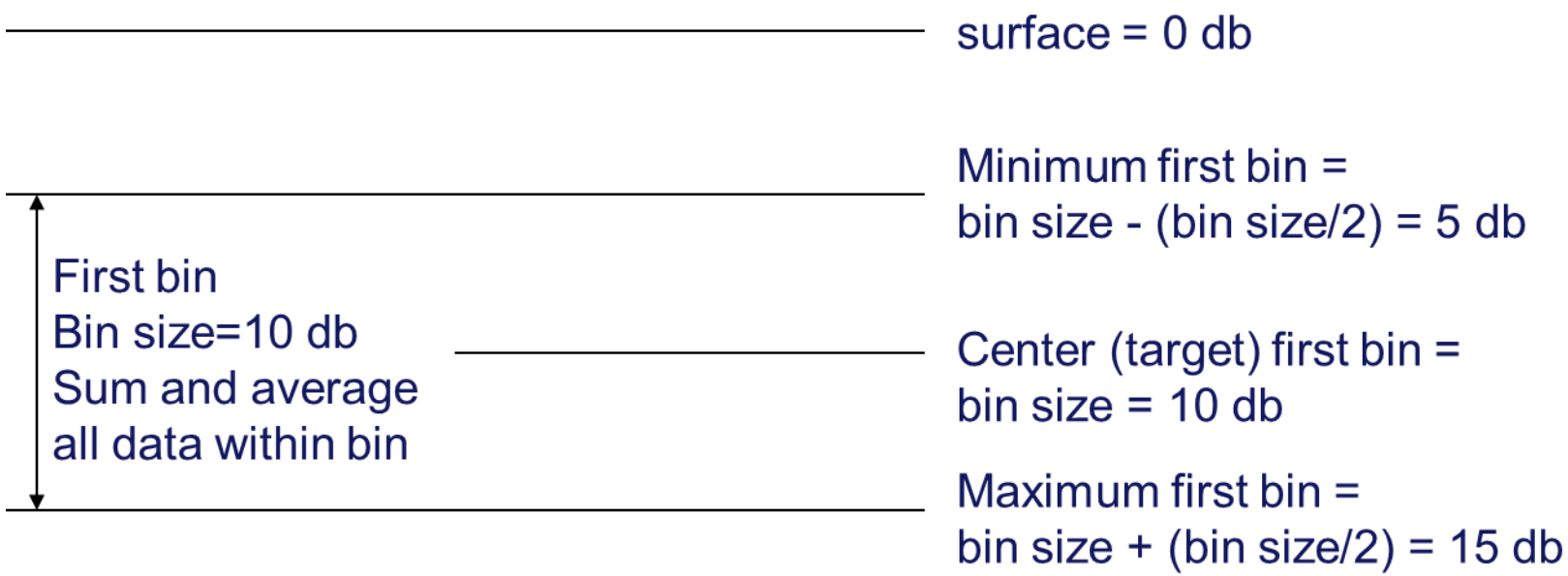


Bin Average

- Reduces size of a data set by statistically estimating data values at even intervals *(e.g., every meter, every 10 meters, etc.)*
- Can work in depth (meters), pressure (decibars), time, or by scan
- Can bin average upcast, downcast, or both
- If bin averaging upcast and downcast, keeps upcast bins and downcast bins separate
- Surface bin is treated separately
- Two methods: Interpolated and not interpolated

Bin Average Protocol: Pressure, Not Interpolated

Data within a bin is averaged by summing and dividing by number of points within bin

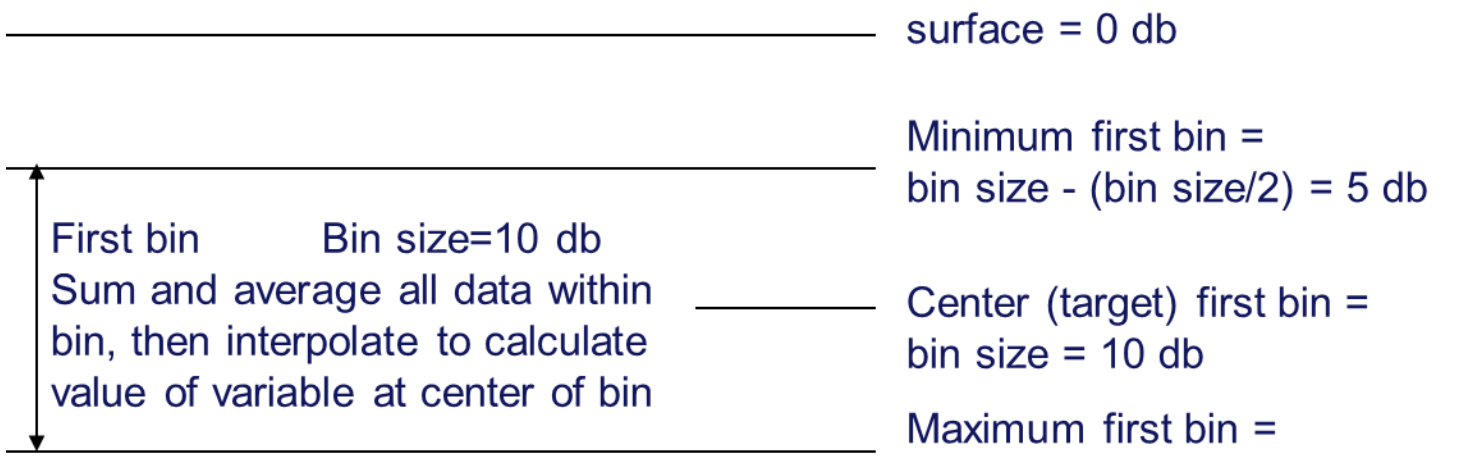


Bin Average Protocol: Pressure Interpolated

A linear estimate of variable Xi at bin pressure Pi:

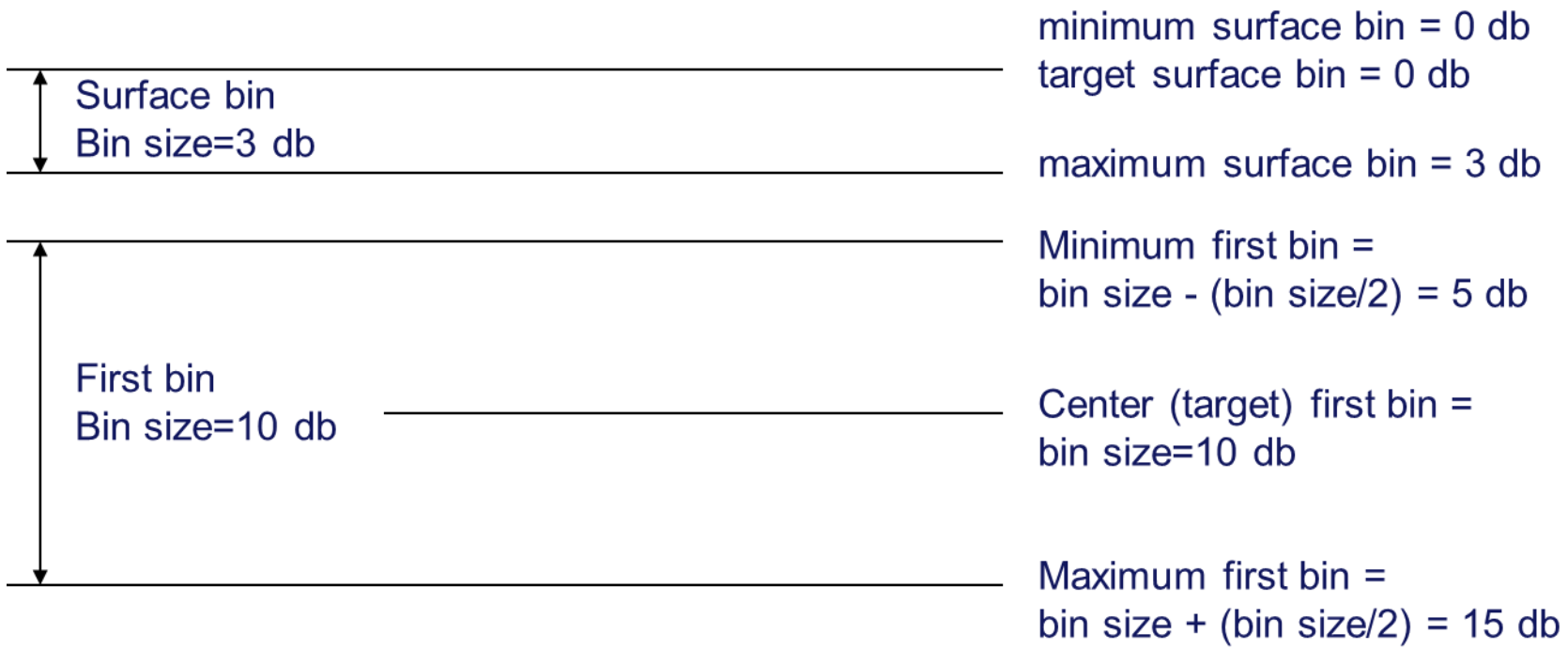
$$Xi = \frac{(Xc - Xp) * (Pi - Pp)}{(Pc - Pp)} + Xp$$

P_p =average pressure of previous bin
P_c =average pressure of current bin
P_i = center value for pressure in current bin
X_p =average value of variable in previous bin
X_c =average value of variable in current bin



The Surface Bin

Surface bin constrained by user data entries: minimum, maximum, and assigned pressure or depth



Bin Average

General tips:

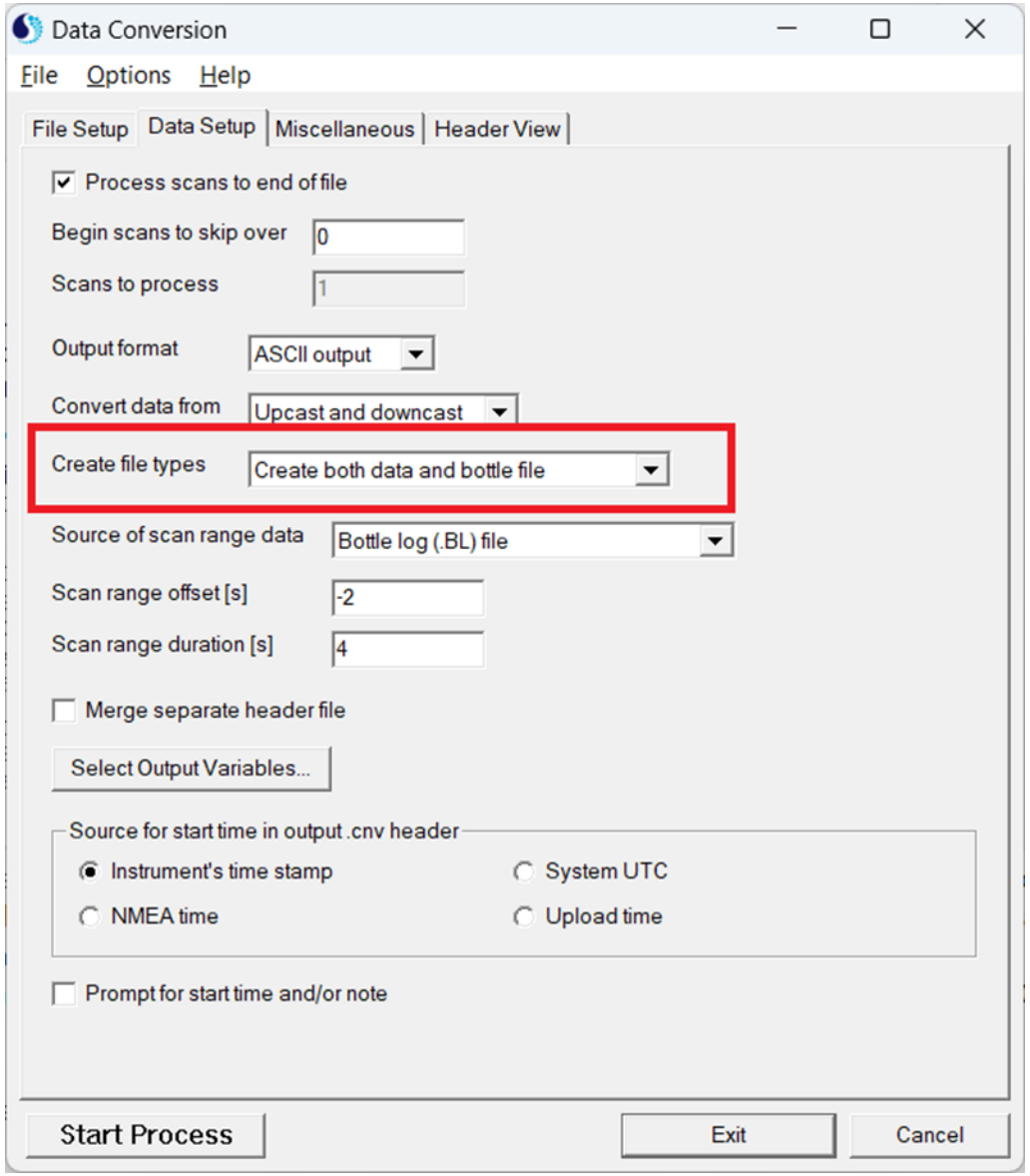
- Bins with 1 sample are not very statistically accurate
- You may exclude scans marked as bad in previous processing steps
- The surface bin is processed separately from the other bins
- Surface bins are difficult to calculate if you use a small bin interval *(i.e., under 10 meters)*

Correlating CTD Data with Water Samples

- Water sampler closure events are captured in data
- SBE 32 Carousel uses a list of scan numbers created by Seasave, .bl file
- This information is used by Data Conversion module to extract CTD data at time of water sampler closure into a .ros file
- Extracted data may be summarized into a table by Bottle Summary module

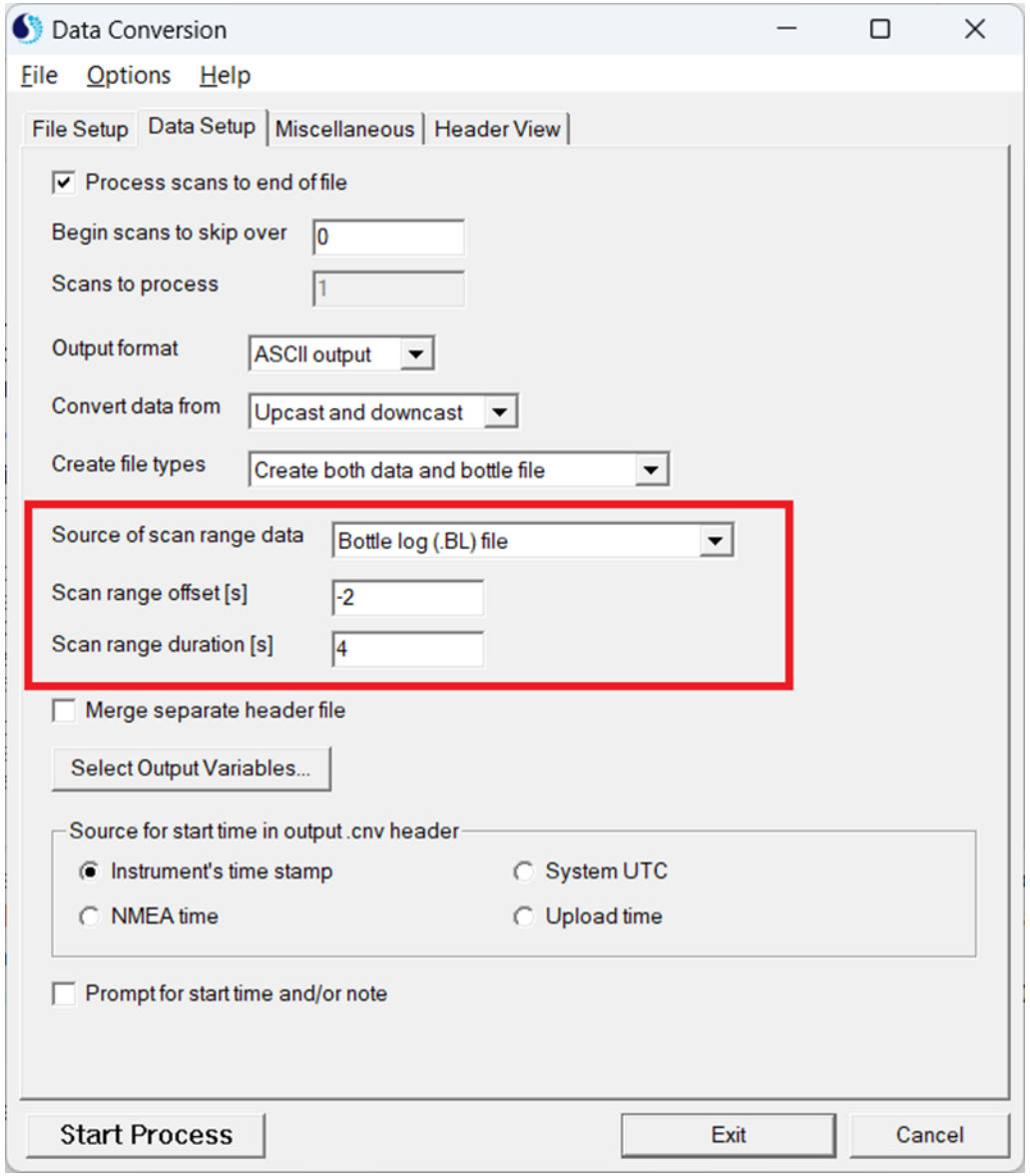
SBE Data Processing: Extracting CTD and Bottle Data

- **Data conversion** step
- You may create a .cnv and a .ros file
- The source of the data is your .bl file
- Data written to the .ros file is specified in the output variable selection dialog



SBE Data Processing: How Much Data per Bottle Closure

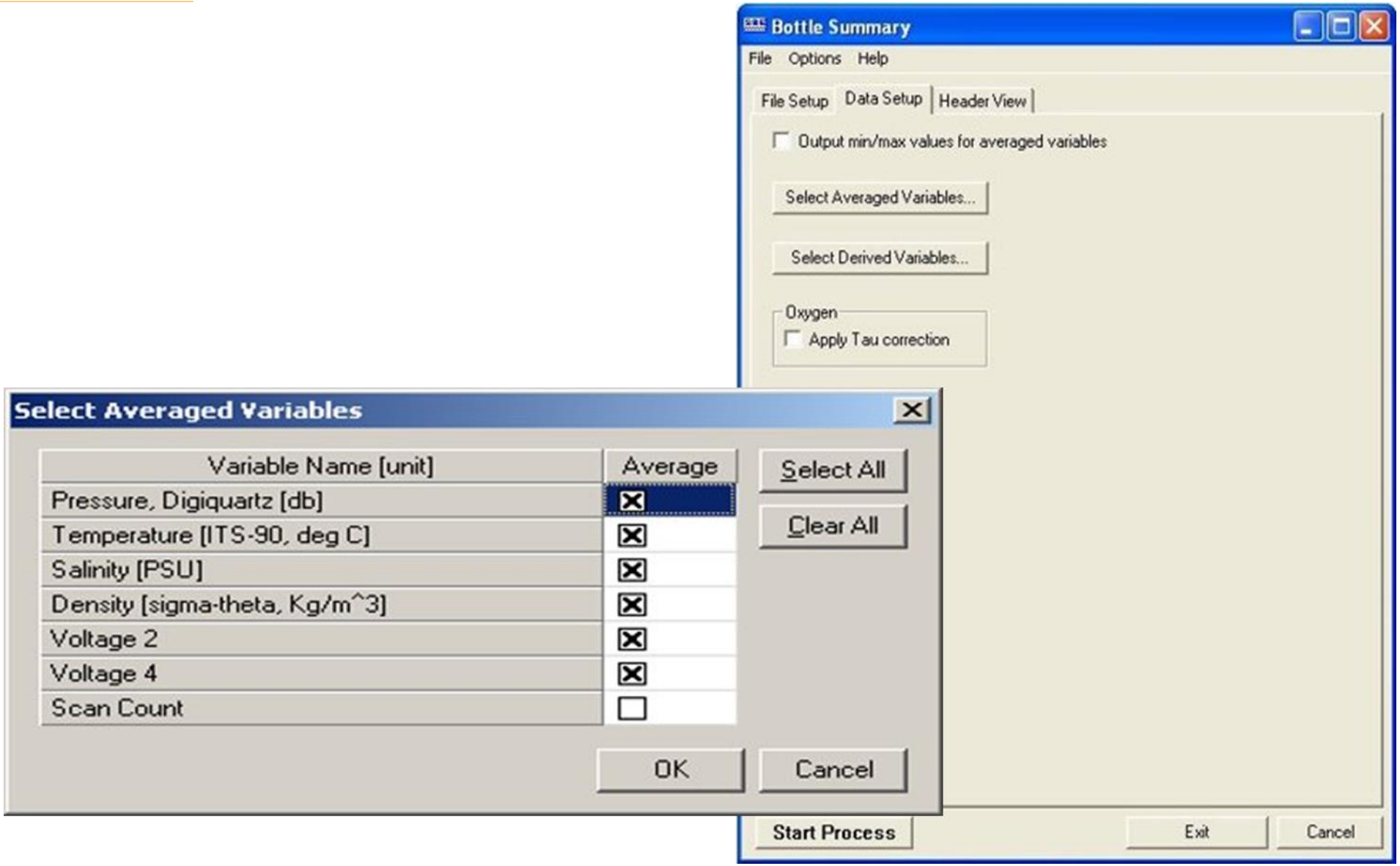
- Data extraction is referenced to the time of closure
- Scan range offset is how many seconds before the bottle closure to begin extracting data
- Scan range duration is how many seconds total to extract data



Summarizing and Tabulating Data

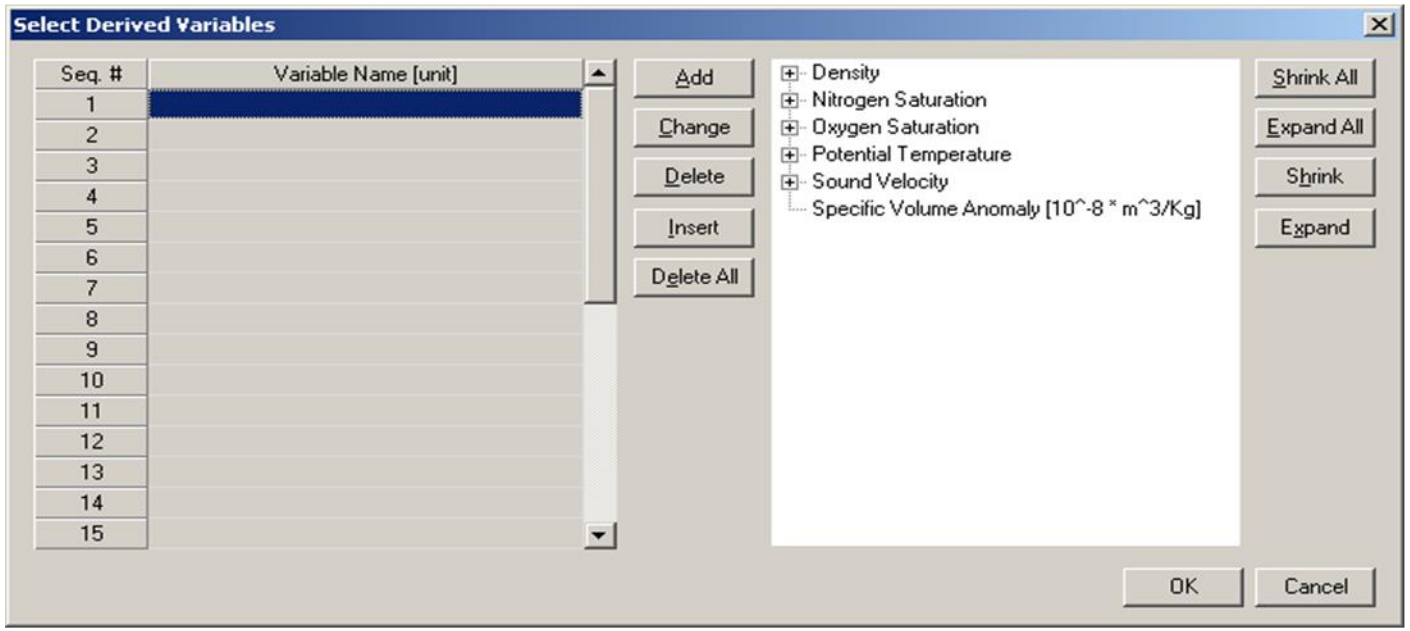
- Bottle Summary module creates a table of averages and standard deviations from data in .ros file
- .ros file must contain pressure, temperature, and conductivity or salinity
- additional parameters may be derived from averaged variables
- data is output to a .btl file
- if a .bl file is present bottle numbers are inserted in .btl file

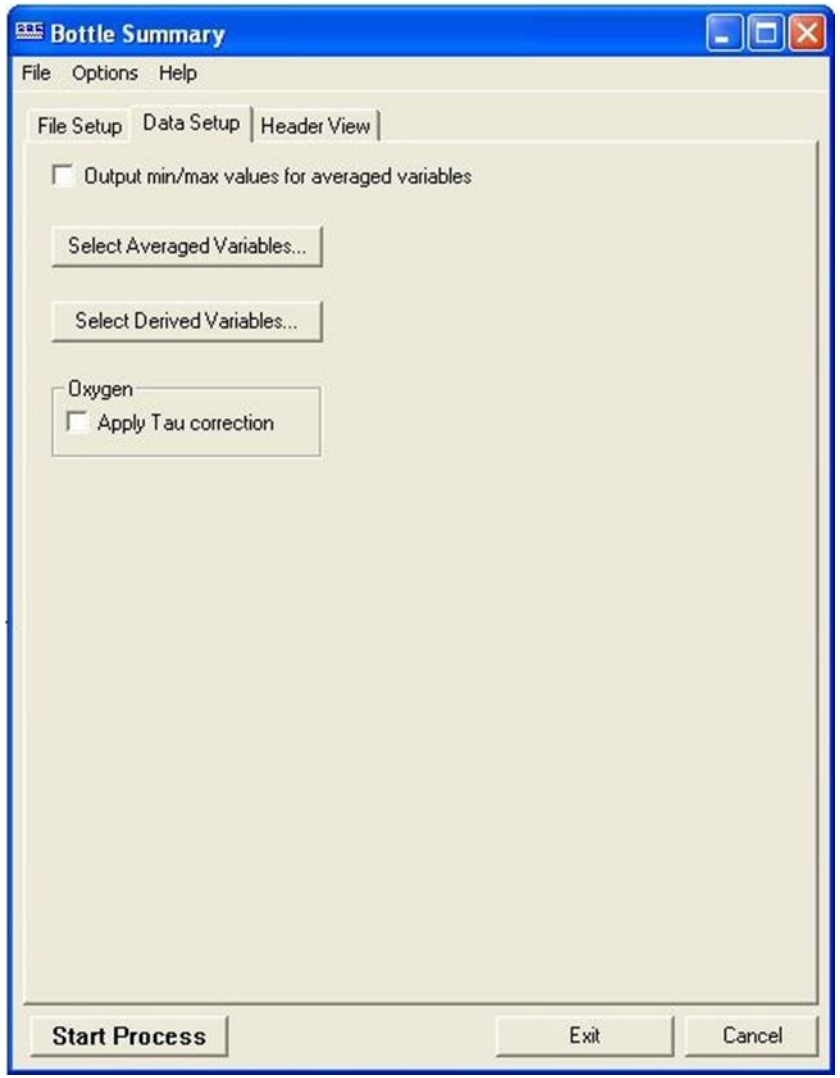
Bottle Summary



Deriving Parameters

Parameters derived from the averages may be added the .btl list





Care and Cleaning of Conductivity Cells

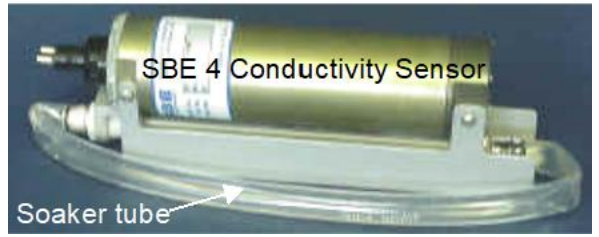
If you want to keep it as close as the last calibration:

- Agitate a non-ionic surfactant warmed to 40 ºC through the cell many times in a washing action. Fill the cell with the solution and let it soak for 1 hour. Drain and flush with warm, fresh, clean water to fill the cell five times or until rinsed thoroughly.
- Agitate a 500-1000 ppm Bleach solution warmed to 40 ºC through the cell in a washing action for 2 minutes. Drain and flush with warm fresh, clean water for 5 minutes or until rinsed thoroughly.

**For severely fouled sensors repeat the procedure up to 5 times*

If you want to apply post-cruise calibration coefficients:

- Gently rinse with DI water in between casts
- Return the sensor to Sea-Bird for post-cruise calibration and new coefficients



Do not put a brush or object (e.g., cotton swab) inside the conductivity cell to clean it or dry it.

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Thank you!

mchristopoulou@seabird.com

Supplementary Slides

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Post-Processing Functions for Profiling CTDs

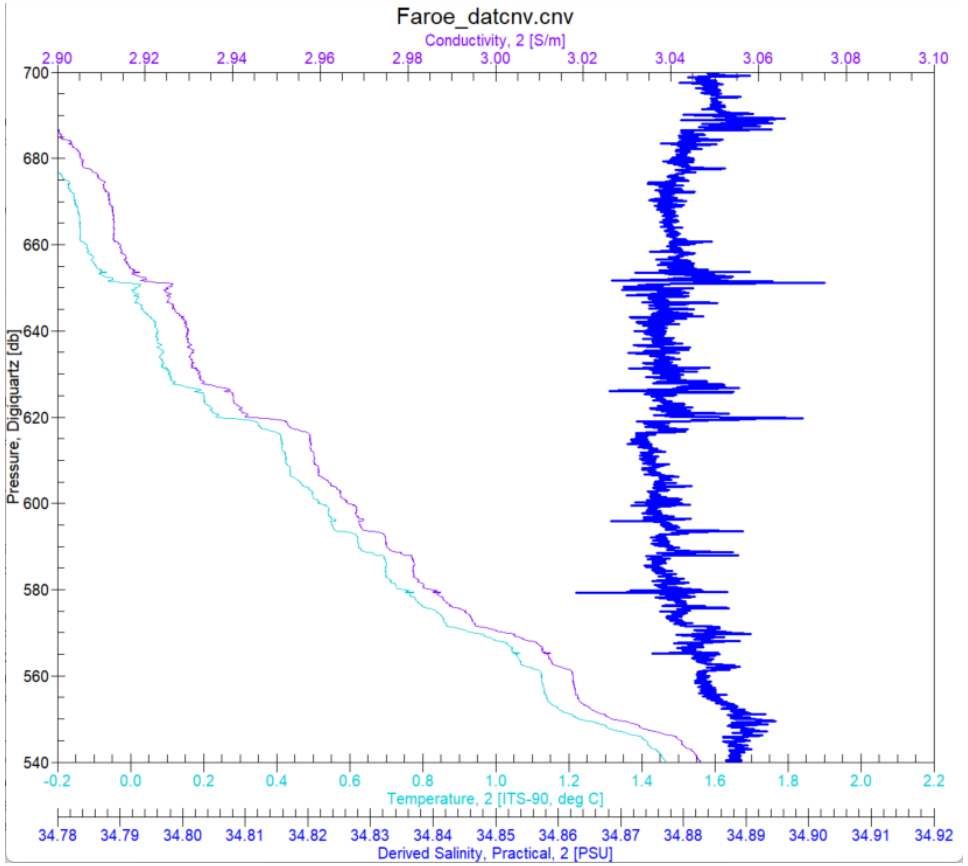
- **Data Conversion** converts data from hexadecimal to engineering units
- **Filter** refines response time of sensors and smooths digital noise in Pressure data
- **Align CTD** coordinates measurements of T, C, and P on same parcel of water
  - Other variables as well, as needed
- **Cell Thermal Mass** corrects conductivity sensor thermal lag error for a given flow rate determined by pump speed or estimated based on descent rate
- **Loop Edit** (*Optional*) reduces ship heave effects by marking scans "badflag" if scan fails minimum velocity criteria set by user
- **Wild Edit** (*Optional)* or (Median) Filter to remove outliers
- **Derive** takes newly aligned and corrected independent variables (T, C, P, Oxvolts) and computes dependent variables (Salinity, Density, Oxygen Concentration)
- **Bin Average** statistically averages data blocks into bins that are evenly spaced or interpolated pressure, depth, scan count, or time blocks

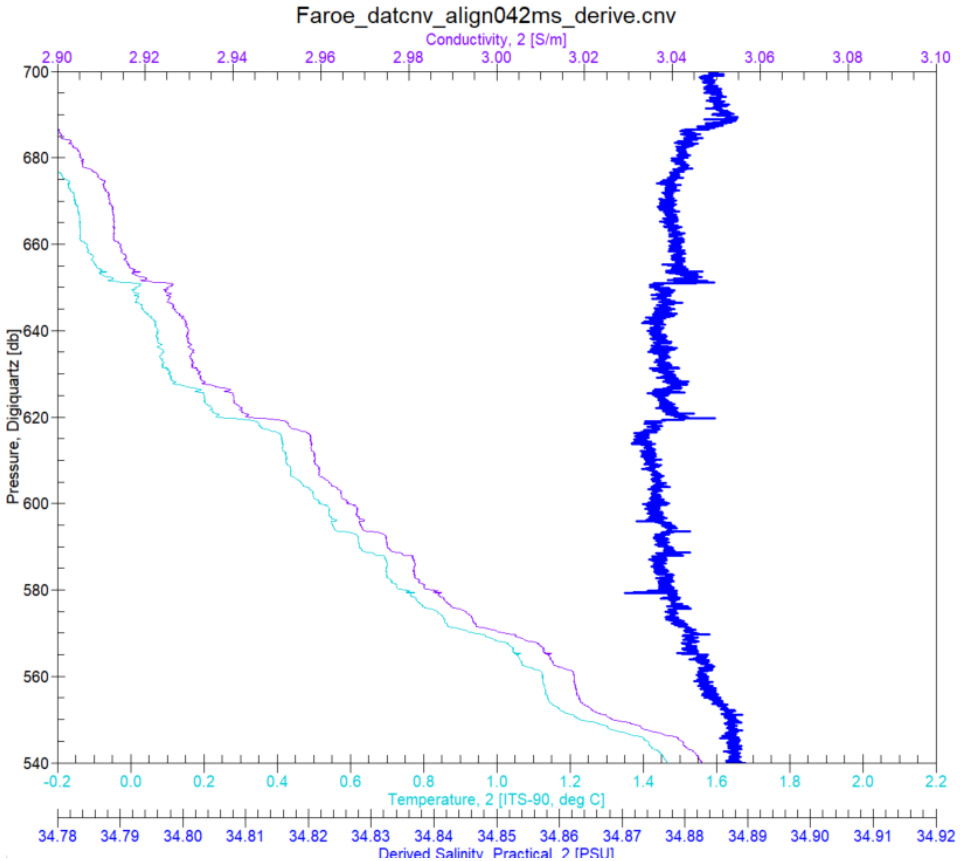
Post-Processing Functions for Profiling CTDs

Special Post-Processing Functions:

- **Derive TEOS-10** takes newly aligned and corrected independent variables and computed dependent variables using the *Thermodynamic Equation of SeaWater 2010 (TEOS-10)*
- **Buoyancy** calculates Brunt-Väisälä or buoyancy frequency over a specified pressure intervals
- **Window filter** smooths data using a median filter or four, size-adjustable windowed filters: boxcar, cosine, triangle and Gaussian.
- **Command Line Options** can be used to run all modules by the command line or a batch processing script

Misalignment





Water Sample Triggers

- Soak triggers in soap and water
- **Never lubricate triggers**
- Check 3 screws holding trigger assembly to pylon for over-tightening, which causes distortion of trigger assembly