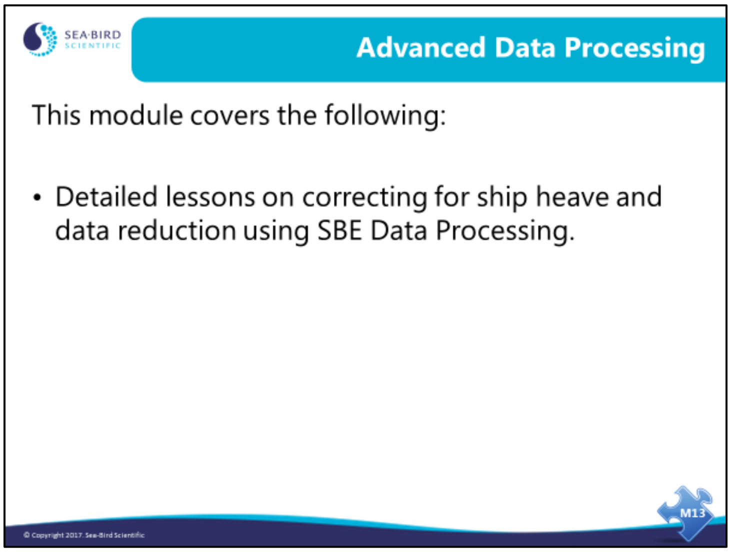
Advanced Data Processing: Ship Heave and Data Reduction

Sea-Bird Scientific University Module 13

Overview

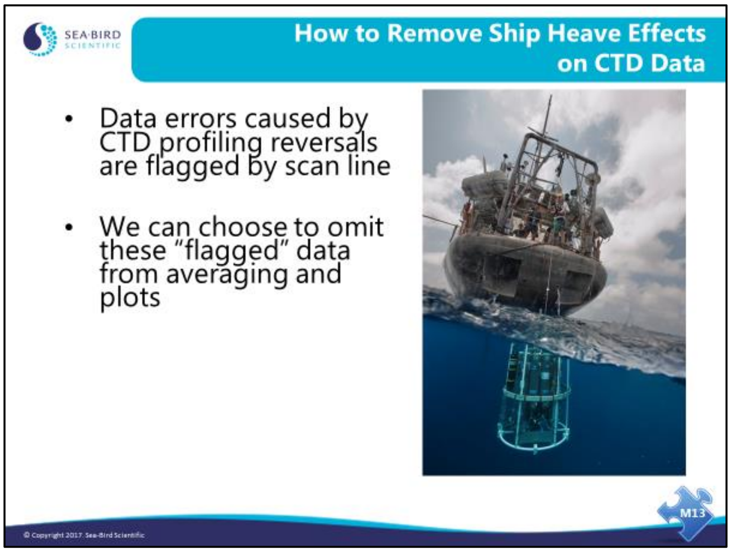


This section of the course covers advanced data processing when profiling. We will discuss the removal of the fairly gross effects of ship heave and talk about bin averaging your final data.

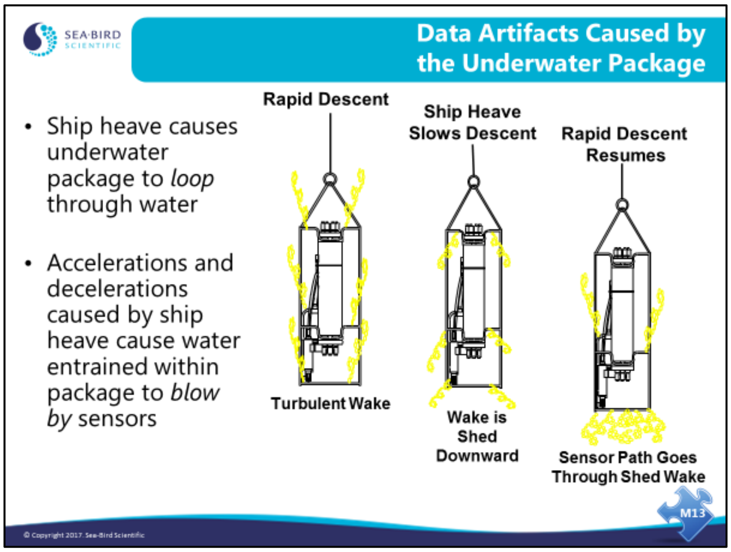
When we finish this module you should be able to:

- Remove data artifacts caused by ship heave.
- Bin Average to reduce your data set, producing data at even pressure or depth values.

Data Artifacts Induced by Ship Heave



Data Artifacts Induced by Ship Heave (*continued*)

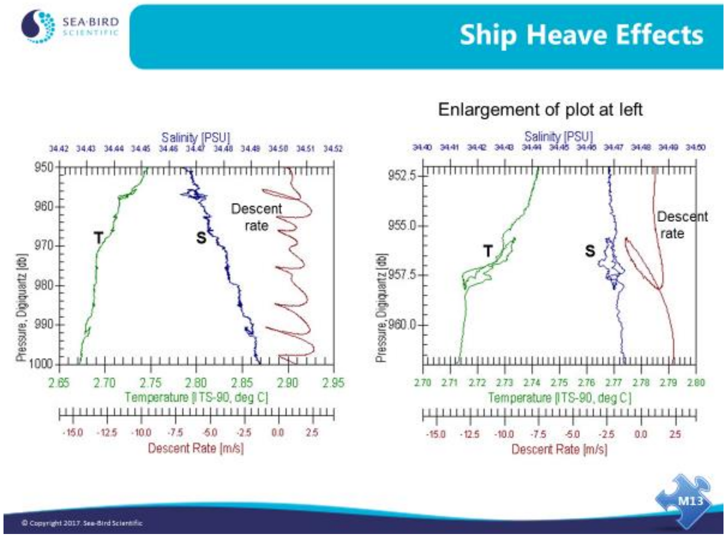


Ship heave is the rocking motion of the ship. Most CTD deployments are made with a small boom or an A-frame that leans out from the ship, giving some distance between the sea cable and the side of the ship. Ship rocking has the effect of pulling up on the sea cable when the ship rocks in one direction and slackening the sea cable when it rocks in the other. This heaving action causes the underwater package to decelerate when the sea cable is pulled up and accelerate when it goes slack. Most instrument packages have sufficient cross section that the deceleration effect is more pronounced than the acceleration.

As the instrument decelerates, water that is entrained within the package can continue downward past the sensors. This water is of different temperature and conductivity than the water at the bottom of the package, and it causes a sampling error.

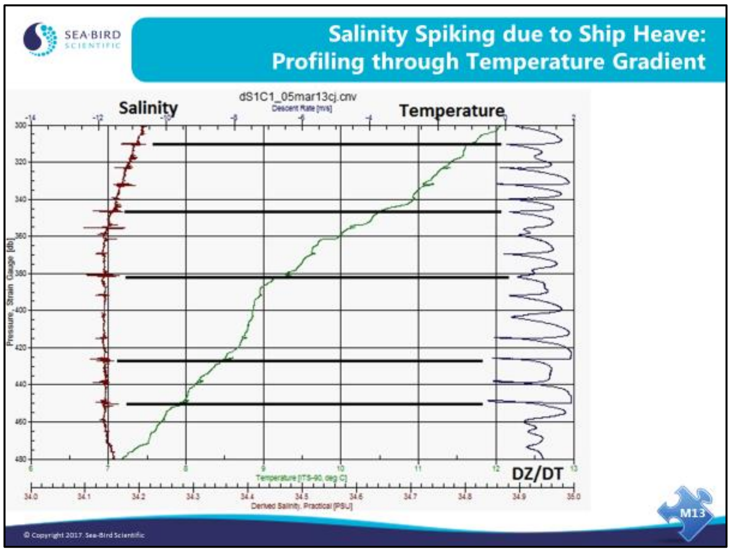
Further, in cases of radical ship heave, the instrument package can have a trajectory through the water column that describes loops. It goes without saying that this sort of behavior causes sampling errors.

Data Artifacts Induced by Ship Heave (*continued*)

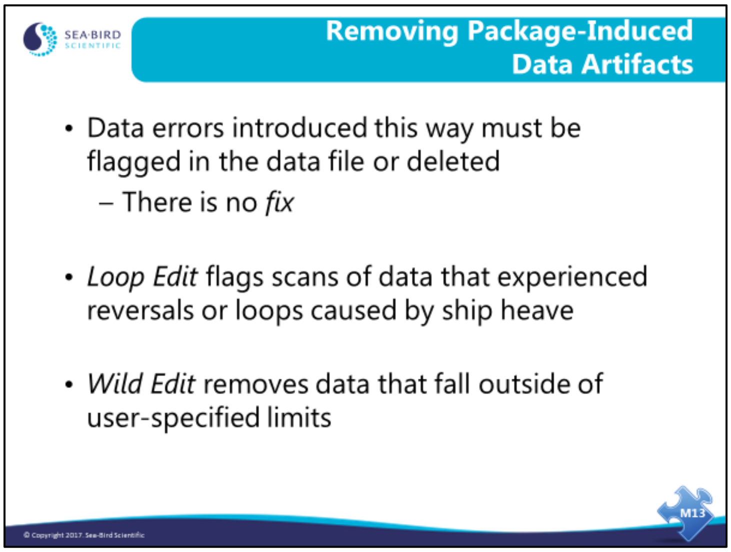


These two plots show the effect of ship heave. Both plots show descent rate in brown. The plot on the left shows that each time the descent rate drops, the temperature and salinity traces are disturbed. The plot on the right is an enlargement of a portion of the left plot, showing the loop trajectory that was mentioned previously.

Data Artifacts Induced by Ship Heave (*continued*)



Data Artifacts Induced by Ship Heave (*continued*)



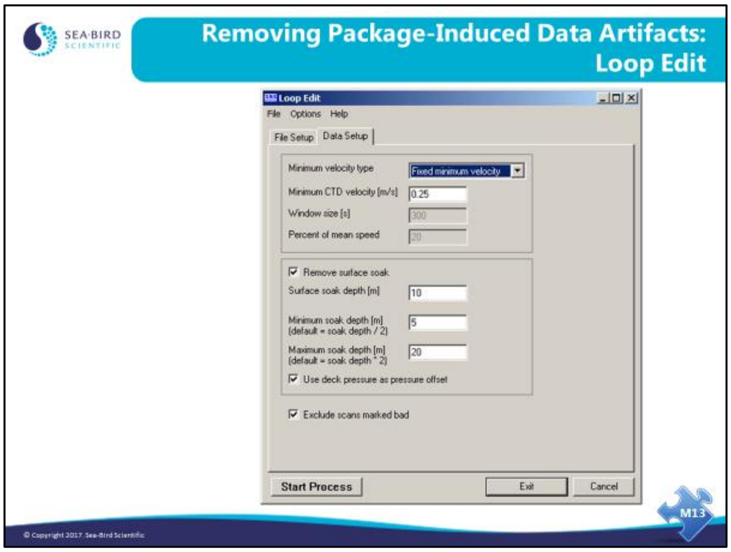
The error caused by ship heave comes from the instrument package disturbing the water that it is trying to sample. Because of this, there is no numerical solution for the problem. SBE Data Processing has two editing modules that remove the offending data. As winch technology improves, we can expect to see vessels equipped with motion compensation capability, which will greatly reduce this problem. Until that is available, you may want to profile a bit more quickly to reduce the effect of ship heave in rough water.

Loop Edit marks data collected when the CTD loops through the water or decelerates sharply.

Wild Edit marks data that falls outside of user-specified limits, given as standard deviations of a window of data; this *bad* data may be caused by a telemetry problem or perhaps a critter or piece of debris going through the conductivity cell.

Data that is marked by these modules can be omitted in subsequent processing steps.

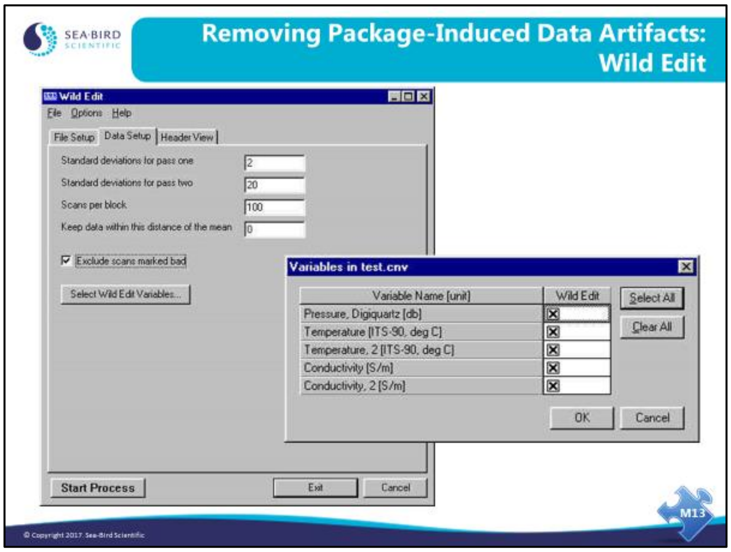
Data Artifacts Induced by Ship Heave (*continued*)



For Loop Edit:

- The default minimum velocity is 0.25 m/sec, which is 25% of the typical nominal descent rate of 1 m/sec. Typically, you should use the *Percent of mean speed* algorithm if the cast had a variable descent rate; otherwise, use *Fixed minimum velocity*.
- If *Remove surface soak* is selected, the scans related to the surface soak are also marked. See the SBE Data Processing manual or Help files for details on setting up the soak depth parameters. The *Use deck pressure as pressure offset* selection relates only to the marking of surface soak data, and has no effect on the pressure data in the file.

Data Artifacts Induced by Ship Heave (*continued*)



Activity: Remove Loops

Explanation: For this activity, we convert the raw data in *Data Conversion*, then *Filter* the data, and look for loops with *Loop Edit* using two different methods. You should end up with the following files to plot in *Sea Plot*:

- AArctic.cnv — original file, not filtered or corrected for loops
- AArcticFilterP.cnv — corrected for loops using percent of mean speed
- AArcticFilterF.cnv — corrected for loops using fixed velocity

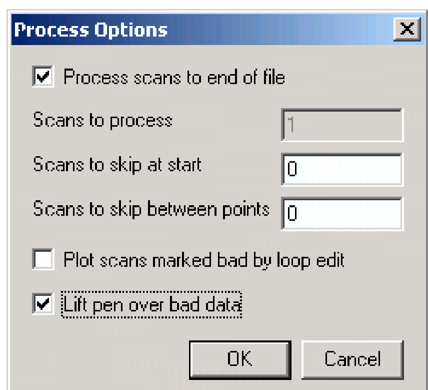
1. In SBE Data Processing, run *Data Conversion*:
   - Use C:\Data\Module9\Loop\AArctic.dat and .con
   - Convert downcast only
   - Output
     Time, Elapsed -> seconds
     Pressure, Digiquartz -> db
     Temperature -> ITS-90 -> deg C
     Descent rate

2. In SBE Data Processing, run *Filter*:
   - Filter pressure with time constant 0.15 seconds
   - Name append *Filter*

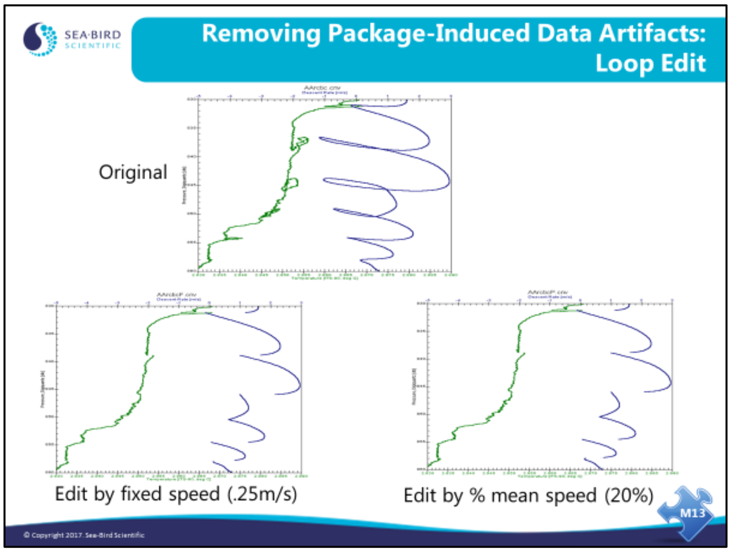
3. In SBE Data Processing, run *Loop Edit* **two times**:
   - Use AarcticFilter.cnv as input file each time
   - **Un**check *Remove surface soak* and *Exclude scans marked bad*.
   - Run with name append *P*, percent mean speed, 300 second window, 20% mean speed
   - Run with name append *F*, fixed minimum velocity, 0.25 m/sec

4. Open **three copies** of SBE Data Processing; run *Sea Plot* **in each copy** to compare results:
   - PlotAarcticFilter.cnv in one copy, AArcticFilterP.cnv in the second copy, and AArcticFilterF.cnv in the third copy.
   - On Plot Setup tab, click *Process options* button, and check *Lift pen over bad data*
   - Y axis Pressure (830 to 860 db), X axis1 Temperature (2.83 to 2.89 deg C), X axis2 Descent rate (-5 to 3 m/sec)

   Note: An alternate way to do this exercise is to use an overlay plot to plot all three files on one plot, but you may decide that the plot is too *busy* to be useful.

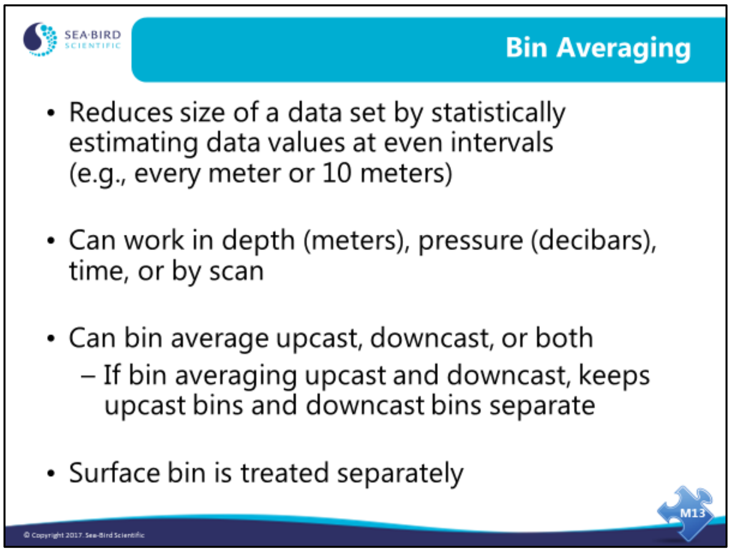


Activity: Remove Loops (*continued*)



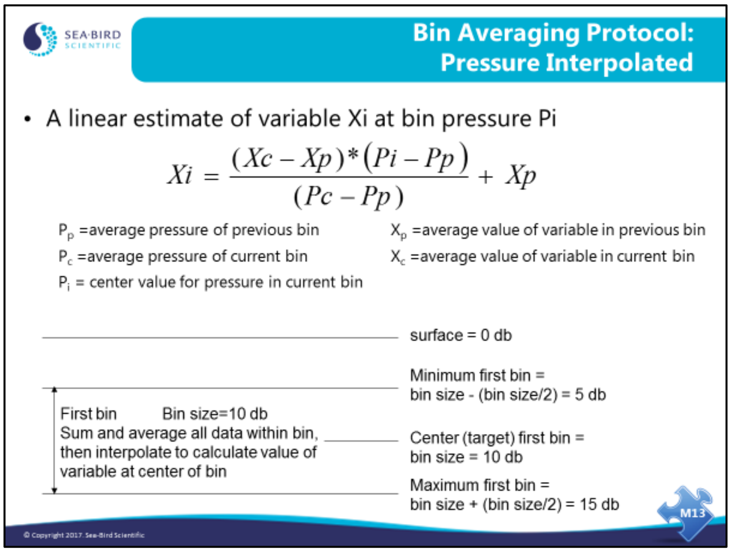
Here is the example of loopy data that we showed earlier. The bottom two plots have been edited by the two means available. Both plots show very similar results. The bottom left plot is made by editing out data that drop below a fixed speed, in this case 0.25m/s. The bottom right plot is made by editing data that drops below 20% of the mean speed calculated over a 5-minute (300-second) window; this method gives you a bit more flexibility.

Bin Averaging



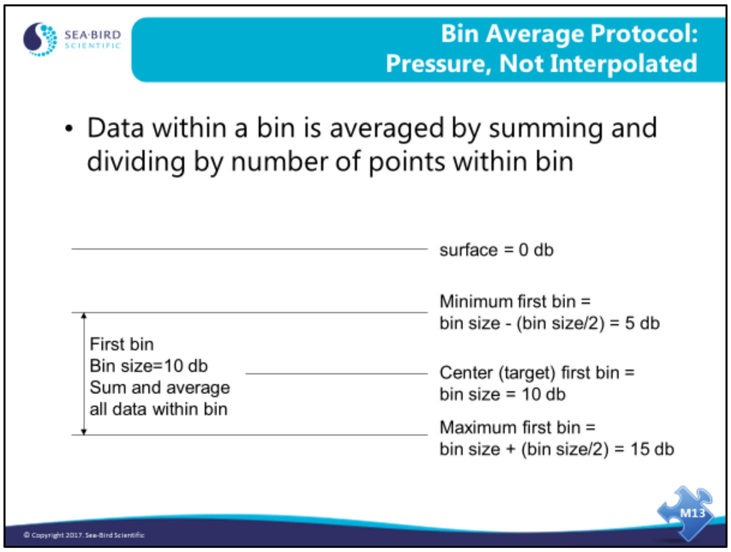
Bin averaging is a means of reducing your data set to a more tractable, and perhaps a more meaningful, size. The Bin Average module makes a statistical estimate of data values at a user-prescribed interval based on the surrounding data. You can bin data on the even meter or 10 meters. You can bin data with a bin size that represents the resolution of your instrument. For time series measurements, you can bin on time interval.

Bin Averaging: Algorithm



An estimate of each variable is made using the average value of that variable and pressure in the previous bin, and the average values of the variable and pressure in the current bin. Bin averaging with interpolation provides output data at regular intervals (for example, 10 meters, 20 meters, etc.).

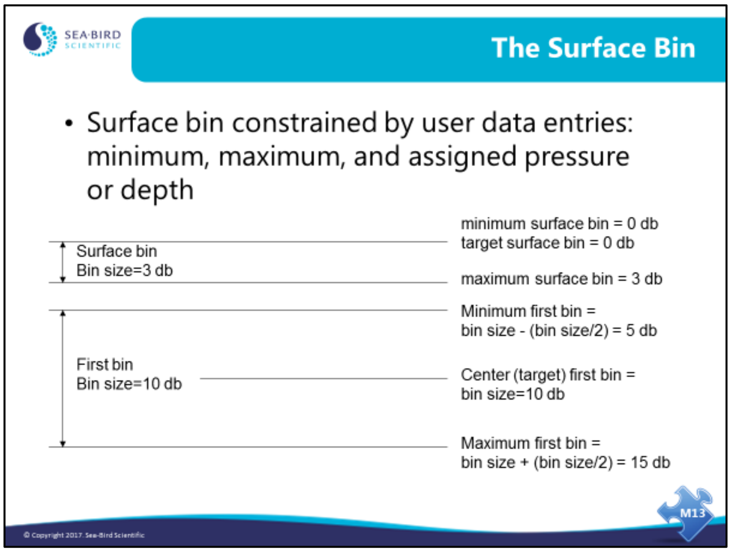
Bin Averaging Algorithm (*continued*)



This protocol averages all the data within the bin, producing uneven bin pressures or depths. For example, if you are binning on 10-meter intervals, the first bin start is 5 meters and the end is 15 meters. All data within this window is averaged, producing a bin depth of approximately 10 meters (e.g., 10.123 meters).

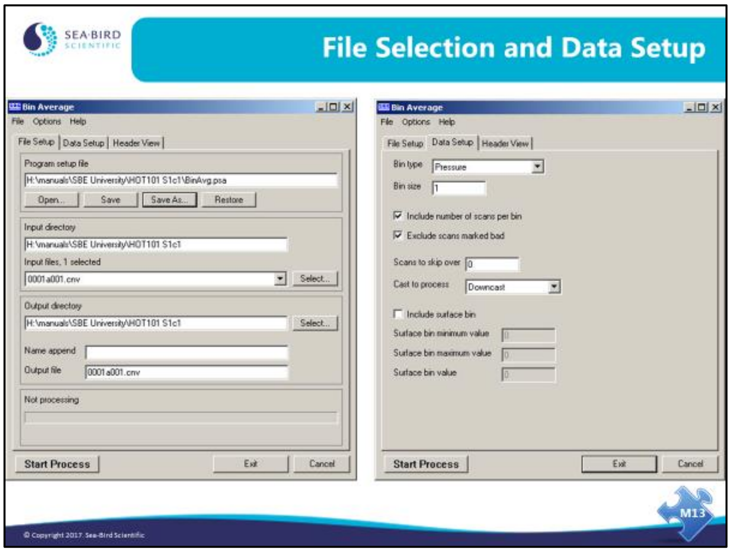
Note that some data bases require data on even intervals (10 m, 20 m, etc.), so averaging without interpolation will not meet the needs of those data bases; use bin averaging with interpolation instead.

Bin Averaging: Surface Bin



The surface bin is handled differently because the previous bin would be up in the air. The surface bin is assigned a beginning pressure or depth, an ending pressure or depth, and a target pressure or depth.

Bin Averaging: File Selection and Data Setup



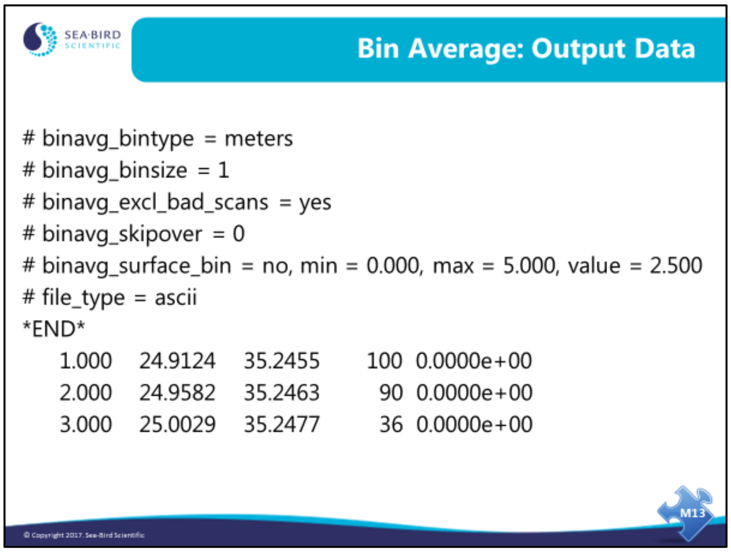
The Data Setup tab allows your choice of pressure, depth, time, or scan bins. You can include the number of scans per bin in the output file, which is useful for evaluating data from instruments with a low sample rate. Bins with 1 sample in them are not very accurate statistically.

You can skip data that you acquired while checking out your instrument before the cast started. Similar to previous processing, you can process the upcast, downcast, or both.

Earlier in this module, we discussed techniques for removing suspect data. These data are marked in the data set as *bad scans*. When setting up *Bin Averaging*, you may exclude scans marked bad by previous processing steps.

As mentioned earlier, the surface bin is handled separately. Note that in our example the surface bin is not included, because we are binning on a 1-meter interval. If you bin on a small interval, it is very difficult to calculate a surface bin. For example, with 1-meter bins, a surface bin would run from 0 to 0.5 meters with value 0.25 meters; depending on the profiling and sampling speeds, there would be few samples within that depth. The surface bin is useful for a coarser bin size. For example, with 10-meter bins, the first bin starts at 5 meters and runs to 15 meters. You can succeed in calculating a surface bin that runs from 0 to 5 meters with value 2.5 meters.

Bin Averaging: Output Data



Bin Average processes all variables in the input .cnv file, and inserts a column before the error flag column if you selected *include number of scans per bin*.

The output columns for the example bin averaged data above are:

- Bin depth
- Temperature (°C)
- Salinity (PSU)
- Number of scans per bin (only if *Include number of scans per bin* was selected)
- Error flag

Activity: Bin Average

1. In SBE Data Processing, run *Bin Average* to create 5 decibar bins:
   - Use C:\Data\Module9\BinAverage\Hawaii.cnv
   - Name append *B*
   - Data Setup
     Choose Pressure for *Bin Type*
     Enter *Bin size* of 5
     Check *Include number of scans per bin*
     Check *Exclude scans marked bad*
     Skip over 0 scans
     Process the downcast
     Include the Surface bin
       Surface bin minimum value 0
       Surface bin maximum value 5
       Surface bin value 2.5

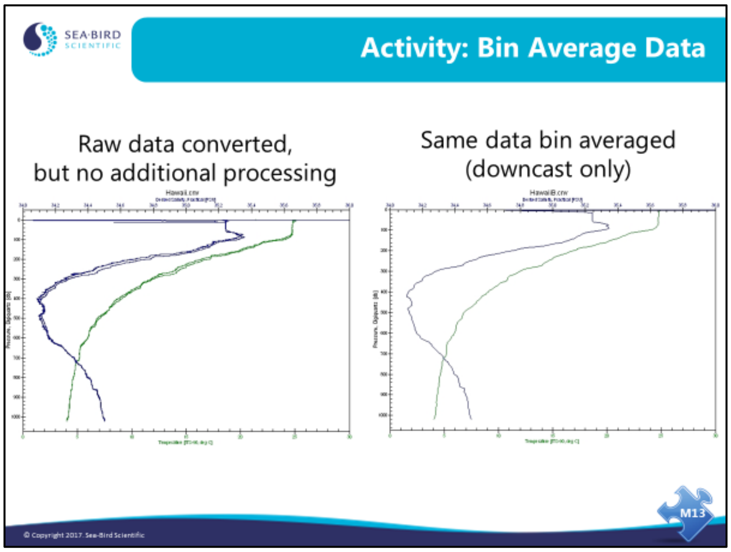
2. Open HawaiiB.cnv in Notepad or Wordpad and take a look at the header and data.

3. If you have time, plot the full data set and the bin averaged data set:
   - Open 2 copies of SBE Data Processing
   - Plot Hawaii.cnv in one, and HawaiiB.cnv in the other

If you have time, bin average 19*plus* data (C:\Data\Module9\BinAverage\Miami.cnv):

- 1 decibar bins
- Include surface bin
  surface bin minimum value 0
  surface maximum value 1
  surface bin value 0.5

Activity: Bin Average *(continued)*



The plot on the left is one we looked at in Module 3, for data that had been converted using Data Conversion, but not yet *processed* using the advanced processing techniques we reviewed today. That plot shows both the upcast and downcast.

The plot on the right is for the same data, but bin averaged. Notice that many of the features are smoothed out when looking at Bin Averaged data. If you will be using any of the advanced processing techniques we discussed today, **do not Bin Average data before you do the advanced processing.**

Recommended SBE 911 plus Profiling CTD Data Processing Steps

- DATA CONVERSION
  - Output downcast and upcast of all parameters in a single file
  - **Only process independent parameters** (T, C, P, Oxygen Raw Volts, Modulo Errors, etc.)
  - Only output converted variables (salinity, DO concentration) if comparing to water samples
  - Enable oxygen deep-water hysteresis correction on Miscellaneous tab

- FILTER
  - Only if continuous time series and no Pressure outliers
  - Filter only Pressure at +0.15 sec

- ALIGN CTD
  - Check header file, as this step may be completed already.
    SBE 11 Deck Box usually advances primary conductivity +0.073 sec,
    and may also advance secondary conductivity
  - Advance Oxygen Raw (Volts) 2-3 sec

- CELL THERMAL MASS
  - ALWAYS apply this correction in saltwater applications on moving platforms (not moored)
  - Do NOT apply this correction in Freshwater applications
  - Parameters to use: Alpha = 0.03 and Tau = 7 sec

- LOOP EDIT
  - Only if ship heave a problem (plot descent rate – check for loops or high standard deviations in descent rate)
  - Use minimum fall speed according to CTD descent rate plots

- DERIVE
  - **Compute Salinity, DO concentration, and other dependent variables** (Density, Sound Velocity, Specific Conductance, etc.)
  - Note: Tau correction for oxygen can be selected, if desired. If Tau correction was previously selected during Data Conversion step, do NOT apply again

- BIN AVERAGE
  - If desired, average data into depth, time, or pressure bins AFTER DERIVING computed variables. Only needed for reducing size of a data set

Recommended SBE 19plus V2 Profiling CTD Data Processing Steps

- DATA CONVERSION
  - Output downcast and upcast of all parameters in a single file
  - **Only process independent parameters** (T, C, P, Oxygen Raw Volts, etc.)
  - Only output converted variables (salinity, DO concentration) if comparing to water samples
  - Enable oxygen deep-water hysteresis correction on Miscellaneous tab

- FILTER
  - Only if continuous time series and no outliers
    Filter Pressure at +1.0 sec, and Temperature and Conductivity at +0.5 sec

- ALIGN CTD
  - Advance Temperature +0.5 sec, Conductivity 0-0.1 sec, and
    Oxygen Raw (Volts) 3-5 sec

- CELL THERMAL MASS
  - ALWAYS apply this correction in saltwater applications on moving platforms (not moored)
  - Do NOT apply this correction in Freshwater applications
  - Parameters to use: Alpha = 0.04 and Tau = 8 sec

- LOOP EDIT
  - Only if ship heave a problem (plot descent rate – check for loops or high standard deviations in descent rate)
  - Use select minimum fall speed according to CTD descent rate plots

- DERIVE
  - **Compute Salinity, DO concentration, and other dependent variables**
    (Density, Sound Velocity, Specific Conductance, etc.)
  - Note: Tau correction for oxygen can be selected, if desired. If Tau correction was previously selected during Data Conversion step, do NOT apply again

- BIN AVERAGE
  - If desired, average data into depth, time, or pressure bins AFTER DERIVING computed variables. Only needed for reducing size of a data set

Recommended SBE 25plus Profiling CTD Data Processing Steps

- DATA CONVERSION
  - Output downcast and upcast of all parameters in a single file
  - **Only process independent parameters** (T, C, P, Oxygen Raw Volts, etc.)
  - Only output converted variables (salinity, DO concentration) if comparing to water samples
  - Enable oxygen deep-water hysteresis correction on Miscellaneous tab

- FILTER
  - Only if continuous time series and no outliers
  - Filter Pressure at +0.5 sec

- ALIGN CTD
  - Advance Conductivity +0.1 sec, and Oxygen Raw (Volts) 3-5 sec

- CELL THERMAL MASS
  - ALWAYS apply this correction in saltwater applications on moving platforms (not moored)
  - Do NOT apply this correction in Freshwater applications
  - Parameters to use: Alpha = 0.04 and Tau = 8 sec

- LOOP EDIT
  - Only if ship heave a problem (plot descent rate – check for loops or high standard deviations in descent rate)
  - Use select minimum fall speed according to CTD descent rate plots

- DERIVE
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