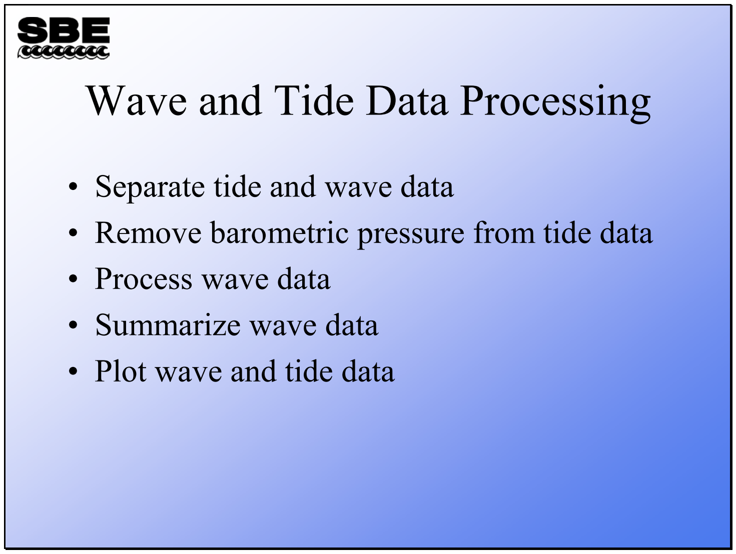
Module 14

Wave and Tide Instruments: Data Processing

Overview

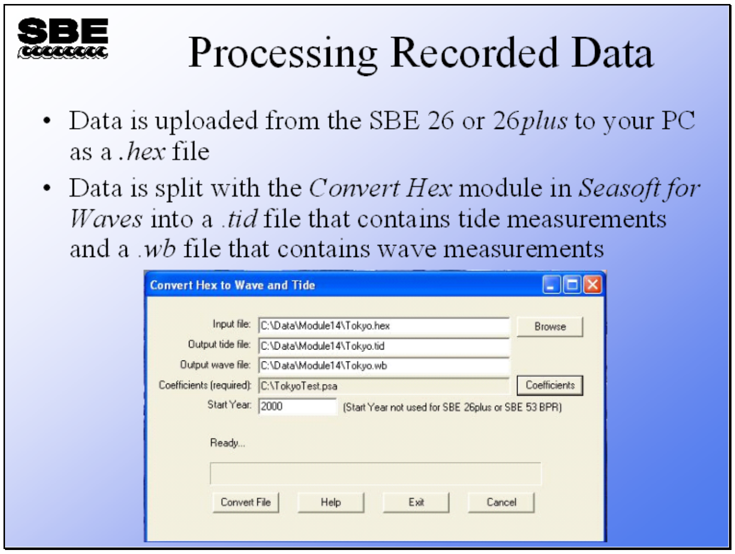


We are going to discuss how to process wave and tide data in our final module. We will work through each of the processing steps with explanations and examples.

By the end of this module you should be able to:

- Process your wave and tide data
- Critically examine your data

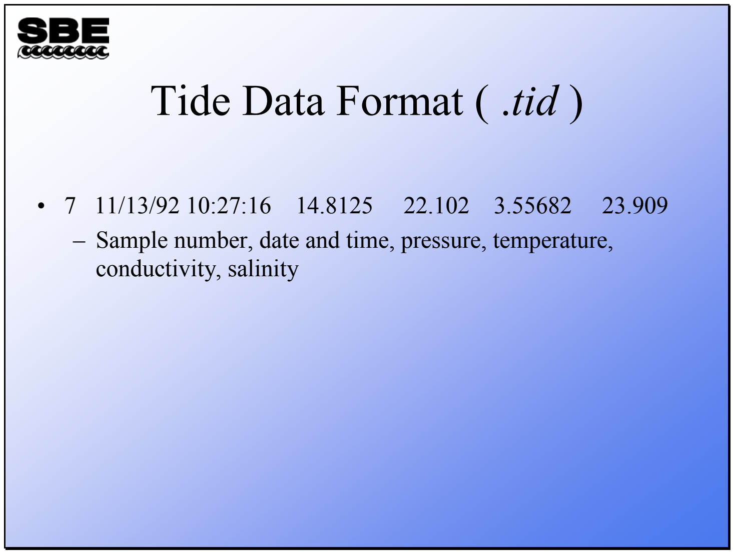
Separating into Wave Data and Tide Data: *Convert Hex*



Data that comes from the SBE 26 or 26*plus* has wave burst data embedded in the tide data. The first step is to split this data (*.hex*) into 2 files (*.tid* and *.wb*).
For the SBE 26, you need to enter temperature calibration coefficients, (optional) conductivity calibration coefficients, and pressure slope and offset (to make small corrections for pressure sensor drift between calibrations). For the SBE 26*plus*, only enter the pressure slope and offset; the other calibration coefficients were programmed into the instrument.

You might notice that the dialog box mentions the SBE 53 BPR (Bottom Pressure Recorder). The SBE 53 measures full ocean depth water level with extremely high resolution, accuracy, and stability. It has some similarities to the SBE 26*plus*, but does not measure waves.

Separating into Wave Data and Tide Data: *.tid* File Format

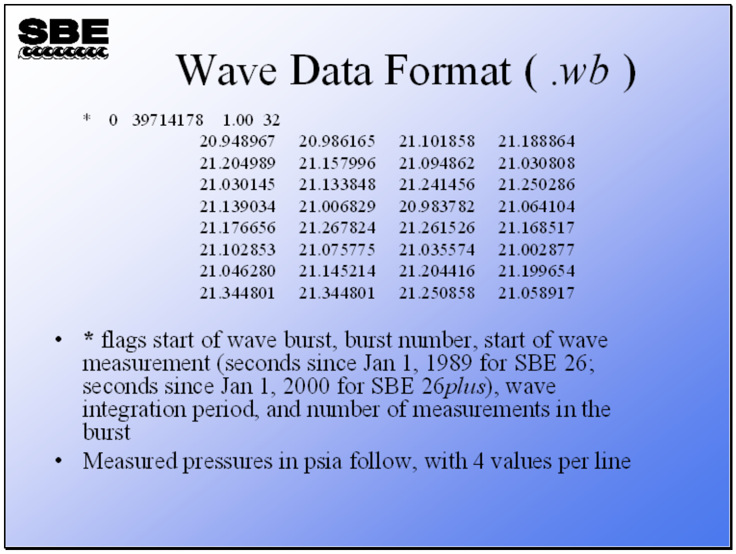


The data format is:

- First column - tide measurement number
- Second and third columns - date and time of the beginning of the tide measurement
- Fourth column - measured pressure in psia
- Fifth column - measured water temperature in °C
- Sixth column - measured conductivity in S/m
- Seventh column - calculated salinity in PSU

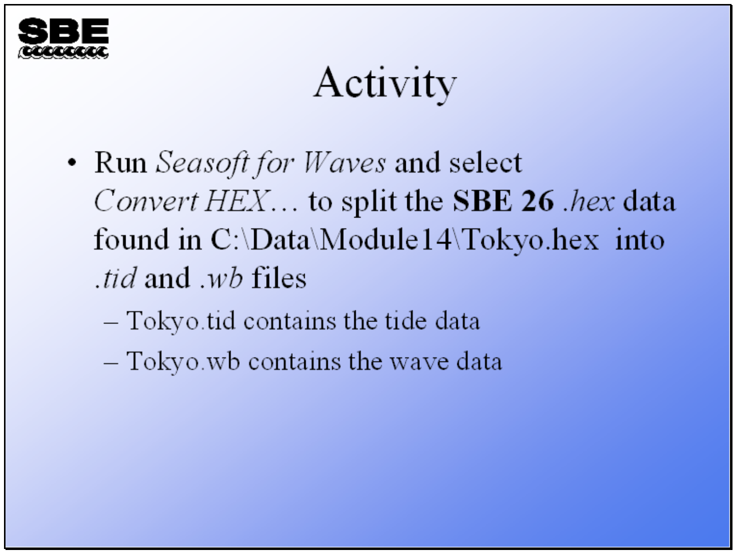
Note that if conductivity logging is not enabled (conductivity = NO in the status display), the sixth and seventh columns of the above table will not be included in the *.tid* file.

Separating into Wave Data and Tide Data: .*wb* File Format



For the SBE 26*plus*, the * line is preceded by a line identifying the data as coming from the 26*plus*, so the software knows that the time is referenced to 2000 instead of 1989.

Activity



Click Start -> Programs -> Sea-Bird ->SeasoftWaves

Click Run -> Convert HEX

In the Convert Hex to Wave and Tide dialog box, click Browse to select c:\data\module14\tokyo.hex.

Click Coefficients. In the Coefficient Configuration dialog box, select the SBE 26 and enter these temperature sensor calibration coefficients:

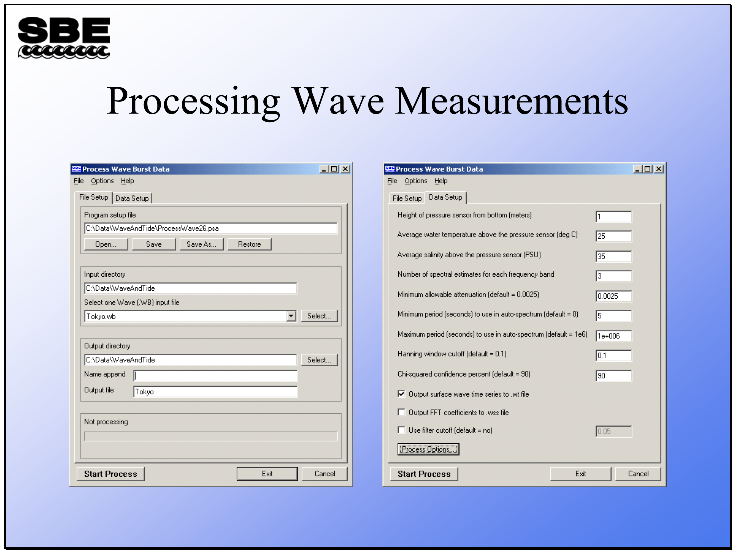
A0 = 9.99463500 E-04
A1 = 2.43988930 E-04
A3 = 1.37995400 E-07

Click Save As, and save as tokyo.psa.
(Note: This example file is from the SBE 26. For the SBE 26*plus*, temperature and conductivity coefficients are not entered in Convert Hex. T and C coefficients are programmed into the 26*plus* at Sea-Bird; they can be viewed and modified in SeatermW with user-input commands.)

In the Convert Hex to Wave and Tide dialog box, enter a Start Year of 1995.

Click Convert File.

Processing Wave Measurements:
Process Wave Burst Data



Next we are going to process wave bursts. We want to know the wave heights, as well as the frequencies of the waves. Recall from our discussion of linear theory that we assume the observed waves are a combination of several different individual waves. We seek to determine the frequency or period of each of these waves, as well as the amount of energy they have.

The processing application uses the height of the SBE 26 or 26*plus* above the bottom, water temperature, and salinity to determine the density of the water above the instrument.

Output data provides:

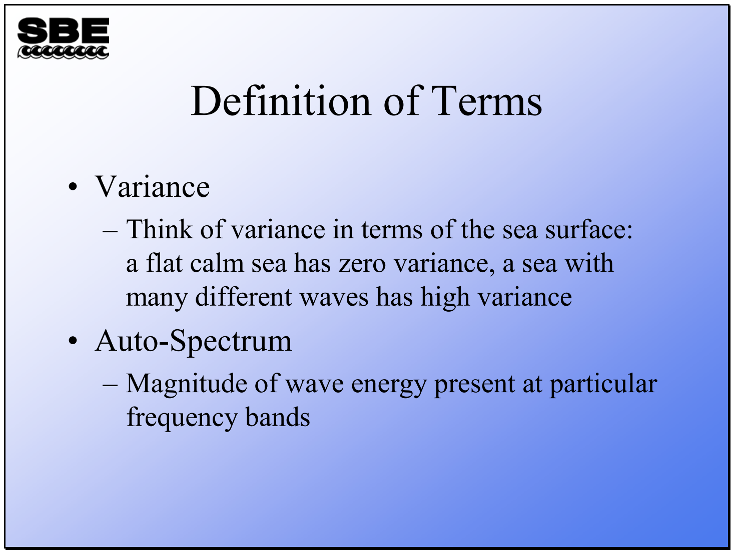
- Auto-spectrum data

  Shows what frequency waves were present by calculating the power or energy present in each of the frequency bands

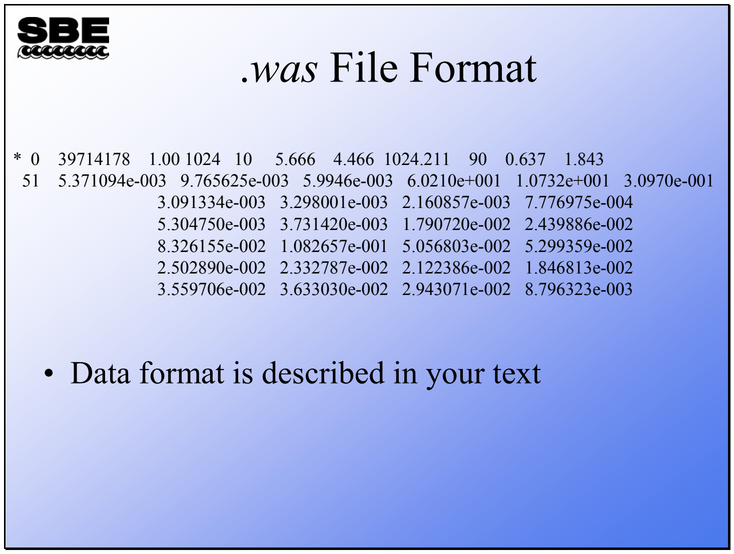
- Time series data

  Shows what the wave heights were and what the actual signal looked like

Processing Wave Measurements: *Process Wave Burst Data* (*continued*)



Processing Wave Measurements: *.was* File Format



Lines beginning with * flag the beginning of the data for a wave burst.

Line 1 contains (in the following order):

- burst number
- start of wave burst (seconds since Jan 1, 1989 for SBE 26; seconds since January 1 2000 for 26*plus*)
- wave integration time (seconds)
- number of points in the wave burst
- number of spectral estimates for each frequency band
- water depth (meters)
- pressure sensor depth (meters)
- density (kg/m^3)
- Chi-squared confidence interval (percent)
- multiplier for Chi-squared lower bound
- multiplier for Chi-squared upper bound

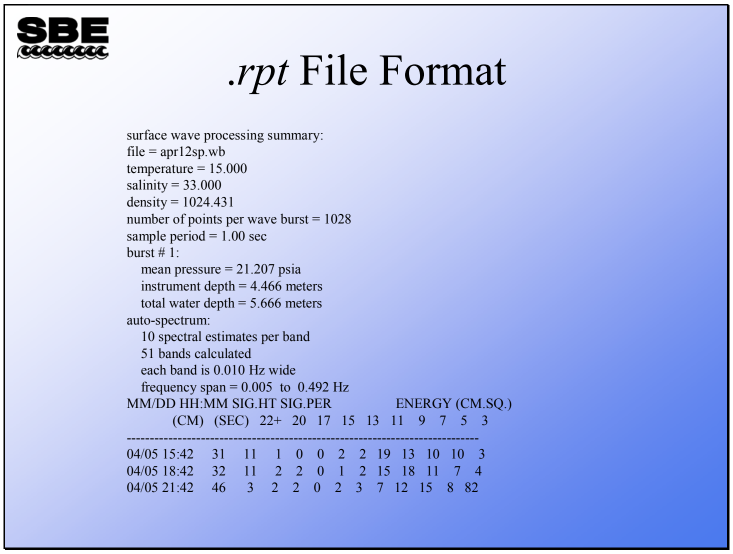
Line 2 contains (in the following order):

- number of frequency bands calculated
- frequency of the first frequency band (Hz)
- interval between frequency bands (delta f) (Hz)
- total variance (meters squared)
- total energy (Joules / $meters^2$)
- significant period (seconds) = frequency band with the greatest variance
- significant wave height (meters) = 4 x sqrt(total variance)

The remaining lines contain the values (beginning with the first frequency) for the Auto-Spectral density function <Gaa>. The units are $meters^2$ / Hz. To obtain the variance (m^2) in a frequency interval delta f (Hz), multiply the value of <Gaa> by delta f.

Once again, for the SBE 26*plus*, the * line is preceded by a line identifying the data as coming from the 26*plus*, so the software knows that the time is referenced to 2000 instead of 1989.

Processing Wave Measurements: *.rpt* File Format



The energy (cm^2) is the sum of the variance over the indicated frequency band:

The 9 second wave period column is the sum of the variances where the frequency is between 1/10 Hz and 1/8 Hz.

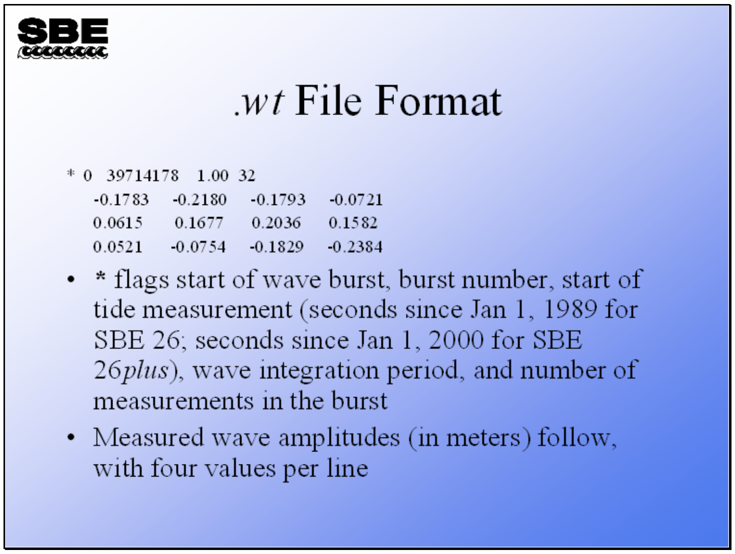
The 20 second wave period column is the sum of the variances where the frequency is between 1/22 Hz and 1/18 Hz.

The 22+ second wave period column is the sum of the variances of all the frequencies less than 1/22 Hz.

Significant period is:

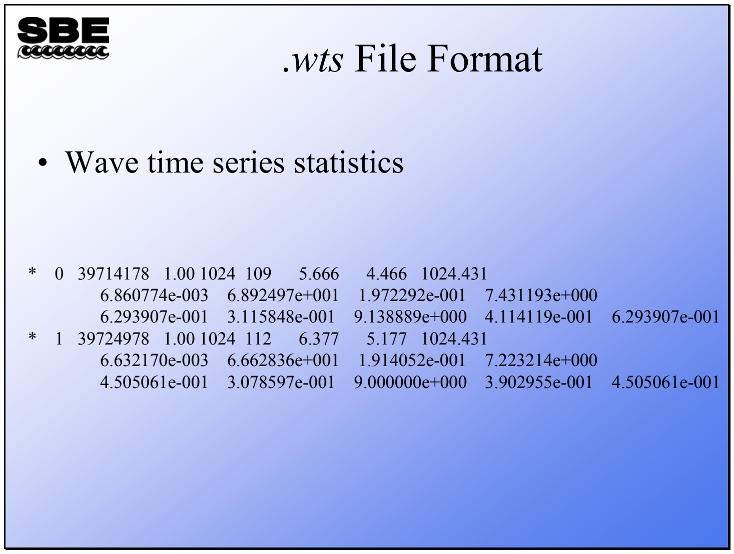
1 / (band averaged frequency with the greatest variance)

Processing Wave Measurements: .*wt* File Format



Once again, for the SBE 26*plus*, the * line is preceded by a line identifying the data as coming from the 26*plus*, so the software knows that the time is referenced to 2000 instead of 1989.

Processing Wave Measurements: .*wts* File Format



Lines beginning with * flag the beginning of the data for a wave burst.

Line 1 contains (in the following order):

burst number
start of wave burst (seconds since January 1, 1989 for SBE 26; seconds since January 1, 2000 for SBE 26*plus*)
wave integration time in seconds
number of points in the wave burst
number of individual waves found
water depth (meters)
pressure sensor depth (meters)
density (kg/m^3)

Line 2 contains (in the following order):

total variance of the time series (meters^2)
total energy of the time series (Joules/meters^2)
average wave height (meters)
average wave period (seconds)

Line 3 contains (in the following order):

maximum wave height (meters)
significant wave height (meters) = average height of the largest 1/3 waves
significant period (seconds) = average period of the largest 1/3 waves
$H_{1/10}$ (meters) = average height of the largest 1/10 waves
$H_{1/100}$ (meters) = average height of the largest 1/100 waves

If there are less than 10 waves, $H_{1/10}$ is set to 0.
If there are less than 100 waves, $H_{1/100}$ is set to 0.

Once again, for the SBE 26*plus*, the * line is preceded by a line identifying the data as coming from the 26*plus*, so the software knows that the time is referenced to 2000 instead of 1989.

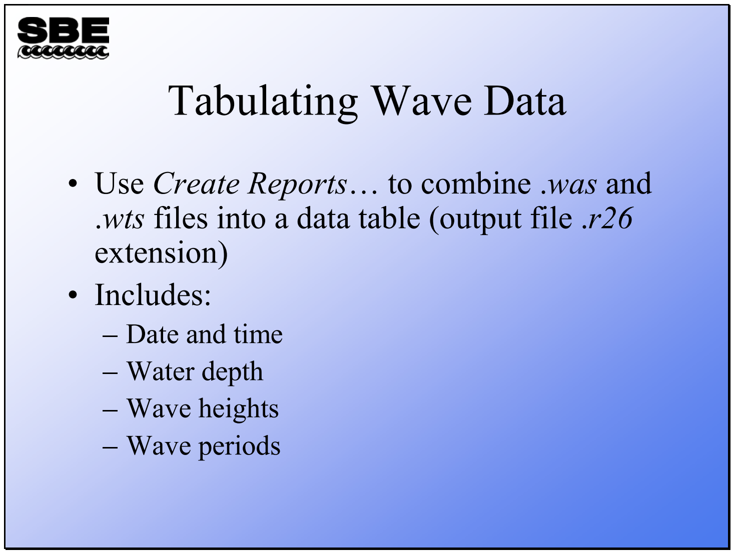
Activity

SBE

Activity

- Run *Process Wave Burst Data* on the data from the last activity: C:\Data\Module14\Tokyo.wb
  - Tide gauge is 1 meter off the bottom
  - Temperature is 25 degrees C
  - Salinity is 35 PSU
  - 8 spectral estimates per band
  - Leave all other parameters as defaults

Tabulating Wave Data: *Create Reports*



Below is the file format for an *.r26* file. This file is the combination of *.was* and *.wts* files.

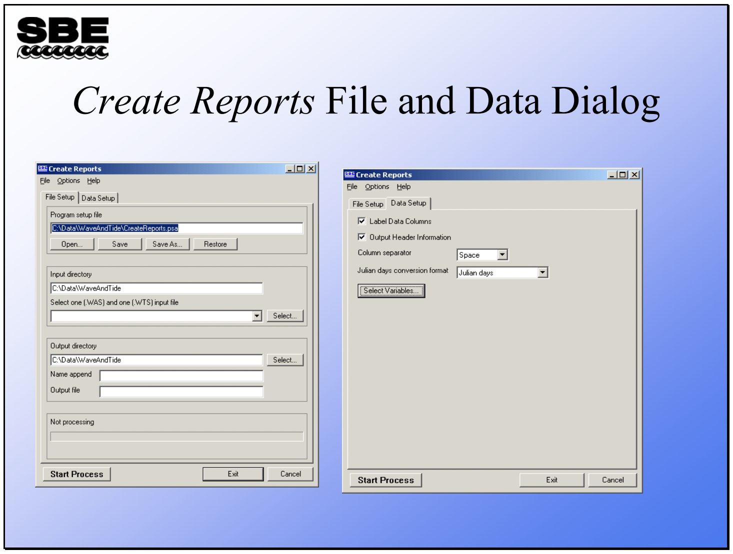
- From Surface Wave Time Series Statistics:

variable	**column label**
time	time
burst number	burst
pressure sensor depth	depth
number of waves	nwaves
variance	var-wts
energy	energy-wts
average wave height	avgheight
average wave period	avgper
maximum wave height	maxheight
significant wave height	swh-wts
significant wave period	swp-wts
$H_{1/10}$	H1/10
$H_{1/100}$	H1/100

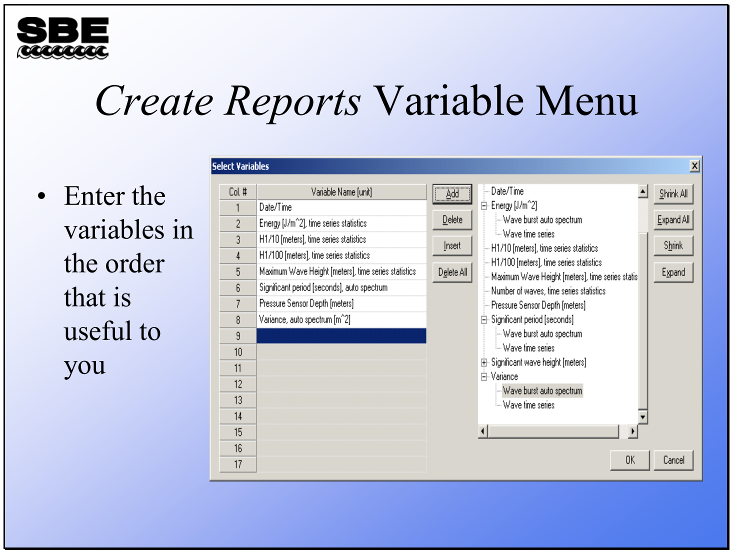
- From Wave Burst Auto-Spectrum Statistics:

variable	**column label**
variance	var-was
energy	energy-was
significant wave height	swh-was
significant wave period	swp-was

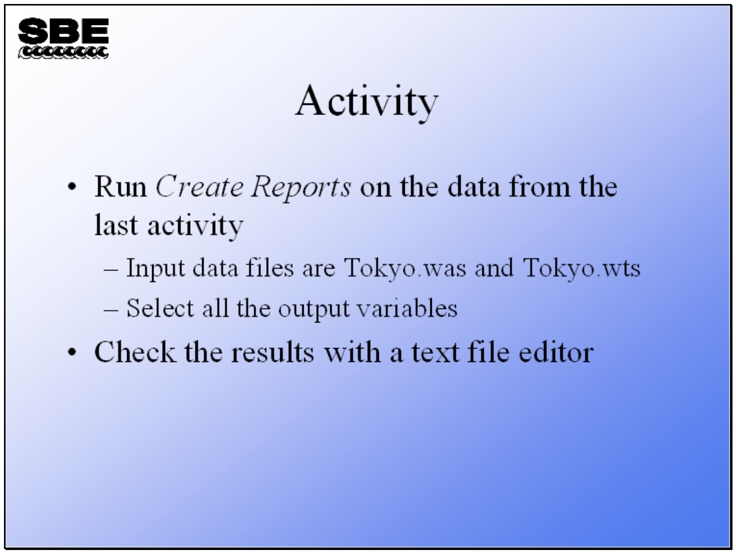
Tabulating Wave Data: *Create Reports* (*continued*)



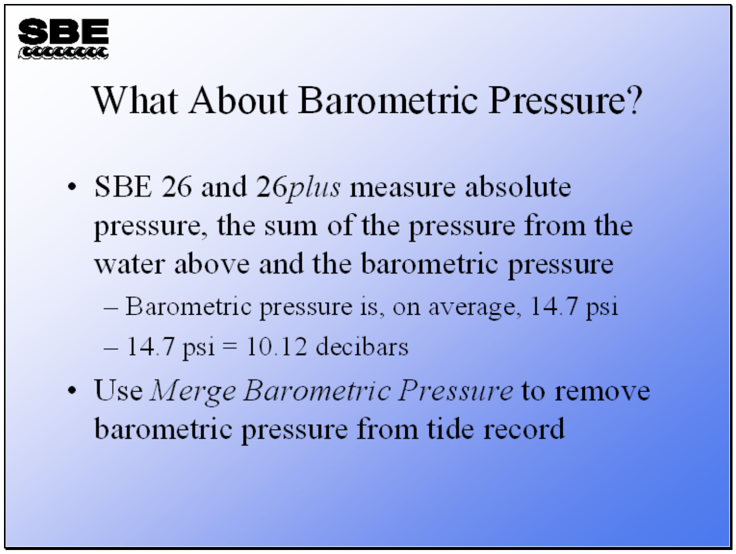
Tabulating Wave Data: *Create Reports* (*continued*)



Activity

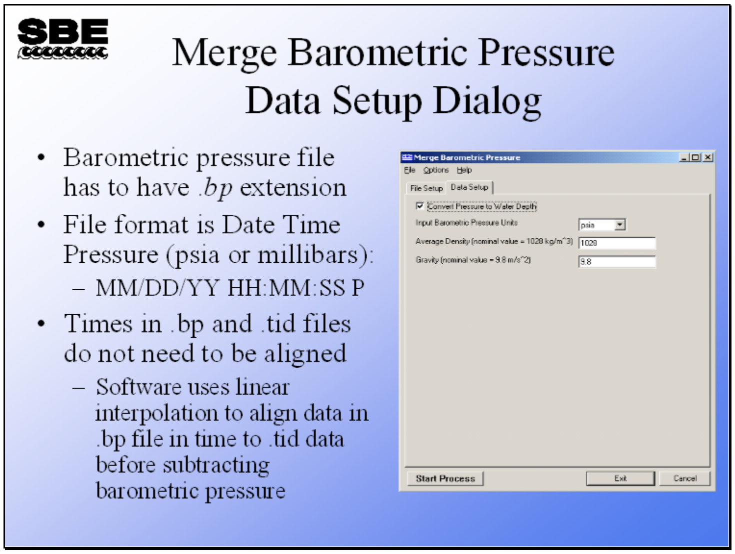

SBE
Activity
• Run *Create Reports* on the data from the last activity
– Input data files are Tokyo.was and Tokyo.wts
– Select all the output variables
• Check the results with a text file editor

Removing Barometric Pressure from Tide Data: *Merge Barometric Pressure*

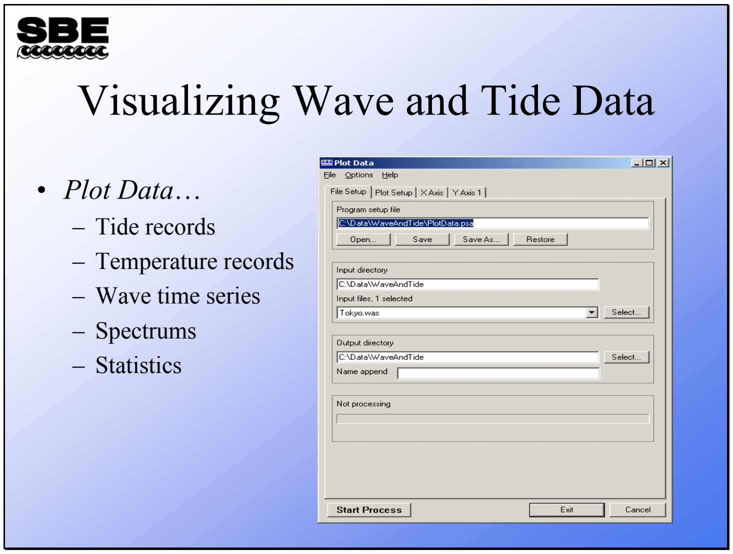


In some places, particularly micro tidal places, barometric pressure can be a significant part of the tidal signal. The *Merge Barometric Pressure* module allows you to input a time-stamped barometric data set and remove the barometric pressure from your tide measurement. The input data for *Merge Barometric Pressure* is date, time, and pressure in millibars or psia.

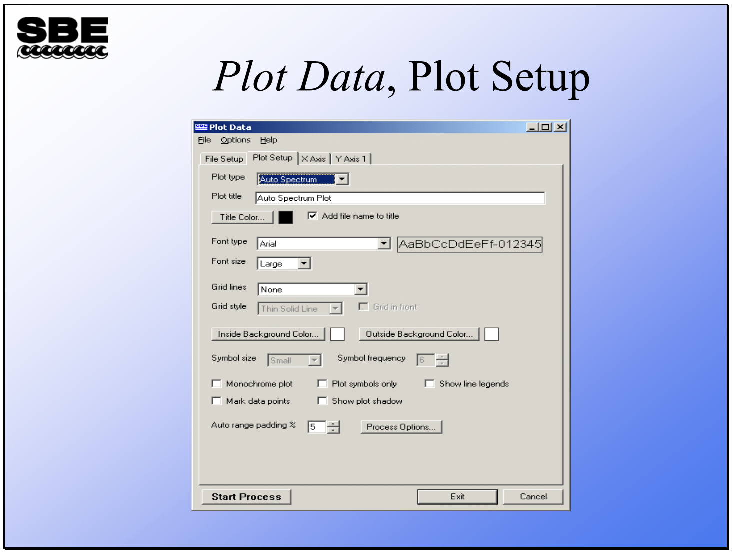
Removing Barometric Pressure from Tide Data: *Merge Barometric Pressure* (*continued*)



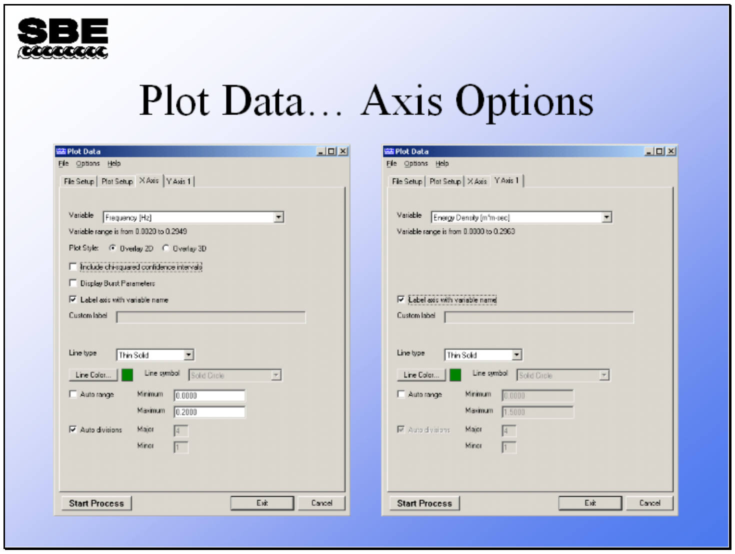
Graphing Wave and Tide Data: *Plot Data*



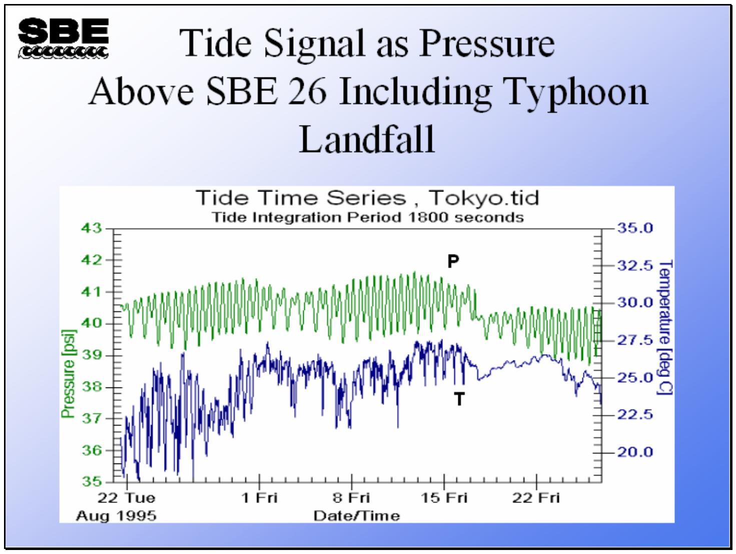
Graphing Wave and Tide Data (*continued*)



Graphing Wave and Tide Data (*continued*)



A Wave and Tide Example



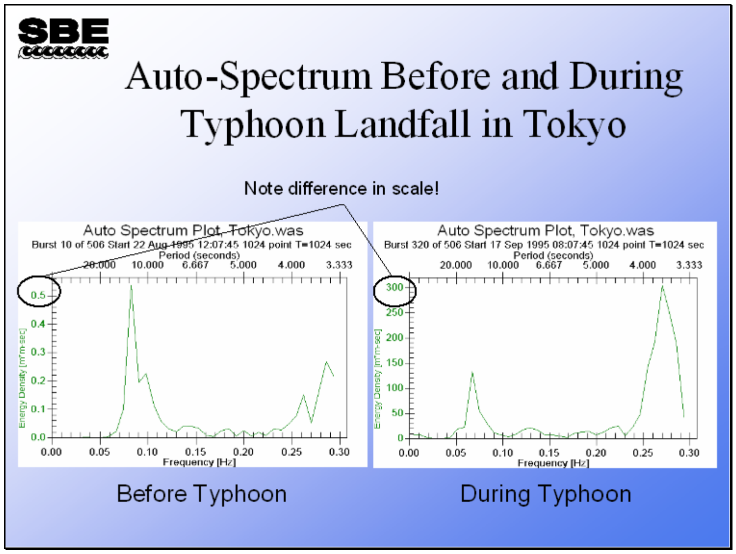
Our example data comes from Tokyo harbor. During this deployment a typhoon made landfall. In this deployment the SBE 26 was fixed in 18 meters of water and was 1 meter off the bottom. Wave bursts were 600 samples long (Why would this be a silly thing to do?).

The green line is the pressure (tide) signal. Note that when the Typhoon comes ashore there is a disruption in the normal tidal cycle, and the pressure above the 26 drops. What could cause the mean water height to suddenly become lower after the typhoon?

The blue line is the temperature recorded by the SBE 26 before and after the typhoon comes in. Note that in this plot the tidally influenced temperature signal all but disappears after the storm.

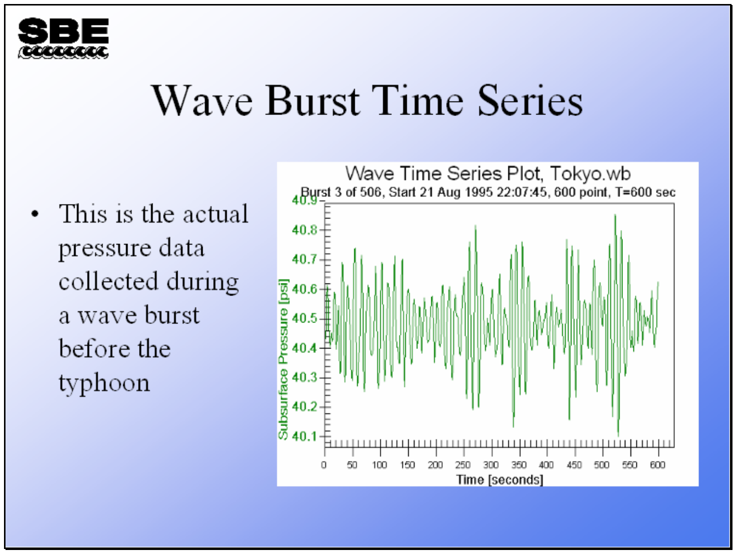
The answer to what is going on is that the platform to which the SBE 26 was attached was moved into shallower water by the typhoon. Will this movement influence the wave spectrum estimates?

A Wave and Tide Example (*continued*)

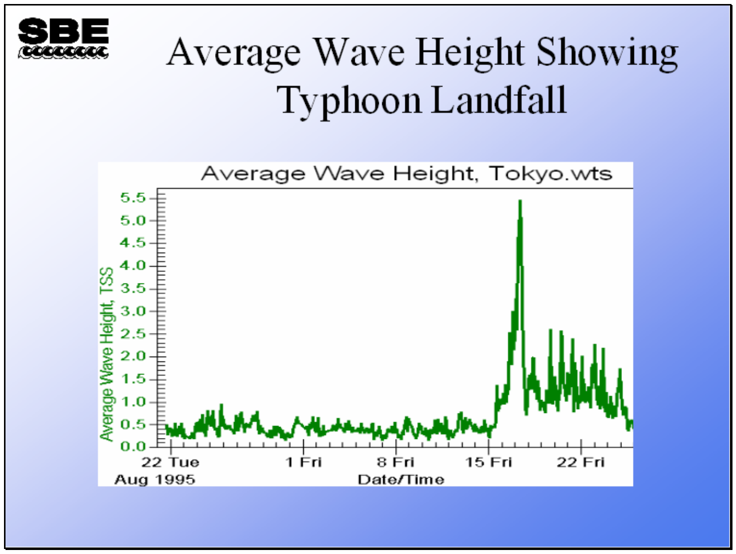


The auto-spectrum plots clearly show the arrival of longer period waves of considerably higher energy.

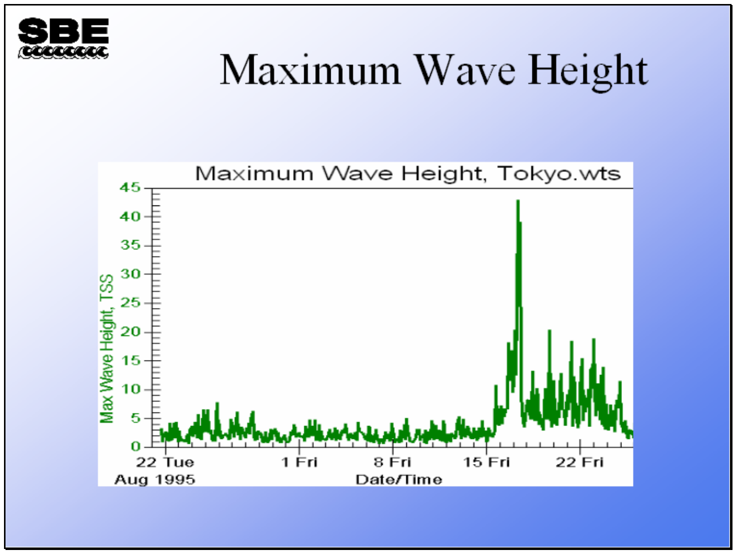
A Wave and Tide Example (*continued*)



A Wave and Tide Example (*continued*)

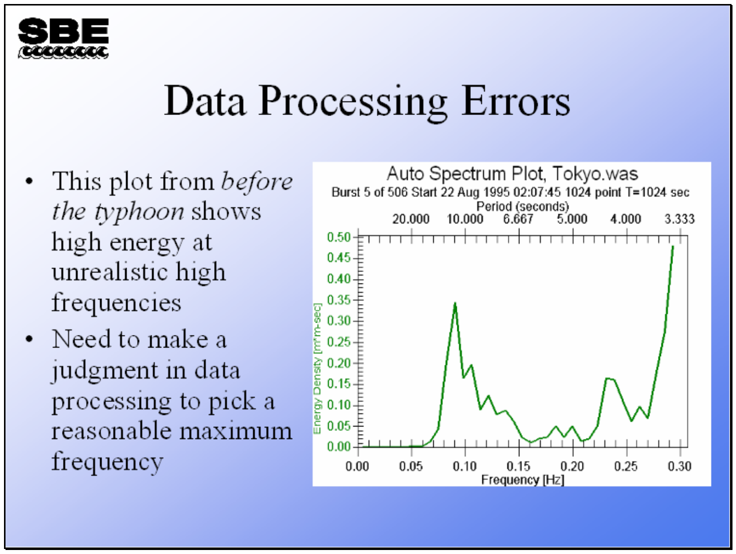


A Wave and Tide Example (*continued*)



Here are the maximum wave heights. See anything funny going on here?

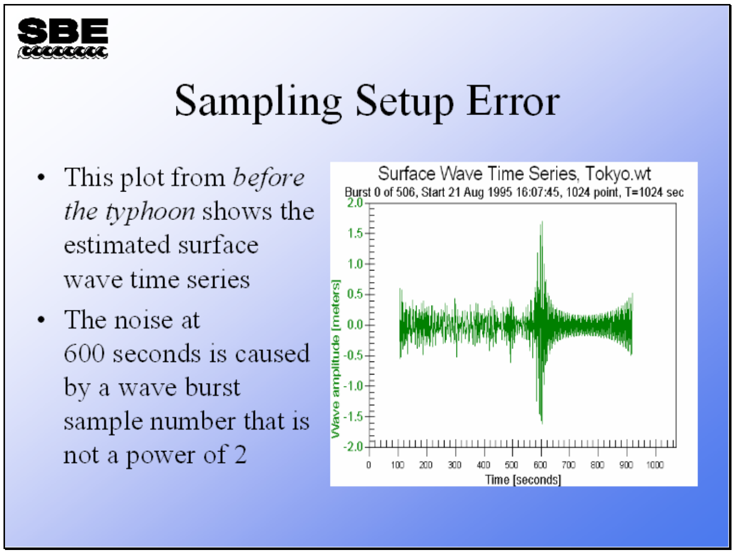
A Wave and Tide Example, Processing Errors



If you look at the entire auto-spectrum, you will often find a large signal at the end of the plot. This is usually an artifact in the data that is caused by the dispersion relation. The calculated attenuation coefficient is erroneously applied to noise, causing the appearance of high energy at high frequencies.

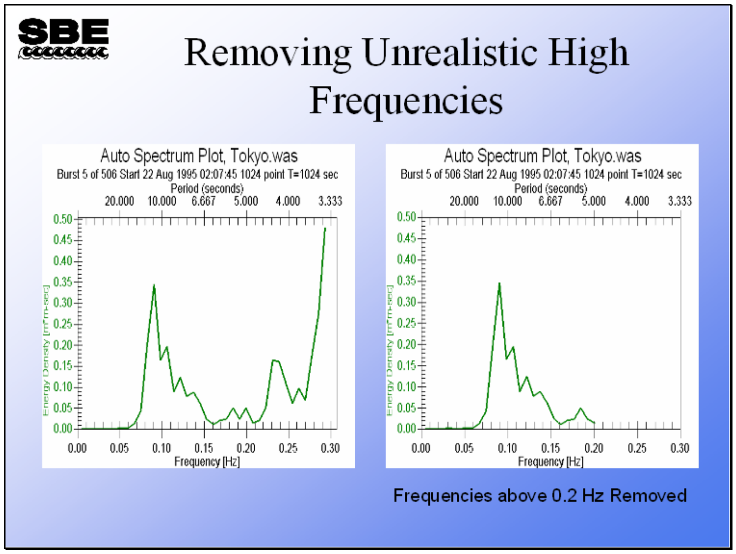
The artifact can be removed by setting the *Minimum period to use in autospectrum* to a reasonable value. You can test this by processing your data with and without the *Minimum period* and comparing autospectrum and the surface wave time series.

A Wave and Tide Example, Sampling Setup Errors



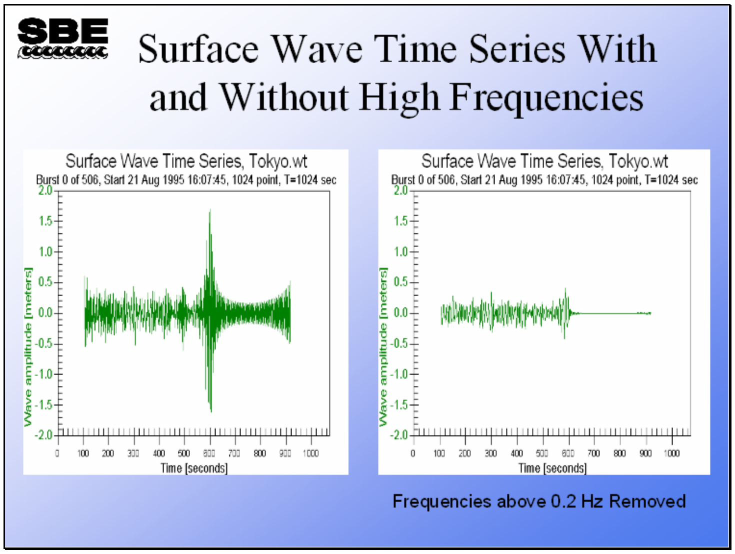
This is an interesting plot. Recall that when we were looking at the plots earlier, the wave burst sample size of 600 points was mentioned. Also recall that wave burst data must have a number of samples that is a power of 2. If the number of samples is not a power of 2, it is padded with the mean water level out to a power of 2. You can see that there is a disturbance in the plot around the 600-second mark and diminished magnitude after it. This is a processing artifact due to the mismatched burst size and high frequency noise being interpreted as wave signal.

A Wave and Tide Example, Correcting Processing Errors



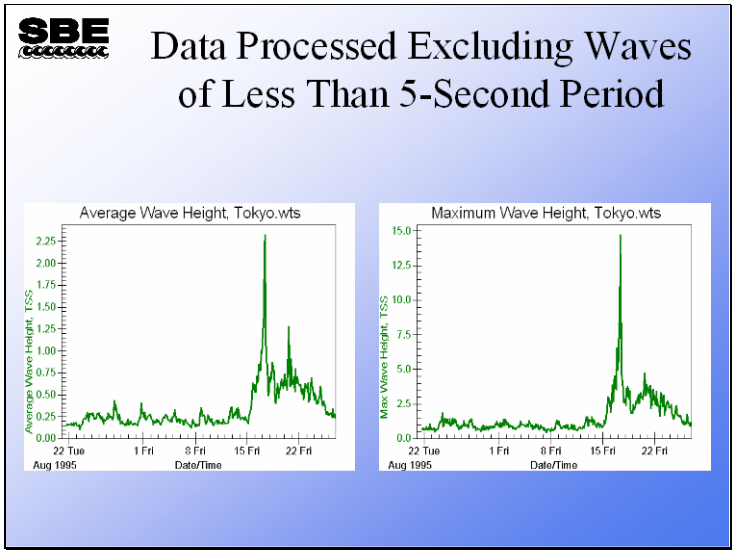
In the plot on the right we have removed all data with period shorter than 5 seconds (corresponding to a frequency of 0.2 Hz). Note that the auto-spectrum shows energy in mainly one frequency band and seems much more believable.

A Wave and Tide Example, Correcting Processing Errors



Removing the high frequency (noise) component of the signal also cleans up the surface wave time series. In the plot on the right, the data artifact beginning at the point where the data is padded to make a power of 2 number of samples is suppressed.

Processing Wave Data: Reality Check



We've recalculated average wave height and maximum wave height, after removing wave periods less than 5 seconds (frequencies greater than 0.2 Hz). These are much more believable than the previous plots.

Activity


SBE
Activity
• Check out your auto-spectrum and time series data with *Plot Data*