# A Cheat Sheet for Processing with Wavesmon 4.04

This version is for the
5 beam Sentinel V ADCP
And all other Workhorse Sentinel ADCPs
Updated 3/20/2021
Marinna Martini, P.E.

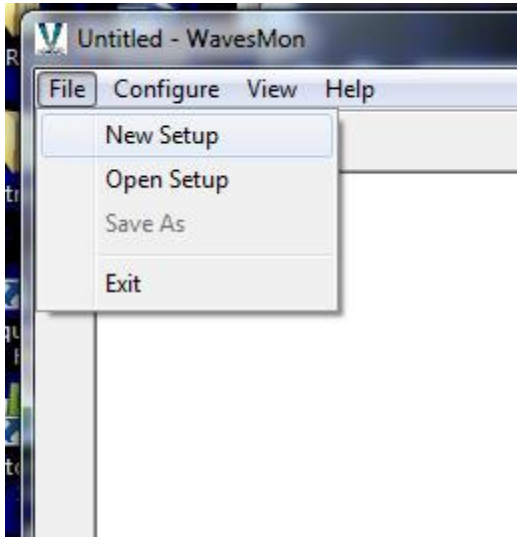
# Things to keep in mind:

- This is a guide to things to pay attention to when setting up wavesmon.
- Wavesmon is now embedded in Velocity, a software package by Teledyne RD Instruments. Screen shots here may no longer exactly match.
- **Screenshots are from wavesmon version 4.04**
- You might want to make a copy of this presentation and mark it up as a record of your processing.
- Brandon Strong, who was the main force behind wavesmon, left Teledyne in 2017. You will see notes I have attributed to him throughout.
- Throughout these notes, I compare approaches for several experiments I participated in, and processed data for, while I was at USGS. Since they were produced for the US Government, these notes are in the public domain per: https://www.usgs.gov/information-policies-and-instructions/copyrights-and-credits#copyright

- Charlene Sullivan was the first to vet the use of wavesmon during the Myrtle Beach project. She had some recommendations for wavesmon settings
- Cape Hatteras 09 was a typical waves deployment
  - 2048 samples at 2 Hz hourly with 0.5 m bins using waves mode (H commands)
  - Packets data (i.e. full profile was not saved during wave data collection to save memory)
  - Data for mean currents (PD0) need to be split from wave packets before processing
- Cape Hatteras 10 (Nearshore) was an experimental waves deployment – the Workhorses were set to record similarly to the Aquadopps.
  - 1024 samples at 1 Hz hourly, 0.4 m bins, using burst sampling mode (TB, TC commands)
  - Full profile data were always saved, mean currents to be calculated from these.
- Fire Island 2014 had many ADCPs similar to Cape Hatteras 09 setup with the following twist
  - Fine sediment and no zeroing of pressure was a problem at some sites

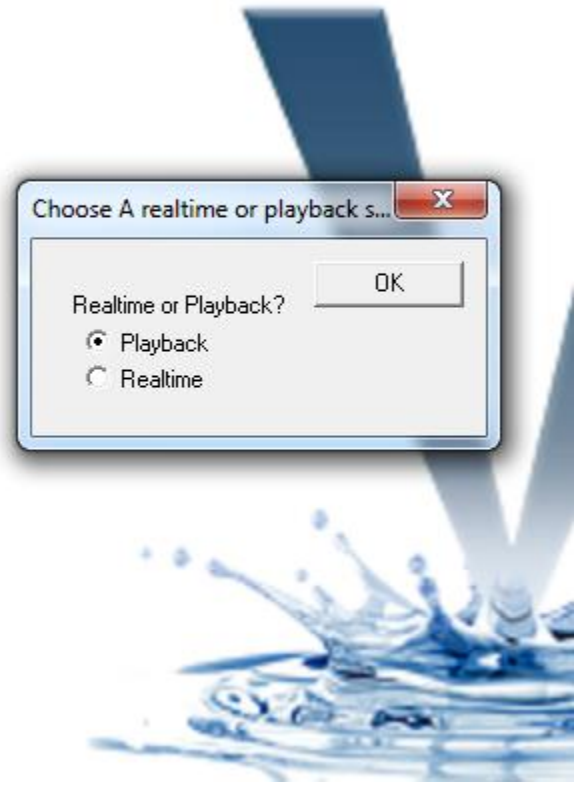
# Starting a new processing run

- First, make a directory in which the waves output will go. It will be many small text files.
- New Waves Project

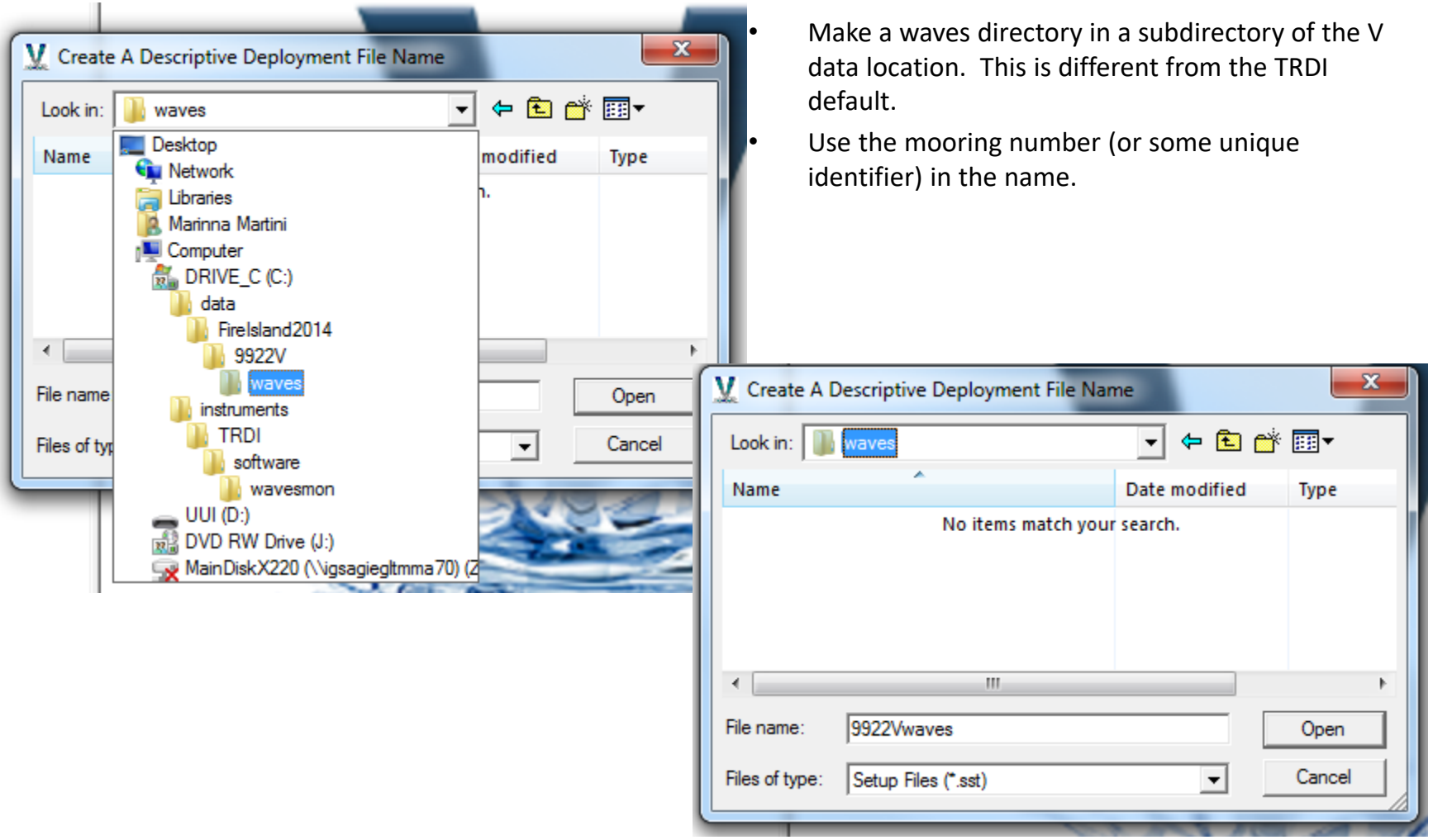


# Select Input Type

- Playback

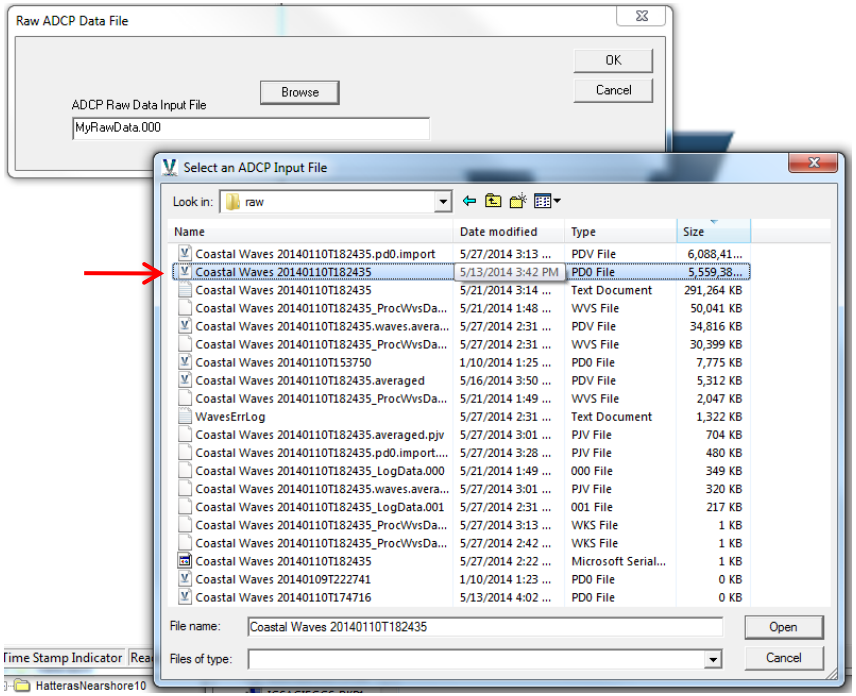


# Set Up The Directory

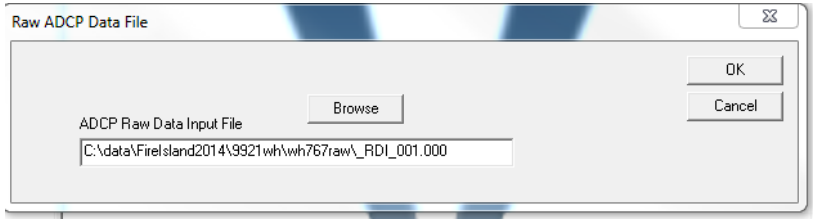



- Make a waves directory in a subdirectory of the V data location. This is different from the TRDI default.
- Use the mooring number (or some unique identifier) in the name.

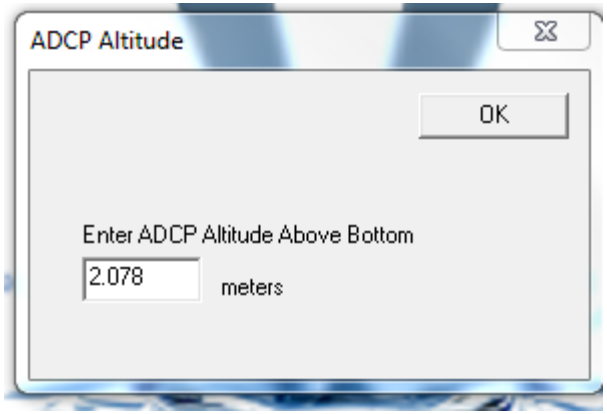
# Select the Raw Data File




- Find the original raw data file. It should be .PD0
- Finding the raw data might be tricky if you have already processed the data using the Velocity software, as Velocity outputs more PD0 files.
- For Workhorse Sentinels, the *.000 or *.PD0 file names as always (see below)
- When you open the file, if the data were not sampled at 2 Hz, you will get a notice.

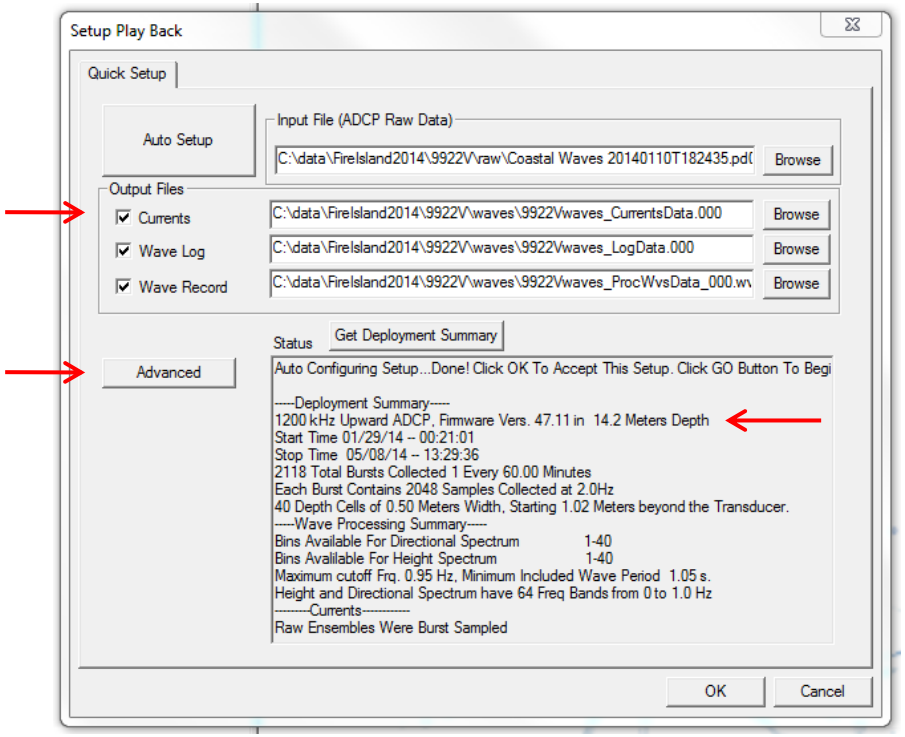


# Deployment Info



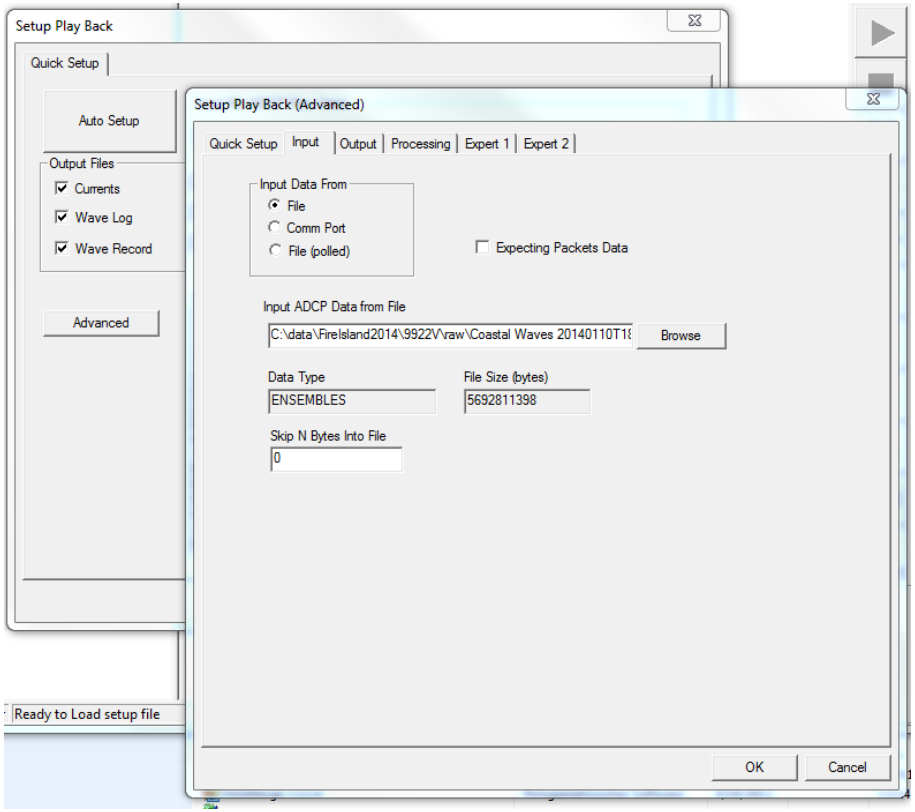

- Height above bed is all this version offers to change at this point

# Output Choices



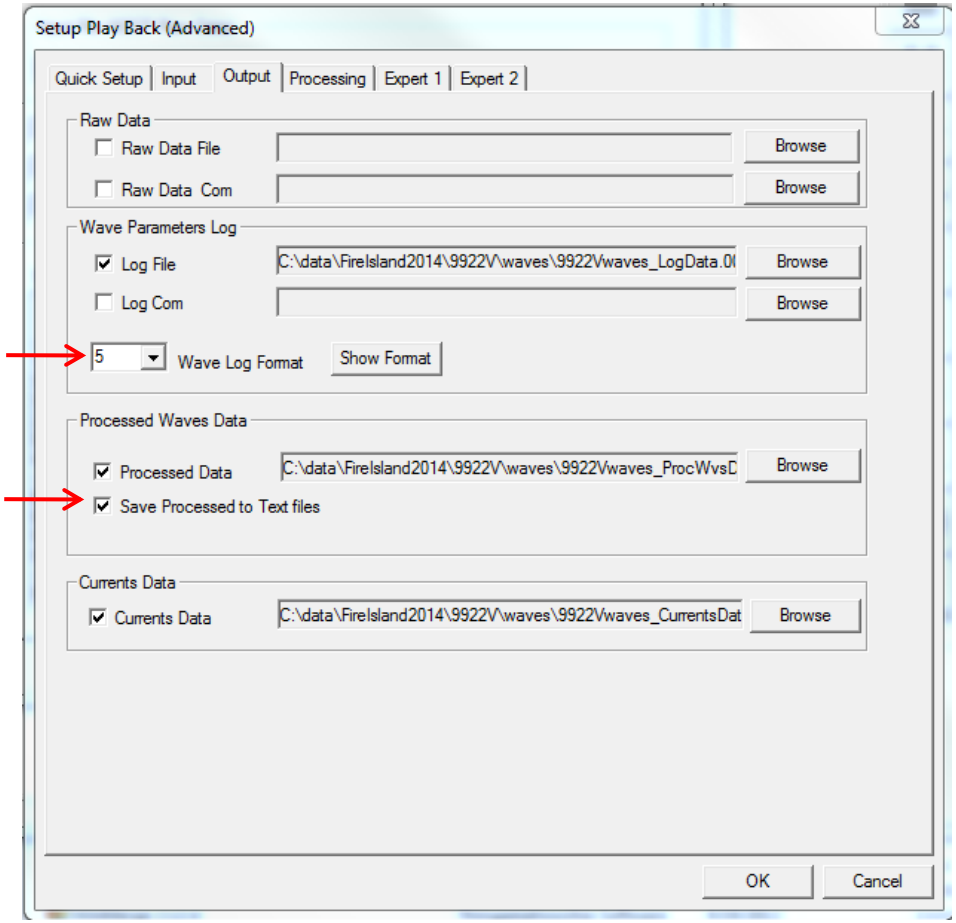

- Do output currents data, the default is unchecked.
- Pay attention to the depth in the deployment summary. If there's a problem with the depth sensor, this will not be correct here.
- Go to advanced

# Output Choices: Input tab



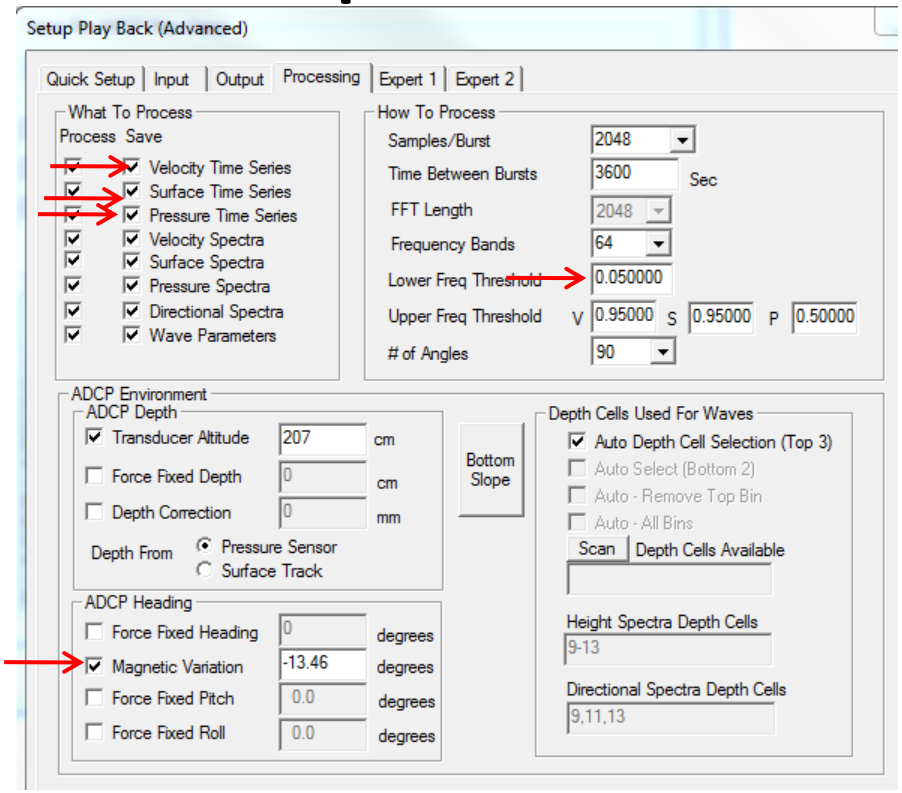

- Nothing to change here.
- The V saves single ping data as its default.

# Output Choices: Output tab




- We want to save the processed data to text files.
- The wave toolbox expects wave log parameter format #5, the details are in the notes for this slide.
- Format 5 is special because it is fully comma delimited.

# Output Choices: Processing tab



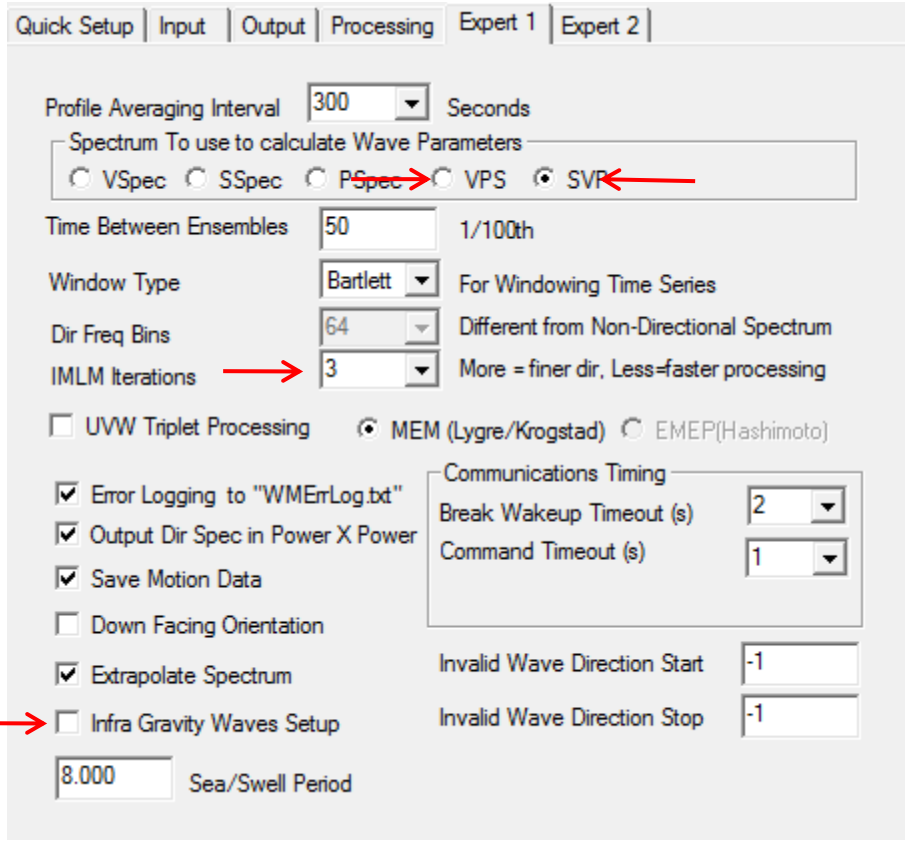

- Make sure the sampling here matches how the instrument was programmed for wave bursts (or bursts, or continuous)
  - For continuous data, check that you have sampling intervals that you intend, e.g. 17 min every hour used to compute statistics
- Transducer Altitude only to the nearest centimeter
- Magnetic Variation to be applied, West is negative
- We want all the time series types for comparison
- Lower Freq Threshold
  - Charlene: 0.05
  - Default 0.03

# Note on FFT implementation

From Teledyne RD Instruments documentation:
4. Zero Fill: The fastest FFT algorithms operate on time series that are powers of 2. Because of this we have typically operated on 2048 samples when performing waves processing. Often our customers would like to collect 20 minutes or 30 minutes of data, at 2 Hz, which does not correspond to a power of 2. In the older implementations we used the data that is the nearest power of 2 smaller, for waves processing. Currently we choose an FFT length that is the nearest power of 2 larger, fill the unmeasured samples with zeros and normalize the resulting spectra by the ratio (FFT samples/ measured samples) to account for the power. This is a standard approach in spectral processing. The FFT length is determined automatically and does not require user control. The value to the end user is:
• Every last collected sample is used in the calculation.
• There are no sampling interval limitations. People can choose whatever they want.
• The software gets simpler and the whole idea of FFT length goes away entirely.
• Historic data recorded with default settings (2400 samples) can be reprocessed with an immediate 20% improvement).
• Comparisons with Buoys and others can use the exact same sampling time regardless of the number of samples.
• Implementation: The samples per burst or Burst Length can be any number. The FFT length is determined by selecting the next larger power of two. The Burst Length is the number of samples loaded into the WaveRecord data structure and used throughout the processing at every stage until the actual FFT is performed. In this fashion the raw data can be output or manipulated by other processes without the arbitrary power of two limitation. Frequency banding of the output spectra is determined by the (power of two) FFT length.

Brandon Strong 11/4/2014: Wm4x extrapolates the unmeasured part of the spectrum. So if the measurement was taken too deep it does a best guess at the highest frequencies based on the last measured value and the frequency drop we expect from mother nature. This should improve the results over 3x but will not provide wave direction at unmeasured frequencies.

# Output Choices: Expert 1 tab

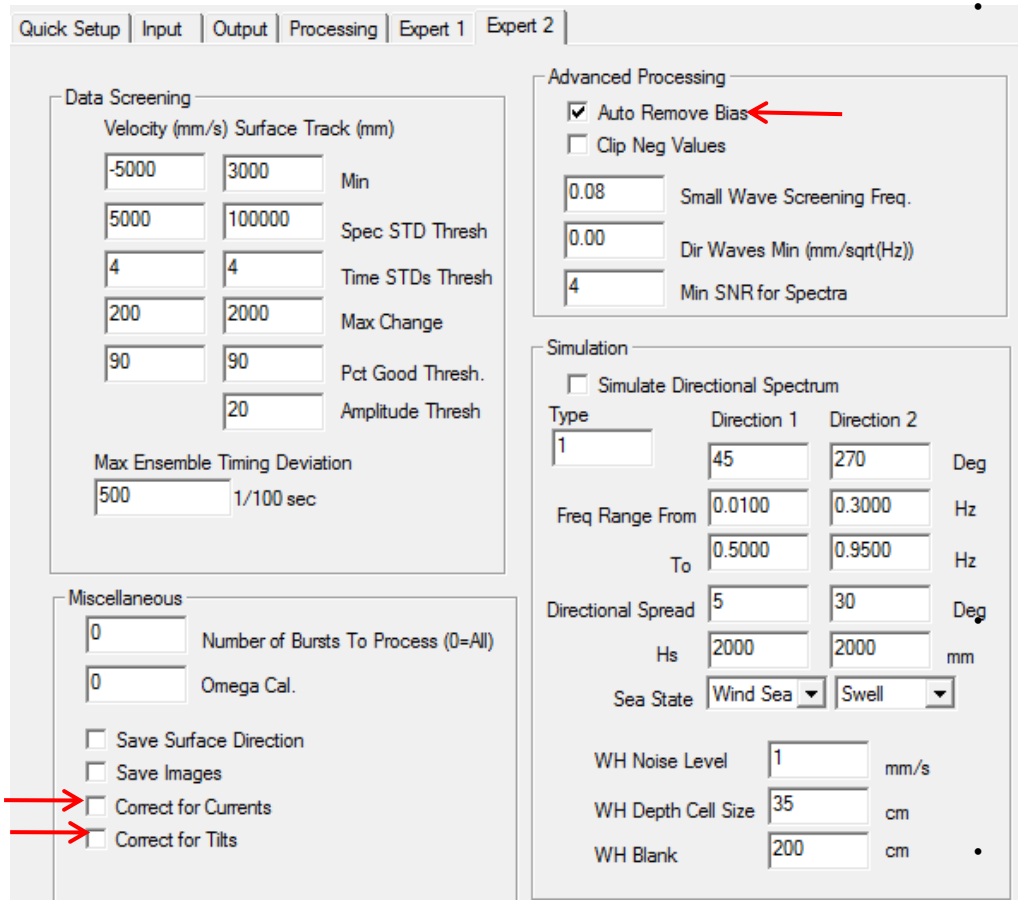



All these have changed significantly.

- Spectrum to use depends on presence of a vertical beam
  - For Sentinel V we want the default SVP to use the vertical beam's surface following as the primary source of wave statistics – better than pressure
  - For Workhorse Sentinels without a vertical beam, we want VPS for velocity spectrum to be the primary source of wave statistics
- Make sure the sampling here matches how the instrument was programmed for currents
- Lower Freq Threshold
  - Charlene: 0.05
- IMLM iterations
  - Charlene: 3 is most efficient
  - For Fire Island, we want fine resolution of wave direction, so we change this to 3
- Infra Gravity Setup
  - This might be good to turn on for sampling that was long (4800 or 9600 samples, e.g. 40 min or longer at 2 Hz.

"The band averaging is the same as it was. If you sampled 2048 samples then you will get that much data in your result. Previously if you sampled 2400 we only used 2048. Now when you sample 2400 we use and output all 2400. There is not a mathematical drawback to zero filling. It is beneficial to our measurement being completely representative of the 20 minute sampling interval and not just 17+min. I do output a root mean square difference between surface track spectrum and velocity derived spectrum." Brandon Strong email 11/4/2014

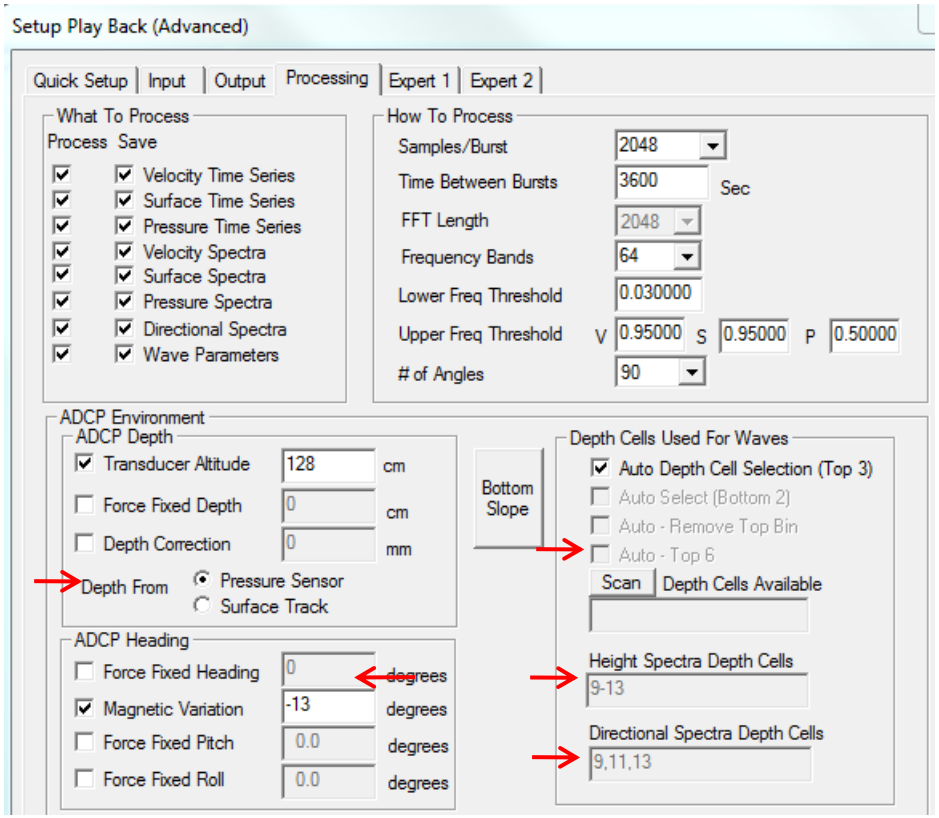
# Output Choices: Expert 2 tab




All these have changed significantly.

- Auto Remove Bias: This switch turns ON and OFF the automatic removal of rectification bias. The default is ON and the only reason to turn it OFF is if someone has collected data at less than 2Hz.
  - TRDI: Each of the techniques for measuring wave height spectra (pressure, surfacetrack, and velocity) has its own set of error sources and its own measurement noise. We assume that the measured time series is a superposition of the signal (waves) and the measurement noise and that the measurement noise is white. The Fourier transformation of white noise is white noise. This white noise has a zero mean distribution; however when we square the frequency spectrum to get power, the noise becomes always positive. This biases the power spectrum by adding a positive offset. To measure this bias the software calculates the mean of the power spectrum at frequencies too high for environmental wave energy. By finding the noise floor of the power spectrum, it can then be removed. This process is done for each of the independent height spectra calculations and is required in order to get good agreement among the three, because the bias has been subtracted from the overall spectrum.
  - Hatteras 09 measured at 2 Hz – ON
  - Hatteras 10 measured at 1 Hz – OFF
- Correct for Currents – Uses the mean currents to correct the wave spectra for the effects of currents. A Doppler shifted dispersion relation is used to calculate wave number "k."
  - TRDI: This should be applied if the currents near the measurement exceed 0.80 m/s.
  - Charlene: apply it
  - Marinna: this is for very strong currents (Brandon says > 1.8 m/s). Prefer to follow TRDI recommendation for OFF
- Correct for Tilts - The tilts switch can partially correct for a badly tilted ADCP. This assumes that the tilt is fixed.
  - TRDI: If the pitch or roll is not greater than 5.0 degrees it is not recommended to turn this on.
  - Charlene: apply it
  - Marinna: prefer to follow TRDI recommendation for OFF

# What if my pressure sensor failed?



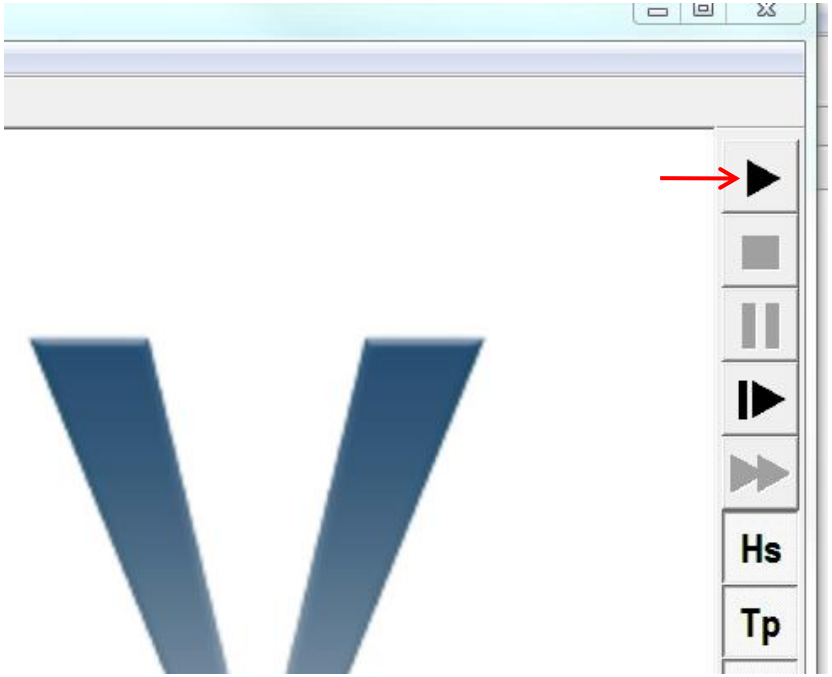

- The first thing to try is to use depth from surface track.
- Otherwise try setting a depth offset, using depth from the pressure sensor. This is if the surface is not detected by surface track.
- Finally, if resorting to fixed depth, depth should be the nominal depth of the ADCP's transducers
- It is best to get the depth right and allow wavesmon to choose the bins. If all else fails, one can choose bins manually. Use winADCP to view the data, and carefully choose bins just below the surface.
  - RDI says (page 24 of the Wavesmon manual):
    - "Height Spectrum Depth Cells. Several depth cells can be chosen, however, if high frequency data is of interest, it is recommended that you choose depth cells that are as close to the surface as possible. Make sure that the highest depth cell is below the surface at low tide."
    - "Directional Spectrum Depth Cells. The direction spectrum algorithm must invert a sensor-by-sensor matrix at each frequency band. Empirically the algorithm appears to achieve good results with three or more depth cells. Theoretically, the depth cells should be chosen with some spread and farther up in the water column so that the array has as much aperture as possible. Be sure that you do not choose depth cells beyond the profiling range of the instrument."

"If you use pressure depth you can set a depth offset. This uses the pressure sensor but offsets the depth used by the amount you specify. You can set a fixed depth, which uses the same depth always (no tidal adaptation). Or you can use depth from surface track. Depth from surface track is best if the surface track was quality and available. It defaults the mean water depth from the vertical beam surface track in Sentinel V. Brandon Strong email 10/24/2014"

"Mean water depth can be a serious issue. In packets mode the mean depth is used to choose the bins saved, in-situ. So the accuracy of the pressure sensor can be really important. Continuous ensembles are easy to handle after the fact in post processing." Brandon Strong email 10/24/2014

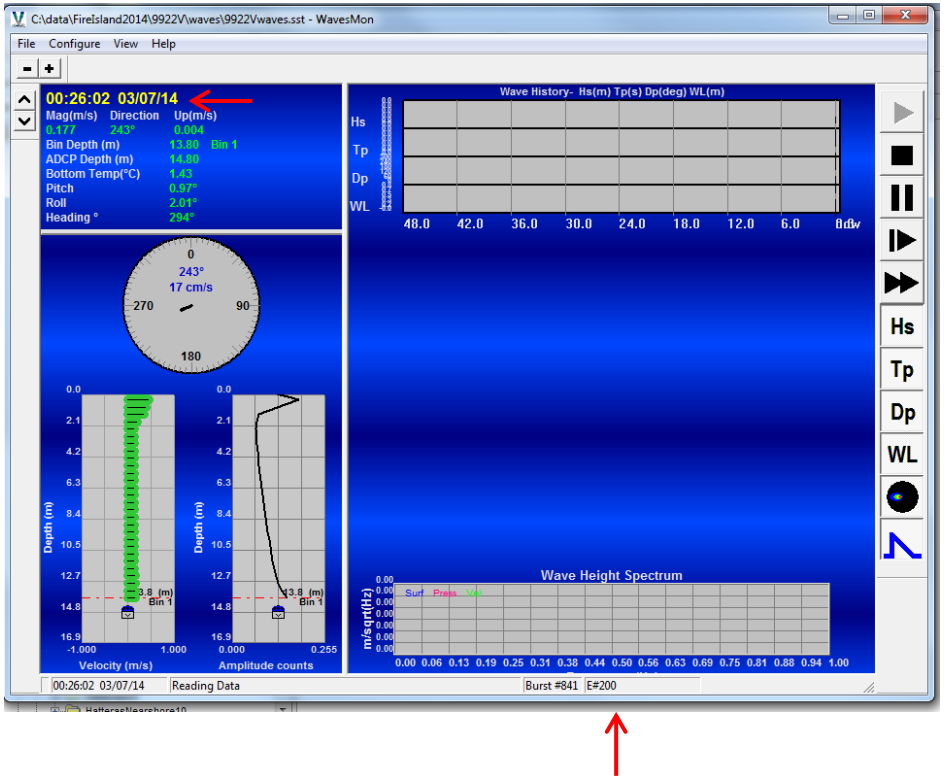
"Wave direction is depth coherent so measuring deeper in the water column does not change the answer. The exception is if the peak period is unmeasured because it is higher frequency and measurement was deep. As you know Dp is the peak direction at the peak period. " Brandon Strong 11/4/2014

# Start Processing



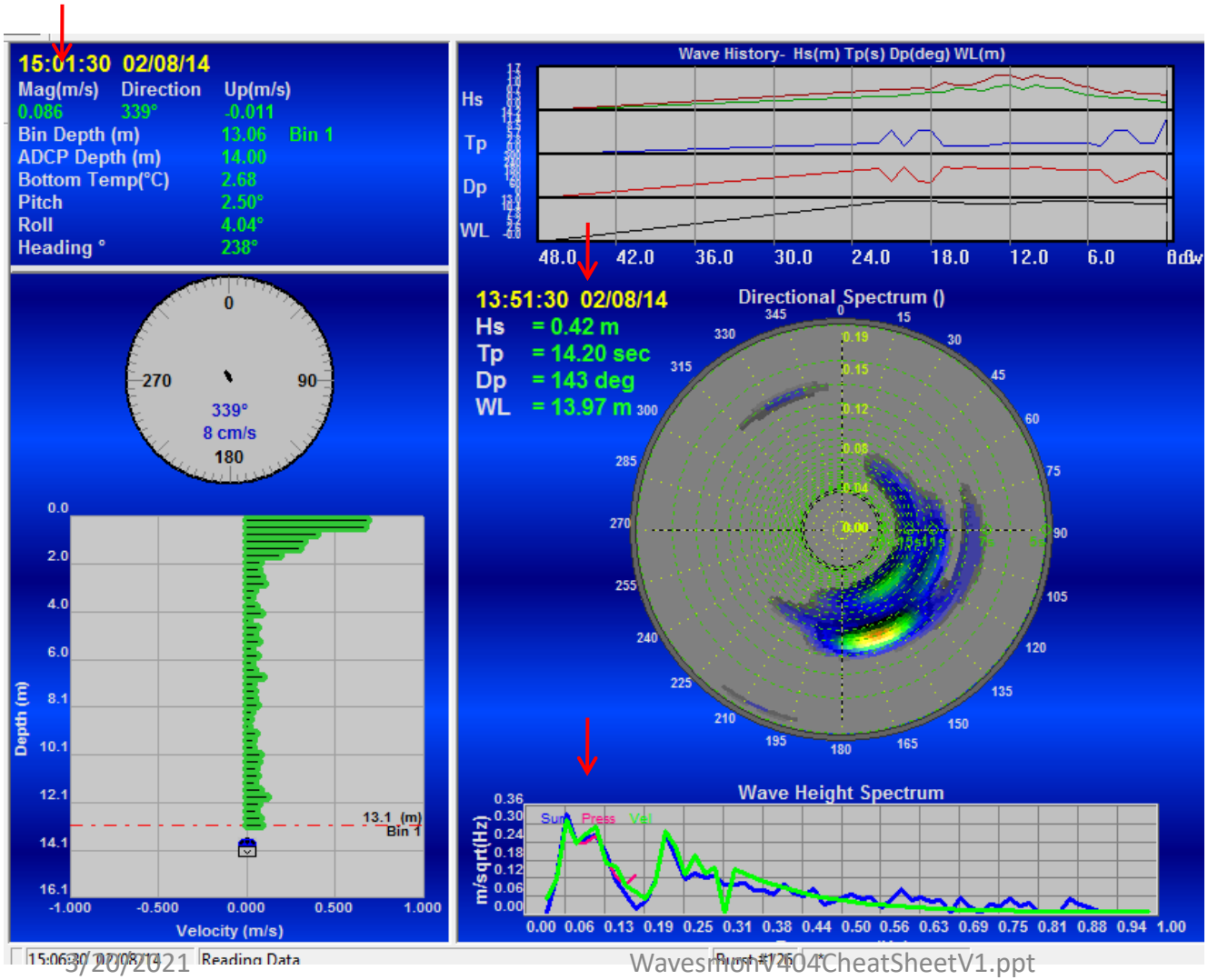

- Hit the play button
- Processing three months took about 15 min

# Check in on your data



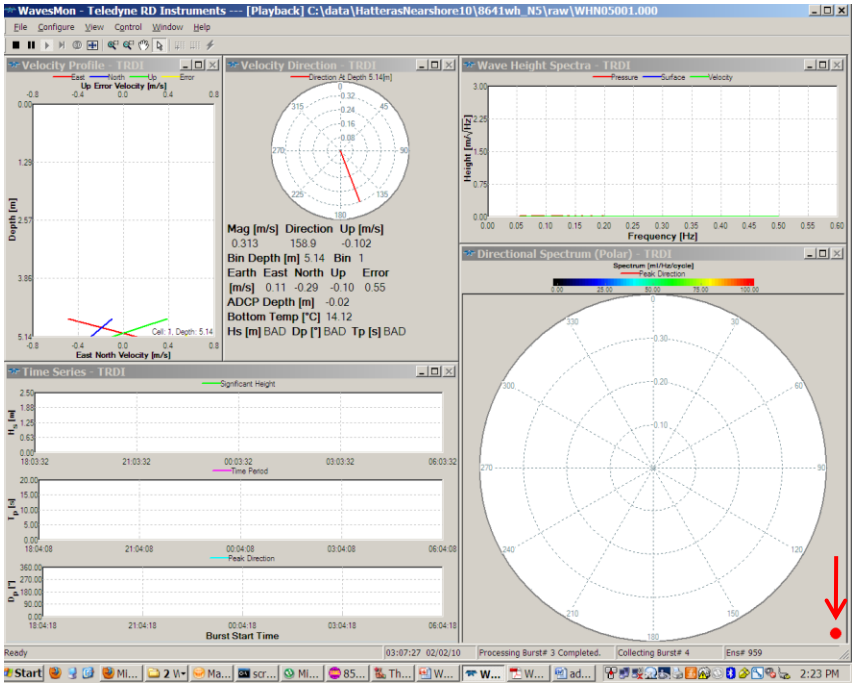

- Screen shot of normal data
- The wave spectra do not display for some reason.
- Note the time stamp. Know what the last time stamp should be so you can make sure all data were processed.
- The Burst processing us usually behind the data collection
- The ensemble number should update rapidly.
- TRDI wavesmon gives three non-directional spectral solutions. The degree to which they agree is an indication of the quality of the wave data.

# Check in on your data



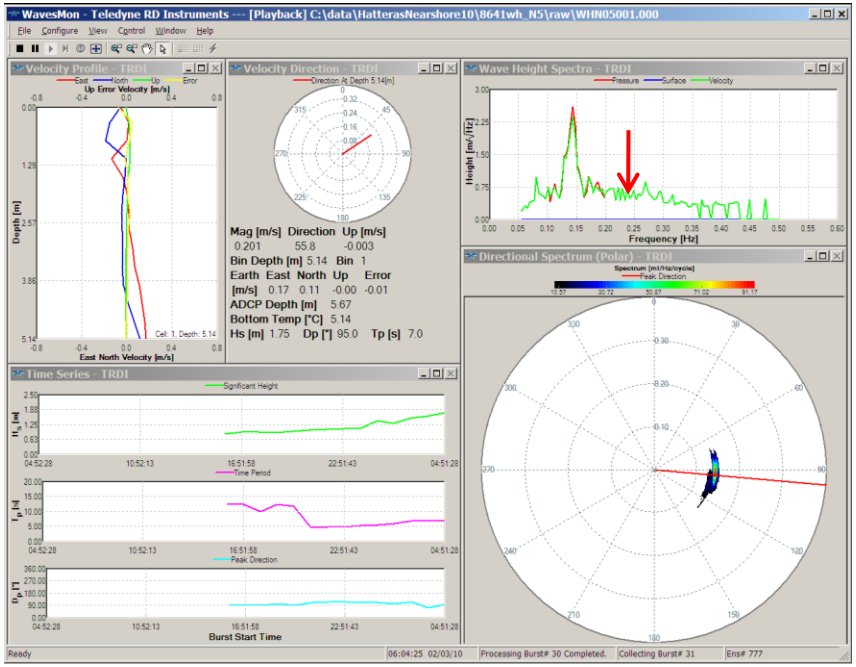

- Screen shot of normal data
- Note the time stamp. Know what the last time stamp should be so you can make sure all data were processed.
- The time stamp should update rapidly.
- TRDI wavesmon gives three non-directional spectral solutions. The degree to which they agree is an indication of the quality of the wave data.

# Instrument out of the Water




- Screenshot of data when instrument is out of the water
- Red don't indicates a problem with the data

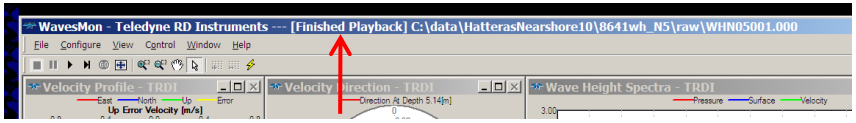
# Lost Contact with Surface

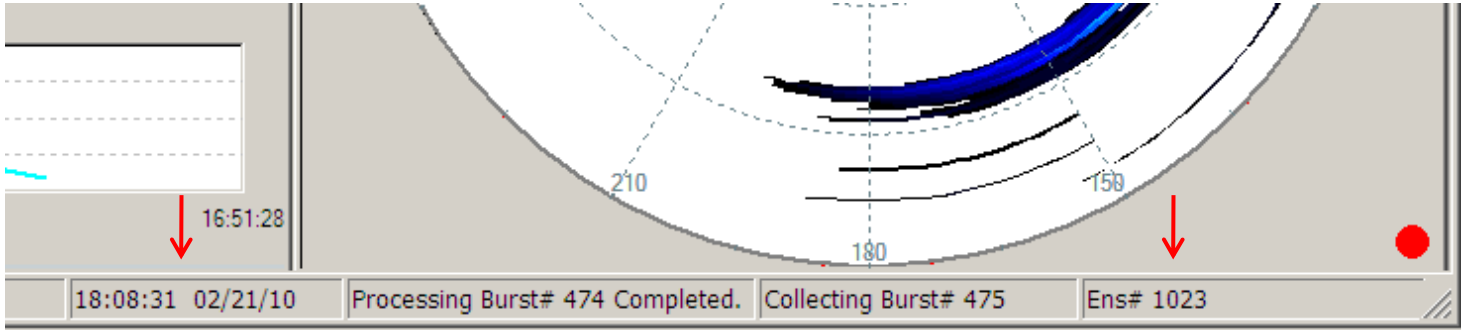



- TRDI wavesmon gives three non-directional spectral solutions. The degree to which they agree is an indication of the quality of the wave data.
- Velocity and surface spectra will go to higher frequencies than pressure, which is attenuated by the depth.
- Since the velocity spectra are calculated from bins near the surface, it can drop out during extreme conditions. This is a case when one might re-process with selected bins, perhaps lower in the water column.
- Waves detected but surface not seen, only two of the spectral lines are visible.
- Good data are still available, note pressure and velocity spectra agree well

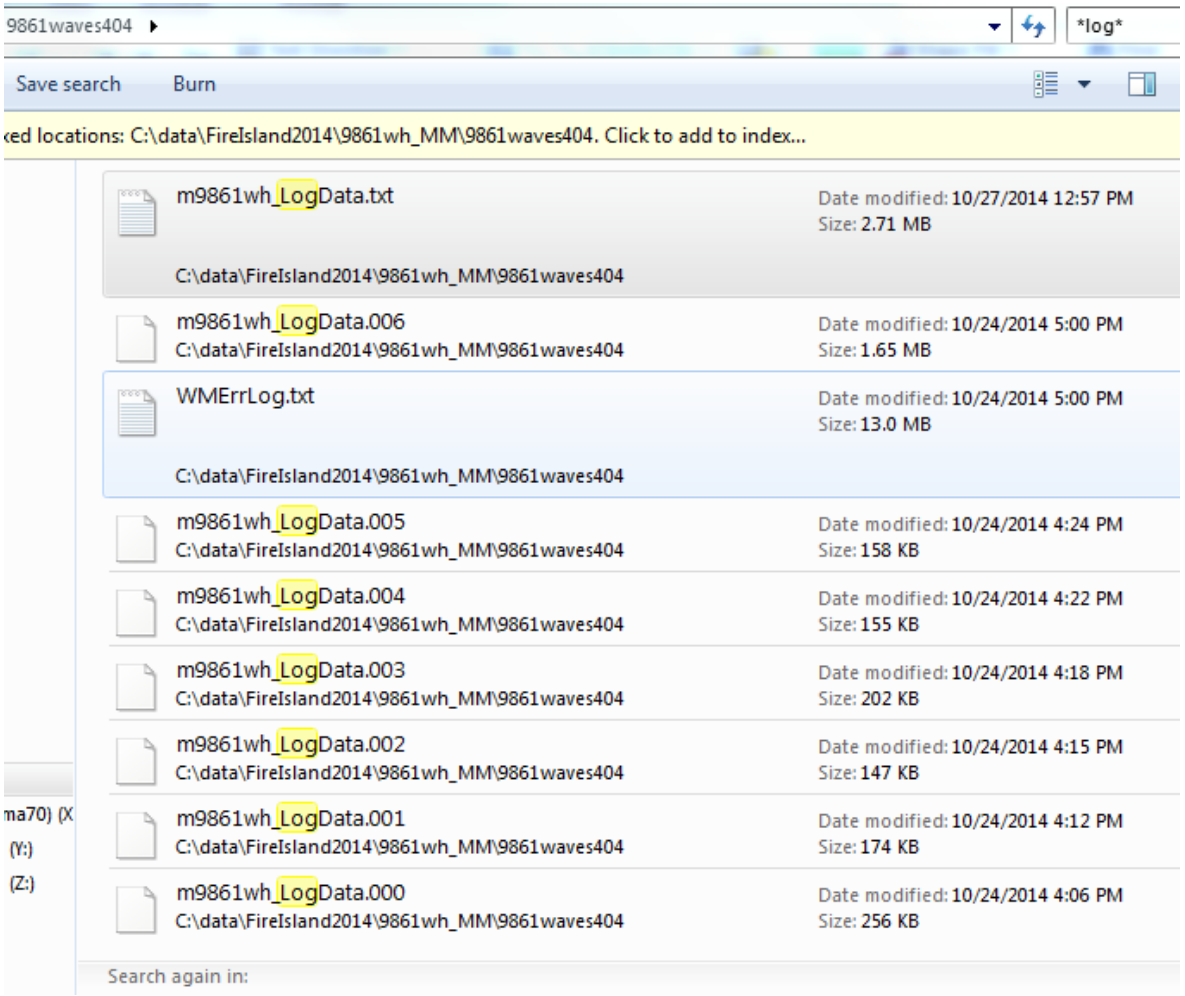
# Data are almost ready for MATLAB

- Your are done when
  - the title bar says finished
  - The date is at the end of your deployment
  - Ens# is no longer updating



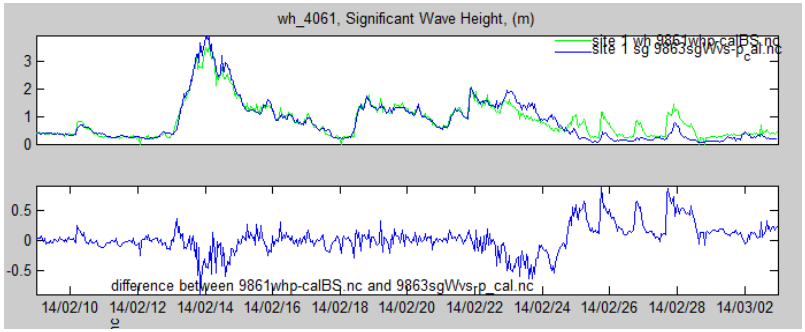
# Check the log files

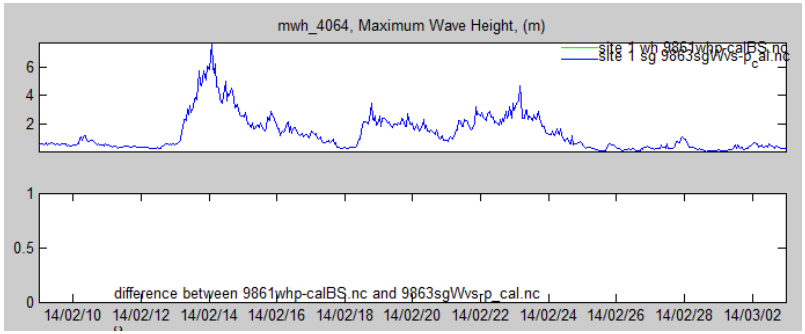



- Wavesmon may output multiple Log Data Files.
- Wavesmon 4.04 does not allow the user to specify larger data files
- Wavesmon 4.04 if run several times may write several LogData files.
- Wavesmon 4.04 if restarted several times will write several LogData files.
- Examine the files. Make sure you know which one contains the full deployment statistics
  - Check the burst number and dates
  - If necessary, concatenate multiple files using a CMD window or in MATLAB using the !
  - Do not overwrite the existing files
  - See example below.
- In your MATLAB script, set settings.logfilename to the name of one file that contains all the #5 format stats data

```
!copy m9861wh_LogData.000+m9861wh_LogData.001+m9861wh_LogData.002+m9861wh_LogData.003+m9861wh_LogData.004+m9861wh_LogData.005+m9861wh_LogData.006
m9861wh_LogData.txt
```

# Where's Max. Wave Height?




- Hmax is in the output file as a variable but there is no (or very little) data
- This would be an issue where surface is lost or pressure is biased

Brandon Strong 11/17/2014:

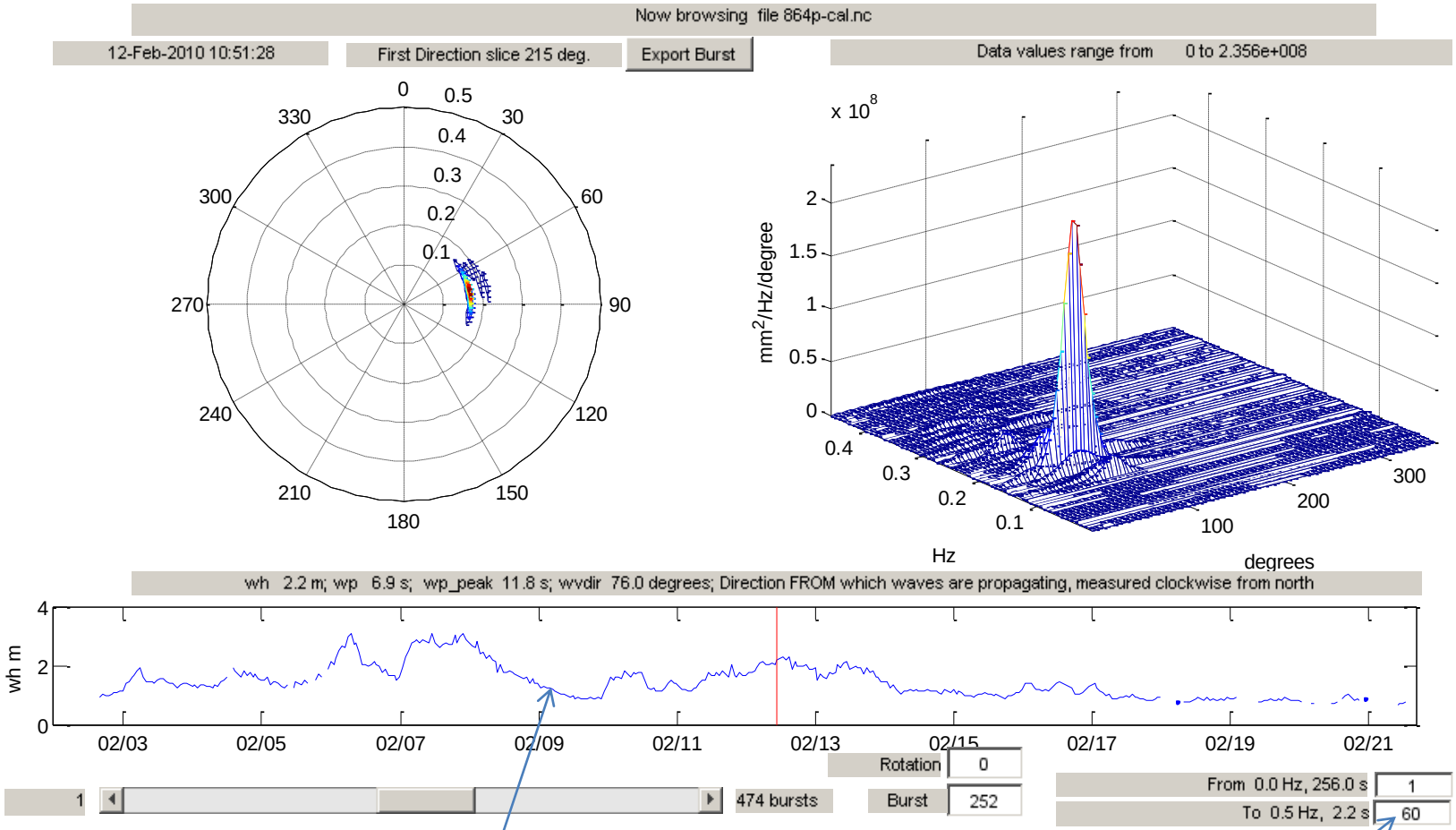
- Hmax is tricky because it is an outlier by definition.
- When we incorporated zero crossing parameters derived from surface track, we did a real measurement for Hmax. The old version simply took Hs and multiplied by 1.27. The new one uses surface track data as long as it is good.
- Zero crossing must be derived from surface track. If surface track data was spurious then Hmax will also be rejected more often.
- In 4 beam workhorse systems surface track is often spurious. There is some logic to try to ensure that there is some agreement amongst the beams about the basic time frame when Hmax occurred. This avoids Hmax becoming an erroneous measurement.
- In vertical beam systems like Sentinel V, the 5$^{th}$ vertical beam is always used for surface track and the results are really robust.

# In MATLAB

```
% --------- set up the information needed by the programs
%
% this is what should be used if using a single source of global attributes
% 9/15/07 etm
% modified to use the universal metadata file : 7751glatt.txt
% change the line below to fit your system path for the location of m_cmg
ncclose all; fclose all; diary off
clear % a good idea
gatt=read_globalatts('..\..\glob_att986.txt');

% assign the rootName based on the Mooring #, then plug in values from
% the global attributes.  UNIX users : check CASE of files carefully!
rootName=num2str([gatt.MOORING 'wh']);
rootName=[rootName '1'];   % ADCP is usually the top thing, but it could be
                % second or third- change this value accordingly
%% the basics
% The capitalizations are important, these field names are written as the
% attribute names in the .nc file
settings.outFileRoot = rootName; %a string specifying the name given to the
%                       NetCDF output files, in single quotes
%                       excluding the NetCDF file extension .nc
settings.MOORING = gatt.MOORING; % mooring number (USGS) or other identifier
settings.Deployment_date = gatt.Deployment_date; % the in water time
settings.Recovery_date = gatt.Recovery_date; % the out of water time
settings.DATA_ORIGIN = gatt.DATA_ORIGIN; % with collaborator's data, could be USC, etc.
settings.WATER_DEPTH = gatt.WATER_DEPTH; % m (DO NOT OMIT!)
settings.WATER_DEPTH_datum = 'Mooring Log';
settings.EXPERIMENT = gatt.EXPERIMENT;
settings.PROJECT = gatt.PROJECT;
settings.DESCRIPT = gatt.DESCRIPTION;
settings.DATA_CMNT = '';  % your metadata
settings.SciPi = gatt.SciPi;
settings.latitude = gatt.latitude; % negative degrees in western hemisphere
settings.longitude = gatt.longitude; % always positive degrees in northern
%settings.platform_type = gatt.platform;
settings.magnetic_variation_at_site = gatt.magnetic_variation;
settings.magnetic_variation_applied = gatt.magnetic_variation;
settings.wavesmon_isV = 'no';

settings.ADCP_serial_number = 6983;
settings.ADCPBinSize = 0.3; % meters
settings.wavesmon_version = 4.04;
settings.metafile_name = mfilename;
settings.metafile_author = 'Martini';
settings.metafile_version = 0.0;
% this is the name of the output #5 log file of stats data
% olderwavesmon this file was *_Log5.*
% wavesmon 4.04 and up it is
% you may need to concatenate the files here, if so, use .txt as the
% extension
settings.logfilename = 'm9861wh_LogData.txt';

diary(sprintf('run%s',datestr(now, 30)))

% output had many log files. need to concatenate
!copy
m9861wh_LogData.000+m9861wh_LogData.001+m9861wh_LogData.002+m9861wh_LogData.003+m9861wh_LogData.004+m9861wh_LogData.005+m9861w
h_LogData.006 m9861wh_LogData.txt

adcpWvs2nc(settings);

diary off
```

- Translate data to netCDF using the wave toolbox m_cmg\branches\mm_branch\wave_tbx
  - adcpWvs2nc
  - Example script at left uses read_globalatts to grab metadata
- View data with browseWaveburstNative and browseWaveStatsNative (see next slide)

browsewaveburst('wavefile','864p-cal.nc') or browseWaveburst('wavefile',wavefilename,['velfile',velfilename])




Click in plot to go directly to a time period

A smaller range of frequencies will render faster, max is 128

Other notes from Brandon Strong:

- We always recommend 2Hz sampling because the automated algorithm that measures noise floor operates well between 0.8 and 1Hz. (no wave energy there so it's a good measure of noise floor). If you sampled at 1Hz, all bets are off. Is this data sampled at other than 2Hz?
- Very noisy velocity data might be cause by other things as well. I would be happy to review this data.
- Very small waves tend make the noise floor look large. At this point I am speculating. I can usually figure out everything to know with a little hands on the data.
- If you use pressure depth you can set a depth offset. This uses the pressure sensor but offsets the depth used by the amount you specify. You can set a fixed depth, which uses the same depth always (no tidal adaptation). Or you can use depth from surface track. Depth from surface track is best if the surface track was quality and available. It defaults the mean water depth from the vertical beam surface track in SentinelV.
- The auto upper cutoff algorithm is more robust and slightly more conservative. The new processing looks better. The pressure
- The extrapolation does a good job of filling in the spectrum that was not measured. This may change mean calculations a little.
- The pressure data now has an auto cutoff algorithm as well that cuts off the unmeasured tail. It does not do an extrapolation since we often don't measure very much and we usually have other sources for spectra.
- The Hmax calc in old software was simply 1.27* Hs. In the new software we are doing zero crossing analysis of the surface track data when it passes screening. When surface track is good then Hmax is available and a genuine measured peak to trough or trough to tpeak transition is used. So Hmax should change.
- A discontinuity error may be from not being able to save the configuration. It was not clear what was done to create this problem. Use the setup files to open or re-open data sets, not the data files.

# ASCII Output Format 17

($WAVES17,BurstNum,year/month/day,hour:minute:second,Hs,Tp,Tz,T01,Tinv1,Dp,Dm,S0,WaterLevel,Temperature,HsSwell,TpSwell,DpSwell,HsSea,TpSea,DpSea,H13,T13,
H10,T10,Hmax,Tmax,SurfTrackGd*HH)

Symbols

| | | |
|---|---|---|
| YY | Year | |
| MM | Month | |
| DD | Day | |
| HH | Hour | |
| mm | Minute | |
| ss | Second | |
| cc | 1/100ths seconds | |
| Hs | Significant Wave Height | = 4*sqrt(area under the power spectrum) |
| Tp | Peak period | = Wave period associated with the largest peak in the power spectrum |
| Dp | Peak Direction | = peak direction at the peak period. |
| Tz | Mean Zero Crossing Period | = sqrt(m0/m2) |
| T01 | Mean Wave Period | = m0/m1 |
| T-1 | Energy Period | = m-1/m0 |
| Dm | Mean Direction | |
| S0 | Directional Spreading = Sum(sqrt(2(1-r1(f))df), r1(f) = sqrt(a1^2(f)+b1^2(f)) | |
| WaterLevel | Bottom to Surface | |
| Temperature | Water Temp at the ADCP | |
| HsSwell | Significant Wave Height Longer Than 8s Period | |
| TpSwell | Peak Period >8s | |
| DpSwell | Peak Direction >8s | |
| HsSea | Significant Wave Height <8s | |
| TpSea | Peak Period <8s | |
| DpSea | Peak Direction <8s | |
| H13 | Height Average of Top 1/3 Largest Waves from Zero Crossing Analysis | |
| T13 | Period Average of Top 1/3 Largest Waves from Zero Crossing Analysis | |
| H10 | Height Average of Top 1/10 Largest Waves from Zero Crossing Analysis | |
| T10 | Period Average of Top 1/10 Largest Waves from Zero Crossing Analysis | |
| Hmax | Height of Largest Wave from Zero Crossing Analysis | |
| Tmax | Period of Largest Wave from Zero Crossing Analysis | |
| SurfTrackGd | Surface Track Good Quality Indicator (0/1) | |
| HH | NMEA Checksum 2 Hexidecimal Digits | |

# ASCII Output Format 5

Format 5:
Updated with each burst of waves data.
Ascii text, comma delimited line for each burst of data.
Like Format 3 only it outputs a full resolution profile.

Burst#,YY,MM,DD,HH,mm,ss,cc,Hs(m),Tp(s),Dp(deg),Depth(mm),Hmax (m),Tmean(s),bins,depthlevel1Magnitude(m/s),depthlevel1Direction(deg),..., depthlevelNMagnitude(m/s),depthlevelNDirection(deg)

Symbols

| | | |
|---|---|---|
| YY | Year | |
| MM | Month | |
| DD | Day | |
| HH | Hour | |
| mm | Minute | |
| ss | Second | |
| cc | 1/100ths seconds | |
| Hs | Significant Wave Height | = 4*sqrt(area under the power spectrum) |
| Tp | Peak period | = Wave period associated with the largest peak in the power spectrum |
| Dp | Peak Direction | = peak direction at the peak period. |
| Tz | Mean Zero Crossing Period | = sqrt(m0/m2) |
| T01 | Mean Wave Period | = m0/m1 |
| T-1 | Energy Period | = m-1/m0 |
| Dm | Mean Direction | |
| S0 | Directional Spreading = Sum(sqrt(2(1-r1(f))df), r1(f) = sqrt(a1^2(f)+b1^2(f)) | |
| WaterLevel | Bottom to Surface | |
| Temperature | Water Temp at the ADCP | |
| HsSwell | Significant Wave Height Longer Than 8s Period | |
| TpSwell | Peak Period >8s | |
| DpSwell | Peak Direction >8s | |
| HsSea | Significant Wave Height <8s | |
| TpSea | Peak Period <8s | |
| DpSea | Peak Direction <8s | |
| H13 | Height Average of Top 1/3 Largest Waves from Zero Crossing Analysis | |
| T13 | Period Average of Top 1/3 Largest Waves from Zero Crossing Analysis | |
| H10 | Height Average of Top 1/10 Largest Waves from Zero Crossing Analysis | |
| T10 | Period Average of Top 1/10 Largest Waves from Zero Crossing Analysis | |
| Hmax | Height of Largest Wave from Zero Crossing Analysis | |
| Tmax | Period of Largest Wave from Zero Crossing Analysis | |
| SurfTrackGd | Surface Track Good Quality Indicator (0/1) | |
| HH | NMEA Checksum 2 Hexidecimal Digits | |