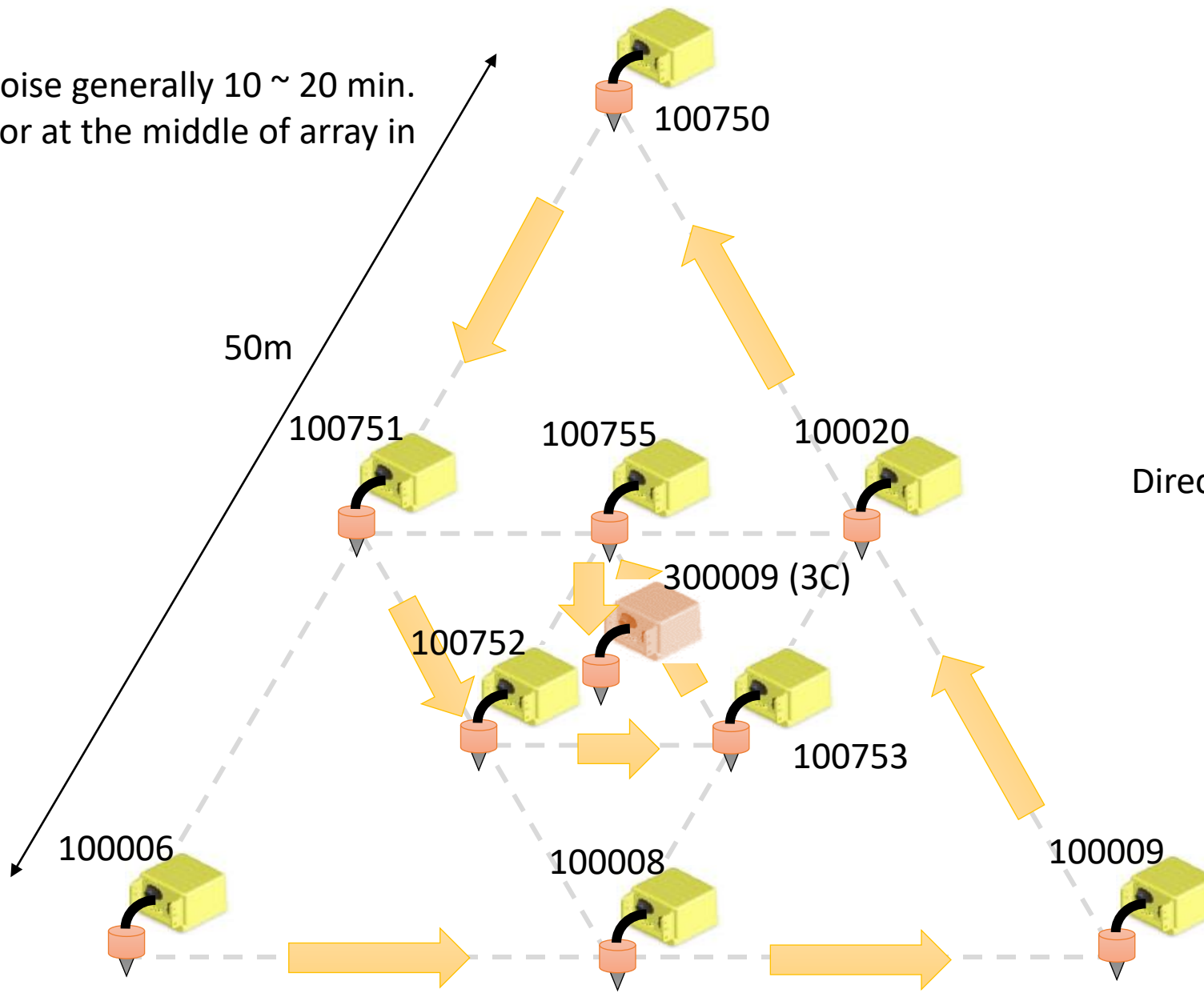


# Tutorial for 1D passive surface wave (microtremor array measurements : MAM) and horizontal to vertical spectral ratio (H/V or HVSR) processing using SeisImager/SW

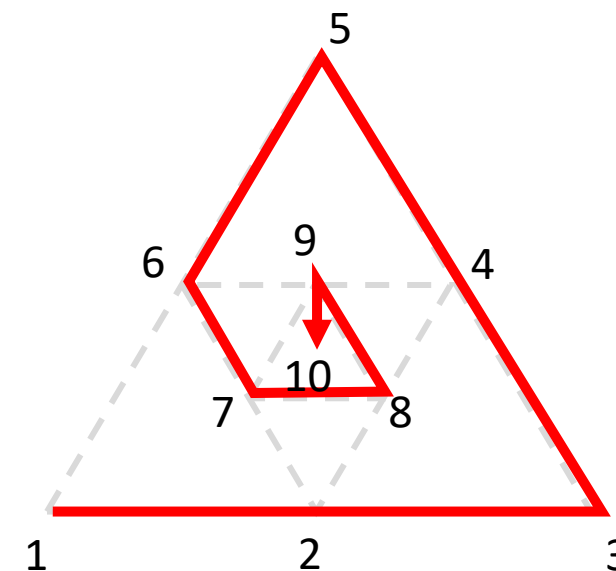
- Processing 9 vertical and 1 three component ambient noise data obtained by 1C/3C Atom.
- SeisImager/SW license is required.
- Download the latest installer from :  
<https://seisimager.com/download/SeisImager.zip>
- Download the example data (Triangle 10) from :  
[http://seisimager.esy.es/GeophysicalDatabase/mam\\_1d\\_hvsr.zip](http://seisimager.esy.es/GeophysicalDatabase/mam_1d_hvsr.zip)
- See *“SeisImager/SW™ Manual Addendum (H/V)”* or *“SeisImager/SW-Pro™ Manual”* for more details

# Acquisition geometry (example data)

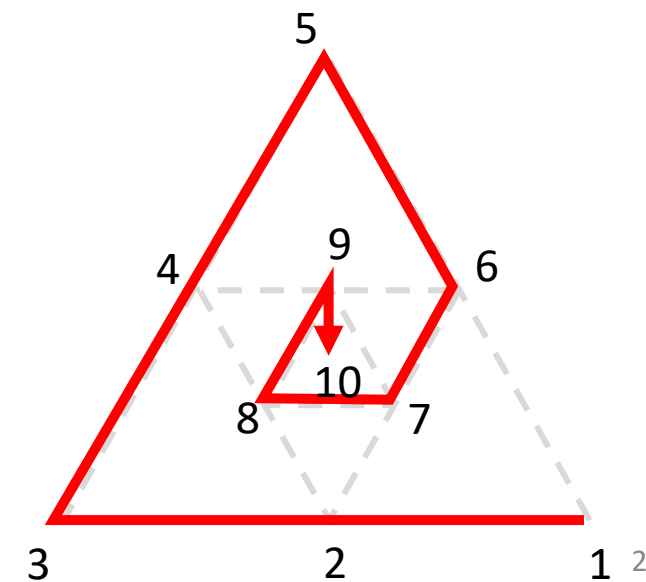
Record ambient noise generally 10 ~ 20 min.  
Deployed 3C sensor at the middle of array in  
this example.



Deploy receivers from small to  
large in Atom's ID order

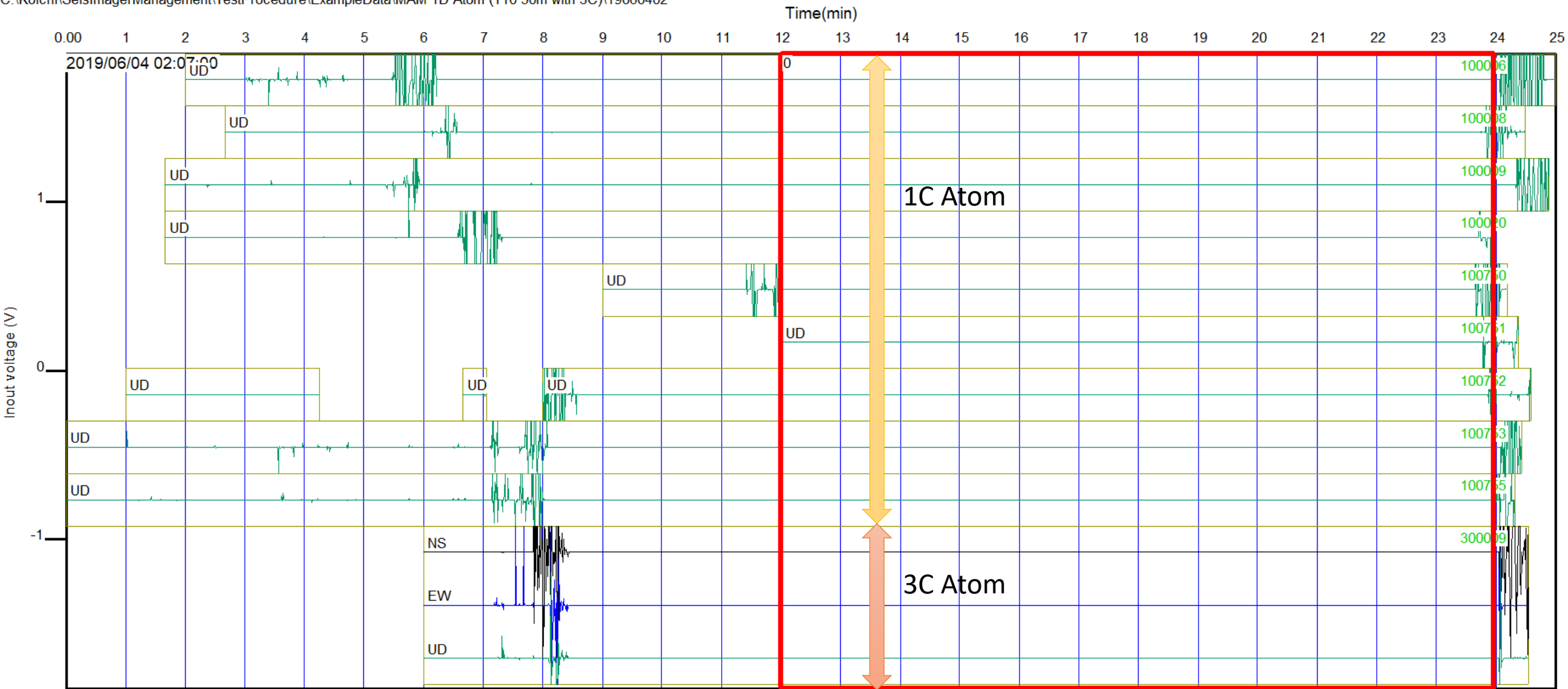


Direction of sensor order is not matter



# Raw data

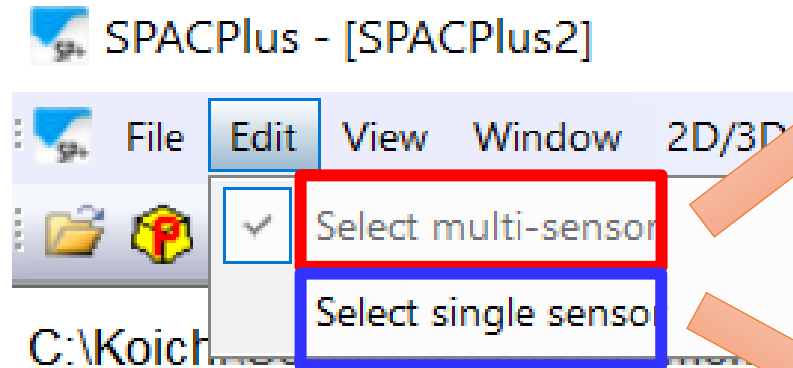
C:\Koichi\SeisImagerManagement\TestProcedure\ExampleData\MAM 1D Atom (T10 50m with 3C)\19060402



# Select a common time block (CTB) for MAM or H/V processing

You can select either all sensors or a single sensor.

Use “Edit”, “Select multi-sensor” or “select single sensor” to switch to select all or single sensor(s).




Select all sensors for MAM analysis.

Select a single sensor for H/V (HVSr) analysis.

Select a common time block (CTB)  
for MAM processing

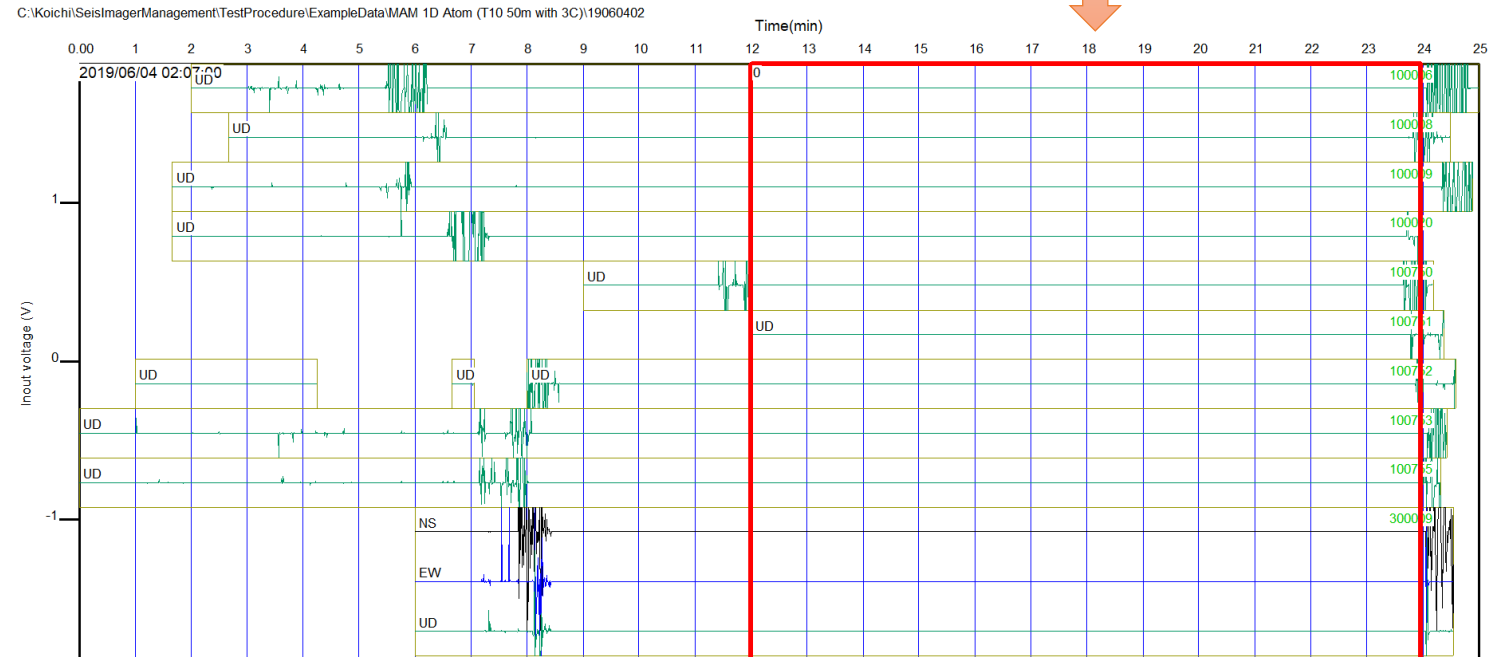
Select a CTB to be processed. Use left or right key to change a selected CTB.



Click  to select a common time block.



CTB to be selected.



# Select a common time block (CTB) for MAM processing

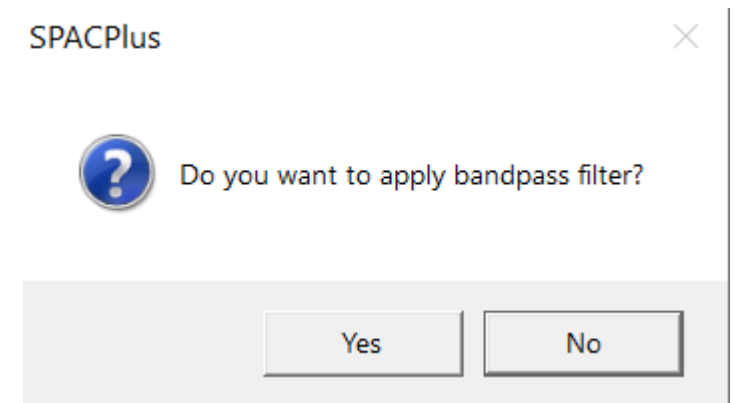
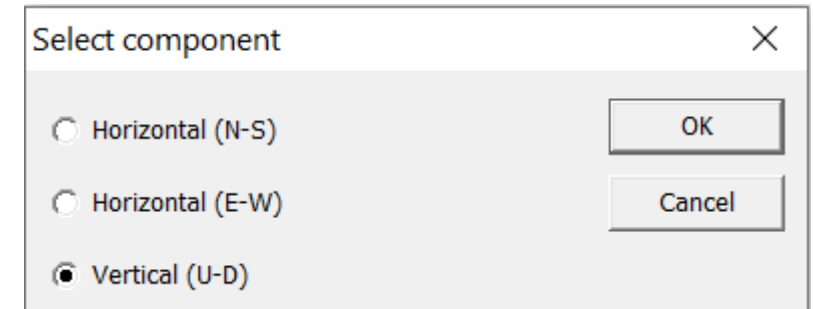
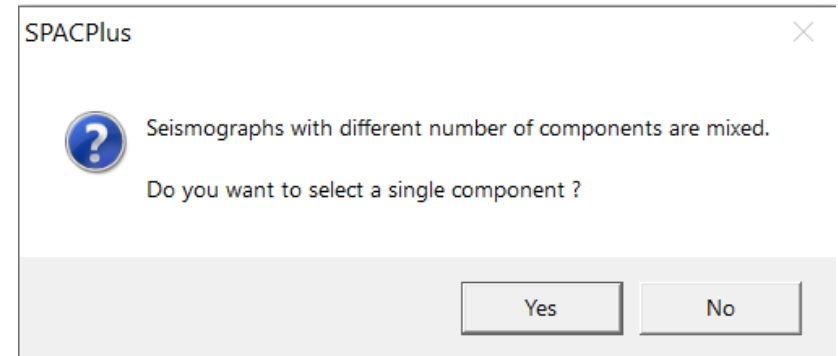
If data include 3C sensor, it asks selecting a single component or no.  
Click “Yes” for normal MAM processing using vertical component.



Select “Vertical (U-D)” for normal MAM processing using vertical component.

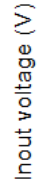


Bandpass filter is usually not necessary using 2Hz geophone.  
Click “No” to continue.



Selected common time block (CTB) appears in different Window.

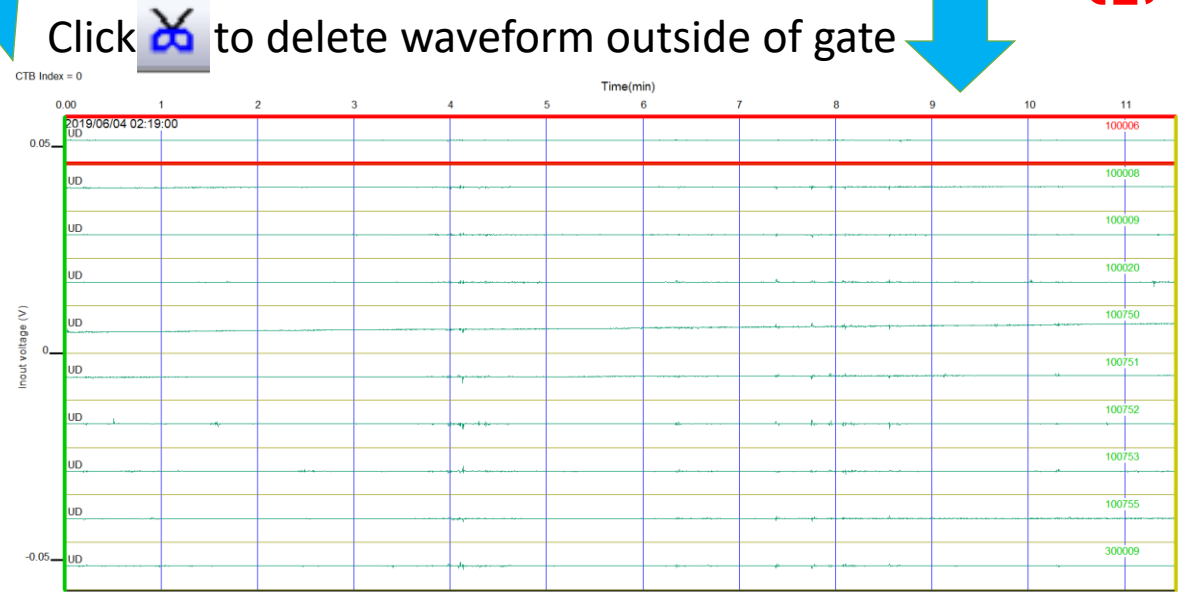
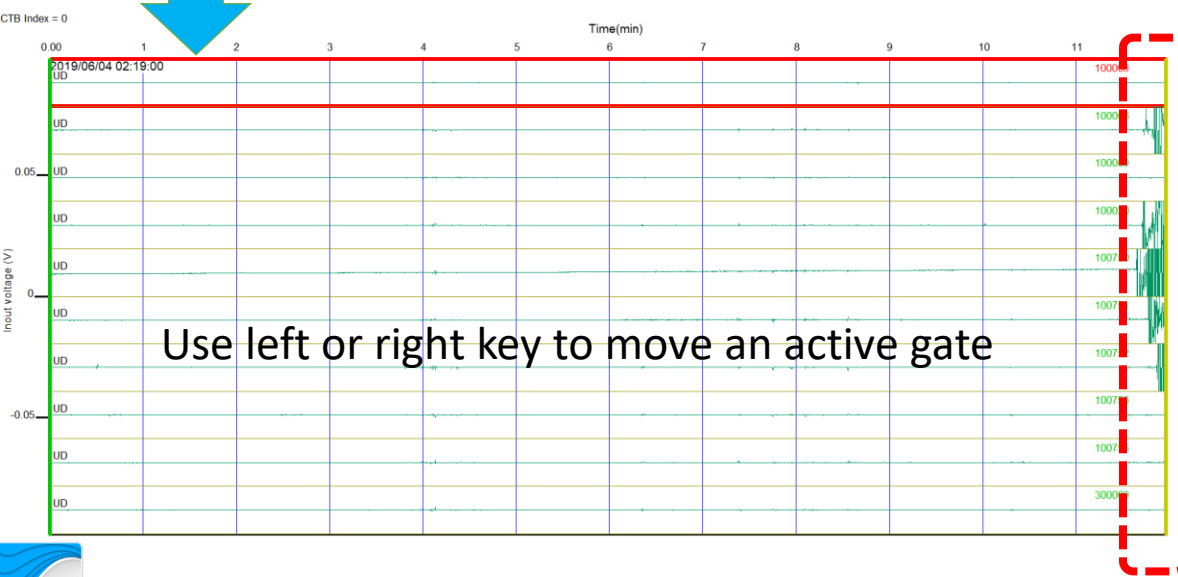
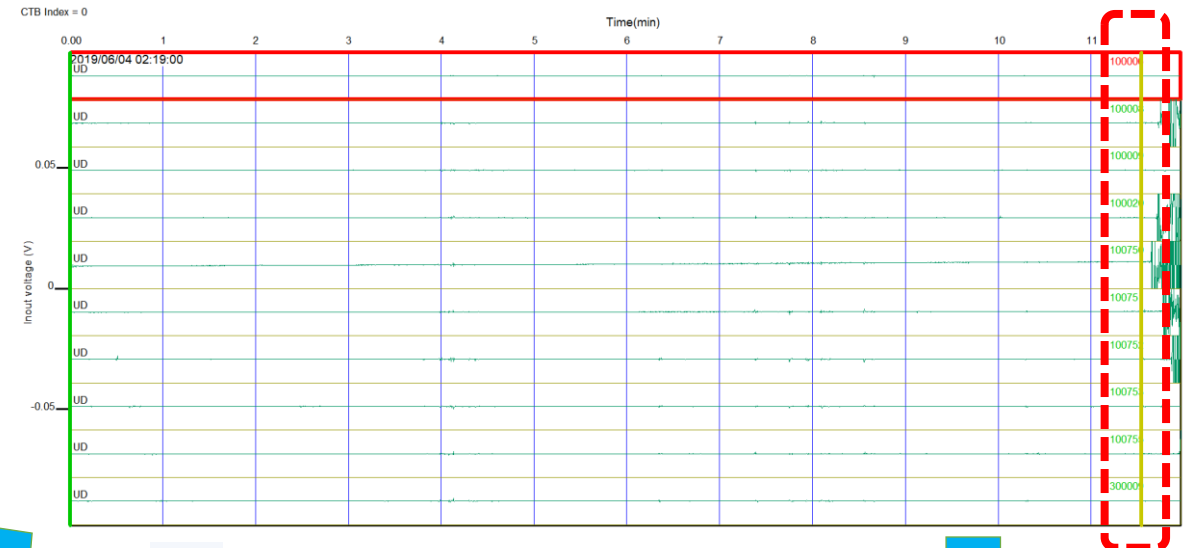
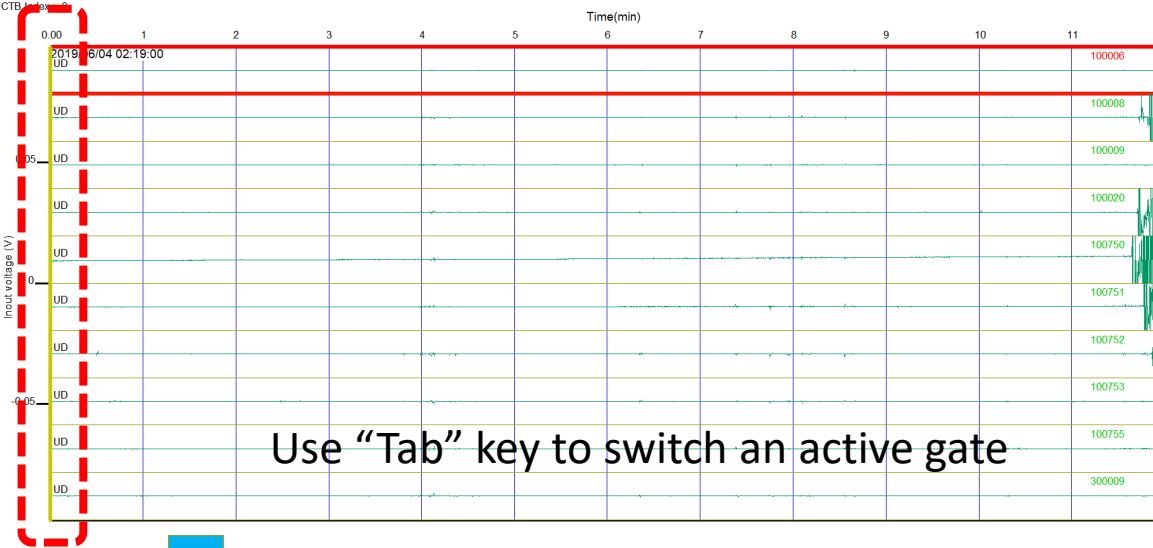
Time(min)



# Delete waveform outside of gate (optional)


Active gate

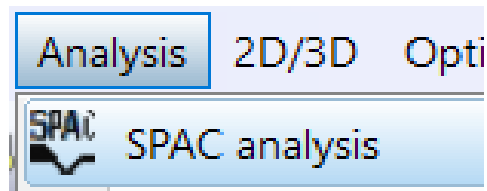
Active gate





# Calculate phase velocities by spatial autocorrelation (SPAC)

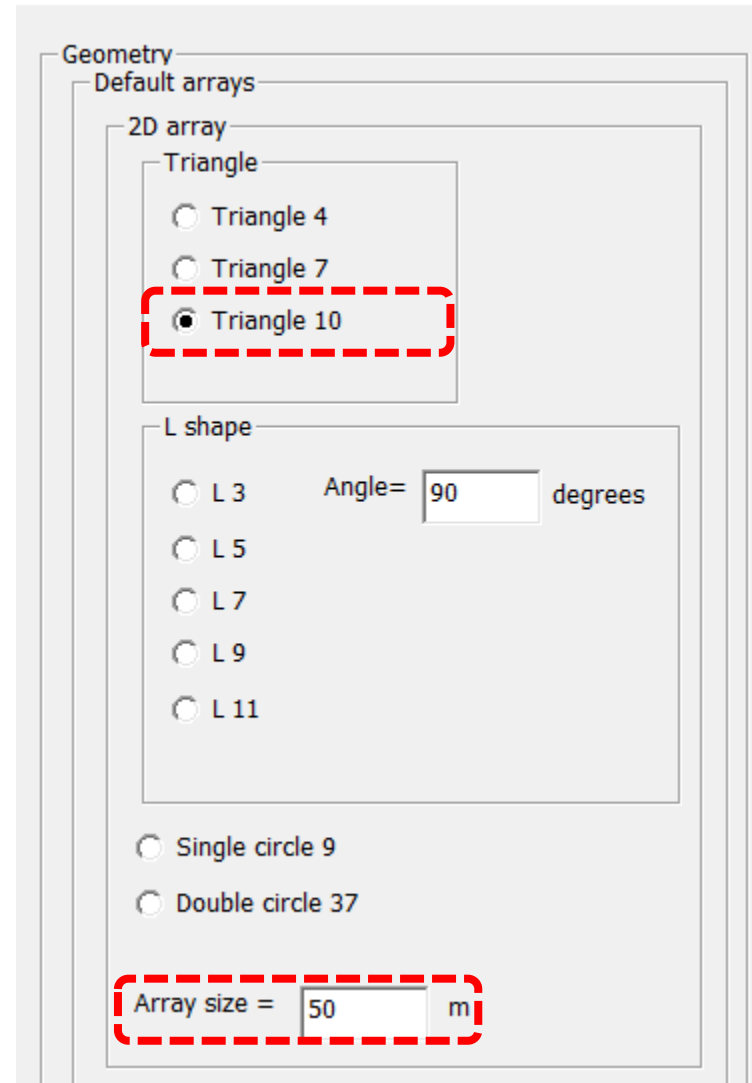
Click  or select “Analysis”, “SPAC analysis”.



Select “Triangle 10” and set “Array size” to 50 m.

Click “OK” to continue.

## 2D SPAC

A screenshot of the '2D SPAC' configuration dialog box. It has a 'Geometry' section with 'Default arrays'. Under '2D array', there are three radio button options: 'Triangle 4', 'Triangle 7', and 'Triangle 10'. 'Triangle 10' is selected and highlighted with a red dashed box. Below this is an 'L shape' section with radio button options 'L 3', 'L 5', 'L 7', 'L 9', and 'L 11'. To the right of these is a text field 'Angle=' with the value '90' and the unit 'degrees'. At the bottom, there is a radio button for 'Single circle 9' and another for 'Double circle 37'. At the very bottom, there is a text field 'Array size =' with the value '50' and the unit 'm', which is also highlighted with a red dashed box.

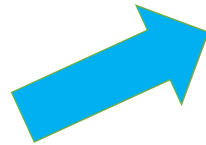
# Set up acquisition geometry manually (optional)

Click “Open array file”.

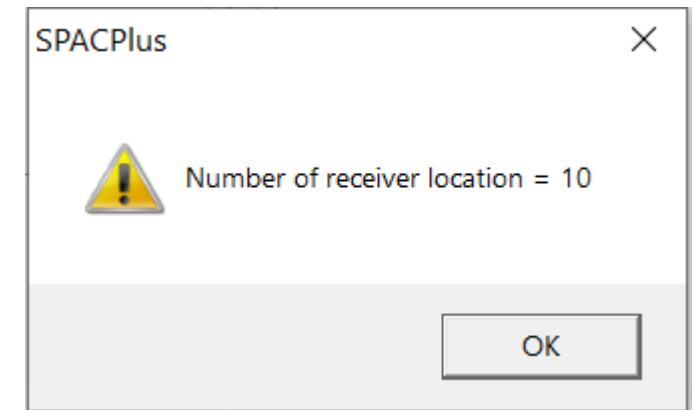
Prepare geometry as an ASCII file

**X**      **Y**

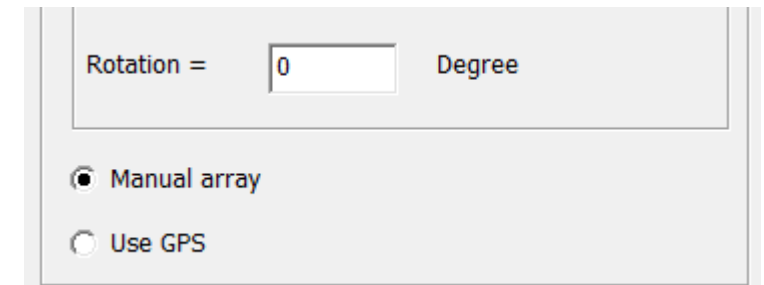
0.000000	0.000000
25.000000	0.000000
50.000000	0.000000
37.500000	21.650635
25.000000	43.301270
12.500000	21.650635
18.750000	10.825317
31.250000	10.825317
25.000000	21.650635
25.000000	14.433757






Select the file and confirm number of sensors.

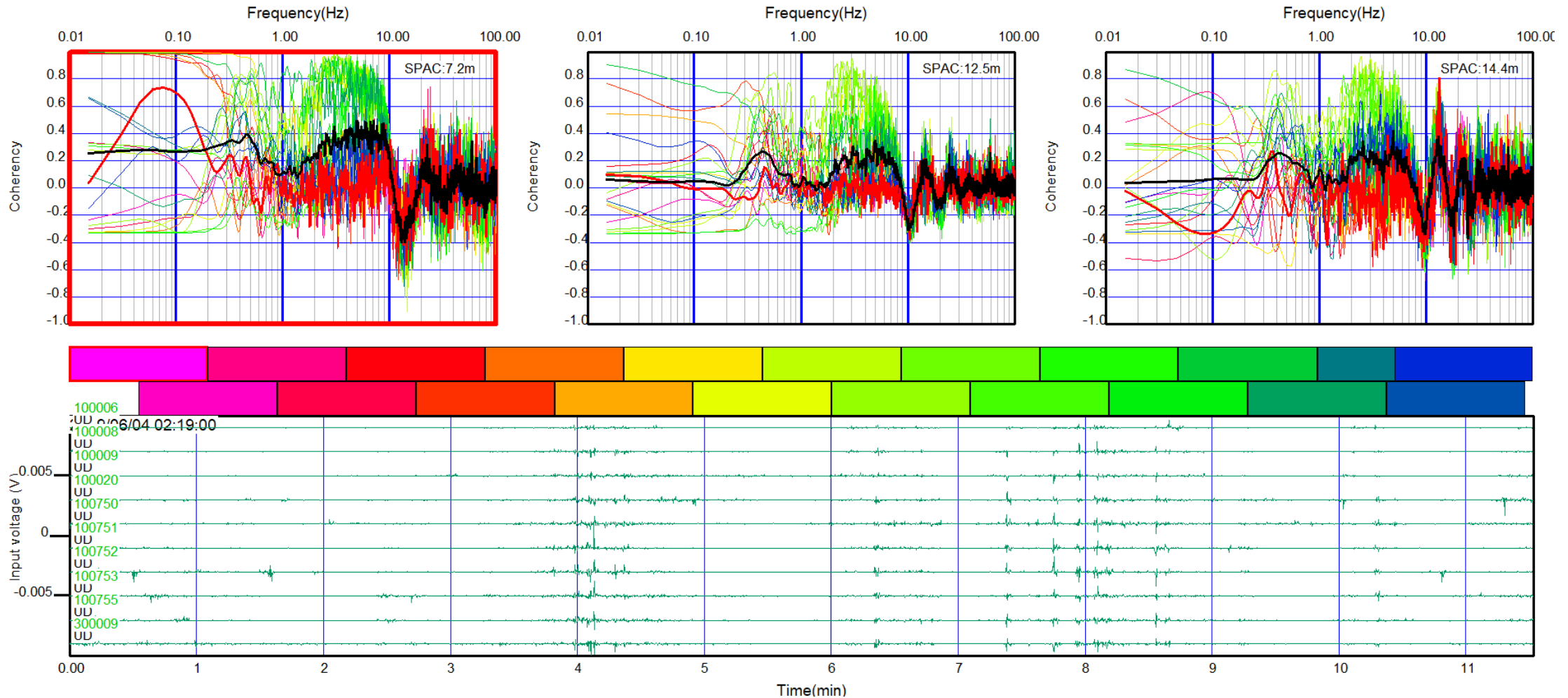


Select “Manual array” and click “OK” to continue.




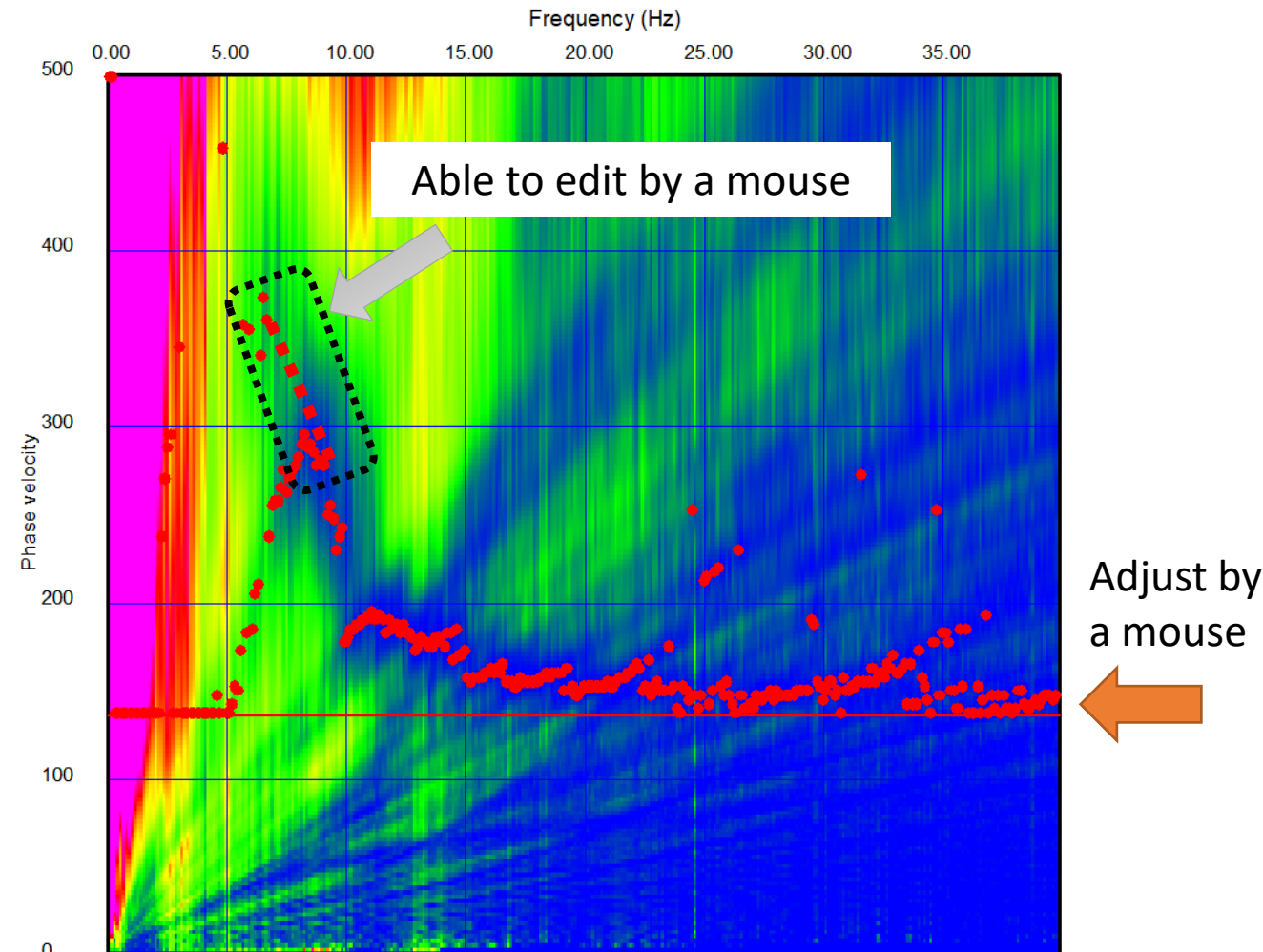
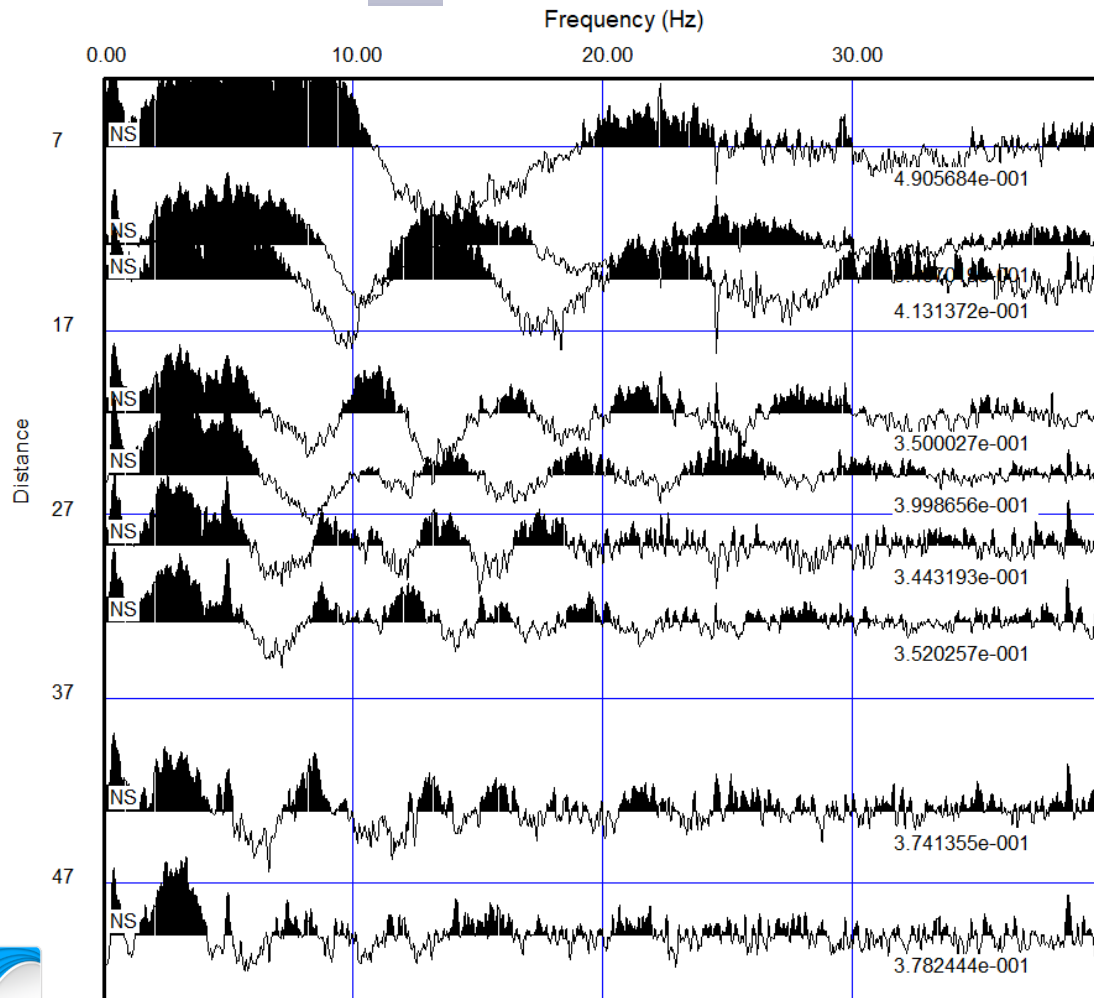
# Spatial autocorrelations

Spatial auto correlations appear. When number of receiver separation is more than three, use   buttons to scroll receiver separations to be shown. Click  or select “Phase velocity analysis”, “Phase velocity window” and all spatial auto-correlations and a frequency domain phase velocity image appear in another window.



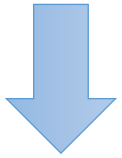
# All spatial autocorrelations and phase velocity image in frequency domain

To set the minimum phase velocity to be picked, adjust a red horizontal line in a phase velocity image in frequency domain by a mouse. Click  or select "Surface wave analysis", "Show phase velocity curve(s)", "Launch WaveEq".

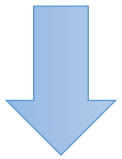


# Launch WaveEq

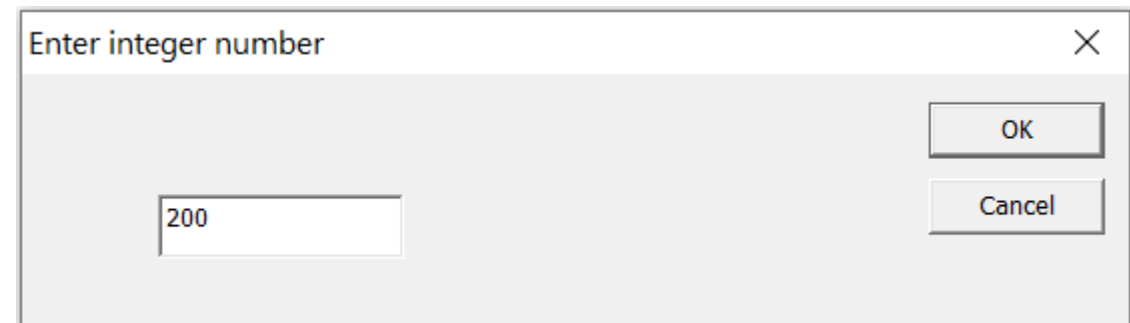
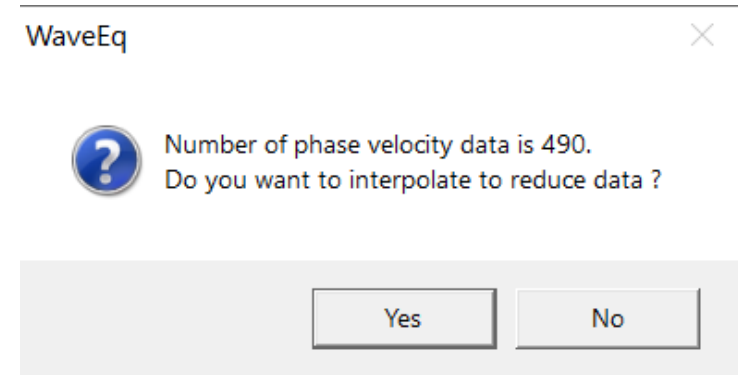
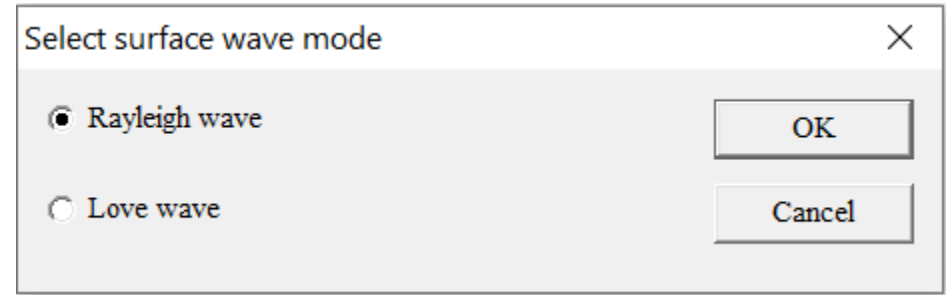
Select “Rayleigh wave”.



You may reduce number of phase velocities to speed up inversion

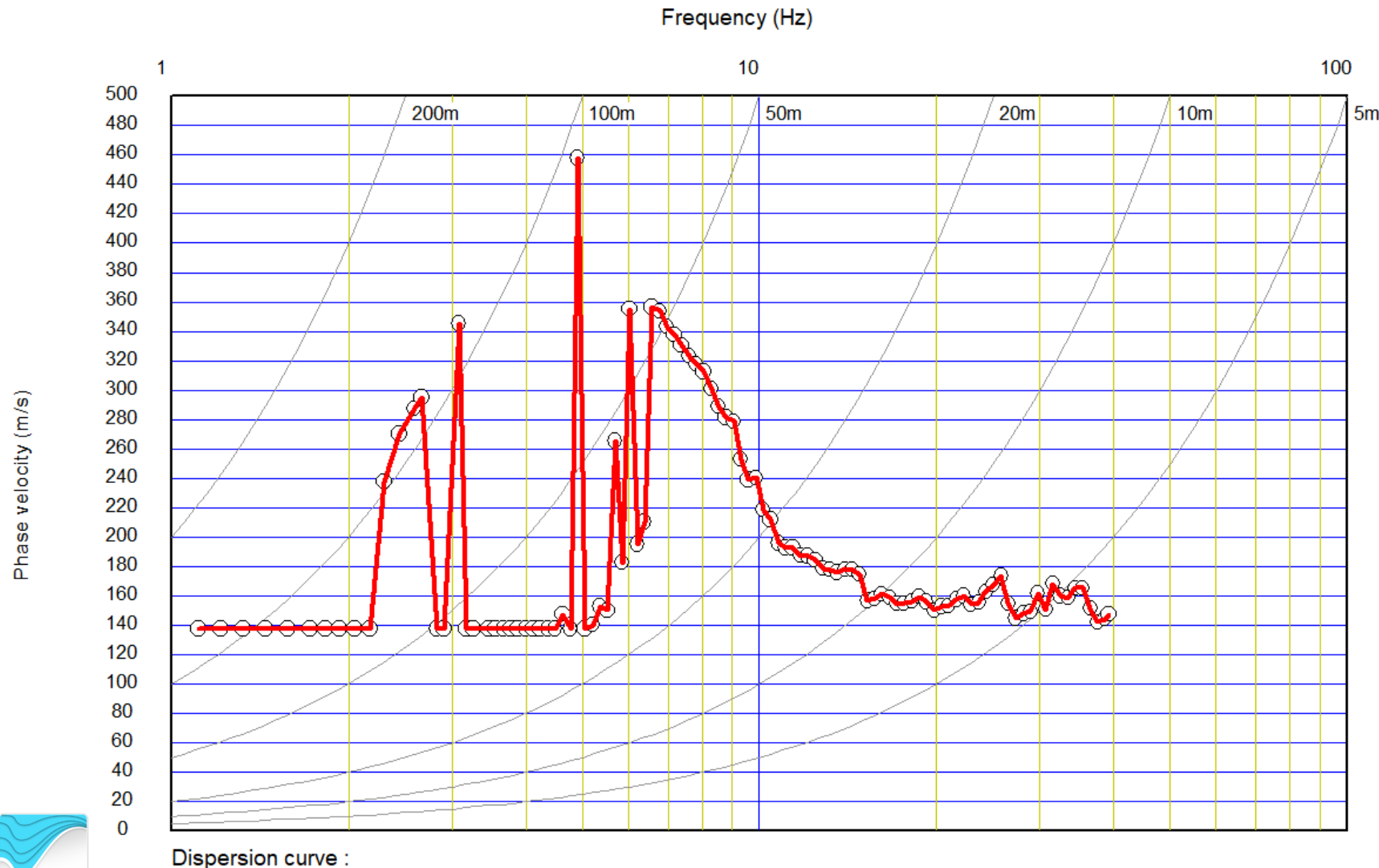


Set 100 to 200 for number to be reduced.



# Showing a dispersion curve in WaveEq

WaveEq launched and a dispersion curve appears



Select "View", "Axis configuration" or "Press "Ctrl+A" to change axis configuration.

Axis configuration

	Minimum	Maximum	Interval	
X-axis	1	100		Hz
<input checked="" type="checkbox"/> Log				
Y-axis	0	500	20	m/sec

OK Cancel

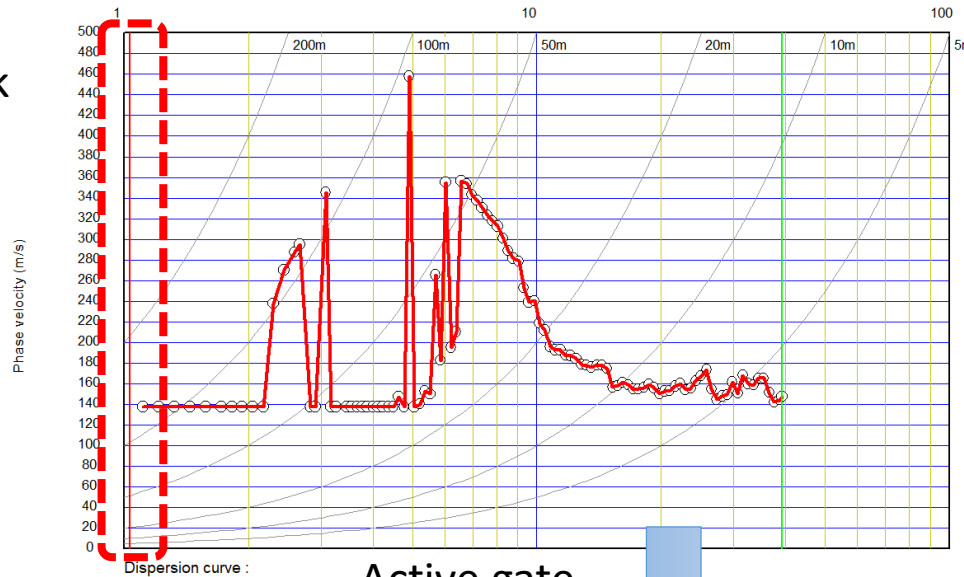
Use   to select

# Delete phase velocities outside of gate

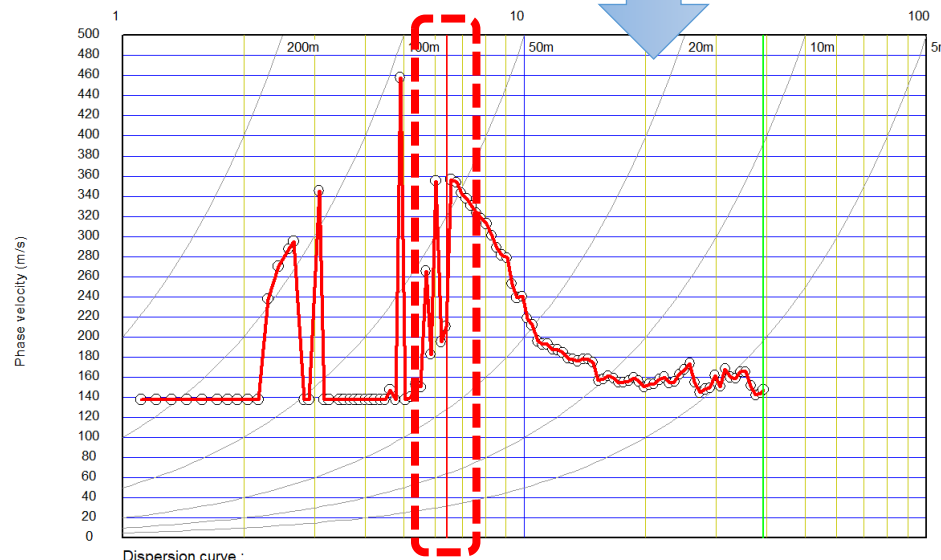
Select “Dispersion curve”, “Delete pick outside of gate” or press “Ctrl+X”

Move left side gate by left or right key and hit “Enter” key.

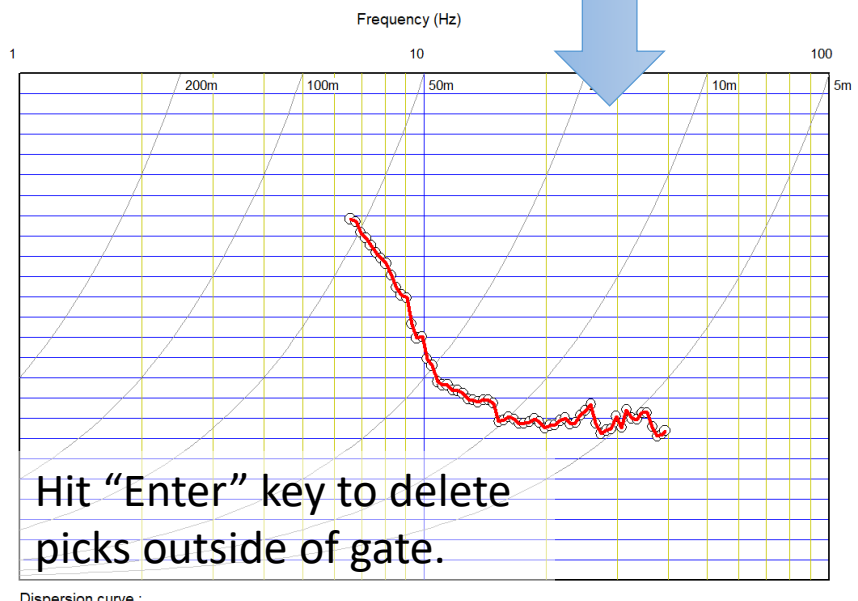
Active gate



Active gate

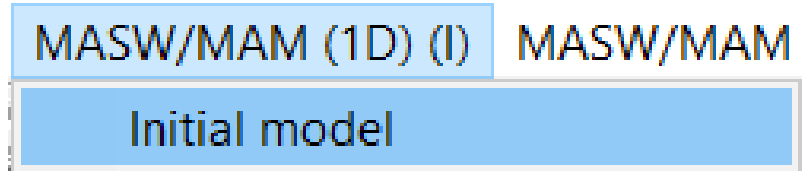


Active gate



# Generate initial model

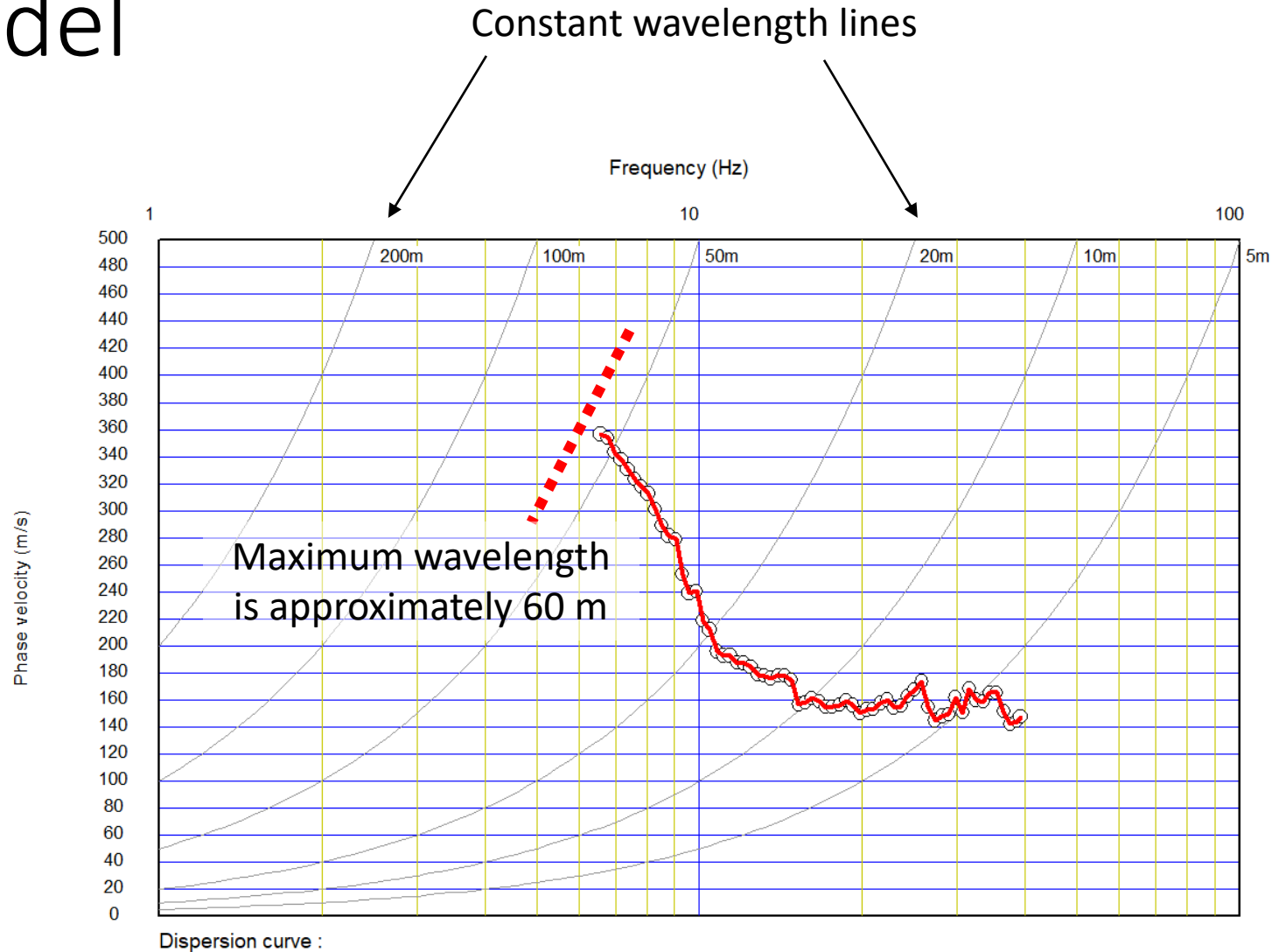
Select “MASW/MAM (1D)”, “Initial model”.



Depth of model is generally size of array or  $1/2 \sim 1/3$  of maximum wave length



A screenshot of a dialog box titled 'Initial model for inversion'. It contains two input fields: 'Depth =' with the value '30' and 'm', and '# of layer =' with the value '15'. On the right side, there are three buttons: 'OK', 'Cancel', and 'Advanced menu'.



Select “View”, “Setup constant wavelength lines” to show wavelength lines on dispersion curves.



# Initial velocity model



Show velocity model.



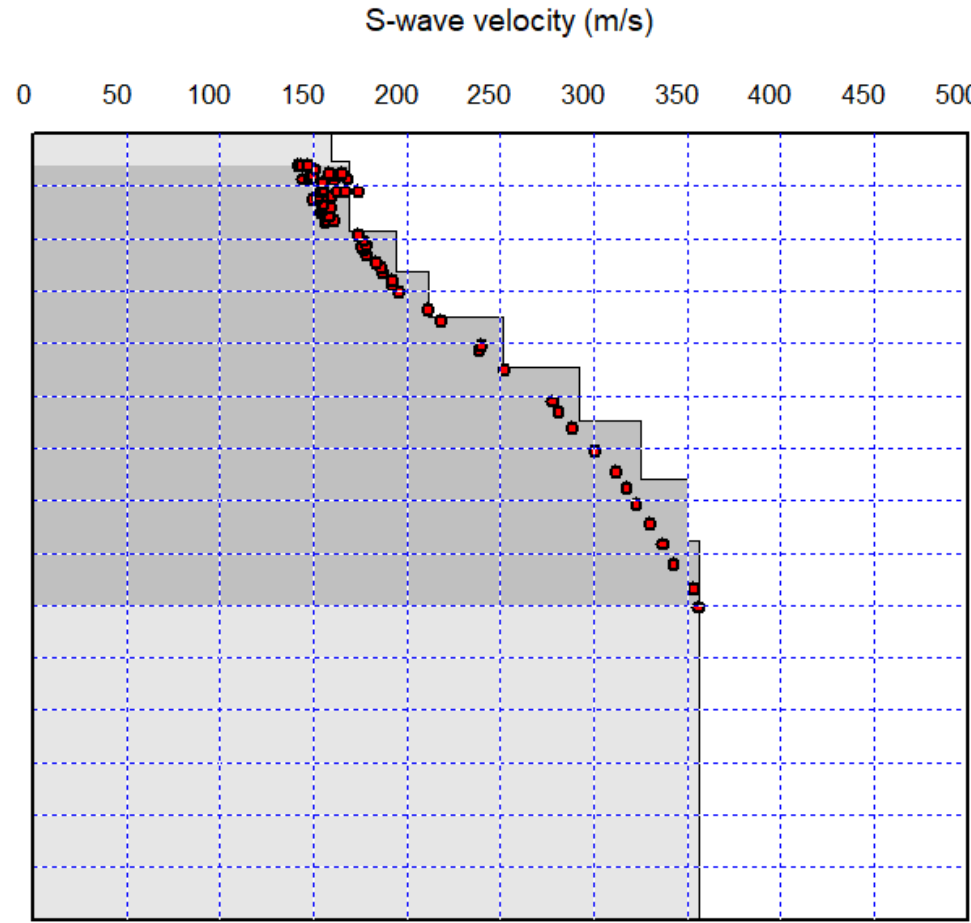
Show dispersion curve.



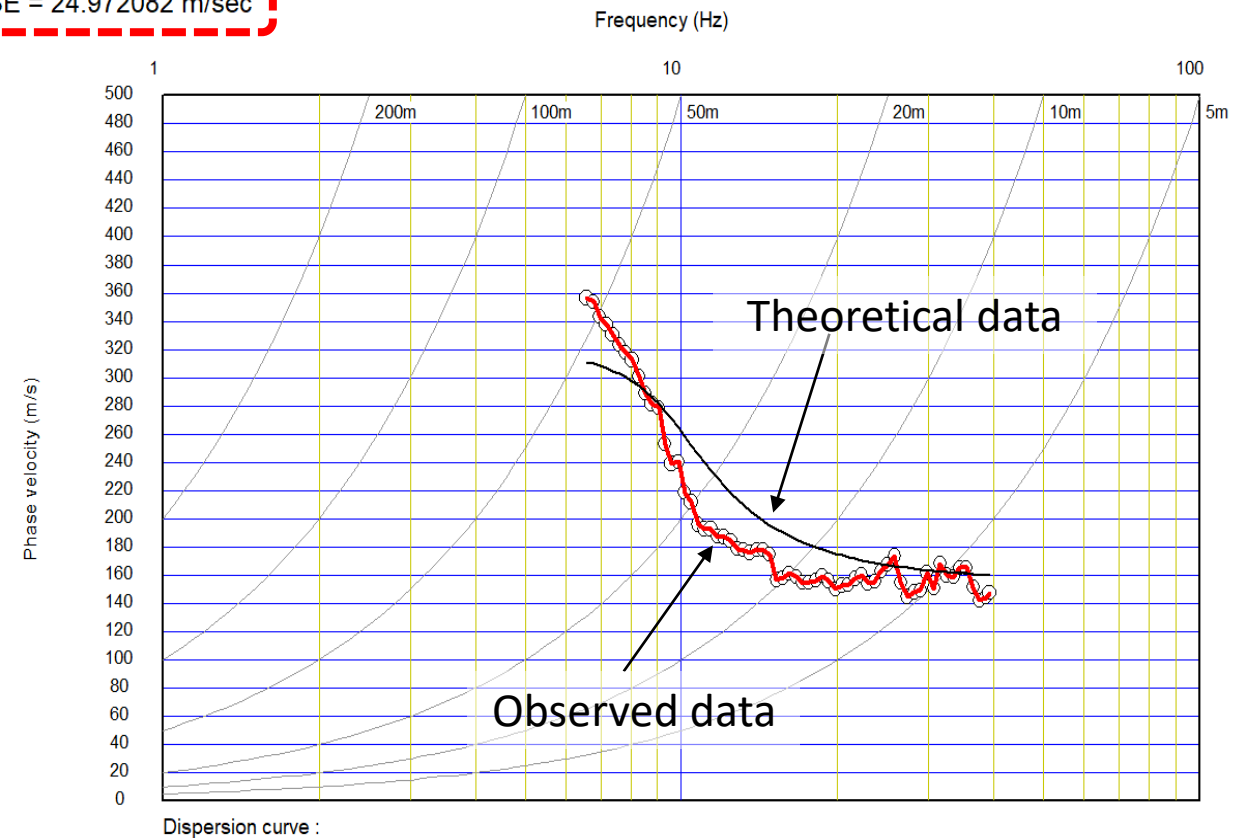
Calculate theoretical dispersion curve.

Average Error

RMSE = 24.972082 m/sec



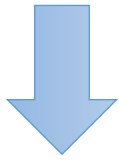
S-wave velocity model (initial) :



Dispersion curve :

# Inversion

Select “MASW/MAM (1D)” to apply inversion.



Set number of iterations (5 is generally fine).

MASW/MAM (1D) (I)

Initial model

Inversion (LSM)

Least Square Method

Iteration =

OK

Cancel

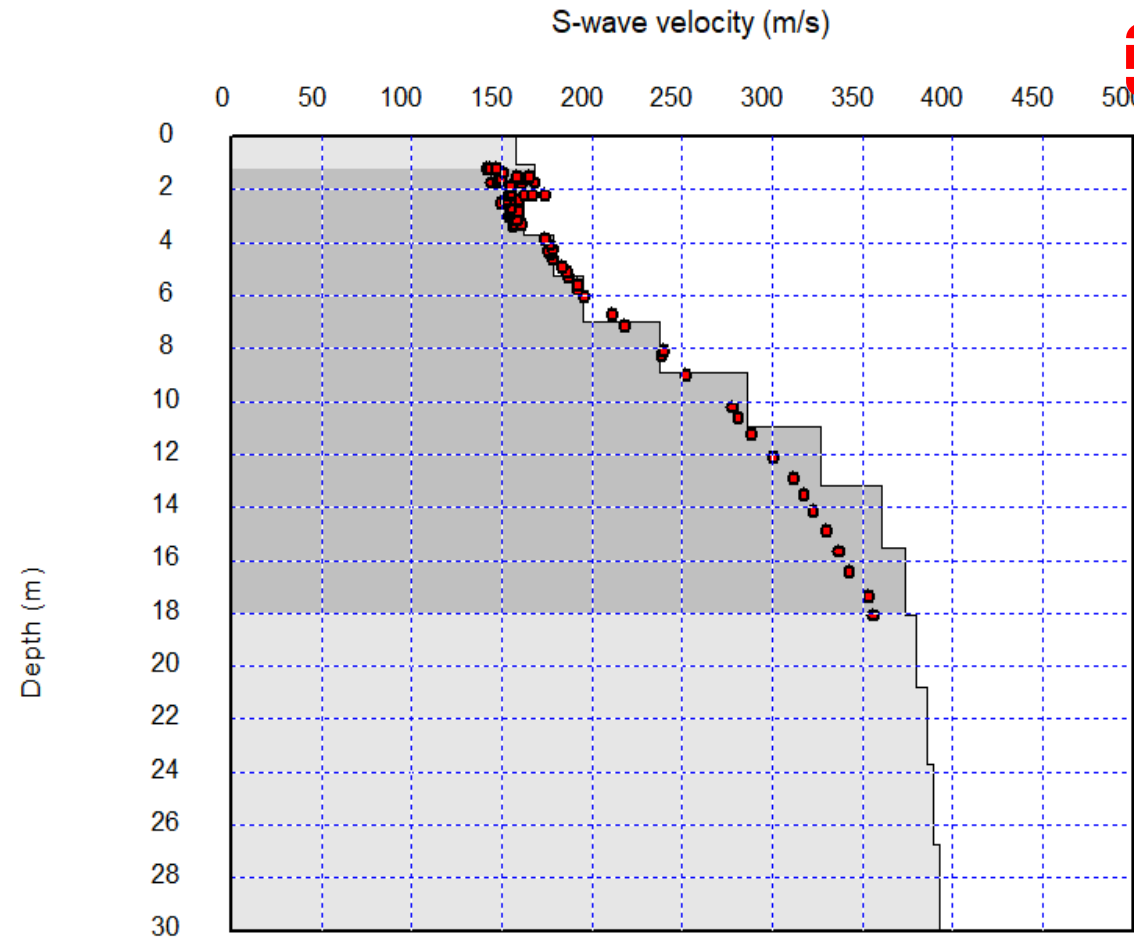
Advanced menu

# Inverted results

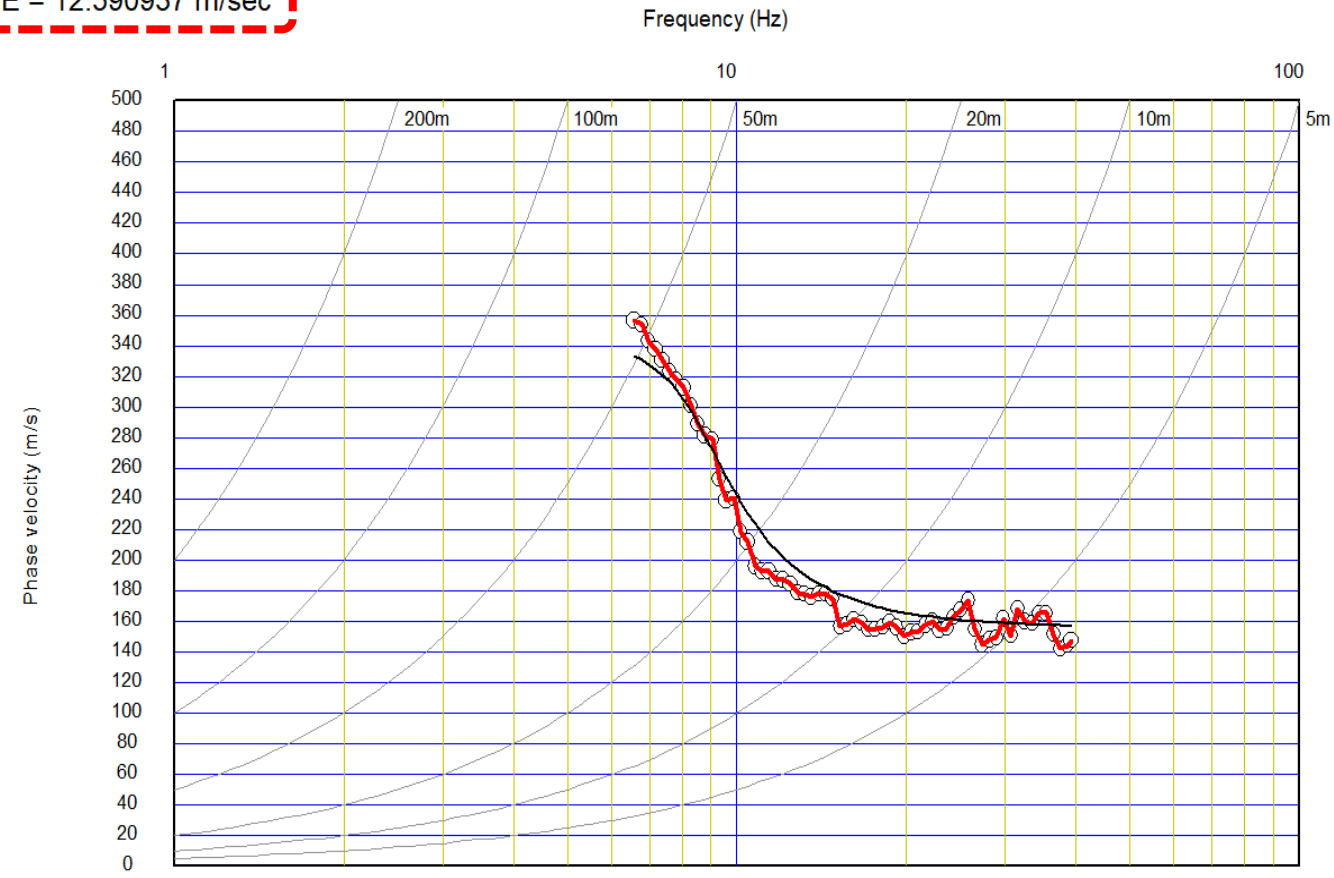
Make sure RMSE decreased after inversion.

Average Error

RMSE = 12.590937 m/sec



S-wave velocity model (inverted) :

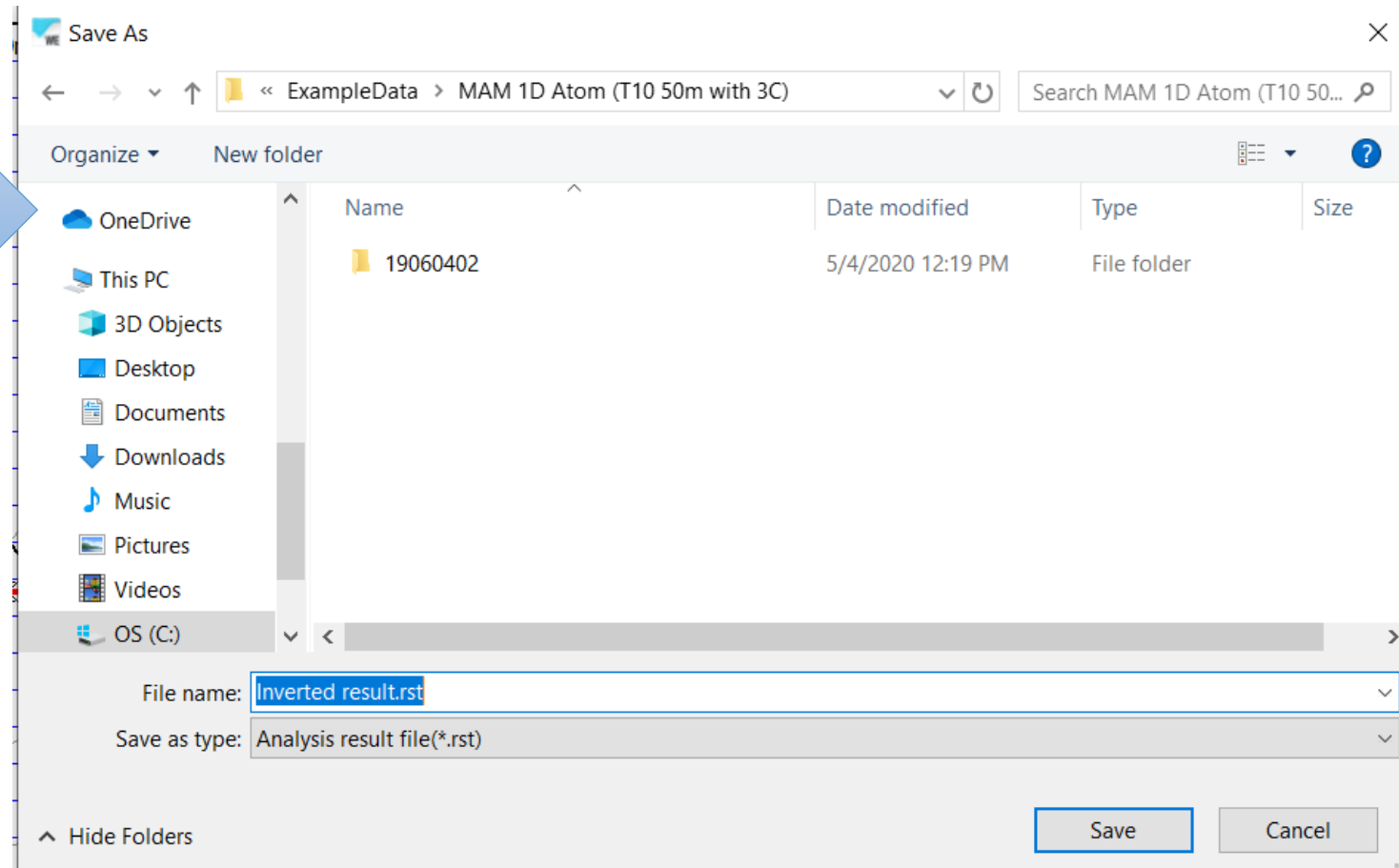
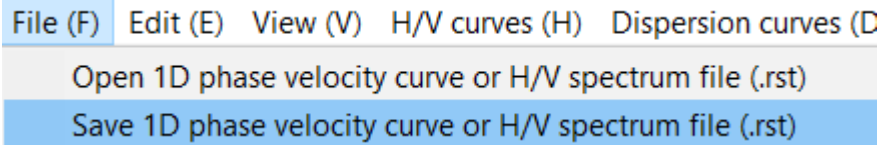


Dispersion curve :

# Save analyzed result

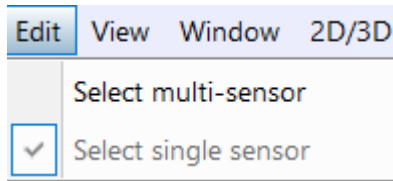
Select “File”, “Save 1D phase velocity curve or H/V spectrum file (.rst)”.

Save a file with extension (.rst).



# Select a common time block (CTB) for H/V processing

Select “Edit”, “Select single sensor” to select a single sensor for H/V analysis.



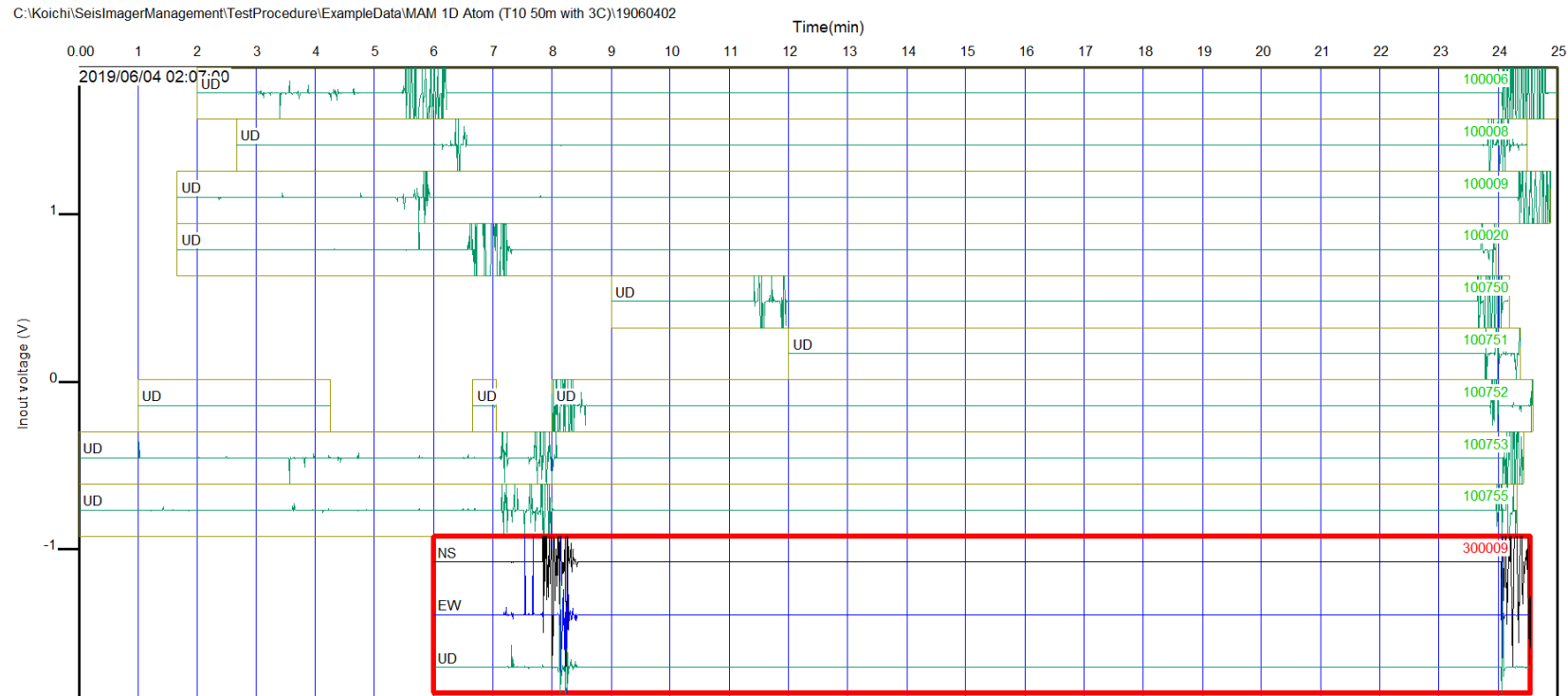
Select a sensor (CTB) to be processed. Use shift+ up/down to change a sensor and left or right key to change a selected CTB.



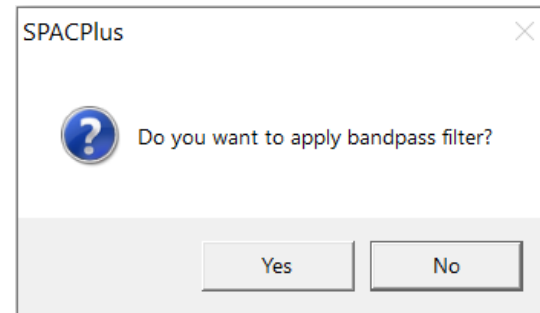
Click to select a common time block.



Bandpass filter is usually not necessary using 2Hz geophone. Click “No” to continue.

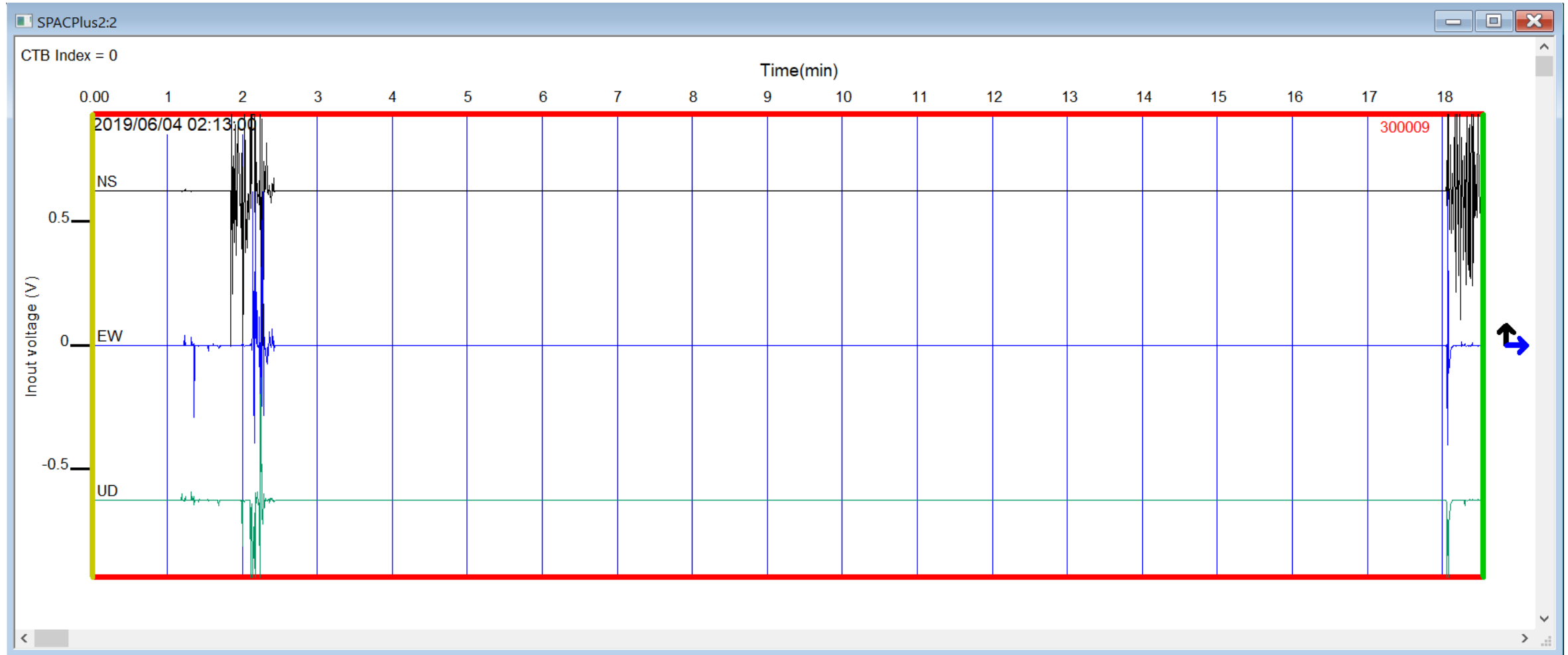


CTB to be selected.



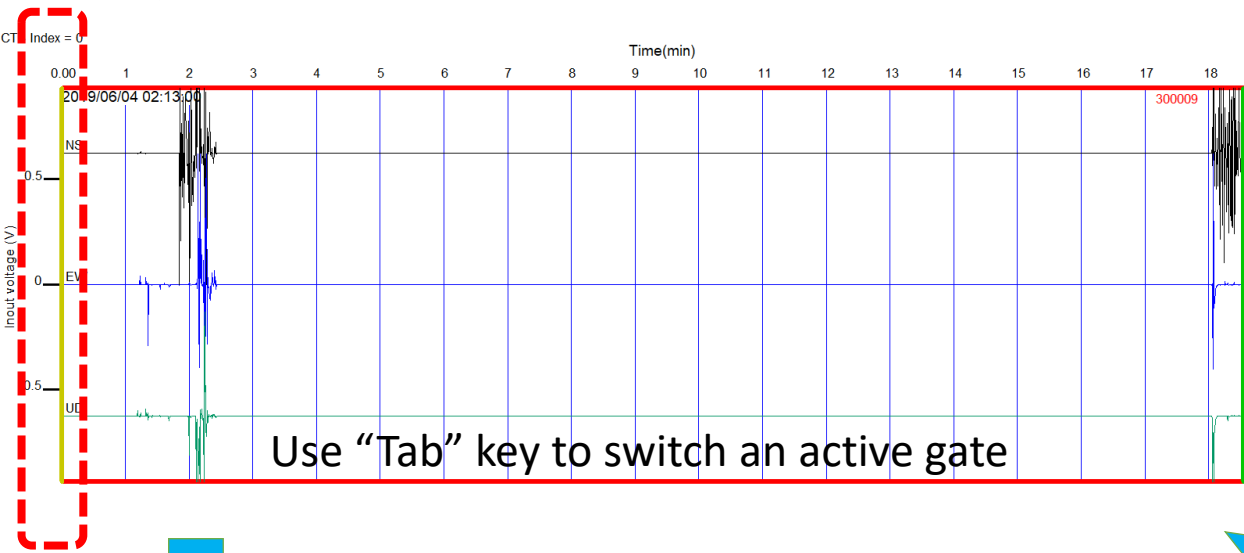
# Common time block (CTB)

Selected common time block (CTB) appears in different Window.

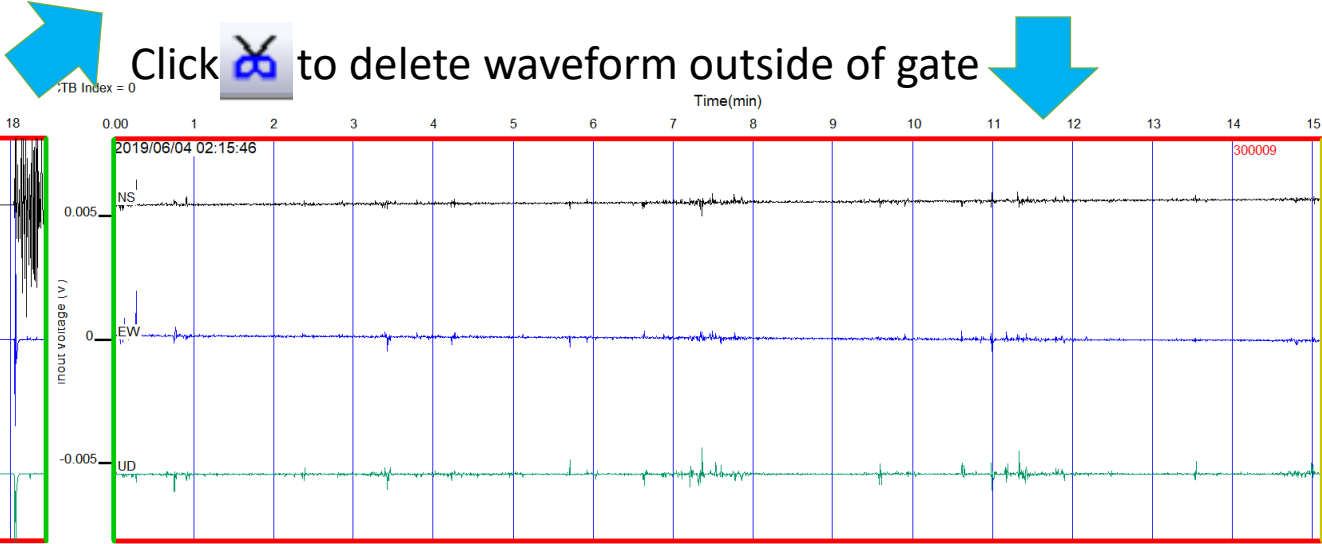
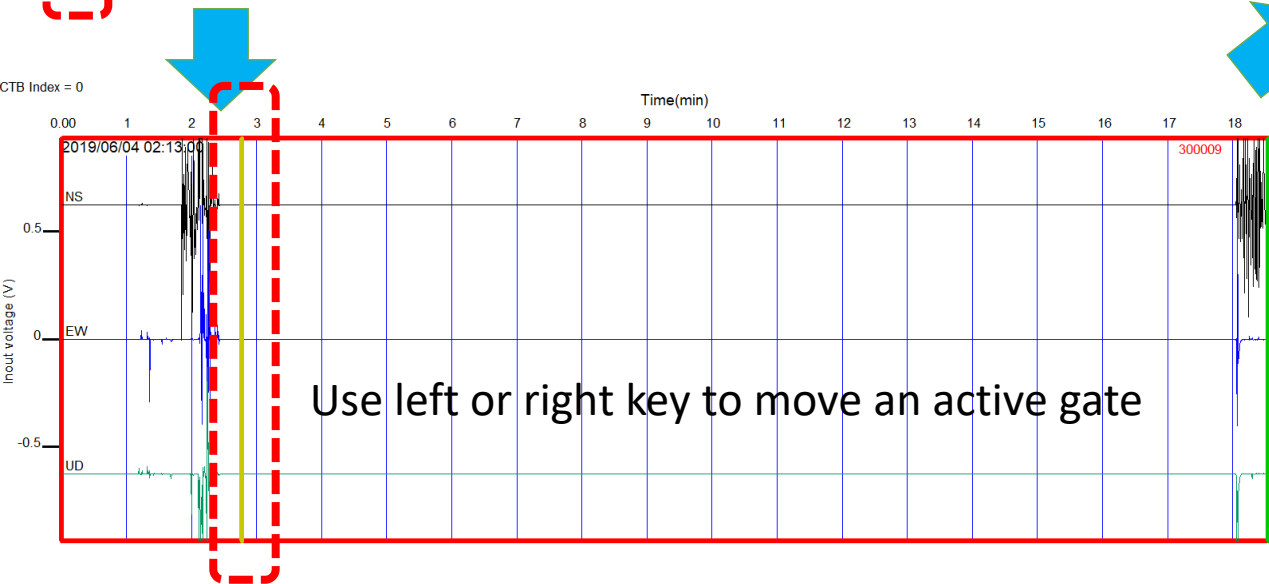
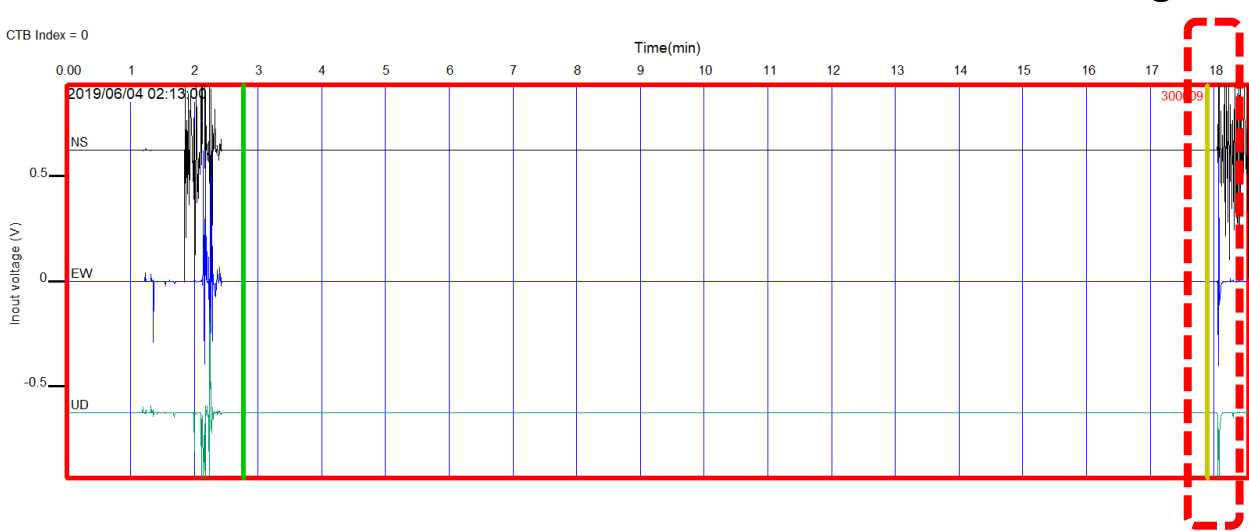


# Delete waveform outside of gate (optional)

Active gate



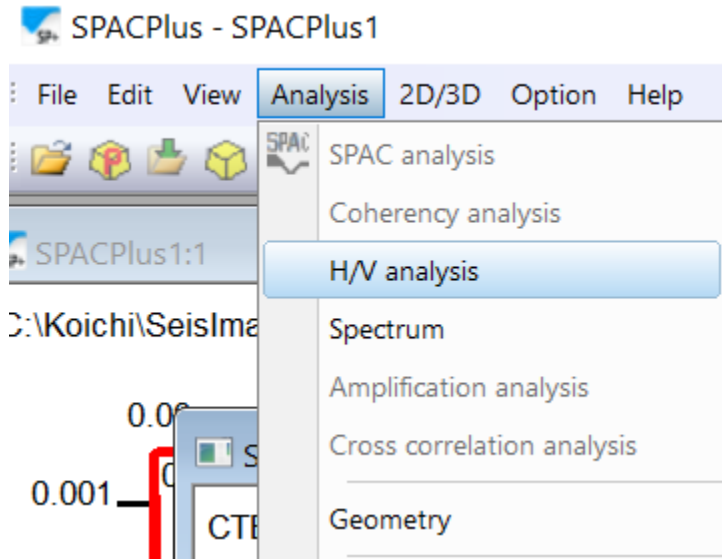
Active gate



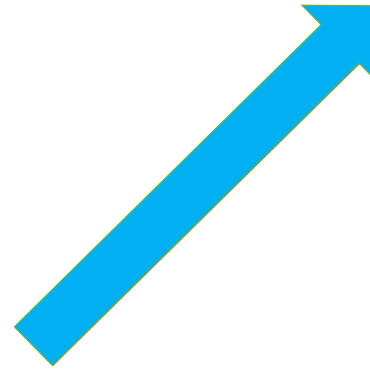
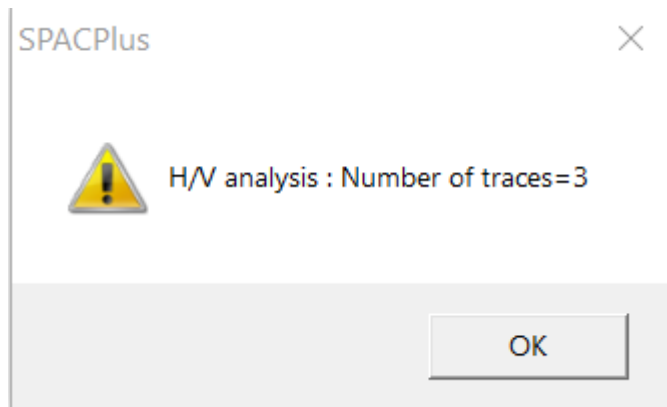
# Calculate horizontal to vertical spectral ratio (H/V)

Select "Analysis", "H/V analysis" to calculate H/V spectrum.

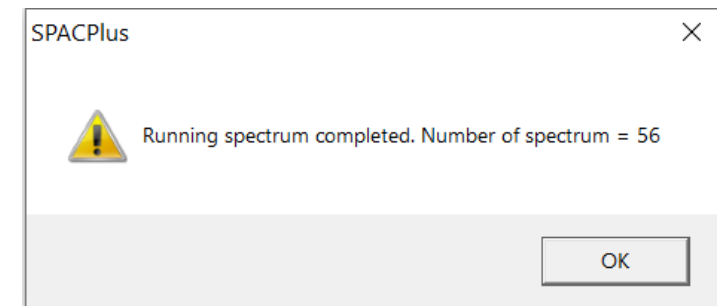
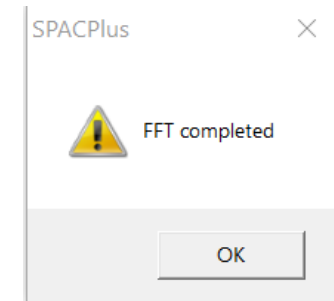
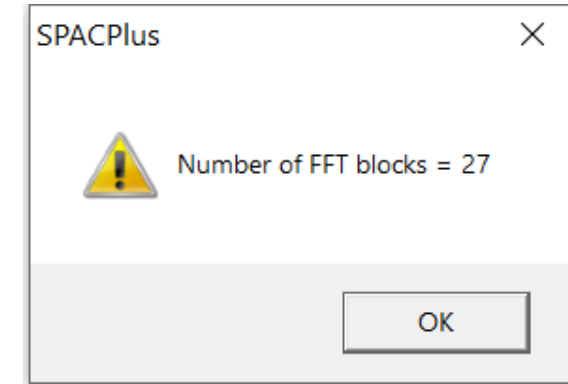
H/V spectra are calculated for each FFT block at first.



Confirm number of traces. It should be three.



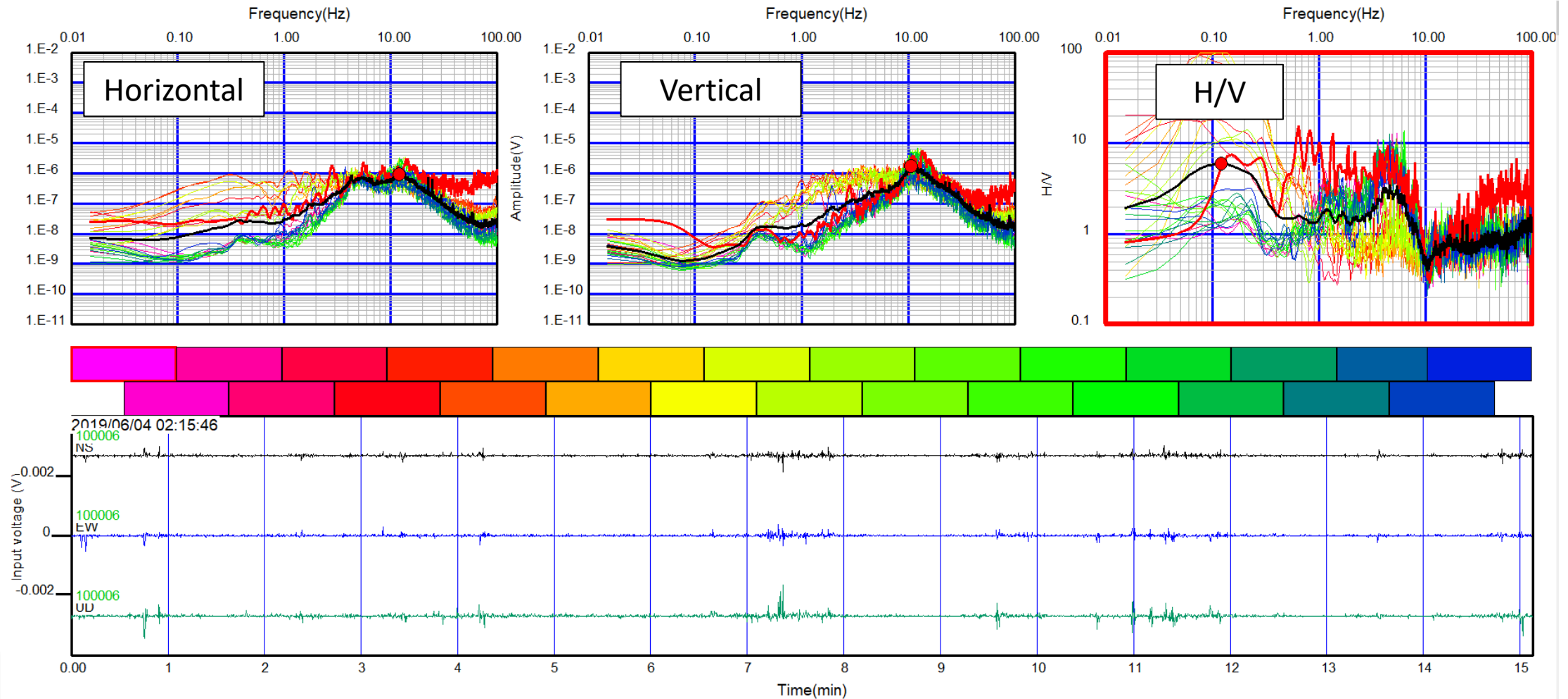
Confirm messages.





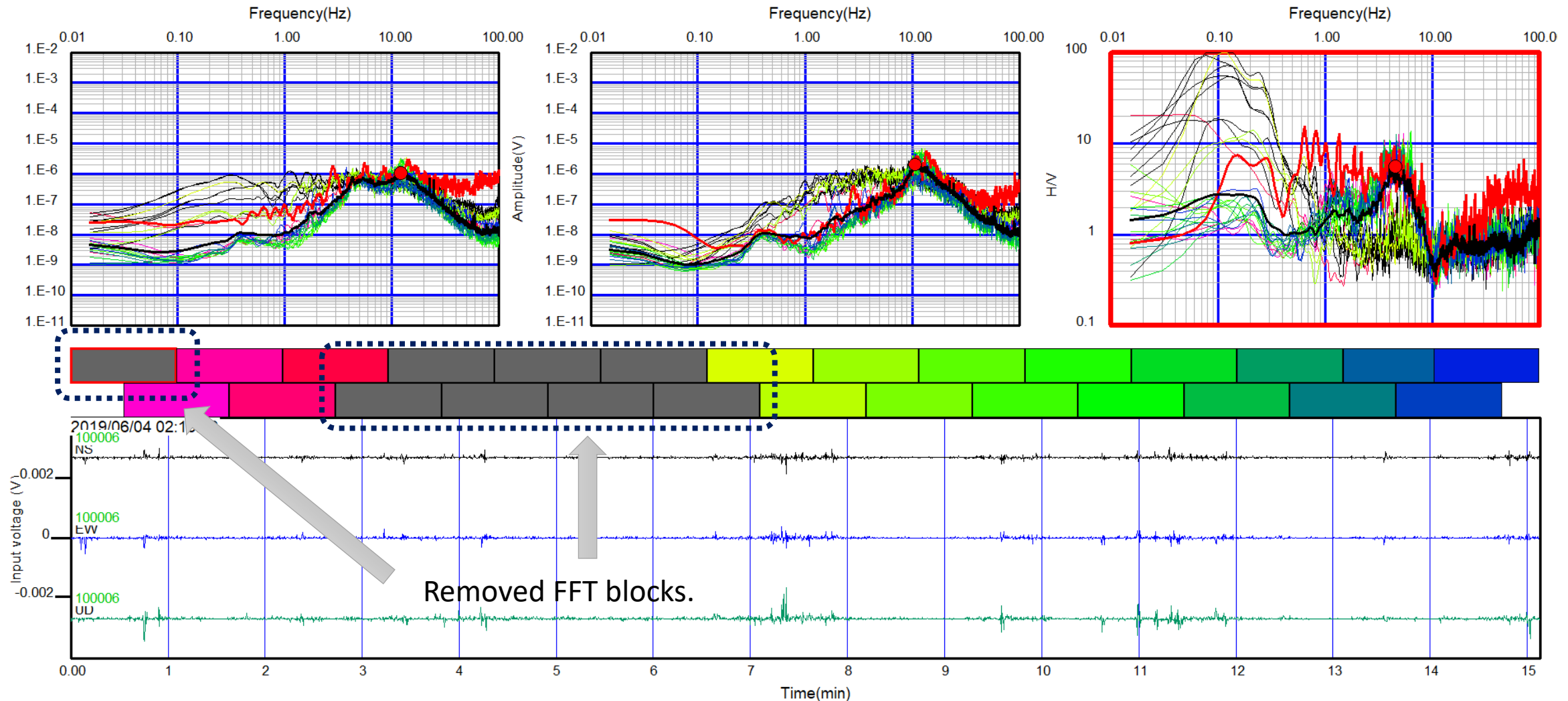
# Show horizontal to vertical spectral ratio (H/V)

Horizontal, vertical, and H/V spectra are shown in new window. Color rectangles at the middle of the window indicates FFT blocks. Rectangle colors correspond to thin lines in the spectra. Bold black lines in the spectra indicate averaged spectra. Blocks including irregular noises can be removed by delete key. Deleted blocks are shown as gray.



# Edit horizontal to vertical spectral ratio (H/V)

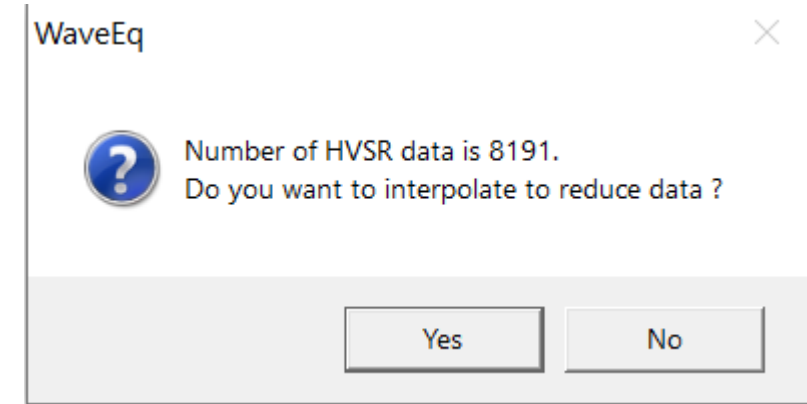
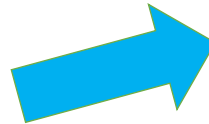
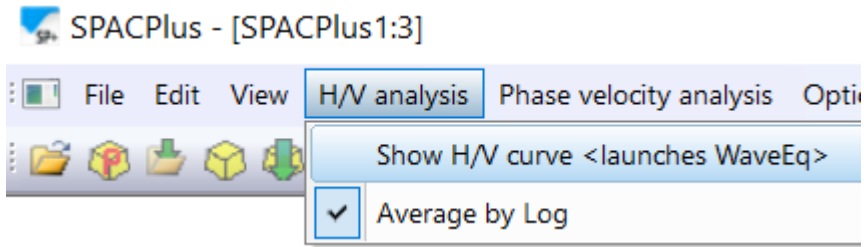
FFT blocks including large noises were removed from average.



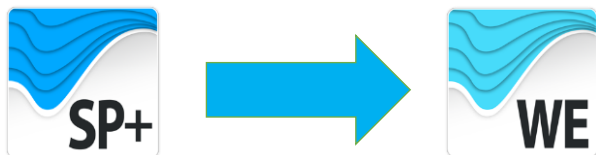
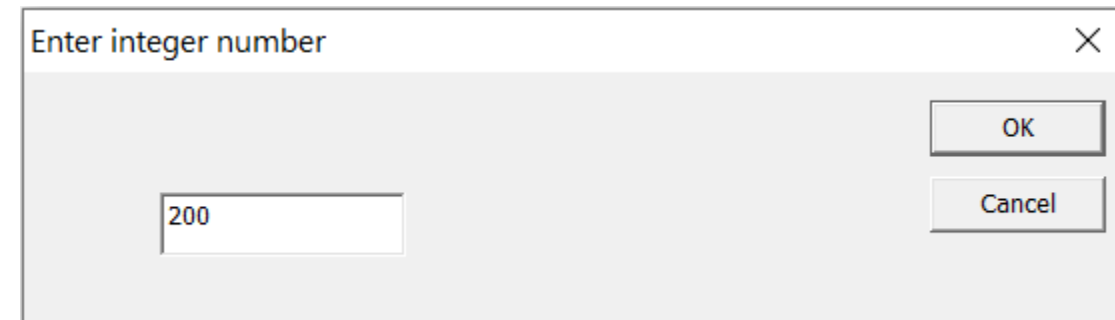
# Show H/V spectrum by WaveEq

You may reduce number H/V to speed up inversion and reduce file size.

Select “H/V analysis”, “Show H/V curve <launches WaveEq>” for further processing.

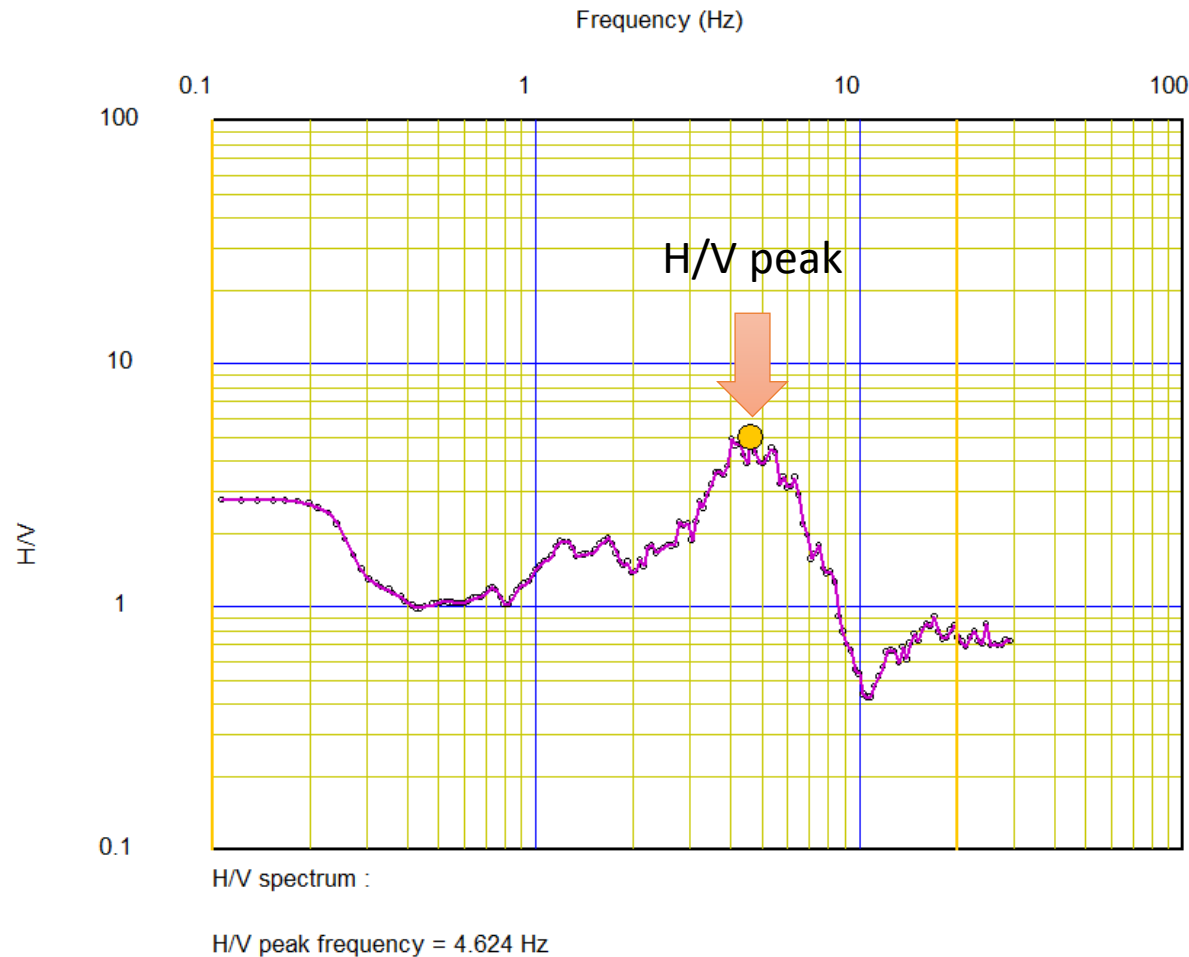


Set 100 to 200 for number to be reduced.



# Showing a dispersion curve in WaveEq

WaveEq is automatically launched and H/V spectrum appears.



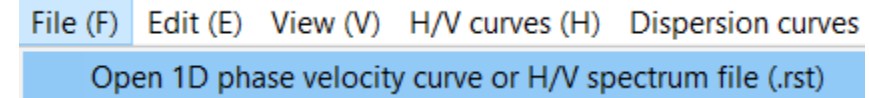
Use “Ctrl+X” to delete H/V data outside gate.

Use “Ctrl+H” to define a frequency range to pick a peak frequency.

See “*SeisImager/SW™ Manual Addendum (H/V)*” or “*SeisImager/SW-Pro™ Manual*” for further processing.

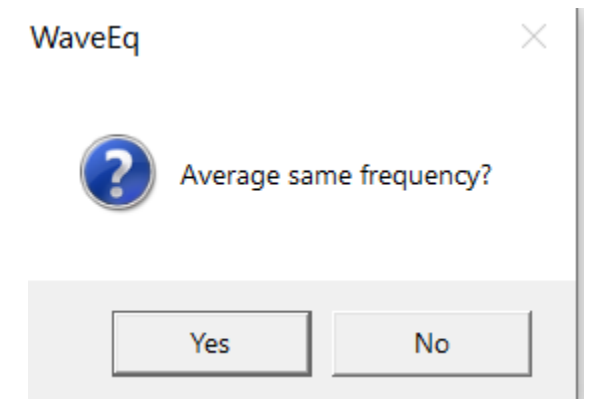
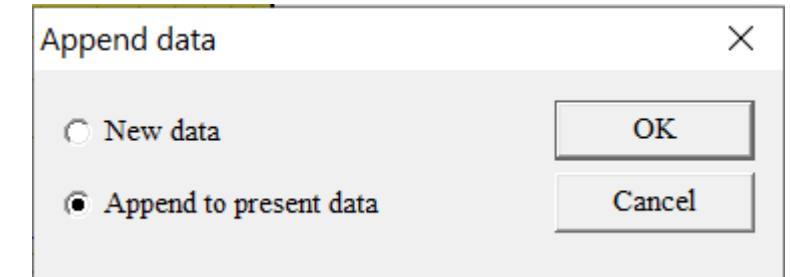
# Combine dispersion curve and velocity model

Select “File”, “Open 1D phase velocity curve or H/V spectrum file (.rst)”

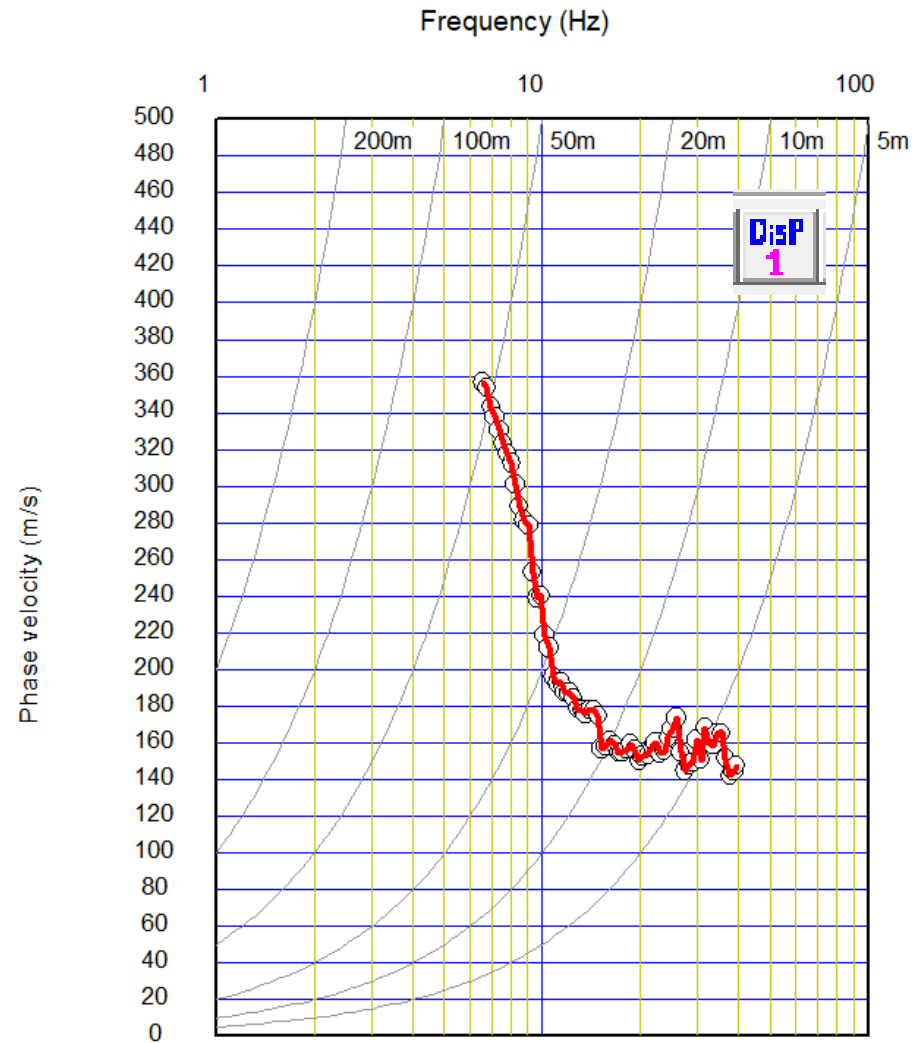


Select .rst file containing a dispersion curve and a velocity model.

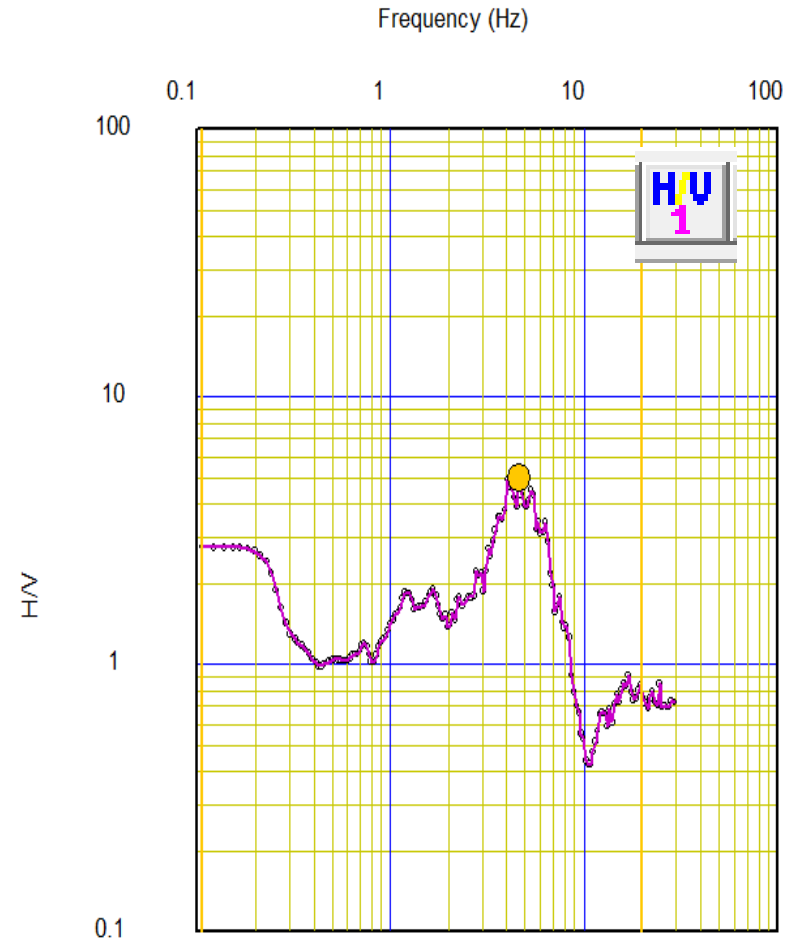
Append to present data.



# Dispersion curve, H/V, and velocity model

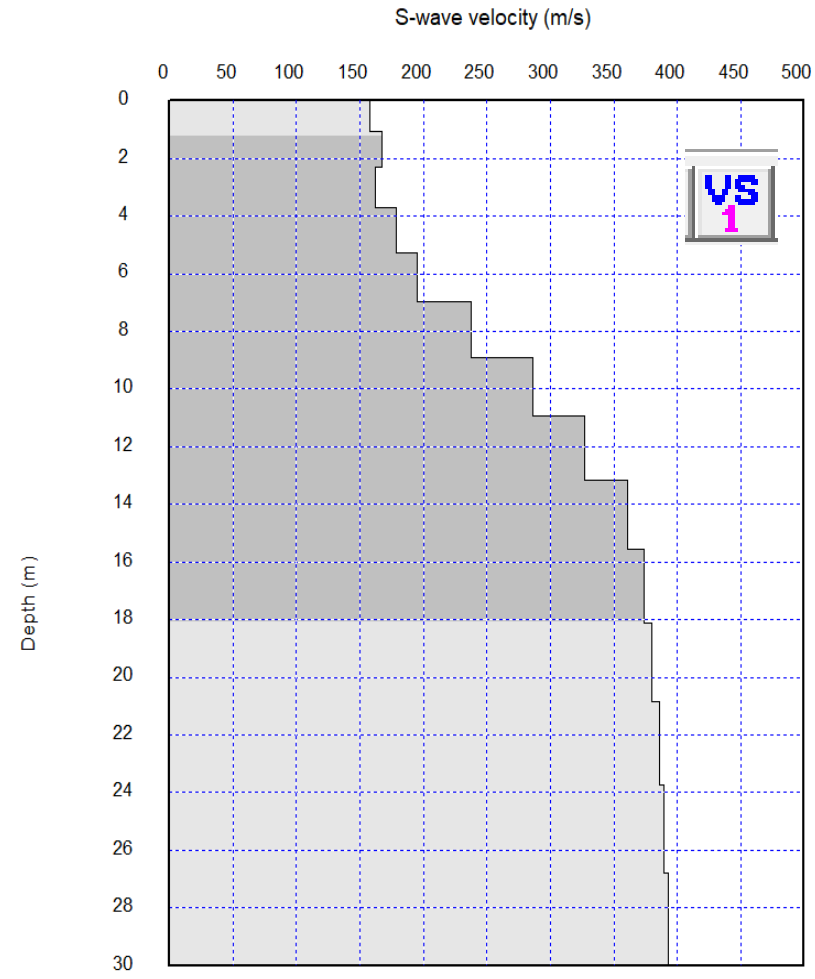


Dispersion curve : Inverted result.rst



H/V spectrum : Inverted result.rst

H/V peak frequency = 4.624 Hz

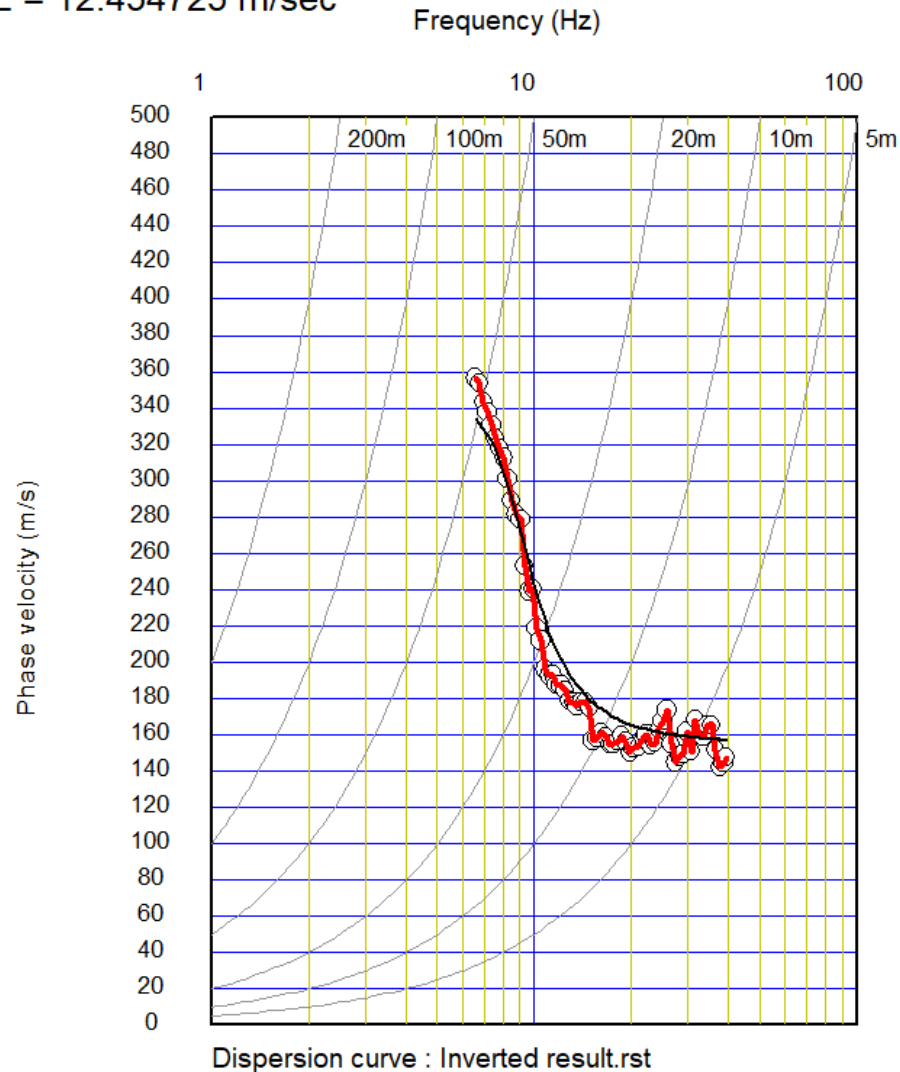


S-wave velocity model : Inverted result.rst

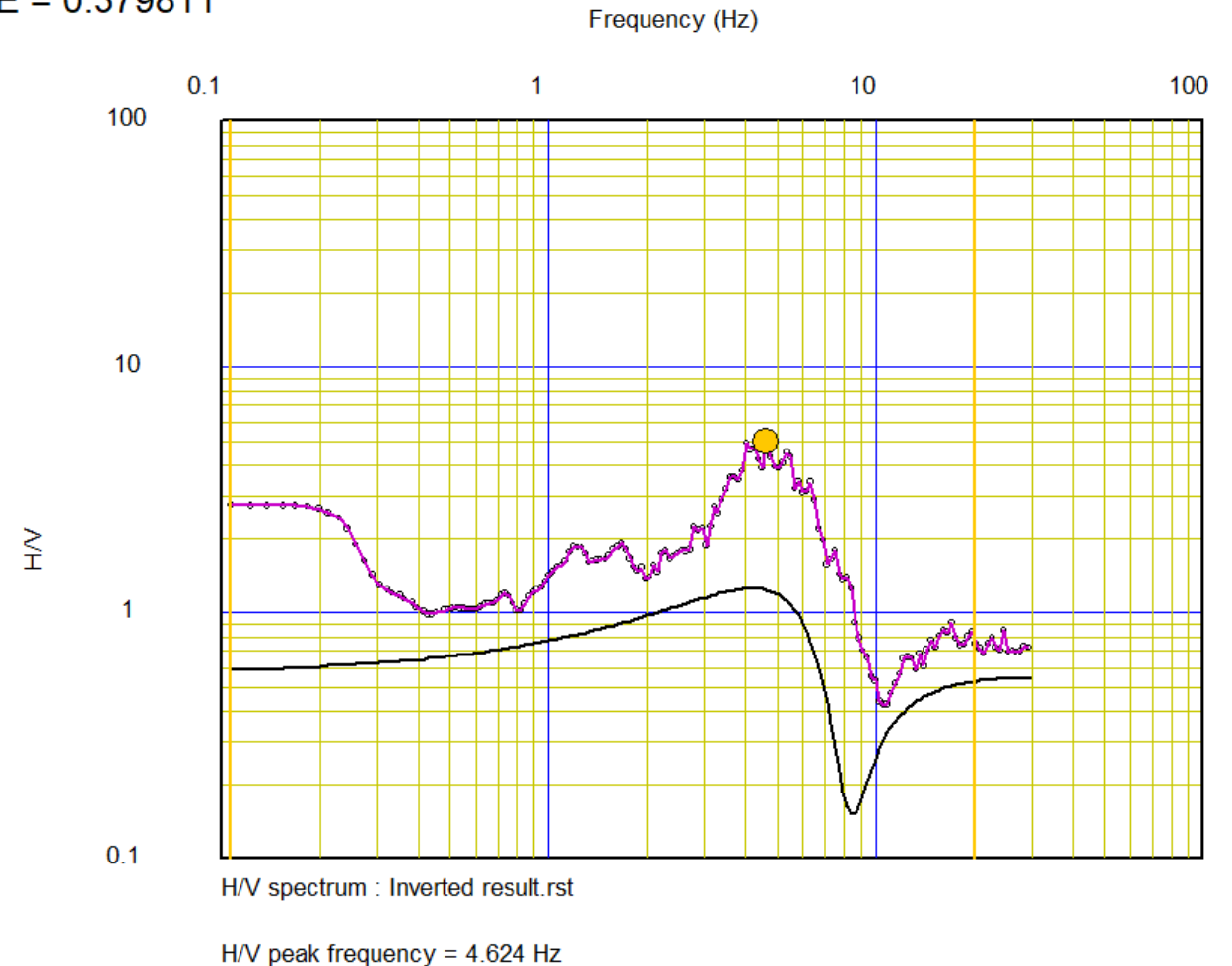
# Calculate theoretical dispersion curve and H/V

Click  to calculate theoretical dispersion curve or H/V.

RMSE = 12.454725 m/sec



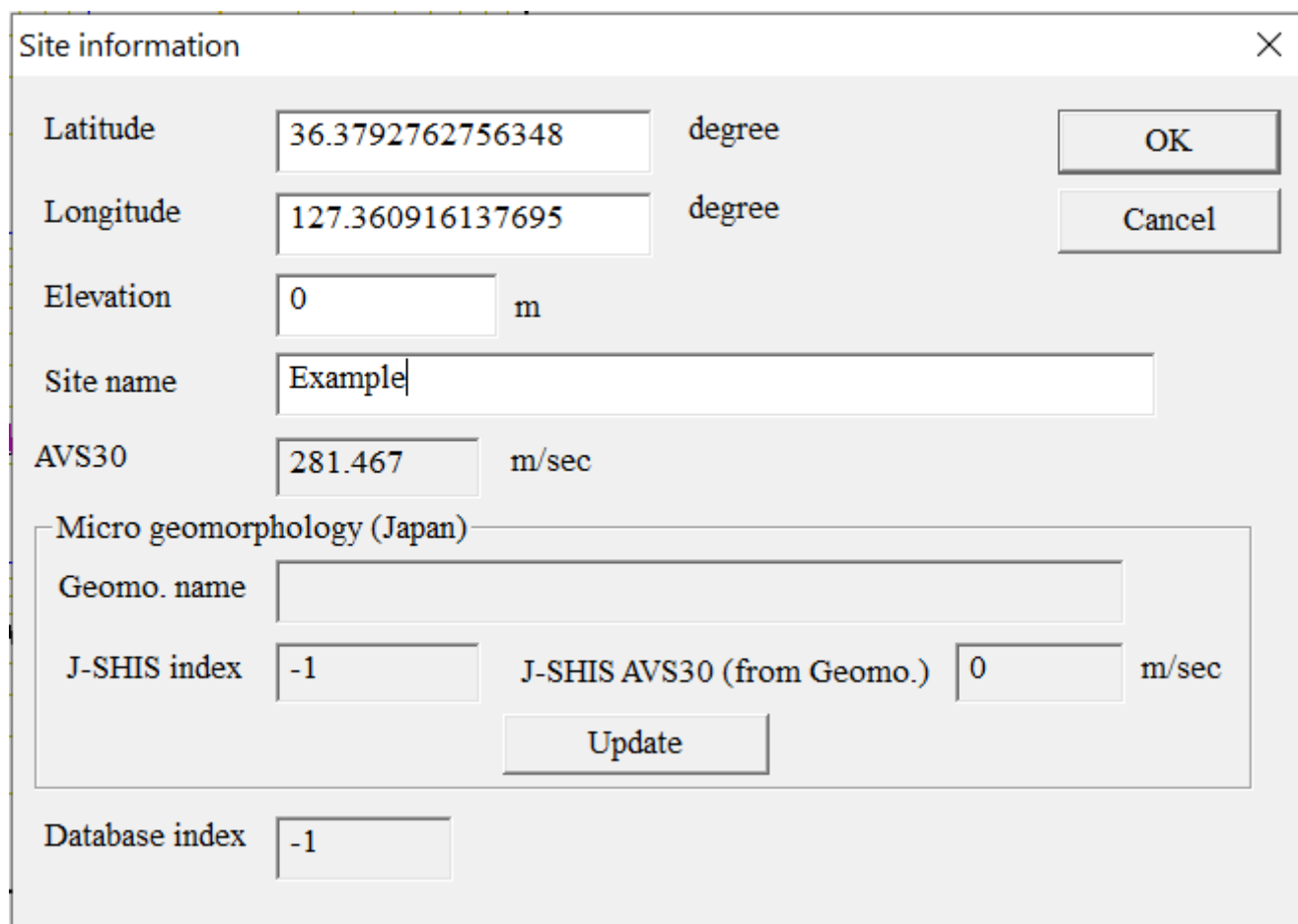
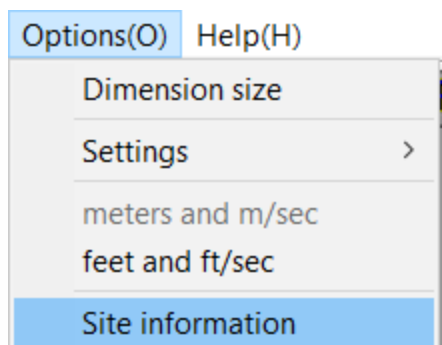
RMSE = 0.379811



# Set up site information

Select “Options”, “Site information” to set up site information.

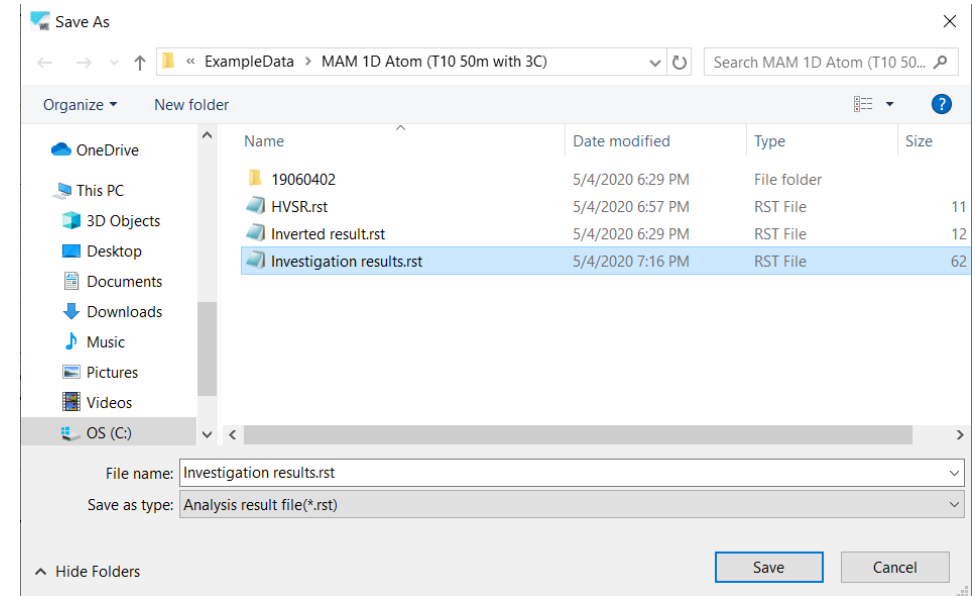
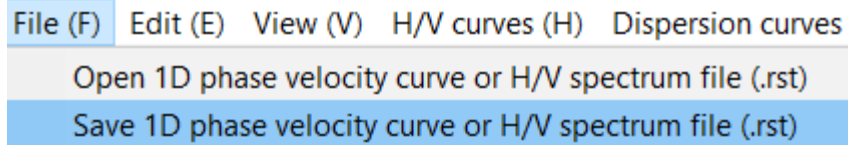
Latitude and longitude are automatically set from GPS information in Atom files. Confirm coordinate and set site name.

A screenshot of a 'Site information' dialog box. It contains several input fields and buttons. The 'Latitude' field is set to '36.3792762756348' with a 'degree' unit. The 'Longitude' field is set to '127.360916137695' with a 'degree' unit. The 'Elevation' field is set to '0' with a 'm' unit. The 'Site name' field contains the text 'Example'. The 'AVS30' field is set to '281.467' with a 'm/sec' unit. Below these is a section titled 'Micro geomorphology (Japan)' which contains a 'Geomorphology name' field, a 'J-SHIS index' field set to '-1', and a 'J-SHIS AVS30 (from Geomorphology)' field set to '0' with a 'm/sec' unit. There is an 'Update' button below the 'J-SHIS' fields. At the bottom of the dialog is a 'Database index' field set to '-1'. 'OK' and 'Cancel' buttons are located on the right side of the dialog.



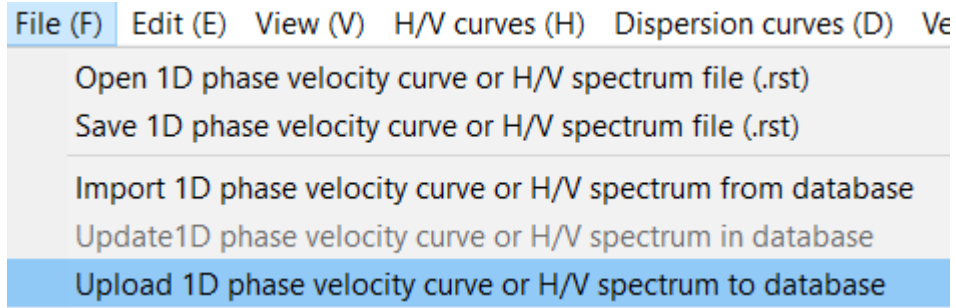
# Save investigation results to an ASCII file in PC

Select “File”, “Save 1D phase velocity curve or H/V spectrum file (.rst)” to save results to an ASCII file in PC.



# Upload investigation results to database

Select “File”, “Upload 1D phase velocity curve or H/V spectrum to database” to upload results to database.



Enter username and password.

A dialog box titled 'Username and password' with a close button (X). It contains two input fields: 'Username' with the placeholder text 'Username' and 'Password' with placeholder text '\*\*\*\*\*'. There are 'OK' and 'Cancel' buttons to the right of the fields.

Set database information. Check “Open to public” if you want to open data to public.

A dialog box titled 'Database information' with a close button (X). It contains a 'Database selection' section with two dropdown menus: 'User name' (set to 'SeisImager') and 'Project name' (set to 'San Jose'). There are 'OK' and 'Cancel' buttons to the right. At the bottom, there is a checkbox labeled 'Open to public' which is checked.

Select “1D surface wave method” and click “OK” to upload.

A dialog box titled 'Select survey type' with a close button (X). It contains three radio button options: '1D surface wave method (MASW and/or MAM)' (which is selected), '2D surface wave method', and 'Seismic logging'. There are 'OK' and 'Cancel' buttons to the right.