6. Data processing using SeisImager

- Data downloading from Atom
- 1D active/passive surface wave method (data obtained by Atom)
- 2D active surface wave method based on CMP-CC (data obtained by Geode)
- 3D passive surface wave method based on CMP-SPAC (data obtained by Atom)
- Higher modes and inversion using effective mode based on Genetic Algorithm

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- Higher modes and inversion using effective mode based on Genetic Algorithm

Data downloading from Atom

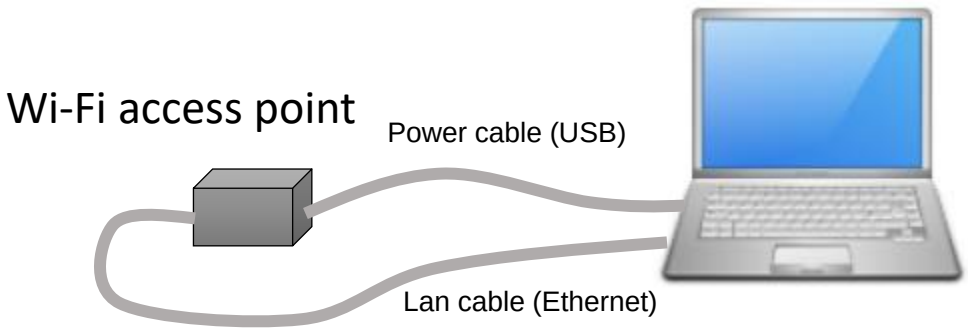
A. Copy data from SD card
   Remove the SD card from each Atom box and directly copy waveform files. Data files are saved in folders as shown above.

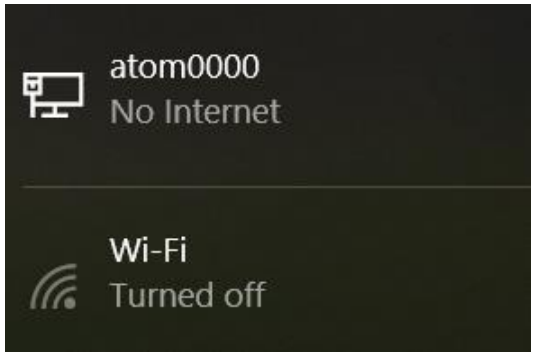
B. USB
   Connect the USB cable from your PC to your Atom and download waveform data files in SPACPlus using the following menu commands: [File]>>[ATOM(USB)]>>[Download via USB]. Set Baud rate to 3686400. Download the USB driver from a link shown below and install it at first time.

C. Wi-Fi
   Geometrics Atom Downloader downloads waveform data files via Wi-Fi using a special access point connected to your PC. Wireless downloading is faster than downloading via USB connection with data downloading from several Atom units simultaneously. SPACPlus also downloads waveform data via Wi-Fi if the Atom Downloader is not available (see Appendix A for the details). Follow the procedure shown below to download waveform data using the Geometrics Atom Downloader.

Download waveform data via Wi-Fi using the Geometrics Atom Downloader (1)

1) Turn off each Atom to stop recording data.
2) Plug in a Wi-Fi access point (SSID of “atom0000”) to your PC.
3) Connect your PC to “atom0000” by LAN cable (strongly recommended) or Wi-FI. Do not connect both Lan cable and Wi-Fi to the access point. It is better to turn off Wi-Fi to make sure only the Lan-cable is connected to the access point.

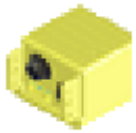




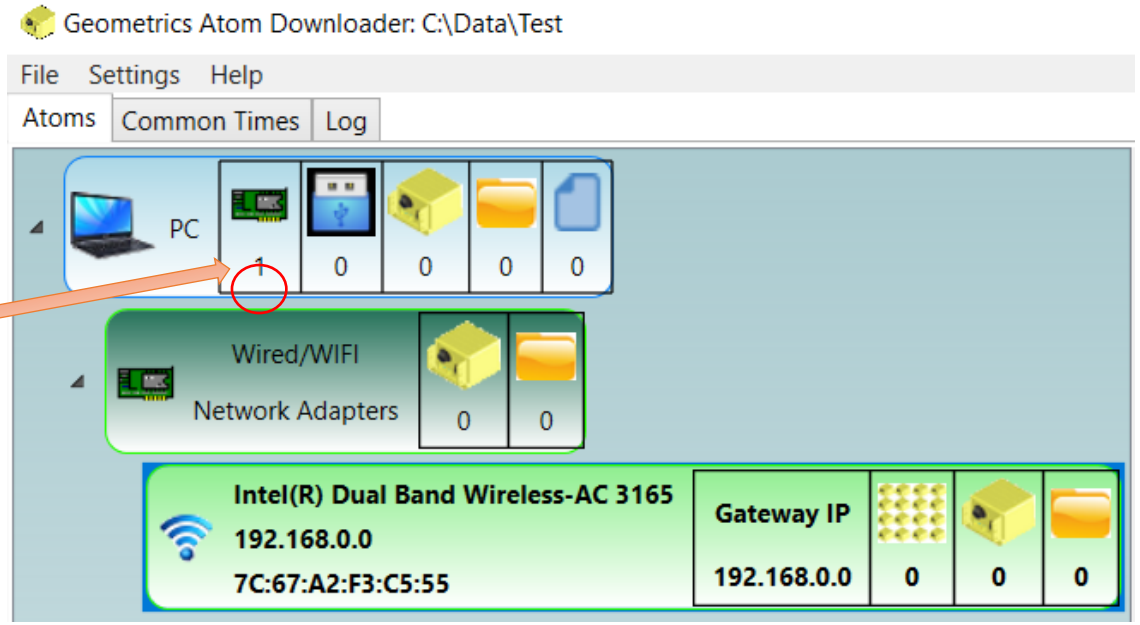
Connected to Ethernet by Lan-cable (should be No Internet).

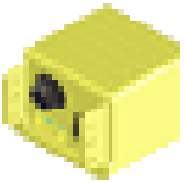
Wi-Fi is turned off.

Download waveform data via Wi-Fi using the Geometrics Atom Downloader (2)

4) Launch Geometrics Atom Downloader 
5) Select [Settings]>>[Data Folder Location] and select a folder to which data to be downloaded
6) Display shown below appears on the window. Make sure one or two networks were found.

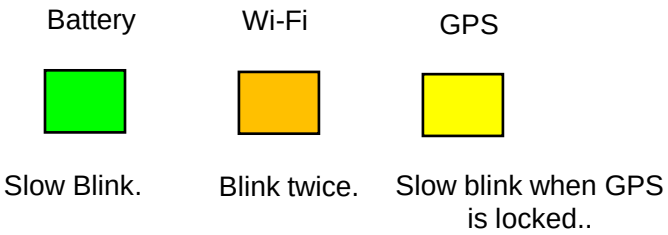
Number of networks

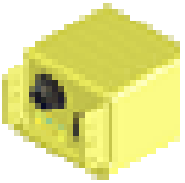




Download waveform data via Wi-Fi using the Geometrics Atom Downloader (3)

7) Turn on all Atom units
The Atom units enter download mode when they find the access point named “atom0000”. In this mode, the data recording does not start.

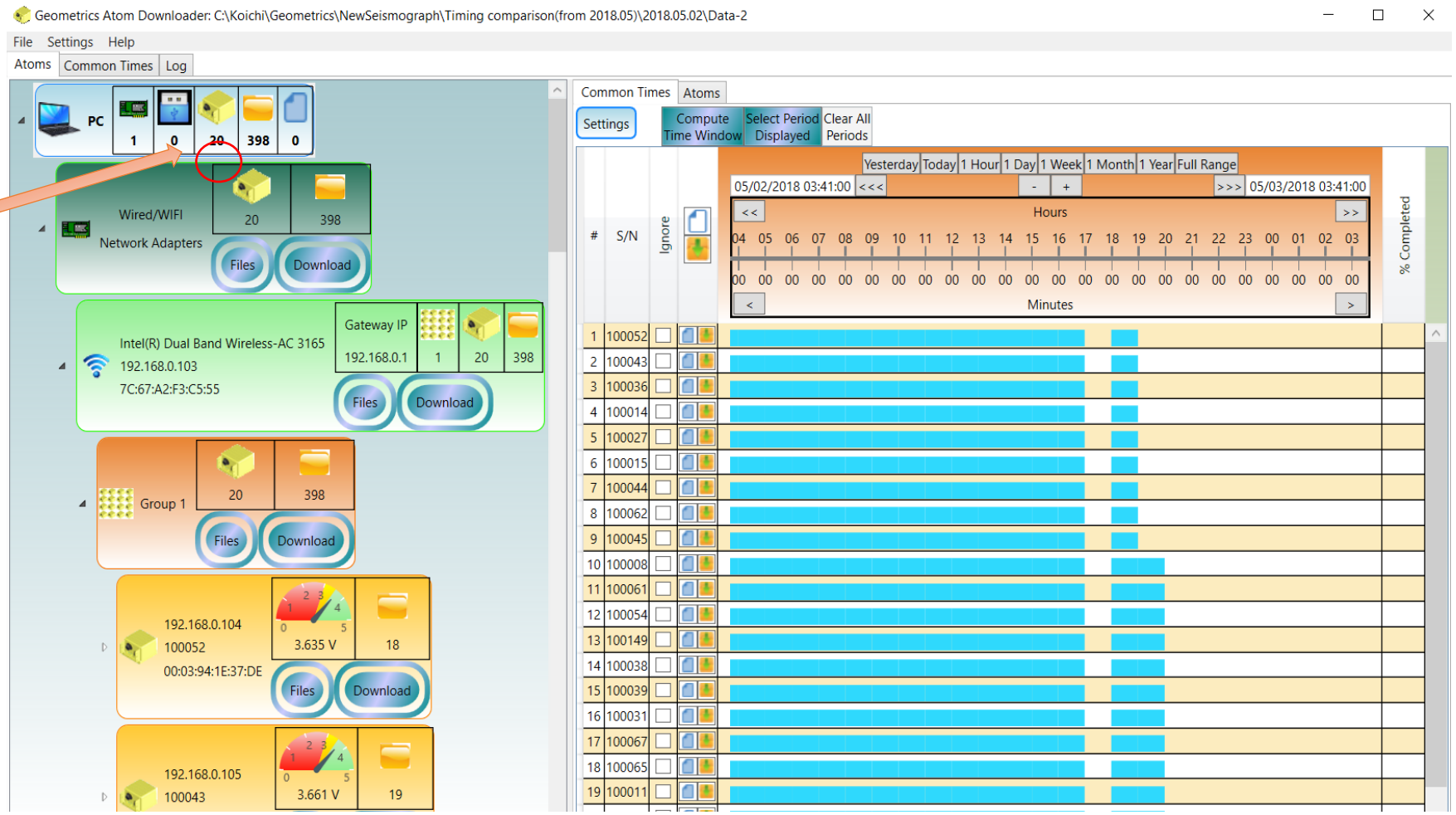


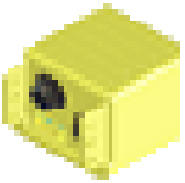


Download waveform data via Wi-Fi using the Geometrics Atom Downloader (4)

8) Atom IDs appear on the Atom Tree Window of the Downloader.

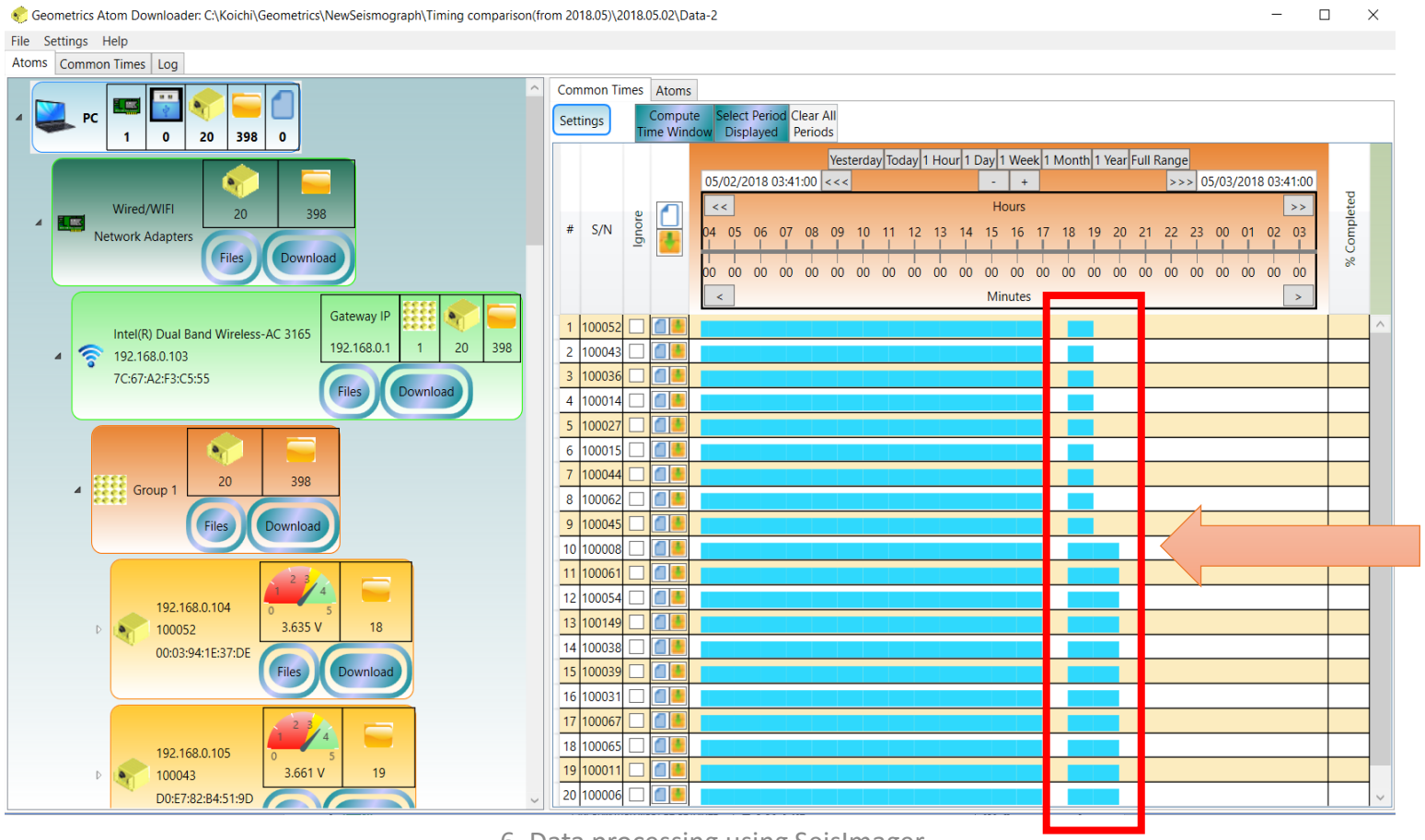
Number of Atom units





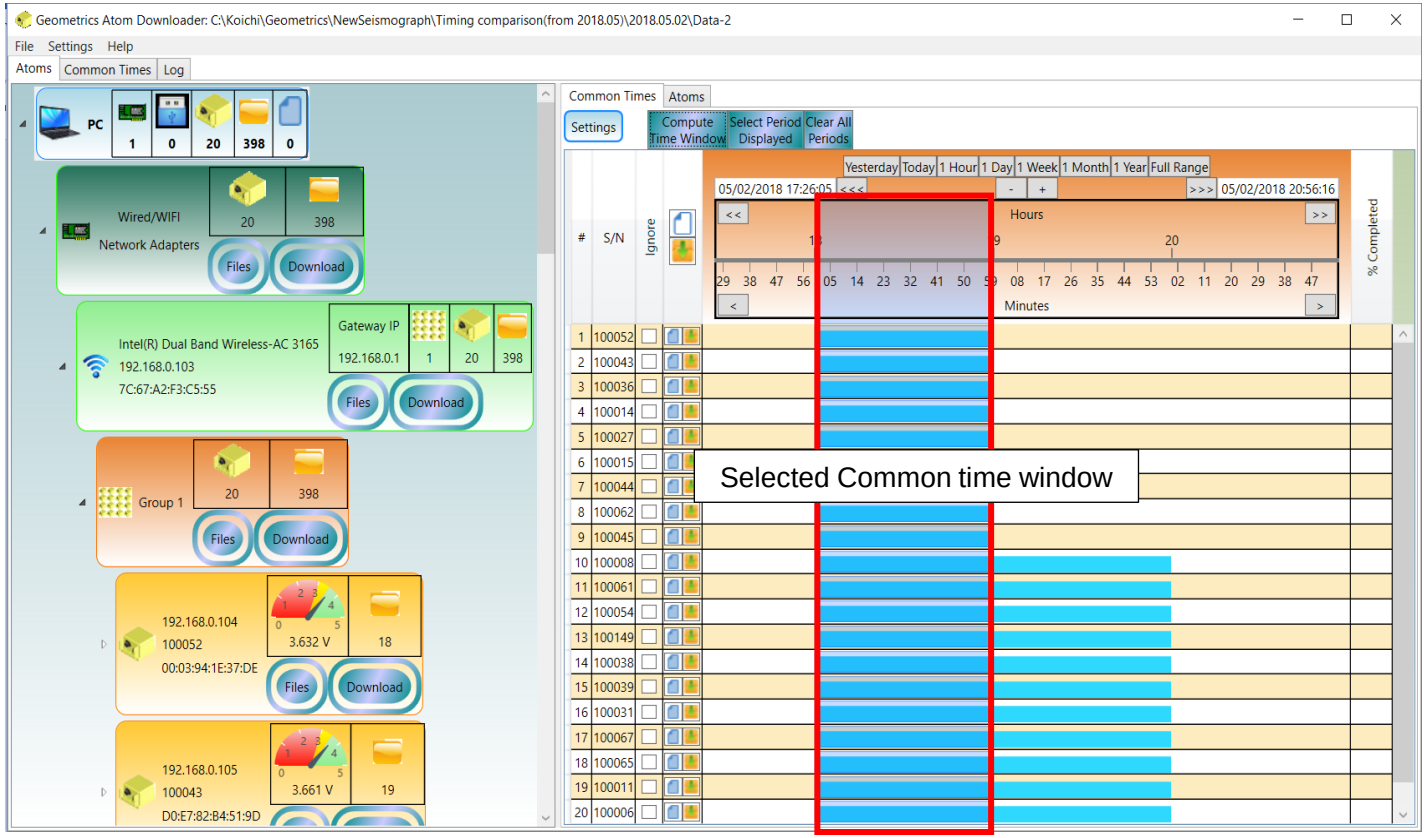
Download waveform data via Wi-Fi using the Geometrics Atom Downloader (5)

9) Select a time range from which data will be downloaded by a mouse in the windows at right hand side.



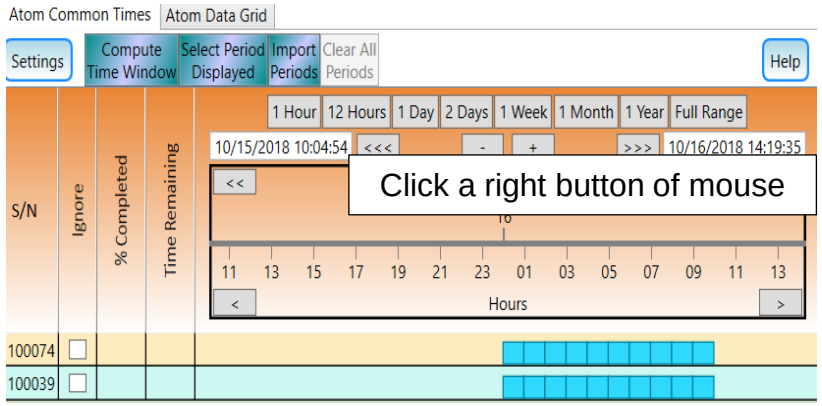
Download waveform data via Wi-Fi using the Geometrics Atom Downloader (6)

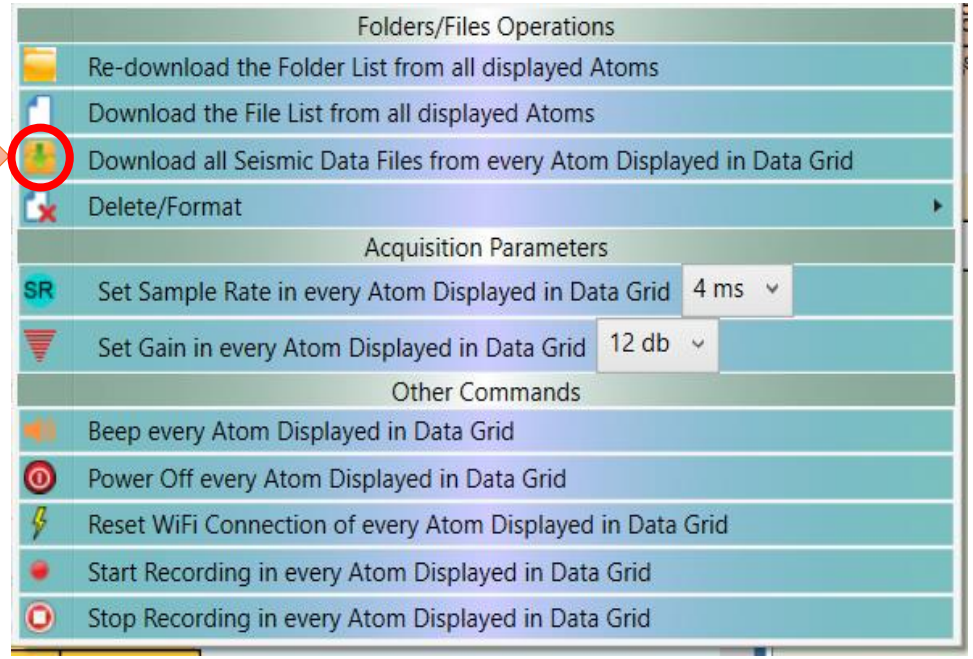
10) Click [Compute Time Window] to download common time windows (blocks) or [Select Period Displayed] to download all data displayed in the window.

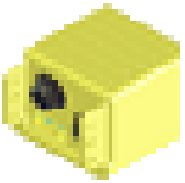


Download waveform data via Wi-Fi using the Geometrics Atom Downloader (7)

11) Click a right button of mouse in time scale above the Atom data grid to show sub menu.
12) Select in the sub menu to start download data.







Download waveform data via Wi-Fi using the Geometrics Atom Downloader (8)

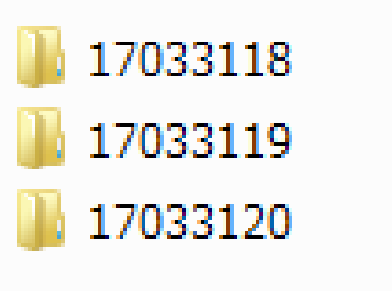
13) During the download process, progress appears on a display similar to the one shown below. After download completed, completion at the far-right column must be 100 at all rows.

Data format

Downloaded waveform data is saved in binary files with extension ".atm. The files can be opened by Pickwin.

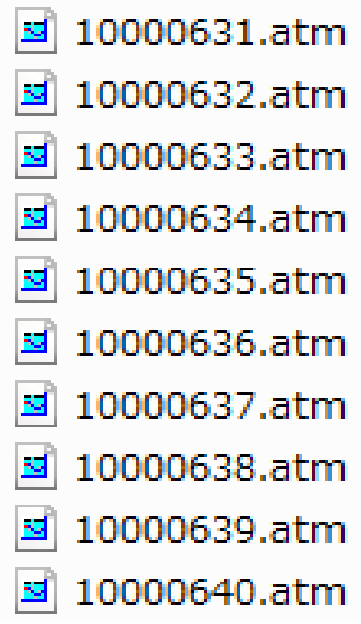
Folder for each hour.

The data files are automatically saved to the date and time (UTC) the data is collected. In the example shown below, the folders represent data collect on March 31st, 2017 between 18:00 and 20:00 UTC.



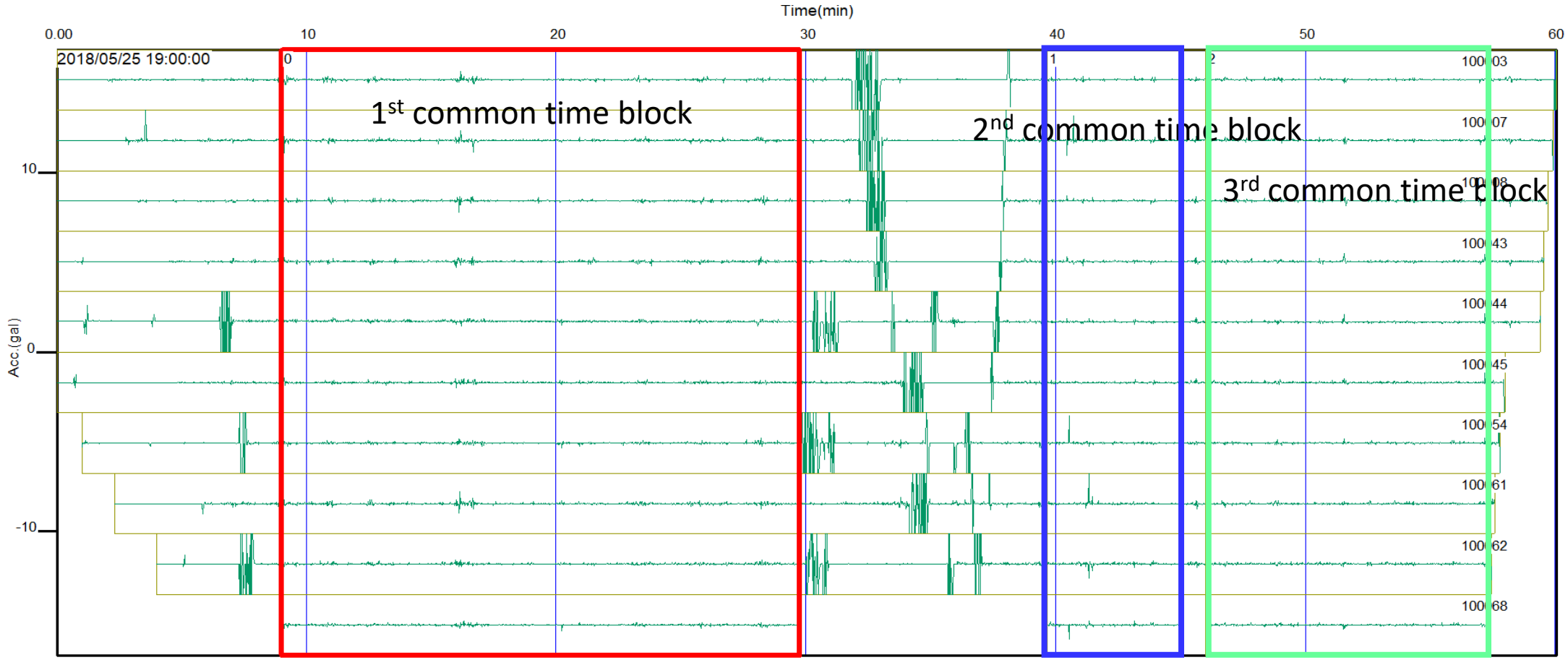
Waveform data file.

Collected data are stored in files named for the Atom unit's ID and time in minutes. In the example shown below, files are recorded with Atom unit 100006 from 31 to 40 min.



Export waveform data as SEG2 or ASCII file using SPACPlus in SeisImager

Downloaded waveform data can be exported as SEG2 or ASCII file using SPACPlus in SeisImager. Data are exported with each Common Time Block (CTB) during which all Atom units were recording data. An area surrounded by a red rectangle is a “Common Time Block (CTB)”. In SPACPlus, waveform traces appear in order from lower to higher Atom ID numbers.



6. Data processing using SeisImager

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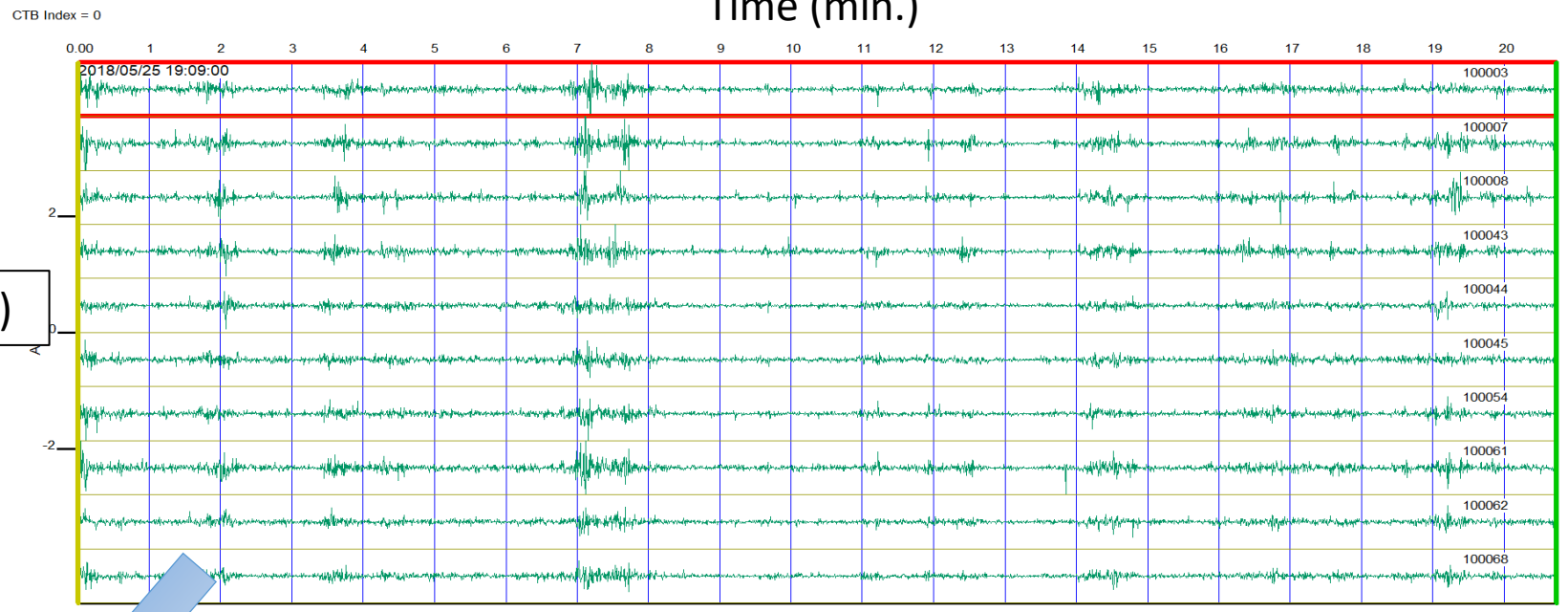
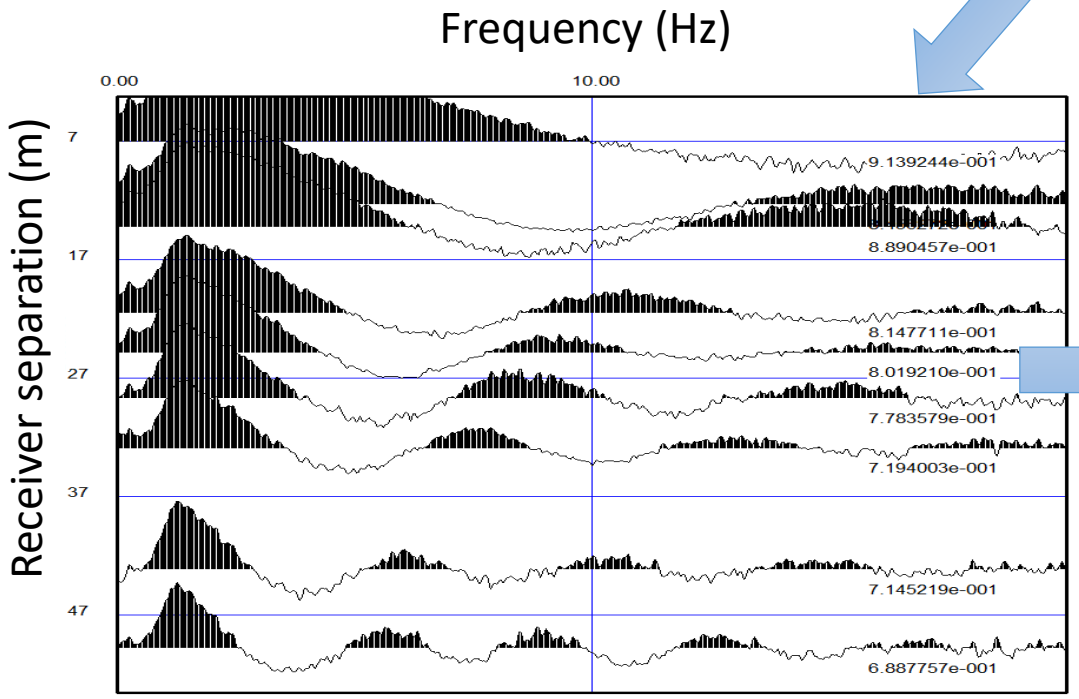
- 3D passive surface wave method based on CMP-SPAC (data obtained by Atom)
- Higher modes and inversion using effective mode based on Genetic Algorithm

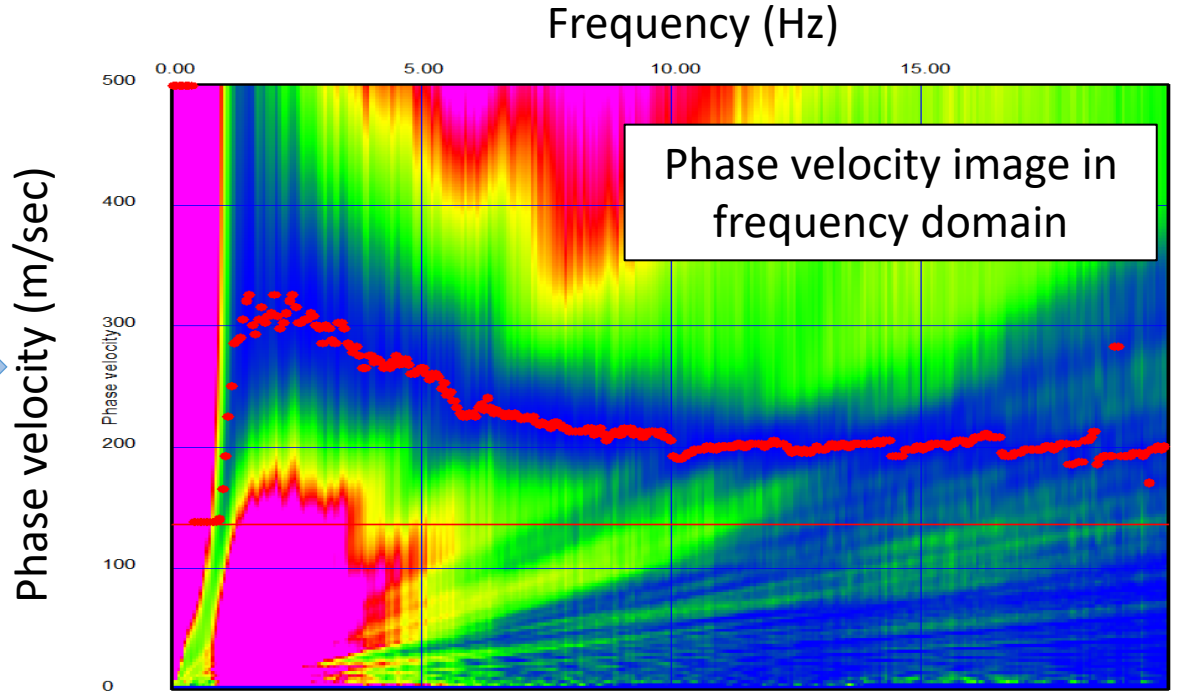
Data processing

Raw data (noise)



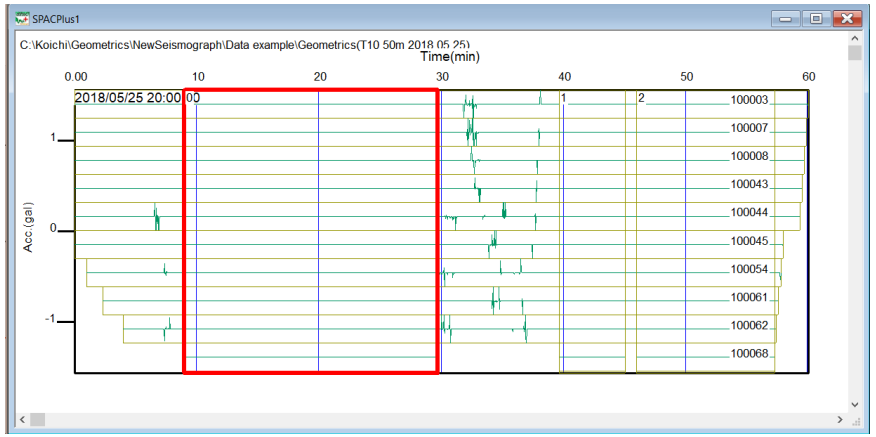
Coherency (cross correlation)





Window structure of SPACPlus

Main window (multi-CTB)



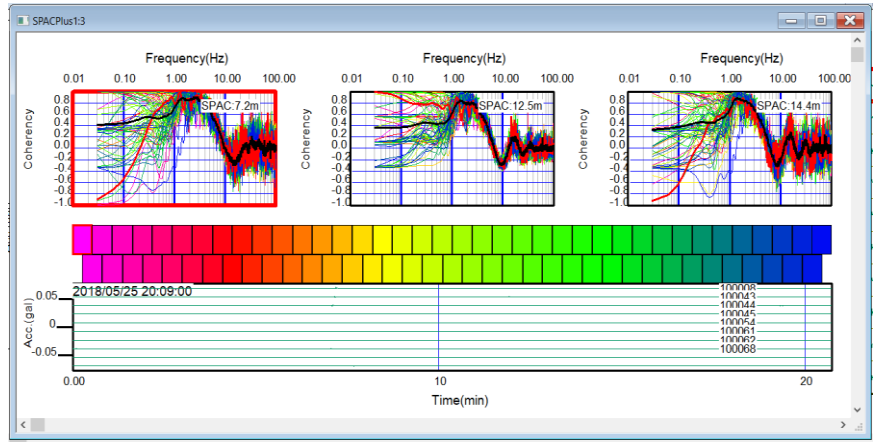
Main window

Select one CTB

Common time block (CTB) window

Geometry window

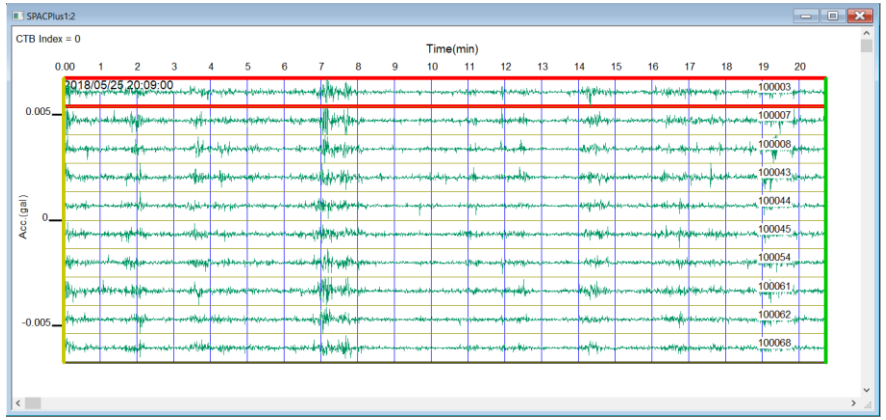
SPAC window (single-CTB)



Set geometry and calculate SPAC

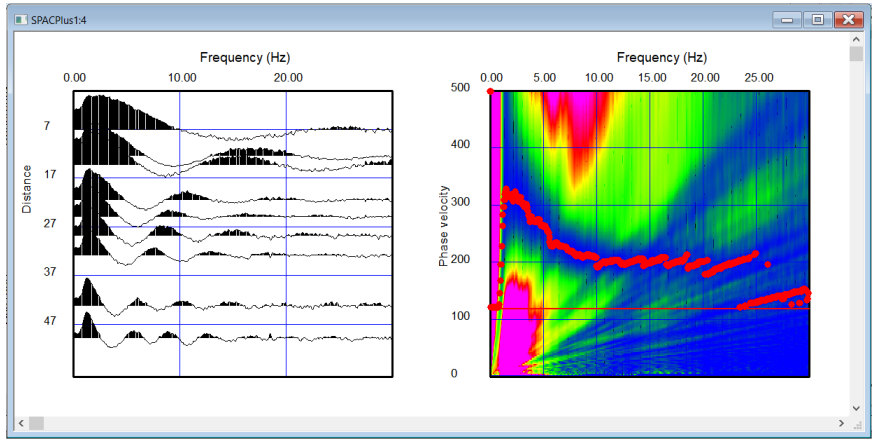
SPAC window

CTB window (single-CTB)



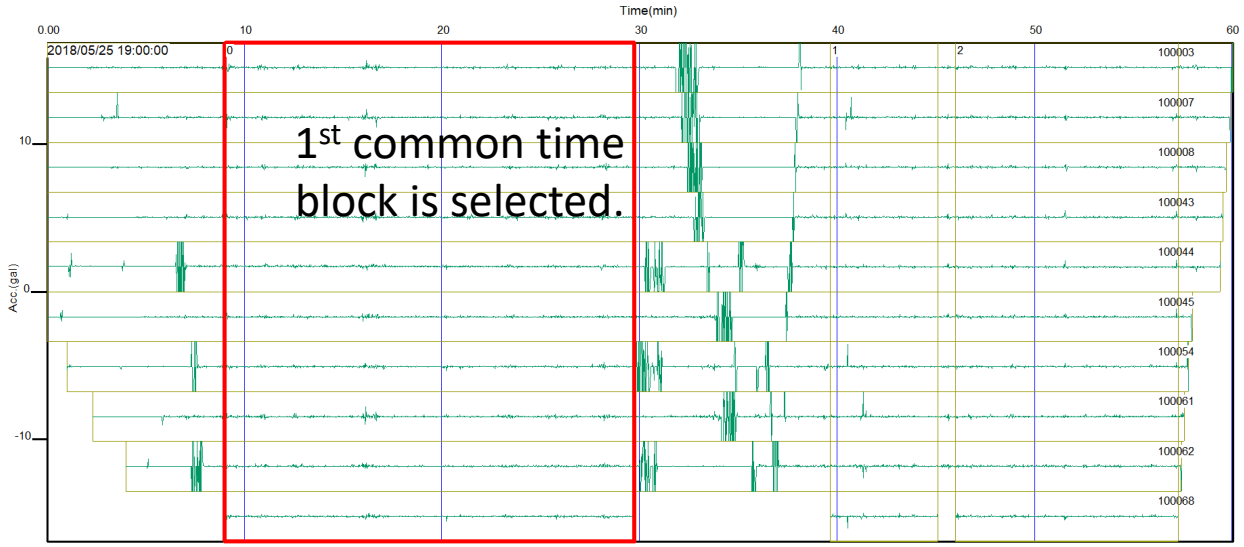
Phase velocity window

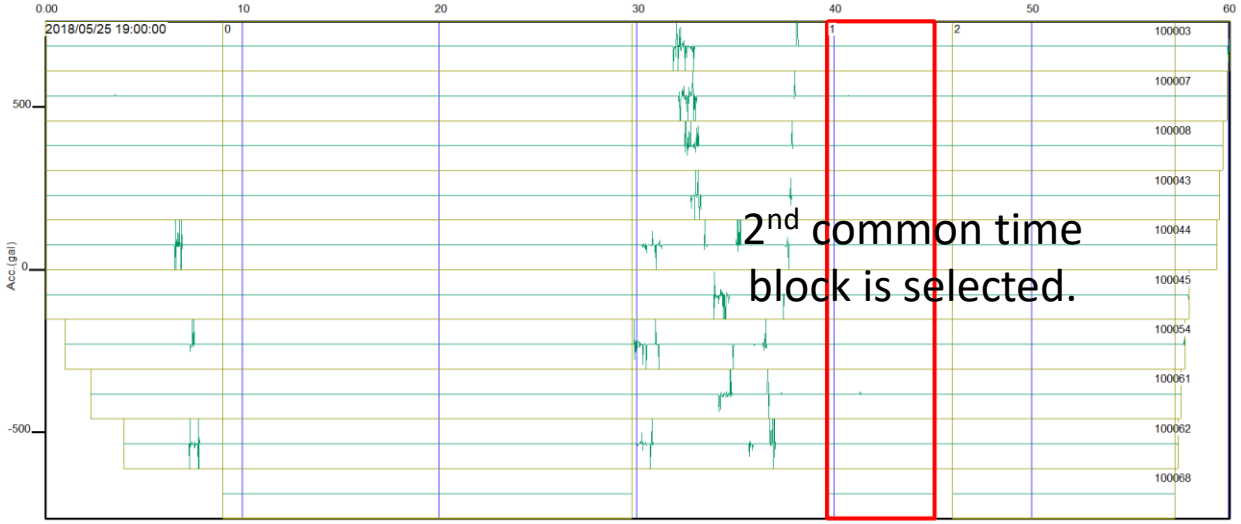
Phase velocity window (single-CTB)



Select a common time block to be processed

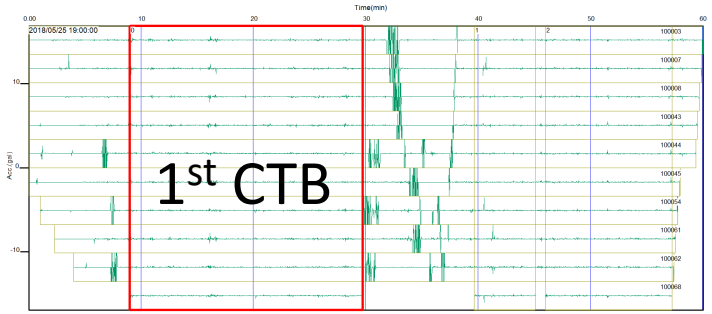
Select a common time block (CTB) to be processed, using left and right arrows if several tables are shown.

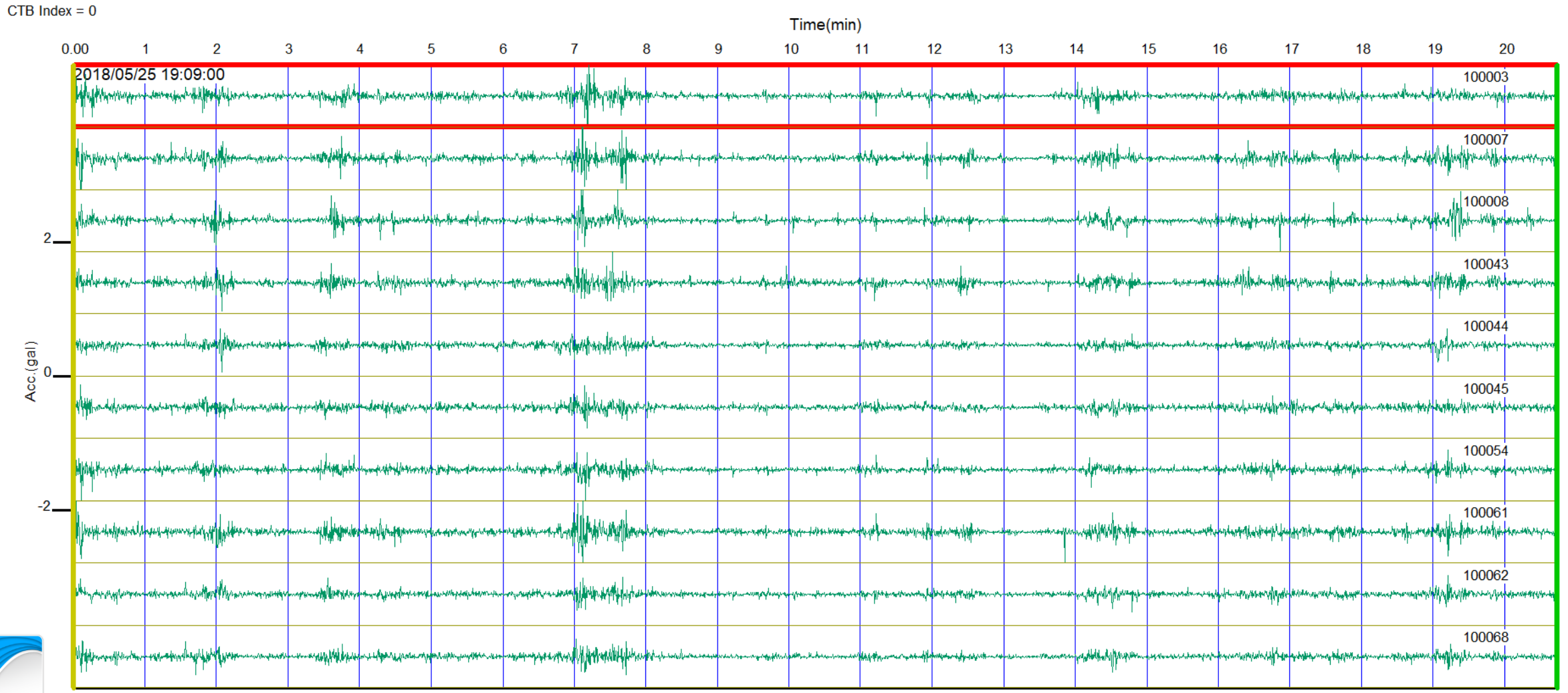




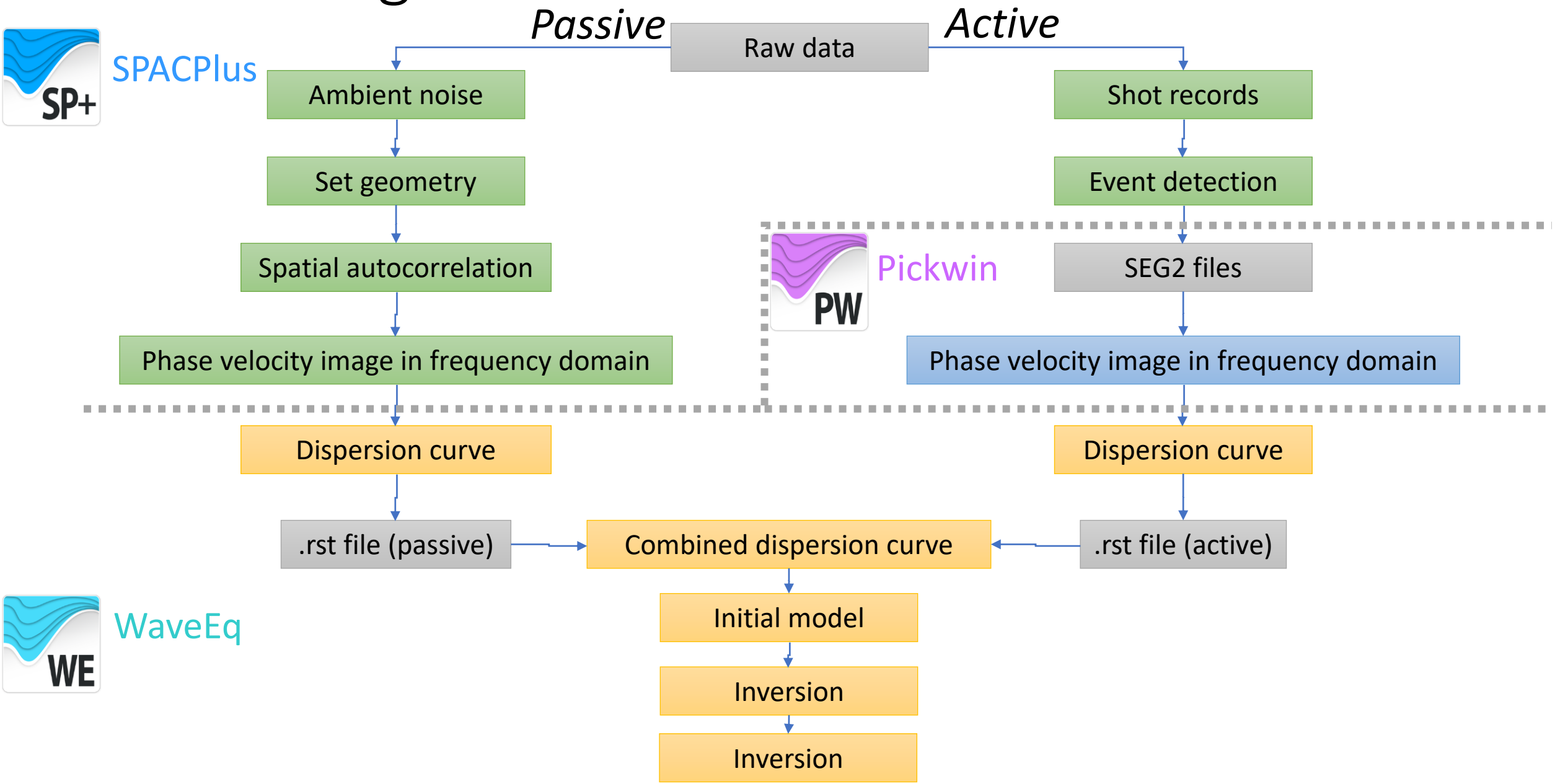
Processing ambient noise data

Click CTB or select [Window]>>[Processing window] and the selected 1st CTB data (in a red rectangle) will appear in another window.



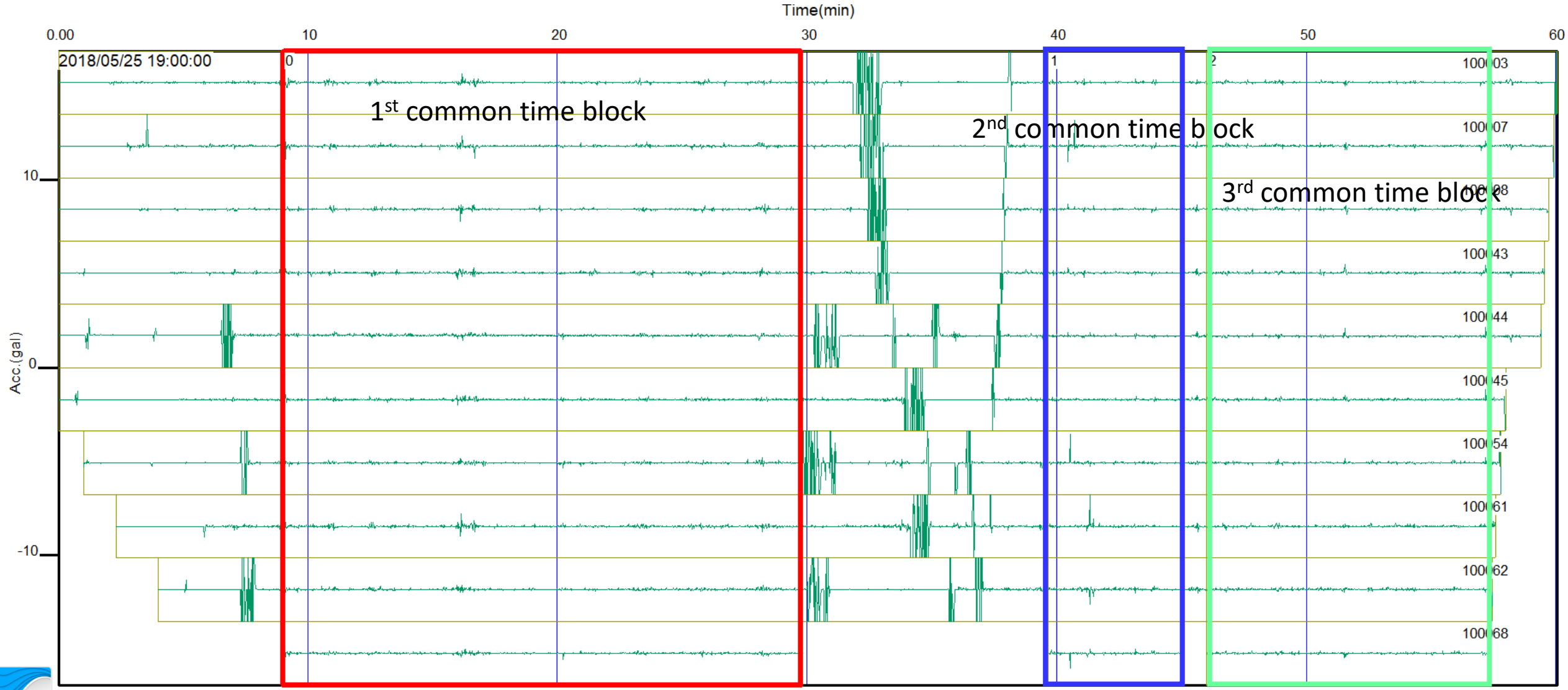


Processing flow



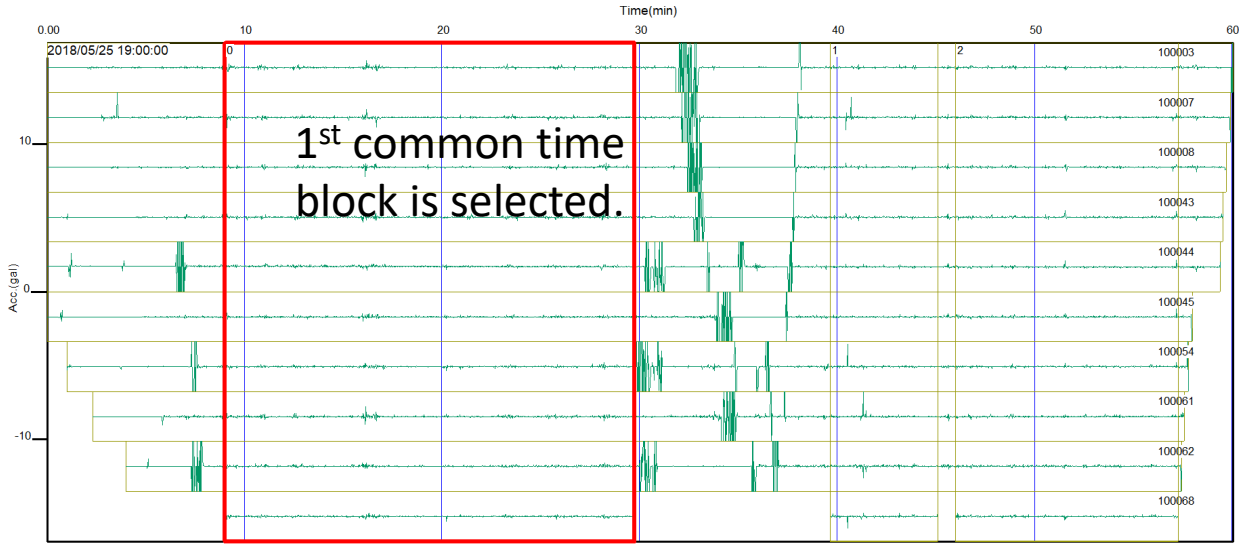
Raw data

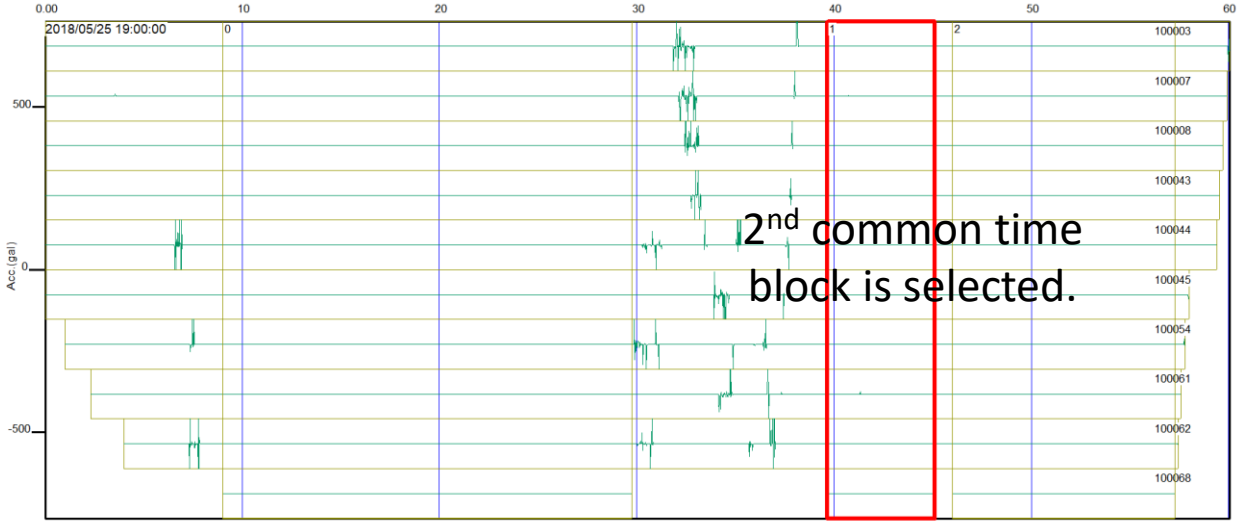
In SPACPlus, waveform traces appear in order from lower to higher Atom ID numbers. An area surrounded by a red rectangle is a “Common Time Block (CTB)” during which all Atom units were recording data.



Select a common time block to be processed

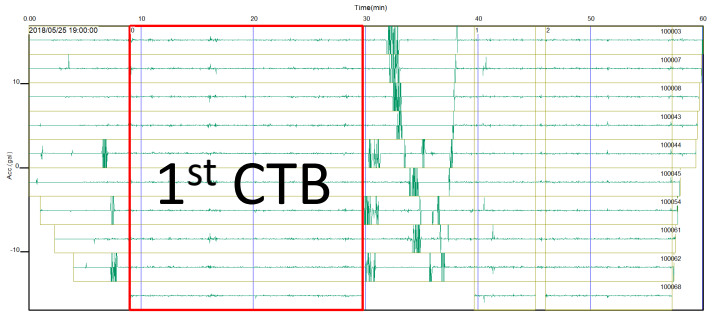
Select a common time block (CTB) to be processed, using left and right arrows if several tables are shown.

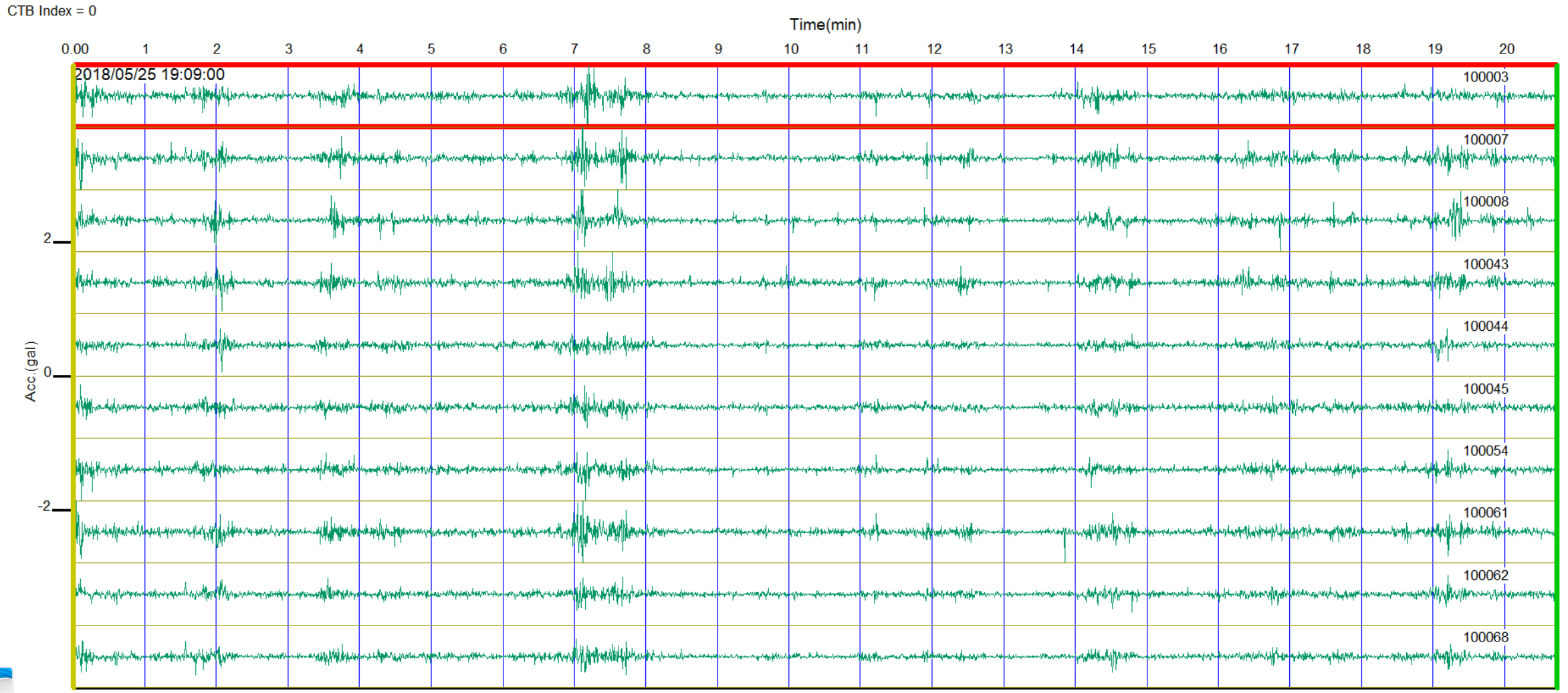




Processing ambient noise data

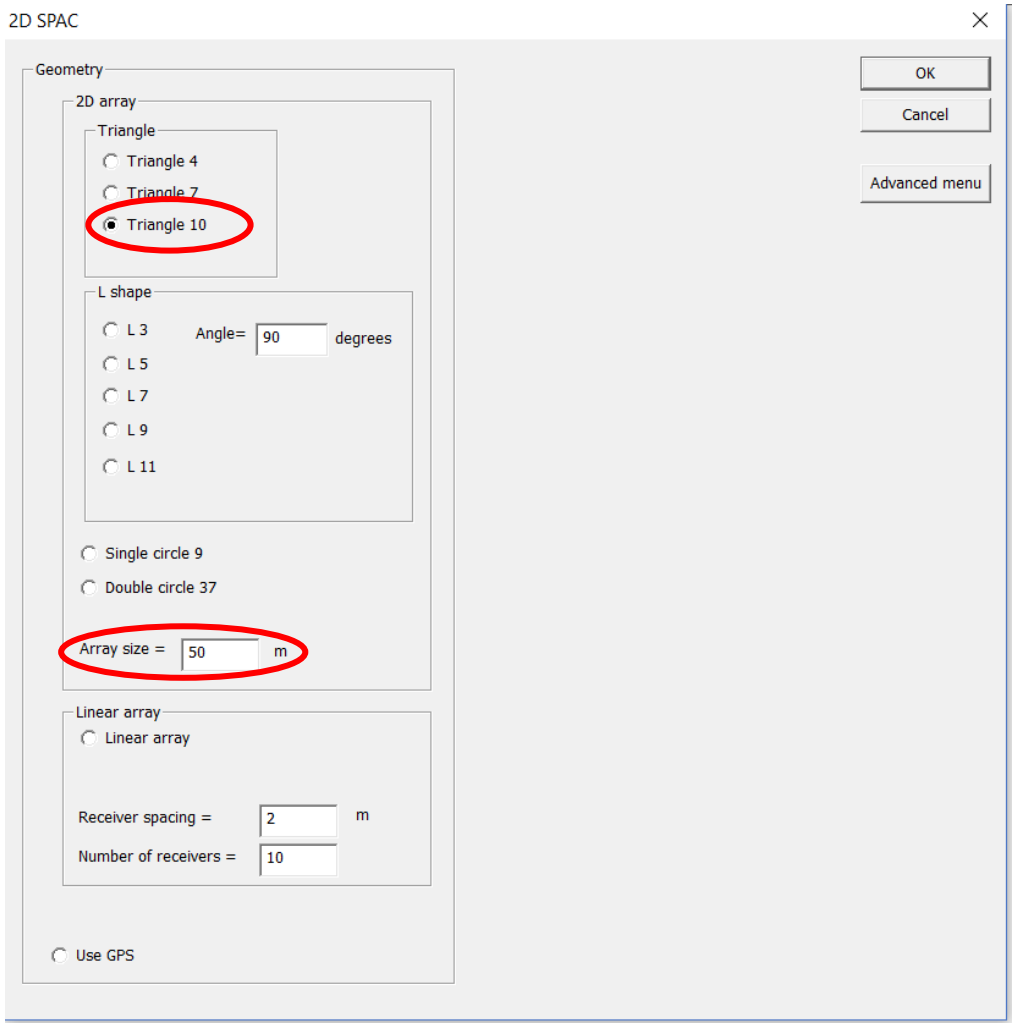
Click CTB or select [Window]>>[Processing window] and the selected 1st CTB data (in a red rectangle) will appear in another window.





Set up geometry

Click  or select [Analysis]>>[SPAC analysis] to process passive surface wave data in terms of Spatial Auto Correlation (SPAC). A dialog appears for setting the shape and size of the array. Select “Triangle 10” and put “50” for “Array size”. Click “OK” to proceed.



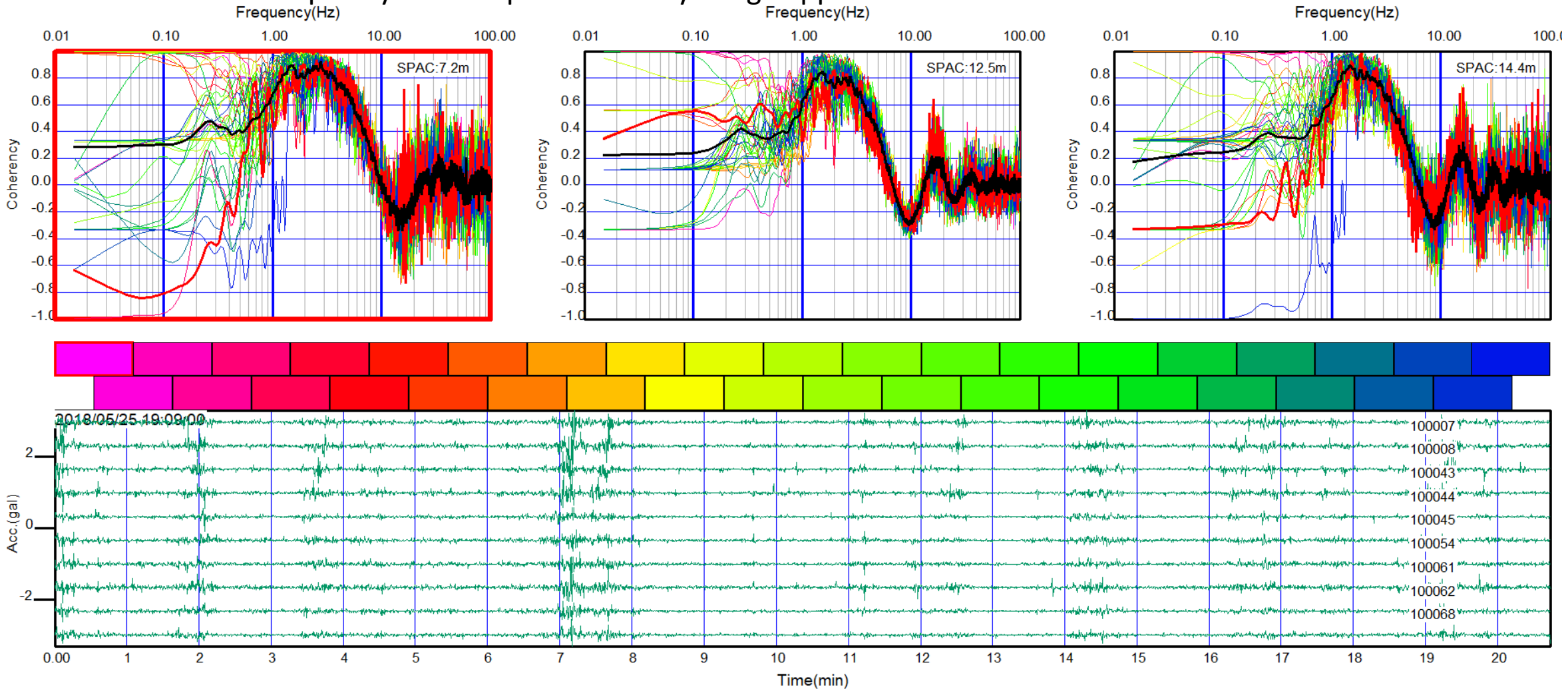
If your geometry is not listed in default arrays, click “Advanced menu” and “Open array file” and select array file. The array file is a simple ASCII file that mentions X and Y coordinate of geophones.

Example of array file.

```
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
```

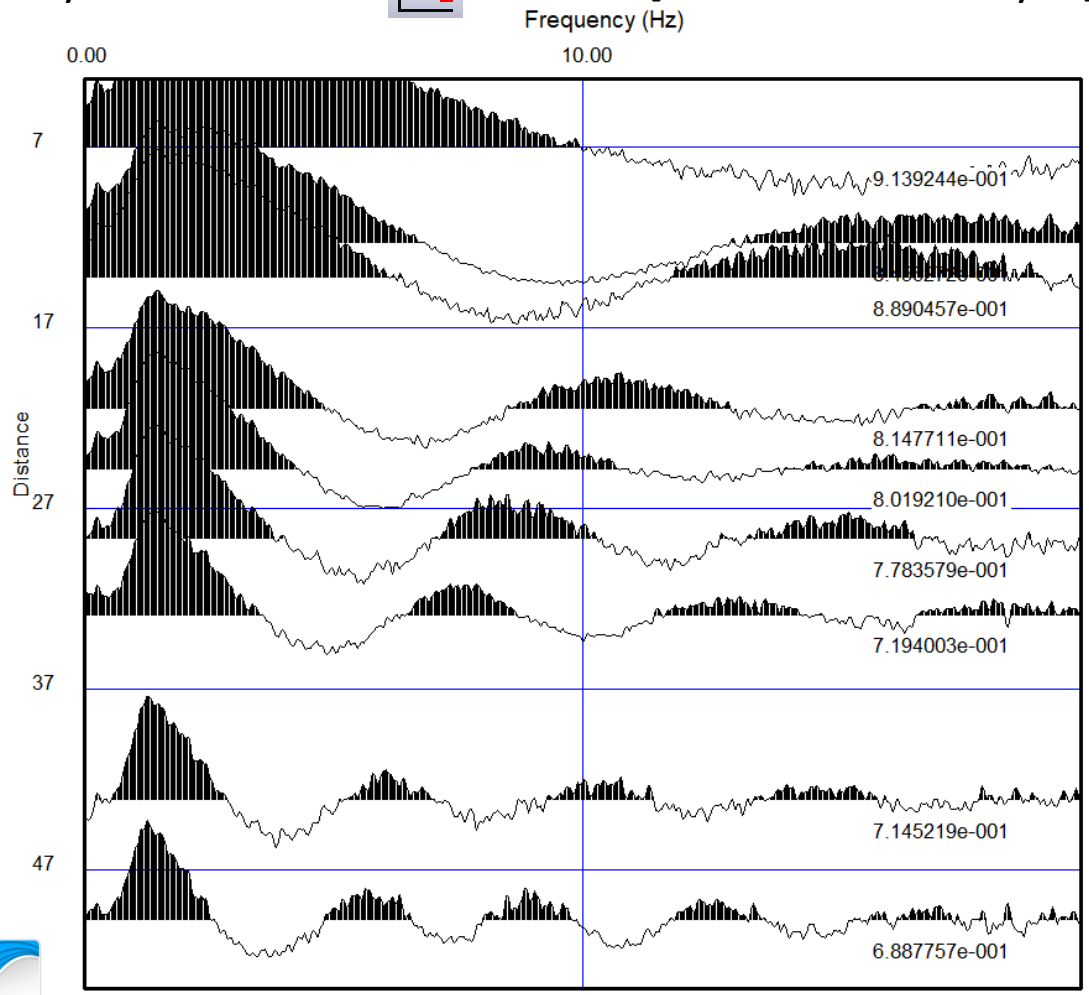
Spatial autocorrelations by frequencies

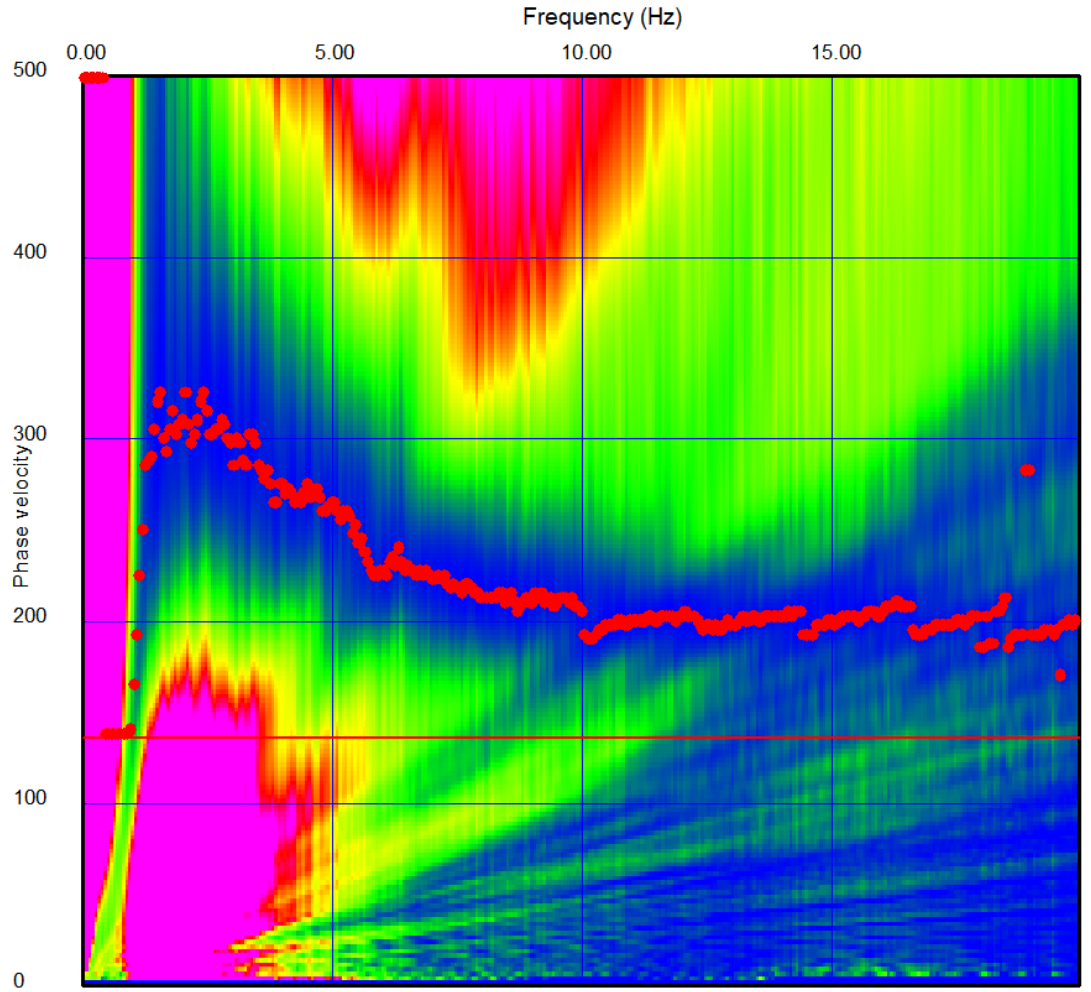
Spatial auto correlations appear. When number of receiver separation is more than three, use  buttons to scroll receiver separations to be shown. Click  or select [Phase velocity analysis]>>[Phase velocity window] and all spatial auto-correlations and a frequency domain phase velocity image appear in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



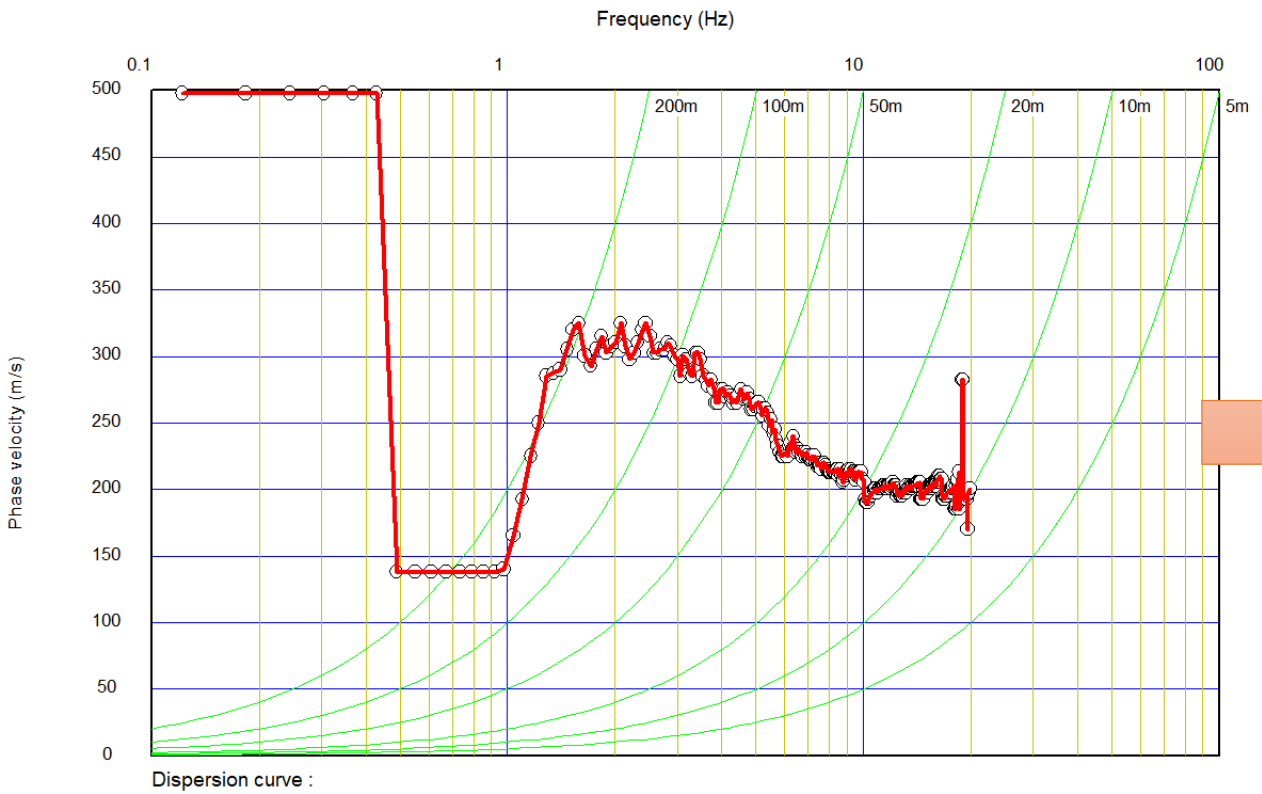


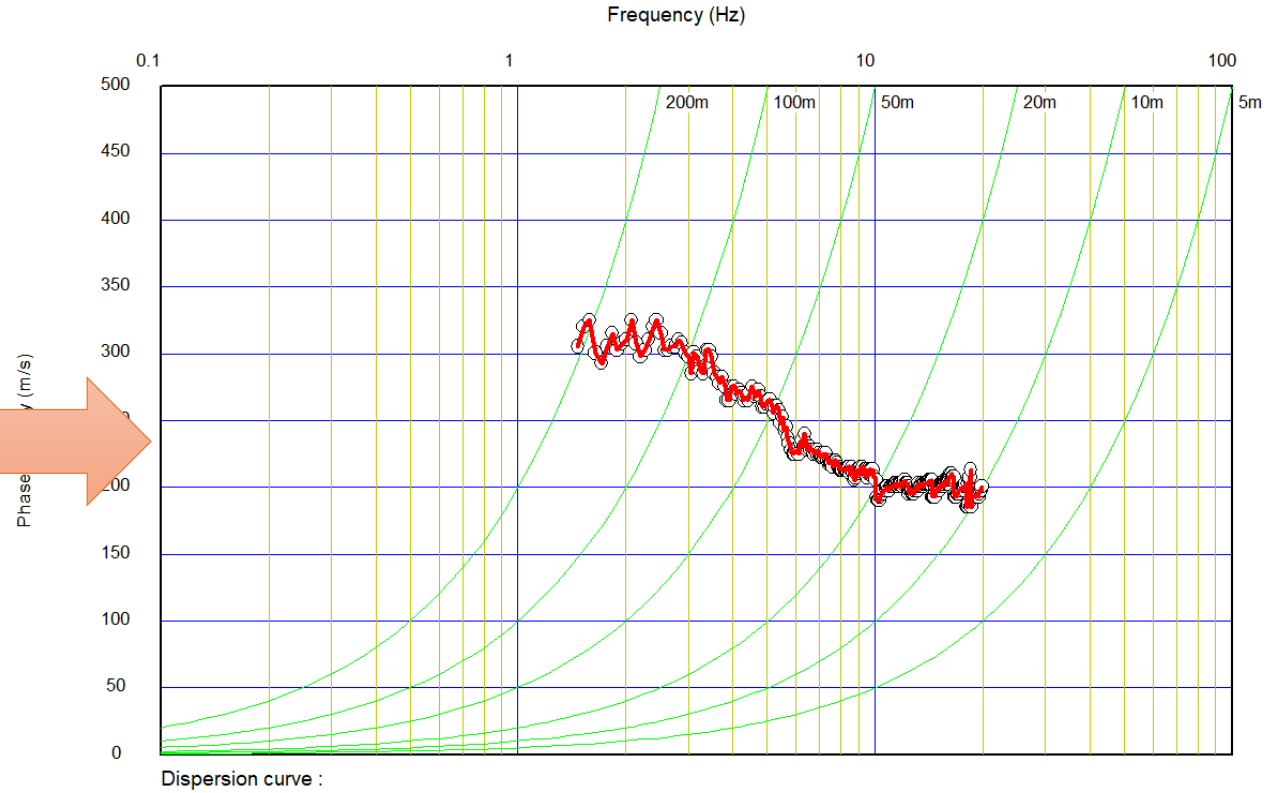
Adjust by a mouse

Editing a dispersion curve in WaveEq

Delete noises or unnecessary frequency range.

Use  or  to select phase velocities.
Hit delete key to delete the selected phase velocities.

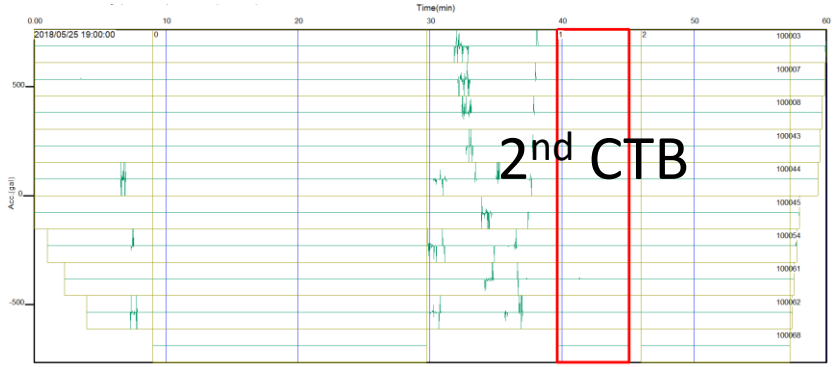


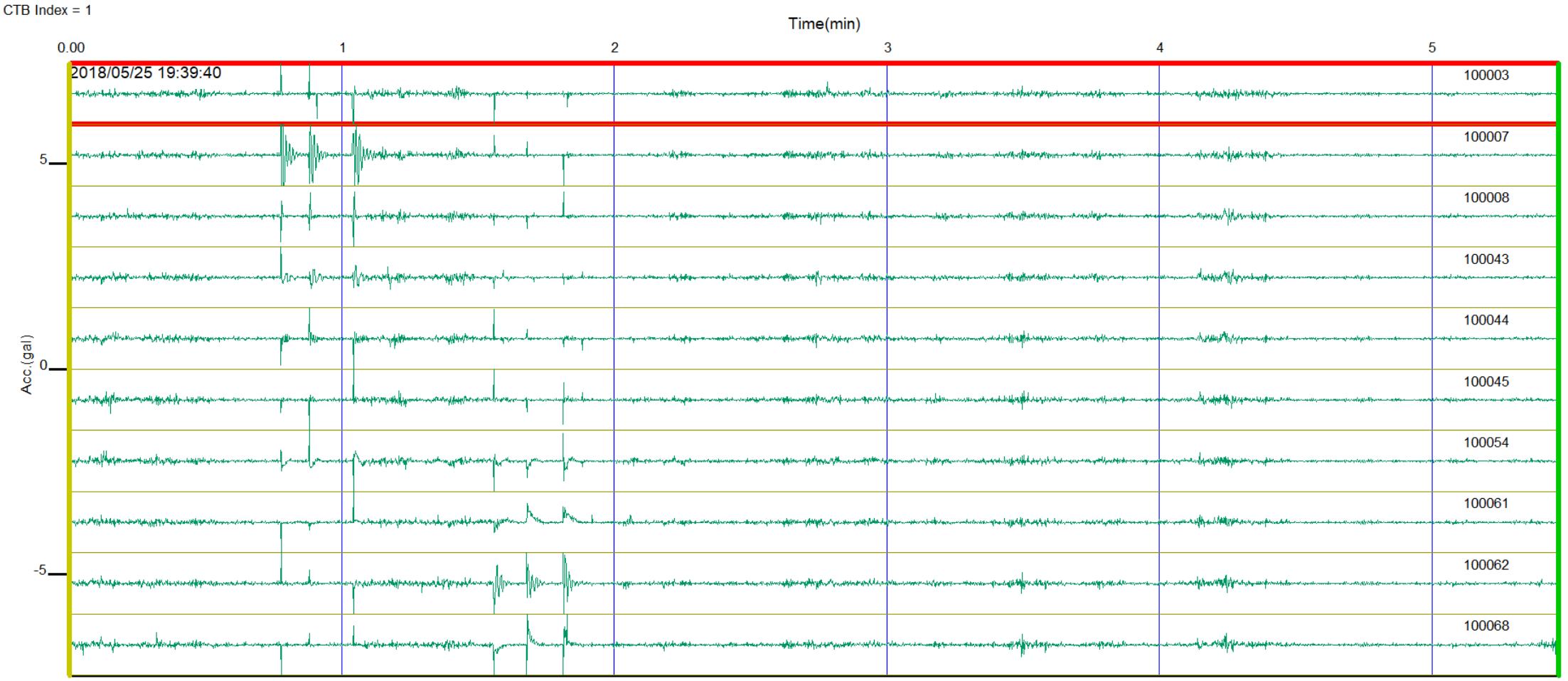


Select [File]>>[Save 1D phase velocity curve or H/V curve (.rst)] to save a dispersion curve to data file.

Processing active data (MASW)

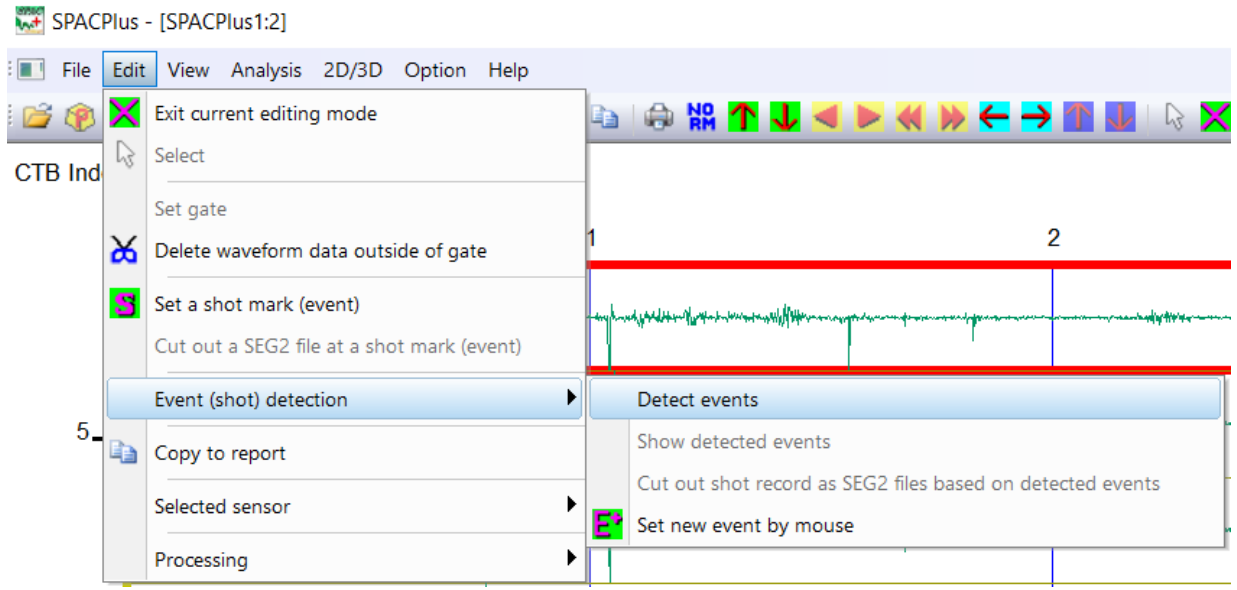
Click CTB or select [Window]>>[Processing window] and the selected 2nd CTB data (in a red rectangle) will appear in another window.

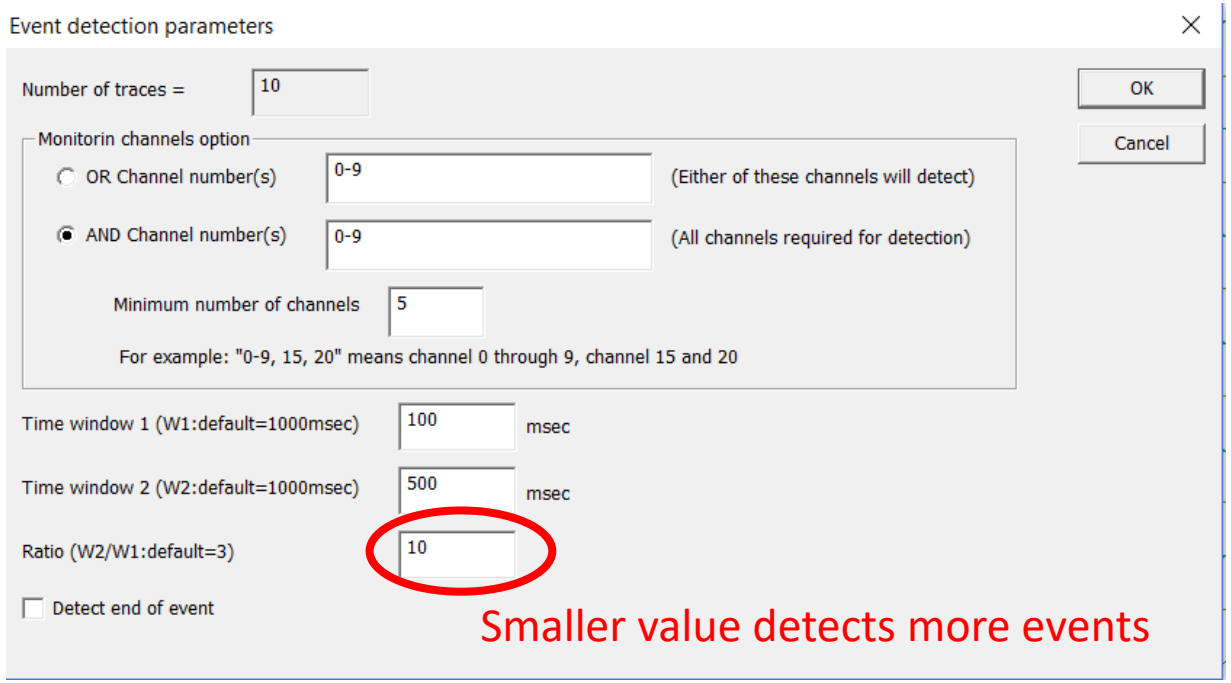




Detect shots by event detection

Select [Edit]>>[Event (shot) detection]>>[Detect events] and set event detection parameters.

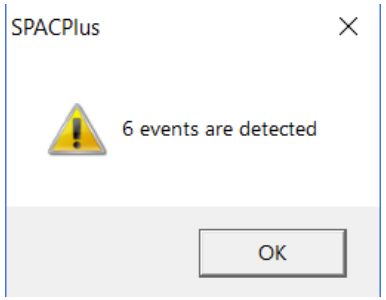




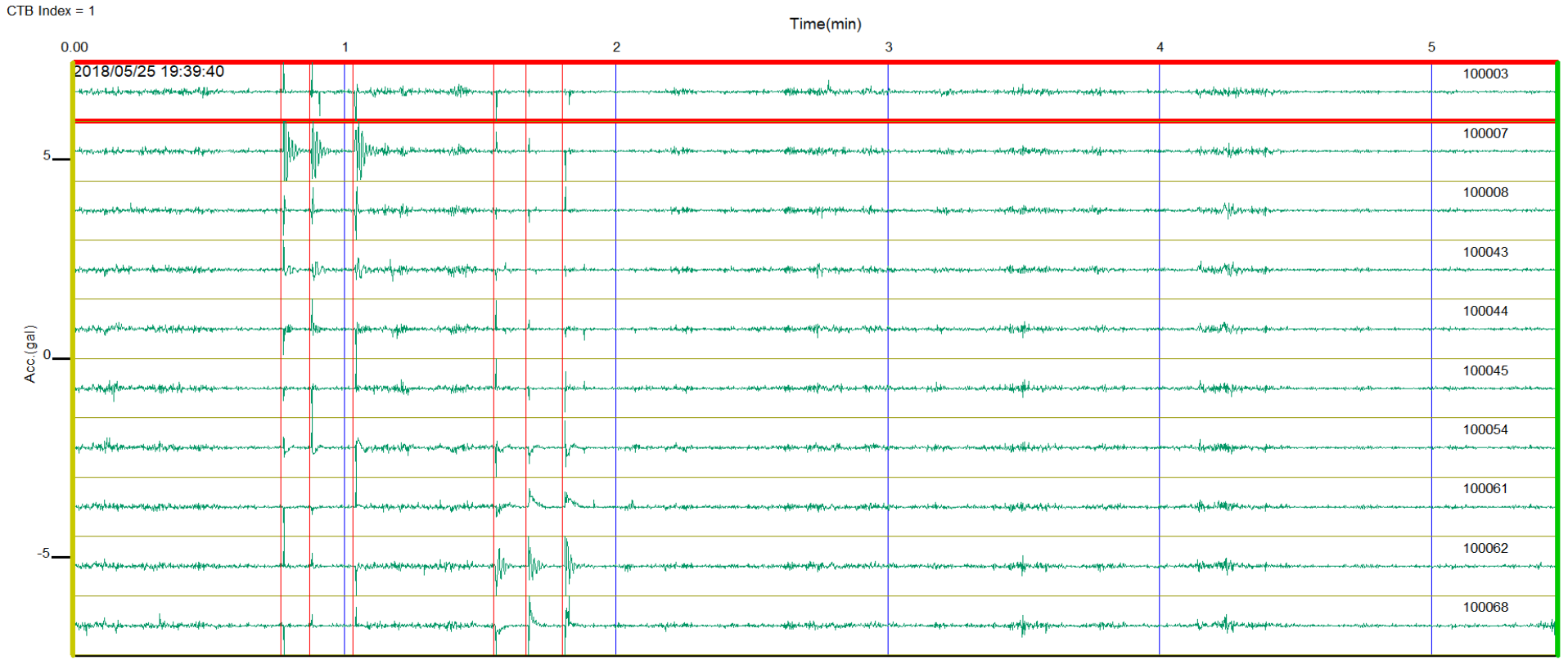
Click “OK” to detect events (shots).

Detect shots by event detection

Number of detected events appears.



Detected events (shots) are shown . Adjust the settings and repeat the detection until appropriate detections were obtained.



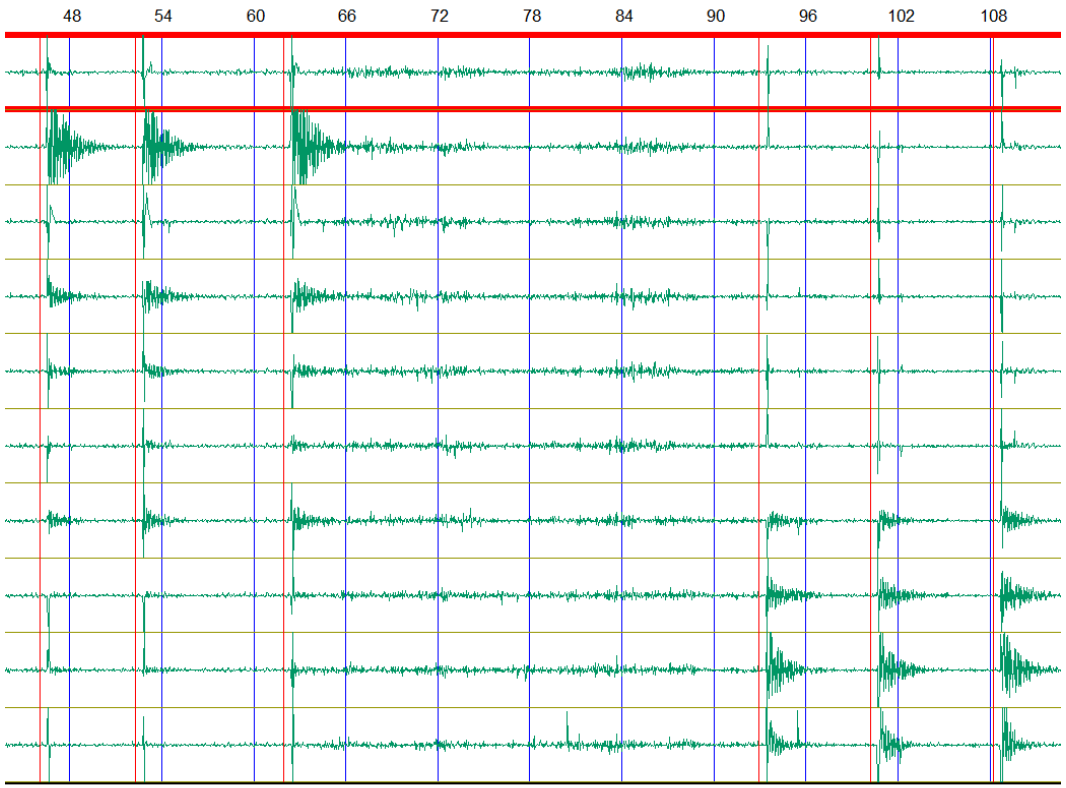
Edit detected shots

Change horizontal (time) scale.

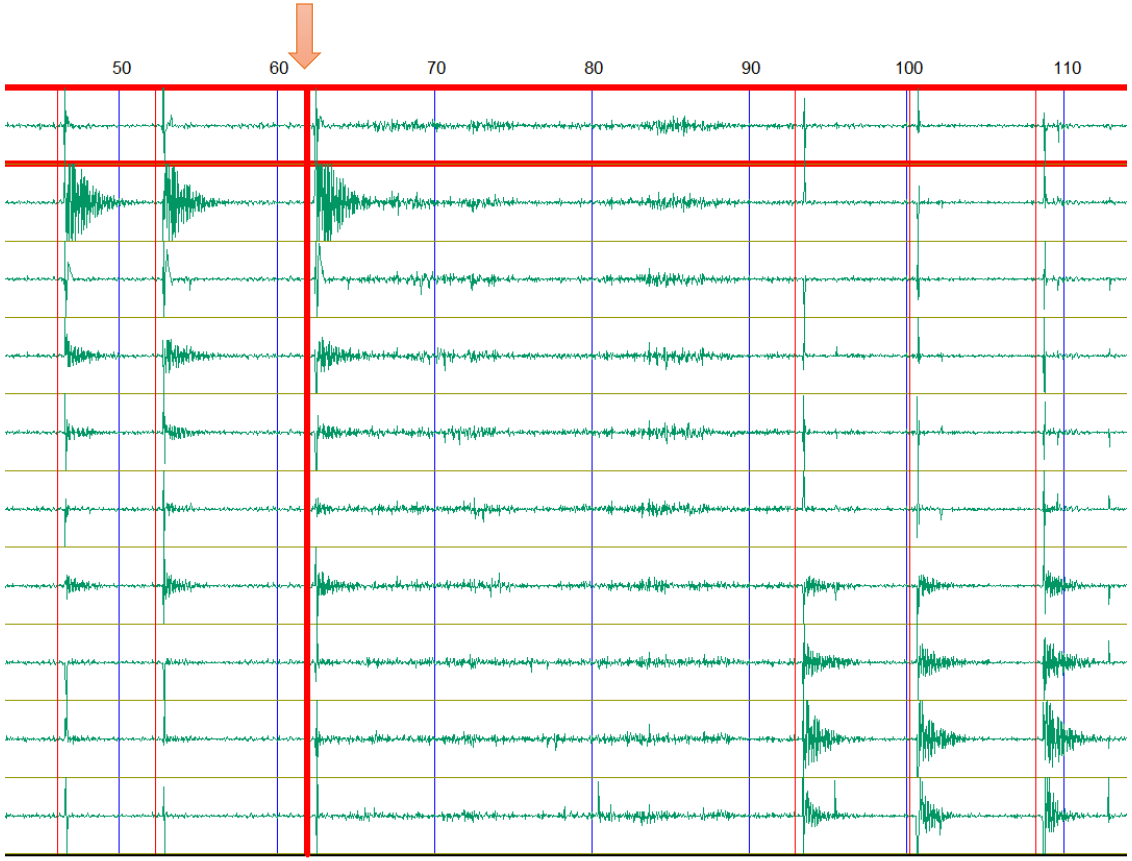
Change amplitude.

Add new event by clicking a left button of a mouse.

Select a detected event. Selected event is shown as a red bold line.
Hit delete key to delete the detected event.
Use a mouse to move the event (left button down).

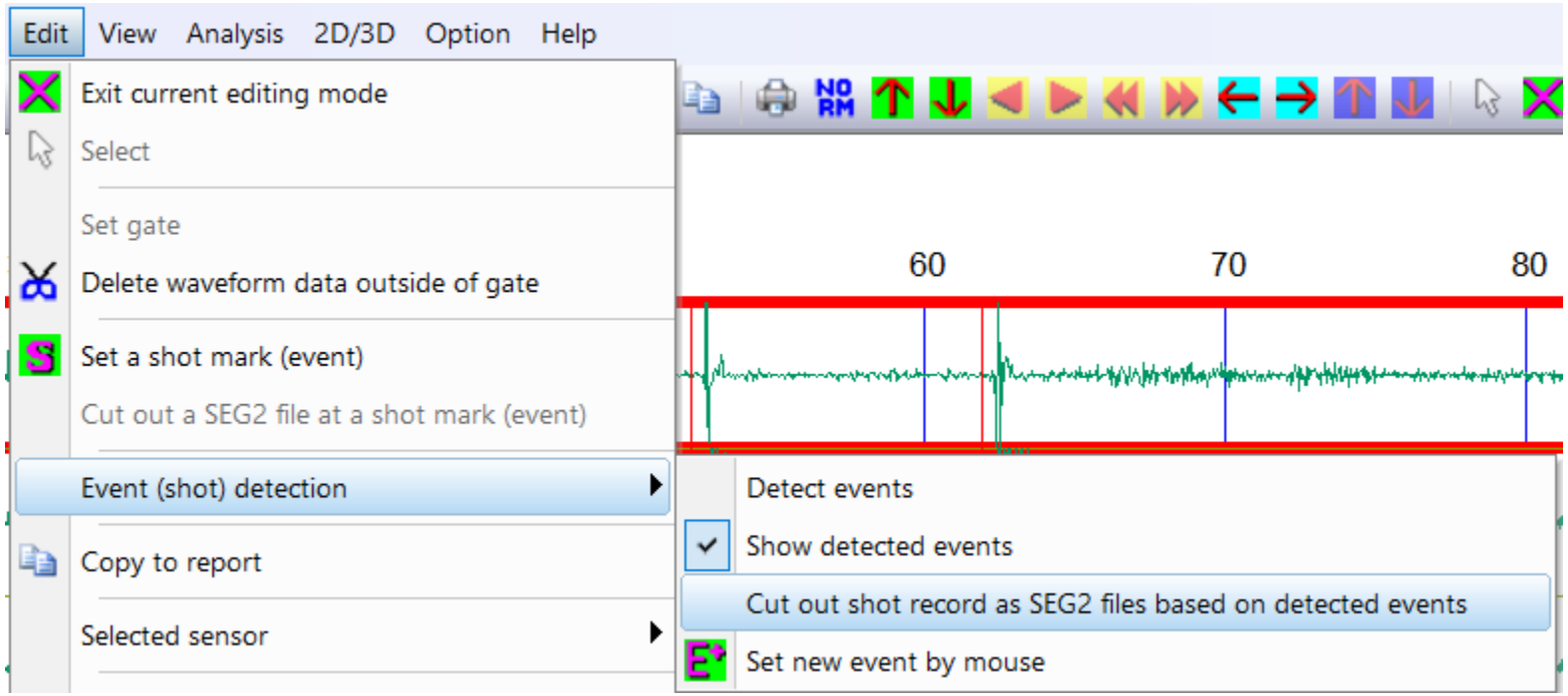


Selected event

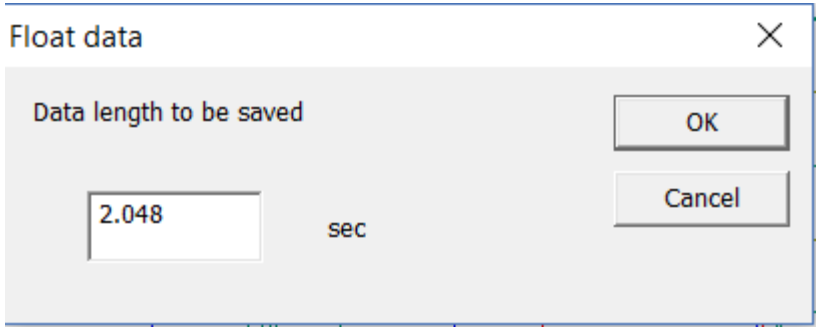


Show detected shots by Pickwin

Select [Edit]>>[Event (shot) detection]>>[Cut out shot record as SEG2 files based on detect events].

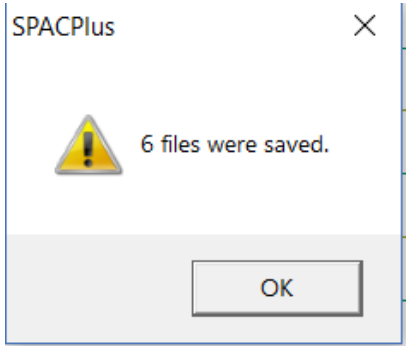


Enter data length.



Shot records are saved as SEG2 files

Number of saved files appears.



Shot records were saved as SEG2 files (.sg2) in a folder being selected.

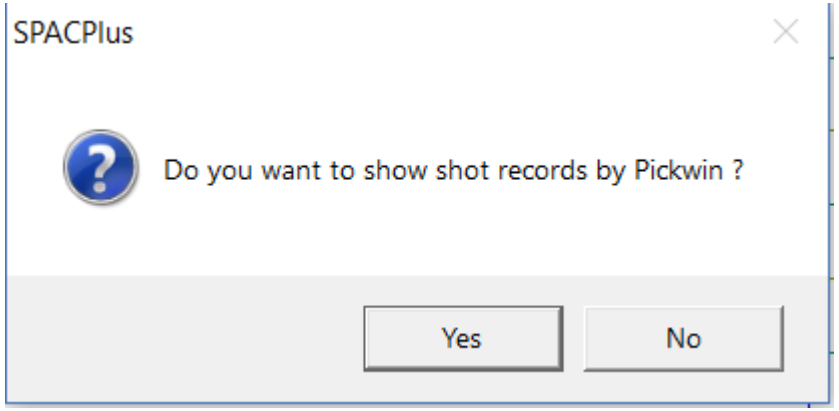
event_0000.sg2	5/28/2018 5:30 PM	SG2 File	30 KB
event_0001.sg2	5/28/2018 5:30 PM	SG2 File	30 KB
event_0002.sg2	5/28/2018 5:30 PM	SG2 File	30 KB
event_0003.sg2	5/28/2018 5:30 PM	SG2 File	30 KB
event_0004.sg2	5/28/2018 5:30 PM	SG2 File	30 KB
event_0005.sg2	5/28/2018 5:30 PM	SG2 File	30 KB

A shot and file list was saved in an XML file.

EventList.xml	5/28/2018 5:30 PM	XML Document	3 KB

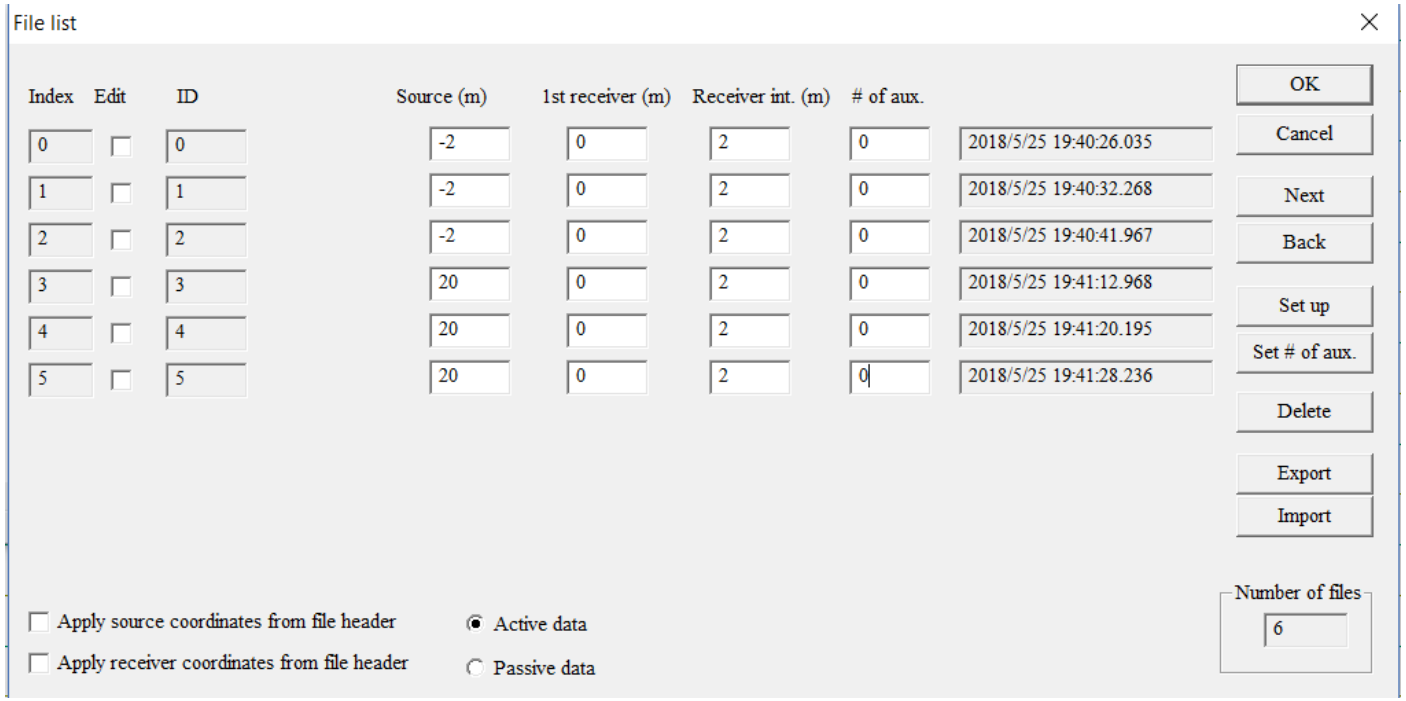
```
<?xml version="1.0" encoding="SHIFT_JIS"?>
- <line>
    <line_name>line_name</line_name>
    <line_id>0</line_id>
    <sxw_menu>0</sxw_menu>
    <geometry_information>4</geometry_information>
    <data_information>0</data_information>
    <file_type>0</file_type>
    <apply_source_position>0</apply_source_position>
    <apply_receiver_position>0</apply_receiver_position>
  - <file_list>
    - <file>
        <file_name>event_0000.sg2</file_name>
        <id>0</id>
        <file_type>0</file_type>
        <shot_distance>0.000000</shot_distance>
        <first_receiver>0.000000</first_receiver>
        <receiver_interval>1.000000</receiver_interval>
        <number_of_auxiliary>0</number_of_auxiliary>
        <i_source_component>2</i_source_component>
        <start_date_time>2018/5/25 19:40:26.035</start_date_time>
      </file>
    + <file>
    + <file>
    + <file>
    + <file>
    + <file>
    </file_list>
</line>
```

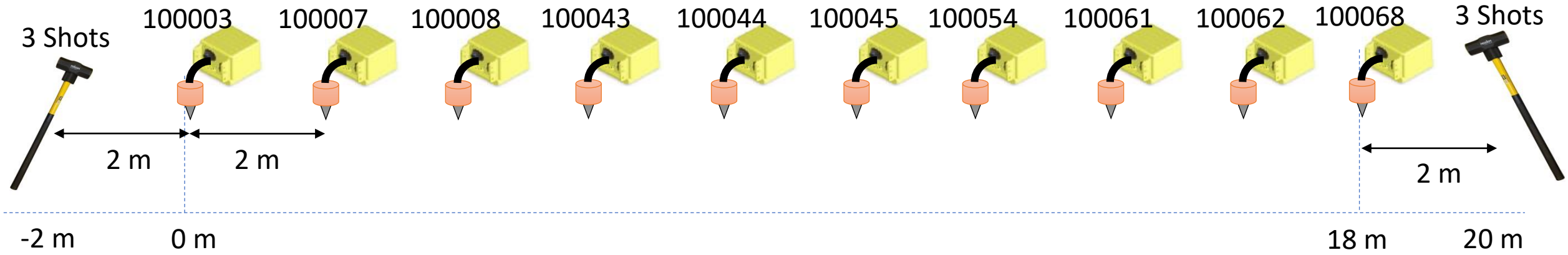
Click “Yes” to continue the processing.



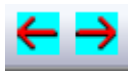
Set up geometry

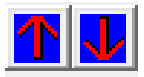
A list of shot records appear in a dialog box. Set up source location, receiver interval etc.





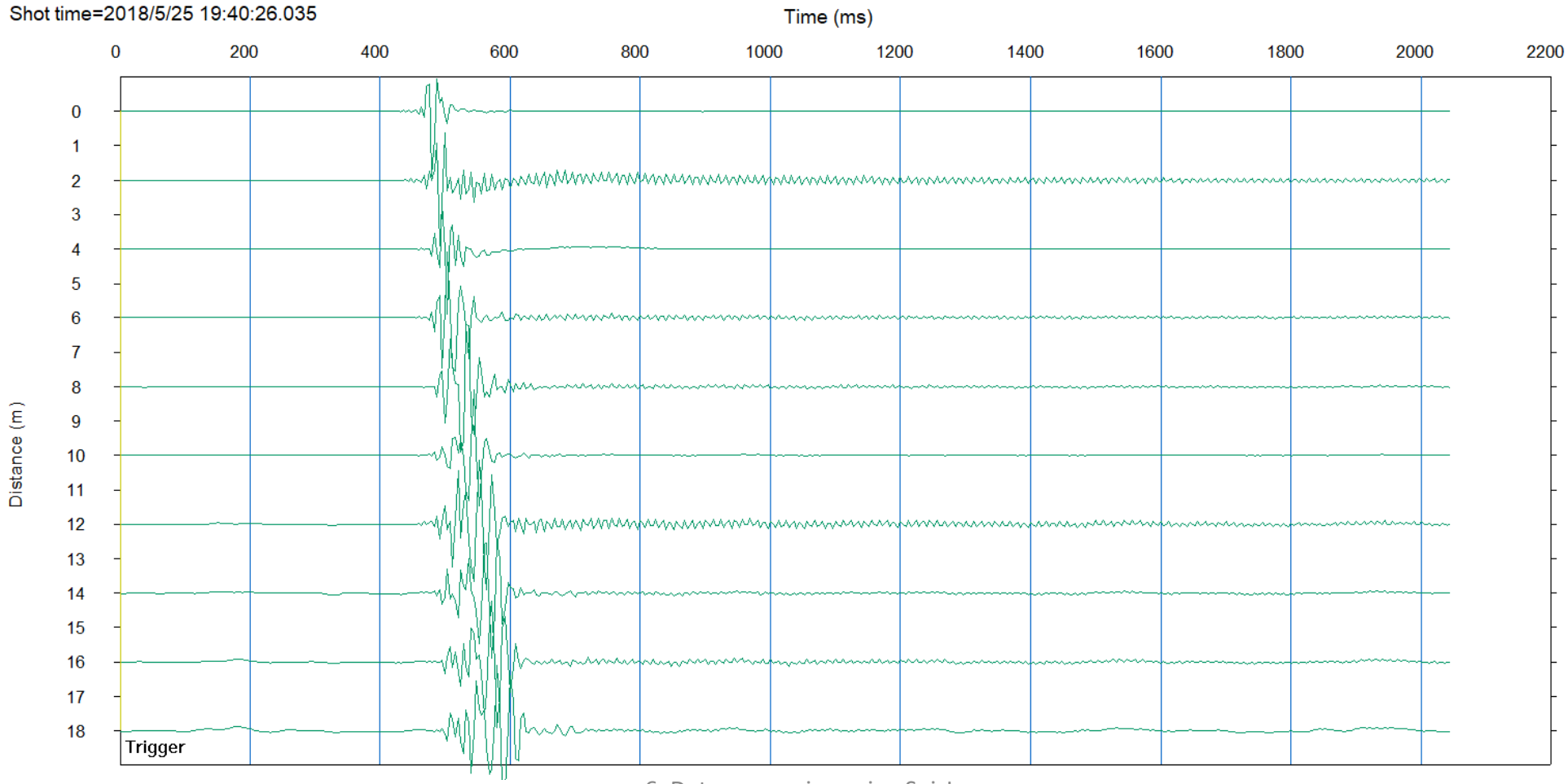
Individual shot record shown by Pickwin


Change horizontal (time) scale.


Change distance scale.


Change amplitude.

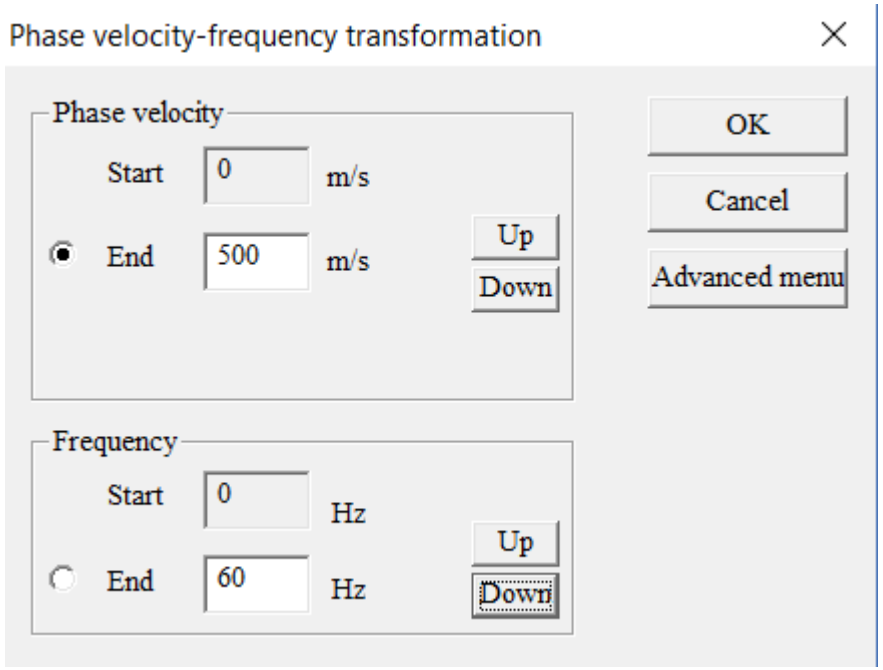

Scroll shot records.



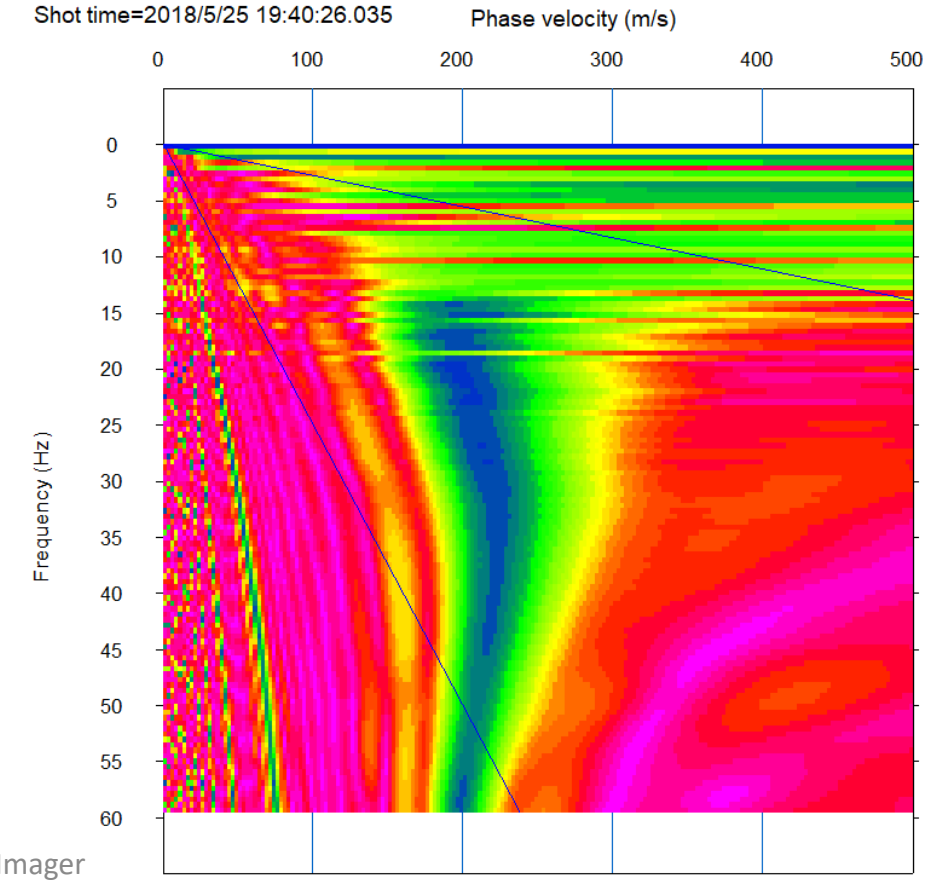
Transform to phase velocity image in frequency domain

Select [Surface wave analysis]>>[Phase velocity frequency transformation] or press “Ctrl+D” to transform data to a phase velocity image in frequency domain.

Set up max. phase velocity and max. frequency.

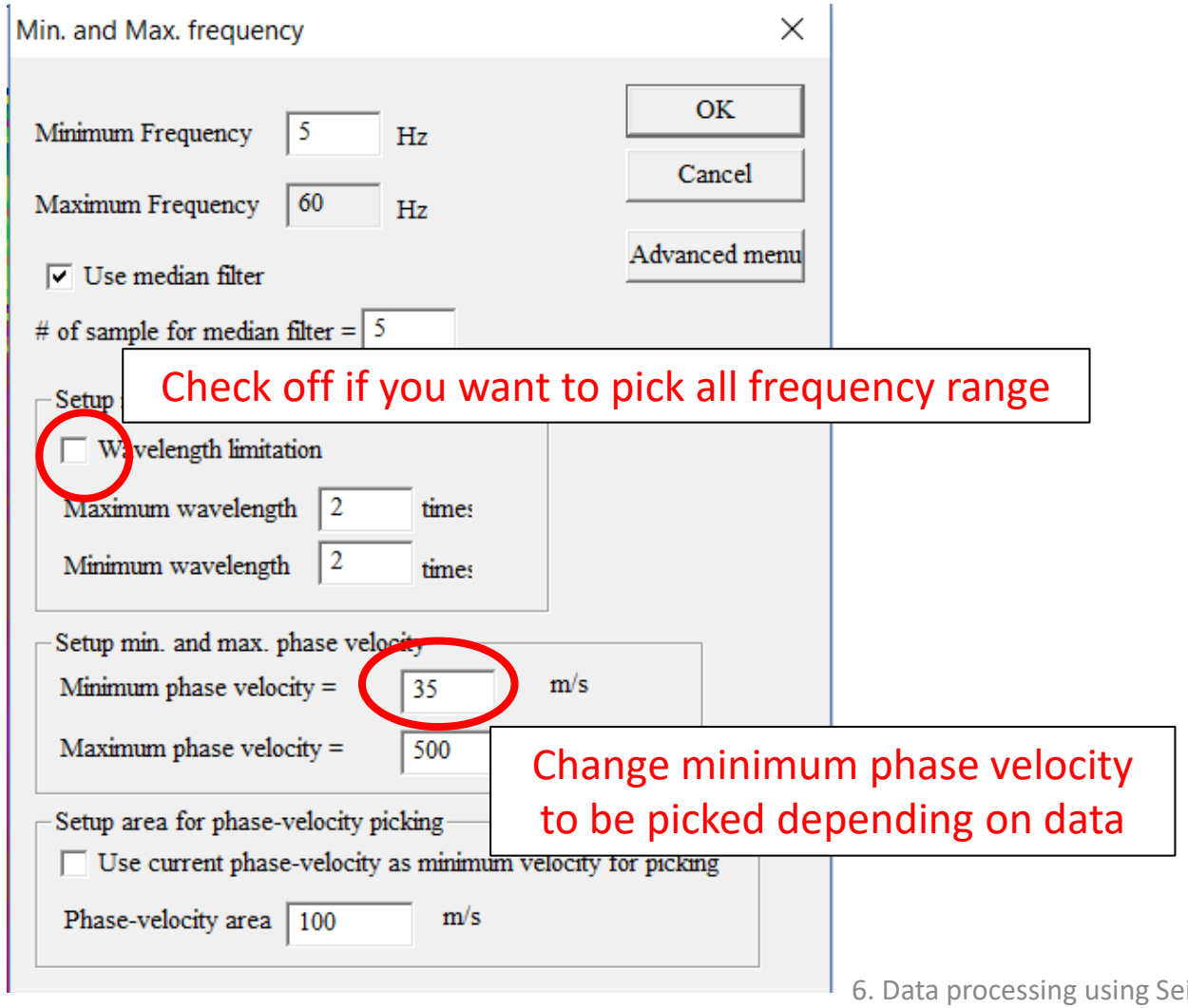


A phase velocity image in frequency domain appears.



Pick phase velocities

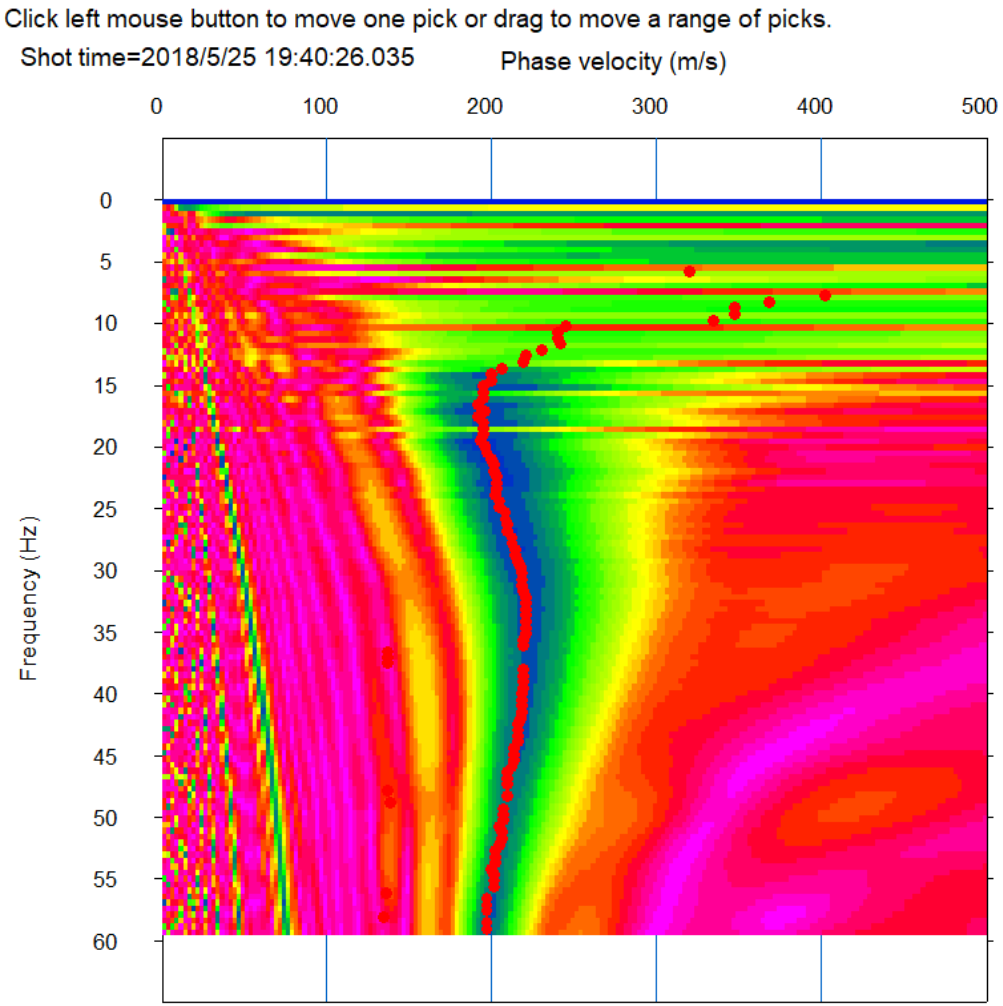
Select [Surface wave analysis]>>[Pick phase velocity (1D)] and set up parameters.
Click “Advanced menu” to set up detailed parameters.



Check off if you want to pick all frequency range

Change minimum phase velocity to be picked depending on data

Picked phase velocities appear on a phase velocity image in frequency domain.
Click left mouse button to move one pick or drag to move a range of picks.

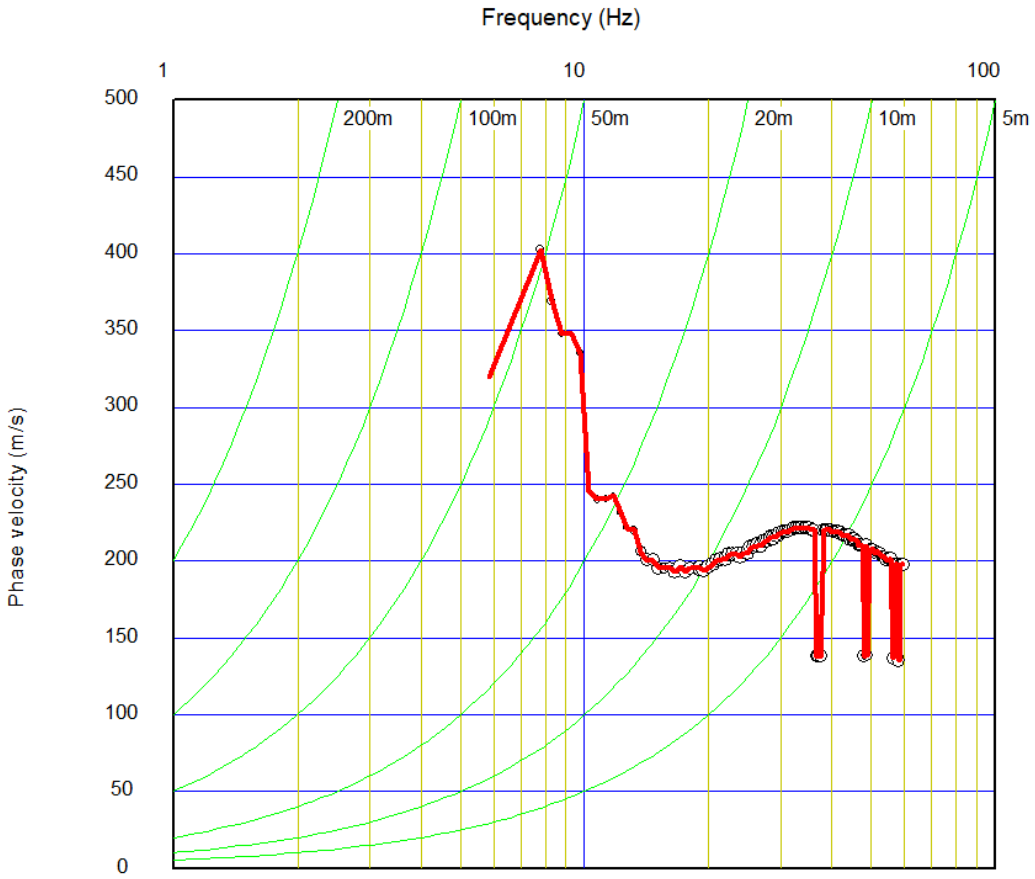


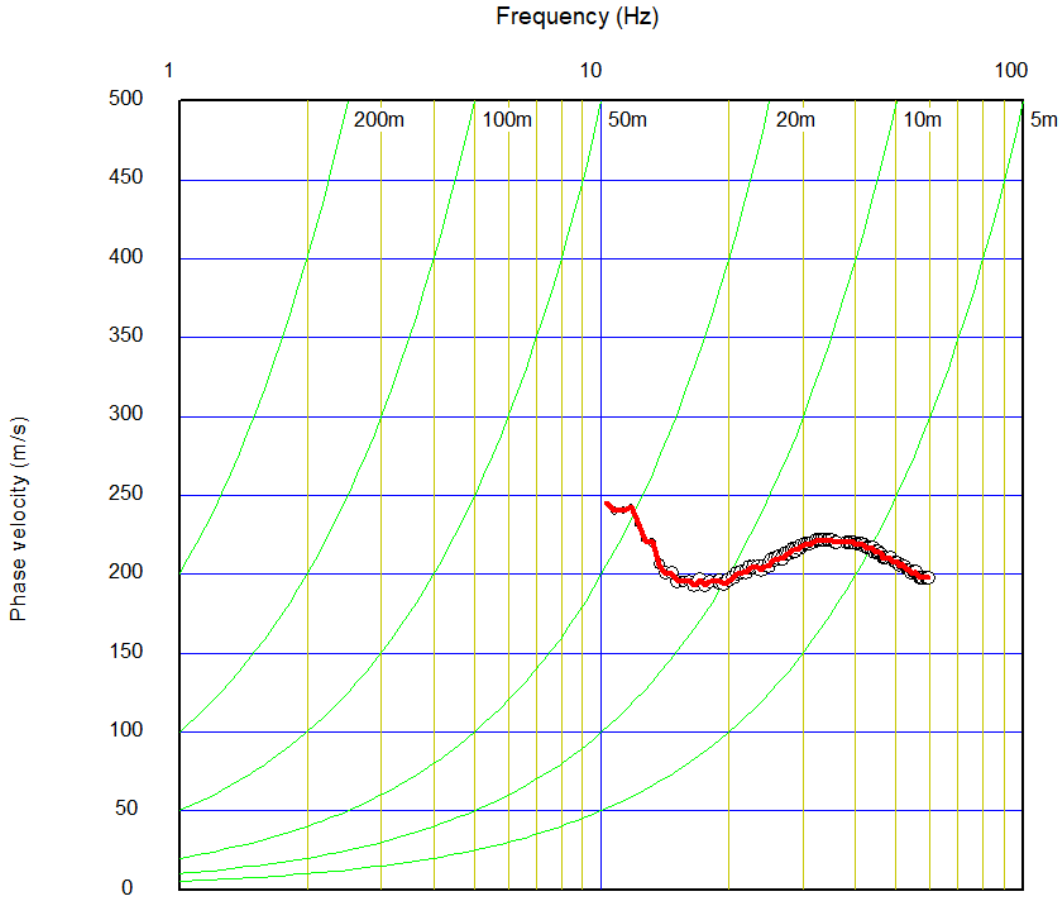
Select [Surface wave analysis]>>[Show phase velocity curve (1D) <Launch WaveEq>].

Editing a dispersion curve in WaveEq

Delete noises or unnecessary frequency range.

Use  or  to select phase velocities.
Hit delete key to delete the selected phase velocities.

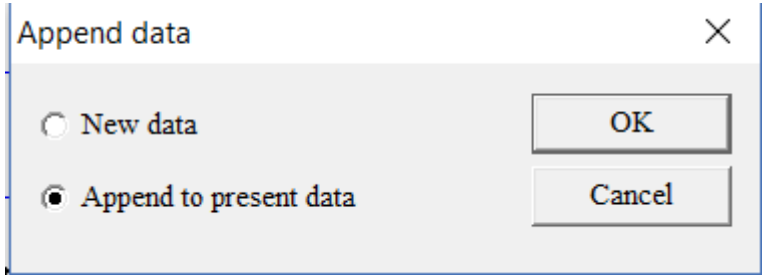




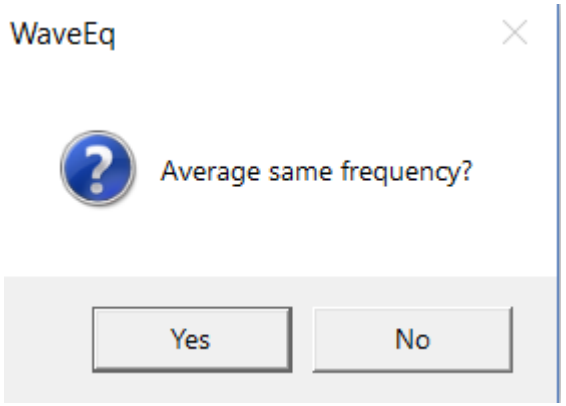
Select [File]>>[Save 1D phase velocity curve or H/V curve (.rst)] to save a dispersion curve to data file.

Combine active and passive dispersion curves

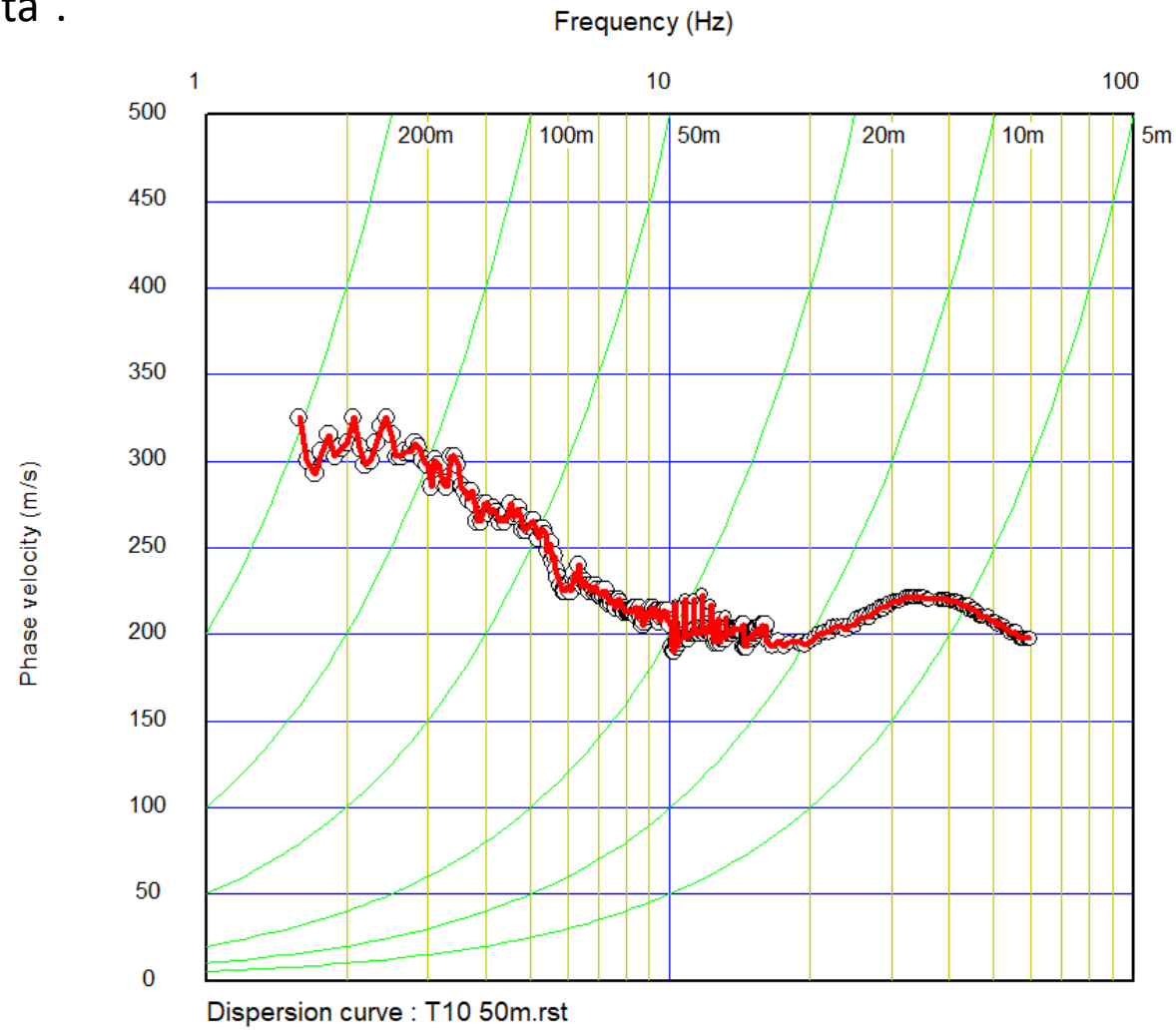
Select [File]>>[Open 1D phase velocity curve or H/V curve (.rst)].
Select a passive data file (.rst) and choose “Append to present data”.



Data will be automatically averaged if “Yes” is chosen.
Choose “No” if you want do not want to average automatically.

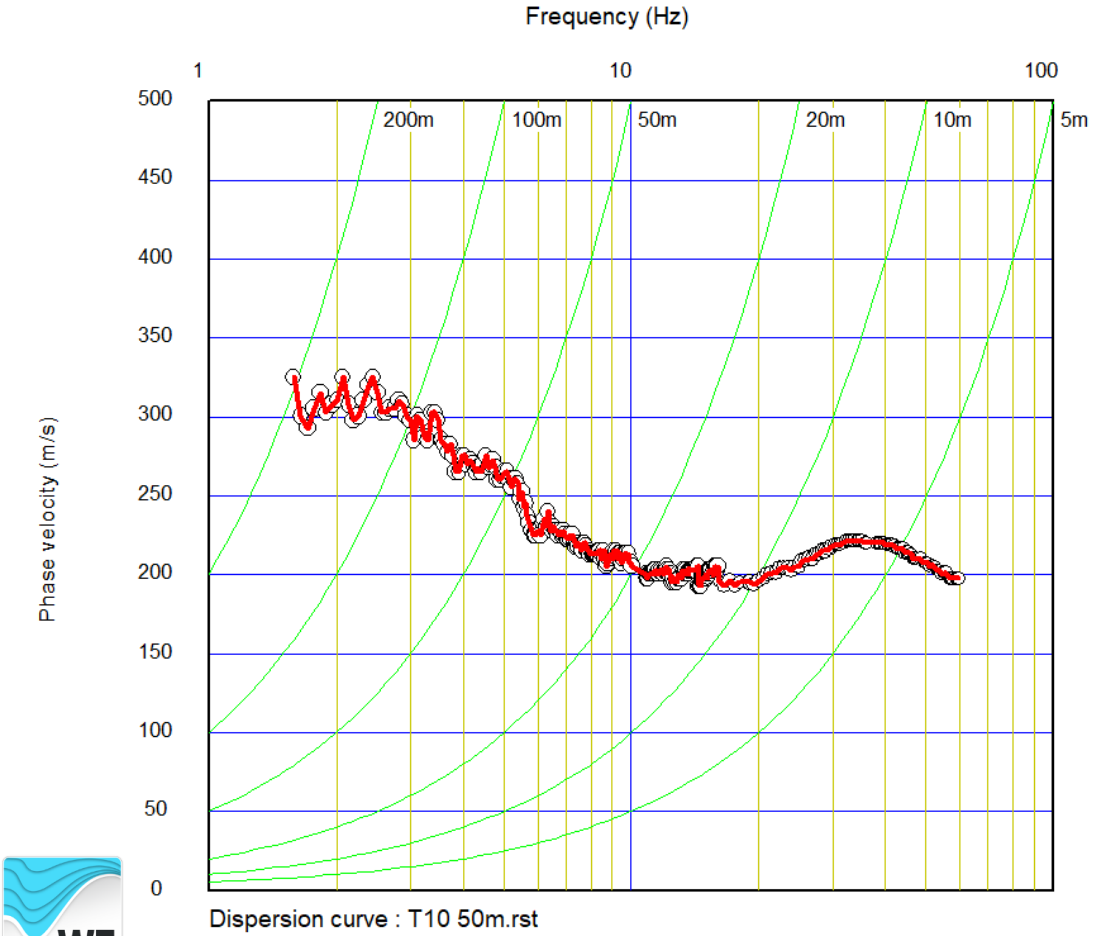


Active and passive phase velocities are shown together.

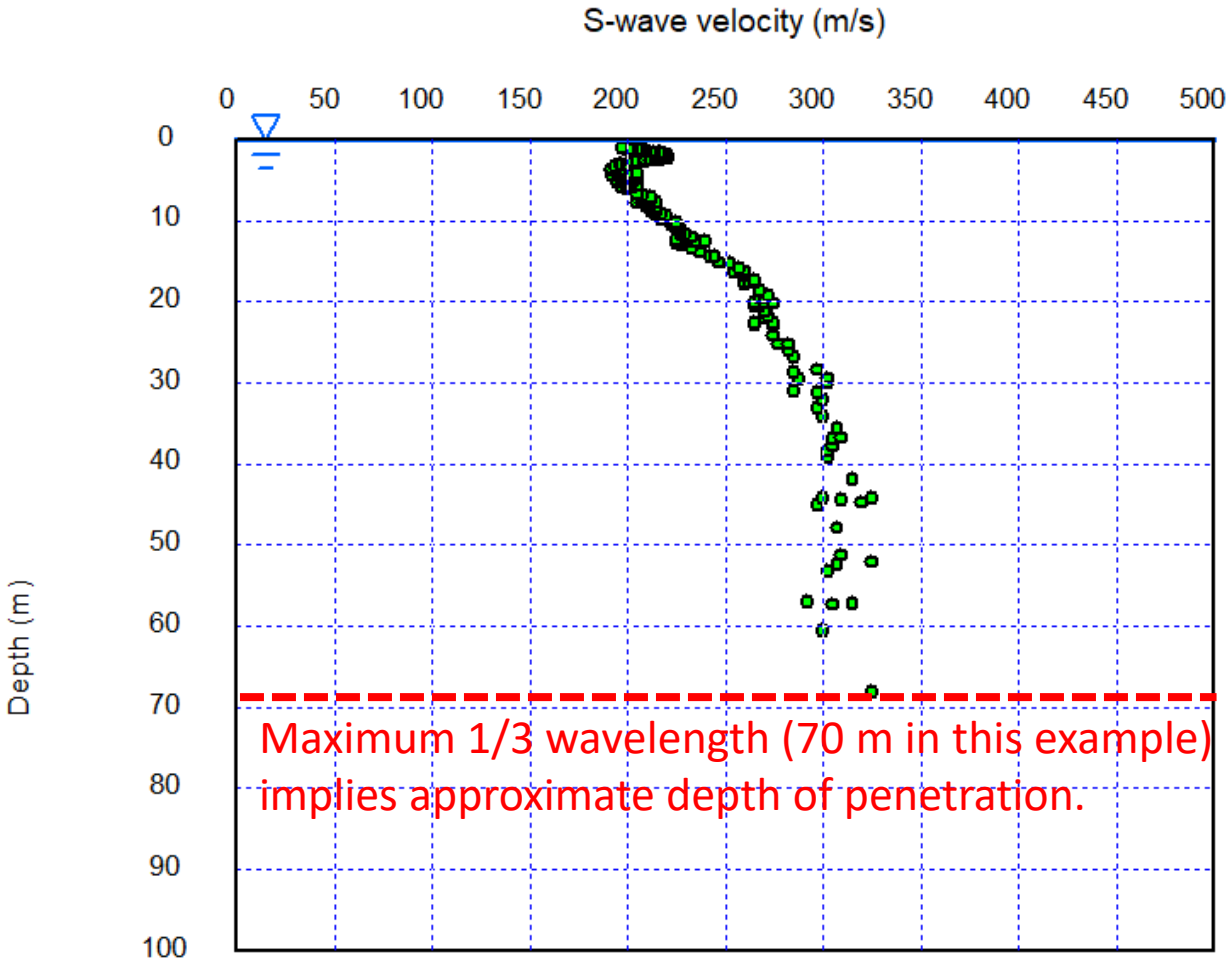


Editing active and passive dispersion curves in WaveEq

Delete noises or unnecessary frequency range.

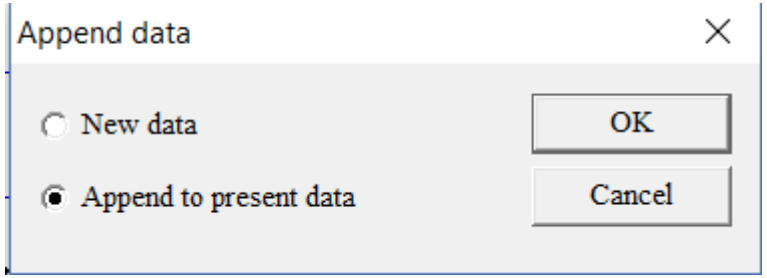


Crick V_R to evaluate approximate depth of penetration.
Green circles indicates 1/3 wave length.

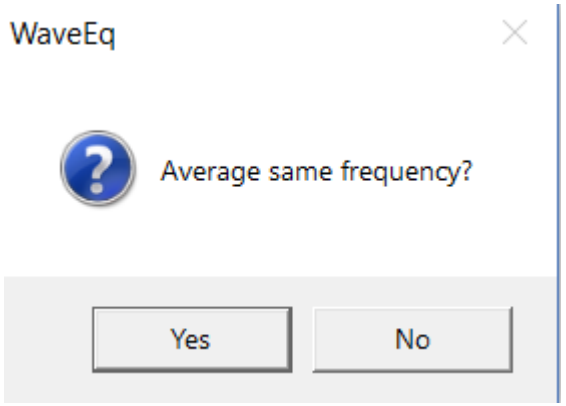


Combine active and passive dispersion curves

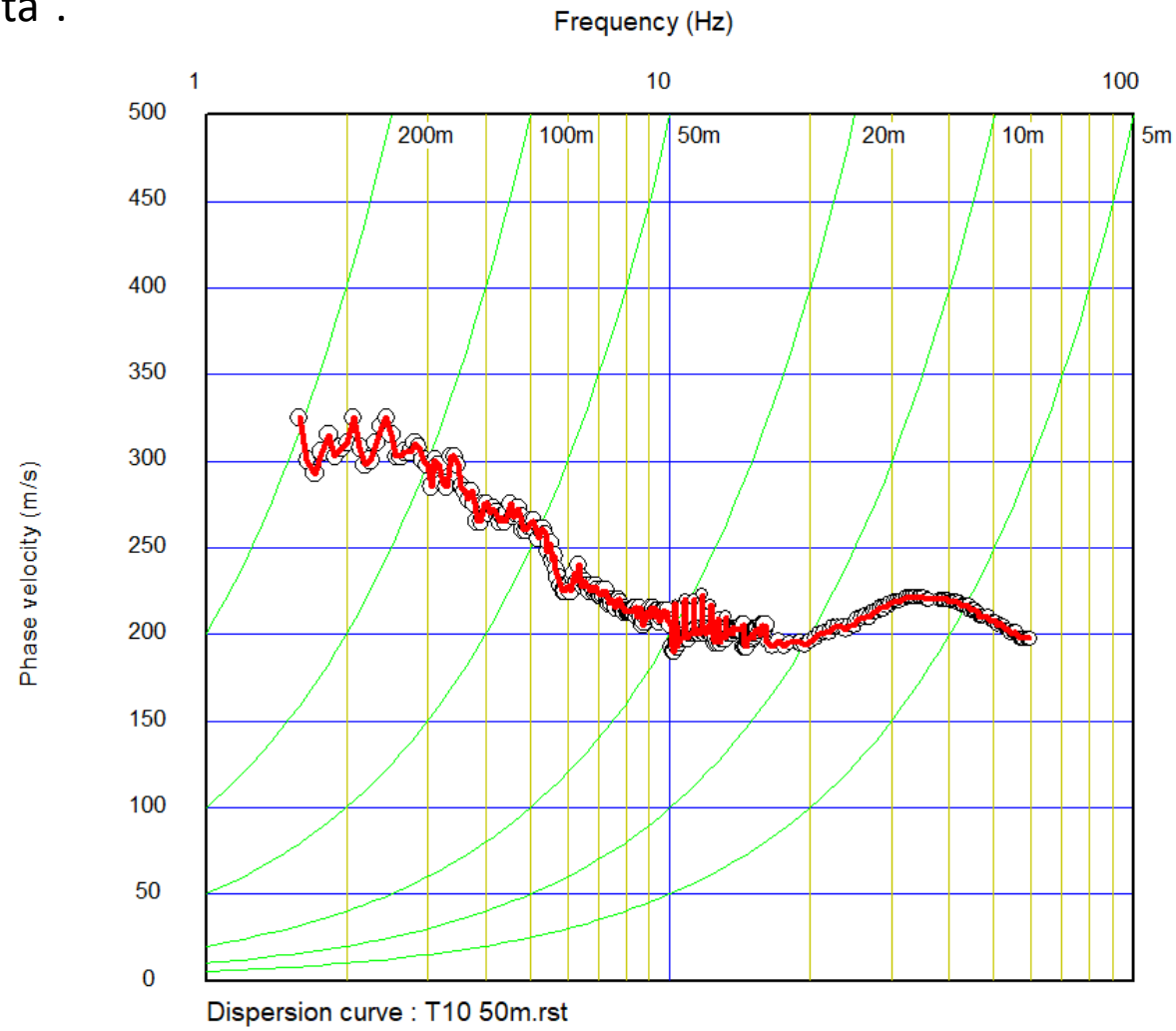
Select [File]>>[Open 1D phase velocity curve or H/V curve (.rst)].
Select a passive data file (.rst) and choose “Append to present data”.



Data will be automatically averaged if “Yes” is chosen.
Choose “No” if you want do not want to average automatically.

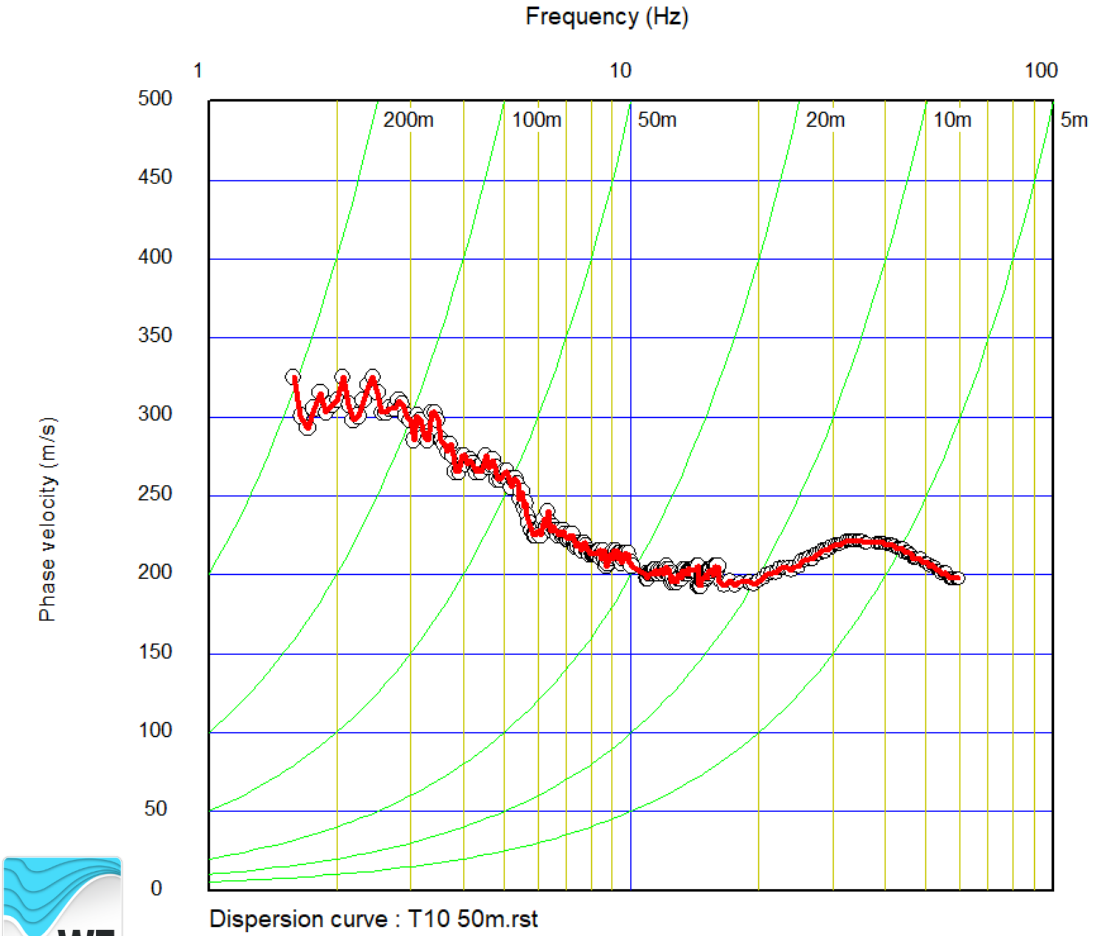


Active and passive phase velocities are shown together.

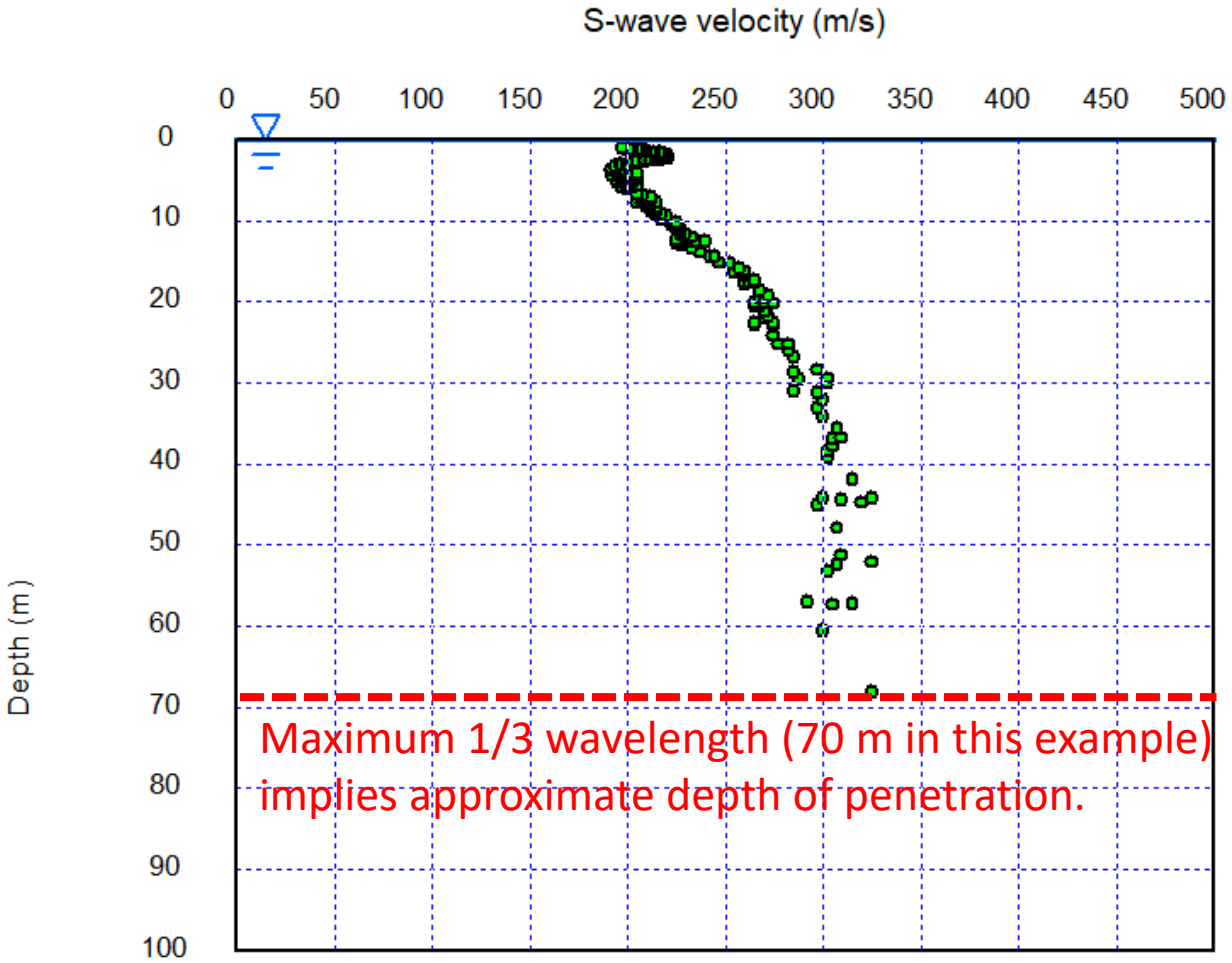


Editing active and passive dispersion curves in WaveEq

Delete noises or unnecessary frequency range.

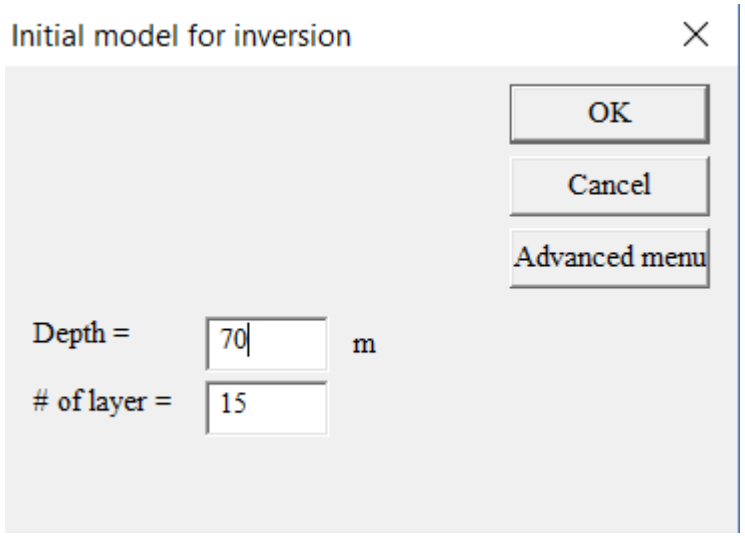


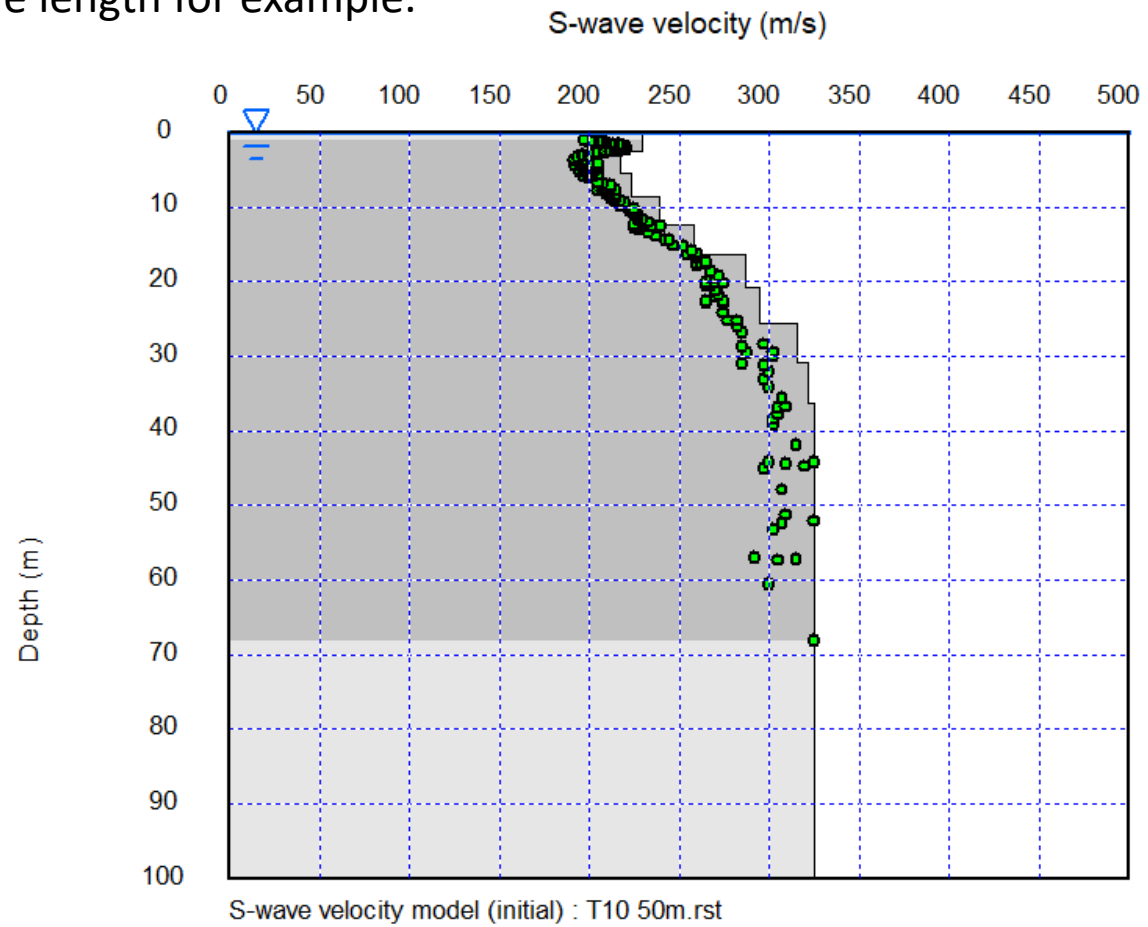
Crick V_R to evaluate approximate depth of penetration.
Green circles indicates 1/3 wave length.



Initial model

Select [Surface wave analysis]>>[MASW (1D)]>>[Initial model] to built an initial model.
Set “Depth” based on a penetration depth implied by 1/3 wave length for example.

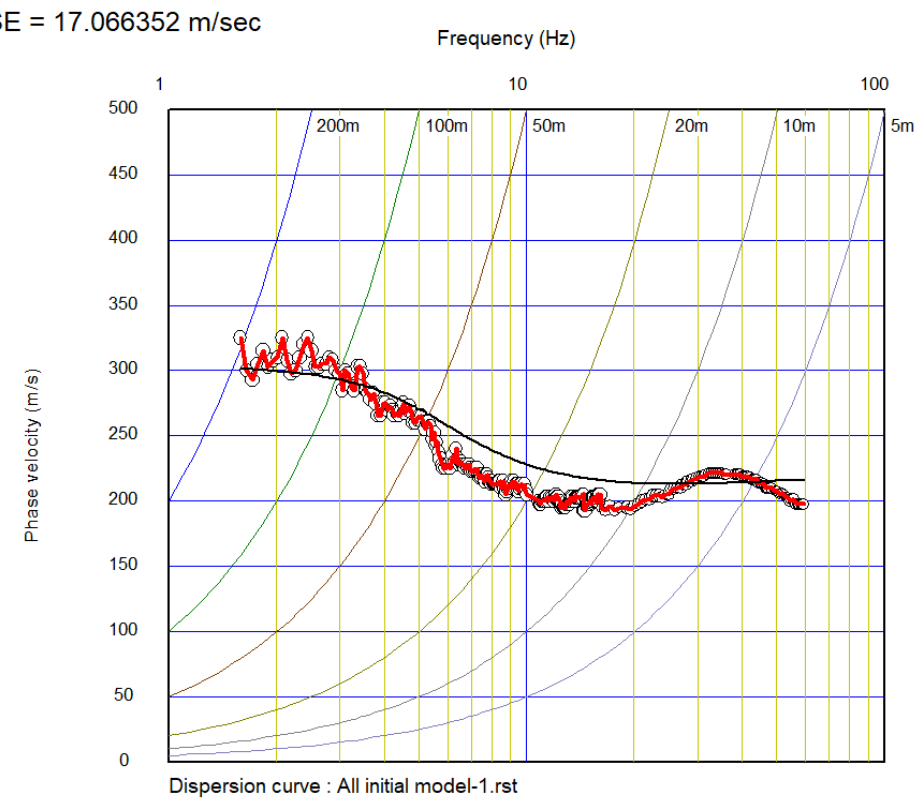




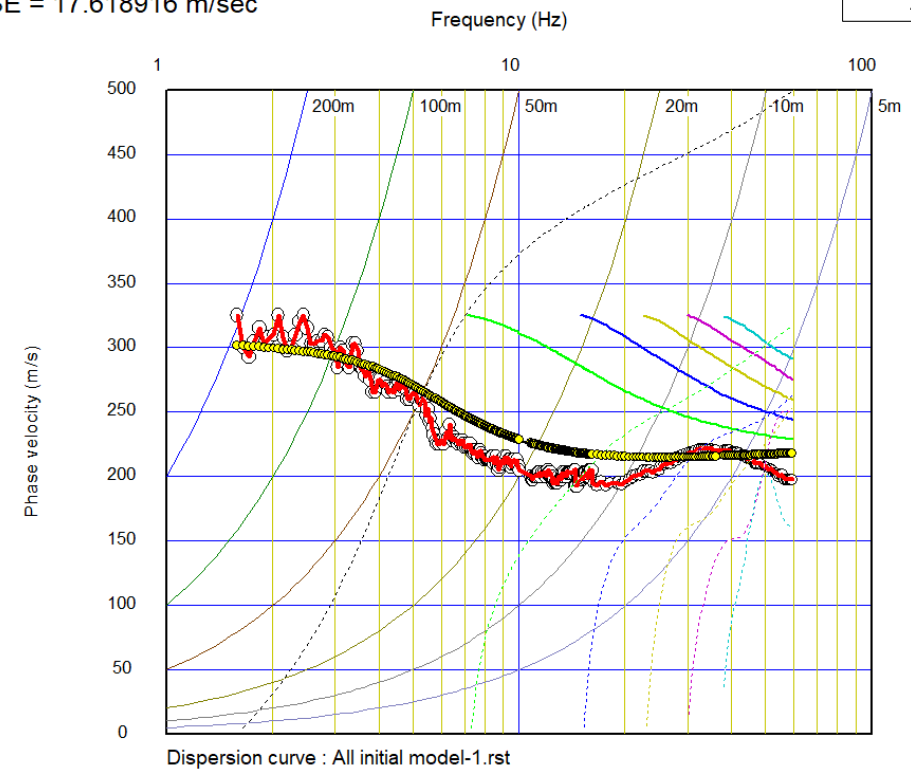
Comparing observed and theoretical dispersion curves

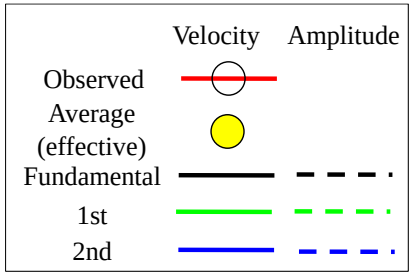
Click  to compare observed and theoretical dispersion curves.

Fundamental mode 



Higher mode (effective mode) 





Selection of inversion method

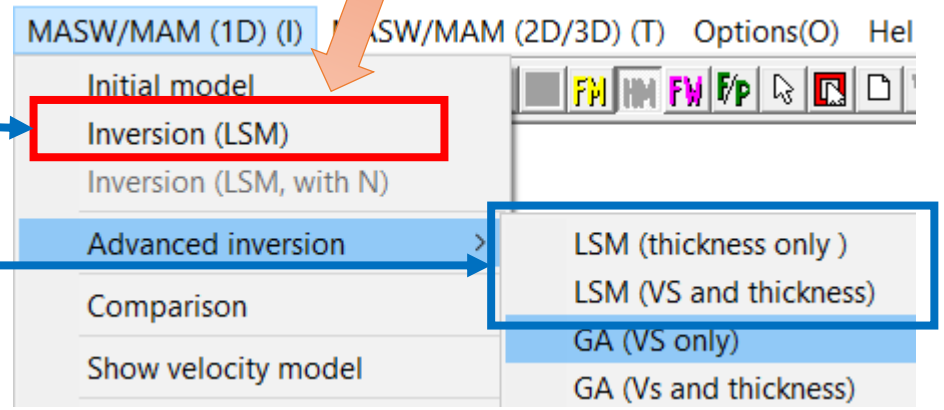
Use this one (change only VS) when number of layer is large (> 5)

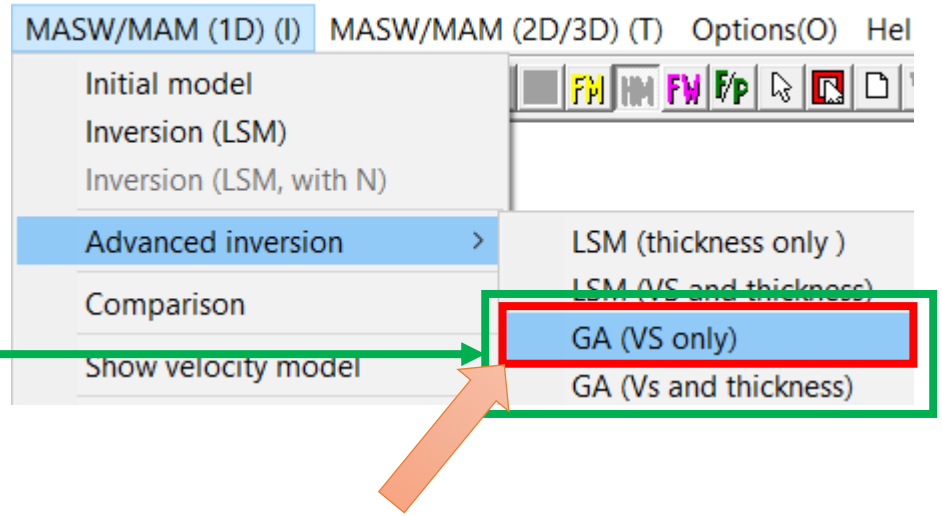
Fundamental mode → Least squares method (LSM)

Dispersion curve is smooth and continuous

Higher mode (effective mode) → Genetic algorithm (GA)

Dispersion curve may be discontinuous

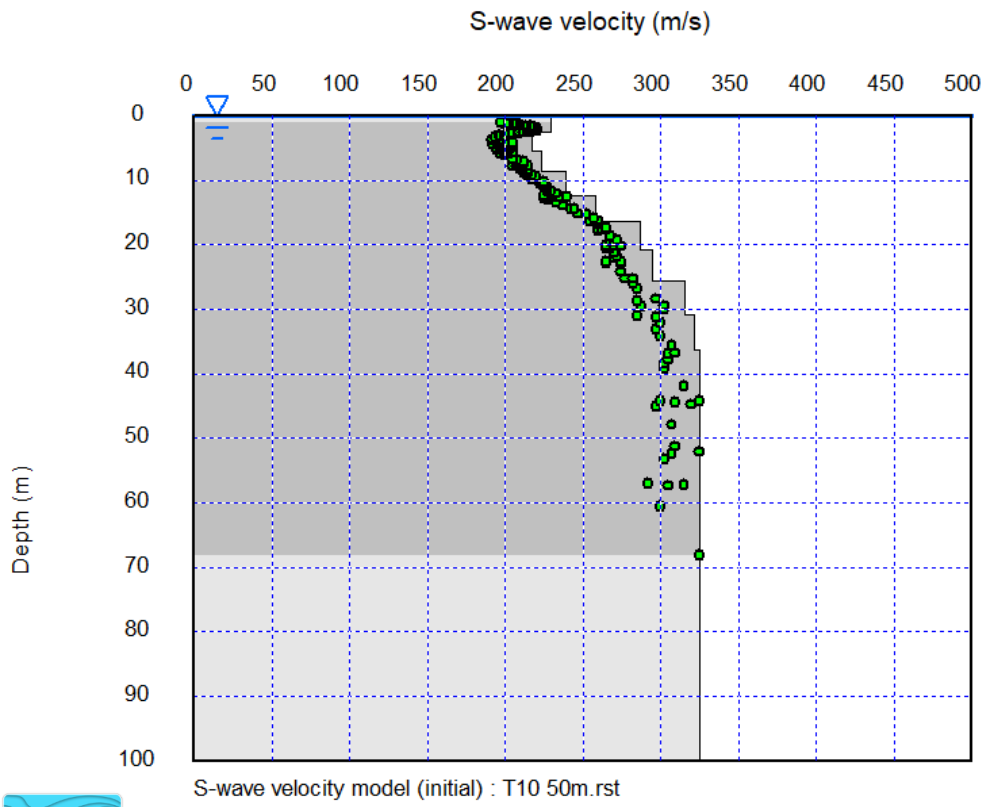




Use “VS only” when number of layer is large (> 5)

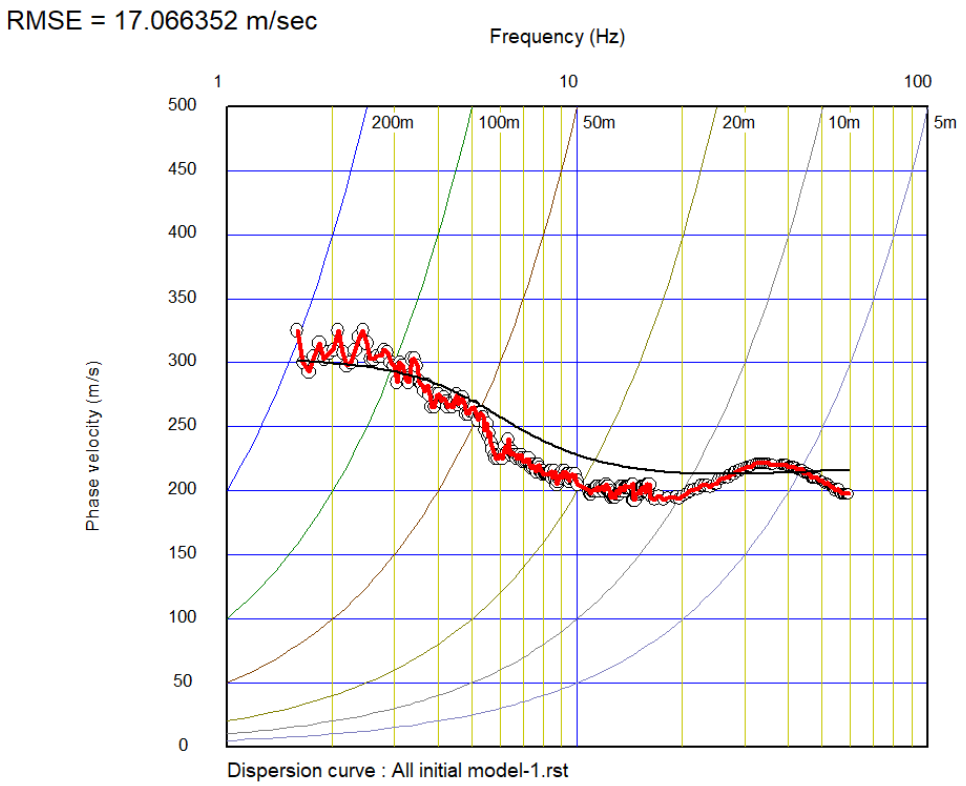
Inversion using fundamental mode based on least squares method (LSM)

Initial S-wave velocity model

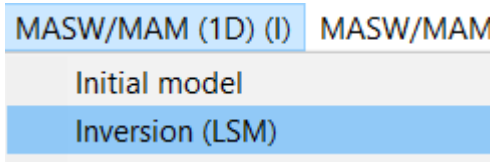


Comparison of observed and theoretical (fundamental mode) dispersion curves

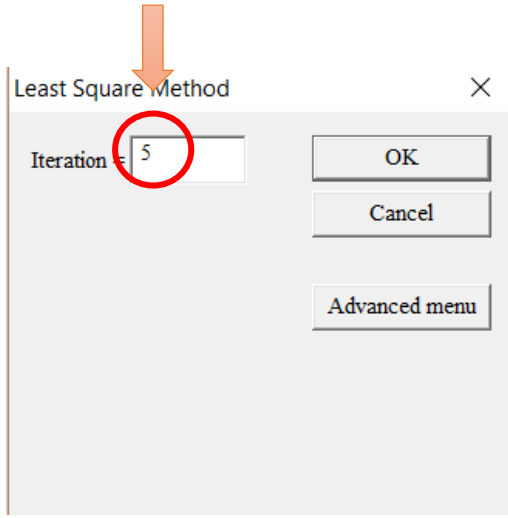
Fundamental mode 



Select “MASW/MAM (1D)”, “Inversion LSM” to start the inversion.

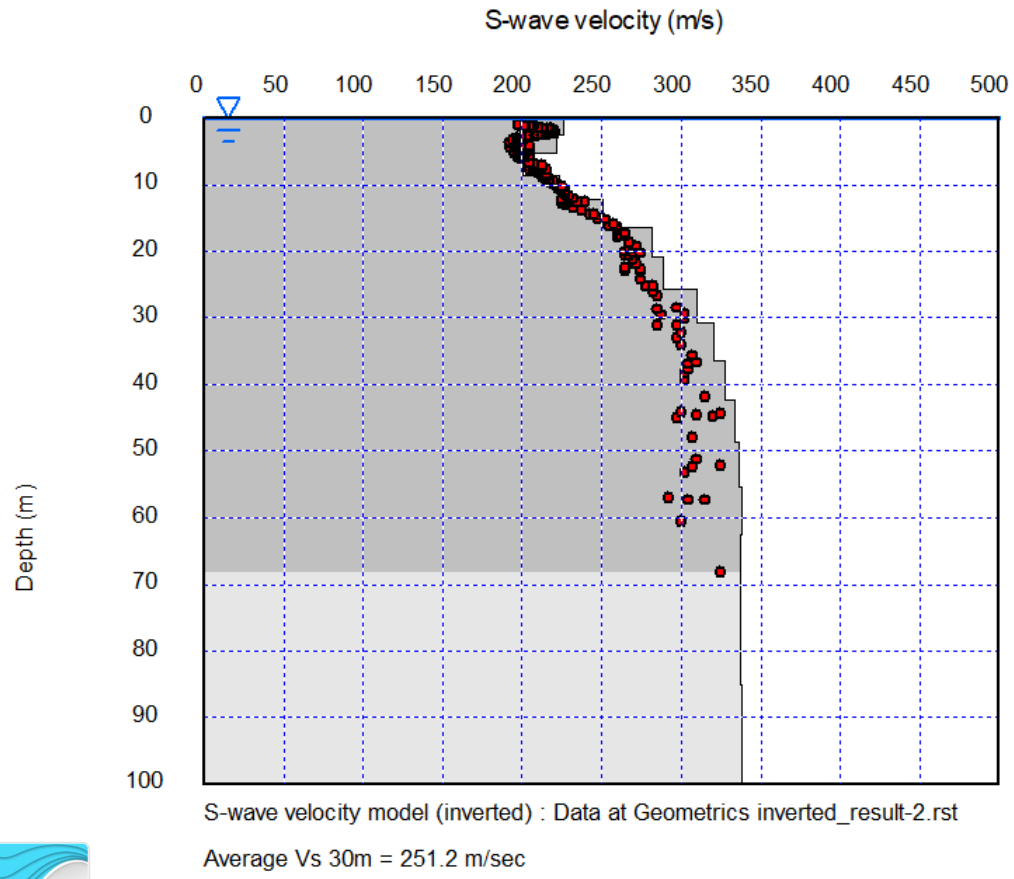


Number of iteration

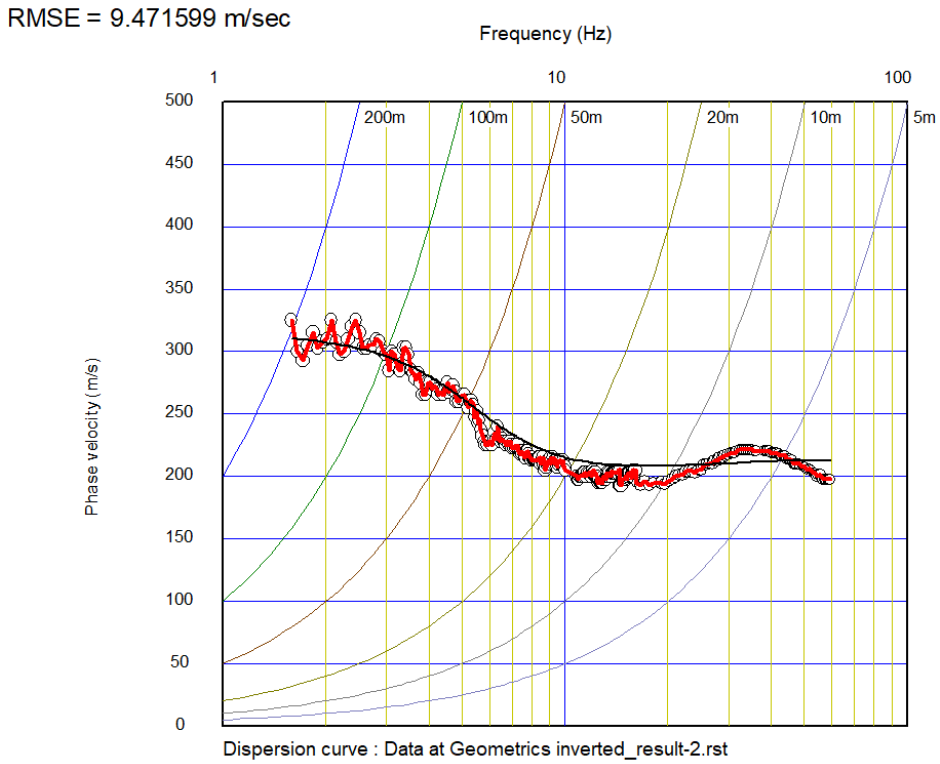


Inversion using fundamental mode based on least squares method (LSM)

Inverted S-wave velocity model



Comparison of observed and theoretical (fundamental mode) dispersion curves



Conversion process is automatically saved in "RMSE.txt"

RMSE.txt

Iteration=0 RMS=17.066352 m/s (7.017373%)
Iteration=1 RMS=14.895001 m/s (6.135052%)
Iteration=2 RMS=13.102761 m/s (5.401269%)
Iteration=3 RMS=11.647438 m/s (4.792031%)
Iteration=4 RMS=10.462912 m/s (4.280407%)

6. Data processing using SeisImager

- Data downloading from Atom
- 1D active/passive surface wave method (data obtained by Atom)
- 2D active surface wave method based on CMP-CC (data obtained by Geode)
- 3D passive surface wave method based on CMP-SPAC (data obtained by Atom)
- Higher modes and inversion using effective mode based on Genetic Algorithm

Tutorial for 2D MASW processing using SeisImager/SW-2D

6. Data processing using SeisImager

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- 3D passive surface wave method based on CMP-SPAC (data obtained by Atom)
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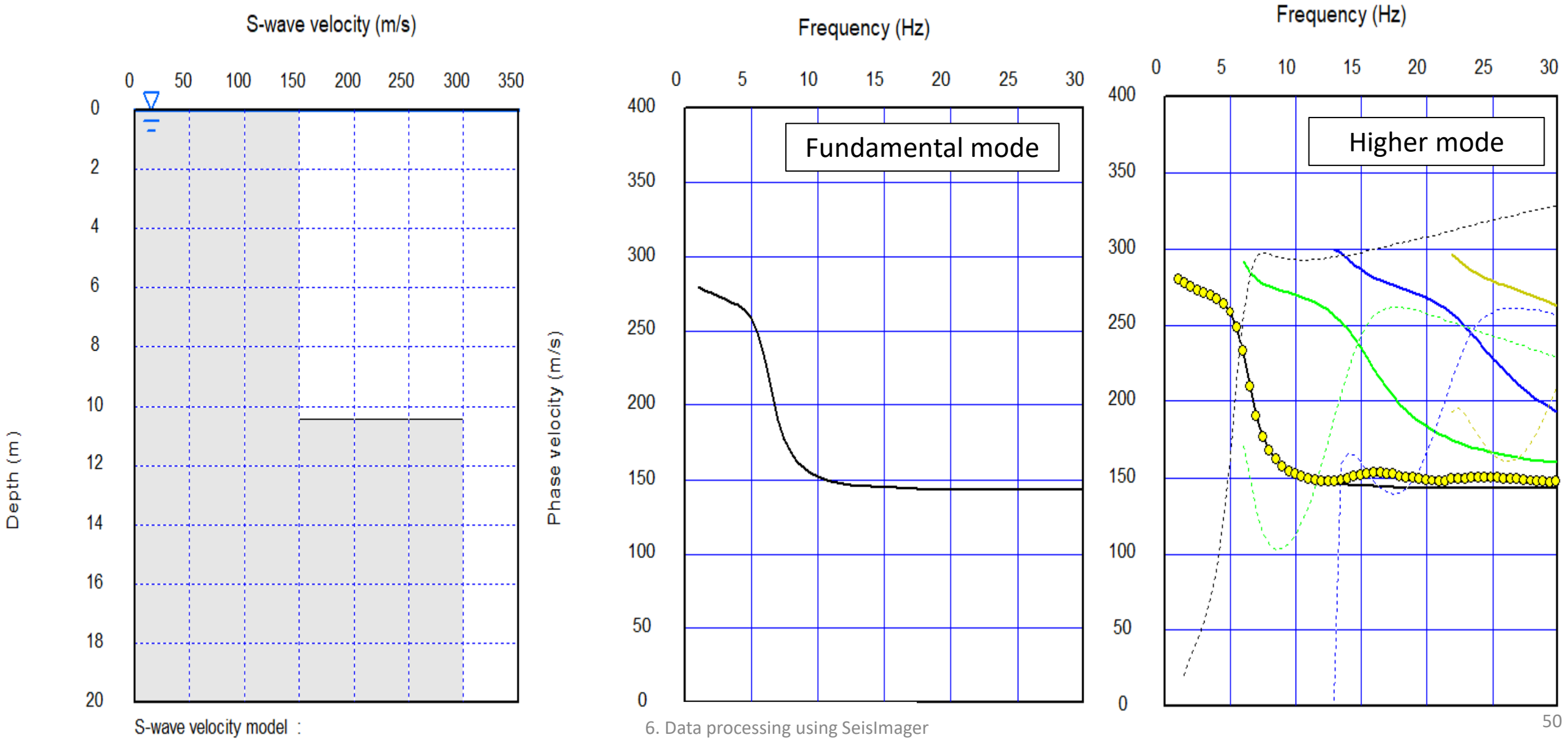
Tutorial for ambient noise tomography processing using SeisImager/SW-3D

6. Data processing using SeisImager

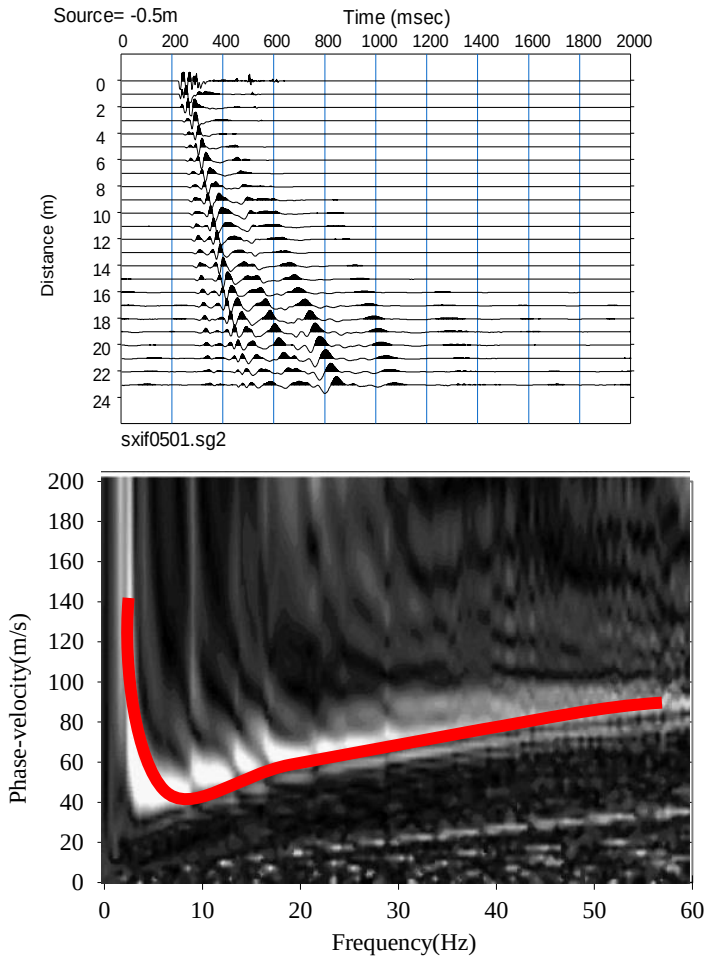
- Data downloading from Atom
- 1D active/passive surface wave method (data obtained by Atom)
- 2D active surface wave method based on CMP-CC (data obtained by Geode)
- 3D passive surface wave method based on CMP-SPAC (data obtained by Atom)
- Higher modes and inversion using effective mode based on Genetic Algorithm

Higher mode (active and passive)



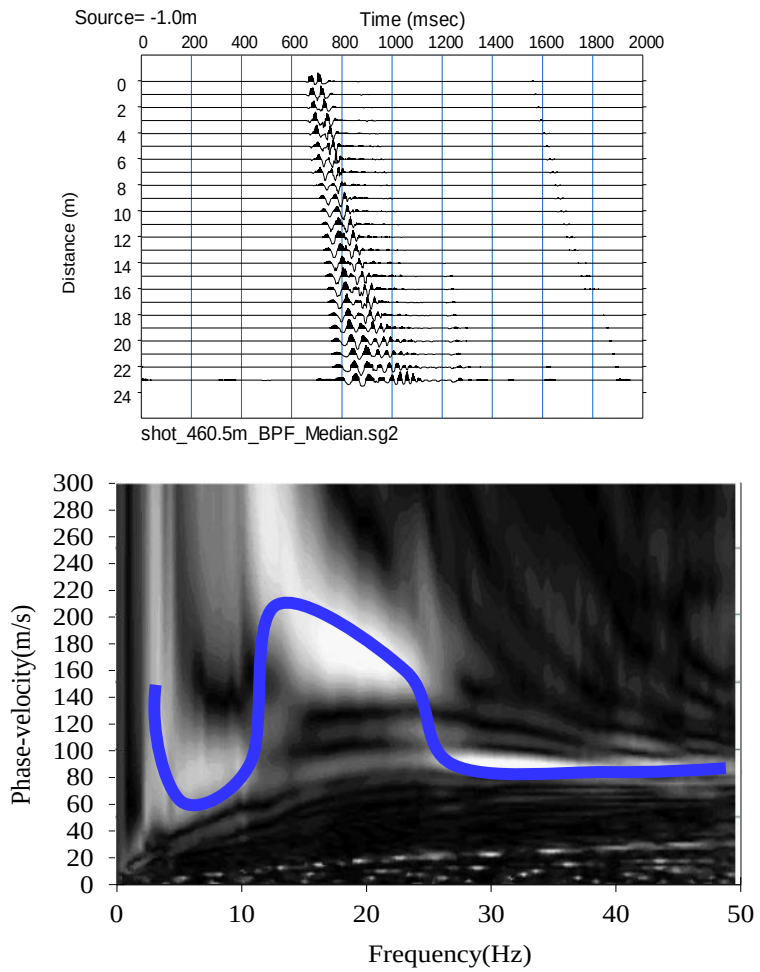
Example of observed waveform data including higher modes

Case-1 (active)

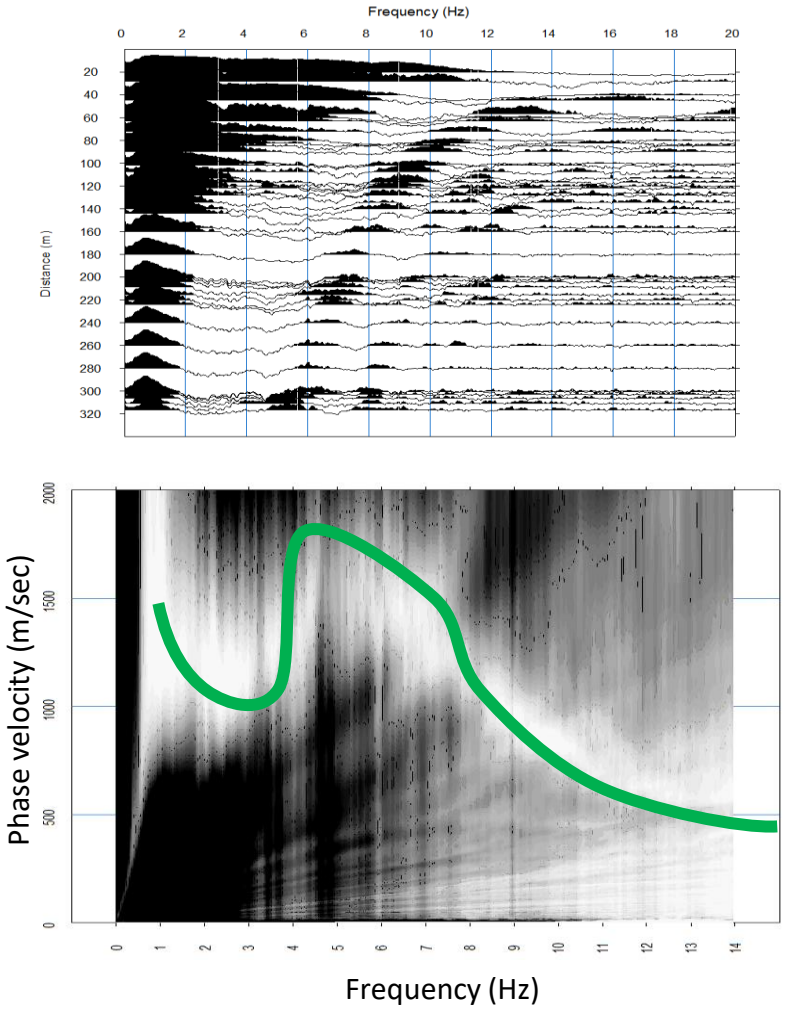


b)

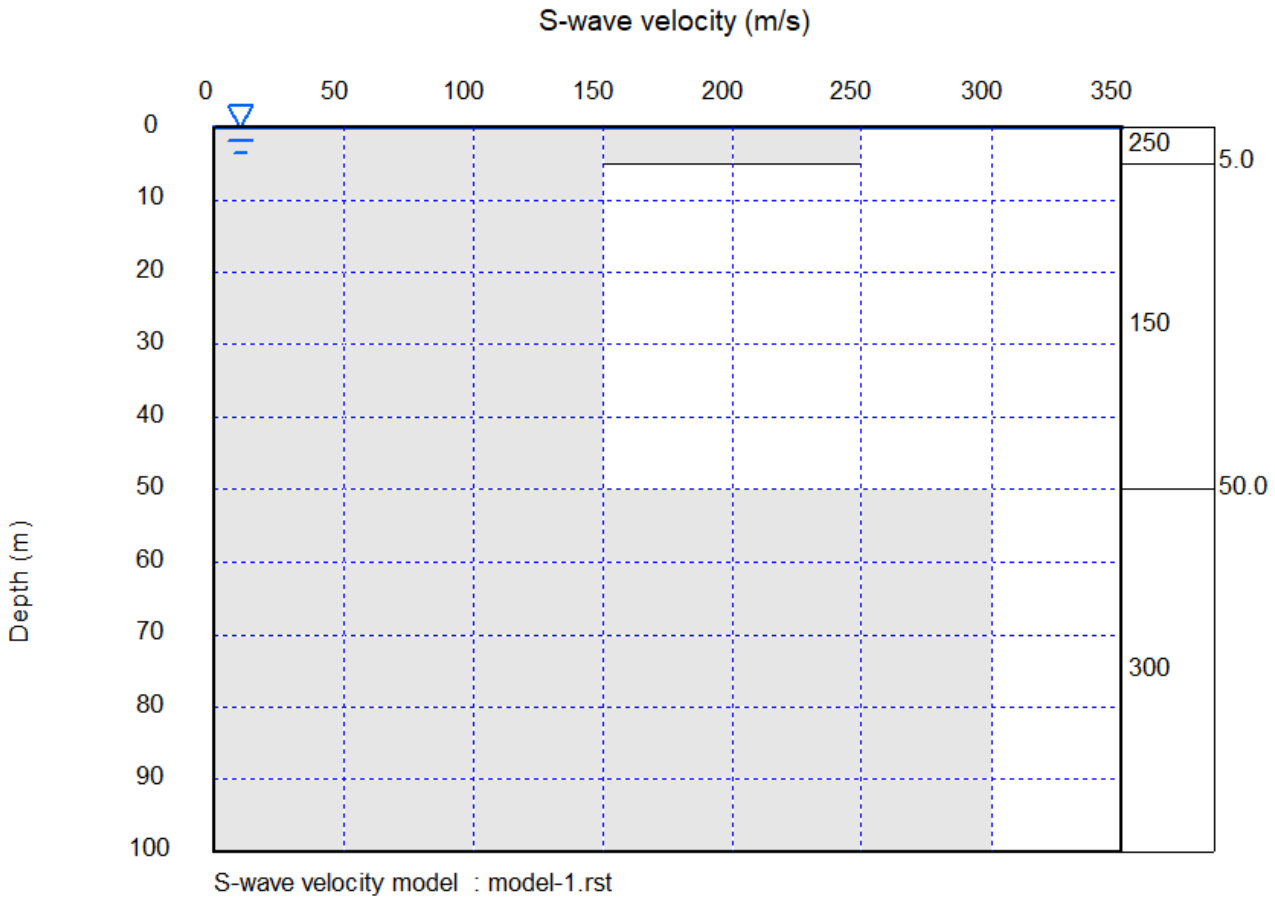
Case-2 (active)

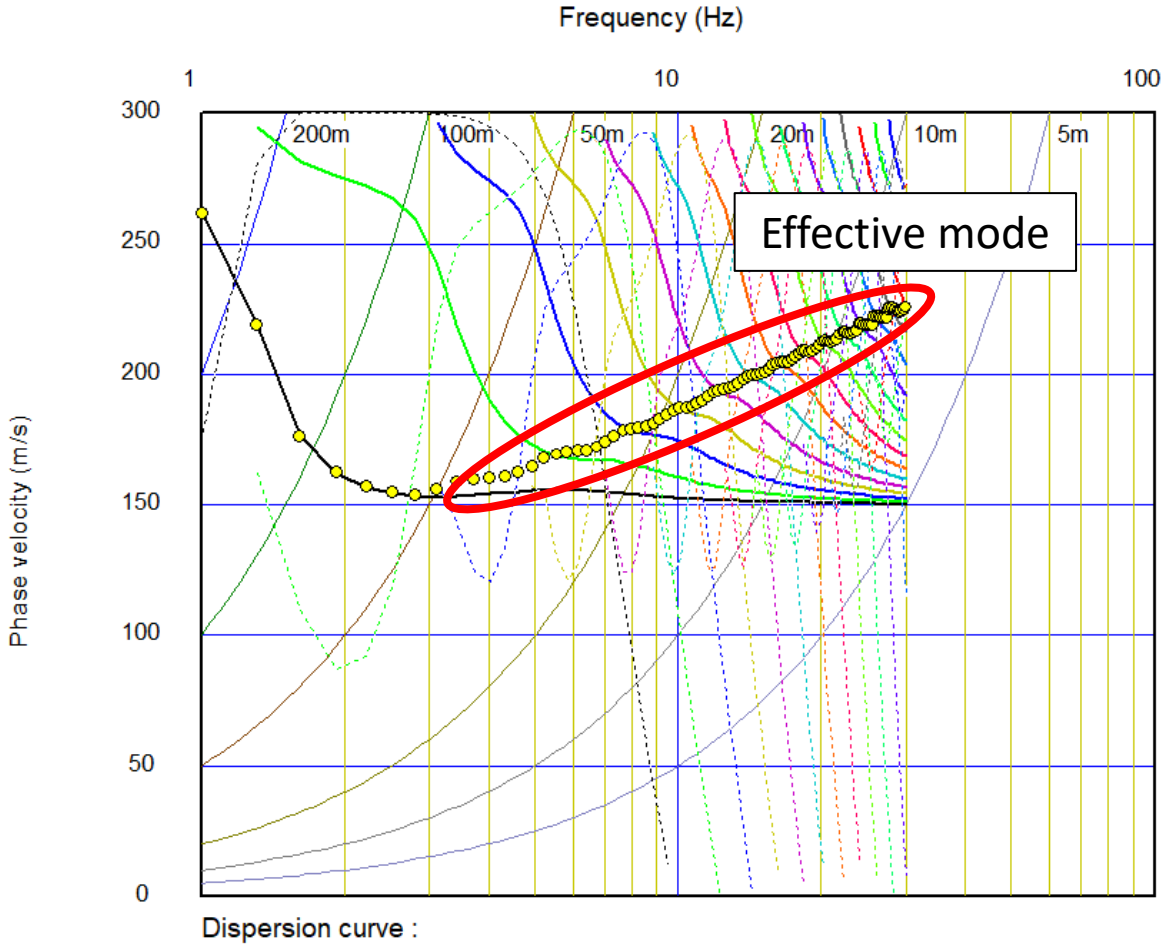


Case-3 (passive)

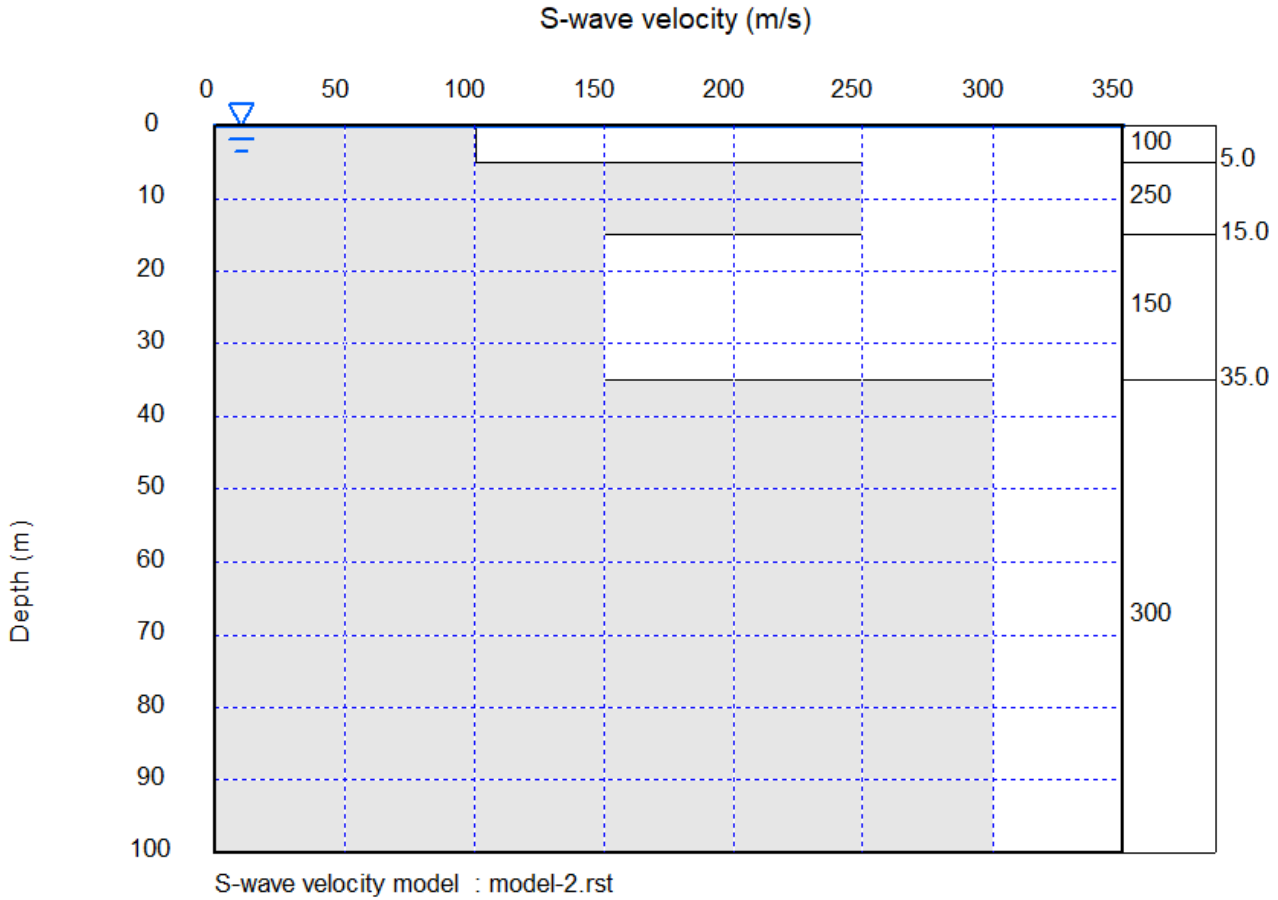


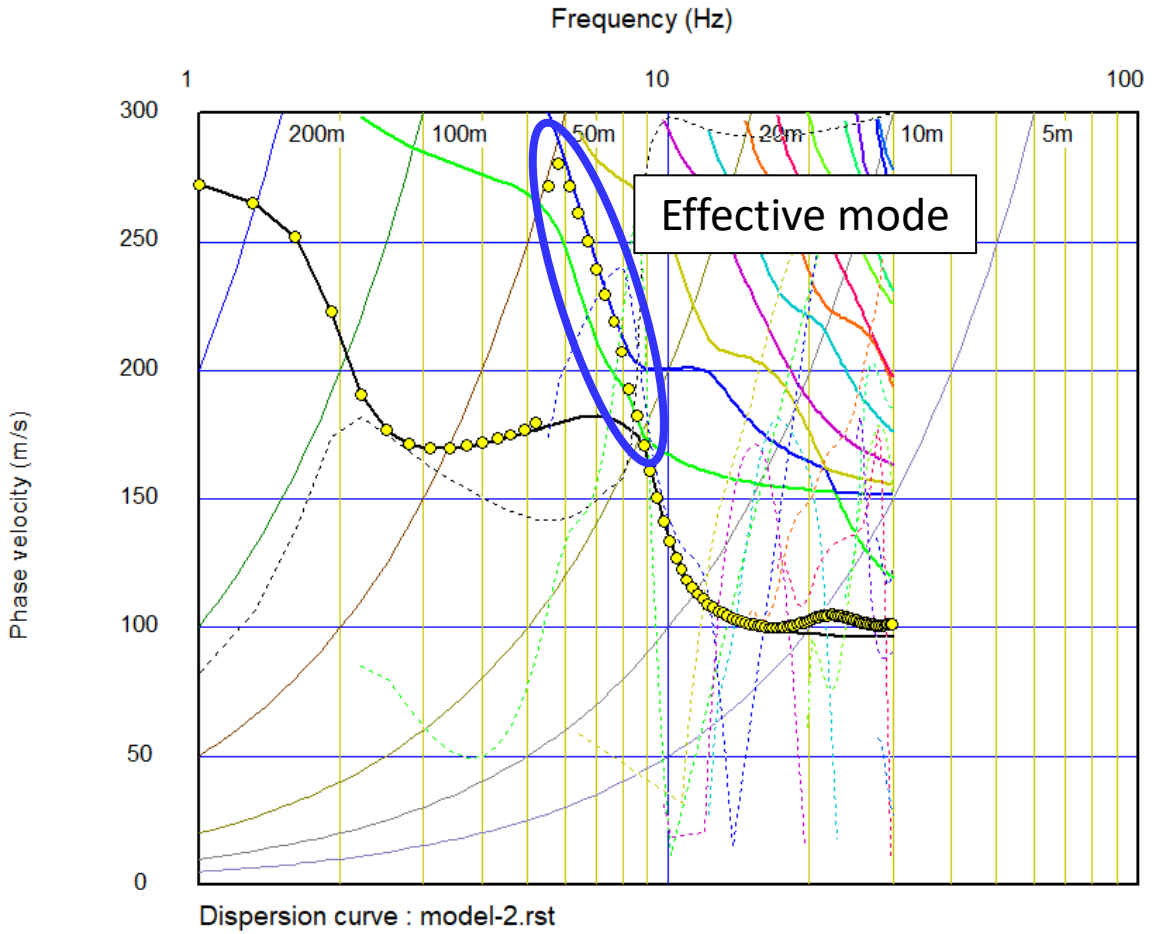
Case 1 : Higher mode example (High velocity on top)



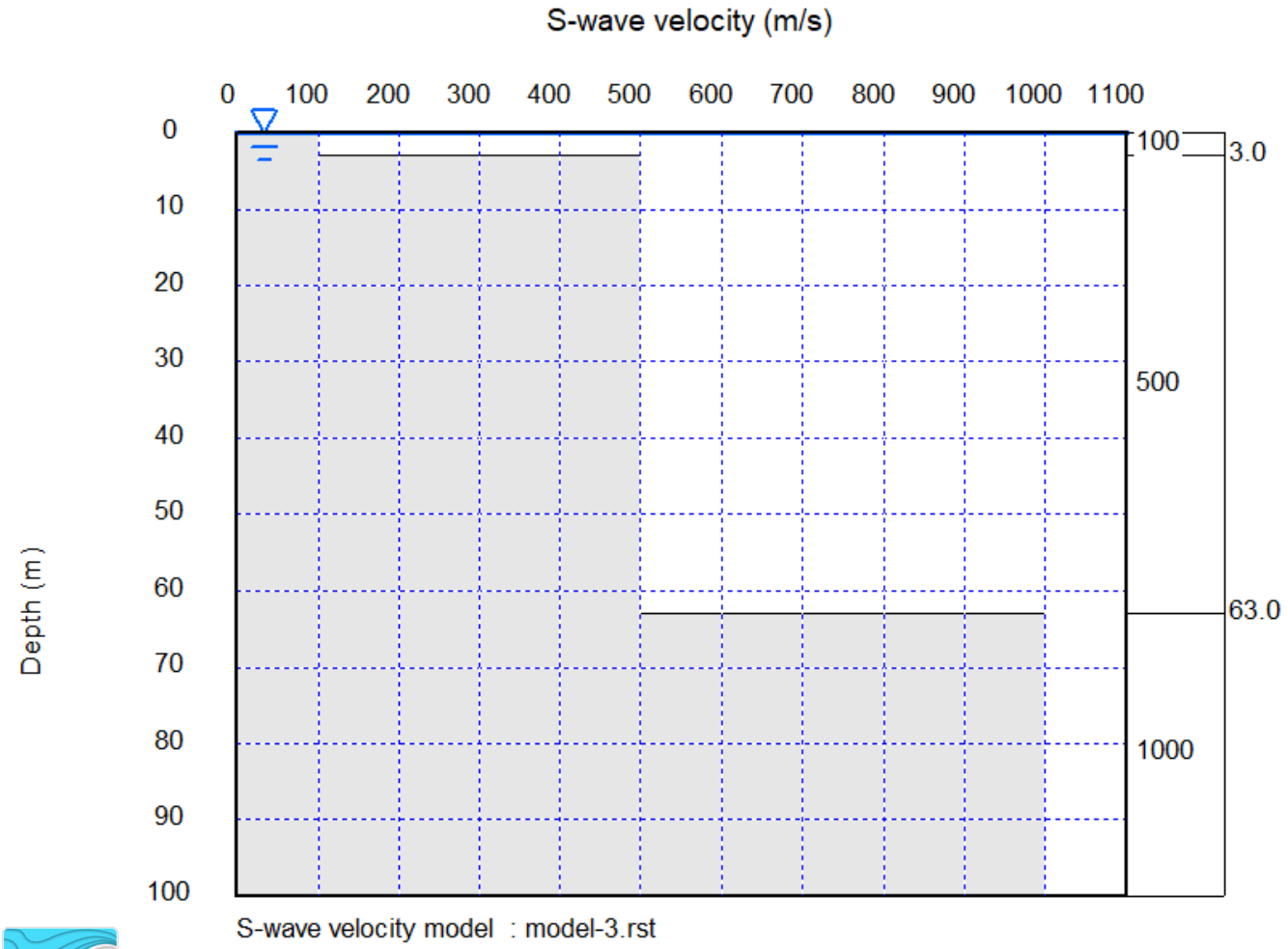


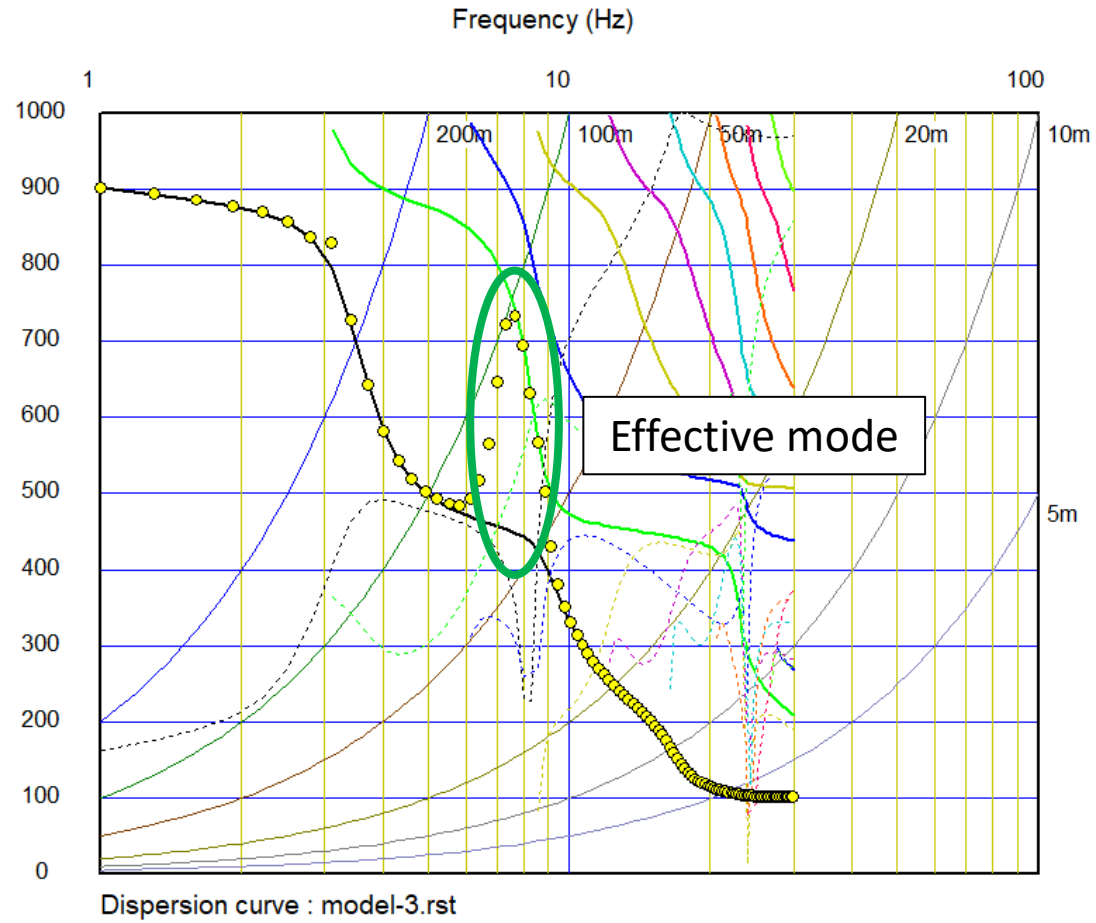
Case 2 : Higher mode example (Reversed layer)





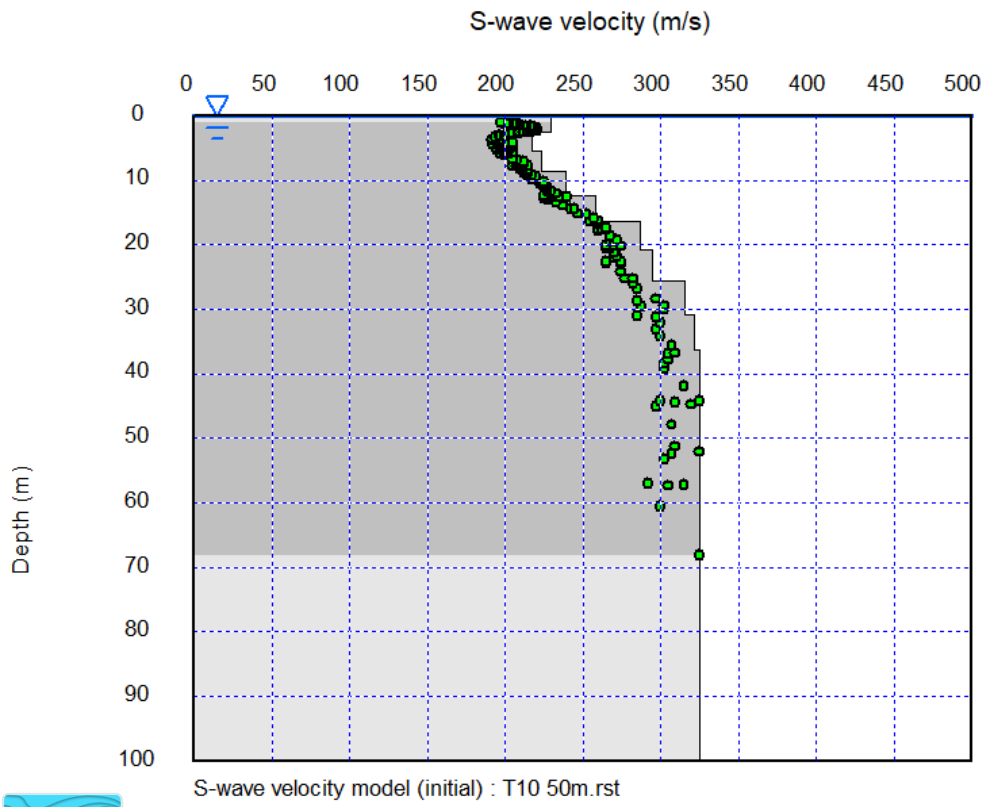
Case 3 : Higher mode example (large velocity contrast at surface)





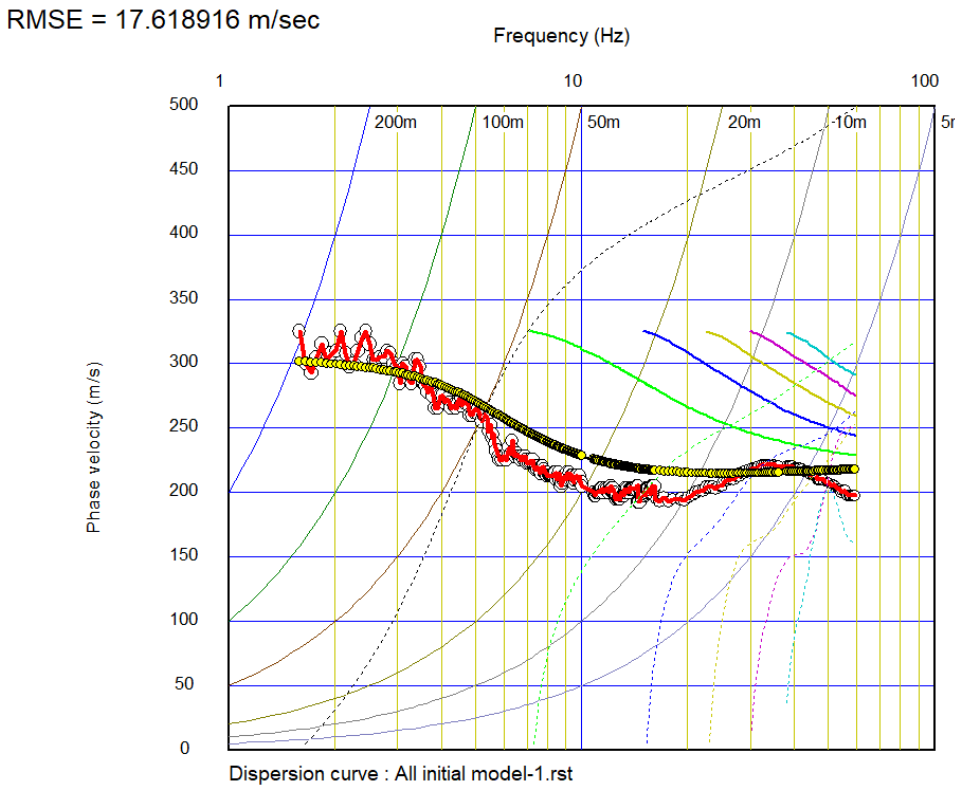
Inversion using effective mode based on Genetic Algorithm (GA)

Initial S-wave velocity model

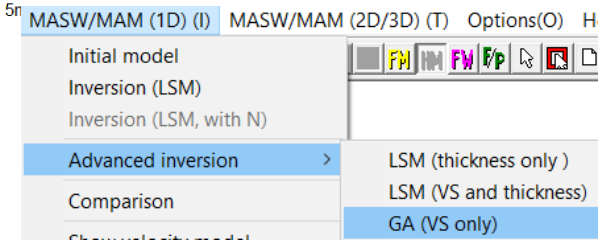


Comparison of observed and theoretical (fundamental mode) dispersion curves

Effective mode

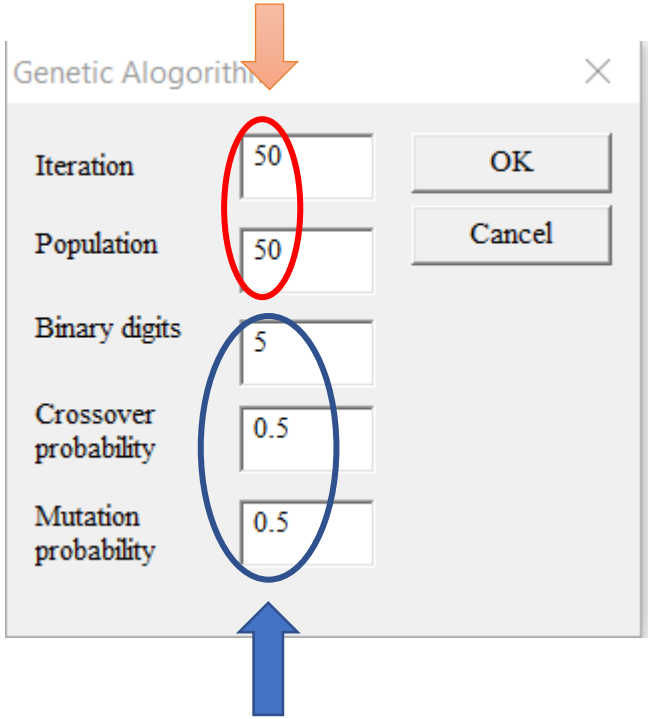


Select “MASW/MAM (1D)”, “Advanced inversion”, “GA (VS only)” to start the inversion.



Inversion using effective mode based on Genetic Algorithm (GA)

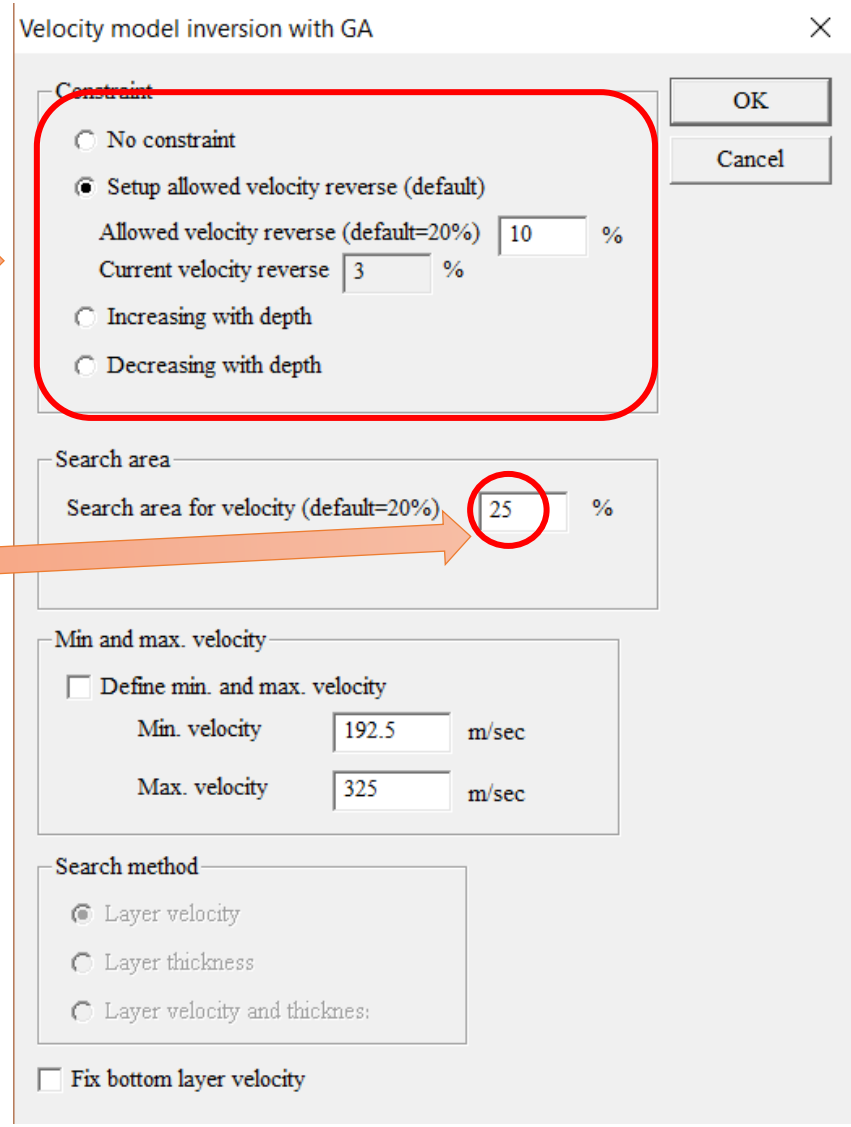
Number of calculation is iteration by population (50 x 50 =2500 in this example). More calculation takes longer computation time.



No need to change default parameters.

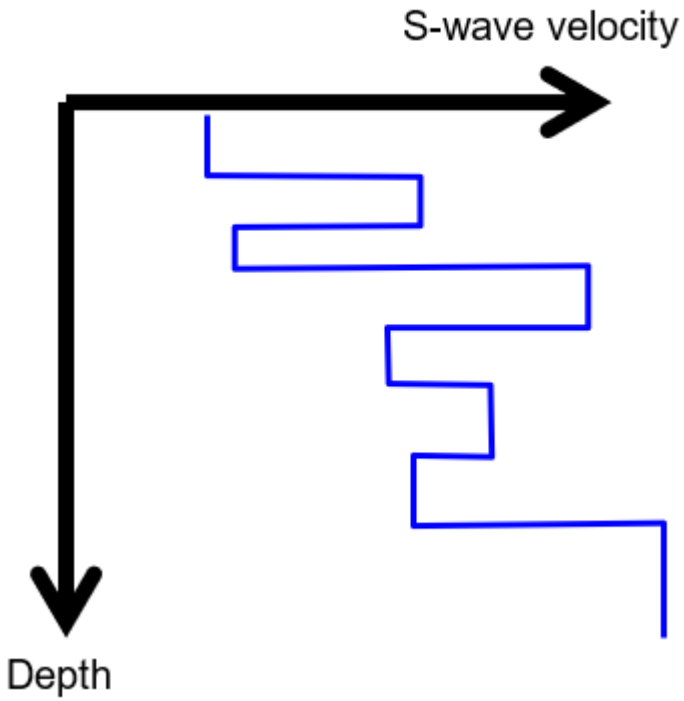
Constraint is quite important and will be described in next pages

Search area of GA is defined based on initial model

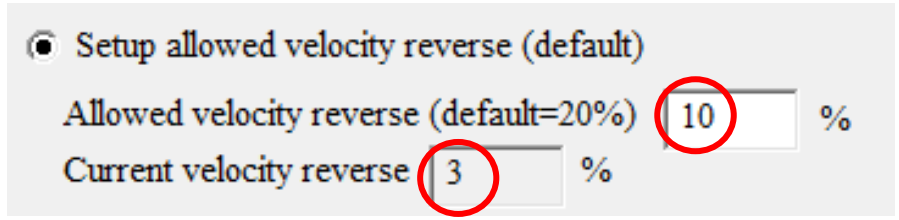


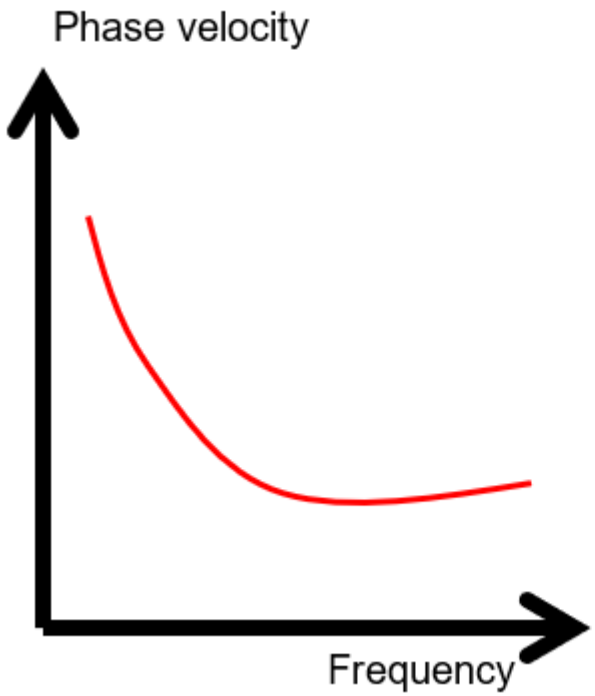
Constraint in Genetic Algorithm (GA)

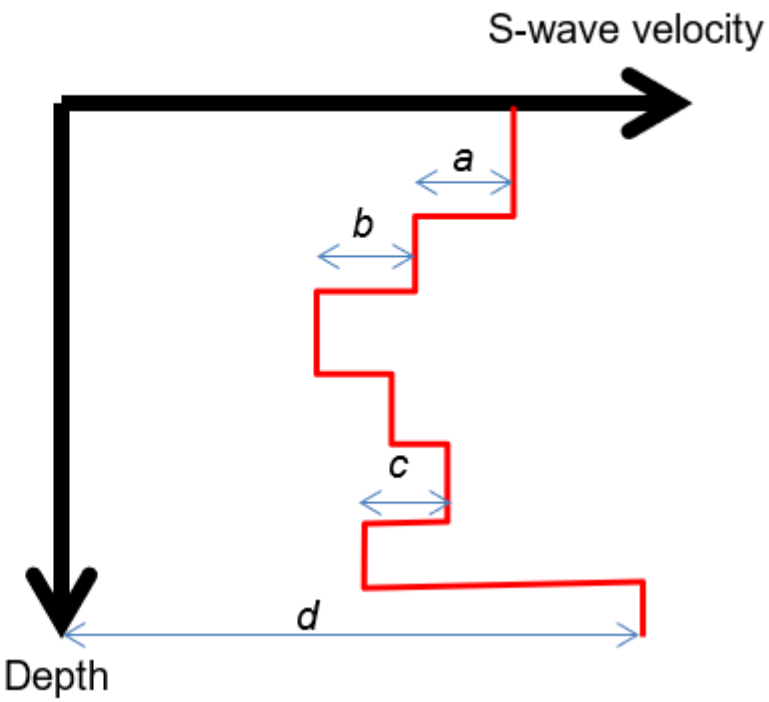
Usually unstable and keep search area to be small.



Use this one when dispersion curve has slight velocity reverse.





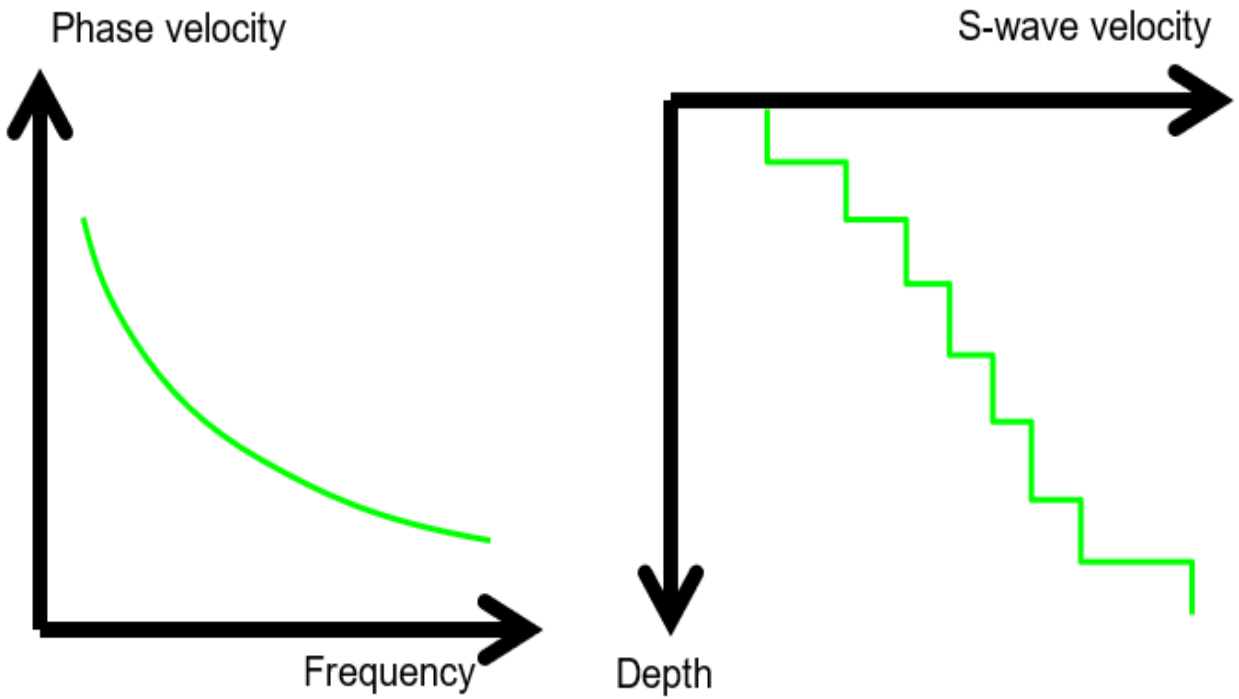


$$P(\%) = \frac{a+b+c}{d} \times 100$$

Constraint in Genetic Algorithm (GA)

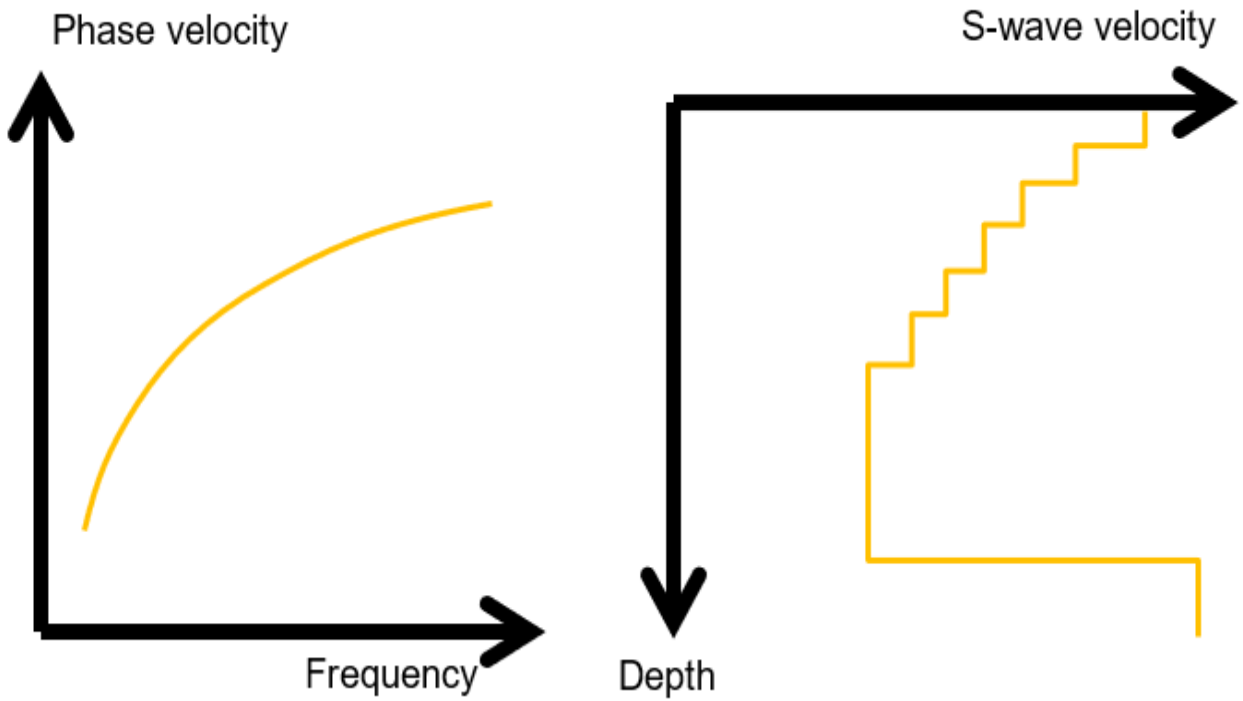
◉ Increasing with depth

Use this one when dispersion curve has no velocity reverse.

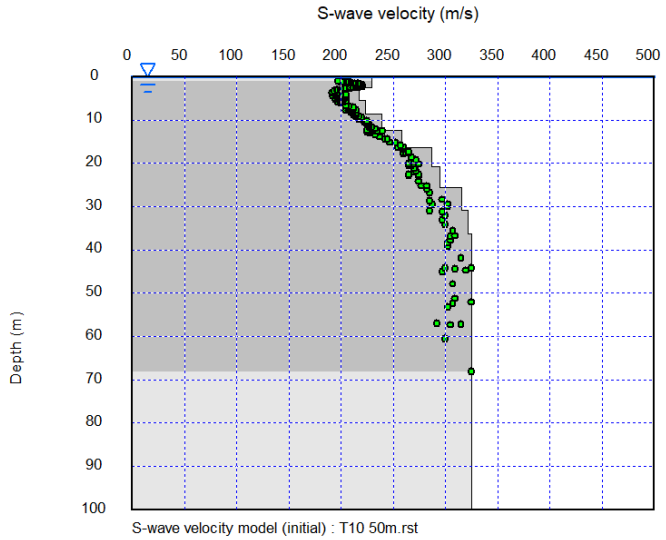


◉ Decreasing with depth

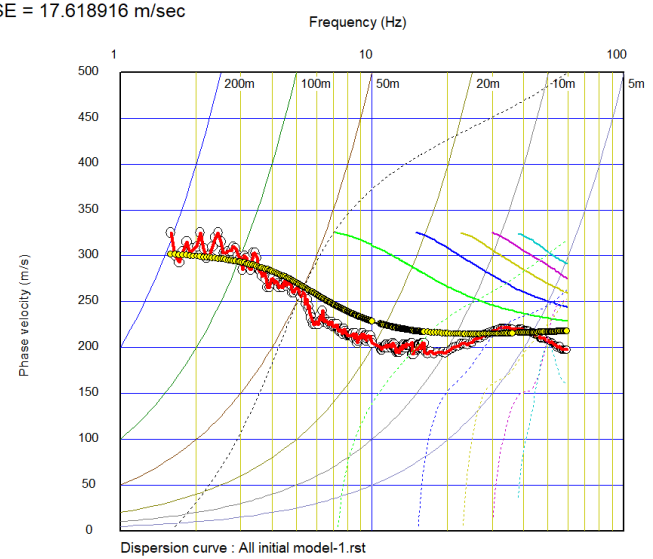
Use this one when dispersion curve has significant velocity reverse.

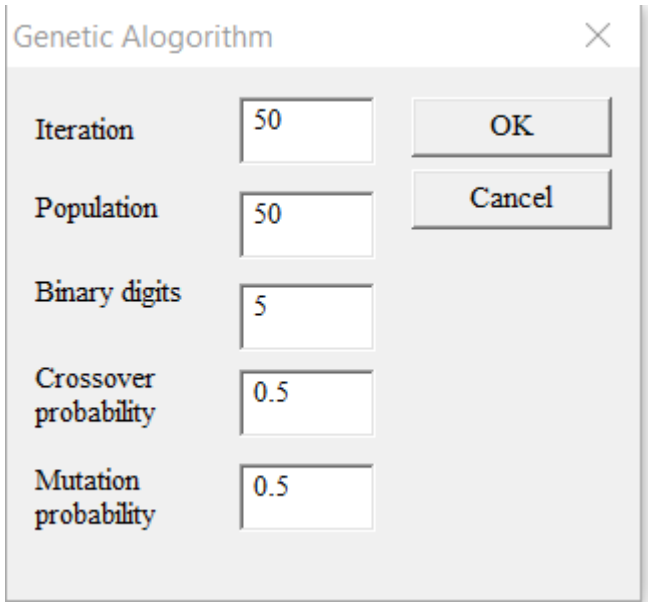


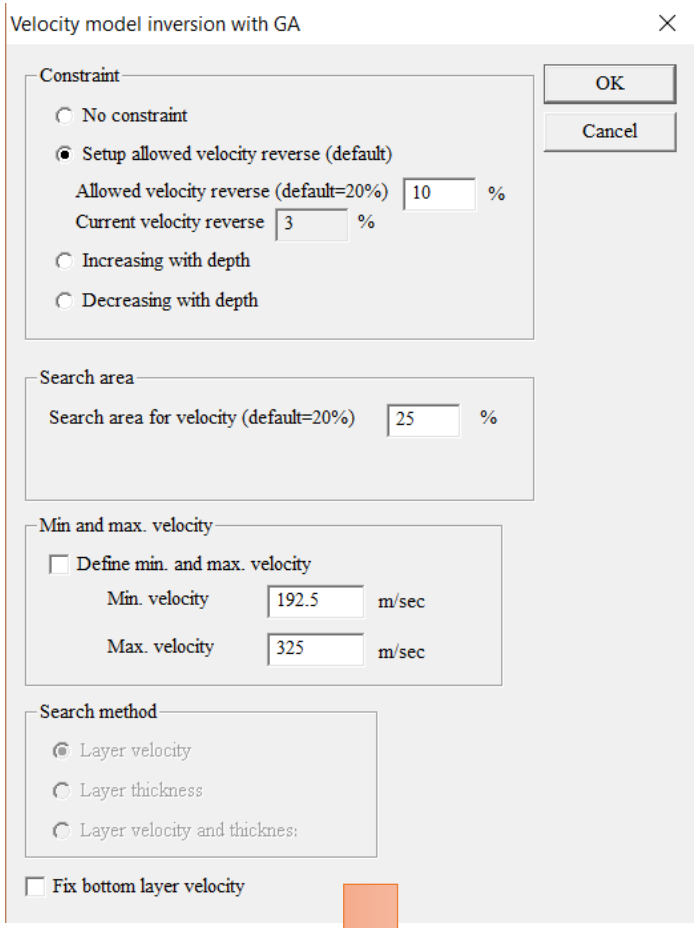
Calculation example of Genetic Algorithm (GA)



RMSE = 17.618916 m/sec







During inversion the latest error is saved in “CurrentError.txt”.

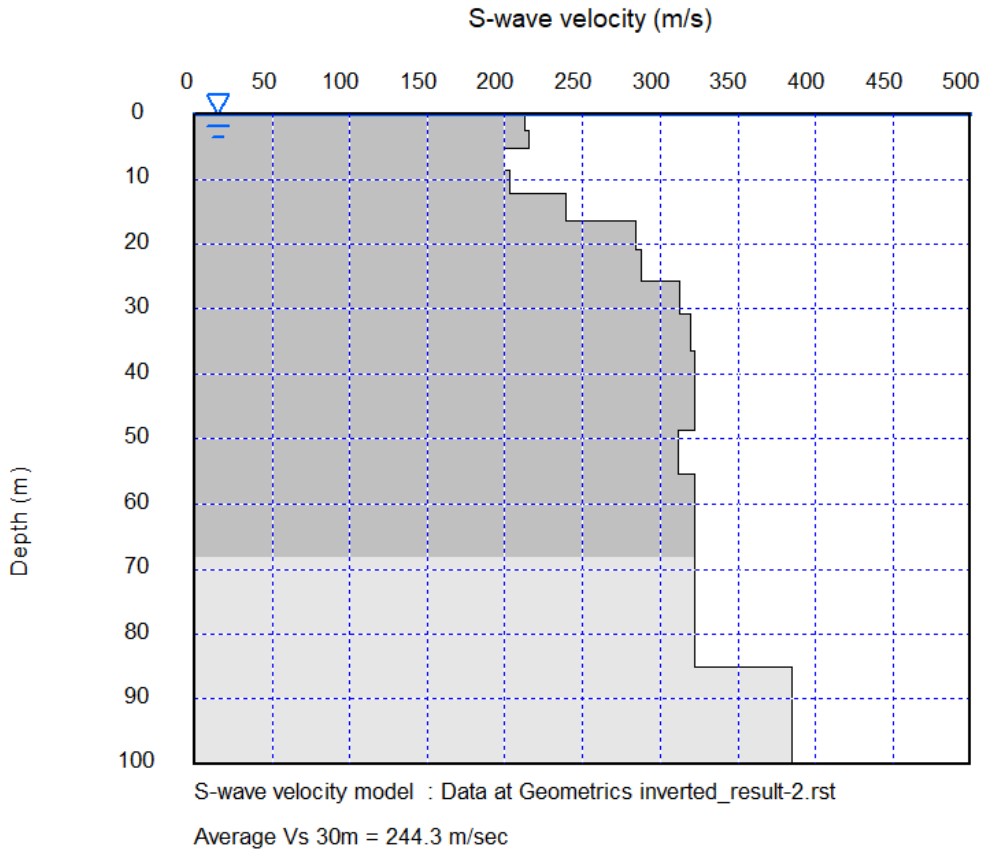
CurrentError.txt

Iteration= 35 Minimum RMS= 7.139146 in 15 Average RMS= 10.344242 Reject= 10

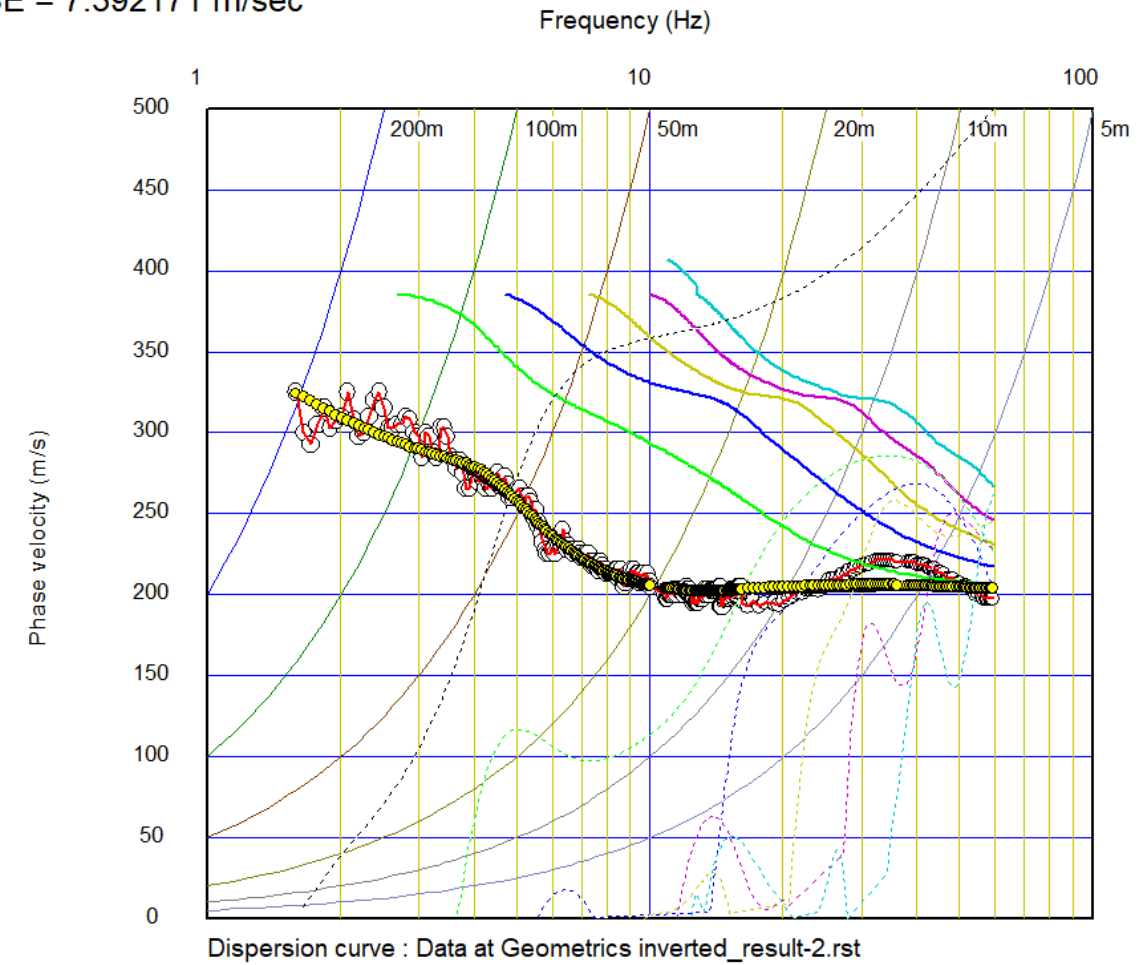
Calculation example of Genetic Algorithm (GA)

The best model obtained from GA

Index=0 Total error=0.007392



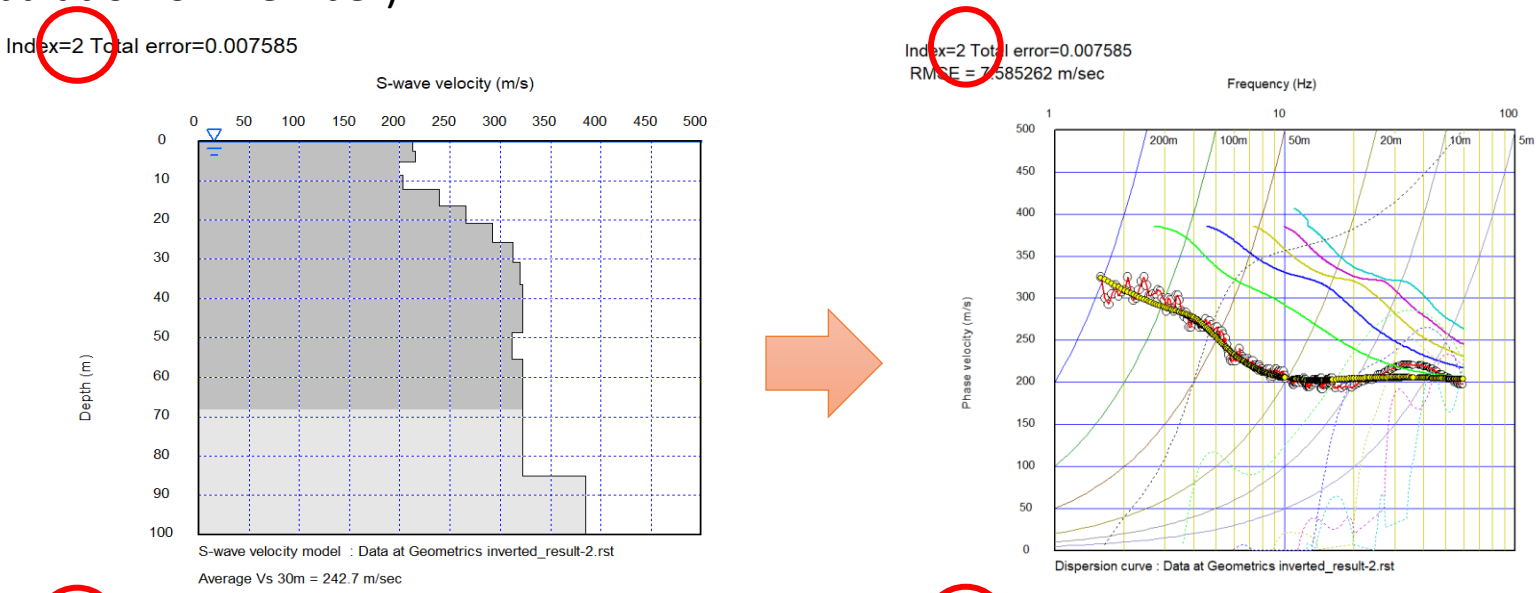
Index=0 Total error=0.007392
RMSE = 7.392171 m/sec



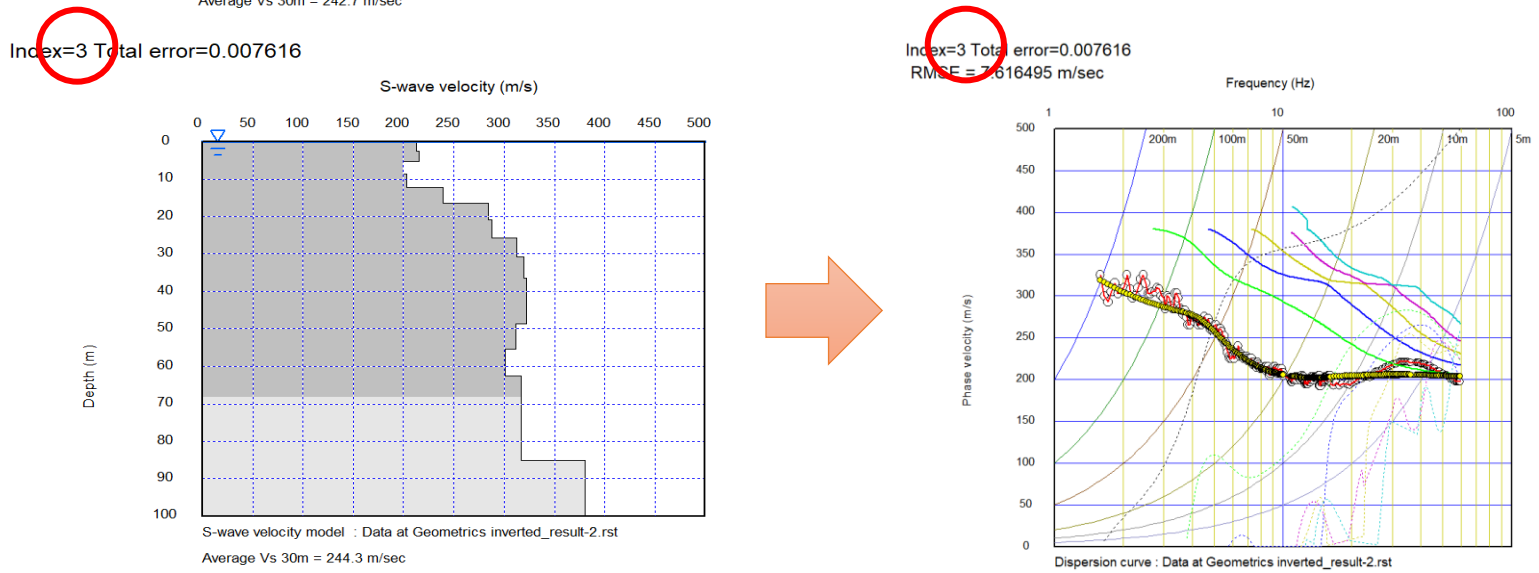
Solution members obtained from GA

GA provides candidates of model (population or member).

2nd place



3rd place

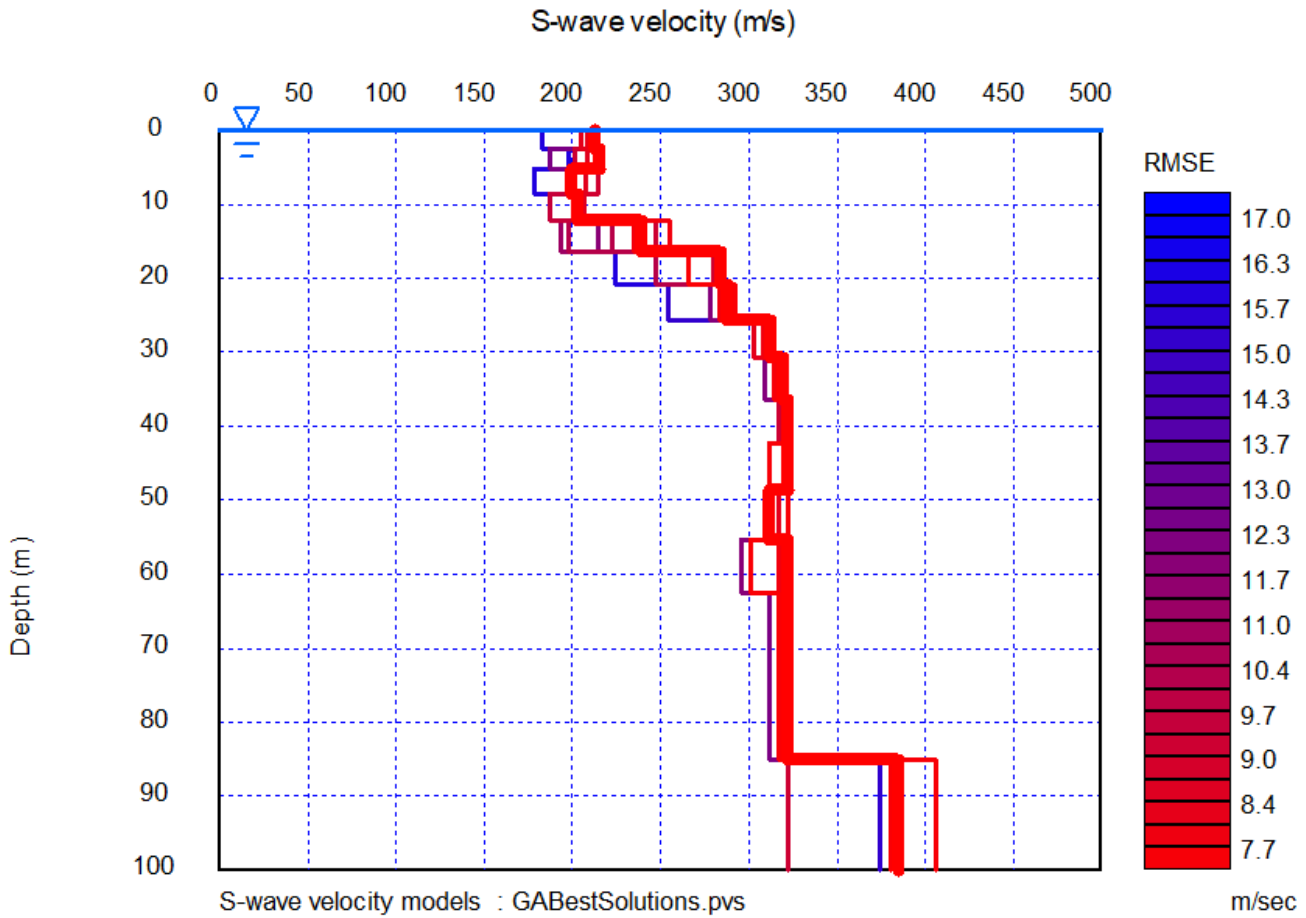


Use  buttons to scroll solution members.

Solution members obtained from GA

Click 

to show all solution members.



Speed up calculation

To speed up calculation, check “Options”, “Advanced options”, “Parallel processing” to on.
WaveEq uses all processors in a PC.