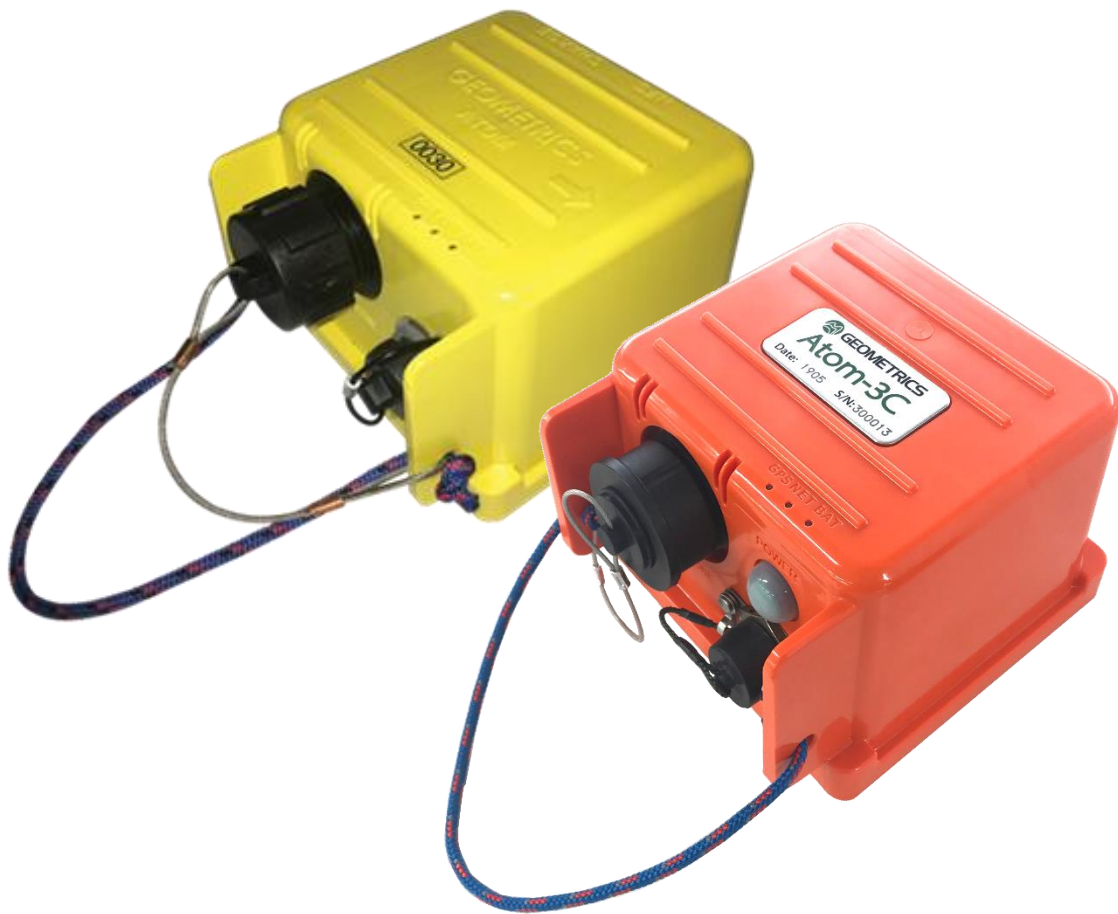


# Passive and Active Seismic Surface Wave Surveying Using the Atom/Atom-3C and SeisImager/SW



**GEOMETRICS**  
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## 1. Introduction

This manual summarizes data acquisition and processing of seismic survey. It particularly focuses on 1D passive and active surface wave methods using 10 ~ 12 Atom acquisition units (AUs) for average S-wave (shear wave or secondary wave) velocity to a depth of 30 m (AVS30). See “SeisImager/SW™ Manual”, “SeisImager/SW™ Manual Addendum (H/V)” and “SeisImager/SW-Pro™ Manual” for the detailed analysis of dispersion curves and/or H/V curves.

Figure 1.1 summarizes software suite and modules will be mentioned in this manual and outline of data processing. Two software suites, Geometrics Atom Downloader and SeisImager will be used to download waveform data from Atom and to process the data. Geometrics Atom Downloader downloads waveform data from Atom AUs via Wi-Fi and save it raw data files (.mtn). SPACPlus reads the raw data, edits and pre-process raw data and save it as SEG2 files. It also calculates an 1D dispersion curve from ambient noise data. Pickwin takes over pre-processed data and applies 2D or 3D dispersion curves. Pickwin also directory reads the raw data file (.mtn). WaveEq applies various inversions to 1D to 3D dispersion curves and provides 1D to 3D S-wave velocity model. The SPACPlus also downloads data from Atom AUs and set up acquisition parameters via Wi-Fi or USB.

Although the manual mainly describes data acquisition and processing for 1D passive and active surface wave methods, Atom can be used for other seismic surveys such as refraction and reflection. SPACPlus cuts out and saves shot records as SEG2 files and Pickwin and Plotrefa take over these data and applies refraction or general seismic processing.

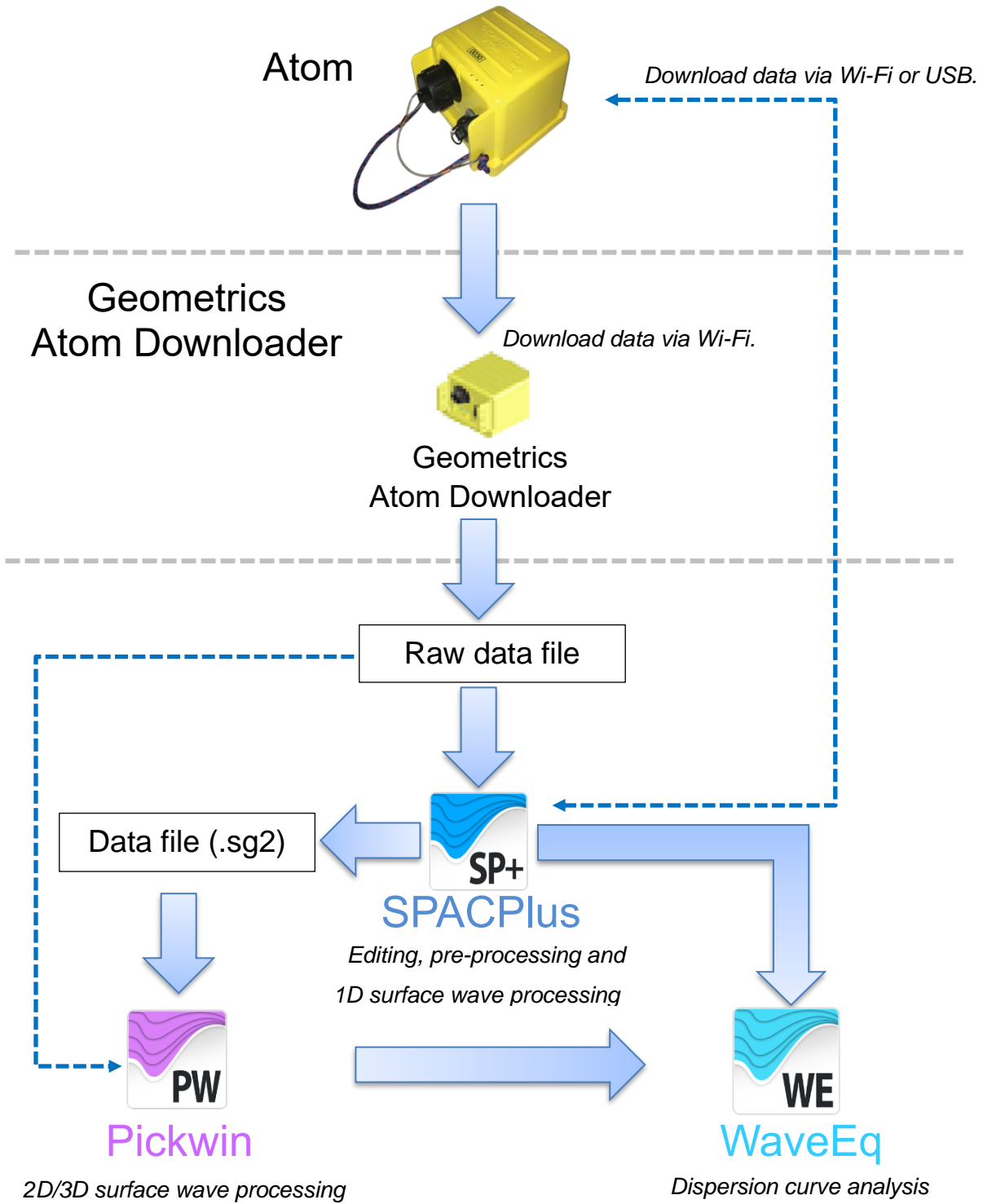


Figure 1.1 Software suite and modules described in the manual and outline of processing.

## 2. Typical survey configuration for microtremor array measurements (MAM)

1) In microtremor array measurements (MAM), the array size (or maximum separation of receivers) must be larger than the depth of investigation. For example, the array size must be bigger than approximately 30 m in the investigation for an AVS30 investigation. SeisImager allows four set types of array configurations as well as a custom option. Figures 2.1 through 2.5 illustrate the various set configurations. Note that “Array size” in the Figures is the definition used for processing in SeisImager and not the same as the maximum receiver separation. See SeisImager/SW manual for more details. As in Figure 1, the black line represents the order of the Atom’s ID and the green inverted triangles represent each Atom.

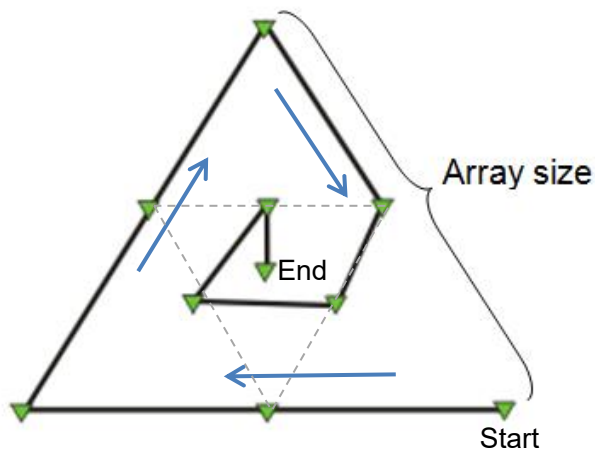


Figure 2.1 Map view of MAM survey equilateral triangle spread configuration with 10 geophones (Triangle 10).

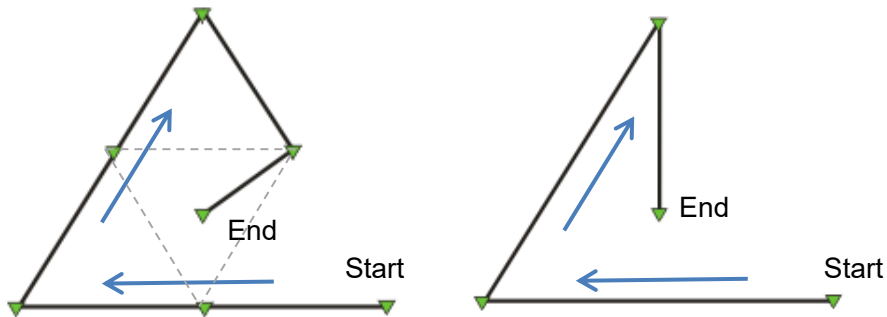


Figure 2.2 Map view of MAM survey equilateral triangle spread configurations with 7 (Triangle 7) and 4 geophones (Triangle 4).

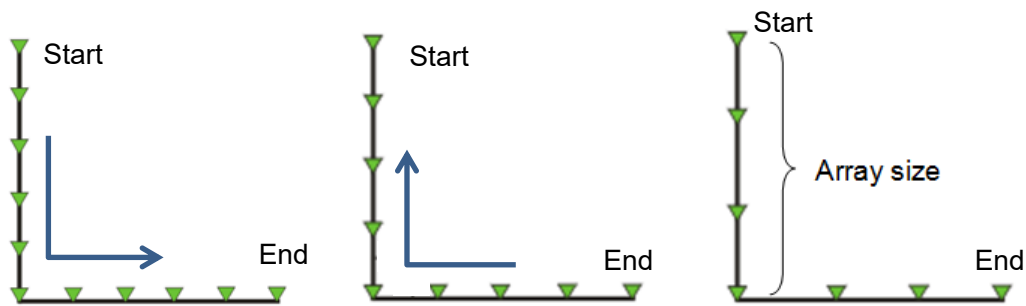


Figure 2.3 Map view of MAM survey L-shape spread configurations with 11 (*L11*), 9 (*L9*), and 7 (*L7*) geophones. An angle between two edges does not need to be 90 degrees.

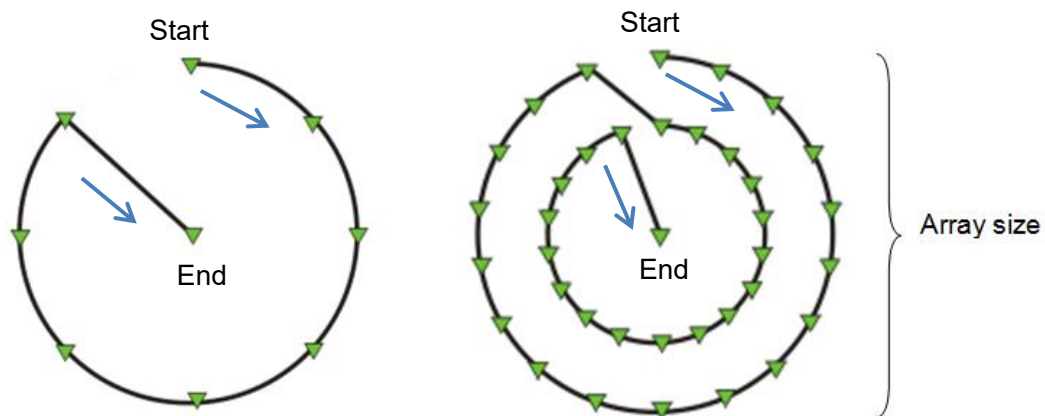


Figure 2.4 Map view of MAM survey circle spread configurations with 8 outer geophones on one circle and one center geophone (*Single circle 9*) and 18 geophones in two circles and one center geophone (*Double circle 37*).

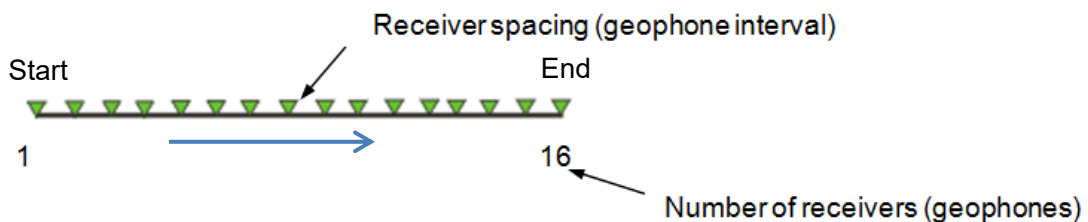


Figure 2.5 MAM survey linear spread configuration using all channels, one per geophone.

2) A typical example of a T-shape array and an L-shape array for an AVS30 survey using Atom units is shown in Figures 2.6 and 2.7. For the sake of simplicity, deploy the Atoms in numerical order of ID. In this example, the Atom ID's are 10006 to 100049 (T-shape) or 100050 (L-shape).

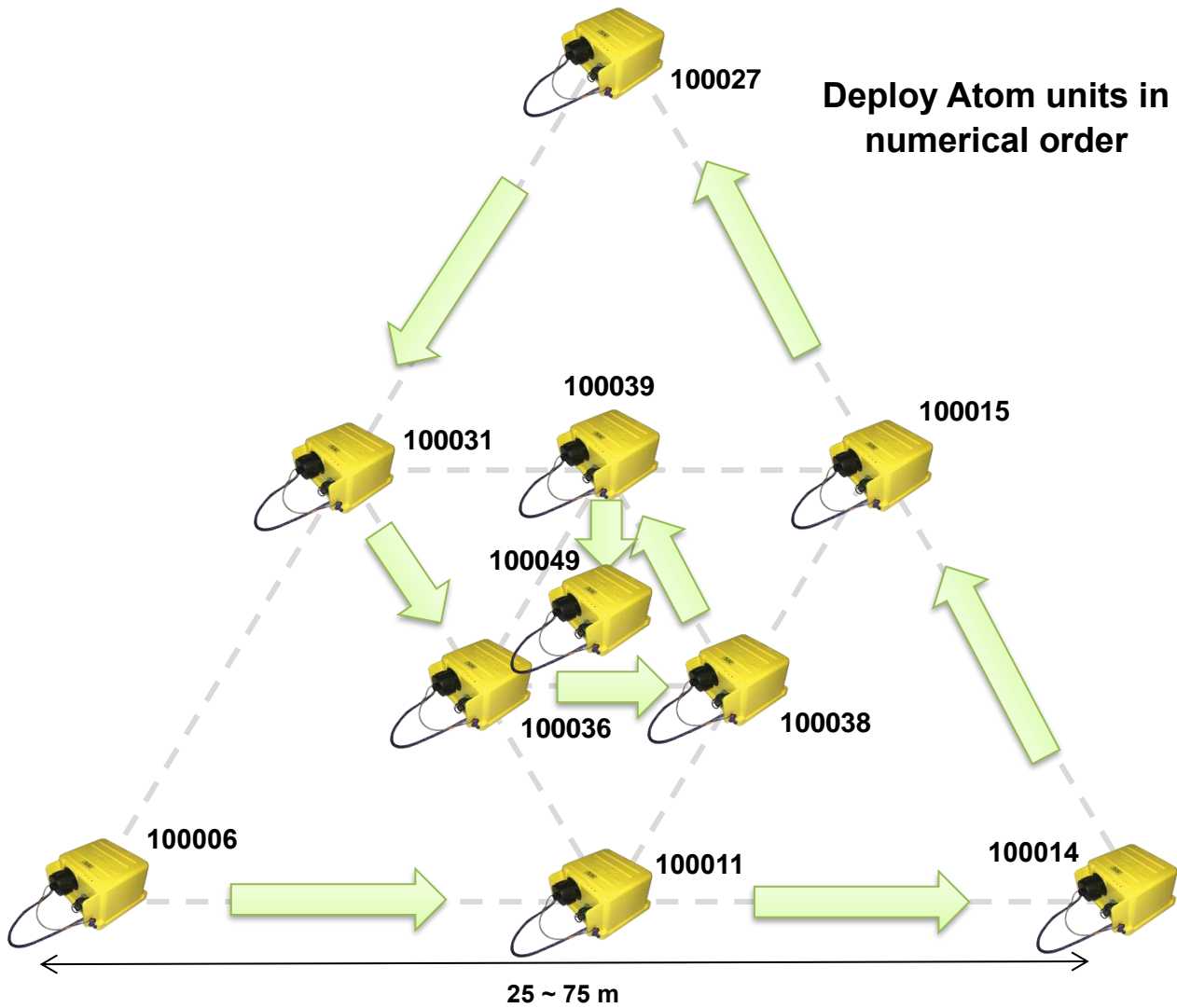


Figure 2.6 T-shaped array (T10) using 10 Atom AUs.



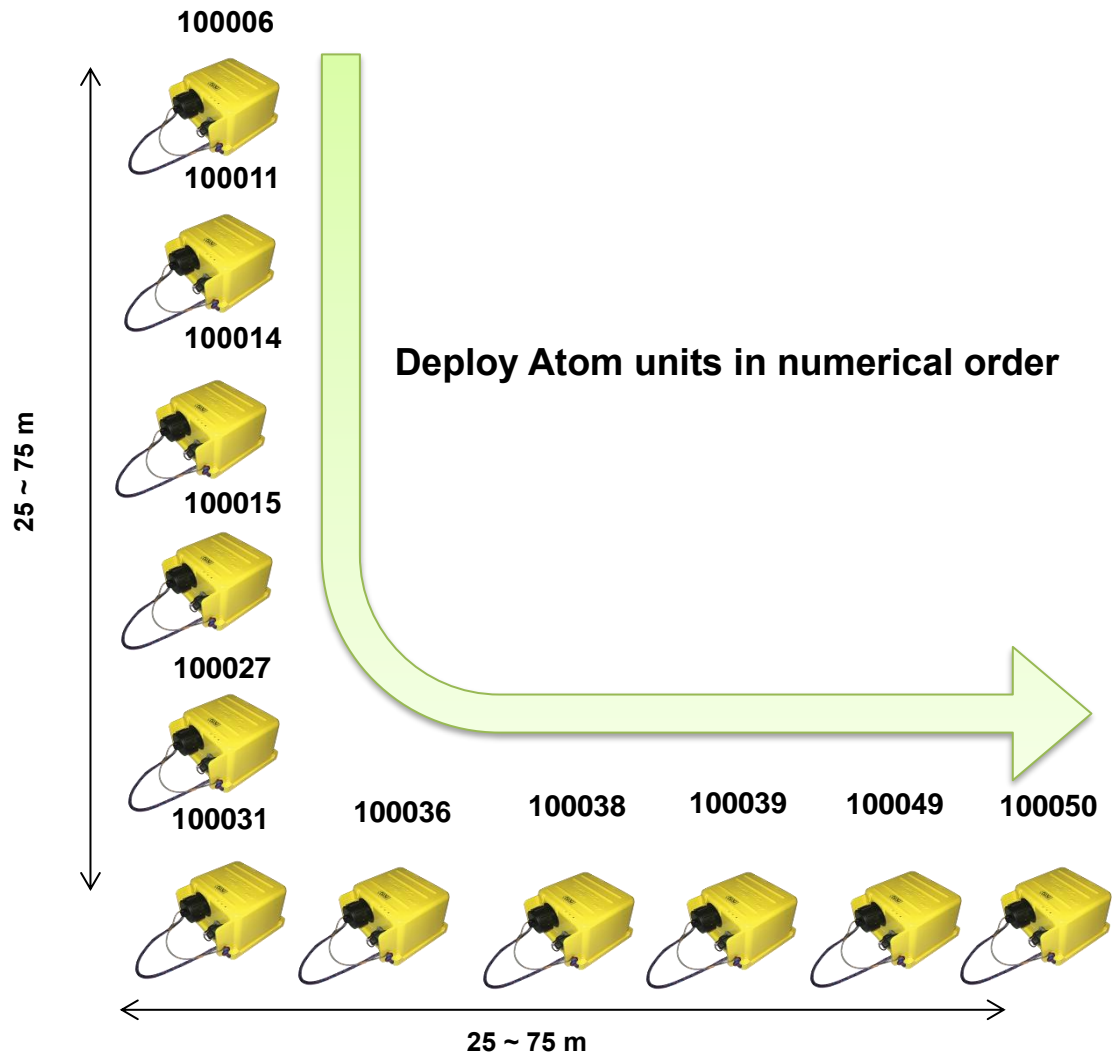


Figure 2.7 L-shaped array (L11) using 11 Atom AUs.

During processing, waveform traces are shown and processed in the numerical order of each Atom unit's ID.

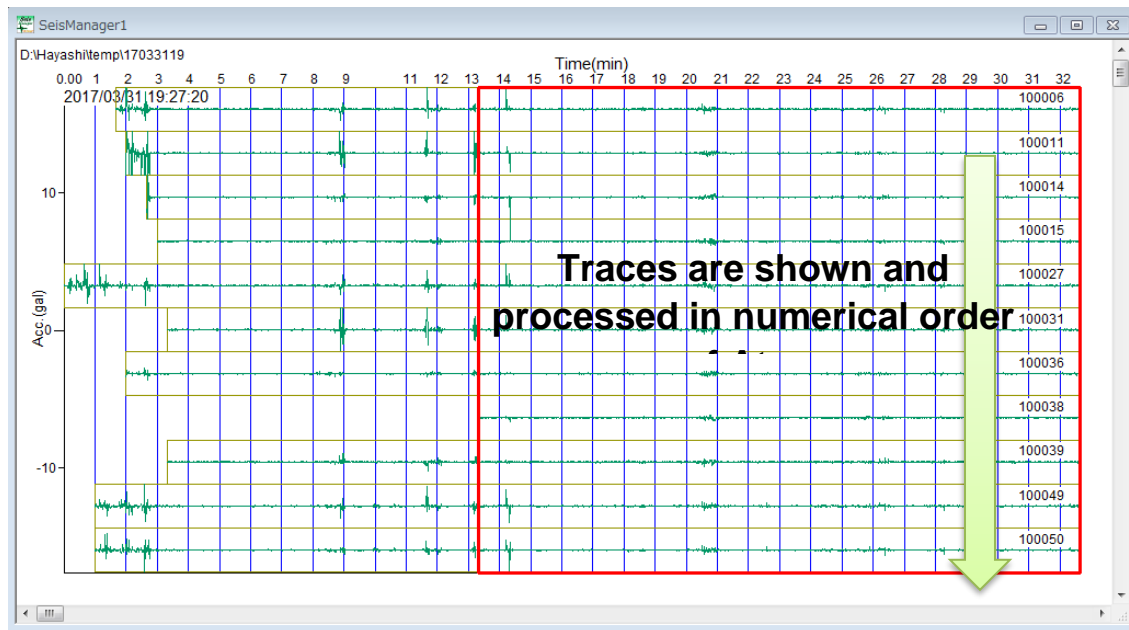


Figure 2.7 Example of data obtained from Atom units.

### 3) Data acquisition

For an S-wave velocity investigation, such as an AVS30, record between 15 to 30 minutes of ambient noise per survey. This will be sufficient for surveys with penetration depth of 30 to 100 meters. As arrays become larger, increase the recording time. Standard recording time for different size arrays is summarized in Table 2.1. Note that the standard time is just a rough indication and is dependent on site conditions. For surveys larger than 100 meters in urban areas, it is better to acquire the data at night.

Table 2.1 Array size and standard recording time

Array size or investigation depth (m)	Recording time (min.)	Remark
< 30	> 15	NA
30 ~ 100	> 30	NA
100 ~ 500	> 45	In urban areas, survey at night
500 <	> 60	In urban areas, survey at night

### 3. Typical survey configuration for multi-channel analysis of surface waves (MASW)

In multi-channel analysis of surface waves (MASW), the array size (spread length or maximum separation of receivers) must be larger than the double of investigation depth. For example, the array size must be bigger than approximately 20 m in the investigation depth of 10 m. Figures 3.1 illustrates the typical configurations.

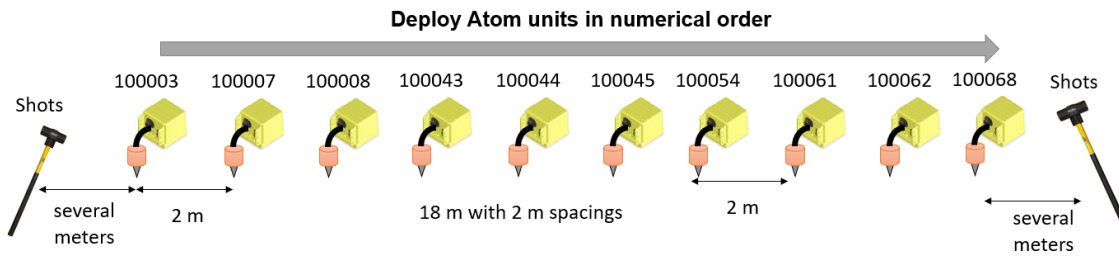


Figure 3.1 Typical source-receiver geometry for multi-channel analysis of surface waves (MASW).

#### 4. General operation of Atom

The atom generally has two modes of operation. The first is the recording mode without Wi-Fi and the second mode is downloading with Wi-Fi.

Table 4.1 Recording mode and downloading mode

Mode	Wi-Fi	Wi-Fi LED	Operation
Recording	Off	No blinking or blink once	Recording data
Downloading	On	Blink twice or three times	Downloading data Set up acquisition parameters

The behavior of Atom is different according to the presence or absence of a power button. Figure 4.1 describes the behavior of Atom with a power button. Figure 4.2 describes the behavior of Atom without a power button when turned on.

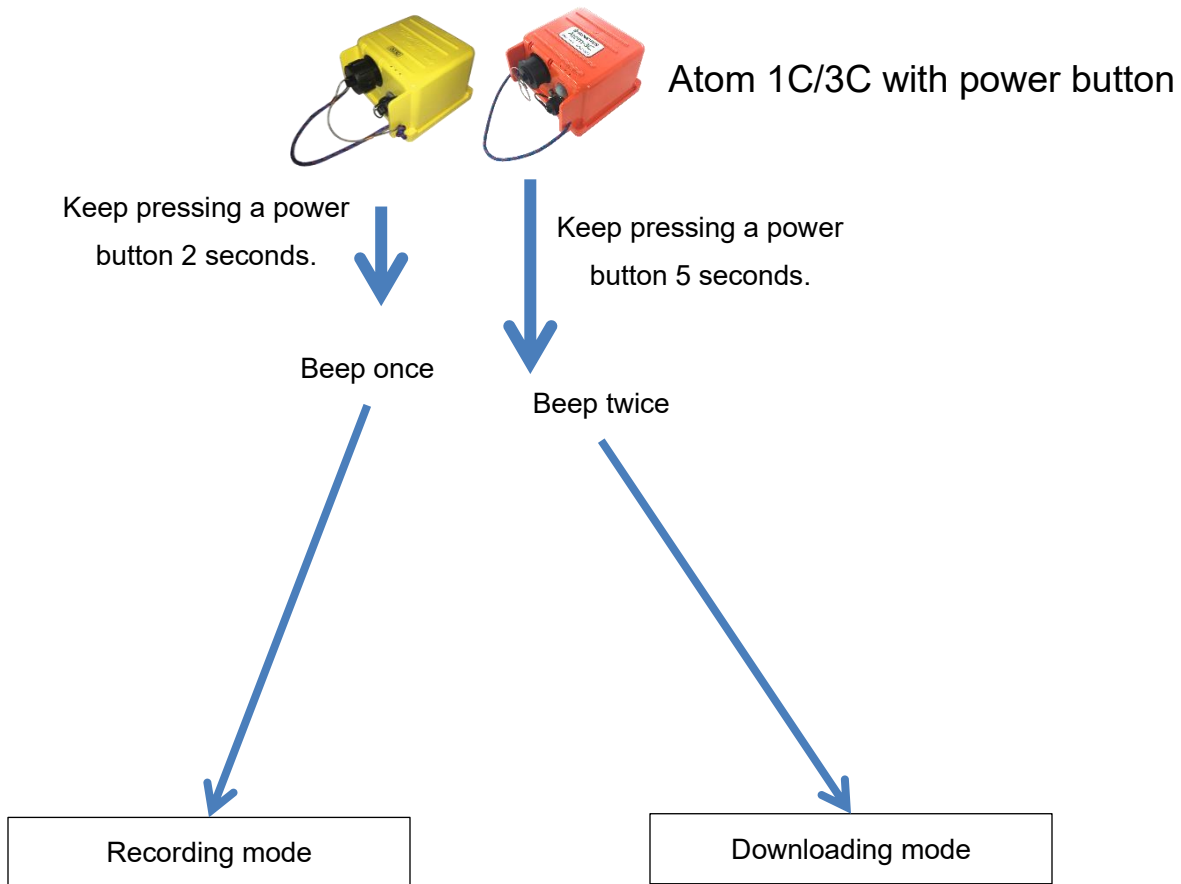


Figure 4.1 Recording mode and downloading mode for Atom with a power button.

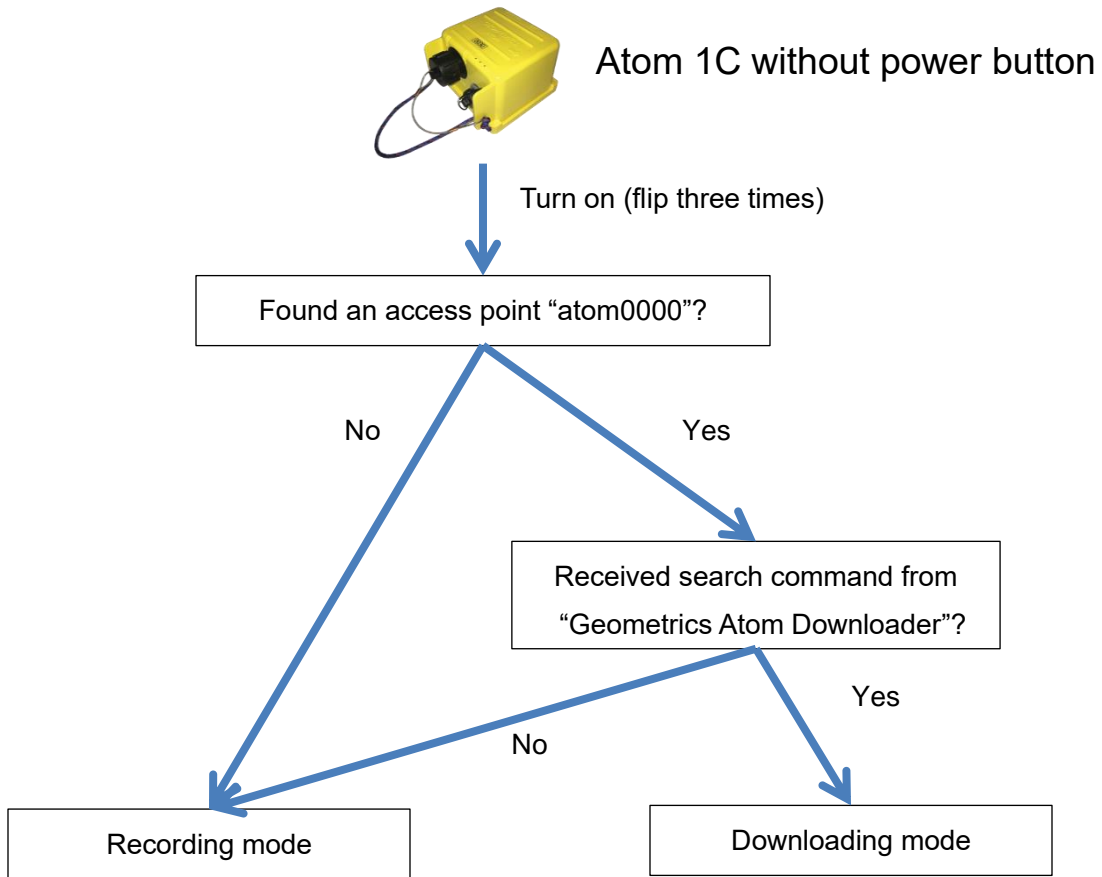


Figure 4.2 Recording mode and downloading mode for Atom without a power button.

Operations for the Atom's two modes can be summarized as follows:

A) Atom with a power button (1C/3C)

1) Recording mode

1-1 : Keep pressing a power button 2 seconds.

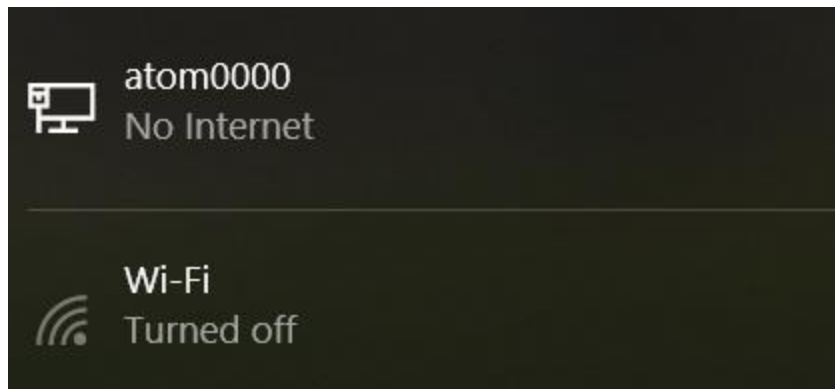
1-2 : Beep once.

2) Downloading mode

2-1 : Turn off Atom.

2-2 : Turn on access point "atom0000".

2-3 : Connect PC to the access point "atom0000" by LAN cable (recommended) or Wi-Fi.



2-3 : Launch Geometrics Atom Downloader



2-4 : Keep pressing a power button 5 seconds.

2-5 : Beep twice.

B) Atom without a power button (1C)

1) Recording mode

1-1 : Turn off Atom.

1-2 : Turn off access point "atom0000".

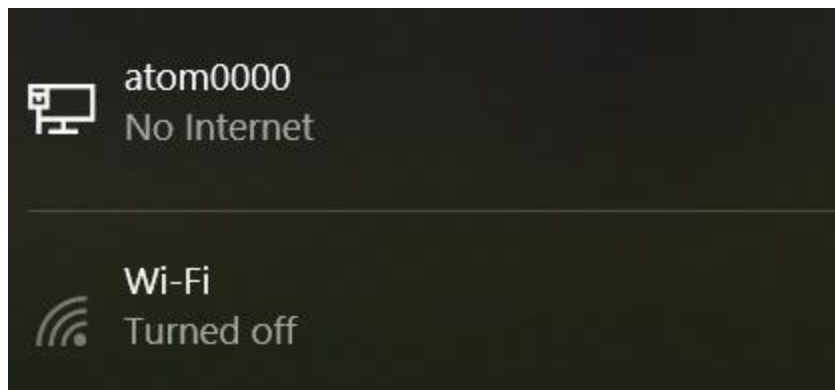
1-3 : Turn on Atom.

2) Downloading mode

2-1 : Turn off Atom.

2-2 : Turn on access point "atom0000".

2-3 : Connect PC to the access point "atom0000" by LAN cable (recommended) or Wi-Fi.



2-4 : Launch Geometrics Atom Downloader



2-5 : Turn on Atom.

## 5. LED Colors on Atom

Atom has three LEDs as shown in Figure 5.1. The use of LEDs is described in following sections.



Figure 5.1 Color LEDs of Atoms.



6. Start and stop recording

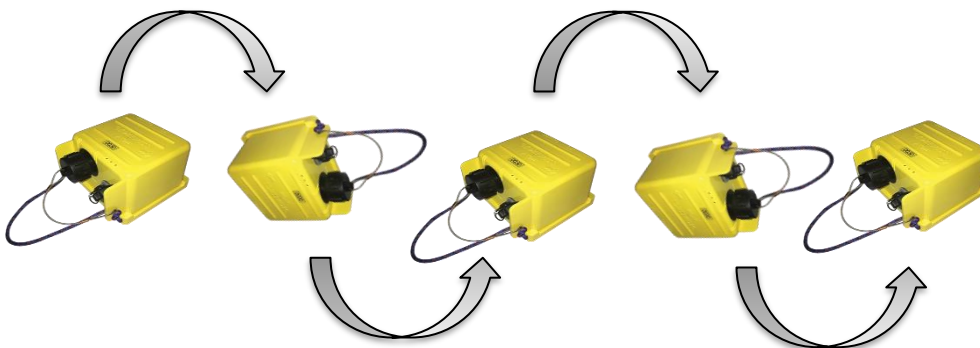
To begin recording, keep pressing a power button 2 seconds if an Atom has a power button.



Unit Beeps once when the Atom is turned on or off.

Figure 6.1 Turning on and off of Atom units with a power button.

To begin recording, turn each unit over slowly three or four times if an Atom does not have a power button.



Unit Beeps once when the Atom is turned on or off.

Figure 6.2 Turning on and off of Atom units without a power button.

Atom can be turned off via the Wi-Fi connection (8. Confirm or set up the Atom's acquisition parameters via Wi-Fi). To distinguish measurements, turn off and on one unit at the beginning or ending of the measurements.

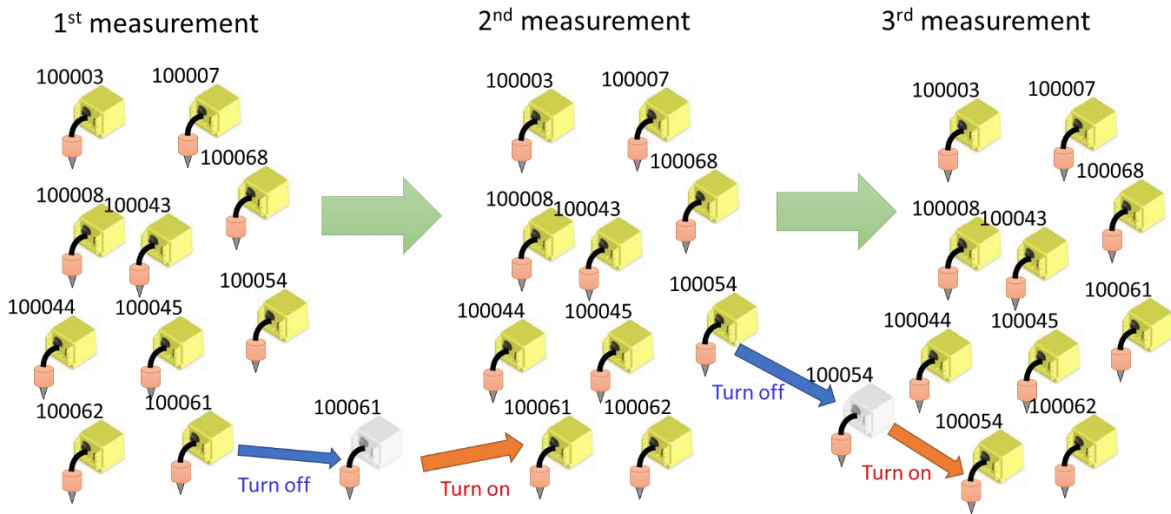


Figure 6.3 Turning on and off of Atom units between measurements.

When power is turned on, the LED indicator lights show the following:

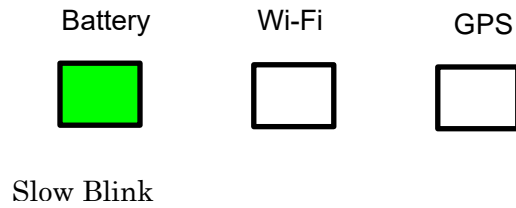


Figure 6.4 LEDs when Atom is turned on.

When GPS is locked:

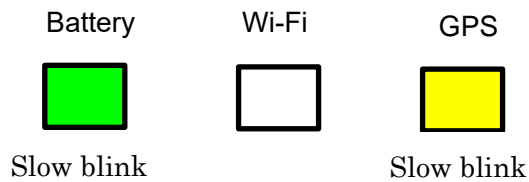


Figure 6.5 LEDs when Atom is locked on the GPS.

After recording begins: (recording automatically starts several tens of seconds after GPS is locked).

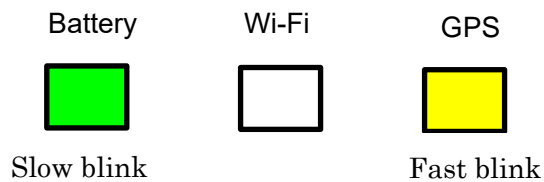


Figure 6.6 LEDs when Atom is recording data.

## 7. Battery status

The battery lasts approximately 60 to 70 hours from a full charge.

Battery status when data is being recorded (full battery).

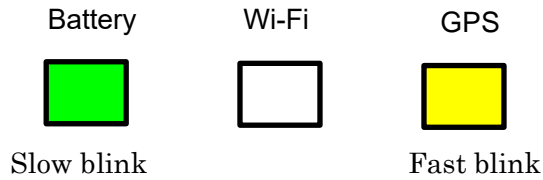


Figure 7.1 LEDs while data is being recorded (full battery).

Battery status when data is being recorded (less battery).

As the battery charge decreases, the green and red lights alternate. It usually takes more than 40 hours of use after a full charge for the red LED to start blinking.

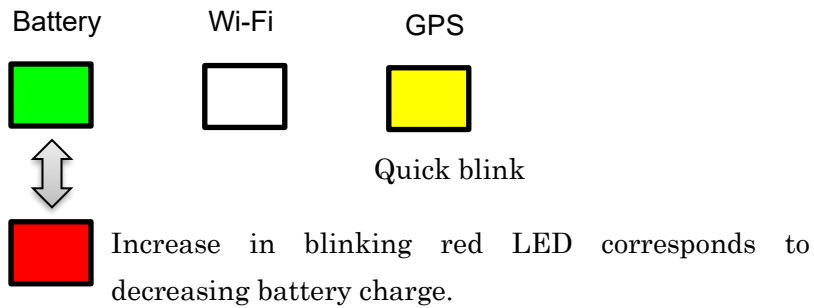


Figure 7.2 LEDs while data is being recorded

Battery status when data is being recorded with a very low battery



Figure 7.3 LEDs when data is being recorded with a very low battery

## 8. Confirm or set up the Atom's acquisition parameters via Wi-Fi

Use Geometrics Atom Downloader confirm or set up Atom's Acquisition parameters. The parameters can be also confirmed or set up using SPACPlus via Wi-Fi or USB. See appendix A and C for the more details about SPACPlus.

- 1) Turn off and stop recording for all Atom units.
- 2) Plug in a Wi-Fi access point to your PC.
- 3) Connect your PC to "atom0000" by LAN cable (recommended) or Wi-Fi. Do not connect both LAN cable and Wi-Fi to the access point.

4) Launch Geometrics Atom Downloader



5) Display shown below appears on the window. Make sure one or two networks were found.

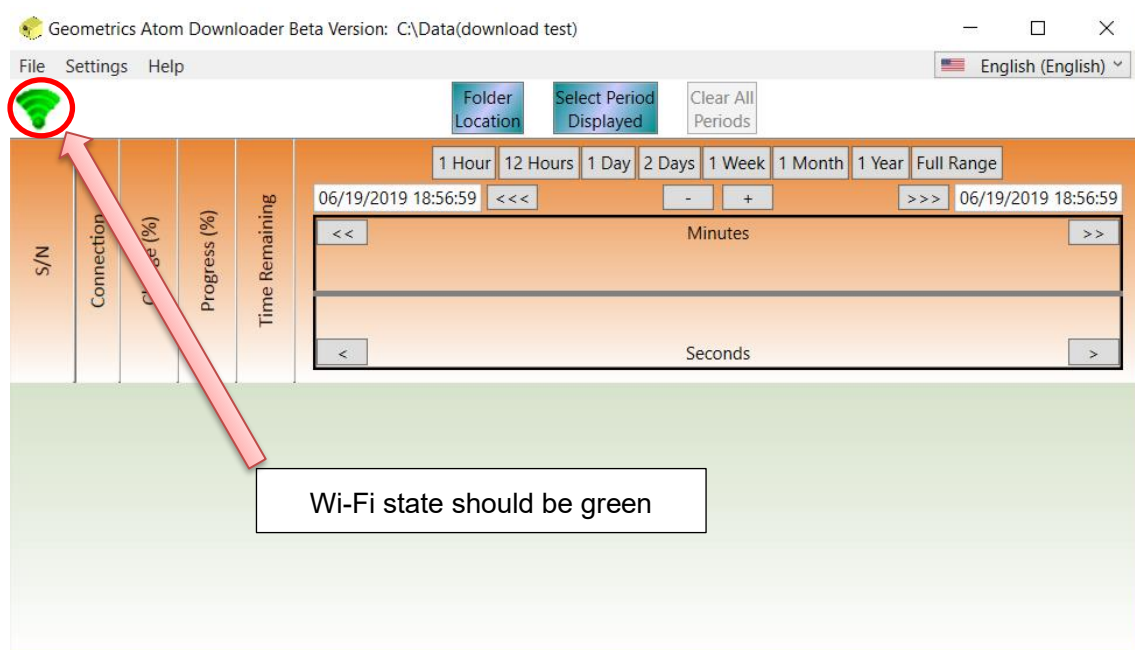


Figure 8.1 Display of Geometrics Atom Downloader when no Atom was found.

6) Turn on all Atom units.

The Atom units automatically being download mode (Figure 8.2) when they locate the access point “atom0000”. In this mode, data recording does not start.

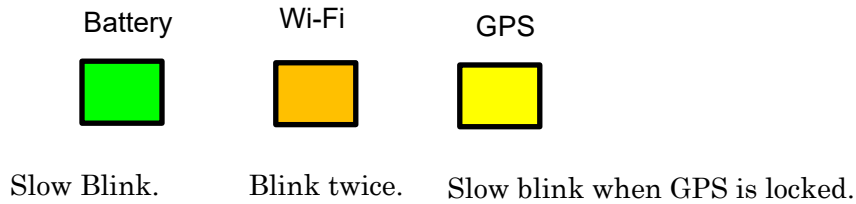


Figure 8.2 LEDs when Atom is ready to be controlled from

The Geometrics Atom Downloader shows the number of Atom AUs found. It also shows the ID and battery status.

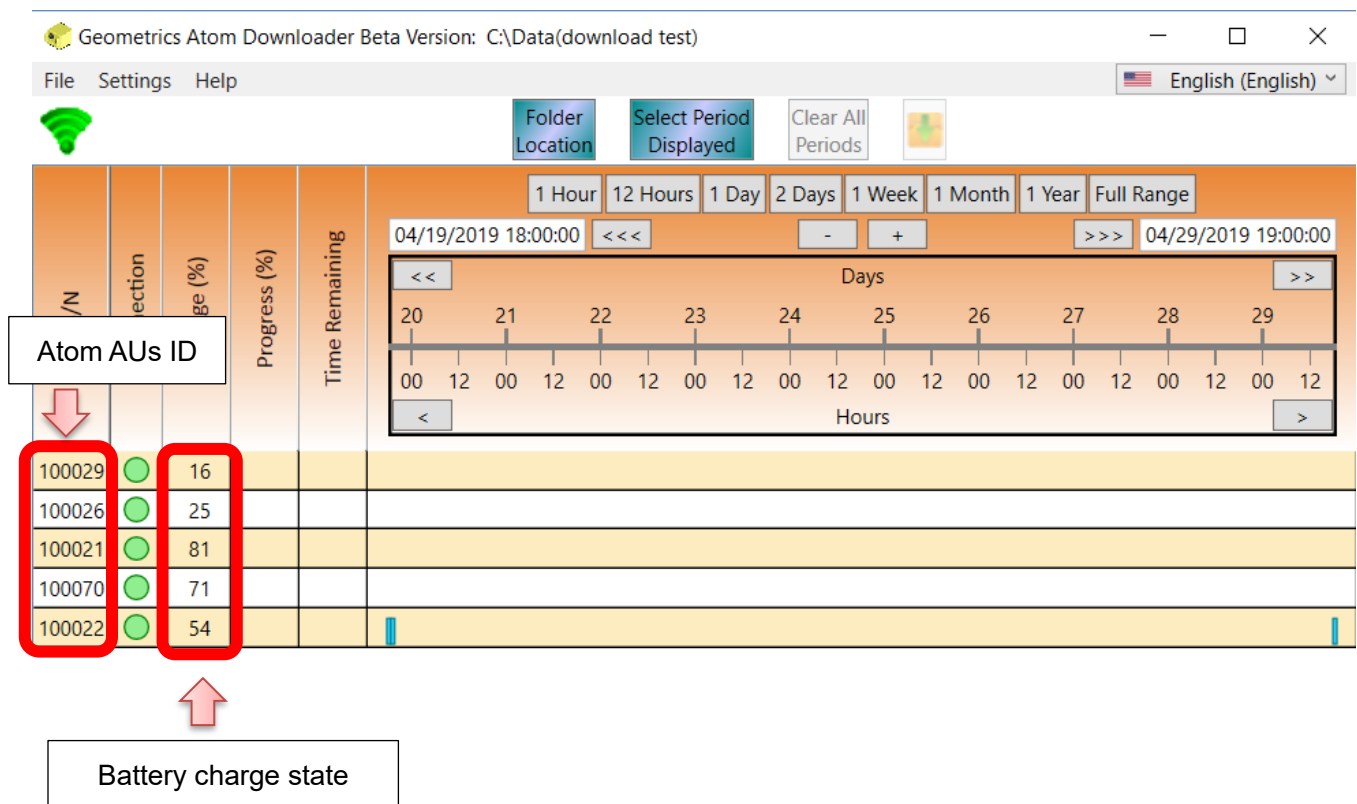


Figure 8.3 Display of the Geometrics Atom Downloader when 5 Atom AUs were found.

7) Click a right button of a mouse and show sub menus to confirm or set up acquisition parameter of Atom AUs. Use the menu to format SD card in Atom AUS or turn off Atom AUs as well.

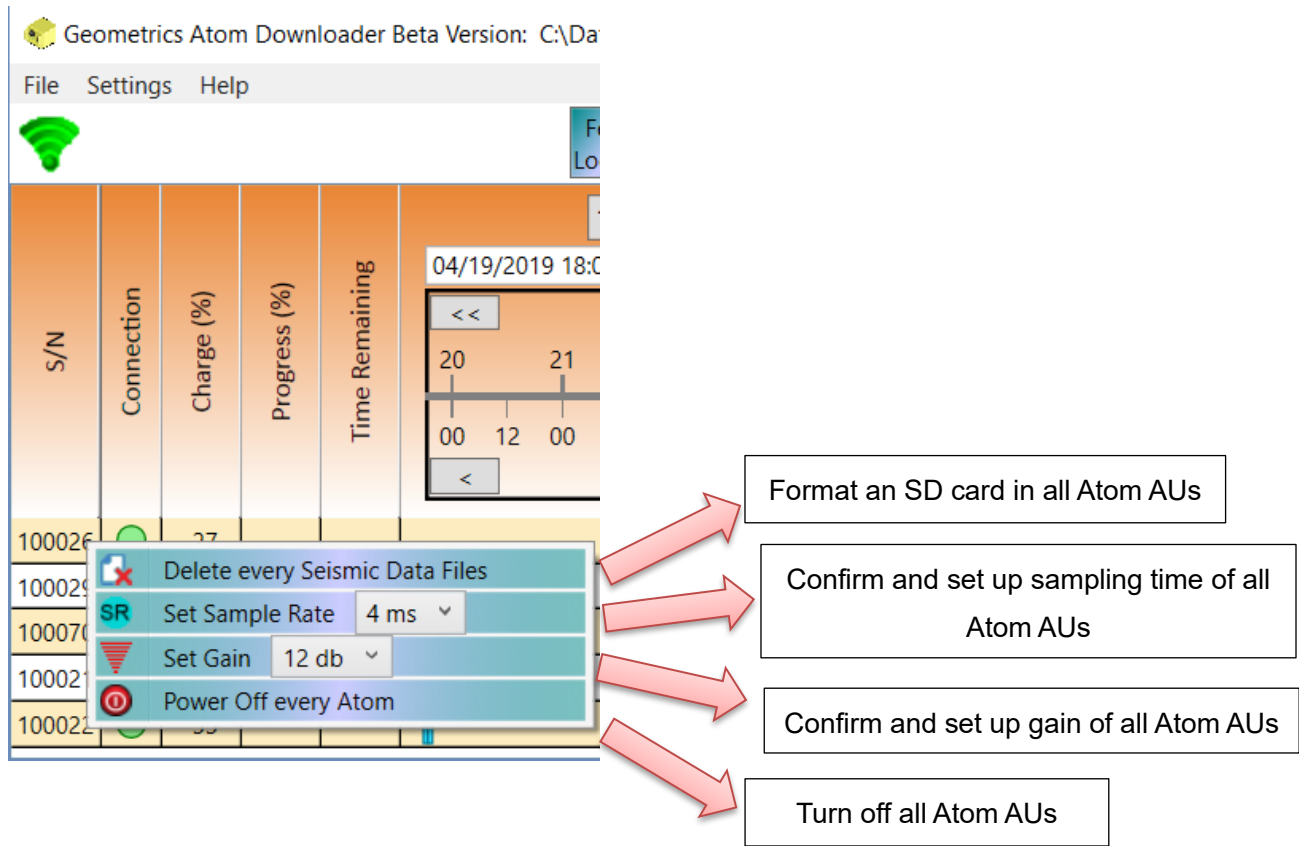


Figure 8.4 Click a right button of a mouse to confirm or set up acquisition parameter.

8) To confirm more detailed setting of Atom AUs, switch the Atom Downloader to the advanced mode. Select [Settings]>>[Restart Atom Downloader in Advance Mode].

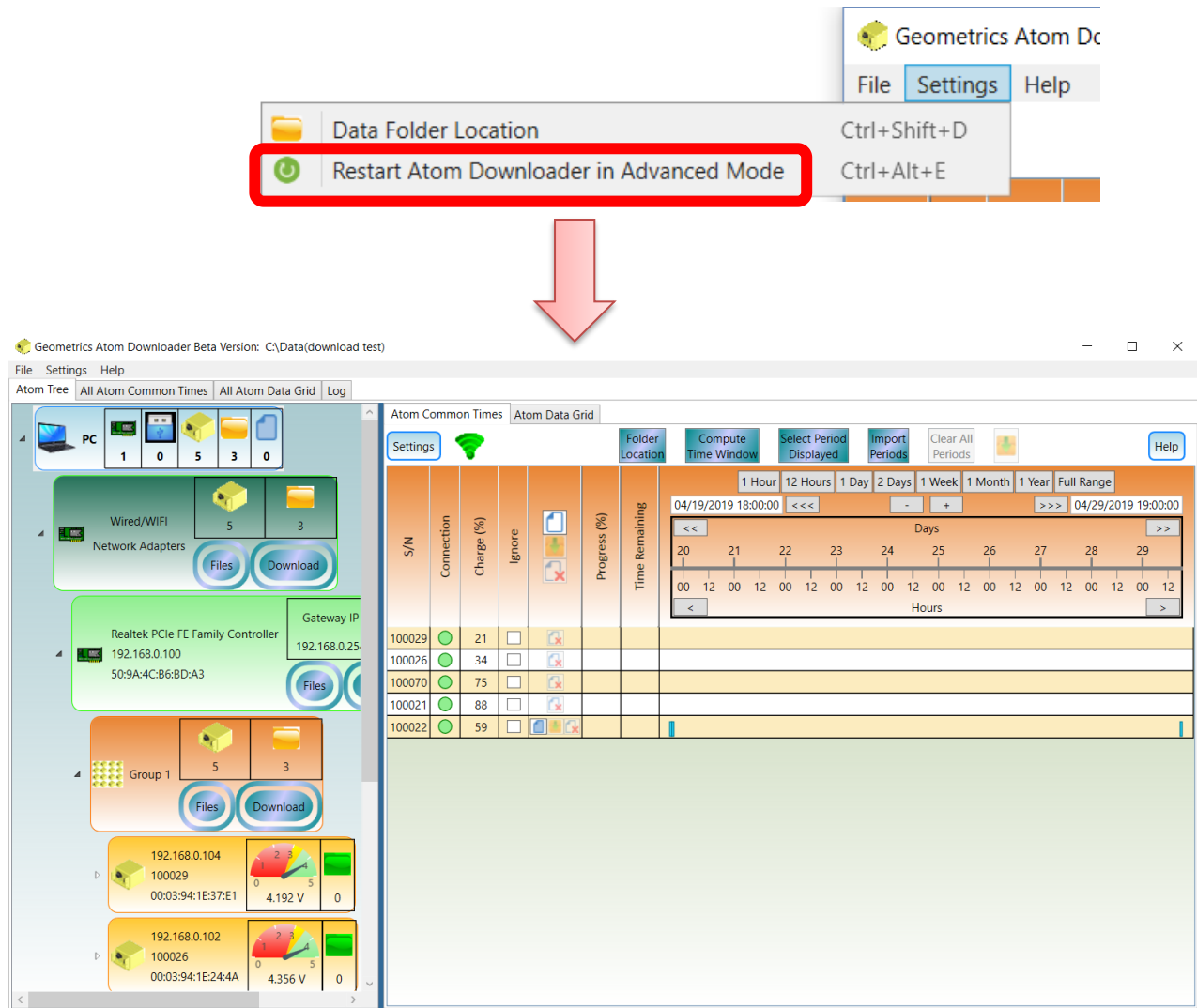


Figure 8.5 Switch the Atom Downloader to the advanced mode.



9) Click [All Atoms Data Grid] tab on the left side window of the Downloader, you will see each Atom units' ID, IP address, battery voltage, battery charge state, sampling time and pre-amp gain etc. Note that the default setting of passive surface wave methods is 4.00 ms and 12.0 db,

Geometrics Atom Downloader: C:\Data(2018.07.08)

File Settings Help

Atoms Tree All Atoms Common Times All Atoms Data Grid Log

#	S/N	IP	Mac Address	Voltage	Current	Charge	Sample Rate	Preamplifier Gain
1	100047	192.168.0.108	00:03:94:1E:37:D4	3.634 V	-171 mA	49 %	4 ms	12 dB
2	100042	192.168.0.106	D0:E7:82:B4:58:CB	3.656 V	-256 mA	47 %	4 ms	12 dB
3	100072	192.168.0.105	D0:E7:82:B4:52:81	3.652 V	-256 mA	55 %	4 ms	12 dB
4	100056	192.168.0.104	D0:E7:82:B4:40:E7	3.645 V	-264 mA	49 %	4 ms	12 dB
5	100020	192.168.0.103	D0:E7:82:B4:43:B9	3.530 V	-259 mA	48 %	4 ms	12 dB
6	100049	192.168.0.102	00:50:43:02:FE:01	3.644 V	-258 mA	38 %	4 ms	12 dB
7	100016	192.168.0.107	00:03:94:1E:37:D2	3.693 V	-180 mA	59 %	4 ms	12 dB
8	100051	192.168.0.101	00:03:94:1E:37:DD	3.697 V	-174 mA	49 %	4 ms	12 dB
9	100074	192.168.0.100	00:03:94:1E:37:CC	3.718 V	-171 mA	58 %	4 ms	12 dB
10	100065	192.168.0.109	00:03:94:21:35:03	3.687 V	-167 mA	57 %	4 ms	12 dB

Figure 8.6 Example of Atoms Data Grid showing the acquisition parameters and conditions of each Atom AU (Advanced Mode).

10) To change the Atom unit's acquisition parameters, click a right button of a mouse in group (to change all AUs in group) or in each Atom (to change individual AU) to show sub menus.

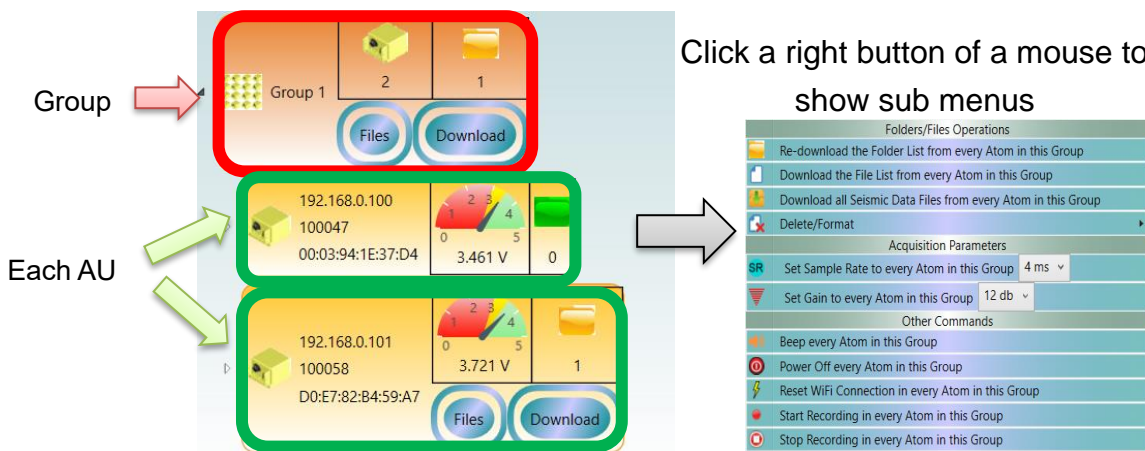


Figure 8.7 Click group or individual Atom to change acquisition parameters (Advanced Mode).

9) Select sampling time and preamp gain in a dialog box.

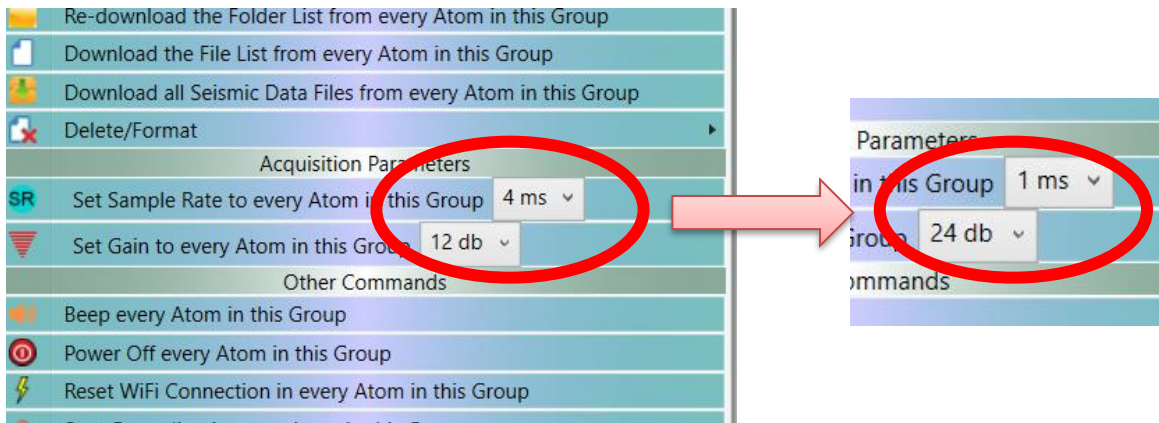


Figure 8.8 Change sampling time and/or preamp gain (Advanced Mode).

10) Confirm changes to the acquisition parameters, in the Atom Data Grid.

Note that if the MC version is smaller than 1.39, acquisition parameter may not be changed by Atom Downloader. Use SPACPlus to change the acquisition parameter if the Atom Downloader did not work. See Appendix A for the details.

Settings

Acquisition parameters

#	S/N	IP	Mac Address	Voltage	Current	Charge	Sample Rate	Preamp Gain	MC Version
1	100047	192.168.0.100	00:03:94:1E:37:D4	3.518 V	-175 mA	56 %	1 ms	24 db	1.41
2	100065	192.168.0.103	00:03:94:21:35:03	3.757 V	-175 mA	54 %	1 ms	24 db	1.41
3	100058	192.168.0.101	D0:E7:82:B4:59:A7	3.703 V	-268 mA	55 %	1 ms	24 db	1.41
4	100003	192.168.0.104	D0:E7:82:B4:51:C7	3.805 V	-263 mA	46 %	1 ms	24 db	1.45

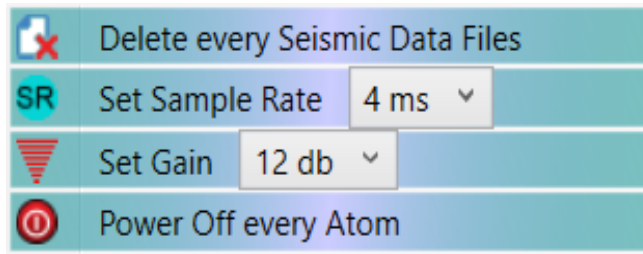
MC version

Figure 8.9 Acquisition parameters shown in Atoms Data Grid (Advanced Mode).

## 9. Use Wi-Fi to turn off all Atom units

1) To turn off all Atom units, show a sub menu by clicking a right button of a mouse (either on group or on each AU in the Advanced Mode). Select [Power off every Atom] in the Simple Mode or [Power off every Atoms in the Group] of [Power off this Atom] in the Advanced Mode to turn off Atom units.

### A) Simple Mode (default)



### B) Advanced Mode



Figure 9.1 Sub menu to turn off Atom units.

2) Confirm all boxes were turned off.

## 10. Battery charging

Charging begins when the Atom is connected via charging cable to the USB connector.

Battery charging status (during charging).

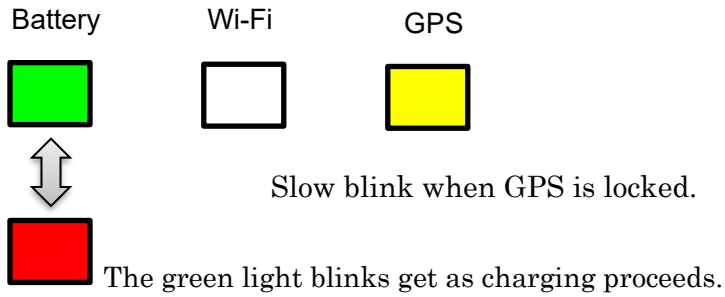


Figure 10.1 LEDs when Atom is being charged.

Battery charging status (charging complete).

Charging takes approximately 10 hours from fully discharged battery.

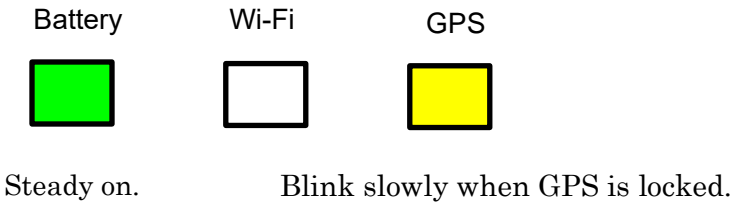


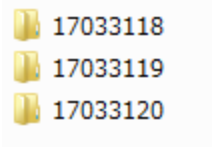
Figure 10.2 LEDs when battery fully charged.

## 11. Data format

An Atom AU save recorded waveform data to an SD card as a binary file every minute. The format of the raw waveform data file is described in Appendix D. It is the almost same as MT-Neo files. The extension is “.atm” instead of “.mtn”. The files can be opened by Pickwin.

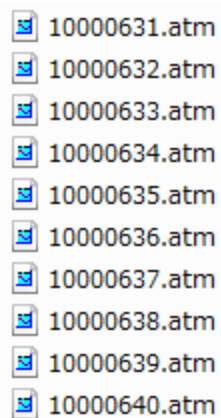
### Folder for each hour.

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 31<sup>st</sup>, 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.



## 12. Data download

There are three methods for retrieving data from the 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.

[http://seisimager.esy.es/atom/utility/CDM\\_2\\_08\\_30.zip](http://seisimager.esy.es/atom/utility/CDM_2_08_30.zip)

See Appendix B for the details.

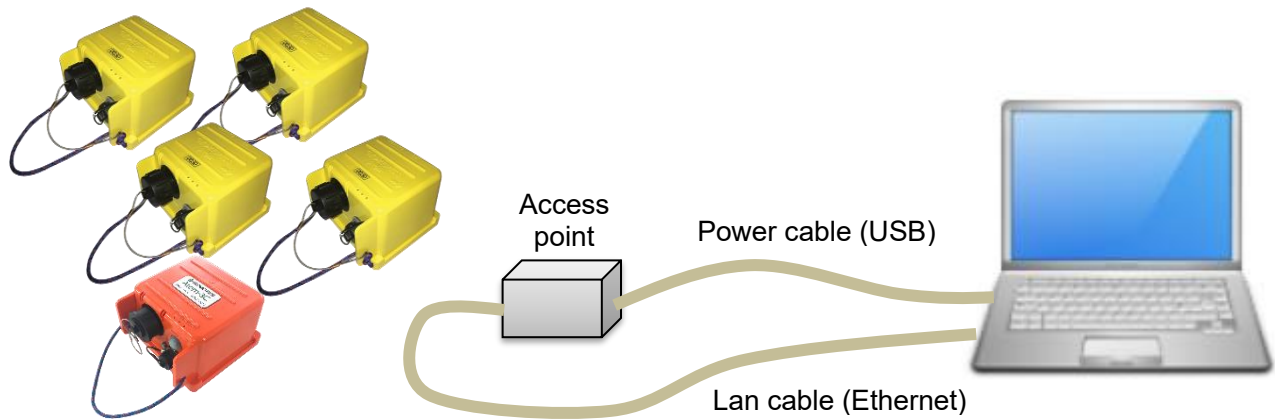
### *C) Wi-Fi*

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). Note that the download using SPACPlus is not officially supported and the use of Geometrics Atom Downloader is strongly recommended. Follow the procedure shown below to download waveform data using the Geometrics Atom Downloader.

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.



Put Atom AUs within several meters from an access point.

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

Wi-Fi is turned off.

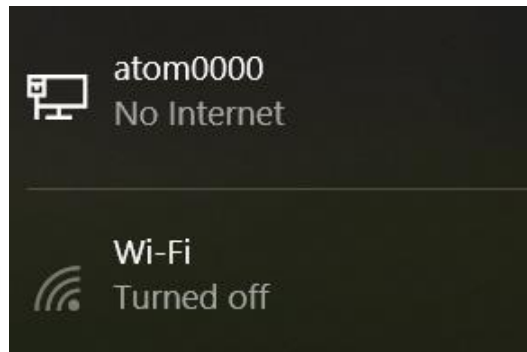


Figure 12.1 Connecting access point to PC by Lan-cable.

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 Wi-Fi state is green.

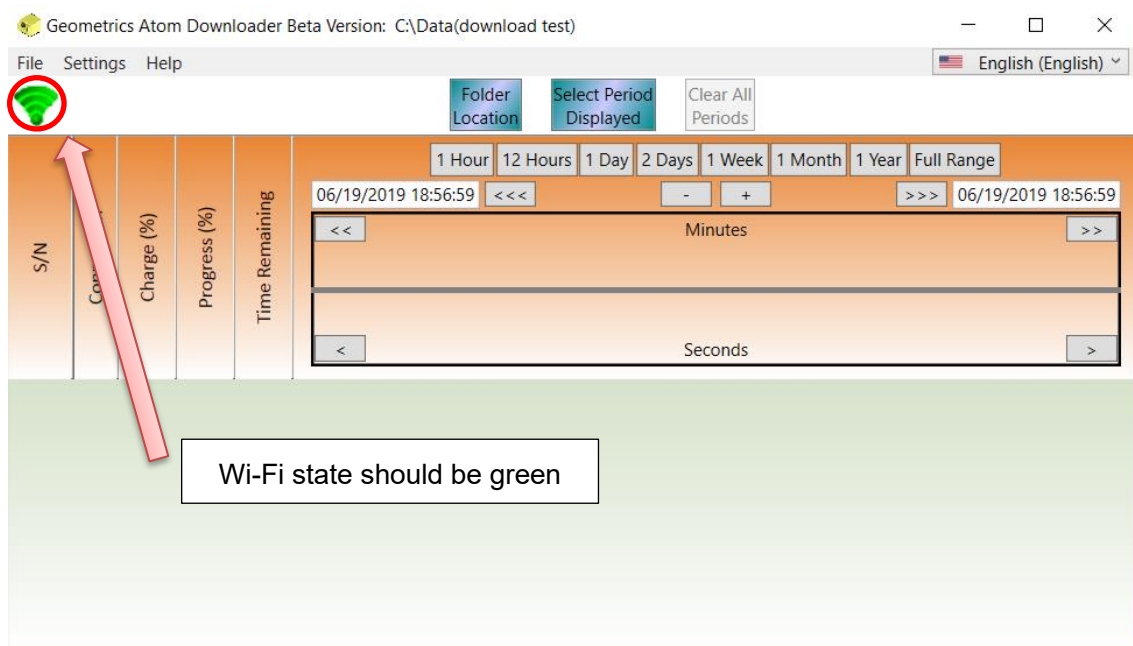


Figure 12.2 Display of Geometrics Atom Downloader when no Atom was found.

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.

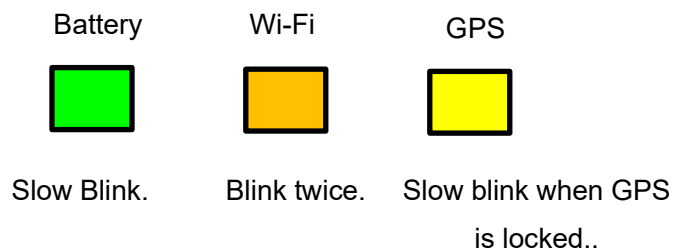
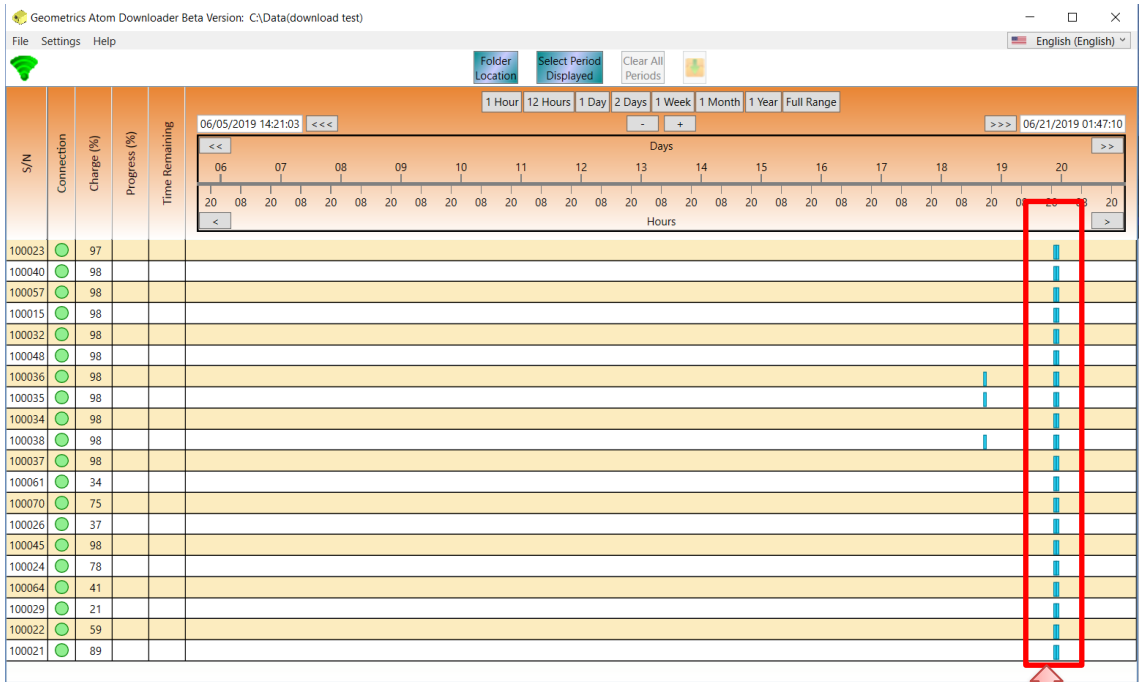


Figure 12.3 LEDs when Atom is ready to download





9) Select a time range from which data will be downloaded by a mouse or clicking buttons [1 hour], [12 hours], [12 hours], [1 day] etc. on the top of the window.



Select by a mouse.

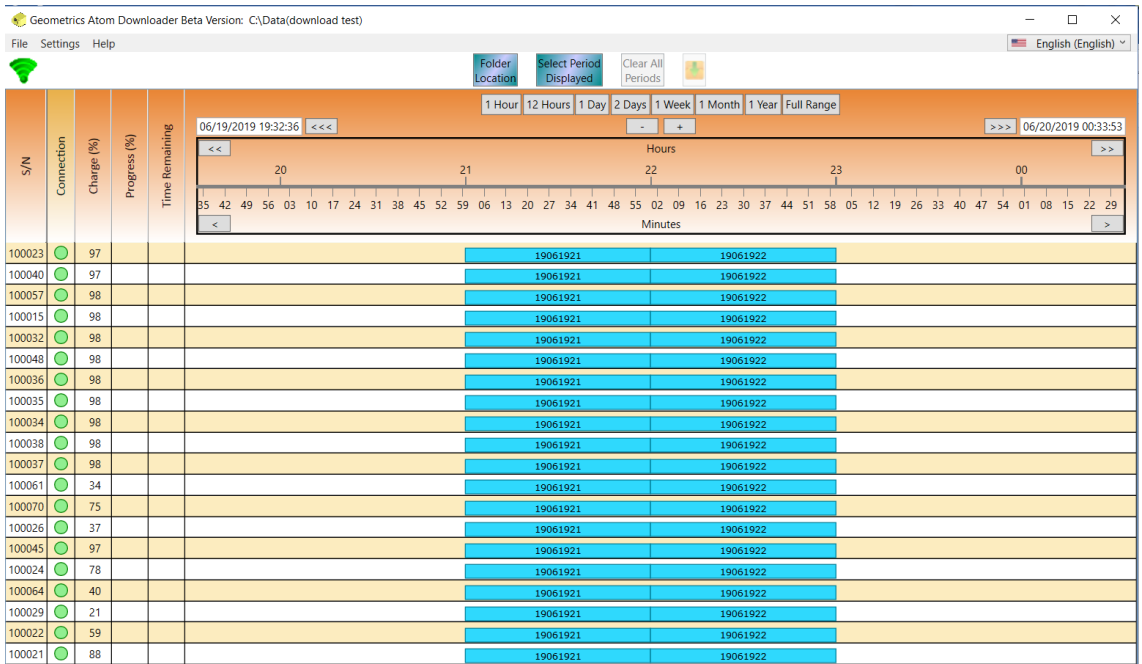



Figure 12.5 Selection of data to be downloaded.

10) Click  to select a time period to be downloaded.

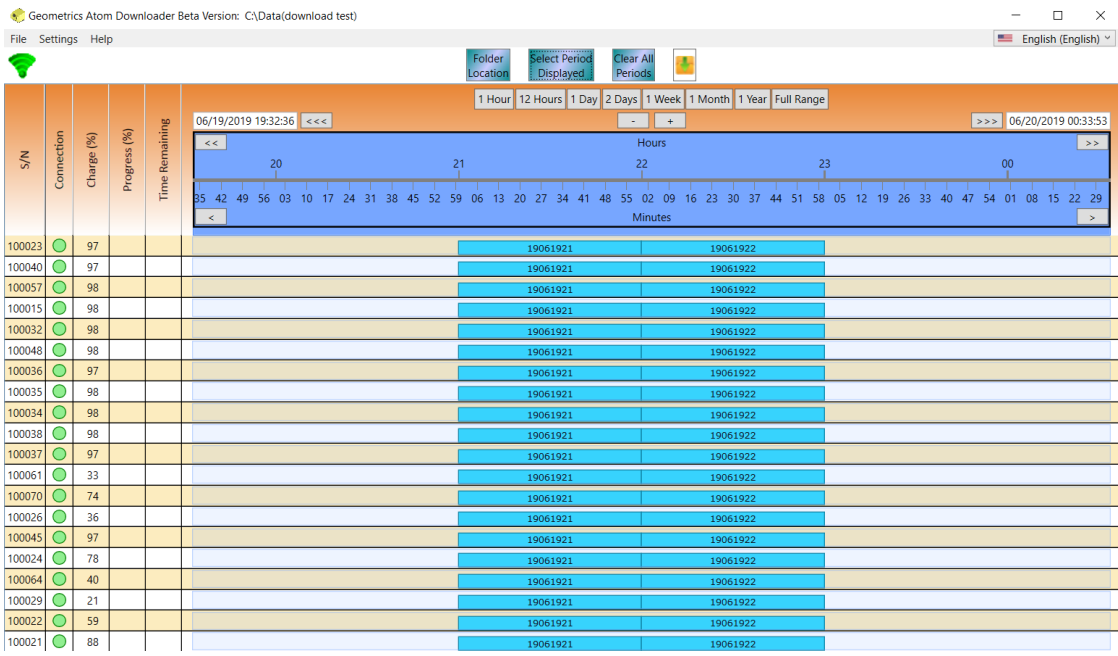



Figure 12.6 Selection of data to be downloaded.

11) Click  to start downloading the selected time period.

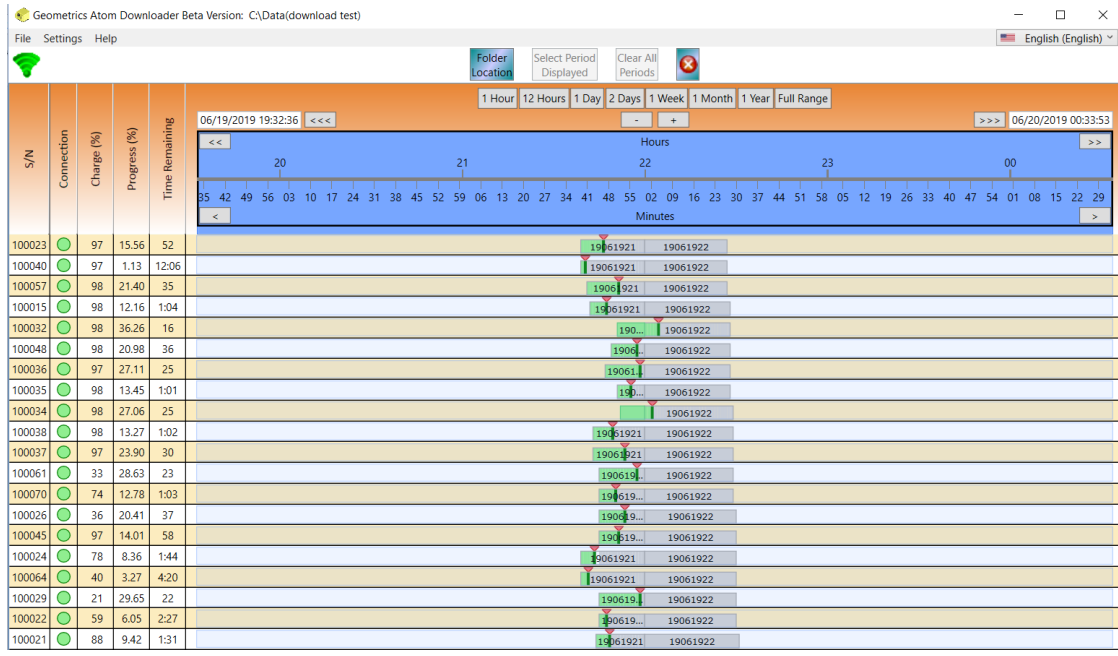


Figure 12.7 Example of display middle of download.

12) [Progress] comes to 100 % and [Time remaining] comes to blank at the end of download.

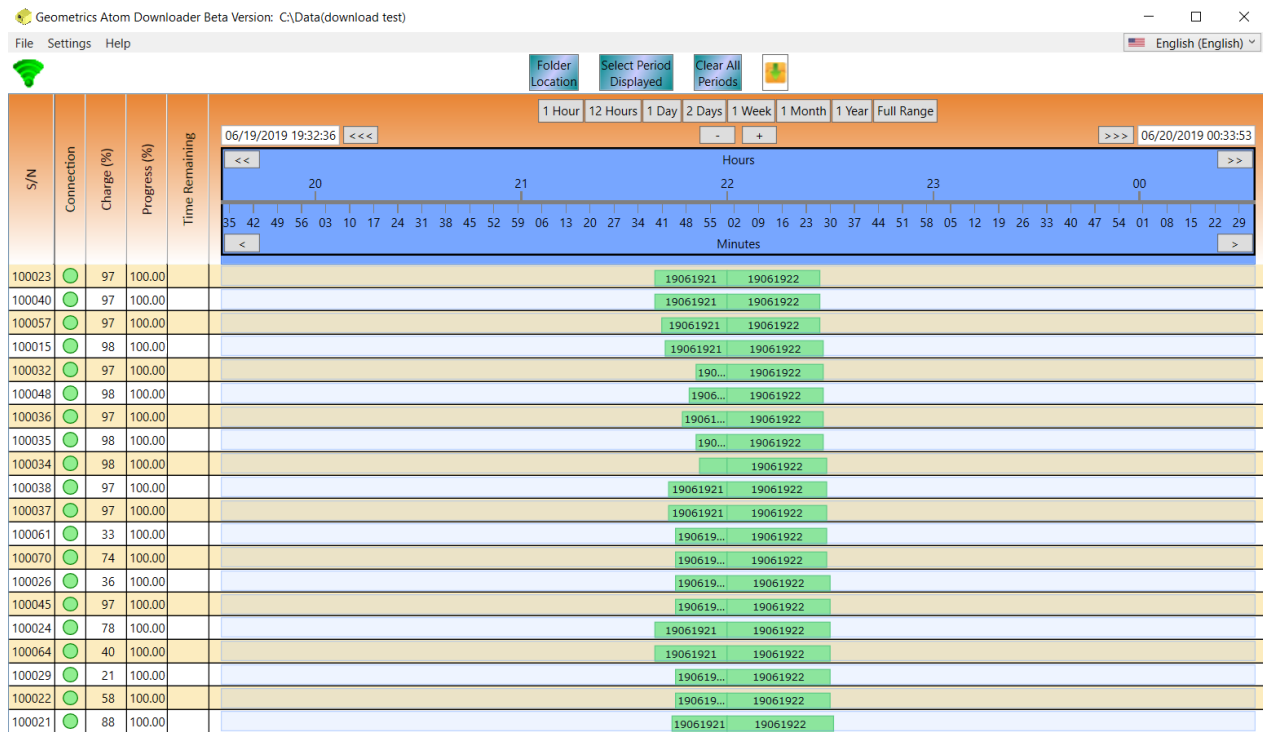


Figure 12.8 Example of display end of download.

13) More download options are available in the Advanced Mode. Click [Compute Time Window] to download common time windows (blocks) or [Select Period Displayed] to download all data displayed in the window.

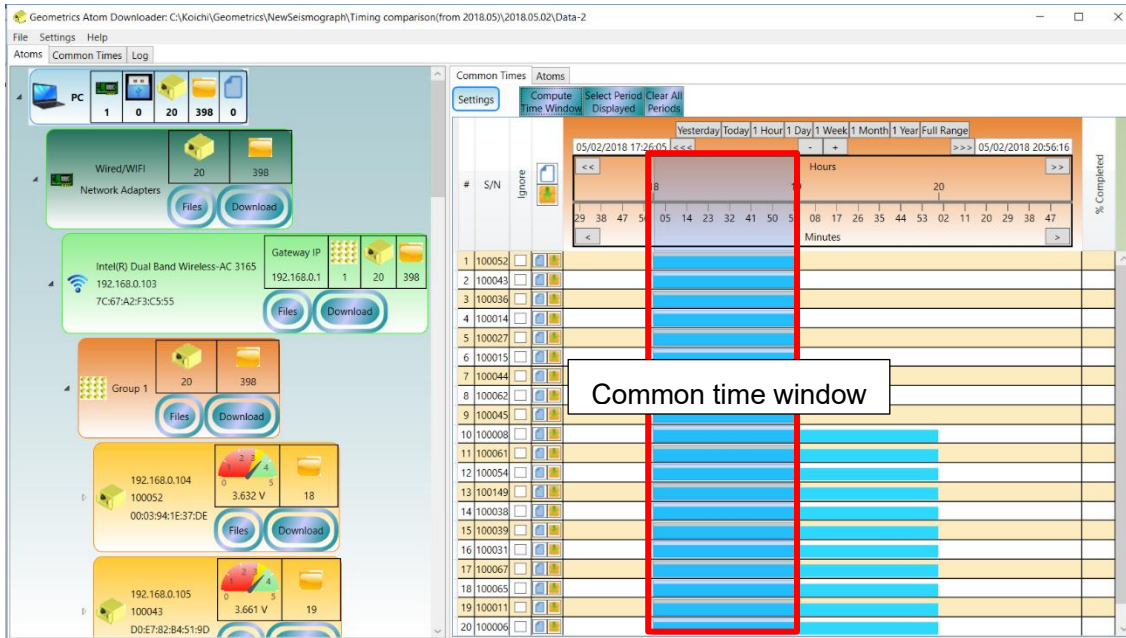


Figure 12.9 Selection of data to be downloaded (Advanced Mode).

14) Click a right button of mouse in time scale above the Atom data grid to show sub menu.

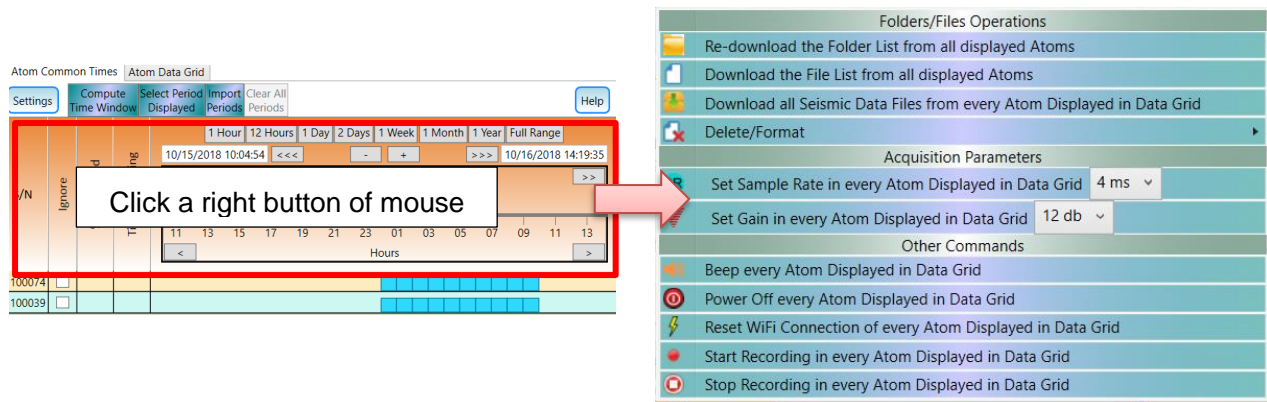



Figure 12.10 Click a right button of mouse to show sub menu (Advanced Mode).

15) Select  in the sub menu to start download data.

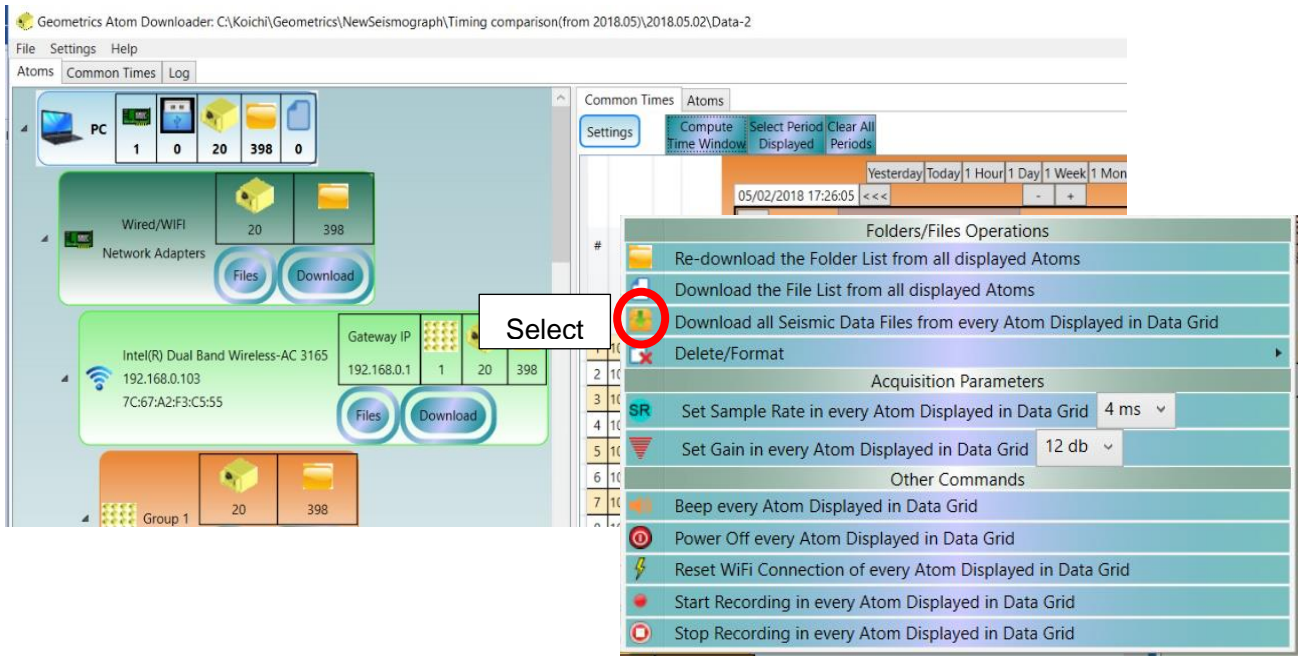



Figure 12.11 Select  to start download data (Advanced Mode).



16) 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. Downloaded data has a folder and file structure shown in 11. **Data format.**

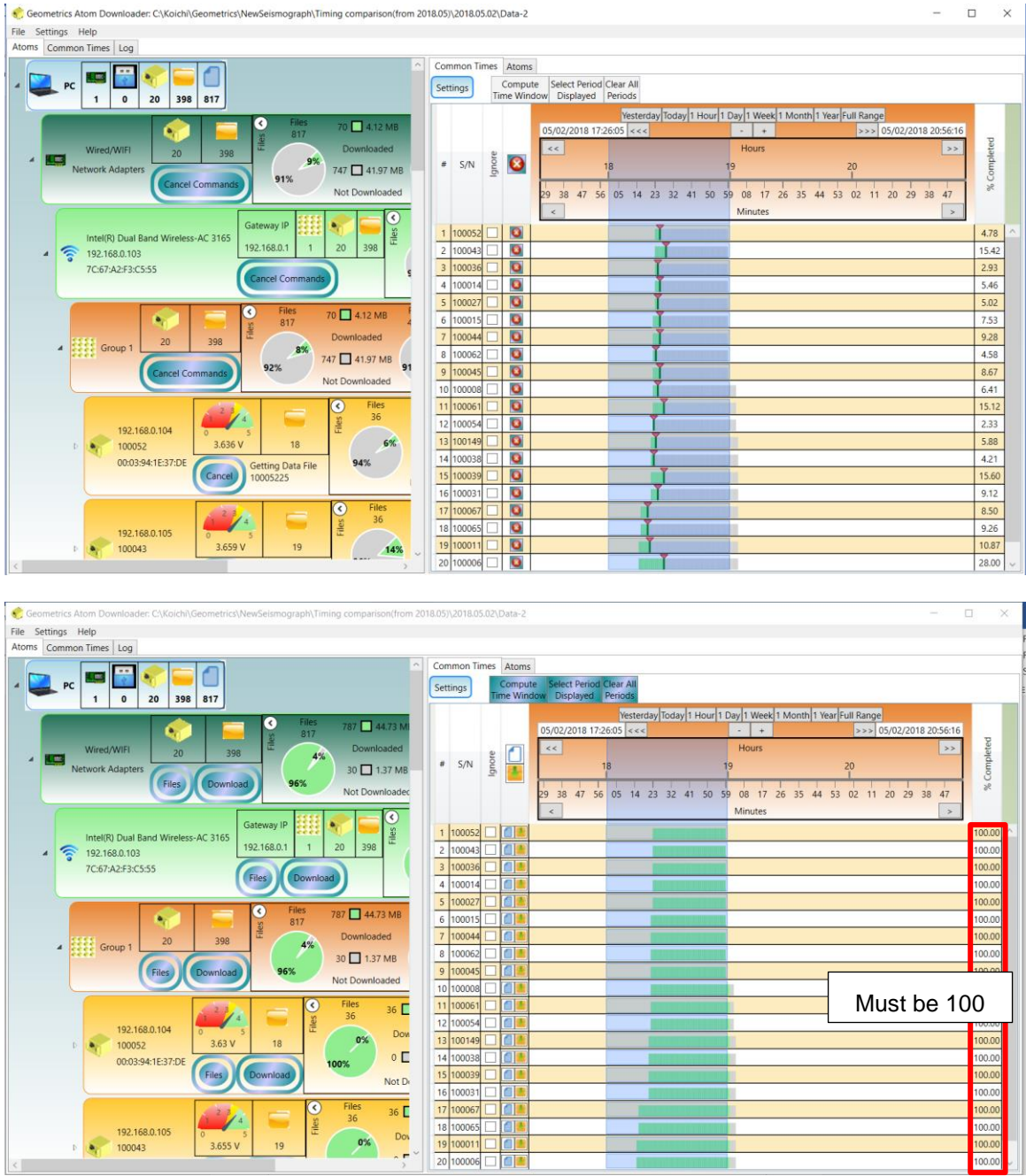

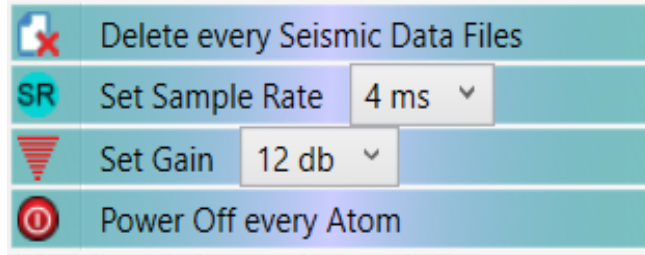


Figure 12.12 Example of display middle (top) and end of download (bottom) in Advanced Mode.

### 13. Format SD card and delete data directory

1) To delete all data in Atom AUs or format SD card in the AUs, show sub menus (in Atom Tree Window (left hand side) in Advanced Mode) and select .

A) Simple Mode (default)



B) Advanced Mode

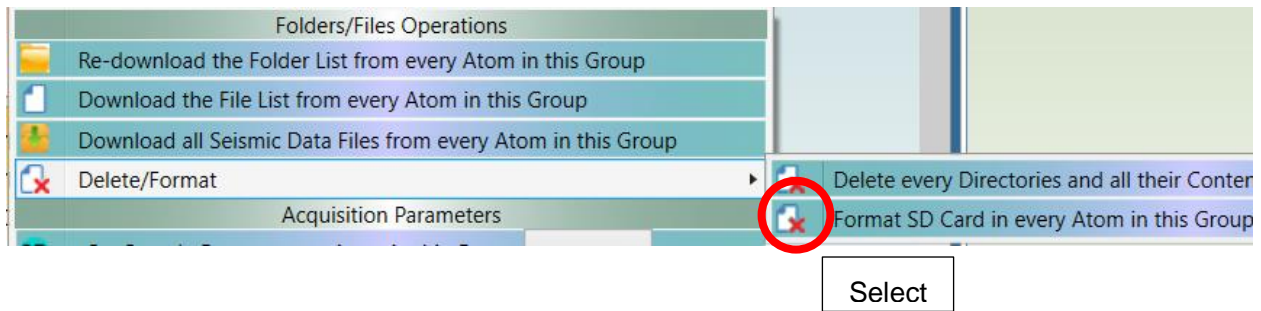



Figure 13.1 Select  to delete data directories.

2) Waveform data in Atom AUs can be deleted per directory. To delete directory, select the data in the Atom Common Times Window (right hand side) just like data download and show sub menus and select .

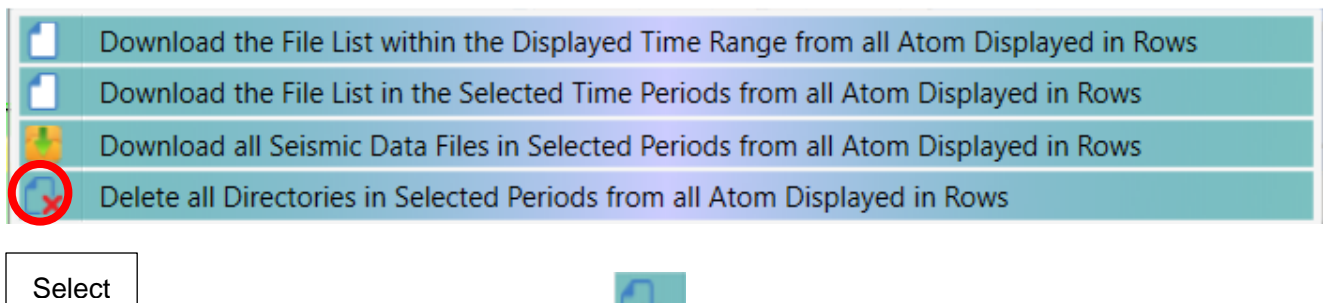



Figure 13.2 Select  to delete data directories.



## 14. 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. The standard data exporting procedure is summarized below.

1) Click  or select [File]>>[Open folder] to select a folder to which waveform data were downloaded. After selecting the folder, the waveform data appears as shown below. Waveform traces appear in order from lower to higher Atom ID numbers. Data processing may be resumed for previously downloaded by selecting File]>>[Open folder used the last time]. An area surrounded by a red rectangle is a “Common Time Block (CTB)” during which all Atom units were recording data. Select a CTB to be processed, using left and right arrows if several CTBs are shown.

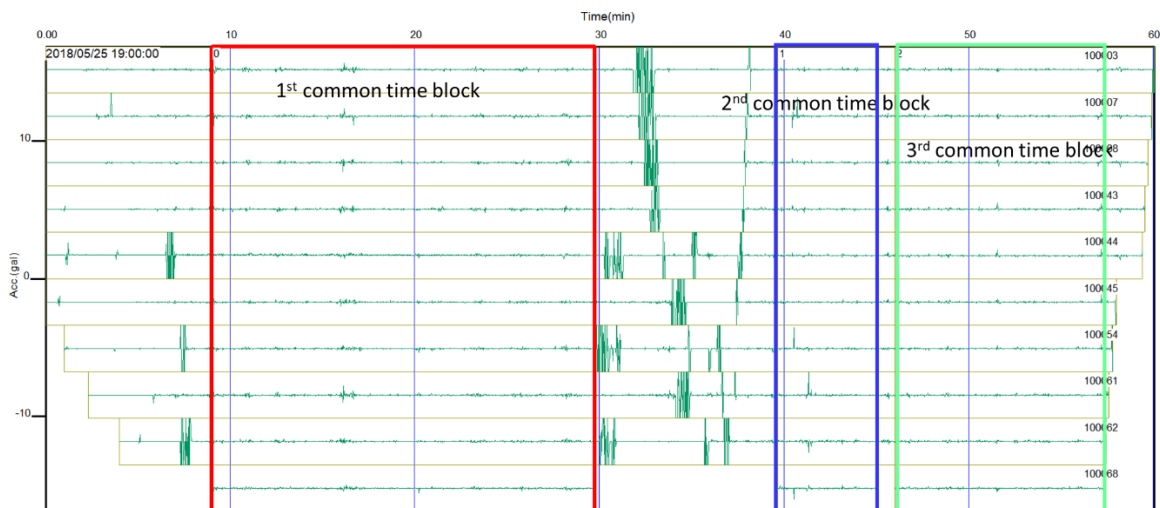


Figure 14.1 Selecting the Common Time Block (CTB)..

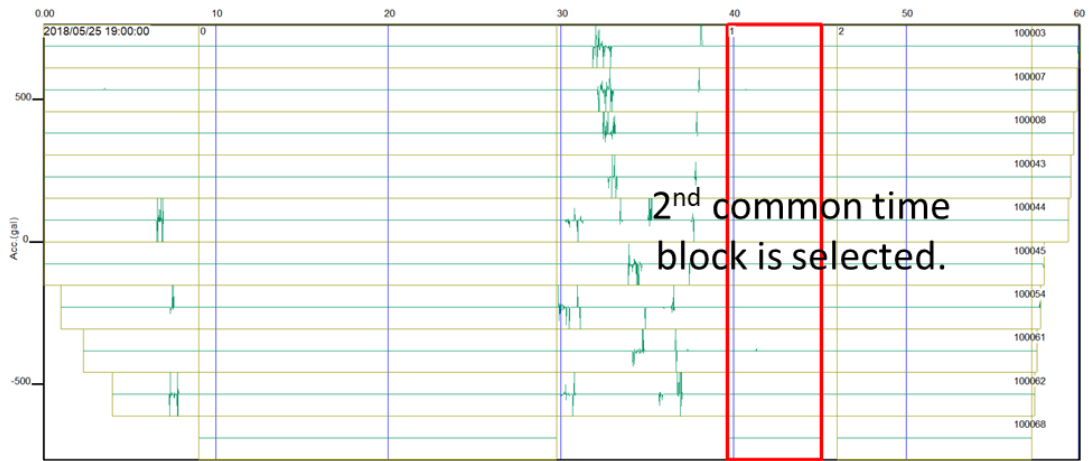
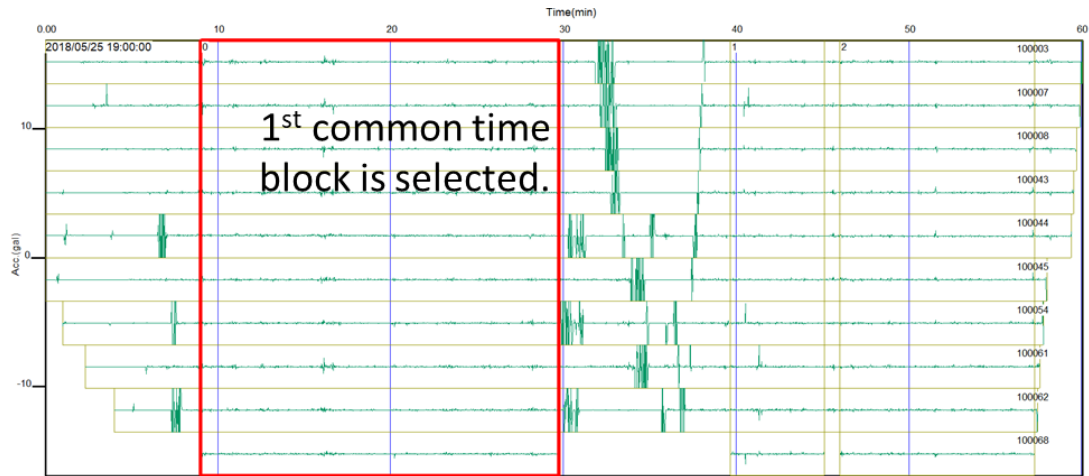



Figure 14.2 Selecting the Common Time Block (CTB)..

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

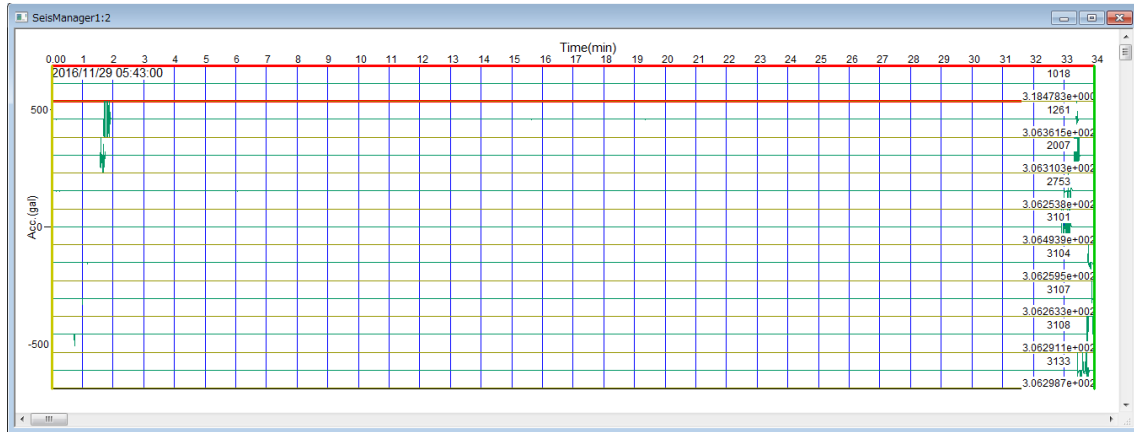


Figure 13.5 Data from the Common Time Block.

3) *Optional* : Use left and right arrow keys to move gates and the TAB key to switch a gate to be set.

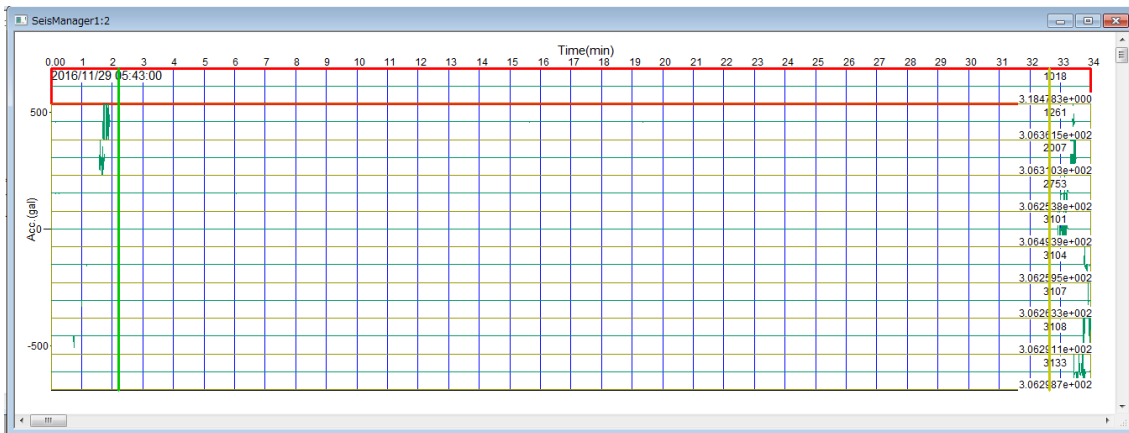



Figure 14.3 Window showing the gates (green and yellow lines).

4) *Optional* : Click  or select [Edit]>>[Delete waveform data outside of gate] to delete the waveforms outside of the gates.

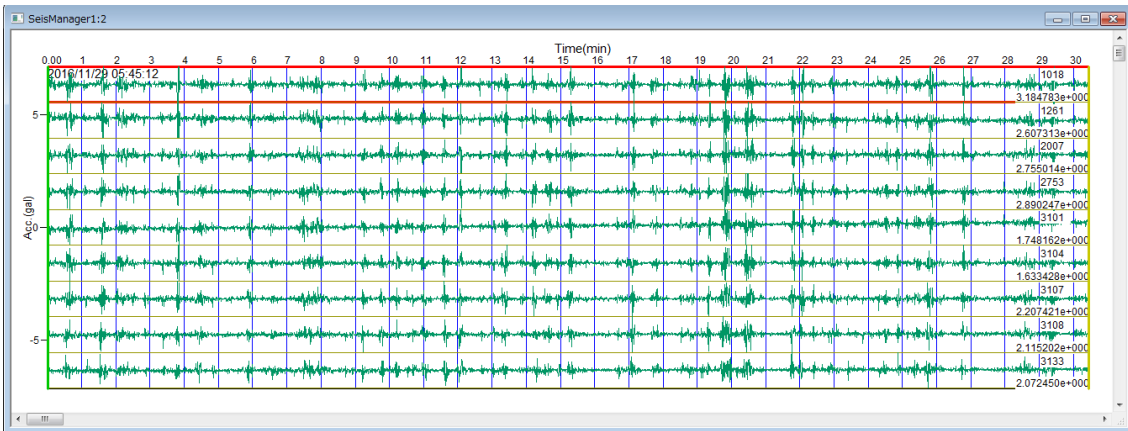


Figure 14.4 Window showing selected data after removing unwanted waveforms.

5) Optional : Select [Window]>>[Geometry] to show GPS location as recorded by the Atom units.

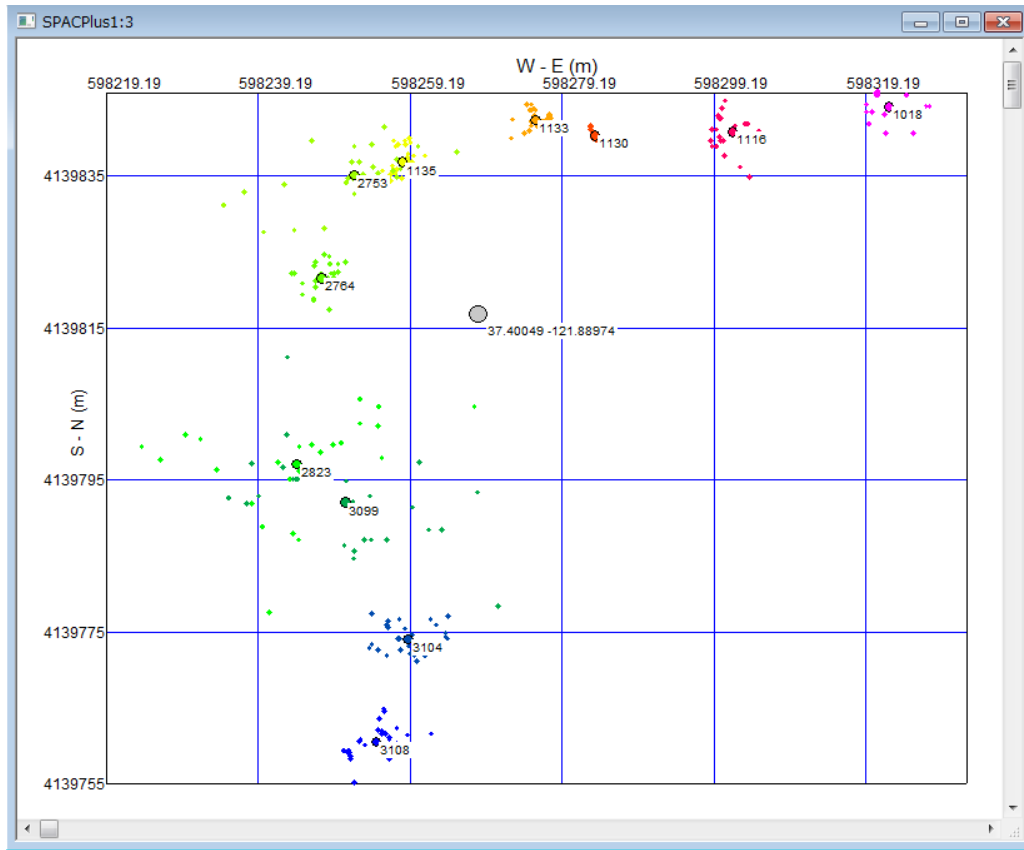


Figure 13.8 GPS location recorded by Atom units. Small dots indicate GPS locations recorded by each Atom unit each minute. Medium size circles indicate averaged GPS location over currently selected time block for each Atom. The large gray circle indicates averaged location of all Atom units.

6) To save the waveform data in CTB as a SEG2 file, select [File]>>[Save waveform data as SEG2 file].

7) To save the waveform data in CTB as an ASCII file, select [File]>>[Save waveform data as ASCII file].

## 15. Basic passive data processing using SPACPlus in SeisImager.

The basic data processing procedure for 1D passive surface wave method (microtremor array measurements) is summarized below. Data from an Atom system is processed in the similar way that MASW or MAM surveys are processed using traditional seismographs such as the Geode. After picking dispersion curves, perform the data analysis using SeisImager/SW. See “SeisImager/SW™ Manual”, “SeisImager/SW™ Manual Addendum (H/V)” and “SeisImager/SW-Pro™ Manual” for the detailed analysis of dispersion curves and/or H/V curves. See the section 16 for the data processing procedure for active data recorded by Atom and the section 17 to combine active and passive data.

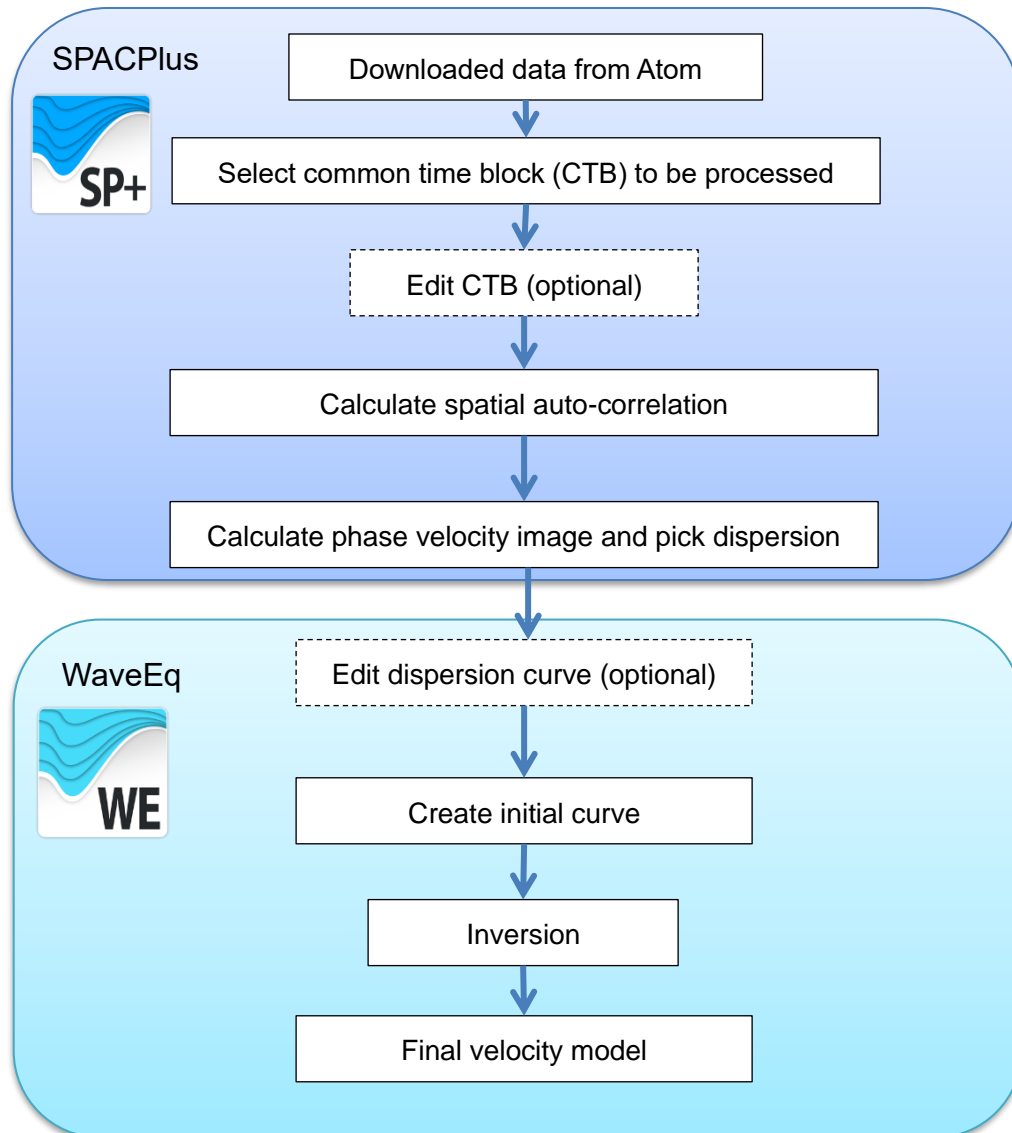


Figure 15.1 Basic data processing procedure for microtremor array measurements.

SPACPlus consists of several processing windows which will sequentially appear during processing. Each window can be viewed one at a time. Several common time blocks (CTB) can be shown in the Main window. A single CTB can be analyzed at one time. Coherences calculated from several different CTBs can be appended in the Phase velocity window. Delete other windows (CTB, Geometry, and SPAC) except the Main window and the Phase velocity window when starting analysis for new CTB,

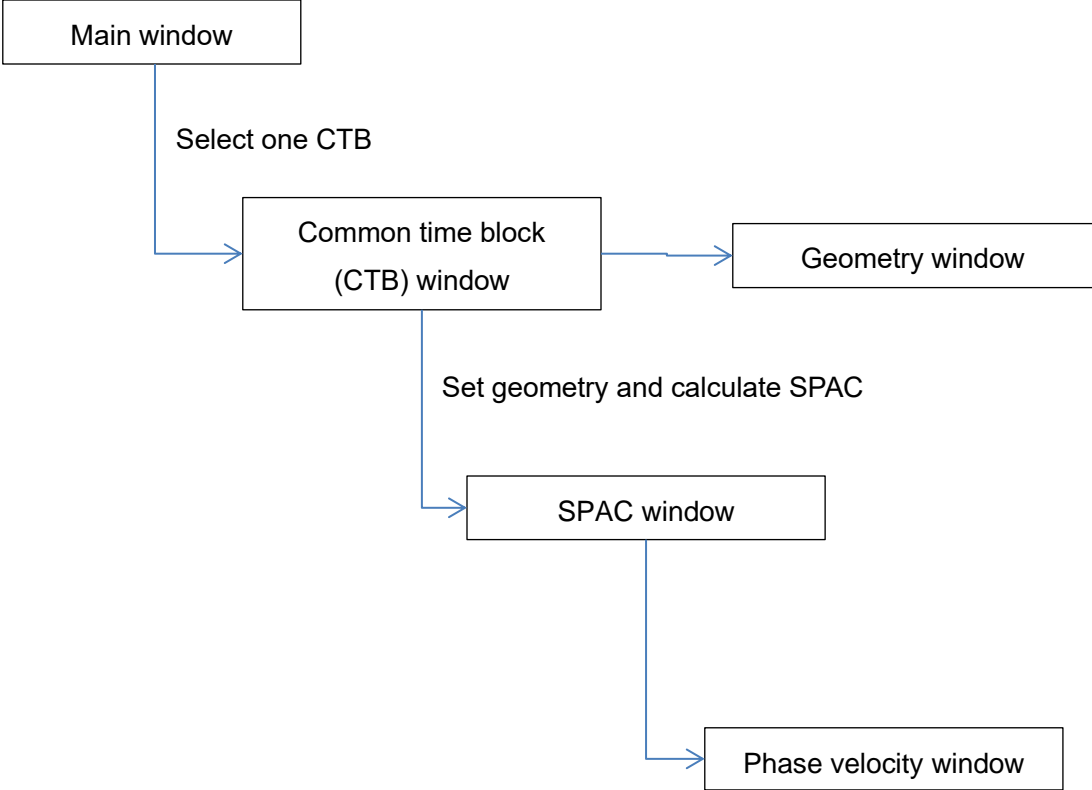


Figure 15.2 Windows that appear in SPACPlus.

1) Data processing starts from a CTB. Select a CTB to be processed just like exporting waveform data described in previous section.

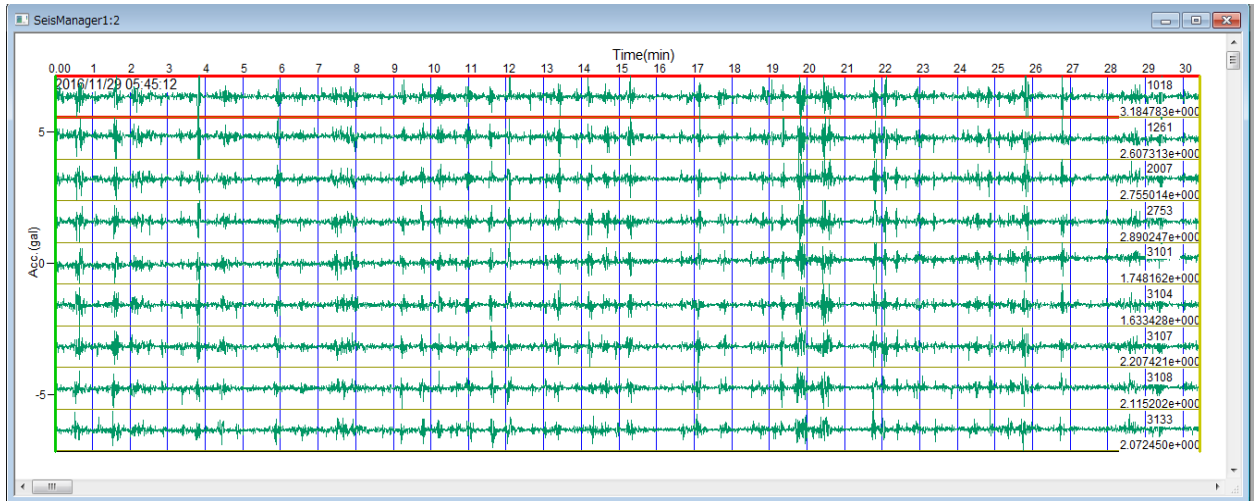



Figure 15.3 Example of Common Time Block (CTB).



2) 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. Check “Use GPS” if GPS location is used for SPAC processing.

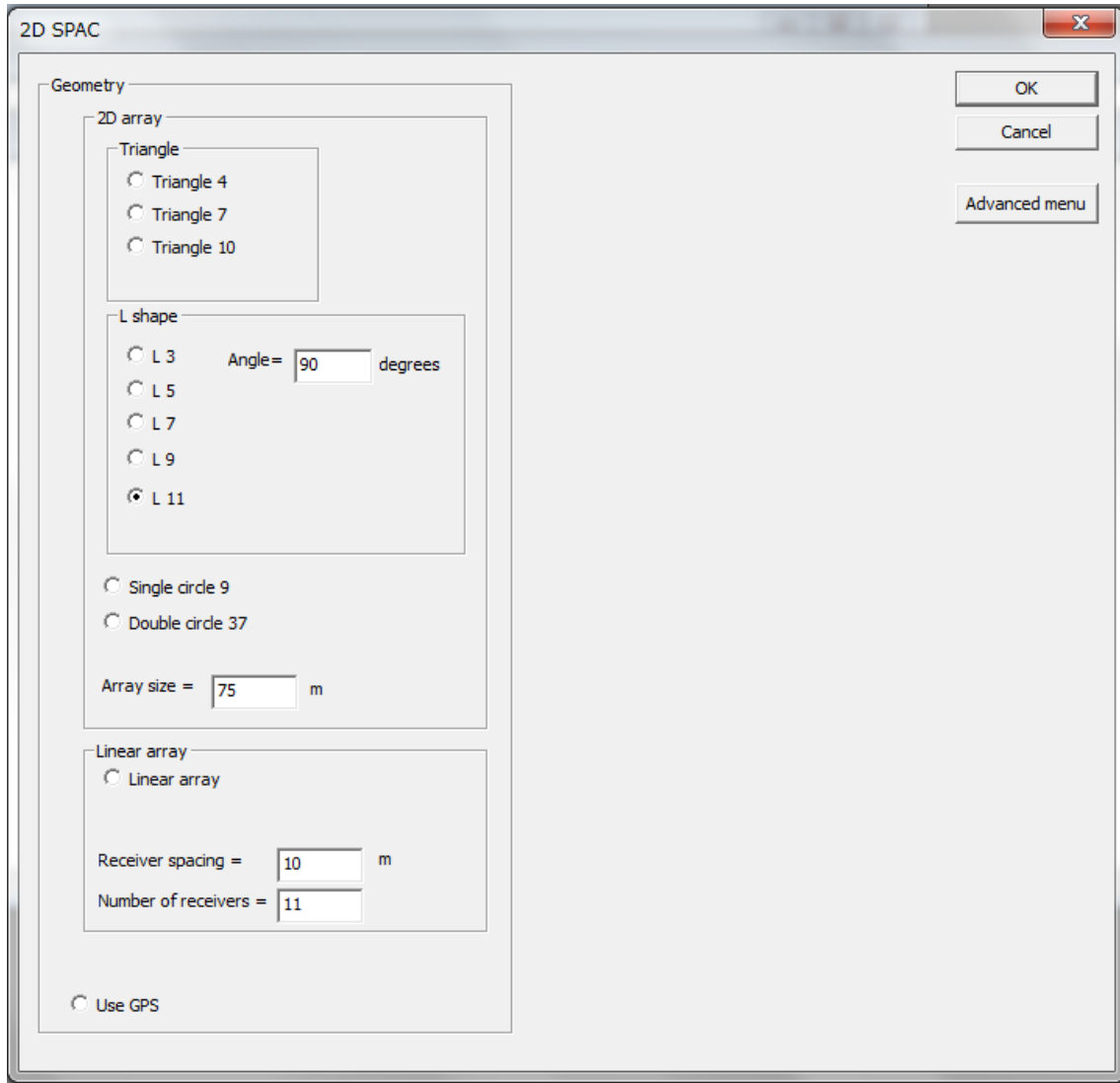


Figure 15.4 Dialog box for setting array shape and size.

To view other options, click [Advanced menu]. To use a custom array configuration, click [Open array file]>> and select an ASCII file containing X-Y location of sensors. Make sure [Manual array] is checked on if you opened an Array file.

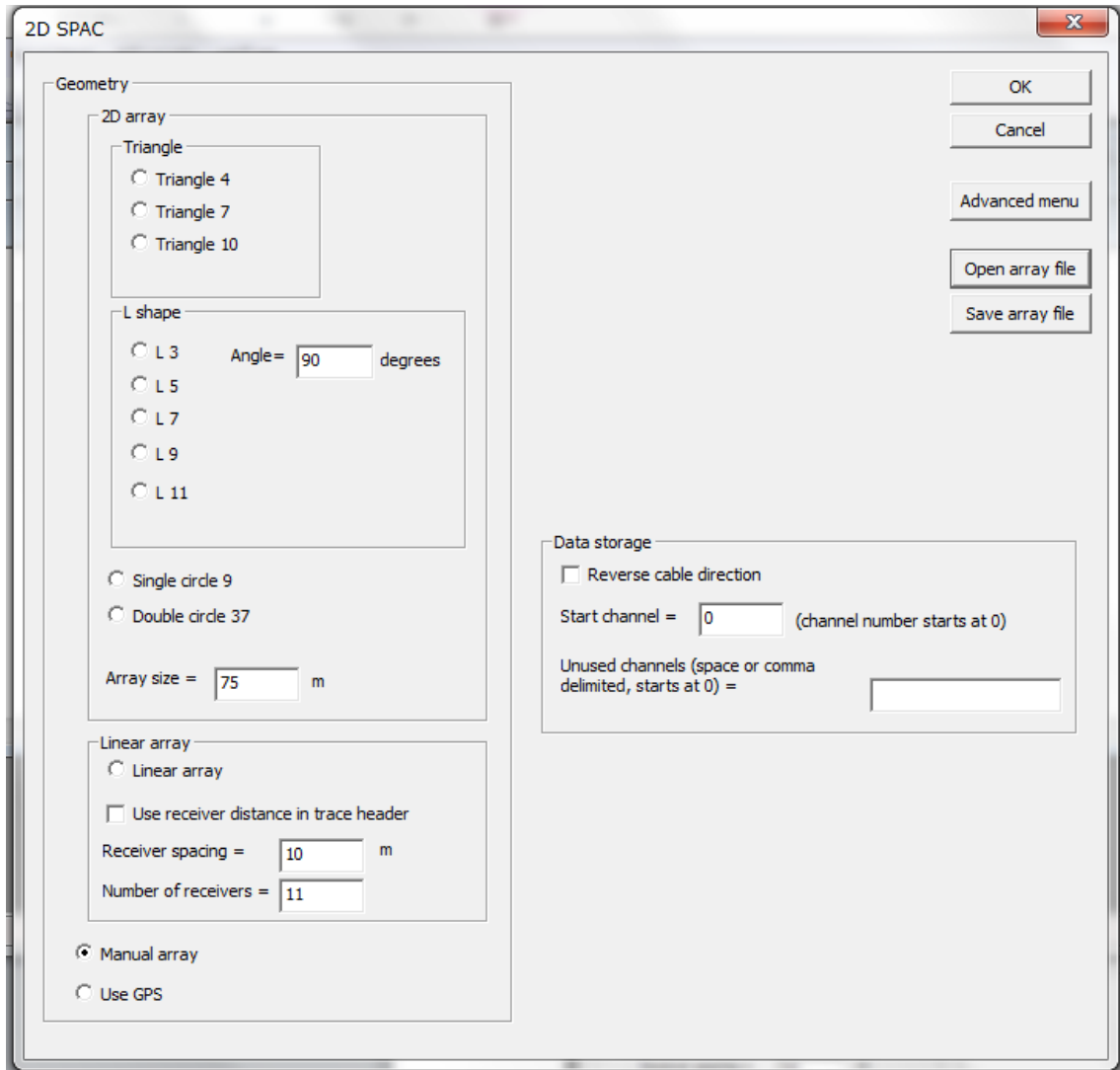



Figure 15.5 Dialog box for setting custom configurations.

An example of array file is shown below:

```

-0.000000 75.000000
-0.000000 60.000000
-0.000000 45.000000
-0.000000 30.000000
-0.000000 15.000000
-0.000000 0.000000
15.000000 0.000000
30.000000 0.000000
45.000000 0.000000
60.000000 0.000000
75.000000 0.000000

```

3) Spatial auto correlations appear. When number of receiver separation is more than three, use  buttons to scroll receiver separations to be shown.

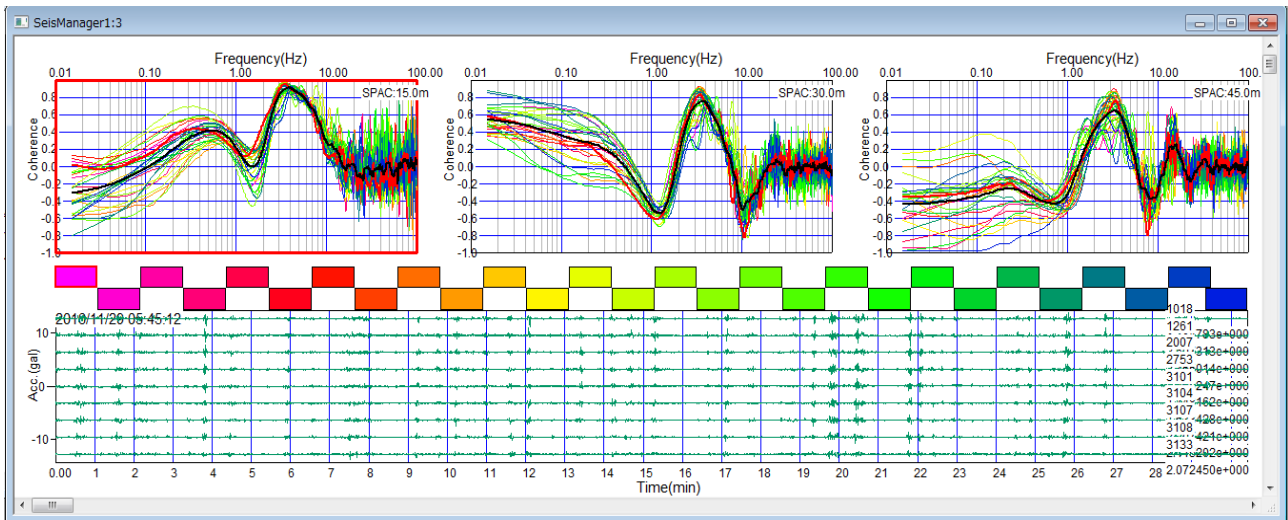



Figure 15.6 Spatial auto correlations.

4) *Optional* : Select [File]>>[Save SPAC data as SEG2 file] to save all spatial auto-correlations into a SEG2 file. Use Pickwin to process saved SEG2 files.

5) 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.

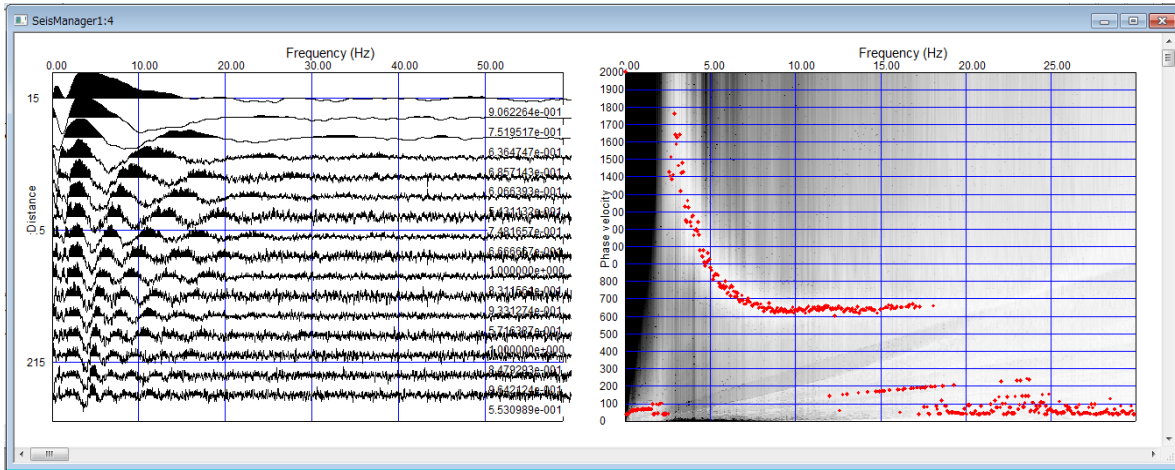



Figure 15.7 Phase velocity image and dispersion curves.

6) *Optional* : Use [Surface wave analysis]>>[Set up phase velocity image] to change the configuration (min. and max. phase velocities etc.) of the phase velocity image and picking.

7) To launch WaveEQ and display dispersion curves on your display, click  or select [Surface wave analysis]>>[Show phase velocity curve(s)] >>[Launch WaveEq].

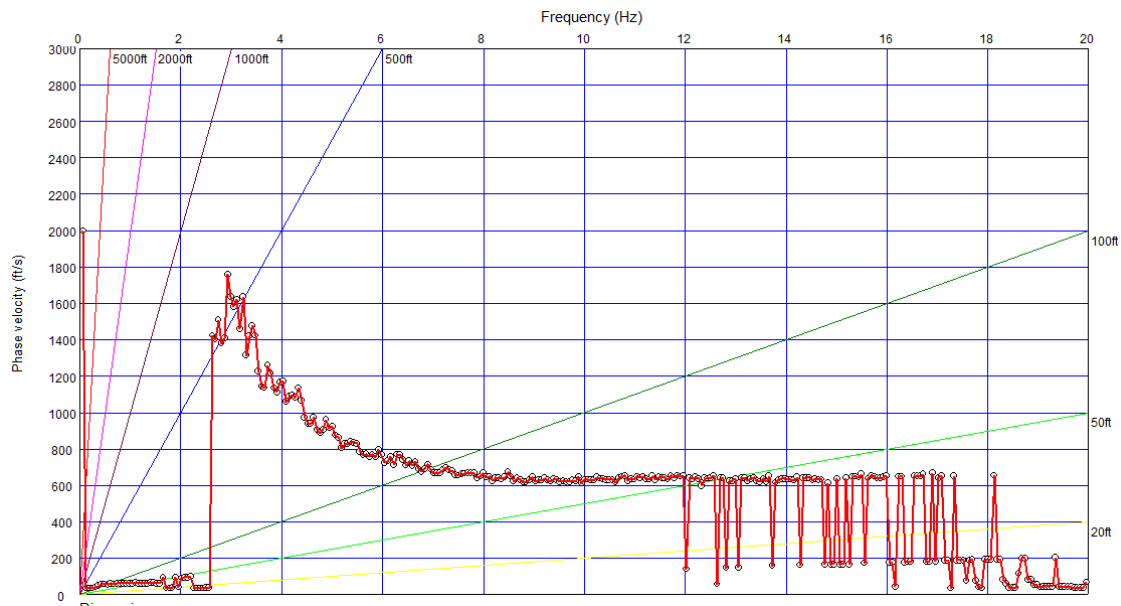



Figure 15.8 Dispersion curve with phase velocity

## 16. Basic active data processing using SPACPlus and Pickwin in SeisImager.

Acquisition parameter for active survey is the same as typical passive recording (4 ms sampling and 12 db gain). Data acquisition does not need a trigger. Make sure all Atom units are recording and swing a hammer or drop a weight at the appropriate shot location. It is better to note a number of shots, location and approximate time of each shots.

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

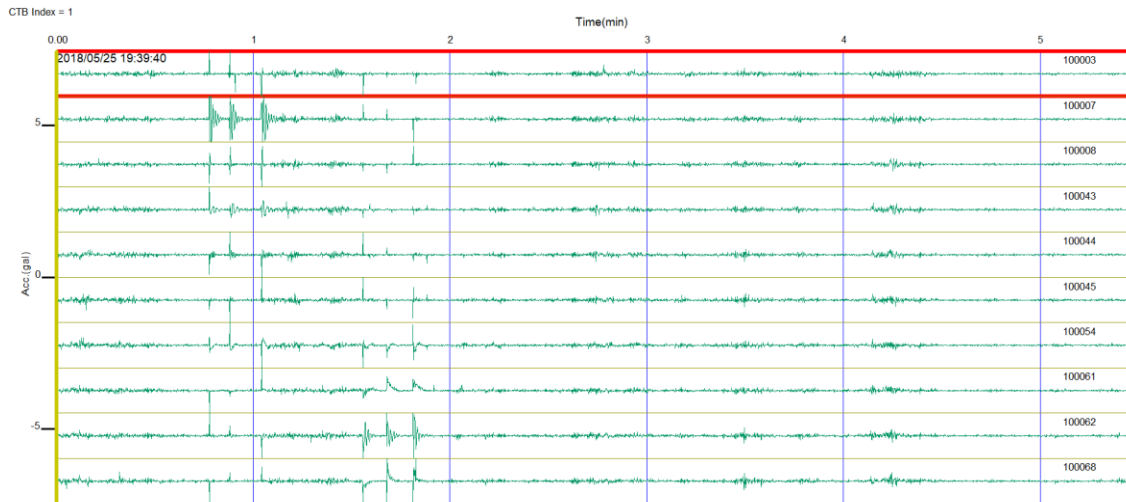


Figure 16.1 Active data from the Common Time Block.

2) To detect shots (events), select [Edit]>>[Event (shot) detection]>>[Detect events] and set event detection parameters.

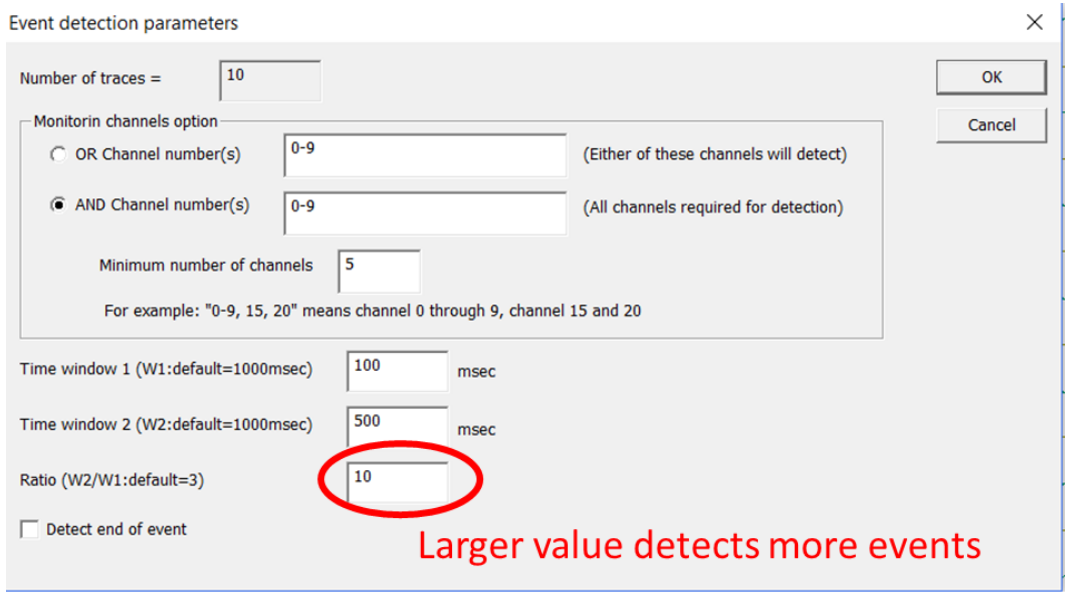
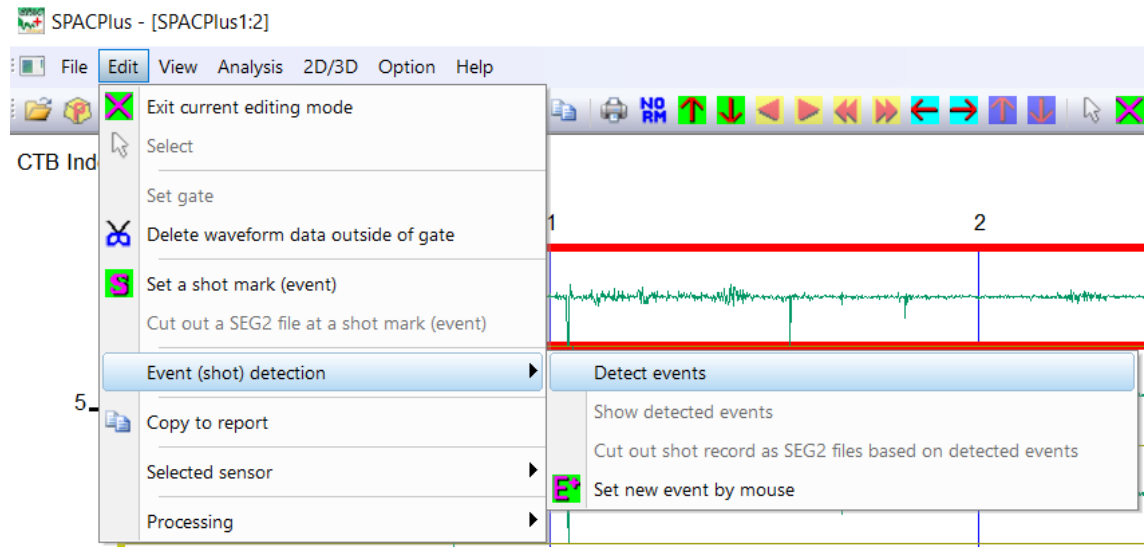
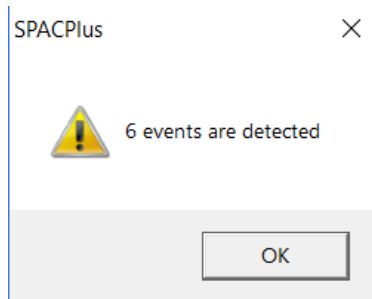


Figure 16.2 Example of parameters for event detection.

3) Number of detected events appears.



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

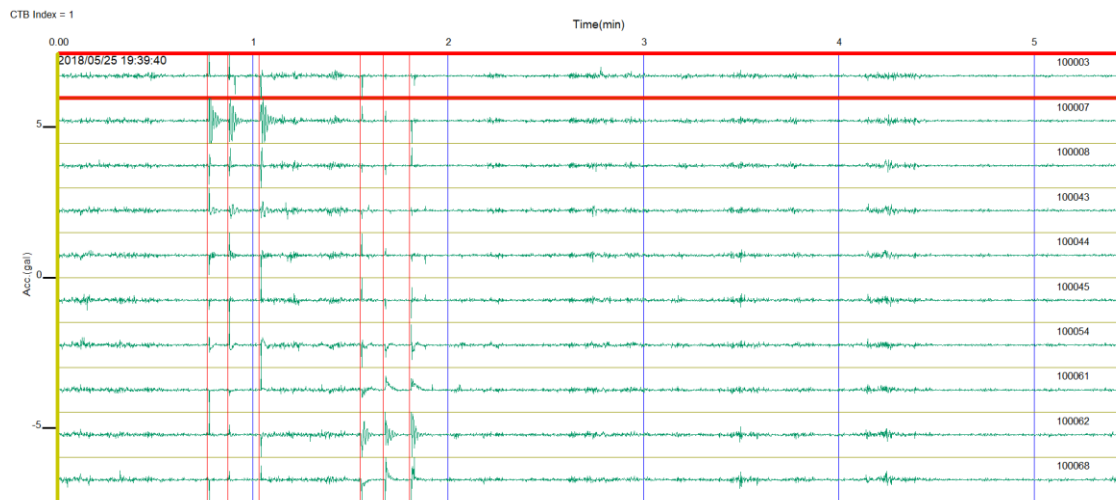





Figure 16.3 Detected events (shots).

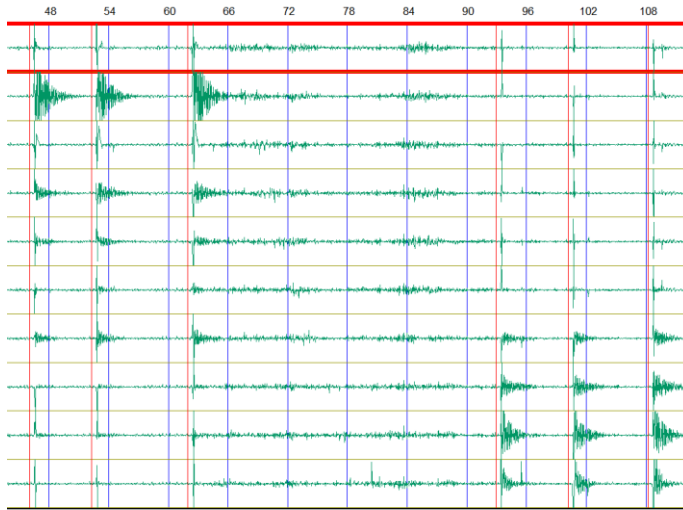



5) Detected shots can be edited as shown below.

 Change horizontal (time) scale.

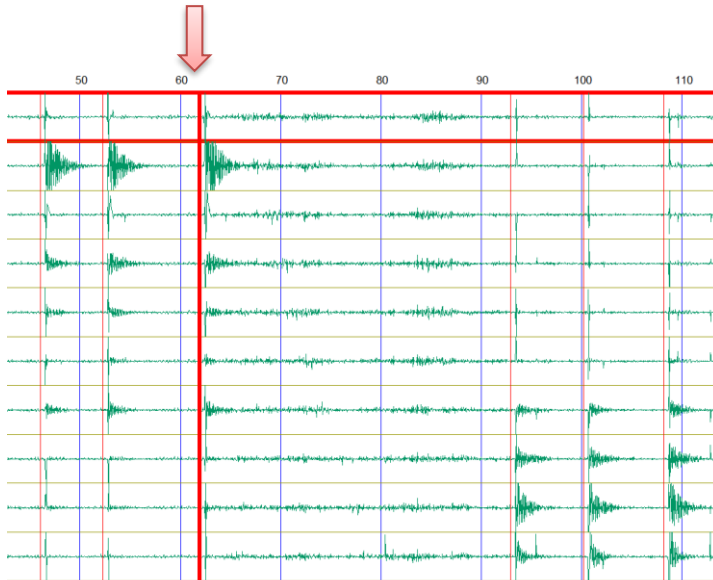
 Change display amplitude.

Use  to Add new event (shots) by clicking a left button of a mouse.

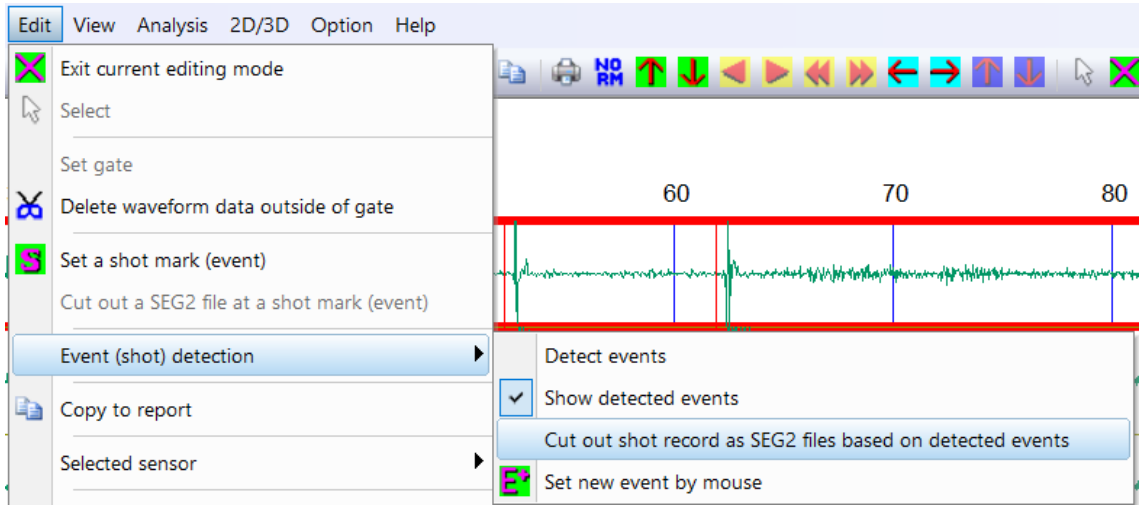


Use  to select a detected event. Selected event is shown as a red bold line. Hit delete key to delete the detected event. Use a mouse to move the event (left button down).

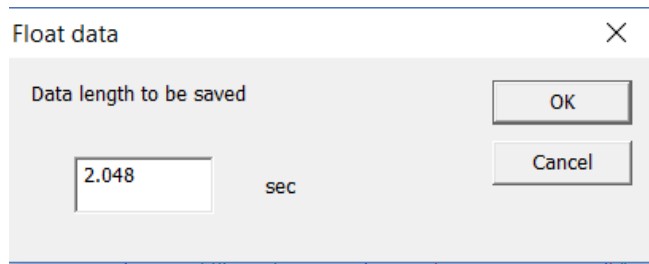
Selected event



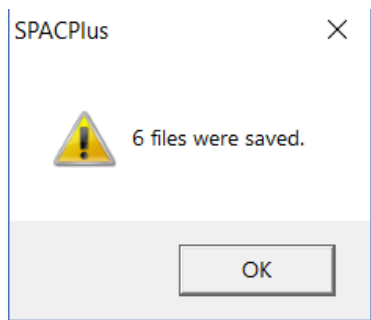
6) To show detected shots by Pickwin, select [Edit]>>[Event (shot) detection]>>[Cut out shot record as SEG2 files based on detect events].









Enter data length of shot records to be cut out.



Number of saved shot record files appears.



The shot record files 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

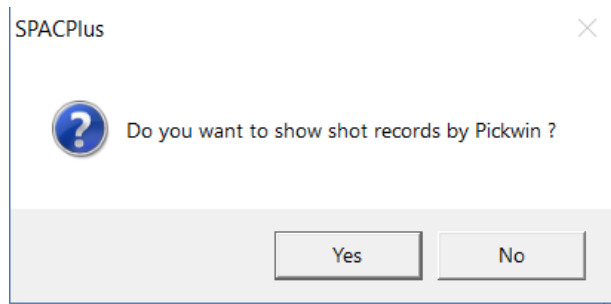
A file list was saved in an XML file in the same folder.

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

The XML file contains a list of shot record files.

```
<?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>
    <l_source_component>2</l_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 launch Pickwin and continue the processing.



7) Pickwin is launched and the list of shot records appear in a dialog box. Set up source location, receiver interval etc. Figure 14.4 shows the setting for the sample data described in the section 17. Figure 14.5 shows the source-receiver configuration of the sample data corresponding to the Figure 14.4.

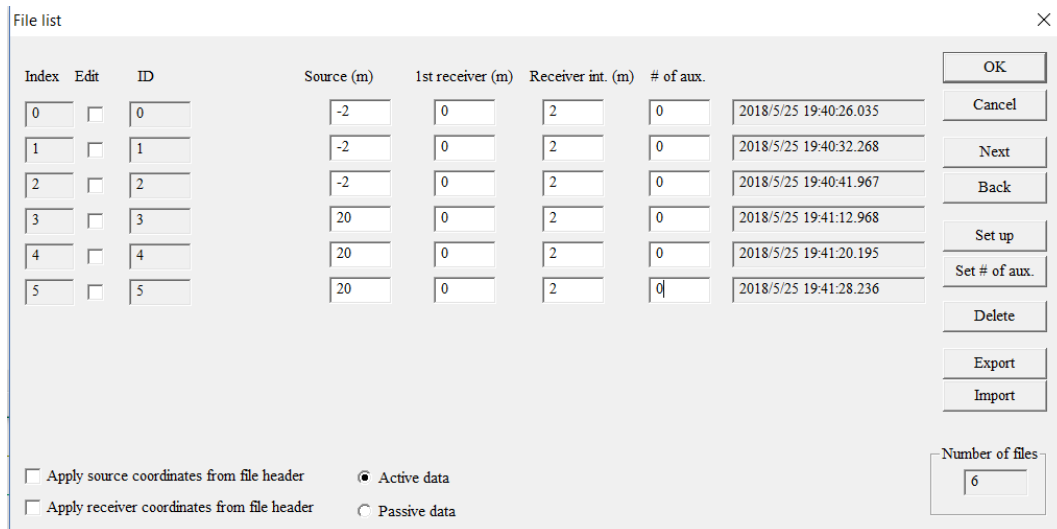


Figure 16.4 File list shown by Pickwin.

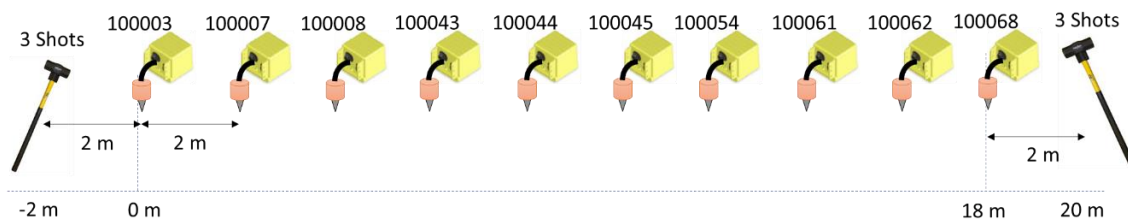


Figure 14.5 Source-receiver configuration corresponding to the Figure 14.3.

8) Individual shot record shown by Pickwin. This manual describes a data processing of active surface wave methods from here. General seismic data processing, such as picking first arrival for refraction analysis, is also possible. See “SeisImager/2D™ Manual” for the detail of refraction processing using SeisImager/2D.



Change horizontal (time) scale.



Change amplitude.



Change distance scale.



Scroll shot records.

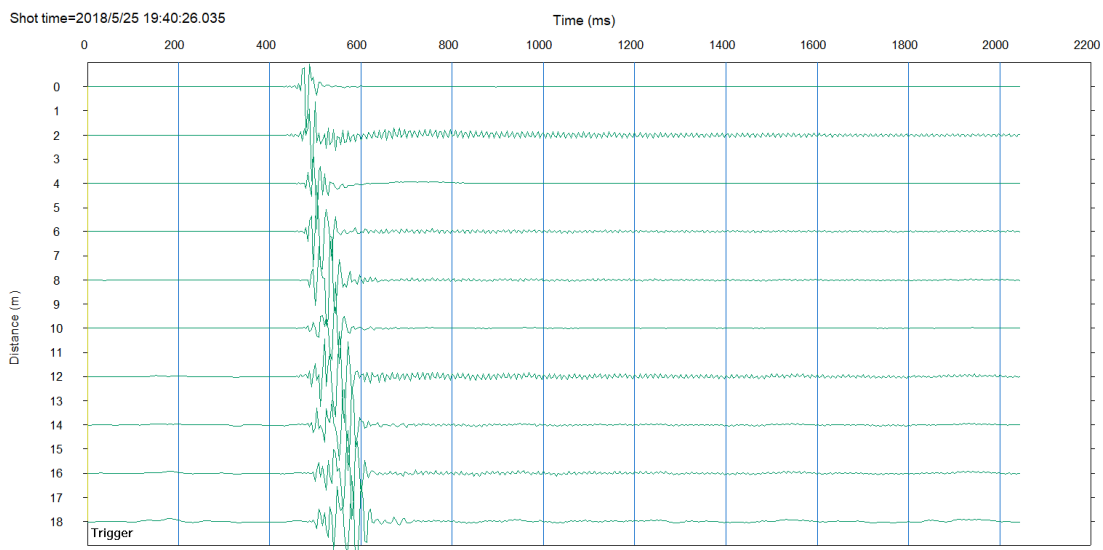
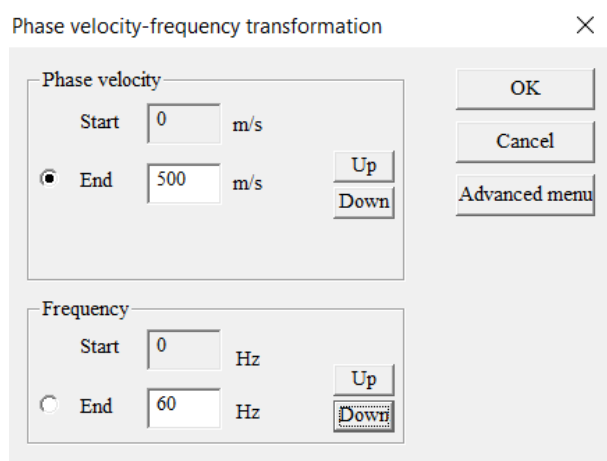


Figure 16.6 Example of individual shot record shown by Pickwin.

9) To transform time domain waveform data 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.

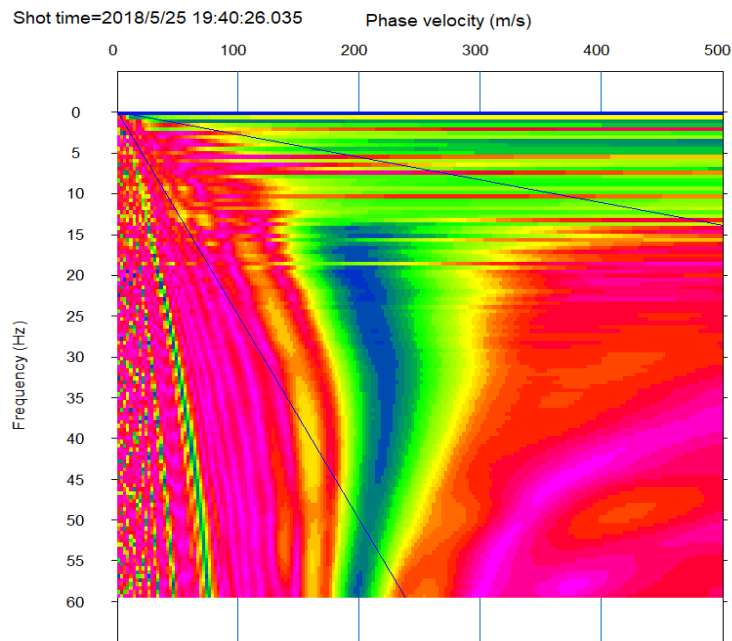


Figure 16.7 Phase velocity image in frequency domain.

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

The image shows a software dialog box titled "Min. and Max. frequency" with a close button (X) in the top right corner. The dialog contains several input fields and checkboxes. The "Minimum Frequency" is set to 5 Hz and the "Maximum Frequency" is set to 60 Hz. There is a checked checkbox for "Use median filter" and a field for "# of sample for median filter" set to 5. A "Setup" section contains a checkbox for "Wavelength limitation" which is circled in red. Below it are fields for "Maximum wavelength" and "Minimum wavelength", both set to 2 times. Another section is titled "Setup min. and max. phase velocity" and contains a field for "Minimum phase velocity" set to 35 m/s, which is also circled in red. Below that is a field for "Maximum phase velocity" set to 500. A final section is titled "Setup area for phase-velocity picking" and contains a checkbox for "Use current phase-velocity as minimum velocity for picking" and a field for "Phase-velocity area" set to 100 m/s. On the right side of the dialog, there are three buttons: "OK", "Cancel", and "Advanced menu". Two red callout boxes with black borders are overlaid on the dialog. The first callout box, containing the text "Check off if you want to pick all frequency range", points to the "Wavelength limitation" checkbox. The second callout box, containing the text "Change minimum phase velocity to be picked depending on data", points to the "Minimum phase velocity" input field.

Min. and Max. frequency

Minimum Frequency 5 Hz

Maximum Frequency 60 Hz

Use median filter

# of sample for median filter = 5

Setup

Wavelength limitation

Maximum wavelength 2 times

Minimum wavelength 2 times

Setup min. and max. phase velocity

Minimum phase velocity = 35 m/s

Maximum phase velocity = 500

Setup area for phase-velocity picking

Use current phase-velocity as minimum velocity for picking

Phase-velocity area 100 m/s

OK

Cancel

Advanced menu

Check off if you want to pick all frequency range

Change minimum phase velocity to be picked depending on data

11) 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.

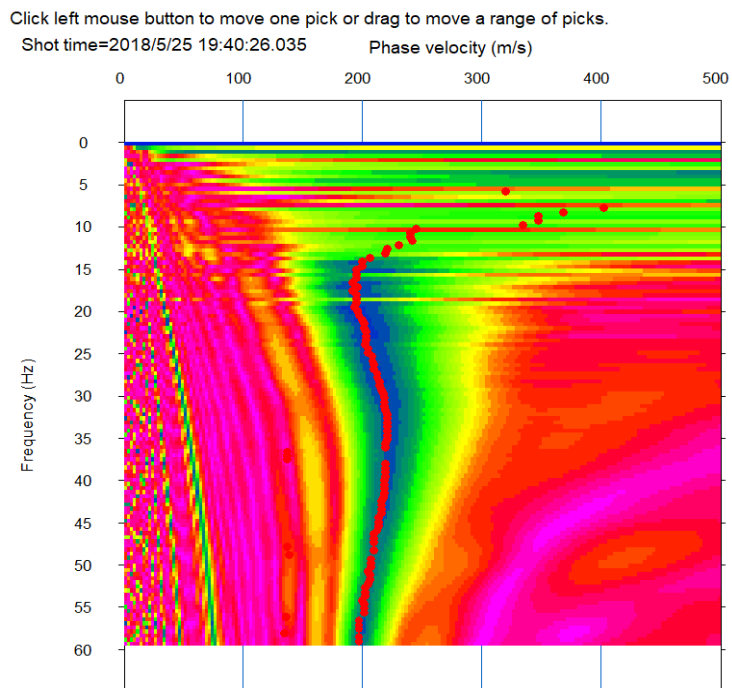


Figure 16.8 Picked phase velocities on the phase velocity image in frequency domain.

12) To show a dispersion curve by WaveEq, select [Surface wave analysis]>>[Show phase velocity curve (1D) <Launch WaveEq>].



## 17. Combine passive and active surface wave data.

This section briefly summarizes a processing flow of combined analysis of active and passive surface wave data obtained by Atom after both dispersion curves were picked. See “SeisImager/SWTM Manual”, “SeisImager/SWTM Manual Addendum (H/V)” and “SeisImager/SW-ProTM Manual” for the general and detailed analysis of dispersion curves and/or H/V curves. Figure 15.1 shows the processing flow of combined analysis.

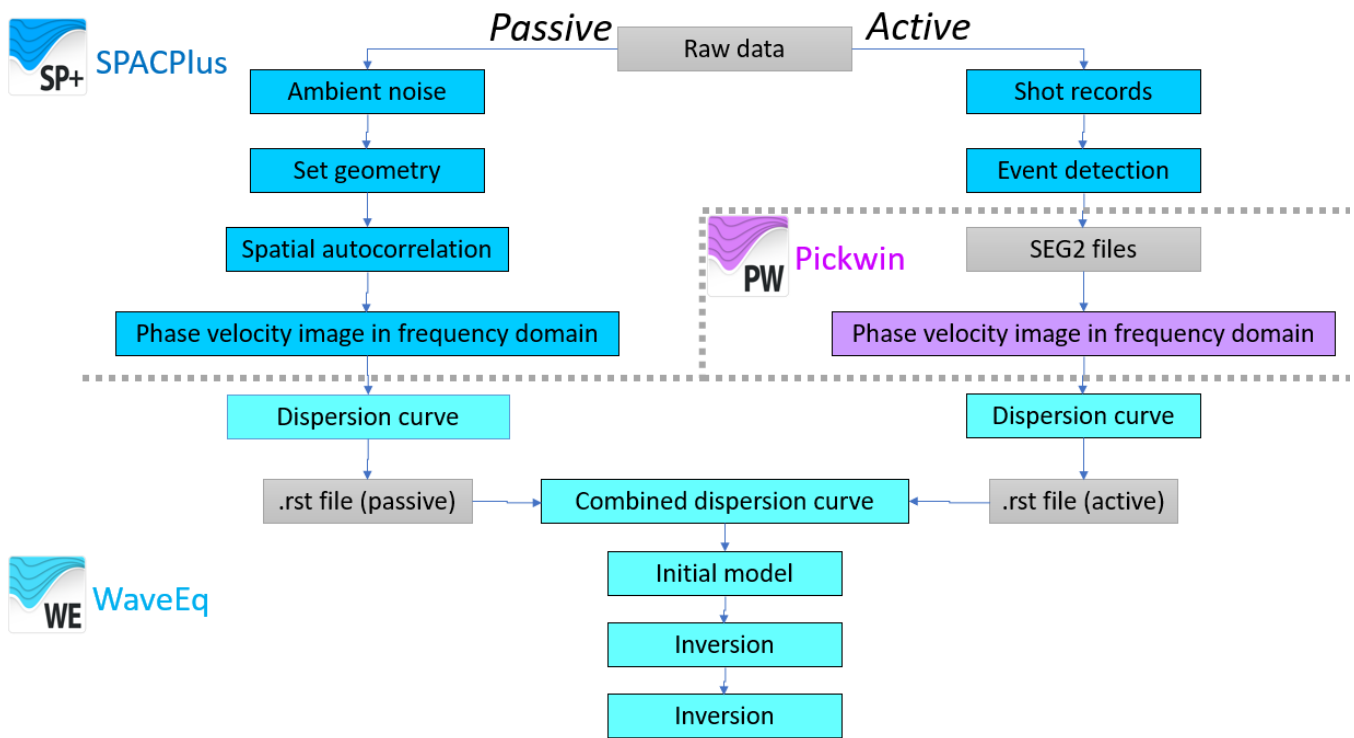




Figure 17.1 Processing flow of passive and active surface wave methods.

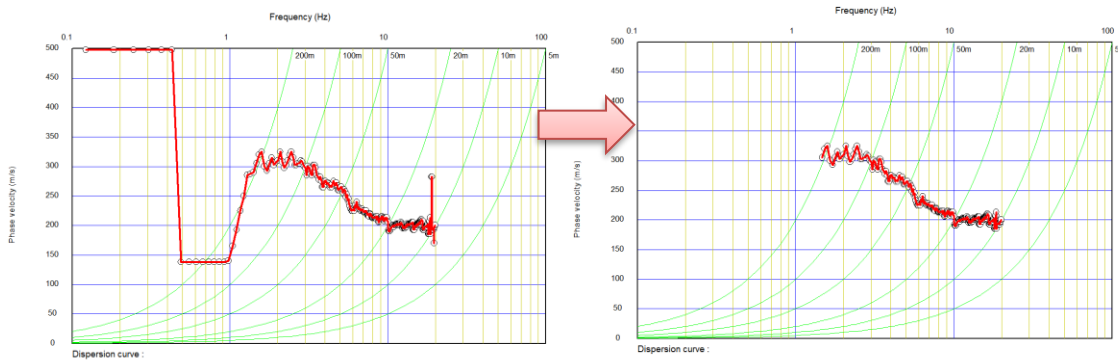
1) Delete noises or unnecessary frequency range.

Use  or  to select phase velocities

Select [Dispersion curves]>>[Delete picks outside of gate] or Ctrl+X to set unnecessary frequency range.

Hit delete key to delete the selected phase velocities.

Passive data :



Active data :

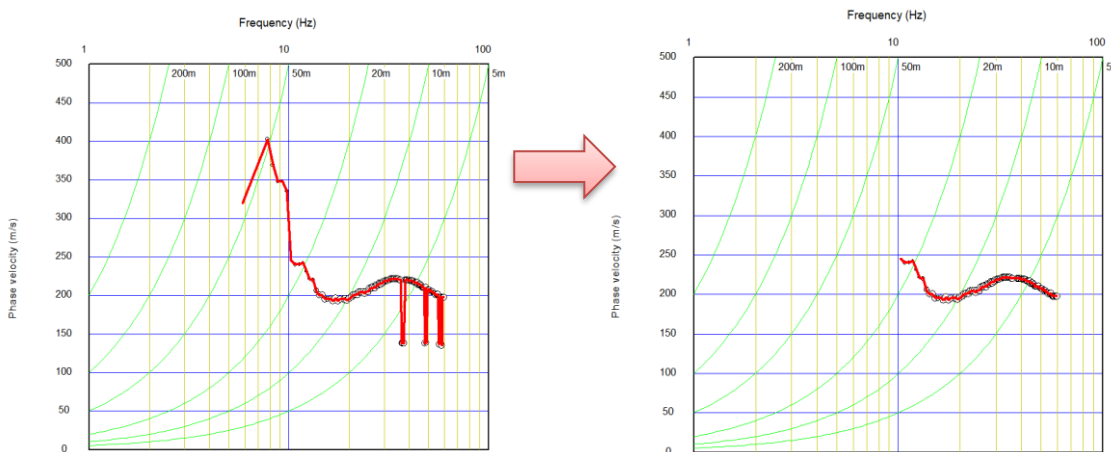
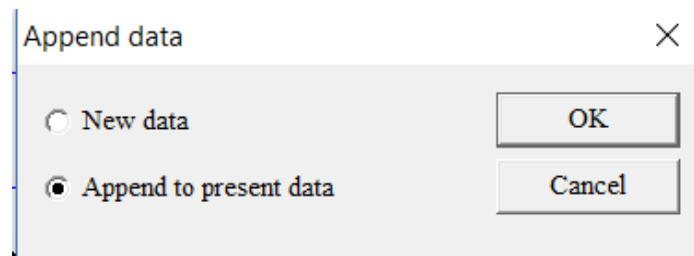


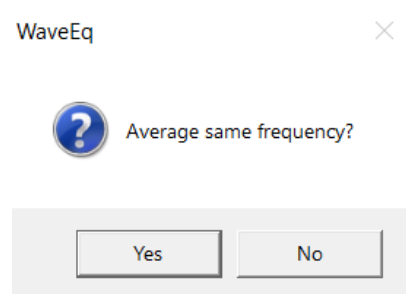
Figure 17.2 Examples of dispersion curve editing.

2) Passive and active dispersion curves must be individually saved as .rst files. To save dispersion curves, select [File]>>[Save 1D phase velocity curve or H/V curve (.rst)] to save a dispersion curve to data file.

3) To combine active and passive dispersion curves, open one of two files by [File]>>[Open 1D phase velocity curve or H/V curve (.rst)]. Then open another file [File]>>[Open 1D phase velocity curve or H/V curve (.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.

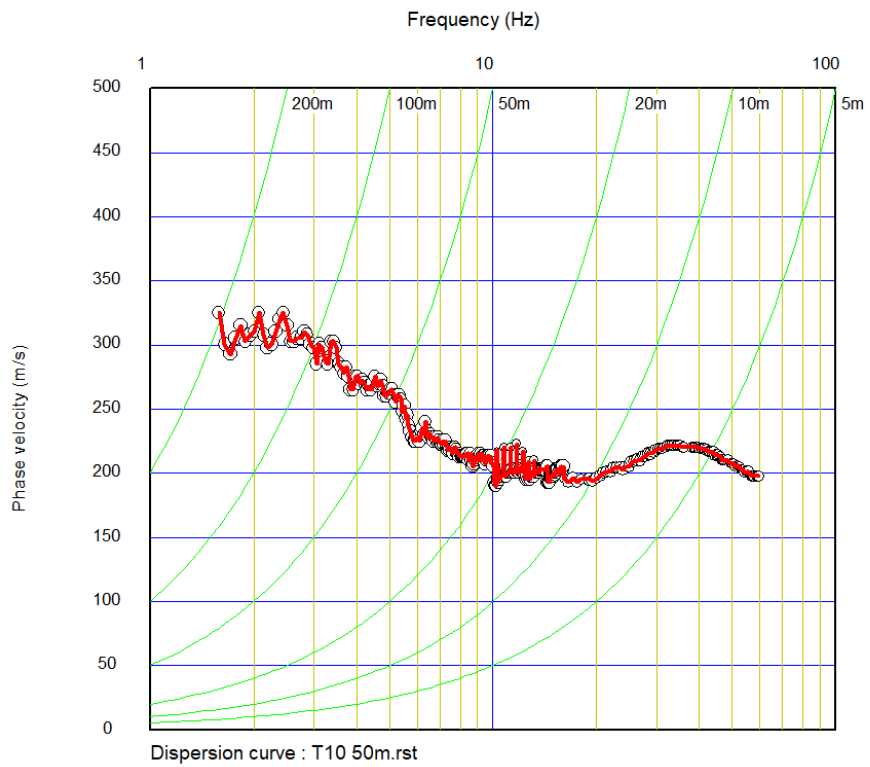


Figure 17.3 Active and passive dispersion curves.

4) Edit active and passive dispersion curves to delete noises or unnecessary frequency range.

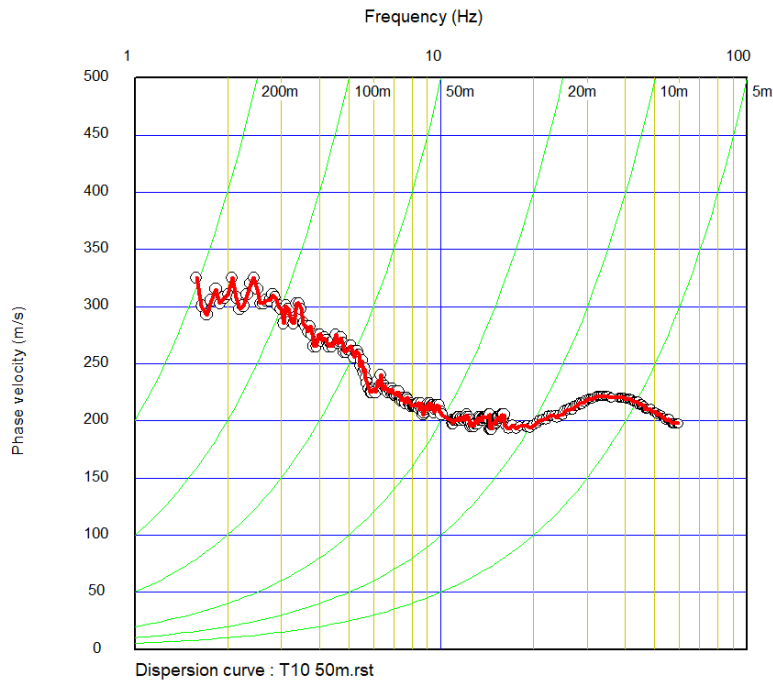



Figure 17.4 Edited dispersion curves.

5) It is better to inspect penetration depth before generating an initial model. Click  to evaluate approximate depth of penetration. Green circles indicate 1/3 wave length.

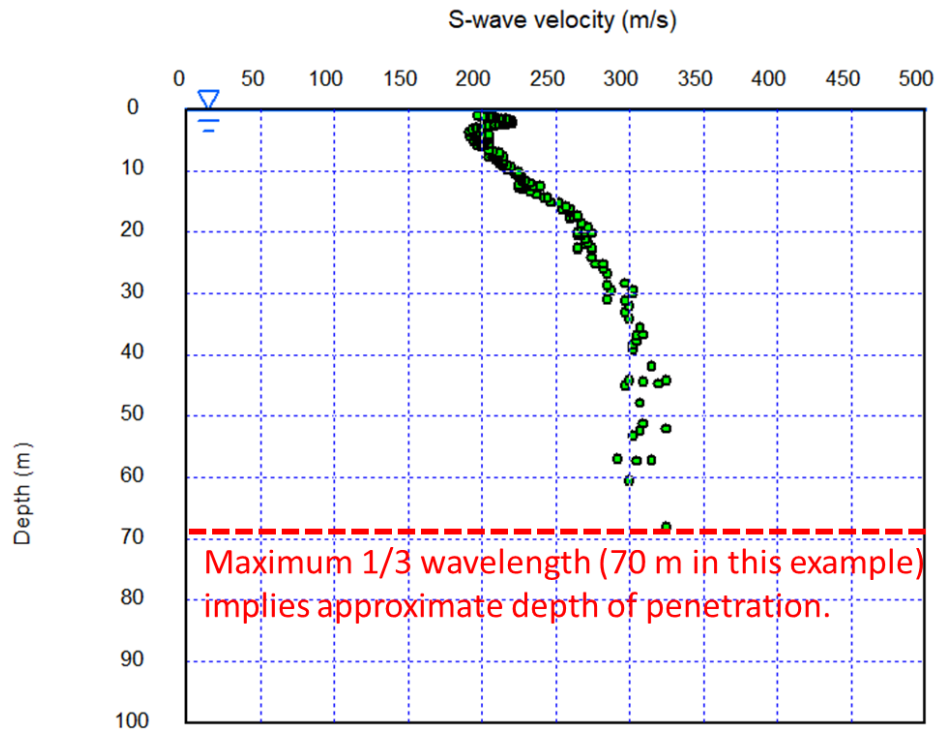
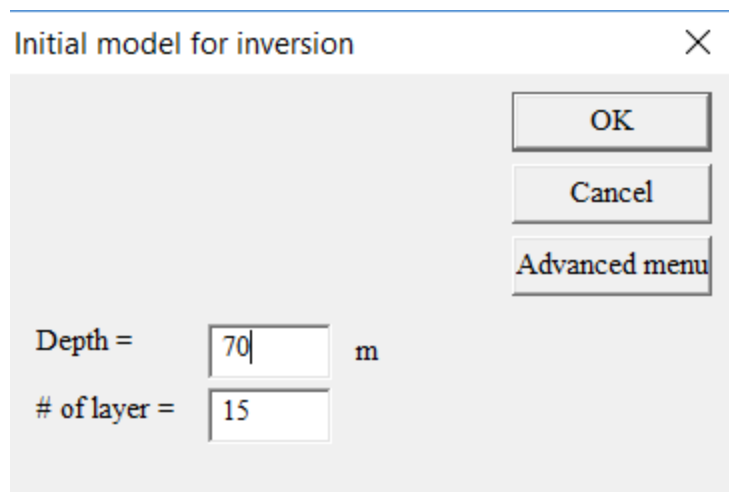


Figure 17.5 1/3 wavelength implies approximate depth of penetration.

6) To generate 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.



7) Refer “SeisImager/SW™ Manual” and “SeisImager/SW-Pro™ Manual” for the inversion of dispersion curves from this point.

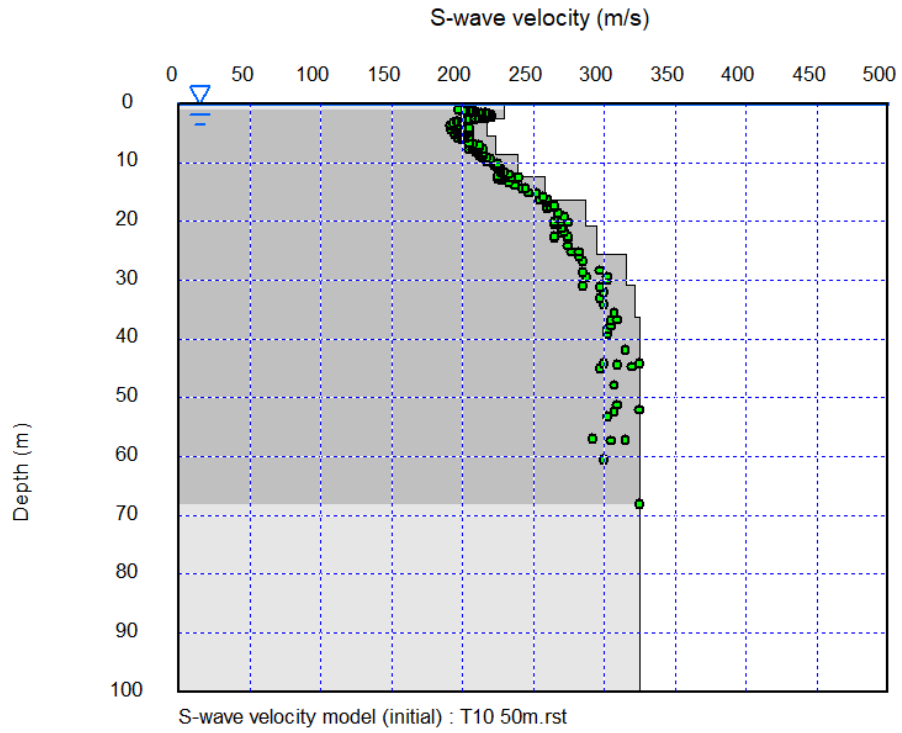


Figure 17.6 Example of initial model.

## 18. Data acquisition using three-channel (3C) Atom and basic processing of 3C data

If default 3C 2 Hz sensor is used, SeisImager assumes X component (1<sup>st</sup> channel) corresponds to East-west and Y-component corresponds to North-south as shown in Figure 18.1. Channel number, sensor notation, and polarity of each component are summarized in tables.

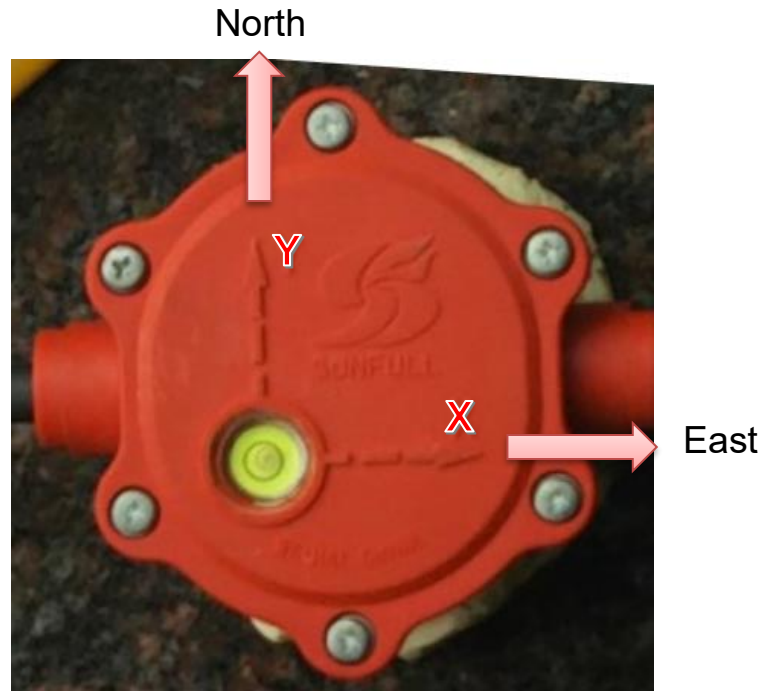


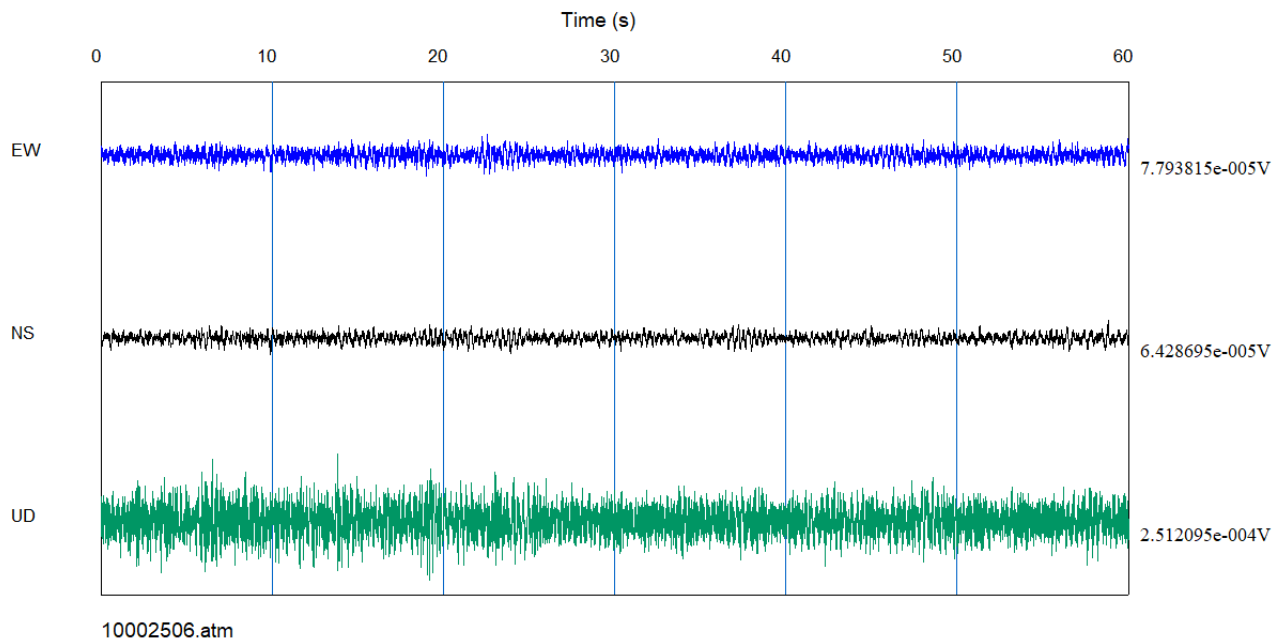
Figure 18.1 Default arrangement of three-component (3C) sensor.

Table 18.1 Channel number, sensor notation, and polarity with configuration shown in Figure 18.1

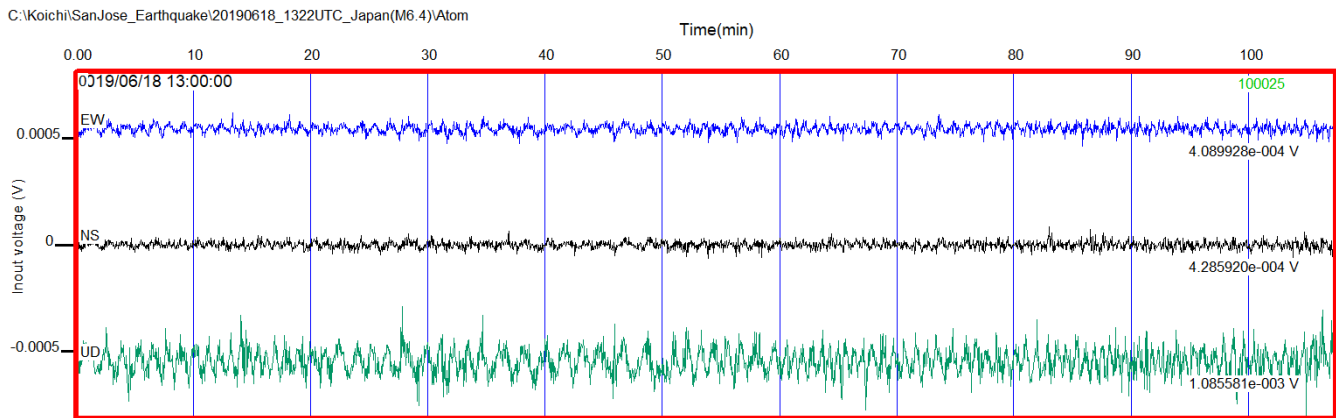
Channel number	Component	Sensor notation (2 Hz)	Positive polarity	Default color in Pickwin or SPACPlus
1	Horizontal 1 (EW)	X	West	Blue
2	Horizontal 2 (NS)	Y	South	Black
3	Vertical		Down	Green

Figure 18.2 shows an example of 3C waveform data shown in Pickwin and SPACPlus.





(a) Example of 3C data shown by Pickwin.



(b) Example of 3C data shown by SPACPlus.

Figure 18.2 Example of 3C waveform data shown in Pickwin (a) and SPACPlus (b).

## 19. Sensitivity correction

Raw waveform data obtained by using geophones can be converted to absolute velocity or acceleration based on geophone sensitivity. To correct geophone sensitivity, select [Option]>>[Processing]>>[Geophone sensitivity correction] in a complete menu of Pickwin or [Edit]>>[Processing]>>[Geophone sensitivity correction] in a CTB window of SPACPlus. Set up sensitivity parameters, natural frequency, damping and sensitivity, in a dialog box. Applying LCF suppresses the divergence in low frequency range. Check [Convert to acceleration] to convert waveform data to the acceleration. Otherwise, the result will stay at velocity. Positive polarity is South, West, and Down using a 3C Atom and default sensor (Sunfull 2 Hz). Note that setting sensitivity negative make the polarity to North, East, Up that is commonly used in seismology.

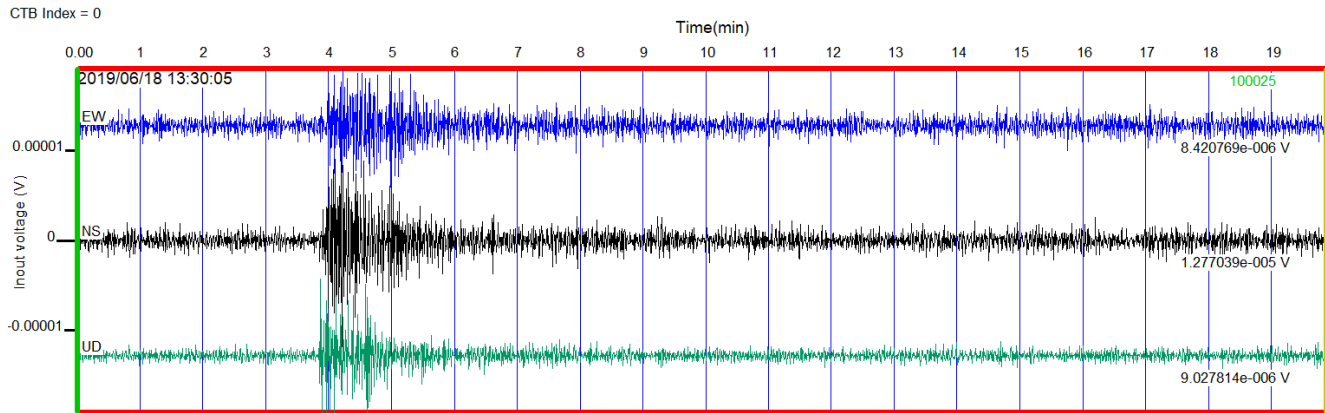
	Natural frequency (Hz)	Damping	Sensitivity
H1	2.32558	0.8543	-0.211
H2	2.32558	0.8543	-0.211
V	2.17391	0.8802	-0.212
LCF	0.01	Hz	

Convert to acceleration

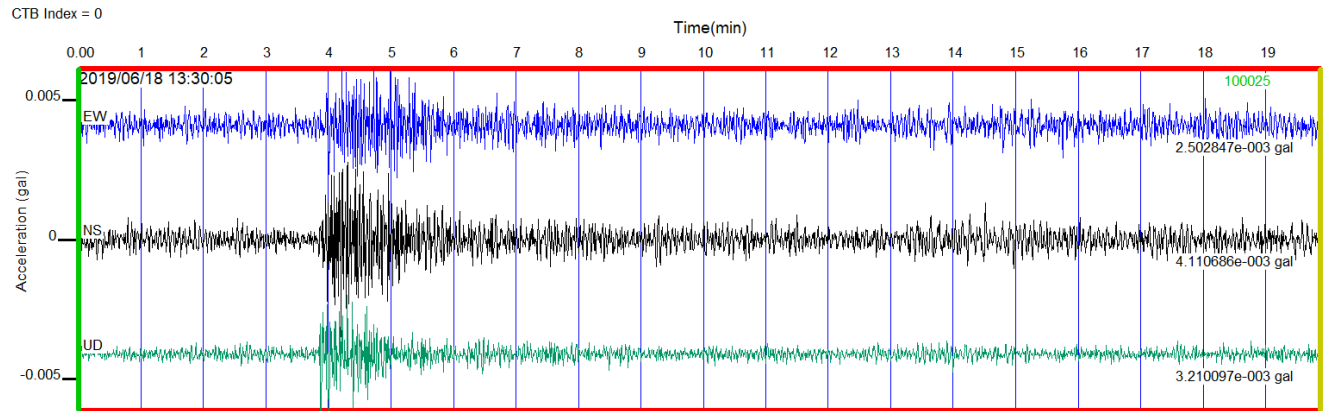
OK Cancel

Figure 19.1 Setup of geophone sensitivity parameters.

Figure 19.2 shows an example of sensitivity correction.



(a) Raw waveform data.



(b) Acceleration converted using geophone sensitivity parameters.

Figure 19.2 Example of sensitivity correction.

## 20. Huddle test

A huddle test is strongly recommended before starting data acquisition to make sure that the character of the sensor is identical between all of the Atom units. A procedure of huddle test is summarized below.

1) Put all Atom units at one place as shown in Figure 20.1.



Figure 20.1 Huddle test.

2) Record 10 ~ 15 minutes of ambient noise data.

3) To process huddle test, download data from Atom units and select a common time block (CTB). Coherencies will be calculated between the trace in the red rectangle and all other traces.

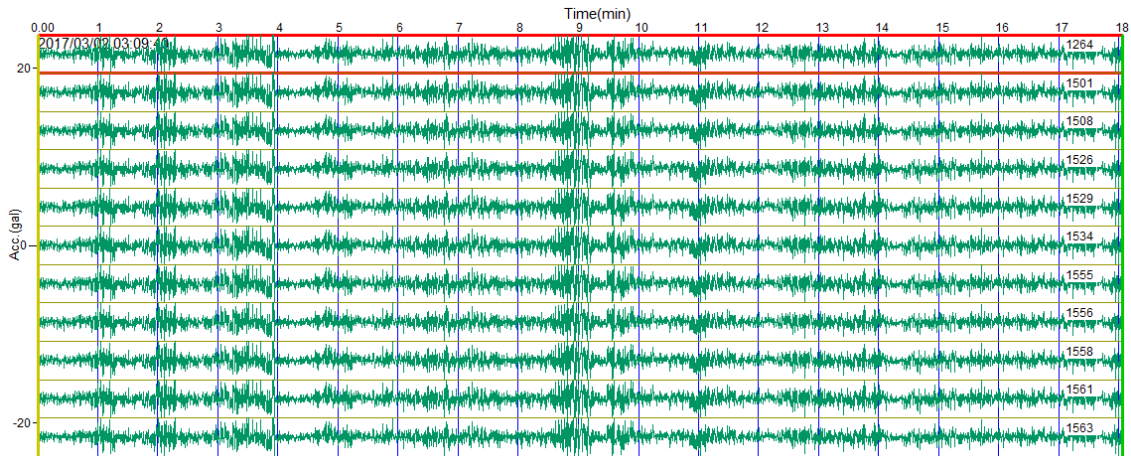



Figure 20.2 Example of ambient noise data for a huddle test.

4) Select [Analysis]>>[Coherency analysis] and coherencies appear in another window. Use  buttons to scroll receiver separations to be shown.

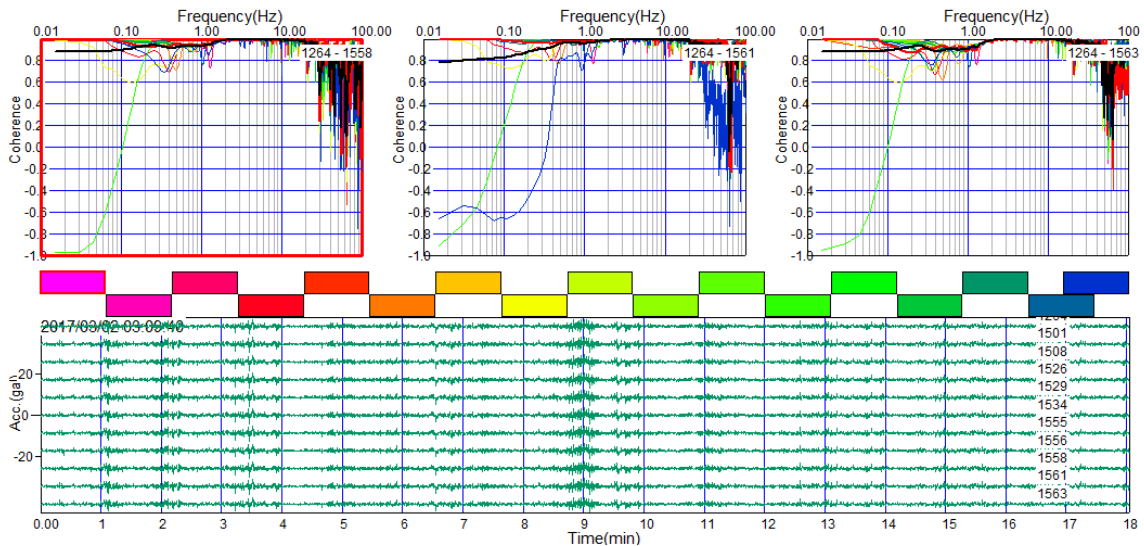



Figure 20.3 Example of coherencies calculated from huddle test data together with the raw data.

5) Click  or select [Phase velocity analysis]>>[Phase velocity window] and all coherencies appear in another window.

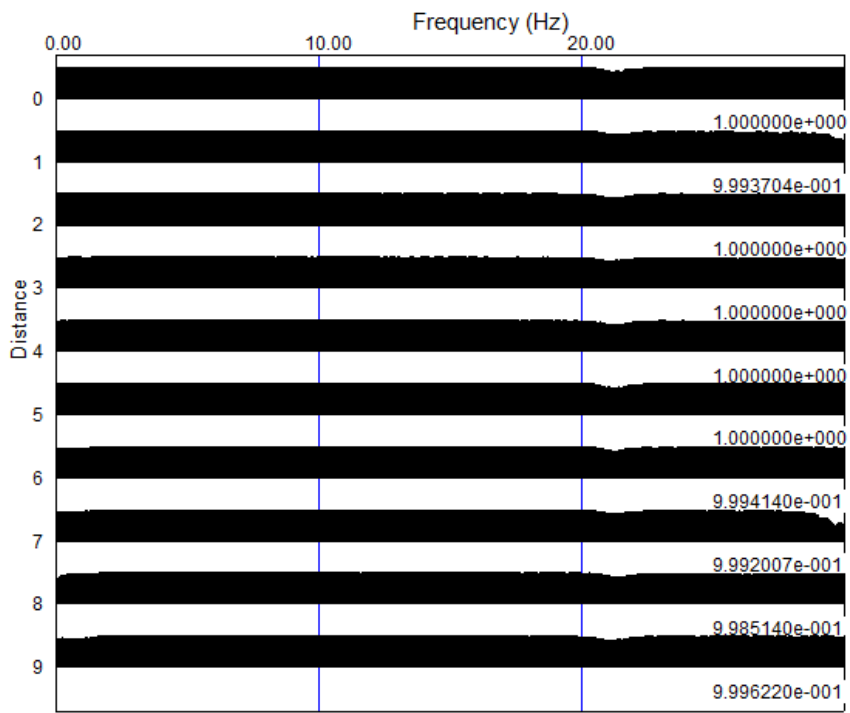


Figure 20.4 Example of coherencies calculated from huddle test

## 21. Data example

Data example used in the manual can be downloaded from :

[http://seisimager.esy.es/GeophysicalDatabase/t10\\_50m.zip](http://seisimager.esy.es/GeophysicalDatabase/t10_50m.zip).

Sample data shown above includes following data.

1. Nested triangles of 50 m with 10 receivers recording ambient noise (Figure 21.1).
2. Linear array of 10 receivers with 2 m spacings recording active sledge hammer data (Figure 21.2).
3. Linear array of 10 receivers with 2 m spacings recording ambient noise. This measurement is not necessary.

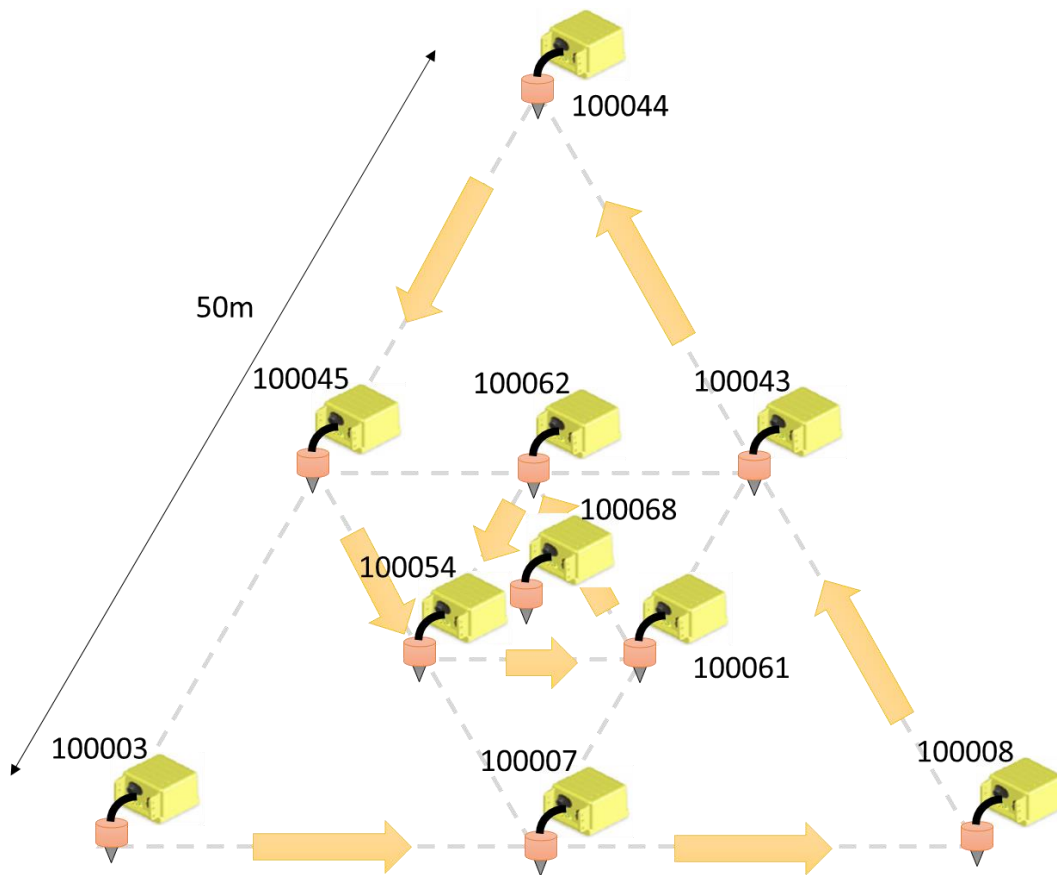


Figure 21.1 Nested triangles of 10 receivers.

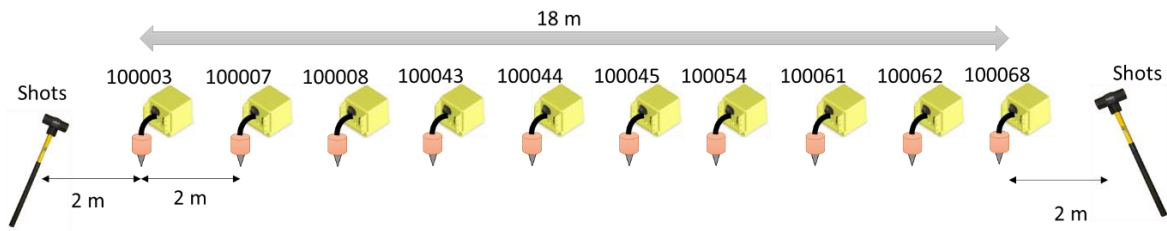


Figure 21.2 Linear array of 10 receivers with 2 m spacings





**Appendix A : Confirm or set up the acquisition parameters using SPACPlus**

A1) Turn off and stop recording for all Atom units.

A2) Plug in a Wi-Fi access point to your PC. Remove the LAN cable and disable your firewalls and Bluetooth.

A3) Connect your PC's Wi-Fi to "atom0000". There should not be "Internet access".

A4) Launch SPACPlus  and click  or select [File]>>[Atom(Wi-Fi)]>> [Start searching for boxes].

A5) Message shown below appears on the window.

Number of ATOM currently respond = 0 (total number in the session = 0)

A6) Turn on all Atom units.

The Atom units automatically being download mode when they locate the access point "atom0000". In this mode, data recording does not start.

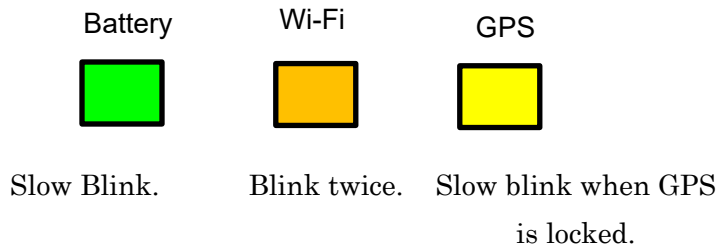



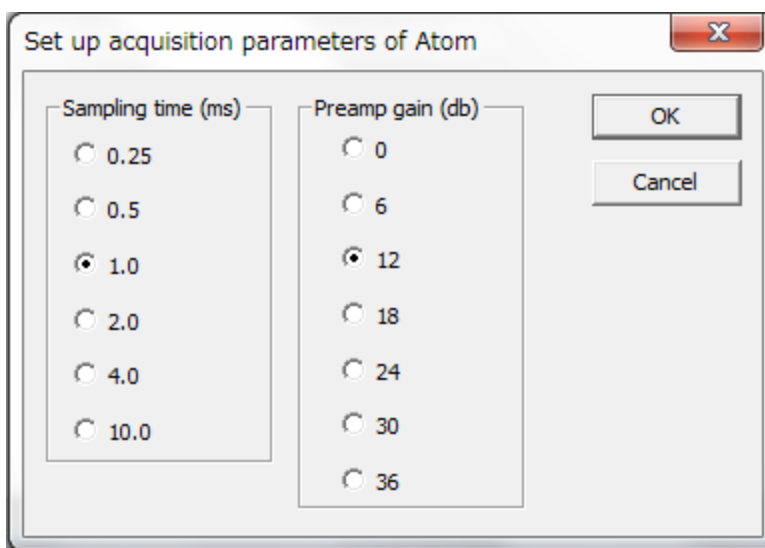
Figure 8.1 LEDs when Atom is ready to be controlled from

A7) In the SPACPlus window, you will see each Atom units' ID, IP address, battery voltage, sampling time and pre-amp gain. The number of Atom units shown in SPACPlus may fluctuate. Note that the default setting of passive surface wave methods is 4.00 ms and 12.0 db,

Number of ATOM currently respond = 2 (total number in the session = 2)  
100049 (192.168.0.102) 3.883V 4.00ms 12.0db  
100050 (192.168.0.101) 3.819V 4.00ms 12.0db

A8) To change the Atom unit's acquisition parameters, click  or select [File]>>[Atom (Wi-Fi)]>> [Set up acquisition parameter].

A9) Select sampling time and preamp gain in a dialog box and click OK.



A10) Confirm changes to the acquisition parameters.

```
Number of ATOM currently respond = 2 (total number in the session = 2)
100049 (192.168.0.102) 3.854V 1.00ms 12.0db
100050 (192.168.0.101) 3.785V 1.00ms 12.0db
```



A11) Acquisition parameter can be confirmed or set up via USB using SPACPlus. Use [File]>>[Atom (USB)]>>[Show Atom AU status] or [Set up acquisition parameter via USB] to confirm or set up acquisition parameters respectively. To use USB, see Appendix C for more details.

## Appendix B : Data download using SPACPlus

B1) Turn off each Atom to stop recording data.

B2) Plug in a Wi-Fi access point to your PC. Remove the LAN cable, turn off your Bluetooth and any firewalls.

B3) Connect your PC's Wi-Fi to "atom0000".

B4) Launch SPACPlus  and click  or select [File]>>[ATOM(Wi-Fi)]>>[Start searching for boxes].

B5) Message shown below appears on the window.

Number of ATOM currently respond = 0 (total number in the session = 0)

B6) 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.

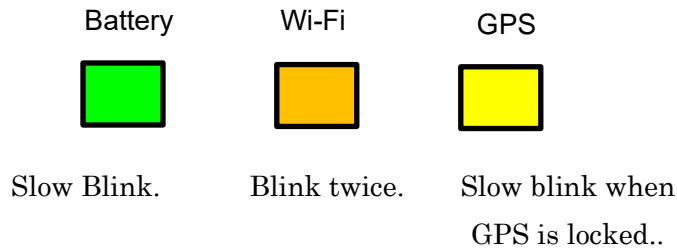



Figure A.1 LEDs when Atom is ready to download

B7) Atom IDs appear on the window of SeisImager (number of Atom units shown in SeisImager may fluctuate).

Number of ATOM currently respond = 2 (total number in the session = 2)  
100049 (192.168.0.102) 3.883V 4.00ms 12.0db  
100050 (192.168.0.101) 3.819V 4.00ms 12.0db

B8) Store data into selected directory by clicking  or selecting [File]>>[Change destination folder].

B9) In SPACPlus click  or select [File]>>[ATOM(Wi-Fi)]>>[Download folders]. Select the date and time in hours to download the waveform files.

Day selection ×

	Year	Month	Day		
<input type="checkbox"/>	2018	6	21	313 files	
<input type="checkbox"/>	2018	6	22	278 files	
<input type="checkbox"/>	2018	6	28	14 files	
<input type="checkbox"/>	2018	6	29	68 files	
<input type="checkbox"/>	2018	7	6	960 files	
<input type="checkbox"/>	2018	7	20	134 files	
<input type="checkbox"/>	2018	7	23	54 files	
<input type="checkbox"/>	2018	7	24	2 files	

Figure B.1 Selection of data to be downloaded.

B 10) Data for multiple dates cannot be downloaded at the same time. Downloaded data have a folder and file structure shown in 11. **Data format.**

During the download process,, progress appears on a display similar to the one shown below.

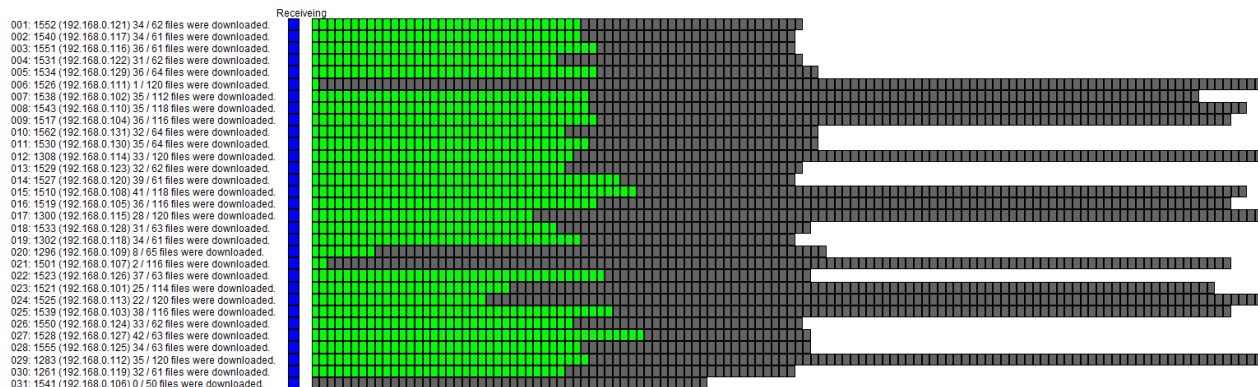


Figure B.2 Example of display during download.

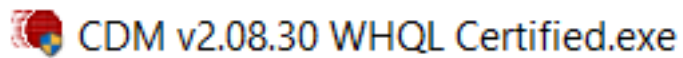
## Appendix C : Data download using SPACPlus via USB

C1) Insulation of USB driver.

Download USB driver from a link shown below.

[https://www.dropbox.com/s/bf38ut5t2ayob8l/CDM\\_2\\_08\\_30.zip?dl=0](https://www.dropbox.com/s/bf38ut5t2ayob8l/CDM_2_08_30.zip?dl=0)

Unzip the downloaded file and double click an installer of USB driver.

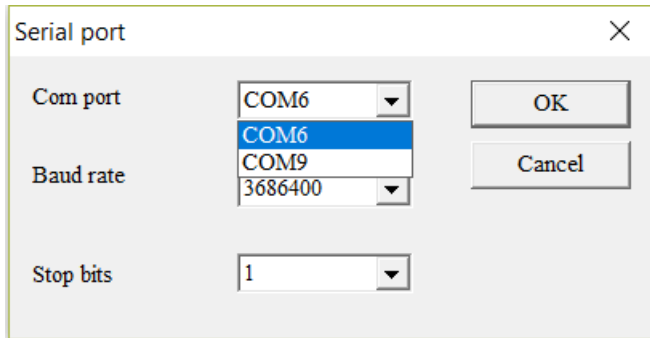


C2) Find a COM port to be used for Atom

Before downloading data using SPACPlus via USB, comport number to which Atom is connected must be figured out. There are two ways to fund the comport number.

A) Use SPACPlus

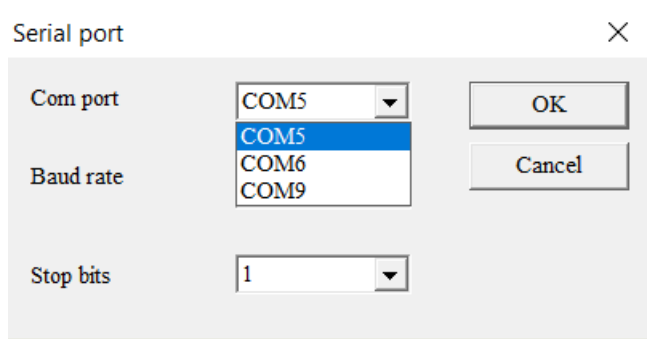
Before connecting Atom to a PC, launch SPACPlus and select [File]>>[Atom (USB)]>>[Show Atom AU status]. A dialog box shows currently available serial ports (COM6 and COM9 in example shown below).



Close SPACPlus.

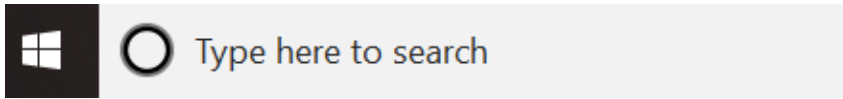
Connect an Atom to the PC by an USB cable and launch SPACPlus again.

Select [File]>>[Atom (USB)]>>[Show Atom AU status] and new comport (COM5 in example shown below) indicates the comport number Atom is attached.

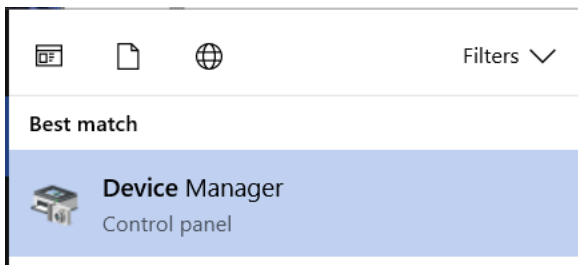


B) Use device manager

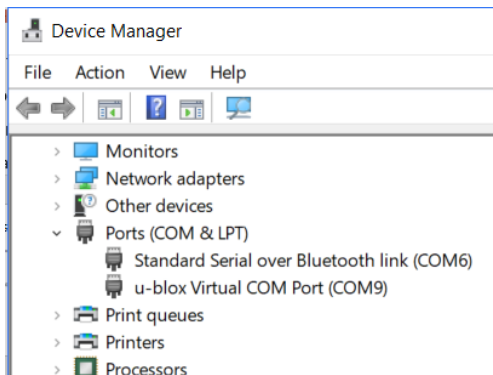
To find and launch device manager, put "device manager" in windows search.



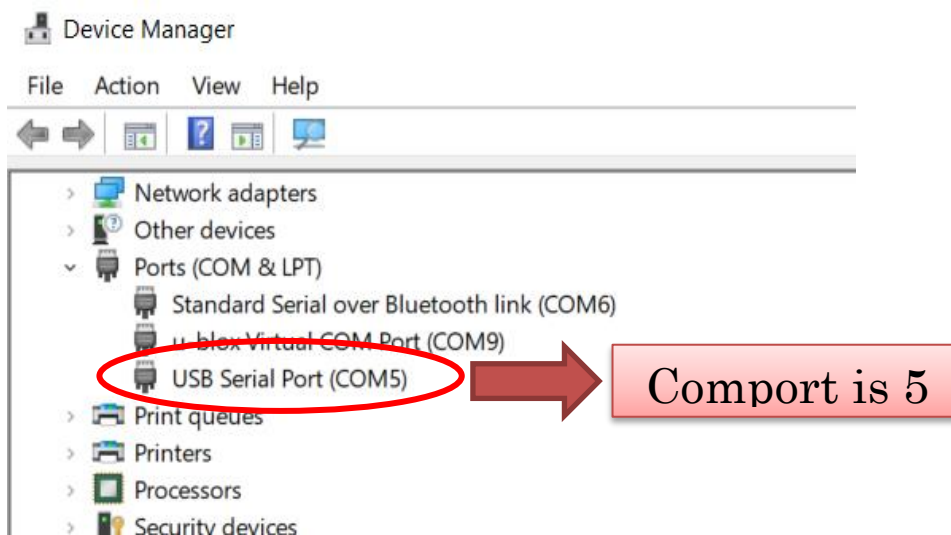
Launch device manager.



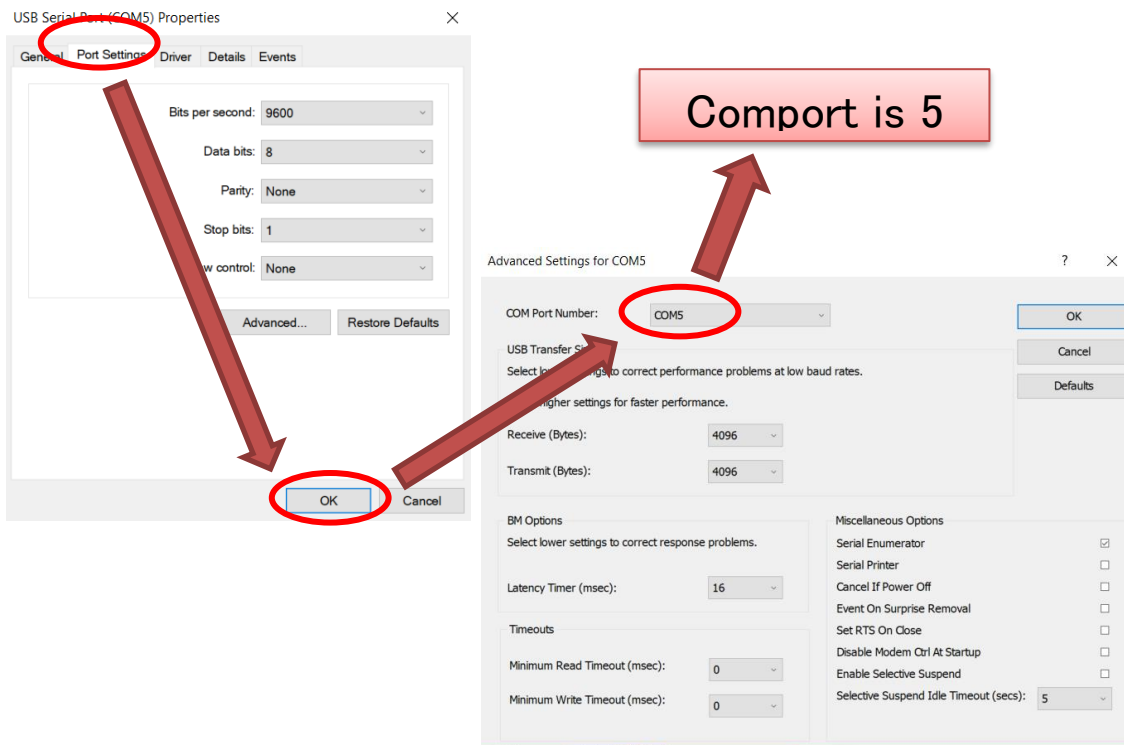
Device manager appears as shown below before plug in USB/charge cable to Atom.



Plug in USB/charge cable to Atom and new comport for Atom appears.



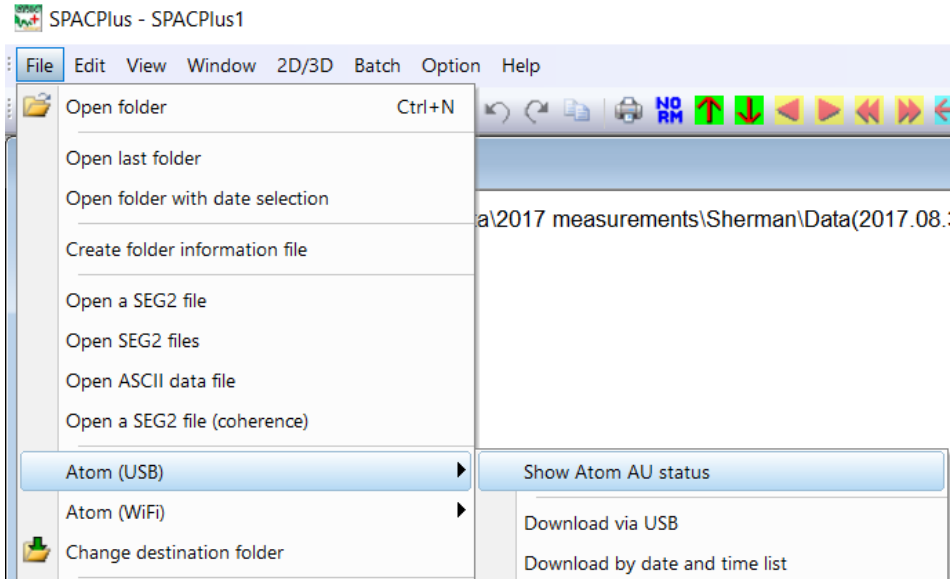
If comport number is not shown in the device manager, right click the comport for Atom and show "Properties".



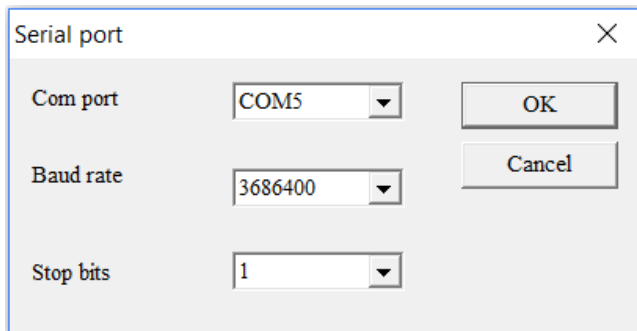


### C3) Show Atom AU status by SPACPlus

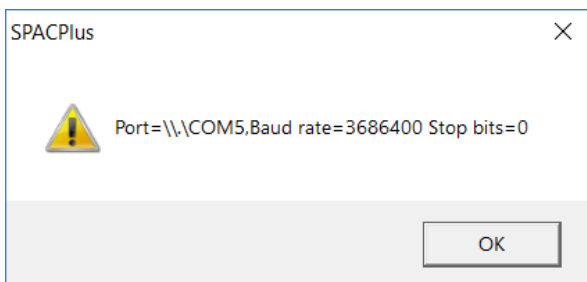
It is better to show the Atom AU status to confirm the connection and status of Atom unit before downloading data. Launch SPACPlus and select [File]>>[Atom (USB)]>>[Atom AU status"] to show Atom SU status.



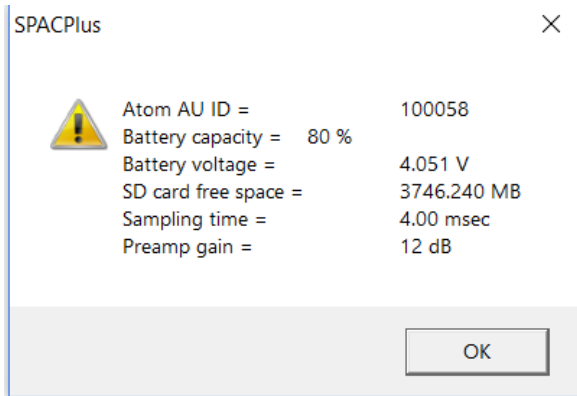
Select comport and set baud rate to 3686400.



Message shown below implies that the comport was successfully opened.

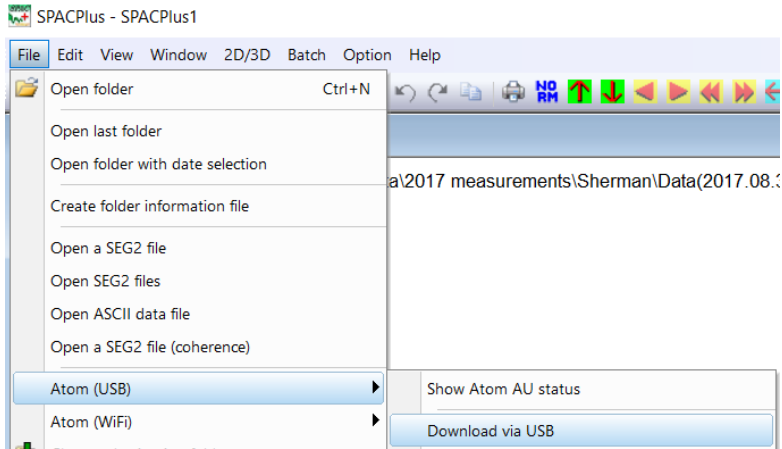


Click "OK" and Atom AU status appears.

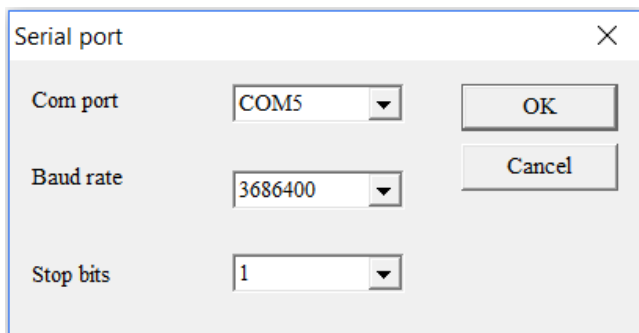


#### C4) Download data from Atom AU

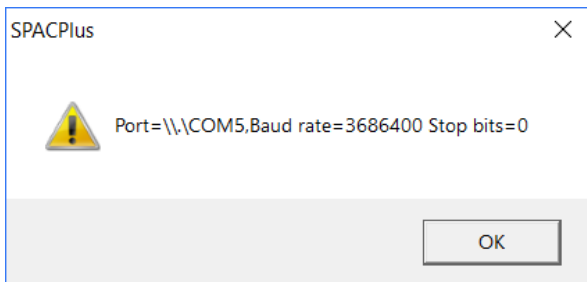
Select [File]>>[Atom (USB)]>>[Download via USB] to download data.



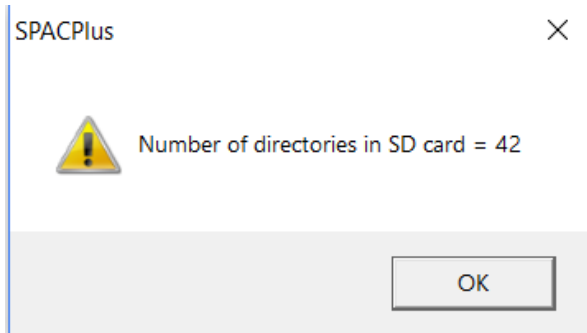
Select comport and set baud rate to 3686400.



Message shown below implies that the comport was successfully opened.



Number of directories appears.



Selection of data is the same as Wi-Fi.

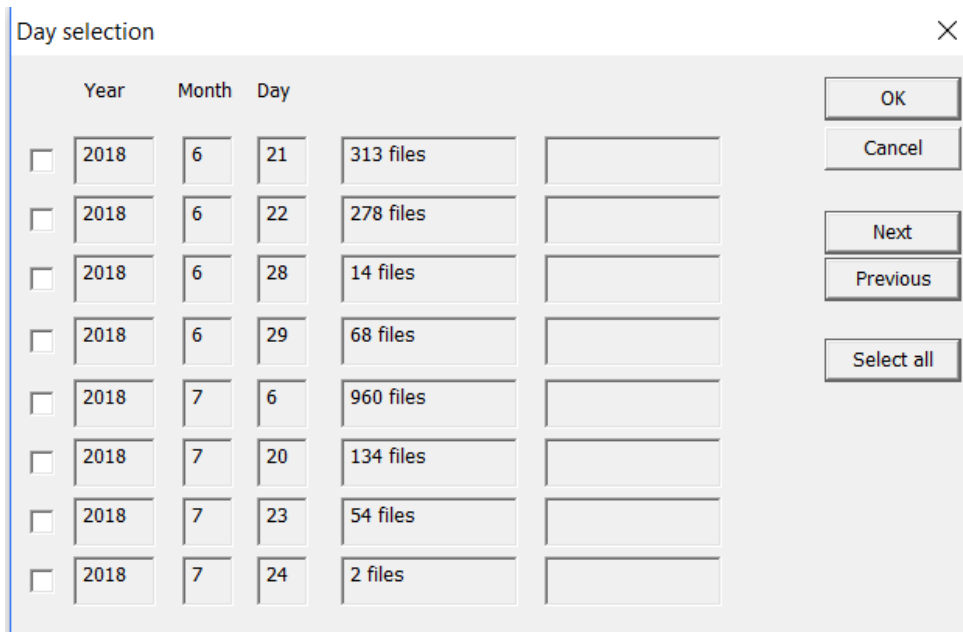


Figure C.1 Selection of data to be downloaded.

## Appendix D : Raw data format

### D1) Configuration of the data file

The data file is configured using the header part and data part. In the header part, the measurement conditions etc. are recorded in the text format, and in the data part, the measurement data is stored in the binary format.

Header part (text) 512 Bytes
Data part (binary)

### D2) Format

#### Header part 512 Bytes

Address	Number of bytes	Example	Description
0	6	Atom	Atom file header
6	2	CR-LF	Carriage return / Line feed
8	6	100025	Serial number (ID)
14	2	CR-LF	Carriage return / Line feed
16	4	1.00	Version of the header
20	2	CR-LF	Carriage return / Line feed
22	4	0512	Size of the header (byte)
26	2	CR-LF	Carriage return / Line feed
28	4	0016	Size of 1 datum (byte)
32	2	CR-LF	Carriage return / Line feed
34	2	00	00 (fixed)
36	2	CR-LF	Carriage return / Line feed
38	6	100025	Serial number (ID)
44	2	CR-LF	Carriage return / Line feed
46	1	3	Number of sensors 1, 3
47	2	CR-LF	Carriage return / Line feed
49	1	1	Used sensor 0: Internal, 1: External
50	2	CR-LF	Carriage return / Line feed
52	2	24	Number of bits of A/D conversion

Address	Number of bytes	Example	Description
54	2	CR-LF	Carriage return / Line feed
56	5	0000	Input range Vp-p (mV)
61	2	CR-LF	Carriage return / Line feed
63	3	010	Data sampling interval (ms) 002, 004, 010, 020, 050
66	2	CR-LF	Carriage return / Line feed
68	3	001	ch-x gain 001, 002, 004, 008, 016, 032, 064
71	2	CR-LF	Carriage return / Line feed
73	3	001	ch-y gain 001, 002, 004, 008, 016, 032, 064
76	2	CR-LF	Carriage return / Line feed
78	3	001	ch-z gain 001, 002, 004, 008, 016, 032, 064
81	2	CR-LF	Carriage return / Line feed
83	3	OFF	OFF(fixed)
86	2	CR-LF	Carriage return / Line feed
88	10	YYYY/MM/DD	Measurement start year, month, and day
98	2	CR-LF	Carriage return / Line feed
100	8	hh:mm:ss	Measurement start time
108	2	CR-LF	Carriage return / Line feed
110	62		Observation name. Alphameric characters and symbols. Blank is a space (0 x 20)
172	2	CR-LF	Carriage return / Line feed
174	62		Observation point. Alphameric characters and symbols. Blank is a space (0 x 20)
236	2	CR-LF	Carriage return / Line feed
238	6	+00 : 00	Time difference from UTC
244	2	CR-LF	Carriage return / Line feed
246	11	Nddmm.mmmmm	Latitude N or S, dd: degree, mm.mmmmm: minute
257	2	CR-LF	Carriage return / Line feed
259	12	Edddmm.mmmmm	Longitude E or W, ddd: degree, mm.mmmmm: minute
271	2	CR-LF	Carriage return / Line feed

Address	Number of bytes	Example	Description
273	8	+0000.00	Sea level altitude (m)
281	2	CR-LF	Carriage return / Line feed
283	6	+25.00	Temperature before measurement (°C)
289	2	CR-LF	Carriage return / Line feed
291	6	+25.00	Temperature after measurement (°C)
297	2	CR-LF	Carriage return / Line feed
299	16	JA-40GA	Name of the used sensor. Alphameric characters and symbols.
315	2	CR-LF	Carriage return / Line feed
317	3	008	X-axis, Y-axis pre-amp gain
320	2	CR-LF	Carriage return / Line feed
322	3	008	Z-axis pre-amp gain
325	2	CR-LF	Carriage return / Line feed
327	183	...	Space (0x20)
510	2	CR-LF	Carriage return / Line feed

Data part 1 measurement is 16 Bytes (3 component data)

Address	Number of bytes	Item	Remark
0	4	ch-x (E-W)	A/D conversion value (little endian)
4	4	ch-y (N-S)	A/D conversion value (little endian)
8	4	ch-z (Vertical)	A/D conversion value (little endian)
12	2	Status flag	See status flag shown in below
14	2	Reserved	0x0000

Data part 1 measurement is 4 Bytes (1 component data)

Address	Number of bytes	Item	Remark
0	4	ch-z (U-D)	A/D conversion value (little endian)

Status flag

Byte 1								Byte 0							
15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
Not used									Not used			Number of GPS satellites			



## Appendix E : Specifications

The specifications of Atom are shown below.

Model	1 C	3 C
Channels:	1 channel per AU.	3 channel per AU.
A/D:	32-bit (24-bit result).	
Dynamic Range:	128 dB measured at 2 ms, 12 dB.	
Bandwidth:	0.2 Hz to 1,650 Hz.	
Distortion (THD):	0.001% at 2ms, 0.2 to 25 Hz.	
Common Mode Rejection:	114 dB at 60 Hz.	
Noise Floor:	0.11 $\mu$ V, RFI at 2 ms, 12 dB.	
Maximum Input Signal:	1.6 V, 12 dB; 100 mV, 36 dB.	
Input Impedance:	20 kOhm, 0.01 $\mu$ f.	
Preamplifier Gains:	0, 12, 24, or 36 dB.	
Sample Intervals:	0.25, 0.5, 1, 2, 4, and 10 ms.	1, 2, 4, and 10 ms.
Data Transmission:	Standard 802.11g WiFi; each AU appears as a DHCP client.	
Data Format:	Common Time Blocks (CTBs) saved in proprietary ATM format, ASCII, or SEG-2; miniSEED, SAC, and SAF coming soon.	
Data Storage:	4 GB standard; expandable to 32GB.	8 GB standard; expandable to 32GB.
Geophone Test:	Tap test with LED indicator.	
Ports:	One 2-pin LCK connector for geophone input, one 10-pin connector for battery charger.	One 10-pin connector for geophone input, one 10-pin connector for battery charger.
Power:	Internal 10Ah NiMH battery pack.	Internal 9Ah NiMH battery pack.
Charger:	Single cable for one AU or multi-port charger for 6 AUs; charging current of 1.5 Amps per AU, 9 hours for full charge.	
Environmental:	Operates from -20°C to +55°C (-4°F to +131°F).	
Waterproof and dustproof.	Passes MIL810E/F vibration test and 14-point	Equivalent to IP68