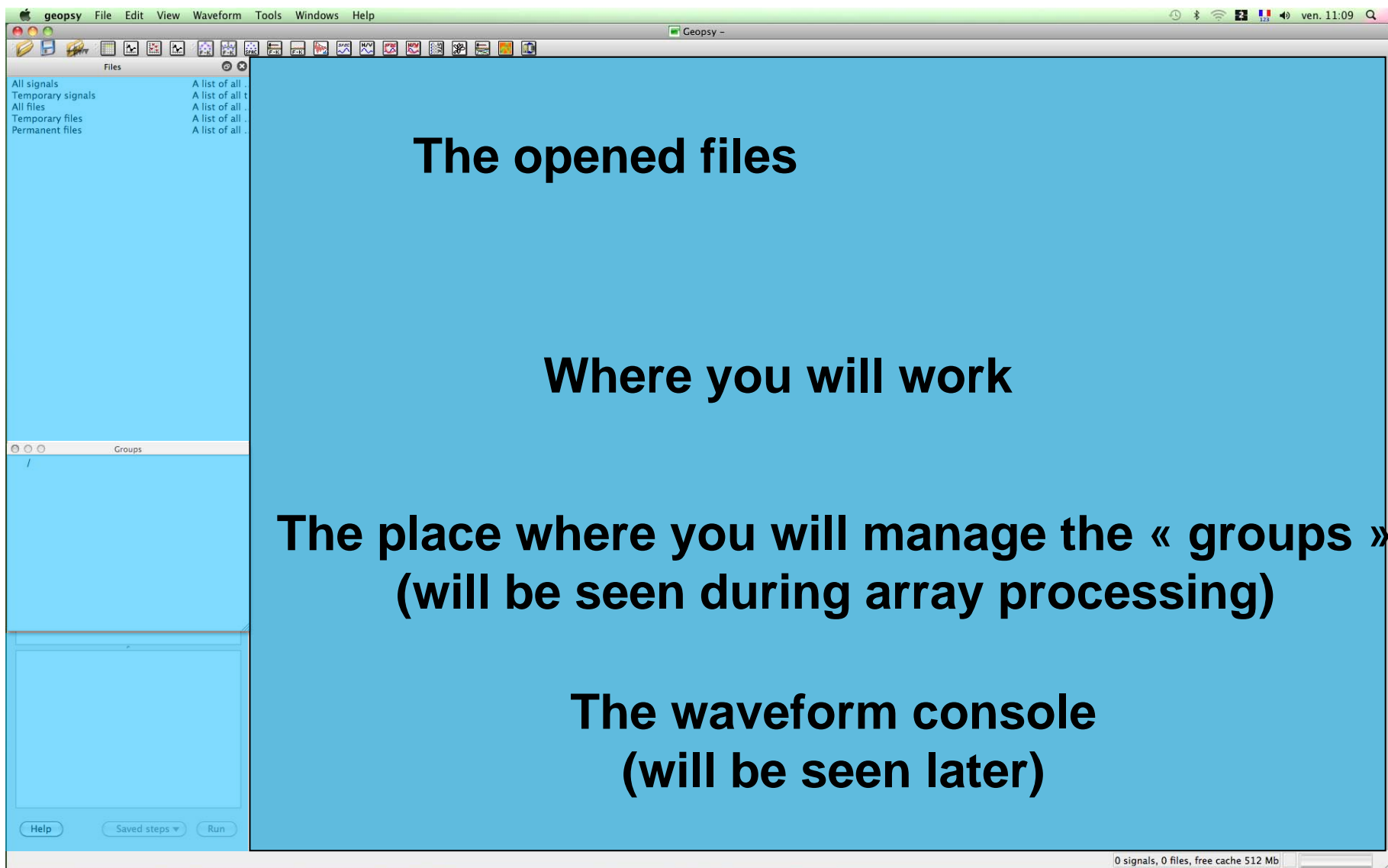


Using Ambient Vibration Techniques for Site Characterisation

Single station measurement: H/V

TUTORIAL

Start Geopsy



Start Geopsy

The screenshot shows the Geopsy software interface. The top menu bar includes 'geopsy', 'File', 'Edit', 'View', 'Waveform', 'Tools', 'Windows', and 'Help'. Below the menu is a toolbar with various icons. A 'Files' panel on the left lists 'All signals', 'Temporary signals', 'All files', 'Temporary file', and 'Permanent file'. A 'Groups' panel is also visible. The main workspace is a large grey area. At the bottom, there are buttons for 'Help', 'Saved steps', and 'Run'. The status bar at the bottom right shows '0 signals, 0 files, free cache 512 Mb'.

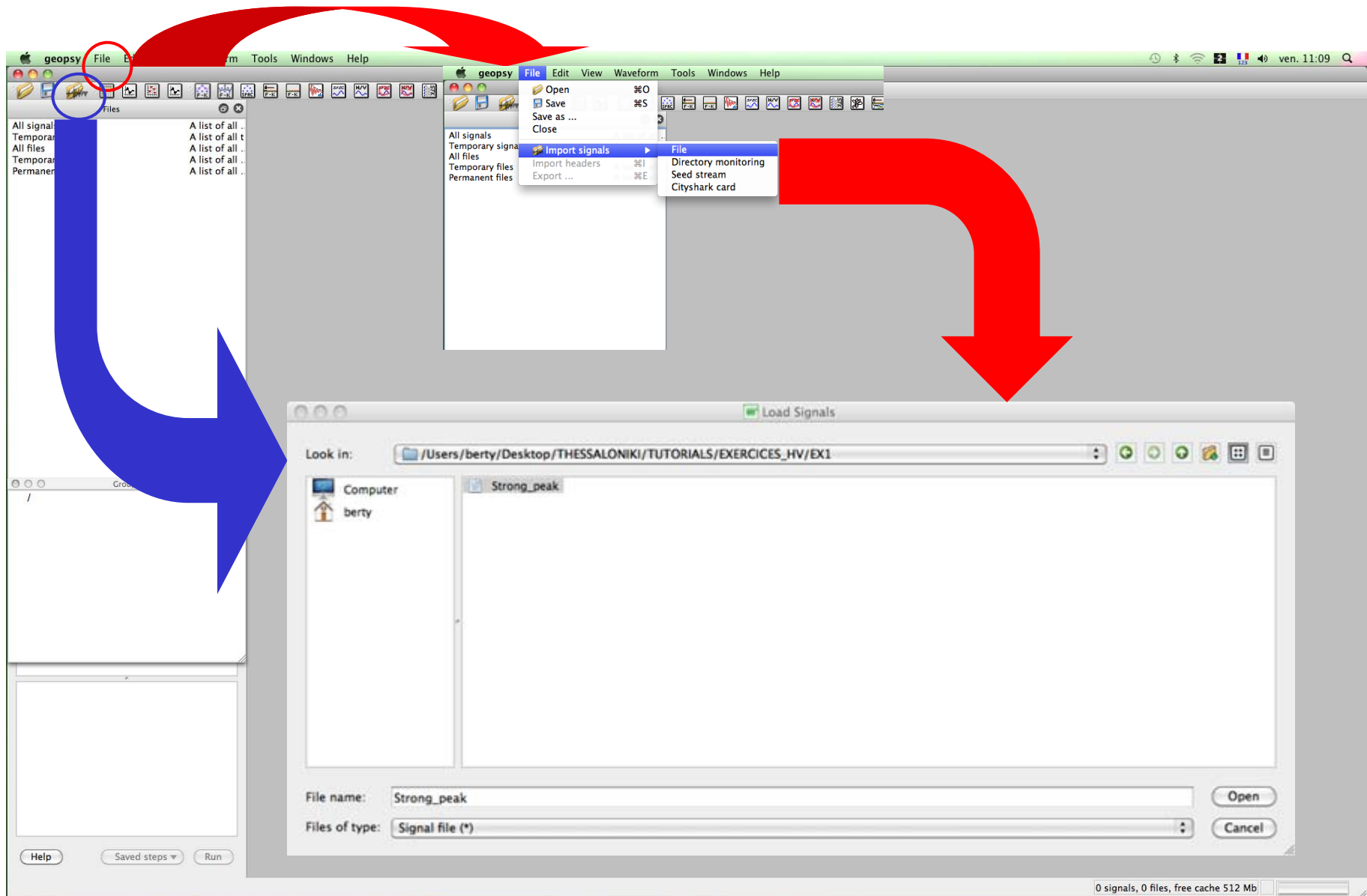
Open files
 (table, waveform, map [if coordinates])

**Database
 (open, save)**

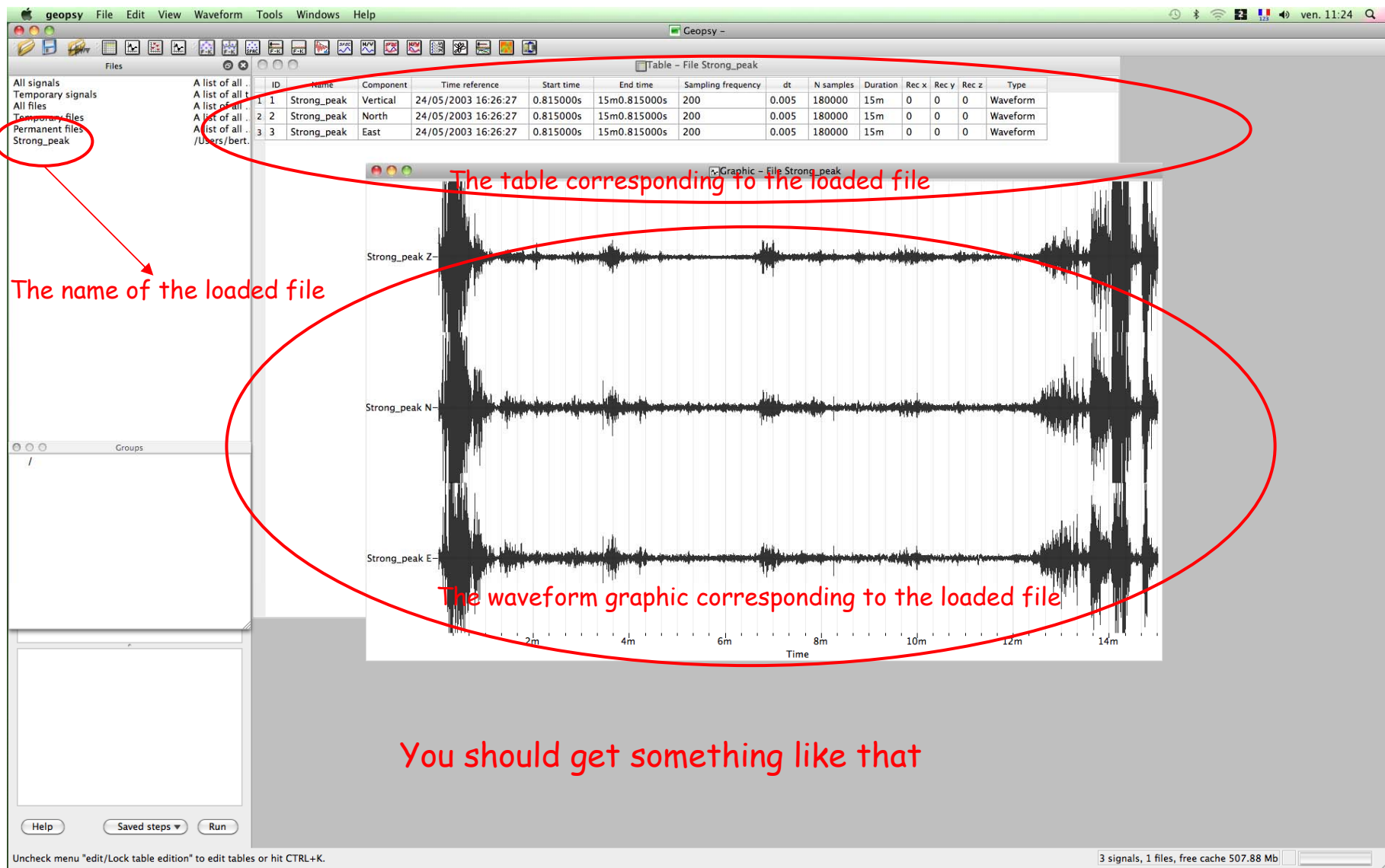
**Processing tools
 (H/V, spectrum, FK, HRFK, damping...)**

Loading signals

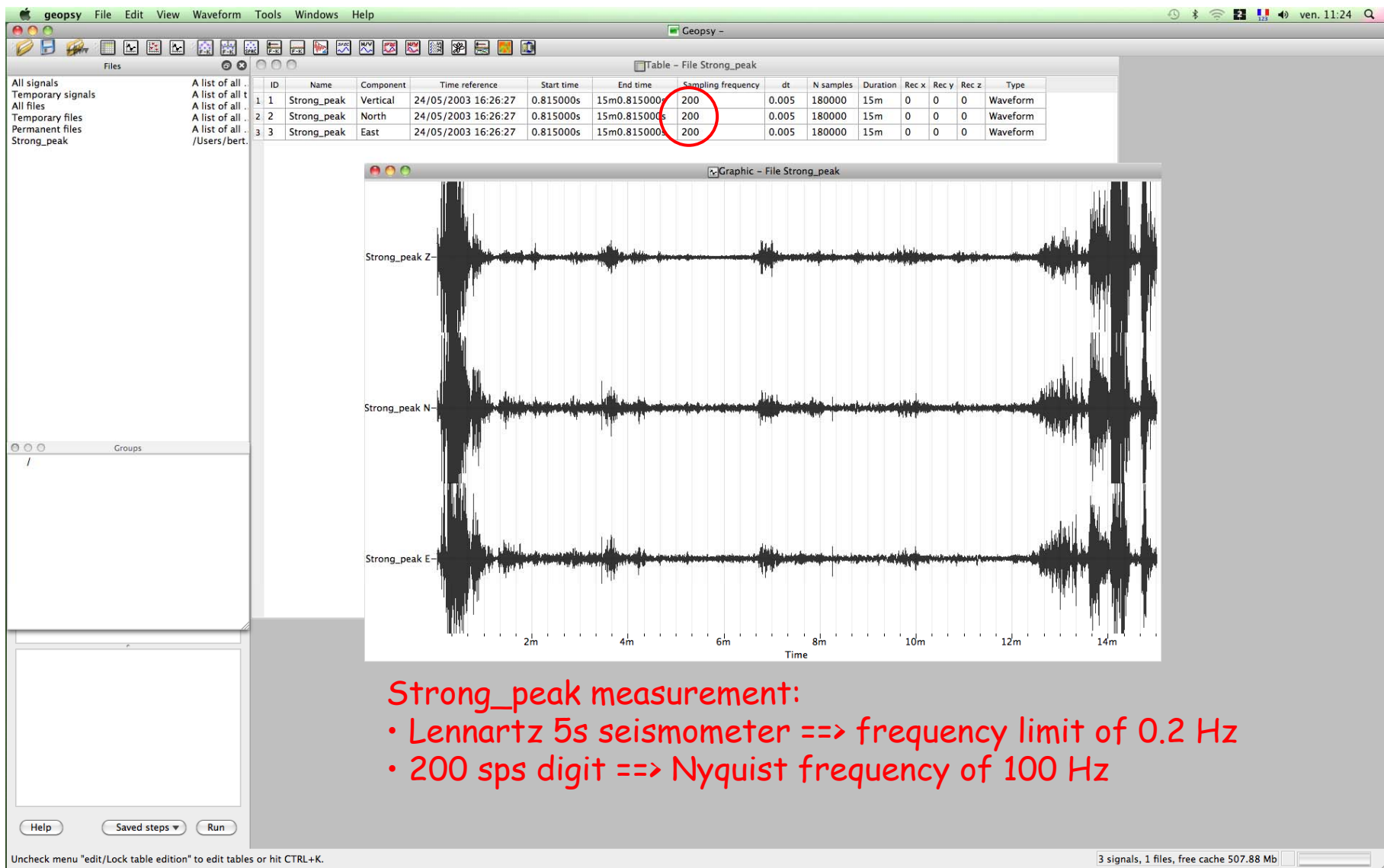
Directory EXERCISES_HV/EX01



Loading signals Directory EXERCISES_HV/EX01

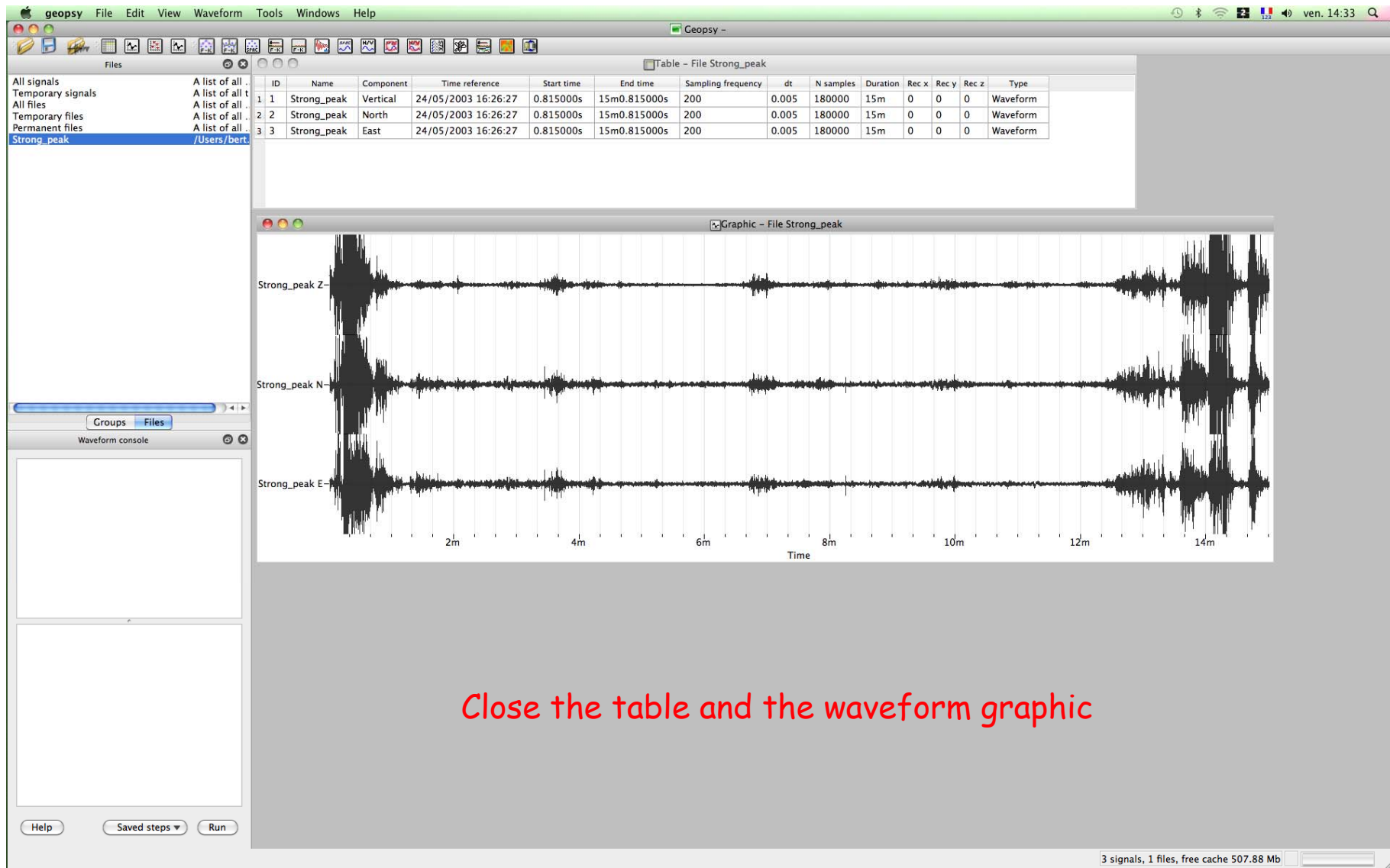


Loading signals Directory EXERCISES_HV/EX01



Manipulating the data

Possibility to open table and graphic



Close the table and the waveform graphic

Manipulating the data

Possibility to open table and graphic 1

The screenshot shows the Geopsy software interface. On the left, the 'File' menu is open, and the 'Strong_peak' file is selected. A red arrow points from the 'Strong_peak' file name in the file list to the 'Table - File Strong_peak' window. Another red arrow points from the 'Strong_peak' file name to the 'Graphic - File Strong_peak' window. The 'Table - File Strong_peak' window displays a table with the following data:

ID	Name	Component	Time reference	Start time	End time	Sampling frequency	dt	N samples	Duration	Rec x	Rec y	Rec z	Type
1	Strong_peak	Vertical	24/05/2003 16:26:27	0.815000s	15m0.815000s	200	0.005	180000	15m	0	0	0	Waveform
2	Strong_peak	North	24/05/2003 16:26:27	0.815000s	15m0.815000s	200	0.005	180000	15m	0	0	0	Waveform
3	Strong_peak	East	24/05/2003 16:26:27	0.815000s	15m0.815000s	200	0.005	180000	15m	0	0	0	Waveform

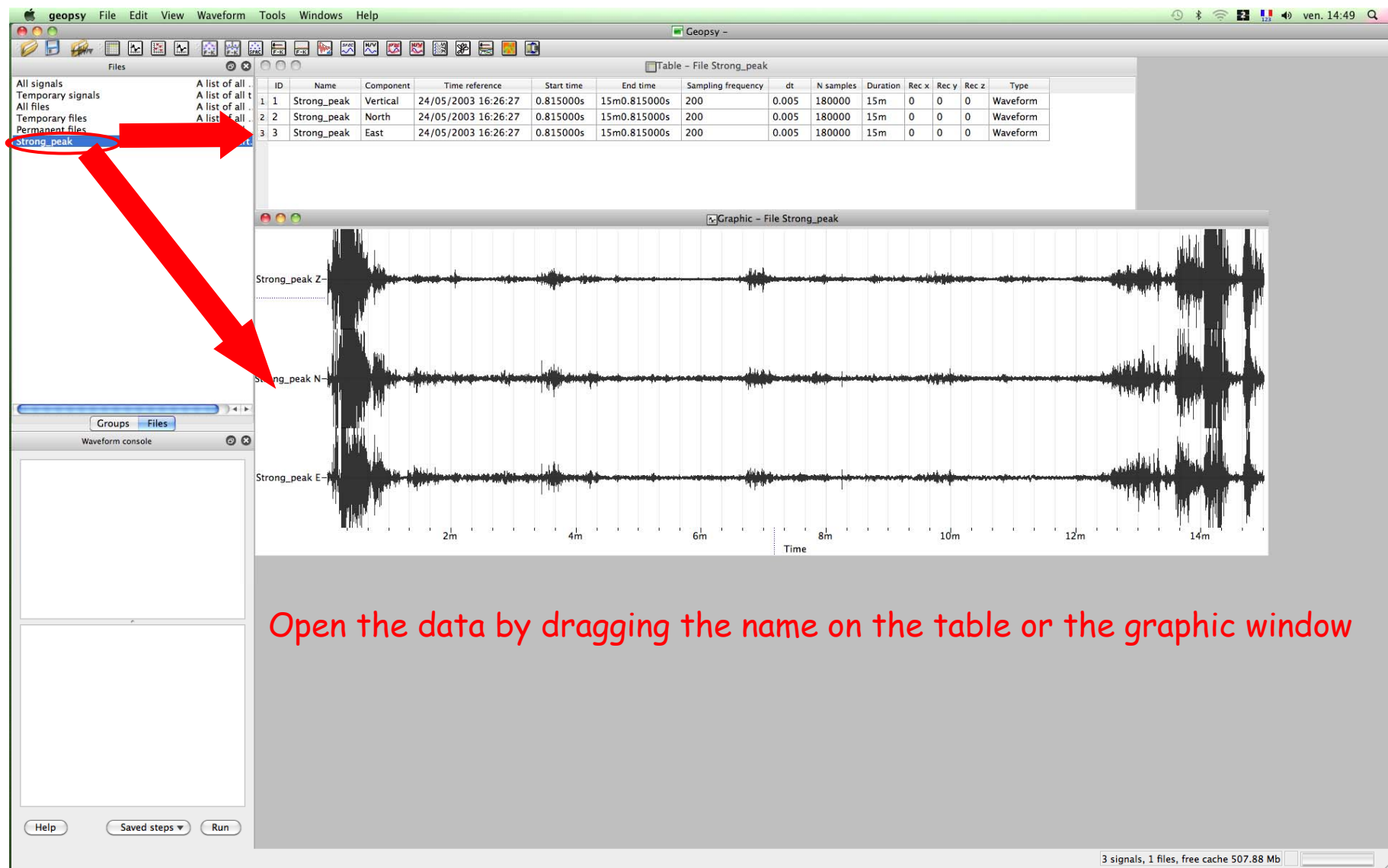
The 'Graphic - File Strong_peak' window displays three stacked waveform plots labeled 'Strong_peak Z', 'Strong_peak N', and 'Strong_peak E'. The x-axis is labeled 'Time' and ranges from 0 to 14m. The y-axis represents amplitude. A red arrow points from the 'Strong_peak' file name in the file list to the 'Graphic - File Strong_peak' window.

Open the table by dragging the name on the table icon

Open the graphic by dragging the name on the graphic icon

Manipulating the data

Possibility to open table and graphic 1 2



Manipulating the data

Possibility to open table and graphic

1

2

3

geopsy File Edit View Waveform Tools Windows Help

Geopsy -

Files

All signals: A list of all...
Temporary signals: A list of all...
All files: A list of all...
Temporary files: A list of all...
Permanent files: A list of all...
Strong_peak: /Users/bert...

ID	Name	Component	Time reference	Start time	End time	Sampling frequency	dt	N samples	Duration	Rec x	Rec y	Rec z	Type
1	Strong_peak	Vertical	24/05/2003 16:26:27	0.815000s	15m0.815000s	200	0.005	180000	15m	0	0	0	Waveform
2	Strong_peak	North	24/05/2003 16:26:27	0.815000s	15m0.815000s	200	0.005	180000	15m	0	0	0	Waveform
3	Strong_peak	East	24/05/2003 16:26:27	0.815000s	15m0.815000s	200	0.005	180000	15m	0	0	0	Waveform

Dragging a line (or more) from the table to the graphic window, add the selected data to the waveform graphic

Graphic - File Strong_peak

Strong_peak Z-
Strong_peak N-
Strong_peak E-

Groups Files
Waveform console

Help Saved steps Run

3 signals, 1 files, free cache 507.88 Mb

Dragging the waveforms to the table window, you add all the waveforms data to the table

Manipulating the data

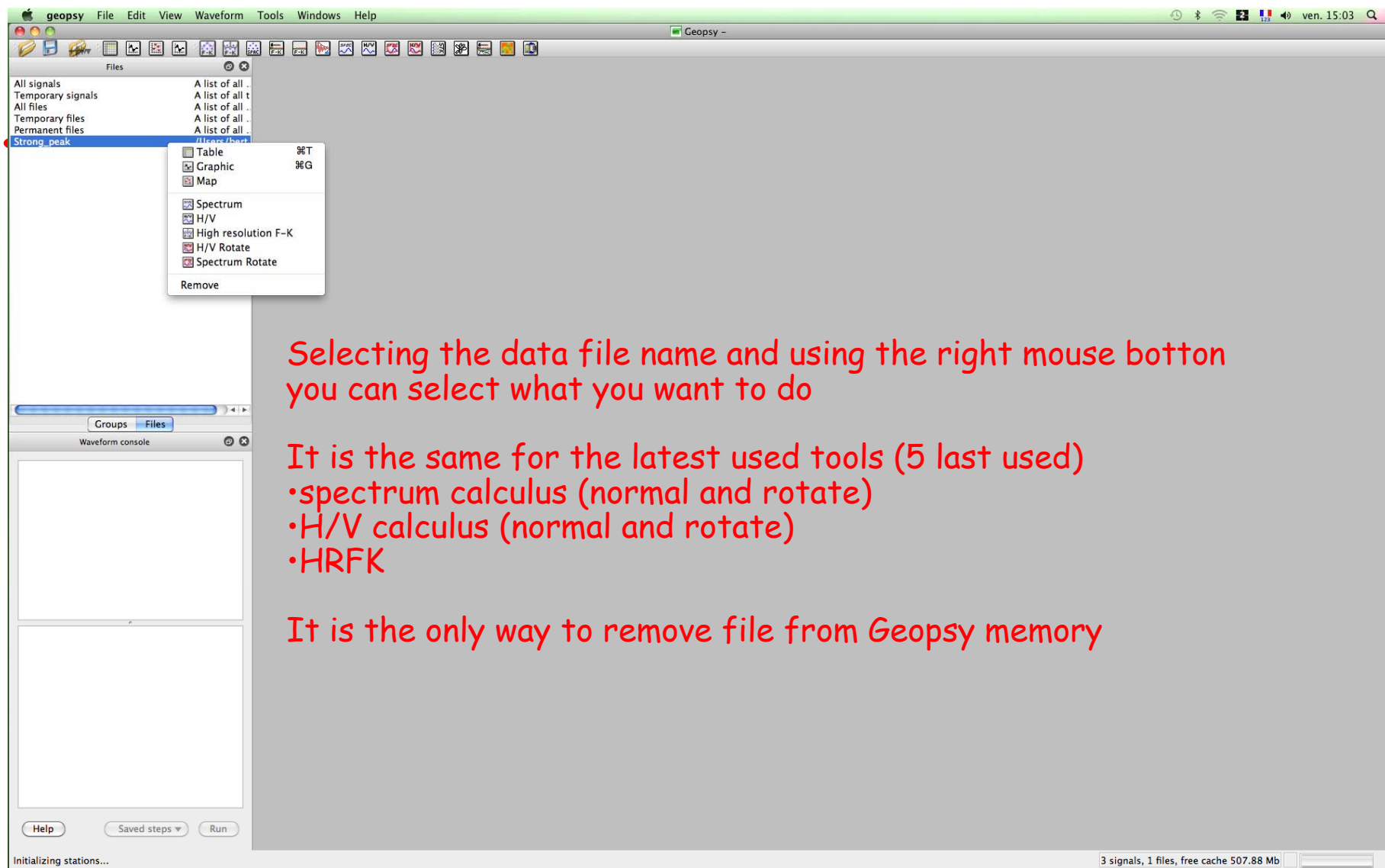
Possibility to open table and graphic

1

2

3

4



Selecting the data file name and using the right mouse button you can select what you want to do

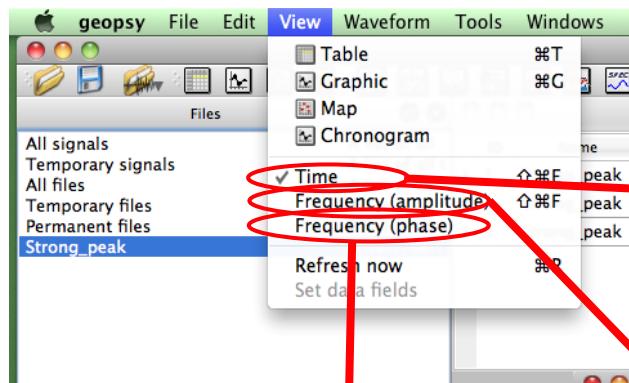
It is the same for the latest used tools (5 last used)

- spectrum calculus (normal and rotate)
- H/V calculus (normal and rotate)
- HRFK

It is the only way to remove file from Geopsy memory

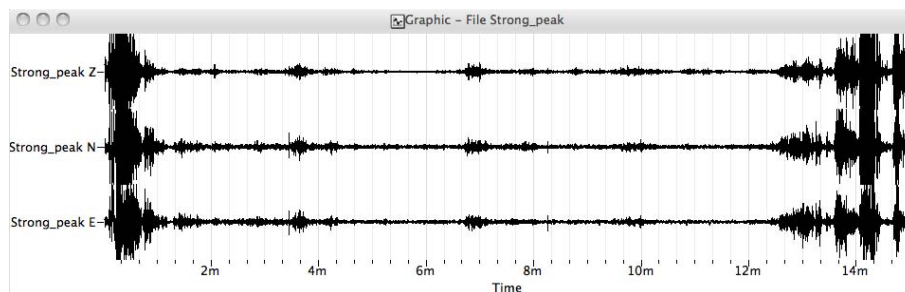
VIEW Menu

HOW TO PRESENT THE DATA

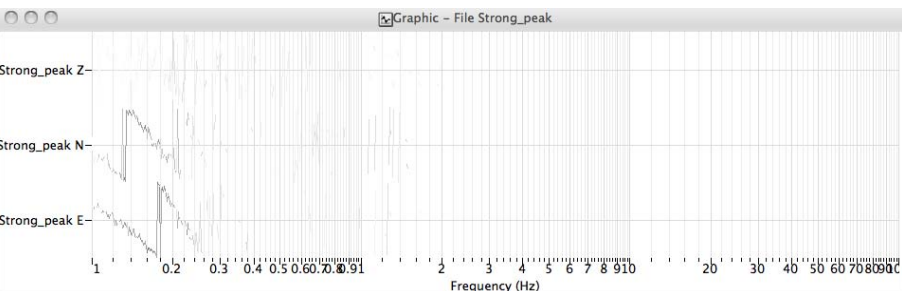


No distortion of the signal, only various ways to present the same thing

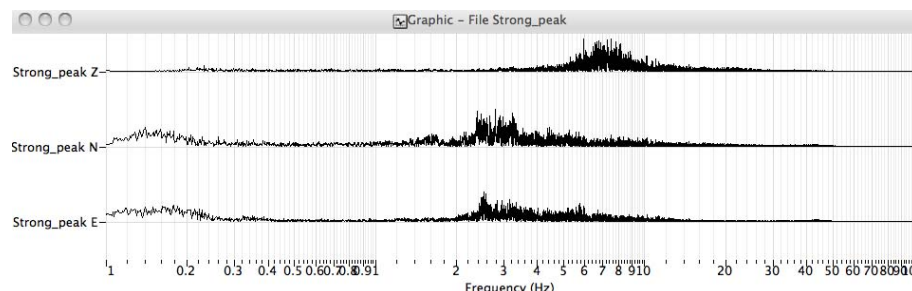
presents the data
• in time series (normal)



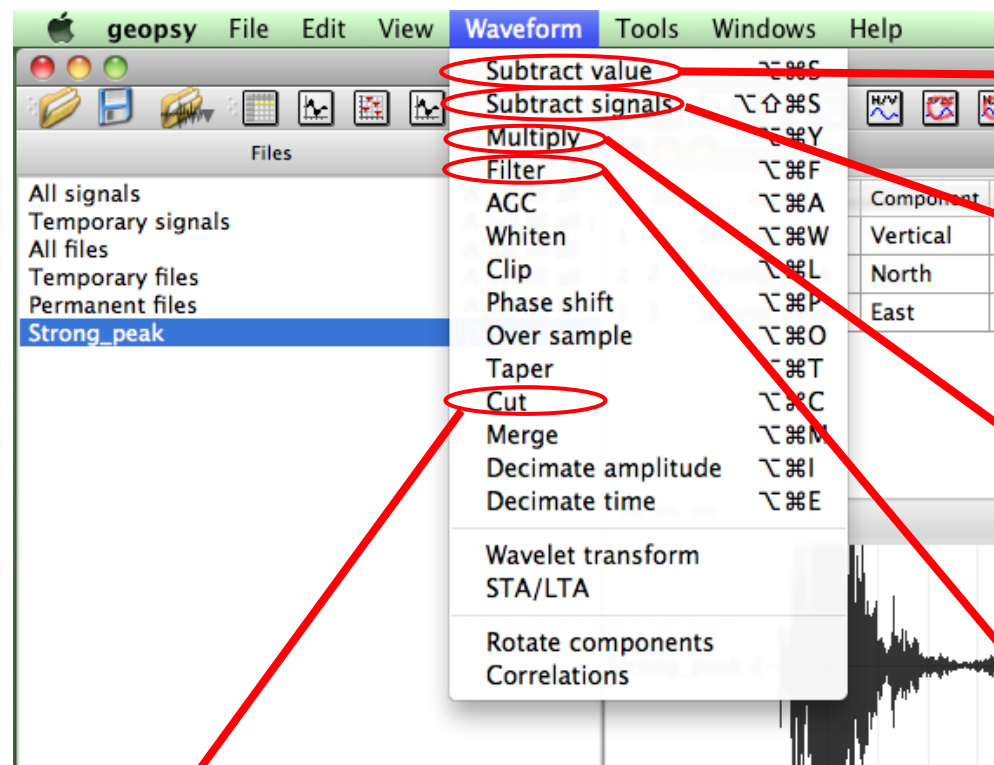
presents the data
• in frequency-phase content



presents the data
• in frequency-amplitude content



WAVEFORM TOOLS (main)



Subtract value: Offset removal
 • given value
 • mean value (of the whole waveform)

Subtract a signal to other signal
 Can be useful for building purposes
 Do the subtraction sample to sample

Multiply the signal amplitude
 by a given value

Cut: allow you to cut the signal
 useful to select specific part of
 the waveform

Frequency filter:
 • high pass
 • low pass
 • band pass
 • band reject

Never forget to use the waveform console

(WINDOWING - GENERAL)

Close all the windows opened

Plot the « Strong_peak » waveform

Select H/V graphic icon => a « H/V toolbox » opens (followed by the file name)

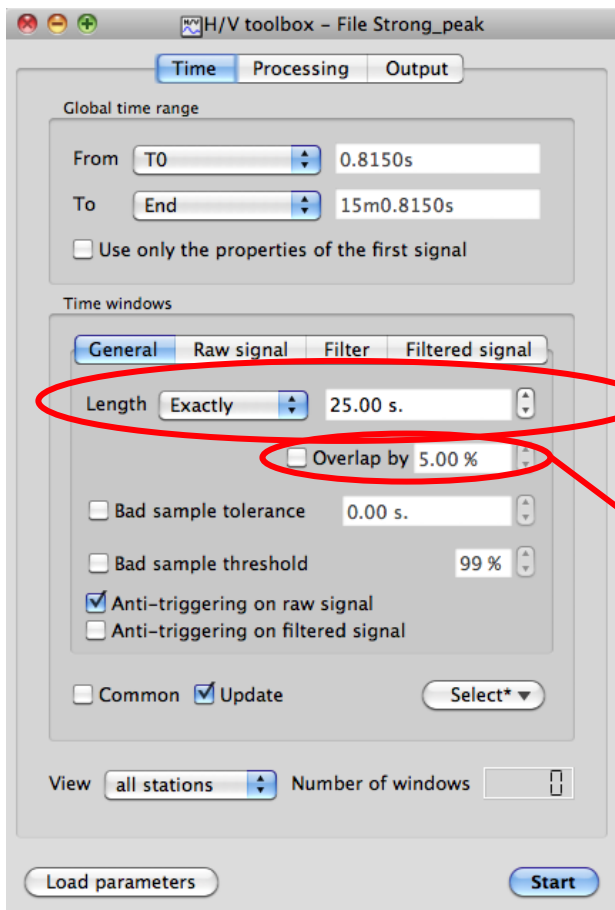
Time (windowing)
Processing (smoothing/type of HV)
Output (graphic/files)

Global time setting tool
Works like the « waveform/Cut » tool
Allows you to reject parts of the signal
(beginning and end)

Windowing setting

Windowing results

Start the computation



Time window length (idea of the geology)

EXACTLY: you give the time window length

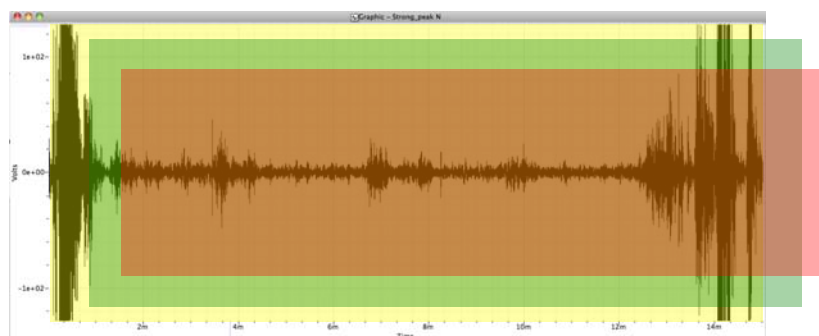
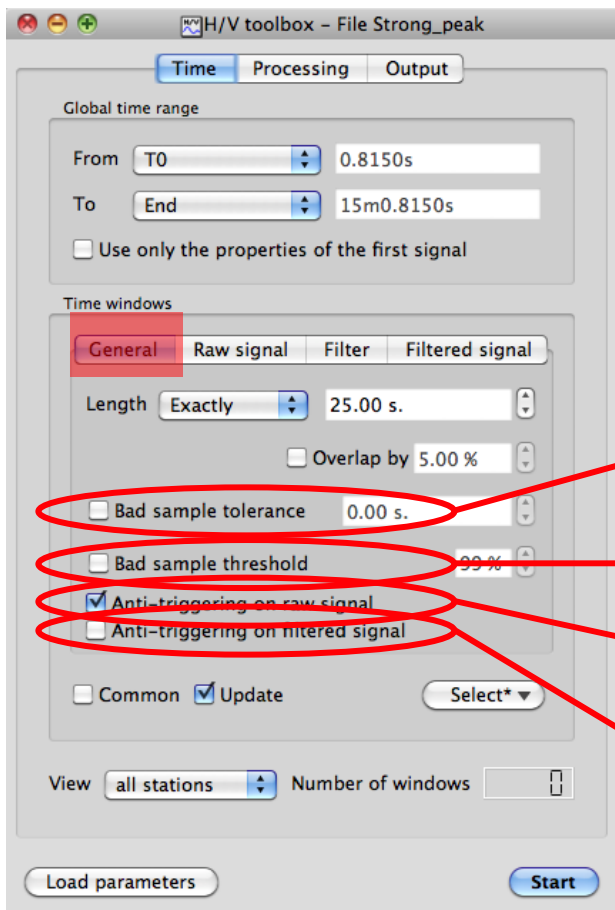
AT LEAST: you give a minimum and a maximum time window length. So a window has the minimum fixed length and increases its length until the maximum fixed length or a sample rejected by the anti-trigger

This option forces the program to define the windows with an overlap (useful if you are short in time recording)

But (10/window length) could not be lower than the natural frequency of the seismometer

→ 25 s time window length allows to analyze until 0.4 Hz
→ 5 s cut-off period seismometer allows to use time window of 50 s maximum length.

$$10/w_l > f_{\text{seismometer}}$$



You allow the anti-trigger to accept some « bad » samples (problem of « glitch » for example)

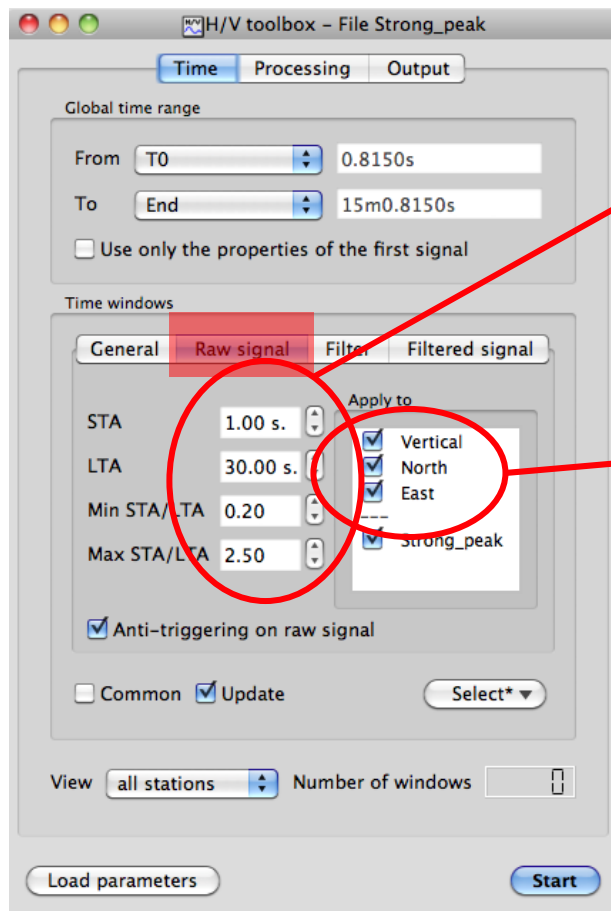
You force the anti-trigger to consider some samples as « bad », introducing a limit in amplitude

The anti-trigger algorithm is applied on the original signal (as fixed)

You apply an anti-trigger algorithm on a filtered signal (as fixed), but the H/V computation is done on the unfiltered signal

All the options can be used at the same time

(WINDOWING - ANTI-TRIGGER)



Define the anti-trigger parameters (STA, LTA, minimum ratio, maximum ratio) Here, the values of 1, 30, .2 and 2.5 are the commonly used values. They can be changed when you want. Do not hesitate to use these parameters, but beware !!!!!

The anti-trigger is applied on the 3 components
Can be useful if you have too heavy noise on one or two components.

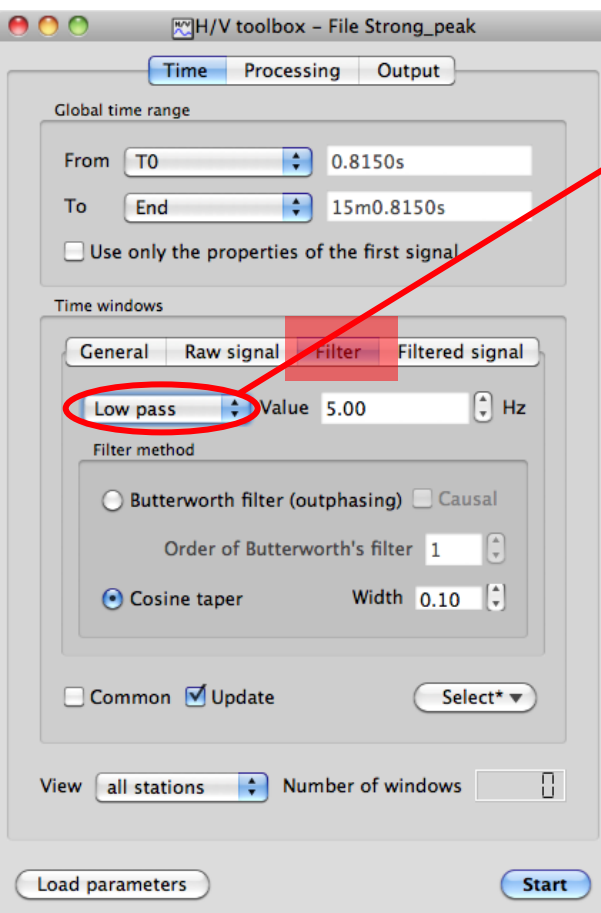
Beneath, you can define where this anti-trigger will be applied (file name)

(WINDOWING - ANTI-TRIGGER USING FILTER OPTION)

Filter and Filtered signal

- allow to use an anti-trigger algorithm on a filtered signal
- can be done with or without normal anti-trigger (on raw signal)

Can be used when the signal presents bursts of energy

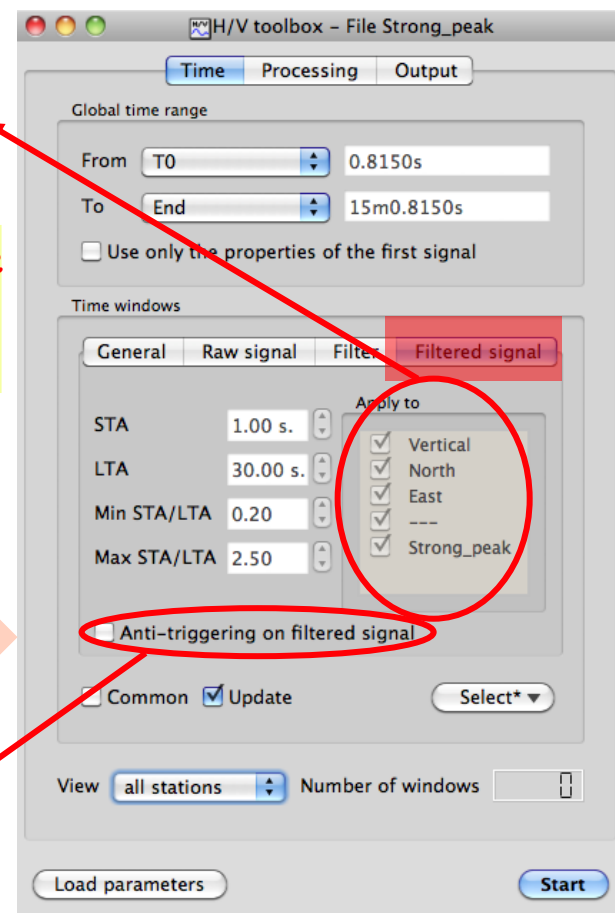


If these parts are grayed, the anti-trigger on **filtered signal** is not used

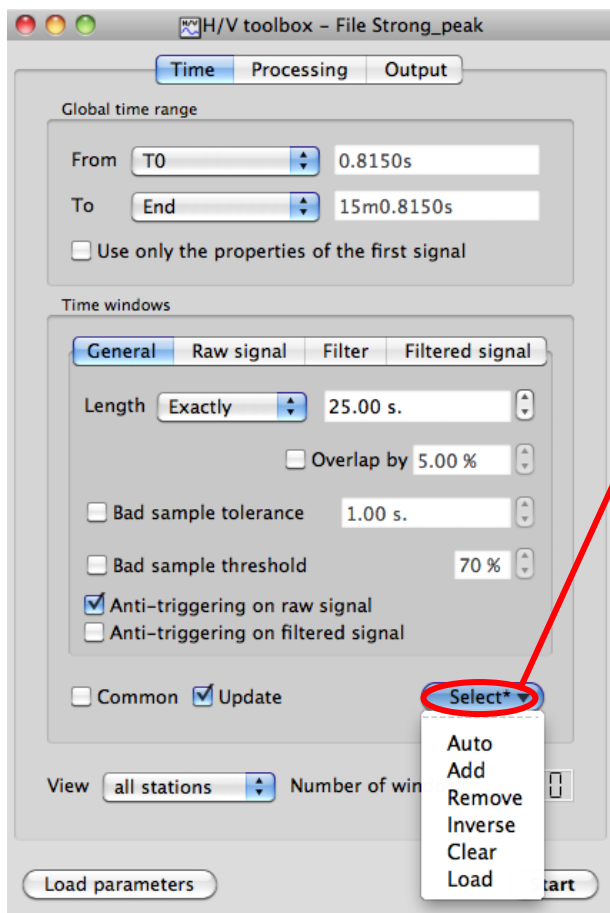
The filter options are the same that on « Waveform-Filter » menu

The « filtered signal » is equal to the LTA/STA options of the raw signal

You can activate the filter option from here



H/V (basic use)



If you clic on « Select », a menu appear with 6 possibilities

- « Auto »: to apply the active windowing options
- « Add »: will be seen later on
- « Remove »: will be seen later on
- « Inverse »: to inverse the windowing
- « Clear »: to clear the windowing (no more windows)
- « Load »: to load a windowing from a file (external file)

If « Select » is followed by a star (*), that means:

- no windowing has been applied (at the beginning for example)
- you have already applied a windowing but you have changed some options without using them

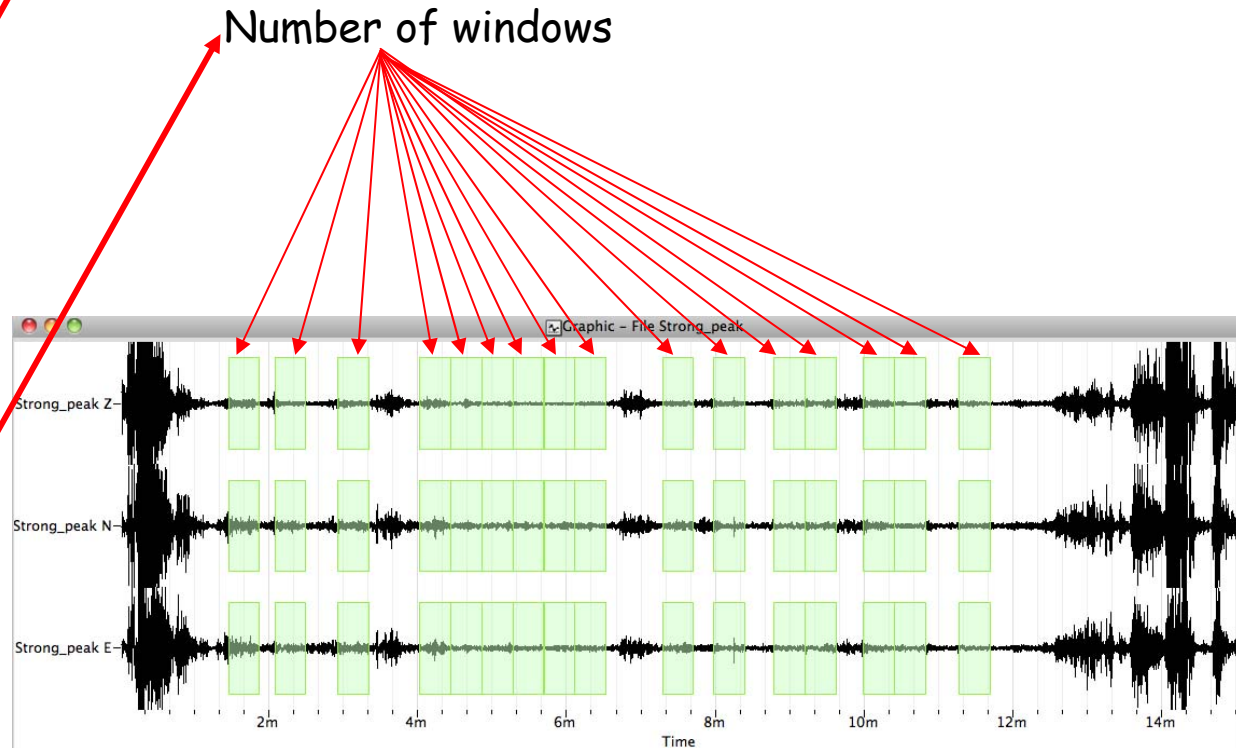
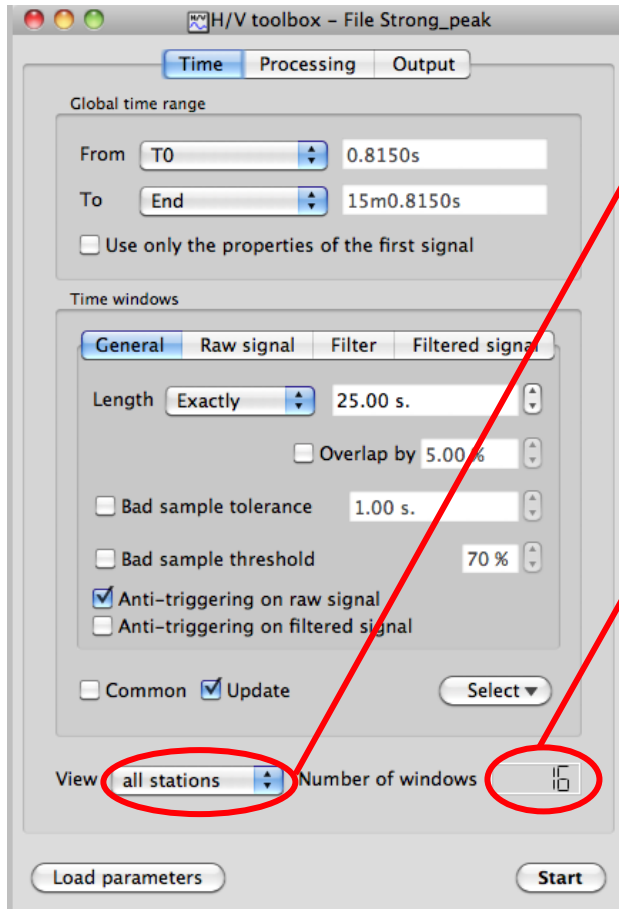
For now, there is only windowing processing, no H/V computation

CLIC ON « AUTO »

H/V (windowing)

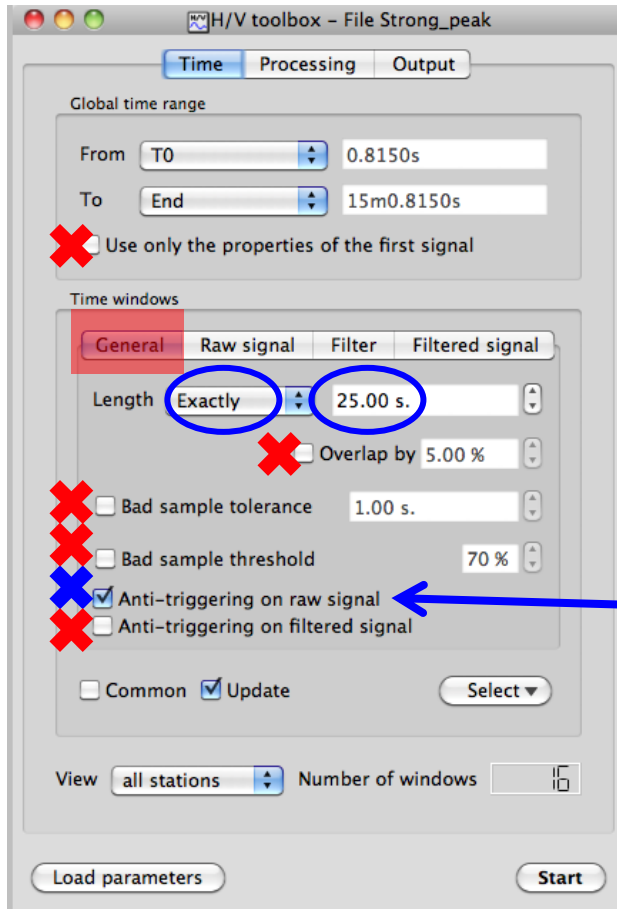
For the moment, there is only windowing processing, no H/V calculus

It is basically for all the stations (3 components rec.)
It can be checked for each record (pop-up menu)



H/V (windowing)

If you do not obtain that, check the options you have

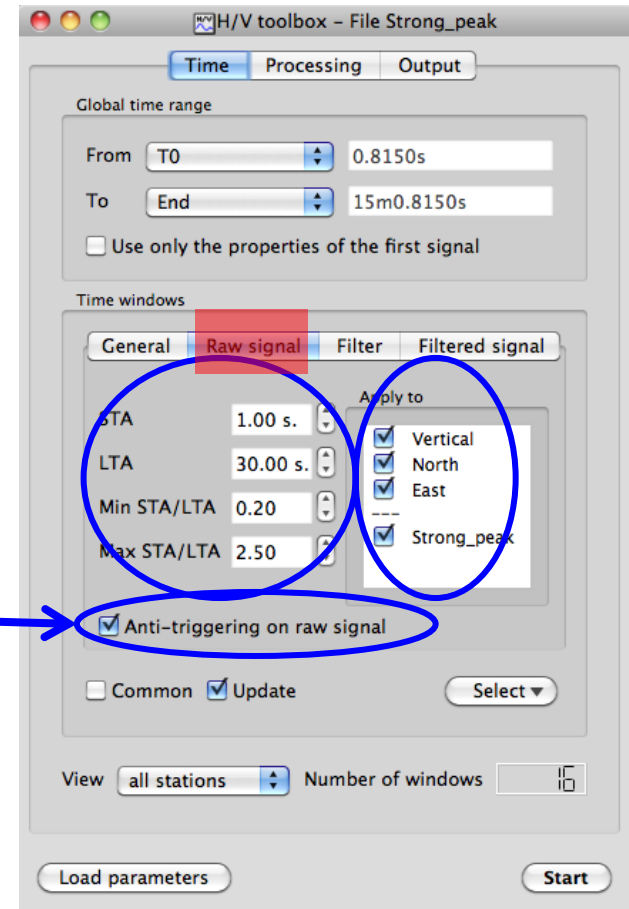


In red: not active option

In blue: active option

Check the values and
in which component
they are applied

the same

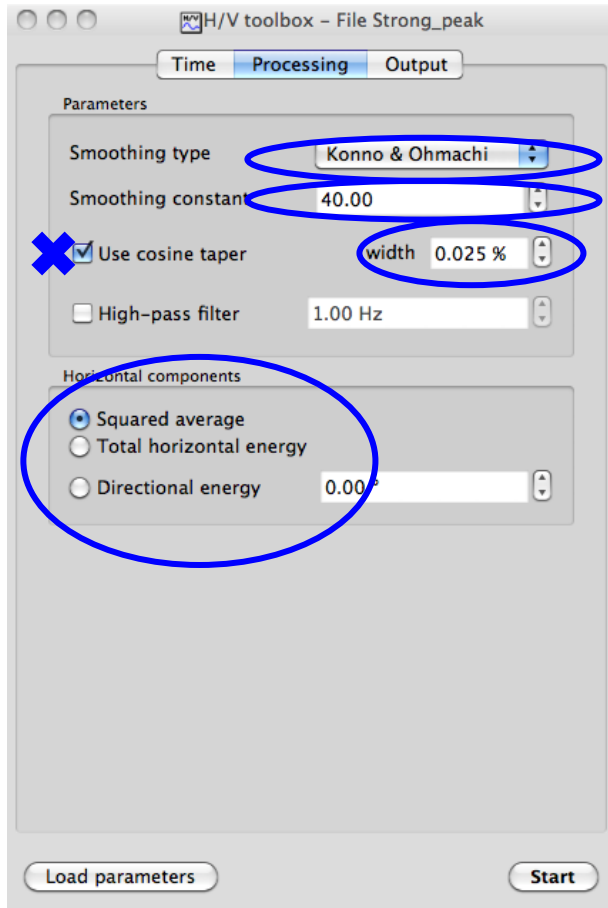


ON « GENERAL » PANEL

ON « RAW SIGNAL » PANEL

H/V

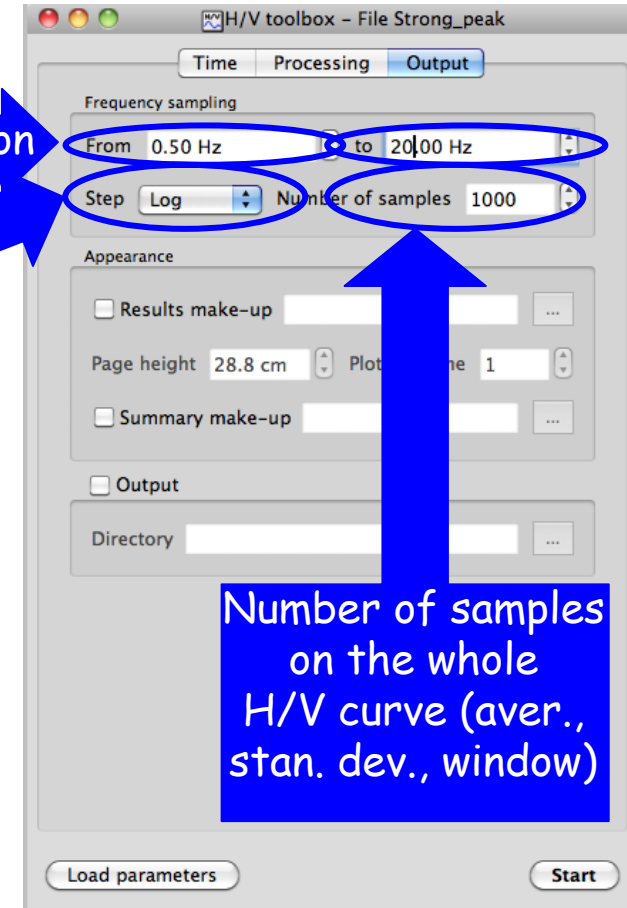
(processing and output)



Parameters generally used

Range for the H/V computation

Type of sampling step: lin - log

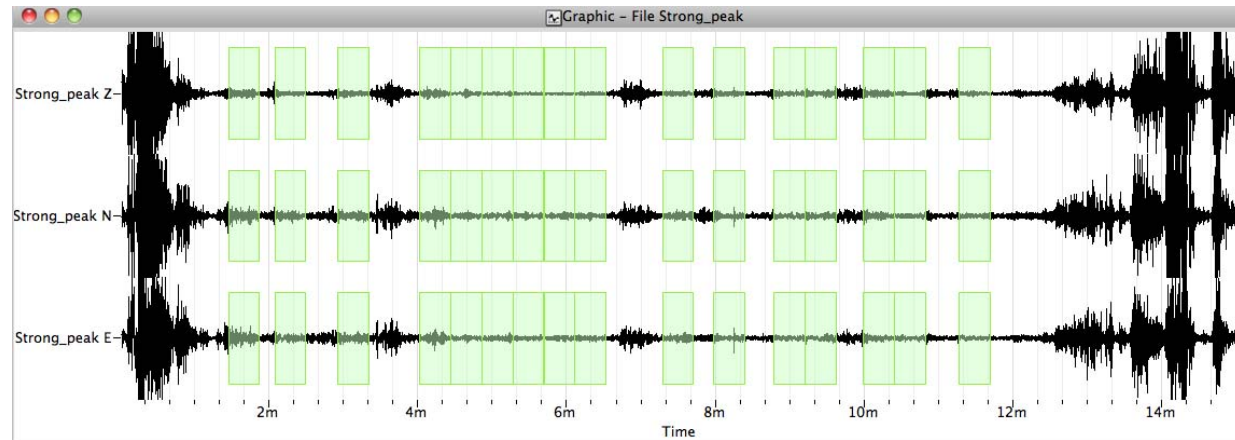
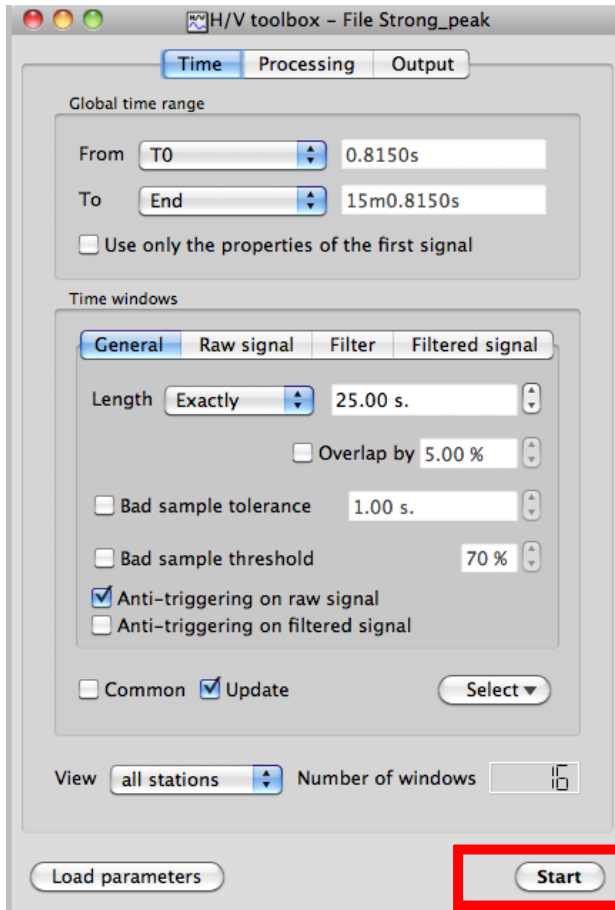


Number of samples on the whole H/V curve (aver., stan. dev., window)

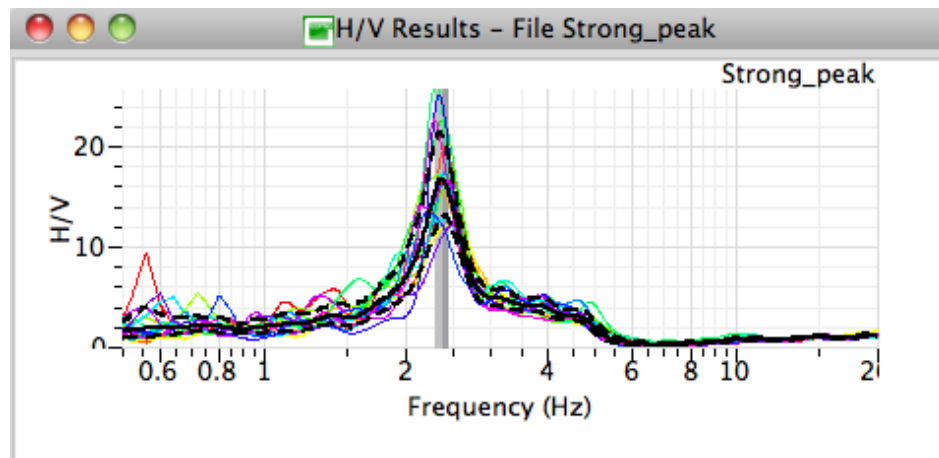
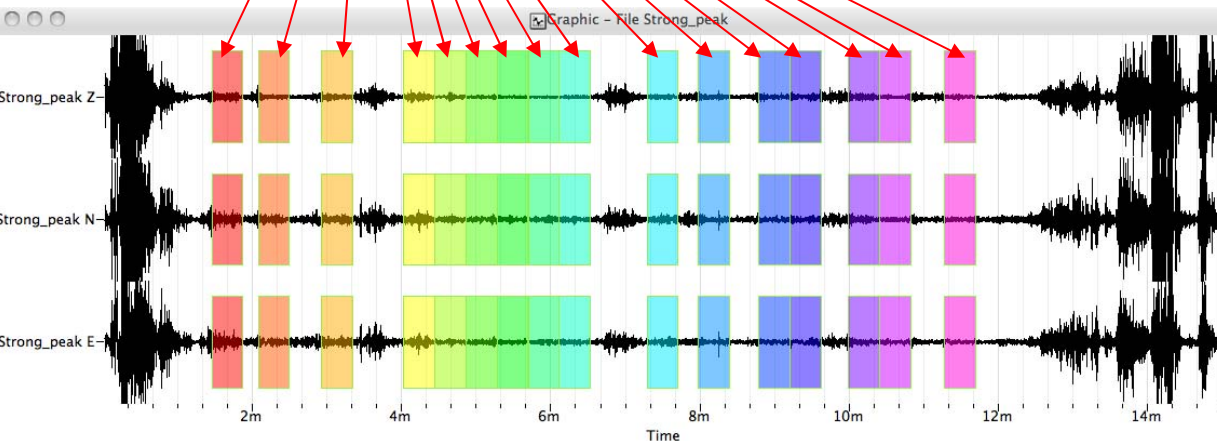
The frequency range for the H/V computation is varying upon the window length (seismometer and geology) and the sample frequency acquisition

H/V (computed)

If all is fine



Click on « Start »



H/V toolbox - File Strong_peak

Time Processing Output

Global time range

From T0 0.8150s

To End 15m0.8150s

☐ Use only the properties of the first signal

Time windows

General Raw signal Filter Filtered signal

Length Exactly 25.00 s

☐ Overlap by 5.00 %

☐ Bad sample tolerance 1.00 s

☐ Bad sample threshold 70 %

☒ Anti-triggering on raw signal

☐ Anti-triggering on filtered signal

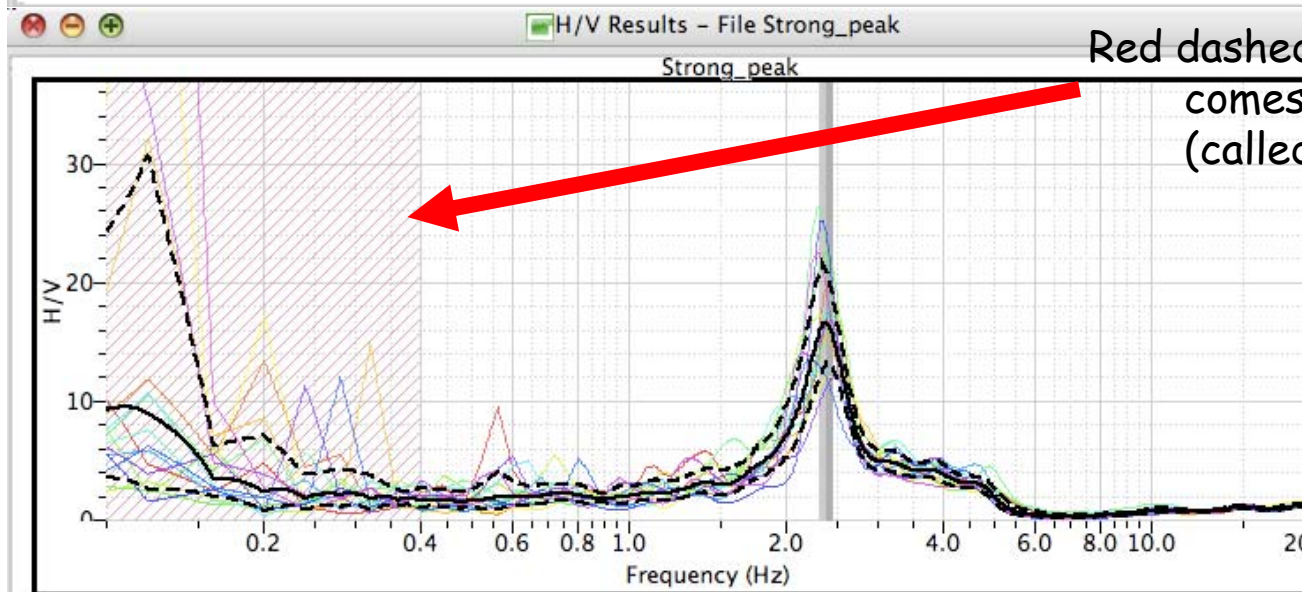
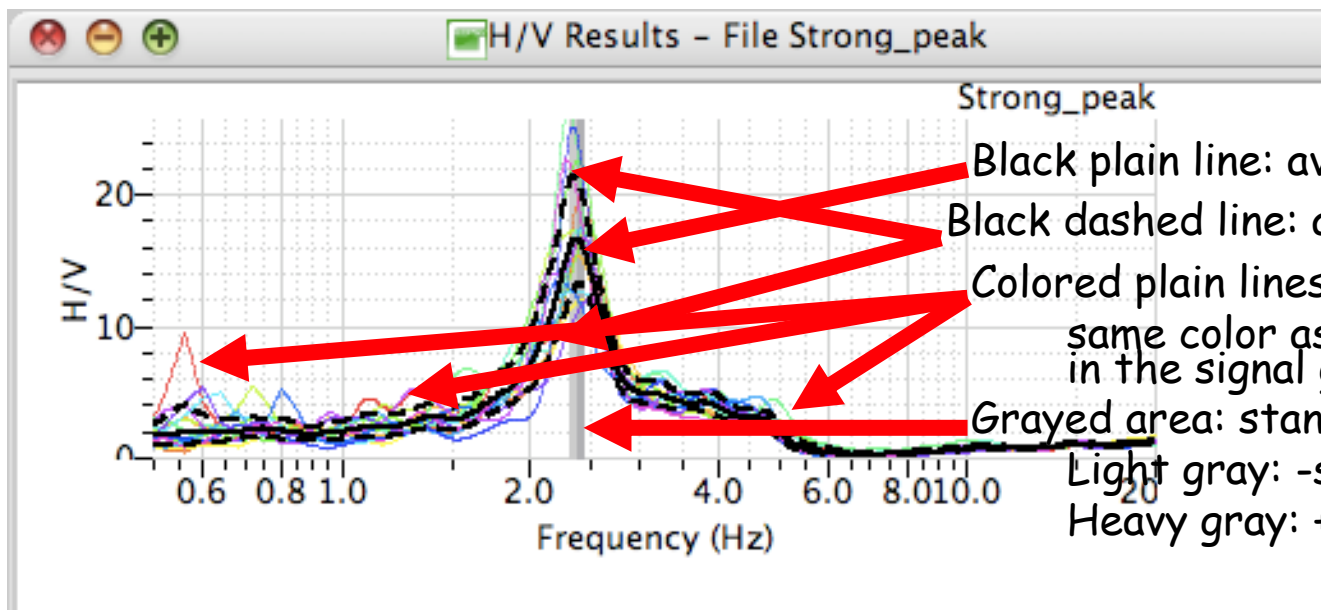
☐ Common ☒ Update Select

View all stations Number of windows 16

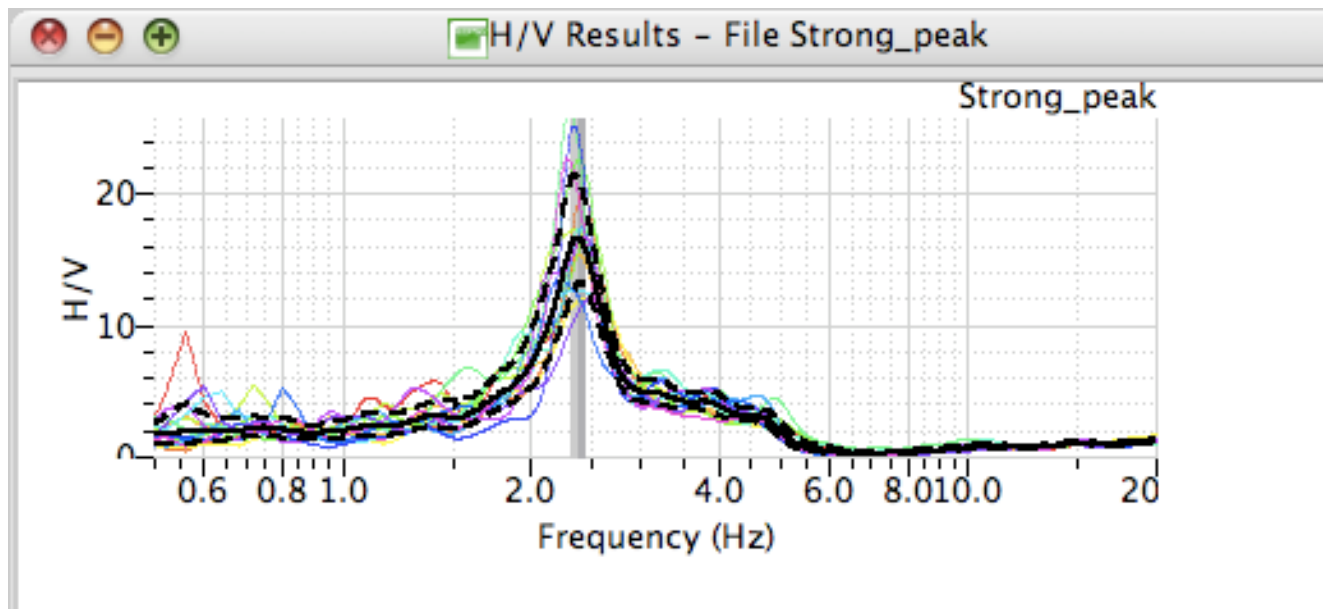
Load parameters Start

THE H/V CURVE !!!!!

H/V (computed)



H/V (computed)



$$f_0 = 2.38 \text{ Hz}$$

$$A_0 \approx 16$$

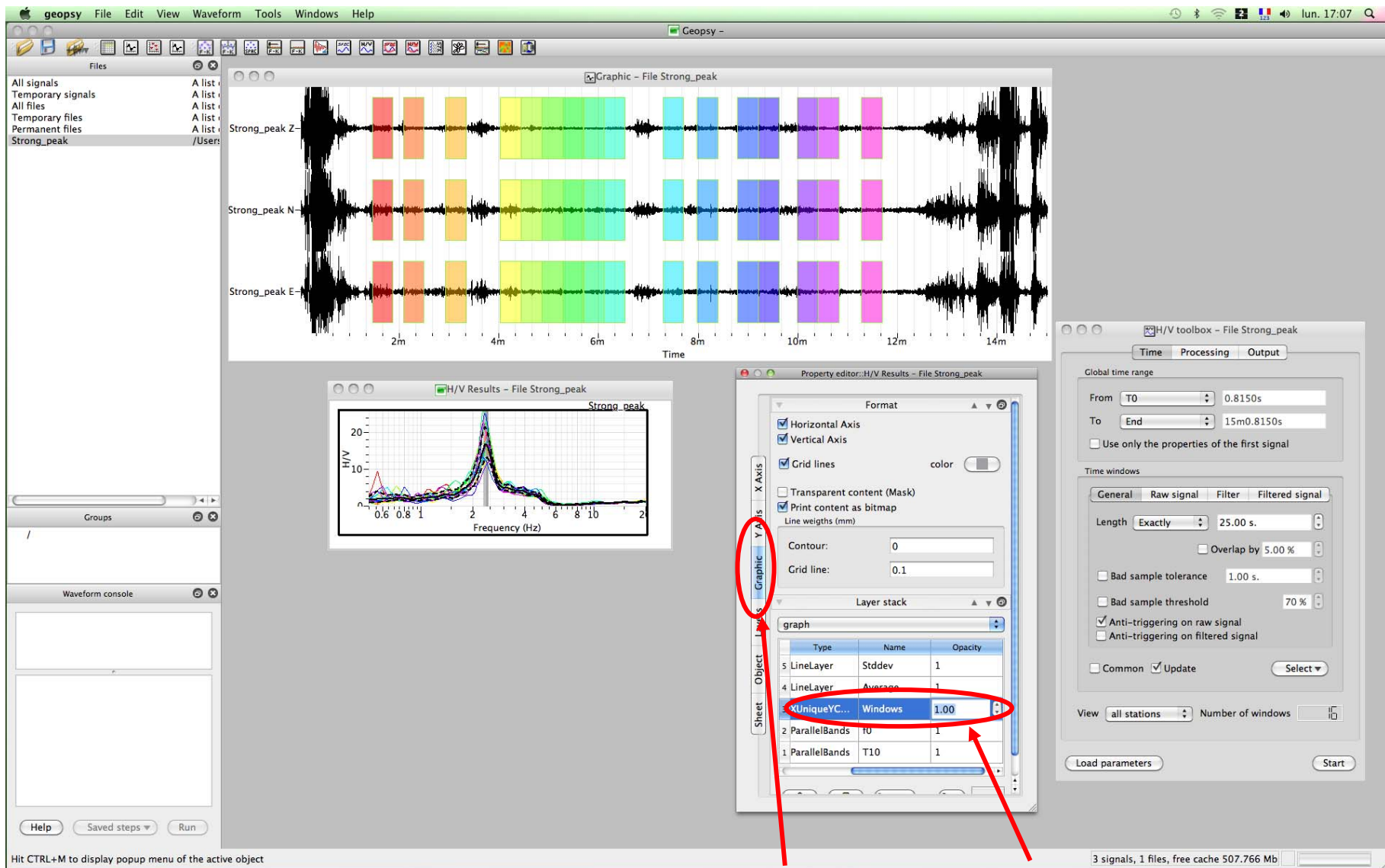
WARNING !!!!!!!

This type of H/V curve
(so strong, so nice)

VERY RARE

H/V (solution 1)

(computed: remove window curves displaying)

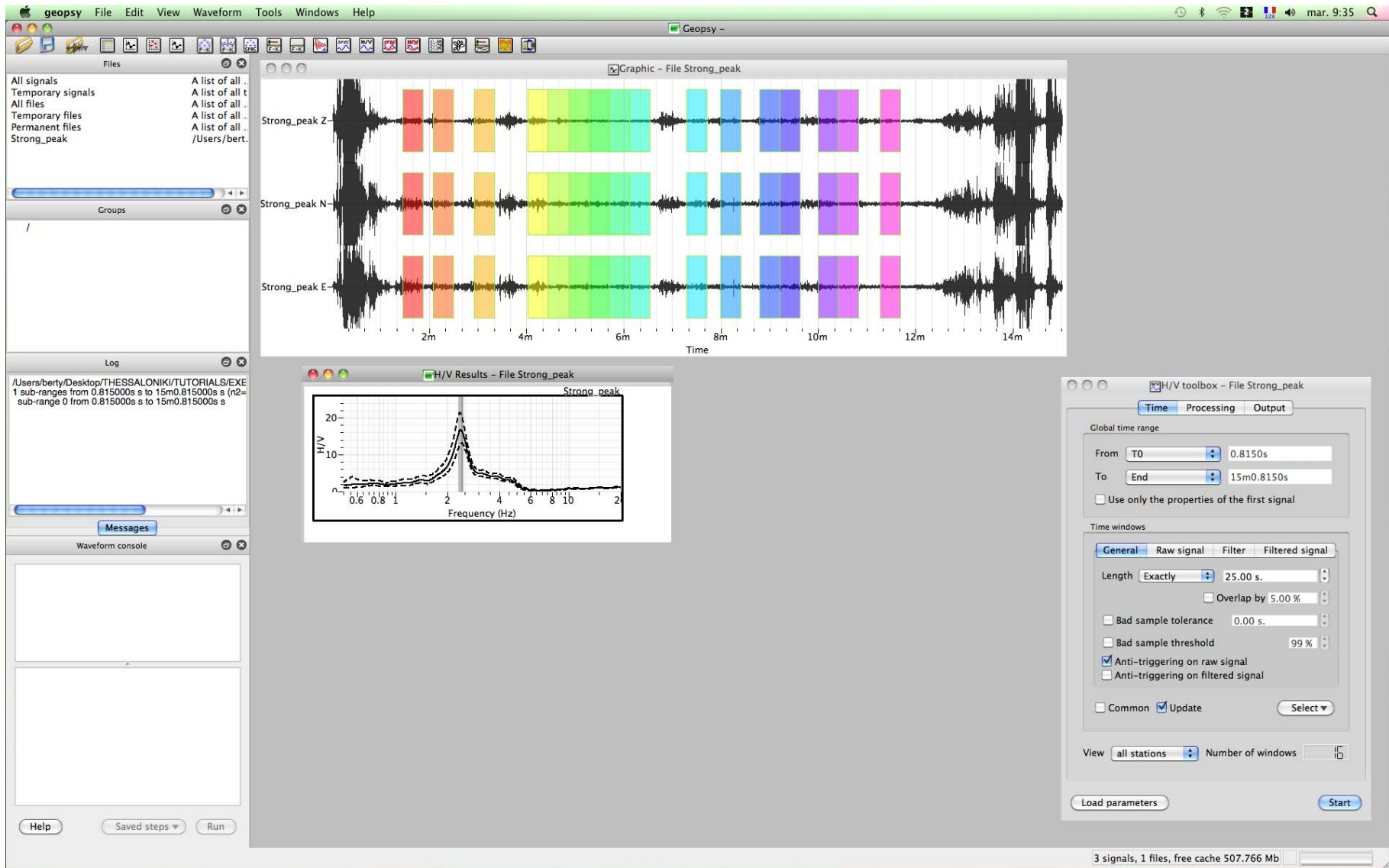


Right click mouse and select « properties » Graphics: Put « windows » at 0
or « double-click » on the H/V graph

February, 2010, Thessaloniki, Greece

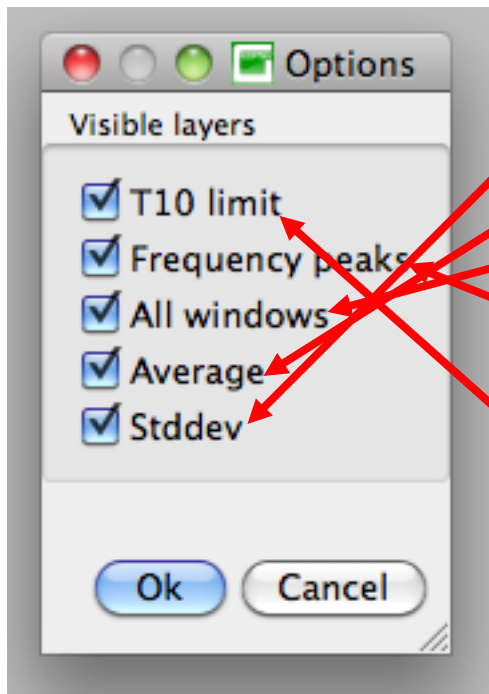
H/V (solution 2)

(computed: remove window curves displaying)



H/V presentation

We show you how to remove the window H/V curves
But you can do much more, on both menus.....



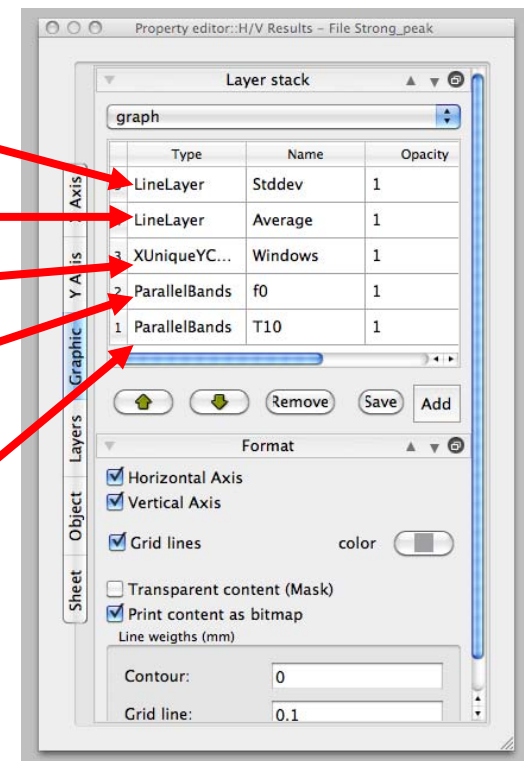
Remove the standard deviation of the averaged H/V curve

Remove the averaged H/V curve

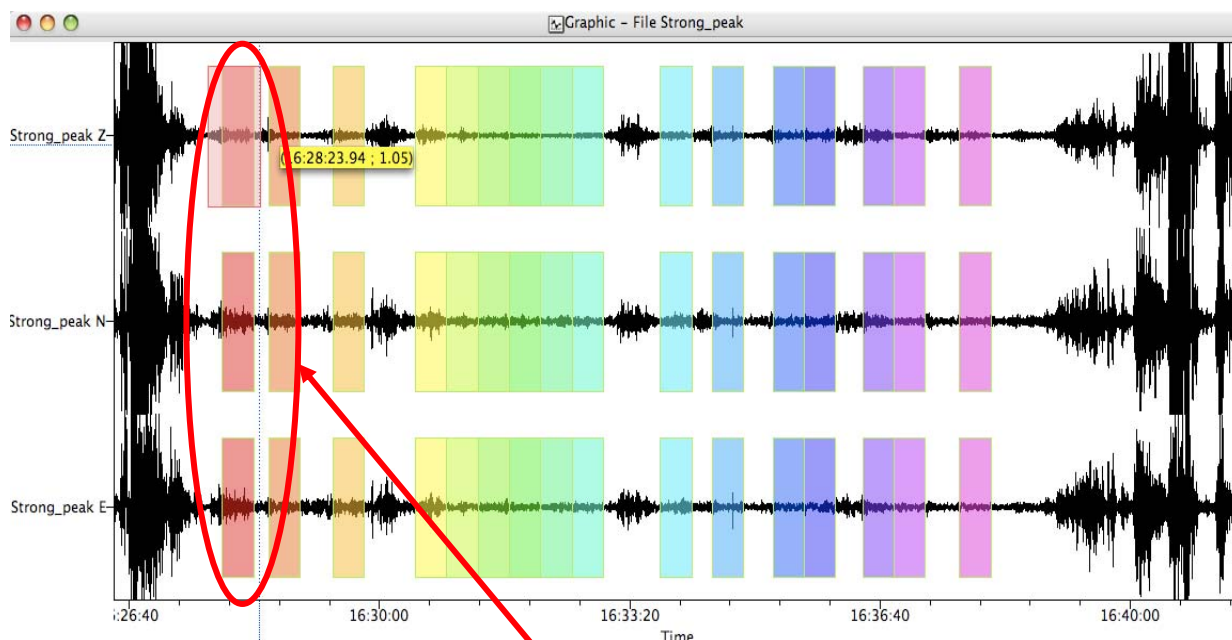
Remove the window H/V curves

Remove the averaged f_0 and its standard deviation

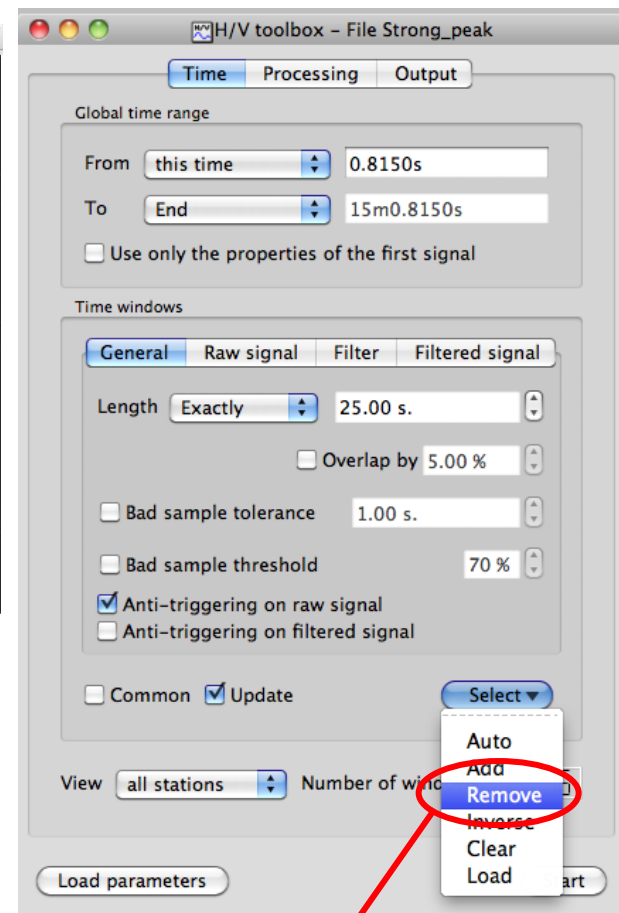
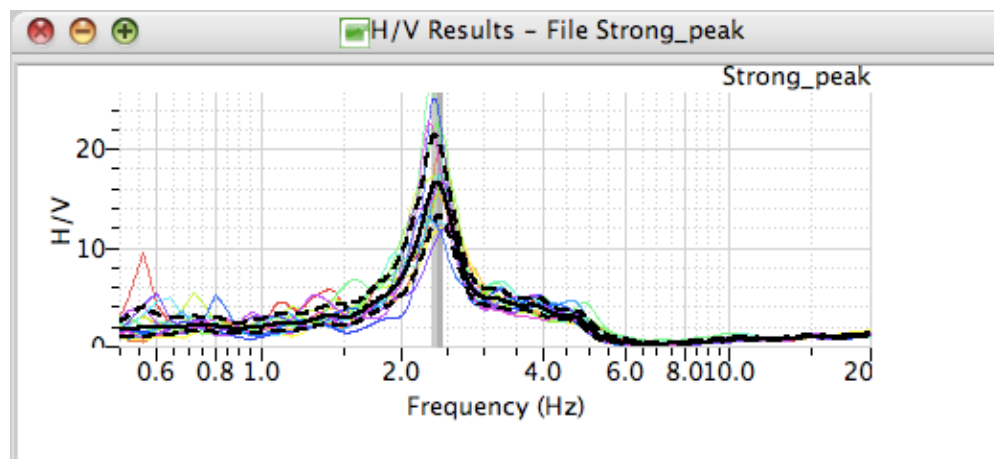
Remove the lower frequency of your processing (time window or natural frequency of your seismometer)



(computed remove window - 1)



Then click on the graphic window and select the window(s) you want to remove

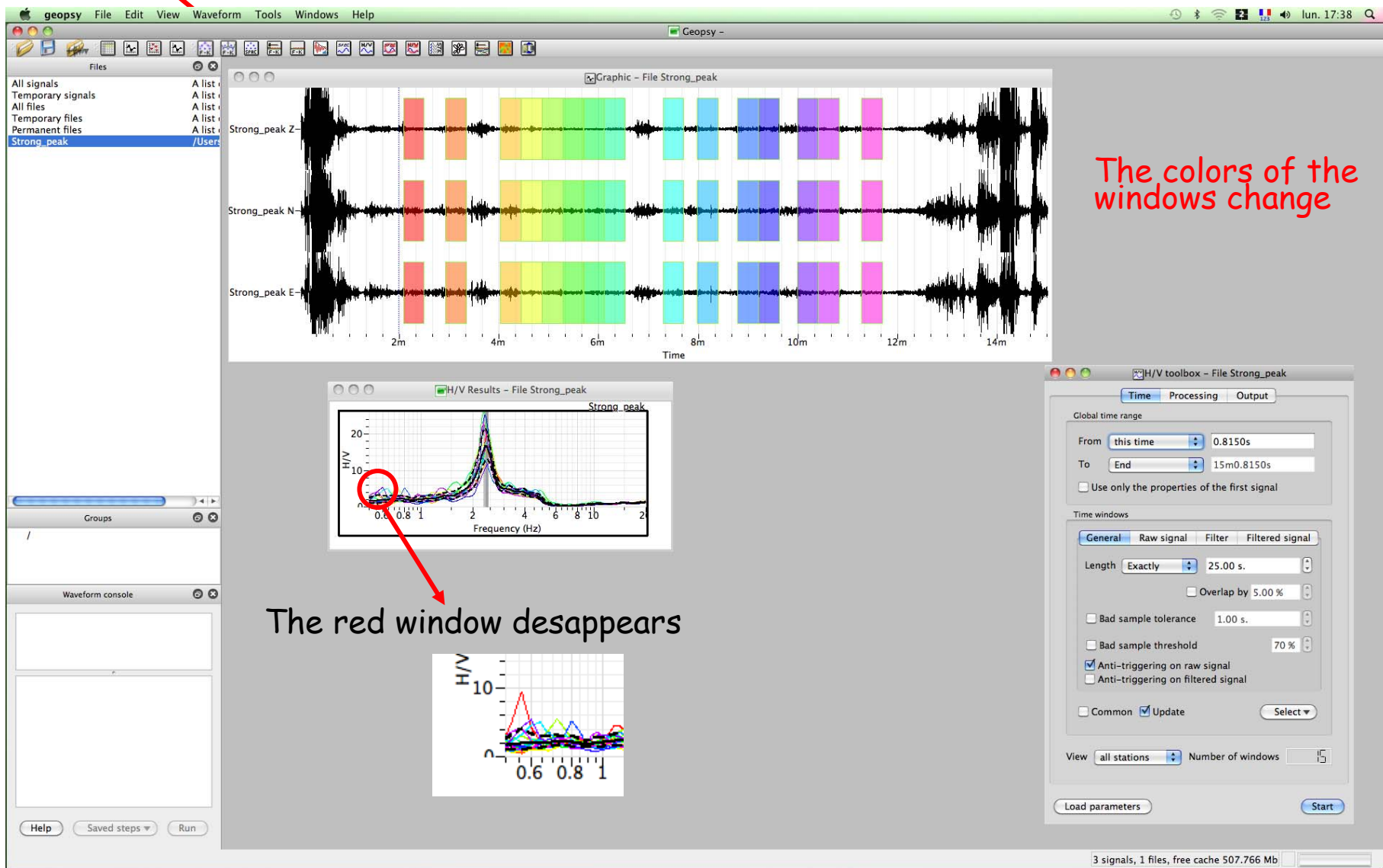


On the « Select » pop-up menu, click on « remove ». From now, you are in « remove » mode

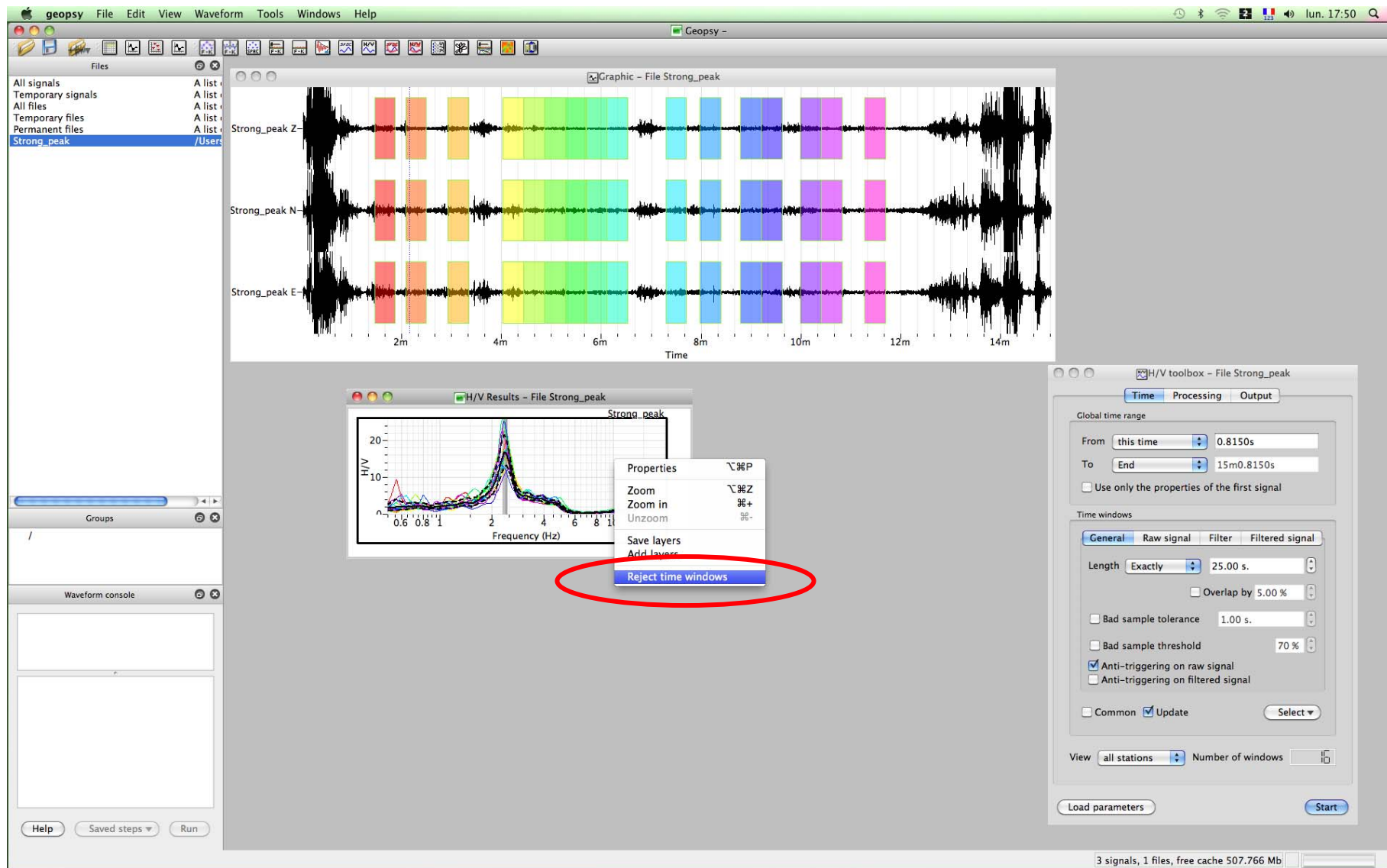
THE H/V curve doesn't change !!!!!

(computed remove window - 1)

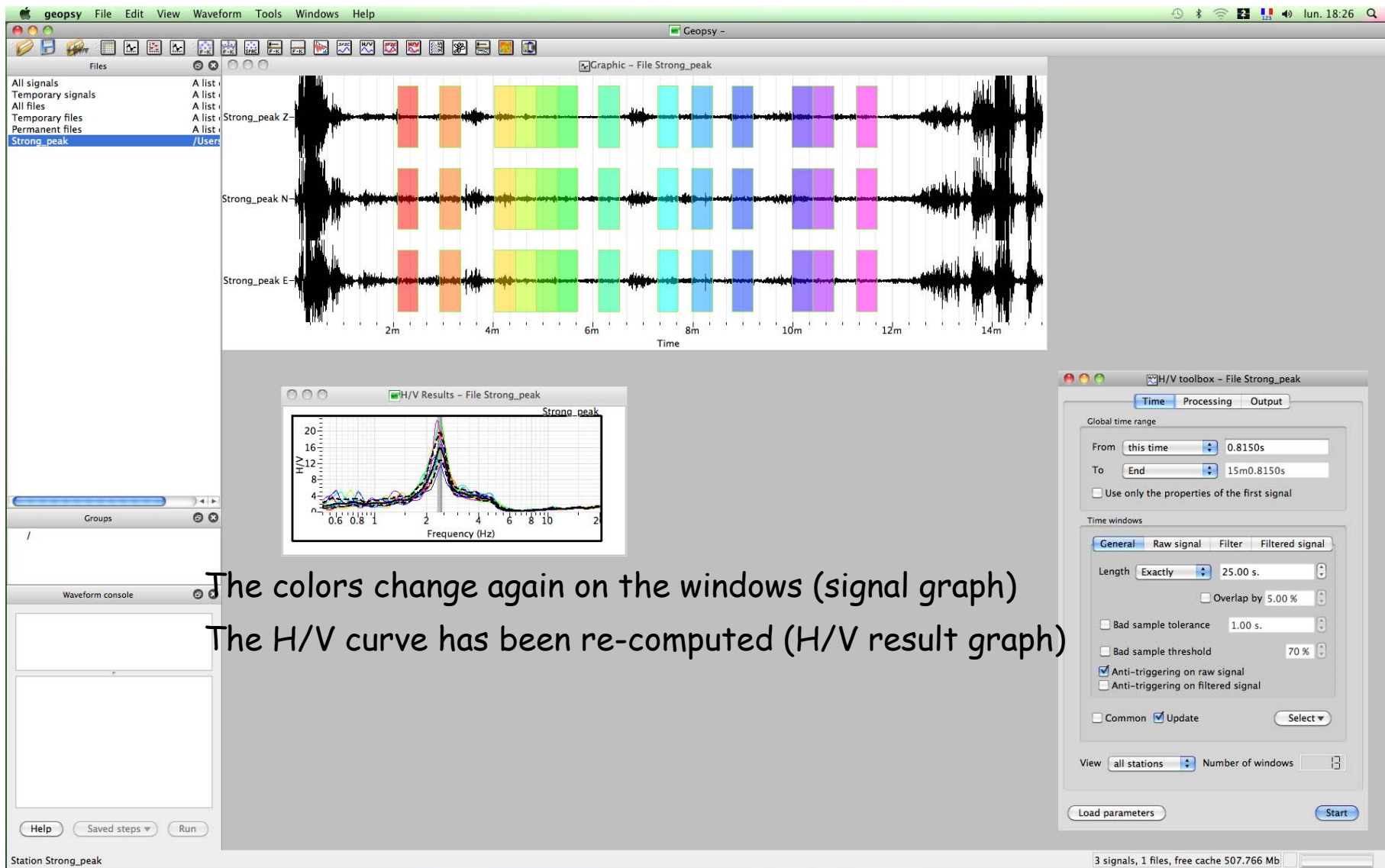
The selected window disappears



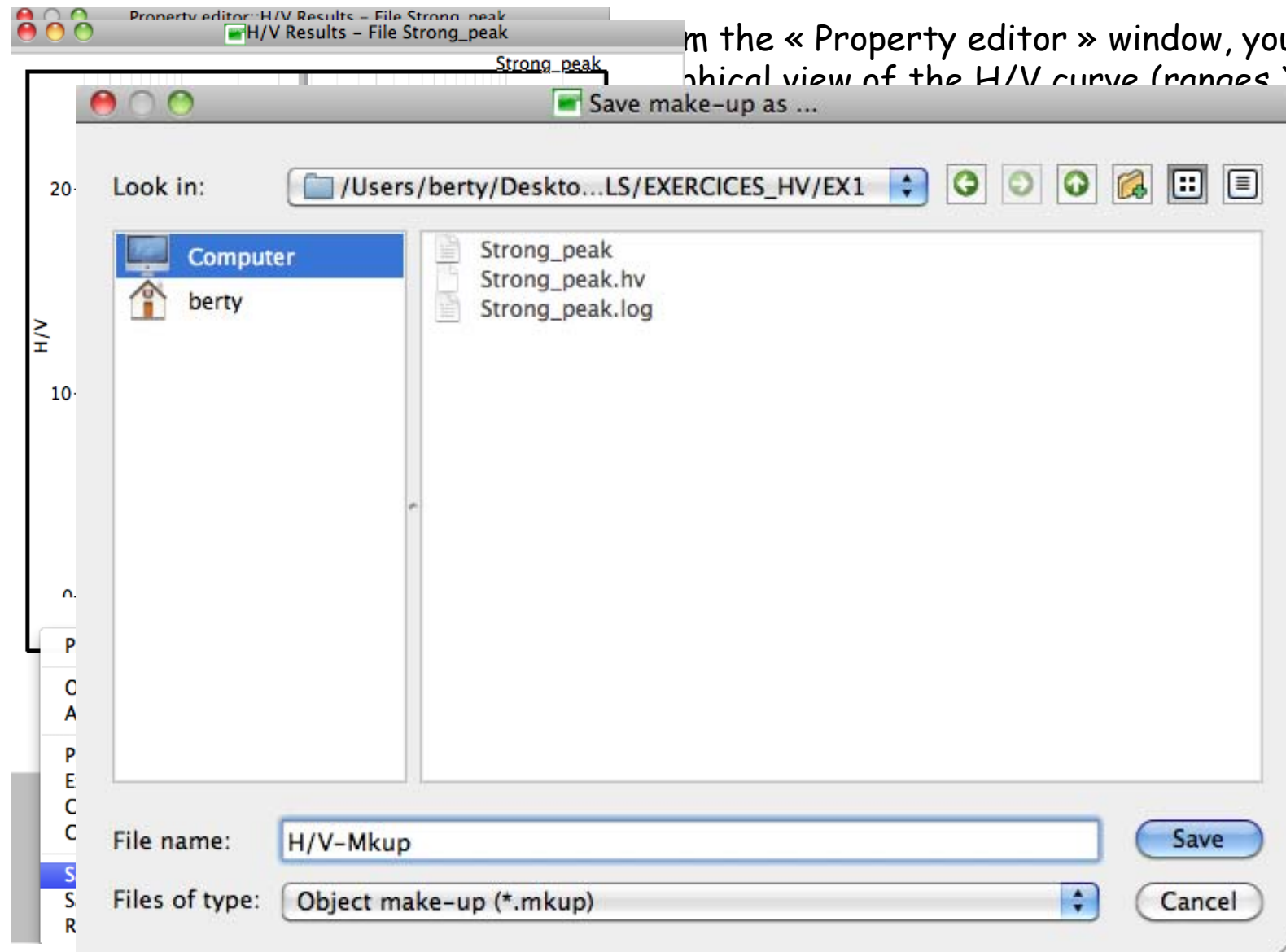
(computed remove window - 2)



Click on the right button of the mouse and select « reject time windows »



H/V MAKE-UP (program the graphics-1)



from the « Property editor » window, you can modify the graphical view of the H/V curve (ranges X and Y, type of

to save its
added when you
t

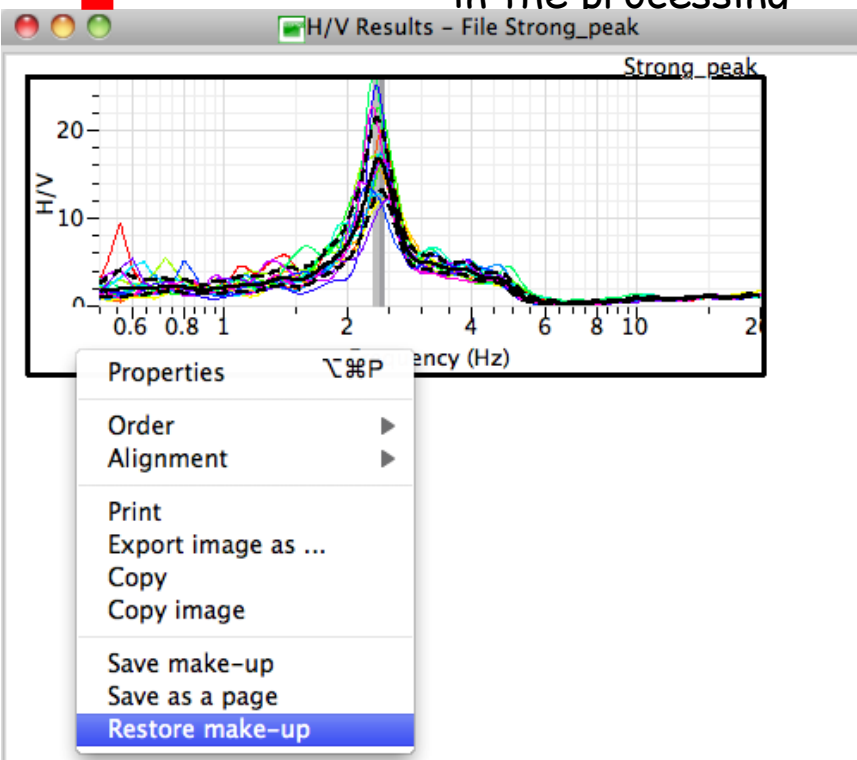
(inside graphic)

ers

H/V MAKE-UP (program the graphics-2)

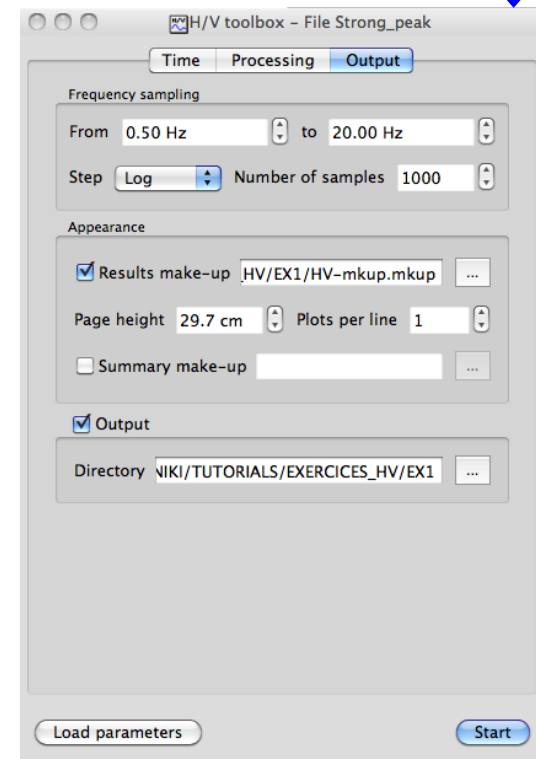
When your make-up file is saved, you can call it:

- manually
- automatically as an input in the processing



In the H/V toolbox, choose the « output » window

- check the « Results make-up » option
- choose the make-up file
- the make-up will be directly applied during the processing

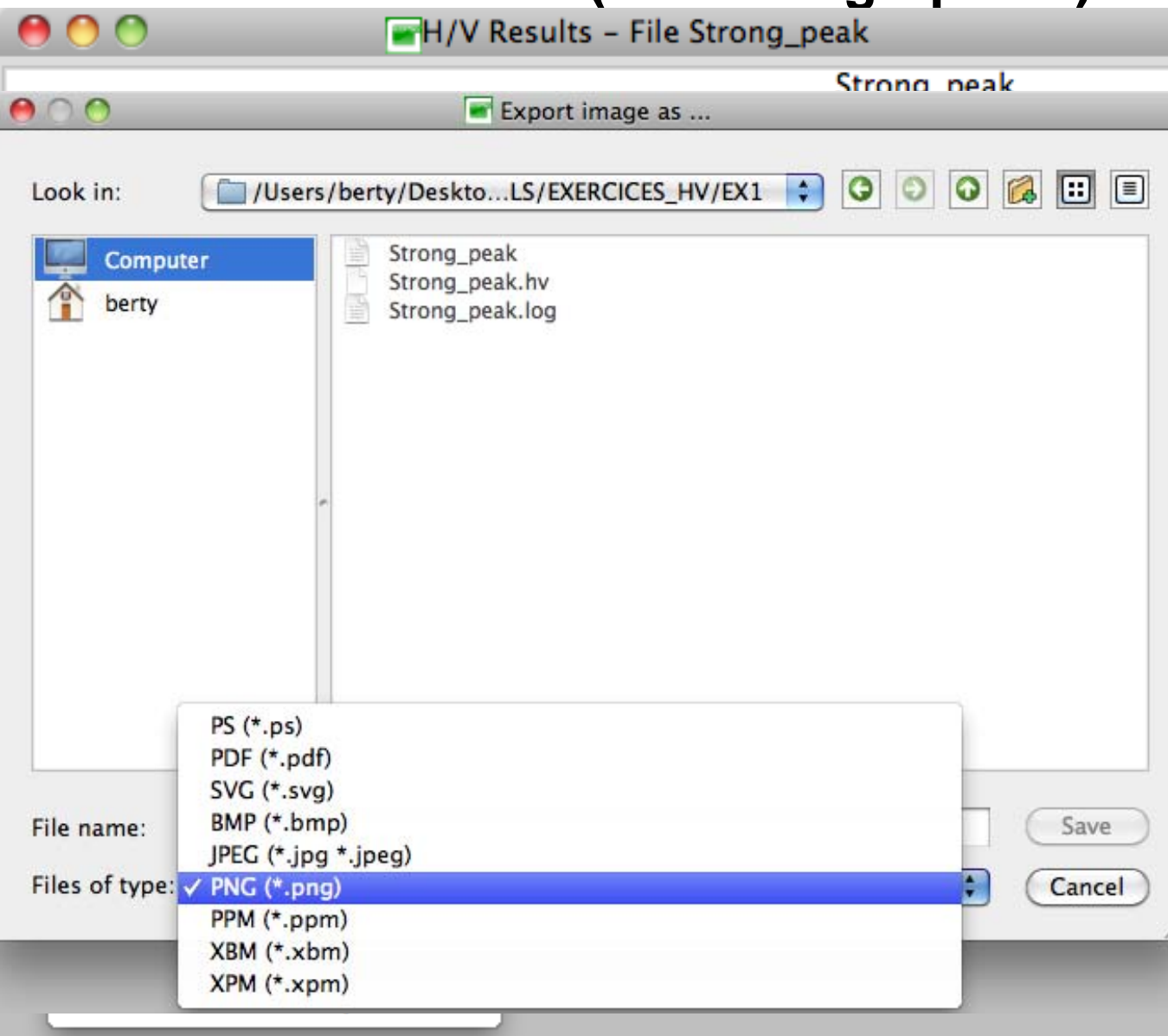


From inside the graphic, you open the pop-up menu and you choose the « Restore make-up » option

- a new window opens allowing you to choose the file
- the make-up is directly applied

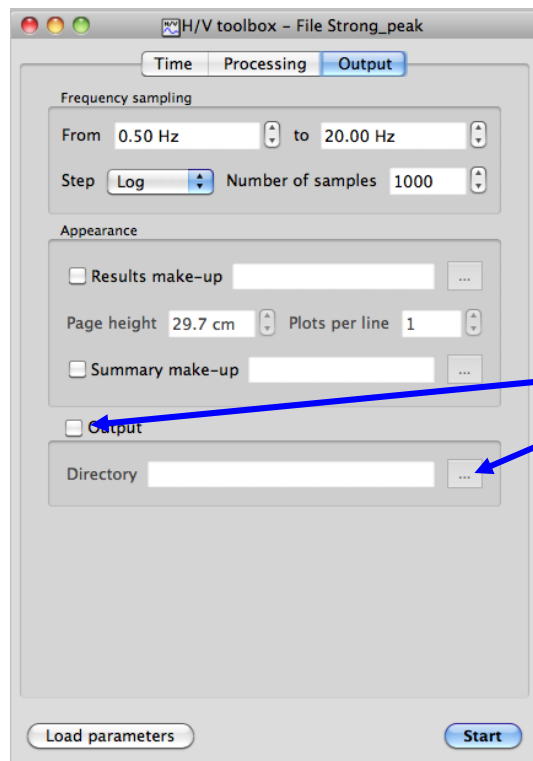
H/V OUTPUT

(save the graphics)



Click on the right button inside the yellow part.

- A pop-up menu appears
- Select
« Export image as... »
- a new window appears
 - ➔ Give the name for the file
 - ➔ Choose the type of graphic file you want



Until now, we have checked the graphic part, but the processing and the results can be saved in files:

- H/V results → «station_name».hv
- the H/V processing parameters → «station_name».log

You need to define where (in your HD) the files can be saved

- select the « Output » option
- choose the file to save the results

For this practice, select the « EXERCICES_HV/EX1 » folder

H/V OUTPUT (HV file)

Strong_peak.hv

Last Saved: 16/0...

File Path: ~/D...k.hv

```

# GEOPSY output version 1.1
# Number of windows = 16
# f0 from average 2.36653
# Number of windows for f0 = 16
# f0 from windows 2.3824 2.3899 2.4557
# Frequency Average Min Max
0.5 1.65306 1.07688 2.53753
0.50185 1.66029 1.07195 2.57154
0.503706 1.66629 1.06464 2.60793
0.50557 1.67184 1.05586 2.64666
0.50744 1.67453 1.04328 2.68774
0.509317 1.67672 1.02935 2.73122
0.511201 1.67753 1.01328 2.77722
0.513092 1.6769 0.99587 2.82593
0.514991 1.67472 0.974652 2.87764
0.516896 1.67086 0.951919 2.93279
0.518888 1.66514 0.92669 2.99203
0.520727 1.66653 0.91092 3.04891
0.522654 1.68204 0.913925 3.09571
0.524587 1.69788 0.916372 3.14293
0.526528 1.71167 0.918278 3.19056
0.528476 1.72581 0.91966 3.23861
0.530431 1.73951 0.920531 3.2871
0.532393 1.75276 0.920901 3.33604
0.534362 1.76557 0.920701 3.38544
0.536339 1.77795 0.920178 3.43532
0.538323 1.78988 0.919697 3.48569
0.540315 1.80138 0.917544 3.53658
0.542314 1.81243 0.915521 3.58801
0.54432 1.82303 0.91383 3.64001
0.546334 1.83317 0.910071 3.6926
0.548355 1.84285 0.906642 3.74581
0.550383 1.85206 0.902741 3.79969
0.552419 1.86079 0.898362 3.85427
0.554453 1.86902 0.893499 3.9096
0.556514 1.87673 0.888143 3.96572
0.558573 1.88393 0.882285 4.02271
0.560639 1.89294 0.885262 4.08065
0.562713 1.90026 0.900402 4.08025
0.564795 1.9184 0.93071 3.95424
0.566884 1.9294 0.952211 3.9094
0.568982 1.93929 0.972916 3.86556
0.571087 1.94812 0.992829 3.82257
0.573199 1.95588 1.01194 3.78033
0.57532 1.96261 1.03024 3.73875
0.577448 1.96829 1.04771 3.69777
0.579584 1.97295 1.06431 3.65733
0.581728 1.97656 1.08 3.61739
0.58388 1.97911 1.09473 3.57794
0.58604 1.9806 1.10845 3.53897
0.588208 1.98099 1.12108 3.50049
0.590384 1.98026 1.13254 3.46251
0.592566 1.97837 1.14274 3.42508
0.594761 1.97527 1.15154 3.38825
0.596961 1.97091 1.15883 3.35209
0.599169 1.96521 1.16442 3.31671
0.601386 1.96338 1.17398 3.28357
0.603611 1.96387 1.18596 3.25203
0.605844 1.96365 1.19705 3.22121
0.608085 1.96273 1.2072 3.19111
0.610334 1.96189 1.21639 3.16173
0.612592 1.95974 1.22456 3.13309
0.614858 1.95566 1.23168 3.10521
0.617133 1.95185 1.23767 3.07813
0.619416 1.94728 1.24247 3.0519
0.621708 1.94193 1.24599 3.02657
0.624008 1.93576 1.24816 3.00222
0.626316 1.92881 1.24887 2.97894
0.628633 1.92097 1.24801 2.95681
0.630959 1.91224 1.24547 2.93596
0.633293 1.90256 1.24112 2.9165
0.635635 1.89187 1.23481 2.89859

```

Lines with « # » indicating no data set.

- nb windows
- the f_0 coming from the averaged curve
- the f_0 coming from the window curves (+ stand. dev.)

The H/V curve

- frequency (f_{curve})
- value of the averaged H/V curve at f_{curve}
- the standard deviation (+/-) at f_{curve}

H/V OUTPUT (log file)

```

Strong_peak.log
Last Saved: 16/02/10 10:36:02
File Path: ~/Desktop/THESSAL...V/EX1/Strong_peak.log

*** Parameters ***
SIGNAL FILE NAME = Strong_peak
WINDOW MIN LENGTH (s) = 25
WINDOW MAX LENGTH (s) = 50
WINDOW LENGTH TYPE (s: least/exactly/freq. dep.) = exactly
DO BAD SAMPLE TOLERANCE (y/n) = n
BAD SAMPLE TOLERANCE (s) = 0
DO WINDOW OVERLAP (y/n) = n
WINDOW OVERLAP (s) = 5
DO BAD SAMPLE THRESHOLD (y/n) = n
BAD SAMPLE THRESHOLD (s) = 90
ANTI-TRIGGERING ON RAW SIGNAL (y/n) = y
USED RAW COMPONENTS = y, y, y, n, y
RAW STR (s) = 1
RAW LTA (s) = 30
RAW MIN SLTA = 0.2
RAW MAX SLTA = 2.5
ANTI-TRIGGERING ON FILTERED SIGNAL (y/n) = n
FILTER TYPE (low pass/high pass/band pass/band reject) = low pass
FILTER METHOD (butterworth/taper) = taper
FILTER MIN FREQUENCY (Hz) = 5
FILTER MAX FREQUENCY (Hz) = 10
FILTER CRUSAL (y/n) = n
FILTER ORDER = 1
FILTER WIDTH = 0.1
USED FILTERED COMPONENTS = y, y, y, n, y
FILTERED STR (s) = 1
FILTERED LTA (s) = 30
FILTERED MIN SLTA = 0.2
FILTERED MAX SLTA = 2.5
SMOOTHING TYPE (kono/chebyshev/constant band/proportional/no smoothing) = kono/chebyshev
SMOOTHING CONSTANT = 40.00
DO COSINE TAPER = true
TAPER WIDTH = 0.825
DO HIGH PASS = false
HIGH PASS FREQUENCY = 1
MINIMUM FREQUENCY = 0.5
MAXIMUM FREQUENCY = 20
INVERSED FREQUENCY = n
SAMPLES NUMBER FREQUENCY = 1000
SAMPLING TYPE FREQUENCY (0=log, 1=linear) = 0
HORIZONTAL COMPONENTS = Squared
HORIZONTAL AZIMUTH = 0
*** End Parameters ***

*** Windowing Log ***
Automatic windowing
Adding window from 87.32 to 112.32 s.
Adding window from 124.68 to 149.68 s.
Adding window from 175.555 to 200.555 s.
Adding window from 241.77 to 266.77 s.
Adding window from 266.775 to 291.775 s.
Adding window from 291.78 to 316.78 s.
Adding window from 316.785 to 341.785 s.
Adding window from 341.79 to 366.79 s.
Adding window from 366.795 to 391.795 s.
Adding window from 437.51 to 462.51 s.
Adding window from 478.885 to 503.885 s.
Adding window from 527.415 to 552.415 s.
Adding window from 552.42 to 577.42 s.
Adding window from 599.32 to 624.32 s.
Adding window from 624.325 to 649.325 s.
Adding window from 676.645 to 701.645 s.
*** End Windowing Log ***

*** Time Windows ***
# Number= 16
# Start time      End Time      Window length
87.32      112.32      25
124.68      149.68      25
175.555      200.555      25
241.77      266.77      25
266.775      291.775      25
291.78      316.78      25
316.785      341.785      25
341.79      366.79      25
366.795      391.795      25
437.51      462.51      25
478.885      503.885      25
527.415      552.415      25
552.42      577.42      25
599.32      624.32      25
624.325      649.325      25
676.645      701.645      25
*** End Time Windows ***

```

File name

Global parameters (anti-trigger, bad sample, ...)

Values for all parameters
(anti-trigger, bad sample, ...)

Processing parameters (smoothing, type of H/V...)

Parameters for the H/V curve (frequency limit,
nb samples....)

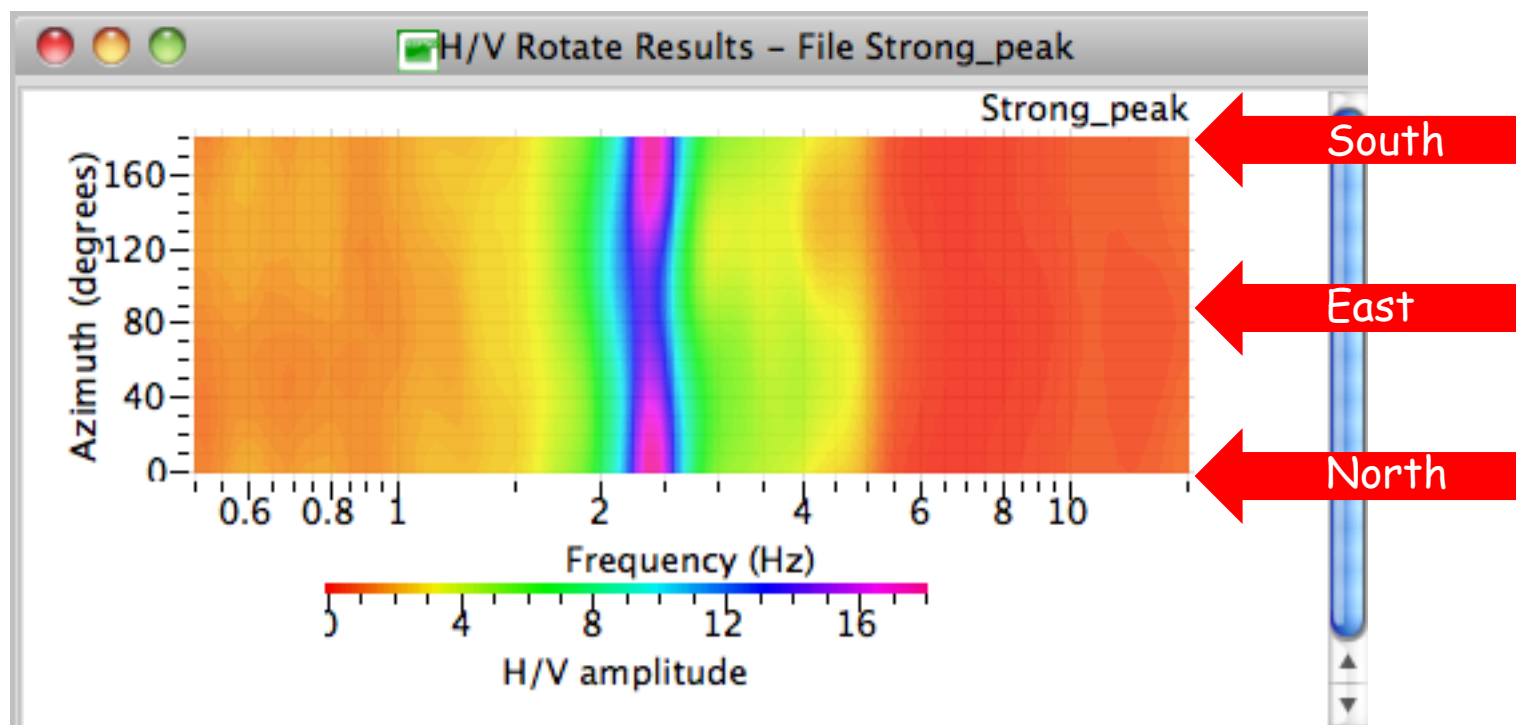
The results of the windowing (i.e. the time wind.)

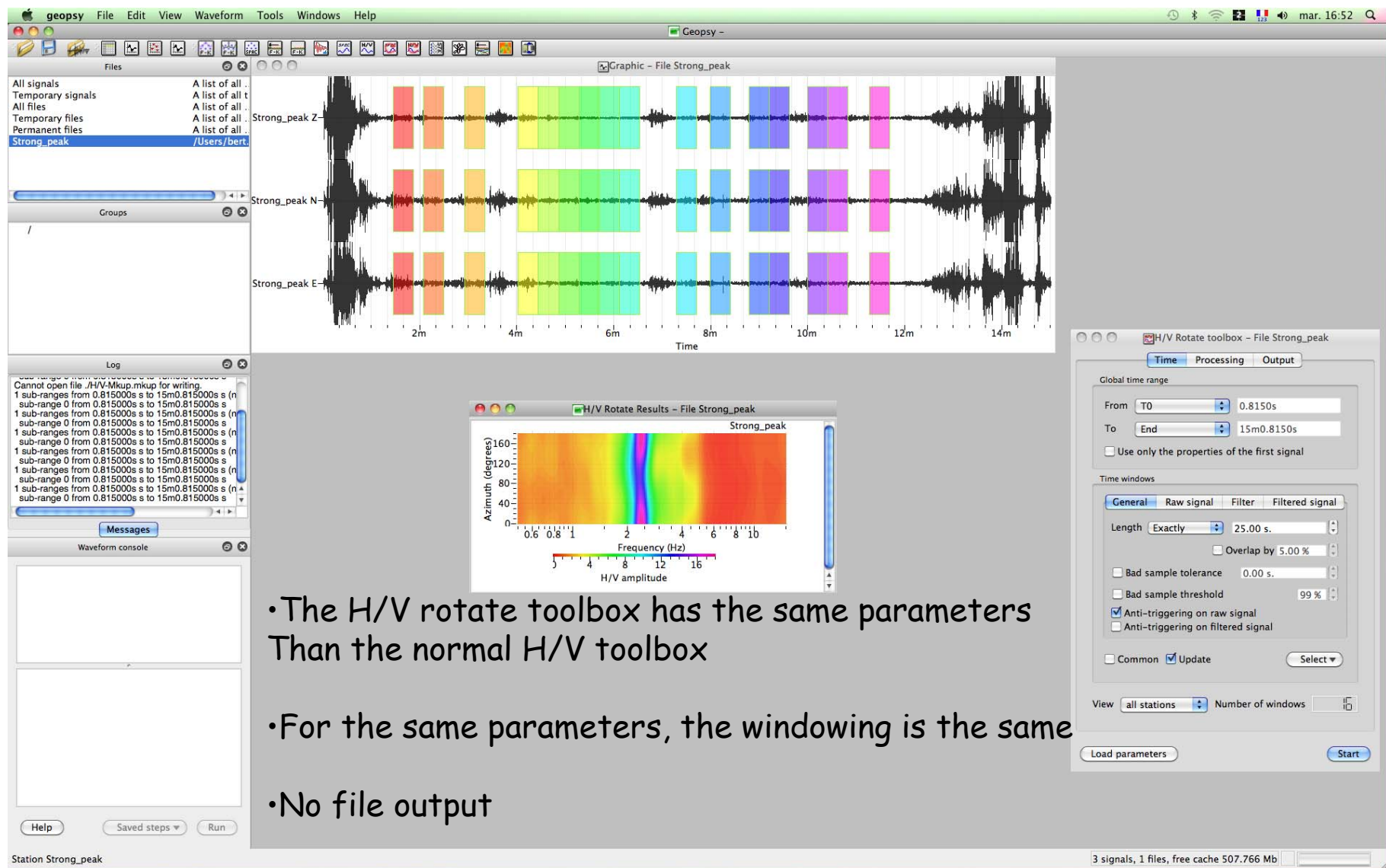
The used windows

H/V ROTATE

H/V ROTATE

- Compute H/Vs with an horizontal component spanning different azimuths
- Azimuth is counted clockwise from the North (symmetry)
- Useful to check whether a site is 1D





BEFORE H/V PROCESSING THE ENERGY SPECTRUM

Verifying the energy spectrum
It is not mandatory, but it is strongly recommended

GEOPSY

array tools

SPEC

damping

H/V

FK

Capon

MSPAC

MASW

Normal Rotate

Normal Rotate

THE ENERGY SPECTRUM

We will work on EX2: 3 files in a SAC format

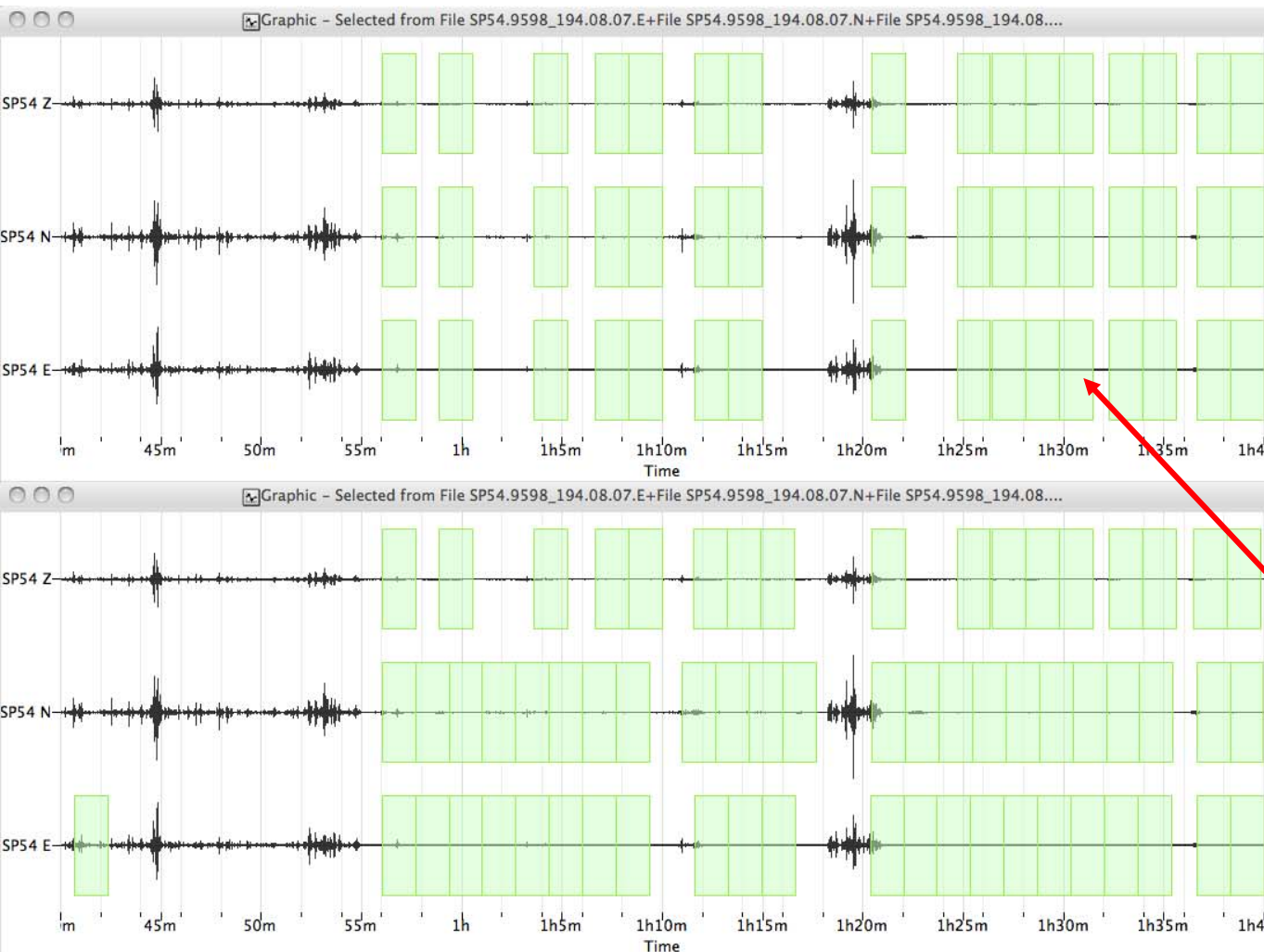
The « Spectrum toolbox » and the « Horizontal Spectrum Rotate toolbox » have the same functionalities as the H/V tools. As you familiarized yourself with H/V toolboxes, it will be very easy for you to use the spectrum tools.

Spectrum toolbox

There is no difference with the « H/V toolbox », except:

- the window definition is not synchronous on the 3 components as in the « H/V toolbox » but you can force the synchronization (check the « Common » option)

THE ENERGY SPECTRUM



Spectrum toolbox - Selected from File SP54.959...

Time Processing Output

Global time range

From T0 40m

To End 1h40m

☐ Use only the properties of the first signal

Time windows

General Raw signal Filter Filtered signal

Length Exactly 100.00 s.

☐ Overlap by 5.00 %

☐ Bad sample tolerance 0.00 s.

☐ Bad sample threshold 99 %

☒ Anti-triggering on raw signal

☐ Anti-triggering on filtered signal

☒ Common ☒ Update

Select

View all stations Number of windows 40

Load parameters Start

The « Spectrum toolbox » and the « Horizontal Spectrum Rotate toolbox » have the same functionalities as the H/V tools. As you familiarized yourself with H/V toolboxes, it will be very easy for you to use the spectrum tools.

Spectrum toolbox

There is no difference with the « H/V toolbox », except:

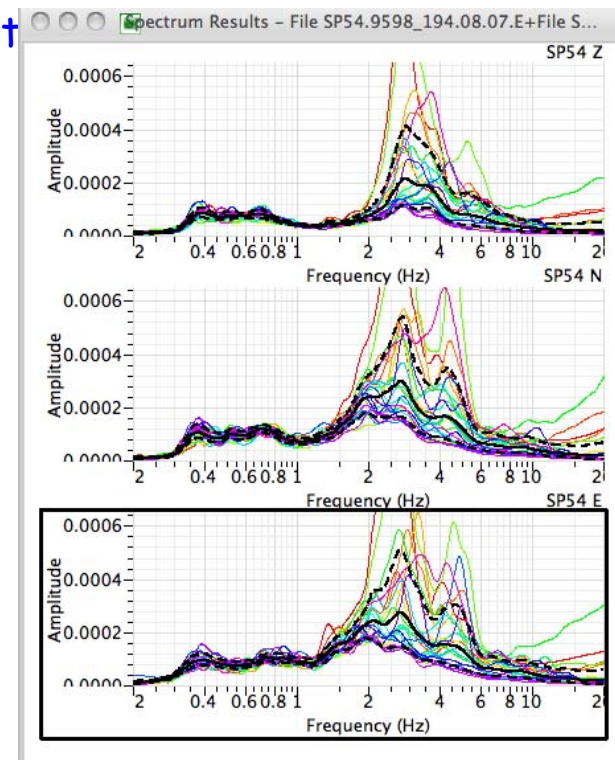
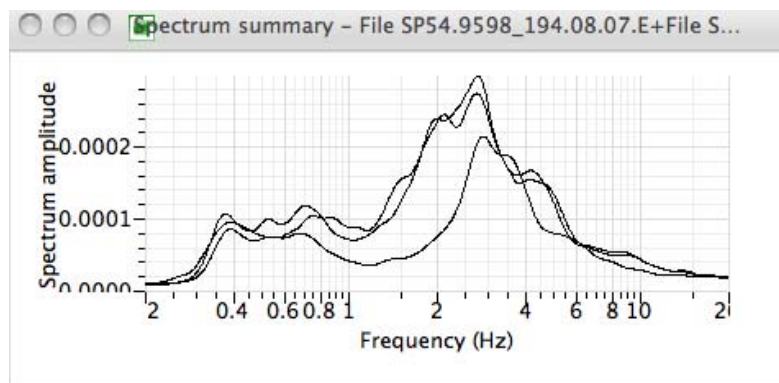
- the window definition is not synchronous on the 3 components as in the « H/V toolbox » but you can force the synchronization (check the « Common » option)
- the output files: 2 files (**station_name_ZNE.spec**) and (**station_name_ZNE.log**) are created for each component

THE ENERGY SPECTRUM

Spectrum toolbox

There is no difference with the « H/V toolbox », except:

- the window definition is not synchronous on the 3 components as in the « H/V toolbox » but you can force the synchronization (check the « Common » option)
- the output files: 2 files (**station_name_ZNE.spec**) and (**station_name_ZNE.log**) are created for each component
- 2 graphics are created:
 - a graphic displaying 3 graphs (one for each component)
 - a synthetic graph displaying the 3 averaged curves



1- load the 3 files in Geopsy (EXERCISES_HV/EX02)

- very long record (3h50)
- at 100 sps —————→ Upper frequency limit: 50 Hz
- done with a Lennartz LE3D-5s —————→ Lower frequency limit: 0.2 Hz
Useful window length: 50 s. max

2- As you can observe some strong noise, we will cut the signal to conserve 120'

- cut the signal (in graphic or table) in-between 20' and 2h20'
- open the « Spectral toolbox » by dragging your signal to the spectrum tool

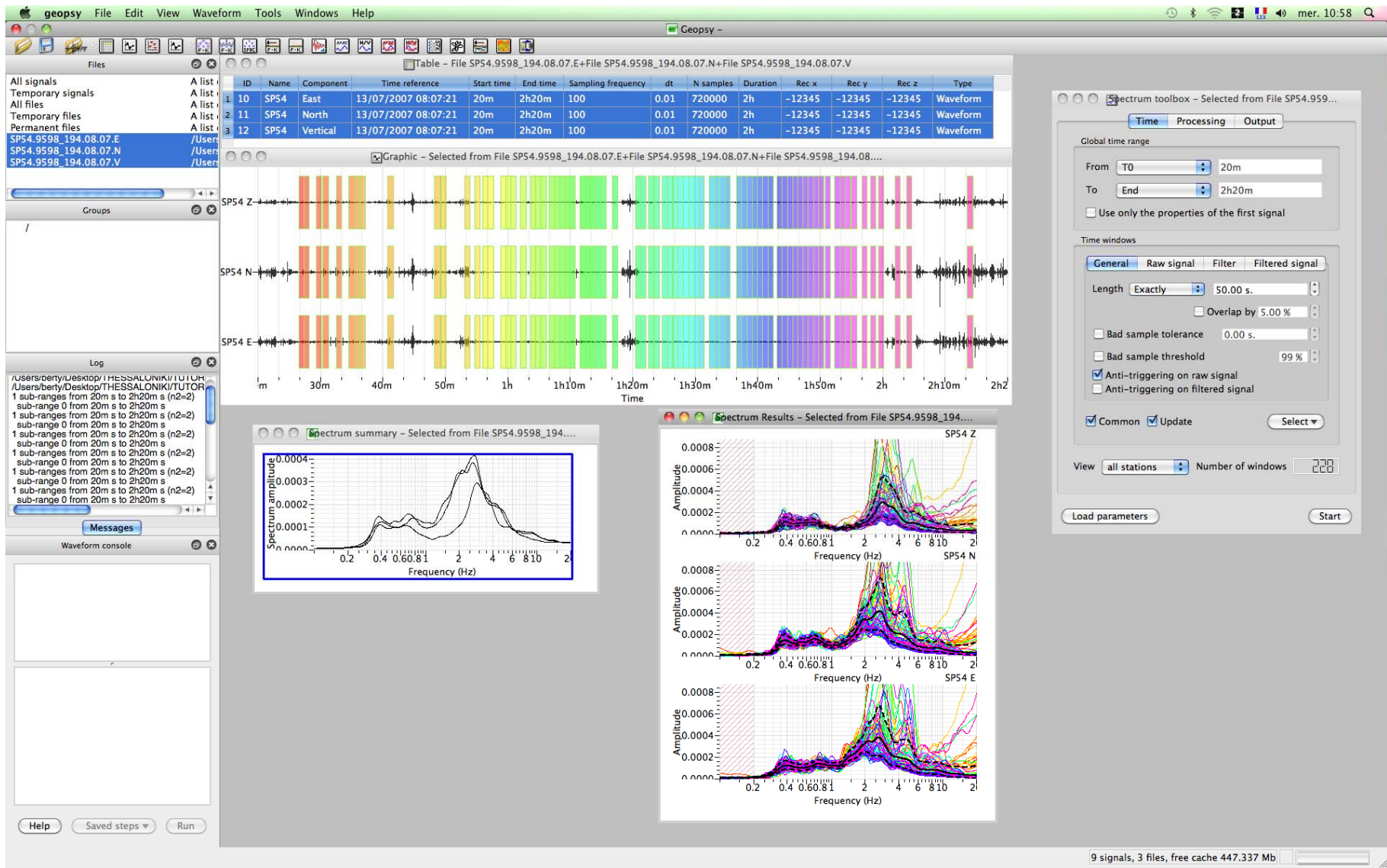


3- We fix:

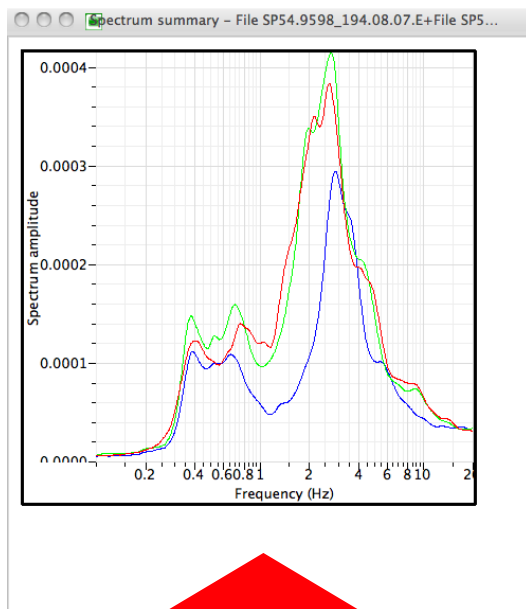
- the use of an anti-trigger (raw signal, [1 - 30 - 0.2 - 2.5]) with 50 s. windows
- the frequency in a {0.1 - 20} Hz range with 1000 log samples
- normal processing (K&O, 40, cosine taper 5%)
- « Common » option to obtain a windowing identical to the H/V processing

4- « Select - Auto » (you may obtain 228 windows, 76 for each component)

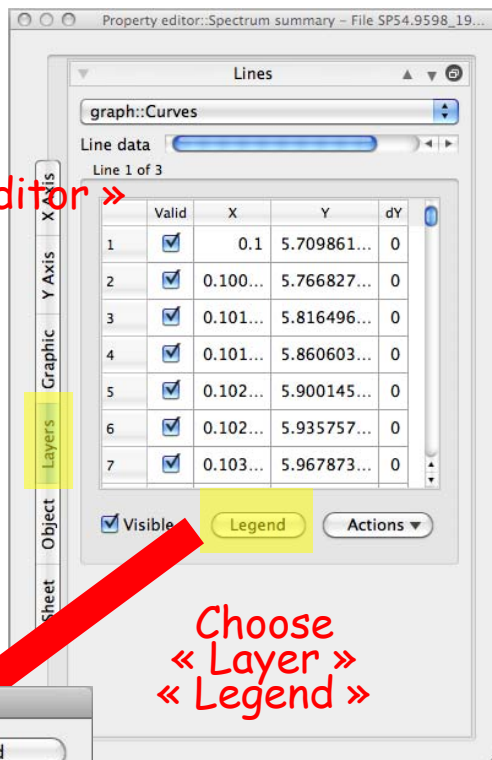
5- « Start »



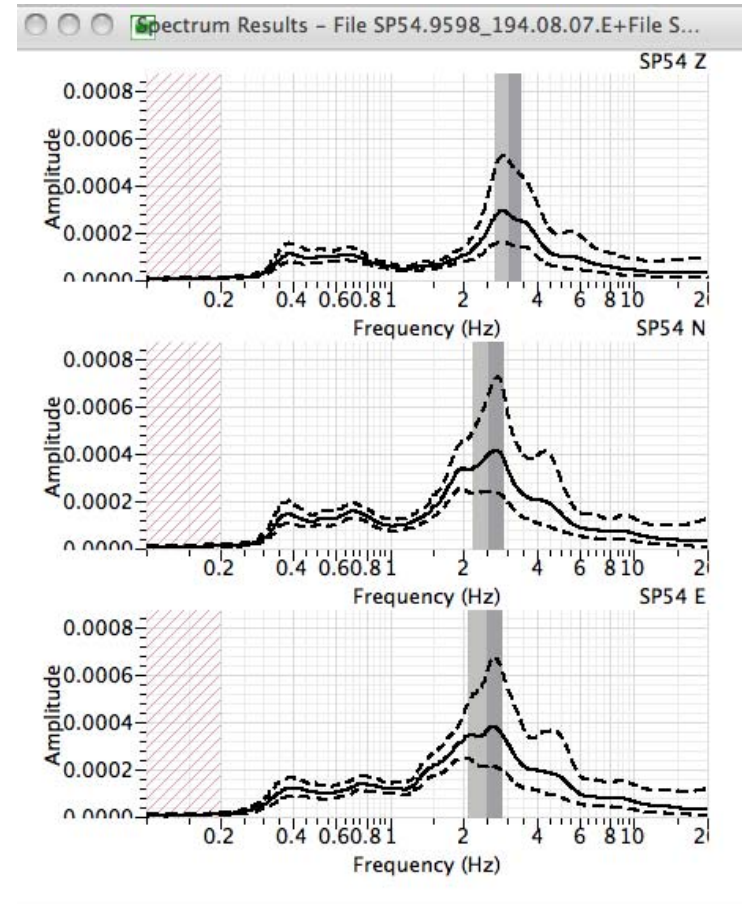
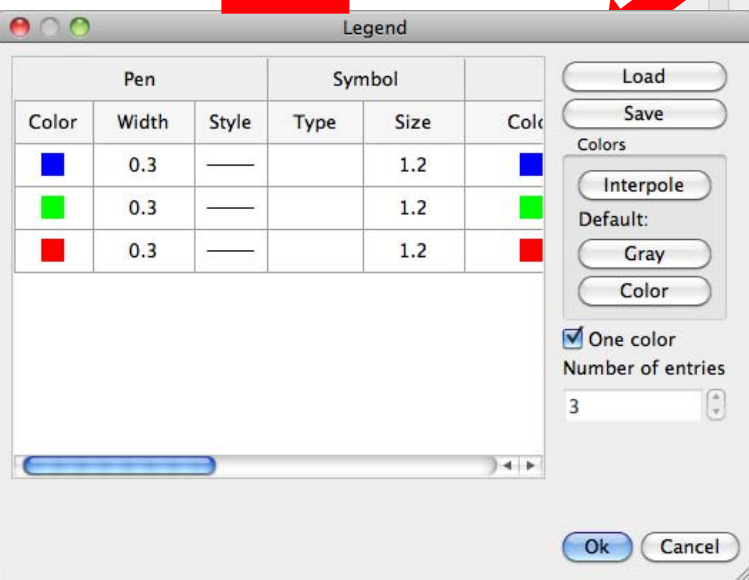
THE ENERGY SPECTRUM



Open
Property editor »

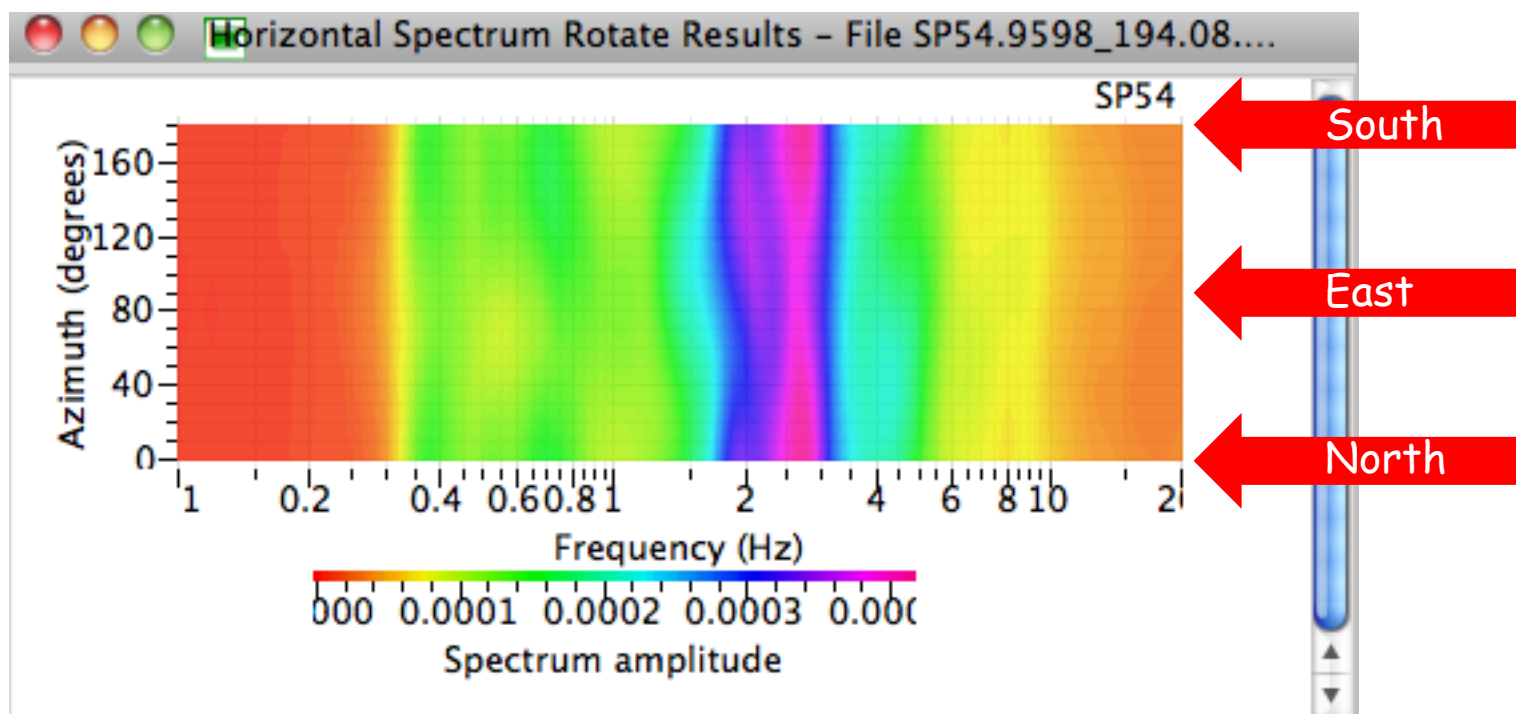


Choose
« Layer »
« Legend »



THE SPECTRUM ROTATE

- This tool works as the "H/V rotate toolbox"
- It computes spectra with horizontal components spanning different azimuths
- Azimuth is counted clockwise from the North (symmetry)
- Useful to check the energy spatial « release »



Work on data of EX3 (file MECHANICAL)

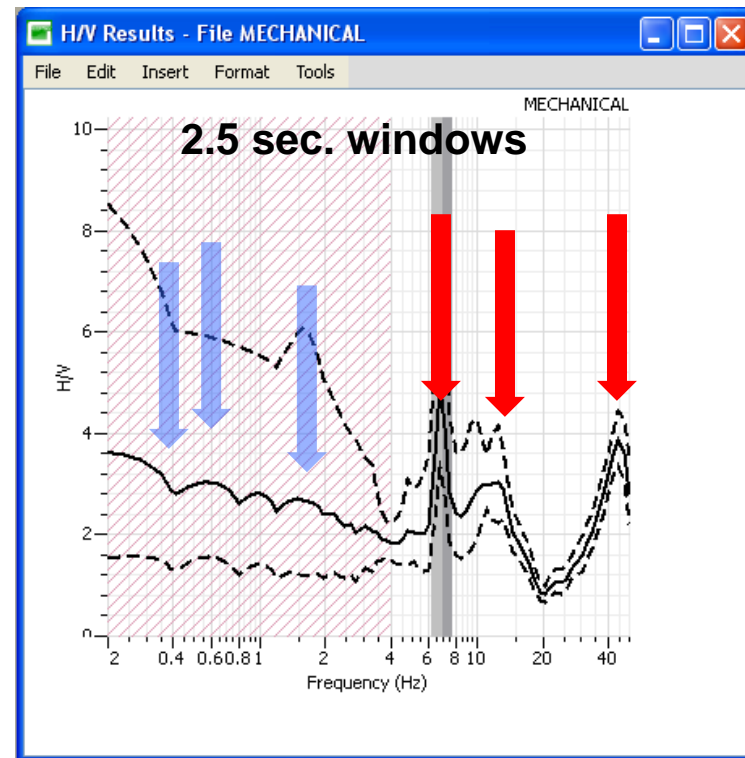
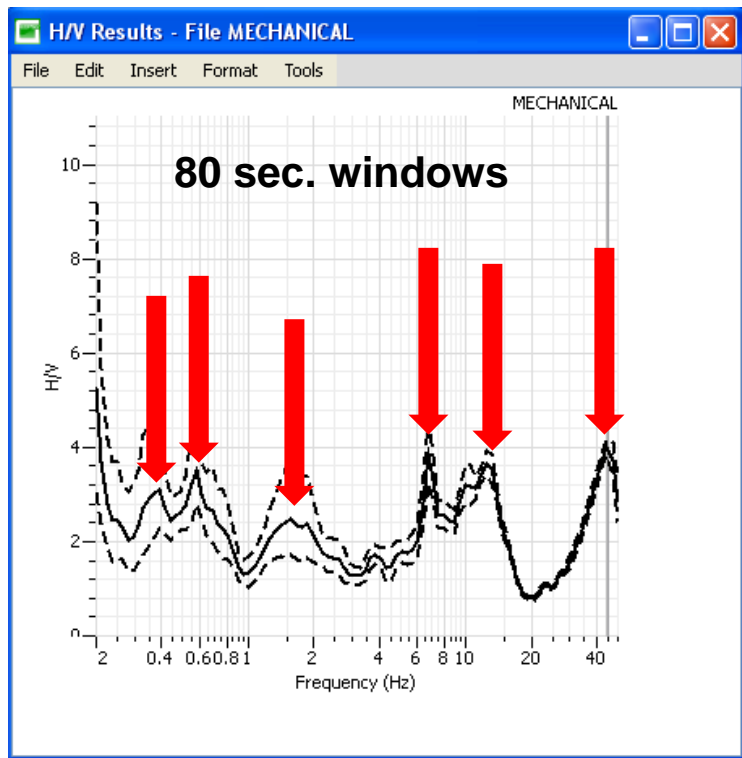
Record made by a CityShark II

- 200 sps ————→ Nyquist at 100Hz
- Seismometer: Lennartz LE-3D-5s. ↗ Window of 50 s.
↘ Lower lim. at 0.2 Hz
- Anti-trigger as usual

Parameters for H/V

FEW MOMENTS TO PLAY WITH DATA

Time windowing

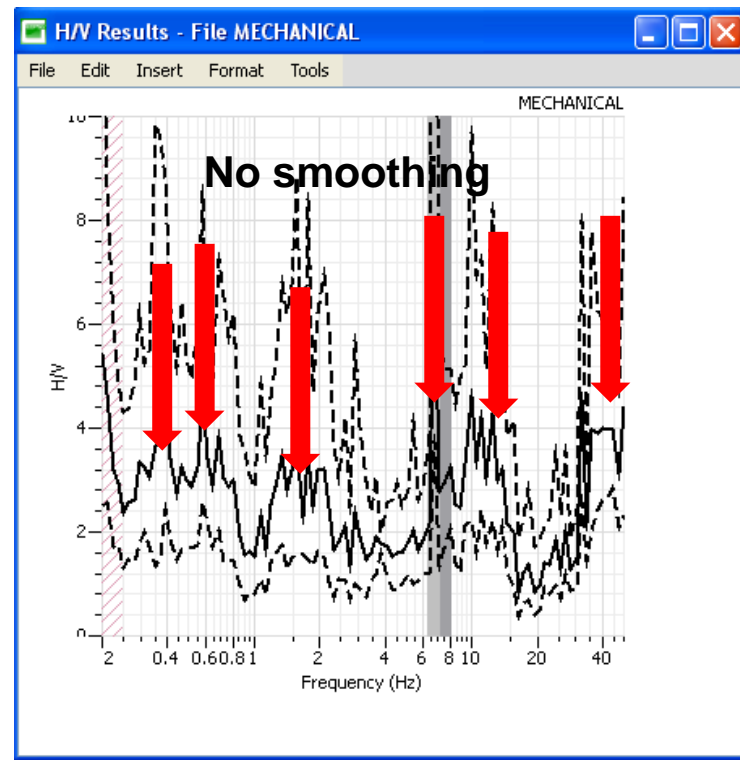
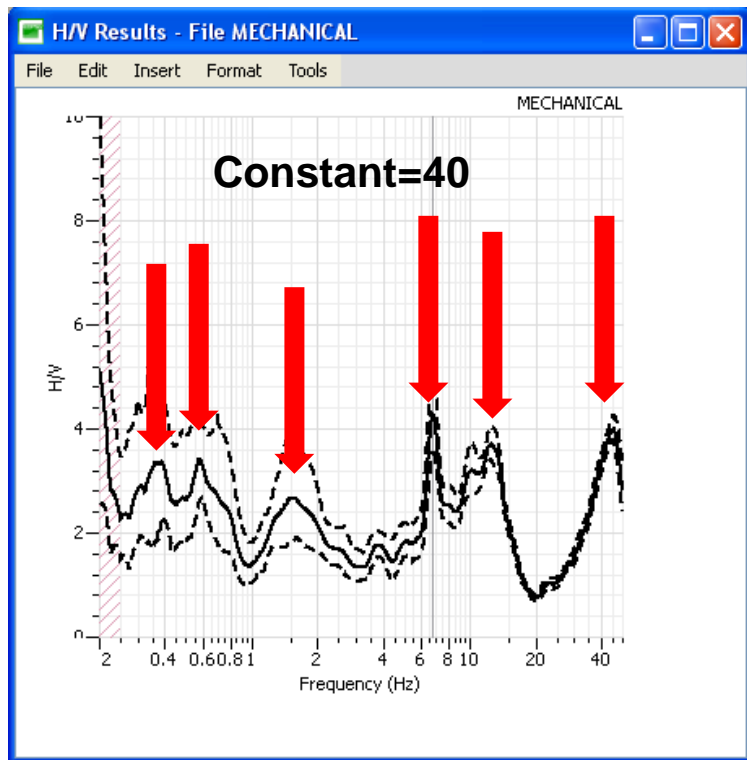


BE CARREFUL!!!!!!

The window time length affects strongly the peaks, especially in the lower frequencies
 Even if you are sure (by geology-geotechnical data) of the “presumed” frequency peak
 Be secure by increasing the length as much as you can

FEW MOMENTS TO PLAY WITH DATA

Konno and Ohmachi smoothing

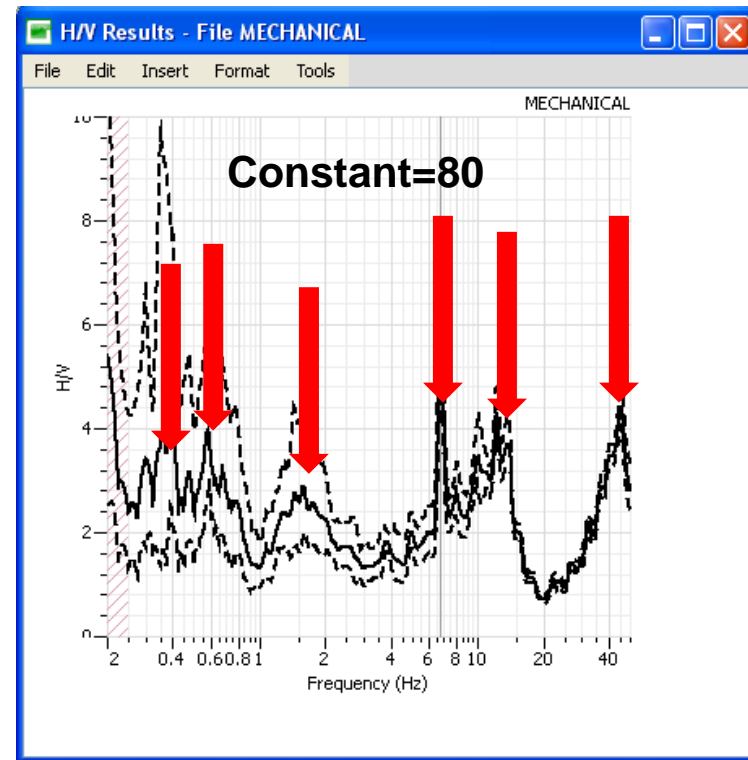
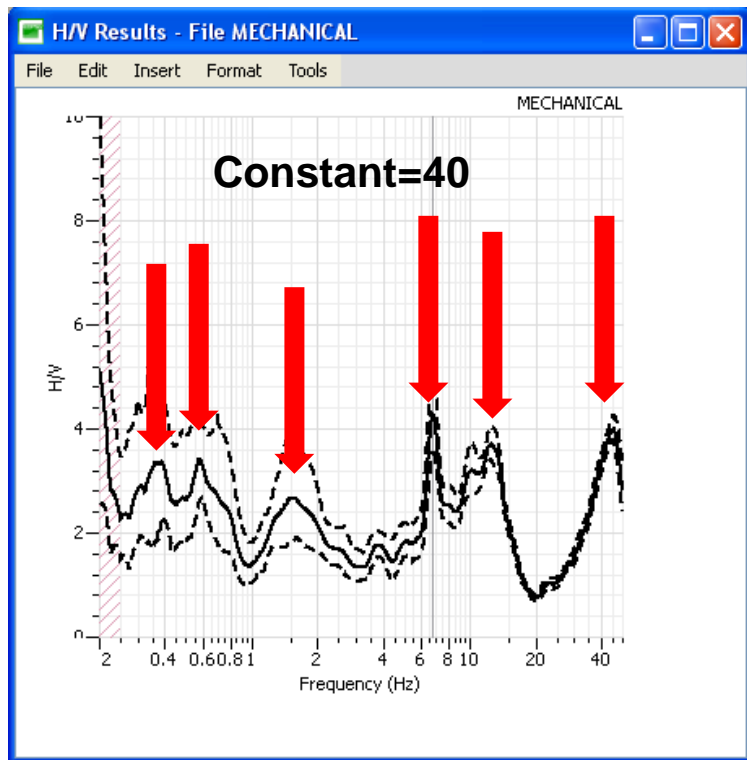


BE CAREFUL!!!!!!

No smoothing makes the H/V curve strongly difficult to interpret

FEW MOMENTS TO PLAY WITH DATA

Konno and Ohmachi smoothing

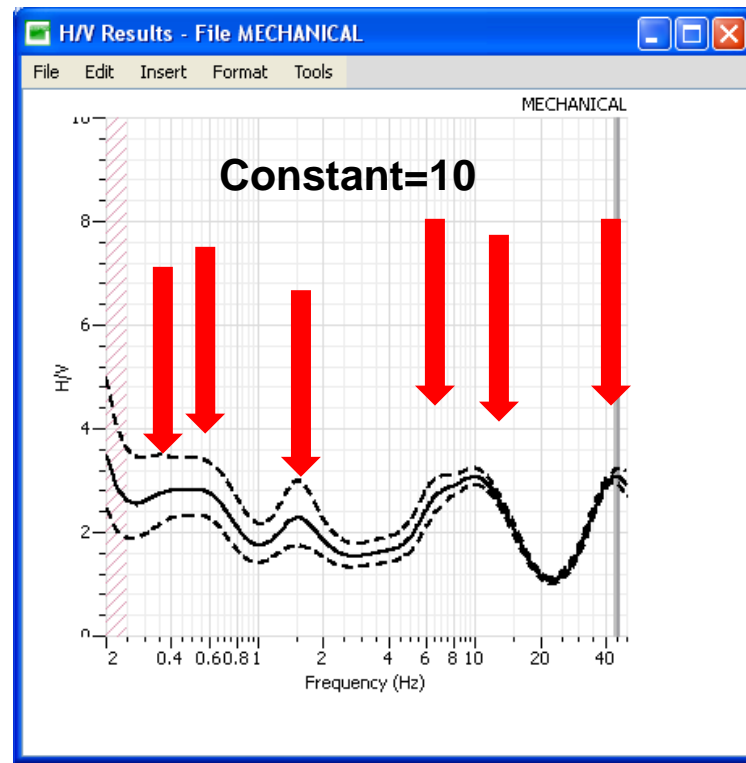
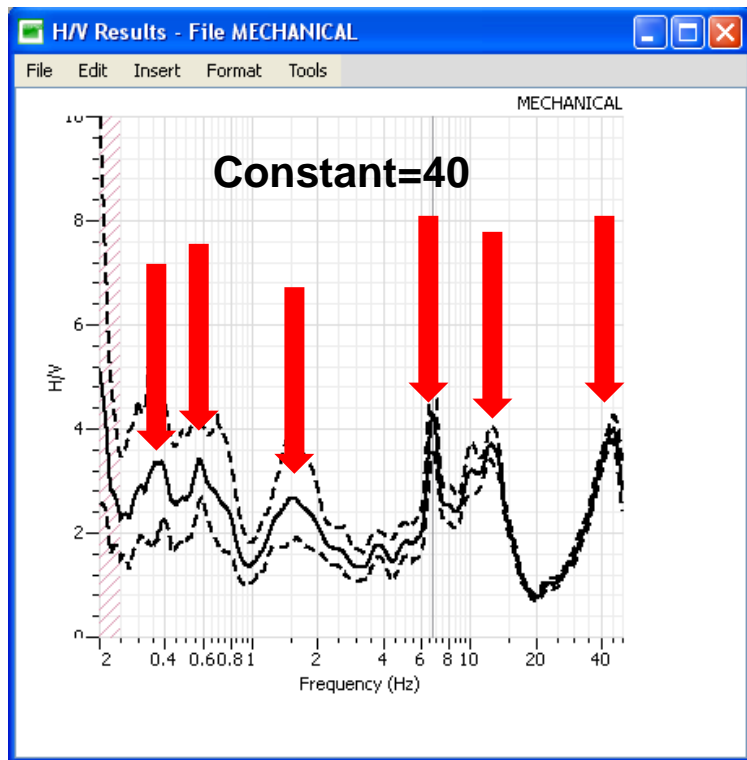


BE CARREFUL!!!!!!

**Increasing the K&O constant makes the H/V curve more difficult to interpret
There are too many details.**

FEW MOMENTS TO PLAY WITH DATA

Konno and Ohmachi smoothing






BE CARREFUL!!!!!!

**Decreasing the K&O constant makes the H/V curve not enough detailed
so more difficult to interpret, you can miss some peaks !!!!**

THE DAMPING TOOL

Work on data of EX3 (file MECHANICAL)

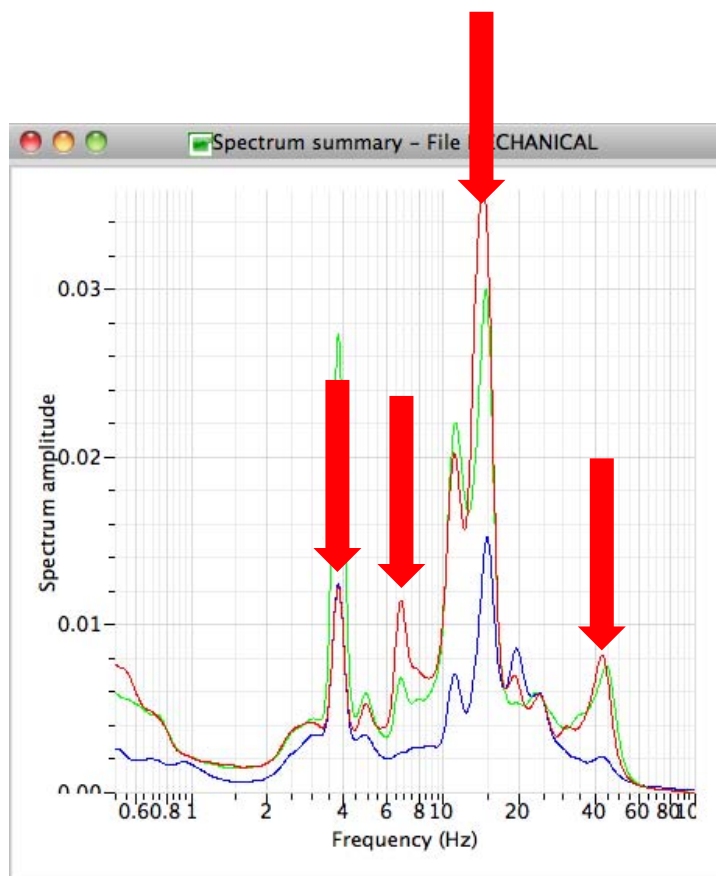
Record made by a CityShark II

- 200 sps  Nyquist at 100Hz
- Seismometer: Lennartz LE-3D-5s.  Window of 50 s.
 Lower lim. at 0.2 Hz
- Anti-trigger as usual

Parameters for Spectrum or H/V

THE DAMPING TOOL

Compute the Spectrum and Rotate Spectrum in-between 0.5 and 100 Hz

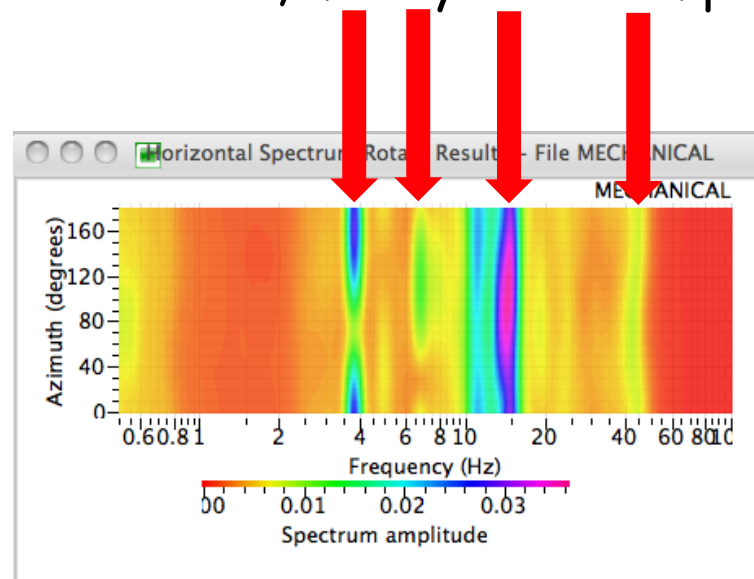


A peak at 3.8 Hz, mainly in **N-S** direction

A peak at 6.7 Hz, mainly in **E-W** direction

A peak at 14.8 Hz, mainly in **E-W** direction

A peak at 43.2 Hz, mainly on H comp.



THE DAMPING TOOL

Compute the H/V curve in-between 0.5 and 100 Hz

Spectrum We observe 5 peaks (H/V)

- 0.58 Hz
- 1.55 Hz
- 3.8 Hz
- 6.7 Hz
- 14.8 Hz
- 43.2 Hz

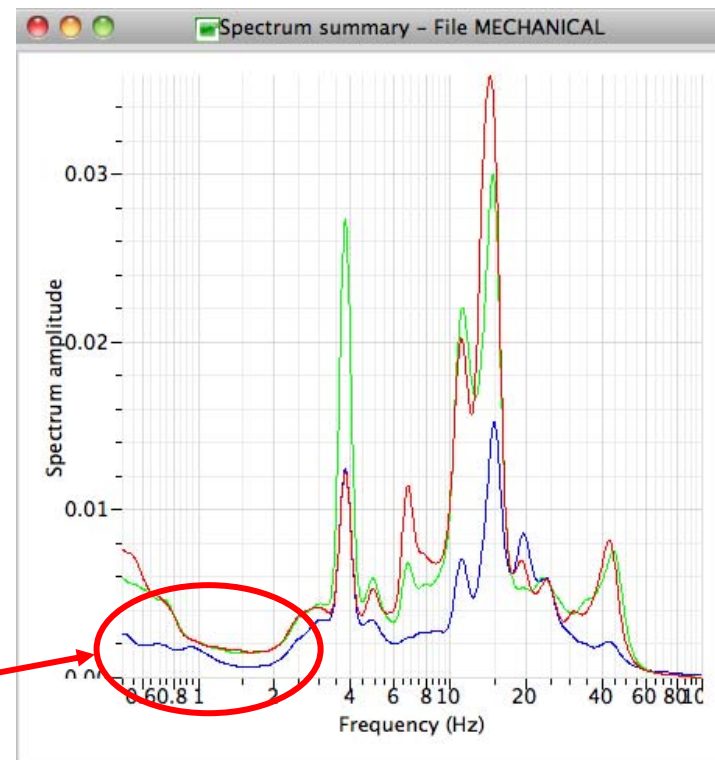
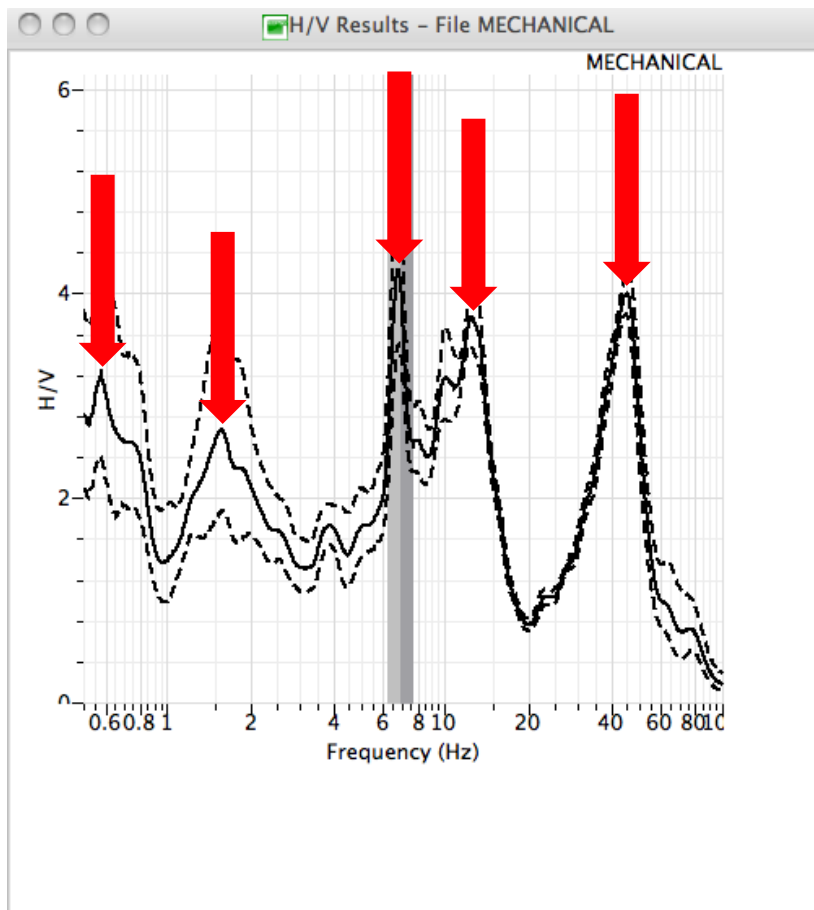
• 0.58 Hz

• 1.55 Hz

• 6.75 Hz

• 12.45 Hz

• 45.75 Hz



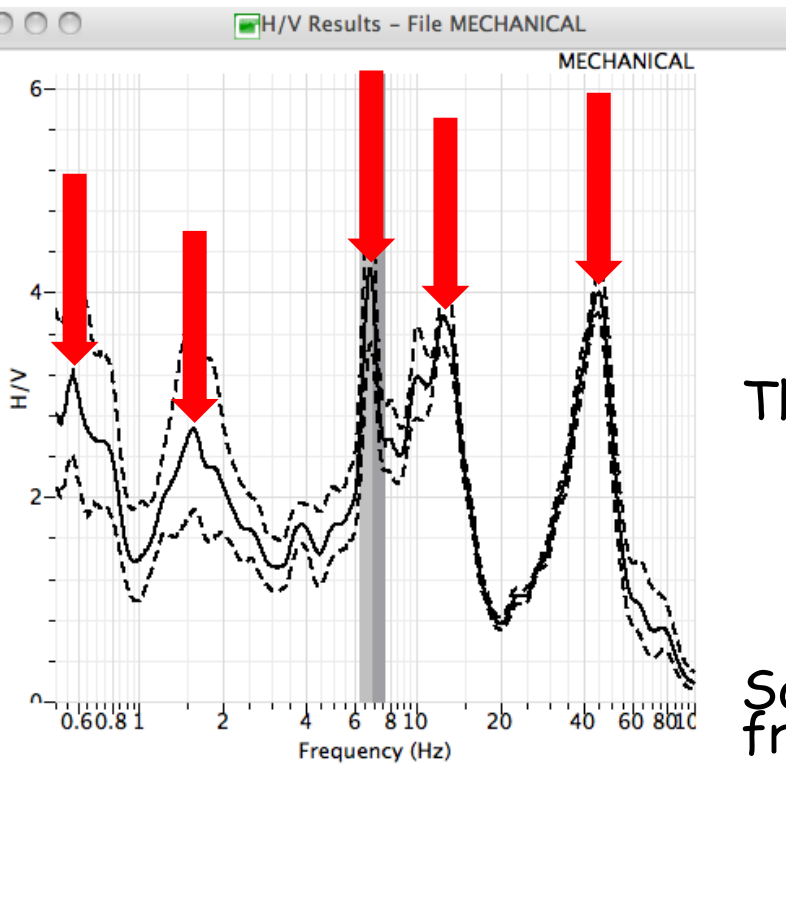
In these frequencies, there is no peak in energy. So the H/V peaks have a natural origin. But, it is better to confirm the origin.

THE DAMPING TOOL

Compute the H/V curve in-between 0.5 and 100 Hz

Spectrum We observe 5 peaks (H/V)

- 0.58 Hz
- 3.8 Hz
- 6.7 Hz
- 14.8 Hz
- 43.2 Hz
- 1.55 Hz
- 6.75 Hz
- 12.45 Hz
- 45.75 Hz



The 2 first peaks:
natural peaks (to be confirmed)

So, we will check the damping for these frequencies to verify their origin

- 1.55 Hz (presumed as natural peak)
- 6.75 Hz ??
- 12.45 Hz ??
- 45.75 Hz ??

THE DAMPING TOOL

Verifying the origin of the « 1.55 Hz » H/V peak

Open the « damping toolbox » by dragging the name or signal or table onto this icon:



It will open:

- the « Damping toolbox »
- a signal window (not used)

As we want to check the damping at a defined frequency, we have to isolate a frequency band using a « Band pass » filter.

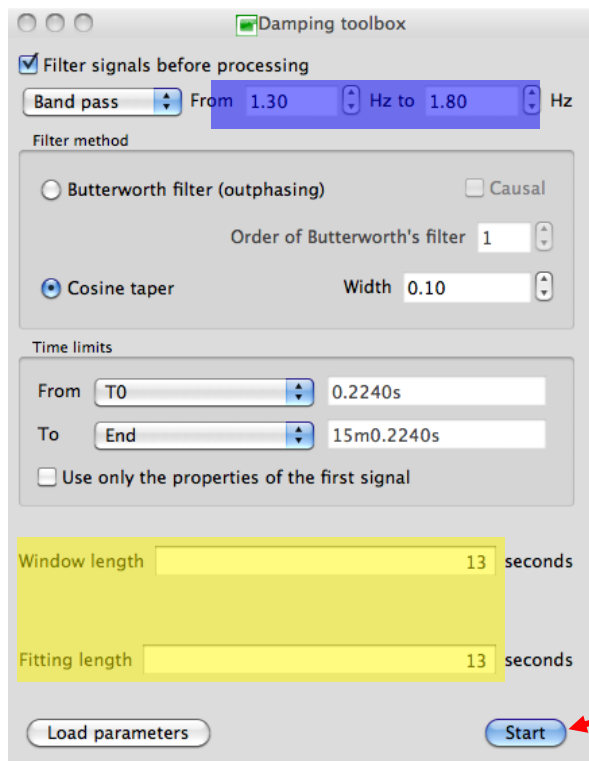
The frequency band is defined about ± 0.25 Hz from the target frequency

So, here, we fix the band between 1.3 and 1.8 Hz

Then click on « Start »

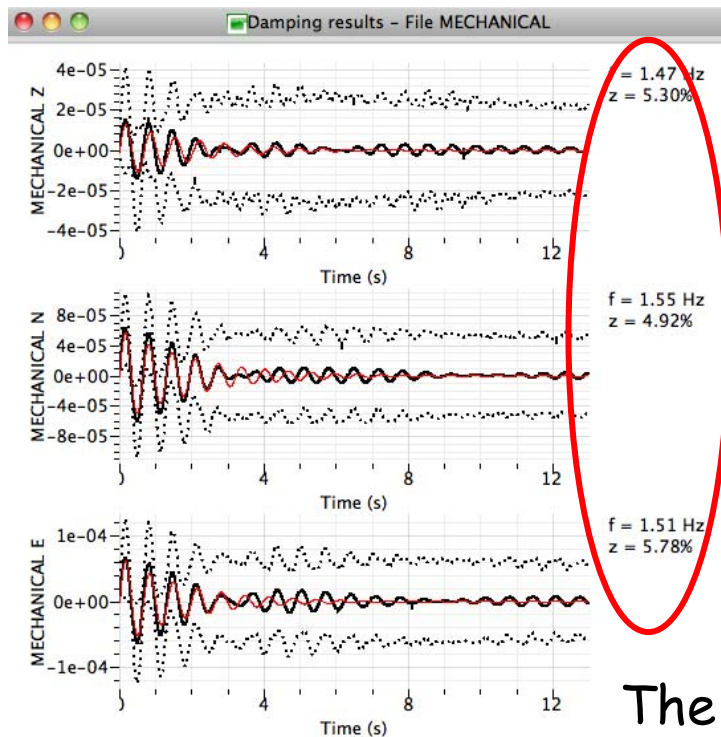
For the « Window length » and « Fitting length »

- we want to check the stability for a time window length of about 20 wavelengths
- here $20/1.55 \approx 13$ sec.



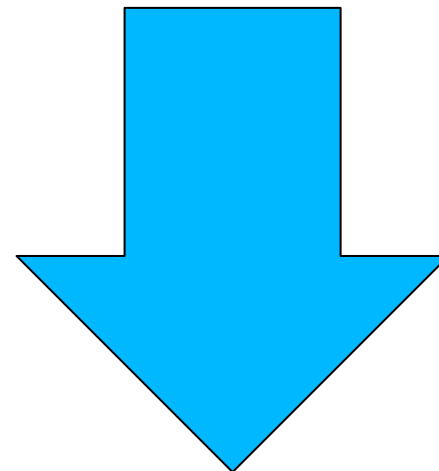
THE DAMPING TOOL

Verifying the origin of the « 1.55 Hz » H/V peak



The results vary slightly:

- the frequencies are close
- the computed damping is over 1.0



The checked frequency is not SUSTAINED and can be assumed as NATURAL

The « 1.55 Hz » H/V peak is suitable.

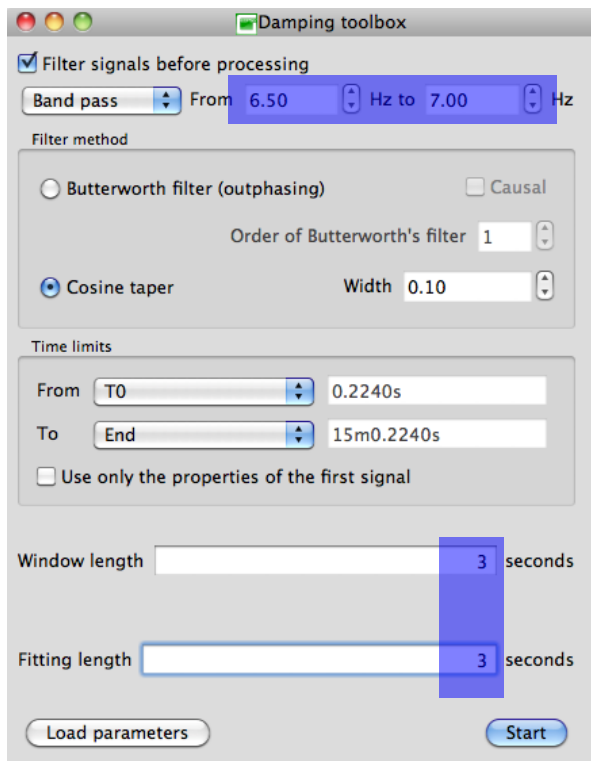
THE DAMPING TOOL

Verifying the origin of the « 6.75 Hz » H/V peak

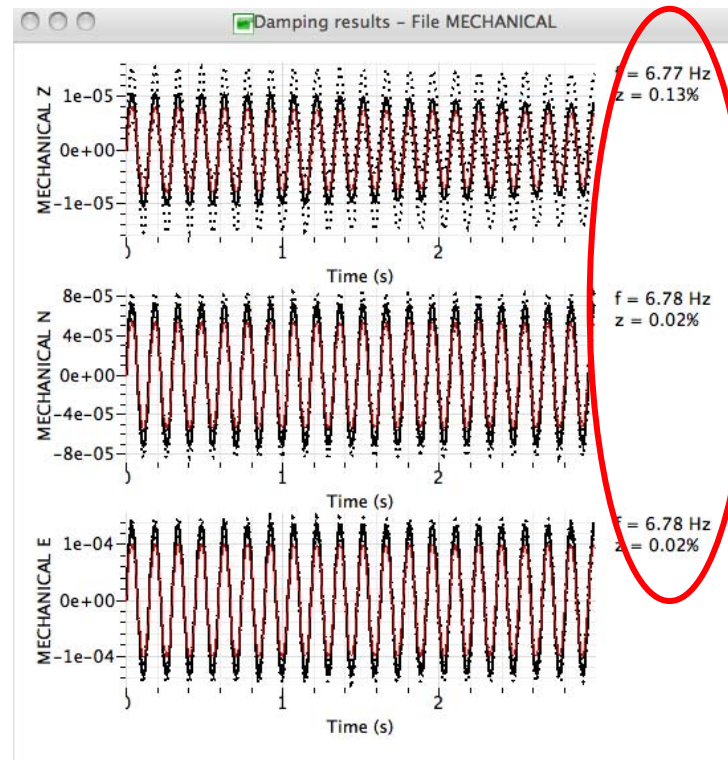
Open again the « Damping toolbox »

Fix the frequency band between 6.5 and 7.0 Hz

The « Window length » is $20/6.75 \approx 3$ sec.



The results are homogeneous:
 • the frequencies are equal
 • the computed damping is strongly less than 1.0



The checked frequency is **STRONGLY SUSTAINED**
 and can be assumed as **ANTHROPIC** and **NOT NATURAL**

The « 6.75 Hz » H/V peak is an industrial peak

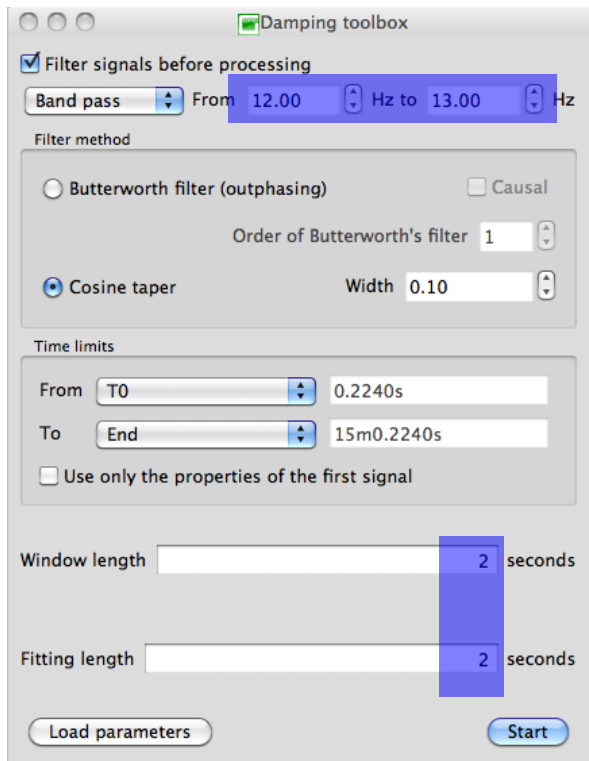
THE DAMPING TOOL

Verifying the origin of the « 12.45 Hz » H/V peak

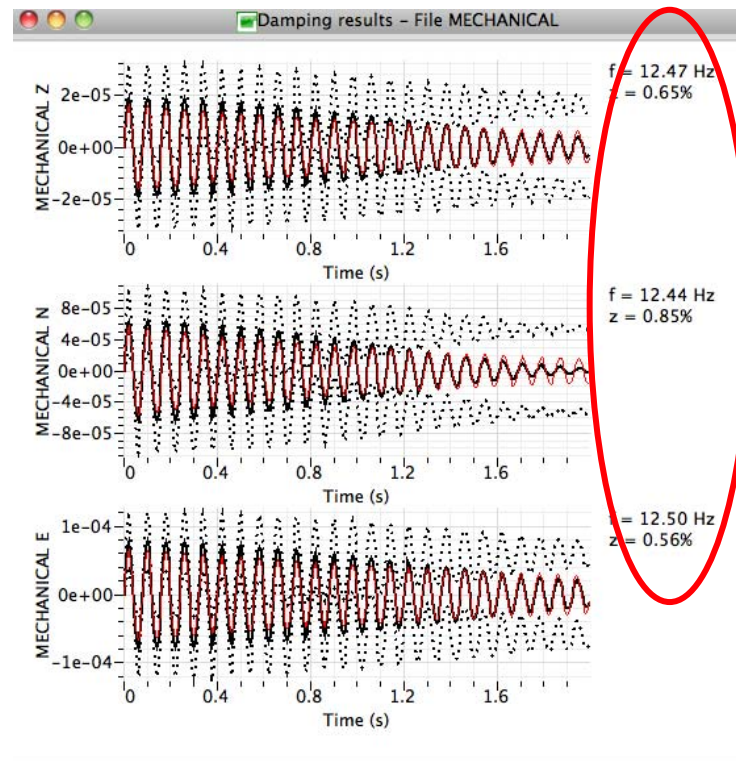
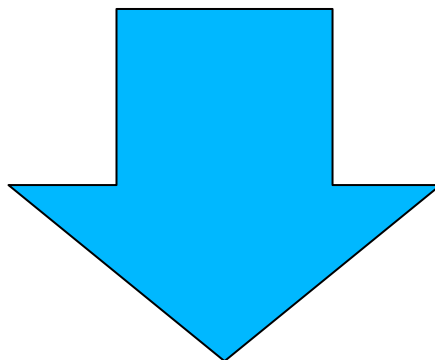
Open again the « Damping toolbox »

Fix the frequency band between 12 and 13 Hz

The « Window length » is $20/12.45 \approx 2$ sec.



The results are homogeneous:
 • the frequencies are equal
 • the computed damping is less than 1.0



The checked frequency is SUSTAINED
 and can be assumed as ANTHROPIK and NOT NATURAL

The « 12.45 Hz » H/V peak has an industrial origin

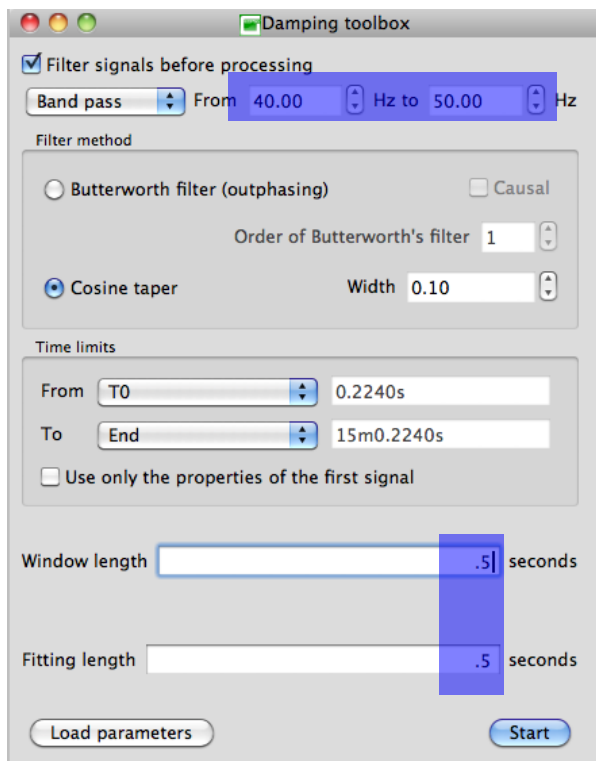
THE DAMPING TOOL

Verifying the origin of the « 45.75 Hz » H/V peak

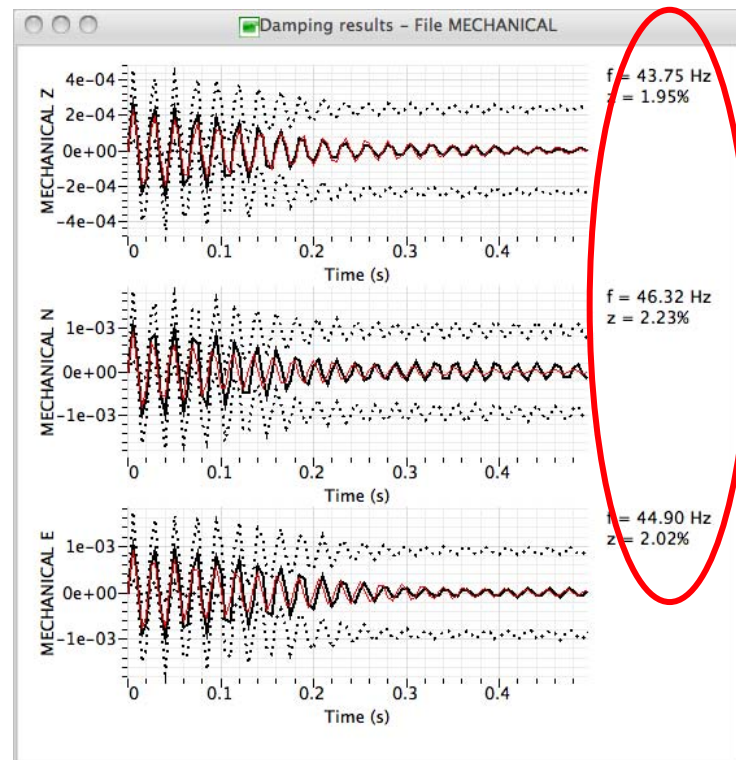
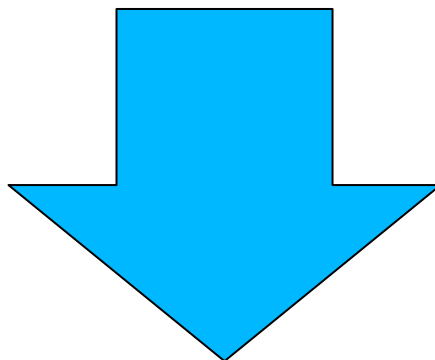
Open again the « Damping toolbox »

Fix the frequency band between 40 and 50 Hz

The « Window length » is $20/45.75 \approx 0.5$ sec.



The results are
NOT homogeneous:
• the frequencies
are unstable
• the computed
damping is over 1.0



The checked frequency seems to be NOT SUSTAINED
and can be assumed as NATURAL, but for me this frequency is doubtful

The « 45.75 Hz » H/V peak seems to be NATURAL (????)

SESARRAY PACKAGES

GEOPSY

array tools

FK Capon MSPAC MASW

SPEC

damping

H/V

Normal Rotate

Normal Rotate

figure

figures

gp tools

*Dispersion curves
Ellipticity curves
Autocorr. Curves
...*

warangps

Array response

Post-processing

max2curve

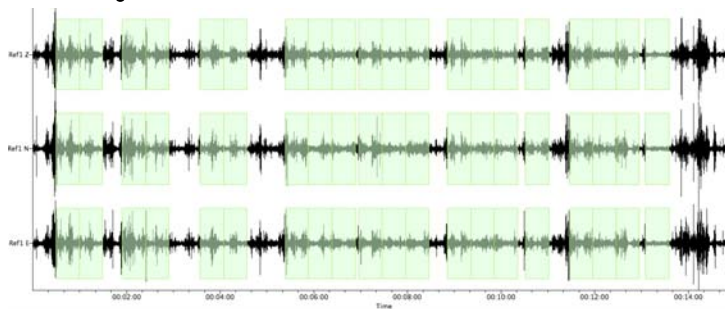
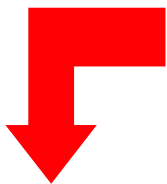
spac2disp

DINVER

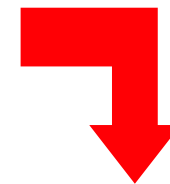
inversion

H/V computation (as in Geopsy)

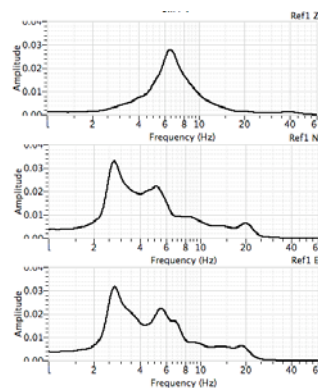
Selection of the n most stationary windows



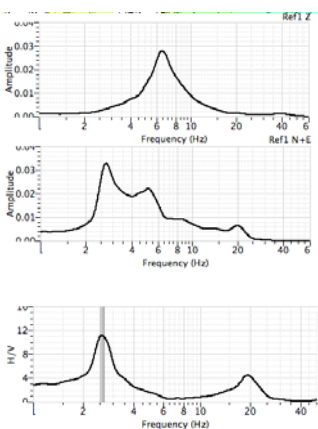
(STA/LTA anti-trigger algorithm)



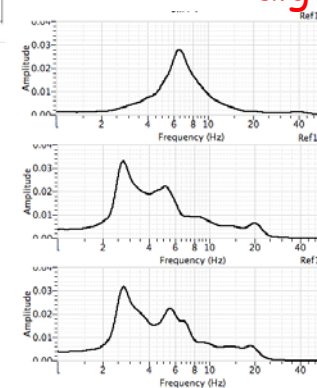
Computation of Fourier amplitude spectra + smoothing



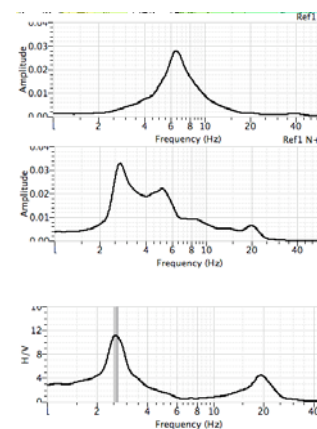
Average of horizontal components



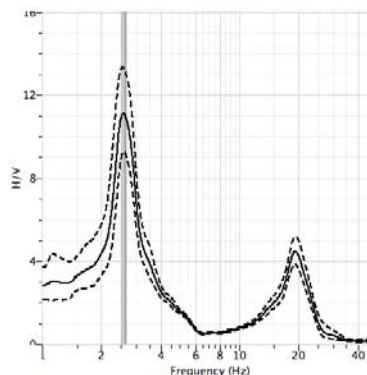
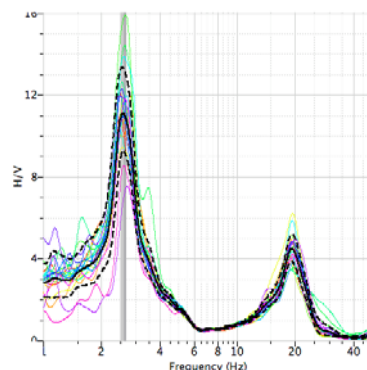
For each window of each component



For each window

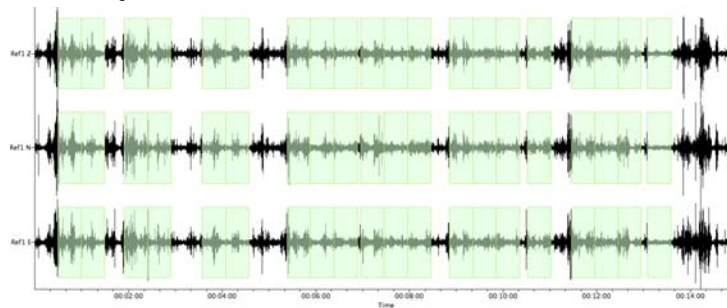
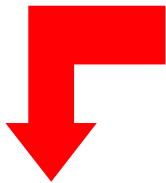


Computation of the average H/V + standard deviation

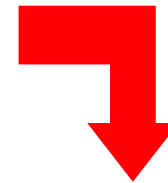


H/V computation (as in Geopsy)

Selection of the n most stationary windows



(STA/LTA anti-trigger algorithm)



1: removal offset for all the waveforms

2: determination of the STA/LTA value for each sample of each component

2-1: verification is the ratio fits the STA/LTA given limits

2-2: determination of time sample series fullfilling the given time length limits

STA/LTA computation

-2 sliding windows at the same time

- a short one (STA), with a time length you fix yourself (0.5 - 2 sec): t_{sta}

- a long one (LTA), with a time length you fix yourself (15 - 60 sec): t_{lta}

- on each window, you calculate the mean value of the waveform

-the ratio STA/LTA is computed and then compared to the fixed boundaries (low and high)

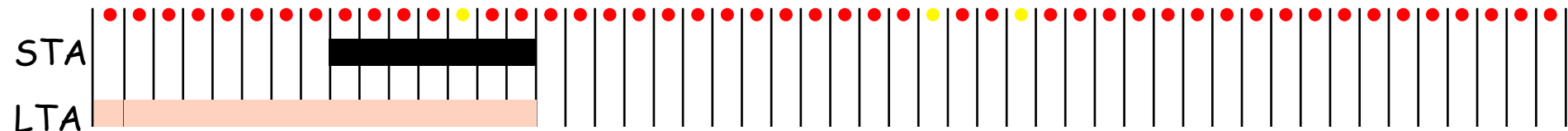
-the calculated ratio (so the sample) is conserved or rejected

-all the process is done for the next sample (for STA and LTA)

● = 1 ● = 11

STA average on 2 samples
LTA average on 10 samples

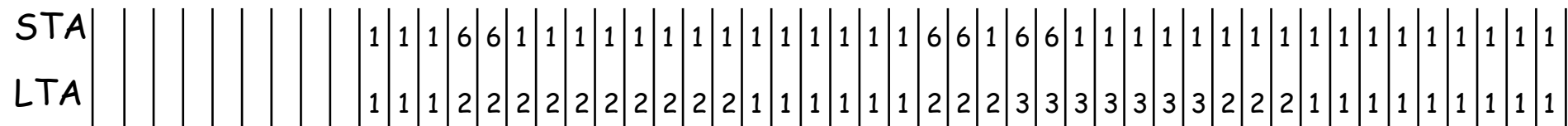
Sample space



Value space

$$V_{10(STA)} = \left(\sum_{i=9}^{10} abs(value(i)) \right) / 2$$

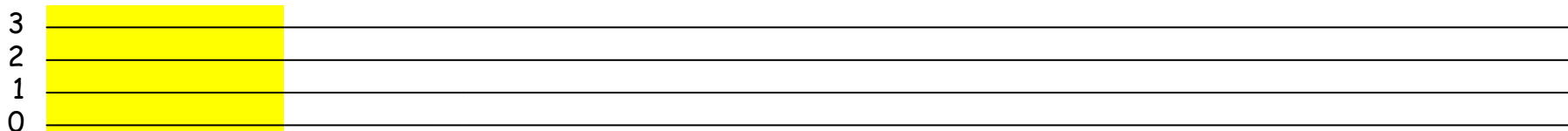
$$V_{n(STA)} = \left(\sum_{i=n-1}^n abs(value(i)) \right) / 2$$



$$V_{10(LTA)} = \left(\sum_{i=1}^{10} abs(value(i)) \right) / 10$$

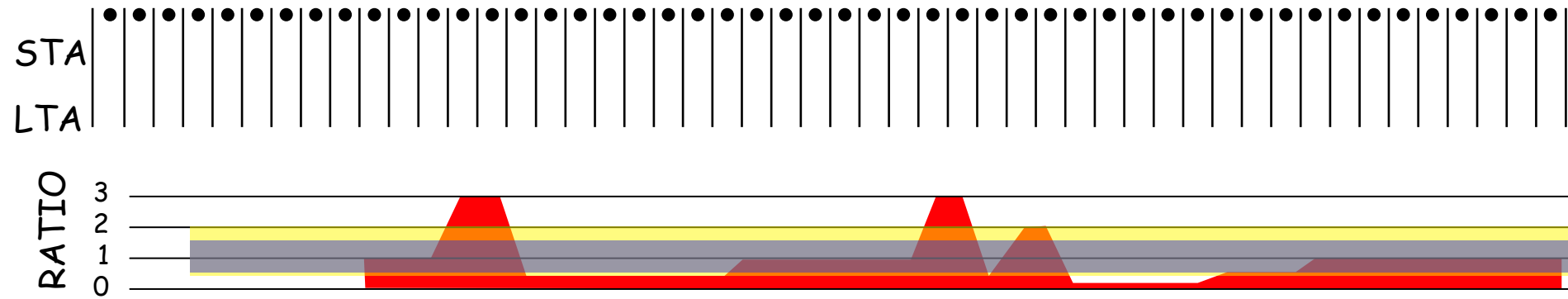
$$V_{n(LTA)} = \left(\sum_{i=n-9}^n abs(value(i)) \right) / 10$$

RATIO



STA/LTA ratio calculus

Sample space



Case one: you fix a ratio STA/LTA in-between 0.6 and 1.4



Case two: you fix a ratio STA/LTA in-between 0.5 and 2.0



Larger is the boundaries difference less drastic you are in your selection

WINDOWING DETERMINATION

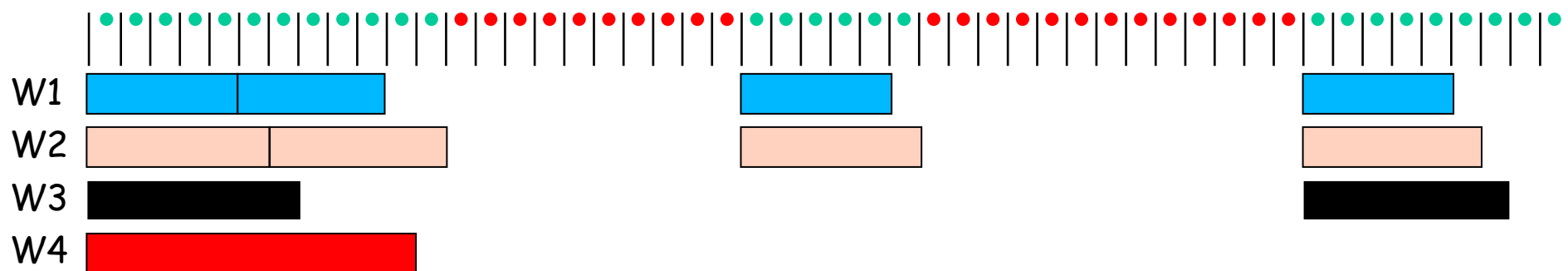
W1: 5 samples

W2: 6 samples

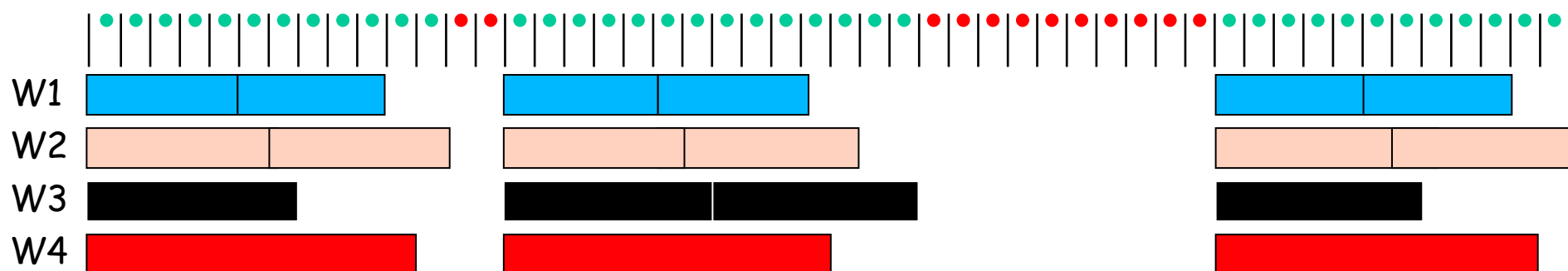
W3: 7 samples

W4: 11 samples

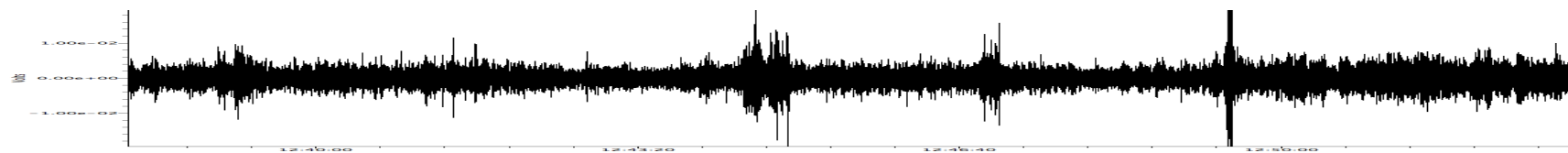
Case one: you fix a ratio STA/LTA in-between 0.6 and 1.4



Case two: you fix a ratio STA/LTA in-between 0.5 and 2.0



STA-LTA AND WINDOWING REAL CASE



1-30



5-30



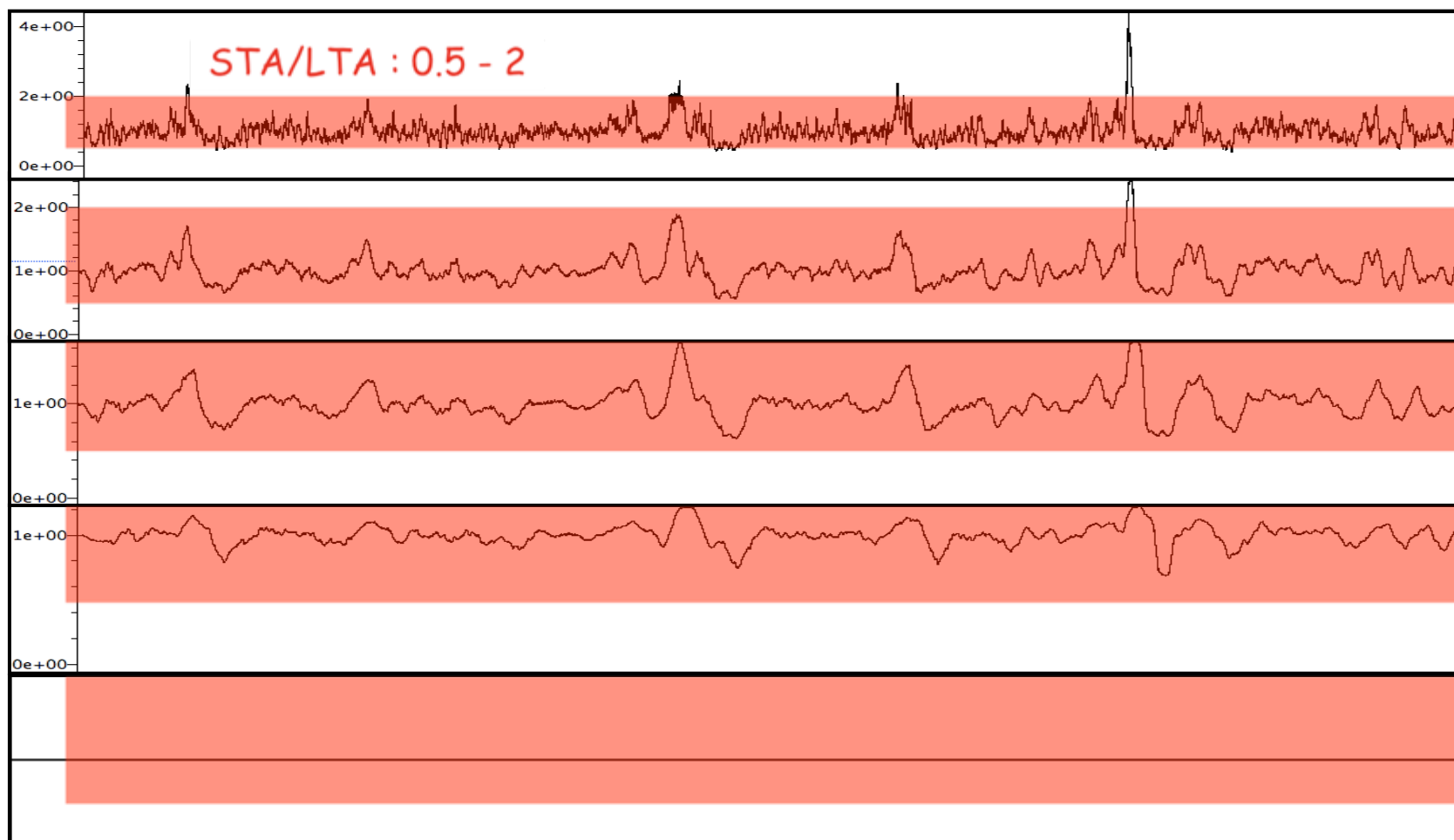
10-30



20-30

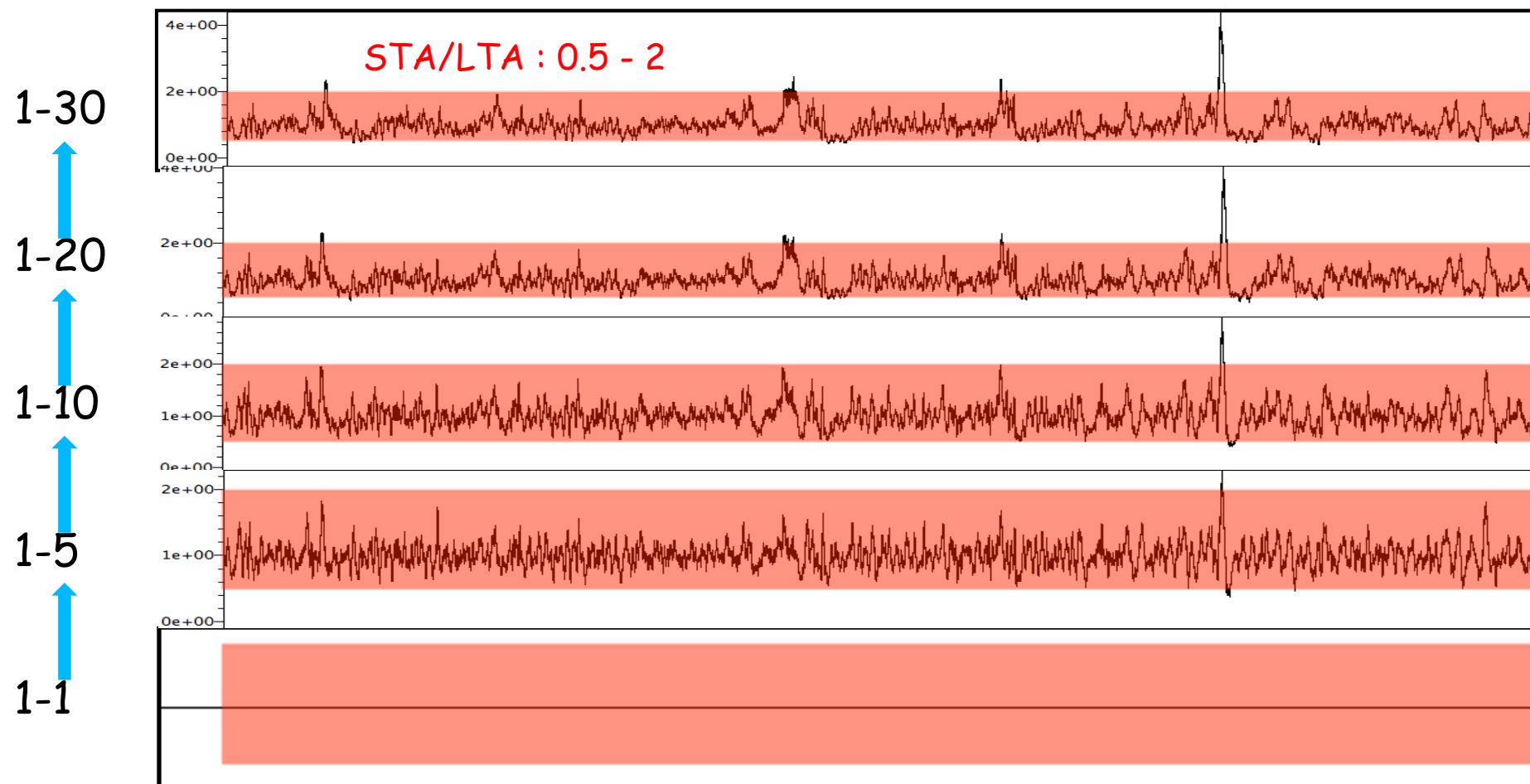
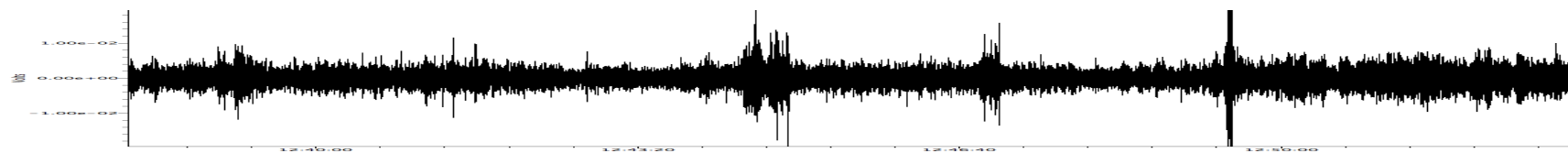


30-30



Increasing the t_{STA} , you smooth and stretch the STA/LTA ratio, until a flat line
You are less selective

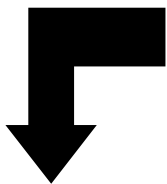
STA-LTA AND WINDOWING REAL CASE



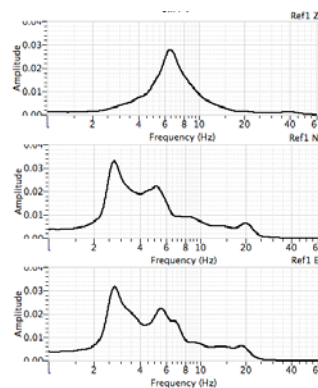
Increasing the $tLTA$, you only amplify the STA/LTA ratio, from a flat line
You are more selective

H/V computation (as in Geopsy)

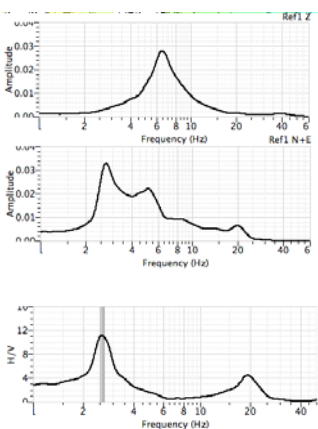
Selection of the n most stationary windows



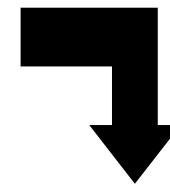
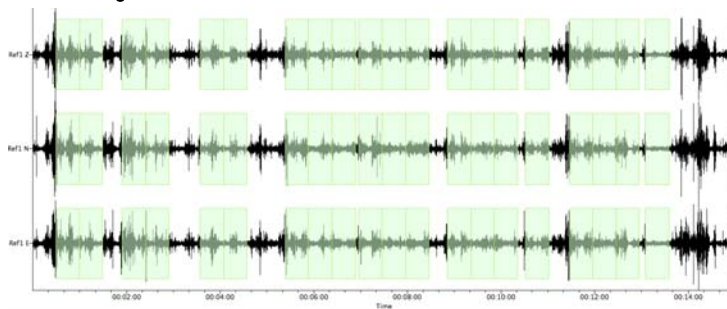
Computation of Fourier amplitude spectra + smoothing



Average of horizontal components

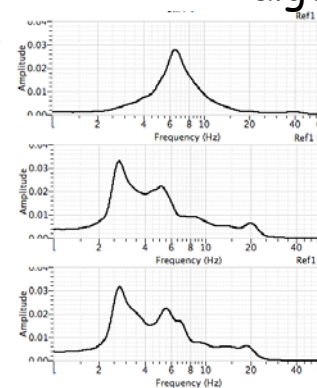


Computation of the average H/V + standard deviation

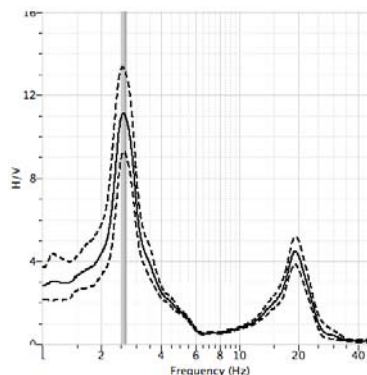
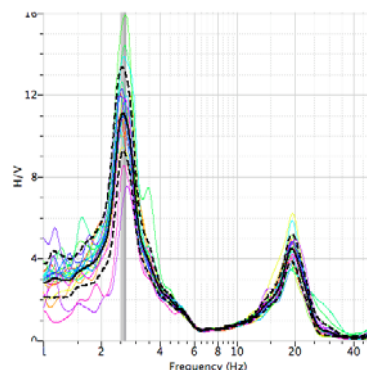
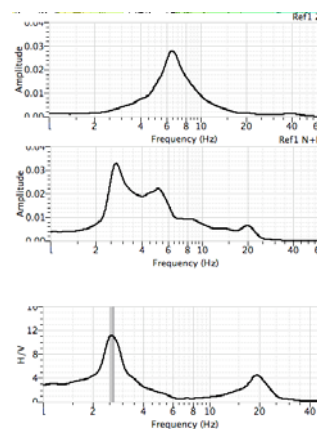


(STA/LTA anti-trigger algorithm)

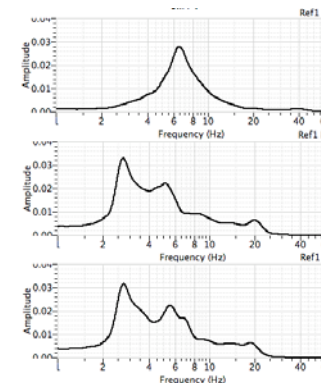
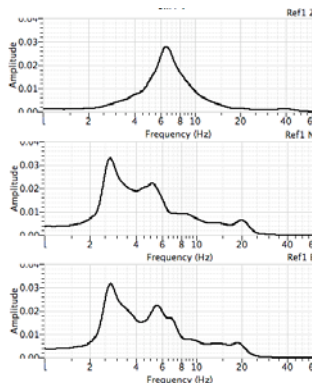
For each window of each component



For each window



Computation
of Fourier
amplitude
spectra
+ smoothing



For each
window of
each
component

Smoothing with the "Konno-Ohmachi" function

$$\frac{\sin\left(\left(\log_{10}\left(\frac{f}{f_c}\right)\right)^b\right)}{\left(\left(\log_{10}\left(\frac{f}{f_c}\right)\right)^b\right)^4}$$

f is the frequency,
 f_c is the central frequency,
 b is the bandwidth coefficient.

Constant

The smoothing function has a triangular shape centered on the current frequency and its width is equal to "Band width"

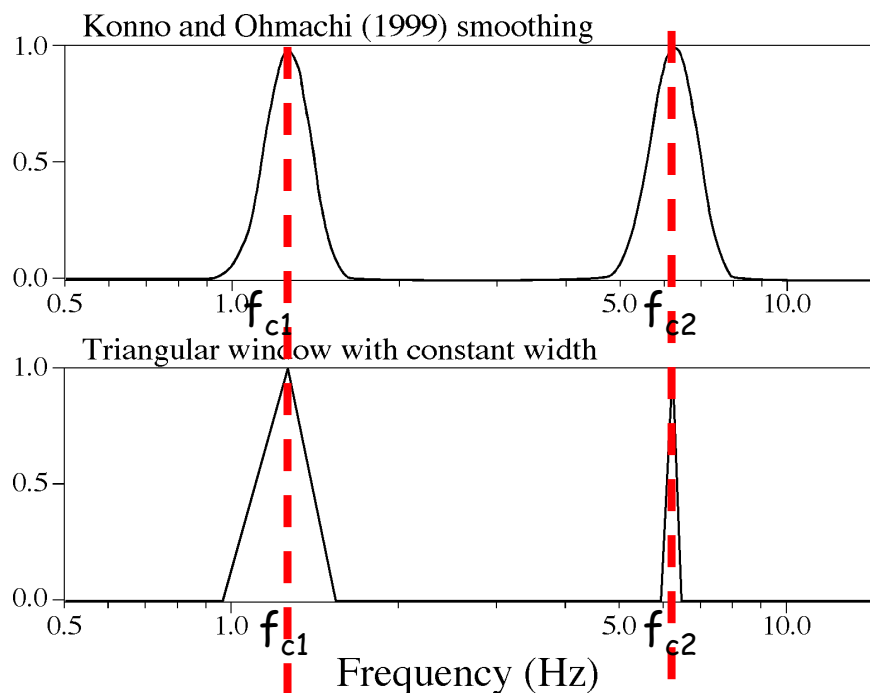
Proportional

The smoothing function has a triangular shape and its width depends upon the current frequency. The half width is defined by percentage*frequency. The value of "percentage" cannot be greater or equal to 100%.

$$\frac{\sin\left(\left(\log_{10}\left(\frac{f}{f_c}\right)\right)^b\right)}{\left(\left(\log_{10}\left(\frac{f}{f_c}\right)\right)^b\right)^4}$$

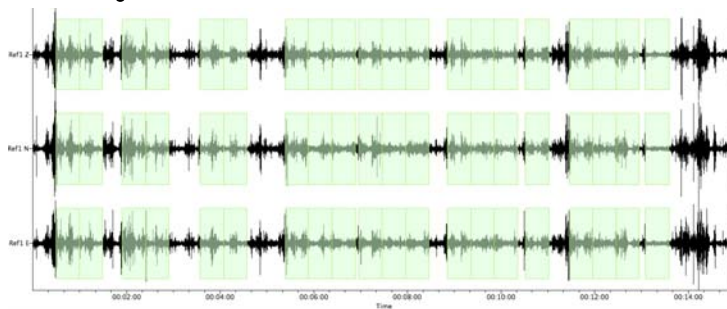
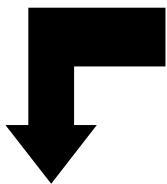
Konno and Ohmachi smoothing (1999)

- constant bandwidth in a logarithmic scale
- recommended because this smoothing function preserves the different number of points at low and high frequency

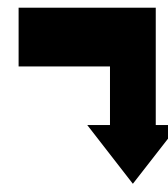


H/V computation (as in Geopsy)

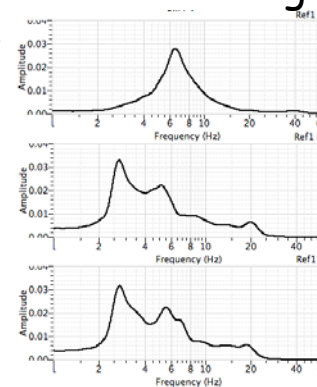
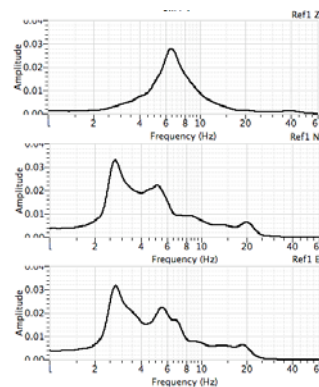
Selection of the n most stationary windows



(STA/LTA anti-trigger algorithm)

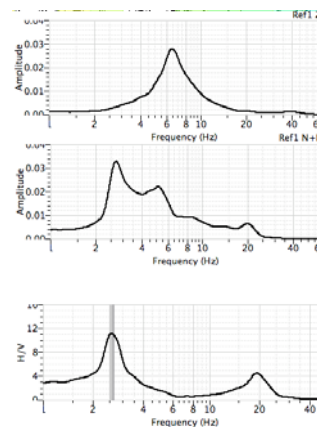
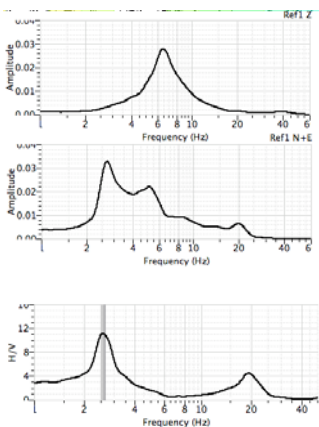


Computation of Fourier amplitude spectra + smoothing



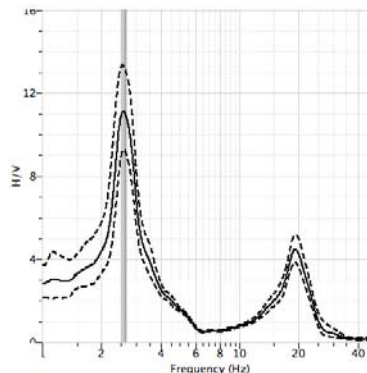
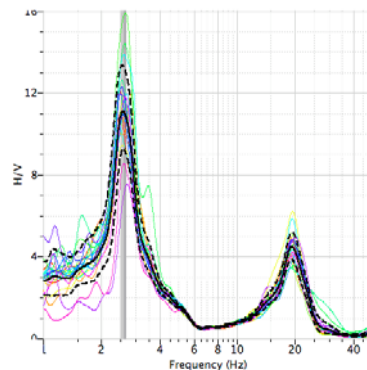
For each window of each component

Average of horizontal components



For each window

Computation of the average H/V + standard deviation



H/V COMPUTATION (as implemented in Geopsy)

Squared average

- Fourier amplitude spectra (for each window)
- combination of horizontal spectra (for each window)

$$H(f) = \sqrt{\frac{N^2(f) + E^2(f)}{2}}$$

- smooth of H and V (for each window)
- computation of H/V

Based on total horizontal energy

- Fourier amplitude spectra (for each window)
- combination of horizontal spectra (for each window)

$$H(f) = \sqrt{N^2(f) + E^2(f)}$$

- smooth of H and V (for each window)
- computation of H/V

H/V COMPUTATION (as implemented in Geopsy)

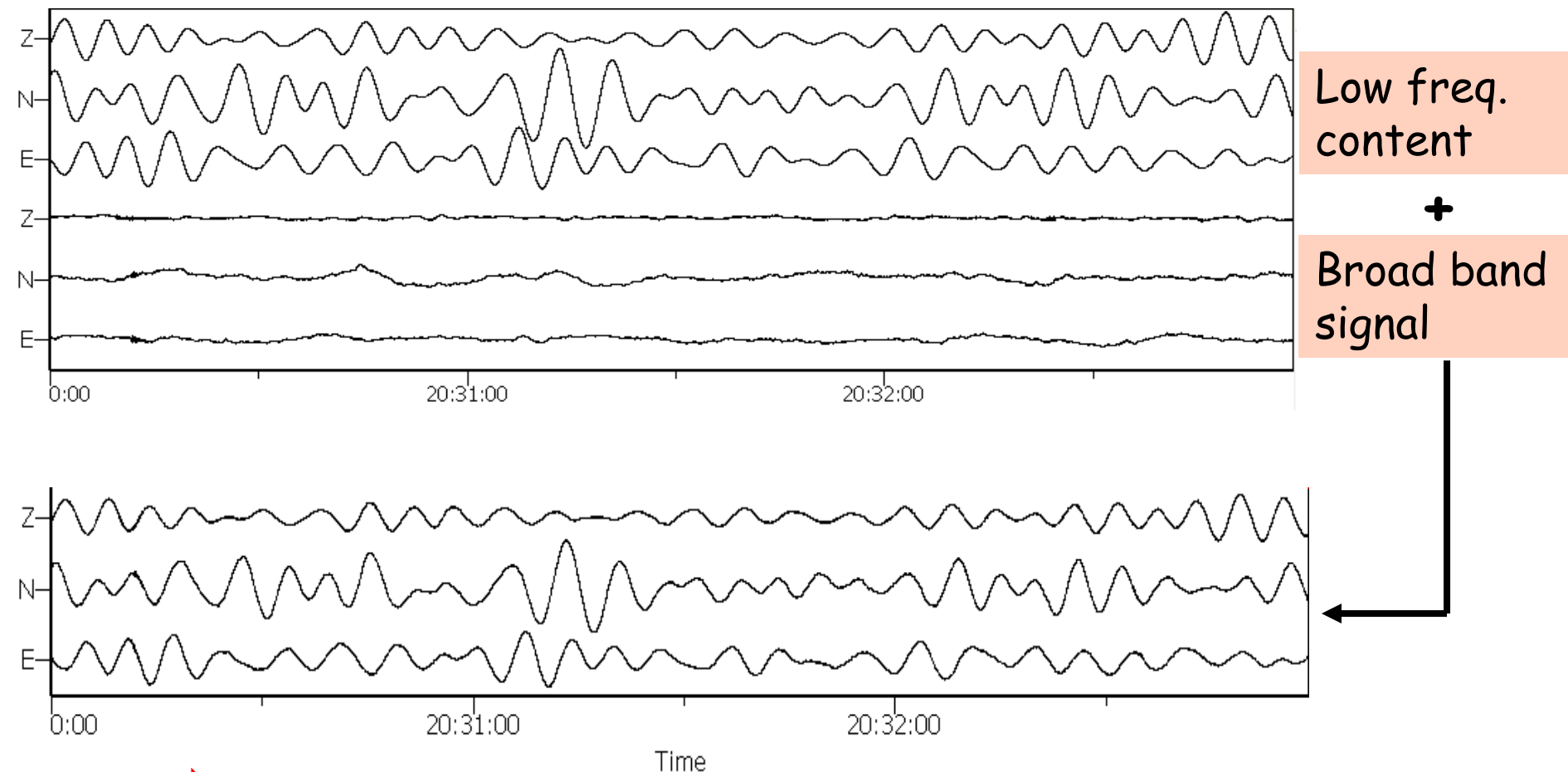
Sometimes, the taper size used in the pre-processing has a strong influence at low frequency. If the signal contains a strong and very low frequency component, then cutting into short time windows may strongly distort the observed spectra and H/V. Even when using the minimum window length criteria according SESAME reports (i.e. 10 times the corresponding period for the minimum frequency of interest) may be not enough to ensure a reliable H/V estimation.

In order to avoid such "tapering effects", signals can be high-pass filtered before computing the H/V and spectra curves (Geopsy option).

The higher value for the frequency of the high-pass filter is the minimum 'reliable' frequency, i.e. $10/\text{window_length}$.

H/V COMPUTATION (taper effects)

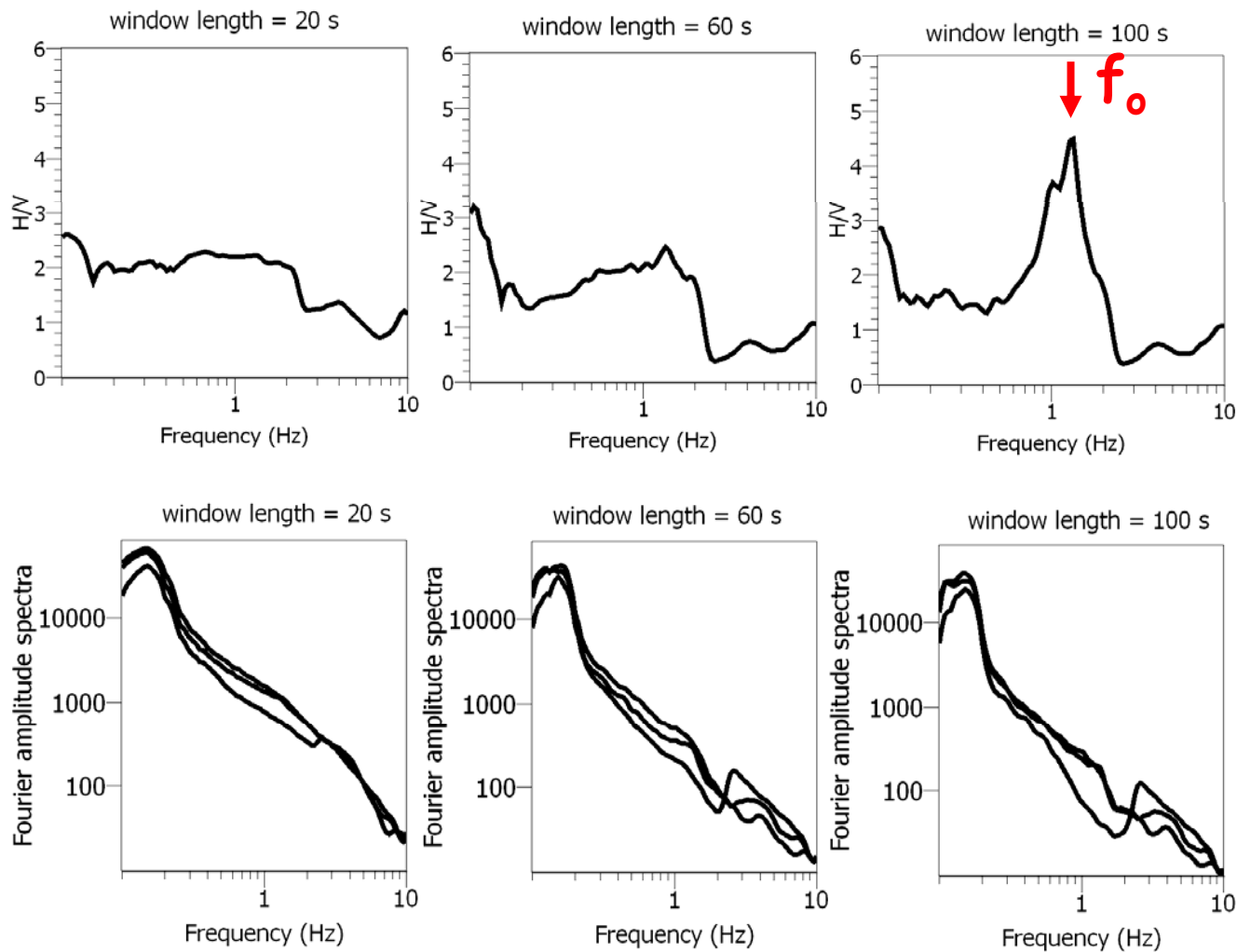
- signal at a site having a resonance frequency around 1 Hz
- you add a low frequency component within [0.1-0.2 Hz]



➡ Normally, with 10 sec. windows, you are able to define the peak

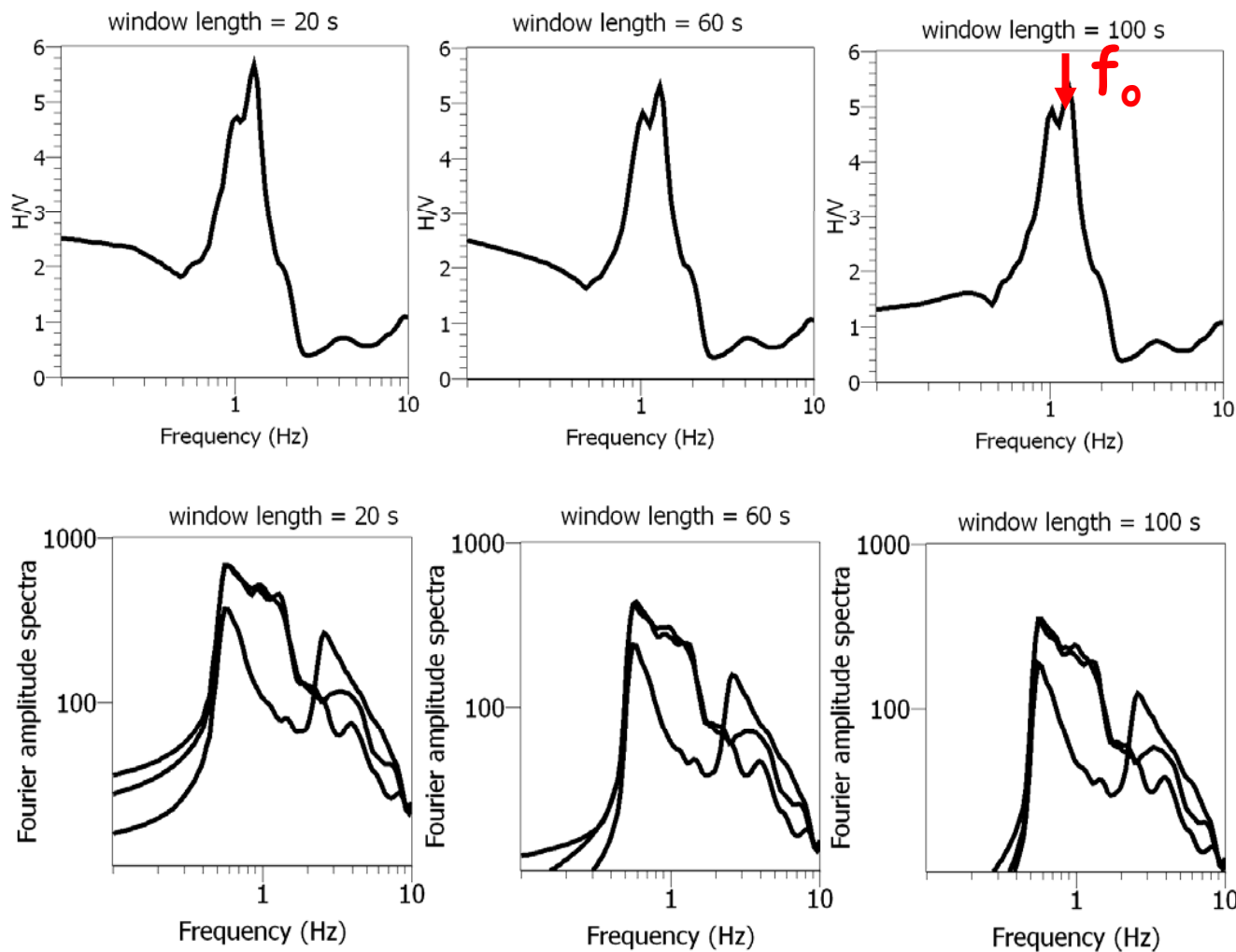
H/V COMPUTATION (taper effects)

no high pass filter



H/V COMPUTATION (taper effects)

high-pass filter at 0.5 Hz



H/V COMPUTATION (Synthesis)

Signal

-----○-----

Windowing (STA/LTA, window length)

-----○-----

FFT + smoothing of each window of each component +NS-EW averaging

-----○-----

Computing of the H/V curve for each window

=> automatic computing of the main peak (f_0) on each H/V curve (window)

=> error on H/V main peak (f_0) defined in automatic peaking way

-----○-----

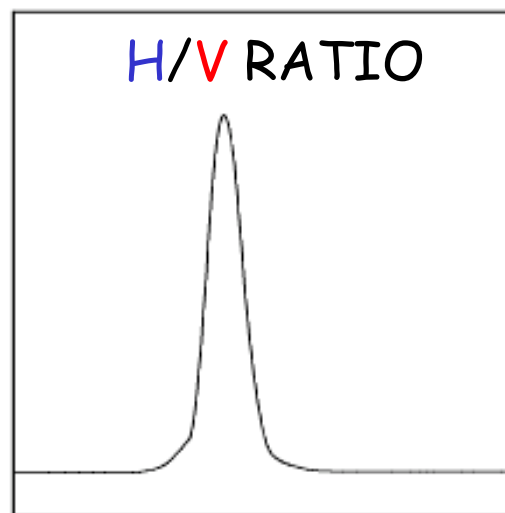
Computing the averaged H/V curve

=> averaged H/V curve

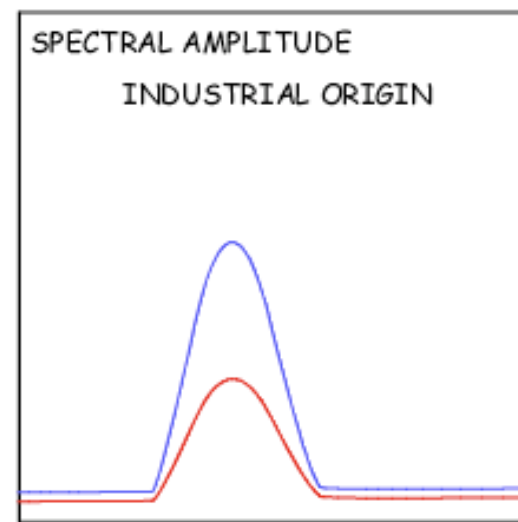
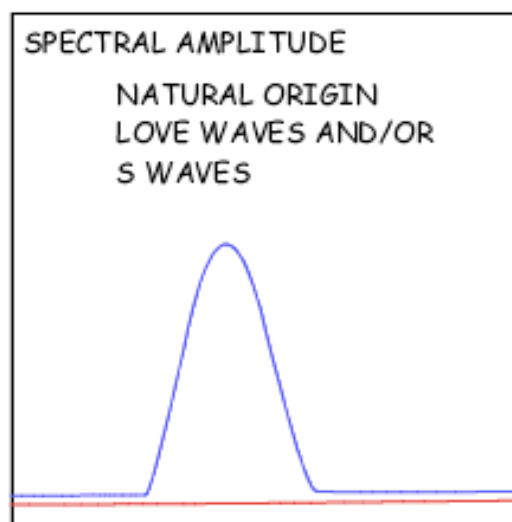
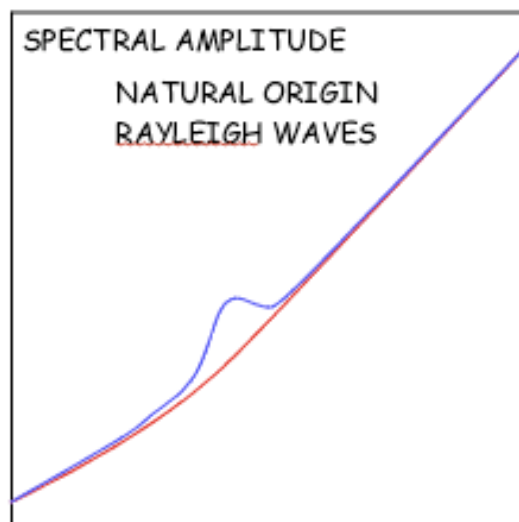
=> computing of the standard deviation

Some keys for H/V interpretation

The probable peak origin ?



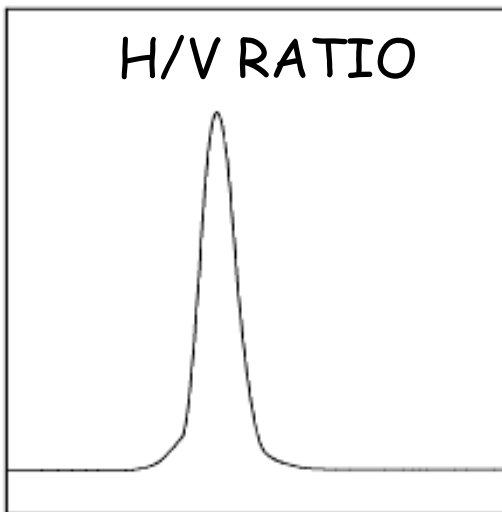
Following the spectral amplitude shape, you can define an origin for your peak at least the more probable origin.



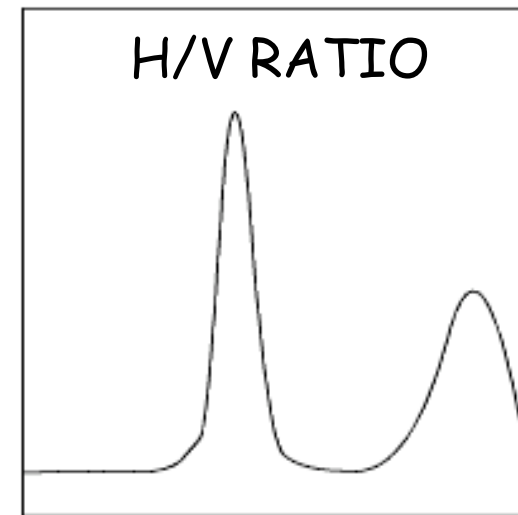
Some keys for H/V interpretation The structure beneath ?

Following the H/V curve shape, you can « evaluate »
the structure beneath your measurement.

Simple and unique
1D structure with
only one interface



Simple and multiple
1D structure with
various interfaces



Some keys for H/V interpretation The structure beneath ?

Following the H/V curve shape, you can « evaluate »
the structure beneath your measurement.

Complexe:
2-3D structure with
at least one interface

