



J-SESAME: A STANDARDIZED SOFTWARE SOLUTION FOR THE H/V SPECTRAL RATIO TECHNIQUE

Kuvvet ATAKAN¹, Pierre-Yves BARD², Fortunat KIND³, Bladimir MORENO^{1,4}, Pedro ROQUETTE⁵, Alberto TENTO⁶ and the SESAME-Team⁷

SUMMARY

Recently a European project **SESAME** (Site EffectS assessment using AMbient Excitations) was initiated aiming to study the site effects assessment techniques using ambient vibrations. Within the framework of the SESAME, one of the specific tasks was focused on data processing routines in the H/V spectral ratio technique. A dedicated software J-SESAME is now developed which aims to standardize the different processing routines. It is developed using Java programming language to provide platform-free operation capacity. The J-SESAME software is designed around a user-friendly graphical user interface (GUI), providing extensive functionality to the user. The software has four main modules: the data browsing module, the window selection module, the processing module and the data display module. In addition to the parameter selection flexibility, a set of pre-defined recommended parameter settings are provided as default values to allow also the inexperienced users to conduct correct analysis. A simple new waveform data format is defined in ASCII for easy data conversion from different acquisition systems. In addition, the widespread GSE-format is also supported. The J-SESAME software is available at <http://sesame-fp5.obs.ujf-grenoble.fr> for downloading free of charge for non-commercial use.

¹ Department of Earth Science, University of Bergen, Allegt.41, N-5007 Bergen, Norway, E-mail: Kuvvet.Atakan@geo.uib.no Tel:+47-55-583600, Fax:+47-55-583660

² LGIT, Grenoble, France

³ ETH, Zurich, Switzerland

⁴ CIGES, Santiago de Cuba, Cuba

⁵ ICTE, UL, Lisbon, Portugal

⁶ IRRS, CNR, Milano, Italy

⁷ SESAME-Team: Acerra,C.,Alguacil,G.,Azzara,R.,Blarel,F.,Bonneyfoy-Claudet,S.,Borges,A., Cara,F.,Chatelain,J-L.,Cornou,C.,Cultrera,G.,Dimitriu,P.,Dunand,F.,Duval,A-M.,Faeh,D., Grandison,M.,Guéguen,P.,Guilier,B.,Havskov,J.,Jongmans,D.,Koller,M.,Marcellini,A., Moczo,P.,Ohrnberger,M.,Rao,S.,Ripperger,J.,Scherbaum,F.,Sørensen,M.B., Teves-Costa,P.,Theodulidis,N.,Vidal,S.,Vollmer,D.,Zacharopoulos,S.

INTRODUCTION

A significant part of damage during strong or moderate ground shaking is associated with local site effects. Detailed assessment of site effects and the predominant frequencies on which significant amplification occurs can be obtained using empirical or analytical techniques. Among the empirical techniques, the H/V spectral ratio of the ambient vibrations (microtremors), has been widely used in microzonation studies due to its cost-effective nature. Within the framework of the SESAME Project one of the work packages is devoted to the development of robust software for data analysis applying the H/V technique. The main goal of this work package is to develop a multiplatform processing software (J-SESAME) to be used as a standard procedure in processing the microtremor data using H/V technique. All existing software that was previously used in processing the microtremor data using the H/V technique are tested and an optimum solution for the analysis is deduced. The J-SESAME software is developed using the Java Programming Language, for multiplatform operation capacity. In addition the J-SESAME is designed using a modular concept for the different parts, allowing flexibility for further developments. The user is guided through the browsing module (i.e. graphical user interface, GUI) of the software and the window selection and the processing modules provide the input data selection and computation of the H/V spectral ratios. The display module is then responsible for producing visualization of the processed data in an easy and flexible way. This modular development also allows utilizing the best possible solution for the programming language to be used. In the case of the window selection and processing modules, the software codes are in Fortran, whereas the browsing and the display modules are developed using the Java Programming language.

SOFTWARE DESIGN

The general design of the J-SESAME is based on a modular architecture as shown in Figure 1. There are basically four main modules: the browsing module, window selection module, processing module and the display module. The main functionalities are integrated through a graphical user interface, which is part of the browsing module. The display module is also tightly connected to the browsing module, as there is close interaction between the two modules due to the integrated code development in Java. The window selection and H/V processing modules act independently and are called from the browsing module to perform specific computations based on user defined optional parameters. The flowchart of the main processing in the J-SESAME software is shown in Figure 1. The location of the software codes and the different parameter files, as well as the output is organized set by the user through the general configuration parameter settings, which is included under the “config” pull-down menu. The parameter default values for different options of the software are also organized under the same menu with relevant titles. The user is expected to check the default values, which are shown and (if not satisfied) the user is then requested to change them with the desired values. Once the appropriate parameter values are chosen, they will be applied for the remaining computations. In the present version two waveform file formats are supported: GSE and SAF (SESAME ASCII Format).

BROWSING MODULE

Browsing module is entirely developed in Java, which is based on a graphical user interface that communicates with the window-selection and processing modules. The processed data is then visualized through the display module for manual inspection and different output options are provided (Figure 2). The main philosophy of the browsing module is to organize the data in individual projects. For each project, the corresponding waveform files are kept in a directory structure and is accessed through the configuration parameters, which keeps the filenames associated with this project with full path description

on the computer. In addition, the processing parameters that are used in each project are kept in the same project file under the configuration options.

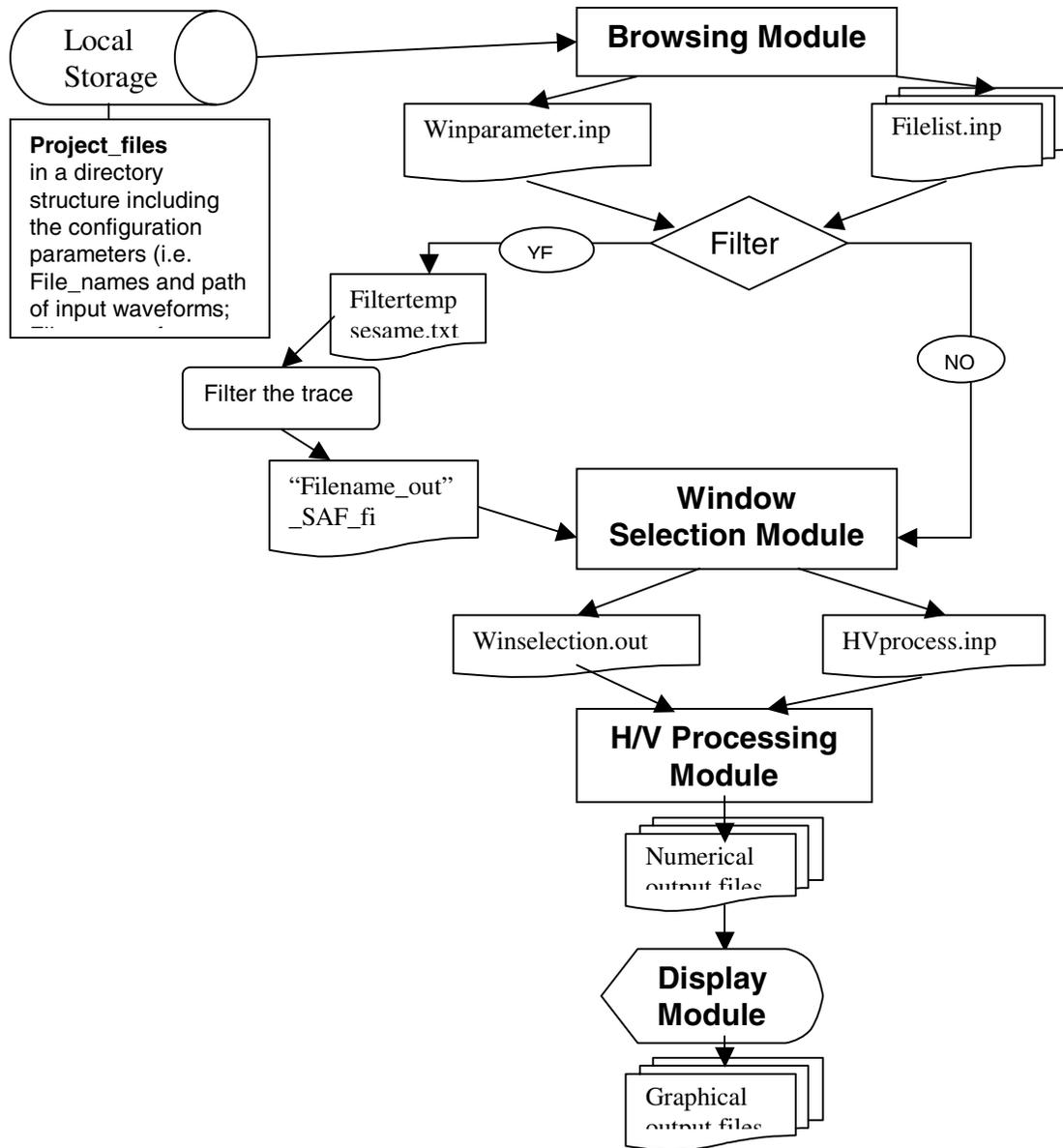


Figure 1. Flow chart of the J-SESAME software showing the main modules and their interactions.

After defining a new project, the user creates different sites under which the corresponding data collected for each site are archived in the configuration as a tree-structure (i.e. each project contains several sites and each site contains several data files). This process allows the user to organize the data into individual sites easily by dragging on the directory structure or by inserting several files into each site using the mark and copy options. The default parameters for processing can then be displayed through the pull-down

menu (Figure 3) under the configuration (and if desired can be changed) and the entire project can be saved as a “project file”. A saved project can be uploaded (with the same configuration and parameter settings) for later usage.

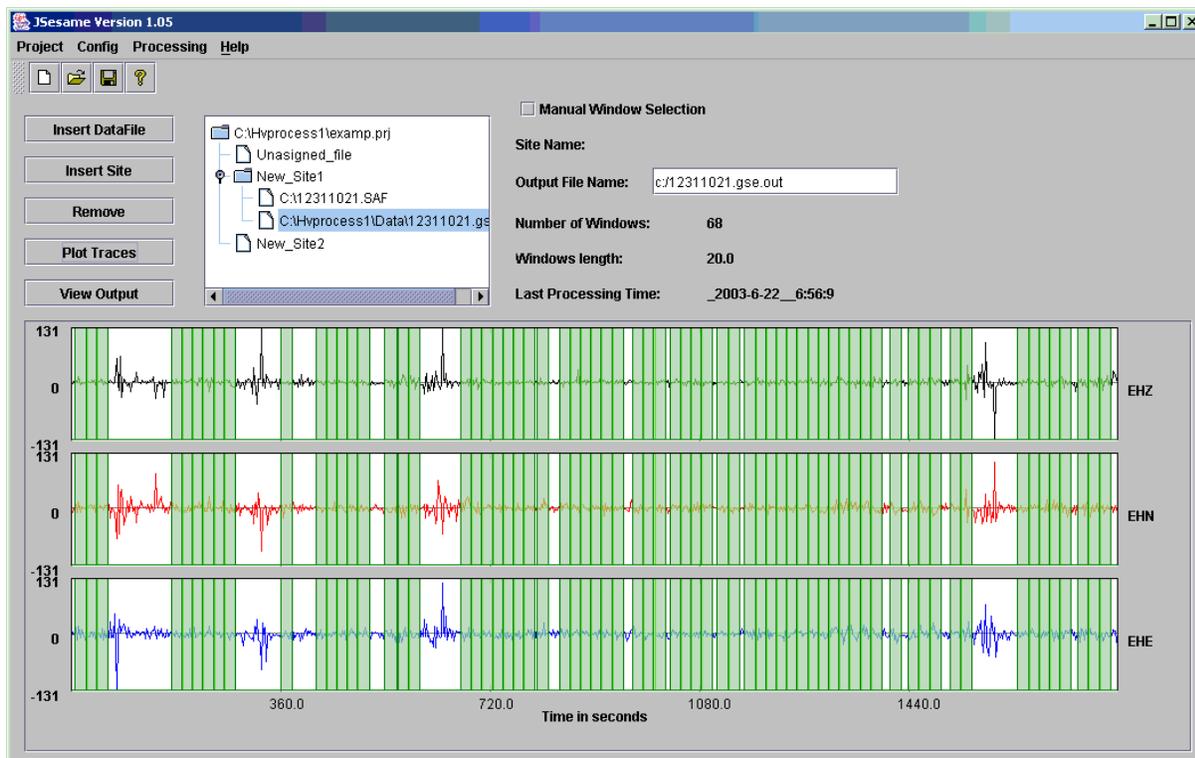


Figure 2. The general layout of the J-SESAME software. The automatically selected windows (in green) are chosen for further processing.

Once the data are organized under the project structure, the user then has the possibility to plot the waveform files (three components on the screen) for manual inspection. After the visual inspection, based on user defined (or default) parameters, user can select the time-windows either automatically or manually using the window selection module. The selected windows are then processed by the H/V processing module either as a single file or as a series of files usually corresponding to the same site. The H/V spectral ratios and the averages as well as other display options are then plotted using the display module.

In case there is difficulty in selection windows automatically due to transients or other problems in the data (such as spikes), there are filter options, where the user can apply either low-pass, high-pass or band-pass filter. The filtered traces are then displayed to the user for window selection. In this process, a comparison is also made between the windows selected both on the filtered and on the unfiltered trace. The common windows are then used for further processing. Naturally, only the original unfiltered traces are used for the H/V ratios. This filtering option allows the user to work also with difficult data sets.

The display module conducts the different plotting options, however, this process is not transparent to the user. The only thing the user has to do is to click on the output display button when the processing is completed. The different outputs are displayed through a series of windows.

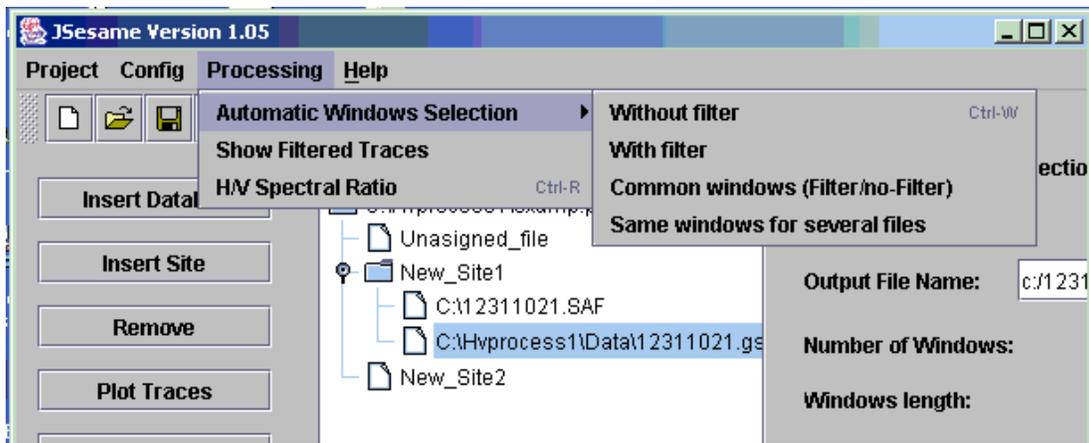
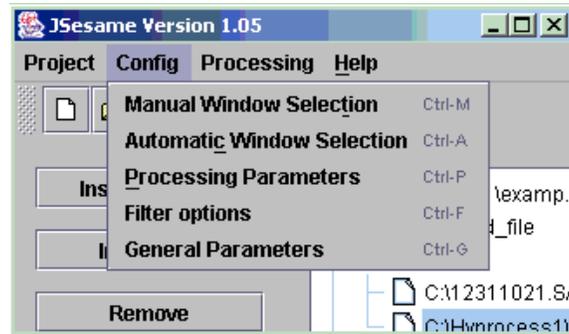
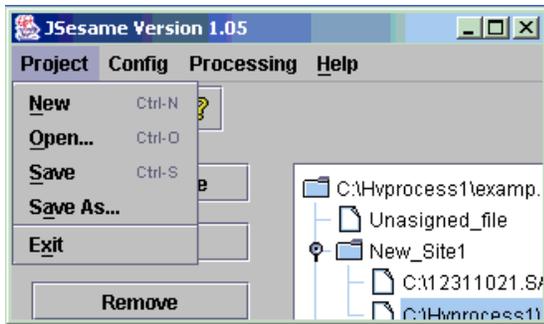


Figure 3. The different pull-down menu's for various functions of the J-SESAME.

WINDOW SELECTION MODULE

Besides the manual selection directly from the screen, which is often the most reliable, but also the most time consuming, an automatic window selection module has been introduced in view of processing large amounts of data. The objective is to keep the most stationary parts of noise, and to avoid the transients often associated with specific sources (pedestrians, close traffic, etc.). This objective is exactly the opposite of the usual goal of seismologists who want to detect signals, and have developed specific "trigger" algorithms to track the unusual transients. As a consequence, we have used here an "antitrigger" algorithm, which is exactly the opposite: it detects transients but it tries to avoid them.

The procedure to detect transients is classically based on a comparison between the short term average "STA", i.e., the average level of signal amplitude over a short period of time, denoted "tsta" in the (typically around 0.5 to 2.0 s), and the long term average "LTA", i.e., the average level of signal amplitude

over a much longer period of time, denoted "lta" (typically several tens of seconds). When the ratio sta/lta exceeds an a priori determined threshold (typical values are between 3 and 5), then an "event" is detected. These parameters are optional and can be changed (Figure 4).

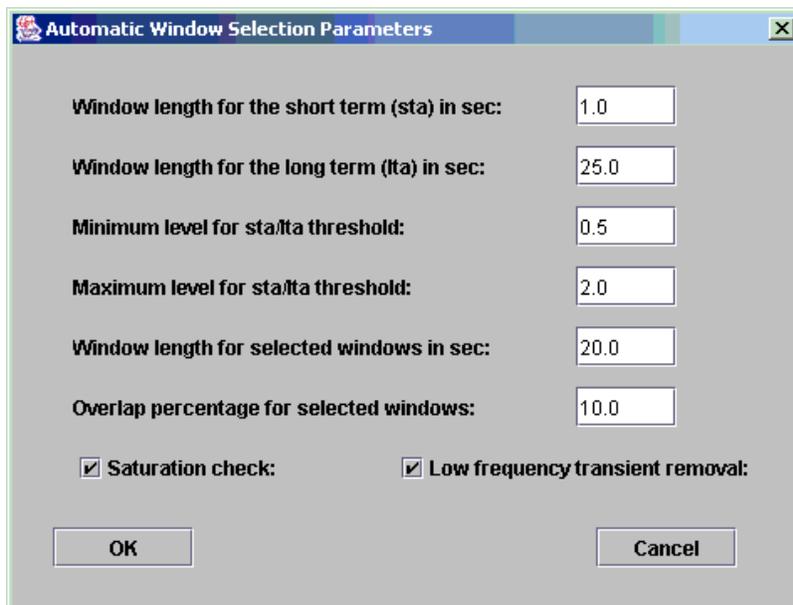


Figure 4. Automatic window selection parameters

In our case, we want to select windows without any energetic transients: it means that we want the ratio sta/lta to remain below a small threshold value s_{max} (typically around 1.5 – 2) over a long enough duration. Simultaneously, we also want to avoid noise windows with anomalously low amplitudes: we therefore also introduce a minimum threshold s_{min} , which should not be reached throughout the selected noise window.

There are also two other criteria that may be optionally used for the window selection:

- One may wish to avoid signal saturation – as saturation does affect the Fourier spectrum. As gain and maximum signal amplitudes are not mandatory in the SAF and GSE formats, the program looks for the maximum amplitude over the whole noise recording, and automatically excludes windows during which the peak amplitude exceeds 99.5 % of this maximum amplitude. By default, this option is turned on.
- In some cases, there might exist long transients (for instance related to heavy traffic, trains, machines etc.) during which the sta/lta will actually remain within the set limits, but that may be not representative of real seismic noise. Another option is therefore introduced to avoid "noisy windows", during which the lta value exceeds 80% of the peak lta value over the whole recording. By default, this option is turned off.

The program automatically looks for time windows satisfying the above criteria; when one window is selected, the program looks for the next time window, and allows two subsequent windows to overlap by a specified amount "roverlap" (default value is 20%).

Alternatively, the raw signals can be filtered first to avoid unwanted transients, such as spikes. The automatic window selection can then be applied to the filtered trace. However, once the windows are

selected, further processing is applied on the original trace. Filter parameters are optional and can be changed (Figure 5).

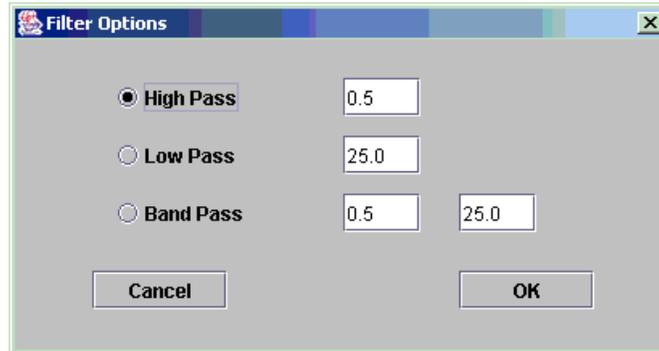


Figure 5. Filter options.

An independent Fortran subroutine is written, for which:

- The input parameters are the selection parameters (tsta = sta window length; ltta = lta window length; [smin, smax] = lower and upper allowed bounds for the sta/lta ratio; tlong = noise window length over which the sta/lta should remain within the bounds; yes/no (1/0) parameters for turning on or off the saturation and "noisy window" options; overlapping percentage allowed for two subsequent windows)
- The output parameters are a file with the noise file name, the begin and end times of each selected window, the recording status of each component: the main processing module then reads this file, and performs the H/V computation over each selected window.

PROCESSING MODULE

Main processing module is developed in FORTRAN90. It conducts H/V spectral ratio computations and the other associated processing such as DC-offset removal, filtering, smoothing, merging of horizontal components, etc., on the selected windows for individual files or alternatively on several files as a batch process. The instrument response is assumed to be removed by the user (in the case of identical components H/V ratios should not be affected by the instrument response). Main functionalities of the processing module are described below:

- FFT (including tapering)
- Smoothing with the following options
 - Konno & Ohmachi
 - Moving average
 - Linear
 - Triangle window
- Merging two horizontal components with the following options
 - No merging
 - Arithmetic mean
 - Geometric mean
 - Quadratic mean
 - Complex merging
- H/V Spectral ratio
- Average of several (H/V) ratios

- Error estimates on spectral ratios

The parameter setting for the above options are controlled through an input file (Figure 6).

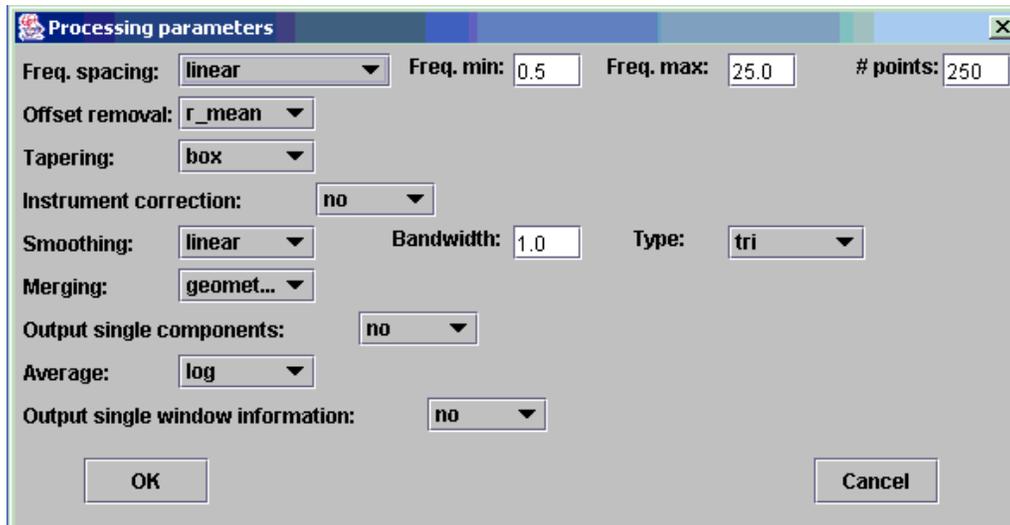


Figure 6. Processing module parameters for H/V spectral ratio

DISPLAY MODULE

The ‘Display Module’ was developed using the Java programming language. In the following, the main functionalities of the display options are given.

- In general zooming is possible on all plots by left mouse button click and drag. Clicking once on the plot with left mouse button returns back to original trace.
- Right hand button of the mouse is used for highlighting a selected window. Clicking once again will give the option of deleting the window (available only in the browsing module).
- In the output window the title used is the name of the output file (Figure 7).
- In the output window all processing parameters present in the parameter file are shown (Figure 4).
- A legend that shows the meaning of each of the curves (Figures 7 and 8).
- It is possible to change the settings of each chart by clicking on the small box on the upper right corner. The settings include:
 - The colours
 - The line patterns and thickness
 - Showing (or not) the chart gridlines
 - Showing (or not) box axis
 - The font properties of the various fonts
 - Which curves to show
 - Saving format options
- The windows are resizable.
- User option to change between logarithmic and linear scales. The user is also able to change the limits in the scale.

The different output windows are shown in figures 7 and 8.

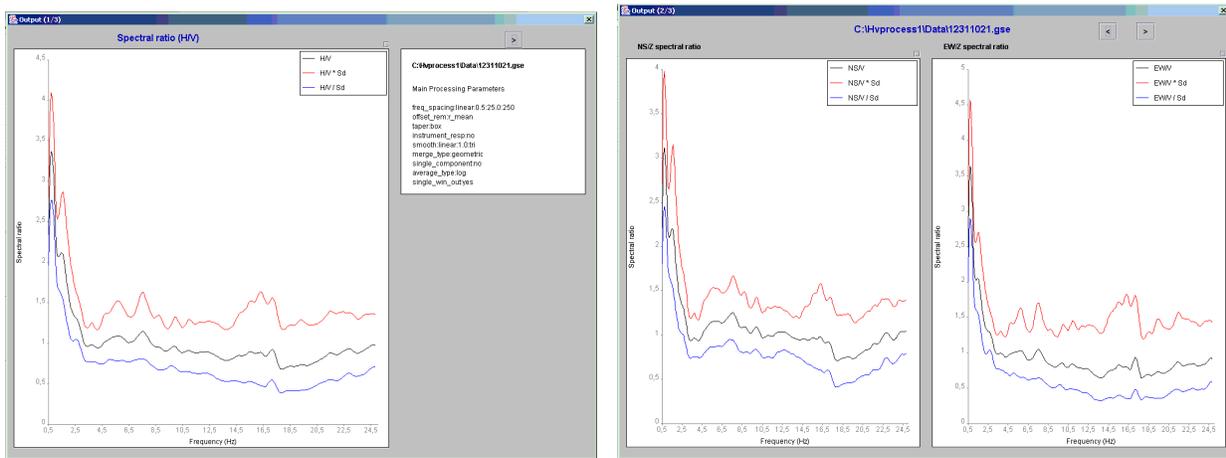


Figure 7. Two outputs from the display module: the average H/V spectral ratio and the standard deviation (left diagram); and the H/V spectral ratios for individual horizontal components (right diagram).

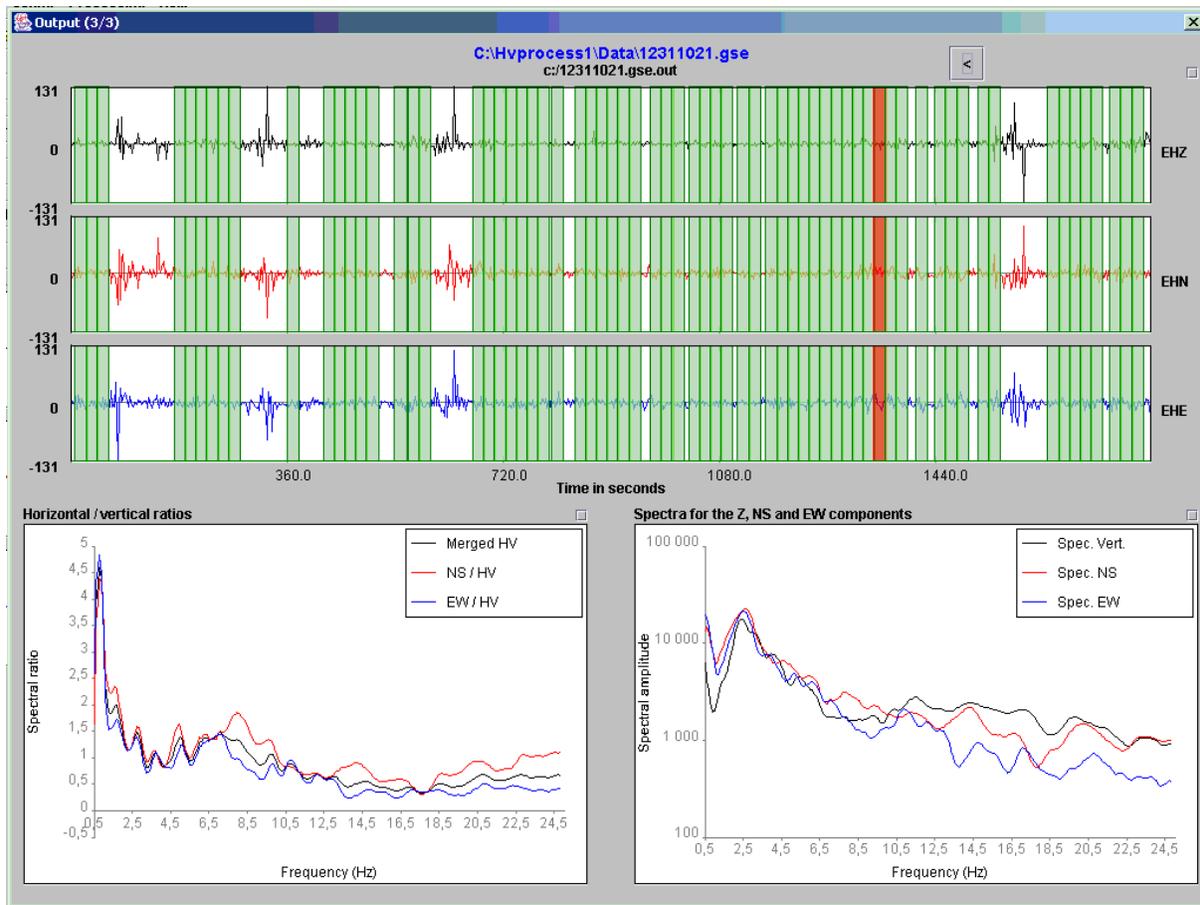


Figure 8. H/V spectral ratios of merged horizontal components (black), NS/V (red) and EW/V (blue) and the Fourier amplitude spectra for the individual windows for the vertical component (black), NS component (red) and the EW component (blue).

USING J-SESAME

The user interaction with JSESAME can be classified as: (1) Organizing the information, (2) processing the information and (3) displaying the results. The interface has a main window where the user can create a new project or loaded an existing project, plot the traces on the screen, perform automatic or manual window selection, apply the H/V spectral ratio computations and see all the results in a user-friendly interface. Only two waveforms data format are accepted: GSE and SAF (SESAME ASCII Format). The extension of the data files is required to be one of these words (GSE or SAF).

Configuring the program

JSESAME has several configuration variables to be set up by the user. In order to configure the variables, you have to click the item menu <Config> (Figure 3). The configuration parameters are shown in five dialog boxes. The first one is for configuring the automatic window selection, the second for the manual window selection, the third for the H/V processing module, the fourth for the filters parameters and the last one for general configuration parameters. Note it is very important set the correct path for the window selection and processing module programs since they are external commands called by J-SESAME (Figure 9).

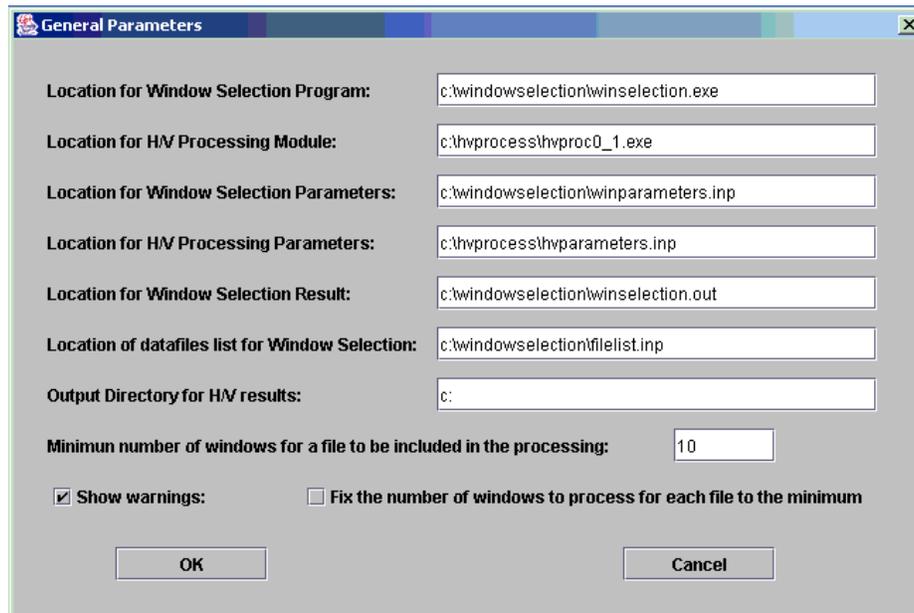


Figure 9. General parameters

Creating a new project

The structure of the project has a tree shape where the data files are grouped by sites when several noise measurements are performed for a single location. Data files grouped in the “Unassigned_file” node are treated independently. That is the user has only one data file for each site. Each node in the tree has several parameters shown on the right side of the tree. The “Site name” and the “Output File name” parameters can be modified by the user. The changes are applied after pressing the RETURN key. Data file nodes can be dragged and dropped through the tree structure. For inserting new data files or sites and removing nodes from the project, users can press the corresponding button shown on the left side of the tree. The tree structure allow for multi-selection of nodes, which means that batch processing can be performed for several sites or individual data files. The project can be saved by using the item menu <project> or by using the tools bar shown below the menu.

Plotting data files

The highlighted or selected data-file can be plotted by pressing the button <Plot traces>. All the selected windows will be shown (Figure 10). Zooming can be done by clicking the left button of the mouse, then drag the mouse and release the button at the end of the selected time of the window. Clicking the left mouse button on anywhere on the plot will take you back to the original trace before zooming.

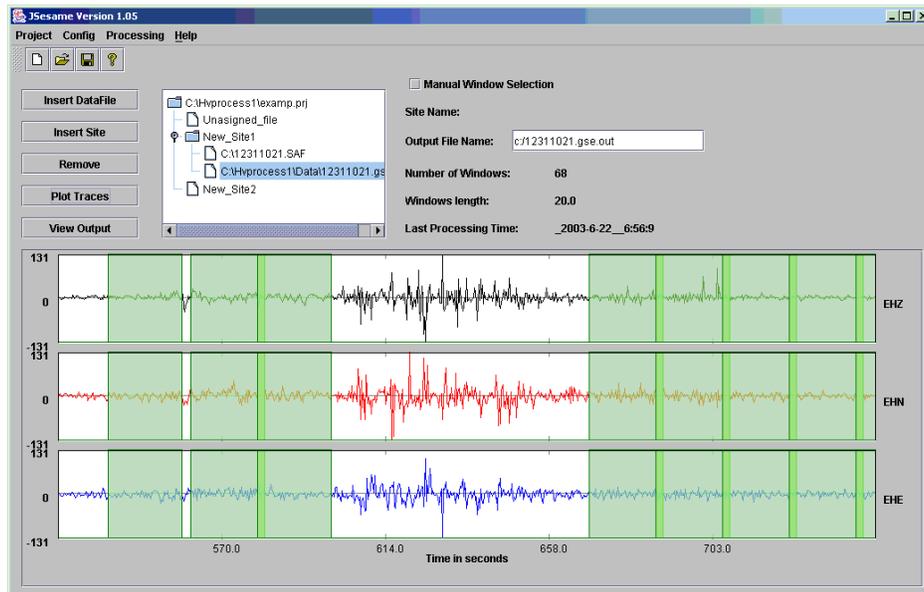


Figure 10. Zoomed traces with the selected windows

Selecting windows

Windows can be selected automatically or manually. The manual window selection can be done if the check-box labeled as “Manual window selection” (Figure 2) is active. The window is selected using the same procedure as zooming action. Individual windows can be removed by clicking the right button of the mouse twice: one click for selecting the window and another click for the deleting action. Automatic window selection can be performed in four different ways. The first one is applied to the original traces. The second is applied to the filtered trace with the filter selected in the <Config> option. The third is the common windows between the original and the filtered traces. The last option keeps the same selected windows of the first file for the rest of the selected files. This option makes sense when the user highlights (select) a group of files from the project.

Plotting filtered traces

The selected data-files can be filtered with the previous selected filter in the <Config> option (Figure 3) and then plotted on the screen. This option is available within the <Processing> menu item. The selected windows for the plotted data-file are also shown.

Computing H/V spectral ratio

The processing module is applied according to the selected nodes in the tree. If the selected node is a site, then all the selected windows of the data-files collected for this site will be used for computing the average H/V spectral ratio. Output for each window also can be obtained by setting up the configuration parameters of the processing module (Figure 6). Batch processing will be performed when several sites or data-files are selected.

Showing output results

By pressing the <View Output> button (Figure 2) the user can navigate through three dialog boxes. The first dialog box (Figure 7) shows the H/V spectral ratio of the merged horizontal components. The second dialog box (Figure 7) shows the H/V spectral ratio for each one of the NS and EW components. The third one (Figure 8) shows the spectral ratio of the merged (H), NS and EW horizontal components and the spectra of Z, NS and EW for each individual window, if “output single window information” is selected in the configuration parameter of the processing module. To select an individual window the user has to click the right button of the mouse on it. Zooming action can be done over the spectrum using the same procedure explained above. Individual values of the spectrum can be shown by clicking the middle button of the mouse over the spectral curve.

ACKNOWLEDGEMENTS

The SESAME project (Project No. EVG1-CT-2000-00026), is supported by the European Commission – Research General Directorate. A number of individuals have provided valuable contributions at different stages of the development. We thank Paula Teves-Costa (ICTE/UL, Lisbon), Jean-Luc Chatelain and Bertrand Guillier (RD, LGIT, Grenoble), and Jens Havskov (UiB, Bergen) for constructive suggestions, to Fabrizio Cara (INGV, Rome), Anne-Marie Duval (CETE, Nice) for testing the earlier version and suggesting the default parameter values. Finally, we thank all the SESAME project participants from the different participating institutions, who have contributed to J-SESAME in different ways.