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Geophysics Andalusian Institute

THEORETICAL PHYSICS AND THE COSMOS DEPARTMENT

ANDALUSIAN INSTITUTE OF GEOPHYSICS AND PREVENTION OF SEISMIC DISASTERS

"System for plotting 24-hour seismic records in one-hour segments and on one continuous plot"

(Sistema para graficar registros sísmicos de 24 horas en segmentos de una hora y en días continuos)

USER MANUAL: VERSION 1.0

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General Index

1.- Introducción

Back to Index

The module "*System for plotting 24-hour seismic records in one-hour segments and on one continuous plot*" offers a simple and user-friendly interface, allowing for easy and efficient management of displaying complete 24-hour records in one-hour segments. The program can also generate a graph of the entire day. The main interface provides an English version of the system. In the annexes, you will find information about the folder structure and its contents.

The easy access to two options for obtaining daily record graphs (*such as records in MSEED format*), "24-hour graph by the hour" and "continuous 24-hour graph," along with the option to set the preferred magnitude to display earthquakes from the global FDSN (*International Federation of Digital Seismograph Networks*), as long as the connection is available, and the ability to use digital filtering techniques, provides a reliable, simple, and fast automatic tool. This tool can assist researchers and observatory operators in separating a full day's record, stored as a single file by the equipment, into an hourly seismogram, making it easier to identify seismic events that occur each hour of the day.

The application, through its incorporated libraries, allows for the reading of various seismic formats such as SAC, MSEED, GSE2, EVT, WAV, among others. Various filtering techniques can then be applied, automatically providing added value to the operator's expertise by enabling faster and more accurate identification of seismic waves compared to manual analysis in a continuous record.

The first version of this system consists of a single interface that includes tools for signal filtering and the two types of graphs that can be used: "24 hours (*Full Day Chart*)" and "Continuous in a single graph (*Continuous Day*)". Additionally, the system provides the ability to save graphical results in various formats, such as PNG, JPG, EPS, PS, PDF, RAF, TIF, among others.

The module and the entire system have been developed in Python, version 3.8.6. (The set of libraries is compatible with version 3.10.10). Additionally, a series of open-access libraries are included, which, in conjunction with Python, enable the use of graphical and analytical tools, providing ease of use and enhancing computational power for the user. Some of the main elements and libraries used are listed below:

- **Matplotlib**: Used for creating static, animated, and interactive visualizations in Python. (https://matplotlib.org/stable/users/index.html)
- **NumPy**: A library for numerical operations in Python. (https://numpy.org/doc/stable/user/quickstart.html)
- **PyQt5**: A tool that links with the graphical library Qt5 in C++ (https://pypi.org/project/PyQt5/)
- **Obspy**: A Python toolbox for seismology. (https://docs.obspy.org/)
- **Tkinter**: Graphical User Interface (GUI) (https://docs.python.org/3/library/tkinter.html)

Another key feature of the system is its definition as a cross-platform application, meaning it can operate on various platforms or operating systems, such as Windows (7, 8, 10, 11) in both 32-bit and 64-bit versions. It also supports Linux systems, such as Ubuntu and other similar systems (Debian, Red Hat, Fedora, SUSE, etc.), macOS, and Android for tablets and mobile devices (with Python appropriately adapted for these devices).

NOTE: In the appendices of this document (*as well as in the Readme.txt and Initial_requirements.txt files*), you can find general information on installation for Windows and Linux systems, as well as guidelines for installing the main programs and additional libraries required by Python to properly execute the developed programs in its environment.

Back to Index

2.- Initial Screen of the System

In the appendices of this document and in the "**README.txt**" file included in the "***Documents***" folder, you will find instructions for installing the system on Windows (*the process on Linux systems is similar*). Essentially, you need to perform two actions:

a) Copy the "Set_tools_System_1_1" folder to "My Documents" on Windows.
b) Copy the "Set_tools_System_1_1.bat" file to the Windows desktop.

Additionally, there are instructions for installing the necessary Python libraries on the system. Once "Set_tools_System_1_1.bat" has been copied to the desktop, you need to right-click on it and select "Run as administrator."

Fig. 1 Popup Window when Right-Clicking on the "Set_tools_System_1_1.bat" File

In the window that opens, click the "Yes" button when prompted with "*Do you want to allow this app to make changes to your computer*?" This is a warning message. However, the application does not make any changes, so you should trust its execution.

Upon clicking "*Yes*," the following command window opens, welcoming you to the system.

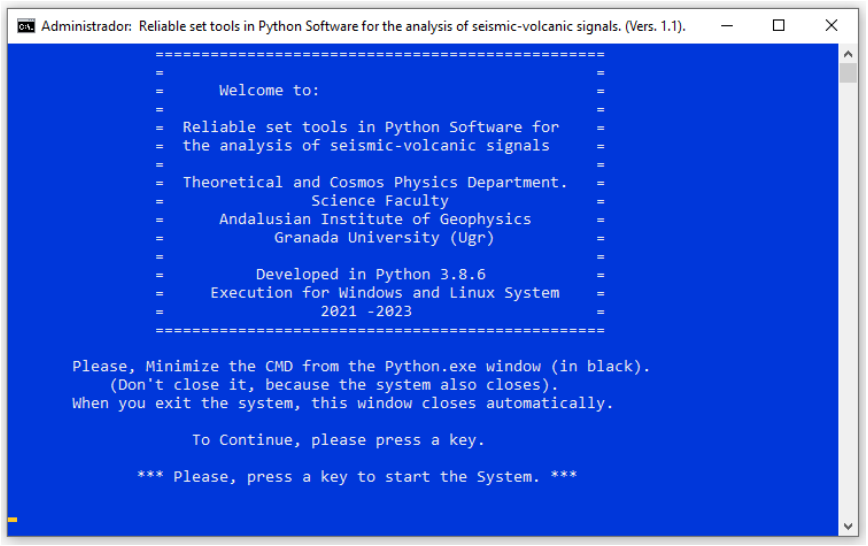


Fig. 2 Welcome Screen and Instructions for Loading the System.

After reading the information in the window, you simply need to press any key to access the system's initial screen. The folder should already be copied to "***My Documents***," and the "**Set_tools_System_1_1.bat**" file contains all the loading instructions.

The system's initial screen is "**Menu.py**". It appears when any key is pressed on the Welcome screen. Additionally, the Python command window or console is displayed, similar to the following:

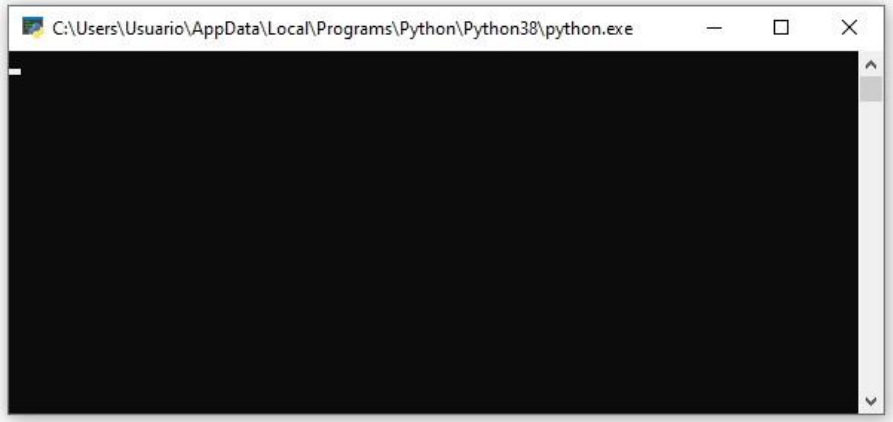


Fig. 3 Python Console (CMD) Window (*Should be minimized*)

To avoid obstructing the view, you can and should "minimize" this screen. Do **not** close it, as this would also close the system's startup window. Once you have finished working with the system, this window will close automatically. The initial presentation screen of the system (the module menu) "**Menu.py**" is as follows:

NOTE: When pressing or clicking on a module button, the startup window will close and the module window will open (*this may take a little time depending on the PC's memory. It is recommended to have at least 8 GB of memory in the system, with 16 GB being ideal*).

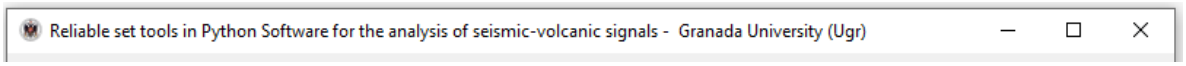
Fig. 4 **Main Menu Screen.** The module to be worked on is highlighted. Module 3 (*Plotting 24-hour Seismic records*).

2.1.- Elements of the Initial Screen

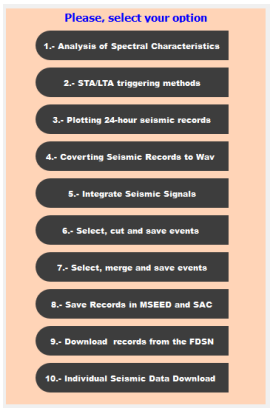
As observed in the previous figure, the initial or presentation screen is a simple window composed of:

a) A top toolbar with basic information about the module.
b) On the left side, there are 10 execution buttons or command buttons for each module of the system.
c) At the bottom, there is a command button that allows for exiting the system.
d) Additionally, it features a background image representing a volcano (Masaya in Nicaragua), and three images with the logos of the University of Granada, the Andalusian Institute of Geophysics, and the Department of Theoretical and Cosmic Physics.

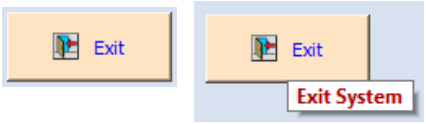
a) At the top, the icon of the University is visible, along with the module title and a reference to the University of Granada (UGR).



b) On the left side, there are 10 execution buttons or command buttons for each module of the system. When the mouse pointer is placed over each button, it is highlighted in white to indicate that it is being selected. Clicking on a button closes the startup menu window and opens the window for the indicated module (this may take a little time depending on the PC's memory).



c) At the bottom, there is a command button: **Exit**. When the mouse pointer is placed over each button, a text appears indicating the action of that button (Exit System, Start System).



If you click the "Exit" button, a window will appear asking the user if they are sure they want to leave the system.

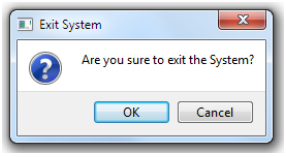


Fig. 5 Text Box Indicating Whether You Want to Exit the System.

If you click "**OK**," the screen will close and the system will exit. If you click "Cancel," you will remain on the initial screen.

3.- Analysis Screen.

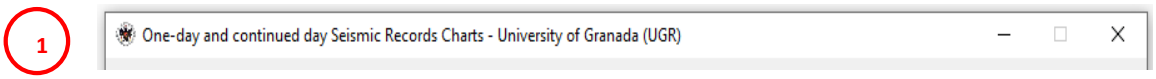
By clicking on the "*Menu*" option (see Fig. 4), you access the "*analysis screen*", which is the main interface of the module where activities such as reading records, selecting the magnitude, and plotting seismic signals are performed. This screen is composed of the following sections:

Fig. 6 Elements of the System Analysis Screen.

1. **Title Area**
2. **Record Selection, Magnitude, and Input Clearing Block**:
   a) Command buttons: *Load Record*, *Clean Input*
   b) Data Input (Minimum Magnitude), which is set to 6.5 by default at startup.
3. **Filter Block**
4. **Graphic Commands Block**:
   Command buttons: *Full Day Chart* (Gráfico de día completo), *Continuous Day* (Día continuo).
5. **Path, Back, and Exit Block**:
   a) Path to the physical location of the record to be analyzed.
   b) Command buttons: *Go Back/Retroceso*, *Exit/Salida*.

The main interface is initially configured, as shown in the image, to display a "low-pass" filter type, with the corresponding "Frequency Hz" input box active, and a minimum moment magnitude (Mw) of 6.5.

The screen is composed of various elements for use. At the top, you can see the program name, icon, and university name, as the title (1).



The elements that make up the main screen are detailed below.

3.1.- Elements of the Analysis Screen.

In addition to number (1), the 4 elements of the analysis screen are distributed into three main blocks, numbered from (2-5) in the red circles.

3.1.1.- Record Selection Block, Magnitude, and Input Cleaning.

Fig. 7 Selection Elements Block. In the green circles: a) Command Button: Load Record, b) Data Input: Minimum Magnitude (default = 6.5), c) Command Button: Clean Input.

3.2.- Selection Block Elements.

This block is configured (green circles in the previous figure) primarily by the section that groups the action buttons for loading the record and data cleaning: a) Command Buttons: Load Record (a), Clean Input (c), as well as the minimum magnitude input (b).

When hovering the mouse pointer over the two action buttons, a message displays the actions they perform.

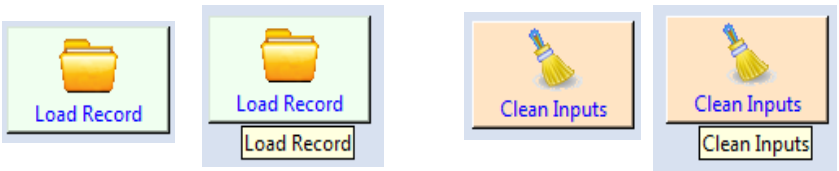


Fig. 8 Record and Data Cleaning Buttons. The action messages for each button are displayed.

As observed, the "*Load Record*" button performs the search and loading of seismic records in various formats. The "*Cleaning*" button clears or deletes the input elements, in addition to closing any existing graphs, leaving the analysis screen as it was at the beginning, ready for a new search and a new analysis of seismic events.

3.2.1.- Load Record Button. a

The action of the "*Load Record*" button allows a window explorer to open upon clicking (*by default, the path is set to the root directory "C" of the PC*), presenting options for various file formats to search for, and enabling the user to perform this search in the computer's directory. This is shown in the following screen. The "Minimum Magnitude" data input field is initially inactive; upon clicking the load button, this field is activated, allowing the default value to be modified.

3.2.2. – Minimum Magnitude Data Input Box.

b

Fig. 9 Minimum Magnitude Data Input Selection Screen.

Initially, this data input box is deactivated and has a default value of 6.5 (measured in "*Moment Magnitude*" (Mw) degrees), as shown in the figure. The data input for this box is activated by clicking the load record button, at which point the magnitude can be modified.

This data is used for the 24-hour record, as presenting a lower value, for example, 4.9, prompts the system to connect remotely to a data server of the global FDSN network to obtain and mark earthquakes of that magnitude or similar that have been detected by sensors at each moment in time. The representation of this data depends on whether the server is available at that moment; otherwise, no markers will appear on the resulting graph. In contrast, for continuous recording, the magnitude data is irrelevant, so it is not needed, and the final figure will appear regardless of the value assigned to that input box.

There are three data entry validations for this object.

a) If no value is entered in the box and it is left empty when attempting to represent a 24-hour record, an error window will appear to indicate the issue, prompting the user to enter a valid value.

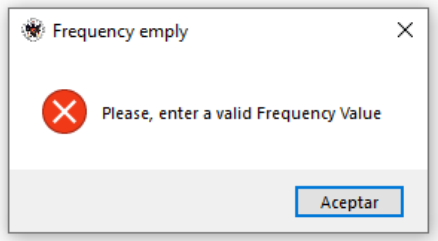


Fig. 10 Validation Screen for Empty Inputs in the “Minimum Magnitude” Data Box.

b) If a magnitude value of 10 or greater is entered, it will generate another error.

Fig. 11 Validation Screen for Magnitude Inputs Greater Than or Equal to 10 Degrees (Mw).

c) The third validation checks for invalid inputs, such as letters or characters instead of numbers (See Part (2) of Figures: 17, 19, 21).

When clicking the *Load Record* button, the following appears:

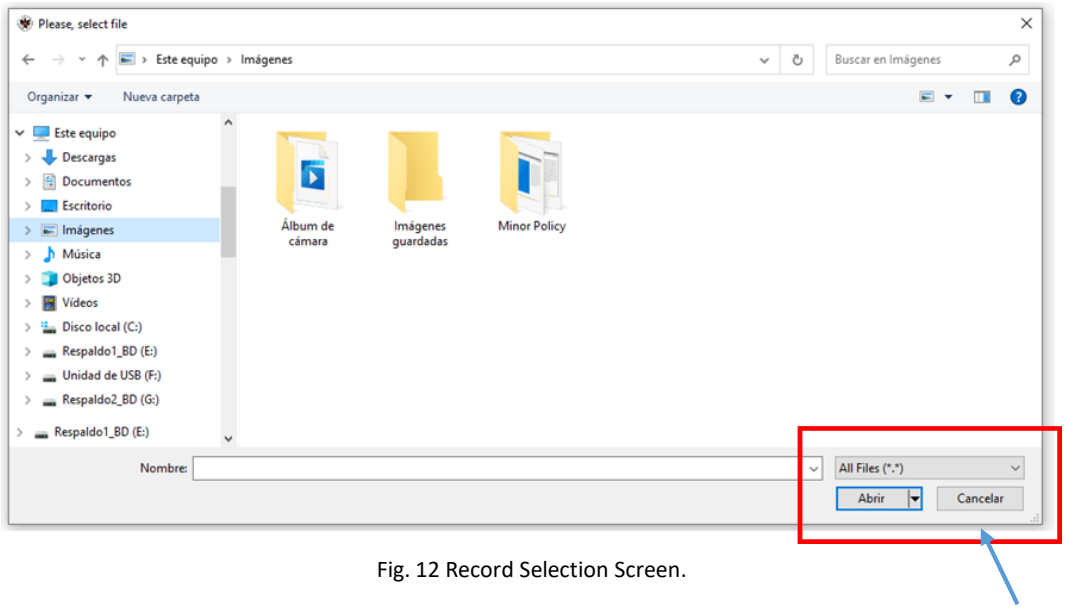


Fig. 12 Record Selection Screen.

In this screen (*the language is determined by the operating system*), records are selected based on the desired format (*red box*) such as SAC, MSEED, GSE2, EVT, etc. By default, it is set to "*All Files*". This is made possible through the seismic format reading "*Obspy*" library.

Once selected, click the "*Open*" button to load it onto the analysis screen. If not, clicking the "*Cancel*" button will return the action to the analysis screen. The process of selecting a record is shown in the following screen.

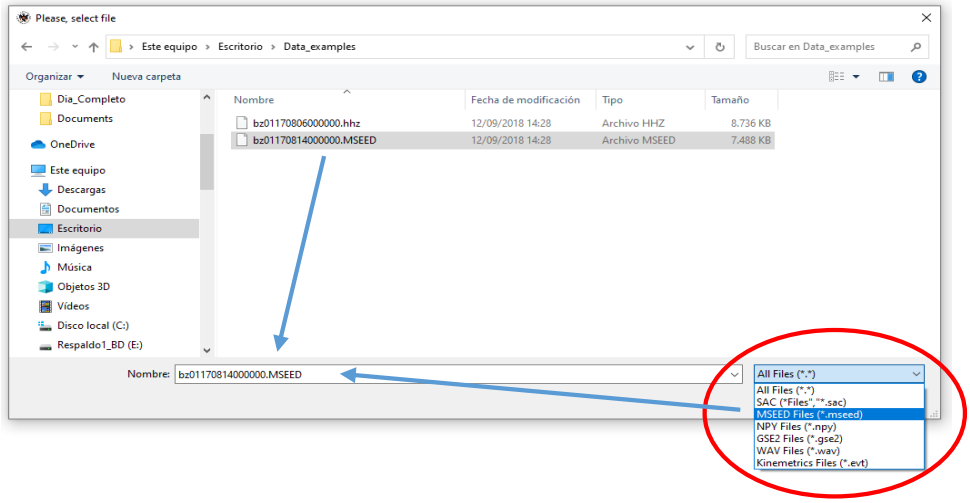


Fig. 13 Example Screen for Selecting an "MSEED" Format Record.

In the screen, the lower right corner shows, highlighted by the red circle and indicated by the arrow, a list of the most common seismic formats supported and/or used in observatories and institutes worldwide (*SAC*, *MSEED*, *GSE2*, *WAV*, *EVT*).

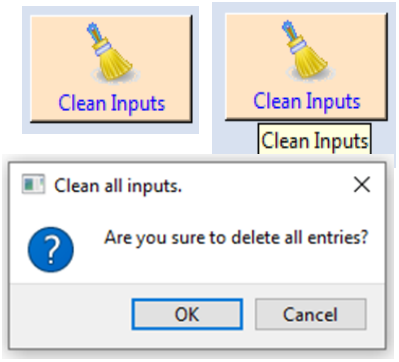
When a specific type is selected, the records corresponding to that format are displayed. For example, the "MSEED" files. By clicking on the desired record, as shown, it will populate the "*Name*" box. At this point, clicking the 'Open' button from the previous screen will load the "*Record Path to Load*" of the physical location of the record in the system. This path will appear in the 'File Path' box located at the bottom of the analysis screen.

Fig. 14 File Path Box, displaying the location of the record.

This is an important aspect, as it determines whether the physical file where the record is stored on the computer can be located for analysis. If the file is invalid, missing, or if the parameters are incorrect, a validation window will appear to indicate the issue (*See Part (2) of Figures: 17, 19, 21*).

3.2.3.- *Clean Inputs* Button.

Clicking this button clears all entries on the screen. It will clean the data entry text boxes and the path or folder where the record to be downloaded will be stored, and it will delete all active entries with data at that moment.
It restores the initial values of the main interface (*see Fig. 6*). When you place the mouse pointer over it, a message appears indicating its function. Clicking the button opens a window asking the user if they are sure they want to delete the data entries. If confirmed, it clears all entries and returns the interface to its initial state. Otherwise, the current entries remain in the interface.



4.- Filter Type Selection Block.

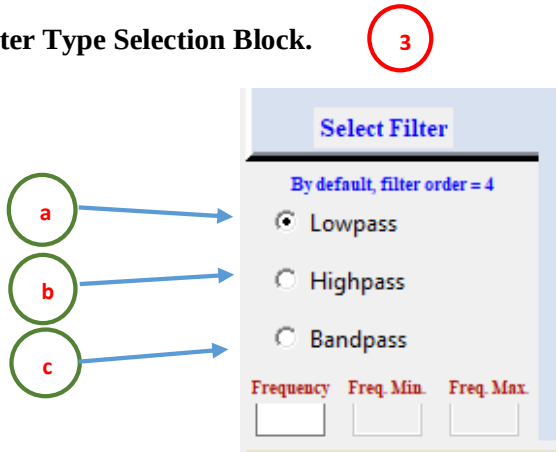


Fig. 15 Selection of filter type using 'Radio Buttons' marked by the green circles (a, b, c). Initially, the 'Lowpass' filter is selected, which activates the Frequency box.

In the previous figure, the block that determines the various types of filters available for analyzing records is shown. Here, as can be seen, the most commonly used filter calculations are located: Lowpass, Highpass, and Bandpass. When selecting each of these elements, one or more of the boxes at the bottom of the image will be activated, corresponding to the data inputs for performing the calculations. The initial value [a] "Lowpass", as well as the "Frequency" box, are active at the start of the program.

4.1.- *Lowpass*[1] filter type.

Fig. 16 Example of Lowpass Filter Selection. The 'Frequency' input is indicated by the red circle. When both the Lowpass and Highpass types are selected, the Minimum Frequency and Maximum Frequency input boxes are deactivated.

This is the type that is active by default when starting the program, along with the frequency box in Hz (Frequency). If another type is activated during the process and then this filter type is selected again, the box will be activated:

a) Filter Frequency (Hz): A floating-point value. A valid frequency value must be entered here for the desired filter calculation (red circle). In the example, the value is "4 Hz."

The 'Min Frequency (Hz)' and 'Max Frequency (Hz)' boxes remain inactive. If an empty or incorrect input occurs, an error message box similar to the following will be displayed.

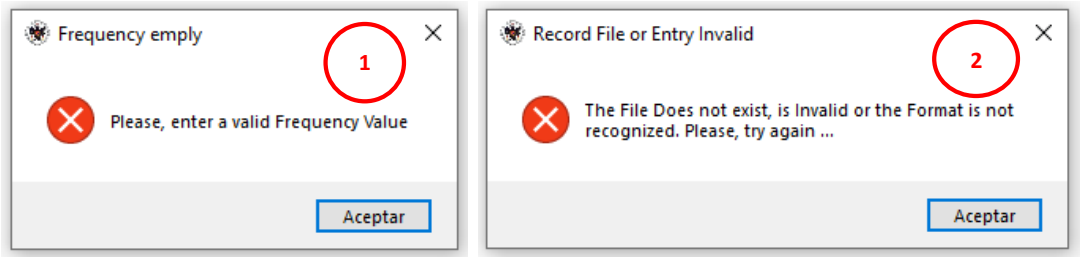


Fig. 17 Validation of Inputs in the Lowpass Filter: (1) Empty Input, (2) Invalid Input (characters or letters instead of numbers)

This indicates that a data error has occurred, either due to (1) an empty input or (2) an invalid input, such as entering characters like 'ehdsgf' instead of numbers.

[1] The Lowpass filter blocks high-frequency signals and allows low-frequency signals (frequencies below the cutoff frequency) to pass through

4.2.- *Highpass*[2] filter type.

Fig. 18 Example of Highpass Filter Selection. The 'Frequency' input is indicated by the red circle. When both Lowpass and Highpass types are selected, the Minimum Frequency and Maximum Frequency input boxes are deactivated.

Similarly to the previous filter, in the Highpass filter type, the 'Frequency' box is activated:

a) Filter Frequency (Hz): A floating-point value. A valid frequency value must be entered here for the desired filter calculation (*red circle*). In the example, the value is "8 Hz.".

The 'Min Frequency (Hz)' and 'Max Frequency (Hz)' boxes remain inactive. If an incorrect input occurs, an error message box similar to the following will be displayed.

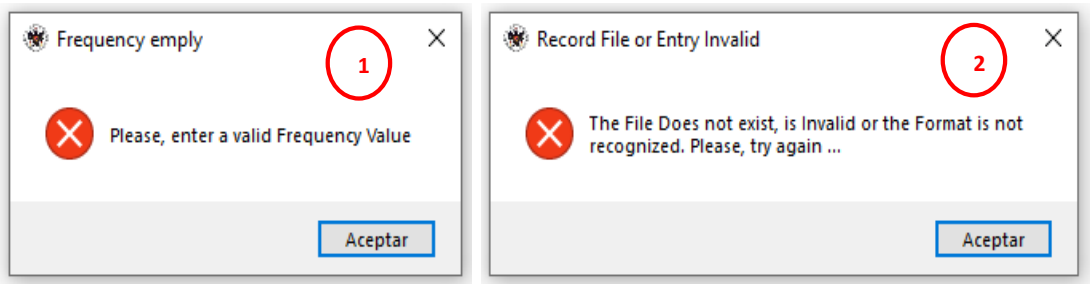


Fig. 19 Validation of Inputs in the Highpass Filter: (1) Empty Input, (2) Invalid Input (characters or letters instead of numbers).

This indicates that a data error has occurred, either due to (1) an empty input or (2) an invalid input, such as entering characters like 'ehdsgf' instead of numbers.

[2] The **Highpass Filter** blocks low-frequency signals and allows high-frequency signals (*frequencies higher than the cutoff frequency*) to pass through.

4.3.- *Bandpass*[3] filter type.

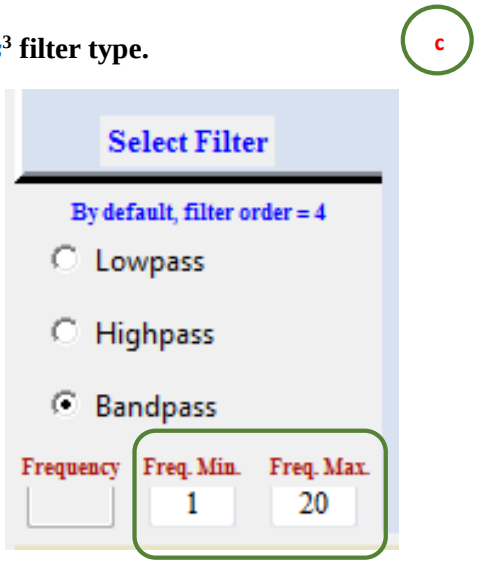


Fig. 20 Example of Bandpass Filter Selection. In the green rounded rectangle, the "**Minimum Frequency (Hz)**" and "**Maximum Frequency (Hz)**" inputs are shown. The Frequency input box is deactivated.

Unlike the previous two, the 'Minimum Frequency' and 'Maximum Frequency' input boxes are activated:

a) Minimum Filter Frequency (Hz): A floating-point value. A valid value must be entered here for the minimum frequency (green rounded rectangle) to calculate the start of the central window. In the example, the value is "1 Hz.".

b) Maximum Filter Frequency (Hz): A floating-point value. A valid value must be entered here for the maximum frequency (green rounded rectangle) to calculate the end of the central window. In the example, the value is "20 Hz.".

The "Frequency (Hz)" input box remains inactive.

If an incorrect input occurs, an error message box similar to the following will be displayed.

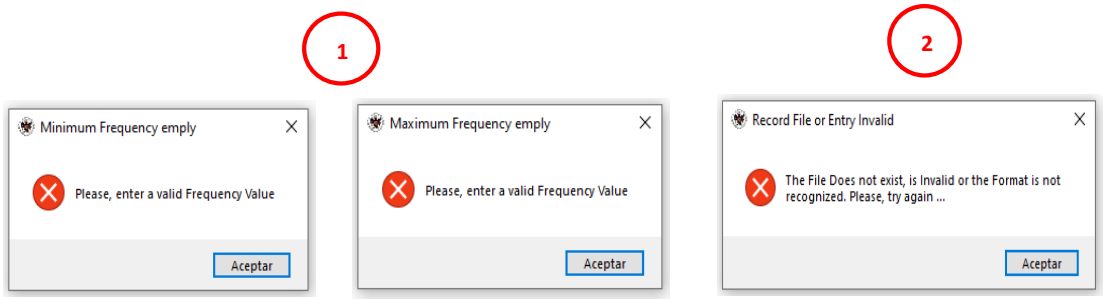


Fig. 21 Validation of Inputs in the Bandpass Filter: (1) Minimum and Maximum Frequencies empty, (2) Invalid Input (characters or letters instead of numbers).

This indicates that a data error has occurred, either due to (1) an empty input in either the minimum or maximum frequency, or (2) an invalid or incorrect input, such as entering characters like "ehdsgf" instead of numbers.

[3] The Bandpass filter allows spectral content to pass only within a range around the central frequency. This range is defined by a minimum frequency and a maximum frequency. It removes noise associated with both low and high frequencies that are outside this specified range.

5.- Graphic Commands Block. 4

This block consists of two command buttons: a) Full Day Chart and b) Continuous Day, which allow the display of graphs based on the selected filter parameters and magnitude that correspond to the desired representation. For example, to represent 24-hour records in hourly graphs from 00:00:00 – 01:00:00 to 23:00:00 – 00:00:00, the desired filter parameters and the minimum frequency value must be determined. In contrast, if the goal is to represent the continuous day in a single graph, the filter values are needed, but the minimum magnitude value is not required and is omitted from the calculation. This is shown in the following image.

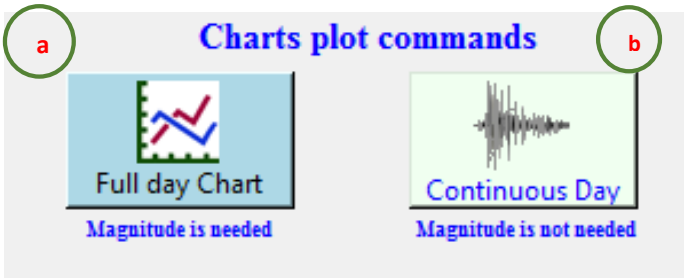
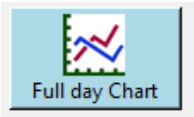


Fig. 22 Graphic Commands Block

5.1.- 24-Hour Chart Button (Full Day Chart). a



When clicking the 24-Hour Chart button (Full Day Chart), a seismic record graph is presented, consisting of lines where each line represents one hour of records, ranging from 00:00:00 – 01:00:00 to 23:00:00 – 00:00:00. Each line shows the seismic events corresponding to the data collected by the sensor. Valid parameters must be entered beforehand for what is to be graphed. These parameters are as follows, in the recommended order:

a) "Load the seismic record using the command button (Load).
b) Select the type of filter to be implemented and enter a valid value in the corresponding input boxes.
c) Enter a valid value in the 'Minimum Magnitude' box.

For this type of graph, it is necessary to use the 'Minimum Magnitude' data. Once these actions are completed, you will click the button, and the graph will be displayed according to the parameters. The graphical results will be shown later in this document, along with the output examples for each case.

If you want to graph by clicking the 'Full Day Chart' button and there is an invalid input, a nonexistent record, or an out-of-range format in any of the boxes, a validation will appear, similar to the previously seen objects. This validation displays a dialog box indicating that a specific action must be taken to correct the input error. These dialog boxes also allow the program to continue running without severe interruptions due to missing data. The validations for null or incorrect inputs are as follows:

First, the validation for an empty or invalid record input.

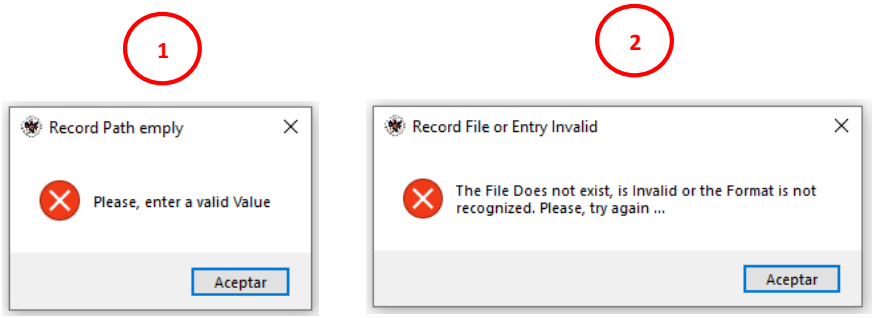


Fig. 23 Validation for empty input (1) and invalid input or format (2) in the path area that contains the physical location of the record to be loaded.

Additionally, in case of an error, dialog boxes for filter input validations, as seen in the previous sections (See Figures 17, 19, and 21), will be displayed. Finally, the validation for the minimum magnitude input (See Figure 10 for an empty input and See Figure 11 for indicating that the magnitude input is greater than or equal to 10 degrees (Mw)).

5.2.- Continuous Day Chart Button.

When clicking the Continuous Day Chart button, a seismic record graph is presented, consisting of lines where each line represents one hour of records, ranging from 00:00:00 – 01:00:00 to 23:00:00 – 00:00:00. Each line shows the seismic events corresponding to the data collected by the sensor. Valid parameters must be entered beforehand for what is to be graphed. These parameters are as follows, in the recommended order:

a) Load the seismic record using the command button (Load).

b) Select the type of filter to be implemented and enter a valid value in the corresponding input boxes.

For this type of graph, the 'Minimum Magnitude' data is **NOT** necessary. Once these actions are completed, you will click the button, and the graph will be displayed according to the parameters. The graphical results will be shown later in this document, along with the output examples for each case.

If you want to graph by clicking the 'Continuous Day' button and there is an invalid input, a nonexistent record, or an out-of-range format in any of the boxes, a validation will appear, similar to the previously seen objects. This validation displays a dialog box indicating that a specific action must be taken to correct the input error. These dialog boxes also allow the program to continue running without severe interruptions due to missing data. The validations for null or incorrect inputs are as follows:

First, the validation of empty or invalid input for the registration.

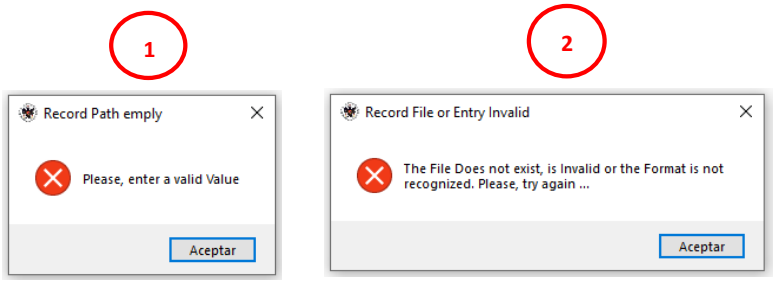


Fig. 24 Validation of empty input (1) and invalid input or format (2) Empty record in the path area that contains the physical path of the record to be loaded.

In case of an error, dialog boxes for input validation of the filters, as shown in previous sections (see Figures 17, 19, and 21), are displayed. Since the 'minimum magnitude' value is not required, no validation is performed on the input field for this data type.

Once the graphs are created, either in the 24-hour format or the continuous type, the graph can be saved according to the selected format. To do this, the graphical toolbar is used (*see Matplotlib Tools, Pages 28-33*).

IMPORTANT NOTE: It is recommended that once the graph has been viewed and saved, it should be closed before creating a new graph. After this, more parameters or filter types can be used to generate new graphs with the same seismic record that has been loaded, and these graphs can be saved in the desired location and format.

6.- Route, Return, and Exit Block. 5

This block consists of: Two command buttons: a) Go Back (return) and b) Exit. Additionally, c) the area where the physical path of the seismic record to be loaded is displayed (Record Path to Load).

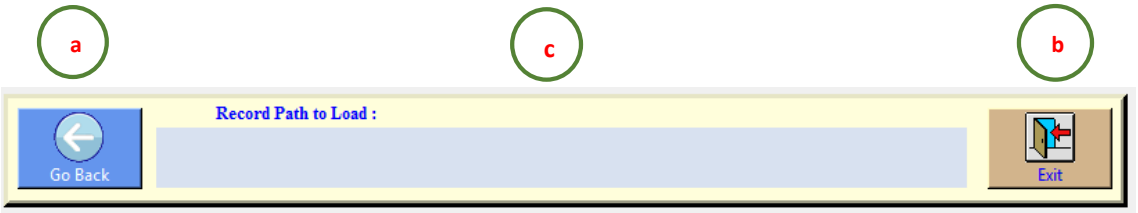
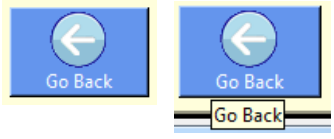


Fig. 25 Command button block (a) Return/Go Back, (b) Exit, and the physical path of the file to be loaded (c).

This last block consists of the following elements:

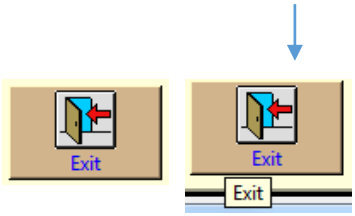
6.1.1.- "*Go Back*" Button (a).

It allows returning to the initial presentation screen of the system (**Menu.py**). When hovering the mouse pointer over it, a message is displayed indicating its function.



6.1.2.- "*Exit*" Button (b).

It allows for complete exit from the system (*after displaying a screen that asks if you wish to leave the system*). When hovering the mouse pointer over it, a message is displayed indicating its function.



In the same way as on the home screen, if the 'Exit' button is pressed or clicked, a window appears asking the user if they are sure they want to leave the system.

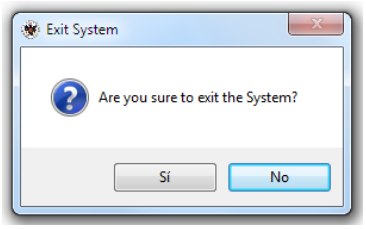


Fig. 26 Text box indicating if you want to exit the system.

By clicking the 'Yes' (**Yes/OK**) option, the screen closes and the exit from the system is completed. By clicking the 'No' (**Cancel**) option, the dialog box shown in the following figure appears, and the user continues on the analysis screen.

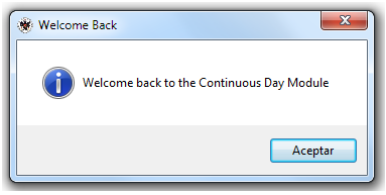
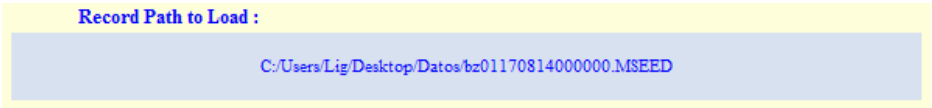


Fig. 27 Text box that indicates welcome back to the system.

6.1.3.- File path display area / Record path to Load (c).

In this area, the path (disk/folder/file), or 'path' of the physical file (where it is stored on the computer) is displayed, so that it can be accessed by the system to perform the necessary calculations.

An example of the output when performing the calculations is shown in the following image.



The 'Path' (on the computer - PC) of the physical location of the record to be loaded is shown.

7.- Graphical Results of the Record Selection.

Next, examples of final results from the filtering and analysis process according to the STA/LTA method will be presented.

7.1.- Example of filtering selection results and 24-hour graph.

According to the entire process described above, the steps to follow to represent a 24-hour graph are very simple and consist of the following items:

a) Open or select a specific record (the file path of the record to load is displayed. By default, the initial path is in the root directory "**C**" of the PC, whether in Windows or Linux).
b) Select the type of filter (Low-Pass, High-Pass, Band-Pass).
c) According to the type of filter, input the filter parameter values.
d) Enter the Minimum Magnitude data.
e) Click the "***Full Day Chart***" button to graph the record.

All of this will present:

The output of this analysis will consist of a graph of the signal from the record composed of segments one hour in duration. Therefore, 24 lines will be displayed in the final seismogram. From this, you can zoom in or save it in various formats. Zooming is done using the Zoom tool [Magnifying Glass ] on the resulting graphs (see Matplotlib Tools, Pages 28-33).

According to the type of filter, the interfaces and final graphs are shown in the following figures.

7.1.1 Interface and Graph of the Record with a 4 Hz Lowpass filter and magnitude 6.5 Mw.

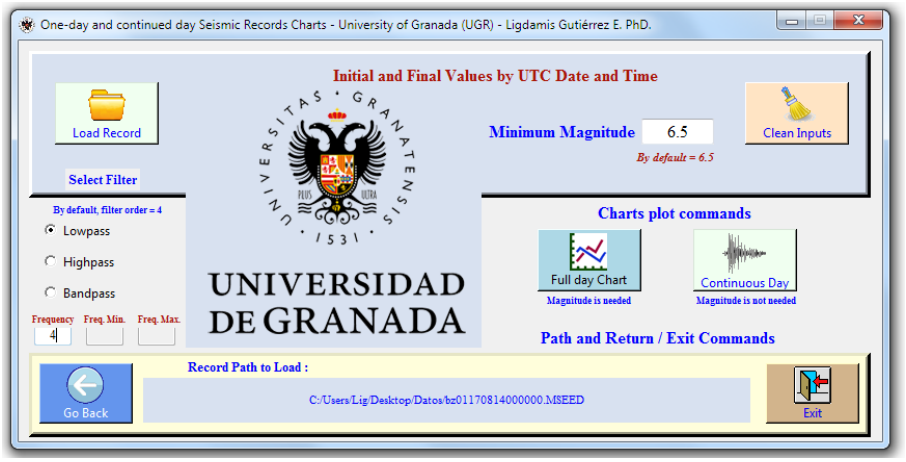


Fig. 28 Interface with the loading data and parameters to be used for the 24-hour graph of the seismic record.

The resulting graph with these parameters is shown in the following figure.

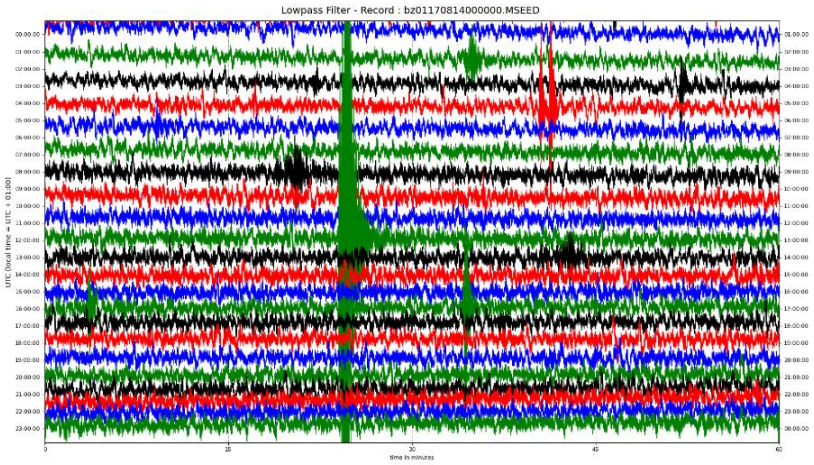


Fig. 29 Graph of the 24-hour seismic record, using a 4 Hz low-pass filter and a magnitude of 6.5 Mw.

7.1.2 Interface and Graph of the Record with a 4 Hz Lowpass filter and magnitude 4.9 Mw.

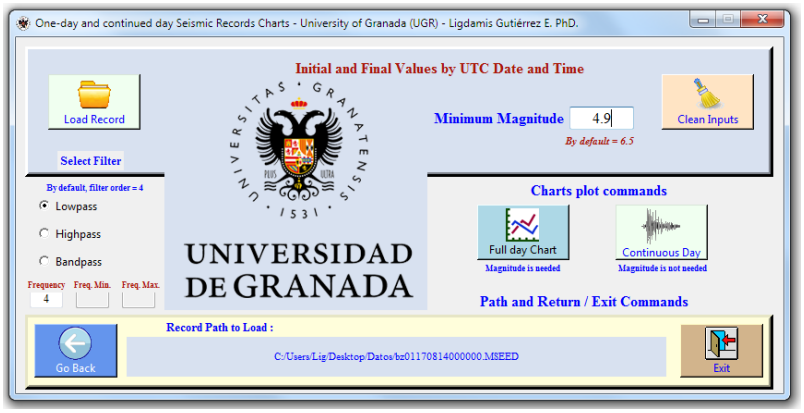


Fig. 30 Interface with the loading data and parameters to be used for the 24-hour graph of the seismic record.

The resulting graph with these parameters is shown in the following figure.

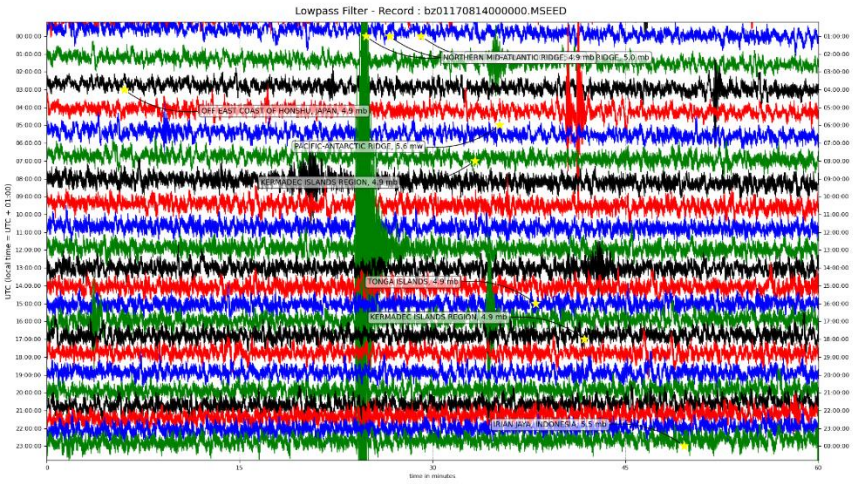


Fig. 31 Graph of the 24-hour seismic record, using a 4 Hz low-pass filter and a magnitude of 4.9 Mw.

It can be observed in the previous image that, with the lower magnitude, earthquake marks with their respective locations around the planet are presented. These are the earthquakes detected by the sensor. This is possible because the program connects to the FDSN (*International Federation of Digital Seismograph Networks*) global network server for the location of these earthquakes on the seismogram. However, this is subject to the server being available, as it may not always be active or accessible. If not, these marks will not appear. A zoom-in from the first to the ninth hour, where the marked distant events are better appreciated, is shown in the following image.

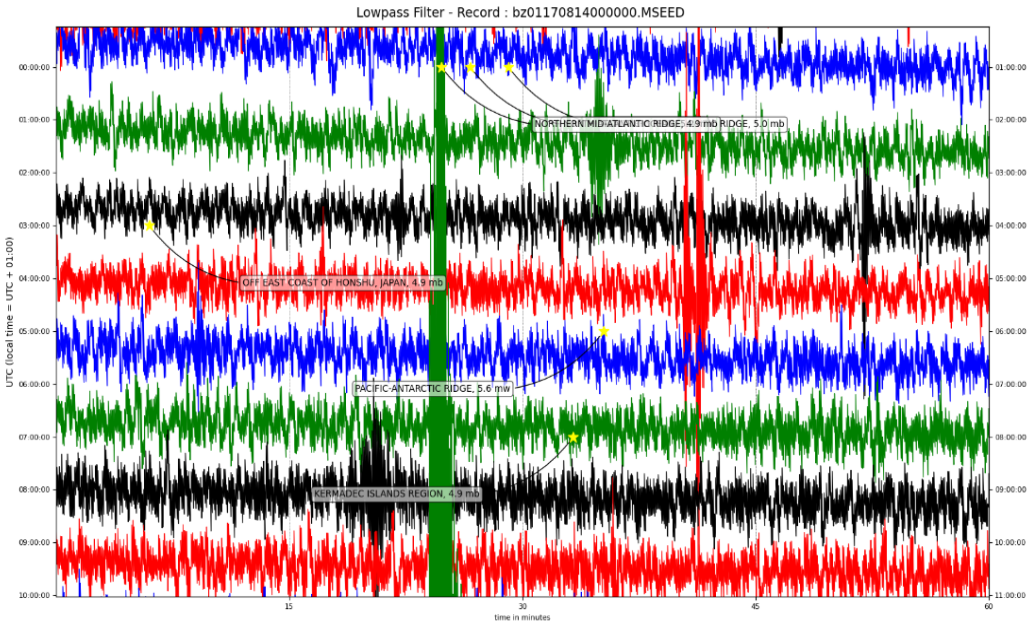


Fig. 32 Zoom of the 24-hour seismic record graph, using an 8 Hz high-pass filter and a magnitude of 4.9 Mw.

7.1.3 Interface and Graph of the Record with an 8 Hz Highpass filter and magnitude 6.5 Mw.

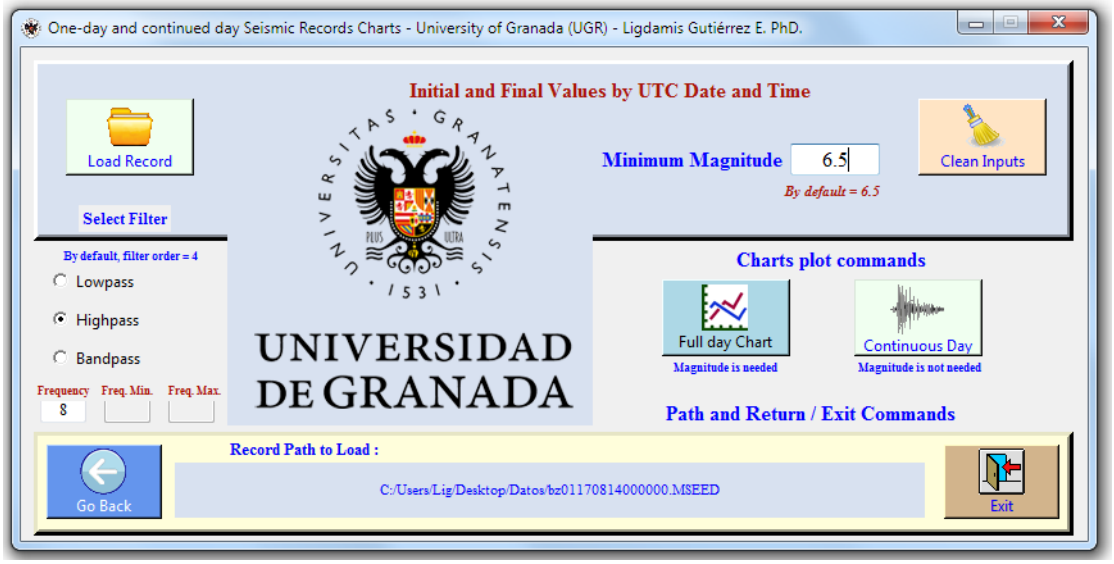


Fig. 33 Interface with the loading data and parameters to be used for the 24-hour graph of the seismic record.

The resulting graph with these parameters is shown in the following figure.

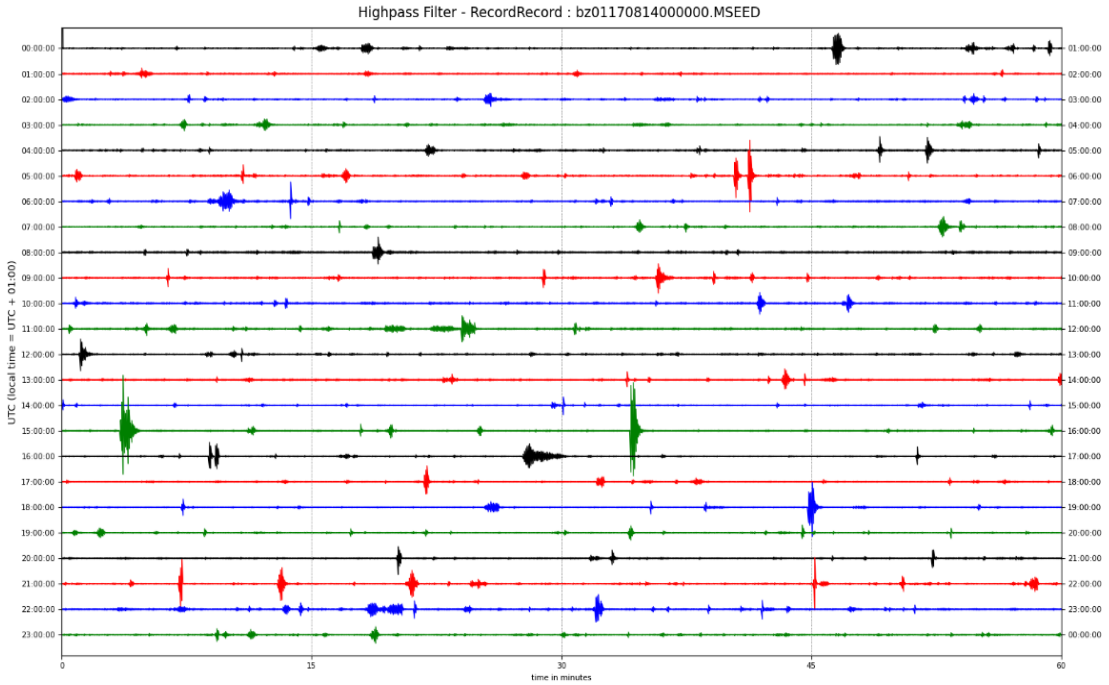


Fig. 34 Graph of the 24-hour seismic record, using an 8 Hz high-pass filter and a magnitude of 6.5 Mw.

It can be seen in the image that the background tremor is much lower than when representing the image with a low-pass filter.

7.1.4 Interface and Graph of the Record with an 8 Hz Highpass filter and magnitude 4.9 Mw.

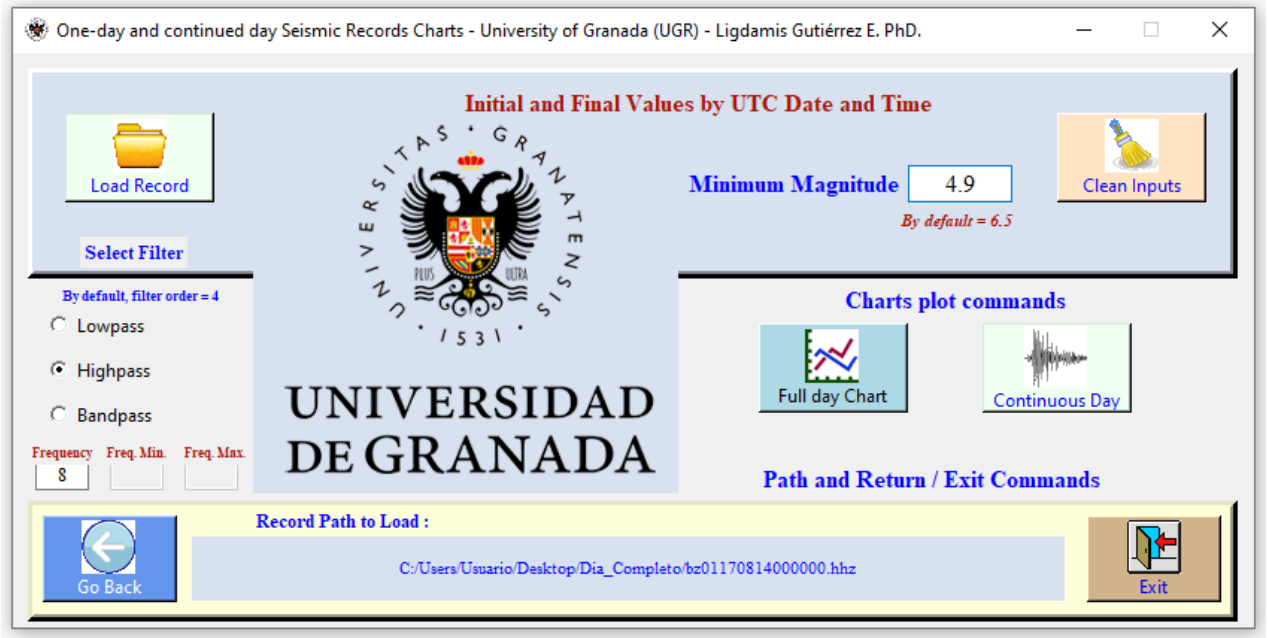


Fig. 35 Interface with the loading data and parameters to be used for the 24-hour graph of the seismic record.

The resulting graph with these parameters is shown in the following figure.

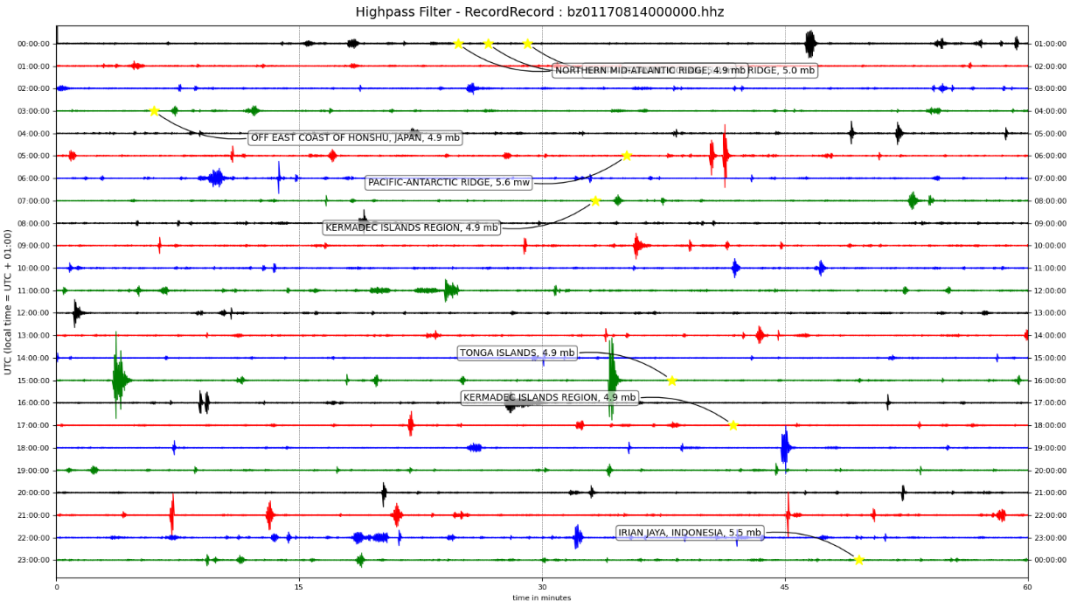


Fig. 36 Graph of the 24-hour seismic record, using an 8 Hz high-pass filter and a magnitude of 4.9 Mw.

In the previous image, the marks of distant earthquakes detected by the sensor can be seen. A zoom-in from the first to the ninth hour, where the marked distant events are better appreciated, is shown in the following image.

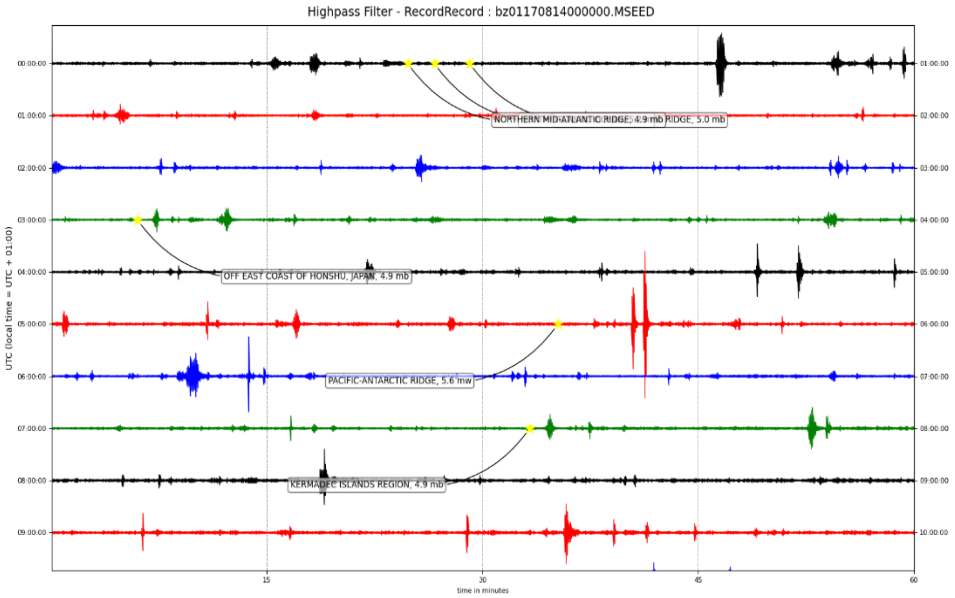


Fig. 37 Zoom of the 24-hour seismic record graph, using an 8 Hz high-pass filter and a magnitude of 4.9 Mw.

As can be seen in the previous image, the marks of the distant earthquakes detected by the sensor are better defined at specific moments in time. This is useful if the goal is to discriminate against those seismic events that do not correspond to or are not located near the volcanic edifice, indicating that the source is nearby.

However, if the goal is to keep the record clean, a higher magnitude should be chosen.

7.1.5 Interface and Graph of the Record with a Bandpass filter with a minimum frequency of 1 Hz, a maximum frequency of 20 Hz, and a magnitude of 6.5 Mw.

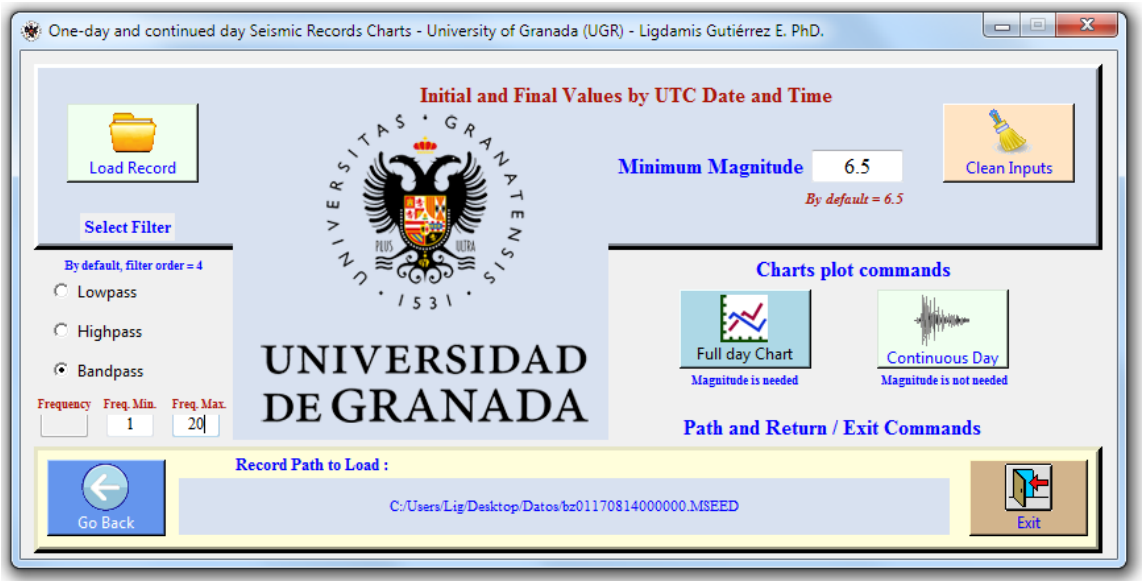


Fig. 38 Interface with the loading data and parameters to be used for the 24-hour graph of the seismic record.

The resulting graph with these parameters is shown in the following figure.

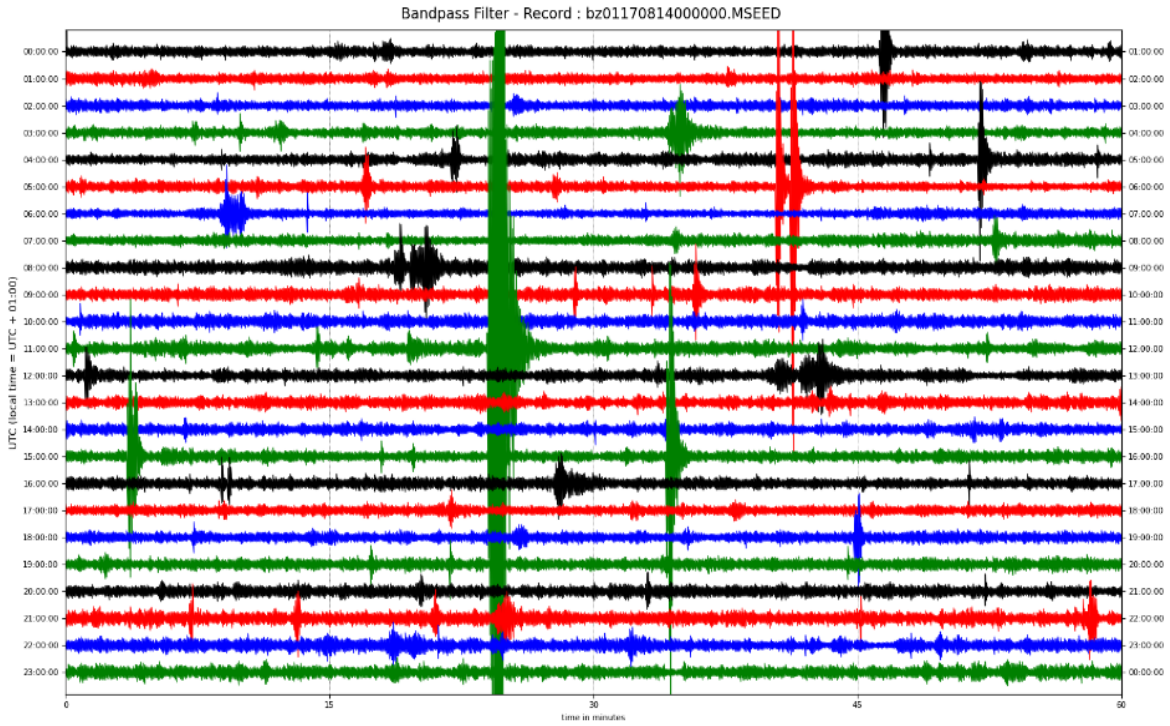


Fig. 39 Gráfica del registro sísmico de 24 horas, utilizando un filtro paso-banda con frecuencia mínima de 1 Hz, frecuencia máxima de 20 Hz y una magnitud de 6.5 Mw.

7.1.6 Interface and Graph of the Record with a Band-Pass filter with a minimum frequency of 1 Hz, a maximum frequency of 20 Hz, and a magnitude of 4.9 Mw.

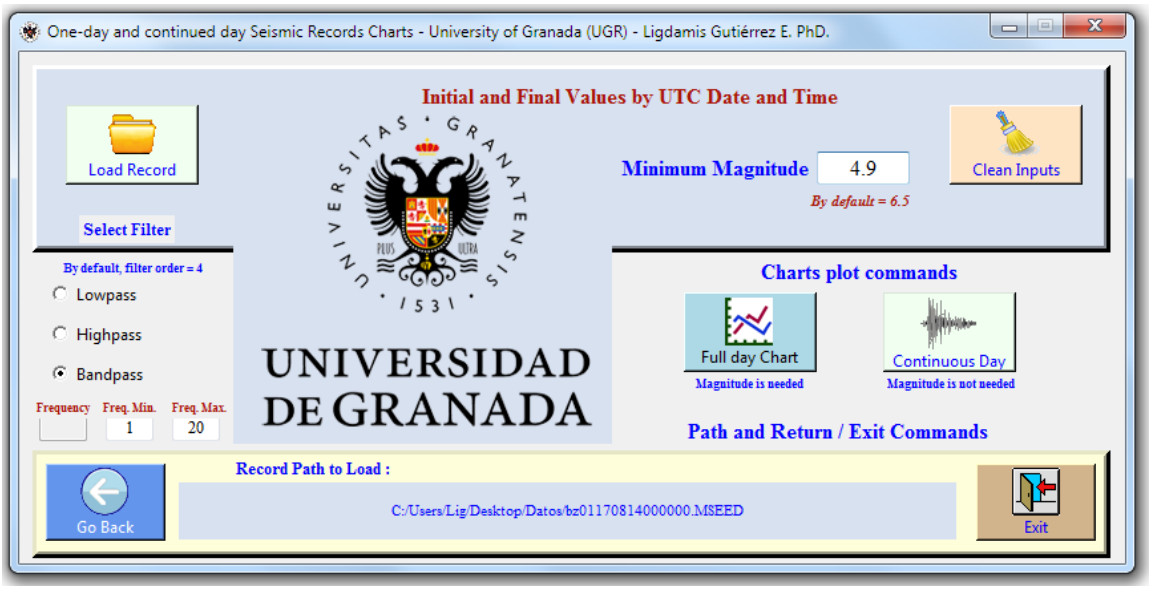


Fig. 39 Interface with the loading data and parameters to be used for the 24-hour graph of the seismic record.

The resulting graph with these parameters is shown in the following figure.

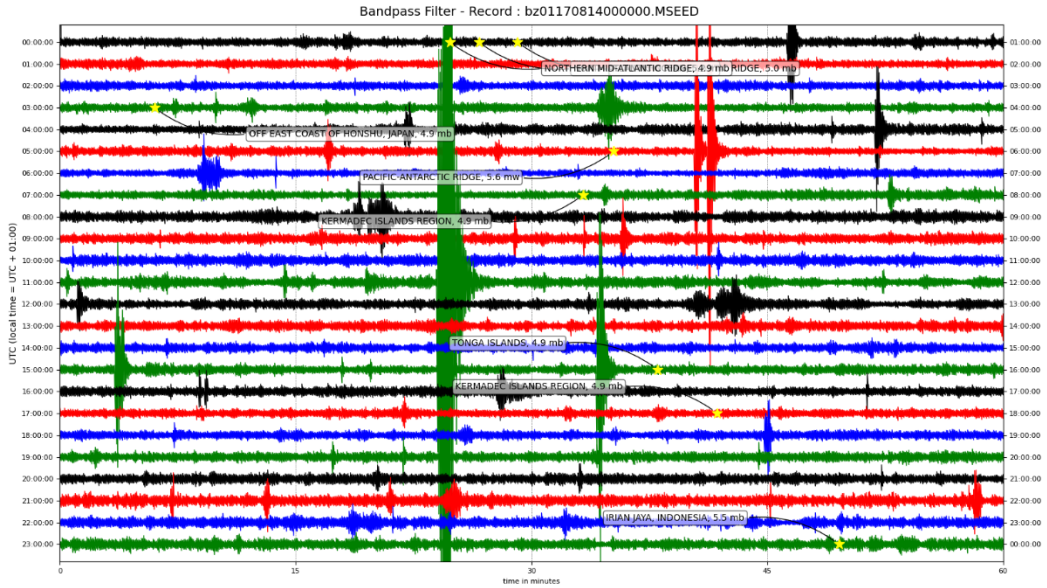


Fig. 40 Graph of the 24-hour seismic record, using a band-pass filter with a minimum frequency of 1 Hz, a maximum frequency of 20 Hz, and a magnitude of 4.9 Mw.

In the previous image, the marks of distant earthquakes detected by the sensor can be seen. A zoom-in from the first to the ninth hour, where the marked distant events are better appreciated, is shown in the following image.

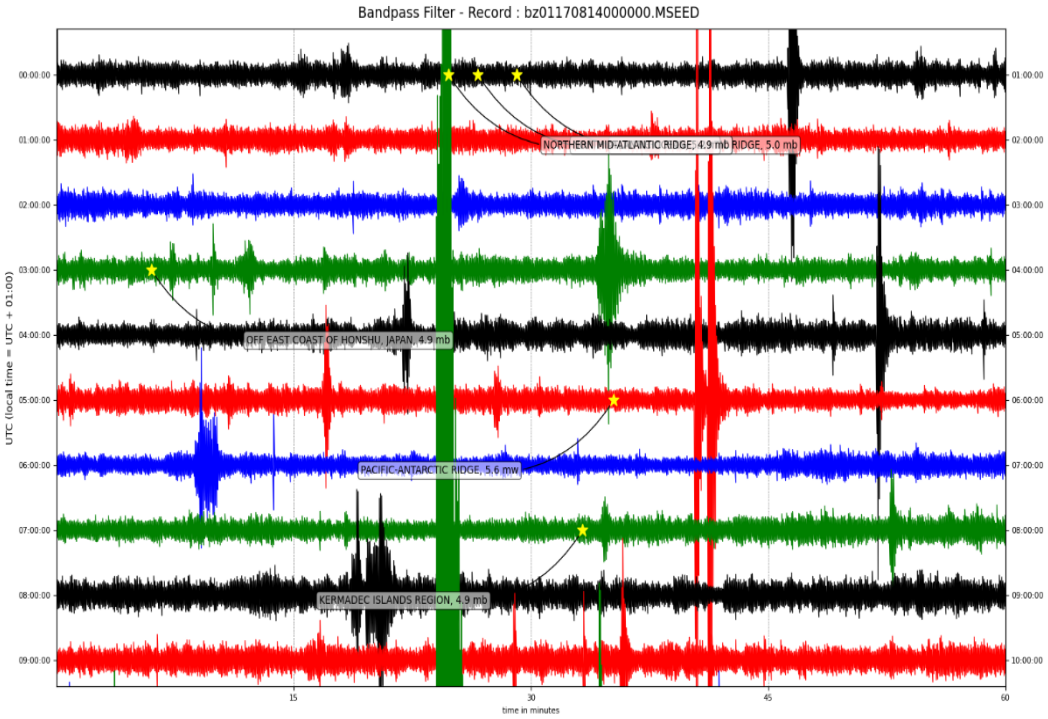


Fig. 41 Zoom of the 24-hour seismic record graph, using a band-pass filter with a minimum frequency of 1 Hz, a maximum frequency of 20 Hz, and a magnitude of 4.9 Mw.

NOTE: In conclusion, it is the observer who must decide which of these filters to use in order to better analyze the seismic events present within the seismograms, thereby building better seismic databases that can be used in future recognition and training systems to develop improved early warning systems.

7.2.- Example of results from filter selection and continuous graphs.

The steps to represent a continuous graph of a seismic record are very simple and consist of the following items:

a) Open or select a specific record (the record file path is displayed). By default, the initial path is in the root directory "C" of the PC, whether in Windows or Linux.
b) Select the type of filter (Low-Pass, High-Pass, Band-Pass).
c) According to the type of filter, enter the filter parameters.
d) Click the "Continuous Day" button to graph the record.

NOTE: The Minimum Magnitude data is irrelevant and therefore is not considered for the calculation of the resulting graph.

The output of this analysis will consist of the graph of the continuous record signal. Therefore, a single line will be visualized in the final seismogram. This can be zoomed in on or saved in various formats.

NOTE: In this section, only the resulting graphs are presented, as the interfaces that generate them are similar to those presented in the previous section.

7.2.1 Graph of the continuous record with a 4 Hz Lowpass filter.

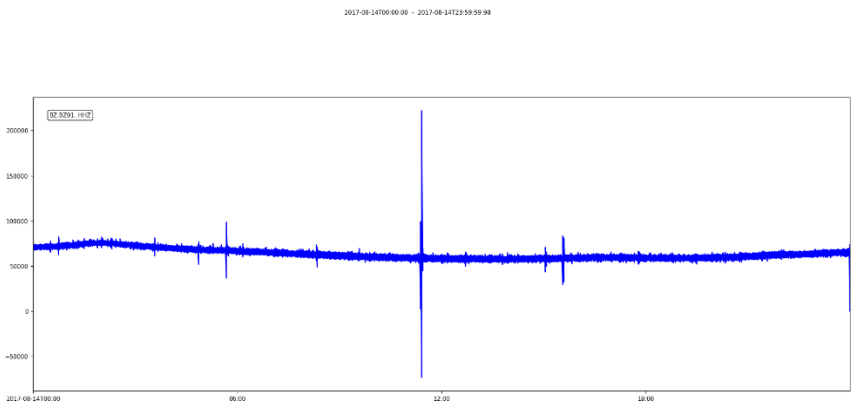


Fig. 42 Graph of the continuous seismic record using a 4 Hz low-pass filter.

7.2.2 Graph of the continuous record with an 8 Hz highpass filter.

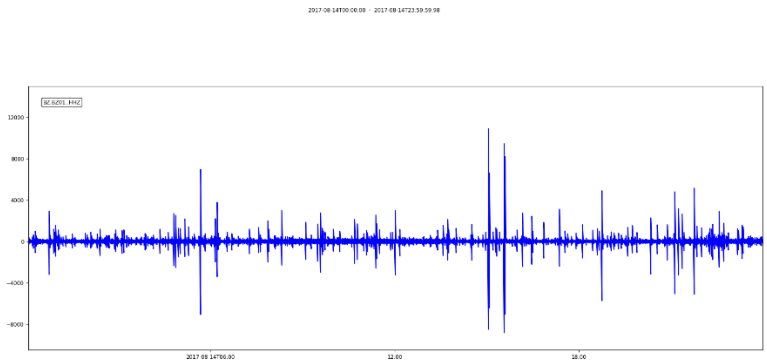


Fig. 43 Graph of the continuous seismic record using an 8 Hz high-pass filter.

7.2.3 Graph of the continuous record with a band-pass filter with a minimum frequency of 1 Hz and a maximum frequency of 20 Hz.

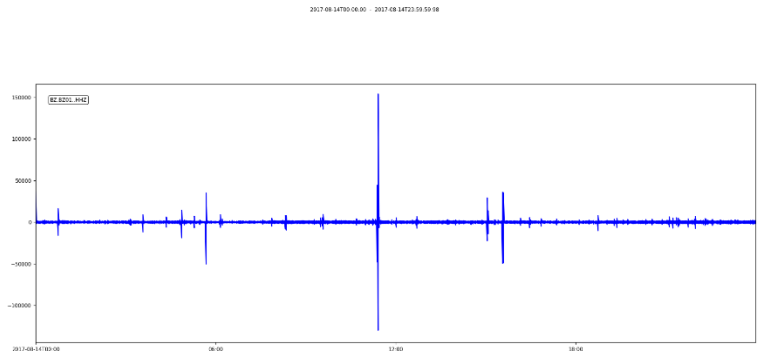
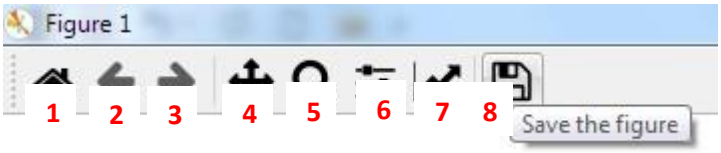


Fig. 44 Graph of the continuous seismic record using a band-pass filter with a minimum frequency of 1 Hz and a maximum frequency of 20 Hz.

8.- Toolbar of Graphs (Matplotlib Library).

In the construction of graphs, the *Matplotlib* library's graph screen has a set of very useful tools that allow you to visualize, edit, and save graphs in various formats. At the top of the Matplotlib graph screen that appears when a graph is created, there is a toolbar similar to the following:



From left to right, the icons representing the actions to be performed are:

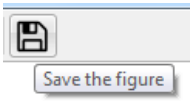
1. Reset original view: Restores all graphs to the initial state.
2. Back to previous view: Preview of the selected graph.
3. Forward to next view: Forward view of the next image.
4. Left button pans, Right button zooms, x/y fixes axis, CTRL fixes aspect. Moves the graph and axes left or right, zooms in or out, fixes the x/y axis, and fixes the aspect with CTRL.
5. Zoom to rectangle: Through a rectangle, zooms in on the selected graph.
6. Configure subplots: Configuration of subplots (Borders and spacings).
7. Edit axis, curve and image parameters: Editing the parameters of the graph. Select the axes or graph and edit elements such as title, coordinates (X, Y), and curve parameters (lines, markers) in styles, colors, and size.
8. Save the figure: Saves the graph in several formats.

This document does not delve into each of them; it only highlights the use of those that are generally more commonly used, such as (1, 2, 5, 7, and 8).

In the above graphs, the use of the zoom tool (5) has been observed. Tools 2 and 3 allow zooming in or out individually for each graph. Option 1 allows restoring all elements or subplots of the graph to their initial values (*each individual graph or part of the window*). As for option 8, it allows saving the graph in various formats. The rest are straightforward, and it is up to the user to explore each of them. Now, the processes for "***editing***" and "***saving*** or ***storing***" the graphs (*Numbers 7 and 8*) are detailed below.

8.1.- *Saving Graphs.*

The process of saving graphs is very simple. Click on the icon of tool number 8 (Save the figure).



This opens an explorer window, similar to those in Windows (depending on the language or system used), where you can select the folder or directory where the graph will be saved.

Additionally, provide a name and select the desired format type. This can be done at the bottom of the explorer window (red circle in the image), where various format types available for saving are selected. The screen resembles the following.

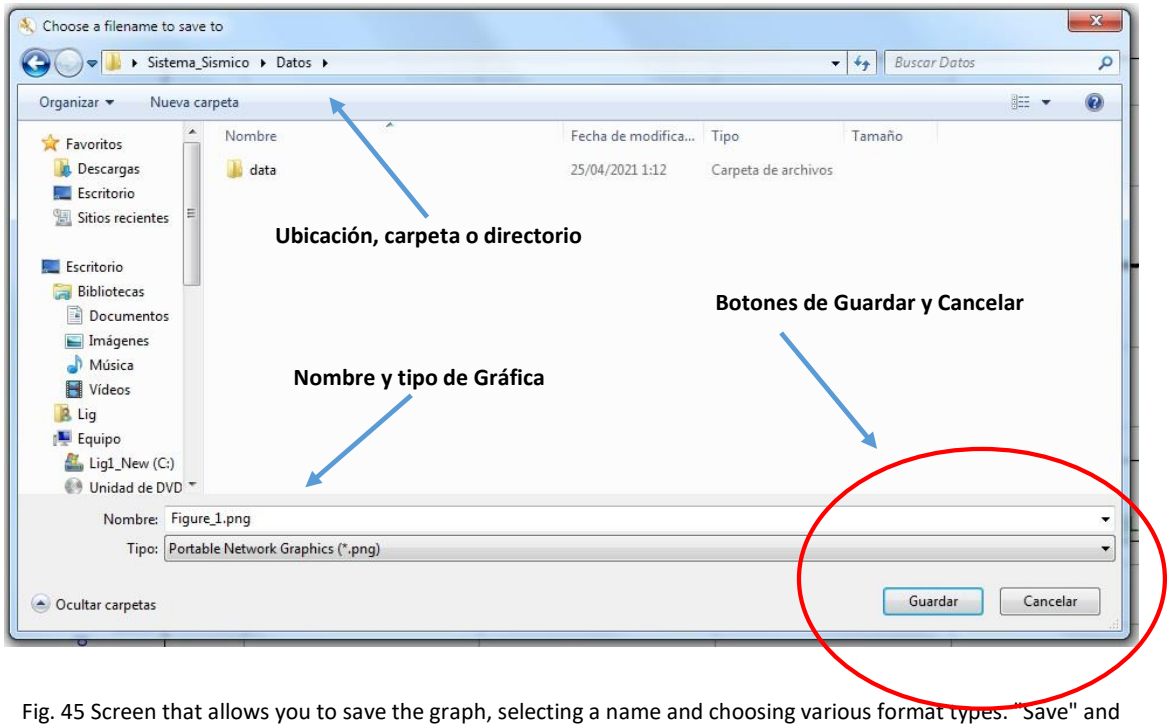


Fig. 45 Screen that allows you to save the graph, selecting a name and choosing various format types. "Save" and "Cancel" buttons are provided to complete or cancel the process.

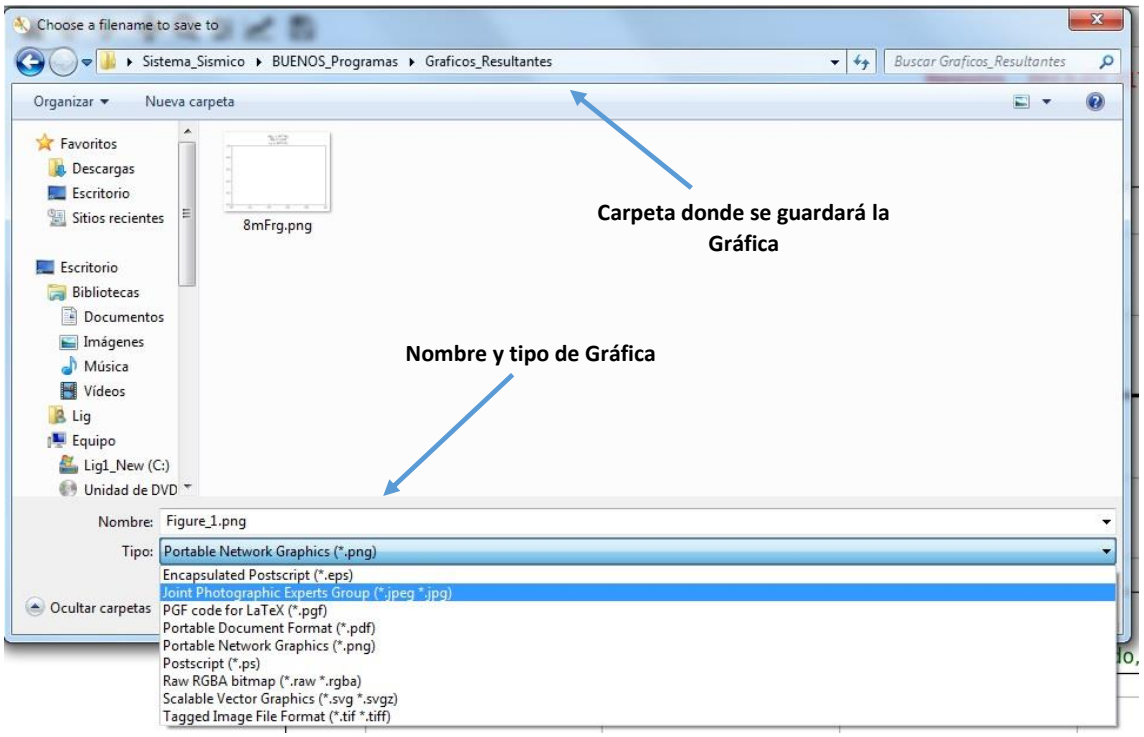


Fig. 46 Screen where you can see the types of formats available to save the graph.

The previous figure shows a list of the available file formats, the following image presents this list in more detail:

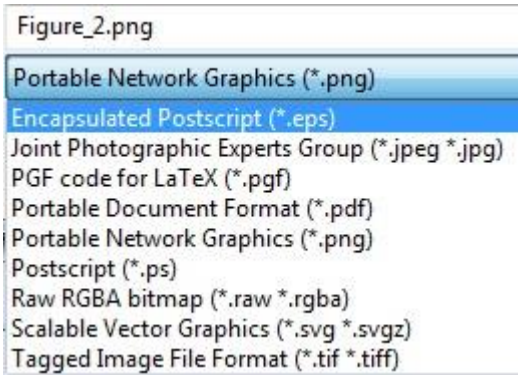
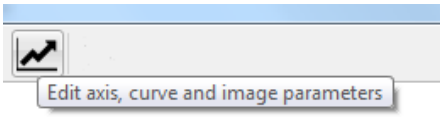


Fig. 47 List of available formats for saving the graph generated by the analysis.

Once you have selected both the name and the desired file format, and the location of the folder or directory where the graph will be saved, click the "*Save*" button (*See Fig. 45*), and the graph will be stored and available for further use as needed.

8.2.- Editing Axes and Images in Graphs.

Through the "Edit" button, point 7 (*See page 28*) of the graph toolbar (*Edit axis, curve and image parameters*), it is possible to edit or modify the parameters of the axes, images, and curves of the graphs.



For example, to modify the parameters of the image of a spectrogram, click on this command button. A "*Customize*" dialog box appears, indicating which of the "*axes*" in the graph areas you want to edit or modify. After selecting, click the "OK" button. This dialog box is similar to the following.

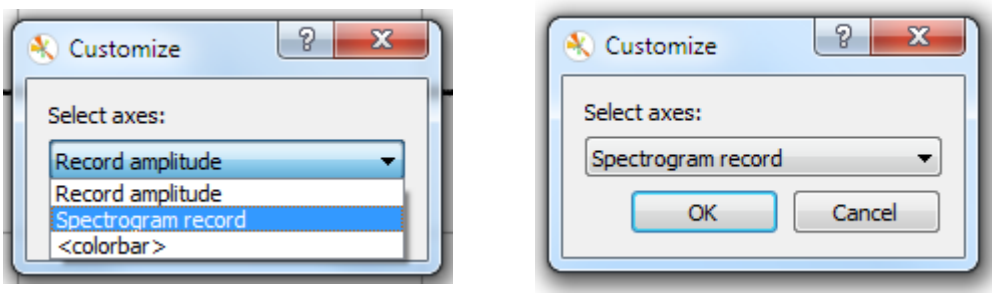


Fig. 48 Customize dialog box, the spectrogram axis has been selected.

Once the desired axis is selected, and the "OK" button is clicked, a new window with the options in the figure is presented. Here, various values of the selected axis are edited, in this case, the spectrogram (*Axes and Images*). The dialog box is as follows.

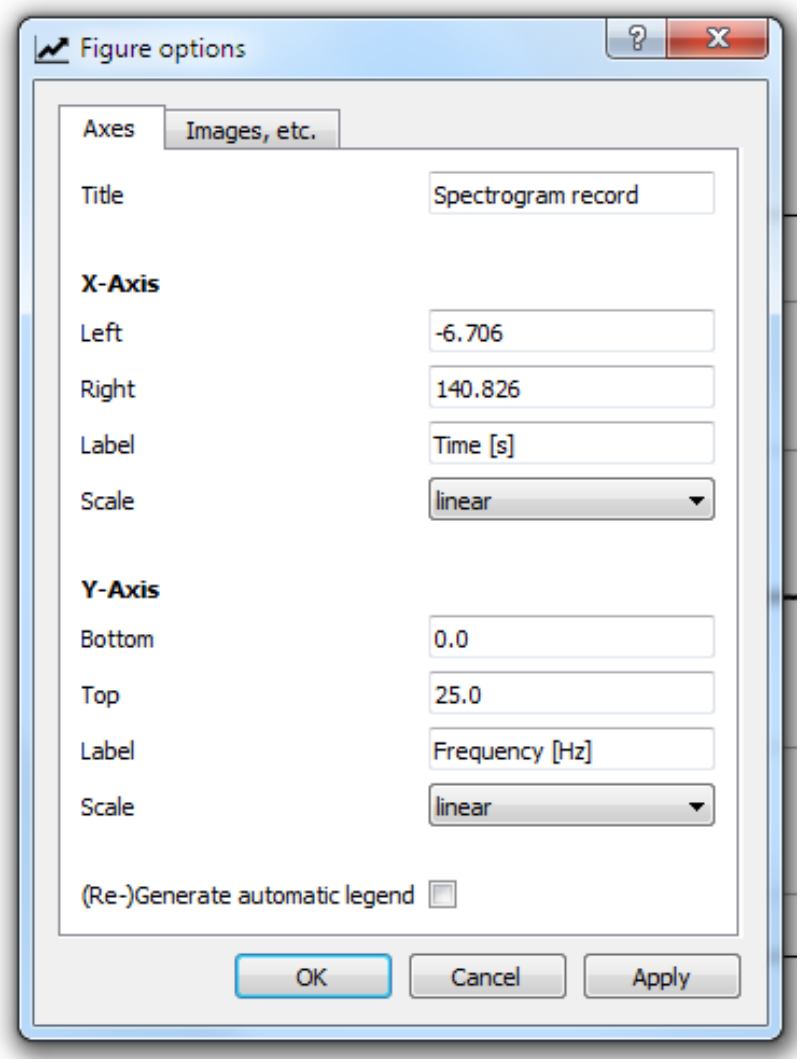


Fig. 49 Dialog box for editing options for the title and axes of the figure.

In this "*Axes*" section, as you can see, you can edit or modify the values or parameters of the title and the "X" and "Y" axes of the graph. For our example, we want to modify the image, so we will select the tab indicating this option. The image presented is as follows.

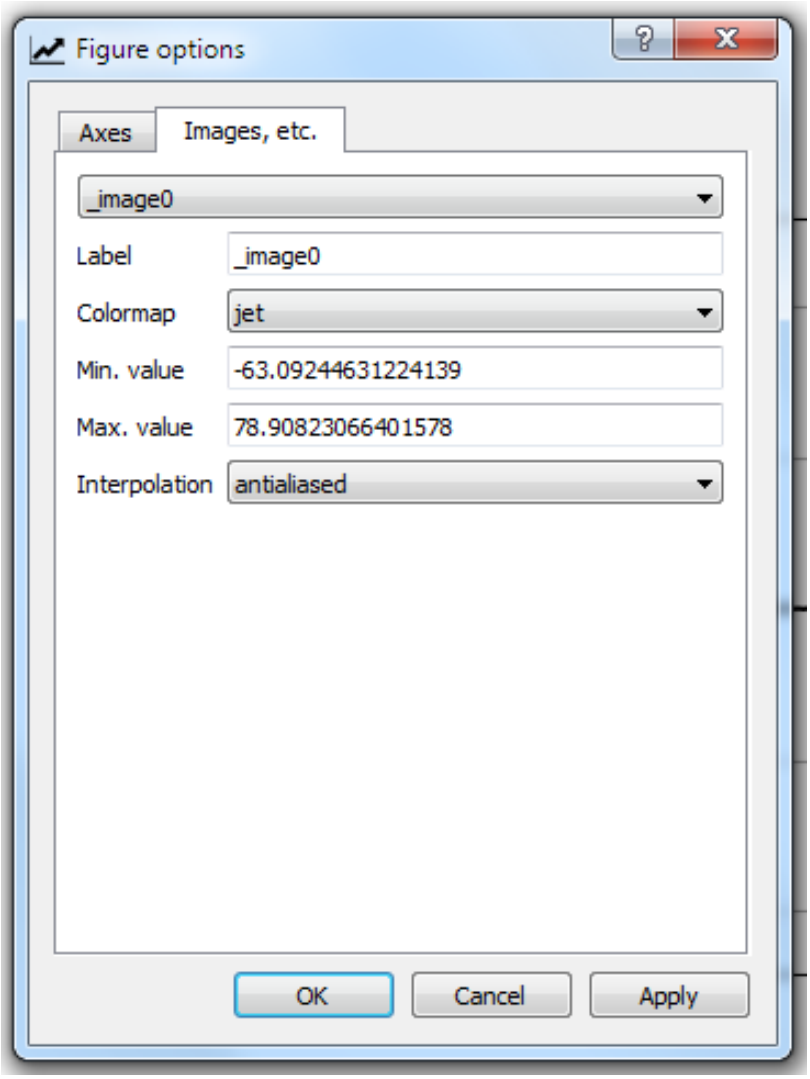


Fig. 50 Dialog box for editing options for image parameters.

As seen in the image, various parameters can be modified, including labels, the color map or "*Colormap*", used in the spectrogram, minimum and maximum values, and interpolation. The default value for the "*Colormap*" is set to "**jet**". The minimum and maximum values for this color map and the interpolation used are assigned by default to the image, but they can be modified according to the operator's interest.

The list of editable parameter values for both "*Colormap*" and "*Interpolation*" is presented in the figure on the next page.

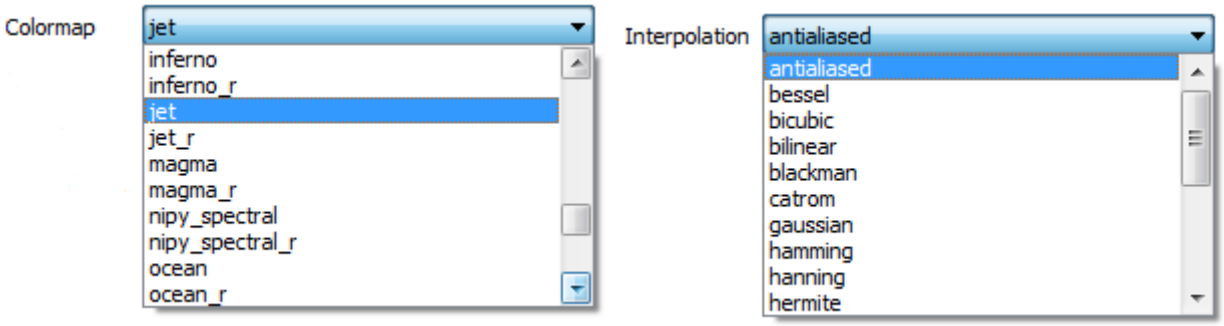


Fig. 51 Dialog boxes for editing some of the parameters of "*Colormap*" and "*Interpolation*" to select in the graph.

CONCLUSION: The system is designed to be an easy-to-use, accessible, and comprehensible tool. It features a user-friendly interface that provides reliable technological assistance to the human operator in analyzing seismic records, both tectonic and volcanic. The simplicity of this first version lies in the fact that it consists of a single module, which includes several digital filter analyses frequently used in the study of a specific seismic signal (low-pass, high-pass, and band-pass), allowing for the creation of 24-hour seismogram graphs segmented into one-hour intervals. In future versions or updates beyond the current version (1.0), additional modules may be added containing various types of analyses, functionalities, or different methods for representing multiple graphs to enhance the study and research of the scientific community.

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END of the document.

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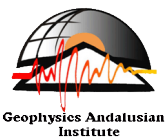

APPENDIX A

A1.- Installation of Python and Additional Libraries

A1.1. Package Content.

The main folder "***Analysis_System_1***", It contains two folders with the programs (codes and interfaces in English and documentation in Spanish and English), organized as follows:

a) Folder **"*Reliable_set_tools_system_1*"**: (*seismic analysis system assembly*). This folder must be copied to "*My Documents*". Contains the following elements:

   a. Subfolder: "***Images***" " Images necessary for program interfaces.

   b. Program: ***Menu.py***. Startup program, presentation and calling of individual modules.

   c. Program: "***Days_1.py***". Main program (*interface*), for the analysis and management of presenting complete 24-hour records in one-hour duration segments.

b) Folders (*Document_ES and Document_EN, depending on the language; English or Spanish*). For *English* "***Document_EN***": It consists of the following items:

   a. User Manual for the module: "***3_Manual_One_Day_Records_EN.pdf***" in PDF, written in English, with the necessary documentation for the use of the system interfaces. In addition, the rest of the manuals for the other modules (1-10) that make up the system are found.

   b. "***Initials Requirements.txt***" file. File containing the libraries needed to be installed on Windows through "Pip", once Python is installed.

   c. File "***README.txt***": File with general instructions for system installation.

   d. File "***Set_tools_System_1_1.bat***", batch processing executable file. It must be copied to the desktop, from there by right clicking "run as administrator", it will start the system by calling the main menu. The file will automatically search for the startup program (Menu.py) that is located in the "Set_tools_System_1_1" folder that has been previously copied to "My Documents" and will start Python, executing said program.

The system has all the elements (*programs and interfaces*) in English, except for the user manual, which is written in both Spanish and English. To install on Windows, two main actions should be taken after downloading and extracting the ". Rar" files. The first is to copy the entire folder (a) to the "*My Documents*" folder on the PC.

a) From the main folder (**Analysis_System_1**), copy the subfolder "**Document_EN**" to "**My Documents**" in Windows.

b) Copy the file "**Set_tools_System_1_1.bat**", from the "(Document/Document_ES or Document_EN)", depending on the version (Spanish or English), to the Windows desktop.

This ensures the proper use of the program. Now, we will proceed with the installation of the Python language and additional Python libraries on Windows.

A1.2.- Installing Python on Windows.

Python is an interpreted, multi-platform, and multiparadigm programming language (*it works on various operating systems, including Windows, Linux, and Mac*), utilizing two or more programming paradigms within a program-object-oriented, reflective, imperative, and functional.

In addition, Python can be enriched by a large number of programming modules, libraries, packages, or libraries installed through its package manager, "**Pip**." On Linux, the Python program and its manager "**Pip**" are installed together with the operating system. In Windows systems, however, where Python is not a native language, it is necessary to install this language beforehand by downloading the appropriate version from the Python distribution website at the following address: https://www.python.org/downloads/
On the website, the correct version should be selected based on the type of operating system on the computer, including whether it is 32 or 64 bits.

To be installed on both 32 and 64-bit systems, it is essential to note that this document and the software were created with the version available at that time, which was "Python 3.8.6", and many more versions have emerged since then. A more modern and adaptable version to the software (recommended) is "Python 10.10".

Users need to check if more advanced versions do not interfere with some of the installed libraries, such as "*Obspy*," for example. This is because everything related to Linux systems is constantly changing with updates that Python and Linux-based systems make. It is advisable to visit the website and download the most stable or tested updated version of Python that works well with this software.

Once downloaded, run it as an administrator (*right-click and "run as administrator"*), and the software installation wizard will guide you through the necessary steps (*just follow the instructions*).

The process takes only a few minutes. It is "recommended" to indicate during the process, when asked, to include an access path in the system's "**Path**" so that Python can be accessed from any location in Windows. If this is not done during the installation process, it must be done manually by modifying the environment variables (more complicated) to include the path from where Python is installed. This will not be necessary (*if indicated at the beginning*) through the installation wizard.

A1.3.- Installation of Additional Libraries.

The next step is to ensure that Python and its file manager or package manager (**Pip**) have been installed correctly. "**Pip**" (*file and library manager*) is crucial because it allows the installation of additional libraries that Python needs to run the created programs. To do this, open the Windows console window, or "*CMD*." The CMD, or command prompt, is a command-line interpreter.

Accessing the CMD is possible by typing, searching for the Windows logo key (a window), located between the "Ctrl" and "Alt" keys at the bottom left of the keyboard. Pressing this key, plus (+) the letter "**R**" key, will open a "Run" program window, similar to the following.

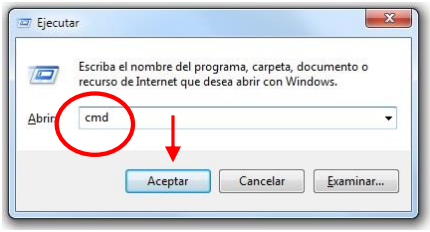

Fig. A1 Screen run in Windows. In the red circle, type "cmd" and click "OK."

As seen in the figure above, type "cmd," click "OK," which will open the Windows command prompt window.

Another way to do this is at the bottom of the desktop, in (W7) or next to (W10) the Windows "Start" button. There is the search section, indicated by the magnifying glass icon. This indicates a search for programs, similar to the following.

Fig. A2 Windows Program Search Screen.

In the box that says "Search programs and files" (Windows 7) or "*Type here to search*" (Windows 10), type "cmd" as well. This action or the previous one will bring up the Windows command prompt (CMD), similar to the following (W7).

Fig. A3 Windows 7 Command Prompt (CMD) Screen.

The same applies to versions: Windows 10 (W10) or Windows 11 (W11).

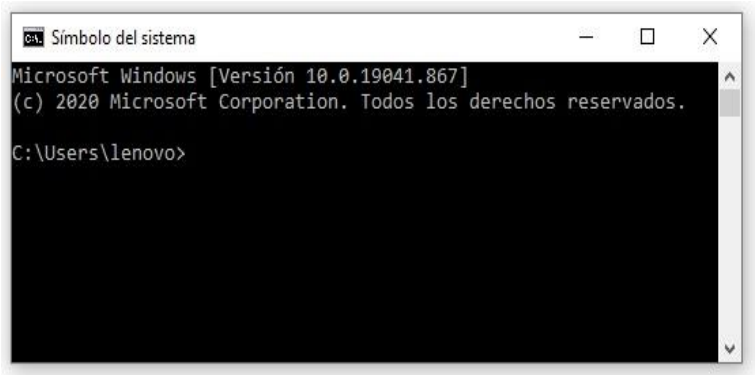

Fig. A4 Command Prompt (CMD) Screen in Windows 10.

Once on this screen, to verify that both Python and its package manager "pip" have been installed correctly, type the following commands: Python -V, and to check "pip," type: pip -V. This is shown in the following figure.

Fig. A5 CMD Screen, indicating Python and pip versions in Windows.

The output of typing "-V" in Python indicates invoking the installed version. In this case, it can be seen that it is "3.8.6" (*The library set is compatible with 3.10.10 version*). This has been possible from any location in the system because the Python script has been installed, remember, in the "**path**" or route found in the system's environment variables. Also, after typing "pip -V", it can be seen that the Pip version is "*20.2.1*." At this point, it is recommended to update this version since, by default, "Pip" is installed along with "Python", but it does not install the latest or most up-to-date version. To do this, in the CMD window or console, type the following command (*Windows/Linux*): On Windows, type "python," and on Linux, type "python3".

Windows: > python –m pip install –upgrade pip | Linux: $ sudo python3 –m pip install –upgrade pip

This indicates that "Pip" will be updated to its most recent version (*On Linux, as a "superuser," i.e., with "sudo" at the beginning*). It is shown in the following screen.

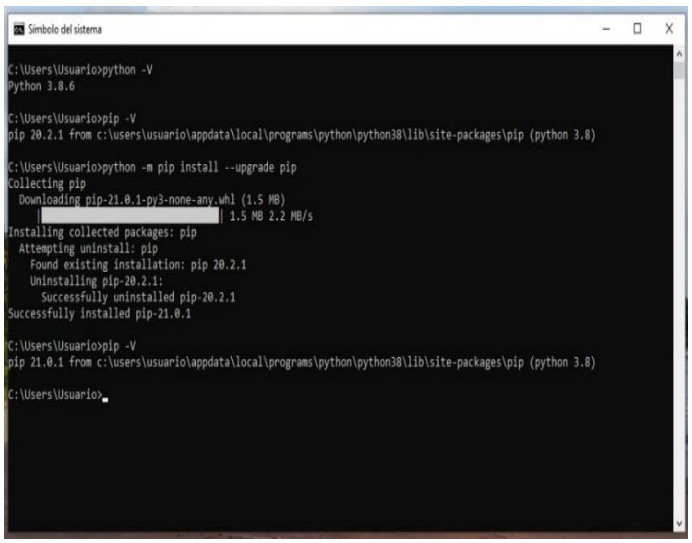

Fig. A6 Screen showing the update and verification of the new version of pip in Windows.

As can be seen, when typing again (**pip -V**), once Pip is updated, the version is 21.0.1. With this, Python and Pip are already installed and updated. Pip, as mentioned, is very important because with this manager, all the necessary libraries and packages are installed so that Python applications can be executed correctly and without errors. To use the system, you must proceed to install the necessary packages or libraries through Pip.

Next, we will proceed to explain how, in a simple and completely automatic way, the most commonly used and general libraries that Python needs will be installed on the system. Libraries such as, for example, "*obspy*," which is the open-source library or software based on Python for processing seismological data. Also, "***matplotlib***," which is a library for generating graphics from data contained in lists or arrays in Python and its mathematical extension "***NumPy***," among others, which the system needs for its execution (*See Annex B*).

A1.4 Automatic Installation of Libraries on Windows and Linux from PIP.

The advantage of having already installed and updated Pip in Windows is that you can install all the libraries that Python needs to run the system.

Additionally, in the "***Document***" folder, the "***Readme.txt***" file contains instructions for this installation. So the user only needs to follow the instructions, and the necessary packages will be installed on the computer (PC) automatically by Pip, both on Windows and Linux. The required libraries are in the file called "***Initial_requirements.txt***", included in the "***Document***" folder of the downloaded installation files and in **Annex B**.

In a Windows Command Prompt (**Cmd**) window, actions are taken for each of the commands indicated in the file, following the instructions. The installation should not present problems on Windows and Linux systems. If any library encounters an error during installation (*shown in red in CMD*), you should consult the documentation for that library or check if the correct or recommended version of Python is being installed (*version 3.8.6 and/or 3.10.10*). The installation on Linux systems (*See README.txt*) is similar and simpler. Copy the main folder to the desktop, the personal folder, etc. From that location, open a command prompt, and simply type:

"***$ python3 Menu.py***" to start the system.

Back to Index

APPENDIX B:

INSTALL PYTHON LIBRARIES FOR THE PROPER FUNCTIONING OF THE SYSTEM.

1.- **PIP**: The **Pip** (*Preferred Installer Program*) is the package or package management manager used to install and manage software packages written in Python. When installing Python, Pip is installed by default. To check the version of Python or PIP, type the following in a console or CMD:

python - V / pip – And to see the list of installed pip packages: -> pip list

Usually, you need to update the version of pip with which Python is installed. For this, type the following command in the command prompt (CMD). In Linux and Mac systems, "**sudo**" is placed at the beginning to indicate super-user permissions.

Python –m pip install - - upgrade pip / (LINUX) -> sudo python –m pip install - - upgrade pip

Once downloaded and installed, you can check the version again with the first command, and you will see that the version has changed and been updated. Now that pip is updated, we will proceed to install the necessary packages for Python to work correctly with the applications.

2.- .- **PyQt Installation**: This is a Python binding for the Qt library written in the C++ language. It is used for creating and using graphical user interfaces (GUI) in Python. Type the following in the command prompt (CMD).

pip install PyQt5 / (LINUX & Mac) -> sudo python install PyQt5

3.- **Matplotlib library Installation**. Matplotlib is the library that allows the creation and visualization of graphics. Type the following:

pip install matplotlib / (LINUX & Mac) -> sudo python install matplotlib

4.- Install the **Obspy** library. This library is for handling seismic signals. Type the following:

pip install obspy / (LINUX & Mac) -> sudo python install obspy

5.- Install **Thinter**: Thinter is a graphical user interface (GUI). Type the following:

pip install tk / (LINUX & Mac) -> sudo python install tk

6.- Install **quantecon**: This library is used for spectrum estimation, Periodogram, Fourier transform. Type the following:

pip install - - upgrade quantecon / (LINUX & Mac) -> sudo python install - - upgrade quantecon

7.- Update a library for **matplotlib**. To avoid problems with graphics, install the following:

pip install msvc-runtime / (LINUX & Mac) -> sudo python install msvc-runtime

8.- Install **easygui** for the graphical interface:

pip install easygui / (LINUX & Mac) -> sudo python install easygui

9 Install **PyWavelets** for CWT handling.

pip install PyWavelets / (LINUX & Mac) -> sudo python install PyWavelets

10.- Install **plotly** for handling and assisting with graphics along with Matplotlib.

pip install plotly / (LINUX & Mac) -> sudo python install plotly

11.- Install "**pyaudio**", for audio management. Python bindings for PortAudio v19, the cross-platform audio I/O library

python -m pip install pyaudio / (LINUX & Mac) -> sudo apt-get install python3-pyaudio

Finally, type "pip list" to see the installed libraries. Optionally, you can create a file called "***requirements.txt***" that will contain all the libraries that the PC will use. The "***requirements.txt***" file must be in the current directory. The instruction to do this is as follows:

pip freeze > requirements.txt