Waveform analysis tools in Seismology

SeismoGRAPHer

FOR WINDOWS

Full Version

(V.3.7.4)

User Manual

Sgraph© 2008–2010
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About *Sgraph*

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Preface

Sgraph descriptions

Sgraph is a program for Seismological data analysis. It provides facilities to plot and analyse different types of data format. It is a FORTRAN *Quick-Win* application in which dialogs are used to easily read and write information. The FORTRAN graphic libraries are used for the plotting routine. In addition, Post Script facilities are inserted to obtain a PS version of the ***Sgraph*** plotting**.**

The idea of writing this program comes during my master study. I faced a lot of problems to analyse the data of the only digital seismographic station (KEG) in Egypt at that time. The data of this station has a special format that needs to be reformatted to fit in the available software at that time (PITSA). ***Pitsa*** helps a lot. But every time I use it I need to reformat my data. The idea of ***Pitsa*** attracts me so much in a way I decided to make a similar plotting program just for reading my own unique format. The idea grows up until the *Quick-Win* FORTRAN comes to my hand. ***Sgraph*** starts and step by step I insert all subroutines I need to establish my PhD study. I decided to insert all the required data formats that I met to make it easier for the researchers to read and analyse data. Finally, I found ***Sgraph*** a special program in seismology and I realize that it is important to be released for researchers, and here it is.

In this version, the program read the data format of the types ***ASCII SAC, Binary SAC, Multicolumn ASCII data***, ***GSE formats, Y-format (Nanometrics), and Focal mechanism files.***.

The program provides the principle waveform analysis tools such as, ***Zooming, Integration, Differentiation, Filtering, FFT, Convolution, Correlation, ..etc***.

Inversion processes are utilized in ***Sgraph*** to solve either linear or nonlinear seismological problems. SVD (Singular Value Decomposition) tools are used for the linear problems (e.g. travel time/slowness, Wadati Diagram, and others). ***Marquard*** inversion tools are used to solve the nonlinear problems (i.e., Brune models, Q vs Freq, MLTW, and others (see text below for detail). Global optimization method represented

by Genetic Algorithm is implemented for waveform modelling, MLTW inversion, and PGV-distance relation.

Intensive tools for constructing synthetic seismograms and waveform modelling are provided. The Generalized Ray Theory (GRT) and Discrete Wave Number (DWN) methods are available in ***Sgraph*** in a simple way. The waveform modeling process is performed in ***Sgraph*** through many advanced tools such as, Genetic Algorithm (GA), ***GRT, Navigation, Comparison,*** and others.

Phase identification tools are also included in special routines like ***Insert phase, Search phase, Compare phases*** and others. Comprehensive tools for manual and Auto phase picking are provided.

The earthquake hypocentral location tool is newly inserted in this version. The picking tool and the station info provide the required information to accomplish a complete hypocentral location procedure by using the ***hypoinv2000*** code that is directly linked with ***Sgraph***. A ***GMT*** (Generic Map Tools) script available and automatically executed to generate a PS plot of the hypocentral map with the event location and its information (The GMT package should be installed for the mapping tools).

Restricted versions of ***Sgraph*** provides some advanced techniques not available in the free versions, those techniques are, the ASPO technique for focal mechanism estimation; spectral and inversion method for Site effect estimation; The Multiple Lag Time Window (MLTW) technique and Q-coda method for attenuation study. All those techniques are discussed in detail in this manual.

One important feature of ***Sgraph*** is the variety of the output data type. S***graph*** maintains the 'Saving' of the analysed waveforms in many ways. The whole analysed traces can be either saved in one compressed binary file "***SAN***" (**S**eismic **AN**alysis file) to be used later; or saved individually in one- or two-column *ASCII* data files to be plotted in other plotting programs; or it can be saved in ***SAC*** format to be read by "***SAC"*** program (Seismic Analysis Code) for further analysis. Saving data as GSE (INT and CM6) and WAV formats are also included. An audio (WAV) copy of the recorded traces can also be obtained.

In general, ***Sgraph*** consists of useful tools to perform successful researches in waveform analysis. Some parts look like the "***SAC***" program (William, et al. 1990), other parts like "***Pitsa***" (Franck and James, 1992). However, the integration of all the principle tools with the ***Sgraph*** tools makes ***Sgraph*** special. Many parts of this code are

taken from different sources like Numerical recipes, Seismic Analysis Code (SAC), ***Seisan*** code, and some others.

Zooming, Navigation and Picking tools are modified in this version for a better usage of mouse and keyboard control.

How to install:

The installation disk consists of the ***Sgraph*** setup file necessary to install the ***Sgraph*** package in your system. For the location purpose, the ***GMT*** package and ***PostScript*** viewer are included as well. The user has to install them individually if it doesn't installed in the System.

To install ***Sgraph*** package, do the following:

- Launch the installation file: Sgraph_setup.exe
- Follow the setup procedures to save the application in the desired location.

N.B. This version is only valid for the win32 windows systems platform. (Win95, Win98, Win98SE, Win2000, WinXp, Vista).

Program arguments:

***Sgraph* can read file names of different formats by passing through arguments.**

Using the console window, or Windows Commander, a file can be opened by *Sgraph* directly by typing its name after the *Sgraph* launching command.

- From the ***Sgraph*** working folder, type "Sgraph" following by space following by the filename(s) to open.
- The file could be of any type. ***Sgraph****,* in this version, automatically detects the type of file and open it by the appropriate way.

EX: To open the file "green.sac" by Sgraph.
Simply type: " Sgraph green.sac "

The description of the different file formats supported by ***Sgraph*** will be discussed in the next sections.

Because the ***Sgraph*** supports a wide range of file types, it is convenient to associate the different file extensions to ***Sgraph***. This can be done using the windows explorer folder option or the windows commander (see the OS helping manual for how to do). Use icons provided by ***Sgraph*** for the corresponding data formats, this makes it easier to distinguish the different data formats from among the variety of files in the working folder. Once this is done, the specified files can be opened directly by ***Sgraph*** by double click on it.

N.B. Every time a file is opened this way, a new Sgraph program will be launched. This will exhaust the computer memory. It is recommended to close the old Sgraph before open another file.

File opening and filters

Multifile opening: ***Sgraph*** gives the ability to open multiple files simultaneously. Selection is done following windows way. Up to 200 files can be selected at once. *Sgraph* will ask for the required parameters file by file.

Filter specification: From the filter box, a specific file terminals (wildcard) can be requested (e.g. *.uer,*.001, etc...). This is useful for reading a specific file types among a big number of files.

File acceptance

For managing the Computer memory, *Sgraph* has two types of memory storage; a temporary storage for the files just being read and locatable storage for the accepted files.

For files just being read or being processed a dialog asking for (***Add, Replace, Repeat, Ignore***) is appeared for managing traces (See the next figure).

Figure 1: Process/trace Accept dialog box

The "***All***" check box controls the multitrace entry. If checked, the selected value (or process) will be applied to all coming traces (e.g. Add all, Replace all, Ignore all). To add a specific window only use zoom button. See the next table.

The button 'Put in Memory' serves to add the current trace in a temporary memory (Buffer) to be used for further analysis. The idea of this buffer is to use the current trace in another tools on air, or without put it in the main memory. It is important to say that this buffer stores only one trace. The user has not to use it for routine that requires multiple traces. Moreover, the user have to finish work with the trace in memory before opening a trace from disk or do a single trace selection ***(Sgraph*** buffer is used internally for memory management). To continue work with the trace in memory, select ***Memory*** button from the select trace dialog (see the section of single trace selection below).

	All (Checked)	**All (not Checked)**
Add	Add all traces	Ask again for the coming traces
Replace	Replace all traces (this will delete all the old traces)	Ask again for the coming traces
Ignore	Ignore all traces (this will ignore all the coming traces in operation)	Ask again for the coming traces
Repeat	……..	If during reading file: Open a new file. If during a procedure: Repeat the procedure.
Put in memory	Put the current trace in temporary memory (not added to work screen). The user can apply any of the Sgraph tools on it before add it to the permanent memory.	
In case the Replace button in clicked the following check boxes are taken into consideration : ✧ **Replace plot : Force the replacement of all the current traces = delete all before open** ✧ **Replace trace: Normal case, replace the current trace.**		

✧ **Custom replace: Force to replace a customized trace.**

Data insertion

For the interaction between "user" and *Sgraph*, a dialog box is used. This dialog is the main way to insert the required parameters needing for the requesting process.

The insertion of data has different types; single value entry, and multiple values entry. For that, specific typing rules are used.

Typing rules:

1- ***For one value data: Value should be a number (real or integer). Any character is not permitted.***
2- ***For multiple value data: Values should be numbers separated by spaces or comas.***
3- ***Some tools require mathematical operators; only (+,-,*,/,^) are permitted (Spaces are not permitted with this).***
4- ***If asking for trace indices, values should be within the plotted trace range.***
5- ***For range of data: Type the two data limits separated by ':'.***

EX: [1:10] = from 1 to 10.

6- ***For selecting all traces: Type '0'. This is a special request when asking for applying the process on all traces. For example when delete, [0] means, delete all. (Notice, this is applied only when asked about trace indices).***
7- ***No parentheses or spaces with separators are permitted.***

N.B. The permitted separator characters are [+-/^ :,].*

For bad typing, an error message will appear.

Trace Selection

Because of the different tools included in ***Sgraph***, some of these tools are applied to a single trace, other tools are applied to multitraces and others can be applied to both cases. For that, the trace selection will differs from a tool to another. ***Sgraph*** uses two dialogs to receive trace selection.

Single trace selection:

Select a single trace from the box given in the following dialog box.

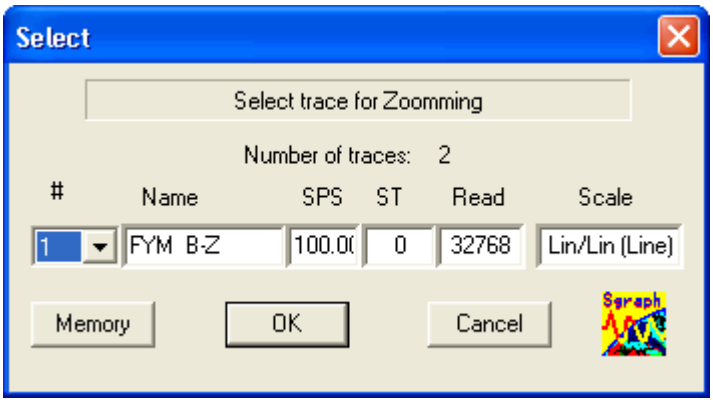


Figure 2: Single trace selection dialog box

the *Memory* button serves to select the trace that was stored in temporary memory instead of the conventional traces in the working memory. To store trace in memory, see the above 'Add trace' section.

Multiple trace selection:

This is similar to the data insertion dialog but instead it deals with trace indices. This also accepts (0) as select all traces.

Menu

These are the complete functions and tools included in *Sgraph*. These tools can not be accessed from other place instead of the main menu (In this version). Here we will describe the different tools and techniques provided in the form of 'Menu' and 'How to do'.

1 File

1.1 Load:

Function: Load the previously saved ***SAN*** file (**S**eismic **AN**alysis file).

It is a specific binary file written by ***Sgraph***. It consists of the complete information of the traces previously saved. (i.e., number of points, sampling rate, scales, trace names, data limits, azimuth, distance, etc.). Single event or multiples of events might be saved as SAN file. This is useful for saving the processed data for further analysis. See the *Save* menu for how to save a SAN file.

Select as much SAN files as required, then the following dialog box will appear listing event names and the corresponding stations existing in the selected files. Use the station name wildcard and component check boxes to retrieve specific station names and components.

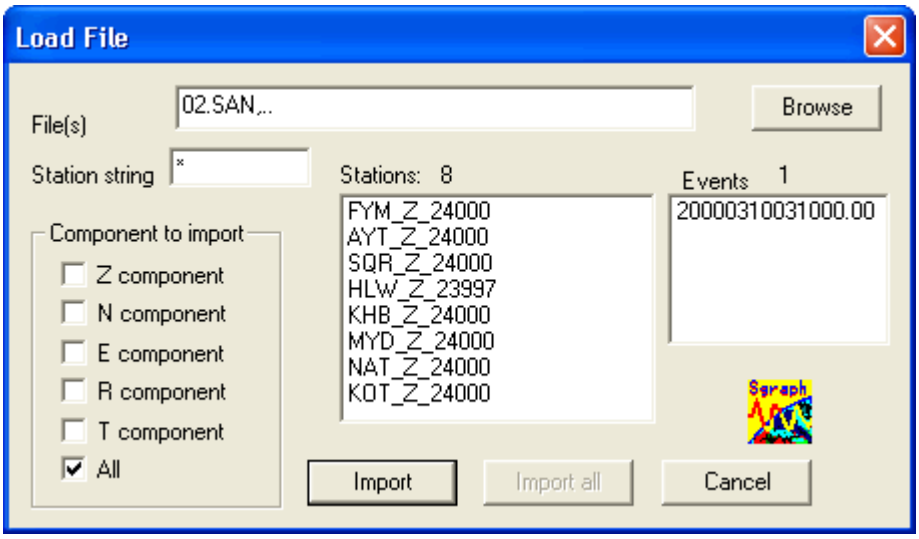


Figure 3: A typical dialog box to retrieve the data from SAN file(s).

1.2 New:

Function: Open the different formats of data from a specific folder to be plotted and analyzed. This is the main routine to open all types of data supported by Sgraph.

1.2.1 Data format

Sgraph supports different types of data formats. For a better performance, it is recommended to select the type of the data going to be opened using the following Data format dialog box.

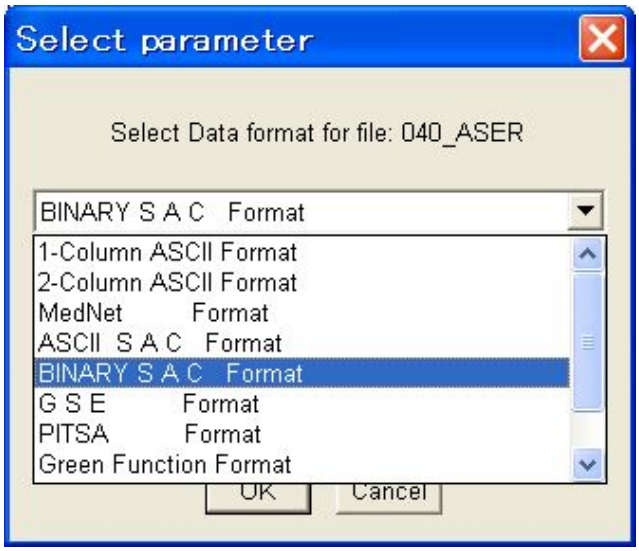


Figure 4: A typical dialog box to select the data format.

The different data formats available in ***Sgraph*** are listed in the dialog box and described as follows:

- ***One- Column/auto ASCII format:***

  This format type is used to open an unknown data or a 1-Column data file representing the amplitude value of the record.

  This could be of three types:

  1. Sgraph 3.0 Y-format. In which complete data information is saved as header preceding a 1-column ASCII data. This is a pre-saved file

by ***Sgraph***. It is automatically identified once open the file by any ASCII type.

2. Any 1-Column data file with or without header. The header will be automatically skipped by ***Sgraph***. The value read represents the Y-Axis or amplitude value of the trace. Time axis is calculated according to the sampling rate inserted by the user in the info dialog box during the file opening.
3. Unknown ASCII files of single or multi-columns. If multi-column data, a special dialog box will appear to show a part of data and to specify the columns corresponding to X and Y axis. The typical multicolumn dialog box is shown below. (Notice, multicolumn data should be only numbers).

- ***Two-Column/auto ASCII format:***

This format type used to open an unknown data or a 2-Column data file.
This could be of three types:

1. Sgraph 3.0 XY-format. In which complete data information is saved as header preceding a 2-column ASCII data. This is a pre-saved file by ***Sgraph***. It is automatically identified once opened by any ASCII type format.
2. Any 2-Column data file with or without header. The header will be automatically skipped by ***Sgraph***. The value read represents the time and amplitude values of the trace. The sampling rate is automatically calculated from the data and assigned to the trace. No need for any additional information corresponding to the trace of this type.
3. Unknown ASCII files of single or multi-columns. Same as the above one-column data format.

- ***Mednet Format:***

To force the program to read a MedNet Very Broadband seismic network format. It is an ASCII file consisting of a header and 8 column data. The program extracts all the required information from the header.

- ***SAC ASCII format:***

To open an SAC ASCII data format. The file could be pre-saved by ***SAC*** program or any ASCII SAC format in UNIX or PC environment. The program extracts all the required information from the SAC headers.

- ***SAC Binary format:***

To open a SAC Binary format. The file could be pre-saved by SAC program or any Binary SAC format in UNIX or PC environment. ***Sgraph*** can save a Binary SAC file format to be read directly by SAC program. It is important to notice that ***Sgraph*** saves all information related to the analysed trace in the SAC headers including the Picked Phases (the first 9 phases), event name, origin time, Magnitude, Moment, etc. Some of this information can not be read by SAC program because it is stored in some of the "USER" headers. This newly stored information can be read only by ***Sgraph***.

- ***GSE format:***

To open a **Global Seismic Exchange (GSE)** file format in either INT or CM6 formats. If not known, the program detects the format automatically. ***Sgraph*** extracts all the required information from the GSE header. See appendices 7, 8 for the description of GSE format.

- ***Y-format (nanometrics):***

To open Y-format data. This format provided by "Nanometrics" and used by the Egyptian National Seismological Network (ENSN) as the storing format. ***Sgraph*** can open Y-format data of ASCII type directly and plot all the file if it did not exceed the maximum point allowed. The Y-format file of Binary type is converted first into ASCII type by using the "Y5dump" code necessary for this case (this is done internally). The program extracts all the required information from the header.

Note: Make sure that the "Y5dump" code and its "lib,dll's " files exist is the folder ("*installing folder*"¥bin¥). This is done automatically when install ***Sgraph*** in the proper way (See above how to install ***Sgraph***).

- ***PITSA format:***

To open a PITSA file format. This format is Pitsa specific format in which data is stored in 1-column ASCII data preceding by headers corresponding to the trace start date, Sampling rate, Number of points, etc. This format is automatically recognized by Sgraph. The program extracts all the required information from the header.

- ***Green Function format:***

To open a pre-saved Green function file. This is a ***Sgraph*** specific format generated from the GRT tool. (See Appendix 4 for detail). ***Sgraph*** gives the

green's function dialog needed for the insertion of the synthetic seismogram parameters.

- ***Focal mechanism Plot:***

To plot a pre-saved Focal mechanism file. This is a ***Sgraph*** specific format generated from the Mecha tools..

Table summarizing the different data format supported by ***Sgraph:***

#	Data Format	Description
1	**1- Column/auto ASCII**	Unknown or a 1-column data file represents the amplitude value of the record.
2	**2- Column/auto ASCII**	Unknown or a 2-column data file. The first column is the time and the second column is the amplitude. Sampling rate is automatically calculated.
3	**MedNet**	The MedNet Very Broadband seismic network format. It is an ASCII file consists of a header and 8 column data. The program extracts all information needing from the header.
4	**SAC ASCII**	The SAC ASCII format. No need to insert any information.
5	**SAC BINARY**	The SAC BINARY format, No need to insert any information.
6	**GSE**	GSE format either INT or CM6. The program detects the format automatically.
7	**Y-format (Nanometrics)**	Y-format from Nanometrics either Binary or ASCII type.
8	**PITSA**	PITSA format. The program detects the format automatically.
9	**Green Function**	The generalized ray theory green's function format. (See Appendix 3 for detail).
10	**Focal mechanism Plot**	A specific focal mechanism text format. This is Sgraph pre-saved file. It represent the stereographic projection of a given strike, dip and slip of fault planes. Many planes can be presented simultaneously and can be plotted in any plotting software as discontinuous X,Y data. See Focal mechanism section for detail.

1.2.2 Multi-column Data dialog box:

The multi-column data requires a special way to manipulate the data columns and to specify the columns to plot. This is done by using following dialog box:

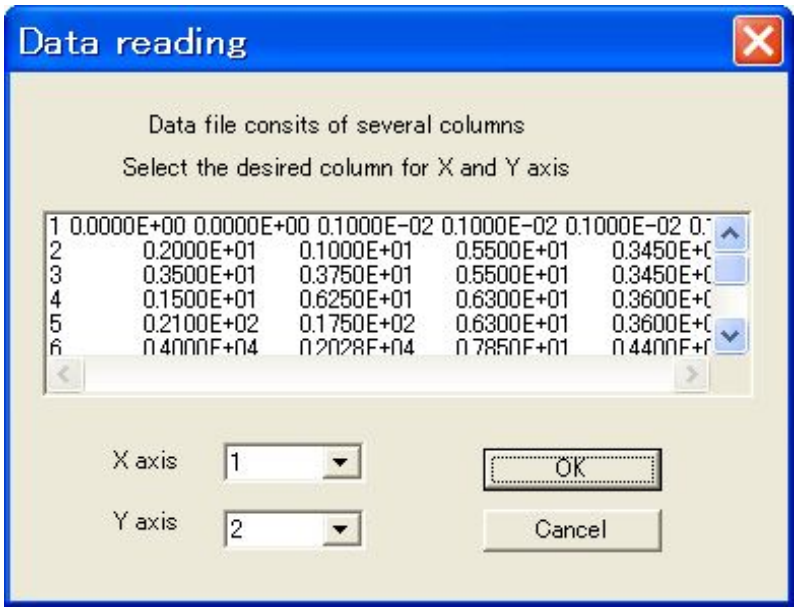


Figure 5: Typical multicolumn data reading dialog box.

The dialog exhibits a sample of the data read and receives the X-Axis and Y-Axis data through the corresponding boxes.

- **Insert the column where to read the X-axis data**: Select the column number of X-axis. Select "Construct" to generate the X-axis from the sampling rate value entered in the info box.
- **Insert the column where to read the Y-axis data:** Select the column number of Y-axis. Select "All" to read all columns in trace/column way.

Headers and uneven row formats will be skipped in the beginning of file. The program checks the validity of data line by line and decides the number of columns in the file and read them accordingly and associates every trace with its corresponding column. The program stops reading when a change in data format occurs or characters found among the data.

1.2.3 Data information:

If the data being read is of ASCII format type (except *the Sgraph X and XY* format) additional information needed to be inserted to plot the trace(s) correctly. This information is inserted through the *Info* dialog box. Particularly, in the case of the one-column ASCII data format without header, it is required to insert the

sampling rate of the trace being read (Default is 100 samples per sec). Sometimes, it is necessary to skip some points (*Nskip*) from the beginning of file or read a specific number of points (*Nread*). The *Nskip* and *Nread* and many other information related to station or event can be inserted through the *Info* dialog box.

Info dialog box:

This dialog is the main dialog box for viewing and receiving data information of the file opened or being opened (for ASCII format only). It shows the total number of traces already plotted and their information stored in memory. The following is the typical Info dialog box.

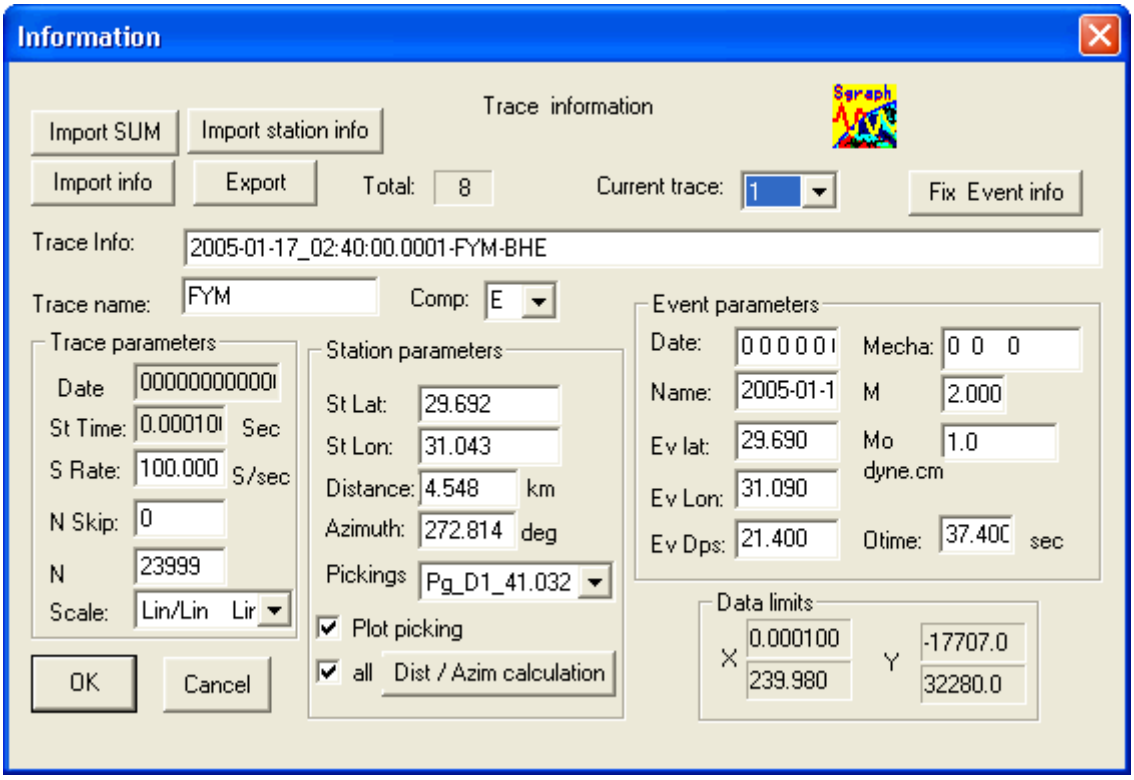


Figure 6: Typical trace information dialog box.

The parameters shown in the dialog are described in the following table:

Parameter		Description	Remark
Main	**Trace Info**	A text describing the current trace.	- Optional, - Showed at the topmost part of each trace if "***Display info***" is checked in ***Setup***. - Default Info is extracted automatically from data file - Useful for giving detail information of the trace.
	Trace	Trace name	- It represents the station name/component or filename

	name		(Optional). - Shown at the rightmost part of each trace. - Extracted automatically from data file if exist. Otherwise, filename is used - Used in sorting and save traces.
	trace date	Starting date of the current trace.	- String describing the trace starting year, month, day, hour, min - Extracted automatically from data file.
Trace parameters	**St Time**	Starting time of the trace (sec).	- Starting time in second - Extracted automatically from data format.
	S Rate	Sampling rate of the trace in sample/sec	- Default =100 s/sec. - Required only in the case of Y- format. In other data format, it is automatically selected.
	N Skip	Number of points to skip (NSKIP)	- Default =0. - Number of lines to be skipped from the file being read. It has no effect on traces already plotted. - This is useful for skipping the header in the X and X-Y formats.
	N Read	Number of points to read (NRead).	- Default=0 (read all). - Number of points to read from the file after NSKIP. The program ignore any points exist in the file after "NRead", and read the available points if less than "NRead".
	Scale	Scale of the X-axis	- Scale of the current trace - Available scales are : Log-Log, Lin-Lin, Log-Lin, Lin-Log, Lin-Lin
Station parameters	**St Lat**	Station latitude (degree)	- Extracted automatically from data file if exists.
	St Lon	Station longitude (degree)	- Extracted automatically from data file it exists.
	Distance	Epicentral distance	- Default=0 - Used for record section plotting and sorting traces. - Extracted automatically from data file if exists. - Distances are in km as default as long as range is less than 1000 km. Otherwise, distance on Degree.
	Azimuth	Azimuth to the station (in degree)	- Default =0 - Used for record section plotting. - Extracted automatically in SAC format
	Pickings	Picking arrival times (sec)	- The list box given consists of 99 different arrival times picked from the given trace. - In case of SAC format only 10 phases are read from the (T0-T9) User-defined time pick in the SAC headers. During save in SAC format, selection of only 10 phases is allowed.
Event parameters	**Name**	Origin date of the current event.	- Optional - Extracted automatically from data file if exists.
	Event date	Origin date of the current event.	- String describing the event date (Optional). - Extracted automatically from data file; SUM file or after location procedure.
	EV Lat	Event latitude (degree)	- Extracted from data file; SUM file or after location procedure.
	EV Long	Event Longitude (degree)	- Extracted from data file; SUM file or after location procedure.
	EV Dps	Event depth (km)	- Extracted from data file; SUM file or after location procedure.
	Otime	Event origin time (sec)	- Extracted from data file; SUM file or after location

			procedure.
	Magnitude	Event Magnitude	- Extracted from data file or SUM file if exists
	Moment	Event Moment (N.m)	- Extracted from data file or from internal estimation
	Mechanism	Event Strike Dip, slip (^{0})	- Extracted from data file or from internal mechanism estimation
	Fix event info	Flag for fixing the entire event information of all traces to the current one.	- Click to fix event information of all the entire traces to the current trace.
Data limits	**X**	Minimum and Maximum values of time Axis (sec)	- It is automatically selected and can not be changed in the current version.
	Y	Minimum and Maximum values of Y Axis.	- It is automatically selected and can not be changed in the current version.

Remarks

- For displaying or changing the information of the given trace, switch on to its index from the combo box (Marked in Blue).
- Mostly of the parameters given in the *Info dialog* box can be changed in any time during the ***Sgraph*** job.
- When changing any parameter, the information will be automatically updated into memory. "***Update***" button is not currently used.
- '***Export SUM'*** button is used to save all the info parameters of the traces currently in memory.
- '***Import SUM***' button is used to import event information corresponding to a set of traces. The user will be prompted to type the desired trace(s) and the corresponding SUM file.
- '***Import Info***' button is used to import a pre-exported event information corresponding to a set of traces.
- The distance and azimuth value can be either calculated from the existing locations of the station and event by pressing the "Dist/Azim calculation" button, or imported from an external (INFO) file by using the "***Import***" button. An example of the info file is as follow:

Info file example

```
N.TKHH     0.000     0.000   146.441   352.825
 N.OBMH     0.000     0.000   141.616     1.392
 N.FKCH     0.000     0.000   135.301   338.271
 N.KIDH     0.000     0.000   142.998    30.010
 N.SNTH     0.000     0.000   142.465   330.117
 N.MYMH     0.000     0.000   121.171   354.323
 N.OTUH     0.000     0.000   119.552     8.210
 N.TAGH     0.000     0.000   132.605    27.671
```

The data descriptions of the info file in sequence are: Trace name, not used, not used, distance (km), azimuth (degree).

1.2.4 Green's Function dialog box

For the green function format, the following dialog box will appear for the insertion of the synthetic parameters required for plotting the synthetic seismograms. This dialog box is used also for the *EMPIRE* tool to construct the empirical green's function synthetics (See *EMPIRE* section for more detail).

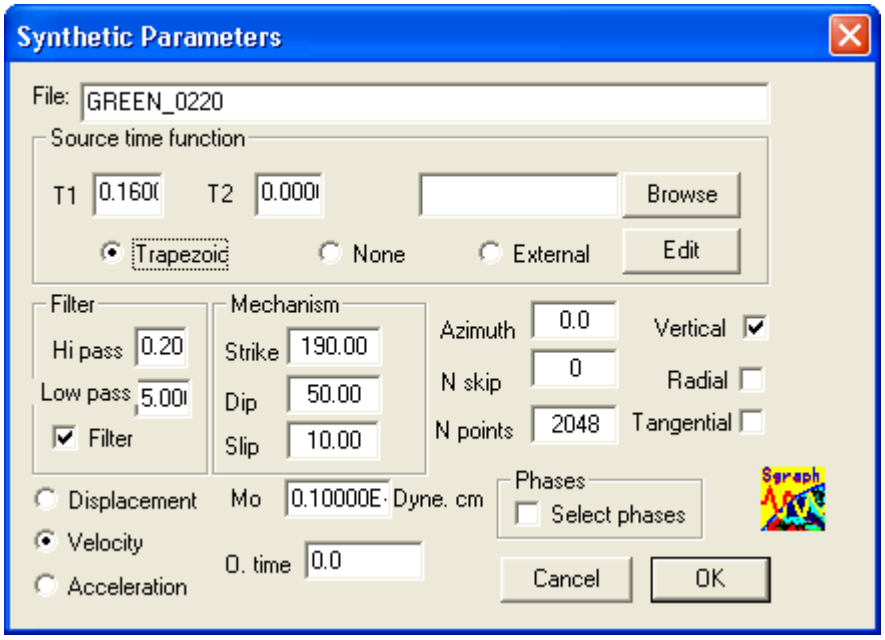


Figure 7: Typical Green's function dialog box.

These parameters are as follows:

Parameter	Description	Remark
Mechanism	Strike, Dip, Slip values and seismic moment	Focal mechanism: strike, dip and slip angles in degree and seismic moment in dyne.cm/10^{20}.
Source time function (STF)	**Trapezoid** : Trapezoid of T1, T2 parameters will be constructed and Convolved with synthetics **None**: No source time function will be convolved **External :** Browse to a file containing the customized source time function	T1=Rise time T2=Duration If T2 is (0) the resulting is a triangle pulse of T1 duration. -External STF is a 2-column ASCII file similar to that constructed by ***test signal*** tools.
Filter	Band path filter parameters Hi= Hi cut frequency Low= Low cut frequency	Unchecked the Filter check box for not using filter.
Azimuth	Azimuth to the station in degree.	
Nskip	Number of points to skip from green's	

	file.	
Npoints	Number of points to read from green's file.	Default = all. If Zero, the maximum of allowed number will be read.
Components to construct	Check Vertical, Radial or Tangential component to construct.	At least 1 component should be checked
Select Phases	Select/don't select phases from the ray file.	If checked: Gives ability to select phases from the predefined phases in the ray file used in GRT.

- Repeat the process with different parameters until getting accepted result.

Sgraph supports only 99 phases per trace. In case of GRT synthetic seismograms, this number is much exceeded. For that reason it is necessary to select some important phases among the entire phases.

If "*Select phases*" is checked, the following dialog will help for this purpose

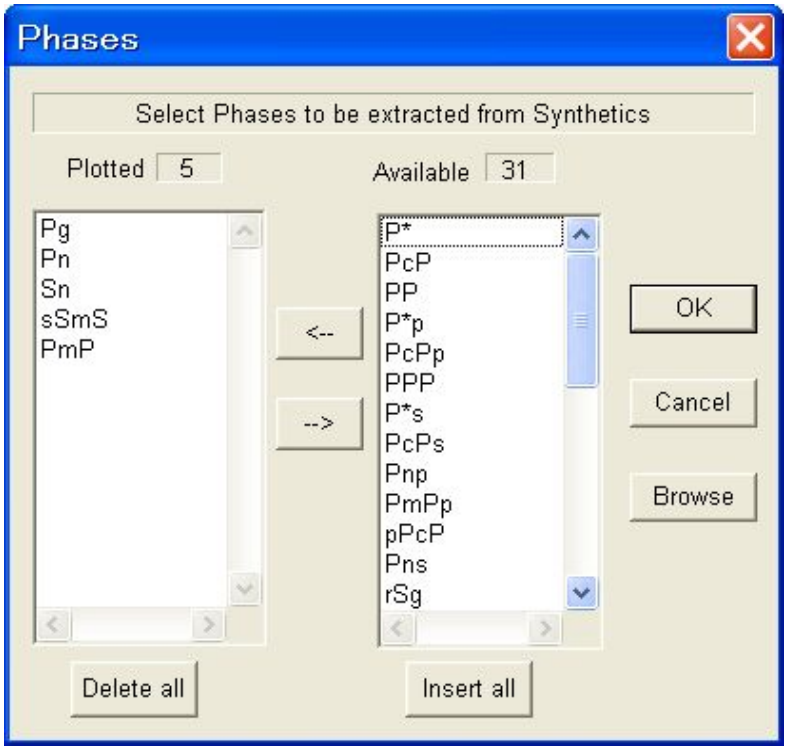


Figure 8: Typical Phase selection dialog box.

In the above dialog box, all phases pre-assigned in the ray file are listed in the "***Available***" box. (See appendix 3 for more detail).

To select the desired phases to be used in ***Sgraph*** do the following:

- Select the phase(s) from the "Available box"(by Marking or extend marking the desired phases).
- Click the ← button to transfer the selected phases to the "Plotted box" to be considered in ***Sgraph*** processes. To insert all, press "***Insert all***" button. It one phase is selected, double click on the phase to select.
- To remove phase(s) from the Plotted box, Mark them and click the → button. To delete all, press "***Delete all***" button.

See the modeling section for more detail on the usage of synthetic phases.

1.3 Open station

Function: Open trace(s) of a specific station name and/or component from a set of selected files from disk.

This is used to open a large number of files from successive folder in one step. This is done by using the following dialog box.

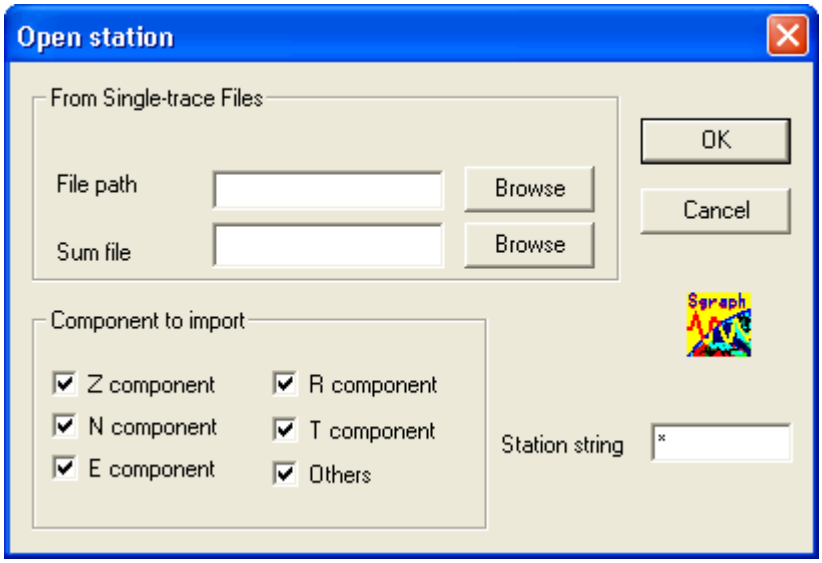


Figure 9: Typical open station dialog box.

It is considered that the data are stored into folders. Every folder corresponds to specific event. Browse the root of the single trace data files (SAC, ASCII, Y,..etc) from the file path box. Browse the corresponding Sum files path from the sum file box. The sum files path consists of the summary file of all the data The sum file name should be the same as the data folder name. Specify the component and the station string to import. After importing all the traces, check the info dialog box to make sure the event information are correctly imported form the sum files.

This tool is important for the site response study by inspecting the common station different events traces.

1.4 Delete

Function: Delete a specific trace(s) from the working window.

Insert the corresponding trace indices separated by space or coma. (Index is written in the rightmost side of the trace) or insert (0) to delete all traces. A confirmation dialog will ask to confirm the deletion of traces.

N.B.

- A*fter the trace deletion is confirmed, it cannot be recovered again.*
- After the trace deletion, the indices of the next traces will be changed. So, when you assign traces to be deleted, delete it at once otherwise you should assign traces again.

1.5 Info

Function: Display or change trace(s) information.

Select the desired trace using the combo given. The Information will be updated when changing the trace index listed in the Combo box. (See the ***Info dialog*** section for more details)**.**

1.6 Edit Data

Function: Edit data file using *Notepad.*

Open any data file using the windows Notepad to be edited or checked.

Select the desired file name and edit in the opened "***Notepad"*** window then save the file and close "***Notepad***". Notice, only Notepad is available for the data editing in ***Sgraph***. It is recommended to edit the large-sized files by an external editor.

1.7 Setup

Function: Change the *Sgraph* plotting setting like colors, graph options and file naming method.

Changing is held through the following dialog:

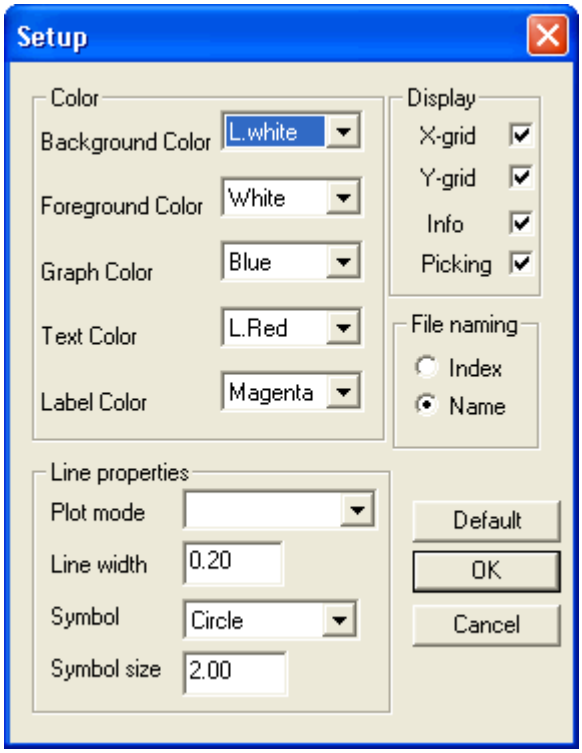


Figure 10: Typical Setup dialog box.

Setup parameters

- **Colors**: Background, foreground, Graph, Text and Label colors.

- **Display**: Switch on/off plotting the X-grid, Y-grid lines, Info and phase pickings.
- **File naming**: File naming method in the case of multi trace saving in SAC and ASCII formats.

  - When saving multiple of files in SAC or ASCII format, file names is taken either related to index value (e.g. ***.001, ***001.SAC.. etc) or from the trace name.(e.g. ABC.001, ABC.SAC).
  - Default is Name method.

  The naming technique is shown in the following table.

Naming method	Index	Name
ASCII Formats	ABC.001, ABC.002, …etc	ABC***.001, ABC***.002, etc.
SAC Format	ABC001.SAC, ABC.002.SAC, …etc	ABC***.SAC, ABC***.SAC …etc.
GSE Format	ABC001-INT.GSE (for GSE INT)	ABC***-INT.GSE
	ABC001-CM6.GSE (for GSE CM6)	ABC***-CM6.GSE

Where, ABC: File name inserted in the ***Save file*** dialog (constant for all files)
***: trace(s) name
001: Trace index.

Sgraph displays the new setting after closing the *Setup* dialog box. A confirmation dialog box will ask for save the new setting. The setting will be saved in an ASCII file named **'SGRAPH.SET'**. ***Sgraph*** searches for this file when start up. If not found, the default setting will be used.

N.B.:. The default and the user defined magnitude formula coefficient are saved in this file once the magnitude tool is called.

Example of a typical 'Sgraph.set' file

```
SGRAPH CONFIGURATION FILE
15    BACKCOLOR
 7    FOREGROUND COLOR
 1    GRAPHIC COLOR
12    TEXT COLOR
 5    LABEL COLOR
 0    Plot mode
 0.20  Line width
```

```
 7      Symbol
 2.00    Symbol size
    T   X GRID LINES
    T   Y GRID LINES
    T   DISPLAY INFO
    F   INDEX NAMING
    T   PLOT PICKING
MAGNUTIDE
 2
  0.833000  0.000740  1.260000  ML=Log(A)+0.833Log(r)+0.00074*
  0.700000  0.000400  1.400000  ML(QQ)
```

1.8 PS preferences.

***Sgraph* uses a facility to convert the screen plot into a Post Script file. *PS preferences* dialog box receives the Post Script plotting parameters.**

The plotting parameters in the PS file can be same as the ***Sgraph*** plotting parameters defining in "***Setup***" (Default) or can be customized.

The following dialog defines the PS plotting parameters.

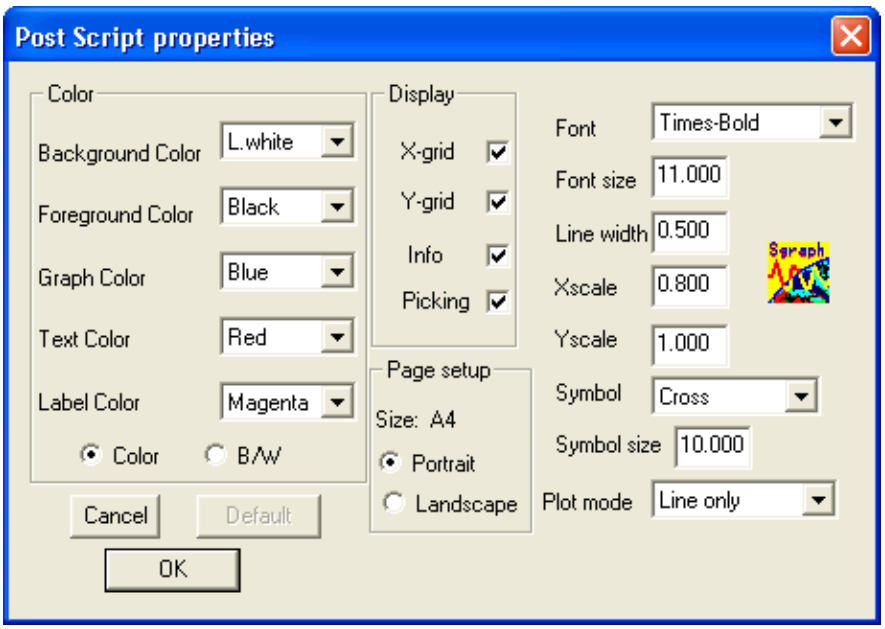


Figure 11: Typical Post script properties dialog box.

- The page size is only A4 in this version. Portrait and landscape modes are allowed.
- Text fonts and symbols can be chosen for a better plot. Plot mode can be line without symbol, symbol without line or both.
- Plot can be coloured or Black and white plot.

The PS file is available for a single trace, multi traces or a record section trace. The single/multi trace PS plot can be done using the ***Save as PS*** menu discussed below. The record section PS plot can be done using the ***Record section dialog*** discussed later.

1.9 Save data:

Tools for saving the current traces in different formats. For all data format, insert the trace index to save and the output data format.

Insert a file name (without extension) in the save file dialog box. Null file is accepted to have a full automatic file naming.

Save data formats allowed in ***Sgraph*** are as follow:

1.9.1 Save One-Column ASCII data (Sgraph 3.0 Y-format)

Function: Save the selected traces as 1-Column ASCII format preceding by set of headers. This is a specific format of ***Sgraph*** called "*Sgraph 3.0 Y-format*". It consists of headers combining all information related to the saved file including the phase pickings; station and event information (See appendix 4 for the description of this format). The file can be easily edited or plotted in other drawing software.
Traces are saved in separate files named according to the naming method discussed in the setup section.

1.9.2 Save Two-Column ASCII data (Sgraph 3.0 XY-format)

Function: Save the selected traces as 2-Column ASCII format preceding by set of headers. This is a specific format of ***Sgraph*** called

"*Sgraph 3.0 XY-format*". It consists of headers combining all information related to the saved file including the phase pickings; station and event information. See appendix 4 for the description of this format. The file can be easily edited or plotted in other drawing software.

Traces will saved in separate files named according to the naming method discussed in the setup section.

1.9.3 Save Binary SAC format

Function: Save the selected traces in Binary SAC format.

A full header SAC file will be written for the selected trace(s) including all trace, station and event information. All information will be saved in the corresponding header. Magnitude and Seismic moment are saved in USER0 and USER1, respectively. Phases picking are stored in the corresponding 9 SAC headers.

Traces will be saved in separate files named according to the naming method discussed in the setup section.

N.B. Only the first 9 phases are saved, other phases will be omitted. The focal mechanism values will be lost when saving trace in SAC format.

1.9.4 Save SAN Format (Seismic ANalysis format)

Function: Save the entire set of traces in a Binary file including all traces information. This a special format for ***Sgraph*** in which a compressed Binary file is constructed to combine the entire set of traces in one file. To save a SAN file, insert the desired trace(s) to save and the SAN file name.

The saved SAN file can be opened by the ***Load*** menu discussed above.

1.9.5 Save GSE (INT) and (CM6) format

Function: Save the selected traces as a Global Seismic Exchange (GSE) format either uncompressed integer data (INT) or compressed (CM6) data. Station and event information will be saved in the GSE header.

Traces are saved in separate files named according to the naming method discussed in the setup section.

N.B. Some information relating to the trace(s) being saved will be missed when save data in this format. The GSE header can not support all the information exists in Sgraph as a result the excess information will be lost.

1.9.6 Save WAV format

Function: Save the selected traces as a WAV audio format that can be opened by any WAV player (i.e. Windows media player and Real player).

The seismic traces might be resampled for a higher sampling rate before waved as WAV file to simulate the audio frequency.

1.10 Save as BMP

Function: Save the working window as a Bitmap image (BMP).
This menu makes a BMP file for the traces being displayed in Sgraph window. Insertion of the BMP file name is only required. To save a specific graph type or trace(s) use the graph tools (e.g., *redraw*, *Draw Spec, multitrace*, etc..) before save BMP. (See the *Graph* menu for details of this menu).

1.11 Save as PS

Function: Save the selected traces as a Post Script file (EPS).
Similar to save data formats. ***Sgraph*** makes a PS version of the selected trace(s) in separate EPS files.

Once this menu is selected, the PS preferences dialog box will appear. Any of the PS parameters can be changed if needed.

- Insert the desired trace(s) index in the dialog box following the typing rule. The saved traces will be similar to those being plotted in ***Sgraph*** by ***Draw Spec*** menu.

- Insert a file name (without extension) in the ***Save file*** dialog box. The file name will have extension "EPS". No naming method is used in this case.
- To save a record section, use the Save PS button in the dialog box.

1.12 Print

Function: Print the working screen to the default printer.
The desired traces can be printed during ***Zoom***, ***Draw Spec***, ***Multitrace*** or ***Compare*** tools.

1.13 Quit

Function: Quit the program.
Save your work before quitting.

---

2. Routine tools

This menu consists of the principle waveform analysis tools. Refer to section 1 for the trace selection and the data entry of these tools.

2.1 Zoom

Function: Zoom in the selected trace.

How to do?

- The mouse is using to drag and stretch the trace to the desired window limits.
- ***Left-Click*** on the trace and move mouse to drag.
- ***CTRL+left-Click*** to stretch/destretch trace.
- ***Double-Click*** to reset the original trace limits.
- ***Right-Click*** to exit and confirm the current window limits.

N.B. Zooming routine can be applied in time domain and frequency domain traces as well, in the last case, it uses as a type of filtering

---

2.2 Tapering

Function: Apply Cosine tapering on the selected trace by using the following function:

$$Y(i) = TAP - TAP*COS(PI*(i-1)/N)$$

Insert 'TAP' value between 0 and 1

2.3 Fast Fourier

Function: Apply Fast Fourier Transformation (FFT) on the selected trace.

Number of points used must be of integer power of 2. If not, the least closely 2^n+1 value will be used.

N.B. This routine is only available for time domain traces.

2.4 Inv. Fourier

Function: Apply the Inverse Fast Fourier Transformation (IFFT) on the selected trace.

Convert the frequency domain trace into its corresponding time domain state. The number of points of the new trace will be twice the number previously used in the FFT.

N.B.

- *This routine is only available for Frequency domain traces*
- *Only FFT traces produced by **Sgraph** can be inverted into their time domain trace.*
- *The Inverse FFT can not recover FFT traces of the Saved San file or external FFT traces.*

2.5 Phase Trans.

Function: Transformation of the selected trace into its Phase domain trace. It is a simple conversion from the time domain trace into a phase domain trace. The phase domain is transformed by using the following formula:

$$P(f) = e^{\tan^{-1}(iY(f)/Y(f))}$$

2.6 Envelop Trans

Function: Transform the selected trace into its envelop. This is done by using the FFT transform of the selected trace after omitting the imaginary part. The envelope Env(t) of a given trace (y(t) can be calculated as:

$$Env(t) = IFFT(ABS(Y(f)/N/2))$$

Y(f) is the frequency domain of the given trace with null imaginary part.

2.7 Hilbert transform

Function: Do the Hilbert transform of a selected trace.

Insert the desired trace(s) index to be transformed

2.8 Integration

Function: Integrate the selected trace using Fast Fourier Transformation.

The FFT trace is divided by the angular frequency (ω) before re-transform again into time domain.

2.9 Differentiation

Function: Differentiate the selected trace using Fast Fourier Transformation. The FFT trace is multiplied by the angular frequency (ω) before re-transform again into time domain.

2.10 Rotation

Function: **Rotate the selected North and East components into Radial and Tangential components**.

The mathematical formulation of the rotation process is as follows:

$$R(t) = N(t) * Cos(\theta) + E(t) * Sin(\theta)$$
$$T(t) = N(t) * Sin(\theta) + E(t) * Cos(\theta)$$

Where, R(t) and T(t): the radial and tangential time series
N(t) and E(t): the north and east time series
θ: The rotation angle

How to do:

- Insert trace(s) index of the North, East components.

The Azimuth will be extracted from the "***Info***" buffer. Be sure that the azimuth value in ***Info*** is correct. If not, modify it manually.

Use " ***Ignore***", "***Add***" or "***Replace***" to treat the old traces.
EX: 1,2 = (North comp is trace 1, East is trace 2)

2.11 Add noise

Function: **Add a random noise to the selected trace.**

The noise signal is proposed to be the average of three types of sine waves with different frequencies and amplitudes (ref.). This can be represented as follows:

Y1 = a1* rand * Sin (F1)
Y2 = a2* rand * Sin (F2)
Y3= a3* rand * Sin (F3)

For a combination of these functions with randomly weighed amplitude the noise signal can be expressed follows:

Noise = (Y1 + Y2 + Y3)/3.

The default frequencies used for F1, F2 and F3 are 10.0, 2.0, 0.1 Hz, respectively. The amplitude of Y1 is less by 10 % from the others.

To add noise to any trace, select the appropriate frequencies and the S/N ratio. The resulted noisy trace will be given for the acceptance.

2.12 Plot Mecha

Function: Plot the focal mechanism stereographic projection of a given strike , dip and rake values.

How to do:

- Insert the strike, dip, rake values need to be plotted.

The lower hemi sphere stereographic projection plot will be shown on the screen. The two nodal planes are given with the azimuth and plunges of the P and T axis.

The file "Nodal.dat" will be generated directly after plotting the mechanism plot. To save the file as other name, type the new name in the dialog box given. The "Nodal.dat" file can be plotted directly as a Line plot in ***Grapher*** program (Golden Software).

The following figure is a typical Mecha plot of 45, 45 and 60, for strike, dip and rake, respectively.

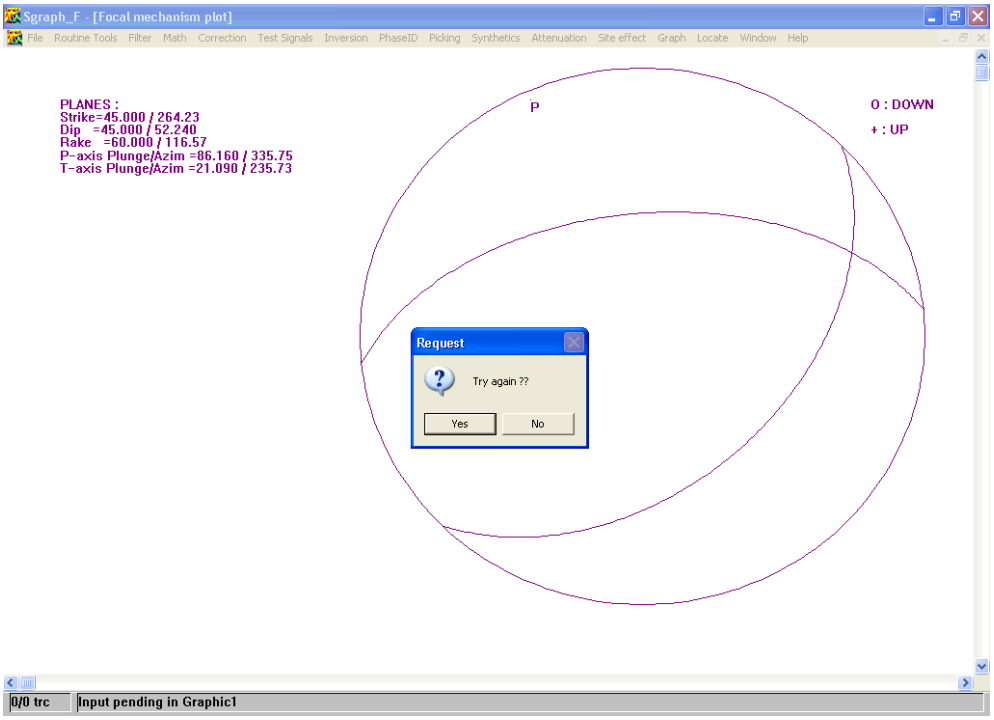


Figure 12: Typical Mecha plot dialog box.

2.13 Wadati diagram

Function: Plot the Wadati diagram of the selected traces.

What is Wadati diagram?

It is a relation between the S-P time and the P arrival time. The linear regression of this relation reveals the origin time and the (Vp/Vs) -1. The linear fitting of this relation is done by using the SVD inversion in ***Sgraph*** tools**.**

How to do:

- Select a set of traces of valid P and S phases.
- The corresponding S-P vs P relation is shown to be added or ignored.
- The linear regression of this plot will be automatically shown with the resulted O.T and VP/Vs with their corresponding rms, as shown in the next figure.

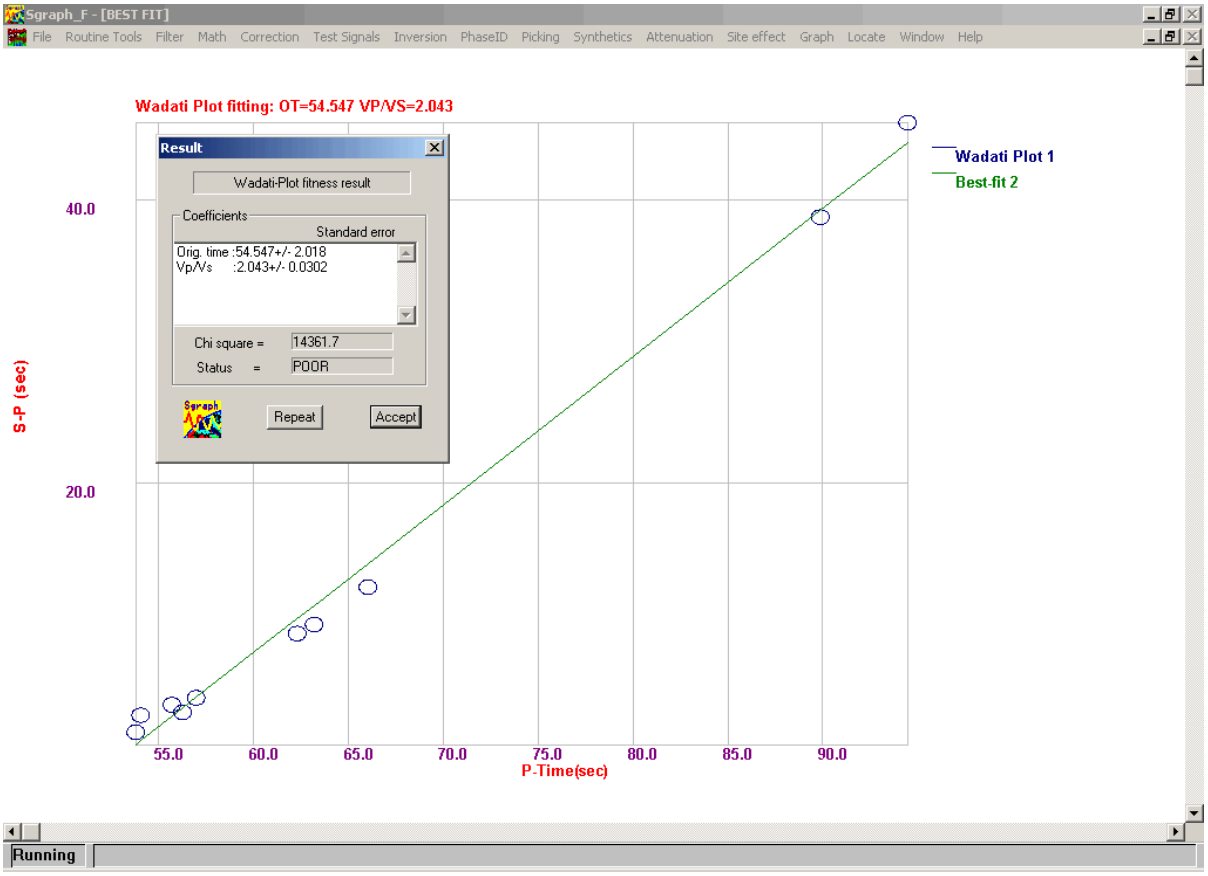


Figure 12: A typical screen-shot of the Wadati diagram linear regression dialog box.

The Wadati diagram plot can be manually inverted for the O.T and Vp/Vs parameters by using the inversion tool as shown bellow.

2.14 Magnitude

Function: **Estimate the trace magnitude of a given trace by picking up the maximum amplitude.**

In this tool, ***Sgraph*** is able to estimate the magnitude of a given trace by navigating and picking the maximum amplitude. The magnitude formula used in the calculation is initially set to the ML formula used in the Egyptian National Seismic Network (ENSN), which is as follows:

$$ML = Log\ (a) + 0.833\ log\ (R) + 0.00074$$

Where A is the peak to peak amplitude in meter measured from the simulated Wood-Anderson record, R is epicentral distance in Km .

To accomplish this condition, the Picking process is held after the instrumental correction and Wood Anderson simulation. This is internally done by default. The peak to peak amplitude in this process is stored in memory and in SAN file. It is also possible to pick the Peak to peak Wood Anderson amplitude by the Picking tool (see picking menu). All set of amplitude picking is used later in the location process to calculate the XMAG magnitude (See Hypoinv2000 documentation and the ***Location*** section in this manual).

How to do :

- Select the menu magnitude.
- Select the trace to calculate the magnitude from (either instrumentally corrected or not).
- Follow the Amplitude picking procedure, stretch, and drag trace until a clear view of the maximum amplitude then press R-click mouse button. Once you got the cross cursor, press two successive L-click mouse button for the two peaks of the maximum amplitude. Confirm the selection by answering the given message.
- The following dialog will appear:

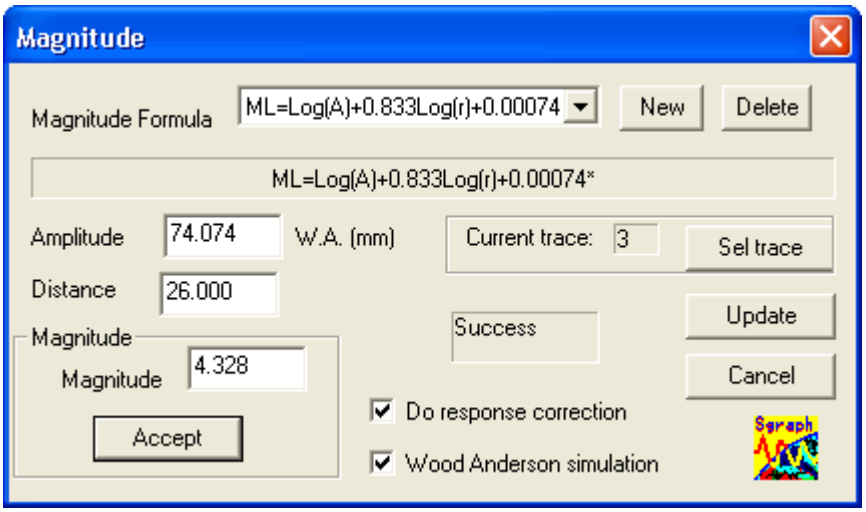


Figure 13:Typical Magnitude estimation dialog box.

- The traces amplitude and the trace distance will be written in the corresponding box. The resulted magnitude value of the default formula will be given in the Magnitude box.
- Change the magnitude formula if needed.
- To retrace amplitude, press '*Amplitude*' button.
- To accept the resulted magnitude and store it into Info buffer, press 'Accept' button.
- If it is not required to correct the instrument and/or simulate to Wood Anderson, uncheck the corresponding boxes and retrace amplitude.

To add a new magnitude formula press '*Add*' button and use the following dialog box:

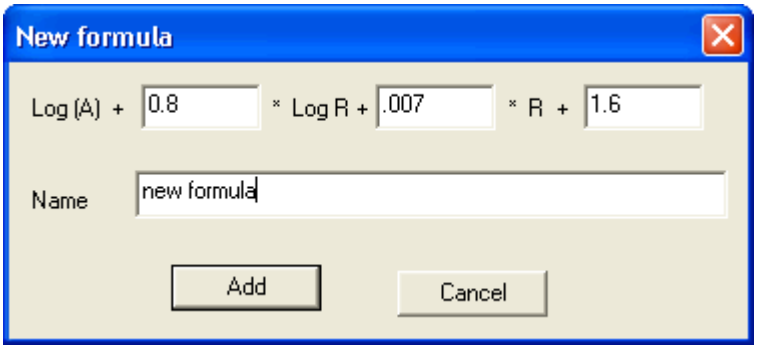


Figure 14: Typical dialog box of the new magnitude formula insertion.

- Fill in the appropriate values of the new formula and write a label name of the formula then press '*Add*' button. This formula will be inserted in the magnitude formula list of the magnitude dialog box to be used for magnitude estimation.

The new formula(s) will be saved in the *'Sgraph.set*' file and will automatically loaded with the next ***Sgraph*** execution.

3 Filter

This menu is used to apply filters to the selected traces. The filtering process consists of two steps, one is the filter kind (i.e., low pass, high pass, etc..) . The other is the filter type (i.e., Butterworth, Chebyshev, etc..). The user has to select first the filter kind from the filter menu (shown below), then select the filter type from the dialog box given.

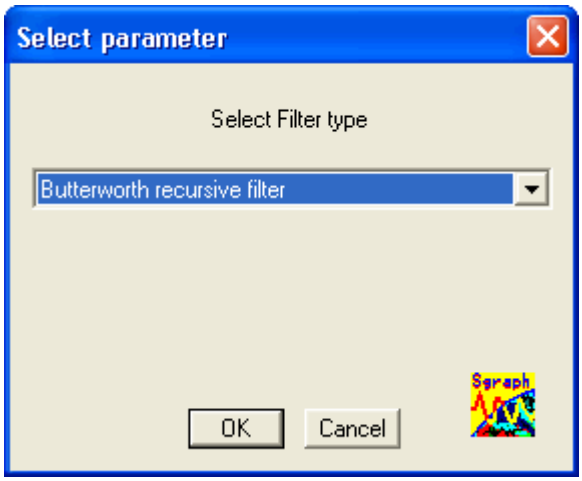


Figure 15: A typical screen-shot of the filter type selection dialog box.

Filter types included in ***Sgraph*** are as follow:

- Butterworth recursive filter
- Butterworth filter (XAPIIR library)
- Bessel filter (XAPIIR library)
- Chebychev filter type C1 (XAPIIR library)
- Chebychev filter type C2 (XAPIIR library)
- Moving average filter

The XAPIIR library is the same routine used by ***SAC*** program.

In case of moving average filter type insert only odd numbers up to 11 [1,3,..11].

This filter can be specifically applied to frequency domain trace for smoothing the spectral traces.

3.1 Hipass

Function: Apply High-pass filter with any filter type on the selected trace(s).

Select the filter type from the given dialog box and then insert the High-cut frequency.

3.2 Lowpass

Function: Apply Low-pass filter with any filter type on the selected trace(s).

Select the filter type from the given dialog box and then insert the Low-cut frequency.

3.3 Bandpass

Function: Apply Band-pass filter with any filter type on the selected trace(s).

Select the filter type from the given dialog box and then insert the High-cut frequency.

3.4 PoleZero

Function: Apply a customized Pole and Zero filtering on the selected traces.

In this menu Sgraph uses the Pole and Zero values given either from a Pole-Zero file (POZ) or from built-in or user-defined values assigned in the given response file. The selected values will be used to construct the corresponding filter to be convolved with the selected trace.

- Prepare a Pole-Zero file of the appropriate filter parameters. This tool can be used to simulate a specific instrumental response of known Pole and zero values or by built-In instruments.
- Use the given dialog box to browse the Pole-Zero file or select a specific instrument type.

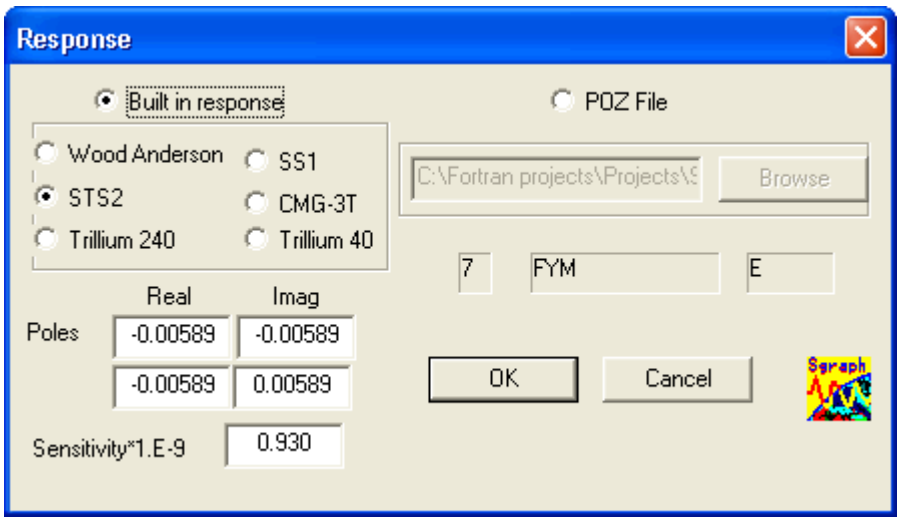


Figure 16: Typical dialog box of the Pole and Zero filter and instrumental correction.

The above dialog box gives the ability to use Pole-Zero values either from built-in responses or from external file or manually inserted.

- Check the POZ file box to browse a user made POZ file. See Appendix 1 for detailed description of POZ file format.

- Check the Built-In Response to use one of the following:

- Wood Anderson instrument
- SS1, short period SS1 instrument.
- STS2, Strekeizen2 Broad band instrument.
- Trillium40
- Trillium240
- CMG-3T

The resulted traces are in meter.

This process is internally used in the magnitude menu by simulating the trace into Wood Anderson instrument before the Amplitude Picking process. See the Instrumental response section

4 Math

These routines perform mathematical operations with traces. Some routines are single-trace processes. Others are multiple-trace processes. The appropriate dialog box will be given for trace insertion.

In all these routines insert or select the desired trace(s) with which the operation is to be applied. Then, follow the dialog box request for operation discussed below. Data and/or operators should be inserted following the typing rule.

4.1 Power order

Function: Raise the amplitude of the selected trace(s) to the power "n".

-Insert a real value "n" whose trace will be powered to. i.e. $(Trace)^N$.

4.2 Multiplication

Function: Multiply the amplitude of the selected trace(s) with the value "X".

-Insert the multiplication real value "X" whose trace will be multiplied with. (Trace) * X

4.3 Area under curve

Function: Calculate the area under curve for the selected trace.

-The area under curve will be hachured and the area value will be given.

4.4 Normalization

Function: **Normalize the amplitude of selected trace(s).**

4.5 Absolute

Function: **Absolute of the selected trace(s).**

4.6 Cumulative Sum

Function: **Calculate the cumulative sum of the selected trace**.

This is useful for the onset detection. It shows the abrupt changes in wave amplitude. The mathematical formulation of the Cumulative Sum is shown in the numerical Recipes book (Press et al., 1989).

4.7 CrossCalc

Function: **Interact with traces mathematically.**

Insert the desired trace indices separated by a mathematical operator. The accepted operators are (+,-,*,/,^). ('^' is the power).

EX: 1*2+3 = multiply trace 1 by trace 2 and add the result to trace 3.

N.B. -The trace indices and operators should be inserted without spaces or parentheses in between.

4.8 Spectral Ratio

Function: Perform a spectral ratio operation between two frequency domain traces. This tool is used in site correction process.

The process is performed for any frequency domain trace. The resampling process will be conducted on the second trace to be synchronized in frequency values.

-Insert the two trace indices separated by a space.

4.9 Power Spectrum

Function: Perform a Power spectrum operation to a frequency domain trace.

The power spectrum process (Pspec) between Y1,Y2 frequency traces is expressed as follows:

$$Pspec(f) = Y1(f) \cdot Y2(f)$$

-Insert the two trace indices separated by a space.

4.10 Cross Spectrum

Function: Perform a Cross spectrum operation between two frequency domain traces.

The cross spectrum process (Xspec) between Y1,Y2 frequency traces is expressed as follows:

$$Xspec(f) = Y1(f) \cdot Y2(f)^{*}$$

Where '*' is complex conjugate

-Insert the two trace indices separated by a space.

4.11 Cross correlation

Function: **Calculate the cross correlation between two traces.**

- Insert the indices of the desired 2 traces. The Cross correlation curve and the maximum correlation value with its corresponding lag time will be given.

4.12 Multi Cross correlation

Function: **Calculate the Multi cross correlation of selected traces.**

This process perform a successive X correlation processes between a set of traces providing a 2-D mapping of cross-correlation coefficient and lag time. The resulted values will be save in "MCORR.DAT" file.

- Use the given section dialog to select the window and the indices of the traces needed for correlation. (Don't use a long sample of traces, this will last a long time).

A typical example a 4 traces Multi cross correlation file is given below:

```
1   1   1.0000    0.0000
1   2   0.2110    0.2700
1   3   0.2222-48.5800
1   4   0.1652-51.6700
2   2   1.0000    0.0000
2   3   0.2241-50.4500
2   4   0.2168-49.3700
3   3   1.0000    0.0000
3   4   0.1928 -0.3800
4   4   1.0000    0.0000
```

The description of this file is a follows:

First two numbers are indices of traces being correlated, third number is the maximum X-correlation coefficient of that set, last number is the lag-time at the maximum correlation .

4.13 Auto correlation

Function: **Calculate the auto correlation of a selected trace.**

-Select a trace to be auto correlate. The auto correlation curve will be given.

4.14 Convolution

Function: **Convolve two selected traces.**

-Insert the indices of desired 2 traces to convolve.

Result is: *trace1 * trace2*

4.15 Deconvolution

Function: **Deconvolve two selected traces.**

-Insert the indices of desired 2 traces to deconvolve. The second one is the denominator.

Result is: *trace1 / trace2*

4.16 Distribution

Function: **Calculate the distribution curve of a selected trace.**

- Select a trace to calculate the distribution.

The result is a point curve representing the recurrence of every Y value. X-axis is the Y value. Y-axis is the recurrence or number of occurrence of this value within the entire trace.

4.17 Statistics

Function: **Calculate some statistical parameters of a selected trace (*e.g. Mean, Standard deviation, Root mean square, number of points)***

- Select a trace to calculate its statistics.

4.18. Resampling

Function: **Resample a selected trace with another sampling rate.**

- Insert the desired trace(s) index to be resampled .
- Insert the new sampling rate in sample/sec.

4.19. Calculator

Function: **Open the Windows Calculator as a helping tool in waveform analysis.**

---

5 Correction

5.1 Instrumental

Function: **Remove the instrumental response from the selected trace(s)**.

Sgraph uses the user defined POZ file to deconvolve the station response from the selected trace. (See the PoleZero filter for more detail).

Sgraph assumes that the POZ file name of the given trace is found in the Sgraph response folder and constructed from the trace name (or station name) and the component type as follows:

POZ file name = Tracename_comp.poz

EX: FYM_Z.POZ

In case the POZ file is not exiting in the Response folder the Response dialog box (See filter section) will appear for browsing a different file or use built-in responses.

5.2 Site correction

Function: **Correction the seismic traces from a defined site effect signal. This is done by performing the spectral ratio between the observed trace and the Site effect trace and give the resulted trace in the time domain.**

This process is internally done in the *Site effect* tool. Where, it corrects the corresponding observed traces from the resulted Site effect (see *Site Effect* section for detail).

5.3 Remove DC

Function: **Remove the DC trend from the selected trace(s).**

5.4 Remove O.T.

Function: **Remove the Origin time from the arrival time trace(s).**

The arrival time trace is subtracted from the origin time to produce the travel time trace.

The origin time stored in buffer will be used in this process, if no origin time is stored the program prompt of it.

N.B. Make sure to insert the correct O.T. value before proceeding.

5.5 Reduce T.T

Function: **Reduce the selected trace(s) by the ratio (distance/velocity).**

- Insert trace(s) index to be reduced,
- Insert the reduced velocity.

The distance of the selected traces will be extracted from the "***Info***" buffer. Be sure that the distance values in ***Info*** are correct. If not, modify it manually.

---

6 Test Signal

Function: **Construct several types of signals for data analysis and testing.**

The data in these tools are inserted through the following test signal dialog.

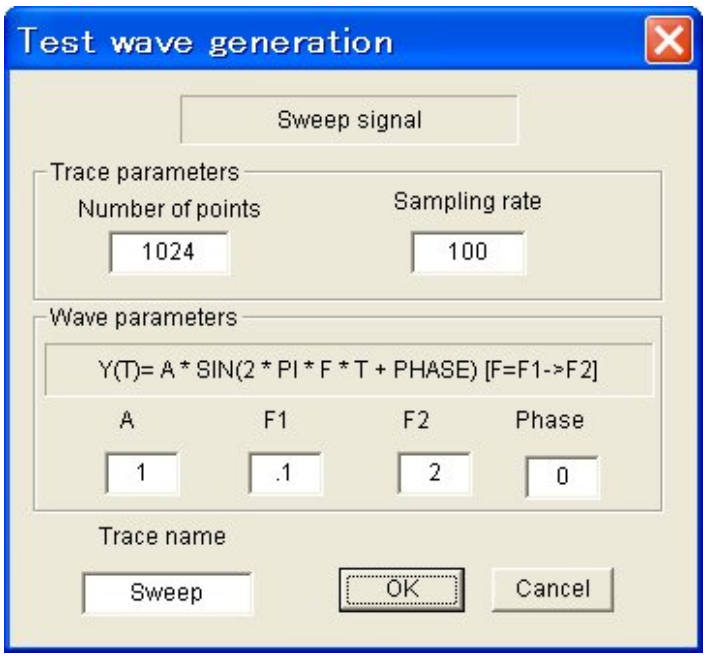


Figure 17: Typical dialog box of the Test wave generation.

Fill in the trace parameters (number of points and sampling rate) of the resulted signal and follow the dialog request for each signal.

6.1 Line

Construct a line function of amplitude (A):

$$Y(t) = A.$$

- Insert the amplitude "A" of the function.

6.2 Spike

Construct a Spike of amplitude A and position T:

$$\mathbf{Y(t) = 0} \quad \text{at} \quad [t \neq T] \quad \text{and} \quad \mathbf{Y(t) = A} \quad \text{at} \quad [t = T].$$

- Insert the amplitude (A)
- Insert the spike position in the trace (T) in sec.

(Times should be within the trace limits)

6.3 Step Function

To construct a step function of Amplitude (A) and duration T1+T2:

$$\boldsymbol{Y(t) = 0} \quad \text{at } [T1 > t > T2] \text{ and } \boldsymbol{Y(t) = A} \text{ at } [T1 < t < T2].$$

- Insert the amplitude (A)
- Insert the Starting time of step (T1) in sec.
- Insert the Ending time of step (T2) in sec.

(Times should be within the trace limits)

6.4 Sine/Cosine wave

Construct a Sine wave trace of amplitude (A), Frequency (F) and Phase (P):

$$Y(t) = A * Sin\ (\ 2\ \pi\ Ft + P)$$

- Insert the amplitude (A) of Sin wave
- Insert the Frequency (F) in Hz.
- Insert the Phase (P) in Deg.

6.5 Brune disp/vel

Construct a simulation of Brune function for displacement and velocity spectra. For a flat part (Ωo) and Corner frequency (fc) the Brune model displacement is expressed as :

$$Y(f) = \frac{\Omega o}{1 + (\frac{f}{fc})^s}$$

Brune model for velocity is the same function multiplied by 2*PI*F

- Insert the Flat part (**Ωo**)
- Insert the Corner Frequency (fc) in Hz
- Insert the slope fall off (s).

6.6 Sweep

Construct a Sweep function of amplitude (A) and frequency ranging from F1 to F2.

$$Y(t) = A * Sin(2 \pi F), \quad \textbf{F= [F1:F2]}$$

- Insert the amplitude (A) of Sine wave
- Insert the Frequency (F1) in Hz., the lower frequency of the signal.
- Insert the Frequency (F2) in Hz., the higher frequency of the signal.

6.7 Mixed

Construct Sinusoidal wave of amplitude (A), Frequency (F) mixed with attenuation operator of power (P).

$$Y(t) = ASin(2\pi Ft).e^{-Pt}$$

- Insert the maximum amplitude (A) of the signal.
- Insert the Frequency (F) in Hz.
- Insert the attenuation operator (P).

6.8 Polynomial

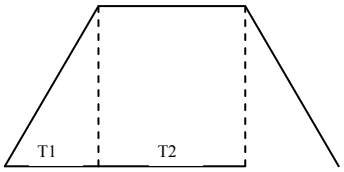
Construct a polynomial function of the degree "3".

$$Y(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3$$

- Insert the coefficients: a0 (A), a1(B), a2 (C) and a3 (D).

6.9 Trapezoid

Construct a trapezoid with Rise time (T1) and Duration T2



- Insert the trapezoid rise time (T1) in sec
- Insert the trapezoid duration (T2) in sec.

N.B. A triangular function can be constructed by inserting the value T2=0.

6.10 Noise Signal

Construct a randomized noise signal as proposed in the *Add noise* section.

- Insert the S/N ratio (relative to 1)
- Insert F1, F2, F3 frequencies in Hz.

---

7 Inversion

Function: Apply matrix inversion tools on the selected trace with respect to built-in functions.

Sgraph makes the mathematical regression between selected trace(s) and a selected function and plot the best-fit curve with the solved parameters and errors. For more information of the inversion tools refer to *Press et al*. (1989).

The inversion is either linear type (SVD) for polynomial, arrival time fitting and Wadati diagram fitting; or nonlinear inversion type (Marquard) for the Brune displacement and Brune velocity models. Inversion for Q-Freq relation, PGV-Dist relation, and MLTW are also provided. Because the requirements of the last three relations are not able to be extracted from the working traces, those are either implemented internally or from individual menu.

The next table shows the available functions for the SVD and Marquard inversions.

Inversion tool	Function name	Formula	Unknown parameters
Linear inversion (SVD)	**Polynomial**	$\mathbf{a_0} + \mathbf{a_1}*X + \mathbf{a_2}*X^2 + \ldots a_n*X^n$	**A_0, a_1,a_2, … a_n**
	Arrival time vs distance	$T = t_0 + \Delta t$ (V=slowness)	**Origin time, Vp**
	Wadati diagram	S-P time = a0 + a1*T (T = arrival time)	**Origin time, Vp/Vs**
Nonlinear inversion (Marquard)	**Brune model displacement**	$Y(f) = \frac{\Omega o}{1 + (\frac{f}{fc})^s}$	**Flat part, corner frequency**
	Brune model velocity	$Y(f) = \frac{\Omega o * 2 * PI * f}{1 + (\frac{f}{fc})^s}$	**Flat part, corner frequency**
	Q vs Freq	$Q = Qo\ f^n$	**Qo, n**
Genetic Algorithm	**MLTW**	Energy function (see MLTW section)	See MLTW section
Genetic Algorithm	**PGV-Dist**	Peak ground velocity- distance relation.	**C1, C2 C3,** and **C4** coefficients representing, amplitude scaling, Magnitude scaling, geometrical

spreading and anelastic attenuation, respectively.

7.1 Linear fit (SVD)

Linear inversion using Singular Value Decomposition. Available functions are:

The polynomial function, Arrival time function and Wadati plot.

- **Polynomial function:**

Polynomial function of n orders. This is internally used to solve the linear fitting problems (i.e. polynomial of order 1). As a tool it can be used for the linear regression of any dataset.

- **Arrival time vs distance relation:**

$$T = t_0 + \Delta t$$

Where,

T: is the phase arrival time
to: Origin time
△: epicentral distance
t : slowness of the phase.

This is an application of the one-order polynomial fitting for the slowness (t) and the origin time (t_0) of the selected traces. According to the behaviour of the arrival times with distance, the best-fit curve reveals the appropriate apparent velocity (1/t) and the origin time.

How to fit the arrival time curve for a set of traces.

- Select the ***SVD*** tool from inversion menu.
- Insert trace indices of to be used in inversion. Each trace must have at least one phase picked.

- From the given dialog box (Record section dialog box) select the respected phase to be used in inversion from the onset phase list box.
- Select the function "Travel time fitting" from the inversion functions dialog box.
- If the inversion succeeded, the picking and the fitted curves with their corresponding standard error will be given.
- Repeat the inversion for different traces and functions if required.

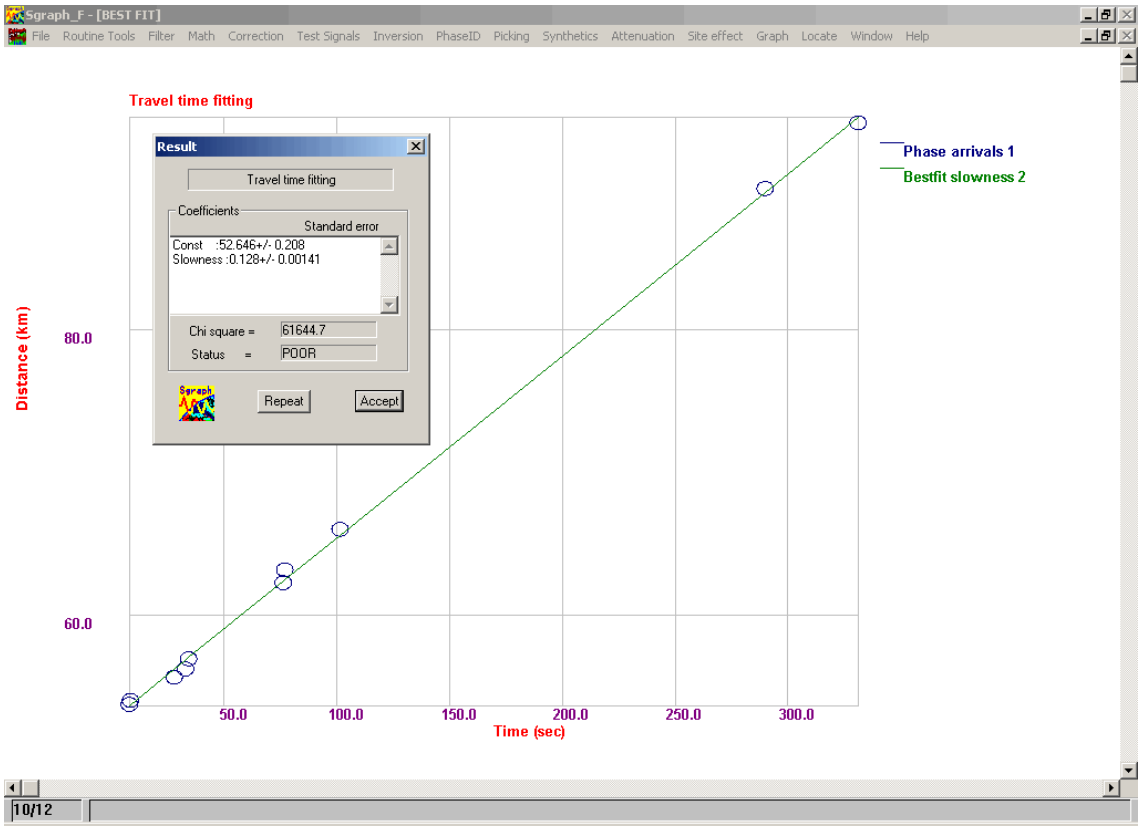


Figure 18: A typical example of the linear regression of Pg arrivals. Blue curve is Pg arrival times versus epicentral distance. Green is the corresponding best fit curve. Internal dialog box shows the resulted values of to and t.

- **<u>Wadati diagram:</u>** **S-P time = $a_0 + a_1$*T**

Another application of the one-order polynomial fitting where the relation between the S-P time vs P arrival reveals the Vp/Vs value and the origin time.

<u>How to fit the Wadati diagram plot:</u>

The Wadati plot is automatically constructed and fitted by using the Wadati plot menu (see above).

For a previously constructed Wadati plot, a fitting can be done by the next steps:

- Select the ***SVD*** tool from inversion menu.
- Insert trace index of the previously constructed Wadati plot
- Select the function "**Wadati plot function**" from the given dialog box.

- If the inversion succeeded, the observed points (Open circles) and the best-fit line will be shown. The resulted Vp/Vs and origin time with their corresponding errors will be shown in the giving dialog box. The resulted line can be added to the ***Sgraph*** traces (if desired). See the Wadati plot menu (above) for a typical screenshot of the Wadati plot fitting.

7.2 Nonlinear fit (Marquard)

None-linear inversion using Marquard method.

The available functions are the following:

- **Brune1 for Displacement (see the above table),**
- **Brune1 for Velocity (see the above table).**
- **Brune2 for Displacement (under construction)**
- **Brune2 for Velocity (under construction)**
- **PGV-dist relation (see text below)**

How to fit a spectral trace with Brune model

- Select the ***nonlinear fit*** menu for inversion.
- Select the suitable trace to fit
- From the given dialog box select the function corresponding to the selected trace for inversion (e.g. Brune displacement or Brune velocity).
- If the inversion succeeded, the resulted fitted line and solved parameters will be shown with the corresponding standard errors.
- Repeat the inversion for different traces and functions if required.
- Resulted curve can be added as a new trace to the ***Sgraph*** list.

Next Figure shows typical inversion of Brune displacement spectral fitting.

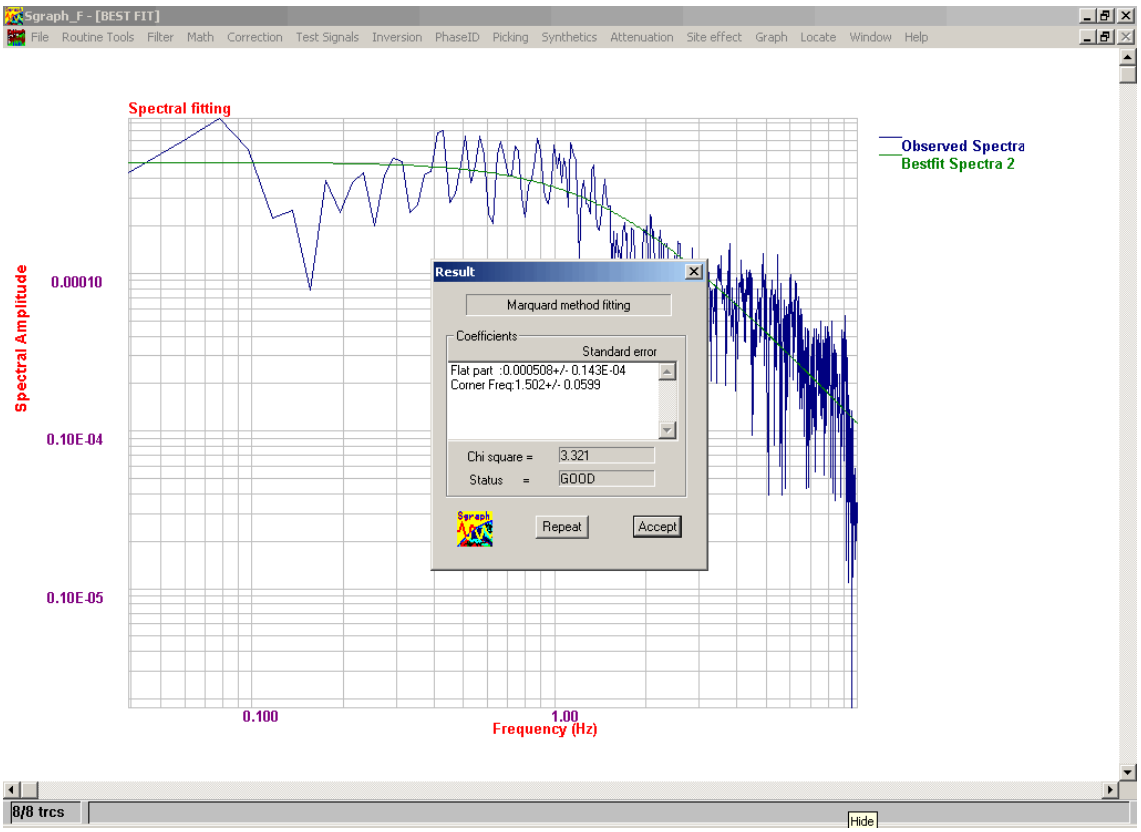


Figure 19: A typical example of the nonlinear inversion of Brune model displacement function. Blue curve is observed FFT trace, green curve is the corresponding best fit curve. Internal dialog box shows the resulted values of Flat part and corner frequency.

Source Parameters estimation:

According to the calculated spectral parameters, the earthquake source parameters are automatically estimated. The seismic moment (Mo) is directly estimated form the solved Flat part by using the Keilis-Borok (1959) relationship:

$$Mo = 4\pi\rho v^3 R \frac{\Omega o}{F U_{\vartheta\varphi}}$$

Where, ρ is the density of the medium, R is the epicentral distance, v is the P-wave velocity, F is the free surface factor (assumed as 2), and $U_{\theta\varphi}$ is the mean radiation pattern (0.55). Accordingly, moment magnitude (Mw) is estimated by using Kanamori (1977) relationship:

$$M_w = \log(\frac{Mo}{1.5}) - 10.73$$

The source radius (r) and stress drop (Δσ) are estimated following Madariaga (1976):

$$r = 0.32\frac{Vp}{f_c}$$

$$\Delta\sigma = \frac{7Mo}{16r^3}$$

Next figure shows typical dialog box of the earthquake source parameters estimation of the previous spectral fitting.

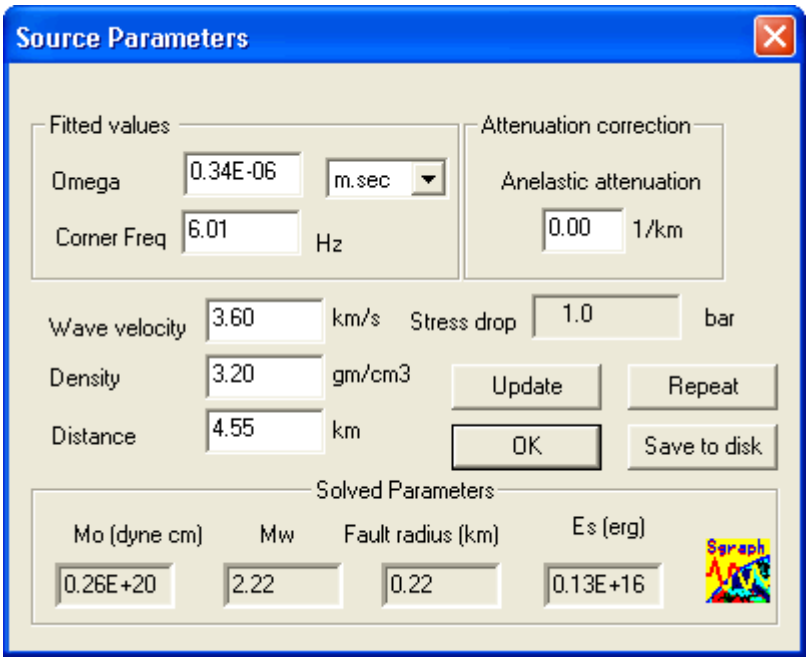


Figure 20: A typical example of source parameters estimation dialog box.

The above dialog box consists of all the parameters required for the source parameters estimation. The fitted spectral parameters are inserted in place. It is important to change the unit of the flat part (m.sec or cm.sec) that corresponds to the windows used if required. This is to keep the resulted seismic moment in dyne.cm. The wave velocity and density are required parameters for the Keilis-Borok equation. Insert the appropriate wave velocity and density according to the window selected. Moreover, the anelastic attenuation box is used to correct the spectra from attenuation. Insert the appropriate value if desired. Use 'update' button to update the calculation. Use 'Repeat' button to

repeat the spectral fitting. Use *'Save to disk'* button to save the resulted parameters in an external file.

7.3 PGV-Dist relation : (Peak ground velocity- distance relation)

This tool implements a nonlinear inversion for PGV values measured from a range of distance for a given earthquake magnitude value. A maximum distance points can be used up to 999 points and number of magnitude values is up to 99. An example of a pre-defined PGV-distance relation file in which the PGV is given for a number distance points and different magnitude values is shown in Appendix 9.

The PGV attenuation relation with distance R for a given magnitude (M) is given by:

$$Ln\ (PGV) = C1 + C2*M + C3*\ LOG\ (R) + C4*R$$

Where, C1, C2, C3 and C4 represent the Scaling coefficient, Magnitude coefficient, Geometrical spreading and anelastic attenuation, respectively.

Simply, *Sgraph* searches for the values of those coefficients that best-fit the observed PGV values by Genetic Algorithm.

How to do ?

-Use the PGV-Dist menu to browse for the pre-defined PGV-Dist file.
-The respected values of the PGVs with different magnitudes will be plotted and a genetic dialog box will be prompted.
- Enter the appropriate searching parameters.
- The searching procedure will start and the plot will update when best fit increase.
- The observed, best-fit-data and the resulted coefficient will be saved in the file "PGV-Dist_res.dat".

---

8 PhaseID

Tools for phase identifications using travel time table or synthetic data. These tools use 2 types of phase data sources and 2 types of phase identification modes. This makes it easy to identify phases from observed or synthetic traces. The 2 modes of identifications maintain the user to either search about the phase corresponding to the selected wavelet (Search mode) or insert a specific phase to know its corresponding wavelet (Insert mode).

Phase data sources:

1 -Green function file:

This is the output file given from the GRT Algorithm (see Appendix 3). It consists of all the information needed to extract phases used in generating the synthetic seismograms.

-Insert the origin time of the selected trace to fit with the travel time of phases.

2-Travel time table:

This is a user supply Travel Time Table. It gives the different phase names and their travel times for the given distances.

-Insert the Origin time and distance to extract data from table. (See Appendix 2 for more information)

8.1 Search Phase

Function: **Identify the phase name and type of a specific wavelet.**

How to do?

-Select the desired trace to use.

- Do the required adjustment in the trace using the given navigation tools (see ***Navigation*** for more details). If none, press No

-Select the source of phases, either from "*LOADED TABLE"* or "*ASERIESO"*.

If "*LOADED TABLE*":

- Insert the origin time and distance to extract phases from table. (If there is no table in memory, you will be asked to load a table).

If "*ASERIESO*":

- Select the Green function file name.
- Insert the suitable origin time to match the arrival times of the plotted trace.

If phases are successfully retrieved from the above two sources, do the following:

- **Left Click** over the plotted trace on the desired place will insert the closest phases to this position.
- **Left Click** again will remove the plotted phases in this position.
- **Right Click** to return.

N.B. once the desired phases are plotted. The phases will be stored in memory for further use.

8.2 Insert Phase

Function: Insert a specific phase name over the plotted trace in its exact arrival time.

How to do?

- Select the desired trace to use.
- Do the required adjustment in the trace using the given navigation tools (navigation for more details). If none, press "No"
- Select the source of phases, either from "*LOADED TABLE"* or "*ASERIESO".*

If "*LOADED TABLE*":

- Insert the origin time and distance to extract phases from table. (If there is no table in memory, you will be asked to load a table).

If "*ASERIESO*":

- Select the corresponding green function file.
- Insert the suitable origin time to match the arrival times of the plotted trace.

If phases are successfully retrieved from the above two sources, the *Insert phase* dialog box will appear as follows:

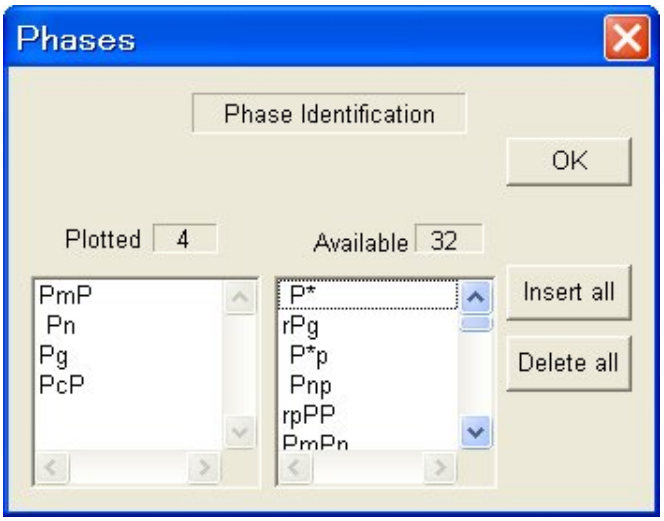


Figure 21: A typical screenshot of phase identification dialog box.

The Phase identification dialog box consists of two list boxes.

A right-side box listing all the available phases found in table or in *green* file; and a left-side box listing the plotted phases.

- **Double-Click** on the desired phase from the right-side list box to be inserted and plotted at the corresponding position overlaying the trace.
- **Double-Click** on the desired phase from the left-side list box to be removed from the plot.
- **OK** to return.

The following figure shows a typical example of ***Sgraph*** phase identification routine.

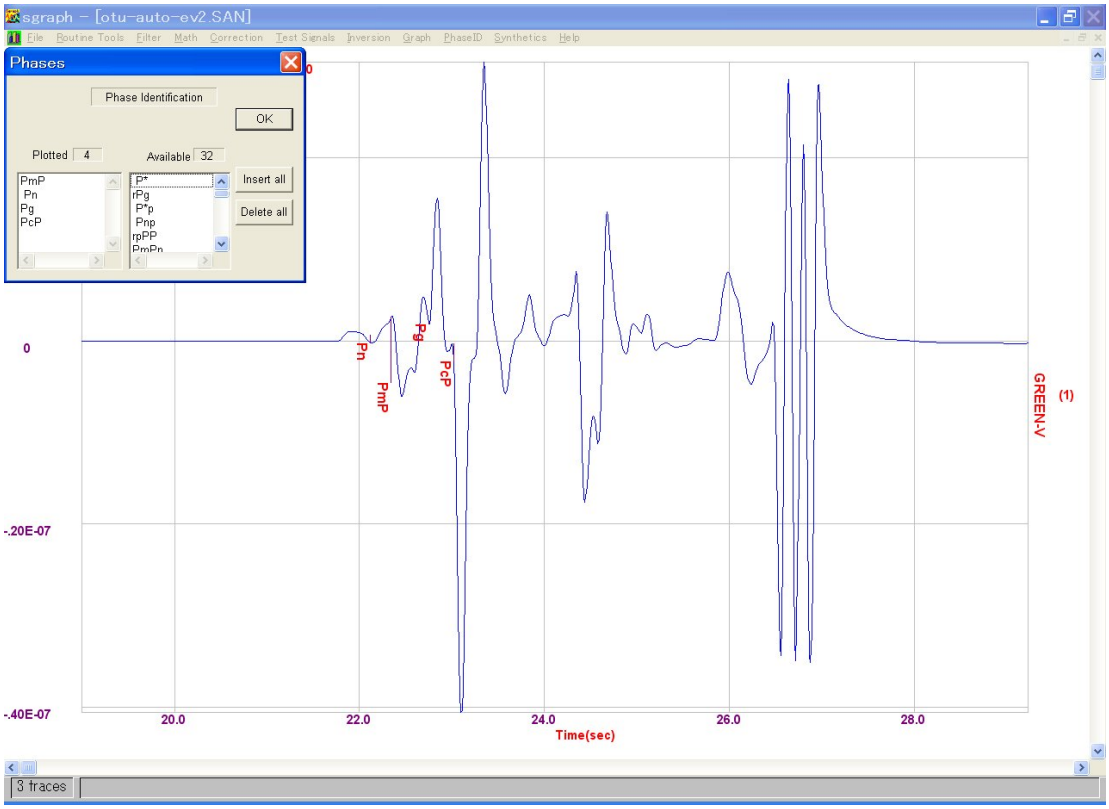


Figure 22: A typical example of the Phase identification routine. In this screen, the phase(s) selected in the dialog box will be plotted in its corresponding time in the trace.

8.3 Compare Phase

Function: Compare a given set of phases with different traces.

This routine is almost the same as "***Compare***" tool, but instead of using 2 traces, we use one trace and a set of phases.

How to do:

- Follow the same way as ***"Compare"*** for selecting trace 1.
- Insert the source of phases (either "*TABLE"* or "*ASERIESO"*).

The phases which are already selected in the "***Insert phase***" or "***Search phase***" modes or which are flagged in the *RID* file will be plotted over the trace at their corresponding arrival times. (Be careful to insert a suitable origin time).

- To drag phases over the plotted trace, follow the same procedures of "Compare" in the graph menu.

The next figure shows a typical example of ***Sgraph*** *compare phase* routine.

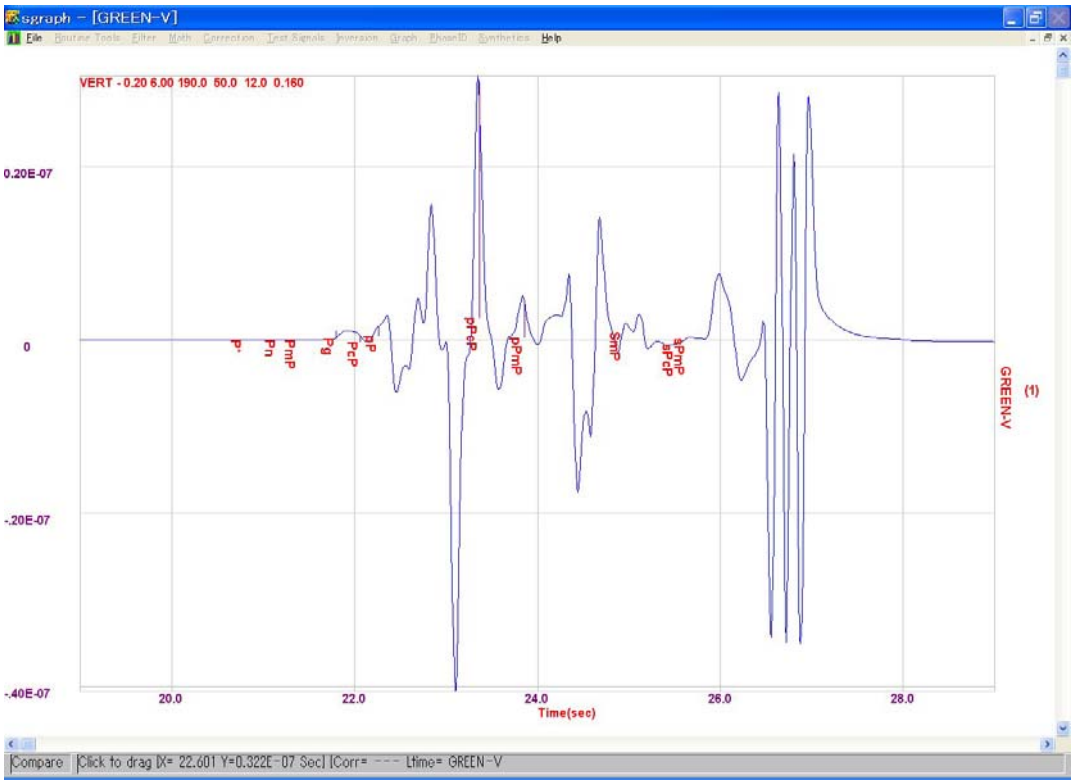


Figure 23: A typical example of the Compare phase routine. In this screen, the nominated phases (in red) can be moved forward/backward over the trace in use as a way to observe the most represented phases in waveform.

N.B. If the travel times of phases are not suitable with the plotted trace, there might be phases appeared for the first while that because phases are either located after or before the window limits. Drag phases backward or forward until find the phases.

8.4 Save Phases

Function: Save the selected phases of either the Search or insert mode.

N.B. The saved phases produced by ***Sgraph*** *cannot be used in Phase ID tools for this version.*

8.5 Load Table

Function: **Load a user supply travel time table to be used in the Phase Identification and comparison tools.**

-Insert the filename of travel time table. See Appendix 2 for the table format Once the table is loaded it will be available as long as *Sgraph* is running**.**

---

9 Picking

Here are comprehensive tools for picking phases either manually or automatically. Modification and deletion of phases are provided similarly. The amplitude picking is also provided. ***Sgraph*** has the ability to support 99 phases per trace. Each phase is stored in a string consisting of the Phase name, Phase polarity, Phase weight and Phase time. The string takes the following form:

Pg_D0_12345.00

Where:
Pg : Phase name
D : Polarity D or U
0 : Weight: 0-3
12345.00: Phase time in sec. Relative to the starting time of the trace.

This string is automatically constructed after phase picking and is shown in the Info dialog in the picking box.

To pick phases or amplitude from the given traces, the ***Picking*** dialog box is given, as shown below:

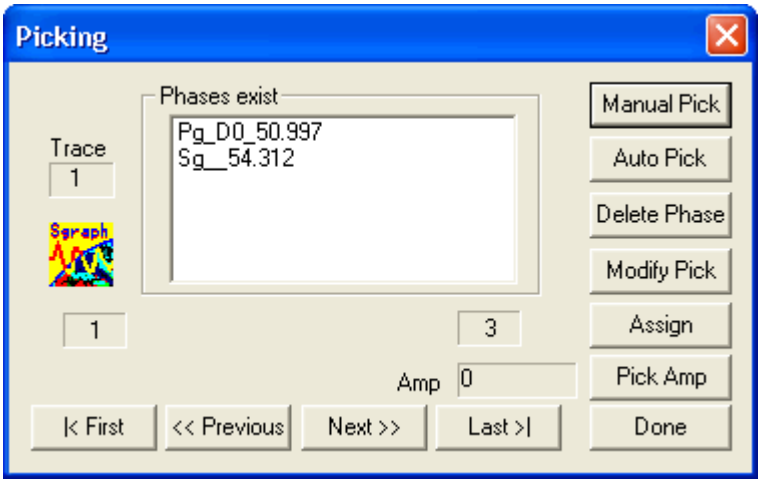


Figure 24: Typical PhasePicking dialog box.

In the next menu, the functionality of this dialog box will be explained in detail.

9.1 Pick/Del Phases

Function: Picking or deleting phases.

The above dialog will be given once this menu is selected. By using this dialog, you can run over the entire *Sgraph* traces (the time domain traces only) and pick, modify, delete any phase.

Change trace:

Once the Picking dialog appears, watch the ***Trace#*** value. This shows the current trace in process.

To change the trace under process

Use: **|< First :** Jump to the 1st trace in sequence
>| Last: Jump to last trace in sequence.
<< Prev: Go to the previous trace
>> Next: Go to next trace.

Pick phase automatically:

Press "***Auto pick"***:

The auto pick routine is applied on the current trace. If pick succeed, the resulted picking will be added automatically to the current phases having a name of "***Pa***" (**a**uto pick). The polarity is given "?" and weight is given "3" because auto pick can not calculate them. Modify them by using the "***Modify Pick***" button, see below.

Pick phase manually:

Press ***Manual picking.***

- Follow the zoom tool to stretch and adjust the trace until the phase appears clearly in an appropriate window than press ***Right-Click*** mouse.
- When the cursor appears as a cross, put the cursor over the exact time of phase and **Left-click** mouse.
- Insert/select the phase name, polarity, and weight, in the phase dialog box given below then press ***Accept.*** The phase string is constructed and added as a new phase belongs to the trace under processing.

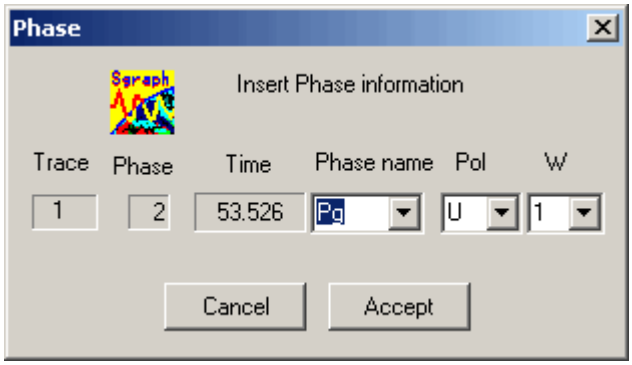


Figure 25: Typical example of phase information insertion dialog box.

- After phase acceptance, the trace window will show again to pick another phase if needed.
- To finish picking in that trace ***Right-Click*** mouse twice.
- Make sure that the phase is inserted in the picking dialog "***Phase exist*** " box.

Modify Phase:

- Select (Highlight) a Phase to modify from the "***phase exists***" box and press "Modify Pick" button.
- A picking process will start giving a cross cursor to pick a phase. If you don't need to change phase time, ***Right-Click*** mouse.
- The phase dialog will appear to modify its contents. Phase name, Polarity or weight.

N.B.: Select only one phase at a time to be modified, if multiple phases are selected; only the first will be used.

Delete Phase(s):

- Select (Highlighted) phase(s) to be deleted from the "***Phase exists*** " box and press "***Delete Phase***" button. Multi-selection is accepted.
- A confirmation dialog will ask to confirm the deletion. Press yes if you are sure to delete (NO UNDO FOR THIS PROCESS).

Assign Phases:

In the case of picking a phase from traces belong to same station (e.g. three components), it is convenient to assign the picking from one trace to others. In other words, instead of pick the P-phase from every trace individually, we can pick only one trace and assign the same phase time and name to other traces. This can be done by "***Assign phase***".

- Select (Highlight) the phase to be associated to other traces.
- Press ***"Assign phase".***
- Select a trace from the given box to be assigned with the same phase.
- Watch the trace information shown in the dialog to make sure of the trace being assigned.

Repeat the process of any other trace having the same condition.

Amplitude picking:

To pick the Peak to Peak amplitude for the given trace, use the 'Pick amplitude' button. Once the 'Pick amplitude' button is pressed the current trace will be corrected instrumentally and simulated to Wood Anderson seismogram. During the instrumental correction process, ***Sgraph*** searches for the default file name of the POZ file for the current trace. In case the file does not exist, the response dialog box will be prompted for the response parameters (see response correction section).

After this point, the picking navigation tool will be executed to enable the adjustment of waveform to get a clear view of the maximum waveform amplitude.

- Move/stretch trace for the maximum amplitude, then right-click mouse.
- Press two successive left-click muse button at the minimum and maximum phase amplitude.

The picking amplitude values of the entire traces will be stored in memory and will be stored in SAN files.

N.B. – The assign phase will be added to the new trace as a new phase with same time, name, polarity and weight.

9.2 Auto Picking

Function: Apply auto picking tool to specific trace(s).

Insert the index of trace(s) desired to be auto picked.

The auto picking routine will run assigning auto pick phase (***Pa***) for every trace (if succeed). If not succeed, ***Sgraph*** gives warn.

In the case when the "***Pa***" phase coincides with a pre-existing phase, a request will appear to confirm the replacement or ignorance of the new picking.

9.3 S-Pick Calc.

Function: Calculate the S-phase arrival time from a predefined P-phase by using the VP/Vs relation and Origin time. (VP/Vs = Sqrt (3) as fixed value)

This tool provides a rough estimation of S-wave arrival only for the purpose of windowing. It is not accurate enough to be used for location or the travel time estimation. Make sure to revise this picking by using the Picking tools for more S-wave precision.

9.4 Assigning Phases

Function: Assign a set of phases to a specific trace.

Insert the indices of the source and target traces.

- **Source trace**: trace from which the phases are used.
- **Target trace**: trace to which the phases will be assigned.

9.5 MCCC

Function: Perform Multi-Channel Cross Correlation technique (VanDecar and Crosson, 1990).

The idea is to invert a manually picked data set in a least square sense to obtain a new set of picking depending on the cross correlation between the entire set of traces. See VanDecar and Crosson (1990) for more detail.

It is required to assign a correlation window parameters within which the correlation will be performed and some other parameters to control the MCCC process. These are done using the following dialog box.

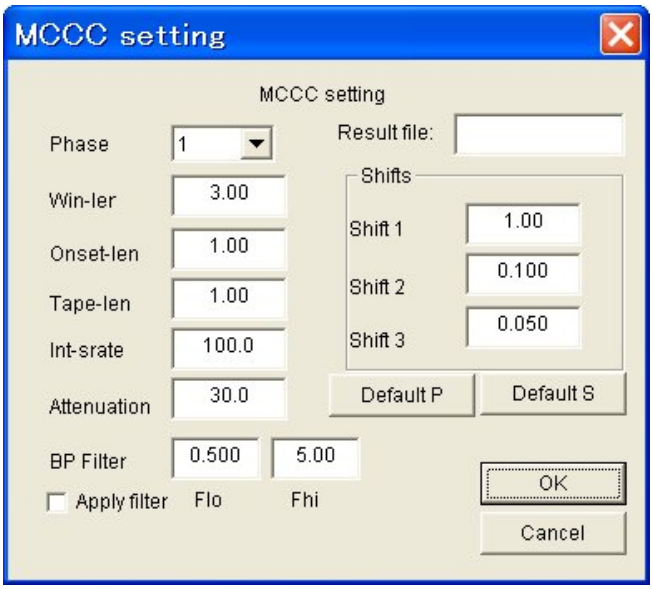


Figure 26: Typical MCCC setting dialog box.

The dialog box content is described as follows:

- Phase: The phase index to be used. Phase 1 is the only permitted phase in this version.
- Win-len: whole correlated window length in sec
- Onset-len: Onset time duration.
- Tapering len: Tapering window length.

- Int. srate: Sampling rate of data to be used in resampling.
- Attenuation: Attenuation value_
- BP filter: Band pass Chebyshev filter values if the "Apply filter" box is checked.
- Shifts: Levels of coarseness in the search
  - shift1, shift2, shift3: Shifting values in sec for level1, level2 and level3.
- Default P and S button are used for the default values for either P or S wave picking.

After inserting the appropriate values, the selected traces will be aligned and plotted according the inserted parameters. The typical MCCC window is shown below.

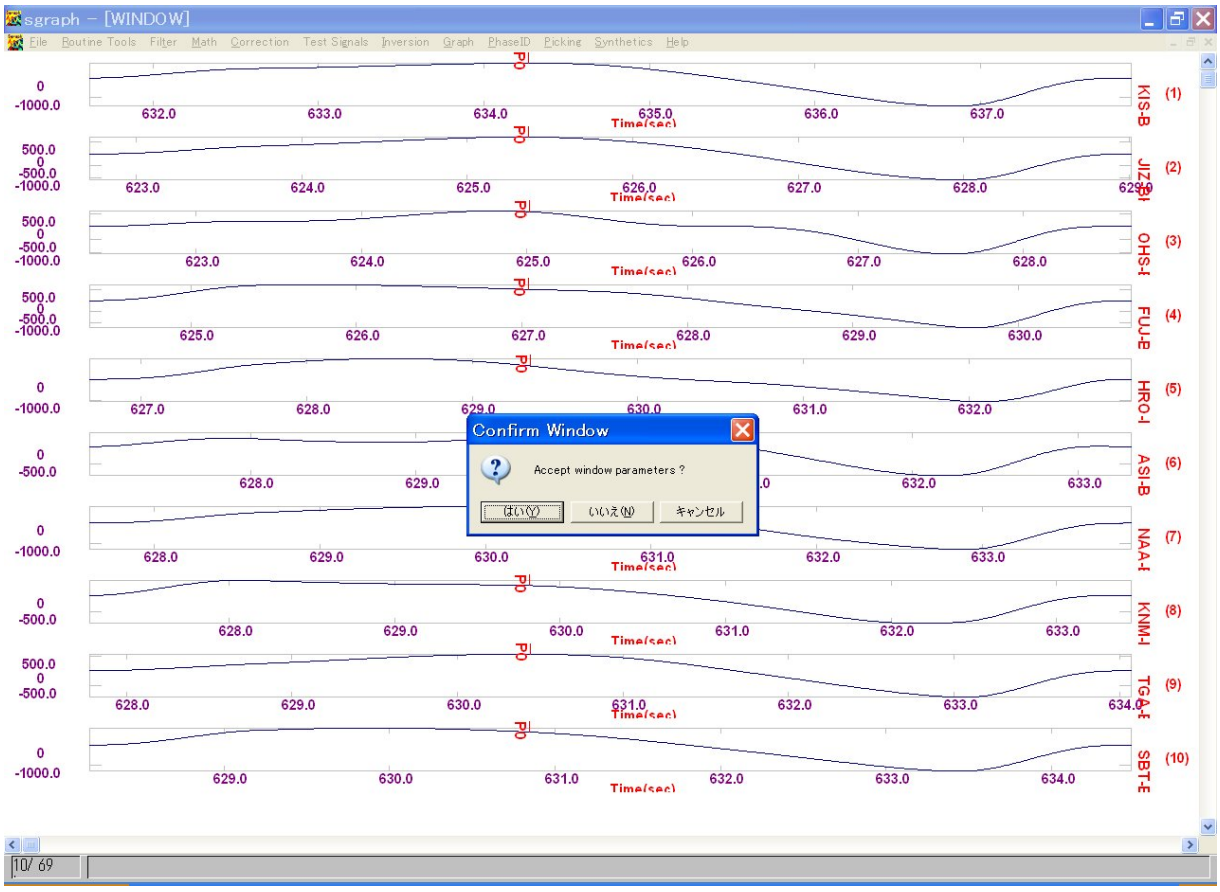


Figure 27: A typical screen-shot the MCCC windowing routine.

If the window parameters are not preferable, press "*NO*" to return to the window parameter dialog.

If acceptable, press "*YES*", the following dialog will appear.

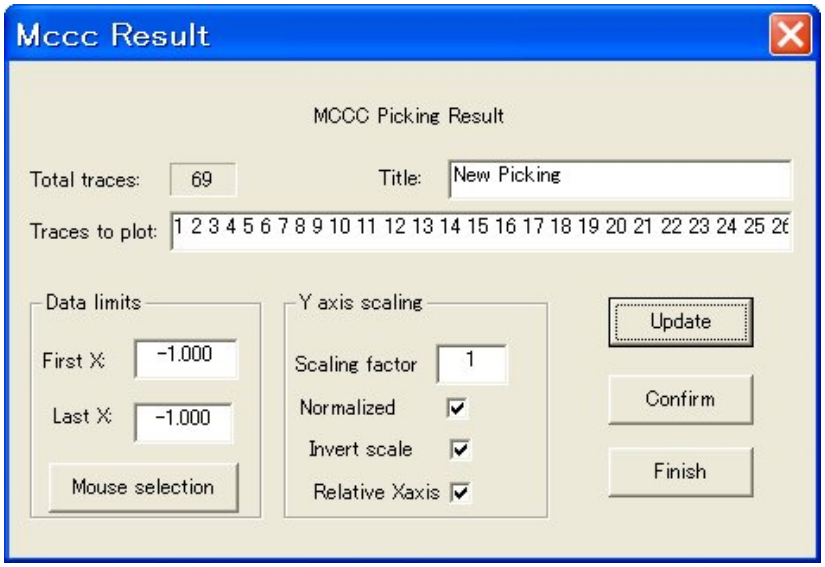


Figure 28: Typical MCCC Result dialog box.

This is a typical ***"MCCC Result"*** dialog box. The MCCC result is plotted in a record section plot of Equi-distant type.

The purpose of this dialog is to show the MCCC result with a convenient way.

→ It is important to notice that the trace indices needed here is not the actual trace indices but the trace number in the order of selection. I mean the first selected trace will have index1 and so on.

How to see results:

- Insert the trace(s) indices to be shown, [0] to show all.
- Insert data limits to focus for a specific part of the trace. Or press ***"Mouse selection"*** button for mouse selection tools.
- The Scaling factor, Normalization and Relative X-axis are the same as in Record Section Dialog.
- The correlated window of the traces will be plotted in the equidistant section overlaying by the original picking noted as "P0" and the MCCC picking noted as "P1".
- Press "Update" to Update/Draw the selected parameters.
- After visual checking of the whole set of traces observing the original (P0) and the final picking (P1), confirming that the MCCC improved the picking go to the next step.

- Press ***"Confirm"*** button to open the "Confirm Dialog" as follows.

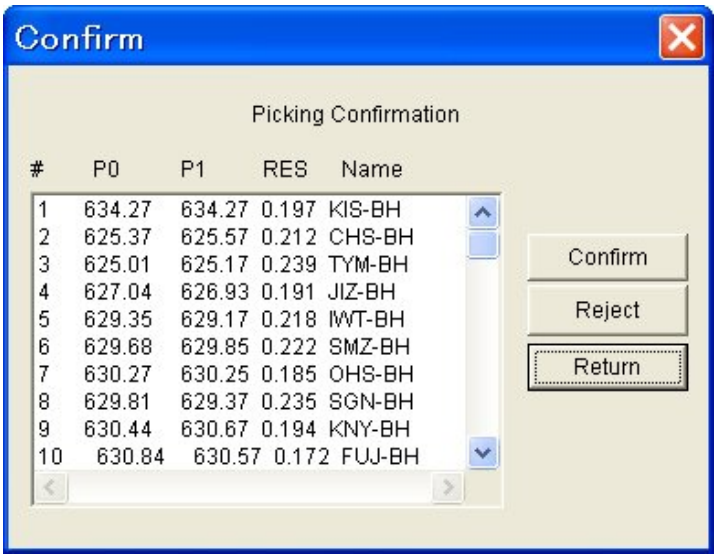


Figure 29: Typical MCCC confirm result dialog box.

The description of the list box content of this dialog is as follows

[Trace index] [Original picking] [MCCC picking] [Residual] [Trace name].

N.B. The residual above is the standard deviation of the residuals associated with the corresponding trace. (Equation 8, page 158, VanDecar and Crosson, 1990).

How to confirm picking:

- Mark on the trace(s) lines needed to be confirmed.
- Confirm the picking by pressing "***Confirm***" button. This will replace the original picking with the new one.
- Press "***Reject***" to exit without confirmation. This will keep the original picking as it is.
- Press "***Return***" to go back to the "MCCC Result" dialog box to show another set of traces.

→ Once "***Confirm***" Button is pressed, the MCCC picking and either replace the original picking or added as new pickings. Follow the given dialog for the appropriate usage of the MCCC picking.

For the non-marked lines, the picking value will be rejected.

9.6 Delete Picking

Function: Delete the entire set of phases from a selected trace(s) at once. The process is a faster way than the delete phase in the Picking dialog. It is used to delete all phases from a set of traces.

- Insert the desired trace(s) to delete phases from.
- A confirmation dialog will ask to confirm the deletion. Press yes if you are sure to delete (NO UNDO FOR THIS PROCESS).

9.7 Load Picking

Function: Load picking previously saved by Sgraph.

-Select the File name saved by Sgraph.

Once loaded the picking values will be shown in the plotting traces and in "*Info*"

9.8 Load SAC Picking

Function: Load data picking previously saved by SAC. The SAC picking file is the Standard file id "B" form. (See SAC document for more detail)

- Select the File name saved by SAC.

Once loaded the picking values will be shown in the plotting traces and in "*Info*"

9.9 Save Picking

Function: Save the current picking.

The entire phases existing in ***Sgraph*** will be saved in "DAT" format of comma separator. The format preserves all the information of the station location and the phase's arrival time, polarity and weight. The file is tabulated in a rows and column. Each row is a set of one trace phases. Columns are in sequence:

Index, station name, long, lat, phase1, phase2, phase3 ,etc…

The phases are sorted in the order of arrival in the first trace. Phases that doesn't exist in a given trace(s) are replaces by a Null values. See Appendix 8.

10 Synthetic

This section explains tools for generating synthetic seismograms using different techniques and performing 1-D waveform modelling.

The available techniques in this *Sgraph* version are:

- **The Generalized Ray Theory (GRT) (Helmberger, 1974, 1983)**
- **Discrete Wave Number (DWN) (Bouchon, 1981)**

10.1 GRT (Generalized Ray Theory)

Function: Construct synthetic seismograms for a given velocity model and ray types using the Generalized Ray Theory (GRT). See Helmberger (1974, 1983) for detail.

How to do?

To construct a successful synthetic seismogram the following are needed:

- **Model file:**

This is the velocity model of the media in "MODEL" format (See Appendix 3 for detail).

- **Ray file:**

This is file consisting of the specific rays to be generalized in synthetic seismograms. This should be in "RAY" format (see Appendix 3).

- Fill in the ***GRT*** dialog (shown below) with the required parameters to generate the Green's function and ASERIESO files.

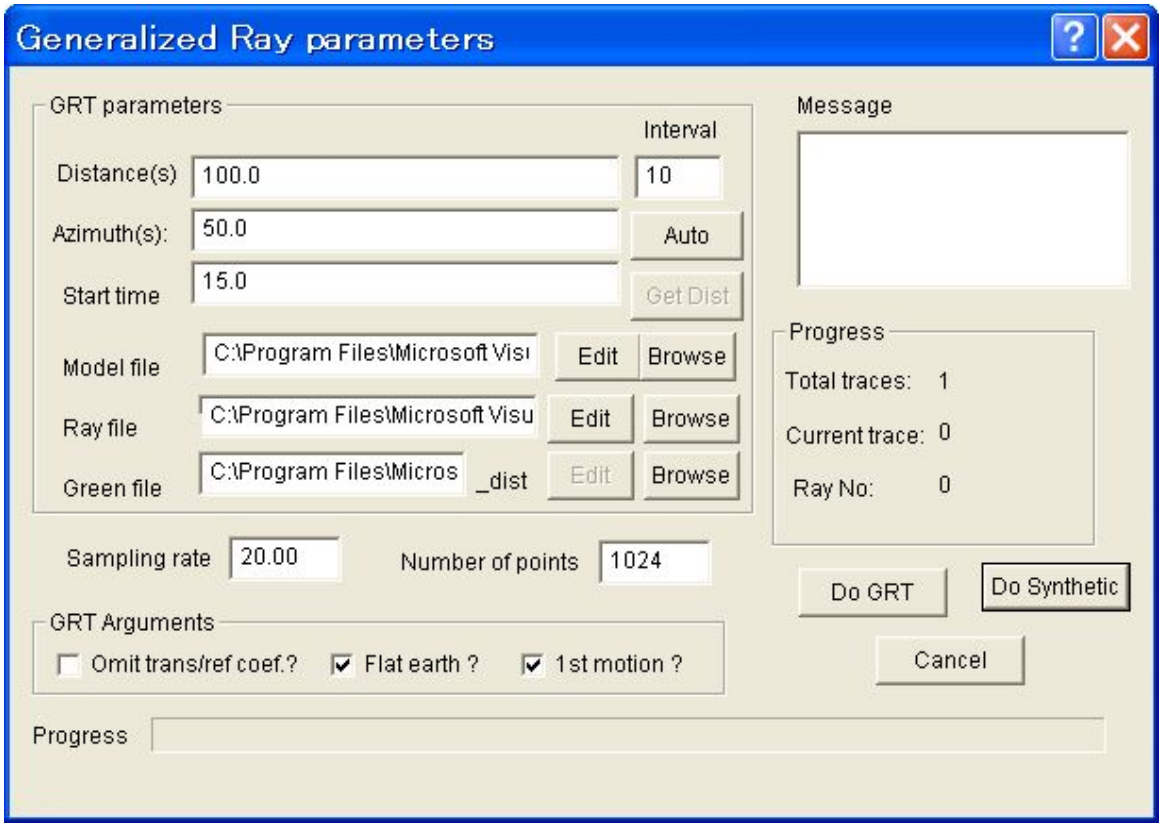


Figure 30: Typical dialog box of the Generalized Ray parameters insertion.

The descriptions of these parameters are in the following table.

Parameter	Description	Remark
Distance(s)	Set of epicentral distance of synthetics (in km).	Default: 100 km
Azimuth(s)	Set of Azimuth for synthetics (in Degree)	Default: 50 km
Interval	Interval of distance range in km	Default: 10 km
Start time	Start time of the synthetic (in sec)	= Distance /7 If not, synthetic record may be outside window length. -This value is automatically selected when press **Auto**
Sampling Rate	Sampling rate of synthetics	Default : 20 SPS
Auto	Automatic setting of distances Azimuth and starting times.	Press to do automatic set of distance values using the inserted interval

		value. The starting time is selected automatically.
Model file name	Model file name in "MODEL" format	Velocity model, control parameters of GRT (See appendices for detail).
Ray file name	Ray file name in "RAY" format	Ray segments to be used in GRT. (See appendices for detail)
Green's file name	Output name of the green's function file.	This is the base of the Green's function file. The distance value will be attached to this name for synthetic. This can be opened directly using Open menu to construct synthetic seismograms.

- Fill in the distance box with the desired distances (using the typing rule). For range of distance use ':' between the 2 distance range. Make sure to insert a suitable interval value in the **interval** box. Press 'Auto' button to set the required distance. See the total trace box to verify the number of traces in the accepted range. The Azimuth values will be constant in all distances as default, modify it if required.
- Check the GRT arguments checkboxes for the suitable case.
- Press "***START***" to start GRT.

The "M*essage*" box displays the progress result of the GRT technique. For every distance range a green's function file will be constructed having a name proceed by '_' and the equivalent distance. The progress bar shows the progress rate for every file.

- If the GRT progress is successfully finished, press "***Synthetic***" button to open the green's function dialog box needed to construct the synthetic seismograms.
- Fill in the green's function dialog (see green function section) to construct the synthetic seismogram.

10.2 Wave Number (Discrete Wave Number method):

(This tool under development)

This tool employs the Discrete Wave Number method (Bouchon, 1981) and the method of reflectivity and transmissivity matrices of Kennett (Muller, 1988) to construct synthetic seismograms of a specific model and distance ranges. This code is compiled from the ***Seisan*** package (Jen, 1992) after appropriate modifications.

This is done by using the following dialog box.

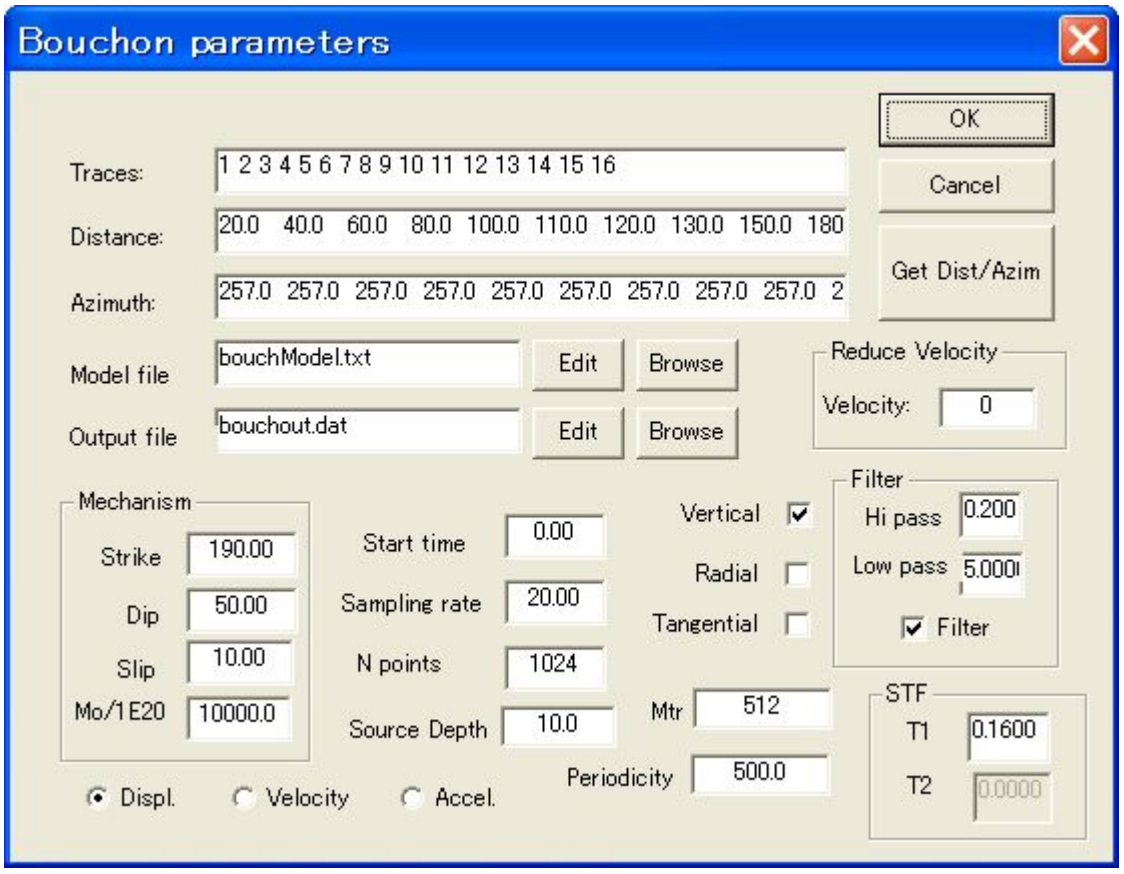


Figure 31: A typical Bouchon parameters dialog box.

The above dialog consists of all the requirements to perform a DWN seismogram.

How to do DWN synthetic seismograms:

- Fill in the Distance, azimuth, focal mechanism, Source time function (STF), filter value, etc...
- Specify, sampling rate, number of points, depth.
- Browse/insert model file (as in Appendix 7).
- Browse/insert output file (green's function file).

- To synthesize specific trace(s) that are loaded in ***Sgraph,*** insert their indices and press "**Get Dist/Azim**" to retrieve their corresponding distance and azimuth.
- To synthesize a specific distance range, fill in the box (no need to fill the trace index in this case).
- Specify the trace type (displacement, velocity, acceleration) and components to construct (Vertical, Radial, Tangential).
- To construct synthetic seismograms press "**OK**". Sgraph constructs the specified Synthetic seismograms from the output file and consider them as new traces in ***Sgraph***.

For more information related to DWN refer to Bouchon (1981).

10.3 Modeling:

Function: Perform a complete waveform modelling tools by using genetic algorithm.

Here is powerful tools for matching the observed and synthetic seismograms and solve the different parameters of 1-D velocity model and focal mechanism corresponds to a set of observed seismograms. Abdelwahed (2006); and Abdelwahed and Zhao (2005) 2006) develop this technique originally for a single 3-component station by using a manual iterative technique to estimate the velocity structure beneath southwest Japan. In this version of ***Sgrap***h, the technique is provided after being improved to be applied on multiple of stations and to search the modelling parameters automatically by the micro-genetic algorithm. This makes the waveform modeling process faster and more stable.

The idea of performing the waveform modelling is to compare the synthetic seismograms constructed by using the GRT technique with the corresponding observed seismograms. The genetic algorithm is employed to handle the search over the entire velocity model or focal mechanism parameters. The genetic search is guided by the maximum cross correlation coefficient between the observed and synthetic traces. The micro-genetic (micro-GA) algorithm (Caroll, 1996) is used to handle a large parameter space of the velocity model parameters which is appropriate for the modelling technique.

General strategy:

The general strategy of the modelling routine is summarized as follows:

- Apply the ***GRT*** technique for the parameters inserted in the "*Modeling*" dialog and considered as initial values.
- Apply the genetic search algorithm starting from the initial values and search for the parameters that maximizes the evaluation function.
- The evaluation function is either the maximum cross correlations between the observed and synthetic traces or additional factor representing phase travel time residuals is added, as shown later.

To start the modelling process at least one trace should be plotted in loaded in ***Sgraph*** with full information. The trace represents observed traces to be modelled.

To handle the entire observed traces in the modelling, the distance, azimuth, number of points and component type are retrieved from the info buffer and could not be changed during the modelling process. The trace selections are held through a dialog similar to the record section dialog (see record section tool) in which the selection of traces from within the existing traces are to be made. The window of modelling is also selected by the same dialog in a way similar to the record section limits by either inserting the window limits in seconds or by mouse tool. The selected traces and the window limits can be changed any time within the modelling dialog box. This maintains the exclusion of the none-appropriate traces during the modelling. The modelling dialog box will appear once the selection is confirmed by OK button. This is shown below.

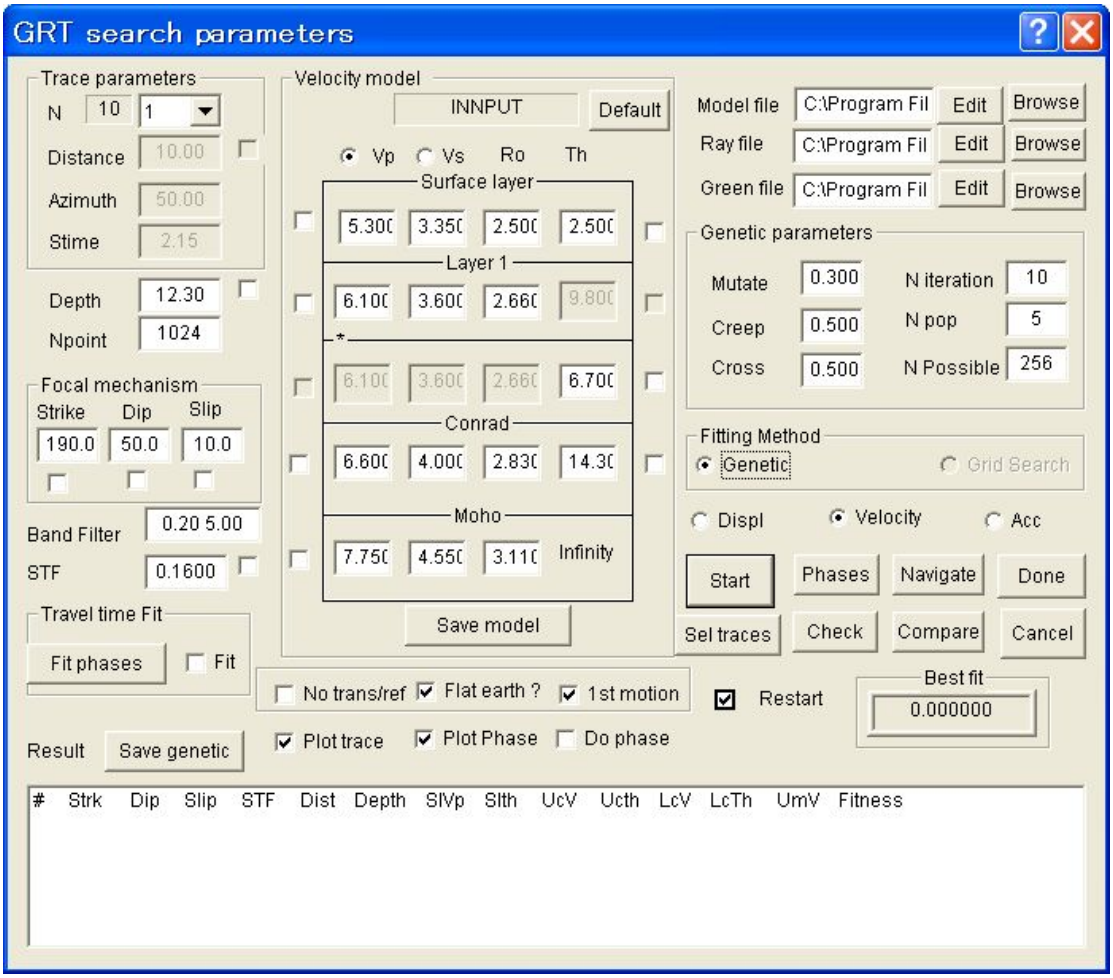


Figure 32: A typical screenshot of the Sgraph modelling dialog box.

This dialog box consists of all the requirements to perform the full waveform modelling process either manually or by using the Genetic Search. The first appearance of the modelling dialog box uses the default values of all the modelling parameters.

The data insertion in this dialog takes 3 forms.

1 – **Files names**: Input files: Model file, Ray file
Output files: green file
In all cases, the file name can be either browsed using the ***"Browse"*** button or edited using **"*Edit*"** button.

2- **Direct insertion of parameters:** Like velocity models, focal mechanism, STF, Filter, genetic parameters and others.

3- **Check and Radio boxes:** Used to switch on /off some process or assigning the active parameters.

The description of the parameters appears in the dialog box are shown in the following table:

Parameter		Description	Remark
Trace and hypocentral parameters	**Distance(s)**	Epicentral distance (km)	Retrieved from the INFO buffer
	Azimuth(s)	Azimuth (degree)	Retrieved from the INFO buffer
	Depth	Event Depth(km)	Retrieved from the model file and can be modified
Focal mechanism parameters	**Strike**	Strike value (degree)	
	Dip	Dip value (degree)	
	Slip	Slip value (degree)	
Velocity model parameters	**Vp, Vs, Ro, Th (Surface layer)**	**Vp**: P-wave velocity (km/s) **Vs**: S-wave velocity (km/s) **Ro**: Density (kg/cm3) **Th**: Thickness (km)	
	Vp, Vs, Ro, Th (Layer1)		
	Vp, Vs, Ro, Th (Auxiliary Layer)		This layer is where the source lives. It is considered the same as layer 1. It is added here just for the purpose of variable focal depth.
	Vp, Vs, Ro, Th (Lower crust)		
	Vp, Vs, Ro, Th (Upper mantle)		
Genetic parameters	**Mutate**	Mutation value	Range [0-1]
	Creep	Creep values	Range [0-1]
	Cross	Crossover value	Range [0-1]
	N iteration	Number of iteration	Default=10
	N pop	Number of population	Default =5
	N possible	N possibility/parameter	Range=[2^n] Default=128
Fitting method	**Genetic**	Use genetic algorithm	
	Grid search	Not used in this version	

The upper right corner of the dialog box receives the file names used in the modelling. The basis of the modelling process is the model and ray files. Those files are similar to those discussed above in the GRT tools. If the default model and ray file names are not

found, a warning message will appear. It is necessary to locate the names and paths correctly for all the files input or output used in the modelling. If the model file is successfully loaded, the velocity model boxes will be filled by the model values.

The upper left of the dialog exhibits the distance, azimuth, and starting time of the selected traces. Click on the combo box in the trace parameter part to switch to other trace parameter values. These values retrieved from the info buffer and can not be changed from this dialog. If required, modify the values from the info dialog box.

The middle left part shows the focal depth and number of points in the synthetic response (NPOINT). The focal depth is retrieved from the model file name. (See Appendix 3 and GRT user manual for model file format).

The number of point in response (NPOINT) should be selected properly. If NPOINT is smaller than enough, the synthetic will be short and will not exhibit the necessary phases. On the other hand, if it is large than enough, it is time consuming since a time will be spend to calculate response outside the window selected. In general, a value of 512 and 1024 are sufficient for short and large distance, respectively.

The focal mechanism part receives the strike, dip, and slip and the source time function of the synthetics in construct. The STF receives the width of a triangular source time function of the synthetic in construct. Fill in with the appropriate values.

The component (V, R, T) of synthetic is selected similar to the corresponding observed trace that is stored in INFO. The type of trace, Displacement, Velocity or Acceleration, should be properly selected to be similar to the type of the observed traces.

Model parameters:

The model parameters used in the modelling are the values in the velocity model boxes and the focal mechanism, STF, and depth. These are described in the next table.

	Parameter
Hypocentral parameters	Distance
	Depth
Focal mechanism	Strike
	Dip
	Slip
Source time function	STF

Velocity model	Surface layer Vp
	Surface layer thickness
	Upper crust Vp
	Upper crust thickness
	Lower crust Vp
	Lower crust thickness
	Vp (Upper mantle)
	Vp/Vs

- The check boxes in the vicinity of the modelling parameters are used to switch on the parameter need to be searched. At least one parameter should be checked before starting the modelling search. The genetic search will run over the checked parameters only.

The estimation of Vs is held through the Vp/Vs parameter. It is assumed that the Vp/Vs relation is fixed for the entire model. The radio button (Fix Vs) at the bottom of the velocity model part is used to keep the initial values of Vs fixed during the search. If (Fix Vs) is not checked, the Vs will be calculated as Vp/Vs relation entered. If Vp/Vs parameter is requested for search, the (Fix Vs) radio button will have no effect.

Model parameter space

The search space for the 12 model parameters are inserted through the following dialog box.

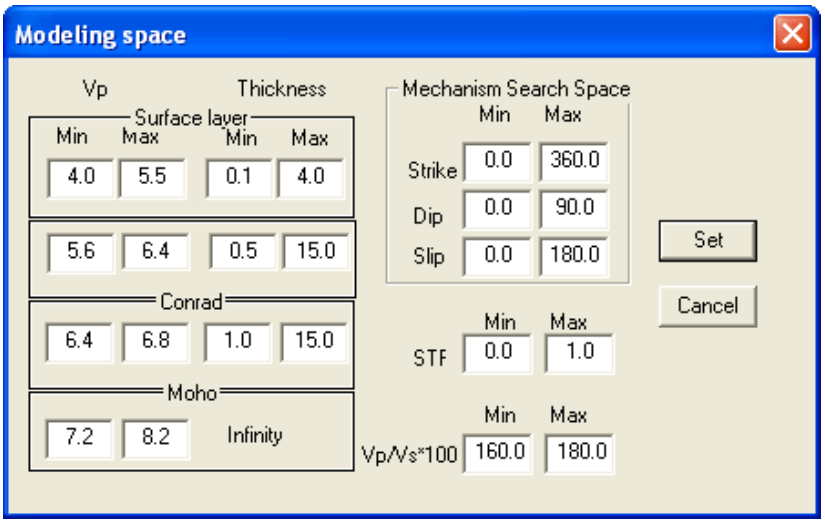


Figure 33: Typical dialog box of the model parameter space insetion.

Fitness function:

The objective function used in ***Sgraph*** is the normalized cross correlation function proposed by Saikia (2000) as a direct measure of the degree fitness between the observed and synthetic data. For i[th] station and j[th] component, the normalized correlation function is defined by:

$$C_{ij}(t) = \frac{O_{ij}(t) \otimes S_{ij}(t)}{\max[\sqrt{[O_{ij}(t) \otimes O_{ij}(t)][S_{ij}(t) \otimes S_{ij}(t)]}} \quad (1)$$

where, O(t) and S(T) the observed and synthetic seismograms, $\otimes$ denotes the cross correlation process. The denominator serves to normalize both the data and synthetic and the nominator makes the function insensitive to the absolute amplitude. Thus, for "nst" stations and "ncomp" components, the best-fit function is proposed to be:

$$Bestfit = \frac{\max\left[\sum_{i=1}^{nst}\sum_{j=1}^{ncomp} C_{ij}(t)\right]}{nst + ncomp} \quad (2)$$

Dialog buttons description:

The function of the modelling box buttons are as follows:

Button	Function
Start	Start genetic search using the current parameters
Phases	Conduct phase identification process for the resulted synthetics.
Navigate	Conduct navigation process for resulted traces.
Compare	Conduct Compare process for the observed and resulted traces with the active phases.
Done	Accept the current solution and return.
Check	Apply the GRT technique once for the inserted parameters.
Save model	Save the model in "MODEL" format
Save genetic	Save the genetic results shown in the result box.
Default	Load the velocity model from the current model file
Edit	Edit the file content by using notepad.
Browse	Browse the file name

Cancel	Cancel the process and return.

Start: Start the genetic search taking the parameter inserted as an initial trial. The process proceed until the N iteration reached (This process can not be interrupted). During this process, the dialog box is closed and the synthetic-observed comparison will be plotted with the corresponding model parameters and the fitness value. The parameters values appear in place of the info of the plotting graph. When the process finished, the synthetics corresponding to the best parameters are plotted, the new parameters are filled in place and the best fitness will be written in the *Bestfit* box of the dialog. The ***Restart*** check box is used to re-search or continue-search for parameters. If it is checked, the previous search memory will be removed and the genetic starts from the beginning. If not checked, the search continues to search starting from the last generation. This is useful to divide the search into several parts to observe the validity of the modelling parameters or the genetic behaviour.

Phases: Select phases from the ray nominated phases. This is used for the alignment of the correlation window and/or the phase joint inversion. A phase selection box will appear exhibiting the existence phases in the farthest synthetic. Select the desired phases as discussed in the *GRT* tool.

Check: Perform a one-shot modelling. The current parameters are used to construct synthetic seismograms and estimate the fitness value. The synthetic-observed comparison plot corresponding to the current parameters will be shown. The new parameters are filled in place and the fitness value will be written in the *Bestfit* box of the dialog.

Navigate: Apply the Navigation tool on a selected trace. Insert the trace index corresponding to the selected traces (not the real index). Do the navigation as discussed in the *Navigate* tool.

Seltraces: Reselect the traces for the modelling process. This close the modelling dialog box and open the trace selection box as discussed early in this part. Reinsert the traces to be used, reinsert window limits and press OK to return to the modelling dialog box with preserving the same parameters.

Compare: Apply the Compare tool over a selected observed-synthetic pair. Select the index of the desired observed trace (index of selection) and do ***Compare*** as discussed in the ***Compare*** tool.

Done: This is used after the satisfaction of the modelling. The new synthetics are considered new traces in the *Sgraph* to follow the "Accept, replace, Ignore" commands. For the importance of the phases produced in the modelling. It is possible to assign the phases to the corresponding observed traces during the acceptance of the synthetics. The important of this is the identification of the later phases on the corresponding observed traces.

Cancel: Cancel the whole process and redraw the original traces.

How to perform waveform modelling:

Step 1: GRT initial model

- Insert the appropriate velocity model (manually in the boxes or by browse)
- Insert the appropriate ray file to use.
- Insert the initial values of the focal mechanisms and STF and if required insert the filter values.
- Check boxes of the parameters need to be solved. At least one parameter should be checked before starting the modelling search. The genetic search will run over the checked parameters only.
- Press "***Check***" to do a one-shot modelling to have a preview of the resulted synthetics. Do the appropriate modification in the trace window limits by used "***Seltraces"*** if required.
- Try different parameters and velocity models until satisfied with the best initial synthetic.
- Use "***Phase***" button to conduct the phase identification routine to activate the desired phases. These phases are extracted from the green function of the farthest distance.
- Use "***Compare***" button to compare the observed with the synthetic traces overlying by the active phases. If the comparison is not acceptable, Change the different parameters manually from the dialog box and press "***Check***" to update.
- Use "***Navigate***" if needed
- When the synthetic is found suitable move to the next step.

Step 2: Do genetic search

- Insert the proper genetic parameters (mutate, cross, N iteration, N population... etc) for the genetic search.

- Switch on/off the parameters that need to be searched for. This is done by check/unchecked the box preceding those parameters. In other words, the genetic algorithm will only search for those checked parameters; the others will be kept constant. Total numbers of parameters that can be searched are 13 (see the table above).
- Press "***Start***", to start the search. Check the "***Restart***" button to clear the previous genetic searches. If "***Restart***" button is not checked, the genetic search will continue from the last iteration result. Don't change the searching parameters in this case. During the search, the resulted synthetic traces will be plotted with. The search can not be interrupted.
- Once the search finished, compare the resulted synthetic with the observed using "***Compare***".
- If the results are not good enough, change the initial values or/and the genetic parameters and try again.
- If the results are acceptable. Save the resulted model using, "***Save model***" button. Save the genetic result if needed using "***Save genetic*** "button.
- The resulted green's function will be saved in the ***green files***.
- Press "***Done***" button to accept the resulted synthetics and move to the accepting procedures of ***Sgraph***, to decide either *Add*, *Replace* or *ignore* the resulted traces.

Additional option.

Travel time joint modelling:

The above tools deal with the waveform as the only source of the propagation path information. However, the genetic algorithm needs additional information on the arrival phases to increase the efficient of the search. This is strongly needed when too much parameters are searched or in the case of the trade off.

How it works:

The idea is to use the arrival time value of a given phase or (phases) say "Pg" and use in the evaluation function of the genetic search.
Normally, the theoretical travel times of the phases included in the Green's function file are calculated with correspondence with the new synthetic. If this option is used, the evaluation function of the genetic algorithm will become a combination between the cross correlation and the ***rms*** of the observed and theoretical travel times. This will

force the genetic search to look for the synthetic whose arrival phases are closely to the user insertion and in same time has a good matching with the observed trace.

How to do:

- Check the "***Fit***" button from the travel time fit area of the dialog box.
- From the Combo box, select the phase name of which the travel time value is to be inserted. Here you can use many phases as long the travel time values are accurately known. The available phases are as follow:

(Pg, Sg, P*, PcP (Conrad reflected), Pn, PmP, pP, pPcP, pPmP, sScS, SmS, sS, sScS, sSmS).

- Insert the travel time of the selected phase in the text box just to the right,
- Repeat the last 2 steps for other phases if needed.
- Select the desired parameters to search following the above section and press ***"Start"***. Make sure the "***Fit***" button is pressed while the genetic search is working.
- Only phases of none-zero travel time values will be used in the evaluation.
- Press "***Reset***" button for zeroing the travel time value of all phases.

Important notes for waveform modelling:

- Don't use a large iteration number or population number in the genetic search. The process can not be interrupted and may take too much time to finish. The total number of GRT running in the genetic search is N population* N iteration. In case large number of iteration is needed, divide it into parts while uncheck the "***Restart***" button.
- Avoid using Ray file of big number of rays. That will slow down the ***GRT*** routine and accordingly, slowing the genetic search.
- Avoid using too much searching parameters. This will increase the chance of the trade off in the search.
- Avoid using a large correlation window, this will slowing the process.
- The genetic algorithm will use the same number to point in the synthetic trace you used in the first step. This can not be changed in the Modelling Dialog.
- The focal mechanism and the velocity model can not be solved instantaneously in one search. It produces a trade off.
- If the observed trace is not suitable for the synthetic parameters used, the search will fail.
- In case the travel time fitting option is used, avoid using too much phases. These will miss-guide the search if they are not accurately inserted.

10.4 EMPIRE (for restricted versions only):

What is EMPIRE ?

Empire is a tool to calculate the empirical Green's tensor derivatives (EGTD) from weak events (Vladimir Plicka). This tool inverts the time domain traces of weak events recorded at a specific station. The simulation of a seismogram of user defined focal mechanism is also provided.

How to do EMPIRE

- Select the time domain traces of a specific station by using the open station tool, or from multi SAN files.
- Make sure that the Event and station information is correctly inserted in the INFO dialog box, if not fill it correctly.
- Click Dist/Azim button to calculate Distance and azimuth of traces (if not calculated).
- Pick the first onset of all traces including the Polarity by using the ADD/Pick tool. (See Picking section in this manual for detail).
- Select SYNTHETIC/EMPIRE menu.
- Insert the traces and window needed to be used in EMPIRE (same as modelling part in Sgraph, see Modelling part in this manual).
- Once the traces are selected, the inversion will start internally and the resulted EGTD will be shown (this process consumes some time depending on the window length and number of traces used).
- The synthetic Dialog box will then be given. Fill in the appropriate values of the focal mechanism parameter to construct the corresponding synthetic seismogram.

10.5 ASPO (for restricted versions only)

What is ASPO ?

ASPO is a tool to determine the focal mechanism of a set of (source-station) paths by using the **A**mplitude **S**pectra and **PO**larity technique (Zahradnik et al, 2001). ASPO search for focal mechanism and moment values for the best-fit Observed-Synthetic traces. The technique is proven to be powerful, insensitive to crustal model.

For more detail, See, Zahradnik et al. (2001).

How to do ASPO

- Load the traces needed to be solved.
- Make sure that the Event and station information is correctly inserted in the INFO dialog box, if not fill it correctly.
- Click Dist/Azim button to calculate Distance and azimuth of traces (if not calculated).
- Make sure that the component box in INFO is correctly inserted for all traces. (ASPO only accept ZRT and ZNE components).
- Pick the first onset of all traces including the Polarity by using the ADD/Pick tool. (See Sgraph user manual for detail).
- Select SYNTHETIC/ASPO menu.
- Insert the traces and window needed to be used in ASPO (same as modeling part in Sgraph , see Sgraph user manual).
- The ASPO dialog will now appear:
    - Fill in the box you find related to event information and filter bands. (Defaults are the ASPO default values).
    - Make sure that response file exists in the working folder, otherwise browse on it.
    - If response is unchecked no need to do this.
    - Make sure the crustal structure exists in the working folder. This should be prepared according to the area of study. Formats should be same as the "CRUSTAL.dat" provided in the synthetic folder here.
    - Press OK
    - If the things going well, you will have the CHECK ASPO windowing plot in which the Observed before and after processing is shown to be checked. If the traces appear appropriate, press Next/Accept all. If not press return to repeat the trace selection.
    - The processed traces used in ASPO are saved in:
        - time traces : ***_t.dat where ***: trace name
        - frequency traces: ***_f.dat where ***: trace name

  - Wait for a while in this step, the green vectors need time to be constructed.
  - Once finished, the synthetic spectrum will be displayed for the 1st 10 receivers (Z-component only) to make sure that the synthetic seismograms are reliable.
- The grid search dialog will now appear:
- Fill in the frequency band within which the error is to be evaluated.
- Fill in the grid search limits for strike dip and slip (coarse and fine search).
- In the next step, the comparison between the observed and synthetic spectra for the decreasing errors search once the coarse search ended.

The best values are selected according to polarity distributions and the fine search will proceed to fine search the least error in the fine range.

The best-fit synthetic traces are saved in:

time traces	***_t_best.dat	where ***: trace name
frequency traces	***_f_best.dat	where ***: trace name

The Nodal.dat file constructed by ASPO will be displayed on the screen.
The best values of strike, dip, slip, and moment will appear in a dialog box.

  - Press TRY AGAIN to repeat the search with other parameters.
  - Press accept to return to SGRAPH main screen.
  - The intermediate files will be deleted at this stage to save the storage space.
  - Press plot synthetics to plot the best-fit time domain synthetic traces.

- Files created by SGRAPH ASPO
  - ALLMOM.dat: contains all the grid search trials with errors, best moment is included.
  - BESTMOM.dat: contains the trial of the minimum error for all frequencies, from here the moment is evaluated.
  - VSE.dat: best trials within 5% error range
  - ZNA.dat : best polarity and amplitude (VSE.dat) satisfying solution
  - ZNA_OPT.dat : Best polarity satisfying solution
  - NODAL_OPT.dat : Nodal planes from ZNA_OPT.dat file
  - NODAL_BEST.dat : Nodal planes best of ZNA_OPT.dat file

For make sure of the reasonability of the solution.

- PLOT the files ALLMOM.dat, BESTMOM.dat, VSE.dat, ZNA.dat, ZNA_OPT.dat in the "SEARCH.GRF" file provided with this package.
- Inspect the global minima of the different parameters within the search and the satisfaction of polarities and amplitude.

10.6 Model to GRF:

Convert the crustal model file format used in the GRT routine into an appropriate plotting format. This tool is used to plot the initial and final velocity model used in the modeling.

How to do ?

-Insert /browse the INNPUT file.

- The output file name with have the same name with the extension 'DAT'.

The resulted file is a XYZ file representing, Depth, VP and VS. It can be plotted in Grapher application as velocity model steps..

10.7 Path to BLN:

Construct a BLN file corresponding to the selected Source-receiver paths. This is used to make a post map file for the traces used in modelling to be plotted with the base map in plotting software.

How to do

-Insert /browse the desired trace(s)

-Insert/browse the output file name (without extension)

The resulted file is a BLN file used directly in a Surfer application as a base map file.

11 Attenuation

(for restricted versions only)

I*n* this menu, a set of tools for seismic Attenuation studies are included. Those studies uses the waveform of the respected traces to estimate either the Quality factor of Shear wave (QS) or the Coda wave attenuation (Qcoda) or an approach to separate the scattered attenuation and the intrinsic attenuation in the Multiple lag time widow (MLTW) technique.

11-1 Qs Spectral ratio: Single station method, Giampiccolo et al., 2007)

The observed amplitude (A(f)) of body wave at frequency f can be related as:

$$A(f) = Ao(f)R(f)e^{-\Pi ft/Q} / r$$

Where, Ao spectral amplitude at the source, R, site response, r source-receiver distance. Having assigned two frequencies f1, f2 , we have the following

$$\ln\frac{A(f1)}{A(f2)} = \ln\frac{Ao(f1)}{Ao(f2)} + \ln\frac{R(f1)}{R(f2)} - \frac{\Pi(f1-f2)t}{Q}$$

Ao, and R are independent on travel time t, thus, the above function plotted versus t will display a slope of -π(f1-f2)/Q. See Giampiccolo et al, (2007) for detail.

thus, using the SVD method in Sgraph, Q can be solved.

How to do:

- Fill in the following dialog box with the appropriate frequencies. Here f1 varies from low to high frequency band. f2 is constant.
- Fill in the output file name
- Insert the trace indices to use.

The FFT of the selected traces will be shown and the output file is written.

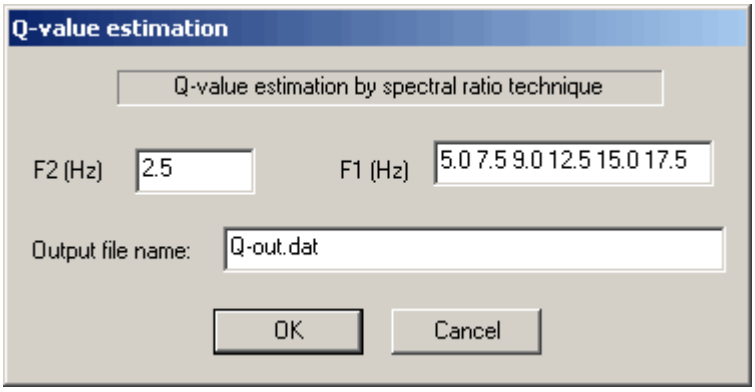


Figure 34: Typical dialog box of the Quality factor estimation.

11-2 MLTW (Multiple Lag Time Window technique, Hoshiba (1993)

MLTW overview

The basis of the MLTW technique (Hoshiba, 1993) is to measure the seismic wave energy as a function of distance and frequency for three consecutive time windows defined on the seismogram of a local event, starting from the S-wave onset. The window length is chosen in such a way the first window contains a significant contribution of the direct S-wave energy and the last two windows mainly contain the contribution of the scattered energy. The integrated seismic energy for the three time windows is calculated by measuring the rms amplitudes over bandpass filtered seismograms. Each integral is normalized according to the coda-normalization method (Aki, 1980) to correct for different source and site amplifications (Giampiccolo et al., 2006; Goutbeek F.H., 2004).

The MLTW method, not only calculate the Q coda attenuation factor but also, separate the scattering attenuation from intrinsic absorption.

The attenuation due to intrinsic absorption and scattering can be characterized by the extinction length **Le**, the distance over which the primary S-wave energy is decreased by e^{-1}, and the seismic albedo, Bo, the ratio of the scattering loss over the total energy loss (Wu, 1985):

$$Le^{-1} = (Qs^{-1} + Qi^{-1}).\ 2\ \pi\ f\ /\ v$$

$$Bo = Qs^{-1}/Qt^{-1}$$

Refer to Hoshiba et al., 1991, Hoshiba, 1994, Goutbeek et al., 2004. The energy ratio of the three windows with respect to constant lag time window reference (i.e. E(w1)/E(wref), E(w2)/E(wref), E(w3)/E(wref)) representing the behavior of the coda wave attenuation with respect to distance and reveal the values of Le-1 and Bo. Sgraph estimates the Le-1 and Bo values by using the Genetic Algorithm.

The full algorithm to conduct the Multiple Lag Time Window technique is inserted in Sgraph and can be applied to any analysed traces to estimate the Qcoda attenuation and separates the intrinsic and scattering attenuation in terms of Q_t, Q_s and Q_i.

How to do

Prepare a set of analyzed traces belongs to on earthquake and do the following:

- Pick P and S- Phases.
- Import the corresponding SUM file if needed.
- Do Dist/Azim calculation to calculate distance and Azimuth if not yet done.
- Sort the entire traces with respect to distance from (graph/sort menu) to check the phase slowness with distance.
- Do the instrumental correction for the entire traces.
- Save the analyzed traces as SAN file.

Repeat the above steps for the entire set of earthquakes need to study the attenuation and follow the steps below for every SAN file individually:

- Click on Attenuation/ MLTW menu
- Select the appropriate traces to use in this approach. Select the traces according to the maximum distance available in the whole SAN files that will be used.
- Fill in the MLTW dialog box that will appear (description is shown below).

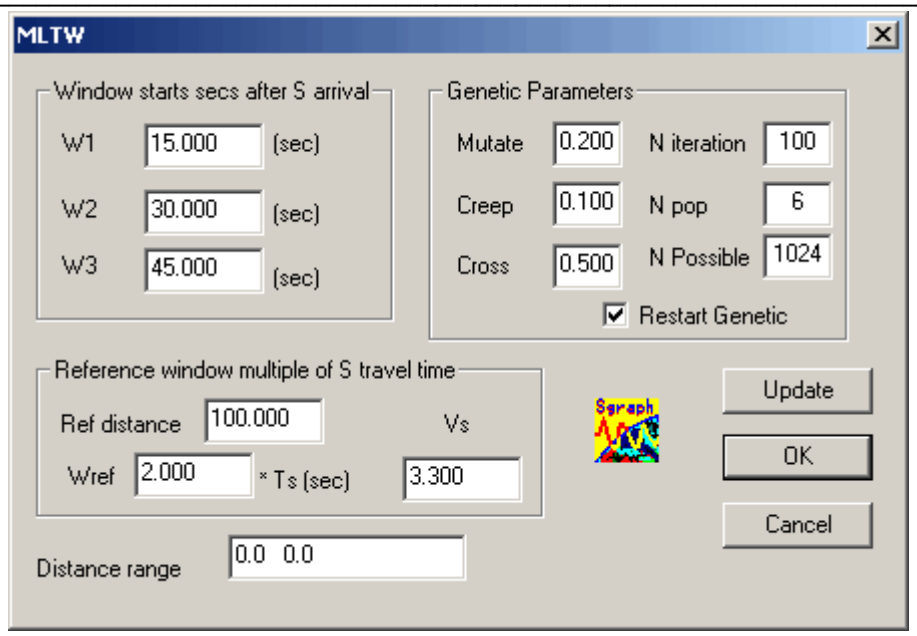


Figure 35: Typical screenshot of the MLTW dialog box.

Where:

- **W1, W2, W3** are the end limits of the three windows starting from the S arrival. The default values are the optimum values proposed in the method.
- **Genetic parameters**: Control the genetic search (same as the Modeling section).
- **Reference window**: Assign the reference window starting time to be at a constant lag time to all the traces.
  - **Ref distance**: The maximum distance at which the attenuation need to be estimated.
  - **Wref**: Reference window lag time relative to S-wave arrival. Default is 2 sec. If Wref = 1, reference window starts at S-wave for the maximum distance trace.
- **Vs**: S-wave velocity.

Press update to check the validity of the inserted values of windows parameters, the following plot will be shown

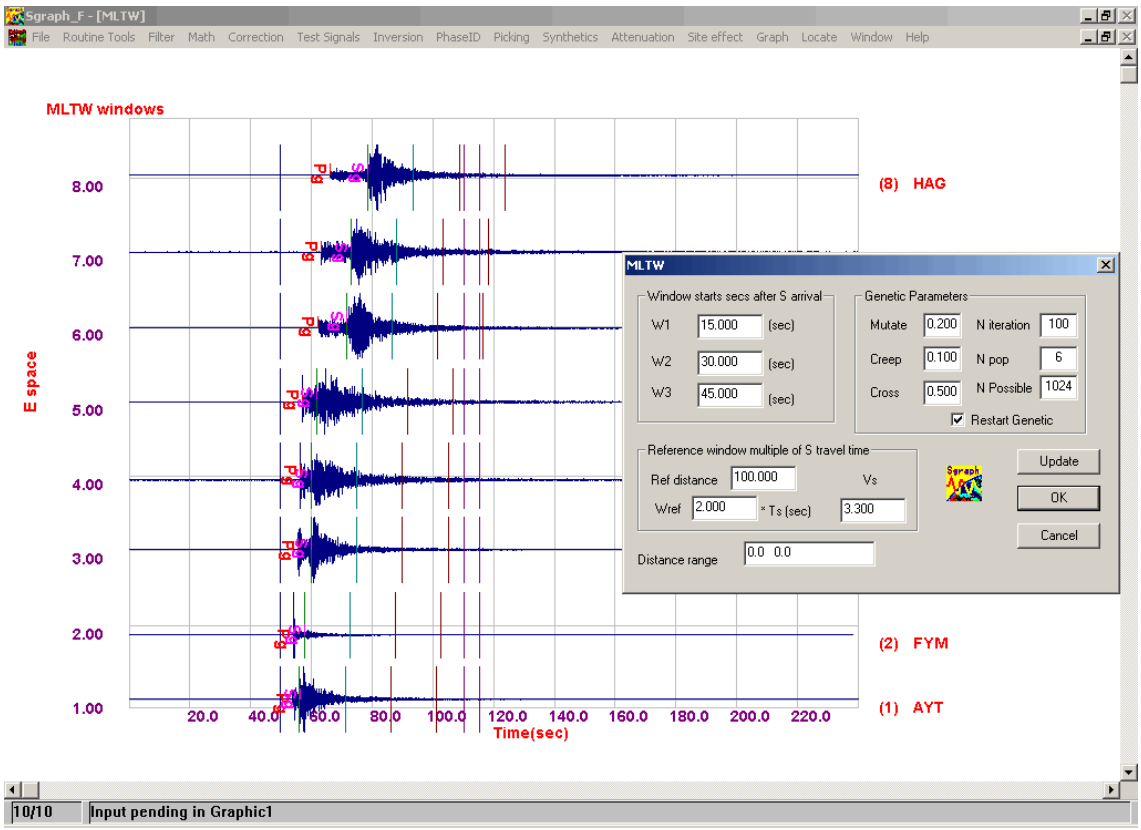


Figure 36: Typical screen-shot of selected traces used in the MLTW tool and the corresponding windows limits.

- The first line mark in the above figure is the O.T mark. The three windows are represented by successive lines. The reference window is a smaller window with the purple color.
- If the window limits are acceptable, press OK.

- The E(wi)/E(wref) values of the selected traces will be plotted versus hypocentral distances and the genetic search will starts according to the genetic parameters inserted until reach the best values of Le^{-1} and Bo that fit the observed. From these best values, the Qi, Qs, Qt will be calculated. A typical example of Energy curves is shown in the next figure.

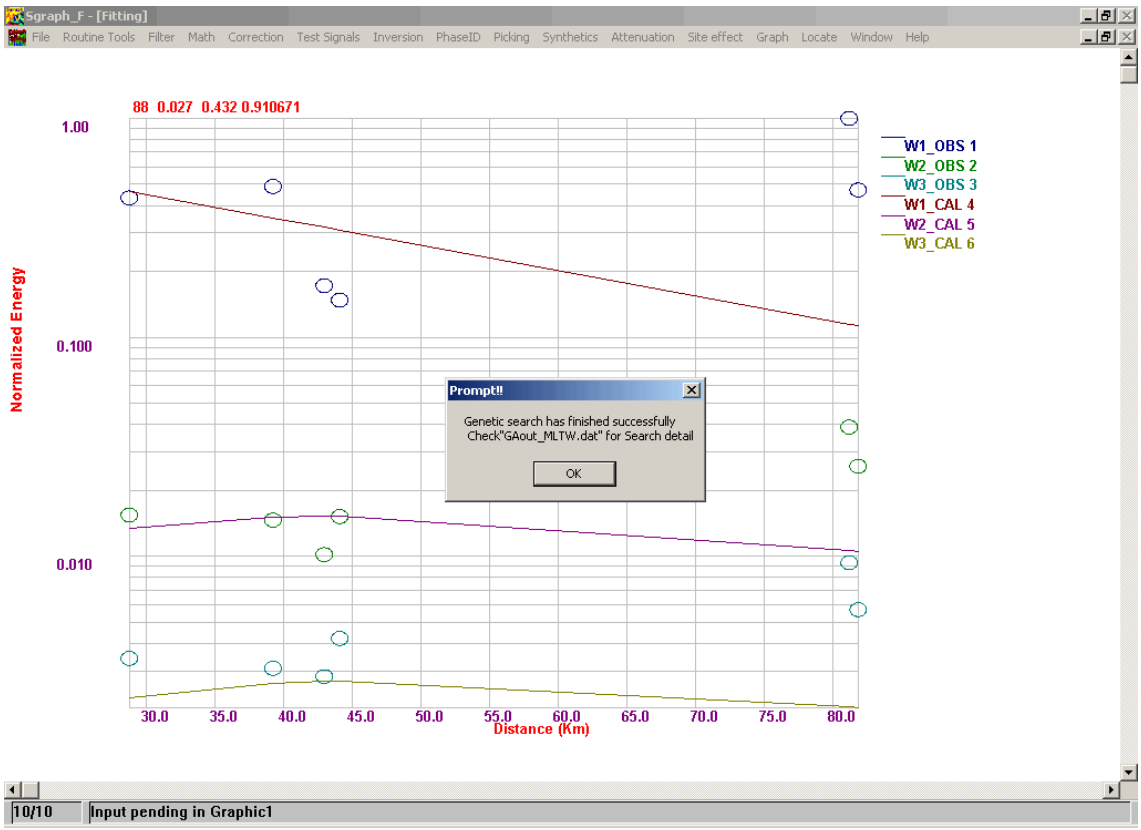


Figure 37: Typical screen-shot of the MLTW result. Circles represent observed data, lines represent the best-fit curves.

- For frequencies from 1 to 24 Hz, the Qt, Qi and Qs are estimated. Sgraph fit the Q vs frequencies by using the Marquard inversion tool. This reveals the Qo and n values. A typical example of Q-Freq fitting is shown below.

- All the above processes are saved in a file having a name of ***Qcoda_res.dat. Where *** is the event time tag. The genetic results are saved in 'Gaout_MLTW.dat' file.

The *Qcoda_res* file consists of all information required to plot the Energy curves and Q –Freq. Curves either the observed or the calculated ones. It can be used to plot the result in another Plotting program. DONOT MODIFY THIS FILE. It will be used in the next steps.

Repeat the above processes to all other SAN files of the different earthquakes.

The following figure shows the Q-freq best-fit curve for the last frequency (24 Hz). The dialog box summarizes the entire MLTW results including the Le^{-1}, Bo and their corresponding Qs, Qi, Qt for the frequencies 1,3,6,12,20, 24 Hz. The resulted Qo, and n are also provided with their rms error. All this information is stored in the 'Qcoda_res.dat' file.

To complete the MLTW technique, combine the Qcoda_res files in one file. This is done by using the MLTW_INV menu described below.

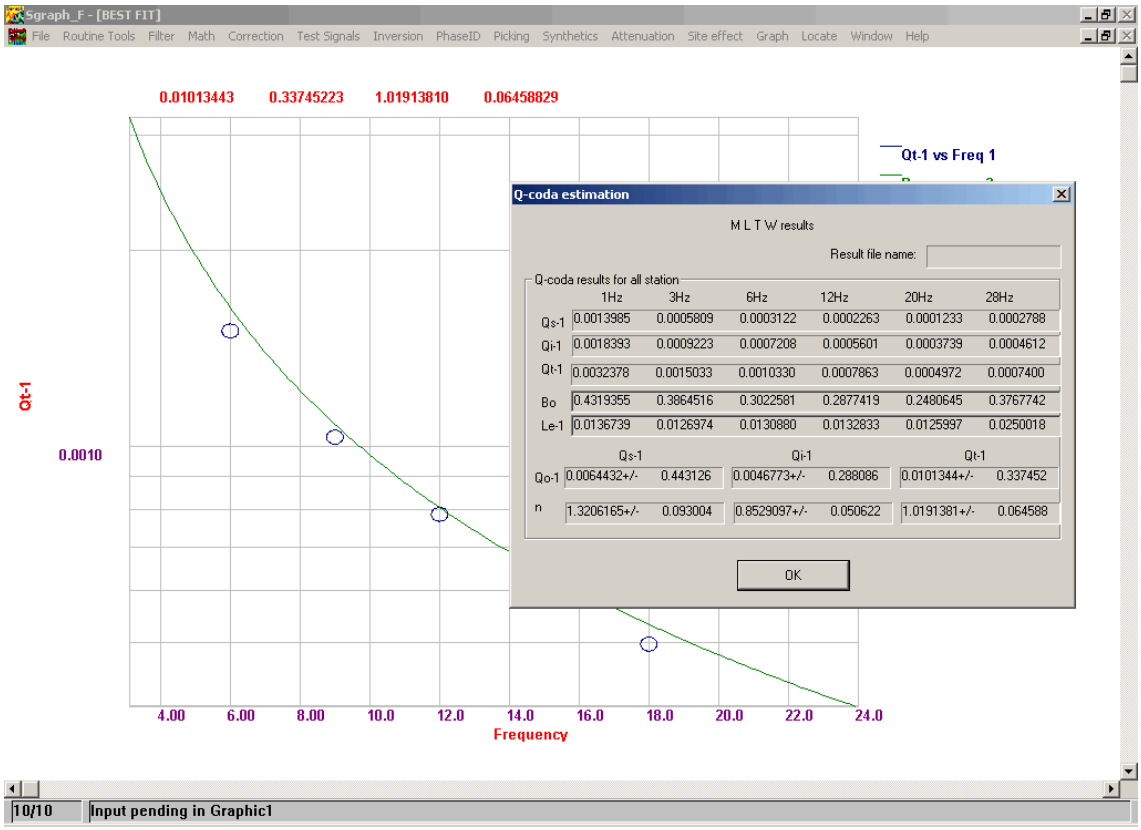


Figure 38: Typical screen-shot of the Q-freq. best-fit curve with the entire MLTW resulted parameters.

11-3 MLTW_INV

Combine a set of *Qcoda_res* files to a one file and do the inversion as the above.

How to do:

- Select the *Qcoda_res* files that have been done in the previous step.
- Fill-in the appropriate genetic parameters for the inversion.
- Watch the searching process for all the 5 frequency values and press OK in the given dialog box.
- Watch Q-Frequency fitting plot for the three windows.

At this step, the Attenuation parameters have been solved.

The resulted values of all the process are stored in the file"MLTW_res.dat".

N.B.

• *The selected traces used in the MLTW tool should be of epicentral distance less than the reference distance.*

• The event information, particularly the Origin time, of all traces should be accurately inserted.

12 Site effect

(for restricted versions only)

Function: Estimates the site effect by :

- **Inversion method, Moya et. Al., (2000)**

12.1 Inversion method

Review of the method:

If the observed spectrum of a given station is O(f) and the source spectra are S(f), the site response G(f) can be expressed as:

$$G(f) = O(f)/S(f)$$

The method is based on the estimation of the best Omega-square models S(f) that fit the observed traces of single station and different events. This reveals the common site effect of this station. For more information refer to Moya et al. (2000). Sgraph in this tool applies intensive genetic algorithm scheme to search for the large space of unknown parameters of number equal twice the number traces. This done by using the '**Inversion method**' menu

How to do:

Prepare a set of traces of single station different events. Each trace should have accurate information of source and station (to see how to open traces of a specific station see ***Open Station*** section in the ***File*** menu). Pick P and S arrivals in all traces and save it to a SAN file then do the following:

- Select the appropriate traces by using the record section dialog box given.
- Select the window limits to be in the S-wave part by assigning the desired window length starting from the existing S phase (see ***Record Section*** section to see how to do this).

- Press update to check the validity of the selected traces and window limits. If accept the selection, press OK.
- Fill in the Site effect dialog box, as follows:

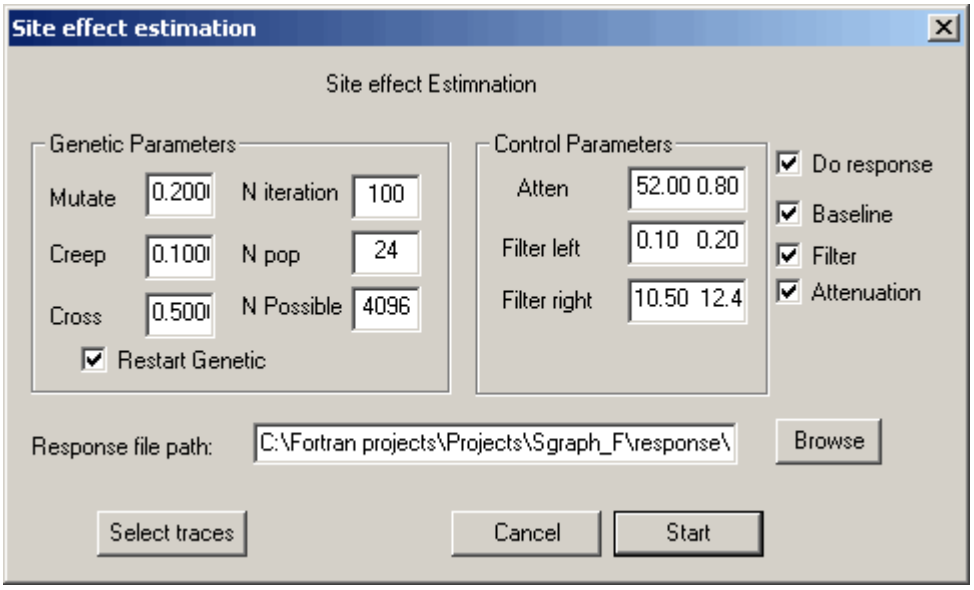


Figure 38: Typical Site effect dialog box.

The Genetic Algorithm parameters are the same as Modeling, and MLTW sections. Check the boxes to activate the Response correction (if not done), Baseline correction, Filter, and Attenuation. Browse the response file for all stations used (in case the ***Do response*** box is checked). Write the appropriate values of filter and attenuation if required. **Atten** is the Qo, eta values. To reselect traces, press ***Select traces.*** After confirmed the inserted values press ***Start***

.

- The FFT of the selected traces after the response, filter and attenuation correction will be shown in overlay plot. In case the FFT shape is not acceptable, or traces need to be reselected, press ***No***. if the FFT is acceptable, press ***Yes.***
- The genetic algorithm will start to optimize the best source spectral parameters for every trace and plot the Site effect plot for the best fit trials. When stopped, the GA results and the solved parameters will be saved as 'Gaout_site.dat'. The average resulted site effect is shown and saved as 'site_rep.out'. The resulted site response can be added to the Sgraph traces or ignored.

This process can be repeated several times for different stations for better results.

N.B. The resulted files, (Gaout_site.dat, site_resp.out) will be overwritten in every trial.

13 Graph

This menu consists of all routines related to trace plotting

13.1 Draw All

Function:

- Redraw all traces exit in ***Sgraph*** in a long window

Note: ***Sgraph*** may need a few seconds to Redraw 99 traces of maximum limit of data points. Try to avoid using this option when ***Sgraph*** is full loaded (time consuming). Instead use the ***Draw Spec*** menu in which a specific trace index is plotted. See notes in next menu.

13.2 Draw Spec

Function:

- Draw a specific trace(s) index in the working window

How to do:

The data insertion for this function is either single or multiple values.
Insert trace(s) index to be plotted

- If single number is inserted, this will be considered the index of one single trace to be plotted.
- If multiple numbers (following the typing rules) are inserted. It will be considered the set of selected traces to be plotted.
- Again "0" to plot all traces.

N.B.

- *Plotting a big trace in Sgraph is a time consuming. A single Max points trace may take 10s second to be plotted. It is a non interruptible job. In this case it is recommended to draw only the important traces to proceed your work in Sgraph smoothly.*
- *By default, after every process in Sgraph only the 1st 10 traces are plotted.*

13.3 Multitrace

Function: Display traces in sequence with a specific intervals.

How to do:

- Insert the desired trace(s) index to plot. The number of traces you insert will be the number of traces per window.
- Insert window limits in second. Should be in the time range of the plotted traces. "0" to plot all time range.
- The requested traces will be plotted in one window.
    - ✧ Press **Left Click** mouse button for the next group of traces (Endless cycle). The number of traces to display in each cycle is the number of traces selected.
    - ✧ Press **Right Click** mouse button to exit.

13.4 Overlay

Function: Plot traces overlaying each other in a single graph with common X and Y scale.

Every trace will have a different color, legend will be shown at the rightmost part of the graph.

- Insert the desired trace(s) index to plot.
- Press **Right Click** mouse button to exit.

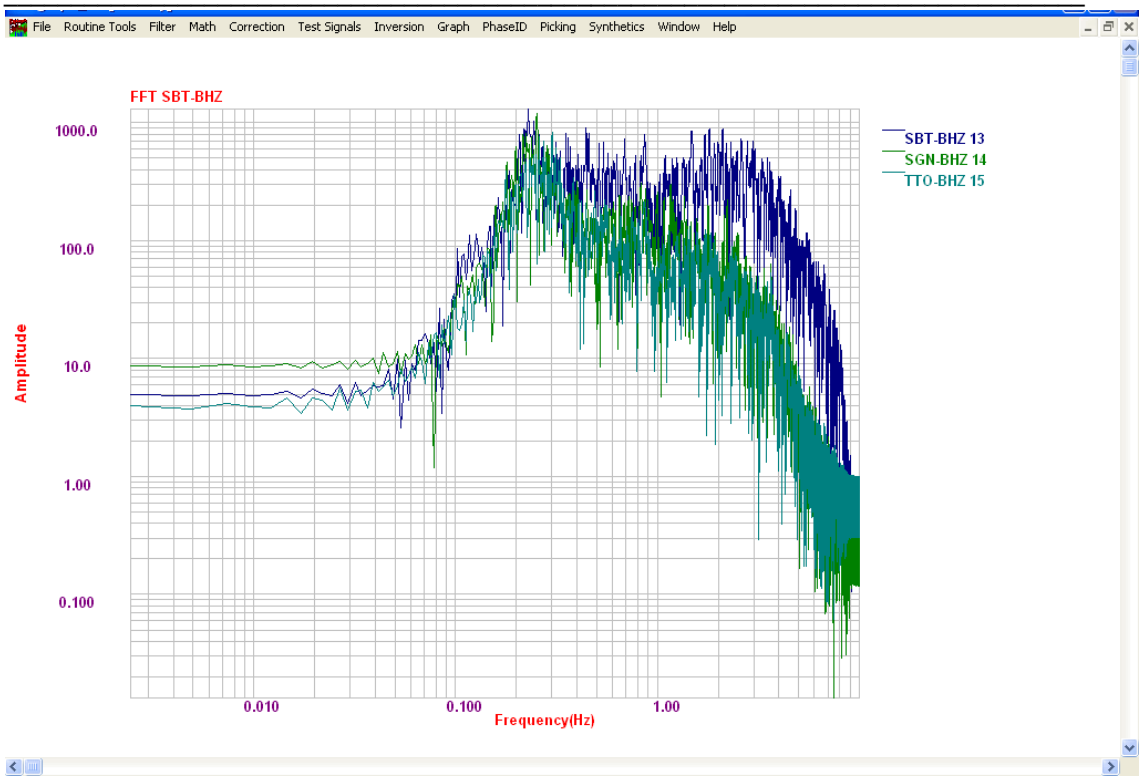


Figure 39: A Typical screen-shot of an overlay plot.

13.5 Record section

Function: **Plot the record section of the selected traces.**

Tool for plotting traces with respect to distance, Azimuth or Equal spacing.

How to do: Fill in the record section dialog box parameters.

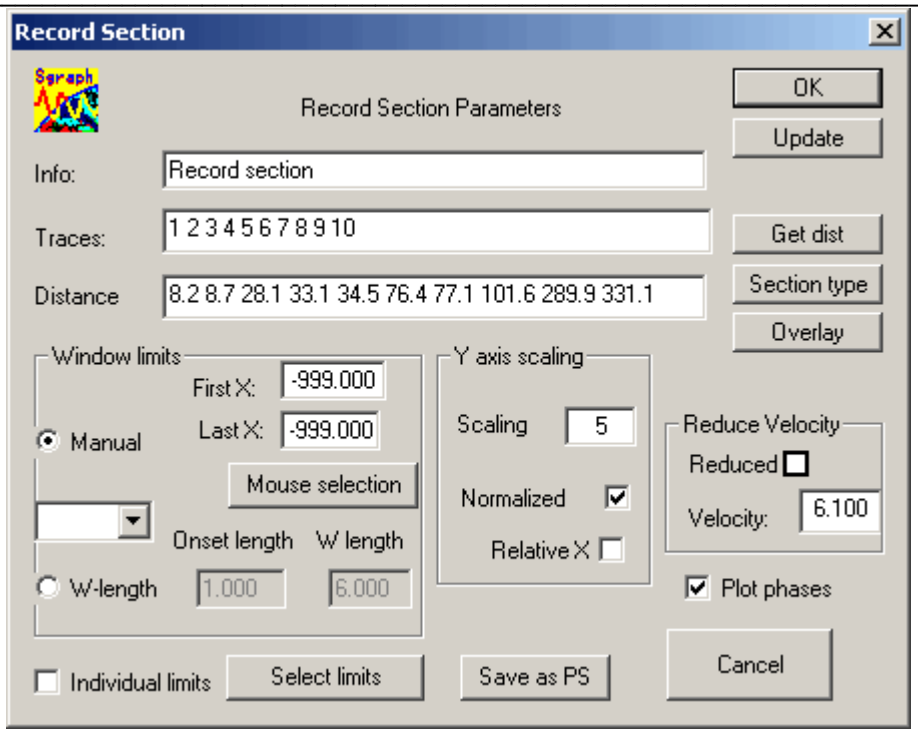


Figure 40: Typical Record Section dialog box.

- Insert Record section title (optional)
- Insert traces in sequence
- Insert the corresponding distances in sequence. Press "***Get dist***" to retrieve the stored distances from ***Info***. Or insert the desired values.
- Insert Window limits:
  - Use ***Manual*** to insert the minimum and maximum limits of the common X-axis.
    - Insert traces Min x-axis limits in sec. (-999=all).
    - Insert traces Max x-axis limits in sec (-999=all).
      Or. Use mouse selection to select two limits of the desired window (similar to ***Zooming*** menu).
      - In mouse selection mode, a right-click will reset the limits to the original state.
  - Use ***W-length*** to insert limits relative to the first picked phase in each trace.
    - Insert Onset length (sec). Time before the 1st picked phase in each trace
    - Insert W length (sec). Time length of that trace(s).
    - If a trace has no phases, this length will be applied on the first sample of the trace.

Traces out of the selected limits will be omitted.

In case the desired window length is not uniform or the above window limits tools are not appropriate, check '***Individual limits***' and click the '***Select limits'*** button. This will maintain the selection of window limits for every trace individually by using mouse.

- Insert scaling factor [1-9] to increase/decrease the trace amplitudes and improve the trace appearance.
- Check "***Normalized"*** to normalize the plotted traces. If not checked, traces will be plotted relative to the 1st plotted trace in the section.
- Check "***Relative X axis"*** to force the whole traces to follow the time axis of trace 1.
- Check "***Reduced"*** to reduce traces with inserted reduced velocity.
- Use section type to select the type of the plotted section, either *Distance*, *Azimuth* or *Equi-spaced* plot. Default is distance.
- Check "***Plot phase"*** to plot the traces with the corresponding phases.
- Press "***Update"*** to see the record section plot. Re-insert or modify values for the convenient view.
- Press :***Show info***" to display info dialog box to check traces information.
- Press :***Spec traces***" to use traces of specific characteristics (station name or component, specific event, etc..
- Press ***Overlay*** to plot a "Time-distance" data from an external file overlaying the section.
- Press: ***Save as Ps*** to save a copy of the entire section in a Postscript file.

- After plotted the record section, use redraw to plot the original working window. This is not automatically redrawn to allow printing the screen if needed.

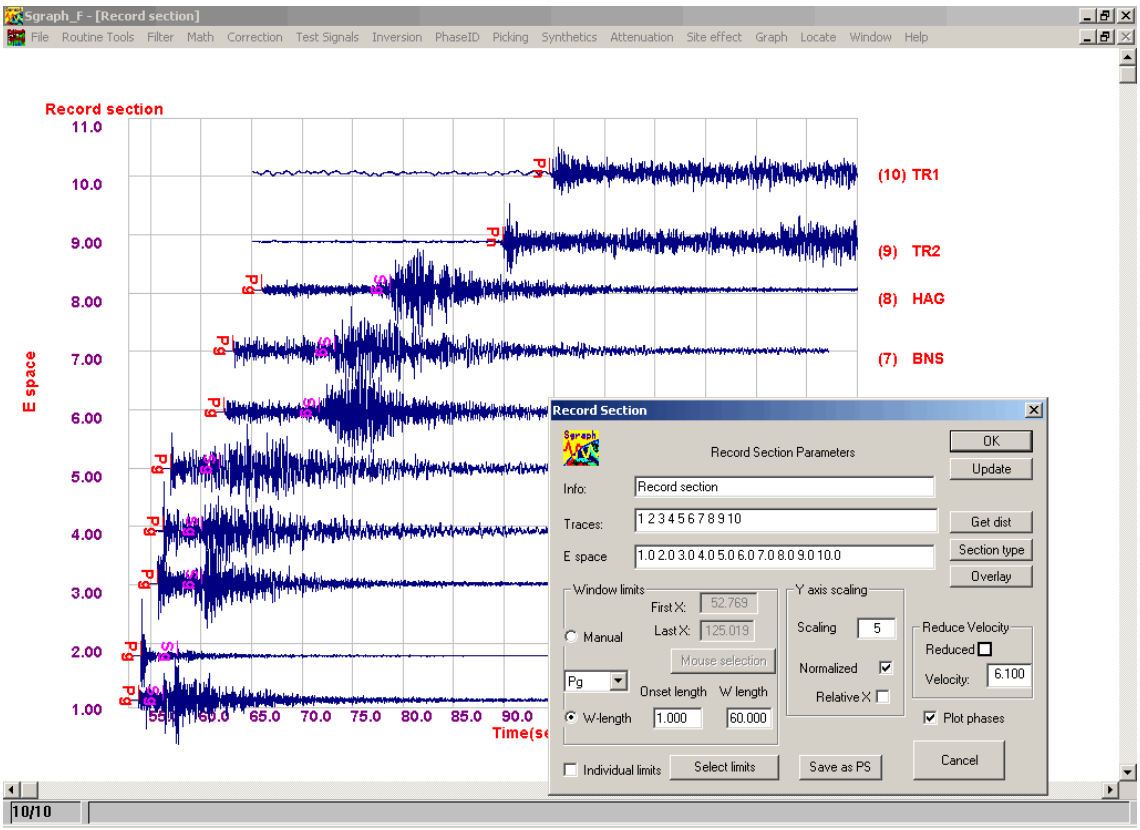


Figure 41: A typical screen-shot of an equi-spaced record section of 60 sec window limit.

13.6 Rearrange

Function: **Rearrange traces**. Replace or exchange trace positions within the window.

How to do:

- -Insert the indices of the 2 traces to be rearranged in a format "From-To".
  - ✧ 1st number is the current index of the trace needed to be moved (INDX1).
  - ✧ 2nd number is the trace new index (INDX2)
- -Select either "Insert" or "Exchange".
  - ✧ Press ***"Insert"*** to move trace INDX1 directly after the trace (INDX2).

✧ Press ***"Exchange"*** to exchange the position of the traces INDX1 and INDX2.

13.7 Sort

Function: **Sorting of traces with respect to Distance, Azimuth or Name.**

-Select the desired sorting parameter from the Combo box given.
-***Sgraph*** retrieves the required information from the ***Info*** buffer.
- The entire traces in ***Sgraph*** will be sorted with respect to the selected sorting parameter.

13.8 Merge

Function: **Merging two traces in one time scale.**

How to do:
-Insert the indices of the 2 traces to be merged. The second trace will be merged after the first one.

This merging routine is also called during the opening of a filename that has similar name of the current plotted traces. In this case ***Sgraph*** asks for (***Merge, Open new, Ignore***).

Merge: Merge and replace the existing trace.
Open new: Add the trace with the same name.
Ignore: The new file is ignored.

13.9 Align

Function: **Aligning traces relative to a selected position.**

How to do:
Insert the indices of the traces to be aligned.
- Locate by mouse the desired time to be aligned in each trace.

All the selected traces will be aligned leftward or rightward relative to the first trace.

N.B. –Data values outside the plotting window will be lost. And new points of zero amplitude will be added to complete the data alignment.

* - *Time scale of the original traces can not be recovered.*

13.10 Navigate

Function: Navigate through a selected trace by stretching the Axis ranges and moving Forward/Backward along the trace.

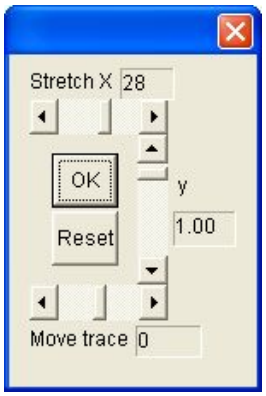


Figure 41: Navigation dialog box.

How to do:

Follow the navigation dialog box buttons:

Vertical bar: Increase and decrease amplitude.

Upper horizontal bar: Stretch and Compress the horizontal axis.

Lower horizontal bar: Moving trace forward and backward.

Reset: Return to the original position.

- **Press OK** button to close the navigation dialog and proceed the work in Sgraph.

N.B. X,Y values of the mouse position is displayed in the lowermost window message box

---

13.11 Compare

Function: Comparison of two traces. The two traces are overlaying and one is displaced over the other.

How to do?

- Insert 2 traces indices to be compared.

- Zoom along the first trace until the desired part of comparison is reached; this is done by the same way as zoom tool.
- Click "**Yes**" for relative amplitude, "**No**" for absolute amplitude.
  - ➢ Relative amplitude: Trace2 amplitude is plotted with its own amplitude scale.
  - ➢ Absolute amplitude: Trace2 amplitude follows the amplitude scale of trace1.

Now, the second trace will appear overlaying the first one.
To displace the second trace, do the following:

- ✧ Select a catching point on the 2nd trace and *Click left*-button mouse.
- ✧ Drag the trace by moving the mouse while keeping the left button pressed.
- ✧ Release and move mouse to change the catching position.

- During this process the correlation value and the lag time between the two traces are displayed in the lower window message. It is allowed to print or save the working screen.
- Right click to return to main window.

The following figure shows an example of comparing two traces.

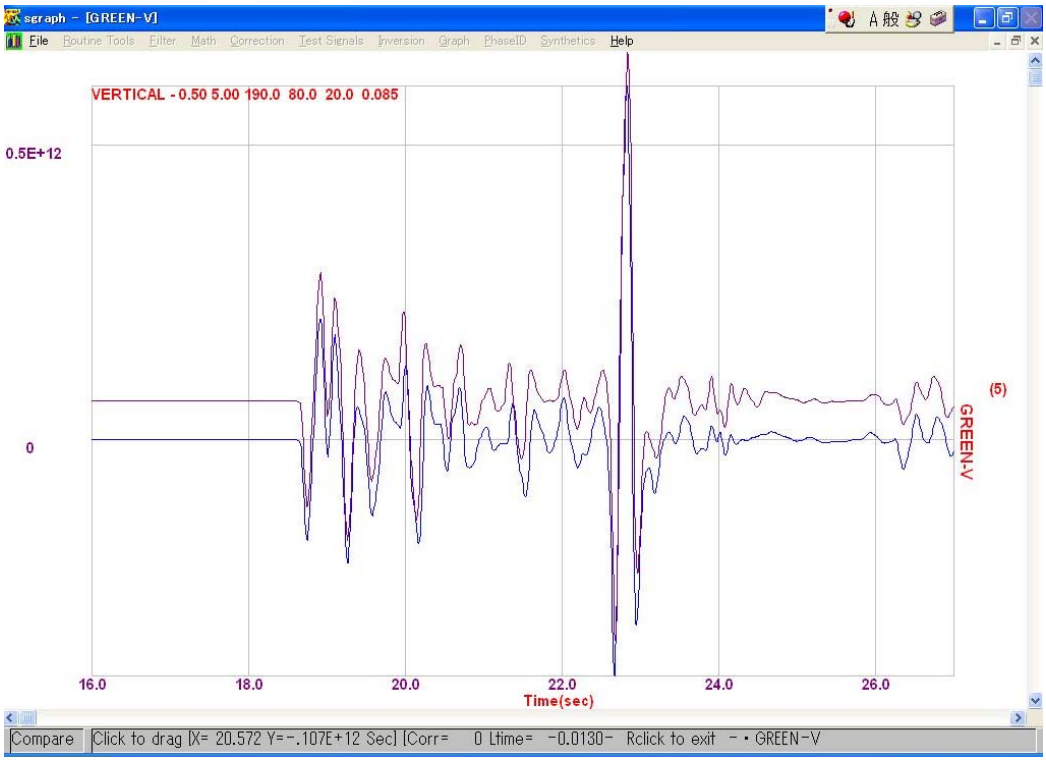


Figure 42: A typical screen-shot of the trace comparison tool. The brown trace is moved forward/backward over the fixed blue trace. The correlation

coefficient between the two traces is calculated in every position and written in the lower part of the window.

This tool is very important in the waveform modelling studies since it maintains the comparison between the observed and synthetic traces for both the period and amplitude.

N.B

- *Comparison is not allowed for frequency domain traces.*
- *The first trace, after the navigation step, could not be changed during the displacement of the second trace.*
- *The user can not change the amplitude or x axis of the second trace during the comparison procedure; it is completely following the first trace.*

14 Location

Sgraph provides integrated tools to estimate the hypocentral location efficiently using the *Hypoinv2000* code. Sgraph, as an analysis program that serves to simplify the waveform analysis and phase picking, exports the station information and phase picking stored in *info* database into phase cards file *'HypoSgraphIn'* that is used by the hypoinv2000 program in a simple way. The user inserts the commands and file names in a dialog box that maintains the browsing and editing of any file before and after location. *Sgraph* generates a command file *'Sgraph.hyp'* accordingly and use all this information to calculate the hypocentral location by calling the included *Hypoinv2000* program externally. Mapping tools are also included in *Sgraph* to generate a PS map of the hypocentral location and the event information. This is maily based o the *GMT* scripts. The *GMT* package should be installed for this purpose. In the next section we will describe how to use the Location and mapping tools and the corresponding dialog boxes.

14.1 Hypoinverse

Used to estimate the hypocentral location of an earthquake from an analysed Sgraph traces or from an existing Hypoinv2000 phase card file. This is done through the following dialog box:

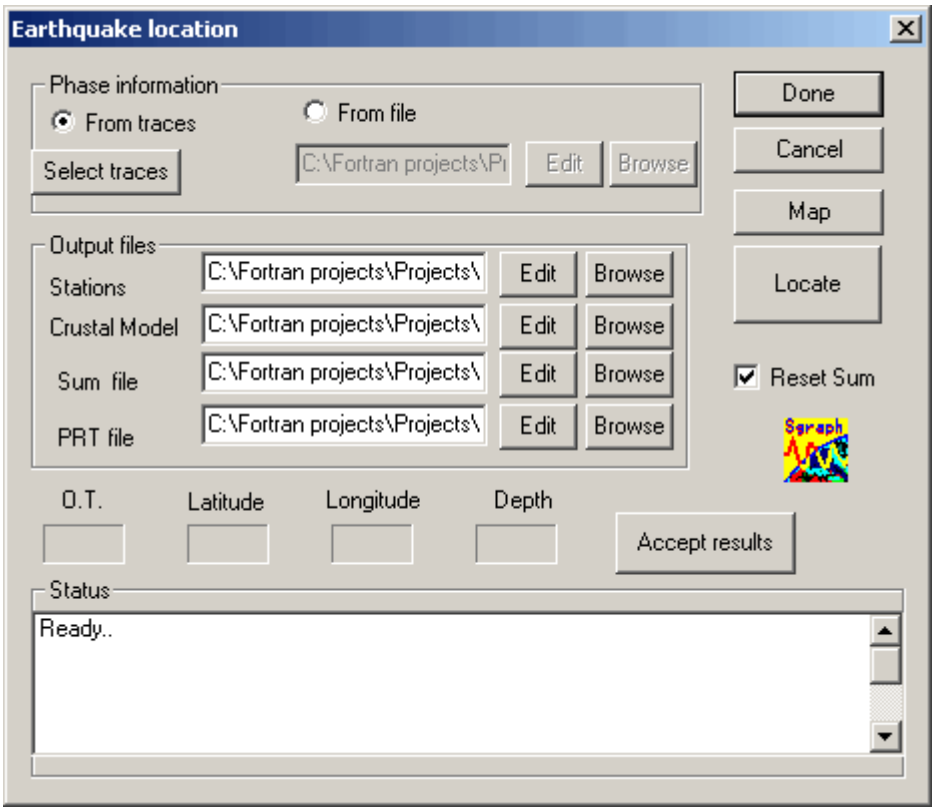


Figure 43: Typical Earthquake Location dialog box.

The description of the above dialog box is as follows:

Phase information: select the source of phase information either from traces or from existing file.

If From file: Browse on the existing phase card file.

If From traces: Select the traces previously prepared and accurately picked. The popular record section dialog box will appear for the selection. Once done, the phase card file will be generated. To check on the corresponding phase card file, press "*From file*" check box and *Edit* the file *'HypoSgraphIn'*.

Output files: Browse the Station, crustal model, Sum and PRT file: the default files are listed in the next table.

File	Default name	Description
Station file	**.¥info¥stations.hinv**	**Public file, used as the source of station information in all Sgraph tools**
Crustal model file	**.¥hypoinv2000¥hypoinverse¥models¥crustalmodel.crh**	**Pre-existing model file**
SUM file	**.¥hypoinv2000¥hypoinverse¥HypoSgraph**	**Summary file for all events located**

PRT file	**.sum** **.¥hypoinv2000¥hypoinverse¥HypoSgraph .prt**	**by Sgraph** **PRT file for location process information**

How to locate an earthquake

To locate an earthquake, do the following:

(For an existing phase file skip the first 2 steps.)

- ✧ Open a set of traces corresponding to the respected event.
- ✧ Pick all the clear phases from all traces using the picking procedure.
- ✧ Click on menu: Location/Hypoinverse
- ✧ Fill in the location dialog box with the appropriate file names press *Locate* button.
- ✧ If not successful check the PRT file for error detail.
- ✧ For a successful location, the resulted values will be shown in place in the dialog box and the message area will show the detail. The event location will automatically passes to the GMT script to generate a location map of the solved event.
- ✧ Press Map to plot the Map.
- ✧ To confirm and accept the resulted location, press accept result. This will replace the existing event information with the resulted one.

N.B. –The Distance /Azimuth calculation is automatically calculated for the new event information.

-Make sure that the stations and component selected for the location procedure exist in the stations.hinv file.

-The location process produces many helping files; those will be replaced every time the procedure runs.

- To plot a location map, the script used a file named 'Event.dat' which is resulted from the location process.

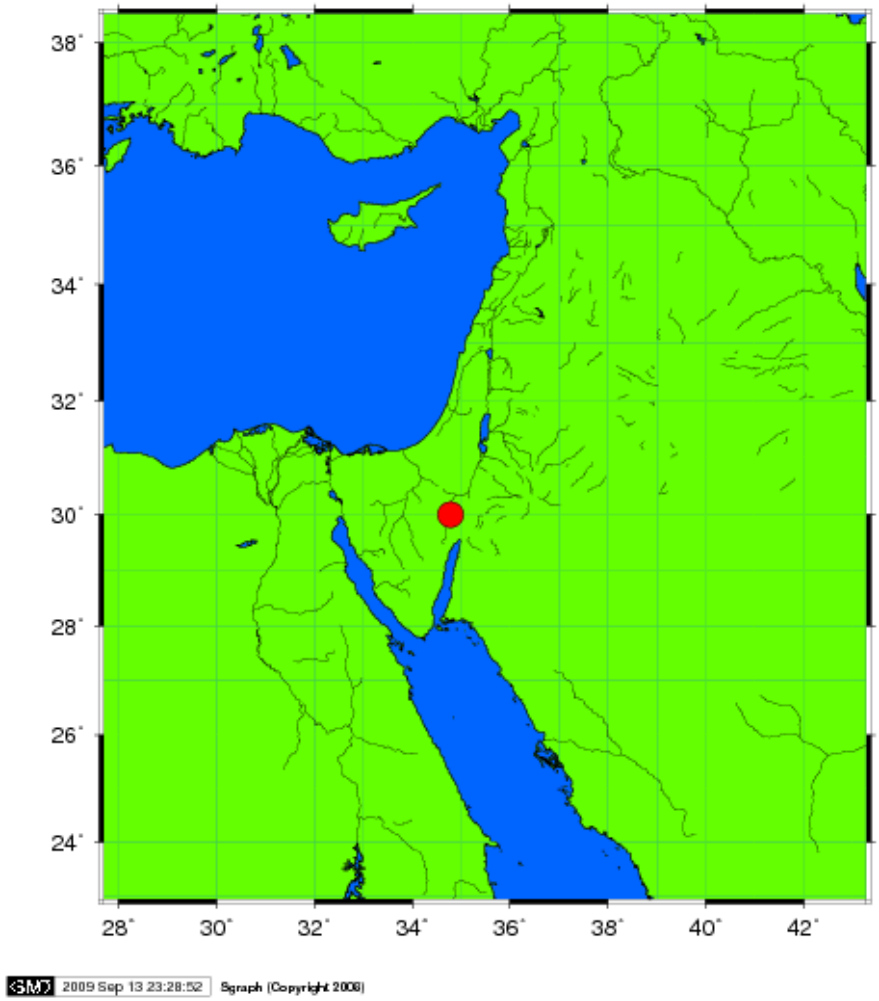


Figure 44: Example of a location map resulted from the location process and mapping tools.

14.2 Genmap: Plot a location map of a customized event.

Select a file for a specific Lat long value to be plotted in PS map

The file should be a GMT PSTEXT format similar to 'Event.dat' file as follows:

34.7845 29.9885 12 0 1 0200908260631

representing, long, lat, font size, rotation angle, font and text, respectively. Refer to GMT user guide for more information.

14.3 Plot map: Execute the Postscript viewer to show a map

Select the respected PS file to show.

A PS viewer should be installed to apply this tool.

Last modified: June 2010

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List of Figures

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Appendix 1

Pole and Zero file format description

Used in **- Pole-Zero filter.**
-Instrumental response.

Description:

A text file contains the pole and zero information of a given filter response.

Formats are as follows:

- `line1: POZ and comment as a header. 'POZ' must be here as an indication of the POZ file`
- `Line2: Number of zeroes (nz).`
- `Line3:3+nz: Real component of zero followed by Imaginary component of zero (listed in lines up to number of zeroes).`
- `Line3+nz+1: Number of poles (np).`
- `Line3+nz+1:3+nz+1+np: Real component of pole followed by Imaginary component of pole (listed in lines up to number of poles).`
- `Last last line: the word 'Sensitivity'. (any text is ok).`
- `Last line: sensitivity value in free format, contains the filter gain, or the sensitivity of the station response (In case of the instrumental response).`

Example of a POZ file

```
POZ   "SGRAPH Pole zero response file"    SS1 response
2       NZEROS
0. 0.
0. 0.
2       NPOLES
-0.707000  0.707000
-0.707000 -0.707000
Sensitivity
0.94E-9
```

Appendix 2

Travel time table file format description

Used in

- Phase Id routines
- Insert phase
- Search phase.
- Compare Phase.

Description: A text file contains the information of phase names and travel times for the different distances. Once read by *Sgraph,* it stays in memory as long as ***Sgraph*** is running.

Table format description:

- -Line1: Table title, could be any text.
- -Line2:
  - -1st column: "DIST"
  - -Next columns: Phase names in sequence.
- -Next lines
  - -1st column: Distance of the current arrival times
  - -Next columns: The arrival times of the phases listed in the 1st column, respectively (free format).

And so on..

Example of travel time file:
Travel time table: TT JAPAN 2 *DIST Pg Pn P* PcP PmP PP PPP* *10 2.7108 0 0 4.6547 8.7804 3.5189* *20 3.3000 0 0 5.9900 10.000 5.0000* *-------*

Appendix 3

GRT File format descriptions

1. MODEL file format

Used in :

- **GRT**
- **Modeling**

The model is placed in file originally called INNPUT but now can have any name. A sample model file is shown below.

```
 2     1     3     2 3250      2.50000004E-02
  6
1.000000E-03    1.000000E-03    1.000000E-03    0.000000E+00
5.500000E+00    3.480000E+00    2.660000E+00    5.500000E+00
6.300000E+00    3.640000E+00    2.770000E+00    5.500000E+00
6.301000E+00    3.640100E+00    27701000E+00    5.000000E+00
6.700000E+00    3.870100E+00    2.800000E+00    1.900000E+01
7.800000E+00    4.500000E+00    3.300000E+00    4.000000E+02
```

The first line consists of 6 fields.

2 5 4 2 3250 2.50000004E-02

The first five are integers consisting of "I5" format and the last is a real number of E18.8 format (e.g. 5I5, E18.8)

1st number : Determine if we are using a whole or half space.

Half space =2

Whole space= 0

2nd number: The number of terms in the series to be considered. Normally a value of one is used, but using more terms will give a better result. (Maximum is 12)

3rd number : The source layer. This number specifies the layer in which the source is at the bottom of. Source is contained within a layer, so an actual layer Created by Guest3must be split into two layers to accomplish this. The lower layer must have velocities and densities slightly higher than the layer above.

This aids in calculating reflection and transmission coefficients across these boundaries.

4th number: Specifies if the source and receiver are in fluid or solid.

Fluid = 0

Solid= 2

5th number: Number of points. This is the number of points used to create the response but it is actually twice the number of points output.

6th number: Half of sample interval used in the output

Second line: Consists of one integer (I8) specifying the number of layers in the model

Rest of lines: Specifies the velocity layers. Each line represents one layer.

1.000000E-03	*1.000000E-03*	*1.000000E-03*	*0.000000E+00*
5.500000E+00	*3.450000E+00*	*2.400000E+00*	*2.000000E+00*
5.500100E+00	*3.450100E+00*	*2.400100E+00*	*3.500000E+00*
6.300000E+00	*3.600000E+00*	*2.670000E+00*	*1.500000E+00*
6.300100E+00	*3.600100E+00*	*2.670100E+00*	*2.100000E+01*
7.850000E+00	*4.400000E+00*	*3.420000E+00*	*4.000000E+03*

The above numbers are (4E15.6) format describing the model as follows:

1st number: P-wave velocity Vp in km/s

2nd number: S-wave velocity Vs in km/s

3rd number: Density in gm/cm^3

4th number: Layer thickness in km.

All interfaces with similar velocities and densities need to be changed slightly of the calculation of the reflection and transmission coefficients. This change involves a difference of 0.0001. Source layers are of this type since source has to be contained entirely within a layer. An example is shown below:

5.500000E+00	*3.450000E+00*	*2.400000E+00*	*2.000000E+00*
5.500100E+00	*3.450100E+00*	*2.400100E+00*	*3.500000E+00*

The source is at the bottom of layer 3. Layer 3 is 10.5 km thick and has a Vp of 6.3 km/s. and Vs of 3.64 and density of 2.77 g/cm^3. However, the source lies 5.5 km deep into the layer from the top of the layer.

The top layer is always a very small layer with a thickness of 0.0 km and a very small velocity 0.001 km/s. Basically, it specifies the layer where receiver lives and the Vp, Vs and density does not effect the solution.

```
2     5     4     2 3250     2.50000004E-02
 6
1.000000E-03   1.000000E-03   1.000000E-03   0.000000E+00
5.500000E+00   3.450000E+00   2.400000E+00   2.000000E+00
5.500100E+00   3.450100E+00   2.400100E+00   3.500000E+00
6.300000E+00   3.600000E+00   2.670000E+00   1.500000E+00
6.300100E+00   3.600100E+00   2.670100E+00   2.100000E+01
7.850000E+00   4.400000E+00   3.420000E+00   4.000000E+03
```

-For more detail see the GRT user manual.

1. RAY file format

Used in : -GRT, Modelling, PhaseId

Ray File (description):

It is a file containing the rays used in calculating the response.

A typical example of a ray file is as follows:

```
5  6  3
 2 2 1
 1 5 5
 3 3 2 1                    $Pg
 1 5 5 5
 5 3 2 2 2 1                $PP
 1 5 5 5 5 5
 7 3 2 2 2 2 2 1            $PPP
 1 5 5 5 5 5 5 5
 5 4 4 3 2 1                $PcP
 1 5 5 5 5 5
```

Format and description are as follows:

First line consists of three values; the first is the number of rays; the second is number of layers in velocity model used; third is the source layer. Here, the source lives at the top of the third layer from a 6 layer model; and number of rays is 5. Rays are specified as bocks of two lines.

```
3 3 2 1          $Pg
1 5 5 5
```

1st line describes what layer the ray will traverse in each segment.
2nd line describes the modes of that particular segment.

The first ray is never computed so it is left as

```
2 2 1
1 5 5
```

The second ray then becomes the first ray so this is where we will start to describe.

1st line: *3 3 2 1 $Pg*

1st number: Number of ray segment.

Rest of numbers: specify the ray crossed for every segment.

$: denotes a text for the phase name (used in Sgraph only). This is optional, If needed should be anywhere after the ray segment in this line.

2nd line: *1 5 5 5*

1st number: Multiplication factor for that ray. This is to make it easier to add symmetric rays paths without add a new ray.

2nd number: Source type. Valid source types are P, SV or SH.

P : 5
SV : 3
SH : 4

See the following table.

This also describes the velocity in the source layer. Generally, P and SV sources show up in the Vertical and Radial components, while SH sources are strictly on tangential.

Rest of numbers: Modes of ray segments. Valid modes are P or S types only.

P: 5
S: 3

Modes for SH (4) sources are S-waves (3). But sources that are SV (3) or P (5), can have P (5) and S (3) wave type. See the following table.

Table describes the source and ray modes:

Identifier	Source	Mode	Following modes
3	SV	SH or SV	S and P (3 and 5)

4	SH	n/a	Only SH
5	P	P	S and P (3 and 5)

Description of ray 1

3 3 2 1 $Pg

1 5 5 5

This ray consists of 3 segments, it starts in layer 3 and traverse layer 2 and finally 1. It is a P source and consists only of P waves.

-For every ray a "$" followed by the phase name is necessary for the ray nomination used in the "PhaseID" , "GRT" and "Modeling" tools. Otherwise the phases will not be nominated. Only the nominated phases will be flagged as available phases to be read and display in the "Available" box of phase selection dialog. Notice, the ray file consists on the direct, upgoing and downgoing reflected phases. The head waves are automatically generated by GRT according to the critical angle condition.

For more details see the GRT manual.

Appendix 4

"Sgraph3.0 Y" and "Sgraph3.0 XY" File formats description

This format in general is an ASCII format combining all the trace data and information.

The following is an example of Sgraph3.0 Y of a trace consists of 10 phases.

```
# Sgraph 3.0    Y-format

Trace Information: GREEN-V                Z      2.00      20.00   1024      20.000      300.000        0.000        0.000 0
VERT - 0.20 6.00 190.0    50.0    12.0    0.160
Event Information:                                                  0.000       0.000       0.000      0.000 0.0    1.000
Phases information:    10
Pg_??_3.7713              Sg_??_6.0122                PmP_??_8.7569              ScS_??_6.1987                sPmP_??_11.2733
SmS_??_15.1587            sSmS_??_18.1728             PcP_??_3.7272              sPcP_??_5.7008               pPmP_??_10.6635

 0.35232E+09
 0.25166E+09
 0.23488E+09
-0.10066E+09
 0.92275E+08
 0.27682E+09
-0.23488E+09
-0.33554E+09
-0.60398E+09
-0.67109E+09
```

The descriptions of this format are as follows:

- **line 1**: consists of **'# Sgraph 3.0 Y-format'** or **'# Sgraph 3.0 XY-format'.** This is the format specifier of Sgraph. If it is not found, the file will be considered as an unknown multi column file.
- **line 2:** Void
- **line 3:** Trace information, in sequence:

  Station name, Component, Starting time, Sampling rate, Number of points, Epicentral distance, Azimuth, Station latitude, Station longitude, Scale (0=lin, 1=log,3=min), Trace info.
- **Line 4:** Event information, in sequence:

  Event name, Time string, Origin time, Event latitude, Event longitude, Event depth, Magnitude, Moment.
- **Line 5:** "Phase information:" followed by number of phases to be read in the next lines in 5 phases/line. Each phase is a string of 30 characters representing the phase name, polarity, weight and time**.**
  - **Next lines:** Phases strings in 5 phases/line.

After the phases strings, a void line followed by the data values.

In the case of *"Sgraph3.0 Y"* format , data represents the amplitude values of the trace in one column.

In the case of "*Sgraph3.0 XY*" format, data represents the time and amplitude values in two columns.

Appendix 5

GSE (INT) File format description

```
WID2 2005/02/11 10:26: 4.269 CNB     S          INT      12034   100.000000     0.10E+01     1.000
0.0   0.0
STA2                 0.00000      0.00000                 0.000 0.000
DAT2
         10454
          4516
         -5807
          -823
          6792
           533
         -5189
          3287
         13938
          3116
        -10581
         -2345
          6812
          1572
```

See GSE format description for details

Appendix 6

GSE (CM6) File format description

```
WID2 2005/03/09 05:48:55.526 NCD  S        CM6    15354  100.000000   0.10E+01   1.000
0.0  0.0
STA2                0.00000    0.00000              0.000 0.000
DAT2
g+lQtRxPVVJkyNcGgPkp1UrBzAnLUs4lWFYTUuAklKa+rJkTjHvCZMu6WMUmIks2Z9ZAq8i6kqHgHhDk
t-UlTwQaSh9kwJUn9X6xKvAUvAVIlXFVh3krCkn1Vi-kqDku1Ut8Ul3kvScMZLzEUmToSwDbQSXTXNyF
e+V8wIUq8kq1lEVX-laHiRgRlbFVc2vJkmCUwTkq2Um-pOkl2UqCvRfDsTn5YHyRVhSlg2o-Vr8nVEWX
0WVBoWJVY1Wc4mr0VYKVlInwRXeMzBmhCYhDoVSVdIVu9nn0Xh0lk4kx9Wi8mi8VYEUrHmUIVmPpSkrO
VUOksTmDUz2kxEsGVY+q1kuBfLUkLlVIUv9YGlVHVYBkpOZSdMkqHUnIvIZMaCwFUIfSkkBZHUw6lkTU
zQmPlY+Wf0loEy7VY3ky+VdSkrIks7UkAUm9hDlqKUrHUrCks3cTqIW-c1VQt-l4XPXMo7yOUkAqPeEY
0lW6Vd0t7kx+VZGkrGVAUr+kt1bFY2koLUr6jHlf4Ux-fPmUJVtJc2lYRUs-y3d5knFVfJsMmbFWo6kl
ClXTVb9kyQUk8UkHlWNj4gDkqEUl9n-ksSVWDkPky4UrMpIlEYDkn8Uy4zPr9Uy1lVTiKZKkp9Uu4yKU
```

See GSE format description for details

Appendix 7

Discrete Wave number files format description

Bouchon model file

Used in :

- **Wave Number**

A sample model file is shown below.

```
4                    (MRO)
 2.4    5.28   3.33   2.5      1000.   1000.
 14.9   6.1    3.53   2.6      1000.   1000.
 12.5   6.65   3.8    2.7      1000.   1000.
  0     7.75   4.8    3.1      1000. 1000.
```

The first line Consists of one integer (I8) specifying the number of layers in the model
Rest of lines: Specifies the velocity layers. Each line represents one layer and consists of 6 fields.

1st field : Layer thickness in km.
2nd field: P-wave velocity Vp in km/s
3rd field: S-wave velocity Vs in km/s
4th field: Density in gm/cm^3
5th field: Quality factor of P-wave (Qp)
6th field: Quality factor of S-wave (Qs)

Bouchon output file format

```
      1024     300.000000000000          300.000000000000                    1
 200.000000000000
  0.17263E-10  -0.37020E-16   0.17263E-10  -0.37020E-16   0.50918E-10  -0.10298E-15
  39
  0.14181E-10   0.52669E-11   0.14181E-10   0.52669E-11   0.59757E-10  -0.14330E-11
  34
  0.45346E-11   0.34500E-10   0.45346E-11   0.34500E-10   0.62269E-10  -0.10133E-10
  34
  0.59807E-10  -0.16782E-10   0.59807E-10  -0.16782E-10   0.15305E-10  -0.76655E-11
  37
 -0.56141E-10   0.59288E-10  -0.56141E-10   0.59288E-10   0.13258E-10   0.32048E-10
  32
  0.24791E-09   0.66687E-10   0.24791E-09   0.66687E-10   0.10728E-09   0.13676E-09
  21
  0.15246E-09   0.30687E-10   0.15246E-09   0.30687E-10   0.24980E-09  -0.31451E-11
  24
  0.31767E-09  -0.41248E-10   0.31767E-09  -0.41248E-10   0.21683E-09  -0.12153E-09
  21
  0.41910E-09  -0.13013E-09   0.41910E-09  -0.13013E-09   0.77959E-10  -0.22553E-09
  21
 -0.41526E-09  -0.47295E-09  -0.41526E-09  -0.47295E-09   0.41038E-10  -0.19853E-09
```

Appendix 8

Save picking format description

#	ST	Comp	Dist	Azim	Pg	Sg	PmP	ScS	sPmP	SmS	sSmS	PcP	sPcP	pPmP
1	GREEN-V	Z	20.00	300.00	3.771	6.012	8.757	6.199	11.273	15.159	18.173	3.727	5.701	10.663
2	GREEN-R	R	20.00	300.00	3.771	6.012	8.757	6.199	11.273	15.159	18.173	3.727	5.701	10.663
3	GREEN-V	Z	40.00	280.00	7.341	11.703	10.382	11.622	12.737	17.978	20.615	6.860	8.699	12.090
4	GREEN-R	R	40.00	280.00	7.341	11.703	10.382	11.622	12.737	17.978	20.615	6.860	8.699	12.090
5	GREEN-V	Z	60.00	260.00	10.955	17.464	12.631	17.152	14.837	21.884	24.140	10.026	11.852	14.147
6	GREEN-R	R	60.00	260.00	10.955	17.464	12.631	17.152	14.837	21.884	24.140	10.026	11.852	14.147
7	GREEN-V	Z	80.00	240.00	14.580	23.243	15.227	22.698	17.322	26.398	28.348	13.196	15.020	16.596
8	GREEN-R	R	80.00	240.00	14.580	23.243	15.227	22.698	17.322	26.398	28.348	13.196	15.020	16.596

Appendix 9

PGV-Dist file format:

A typical PGV-Dist format is shown below :

```
8 4
4 5 6 7
5.7 0.0012562 0.039725 1.2562 39.725
6 0.0006404 0.020251 0.6404 20.251
25 0.0012149 0.038418 1.2149 38.418
31 0.00074498 0.023558 0.74498 23.558
49 0.00040713 0.012874 0.40713 12.874
60 0.00020093 0.0063539 0.20093 6.3539
81 0.00080395 0.025423 0.80395 25.423
100 0.00044235 0.013988 0.44235 13.988
```

Where:
Line 1 : number of distance points, number of magnitude values [N M]
Line2 : magnitude values [M_1,M_2,M_3, .. M_M]
Line (3:N+3) [Distance, PGV_1, PGV_2, PGV_3,… PGV_M]

Sgraph Limitations:

Maximum points to Read	2^{15}
Maximum number of traces	50
Maximum number of Phases in synthetics	999
Maximum number of Phases in files	99
Graph quality	GUI + Post script
Printing	Screen + Post script

Notice

-This version is released only for the purpose of research. It is strictly forbidden to use it for other purposes or for commercial use without permission from the author.

-If you have obtained the program from other sources than the author or you still did not sign the user agreement letter, please do it immediately and send it to the author.

-Your information is important to get the updated versions of Sgraph. Information and will never be shown to public. This will facilitate the author survey for program users to follow up bugs and research results.

-It is highly appreciated if you send us a copy of the studies that has been done by this program.

-This program is still under development. The author is not responsible for any inconvenience or invalid results produced by this program. For more explanation of this program contact the author.

-Any advice or request concerning to the program are welcomed through my email.

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Thank you for using Sgraph

Notes:

Sgraph

FOR WINDOWS

Full Version

(V.3.7.4)

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