Introduction to the processing of seismic reflection data within REFLEXW

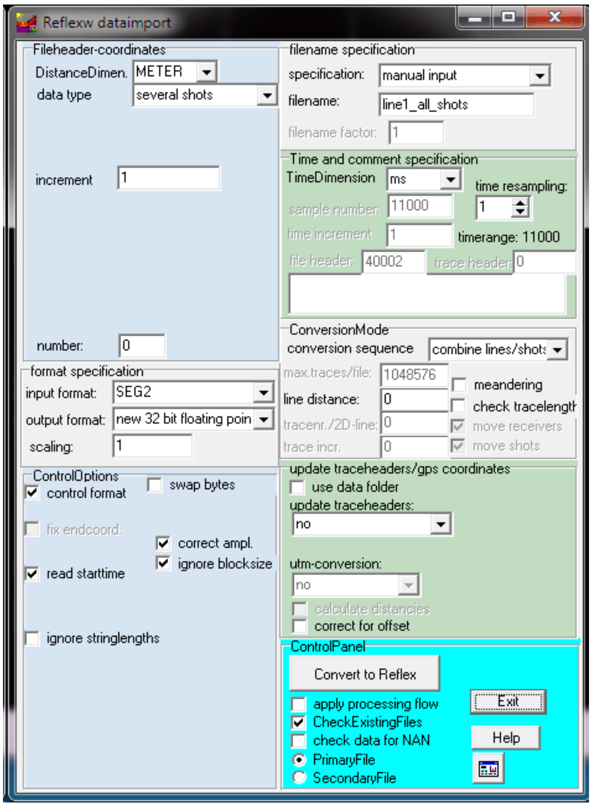
In the following the complete processing of seismic reflection data is described including import of the seismic data (chap. I), crosscorrelation (optional for vibration data, chap.II), setting the geometry (chap. III), filtering the shot data (chap. IV), performing the velocity analysis and stacking (chap. V). Please use in addition to this user‘s guide the handbook and the online help.
The guide describes both the processing of “normal” shot data and of horizontal vibration data. The processing of horizontal vibration data needs some more steps which are highlighted by red.

I. Import the data (done within the module 2D-dataanalysis)

1. enter the module **2D-dataanalysis**

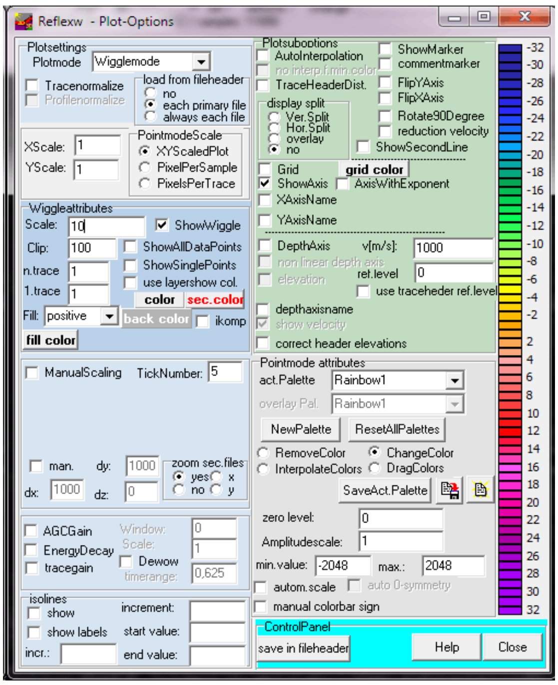
2. activate the option **file/import**

3. choose the following options within the **import menu**:



data type: several shots
increment: average receiver increment (this increment is used for the equidistant display of the data - the stacking is done based on the traceheadercoordinates which may also be nonequidistant - see also chapter II setting the geometry).
outputformat: new 32 bit floating point for a higher data resolution.
To be considered for SEGY or SEG2-data: the option swap bytes controls if the original data originate from UNIX (activate option) or DOS-machines (deactivate option). If the conversion fails try to change this parameter.
filename specification: manual input
filename: any name (e.g. line1_all_shots)
TimeDimension: ms
conversion sequence: combine lines/shots
line distance: no meaning, may be set to increment
number: no meaning, may be set to 0

The following **plot options** may be set for example (the option may be activated within the import menu (the speed button below the help option)):



Plotmode: Wigglemode
XYScaledPlot activated
Scale: setting depends on the amplitude values of the data. The amplitude values multiplied with scale gives the wiggles size in pixels. The value must be adapted to the original data values.
Optionally you also may activate the option Tracenormalize. Then the option Scale directly gives you the wigglesize in pixels.

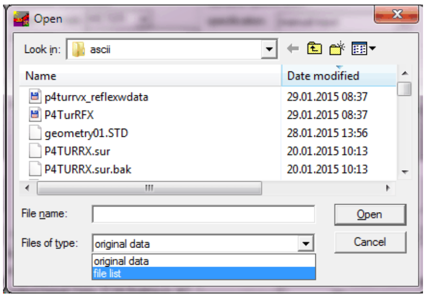
4. activate the option **Convert To Reflex**: the wanted shots must be chosen and they are automatically combined into one single datafile containing all the shots.

There are 2 different possibilities of choosing the datafiles:

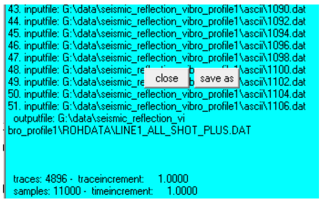
a.. choose the datafiles from the openfile dialog (multiple choice using the shift or str-key) : all choosen original data files are sorted with ascending order of the filenames. Problems may occur if the files don't have the same length (e.g. file1, file2,..., file11). In this case a warning message appears. In order to avoid this the filenames should be chosen in such a way: file001, file002, ... file125.

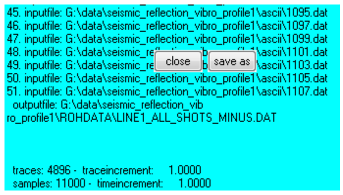
b. open an external ASCII-filelist with the extension "lst": the external filelist contains all wanted datafiles in an arbitrary order (one row contains one filename). The datafiles must be stored under the same path like the ASCII-filelist. Example:

TEST__02.sg2
TEST__01.sg2
TEST__03.sg2
TEST__04.sg2



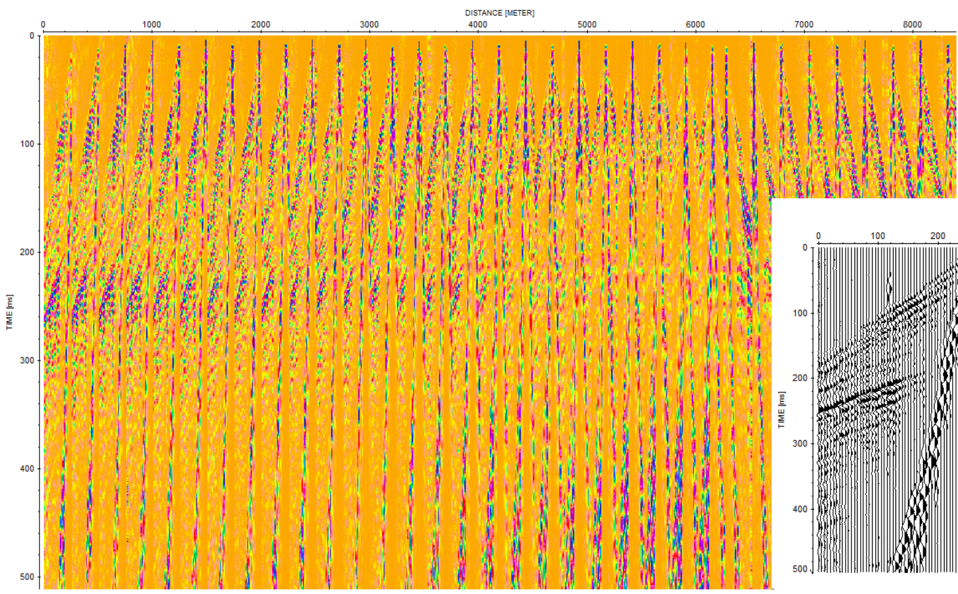
The horizontal vibrator may have two different excitation directions (plus and minus). The data of these different excitation directions must be imported separately.

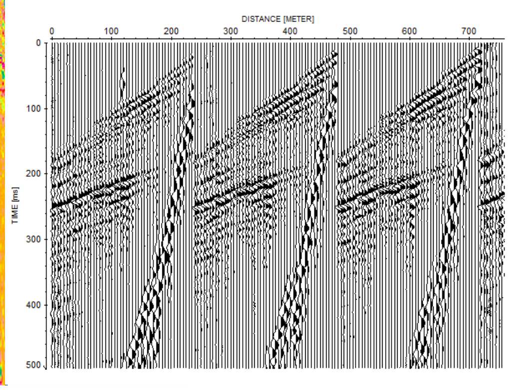




After having chosen all the wanted datafiles the combined datafile including all the shots is displayed using the actual plot settings. Because of the normally huge number of traces and the choosen plotmode (Wigglemode, XYScaledPlot) the screen display resolution may be too small to plot the data correctly (XScale too small). In this case choose the Zoom-option in order to only display a small part of the data in x-direction. The plot option point mode allows y higher resolution but it is not so useful for the further processing, e.g velocity analysis.

NOTE: The standard display within the 2D-dataanalysis uses the product of the given traceincrement and the actual tracenumber for the axis display. Therefore this display does not represent the correct coordinates for the combined shot data and you may ignore them. But you don't have to worry about them because the subsequent sorting and stacking is always done based on the traceheader coordinates (see chap. III). The coordinates of resulting stacked section (see chap. V) however are displayed correctly within the standard display.



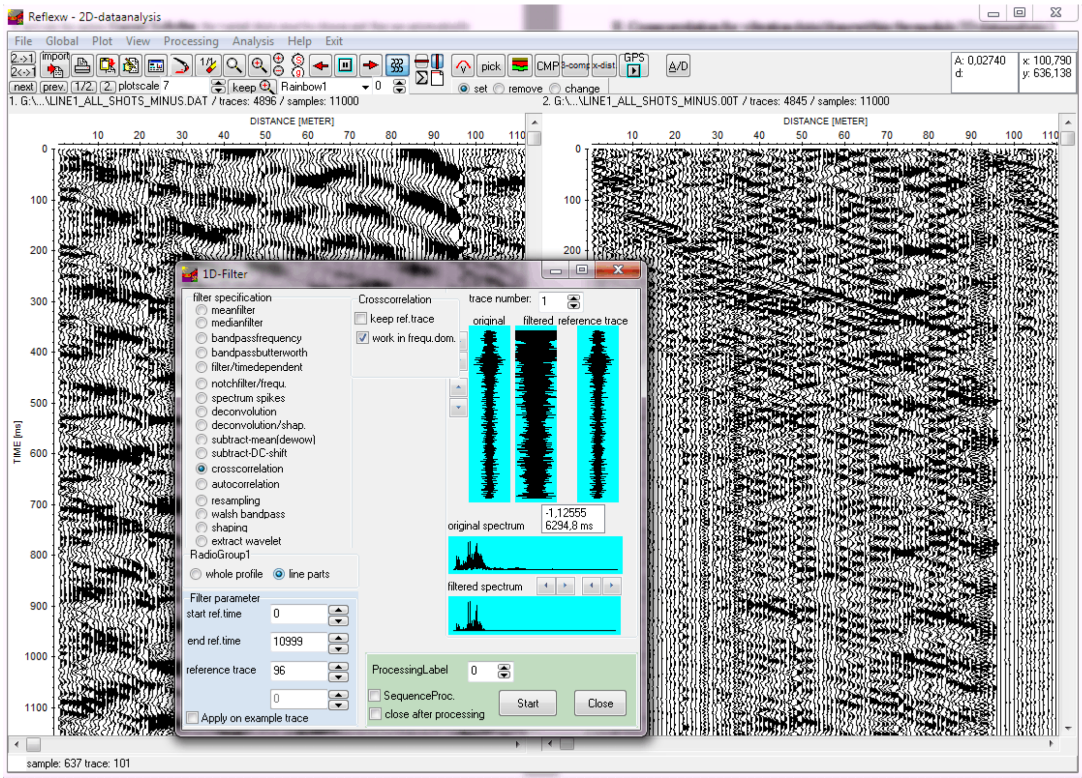


II. Crosscorrelation for vibration data (done within the module 2D-dataanalysis)

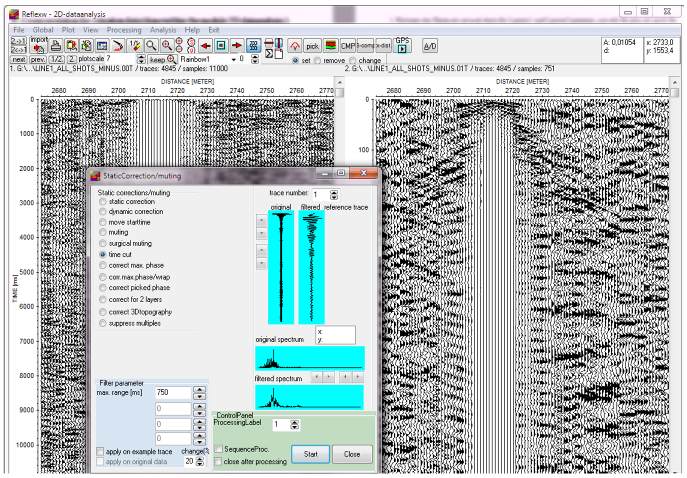
If the data have been acquired using a vibrator the data must be first crosscorreltated with the sweep signal before these can be interpreted. The vibrosource emits a long sinusoidal signal with varying frequency over several seconds (in this case 10 s). The recorded signal is a mixture of many time-delayed copies of the signal. Cross-correlation is then used as a trace compression using the original signal and the observed data to unravel all of this.
The processing flow:

1. Load the file containing all combined shots
2. Enter processing/1D-filter
3. Activate crosscorrelation
4. Enter the start and end reference time (normally the total time range, also by default)
5. Enter the postion of the reference trace, in this case channel no. 96 respresents the sweep signal
6. Activate the option lineparts if the datafile consists of several individual shot datasets
7. Deactivate the option keep ref.trace because the sweep signal is no longer necessary
8. The method works both in time and frequency domain. Both methods produce similar results but the frequency domain method is faster.

The resulting crosscorrelated traces now are comparible to "normal" shot data (e.g. using a hammer or an explosive source).



It is recommended to restrict the timerange, in this case to 750 ms, using the option timecut under processing/static correction



III. setting the geometry

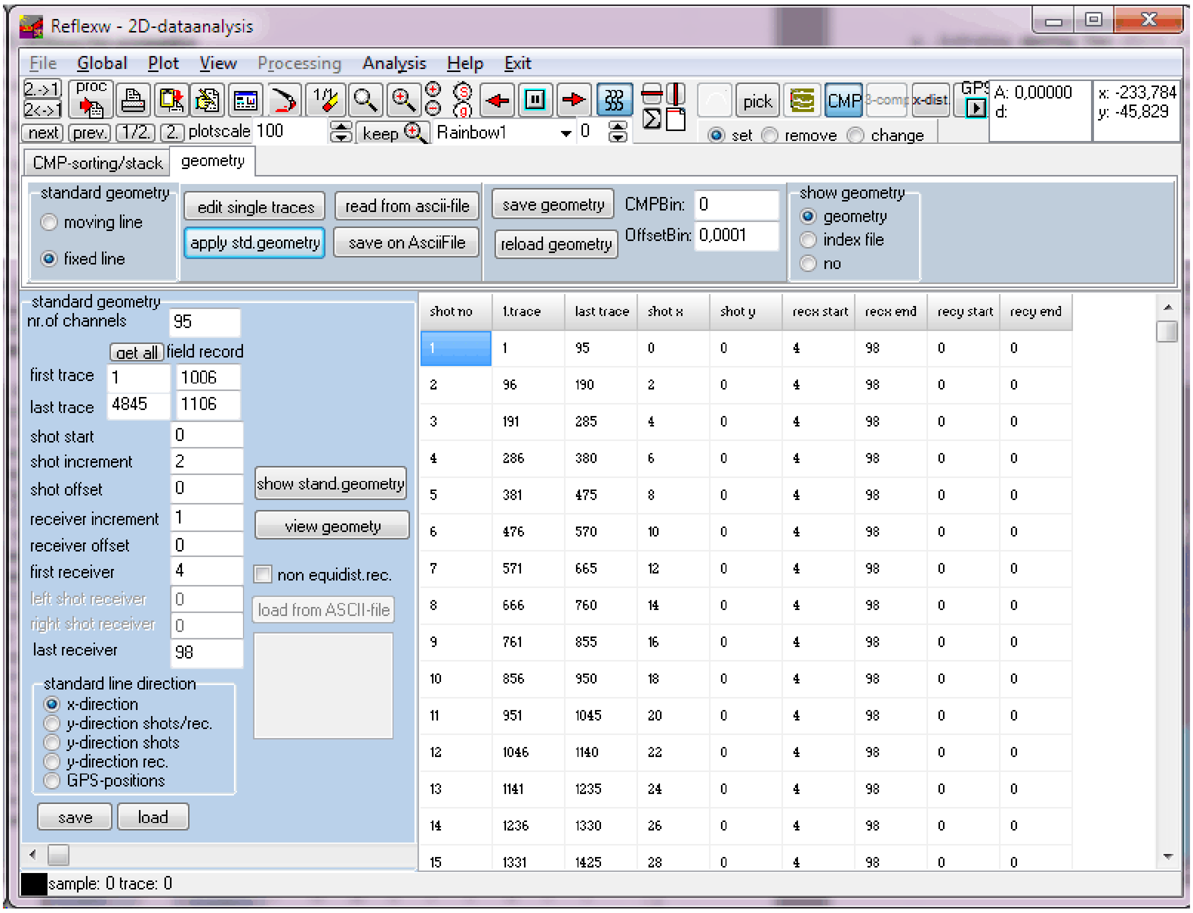
1. activate the option **CMP** within the 2D-dataanalysis

2. activate the option **geometry**

If the geometries have been already entered during the data acquisition and REFLEXW allows to automatically take over these geometries the geometry is shown in a tabella with shot number, shot position and receiver line position. If the geometry is okay you may leave the geometry settings by deactivating the option CMP and go on with chapter IV.
If the geometry is not correct you must proceed with the following steps:

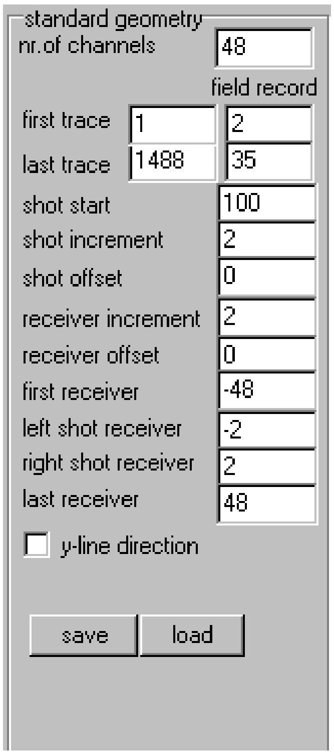
3. There are different possibilities to define the geometry. The most convenient way is to use a standard geometry (option **moving line** and option **fixed line**) for a selectable number of traces. Apart from the standard geometry it is also possible to edit the geometry of single traces (option **edit single traces**) or to load the geometry from an ASCII-file (option **read from ASCII-file**).

a. Activating **fixed line** allows you to define the geometry for a fixed geophone line for different shot points. An example of the input parameters is shown on the next figure. Nr.of channels is the number of channels per shot. First and last trace define the range on the profile for which the standard geometry should be valid. This gives you the opportunity to declare standard geometries for different ranges of the profile. Instead of the first and last trace it is also possible to define the range using the original field record numbers. Shotstart is the position of the shot of the first ensemble, shot increment is the distance between successive shots and shot offset is the distance between a shot and the profile in perpendicular direction. Receiver increment is the distance between successive receivers and receiver offset is the distance between a geophone and the profile in perpendicular direction. First receiver and last receiver define the position of the geophones with respect to the shot. These are the absolute coordinates in contrast to moving line where relative coordinates (to the shot) are used.



shot no	1.trace	last trace	shot x	shot y	recx start	recx end	recy start	recy end
1	1	95	0	0	4	98	0	0
2	96	190	2	0	4	98	0	0
3	191	285	4	0	4	98	0	0
4	286	380	6	0	4	98	0	0
5	381	475	8	0	4	98	0	0
6	476	570	10	0	4	98	0	0
7	571	665	12	0	4	98	0	0
8	666	760	14	0	4	98	0	0
9	761	855	16	0	4	98	0	0
10	856	950	18	0	4	98	0	0
11	951	1045	20	0	4	98	0	0
12	1046	1140	22	0	4	98	0	0
13	1141	1235	24	0	4	98	0	0
14	1236	1330	26	0	4	98	0	0
15	1331	1425	28	0	4	98	0	0

b.. Activating **moving line** allows you to define the geometry for a geophone line moving with the shots. An example of the input parameters is shown on the right figure. Nr.of channels is the number of channels per shot. First and last trace define the range on the profile for which the standard geometry should be valid. This gives you the opportunity to declare standard geometries for different ranges of the profile. Instead of the first and last trace it is also possible to define the range using the original field record numbers. Shotstart is the position of the shot of the first ensemble, shot increment is the distance between successive shots and shot offset is the distance between a shot and the profile in perpendicular direction. Receiver increment is the distance between successive receivers and receiver offset is the distance between a geophone and the profile in perpendicular direction. First receiver, left shot receiver, right shot receiver and last receiver define the position of the geophones with respect to the shot.



c. The option **read from ascii-file** allows you to read the geometry from an ASCII-file. The ASCII file must exist under the path ASCII and must have the extension DST. Each line of the ASCII file contains the following 6 informations:
tracenumber distance Shot-X-Pos Shot-Y-Pos receiver-X-Pos receiver-YPos
Defining the tracenumber gives you the opportunity to read the geometry only for a distinct part of the data.

d. The option **edit single traces** allows you to change the geometry of each trace individually. When activating this option the trace header Edit menu will be opened where you can edit the shot and receiver coordinates for each trace separately.

4. If you want to apply a standard geometry (3.a or 3.b) you must activate the option **apply std. geometry** in addition.

5. If necessary enter an additional standard geometry and apply it onto the profile or choose one of the other geometry edit possibilities.

6. If the geometry setting is finished choose the option **save geometry** in order to save the geometry within the traceheader coordinates of the file.

7. Now the file is ready for pre-stack processing and stacking.

IV. pre-stack filtering (done within the module 2D-dataanalysis)

The aim of the pre-stack filtering is to prepare the dataset for the subsequent stacking. Therefore the most important processing steps are:
- energy normalization
- elimination or suppression of the surface waves and other non desired waves

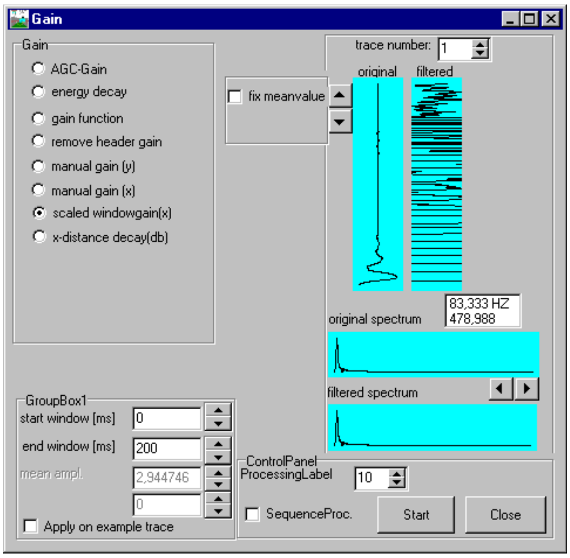
The energy normalization should be the first filter step especially if you are using multi-channel filters (e.g. FK-filter) for the suppression of non desired waves.. This filter step is applied to correct for the amplitude effects of wavefront divergence and damping. It is also necessary if a subsequent filter shall be applied for eliminating the surface waves.
The easiest way would be a manual gain function, e.g. manual gain (y). In the case of strong surface waves this gain recovery function is not very suitable. In this case the filter scaled windowgain(x) may be a good choice.
To bo considered: Filtering and stacking are always done on the true amplitude data. The option tracenormalize within the plotoptions is only a plotoption and does not effect the filtering/stacking process. Therefore the option tracenormalize within the plotoptions should be deactivated because otherwise the effect of the energy normalization may not be controlled correctly.

The second filter step consists of the elimination of the surface waves and other non desired waves. For that purpose you may distinguish between editing and 2D-filter steps.
Editing may be used for muting (set to zero) special data parts or to delete single traces or trace ranges. 2D-filters may be used to suppress unwanted signals. A FK-filter may be a good choice.

IV.1 prestack filter sequence for data exhibiting surface waves

In the following the processing using a scaled windowgain(x) and a FK-filter is described:

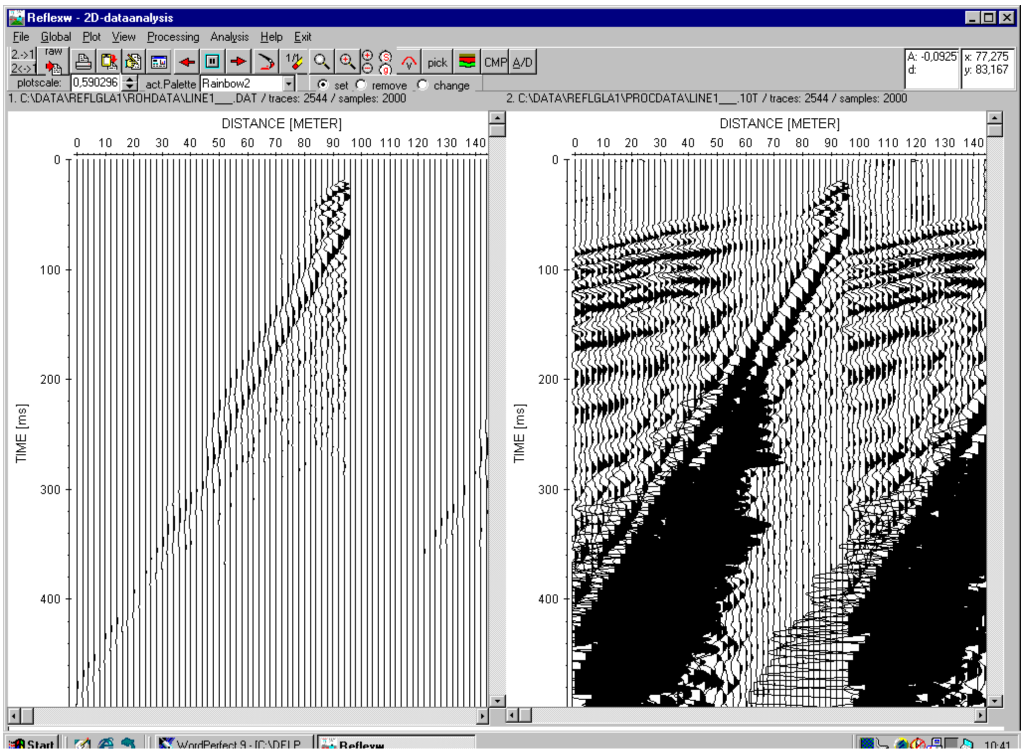
1. load the wanted raw data for which the geometry has already been defined (all shots are stored within one file, see chap. I and II).



2. enter the <u>first</u> filter step using the option **Processing/gain**.

3. The **Gain window** appears. Enter the following parameters or options:
- activate the option **scaled windowgain(x)**
- enter the filterparameter **start window** and **end window**, the window size should be choosen in such a way that a good energy normalization is fulfilled. Default values are:
start window: 0
end window: the traveltime of the main reflection at the greatest distance offset.
- enter the wanted **ProcessingLabel**
- **start** the filtering

4. The filtered data have been plotted into the secondary window (depending on the settings of the screen splitting within the plot option menu). Whereas in the original data only the surface waves and the very first arrivals are visible due to the non normalized display the filtered data show clear refracted waves for all distancies and some reflections. Now **close** the filter window and you must enter the option **File/ChangeSecondToPrimary** in order to use the filtered dataset for the next desired filter step.



5. Choose the filter which allows to eliminate or at least decrease the surface waves.

Surface waves normally differ from the body waves in two siginifant characteristics. These properties involve the frequency and the apparent velocity. Both are often significantly lower than those of the body waves.

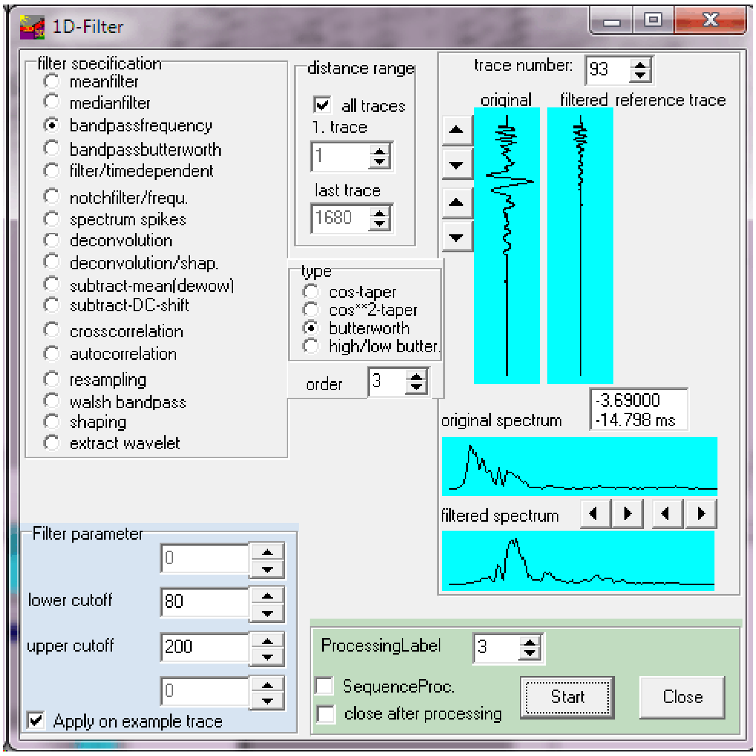
If a lower frequency content is inherent a **high pass bandpassfiltering** is the best choice.

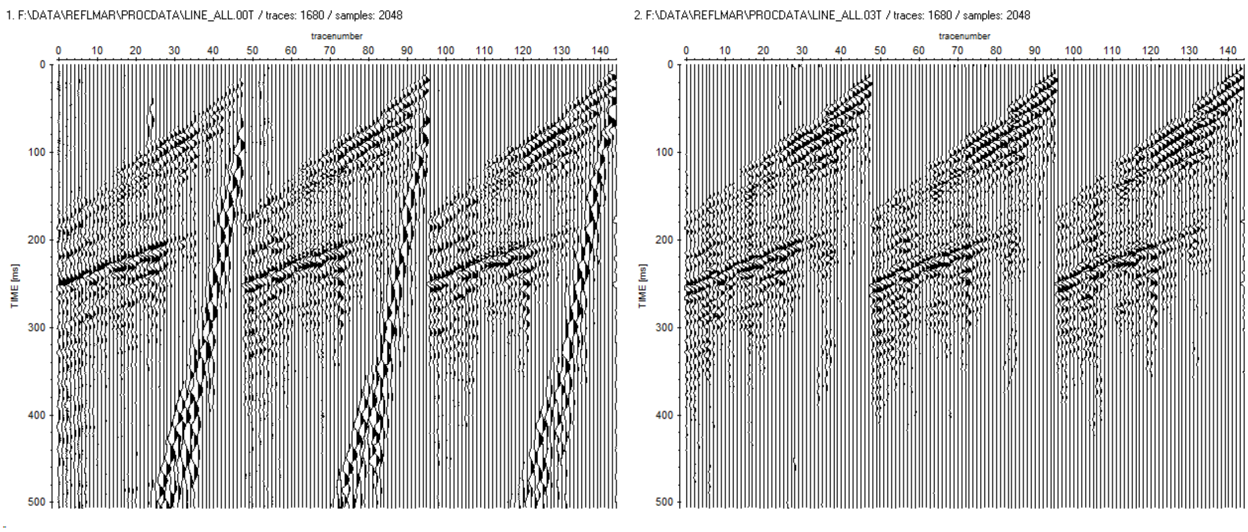
5.1 enter **processing/1D-filter** and choose **bandpassfrequency**

For the tapering the butterworth type of the order 3 is often useful.

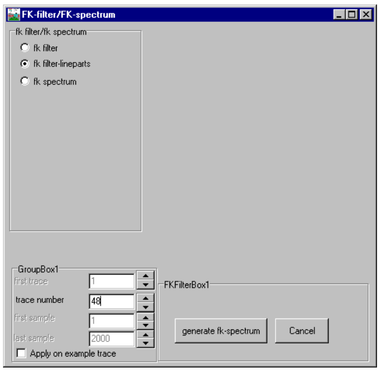
Enter the wanted lower and upper cutoff frequency. If the option Apply on example trace the original and the filterd trace as well a the original and the filtered spectrum are displayed.

In this case the high pass bandpass filtering allowed a very well elimination of the surface waves - see picture below.



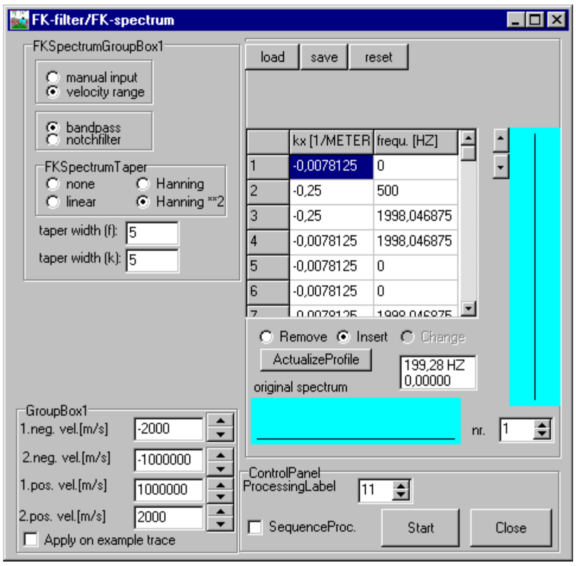


If the bandpass filtering is not sufficient a **fk-filtering** might be useful. Here it must be considered that no spatial aliasing occurs. This may happen if very low velocities are present together with a too high receiver increment. Then after applying the fk-filter some energy of the surface waves will remain.

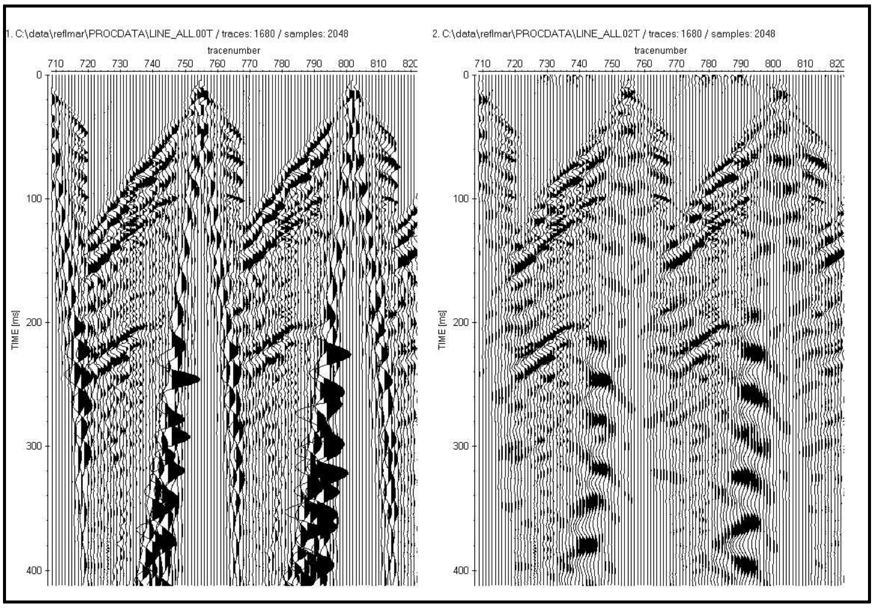


5.2 enter the second filter step using the option **Processing/FK-filter/FK-spectrum**.

The FK-filter/FK-spectrum window appears. Enter the following parameters or options:
- activate the option **fk filter-lineparts**
- enter the filterparameter **tracenumber** (corresponds to the number of traces per shot)
- activate the option **generate fk-spectrum**

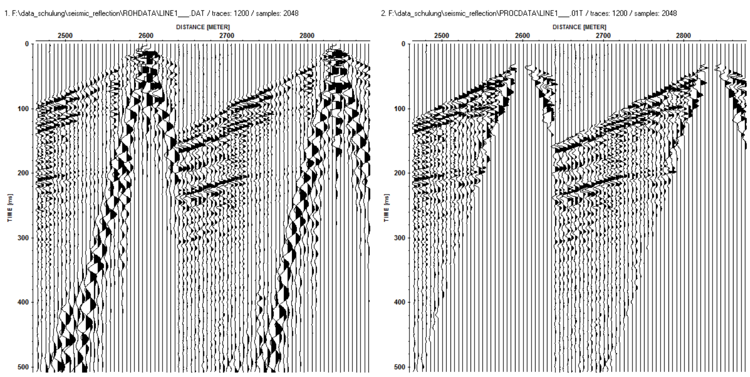


A new FK-filter/FK-spectrum window appears. Enter for example the following parameters or options:
- activate the option **velocity range**
- activate the option **bandpass**
- activate the option **Hanning **2**
- enter 5 for the **taper widths**
- enter the **velocity fan** for example:
1.neg.vel. to -2000, 2.neg.vel. to -1000000, 1.pos.vel. to 1000000 and 2.pos.vel. to 2000. These values may differ significantly from case to case. The velocity fan should be set in such a way that all non desired onsets are suppressed.
- enter the wanted **ProcessingLabel**
- **start** the fk-filtering



The filtered data have been plotted into he secondary window (depending on the settings of the scree splitting within the plot option menu). The surface waves as well as the first arrivals (refracted waves) are quite well suppressed. If the result is sufficient the pre-processing is finished and you may continue with chapter V. If not some other filter or editing steps must be performed.

5.3 muting

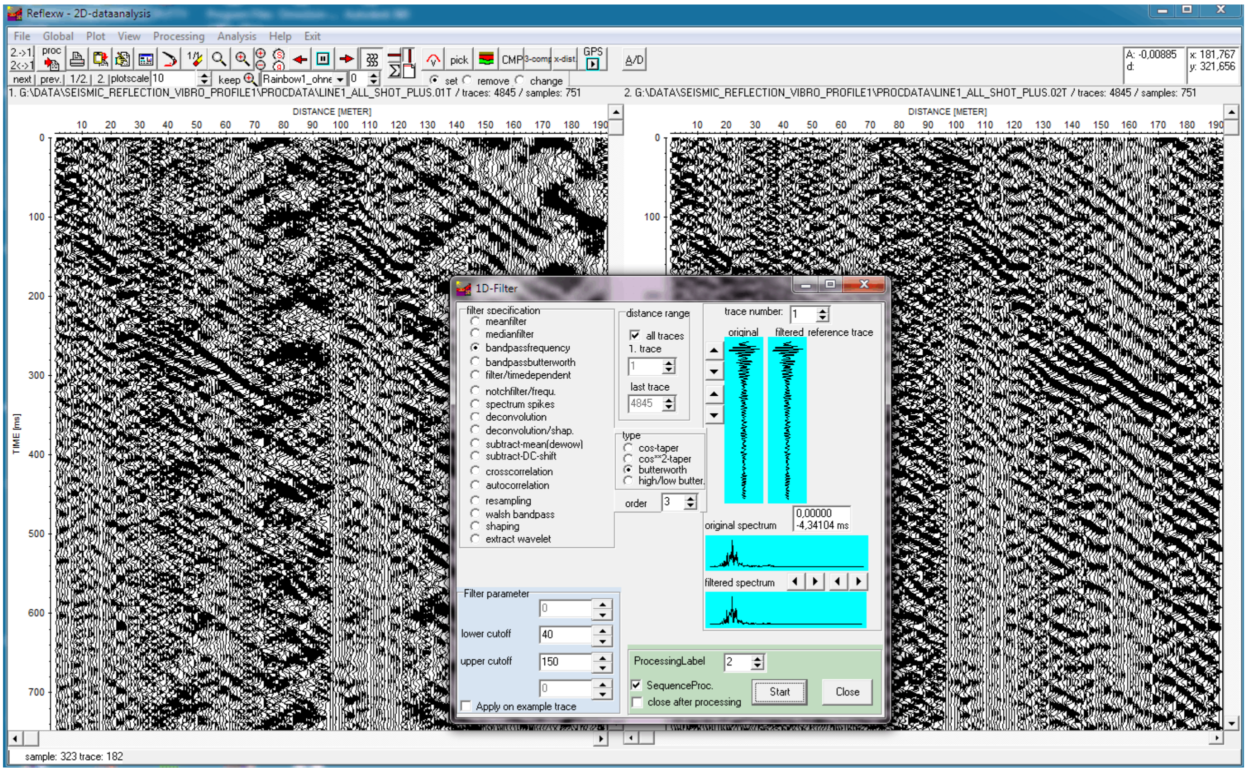


If both the bandpassfiltering and the fk-filtering do not work the surface waves may be muted, either using a surgical mute by defining apparent velocity trajectories (see picture on the right) or by manually entering a muting curve.

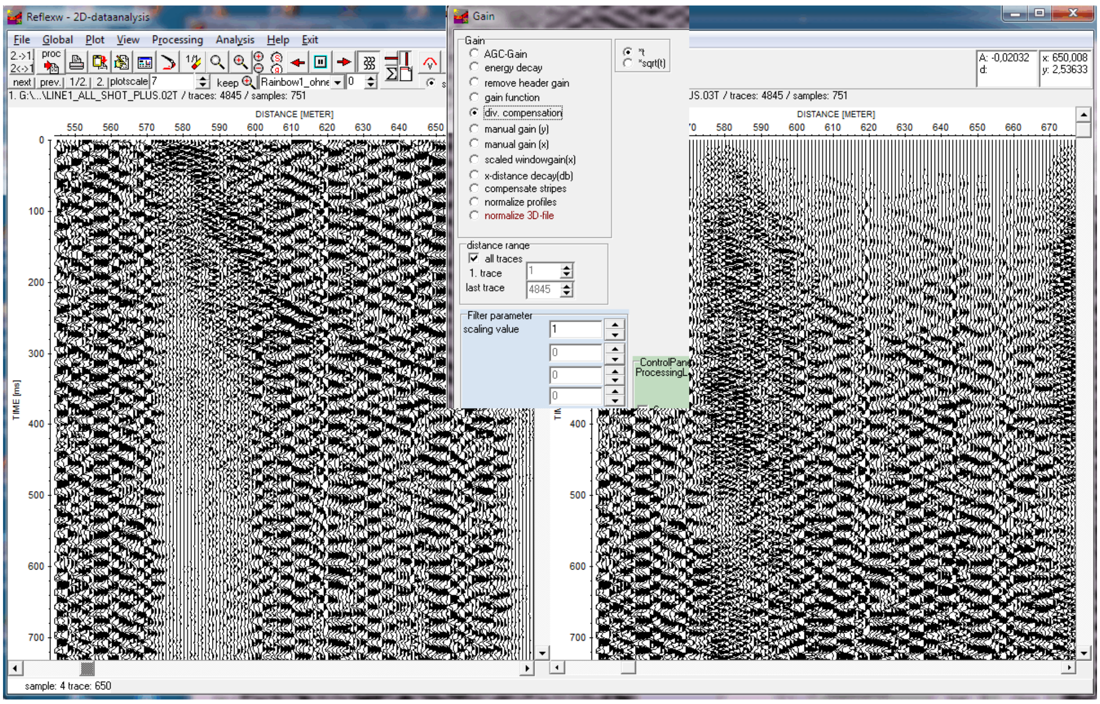
IV.2 prestack filter sequence for horizontal vibration data

1. load the wanted raw data for which a crosscorrelation has been done and the geometry has already been defined (all shots are stored within one file, see chap. I to III).

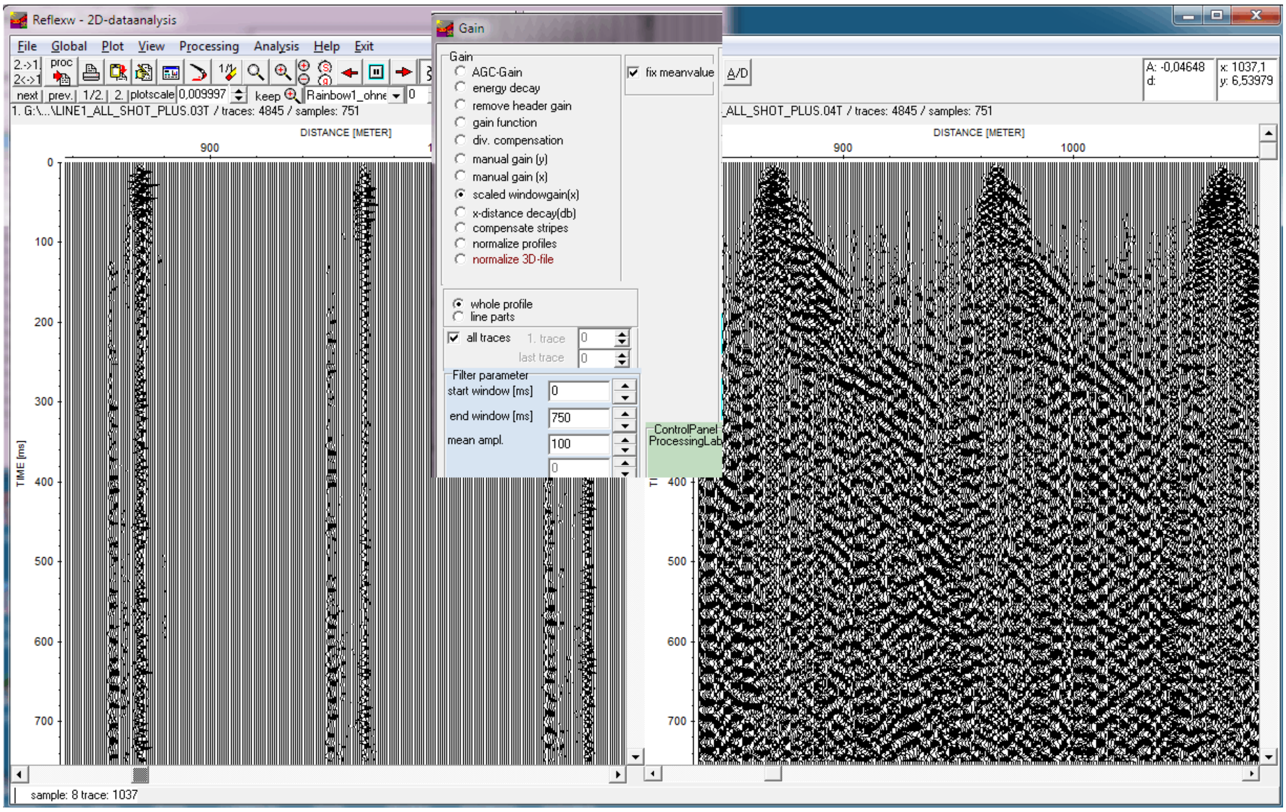
2. enter the first filter **bandpassfrequency** within Processing/1D-filter, in this case a frequency range between 40 and 150 Hz and a butterworth taper of order 3 has been used. The tracenormalize plotoption has been activated in order to view the filter effects.



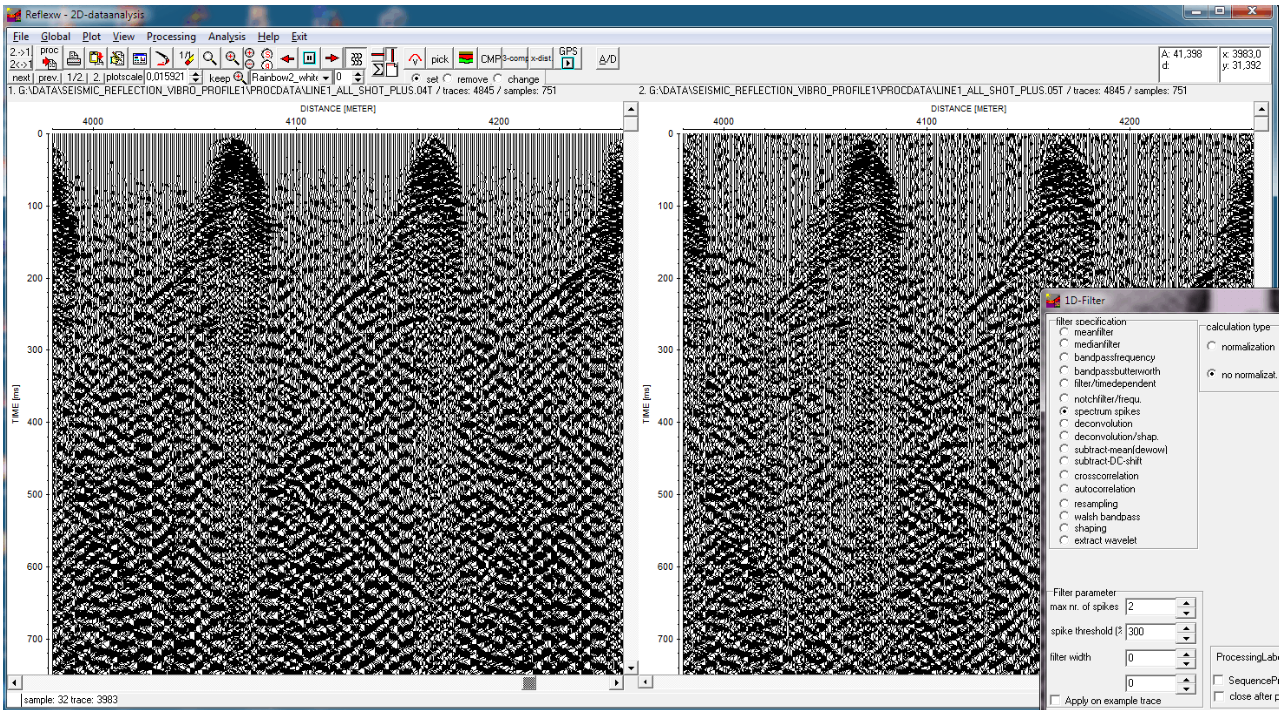
3. Enter the second filter step **div. compensation** under processing/gain which compensate for the geometrcial divergence losses



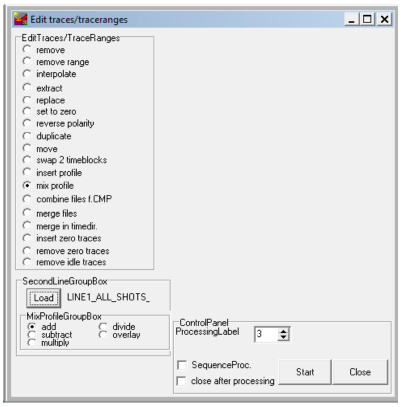
4. Enter the third filter step **scaled windowgain (x)** under processing/gain which facilitates the amplitude equality distribution in x-direction for a y(time)-window to be specified. The tracenormalize plotoption has been deactivated in order to view the true amplitude representation.

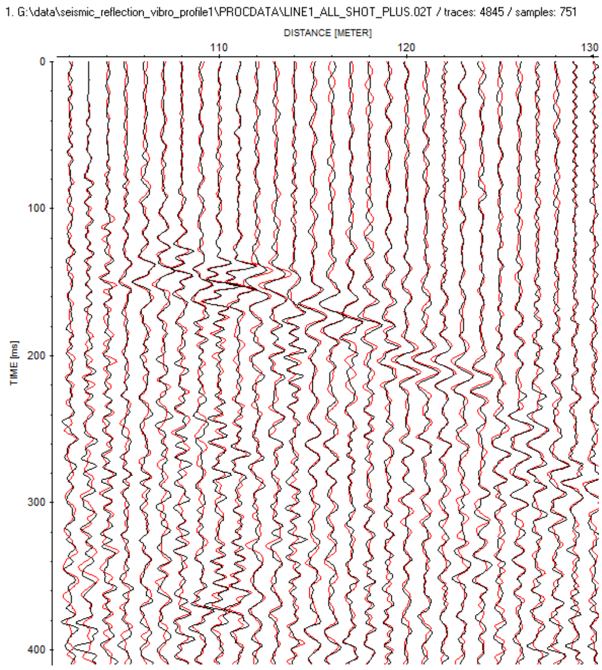


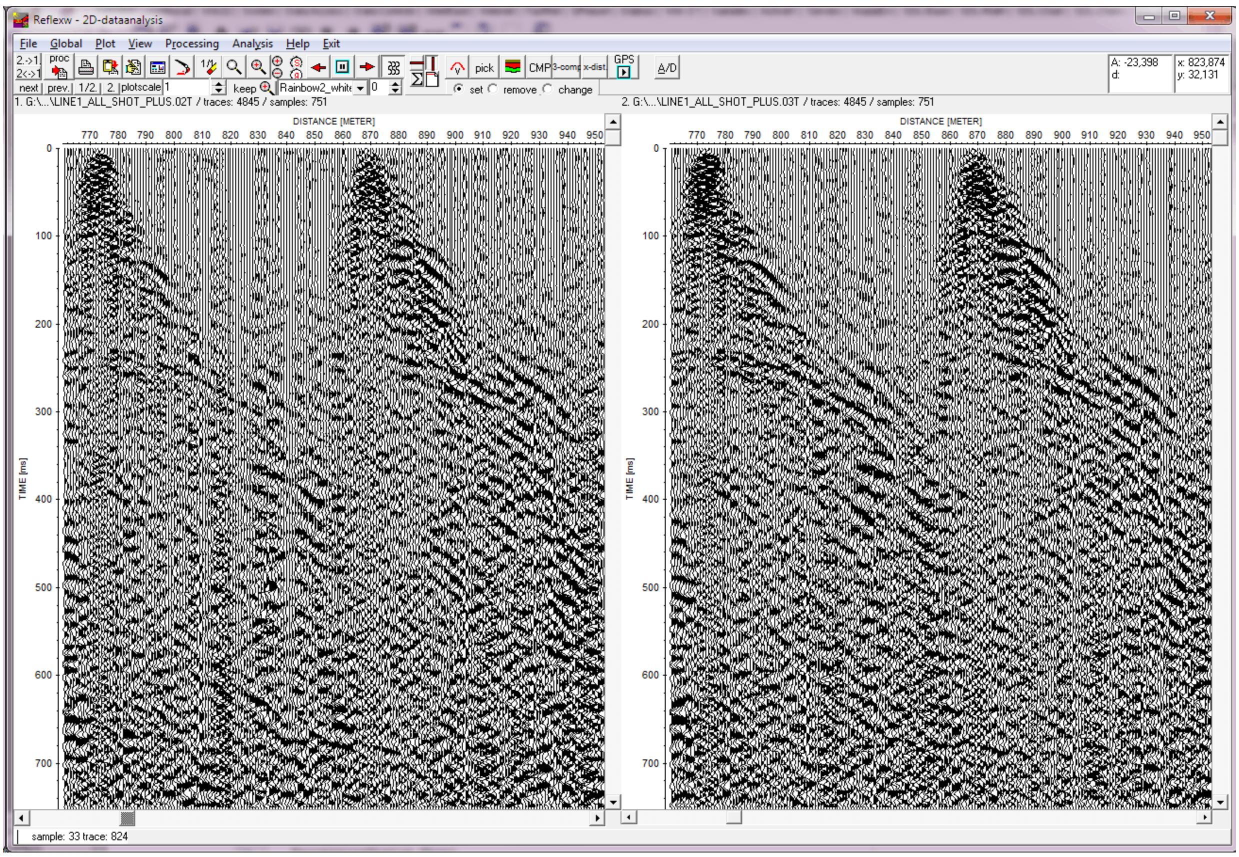
5. Enter the fourth filter step **spectrum spikes** under processing/1D-filter which is suitable for suppressing nearly mono-frequency noise which is not restricted to a special frequency but may vary from trace to trace.



6. The filter steps described above must be applied on the two datasets of different signal excitation (plus, minus). Now the processed data may be combined using the option **mix profile** with suboption add. Although the original non crosscorrelated data of course exhibit different signs (plus and minus signal excitation) both datasets must be added because the different signs will be lost during the crosscorrelation process.







Now the data are ready for stacking (see chap. V).

Within this chapter we have discussed two example of a possible pre-processing. It is not possible to give some general rules for the processing because of the huge different problems involved with the datafiles. In any case a gain recovery (energy normalization) and a suppression of the unwanted onsets must be performed.

V. velocity analysis and stacking (done within the module 2D-dataanalysis)

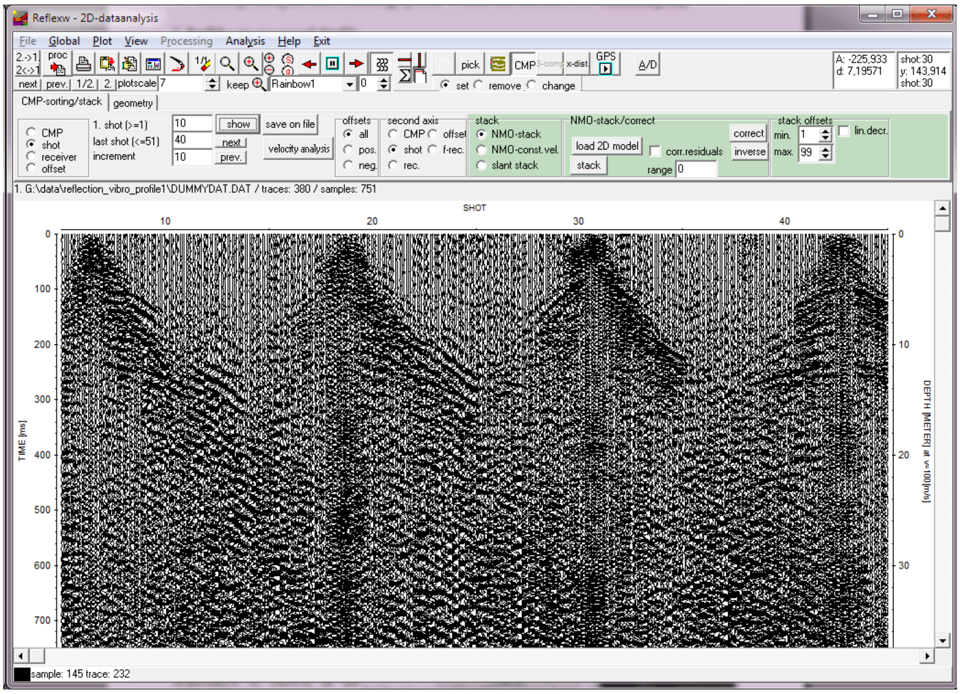
1. **load** the pre-processed datafile

2. activate the option **CMP** within the 2D-dataanalysis

3. click on **CMP-sorting/stack**

4. Choose the sorting option **CMP** or **SHOT**

5. choose the **first** and **last** CMP (or SHOT) and the **increment** for which a velocity analysis shall be done (example 10 for the first shot, 40 for the last shot and 10 for the increment in order to do the velocity analysis for 5 different shots).



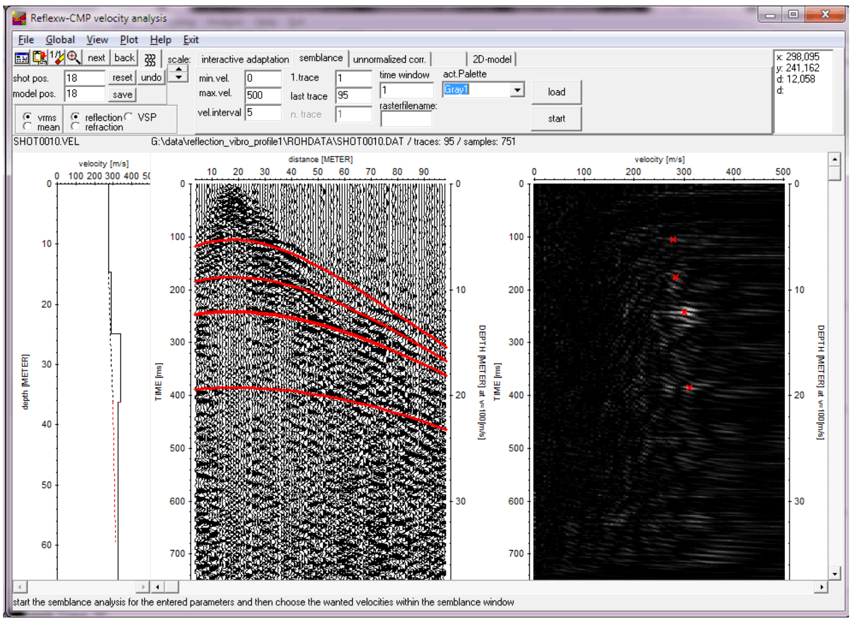
6. activate the option **velocity analysis**

7. the mean **traceincrement** for the ensembles is asked for. This increment is used for the equidistant display of the CMP or shot-ensembles.

8. The velocity analysis menu opens with the first CMP(shot)-data ensemble loaded. On the left the actual layer model is shown (by default one single layer included). On the right the CMP (or Shot) is shown.

9. Activate the option **semblance** or **unnormalized corr.** for doing a first estimation of the velocity model.

10. Enter the velocity range and increment and **start** the semblance analysis. The semblance is shown in an additional window.



11. set the left mouse button at the wanted positions within the semblance analysis window in order to create a velocity model. The velocity model on the left is automatically updated.

12. Activating the option **interactive adaptation** allows you to refine the model - for a detailed description of the options see online help.

13. **Save** the model

14. click on **Next** to proceed with the next CMP (shot).

15. The last velocity model remains and you may refine the model using the interactive adaptation or may create a completely new model using the semblance or unnormalized corr. (see point 9).

16. **Save** the velocity model.

17. Repeat step 14 until 16 until the last wanted CMP (shot) is reached

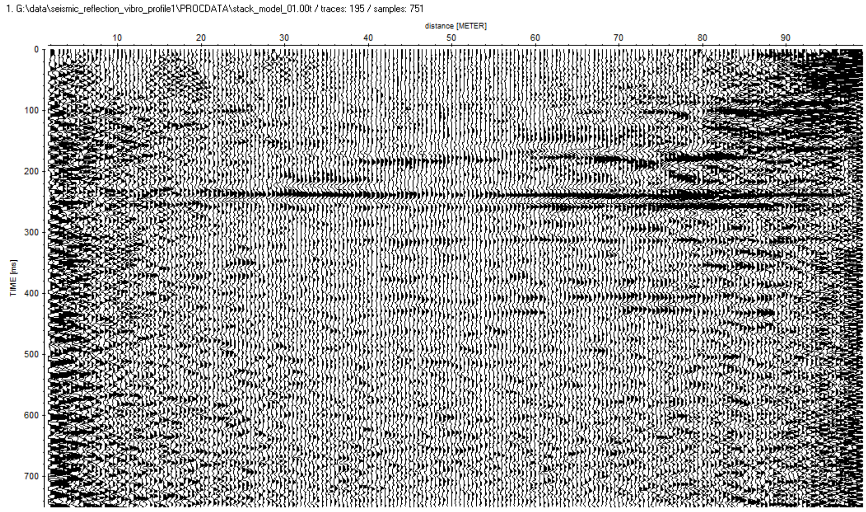
18. Activate the option **2D-model**

19. **create** a new 2D-model - after having activated the option create you are asked for the wanted 1-dimensional velocity model. Choose the wanted models from the open file dialog (multiple choice using the shift or str-key), enter a filename of the 2D-model and the interpolated 2D-model is plotted into the right window.

20. **Exit** the CMP-velocity analysis menu.

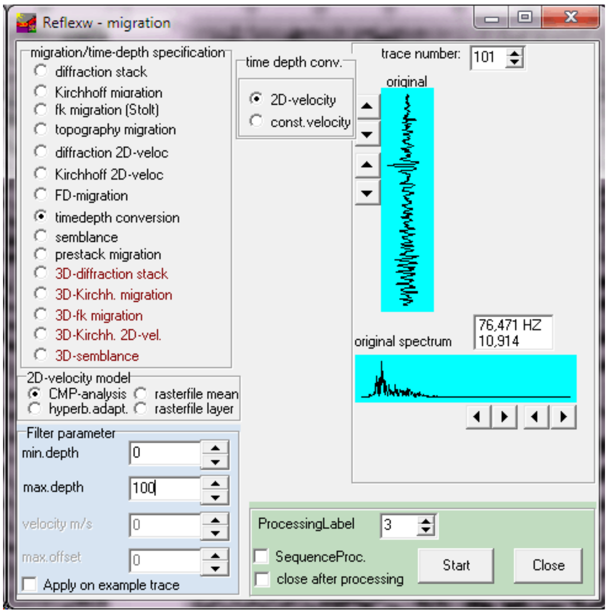
21. Choose **NMO-stack** and load the wanted 2D-model using the option **load 2D-model**.

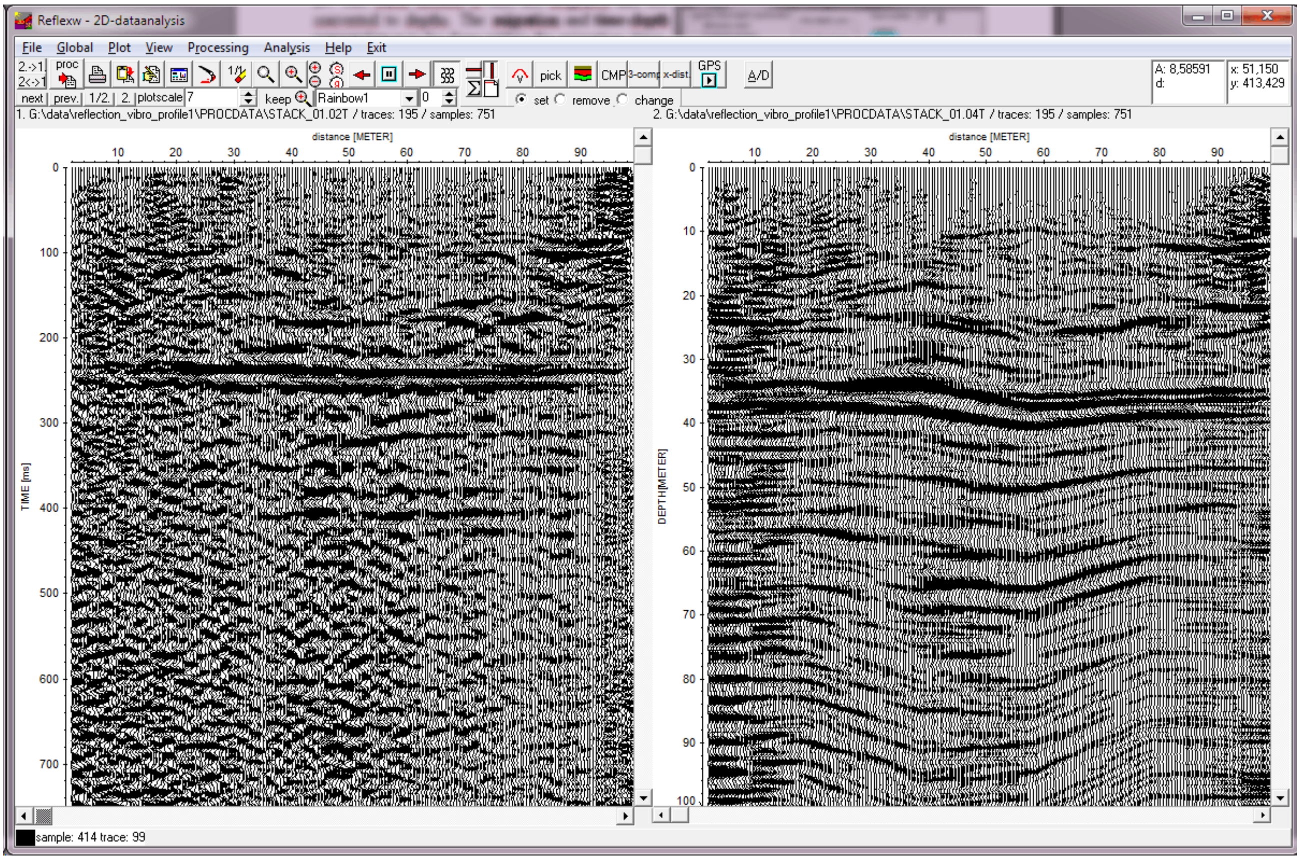
22. Enter the wanted sorting ensemble (e.g. CMP) and enter the ensemble range for the stacking (e.g.: 1. CMP and last CMP and increment whereby the increment should be set to 1). Start the stacking using the option **stack**. Enter a filename for the stacked data and enter the traceincrement (a calculated value based on the fileheader traceincrement of the original file is given by default). The stacked section is stored under the path procdata using the processing label 0 and is shown in an additional window. To be considered for the stack section: The default value of the trace increment is given by the number of stack traces and the coordinate range. If this mean traceincrement does not equal any increment between successive stack traces the resulting stack traces are obviously not equidistant. This may happen for example if the shot interval is not equidistant for all shots. In this case the program (from version 3.03) gives a warning message and asks if equidistant traces based on the mean traceincrement shall be made from the non equidistant stack section. If this procedure is cancelled the resulting stack section not equidistant and you must activate the plotoption TraceHeaderDistancies (only enabled for the wiggle mode) or you must make the stack section equidistant afterwards.



23. Now the stacking is finished and you may look for it and do some **post-processing** within the 2D-dataanalysis (see also guide filtering). For that purpose deactivate the option CMP and load the stacked section.

24. The stack section is still not migrated and not converted to depths. The **migration** and **time-depth conversion** may be done within the migration /time-depth converison menu. The example shows the processing based on the same 2D-velocity model used for the stacking. For the migration the Kirchhoff 2D-veloc. option has been used and for the timedepth conversion the parameters shown on the right. The lower panel shows the original stack section (left) and the the section after migration and timedepth converison (right).





VI. Prestack migration as an alternative to the standard NMO-stacking

The prestack migration is an alternative possibility for getting a stacked section. The resulting section is automatically migrated and converted to depth.

1. load the pre-processed datafile

2. Enter the processing option prestack migration under processing/migration

3. Enter the 2D-velocity model and the max. depth as well as the min./max. offsets. If a 2D-velocity shall be the same of the migratio use curved ray slow.

4. The lower panel shows the comparison of the prestack migrated section and the NMO-stacked section including migration and timedepth converison.