SEISAN tutorial

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1 Introduction

The SEISAN distribution includes 4 test events, 2 local events and 2 distant events. The intention with this tutorial is to explain how SEISAN works and to demonstrate the most often used functions without having to install the test data set and follow the much more extensive SEISAN training course.

Since the previous version of this tutorial (2014), there have been many changes in the software and the most important is the new Nordic format, Nordic2, (version 12, June 2021) which makes SEISAN able to record more parameters and in particular, use the full SNCL codes. In addition, for each phase, there is the possibility to include both agency and author of the phase to keep track of where the phases come from. For this reason, two more test events in Nordic2 format have been included. However, most of the exercises will be using the Nordic format since there is little difference in operation. But we strongly recommend to start using the new format, which also is accepted by ISC. Both formats can be used in nearly all programs, and it is easy to convert from one to the other with program NOR2NOR2.

The distribution is set up to read both Nordic and Nordic2 and all output will be in Nordic2. If you want to exclusively work with Nordic format, set parameter NORDIC_FORMAT in SEISAN.DEF in DAT to 0.0. Using 1.0, both formats are used and 2.0 only Nordic2 can be used.

NOTE: Not all figures have been updated to reflect the latest version of SEISAN but the commands given are correct and old commands no longer available have been removed.
In this tutorial a Windows OS is used to describe the SEISAN commands and file system.
Linux users can use the same SEISAN commands in a terminal.

It is assumed that SEISAN is installed under C:\seismo, readings and other parameters are in S-files under test database TEST in the directory named C:\seismo\REA, waveform files are in

C:\seismo\WAV, calibration files are under C:\seismo\CAL and other parameter files under C:\seismo\DAT. All work is done in a DOS command window in Windows or a terminal window under Linux. SeisanExplorer uses in addition its own window.

Since there are four events, there are also four S-files. The events' S-files (files with locations, readings etc., see example below) are already installed in the test database TEST under REA in directory see C:\Seismo\REA\TEST_\1996\06 for the Nordic format and the files are

```
03-1955-40D.S199606
25-0337-31L.S199606
```

and the Nordic2 files are in c:\seismo\REA\TEST_\2021\02

```
13-1407-10D.S202102
23-0514-03L.S202102
```

Two files have D in front of the '.' and are distant events, the other two have an L and are local events.

Most of the exercises will be made with the 1996 data unless specifically mentioned otherwise.

2 Get access to the events, EEV

In order to get access to the events directly from any directory, the command eev is used. It is also possible to use the GUI SeisanExplorer (section 13), however it is easier to understand the use of SeisanExplorer when standard SEISAN commands have been used so SeisanExplorer will be introduced later.
EEV normally works with one month at a time so the command to connect to the two events from 1996 is

```
eev 199606
```

When the system is installed, the default database (a directory in REA) is TEST, so EEV will automatically connect to the TEST database. After giving the above command, you should see

```
1996  6 Reading events from base TEST_  2
#    1  3 Jun 1996 19:55 35  D  47.760 153.227  0.0  N 1.1 5.6WHRV   12  ?
```

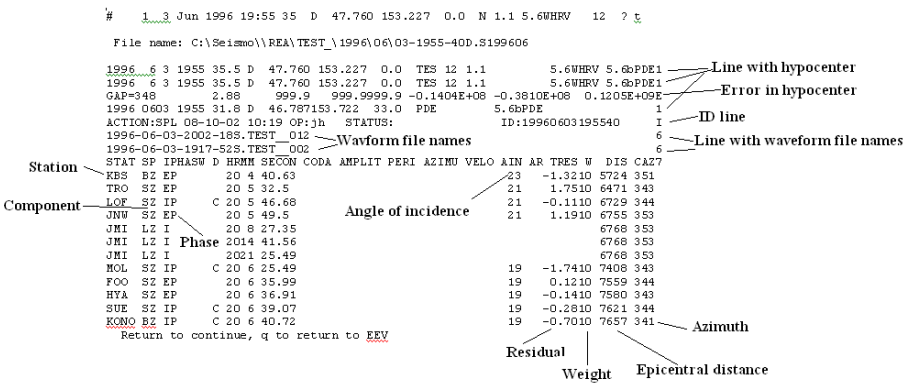
First there is a message telling how many events there are for June 1996, in this case 2 but it could be up to 200 000. Then follows origin time, 'D' for distant event, latitude, longitude and depth, 'N' to indicate a new event, rms of travel time residuals (1.1), magnitude 5.6 Mw from Harvard. 12 is the number of stations with observation listed in the S-file.

Go the second event (local) by pressing enter and you get

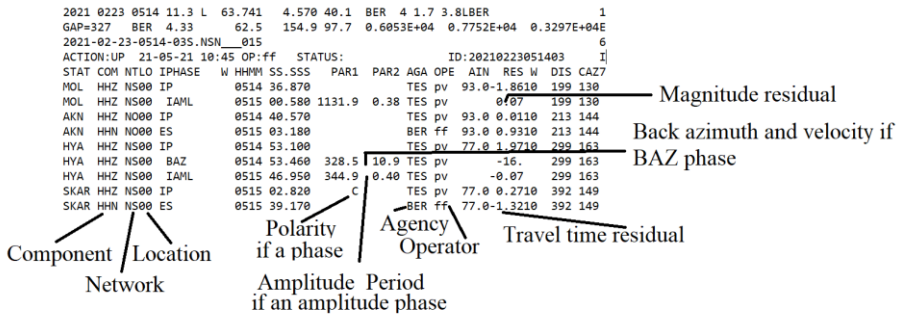
```
1996  6 Reading events from base TEST_  2
#    1  3 Jun 1996 19:55 35  D  47.760 153.227  0.0  N 1.1 5.6WHRV   12  ?
#    2 25 Jun 1996 03:37 31  L  61.689   3.259 15.0  N 3.0 3.3LTES   35  ?
```

3 Inspect the content of the S-file

Enter again will go back to the first event. List the file by typing ‘t’ and you get:



The most important explanations are given. The same file can also be edited using command ‘e’. Note there are several hypocenter lines, but the first one is the main line used, the others are for additional information. Note also that the event has two waveform files associated with the event. In a similar way we can inspect the local event in Nordic2 format from 2021. The most important changes are explained:



Where are the waveform files?

SEISAN will look for the waveforms in the current directory and in WAV. To check where the waveform files used are, type ‘w’ and you get:

```
#    1  3 Jun 1996 19:55 35  D  47.760 153.227  0.0  N 1.1 5.6WHRV   12  ? w
 Full path name    :  C:\Seismo\\WAV\1996-06-03-2002-18S.TEST__012
 Full path name    :  C:\Seismo\\WAV\1996-06-03-1917-52S.TEST__002
#    1  3 Jun 1996 19:55 35  D  47.760 153.227  0.0  N 1.1 5.6WHRV   12  ?
```

and it is seen that the 2 waveform files used are located in WAV.

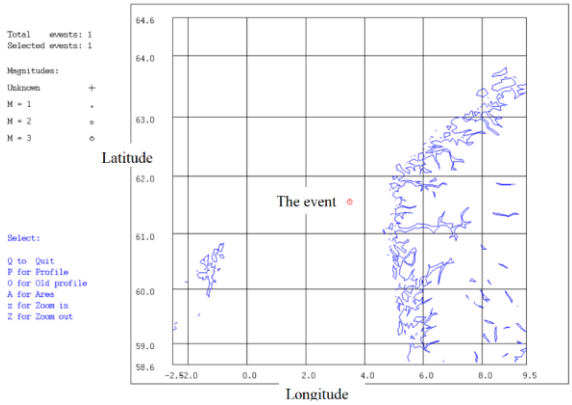
List of commands in EEV

Type '?' and enter and the list of EEV commands are given:

```
-----------------------------------------------------------------------
 Help on EEV, all commands are given in lower case
 -----------------------------------------------------------------------
 1  *** Basic commands
 2  *** Navigation in EEV
 3  *** Event information
 4  *** File operation like copy, delete, email etc.
 5  *** File modification and edit, add data
 6  *** Archive and waveform files
 7  *** Hypocenter location
 8  *** Plot signals and time sequece analysis
 9  *** Plot epicenter
10  *** Plot spectra, magnitudes vs distance, wadati, picture etc
11  *** Automatic routines for picks, amplitudes and spectra
12  *** Fault plane solution, plot, manipulation
13  *** Moment tensor
14  *** Synthetic seismogram and travel times
15  *** Macroseismic information
16  *** Explosion information
17  *** Other commands


 Give a number for topic, 0 for whole list, enter to terminate
2

*** Navigation in EEV

 B:        Back one event
 #xx:      Go to event # xx, also works without the #
 DRddhhmm: Go to first event on day dd, hour hh, min mm
 Yyyyymmdd Go to first event at or after yyyymmdd, give at least year,
           only for local data base or index file
 Eyyyymm:  Let EEV session end with year yyyy and month mm
 Jyyyymm BAS:Jump to year yy and month mm in base BAS
 Sxxxxxx:  Search for next two events which are within xxxxxx seconds.
           is blank, a default of 180 secs is used
 SS:       Find next unprocessed event in base

Get list (enter), q to terminate
```

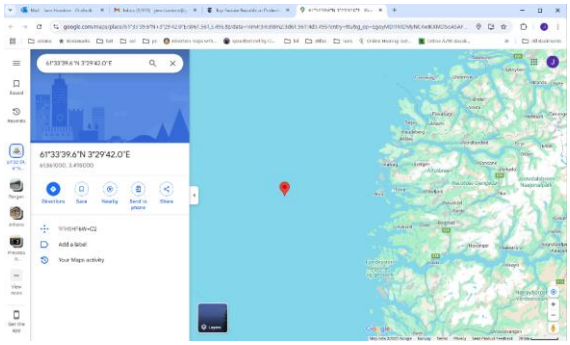
4 Plot the epicentre

Go to the second event in June 1996, type 'map' and you get



The map used is not very detailed. It can be replaced with a more detailed map, changed in file C:\seismo\DAT\SEISAN.DEF. The size of the map and optionally also plotting stations can also be specified in SEISAN.DEF. If there is access to Internet, Google can be used. Type 'gmap'

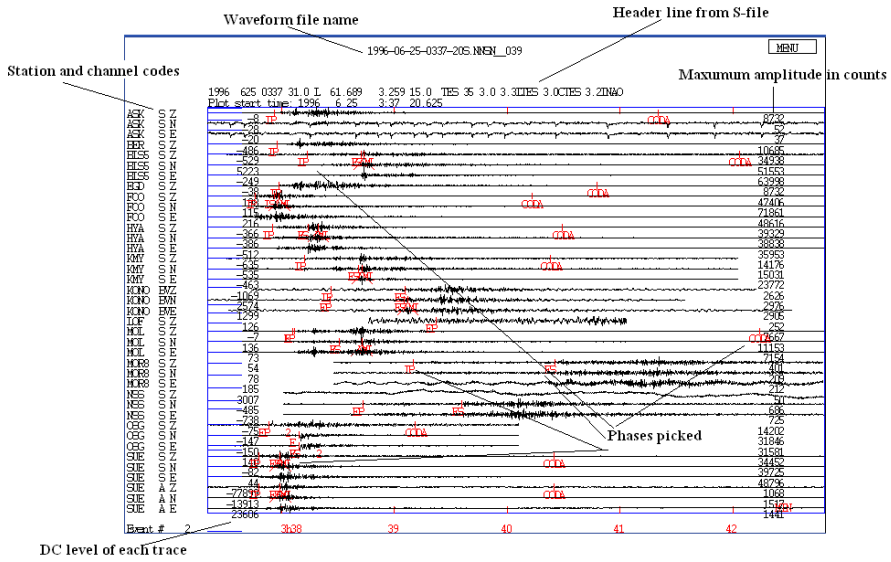
and you get



Many events can be plotted outside EEV with MAP, MAPG (GMT) or GMAP.

5 Plot waveforms, multi trace mode

Go to the second event, type ‘po’ and you will see:

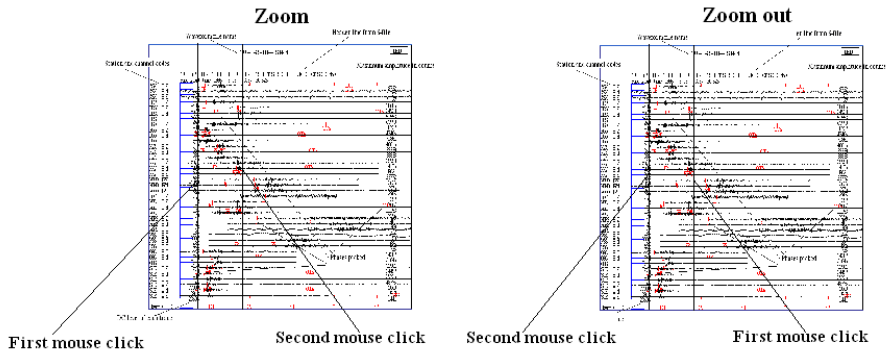


NOTE: The end of the coda is now plotted with phase name END, while in the figure above the old name CODA is used.

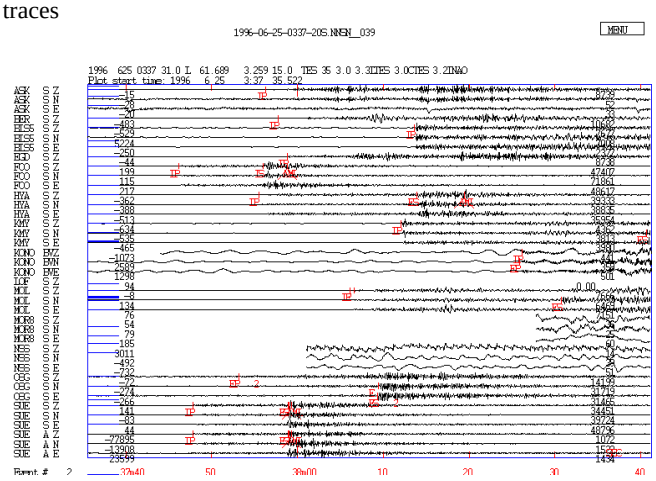
Command ‘p’ will also plot events but then there are more choices, so it is simplest to use ‘po’. If only channels with readings are to be plotted, use command ‘pp’.

5.1 How to zoom

Zoom: Put cursor among the traces at position for start of zoom, click on end of zoom. To zoom out, do the opposite. See illustration below.

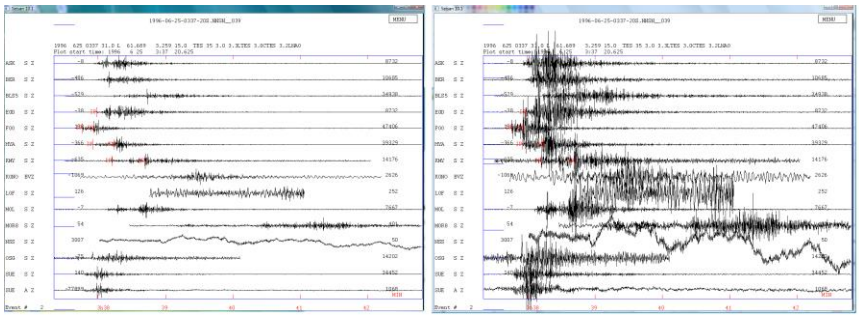


The zoomed traces



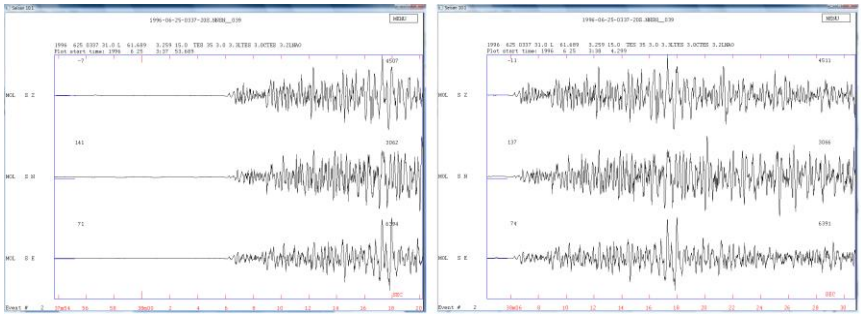
5.2 How to change amplitude, up down arrow keys

The amplitude on the plot can be made larger or smaller with the arrow keys up and down. The example below shows the effect of pressing the arrow key up two times.



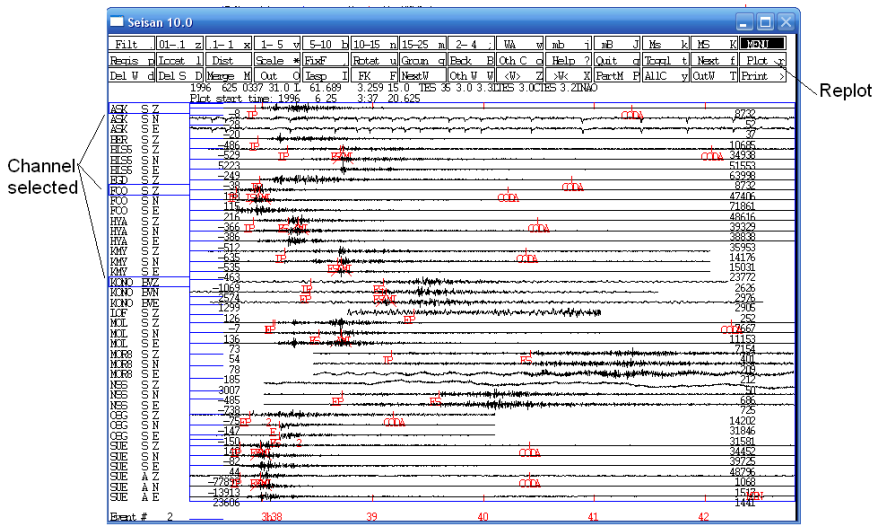
5.3 How to scroll the plot left and right, horizontal arrow keys

The first plot below shows a zoom of 3 traces. In order to see the rest of the signal zoomed, the whole plot can be moved left and right with the horizontal arrow keys. The plot below left shows the original zoom and the plot right, the plot after pressing the right arrow keys 3 times.

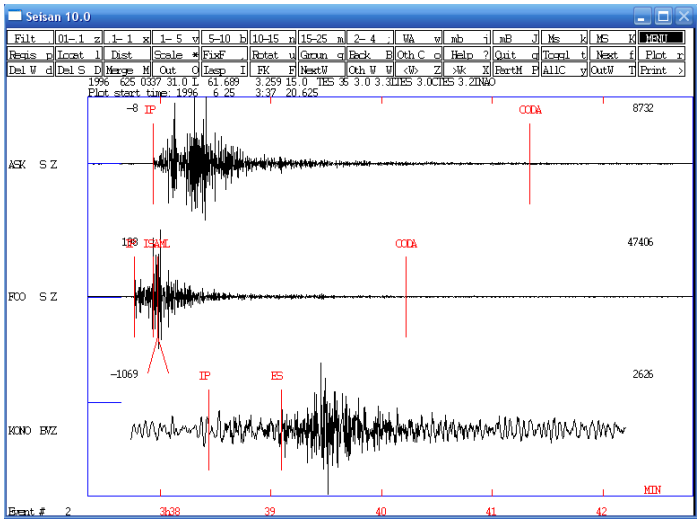


5.4 Select channels on plot

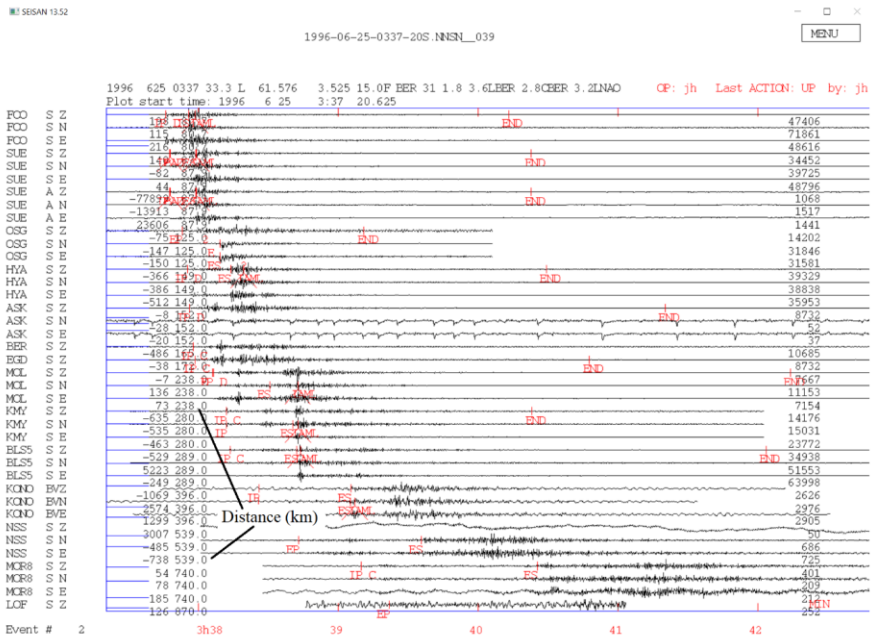
Select the channels by clicking on the channel name and then click on Plot, see figure below



and the plot with the 3 channels will follow.



A useful option is also to plot the channels in distance order by pressing Dist or '_':

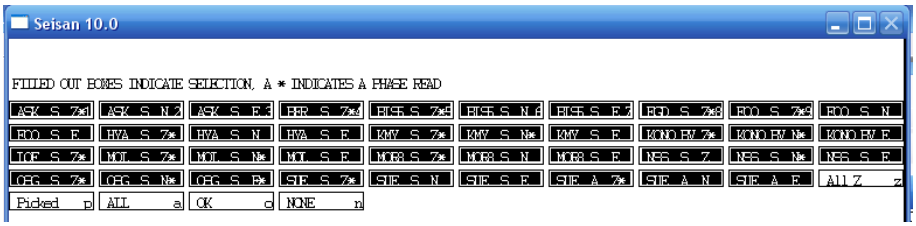


Optionally, the distance can be plotted above each trace. This is selected in `MULPLT.DEF`

```
PLOT DISTANCE       0: no 1: epi 2: hyp  1.0
```

A range of channels can be selected by using left-mouse click on the first channel and right-mouse click on the last channel

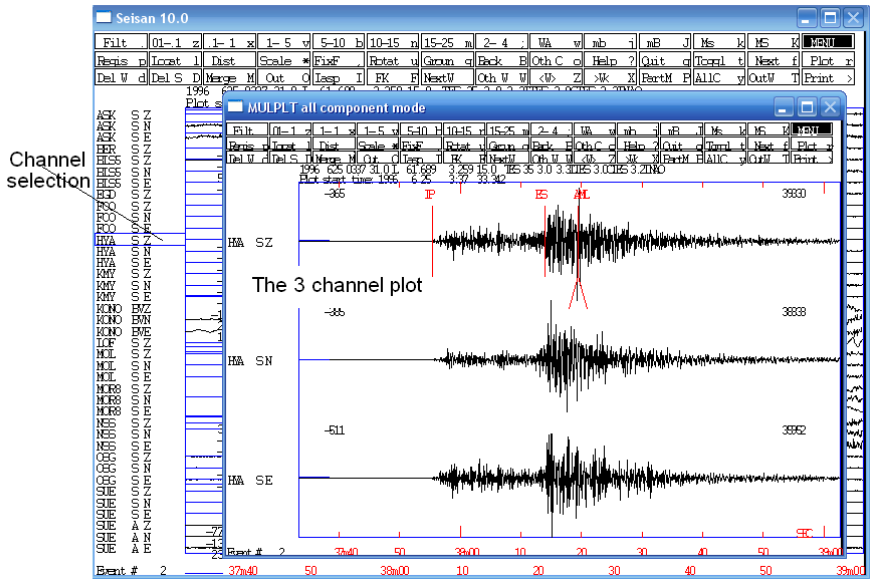
Select channels by using the list of channels**:** On menu, press Oth C (or ‘o’ on keyboard) and channel selection list comes up**:**



It is now possible to select and deselect channels. All channels with readings can be selected or only Z-channels. Press ok or ‘f’ on keyboard and the multi trace plot comes up again. This menu will also come up if you press ‘p’ from EEV.

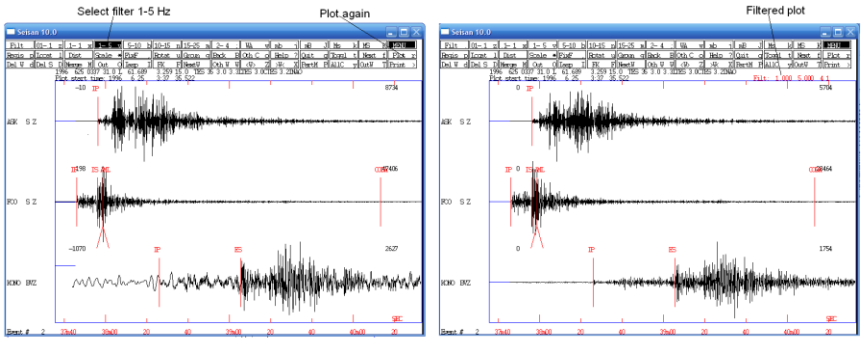
5.5 Plot all components for a selected station

Select one channel as shown above, press ‘y’ and the plot show 3 channels. In this case some zooming was done before pressing ‘y’. To return to the multi trace plot press ‘y’ or ‘t’.



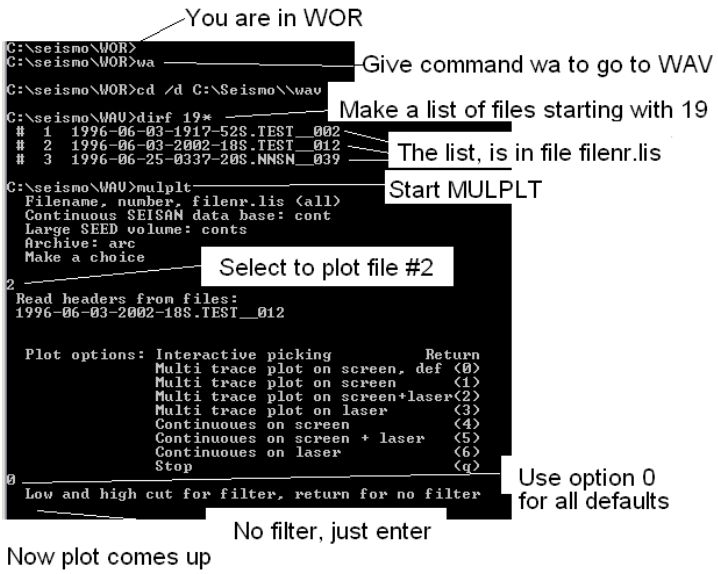
5.6 How to filter traces

We will use the example above where stations ASK, FOO and KONO were selected. On the menu, select a filter or use the corresponding keys on the keyboard. Press Plot or ‘r’ and the filtered plot appears. Plot again and the filters are removed. In this example, the effect of the 1-5 Hz filter is mostly seen on the 3rd channel, broad band station KONO.

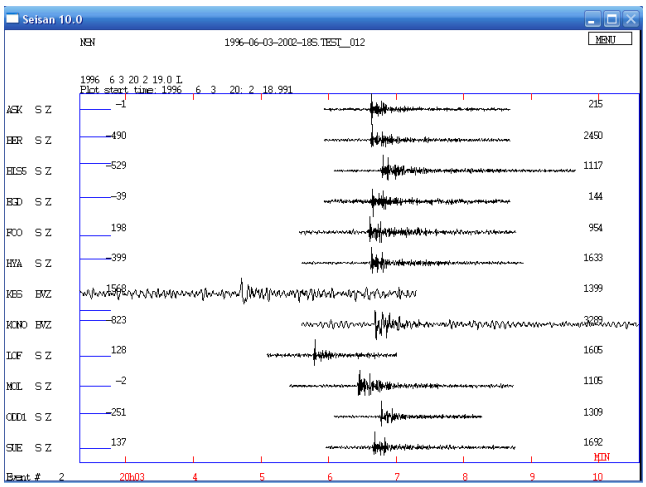


5.7 Plot an event directly with MULPLT without using EEV

The waveform files are in the WAV directory. Go to the WAV directory, make a list of the waveform files and plot one of them:



Note that now there are no phase arrival readings indicated on the plot since the plot is not made from EEV and therefore it is not referenced to the S-file with the readings.

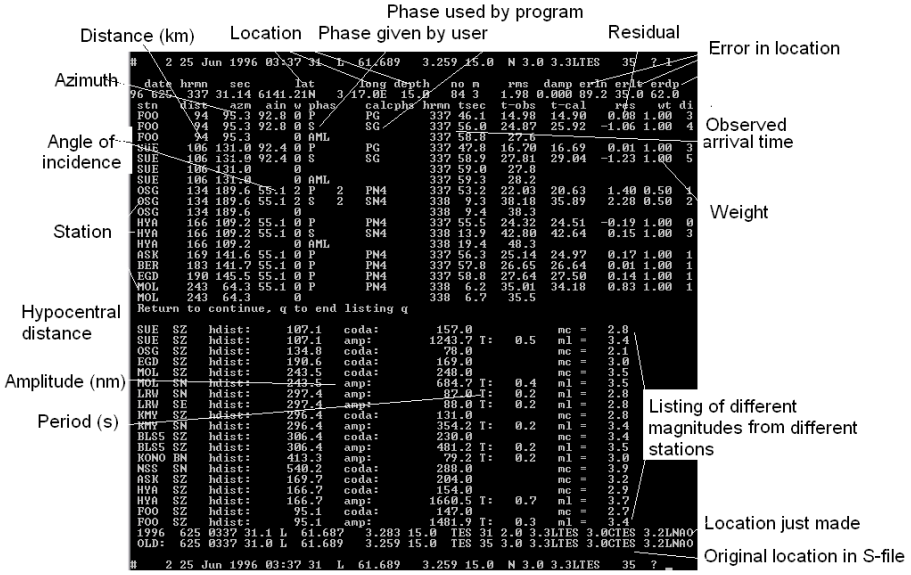


However, if phase picks are made, they will be saved in a temporary file `mulplt.out` when quitting MULPLT. The file is overwritten next time MULPLT is used.

6 Locating events

6.1 Locate a local event using phases in S-file

Select the local event in EEV. Use command ‘l’ (note this is lower case L and not the number one ‘1’) and the result is



The most important output values are explained. Note that the location made currently is slightly different from the location in the S-file. The location in the S-file will remain until updated with command ‘u’.

Update S-file

```
#    2 25 Jun 1996 03:37 31  L  61.687   3.283 15.0    2.0 3.3LTES   31  ? u
 Give operator code, max 4 characters
jh

  date hrmn   sec      lat      long depth   no m    rms  damp erln erlt erdp
96 625  337 31.04 6141.39N   3 15.7E  15.0   82 3   1.99 0.000 89.8 35.9 65.2
 stn   dist   azm  ain w phas    calcphs hrmn tsec  t-obs  t-cal    res   wt di
 FOO     95  95.4 92.7 0 P       PG       337 46.1  15.08  15.08   0.00 1.00  1
 FOO     95  95.4 92.7 0 S       SG       337 56.0  24.97  26.24  -1.27 1.00  2
.
.
.
 BLS5 SZ   hdist:     307.4   coda:        230.0            mc =   3.4
 BLS5 SZ   hdist:     307.4   amp:         481.2 T:   0.2   ml =   3.5
 KONO BN   hdist:     414.3   amp:          79.2 T:   0.2   ml =   3.0
 NSS  SN   hdist:     541.2   coda:        288.0            mc =   3.9
 1996  625 0337 31.0 L  61.690   3.261 15.0  TES 31 2.0 3.3LTES 3.0CTES 3.2LNAO
```

```
 OLD:  625 0337 31.1 L  61.687   3.283 15.0  TES 31 2.0 3.3LTES 3.0CTES 3.2LNAO

  You are now about to overwite the current event in the database.
  with the solution just shown
  The catalog is not updated !!!!!
  Sure you want to update, (y/n) ?
y
#    2 25 Jun 1996 03:37 31  L  61.690   3.261 15.0    2.0 3.3LTES   31  ?
```

The old location and residuals in S-file have now been overwritten.

6.2 Locate a distant event using phases in S-file

Select a distant event in EEV. Use command ‘l’ and the result is

```
#    1  3 Jun 1996 19:55 20  D  45.736 154.919  1.0  N 2.2 5.6BPDE   15  ? l

  date hrmn   sec      lat      long depth   no m    rms  damp erln erlt erdp
96 6 3 1955 20.07 4544.24N 154 54.9E   0.2   14 3   2.15 0.000999.9999.9999.9
 stn   dist   azm  ain w phas    calcphs hrmn tsec  t-obs  t-cal    res   wt di
 KBS   5966 351.7 22.5 0 P       P       20 4 40.6 560.56 562.55  -1.99 1.00 26
 KBS   5966 351.7      0 IAMs_20         2026 45.9 1885.8
 TRO   6725 343.8 20.9 0 P       P       20 5 32.5 612.43 610.95   1.48 1.00 20
 LOF   6981 344.8 20.4 0 P     C P       20 5 46.7 626.61 626.55   0.06 1.00  8
 JNW   6993 354.0 20.3 0 P       P       20 5 49.5 629.43 627.23   2.20 1.00 30
 JMI   7007 354.0      0                 20 8 27.3  787.3
 JMI   7007 354.0      0                 2014 41.6 1161.5
 JMI   7007 354.0      0                 2021 25.5 1565.4
 MOL   7660 344.5 19.0 0 P       P       20 6 25.6 665.56 666.02  -0.46 1.00  0
 FOO   7811 345.2 18.6 0 P       P       20 6 36.0 675.92 674.39   1.53 1.00  1
 FOO   7811 345.2      0 IAmb            20 6 36.9  676.8
 HYA   7833 344.5 18.6 0 P       P       20 6 36.9 676.84 675.58   1.26 1.00  1
 SUE   7873 345.2 18.5 0 P     C P       20 6 39.1 679.00 677.78   1.22 1.00  1
 KONO  7911 342.2 18.4 0 P     C P       20 6 40.7 680.65 679.96   0.69 1.00  3
 ASK   7924 344.7 18.4 0 P       P       20 6 37.2 677.17 680.57  -3.40 1.00  2
 BER   7931 344.6 18.4 0 P       P       20 6 37.4 677.36 680.97  -3.61 1.00  2
 EGD   7945 344.6 18.4 0 P       P       20 6 38.4 678.35 681.72  -3.37 1.00  2
 ODD1  7952 343.8 18.3 0 P       P       20 6 45.6 685.50 682.24   3.26 1.00  2
 Return to continue, q to end listing
 BLS5  8006 343.7 18.2 0 P       P       20 6 46.3 686.26 685.15   1.11 1.00  2
 BLS5  8006 343.7      0 IAmb            20 6 48.0  688.0

 KBS  LZ    dist:    5966.0   amp:        1454.7 T:  18.0   Ms =   5.1
 BLS5 SZ    dist:    8006.0   amp:          94.2 T:   0.9   mb =   5.9
 FOO  SZ    dist:    7811.0   amp:         213.1 T:   1.1   mb =   6.2
 1996  6 3 1955 20.1 D  45.737 154.914  0.2  TES 15 2.2 5.1sTES 6.1bTES 5.6BPDE
 OLD:  6 3 1955 20.2 D  45.736 154.919  1.0  TES 15 2.2                 5.6BPDE
```

The explanation is the same as for the local event above. However, the magnitudes calculated are now Ms and mb and the distances are much larger. The model used for location is the global IASP91 model.

7 Pick phases

7.1 Delete all old phases

Before picking phases, for the purpose of this tutorial, all the phases for the event should be deleted. Select the local event. The phases can be deleted with the editor or with an EEV command. The EEV command is ‘dels’, see example below, where all phases have been deleted.

```
 1996  6 Reading events from base TEST_  3
#    1  3 Jun 1996 19:55 35  D  47.760 153.227  0.0  N 1.1 5.6WHRV   12  ?
#    2 25 Jun 1996  3:37 31  L  61.690   3.261 15.0    2.0 3.3LTES   31  ? dels
```

```
 Give line to delete or keep, terminate with 0
 1: Lines with P-phase             Not delete
 2: Lines with S-phase             Not delete
 3: Lines with SPEC-phase          Not delete
 4: Lines with IAML-phase          Not delete
 5: Lines with IASP-AMP phase      Not delete
 6: Lines with AM, AT and AS phase Not delete
 7: Lines with END phase           Not delete
 8: Lines with BAZ phase           Not delete
 9: Lines with any phase           Not delete
10: Lines with fp solutions        Not delete
11: Phases with given stations     Not delete
12: WAV references, line type 6    Not delete
13: Old ID lines                   Not delete

9
 Give line to delete or keep, terminate with 0
 1: Lines with P-phase             Not delete
 2: Lines with S-phase             Not delete
 3: Lines with SPEC-phase          Not delete
 4: Lines with IAML-phase          Not delete
 5: Lines with IASP-AMP phase      Not delete
 6: Lines with AM, AT and AS phase Not delete
 7: Lines with END phase           Not delete
 8: Lines with BAZ phase           Not delete
 9: Lines with any phase           Not delete
10: Lines with fp solutions        Not delete
11: Phases with given stations     Not delete
12: WAV references, line type 6    Not delete
13: Old ID lines                   Not delete
0
 1996  625  337 31.0 L  61.690   3.261 15.0  TES 31 2.0 3.3LTES 3.0CTES 3.2LNAO
 Give operator code, max 4 characters
jh

 Number of events in input file           1
 Number of deleted lines          68
 Output file name is dels.out
#    2 25 Jun 1996  3:37 31  L  61.690   3.261 15.0    2.0 3.3LTES   31  ?
```

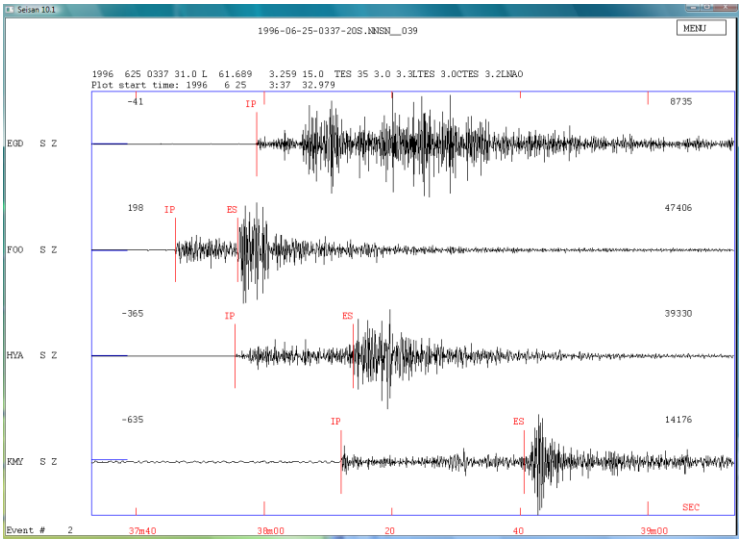
All phase lines have now been deleted, see content of S-file below

```
1996  625  337 31.0 L  61.690   3.261 15.0  TES 31 2.0 3.3LTES 3.0CTES 3.2LNAO1
 GAP=153       21.23      35.9    89.8 65.2 -0.6139E+03  0.8616E+03  0.3554E+00E
 1996  625  337 31.9 L                        BER        3.1WBER               1
 1996-06-25-0337-20S.NNSN__039                                                 6
     327.2      62.0     -11.2     0                                          3
ACTION:DPH 14-02-12 16:57 OP:jh   STATUS:               ID:19960625033731     I
 STAT SP IPHASW D HRMM SECON CODA AMPLIT PERI AZIMU VELO AIN AR TRES W  DIS CAZ7
```

The ‘ACTION’ line now indicate DPH, delete phases, by operator (OP:jh).

7.2 Pick new phases

In order to make it simple, plot only the Z-traces for 4 stations (figure below). In order to pick the P-phase, move the cursor to P and press ‘1’ and the phase appears on the plot. The phase is indicated with IP, where the ‘I’ indicates impulsive. Similarly pick S by moving the cursor to the S and press ‘8’ and the S-reading ES appear where E indicates emergent. Normally, S-phases should be read on the horizontal components. For picking other phases, see later.



From the plot, phases have now been read for P and S for 3 stations and for P only for one station (EGD). Quit plot with ‘q’ and the S-file now has the readings. List the S-file with ‘t’:

```
#    2 25 Jun 1996  3:37 31  L  61.690   3.261 15.0    2.0 3.3LTES   31  ? t

 File name: C:\Seismo\\REA\TEST_\1996\06\25-0337-31L.S199606

1996  625  337 31.0 L  61.690   3.261 15.0  TES 31 2.0 3.3LTES 3.0CTES 3.2LNAO1
GAP=153       21.23      35.9    89.8 65.2 -0.6139E+03  0.8616E+03  0.3554E+00E
1996  625  337 31.9 L                       BER        3.1WBER                1
1996-06-25-0337-20S.NNSN__039                                                6
    327.2      62.0     -11.2     0                                          3
ACTION:DPH 14-02-12 16:57 OP:jh   STATUS:              ID:19960625033731     I
STAT SP IPHASW D HRMM SECON CODA AMPLIT PERI AZIMU VELO AIN AR TRES W  DIS CAZ7
EGD  SZ IP        337 58.55
HYA  SZ IP        337 55.38
HYA  SZ ES        338 14.40
FOO  SZ IP        337 46.03
FOO  SZ ES        337 56.09
KMY  SZ IP        338 12.02
KMY  SZ ES        338 41.42
```

7.3 Locate event

The event can now be located with command ‘l’

```
#    2 25 Jun 1996 03:37 31  L  61.689   3.259 15.0  N 3.0 3.3LTES   35  ? l

  date hrmn    sec       lat      long depth    no m     rms  damp erln erlt erdp
96 625  337 31.48 6135.62N    3 23.0E   4.9     7 3   0.31 0.000 12.0  9.0  6.7
 stn   dist   azm  ain w phas    calcphs hrmn tsec  t-obs  t-cal    res   wt di
 FOO     88  89.0 93.2 0 P       PG       337 46.0  14.55  14.25   0.31 1.00 11
 FOO     88  89.0 93.2 0 S       SG       337 56.1  24.61  24.79  -0.18 1.00 23
 HYA    157 106.4 50.4 0 P       PN4      337 55.4  23.90  24.48  -0.58 1.00 10
 HYA    157 106.4 50.4 0 S       SN4      338 14.4  42.92  42.59   0.33 1.00 23
 EGD    178 145.1 50.4 0 P       PN4      337 58.6  27.07  27.05   0.02 1.00  4
 KMY    285 158.0 50.4 0 P       PN4      338 12.0  40.54  40.29   0.26 1.00  8
 KMY    285 158.0 50.4 0 S       SN4      338 41.4  69.94  70.10  -0.16 1.00 22

 HYA  SZ   gdist:     125.3   mom:          14.4   mw =   3.5
 1996  625 0337 31.5 L  61.594   3.383  4.9  TES  4 0.3 3.5WTES         3.2LNAO
 OLD:  625 0337 31.0 L  61.689   3.259 15.0  TES 35 3.0 3.3LTES 3.0CTES 3.2LNAO
```

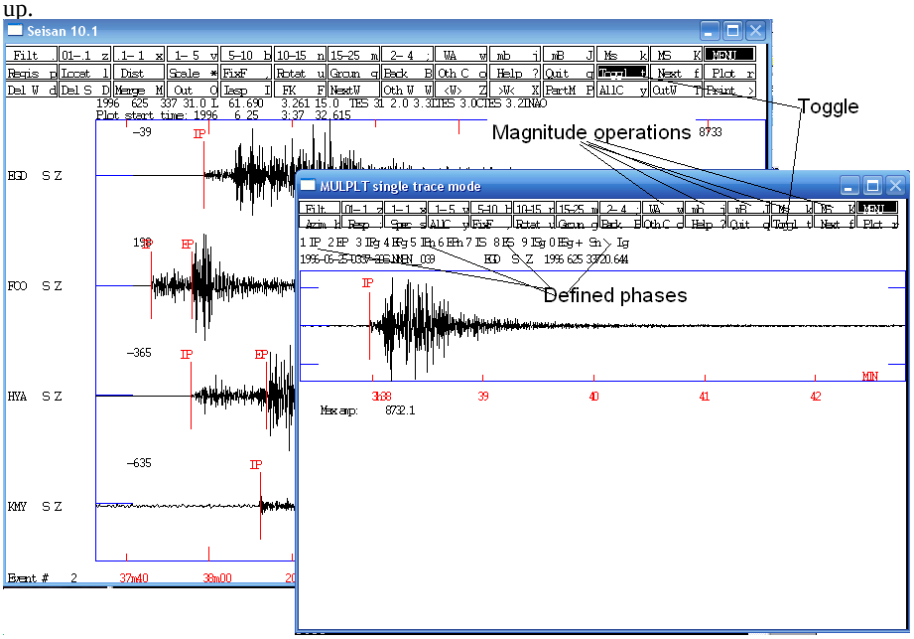
Notice that the location has changed about 11 km due to using fewer stations. The magnitudes `3.3LTES 3.0CTES` from agency TES (the default set up with the test data) have also disappeared since no amplitude or coda lengths were read, see later. The magnitude `3.2LNAO` is still there. This is a magnitude from a different agency (NAO) and since it is written in 3. magnitude position, it will not be deleted. This is a way for SEISAN to keep a magnitude from other agencies for comparison.

7.4 Picking phases with more accuracy

Picking phases using multi-trace screen is often not very accurate since it is difficult to zoom on several traces with different arrival times at the same time. So phases are mostly picked in single trace mode or three-component mode (see 5.5), where it is also easy to pick S on horizontal components. The other option is to use scrolling with the arrow keys to continue to use multi trace mode, see 5.3. In all cases, it might also be an advantage to amplify the amplitude with the vertical arrows, see 5.2.

7.4.1 Single trace mode

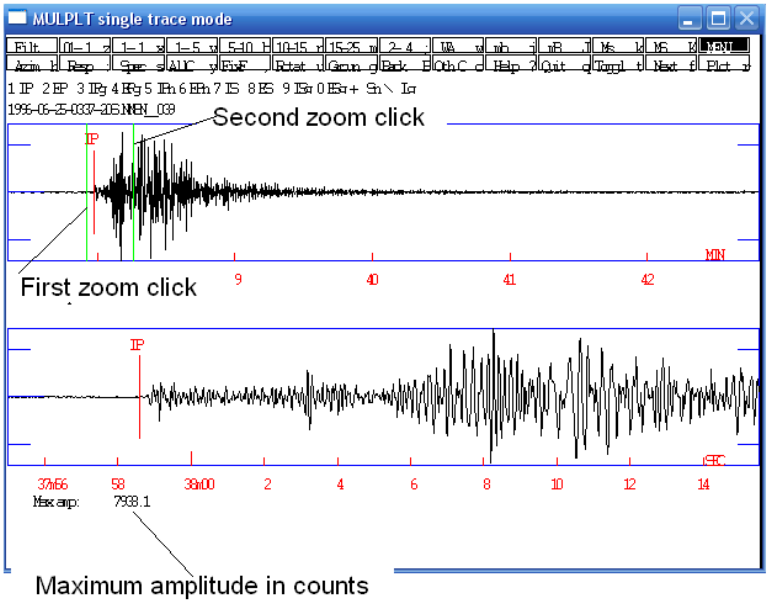
From the multi-trace mode, press 'Togl' (or 't') on the menu and a single trace window comes up.



This window has different options in the menu as compared to the multi-trace window and is meant to be used for operations taking place with a single trace. The phases defined on the keyboard are shown (all also defined in multi-trace mode). Some magnitude operations are also indicated, see 8. To go back to multi-travel mode, press Togl again.

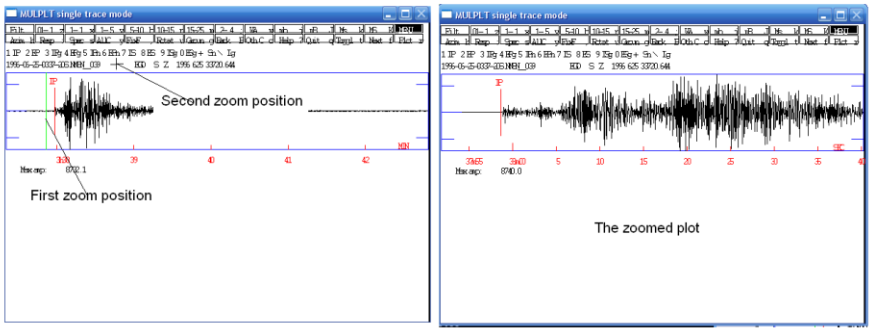
7.4.2 Zoom in single-trace mode

Zoom can be done in 2 ways. The first method is to zoom on the top trace and the zoomed signal is shown on the bottom trace. The zoom clicks are done *inside* the top plot:



To un-zoom or re-plot the top trace again, press ‘Plot’ or ‘r’ on keyboard.

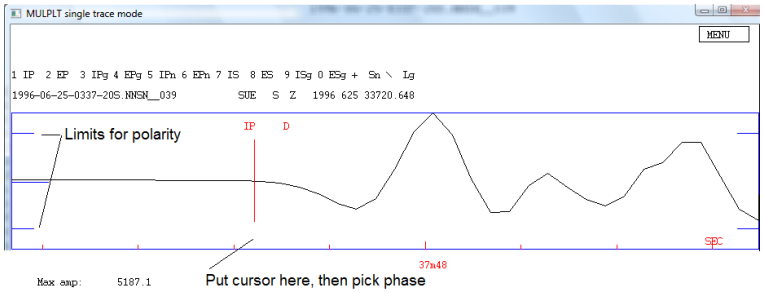
The second method is to zoom on the top trace only. The first zoom click is inside frame with the plot and the second is *outside*:



Phases can be read on all plots in single-trace mode, however if a lower plot is shown, readings can only be done there. On the top trace several zooms can be done until the desired resolution is obtained.

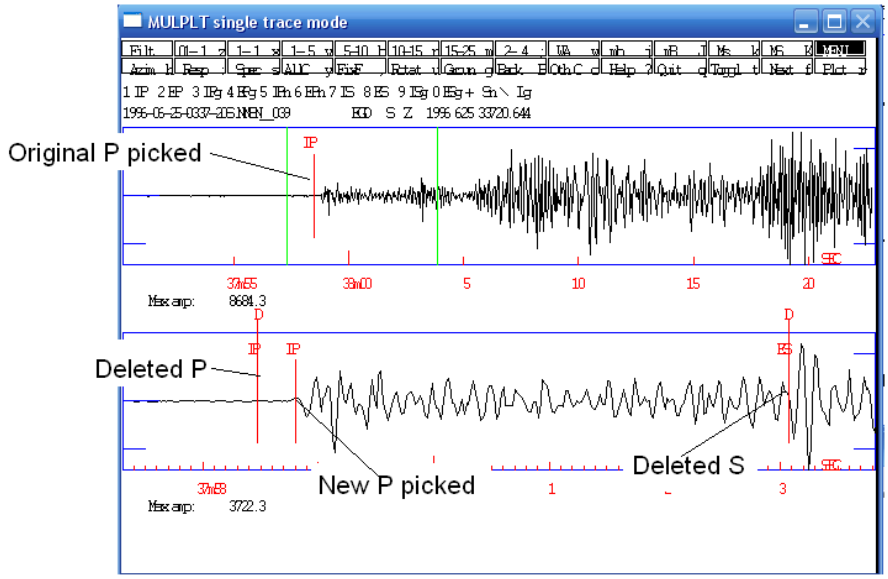
7.4.3 Pick polarity in single trace mode

Polarity can be picked at the same time as a phase is picked. Polarity can be picked in multi-trace and single-trace mode but is simplest in single trace mode. Below is a zoomed signal in single-trace mode so the polarity is clearly seen. For the polarity to be picked, the cursor must be above or below the "Limits for polarity" marker. Put the cursor as indicated below, press '1' and the result is as shown. If there is a reading from before without polarity, just repick the same phase.



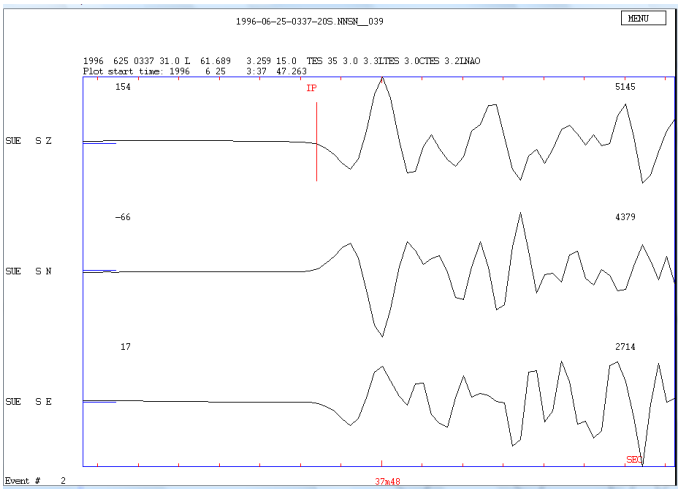
7.4.4 Deleting and re-picking phases

A phase can be re-picked without deleting the old pick, the old phase will automatically be deleted when the same phase (NOTE: IP and EP are considered different) is re-picked on the same channel, see P-phase below. A phase can also be deleted by putting the cursor near the phase and pressing 'd' on keyboard as illustrated with the S-phase below.

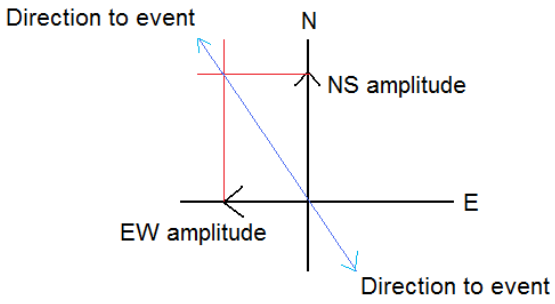


7.5 Locating an event with one station, three component method

It is sometimes useful to get a location with only one station. This requires good three component data where the P-waves of the 3 components correlate well. Plot the 3 SP components of the station SUE for event 2:

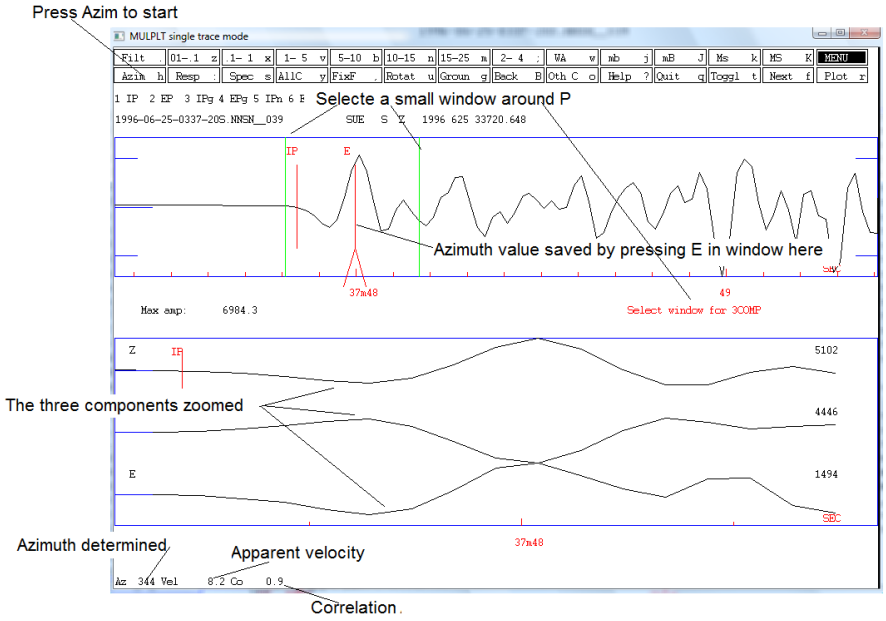


You can see that the P-phases on the 3 components look similar. The NS amplitude is positive and the EW amplitude negative, of similar amplitude as the NS so the direction to the event from the station is either between 90 and 180 degrees or 270 and 360 degrees:



From the polarity of the Z it is seen that the direction to the event is NW. With the direction to the event and the P and S-time, the location can be calculated, however the depth will be fixed. The back-azimuth from the station to the event can be determined in single trace mode by correlating the 3 traces.

- Select the local eventh, June 1996.
- Plot station SUE in single trace mode.
- Zoom on top trace to see the P clearly.
- Press Azim and then select a small window around the P.
- A plot will appear, and it shows the 3 components and the results of the correlation.
- If acceptable (correlation must be positive and as large as possible), press ‘e’ on top trace and the value are save as an E-phase.



Traces are not always so nice, so the procedure might have to be repeated a few times to get a good result. Many times the signal must also be filtered to get good results and a shorter window used. Press the filter before Azim in that case. The S-file now has the added line:

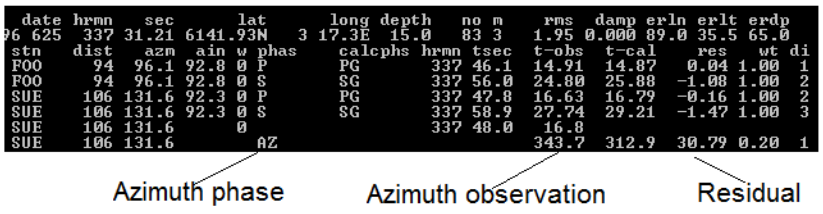
```
STAT SP IPHASW D HRMM SECON CODA AMPLIT PERI AZIMU VELO AIN AR TRES W  DIS CAZ7
SUE  SZ E         337 48.00                  343.7  8.2
```

and on the plot a phase E with an amplitude symbol is added to indicate reading of back-azimuth. In the new format the line would be

```
STAT COM NTLO IPHASE    W HHMM SS.SSS    PAR1  PAR2 AGA OPE  AIN  RES W  DIS CAZ7
SUE  S Z       BAZ       0337 48.000  343.7   8.2 BER jh
```

and the phase on the plot would be BAZ.

Locate the event:



and it is seen that the ‘error’ in the back-azimuth is 30 degrees, a bit large. The event can now be located with only SUE (removing all other phases in S-file) and we get

```
  date hrmn   sec      lat      long depth   no m    rms  damp erln erlt erdp
96 625  337 32.84 6152.25N   4 15.4E  15.0    3 2   0.00 0.000  5.4  3.7  0.0
 stn   dist   azm  ain w phas    calcphs hrmn tsec  t-obs  t-cal    res   wt di
 SUE     95 163.3 92.8 0 P       PG       337 47.8  15.00  15.01  -0.00 1.00 25
 SUE     95 163.3 92.8 0 S       SG       337 58.9  26.11  26.11   0.00 1.00 25
 SUE     95 163.3        AZ                         343.7  343.7  -0.01 0.20 50
 SUE     95 163.3      0                  337 48.0   15.2
 SUE     95 163.3      0 AML              337 59.3   26.5

 SUE  SZ   hdist:      95.8   coda:        150.0            mc =   2.8
 SUE  SZ   hdist:      95.8   amp:        1243.7 T:   0.5   ml =   3.3
 1996  625 0337 32.8 L  61.871   4.257 15.0  TES  1 0.0 3.3LTES 2.8CTES 3.2LNAO
 OLD:  625 0337 31.2 L  61.699   3.289 15.0  TES 31 1.9 3.3LTES 3.0CTES 3.2LNAO
```

And it is seen that the location has changed substantially. The exact change in km is given in output file `print.out`. The print.out file can be inspected from EEV with command ‘ep’. There are many sources of error in determining the azimuth: bad s/n, wrong sensor orientation and different gain of the 3 components.

8 Magnitude

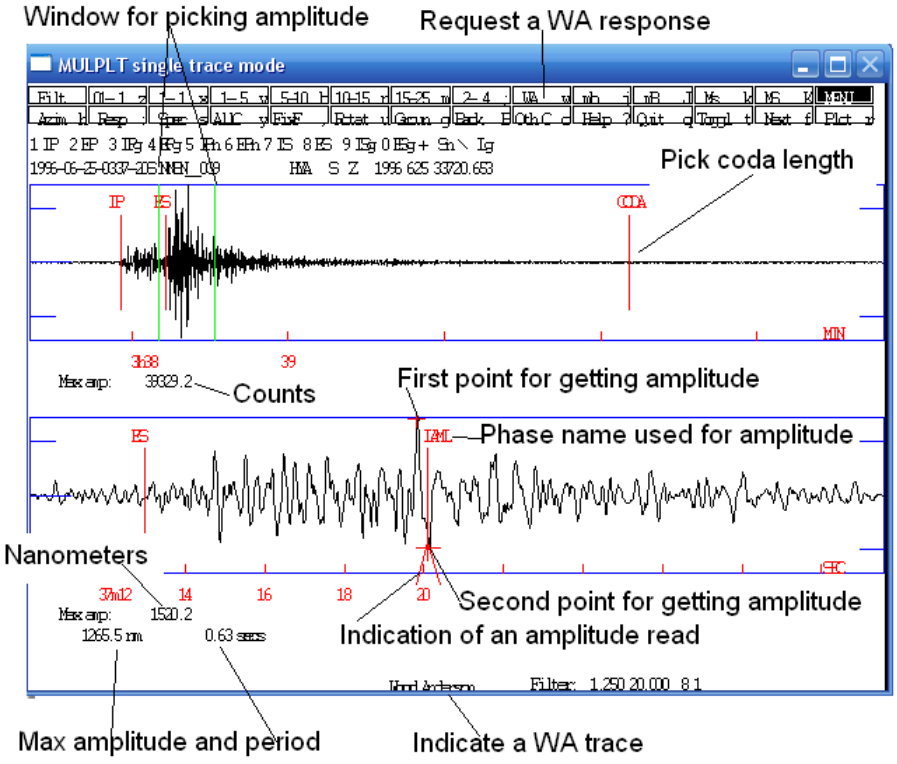
Magnitudes are usually calculated using maximum amplitudes on the Z-channels although amplitude for Ml, by definition should be read on the horizontal components. However, the practice is often to read on vertical channels for Ml. Magnitudes can also be calculated from the coda length if no response function is available or the spectrum of the P and S waves. For all amplitude based magnitudes, the amplitudes are read on a trace which has been corrected for the instrument response and then simulating a classical instrument. Response functions for the channels used must therefore be present, usually in the CAL directory. For the four test events, the following response files are available:

```
AKN__HH_E.2013-01-17-1054_GSE
AKN__HH_N.2013-01-17-1054_GSE
AKN__HH_Z.2013-01-17-1054_GSE
BSD__HH_Z.2000-06-19-0000_GSE
HOMB_HH_Z.2018-06-04-0000_GSE
HYA__HH_E.2017-12-21-0000_GSE
HYA__HH_N.2017-12-21-0000_GSE
HYA__HH_Z.2017-12-21-0000_GSE
HYA__S__Z.1994-02-09-1200
KONO_BV_Z.1991-06-24-1800
KONO_L__Z.1991-06-24-1800
MOL__HH_E.2019-06-19-0000_GSE
MOL__HH_N.2019-06-19-0000_GSE
MOL__HH_Z.2019-06-19-0000_GSE
MUD__HH_Z.2000-06-19-0000_GSE
ODLO_HH_E.2019-05-14-0000_GSE
ODLO_HH_N.2019-05-14-0000_GSE
ODLO_HH_Z.2019-05-14-0000_GSE
RESP.GE.DAG..BHZ
RESP.GE.KBS.10.BHZ
RESP.IU.KONO.10.LHZ
SKAR_HH_E.2018-09-20-0000_GSE
SKAR_HH_N.2018-09-20-0000_GSE
SKAR_HH_Z.2018-09-20-0000_GSE
TRO__S__Z.1993-08-06-1200
```

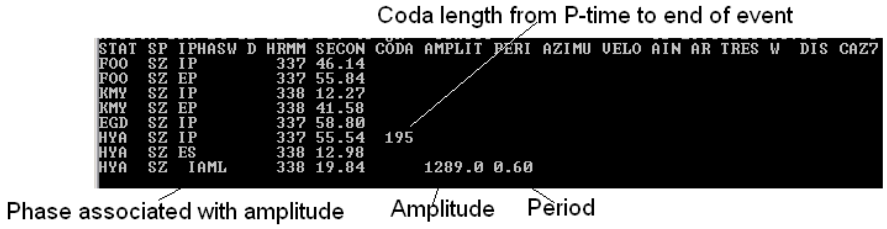
For files in GSE format (ending with GSE), the first 5 characters is the station, the following 4 the component and then follow the data from which the response is valid. For files in RESP format, following RESP, we have network, station, location and component. The valid period is inside the file.

8.1 Local magnitude Ml and coda magnitude Mc

The local magnitude is picked on a trace simulating the Wood-Anderson seismograph. Select station HYA in single trace mode. Pressing WA in menu and then selecting a window and the corrected trace (amplitudes in nm ground motion) will come up:



The amplitude is then picked manually by moving the cursor to one extreme, press ‘a’ on keyboard, move to the opposite extreme, press ‘a’ on keyboard. The amplitude and period is then printed on the bottom of the plot and the phase IAML is indicated on the plot. The phase has an indication on the bottom (a hat) indicating that this phase has an amplitude associated.
The max amplitude can also be measured automatically by pressing ‘A’ with the cursor anywhere on the plot. If using automatic picking, check carefully that the automatic determination seems reasonable (automatic pick will be plotted).
The coda length is picked by pressing ‘c’ on keyboard at the location where the event trace disappears into the noise. A coda label ‘END’, will appear on the plot when ‘c’ is pressed. Coda magnitude should only be used if there is no calibration available. The content of the S-file is now:



and locating (using 'l') gives the following result:

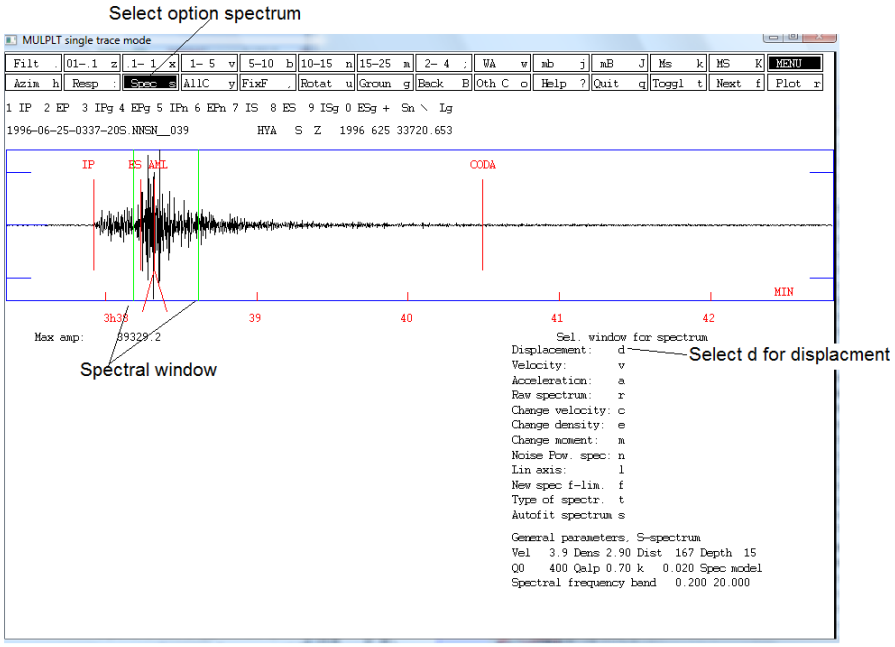
```
#    2 25 Jun 1996  3:37 31  L  61.690   3.261 15.0    2.0 3.3LTES   31  ? l

  date hrmn    sec      lat      long depth   no m    rms  damp erln erlt erdp
96 625  337 31.98 6141.79N   3 23.1E  19.2    5 3   0.03 0.000 10.0  9.0  4.9
 stn   dist   azm  ain w phas    calcphs hrmn tsec  t-obs  t-cal    res   wt di
 FOO     89  96.4 97.1 0 P       PG       337 46.1  14.16  14.16   0.00 1.00 27
 FOO     89  96.4      0 P                337 55.8   23.9
 HYA    161 110.3 55.1 0 P       PN4      337 55.5  23.56  23.56   0.00 1.00 27
 HYA    161 110.3 55.1 0 S       SN4      338 13.0  41.00  41.00   0.00 1.00 26
 HYA    161 110.3      0 IAML             338 19.8   47.9
 EGD    187 147.1 55.1 0 P       PN4      337 58.8  26.82  26.88  -0.05 1.00  7
 KMY    295 158.9      0 P                338 41.6   69.6
 KMY    295 158.9 55.1 0 P       PN4      338 12.3  40.29  40.25   0.04 1.00 13

 HYA  SZ   hdist:     162.1   coda:        195.0            mc =   3.1
 HYA  SZ   hdist:     162.1   amp:        1289.0 T:   0.6   ml =   3.6
 1996  625 0337 32.0 L  61.697   3.385 19.2  TES  4 0.0 3.6LTES 3.1CTES 3.2LNAO
 OLD:  625  337 31.0 L  61.690   3.261 15.0  TES 31 2.0 3.3LTES 3.0CTES 3.2LNAO
```

Ml and Mc are now calculated, for explanation of output, see section 6.1. If magnitudes are calculated for more than one station, the event magnitudes are the averages.

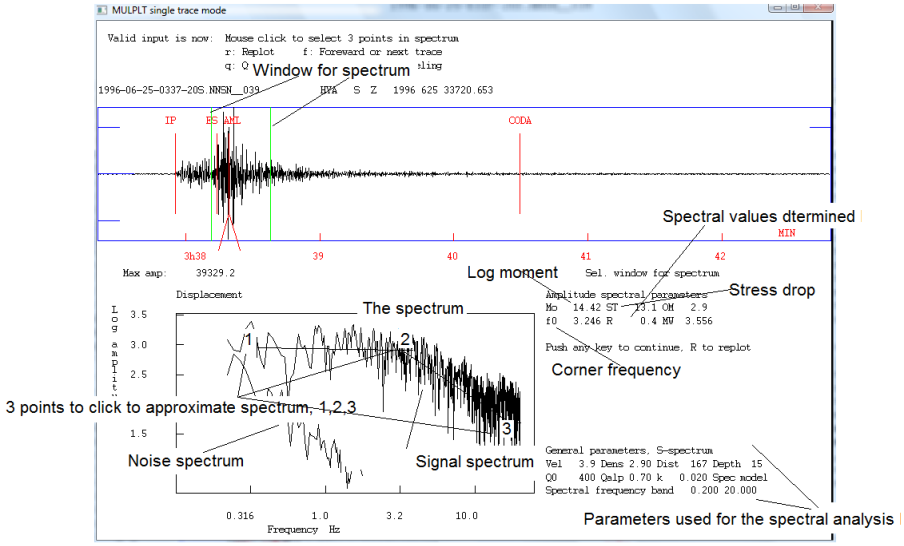
8.2 Spectral magnitude Mw for a local event

The spectral magnitude Mw is calculated from the spectral level of the S or P-wave. Select the local event from June 1996 and plot station HYA S Z in single trace mode. We will now make the displacement spectrum of the S-wave:

Commented [LO1]: Check, sentence was strange.



After pressing ‘d’, the following window comes up from where the spectral parameters can read manually:



After pressing the 3 points for the spectrum, press ‘f’ and the spectral values determined are displayed. They are also now saved in the S-file as SPEC lines:

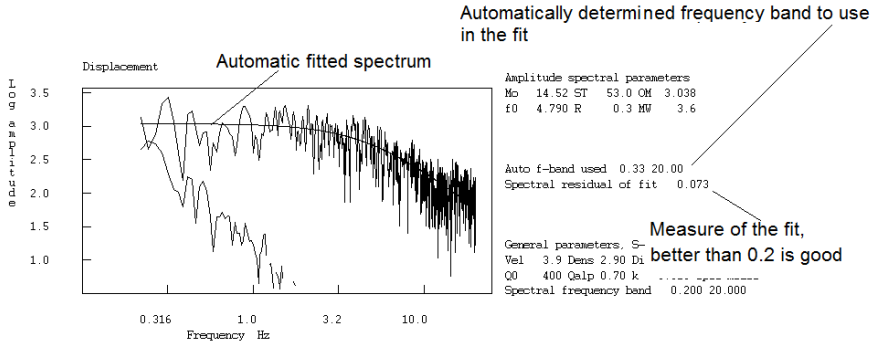
```
1996  625 0337 31.0 L  61.689   3.259 15.0  TES 35 3.0 3.3LTES 3.0CTES 3.2LNAO1
SPEC HYA S   Z MO 14.4 ST 13.1 OM 2.94 f0 3.25 R0.4446 AL 1.70 WI 25.7 MW  3.6 3
SPEC HYA S   Z T 33811 K 0.020 GD  167 VS 3.90 DE 2.90 Q0400.0 QA 0.70 VS 3.90 3
```

In Nordic2 format a similar output is :

```
STA  COM NTLO  OM   F0 AL      T  WI   GD  MO ST   R   K   VX  DE  Q0  QA Q1  MWS
HYA  S Z       3.14.570.0 3381138.8151.814.5 450.32.0203.91S2.91 4000.701.0 3.6S
```

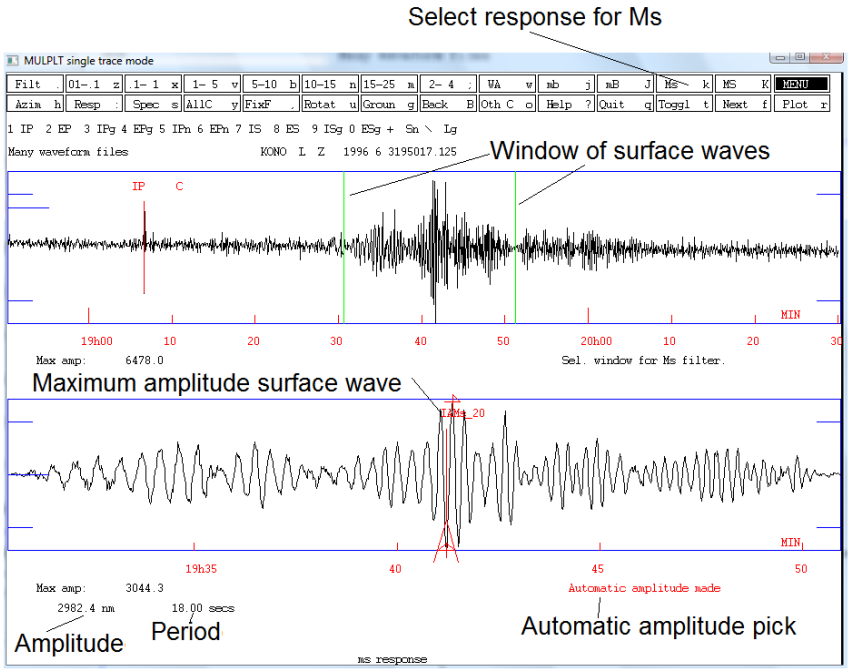
giving a bit more information than the Nordic format. The spectral parameters are now on a S-line,. Spectral parameters used for the analysis are mostly found in file MULPLT.DEF in DAT but SEISAN.DEF also gives the possibility for a detailed Q-structure if the single Q-relation from MULPLT.DEF is not to be used.

The spectrum can also be fitted automatically by giving option Autofit spectrum ('s') instead of 'd' just before the spectrum comes up. This will often be more reliable than the manual fit but must be checked, particularly for correctness of the automatically selected frequency band used.



8.3 Pick amplitude for surface wave magnitude Ms

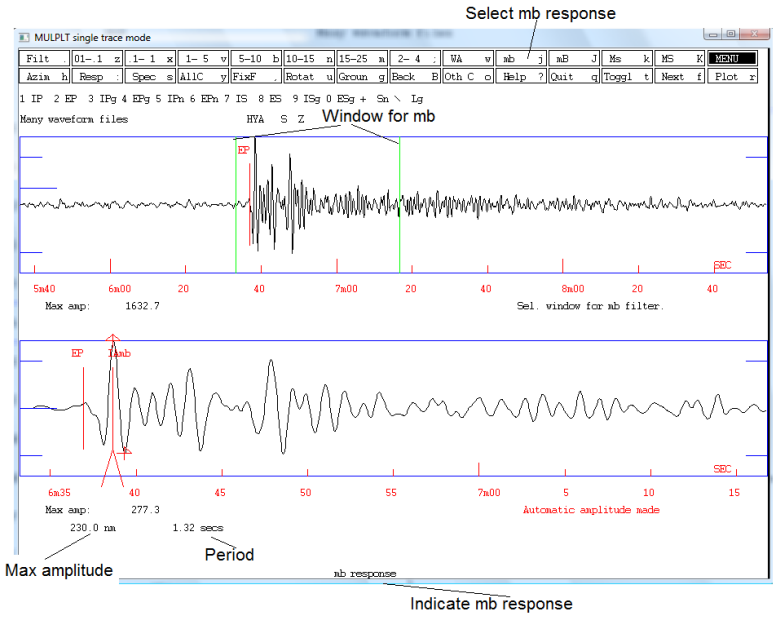
The amplitude for Ms magnitude is picked on a trace simulating the World Wide Standard long period seismograph. Ms is used for distant events and read in the surface wave train. The distance must be at least 20 degrees. Select station KONO in single trace mode for the first event. Pressing Ms in the menu and then selecting a window and the corrected trace (amplitudes in nm ground motion) will come up:



The period is supposed to be in the range 18-22 s, if not select another part of the surface wave train. In practice it is often read outside this range. The amplitude might not be the largest in the surface wave train, but usually it is.

8.4 Pick amplitude for body wave magnitude mb

The amplitude for mb magnitude is picked on a trace simulating the World Wide Standard short period seismograph. mb is used for distant events more than 20 degrees away and read on the P-wave. Both broadband and short-period records can be used. Select station HYA in single trace mode for the first event. Pressing mb in the menu and then selecting a window and the corrected trace (amplitudes in nm ground motion) will come up:

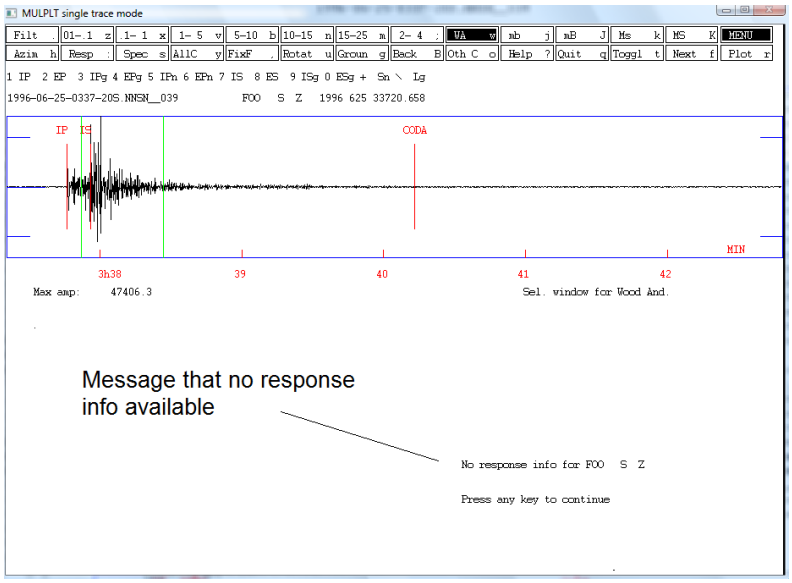


8.5 Amplitude for broadband mB and MS

Both are used with distant events. The mB amplitude is picked in the P-wave train and the MS amplitude in the surface wave train. For MS, the maximum is always used irrespective of the period. The two amplitudes are picked with similar steps as amplitudes for Ml, mb and Ms. mB and MS are considered more reliable since they do not depend on the use of old WWSSN filters and for Ms there is no requirement of using the 18-22 s period range.

8.6 What happens if no response file

Plot FOO S Z in single trace mode and try to make a reading for Ml. The following response comes up:



So if the response file is not available, it is simply not possible to get an amplitude corrected reading. This is also the case for any other amplitude used for magnitudes.

9 Putting in new waveform data

This section will show you how to put in your own data into SEISAN. It will be illustrated with the data already there and we will pretend it is new.

- Go to WOR directory: `wo`
- Make a directory under WOR called e.g. new: `mkdir new`
- Move the events to new: `move C:\seismo\wav\1996* new`
- Go to new directory: `cd new`

We are now pretending that one or several new events are present in directory named ‘new’ and they should now be processed in SEISAN. The first thing needed for this is to create S-files corresponding to the waveform files so that phase readings etc. can be stored. When working with new events there are 2 choices for how to organize them in a SEISAN database: if many events, it is best to store the S-files in a regular database as already illustrated with the TEST

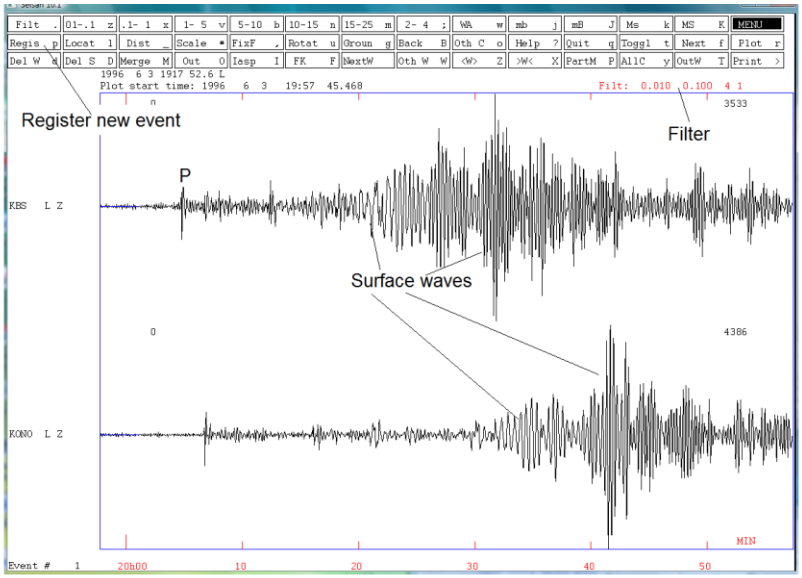
database. If few events or events scattered over several years, it is simpler to use a so-called "local" database meaning all S-files are in a single directory. Both cases will be illustrated.

9.1 Putting data in a local database, one event at a time

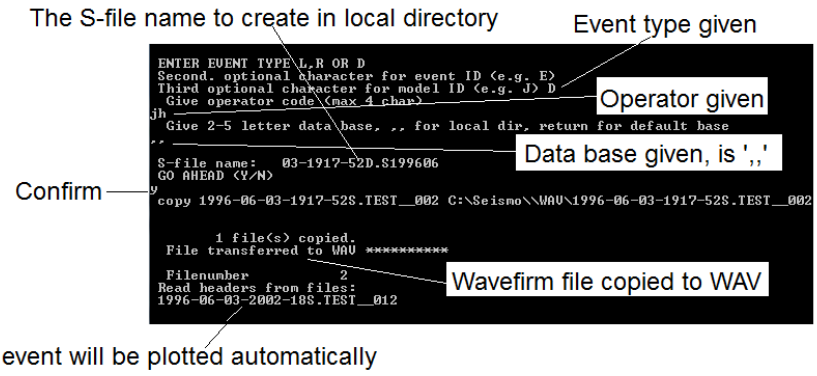
In the 'new' directory make a list of the 'new' waveform files with dirf. dirf make a file, `filenr.lis`, with the list of files also listed on the screen:

```
C:\seismo\WAV\new>dirf 1996*
 #   1  1996-06-03-1917-52S.TEST__002
 #   2  1996-06-03-2002-18S.TEST__012
 #   3  1996-06-25-0337-20S.NNSN__039
```

Now plot the first event with MULPLT, see 5.7 how to do that. The idea is to inspect each event to see if it is an event (in this case we know it is), decide which kind of event (local, regional or distant) and create an entry into the database (an S-file) corresponding to each event (waveform file). Since it is a local database, there is no need for a REA structure, all S-files will end up in the working directory, here 'new'.



The event has been filtered and zoomed (see 5.1) to better see the signals. Notice that you can tell from the low frequency surface waves and the long duration of the signal that this is a distant event. Now register the event by pressing 'Regis' (or 'p' key) and control goes back to the text window where three prompts are made (for type of event, database to store it in, and operator initials):



An S-file has now been created in the local directory and the corresponding waveform file has been copied to WAV. The idea behind the copy is that if the user is inspecting a series of waveform files of which many might be false triggers, only the 'real' events are going to the WAV database and at the end all waveform files in the local directory can be deleted. At the end of the registration process, the next event is plotted automatically. Register that one also as a distant event. The last waveform file is the local event, so register that as local (L or l) when prompted for event type. MULPLT then stops. A total of 3 waveform files events have been registered as events.

9.2 How to work with the newly registered events in a local database

There are now 3 S-files and the original waveform files in the 'new' directory:

```
 Directory of C:\seismo\WOR\new

21.02.2014  18:54    <DIR>          .
21.02.2014  18:54    <DIR>          ..
21.02.2014  18:36               410 03-1917-52D.S199606
21.02.2014  18:54               410 03-2002-18D.S199606
18.02.2014  18:29            51 168 1996-06-03-1917-52S.TEST__002
18.02.2014  18:29           356 128 1996-06-03-2002-18S.TEST__012
18.02.2014  18:29         2 228 488 1996-06-25-0337-20S.NNSN__039
21.02.2014  18:54               410 25-0337-20L.S199606
21.02.2014  16:14               239 filenr.lis
21.02.2014  18:54               328 mulplt.out
              8 File(s)      2 637 581 bytes
              2 Dir(s)  175 247 822 848 bytes free
```

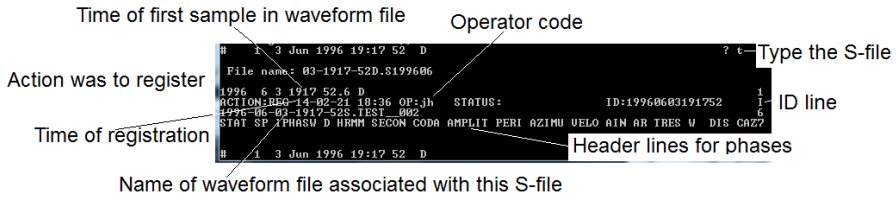
In order to access these events, simply type 'eev':

```
C:\seismo\WOR\new>eev

  Local directory
 Reading events from base ,,     3
#    1  3 Jun 1996 19:17 52  D                                          ?
```

Since there is no database directory structure, EEV will work with all events (S-files) in the local directory so there is no need to give year and month. The waveform files can then be deleted from 'new' since they are now also in WAV.

9.2.1 Content of a newly registered S-file

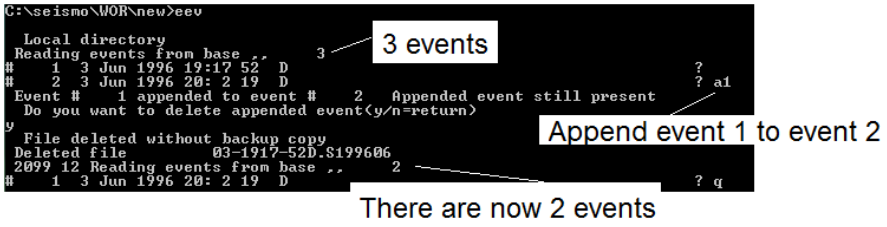
The content of the file can be seen by either editing it (‘e’) or typing the file (‘t’):



The S-file is now ready for reading phases.

9.2.2 Merging events

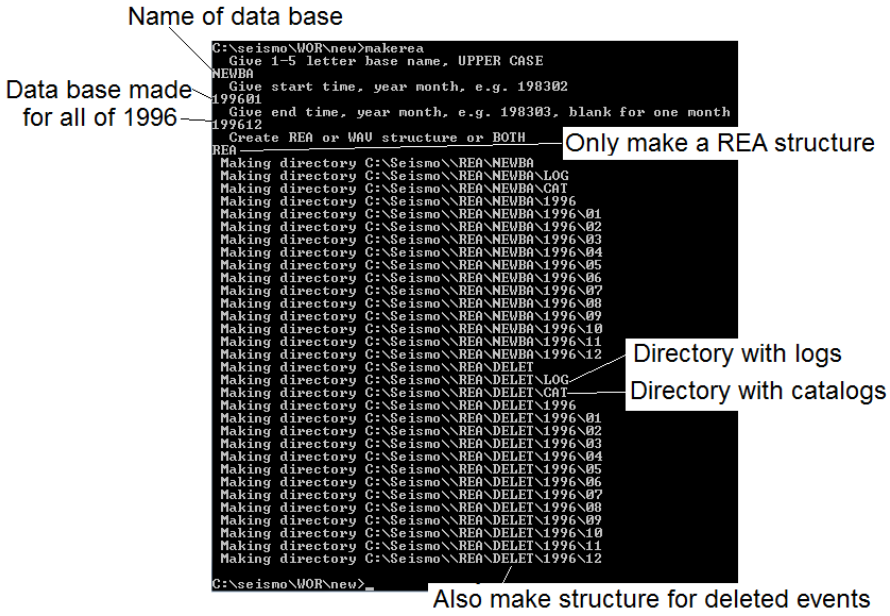
We now have new S-files in the local database but there are only 2 different events. This is because the first teleseismic event has two waveform files and each has been registered as a new event while it should only be one event (S-file). In EEV the events can be merged together. Position the cursor at the events you want to move another event into:



9.3 Putting new data into a named SEISAN database

9.3.1 Making the database structure

The difference of a SEISAN database with the local database is that the S-files are in a hierarchical structure of directories, which is better than the local database for organising a large number of events. The TEST database is such a database. The first step is to create the structure. This is done with program MAKEREA. Note that databases in SEISAN are limited to 5 characters. Assuming the new database will be called NEWBA, here is a run of MAKEREA:



The structure for putting S-files of the year 1996 is now in place. A similar structure can be made for waveform files. This is used if many events are used so to avoid having a lot of files in WAV, the waveform files would then be in a WAV structure.

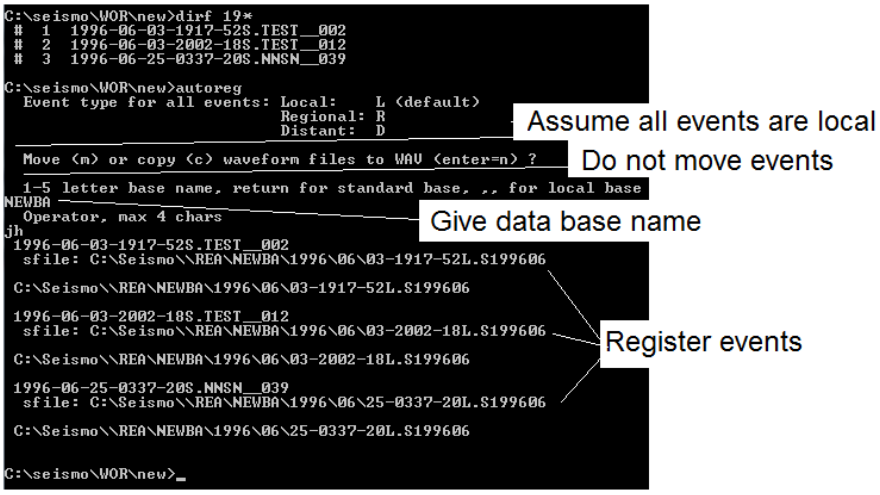
9.3.2 Putting in events in a named SEISAN database

The procedure is just like putting in events in a local database, (see 9.1), the only difference is that instead of using database name ‘,,’, the named database name (NEWBA) is used.

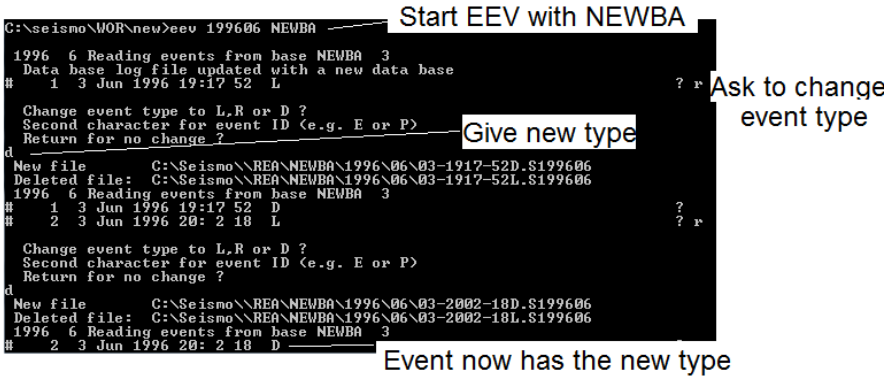
9.3.3 Registering many events with one command

In many cases you will get many waveform files which are already known to be events, there is no need to inspect each individually. All the S-files corresponding to the waveform files can then be made in one operation with program AUTOREG. Assuming that the database NEWBA has been created (section 9.3.1) the procedure is, using the test data in C:\seismo\WOR\new:

- Got to ‘new’ directory
- Make a dirf of 19* files
- Run the program autoreg



When using AUTOREG, all events must be given the same distance indicator (L, R or D). In our case there were both a local and a distant event, so the event types must be corrected manually using EEV:

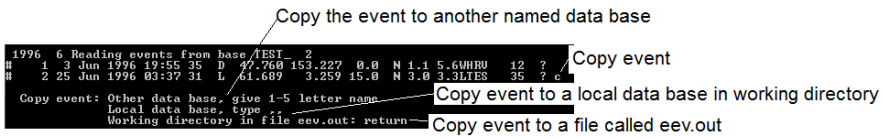


10 Taking out and putting in data in a SEISAN S-file database

A SEISAN database is the S-files, either in a named database or a local database. There are tools for taking one or many events out of the database and putting them in again, either in the same database or another database somewhere else.

10.1 Taking out individual events with EEV

It is possible to copy directly from the directory where the S-file is. However, EEV can do it more easily. The command 'c' will start the copy process of events from the event list used by EEV, usually one month:

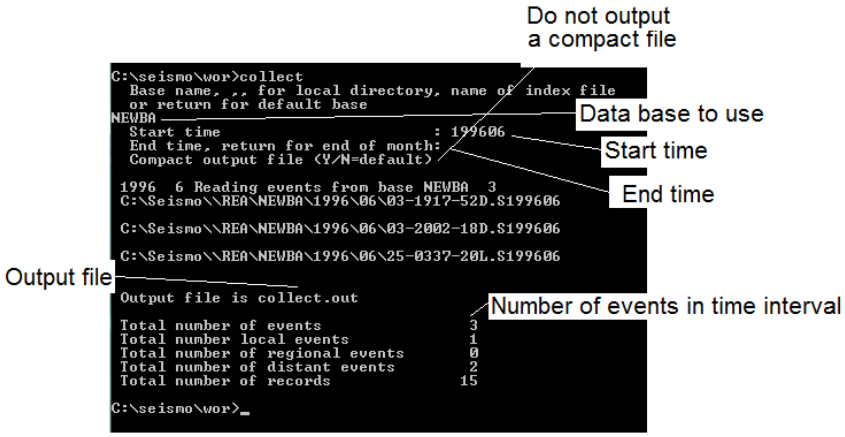


The copy can be repeated so the `eev.out` file can contain many events. Next time EEV starts up, `eev.out` is deleted.
Many events following each other n time can also be copied to `eev.out` with command 'cm':

```
1996  6 Reading events from base TEST_  2
#     1  3 Jun 1996 19:55 35  D  47.769 153.216  0.7    1.1  5.0sTES  12  ? cm
  Copy events to eev.out, how many starting from current ?
2
#     1  3 Jun 1996 19:55 35  D  47.769 153.216  0.7    1.1  5.0sTES  12  ?
```

10.2 Taking out many events with COLLECT

If many S-files in a given time interval are to be extracted, the program COLLECT can be used. COLLECT will select events in a time range over months or years. If selected events (like only the largest ones) are to be extracted out, the program SELECT can be used. Using COLLECT:



The `collect.out` file will contain all S-files selected with one blank line between them. A compact file is a file with only the first header line for all events. Taking out all 4 events:

```
c:\Seismo\WOR>collect
  Base name, ,, for local directory, name of index file
  or return for default base
```

```
  Start time                      : 199606
  End time, return for end of month: 202102
  Compact output file (Y/N=default)

 1996  6 Reading events from base TEST_  2
 c:\seismo\REA\TEST_\1996\06\03-1955-35D.S199606
 c:\seismo\REA\TEST_\1996\06\25-0337-32L.S199606
 1996  7 Reading events from base TEST_  No data for year and month: 1996  7
 1996  8 Reading events from base TEST_  No data for year and month: 1996  8
 base TEST_  No data for year and month: 2017  3
…
…
…
 2021  1 Reading events from base TEST_  No data for year and month: 2021  1
 2021  2 Reading events from base TEST_  2
 c:\seismo\REA\TEST_\2021\02\13-1407-10D.S202102
 c:\seismo\REA\TEST_\2021\02\23-0514-03L.S202102

 Output file is collect.out

 Total number of events                4
 Total number local events             2
 Total number of regional events       0
 Total number of distant events        2
 Total number of records             172
```

COLLECT will check every month in the time range.

10.3 Selecting parts of the data in a 'nice format', program REPORT

To select out part of the data in 'readable' format use REPORT. The file `collect.out` will be used as input:

```
report collect.out
  Below is shown parameters which can be chosen for output.
  A return will chose all, placing any character under a field
  will chose that parameter in the output. Each field starts
  with a capital letter and ends within the following blank.
  The order of the output can be changed by placing a number
  under the field and fields will be written out in the order
  of the numbers. E after time, lat, lon and dep are errors,
  L E is distance and event id s, F is both fix flags and A is
  agency for magnitude.
  The following example shows that Mc, Depth(Dep) and Time with
  error are selected and written out in given order.
Date TimeE L E LatE LonE Dep E F Aga Nsta Rms Gap McA MlA MwA MbA MsA MWA Fp Spec Macro Local MBA MSA
      30  45           20                    10

Date TimeE L E LatE LonE Dep E F Aga Nsta Rms Gap McA MlA MwA MbA MsA MWA Fp Spec Macro Local MBA MSA
 x           x    x              x
  Number of output fields          4

  Number of events                                  4
  Number of events with spectra:                    1
  Number of events with fault plane solution:       1
  Number of events with error estimates:            4
  Number of events with mc            :             1
  Number of events with ml            :             2
  Number of events with mw            :             0
  Number of events with mb            :             2
  Number of events with mB            :             2
  Number of events with ms            :             2
  Number of events with mS            :             1
  Number of events with mw            :             1

  Output report file is report.out
  Output nordic file is report_n.out
  Output of choises used in report.inp
```

Here we have chosen to select output of date, latitude, longitude and number of stations and the output file `report.out` is:

```
 Year Date Latitud Longitud NST
 1996 0603  47.769  153.216  12
 1996 0625  61.576    3.525  31
 2021 0213  36.971  142.514   6
 2021 0223  63.741    4.570   4
```

10.4 Selecting events according to specific criteria, program SELECT

The SELECT program can select events in a given time range (like COLLECT) and in addition use many other parameters like event type, location and magnitude. We will now select all events smaller than magnitude (any magnitude type) 4:

```
select
  POSSIBLE INPUT IS:
     DEFAULT DATA BASE: ENTER
     ALTERNATIVE DATA BASE, GIVE 1-5 LETTER CODE:
     FILENAME FOR ONE FILE, MUST BE 6 OR MORE CHARACTERS OR HAVE A .

  Type of base: CAT (c) or Sfiles (s) (enter):

  Start time (blank is 1980), yyyymmddhhmmss:199606
  End time, enter for end of month          :202102

             PARAMETERS

      1   - Fault Plane Solution
      2   - Earthquake Felt
      3   - Magnitude Type(s)
      4   - Distance ID(s)
      5   - Event ID(s)
      6   - Magnitude Limits
      7   - Latitude Limits
      8   - Longitude Limits
      9   - Depth Limits
      10  - RMS Limits
      11  - Number of Stations Limits
      12  - Hypocenter Errors Latitude Limits
      13  - Hypocenter Errors Longitude Limits
      14  - Hypocenter Errors Depth Limits
      15  - Minimum Number of Polarities
      16  - Hypocenter Agencies
      17  - Magnitude Agencies
      18  - Station Codes, components, distance range and phase
      19  - Polygon
      20  - Use all header lines
      21  - Search for text string in S-file
      22  - Gap range
      23  - Phases
      24  - Volcanic subclasses
      25  - Moment tensor solution
      26  - Distance from point

  SELECT NUMBER TO CHANGE PARAMETER, RETURN TO SEARCH: 6

  Minimum Magnitude, return for default:

  Maximum Magnitude, return for default: 4
```

```
            PARAMETERS

      1   - Fault Plane Solution
      2   - Earthquake Felt
      3   - Magnitude Type(s)
      4   - Distance ID(s)
      5   - Event ID(s)
      6   - Magnitude Limits                      -990.0        4.0
      7   - Latitude Limits
      8   - Longitude Limits
      9   - Depth Limits
      10  - RMS Limits
      11  - Number of Stations Limits
      12  - Hypocenter Errors Latitude Limits
      13  - Hypocenter Errors Longitude Limits
      14  - Hypocenter Errors Depth Limits
      15  - Minimum Number of Polarities
      16  - Hypocenter Agencies
      17  - Magnitude Agencies
      18  - Station Codes, components, distance range and phase
      19  - Polygon
      20  - Use all header lines
      21  - Search for text string in S-file
      22  - Gap range
      23  - Phases
      24  - Volcanic subclasses
      25  - Moment tensor solution
      26  - Distance from point

  Default value assumed.
  SELECT NUMBER TO CHANGE PARAMETER, RETURN TO SEARCH:
 1996  6 Reading events from base TEST_  2
 1996  7 Reading events from base TEST_  No data for year and month: 1996  7
 1996  8 Reading events from base TEST_  No data for year and month: 1996  8
….
….
….
 2020 12 Reading events from base TEST_  No data for year and month: 2020 12
 2021  1 Reading events from base TEST_  No data for year and month: 2021  1
 2021  2 Reading events from base TEST_  2

  TOTAL NUMBER OF EVENTS IN TIME INTERVAL            4
  NUMBER OF DISTANT EVENTS   - - - - -               2
  NUMBER OF REGIONAL EVENTS  - - - - -               0
  NUMBER OF LOCAL EVENTS     - - - - -               2
  ---------------------------------------------------
  NUMBER OF EVENTS SELECTED *************            2
  NUMBER OF WAVEFORM FILES SELECTED                  2
  NUMBER OF INDEXES SELECTED                         2
  SELECTED EARTHQUAKES ARE IN:         select.out
  LOCAL INDEX FILE IS:                  index.out
  NAMES FOR WAVEFORM FILES IN: waveform_names.out
  SELECT COMMANDS IN:                 select.inp
```

The events are found in `select.out`. In addition a file `index.out` is made:

```
 1  c:\seismo\REA\TEST_\1996\06\25-0337-32L.S199606
 2  c:\seismo\REA\TEST_\2021\02\23-0514-03L.S202102
```

which gives links to the selected events which then can be accessed directly by EEV

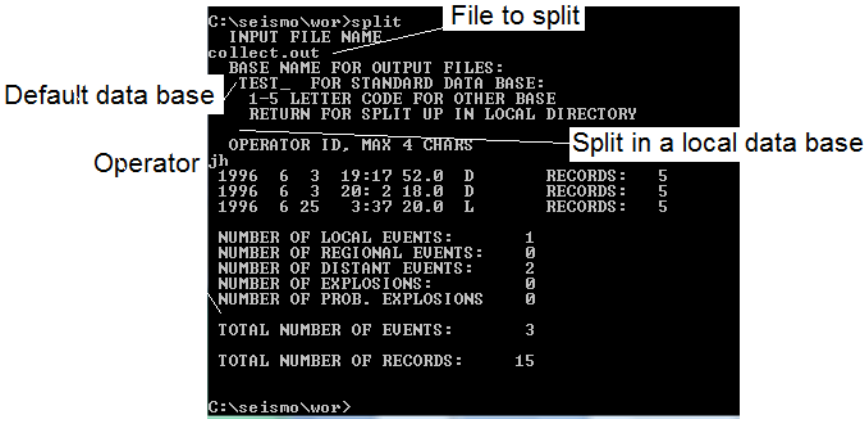
```
eev index.out

 Give operator code, max 3 characters
jh
  Number of events in index file:            2
```

```
#     1 25 Jun 1996 03:37 33  L  61.576   3.525 15.0F   1.8  3.6LBER  31  ?
```

In this way the user can work directly in the data base with a subset of events spread over large time interval.

10.5 Putting data from a multiple S-file into the database with SPLIT

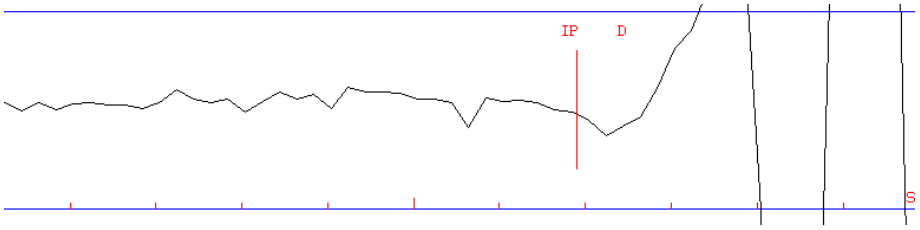
Data collected in a file with many events (S-files), also called a CAT file, can be split up and distributed in the database structure or placed in a local database. The `collect.out` file from above can be used:



11 Fault plane solution

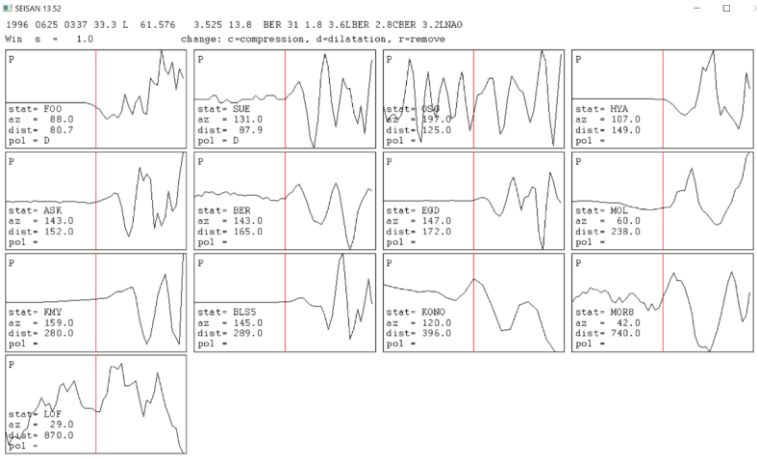
SEISAN has 4 different programs for fault plane solutions, two of which also work with amplitudes. Here we will demonstrate two popular programs with polarities, FOCMEC and FPFIT.

Select the local event and pick all the possible polarities on the Z-channels (select as shown in 5.4), see 7.4.3 how this is done. Some traces are not so clear so use a lot of zoom and maybe amplify trace amplitudes (see 5.2). In the example below for station ASK, Z-component, both zoom and amplification has been used to clearly see the polarity. It is a very weak dilatation but would probably often be picked as compression.



A fast alternative for picking polarities, if reasonably clear, is to use command ‘pol’ in EEV. The program plots by default 1 s around the P (user selectable):

```
Input S-file  c:\seismo\REA\TEST_\1996\06\25-0337-32L.S199606
  total window duration (default 1s):

  P-onset position as percentage of total duration (10-90%; def 50% = middle):

  window length in seconds for averaging (deault is 0)

  Number of wav-files present           1
 c:\seismo\WAV\1996-06-25-0337-20S.NNSN__039
  Total number of channels available:          39
 1996 0625 0337 33.3 L  61.576   3.525 13.8  BER 31 1.8 3.6LBER 2.8CBER 3.2LNAO
  available components:
FOO   SZ SUE   AZ OSG   SZ HYA   SZ ASK   SZ BER   SZ EGD   SZ
MOL   SZ KMY   SZ BLS5  SZ LRW   SZ KONO  BZ OWE   SZ NRA0  SZ
OHO   SZ OBR   SZ ORE   SZ MFI   SZ OTO   SZ HFS   SZ MCD   SZ
MDO   SZ EDU   SZ ESY   SZ EDI   SZ MOR8  SZ LOF   SZ FIA0  SZ
ARA0  SZ APA0  SZ

 Components auto selected to use
FOO   S  Z SUE   A  Z OSG   S  Z HYA   S  Z ASK   S  Z BER   S  Z EGD   S  Z
MOL   S  Z KMY   S  Z BLS5  S  Z KONO  BV Z MOR8  S  Z LOF   S  Z
```



In each window, the user can now pick, change or delete the polarity and the result will be stored in the S-file.

Before attempting a fault plane solution, make sure the depth is reasonable and not zero. For this event it should be between 10 and 25 km. If not ok, the depth should be fixed in the S-file by putting an ‘F’ in column 44 on header line. This is done with command ‘fix’ in EEV.

First the FPFIT program is used. It will automatically find a solution in a least squares sense. It does not mean it is a correct solution but the best with the available data. Use command ‘fp’.

```
#    2 25 Jun 1996 03:37 33  L  61.576   3.525 15.0    1.8  3.6LBER  31  ? fp

  **** now locating with hyp as a preparation ***

 c:\seismo\REA\TEST_\1996\06\25-0337-32L.S199606
 Number of spectra available and number used in average     1     1
 #        0  1996 0625 0337 33.2 L  61.576   3.525 13.8  BER 31 1.8 3.6LBER 2.8CBER
  If location not ok, result might be unpredictable
  Return to continue (y=return/N)

  Number of phases          33
Number of events used   1
 Fpfit uses 3-letter LOWER-CASE commands, which can be followed by
 parameters in free-format, or which display current values & generate prompts.
 Type "hel" for information  on available commands.
 yes?    #      ORIGIN TIME          LOCATION          DEPTH    MAG   DDR  DIP  RAKE CNVRG
  ---- ------------------- ------------------  -----    ---  ----- ---  ---- -----
    1 1996 625  337 33.25 61n34.55   3e 31.5   13.8    1.0    90   41    38
      MULTIPLE SOLUTION                                       228   53    58
      MULTIPLE SOLUTION                                       118   57   158
 yes?
 Fit  0.090
 Errors in strike, dip and rake    2.0   5.0  42.0

       0.0      41.0      38.0  2.0  5.0 42.0  0.1  0.1               FPFIT    F
 ================================

 Fit  0.090
 Errors in strike, dip and rake    2.0   5.0  42.0

 .... updating database with FPFIT fault plane solution
```

NOT reliable

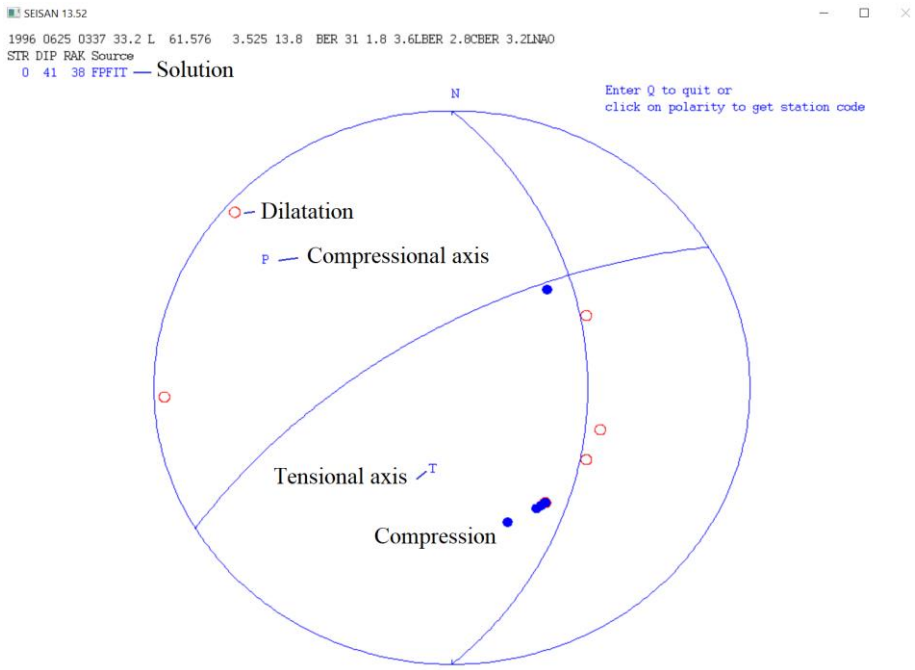
Strike +90, dip, rake

In this case multiple solutions are found and the first is saved in the S-file. Below is part of S-file with the solution. The fault plane solution is indicated with ‘F’ in last column.

```
1996 0625 0337 33.3 L  61.576   3.525 15.0  BER 31 1.8 3.6LBER 2.8CBER 3.2LNAO1
      0.0      41.0      38.0  2.0  5.0 42.0  0.1  0.1           BER FPFIT    F
```

Strike, dip, rake Errors Agency, program used

We can now plot the solution with command ‘fo’. It is seen below that all polarities but one fits the solution and it is also seen that other solutions are possible. To plot without the polarities, use command ‘poo’.

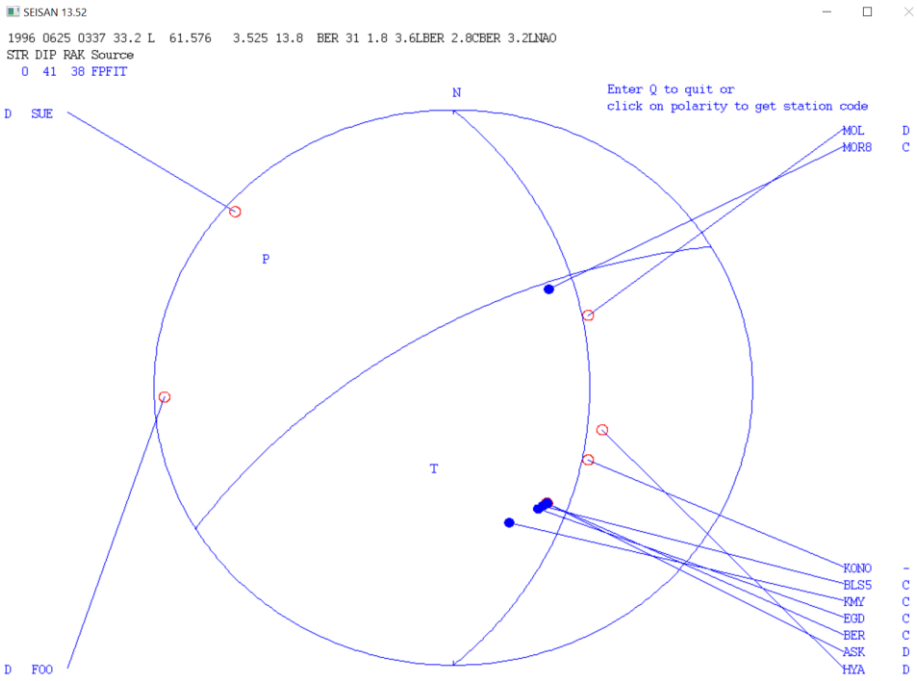


It is possible to see which stations belong to which polarities, give command ‘f’.

```
#    2 25 Jun 1996 03:37 33  L  61.576   3.525 15.0    1.8  3.6LBER  31  ? f

  **** now locating with hyp as a preparation ***

 c:\seismo\REA\TEST_\1996\06\25-0337-32L.S199606
 Number of spectra available and number used in average     1     1
 #        0  1996 0625 0337 33.3 L  61.576   3.525 13.8  BER 31 1.8 3.6LBER 2.8CBER
  If location not ok, result might be unpredictable
  Return to continue (y=return/N)


Number of polarities:           11
 No amplitude data available

 Total number of polarities and amplitude ratios used =  11  gap in az = 109.0  gap in ain =  49.0

  Stop                    (Q)
  Plot saved solution(s)  (1)
  Plot new solutions      (2)
  Plot selected solution  (3)
  Find new solutions      (4)
  -1, -2, -3 also plot station
-1
```

Chose -1

and the following plot comes up showing stations and polarities:



Notice that the symbol for compression for KONO is '–' and not D since the polarity is read on an emergent P, EP.

We will now try the FOCMEC program. This program will by default not automatically find a solution but show all the solutions possible within some given criteria. FOCMEC can also work with amplitude ratios but here only polarities will be used. Start with command 'f'.

```
#    2 25 Jun 1996 03:37 33  L  61.576   3.525 15.0    1.8  3.6LBER  31  ? f

  **** now locating with hyp as a preparation ***

 c:\seismo\REA\TEST_\1996\06\25-0337-32L.S199606
 Number of spectra available and number used in average     1     1
 #        0  1996 0625 0337 33.3 L  61.576   3.525 13.8  BER 31 1.8 3.6LBER 2.8CBER
  If location not ok, result might be unpredictable
  Return to continue (y=return/N)


Number of polarities:          11
 No amplitude data available

 Total number of polarities and amplitude ratios used =  11  gap in az = 109.0  gap in ain =
49.0

  Stop                    (Q)
  Plot saved solution(s)  (1)
  Plot new solutions      (2)
  Plot selected solution  (3)
  Find new solutions      (4)
```

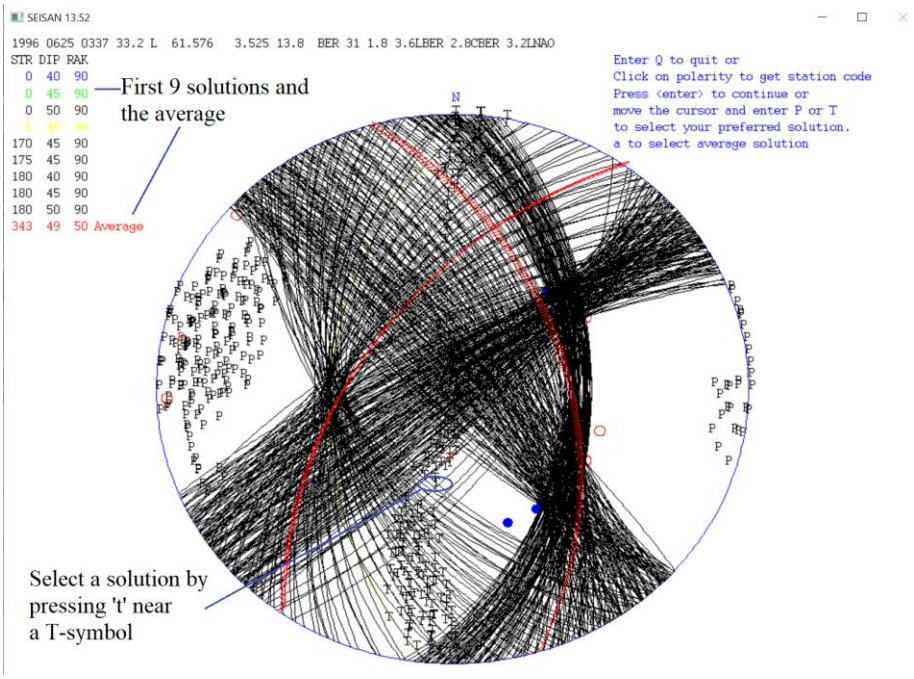
```
  -1, -2, -3 also plot station
4
 There are  11 polarity readings
 Use relative weight, y/n=default

 Maximum number of allowed polarity errors, enter for 0

 Degree increment in search, enter for default  2

  Mon Mar 31 08:46:15 2025 for program Focmec
 -----
 Input from a file focmec.dat
   1996 0625 0337 33.3 L  61.576   3.525 13.8  BER 31 1.8 3.6LBER 2.8CBER 3.2LNAO
 Polarities/Errors:  P 011/00  SV 000/00  SH 000/00
 There are no amplitude ratio data
 The minimum, increment and maximum B axis trend:     0.00    2.00  358.00
 The limits for the B axis plunge:     0.00    2.00   90.00
 The limits for Angle:     0.00    2.00  178.00
  Strike    Dip    Rake    Pol: P     SV    SH
  There are            0  acceptable solutions.

  Stop                     (Q)
  Plot saved solution(s)   (1)
  Plot new solutions       (2)
  Plot selected solution   (3)
  Find new solutions       (4)
  -1, -2, -3 also plot station
4
 There are  11 polarity readings
 Use relative weight, y/n=default

 Maximum number of allowed polarity errors, enter for 0
1
 Degree increment in search, enter for default  2

  Mon Mar 31 08:46:27 2025 for program Focmec
 -----
 Input from a file focmec.dat
   1996 0625 0337 33.3 L  61.576   3.525 13.8  BER 31 1.8 3.6LBER 2.8CBER 3.2LNAO
 Polarities/Errors:  P 011/01  SV 000/00  SH 000/00
 There are no amplitude ratio data
 The minimum, increment and maximum B axis trend:     0.00    2.00  358.00
 The limits for the B axis plunge:     0.00    2.00   90.00
 The limits for Angle:     0.00    2.00  178.00
  Strike    Dip    Rake    Pol: P     SV    SH
   -0.00   40.00   90.00       1.00  0.00  0.00
   -0.00   42.00   90.00       1.00  0.00  0.00
  ..
  ..
  161.21   49.12   74.04       1.00  0.00  0.00
  161.92   51.04   74.49       1.00  0.00  0.00
The maximum of  500 solutions has been reached and the search is stopped

  Stop                     (Q)
  Plot saved solution(s)   (1)
  Plot new solutions       (2)
  Plot selected solution   (3)
  Find new solutions       (4)
  -1, -2, -3 also plot station
4
 There are  11 polarity readings
 Use relative weight, y/n=default

 Maximum number of allowed polarity errors, enter for 0
1
 Degree increment in search, enter for default  2
5
  Mon Mar 31 08:46:47 2025 for program Focmec
 -----
 Input from a file focmec.dat
   1996 0625 0337 33.3 L  61.576   3.525 13.8  BER 31 1.8 3.6LBER 2.8CBER 3.2LNAO
 Polarities/Errors:  P 011/01  SV 000/00  SH 000/00
 There are no amplitude ratio data
 The minimum, increment and maximum B axis trend:     0.00    5.00  355.00
 The limits for the B axis plunge:     0.00    5.00   90.00
 The limits for Angle:     0.00    5.00  175.00
```

No solution, chose 1 polarity error

Too many solutions, search with a larger grid

```
  Strike     Dip     Rake     Pol: P      SV     SH
   -0.00    40.00    90.00        1.00   0.00   0.00
   -0.00    45.00    90.00        1.00   0.00   0.00
   -0.00    50.00    90.00        1.00   0.00   0.00
  ..
  ..
  320.00    90.00   -0.00        1.00   0.00   0.00
  325.00    90.00   -0.00        1.00   0.00   0.00
  There are           226  acceptable solutions.

  Stop                      (Q)
  Plot saved solution(s)    (1)
  Plot new solutions        (2)
  Plot selected solution    (3)
  Find new solutions        (4)
  -1, -2, -3 also plot station
2
```

and this folows:



The search was limited to a requirement that all polarities are ok, however, often there are no solutions without allowing some bad polarities. The search was repeated allowing 1 polarity error but that gave too many solutions and a 5 deg grid was used to get less than 500 solutions. It is seen that hundreds of solutions is possible so this fault plane solution is not very constrained. To get an idea of the dominate trend of the solutions, the average solution is calculated. This can be used to automate FOCMEC by making an average solution of the many possibilities (commands ‘fa’ and ‘faa’). FOCMEC can also use amplitude ratios to further

improve the solutions. See the SEISAN manual and the SEISAN tutorial for making fault plane solutions.

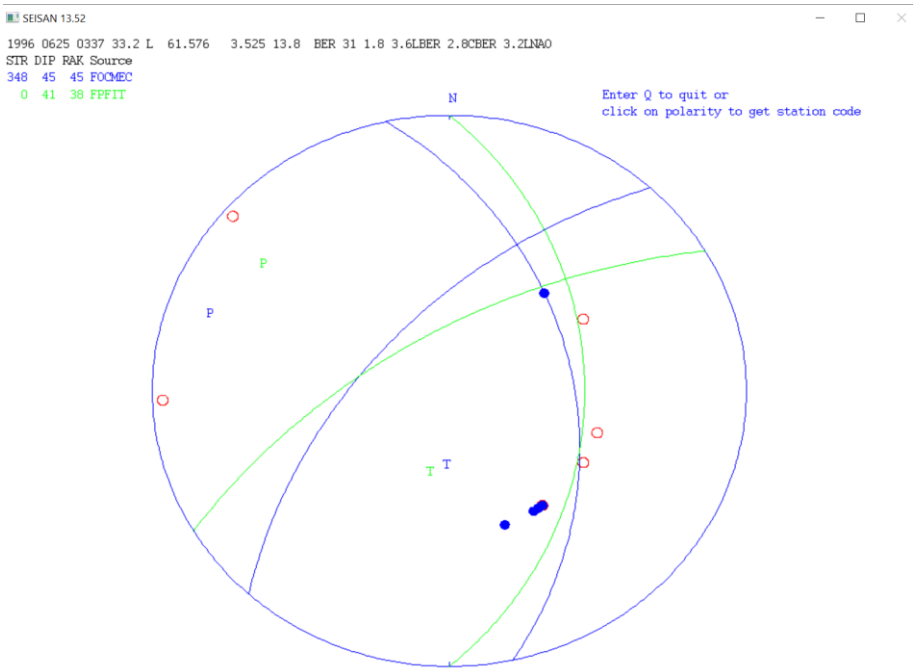
One of the solutions can be selected by moving the cursor to the corresponding P or T and pressing ‘p’ or ‘t’. The solution should then be saved:

```
  Stop                      (Q)
  Plot saved solution(s)    (1)
  Plot new solutions        (2)
  Plot selected solution    (3)
  Find new solutions        (4)
  -1, -2, -3 also plot station
2
  Save solution (y/n)
y

  Stop                      (Q)
  Plot saved solution(s)    (1)
  Plot new solutions        (2)
  Plot selected solution    (3)
  Find new solutions        (4)
  -1, -2, -3 also plot station
q
```

and there are now 2 fault plane solutions in S-file, indicated by the F-lines:

```
1996 0625 0337 33.3 L  61.576   3.525 15.0  BER 31 1.8 3.6LBER 2.8CBER 3.2LNAO1
    347.70     44.81     44.81                              1    BER FOCMEC   F
       0.0      41.0      38.0  2.0  5.0 42.0  0.1  0.1           BER FPFIT    F
```

The 2 solutions can be plotted with command ‘fo’ as before and we get:



It is seen that the two solutions are similar but FOCMEC also had very different solutions however, the FOCMEC average solution is similar to the FPFIT solution and could have been selected by pressing 'a'. The average solutions is what is used in automatic mode. It is always useful to compare solutions from different programs. Doing the exercise yourself might result in quite different solutions since some polarities are uncertain.

12 Parameters the user must modify to work with his/her new data

Local earthquakes

A few parameters must be entered or modified for local use:

- Coordinates for the stations, found in `STATION0.HYP` in DAT
- Crustal model, see parameters in `STATION0.HYP`
- Magnitude scales for local earthquakes, see parameters in `STATION0.HYP` Response files for all channels needed for magnitudes and other types of analysis. The response files are in CAL.
- Parameters for spectral analysis are found in MULPLT.DEF in DAT and in SEISAN.DEF in DAT

Distant earthquakes

- Coordinates for the stations, found in `STATION0.HYP` in C:\seismo\DAT
- Response files for all channels needed for magnitudes and other types of analysis. The response files are in C:\seismo\CAL.

13 Using SeisanExplorer (SE)

The GUI interface SeisanExplorer, hereafter called SE, is intended to replace/supplement EEV and expand the graphical options in SEISAN. The most basic EEV commands have been implemented with the addition of some commands not present in EEV.
SE loads S-files from a SEISAN database. Only the S-files that are within a user specified time interval are read. You may also load an index file, a local database or a CAT file (like collect.out). In this case, the currently set time interval is ignored, and time interval is adjusted automatically to fit the loaded data. All information in the S-files is stored in memory for fast access. For more information, see the SEISAN manual. In the following, some of the exercises done with EEV will now be done with SE as well as some which cannot be done with EEV.
When doing these SE exercises, it is assumed that you have done most of the previous exercises (at least until 7.3) so you are familiar with the basic SEISAN.

NOTE: There is a bug in SE in the distribution for SEIAN version 13.52 and the precompiled Linux version is an old version. On the SEISAN web site a correct version for Windows is found but the Linux version is 13.52 .If using the distributed version for Windows and Linux, it can work if the following line in SEISAN.DEF is corrected:

Change this

```
NORDIC_FORMAT 0.0:old 1.0:both 2.0:new  1.0
```

to this:

```
NORDIC_FORMAT                         1.0
```

13.1 Get access to the events, open data base

The simplest way is to use SE is a similar command than for EEV. Writing

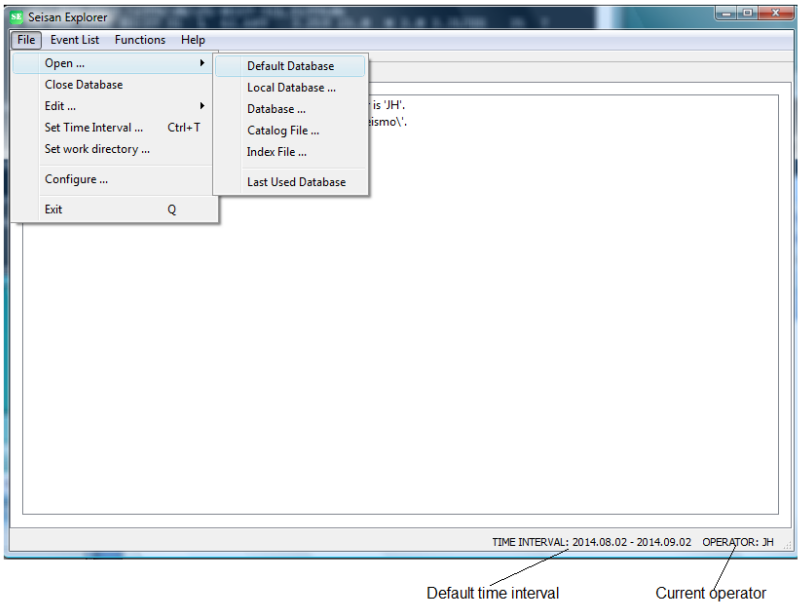
```
se 199606
```

will open SE for data for June 1996. The length of the time window is by default one month. However, SE can open data for any time period so the command

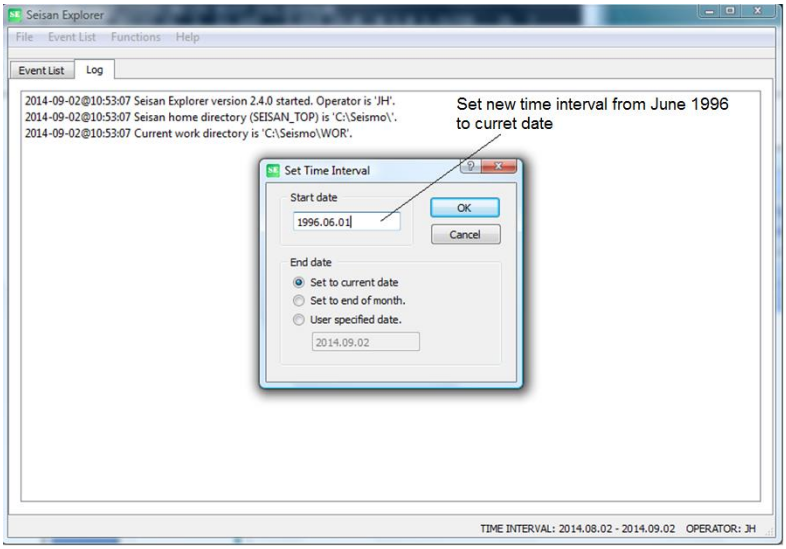
```
se 199606 202102
```

will read all our test events which is nice option not available in EEV.

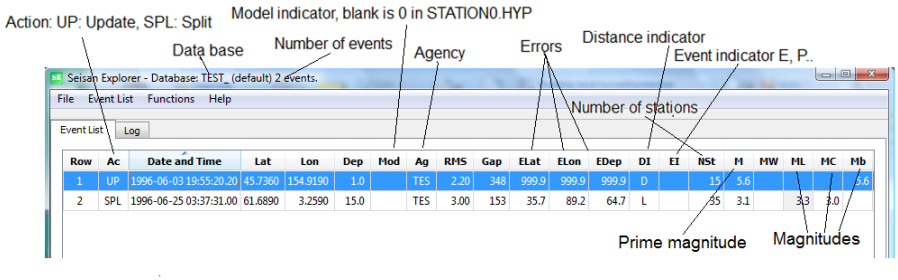
SE can also use its graphical interface to open the data base. SE is then started by using the SE icon or writing ‘se’ on prompt line. The first task is to read in data in SE. Here we will read from the default data base. This is done by pressing File/Open/Default Database as shown below.



The next step is to select the time interval. Here we only have data from June 1996 so that is put as a start date. End date is by default the current date but can be set to any other date. The Log window (below) shows current status and possible error messages.



The 2 events from the database are now loaded in and some of the information is displayed for each event (figure below). The amount displayed can be defined in Event List/Select Columns. Note that in contrast to EEV, all magnitude types can be displayed. There is also a prime magnitude M which is the preferred magnitude of the available magnitudes. The preference is set in SEISAN.DEF, see SEISAN manual, section “Magnitudes in SEISAN”.
Once the events have been read in, one or several events can be selected for operation. A single event is selected by clicking on its line and the line is highlighted. Several events can be selected by ctrl click.

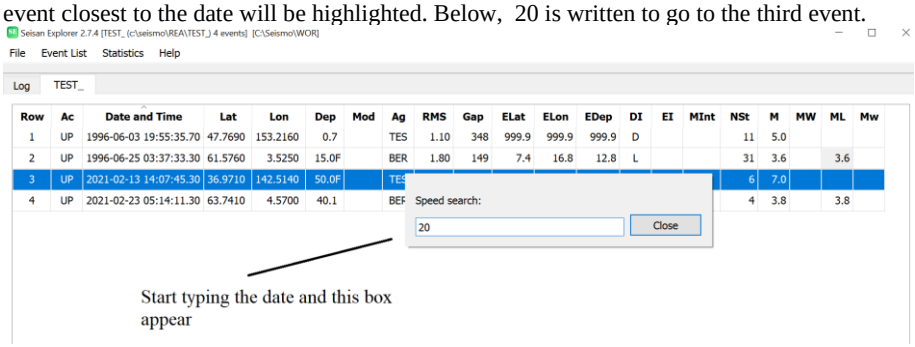


If the Log window remains due to errors when reading in events (listed in red), Event list (next to Log) must be clicked to get list of events.

13.2 Navigate in SE

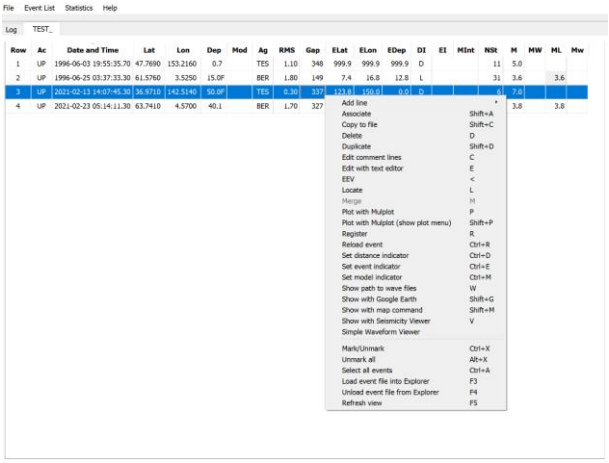
Read in all the test events with command se 199606 202102

Events can be selected by clicking on the event. For many events, move down or up with Page down or up. An event can also be found by date. Start writing a date, like 20 and the active event closest to the date will be highlighted. Below, 20 is written to go to the third event.



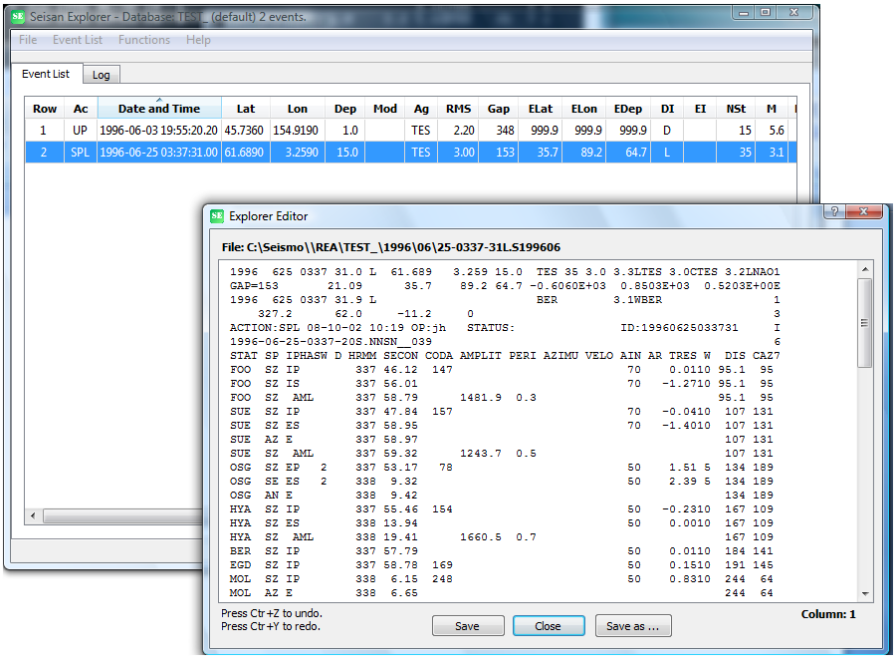
13.3 Operations in SE

Once an event (or several events for some options) has been selected, a right click on the event will show the options as shown below. All options have a one letter key press as a shortcut.



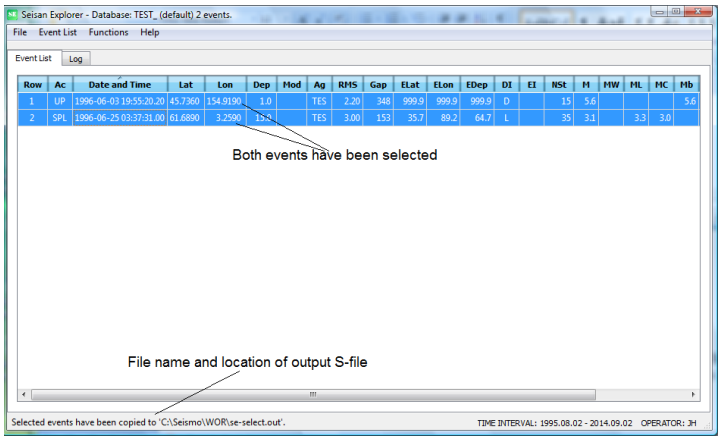
13.3.1 Edit or display content of S-file

Edit with text editor, ‘e’. Note that you cannot use SE while giving control to another action or program like the editor. Control returns to SE when the editor is closed. Below is an example.



13.3.2 Export data

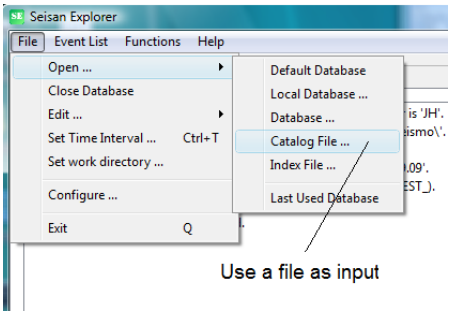
The events highlighted can be copied out to an S-file with option Copy to file or key press ‘c’. The output file will be given a default name and written in the default work directory (can be changed under File/Set work directory). The message of the location and name of output file appears briefly at the bottom of SE box, see below.



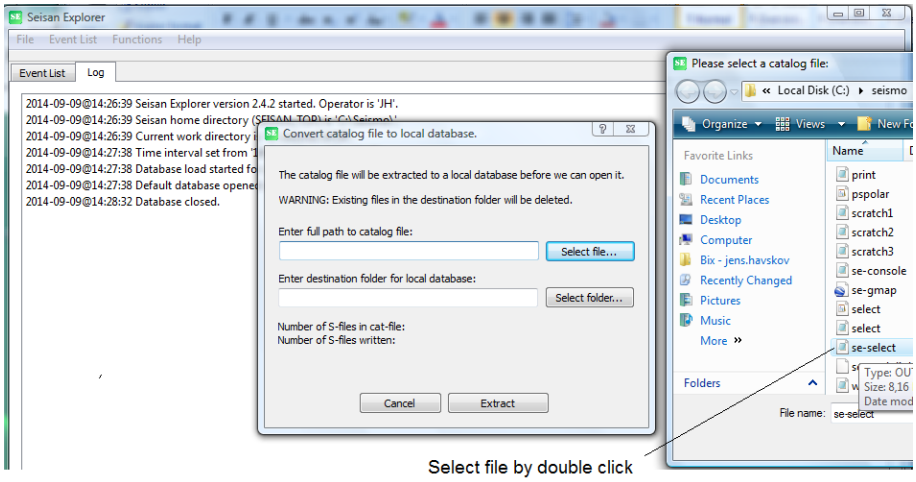
13.3.3 Import of data

It was shown above how to open a data base. SE has the added capability (compared to EEV) that it can work directly with a catalog file (file with many S-files). An example above was the exported file `se-select.out`. We will use this file as an example.

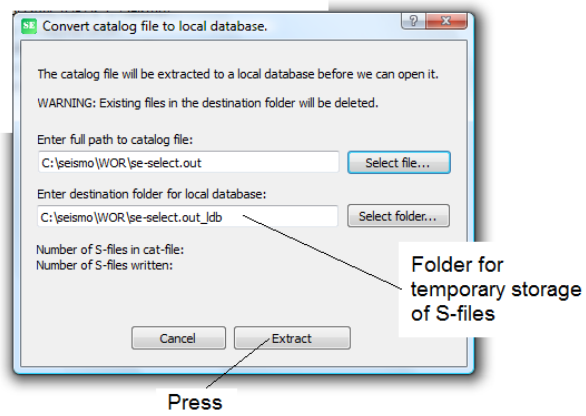
First select option Open/Catalog file:



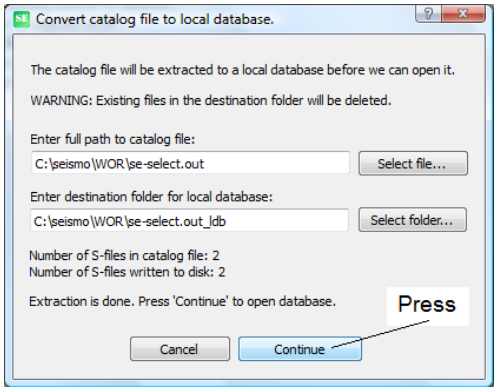
Then use the file browser to select the file:



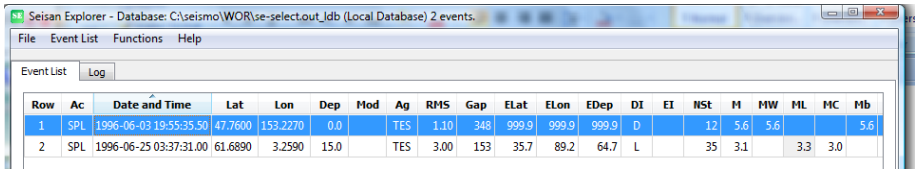
The file has now been selected. At the same time an output directory where the temporary S-files will be placed has been suggested. SE will take the input catalog file and split it up in the temporary folder to do the work.



The message is now that there were two events (2 S-files). Press continue to continue.



The data now come up and normal work can be done.

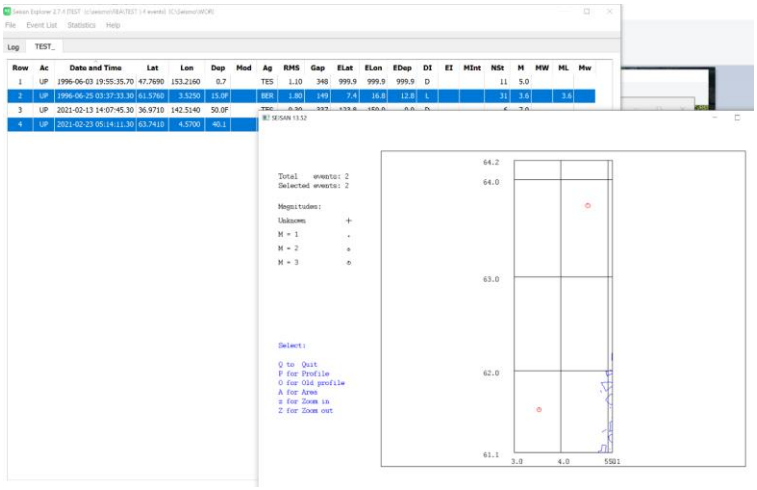


When SE is closed, the data (changed or not) is optionally stored back into the original catalog file. The temporary directory with S-files remain until deleted by the user.

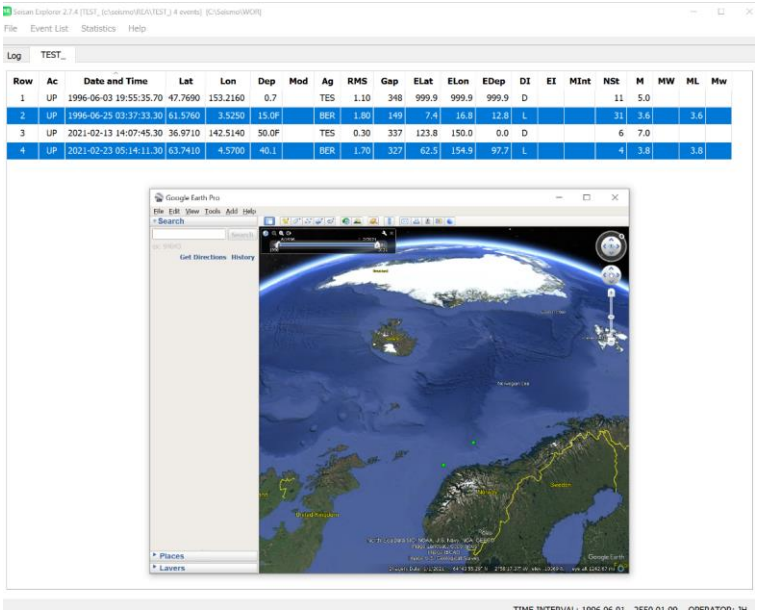
13.3.4 Plot epicentres

Maps can be made with MAP or GoogleEarth

Selecting the 2 local events, the map is shown with command ‘M’

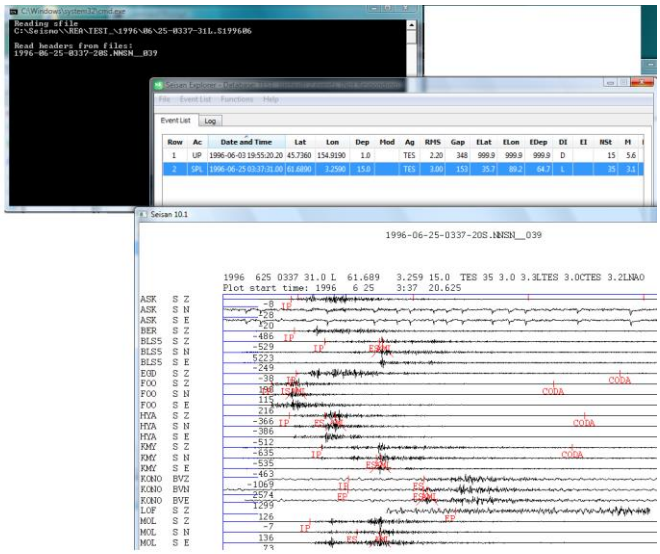


The same two events can be plotted with GoogleEarth. First start GoogleEarth, highlight the two events and press ‘G’ and open the file `gmap.cur` in GoogleEarth.



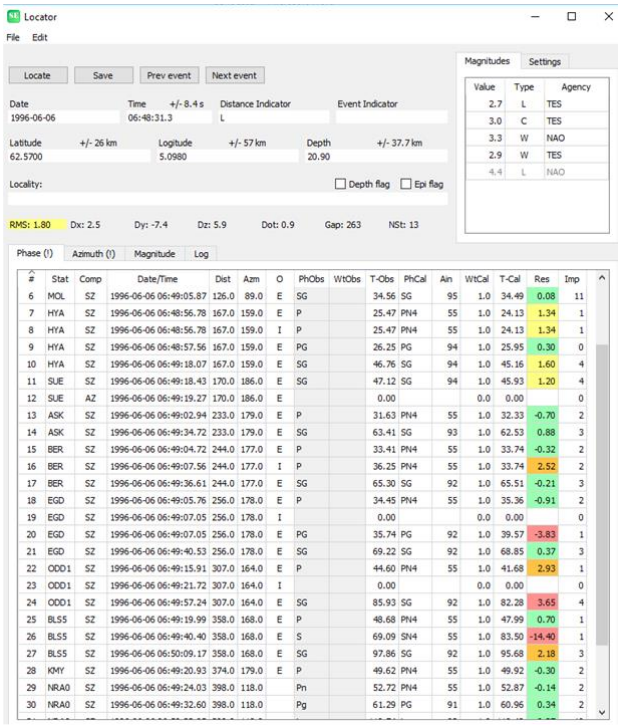
13.3.5 Plot waveforms

Option ’Plot with Mulplt’ is ‘p’. MULPLT comes up with all defaults (like ‘po’ in EEV) and the DOS message window (terminal window under Linux) is also shown. A quit in MULPLT returns control to SE. New picks or changes are automatically saved in the data base on return to SE.

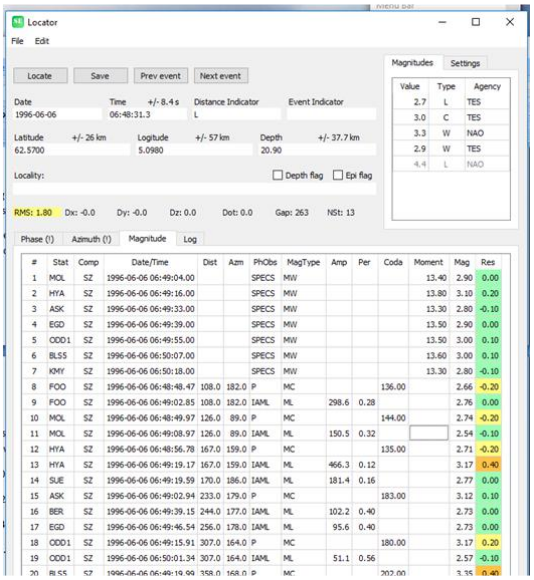


13.3.6 Locate an event

The event is located with Locate or key press ‘l’. Use the local event. Once ‘l’ has been pressed, the locater window comes up and to relocate the event ‘Locate’ must pressed and the following window comes up:



It has detailed information about the location like difference in location from previous location (dx, dy, dz, dot) (also found in `print.out`). A useful feature is that residuals are color coded so it is easy to find the bad residuals. The magnitudes are shown in the magnitude window (press tab magnitude):

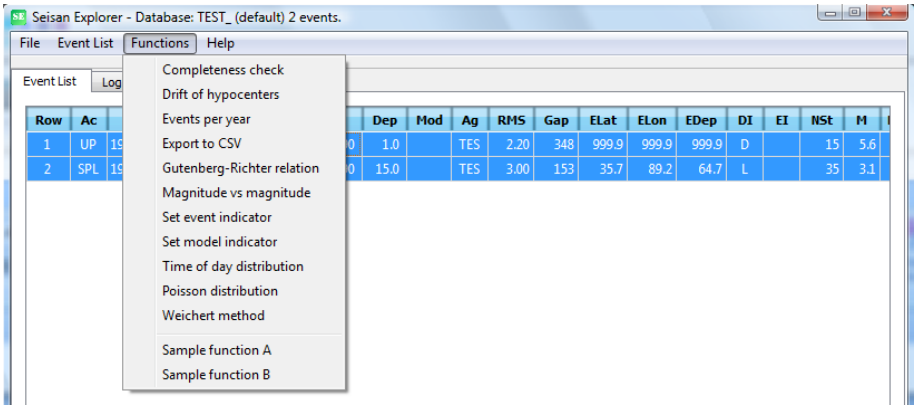


The magnitude residuals are also color coded to make it easy to find the deviating magnitudes. Since the location option can stay open at the same time as the trace data is displayed, it is possible to go the MULPLT window and change some reading and then back to the location window to see the effect.

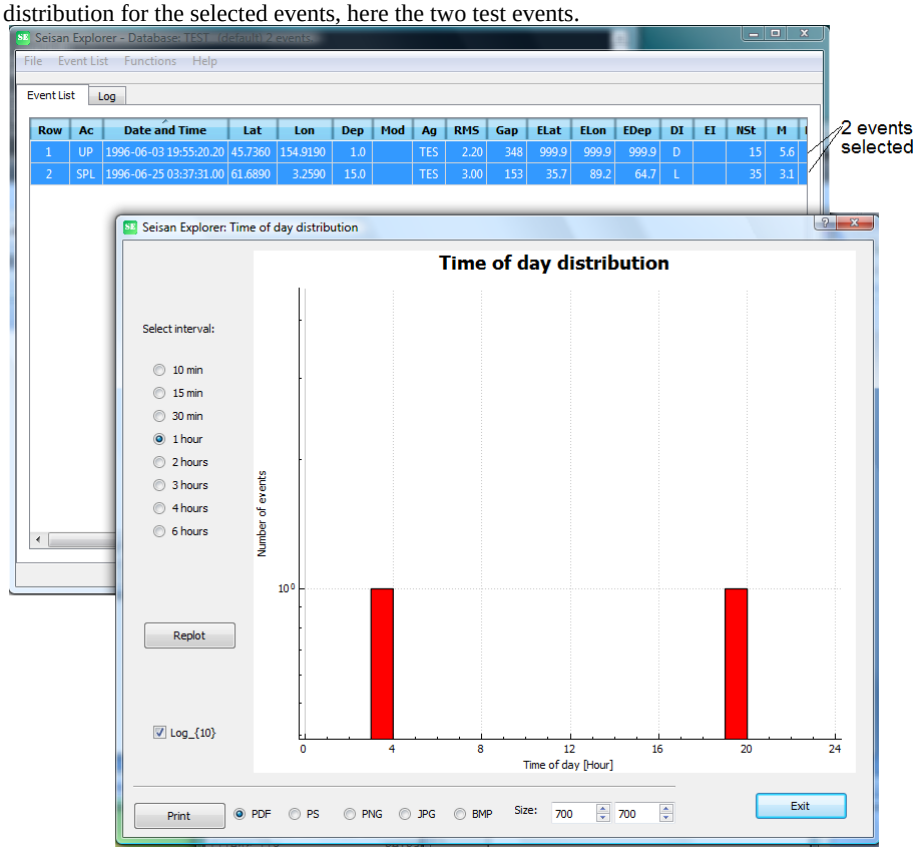
13.4 Functions in SE

NOTE: In current version of SE, the Tab Functions is now called Statistics, the figures below have not been changed.

On a selected data set of many events, SE has a series of functions many of which are not found elsewhere in SEISAN. There are particularly useful options for seismic hazard analysis. The functions are selected under Functions, see below.

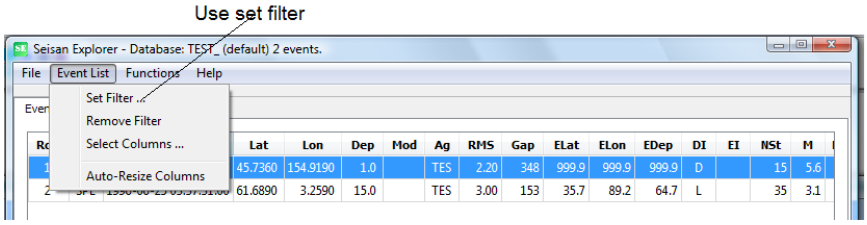


Two events is hardly enough for most functions, however we can demonstrate the time of day distribution for the selected events, here the two test events.

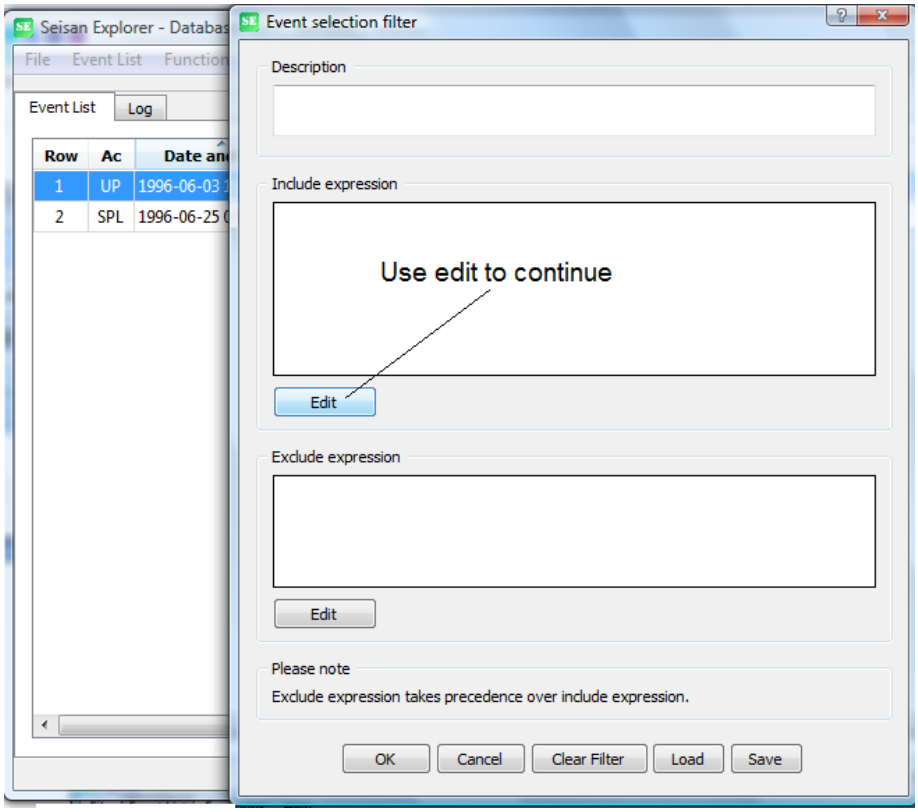


13.5 Event selection filter

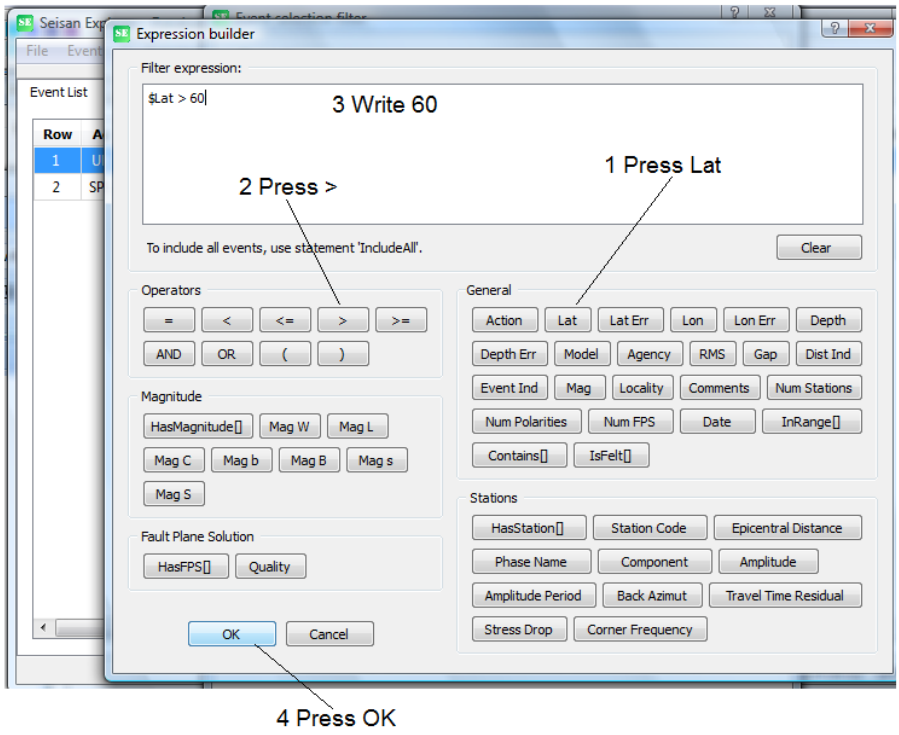
SE has a very sophisticated event selection filter whereby a subset of loaded events can be selected according to user set criteria. Both include and exclude filters can be used and there is a large number of parameters that can be used in the selection criteria. The filter is found under Event List/Set Filter, see below.



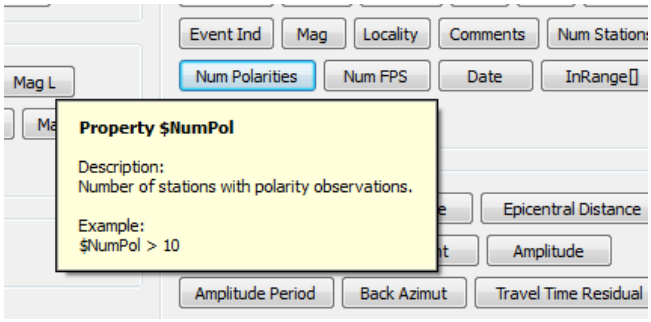
The filter selection box now comes up and the user has to chose if an include or an exclude filter is to be defined, here we will use only include, see below.



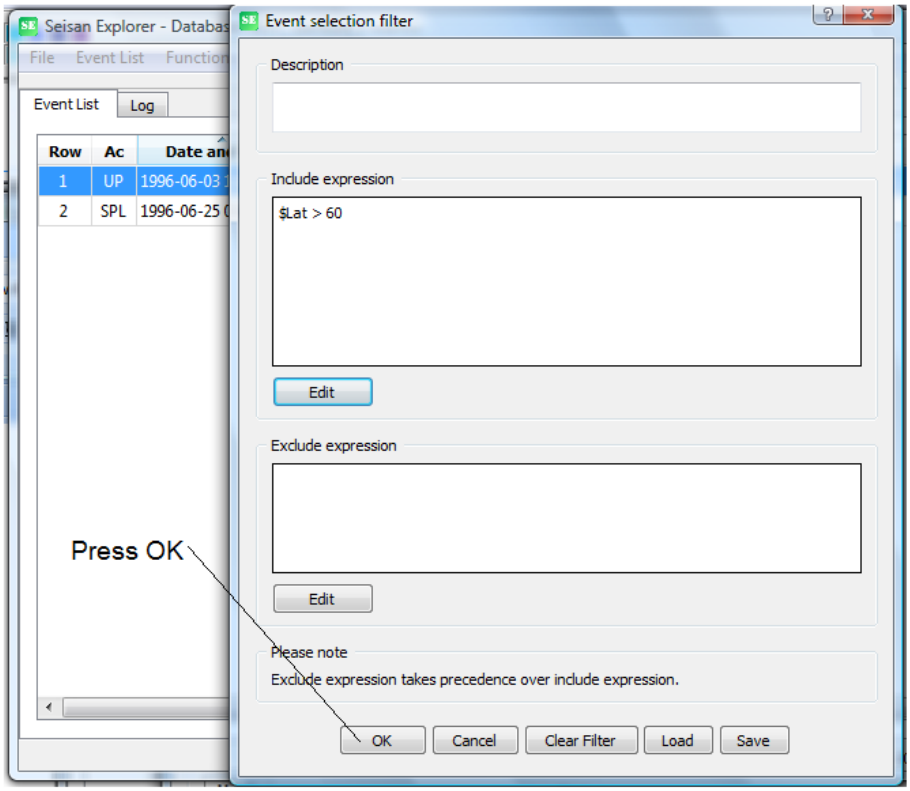
Once Edit has been clicked, the parameters which can be selected are shown. In the example here all events with latitude > 60 deg will be chosen, see below.



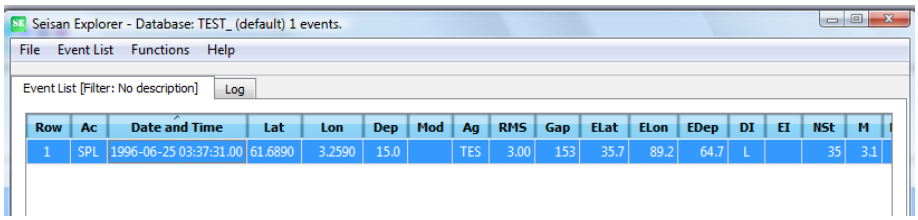
The selection parameters have help boxes. Right click on parameter. Below is an example of the explanation for minimum number of stations with polarity readings.



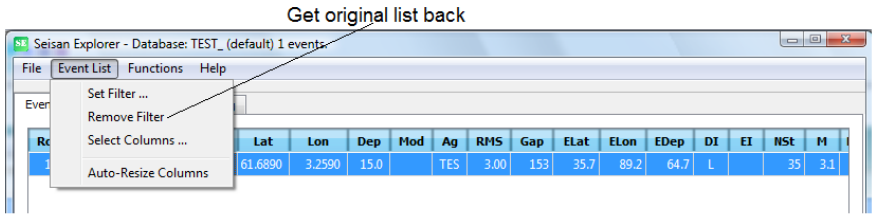
Once selection is finished, press OK and OK to run filter.



Now there is only one event left. A function can now be used on the selected subset or the events can be written out with the Copy to File option.

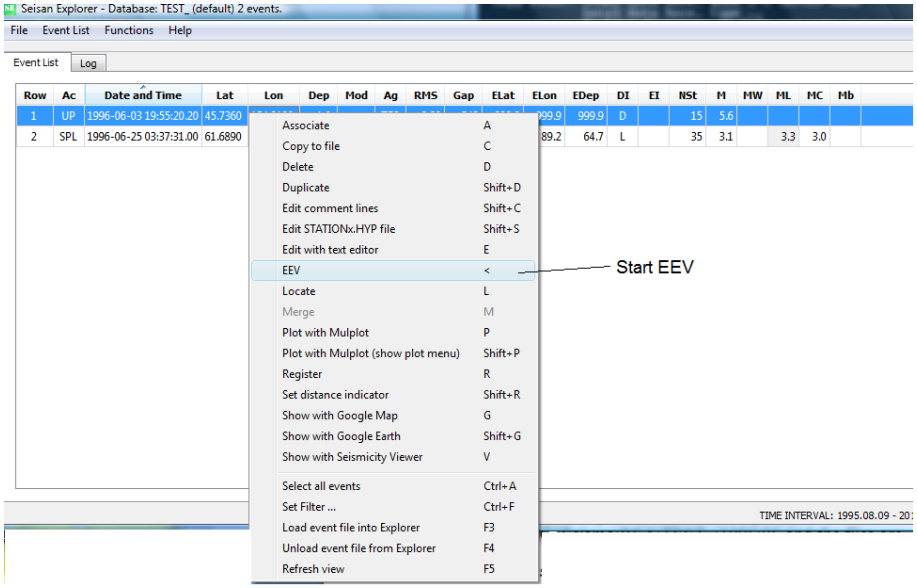


The original list can be restored by using Event List/Remove filter.

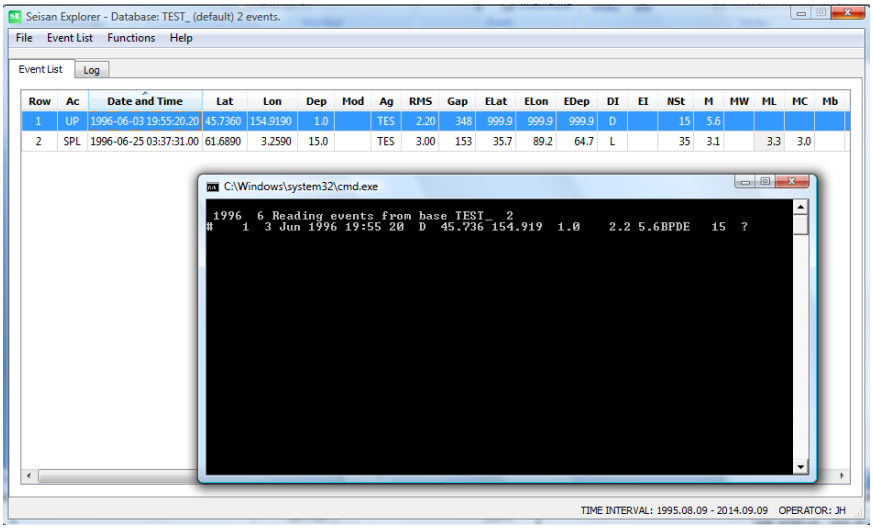


13.6 How to get the remaining EEV commands in SE

The commands not yet implemented in SE can be executed via the EEV interface.



You get



All the usual EEV commands are now available. When quitting, control goes back to SE and the data base read into SE is updated.

Acknowledgement: Paul Friberg corrected this document in version from 2014.