

SEISAN Version 8.1 - introductory training course

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Introduction

This SEISAN training course is intended as a short introduction to SEISAN and how to use it. It assumes some knowledge of basic seismological processing and basic computer knowledge. During the course, the SEISAN manual, version 8.1 (Havskov and Ottemöller, 2003), will be used. The goal of the exercises is to be able to handle the SEISAN database, pick phases, locate the events and display the results. There is also a short exercise in doing fault plane solutions and determining spectral parameters. SEISAN is a large system with many options and this course will only deal with the most basic operations. However, it should hopefully be sufficient to get started with SEISAN.

Overview of SEISAN

The main goal of SEISAN is to have a simple system for routine processing of all kinds of seismic observatory data, whether digital, analog, broad band, teleseismic or local data. Another important goal is to be able to store and retrieve all data in a single system so that when one analysis like spectral analysis requires a hypocenter and an attenuation function, these parameters should automatically be available if obtained at some earlier time or already given in a parameter file. In SEISAN, this is achieved by having a simple event oriented database storing all data in chronological order. Once the user has found the relevant event to work with, no other steps are needed to access all data related to this event. This requires that station coordinates, crustal models etc. are stored in a standard way.

Batch processing: Since SEISAN is used for routine observations, there is also a need for processing large data sets in one go. In SEISAN, any part of or all of the database can be reprocessed with new parameters. If e.g. a new crustal model becomes available, a single command will relocate all events in the database and give the changes in location relative to the old model. If trace plots are required for any number of events, this can also be done with one command.

Computer independent: The system operates on UNIX (Solaris, Macintosh and Linux) and Windows95/2000/NT/XP and all types of files can be moved between the systems without any kind of reformatting. It is thus e.g. possible to preprocess data on a PC and move the data to Sun for further processing and storage.

Advanced analysis: By having all parameters collected in a single database, and by adjusting well known analysis programs like PITSA and SAC2000 (both Unix) to SEISAN, further data analysis becomes much easier compared to having to reformat data for each new analysis tool. Thus SEISAN has a series of well known analysis programs integrated and has as a goal to integrate more to take advantage of the unified database and associated formats in SEISAN.

Learning SEISAN then involves as a first major step to become familiar with the database and how to manipulate data in the database as well of how to input and output data from the database. Once this is mastered, different kinds of analysis can be done following similar steps.

Installation

If SEISAN already has been installed, skip this section.

SEISAN for PC and Sun is normally distributed on a CD, and it is also available on the web http://www.geo.uib.no/Seismologi/SOFTWARE/SEISAN_8.1/. Here it is assumed that a CD is available. Normally SEISAN comes in one file, an installation file for PC and a compressed tar file for Unix.

- Copy the file from the CD to the directory under which SEISAN is going to be installed or install directly from CD.

- Follow the instructions in the SEISAN manual section 3. In order to get SEISAN operating with the test data included, the only parameters to set are the paths to the database and software. For PC installation, use all defaults. The remaining parameters can be dealt with later.

Once the software has been installed and paths set, reboot the computer (on Sun, source the .SEISAN file).

- Give a command (e.g. 'wo' to move to working directory) to check that it is installed. If that works, try command dirf, if no protests, the software is successfully installed.

The test data set is not part of the full distribution and must be installed separately. To install the test data, copy the file 'testdata_8.1.tar.Z' to the SEISAN_TOP directory and restore the data as described for the SEISAN software. The test data will be installed in data base TEST and a special station file STATIONt.HYP will be copied to DAT. The name is different from the standard STATION0.HYP in order to not overwrite the users own station file. To work with the test data, it is recommended to change the default database to 'TEST' (on PC, add line set def_base=test_ in autoexec.bat or set environmental variable def_base, this step might also be done by the installation program).

In order to print, a PostScript printer must be available and file seisan_pr.bat in COM directory must be configured, see manual section 3.3.

Basics of the SEISAN database

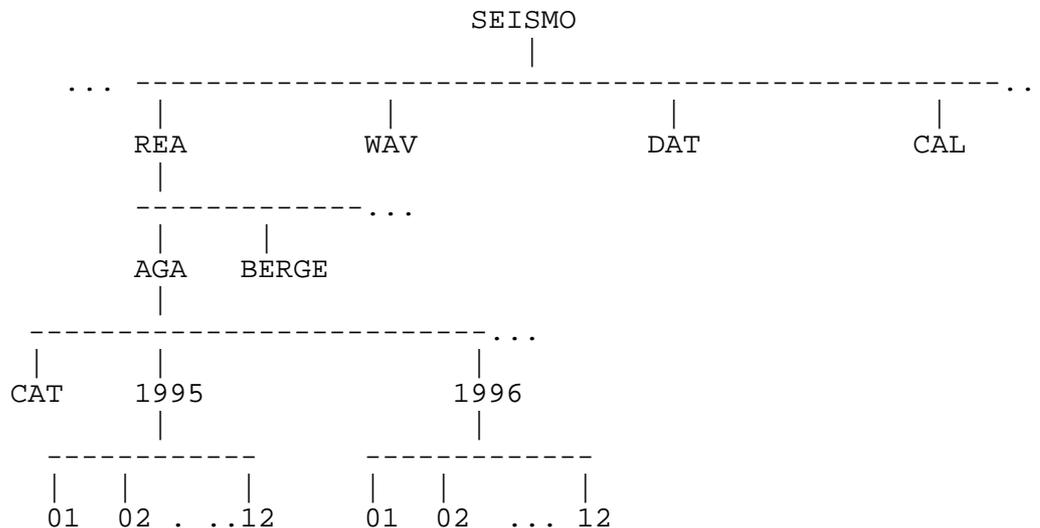
The data is organized in a database like structure using the file system. The smallest basic unit is a file containing original phase readings (arrival times, amplitude, period, azimuth, apparent velocity) for one event. The name of that file is also the event ID, which is the key to all information about the event in the database. Although the database in reality only consists of a large number of sub-directories and files (all of which the user has access to), the intention is that by using the surrounding software, the user should rarely need to access the files directly, but rather do all work from the user's own directory using the SEISAN software.

The whole SEISAN system is located in sub directories residing under the main directory SEISMO (can have a different name). The database and associated parameter files consist of the following:

REA:	Earthquake readings and full epicenter solutions in a database
DAT:	Parameter and fixed data files, e.g. station coordinates
WAV:	Digital waveform data files
CAL:	System calibration files

The directory structure is used as a tree like structure for quick access to individual files in the REA directory, which therefore will appear as a simple database to the user. Figure 1 shows the tree structure of the SEISAN database.

Figure 1 Directory tree structure of SEISAN database part.



REA directory and database

The REA directory contains phase readings and derived source information like hypocenters, fault plane solutions etc. The REA directory has one or several sub-directories corresponding to separate databases (max 5 characters), for simplicity it is here assumed that only the database AGA is present (see Figure 1). For quick reference and interactive work the events are stored in single files (S-files) in yearly directories and monthly sub-directories. When new data is entered into the database, it is stored as individual event files. However, once the interactive work has finished, the single event files are overwritten with the final location and additionally stored in monthly files, which are only changed when updating the database.

The monthly files, called CAT-files for catalog, are stored separately in the CAT directory and primarily used for quick searching and backup for the single files.

The key files in the database are the S-files (single event file). Each S-file contains original phase readings in the Nordic format (see example below) which includes file names of all corresponding waveform files. One event is one file. Each event has an ID line. The ID line contains a unique ID which will follow the event through all following operations. The ID line also contains status information about the event like last action as e.g. when it was updated.

Table 1 A typical S-file

The first line is the header with origin time, location and magnitudes, in this case 2 magnitudes. The line type (last column) is 1.

The second line gives the event ID, line type 1.

The third line gives the name of the associated waveform file, in this case from Sun, line type 6.

The fourth line is a comment line, line type 3.

The fifth line is a header line for the phase lines, line type 7, followed by the phases lines, one per line. The abbreviations are:

Input parameters:

```

STAT SP      : Station and component
IPHAS       : Phase with onset
W           : Phase weight, HYP071 style
HRMM SECON  : Hour, minute and seconds
CODA        : Coda length (secs)
AMPLIT PERI: Amplitude (nm) and period (sec)
AZIM VELO   : Azimuth (deg) and apparent velocity of arrival at station
AIN         : Angle of incidence
    
```

Output parameters:

```

AR          : Azimuth residual
TRES        : Arrival time residual
W           : Weigh used in location
DIS         : Epicentral distance in km
CAZ         : Azimuth from event to station
    
```

```

1993 1014 1638 24.1tL 58.285 6.356 16.0 BER 8 .8 2.6CBER 2.3LNAO 1
ACTION:UPD 97-03-25 21:28 OP:jh STATUS: ID:19931014163824 I
1993-10-14-1638-01S.NSN_23 6
535 SOUTHERN NORWAY, this line is comment 3
STAT SP IPHASW D HRMM SECON CODA AMPLIT PERI AZIMU VELO AIN AR TRES W DIS CAZ7
KMY SZ EP 1638 43.75 99 .010 122 328
KMY SZ ES 1638 59.09 .810 122 328
BLS5 SZ EP 1638 44.83 101 .210 127 3
BLS5 SZ ES 1638 59.60 -.210 127 3
ODD1 SZ EP 1638 53.18 122 .910 182 5
EGD SZ EP 1638 57.89 122 -.3 9 230 343
EGD SZ ES 1639 23.23 -.2 9 230 343
BER SZ EP 1638 59.23 105 -.3 9 241 346
ASK SZ EP 1639 0.91 113 -.2 9 254 344
ASK SZ ESG 1639 33.37 -1.9 9 254 344
SUE SN EP 1639 9.70 156 .2 9 322 343
NRA0 S EPn 1639 19.25 20.0 1.7 20.4 9.452.0 -8 -.1 9 401 49
NRA0 S EPg 1639 26.92 228.7 6.7 6.0 0 -1.9 9 401 49
NRA0 S ESn 1640 01.69 232.3 4.7 3.6 3 1.4 9 401 49
NRA0 S ELg 1640 15.09 222.4 3.4 6.2 -6 -.4 9 401 49
    
```

For more details on the S-file, see Appendix 1 in the SEISAN manual.

The S-files are used as input for location and, when making a permanent update, also for output. Events are classified either as L, R or D for local, regional or distant event respectively. This information is given in the header line of the S-file as well as in the S-file name. The t in front of the L indicates the station file used, in this case STATIONt.HYP to be used with test data. Normally this field is blank indicating that the standard STATION0.HYP is used.

Interactive work with the S-files in the database is done with the program EEV. This program will enable the user to point to any event in the database and to do interactive work with that event. Alternative programs (SEISAN (PC only) or JSEISAN), doing part of what EEV is

doing, using a graphical interface, are available. However, the basic and fastest operation is with EEV.

The catalog in the CAT directory is accessed ONLY with the SELECT command. This command searches the database for events of particular interest. Data in the CAT directory are updated only through the UPDATE program.

Waveform data, the WAV directory

This directory contains files with digital waveform data. The directory normally has no sub-directories or any other organization since there is only room for a small part of the waveform data corresponding to the entries in the REA database. However, in case of using very large disks, WAV can also be subdivided (see SEISAN manual).

SEISAN reads waveform data in SEISAN, SAC ASCII, SAC (Unix only), SEED, MINISEED and GSE format.

The S-file will, in addition to seismic parameters, have a list of waveform file names associated with the event (see example above, line type 6 lines). This means that the S-file contains ALL information about available data for a particular event.

The analysis system (like EEV) will always look in the users own directory and then in WAV for a waveform file.

Calibration data, the CAL directory

The CAL directory contains calibration files, one for each channel of digital data. For details see SEISAN manual. For this exercise, it is assumed that the calibration files are already there.

Parameter files, the DAT directory

The DAT directory contains station files, program parameter files with information like channels to be plotted on default. Parameters used for spectral analysis are also stored here as well as map contours. Changes to the files in this directory will only have to be done occasionally, and most often when a new crustal model is to be used or new stations added. It is assumed for this exercise, that no changes are needed. The station and model file used with these test data is 'STATIONt.HYP'

EXERCISES

In all the following exercises, a reference to a section, refers to SEISAN 8.1 manual.

Exercise 1: Interactive work with the database using EEV

COMMANDS CAN BE ENTERED IN UPPER OR LOWER CASE EXCEPT ON SUN WHERE PROGRAM NAMES MUST BE GIVEN IN LOWER CASE.

These exercises are based on a set of test data, which are stored in the database TEST. Before you start, check that the TEST database is set as default database (section 3.1). Data are available for the following months: September 1993, June 1994, October 1994, August 1995, November 1995, June-July 1996, August 1997, August 1998, September 1999 and February 2000. A list showing location and magnitude for these events is given in the Appendix. Waveform data is available for all events in the test database and additional continuous data is available for January 2003. For details of EEV, see section 4.4.

Always work in the work directory `seismo\wor`, use command `'wo'` to get there.

Type `'eev 199606'`, that points you to the first event for June, 1996. You will see the essential information about the event like origin time, location and magnitude. The letters L, R or D indicate whether it is a local, regional or distant event. To move around the data for that month, try the following commands (terminated with a enter)

- Enter: go to next event
- `'b'`: move back one event
- `'3'`: move to event # 3
- `'d23'`: move to the first event on the 23rd or later

The event shown, can be operated on with several commands (upper or lower case), try these:

- t: type the event (S-file) to see the parameters for the event
- tt: ----- only header line
- e: edit event file
- l: locate event
- d: delete event (do not confirm !!)
- q: quit EEV

Note: The editor is NOTEPAD on PC and vi on Sun. To change to another editor, see section 3.1.

To see all commands in EEV, type `'?'`

Question 1.1

How many events does the month have (June 1996) ?

Question 1.2

How many local, regional and distant events are there ?

Question 1.3

What happens when you use enter when positioned at the last event of the month ?

Question 1.4

Use event: 7 June 1996, 13:25

Locate event (command 'l') : The last output line gives the location in decimal degrees. How does that location compare to the database location ?

Edit the event (command 'e') and change the P-reading for station KMY by +5 seconds. Locate again, what is the difference in the location ? Examine the details of the location in file print.out. This can be done from EEV with command 'onotepad print.out' (PC) or 'ovi print.out' (SUN). 'o' in front of 'onotepad' means giving the command notepad to the operating system.

How many iterations was used to locate the event ?

Question 1.5

Use event: 5 July 1996, 02:20

Edit the event and add the following readings to the event:
station ASK, component SZ, phase EP, time 0221 0.57, coda 87
station ASK, component SZ, phase ES, time 0221 12.66

Exit from the editor and relocate event. Does the new station appear on the output ? How much did the location change ?

Question 1.6

Try command 'c' to copy event file to working directory. Explain what it does and check that it works.

Question 1.7

Try command 'r', explain what it does.

If you have SEISAN installed on a Windows system, try the same commands.

Question 1.8

As mentioned above, all events for June and July 1996 have digital waveform files available. Make a cross-check between the file names of waveform files in the WAV directory (type WA to go there) and the events in the database (check for line type 6 in the S-file). Try the 'w' command in EEV.

Exercise 2: Selecting data from the database and making an epicenter map

An important task is to extract data out of the database for further analysis like epicenter plotting or exchange with other agencies. If the database has been updated, meaning that data is available in the CAT directory, this is most easily done with the SELECT command (section 6.4), otherwise use the COLLECT command (section 6.5). These commands will extract data out of the database in any given time interval, and the SELECT program can in

addition use many selection criteria (magnitude, location etc.) to further limit the data extraction. The data is extracted to one file in the same format with events separated with a blank line. For this exercise, only the SELECT program will be used.

Go back to WOR directory with command 'wo'. Start the select program with command SELECT, use time limits 199309 to 199808 and default database (CAT data base). When menu comes up, select option 6 (magnitude range) and use 2.5 as minimum magnitude, make another return. You will now get an output file select.out with selected events. Edit the file to see what it looks like.

Question 2.1

How many events were selected out of the total available ? How many waveform files were available for these events ? How was the distribution of local, regional and distant events in the data base ?

Plot the selected events using command EPIMAP. Follow instructions, section 6.3 , use defaults for most parameters and select.out as input epicenter file name. The latitude - longitude range should be 59-63 and 0-10 respectively. Map projection can be e.g. Mercator. EPIMAP generates a file epimap.inp with the plot commands every time it runs. This file can be edited to run the same map with e.g. a new input file. Try the command 'epimap epimap.inp' to plot the same map again without answering questions.

Question 2.2

When the plot is on the screen, try commands 'p' and 'z', explain what they do.

Optional if on PC: Plot epicenters with w_emap

Install w_emap from SUP, see SEISAN manual section 6.3.1. W-emap will automatically plot the event in hyp.out, so first make a location with EEV, then call up w_emap. Try zooming option etc. The file select.out can also be plotted using option hypocenters.

Exercise 3: Putting new data into the database

Data can come into the database in two forms, parameter data and/or waveform data (see exercise 4). For this exercise, it is assumed that parameter data (readings) are available from a different agency. Data can also be manually entered through SEISAN program NEWEVE. For the exercise, a test file with readings from August 1996 is available (file name august.96 in DAT directory). The format is the same as used in all other S-files and CAT files. In order to put the data into the database, the necessary directory structure must be in place. If not already there, create it with command MAKEREA (section 3.3). Make a directory structure for all of 1996 and use database name TEST.

Question 3.1

How many directories were made with MAKEREA ?

Go to the DAT directory using command 'da' and check that file august.96 is there. Now that the directory structure is in place, the data is put into the database with program SPLIT (section 6.6), which splits up the input file, containing many events to single S-files in the database.

Question 3.2

Use EEV on the month of August 96, and find out how many events there are.

Exercise 4: Plotting digital data

Digital data is plotted and analyzed with program MULPLT. The program is capable of doing general phase picking, correct for instrument response, produce ground corrected seismograms for determining M_l , M_b or M_s , determine azimuth of arrival for 3 component stations and do spectral analysis. The program can also read in theoretical arrival times for global phases to help with the identification of phases.

MULPLT operates either as a database independent program (started with command MULPLT), in connection with the database (started from EEV with command 'p') or using a continuous data base started by command MULPLT. If the program works independently of EEV, it will create an output file mulplt.out in Nordic format with the readings and results of spectral analysis.

Running MULPLT using command MULPLT, the program asks for a file name or file number of a waveform file. To use the number, it is assumed that a list of interesting files has first been created and numbered in a file FILENR.LIS using command DIRF, see section 6.8. By giving the number, the file corresponding to the number is used. By giving a '?', the list with numbers is displayed and a number can be given. In the first exercise, MULPLT will be used from EEV.

- Start EEV on June 1996
- Try several events in this month
- Type 'p' to plot. Chose filename if more than one and plot with option '0' (section 6.2.1), press return for no filter
- When plot comes up try the following:
Get options: Click on the 'MENU' bar. MENU or single letter commands can be used

Zoom: Put cursor to the left, push left mouse button or space bar, move mouse to the right, repeat

Back to original: Do above in reverse order (right - left)

Filter: Click filter limits (e.g. '.1-1.0') 0.1 to 1.0 Hz, click on 'Plot' or push 'x' followed by 'r'

Push 'b', then 'r' (filtered from 5 to 10 hz)

- Select channels: Click on 'Oth C' and select channels. Alternatively, on trace plot, click on channel name on left hand side and type 'r' or click on 'Plot'
- Plot one channel at a time: Click 'Toggle' or press 't', back to multi trace do the same
- All commands are one key press or click on menu, to see all type '?' or click on 'Help'
- Quit by typing 'q' or click on 'Quit', you are now back to EEV

Plotting events directly with MULPLT without using the database:

Move to WAV directory	:	'wa'
Make a list of waveform files	:	'dirf 199*.*', use all files starting with 199
Check list of files (optional):	'	type filenr.lis', on Sun 'cat filenr.lis'
Plot event	:	'mulplt', give event number e.g. '2', then option '0'
Plot next event in list	:	Press 'f' or click on 'Next'

In this way, many events can sequentially be plotted for quick inspection.

Question 4.1: Are all channels available in one waveform file plotted ?

Plotting continuous data (see section 2.2.2)

SEISAN can store continuous waveform data using S-file data bases for each stream of data. The structure of the continuous data is defined in SEISAN.DEF and has been preinstalled with the test data. Continuous LPZ data (5 Hz sample rate) is installed for stations JMI, NSS and RUND for January 22, 2003. The corresponding data bases are called CJMI, NSS and CRUND respectively.

- Start MULPLT, use option 'cont'
- Choose start time and time window 20030122 and 60 respectively. Choose multitrace plot on screen (0 or 1). This will plot 60 minutes of data from all 3 station and no file overlaps are visible to the user.
- Try zoom and single trace mode.
- Go forth and back in continuous data with 'Next' and 'Back' and find an event, note overlap.
- Extract out the event by zooming on desired section and then use option 'Out' to make a waveform file with zoomed section.
- Plot the event from the extracted files.

Plotting one file in continuous data base from NSS:

- Start EEV with command eev 20030122 CNSS
- Plot a single 20 min continuous file with 'po'
- Plot next file with 'f'

Plotting 24 hours, one channel:

- Start EEV with command eev 20030122 CNSS
- Get plot menu with 'p'
- Chose option 4
- Use no filter, 3600 s per line, end time to end of month, max count 40000, 24 lines per page, station NSS, component L Z (NB: Two spaces between L and Z).

A 24 hour plot is now shown and the first large event is clearly seen. However, there is also a smaller 2. event in this data set (Appendix). Try to use one of the above plotting methods to find it, filtering might be needed.

Putting a new digital recorded event into the database:

- Move to DAT directory ('da') and make list of files 'dirf 199*'
- Start MULPLT, when asked about filename, answer '?' to get the event list, select the event from August 96 (1996-08-15-2340-35S.TEST_009), use option '0' to plot the event.
- When event is on the screen, click on 'Regis' (or type 'p') and answer questions (event is local) (section 6.2.5), then quit.

The event is now put into the database as a new event. Check that it is there by using EEV on August 96.

- Change the model used for this event to 't'; this is done by changing in the first line of the s-file the character in column 21 to 't'.

Question 4.2

What information is now available for the August event in the database ?

Exercise 5: Phase picking

Phases picked will enter the database and, when plotting from EEV, phases already present in the S-file will be shown on the plot. In this exercise, phases will be picked and put into the database. Optional phases can be picked in single or multi trace mode, to toggle between the two modes in mulplt press 't'.

Local event

- Start EEV for August 96
- Move to event on August 15 at time 23:40 using the 'd15' command, this event was registered in Exercise 4
- Plot event with 'p' or 'po' for no questions

Question 5.1: Are there phases picked already for this event ?

- Go back to EEV and type the event with command 't'

Question 5.2: Are there readings available in the database (S- file) ?

- If readings are already present, edit the event and delete all phase lines (lines below the phase header line), DO NOT DELETE OTHER LINES.
- Plot event in single trace mode, press return when mulplt asks for plot option. The first trace will be shown on the screen.

It is essential to zoom, this in single trace mode is done by putting the mouse to the left and pressing the left mouse button and then to the right, but above the trace window. Try to zoom putting the right mouse click in or outside the trace window. What is the difference? To zoom out again press 'r' for replot.

Try different filters when picking phases.

When the trace is zoomed, move cursor to the P-phase for the first trace, press '1', move to the S-phase press '8' and to the end of the coda and press 'c' (phase keys are defined on the top of the screen in single trace mode). As the phases are picked, they will be displayed. Pick also phases with polarity. Go to the next trace pressing 'f' and pick phases, until you get back to eev.

- Check readings available : 't' for type to see readings

Question 5.3: How many phase lines are present in S-file ?

- Locate event : 'l'

Question 5.4: Does the location and magnitude look 'reasonable' (compare with Appendix), how big is the RMS and how large is the largest residual ?

Phases can also be picked in multi trace mode, try. Looking at the phase picks in multi trace mode might be useful to get an overview.

Question 5.5: What is the advantage of using single trace mode compared to multiple trace mode when picking phases ?

- In EEV, use command 'update', explain what happens, what changes do you see in the S-file ?

Distant event

- Start EEV for August 1998, there is only one event
- Plot the waveform file 1998-08-04-1902-47.TEST__011, which has broadband recordings
- In single trace mode, pick the first arriving signal as P ('1') for all traces
- Locate event and compare with PDE location, which is given in the S-file

Question 5.6: How do the location compare to PDE location?

Exercise 6: Magnitude determination

All currently used magnitudes can be determined with SEISAN. In exercise 5, coda magnitude was calculated, here we shall calculate local magnitude MI, body wave magnitude Mb and surface wave magnitude Ms. In order to determine magnitudes based on amplitudes, response information must be available in the system. The response files have already been installed in the CAL directory for this exercise. The definition of the magnitude scales are given in section 6.1.1

Local magnitude MI

In order to determine MI, amplitudes must be read on a Wood Anderson seismograph. In SEISAN, the original trace is corrected for instrument response and converted to a synthetic Wood Anderson trace. Then the maximum amplitude is automatically read and assigned the phase name AML.

- Select the August 1996 event from exercise 5, which has a local magnitude of 1.6, plot the event in single trace mode. Select Wood Anderson trace by clicking on 'WA', select a window around the maximum amplitude. The lower trace will now show the Wood Anderson simulated trace with amplitude scale of nanometers. Pick the amplitudes (using 'a' at top and bottom of maximum amplitude) for all stations and exit plot.

Question 6.1

Inspect the amplitude readings in the database (S-file), how do the amplitudes vary with distance ?

- Locate the event. At the end of the listing, the magnitudes calculated for each station are shown.

Question 6.2

How well do the MI values for the different stations agree ?

Body wave magnitude Mb

Mb is defined using SP seismographs with a peak gain around 1 sec. Modern SP instrument have a flat velocity response from 1 to e.g. 20 Hz so, like for MI, SEISAN simulates the old SP response.

- Select event June 3,1996 at 19:55, plot file '1996-06-03-2002-18S.TEST__012' in single trace mode. Click on 'Mb' button and select a window around the P-phase. On the lower trace, the corrected seismogram will appear. Pick amplitudes for several stations and exit the plot. The amplitudes will be stored with phase name AMB. Try using both manual (a) and automatic (A) amplitude picking.

- Locate event, the magnitudes will appear for each station

Question 6.3

How well do Mb for different stations agree, how do they agree with PDE magnitude (found in S-file) ?

Surface wave magnitude

Ms is supposed to be read near the 20 sec period. In SEISAN, this is simulated by making the instrument correction and filtering between 16 and 24 secs.

- Select the same event as for Mb, plot file '1996-06-03-1917-52S.TEST__002' in single trace mode. Since this is LP data from a broad band station, it is an advantage to filter to 'see' the signals. Try with filter 0.01 0.1 Hz on the LZ channel. Click on 'Ms' and select a window around the surface waves. On the lower trace, read the maximum amplitude, go to next trace with 'F' and quit. The amplitude will be stored with phase name AMS.

Question 6.4

What is the period and amplitude read (remember units) ?

- Locate the event.

Question 6.5

How does your determined Ms compare to the PDE magnitude (found in S-file)?

Note: Phase names AML, AMB and AMS are IASPEI approved names as of July 2003.

Determining b-value

The program to calculate b-value is called 'bvalue'. Start the bvalue program and use the file august.96 as input (in DAT). Use coda magnitudes, a magnitude step of 0.2, range 2.5 to 4.0 and fixed b-value of 1.0. Then use least square to calculate b-value and plot.

Question 6.6

What is a and b-values ?

What is the detection threshold ?

Was the range 2.5 to 4.0 correct ?

-Test the use of other parameters like another magnitude step, or using maximum likelihood

Question 6.7

How stable are the a and b-values

-Redo the exercise using MI

Question 6.8

How do the results compare using Mc and MI ?

Exercise 7: Fault plane solution

In SEISAN, the fault plane solution for an event can be determined with first motions and/or amplitudes (section 6.1.6). Polarities are picked by placing the cursor at the top or bottom of the seismogram when the phase is picked.

- Select one of the events 25 June 1996, 03:37 and 12 August 1997, 08:14 and determine polarities for all stations. The polarities are best seen when using zoom in zoom, in single trace mode. Fix the depth to 15 km. Then choose option 'f' and proceed with determining the fault plane solution (section 6.16).

Question 7.1

How well is the solution constrained ?

Compare your results to (strike: 327, dip: 62, rake: -11) for the first event and (strike: 184, dip: 64, rake: 16) for the second.

Question 7.2 Using amplitudes

For the event 12 August 1997, read Pg and Sg amplitudes on the vertical component for stations BLS5 and ODD1 without applying instrument correction. Again use FOCMEC to search for possible solutions and enter numbers for maximum error on the amplitude ratio data. Try to allow for either 0 or 2 ratio errors and see how this changes the solution. Are

you able to better constrain the solution using the amplitude ratios? Also see the output in focmec.lst.

Exercise 8: Spectral analysis

The standard displacement spectral analysis determining seismic moment, stress drop and source radius can be done with SEISAN (section 6.2.11). As with other parameters, the results of the analysis is stored in the database. In addition to the spectral parameters, the moment magnitude M_w will also be determined using the seismic moment and the hypocentral distance. It is therefore important, before doing any spectral analysis, that the database has been updated, meaning that epicentral distances are stored in the database. See also document qspec.pdf in INF for more info on spectral analysis and source parameters.

- Select the event on 12 August 1997 at 08:14, plot in single trace mode
- Click on 'Spec' on the menu and select a window around the S-waves (about 10 - 20 secs long), select displacement spectrum when question comes up. The displacement spectrum is now displayed.

Question 8.1

Does the spectrum look 'right' meaning a flat level and a clear decay ?

Note that the noise spectrum is also displayed. This will give an indication of which frequency band can be used for the spectrum. If the signal spectrum is not above the noise spectrum, this part of the spectrum cannot be used and the spectrum will look 'funny', probably the spectral level increases strongly towards low frequencies.

- Determine the lower frequency limit to be used (probably in the range 0.2 to 1.0 Hz) and limit the spectrum by using the option 'F' after selecting the spectrum or change the parameter file MULPLT.DEF in DAT (SEISAN manual section 6.2.12). The upper frequency limit can be set to 50 Hz. Redo the spectrum.

Question 8.2

Does the spectrum look 'right' now ?

- With cursor, select the 3 points defining the spectral level and slope, enter 'f' and the spectral values are displayed. Enter 'f' again and the values are stored in the S-file. Repeat for all traces. Quit the plotting program. To calculate the average values of the parameters, use the 'update' option in EEV.

Question 8.3

Are the spectral parameters stored in the S-file ?

Question 8.4

How does the M_w magnitude compare to M_l ?

Question 8.5

How big is the stress drop and source radius ?

Exercise 9: Reading global phases using IASPEI91 tables

The IASPEI91 travel time tables can be used to help reading phases (section 6.20.1). In order to calculate the theoretical times, the hypocenter and origin time must be known. In SEISAN, this means that the data is available in the S-file in the header line or another hypocenter line (type 1). Chose one of the events, which have broadband and long period data:

29 September 1993, 22:25
16 June 1994, 18:41
4 October 1994, 13:22
10 June 1996, 01:04
4 August 1998, 18:59

- Pick phases for the stations of interest, this could just be E phases.
- Calculate theoretical times: Command 'iasp' from EEV. This will calculate theoretical arrival times for all stations given in the S-file.
- Plot broadband and long period data first in multi and then in single trace mode, use filter 1-5 Hz for broadband and 0.01-0.1 Hz for long period. The theoretical phase will now be displayed with a prefix 'y' and displayed below the trace. There will be very many phases, try to zoom to identify a few. Phases are picked by pressing 'y' and labeled with the name of the closest calculated phase name in time.

Question 9.1

Which phases could be identified?

Question 9.2

First identify P phases for one of the events June 16, 1994 at 18:41 and June 10, 1996 at 01:04, and locate. Then try to identify pP and sP and relocate. What can you say about the depth (compare to PDE)?

Exercise 10: Waveform formats in SEISAN

SEISAN can deal directly with a variety of waveform formats. This exercise will demonstrate the use of these formats: SEISAN, GSE, SEED, MINISEED and SAC.

The data files to be used in this exercise are located in the WAV directory; filenames are 2005-06-13-2252-24.009.seed and 2005-06-13-2252-24.009.miniseed for data in SEED and MINISEED format, respectively. The data in both files are identical. The difference is that the SEED file contains full instrument response information while this information is missing from the MINISEED file. Data centers such as IRIS and Orfeus provide data in SEED format and optionally in MINISEED. This exercise demonstrates how these data together with the instrument response can easily be used with SEISAN.

First, use MULPLT to plot the two files and register one of them in the TEST database. Make sure entries have been created for 200501, use program makerea. Then from EEV start MULPLT to pick P phases and amplitudes. In single trace mode, also plot the response by clicking on the 'Resp' box (the SEED response files are already in the CAL directory see exercise 11 on how to do that). You can also enter the event location (Appendix) using 'inputepi' in EEV and try option 'iasp' in EEV. Also try to compute a noise power spectrum in MULPLT, do this by going to single trace mode in MULPLT. Then select 'Spec' or press 's' to compute spectrum. Select a window before the signal arrival, then press 'n'.

Next convert the MINISEED file to the different formats supported by SEISAN. Run program DIRF to create filenr.lis file. Then convert using the program WAVETOOL. Create files in the following formats: SEISAN, GSE and SAC (Unix only), by running the program several times. When writing SAC files, single trace files will be written out. Check that you can read all files created into MULPLT. SEED, SAC and GSE have 3 character component codes. When converting component codes, SEISAN uses the files gsesei.def and sacsei.def in the DAT directory. These files may have to be changed to give you the same component codes in all formats.

Question 11.1

Compare the time it takes to read the data files into MULPLT and compare file sizes.

Exercise 11: Response in SEISAN

SEISAN can work with response files in SEISAN, GSE and SEED formats on all platforms. This exercise will demonstrate how to make a simple SEISAN response file from instrumental parameters and how to extract and use response from SEED files.

Make a SEISAN response file, section 6.31 and Appendix 3

SEISAN response files are stored in the CAL directory. In order for SEISAN to find the response file, the file name must be written following the exact SEISAN or SEED convention. The file name must reflect station and component codes. For SEISAN files the data from which date the file is valid is incorporated in file name while for SEED files it is given inside the file.

In most systems, the two most important units are the sensor and the digitizer. The simplest and most understandable way of giving response information is as follows:

Sensor: free period, damping and generator constant
Digitizer: sensitivity and anti alias filters

For modern digitizers, the anti alias filter (lowpass) is very sharp and cuts off frequencies from just below the Nyquist frequency. There is no need to correct for gain for this type of filter and only the digitizer sensitivity is used.

Make a SEISAN response file of type FAP (frequency and phase) for a seismic recorder using the following parameters:

Free period: 120 s
Damping: 0.7

Generator constant: 1500 V/m/s
Digitizer sensitivity: 1 000 000 counts/V
Amplifier gain: 0 dB

Make sure you answer yes for SEISAN response file and give some code and component.

Question 11.2

How many output files were generated and what do they contain ?
Compare the file to the one for JMI LZ (in CAL), are they identical ?

Extract a SEED response file and test

The SEED response files can be extracted from the SEED file with program rdseed (included with SEISAN). For the test data file, the command would be

```
rdseed -R -f 2005-06-13-2252-24.009.seed
```

A response file for each channel of the SEED file will be extracted in the working directory. File names are e.g.

RESP.GE.DSB.00.BHE

where RESP means response file, GE is network code, DSB is station code, 00 is location code (empty in example) and BHE component code. SEISAN will automatically find these files if they are placed in the CAL directory.

Question 11.3

How many response files were generated ?
Are the response files identical to the preloaded files in CAL ?

Remove all RESP-type response files from CAL. Try to plot event from exercise 10, what happens when looking for the response file ?

Copy in the newly generated RESP-files, are they found by MULPLT?

Exercise 12: Additional exercises in earthquake location

These exercises will demonstrate more methods related to earthquake location. For more background material on earthquake location, see epi.pdf in the INF directory.

Wadati diagram

- Make Wadati diagram for local events (#3 and 6 have sufficient readings) in June 1996, with and without using all types of phases (option 'wad' in eev).

Question 12.1

What are V_p/V_s ratios for each event ?

- Select event June 7, 13:25, 1996. Assuming that phases read are most accurate for stations less than 100km distance.

Question 12.2

Which station has the worst fit to the Wadati diagram ?

Question 12.3

Is the bad fit also reflected in the residuals of the location ?

- Check if the residuals can be improved by
 - Changing phase identification
 - Assuming a timing error (put $w=9$ on P)

Phases of local earthquakes

- Use event June 25, 1996. Select stations at a distance range where both Pn and Pg can be seen. Plot traces and look for additional phases. On stations MOL and HYA, some additional phases are seen.

Question 12.4

Can you identify the additional phases ?

- Try to read additional phases and relocate.

Question 12.5

Do they fit ?

Question 12.6

Is there a change in depth (also check with 'rmsdep') ?

Depth

- Use event of June 7, 1996. The depth has been fixed to 12 km by the F-flag in the S-file header line (just after 12.0). Remove the depth flag to let depth be free. Relocate event.

Question 12.7

What is the new depth ?

Question 12.8

Is the new depth reliable, check with eev command 'rmsdep' and the error estimates. ?

- Now use distance weighting to use only stations nearer than 110 km. Edit the S-file manually and weight out stations further away than 110 km. Relocate.

Question 12.9

What is the difference in hypocenter ?

Question 12.10

Check with 'rmsdep', how reliable is the depth, how comparable to the error estimate ?

- Play with inclusion of more phases and adding of more Pg or Pn and note the influence on the depth.

Gridsearch

- Use local event June 25, 1996 and use command 'grid' in eev. First try with a large grid (latitude 40-70, grid 1, longitude -20-20, grid 1). Plot the contours.

Question 12.11

Is there an indication of more than one minimum ?

- Now try finer and finer grids to refine the solution.

Question 12.12

Does the shape of the grid give an indication on station geometry ?

- Use distant event of June 3, try a grid of 30-80 N, grid 5 and 0-180 E, grid 5.

Question 12.13

Is the minimum well defined ? Any indication of error ?

- Weight out all stations except HYA, SUE and BLS5. This is now a very small network for global location.

Question 12.14

Can you locate the event with normal location ?

Question 12.15

Do a grid search location, any local minima ?

Question 12.16

How do the errors compare from grid search to location error (in file print.out or hyp.out).

3 component analysis for azimuth determination

The purpose of this exercise is to determine the azimuth of arrival using a 3 component station (section 6.2.9) and consequently be able to locate with one station.

Local event:

- Chose the event of June 25, 1996. Use station SUE. The azimuth can be determined using different filters.

Question 12.17

Which filter gives the most consistent result ?

Once a good correlation coefficient has been obtained, the azimuth can be saved by associating it with the phase E or any other phase. By relocating the event, you will get an azimuth residual which will give an idea of how good the azimuth observation is.

- Eliminate all readings from other stations and relocate event with only P, S and azimuth.

Question 12.18

How different is the solution from the network solution ?

Distant event:

Chose event October 4, 1994 and use station CMB.

- This event has no readings so determine azimuth, P and S and locate.

Question 12.19

Compare the solution to PDE as given in S-file, how different ?

Array analysis

This exercise will use a distant event recorded with the NORSAR array and demonstrate how to determine azimuth with the FK-method using array data (section 6.29).

- Select the event 13 September, 1999 and plot traces in multitrace mode. Select only Z-channels and use a window around the P-phase (5-10 s long) and use the FK option from menu or 'F' from keyboard. Use all defaults for all questions (just enter) and the FK-plot comes up. The direction of maximum power is shown on the plot and automatically selected. If OK, press S to keep it. The trace plot comes up again and the azimuth can now be associated with any phase like for 3 component analysis. Repeat the exercise with the S-phase.

- Pick a P-phase and an S-phase (seen most clearly if filter 0.01-0.1, key z is used), locate event.

Question 12.20

How does the location compare to the PDE solution ?

Question 12.21

How realistic are the apparent velocities values for both P and S waves ? Is the ratio between velocities realistic ?

- Test with different windows and filters and make a table of the results.

Question 12.22

Describe the sensitivity of the results as a function of parameters used.

- Use the 3-component station NRAO to determine azimuth.

Question 12.23

How do the azimuth from the array analysis compare to the 3-component determination (P-wave only), can you say anything about stability in determination depending on window and filter ?

Acknowledgments

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References

Havskov, J and L. Ottemöller (2005), editors. SEISAN: The earthquake analysis software for Windows, SOLARIS, LINUX and MACKINTOSH Version 8.1. Manual, Department of Earth Science, University of Bergen, Norway.

Appendix

List of epicenters for which waveform data is available:

1993	929	2225	48.6	D	18.066	76.451	6.8	PDE625	6.3BPDE	6.2SPDE	6.2WGS	1	
1994	616	1841	28.3	D	-15.250	-70.2941	199.5	PDE401	5.6BPDE	5.8BBRK	6.0WGS	1	
1994	10	4	1322	55.8	D	43.773	147.321	14.0	PDE672	7.3BPDE	8.1SPDE	7.9SBRK1	
1995	822	0141	6.5	L*	60.353	2.734	23.0	BER 13	0.8	2.7CBER	2.3LBER	2.2LNAO1	
1995	1120	0401	59.4	L*	60.064	5.400	5.0	BER 12	0.8	2.3CBER	2.0LBER	2.1LNAO1	
1996	6	3	1955	40.1	D	47.715	153.256	33.0	BER 15	1.1	5.3SBER	6.0BBER	5.6BPDE1
1996	6	6	0648	30.5	L*	62.636	5.064	14.5	BER 13	1.3	3.0CBER	2.9LBER	3.0LNAO1
1996	6	7	1325	29.1	L*	59.841	5.127	12.0	BER 12	1.1	2.2CBER	1.9LBER	2.0LNAO1
1996	610	1	4	47.0	D	-13.481	167.1302	200.1	PDE301	5.8BPDE	5.9SPDE	6.7WGS	1
1996	623	0117	57.8	D	51.636	159.828	33.0	BER 16	0.4	5.4SBER	5.5BBER	5.4BPDE1	
1996	625	0337	31.9	L*	61.655	3.368	17.0	BER 35	1.4	3.0CBER	3.2LBER	3.2LNAO1	
1996	7	5	0220	47.1	L*	61.264	4.797	20.0	BER 11	1.0	2.2CBER	2.0LBER	1.9LNAO1
1996	713	0556	46.9	L*	61.388	4.048	12.0	BER 9	1.0	2.1CBER	1.5LBER	1.6WBER1	
1996	718	0946	51.4	L*	60.156	2.071	15.0	BER 9	1.1	2.5CBER	1.8LBER	2.1WBER1	
1996	718	2255	6.0	D	51.438	157.737	29.9	BER 18	0.4	5.7BBER	5.5BPDE1		
1996	726	0742	11.9	L*	61.739	2.377	15.0	BER 9	0.4	2.4CBER	1.8LBER	2.0WBER1	
1996	815	2341	13.2	L*	59.883	5.745	6.0F	BER 12	0.9	2.1CBER	1.6LBER	1.6LNAO1	
1997	812	0814	24.1	L*	59.819	6.647	12.0F	BER 14	1.0	2.7CBER	2.8LBER	3.4LNAO1	
1998	0804	1859	18.2	D	-0.551	-80.411	19.0	PDE	6.2BPDE			1	
1999	913	1155	28.0	D	40.740	30.030	0.0	PDE	5.8BPDE			1	
2000	2	1	1242	20.2	L*	61.606	4.689	0.0	BER 13	1.4	2.1CBER	2.3LBER	2.3LNAO1
2000	210	0617	57.1	L*	61.771	4.515	6.0F	BER 20	1.4	2.9CBER	3.6LBER	3.3WBER1	
2000	210	1740	7.2	L*	61.845	4.410	2.5	BER 16	1.3	2.5CBER	3.0LBER	3.0LNAO1	
2003	122	2	6	34.6	D	18.770-104.104	24.0	PDE551	6.5BPDE	7.6SPDE	7.6WGS	1	
2003	122	1941	38.5	D	18.822-104.374	10.0	PDE308	5.6BPDE	5.6SPDE	6.2WHRV1			
2005	613	2244	33.0	D	-19.9	-69.1	111.0	ORF	7.9BPDE			1	