Introduction to SEISAN

and

Computer exercises in processing earthquake data

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Preface

The computer exercises in this document serve a dual purpose:

- Provide exercises linked to our book "Routine data processing in earthquake seismology" processing referred to as 'the processing book' (Havskov and Ottemöller (2010).
- Give both basic and advance training in SEISAN independent of the processing book, but with reference to the book in case the user needs more seismological background.

SEISAN has been chosen as the processing software to illustrate the problems discussed in the book since most examples in the processing book have been made using SEISAN. Several of the exercises have been used in earlier SEISAN training courses.

This SEISAN training course thus covers both a short introduction to SEISAN and how to use it as well as more advanced aspects. It assumes some knowledge of basic seismology and basic computer knowledge. During the course, the SEISAN manual, (Ottemöller et al., 2010, will be used. The goal of the basic exercises is to be able to handle the SEISAN database, pick phases, locate the events and display the results. The advanced exercises will deal with all the topics described in the processing book like fault plane solutions, determining spectral parameters, basic array processing etc.

The exercises for learning the very basic operation of SEISAN are covered in Exercise 1 and 2 of this document. Otherwise, the exercise (numbers and titles) in this document follow corresponding chapters in the processing book and most of the exercises follow the processing book. However, some exercises in this training document cover more than one chapter in the processing book and some exercises are more easily done before others. E.g. earthquake location and phase picking are closely related topics, but dealt with in different chapters in the processing book. The exercises can be made entirely independently of the processing book provided the user has some basic seismological knowledge.

These exercises should thus be useful for both new users and users with experience in seismology and earthquake processing.

In addition to this course, SEISAN also has document illustrating the steps involved when analyzing seismic records. This is more a demonstration than a course. Examples are given for local, regional and teleseismic earthquakes. This is done by giving representative screen plots together with explanatory texts that follow the figures. This document is part of the New Manual of Seismological Observatory Practice manual (http://bib.telegrafenberg.de/publizieren/vertrieb/nmsop/). All the data used are also included with the test data. In SEISAN, the document is found in INF: nmsop_is11.7_seisan.pdf.

EXERCISE 1

SEISAN basics

1.1.   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 and Unix-like systems (Solaris, Macintosh and Linux) and Windows 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.

1.2.   Installation of SEISAN and training data

If SEISAN and the training data already has been installed, skip this section.

SEISAN for PC and Sun is normally distributed on a CD or downloaded from internet. Here it is assumed that a CD is available. Normally SEISAN comes in one file, an install 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 installation instructions in the SEISAN manual. In order to get SEISAN operating with the test data available, the only parameters to set are the paths to the database and software (Unix distribution). The remaining parameters can be dealt with later.

Once the software has been installed and paths set, reboot the computer (on Unix, 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 training data is available in a separate file seisan_training_data.tar.gz. This training data contains data for basic and advanced exercises as well as all the data used in the processing book.

The training data set is not part of the distribution and must be installed separately. Installing on PC, WINZIP must be used, otherwise the ASCII files might remain in Unix format. WINZIP automatically detects that the file was written on a Unix system and converts the ASCII files to PC format. The latest version of WINZIP is not free, but older free versions also work under Windows Vista and Windows 7. WINZIP 9 has been tested with the current training data set.

The basic training data will be installed in data base TEST and the corresponding response files to CAL or local training data directories. The remaining parameters files are the ones installed with SEISAN so they are already linked to the basic test data set. To work with the basic test data, it is recommended to change the default database to 'TEST' (on PC this is done by default during installation), add line set def_base=TEST on Unix.

The training data set for advanced exercises consists of data sets from different regions and networks. These data sets will require different parameter files so each data set is collected in one separate directory under WOR. Each data set consists of S-files, waveform files, calibration files and parameter files and the intention is to work with the data in a local data base in each directory.

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

1.3.   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, back 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 1.1 Directory tree structure of SEISAN database part.

```
                              SEISMO
                                |
    ... ------------------------------------------------...
         |            |                  |              |
        REA          WAV                DAT            CAL
         |
    -------------...
    |        |
   TEST    BERGE
    |
 --------------------------...
   |      |                 |
  CAT    1995              1996
         |                  |
   ------------        ------------
   |   |     |         |   |      |
  01  02 . ..12       01  02 ... 12
```
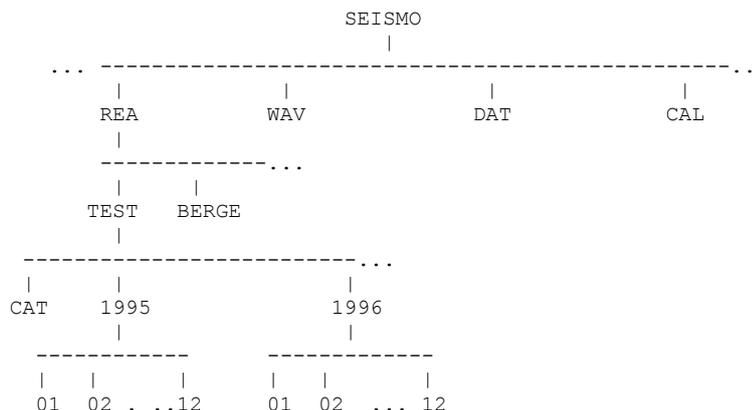
1.3.1.   REA directory and database

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 1.1). 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 1.1 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 I.
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 phase lines, one per line. The abbreviations are:

Input parameters:

```
STAT SP    : Station and component
IPHAS      : Phase with onset
W          : Phase weight, HYPO71 style
HRMM SECON : Hour, minute and seconds
CODA       : Coda length (secs)
AMPLIT PERI: Amplitude (nm) and period (sec)
AZIM VELO  : Back azimuth (deg) and apparent velocity of arrival at
station
AIN        : Angle of incidence

Output parameters:
AR         : back 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 24.1 L  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.

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 UPD400002ATE program.

1.3.2.   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 binary, SEED, MINISEED and GSE format. Other format must be converted to one of these format using SEISAN or other programs.

The S-file will, in addition to seismic parameters, have a list of waveform file names p

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.

1.3.3.   Calibration data, the CAL directory

The CAL directory contains calibration files, one for each channel of digital data. For details see SEISAN manual. For the exercises in this document, it is assumed that the calibration files are already there as installed with the training data set. Like for waveform files, calibration files can also be in the local directory, which is searched before the CAL directory.

1.3.4.   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 these exercises, that no changes are needed. The station and model file used with these training data is found in 'STATION0.HYP'

1.4.   Basic SEISAN exercises

The following exercises will give a basic introduction into the operational aspects of SEISAN. The user must be familiar with these basic operations before continuing with other exercises.

1.5.   Interactive work with the data base using EEV

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

These exercises are based on a set of training data, which are stored in the database TEST as well as in subdirectories under WOR. Before you start, check that the TEST database is set as default database (SEISAN installation section). Data availability is listed in the appendix giving location and magnitude for most events. 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 SEISAN section "Using SEISAN"..

Always work in the work directory seismo\wor, use command 'wo' to get there. This has the purpose of having all scratch files there. You can also work in any other directory of your choice, but preferably not one of the SEISAN directories.

- -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):

    o   Enter: go to next event
    o   'b' : move back one event
    o   '3':   move to event # 3
    o   '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 !!)

Note: The editor is NOTEPAD on PC and vi on Sun/Linux. To change to another editor, see SEISAN installation section.

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

Question 1.5.1

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

Question 1.5.2

How many local, regional and distant events are there ?

Question 1.5.3

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

- Use event: 7 June 1996, 13:25
- Locate event (command 'l'): The second last output line gives the location in decimal degrees and the last line the location in data base (S-file header line), which is also seen on the prompt line.

Question 1.5.4

How does the new location compare to the database location ?

- -Edit the event (command 'e') and change the P-reading for station KMY by +5 seconds. Locate again.

Question 1.5.5

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.

Question 1.5.6

How many iterations was used to locate the event ?

- 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.

Question 1.5.7

Does the new station appear on the output ?
How much did the location change ?

- Try command 'c' to copy event file to working directory.

Question 1.5.8

Explain what it does and check that it works.

Question 1.5.9

Try command 'r', explain what it does.

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.

Question 1.5.10

What is the w-command doing?
Do you find all waveform files given in S-files?

1.6. 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 and locations in S-files have been updated), this is most easily done with the SELECT command (SEISAN section "Programs and commands"), otherwise use the COLLECT command.. 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 enter. You will now get an output file select.out with selected events.
- Edit the file to see what it looks like.

Question 1.6.1

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, SEISAN section Epimap in "Programs and commands" , 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 1.6.2

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

- If on PC: Plot epicenters with w_emap
- Install w_emap from SUP, see SEISAN manual for information on w-emap.
- Plot all events using command W_emap select.out
- W-emap will also 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.

1.6.1. Mapping events with Google Earth

SEISAM can plot epicenters using both Google Earth and Google Map, here is an example of using Google Earth.

- Convert the selected events to the Google Earth input format KML, using the command GMAP. Follow instructions for advanced GMAP, in the SEISAN manual.

Question 1.6.3

How many explosions are there?

- Open output file with Google Earth.

Question 1.6.4

How many onshore events are there in Norway?

1.7. Putting new data into the database

Data can come into the database in two forms, parameter data and/or waveform data (see 1.8). 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 WOR/catalogs 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..

- Make a directory structure for all of 1996 and use database name TEST.

Question 1.7.1

How many directories were made with MAKEREA ?

- Go to the WOR/catalogs directory using command 'wo' and 'cd catalogs', 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, which splits up the input file, containing many events to single S-files in the database.

Question 1.7.2

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

Putting data into a local data base

Now data can also be put into as so-called local data base meaning all S-files are in one directory. This can be practical for test data set or smaller data sets and this is also how the additional training data sets are stored (under WOR).

- Make a directory august under WOR: From WOR, write mkdir august
- Copy the august test data file to .\WOR\august.
- Go to WOR\august: cd august
- Use split program to split file, enter for split in local directory
- Use EEV to access data: type eev without argument

Question 1.7.3

How many events are present?

1.8. 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, m_B, M_S or M_s, determine back azimuth of arrival for 3 component stations, particle motion, do spectral analysis and more. 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. . By giving a 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' , press return for no filter.
- When the plot comes up try the following:
    - Get options: Click on the 'MENU' bar. MENU or single letter commands can be used

o Zoom: Put cursor to the left, push left mouse button or space bar, move mouse to the right, repeat
o Back to original: Do above in reverse order (right - left)
o Filter: Click filter limits (e.g. '.1-1.0') 0.1 to 1.0 Hz, click on 'Plot' or push 'x' followed by 'r'
o Push 'b' , then 'r' (filtered from 5 to 10 Hz)
o Select channels: Click on 'Oth C' and select channels or click on channel name on left hand side and type 'r' or click on 'Plot' or
   Click on channel name to the left of plot to select one channel, or
   click on first channel and then last channel with mouse right click.
o Plot one channel at a time: Click 'Togle' or press 't', back to multi trace mode press 't' again
o Plot all channels for a particular station: Select channel, click AllC or press 'y'. All channels for that station is shown. Click 'AllC' or 'y' to go back.
o All commands are one key press or click on menu, to see all type '?' or click on 'Help'
o Quit by typing 'q' or click on 'Quit', you are now back to EEV

1.8.1. 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 1.8.1

Are all channels available in one waveform file plotted ?

1.8.2. Plotting continuous data from SEISAN continuous data base

SEISAN can store continuous waveform data using S-file data bases for each stream of data (see SEISAN section 'Structure of SEISAN'). The structure of the continuous data is defined in SEISAN.DEF and has been preinstalled with the training 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 JMI, NSS and RUND 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 stations 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.

1.8.3. Plotting one file from continuous data base NSS:

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

1.8.4. Plotting 24 hours, one channel

This plot will look lie a helicorder plot.

- Start EEV with command eev 20030122 NSS.
- 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. NOTE, THERE ARE 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 second event in this data set in the time range 18- 22 hours. Try to use one of the above plotting methods to find it, filtering. (e.g. 0.01 to 0.1 Hz) might be needed.

1.8.5.   Plotting continuous data from an archive

Data acquisition systems or data centers often use archives of day files in MiniSeed format, see SEISAN manual. There are two similar structures, BUD and SeisComp, and SEISAN can read both and will automatically detect which one is present. TEST data is available for 6 stations and one day.

- Go to WOR directory since archive is installed under WOR. It is in subdirectory archive.
- Start MULPLT.
- Select option arc since this is an archive.
- Choose start time and time window 20110129 and 60 respectively. Choose multitrace plot on screen (0 or 1). This will plot 60 minutes of data from all 6 stations.
- Select all channels
- 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.

1.8.6.   Plotting event data in an archive from EEV

SEISAN can also plot a data section from an archive directly from EEV by giving a reference to the archive channel in the S-file. In this way there is no need for individual waveform files linked to the S-file. An example is given for the data used in the archive above.

- Start EEV for January 2011, there is only one event.

- Use command 'w' to check waveform data and the reference to the archive will be shown, stored in type 6 lines.

- Use command 'po' to plot the data.

1.8.7. Plotting data from a large SEED or MiniSEED file

It is common practice to record data in MiniSEED day files, usually of one channel. It is also common to extract large SEED files from data centers (e.g. one month of data). SEISAN cannot plot the whole file, but can plot sections of the file and interactively extract the plotted section.

- Go to directory WOR/new, there is the file KONO.BHZ_10.IU.2008.236 which is a day file for August 23, 2008 for station KONO. Sample rate is 40.
- Start MULPLT and use option conts, give above file name (or number if DIRF has been used) as input. The start time and length of file now comes up. If starting at beginning of file, just enter and then give time window to look at, e.g. 60 minutes. Then proceed to plot data using plot option 0 and no filter.
- Plot whole file in e.g. time windows of 60 minutes and check for events. If no events, try to repeat the plot using either filter 5 − 10 Hz for local events or 0.01-0.1 Hz for distant events.
- If an event is found, then the time window seen on the screen can be extracted by pressing 'Out' on menu. Try that for an event. The name of the extracted event file is given in the text window (DOS window for MULPLT on PC).

Question 1.8.2

What is the start time and duration of the day file ?
Give times of local and distant events.
What is the size of the day file and the extracted event file in Mbytes ?

1.8.8. Putting a new digital recorded event into the database

The new event file 1996-08-15-2340-35S.TEST_009 is located in directory new under WOR

- Move to new directory ('cd new' from WOR) and make list of files 'dirf 199*'
- Start MULPLT, when asked about filename, answer '?' to get the event list, select the event from August 1996 (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), 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.

Question 1.8.3

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

1.9. Using SeisanExplorer

The GUI interface SeisanExplorer, hereafter called SE, is intended to replace EEV and expand the graphical options in SEISAN. The most basic EEV commands have been implemented with addition of some commands not present in EEV.

SE loads S-files from a SEISAN database. Only the S-files that falls 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.

1.9.1. Open TEST data base and read in all events

- Start SE by writing se on command line or use icon SE.
- Goto file/open/default data base.
- Give time interval from 1990.
- Click on Event List

All events are now displayed with basic information.

1.9.2. Navigate in TEST data base

- Click on an event to make that the active event.
- Go to an event by date by start writing a date anywhere, start with year.

1.9.3. Actions on a single event

- Right click to see options.
- Edit event by pressing e.
- Plot an event with MULPLT by pressing p.
- Locate an event by pressing l.

- Map an event by). pressing g (Google Map, requires Internet access).

When another program is running, like MULPLT, SE is locked and will only be active when the program terminates.

1.9.4.   Actions on with multiple events

All events on display can be selected with ctrl a. Several events can also be selected manually by clicking on them. Events can be ordered according to e.g. magnitude by double clicking on respective column header, e.g. on M for magnitude.

- Select 5 events by using ctl and click. The 5 events will now be highlighted.
- Plot epicenters with command g for Google Map.
- Plot epicenters with G for Google Earth.). To see the plot, go to WOR and click on se-gmap.
- Select all events, click functions/Events per year. This plots a yearly statistics.
- Search in displayed events: Select Event List/Set Filter. There are now several possibilities for selection e.g. a lat-long window and/or a magnitude range (like in SELECT). Edit).Include expression and use buttons to make a selection statement: $Lat > 50 AND $Lon > 0 AND $Lon < 40. Then Ok and Ok. Now only the selected event will be seen on the screen and they can be plotted with e.g. g.

EXERCISE 2

Signal processing and phase reading

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. Phases can be picked in single or multi trace mode, to toggle between the two modes in MULPLT, press 't'.

2.1.   Phase reading and location of a local event

- Start EEV for August 1996.
- Move to event on August 15 at time 23:40 using the 'd15' command, this event was registered in 1.8.8.
- Plot event with 'p' or 'po' for no questions.

Question 2.1.1

Are there phases picked already for this event ?

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

Question 2.1.2

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. In single trace mode this 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.

Question 2.1.3

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 2.1.4

How many phase lines are present in S-file ?

- Locate the event with command 'l' from EEV
.

Question 2.1.5

Does the location and magnitude look 'reasonable' (compare with Appendix or the location in the S-file), how big is the RMS and how large is the largest residual ?

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

Question 2.1.6

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

- In EEV, use command update.

Question 2.1.7

Explain what happens, what changes do you see in the S-file?

2.2.   Phase reading and location of a 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 2.2.1

How does the location compare to the PDE location?

2.2.1.   Automatic mapping the event in Google Earth after location.

- Open the file DAT/gmap-automatic.kml with Google Earth (if your working directory is not C:/seismo/WOR you must change the path in gmap-automatic.kml). You now get up the plot.).

Question 2.2.2

What is the black line?

- Locate event number 2.

Question 2.2.3

What happens in Google Earth? What is the station colors showing?

2.2.2.   Map epicenter in a browser with Google Maps

- In EEV use the command GMAP, open the gmap.html file in a browser. Under Windows this can be done by just typing gmap.html at prompt line.

Question 2.2.4

 Is the event offshore?

2.3. Theoretical travel times

In all SEISAN operations involving earthquake location, theoretical travel times are calculated. For local earthquakes, a flat earth with a model given in STATION0.HYP is used while the global travel times are calculated using the IASP91 model. The global times can be calculated using program TTIM.

2.3.1. Compare local travel times to IASP91 travel times

- Select local event 1996 0606 06:48, locate event (l) and observe the travel time for station HFS (column t-cal on location screen). Calculate the corresponding travel time with TTIM, remember that one degree is 111.2 km. Compare the travel times.

Question 2.3.1

Which model gives the fastest travel time and what does this tell you about the local Norwegian model compared to the global model?

2.3.2. Reading global phases using IASP91 tables

The IASPEI91 travel time tables can be used to help reading phases . 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 2.3.2

Which phases could be identified?

- 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.

Question 2.3.3

What can you say about the depth (compare to PDE)?

EXERCISE 3

Response files and seismic formats

3.1.   **Response in SEISAN**

SEISAN can work with response files in SEISAN, GSE, SAC 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

In SEISAN, response files are normally stored in the CAL directory, however in SEISAN versions higher than 8.2, the response files can also be stored in the working 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 date from which the file is valid is incorporated in the 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

- Make a SEISAN response file of type FAP (frequency and phase) using the following parameters:
- Free period: 120 s
- Damping: 0.7
- Generator constant: 1500 V/m/s
- Digitizer sensitivity: 1 000 000 counts/V

Most modern digitizers use digital anti alias filters when down-sampling the data. These filters are very sharp and correction for their amplitude is not done. However, it is important to know in case of Finite Impulse Response (FIR) filters whether they are linear phase (most common) or minimum phase. The linear phase version is acausal and can move energy ahead of the real signal, this can be corrected for (not in SEISAN). So,

ideally this information should be included in the response files (possible in GSE and SEED response file).

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

Question 3.1.1

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 ?

Make a GSE format response file

SEISAN can use GSE response files directly and they can be created with the RESP program. Run the RESP program as above, but select 'GSE PAZ' as output format.

Question 3.1.2

How many poles and zeros are used to describe the instrument response?
Use plotting program PRESP to compare the SEISAN and SEED response files just created.

3.2.   Extract a SEED response file and test

The SEED response files can be extracted from the SEED file with program rdseed (included with SEISAN). The SEED file 2005-06-13-2252-24.009.seed in WOR/new is used for this exercise. On Windows, this file is corrupt since WinZip wrongly identifies SEED files as ASCII files so a correct file must be put in place first. Unzip the file seed.zip in WOR/new to overwrite 2005-06-13-2252-24.009.seed.

For the test data file, the command to extract a response file is

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

NOTE: The Windows version of rdseed (unknown origin) does not seem to work some times.

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.BHE

where RESP means response file, GE is location code, DSB is station code and BHE component code. SEISAN will automatically find these files if they are placed in the CAL directory or the working directory.

- Go to WOR/new directory
- Make SEED response files with command rdseed -R -f 2005-06-13-2252-24.009.seed

Question 3.2.1

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 2005 0613 22:52 from WOR directory (copy waveform file to WOR).

- Plot the event from WOR/new directory.

Question 3.2.2

What happens when looking for the response file in WOR and in WOR/new ?

- Copy the newly generated RESP-files to CAL

Question 3.2.3

Are the response files found by MULPLT when plotting from WAV?

3.3.   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 WOR/new 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. On Windows, the SEED file is corrupt since WinZip wrongly identifies SEED files as ASCII files so a correct file must be put in place first. Unzip the file seed.zip in WOR/new to overwrite 2005-06-13-2252-24.009.seed. The difference between SEED and MiniSEED files 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.
- Use MULPLT to plot the two files and register one of them in the TEST database
- From EEV start MULPLT to pick P phases and amplitudes.

- In singe trace mode, also plot the response by clicking on the 'Resp' box (the SEED type response files have already been put into 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.
- 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 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 file sacsei.def or gseisei.def in the DAT directory. These files may have to be changed to give you the same component codes in all formats. Compare the time it takes to read the data files and check file sizes.

Question 3.3.1

Which format plots fastest?

EXERCISE 4

Signal processing exercises

Signal processing is dealt with in several sections of this exercise document. In this exercise we will specifically look at filtering, response correction and particle motion. Spectral analysis is dealt with in Exercise 8.

4.1.   Filtering and phase reading

This exercise will demonstrate some of the effect on phase reading when using a filter. Note that SEISAN can filter one way pressing the filter key once (gives a phase shift) or filter both ways pressing the filter key twice (no phase shift). When selecting a filter from the menu, only one way filtering can be used. In general it is desirable to read phases on unfiltered traces, which might require zooming, however in some cases the arrival is not seen without filtering.

If a filter upper limit is higher than or equal to half the sampling rate, no filtering can be made and an error message is displayed.

- Select distant event 1996 0623 01:28 and plot signals in multi trace mode.
- Select KONO BVZ and 'L_Z' and plot the two traces in a one minute window around the P. There is already a P picked on the BVZ channel.
- Use the following filters: 1-5 Hz one and two ways (v or vv), 0.1-1.0 Hz (x) and 0.01.0.1 (z) and observe the waveform relative to the "correct" phase pick.

Question 4.1.1

Can the P-phase be read on any or both of the original traces ?
Is the original phase pick correct ?
What happens with the P-phase signal when using the filter both ways as opposed to one way ?
Which filter would be most correct to use on BVZ and L Z channels respectively ?

- Select local event 2000 0210 06:17 and plot channel KONO B Z.
- Determine the P-arrival without filter (if possible) and with different filters.

Question 4.1.2

Is it possible to read P-Phase without filter ?
Which filter gives the most reliable P-time and why ?

4.2.   Particle motion

Particle motion will give an indication of the actual ground motion in different directions.

- Select event 1996 0625 03:37 and plot the three components for station SUE.
- Zoom in a 1 sec window around the P-phase and make the particle motion plot with option PartM on menu and observe the particle motion plots.
- Estimate the back azimuth of arrival for the EW vs NS plot.
- Repeat the test with a shorter window around P.

Question 4.2.1

Do the plots show a clear direction of particle motion ?
Can the back azimuth be correctly estimated, compare to results of exercise in section 5.8 ?
How do the results from the short and long windows compare ?

- Select distant event 2001 0113.
- Repeat the previous exercise using the KONO LP channels and the P-phase.

4.3.   Signal rotation

Signal rotation means rotating the N and E components into the radial (R) and transverse (T) directions and the back azimuth will be displayed on the trace.

- Select event 1993 0924 22:25 and plot BH-traces for station LSA. Clear P and S-waves are seen and not so clear surface waves.
- Rotate traces pressing Rotat on menu followed by Plot.
- Filter the rotated traces with 0.01-0.1 Hz filter (z).

Question 4.3.1

How does the P-phases compare in amplitude on original and rotated traces ? How is the difference explained by rotation. Same for S-phases (if in doubt where S is, use option IASP) ?
Are the above features enhanced on the filtered traces ?
rseen (use filter)? What is the time difference between Love and Raleigh waves?

4.4.   General correction of a signal for response

In SEISAN it is possible to remove the effect of the instrument and generate a seismogram showing displacement in nm. This is done in picking mode in MULPLT.

The requirement is that the response file is present in the system. Make sure this operation is not done on a clipped signal.

Where is the response file and how is it made ? Print an example of the text response file.

- Chose the local earthquake (June 25 3:36, 1996) and generate a true ground motion signal (option Groun) for station FOO S Z. Since the instrument is short period, you cannot correct for the response down to very low frequencies and a filter must be chosen at the same time as the instrument removal is done.

- Make displacement, velocity and acceleration signals without a filter.

Question 4.4.1

How does the signal look, all reasonable ? If not, why ?

- Use a filter 0.1 to 10 Hz and re-make all 3 signals.

Question 4.4.2

How does the signal compare to the above without filter ?

Question 4.4.3

How does the frequency content compare in the 3 types of signals.

EXERCISE 5

Earthquake location

Some basic exercises are done in sections 2.1 and 2.2 in connection with phase picking. In this exercise more topics related to earthquake location are covered. Chapter 5 in the processing book gives the background.

5.1.   Wadati diagram

- Make Wadati diagrams for local events in June 1996, with and without using all types of phases (option 'wad' in EEV).

Question 5.1.1

What are Vp/Vs ratios for each event ?

- Select event June 7, 13:25, 1996.
- Do a Wadati diagram.

Question 5.1.2

Which station has the worst fit to the Wadati diagram ?
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, done in S-file under W).

5.2.   Travel time plot

Use the same event as in the previous exercise. From EEV use option 'ttplot' to generate travel time plot. The program displays P and S travel times as a function of distance and can be used to identify picks that don't fit. The theoretical travel times are indicated on the plot .

Question 5.2.1

Check travel times for the bad stations observed in the Wadati diagram.

5.3.   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 5.3.1

Can you identify the additional phases ?

- Try to read additional phases and relocate.

Question 5.3.2

Do they fit ?

Question 5.3.3

Is there a change in depth when using additional pahses (also check with 'rmsdep') ?

5.4.   Error estimates of a local earthquake

The hypocenter location is given with error estimates which depends on the number of stations used, their configuration, the residuals and a priori estimates of the reading errors (set up in STATION0.HYP, RESET TEST parameters 85 and 91. Essentially, if few stations are available, the a priori estimate of arrival time errors becomes critical. In this exercise, testing of the errors will be made using these parameters.

- Select (EEV) event 2006 1220 03:28. Inspect the S-file and note down the errors (E-line). Also check the STATION0.HYP file in DAT and note down the a priori estimate of the reading error.
- Change the a priori reading error in STATION0.HYP to 1.0 and relocate. Check the new error estimate in the listing on the screen or file hyp.out.
- After location, change STATION0.HYP back to what is was so other exercises are not affected (alternatively copy STATION0.HYP to current directory, change it there and delete when finished with exercise. Remember, the location program always checks in local directory first for a STATION0.HYP file)

Question 5.4.1

What was the original error estimate in latitude, longitude and depth ?
What was the original a priori estimate of reading error ?
How much did the error estimate change when changing the a priori error estimate ?
Can you explain the change ?

- Delete or weight out the readings for all stations except STOK, STOK1 and STOK2. Redo the above two tests.
- Plot the signals for stations STOK, STOK1 and STOK2 and estimate the reading accuracy.
- Change the a priori error estimate to the actual reading accuracy and relocate.
- Estimate the depth with RMSDEP (see also section 5.5)

Question 5.4.2

What is the estimated reading accuracy ?
Does the reading accuracy correspond to the default a priori estimate of reading accuracy ?
What is the error estimate for the two test value reading errors as well as the actual reading accuracy value ?
Can you explain the difference in error estimates of the hypocenter for the 3 cases ?
Considering the small size of the network, the residuals, the result using RMSDEP, which error estimate, if any, do you consider the most realistic ?

5.5.   Hypocentral depth, local event

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 5.5.1

What is the new depth ?

Question 5.5.2

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.

- This can be done in 3 ways:
    o Edit the S-file manually and weight out stations further away than 110 km.
    o Edit the STATION0.HYP file and set xnear and xfar to 110 km.
    o Set xnear and xfar for current event only using EEV command inputx. For this to work RESET TEST(107) must be set to 1.0 in STATION0.HYP.
- Relocate.

Question 5.5.3

What is the difference in hypocenter ?

- Check the depth with 'rmsdep'.

Question 5.5.4

How reliable is the depth, how comparable to the error estimate (E-line in S-file. Also see the hyp.out file) ?

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

5.6.   Gridsearch

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

Question 5.6.1

Is there an indication of more than one minimum ?

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

Question 5.6.2

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

- Use distant event of June 3, 1996 and try a step of 30-80 N, step 5 and 0-180 E, step 5.

Question 5.6.3

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.
- Locate event normally
- Locate event with grid search

Question 5.6.4

Can you locate the event with normal location ?
Can you locate the event with grid search ?

Question 5.6.5

Is there an indication of more than one minimum when using grid search ?

Question 5.6.6

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

5.7.   Using different models

SEISAN can use individual models for each event as indicated in the S-file in column 21 in the header line. Normally this field is blank indicating that the STATION0.HYP file is used. However, using e.g. the character x, file STATIONx.HYP will be used (note that on Linux, upper and lower case is different but not on Windows). It is also possible to locate local events with the global model.

- Select event July 13, 1996.
- Change the model indicator to N using EEV command m.
- Locate the event. The model in STATIONN.HYP has a changed velocity in the first layer compared to STATION0.HYP

Question 5.7.1

How much did the location change?

- Change to model to the global model by changing distance indicator L to D using EEV command r. Change model indictor back to blank with command m.
- Locate event.

Question 5.7.2

How much did the location change?

5.8.   Three component analysis for back azimuth determination and one station location

The purpose of this exercise is to determine the back azimuth using a 3 component station and consequently be able to locate with one station. Remember that the solution

obtained is likely not to be reliable and the procedure has to be used with care in routine practice.

5.8.1. Local event

- Chose the event of June 25, 1996. Use station SUE. The back azimuth can be determined using different filters.
- Use option Azim from menu in single trace mode.

Question 5.8.1

Which filter gives the most consistent result ?

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

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

Question 5.8.2

How different is the solution from the network solution ?

5.8.2. Distant event

- Chose event October 4, 1994 and use station CMB.
- This event has no readings so determine back azimuth, P and S and locate.

Question 5.8.3

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

5.9. Global location with one station, 3 stations and depth

A global location using several stations was done in section 2.2. In this exercise, a location will be done with one station and back azimuth as well as with a few stations. Also depth will be determined with the help of the pP phase. See also section 7.4, where the same event is used for location with all stations available in a waveform file.

- Plot event 2007 1116 03:13 from EEV.
- Pick P and S on station TUC
- Use option Azim from menu in single trace mode and determine back azimuth for the P-wave. Use a 3 s window around the P-phase. The correlation should be better than 0.8.. Save the back azimuth on phase E (push e).
- Locate the event.

Question 5.9.1

How much does the epicenter deviate from the PDE location given in S-file header ?
What is the depth ? Can it be considered reliable?

- On station TUC, also read the pP –phase. This is the first larger phase after P. The pP-phase is not in the default phase list so one of two options can be used to enter pP:
  - Read another phase like eP, E etc and manually edit the S-file to give the phase the name pP
  - Use IASP option to show where the pP is expected to be. To read it, place cursor at phase start time and press y.
- Locate the event.

Question 5.9.2

How accurate is the depth now compared to the PDE solution ?
Did the hypocenter improve significantly ?

- Add P-readings of more stations, one at a time until the epicenter is within 100 km of the PDE solution.

Question 5.9.3

How many station are needed to get a location within 100 km of the PDE solution ?

5.10.   Determine V_p/V_s ratio for a region

In exercise 5.1, the Wadati diagram was used to determine V_p/V_s for a single event in order to check the readings. For regions, it is important to know the velocity ratio to get correct hypocenter locations. This exercise will demonstrate how a catalog of readings can be used to determine a regional V_p/V_s with program WADATI. The phases must be of the same type to be used (like Pg and Sg) and all phases are used irrespective of weight.

- Select all events in area 59-62˚ N and 0-12˚ E using file august.96 in directory WOR/catalogs.

- Start program WADATI and
  - Use select.out as input file.
  - Option 1 for Wadati calculation.
  - Set minimum number of stations to 4.
  - Maximum RMS to 0.5.
  - Minimum correlation coefficient of the linear fit S-P time vs P-time to 0.95.

Question 5.10.1

How many of the event fulfilled the selection criteria for calculating V_p/V_s ?
Is the average V_p/V_s 'reasonable' compared the theoretical value of 1.73 ?

EXERCISE 6

Magnitudes

All currently used magnitudes can be determined with SEISAN. Earlier, coda magnitude was calculated, here we shall calculate local magnitude M_L, body wave magnitude m_b and m_B and surface wave magnitudes M_s and M_S. Moment magnitude exercises are covered in Exercise 8. 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 SEISAN under the section for the hypocenter program HYP. General information about magnitudes is found in the processing book Chapter 6.

6.1.   Local magnitude M_L

In order to determine M_L, 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 manually or automatically read and assigned the phase name IAML.

- Select the event 1996 0705, which has a local magnitude of 2.0, 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 for all stations and exit plot.
- Make sure a response is available before reading amplitude (no message "No response info**").

Question 6.1.1

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.

Is response information available for each station ?
How well do the M_L values for the different stations agree?

6.2. Body wave magnitude m_b

m_b 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 M_L, SEISAN simulates the old SP response.

- Select event June 3, 1996 at 19:55, plot in single trace mode.
- Use SP or BB stations (not ASK or EGD).
- 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 IAmb. Note, some stations might not have response information. Also do not use stations ASK and EGD since they have inadequate low frequency resolution and the signals will blow up.
- Try using both manual (a) and automatic (A) amplitude picking.
- Locate event, the magnitudes will appear for each station.

Question 6.2.1

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

6.3. Broad band body wave magnitude m_B

m_B is determined using the maximum velocity on broad band records flat for velocity in the period range 0.2 – 30 s. Thus most broad band records can be used directly without any correction for instrument shape. However, SEISAN always tries to make a velocity record in the 0.2 – 30 s range irrespective of the instrument type and in some cases with large events, m_B can also be determined using SP records as the following example will show.

- Select event February 22, 2006 at 22:19 and plot the 3 stations in multi trace mode.
- Zoom around the P and notice the clear difference in frequency content between the SP and broad band station.
- Click on 'mb' button and select a window around the P-phase. Notice how the signals now look similar and therefore also will produce similar mb.
- Click on 'mB' button and select a window around the P-phase of about 2 min. length. Notice how the signals now look similar and therefore also will produce similar m_B. The amplitudes will be stored in nm/s and the phase name is IVmB_BB.

- Read amplitudes for m_b and m_B for the 3 stations.
- Locate event, the magnitudes will appear for each station.

Notice that a magnitude might not be calculated due to period limitations, see SEISAN manual. The most important is that the period must be less than 3 s for m_B to be calculated.

Question 6.3.1

How do the m_b and m_B magnitude compare to each other and to the reported values of m_b M_s and M_w ?

6.4.   Surface wave magnitude M_s

M_s is supposed to be read near the 20 sec period on a WWSSN seismogram. In SEISAN, this is simulated by making the instrument correction and then using the WWSSN LP response.

- Select event 1996 0603 19:55, plot stations KBS and KONO (L_Z) 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 displacement amplitude in nm will be stored with phase name IAMs_20.

Question 6.4.1

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

- Locate the event.

Question 6.4.2

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

6.5.   Broad band surface magnitude M_S

The M_S magnitude is determined from the velocity traces of broad band records broad flat for velocity in the period range $3 - 60$ s. Thus most broad band records can be used directly without any correction for instrument shape. However, SEISAN always tries to make a velocity record in the $3 - 60$ s range irrespective of the instrument type and in

some cases with large events, M_S can also be determined using records with a more narrow bandpass. M_S will up to magnitude 7.5 to 8.0 give similar magnitudes than M_s, however it is easier to use since there is not the period restriction to the 18-22 s band.

- Select event February 22, 2006 at 22:19 and plot KONO B0 Z, single trace mode.
- Click on 'mS' button and select a window around the surface waves.
- Read amplitudes for M_S. The velocity amplitude is stored in nm/s under the phase name IVMs_BB.
- Locate the event to calculate the magnitude.

Note: Phase names AML, AMB and AMS were IASPEI approved names as of July 2003 and used in SEISAN until version 8.3, where the current IASPEI names are used. SEISAN is backwards compatible and will use the old names.

6.6. Automatic amplitude and coda length picking, one trace

Coda length and amplitude can be picked semi-automatically on 'well behaved' traces. For coda length, C is pressed instead of c and the end of the coda is determined based on parameters given in MULPLT.DEF. Automatic amplitude picks are done by pressing A instead of a, and a hardwired routine is used to find the maximum amplitude. In both cases, the picks are shown on the screen so the user can verify if the automatic values should be used.

- Select a few stations used in exercises 6.1 to 6.4 and note down the manual pick values of coda lengths and amplitudes.
- Pick the same values automatically.

Question 6.6.1

Is there a significant difference between manual and automatic pickings ?
In which ways are the differences dependent on signal quality ?

6.7. Automatic amplitude for M_L and spectral M_w for one event

The AUTOMAG program, started with command am from EEV, will determine maximum WA amplitudes and do automatic spectral analysis for all Z-channels with readings in the S-file provided the signal to noise ratio is acceptable, that the data is present and that a calibration file is given, see SEISAN manual for more details. The results are written to the S-files and on next update, averages are calculated. Once the

automatic determination is finished, the results (spectra and location of automatic amplitude) can be displayed graphically with command ps and the user can delete the results which do not look correct. The corresponding lines in the S-file will be deleted.

- Select events June 25, 3:37, 1996 and use command am.
- Use command ps to plot the results.
- Locate the event.

Question 6.7.1

How many traces have automatic Ml and how many have automatic Mw?
Does some of the spectra or amplitude picks look wrong, or is there an indication in the magnitude values that they are wrong?
Is the automatically determined Ml different from the original manually determined Ml?

6.8. Compare m_b and M_s

It is often useful to compare magnitudes of different kinds or from different agencies to either spot errors or make relations between different magnitudes. Program MAG is here used. The data to test is one year of data from ISC.

- Go to directory ./WOR/catalogs.
- Start program MAG, the input should be:
  - bISC sISC   To compare m_b and M_s from ISC
  - Input file is 2002.isc
  - Answer yes to plot data

Question 6.8.1

How many events have both ISC magnitudes?
What is the average m_b and M_s, as expected ?

EXERCISE 7

Focal mechanism

In SEISAN, the fault plane solution for an event can be determined with first motions and/or amplitudes. Polarities are picked by placing the cursor at the top or bottom of the seismogram when the phase is picked. There are 3 basic programs using polarities: FOCMEC, FPFIT and HASH while PINV might be a help to get an idea of the solution. There are two programs which can use amplitudes: FOCMEC and HASH.

An additional fault plane solution exercise is given in section 12.4 using data extracted from ISC.

7.1.   Focal mechanism using polarities only

- 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.
- Choose option 'f' (program FOCMEC) and proceed with determining the fault plane solution.

Question 7.1.1

How well is the solution constrained ?

- For the selected event, determine fault plane solution with FPFIT using command fp, with HASH using command fh and PINV using command 'fi' in EEV. Notice that each solution is stored as an addition line giving the program name so all solutions can be plotted together with solution selected using FOCMEC. All solutions can be plotted together with command po in EEV.

Question 7.1.2

How do the solutions compare ?

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

Many focal mechanism solutions in a CAT file can be plotted with W_EMAP, EPIMAP or FOC.

This event has a bit unclear polarities so different solutions might be obtained. A more constrained event is a deep Argentinean event located in WOR/Argentina. The event has already been processed so it is recommended to delete all phase readings to start a new processing:

- Edit file and delete all phases

- Select only the Z-channels

- Read all P-phases with polarity

- A few S-phases should be read to stabilize the location

- Do processing as above

7.2.   Focal mechanism using polarities and amplitudes

Using FOCMEC it is possible to also use amplitude ratios, which can help to constrain the solution when few polarities are available. As the use of amplitudes ratios is not without problems, it should ideally only be used to select from few solutions that are obtained using polarity data. If a solution is very poorly constrained, amplitude ratios should be used with caution to constrain the solution. Since the amplitude rations are used, there is no need to correct for the instrument response provided all 3 components have the same response. When picking amplitudes, SEISAN therefore will ask the user to confirm that it is indeed desired to store the uncorrected amplitudes. In order to get a reliable focal mechanism, at least one polarity must be read, more than one is desirable. *Make sure not to use clipped data.*

- Select event 12 August 1997 and plot all traces. Rotate the seismogram with command Rotat in menu.
- Pick polarities on most reliable stations and attempt a solution based on polarities only.
- Use FOCMEC to search for possible solutions.
- Read Pg amplitudes on vertical components for station BLS5 and FOO without applying instrument correction. Make sure to select AMPG for amplitude type. Answer yes that you want to save the data without instrument correction.
- Read Sg amplitudes on the vertical and transverse components for stations BLS5 and ODD1 without applying instrument correction. Make sure to select AMSG for amplitude type.
- Use FOCMEC again, now with the amplitude ratios. Enter number for maximum error on the amplitude ratio data (use default initially). A grid of 5 degrees is suggested. There should be 6 amplitude ratios. Try to allow for 0 ratio errors and gradually increase polarity errors to get a solution. Use default

amplitude error and 2 degree grid. If too many solutions, add more amplitude data. Also see the output in focmec.lst.
- Use HASH to make a solution.

Question 7.2.1

Is it possible to get a solution with polarity data only ?
Are you able to better constrain the solution using the amplitude ratios?
How much data is needed to get a reliable solution and which error limits were used ?
How does FOCMEC and HASH compare?

7.3. Focal mechanism using ISC data

Many stations report polarities to the ISC so here is another source of data for making fault plane solutions. Here the catalog data already available will be used. In exercise 12.4, data selected over internet will be used.

- Go to WOR/catalogs
- Use program SELECT so select out events with more polarities than 40 from file 2000-0101.isc: INPUT 2000-0101.isc, Start time: Enter, End time: Enter, Option 15: 40. Now one event is selected.
- Put event into a local data base using SPLIT, input file is select.out (see section 1.7).
- Use EEV to interact with event (EEV with no arguments) Fix the location and depth to the ISC given values (FF in column 44-45) on S-file header line.
- Locates to see that most stations are there.
- Make the fault plane solution with 'f', 'fp', 'fh' and 'fi'

Question 7.3.1

The event might have several solutions using FOCMEC, how do they compare ?
How is the solution using the other programs compared to the selected from FOCMEC ?

Are any of the solutions comparable to the solution given in the S-file (Harvard solution, compare numbers or enter Harvard solution as an F-fline with 'O' in column 79).

7.4. Focal mechanism using global waveform data and polarities and amplitudes

The purpose of this exercise is to make a fault plane solution using raw waveform data from the global network, which is easily available from an international data center. In

this case the data has been collected using Wilber at IRIS DMC
(http://www.iris.edu/cgi-bin/wilberII_page1.pl)

- Plot event 2007 1116 03:13 from EEV.
- Pick P and polarity on as many stations as possible (remember only vertical
  channels). For some stations, a lot of zooming is needed to clearly see the
  polarity and the first onset can be small compared to the following amplitudes.
  It is important to pick the absolute first onset irrespective of amplitude. See e.g.
  station WCI, which should have compression.
- Locate event.

Question 7.4.1

Is your location acceptable compared to the PDE solution in both epicenter and depth ?
How large is the deviation ?

- Using an acceptable location (either your own or PDE by fixing the hypocenter
  (FF in columns 44-45 on header line), make the fault plane solution. Assume
  no polarity errors and use a 10˚ grid for searching. If no solution, try 5˚. If still
  no solution, try with one polarity error. Save the best solution in the S-file.
- Test with smaller and smaller grid size to evaluate the stability of the solution.

Question 7.4.2

Describe the condition for getting a solution.
How many solution are available using a 5˚ grid and no polarity errors ? 5˚ grid and 1
polarity error ? Are the solutions similar ?
Does a small grid size give solution completely different from the 'good one' ?
What kind of fault does the solution represent ? Is that an expected fault for this
subduction zone ?

- The Centroid Moment Tensor (CMT) solution is strike=177˚,   dip=29˚, and
  rake=-44˚. Compare the solution to your solution by plotting the two together.
  This is done by adding a type-F line to the S-file and putting an O in column
  79.

Question 7.4.3

How close are the CMT solution and your solution, acceptable ?

The solution can now be further improved by using amplitudes.

- Read amplitudes for P and S from stations QSPA, vertical channel only. Make
  sure maximum P and S is used. If in doubt where S is found, use option IASP
  to calculate theoretical times. Use phase AMPN.

- Make a new fault plane solution, allow zero polarity errors, zero amplitude errors and 0.2 or 0.3 error in amplitude ratio. If this does not work, try other combinations.

Question 7.4.4

Is it possible to improve the solution compared to the solution with only polarities ?

7.5. Composite fault plane solution

When little data is available for one event, several events in a small area might be used together to make a composite fault plane solutions. In this example 6 small events recorded with a three station network will be used.

- Select the events from the data base (program SELECT) using the criteria: Station STOK must be present and the events must be local. 6 events should be selected.
- Pick the polarities on stations STOK, STOK1 and STOK2 for all events by using commend 'eev index.out' to save data to data base.
- Locate all events using HYP, input file is index.out
- Do the composite fault plane solution with FOCMEC, command is 'focmec'. The selected solution is saved in fps.out.
- Do the composite solution using the other programs. The output will be added to existing solutions in fps.out.
- The solutions can be plotted together using program FOC and using fps.out as input file.

Question 7.5.1

How well is the solution constrained by FOCMEC ? Any estimate of the error ?
How well do the solution compare using FOCMEC and the other programs ?

7.6. Moment tensor inversion

SEISAN has, from version 9.1, an integrated moment tensor inversion program based on the Dreger software (Dreger, 2003). It can be used at regional distances for earthquakes larger than about 4.0 although smaller events also can be used if the phases are very clear. For more details, see the SEISAN manual. The manual also has a cookbook of steps to follow to do moment tensor inversion which must be followed for this exercise. See also Dreger tutorial, mt_dreger.pdf in INF.

Example 1 Shallow California earthquake

The test data set has the test data given by Dreger in his software example, The model used by Dreger is also the model put into STATIONc.HYP which is located in DAT.

- Select the test-event: eev 19980812
- Make sure all stations has readings, fix the depth to 8 km and fix the hypocenter to the given hypocenter. Read polarities, used for check later.
- Follow the steps in the cookbook
- If a good solution, save it to the S-file
- Plot fault plane solution and compare to the Dreger solution or solution given in S-file.

Question 7.6.1

How close is the solution to the correct solution ?

Do all the polarities fit ?

- Edit the S-file and take out stations or/and components and rerun just the inversion part (command mti). Take out data until the solution is no longer near the correct solution.

Question 7.6.2

How much data (stations and components) are needed to get a reasonable solution ?

Example 2 Deep Argentinean earthquake

This event has many stations and the data is from a field experiment (courtesy INPRES and University of San Juan). The data is located in WOR/Argentina together with S-file, calibration files and station file. The parameters for modeling 5 stations are already put into the file so it is just a question of selecting the data and generating the Greens function file. Since this is a deep event, it is the S-phases which are modeled. The S-file has readings with polarities from most station as well as the CMT solution.

- Plot event and select stations CHIL, CLAR, LEON, PATO and USPA, use the time window which comes up.
- Rotate data
- Plot instrument corrected for velocity with filter 0.02 - 0.05 Hz.
- Write out file mulplt.wav by pressing OutW, back to EEV
- Generate Green's functions, command mtg
- Run inversion by command mti, save solution to S-file
- Do a fault plane solution using FPFIT, command fp
- Compare all solutions with command fo

Question 7.6.3

How do the solutions compare, is the magnitude comparable to the CMT magnitude ?

The depth from the location used might not be the optimal depth so a test can be made for finding the best depth.

- Edit the S-file, change the SYNT DEPT line to 100.0   10   2.0 meaning start depth of 100 km, try 10 depths of increment of 2 km.
- Generate Green's functions, mtg
- Run inversion, mti

Question 7.6.4

Was there any improvement in fit with a different depths ? How sensitive is the strike, dip and rake to depth ?

7.7.　　Plotting and analyzing many fault plane solutions

In SEISAN, many fault plane solutions means having a CAT file with several events with fault plane solutions. For each event there can be several fault plane solutions for the same event, but only the first one is used. In this section, there are examples of how many events can be plotted and also one example of stress analysis.

Plotting solutions on a map

Select all events in test data base with fault plane solutions using program SELECT. Use all qualities.

- Plot all fault plane solutions with w_emap (Windows) with command: w_emap select.out. Click on focal mechanism for fault plane solutions to be shown.
- Alternatively use EPIMAP and select to plot fault plane solutions, use the whole world since it is not known where the solutions might be.

Plotting many solutions and making stress analysis

- Start program FOC with command foc. Use select.out as input. All fault plane solutions in select.out are now plotted side by side.
- Continue by pressing 'f'. All T and P-axis are now plotted as well as the average stress directions (see SEISAN manual). For each event, the difference between the average slip direction and the individual slip direction is plotted as a function of event number.

Question 7.7.1

In which direction is the average maximum compressive stress (P) and the average minimum compressive stress?

EXERCISE 8

Spectral analysis and Q

The standard displacement spectral analysis determining seismic moment, stress drop and source radius can be done with SEISAN program MULPLT. As with other parameters, the results of the analysis are 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 processing book chapter 8 for more information on spectral analysis and source parameters.

8.1.   Spectral analysis of a local event

- 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 8.1.1

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 (see program MULPLT). The upper frequency limit can be set to 50 Hz.
- Redo the spectrum.

Question 8.1.2

Does the spectrum look 'right' now ?

- With the 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 8.1.3

Are the spectral parameters stored in the S-file ?

Question 8.1.4

How does the M_w magnitude compare to Ml ?

Question 8.1.5

How big are the stress drop and source radius ?

Note that a fit to the spectrum can also be made automatically with command 's'. This is normally more accurate than doing it manually. See also 6.7 for doing automatic spectral analysis for all traces in one event.

8.2.   Influence of Q on a local event

The spectral shape is dependent on the Q-values used for spectral correction.

- Make the S-wave displacement spectrum for the signal used for one station under 8.1 using Q0=10 and Q0=100 and qalpha=0.5. The Q-value is changed in file MULPLT.DEF in directory DAT.

Question 8.2.1

Compare the spectral values and spectral shape and explain any differences.

8.3.   Spectral analysis of a distant event

Spectral analysis of distant events can be useful to get an approximate estimate of the seismic moment (and moment magnitude) and also sometimes an estimate of corner frequency. The geometrical spreading uses an approximation and is only valid if the depth is less than 100 km and only used of the epicentral distance is > 30˚. Correction for Q is using t^* which is entered in place of q_kappa.

In the MULPLT.DEF file, set SPECTRAL KAPPA to 1.0 and set SPECTRAL Q and SPCTRAL QALPHA to blank (not used). It is convenient to copy MULPLT.DEF to the working directory and change the local copy of MULPLT.DEF, which is then used by MULPLT since MULPLT always first looks in the local directory for MULPLT.DEF. Since the spectrum only is reliable below 0.5 - 1 Hz, limit the spectrum to 0.01-2.0 Hz by setting SPECTRAL_FBAND. The spectrum limitr can also be set temporarily with option 'f' when doing spectral analysis ('Change spec f-lim') just before selecting type of spectrum.

- Select event 2006 0222 22:19.
- Make spectral analysis of the P-waves for station KMY S Z and KONO B0Z. The spectral window is selected to be 40 s for KMY and 100 s for KONO. Calculate the P-wave spectra and determine moment magnitude and stress drop using only the part of the signal spectrum that is above the noise spectrum.
- Tabulate the values.

Question 8.3.1

In what frequency band does the spectra have acceptable signal to noise ratio ?

Question 8.3.2

Can the corner frequency be estimated from both spectra ? Are the corner frequency and stress drop reasonable ?

Question 8.3.3

Compare the moment magnitude to the magnitude values given for this event in the S-file. Can both spectra be used for M_w ?

8.4. Spectral analysis for an event recorded both locally and globally

In this example, one event will be used to compare the result of spectral analysis at a local distance and a global distance. Copy MULPLT.DEF to working directory so that changes are only made locally.

- Select event 2007 1002 18:00.
- If the event has not been located, read sufficient P-phases to make a location similar to the reported one. Update the event.
- Check MULPLT.DEF to make sure attenuation has been set to local earthquakes (see 8.3).
- Make a spectrum at a short distance by using station SDPT, vertical channel. The time window for the spectral analysis should be the whole P-wave train to make sure it is long enough to determine the corner frequency for this medium size event.
- Read spectral level and corner frequency and calculate moment and stress drop. Try different determination and compare the results to get an idea of the sensitivity to the manual determination.
- Change MULPLT.DEF to calculate spectrum for a distant event: Set Q and Qzero to zero and kappa (t*) to 1.0 for making a P-wave spectrum.
- Make the P-wave spectrum of station TLY, vertical channel, use a time window of about 2 minutes. Restrict the spectrum to 0.001 1.0 Hz (see 8.3). Also test sensitivity to the manual determination.

Question 8.4.1

Compare the values of moment magnitude for the determination at local and global distances. Is the moment magnitude comparable to what has been determined internationally ?

Question 8.4.2

Compare the stress drops. What range of stress drop is obtained by varying the manual determination ? Are the stress drops in the 'normal range' of 10 – 100 bar ?

8.5.   Velocity and acceleration spectra

SEISAN can also make velocity and acceleration spectra.

- Select the event on 12 August 1997 at 08:14, plot in single trace mode using station HYA.
- Click on 'Spec' on the menu and select a window around the S-waves (about 10 - 20 secs long). Make sure the frequency band used is 0.5 -25 Hz in order to use range with best signal to noise ratio (set in MULPLT.DEF or with command F).
- Make the velocity and acceleration spectra.

Question 8.5.1

Explain how spectra are expected to look and why.
Do the spectra look as expected ?
Does the acceleration spectrum indicate that correct attenuation has been used ?
What are the y-axis units of all 3 types of spectra ?

8.6.   Noise spectra

SEISAN can make the so-called noise power density spectra and compare to the Peterson noise curves (see processing book, Chapter 4). The reason we deal with this here and not in Exercise 3 is that it is done in a similar way as spectral analysis, The purpose of the exercise is to make noise spectra of two stations, compare to the Peterson curves to check if good stations and evaluate the low frequency limit of the station. It is assumed that in the frequency band where the spectrum has overall the same shape as the Peterson curves, that the spectrum represents the ground noise and thus the station has resolving power in that frequency range. Once the noise spectrum, at low frequencies starts to increase relative to the Peterson curve shape, the instrument can no longer resolve the ground noise, which indicates the instrument low frequency limit. It should also be mentioned that if the noise spectrum is outside 'acceptable' limits, it might simply be due to a wrong calibration file.

- Select the event on 12 August 1997 at 08:14.
- Plot in single trace mode using station KONO.
- Click on 'Spec' on the menu and select the longest window possible in the noise before the P-phase. Make sure the frequency band used is 0.01 -10 Hz. (set in MULPLT.DEF or with command 'f').
- Press 'n' to get the noise spectrum.

Question 8.6.1

Is the spectrum within the Peterson low and high noise limits ?
In which frequency range can the station resolve the noise ?
God or bad station ?

- Make the same spectrum with station FOO

Question 8.6.2

Is the spectrum within the Peterson low and high noise limits ?
In which frequency range can it resolve the noise ?
God or bad station ?

8.7. Relative spectra for Nakamura method using SPEC

The Nakamura method calculates the relative spectra of the horizontal to vertial components using seismic background noise. This does not require event data and can be done with continuous noise data. In the first example we will use the noise before the event in an event data file. There is no need to use S-files since only noise is used and the waveform files are used directly as input. However, S-files can also be used as input since they contain the waveform file name, see SEISAN manual.

- Copy the parameter file spec.par.osg from ./WOR/parameters to WOR. This is the input parameter file for SPEC.
- Copy waveform file 1996-06-25-0336-34S.TEST__032 from WAV to WOR.
- Make a dirf of 1996-06-25*, the filenr.lis is now input event file for SPEC.
- Start program SPEC.
  - Use option 1 to see the plots.
  - Use spec.par.osg as input for parameter file.
  - Use filenr.lis as input file for events.
- The signals and spectra are now plotted for station OSG, notice the absolute levels of the spectra and the relative spectra. The signal plot shows the window used for the spectra.
- Go forward (f) twice and the plots for station MOR are seen.

Station OSG is on the sediments of the sea bottom and station MOR is on hard rock.

Question 8.7.1

Describe the differences in the two relative spectra. Can the difference be related to the subsoil conditions ?

For the Nakamura method, the average of many noise spectra is normally used. In this second example, we will use data from the broad band station TRO to make a series of 20 spectra and calculate the average.

- Copy the parameter file spec.par.tro from ./WOR/parameters to WOR. This is the input parameter file for SPEC.
- Copy waveform file 2010-02-01-0500-00S.TRO___003_MSEED from WOR/new to WOR.
- Make a dirf of 2010-02-01*, the filenr.lis is now input event file for SPEC.
- Start program SPEC.
  - Use option 0 to see only the final average plot.
  - Use spec.par.tro as input for parameter file.
  - Use filenr.lis as input file for events
- The relative spectra are now plotted for station TRO for components N and Z as well as the average relative spectra.

Question 8.7.2

Are the individual spectra similar ? What kind of subsoil do you think there is under station TRO.

- Change to use the E component instead of the N component and run again.

Question 8.7.3

How does the result compare to the results of using the N component ?

8.8.   Determination of Coda Q

Coda Q is determined with program CODAQ, for details see SEISAN manual. In order to determine coda Q, input data must be available in terms of readings, locations and waveform data. In this section we shall use the example given in DAT and an example of how to do it for data in the TEST data base.

Use prepared example

- Copy files codaq.par and codaq.inp from DAT to WOR (to avoid many output files in DAT). Note, the codaq.inp is an index file prepared for PC with the data installed under \seismo. If your installation is different, the file should be edited to reflect your installation. Like on Linux it could be
    /home/seismo/REA/TEST_/1996/06/07-1325-29L.S199606
instead of

Alternatively you can prepare your own example, as shown below.

- Start CODAQ program with command codaq.
    - Use option 1 for plot on screen.
    - Use defaults for parameter file and file with stations-events (an index file).
    - Observe plots on screen.
    - Run through all plots (enter) to get average results at end.
    - Inspect output files codq.out and codaq1.out.

Question 8.8.1

Which stations were used for coda Q ?

How many "good" Q-values were obtained (meaning within the criteria set in the codaq.par file) ?

Make a data set

- From the test data base, select events in the area 59-62˚ N and 0-12˚ E using program SELECT.
- Run CODAQ using the same parameter file as in previous example
- For station-event input file, use index.out and follow steps as above.

Question 8.8.2

How many "good " Q-values were obtained ?
How is Q-values compared to previous example ?
- Add more stations and/or component by editing the codaq.par file
- Reduce the requirement of correlation coefficient from 0.5 to 0.4 by editing the codaq.par file.

Question 8.8.3

Are there more results after the changes ?
How does the average Q-value change ?

8.9.   Determination of attenuation by spectral modeling

The AUTOMAG program has an option to do a grid search for the best fitting Q0, Qalpha and kappa (see details in SEISAN manual). The user will be asked for input file name, grid parameters, spectral window, frequency range and stations. For each group of events in input file, the average residual will be calculated and the results output in file automag_grid.out in order of increasing average residual. In this way the best fitting spectral parameters can be estimated. The program can work with one of many events as specified in the input file. In this example one event will be used, the California event from August 12, 1998.

- Open event with EEV.

- Make sure P and S-phases have been read for all stations, check location and update event.
- Make an S-spectral analysis of the of BKS Z-channel. Use the automatic option for the spectral fit (s) and note the residual of the spectral fit. The Q-values used are for Norway ($Q=440f^{0.7}$ and kappa=0.7) and might not be appropriate for California. The spectral fit should be compared numerically and visually with the residual using the new Q-values to be determined.
- Make en input file (eev.out) of the event in EEV with command c to be used as input for AUTOMAG.
- Run AUTOMAG: Automag grid
- Use default parameters, select only component BKS SHZ in order to compare to above. Use start Q0 50, interval 100 and 6 trials, use start qalpha 0.1, interval 0.2 and 5 trials, use a fixed kappa of 0.04 (stat 0.04, interval 0 and 1 trial.

36 spectral fits will now be made with the above combination of Q0 and qalpha and the results of the fits will be listed in automag_grid .out in order of increasing average residual (see manual). It is seen that different combinations of Q0 and qalpha give similar fit to the data. An average relation can be made with program AVQ, see SEISAN manual. Determine the best average relation.

Question 8.9.1

How is the new relation compared to the relation for Norway ?

- Insert the new relation in MULPLT.DEF, make sure parameter SPECTRA MODEL is set to 0.0 so attenuation parameters are read form MULPLT.DEF.
- Make a new manual spectral analysis of BKS

Question 8.9.2

How is the spectral fit now compared to the spectral fit using the Norwegian model ?

- Redo the test using all stations in the input file (option ALL for components).

Question 8.9.3

How is the attenuation values compared to using only one station.

EXERCISE 9

Array analysis

This exercise will use a distant event recorded with a regional array (mediun sized) and a local event recorded with a very small array and demonstrate how to determine back azimuth with the FK-method using array data. In addition a regional seismic network will be used as an array to determine back azimuth and apparent velocity using arrival times.

9.1.   Use of a medium size array

For this exercise, the NORESS array will be used.

- 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 back 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 , locate event.

Question 9.1.1

How does the location compare to the PDE solution ?

Question 9.1.2

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.

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

- Use the 3-component station NRAO to determine back azimuth (see 5.8).

Question 9.1.4

How does the back 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 ?

9.2. Use a very small array

This data comes from an 8 station micro-array (300 m diameter) in Panama. The data is found in ./WOR/panama.

- Go to panama directory. In that directory, start EEV, by command eev. You will now have 2 events, which both have array data and local station data (avoid station BRU2 for phase picking). The local STATION0.HYP is also in panama directory.
- Plot the data and locate an event.
- Select only the z-channels of the array (AVB0-7), zoom on a small window around the P-phase, press FK on menu. A new window comes up, perhaps behind plot. Use all defaults and the FK-window comes up.
- If plot 'looks nice', press s to save. Trace plots come up again and press 'e' to associate observation with a phase for a particular station.
- Locate event, note the back azimuth error, an expression of the reliability.
- Test other windows and filters to judge variation in back azimuth determination.
- Test if it is possible to get a similar back azimuth with S-waves (often more difficult due to less correlation between signals).
- Locate the second event with the array only.

Question 9.2.1

How stable are the Az-estimates using different windows and filters?
What is the difference in location using only the array and all the stations ?

9.3. Use a regional network as an array

This exercise is to show how a regional network can be used as an array.

- Use event 1996 0623 01:17. The event already has P-phase readings.

- Calculate back-azimuth and apparent velocity using EEV command pf. Select KONO as reference station and use stations up to 500 km from KONO.
- Plot the relation and save to back azimuth and apparent velocity values.
- Relocate the event.

Question 9.3.1

How well does the P-waves fit a plane wave ?
How reliable is the back azimuth judging from the back azimuth residual obtained with the location ?
Try with other combinations of reference station and distance to evaluate reliability of estimates.

EXERCISE 10

Operation and earthquake statistics

This Exercise deals with exercise in several aspects of analyzing earthquake catalogs and other routine tasks related to network operation like automatic event detection.

10.1.   Detection of events from continuous data

The program CONDET can be used to detect events in one or more continuous databases, either a SEISAN continous data base or an archive (SeisComp or BUD types). It supports three detection algorithms: 1) a standard square STA/LTA, 2) the algorithm suggested by Carl Johnson (http://www.isti2.com/ew/ovr/carltrig_ovr.html), and 3) a cross-correlation detector (which will not be used here). CONDET can do two things, first to search for triggers on each specified station, and second search for a number of triggers from a given number of stations in a time window (this requires the first step has been done).

10.1.1.   Using a SEISAN continous data base

- Go to directory WOR/uk. All waveform data and parameter files are located here while the appropriate data bases already have been installed for 4 stations LMK, LIGL, LICO and LIGR.

- Start by checking the CONDET input file 'condet.par', use SEISAN manual for explanation. Parameters to change in the exercise are the detection algorithm, the respective detection parameters, the filters and the network detection settings. Also check SEISAN.DEF in working directory WOR/uk to see the settings for the continuous databases.

- Now run the program by typing 'condet', it automatically uses condet.par as input file. The program runs one station after the other. The main output files are 'condet.out' listing all the trigger times, 'extract.batch' – a script file to extract the data using the program WAVETOOL, and 'condet.trace' which lists the data intervals that were read. Check all these files.

Question 10.1.1

How many triggers are found for each station?
How does that change when you change the filter settings (use MULPLT to see frequency content)?

- To get network detections, now run program using 'condet –net'. The program reads the condet.out file to get detections from all stations, and it uses the parameters from condet.par to find times at which more than the required number of stations trigger within the given time window. The minimum number of stations is set to 4, requiring all stations in this example. The output from this run is a modified version of the 'extract.batch' file. Check how this has changed.

Question 10.1.2

Question: How many events are detected?

- Now, run 'extract.batch'. Under Unix give command 'source extract batch', under Windows, rename to extract.cmd and give command extract). Check the extracted data file using MULPLT.

Question 10.1.3

Check the length of the file, how does that compare to the settings in 'condet.par'?

- Register the file created to the local database, and use EEV/MULPLT/HYP to pick phases and locate.

10.1.2.   Using an archive continuous data base

The archive data base (SeisComp or BUD) is in directory archive in WOR so work must be done in WOR. The archive consist of 1 day of LP data from the Danish network. This exercise follow the same steps as the previous ones so you can do the same checks, for details see previous exercise. The main difference is that the data is long period to so trigger parameters are different. ...

- Go to WOR
- Copy parameter file condet.par from DAT to WOR
- Run CONDET with command condet
- Follow the steps of previous exercise.

10.2.   Auto pick phases

The program AUTOPICK can pick phases for one or several events already registered in a data base. The program is either operated in EEV for one event using command 'z', or several events are processed using program AUTO. An example parameter file is already set up in DAT.

- Select event 19960705
- Delete already picked phases using the editor, make sure to keep all header lines.
- Give command 'z' and phases should be picked and saved in S-file.
- Plot event and inspect automatic picks
- Locate event

Question 10.2.1

How large are the picking errors?

Question 10.2.2

How much difference is there in the location and magnitude as compared to the manual picks and corresponding location?

The Portuguese network has long used AUTOPIC and therefore have well adjusted parameters. The following event (courtesy Fernando Carrilho) is from the Azores network. The data is located in WOR/azores. The data include AUTOPICK.DEF, station file and calibration files so it can also be used for testing magnitudes. There is one event without readings.

- Go to WOR/azores
- Type eev
- Type z and get the automatic readings
- Check the picks by plotting
- Locate with and without rejecting bad phases
- For the good phases also run command am to get automatic magnitudes
- Compare magnitudes and location to the official location in S-file

10.3.   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 WOR/catalogs).
- Use coda magnitudes, a magnitude step of 0.2, range 2.5 to 4.0 and fixed b-value of 1.0.
- Use least square to calculate b-value and plot.

Question 10.3.1

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 10.3.2

How stable are the a and b-values

- Redo the exercise using M_L

Question 10.3.3

How do the results compare using M_c and M_L ?

10.4. Statistics

10.4.1. Distribution in time

SEISAN can calculate yearly, monthly and daily distribution of number of events as well time of day distribution. Here we shall test the distribution within one month.

- Start the program and use the file august.96 as input (in WOR/catalogs).
- Select the time range of August 1 to 31, 1996. Do not make daily statistics.
- Plot daily distribution and time of day distribution.

Question 10.4.1

Are the events uniformly distributed over the month ?
Are the events uniformly distributed over the 24 hours ? If not what could this indicate ?

10.4.2. Contents of a multi-event file, CAT or compact

An unknown file can be inspected with program NORHEAD which lists all the header lines and gives a total number of events in file.

- Go to directory WOR/catalogs
- Give command norhead 2000-0101.isc

Question 10.4.2

How many events were available in the file?

10.5.   Plotting epicenters, depth sections of hypocenters, error ellipses and fault plane solutions

In section 1.6, epicenters were plotted. In this section more examples of plotting epicenters and hypocenters will be tested as well as plotting error ellipses and depth sections.

- Go to directory WOR/catalogs
- Plot a world seismicity map with EPIMAP using the catalog 2002-2004.isc as input. Use a Mercator projection in the area latitude -80˚ to 80˚, longitude -180˚ to 180˚. Select WORLD.MAP for the map contours.
- Use the zoom function z to zoom in to a subduction zone area e.g. South America.
- Make a depth profile at a right angle to the subduction zone by making a mouse click for the two points along the profile and a third point to indicate the width. One more click will bring up the profile. If the last click is 'f', the two axis in the profile will have the same scale, else auto-scaling is used.
- If on Windows, plot the same data with w_emap using command w_emap 2002-2004.isc. If w_emap is not installed, the install file is found in SUP.

Question 10.5.1

Can the subduction zone clearly be seen ?

What is the angle of subduction ?

- Use the SELECT program to extract all events with fault plane solutions out the data base in the time period 1990 - 2007.
- Plot all events with command (if on Windows) w_emap select.out, click on showing fault plane solutions when plot comes up.

Plotting error ellipses: EPIMAP can plot error ellipses of all events in an input file while w_emap only plots for one event. In order to plot error ellipses, the input data must consist of S-files or a CAT file of S-files since the error information is given in an addition line (the E-line).

- From EEV, locate event 1996 0606 06:48
- Quit from EEV and give command w_emap. Zoom around the epicenter and press errors on the plot. The error ellipse should now be seen.

Question 10.5.2

Is the size of the error ellipse consistent wit the errors given in the S-file (hyp.out) ?

- Select event is the whole data base in the area latitude 59˚ - 62˚ and longitude 0˚ - 10˚.
- Plot events with EPIMAP, remember to answer 'y' to question about plotting error ellipses.
- Make a depth section of the hypocenters

Question 10.5.3

The error ellipse are elongated in the horizontal plane, how is that explained ?
Explain the shape of the error ellipses in the vertical plane, what does it tell us about accuracy of hypocenters ?

10.6.   Felt earthquakes

SEISAN can deal with macroseismic data in various ways and the data can be stored as an integral part of the SEISAN data base. Macroseismic information is included with the test data for event 1999 0529 00:31. The data can be plotted with either EPIMAP directly or from EEV with command MACROMAP (Unix only with GMT installed).

- Go to directory ISO (command is) and inspect the file (edit) 1999-05-29-0031-43.MACRO with macroseismic data.

Question 10.6.1

How many observations points have felt information ?
What is the maximum intensity observed ?
Is there any hypocenter information available, if not, where is it found ?

- While working in ISO - directory, plot the macroseismic information with EPIMAP. Select the area 59-65 N and 4-15 E and use the Europe map. When the question about hypocenter file comes up, use file name 1999-05-29-0031-43.MACRO.

Question 10.6.2

Can you estimate the radius of the felt area from the map ?

- Find the event with EEV: eev 19990529 and type the event to find the reference to the macroseismic information.
- If on a system with GMT installed, plot the observations with command macromap from EEV.

Question 10.6.3

From the GMT map, is there a correspondence between the area of maximum intensity and the epicenter ?

EXERCISE 11

Analysis of a data set

11.1.   Tanzania local network

Using the skills acquired in previous exercises, a set of 10 local events will be used to do a comprehensive analysis. The data set consists of 10 waveform files, a station file and calibration files. The data is located in .\WOR\tanzania

- Create a data base with a name of your choice, register the events into the data base. Install calibration files and station files. However, if you work in directory WOR\tanzania, station file and calibration files can stay there.
- Locate all events and calculate M_c, M_L and M_w, check all events for reasonable fit, RMS should be less than 1.0 s. Check that, for each event, that there is a consistency between different types of magnitudes.
- Make an epicentral map with a depth section.
- Compare the magnitude types obtained using program mag. This means plotting M_L versus M_c and M_L versus M_w.

Question 11.1.1

How is the comparison ?

EXERCISE 12

Data manipulation and import and export of data

SEISAN contains many tools for converting data from one format to another and to import and export data. Some examples have already been given in sections 1.6 to 1.8. In this exercise some more examples of the most common operation will be given covering the following:

- Converting waveform files from one format to another.
- Extracting a complete data set including S-files, waveform files and calibration files.
- Waveform output directly from MULPLT
- Correcting headers in SEISAN waveform files
- Converting waveform files to ASCII files
- Splitting and merging waveform files
- Putting many waveform files into the SEISAN data base

12.1. Converting waveform files from one format to another

There are several programs available. The most general is WAVETOOL, which converts between all the formats supported directly by SEISAN. Other conversion programs work in similar way to WAVETOOL.

- Go to directory WAV, type wa.
- Make a dirf of all files from 1994: dirf 1994*. This gives a list for the files in file filenr.lis
- Start WAVETOOL, give command wavetool. As input file use number 2 so enter the number 2.
- Use all defaults except output format. Choose GSE and enter for the rest of the questions. A GSE output file is now created.

Question 12.1.1

What is the name of the converted file ?
How large is it compared to the input file in SEISAN format ?

Start WAVETOOL again and as input use the name filenr.lis. this will convert all the files in the list. For output format, use MiniSEED.

Question 12.1.2

What is the name of the output files, compare to the input files ?
What are the file sizes ? Why are they different?

12.2.   Extracting waveform and calibration files from a SEISAN data base

We have earlier seen how to extract parameter data using SELECT (see section 1.6). The corresponding waveform and calibration files can then be copied out manually using the information in select.out. This can be a long process if many waveform files are needed, particularly if the waveform files also are stored in a year-month structure. SEISAN therefore has a program GET_WAV to facilitate this process.

Copy events

- Select data using SELECT for the time period 1993 to 1998 and magnitudes in the range 3-5.
- Run program GET_WAV using select.out as input.

Question 12.2.1

How many events were selected ?
Were the waveform files list in select.out all available ?
Were the calibration files for the waveform files all available ?
Inspect file copy_wav.out (Unix)/copy_wav.bat (PC), what is the content ?

- Copy the waveform files from the SEISAN data base to current directory using command copy_wav on PC or 'source copy_wav.out' on Unix.
- Copy the calibration files from the SEISAN data base to current directory using command copy_cal on PC or 'source copy_cal.out' on Unix.

Question 12.2.2

Are files now present in current directory ?

Copy waveform files from a continuous data base

In the training data set, there is continuous data in the SEISAN data base for whole day of January 22, 2004 for the 3 bases JMI, NSS and RUND (see section1.8.2). The data

can be copied by a simple copy, but this exercise will demonstrate how to do it with select and get_wav for part of the data base.

- Fore each of the 3 data bases, use select to extract out S-files in the time period 10-22. For data base use e.g. JMI, search in S-files and give above time interval.
- Run GET_WAV for each select.out and copy the waveform files to current directory as above.

Question 12.2.3

How many waveform files have been copied to current directory ?

12.3.   Creating a SEISAN continuous data base

In section 12.2, 90 waveform files from 3 stations were extracted for a 10 hour interval (20 min files). The purpose of this exercise is to create a new SEISAN continuous data base and enter this data. The following steps are needed:

- Create three new data bases STAT1, STAT2 and STAT3 with MAKERA, make both REA and WAV directories (see also section 1.7) for January 2003.
- Make a dirf for the waveform files from each station, e.g. dirf 2004*NSS*.
- Create the S-files for the continuous data for each station as well as copying the waveform files to the respective waveform directories using AUTOREG.
- Edit the SEISAN.DEF in DAT and add the 3 'new' data bases STAT1, STAT2 and STAT3 (add lines CONT_BASE or modify the existing).
- Go to WOR directory.
- Plot data for the new data base with MULPLT, option cont (see section 1.8.2).

Question 12.3.1

Which directories were created by MAKEREA ?

How many data bases are now available?

12.4.   Getting parameter data from ISC

The ISC has the largest data base of parameter data available anywhere so it is useful to know how to import data from ISC to SEISAN. At ISC only hypocenter information or the complete readings can be selected. In this exercise, a few complete events will be selected and converted to NORDIC format.

- Connect to the ISC web site: isc.ac.uk. Go to Analysis/ISC Bulletin/rectangular Search.
- Search the ISC data base for July 1, 2005, m_b as determined by ISC in the range 4.5-5.0. On bottom of the screen, all boxes should be ticked. Select IMS1.0 as output format.
- When the search is finished, the results are displayed on the screen. Save the data on your local computer by using File/Save As in a file e.g.. isc. FILE TYPE MUST BE SELECTED TO BE Text File. On a PC, the file name would then be isc.txt.
- Convert the file to SEISAN (Nordic) format using program NORIMS:
  - Start with command norims, use option 1 for conversion
  - Input file name is isc.txt
  - Use ISC on header line
  - Enter for No location flag
  - The output file is norims.nor

Question 12.4.1

How many events were found ?
How many events had fault plane solution (seen graphically on ISC output) ?

- Put the data into the standard SEISAN TEST data base using program SPLIT, see exercise 1.7 for an example. There is already data in the data base for that month so the data base structure exists.
- Run EEV on 200507, try to locate one of the ISC events.

Question 12.4.2

How many events are there now for July 2005 ?
When locating the event, is the SEISAN location significantly different from the ISC solution (different model are used, SEISAN uses IASP91, ISC uses JB and/or AK135 and different programs are used) ?
Are there any stations missing ?

- Select event 2005 0701 20:58, fix the location and depth to the ISC given values (FF in column 44-45) on S-file header line.
- Locate to see that all stations are there.
- Make the fault plane solution (see also section 7.3).

Question 12.4.3

The analysis might result in several fault plane solutions, how do they compare ?

Are any of the solutions comparable to the solution given in the S-file (Harvard solution, compare number or enter Harvard solution as an F-fline with 'O' in column 79).

Acknowledgements

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Appendix: TRAINING data available

Training data is available from different networks and stations from around the world. The events consist of local and global data in the magnitude range -0.5 to 8.0. The data is organized in 2 sets:

- o The TEST data base set as default. This data is either from the Norwegian National Seismic Network (NNSN) and from the global network. Corresponding parameter files and calibration files are stored in the standard DAT and CAL directories and the user can work with the data from any directory. The data is accessed by using 'eev yyymm'.

- o Data sets from particular networks. The data is stored in subdirectories to the WOR directory with names corresponding to the particular network or country. In this network directory all relevant information is stored: S-files, waveform files, calibration files and station file. In order to work with the data, the user MUST be in the network directory and use EEV for a local data base. There is also a directory for catalog data.

With reference to the processing book, if no network is mentioned (or NNSN is given), the data is found in the TEST data base. If a reference is given to a particular network, the data is found in network catalog.

The training data is not complete meaning that not all waveform files and calibration files are available for each event. This limitation has been made to reduce the data volume.

Below is given an overview of the data available. The information about each event is the standard S-file header line.

Network or country data sets, names are also directory names in WOR

Azores, Local stations on the Azores Islands

```
2014 11 7  746 36.9 LQ 38.903 -29.153 0.80   IM 14 .30 3.0L IM
```

Andalucia, S. Spain, local network

```
2005  7 2 1258  7.6 L  35.708  -3.407 47.5  IAG 15 0.3 4.2CIAG
2006  1 8 1508 40.9 L  36.860  -3.189  9.3  IAG  6 0.1 2.5CIAG
2006  122 0421 53.4 L  37.462  -2.091 15.4  IAG 10 0.2 2.8CIAG
2007  1 4 2332 32.8 L  37.202  -3.769  2.5F IAG 13 0.3 3.8CIAG 3.4LIAG 3.9WIAG
```

Argentina, temporal network

```
2009  5 8 1344 53.3 L -32.070 -69.674108.0  SJA 35 .30 5.4LSJA 4.8CSJA 5.4WCMT
```

Greenland, regional network

```
2005  1 2 1024 24.7 L  69.123 -53.859 12.0  DNK 13 2.0 3.2LDNK
2005  723 1339 30.4 L  67.091 -53.970 20.0F DNK 10 1.5 3.3CDNK 4.1LDNK
```

Jamaica, national network

```
2000  418 2124 54.5 L  18.188 -76.775 11.3  JAM 10 0.4 3.2LJAM 3.0CJAM
2001  3 4 0211 41.1 L  17.890 -78.145  7.0  JAM  9 0.1 3.1CJAM 3.0LJAM 3.2WJAM
```

Mexico, national network

```
1995 1219 22 4 36.0 L  15.950 -99.170 16.0  MEX        4.7CMEX
1996  715 2123 27.7 R  17.571-101.049 48.2FFISC  5 5.0 6.9WMEX        6.7SISC
```

NMSOP_IS11.7_data, data for the New Manaual of Observatory training data set

```
2012  314 1922 28.2 L  59.526   5.615 13.9  BER 12 0.4 3.4LBER
2012  524 2247 45.1 D  72.943   6.096  8.8F BER 20 1.8 6.3sBER 6.1SBER 6.4bBER
2013  2 9 1416  8.5 D   1.008 -77.514150.1  TES 19 1.3 6.8bTES 7.0BTES
2013  214 1313 54.9 D  67.811 142.173 10.1FFTES 21 5.9 6.8sTES 6.9STES 6.7bTES
```

Panama, local network with a small array

```
2004  2 4 1500 30.4 L   7.440 -83.701 10.0  ANG  4 0.1 3.6CANG
2004  2 5 1923 20.2 L   8.305 -82.925 53.1  ANG  4 0.0 3.2CANG
```

Sudan, national network

```
2006  623 0911 13.9 L  13.563  29.652 15.0F SSN  2 1.0 3.9CSSN 4.0LSSN 3.7WSSN
```

Tanzania, small local network, only waveform data from 1992 local events

```
1992-10-07-1135-29S.NSN___012_MSEED
1992-10-09-0653-12S.NSN___012_MSEED
1992-10-12-0449-33S.NSN___009_MSEED
1992-10-15-0016-36S.NSN___009_MSEED
1992-10-23-0118-22S.NSN___009_MSEED
1992-10-29-0555-42S.NSN___012_MSEED
1992-11-03-2100-58S.NSN___015_MSEED
1992-11-09-0121-08S.NSN___015_MSEED
1992-11-09-0506-53S.NSN___009_MSEED
1992-11-12-1250-20S.NSN___015_MSEED
```

UK, national network

```
2007  428 0718 11.4 L  51.102   1.169  5.3FFBGS124 0.5 4.3LBGS
In addition there is continuous waveform data for 4 stations from April 5, 2008.
```

Venezuela, national network

```
2003  422 1329  9.6 R   6.810 -73.128168.6  FUN 18 0.5 3.8WFUN
```

```
2003 1127 1200 21.1 R   6.802 -73.040153.7FFFUN 22 0.5 4.0WFUN
```

New, additional training data, only waveform data

```
1996-08-15-2340-35S.TEST__          Local event
2005-06-13-2252-24.009.miniseed   Distant event, MINI_Seed format
2005-06-13-2252-24.009.seed       Same as above, SEED format
Seed.zip                          Same as above, to be used on PC
KONO.BHZ_10.IU.2008.236           Day file in MINISeed format
```

Archive, a SeisComp archive

A   standard SeisComp archive from one day , January 29, 2011 and and 6 stations.

Catalogs, catalog data from ISC and NNSN

- o 2002 – 2004.isc: All events with m_b (ISC) > 5 from ISC for 2002-2004. Only hypocenters.
- o 2002.isc: All ISC events with m_b and M_s for 2002. Only hypocenters.
- o 2000-0101.isc: ISC data for two days, January 1-2, 2000. With all phase information.
- o 2006.s-norway: All data from NNSN in southern Norway for 2006. With all phase information.
- o august.96: Data from NNSN for August, 1996.

Parameters, parameter files for running programs

- o spec.par.osg: For spectral analysis for Nakamura
- o spec.par.tro: ---

TEST data base, data from the NNSN and the global network

```
1990 1213 1109 19.8 LE 60.328    5.167  0.0F BER  6 1.3 0.9CBER               1
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 -70.294199.5  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  6.2 L  60.389   2.597 30.3  TES 13 0.7 2.3LTES 2.7CTES 2.2LNAO1
1995 1120 0401 59.1 L  60.052   5.402  1.5  TES 12 0.5 2.0LTES 2.3CTES 2.1LNAO1
1996  6 3 1955 35.5 D  47.760 153.227  0.0  TES 12 1.1        5.6WHRV 5.6BPDE1
1996  6 6 0648 30.4 L  62.636   5.050 15.0  TES 13 0.9 2.9LTES 3.0CTES 3.0LNAO1
1996  6 7 1325 29.2 L  59.846   5.130 12.0F TES 12 0.6 1.9LTES 2.2CTES 2.0LNAO1
1996  610 1 4 47.0 D -13.481 167.130200.1  PDE301      5.8BPDE 5.9SPDE 6.7WGS 1
1996  623 0117 57.8 D  51.678 159.982 30.7  TES 16 0.5 3.5STES 5.5BTES 5.4BPDE1
1996  625 0337 31.0 L  61.689   3.259 15.0  TES 35 3.0 3.3LTES 3.0CTES 3.2LNAO1
1996  7 5 0220 46.5 L  61.287   4.829  8.0  TES 10 0.4 2.0LTES 2.2CTES 1.9LNAO1
1996  713 0556 46.0 L  61.419   3.872 12.2  TES  9 0.5 1.5LTES 2.1CTES 1.6WBER1
1996  718 0946 51.4 L  60.158   2.070 15.0  TES  9 1.1 1.8LTES 2.5CTES 2.1WBER1
1996  718 2255  8.1 D  51.689 157.584 31.1  TES 18 0.5 5.1BTES        5.5BPDE1
1996  726 0742 12.0 L  61.756   2.316 20.8  TES  9 0.4 1.8LTES 2.4CTES 2.0WBER1
1997  812 0814 24.1 L  59.818   6.646 12.0F TES 14 0.6 2.8LTES 2.7CTES 3.4LNAO1
1997 10 6 2345 39.6 L  73.484   7.779 15.0F TES 20 1.3 3.2LTES 3.5CTES 3.0LNAO1
1998  8 4 1859 18.2 D  -0.551 -80.411 19.0  PDE         6.2BPDE               1
1998  812 1410 25.1 L  36.755-121.462  8.0FFBGS  4 0.3 5.2W                    1
1999  529 0031 43.6 L  62.201   4.587 15.0F TES 32 0.7 3.9LTES 3.2CTES 3.8LNAO1
```

```
1999  913 1155 28.0 D  40.740  30.030 10.0  PDE  1                       5.8BPDE1
2000  2 1 1242 20.2 L  61.606   4.693  0.0  TES 13 0.7 2.3LTES 2.1CTES 2.3LNAO1
2000  210 0617 57.4 L  61.760   4.539  6.0F TES 20 0.7 3.6LTES 2.9CTES 3.3WBER1
2000  210 1740  7.2 L  61.847   4.414  2.4  TES 16 0.7 3.0LTES 2.5CTES 3.0LNAO1
2001  113 1733 36.4 D  13.126 -88.268 60.0F TES 21 2.1 7.8STES 6.0BTES 6.4BPDE1
2002  411 1316 27.9 LE 58.202   6.203  0.0F BER  7 0.9 1.8LBER 2.0CBER       1
2003  326 0422  7.8 D   9.220  95.718 33.0F TES 23 0.7 5.5STES 5.5BTES 5.8BPDE1
2004  5 2 1924 53.9 L  59.893   6.271  5.0F TES 16 0.9 1.5LTES 1.3CTES 2.0LNAO1
2004  511 0050 47.7 L  60.017   5.305  7.0F TES 16 0.7 1.8LTES 1.7CTES 2.3LNAO1
2004  7 5 1809 36.9 L  57.505   7.139 15.0FFDNK  5 1.0 2.2LDNK 1.9CDNK       1
2005  731 1544 49.7 L  66.346  13.165  2.8  TES  6 0.4 1.5LTES             1
2005 1023 2001  5.8 L  66.250  13.024  0.0  BER  7 0.4 1.8LBER 1.8CBER       1
2005 11 6 2100 45.0 L  66.278  12.806  0.0  TES  6 0.6 1.6LTES 2.2CTES       1
2006  222 2219 11.9 D -20.915  32.108  6.5  TES 23 1.1 7.1STES 6.4BTES 6.5BPDE1
2006 11 4 1803 34.6 L  66.226  12.724 11.0  TES  3 0.0 0.4LTES-0.2CTES 1.1WBER1
2006 1129 0017 48.3 L  66.423  13.241  9.0  TES  3 0.1-0.4LTES 0.4CTES 0.5WBER1
2006 1220 0328 32.0 L  66.278  13.267  0.0  TES 12 0.5 2.2LTES 2.5CTES 2.4LNAO1
2007  3 8 0503 33.3 D  29.745 139.048135.4  BER 22 0.7 5.2SBER 5.9BBER 5.9BPDE1
2007  928 1338 57.8 D  22.013 142.668260.0  PDE558 1.0 6.7BPDE             1
2007 10 2 18 0  6.9 D  54.511-161.708 32.0  PDE583     6.2BPDE 6.2SPDE 6.3WGCM1
2007 1116 0312 18.2 D  -2.312 -77.838123.0  PDE 189                   6.3BPDE1
2008  221  246 17.9 D  77.080  18.573 10.0  PDE637     5.7BPDE 5.9SPDE 6.1WGCM1
2008  415 2259 51.3 D  51.659 179.402 12.2  BER 18 1.6 6.3SBER 5.6BBER 6.1BPDE1
2009  1 2 0742 46.2 D  31.582 138.537333.4F BER 19 0.4 4.9BBER         4.9BPDE1
2009  115 1749 39.1 D  46.857 155.154 36.0  PDE522     6.9BPDE 7.5SPDE 7.4WUCM1
2011  129  655  0.0 D                                                       1
```

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