Data Analysis in Geophysics
ESCI 7205

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Room 103 in 3892 (long building), x-4929

Tu/Th - 13:00-14:30
CERI MAC (or STUDENT) LAB

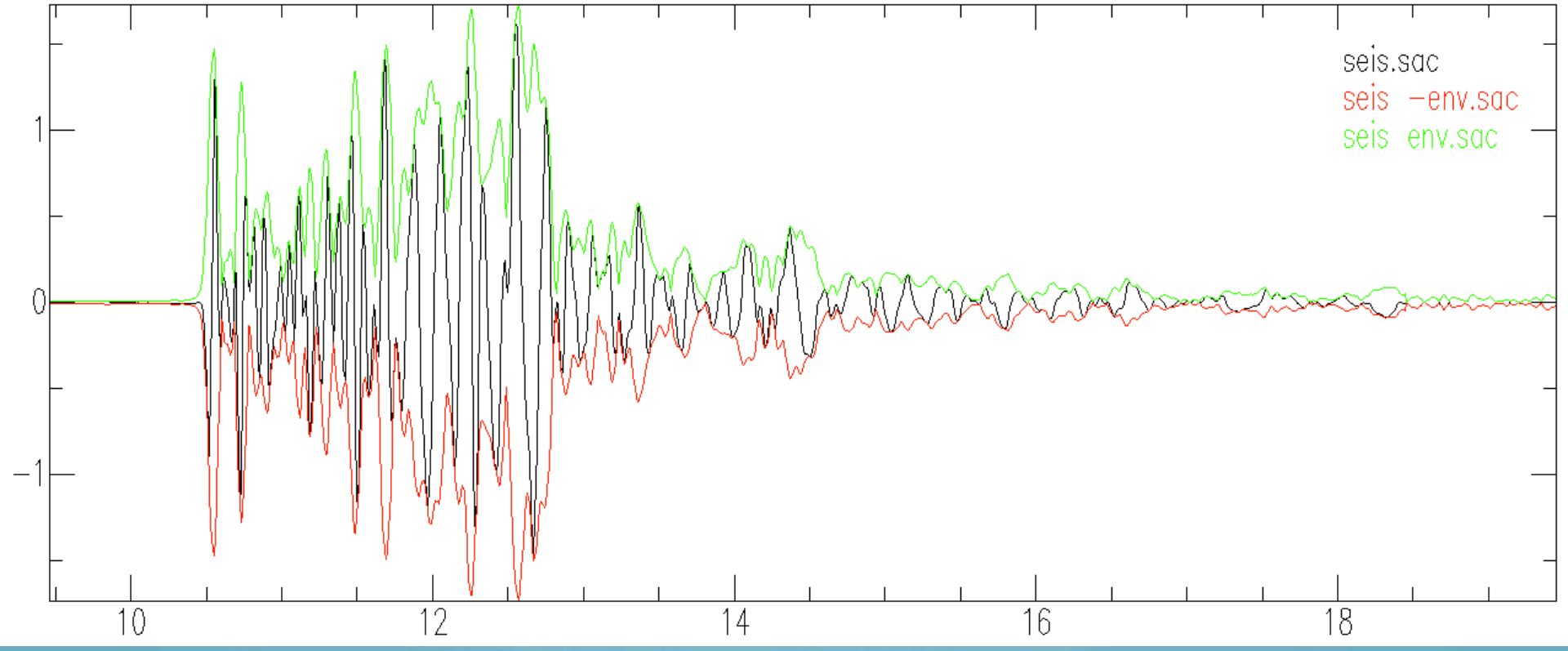
Lab – 11, 10/1/13

SAM: other commands

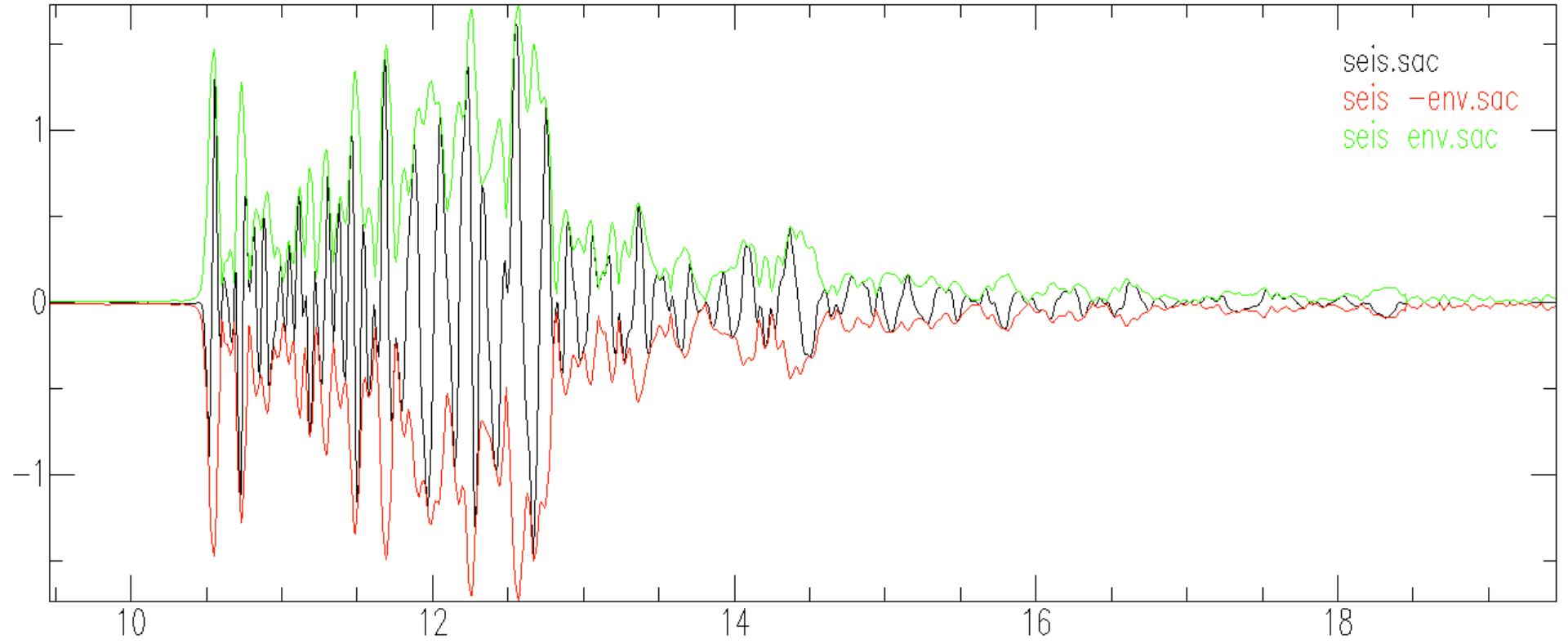
`hilbert`: applies a Hilbert transform (90° phase shift of all frequencies of the signal in the frequency domain).

Applied twice, this flips the sign of the amplitude.

`envelope`: computes the envelope function (for a sine input is $\sin^2+\cos^2=1$) using a Hilbert transform.


seis.sac
seis −env.sac
seis env.sac
1
0
−1
10
12
14
16
18

```
funcgen seismogram
rtrend
w seis.sac
envelope
w seis_env.sac
mul -1
w seis_-env.sac
r seis*.sac
color on inc on
p2
```



Event Analysis Module:

This module is used to pick seismic phases.

An automatic phase picking algorithm can be applied using

APK.

Event Analysis Module:

You can also use

PPK

to pick phases using the graphics cursor.

(PPK is described in the section on Graphics Capabilities).

Event Analysis Module:

Picks can be saved in **HYPO** format using the

OHPF (open HYPO pick file) and

CHPF (close HYPO pick file) commands;

WHPF writes auxiliary cards into the **HYPO** pick file.

Event Analysis Module:

These picks can also be saved in a more general Alphanumeric format using the

OAPF (open alphanumeric pick file) and

CAPF (close alphanumeric pick file) commands.

The picks are also saved in the headers (so all might not be lost if you forget to write them to the pick file – as long as you write out the header or the sac file).

```
sac> ppk
```

Opens X window with all data loaded in memory.

```
sac> ppk perplot 6
```

open 6 files at a time.

Cursors on TEK401X.

```
# cheat sheet:

click on window to make it active

Mouse controls cursor position

zoom in: type "x" to define left side time window, followed by a
left click of mouse to define the right side time window

zoom out: type "o"

p arrival: type "a", or "p" at the time of the p wave arrival.

s arrival: type "t0", or "s" at the time of the s wave arrival.

other phases: type "tX" to place that time in header

quit: type "q"
```

SAC macros

A SAC macro is a file that contains a set of SAC commands to be executed together.

As well as regular commands and inline functions, a SAC macro file can contain references to SAC header variables and blackboard variables that are evaluated and substituted into the command before it is executed.

SAC macros can also have arguments that are evaluated as the macro is executed.

Control flow features such as “if tests” and “do loops” are also available.

These features let you control and alter the order of execution of commands within a macro.

example: macro for creating a plot

```
%vim plot1.macro
r BJT.BHZ* BJT.BHN* BJT.BHE*
xvport 0.1 0.6
qdp off
xlim t1 -5 50
title on "Sumatra Event 2/13/2005 1:22:09 at BJT"
xlabel on "Time, sec"
ylabel on "Digital Counts"
bd sgf
p1
ed sgf
sgftops f001.sgf plot1.ps 1 y
```

example: macro for creating a plot

There are two ways to run the sac macro, from within `sac`

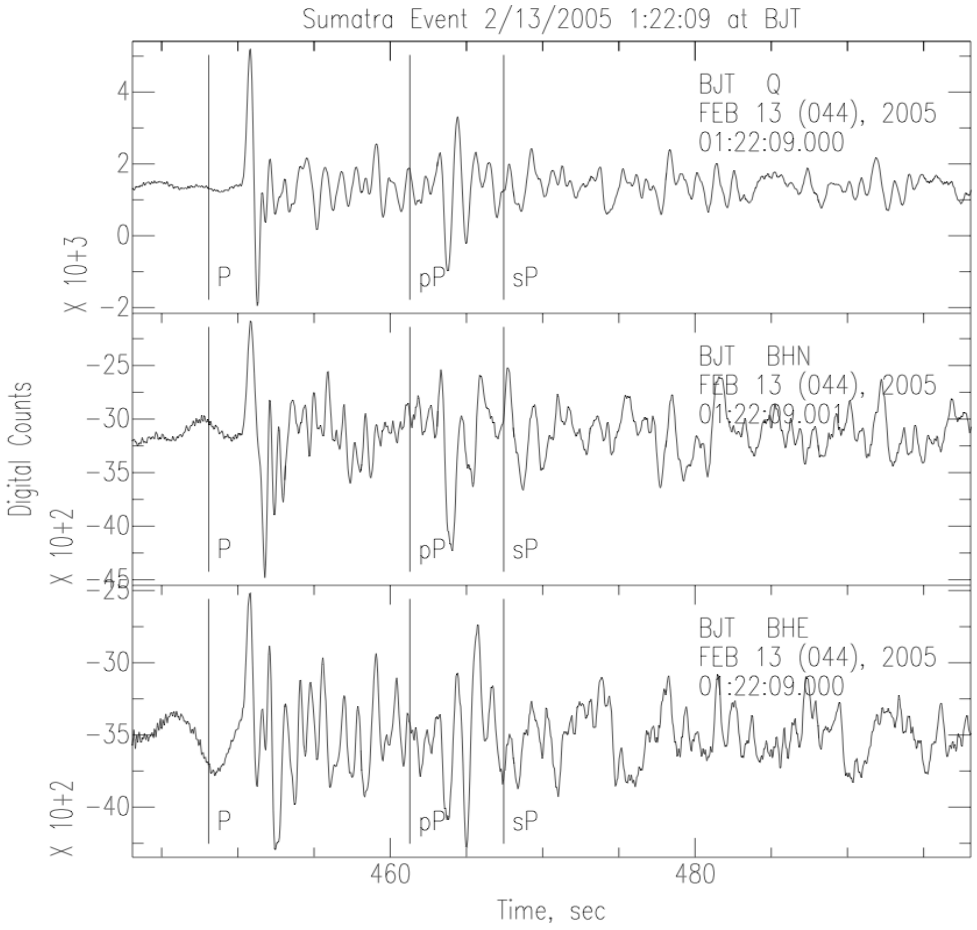
```
%sac
sac> macro plot1.macro
```

or from the command line (two ways)

```
%sac plot1.macro        (may not work on UNIX, did on Prime)

%sac < plot1.macro      (standard UNIX method)
```

Postscript file made by macro.



Order dependent arguments (in macro call)

```
alpaca.ceri.memphis.edu656:> vi prt.macro
r $1 $2 $3
xvport 0.1 0.6
qdp off
xlim t1 -5 50
title on "demo"
xlabel on "Time"
ylabel on "Digital Counts"
bd sgf
p1
ed sgf
sgftops f001.sgf plot1.ps 1 y
```

```
alpaca.ceri.memphis.edu649:> sac

 SEISMIC ANALYSIS CODE [09/04/2008 (Version 101.2)]

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SAC> macro prt.macro AREN.BHZ AREN.167 AREN.257

SAC> quit

alpaca.ceri.memphis.edu650:> ls *.ps

plot1.ps

alpaca.ceri.memphis.edu651:>
```

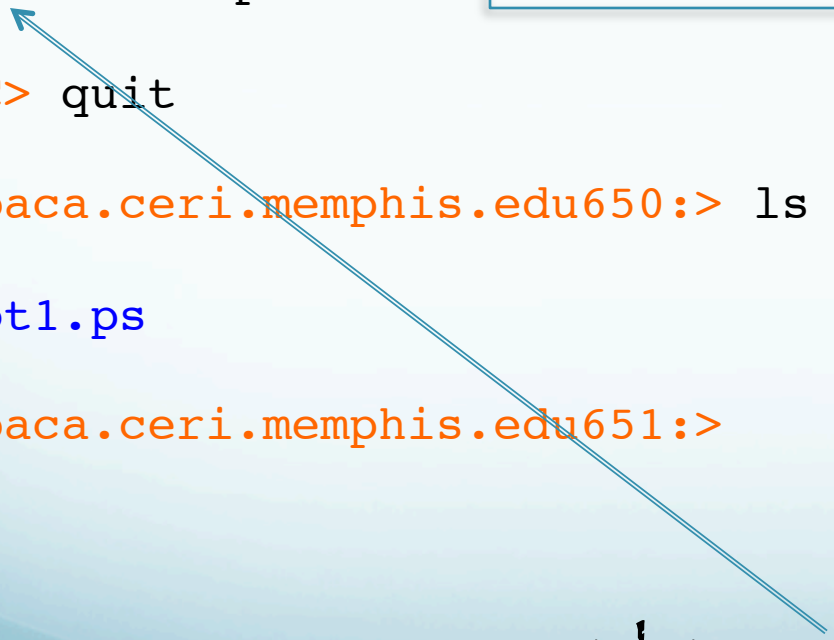

Note: we are within SAC, not at the SHELL command line.

keyword driven arguments (in macro call)

```
%vim plot3.macro
$keys files plot
r $files
xvport 0.1 0.6
qdp off
xlim t1 -5 50
title on "Sumatra Event 2/13/2005 1:22:09 at BJT”
xlabel on "Time, sec”
ylabel on "Digital Counts”
bd sgf
P1
ed sgf
sgftops $plot plot3.ps 1 y

sac>macro plot3.macro files BJT.BHZ.SAC BJT.BHN.SAC BJT.BHE.SAC
plot f001.sgf
```

Default keyword arguments (in macro call)

```
% vim plot3.macro
$keys files plot
$default plot f001.sgf
r $files
xvport 0.1 0.6
qdp off
xlim t1 -5 50
title on "Sumatra Event 2/13/2005 1:22:09 at BJT”
xlabel on "Time, sec”
ylabel on "Digital Counts”
bd sgf
P1
ed sgf
sgftops $plot plot3.ps 1 y

sac> macro plot3.macro files BJT.BHZ.SAC    BJT.BHN_SAC
BJT.BHE.SAC
```

Missing Keyword arguments (in macro call)

Argument query

If you fail to enter a value for an argument on the SAC macro execute line and it has no default value, SAC will ask you to enter a value from the terminal.

```
SAC> macro plot3.macro
files? BJT.BHZ.SAC BJT.BHN.SAC BJT.BHE.SAC
```

SGFTOPS

SUMMARY Converts an **SGF** file to a **POSTSCRIPT** formatted file.

SYNTAX

```
SGFTOPS sgf-file ps-file {width} {YES|NO} {scale} INPUT sgf-file
```

SGFTOPS sgf-file ps-file {width} {YES|NO} {scale} INPUT sgf-file

sgs-file: name of a SAC Graphics File (**SGF**).

ps-file : The desired name for the POSTSCRIPT file.

width : A number specifying the width or thickness of lines in the output file.

This is an integer in the range 1 to 8.

Default is 1.

```
SGFTOPS sgf-file ps-file {width} {YES|NO} {scale} INPUT sgf-file
```

YES|NO : Flag to apply additional scaling.

A value of **YES** turns scaling on, **NO** ignores the additional scale parameter.

scale : An additional scale factor. Can be used for making large or full-size maps.

Blackboard variables.

The blackboard feature can be used to temporarily store and retrieve information.

A blackboard entry consists of a name and a value.

They are used extensively in macros

Blackboard entries are created using the **SETBB** and **EVALUATE** commands.

You can also substitute the value of a blackboard variable directly in other commands by preceding its name with a percent sign ("%").

Default is to print to terminal.

```
sac> setbb c1 2.45
sac> evaluate to c2 %c1 * 2
sac> bp butter co %c1 %c2
sac> evaluate %c1 * 2
 4.9000001e+00
```

The value of a blackboard variable can be obtained using the **GETBB** command.

```
sac> getbb c1 c2
c1 = 2.45
c2 = 4.9000001e+00
```

Blackboard variables can also be saved in a disk file using

`WRITEBBF`

and later restored (`SAC2000`) using

`READBBF`.

There is also
a function called

`UNSETBBV`

which deletes a variable from the blackboard.

Header variables.

SAC header variables can also be evaluated and substituted directly in commands much like blackboard variables.

You must specify which file (by name or number) and which variable to be evaluated.

You must precede this specification with an ampersand ("&")
and you must separate the file and variable names with a comma.

Header variables.

The first example is referenced by file name, the second by file number.

```
sac> read ABC
sac> evaluate to temp1 &ABC,a + 10
sac> evaluate to temp2 &1,depmax * 2
sac> chnhdr t5 %temp1
sac> chnhdr user0 %temp2
```

Concatenation

To prepend simply concatenate the text string with the argument or variable.

```
sac> setbb temp BJT.BHZ.SAC
sac> w XYZ.%temp
XYZ.BJT.BHZ.SAC
```

Concatenation

To append you must repeat the delimiter ($, %, or &) after the argument or variable (surround the string you are appending with the delimiter) and before the text string.

```
sac> setbb temp BJT.BHZ.SAC
sac> w %temp%.XYZ
BJT.BHZ.SAC.XYZ
```

Using various programs to write SAC macros.

SAC macros are essentially just a set of SAC commands and therefore

you can create SAC macros using other programs

(shell scripts, Fortran, c, Matlab, etc.).

This shell script is in a file called **sta.csh**. The shell script runs sac independently for each file matching the name (*${sta}*z) and appends the output of the sac **listhdr** command to the **sta.log** file (loop in shell, not sac).

```
alpaca.ceri.memphis.edu668:> vi sta.csh
#!/usr/bin/csh
# Script to report b, e and t1 sac header values for a given
station
#  usage: sta.csh [NAME]
\rm sta.log
set sta=$1
foreach file ( *${sta}*BH* )
sac <<EOF >> sta.log
r $file
lh b e t1
q
EOF
end
```

```
alpaca.ceri.memphis.edu666:> sta.csh AREN
sta.log: No such file or directory
alpaca.ceri.memphis.edu667:> more sta.log
 SEISMIC ANALYSIS CODE [09/04/2008 (Version 101.2)]
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  FILE: AREN.BHE - 1
 --------------
     b = 7.400000e+04
     e = 7.600000e+04
 SEISMIC ANALYSIS CODE [09/04/2008 (Version 101.2)]
 Copyright 1995 Regents of the University of California
  FILE: AREN.BHN - 1
 --------------
     b = 7.400000e+04
     e = 7.600000e+04
 SEISMIC ANALYSIS CODE [09/04/2008 (Version 101.2)]
 Copyright 1995 Regents of the University of California
  FILE: AREN.BHZ - 1
 --------------
     b = 7.400000e+04
     e = 7.600000e+04
alpaca.ceri.memphis.edu668:> vi stainfo.csh
```

What is this awk line testing if if I apply it to the output of `sta.csh`?

```
awk '{if (/FILE/) f=$2; if ($1=="b") b=$3; if ($1=="e") e=$3; if
(/t1/ && $3>b && $3<e) \ print "r more",f}' sta.log
```

Using shell scripts to run SAC

```
#!/usr/bin/csh
foreach file ( *.SAC )
echo $file

sac << EOF >>! log
setbb eqname Sum_2002_EGF
setbb evlat 2.84
setbb evlon 95.38
setbb chg 6.002

r $file
setbb old &1,o
evaluate to new %old + %chg
ch o %new
ch evlo %evlon
ch evla %evlat
ch kevnm %eqname
wh
cut o 0 8000
r $file
setbb chg2 &1,o
ch allt -%chg2
w over
q
EOF

end
```

Prepare set of sac data (rename, cut)

```
carpincho:sacex smalley$ cp /Volumes/carpincho_TB/charge/data/2001.174*SAC .
carpincho:sacex smalley$ ls
2001.174.00.00.00.0010.YC.PENA.01.BHE.D.SAC  2001.174.00.00.00.0070.YC.CONS.01.BH2.D.SAC  2001.174.00.00.00.0140.YC.AMER.01.BH2.D.SAC
2001.174.00.00.00.0010.YC.PENA.01.BHN.D.SAC  2001.174.00.00.00.0070.YC.CONS.01.BH3.D.SAC  2001.174.00.00.00.0140.YC.AMER.01.BH3.D.SAC
2001.174.00.00.00.0010.YC.PENA.01.BHZ.D.SAC  2001.174.00.00.00.0070.YC.CONS.01.BHZ.D.SAC  2001.174.00.00.00.0140.YC.AMER.01.BHZ.D.SAC
2001.174.00.00.00.0030.YC.HURT.01.BHE.D.SAC  2001.174.00.00.00.0070.YC.RAFA.01.BHE.D.SAC  2001.174.00.00.00.0190.YC.ELBO.01.BHE.D.SAC
2001.174.00.00.00.0030.YC.HURT.01.BHN.D.SAC  2001.174.00.00.00.0070.YC.RAFA.01.BHN.D.SAC  2001.174.00.00.00.0190.YC.ELBO.01.BHN.D.SAC
2001.174.00.00.00.0030.YC.HURT.01.BHZ.D.SAC  2001.174.00.00.00.0070.YC.RAFA.01.BHZ.D.SAC  2001.174.00.00.00.0190.YC.ELBO.01.BHZ.D.SAC
2001.174.00.00.00.0030.YC.MAUL.01.BHE.D.SAC  2001.174.00.00.00.0100.YC.HEDI.01.BHE.D.SAC  2001.174.00.00.00.0240.YC.HUER.01.BHE.D.SAC
2001.174.00.00.00.0030.YC.MAUL.01.BHN.D.SAC  2001.174.00.00.00.0100.YC.HEDI.01.BHN.D.SAC  2001.174.00.00.00.0240.YC.HUER.01.BHN.D.SAC
2001.174.00.00.00.0030.YC.MAUL.01.BHZ.D.SAC  2001.174.00.00.00.0100.YC.HEDI.01.BHZ.D.SAC  2001.174.00.00.00.0240.YC.HUER.01.BHZ.D.SAC
2001.174.00.00.00.0040.YC.RINC.01.BHE.D.SAC  2001.174.00.00.00.0100.YC.JUAN.01.BHE.D.SAC  2001.174.00.00.00.0240.YC.LLAN.01.BHE.D.SAC
2001.174.00.00.00.0040.YC.RINC.01.BHN.D.SAC  2001.174.00.00.00.0100.YC.JUAN.01.BHN.D.SAC  2001.174.00.00.00.0240.YC.LLAN.01.BHN.D.SAC
2001.174.00.00.00.0040.YC.RINC.01.BHZ.D.SAC  2001.174.00.00.00.0100.YC.JUAN.01.BHZ.D.SAC  2001.174.00.00.00.0240.YC.LLAN.01.BHZ.D.SAC
2001.174.00.00.00.0050.YC.LITI.01.BHE.D.SAC  2001.174.00.00.00.0110.YC.PACH.01.BHE.D.SAC  2001.174.00.00.00.0240.YC.SJAV.01.BH2.D.SAC
2001.174.00.00.00.0050.YC.LITI.01.BHN.D.SAC  2001.174.00.00.00.0110.YC.PACH.01.BHN.D.SAC  2001.174.00.00.00.0240.YC.SJAV.01.BH3.D.SAC
2001.174.00.00.00.0050.YC.LITI.01.BHZ.D.SAC  2001.174.00.00.00.0110.YC.PACH.01.BHZ.D.SAC  2001.174.00.00.00.0240.YC.SJAV.01.BHZ.D.SAC
2001.174.00.00.00.0060.YC.AREN.01.BHE.D.SAC  2001.174.00.00.00.0120.YC.BARD.01.BHE.D.SAC  2001.174.17.25.50.2830.YC.ELBO.01.BHE.D.SAC
2001.174.00.00.00.0060.YC.AREN.01.BHN.D.SAC  2001.174.00.00.00.0120.YC.BARD.01.BHN.D.SAC  2001.174.17.25.50.2830.YC.ELBO.01.BHN.D.SAC
2001.174.00.00.00.0060.YC.AREN.01.BHZ.D.SAC  2001.174.00.00.00.0120.YC.BARD.01.BHZ.D.SAC  2001.174.17.25.50.2830.YC.ELBO.01.BHZ.D.SAC
2001.174.00.00.00.0060.YC.NIEB.01.BHE.D.SAC  2001.174.00.00.00.0130.YC.NEGR.01.BHE.D.SAC  2001.174.17.29.16.2900.YC.ELBO.01.BHE.D.SAC
2001.174.00.00.00.0060.YC.NIEB.01.BHN.D.SAC  2001.174.00.00.00.0130.YC.NEGR.01.BHN.D.SAC  2001.174.17.29.16.2900.YC.ELBO.01.BHN.D.SAC
2001.174.00.00.00.0060.YC.NIEB.01.BHZ.D.SAC  2001.174.00.00.00.0130.YC.NEGR.01.BHZ.D.SAC  2001.174.17.29.16.2900.YC.ELBO.01.BHZ.D.SAC
carpincho:sacex smalley$ rename.sh SAC 8 10
carpincho:sacex smalley$ ls
AMER.BH2        BARD.BHZ        HEDI.BHN        JUAN.BHE        LLAN.BHZ        NIEB.BHN        RAFA.BHE        SJAV.BHZ
AMER.BH3        CONS.BH2        HEDI.BHZ        JUAN.BHN        MAUL.BHE        NIEB.BHZ        RAFA.BHN
AMER.BHZ        CONS.BH3        HUER.BHE        JUAN.BHZ        MAUL.BHN        PACH.BHE        RAFA.BHZ
AREN.BHE        CONS.BHZ        HUER.BHN        LITI.BHE        MAUL.BHZ        PACH.BHN        RINC.BHE
AREN.BHN        ELBO.BHE        HUER.BHZ        LITI.BHN        NEGR.BHE        PACH.BHZ        RINC.BHN
AREN.BHZ        ELBO.BHN        HURT.BHE        LITI.BHZ        NEGR.BHN        PENA.BHE        RINC.BHZ
BARD.BHE        ELBO.BHZ        HURT.BHN        LLAN.BHE        NEGR.BHZ        PENA.BHN        SJAV.BH2
BARD.BHN        HEDI.BHE        HURT.BHZ        LLAN.BHN        NIEB.BHE        PENA.BHZ        SJAV.BH3
carpincho:sacex smalley$ sac
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SAC> cut 74000 76000
SAC> r *BHE* *BHN* *BHZ*
AREN.BHE BARD.BHE ELBO.BHE HEDI.BHE HUER.BHE HURT.BHE JUAN.BHE LITI.BHE LLAN.BHE MAUL.BHE NEGR.BHE NIEB.BHE PACH.BHE PENA.BHE RAFA.BHE RINC.BHE
AREN.BHN BARD.BHN ELBO.BHN HEDI.BHN HUER.BHN HURT.BHN JUAN.BHN LITI.BHN LLAN.BHN MAUL.BHN NEGR.BHN NIEB.BHN PACH.BHN PENA.BHN RAFA.BHN RINC.BHN
AMER.BHZ AREN.BHZ BARD.BHZ CONS.BHZ ELBO.BHZ HEDI.BHZ HUER.BHZ HURT.BHZ JUAN.BHZ LITI.BHZ LLAN.BHZ MAUL.BHZ NEGR.BHZ NIEB.BHZ PACH.BHZ PENA.BHZ
RAFA.BHZ RINC.BHZ SJAV.BHZ
 WARNING: Start cut greater than file end for file ELBO.BHE
 WARNING: Start cut greater than file end for file ELBO.BHN
 WARNING: Start cut greater than file end for file ELBO.BHZ
 WARNING: Unable to read some files  reading the rest of the files.
SAC> w over
```

```
carpincho:sacex smalley$ sac
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SAC> read *
AMER.BH2 AMER.BH3 AMER.BHZ AREN.BHE AREN.BHN AREN.BHZ BARD.BHE BARD.BHN BARD.BHZ CONS.BH2 CONS.BH3 CONS.BHZ ELBO.BHE ELBO.BHN ELBO.BHZ HEDI.BHE
HEDI.BHN HEDI.BHZ HUER.BHE HUER.BHN HUER.BHZ HURT.BHE HURT.BHN HURT.BHZ JUAN.BHE JUAN.BHN JUAN.BHZ LITI.BHE LITI.BHN LITI.BHZ LLAN.BHE LLAN.BHN
LLAN.BHZ MAUL.BHE MAUL.BHN MAUL.BHZ NEGR.BHE NEGR.BHN NEGR.BHZ NIEB.BHE NIEB.BHN NIEB.BHZ PACH.BHE PACH.BHN PACH.BHZ PENA.BHE PENA.BHN PENA.BHZ
RAFA.BHE RAFA.BHN RAFA.BHZ RINC.BHE RINC.BHN RINC.BHZ SJAV.BH2 SJAV.BH3 SJAV.BHZ
SAC> listhdr
  FILE: AMER.BH2 - 1
 --------------

      NPTS = 3455983                        B = 0.000000e+00
         E = 8.639955e+04                IFTYPE = TIME SERIES FILE
     LEVEN = TRUE                         DELTA = 2.500000e-02
      IDEP = UNKNOWN                     DEPMIN = -2.000632e+06
    DEPMAX = 2.115793e+06                DEPMEN = -6.740461e+02
    KZDATE = JUN 23 (174), 2001          KZTIME = 00:00:00.014
     KSTNM = AMER                         CMPAZ = 6.000000e+00
    CMPINC = 9.000000e+01                  STLA = -3.570000e+01
      STLO = -7.110487e+01                 STEL = 6.360000e+02
      STDP = 0.000000e+00                 KHOLE = 01
    LOVROK = TRUE                         NVHDR = 6
     SCALE = 1.048580e+09                 NORID = 0
     NEVID = 0                           LPSPOL = FALSE
    LCALDA = TRUE                        KCMPNM = BH2
    KNETWK = YC

SAC> chnhdr EVLA -16.27
SAC> chnhdr EVLO -73.64
SAC> listhdr
  FILE: AMER.BH2 - 1
 --------------

      NPTS = 3455983                        B = 0.000000e+00
         E = 8.639955e+04                IFTYPE = TIME SERIES FILE
     LEVEN = TRUE                         DELTA = 2.500000e-02
      IDEP = UNKNOWN                     DEPMIN = -2.000632e+06
    DEPMAX = 2.115793e+06                DEPMEN = -6.740461e+02
    KZDATE = JUN 23 (174), 2001          KZTIME = 00:00:00.014
     KSTNM = AMER                         CMPAZ = 6.000000e+00
    CMPINC = 9.000000e+01                  STLA = -3.570000e+01
      STLO = -7.110487e+01                 STEL = 6.360000e+02
      STDP = 0.000000e+00                  EVLA = -1.627000e+01
      EVLO = -7.364000e+01                KHOLE = 01
      DIST = 2.167411e+03                    AZ = 1.738032e+02
       BAZ = 3.526821e+02                 GCARC = 1.948290e+01
    LOVROK = TRUE                         NVHDR = 6
     SCALE = 1.048580e+09                 NORID = 0
     NEVID = 0                           LPSPOL = FALSE
    LCALDA = TRUE                        KCMPNM = BH2
    KNETWK = YC

SAC> wh
```

Read in sac files, list and change header, write headers.

```
carpincho:sacex smalley$ sac
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SAC> r AREN.BHE AREN.BHN
SAC> qdp off
SAC> p1
```
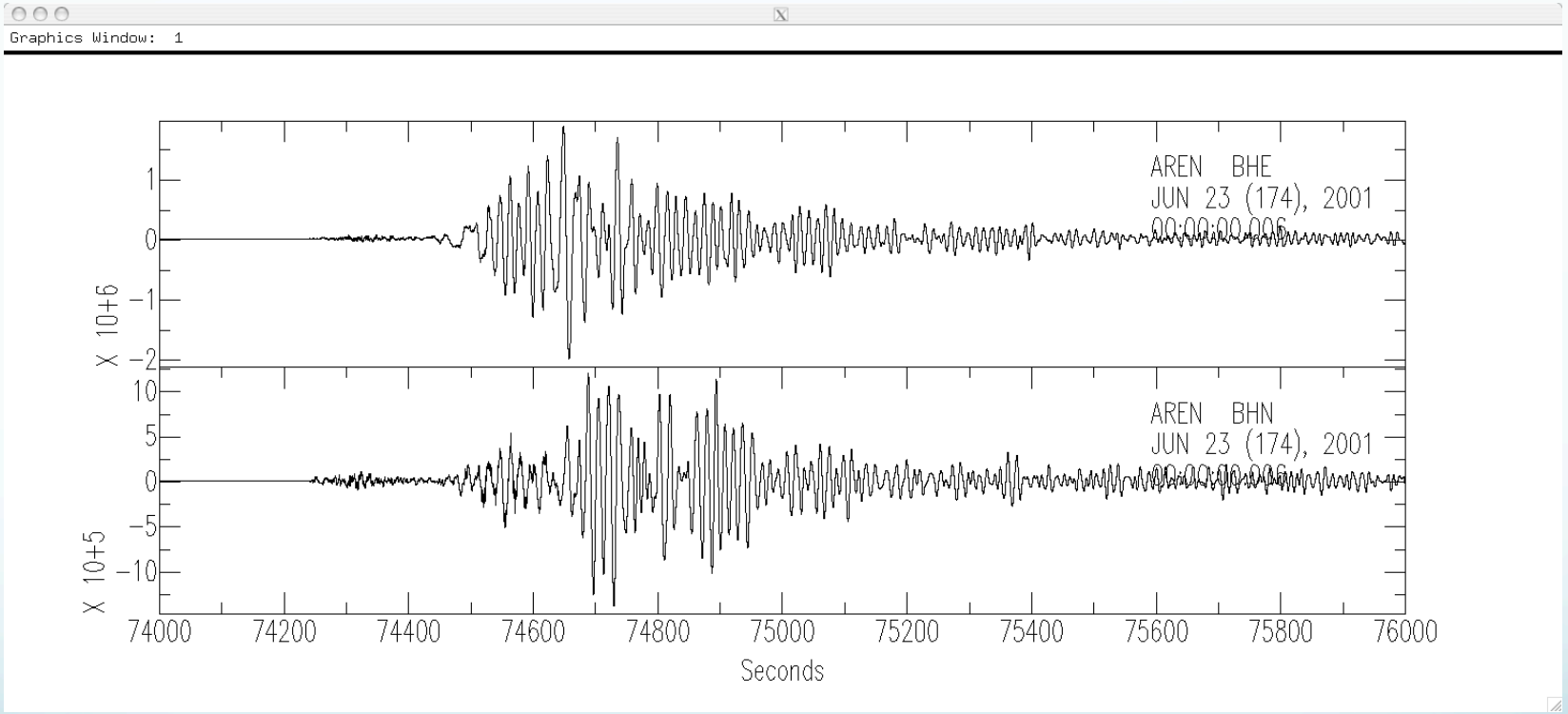
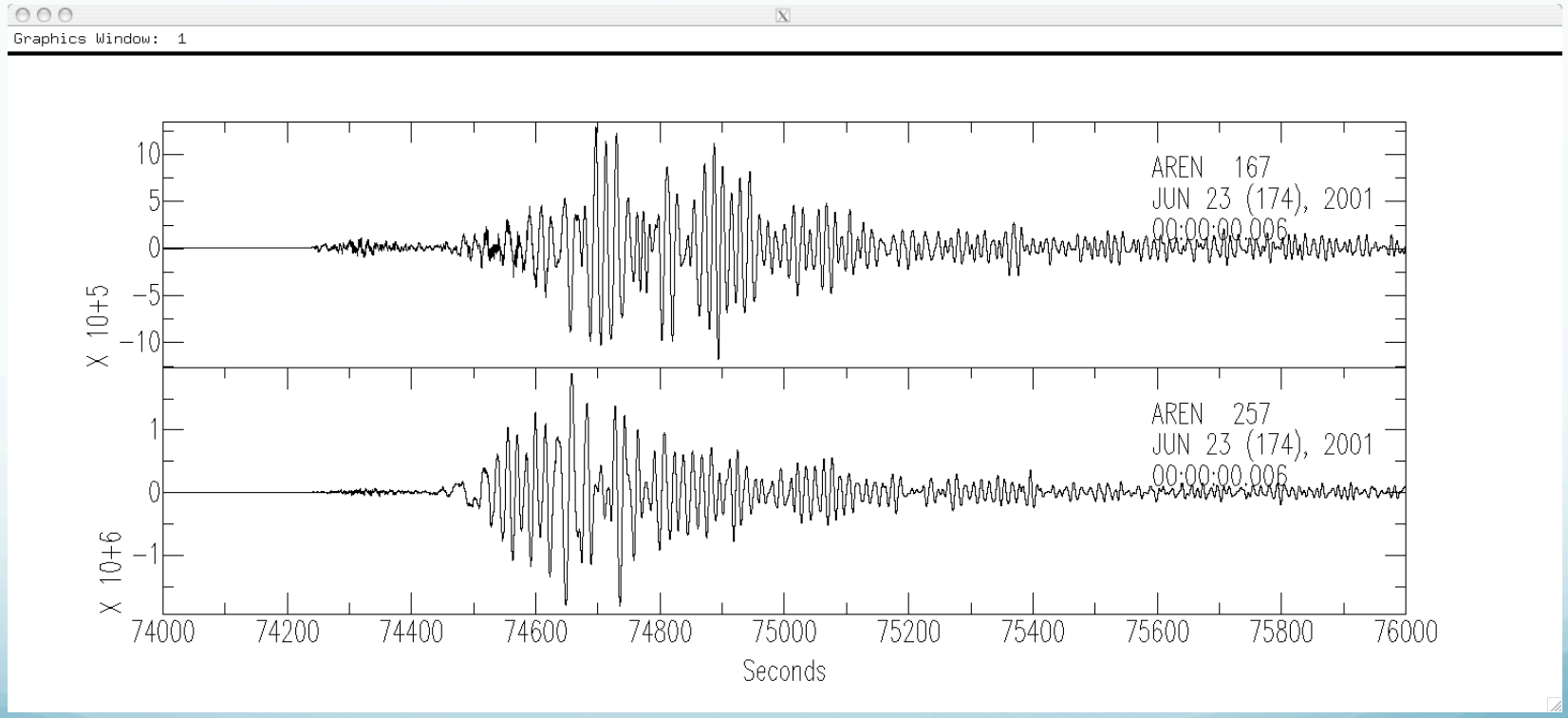

read in, plot horizontals



```
SAC> rotate to gca
SAC> p1
SAC> write
```

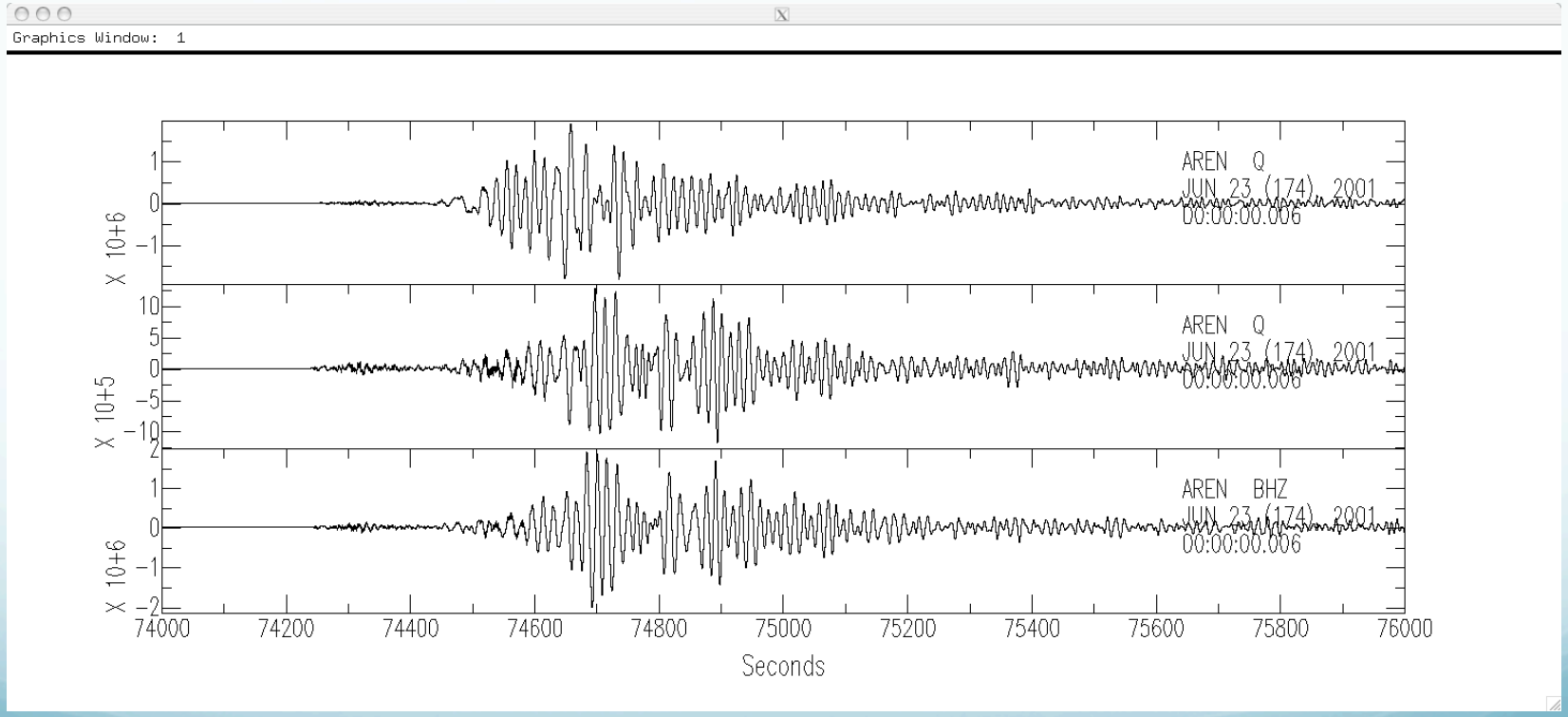
Rotate and save rotated seismograms to disk



```
SAC> read AREN.257 AREN.167 AREN.BHZ
SAC> p1
```

read in rotated seismograms (the 257 and 167) and vertical to show all 3

Notice love waves on top one and rayleigh waves (90° phase shift from vertical)



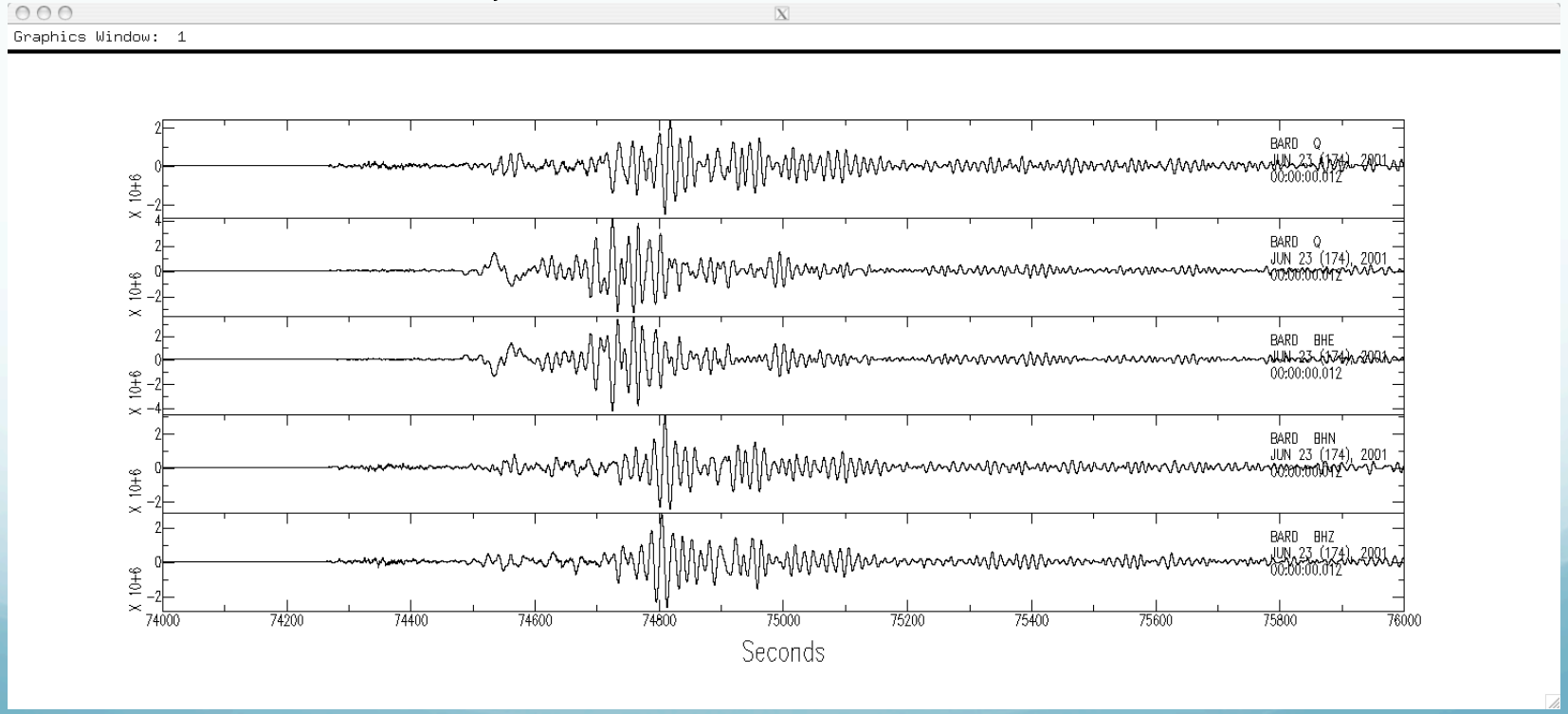
```
FILE: AREN.257 - 1
--------------

     NPTS = 80001                        B = 7.400000e+04
        E = 7.600000e+04                 IFTYPE = TIME SERIES FILE
    LEVEN = TRUE                         DELTA = 2.500000e-02
     IDEP = UNKNOWN                      DEPMIN = -1.824698e+06
   DEPMAX = 1.883052e+06                 DEPMEN = -8.282498e+03
   KZDATE = JUN 23 (174), 2001           KZTIME = 00:00:00.006
    KSTNM = AREN                         CMPAZ = 2.568291e+02
   CMPINC = 9.000000e+01                 STLA = -3.361547e+01
     STLO = -6.951091e+01                STEL = 2.786000e+03
     STDP = 0.000000e+00                 EVLA = -1.627000e+01
     EVLO = -7.364000e+01                KHOLE = 01
     DIST = 1.965666e+03                    AZ = 1.685817e+02
      BAZ = 3.468291e+02                 GCARC = 1.766853e+01
   LOVROK = TRUE                         NVHDR = 6
    SCALE = 4.194300e+08                 NORID = 0
    NEVID = 0                            NWFID = 15
   LPSPOL = TRUE                         LCALDA = TRUE
   KCMPNM = Q                            KNETWK = YC

 FILE: AREN.167 - 2
--------------

     NPTS = 80001                        B = 7.400000e+04
        E = 7.600000e+04                 IFTYPE = TIME SERIES FILE
    LEVEN = TRUE                         DELTA = 2.500000e-02
     IDEP = UNKNOWN                      DEPMIN = -1.190844e+06
   DEPMAX = 1.274883e+06                 DEPMEN = 3.710197e+02
   KZDATE = JUN 23 (174), 2001           KZTIME = 00:00:00.006
    KSTNM = AREN                         CMPAZ = 1.668291e+02
   CMPINC = 9.000000e+01                 STLA = -3.361547e+01
     STLO = -6.951091e+01                STEL = 2.786000e+03
     STDP = 0.000000e+00                 EVLA = -1.627000e+01
     EVLO = -7.364000e+01                KHOLE = 01
     DIST = 1.965666e+03                    AZ = 1.685817e+02
      BAZ = 3.468291e+02                 GCARC = 1.766853e+01
   LOVROK = TRUE                         NVHDR = 6
    SCALE = 4.194300e+08                 NORID = 0
    NEVID = 0                            NWFID = 31
   LPSPOL = TRUE                         LCALDA = TRUE
   KCMPNM = Q                            KNETWK = YC
```

cmpaz has azimuth of rotated traces

One is azimuth (radial), other is perpendicular (transverse)

```
SAC> READ BARD.BHE BARD.BHN
SAC> qdp off
SAC> p1
SAC> rotate to gcp
SAC> p1
SAC> write KSTCMP
SAC> ls
AMER.BH2        AREN.BHZ        CONS.BH3        HEDI.BHZ        JUAN.BHE        LLAN.BHN        NEGR.BHZ        PENA.BHE        RINC.BHN
AMER.BH3        BARD.168        CONS.BHZ        HUER.BHE        JUAN.BHN        LLAN.BHZ        NIEB.BHE        PENA.BHN        RINC.BHZ
AMER.BHZ        BARD.258        ELBO.BHE        HUER.BHN        JUAN.BHZ        MAUL.BHE        NIEB.BHN        PENA.BHZ        SJAV.BH2
AREN.167        BARD.BHE        ELBO.BHN        HUER.BHZ        LITI.BHE        MAUL.BHN        NIEB.BHZ        RAFA.BHE        SJAV.BH3
AREN.257        BARD.BHN        ELBO.BHZ        HURT.BHE        LITI.BHN        MAUL.BHZ        PACH.BHE        RAFA.BHN        SJAV.BHZ
AREN.BHE        BARD.BHZ        HEDI.BHE        HURT.BHN        LITI.BHZ        NEGR.BHE        PACH.BHN        RAFA.BHZ        saveorig
AREN.BHN        CONS.BH2        HEDI.BHN        HURT.BHZ        LLAN.BHE        NEGR.BHN        PACH.BHZ        RINC.BHE
SAC> read BARD*
BARD.168 BARD.258 BARD.BHE BARD.BHN BARD.BHZ
SAC> p1
```

Read in/plot all 5 after rotation



Do rotation with macro
Note filenames of rotated data

```
carpincho:sacex smalley$ more elbo.macro
read ELBO.BHE ELBO.BHN
rotate to gca
w KSTCMP
quit

carpincho:sacex smalley$ sac < elbo.macro
 SEISMIC ANALYSIS CODE [09/04/2008 (Version 101.2)]
 Copyright 1995 Regents of the University of California

carpincho:sacex smalley$ ls
AREN.167        BARD.258        ELBO.BHE        HUER.BHE        JUAN.BHE        LLAN.BHE        NEGR.BHE        PACH.BHE        RAFA.BHE        elbo.macro
AREN.257        BARD.BHE        ELBO.BHN        HUER.BHN        JUAN.BHN        LLAN.BHN        NEGR.BHN        PACH.BHN        RAFA.BHN
AREN.BHE        BARD.BHN        ELBO.BHZ        HUER.BHZ        JUAN.BHZ        LLAN.BHZ        NEGR.BHZ        PACH.BHZ        RAFA.BHZ
AREN.BHN        BARD.BHZ        HEDI.BHE        HURT.BHE        LITI.BHE        MAUL.BHE        NIEB.BHE        PENA.BHE        RINC.BHE
AREN.BHZ        ELBO.168        HEDI.BHN        HURT.BHN        LITI.BHN        MAUL.BHN        NIEB.BHN        PENA.BHN        RINC.BHN
BARD.168        ELBO.258        HEDI.BHZ        HURT.BHZ        LITI.BHZ        MAUL.BHZ        NIEB.BHZ        PENA.BHZ        RINC.BHZ
```

Use macro to rotate all seismograms in directory

```
carpincho:sacex smalley$ vi makerotatemacro.sh
#!/bin/sh
OUT=all.macro
STNNAMES=`ls *.BHZ | nawk 'BEGIN {FS="."}{print $1}'`
for stn in $STNNAMES
do
#echo process $stn
echo r $stn.BHE $stn.BHN >> $OUT
echo rotate to gcr >> $OUT
echo w KSTCMP >> $OUT
done
echo quit >> $OUT
sac < all.macro:wq
carpincho:sacex smalley$

carpincho:sacex smalley$ ls
AREN.BHE        HEDI.BHZ        LITI.BHN        NIEB.BHE        RAFA.BHZ
AREN.BHN        HUER.BHE        LITI.BHZ        NIEB.BHN        RINC.BHE
AREN.BHZ        HUER.BHN        LLAN.BHE        NIEB.BHZ        RINC.BHN
BARD.BHE        HUER.BHZ        LLAN.BHN        PACH.BHE        RINC.BHZ
BARD.BHN        HURT.BHE        LLAN.BHZ        PACH.BHN        all.macro
BARD.BHZ        HURT.BHN        MAUL.BHE        PACH.BHZ        elbo.macro
ELBO.BHE        HURT.BHZ        MAUL.BHN        PENA.BHE        huer.log
ELBO.BHN        JUAN.BHE        MAUL.BHZ        PENA.BHN        huer.macro
ELBO.BHZ        JUAN.BHN        NEGR.BHE        PENA.BHZ        makerotatemacro.sh
HEDI.BHE        JUAN.BHZ        NEGR.BHN        RAFA.BHE
HEDI.BHN        LITI.BHE        NEGR.BHZ        RAFA.BHN

carpincho:sacex smalley$ makerotatemacro.sh
 SEISMIC ANALYSIS CODE [09/04/2008 (Version 101.2)]
 Copyright 1995 Regents of the University of California

carpincho:sacex smalley$ ls
AREN.167        HEDI.BHE        JUAN.BHZ        NEGR.255        PENA.BHN
AREN.257        HEDI.BHN        LITI.171        NEGR.BHE        PENA.BHZ
AREN.BHE        HEDI.BHZ        LITI.261        NEGR.BHN        RAFA.165
AREN.BHN        HUER.154        LITI.BHE        NEGR.BHZ        RAFA.255
AREN.BHZ        HUER.244        LITI.BHN        NIEB.167        RAFA.BHE
BARD.168        HUER.BHE        LITI.BHZ        NIEB.257        RAFA.BHN
BARD.258        HUER.BHN        LLAN.154        NIEB.BHE        RAFA.BHZ
BARD.BHE        HUER.BHZ        LLAN.244        NIEB.BHN        RINC.157
BARD.BHN        HURT.168        LLAN.BHE        NIEB.BHZ        RINC.247
BARD.BHZ        HURT.258        LLAN.BHN        PACH.161        RINC.BHE
ELBO.168        HURT.BHE        LLAN.BHZ        PACH.251        RINC.BHN
ELBO.258        HURT.BHN        MAUL.171        PACH.BHE        RINC.BHZ
ELBO.BHE        HURT.BHZ        MAUL.261        PACH.BHN        all.macro
ELBO.BHN        JUAN.161        MAUL.BHE        PACH.BHZ        elbo.macro
ELBO.BHZ        JUAN.251        MAUL.BHN        PENA.165        huer.log
HEDI.160        JUAN.BHE        MAUL.BHZ        PENA.255        huer.macro
HEDI.250        JUAN.BHN        NEGR.165        PENA.BHE        makerotatemacro.sh
carpincho:sacex smalley$
```

```
carpincho:sacex smalley$ more all.macro
r AREN.BHE AREN.BHN
rotate to gcr
w KSTCMP
r BARD.BHE BARD.BHN
rotate to gcr
w KSTCMP
r ELBO.BHE ELBO.BHN
rotate to gcr
w KSTCMP
r HEDI.BHE HEDI.BHN
rotate to gcr
w KSTCMP
r HUER.BHE HUER.BHN
rotate to gcr
w KSTCMP
r HURT.BHE HURT.BHN
rotate to gcr
w KSTCMP
r JUAN.BHE JUAN.BHN
rotate to gcr
w KSTCMP
r LITI.BHE LITI.BHN
rotate to gcr
w KSTCMP
r LLAN.BHE LLAN.BHN
rotate to gcr
w KSTCMP
r MAUL.BHE MAUL.BHN
rotate to gcr
w KSTCMP
r NEGR.BHE NEGR.BHN
rotate to gcr
w KSTCMP
r NIEB.BHE NIEB.BHN
rotate to gcr
w KSTCMP
r PACH.BHE PACH.BHN
rotate to gcr
w KSTCMP
r PENA.BHE PENA.BHN
rotate to gcr
w KSTCMP
r RAFA.BHE RAFA.BHN
rotate to gcr
w KSTCMP
r RINC.BHE RINC.BHN
rotate to gcr
w KSTCMP
quit
```

Look at the sac macro written by the shell script

Use SAC macros to try to automate SAC as much as possible.

- Saves time if have to do it over and over.

- Documents what you did – you can reproduce it exactly.

Notice importance of

- Organization/structure

- Naming conventions

Take advantage of them to automate processing.

SAC subprocesses

Spectral Estimation Package – spe

Signal Stacking Subprocess – sss

http://www.iris.edu/software/sac/commands/spe.html

SAC subprocesses

A subprocess is effectively a small program within the main SAC program. You start a subprocess by typing its name (SPE in this case.)

You can terminate it and return to the main program using the

QUITSUB or QUIT

commands.

http://www.iris.edu/software/sac/commands/spe.html

SAC subprocesses

While within a subprocess, you can execute any command belonging to that subprocess plus a limited number of main SAC commands.

See the manual for the list of main SAC Commands executable from within either the SPE or SSS subprocess

http://www.iris.edu/software/sac/commands/spe.html

Spectral Estimation Package – SPE

SPE is a spectrum estimation package intended primarily for use with stationary random processes.

It contains three different spectral estimation techniques:

Power Density Spectra (PDS),
Maximum Likelihood Method (MLM), and
Maximum Entropy Method (MEM).

http://www.iris.edu/software/sac/commands/spe.html

SPE Commands

COR : Computes the correlation function.

MEM : Calculates the spectral estimate using Maximum Entropy Method.

MLM : Calculates the spectral estimate using Maximum Likelihood Method.

PDS : Calculates the spectral estimate using Power Density Spectra Method.

http://www.iris.edu/software/sac/commands/spe.html

SPE Commands

PLOTCOR : Plots the correlation function.

PLOTPE : Plots the RMS prediction error function.

PLOTSPE : Plots the spectral estimate.

http://www.iris.edu/software/sac/commands/spe.html

SPE Commands

READ : within **SPE** works the same as in the main **SAC** program with two exceptions.

First, only ONE file may be read in while in **SPE**.

Second, executing this command deletes any correlation function or spectral estimate that may already have been computed.

http://www.iris.edu/software/sac/commands/spe.html

SPE Commands

READ

Parameters within SPE, such as the number of prewhitening coefficients or the window type and length, are not changed when read is executed.

To reinitialize all SPE parameters, terminate the subprocess using the QUITSUB command and then start it over again.

http://www.iris.edu/software/sac/commands/spe.html

SPE Commands

WRITECOR : Writes a **SAC** file containing the correlation function.

WRITESPE : Writes a **SAC** file containing the spectral estimate. Their abbreviated names are also allowed.

http://www.iris.edu/software/sac/commands/spe.html

There are two primary differences between **SPE** and the main **SAC** program.

Only one data file can be processed by **SPE** at a time.

This is because **SPE** produces and stores a number of auxiliary functions (the correlation function, the prediction error function, and the spectral estimate itself) as it proceeds.

This restriction to a single data file may be removed in the future.

http://www.iris.edu/software/sac/commands/spe.html

The second difference is that, unlike **SAC** itself, there is a specific order or progression in which the commands are generally executed.

Initialization (done with **spe** command), read, correlation, estimation, termination

http://www.iris.edu/software/sac/commands/spe.html

Signal Stacking Subprocess – `sss`

primarily a package for doing signal stacking (i.e. summation or beamforming).

http://www.iris.edu/software/sac/commands/sss.html

SSS

Each signal (i.e. SAC file) has properties such as a static delay, epicentral distance, weighting factor, and polarity associated with it.

In addition, dynamic delays can be calculated using a normal moveout or refracted wave velocity model.

http://www.iris.edu/software/sac/commands/sss.html

SSS

Certain delay properties can be automatically incremented between summations.

Files are easily added to or removed from the stack file list.

The time window for the stack is easily adjusted.

http://www.iris.edu/software/sac/commands/sss.html

SSS

Files which do not contain data throughout the stack time window are filled with zeros.

The stack file list can be plotted with or without the summation.

Each summation can be saved on disk for later use.

http://www.iris.edu/software/sac/commands/sss.html

sss

A record section plot is also included in this subprocess.

http://www.iris.edu/software/sac/commands/sss.html

SSS Commands (in alphabetical order)

ADDSTACK : Add a new file to the stack file list.

CHANGESTACK : Change properties of files currently in the stack file list.

DELETESTACK : Deletes one or more files from the stack file list.

DELTACHECK : Change the sampling rate checking option.

http://www.iris.edu/software/sac/commands/sss.html

SSS Commands

DISTANCEAXIS : Define the record section plot distance axis parameters.

DISTANCEWINDOW : Controls distance window properties on subsequent record section plots.

GLOBALSTACK : Sets global stack properties.

INCREMENTSTACK : Increments properties for files in the stack file list.

http://www.iris.edu/software/sac/commands/sss.html

SSS Commands

LISTSTACK : Lists the properties of the files in the stack file list.

PLOTRECORDSECTION : Plots a record section of the files in the stack file list.

PLOTSTACK : Plots the files in the stack file list.

http://www.iris.edu/software/sac/commands/sss.html

SSS Commands

QUITSUB or **QUIT** : Terminates the Signal Stacking Subprocess.

SUMSTACK : Sums the files in the stack file list.

TIMEAXIS : Controls the time axis properties on subsequent record section plots.

TIMEWINDOW : Sets the time window limits for subsequent stack summation.

http://www.iris.edu/software/sac/commands/sss.html

SSS Commands

TRAVELTIME : Computes traveltime curves for pre-defined models or reads traveltime curves from ascii text files.

VELOCITYMODEL : Sets stack velocity model parameters for computing dynamic delays.

VELOCITYROSET : Controls placement of a velocity roset on subsequent record section plots.

http://www.iris.edu/software/sac/commands/sss.html

SSS Commands

WRITESTACK : Writes a stack summation to disk.

ZEROSTACK : Zeros or reinitializes the signal stack.

http://www.iris.edu/software/sac/commands/sss.html

Returning to example using data from the Maule earthquake.

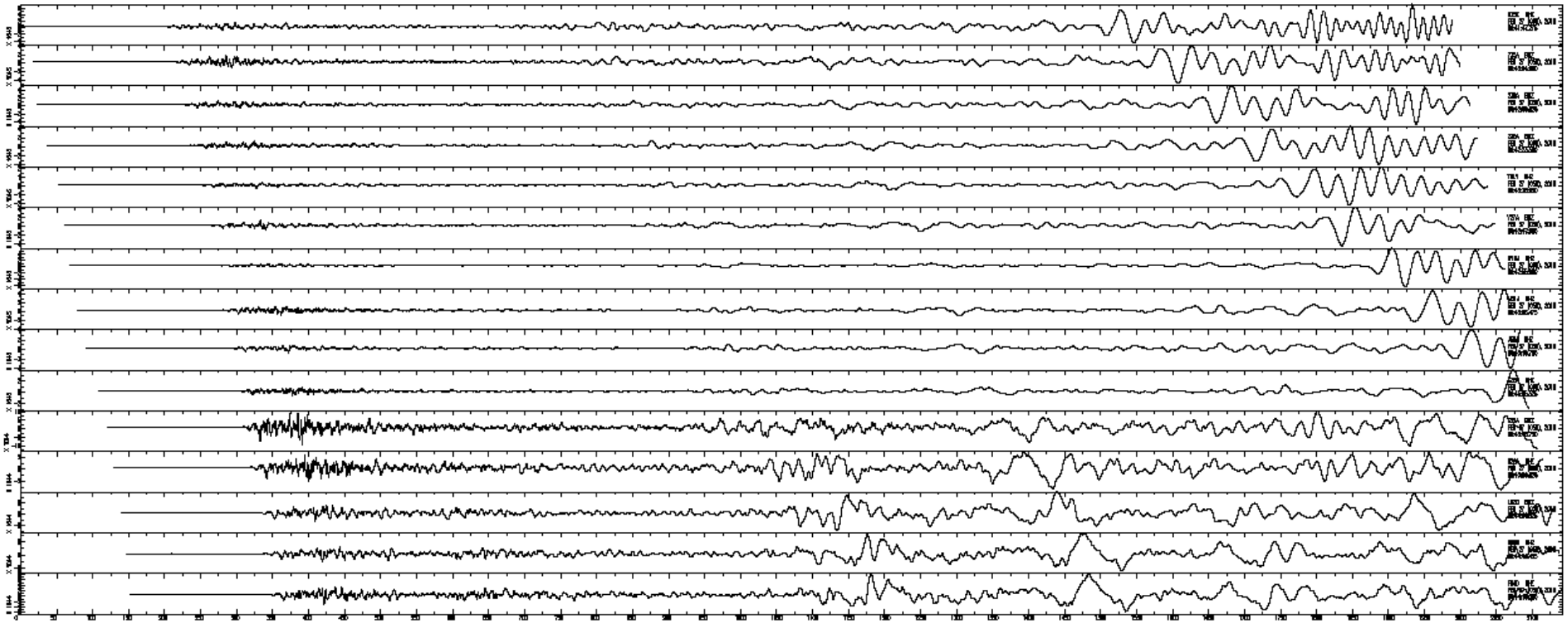
Convert SEED file obtained from IRIS DMC to a SAC file using `rdseed`.

```
Robert-Smalleys-MacBook-Pro:-bash:sac_sample_data:520 $ rdseed
<< IRIS SEED Reader, Release 4.7.5  >>
Input  File (/dev/nrst0) or 'Quit' to Exit: maule.seed
Output File (stdout)     :
Volume #  [(1)-N]   :
Options [acCsSpRtde]     : d
Summary file (None) :
Station List (ALL)  :
Channel List (ALL)  :
Network List (ALL)  :
Loc Ids (ALL ["--" for spaces])    :
Output Format [(1=SAC), 2=AH, 3=CSS, 4=mini seed, 5=seed, 6=sac ascii, 7=SEGY] : 1
Output file names include endtime? [Y/(N)]
Output poles & zeroes ? [Y/(N)]y
Check Reversal [(0=No), 1=Dip.Azimuth, 2=Gain, 3=Both]:
Select Data Type [(E=Everything), D=Data of Undetermined State, R=Raw waveform Data, Q=QC'd
data] :
Start Time(s) YYYY,DDD,HH:MM:SS.FFFF :
End Time(s)   YYYY,DDD,HH:MM:SS.FFFF :
Sample Buffer Length [2000000]:
Extract Responses [Y/(N)]     : y
Writing TA.035Z..BHE, 79494 samples (binary), starting 2010,058 06:41:50.2750 UT
Writing TA.035Z..BHN, 79511 samples (binary), starting 2010,058 06:41:50.1500 UT
…
Input  File (/dev/nrst0) or 'Quit' to Exit: Quit
Robert-Smalleys-MacBook-Pro:-bash:sac_sample_data:521 $ ls
```

```
Robert-Smalleys-MacBook-Pro:-bash:sac_sample_data:521 $ ls
2010.058.06.41.47.2750.TA.035Z..BHZ.R.SAC                   RESP.TA.J30A..BHE
2010.058.06.41.50.1500.TA.035Z..BHN.R.SAC                   RESP.TA.J30A..BHN
2010.058.06.41.50.2750.TA.035Z..BHE.R.SAC                   RESP.TA.J30A..BHZ
2010.058.06.41.58.6750.TA.735A..BHN.R.SAC                   RESP.TA.L02D..BHE
2010.058.06.42.00.2000.TA.735A..BHE.R.SAC                   RESP.TA.L02D..BHN
2010.058.06.42.04.9000.TA.735A..BHZ.R.SAC                   RESP.TA.L02D..BHZ
2010.058.06.42.09.8250.TA.239A..BHZ.R.SAC                   RESP.TA.M31A..BHE
2010.058.06.42.16.1750.TA.239A..BHN.R.SAC                   RESP.TA.M31A..BHN
2010.058.06.42.16.3500.TA.239A..BHE.R.SAC                   RESP.TA.M31A..BHZ
2010.058.06.42.20.1250.TA.Z35A..BHN.R.SAC                   RESP.TA.TUL1..BHE
2010.058.06.42.20.9750.TA.Z35A..BHE.R.SAC                   RESP.TA.TUL1..BHN
2010.058.06.42.23.5000.TA.Z35A..BHZ.R.SAC                   RESP.TA.TUL1..BHZ
2010.058.06.42.30.9750.TA.TUL1..BHN.R.SAC                   RESP.TA.V27A..BHE
2010.058.06.42.36.6000.TA.TUL1..BHE.R.SAC                   RESP.TA.V27A..BHN
2010.058.06.42.38.9500.TA.TUL1..BHZ.R.SAC                   RESP.TA.V27A..BHZ
2010.058.06.42.39.8000.TA.V27A..BHE.R.SAC                   RESP.TA.W18A..BHE
2010.058.06.42.47.9500.TA.V27A..BHZ.R.SAC                   RESP.TA.W18A..BHN
2010.058.06.42.50.0250.TA.V27A..BHN.R.SAC                   RESP.TA.W18A..BHZ
2010.058.06.42.54.5250.TA.W18A..BHN.R.SAC                   RESP.TA.Z35A..BHE
2010.058.06.42.55.9000.TA.W18A..BHZ.R.SAC                   RESP.TA.Z35A..BHN
2010.058.06.43.01.0250.TA.W18A..BHE.R.SAC                   RESP.TA.Z35A..BHZ
2010.058.06.43.06.4750.TA.M31A..BHZ.R.SAC                   SAC_PZs_TA_035Z_BHE__2010.009.00.00.00.0000_99999.9999.24.60.60.99999
2010.058.06.43.07.0000.TA.M31A..BHN.R.SAC                   SAC_PZs_TA_035Z_BHN__2010.009.00.00.00.0000_99999.9999.24.60.60.99999
```

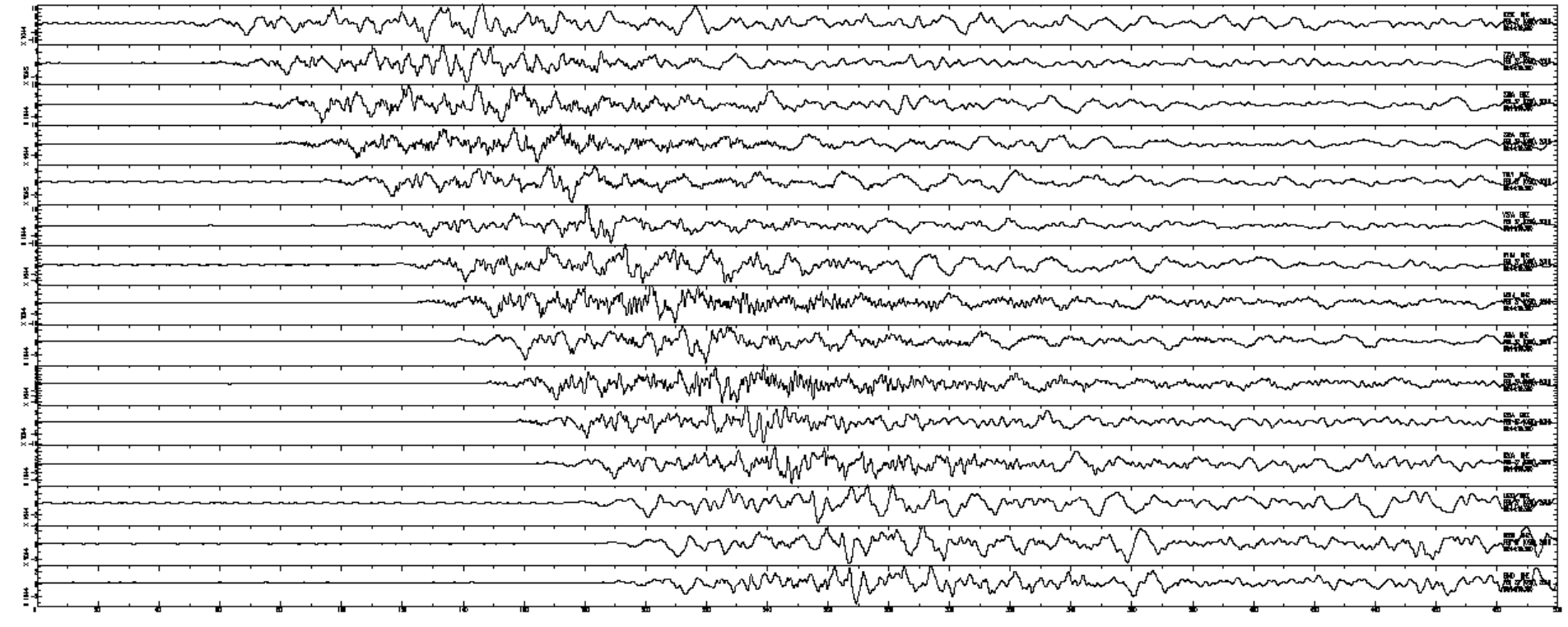
The names are a bit unwieldy (but leave for now)

```
Robert-Smalleys-MacBook-Pro:-bash:sac_sample_data:522 $ sac
 SEISMIC ANALYSIS CODE [07/29/2009 (Version 101.3)]
 Copyright 1995 Regents of the University of California

SAC> read *BHZ*SAC
SAC> read *BHZ*SAC
2010.058.06.41.47.2750.TA.035Z..BHZ.R.SAC 2010.058.06.42.04.9000.TA.735A..BHZ.R.SAC
2010.058.06.42.09.8250.TA.239A..BHZ.R.SAC 2010.058.06.42.23.5000.TA.Z35A..BHZ.R.SAC
2010.058.06.42.38.9500.TA.TUL1..BHZ.R.SAC 2010.058.06.42.47.9500.TA.V27A..BHZ.R.SAC
2010.058.06.42.55.9000.TA.W18A..BHZ.R.SAC 2010.058.06.43.06.4750.TA.M31A..BHZ.R.SAC
2010.058.06.43.18.7500.TA.J30A..BHZ.R.SAC 2010.058.06.43.35.5250.TA.G28A..BHZ.R.SAC
2010.058.06.43.48.7500.TA.E25A..BHZ.R.SAC 2010.058.06.43.56.8250.TA.D20A..BHZ.R.SAC
2010.058.06.44.06.8250.TA.L02D..BHZ.R.SAC 2010.058.06.44.14.4250.TA.G03D..BHZ.R.SAC
2010.058.06.44.19.3000.TA.F04D..BHZ.R.SAC
SAC> qdp off
SAC> p1
```



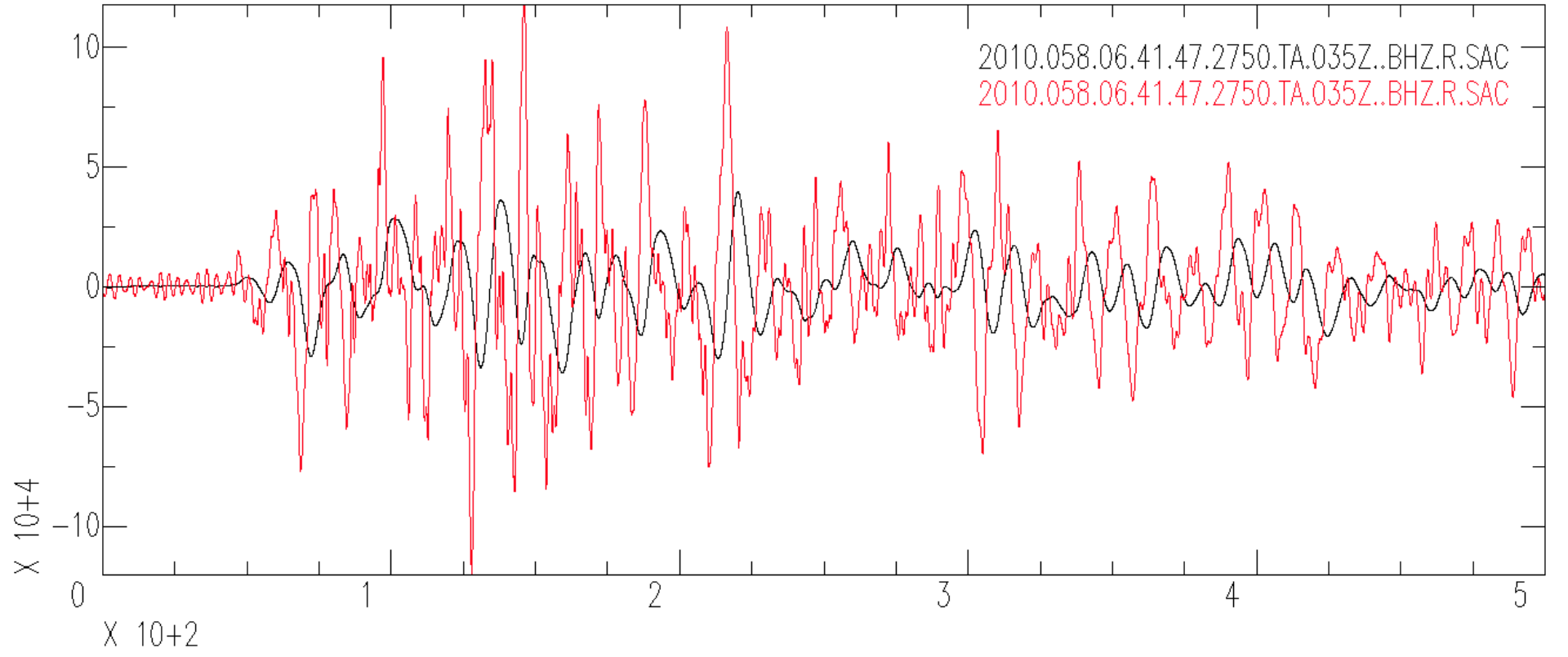
In SAC

read
synch
write headers (now the headers in the disk files are compatible)
cut (is with respect to time zero after the synch)
read again
xlim (to zoom in on beginning)



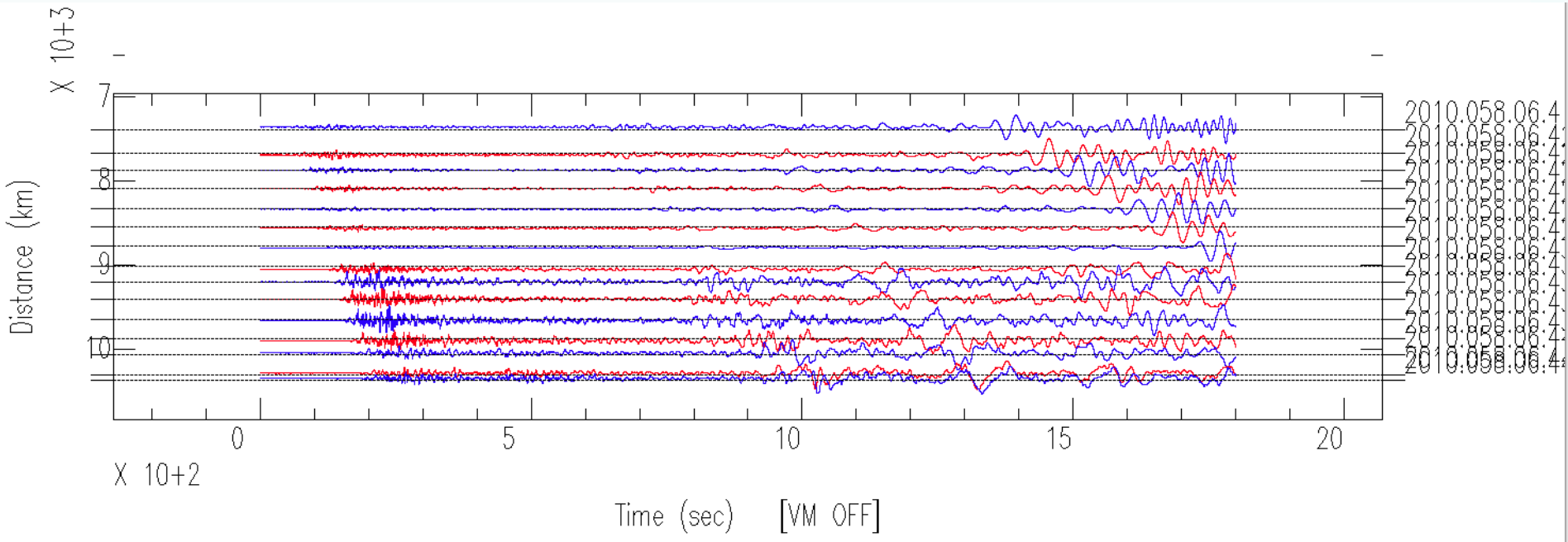
In SAC

low pass filter
reread
color on increment on
plot2


2010.058.06.41.47.2750.TA.035Z..BHZ.R.SAC
2010.058.06.41.47.2750.TA.035Z..BHZ.R.SAC
10
5
0
−5
−10
X 10+4
0
1
2
3
4
5
X 10+2

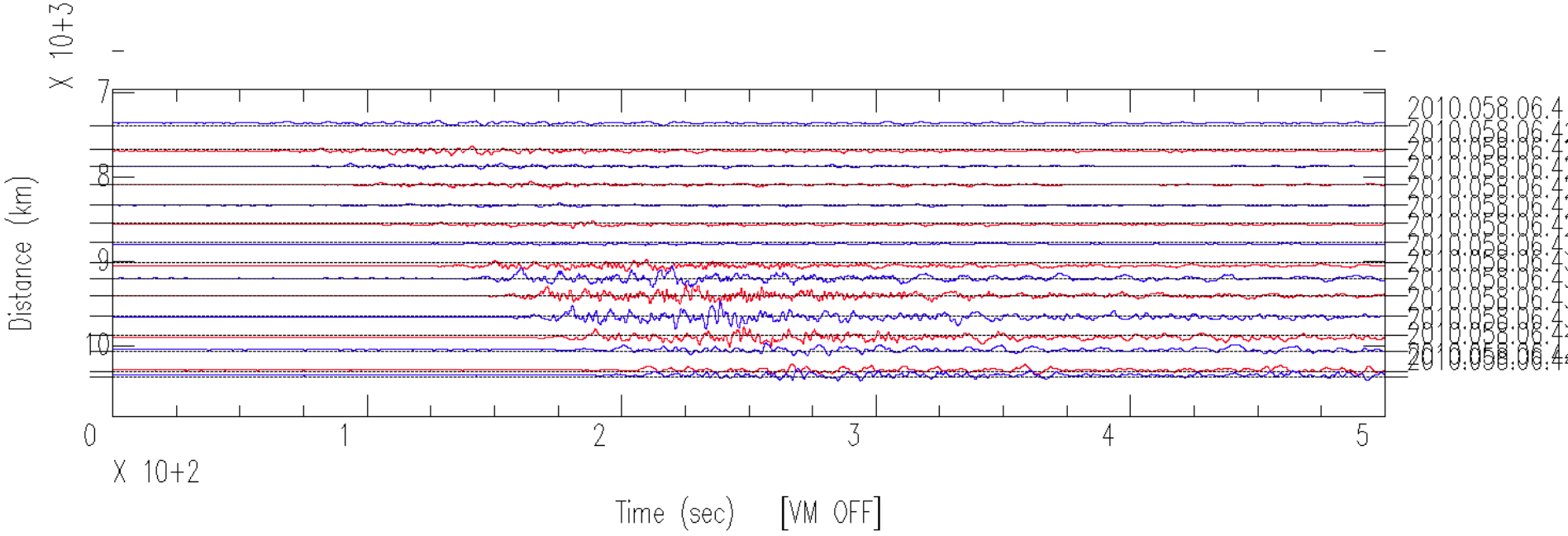
Signal Stacking Subprocess

plotrecordsection



Signal Stacking Subprocess

timewindow (not xlim)



Signal Stacking Subprocess

Record section with reduction velocity