Workshop on Geophysical Data Analysis and Assimilation

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**Frequency-time analysis & Moment Tensor Inversion programs
(tutorial)**

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**Frequency-time analysis
& Moment Tensor Inversion programs**

(tutorial)

Your first actions after 1-st login:

Enter $HOME directory and execute script /**opt/fmt/structdir**.

A structure of directories will be created in your $HOME. Directories Tohoku2012 and

Sumatra_12_04_2012 with needed subdirectories and files correspond to the earthquakes

which will be studied during the exercises.

Close the console.

I. Tohoku earthquake, 11.03.2011, $M_w = 9.1$

1. Floating filtering of records

1.1. Enter directory $HOME/Tohoku2012/FTAN
1.2. Execute command:
> **ftan**

1.3. *New/Open* start.
Click on *New* tab window will appear
Brows:
> $HOME/Tohoku2012/DB/Wilber_LH.wfdisc
> $HOME/Tohoku2012/DB/Wilber_LH.instrument
> $HOME/Tohoku2012/DB/Wilber_LH.origin

Click on OK. Start window will disappear.

1.4. Click button and assign following bandpass filtering parameters:
short period zero = 150, short period corner = 170, long period corner = 530, long period zero = 550.

1.5. Click button and assign following bounds for FTAN diagram:
group velocity from 2 to 8, periods from 150 to 550.

1.6. Until you didn't select a station and a channel to be processed the light of semaphore button is
red . Click on '+' near selected station, available channels will appear. Click on one of them.
The semaphore light will change to yellow . The program is ready for processing of selected
seismograms. Click on semaphore button. The semaphore light will change to green , and
selected waveforms will be plotted.

1.7. To apply bandpass filtering click on the button .

1.8. Click on the button to view FTAN maps for selected components and to make floating
filtering (see an example of processing below and reference dispersion curves shown on the last
page of this tutorial).

1.9. Clicking correspondent button view the results of processing:

 - View calculated group velocity curves.

 - View cleaned and raw amplitude spectra.

 - View estimated polarization anomalies.

 - View cleaned and raw seismograms.

 - View a FTAN diagrams for cleaned and raw records.

1.10. To save results click the button . The **Save Records Dialog** will appear.
Click component toggle buttons required to be saved. Click OK button to save records.

1.11. Select next station-channel. Button changes green color to yellow and you can work
with new selection.

1.12. After you finished the processing of all records push the button to save results.
The **Save Location As Dialog** will be invoked for selection of directory name. Click the 'Create
New Folder' toolbar button to create a new directory (mentioned further as **FLT**).

Note: The results can be saved by pushing the button ![save] after any seismogram's processing is finished. It is recommended to save the results few times during the session.

Recommended components to be saved and correspondent period ranges for floating filtering:

Record	Tmin	Tmax
HRVT	200	500
HRVZ	200	500
SLBST	200	500
SLBSZ	200	500
PPTFT	230	500
PPTFZ	200	500
SNZOT	200	500
SNZOZ	200	500
PAFT	200	500
PAFZ	200	500
RERT	200	500
RERZ	200	500
LSZT	200	500
LSZZ	200	500
TAMT	200	500
TAMZ	200	500

Map, centered at 37.680000:143.029999
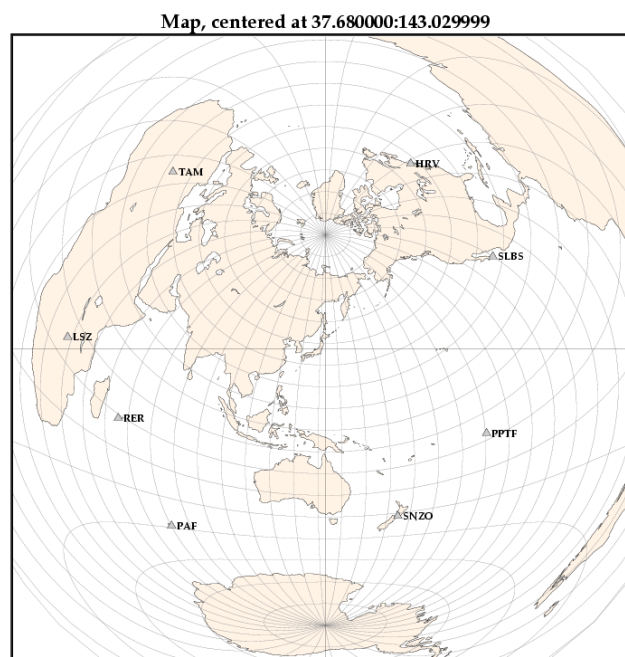
3. Moment Tensor & Source Depth Inversion.

2.1. Enter directory $HOME/Tohoku2012/MomTens.

2.2. Execute command **MomTens**. The main window of the program will appear.

2.3. Push button ![icon] to start a New Project.

Define Project Directory -   type Project Name (**Inversion** for example);

Filtered Wave Form Disc DB Name -   browse directory $HOME/Tohoku2012/FTAN/FLT (if you saved the directory with results of floating filtering under name **FLT**), and click **table.wfdisc**.

Instrument, Site, Sensor DB Root Names - browse directory HOME/ Tohoku2012/DB and click on 'Wilber_LH.site' for example

Origin Info Event Db Name   - browse directory HOME/ Tohoku2012/DB and click on 'Wilber_LH.origin'

Note: Next time you can just use ![folder icon] to open Project Name **Inversion**, if you have saved it.

2.4. To select records to be used for the inversion push button ![waveform icon] . In this example all the records are recommended to be used, so push button 'OK'.

2.5. Push button ![αβρ icon]
Click on the button '3SMAC MODEL' – the structure models for all stations will be calculated.

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Click on the 'Crust2_0' model in the left column. Click on the button 'Get Source Model from' and on radio button 'Model list' at the bottom . Click 'OK'.

2.6. Push button .

During filtering by FTAN program you determined for every wave the spectral domain where the signal is of a good quality. It is given by maximum and minimum periods on the page 4. Type these period values in the text boxes "T min" and "T max" in the uppermost left part of the window. During typing the cursor must be situated in the text box. To associate this pair of values to any record click on the correspondent record name.

Parameters to be given in the right frame (Spectral rage):

Tmin=300, Tmax=500, Nw=15 points FFT = 32768

Type in the text box "T min" at the bottom 300.

Push 'Get' button. Click 'OK'.

2.7. Push button .
Recommended grid characteristics:
6.0	-	Initial Depth
5.0	-	Depth Step
19	-	Number of Depth Values
45.0	-	Initial Dip
5.0	-	Dip Step
10	-	Number of Dip Values
0.0	-	Initial Strike
5.0	-	Strike Step
37	-	Number of Strike Values
0.0	-	Initial Slip
5.0	-	Slip Step
37	-	Number of Slip Values

2.8. Push the button   to start the inversion.

 2.9. View of results:

  Viewing the results.

Perform the inversion with focal mechanism angles' step equal to 3 degrees instead of 5.

Repeat 2.1-2.9 with following differences:

(a) Type different from the first one project name in 2.3 (**Inversion1** for example)

(b) Type following values in 2.7:

2.7. Push button .

Recommended grid characteristics:

6.0	-	Initial Depth
5.0	-	Depth Step
19	-	Number of Depth Values
45.0	-	Initial Dip
3.0	-	Dip Step
16	-	Number of Dip Values
0.0	-	Initial Strike
3.0	-	Strike Step
61	-	Number of Strike Values
0.0	-	Initial Slip
3.0	-	Slip Step
61	-	Number of Slip Values

I. Sumatra earthquake, 11.04.2012, M_w = 8.6

1. Floating filtering of records

1.3. Enter directory $HOME/Sumatra_11_04_2012/FTAN

1.4. Execute command:

ftan

1.3. *New/Open* start.

Click on *New* tab window will appear

Brows:

$HOME/ Sumatra_11_04_2012/DB/ Sumatra.wfdisc

$HOME/ Sumatra_11_04_2012/DB/ Sumatra.instrument

$HOME/ Sumatra_11_04_2012/DB/ Sumatra.origin

Click on OK. Start window will disappear.

1.6. Click button ![icon] and assign following bandpass filtering parameters:
short period zero = 100, short period corner = 125, long period corner = 350, long period zero = 400.

1.7. Click button ![icon] and assign following bounds for FTAN diagram:
group velocity from 2 to 6, periods from 100 to 400.

1.6. Until you didn't select a station and a channel to be processed the light of semaphore button is
red ![icon]. Click on '+' near selected station, available channels will appear. Click on one of them.
The semaphore light will change to yellow ![icon]. The program is ready for processing of selected
seismograms. Click on semaphore button. The semaphore light will change to green ![icon], and
selected waveforms will be plotted.

1.7. To apply bandpass filtering click on the button ![icon].

1.8. Click on the button ![icon] to view FTAN maps for selected components and to make floating
filtering (see an example of processing below and reference dispersion curves shown on the last
page of this tutorial).

1.9. Clicking correspondent button view the results of processing:

![icon] - View calculated group velocity curves.

![icon] - View cleaned and raw amplitude spectra.

![icon] - View estimated polarization anomalies.

![icon] - View cleaned and raw seismograms.

![icon] - View a FTAN diagrams for cleaned and raw records.

1.10. To save results click the button ![icon]. The **Save Records Dialog** will appear.
Click component toggle buttons required to be saved. Click OK button to save records.

1.11. Select next station-channel. Button ![icon] changes green color to yellow ![icon] and you can work
with new selection.

1.12. After you finished the processing of all records push the button ![icon] to save results.
The **Save Location As Dialog** will be invoked for selection of directory name. Click the 'Create
New Folder' toolbar button ![icon] to create a new directory (mentioned further as **FLT**).

Note: The results can be saved by pushing the button after any seismogram's processing is finished. It is recommended to save the results few times during the session.

Recommended components to be saved and correspondent period ranges for floating filtering:

Record	Tmin	Tmax
UNMT	200	300
UNMZ	200	250
INUT	200	300
INUZ	200	300
KIPT	200	300
KIPZ	200	300
PPTFT	200	300
PPTFZ	200	250
CANT	200	300
CANZ	200	300
PAFT	200	300
PAFZ	200	300
RERT	200	300
RERZ	200	300
TAMT	200	300
TAMZ	200	300
FDFT	200	300
FDFZ	200	300
SSBT	200	300
SSBZ	200	300
IVIT	200	300
IVIZ	200	300

Map, centered at 2.348000:93.071999
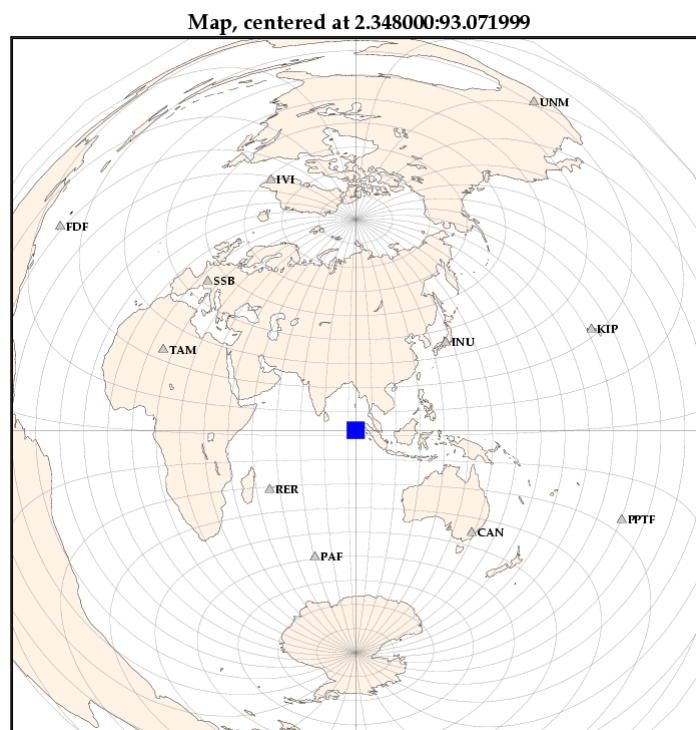
3. Moment Tensor & Source Depth Inversion.

2.1. Enter directory $HOME/Sumatra_11_04_2012/MomTens.

2.2. Execute command **MomTens**. The main window of the program will appear.

2.3. Push button to start a New Project.

Define Project Directory -   type Project Name (**Inversion** for example);

Filtered Wave Form Disc DB Name -   browse directory $HOME/Sumatra_11_04_2012/FTAN/FLT (if you saved the directory with results of floating filtering under name **FLT**), and click **table.wfdisc**.

Instrument, Site, Sensor DB Root Names - browse directory HOME/Sumatra_11_04_2012/DB and   click on 'Sumatra.site' for example

Origin Info Event Db Name   - browse directory HOME/Sumatra_11_04_2012/DB and   click on 'Sumatra.origin'

Note: Next time you can just use to open Project Name **Inversion**, if you have saved it.

2.4. To select records to be used for the inversion push button ![wave icon] . In this example all the records are recommended to be used, so push button 'OK'.

2.5. Push button ![αβρ icon]
Click on the button '3SMAC MODEL' – the structure models for all stations will be calculated. Click on the button 'Get Source Model from' and on radio button '3SMAC' at the bottom . Click 'OK'.

2.6. Push button ![ω icon] .

During filtering by FTAN program you determined for every wave the spectral domain where the signal is of a good quality. It is given by maximum and minimum periods on the page 8. Type these period values in the text boxes "T min" and "T max" in the uppermost left part of the window. During typing the cursor must be situated in the text box. To associate this pair of values to any record click on the correspondent record name.

Parameters to be given in the right frame (Spectral rage):

Tmin=200, Tmax=300, Nw=15 points FFT = 32768

Type in the text box "T min" at the bottom 200.

Push 'Get' button. Click 'OK'.

2.7. Push button ![cube icon].
Recommended grid characteristics:
  0.0   -   Initial Depth
  5.0   -   Depth Step
 21   -   Number of Depth Values
45.0   -   Initial Dip
  5.0   -   Dip Step
  10   -   Number of Dip Values
  0.0   -   Initial Strike
  5.0   -   Strike Step
  37   -   Number of Strike Values
  0.0   -   Initial Slip
  5.0   -   Slip Step
  37   -   Number of Slip Values

2.8. Push the button ![wave+ icon] to perform the selection of polarity data, and confirm by pushing OK

2.9. Push the button ![wand icon] to start the inversion.

 2.10.View of results:

![RESULTS icon] Viewing the results.

Perform the inversion with focal mechanism angles' step equal to 3 degrees instead of 5.

Repeat 2.1-2.10 with following differences:

(a) Type different from the first one project name in 2.3 (**Inversion1** for example).

(b) Type following values in 2.7:

2.7. Push button .
Recommended grid characteristics:

0.0	-	Initial Depth
5.0	-	Depth Step
21	-	Number of Depth Values
45.0	-	Initial Dip
3.0	-	Dip Step
16	-	Number of Dip Values
0.0	-	Initial Strike
3.0	-	Strike Step
61	-	Number of Strike Values
0.0	-	Initial Slip
3.0	-	Slip Step
61	-	Number of Slip Values

Example of processing performance

Until you didn't select a station and a channel to be processed the light of semaphore button is red ▮. Click on '+' near selected station, available channels will appear. Click on one of them. The semaphore light will change to yellow ▮. The program is ready for processing of selected seismograms. Click on semaphore button. The semaphore light will change to green ▮, and selected waveforms will be plotted
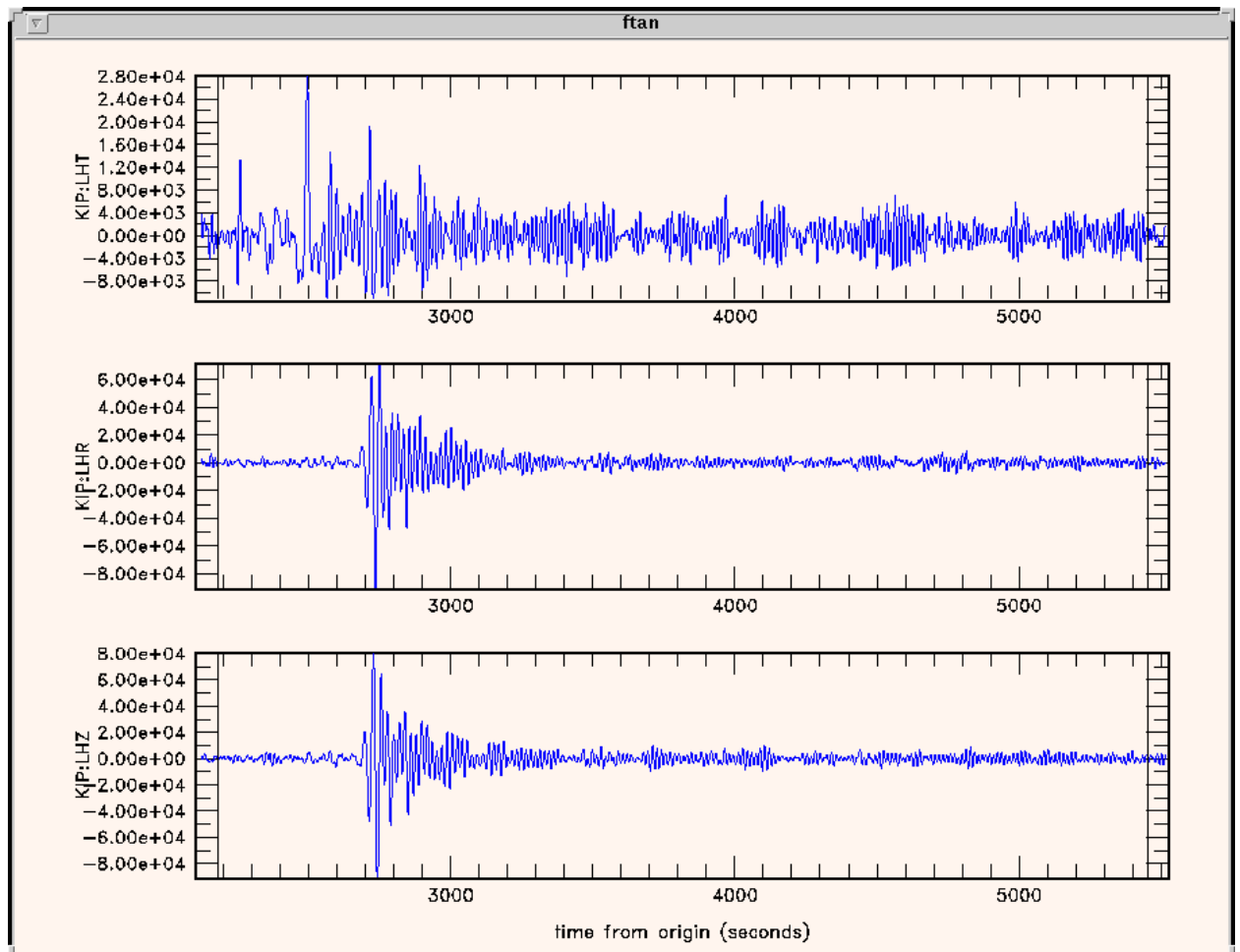
Note, that the raw waveforms can be plotted at any moment by clicking on the button ▮ .

To apply bandpass filtering click the button .   Filtered records will be plotted

To view FTAN maps for selected components and to make floating filtering push the button .
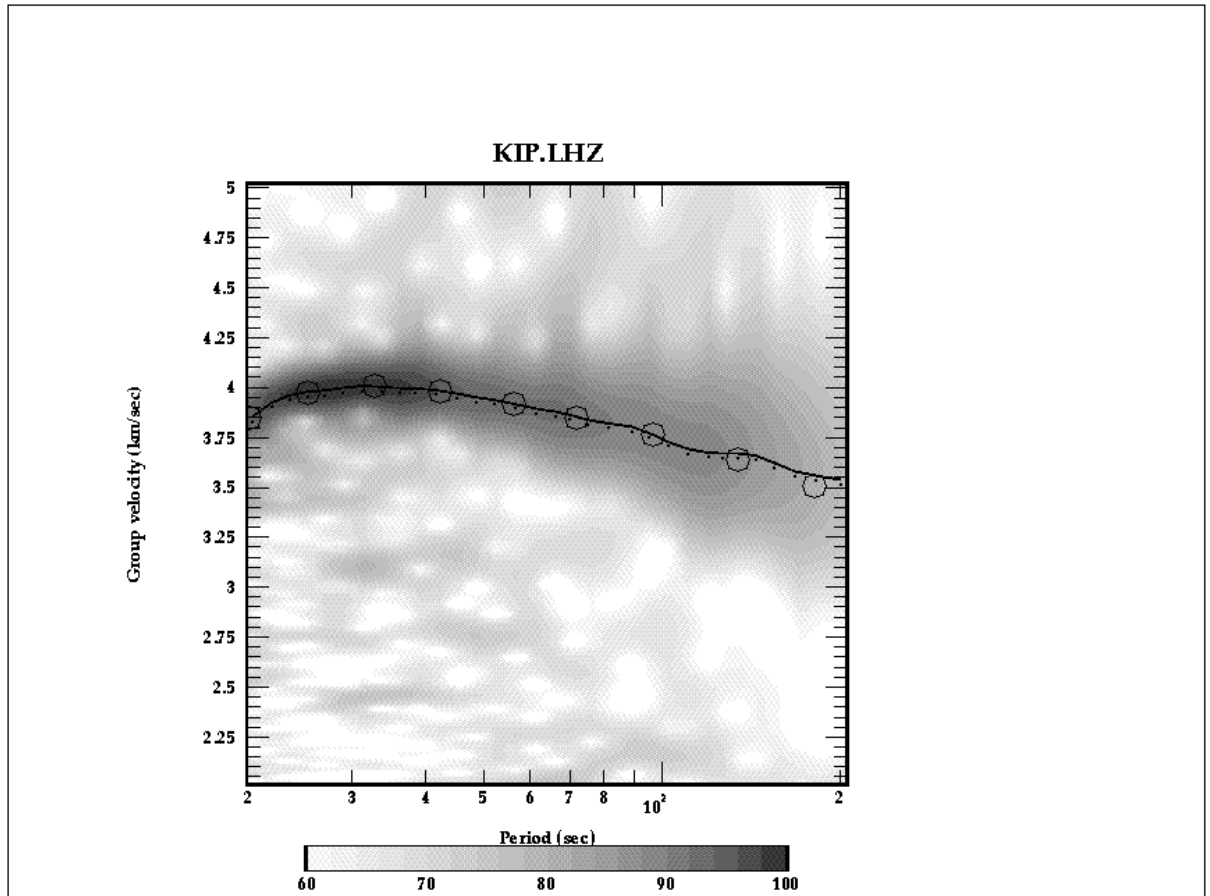
To make a floating filtering it is necessary to plot dispersion curve to make phase equalization (black circles). Use mouse to do this. Click left mouse button to put a point and the right one to delete the point nearest to cursor location. Type "e" to finish the plotting.

The picture of envelope of signal will appear:
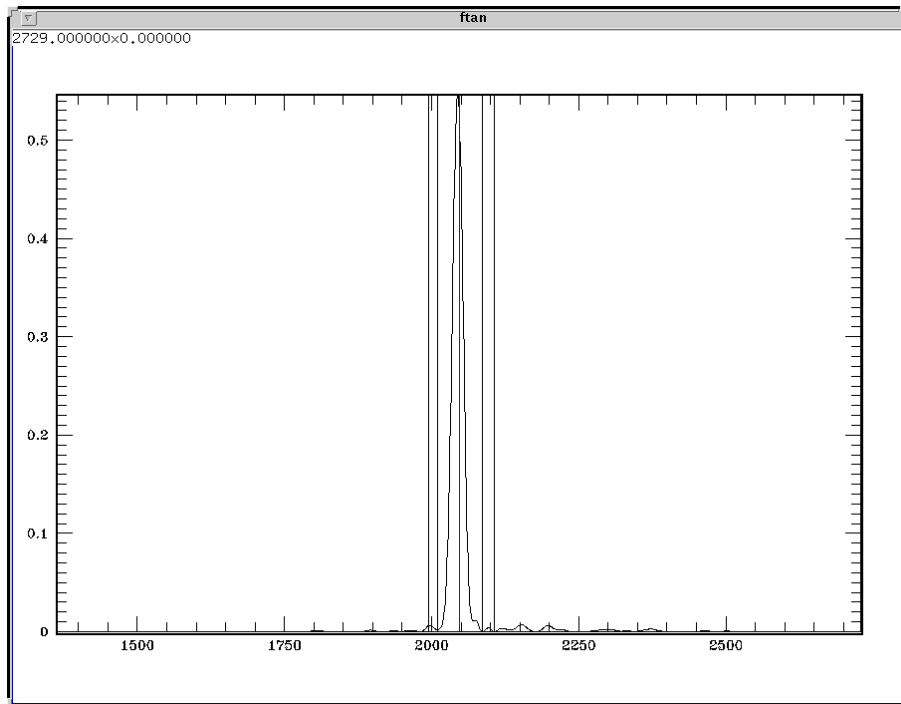
It is necessary to cut a signal which you've selected. This signal is concentrated near the center of picture (red vertical line). To do this you must set four points to define the filtering window with cosine edges. Use the same commands as above.

The picture of FTAN map for a cleaned signal will appear:
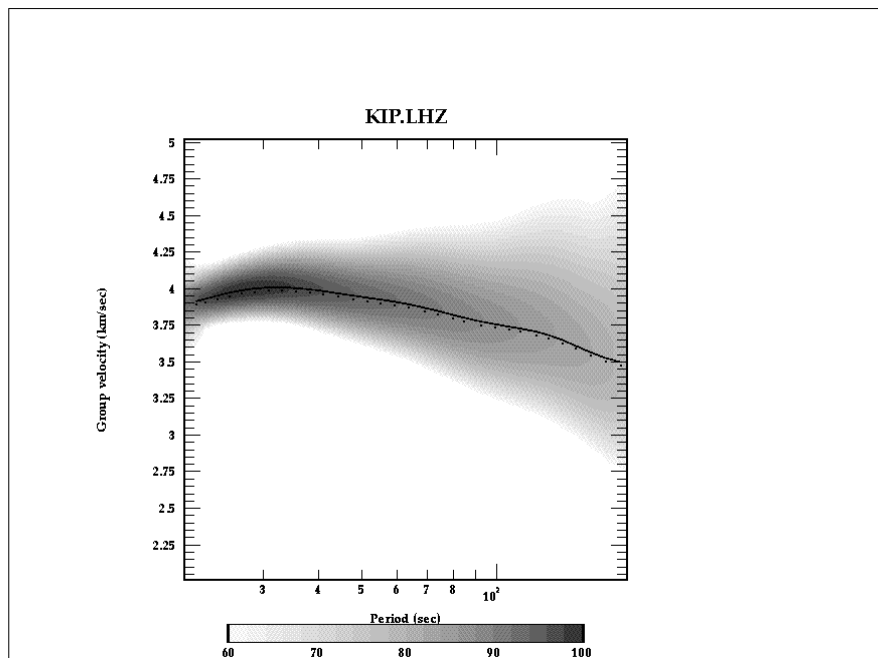
You can continue with filtering of this component. If you're satisfied with the result of filtering type "y". FTAN diagram of next component will appear.

Note: to interrupt the floating filtering process type "q" .

View of results

To view results of FTAN calculation of group velocities click button ![VEL]. Here is an example of group velocities plotting. The thin lines are theoretical curves.
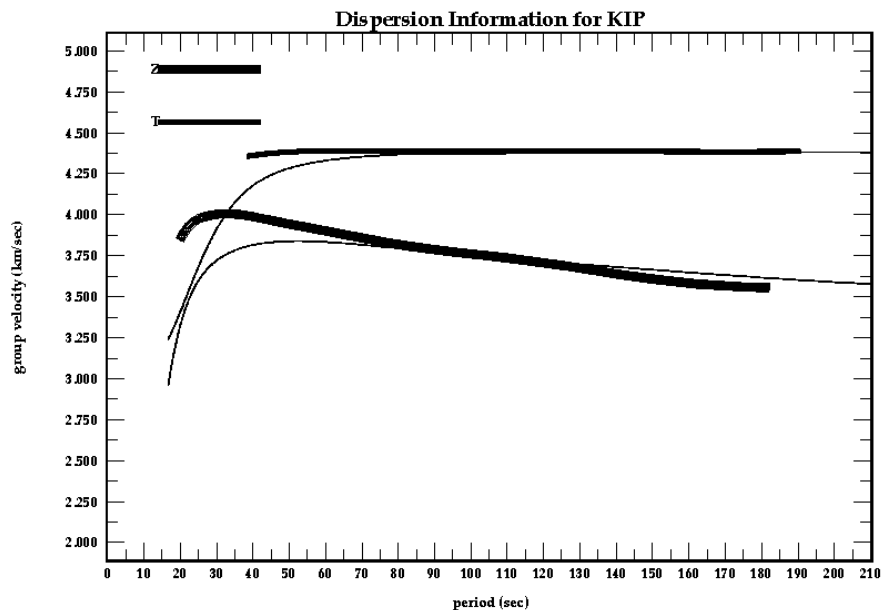
To view amplitude spectra push the button ![AMP] .
Here is an example of picture of amplitude spectra.
Thin lines present the amplitude spectra of raw signals; thick lines present the amplitude spectra of cleaned signals.
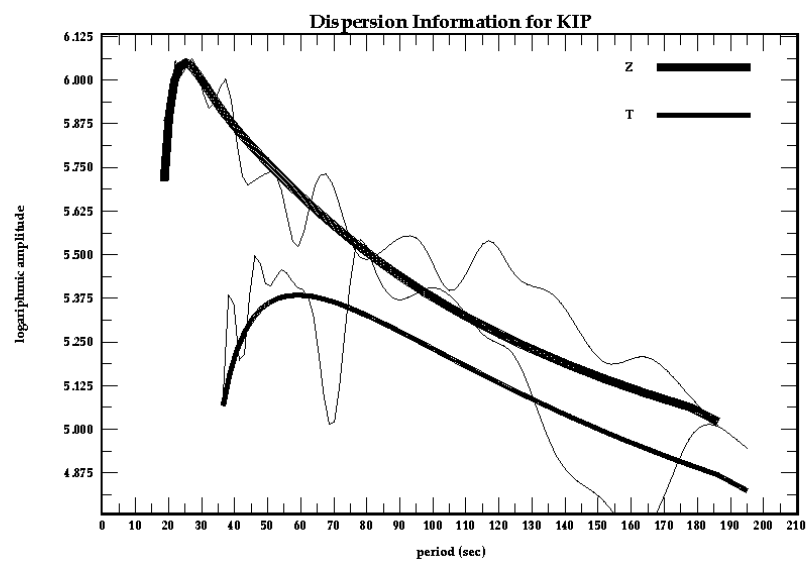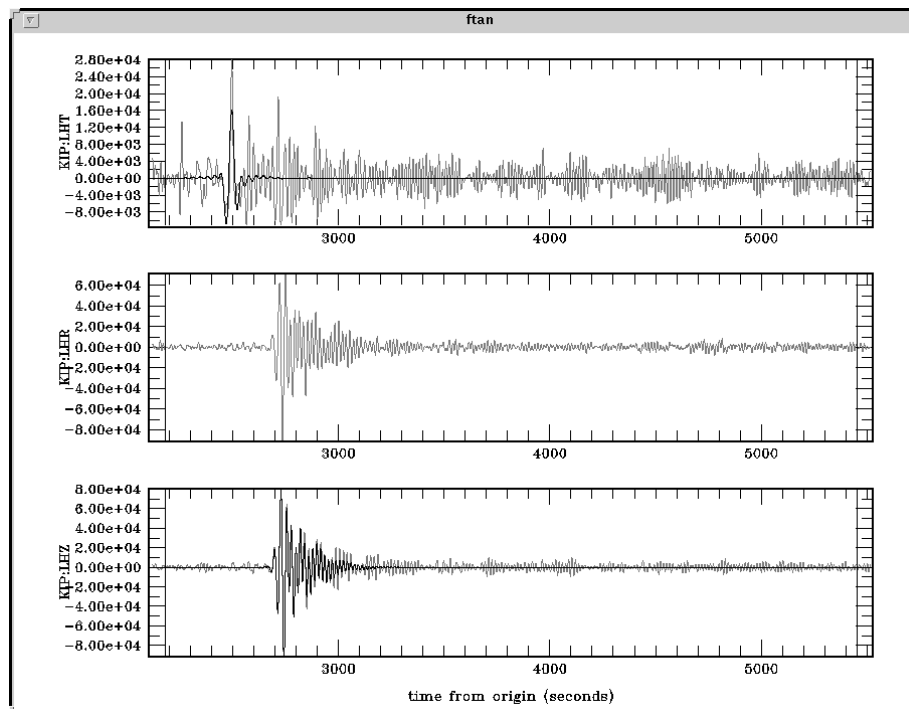
To view the FTAN estimates of polarization anomalies push the button .

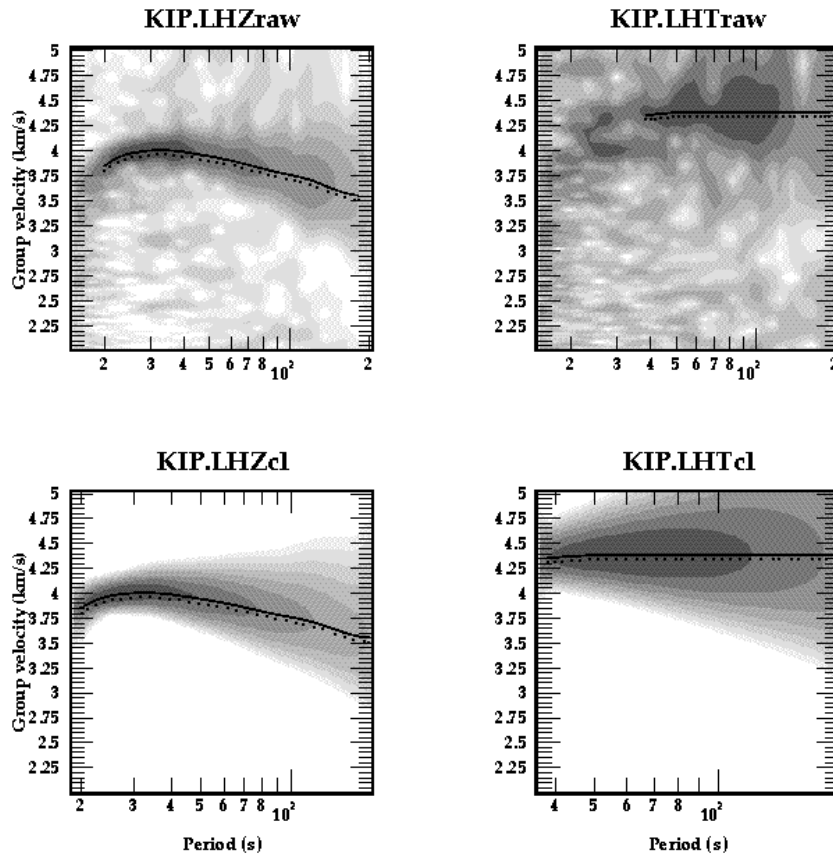Here is an example of picture of polarization anomalies:
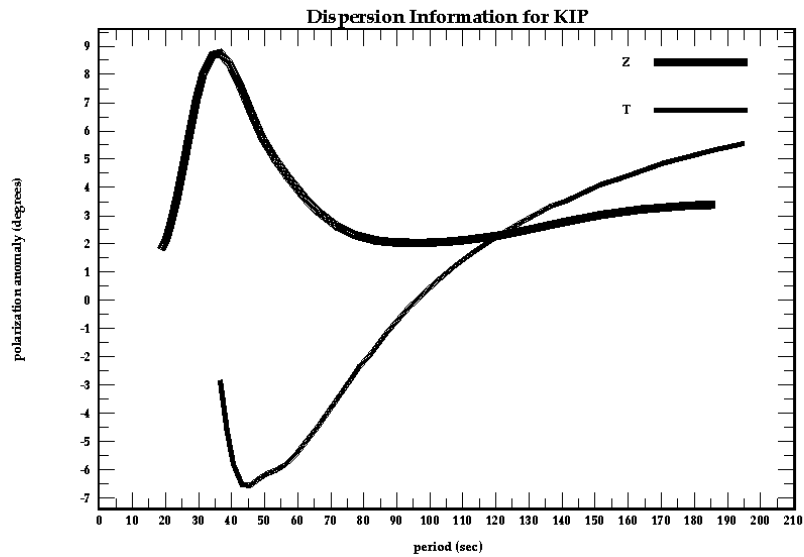
To view the picture of cleaned and raw seismograms push the button .

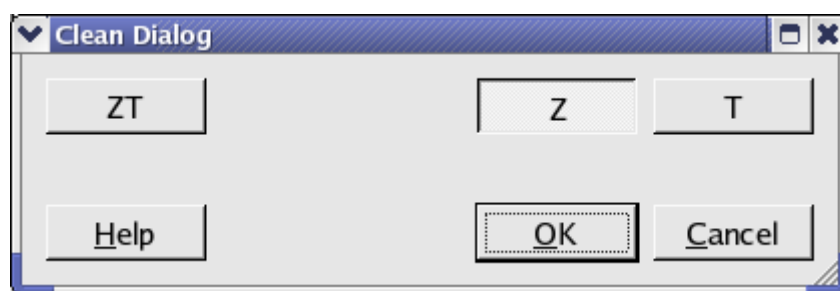Here is an example of picture of filtered and raw signals:

To view a picture of FTAN diagrams for cleaned and raw records push the button ![eye icon]. Here is an example of picture of FTAN maps for filtered and raw seismograms:
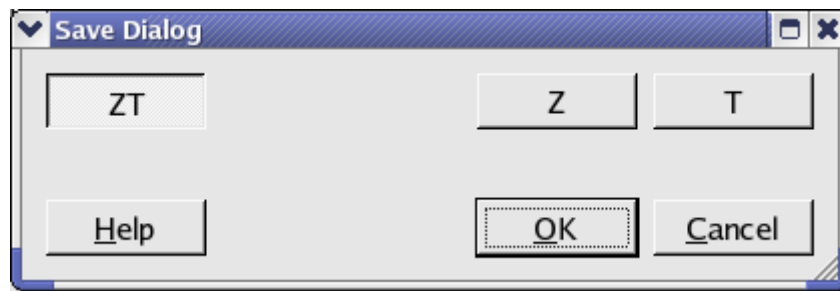

To clean any of processed components push the button ![clean icon]. The **Clean Records Dialog** window will appear.

Click component toggle buttons required to be cleaned. Click OK button to perform the cleaning, or Cancel - to close the window without cleaning.
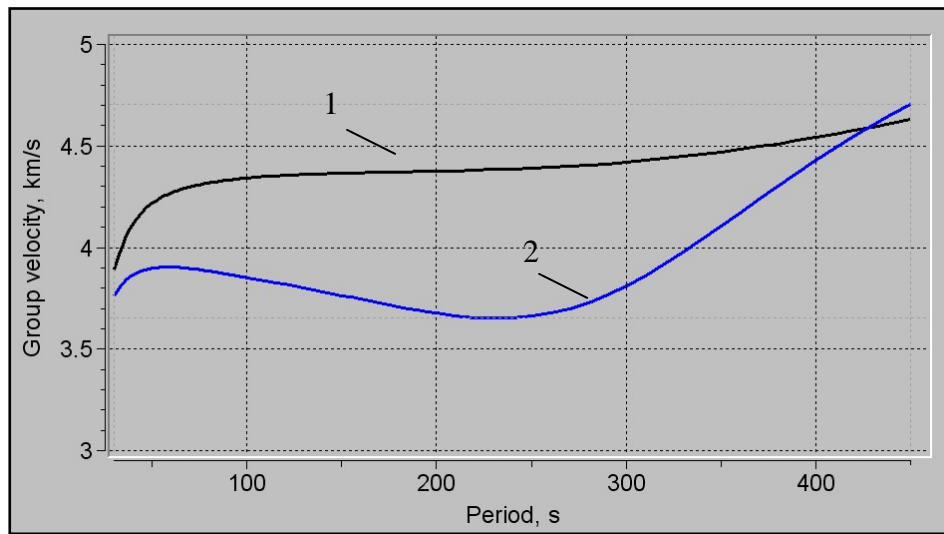
To save results click the button . The **Save Records Dialog** will appear.

Click component toggle buttons required to be saved. Click OK button to save records, or Cancel - to close the window without saving.

Select next station-channel. Button changes green color to yellow and you can work with new selection.

Reference group velocity curves

Group velocity curves for fundamental Love (1) and Rayleigh (2) modes for model PREM