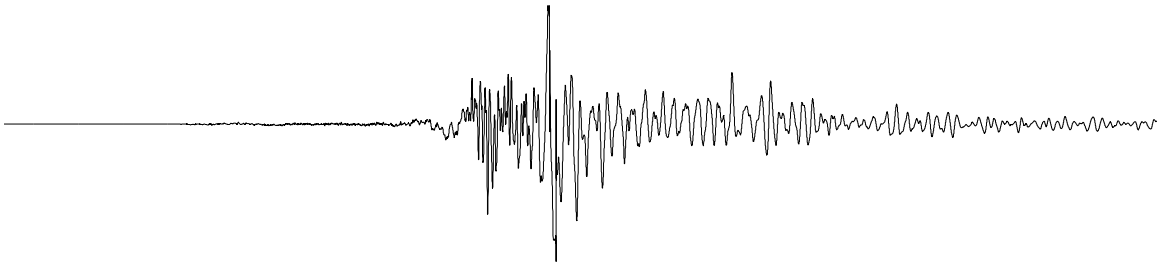

Crazyseismic

A MATLAB GUI-Based Software Package for

Passive Seismic Data Preprocessing

User's Manual

Version 3.3

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1 Overview

1.1 What is Crazyseismic?

Crazyseismic is a MATLAB-GUI based software package for passive seismic data preprocessing. It provides an interactive graphic user interface for researchers to easily and efficiently process large-volume seismic data while facilitating data quality control. For more details, please refer to Yu et al. (2017, SRL).

1.2 What does Crazyseismic do?

Crazyseismic is designed to be universally applicable to major body-wave phases in seismology. It is mainly used for **seismic data selection** and **phase arrival time picking**. But it can also be used for **principle component analysis** and **source deconvolution**. It can handle either single-component or two-component seismic traces.

1.3 What is special of Crazyseismic?

Three key features make Crazyseismic distinct from other seismic processing software:

- **Simplicity**

All functions of Crazyseismic are imbedded in one graphic user interface, so that users can process data by simply using mouse click or hot keys.

- **Efficiency**

Built-in functions such as phase travel-time calculation and multi-channel cross correlation improve the efficiency of data processing. The human-machine interactive nature of Crazyseismic also facilitates data quality control.

- **Extensibility**

Crazyseismic is an open-source software package. Users can modify the package to meet their specific demands.

2 Requirements

2.1 System and Platform

Crazyseismic is a MATLAB-GUI based software package. It can be executed on a variety of operation systems (e.g. Window, Linux, or Mac OS). The only prerequisite is to get MATLAB installed (Signal Processing and Mapping toolboxes are required). The code has been tested for MATLAB version R2012a and R2016a. Please contact the following author if you cannot run the software properly.

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2.2 Data preparation

2.2.1 Data format

For the current version, we accept SAC format seismic data, which is standard seismic data format in the seismology community. For more details on the SAC format, please visit the following website:

http://ds.iris.edu/files/sac-manual/manual/file_format.html

In the SAC format data, the following information must be written into the header:

- Earthquake information
  - Earthquake origin time:
    header.o
  - Earthquake location: Latitude/Longitude/Depth
    header.evla, header.evlo, header.evdp
- Station information
  - Station location: Latitude/Longitude
    header.stla, header.stlo

- Station and network name
  header.kstnm, header.knetwk

❖ Data information

- Data begin/end time
  header.b, header.e
- Data sampling rate
  header.delta
- Number of data points
  header.npts

2.2.2 Data layout

Gathers

Seismic data are usually stored either by (1) **Event gathers** or (2) **Station gathers**.

Event gathers: Seismic traces from different stations are stored in each event folder.
Station gathers: Seismic traces from different events are stored in each station folder.
Both of them are accepted, although event gathers are preferred.

Lists

To load seismic data, Crazyseismic reads two types of lists: (1) **Event list (or Station list)** and (2) **Data file list**.

❖ Event list (or Station list)
  An event list contains (absolute) paths of all events

❖ Data file list
  In each event folder, a data file list contains names of SAC files (usually of same component, e.g. vertical component).

3 Architecture

3.1 Main programs

3.1.1 Crazyseismic_Pick

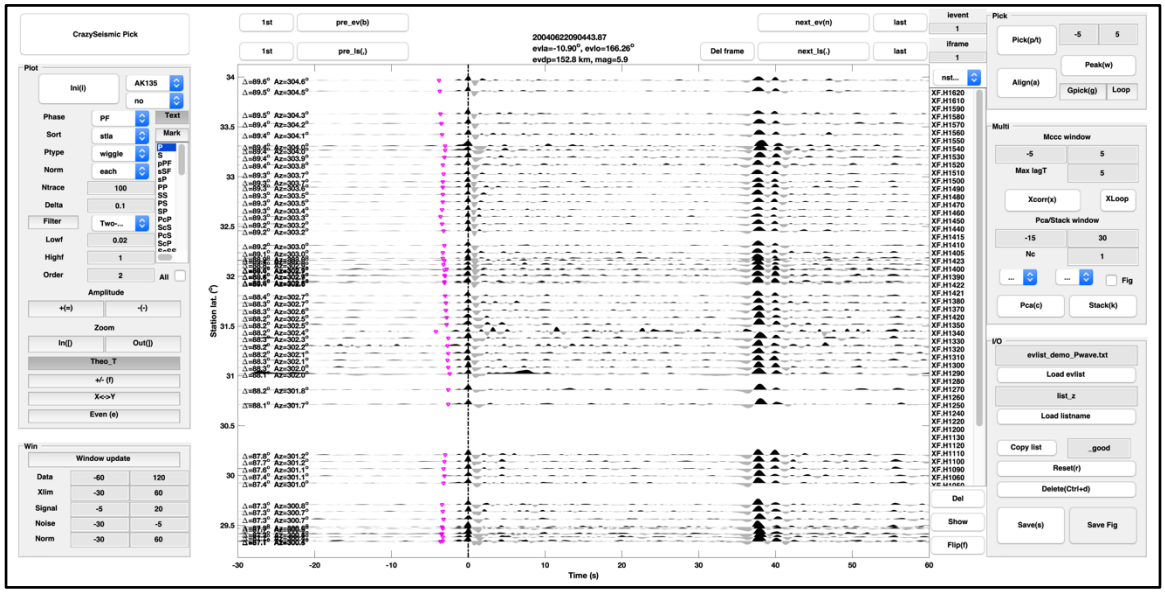


Figure 1 Crazyseismic_Pick interface

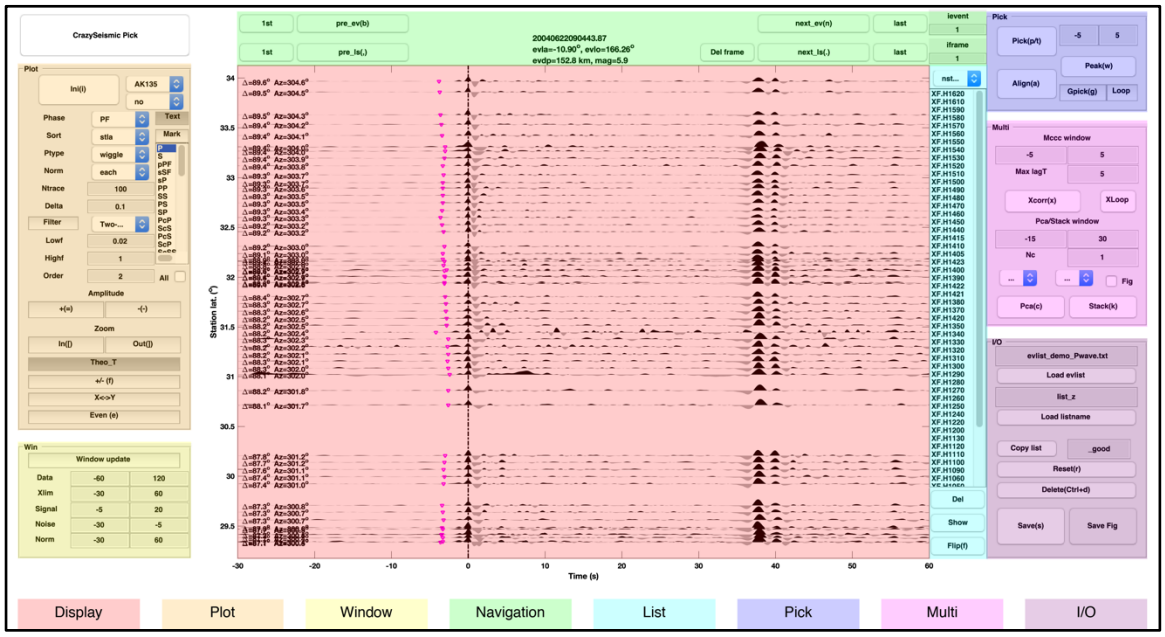


Figure 2 Eight panels of Crazyseismic_Pick

Figure 1 shows the graphic interface of "Crazyseismic _Pick". It contains eight functional panels (Figure 2):

- ❖ Display panel — *displays seismic waveforms*
- ❖ Plot panel — *controls plotting parameters*
- ❖ Window panel — *controls time windows*
- ❖ Navigation panel — *navigates among events or frames*
- ❖ List panel — *lists station/file names*
- ❖ Pick panel — *picks phase arrival times*
- ❖ Multi panel — *controls multi-channel cross correlation and principal component analysis parameters*
- ❖ I/O panel — *controls input/output parameters*

3.1.2 Crazyseismic_Decon

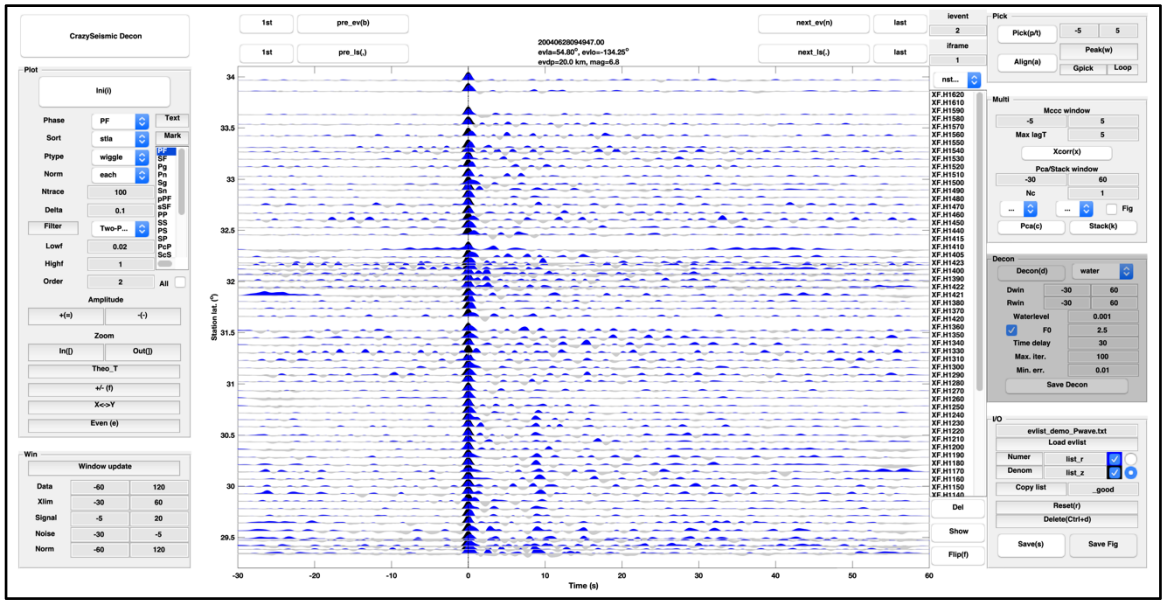


Figure 3 Crazyseismic_Decon interface

Figure 3 shows the graphic interface of "Crazyseismic _Decon". In addition to all panels in "Crazyseismic_Pick", it has an additional deconvolution panel.

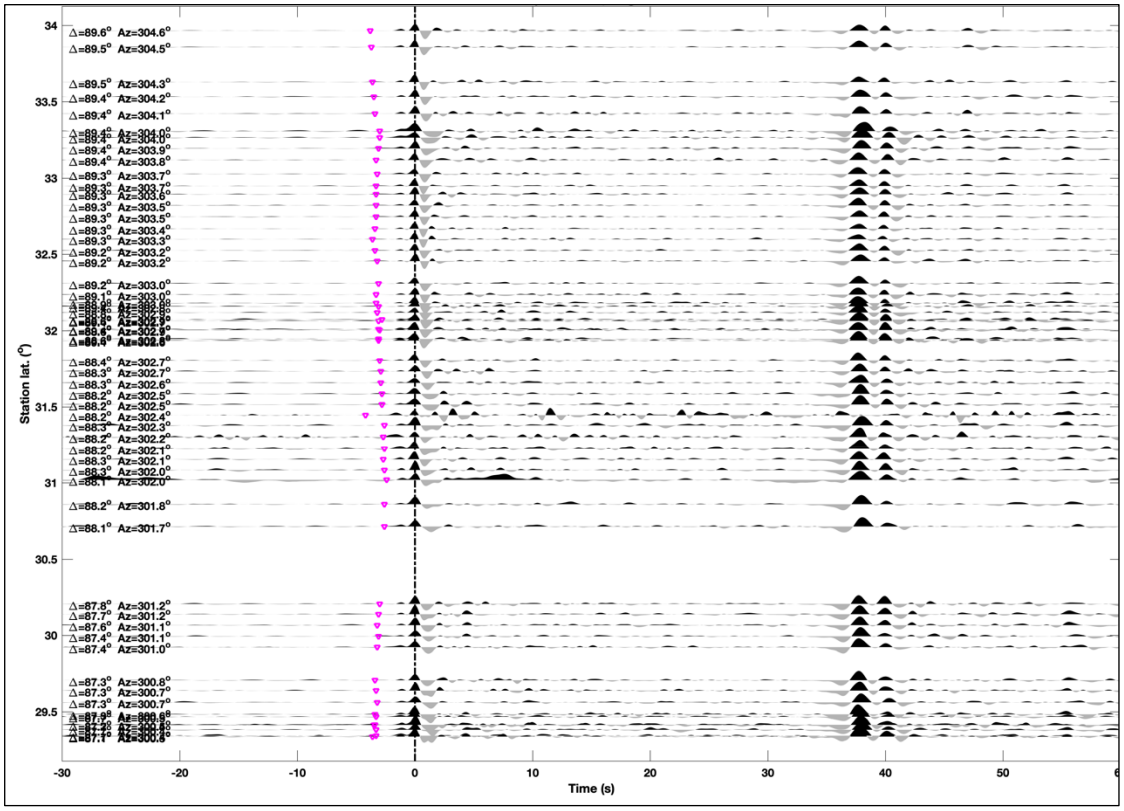
- ❖ Deconvolution panel: *deconvolves one component from the other*

3.2 Detailed description

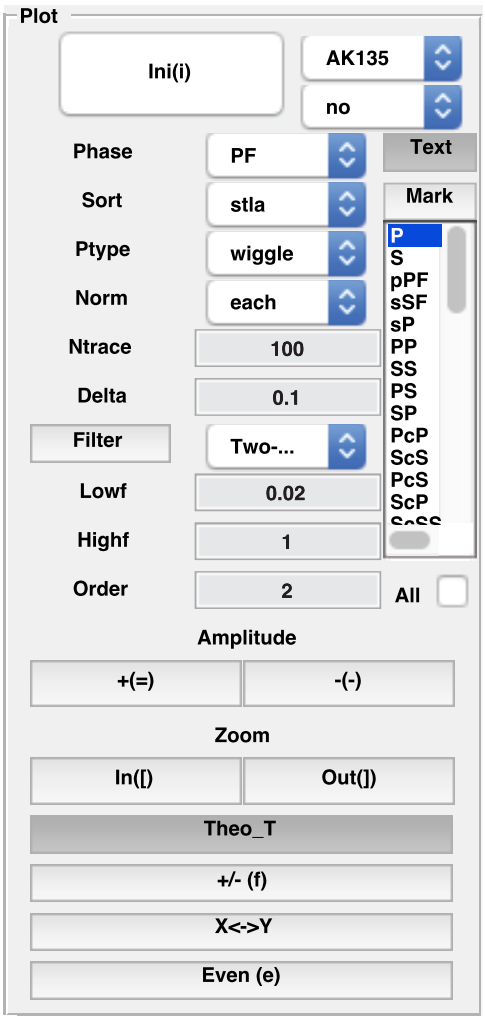
3.2.1 Details of “Crazyseismic_Pick”

❖ Display panel

The central part of the graphic user interface is for displaying seismic traces.



❖ Plot panel



- **Ini (i):** Initialize the plot of current event
- **Phase:** Reference seismic phase. Zero time is relative to the reference phase.
- **Sort:** Sorting traces by following parameters
  dist: Epicentral distance
  baz: Back azimuth
  snr: Signal-to-noise ratio
  …
- **Ptype:**
  Plot type: trace or wiggle
- **Norm:** Normalization type
  each: Each trace is independently normalized;
  all: All traces are normalized with the same factor
- **Ntrace:** Number of traces per frame
- **Delta:** Data sampling rate (in seconds)
- **Filter:** 1-pass, 2-pass Butterworth filter or Minimum phase filter
  - Lowf: low frequency (in Hz)
  - Highf: high frequency (in Hz)
  - Order: filter order

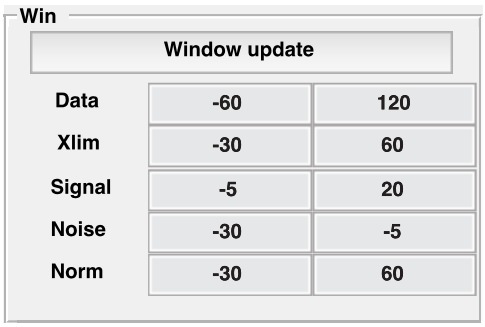
  If Lowf=0, Highf>0, low pass filter;

  If Highf=0, Lowf>0, high pass filter;

  If Highf > Lowf > 0, band pass filter

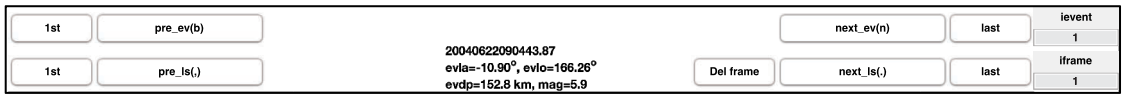
  Others, no filter
- Model for travel time calculation: ak135/prem/iasp91
- No/int/deri/sqrt/4th: get the original/integral/derivative/square root/4th root of each trace
- **Text:** Text trace parameters, e.g. distance, back azimuth
- **Mark:** Mark seismic phases selected in the phase list below
- **All**
  Check to mark all phases in the phase list above
- **Amplitude**
  - + (=): Increase amplitude
  - – (–): Decrease amplitude
- **Zoom**
  In([)/Out(]): Zoom in/out in the time axis
- **Theo_T:** Show theoretical phase arrival time
- **+/- (f):** Flip polarities for the event
- **X<->Y:** X-Y plot reverse
- **Even (e):** Evenly/unevenly distributed

❖ Window panel



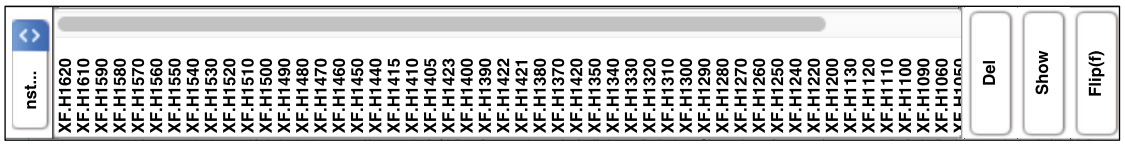
- **Window update**
  Click this button to update all time windows (in seconds) in this panel
- **Data**
  Data time window
- **Xlim**
  Display time window
- **Signal**
  Signal time window (along with noise window to calculate SNR)
- **Noise**
  Noise time window
- **Norm**
  Normalization time window

❖ Navigation panel



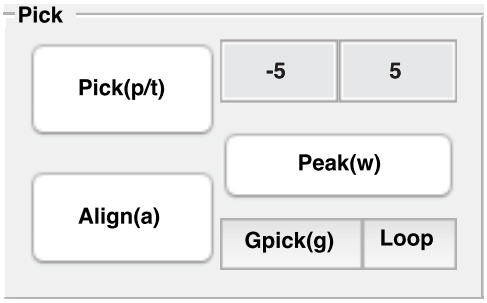
- **(Above) 1st, pre_ev(b), next_ev(n), last**
  First event, previous event, next event, last event
- **(Below) 1st, pre_ls(,), next_ls(.), last**
  First frame, previous frame, next frame, last frame
- **(Right) ievent, iframe**
  Event index, frame index

❖ List panel



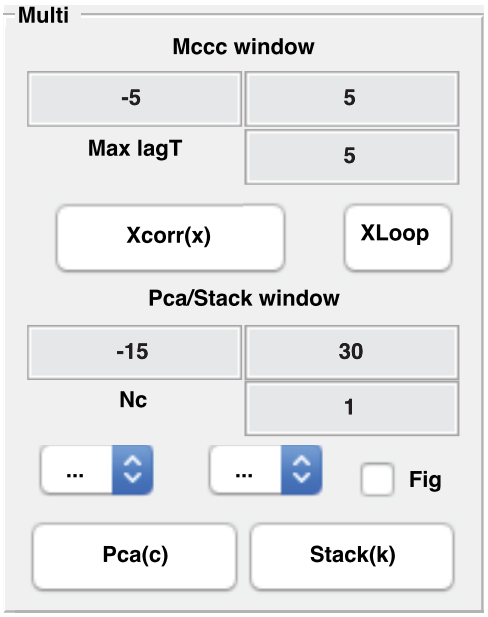
- **Text name**
  nstnm: [network].[station_name]
  stnm: station_name
  filename: filename
- **Del**
  Delete selected traces
- **Show**
  Reshow selected traces
- **Flip (f)**
  Flip the polarity of selected traces

❖ Pick panel



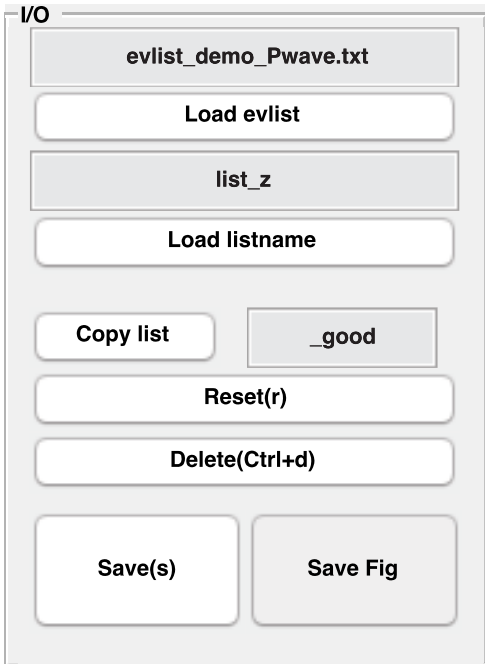
- **Pick (p/t)**
  Click this button to start picking
  Left click to continue draw the phase-picking line; right click to stop. The intersection between the phase-picking line and traces are picked phase arrival times.
- **Align (a)**
  Align traces after picking
- **Peak (w)**
  Automatically align traces by finding the peak in the time window defined above
- **Loop**
  Click this button to apply Peak function to all following events
- **Gpick(g)**
  Select a trace using graphic input from a mouse or cursor

❖ Multi-channel panel



- **Mccc window**
  Multi-channel cross correlation time window
- **Max lagT**
  Maximum time lags
- **Xcorr (x)**
  Multiple-channel cross correlation
- **XLoop**
  Apply multiple-channel cross correlation to all following events
- **Pca/Stack window**
  Time window for principle component analysis (PCA) or stacking
- **Nc**
  Number of components of PCA
- **Pca (c)**
  Apply PCA and save data
- **Stack (k)**
  Apply stacking and save data
- **Data group for Pca/stack**
  all: All traces for the event
  frame: Traces in the current frame
  select: Selected traces
- **Data type for Pca/Stack**
  raw/filter: Raw or filtered data
- **Fig**
  Check to show results

❖ I/O panel



- **Load evlist**
  Click this button to load event list
- **Load listname**
  Click this button to load data file list
- **Copy list**
  Save selected traces as a sub list
- **Reset (r)**
  Reset the event
- **Delete (Ctrl+d)**
  Delete the current event (make an empty phase file list)
- **Save (s)**
  Save event (generate or update information in the phase file list)
- **Save Fig**
  Save current interface as a figure in the event directory

❖ Hot keys

When the '**Crazyseismic Pick**' icon in the top left is highlighted, you can use hot keys. Hot keys are shown in the bracket of corresponding functions.

❖ Travel time adjustment with keyboards

First, get into the list panel and select traces. The hot key to enter/exit the list panel is "Alt" or "Command" (Check your system shortcut to avoid conflicting).

- Press up/down arrows to navigate among stations
- Hold Ctrl for multiple selections
- Press Ctrl + a to select all stations

Then, adjust phase travel times.

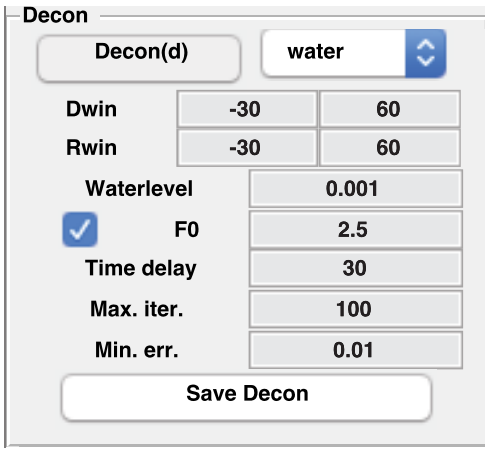
- Press left/right arrows to shift traces
- Press Ctrl (or Command) + left/right arrows to make fine adjustment
- Press Shift + left/right arrows to make coarse adjustment

Finally, save changes by pressing the Save button in the I/O panel.

3.2.2 Details of "Crazyseismic_Decon"

Most panels in "Crazyseismic_Decon" are the same as that in "Crazyseismic_Pick". The major difference is the deconvolution panel.

❖ Deconvolution panel



- **Decon (d)**
  Apply deconvolution
- **Decon type**
  water: frequency domain waterlevel deconvolution
  iter: time-domain iterative deconvolution
- **Dwin**
  Data time window for deconvolution
- **Rwin**
  Deconvolution result time window
- **Waterlevel deconvolution parameters**
  waterlevel: waterlevel value
  F0: Gaussian factor (filter gain is 0.1 at a frequency of roughly F0/2 Hz)
- **Left box**
  Check to apply same filter as that in the plot panel to the deconvolution results
- **Time delay**
  Time delay of deconvolution results
- **Iterative deconvolution parameters**
  Itmax: maximum iteration number
  Minerr: Minimum error
- **Save Decon**
  Save deconvolution results as SAC files

4 Tutorial

This tutorial shows two examples of using Crazyseismic to process seismic data for: (1) **Phase arrival time picking** and (2) **Deconvolution**. Two potential field applications in seismology are seismic tomography and *P*-wave receiver functions, respectively.

4.1 Phase travel time picking

Step 1. Generate Event list and Data file lists

Use "**y_gen_listname.m**" to generate both event list and data file lists

Event list (e.g. "evlist_demo_P.txt") should contain paths like this:

```
[PATH]/20040622090443.87
[PATH]/20040628094947.00
…
```

(*PATH is the absolute or relative path for parent directory of all events; 20040622090443.87 is the name of the event folder*)

Data file list (e.g. "list_z") in each event folder should look like this:

```
2004.174.09.16.12.2980.XF.H1010.01.BHZ.M.SAC
2004.174.09.16.12.7950.XF.H1030.01.BHZ.M.SAC
…
```

Step 2. Run "Crazyseismic_Pick" and load in data

- Run "**y_Crazyseismic_Pick.m**" in Matlab
- **Load evlist**

In the I/O panel, click the "Load_evlist" button to select the event list.

- **Load data file list**

Then, click the "Load_listname" button to choose the data file list. It will then automatically load SAC files in the list into Matlab.

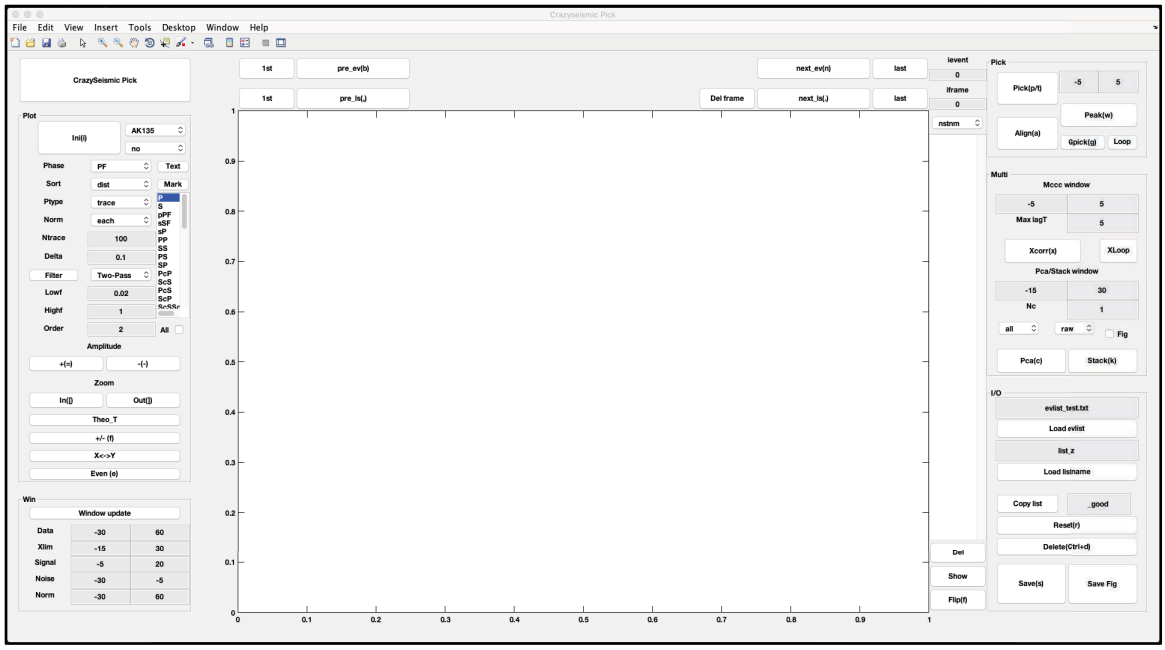


Figure 4 Initial Crazyseismic_Pick interface

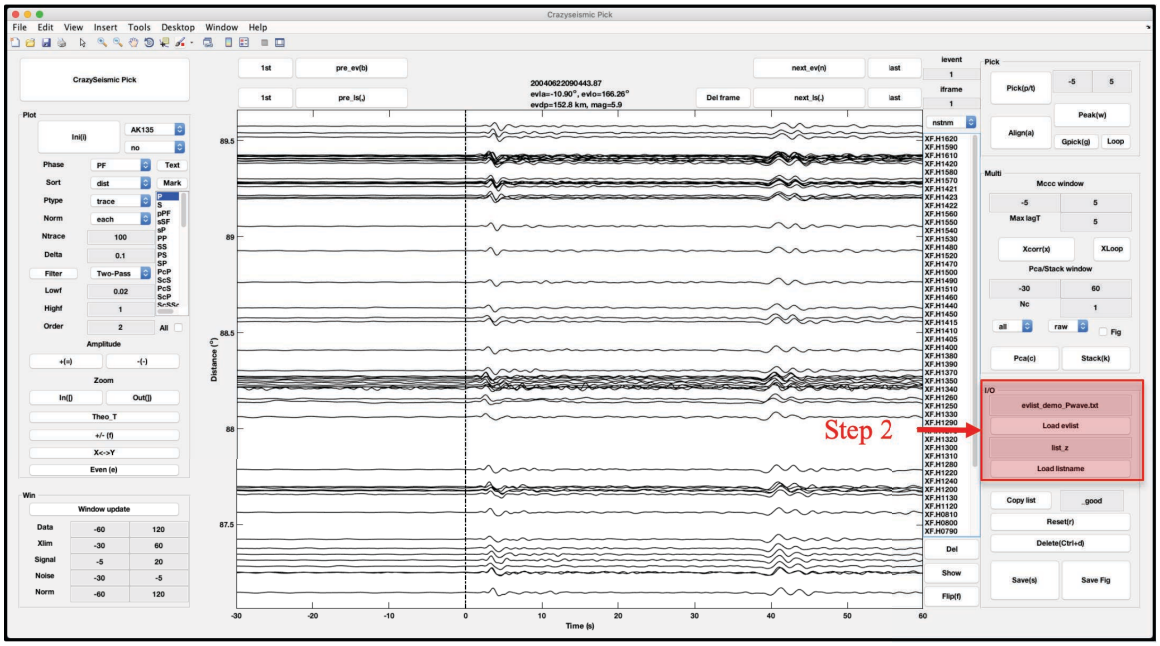


Figure 5 Displaying traces after load in event list and data file list

Step 3. Select seismic phases and modify parameters

- Select the reference seismic phase in the phase popup menu in the Plot panel.
- Adjust parameters if necessary.

***For example**, to change the frequency band of the filter, you can input corresponding values in "Lowf" and "Highf", and then click the "Filter" button to update the data. You can also sort traces by epicentral distances (dist), back azimuth (baz), or others.*

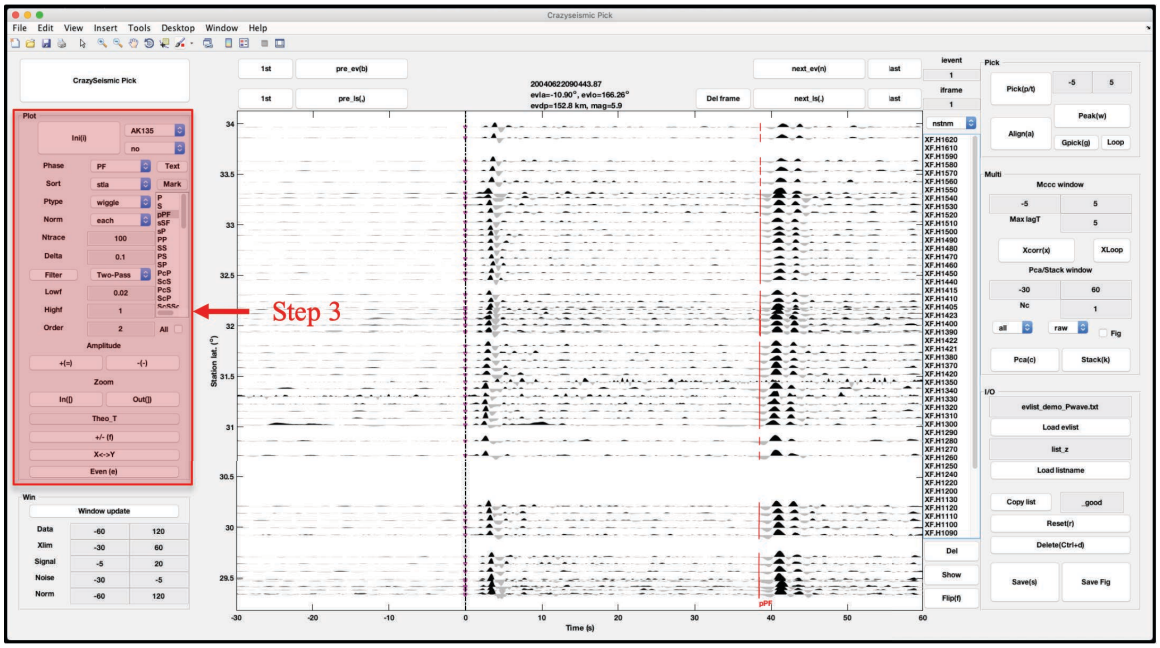


Figure 6 Interface after changing plotting parameters. Here, traces are sorted by station latitude; plot type from "trace" to "wiggle"; theoretical P-wave arrival time (purple inverted triangles) and the relative arrival time of its depth phase pP (red bars) are shown.

Step 4. Delete bad traces or events

- Delete bad traces

  To select seismic traces, click their corresponding names into the List panel. Selected traces are highlighted. One way to quickly locate a trace is using graphic input from a mouse or cursor by first click "**Gpick(g)**" and then mouse click a point near the trace. To delete bad traces, click the "**Del**" button in the List panel or the "Delete" button in your keyboard.

- Recover deleted traces

  Click the "**Show**" button.

- Flip polarity of selected traces

  Click the "**Flip (f)**" button.

- Delete the event

  Click the "**Delete (Ctrl+d)**" button in the I/O panel. It will then automatically go to the next event.

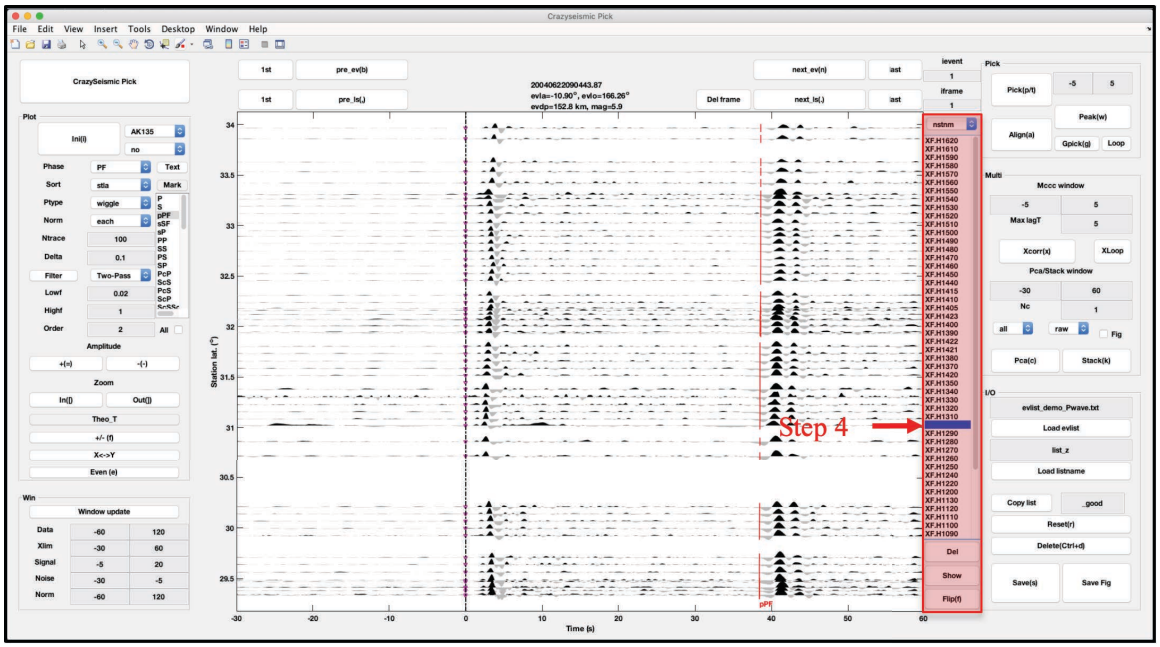


Figure 7 Bad trace of station XF.H1300 is removed

Step 5. Picking phase travel times

For convenience purpose, we provide several ways for phase travel time picking.

- Use "**Pick (p/t)**" and "**Align (a)**" in the Pick panel

  Click the "**Pick (p/t)**" button to start drawing a line. Left click to continue and right click to finish. The intersections between the line drawn and seismic traces will be the picked phase travel times. Then, click the "**Align (a)**" button to align them.

- Use "**Peak (w)**" in the Pick panel

  The "**Peak (w)**" button will automatically align traces by their peaks in the defined time window. "**Peak Loop**" is used for automatically peak alignment for all events.

- Travel time adjustment in the List panel

  Click names of traces in the List panel and use "left arrow" or "right arrow" to shift traces. Hold "Shift" for coarse adjustment and "Ctrl" for fine adjustment.

- Use multi-channel cross correlation in the Multi panel

  You can also align multiple traces using the "**Xcorr (x)**" button. This will give more accurate relative phase arrival time measurements.

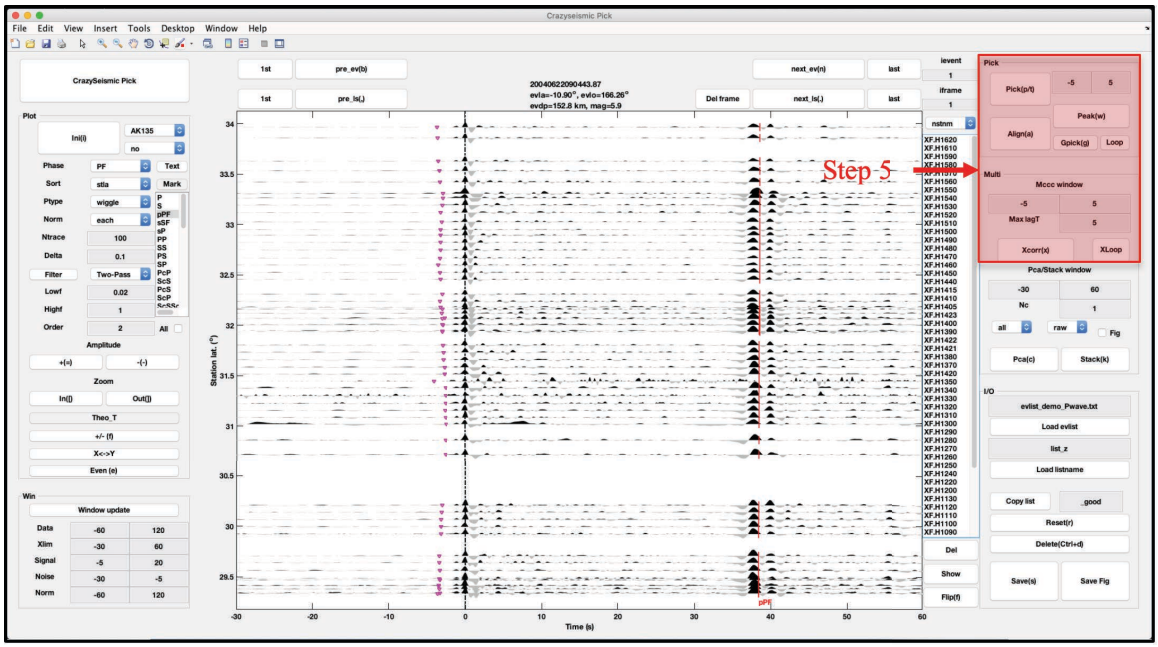


Figure 8 Trace alignment by picking the maximum peak of the P wave

Step 6. Save changes and go to the next event

- Navigate among frames

  Click "**1st**", "**pre_ls (,)**", "**next_ls (.)**", or "**last**"

- Save processed event

  Click "**Save (s)**" in the I/O panel

- Go to next event

  Click "**next_ev (n)**"

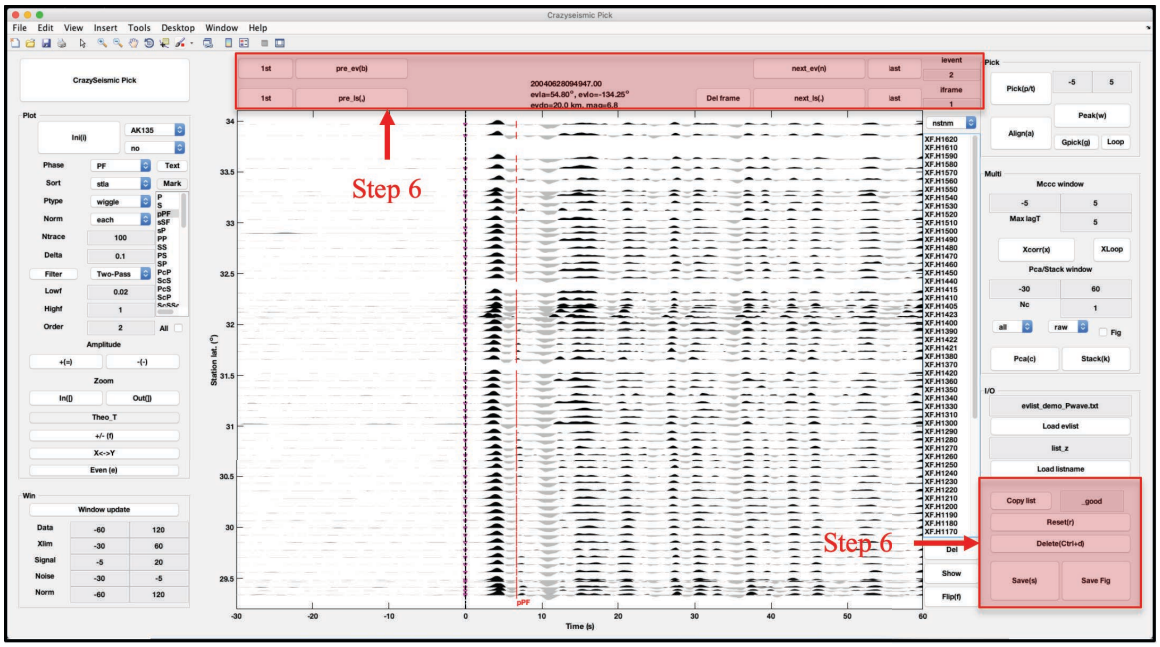


Figure 9 Process next event

Output phase file list

The output will be a phase file list in each event folder. Its name is a combination of the name of the data file list and the seismic phase.

***For example**, if the name of the data file list is "list_z", then the name of the phase file list of P wave will be "list_z_P.txt".*

The phase file list should look like this:

```
#filename theo_tt tshift obs_tt polarity stnm netwk rayp stla stlo stel evla evlo evdp dist az baz snr0 xcoeff0
2004.174.09.16.12.2980.XF.H1010.01.BHZ.M.SAC 748.639442 0.000000 748.639442 1 H1010 XF 0.043292
29.335501 85.836403 4753.000000 -10.902000 166.259003 152.800003 87.146095 300.472839 104.036608
1.000000 1.000000
…
```

(theo_tt is theoretical travel time; tshift is shifted travel time; obs_tt is picked travel time; polarity records the polarity change of seismic traces. +1: no change, -1: change of polarity; stnm is station name; netwk is network name; rayp is the phase ray parameter; stla, stlo, stel are station latitude, longitude and elevation, respectively; evla, evlo, evdp are event latitude, longitude and depth, respectively; dist is epicentral distance; az and baz are azimuth and back azimuth, respectively; snr0 and xcoeff0 are not used.)

4.2 Deconvolution

Since most function in "Crazyseismic_Decon" is similar to "Crazyseismic_Pick", we will only introduce the deconvolution function here.

Steps 1-6. Do all necessary data preprocessing

- Run "**y_Crazyseismic_Decon.m**"
- Load in both the **denominator** and **numerator** data file lists
- Go over steps 1-6 as that in travel time picking session.

Step 7. Deconvolution

There are two deconvolution options:

- Frequency domain waterlevel deconvolution

➢ Time domain iterative deconvolution

Simply adjust corresponding parameters and click the "**Decon (d)**" button, you will get the deconvolved results. If you want to save results as SAC format data, click the "**Save Decon**" button.

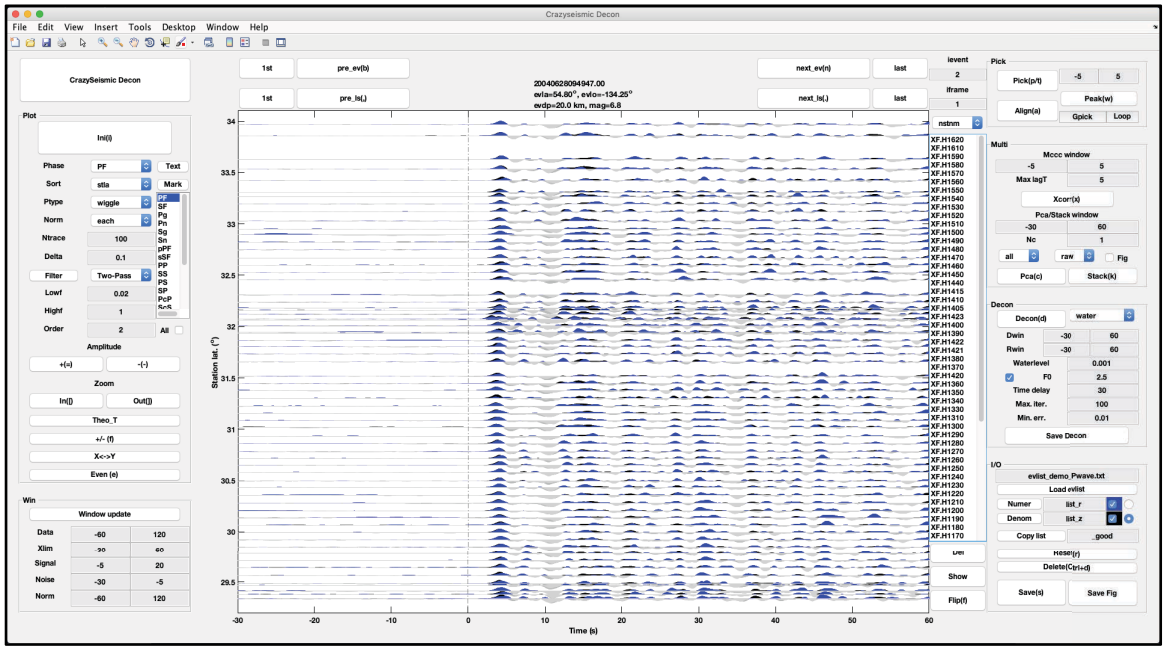


Figure 10 Crazyseismic_Decon interface showing both vertical and radial-component traces

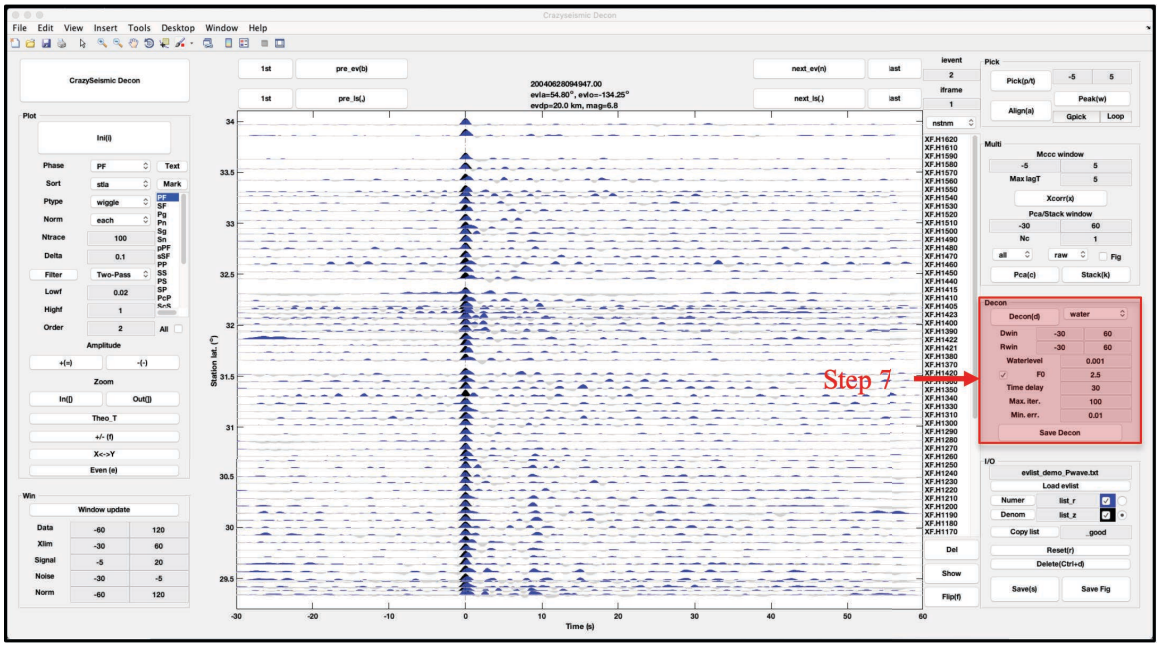


Figure 11 Radial P-wave receiver functions

5 Summary

Crazyseismic is a MATLAB-GUI based software for passive seismic data preprocessing. Major features of this software include its simplicity and high-efficiency. All functions are grouped into one single GUI interface, so that users can process data by simply using mouse click or hot keys. The imbedded phase travel time calculator and multi-channel cross correlation function not only accelerate arrival time picking but also improve the accuracy of relative arrival time measurements. Crazyseismic works for a majority of body-wave phases. Essentially it can be extended to any seismic phases defined by users. We hope that Crazyseismic can be a valuable software package for the seismological community.

Acknowledgements

We thank many of our colleagues for testing and commenting on this software. We are also grateful for all people contributed their codes and ideas during the developments of Crazyseismic. The iterative deconvolution code is written by I.W. Bailey based on Ligorria and Ammon's 1999 BSSA paper. The minimum phase filter code is downloaded from Julius O. Smith III's website.

Citation

Please cite the following paper if you find Crazyseismic useful:

Yu, C., Y. Zheng, and X. Shang, 2017, Crazyseismic: A MATLAB GUI-based software package for passive seismic data preprocessing, ***Seismological Research Letters***, 88, no. 2A, 410–415, doi: 10.1785/0220160207. (link)