Tutorial for Beam-forming

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[1] Application

Horizontal slowness (ray parameter) of some phase and back-azimuth of events can be constrained using beam-forming if the geometry of seismic array we use is perfect. Here we say delta-shaped, cross-shaped, circle-shaped and so on.

[2] Basic Principles

Before our journey of executing beam-forming, you need to master its basic principles. To know more details, please reference to the review paper: *ARRAY SEISMOLOGY: METHOD AND APPLICATIONS* by Sebastian Rost and Christine Thomas, 2002.

[3] Data preparation

SAC format files should be prepared and the latitudes (header variation "stla" saved in SAC format file) and longitudes (header variation "stlo" saved in SAC format file) are valid.

[4] Dependencies

a. Linux or Mac OS platform;

b. SAC (Seismic Analysis Code) with version 101.6a, here, to execute band-pass filter;

c. GMT (the Generic Mapping Tools) with marjor version 5, here 5.3.1, to virtualize the outputting results.

[5] Executing Beam-forming

Execute command “make” to compile executable command “beamforming” in current directory. Usage is showed as below,

beamforming <sacfile.lst> <t1> <t2> <fre_low> <fre_high> <slow_low> <slow_high> <slow_step> <baz_step> <output_file>

<sacfile.lst> File containing names of SAC format files;

<t1> Beginning time of cutting SAC files;

<t2> Ending time of cutting SAC files;

<fre_low> Low limitation frequency of band-pass filtering (Hz);

<fre_high> High limitation frequency of band-pass filtering (Hz);

<slow_low> Low limitation of horizontal slowness scanning (second/degree);

<slow_high> High limitation of horizontal slowness scanning (second/degree);

<slow_step> Step length of scanning horizontal slowness; (second/degree)

<baz_step> Step length of back-azimuth scanning (degree);

<output_file> File name of outputting results containing 3 columns:

col1: back-azimuth col2: slowness col3: cross-coefficient.

[6] Executing Example

a. Seismic stations used are showed in Figure 1.

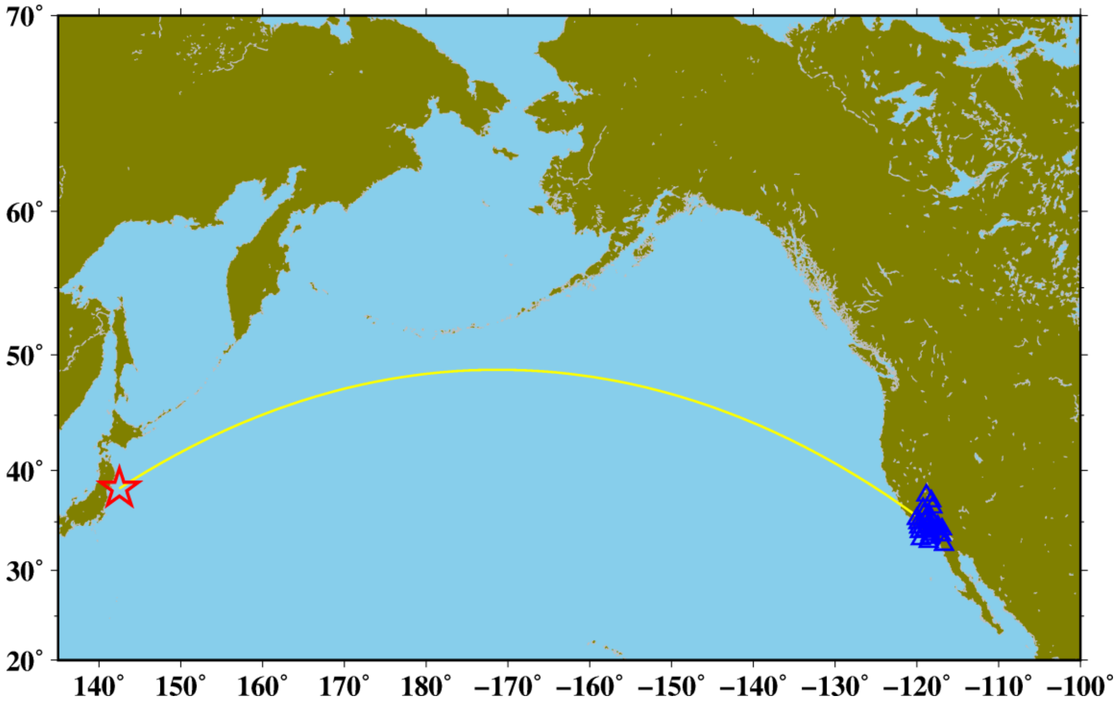


Figure 1. Seismic stations (indicated by blue triangles), array center (denoted with magenta solid circle) and hypocenter (indicated by red solid star).

b. SAC format files are plotted with varying distances in Figure 2.

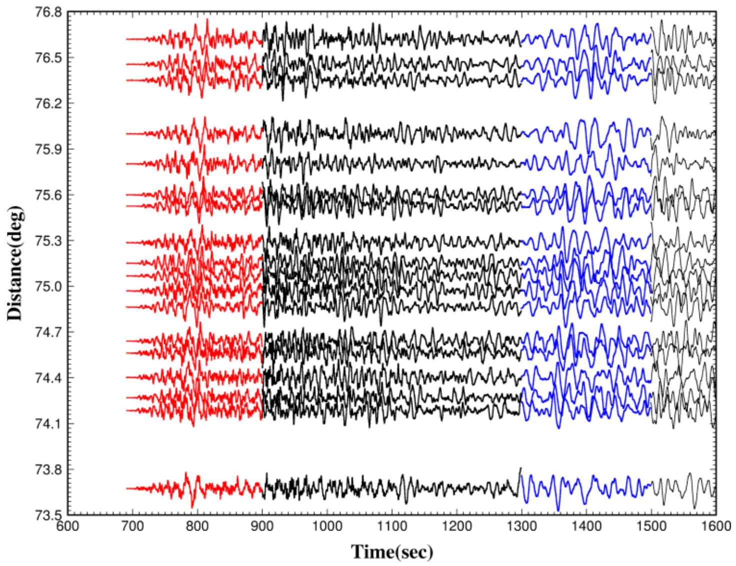


Figure 2. Two time segments (indicated by red and blue solid curves, respectively) are used to execute beam-forming.

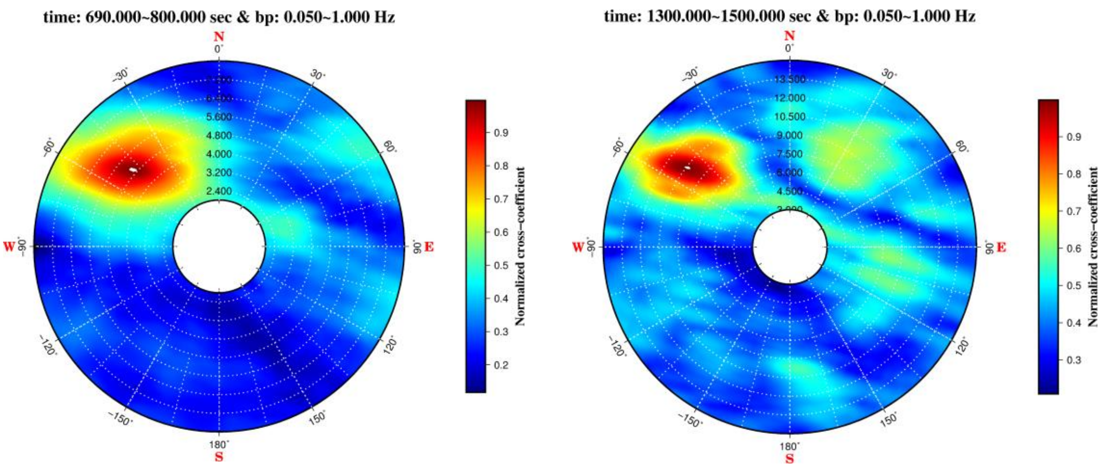
c. Theoretical travel times and ray parameters is computed with iasp91 1-D model (Figure 3).

```
[$]taup_time -h 19.7 -mod prem -evt 38.29630 142.498 -sta 34.9454 -118.936

Model: prem
Distance   Depth   Phase   Travel    Ray Param  Takeoff  Incident  Purist    Purist
  (deg)     (km)   Name    Time (s)  p (s/deg)   (deg)    (deg)    Distance  Name
---------------------------------------------------------------------------------------
   74.98    19.7   P        698.55     5.758     20.68    17.48    74.98   = P
   74.98    19.7   PcP      712.02     4.292     15.26    12.94    74.98   = PcP
   74.98    19.7   PKiKP   1048.00     1.482      5.22     4.43    74.98   = PKiKP
   74.98    19.7   S       1276.13    11.091     22.97    18.61    74.98   = S
   74.98    19.7   SKS     1305.78     7.256     14.79    12.05    74.98   = SKS
   74.98    19.7   ScS     1310.42     8.031     16.41    13.36    74.98   = ScS
   74.98    19.7   SKiKS   1476.53     1.597      3.22     2.63    74.98   = SKiKS
```

Figure 3. Theoretical travel times and ray parameters of corresponding seismic phases computed with 1-D iasp91 model.

d. Executing results of different time segments (Figure 4).



(a) (b)

Figure 4. Beam-forming results. (a) Result with a time window of 690 – 800 seconds and a band-pass of 0.05 – 1 Hz. (b) Result with a time window of 1300 – 1500 seconds and a band-pass of 0.05 – 1 Hz.