

Beam-forming Tutorial

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Before our journey of Beam-forming, some basic principles of it are necessary, see material from article *ARRAY SEISMOLOGY:METHOD AND APPLICATIONS* by Sebastian Rost and Christine Thomas, 2002.

1. Prepare your SAC format data, but note that header variations of SAC file: stlo(longitude of station) stla(latitude of station) are valid;
2. Just run executable program beamforming with arguments as below,

```
beamforming sacfile.lst t1 t2 fre_low fre_high slow_low slow_high slow_step baz_step outputfile
```

<t1>	Beginning time of inputting SAC files
<t2>	Ending time of inputting SAC files
<sacfile.lst>	File containing inputting SAC files
<fre_low>	Low limitation frequency of bandpass filter
<fre_high>	High limitation frequency of bandpass filter
<slow_low>	Low limitation slowness of scanning
<slow_high>	High limitation slowness of scanning
<slow_step>	Step slowness length of scanning
<baz_step>	Step back-azimuth length of scanning
<outputfile>	Outputting results file containing 3 columns col1: back-azimuth col2: slowness col3: cross-coefficient

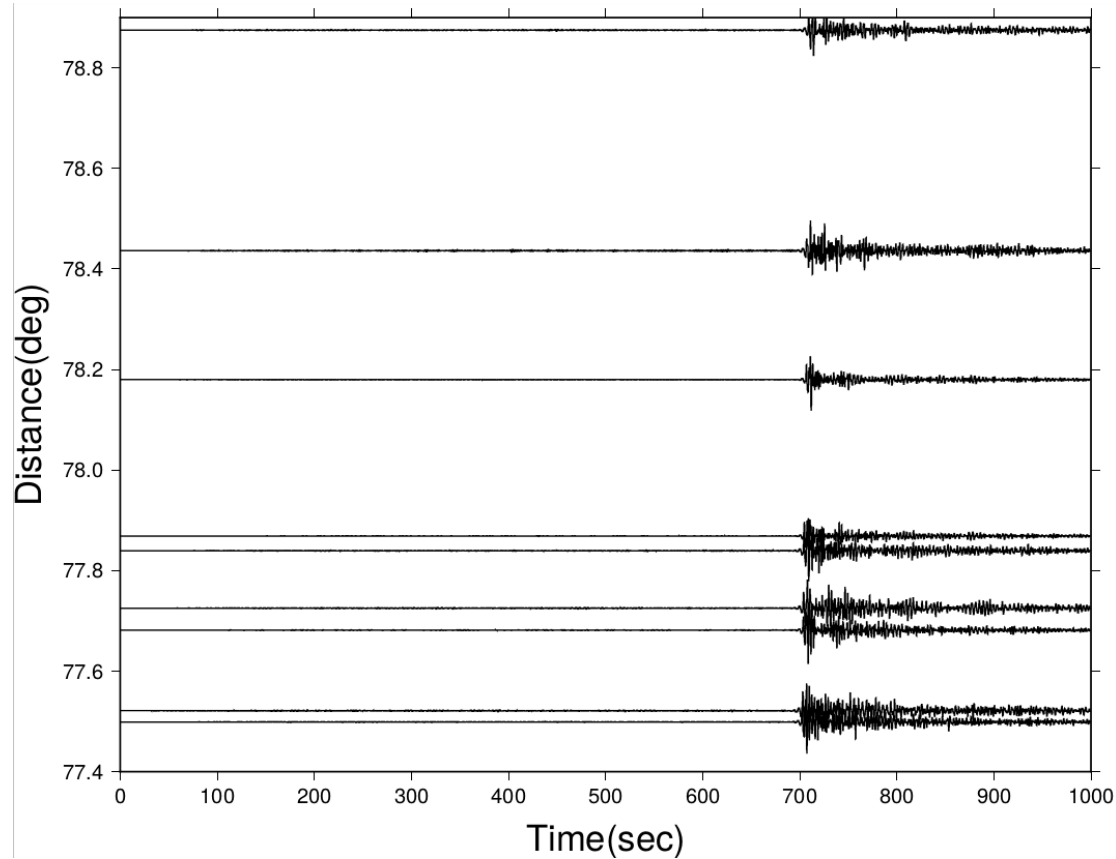
ATTENTION!!! program runs on Linux platform, actually Fedora 25, SAC (Seismic Analysis Code) with version 101.6a is necessary here!

3. plotting script is saved in file “plot.sh”, **ATTENTION**, run “plot.sh” requires GMT(the Generic Mapping Tools), here with version 5.3.1,

5.2.1 will be OK;

4. Here give a an example,

raw SAC format data plotting is given first below



now we get information of this earthquake event:

```
[!]saclst kzdate kztime stlo stla evlo evla evdp gcarc baz f 2011.236.17.46.11.0*.SAC
2011.236.17.46.11.0000.XB.PM05..BHZ.M.SAC 2011/08/24 17:46:11.000 -5.3368 35.2134 -74.538 -7.6203 149.3 77.7252 251.508
2011.236.17.46.11.0000.XB.PM06..BHZ.M.SAC 2011/08/24 17:46:11.000 -5.639 35.3086 -74.538 -7.6203 149.3 77.5211 251.297
2011.236.17.46.11.0000.XB.PM09..BHZ.M.SAC 2011/08/24 17:46:11.000 -5.1145 35.0273 -74.538 -7.6203 149.3 77.8395 251.686
2011.236.17.46.11.0000.XB.PM18..BHZ.M.SAC 2011/08/24 17:46:11.000 -4.8195 34.15 -74.538 -7.6203 149.3 77.7984 252.048
2011.236.17.46.11.0000.XB.PM20..BHZ.M.SAC 2011/08/24 17:46:11.000 -5.0329 33.9064 -74.538 -7.6203 149.3 77.5548 251.968
2011.236.17.46.11.0000.XB.PM21..BHZ.M.SAC 2011/08/24 17:46:11.000 -5.3197 33.7205 -74.538 -7.6203 149.3 77.2702 251.832
2011.236.17.46.11.0001.XB.PM15..BHZ.M.SAC 2011/08/24 17:46:11.000 -4.6997 34.4694 -74.538 -7.6203 149.3 77.9909 252.057
2011.236.17.46.11.0200.XB.PM12..BHZ.M.SAC 2011/08/24 17:46:11.020 -4.6084 34.8505 -74.538 -7.6203 149.3 78.1797 252.037
```

then calculate predicted information of what seismic phase we are interested, here PcP, directed P, maybe there arrival times are not really divergent.

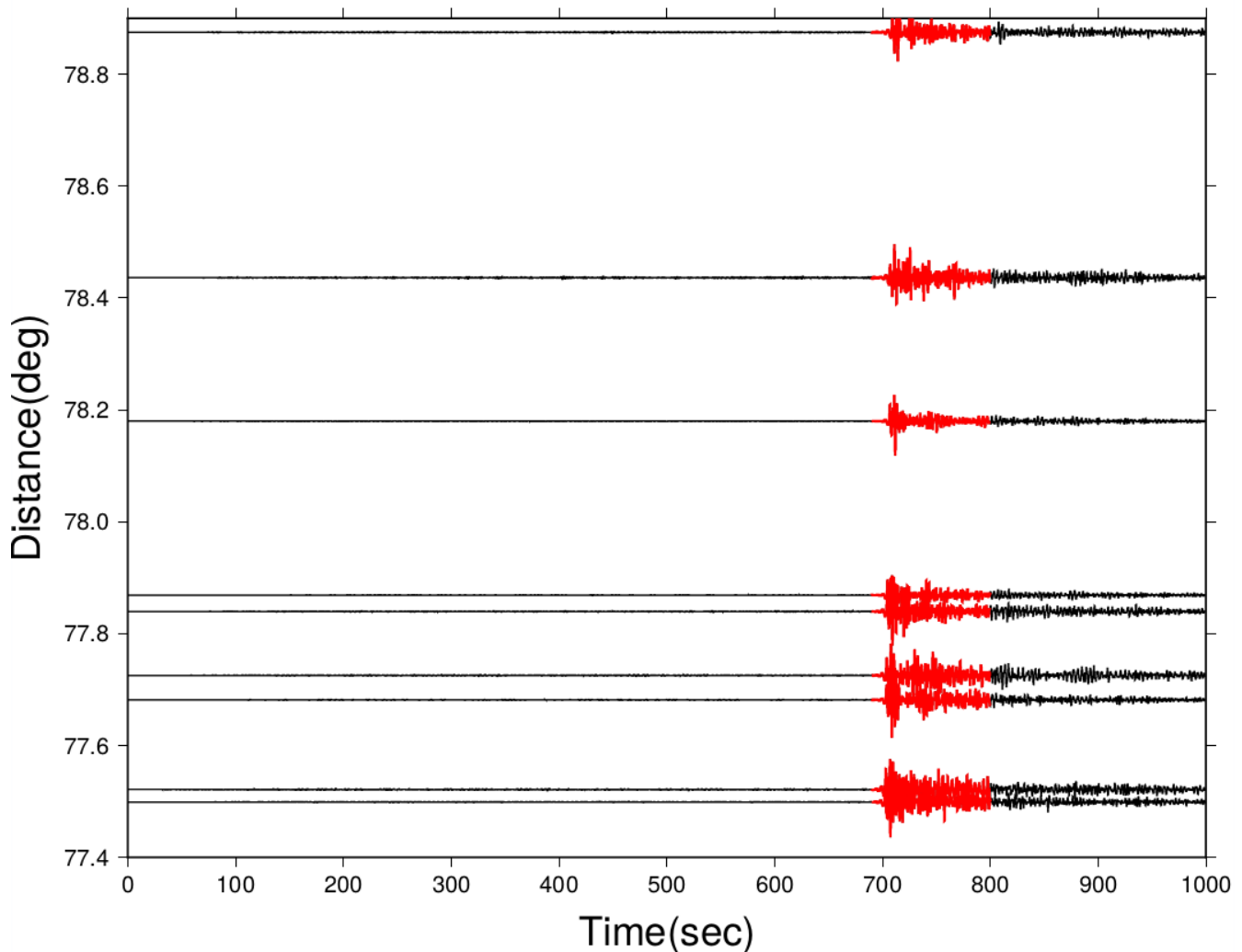
```
[ $\$$ ]taup_time -h 149.3 -deg 77.8 -mod prem
```

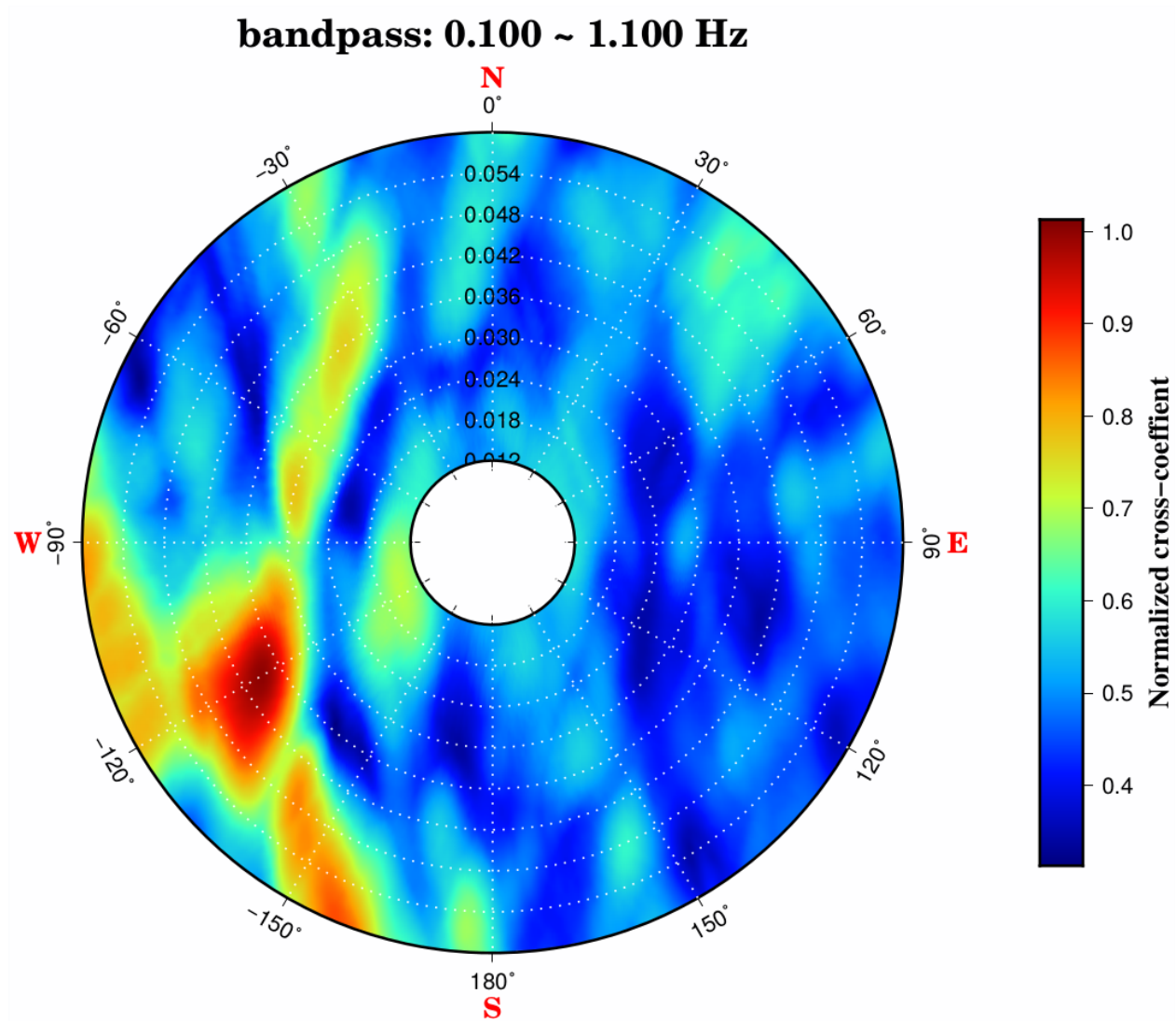
Model: prem

Distance (deg)	Depth (km)	Phase Name	Travel Time (s)	Ray Param p (s/deg)	Takeoff (deg)	Incident (deg)	Purist Distance	Purist Name
77.80	149.3	P	699.72	5.511	24.06	16.71	77.80	= P
77.80	149.3	PcP	708.84	4.331	18.69	13.06	77.80	= PcP
77.80	149.3	pP	735.51	5.598	155.53	16.98	77.80	= pP
77.80	149.3	PKiKP	1036.17	1.525	6.48	4.56	77.80	= PKiKP
77.80	149.3	S	1280.67	10.685	25.93	17.91	77.80	= S
77.80	149.3	SKS	1298.08	7.051	16.77	11.71	77.80	= SKS
77.80	149.3	ScS	1305.61	8.113	19.39	13.50	77.80	= ScS
77.80	149.3	sS	1344.31	10.838	153.67	18.17	77.80	= sS
77.80	149.3	SKiKS	1451.99	1.638	3.84	2.70	77.80	= SKiKS

now we execute beam-forming, and result is visualized below,

`beamforming listfile 690 800 0.1 1.1 0 0.06 0.001 1 out.txt`





Result reveals the back-azimuth is 248 degree, which is near to realistic 251 or 252 degree. And the horizontal slowness is 0.039 sec/km namely 4.3366 sec/degree, which indicates the seismic phase PcP.