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 beamforing 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-coeffient

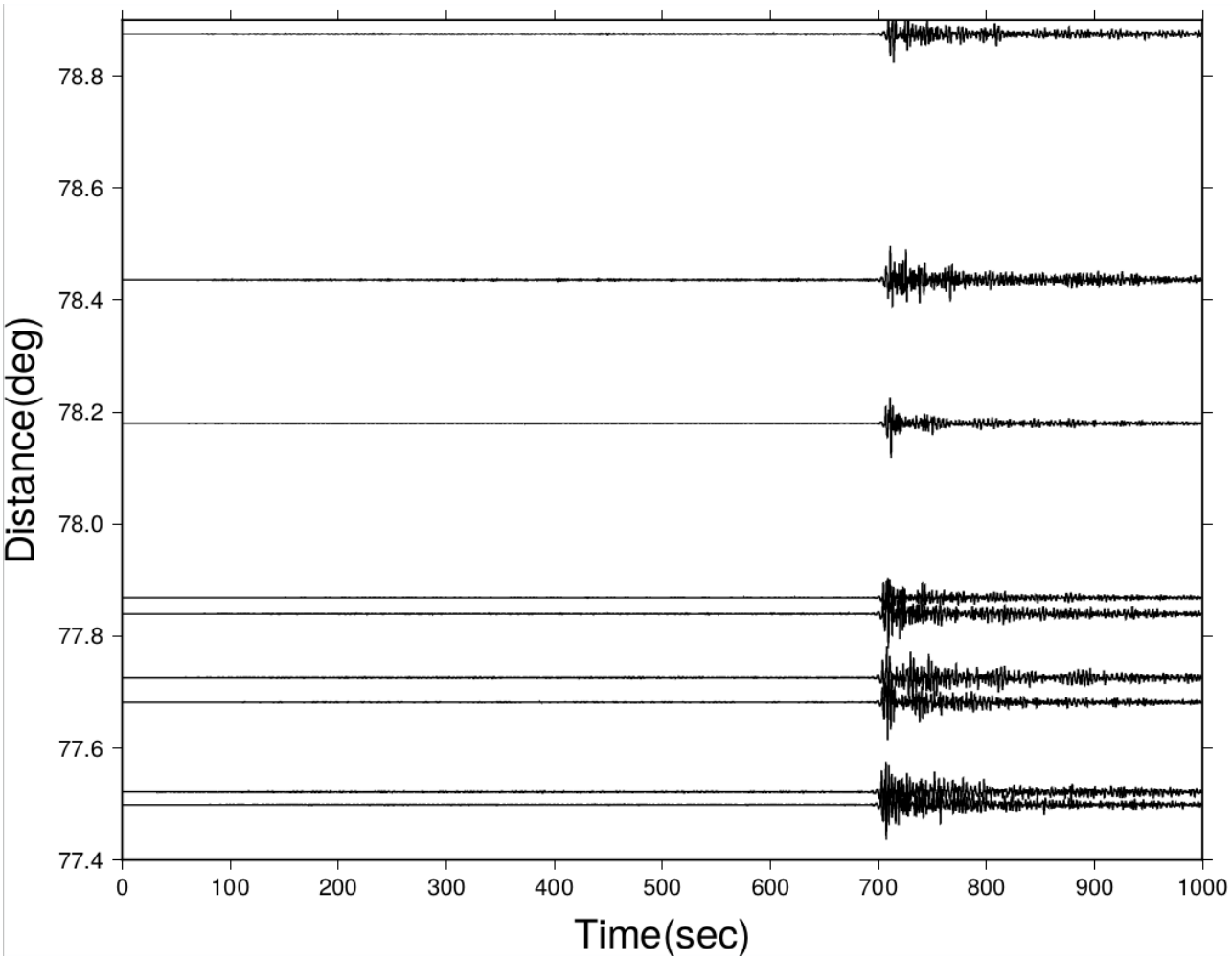
ATTENTION!!! program runs on Linux platform, actually Fedora 25, SAC (Seismic Analysis Code) with version 101.6a is necessary here!

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,**

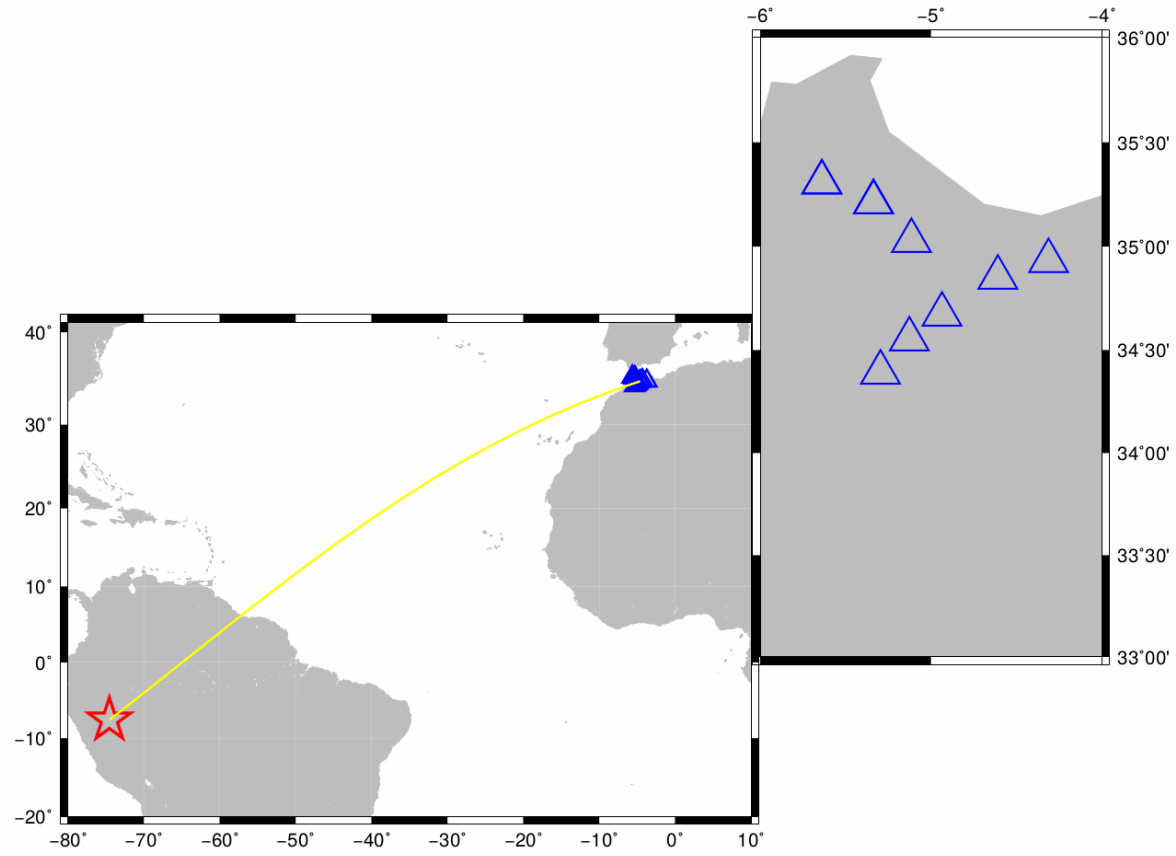
5.2.1 will be OK;

4. Here give an example,

raw SAC format data plotting is given first below



map of seismic stations



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
```

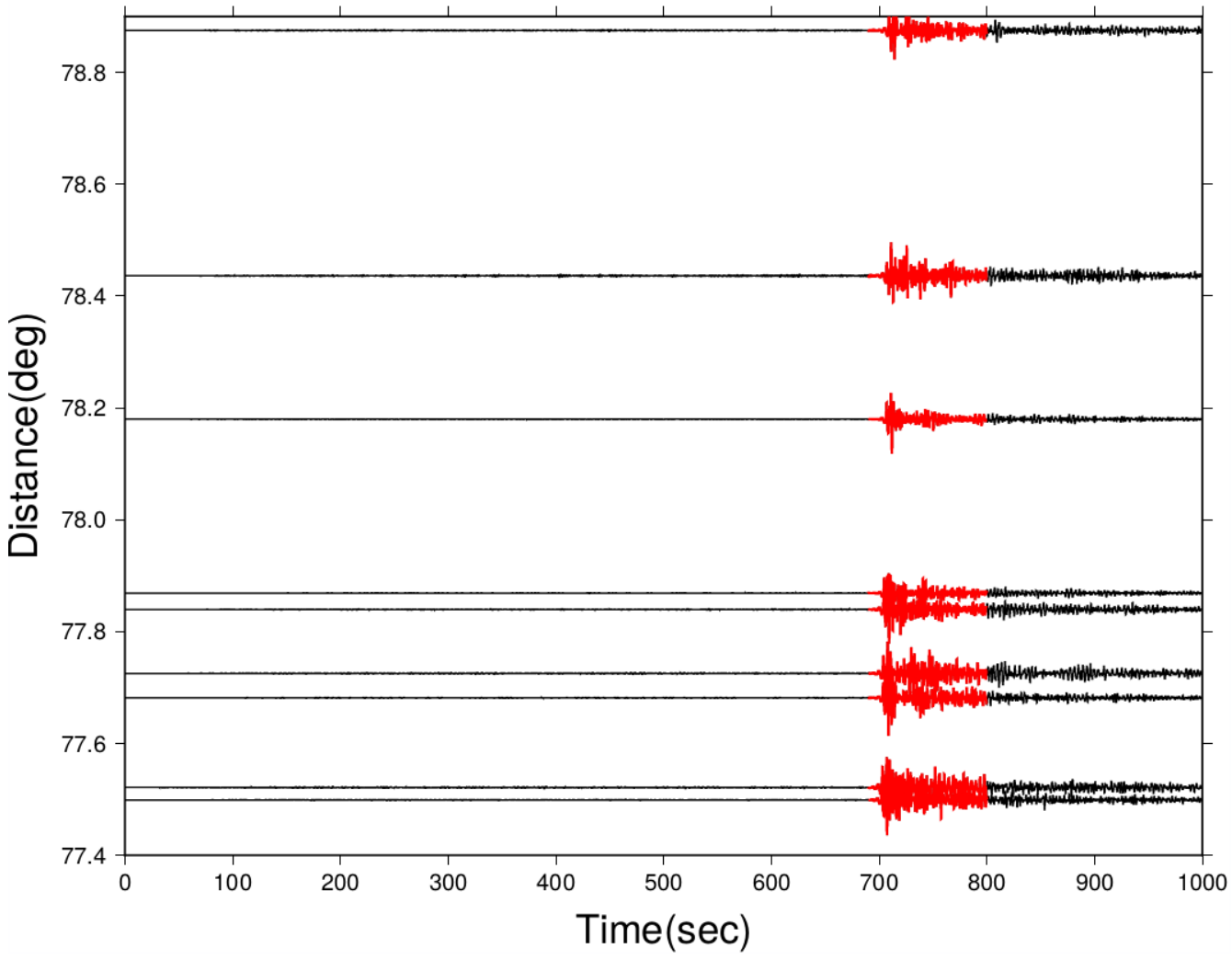
then calculate predicted information of what seismic phase we are interested, here PcP, directed P, maybe there arrival times are not really divergent.

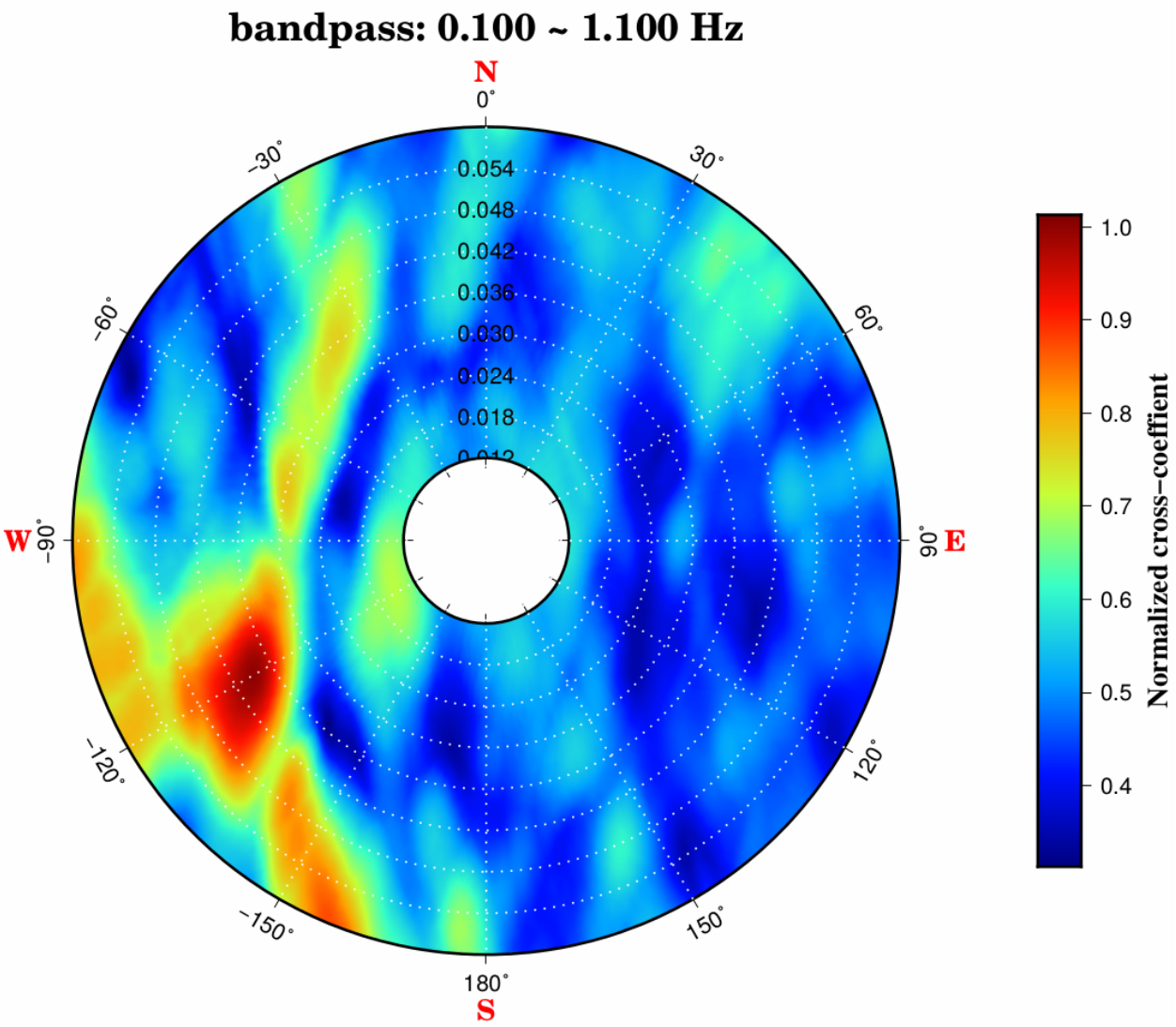
```
[$]taup_time -h 149.3 -deg 77.8 -mod prem

Model: prem
Distance   Depth   Phase   Travel    Ray Param  Takeoff  Incident  Purist    Purist
  (deg)     (km)   Name    Time (s)  p (s/deg)   (deg)    (deg)   Distance   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.