gCAPjoint

EARTHQUAKE SOURCE PARAMETER INVERSION

WITH SEISMIC WAVES

Version 1.0

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Nov. 2018
Updated 8 Jan 2020

Content

1 Introduction

This document describes the installation of Version 1.0 of the gCAPjoint developed by the Waveform Seismology Group of USTC (University of Science and Technology of China). This installation has been tested for the Linux system.

2 Installation on Linux

2.1 Download the Programs

The most recent version of the gCAPjoint will always be available for internet download from the site:
https://github.com/bgpseismology/gCAPjoint

2.2 Dependencies

In order to run the code gCAPjoint, you need to have the following software installed and added to the PATH.

1. Seismic Analysis Code (SAC)
   http://www.iris.edu/dms/nodes/dmc/software/
2. TauP
   http://www.seis.sc.edu/taup/
3. CRUST2.0
   http://igppweb.ucsd.edu/~gabi/crust2.html
4. Frequency-Wavenumber synthetic seismogram (FK)
   http://www.eas.slu.edu/People/LZhu/downloads/fk3.1.tar
5. PSSAC2 or PSSAC
   https://geodynamics.org/svn/cig/seismo/3D/ADJOINT_TOMO/measure_adj/UTIL/pssac2/ PSSAC2
   http://www.eas.slu.edu/People/LZhu/downloads/ PSSAC
6. gCAP1.0
   http://www.eas.slu.edu/People/LZhu/downloads/
7. Numerical Recipes (NR)
   http://www.nr.com/
8. Generic Mapping Tools (GMT)
   http://gmt.soest.hawaii.edu/projects/gmt
9. Ghostscript and Gsview
   http://www.cs.wisc.edu/~ghost/

2.3 Installation of the Programs

The programs will be installed in a directory of your choosing. For example, if you place the downloaded ".zip" or "tgz" file in "/home/baiqp", then you would do the following:
".tgz" gzipped files: Using sh or bash shells:

$ **tar –zxvf *.tgz**

First, go to the gCAPjoint directory:

$ **cd gCAPjoint1.0**

$ **./configure linux**

$ **./Install**

Then you should add the bin/ directory to the ~/.bashrc file:

```
# gcap
export GCAPHOME=/home/baiqp/gCAPjoint1.0
export PATH=/home/baiqp/gCAPjoint1.0/bin:${PATH}
```

$ **source ~/.bashrc**

$ **which tel4**

/home/XXXXX/gCAPjoint1.0/bin/tel4

3 Example

3.1 Download the Broadband Waveforms

1. Visiting the following website: http://ds.iris.edu/wilber3/find_event, and selecting the event in which you interested. After obtaining the SEED compressed file, you should rename them to loc.seed and tel.seed, respectively. Note the SEED file only include the BH? components.

   $ **cd 2010-03-04_Mw6.3**

   ```
   loc.seed  tel.seed
   ```

   then copy the cmds/ to this directory, and move the LeadDataTel.sh to the main directory.

   $ **cp -r XXX/cmds ./**

   ```
   cmds  LeadDataTel.sh  loc.seed  tel.seed
   ```

2. For IRIS WILBER format seed files, extract the SAC file by "sh LeadDataTel.sh". Otherwise you should de-instrument and rotate the SAC file to the great arc by yourself, then cut the window length and multiply 100 to fit the measurement of the forward modeling codes, the units is cm/s.

   $ **cp cmds/LeadDataTel.sh ./**

   $ **sh LeadDataTel.sh**

   ```
   cmds  data  datatel  eveinfo.lst  greenFuncDir  LeadDataTel.sh  SEED
   ```

3. The approach is the same as above for local waveforms, extract the SAC file by "sh LeadDataLoc.sh".

$ **cp cmds/LeadDataLoc.sh ./**

$ **sh LeadDataLoc.sh**

```
cmds  dataloc  eveinfo.lst   LeadDataLoc.sh  SEED
data  datatel  greenFuncDir  LeadDataTel.sh
```

3.2 Green's Functions Calculations

The green's funcitons directory is **greenFuncDir/**.

Note: Only when you know exactly can you use the following scripts.

cmds/fk.sh: calculate the local green's functions.

cmds/tel5.sh: calculate the teleseism green's functions

3.3 Joint Inversion by gCAPjoint

1. Copy the gengcap.sh to the main directory and Specify the input parameters in it.

   $ **cp cmds/gengcap.sh ./**

   $ **sh gengcap.sh**

   ```
   cmds  dataloc  depth.sh  gengcap.sh    LeadDataLoc.sh  SEED
   data  datatel  gcap.sh   greenFuncDir  LeadDataTel.sh
   ```

   $ **sh depth.sh**

2. Waiting for the completion of the joint inversion, view the results in the data or output directory.

   $ **evince data/mecherr.ps**

   $ **evince data/vmodel_24.ps**

   ```
   cmds  dataloc  depth.sh     gcap.sh     greenFuncDir    LeadDataTel.sh  SEED
   data  datatel  eveinfo.lst  gengcap.sh  LeadDataLoc.sh  output
   ```

3.4 Results and Summary

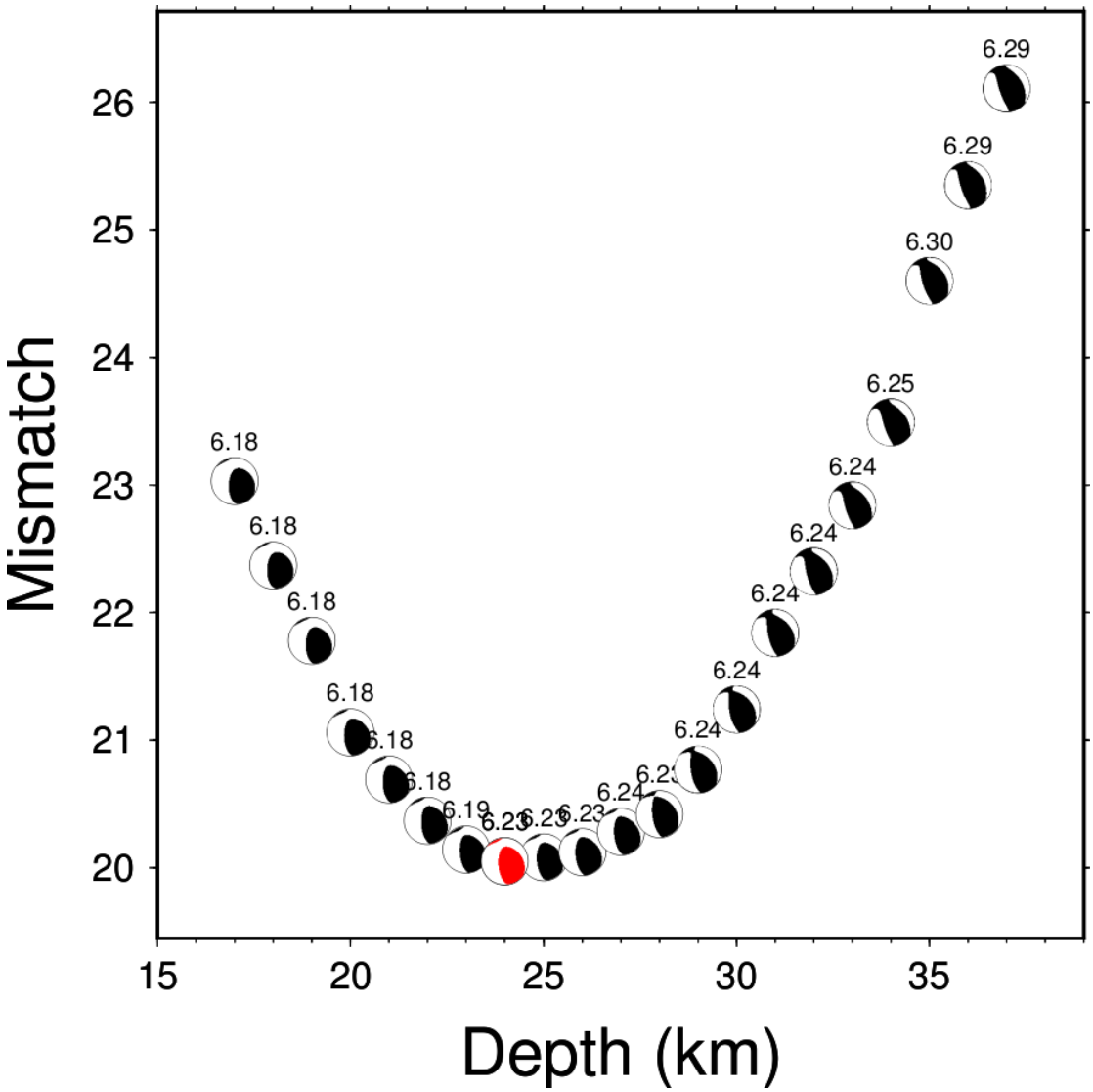

Fig. 1. Depth sensitivity for waveform mechanism. Numbers above the focal sphere indicate moment magnitude (Mw) for each depth. The red focal sphere is the optimal search depth.

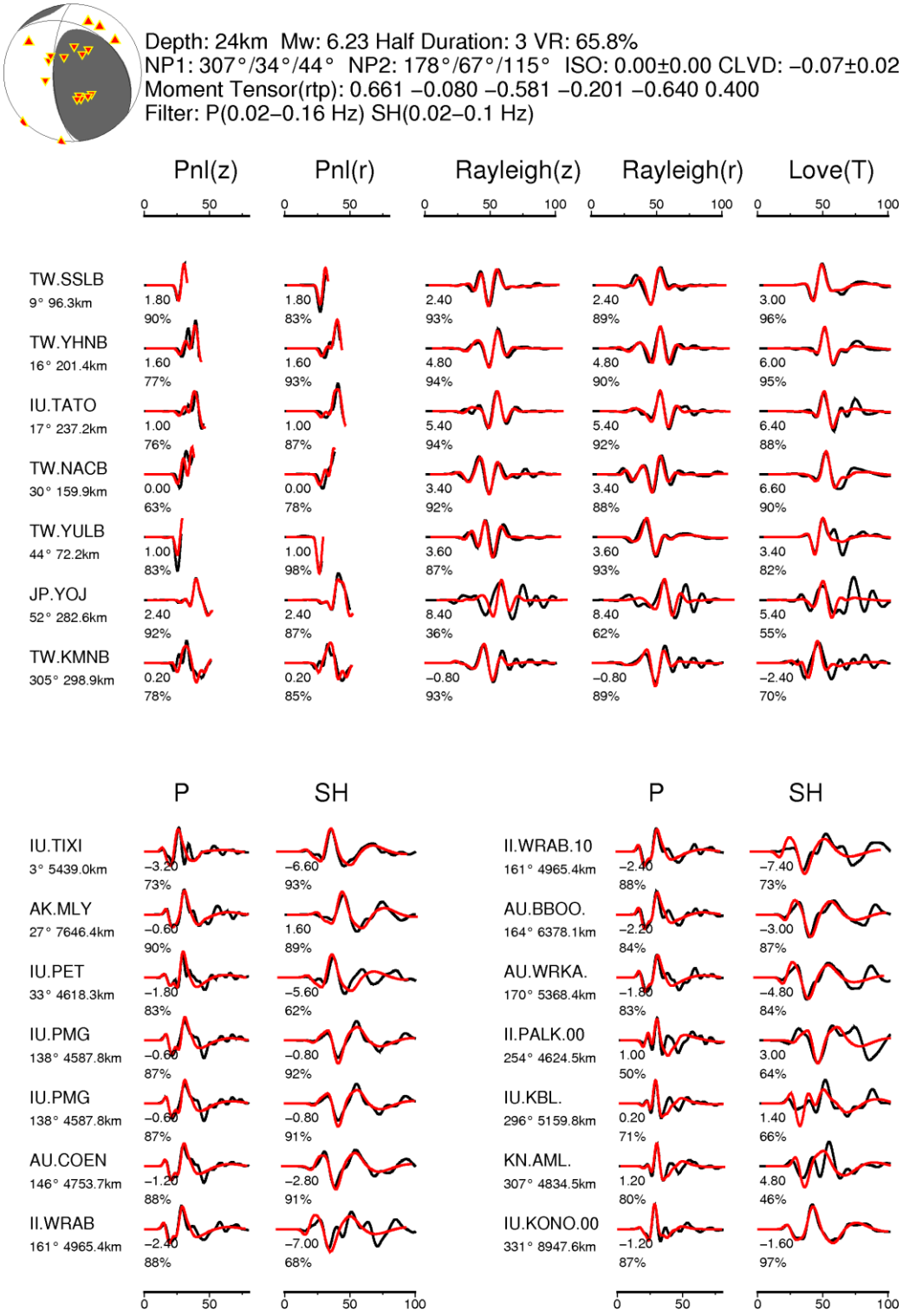

Fig. 2. gCAPjoint waveform inversion for the 2010 M_W6.3 Jiashian earthquake. The black lines are observed data, and the red lines are synthetics. Numbers to the left of the seismograms are times shifts (lower, italicized numbers) and cross-correlation coefficient in percent (upper numbers). Positive time shifts indicate that synthetic waveforms are delayed. The triangles on the focal sphere represent the local stations, whereas the upside-down triangle represent the teleseismic stations.

4 Q&A

4.1 How to cite relevant work

NR: (Press et al., 1996)
GMT: (Wessel and Smith, 1998) GMT4, (Wessel et al., 2013) GMT5, (Wessel et al., 2019) GMT6
SAC, CRUST2.0, TauP: (Goldstein et al., 2003), (Bassin, 2000), (Crotwell et al., 1999)
CAP, gCAP, FK: (Zhu and Ben-Zion, 2013; Zhu and Helmberger, 1996; Zhu and Rivera, 2002)
TEL3: (Kikuchi and Kanamori, 1982), (Chu et al., 2009)
CAPjoint: (Chen et al., 2015)

Reference

Bassin, C., 2000, The current limits of resolution for surface wave tomography in North America: EOS Trans. AGU. 81: Fall Meet. Suppl., Abstract.

Chen, W., S. Ni, H. Kanamori, S. Wei, Z. Jia, and L. Zhu, 2015, CAPjoint, a computer software package for joint inversion of moderate earthquake source parameters with local and teleseismic waveforms: Seismological Research Letters, **86**, no. 2A, 432-441.

Chu, R., L. Zhu, and D. V. Helmberger, 2009, Determination of earthquake focal depths and source time functions in central Asia using teleseismic P waveforms: Geophysical Research Letters, **36**, no. 17.

Crotwell, H. P., T. J. Owens, and J. Ritsema, 1999, The TauP Toolkit: Flexible seismic travel-time and ray-path utilities: Seismological Research Letters, **70**, 154-160.

Goldstein, P., D. Dodge, M. Firpo, L. Minner, W. Lee, H. Kanamori, P. Jennings, and C. Kisslinger, 2003, SAC2000: Signal processing and analysis tools for seismologists and engineers: The IASPEI International Handbook of Earthquake and Engineering Seismology, **81**, 1613-1620.

Kikuchi, M., and H. Kanamori, 1982, Inversion of complex body waves: Bulletin of the Seismological Society of America, **72**, no. 2, 491-506.

Press, W. H., S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery, 1996, Numerical recipes in C. Vol. 2: Cambridge university press Cambridge.

Wessel, P., and W. H. F. Smith, 1998, New, improved version of generic mapping tools released: Eos, Transactions American Geophysical Union, **79**, no. 47, 579-579. http://dx.doi.org/10.1029/98eo00426.

Wessel, P., W. H. Smith, R. Scharroo, J. Luis, and F. Wobbe, 2013, Generic mapping tools: improved version released: Eos, Transactions American Geophysical Union, **94**, no. 45, 409-410.

Wessel, P., J. Luis, L. Uieda, R. Scharroo, F. Wobbe, W. H. F. Smith, and D. Tian, 2019, The Generic Mapping Tools Version 6: Geochemistry, Geophysics, Geosystems, **0**, no. ja. http://dx.doi.org/10.1029/2019gc008515.

Zhu, L., and D. V. Helmberger, 1996, Advancement in source estimation techniques using broadband regional seismograms: Bulletin of the Seismological Society of America, **86**,

no. 5, 1634-1641.

Zhu, L., and L. A. Rivera, 2002, A note on the dynamic and static displacements from a point source in multilayered media: Geophysical Journal International, **148**, no. 3, 619-627.

Zhu, L., and Y. Ben-Zion, 2013, Parametrization of general seismic potency and moment tensors for source inversion of seismic waveform data: Geophysical Journal International, **194**, no. 2, 839-843.