Homework 2 (EAS 8803: OBS. SEISMOLOGY - SPRING SEMESTER 2019)
Graduate Only Total points: 100. Due 03/05/2019

Answer Key

1. The most critical specification of a data logger is its dynamic range, which is defined as the ratio of the largest on-scale measurement divided by the smallest resolvable measurement. Modern seismometers record on digital recorders, which convert the analogue voltage seismometer output to digital counts. The nominal dynamic range is determined by the number of bits used to characterize the voltage. Please compute the dynamic range in terms of both decibels (dB) and orders of magnitude for the following types of digitizers: 8, 12, 16, 20, 24 bits. (Note: One bit is used to determine whether the signal is positive or negative, and each additional bit represents a factor of 2 in dynamic range). (15 point)

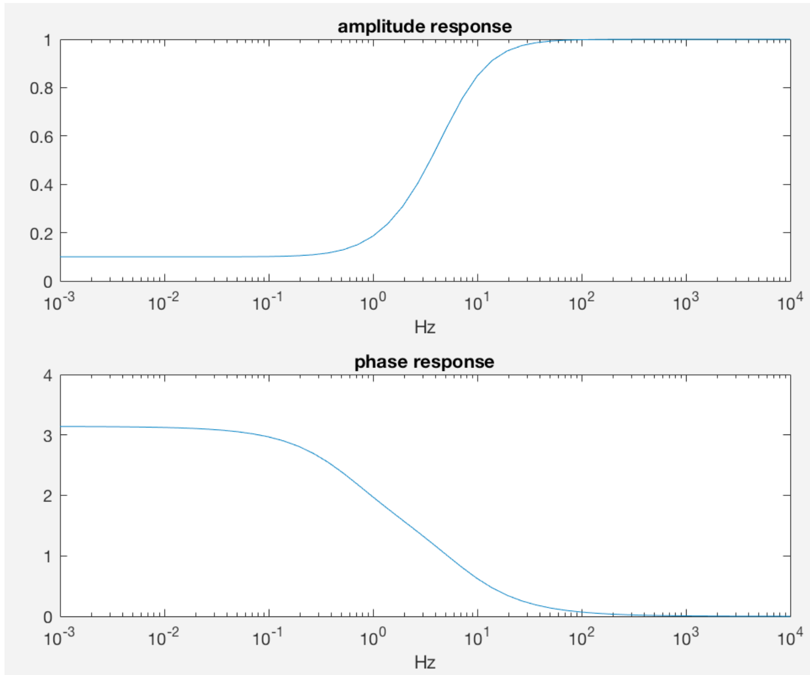
Ans:

Order of Mag. = $\log_{10}(A1/A2) = \log_{10}(2^{(bit-1)})$
dB = Order of Mag. X 20

Bit	Order of Mag.	dB	Rounded Order of Mag.	Rounded dB
8	2.11	42.14	2	40
12	3.31	66.23	3	60
16	4.52	90.31	5	100
20	5.72	114.39	6	120
24	6.92	138.47	7	140

2. Consider a system with a pole and a zero on the real axis of the s-plane. Let the pole position be (-6.28318, 0), and the zero position (0.628318, 0). Please plot the amplitude part of the frequency response function. What is the contribution of the pole and zero to the frequency response function? (15 point)

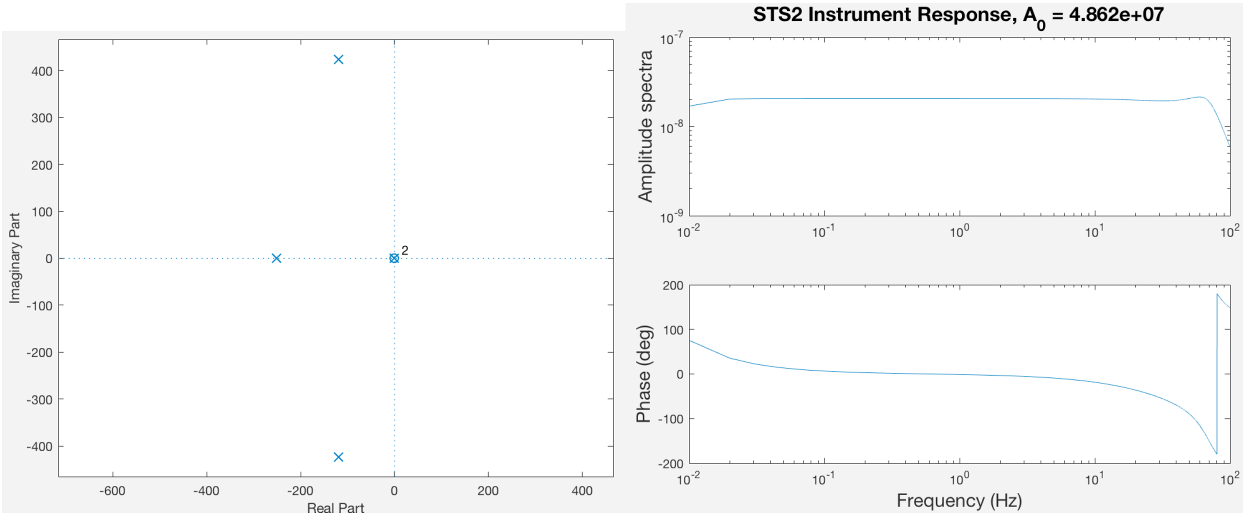
Ans (From Frank Scherbaum's book: of poles and zeros): From the pole and zero positions we expect corner frequency at f_1 = 0.1 Hz (Note: angular frequency of 0.628 radian/s) and $f2$ = 1 Hz (Note: angular frequency of 628 radian/s), respectively. We can see that the frequency response function starts out constant, increases by 20 dB/decade at f_1 then decrease by 20 dB/decade at f_2. Hence a single pole causes the amplitude spectrum (in log-log plot) to increase with a slope of 1 , while a single zero causes it to decrease with a slope of 1.
See computer code hw_2_2.m in
http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/Seis_II_HW2_solution.tar.gz



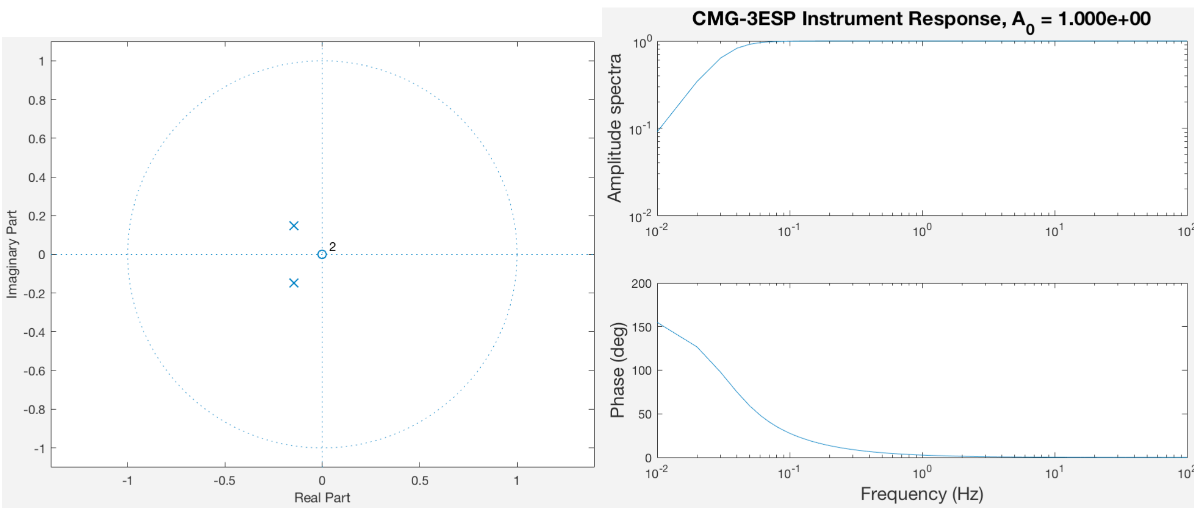
3. Please plot the amplitude and phase spectra of the instrument responses for the following types of seismometers. In addition, please obtain the normalization factor at 1 Hz and plot the pole and zeros on the *z*-plane for each seismometer (20 point):
   Ans:

Name	Natural Freq.	Damping	Zeros	Poles	Normalization factor
Streckeisen STS2	0.0083 Hz (120 s)	0.707 critical	Two at zero	$-0.037 + 0.037i$ $-0.037 - 0.037i$ $-118.752 + 423.4880i$ $-118.752 - 423.4880i$ -251.3270	4.8624×10^7
Guralp CMG-3 ESP	0.033 Hz (30 s)	0.707 critical	Two at zero	$-0.147 + 0.147i$ $-0.147 - 0.147i$	1
Mark Products L-4C3D	1 Hz	0.707 critical	Two at zero	$-4.44 + 4.44i$ $-4.44 - 4.44i$	1.4133
Mark Products L-22D	2 Hz	0.707 critical	Two at zero	$-8.88 + 8.88i$ $-8.88 - 8.88i$	4.1181

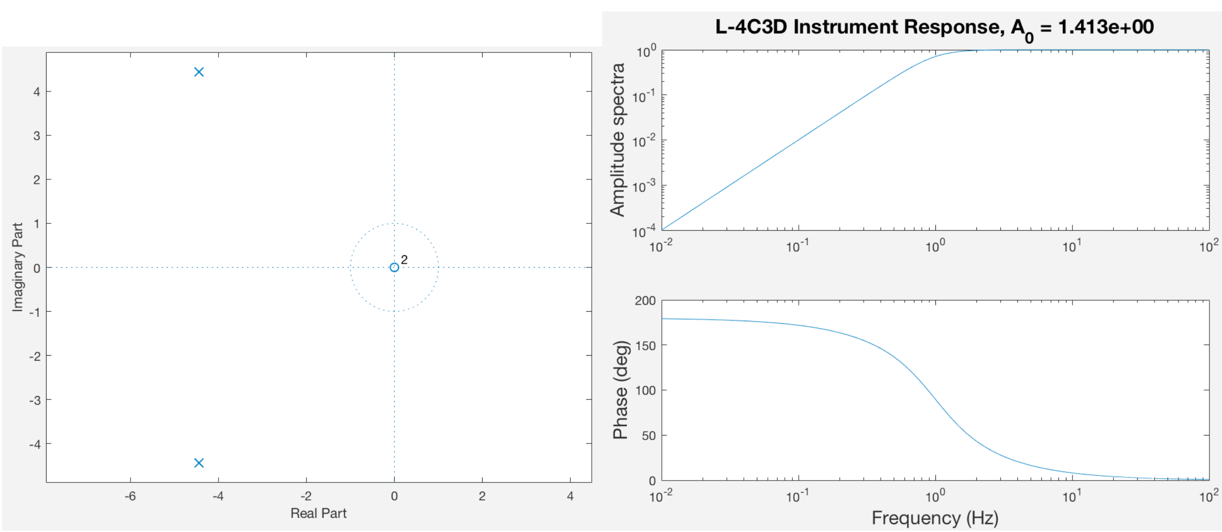
See computer code hw_2_3.m in
http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/Seis_II_HW2_solution.tar.gz



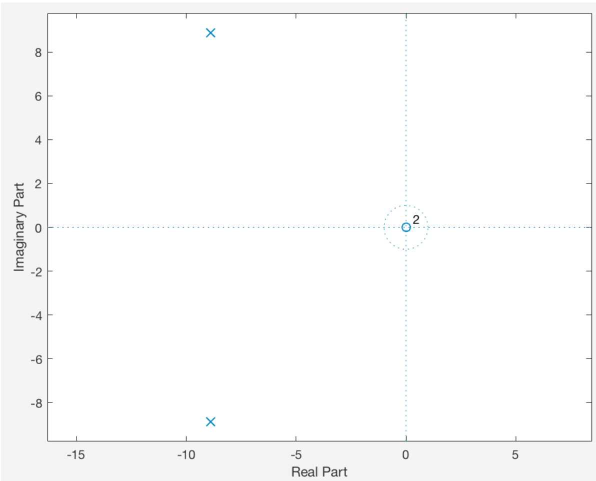
Imaginary Part
Real Part
STS2 Instrument Response, A_0 = 4.862e+07
Amplitude spectra
Phase (deg)
Frequency (Hz)

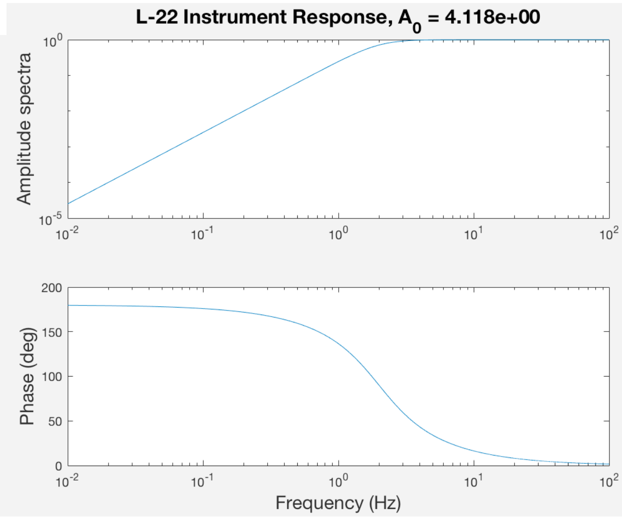


Imaginary Part
Real Part
CMG-3ESP Instrument Response, A_0 = 1.000e+00
Amplitude spectra
Phase (deg)
Frequency (Hz)



Imaginary Part
Real Part
L-4C3D Instrument Response, A_0 = 1.413e+00
Amplitude spectra
Phase (deg)
Frequency (Hz)





4. Please download the instrument response information from the following website (20 points):

http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/RESP.BK.PKD..HHZ

The original data (counts) in SAC format can be downloaded from the following website:

http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/BK.PKD.HHZ.SAC

The original data (counts) in ASCII format can be downloaded from the following website:

http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/BK_PKD_HHZ_SAC.dat

(a) Verify that the Stage 0 (field B058F04) sensitivity is a multiplication of the gain of previous stage (5 point).

Ans:

Stage 1 B058F04	Gain:	1.500000E+03
Stage 2 B058F04	Gain:	4.073350E+05
Stage 3 B058F04	Gain:	1.014770E+00
Stage 4 B058F04	Gain:	9.781120E-01

Final again is equal to multiplication of the above four gain, which is equal to the Sensitivity at Stage sequence number 0.

B058F03	Stage sequence number:	0
B058F04	Sensitivity:	6.064580E+08

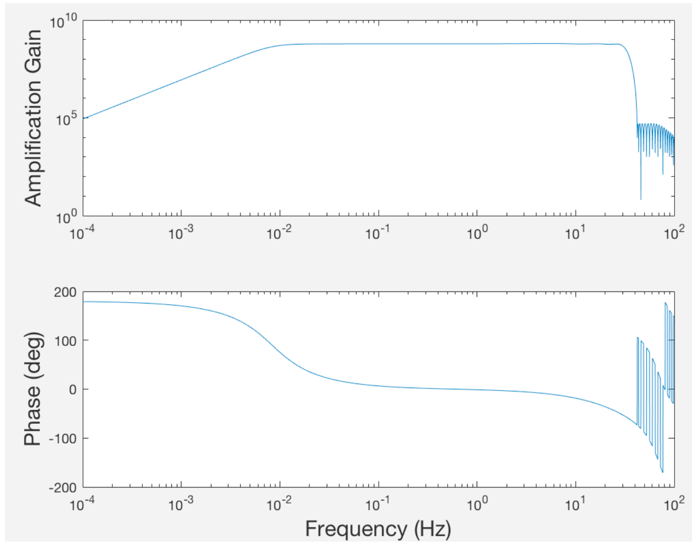
(b) Please use evalresp command to extract, then plot the amplitude and phase spectra of the instrument response (5 point).

Ans:

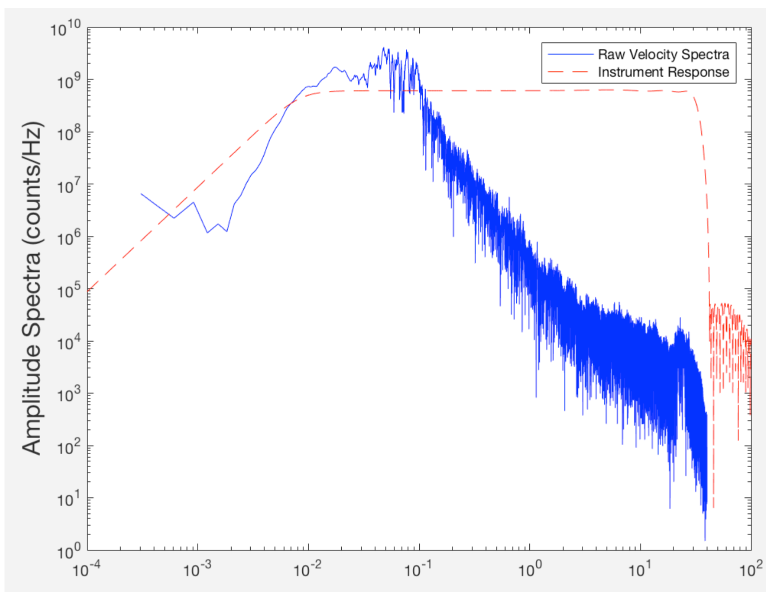
Command: evalresp PKD HHZ 2002 302 0.0001 100 5000 -f RESP.BK.PKD..HHZ

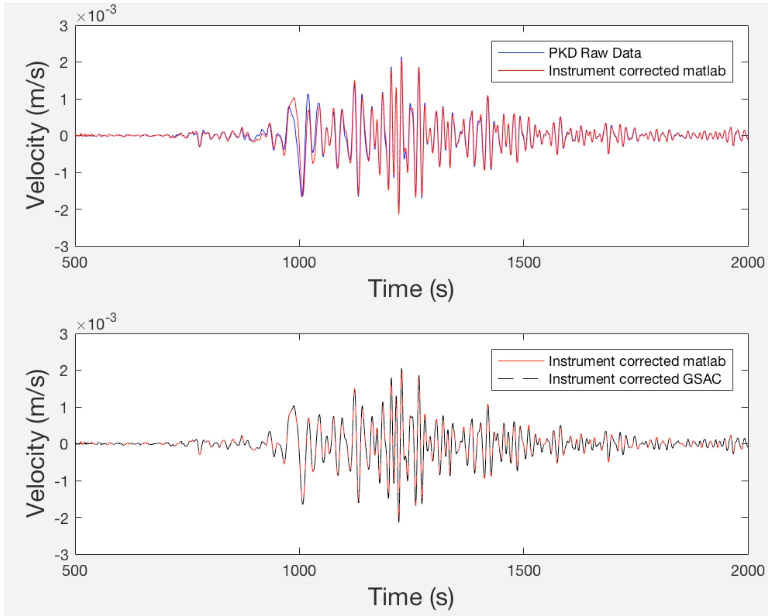
The output is AMP.BK.PKD..HHZ and PHASE.BK.PKD..HHZ

Use any program to plot it out.



(c) Please write your own code to remove the instrument response based on the either the pole-zeros, or the evalresp output to obtain the true velocity in the unit of m/s. Please compare with your results with those obtained using the SAC or GSAC transfer function (25 point).



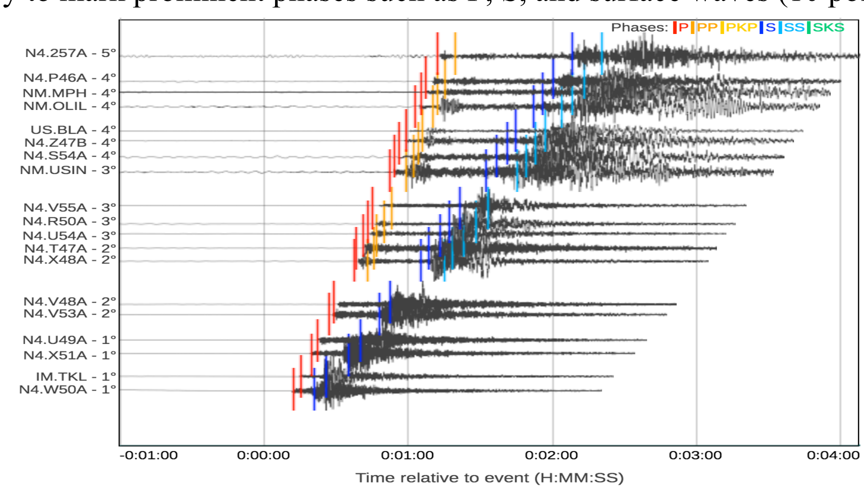


Ans: See computer code hw_2_4.m in
http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/Seis_II_HW2_solution.tar.gz

5. Please select the magnitude 4.4 earthquake occurred in Eastern Tennessee, and download all waveforms (10 min before and 60 min after event time) within 5 degrees from IRIS DMC (1). Then perform the following analysis (either within SAC or by your own program) (30 point)

   (a) Shift the reference time in the data so that its zero time corresponds to the origin time of this event (see related tutorial at http://geophysics.eas.gatech.edu/classes/SAC/). (5 point)

   (b) Plot the record section of the raw vertical component data versus epicentral distances. If you have too many waveforms, you can randomly select 30-50 waveforms to plot. You can use Matlab, SAC or 'pssac' command in GMT (see the SAC tutorial for more details). Try to mark prominent phases such as P, S, and surface waves (10 point)



(c) Select one station that is the further away from the mainshock, but still has reasonable good signal to noise ratio. Remove the instrument response first into displacement. Then rotate it into radial and transverse component. Plot the rotated transverse, radial and vertical data. Identify the Love and Rayleigh waves. (5 point)

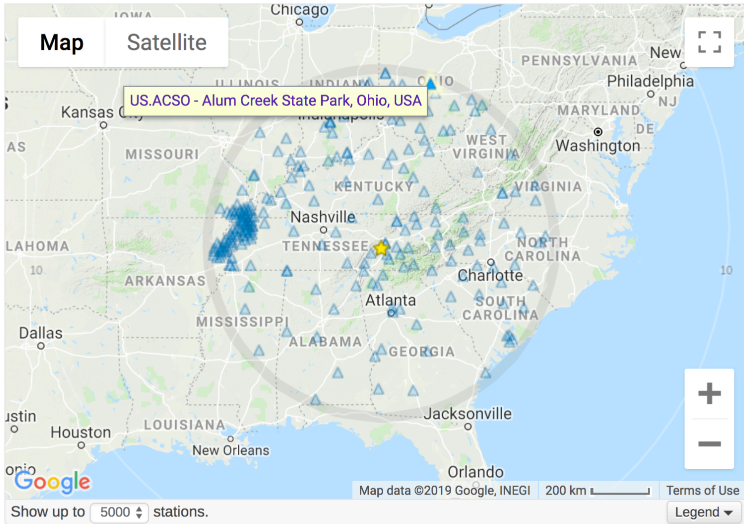
I selected station UC.ACSO, and obtained the pole-zeros file from http://ds.iris.edu/mda/US/ACSO/00/BHZ/?starttime=2012-01-26T00:00:00&endtime=2599-12-31T23:59:59
Note the input is m (and with three zeros). Hence, after we remove the instrument response we will get displacement directly (NOT velocity).

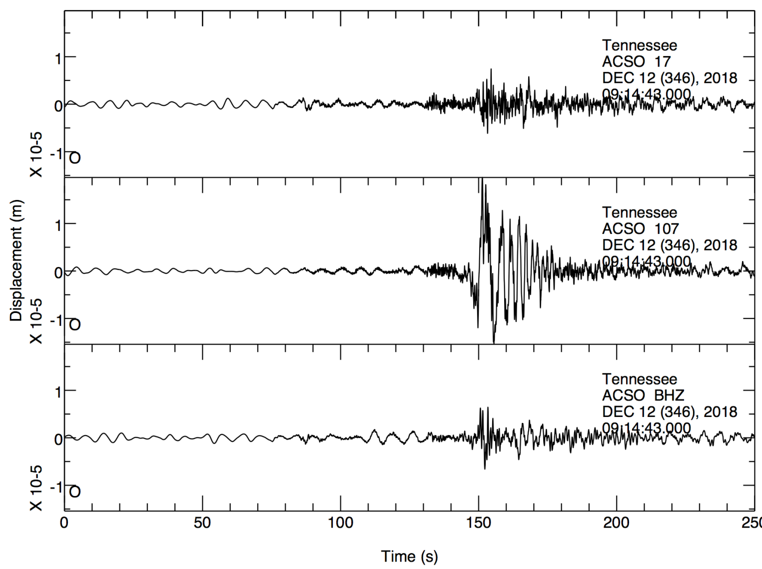
```
SAC> r US.ACSO.00.BH2.M.2018.346.091343.SAC
SAC> rmean
SAC> rtrend
SAC> taper
SAC> transfer from POLEZERO subtype US_ACSO_BH2_pz to none FREQLIMITS 0.02 0.05
16 18
SAC> w append .disp

SAC> r US.ACSO.00.BH1.M.2018.346.091343.SAC
SAC> rmean
SAC> rtrend
SAC> taper
SAC> transfer from POLEZERO subtype US_ACSO_BH1_pz to none FREQLIMITS 0.02 0.05
16 18
SAC> w append .disp

SAC> r US.ACSO.00.BHZ.M.2018.346.091343.SAC
SAC> rmean
SAC> rtrend
SAC> taper
SAC> transfer from POLEZERO subtype US_ACSO_BHZ_pz to none FREQLIMITS 0.02 0.05
16 18
SAC> w append .disp

SAC> r US.ACSO.00.BH1.M.2018.346.091343.SAC.disp
US.ACSO.00.BH2.M.2018.346.091343.SAC.disp
SAC> rotate to GCP
SAC> r more US.ACSO.00.BHZ.M.2018.346.091343.SAC.disp
SAC> qdp off
SAC> xlabel "Time @(s@)
SAC> xlabel "Time @(s@)"
SAC> ylabel "Displacement @(m@)"
SAC> p1
SAC> saveimg US_ACSO_disp.pdf
```





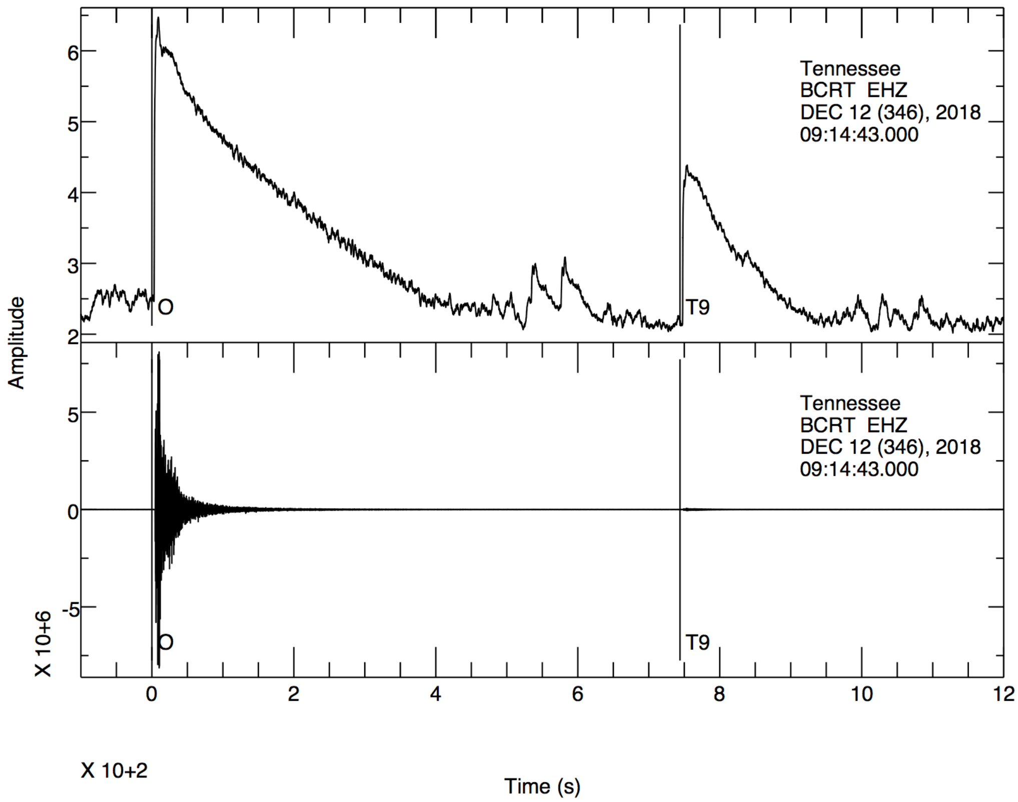
Love wave (in the middle panel) is well present, but Rayleigh wave is not. Why?

(d) Please apply a 5-Hz high-pass filter to the vertical-component of the nearest station, take an envelope function, smooth it and then take a log-based-10 to obtain a smoothed-envelope function. Please identify/pick aftershocks following the mainshock, and compare with the known events listed in the ANSS catalog (http://www.quake.geo.berkeley.edu/anss/catalog-search.html. Note: use https://earthquake.usgs.gov/earthquakes/search/ instead). Comment on what you have found out. (10 point)

IN SAC

```
SAC> r ET.BCRT.00.EHZ.M.2018.346.071443.SAC
SAC> rmean
SAC> hp p 2 n 4 c 5
SAC> envelope
```

```
SAC> smooth h 100
SAC> log10
SAC> r more
SAC> qdp off
SAC> p1
```



Besides the magnitude 4.4 mainshock, there was a magnitude 3.0 aftershock at ~744 s (if you use 10 min of data as suggested you will not see this event), there are at least two small aftershocks around 550 to 600 s. These events were not listed in the USGS catalog.

Note:

1. Your code can be written in any scientific languages (e.g., Fortran, C, Matlab). Please make sure that the code can be compiled under standard Linux machine. Please submit your code electronically to zpeng@gatech.edu, and submit a write-up that includes all the figures.
2. The MatSAC package can be downloaded from the following link: http://geophysics.eas.gatech.edu/people/zpeng/Teaching/MatSAC.tar.gz and the related examples on how to use it can be found at http://geophysics.eas.gatech.edu/people/zpeng/Teaching/SAC_Tutorial/