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Started on	Wednesday, August 3, 2022, 8:10 AM
State	Finished
Completed on	Wednesday, August 3, 2022, 8:20 AM
Time taken	10 mins 6 secs
Marks	20.00/22.00
Grade	**90.91** out of 100.00

Question 1

Correct

1.00 points out of 1.00

Flag question

1. Earthquake Rupture Properties

In our activity today, we will take a closer look at what earthquake ruptures look like on seismograms. These observations will provide us with information about the moment release during the earthquake (related to amount of slip and energy release), the length of the fault that ruptured, and the rate of rupture. I have collected a set of seismograms that record the initial P wave for a recent large earthquake: a magnitude 8.4 subduction thrust earthquake off the coast of Sumatra, Indonesia that happened on September 12, 2007. This earthquake represents the third in series of large events that began with the catastrophic Indonesian earthquake and tsunami in 2004 that killed over 200,000 people. The second event occurred a few months later in 2005, immediately south of the original event. Although the 2007 event is a few years later, the event shows a similar pattern in being south of the 2005 event the preceded it. In other words, the subduction fault has been progressively rupturing further south with each earthquake.

Create a new directory called **rupture** inside your **sac** directory. What is the correct order of commands below to create, check, and then enter this **rupture** directory?

cd ~/sac	1 ✓
cd rupture	4 ✓
mkdir rupture	2 ✓
ls rupture	3 ✓

Check

Please make sure you run these commands now to create, check, and then enter this **rupture** directory.

Correct

Marks for this submission: 1.00/1.00.

Question 2

Correct

1.00 points out of 1.00

Flag question

After you enter this new directory you will need to copy the seismograms for this 2007 earthquake. Those seismograms are in the following database directory: **/home/jovyan/iris_data/SSBWFiles/Seismograms** The seismograms are stored in files with filenames that end in **.SAC** that you can use when trying to copy them. Which command would you use to copy these files to your current **rupture** directory?

Select one:

- a. copy /home/jovyan/iris_data/SSBWFiles/Seismograms/*.SAC .
- b. cp /home/jovyan/iris_data/SSBWFiles/Seismograms .
- c. copy /home/jovyan/iris_data/SSBWFiles/Seismograms .
- d. copy /home/jovyan/iris_data/SSBWFiles/Seismograms/*.SAC
- e. cp /home/jovyan/iris_data/SSBWFiles/Seismograms/*.SAC . ✓
- f. cp /home/jovyan/iris_data/SSBWFiles/Seismograms/*.SAC

Check

Correct

Marks for this submission: 1.00/1.00.

Question 3

Correct

1.00 points out of 1.00

Flag question

Now how do we start SAC?

Select one:

- a. sac ✓
- b. start sac
- c. SAC
- d. start SAC
- e. chmod +X SAC
- f. chmod +x sac

Check

Correct

Marks for this submission: 1.00/1.00.

Question 4

Correct

1.00 points out of 1.00

Flag question

Once inside SAC, how do we load those seismograms into SAC?

Select one:

- a. .SAC
- b. r *.SAC ✓
- c. read .SAC
- d. *.SAC
- e. l .SAC
- f. load *.SAC

Check

Correct

Marks for this submission: 1.00/1.00.

Question 5

Correct

1.00 points out of 1.00

Flag question

After you load the seismograms into SAC, how do you view all of them together on the screen?

Select one:

- a. plot
- b. view
- c. plot2
- d. p1 ✓ Correct. Please do this command if you have not already.

Check

Correct

Marks for this submission: 1.00/1.00.

Question 6

Correct

1.00 points out of 1.00

Flag question

There are a pretty large number of seismograms and they have varying arrival times because they are recorded at various different distances away from the earthquake. To help focus on the P-wave arrival time for each seismogram, which I have already marked the P-wave arrival as time A, we can set a limit for the X-axis to just plot 40 seconds before the P arrival time and 90 seconds after this time. Which command will set the limits for the X-axis?

Select one:

- a. xlim A -40 90 ✓
- b. xrange 40 A 90
- c. xlim -40 A 90
- d. xlim 40 A 90
- e. xrange A -40 90
- f. xrange -40 A 90

Check

Correct

Marks for this submission: 1.00/1.00.

Question 7

Correct

1.00 points out of 1.00

Flag question

Now you can tell SAC to plot these seismograms relative to A time on each seismogram with this command:

```
SAC> p1 relative
```

Hopefully you can see the P wave arrivals a little better now. The next step to improve our ability to interpret the earthquake rupture properties is to make sure we are examining the displacement time series. Do you recall what quantity digital seismometers actually record?

Select one:

- a. voltage ✓
- b. acceleration
- c. velocity
- d. current
- e. displacement

Check

Correct

Marks for this submission: 1.00/1.00.

Question 8

Correct

1.00 points out of 1.00

Flag question

The seismograms we are seeing here have already been converted into velocity by a digitizer. So if our current seismograms measure ground velocity, how would we convert them to ground displacement?

Select one:

- a. differentiation (take the derivative)
- b. integration (take the integral) ✓ Correct. Since velocity is the derivative of displacement, we can integrate our velocity time series to get back to a displacement time series.
- c. multiplication (multiply by a conversion factor)
- d. division (divide by a conversion factor)

Check

Correct

Marks for this submission: 1.00/1.00.

Question 9

Correct

1.00 points out of 1.00

Flag question

It turns out that SAC even has a command called for converting the seismograms into displacement:

```
SAC> int
SAC> p1
```

So now that you are looking at displacement values, we can start to examine the polarity of the observed P waves. By that I mean whether the first arrivals are up or down. For this kind of analysis we want to sort the seismograms by azimuth (the direction they waves go out from the earthquake):

```
SAC> sort az
```

After you sort the seismograms, we want to look at each individual seismogram one at a time. Which command would do that?

Select one:

- a. view
- b. p1
- c. plot2
- d. plot ✓ Correct. Please do this command if you have not already.

Check

Correct

Marks for this submission: 1.00/1.00.

Question 10

Correct

1.00 points out of 1.00

Flag question

What is the order of seismogram station names after sorting by the azimuth? If you are having difficulty seeing the station names using p1, remember that you can use p to view the seismograms individually and hit enter to move between seismograms.

PALK	15 ✓
TARA	4 ✓
PSP01	10 ✓
KIEV	16 ✓
CHTO	18 ✓
KMBO	14 ✓
SNAA	11 ✓
ULN	1 ✓
BLDU	8 ✓
CTAO	6 ✓
KEV	17 ✓
MIDW	3 ✓
PMG	5 ✓
CASY	9 ✓
LSZ	13 ✓
SNZO	7 ✓
SUR	12 ✓
MAJO	2 ✓

Check

Correct

Marks for this submission: 1.00/1.00.

Question 11

Correct

1.00 points out of 1.00

Flag question

Look at the polarity of the first arrivals and identify which stations have initial positive (up motion) or negative (down motion) polarity. We will use this information to make all of the P wave polarities positive to help when measuring seismograms and comparing between them. The polarity of first arrivals is also important for determining the focal mechanism for an earthquake, so determining the polarities can be helpful for that type of processing later.

Using a 1 for positive polarity (first big motion up) and -1 for a negative polarity (first big motion down), what is the polarity recorded at each station?

ULN	1 ✓
MAJO	1 ✓
MIDW	1 ✓
TARA	1 ✓
PMG	1 ✓
CTAO	1 ✓
SNZO	1 ✓
BLDU	-1 ✓
CASY	-1 ✓
PSP01	-1 ✓

SNAA	-1
SUR	-1
LSZ	-1
KMBO	-1
PALK	-1
KIEV	1
KEV	1
CHTO	1

Check

Correct
Marks for this submission: 1.00/1.00.

Question 12
Correct
1.00 points out of 1.00
Flag question

To remove the variable polarity we just described in the previous question, we can multiply each seismogram by its polarity to show all observations with a common polarity. We will use the MUL command that multiplies a seismogram by a given value. You can specify a multiplier for each seismogram by listing them in order. Using your answers to the previous question as a guide, which of the following commands will correctly make all the polarities positive?

Select one:

a. mul 1 1 1 1 1 1 -1 -1 -1 -1 -1 -1 -1 -1 -1 1 1 1
b. mul 1 1 1 1 1 1 1 -1 -1 -1 -1 -1 -1 1 1 1 1
c. mul 1 1 1 1 1 1 1 1 -1 -1 -1 -1 -1 -1 1 1 1
d. mul 1 1 1 1 1 1 1 -1 -1 -1 -1 -1 -1 -1 -1 1 1
e. mul 1 1 1 1 1 1 1 -1 -1 -1 -1 -1 -1 1 1 1 ✓ Correct. Please run this command and then the `p1` command to make sure all seismograms have positive polarity.

Check

Correct
Marks for this submission: 1.00/1.00.

Question 13
Correct
1.00 points out of 1.00
Flag question

2. Rupture Duration

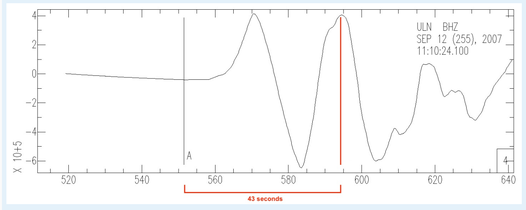
The rupture duration tells us about the length of the fault that ruptures and the rate of rupture. In order to solve for the length of the fault that ruptures (L) and the rate of rupture (V_r), we typically use P waves - more specifically the velocity of P waves (V_p). We also use the minimum (Td_{min}) and maximum (Td_{max}) rupture durations and the mean (average) rupture duration (Td_{mean}) based on the observed duration of the source time function. (Td_{min}) is at the station where the rupture is moving most directly towards, whereas (Td_{max}) is at the station where the rupture is moving most directly away from. This difference in directions for the minimum and maximum rupture durations is due to the Doppler effect - see video for explanation on how the Doppler effect works for sound waves which is the same concept for seismic waves: https://www.youtube.com/watch?v=h4OnBYrbCjY).

Below are equations that relate (Td_{min}), (Td_{max}), (Td_{mean}), V_r, and V_p.

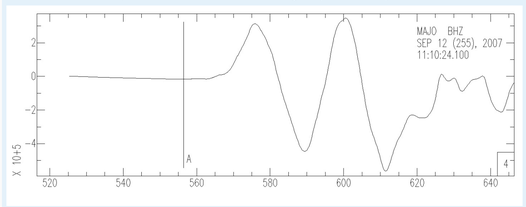
$(Td_{min}) = L (1/V_r - 1/V_p)$
$(Td_{max}) = L (1/V_r + 1/V_p)$
$(Td_{mean}) = L / V_r$
With the measurements of Td and 2 of these equations (Td_{mean} AND Td_{min} or Td_{max}), we can solve for the 2 unknowns: **L** and **V_r**.

** for the questions in this exercise we are going to use 12 km/s for the P wave velocity (V_p)*

First thing, we want to look at how the rupture duration varies over the range of observations we have. Remember the measurements we need to make on the seismograms are the shortest and longest apparent rupture duration. For this event, I would recommend that you measure the time between the first arrival marking (A) and the second big positive peak (red line in the example below). When using p1 to plot all the seismograms in order from top to bottom, you can see that the second large peak actually splits into a pair of peaks in some cases – in this case you should measure to the later peak in this pair. To help give an example of this measurement, I measure this duration to be about 43 seconds on the first seismogram (station ULN, recorded at azimuth ~5 degrees).



What is the measured rupture duration on the second seismogram (station MAJO)?



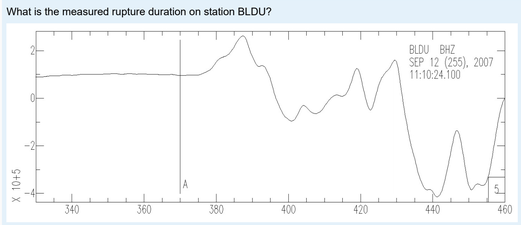
Answer: 45

Check

Correct
Marks for this submission: 1.00/1.00.

Question 14
Correct
1.00 points out of 1.00
Flag question

What is the measured rupture duration on station BLDU?



Select one:

a. 34
b. 59 ✓
c. 77
d. 48

Check

Your answer is correct.
Correct
Marks for this submission: 1.00/1.00.

Question 15
Correct
1.00 points out of 1.00
Flag question

Go ahead and measure the rupture duration on the rest of the seismograms. It will help to write these down or type them into a file, because you will calculate the mean value in a later question. For each station, choose which category the rupture duration you measured occurs in.
NOTE: It can be difficult to get all of these measurements correct on the first try, so the penalty for a wrong answer on this question is only 10%, giving you several additional attempts to receive partial credit. It is just one question out of the whole assignment, so please try to approach this as a learning experience.

KEV	41-50 seconds
MAJO	41-50 seconds
TARA	41-50 seconds
SNZO	41-50 seconds
ULN	41-50 seconds
SUR	51-60 seconds
CTAO	41-50 seconds
PALK	41-50 seconds
KIEV	41-50 seconds
MIDW	41-50 seconds
CASY	61-70 seconds
BLDU	51-60 seconds
PSP01	51-60 seconds
CHTO	41-50 seconds
PMG	41-50 seconds
SNAA	51-60 seconds
LSZ	51-60 seconds
KMBO	51-60 seconds

Check

Your answer is correct.
Correct
Marks for this submission: 1.00/1.00.

Question 16
Correct
1.00 points out of 1.00
Flag question

Which of the following stations is the rupture moving most directly towards?

Select one:

a. PALK
b. CASY
c. CHTO ✓
d. PMG
e. PSP01

Check

Correct
Marks for this submission: 1.00/1.00.

Question 17
Correct
1.00 points out of 1.00
Flag question

Which of the following stations is the rupture moving most directly away from?

Select one:

a. PALK
b. CASY ✓
c. CHTO
d. PSP01
e. PMG

Check

Correct
Marks for this submission: 1.00/1.00.

Question 18
Correct
1.00 points out of 1.00
Flag question

What is the minimum rupture duration?

Answer: 42

Check

Correct
Marks for this submission: 1.00/1.00.

Question 19
Correct
1.00 points out of 1.00
Flag question

What is the maximum rupture duration?

Answer: 62

Check

Correct
Marks for this submission: 1.00/1.00.

Question 20
Correct
1.00 points out of 1.00
Flag question

What is the mean (average) rupture duration? Please calculate this by summing all of your observed rupture duration measurements and then dividing by the number of observations.

Answer: 50

Check

Correct
Marks for this submission: 1.00/1.00.

Question 21
Not answered
0.00 points out of 1.00
Flag question

Using the minimum, maximum, and mean rupture duration you measured and the equations discussed in Question 13, please calculate the rupture velocity. You should use 12 km/s for the P wave velocity for this event. Please make sure to enter a unit for this question.

Answer:

Check

You did not give the correct unit.

Question 22
Not answered
0.00 points out of 1.00

Using the minimum, maximum, and mean rupture duration you measure and the equations discussed in Question 13, please calculate the rupture length. You should use 12 km/s for the P wave velocity for this event. You should make sure to enter a unit for this question.

Answer:

Check

Flag question

You did not give the correct unit.

Finish review