ERTH 1150: Earth's Interior
Lab 7: Seismology

Modified from:
Soule et al., "Project Eddie: Spectral Seismology Module"
https://serc.carleton.edu/eddie/enviro_data/activities/spec_seismo.html

Ortiz and Bravo, "Earthquake Location: triangulation with real data"
https://serc.carleton.edu/ANGLE/educational_materials/activities/205497.html

OBJECTIVES:

- Differentiate P-wave from S-wave
- Learn to identify body and surface waves on a seismic record
- Learn how seismic waves change as you move away from the epicenter
- Use seismic waves to determine earthquake location

INTRODUCATION:
Seismology is the study of earthquakes and seismic waves. When the earth is ruptured, energy is released and propagates in the form of seismic waves. Seismic waves that travel though the interior of the Earth are called **body waves** and seismic waves that travel along the surface of the Earth are called **surface waves**. Body waves travel though the earth with two times of motion called primary and secondary waves. Primary waves are compressional waves whose direction of propagation is parallel to the direction of oscillation. The primary wave has the highest seismic velocity; so on a seismogram it is first on arrival. Secondary waves are shear waves whose direction of propagation is perpendicular to the direction of oscillation. This is the second arrival and is characterized by lower frequency and lower velocity.

Because body waves travel though the Earth's interior, they are primary tools for investigating Earth's properties.

Surface waves propagate along the surface of the Earth and they also have two primary types of motion: Rayleigh and Love waves. Rayleigh waves produce a particle motion that is both longitudinal and transverse with respect to the direction of wave propagation. Love waves create a particle motion that also oscillates transverse to the direction of a wave propagation. ON a seismogram these are characterized by very low frequency and large amplitude.

Because surface waves have high amplitudes and travel along the surface of the Earth, they are what causes most of the damage commonly associated with earthquakes.

PART 1: Seismic Slinky-Modeling P and S waves

For these demonstrations, have two people holding the end of the Slinky as far apart without overstressing it.

Model a P wave/Compressional wave: One person holding the slinky will push the slinky towards the other person.

1. Describe the movement of the slinky. What happens to the P wave as it travels?

2. Does the wave stop when it reaches the end of the slinky?

Model a S wave/Shear wave: One person will move their hand abruptly up and then down (vertical), not toward the other end.

3. Describe the movement of the slinky. What happens to the S wave as it travels?

4. What happens to the amplitude of the S wave as it travels? Why?

5. Which wave was faster, the P wave or the S wave (assuming the energy exerted was the same in both cases)

6. Which wave had the greatest amplitude?

Model an Epicenter-Have a 3rd person pinch a group ~ 1 in thick in the middle of the slinky, which will give tension (stored energy) on both sides of the extended slinky. Quickly release the pinched group.

7. What type of waves are formed when the energy is released?

8. Why is this more like an earthquake than the previous demonstrations?

Model wave interference-Both end members will generate a wave simultaneously. Waves are energy and two waves can occupy the same physical space at the same time, unlike the mass of an object. This is called interference. It can be constructive (waves get bigger when they merge) or destructive (waves get smaller).

9. At the same time, have both people generate P waves. What happens when the waves collide? Is the interference constructive or destructive?

10. At the same time, have both people generate S waves. What happens when the two pulses reach the center of the spring? Is the interference constructive or destructive?

PART 2: Phone seismometer

Download a free seismometer app on your phone. There are a number to choose from that utilize the tree component accelerometer on your phone. The Seismograph app gives you the ability to view the seismograph. If you do not have a phone with this capacity, work with a classmate or your instructor.

Once you have it installed, put your phone on the floor or desk and make a mini-earthquake by jumping up and down-you'll see the signal on your screen! (Make surer that you are able to view the X, Y and Z channels).

11. How does the Z component respond to your stimulus?

12. How do the x and y components respond to vertical motion?

Now, do the same thing but also excite the two horizontal channels with a displacement in the horizontal plane.

13. Describe how different channels record the different types of motion.

Play with trying to create different frequency responses by oscillating the seismometer in the vertical plane until you have a predicable waveform and see how you can make this waveform vary as a function of how fast you oscillate the seismometer.

14. What happens to the waveforms as you change the speed?

Now play around with oscillating the seismometer in the horizontal fields to see the difference between X and Y channels.

15. What did you have to do to make waveforms only in X? Only in Y?

Part 3: Reading a seismogram

We are going to use a software called Seismic Canvas that allows you to import seismic data, plot is up, and do basic analysis.

To download the program go to: https://seiscode.iris.washington.edu/projects/seismiccanvas/files

Once you have installed and opened Seismic Canvas, we are ready to look at some data. We will import a big earthquake and take a look. Starting with a blank Seismic Canvas, import datay by using the IRIS icon.

To get to the event we want to look at, fill in the following on the pop-up window:
Advanced Mode: yes
Start time: 1999/09/30 16:35:00
Duration (minutes): 30
Check vertical only
Select "Continue"

Advanced Criteria-Defaults should be set as follows:
Broadband: yes
Amplitude Values: raw counts
Locations: Primary Location Only

On the next page you will be able to select the network:
Network: GSN (Global Seismic Network)

On the next page you will be given a list of stations with available data. Find the station site at Nanu, Peru (NNA). Select it by checking the NNA box.

Once you have found your station, select Import. You will pull up a seismogram.

16. Use the picking tool (

) to identify the primary and secondary arrivals. The time of your pick is displayed below the plot window in the "Analysis Output" area

    a. What time did the P-wave arrive?

    b. What time did the S-wave arrive?

    c. What is the time of the highest amplitude arrival?

17. Use the time measurement tool ( ) to calculate the time between the primary and secondary arrivals.

18. Since the P-waves, S-waves and Surface waves all originate at the same moment, what does the order of these arrivals tell you regarding their relative speed though the Earth?
19. Stretch your timeline ( ) so that you are able to estimate the frequency of the primary arrivals and secondary arrivals (remember that frequency is equal to the number of oscillations in a given unit of time; frequency = oscillations/time). Estimate the frequency for:

    a. P-waves

    b. S-waves

    c. Surface waves

20. Compare the amplitude of the P-wave and the S-wave to the amplitude of the surface waves. Based on amplitude, which will do the most damage?

Part 4: Global Seismogram Viewer

Got to: http://ds.iris.edu/gsv/

On this website, you are viewing the last 10 years of earthquakes, with size of circle indicating magnitude.

Choose any earthquake and show plot.

21. Where and when was the earthquake you choose?

22. What was the magnitude?

You should be viewing a graph with multiple seismograms, moving away from the Earthquake, with location map at the bottom.

23. As you move further away from the earthquake epicenter, what happens to when the P waves appear?

24. Are the amplitudes of the waves the same at all stations? Why/why not?

Part 5: Find an Earthquake epicenter

Now that you know how to find P and S wave arrival times, you can locate an earthquake using seismic records. You will be given three seismograms that are unfiltered station records from a single event that occurred on August 1, 1999. You will analyze the records using triangulation.

Triangulation uses distance determined from 3 seismic stations to uniquely locate the earthquake. On a map, circles are drawn around each seismic station. The radius of the circle are scaled to estimate the distance from the station to the earthquake. The 3 circles will share one unique intersection that locates the earthquake.

25. Using the seismograms, determine the arrival time of the P and S waves below:

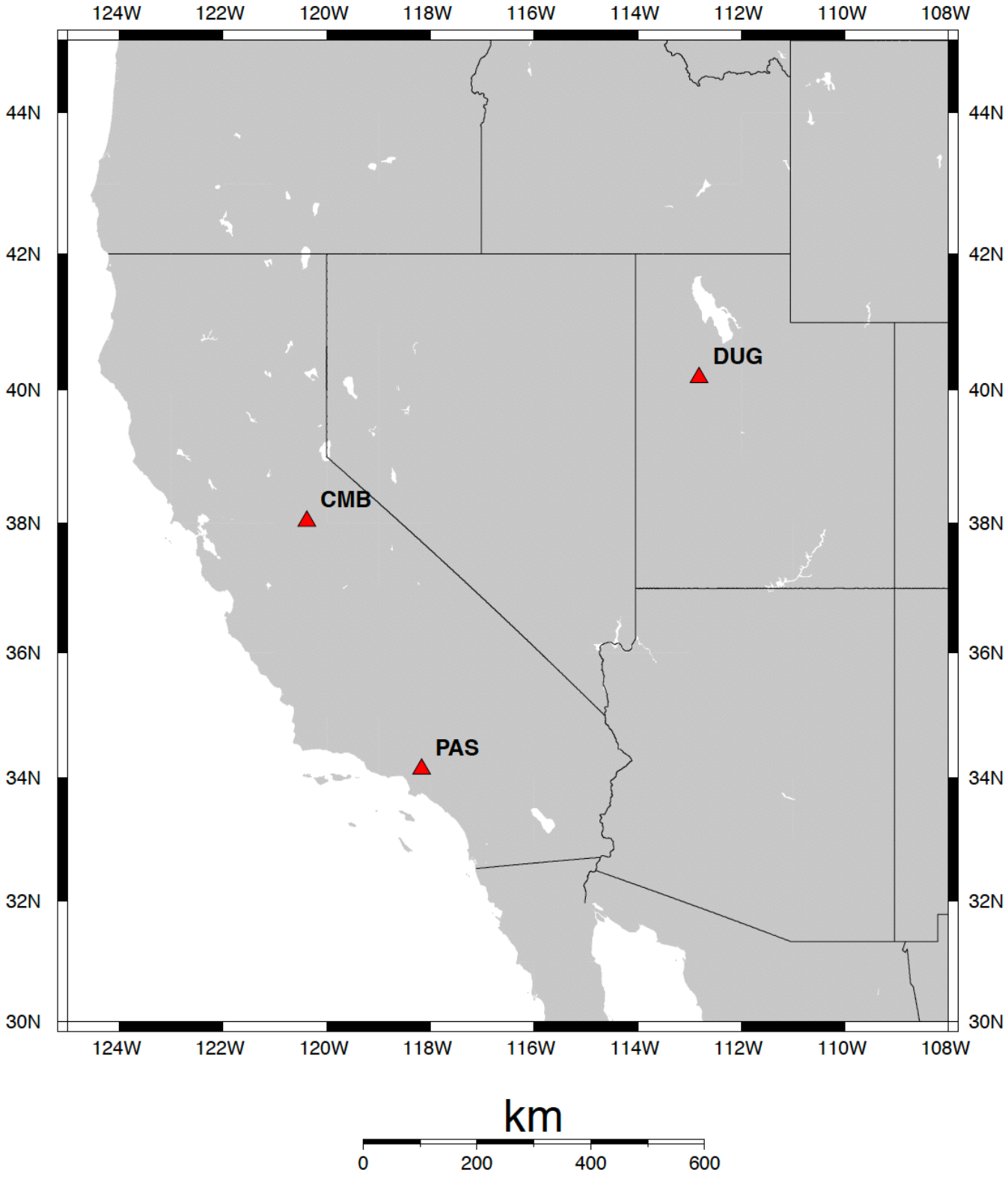
Station	P wave arrival time (seconds)	S wave arrival time (seconds)	S-P time (seconds)
Pasadena California (PAS)			
Dugway Utah (DUG)			
Berkley California (CMB)			

26. For each station, determine the distance from the station to the event using the formula: (S-P time) * 8 km/s

Station	Distance (km)
Pasadena California (PAS)	
Dugway Utah (DUG)	
Berkley California (CMB)	

Now, you will record the distance on the map.

- Find the scale on the map. Using a compass, set the distance between the point and the pencil to find the distance determined for the given station using the map scale. Setting the compass will require estimating
- Place the point of the compass on the station on the map
- Draw a circle around the station. The circle has a radius equal to the distance to the event. The epicenter of the earthquake is somewhere on eh edge of that circle.



27. The point where all the circles overlap is the approximate epicenter of the earthquake. Determine the latitude and longitude of the earthquake and list it below:

Part 6: Earthquakes when you were born

Open the following website belonging to the IRIS Consortium:

http://www.iris.washington.edu/quakes/eventsrch.htm

This site will allow you to enter data for any interval of time between the present and December, 1970.

First, search for the last 24 hours:

28. Describe the occurrence and location of earthquakes over the last 24 hours. Consider plate boundaries, depths, magnitudes.

Enter the 24-hour interval when you were born like to view the occurrence of earthquakes on earth.

29. How many earthquakes were there on your birthday?

30. What type of plate boundary are most earthquakes at?

31. What was the largest earthquake on your birthday?

32. Where was the largest earthquake on your birthday?

33. What was the depth of the largest earthquake on your birthday?

Choose another day of interest and compare the earthquakes.

34. Are there similarities/differences to earthquake occurrence and frequency for this new date and the previous dates?