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Question 1

Correct

1.00 points out of 1.00

Flag question

1. Identifying Seismic Waves

Reading seismograms are like reading an ancient foreign language, so it will take some time to interpret the signals that may look like hieroglyphics when you first look at them. In this analogy, the "tablets" are the seismograms, which comes in 3 different types: up-down (Z component), north-south (N component), and east-west (E component). These are the 3 components that record the complete motion the surface of the earth experiences at any moment during the day. We then look at one of these seismograms (tablets) to see if there are any signals (words) that we can interpret. This is the first issue with reading "seismic", just because you have a seismogram, doesn't mean there are any significant signals on it. Just like an archeologist digging in the dirt, you're looking for an important find that has a recognizable look to it. As you might expect, it takes some time to recognize the different signals, but we will try to walk you through the main types you should look for.

In our activity today, we will use the seismic data you downloaded in SAC Tutorial 2 to continue learning how to use SAC to analyze seismic data. After you login to OpenSARIab, you will need to change your location to the directory called **florida06** inside your **sacdata** inside your **sac** directory. What is the correct command to enter this **florida06** directory?

Select one:

- ☐ a. mv ~/sac/sacdata/florida06
- ☐ b. mv ~/florida06
- ☐ c. mv ~/groupwork/sacdata/florida06
- ☒ d. cd ~/sac/sacdata/florida06 ✓ **Correct, please run this command now if you have not already.**
- ☐ e. mkdir ~/groupwork/sacdata/florida06
- ☐ f. cd ~/groupwork/sacdata/florida06
- ☐ g. cd ~/sacdata/florida06
- ☐ h. mkdir ~/sac/sacdata/florida06
- ☐ i. mkdir ~/florida06

Check

Correct

Marks for this submission: 1.00/1.00.

Question 2

Correct

1.00 points out of 1.00

Flag question

2. P and S Waves

Since the data in the **florida06** directory came from a particular earthquake in the Gulf of Mexico, we should expect to see various seismic waves recorded in this data. In essence, someone has already identified this as the right time to look at the seismograms, whereas the data might have no identifiable signals for many hours leading up to this event. To examine the P and S waves from this earthquake, we will use sac. First run the sac program from the linux command prompt. Next we need to read all of the data into sac. Which of the following commands would achieve this? Choose all that apply.

Select one or more:

- ☒ a. READ \* SAC ✓ **1 of 2 correct answers. If you have not entered this command or the other correct answer, please do so now.**
- ☒ b. r \* SAC ✓ **1 of 2 correct answers. Abbreviations and lower case commands are allowed in SAC. If you have not entered this command or the other correct answer, please do so now.**
- ☐ c. r \*
- ☐ d. r all
- ☐ e. READ \*
- ☐ f. READ ALL
- ☐ g. READ SAC
- ☐ h. r SAC

Check

Correct

Marks for this submission: 1.00/1.00.

Question 3

Correct

1.00 points out of 1.00

Flag question

Which of the following commands would plot seismograms for all 3 components from all 3 stations of data separately on the screen at the same time without allowing you to adjust the zoom?

Select one:

- ☒ a. p1 ✓ **Correct, please run this command now if you have not already.**
- ☐ b. plot
- ☐ c. ppk
- ☐ d. p2

Check

Correct

Marks for this submission: 1.00/1.00.

Question 4

Correct

1.00 points out of 1.00

Flag question

What do you see in the seismograms? Hopefully several bumps that correspond to different arrivals of seismic waves. You should see groups of 3 seismograms that have similar looking signals because these are the 3 components of each station. As we have talked about in class, the P waves travel faster so they should appear first, and the S waves travel slower so they will arrive afterwards. You may also notice surface waves on the seismograms, but we will not be focusing on them in this activity.

When you first open SAC, it is not sure how much data you plan to plot, so it is initially set to make "quick and dirty plots" that only plot a reduced set of your data points on the screen just in case you have read in very large datasets. If you are going to be investigating P and S arrival times, you will want to turn this option off so that you can identify the onset of the arrivals as accurately as possible. You can turn this option OFF and ON with the QDP (Quick and Dirty Plot) command:

```
SAC> qdp off
SAC> p1
SAC> qdp on
SAC> p1
SAC> qdp off
SAC> p1
```

How does the plot look different with QDP OFF or ON?

Select one:

- ☐ a. QDP off removes the cultural noise from the seismogram so the earthquake appears clearer in the signal.
- ☐ b. QDP on shows all of the data points so the seismogram lines can appear bolder because they show more detail, whereas QDP off can look choppy and lighter.
- ☐ c. QDP on and off look the same.
- ☒ d. QDP off shows all of the data points so the seismogram lines can appear bolder because they show more detail, whereas QDP on can look choppy and lighter. ✓ **The "quick and dirty plot" option speeds up plotting by NOT plotting each data point. When this option is on, SAC will compute a section size by dividing the number of data points in the file by the number of data points you want displayed. The larger the file, the more data points in each section. SAC then computes and displays only the minimum and the maximum data point in each section. SAC displays a "desampling factor" (half the section size) in a small box in the corner of the plot when this option is on.**

Check

Your answer is correct.

Correct

Marks for this submission: 1.00/1.00.

Question 5

Correct

1.00 points out of 1.00

Flag question

Another option for plotting that can help the readability of your seismograms is the PERPLOT option that can be used with the P1 and PPK commands. The format for this command is the command name, then the perplot option, then the number of seismograms to show at a time. Once, you run a plot command with this option, you will need to click the enter key in the SAC command prompt window to move to the next set of seismograms. It will say "Waiting" instead of the "SAC" prompt when it is waiting for you to click enter to move to the next set. Which of the following commands would plot the different components for each station together on the same plot, one station at a time?

Select one:

- ☐ a. p1 3 perplot
- ☒ b. p1 perplot 3 ✓ **Correct, please run this command now if you have not already and make sure you click the enter key in the SAC command prompt window to move to the next set of seismograms. It will say "Waiting" when it is waiting for you to click enter to move to the next set.**
- ☐ c. p1 perplot 2
- ☐ d. p1 5 perplot
- ☐ e. p1 2 perplot
- ☐ f. p1 perplot
- ☐ g. p1 perplot 5

Check

Correct

Marks for this submission: 1.00/1.00.

Question 6

Correct

1.00 points out of 1.00

Flag question

3. Picking Arrival Times

For this activity, I would like you to mark the P arrival times and the S wave arrival times on these seismograms and store that information in the data file. We can mark the arrivals using the plot command that allows you to view seismograms separately and adjust the zoom level. Which command is that?

Select one:

- ☐ a. plot
- ☐ b. p1
- ☒ c. ppk ✓ **Correct, please run this command now if you have not already.**
- ☐ d. p2

Check

Correct

Marks for this submission: 1.00/1.00.

Question 7

Correct

1.00 points out of 1.00

Flag question

We used PPK before to just plot data, using the X key to zoom into a particular area of the seismogram where the cursor is positioned (hitting X once for the beginning of the zoom window, hit X again for the end of the zoom window). PPK actually stands for Plot Pick, so we can use it to pick arrival times of the P and S waves (or other arrivals we are interested in). When using PPK to pick **P waves**, you can place your cursor at the time where the P wave arrival starts and use the **P key to set your pick**. SAC then stores your pick (arrival time) in the header information of the SAC file. The first arrival (should be the P wave) is typically **stored in the A variable**.

When using PPK to pick **S waves**, you can place your cursor at the time where the S wave arrival starts and use the **S key to set your pick**. The S wave is typically **stored in the T0 variable**.

There are a series of Tn variables, where n goes from 0 to 9, so other arrivals can be stored in T1 through T9. To set variables T1 through T9 for other arrivals, type T and then the number you want (for example T then 1 for the T1 variable). You will get a chance to practice setting variables T1 through T9 in the next tutorial.

Now we will use PPK to pick the P arrival for station ACSO. Since we only want to pick the arrival on one station right now, you can use the PERPLOT option to only show seismograms from one station at a time, which can help when picking arrival times, especially since we have read in several components (directions of motion) for each station. Note that you also need to use the RELATIVE option (abbreviated REL) to ensure the seismograms are plotted relative to one another.

Which of the following would be the correct command to use the PERPLOT option with the REL option? If you are not sure, you may want to use HELP PPK to review how the PPK command is used.

Select one:

- ☒ a. ppk rel perplot 3 ✓ **Correct, please run this command now if you have not already and make sure you click the enter key in the SAC command prompt window to move to the next set of seismograms. It will say "Waiting" when it is waiting for you to click enter to move to the next set.**
- ☐ b. ppk perplot rel 3
- ☐ c. ppk perplot rel
- ☐ d. ppk perplot 5
- ☐ e. ppk perplot rel 2
- ☐ f. ppk rel perplot
- ☐ g. ppk rel perplot 2
- ☐ h. ppk perplot rel 5

Check

Correct

Marks for this submission: 1.00/1.00.

Question 8

Correct

1.00 points out of 1.00

Flag question

Now go ahead and pick the arrival time of the P-wave using the P key when PPK is running. A key thing to keep in mind when picking the arrival times in SAC is that you should be marking the time when the arrival begins. So in some cases the seismic waves may consist of several peaks and troughs on the seismogram, but we only want to mark the first motion away from the background noise level. If you are unsure where to pick the P-wave, it may help to review the [webinar about picking arrival times in seismograms](#).

Once you have picked the P-wave with the P key, what does PPK use to label the P-wave in the graphics window?

Select one:

- ☐ a. A
- ☐ b. ACSO
- ☐ c. P
- ☒ d. IPU0 ✓ **Correct. This weird 4 character code represents: 1. A description of onset of phase arrival (I = impulsive, E = emergent), 2. The seismic wave phase (P = first P arrival, S = first S arrival), 3. The first motion direction of phase arrival (U = up or compression, D = down or dilatation), and 4. The weight or confidence you have in the arrival (0 = full weight (1.0), 1 = 0.75 weight, 2 = 0.50 weight, 3 = 0.25 weight, 4 = no weight (0.0)).**
- ☐ e. P-wave

Check

Correct

Marks for this submission: 1.00/1.00.

Question 9

Correct

1.00 points out of 1.00

Flag question

To see the effect of picking the P wave, you should exit PPK (type the Q key with you cursor highlighting the PPK plot window - be careful not to type Q and enter at the SAC command prompt because that will quit you out of sac entirely). The use the LISTHDR command (abbreviated LH) to list the arrival time you picked. You can do that like this:

```
SAC> lh picks
```

In this command, PICKS is the option that tells SAC to just print out the key times, and not any of the other header variables. Still, SAC will not be able to show all of the key times for all of the seismograms at one time, so it will say **Waiting** when it wants you to type the enter key to print the next set of seismogram times. Also note that the filenames are listed before each set of times for that file. The P wave arrival time you picked should be listed as the **A** variable. What time did you pick?

Answer:  ✓

Check

This is the time most people would pick the arrival time.

Correct

Marks for this submission: 1.00/1.00.

Question 10

Correct

1.00 points out of 1.00

Flag question

To pick S waves, you should start PPK again, zoom in around the S wave on the ACSO seismograms, and then place the cursor at the start of the S wave and use the S key to set the T0 variable. Picking S waves can be harder than picking P waves since there is more background energy on the seismogram. You may want to review the [webinar on picking seismograms to help with deciding where to pick](#).

What does PPK use to label the S wave in the graphics window after to you pick it with the S key?

Answer:  ✓

Check

Correct

Marks for this submission: 1.00/1.00.

Question 11

Partially correct

0.75 points out of 1.00

Flag question

Then quit from PPK and list the pick times stored in the header (refer to question 9 if you can't recall the command). What time did you pick for the S wave?

Answer:  ✓

Check

Close, you are within 1 second where most people would pick the arrival time. Although this is where the larger signals start on this seismogram, this is a little later than most people might pick the arrival time. If you zoom in more and focus on the BHZ seismogram, you will see that there are changes in the waveform before this time consistent with a small early arrival.

Partially correct

Marks for this submission: 0.75/1.00.

Question 12

Correct

1.00 points out of 1.00

Flag question

Now you can practice this by making sure you pick the P and S arrivals for all of the stations. When you are in PPK, you can type the N key to move from the first set of seismograms to the second set of seismograms. Once you have picked the arrival time, you can use the Q key to exit from PPK and be able to enter more commands at the command line. Note that you will need to be careful when running the LH command to make sure you identify which A and T0 times correspond to which station. What is the P arrival time for station ISCO?

Answer:  ✓

Check

This is the time most people would pick the arrival time.

Correct

Marks for this submission: 1.00/1.00.

Question 13

Partially correct

0.75 points out of 1.00

Flag question

What is the S arrival time for station ISCO?

Answer:  ✓

Check



Although there is some movement in the seismogram at this time, it is hard to justify that the movement is above the background noise that is visible in the time leading up to this. Most people would pick a time later than this.

Partially correct

Marks for this submission: 0.75/1.00.

Question 14

Correct

1.00 points out of 1.00

Flag question

What is the P arrival time for station HLID?

Answer:

300

Check

This is a little earlier than some people might pick the arrival time, but if you zoom in enough, you will see that there are changes in the waveform during this time consistent with a small early arrival.

Correct

Marks for this submission: 1.00/1.00.

Question 15

Correct

1.00 points out of 1.00

Flag question

What is the S arrival time for station HLID?

Answer:

590

Check

This is the time most people would pick the arrival time.

Correct

Marks for this submission: 1.00/1.00.

Question 16

Correct

1.00 points out of 1.00

Flag question

Now that you have marked the P and S arrival times on the seismograms, you will want to save the results in new data files with .picks appended to the end of the file name. Here is the command to achieve that:

`SAC> write append .picks`

How many files with names ending in .picks were generated?

Answer:

6

Check

Correct

Marks for this submission: 1.00/1.00.

Question 17

Correct

1.00 points out of 1.00

Flag question

#### 4. Listing SAC Variables In Linux

Now you can exit sac with the QUIT command. When you return to the Linux command line, I want to introduce you to a useful command that can access the pick times stored in the header of the SAC data files. This command is `sac1st` and it functions similar to the LH command in SAC. Go ahead and type it at the linux command prompt.

`(iris) jupyter<your_username>:~/sac/sacdata/Florida06> sac1st`

What output does it produce?

Select one:

- ☐ a. sac1st: Command not found.
- ☒ b. Usage: sac1st header\_lists f file\_lists  
ex. sac1st delta npts kstmm f sac1st1 sac1st2  
sac1st help - outputs a list of possible values ✓
- ☐ c. (no output)
- ☐ d. Usage: sac1st header\_lists f file\_lists
- ☐ e. sac1st help - outputs a list of possible values
- ☐ f. (the sac1st man page)

Check

Your answer is correct.

Correct

Marks for this submission: 1.00/1.00.

Question 18

Correct

1.00 points out of 1.00

Flag question

The output from the previous question is explaining how to use `sac1st`. The first set of information to include after the command name is which header variables you want to list. If we want to see the P wave times, we could choose `a`. Then we need to type `t`, followed by a list of files that we want to see that header variable for. You can use wildcards (e.g., `*` and `?`) to specify multiple similar filenames. Which command would list the P wave times we stored in the BHZ files? You might want to try some of these commands to see which one works.

Select one:

- ☐ a. sac1st A f "BHZ".SAC
- ☒ b. sac1st a f "BHZ".picks ✓
- ☐ c. sac1st P f "BHZ".SAC
- ☐ d. sac1st a f "BHZ".SAC
- ☐ e. sac1st P f "BHZ".picks
- ☐ f. sac1st A f "BHZ".picks

Check

Correct

Marks for this submission: 1.00/1.00.

Question 19

Correct

1.00 points out of 1.00

Flag question

Which command would list the S wave times we stored in all of the .picks files? Again, I would recommend that you try some commands on the virtual machine to see which one works.

Answer:

sac1st TO t \*.picks

Check

Correct

Marks for this submission: 1.00/1.00.

Question 20

Correct

1.00 points out of 1.00

Flag question

A nice feature of `sac1st` is that it can print out multiple header variables for each file. This can be particularly helpful when looking at P and S arrival times, as the real arrival times would be measured relative to the origin time of the earthquake. The origin time is stored in the O header variable in our files. Which of the following commands would list the origin time, P wave time, and S wave time for each of our .picks files?

Select one:

- ☒ a. sac1st O A TO t \*.picks ✓ This works, but it is more common to use lowercase letters for the header variables.
- ☐ b. sac1st o a TO t \*.picks
- ☐ c. sac1st o,a,TO t \*.picks
- ☐ d. sac1st O,P,S \*.picks
- ☐ e. sac1st O,A,TO \*.picks
- ☐ f. sac1st O P S \*.picks

Check

Correct

Marks for this submission: 1.00/1.00.

Question 21

Correct

1.00 points out of 1.00

Flag question

Depending on how you picked the seismograms in SAC, you may have noticed a value of -12345 for some of the arrival times in your files. This value is the special "undefined" number for SAC. It means that those variables have not been set. If you only picked P and S times on some components but not others, then you will see this value for the components that you did not pick on. If you picked a P and S time for every component of every station, then you will not see this value. In either case, it is helpful to point this value out because you can use it in SAC to set variables back to the undefined state if you decide you made the wrong choice.

Focusing on the values you did set in the output of `sac1st`, what is the actual travel time of the P wave from the earthquake origin time to the P wave arrival at station ACSO? You will need to do the math to calculate this time from start (origin) to finish (P wave arrival time).

Answer:

300

Check

Correct

Marks for this submission: 1.00/1.00.

Question 22

Correct

1.00 points out of 1.00

Flag question

Focusing again on the values you did set in the output of `sac1st`, what is the actual travel time of the P wave from the earthquake origin time to the P wave arrival at station HLID? You will need to do the math to calculate this time from start (origin) to finish (P wave arrival time).

Answer:

554

Check

Correct

Marks for this submission: 1.00/1.00.

Question 23

Correct

1.00 points out of 1.00

Flag question

#### 5. Rotating to Examine the SV and SH Seismic Waves

Now we should return to SAC for one final look at the S waves. Once inside SAC, you should read in the horizontal components of the HLID station that have the pick times we made before. Which command would achieve this?

Select one:

- ☐ a. r "HLID"\*. SAC
- ☐ b. r "HLID"\*.picks
- ☐ c. r "BHN".picks "BHE".picks
- ☐ d. r "BHN".SAC "BHE".SAC
- ☒ e. r "HLID"BHN".picks "HLID"BHE".picks ✓
- ☐ f. r "HLID"BHN".SAC "HLID"BHE".SAC

Check

Correct

Marks for this submission: 1.00/1.00.

Question 24

Correct

1.00 points out of 1.00

Flag question

We are going to focus on the S wave now, but since I am not sure whether you have picked the S wave on both of the horizontal components, I am going to teach you how to remove any S wave picks if you have made them already. Recall that we discussed the "undefined" value for SAC a few questions ago. We can set header variables to this undefined value with the CHNHDR command in SAC that stands for CHaNge HeaDeR (abbreviated CH). The format for this is the command name, the variable name, and the value to set it to. Which of the following would reset the S wave arrival times for the files in memory to undefined?

Select one:

- ☐ a. ch S 0
- ☐ b. ch S -12345
- ☐ c. ch ID 1234567890
- ☐ d. ch S 1234567890
- ☐ e. ch a 1234567890
- ☐ f. ch a 0
- ☐ g. ch a -12345
- ☐ h. ch ID 0
- ☒ i. ch ID -12345 ✓ Correct, please run this command if you have not already.

Check

Correct

Marks for this submission: 1.00/1.00.

Question 25

Correct

1.00 points out of 1.00

Flag question

Now you should pick the S wave arrival time with PPK. Once you do that, you should make sure these arrival times are stored in the files. Which of the following commands would save the times into these files?

Look back to SAC Tutorial 1 if you are having trouble

Select one:

- ☐ a. save files
- ☐ b. write times
- ☐ c. save \*.SAC
- ☐ d. save \*.picks
- ☐ e. write \*.picks
- ☐ f. save times
- ☐ g. write \*.SAC
- ☒ h. write over ✓

Check

Correct

Marks for this submission: 1.00/1.00.

Question 26

Correct

1.00 points out of 1.00

Flag question

Now that both seismograms have the S wave picked, we can use the XLIM command to help us automatically zoom in around the S wave. The XLIM command allows you to specify the minimum and maximum limits to the X-axis that are relative to a header variable time. For example, you can run this command to show the first 400 seconds after the origin time (o) of the earthquake:

`SAC> xlim o 0 400`

`SAC> pl`

What can you see in this plot? Choose all that apply.

Select one or more:

- ☐ a. The end of the seismogram
- ☒ b. The P-wave ✓
- ☐ c. The surface waves
- ☒ d. The start of the seismogram ✓
- ☐ e. The S-wave

Check

Correct

Marks for this submission: 1.00/1.00.

Question 27

Correct

1.00 points out of 1.00

Flag question

Which command would plot 15 seconds before and after the S-wave arrival time?

Select one:

- ☐ a. xlim S 15 15
- ☐ b. xlim o -15 15
- ☒ c. xlim ID -15 15 ✓ Correct, please run this command if you have not already and then plot the results.
- ☐ d. xlim S -15 15
- ☐ e. xlim o 15 15
- ☐ f. xlim ID 15 15

Check

Correct

Marks for this submission: 1.00/1.00.

Question 28

Correct

1.00 points out of 1.00

Flag question

If you have successfully viewed the plot 15 seconds before and after the S-wave arrival time, you may notice that the S wave arrival time appears to be slightly different for these two horizontal components. At this point it is important to remember that there are two types of S waves. To make sure we are clear on this, please match the waves with their definitions.

not polarized (vibration parallel to the ray path)

P

✓

radially polarized (vibration perpendicular to the ray path but in the plane defined by the ray path)

SV

✓

transversely polarized (vibration perpendicular to the ray path but perpendicular to the plane defined by the ray path)

SH

✓

Check

Correct

Marks for this submission: 1.00/1.00.

Question 29

Correct  
1.00 points out of 1.00  
Flag question

It is possible that the different arrival times on the North-South component (BHN) and the East-West component (BHE) correspond to different arrival times for SV and SH. We can use SAC to test this because we can convert the BHN and BHE components to the Radial and Transverse components. SAC knows the orientation of the Radial and Transverse components in this case because the seismograms we downloaded have the earthquake and station locations stored in the header. SAC has already calculated the azimuth of the ray path, so all it has to do is rotate the energy from the North-South coordinate system to a coordinate system the is oriented along the ray path azimuth. Seismologists often describe this ray path azimuth to be defined by a Great Circle Path that is a line the goes through the earthquake and station but also goes 360 degrees around the entire Earth. Fortunately, SAC does this math for you when you use the ROTATE command with the TO\_GCP option:

SAC> rotate to gcp

I would also recommend that you remove the mean amplitude of these seismograms to make it easier to talk about positive amplitudes and negative amplitudes. You can do that with the RMEAN command:

SAC> rmean

SAC> p1

The results of the ROTATE command are to create the Radial component in the first seismogram and the Transverse component in the second seismogram. Which of the following are correct based on the resulting plot?

Select one:

- ☒ a. The initial arrival time of the SH and SV waves are about the same. ✓
- ☐ b. The initial arrival time of the SH is 6 seconds later than the SV.
- ☐ c. The initial arrival time of the SV is 6 seconds later than the SH.
- ☐ d. The initial arrival time of the SV is 12 seconds later than the SH.
- ☐ e. The initial arrival time of the SH is 12 seconds later than the SV.

Check

Correct

Marks for this submission: 1.00/1.00.

Question 30

Correct  
1.00 points out of 1.00  
Flag question

Which of the following are also correct based on that resulting plot? Choose all that apply.

Select one or more:

- ☐ a. The SV seismogram has a large negative arrival starting 3.5 seconds after the initial positive arrival.
- ☐ b. The SH seismogram has a large negative arrival starting 6 seconds after the initial positive arrival.
- ☐ c. The SH seismogram does not have a large negative arrival after the initial positive arrival.
- ☒ d. The SH seismogram has a large negative arrival starting 3.5 seconds after the initial positive arrival. ✓
- ☐ e. The SV seismogram does not have a large negative arrival after the initial positive arrival.
- ☒ f. The SV seismogram has a large negative arrival starting 6 seconds after the initial positive arrival. ✓

Check

Correct

Marks for this submission: 1.00/1.00.

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