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Started on	Saturday, July 30, 2022, 8:19 AM
State	Finished
Completed on	Tuesday, August 2, 2022, 9:48 AM
Time taken	3 days 1 hour
Marks	39.50/48.00
Grade	**82.29** out of 100.00

Question 1

Correct

1.00 points out of 1.00

Flag question

For this assignment, you will be using IRIS's Global Seismogram Viewer (GSV) which can be found at http://ds.iris.edu/gsv/

This web app is being developed to help people review "record sections" of global recordings of moderate to large-sized earthquakes. Global in this context means more than a few hundred kilometers, and the magnitude range is about 5 to 8. There are a set of earthquakes loaded into this app for you to choose from. Go ahead and click on the different events to bring up a plot that shows the "record section" for that earthquake.

What are some general patterns that you observe when looking at the record sections for several earthquakes in the Global Seismogram Viewer? You should also consider some key differences between the GSV you are working with today and the LSV we looked at in the last assignment.

Answer: GSV shows the earthquacke events from all around the globe

Check

Correct
Marks for this submission: 1.00/1.00.

Question 2

Correct

1.00 points out of 1.00

Flag question

This assignment will focus on the record section for the January 12, 2010 Earthquake in Haiti. You should be able to zoom in to find this event on the main GSV map. If you have trouble locating it, you should be able to access it via this direct link.

What is the magnitude of this earthquake?

Answer: 7

Check

Correct
Marks for this submission: 1.00/1.00.

Question 3

Correct

0.67 points out of 1.00

Flag question

Which of the following statements best describes the observed P-wave arrival times at each of the distances where we have stations in this record section?

Select one:

- a. A set of observations that follow a curved line with a jump where the values increase abruptly ✓
- b. A set of observations that follow a curved line with a larger slope at larger distances
- c. A set of observations that follow a curved line with a smaller slope at larger distances
- d. A set of observations that follow a straight line

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 4

Correct

0.00 points out of 1.00

Flag question

Based on what we have discussed in an earlier assignment, which of the following would help explain why the P wave arrival appears to be missing at distances beyond 100 degrees? Read the choices carefully!

Select one:

- a. The outer core creates a triplication. To get distances larger than 100 degrees, the ray path would have to go through the faster liquid outer core, which would cause it to turn upward and end up at a further distance than expected.
- b. The outer core creates a shadow zone. To get distances larger than 100 degrees, the ray path would have to go through the slower liquid outer core, which would cause it to turn downward and end up at a further distance than expected. ✓
- c. The lower mantle creates a shadow zone. To get distances larger than 100 degrees, the ray path would have to go through the slower liquid lower mantle, which would cause it to turn downward and end up at a further distance than expected.
- d. The inner core creates a magnetic anomaly. To get distances larger than 100 degrees, the ray path would have to go through the slower liquid inner core, which would cause it to turn downward and end up at a further distance than expected.

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.00/1.00**.

Question 5

Correct

1.00 points out of 1.00

Flag question

This feature illustrates how seismograms recorded at this global scale can be used to learn about the deeper structure of the Earth's interior. In our last assignment, you used seismograms at the local scale to estimate the seismic wave speeds in the crust and uppermost mantle. In this assignment, you will learn how to use a record section of seismograms to estimate the seismic wave speeds in the rest of the mantle.

Let's begin with the station in this record section that occurs at the closest distance to the earthquake. What is the name of this station?

Answer: SDV

Check

Correct
Marks for this submission: 1.00/1.00.

Question 6

Correct

1.00 points out of 1.00

Flag question

How far away is this station from the earthquake in kilometers? Recall that the popup window when the mouse is over a seismogram displays the distance in degrees, and the x-axis provides a reminder of the conversion to kilometers.

Answer: 1110

Check

Correct, 10 degrees * 111 km/deg. We also accept 10 degrees * 110 km/deg

Correct
Marks for this submission: 1.00/1.00.

Question 7

Correct

1.00 points out of 1.00

Flag question

What is the arrival time at this station in seconds? Be sure to convert the time from HH:MM:SS to just seconds. As in the last tutorial, you can click and drag to zoom into the seismogram, and click "Reset Zoom" to zoom back out.

Answer: 147

Check

Correct, the arrival occurs between 00:02:23 and 00:02:27

Correct
Marks for this submission: 1.00/1.00.

Question 8

Correct

1.00 points out of 1.00

Flag question

In our last assignment, the distance and arrival time at the closest station provided a means to estimate the seismic wave speed in the uppermost crust. This was due to the station being close enough to the earthquake that the energy could travel relatively straight path from a depth of a few km to the surface not far away. In this case, the station is over 1000 km away, so it will travel a curved path down to about 100 km depth and then bend back upward to the station. The velocity we calculate from this station provides a rough estimate of the seismic wave speed in the upper 100 km of the Earth in the southern Caribbean region. What is the seismic wave speed calculated from the observation at this station in km/s?

Answer: 7.55

Check

Correct
Marks for this submission: 1.00/1.00.

Question 9

Correct

1.00 points out of 1.00

Flag question

In our last assignment, we estimated the speeds of the average crust and uppermost mantle. A key aspect of this was measuring the slope of the arrival times with respect to distance in a record section. What does the slope represent?

Select one:

- a. distance
- b. slowness ✓ Precisely, the slope is the horizontal slowness based on the time per distance, but in the last assignment the horizontal slowness was a good approximation of the slowness because the path was approximately horizontal. We took the inverse of this value to obtain the velocity (distance per time).
- c. arrival time
- d. two-way travel time
- e. velocity

Check

Correct
Marks for this submission: 1.00/1.00.

Question 10

Correct

1.00 points out of 1.00

Flag question

We will attempt to use this same strategy in our assignment today, but we will see that things are not as simple at a larger global scale.

Stations between 30 and 90 degrees distance are generally assumed to spend a lot of their ray path in the lower mantle. Seismograms at these distances tend to have limited effects from the structure they travel through because the lower mantle appears to be relatively homogenous compared to other layers inside the earth. This feature makes seismograms at these distances ideal for studying the source properties of an earthquake (e.g., rupture velocity) or for studying local effects near the station (e.g., receiver function).

What is the first station to appear in this distance range?

Answer: SDCO

Check

Correct
Marks for this submission: 1.00/1.00.

Question 11

Correct

1.00 points out of 1.00

Flag question

What distance is this station from the earthquake in kilometers?

Answer: 3885

Check

Correct, 35 degrees times 111 kilometers per degrees

Correct
Marks for this submission: 1.00/1.00.

Question 12

Correct

0.00 points out of 1.00

Flag question

Considering the distance of this station within the range of 30 to 90 degrees, where do you think this seismic wave primarily samples the Earth's interior?

Select one:

- a. the top of the core
- b. the top of the lower mantle ✓
- c. the middle of the upper mantle
- d. the top of the upper mantle
- e. the bottom of the lower mantle
- f. the bottom of the upper mantle
- g. the bottom of the core
- h. the middle of the lower mantle

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.00/1.00**.

Question 13

Correct

0.67 points out of 1.00

Flag question

What is the approximate arrival time at this station in seconds? Note that the time is reported in minutes and seconds so you will need to convert to just seconds.

Answer: 413

Check

Correct, the arrival occurs between 00:06:49 and 00:06:53

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 14

Correct

1.00 points out of 1.00

Flag question

In order to use the strategy from the last assignment to estimate the velocity in the upper and lower parts of the lower mantle, we will estimate the slope in the record section between two stations in the first half of the 30 to 90 degree range and then do the same for the second half of the 30 to 90 degree range.

Which station name is closest to the middle of this distance range?

Answer: TRQA

Check

Correct
Marks for this submission: 1.00/1.00.

Question 15

Correct

1.00 points out of 1.00

Flag question

At approximately what distance is this station relative to the earthquake? I want your answer in kilometers, not degrees.

Answer: 6327

Check

57 degrees times 111 kilometers per degree

Correct
Marks for this submission: 1.00/1.00.

Question 16

Correct

0.67 points out of 1.00

Flag question

What is the approximate arrival time at this station in seconds? Note that the time is reported in minutes and seconds so you will need to convert to just seconds.

Answer: 588

Check

Correct, the arrival occurs between 00:09:45 and 00:09:48

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 17

Correct

1.00 points out of 1.00

Flag question

What is the difference in distance between this station and the station near 30 degrees? I will assume your answer is in kilometers.

Answer: 2442

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 difference in arrival time between this station and the station near 30 degrees? I will assume your answer is in seconds.

Answer: 175

Check

Correct
Marks for this submission: 1.00/1.00.

Question 19

Correct

1.00 points out of 1.00

Flag question

Based on the slope between these data points, what is the approximate speed in the upper part of the lower mantle? I will assume your answer is in km/s.

Answer: 13.9

Check

Correct
Marks for this submission: 1.00/1.00.

Question 20

Next, we will estimate the speed in the lower part of the lower mantle. In order to use the strategy from the last assignment to estimate the velocity in the upper and lower parts of the lower mantle, we will estimate the slope in the record section between two stations in the first half of the 30 to 90 degree range and then do the same for the second half of the 30 to 90 degree range.

Correct

1.00 points out of 1.00

Flag question

Which station name is closest to the end of this distance range, but still less than 90 degrees?

Answer: KIEV

Check

Correct
Marks for this submission: 1.00/1.00.

Question 21

Correct

1.00 points out of 1.00

Flag question

At approximately what distance is this station relative to the earthquake? I want your answer in kilometers, not degrees.

Answer: 9213

Check

83 degrees times 111 kilometers per degree

Correct
Marks for this submission: 1.00/1.00.

Question 22

Correct

1.00 points out of 1.00

Flag question

What is the approximate arrival time at this station in seconds? Note that the time is reported in minutes and seconds so you will need to convert to just seconds.

Answer: 748

Check

Correct, the first arrival is between 12:27 and 12:31.

Correct
Marks for this submission: 1.00/1.00.

Question 23

Correct

1.00 points out of 1.00

Flag question

In order to estimate the properties in the lower part of the lower mantle, we should compare this station to the station in the middle of the 30 to 90 degree distance range. What is the difference in distance between this station and the station near 60 degrees? I will assume your answer is in kilometers.

Answer: 2886

Check

Correct
Marks for this submission: 1.00/1.00.

Question 24

Correct

1.00 points out of 1.00

Flag question

What is the difference in arrival time between this station and the station near 60 degrees? I will assume your answer is in seconds.

Answer: 160

Check

Correct
Marks for this submission: 1.00/1.00.

Question 25

Correct

1.00 points out of 1.00

Flag question

Based on the slope between these data points, what is the approximate speed in the lower part of the lower mantle? I will assume your answer is in km/s.

Answer: 18.03

Check

Correct
Marks for this submission: 1.00/1.00.

Question 26

Correct

0.67 points out of 1.00

Flag question

To see how well we have estimated the velocities inside the lower mantle, we will compare the predicted arrival times from a simple velocity model using our estimates. Velocity models are often determined by comparison of observed arrival times and model predictions, often using an inversion like travel time tomography. Today you will be employing a forward modeling strategy, often referred to as "guess and check". Our starting guess will be from velocities we just estimated, and we will check by using TauP to predict the arrival times.

The next part of the assignment will be accomplished on the OSL desktop, so we should create a directory called **gsv** inside the network directory we created in the last assignment. Which of the following commands would ensure you create this directory in the correct location?

Select one:

- a. mkdir gsv
- b. mkdir network/gsv
- c. cd ~/network/gsv
- d. cd gsv
- e. mkdir ~/gsv
- f. mkdir ~/network/gsv ✓ Correct. Now make sure you enter this directory with the `cd ~/network/gsv` command.
- g. cd network/gsv
- h. cd ~/gsv

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 27

Correct

1.00 points out of 1.00

Flag question

In order to compare the predictions to the observations, we need to download the seismograms we have been examining in the GSV. We will use FetchData to get these seismograms, but we need to identify the details of this earthquake first using FetchEvent. Based on what is provided by the GSV, we can search for the event using the date and time information by the GSV page. Which of the following would use that information to find the earthquake?

Select one:

- a. FetchEvent -s 2010-01-12T21:53 -e 2010-01-12T21:53
- b. FetchEvent --mag 7:10
- c. FetchEvent -s 2010-01-12T21:53 -e 2010-01-12T21:54 ✓ Correct. Go ahead and run this command to get the information about this earthquake.
- d. FetchEvent -s 2010-01-12 -e 2010-01-12
- e. FetchEvent -m 7 -s 2010-01-12

Check

Correct
Marks for this submission: 1.00/1.00.

Question 28

Correct

0.17 points out of 1.00

Flag question

Using the output from the command in the previous question, what is the precise, formatted origin time information? The format we need for FetchData is YYYY-MM-DDThh:mm:ss.sss

Answer: 2010-01-12T21:53:10.410

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.17/1.00**.

Question 29

Correct

0.67 points out of 1.00

Flag question

We will need to use FetchData to get the seismograms that occur at distances prior to 90 degrees. Since this is 7 different stations, we should use a script to automate the process. Create a script entitled **gsv.csh** with `gedit` and make sure to add **#!/bin/csh** to the first line. Then you can use the `foreach` command to create a loop that will go through each station.

An example of the format of the command is: foreach num (1 2 3 4 5)

Which of the following would create a variable called **sta** and loop through the station names?

Select one:

- a. foreach (SDV SDCO PTGA SACV TRQA KDAK KIEV)
- b. foreach sta (SDV SDCO PTGA SACV TRQA KDAK KIEV ARU KURK BJT ENH PALK WRAB KAPI)
- c. foreach sta SDV SDCO PTGA SACV TRQA KDAK KIEV
- d. foreach sta (SDV SDCO PTGA SACV TRQA KDAK KIEV) ✓
- e. foreach (SDCO SACV TRQA KDAK KIEV)

Check

Your answer is correct.

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 30

Correct

0.67 points out of 1.00

Flag question

The next command in the script should be the FetchData command. Go ahead and write `FetchData` into the next line of the script, but we will need to figure out which options need to be added to the end of this command. Which of the following options would be needed to retrieve 30 minutes of data and metadata from the broadband vertical channel for each station?

Reminder: In your script, make sure to indent commands that are inside the foreach loop!

Select one or more:

- a. -o gsv.meta
- b. -m gsv.meta ✓ 1 of 5 correct answers
- c. -m gsv.mseed
- d. -s 2010-01-12T21:53:10.4 -e 30
- e. -o gsv.mseed ✓ 1 of 5 correct answers
- f. -s 2010-01-12T21:53:10.4 -e 30M ✓ 1 of 5 correct answers
- g. -s sta
- h. -C "BHZ" -L 00 ✓ 1 of 5 correct answers
- i. -S $sta ✓ 1 of 5 correct answers
- j. -c "BHZ" -l 00

Check

Go ahead and finish adding to your FetchData command in your script by adding these options so your full command should look like this:

```
FetchData -S $sta -C "BHZ" -L 00 -s 2010-01-12T21:53:10.4 -e 30M -o gsv.mseed -m gsv.meta
```

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 31

Correct

0.00 points out of 1.00

Flag question

After the FetchData script, you will need to run mseed2sac to create a SAC file you can read with sac. We will add a new option -E to mseed2sac this time to specify the event information. Go ahead and run `mseed2sac -h` at the command line to learn about the format for this option. Which of the following would correctly specify the -E information for this earthquake?

Select one:

- a. -E 2010,01,12,21:53:10/-72.588/18.3823/15
- b. -E 2010,012,21:53:10/18.3823/-72.588/15 ✓
- c. -E 2010,012,21:53:10/-72.588/18.3823/15
- d. -E 2010-01-12T21:53:10/-72.588/18.3823/15
- e. -E 2010,01,12,21:53:10/18.3823/-72.588/15
- f. -E 2010-01-12T21:53:10/18.3823/-72.588/15

Check

Go ahead and add this command to your script: mseed2sac gsv.mseed -m gsv.meta -E 2010,012,21:53:10/18.3823/-72.588/15

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.00/1.00**.

Question 32

Correct

1.00 points out of 1.00

Flag question

The last thing you need in your script is an `end` command to let linux know you have reached the end of your loop. So add the `end` command at after the mseed2sac command in your script, but don't indent the `end` command! Go ahead and save it and then make the script executable:

```
(iris) jupyter-[your_username]:~/network/gsv> chmod +x gsv.csh
```

Now run the script.

```
(iris) jupyter-[your_username]:~/network/gsv> ./gsv.csh
```

You can use `ls` to review the results. What is the name of the SAC seismogram file for station SDV?

Answer: IU.SDV.00.BHZ.M.2010.012.215310.SAC

Check

Correct
Marks for this submission: 1.00/1.00.

Question 33

Correct

1.00 points out of 1.00

Flag question

Now read all seven of the files into sac and plot them:

```
SAC> r *SAC
SAC> p1
```

This plot should look different than the GSV record section because the stations will be sorted in the order they are read in, meaning they are sorted alphabetically. You can sort the stations by distance with the sort command. Which SAC header variable has the distance value in kilometers stored in it? Recall that you can use the `lh` command to list the header variables for SAC files in memory.

Answer: DIST

Check

Correct, go ahead and run the command: `sort dist`

Correct
Marks for this submission: 1.00/1.00.

Question 34

Correct

1.00 points out of 1.00

Flag question

Go ahead and plot the stations sorted by distance. Note that sometimes SAC has trouble plotting multiple seismograms after sorting. If you get a blank screen when you type p1, try plotting with ppk and then try p1 again. If that still doesn't work, you may need to exit SAC and start over again by reading the files again, sort them again, and then try plotting again.

To make sure this worked correctly, which station is plotted at the bottom of your view when sorted by distance? If the plots are difficult to see, we recommend you make them full screen.

Answer: KIEV

Check

Correct
Marks for this submission: 1.00/1.00.

Question 35

Correct

1.00 points out of 1.00

Flag question

Now we will use TauP to construct a velocity model to compare with the observations. You will need to exit sac and open a new file with `gedit` called **model.tvel** to store the velocity model information. The format for this file is to use the first line as a comment, starting with a # symbol. I would recommend you add text briefly describing we are constructing our own velocity model for the 2010 Haiti earthquake. The second line of this model file is the number of layers in the velocity model, which will be 9 for our example. Next you need to add this text that indicates the depth (in kilometers), P velocity (km/s), S velocity (km/s), and density (g/cm^3) in the 4 columns. Here is what you should add as the starting model:

```
0.0000 5.5000 3.200 2.800
40.000 6.6000 3.800 2.900
40.000 8.0000 4.750 3.300
660.00 13.500 6.000 4.000
2900.0 18.000 8.000 6.000
2900.0 8.0000 0.000 10.00
5150.0 10.500 0.000 12.00
5150.0 11.000 3.400 12.60
6371.0 11.300 3.500 13.00
```

Make sure to save this file with gedit.

What is the thickness of the crust in kilometers in this velocity model? You can review information about the structure of the Earth if you are not familiar with all of the layers.

Answer: 40

Check

Correct
Marks for this submission: 1.00/1.00.

Question 36

Correct

1.00 points out of 1.00

Flag question

What is the depth of the boundary between the upper and lower mantle?

Answer: 660

Check

Correct
Marks for this submission: 1.00/1.00.

Question 37

Correct

1.00 points out of 1.00

Flag question

What is the depth of the core-mantle boundary?

Answer: 2900

Check

Correct
Marks for this submission: 1.00/1.00.

Question 38

Correct

1.00 points out of 1.00

Flag question

Note that I have inserted the approximate velocities you estimated for the top and bottom of the lower mantle into this velocity model. However, there is an issue with estimating the velocities of the lower mantle simply using the slope of the travel time curve. A key problem with this kind of calculation is that the P wave does not travel along the surface of the earth, and instead travels along a curved path through the earth. So the epicentral distance is not accurate for the true path the seismic wave took through the earth. This is why the slope of the travel time curve said to give us a measurement of the horizontal slowness, not the true slowness (inverse of the velocity). A series of equations that describes the relationship between these parameters is:

horizontal slowness = delta-T / delta-X = slowness * sin (incidence angle) = sin (incidence angle) / velocity

The incidence angle is measured from a vertical line, so 0 if vertical and 90 degrees if horizontal. In the case where seismic waves are traveling nearly horizontal, sin (90) = 1, so the equation is simplified to:

horizontal slowness = delta-T / delta-X = slowness = 1 / velocity

This is the case from the previous assignment where we could use the slope to directly estimate the velocity. In the case we are looking at in this assignment, the seismic waves traveling down to the lower mantle come back with an incidence angle between 0 and 90. Let's rearrange the equation to help us understand how this would affect our estimate of the velocity:

delta-X / delta-T * sin (incidence angle) = velocity

How would incidence angles less than 90 degrees affect the velocity estimate?

Select one:

- a. accounting for less horizontal paths would not affect the value of our velocity estimate
- b. accounting for less horizontal paths would decrease the value of our velocity estimate ✓ Yes, this means our velocity estimates are probably too high.
- c. accounting for less horizontal paths would increase the value of our velocity estimate

Check

Correct
Marks for this submission: 1.00/1.00.

Question 39

Correct

1.00 points out of 1.00

Flag question

Lets test this idea by predicting the arrival times from the model that you created. Taup needs to generate a model it can use from the model.tvel file you created. It does with with the taup_create command. Go ahead and run this command:

```
(iris) jupyter-[your username]:~/network/gsv> taup_create -tvel model.tvel
```

What file did it create?

NOTE: If running the command produces an error `Check your velocity model`, then you probably have something wrong in the format of the **model.tvel** file. If this happens, it usually means that you should review this file in gedit and make sure it has a first line comment, and second line with a number on it, and then all the remaining lines would be 4 columns of numbers that you copied from Question 35. You should also check to make sure there is not any extra blank lines at the end of your file.

Answer: model.taup

Check

Correct
Marks for this submission: 1.00/1.00.

Question 40

Correct

0.67 points out of 1.00

Flag question

Next we should use this model to estimate the predicted arrival times. We can do this with the following command:

```
taup_time -mod model.taup
```

but we would need to specify the earthquake and station information for each case to get the time we can compare with our observations.

Fortunately, there is another TauP command called `taup_setsac` that can use the event and station information in a SAC file as input for determining arrival times. Type `taup_setsac` into the command line to see the usage information for this command. Based on the usage information, which of the following components would be needed to use our velocity model to insert the P wave into the T1 variable and S wave into the T2 variable? Note that we entered the depth information in kilometers when using the mseed2sac command earlier.

Select one or more:

- a. -mod model.taup ✓ 1 of 5 correct answers
- b. -pf model.taup
- c. -ph P-T1 S-T2
- d. taup_time
- e. -evdpkm ✓ 1 of 5 correct answers
- f. -pf model.tvel
- g. -mod model.tvel
- h. *SAC ✓ 1 of 5 correct answers
- i. -ph P-1,S-2 ✓ 1 of 5 correct answers
- j. taup_setsac ✓ 1 of 5 correct answers

Check

Go ahead and run the full command: taup_setsac -mod model.taup -ph P-1,S-2 -evdpkm *SAC

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 41

Correct

0.67 points out of 1.00

Flag question

Now you can read the seismograms into sac with the predicted times:

```
(iris) jupyter-[your username]:~/network/gsv> sac
SAC> r *SAC
SAC> sort dist
SAC> p1
```

*you can also plot with `ppk perplot 1` to be able to zoom in to see the difference between the predicted and observed first arrival

How does the predicted P time compare to the first arrival in the observed seismograms at small distances (for stations less then 50 degrees)? If the plots are difficult to view, increase the size of or full screen the plot window.

Select one:

- a. the predicted time is generally slightly later (<20 seconds) than the observed time
- b. the predicted time is generally much earlier (>20 seconds) than the observed time ✓
- c. the predicted time is generally slightly earlier (<20 seconds) than the observed time
- d. the predicted time is generally much later (>20 seconds) than the observed time

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 42

Correct

0.00 points out of 1.00

Flag question

What does this tell us about our velocity model?

Select one:

- a. the velocity in the lower part of the lower mantle is too slow
- b. the velocity in the lower part of the lower mantle is too fast
- c. the velocity in the upper part of the lower mantle is too fast ✓
- d. the velocity in the upper part of the lower mantle is too slow

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.00/1.00**.

Question 43

Correct

1.00 points out of 1.00

Flag question

How does the predicted P time compare to the first arrival in the observed seismograms at large distances (for stations greater than 50 degrees)?

Select one:

- a. the predicted time is generally much later (>100 seconds) than the observed time
- b. the predicted time is generally slightly later (<100 seconds) than the observed time
- c. the predicted time is generally much earlier (>100 seconds) than the observed time ✓
- d. the predicted time is generally slightly earlier (<100 seconds) than the observed time

Check

Correct
Marks for this submission: 1.00/1.00.

Question 44

Correct

0.33 points out of 1.00

Flag question

What does this tell us about our velocity model?

Select one:

- a. the velocity in the lower part of the lower mantle is too fast ✓
- b. the velocity in the lower part of the lower mantle is too slow
- c. the velocity in the upper part of the lower mantle is too slow
- d. the velocity in the upper part of the lower mantle is too fast

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.33/1.00**.

Question 45

Correct

1.00 points out of 1.00

Flag question

These findings should be consistent with what we anticipated earlier: We did not account for the incidence angle when estimating the velocity from the slope of the travel time curve.

Now you should try lowering the velocity in your model until the arrival time is approximately correct (differences less than 20 seconds) at each of the seven stations.

But before you change anything, what is the starting P velocity in your model.tvel file at the top of the lower mantle?

Answer: 13.5

Check

Correct. Bear in mind that the velocity you just determined this is too fast.

Correct
Marks for this submission: 1.00/1.00.

Question 46

Correct

1.00 points out of 1.00

Flag question

What is the starting P velocity in your model.tvel file at the bottom of the lower mantle?

Answer: 18.0

Check

Correct. Bear in mind that the velocity you just determined this is too fast.

Correct
Marks for this submission: 1.00/1.00.

Question 47

Correct

1.00 points out of 1.00

Flag question

Now you should start changing these two P wave velocity values in your model until your predicted times match the observation times. To help you with this process, here is the order of commands that you may want to use to accomplish this:

```
(iris) jupyter-[your username]:~/network/gsv> gedit model.tvel &
(iris) jupyter-[your username]:~/network/gsv> taup_create -tvel model.tvel
(iris) jupyter-[your username]:~/network/gsv> taup_setsac -mod model.taup -ph P-1,S-2 -evdpkm *SAC
(iris) jupyter-[your username]:~/network/gsv> sac
SAC> r *SAC
SAC> sort dist
SAC> p1
```

This can take some time but try modifying those two P wave velocities until all of the predicted P arrival times are within 20 seconds of the observation. You will be performing the "guess and check" part of forward modeling to accomplish this.

Once you have successfully predicted the observed P arrival times within 20 seconds, what P wave speed did you find at the top of the lower mantle (660 km)?

If you get confuse, you can "start over" by copying the starting values from Question 35 and pasting them into model.tvel. Also recall from that question that the first line of this file should start with a # symbol and the second line should have the number 9 to indicate how many layers in the velocity model.

Answer: 11.00

Check

Correct
Marks for this submission: 1.00/1.00.

Question 48

Correct

0.67 points out of 1.00

Flag question

What P wave speed did you find at the bottom of the lower mantle (2900 km)?

Answer: 13.5

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Finish review