GG 304L: Solid Earth & Planets Lab

LAB 7: Using "Linray" and Understanding the Effects of Velocity Structure on Travel-Time Versus Distance Seismograms

Due Tuesday 17 March

The Matlab script "linray.m" was written by F. Duennebier to model seismic ray paths and travel-time versus distance curves. You will be using this program to model your data from our survey at Kualoa Beach Park so here is your chance to learn how to use it. The second purpose of this lab is to help you develop some intuition of how/why various aspects of travel time curves depend on variations in velocity in 1-D (i.e. only vertically). Copy the files "*linray.m*", "*vmod.m*", and "*calc_raypath.m*" from the GG304 directory to your home directory.

1) Run the program *linray*. The first question asks you to specify a starting 1-D velocity model. Hit "enter" to start with an arbitrary model. The second question asks you to specify the number of layers in your velocity model. Hit "enter" for the default number of 3 layers. The left diagram in Figure 1 shows the starting velocity model. Each layer is separated by velocity "nodes", whose numbers are labeled next to the node. The upper right plot shows calculated ray paths. The lower right plot shows calculated travel times versus x for all rays leaving the source between angles *startangle*=1° and *endangle*=89° from vertical. The colors of the ray paths and the arrival times correspond to rays that turn horizontal in each of the three layer; e.g., red denotes all rays that "turn in" layer 2. Please answer the following questions.

(a) Why does Travel Time (T) increase with Shot-Receiver Distance, x?

(b) The ray parameter p at each point of the curve equals the slope at each point, dT/dx. Why does the ray parameter and slope dT/dx decrease with increasing distance, x?

(c) From the given velocity profile, calculate the minimum and maximum ray parameter p of rays turning in layer 1 (it will save time to make a small Matlab script to answer question 1(b), 1(c), 1(e) as you will be asked these questions a couple times more in this lab).

(d) From the known velocities calculate minimum and maximum take-off angle of rays turning in layer 1.

(e) Make a copy of this figure . From the synthetic seismogram (i.e., travel time versus shot-receiver distance plot) estimate the average velocities of layers 1 and 2 (pencil is fine). Your estimates should be close to the average velocities specified by your velocity model.

(f) Estimate thickness of layer 1 by approximating these curve refractions as head waves like you did in the previous lab and homework. How do these estimates compare with the "real" layer thickness? Do the comparisons make sense given what you know about your approximation versus the real structure?

2) Let's examine how velocities and thicknesses of layer 2 affect the travel time curves. Rerun *linray*. At the third question hit "return" to "modifying velocity model". For the next two questions, enter "3" to specify that you will be changing only velocity node 3. You can now use a left click of the mouse on the velocity profile diagram to specify the new location of node 3. Click your mouse at approximately depth, z=10 m and velocity v~2.5 km/s. This will increase the velocity of the top of the lower layer, increase the gradient in layer 2, but keep the thickness of layer 2 the same (you can easily readjust this point by repeating the above steps). Make a copy of figure and carefully compare the new ray paths and travel times with the case in problem (1).

(a) Does this change the ray paths & travel times of rays turning in layer 1?

(b) Do arrivals from layer 2 (red) appear sooner or later than the case in problem 1? Why? How does the slope in *T* vs. *x* change for the red arrivals. Why?

(c) What are the minimum & maximum *p* and take-off angles of rays turning in layer 2?

(d) Why are there fewer rays turning in layer 3?

3) Rerun *linray*. Beginning from the default starting model, move node 3 up to *z*=5m keeping the same velocity (*v*~2.2 km*/s).* Relative to the starting model, this modification increases the velocity gradient in layer 2 but decreases its thickness. <u>Make a copy of the figure.</u>

(a) Does this change the ray paths and travel times of rays turning in layer 1?

(b) Compared to the reference model, how does this modification change the ray paths and travel times of rays turning in layer 2? You should notice that the rays turn in the upper part of layer 2 bend more sharply, appear at shorter offsets, and appear sooner than rays turning in layer 1 (blue). These overlapping arrivals start to form a small "X" in the travel time plot. This "X" pattern is known as a "triplication".

(c) How does this modification change the ray paths and travel times of rays turning in layer 3?

4) Rerun *linray*. Move node 3 to same depth as node 2 (*z* = 2.5 m) but keeping the same velocity (*v*~1.5 km/s). You should see the triplication become much larger than in the case for problem 3. You should also notice that the velocity profile mimics two discrete layers with different velocities. The arrivals from rays turning in layers 1 (blue) and 3 (green) are nearly linear in figure 2 and mimic what is predicted for two discrete layers as discussed in class. <u>Make a copy of this figure</u> and use the blue and green arrivals to estimate the thickness of layer 1 approximating the arrivals as head waves.

5) Now let's look at changes in layer 1. Rerun *linray* and from the starting model, move node2 half way up along the velocity profile; i.e., make layer 1 half as thick but preserve the same velocity gradient. How does decreasing layer thickness change the distance over which layer 1 arrivals are first arrivals? (there's no need to keep this plot)

6) Rerun *linray* and from the starting model move node 2 to a velocity slightly less than node 3, keeping its original depth that the same. How does increasing the velocity gradient in layer 1 change the distances and times that layer 1 arrivals appear first in the travel-time plot?

7) Finally, let's examine the effects of a low velocity zone. From the starting model, move velocity node 2 ("1st node to modify" is 2) to *v*~1.5 km/s keeping the depth the same and move node 3 ("last node to modify" is 3) to *z*~10 m and *v*~1.0 km/s.

(a) What is min/max ray parameter *p* and take-off angle in layer 1

(b) Why do no rays turn in layer 2 (hint what ray parameters would turn in layer 2?).