Geov112 - Exercise Set 4 (Deadline: 6 October 2017)

The geophysical background of these exercises can be found in paragraphs 4.1-4.4 from Fowler. We will continue to look at Global seismology and Seismic Exploration/Regional seismology. We will also begin to study Earthquakes in a bit more detail.

1. **Matrix computations.** In this exercise we will use some Matlab commands to create and manipulate matrices.

   (a) Create a matrix A with 7 columns and 7 rows that has zeros everywhere except on the diagonal and the first row, where the elements are equal to three (hint: you can use one or more of the following Matlab commands: `zeros`, `ones` and `eye`. Try to use as few Matlab commands as you can.

   (b) Give the Matlab command that assigns the value of 5 to the element in A on the third row and third second column and save the new matrix.

   (c) Give the Matlab command that assigns the value of -6 to the element in A on the sixth row and third column and save the new matrix.

   (d) Find out from the help pages what the Matlab commands `max(A)` and `min(A)` do and explain this in your own words.

   (e) Give the Matlab command that computes the maximum element of A.

   (f) Give the Matlab command that computes the minimum element of A.

   (g) Compute by hand the sum of all the elements of A.

   (h) Use the Matlab command `sum(A)` to compute the sum of all the elements of A.

2. **Global Seismology: Traveltimes of P, PcP, PKIKP and PKJKP** If an earthquake is strong enough (magnitude over 4) then it gets recorded by seismometers worldwide. The arrivals that are recorded travel through the crust, mantle and/or core. The main arrivals are so important that they have been given special symbols. For example the P wave that is reflected at the core-mantle-boundary (CMB) is denoted PcP. Fowler has a table explaining all the main symbols on page 126. Make sure you know the meaning of all these symbols! In this exercise we are going to compute the travel times of certain arrivals using a simple velocity model: we assume that the crust and mantle have a P-velocity of 12.6 km/s, that the P-velocity in the outer core is 9.4 km/s and that the P-velocity in the inner core is 11.6 km/s. We also assume that the S-velocity in the inner core is 3.4 km/s.

   (a) If an earthquake happens in San Francisco at the surface and is recorded in Bergen then compute the travel time of the P phase. For this and the following exercise use Matlab.

   (b) Similarly compute the travel time of the PcP phase. For this it helps if you draw a diagram of the ray path and remember that you know the epicentral distance.

   (c) Compute the travel time of the PKIKP wave that travels from an earthquake at the Earth's surface straight down to the other side of the Earth.

   (d) Do the same for the phase PKJKP.

   (e) Describe the PKIKP and PKJKP phase in your own words (i.e. through which layers are they traveling and are they a P-wave or a S-wave).

   (f) Look up the travel time of PKIKP from Figure 4.16 and explain the difference with your computation.

(g) Most phases have been observed for almost 100 years. However, PKJKP was not observed until 2005. What information is contained in the travel time of this phase that would be useful for the geosciences and that is difficult to obtain otherwise?

(h) Give the acronym for the phase that travels as a P-wave through the mantle and gets reflected from the inner core boundary.

3. **'For loop' exercise**

   (a) Compute the sum $2 + 4 + 6 + 8 + 10 + \ldots + 100$ by creating an array.

   (b) Do the same by using a for loop (this exercise also shows that you have to be careful when using for loops: you can sometimes do the computations in Matlab using a simpler way).

4. **Exploration Seismics/Regional Seismology III**

   (a) Use the layer over halfspace model used in Exercise 7 (3rd exercise set) to plot the raypaths of the reflected waves recorded at 5 km , 10 km, 15 km and 20 km. Do not use a 'for' loop in this case. In this case there is no need to plot the axes, so you can use the `axis off` command. Also plot the surface and the reflector, but use thicker lines for these.

   (b) (Optional) Use a 'for' loop to plot the ray paths of the reflected wave recorded at seismometers that are 4 km - 20 km distance from the source and 2 km apart.

5. **Earthquake Seismology I: Statistics of Worldwide Earthquakes in September 2015.** Information about earthquakes (latitude, longitude, depth and magnitude) is given by many institutions and websites. An example is the Northern California Earthquake Data Center run by UC Berkeley and the US Geological Survey (www.ncedc.org). In particular, it is possible to download information on earthquakes that have occurred worldwide. The webpage for this is:
   http://www.ncedc.org/anss/catalog-search.html
   Information on searching can be found on:
   http://www.ncedc.org/anss/catalog-search-help.html
   Take a few minutes to test some searches (remember that in the US date notation is different from that in Europe: e.g. 06/08 is 8 June and not 6 August).

   (a) Look up all earthquakes that were recorded in the last 20 days that had a magnitude 3 or higher. Use the 'Catalog in CSV format' option (CSV stands for Comma Separated Values and is a useful format to use in Matlab) and then copy and paste all the earthquake info (not the headers) in a .txt file that you save in the directory that you use for this exercise. Call this file 'earthq2017.txt'. This file is your input for the Matlab program you will write in this exercise. You can read this file into Matlab by using the Matlab commands:
   `fid = fopen('earthq2017.txt');`
   and
   `eqdata=textscan(fid,'%s%f%f%f%f%s%f%f%f%f%s%f','Delimiter',',');`
   This line looks complicated but is easy to understand. It reads all the columns in the .txt file (12 in total). Some of these columns are numbers (or floating points, indicated by %f) and some are strings (indicated by %s). All columns are separated by a 'Delimiter' (a comma in this case). You do not need to remember these commands for the exam. Remember

that you can extract columns from 'eqdata' in the same way as you did when extracting columns from the iasp91 model. Plot the distribution of these earthquakes versus magnitude (0, 1, 2 etc.).

(b) Compute the average magnitude and its standard variation of these earthquakes.

(c) Compute the average depth and its standard variation of these earthquakes.

(d) The distribution of earthquakes with depth is also very interesting. Plot the statistics of earthquake occurrence as a function of depth (with intervals of 10km and 30km). Discuss your results.

(e) Study all the earthquake data from earthq2016.txt and give a 10 sentence summary of what you notice about the depths and magnitudes of these earthquakes.

6. **Earthquake Seismology II: Worldwide distribution of earthquakes**.

(a) In this and the following exercise you can download the earthquake data from the USGS webpages as we did in exercise 5. How many earthquakes with magnitude 8 and higher happened in the period 2005-2016?

(b) Use the previous exercise to compute (approximately) the number of earthquakes with magnitude 8 that occur every year. You don't hear about all these earthquakes in the news. Why is that?

(c) Plot the location of these earthquakes. The coastlines can be plotted using the following Matlab commands:

```
worldmap world
load coast
geoshow('landareas.shp', 'FaceColor', [0.15 0.5 0.15])
```

Make sure you use capital letters where needed as Matlab is case sensitive (i.e. 'F' is not the same as 'f'). Once you have the latitudes and longitudes stored as arrays, for example `lateq` and `loneq`, then you can plot the locations using:

```
geoshow(lateq,loneq,'Marker','.','MarkerEdgeColor','red','DisplayType','point');
```

(d) Use this list of earthquakes to determine how many earthquakes with magnitude 7 or higher happen every month.

(e) Use this list also to determine how many earthquakes with magnitude 8 happen every year.

(f) Compare your answers with the table given on page 115 in Fowler and discuss the differences.

(g) How are the locations of these earthquakes correlated with plate boundaries?