

# GEOL 308L: Natural Hazards

## Lab 07: Seismic Hazards

You and your imaginary friend have been hired to evaluate a seismic hazard model based upon an empirical Ground Motion Prediction Equation (GMPE) originally published in 1981. There have been major improvements in GMPE calculations since then and this analysis will be used to justify an updated analysis for northern California. Your imaginary team will conduct a GMPE analysis and compare those results with the results from modeling conducted by the USGS for their “ShakeMap scenarios.” Below is a plot showing Peak Ground Acceleration modeled for earthquakes of different magnitudes (Joyner and Boore, 1981). Below the lot is a map from the USGS Scenario ShakeMap for an M 9.0 earthquake on the Cascadia subduction zone. This map is created using a GMPE and can be viewed here:

[https://earthquake.usgs.gov/scenarios/eventpage/gllegacycasc9p0expanded\\_se#executive](https://earthquake.usgs.gov/scenarios/eventpage/gllegacycasc9p0expanded_se#executive).

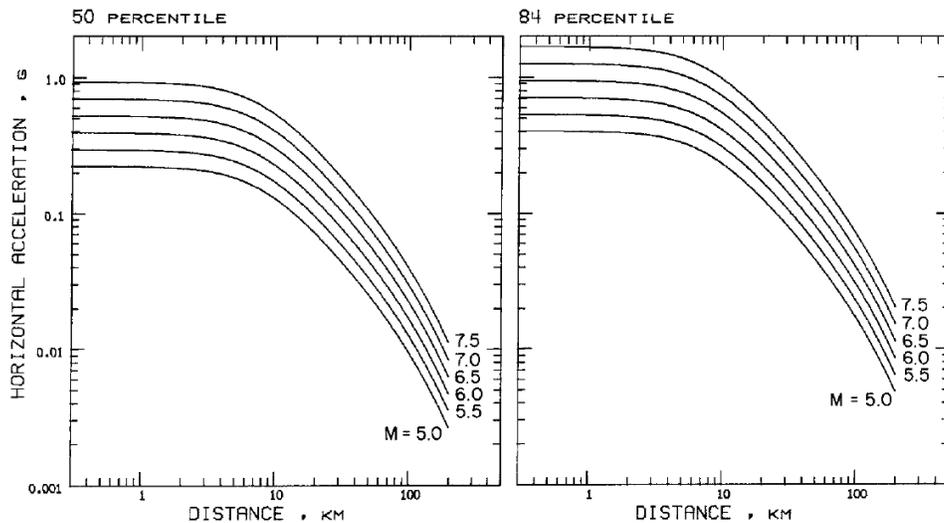
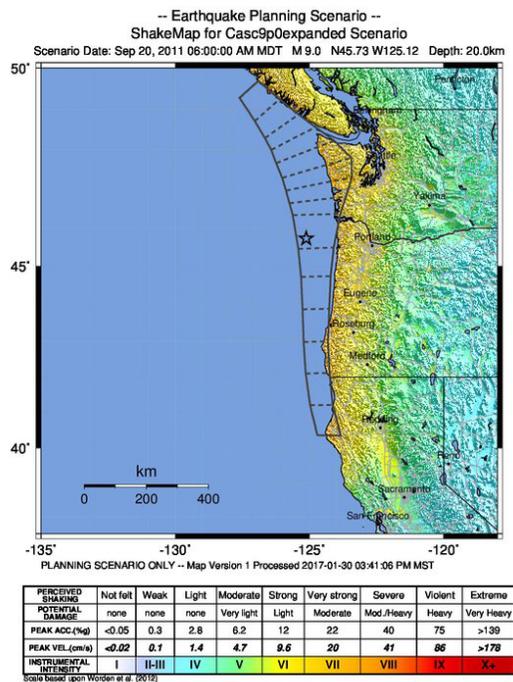


FIG. 4. Predicted values of peak horizontal acceleration for 50 and 84 percentiles as functions of distance and moment magnitude.



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### Objectives

The student will learn to:

- Understand and apply a Ground Motion Prediction Equation to various earthquake sizes and distances
- Estimate ground motions expected from an earthquake on the Cascadia subduction zone

### Background on GMPE

GMPEs are regressions based upon empirical relations between ground motions observed following earthquakes and the distance to those earthquakes at the observation location. The observations used are from various types of seismometers and accelerometers. As seismic waves transmit through earth materials (like the crust), the energy content is attenuated. This is why these are also called attenuation relations. Initially, these attenuation relations were developed in the 1980s and 1990s. Since then, tens of thousands of earthquakes have been added to the global and regional databases from which these regressions are formulated.

Ground motions can be evaluated based upon their magnitude of shaking, as well as the frequency content of the shaking. One measure is Peak Ground Acceleration (PGA). PGA is measured in units of “g” (gravitational acceleration). This unit is defined as  $g = 9.8 \text{ m/s}^2$ . Other measures include Peak Ground Velocity (typically in cm/s or m/s) and Arias Intensity (m/s). There have also been attempts to relate these ground motion measures with earthquake intensity, like Modified Mercalli Intensity.

### Assignment

Your predecessor conducted some GMPE analyses in the 1980s using a relation from Joyner and Boore (1981). Unfortunately, they left without providing any information about where their work was located on the server. Subsequently, the server exploded and all data were lost. You will need to reconstruct the analyses conducted by your predecessor prior to being able to compare those results with the USGS model.

You will first evaluate the Joyner and Boore (1981) GMPE in a spreadsheet. Then you will apply this GMPE to Humboldt and Del Norte counties in northern California. Finally, you will compare these results with the results from the USGS ShakeMap Scenario.

Remember to place all your data on the D drive in a directory called e.g. `../patton/lab_07`

### Part I. GMPE Analyses

Joyner and Boore (1981) utilized data from strong-motion seismometers to develop relations between ground motions, earthquake magnitude, and distance to the earthquake. These were based upon hundreds of measurements. Your predecessor used the equation for PGA presented in their abstract. Rearranged to solve for PGA here:

$$A = 10^{(0.249 * M - \log(R) - 0.00255 * R - 1.02)}$$

$$R = (D^2 + 7.3^2)^{0.5}$$

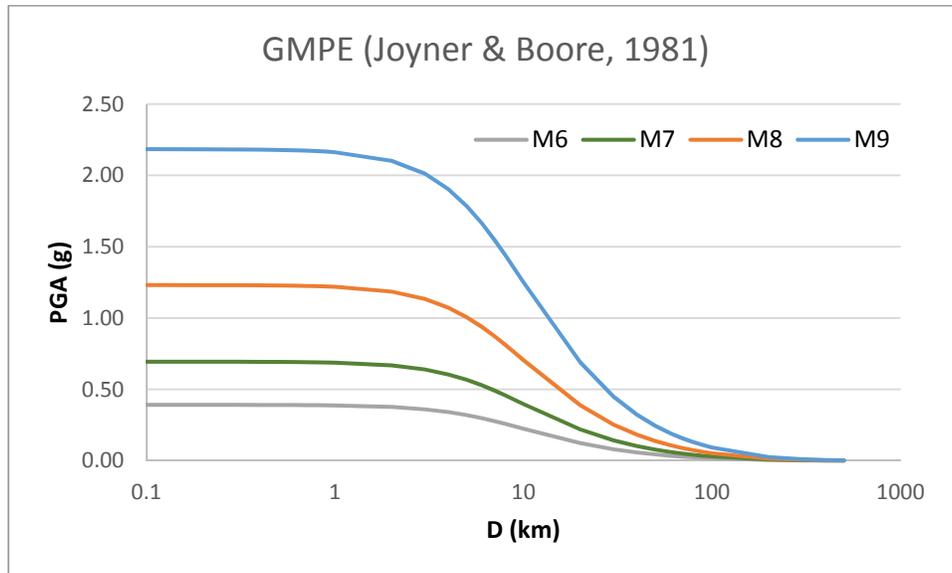
Where A is Peak Ground Acceleration ( $\text{m/s}^2$ ), M is earthquake magnitude, and D is distance to the fault.

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### Part I A. Spreadsheet

The first step is to try applying these formulas in a spreadsheet. Create a spreadsheet with the following columns: M6, M7, M8, M9, D, R, and PGA. For each M column, enter the magnitude 6, 7, 8, or 9. For the D column, enter distances 0.1, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, and 200. For the R column, enter the formula listed above. For the PGA column, enter the formula listed above. Drag the formulas down so that all rows and all columns have data for each distance. Create a plot for the PGA vs. distance for each of the 4 magnitudes. This plot will go into your report in Part III. Mine looks like this:



### Part I B. Raster Analyses

Place the base data zip file "GEOL\_308L\_lab\_07\_data\_part\_I.zip" located in the T:\jrp2\GEOL\_308L\labs\lab\_07 directory into your D drive directory (in a folder called "original" in a folder called "part\_I.") Right click and "7-zip/extract here." Launch ArcMap and load the three data sets. These three data sets all share the same coordinate system, UTM NAD1983 zone 10N.

- Modeled\_slab\_grid\_ut83.tif – the CSZ megathrust fault as modeled by McCrory et al., 2012
- Dem\_km\_ut83.tif – a DEM of the CSZ region as used by McCrory et al., 2012
- Humbo\_deldno.shp – a polygon shapefile representing the outline of Humboldt and Del Norte counties

#### Step By Step

1. Clip the raster data to the county polygon. Use the toolbox: Data Management Tools/Raster/Raster Processing/Clip. Do one raster at a time and use the county polygon to control the clip. Navigate and give your new files cool names like, "dem\_norcal.tif" and "slab\_norcal.tif." For NoData, use a value like -1000. Don't forget to include the file extension ".tif."
2. Create a new raster that represents the distance between the ground surface and the megathrust fault. Use the raster calculator to subtract these two newly clipped rasters to make a new raster

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with a cool name like, "slab\_dist\_km.tif." Consider the units when you write the raster algebra (the slab is in negative units). The slab distance should range from ~9 km to ~35 km.

3. You will want to then create a raster to represent "R" in the GMPE formula. Use raster calculator and navigate and give your new raster a cool name like, "slab\_Rdist.tif." For one to calculate the square of a number (e.g. 5<sup>2</sup>), we would use the following syntax, "Power(5,2)."
4. Create a PGA raster using the Joyner and Boore (1981) GMPE relation that you plotted using the spreadsheet. Do this for two earthquake sizes, M 8 and M9. After you have completed this, check the results by comparing the range in PGA with the data in your spreadsheet. They should match pretty well. If not, it is time to go back to the drawing board (the raster calculator). If we want to take the log of 22, we would use the following syntax, "Log10(22)."
5. Create contours for each of these PGA rasters. Use a contour interval of 0.1 units. The tool is found in the "Spatial Analyst/Surface" tool box directory. Save these with cool names like "norcal\_PGA\_M9\_cont\_01.shp."
6. For each PGA map, create an MMI raster using the relations developed by Trifunac and Brady, 1975. Use raster calculator to create a new raster and call it something cool like "norcal\_MMI\_M9.tif." They found that MMI could be estimated from PGA data using the following formula:  
$$\text{MMI} = 1/0.3 * (\log_{10}(\text{PGA} * 980) - 0.014)$$
7. Create contours for each of these MMI rasters and call them something cool like "norcal\_MMI\_M9\_cont\_01.shp." Use a contour interval of 0.1.
8. Prepare a layout with two data frames, one displaying PGA and one displaying MMI. Have the contour data plotted on top of the raster data. Use similar color ramps for each raster data set and similar color choices for each contour data set. Use the standard map composition components. Export the map as a pdf or a jpg.
9. Save your MXD file and launch a new ArcMap application for the next part.

#### **Part II. USGS ShakeMap Scenario**

We will now use the USGS ShakeMap Scenario GIS data with which to compare our results.

Place the base data zip file "GEOL\_308L\_lab\_07\_data\_part\_II.zip" located in the T:/jrp2/GEOL\_308L/labs/lab\_07 directory into your D drive directory (in a folder called "original" in a folder called "part\_II.") Right click and "7-zip/extract here." Launch ArcMap and load the three data sets. These three data sets all share the same coordinate system, UTM NAD1983 zone 10N.

- mi\_ut83.tif – MMI data from the CSZ ShakeMap Scenario
- pga\_ut83.tif – PGA data from the CSZ ShakeMap Scenario
- Humbo\_deldno.shp – a polygon shapefile representing the outline of Humboldt and Del Norte counties

#### Step By Step

1. Clip the raster data to the county polygon. Use the toolbox: Data Management Tools/Raster/Raster Processing/Clip. Do one raster at a time and use the county polygon to control the clip. Navigate and give your new files cool names like, "norcal\_usgs\_mi\_ut83.tif" and "norcal\_usgs\_pga\_ut83.tif." For NoData, use a value like -1000. Don't forget to include the file extension ".tif."

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2. Create contours for each of these rasters. Use a contour interval of 0.1 units. The tool is found in the “Spatial Analyst/Surface” tool box directory. Save these with cool names like “norcal\_usgs\_mi\_cont\_01.shp” and “norcal\_usgs\_pga\_cont\_01.shp.”
3. Prepare a layout with two data frames, one displaying PGA and one displaying MMI. Have the contour data plotted on top of the raster data. Use similar color ramps for each raster data set and similar color choices for each contour data set. Use the standard map composition components. Export the map as a pdf or a jpg.
4. Save your MXD file.

### **Part III. GMPE Comparisons**

Spend some time observing the results from your analyses. Think about why they might be similar and why they might be different. If you are unsure about what is the source of variation, consider that the largest factor controlling GMPE relations is the distance from the fault. This will help you compare and contrast the USGS Scenario data with the analyses that you conducted using the Joyner and Boore (1981) GMPE relations.

Prepare a text document that includes the two maps (each with two panels: PGA and MMI). Write at least one paragraph about what GMPE attenuation relations are. Include the plot you created in the spreadsheet software and use this plot to support your discussion. Write at least one paragraph comparing and contrasting these data sets. Email this electronic document to the instructor before Monday 3/20/17 at midnight.

#### References:

Joyner, W.B., and Boore, D.M., 1981. Peak Horizontal Acceleration and Velocity from Strong Motion Records Including Records from the 1979 Imperial Valley, California, Earthquake in BSSA, v. 71, no. 6., p. 2011-2038.

Trifunac, M.D. and Brady, A.G., 1975. On the Correlation of Seismic Intensity Scales with the Peaks of Recorded Strong Ground Motion in BSSA, v. 65, p. 139-162.