Exploring Earthquake Hazards with GIS
Laboratory for *Introduction to Geophysics* , Spring 2007
Prof. Constantin Cranganu
Brooklyn College of the City University of New York

Learning Objectives:

- Students will be able, using GIS, to locate the largest and most destructive earthquakes;
- Students will be able, using GIS, to compare the locations of large earthquakes with the locations of deadly earthquakes;
- Students will be able to investigate changes in the distribution of deadly earthquakes over time.

Prerequisite knowledge and skills:

Basic knowledge of computer operation.
Familiarity with ArcGIS software is desirable, but not necessary.

Introduction

In recent years, GIS (Geographic Information Systems) has emerged as a power investigation tool in many geological and geophysical disciplines: plate tectonics, hydrogeology, environmental geology, volcanology, etc. It goes almost without saying that geologic and geophysical phenomena are spatially distributed. Plate boundaries are dynamically changing over time by subduction, rifting, or collision, aquifer contamination occurs where porous rock underlies agricultural or industrial land, volcanic eruptions influence the climate on long term and humans on short term. Often we understand these phenomena in principle, but we understand them more clearly, and more thoroughly, when we see them on a map. Visualization, being able to "see" spatial relationships and patterns in the geologic landscape, can make a great difference in our understanding of geologic and geophysical issues. An ability to calculate the spatial extent of overlapping variables, such as earthquake magnitude and earthquake casualties, is a key to analyzing earthquake hazards and risks.

A hazard is a potentially dangerous event or process. Risk is the potential loss of life, property, or production capacity due to a hazard. Geologic hazards exist even if lives and property are not endangered. Risk, on the other hand, depends on how those hazards could affect human activities. In general, geologic hazards can't be controlled by humans. However, we can do much to minimize risks through wise land use, timely earnings, and community preparedness.

Exploring earthquake and tsunami hazards is a complex activity, including, among others,

- examining earthquake data to locate the largest and most destructive earthquakes;
- investigating deadly earthquakes patterns through history;
- discovering which factors contribute most to an earthquake's destructive potential;
- exploring the relationship between population, national wealth, and seismic risk.

The current exercise will use ArcGIS software to explore deadly earthquakes throughout history.

The exercise draws upon a book chapter in "Exploring the Dynamic Earth GIS Investigations for the Earth Sciences, ArcGIS Edition", by Hall et al., 2007, Thomson/Brooks/Cole, p. 59 – 65.

Deadly earthquakes

Understanding where and when a major earthquake may strike is critical to assessing risk to life and property. It is also useful in developing plans to reduce that risk.

In this activity, you will investigate questions like “Where do the most damaging earthquakes occur?” You will also compare the locations of large earthquakes with the locations of deadly earthquakes and investigate changes in the distribution of deadly earthquakes over time.

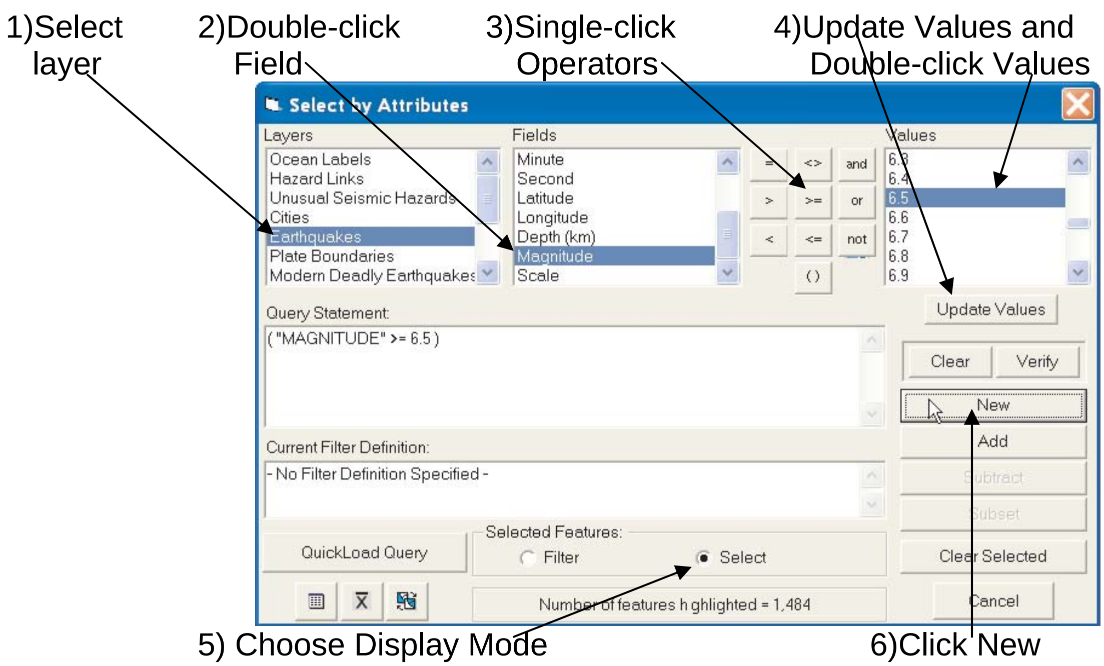
- Launch ArcMap, and locate and open the **Earthquake_Hazards.mxd** file.
- In the Table of Contents, right-click the **Earthquake Hazards** data frame and choose Activate.
- Expand the **Earthquake Hazards** data frame.

This map shows the locations of nearly 12,000 earthquakes of magnitude 5 and greater. They are a representative sample of over 300,000 quakes recorded around the world since 1973
.

Large earthquakes

Most damage occurs from earthquakes with magnitudes of 6.5 and greater.

- Click the Select By Attributes button 
- To see the locations of these powerful earthquakes (of magnitude 6.5 or greater), query the **Earthquakes** layer for **(“Magnitude” >= 6.5)** as shown in steps 1.6:



- Close the Select By Attributes window.
- Now the strong earthquakes are highlighted on your map.
- Turn on the **Plate Boundaries** layer.
- Turn the **Earthquakes** layer on and off to examine the relationship between the large earthquakes and the plate boundaries.

1. At which type of boundary are large-magnitude earthquakes most common?

Large-magnitude earthquakes are most common along convergent boundaries

- Click the Clear Selected Features button . 

Deadly earthquakes

- Turn off the **Plate Boundaries** and **Earthquakes** layers.
- Turn on the **Deadly Earthquakes (Deaths)** layer.
- Select the **Deadly Earthquakes (Deaths)** layer.

The **Deadly Earthquakes (Deaths)** layer shows the locations of historical earthquakes in which one or more people died. Many of these events were magnitude 6or greater, but quakes as small as magnitude 4 caused fatalities and significant damage. Prior to the early 1900s, instruments used to measure earthquakes did not record magnitudes, which were estimated much later from written reports of earthquake damage.

- Turn the **Deadly Earthquakes (Deaths)** and **Earthquakes** layers on and off, and zoom in and out as needed to answer the following question.

2. How do the locations of the deadly earthquakes compare to the locations of the large earthquakes?

The locations of magnitude 6.5+ earthquakes roughly coincide with locations of deadly earthquakes.

- Click the Full Extent button to see the entire map  .

Next, you will compare the locations of deadly earthquakes to the current distribution of the world's population.

- Turn off the **Earthquakes** and **Topography** layers.
- Turn on the **Population Density** and **Deadly Earthquake** layers.

To create the **Population Density** layer, Earth's land area was first divided into a grid. Then, each square of the grid was filled with a color that represents the number of people living within the square.

- Examine the **Population Density** legend.

3. Which color represents high population density? Which color represents low population density?
a. High density — ***dark red***

b. Low density — ***dark blue***

4. In general, how does the population density compare to the locations of deadly earth-quakes?

The deadly earthquakes appear to occur in places with high population density.

5. Aside from earthquake magnitude and population density, what factors do you think might contribute to a higher damage and death toll in a large earthquake?

Answers may include factors such as time of day, income level, soil type, emergency management plans, building design and materials, etc.

- Turn off the **Population Density** layer.
- Turn on the **Topography** layer.

Deadly earthquakes throughout history

Next you will look at how the pattern of deadly earthquakes has changed over the past two centuries. You will determine the number and locations of deadly earthquakes around the world during four time periods from 186 B.C. to the present.

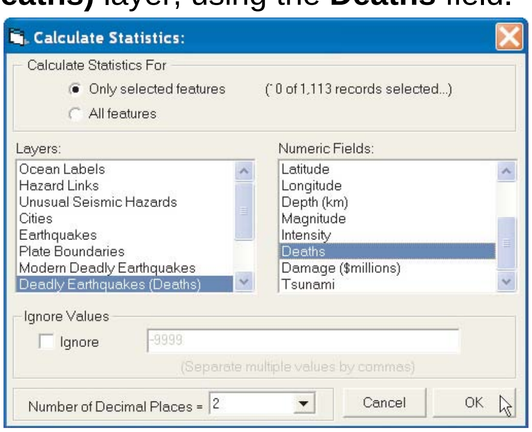
- Click the Select By Attributes button .
- To display only the deadly earthquakes that occurred before A.D. 500.
- query the **Deadly Earthquakes (Deaths)** layer using the following query statement (you will need to type the value “500”):

("YEAR" < 500)

- Click the **New** button.

Now the deadly earthquakes that occurred before A.D. 500 (between 186 B.C. and A.D. 499) are highlighted on your map.

- Click the Statistics button in the Select By Attributes window.
- In the Statistics window, calculate statistics for **only selected features** of the **Deadly Earthquakes (Deaths)** layer, using the **Deaths** field.



- Click **OK**. Be patient while the statistics are calculated.

6. Record the number of quakes (**Number of Records**), number of deaths (**Total**), and deaths per quake (**Mean**) in the table on the following page. In the last row of the table, identify the region(s) of the world where the earthquakes occurred.

- Close the Statistics window.
- Click the **Clear** button in the Select By Attributes window.
- To display only the deadly earthquakes that occurred between A.D. 500 and A.D. 999, query the **Deadly Earthquakes (Deaths)** layer using the following query statement:
  (“YEAR” >= 500) AND (“YEAR” < 1000)
- Click the **New** button.

Now the deadly earthquakes that occurred between A.D. 500 and 999 are highlighted on your map.

7. Repeat the statistics procedure above and record the number of quakes, deaths, and deaths per quake in the table on the following page. Identify the region(s) where the earthquakes occurred.

- Close the Statistics window when you are finished.
- Click the **Clear** button in the Select By Attributes window.
- To display only the deadly earthquakes that occurred between A.D. 1000and 1499, query the **Deadly Earthquakes (Deaths)** layer using the following query statement:
  (“YEAR” >= 1000) AND (“YEAR” < 1499)
- Click the **New** button.

Now the deadly earthquakes that occurred between A.D. 1000 and 14999 are highlighted on your map.

8. Repeat the statistics procedure and record the number of quakes, deaths, and deaths per quake in the table below. Identify the region(s) where the earthquakes occurred.

- Close the Statistics window when you are finished.
- Click the **Clear** button in the Select By Attributes window.
- To display only the deadly earthquakes that occurred between A.D. 1500 and 2005, query the **Deadly Earthquakes (Deaths)** layer using the following query statement:
  (“YEAR” >= 1500)
- Click the **New** button.

Now the deadly earthquakes that occurred between A.D. 1500 and 2005 are highlighted on your map.

9. Repeat the statistics procedure and record the number of quakes, deaths, and deaths per quake in the following table. Identify the region(s) where the earthquakes occurred.

Time period	186 B.C. – A.D. 499	A.D. 500 – 999	A.D. 1000 – 1499	A.D. 1500 – 2005
Number of years	686	500	500	505
Number of quakes *(Statistics - Number of Records)*	*10*	*43*	*90*	*970*
Number of deaths *(Statistics - Total)*	*467,960*	*1,410,000*	*2,430,000*	*6,890,000*
Deaths per quake *(Statistics - Mean)*	*46,796*	*32,716*	*26,972*	*7103*
Deaths per year *(Calculate - see example)*	*682*	*2820*	*4860*	*13,643*
Region(s) *(Identify from map)*	*Middle East, Mediterranean, & Eastern Asia*	*Same as previous period*	*Same as previous period + Europe & Indonesia*	*Same as previous period + Africa, India, & the Americas*

- Close the Statistics and Select By Attributes windows when you are finished.

10. Calculate the average number of deaths per year for each period and record it in the table. (Use the space below for your calculations.)

(see table)

Click the Clear Selected Features button.

11. Describe how the locations of the deadly earthquakes have changed over time.

The distribution of deadly earthquakes roughly follows the proliferation of cultures with written languages. As these cultures spread and the global population grew, reports of deadly earthquakes increased, particularly in regions near active plate margins.

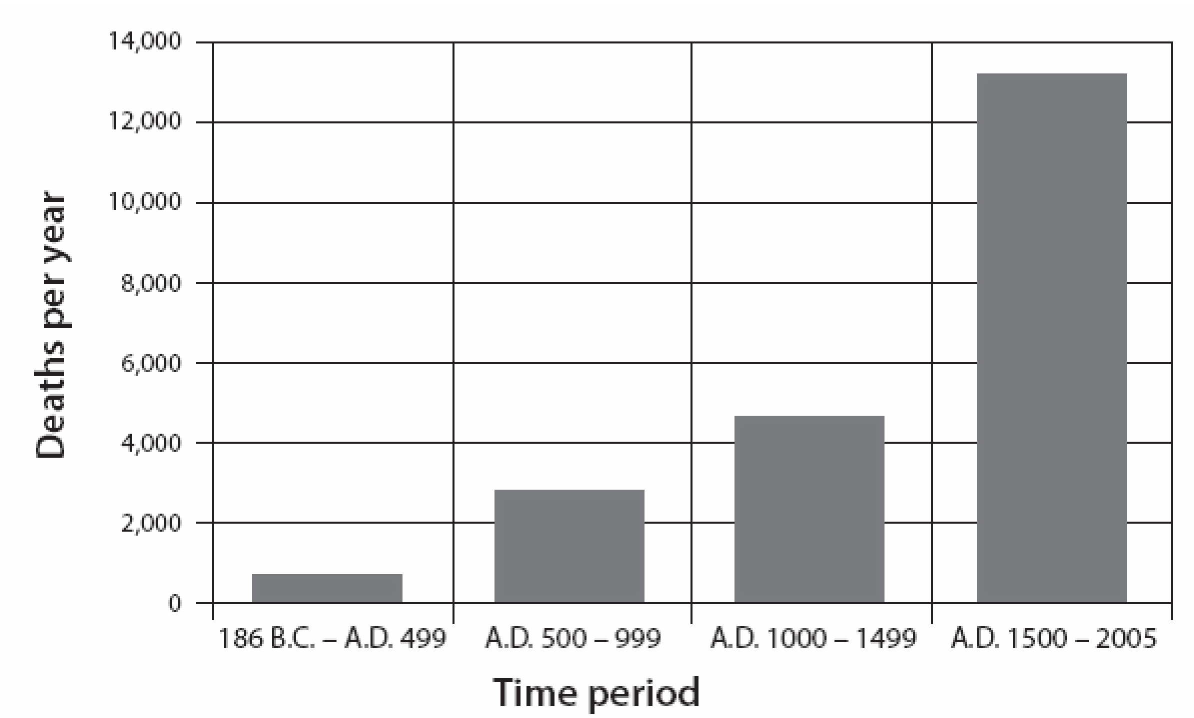
12. How have the numbers of deadly earthquakes changed over time, according to the table?

Both the number and the frequency of deadly earthquakes have increased over time.

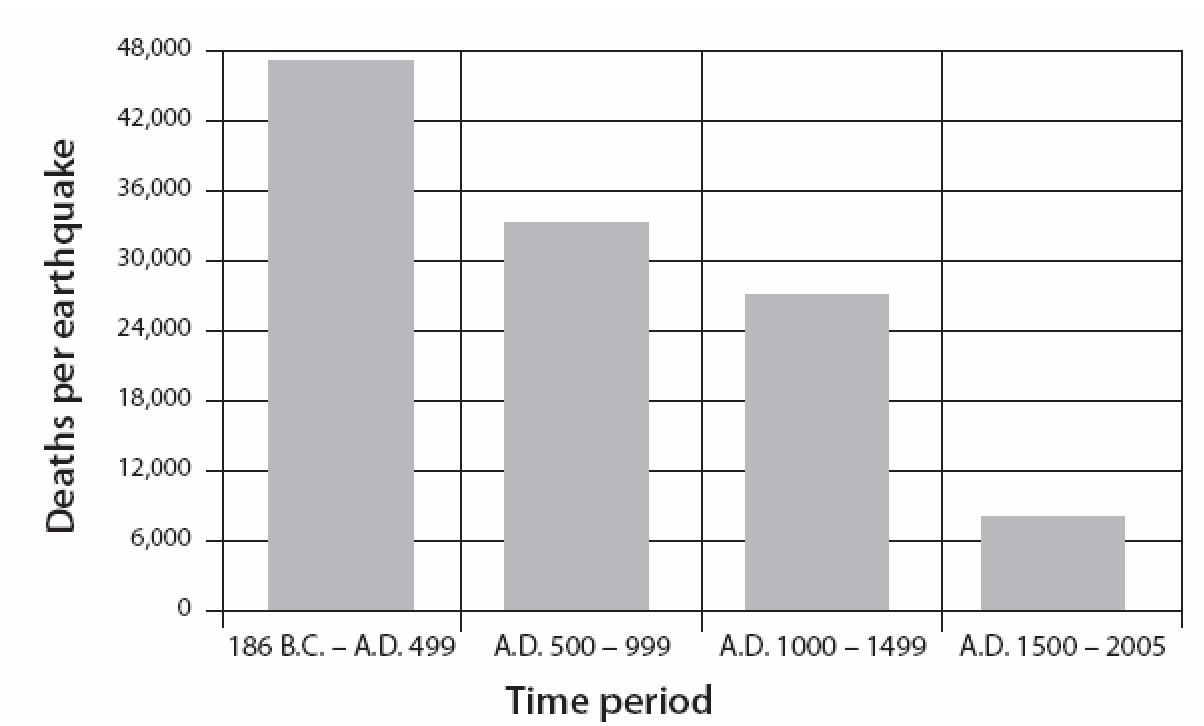
13. How would the ability to record data throughout history affect the pattern of deadly earthquakes shown here? Give an example.

In general, cultures with written languages are more likely to preserve records of major events such as earthquakes. In cultures with oral traditions, this information is frequently lost, and details like dates and numbers of deaths could be confused. For example, even though there were large numbers of people living in Central and South America between A.D. 1000 and 1500, few written records are available for these areas until after the arrival of Europeans in the 1500s.

14. Plot the average number of deaths per year (from the previous table) for each time period as a bar graph in the graph below.



15. Plot the average number of deaths per earthquake (from the first table) for each time period as a bar graph in the graph below.



16. How have the average numbers of deaths per year and deaths per earthquake changed over time?

Deaths per year have increased, while deaths per earthquake have decreased.

17. How might changes in the population distribution and improvements in earthquake detection contribute to these patterns?

More earthquakes are detected today because we have modern equipment to record them worldwide. The number of deaths per earthquake decreased because we learned how to prepare for these events. Deaths per year increased because the population increased in high-risk areas.

18. Do these data show that the number of strong earthquakes has been increasing over the past 2000 years? Explain.

No. The data show only that earthquakes aff ect more people each year as the global population increases.

Quit ArcMap and do not save changes.