SHOOKETH BEYOND NORMAL

A Statistical Modeling of Earthquake Magnitudes Using Exponential and Gumbel Distributions

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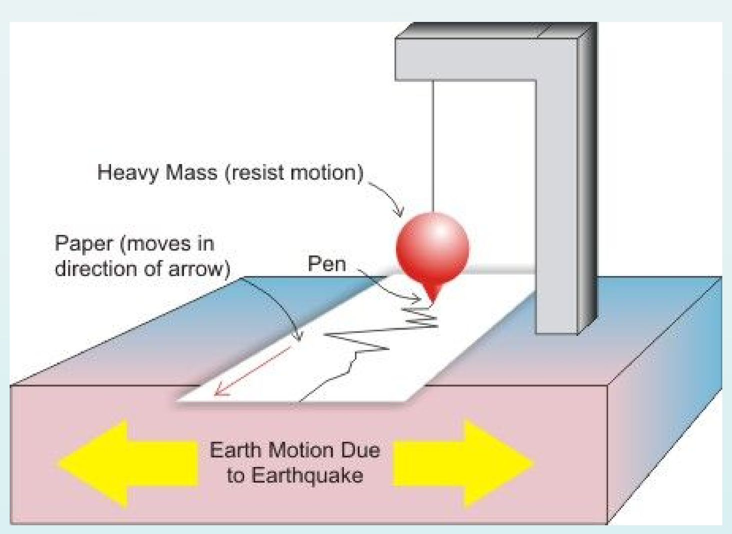
Abstract

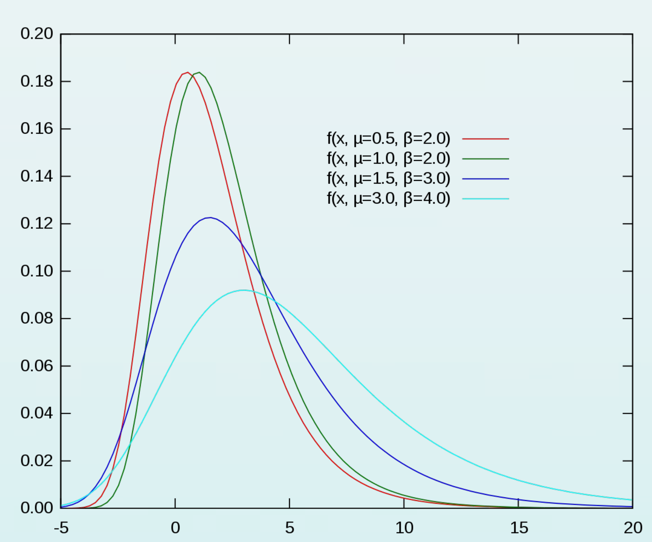
Currently, scientists have no accurate way of predicting earthquakes, making it very difficult to adequately prepare for one. However, by utilizing data from the past and computer models, we were able to simulate realistic earthquake trends, which allowed us to make forecasts on earthquake magnitudes and frequency. We predict that in California, a 7th magnitude earthquake will occur once every 18 years, an 8th magnitude earthquake will occur once every 89 years, and a 9th magnitude earthquake once every ~700 years. In the conterminous US, a 7th magnitude earthquake will occur once every 7 years, an 8th magnitude earthquake once every 35 years, and a 9th magnitude earthquake once every ~200 years.

Our simulation may not be completely accurate for the future, but by comparing our distributions with computer generated ones, we are fairly certain that our model represents the frequency of earthquakes of each magnitude.

Introduction

- The type 1 Gumbel distribution, which we used to model the distribution of extreme values of various samples, helped us predict the frequency of severe earthquakes
- Richter scale: 30 times more energy and 10 times more ground motion than the unit prior to it.
- Seismographs (shown below) are instruments that record the force and duration of earthquakes.





- For reference, since 1975, there has only been 6 earthquakes in the conterminous US with magnitudes 7 or higher, with the highest one being 7.3.
- The equation below formed the basis for our calculations, where *m* is the median maximum earthquake over a time period, *n* is the number of earthquakes necessary to have a reasonable chance (50%) of obtaining *m*, and λ is the rate parameter of the exponential distribution.

$$m = \frac{1}{\lambda}\log n - \frac{1}{\lambda}\log\log 2$$

Hypothesis

Since very few 7th or 8th magnitude earthquakes have been recorded in California, we can reasonably expect that they only occur about once every 100 years in the region. However, a 7th to 8th magnitude earthquake in the continental United States would happen much more frequently, occurring once every 50 years.

To test this hypothesis, we created a Python simulation and fit past data to an exponential curve to predict the frequency of each magnitude of the earthquake.

Methods

1. Get earthquake data from earthquake centers* and limit our data to earthquakes with magnitude $1.6 < x < 9.0$ because smaller earthquakes can often go unrecorded.**
2. Create a histogram of the magnitudes and their frequencies, fitting the magnitudes to an exponential distribution $\lambda e^{-\lambda x}$.
3. By using the λ we found through a Python script, we use the equation mentioned in the introduction to find *n*, the number of earthquakes needed to have a reasonable chance of hitting a target extreme magnitude.
4. Divide *n* by the average number of yearly earthquakes to find the expected number of years for the desired magnitude.

* Data was collected from http://www.ncedc.org/ncedc/catalog-search.html, http://www.ncedc.org/ncedc/catalog-search.html https://earthquake.usgs.gov/earthquakes/search/
** Data was collected for California and conterminous US.

Results

Figure 1

Magnitude	S. California	N. California	USA
6	4 years	4 years	2 years
7	22 years	18 years	7 years
8	122 years	89 years	35 years
9	692 years	462 years	188 years

Figure 2.1

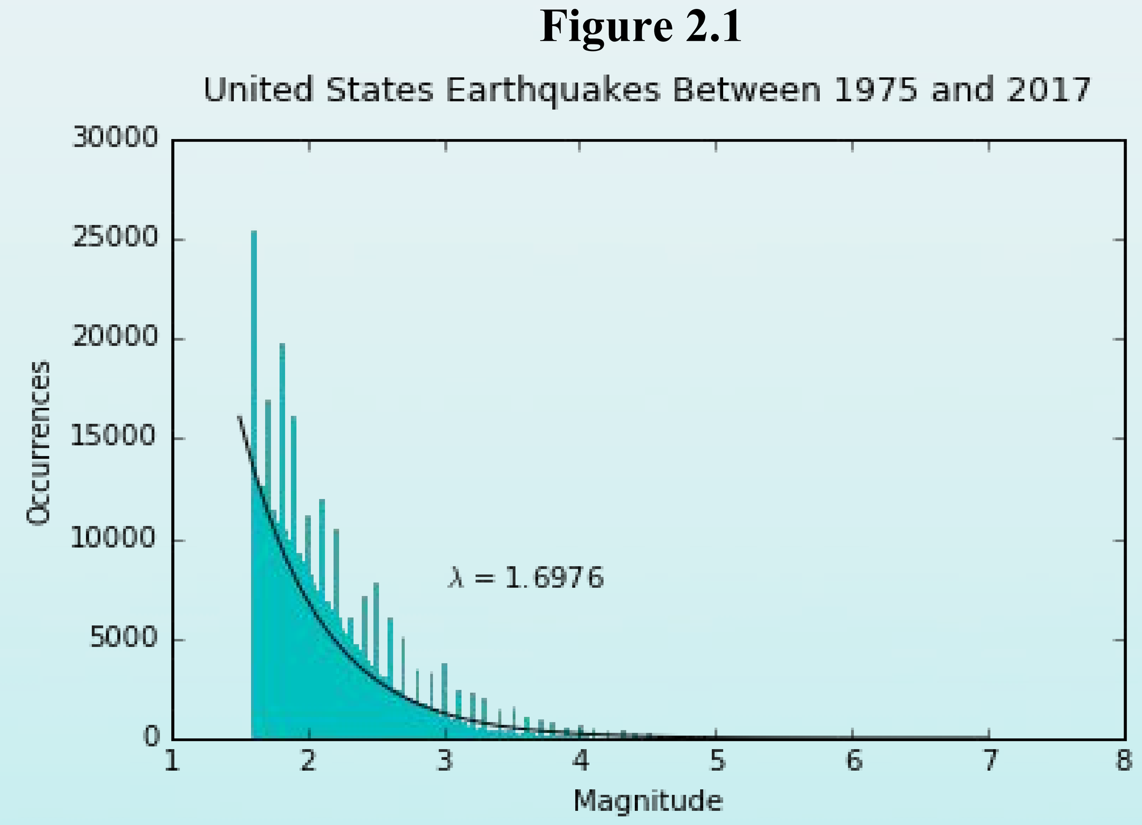


Figure 2.2

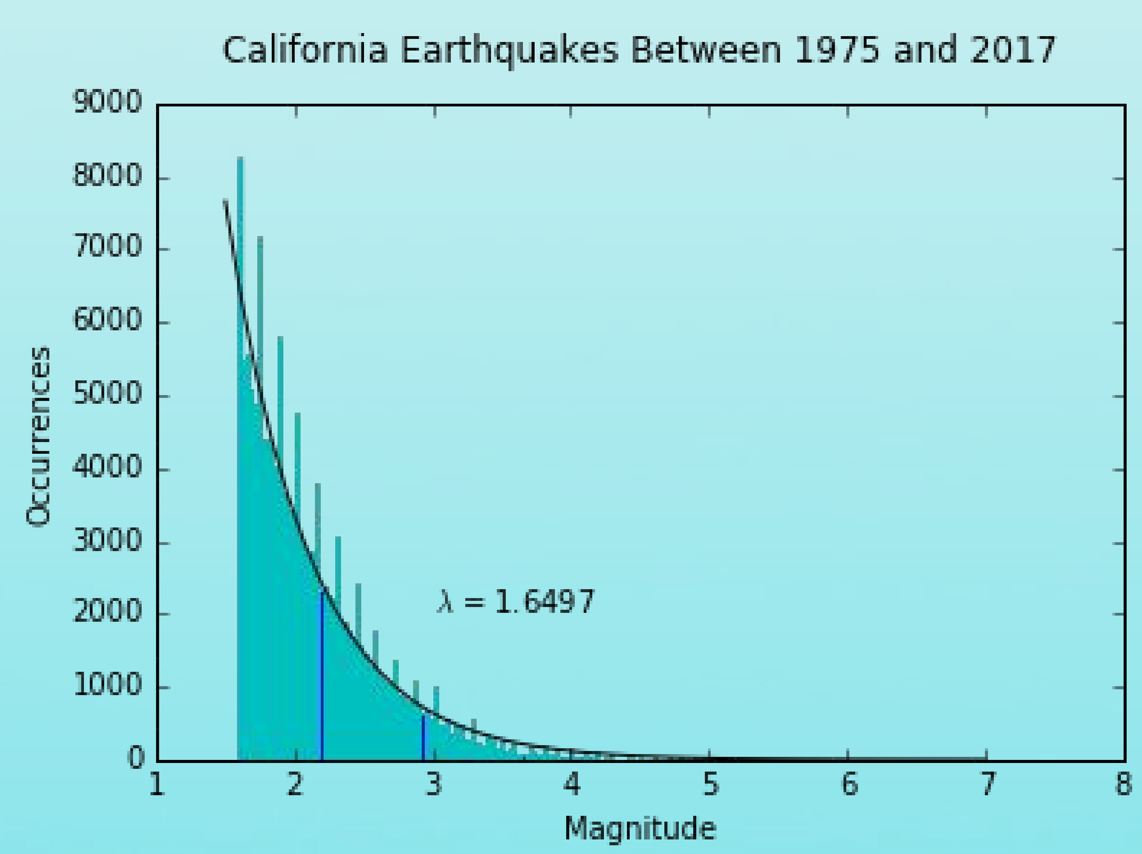


Figure 1. This figure shows the frequency of extreme earthquakes, from magnitudes 6 to 9, in two regions of California and the conterminous US. After evaluation of this graph, we realized that extreme earthquakes happen less often than we expected.

Figure 2.1 and 2.2. These figures show that our data fit the exponential curve. With each increase in magnitude, the frequency of earthquakes decreases exponentially.

Conclusion

Since **Figure 3.1 and Figure 3.2** shows that the maximums from each year from our real data is similar to the Gumbel distribution* we simulated (with λ), we know that our exponential curve is a good fit to our data and our prediction of the frequency of each magnitude is accurate. Any mismatches in the graphs can be attributed to the limited range of years in the data. In the future, predictions will become more accurate due to the increase of available data.

* A Gumbel distribution is used to model the distribution of maximum values from various distributions

Figure 3.1

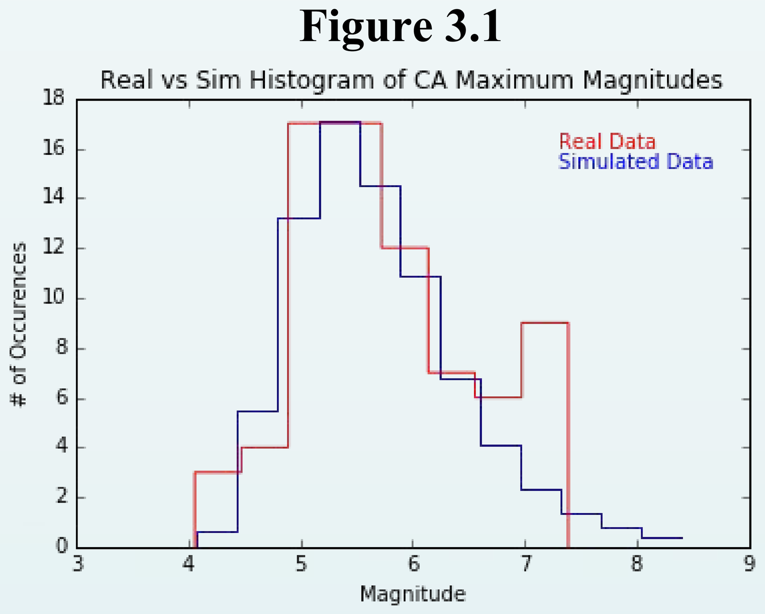
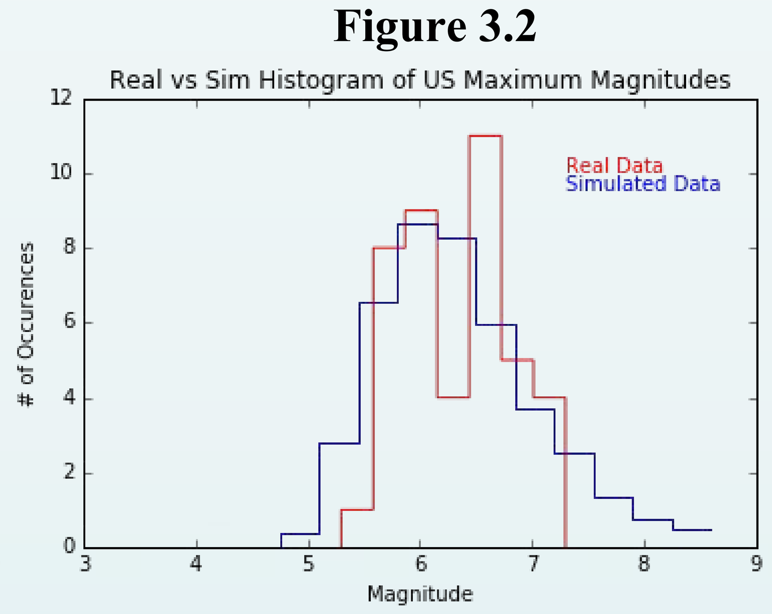


Figure 3.2



Significance

- Successful earthquake predictions can warn people of potential earthquakes to reduce death and destruction.
- Earthquake predictions may be an important step towards enabling emergency measures, therefore minimizing loss of life and property.

Future Directions

1. Acquire more knowledge about factors leading up to earthquakes to better predict when they will strike.
2. Develop more advanced technology to analyze previous earthquakes and use that data to determine the likelihood of similar future shocks.
3. Form more accurate predictions relating to the magnitude and time of future earthquakes.

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