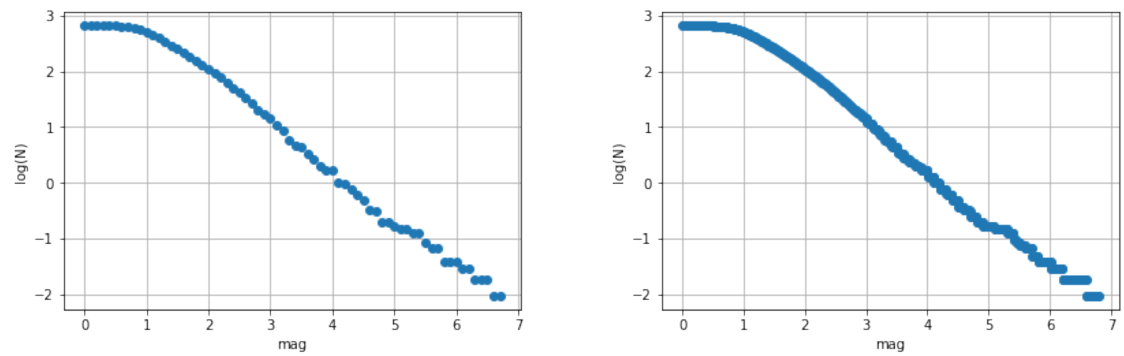
Exercise 2

1. **What do the Gutenberg Richter statistics represent for the earthquake distribution?**

   The Gutenberg Richter statistics represents the relationship between magnitude and frequency of earthquakes in a certain region (local or global).

2. **What happens to the shape of the distribution $\log_{10}(N)$ if you reduce the magnitude bin size by a factor of 10?**



(a) Bin Magnitude = 0.1 (b) Bin Magnitude = 0.01

Figure 1: Change in shape of the distribution for different bin sizes

   In the Figure 1, it is possible see the distribution becomes smoother when the bin size decreases.

3. **Why does the model parameter matrix (G) have a column of 1's?**

   This linear approximation tries to fit the data with a line with the follow equation

$$y_i = a + b \cdot x_i \tag{1}$$

   with $i = 1 \ldots n$, where a and b are the parameters that we want to estimate and n the number of samples (earthquakes). These n equations could be rewritten in matrix form as

$$\underbrace{\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}}_{d} = \underbrace{\begin{bmatrix} 1 & x_1 \\ 1 & x_2 \\ \vdots & \vdots \\ 1 & x_n \end{bmatrix}}_{G} \begin{bmatrix} a \\ b \end{bmatrix} \tag{2}$$

   The G matrix has to have 1's in order to follow the approximation.

4. **What determines the size of G^TG and G^Td?**

   If G is a matrix $n \times 2$, the size of G^TG will be $n \times n$. It means its size depends of the number of samples. On the other hand, d has a dimension $n \times 1$ so G^Td has size 2×1 always.

5. **How well does the Gutenberg-Richter model fit the data? Quantify your answer in terms of uncertainty.**

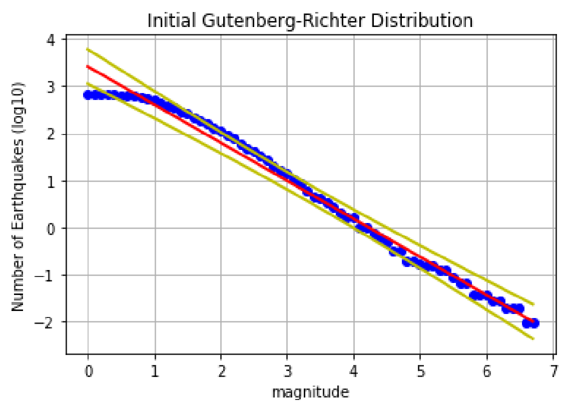


Figure 2: Gutenberg-Richter model. Blue: data, Red: linear estimation, Yellow: uncertainty

   The model (Figure 2) shows to fit with the Gutenberg-Richter model. At least 90% of the data (blue points) is inside of a confidence interval (yellow lines).

6. **Where does the fit begin to breakdown and why?**

   The data does not fit well in for earthquakes with a magnitude less than 1. The reason of this is a small magnitude earthquakes are not detected by the seismic network.

7. **Based on your Gutenberg-Richter coefficients what is the annual rates of a M4 earthquakes? For a M7 earthquake?**

   Based on my results $\log(N \geq m) = 3.42 - 0.809m$. So, there are 1.52 earthquakes with a magnitude bigger than 4 in one year. In the same way, there are 0.23 earthquakes with a magnitude bigger than 5 yearly. It means there are approximately between 1 and 2 M4 earthquakes in a year.

8. **On average how many years are there between M7 earthquakes based on this catalog.**

   Following Gutenberg-Richter, it should be 0.0057 M7 earthquakes per year, it means there are one M7 earthquake each 175 years.

9. **How many M7 earthquakes are in the catalog?**

   There are not M7 earthquakes in the catalog. The biggest is M6.9 .

10. **What is your assessment of the quality or suitability of the forecast of average M7 occurrence?**

    Due to this catalog starts in 1911 and until today there are not M7 earthquakes, it would be highly possible a M7 earthquake (or bigger) in the next 70 years.

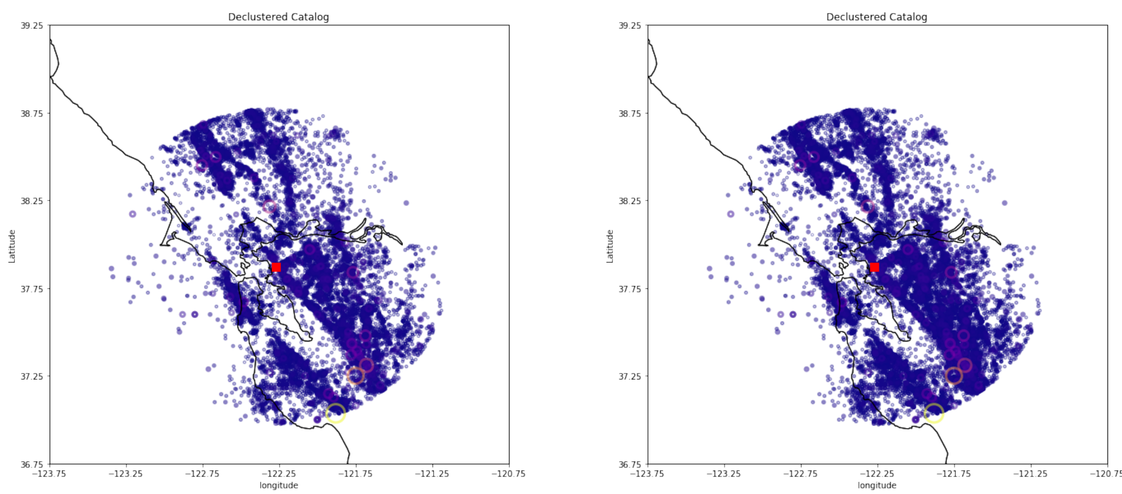
Exercise 3

1. **How many events were removed from the catalog by each declustering algorithm?**

Declustering algorithm	**Total Events**	**Aftershocks Removed**	**Declustered**
Gardner and Knopoff, 1974	69804	45562	24242
Gruenthal	Do not work	Do not work	Do not work
Uhrhammer, 1986	69804	21756	48048

Table 1: Results of declustering algorithms.

2. **Compare the spatial distribution of earthquakes between the raw and declustered catalogs.**



(a) Gardner and Knopoff, 1974 (b) Uhrhammer, 1986

Figure 3: Spatial distribution of earthquakes between the raw and declustered catalogs

In the Figure 3 the spatial distribution of both algorithms are shown. The results are quite similar in both cases.

3. **For the two other methods of declusting, how many events were removed from the catalog?**

See Table 1.

4. **Compare the Gutenberg-Richter A and B coefficients for the three versions of the declustered catalog.**

Algorithm	A Value	B Value
Gardner and Knopoff, 1974	3.448	-0.836
Uhrhammer, 1986	3.221	-0.797

Table 2: Gutenberg-Richter A and B coefficients, $\log(N \geq m) = A - Bm$

5. **What is the annual rate of occurrence of M4 earthquakes for each of the declustered catalogs?**

   Repeating the same analysis done in the previous exercise, there are 1.08 M4 earthquake using the algorithm proposed by Gardner and Knopoff, and 0.9 M4 earthquakes with Uhrhammer's method. Checking the data, there are 95 M4 earthquakes with Gardner and Knopoff's algorithm and 111 M4 earthquakes with Uhrhammer's algorithm in 106 years.

6. **What is the average M7 return period (inverse of annual occurrence of M7 events) for each of the declustered catalogs?**

   In a case the M7 earthquake, with Gardner and Knopoff's method is 296.8 years and with Uhrhammer's method is 271.3 years.

7. **Compare your estimated values with what has been presented in the USGS Earthquake Hazard Assessments of the return period for Hayward fault earthquakes.**

   I could not find the information in USGS website. I hope to be close.

Exercise 4

1. **Which faults were active during Loma Preita?**

   Calaveras and San Andreas Fault.

2. **What could cause aftershocks to occur on faults other than the mainshock fault?**

   It could be a change in the local fluid pressure or maybe a rearrangement in the local stress field.

3. **Here we used a 3-month period beginning at the Loma Prieta Earthquake. Examine the results taking a 6-month period beginning 3 months before the Loma Prieta earthquake. How does the distribution of earthquakes differ for the two time periods.**

   It does not change significantly. The new 3 months show to be less accurate with the model.

4. **How does the estimated P-value compare to values reported in Lay and Wallace?**

   Lay and Wallace report a P-value between 1.0 and 1.4. In my estimation I got a value $P = 1.062$ that is this interval.

5. **Is the aftershock more or less productive than average?**

   The aftershock increases the number of earthquakes in a region. Then, it is always more productive than average.

6. **What is the number of earthquakes per day in the region for the period leading up to the Loma Prieta earthquake?**

   In average one week before it was 5 to 6 earthquakes daily.

7. **How long after the earthquake would does the applied Omori Law predict the that the aftershock rate falls to the pre-event rate of earthquakes?**

   After 60 days the rate of earthquakes becomes constant and similar to pre-event rate.