Predicting the Next Big Impact: Modelling the Rate of Massive Meteorite Strikes

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Abstract

We wished to understand the distributional trend of heavy meteorites that strike the Earth and determine if any probability distributions can serve as effective models. NASA meteorite data from 1980 to 2012 was imported into R after pre-processing. Pre-processing activities involved the following: removal of missing data, irrelevant features to meteorite mass or the year of meteorite impact. Statistical analysis was then restricted to meteorites at or above the 98th percentile for mass. It was found that while the distribution of mass for all meteorites is lognormal, the distribution for the top 2% is severely right-skewed, indicating that an extreme-value distribution could be used to model. Furthermore, the rate of impact for these massive meteorites can be modelled with a zero-inflated negative binomial distribution.

Introduction & Background

In 2013, an asteroid measuring 20 meters wide and weighing 1.3×10^7 kg nearly impacted the Russian city of Chelyabinsk, which houses a population of approximately one million; Popova et al. (2013). This is thought to have resulted in the largest airburst on Earth since the 1908 impact near the Tunguska River in Russia. The amount of energy released from the 2013 event is estimated at 550 – 570 kilotons.

Fortunately, buildings and infrastructure sustained only mild damage. A number of individuals suffered wounds from sunburns and glass shards, but no one was seriously injured.

The outcome of this impact could have been far more devastating. It is therefore imperative that we be able to predict when massive meteorite strikes may occur so that warnings may be issued to citizens and precautions may be taken.

In this work, we review NASA meteorite data with the primary objective of modelling the rate of massive meteorite strikes. Successful development of said model could have implications for the safety and well-being of people across the world. To our knowledge, this analysis of NASA's meteorite data is original.

Objectives

- to investigate the relationship between the mass distributions and years;
- to find a method for modelling the rate of the meteorite strikes.

Methods

Data was acquired from the NASA website:

https://data.nasa.gov/Space-Science/Meteorite-Landings/gh4g-9sfh. This data was exported to Excel for pre-processing. Only the data from 1980 to 2012 was considered reliable. Any missing data were deleted including the features irrelevant to meteorite mass or year of impact. Data was then imported to R for statistical analysis. The programming language R was then used for data visualization and to perform all analyses.

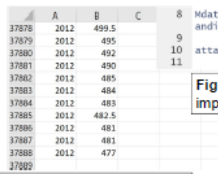
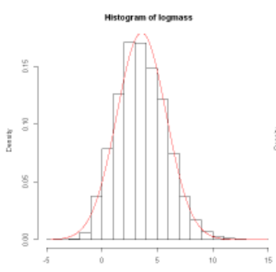


Figure 1. A screenshot of the meteorite data after exported to Excel.

Figure 2. A screenshot of the R code used to import the meteorite data to R.

Results



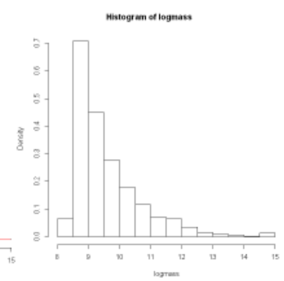
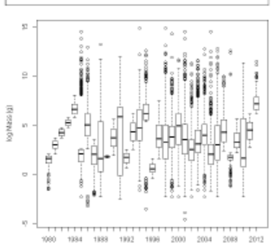
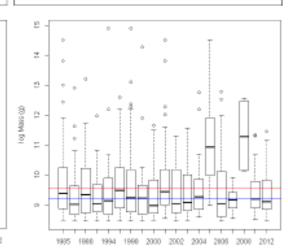


Figure 3. The mass of meteorites for all of the data examined is lognormally distributed (above); Annual boxplots of log mass is shown below.

Figure 4. The distribution of the upper 2% mass for meteorites is heavily right-skewed (above); Annual boxplots of log mass is shown below.





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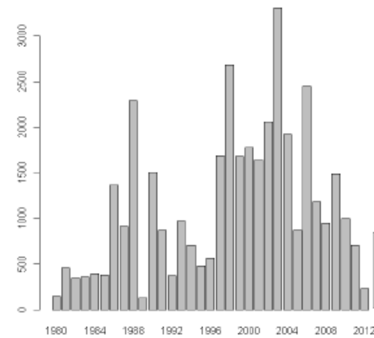
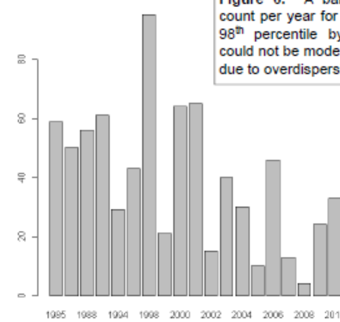


Figure 5. A barplot displays the number of meteorites per year for the entire dataset.

Figure 6. A barplot shows the meteorite count per year for meteorites at or above the 98th percentile by mass. The impact rate could not be modelled with a Poisson process due to overdispersion: $\sigma^2 > \mu$.



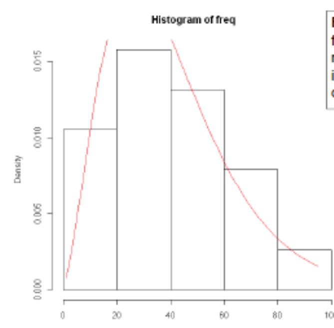


Figure 7. The rate of impact for massive meteorites can be modelled well with a zero-inflated negative binomial distribution.

Conclusions

- The distribution of mass for all meteorites is lognormal.
- The distribution of mass for the top 2% is severely right-skewed, indicating that an extreme-value distribution could be a good fit.
- The rate of impact for massive meteorites can be modelled with a zero-inflated negative binomial distribution.
- Future work will involve further evaluation of the Goodness of Fit of the zero-inflated negative binomial model as well as the extreme-value distributions.

References

1 NASA. (2018, June 27). *Meteorite Landings*. Retrieved from https://data.nasa.gov/Space-Science/Meteorite-Landings/gh4g-9sfh

2 Popova et al. (2013). Chelyabinsk Airburst, Damage Assessment, Meteorite Recovery, and Characterization. *Science*, *342*(6162), 1069–1073. doi: 10.1126/science.1242642

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