Patterns from Space: Meteorites and Earth's Geography

Correlating and Predicting Meteoroid Landing Patterns on Earth's Gravity and Solar Radiation

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Introduction

People study meteoroids falling to Earth to investigate the original materials that formed planets billions of years ago. They analyze meteoroids by tracking the asteroid belt from which these meteoroids originate to understand the history of the solar system. Researchers also study meteoroid landings by recording their fall velocity and the range of effects upon impact with Earth to construct a risk assessment for life on Earth.

This study focuses on two perspectives:

- Studying the variations in the **mass** and **occurrence** of meteoroid landings to explore the patterns. **Data**: NASA Meteorite Landings
- Examining the **spatial variance** of **Earth's gravitational force** and **solar radiation** to explore the correlation with the meteoroid landing distribution, and the potential landings for the next decades will be predicted. **Data**: USGS Gravity and NREL Global Horizontal Solar Irradiance

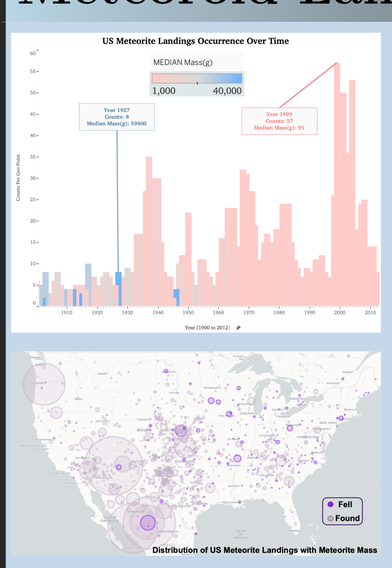
Basic Concepts

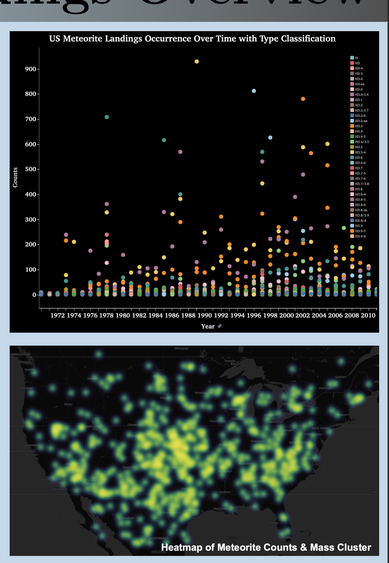
As the asteroid escaped from its century-circling orbit around the Sun, it was affected by the force from universal electrical and magnetic fields, breaking into pieces and burning up upon entering the Earth's atmosphere, creating a streak of light and striking to the surface of Earth. All pieces of outer space 'stone' have been affected by the gravitational force once they broke into the atmosphere, continuing to be radiated by the Sun within and outside the atmosphere.

Since the early 18th century, when Isaac Newton proposed that the Earth is not a perfect sphere, it has been understood that the habitable surface for all life on Earth is flattened at the poles and bulges out near the equator, which leads to a variation in distance approaching the center of Earth. Moreover, the centrifugal force from the circular moving object varies along with its instantaneous motion.

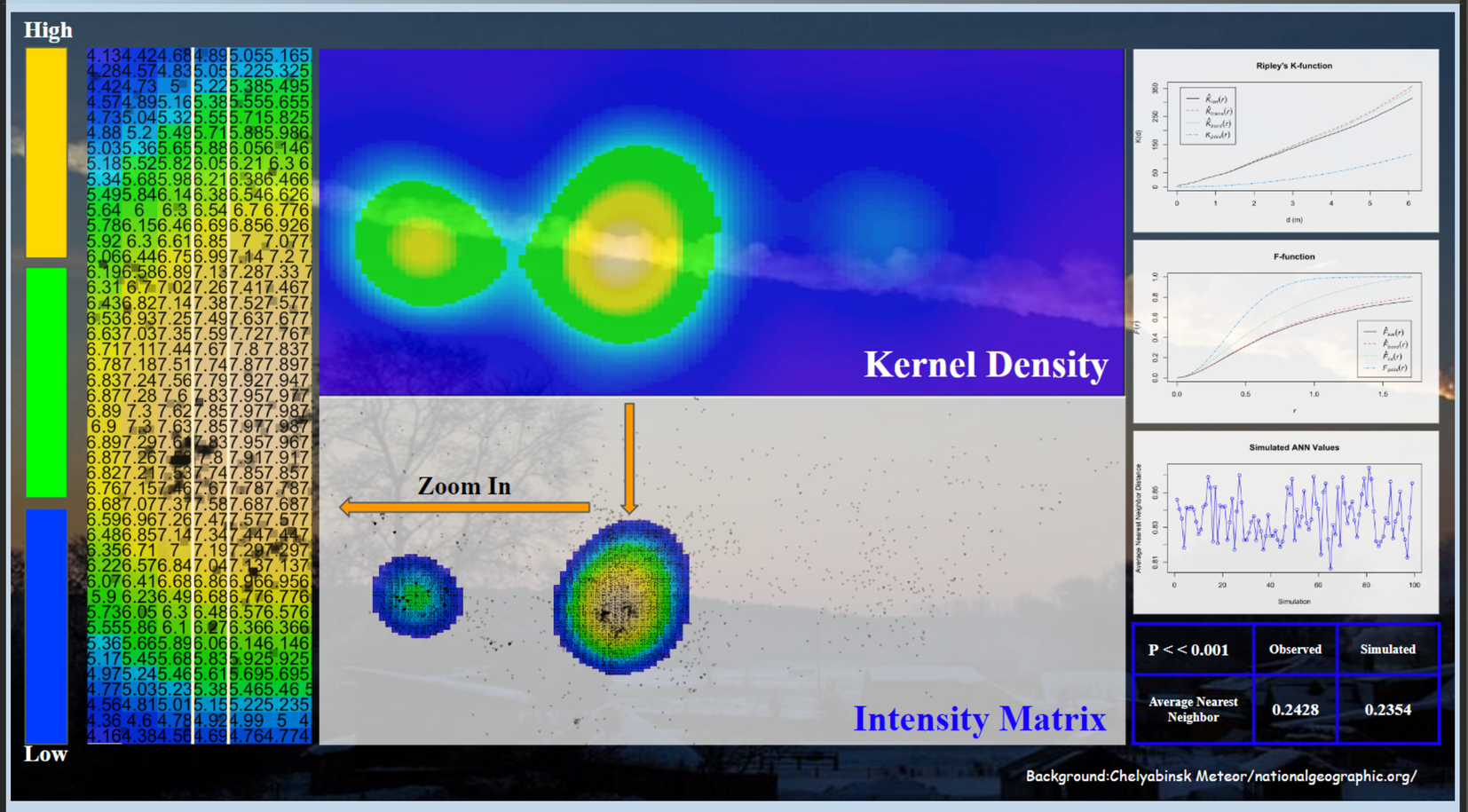
This raises two important factors when evaluating the impact of meteoroid landing: Newton's Law of Motion (F=MA), which brings our attention to gravitational force and radiation, the energy released upon striking.

Meteoroid Landings Overview



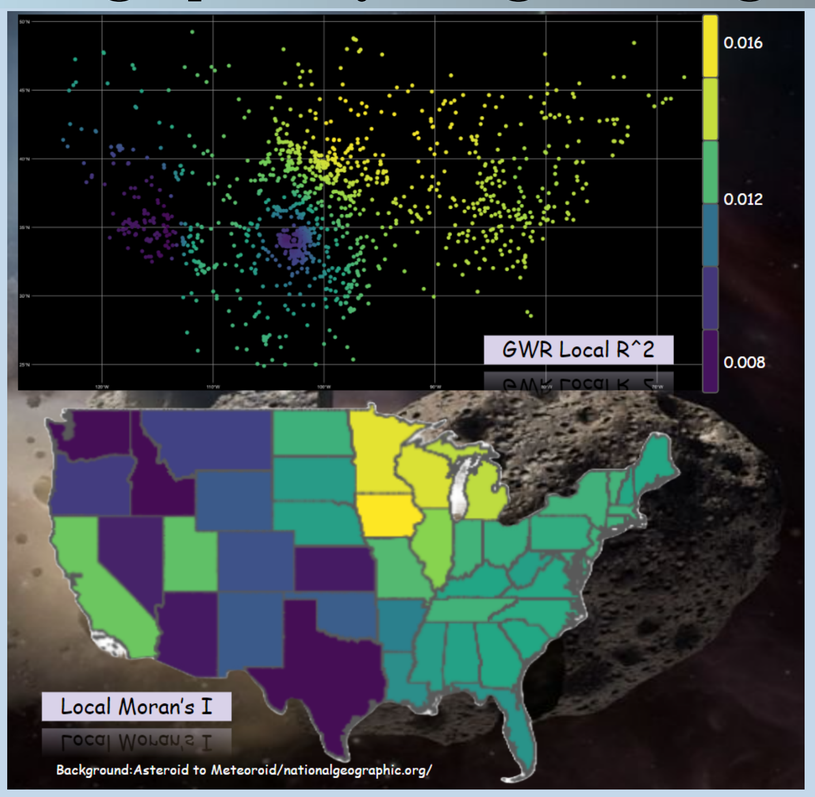


Point Pattern Analysis



The point pattern analysis is initially processed using **kernel density** estimation to generate the intensity matrix. As it approaches the center of the density plots, the intensity increases. Then, we performed a **quadrat test** to check for spatial randomness. The K corrections are greater than the Poisson estimation, which is recognized as significant, consistent with the p-value. However, the expected and observed **ANN** scores are approximately the same, leading to the conclusion of a **random pattern**, with points equally occurring at each location.

Geographically Weighted Regression (GWR)

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Summary of OLS coefficient estimates at data points:
Residuals:       Min      1Q      Median     3Q     Max
                -0.143  -0.103  -0.083     -0.065  25.898

Coefficients:   Estimate Std. Error  t value Pr(>|t|)
(Intercept)      1.08204    0.02125  50.909   <2e-16 ***
gravity_norm    -0.01517    0.02211  -0.686   0.4928
radiation_norm   0.04614    0.02199   2.098   0.0361 *
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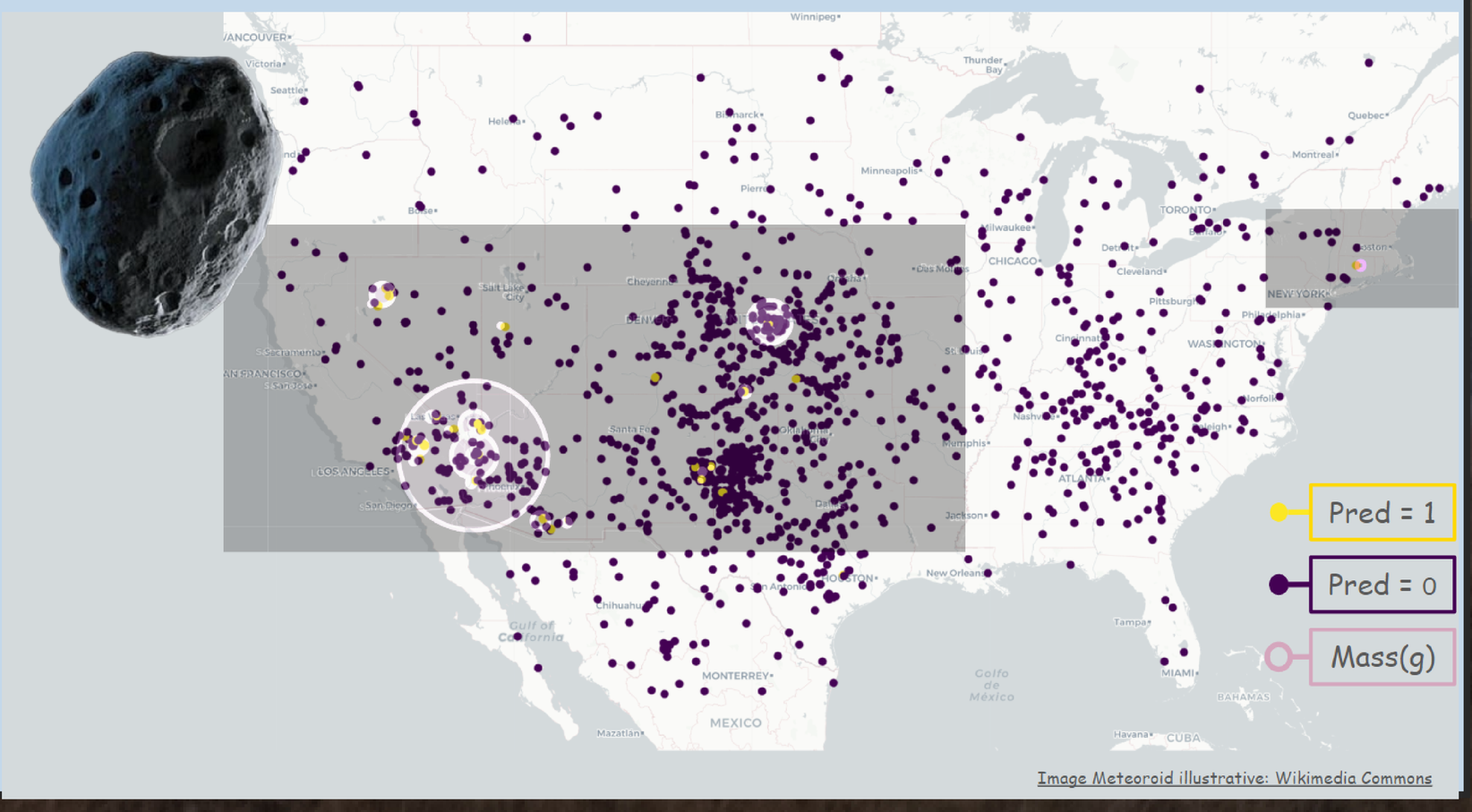
Summary of GWR coefficient estimates at data points:
                  Min.   1Q.     Median   3Q.    Max.    Global
X.Intercept.     1.014  1.063   1.087    1.109  1.223   1.082
gravity_norm    -0.045 -0.028  -0.017   -0.009  0.005  -0.015
radiation_norm   0.009  0.039   0.063    0.188  0.504   0.046
```

The landings data do not show an obvious cluster, suggesting other factors may influence the patterns. In the GWR with target occurrence, gravity is partially significant for some locations. According to the Local Moran's I R^2, polygons in green and yellow have less spatial variance, while radiation shows overall significance for meteorite occurrence in the United States.

By increasing the weight of radiation and lowering the weight of gravity, we used GWR to predict future meteorite landing locations. The yellow labels represent the predicted locations, and the radius of the circles represents the mass. The predicted locations with larger circles indicate higher risk.



Acknowledgements

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