Impact Crater Modeling

Sean Fitze and Julia Ryen Johnston

1 Project Overview

In this simulation, we explore a distinct square segment of a planetary expanse spanning 500 km by 500 km. This region is exposed to impacts occurring at an average frequency of 1 per 1000 years for craters exceeding 10 km in diameter. Our simulation persists until the cumulative impact events on this terrain reach full saturation, as defined in Assumption i. The progression of time is marked by the evolving count of craters, disregarding factors such as erosion and secondary craters. This simulation enhances our comprehension of impact cratering, specifically shedding light on size-frequency distributions, crater counting, and dating models, which are instrumental to planets, moons, and rings.

1.1 Assumptions

(i) Size distribution of the impactors is uniformly 30 km with a frequency of 1 per 1000 years.

(ii) A crater is "obliterated" by an impact when less than 20 percent of the craters rim points are visible. [4.1]

(iii) Craters are recognizable on the surface as long as they remain on the surface. [4.2]

(iv) The surface is "saturated" when the rate of craters increasing is equal to the rate of craters wiped out.

(v) The surface is uniform and unchanging ignoring effects such as erosion, secondary craters, etc.

2 Base Model

The base model of the simulation assumes all five (i-v) parts of Section 1.1 to be true. This simplified celestial body sets a basis for more complex models and offers a general understanding of how saturation is determined.

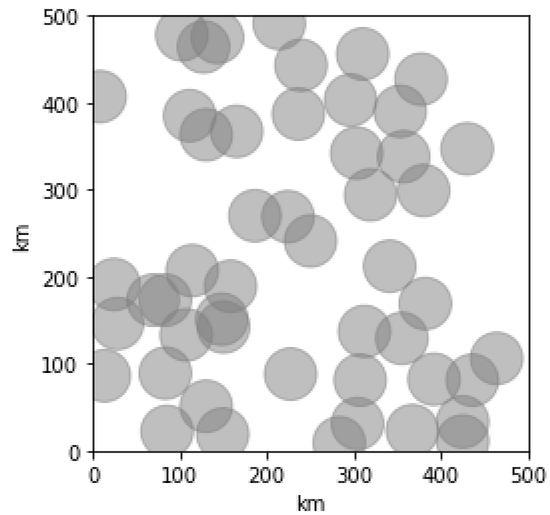

Figure 1: Frame 50 of ['uniform' animation]

Frame 50 shows the craters evident on the surface after 50,000 years, where there is not much saturation present yet due to the small amount of time that has passed. As the animation continues, craters come and go without much variance until saturation, where then the surface begins to fill out at a constant rate.

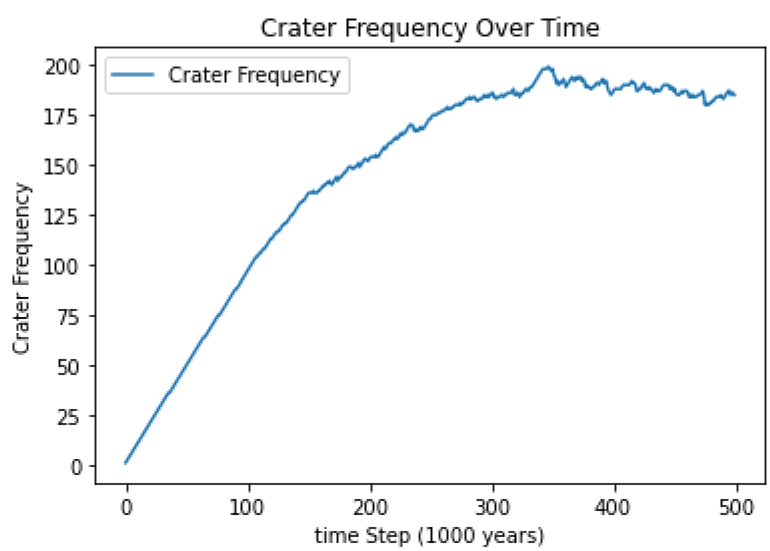

Figure 2: Crater Frequency over Time, uniform size

The time to saturation was around 350,000 years, where the rate of craters increasing is equal to the rate of craters wiped out. The graph in Figure 2 shows resemblance to a logarithmic trend, this is explained by the uniform size. A consistent size yields a stable probability of saturation.

3 Changed Parameters

The later simulation ran included a change to Section 1.1.i. This assumption now is as follows: Size distribution of the impactors has a realistic size-frequency distribution of:

$$\text{Equation 1} \quad N = k * D^{-b}$$

Where N is the frequency, k is set equal to 50, D is the diameter of the crater (10 km to 150 km), and b is set to 1.8. In the base model a uniform 10km was utilized to saturate the surface, the code for crater size frequency was rewritten to no longer just give '10 km', but instead a function based on Equation 1. This was rewritten as:

$$\text{Equation 2} \quad D(N) = \sqrt[-b]{N/k}$$

Equation 2 is now a function dependent on Equation 1, where the size of the crater still has a frequency attached to it. This method was determined best for further coding applications, and yielded the expected data.

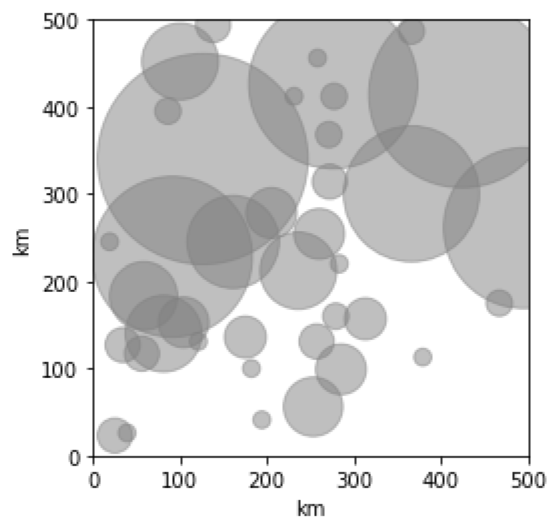

Figure 3: Frame 50 of 'random' animation

The craters evident on the surface of Figure 3 range in diameter from 10 km to 150 km, offering a much more realistic cratered surface where both size and frequency are variable. The animation shows much change in saturation as seen by the opacity of the craters, where it may have been beneficial to continue taking 'data' to see a more defined trend, as also displayed in Figure 4.

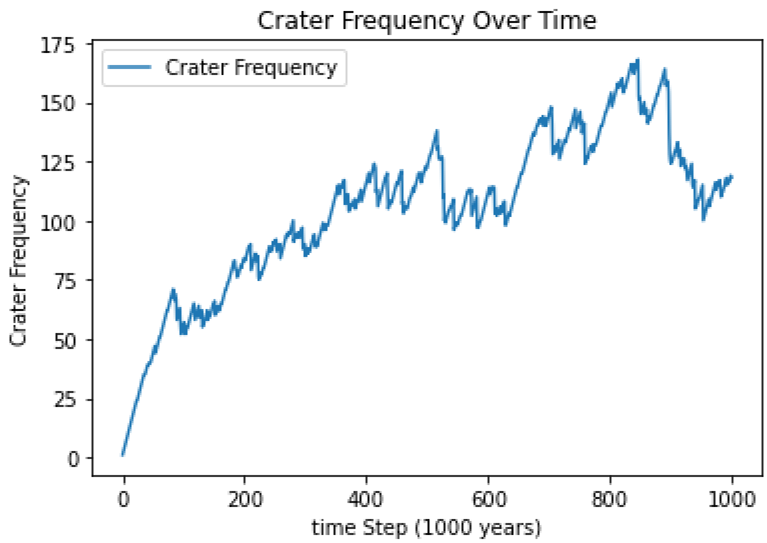

Figure 4: Crater Frequency over Time, variable size

The time to saturation amounted to around 1,000,000 years, where the rate of craters increasing is equal to the rate of craters wiped out. The graph in Figure 4 displays another logarithmic relationship between the variables, but with significant increase in fluctuations. This can be attributed to Section 4.1 where the rim points are not being scaled with size and are calibrated to work most efficiently in the base model simulation.

4 References

4.1 Visualization of Crater Rim Points

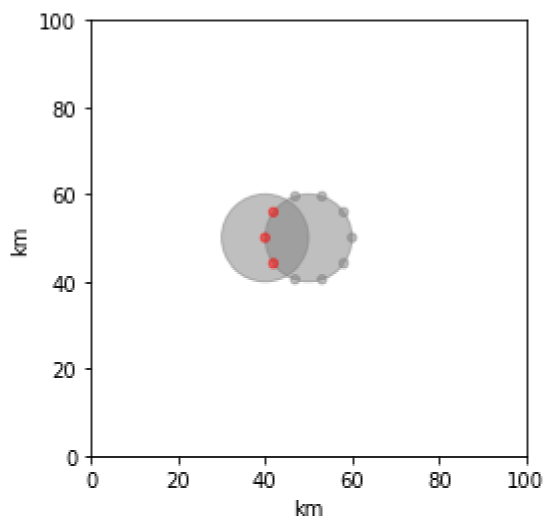

Figure 5: Sample position overlap

Above in Figure 5 shows a crater (right) with visible rim points being 'impacted' and thus displaying a second crater (left). Each crater on the back end of our simulation will have 10 rim points that will undergo a 'check' for position overlap ('illuminated' red dots). A crater is "obliterated", as denoted in Section 1.1.iii, by an impact when less than 20 percent of the craters rim points are visible.

4.2 Surface Parameters

Craters that are "obliterated", as defined in Section 1.1.ii, will be removed from the simulated surface, and therefore be no longer recognizable. This defines the Section 1.1.iii, craters are recognizable as long as they remain on the surface.

4.3 Source Code & Animations

The entirety of the project can be located on GitHub ASTR3750_Project. Underneath the 'sims' folder are also the raw files to each of the images used as well as the animated movies.

4.4 Extra Credit

The video presentation of our project will be added to the GitHub ASTR3750_Project repository prior to November 30th 11:59.