CONSTRAINING THE AGE OF CRUSTAL RESURFACING ON VENUS USING A THEORETICAL CRATER SIZE-FREQUENCY DISTRIBUTION.

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Introduction

It is generally accepted that the bodies of the inner solar system have been exposed to similar populations of impactors. We can get a sense of the energy distribution of these impactors for an orbit by looking at a relatively simple crater size-frequency distribution (CSFD) for an airless body such as the Moon. It is then theoretically possible to extrapolate a mass-velocity-material (iron, stony, etc.) distribution for the impactor population required to form craters of each respective diameter bin, and to migrate this population into another orbit to examine the cratering effects on a body with an atmosphere. In this study, we begin with a CSFD model that has been developed from the crater population on the lunar surface. From this, we determined a range of likely impactor populations, and migrated this population into the orbit of Venus. Finally, we calculated the effects (ablation, disintegration, etc.) of the Venusian atmosphere, and generated a crater population on the surface of Venus as a function of time. By comparing the present-day surface of Venus with the time indicated by the model to achieve a similarly cratered surface, we develop additional constraints regarding the crustal resurfacing age of Venus. Figure 1 shows a flowchart of the numerical model built for this study.

Methodology

Step 1: Reproducing the Lunar CSFD. The numerical model compares two independent production functions, "Neukum's SFD" and "Hartmann's SFD" for the Lunar distribution [1]. From these production functions, the cumulative number and frequency of craters per bin of a final crater diameter (Df) is found. Diameter bins range from 0.02–463 km, at a bin width of $2^{1/2}$. The transient crater diameter (Dt) per bin is then calculated as Dt = (1.18)Df [2]. The Lunar CSFD allows us to see the cratering distribution of an airless planet, with no crustal resurfacing.

Step 2: Impactor Population. An impactor population is extrapolated using an equation from Melosh 1996, where Dt is calculated from the density ratio of the impactor and the target surface, the impactor diameter, impact angle, impact velocity, and the gravity of the target. The impactor diameter is calculated using this equation for each transient crater diameter bin (30). The density ratio of impactor and target surface is calculated for each combination of iron, stony, stony iron, and chondrite with basalt and anorthosite (8). Predetermined impactor populations corresponding to the Late Heavy Bombardment and a more "modern" flux [3] are also examined in this study. The impact velocity is found for an impactor traveling from the inner, average, or outer asteroid belt. Given the Earth's orbital position at the time of impact ranging from 0-180 degrees (181) centered at the Sun, velocity then increases or decreases depending if the Earth is moving towards or away from the impactor respectively.

Step 3: Migrate Impactor Population. The number of impactors that reaches the target body, during a certain timespan, depends on the target's proximity to the Sun and is calculated by Ni = (T∗ND)(Xm/Xt), where Ni is the number of impactors, T is the timespan, ND is the cumulative number of craters for an "average" square kilometer per a billion years, Xm is the distance from the Moon to the Sun, and Xt is the distance from the target to the Sun. Then a random population of impactors of size Ni is pulled from the extrapolated population found previously. Impactors are randomly chosen corresponding to the probability of its impactor type and likelihood of hitting a lunar surface type. The orbital position is chosen randomly for each impactor. The impact velocity is calculated similarly to Step 2 but now towards the target, with velocity increasing as the target's proximity to the Sun increases.

Step 4: Atmospheric Effects. Traveling through the Venusian atmosphere, the impactors are first ablated (altering their diameter, mass, and velocity). Then if the stagnation pressure exceeds the yield strength of the impactor corresponding to its type, it breaks into a certain number of pieces. The broken pieces are then ablated, and the process continues until the impactor is either destroyed or reaches the surface. Calculations for the atmospheric effect on impactors has been previously explained by Baldwin and Sheaffer 1971 [4], and Collins, Melosh, and Marcus 2005 [5]. We assume complete homogeneity of spherical impactors, and do not account for a shallowing trajectory in the atmosphere.

Step 5: Theoretical Venusian CSFD. If the impactor does "survive" atmospheric travel, the impactor/target density ratio, the impactor diameter, impact velocity, impact angle, and the target's gravity are input to the Melosh 1996 transient crater diameter equation used in Step 2. The final crater diameter is calculated similarly to Step 1, and each crater is plotted given a random x, y coordinate to simulate the planet's surface. Cratering overlap is accounted for; however, ejecta blanketing is not simulated in this study. The theoretical CSFD for Venus is found from the cumulative number of craters per diameter bin for any given time span.

Mercury & Mars: Theoretical CSFDs were also made for Mercury and Mars to directly compare cratering rates on terrestrial planets with primary surfaces and little to no atmosphere. Future studies can be made using the Mars distribution to further constrain the age of resurfacing of its northern hemisphere.

Results

Preliminary results show that a theoretical population of impactors can be extrapolated from a range of energies required to form the craters on an airless body. An airless body, like the Moon, does not significantly affect the mass or velocity of an incoming impactor making it an ideal surface to back calculate the impact energy required. When the Venusian atmosphere is added into the equation, the crater population significantly changes from what is seen on the Moon. Many of the smaller impactors do not "survive" atmospheric travel, and the larger impactors form smaller craters than what their respective counterparts would have made on the Moon. By determining the effect of the Venusian atmosphere on an impactor population, we can constrain the size range of impactors that are able to reach the surface, and the timespan that allows for that size and frequency of craters that have formed since the last resurfacing event.

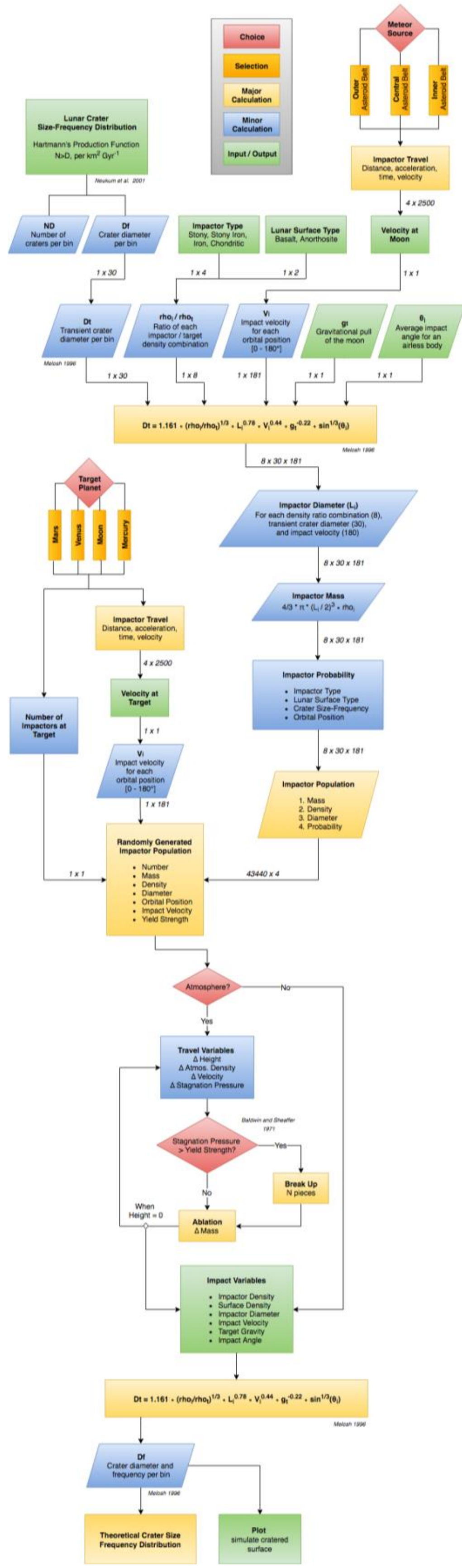

Figure 1: Flowchart representing the MATLAB code built to model the theoretical CSFD for any inner solar system terrestrial planet.

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