CAN SPATIAL STATISTICS BE USED TO IDENTIFY CRATER SATURATION EQUILIBRIUM? M.R. Kirchoff, Southwest Research Institute; 1050 Walnut Street, Suite 300, Boulder, CO 80502, kirchoff@boulder.swri.edu

Introduction: For several decades there has been a debate whether heavily cratered surfaces in our solar system are in "saturation equilibrium" [e.g., 1-3; a state where crater density reaches an (quasi-) equilibrium]. Saturation equilibrium is critical to understand because otherwise crater distribution shape and/or flux can be misinterpreted. This work explores if spatial statistics, which are quantitative measures of objects' distributions in space, could be a complementary approach to crater size-frequency distributions [SFDs; e.g., 1-3] in determining if a heavily cratered surface is saturated.

Background: The use of spatial statistics to study saturation equilibrium was introduced by Lissauer et al. [4] and Squyres et al. [5]. They proposed that a crater distribution would become more spatially uniform (more evenly spaced than expected for a random distribution) as it reached saturation. Their reasoning was that as a crater distribution approached saturation equilibrium the gaps occurring in a random distribution would become occupied, thus producing a more even distribution. Squyres et al. [5] combined a numerical simulation of a steeply-sloped SFD (cumulative slope=-2.7) with observations of heavily cratered terrains on Rhea and Callisto to empirically show this hypothesis could be valid *for this case*. However, neither [4] or [5] expanded the study to other slopes or fully explored why the gaps should get filled in as crater density increased. Therefore, it is still uncertain if other populations will become more uniform as they reach saturation equilibrium.

Methods: My work continues the approach of [5] by combining new numerical simulations with new observations of cratered terrains. The simulation is developed in IDL and varies the input SFD slope, importance of very small craters in erasing craters ("sandblasting"), effectiveness of ejecta in erasing craters, and the remaining percentage of a rim required for a crater to not be considered erased. The dynamic range of the simulated distribution is 1000 and the simulation region is a square with sides ~2x the length of the diameter (D) of the largest crater. The only process erasing craters is the formation of new ones.

For the spatial statistic analysis, I select the Z-statistic (also used by [5]), initially developed by Clark and Evans [6]. The Z-statistic measures the deviation of a spatial distribution away from random using a straightforward comparison between the average observed nearest neighbor value and the expected nearest neighbor value for a perfectly random distribution. A value of $Z=0$ represents a perfectly random distribution, while a value of $Z>0$ would be a more uniform distribution ($Z<0$ is more clustered).

Preliminary Results: Here I present results and discussion related to why the gaps get filled in as saturation equilibrium is approached, and implications for crater distributions of various slopes. For this purpose, I first run a couple of extreme simulations with a single crater size ($D=\sqrt{[\text{simulation area}]/20}$) and no ejecta blanket, but do vary the rim percent. A larger rim percent value means a crater is erased more efficiently by subsequent craters. Therefore, a new crater cannot form very near an older one without erasing it. Consequently, in order to increase the crater density, a new crater must form in a gap between craters. The simulations I present illustrate this. When the rim percent value is large (0.9, Fig. 1), equilibrium density (saturation) is approached quickly (flattening of the curve of # of craters remaining, *n*, vs. total # craters formed, *N*, in Fig. 1a). As crater density is rising, the Z-statistic also increases, indicating a more uniform distribution (Fig. 1b). Fig. 1c shows the spatial distribution of crater centers as this is occurring. After that point, the crater distribution is in a quasi-equilibrium and the crater density and Z-statistic fluctuate. Meanwhile, if the rim percent value is smaller (0.3, Fig. 2), distributions may not reach true equilibrium, have a more gradual flattening, and may remain random. This is because they act more like points and crater centers can form very close to one another, as the erasing efficiency is small.

Implications: These extreme simulations demonstrate that it is the areal nature of craters (a crater cannot form near another one without erasing it) that cause the distributions to become more uniform as they approach saturation equilibrium. However, for real crater SFDs the areal nature becomes complex. For example, a shallow-sloped population will form several large craters that will actually have the effect of erasing many craters possibly far away from the crater center (actually creating a new gap). Furthermore, for a very steeply-sloped population, sandblasting will have the effect that craters can be erased by other craters not included in the spatial statistical analysis (too small); thus, their centers do not replace the crater erased. Therefore, as future work, I will run more simulations varying the slope and other parameters to determine how they affect conditions for saturation and the Z-statistic. Once these are understood, simulation results will be used to interpret the computed Z-statistic of observed crater distributions on surfaces throughout the solar system to better constrain if they are saturated.

References: [1] Woronow, A. (1977) JGR 82, 2447-56. [2] Hartmann, W. K. & Gaskell, R. W. (1997) MAPS 32, 109-21. [3] Marchi, S., et al. (2012) EPSL 325-6, 27-38. [4] Lissauer, J. J., et al. (1988) JGR 93, 13776-804. [5] Squyres, S. W., et al. (1997) Icarus 125, 67-82. [6] Clark, P. J. & Evans, F. C. (1954) Ecology 35, 445-53. MRK acknowledges support from NASA PGG grant NNX12AO51G.

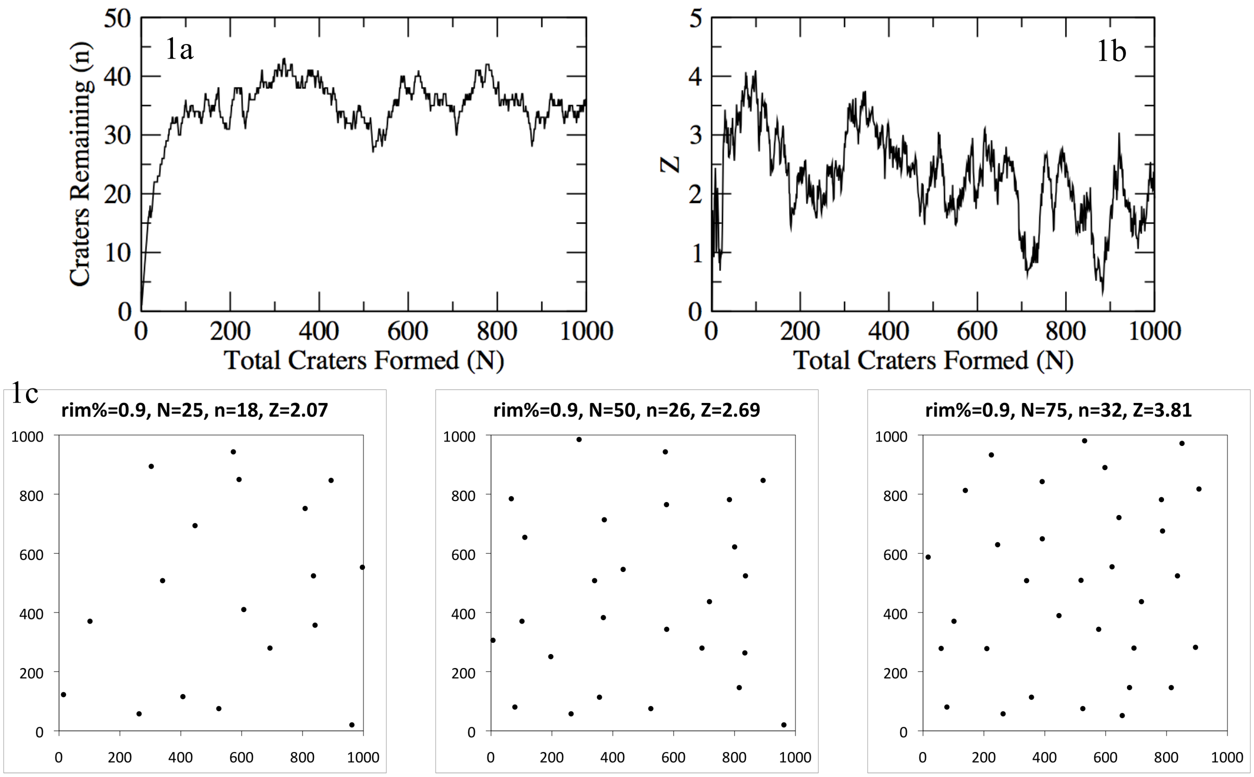

Figure 1. Results from the simulation with rim percent = 0.9. 1a) Number of craters remaining (*n*) as a function of the total number of craters formed (*N*). 1b) Z-statistic (*Z*) as a function of the total number of craters formed. 1c) Spatial distribution of crater centers at points along the simulation.

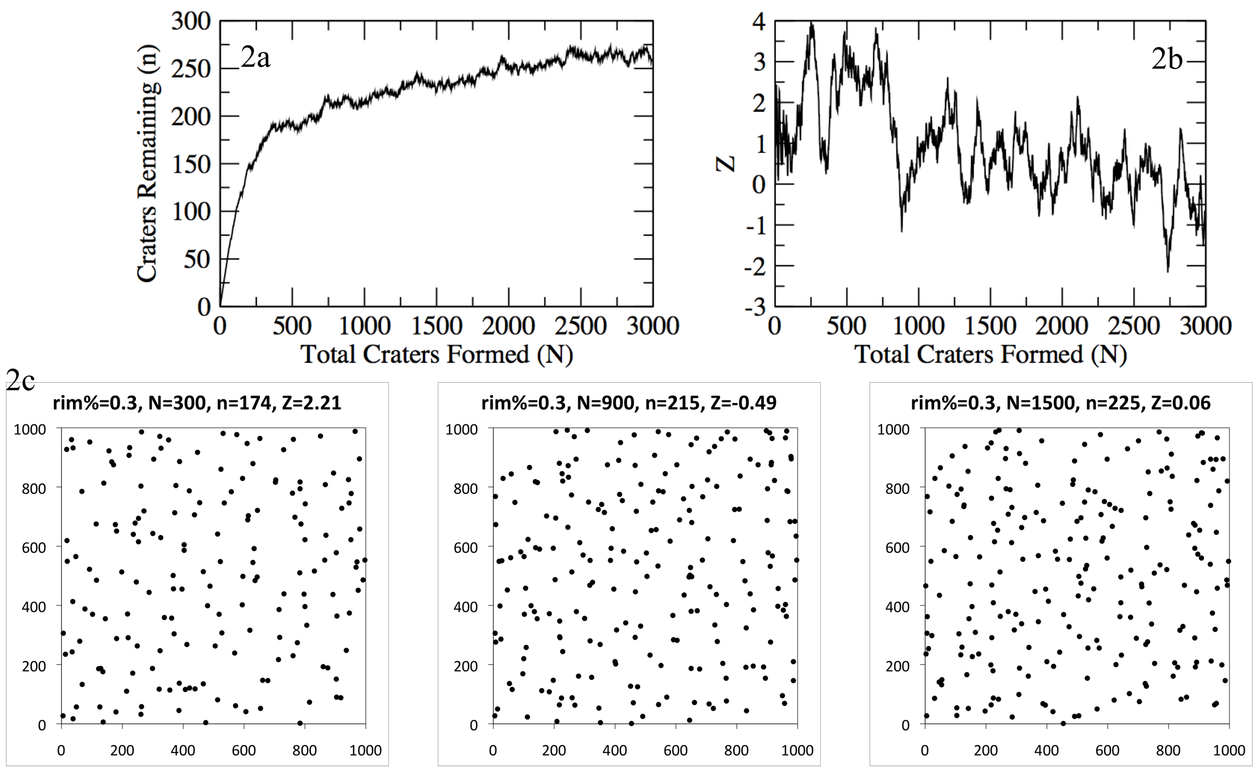

Figure 2. Results from the simulation with rim percent = 0.2. Each plot is as described for Fig. 1.