

**MODELING THE EVOLUTION OF CRATERED TERRAIN IN THREE DIMENSIONS: A STUDY OF CRATER CREATION AND EROSION ON AIRLESS BODIES.** J. E. Richardson, Center for Radiophysics and Space Research, 310 Space Sciences Building, Cornell University, Ithaca, NY 14853, richardson@astro.cornell.edu.

**Introduction:** Monte-Carlo (or stochastic) cratering models have long been a mainstay in the study of cratered terrains. The majority of these models have been geometric in nature, with crater rims represented by circles in a 2D matrix, and which employ mathematical functions to determine the effects of ejecta blanket coverage and the erosion of large craters by smaller ones [1,2,3]. The advantage of these relatively simple models is the ability to conduct a given run (covering billions of years of bombardment) in a relatively short amount of time, and automatically compile crater-count statistics at each time step. The disadvantage of this method is the simplified manner in which crater superpositioning and erosion is handled. Hartmann *et al.* [4] extended these techniques into three-dimensions to produce realistic-looking topography, but required manual crater-counting of the synthetic images produced to obtain useful cratering statistics.

In this work, we present a new Cratered Terrain Evolution Model (CTEM), which utilizes recent advances in the impact cratering scaling-laws [5,6] and our understanding of seismically-induced crater erosion [3] to produce a fully 3D model of crater production and erosion on a given target surface, including downslope regolith migration and automatic crater counting.

**Impact Cratering Scaling-Laws:** The impact cratering scaling relationships are used to relate the size of an impactor to the size of a resulting crater on a given target surface, given several impact parameters [5]. Previously, most applications of these relationships dealt strictly in either the gravity- or strength-dominated cratering regime. However, cratering on a small target body falls into neither regime: gravity and target strength are both important to the size of the final crater. We have therefore adopted the general solution to the transient crater volume scaling relationship given in [5], which includes both gravity and strength terms. The application of a general solution to the crater volume scaling-law permitted us to also find a general solution to the ejecta velocity scaling relationships, described in [6]. These new ejecta velocity scaling-laws permit us to compute ejecta blanket thickness as a function of distance from a given impact site, as well as compute the total mass and fraction of ejecta retained for a given impact.

**Downslope Regolith Migration:** A key feature of the CTEM is the inclusion of downslope regolith migration, triggered either by slope instability or by the

seismic motion generated by nearby impacts. This regolith motion is computed in finite-differencing fashion, using the slope degradation theory described in [3], and which reproduces the analytical model behavior shown in that work. At this point, however, the seismic energy propagation theory used to drive the model is relatively simple and parameterized, with further work necessary to develop this feature.

**Crater Superpositioning and Erasure:** In general, impact craters on airless bodies are erased by three mechanisms: subsequent impacts, which erode and modify the underlying crater; coverage by the ejecta thrown up by other, nearby impacts; and the downslope movement of regolith due to slope instabilities and impact-induced seismic shaking. Fig. 1 shows a demonstration of how all of these effects combine in the CTEM to degrade a once fresh crater to the point of unrecognizability over time. The left-most column in this figure shows one of the 12 model layers which track a vertical "stratigraphic column" at each point around the rim of each crater produced. If the crater's rim is either excavated by a subsequent impact or eroded by downslope regolith motion to less than half of its original vertical relief, or if the crater's rim is covered over by regolith to a depth equal to its current vertical relief, than that portion of the crater's rim is considered to be "erased" and is no longer included.

**Model Application:** Three current problems lend themselves to an application of this model:

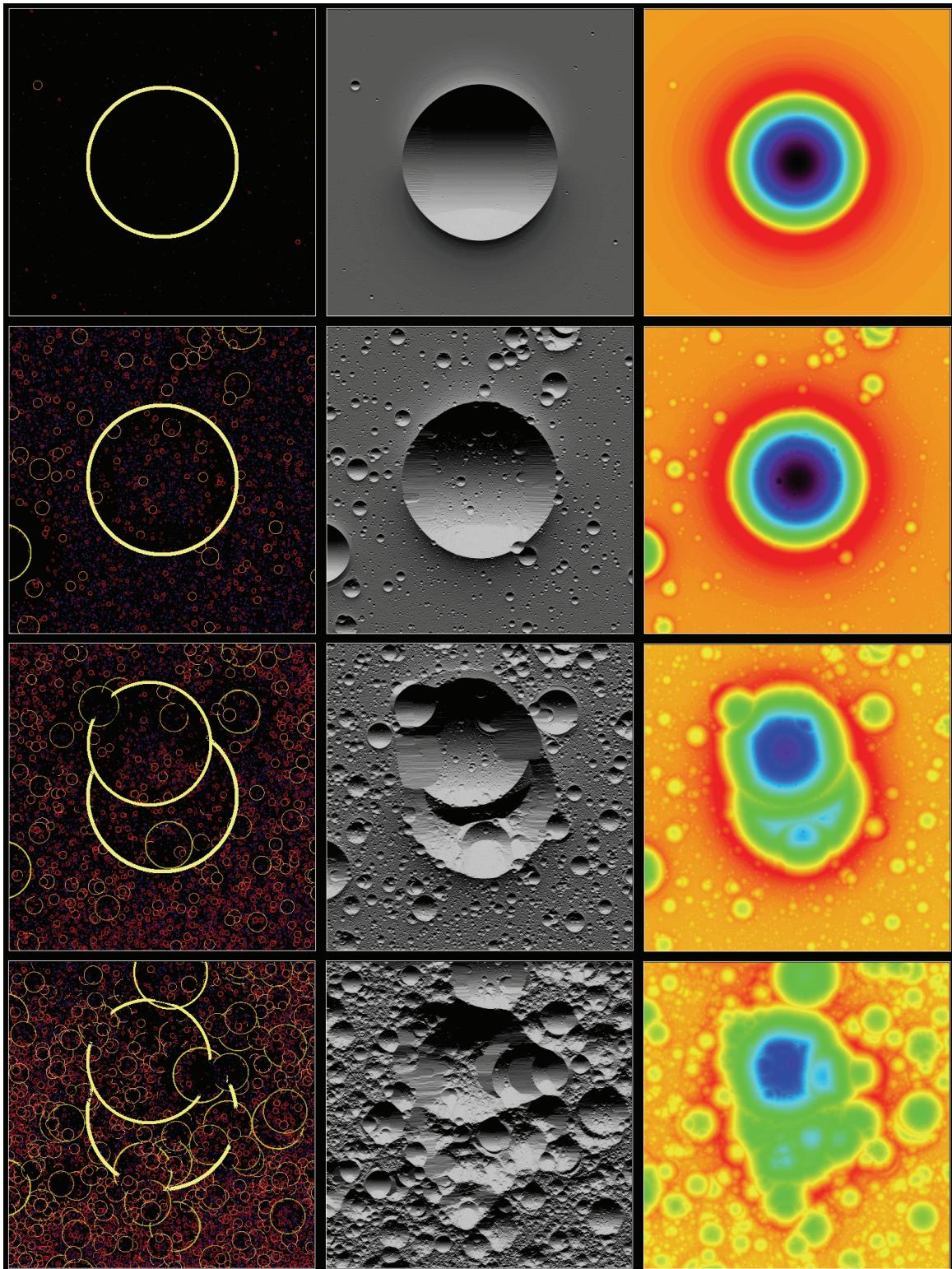
(1) Improving our understanding of crater-count equilibrium ("saturation") levels under various impactor population and target body conditions [1,2,4].

(2) Using forward-modeling to determine the impactor size-distribution necessary to produce a given crater size-distribution, particularly for the outer solar system.

(3) Determining the regional seismic effects of impacts on nearby crater morphologies, particularly for small target bodies, such as 433 Eros [3].

These applications will be discussed in further detail at conference.

**References:** [1] Woronow, A. (1978). *Icarus*, **34**, 76-88. [2] Chapman, C.R. & McKinnon, W.B. (1986). *Satellites*, Univ. Arizona Press, 492-580. [3] Richardson, J.E., *et al.* (2005), *Icarus*, **179**, 325-349. [4] Hartmann, W.K. & Gaskell, R.W. (1997). *Meteoritics and Plan. Sci.*, **32**, 109-121. [5] Holsapple, K.A. (1993). *Ann. Rev. Earth & Plan. Sci.*, **21**, 333-373. [6] Richardson, J.E., *et al.* (2007). *Icarus*, **190**, 357-390.



**Figure 1:** An example of crater degradation as a result of subsequent impacts, where both small and large impacts gradually cause the original, fresh crater to become unrecognizable. The right-hand column in this figure shows the model's digital elevation map as it evolves over time, while the central column shows a shaded-relief view of the same topography. The left-hand column shows the portion of the model used for tracking the degradation of crater rims, for the purpose of compiling crater count statistics at each time step in the model run.