CURRENT STATE OF KNOWLEDGE OF MODERN MARTIAN CRATERING. Ingrid J. Daubar[1], A. S. McEwen[2], S. Byrne[2], M. Kreslavsky[3], L. Saper[4], M. R. Kennedy[4], M. P. Golombek[1]. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91109 (ingrid.daubar@jpl.nasa.gov). [2]University of Arizona, Tucson AZ. [3]University of California Santa Cruz, Santa Cruz CA. [4]Malin Space Science Systems, San Diego, CA, 92191.

Introduction: In the last decade, nearly 500 new, dated impact sites have been identified on Mars based on before and after imaging (Fig. 1). The current cratering rate has been calculated using this data set [1, 2]; however, uncertainties still remain.

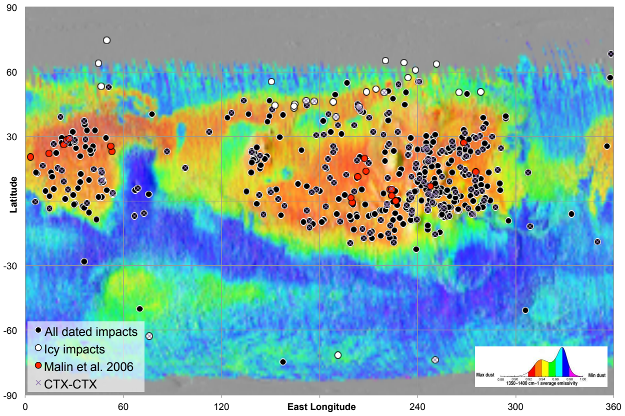

Figure 1: 484 new dated impact sites on a map of the TES Dust Cover Index [9]. Also shown are 19 confirmed sites from [6] & the subset constrained by CTX, which are used to calculate the current cratering rate.

Current measured cratering rate:

Method: New impacts are initially recognized as dark spots in Context Camera (CTX) [4] images that were not present in previous images. The High Resolution Imaging Science Experiment (HiRISE) [5] follows up to confirm an impact origin and measure the craters. We scale the impact size frequency distribution (SFD) to only those areas with repeat coverage and a minimum amount of dust cover, and by a spatial randomness correction. We use an Area-Time Factor (ATF) that is a sum of area covered repeatedly by CTX, multiplied by the time difference between images at each spot [1]. Figure 2 shows the resulting SFD using effective diameters (combined for clusters as in [6]) for 110 impacts with CTX before and after images, scaled to an ATF of 4.68×10^{7} km^{2} yr. Our measured PF falls below model PFs by Ivanov/Neukum [7] and Hartmann [8] by a factor of ~4 over the range 4-30 m diameters. If long-term orbital eccentricity variations are taken into account [7], this discrepancy might increase to a factor of eight for long time periods.

Resulting Production Function: The current cratering rate at Mars was measured by [1] to be 1.7×10^{-6} $D\geq3.9$ $m/km^{2}/yr$. Recently we updated this measured rate to include newer data; the results are nearly identical: 1.8×10^{-6} $D\geq3.9$ $m/km^{2}/yr$ [2]. The surprising near-agreement with model predictions might yet be an accident if the current impact rate is not typical of geologic time, *i.e.*, we can't rule out large short-term fluctuations in the cratering rate.

Spatial distribution: Monte-Carlo analysis of the spatial distribution of this data set [2] leads to the conclusion that randomness of the detected population (even within dusty areas) is rejected with great confidence. Detected craters are not randomly distributed, even within dusty areas with repeat coverage (Fig. 1). Thus the dark spot blast zones are not uniformly created everywhere in dusty regions.

To compensate for the effect of non-uniform crater detection efficiency the PF needs to be increased by a minimum factor of 1.7 in order to make the distribution spatially random [2]. More realistically, this factor probably varies with diameter since it is likely that smaller craters are preferentially missed over certain dusty terrains, biasing the SFD slope.

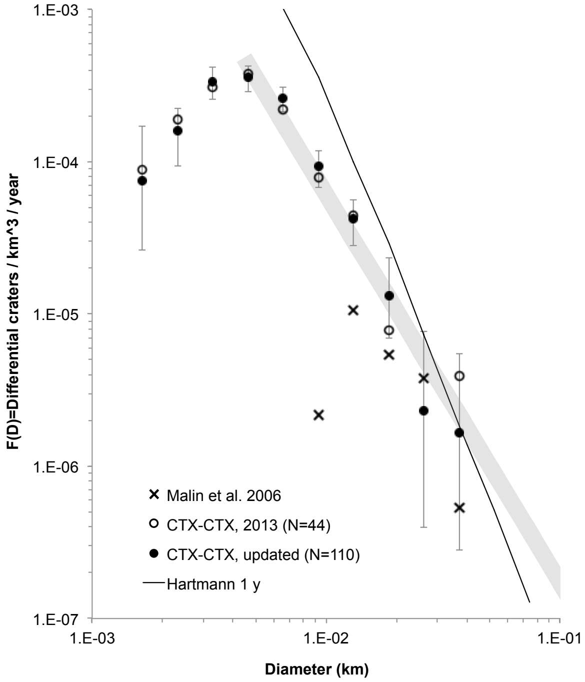

Figure 2: Current SFD for a one-year PF using craters discovered in CTX before and after images [1, 2]. Shaded line is the best fit for craters 4-30 m diameter. Solid line is one-year model from [8] for comparison.

Implications for ages:

Generally, this modern crater PF agrees surprisingly well with the traditional models commonly used to estimate crater retention ages on Mars. The modern PF is lower for D<50 m than the models (Fig. 2), crossing near ~50 m diameter (Fig. 2). The slope of the new crater PF is significantly less steep (smaller negative exponent to linear power-law fit) than the models in this diameter range. This may be a true reflection of the impacting population, but it is more likely it is due either to atmospheric effects, lack of completeness in the observed dated impacts, or inclusion in the models of unrecognized secondaries. We know it is not due to blast zones fading over time, because their lifetimes are ~an order of magnitude longer than the average CTX repeat time over the dusty areas being studied here.

If the modern PF is extrapolated to larger sizes, it would be greater than those models. Using this PF to date a given surface would result in model ages that are higher by a factor of ~four if using small craters (~4–30 m diameter), or lower by some unknown factor (depending on diameter) if extrapolated to larger sizes. Unfortunately all of the observed new craters thus far are smaller than ~50 m, so we cannot yet measure the current martian PF for larger craters.

If these results represent the actual production function of today, and if that trend can be extrapolated to larger crater sizes [e.g. 10], the implication is that the current cratering rate is elevated over the historic average for larger sizes—we are in an impact spike. If true, that would make already surprisingly young surfaces even younger.

The age implications drawn from this present-day PF can differ greatly from those drawn using the lunar-based model PFs for small craters on very young terrains. For example, the SFD of small (diameter 40-400 m) craters on the martian North Polar Layered Deposits follows the same shallow slope as [1-2]. One interpretation is that is an extremely young (less than ~1 ky) primary population [10, 11].

Remaining challenges:

- *Accounting for spatial biases:*
    1. Minimize spatial bias by combination of statistical analysis of observed detections combined with studies of the geological and physical properties of blast-zone-forming vs. non-blast-zone-forming areas to understand controls on formation.
    2. The InSight mission [12] will provide an independent measure of the current cratering rate, which will not be biased to dusty areas [13].
- *Understanding blast zone formation processes* in order to assess completeness of observed data set.
- *Uncertainties at small sizes:* How much of the turndown in the SFD below ~4 m diam is due to atmospheric effects (deceleration, ablation, and fragmentation), and how much is observational (limited by CTX ability to resolve the extended blast zones)? From the model of [14], atmospheric deceleration could explain the shallower slope at small diameters. However, other atmospheric models predict a turn down only for much smaller craters than observed, less than 1 meter diameter [15, 16].
- *Uncertainties at large sizes:* No new craters have been discovered that are larger than ~50 m diameter, so the modern PF is unmeasured for larger impacts. Longer observing timelines and increased areas of detection (e.g. InSight) should improve this.

Conclusions: New meter- to decameter-sized craters on Mars are currently forming at a measurable rate of 3.1×10^{-6} craters/km^2/yr with effective diameters ≥3.9 m. Using this modern PF to estimate retention ages for surfaces with very small craters results in higher ages than those from commonly used models; when extrapolated to larger craters, it implies younger ages.

The published martian model isochrons should be used with great caution for small craters. Our current impact rate statistics provide the best empirical isochrons for the youngest surfaces on Mars, but they still include uncertainties on the order of a factor of four.

References: [1] Daubar *et al.* (2013) *Icarus* 225, 506-516. [2] Daubar *et al.* (2014) *8th Mars Conf.*, Abs. 1007. [3] Banerdt *et al.* (2013) *LPSC*, Abs. 1915. [4] Malin *et al.* (2007) *JGR* 112, 5. [5] McEwen *et al.* (2007) *JGR* 112, 5. [6] Malin *et al.* (2006) *Science* 314, 1573-1577. [7] Ivanov (2001) *SSR* 96, 87-104. [8] Hartmann (2005) *Icarus* 174, 294-320. [9] Ruff and Christensen (2002) *JGR* 107, 5127. [10] Landis *et al.* (2014) *LPSC*, Abs. 2661. [11] Landis *et al.* (2015), *LPSC*, Abs. 1294. [12] Banerdt *et al.* (2013) *LPSC*, Abs. 1915. [13] Daubar *et al.* (2015) *LPSC*, Abs. 2468. [14] Ivanov B. *et al.* (2014) *LPSC*, Abs. 1812. [15] Williams *et al.* (2014) *Icarus* 235, 23-26. [16] Paige *et al.* (2007) *7th Mars Int. Conf.*, Abs. 3392.