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Estimating sub-pixel lunar block distributions

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1. Introduction

Block size-frequency distributions (BSFDs) provide insight to the ejecta and surface roughness in and around craters, and serve as a proxy for the physical state of the substrate [1-4]. This study investigates BSFD (>2.5-m) and how accurately the BSFD can be extrapolated to smaller diameters (down to 10-cm).

Block populations were identified from Lunar Orbiter (LO), Surveyor III (SIII), Chang'E-3 (CE-3), and Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) images (LO [2], SIII [11], CE-3 [3]). Since available pixel scale limits our ability to identify sub-meter scale blocks, our understanding of block distributions down to the 10-cm scale is incomplete – this size range is critical for the interpretation of Mini-RF radar observations [13]. Mini-RF has two modes, S-band (12.6-cm) and X-band (4.2-cm) [13]. In the S-band observations, some polar crater interiors have radar backscatter anomalies with high circular polarization ratios (CPRs) and low CPR for their exteriors, these craters are referred to as anomalous craters [4, 12-13]. Small blocks with diameters near the wavelength of the radar signal [13] and ice are both potential sources of the high-CPR signals [4]. Accurate estimates of the 10-cm block population allow testing of the ice or blockiness hypotheses for the high-CPR signals seen in the anomalous craters.

The NAC pixel scale is 0.5-m (from an altitude of 50-km), which allows for confident identification and measurement of blocks >2.5-m in diameter. The goal of this work is to determine the accuracy of extrapolating from >2.5-m diameter block populations down to 10-cm diameter.

Testing the ice vs. blockiness hypotheses for the anomalous craters is critical for constraining the lunar polar volatile inventory. Currently there are no orbital datasets with the proper pixel scale, so we are stuck with extrapolating from meter-sized blocks visible in orbital images from the NAC (and those to be acquired by ShadowCam, pixel scale of 1.7-m at an orbit of 100-km [10]).

2. Background

Previous studies, determining block populations for potential landing sites on Mars [5-9], compared block populations and how meter and sub-meter-sized blocks are related. They proposed that larger diameter block populations (>1.5-m) can be accurately extrapolated down to 10-cm scales [8], but if the counts were limited to >5-m blocks, the extrapolation accuracy diminished [7]. A lower limit for extrapolation for Mars lends some degree of confidence for similar results at the Moon.

Lunar block populations across a broad size range were derived from LO (>2-m diameters) and SIII images (0.001 to 0.3-m diameters) [2, 11]. Cumulative SFD of the block counts both had negative slopes but the LO slope (blocks 2 to 6.3-m) was steeper than the SIII slope (blocks 0.001 to 0.251-m.) The steeper, negative slope for meter-sized blocks overestimates the number of sub-meter blocks. The difference in slope could mean the population of blocks changes.

Cintala and McBride [2] compared LO coverage of several Surveyor landing sites to the work done by Shoemaker and Morris [11]. From the plots it was found that the Surveyor III site was the closest matched between the SIII and LO counts [2]. More recently, block populations were determined from NAC [6, 14] orbital images and CE-3 surface images [3]. The BSFD also showed roll over as the block size approached the resolution cut off.

3. Method

The maximum diameter was recorded for the blocks [5], as was done for the LO counts [2]. Block counts from a NAC image covering a similar area used for the LO image for the Surveyor III site [2] for analysis. The cut off for the blocks in the NAC image is 2.5-m since the pixel scale for the image is 0.5-m. The new block counts were binned to match the data from Cintala and McBride [2]. The data was plotted on a log-log scale with a power law applied for fitting.

The data for the NACs, Chang'E-3 LCAM, and LO were cut off at 5 times the pixel scale of the image avoiding plotting past the confidence limit of block diameters.

3.1 Block Count Sites

Four sites were selected for this study. Surveyor III (Fig. 1) and the CE-3 (Fig. 2) landing sites were selected to compare with previous work, which included block counts from surface images, allowing direct comparisons between the sub-meter population and the meter population. Block counts were derived from one NAC pair for each site and three CE-3 LCAM descent images.

The two other sites selected were a block field on a low altitude NAC image with pixel dimensions of 0.21 x 0.57-m and processed at 0.2-m pixel scale. This image provided a BSFD with a larger block count area than those of the CE-3 descent images (see Fig 2). A newly formed (October 2012) 70-m impact crater provided an example of the block population around a fresh impact crater.

4. Results

Slope values for the LO [2] and NAC BSFDs are similar but both differ from the SIII slope (Fig. 1). Image resolution and counting errors could contribute to the difference in slopes or, variations in the degradation rate of blocks and thus predicted survival times [1]. Overhead block counts for the CE-3 sites (NAC and CE-3 descent camera) were compared to block counts from the Yutu rover NavCam images [3]. The Chang'E-3 descent LCAM image counts bridge part of the sub-meter to meter block gap (Fig. 2). Yutu NavCam based BSFD [3] has a different slope likely due to the small area and non-representative area imaged by the rover. The slopes for two of the Chang'E-3 LCAM counts (black and purple markers in Fig. 2) match up with the slope from the NAC count, indicating that extrapolation from >2.5-m population to sub-meter blocks is possible.

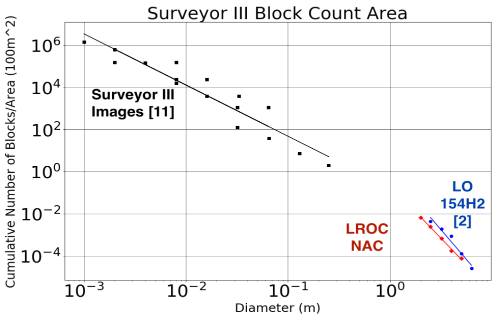

Figure 1: Log plot of size-frequency distribution of block counts for Surveyor III landing site.

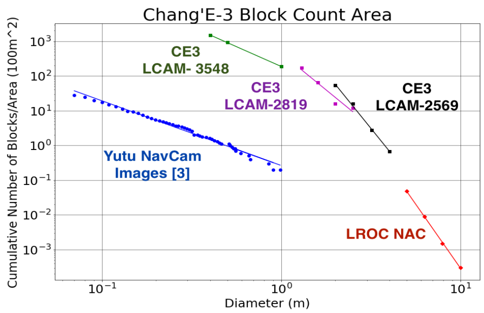

Figure 2: Log plot of size-frequency distribution of block counts for Chang'E-3 landing site.

4. Future Work

Additional comparisons of meter and sub-meter scale block populations are needed to allow more confident extrapolations to smaller diameters from larger diameters. Until high-resolution orbital images are available such extrapolations are required to assess the nature of high-CPR backscatter seen in and out of PSRs and in turn help constrain the lunar polar volatiles inventory.

References

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