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Blocks and small scale topographic reliefs at the ExoMars landing site on Mars

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Abstract

In order to characterize and understand the meter-scale relief features present at the landing site of the ESA-Roscosmos ExoMars 2020 mission, we developed an automatic algorithm to analyze HiRISE images and detect blocks and other small-scale topographic reliefs.

1. Introduction

The goal of this study is to characterize the surface roughness of the final landing site of ExoMars 2020 [1,2] at a spatial scale from several meters to centimeters. The determination of roughness at the meter scale is achieved using HiRISE images, whereas the roughness at the centimeters scale is estimated using the method of [3,4]. At the ExoMars landing site, the major contributors to surface roughness are blocks (i.e., rootless rocks) and small-scale ridges (i.e., elongated topographic forms). Knowledge on the abundance and distribution of these features is important for (i) understanding the geology and the erosional and burial history of the site, and (ii) applying engineering requirements for rover traversability [2]. Here we develop an automatic detection algorithm to characterize roughness over entire HiRISE images, as a complementary approach to visual investigations and manual block counts [e.g., 5].

2. Method

The characterization of small scale roughness requires the extraction of information at a spatial scale below that of HiRISE DTMs calculated with stereo and shape from shading methods [e.g., 6]. We follow the approach of [4] and base the detection of small scale steep reliefs on cast shadows observed by HiRISE. The detection and characterization of small scale steep reliefs is performed as follows:

1) Extraction of 250x250 m^2 sub-frames of HiRISE, calibration to I/Fcos(i), rotation to a constant orientation.

2) Shadow segmentation based on the maximum entropy of a “band” depth frame. The frame is calculated by measuring the decreases in reflectance over varying spatial scales. Removal of isolated pixels and identification of contiguous pixels.

3) Estimation of the size, height and coordinates of groups of pixels, i.e., shadow of reliefs.

The size frequency distribution of features in the range 1.5-2.5 m calculated in the steps above is used to estimate the cumulative fractional area covered by blocks of all (cm and m scale) sizes (k parameter) with the method described in [3,4]. We assume that the model of abundances of centimeter-scale blocks based on Viking landing sites can approximate the properties at the ExoMars landing sites. In some locations, ridges are a major contributor to roughness and are not distinguished from blocks. Therefore the calculated parameter is referred to as k*, as a way to distinguish it from the parameter k calculated using only blocks and reported in other studies [e.g., 4].

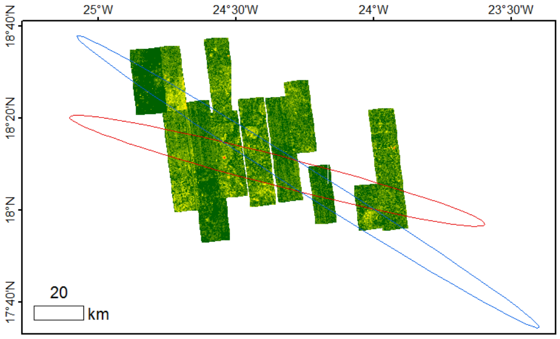

Figure 1: Coverage of roughness maps at the Oxia Planum landing site in color-coded k* values (green:low, yellow:high). k* refers to the cumulative fractional area

covered by blocks and ridges. Ellipses indicate estimated landing locations based on different times of launch.

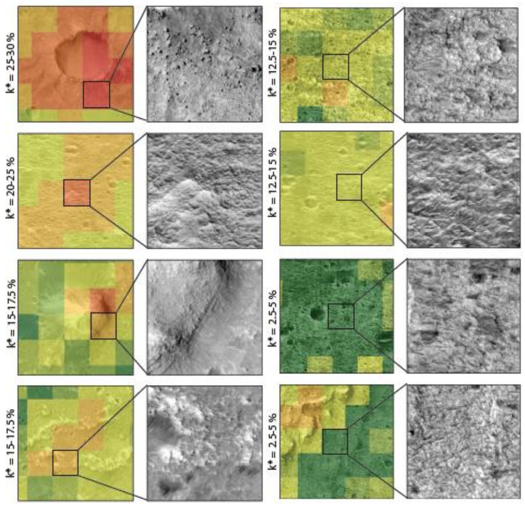

Figure 2: Example of regions of different k* values and associated HiRISE close-ups, within Oxia Planum.

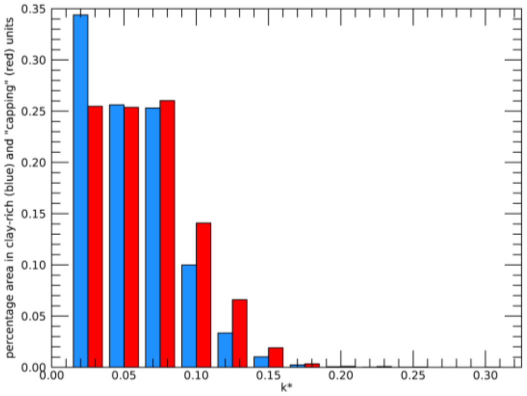

Figure 3: Distribution of k* values for the two main geological units at Oxia Planum: clays-rich unit in blue and “capping” unit in red. k* refers to the cumulative fractional area covered by blocks and ridges.

3. Results and Discussion

Here we use roughness maps (e.g., Figure 1 and 2) to investigate the variation between the two major units defined in the regional scale geological map of Oxia Planum: the clay-rich and the “capping” units [9]. We find that both units have a considerable range of variation and that the “capping” unit has slightly higher abundances of blocks and small-scale ridges (Figure 3). The range of variation might be due the presence of subunits in different erosional states or to non-uniform aeolian coverage. We will discuss whether the difference in roughness between the two units is due to the type of material (clays-rich basement versus capping unit of lava flows) or to erosional hystory (short and recent exposure for the clays-rich unit versus the long exposure time of the capping unit).

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