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Influence of small scale topography on early spring activity in martian polar areas. An example study based on DEM of Inca City region.

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Abstract

By using the newly generated HiRISE DEM of Inca City region with 1-meter spatial resolution we are able to estimate the solar energy distribution over the surface on the scale of topographical irregularities, such as the sides of araneiforms channels. In the present study this DEM serves as a model terrain to test the previously proposed hypothesis of early initialisation of CO_2 activity by solar illumination of topography on the meter-scale [1].

1. Introduction

The Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) has exceptional capabilities to image the Martian surface under low insolation conditions. HiRISE successfully observed the "Inca City" region (81.3°S, 295.8°E) as early as L_s=171.2° – prior to the southern spring equinox. These early observations were intended to define the timing of the very first activity in the polar areas. It is believed that the spring sublimation of CO_2 slab ice creates a set of exotic phenomena in the martian polar areas: cold CO_2 jets, seasonal ice cracks, fan deposits, blotches, and ultimately araneiforms [1, 2, 3, 4]. We observe that, even in the very first spring images, the activity in Inca City has started and created some dark blotches which are inferred to be dust deposits on top of the slab ice. Dark blotches are clearly visible in the inner parts of the Inca City "squares". This is a rather counter-intuitive observation: the centres of the squares get little insolation because they are most of the time shadowed by the surrounding ridges implying that they should be the last areas to become active. On the other hand, the inclined sides of the ridges are expected to be illuminated for a longer time and with lower illumination angle and hence should be active earlier. As the early activity in the depressions was reproduced in all Mars years observed to date, it indicates a general trend.

1.1. Importance of topography

Solar energy input is critical for the timing of spring activity. In this context, variations of surface inclination are important especially in early spring, when orientation towards the sun is one of critical parameters determining the level of solar energy input, the amount of CO_2 sublimation, and hence the level of any activity connected to it. This observation has led to the hypothesis that meter-scale topography was triggering the activity in early spring.

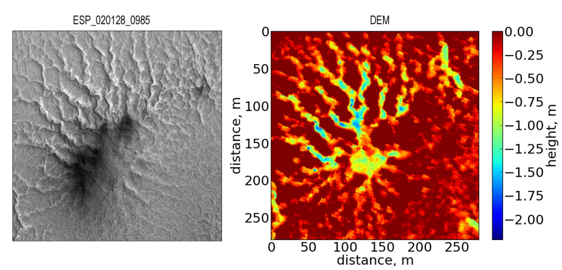

Figure 1: Left panel: Subframe of an early spring HiRISE image of Inca City. Image ESP_020128_0985 was taken at L_s=179.5^o. It shows dark blotches originating from the center of the araneiform. Right panel shows HiRISE DEM subframe of the same location. The general slope of 4^o is removed to highlight araneiform channels.

HiRISE data can be used to create DEMs of the martian surface if two images with different observation geometry are available. Polar areas pose some specific problems because of the oblique illumination conditions and seasonally changing ice cover. Nevertheless a DEM of good quality of Inca City with the spatial resolution of 1 m (Fig. 1) has been generated.

2. General settings of Inca City

The Inca City region is well observed for monitoring the development of the spring activity. This area is intriguing because it shows a rectilinear pattern of ridges which provide orientation and inclination differences. HiRISE DEM provides us with a possibility to study small scale topography in details. Araneiforms of different types [2] can be resolved inside the quasi-squares, as well as boulders and various types of troughs. We have systematically mapped all features over the extent of the Inca City DEM and determined their most relevant geometric properties such as maximum slope, depth and volume. The average depth of the observed features is around 2 m but some very deep araneiforms can reach a depth of 7 m. The typical slopes in the arms of the spiders are about 20°.

3. Insolation model

First, to calculate the position of sun relative to the local surface we use the NAIF SPICE system [5]. Then we use this sun position to calculate if the surface facet is shadowed by neighbouring terrain at a particular time during the day by using local horizon approach [6]. In this approach the maximum angular elevation towards each possible solar aspect is pre-calculated for each facet of the DEM surface. At each time step the position of the sun from SPICE is compared to the maximum elevation in the direction of the sun and a shadowed/non shadowed flag raised. For those facets that are non shadowed the amount of solar energy that reaches them is also given by SPICE accounting for their slope and aspect orientation. In addition the amount of radiation may be decreased accordingly to the temporary changing atmospheric attenuation. In the present state we only calculate direct radiation.

An example of calculation of cumulative solar energy is shown in Fig. 2. Already as early as L_s = 167° some of the facets of this surface are illuminated by the sun and may trigger the CO_2 sublimation. The top left corner of the subframe is shadowed in the very early days by one of the ridges of Inca City positioned directly to the North-East (top left direction in the image frame). One can see that the energy distribution is heterogeneous and maximised on the sides of the channels and other small topographical features.

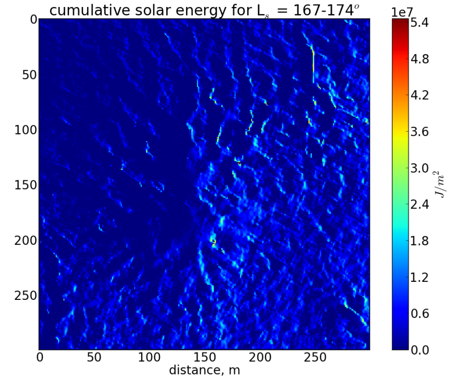

Figure 2: Cumulative energy distribution over the subframe shown in Fig. 1. The energy is integrated over 15 sols starting from the first light at L_s = 167^o.

4. Summary

Our study supports the hypothesis that solar energy in polar areas in spring is directly related to the activity observed. Araneiforms with their highly variable topography provide the perfect setting for starting the activity. With this activity being repeated early on the same locations (around araneitroughs) the erosion of the surface receives positive feedback.

References

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