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High resolution characterization of Martian surface in terms of slope/roughness

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1. Introduction

From the recent high resolution images about Martian surface, various types of the surface are known to be systematically correlated with latitude, which is called as latitude-dependent morphology. They are interpreted as products of climatic control which is induced by variation of the obliquity. The basic type is mantling of dust-ice mixture which has smoother surface than the original surface of mostly aeolian erosion control.

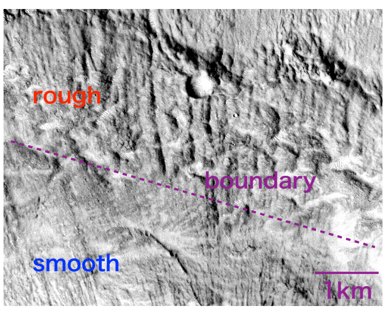

Figure 1: CTX image of the crater at the Utopia Planitia [CTX: P15_006816_2100_XI_30N243W].

A good example of this process can be found for several craters with fresh-looking rays at Utopia Planitia (Fig. 1). Rays can be easily eroded and erased quickly. But in this region, the observed number of craters with rays is larger than that expected from crater chronology.

Our interpretation is as follows: Dust-ice layer covered the rays and protect these from erosion. With the change of climate the covered ice was molten and the dust layer was blown away by wind and the original surface becomes observable (Fig. 2). This interpretation is based on the images of patched structure of smooth and rough surfaces at crater ejecta. The characterization of the surface at 10-50m length scale is critical.

In this presentation we report high resolution estimates of surface roughness/slopes corresponding to various types of latitude-dependent morphology with intention to provide data for future rover exploration. The basic method is photoclinometry applied to HiRISE data to estimate m-scale roughness. [2] have already conducted m-scale topographic mapping for the survey of Phoenix landing site. Our aim is to construct basic data base for roughness/slope statistics of m-scale of typical surface types. Since the coverage of HiRISE image is limited we measure roughness by CTX, MOC and THEMIS-VIS data at coarser length scales. We combine fine scale (m-length scale) roughness spectrum and coarse scale (10-20 m) spectrum to a consistent spectrum. In combination to conventional photoclinometry approach we use thermal infrared images to estimate roughness based on the analysis of [1].

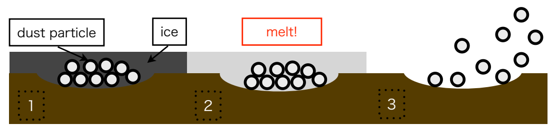

Figure 2: Schematic illustration of the dust-ice layer.

2. Method

We use photoclinometry technique to calculate the topography and surface slope. The resolution is in principle same as the pixel size of the observed image.

We assume that the surface is diffusive and reflect the solar energy equally in all direction.

Basic assumptions are as follows:

1. Image brightness does not depend on the eye (satellite) position.

2. Image brightness controlled by only the surface slope as far as the surface albedo is same.

We assume the Lambertian model.

$$I(x,y) = \frac{(s_x g_x + s_y g_y + s_z)}{\sqrt{(g_x{}^2 + g_y{}^2 + 1)}}. \quad (1)$$

where $I(x, y)$ is the image brightness; g_x and g_y are the surface gradients along x-axis and y-axis directions; (s_x, s_y, s_z) is a unit illumination direction vector.

We use the calculation code of minimization algorithm developed by [3].

3. Target Area

We select several test fields where five different types of images (HiRISE, CTX, MOC, THEMIS-VIS and THEMIS-IR) are available on the same target. They are west of Scaparelli crater, Amazonis Planitia and Eastern part of Utopia Planitia. We also use MOLA profile data for the reference.

4. Results

Figures 3 are the CTX images that we analyze. The resolution of images are ~6m.

We reconstruct 3D shape from the images and apply the 2D FFT to gridded topography data. Averaged power spectrum is calculated as a function of the modified wave number r to make clear the characteristics.

$$Y_{p+1,q+1} = \sum_{j=0}^{m-1} \sum_{k=0}^{n-1} \omega_m^{jp} \omega_n^{kq} X_{j+1,k+1}, \tag{2}$$

$$\omega_m = e^{-2\pi i/m}, \omega_n = e^{-2\pi i/n}, \tag{3}$$

$$r = \sqrt{p^2 + q^2}. \tag{4}$$

Figure 4 shows the averaged power spectrum of the surface roughness of the reconstructed 3D shape.

There exist clear differences in the power spectrum of the surface roughness between the areas in same region (Utopia Planitia). The area A is smoother than the area B at 20m-60m scale and rougher at <15m scale.

5. Summary and Conclusions

1. We reconstruct the 3D shape from the high resolution images.
2. There are differences in characteristic wavelength between the areas.
3. We think that these differences reflect the existence of dust-ice layer and probably ... climate change.

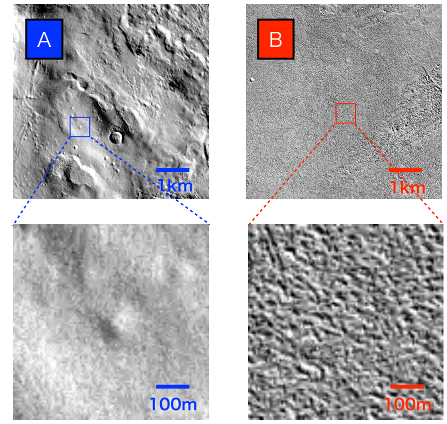

Figure 3: CTX images at the Utopia Planitia (image size is 1024pixel×1024pixel) (A): [CTX: P14_006618_2185_XN_38N238W] (B): [CTX: P13_006262_2145_XN_34N237W].

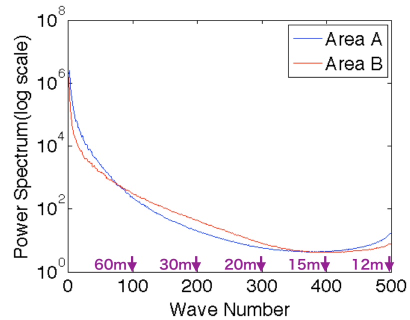

Figure 4: Averaged power spectrum of reconstructed 3D shape.

References

[1] Bandfield, J.L., and C. S. Edwards: Derivation of martian surface slope characteristics from directional thermal infrared radiometry, Icarus, 193, 139-157, 2008.

[2] Kirk, R. L., et al.: Ultrahigh resolution topographic mapping of Mars with MRO HiRISE stereo images: Meter-scale slopes of candidate Phoenix landing sites, J. Geophys. Res., 113, doi:10.1029/2007JE003000, 2008.

[3] Liu, H.: Derivation of surface topography and terrain parameters from single satellite image using shape- from-shading technique., Computers & Geosciences, 29, 1229-1239, 2003.