EPSC Abstracts
Vol. 13, EPSC-DPS2019-1941-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Small Scale Topographical Characterization of Oxia Planum, Mars.

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Abstract

Oxia Planum, in the Arabia Terra region of Mars, will be the site of ExoMars Rosalind Franklin Rover exploration in 2021. Oxia Planum, contains Noachian (i.e. ancient, > 3.7 Ga) terrains that become increasingly eroded towards the crustal dichotomy which separates the ancient southern highlands from the younger southern lowlands. The site has a rich geological history showing diverse aqueous episodes during the Noachian, followed by later volcanic and aeolian/erosional activity. Oxia Planum contains abundant phyllosilicate materials. We perform the topographical characterization of parts of Oxia Planum at metric to hectometric horizontal scales by generating improved high-resolution digital elevation models (DEMs). In this work we focus on slope at different scales that are useful to constrain past and present geological processes and to prepare the future traverse of the rover.

1. Methods

A new method combining photogrammetry and photoclinometry [1] is used in order to produce high quality, large Digital Elevation Models (DEMs) from panchromatic images of Oxia Planum crater region acquired by the Context Camera (CTX) and the High Resolution Imaging Science Experiment (HiRISE) of the Mars Reconnaissance Orbiter. The method integrates an intensity model of the image based on a novel radiative transfer scheme with a two component slope vector and a realistic bidirectional reflectance distribution function (BRDF) of the surface as its main parameters. Two carefully crafted regularization terms are also introduced ensuring the smoothness of the solution and the consistence with photogrammetric information at large scales. The regularized inversion of the model is based on an efficient numerical optimization scheme and means that the method can generate the height field with details missing or distorted in the DEMs generated by photometry, maps of absolute slope, and of intrinsic albedo. The method ensures a spatial resolution that is comparable to that of the imagery and allows the measurements of heights with a relative precision of 1 m with CTX imagery and down to 15 centimeters with HiRISE imagery. The refined DEMs are validated, then carefully characterized by conducting a multi-scale analysis with the Isotropic Undecimated Wavelet Transform of the DEMs. For that purpose we use the IUWT algorithm proposed by [2] which is adapted to discrete 2D fields. Furthermore the reconstruction of the signal is straightforward and is written as the sum:

$$c_J = c_0 + \sum_{j=1}^{J} d_j$$

where c_0 represents the smoothest version of the signal that is considered and d_j the details of the signal at decreasing spatial scales j. The J scales follow a dyadic behavior as the spatial resolution of the jth scale is $r_j = 2^j r_J$, r_J being the initial resolution of the signal (6m for CTX, 1m for HiRISE).

2. Data and products

Table 1 describes the radiometric acquisition conditions of the HiRISE images.

Table 1: HiRISE Image information for Oxia

	Left image	Right image
Image ID	PSP_009880_1985	PSP_009735_1985
Sun elevation	42°	41.°
Sensor elevation	82°	82°
Sun azimuth angle	282°	261°
Phase angle	55°	41.2°

Fig.1 compares the relief shaded version of a DEM generated from HiRISE images by photogrammetry

(top) with our refined DEM (bottom) for a region of interest (ROI) with a high density of craters. The defects initially present in the DEM are removed while increasing the level of details as shown by the improved sharpness of the lower shaded image.

Figure 1

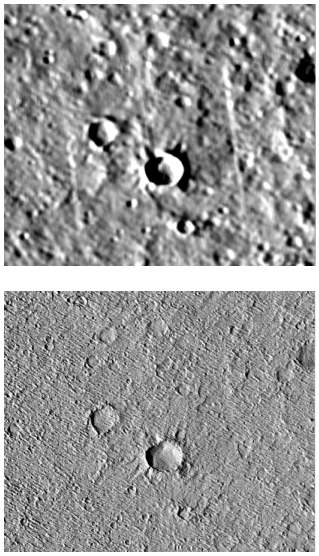

Fig.2 is a false color composition of a reduced portion of the Oxia Planum indicative of the roughness of the scene at three consecutive spatial scales (Red: 1m, Green: 2m, Blue: 4m). The composition is superposed with transparency on the HiRISE orthorectified image. Variations of hues reveal different characteristics of the scene.

The refined DEM versions clearly reveal meaningful planetary features. First reddish colors correspond to small wavy patterns affecting sand deposits inside big craters. They turn to yellow, and then to white if their amplitude increases. Second reddish hues also form digital aureoles around the biggest craters where they reveal the presence of small blocks ejected by the impact. Third bluish colors indicate the deepest structures of the scene (e.g. highly dissected portions of Oxia Planum) or pronounced slope discontinuities (e.g. crater ramparts).

3. Summary and Conclusions

The processing of a series of CTX and HiRISE images of Oxia Planum with our new DEM generation method provides an extremely detailed view of the region's geomorphology at different spatial scales allowing quantitative investigations of stratigraphy, paleohydrology, present aeolian processes and slope statistics. In addition, thermophysical characterization and mineral mapping of Oxia Planum will greatly benefit from improved DEMs and maps of intrinsic albedo. Radiative balance calculations and non linear spectral unmixing are based on these products. Finally the dataset for detailed topographical characterization of Oxia Planum will soon be completed with stereo pair acquisitions by the CaSSIS imager of the Trace Gas Orbiter (ESA) providing color images et 4 m.pixel-1 over the entire region.

Acknowledgements

This research was carried out under the project #3949 TGO ExoMars funded by the French Space Agency CNES. We thank the HiRISE, CTX teams for support with data downlink and processing activities permitting our image experiments and research.

References

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[2] Starck and Murtagh (2002) Handbook of As-tronomical Data Analysis. Analysis, p.338.