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# Topographic correction on HiRISE images

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## Introduction

The topographic correction of satellite images can be exploited to disentangle albedo features from illumination effects induced by topography and to perform spectrophotometric studies based on multi-wavelengths datasets.

In this abstract, we test and evaluate the performance of several photometric models to remove topographic shading from HiRISE images, in a similar manner to what was already proposed by [1] but using a wider selection of models.

## Photometric Models

The reflectance of a surface at a given wavelength depends on the scattering properties of the material of which is made of [2]. This dependence is usually modelled by three angles: incidence, phase and emission (or emergence).

In this abstract, we will consider four photometric models that are widely used in planetary photometry: the Lambert [3], Lommel-Seeliger [4], Akimov [5] and the Minnaert models [2,3,6]. As a future goal we will also include the Hapke model [2], which is possibly the most comprehensive model but that is characterised by a higher number of parameters (and therefore assumptions) than the models here presented.

## Datasets

The incidence and emission angles reported in the labels of publicly available HiRISE images are relative to the central pixel of the image. These angles can be inaccurate in areas with substantial topographic relief, and they will depend on the slope and azimuth of the surface (see [2], formulae 12.9b, c). To compute them, we edited the hiedr2mosaic.py script included in the Ames Stereo Pipeline (ASP, [7]), which is used to obtain a radiometrically calibrated mosaic from the single CCD images of a HiRISE acquisition [8]. In particular, we used the publicly available HiRISE DTM DTEEC_039788_1645_039854_1645_A01, converted to planetary radius values, as shapemodel for the ISIS *spiceinit* tool [9]. After this step we projected the images using the *cam2map* tool in ISIS [9]. The projected images were then used as input in the *phocube* tool in ISIS [9] to compute the local incidence and emission angles for every pixel in the image. The outcomes of this procedure are shown in Figure (1b, c).

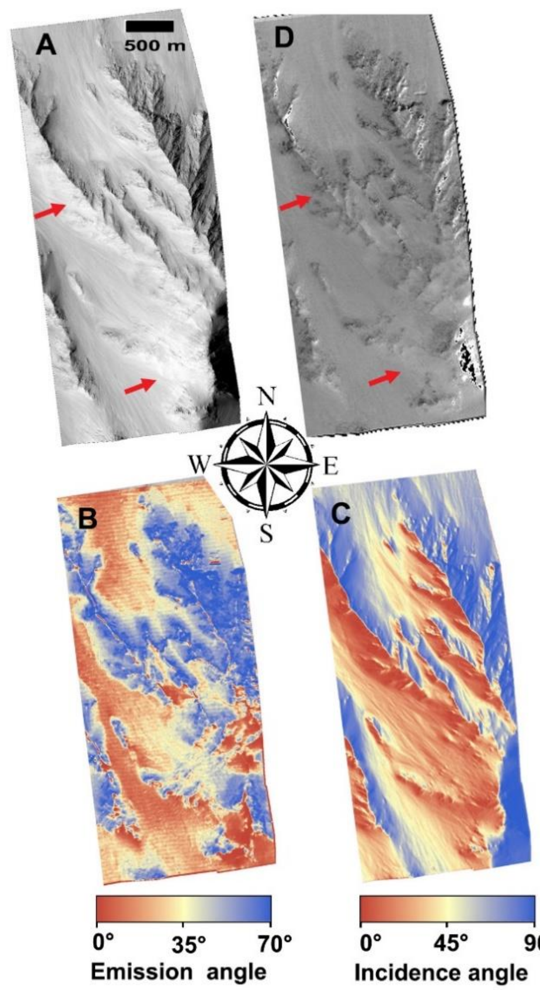


**Figure 1:** A) Image ESP_029331_1645. B) Emission angle map and C) incidence angle map. D) Corrected image. Red arrows indicate example regions where relevant topographic shading has been removed.

## Methods

We apply the topographic correction on two HiRISE images showing bedrock outcrops in the slopes of Eos Chasma (-15.422°,309.554°, see Fig 1a). One image was taken at a low phase angle (ESP_029331_1645, phase=54.6°) and another at high phase (ESP_041199_1645, phase=25.8°). To obtain a topographically corrected image, we computed the Lambert, Lommel-Seeliger and Akimov models using the incidence and emission angles obtained with the phocube tool. For the Minnaert model, we followed the approach of [1]. To evaluate the performance of all topographic corrections we checked if the dependence of the corrected reflectance from the incidence angle is removed, i.e. if the corrected reflectance profile is flat.

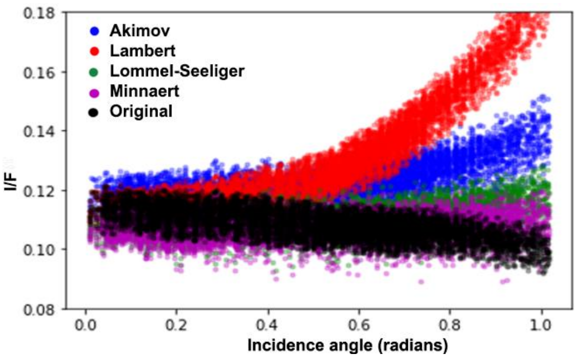


**Figure 2:** topographically corrected values of I/F from ESP_041199_1645 versus incidence angle, in radians.

| Model | Slope | 5% | 95% |
|---|---|---|---|
| Original | -0.0121 | -0.0124 | -0.0118 |
| | -0.0129 | -0.0130 | -0.0128 |
| **Minnaert** | **0.0014** | **0.0010** | **0.0018** |
| | **0.0080** | **0.0077** | **0.0083** |
| Akimov | 0.0175 | 0.0169 | 0.0180 |
| | 0.0820 | 0.0818 | 0.0823 |
| Lambert | 0.0625 | 0.0615 | 0.0634 |
| | 0.0876 | 0.0871 | 0.0881 |
| L. S. | 0.0073 | 0.0069 | 0.0077 |
| | 0.0339 | 0.0336 | 0.0341 |

**Table 1:** performances of all photometric models in terms of median slope of the corrected profile (Fig 2) with 90% confidence intervals, in radians. Top row is for the low phase image, bottom row for the high phase image.

## Results

All the topographic corrections are depicted in Fig. (2), where we plot the corrected reflectance values over the incidence angle for all models. Their performance is evaluated by computing the slope of each corrected reflectance profile in Figure (2). Their median value and 90% confidence intervals are evaluated performing 5000 bootstrap simulations [10] and reported in Table (1). The Minnaert model always performs better, achieving the lowest slopes in the corrected images. The obtained slopes are a factor ≈1.5 lower than in the original image at high phase, and a factor ≈ 10 lower than in the original image at low phase. An example of Minnaert-corrected image is depicted in figure (1d). The comparison with figure (1a) shows that the topographic shading is removed, as indicated by the red arrows. On the contrary, the other models achieve significantly worse corrections. These results imply that, on average, the Martian surface in the slopes of Eos Chasma does not have a Lambertian behaviour. This is probably because of the low albedo of the surface under study. Such interpretation is consistent with other studies [11], which showed that the Martian surface follows a Lambert model only for albedos approaching 1. For future analyses we will include the Hapke model, which is of particular interest because its parameters are directly linked to the properties of the surface [2]. In addition, the achieved photometric correction will be applied to investigate albedo features based on CaSSIS colour observations [12] and DTMs, that are currently being developed through the 3DPD software [13] developed by INAF-Padova (implementing a specific stereo photogrammetric pipeline for the CaSSIS stereo pairs).

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**References**: [1] S. Walter et al., 2011, EPSC Abstracts Vol. 6, EPSC-DPS2011-648, 2011 EPSC-DPS Joint Meeting 2011 [2] Hapke, B., 1993. Theory of Reflectance and Emittance Spectroscopy. CUP [3] McEwen, S. A., 1991, Icarus 92, 2,298-311 [4] Fairbairn, M.B, 2005 Journal of the Royal Astronomical Society of Canada,99,3,92 [5] Akimov, L.A., 1976. Sov. Astron. 19(3), 385–388. [6] Minnaert, M.,1941, ApJ 93, 403–410. [7] Shean, D. E. et al., 2016. ISPRS 116. [8] McEwen, A. S., et al., 2007, J.G.R., 112,E05S02,[9]https://isis.astrogeology.usgs.gov [10] Press et al., 2007, Numerical recipes in C++ : the art of scientific computing [11] Jehl et al., 2008, Icarus, 197,2, 403-428 [12] Thomas,N. et al., 2017,Space Science Reviews, 212,1897–1944 [13] Simioni, E et al., 2017, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-3/W1, 133-139