HRSC Topographic Correction by Empirical Photometric Modeling

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Introduction

We want to use the bundle adjusted orientation information of the High Resolution Stereo Camera (HRSC, [1, 2]) to derive a synthetic photometric model and compare it with the recorded image sequence. This model can serve for several purposes, one of which would be the isolation of albedo features from the topographic shading effects for better contrast stretching results.

Photometric Surface Models

For complete physical photometric models such as the solution by Hapke [3], the necessary parameters can barely be determined from a single HRSC image. Instead, empirical models such as the 2-parameter Minnaert [4] photometric model provide good approximations of the Hapke model for Mars [5]. For every single pixel, the HRSC orientation data together with geometric camera calibration data are used to calculate unit vectors of the Sun and the pixel's position in the Mars-fixed coordinate system. The vector's coordinates are saved as floating-point images exactly aligned to the original image sequence and can then be rectified to the image geometry of the map-projected HRSC DTM. After rotation of these vectors by the slope and aspect angles of the surface, we get the illumination angle ι' of the sun's incidence and the emergence angle ϵ' of the observer relative to the surface normal (for an explanation of the illumination and observer geometries, see Fig. 1). These illumination parameters can be used to calculate synthetic surface models by use of empirical or physical photometric models.

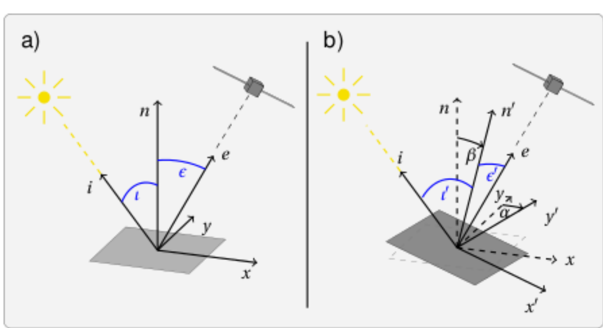

Figure 1: horizontal surface element illuminated by angle ι and observed by angle ϵ (a). The inclined surface element has the effective angles ι' and ϵ' (b).

Atmospheric Correction

As the Martian atmosphere has a big impact on the photometric behaviour of the surface shading, atmospheric correction of the images has to be performed. The contribution of the Martian atmosphere is mainly controlled by its aerosol content [6], with minor contribution of high altitude haze [7]. The atmospheric correction of the images is performed by the `lookup_pathfinder` and the `lookup_detach` programs, using lookup tables to find value pairs of albedo and reflectivity for different observation geometries and optical depth, precalculated based on Mars Pathfinder measurements [8]. Parameter values for the optical depth can determined from the HRSC scenes using the shadow method or the stereo method [9, 10].

Topographic Correction

In many applications of remote sensing images, the cosine correction is applied to reduce the topographic effect from the data. Teillet et al. [11] describe a semi-empirical algorithm for topographic correction of satellite data, the `C-correction`, taking into account the indirect sky illumination on the surface. In a similar way, the Minnaert model can be used to perform a topographic correction:

$$\varrho = \varrho' \frac{\mu_0^k \cdot \mu^{k-1}}{\mu_0'^k \cdot \mu'^{k-1}} \quad (1)$$

with ϱ' being the reflectance on the inclined surface depending on the angles ι' and ϵ', ϱ the corrected reflectance for a horizontal plane, μ and μ_0 the substitutions for $cos(\epsilon')$ and $cos(\iota')$. The parameter k can be determined empirically by linearizing the Minnaert equation logarithmically [12].

Results

On our poster, HRSC images corrected with the cosine correction, the C-correction and the Minnaert-correction will be compared with the original image. Color stability is a first good indicator for the retention of the spectral characteristics of each image band (see Fig. 2). For numerical comparison and validation of the methods, the standard deviations of the reflectance values before and after the corrections are compared, while a statistical regression analysis on the reflectance values shows the reduction of the topographic effect.

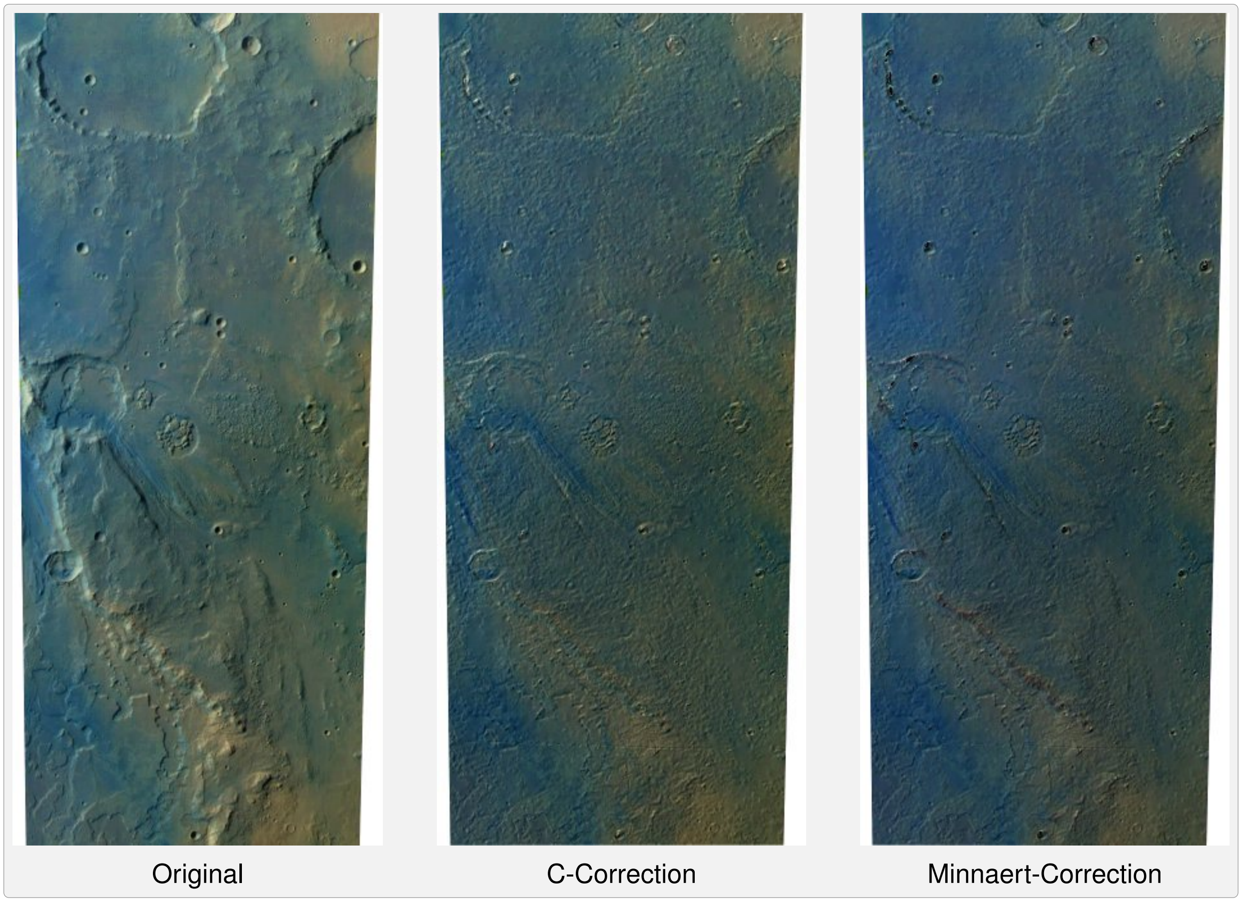

Figure 2: comparison of the original HRSC sequence of orbit 901 (left) and the topographically corrected images (middle and right). A contrast-stretched false color representation of the HRSC scene has been chosen.

Acknowledgements

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