EPSC Abstracts
Vol. 6, EPSC-DPS2011-648, 2011
EPSC-DPS Joint Meeting 2011

HRSC Topographic Correction by Minnaert Photometric Modeling

S. Walter (1), R. Kirk (2), P. C. McGuire (3), G. Neukum (1); (1) Freie Universitaet Berlin, Institute for Geological Sciences, Berlin, Germany (sebastian.walter@fu-berlin.de); (2) U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ, USA; (3) University of Chicago, Dept. of the Geophysical Sciences, Chicago, IL, USA

Introduction

In a systematic approach, we want to use the exact orientation information of an image sequence of the High Resolution Stereo Camera (HRSC, [1], [2]) to derive a synthetic photometric model and compare it with the recorded HRSC image. This model can serve for several purposes, one of which would be the isolation of albedo features from the topographic shading effects.

Atmospheric Correction

The contribution of the Martian atmosphere is mainly controlled by its aerosol content (Lemmon et al. [3]). In this work, we minimize the extinction effect of the atmosphere by choosing a test area with a known value for the optical depth and correcting the image accordingly. The Mars Exploration Rover *Spirit* measured a τ value of 0.9 during its presence in the Victoria crater in 2004, while at the same time the HRSC image of orbit 24 was acquired (Figure 1).

Photometric Surface Model

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 for every single pixel. They are saved in floating-point images exactly aligned to the original image sequence and can then be transformed 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. These illumination parameters can be used to calculate synthetic surface models by use of empirical or physical photometric models.

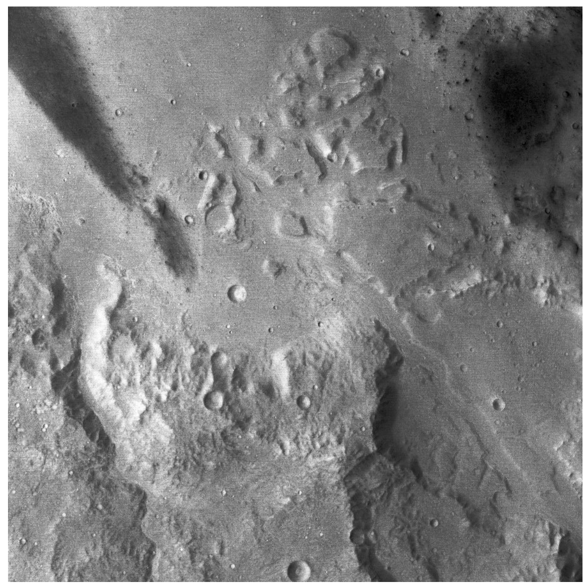

Figure 1: Subset of HRSC orbit 24 (Gusev crater), at the time of Spirit's atmospheric optical depth measurements.

Parameter Estimation

Teillet et al. [4] describe a simple but robust topographic correction method based on the *Minnaert* photometric model, suitable for the statistical determination of the necessary parameters.

Minnaert's law is given by:

$$r_M(\iota, \epsilon, \psi) = A_M \mu_0^k \mu^{k-1} \quad (1)$$

with r_M being the reflectance on the surface depending on the angles ι, ϵ and the wavelength ψ, A_M the *Minnaert Albedo*, μ and μ_0 the substitutions for cos(ϵ) and cos(ι). The parameter k can be determined empirically by linearizing equation 1 logarithmically, leading to equation 2:

$$log(r_M \mu) = log(A_M) + k \times log(\mu_0 \mu) \quad (2)$$

As this method is sensitive to outlier values and the Minnaert model only applies for moderate phase angles, values with high incidence angles are excluded. There could be an error in the regression estimate of k if the albedo varies systematically over the *x* range. To minimize this effect, values with low slope angles are also filtered out. A scatter plot of such a regression for the image subset is shown in Figure 2.

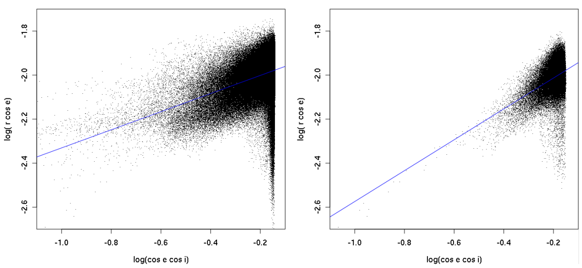

Figure 2: Linear regression of the sample area before (left) and after (right) high incidence and low slope filtering.

The slope of the blue regression line with a value of 0.7 reflects the value of Minnaert's k parameter for the given area. Together with the exact incidence and emergence angles equation 1 can be used to create a synthetic model of the surface. Dividing the original image by the synthetic model, the resulting albedo image isolated from the surface relief is shown in Figure 3.

Outlook

As Veverka et al. [5] point out, the linearization of the Minnaert equation could lead to improper weighting of the data points. To address this issue, the initial guess of the k parameter could be refined by a subsequent nonlinear fit.

For a systematic approach, the atmospheric contribution has to be determined in a preceding processing step. Hoekzema et al. [6] describe robust methods to derive the optical depth of the Martian atmosphere.

Acknowledgements

We gratefully acknowledge funding of this work by the German Space Agency, on behalf of the German Federal Ministry of Economics and Technology.

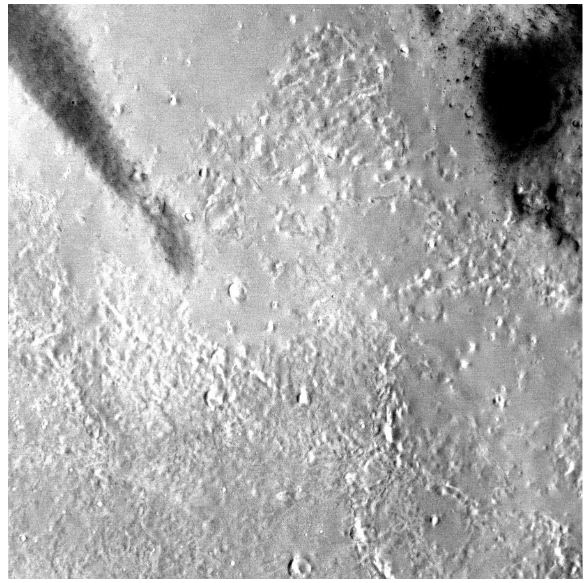

Figure 3: Test image after division by synthetic Minnaert surface.

References

[1] Neukum, G. et al.: HRSC: the High Resolution Stereo Camera of Mars Express, *ESA SP 1240*, pp. 17-36, 2004.

[2] Jaumann, R. et al.: The high-resolution stereo camera (HRSC) experiment on Mars Express: Instrument aspects and experiment conduct from interplanetary cruise through the nominal mission, *EPSL 55*, pp. 928-952, 2007.

[3] Lemmon, M. T. et al.: Atmospheric Imaging Results from the Mars Exploration Rovers: Spirit and Opportunity, *Science 306*, pp. 1753-1756, 2004.

[4] Teillet, P. M. et al.: On the slope-aspect correction of multispectral scanner data, *CJRS 8*, pp. 84-106, 1982.

[5] Veverka, J. et al.: Minnaert Photometric Parameters for the Satellites of Uranus, *Icarus 78*, pp. 14-26, 1989.

[6] Hoekzema, N. M. et al.: Optical depth and its scale-height in Valles Marineris from HRSC stereo images, *EPSL 294*, pp. 534-540, 2010.