PHOTOMETRIC LAMBERT CORRECTION FOR GLOBAL MOSAICKING OF HRSC IMAGE DATA

S. H. G. Walter (sebastian.walter@fu-berlin.de), G. Michael, S. van Gasselt, T. Kneissl, Planetary Science and Remote Sensing Group, Institute for Geological Sciences, Department of Earth Sciences, Freie Universitaet Berlin, Malteserstr. 74-100, 12249 Berlin, Germany

Introduction: The High Resolution Stereo Camera (HRSC) is a push-broom image sensor onboard Mars Express recording the Martian surface in 3D and color [1, 2]. Being in orbit since 2004, the camera has obtained over 3,600 panchromatic image sequences covering about 70% of the planet's surface at 10-20 m/pixel. The composition of an homogenous global mosaic is a major challenge due to the strong elliptical and highly irregular orbit of the spacecraft, which often results in large variations of illumination and atmospheric conditions between individual images. For the purpose of a global mosaic in the full Nadir resolution of 12.5 m per pixel we present a first-order systematic photometric correction for the individual image sequences based on a Lambertian reflection model.

Example region: To give an example for the effect of the photometric correction, we assemble a mosaic from the uncorrected images and compare it with the mosaic of the photometrically corrected images. The planned global HRSC image mosaic effort will be based on the USGS MC-30 quadrangle scheme. For this comparison we chose the half-quadrangle MC-10 east (MC-10E) as the sample area. It covers the eastern part of the Lunae Palus Region with the the dark basin of Chryse Planitia to the east and parts of the Kasei Valles to the west. Furthermore, it covers the high albedo region of Lunae Planum in the south. As such it contains typical features for geomorphologic investigations like low and high albedo areas as well as steep topography and homogenous planes.

HRSC spectral reflectance: During the radiometric calibration of the HRSC data, values for the reflectance scaling factor and the reflectance offset are added to the individual image labels. These parameters can be used for a linear transformation from the original DN values into spectral reflectance values. The spectral reflectance varies with the solar incidence angle, topography (changing the local incidence angle and therefore adding an exta geometry factor for each ground pixel), the bi-directional reflectance distribution function (BRDF) of the surface, and atmospheric effects. Mosaicking the spectral values together as images sometimes shows large brightness differences (see Fig. 1a for the mosaic of the sample region). The major contributor to the brightness differences between two images is the differing solar geometry due to the varying time of day when the individual images were obtained. This variation causes two images of the same or adjacent areas to have different image brightnesses. The histogram of the mosaic in Fig. 1b shows many maxima of the brightness distribution and is obviously not showing the true albedo distribution of the surface. A scatter plot of the spectral reflectance versus the incidence angle (measured as the angle between the Sun and the surface normal) reveals a high (negative) correlation between the pixels' brightness values and their incidence angles (see Fig. 1c).

Photometric correction: As a first-order correction for the varying illumination conditions and resulting brightness variations, the images are corrected for the solar incidence angle by assuming an ideal diffusely reflecting behaviour of the surface. This correction requires the calculation of the solar geometry for each image pixel by an image-to-ground function. For the calculations we are using the VICAR framework [3] and the SPICE [4] library. Under the Lambertian assumption, the reflectance diminishment resulting from an inclined Sun angle can be corrected by dividing the measured reflectance by the cosine of the illumination angle. After rectification of the corrected images, the individual images are mosaicked together (see Fig. 1d). The overall visual impression shows a much better integration of the individual image sequences. Fig. 1e shows the histogram for the mosaic of the corrected images consisting of a narrower bimodal distribution of the values. A small maximum at $\sim$0.2 and a larger maximum at $\sim$0.3 represent the low albedo and the high albedo features from the sample area, respectively. As can be seen in the scatter plot of Fig. 1f, the correction resolves the direct correlation between the reflectance and the incidence angles from the data.

Conclusion/outlook: The Lambert correction shows significant improvements for the purpose of image mosaicking. The correction does not account for topographic, atmospheric or BRDF influences to the measurements. Topographic effects could be treated as described by [5] and [6]. Since the main purpose of the global HRSC image mosaic is the application for geomorphologic studies with a good visual impression of the albedo variations and the topography, the remaining distortions at the image seams can be equalized by non-reversible image matching techniques [7].

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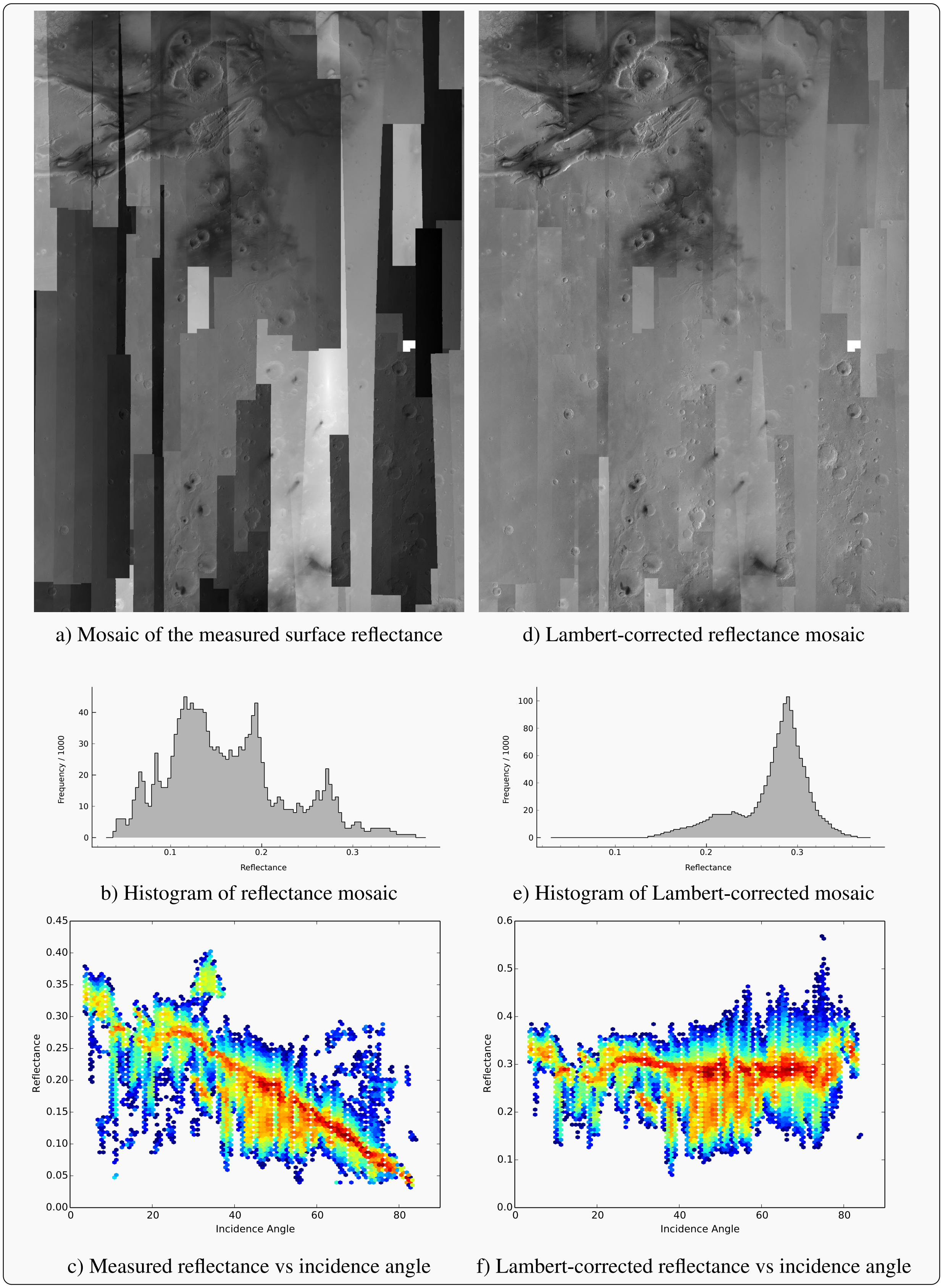
References: [1] G. Neukum et al., ESA SP 1240 (2004), 17–35. [2] R. Jaumann et al., *PSS* 55 (2007), 928–952. [3] URL: www-mipl.jpl.nasa.gov/external/vicar.html. [4] C. H. Acton, *PSS* 44 (1996), 65–70. [5] S. Walter et al., *LPSC XLII*, 2011, #2198. [6] S. Walter et al., *LPS*, 2012 XLIII, #2322. [7] G. Michael et al., *this conference*, #2387.



a) Mosaic of the measured surface reflectance
d) Lambert-corrected reflectance mosaic
b) Histogram of reflectance mosaic
e) Histogram of Lambert-corrected mosaic
c) Measured reflectance vs incidence angle
f) Lambert-corrected reflectance vs incidence angle

Figure 1: Mosaicking results from the example region (MC-10E quadrangle, Lunae Palus region). Panchromatic HRSC Nadir images available as of December 2014 have been used. Top: uncorrected (left) and Lambert-corrected (right) mosaic. Middle: histograms of the respective mosaics. Bottom: scatter plots of the respective reflectance values versus the incidence angles.