

**REMOVAL OF THE TOPOGRAPHY EFFECT FROM PHASE-RATIO IMAGES USING LROC NAC DATA.** S. Velichko<sup>1</sup>, V. Korokhin<sup>1</sup>, V. Kaydash<sup>1</sup>, Yu. Shkuratov<sup>1</sup>, G. Videen<sup>2</sup>, <sup>1</sup>Institute of Astronomy of V.N.Karazin Kharkiv National University, Sumska 35, 61022 Kharkiv, Ukraine (v.v.korokhin@gmail.com), <sup>2</sup>Space Science Institute, 4750 Walnut St. Suite 205, Boulder CO 80301, USA.

**Introduction:** The phase-ratio technique is an effective tool for characterization of lunar surface structure unresolved in images [1-3]. A phase-ratio image shows a distribution of slopes of phase curves over the studied area and can be used, e.g., for studying lunar surface evolution [2,4] or for searching for areas on the Moon with anomalous photometric characteristics [5]. This technique implies dividing images acquired at different phase angles. Such images, being derived from observations carried out under different photometric conditions, are significantly distorted by the influence of topography. False variations of phase ratio caused by local slopes of a surface relief can exceed the variations conditioned by the surface structure (see Figs. 1 and 2). For high resolution data (0.5 m/pixel) of the LRO Narrow Angle Camera (NAC), the problem of accounting for the topography effects is aggravated by the absence of a Digital Elevation Model (DEM) with a suitable resolution sufficient to resolve features such as small craters, scarps, hills, etc. Even the best global DEMs, e.g., SLDEM2015 [6], have dramatically insufficient resolution for compensation of the topography influence on NAC images (Fig. 3). We propose a technique for removal of the effects on phase-ratio distributions using LROC NAC images.

#### The algorithm:

*Step #1. Transformation of initial NAC images to the cylindrical equirectangular projection.* We use the Library of Planetary Cartography (LPC) [7] for this purpose. For the transformations, a constant elevation equal to the average value calculated from [6] for the whole scene is used.

*Step #2. Calculation of local parallax shifts* is performed using the robust correlation algorithm. Typically, we use a round, sliding aperture with  $R = 10$  pixels on the 1<sup>st</sup> iteration and  $R = 5$  pixels on the 2<sup>nd</sup> one. This step produces maps of parallax shifts along the X and Y axes corresponding to the longitudinal and latitudinal directions.

*Step #3. Calculation of the DEM* (Fig. 6) is carried out from an analysis of the parallax-shift maps. For each point of the surface, using the LPC [7], we fit the altitude (declination from mean altitude from Step #1), which provides the parallax shifts coinciding with the ones obtained in Step #2.

*Step #4. Compensation for local slopes on photometric data* is performed by applying the photometric function for calculation of the equigonal

albedo  $A_{eq}$  [2] (Fig. 4) from the apparent albedo  $A$  (radiance factor) (Fig. 1)  $A_{eq}(\alpha) = A(\alpha, \beta, \gamma) / D(\alpha, \beta, \gamma)$ , where  $\alpha$  is the phase angle,  $\beta$  and  $\gamma$  are the photometric latitude and longitude [2] calculated with taking into account local topography slopes using the LPC [7] and maps of slopes derived from DEM obtained in Step #3, and  $D(\alpha, \beta, \gamma)$  is semi-empirical Akimov's disk function [2].

**Results:** We demonstrate application of this technique to a phase-ratio image of a fresh lunar crater formed on September 11, 2013 (~34 meters in diameter with coordinates 17.167°S, 339.599°E) [8] (the arrow in Fig. 1). Comparison of Figs. 2 and 5, helps to avoid over-interpretation of phase-ratio changes inside and around the old craters in the neighborhood just to the north of the fresh crater that is located on the degraded rim of an old crater. Spots of lower values of the phase-ratio  $f(63^\circ)/f(30^\circ)$  inside of the old craters (Fig. 2, without our DEM compensation) disappear in Fig. 5 when accounting for the DEM. This reveals a more symmetric pattern of ejecta blanket of the new crater and could be interpreted as the absence of optical roughness changes in the neighborhood of the old craters due to possible accumulation of near-ejecta material. Large-scale variations of the phase ratio due to topography over the whole scene are also suppressed (cf. Figs. 2 and 5), and the remaining pattern becomes free of artifacts and largely corresponds to real optical roughness [8].

**Conclusion:** We propose a method of removal of the topographic influence on LROC NAC photometric images. The method also provides additional high-quality information about topography of studied areas (cf. Figs. 3 and 6). This technique can be very useful for improvement of the quality of remote-sensing methods for surfaces with complex topography.

**References:** [1] Shkuratov et al. (1994) *Icarus* 109, 168–190. [2] Shkuratov et al. (2011) *PSS* 59, 1326–1371. [3] Kaydash et al. (2012) *JQSRT* 113(18), 2601–2607. [4] Shkuratov et al. (2012) *Icarus* 218, 525–533. [5] Shkuratov et al. (2010) *Icarus* 208, 20–30. [6] Barker et al. (2016) *Icarus* 273, 346–355. [7] Shalygin et al. (2003) *LPSC34* #1946. [8] Kaydash et al. (2018) *Icarus* 311, 258–270.

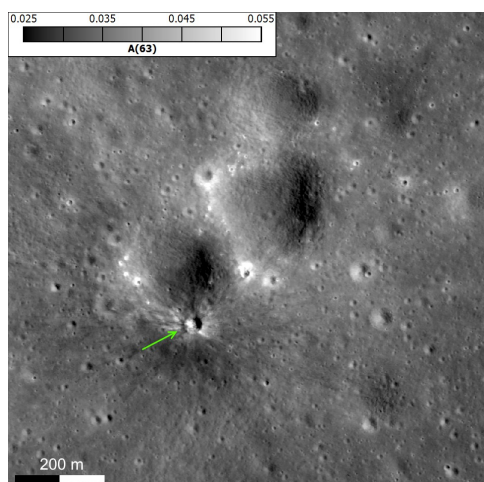


Figure 1. A fresh crater indicated by the arrow on the NAC image M1152000776LC

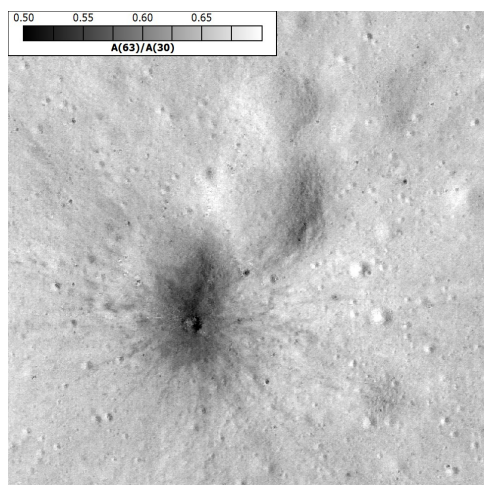


Figure 2. An initial phase ratio  $f(63^\circ)/f(30^\circ)$  image (M1152000776LC/M1151986536LC)

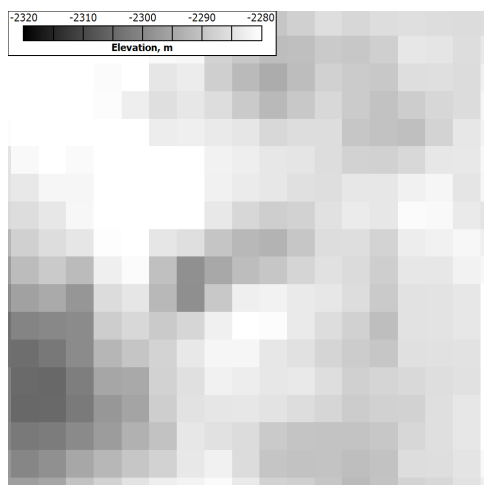


Figure 3. A fragment of SLDEM2015 [6] for the scene under study

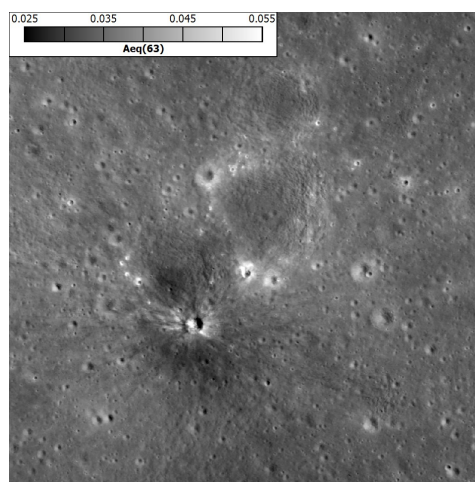


Figure 4. Equigonal albedo image with compensated topography effect

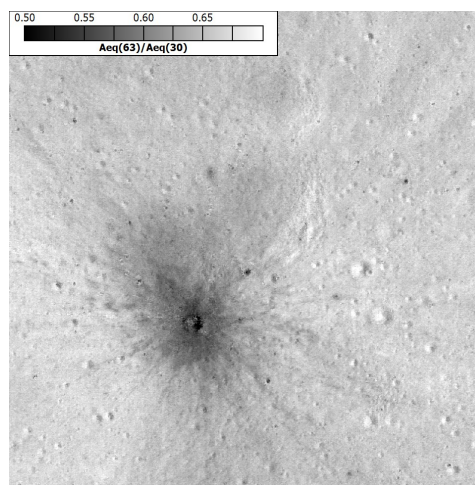


Figure 5. Resulting phase ratio  $f(63^\circ)/f(30^\circ)$  image with compensation for the topography effect

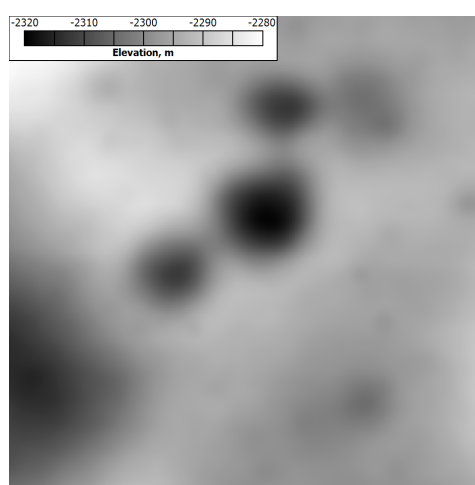


Figure 6. An elevation map obtained from parallax shifts