HIGH-RESOLUTION TOPOGRAPHY RECONSTRUCTION WITH THE IMPROVED PHOTOCLINOMETRY METHOD: A LOOK AT SMALL LUNAR CRATERS. N. V. Bondarenko[1,2], I. A. Dulova[1], [1]IRE, NAS of Ukraine, 12 Ak.Proskury, Kharkov, 61085, Ukraine, [2]Earth and Planetary Sciences, University of California - Santa Cruz, 1156 High Street, Santa Cruz, CA, 95064, USA (nbondar@ucsc.edu).

Introduction: LROC camera onboard LRO mission to the Moon is generating a huge collection of surface images with high spatial resolution. We demonstrate the use of the topography models of lunar surface retrieved from LROC NAC images with the improved photoclinometry method for the study of very small (5 m – 12 m in diameter) impact craters. The improved photoclinometry method is the most mathematically rigorous and allows calculation of the most probable relief according to the source images.

We identified population of small craters for three surface areas and compared their size frequency distributions along with calculated craters depths.

The improved photoclinometry method: The method involves known dependence of the surface facet brightness on its orientation. In contrast to “traditional” photoclinometry (initially proposed by Van Diggelen [1] and solving a mathematically incorrectly posed problem, see [2]), the method of improved photoclinometry is based on the Bayesian statistical approach [3]; it produces the most probable surface height map consistent with source images. Spatial resolution of the retrieved topography is close to the resolution of the source images. The accuracy of calculated heights depends on these images’ noise level (see [4] for more details). At least two images with different solar azimuths are needed to calculate the heights distribution. Solar azimuths normal to each other are the most preferable observational conditions.

To calculate the relief from LROC NAC images we follow procedure described in details in [5]. We calculated surface height distribution through the iteration procedure applying a finite difference method to solve the Poisson equation [5]. We consider Lommel−Seeliger law (isotropic single scattering model) as a priory known photometric function for the calculations. This law appears to be the most preferred photometric function for the purposes of the relief retrieval in mare areas [6].

Source data: We applied the improved photoclinometry method to three 1 × 1 km surface areas in Oceanus Procellarum. For every area we processed three images, which were portions of LROC [7] images M1175752603RE, M1167482442RE (Fig. 1A, 1B), and M1226326635RE [8] for sites A and B; and images M183940370LE, M1167560594LE (Fig. 1C) and M1269957117LE [8] for site C. One of images pair gives the difference between solar azimuth equal to 84.2º and 102.0º for sites A and B, and site C, respectively. Images were transformed to the same sampling of 1 m/pixel and co-registered to each other. Actual resolution is ~1.4 m for sites A and B, and 1.6 m for site C. Initial surface albedo map was calculated at every pixel as an average of three estimates obtained from the three corresponding images using assumed photometric function and known observational conditions.

Results: Topography of areas A, B and C calculated from three source images are shown in Fig. 1 (lower panes). Statistics for heights distributions for sites under study is listed in Table 1.

Table 1. Statistical characteristics of retrieved heights *H* for surface sites A, B and C.

Area		A	B	C
H, m	min	-18.86	-14.69	-22.40
	max	13.97	10.59	20.86
	σ	3.52	3.25	6.26

“min”, “max” – minimum and maximum values; σ - the standard deviation.

We picked up small craters in lunar surface sites under study by an automatic procedure during the process of relief calculations. The automated algorithm searches for concave symmetric shapes in intermediate heights distributions through iteration procedure. The algorithm also checks the stability of the feature shapes through the iterative convergence process and used this stability as an additional criterium for crater identification.

Craters size-frequency distributions for areas under study are shown in Fig. 2. It is obvious that distribution of small craters in site A exhibits a lack of relatively large craters. However, such distributions in sites B and C are very close to each other. The observed differences illustrate the non-uniformity of population of small craters [9] and complexity of geologically recent processes causing their obliteration.

Frequency distributions of calculated depths for craters in sites A and B with diameter of 5 m (Fig. 3a) and with diameter of 7 m (Fig. 3b) point to systematically shallower craters in site A. It can be related to different to site B properties of surface material.

Comparison between particular calculated heights raises a question about uncertainties in an accuracy of these estimates. Since the relief reconstruction procedure involves the second derivatives of height, very small and deep/elevated features are expected to have higher errors. Model calculations gave possible heights errors of ~ 21 cm and ~17 cm for surface features 5 m and 7 m in size, respectively. These error estimates are obtained in relation to the heights root-mean-square deviation for the whole surface area under study (Table 1). However, local accuracy for small-size features is expected to be better. It depends on relation between observational conditions and particular heights/slopes and varies through the area. This problem is still under study.

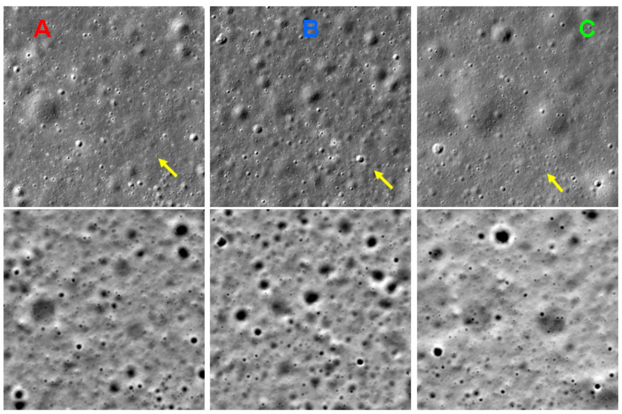

Fig. 1. Lunar surface areas under study (1 × 1 km), **upper row**: initial image, illumination direction is marked with yellow arrow; **lower row**: calculated relief, darker shades correspond to lower heights; **A)** center coordinates: 41.12ºN, 310.04ºE, **B)** center coordinates: 41.18ºN, 310.1ºE (portions of M1167482442RE image), **C)** center coordinates 41.3ºN, 298.11ºE (portion of M1167560594LE image).

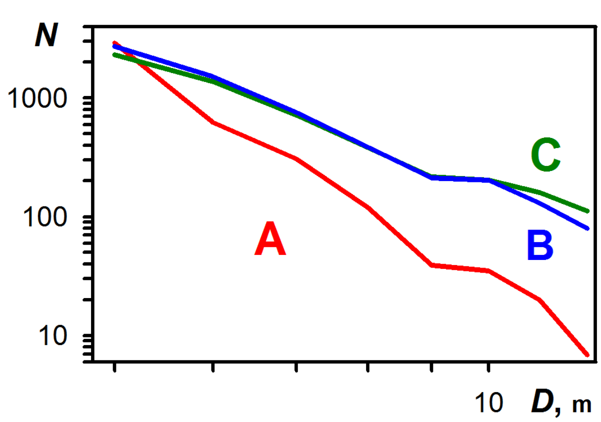

Fig. 2. Differential size-frequency distributions of craters in areas A, B, and C (Fig. 1).

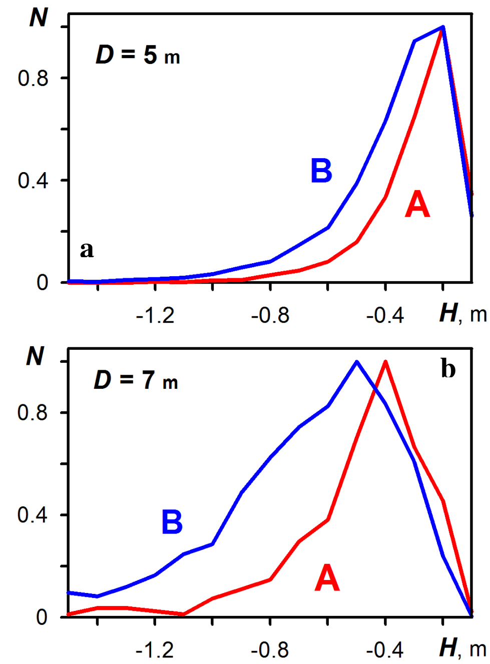

Fig. 3. Craters depths *H* frequency *N* distributions for craters in sites A and B with diameter of 5 m (a) and with diameter of 7 m (b).

Conclusions: Our test results demonstrate that the topography of the lunar surface calculated with the improved photoclinometry method from LROC NAC images enables detailed quantitative studies of small-scale features on lunar mare surface areas, including small craters. Such topographic data allow detection of shallow old craters hardly recognizable in the images. The topographic data can be used, for example, for the studies of crater degradation, in a manner similar to [10], but for much smaller craters. Such studies would be helpful for understanding regolith alteration and transport processes on the lunar surface.

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