THE ACCURACY OF THE SURFACE RELIEF RETRIEVED WITH THE IMPROVED PHOTOCLINOMETRY METHOD AT LARGE AND SMALL SCALES. I. A. Dulova\textsuperscript{1} and N. V. Bondarenko\textsuperscript{2},
\textsuperscript{1}Institute of Radiophysics and Electronics, NAS of Ukraine, 12 Ak. Proskury, Kharkiv, 61085, Ukraine, \textsuperscript{2}Earth and Planetary Sciences, University of California – Santa Cruz, Santa Cruz, CA, 95064, USA, nbondar@ucsc.edu.

Introduction: The interpretation of images taken during space missions for different studies of planetary surfaces often requires knowledge of surface topography. Images themselves can serve as a source of topographic information. The procedure for recalculation of the image’s brightness into surface heights (photoclinometry) was proposed by Van Diggelen [1]. This procedure is based on a priori known dependence of the surface facet brightness on its orientation. The method is still widely used (for example, [2, 3]), though as shown in [4] in its initial formulation [1] it seems to be a mathematically incorrectly posed problem. The improved photoclinometry method (IPM) allows the most probable surface relief retrieval using images. Number of initial images is not limited. At least two images with different solar azimuths (the closer the difference between them to 90\(^\circ\), the better) are needed to define the height gradient.

In this work we discuss the accuracy of the relief retrieved with the IPM at large and small spatial scales.

Heights from Images: The improved photoclinometry method uses following approach: observed images’ brightness has to be recalculated into the slopes field \(t(x,y)\) using a priori known brightness-tilts relation. The gradient of true surface heights \(H(x,y)\) is different from calculated slopes due to a random registration noise \(\delta(x,y)\):

\[
\nabla H(x,y) = t(x,y) - \delta(x,y). \tag{1}
\]

IPM uses the Bayesian inference approach [5] to find the most probable statistical estimation of true heights. We consider the true relief and the image noise to be realizations of stationary Gaussian processes.

Test Calculations: We generated two source surfaces having sizes of 1024\(\times\)1024 px. One surface presents the large-scale topography, it is considered as a background surface \(B\). It was created as a realization of stochastic Wiener process sequentially smoothed with 64 px circular window (Fig.1a). Second source surface is a lunar-like cratered surface \(C\) shown in Fig. 1b. Both surfaces were normalized to heights root-mean-square value \(\sigma_0 = 1\), an average value of their heights is zero. Surface \(C\) can be considered as a kind of “geological noise”. To calculate combined model relief, we add both surfaces according to the \(\sigma_C/\sigma_B\) ratio (CBR). We calculated model reliefs for CBR = 1 (Fig. 1c), 0.25, 0.5, 1 (Fig. 1c), 2, 4, 8.

Every such model relief was used to generate three images illuminated along directions with azimuths of 0\(^\circ\), 135\(^\circ\) and 225\(^\circ\). We add possible noise of registration in every image. Signal-to-noise ratio SNR was equal to 1, 10, 50 and 100. We assumed the Lambert’s law as an a priori known photometric function of the surface. For these experiments, surface albedo was the same over the surface under study. Simulated images were used to retrieve surface heights using IPM realization based on numerical solution of the Poisson equation with the finite difference method.

To estimate an accuracy of heights retrieved with IPM we calculate deviations of calculated relief from the model one. Spatial distributions of absolute values of these differences are shown in Fig. 2 for model relief with CBR = 8, 1, 0.125 and source images having SNR = 1, 50.

To distinguish between large- and small-scale topography we generated a hierarchy of band-pass-filtered digital terrain models DTMs. Each hierarchy member was obtained by sequential smoothing DTM with a progressively larger window of the circular shape. Thus, we obtain the set of three large-scale (L) and small-scale (S) members according to the smoothing window diameters, \(W_1 = 31\) px, \(W_2 = 63\) px, \(W_3 = 127\) px.
Small-scale ($S$) topography was calculated as difference between initial DTM and corresponding large-scale member. Table 1 presents values of heights errors calculated separately for $L$ and $S$ members for different smoothing level. It shows that errors inherit to $S$ is an order of magnitude lower comparing to $L$ related errors. Spatial distributions of absolute values of $L$ and $S$ heights errors for model relief with CBR = 1 are shown in Fig. 3.

**Conclusions:** Heights errors of small-scale retrieved topography is 2-6% if SNR $\geq$ 10. Height errors of large-scale topography can reach ~90%, but in cases of low “geological noise”, CBR $\leq$ 0.5, they do not exceed 20%.