Planetary and Space Science 58 (2010) 1298–1306

Contents lists available at ScienceDirect

Planetary and Space Science

journal homepage: www.elsevier.com/locate/pss

Removal of topographic effects from lunar images using Kaguya (LALT) and Earth-based observations

Viktor V. Korokhin [a,*], Yuriy I. Velikodsky [a], Yuriy G. Shkuratov [a], Vadym G. Kaydash [a], Sergey Y. Gerasimenko [a], Nikolai V. Opanasenko [a], Gorden Videen [b], Carle Pieters [c]

[a] Institute of Astronomy, Kharkiv V.N. Karazin National University, 35 Sumskaya Street, Kharkiv 61022, Ukraine
[b] Space Science Institute, 4750 Walnut Street, Suite 205, Boulder, CO 80301, USA
[c] Department of Geological Sciences, Brown University, Providence, RI 02912, USA

ARTICLE INFO

Article history:
Received 9 February 2010
Accepted 20 May 2010
Available online 26 May 2010

Keywords:
Lunar surface
Photometry
Albedo
Phase function
Topography
Photoclinometry

ABSTRACT

Lunar images acquired at non-zero phase angles show brightness variations caused by both albedo heterogeneities and local topographic slopes of the surface. To distinguish between these two factors, altimetry measurements or photoclinometry data can be used. The distinction is especially important for imagery of phase-function parameters of the Moon. The imagery is a new tool that can be used to study structural anomalies of the lunar surface. To illustrate the removal of the topographic effects from photometric images, we used Earth-based telescopic observations, altimetry measurements carried out with the Kaguya (JAXA) LALT instrument, and a new photoclinometry technique that includes analysis of several images of the same scenes acquired at different phase angles. Using this technique we have mapped the longitudinal component of lunar topography slopes (the component measured along the lines of constant latitude). We have found good correlations when comparing our map with the corresponding data from Kaguya altimetry. The removal of the topographic surface properties allows for the study of the phase-function parameters of the lunar surface, not only for flat mare regions, but for highlands as well.

1. Introduction

An important goal of photometric studies of planetary images is to identify the physical properties of the material covering the surface of planetary bodies. One approach to this problem is to determine the photometric function, i.e., the function of how the intensity of light reflected from planetary areas varies with illumination and observation angles. The angle between vectors from the observed point to the light source and to the observer is the phase angle α. This is the most important angle variable in planetary photometry. The phase function is a component of the photometric function, which depends only on α (Hapke, 1993). The phase functions are determined by the complexity of the structure of the surface. Usually these phase functions have a single sharp maximum at $\alpha=0$ being locally smooth at other α. Therefore, they can be described with a few parameters. The simplest parameters are ratios of phase-function values at different phase angles α; these characterize the slopes of phase curves. The slope also may be characterized with parameters of an analytical curve used for fitting to brightness measurements (see below). Imagery of the Moon can be made in terms of phase-angle ratios for different pairs of α using original well calibrated brightness images. Such imagery is a relatively new and effective tool that can be used to study structural anomalies of the lunar surface (e.g., Shkuratov et al., 1994; Korokhin and Akimov, 1997; Kreslavsky and Shkuratov, 2003; Kreslavsky et al., 2003; Kaydash et al., 2009a, b). For instance, using photometric images acquired with Earth-based telescopes, weak swirls were found in the southern portion of Oceanus Procellarum (Shkuratov et al., 2010). The phase-angle-ratio images allow one to estimate spatial variations of the complexity of unresolved surface roughness and microtopography. However, the resolved topography spoils the images hampering their interpretation.

Brightness variations on images of the lunar surface depend on the spatial distributions of local topographic slopes, albedo (that is, a characteristic of the surface material composition), and the global illumination/observation geometry. The lunar resolved topography influences brightness spatial variations, since the local surface slopes, or height gradients, change the local incident i and emergent e angles. This effect can be especially significant at large phase angles. Removing the influence of the resolved topography requires data on local slopes. Suitable global lunar height distributions have been obtained recently with the Laser Altimeter (LALT) aboard the spacecraft Kaguya (JAXA) (Araki et al., 2009), which we use in our analysis. Photogrammetry, photoclinometry (shape-from-shading) or their combination are techniques that allow one to retrieve

* Corresponding author. Tel.: +38 057 707 5064.
E-mail address: dslpp@astron.kharkov.ua (V.V. Korokhin).

0032-0633/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.pss.2010.05.013