Introduction: The multispectral wide-angle camera (WAC), one of three instruments that comprise the Lunar Reconnaissance Orbiter Camera (LROC) [1,2] is a push-frame imager with seven bandpass filters. Two ultraviolet (UV) filters at 321 and 360 nm are imaged with a cross-track field of view of 60°, and are 4x4 summed on-chip for an effective resolution of 380 m/pixel from a 50-km orbit. Five visible filters (415, 566, 604, 643 and 689 nm) are imaged with separate optics and an effective resolution of 75 m/pixel from a 50-km orbit. In color mode, all filters are exposed simultaneously and 14 lines by 704 samples of each visible filter and 16 lines by 512 samples (summed to 4 lines by 128 samples) of each UV filter are read out. Continuous coverage is obtained by imaging at regular intervals consistent with the spacecraft’s motion. The WAC can also be operated in a monochrome mode in which 14 lines by 1024 samples are read out from only one filter. This mode is used primarily within 10° latitude of each pole. Color observations are consistently acquired at latitudes lower than 80° north and south so that the WAC provides global imaging coverage every 28 days. The spacecraft transitions between β = 90° (terminator orbit) and β = 0° (high noon) over a period of three months, resulting in a large range of illumination conditions at the equator. The wide field of view of the camera also means that within a single observation, phase angles can vary by ±35° cross-track, and the angular offset between filters results in non-uniform viewing geometries between filters (Fig. 1). Whether for global mosaicking or analysis of a single observation, an accurate photometric model is required for photometric normalization.

Photometric model: An empirical photometric function is used to describe the varying illumination conditions. We use the function described by [3]:

\[
\frac{I}{F} = \frac{u_0}{\mu + u_0} f(\alpha)
\]  

(1)

Where the dependence on incidence and emission angles are assumed to be fully described by the Lommel-Seeliger factor and the dependence on phase angle \( \alpha \) is described by a fourth-order polynomial with an additional exponential term to account for the opposition surge.

To study the photometric function at the seven wavelengths of the WAC, we selected observations over a 30 day period that included the \( \beta = 0° \) orbit. Observations in this time period cover phase angles from \( 0° \) to \( -95° \), as most WAC images are obtained with low emission angles at the center of the image. Our dataset included 4386 seven-band images reprojected to a common map format at 3 km/pixel (0.1 pixels/degree at the equator) and the incidence, emission and phase angles were determined at each pixel for each filter. Two large areas were chosen for comparison: a region of the highlands at \( \sim 155° \) E longitude and a portion of the high-titanium maria in Oceanus Procellarum. For both of these areas and for each filter, the empirical function was fit to dark- and flatfield-corrected DN divided by the Lommel-Seeliger factor vs. phase angle.

Results: The function of [3] provides a good match to the WAC phase curve at low phase angles (Fig. 2), but above 60-80° the Hillier function does not

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**Fig. 1.** Left: Image acquired crossing the subsolar point during the \( \beta = 0° \) orbit (M109168446CE, \( 0° \) lat, 10.5° E lon). The 689, 604, and 415 nm bands are in red, green, and blue. The high reflectance streak is the opposition surge, which is at a slightly different position in each filter because each filter has a different emission angle. Right: The phase, emission, and incidence angles of the 643 nm band in red, green, and blue. Phase and emission angles vary from 35° at the edges to 0° at the center, incidence angles range 0-3°.
describe the phase function. As more high-phase observations are examined, other functions will be explored. However, the fits at present provide an adequate method for creating photometrically normalized mosaics at intermediate phase angles (Fig. 3).

The WAC dataset provides an excellent look at the opposition surge that occurs at low phase angles due to shadow hiding and coherent backscatter [e.g. 4,5,6]. Comparison of the WAC derived phase curves at 321, 566 and 689 nm show that the opposition surge is relatively stronger in the UV, but its half-width shows little change with wavelength (Fig. 2). These observations are consistent with shadow hiding and the opposite of what would be expected for coherent backscatter.

**Future work:** The WAC will provide a rich dataset for photometric studies. As repeat coverage at different viewing geometries is obtained, we will examine the photometric function of small uniform areas, removing albedo as a variable. Additional observations at larger phase angles will also be obtained for mare regions, where coverage at present is restricted to <70°. These will be employed to produce a global, photometrically-corrected seven-band mosaic. The multispectral mosaic will be used to study mineralogic variations, particularly ilmenite and olivine, for which the wavelengths of the WAC are ideally suited. Once the more complete phase coverage is in hand, the photometric models of Hapke [7] will also be applied in order to examine the physical properties of the regolith.


Fig. 2. For each filter, the photometric function was evaluated for the highlands and the high-titanium mare Oceanus Procellarum. The phase angle was compared to dark- and flatfield-corrected DN divided by the Lommel-Seeliger factor to account for variations in incidence and emission angles (“Corrected DN”). Left: The highlands phase curve for the 321 nm band and the best-fit function. Center: Phase curve for Oceanus Procellarum at 321 nm. Right: Best fits for the 689, 566, and 321 nm filters for the highlands region, normalized to one at 30° phase.

Fig. 3. Twenty-eight days worth of coverage from the WAC (689, 566, and 321 nm filters in red, green, and blue). The preliminary photometric function described in this work was used to normalize all viewing geometries to 30°. Artifacts seen in the southern hemisphere include off-nadir slews that were left in as part of the testing.