PHOTOMETRIC EXPERIMENTS USING LROC WAC OBLIQUE OBSERVATIONS. H. Sato[1], B. W. Denevi[2], B. Hapke[3], M. S. Robinson[1], A. K. Boyd[1], [1]Arizona State University, 1100 S. Cady Mall, INTDS A116C, Tempe, AZ 85287-3603 (hsato@ser.asu.edu), [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, [3]University of Pittsburgh, Pittsburgh, PA.

Introduction: The Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) typically acquires observations in nadir pointing mode resulting in emission angles (instrument boresight intersection with the surface relative to the surface normal) of 30° at the edge of the 7-color field-of-view [1]. The WAC acquired a special series of forward pitch oblique (30°) observations that extend the range of available photometric angles near the lunar north pole (>50°N, Fig. 1). Additionally during frequent slew (roll) observations in the cross-track direction, the maximum emission angle increases from 30° to >60°. Both types of observations extend the range of emission and phase angles allowing more confident solutions to the Hapke photometric function [2].

Due to the systematic increase in incidence angles toward the pole and the WAC's narrow down-track field-of-view for each wavelength filter [1], the phase range decreases toward the pole resulting in significant uncertainties in photometric normalization and Hapke parameter calculations [3]. Lower phase images from the pole-facing pitch observations minimize such uncertainties. The increased emission angles are especially useful for determination of the parameter φ (filling factor) [4], because reflectance is more sensitive to porosity effects at high incidence and emission angles.

In this study, we estimate fitting residuals at northern high latitudes (>50°N) using the new WAC pitch observations to examine how the current Hapke photometric parameter maps [3,2] (by the "tile-by-tile" method based on nadir observations) are accurate for uncovered low phase ranges at high latitudes. From the slew observations we calculate the parameter φ to see the variation and the regional trends.

Methodology: About 280 images from pitch observations and 1370 images from slew observation (with slew angle >20°) were radiometrically calibrated to radiance factor (*I/F*) and incidence (*i*), emission (*e*), phase (*g*), latitude, and longitude of each pixel were computed based on the WAC stereo DTM (GLD100) [5] using USGS ISIS software [6]. A northern high latitude mosaic was produced by choosing the observation data point (composed of *I/F*, *i*, *e*, *g*) at the lowest phase angle among the multiple repeat observations for each pixel, from pitch and no-pitch observations independently for the comparison.

The model fitting residuals (*RS*) were derived by

$$RS = \left| median\left(\frac{I/F}{model}\right) - 1 \right|$$

where "model" is the Hapke model using the parameter maps [3]. *RS* was computed for each 1° by 1° tile. Lower *RS* means smaller residuals and higher fitting accuracy. The shadow pixels were ignored in *RS* calculation by removing *I/F* < 0.001 and *i* > 90°.

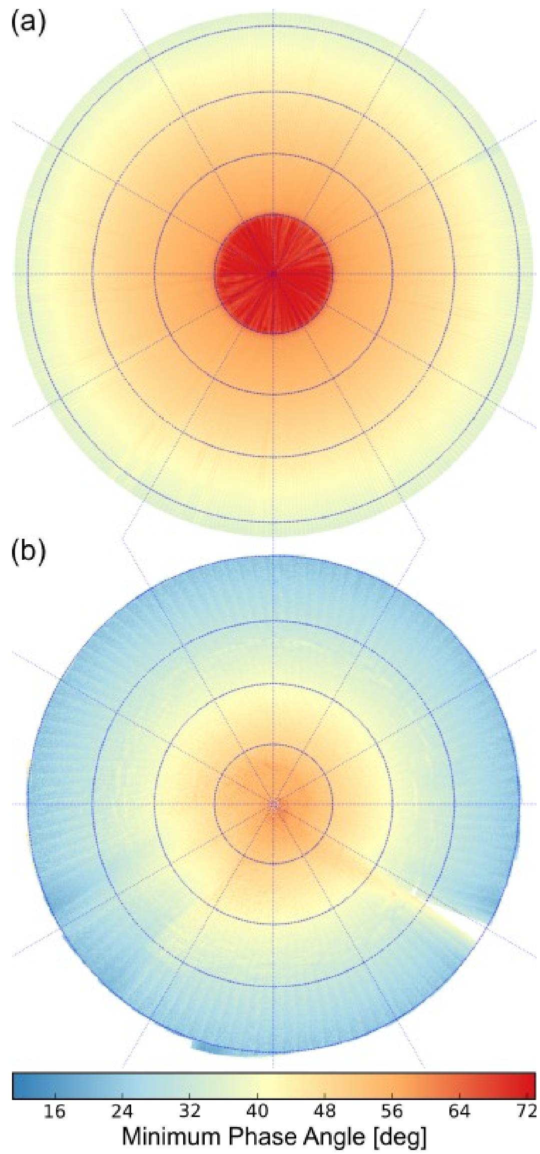

Figure 1. Minimum phase angle from (a) nadir observations and (b) pitch observations from 48°N to 90°N (643 nm).

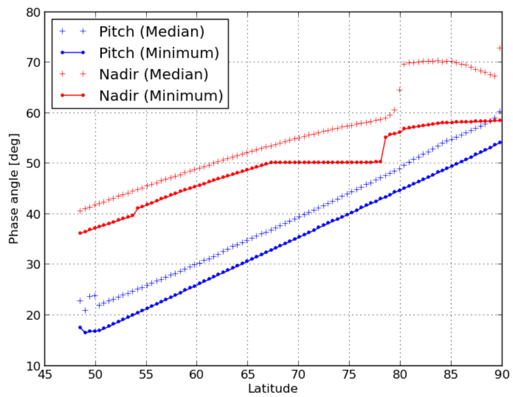

Figure 2. Minimum phase angle as a function of latitude (634 nm).

For the calculation of φ, we set the parameter $B_{S0} = B_{C0} = 0$ to ignore opposition effects and used observations at $g > 30°$. The θ was set to a constant value (=23.4) [3]. Then the remaining four free parameters (w, b, c, and φ) were determined by the same model fitting algorithm and the data reduction scheme applied in [3].

Results and Discussions: The pitch observations cover most areas for latitudes above 50°N (Fig.1b). The minimum phase angles in the covered areas decreased by an average of ~20° (Fig.2) relative to ~32 months of nadir observations (Fig.1a).

For the model fitting residuals (*RS*), the pitch observation are relatively higher than the nadir observation except latitude 74° – 80°N. The parameter maps [3] that were used are based on only the nadir observations that do not cover the low phase angles acquired by pitch observations, resulting in lower fitting accuracies in pitch observation data. The step-by-step parameter calculation [3] minimizes the influence of decreasing phase angle ranges toward the pole, but it is still hard to reproduce same residual levels in uncovered low phase range as the covered high phase data. New parameter maps based on the pitch observations will improve the low phase fitting residuals and the parameter accuracies at high latitudes.

The roll slew observations are sparsely distributed across the whole Moon (Fig.3) with a median slew angle of 26.5°. The dominant emission angle range is higher and wider in the slew observations relative to the nadir observations (Fig.4). The calculated parameter φ, based on the roll slew observations in addition to the nadir observations by the tile-by-tile method for a test area (33°S-20°N, 182-202°E) mostly ranges from 0.1 to 0.3 (the physically possible range is from 0 to 0.524 [4]). No obvious spatial variation was observed. Also in many tiles the φ becomes zero, possibly due to mathematical coupling [7]. An optimized calculation scheme for φ needs to be developed to overcome this effect.

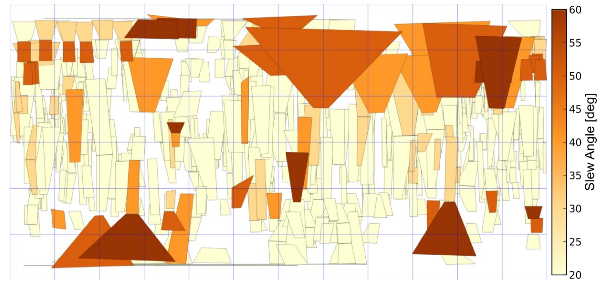

Figure 3. Distribution of the WAC slew observations for 0-360°E, 70°S-70°N. Color corresponds to slew at the beginning of image acquisition.

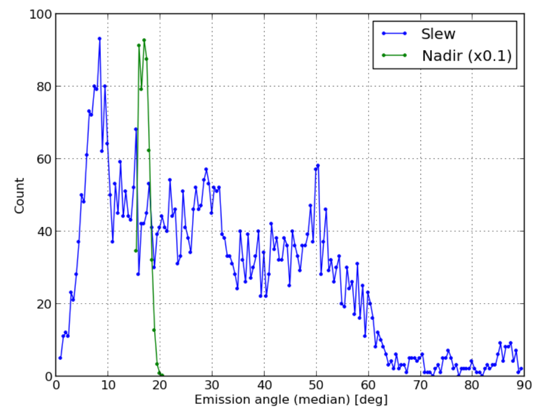

Figure 4. Histogram of emission angles (median for each 2° by 2° tile) from slew and nadir observations.

Future Work: Based on the pitch observations we will recalculate the parameter maps, and examine the surface properties at northern high latitudes (>40°N) using the new maps. Also we estimate the influence of this new parameter map on the normalized I/F at high latitudes. Additional series of pitch observations near the south pole will improve the parameter map accuracies as well as the north pole and allow accurate reflectance comparisons of the north vs south poles or the poles vs the equator.

The parameter φ calculation needs methodological improvements. Comparing the calculated values for WAC data and for the laboratory measured reflectance is also necessary for the ground truth.

References: [1] Robinson et al. (2010) *Space Sci. Rev.*, 150(1), 81-124. [2] Hapke (2012) *Cambridge Univ. Press*, NY. [3] Sato et al. (2013) *JGR*, submitted. [4] Hapke (2008) *Icarus*, 195(2), 918-926. [5] Scholten et al. (2012) *JGR*, 112(E03001). [6] Anderson et al. (2004) *LPS XXXV*, Abstract #2039. [7] Mustard and Pieters (1989) *JGR*, 94(B10), 13,619-13,634.