PHOTOMETRIC NORMALIZATION OF LROC WAC GLOBAL COLOR MOSAIC. H. Sato[1], B. W. Denevi[2], M. S. Robinson[1], B. W. Hapke[3], A. S. McEwen[4], LROC Science Operation Team[1], [1]Arizona State University, 1100 S. Cady Mall, INTDS A120A, Tempe, AZ 85287-3603 (hsato@ser.asu.edu), [2]Applied Physics Lab., Johns Hopkins University, Laurel, MD, [3]University of Pittsburgh, Pittsburgh, PA, [4]University of Arizona, Tucson, AZ.

Introduction: The Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) acquires near global coverage on a monthly basis. The WAC is a push-frame sensor with a 90° field of view (FOV) in BW mode and 60° FOV in 7-color mode (320 nm to 689 nm). WAC images are acquired during each orbit in nomally 10-12° latitude segments with cross track coverage of ~50 km. Before mosaicking, WAC images are radiometrically calibrated to remove instrumental artifacts and to convert at sensor radiance to I/F.

For mosaicking, images are photometrically normalized to common viewing and illumination angles (60° incidence, 0° emission, 60° phase), a challenge due to the wide-angle nature of the WAC where large differences in phase angle (±30°) are observed in a single image line. The light scattering properties of the lunar surface depend on incidence (*i*), emission (*e*), and phase (*p*) angles as well as soil properties such as single-scattering albedo and roughness that vary with terrain type and state of maturity [1]. In order to find the best photometric normalization, we tested 1) seven fitting functions, 2) source image filtering, and 3) a new photometric normalization scheme called "tile-by-tile method".

Fitting function test: Seven fitting functions were tested (see Table1). All functions include Lommel-Seeliger Correction (LSC) [(cos(*i*)/(cos(*i*)+cos(*e*))] [2], and Eq. 1, 2 and 5 fit two dimensions (I/F and *p*), while Eq. 3, 4, 6 and 7 fit four dimensions (I/F, *p*, *i* and *e*). An IDL fitting package (MPFIT) was used for parameter calculations. Starting parameters are obtained from tests on a mare area, by manually changing the initial starting value until the error reached a minimum value.

Orbit-to-orbit WAC frames overlap by at least 50%, thus high and low phase angles can be compared for the same ground in images taken 2 hours apart (very little change in incidence angle). For a test area in Oceanus Procellarum, Eq. 4 gave the best performance (Fig.1), but was less than optimal in other areas. Eq. 7 typically gives relatively stable parameters and results in the best (nearly seamless) mosaic. As we include data acquired over a larger time range to increase the phase coverage, more stable solutions will occur.

Source image filtering: As the fitting area increases, the accuracy of curve fitting decreases due to the larger variety of albedo, composition and topography. Incidence, emission and phase angles for each pixel are computed without yet taking the surface topography into account, thus sloped areas consequently include imprecise angle (*i*, *e*, *p*) values, resulting in data scatter that in turn affects fitting parameter calculations. We applied slope filtering and considered only pixels with slope angles less than one degree in a LOLA DTM [3] (Fig. 2).

Large local albedo contrasts, such as immature ejecta on a mature background, increase the scatter in the fitting. Filtering I/F values that lie away from the main data cloud results in substantially improved fits. Also the curve shapes for each albedo range vary, and such changes occur in a different manner in mare and highland regions (see Fig. 3). Albedo variations are

Table 1. Fitting functions

1	Lommel-Seeliger + Hillier function [4]
2	Lommel-Seeliger + 2nd order exponential decay
3	Modified 2nd order exponentioal decay
4	Lunar-Lambert ([5], eq.4) + 2nd order exponential decay
5	Lunar-Lambert ([5], eq.5) + Henyey-Greenstein single-particle or 2-lobed phase function
6	Basic Hapke function [6] with Henyey-Greenstein single-particle or 2-lobed phase function
7	Simplified Hapke function [6] with opposition surge term

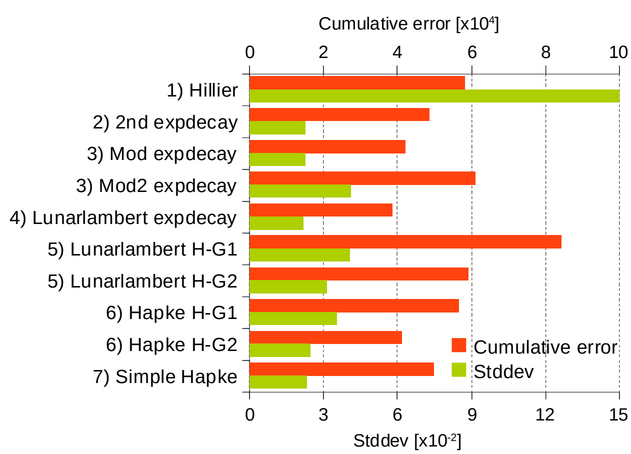

Fig. 1. Errors of photometric normalization at Oceanus Procellarum by various fitting functions. Difference between photometrically normalized I/F at low phase and high phase angle is given as an error at each pixel. Red corresponds to sum of whole pixel errors and green is standard deviation of the error.

dominantly controlled by maturity, FeO and TiO_2 values. The areas classified by these values have different photometric properties even with similar abedo ranges. Comparisons of the parameters for typical locations of high FeO, TiO_2 or optical maturity [1] may help elucidate the effects of surface composition and maturity on photometric properties.

However, albedo filtering requires a pre-existing albedo map aquired at the same wavelength as the target images to be filtered. Also the accuracy of the filter strongly depends on the performance of photometry in pre-existing image. Thus we employed a tile-by-tile method which doesn't require a pre-existing albedo map.

Tile-by-tile method: We developed a tile-by-tile method to overcome the complicated regional variations of photometric properties and albedos. We divided the planet into small tiles and derived photometric parameters within a tile and applied photometric correction to all pixels in that tile. Initially we are using 5° by 5° tiles for latitudes between -60° and 60°, for three months of data (from 4/2010 to 6/2010). Since high latitudes never receive low incidence angles, we normalized to 60° phase and incidence angles. A global mosaic constructed with this method exhibits no recognizable tile seams for much of the Moon and good photometric corrections within each tile. Several failed tiles come from poor fitting mostly due to sparse data due to gores in one or more months or a large albedo boundary within a tile. Additional months will allow us to derive better parameters for even smaller sized tiles, and ultimately pixel-by-pixel photometry correction may be possible.

Conclusion: The best photometric normalization of the LROC WAC global color mosaic is obtained with the simplified Hapke function, slope filtering, and the tile-by-tile method. The simplified Hapke function is stable and gives good performance with less data points, while the Lunar-lambert $+2^{nd}$ order exp-decay gives good performance but is unstable with present data sets. Slope filtering substantially decreases scatter and facilitates curve fitting. Albedo filtering depends on pre-existing albedo map which is not self-contained procedure; the tile-by-tile method represents a better solution.

References: [1] Lucey P. G. et al. (2000) JGR, v105, no E8, p20377-20386. [2] Fairbairn M. B. (2005) J. Royal Ast. Soc. Canada 99, 92-93. [3] Smith D. E. et al. (2009) Space Sci. Rev. 150, 209-241. [4] Hillier J. K. et al. (1999) Icarus 141, 205-225. [5] McEwen A. S. (1991) Icarus 92, 298-311. [6] Hapke B. W. (1993) Theory of Reflectance and Emittance Spectroscopy, Cambridge Univ. Press.

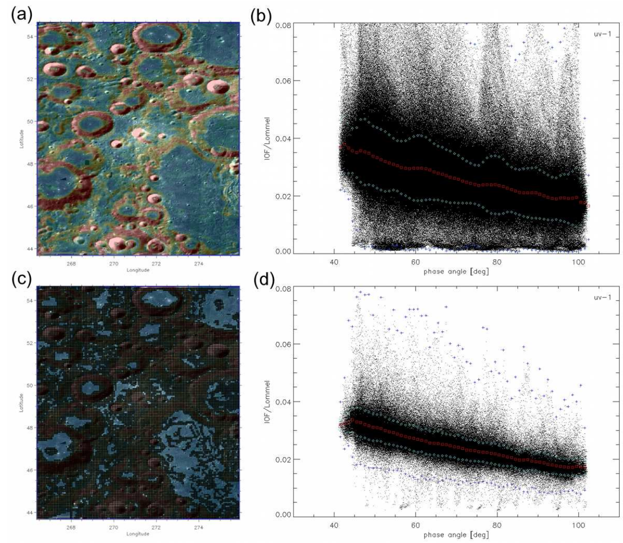

Fig. 2. WAC context mosaic overlayed with colored slope map (a,c) and IOF/LSC vs phase angle plot (b,d), before (upper) and after (bottom) applying slope filter (<1°). Red squares and cyan diamonds in (b) and (d) correspond to average and standard deviation in 1° phase bins. Black areas in (c) were excluded in (d).

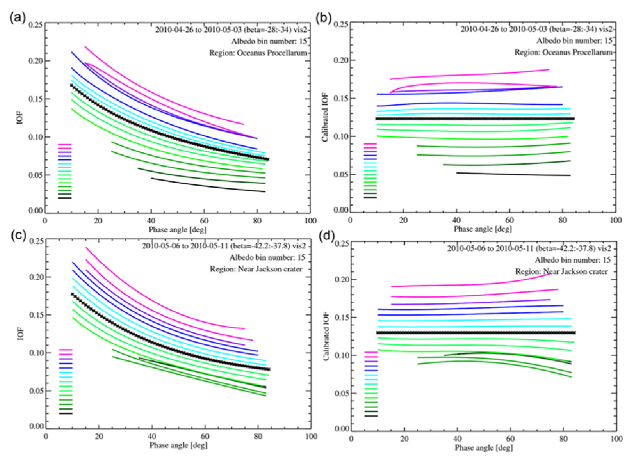

Fig. 3. Fitting curves for 15 discrete albedo groups at 566 nm for mare (a) and highland (c) regions. Curves normalized to the middle albedo range (black curve) are shown in (b) and (d).