PHOTOMETRIC STUDY OVER APOLLO 17 LANDING SITE USING TERRAIN MAPPING CAMERA ONBOARD CHANDRAYAAN-1. *Rohit Nagori, Aditya K. Dagar and A.S. Arya, Space Applications Centre, Indian Space Research Organisation (ISRO), Ahmedabad-380015, India. (*rohitnagori@sac.isro.gov.in).

Introduction: Photometric parameters retrieval using physical models such as Hapke model can reveal a lot about the physical properties over selected Lunar regions [1][2]. However, these retrievals are meaningful only when carried out over region of uniform material properties. Consequently, various studies have retrieved parameters separately for mare and highland regions [3][4], or by applying albedo filtering before retrievals [2]. Terrain Mapping Camera (TMC) onboard Chandrayaan-1 (Ch-1) is a panchromatic imaging camera (0.5µm to 0.85µm) with spatial resolution of 5m and stereo imaging capability in three views of Fore, Nadir and Aft (+25◦, 0◦, -25◦) [5]. In this study, photometric properties were retrieved over Apollo 17 (Ap17) landing site using multi-view images acquired by TMC (Ch-1), and compared with retrieved parameters from laboratory bi-directional reflectance measurement of Ap17 soil sample using Bloomsburg University Goniometer (BUG) [6]. As Ap17 site lies on transition zone between mare and highland regions, effect of demarcating uniform region for parameter retrieval was also demonstrated.

Dataset Description: TMC (Ch-1) image acquired on 7 Jan 2009 over Ap17 landing site was considered for study (TMC_NRN_20090107T011356764 for Nadir radiance image). Dataset contained radiance images for all three views along with ortho-rectified Nadir image, Digital Elevation Model (DEM) image and files containing location and sun position parameters information. Region around Ap17 landing site (20.188 ºN, 30.775 ºE) shown as yellow box overlaid over LRO-WAC mosaic [7] in Fig. 1 was considered for study along with the data of bi-directional reflectance measurements carried out for Ap17 soil (sample 70181) using BUG (available at https://pds-geosciences.wustl.edu/missions/labdata/apollobug.htm) [8]. Ap17 soil sample 70181 was collected about 3 m from ALSEP site in mare part and other details are in [9].

Methodology: TMC-1 images in all three views were seleno-referenced and co-registered with respect to ortho-rectified nadir image. Topographically corrected incidence and viewing zenith and azimuthal angles corresponding to the selected region were generated on per-pixel basis using ancillary information and mathematical formulations for all three views. Subsequently, phase angle information was also generated on per-pixel basis for all three views. Using solar irradiance (convolved with respect to TMC's Spectral Response Function), radiance factor (RADF) images were generated over the selected site. In Fig. 1b, yellow box shows the region selected for analysis. Fig. 2 (left) shows the False Color Composite (R: Fore, G: Nadir, B: Aft) and Fig. 2 (right) shows the Digital Elevation Model (DEM) of the selected region over which Ap17 site has also been marked.

Fig. 3a shows the variation of mean Lommel-Seeliger (LS) corrected RADF with respect to phase angle for selected region containing both mare and highland (R_HM), however, no smooth practical fit was found. Phase angles were binned at 1º interval. For TMC data, only the bins containing number of points greater than 10,000 were considered. As R_HM contained both highland and mare component, a uniform region around Ap17 site containing only mare part was demarcated (R_M). R_M also contained the site of soil sample collection and is shown as cyan color shape in Fig. 1b and planar mare region in Fig. 2 (right). Fig. 3b represents the same graph as Fig. 3a but for region R_M and shows a smooth pattern. A simplified version of Hapke model containing phase function as Single Henyey Greenstein (SHG) and Shadow Hiding Opposition Effect (SHOE) was fit to both the mean RADF/LS data from R_M (TMC) and BUG data of Ap17 site at wavelengths of 550 nm and 750 nm in the same phase range (19º to 35º, number of points in bins > 10000). Genetic algorithm was used as optimization problem solver for fitting. Retrieved parameters are shown in Table 1 for comparison, where 'w' is single scattering albedo, 'b' is the asymmetry factor (values varying between -1 to 1 with value greater than 0 showing backward scattering), 'Bso' and 'hs' showing SHOE amplitude and opposition width respectively. Fig. 4 shows graphical version of fitting.

Table 1: Retrieved parameters comparison.

	w	**b**	**Bso**	**hs**
BUG 550	0.0417	0.1867	0.8056	1
BUG 750	0.0584	0.1993	0.5165	1
TMC	0.0173	0.5427	0.6492	0.5677

Results and Discussion: Fitting of simplified Hapke model to TMC data in Fig. 3b clearly demonstrates that separating mare and highland components is essential step for meaningful parameter retrievals. Fig 4. shows that mean RADF/LS levels for both the laboratory measurements and TMC data are quite comparable. Table 1 shows that 'w' for laboratory measurements is higher as compared to TMC data. Phase function of Double Henyey Greenstein was avoided as the phase

range is very small and so the whole picture can't be accessed. SHG just gives a constricted idea based on the given phase range and both BUG and TMC data are backward scattering in the given phase range with TMC lobe being more sharper. TMC data shows a slight rise in mean RADF/LS values towards lower phase range depicting small opposition effect which is not seen in BUG data (as also inferred from retrieved parameters). All these differences may be due to sample preparation methods (differences in grain size, compactness, etc.), point data collection in laboratory measurement in contrast to whole region in TMC data, etc. which will be further explored.

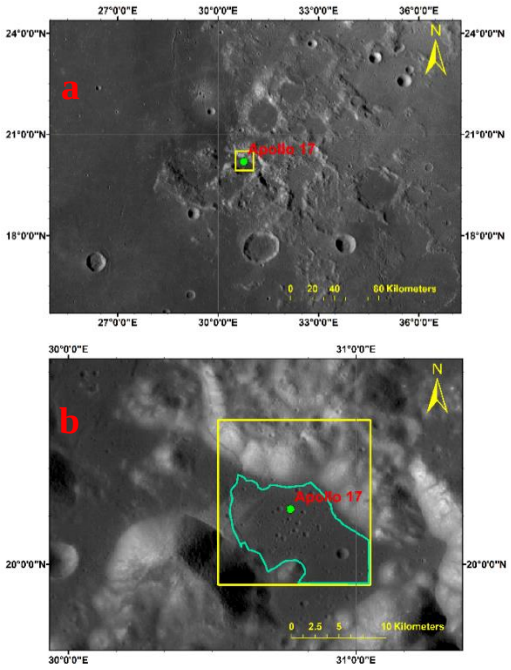

Figure 1: a) It shows the location of Apollo 17 landing site on the transition zone between mare and highland on LRO-WAC mosaic, b) the zoomed version is shown with shape-files of study region considered for analysis.

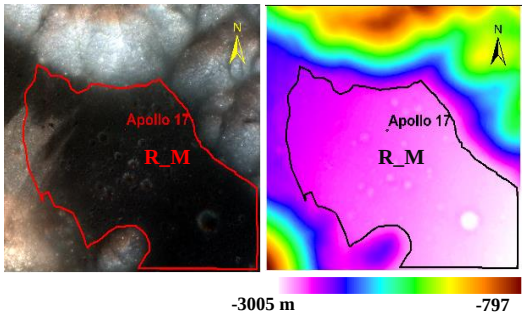

Figure 2: Selected study region around Apollo 17 shown as TMC radiance images' FCC (left) and TMC DEM (right) datasets. Shape-file demarcating mare region also overlaid as red (left) and black (right) on datasets.

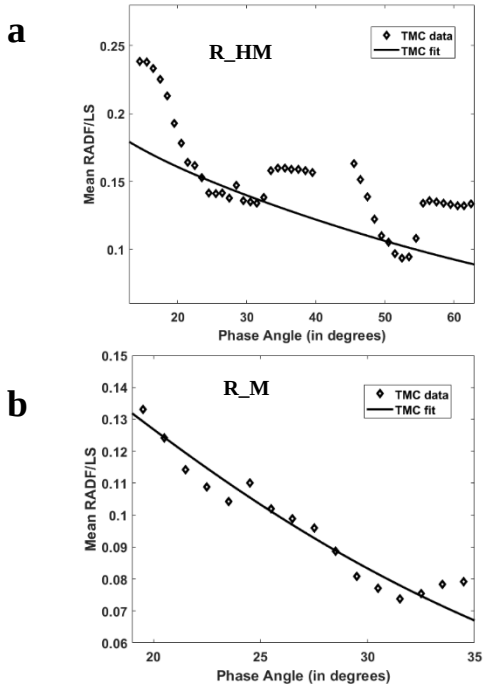

Figure 3: Figure showing mean RADF/LS variation with respect to phase angle for a) whole selected region R_HM and b) region R_M having only mare.

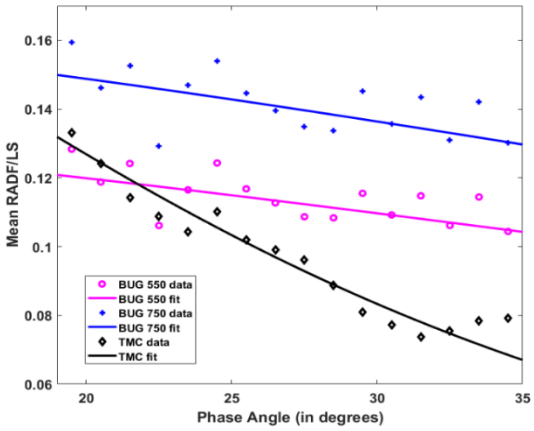

Figure 4: Figure showing mean RADF/LS variation with phase angle for BUG (550 nm, 750 nm) and TMC data over Ap17 site.

References: [1] Hapke B. (1981) J. Geophys. Res., 86(B4), 3039-3054. [2] Sato H. et al. (2014) J. Geophys. Res. Planets, 119, 1775-1805. [3] Besse S. et al. (2013), Icarus, 222,229-242. [4] Xu X. et al. (2020) Remote Sensing, 12(22), 3676. [5] Kumar A. S. et al. (2005) J. Earth Syst. Sci., 114, 717-720. [6] Shepard M. K. (2001) 32nd LPSC, Abstract#1015. [7] Speyerer E. J. (2011) 42nd LPSC, Abstract#2387. [8] Smith E. F. (2019) PhD Thesis, UCLA. [9] Meyer C. (2010) Lunar Sample Compendium.