LUNAR SURFACE TEMPERATURE AND HYDRATION ESTIMATION OVER THE CHANDRAYAAN-3 LANDING SITE USING CHANDRAYAAN-2 IMAGING INFRARED SPECTROMETER (IIRS) MEASUREMENTS UNDER VARIED SOLAR ILLUMINATION CONDITIONS. S. Bhattacharyya1, 2 (satadru@sac.isro.gov.in), A. K. Dagar1, R. P. Rajasekhar1, R. Nagori1 and S. Gupta2. 1Space Applications Centre, ISRO, Ahmedabad-380015, India; 2Dept. of Geology & Geophysics, Indian Institute of Technology, Kharagpur-721302, India.

Introduction: On 23rd August, 2023, India made history and joined an elite club of countries to achieve a soft landing on the Moon. It was also the first ever successful landing in the South Circumpolar Region (SCR) of the Moon. Chandrayaan-3, consisting of a lander and a rover, was a follow-on mission to Chandrayaan-2 to demonstrate end-to-end capability in safe landing and roving on the lunar surface and landed safely at the primary landing site at 69.373°S, 32.319°E, in the inter-crater plains South-East of Manzinus U crater. In the present study, the amount of hydration present in this region has been estimated using Imaging InfraRed Spectrometer (IIRS) instrument onboard Chandrayaan-2 (Ch-2).

Datasets and Methodology: IIRS measures the reflected and emitted radiation from the lunar surface in a wide spectral range of ~800-5000 nm at a high spatial resolution of ~80 m/pixel from the 100-km orbit [1-3]. The level-1 radiance data of IIRS is converted to reflectance by normalizing with the incoming solar flux. The spectral region above 4000 nm is mostly free from the reflected part which was then used for the thermal emission estimation [4].

Subsequent to the estimation and removal of thermally emitted radiance from the spectral radiance of IIRS, the data have been used for the quantitative analysis of the hydration that exists at the landing site. The hydration concentration has been estimated following the methods elaborated in [5]. Firstly, conversion of thermally corrected IIRS reflectance spectra to single scattering albedo (SSA) have been carried out using Hapke’s model [6] and the values parameterized in [7]. The SSA spectra are found to be linearly correlated with the 3000-nm hydration absorption and thus, are preferred over the reflectance spectra in quantifying the absorption strength [5]. SSA spectra are then fitted with a linear continuum between 2670 nm and 3050 nm to quantify the strength of the 3000-nm hydration signature. Finally, the effective single particle absorption thickness (ESPAT) values of Hapke have been computed from the continuum-removed SSA spectra. The ESPAT values are a direct indicator of the absorption band strength of the SSA spectra at a given wavelength. Keeping in view of the average grain size of Apollo soils, we have considered 60–80 μm grain size for quantitative estimation of the hydration concentration (e.g. [8][9]). The estimated hydration is directly correlated with the grain size and thus, in case of a smaller grain size fraction than the above-mentioned size fraction, the amount of hydration will be proportionately higher. Also, the estimated hydration concentration varies with the acquisition time (local lunar time) and surface material differences.

Here, we present the analysis a pre-landing and a post-landing IIRS data that have been acquired under different solar illumination conditions on 19th July, 2021 and 3rd October, 2023 respectively. In pre-landing data, the landing site was missed by a whisker. Nevertheless, both the pre- and the post-landing data covers the same geological unit referred as the inter-crater plains.

Geology of the study area: The Chandrayaan-3 landing site falls on an inter-crater plain formed by the ejecta materials sourced from the pre-SPA and SPA forming impacts and subsequently modified by the ejecta of craters Manzinus U, Manzinus E, Boguslawsky M, Boguslawsky C, Boguslawsky J, Manzinus G, Manzinus N and Boussingault F [10]. CSFD analysis suggests it to be pre-Nectarian (pNec) in age.

Results and discussions: As already mentioned, in this study, a pre- and a post landing IIRS image have been analyzed in order to capture the variations, if any, in the estimated hydration concentrations in the studied region under different solar illumination conditions. Figure 1a shows a mosaic of pre- and post-landing IIRS scenes. The red polygon in figure 1a marks the extent of pre-landing IIRS image and it is apparent from this figure that the pre-landing image covers the part of inter-crater plains immediate east of the landing site. Also, there is a stark contrast in the overall albedo of the images due to the differences in the imaging conditions. The pre-landing image was acquired during the Noon-Midnight phase with an average solar incidence angle of ~72 degrees, whereas the post-landing image was acquired with a mean solar incidence angle of ~88 degrees during dawn-dusk phase in early dawn time.

The study area is characterized by spectra with monotonously increasing spectral slope (spectral reddening) in the longer wavelength that is typical of mature lunar highlands with no significant mafic absorptions
near 1000- and 2000 nm due to the intense space weathering. However, a weak feature is seen near 3000 nm whose shape, band center position and band strength show minor variations in and around the landing site region. Figure 1b and 1c shows the temperature map of the region as derived utilizing the longer wavelength spectral channels of IIRS in 3000-5000 nm spectral regions, specifically using the channels beyond 4000 nm as mentioned in the methodology section. Figure 1b shows the temperature map of the pre-landing data and the mean temperature is estimated to be ~290 K with a maximum temperature of ~340 K recorded along the sun-facing inner flank of a crater present in the NE quadrant of the image in the upper right (Fig. 1b). The average temperature derived from the post-landing image is found to be ~200 K with some sun-facing inner flanks of craters and some very restricted sunlit hummocky terrains recording temperatures ranging from ~250-300 K (Fig. 1c). Figure 1d shows the hydration map of the inter-crater plain that was imaged during the pre-landing phase of acquisition. The hydration concentration of the study area varies from ~0-50 ppm with an average value of ~20 ppm. The relatively higher concentrations of hydration coincide with either the sun-facing inner flanks of craters or with the sun-facing ridges. Overall, the landing site region is hydration poor. Due to the poor lighting condition of the post-landing IIRS scene, hydration map could not be generated.

**Conclusion:** An attempt has been made to characterize the Chandrayaan-3 landing site using the spectral observations obtained by the Chandrayaan-2 IIRS instrument. Both pre- and post-landing images have been studied under varying illumination conditions. In the pre-landing data the average derived surface temperature is ~290 K whereas the same in the post-landing image is found to be ~200 K as the latter was imaged in the early dawn condition. A hydration map has also been generated using the pre-landing image based on Hapke’s ESPAT parameter and the hydration concentration varies from ~0-50 ppm having a mean value of ~20 ppm.


Figure 1 a) shows the 1.6 μm band reflectance for pre- and post-landing IIRS images. Post-landing image is in the front and the extent of pre-landing image is shown by red polygon. b) and c) shows the temperature map for the pre- and post-landing images, respectively, and d) shows the hydration map derived from the pre-landing image.