REGOLITH PROPERTIES IN THE NORTH POLAR REGION OF THE MOON FROM 12.6-CM RADAR POLARIMETRY. Sriram Saran, Anup Das, Dharmendra Pandey, Raj Kumar and Manab Chakraborty, Space Applications Centre (ISRO), Ahmedabad- 380015, India (saran@sac.isro.gov.in)

Introduction: The lunar poles are interesting for their extreme environment and permanently shadowed terrains. Like the rest of the Moon, the poles have been extensively shaped by impacts and are also possible sites for future exploration missions [1]. The lunar North Pole is particularly interesting because it has not been studied extensively so far using ground based observatories due to their limited viewing capabilities.

Radar remote sensing has long been used to study the physical properties of the lunar regolith as it offers the opportunity to probe the regolith to depths of meters to tens of meters, depending upon the radar wavelength and the regolith loss tangent [2]. Radar data can be used to track extended ejecta (including rays) and to identify impact directions, and identification of rays and secondary craters provides constraints on surface ages [3].Previous radar studies of the north pole using high resolution Arecibo S-band data [4] indicated no presence of dense patterns of radar-bright ejecta from small craters on some crater floors. But these results were confined to a small region due to the unfavorable libration for viewing the lunar north pole from Arecibo and hence orbital imaging radar is the only method likely to yield high-resolution images of the north pole. With the availability of two lunar orbital SARs (Mini-SAR on Chandrayaan-1 and Mini-RF on LRO missions) since 2008, high resolution radar imaging of both the poles at 12.6-cm wavelength has been possible for the first time.

In this work, we examine several young, bright craters and impact melt distributions at the north pole of the Moon (>70°N) with images at optical and radar wavelengths to infer the dominant mechanism leading to the formation of rays comprised of primary or secondary ejecta. Some of these features had not been previously identified in imaging data.

Data sources: We used a variety of data sources in this study to better understand the ejecta patterns, impact melt distributions, rock abundance, regolith development, and relative age of the craters. North Pole mosaics of the S-band Mini-RF [5] were used as primary datasets and LROC Wide Angle Camera (WAC) [6], regolith temperature maps from the Diviner radiometer [7] of the Lunar Reconnaissance Orbiter (LRO) mission were used as complimentary datasets to provide additional information about the presence of surface and near-surface rocks.

In this work, mosaics of the first Stokes parameter image (S1), which is a measure of the total average power of the echo and Circular Polarization Ratio (CPR) at 256 ppd (~120 m/pix) resolution were used. High resolution S-band Mini-RF images (at 15 m/pixel) and LROC Narrow Angle Camera (NAC) images (~0.5 m/pix) were also utilized wherever required for detailed analysis. The WAC mosaic and thermal map of the north polar region used in this work are available at a fixed resolution of 100 m/pix and 240 m/pix, respectively. CPR is one of the most useful indicators of surface roughness [1, 4] making this an effective tool for identifying crater ejecta, rays and impact melts which could not be observed in detail at optical wavelengths.

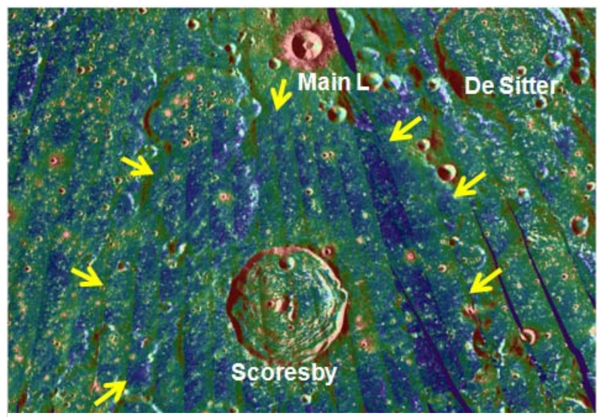

Figure 1 Mini-RF S-band CPR (overlaid on backscatter image) of the Scoresby crater region. North is to the top and the CPR data is colorized, where 0 is purple and 1.2 is red. The approximate extent of the radar dark halo around Scoresby is marked with arrows. Note the Anaxagoras rays that appear from the corner right at the bottom of the image.

Results: Mini-RF data have revealed a number of previously unknown ejecta features and impact melts associated with north polar craters. The most dramatic of these are a radar dark halo around Scoresby crater (77.73°N, 14.13°E) and a radarbright streak that extends from an unnamed crater (75.45°N, 140.8°E) near Seares crater. A concentric region of low CPR values surrounding the bright proximal ejecta layer of Scoresby crater was observed consistent with other radar-dark haloes identified by [8], which was not reported in the previous radar observations. This suggests that the Eratosthenian crater Scoresby could be younger than implied which has a block-poor ejecta layer extending to ~3 crater radii from the crater center, which would transition from radar dark to radar bright as impact gardening disrupts the layer. Enhanced (>1) CPR values were found to be associated with the floors of Anaxagoras, Philolaus, Main L craters, small crater adjacent to Seares crater, secondary craters on the floors of Rozhdestvenskiy, Plaskett and several small unnamed fresh craters, with their proximal ejecta. The enhanced CPR values associated with the floors and proximal ejecta of some Eratosthenian and Copernican (e.g., Anaxagoras, Main L) craters analyzed in this study are readily attributed to impact melt sheets with pervasive meter-scale fracturing, and to abundant decimeter-sized rocks formed by the impact event.

Bright rays were observed around several lunar craters in the Mini-RF images, although they tend to be less pronounced at optical wavelengths like near the Mouchez (Fig. 2, 3), Seares, and Sylvester N crater regions. Another small, bright rayed crater (~3 km diameter) near the Anaxagoras B crater was observed with its rays extending up to 9 crater radii.

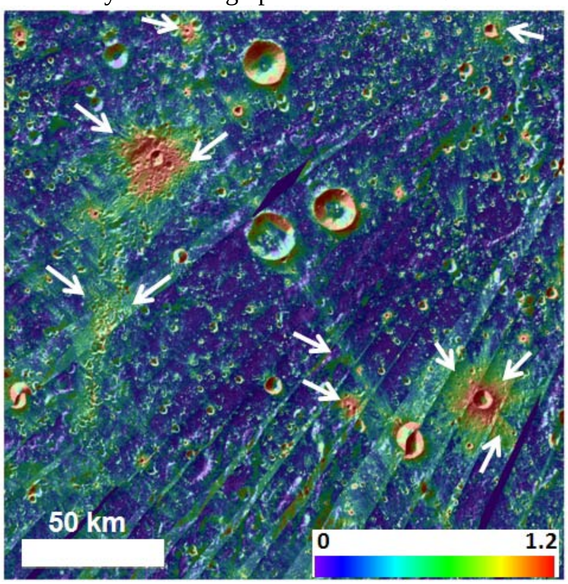

Figure 2 Mini-RF CPR (colorized and overlaid on backscatter image) image of the Mouchez crater (78.38°N, 26.8°W) region. The radar bright regions with abundant wavelength-scale scatterers are indicated with arrows in both the CPR and WAC (Fig.3) images.

Mini-RF data have also revealed interesting extended ejecta patterns surrounding smaller craters. Some of the radar bright craters like the Schwarzschild D, unnamed crater (~13km) on the floor of Rozhdestvenskiy (84.8°N, 172.13° W) and another small crater (79.93°N, 81.25°W) towards the west of Poncelet A crater, have a clear zone-of avoidance and unusual ejecta patterns which are not observed in the corresponding WAC images.

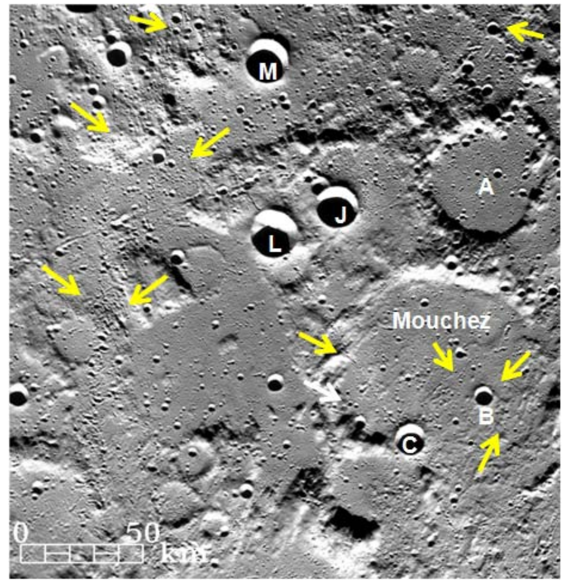

Figure 3 Corresponding LROC WAC image of the Mouchez crater region. The linear crater chains are observed to be more bright in the Mini-RF image compared to the WAC image

The Mini-RF data has also revealed some new impact melt deposits, some of which were not observed in prior radar imaging. The Philolaus impact melt ponds were observed to be smooth in the WAC image, while they are characterized with relatively high CPR values (average of 0.74) indicative of the presence of surface rocks, roughly tens of centimeters in size. The radar-bright secondary crater on the edge of Plaskett crater rim is associated with a small flow feature towards its west, which could not be observed even in the corresponding high resolution NAC images.

Conclusion: We present new results from the S-band polarimetric radar data for the Moon's north polar region (70–90° N), collected using Mini-RF onboard LRO. Significant variations in backscatter and CPR were observed, attributed to changes in the surface and subsurface rock population, across the north polar region. Analysis of more radar bright features complemented by thermal and optical datasets is in progress.

References: [1] Carter, L. M. et al. (2012) *JGR, 117,* E00H09, doi:10.1029/2011JE003911. [2] Campbell, B. A., Campbell, D. B. (2006), *Icarus 180,* 1-7. [3] Wells, K. S. et al. (2010) *JGR, 115,* E06008, doi:10.1029/2009JE003491. [4] Campbell, B. A., et al., (2010), *Icarus 208,* 565-573. [5] Raney, R. K. et al. (2011), *Proc. IEEE 99 (5),* 808-823. [6] Robinson, M. S. et al. (2010), *Space. Sci. Rev., 150,* 81-124. [7] Paige, D. A. et al. (2010), *Space. Sci. Rev., 150,* 125-160. [8] Ghent, R. R. et al. (2005) *JGR, 110,* E02005, doi:10.1029/2004JE002366.