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Anomalous Dielectric Variability in the central peak of Tycho crater on the Moon: New insights from Mini-RF S-band Observations

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One of the unique candidates to explore the evolution of physical surface processes on the Moon is Tycho, a dark haloed impact crater representing well-preserved bright ray pattern and intact crater morphology. Sampling of the central peak in such complex crater formation proves significant in terms of unraveling intriguing science of the lunar interior. With the current state-of-the-art radar technology, it is possible to evaluate the response of the geologic features constrained in the near surface and subsurface regolith environments. This can be achieved by modelling the dielectric constant of media, which is a physical parameter crucial for furthering our knowledge about the distribution of materials within different stratigraphic layers at multiple depths. Here, we used the applicability of Mini-RF S-band data augmented with a deep learning based inversion model to retrieve the dielectric variations over the central peak of the Tycho crater. A striking observation is made in certain regions of the central peak, wherein we observe anomalously high dielectric constant, not at all differentiated in the hyperspectral image and first Stokes parameter image, which usually is a representation of retrieved backscatter of the target. The results are also supported by comparing the variations in the scattering mechanisms. We found those particular regions to be associated with high degree of depolarization, thereby attributing to the presence of cm- to m- scale scatterers buried within a low dielectric layer that are not big enough to produce even-bounce geometry for the radar wave. Moreover, we also observe high rock concentration in the central peak slopes from DIVINER data and NAC images, indicating the exposure of clasts ranging in size from 10 meter to 100s of meter. Furthermore, from surface temperature data, these distinctive outcrops sense warmer temperature at night than the surrounding, which suggests the existence of thermal skin depth in such vicinities. Interestingly, we are able to quantify the pessimistic dielectric constant limit of the large boulder in the middle of the central peak, observable at the Mini-RF radar wavelength, as 4.54 + j0.077. Compared to the expected dielectric constant of rocks, this value is lowered significantly. One probable reason could be the emergence of small radar shadows due to the rugged surface of the boulder on the radar illuminated portion. From our analysis, we showcase the anomalous dielectric variability of Tycho central peak, thereby providing new insights into the evolution of the impact cratering process that could be important for both science and necessary for framing human or robotic exploration strategies.