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SELENE(かぐや) で観測された嵐の大洋・雨の海の高誘電率領域
High permittivity regions in Oceanus Procelluram and Mare Imbrium found by SELENE (Kaguya)

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Introduction: The effective permittivity of the lunar surface material is important for discussion of their composition and porosity. Based on the Maxwell-Garnett mixing model, the bulk density of the lunar surface materials can be derived from their effective permittivity by using the following equation [Fa and Wieczorek, 2012]: ρ [g/m^3] = 4.61 (ε_r - 1) / (ε_r + 2). Bulk density of the lunar surface material depends on the abundances of voids and heavy components such as ilmenite. The dataset obtained by Lunar Radar Sounder (LRS) onboard SELENE (Kaguya) [Ono et al., 2010] enables us to perform global high-resolution mapping of the lunar surface permittivity because the observation was performed from the polar orbiter at an altitude of about 100 km, and in a frequency range around 5 MHz where thermal emissions is negligible. We should note that the echo powers from the lunar surface depends not only on the permittivity but also on the roughness of the lunar surface. As for the roughness, we can use SELENE Digital Terrain Model (DTM) based on Terrain Camera (TC) observation [Haruyama et al., 2008]. We can therefore calculate expected echo powers by applying Kirchhoff Approximation (KA), and compare them with observed echo powers in order to determine the effective permittivity.

Analyses Method: The global distributions of the intensity of the off-nadir surface echo in a frequency range of 4 - 6 MHz in an incident angle range from 10 to 20 degrees were derived from the SELENE/LRS dataset. The median of off-nadir echo intensities were derived in 360 x 180 areas of 1 degree (longitude)x 1 degree (latitude). In addition, we have derived the global distribution of the surface roughness parameters. The RMS height ν can be derived from the SELENE TC/DTM. If we assume the self-affine surface model, the roughness parameters H and s can be obtained by the least square fitting: ν = s Δx^H in a baseline length Δx range from 30 m to 3 km. The off-nadir surface echo power was then calculated by using the radar equation. Assuming KA, the backscattering coefficient in the radar equation can be obtained from the roughness parameters H, s [Bruzzone et al., 2011]. In calculation of the expected echo powers, we have to assume some effective permittivity also. We compared the observed and calculated echo powers with changing effective permittivity assumption, and determined the most plausible effective permittivity.

Results: By applying the analysis method mentioned above, we could obtain the observed and calculated off-nadir surface echo powers. Based on them, we could estimate the effective permittivity of the lunar surface materials. The estimated effective permittivity is 2 - 3 in the highland, 3 - 4 in the maria. In addition, it was found that there areas whose effective permittivity reaching ~5 in the eastern part of Oceanus Procellarum and the western part of Mare Imbrium.

Discussion: By using the estimated effective permittivity of the lunar surface, we can derive the bulk density of the lunar surface materials. The derived bulk density is 1.2 - 1.8 g/cm^3 in the highlands, 1.8 - 2.3 g/cm^3 in the maria, and approximately 2.6 g/cm^3 in the high-permittivity areas in Oceanus Procellarum and Mare Imbrium. The differences of estimated bulk density among the previous studies [Wiezorek et al., 2013; Carrier et al., 1991] and this study could be explained by the depth dependence of the bulk density of the lunar surface soils and rocks. The areas of high permittivity in the eastern part of Oceanus Procellarum and western part of Mare Imbrium coincide with young lava flow units in PKT region. We can consider two possible reasons: (i) The regolith layer is thinner than other mare regions due to short exposure to the meteorite impacts. (ii) The bulk density is higher than other mare regions due to high abundance of the ilmenite.

キーワード: SELENE(Kaguya), 月レーダサウンダ (LRS), 誘電率, 嵐の大洋, 雨の海, デジタル地形モデル (DTM)
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