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Improvement of lunar interior model by SELENE2 geodetic and seismic observations

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On a future Japanese lunar landing mission, the SELENE-2 project, some geophysical observations are planned to improve current knowledge of lunar interior structure. Since both geodetic and seismic observations planned in SELENE-2 mission are useful to constrain the elastic properties and densities of interior materials, combined analyses are more effective to infer the lunar interior structure (e.g., Garcia et al., 2011).

As geodetic observations, VLBI (Very Long Baseline Interferometry) and LLR (Lunar Laser Ranging) are planned. On the VLBI, radio source antennas are mounted on the SELENE-2 lander and orbiter, and both radio waves on lander and orbiter are received at two ground stations. Since one radio source is fixed on the ground, we will be able to measure the trajectory of the orbiter with better accuracy compared with the first SELENE mission on the lunar near-side. Through this observation, we intend to improve the low-order coefficients of gravity field and tidal potential Love number k2 by designing high average altitude of the orbiter. On the LLR, a laser reflector is mounted on the SELENE-2 lander, and distance between the Earth and the Moon is measured with accuracy of about 1 cm using reflection of the laser emitted from the Earth. Through this accurate measurement, we can investigate the lunar rotational motion and tidal deformation, and will obtain information on elastic properties of the lunar interior, flatness of the core-mantle boundary and so on. Finally, combined results of VLBI and LLR observations can be used to improve the values of the moment of inertia and tidal potential Love numbers (h2, k2) which are parameters to constrain lunar interior structures in comparison with results of the first SELENE mission.

On the seismic observation, the Very Broadband (VBB) and the Short Period (SP) seismometers are deployed on the lunar surface by a robotic arm of the SELENE-2 lander. Though we have only one seismic station in the mission and, therefore, can not locate the seismic sources, we can utilize the deep moonquake events (e.g., Nakamura et al., 1982) occurred at the nests located by the past Apollo missions and the meteoroid impact events locatable by impact flashes from the ground observations. In the seismic observation, detections of seismic phases reflected from the core-mantle boundary and refracted converted phases at the crust-mantle boundary are main targets, and these detected seismic phases are important to reveal the lunar core size and crustal thickness beneath the landing site with better accuracy.

In this study, we have performed a simulation to ensure how we can improve a current lunar interior model by combining the expected geodetic and seismic data in the SELENE-2 mission. In this simulation, we utilize the lunar moment of inertia, the mass and the Love numbers as the geodetic data and travel times of the seismic phases as the seismic data to constrain lunar interior. Then, we evaluate a posteriori errors of model parameters such as seismic velocities and density by resolving a linear inversion method using these geodetic and seismic data. In current evaluations, we have preliminary quantitative results that errors of S-wave velocity in lower mantle would be improved by adding the geodetic data to the seismic data, because the geodetic data is sensitive to the deep region and S-wave is hard to pass the region. Then, we could determine the average densities of lunar crust, mantle and core respectively with better accuracy by SELENE-2 geodetic data, if we can reveal the core size and the crustal thickness precisely using the seismic data. We report the results of the simulations, and then discuss especially usefulness of the SELENE-2 geodetic observations in this presentation.

Keywords: Lunar exploration, Lunar interior structure, Gravity observation, Lunar laser ranging, Seismic observation, VLBI