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LLR simulation study for future observations

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Introduction: Lunar Laser Ranging (LLR) measures the distance between laser link stations on the Earth and retroreflectors on the Moon by detecting the time of flight of photons from a high-powered laser pulse emitted from the ground stations. Since the Earth-Moon distance contains information on lunar orbit, lunar solid-body tides, and lunar orientation and rotation, we can estimate the inner structure of the Moon by constraining relevant physical parameters. Several lunar landing missions which will carry new retroreflectors to the lunar surface are under study in several countries. Furthermore, retroreflectors with a larger single aperture are under development for more precise ranging, apart from the conventional array-type retroreflectors that were realized in the Apollo and Luna mission from 1969-1973. It is not obvious how lunar physical parameters such as Love numbers will be better constrained by using range data with higher accuracy. Therefore we have conducted a simulation study of the LLR observations by using the LLR analysis software of JPL.

Method: Simulated data were created by adding noise to the predicted distances between the Earth surface and retroreflectors on the Moon using the lunar ephemeris and range model. The simulated data were fit using a least-square solution, and then the uncertainties of the fit were evaluated. There are high degrees of freedom for the creation of simulated data in terms of the number and locations of retroreflectors, the amount of data from each retroreflector, etc. In this study we set the condition as follows:

-the number of yearly range data was set to be about 600, monthly about 50
-the numbers of range data toward the new retroreflectors are at the same level as for the Apollo 11 and 14 sites
-range accuracy for new retroreflectors was set one order-of-magnitude higher than that of the existing retroreflectors
-locations of the new retroreflectors are near the north pole, near the south pole, and the mid-latitude.

Results and remarks: After about 35 years of observation, the uncertainty of some parameters is reduced by about 1/2 by adding one high-accuracy retroreflector compared to the case in which only existing retroreflectors are ranged. It is suggested that the uncertainty could be reduced by observing high-accuracy retroreflectors more than existing ones, or changing the weighting of data.

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