Combination of Lunar Laser Ranging and Differential Lunar Laser Ranging

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Lunar laser ranging (LLR), i.e., range measurements from an Earth station to a lunar reflector, is carried out for more than 53 years. LLR is important for many fields, e.g., lunar ephemeris, relativity tests and lunar interior modelling. However, due to the limited LLR accuracy related to the challenging tracking conditions, the small number of received photons, the Earth's atmosphere, etc., it is difficult to achieve real breakthroughs for a better understanding of certain parts of the Earth-Moon system, e.g., the lunar interior. In future, an upgraded station with a high-power continuous wave laser at Table Mountain Observatory of JPL will enable a new technique for lunar tracking, i.e., differential lunar laser ranging (DLLR). With a large flux of received photons, the station will realize fast switching between two or more reflectors to attain a novel kind of observation: lunar range differences. DLLR will decrease the atmospheric errors largely, resulting in a very high accuracy for the differential range at the level of ~30 µm. Furthermore, DLLR will significantly improve our knowledge of the lunar interior and benefit the relativity tests. In this study, we investigate the potential of DLLR using simulated DLLR data, where we put some focus on the combination of LLR and DLLR data. DLLR data only with a rather short time span of observations (in the beginning) are merely able to determine the lunar orbit well, which has a negative effect on the estimation of other lunar parameters. However, LLR with its long timespan has the advantage of providing an accurate orbit. By combining with LLR, even DLLR data over a rather short time span (e.g., 5 years) can remarkably enhance the parameter estimation for the lunar interior. We also studied the effects of different kinds of reflector baselines of DLLR on estimating lunar-interior parameters, proving that baselines with longer length and crossing shape are most beneficial for the investigation of the lunar interior.