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Orbit determination and gravity field recovery from tracking data to the Lunar Reconnaissance Orbiter

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The Lunar Reconnaissance Orbiter (LRO), launched in 2009, is well suited for the estimation of the long wavelengths of the lunar gravity field due to its low altitude of 50 km. Further, the orbit of LRO was polar for two years providing global coverage. The satellite has been primarily tracked via S-band (mainly two-way Doppler range-rates and two-way radiometric ranges) from the dedicated station in White Sands and from the Universal Space Network (USN). Due to the onboard altimeter the orbital precision requirement in the radial direction was rigorously defined as 1m. Because simulation studies before LRO's launch showed that this precision could not be reached with S-band observations alone, it was decided to additionally track LRO via optical laser ranges. It is worthwhile to point out that LRO is the first spacecraft in interplanetary space routinely tracked with optical one-way laser ranges. Gravity field recovery from orbit perturbations is intrinsically related to precise orbit determination. This is why considerable effort was made to find the optimum settings for orbit modeling. For a time span of three months we conducted a series of orbit overlapping tests based on Doppler observations to find the optimum arc length and the optimum set of empirical parameters. The analysis of observation residuals and orbit overlap differences showed that the estimated orbits are most precise when subdividing the time span into 2.5 days and estimating one constant empirical acceleration in along track direction. These settings were then used to analyze 13 months of Doppler data to LRO. The processing of the optical one-way laser was difficult due to the involvement of two non-synchronous clocks in one measurement (one clock at the ground station and one clock onboard LRO). The NASA software GEODYN, which was used for orbit determination and parameter estimation, models the LRO clock using a drift rate (first-order term) and an aging rate (second-order term). It seems, however, that this clock parametrization is not able to fully capture the signature posed on the measurement due to the two clocks. The precision of the orbits based solely on laser ranges is considerably lower compared to the Doppler-only orbits. For this reason, our lunar gravity field solution, which was estimated up to degree and order 60, is based solely on Doppler range-rates.