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Precise Orbit Determination of the Lunar Reconnaissance Orbiter and inferred gravity field information

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Abstract

This contribution deals with Precise Orbit Determination of the Lunar Reconnaissance Orbiter, which is tracked with optical laser ranges in addition to radiometric Doppler range-rates and range observations. The optimum parameterization is assessed by overlap analysis tests that indicate the inner precision of the computed orbits. Information about the very long wavelengths of the lunar gravity field is inferred from the spacecraft positions. The NASA software packages GEODYN II and SOLVE were used for orbit determination and gravity field recovery [1].

1. Introduction

The Lunar Reconnaissance Orbiter (LRO) is the first spacecraft in planetary space that is routinely tracked with optical laser ranges. The main tracking data type are radiometric observations though, i.e. Doppler range-rates and ranges. LRO was launched in 2009 and is still operational. The onboard laser altimeter puts constraints to the Precise Orbit Determination (POD) with accuracy requirements of 1m in radial direction and 50-100m in total position [2].

2. Tracking data

LRO is tracked via radiometric observations from the Universal Space Network and the primary station White Sands. Two-way radiometric range-rates and ranges have a nominal precision of 1mm/s and 10m, respectively. Due to the low precision of the range measurements, only Doppler observations were used for this study. In addition, LRO is tracked with optical laser ranges precise to about 10cm. This tracking, however, is much sparser than in case of Doppler range-rates (Figure 1). Moreover, laser ranges are one-way measurements with the disadvantage of two clocks being involved.

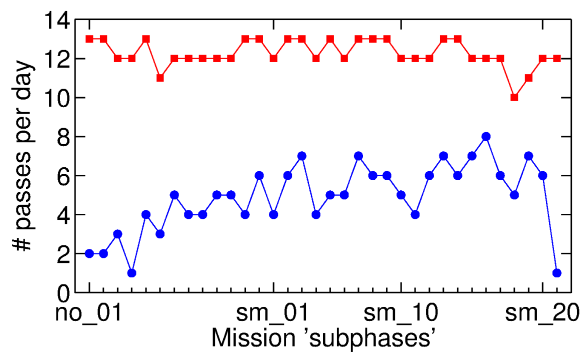

Figure 1: Average number of Doppler passes (squares) and laser ranging passes (circles) per day for the nominal mission phase and the science mission phase. Each phase spans approximately four weeks.

3. Overlap analysis

To find the optimum parameterization for POD, a time span of about 90 days starting in January 2011 was divided into arcs of different lengths: 1.25 days, 2.5 days, and 4.5 days with 6 hours, 12 hours, and 36 hours overlap, respectively. In addition, various setups of empirical accelerations in along-track and cross-track direction were tested. Solely Doppler observations were used, as they are continuously available except for the intervals when LRO is over the farside of the Moon. The highest precision is achieved using an arc length of 2.5 days and estimating constant along-track accelerations (see Figure 2 for details).

4. External validation

We compared our orbits against LRO ephemeris [2] available from SPICE [3], which are based on radiometric observations and have a precision of about 10m in total position. For the same time span as investigated in the course of the overlap analysis (90 days), the differences between our orbits and the SPICE orbits amount to 3.93m, 2.96m, and 0.50m in along track, cross track, and radial direction, respectively, and a value of 5.25m in total position.

5. Summary and Conclusions

Using an arc length of 2.5 days and estimating constant along track accelerations per arc, the overlap analysis revealed that our orbits are precise to 2.4m, 2.2m, and 0.2m in along track, cross track and radial direction, as well as 3.6m in total position. A comparison with an external orbit solution available in the SPICE environment shows only slightly larger differences. Thus, we conclude that the inner precision of our orbits is an appropriate measure for the orbits accuracy. In addition to the Doppler-derived LRO trajectory, we will provide a closer look on the contribution of laser ranges to the spacecraft positioning and LRO-based low-degree gravity field coefficients.

Acknowledgements

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References

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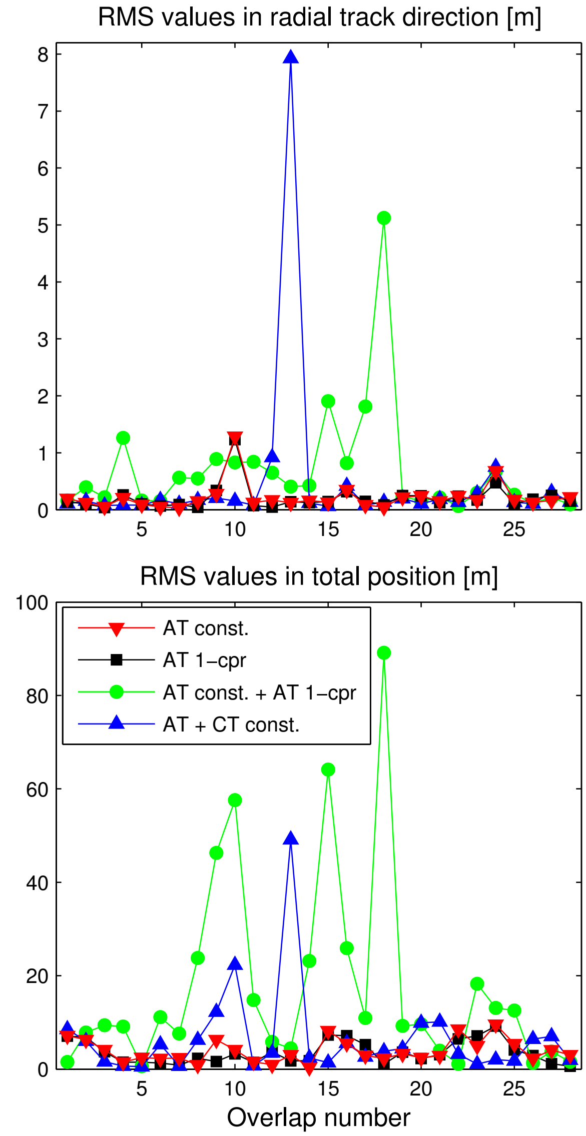

Figure 2: RMS values of overlap differences per arc using an arc length of 2.5 days (12 hours overlap) and various combinations of constant (const.) and one cycle per revolution (1-cpr) empirical parameters in along track (AT) and cross track (CT) directions.