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Impact of improved orbit and rotational models on the locations of the Mars Orbiter Laser Altimeter (MOLA) footprints

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Abstract

We have recalculated the location of the MOLA (Mars Orbiter Laser Altimeter) footprints using an improved orbit trajectory model for the MGS (Mars Global Surveyor) spacecraft and an improved rotational model of Mars. We demonstrate that errors in the Precision Experiment Data Record (PEDR) dataset can be significantly compensated by incorporating these improved models. Updated MOLA spot coordinates may improve results from quantitative surface morphology in local areas, in particular measurements of volumes and slopes. Also, proposed precision geodetic analysis and measurements of Mars rotation parameters [1] may benefit.

1. Introduction

MOLA has been extensively used as reference data for geology and geophysics applications up to the current day, yet it is still based on outdated spacecraft orbit- and Mars rotational models that date back to almost 15 years ago, limiting usage of the data in high-precision geodetic applications. In this paper, we first update the locations of the MOLA footprints using updated Mars trajectory model and Mars rotational model and then we set to visualize and analyze the corresponding impacts of the corrections by comparing to cross-over corrected PEDR dataset.

2. Data

2.1 MOLA records

The MOLA PEDR dataset features a total of 8505 profiles, acquired in the mapping phase from March, 1999 to January, 2001. It contains trajectory information, shot ranges, footprint (geocentric) body-fixed coordinates, as well as range corrections, cross-over adjustments, and other instrument and observation characteristics. The estimated geopositional accuracy of the cross-over corrected footprints is about 100 m horizontally and about 1 m radially [2]. For this study five orbit profiles numbered 1000, 3000, 5000, 7000 and 8000 were selected and used for tests (no data is recorded in the PEDR dataset for orbit 0001).

2.2 Improved orbit model

The MOLA PEDR dataset was processed with an older orbit trajectory model produced by GSFC (Goddard Space Flight Center) dating back to 2003, and the typical accuracy of this model was determined to be about 1 m radial, 10 m along-track, and 3 m across-track [3]. The refined orbit model tested in our study was produced from re-analysis of MGS radio science data and updated gravity field models [3] with the average radial, along-track and cross-track error been improved to be 15 cm, 1.5 m and 1.6 m, respectively.

2.3 Improved rotational model

The MOLA PEDR dataset used the IAU2000 Mars rotational model when transforming the ground point location in the inertial reference system to body-fixed coordinates. Here, the latest rotational model from [4, 5] which also includes seasonal variations of the rotational rate and precession and nutation of the spin axis was investigated.

3. Method

In the recalculation process, timing corrections including the MOLA internal timing bias and the pointing time bias, as well as the range correction due to detector response and range walk have been applied. Meanwhile, consideration has also been made to account for the change of the spacecraft's position during laser shot time of flight. Further, points were excluded where attitude knowledge was missing or where the laser beam incidence/emission angle was larger than 1.4 degrees. In order to assess the impact of the corrections, the revised footprint locations were compared to the cross-over corrected footprint data in the PEDR. Thereby, geodetic differences (geodetic distance) along the surface of the IAU2000 Mars ellipsoid between the pairs of geocentric coordinates were calculated using the improved Vincenty's formulae [6].

4. Results

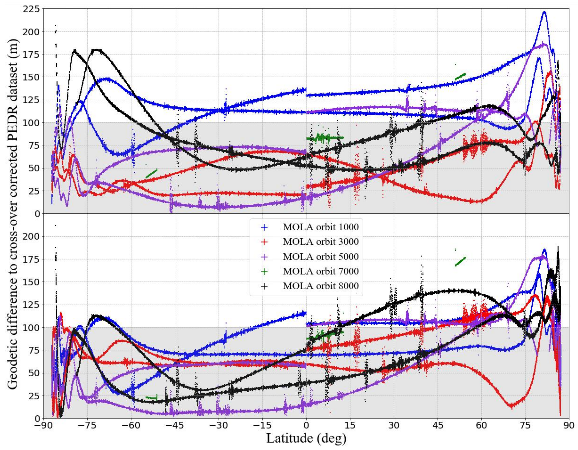

Figure 1: Geodetic difference before (upper) and after (lower) incorporating the improvements

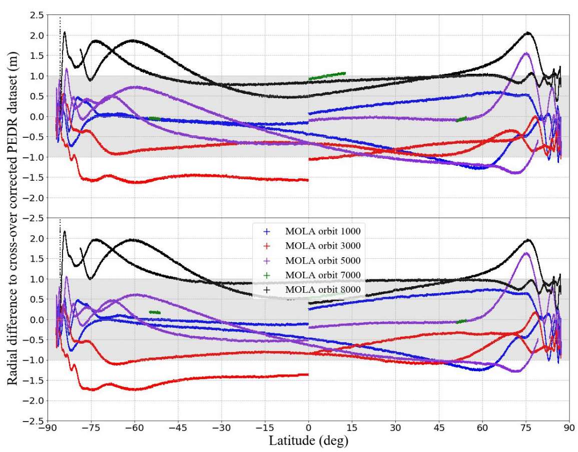

Figure 2: Radial difference before (upper) and after (lower) incorporating the improvements

The comparison to cross-over corrected footprint locations before and after the incorporation of improved orbit and rotational models are shown in Figure 1 and 2. As can be seen from the plots, the cross-over corrections concentrate mainly near the poles; after the improvements have been incorporated, horizontal errors were significantly reduced, especially at the south pole, while the radial errors remained largely unaffected. In addition, an occurrence of large abrupt residuals in Figure 1 was observed to correspond to times when shots were taken off-nadir and when off-nadir angles rapidly changed.

5. Summary

We show that the cross-over correction applied in the MOLA PEDR data results to a large extent from inaccuracies in the Martian rotation model and the MGS trajectory used in the compilation of the PEDR data. The adoption of improved orbit and rotational models can significantly improve the horizontal accuracy of the MOLA dataset. Future efforts on refining MOLA data will be made to account for general relativistic effects on MGS's on-board clock to reduce timing errors.

6. Outlook

We recently proposed to retrieving the Mars rotational parameters by alignment analysis of time-dependent MOLA footprints with static digital terrain models (DTMs) [7]. Unfortunately, the finer parts of rotational parameters (e.g. small nutations) could not be resolved [7]. Thus, the MOLA dataset needs to be further inspected and refined if it is to meet the requirements of this demanding analysis. The ultimate aim of this research is to refine the MOLA dataset to the level that it can be used for the co-alignment analysis and then, with the improved MOLA data we could independently resolve small oscillations in rotational parameters of Mars [1].

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