EPSC Abstracts
Vol. 12, EPSC2018-1100, 2018
European Planetary Science Congress 2018

Measurements of Mars rotational parameters by co-registration of Mars Orbiter Laser Altimeter (MOLA) profiles to Digital Terrain Models

Serena Annibali (1,2), Alexander Stark (1), Haifeng Xiao (2), Jürgen Oberst (1,2)
(1) Deutsches Zentrum für Luft- und Raumfahrt, Berlin, Germany (Alexander.Stark@dlr.de), (2) Technische Universität Berlin, Germany

Abstract

We use co-registration techniques [1] to study rotation parameters of Mars. The technique involves the alignment of two topographic data sets in the three-dimensional space. The method is conceived to operate with the pair of data constituted by laser altimetry profiles (LA) and gridded Digital Terrain Models (DTMs). The transformation is performed from the coordinates of the laser profile to the best matching position on the reference surface of the DTM. In the polar regions of Mars, we aim at co-registering the time-dependent altimetry measurements of the Mars Orbiter Laser Altimeter (MOLA) profiles [2, 6] to the static representation of the DTM in order to retrieve the variation in rotational rate and of the spin axis' orientation over time.

1. The method

The discrepancy between the complementary data sets represents the observable to minimize. For each profile, the adjustment problem is defined by a number of observations *i* (i.e. laser shots) and the relation between the unknown parameters and the observations. It is described by the following cost function to be minimised in a least-squares fashion:

$$\sqrt{\frac{\sum_{i=1}^{n}[h_{DTM}-h_{LA}]_i^{2}}{n}} \rightarrow min$$

The corrections represent the parameters of the co-registration and their optimal value is found through an iteration process. The algorithm is conceived to allow flexibility regarding parametrisation, e.g. we may co-register in map coordinates (line, sample and height), spherical coordinates (λ, θ, h) or Euler angles of rotation (α, δ, W).

2. Applications

2.1 Rotation parameters

The rotation parameters of Mars are typically determined by the radio tracking of spacecraft in orbit around Mars and of landers on the surface. The most recent rotation model includes seasonal variations and terms of nutation. The difference in right ascension and declination between the IAU2000 rotational model [3] and the more recent solution by [4] is plotted in Figure 1 over the time span covered by the MOLA data.

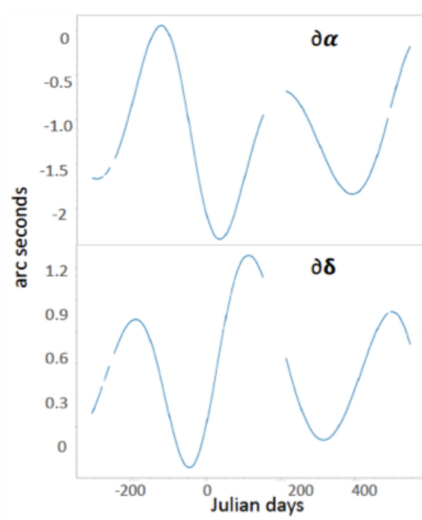

Figure 1: Difference in right ascension ∂α, and declination ∂δ between the IAU2000 and the Konopliv rotation models.

2.2 Co-registration in (α, δ, W) for the polar areas

By co-registration of the set of MOLA PEDR (not cross-over corrected data, 8026 profiles passing through the North pole and 8926 through the South) to the reference DTM we obtain corrections in the range of: ± 0.003° in $\boldsymbol{\alpha}$ on the North pole and ± 0.005° at the

South pole; ± 0.001° in $\boldsymbol{\delta}$ at the North pole and ±0.004° at the South pole. The data show several outliers at the South pole, which suggests relevant bias in pointing data or in orbit reconstruction. After elimination of these outliers from the dataset, we count a total of 6101 profiles at the North pole and 7875 for the South pole, the co-registration to the reference DTM show a residual scatter around in the range ±0.001° (or ±3.6 arc seconds) for $\boldsymbol{\alpha}$, ±0.002° (or ± 7.2 arc seconds) for $\boldsymbol{\delta}$, with standard deviations around 0.0004° (or 1.44 arc seconds).

The final values of the parameters show agreement with the IAU2000 rotation model (linear trend in black line in Figure 2), but we are not able to detect the small oscillations in $\boldsymbol{\alpha}$ and $\boldsymbol{\delta}$ described by the rotation model [4]. The differences in $\boldsymbol{\alpha}$ and $\boldsymbol{\delta}$ are in the order of 1 to 2 arc-seconds (plot Figure 1).

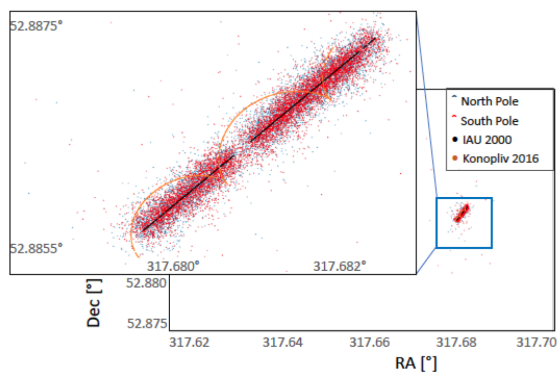

Figure 1: Maps of right ascension and declination of MOLA spot coordinates in the polar regions, from 28 February 1999 to 30 June 2001 (active operating time of MOLA).

3. Results and Outlooks

- The technique was demonstrated to recover rotational parameters of Mars, overcoming MOLA pointing and orbit biases. However, the terms of nutation, lying on the order of < 2 arc seconds, could not be retrieved.

- We aim at improving the accuracy in the corrections of the rotation parameters, in order to retrieve the small variations in right ascension and declination. To this end we want to combine and extend the obtained results by performing additional co-registrations of the laser profiles to stereo DTMs having higher resolution (e.g. HiRISE, HRSC).

- We extend the application to the equatorial regions in order to retrieve the variation in length of day.

Acknowledgements

This work was supported by a research grant from the Helmholtz Association and German Aerospace Center (DLR) (PD-308).

References

[1] Stark et al., 2015, *GRL*, 42, 7881-7889. **[2]** Smith et al., 2001, *JGR-Planets*, 106, 23689-23722 **[3]** Seidelmann et al., 2002, *Celest. Mech. Dyn. Astron.*, 82, 83-111. **[4]** Konopliv et al., 2006, *Icarus*, 182, 23-50. **[5]** Neumann et al., 2001, *JGR-Planets*, 106, 23, 753-768. **[6]** MOLA data on Planetary Data System, ftp://pds-geosciences.wustl.edu/mgs/mgs-m-mola-3-pedr-l1a-v1/mgsl_21xx/