The Mars Gravity Field after 11 Years of Continuous Tracking Data from Mars Odyssey and MRO Missions.

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Introduction: The Mars Odyssey and Mars Reconnaissance Orbiter (MRO) missions have provided more than 11 years of continuous tracking data of spacecraft in orbit around Mars. Mars Odyssey reached Mars orbit on October 24, 2001, and after areobraking, it began its science mapping mission on February 19, 2002. It is currently in orbit at ~400-km altitude. At the end of August 2006, the MRO mission began collecting tracking data for the radio science gravity investigation [1], and it has acquired more than 7 years of tracking data at lower altitudes (255-km periapse and 330-km apoapse).

The combination of Mars Odyssey and MRO radio tracking data allows the determination of the static Mars gravity field to degree and order 110, as well as, an improved recovery of the seasonal J_3 gravity changes. The seasonal mass exchange between the Mars polar caps is best observed in the time-variable zonal coefficients, with amplitude ~20% larger at odd degrees. The 11 years of radio tracking data cover a full solar cycle providing crucial information on the evolution of the seasonal CO_2 cycle.

However, mismodeling of the atmospheric drag, at the lower MRO altitudes, can reduce the benefits of MRO tracking data, and compromise the seasonal gravity monitoring [2]. Therefore, we have implemented a more accurate thermosphere model [3] in our Precise Obit Determination program (GEODYN II, [4]) to better capture and model the atmospheric density variability. We will present the Mars static and seasonal gravity field from 11 years (2002-2012) of Mars Odyssey and MRO tracking data.

Precise Orbit Determination: In order to recover the Martian gravity field (especially the time-variable, long-wavelength coefficients), all the non-conservative forces acting on the spacecraft must be modeled accurately. The three major forces that limit long-wavelength and temporal gravity recovery are solar radiation pressure, atmospheric drag and angular momentum desaturation maneuvers (AMDs).

Since, the MRO AMDs occurred every day for the first few months of the mission, and every two days afterwards, we arranged the start and stop times of the MRO data arcs to exclude these maneuvers. For Mars Odyssey AMDs occurred much more frequently (once or twice per day) and consequently we estimated an impulsive burn at the midpoint of the AMD duration span to compensate for AMD-induced accelerations on the spacecraft.

To compute the effects of radiation pressure and atmospheric drag, the spacecraft are modeled as a set of plates representing the spacecraft bus, the solar panels and the moveable antenna. The orientation of each plate is determined from spacecraft telemetry, and the specular and diffuse coefficients are based upon combination of surface types. The panel reflectivities and the scaling factor for the solar force (C_R=1) are not estimated. Solar radiation pressure mismodeling is absorbed by adjusting a set of empirical once-per-revolution (OPR) along-track periodic accelerations (cosine and sine) over each arc. We have also taken into account self-shadowing between spacecraft components [5].

The atmospheric drag model uses density values from the DTM-Mars model [6]. We adjusted an atmospheric coefficient (C_D) for each MRO orbit and for each Mars Odyssey arc. MRO $C_D s$ are time-correlated within each arc (~3 days) with a time correlation length of one orbital period.

Results: We present here a preliminary global solution of the radio tracking data of MRO arcs only. We downselected 748 arcs of the converged OD solution, excluding all the arcs that were during superior solar conjunctions (Sun-Earth-Probe angle < 20°). A constraint is applied to the higher degree harmonics so that the power spectrum approximately follows a power law. We applied a Mars Kaula power rule ($13 \times 10^{-5}/l^2$) that starts from degree 70.

Figure 1 shows the RMS amplitude of the gravity field (GSFC06-12). The formal errors of the GSFC06-12 solution were calibrated using variance component estimation [7]. We compared our solution with two other fields: MRO110B [2] and MROMGM0032 [7]. Both these solutions were derived from 2 years of MRO data (from 2006 and 2008) and 6 years of Mars Odyssey data (from 2002 to 2008), and the entire set of MGS data.

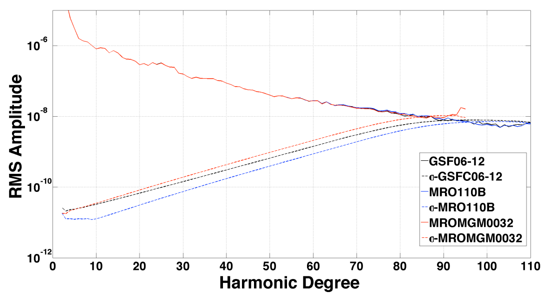

Figure 1 Gravity power spectrum of the estimated field GSFC06-12, MRO110B and MROMGM0032 solutions.

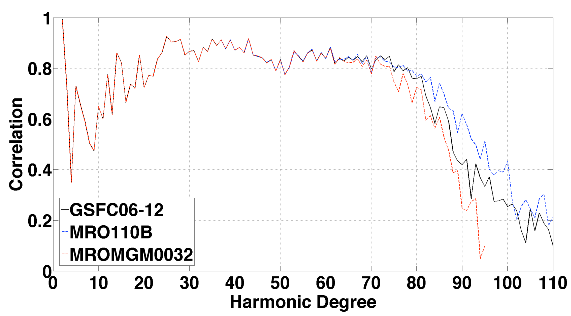

Figure 2 The correlation of the gravity field coefficients with spherical harmonic topography for the same fields of Figure 1.

The MRO110B gravity field was determined at Jet Propulsion Laboratory with their Orbit Determination Program (ODP), using atmospheric density values from the Mars-GRAM 2000 model. The MROMGM0032 gravity was recovered at NASA Goddard Space Flight Center with GEODYN II, using the Stewart-87 model [8]. Looking at the gravity power spectrum and correlations with topography using the MarsTopo2600 model [9] (Figure 2), the GSFC06-12 and MRO110B fields show a better agreement especially in the higher harmonics. The largest improvement comes from the more accurate DTM-model that leads to a more stable solution.

Conclusions and future work: The MRO mission presents an outstanding opportunity to improve the quality of the static gravity field and detect the seasonal vatiation of long-wavelength coefficients along an entire solar cycle. However, uncompensated drag forces on the spacecraft may affect the gravity solution, especially the seasonal variability of the low degree terms.

The inclusion of the DTM-Mars model into our POD program improves the recovery of the spherical harmonic coefficients of the Mars gravity field leading to a much more stable power spectrum. The correlation of gravity with topography is higher, and is in better agreement with the MRO110B solution.

The JPL gravity field was determined after 2 years of MRO data, 6 years of Mars Odyssey data, and the entire set of MGS data. The Mars Odyssey aerobraking transition phase in January 2002 especially can provide crucial information to stabilize the solution at higher degrees and will soon be added to the analysis.

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