MARS GRAVITY FIELD AND THERMOSPHERE FROM MARS RECONNAISSANCE ORBITER. Antonio Genova[1], Sander J. Goossens[2], Frank G. Lemoine[3], Erwan Mazarico[1], David E. Smith[1] and Maria T. Zuber[1]. [1] Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA (genova@mit.edu); [2] Center for Research and Exploration in Space Science and Technology, University of Maryland, Baltimore County, Baltimore, MD 21250, USA; [3] Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA.

Introduction: The Radio Science Gravity Investigation of the Mars Reconnaissance Orbiter (MRO) mission aims to improve the knowledge of the static structure of the Martian gravitational field and characterize its temporal variability, relevant to the planet's internal dynamics and the structure and dynamics of the atmosphere [1]. The 7 years of radio tracking data available can potentially be used to recover the seasonal variation of low-degree zonal gravity coefficients. However, the large errors in atmospheric drag modeling, due to the lower MRO altitude (periapse at 255 km), reduce the benefits of the MRO tracking data. As a result, MRO was not expected to help extend the seasonal gravity monitoring [2]. Here, we focus our work on the implementation of a more accurate thermosphere model in order to not only improve understanding of atmospheric density variability but also to characterize the abundances of some of the atmospheric constituents (CO_2, H, He). Changes in the low-degree spherical harmonic coefficients of the Martian gravity field combined to CO_2 density variability in the Martian thermosphere could be used to track the seasonal cycle of CO_2.

Thermosphere model: A semi-empirical density model, Stewart-87 [3], has been previously included in our precise orbit determination program (GEODYN II; [4]) to reconstruct the MRO trajectory and recover the Mars gravity field. The absence of partial and total density data of the Martian thermosphere above 200 km limits the accuracy of this model. Therefore, we implemented the semi-empirical "Drag Temperature Model (DTM) – Mars" into GEODYN II, to adequately reproduce variations in temperature and (partial) density along the MRO trajectory [5].

Results: In order to recover the Mars gravity field (especially the time-variable long-wavelength coefficients), all the non-conservative forces acting on the spacecraft must be modeled accurately. The two major force models that limit long-wavelength and temporal gravity recovery are solar radiation pressure and atmospheric drag. To compute the effects of radiation pressure and drag, the spacecraft is modeled as a set of plates representing the spacecraft bus, the solar panels and the antenna. The orientation of each plate is determined from spacecraft telemetry and, the specular and diffuse coefficients for each plate are based upon combination of surface types. The MRO panel reflectivities and the scaling factor for the solar pressure force (C_R=1) are not estimated. We adjusted two along-track periodic accelerations, at the orbital frequency (~2 hours), to account for solar radiation pressure mismodeling (self-shadowing, atmospheric dust effects, etc.).

The atmospheric drag model uses density values from the DTM-Mars model. We adjusted an atmospheric drag coefficient (C_D) for each spacecraft orbit. These coefficients are time-correlated within each arc (~3 days) with a time-correlation length of one orbital period. Figure 1 shows the time series of the estimated drag coefficients in the OD process with DTM-Mars compared to C_D obtained previously with Stewart-87. The estimation of C_D with DTM-Mars is more stable and a trend is clearly visible during the Mars year, with maximum C_D coefficients during summer in the southern hemisphere. This trend is due to inaccuracy in the seasonal terms of the various thermosphere constituents of the DTM-Mars model, which were derived from Mars Global Surveyor (MGS) accelerometer and radio tracking data. The MGS spacecraft was in a near-polar, near-circular (altitude ~400km) orbit, therefore, the DTM-Mars could not constrain the behavior of the Mars thermosphere at MRO periapsis altitude.

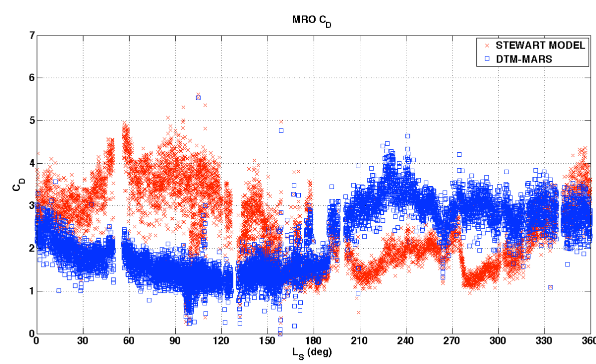

Figure 1. Drag scale factor.

Another piece of information that DTM-Mars is more accurate than Stewart-87 is the trend of the along-track periodic accelerations. Figure 2 shows the cosine, sine and total amplitude terms of the adjusted empirical along track acceleration. Stewart-87 requires along-track acceleration an order of magnitude larger to fit the radio tracking data at the same level.

We will present the radio tracking data analysis of the first 5 years of MRO in orbit about Mars from August 2006 to December 2011. With 5 years of tracking data collection from the MRO spacecraft, we will provide a new Mars gravity field 110x110. Figure 3 shows the surface gravity anomalies of a preliminary solution from the first two years of MRO data.

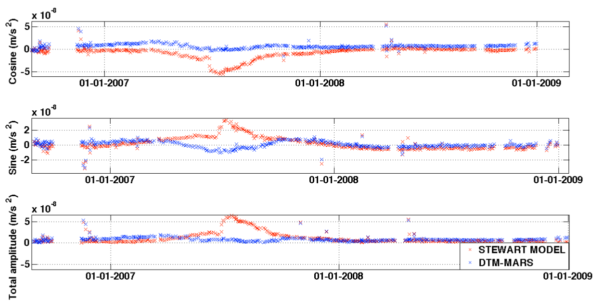

Figure 2. Along-track acceleration expressed as coefficients of cosine, sine and total amplitude.

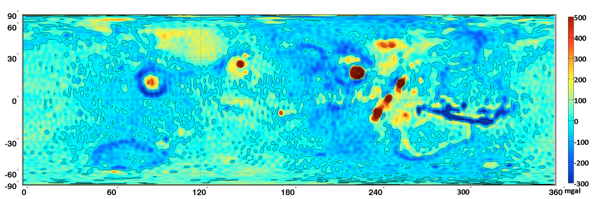

Figure 3. Surface gravity anomalies complete to degree and order 110 with respect to the reference ellipsoid (f = 1/196.9, Re = 3397 km)

Conclusions and future work: The determination of Mars gravity field from MRO radio tracking data requires an accurate thermosphere model to predict the variability of drag effect. Uncompensated drag forces on the spacecraft may affect the gravity solution, especially, the seasonal variability of the low degrees. The inclusion of the DTM-Mars into our OD program significantly improves the recovery of atmospheric density. At this stage, we report a detailed analysis regarding the static gravity field of Mars. We will process additional years of MGS and Mars Odyssey tracking data to recover the seasonal J_3 gravity changes. Furthermore, we will be able to retrieve directly periodic and non-periodic terms of Mars thermosphere constituents such as CO_2, H and He. The variations in the observed total density of CO_2 could be a significant improvement to the DTM-Mars, because carbon dioxide is the major constituent up to MRO pericenter altitude. The evolution of this thermosphere constituent and the Mars seasonal gravity (especially J_3) could be used to measure the seasonal mass of CO_2 that is deposited in the polar regions each fall and winter and sublimed back into the atmosphere every spring and summer.

References: [1] Zuber M. T. et al. (2007) *JGR,* 112, 1-12. [2] Konopliv A. S. et al. (2011) *Icarus*, 211, 401-428. [3] Stewart A. I. F. (1987) JPL PO NQ-802429, Lab. for Atmos. and Space Phys. [4] Pavlis D. E. et al. (2013) GEODYN operations manuals. Contractor Report, SGT Inc. [5] Bruinsma S. and Lemoine F. G. (2002) JGR, 107, 15-1 - 15-13.