MARS THERMOSPHERE MODEL FOR MRO ORBIT DETERMINATION

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The Mars Reconnaissance Orbiter (MRO) mission has acquired more than 7 years of radio tracking data for the radio science gravity investigation. The lower altitude of MRO spacecraft (periapsis at 255 km), which enables high-resolution gravity field model determination, causes significant drag effects that lead to poor results when spacecraft and atmosphere modeling assumptions are not well determined. Reasonable recovery of seasonal variation of any zonal gravity coefficients from MRO tracking data requires an accurate thermosphere model.
A semi-empirical density model, Stewart-87 (Stewart, 1987), has been previously included in our precise orbit determination program (GEODYN II; Pavlis et al., 2013) 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 DTM (Drag Temperature Model) – Mars into GEODYN II to adequately reproduce variations in temperature and (partial) density along the MRO trajectory (Bruinsma and Lemoine, 2002).

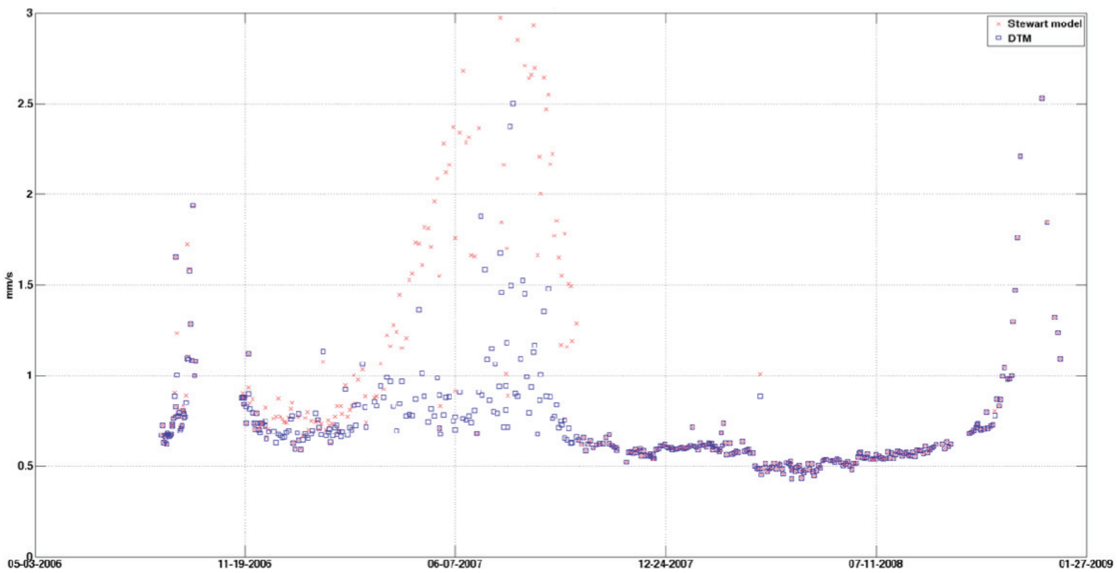

Figure 1 Range-rate fit level with Stewart-87 and DTM-Mars model

We present the radio tracking data analysis of the first two years of MRO in orbit about Mars comparing results of Stewart-87 and DTM-Mars model. Figure 1 shows the level of fit of range-rate observables from August 2006 to December 2008. The DTM-Mars model significantly improves the fit even when Stewart-87 yields large Doppler residuals.

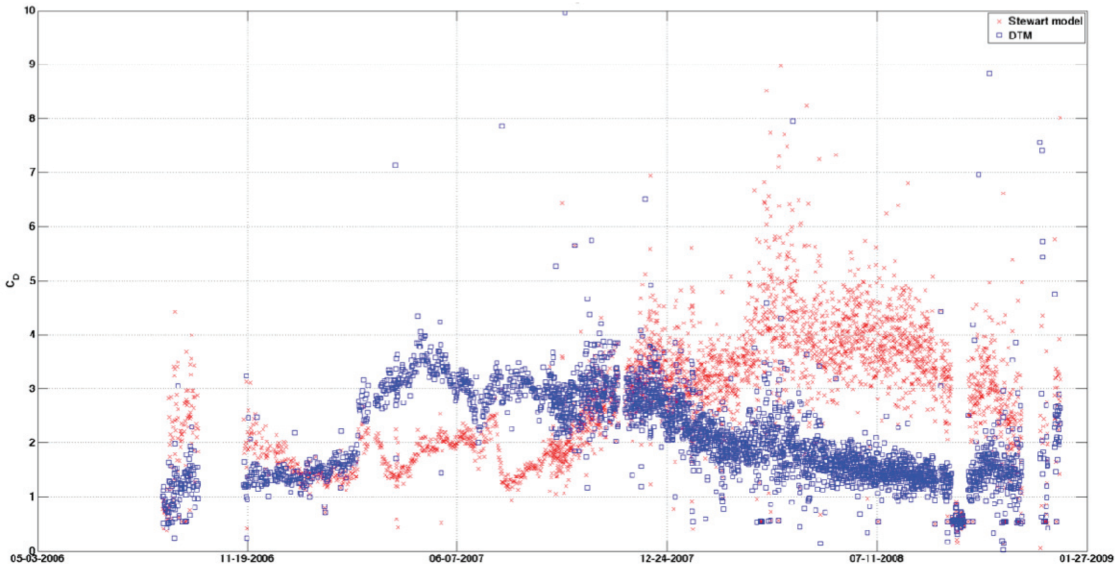

Figure 2 Drag scale factor

We adjusted an atmospheric drag coefficient (C_D) for each spacecraft orbit (~2 hours) in both cases. Figure 2 reports the time series of the estimated drag coefficients in the OD process with Stewart-87 and DTM-Mars. 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 when Mars is at its perihelion. 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.

The inclusion of the drag thermosphere model algorithm into our precise OD program allows us to retrieve directly periodic and non-periodic terms of Mars thermosphere constituents such as CO_2, O and He. The model is based on the hypothesis of static diffuse equilibrium of the thermospheric constituents, valid in the heterosphere, so the total density is reconstituted as the sum of the partial density. We may recover the model coefficients of thermosphere major constituents from radio tracking data in a global fit that adequately covers all atmosphere conditions.

The variations in the observed total density of CO_2 could be a significant improvement to the DTM-Mars model, because carbon dioxide is the major constituent up to MRO periapsis altitude. The evolution of this thermosphere constituent and the Mars seasonal gravity (especially J_3) could be used to measure the seasonal mass of carbon dioxide that is deposited in the polar regions each fall and winter and sublimed back into the atmosphere every spring and summer.