ATMOSPHERIC STRUCTURE OF THE MARTIAN ATMOSPHERE NEAR 250 KM ALTITUDE FROM MARS RECONNAISSANCE ORBITER RADIO TRACKING DATA. E. Mazarico[1], M. T. Zuber[1], F. G. Lemoine[2] and D. E. Smith[2], [1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology 54-510, 77 Massachusetts Avenue, Cambridge, MA 02139 (mazarico@mit.edu), [2]Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771.

Introduction: The latest member of the growing fleet of spacecraft scrutinizing the planet Mars, the NASA Mars Reconnaissance Orbiter (MRO), offers new perspectives for monitoring of the Martian upper atmosphere. Measurements are sparse in the thermosphere/exosphere, even though much progress has been made in the past decade from a range of techniques. Above 200km, an effective technique is Radio Science. Generally used to invert radio tracking data measurements into a gravity field expanded in spherical harmonics [1], it is also a tool for atmospheric studies [2,3]. The principle of adjusting model and spacecraft orbital parameters to best fit the Doppler and Range tracking data can be used in order to adjust a scale coefficient for the atmospheric density instead or in addition to gravity field coefficients. That scale coefficient, or drag coefficient C_D, is directly related to the density measurement: rho_measured = rho_model * C_D. In this study, we use the orbit determination program GEODYN developed at NASA/GSFC to perform preliminary atmospheric density recovery.

Orbit and atmospheric sampling: Launched in August 2005, MRO began the primary science phase in September 2006 after a successful 5-month aerobraking period (March to August 2006). The final science orbit is near-polar and sun-synchronous, similarly to the Mars Global Surveyor (MGS) and Mars Odyssey (ODY). However, MRO orbits at an altitude near 250km, much lower than MGS and ODY (~400km). Due to the slight eccentricity of the orbit and the location of the frozen periapsis (near 87°S), the atmospheric sampling is weighted towards the southern latitude. This was also the case for MGS and ODY, but due to a smaller scale height at MRO altitude and a comparable altitude change, the effect is stronger. Thus, the measurements obtained from radio tracking data in this study only provide monitoring information for the southern latitudes. Besides the constraint of the spacecraft trajectory itself, the other important parameter affecting the effective sampling of the density measurements is their frequency. The drag coefficient estimation time window directly affects the temporal and spatial resolution of the density estimates. By common standards, the measured atmospheric densities, whether at MRO or ODY altitude, are very low. Nevertheless, the altitude difference between ~250km and ~400km represents a 3-order of magnitude difference in terms of atmospheric density, and the increased atmospheric drag enables more frequent estimates. On MGS and ODY, spatial localization of the density measurements was not possible, because the shortest estimations were on the order of one day [2-4]. This corresponds to ~12 full orbits, and the whole range of longitudes is 'averaged' into one single C_D adjustment. With MRO, the daily estimates are much more stable, and we tested estimates once every 6, 3, 2 or 1 orbit. This corresponds approximately to density measurements every the number of orbits multiplied by 15 degrees, both on the day and night hemispheres. An improvement to the adjustment process, to enable the estimation of a constant day-to-night density ratio over a given amount of time, would effectively halve the sampling longitudinal resolution, separating the day and night densities.

Models: The trajectory of the spacecraft is forward-integrated starting from an initial guess of the spacecraft state, using both physical and measurement models. The main forces acting on the spacecraft besides the gravitational interactions are non-conservative forces: direct solar radiation, planetary radiation (solar radiation reflected off the Martian surface and thermal radiation of the Martian surface), and atmospheric drag. For MRO, the drag is the largest of these three, in contrast to MGS and ODY where it was 2-3 orders of magnitude smaller than the solar radiation. The cross-sectional area of the spacecraft necessary for the calculation of those accelerations is obtained from a 12-panel macro-model of the spacecraft, oriented in space according to telemetered quaternions. In this study, we also use the recent implementation of self-shadowing between macro-model plates. Self-shadowing, decreasing the actual cross-section presented, is important for the drag acceleration. The *a priori* atmospheric density model used during the processing of the radio tracking data is the Stewart model [5] described in [3].

Data: All the necessary data was obtained from the JPL FEI or NAIF servers. We processed the data from the start of the science mission to the time of writing of this abstract. A 15-20 day period centered around the solar conjunction (when, viewed from the

Earth, Mars was close to the Sun) where data coverage decreases, especially Range data, and where solar plasma effects are difficult to model. Data is processed in short 'arcs', which for MGS and ODY were generally 5 days long. Here, because the necessary navigation maneuvers are spaced by more than one day, we created two sets of arcs: longs arcs of the same length as was done before (4-5 days, [2-4]); and short arcs that do not include any maneuver. We use those two different sets in order to check the independence of our density measurements from the maneuver acceleration estimation done during the processing, and the data coverage and arc start/stop time choice.

Results: First results show that the daily drag coefficient estimates are stable, and that the obtained time series of atmospheric densities is consistent from arc to arc. All the drag coefficient adjustments are reasonable after the solar conjunction period (i.e., for DOY_{2006}>300), during which the fit of the tracking data is poor, with no Range data present and RMS (root mean square) values as high as ~20 mm/s for the Doppler data, compared ~1mm/s before and after.

The formal uncertainties of the drag coefficient, while excellent in the case of arc-long and daily estimates, increase dramatically for the highest adjustment frequencies (once every 1 or 2 orbits), as shown in Table 1. The large scatter in those latter estimates brings a sizeable portion of the time series to negative values. Thus, recoveries of drag appear unreliable and we focus on estimates at longer periods.

Figure 1 shows the daily estimates of density obtained from both arc sets. The differences can be explained by the different adjustments timings, as well as the inclusion of orbital maneuvers in the long-arc estimates. However, both time series show a similar trend, and both show comparable arc-to-arc variability. Figure 2 shows how more frequent estimates can help detect variability and spatial differences. Measurements once per 6 orbits are just at the limit for the detection of hemispheric differences.

The time series is still too short to able to study the effects of seasons and solar activity on density near 250km, but with the beginning of a new solar cycle, exciting studies of this region of the Martian atmosphere should be possible very soon.

References: [1] Lemoine et al. (2001), *JGR*, 106, 23,359. [2] Forbes et al. (2006), *Science*, 312, 1366. [3] Mazarico E. et al. (2007), *JGR, accepted*. [4] Konopliv et al. (2006), *Icarus*, 182, 23. [5] Stewart A. I. (1987), NASA Technical Report JPL PO NQ-802429.

C_D estimate frequency	relative sigma range (%)
1 / arc	$<10^{-2}$
1 / day or 1 / 12 orbits	$10^{-2} \rightarrow 10^{-1}$
1 / 6 orbits	$5.10^{-2} \rightarrow 10^{0}$
1 / 3 orbits	$10^{-1} \rightarrow 3.10^{0}$
1 / 2 orbits	$5.10^{-1} \rightarrow 2.10^{1}$
1 / orbit	$5.10^{-1} \rightarrow > 10^{2}$

Table 1. Relative formal uncertainties (σ_{CD}/C_D) of the drag coefficient estimations.

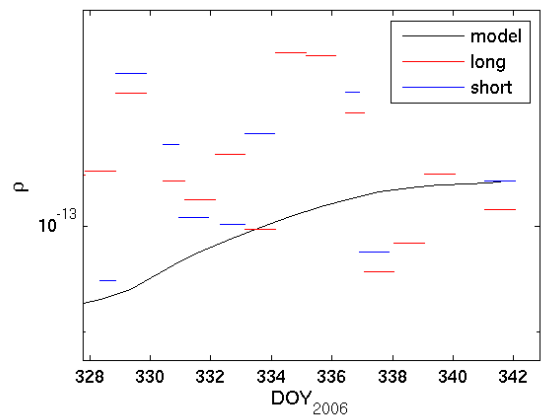

Figure 1. Comparison of daily density estimates estimated from long and short arcs.

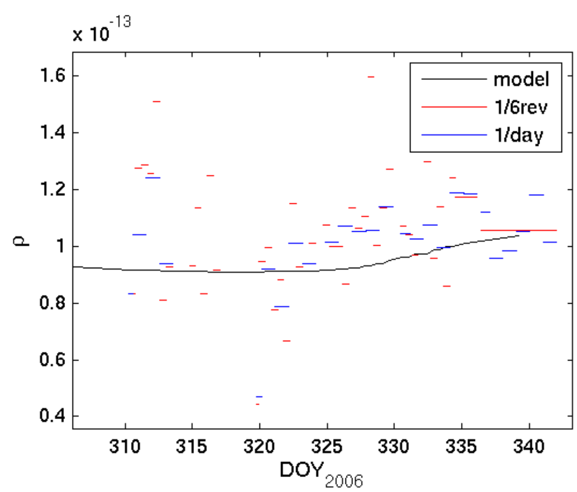

Figure 2. Estimated atmospheric density at 250km above the South Pole, from the long-arc set.

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