FOUR MARTIAN YEARS OF NIGHTSIDE UPPER THERMOSPHERIC MASS DENSITIES FROM ELECTRON REFLECTOMETRY: EXTENDING THE METHOD TO NORTHERN LATITUDES

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Introduction: the long-term dynamics of the Martian upper thermosphere near the exobase (~180 km altitude) are still relatively poorly constrained by data. Electron reflectometry (ER) provides an indirect way to infer, from the shape of electron loss cones, upper thermospheric mass densities at these altitudes, as demonstrated by our earlier work [1, 2]. This method requires detailed knowledge of the magnetic field in near-Mars space and thus was previously limited to ~2% of the planet where 1) the permanent and predictable crustal magnetic field dominates over the spatially and temporally variable magnetotail field and 2) where open magnetic topology allows the formation of loss cones.

Extending the method geographically using the ER crustal magnetic field map. Electron reflectometry is based on the magnetic mirror effect, that is, the reflection of charged particles from regions of increased magnetic field strength. By comparing the pitch angle distribution of electrons moving toward the planetary surface with the distribution of those electrons reflected from the surface, the increase in the magnetic field strength can be determined. ~2.9 million measurements of 90-400 eV electrons from the Mars Global Surveyor (MGS) Magnetometer/Electron Reflectometer (MAG/ER) over 4 Martian years have been combined to produce a map of the field magnitude $|\boldsymbol{B}|$, due to *crustal* sources only, at 185 km altitude (the mean altitude at which the electrons' scattering depth reaches unity) [3], hereafter referred to as B_{185}.

This map represents the permanent, unchanging magnetic field of the crust and is combined with in-situ MAG measurements to construct a 'best-guess' magnetic field profiles as a function of altitude and distance along the magnetic field line (i.e. from the spacecraft position to the collisional atmosphere) to which the electrons are bound. This magnetic profile is used as input to a kinetic model of electron transport and used, along with measured electron loss cones from MAG/ER, to solve for a parameter ψ, which is the base 10 logarithm of the ratio of the mass densities (near the absorption altitudes of 170-200 km) to a mean model reference atmosphere [3]. The coarse angular resolution of the ER instrument (22.5°) precludes any more sophisticated parameterization of the atmospheric density. Best-fit values of ψ are easily converted to inferred mass densities at the mean altitude of greatest sensitivity, 185 km. All inferred densities are at 2 a.m. local time.

Due to uncertainty in field line tracing in situations of very weak crustal field and/or shallow magnetic elevation angles ϕ (i.e. angle between local horizontal and magnetic field), we ignore all data where B_{185} < 20 nT and $|\phi|$ <45°. Further, because of substantially higher magnetic turbulence in the Martian magnetosheath, we only include data collected in the Martian shadow (i.e. solar zenith angle >118°). Figure 1 shows the data coverage map as a function of latitude and longitude. 55.7% of the geographic pixels contain valid data for density probing, compared with 2% with the previous method [2]

For the purposes of this analysis, the data is averaged over all planetary longitudes, divided into bins of 7.5° in latitude and 10° of Mars solar longitude (Ls). It is then boxcar-smoothed over 3 nearest neighbors in both latitude and Ls and shown in figure 2 as a logarithmic color plotted.

Results and discussion: examining figure 2, we observe a couple of repeating features. The first is the overall annual expansion and contraction of the thermosphere due to the changing solar flux, as Mars orbits the sun, of infrared radiation heating the lower atmosphere and ultraviolet radiation heating the upper atmosphere. Densities vary by a factor of 3-5 in the mid-latitudes where we have complete data coverage. Second is the very low densities at southern latitudes near aphelion, particularly near the South pole. The third is consistently high densities (and hence higher temperatures) in the northern winter pole near perihelion, reflecting likely inter-hemispherical circulation and winter polar warming during this part of the Martian year. [4].

There are also some interesting 'anomalous' features. South winter polar densities start to increase every year from their minimum around Ls = 130° but the magnitude of this increase is substantially larger in Mars years 24 and 25 compared with 26 and 27. Also, the behavior of the upper thermosphere before and during the 2001 global dust storm is puzzling, as noted in our earlier work [2]. There is no large general increase in densities during the storm, in fact densities in far southern latitudes rise substantially several months before the onset of the storm, with this increase occurring later (as seasonally expected) as one moves equator-ward. Also unexpected is the very large increase around Ls = 270 in Mars year 27 where densities reach 30 g/km^3 during the usual dust season, though the dust opacity is nothing out of the ordinary for that time of year [2]

This is the first data set of nightside upper thermospheric densities at Mars covering multiple Martian years with reasonably good latitude coverage. We will present comparisons with the Mars thermospheric global circulation model (MTGCM) in an attempt to understand the origin of some of the unexplained features at the top of the Martian thermosphere/bottom of the exosphere. Reproducing some of these features will be the goal of the MTGCM as more complete physics is included therein

References: [1] Lillis et al (2005), GRL, doi:10.1029/2005GL024337. [2] Lillis et al. (2008), Icarus, doi:10.1016/j.icarus.2007.09.031. [3] Lillis et al. (2008), Icarus, doi:10.1016/j.icarus.2007.09.032. [4] Bougher et al. (2006), GRL, 33, L02203.

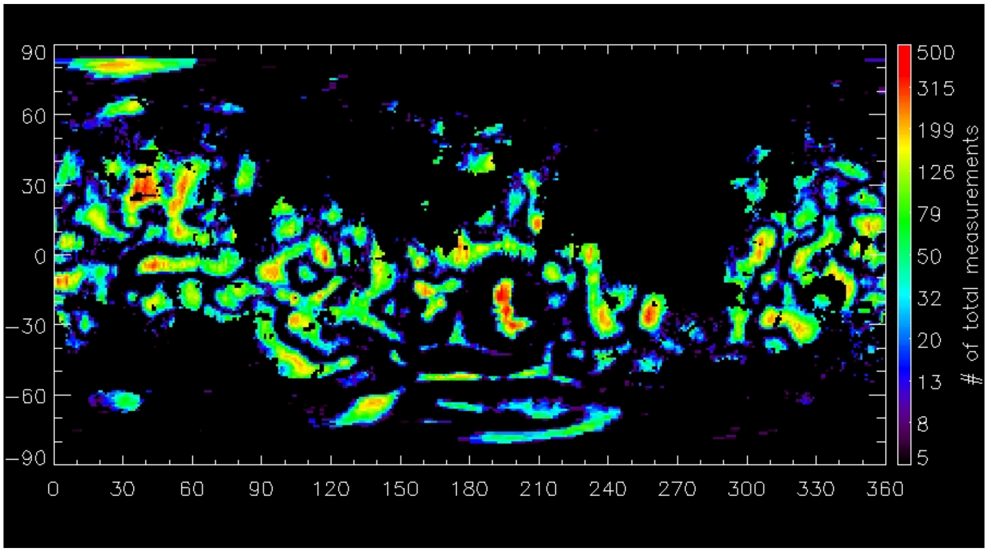

Figure 1: number of measurements in the ER density probing data set as a function of geographic location in 1° x 1° bins.

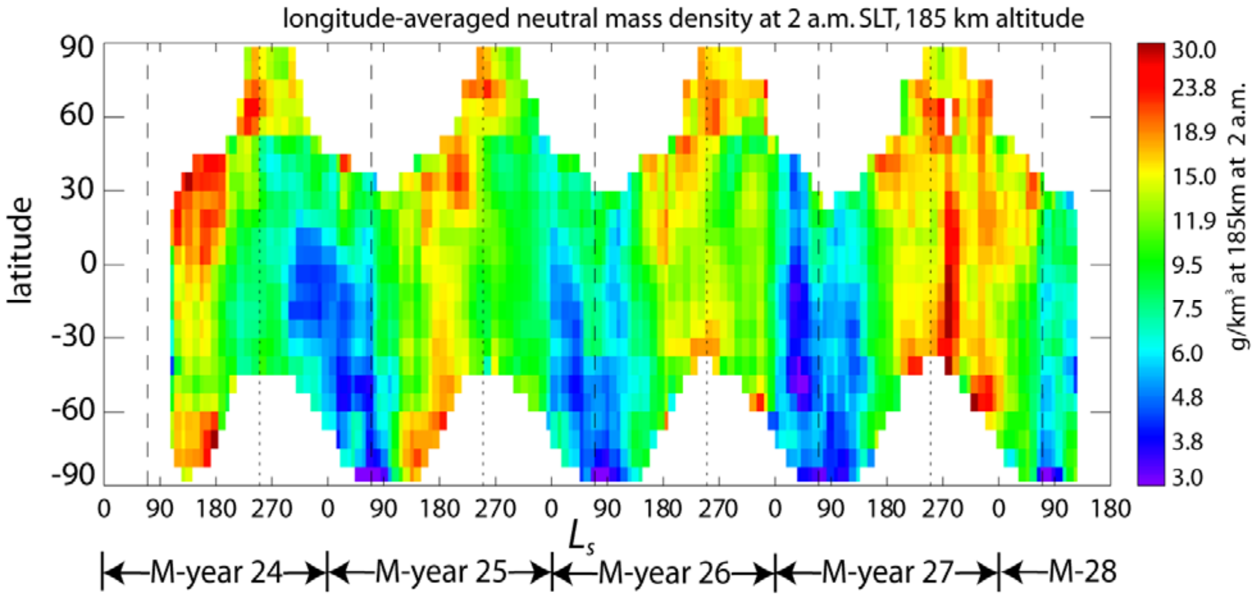

Figure 2: inferred neutral mass densities at 185 km altitude at 2 a.m. local time, averaged over all longitudes where data exist. Note the color bar is logarithmic.