TRENDS IN MARS THERMOSPHERIC DENSITY AND TEMPERATURE STRUCTURE OBTAINED FROM MAVEN ACC/RW AND NGIMS DATASETS: INTERPRETATION USING GLOBAL MODELS.

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Introduction: The Mars thermosphere-ionosphere-exosphere (TIE) system constitutes the atmospheric reservoir (i.e. available cold and hot planetary neutral and thermal ion species) that regulates present day escape processes from the planet [1]. Without knowledge of the physics and chemistry creating this TIE region and driving its variations (e.g., solar cycle, seasonal, diurnal), it is not possible to constrain either the short-term or long-term histories of atmosphere escape. The characterization of this upper atmosphere reservoir is one of the major science objectives of the MAVEN mission [2].

MAVEN in-situ sampling of the topside thermospheric structure began soon after Mars Orbit Insertion in September-2014. Over the first ~300 orbits, periapsis latitudes ranged from about 32° to 74°N; periapsis local mean solar times (LMST) ranged from about 15:00 to 06:00; and corresponding periapsis altitudes ranged from ~200 km down to ~150 km. This initial dayside in-situ sampling lasted until about 17-December-2014, after which the spacecraft periapsis started moving Southward and onto the nightside. During this initial ~3 month period, monthly averaged solar EUV-UV fluxes corresponded to F10.7 ~ 150-160 at Earth (generally solar moderate conditions) and the Martian season advanced from Ls ~ 205 to 254° (between equinox and perihelion conditions).

Not all in-situ MAVEN instruments probing the TIE region turned on and began operations at the same time. For instance, the NGIMS instrument turned on briefly at the time of the Comet Siding Spring encounter, and started nominal science orbit data taking on 15-November-2014. NGIMS datasets include both thermal neutral and ion densities below ~550 km. However, mass densities were obtained much earlier (throughout October 2014) and were derived utilizing spacecraft reaction wheel (RW) datasets below ~200 km, from which scale heights and temperatures were inferred.

We investigate both initial in-situ NGIMS neutral densities/temperatures and RW derived mass densities/temperatures over the first ~300 orbits (mostly dayside conditions) and a sampling of later orbits (when periapsis occurs on the nightside at Northern mid-to-high latitudes). Trends (e.g. latitude, local time, diurnal) of extracted densities and inferred temperatures are compared with corresponding global model simulations in order to understand the variations observed, and the underlying physical processes responsible.

MAVEN Datasets:

Accelerometer/reaction wheel datasets. The Accelerometer Experiment (ACC) uses atmospheric drag accelerations sensed by inertial measurement units (IMU) onboard the spacecraft to recover atmospheric density along the orbiter path and below ~ 160 km [3]. These densities are employed to estimate hydrostatic 'vertical' density and temperature profiles, along track and altitudinal density waves, and latitudinal and longitudinal density variations. In addition, mass densities can be derived utilizing spacecraft reaction wheel (RW) datasets (and the subtraction of all other non-atmospheric torques). This novel technique enables mass densities to be retrieved below ~200 km, from which scale heights and temperatures can also be inferred.

NGIMS datasets. The Neutral Gas and Ion Mass Spectrometer (NGIMS) instrument measures the neutral composition of the major gas species, and the thermal ions in the Martian upper atmosphere. For example, this includes density profiles of He, N, O, CO, N_2, O, O_2, Ar and CO_2, and their major isotopes from the homopause up to about one scale height above the "traditional" exobase, with a vertical resolution of ~5 km and a target accuracy of ~25% for most of these species [4]. Neutral temperatures are derived from neutral scale heights. NGIMS measurements are used to determine the variation of the neutral composition with altitude, latitude, local time, longitude and season from the homopause upward into the exosphere where neutral escape can occur. Variations across a range of solar cycle conditions can also be monitored.

The systematic characterization of the reservoir region, provided in part by NGIMS and ACC/RW instruments, is crucial to move forward with detailed studies of atmospheric loss processes and the determination of volatile escape rates

Mars Global Ionosphere Thermosphere Model: The recently developed and initially validated 3-D Mars Global Ionosphere-Thermosphere Model (M-GITM) [5] is used to address global thermospheric structure over ~150-200 km corresponding to the MAVEN in-situ sampling conditions described above.

In general, the M-GITM code simulates the conditions of the Martian atmosphere from the surface to the exosphere (~0-250 km), utilizing physical processes and subroutines largely taken from previous Mars GCMs [6, 7]. Neutral temperatures, densities (e.g. CO_2, CO, N_2, O, O_2, Ar, mass density) and three-component neutral winds plus dayside ion densities (e.g. O_2+, O+, CO_2+, N_2+, NO+) are simulated. Visible dust opacities are specified to be globally uniform and static for annual averaged conditions (e.g. $\tau = 0.5$).

For this MAVEN sampling period, archived M-GITM simulations were obtained for Ls = 180 (equinox) and Ls = 270 (perihelion) seasonal conditions, along with solar moderate EUV-UV fluxes (F10.7 = 130 at Earth). These M-GITM simulations bracket the inital MAVEN sampling conditions (first 3-months) described above. M-GITM latitude versus local time slices at ~200 km are presented in Figures 1 and 2. These plots illustrate neutral temperatures and underlying horizontal wind directions (and magnitudes). Notice the strong latitudinal gradients in simulated neutral temperatures at Northern mid-to-high latitudes over these dayside local times; these gradients are predicted to be significantly larger for perihelion than equinox conditions. Corresponding CO_2 number and mass densities should vary accordingly (i.e. decreasing in magnitude from these same Northern mid-to-high latitudes at constant altitudes).

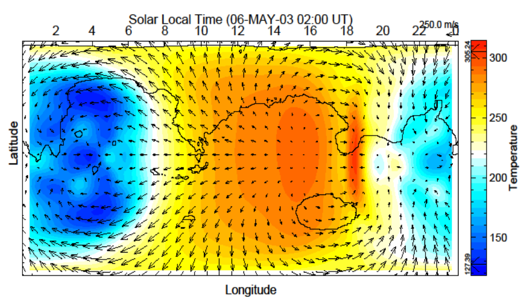

Figure 1. M-GITM (Equinox, solar moderate) latitude vs local time slice at ~200 km. Temperatures (color coded) are displayed along with underlying horizontal wind vectors (representing magnitude & direction). 0°E longitude is located at LT = 12:00 (UT = 12). Maximum horizontal winds approach ~300 m/s. Temperatures range from 127 to 305° K.

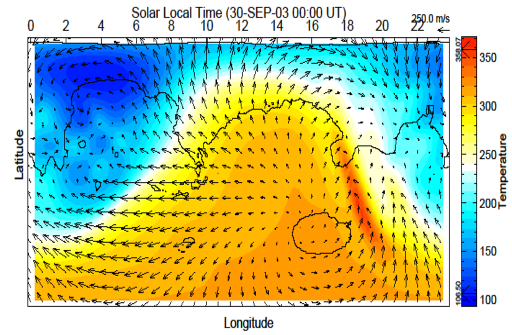

Figure 2. M-GITM (Perihelion, solar moderate) latitude vs local time slice at ~200 km. Temperatures are displayed along with underlying horizontal wind vectors (representing magnitude and direction). 0°E longitude is located at LT = 12:00 (UT = 12). Maximum horizontal winds approach ~350 m/s. Temperatures range from 106 to 358° K.

Data-Model Comparisons and Results: MAVEN datasets (i.e. NGIMS neutral densities, RW mass densities, and inferred temperatures from both) will be compared with corresponding M-GITM simulated outputs in order to investigate thermospheric trends (e.g. latitude, local time, diurnal) and periodic driven variations (e.g., solar cycle, solar rotation, seasonal). Again the objective is to characterize this upper atmosphere reservoir in order to understand the processes that regulate present day escape processes from the planet.

References:

[1] Bougher, S. W., Cravens, T. E., Grebowsky, J. and Luhmann, J. (2014). Sp. Sci. Rev., 182, doi:10.1007/s11214-014-0053-7.

[2] Jakosky, B., et al. (2014). Abstract, pg. 28, 6th Alfven Conference, University College London, 7-11 July 2014.

[3] Zurek, R. W., Tolson, R. H., Baird, D., Johnson, M. Z., and Bougher, S. W. (2014). Sp. Sci. Rev., 182, doi:10.1007/s11214-014-0095-x.

[4] Mahaffy, P. R. et al. (2014). Sp. Sci. Rev., 182, doi:10.1007/s11214-014-0091-1.

[5] Bougher, S. W., et al. (2015). JGR, jgre20354, accepted for publication.

[6] Haberle, R. M., Murphy, J. R., and Schaeffer, J. (2003). Icarus, 161, 66-89.

[7] Bougher, S. W., et al. (2008). Sp. Sci. Rev., 139, 107-141.