Terminator Structures in the Thermosphere and Ionosphere of Mars

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Introduction

The NASA Mars Atmosphere and Volatiles EvolutioN (MAVEN) observations of the Martian thermosphere have indicated the presence of persistent density and temperature structures near the dawn and dusk terminators [Pilinski et al. 2018]. The persistence of these features is inferred from the fact that they are observed in similar locations over the course of different seasons and years. These features were first termed "heat islands" by Bougher et al. [1990] who predicted their existence in early global-circulation models of the Martian thermosphere. We explore the MAVEN neutral composition and ionospheric density data using in-situ measurements and identify near-dusk neutral temperature and density enhancements during the August to December 2016 timeframe. This analysis corresponds with conditions between equinox and northern summer/perihelion. We compare the data with global circulation model results generated for solar conditions corresponding to the time of measurement. The model and data indicate the existence of large-scale temperature perturbations between 18-22 LST.

MAVEN Data

- Neutral Gas and Ion Mass Spectrometer (NGIMS) (descending/ascending) number densities [Mahaffy et al. 2014] (200 km).
- Neutral temperatures (T_n) at 200 km are derived from Argon densities along each ascending and descending pass. The Argon derived densities are shown in **Fig. 2 (a)** and **(b)** and have been smoothed with an 18-orbit averaging window to remove tidal and gravity wave variability.
- Extreme Ultra-Violet (EUV) Lyman-α measured by MAVEN EUV Monitor [Eparvier et al. 2015] was used to drive the MGITM model and is shown by purple triangles in **Fig. 2a**.
- Langmuir Probe and Waves (LPW) electron densities [Andersson et al., 2015] are compared to the neutral densities (200 km).
- Accelerometer (ACC) total mass densities [Zurek et al. 2014] at 200 km.

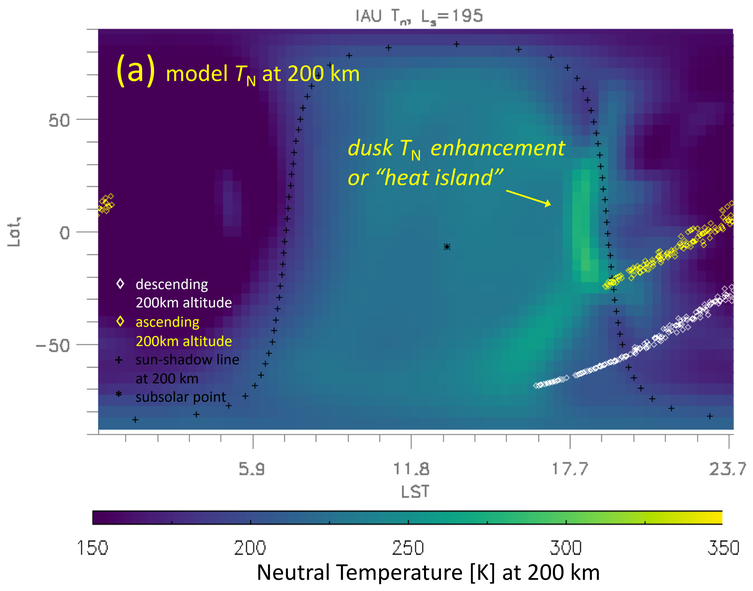
Mars GITM (MGITM)

- The MGITM model has been run at CLASP for conditions corresponding to August (**Fig. 1**), October (not shown), and November (not shown) of 2016. The EUV forcing input was based on MAVEN-EUVM instrument measurements.
- Model densities are interpolated in time and space along the MAVEN orbit and model density profiles are used to estimate a neutral temperature at 200 km altitude. This process is consistent with the derivation of neutral temperatures from the NGIMS data.

Discussion

- MAVEN ascending passes intersect the edge of the modeled dusk T_n enhancement near the end of August 2016 (**Fig. 1a**).
- Model result indicate strong (>50 K from background) dusk T_n enhancements in the Martian thermosphere which are collocated with horizontal and vertical wind shears (**Fig 1b**).
- Two ~40-50 K enhancements are seen near 19.5LST and 21LST (**Fig. 2a & b**) during descending passes. The confidence interval expands significantly in these regions with temperatures during some orbits exceeding 350 K. The model does not predict any such enhancements at these locations indicating that the modeled feature may be horizontally displaced from the observed "heat islands"
- Neutral density enhancements are generally observed at the location of the temperature enhancements (vertical green lines in **Fig. 2 and Fig. 3**). Plasma enhancements also correlate with these neutral features even on the night side.
- Mass densities from accelerometer data at 170 km also indicates enhancements near these locations (grey diamonds)
- The dusk terminator features observed by MAVEN tend to have amplitudes lower than those predicted by the model. This may be caused by the fact that the thermospheric winds, while qualitatively consistent with model results over a climatological average, are highly variable over shorter time scales. This variability, observed in almost all MAVEN measurements especially at night, may diminish the sustained dynamical heating represented in the modeled atmosphere.

Mars GITM (MGITM)



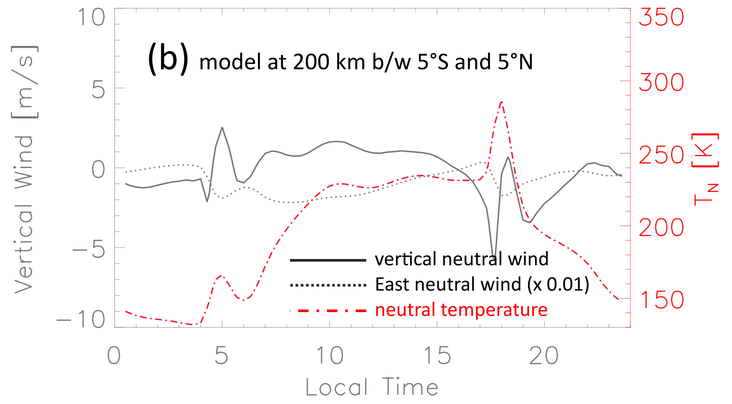


Fig. 1: August 2016 MGITM neutral temperatures at 200 km **(a)** along with location of MAVEN at 200 km altitude for descending (white diamonds) and ascending (yellow diamonds) passes. Modeled neutral temperatures (red) and winds (black) are extracted from the model between 5°S and 5°N latitudes and plotted above **(b)**. Note that the location of the dawn and dusk temperature enhancements corresponds with shears in neutral and horizontal winds.

Data-Model Comparison

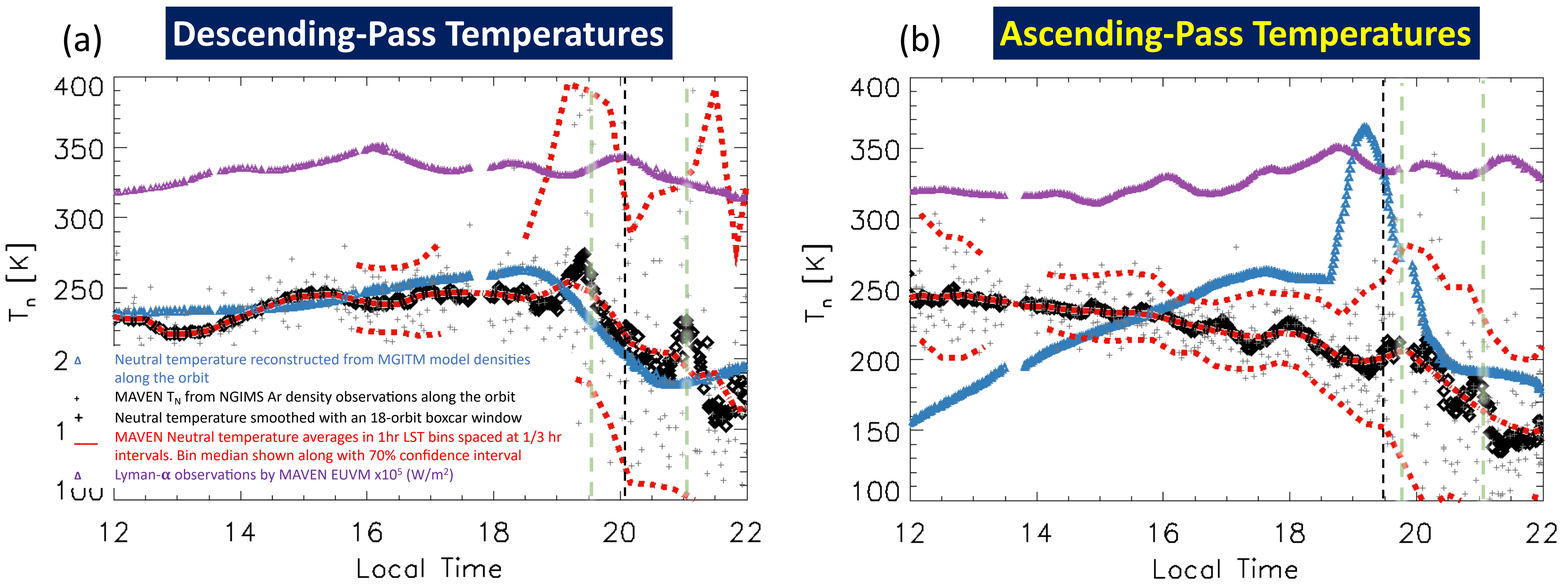


Fig. 2: Neutral temperatures derived from NGIMS Argon densities along the satellite track. Descending/ascending passes are shown on the left/right (panel a/b). Model results are shown in blue while the observed temperatures are plotted in black crosses for orbit by orbit observations, black bold diamonds for the smoothed time series, red lines for the binned results (median and confidence interval), and purple for the Lyman-α. Peaks in the confidence interval indicate significant numbers of above average temperature profiles. We identify neutral structures where these peaks correspond with enhancements of 20K or more in the smoothed results.

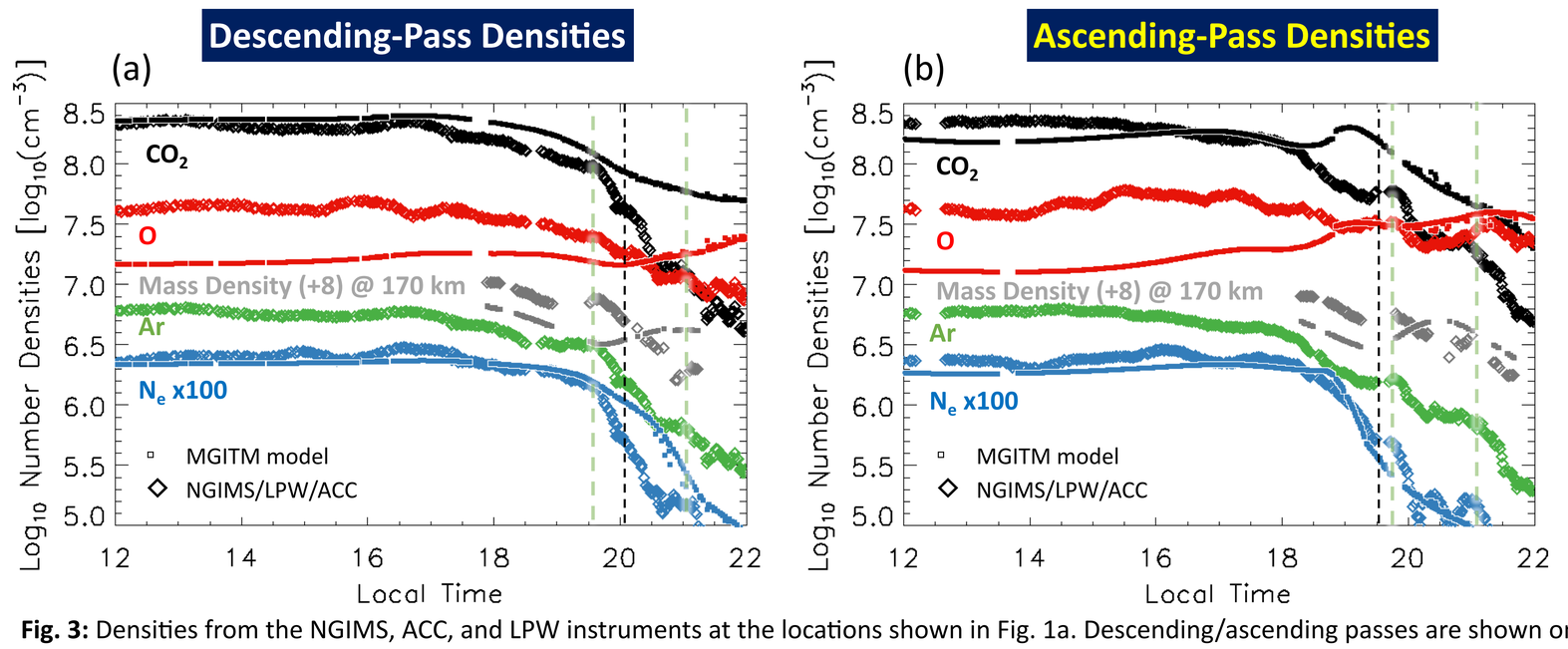


Fig. 3: Densities from the NGIMS, ACC, and LPW instruments at the locations shown in Fig. 1a. Descending/ascending passes are shown on the left/right (panel a/b). Model results are shown with squares while the observations are plotted in diamonds. Vertical dashed black lines indicate the location of the terminator at 200 km altitude. Vertical green dashed lines show the locations of near-dusk enhancements.