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Unveiling Mars nightside mesosphere dynamics by IUVS/MAVEN global images of NO nightglow

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Abstract

We analyze the morphology of the ultraviolet nightglow in the Martian upper atmosphere through Nitric Oxide (NO) δ and γ bands emissions observed by the Imaging Ultraviolet Spectrograph instrument on the Mars Atmosphere and Volatile EvolutioN spacecraft. The seasonal dynamics of the Martian thermosphere-mesosphere can be constrained based on the distribution of these emissions. We show evidence for local (emission streaks and splotches) and global (longitudinal and seasonal) variability in brightness of the emission and provide quantitative comparisons to GCM simulations.

1. Introduction

On the dayside thermosphere of Mars, solar extreme ultraviolet radiation partly dissociates CO_2 and N_2 molecules. O(^{3}P) and N(^{4}S) atoms are carried by the day-to-night hemispheric transport. They preferentially descend in the nightside mesosphere in the winter hemisphere, where they can radiatively recombine to form NO($C^2\Pi$). The excited molecules promptly relax by emitting photons in the UV δ bands and in the γ bands through cascades via the $A^2\Sigma$, v' = 0 state. These emissions are thus indicators of the N and O atom fluxes transported from the dayside to Mars' nightside and the winter descending circulation pattern from the nightside thermosphere to the mesosphere (e.g. Bertaux et al., 2005 ; Bougher et al., 1990 ; Cox et al., 2008 ; Gagné et al., 2013 ; Gérard et al., 2008 ; Stiepen et al., 2015, 2017).

2. Observations

Observations of these emissions have been accumulated into a large dataset of nightside disk images and limb profiles obtained by the Imaging Ultraviolet Spectrograph (IUVS, McClintock et al., 2015) instrument when the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft is at its apoapsis phase along its orbit. An example of observation during winter in the southern hemisphere is illustrated in Figure 1. Complementary information is obtained from limb profiles collected when the MAVEN spacecraft is near periapsis (Stiepen et al., 2017).

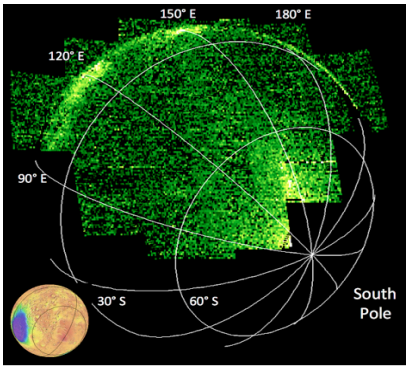

Figure 1 – IUVS observation of the NO Nightglow in disk image mode during winter in the southern hemisphere. The green color code indicates the brightness of the emission. Adapted from Jakosky et al., 2017.

IUVS ultraviolet domain ranges from 110 nm to 340 nm and therefore fully covers the range of the NO δ and γ emission bands. Disk images are accumulated during winter in the southern hemisphere.

3. Waves and tides in the Martian nightside mesosphere

Disk images and limb profiles data both show longitude sectors of enhanced brightness close to the equator during summer and winter conditions. Observations also reveal spots and streaks, indicating irregularities in the wind circulation pattern and possible impact of waves and tides.

The unexpected longitudinal variability of the NO nightglow brightness suggests the importance of dynamical impact of waves on the emission. We note that the observed variations cannot be caused by tides, as they are observed at all nightside local times and during a long period of time. Impact of geographic structure on the nightside mesosphere was not observed so far using the NO nightglow as a tracer of propagating waves in this region of Mars's atmosphere.

4. Seasonal control of the emission and global dynamics

The brightest emission is observed close to the winter pole. Stiepen et al., (2017) showed that the LMD-MGCM globally reproduces the main global seasonal trends observed, especially during equinox. The model however overestimates the altitude of the observed emission and strongly underestimates its brightness at winter. This suggests that the model dynamics transports N atoms to the nightside thermosphere at higher (polar) latitudes than observed toward the winter pole but correctly reproduces the dynamics in southern fall equinox.

5. Summary and conclusions

We make here the first use of disk images showing large and sudden variability in the NO nightglow emission, and thus the nightside mesosphere dynamics.

This dataset addresses pending questions raised by the observations of NO Nightglow at Mars by the SPICAM instrument on Mars Express (e.g. Bertaux et al., 2005 ; Cox et al., 2008 ; Gagné et al., 2013 ; Stiepen et al., 2015) and limb observations of NO Nightglow by the IUVS instrument (Stiepen et al., 2017).

The disk images and limb profiles are compared to those calculated with the LMD-MGCM model (Gonzàlez-Galindo et al., 2009 ; Lopez-Valverde et al., 2011) and the M-GITM model (Bougher et al., 2015) to focus on the seasonal, local time and geographical influences on the NO Nightglow emission. We will also provide a statistical study of the regions of enhanced brightness and discuss possible interpretation from the comparison to the GCM simulations.

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