Seasonal variation of neutral and ion compositions in the Martian upper atmosphere observed by MAVEN/NGIMS

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The Martian thermosphere, exosphere, and ionosphere are intermediate atmospheric regions strongly impacted by coupling from below with the lower-middle atmosphere and coupling from above with external forces, such as solar EUV and solar wind. Atmospheric reservoir in these regions is believed to determine the composition of species that escape to space. Jakosky et al. (2017) and Slipski et al. (2018) recently showed substantial variations in the altitude of a compositional boundary, called the homopause, below which gases are well-mixed by eddy diffusion (homosphere) and above which gases are diffusively separated according to their own scale heights by molecular diffusion (heterosphere). Yoshida et al. (submitted) showed that N_2/CO_2ratio in the lower thermosphere varies seasonally and latitudinally owing to the variation of the homopause altitude. However, the variation of the ionospheric composition, which can escape to space, responding to the lower thermospheric variation has not been well understood.

The variation of the ionospheric composition is observed by Neutral Gas and Ion Mass Spectrometer (NGIMS) aboard Mars Atmosphere and Volatile EvolutioN (MAVEN). The variation of CO_2^+density at 200 km altitude in the ionosphere resembles that of CO_2density at 140 km altitude at the top of the lower thermosphere. Higher CO_2^+density appears near perihelion and lower CO_2^+density near aphelion. Additionally, the observed sinusoidal trend of CO_2^+density suggests that ionospheric density is relatively controlled by the seasonal variation of the neutral upper atmosphere than the long-term variation of solar EUV flux. On the other hand, N^+density shows the opposite trend with CO_2^+density, which could be explained by the fact that the photochemical loss of $N^+$is caused by the reaction with CO_2. We also have investigated the vertical structures of CO_2^+, O_2^+. $O^+$and N^+densities between 150 and 400 km altitude. The closer relationship between the neutral upper atmosphere and ionosphere is also confirmed below 250 km altitude. The scale height of the major ion species is almost two times larger than that of neutral species. We find that CO_2^+density has a largest variation, by a factor of ˜7 at 200 km altitude. Meanwhile, the slopes of ion densities in the photodynamical region between 300 and 380 km altitudes increase compared with those in the diffusion region between 180 and 230 km altitudes in MY34 L_s= 59° - 63°, MY33 L_s= 70° - 73°, and MY33 L_s= 148° -154°, except for in MY33 L_s= 342°- 346°. This fact implies that effects from external forces, such as upward flow and local heating induced by the solar wind interaction, may change the slopes of ion densities in the photodynamical region. Additionally, mixing ratio of CO_2^+/O_2^+can vary along the season in the range of ˜0.017 to ˜0.097, by a factor of ˜6, around 370 km altitude. However, mixing ratios of $O^+/O_2^+$and $N^+/O_2^+$are almost constant and their seasonal variations are unclear. The larger variation of the observed CO_2^+/O_2^+than that of O^+/O_2^+might suggest that CO_2^+escape rate can change by up to a factor of ˜6 due to the ionospheric composition, however, the observed CO_2^+/O_2^+ cannot fully explain the reported ratio of heavy ion escape rates (e.g., Lundin et al., 2009; Carlsson et al., 2006). It may imply that additional mechanisms to change CO_2^+/O_2^+might exist above our observation range.
In this study, we will classify the NGIMS dataset in terms of (1) the intensity of solar wind pressure and (2) the intensity and direction of interplanetary magnetic field to understand the increase of the slopes of ion densities observed in the photodynamical region. Additionally, we will discuss the possibility of local heating by low-frequency waves (e.g., Fowler et al., 2018; Harada et al., 2019). Thus, we can evaluate the connection between the lower thermospheric composition and the ionospheric composition that can

escape to space.

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