Atmospheric compositions in the ionosphere/thermosphere on Mars observed by NGIMS and IUVS on MAVEN

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It is well known that the vertical profile of the composition of a planetary atmosphere is characterized by the compositional boundary, called the homopause, below which gases are well-mixed by eddy diffusion (homosphere) and above which they are diffusively separated according to their own scale heights by molecular diffusion (heterosphere). Since each atmospheric species has a scale height corresponding to its molecular mass in the heterosphere, the mixing ratio of lighter species is expected to increase with altitude above the homopause. The fractionation between the homopause and the exobase determines the relative abundance of species escaping to space [Jakosky et al., 2017]. In addition, the location of homopause altitude influence the thermospheric composition and thereby the species escaping to space [Imamura et al., 2016]. The variations of the atmospheric composition in the thermosphere were poorly constrained due to the complex observing geometry at diverse locations, seasons, and local times of in-situ observations. The relative flux ratios of cold ion outflow, ${O_2}^+$:O^+:${CO_2}^+$, from the Martian atmosphere were analyzed using ion mass analyzers [Carlsson et al., 2006; Ludin et al., 2009; Inui et al., 2018]. In Inui et al. [2018], the ratio of ${O_2}^+$:O^+:${CO_2}^+$ is almost the same as the density ratio at around 260 km altitude in the Martian ionosphere. Thus, the source altitude of the heavy ions is suggested around 260 km or below. To understand the heavy ions escaping from the Martian atmosphere, it is important to know the atmospheric composition in the upper atmosphere and its variation.

In our previous studies, we investigated that the dayside N_2/CO_2 ratio at 140 km altitude in the Martian thermosphere derived from MAVEN Image UltraViolet Spectrograph (IUVS) during the period from October 2014 to May 2018. We found that the N_2/CO_2 at 140 km altitude significantly varied in the range of 0.02 to 0.20, which shows an annual sinusoidal trend. The higher value appears during aphelion and the lower value during perihelion. In addition, we found a clear latitudinal dependence in Northern summer season. The higher value appears in southern winter hemisphere and the lower value in northern summer hemisphere. In order to reveal the drivers of N_2/CO_2 variations at 140 km, we have examined the effects of surface N_2/CO_2, thermospheric temperature, and homopause altitude. Our results imply that the N_2/CO_2 variation at 140 km is mainly caused by the variation of homopause altitude. Inferred homopause altitude derived from IUVS observation shows that the dayside homopause altitude is located between 60 and 140 km and it has an anti-correlation with the trend of N_2/CO_2 at 140 km. We suggested that a stronger heating in the lower atmosphere due to a closer Sun-Mars distance could cause increase in the homopause altitude and decrease in the mixing ratio of N_2 in the upper atmosphere.

In this paper, we investigate dayside number densities of both neutrals (CO_2, N_2, and O) and ions (${CO_2}^+$, ${O_2}^+$, and O^+) species at the exobase (~200 km) using data from MAVEN Neutral Gas and Ion Spectrometer (NGIMS) to consider the relationship between thermosphere and ionosphere. By combining with our IUVS result, we show the relative importance of effects of external forcing (such as solar wind, solar EUV, SEP etc.) and lower atmospheric phenomena (solar insolation, dust loading) on the upper atmospheric composition.