Seasonal variation of the dayside N_2/CO_2 at 140 km altitude derived from MAVEN/IUVS

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It is believed that liquid water was abundant on early Mars, despite Mars being too cold today to sustain significant amounts of liquid water. The most likely explanation is that early Mars had a more-effective greenhouse atmosphere and most part of atmosphere and water have lost to space. Mars Atmosphere and Volatile EvolutioN (MAVEN) mission was designed to explore the loss of gas to space at the present. MAVEN spacecraft revealed highly variable nature of upper atmosphere in density, temperature, and atmospheric compounds (e.g. Mahaffy et al., 2015; Elrod et al., 2017; Stone et al., 2018; Slipski et al., 2018). However, the controlling factor of the variations has yet to be fully characterized due to the limited spatial- and temporal- observing geometry by in-situ measurements. In addition to the effects by the external force, such as solar wind and solar EUV on the upper atmosphere, the effect of lower atmospheric phenomena is also required to account for the substantial variations of upper atmosphere. For instance, the homopause (~120 km altitude) influences the upper thermospheric composition, thereby the species escaping to space [Imamura et al., 2016]. The fractionation between the homopause and exobase determines the relative abundance of species to escape to space [Jakosky et al., 2017]. For this purpose, further investigation around atmospheric boundary from the middle atmosphere to lower thermosphere is crucial for understanding regional coupling between lower and upper atmosphere.

We have investigated the seasonal variation of the N_2/CO_2 ratio at 140 km altitude derived from ultraviolet spectroscopy remote-sensing measurements by Imaging Ultraviolet Spectrograph (IUVS) aboard MAVEN. We used the dataset of level 2 version 13 revision 1 data provided by the Planetary Data System, which includes retrieved CO_2 and N_2 number density profiles derived from dayglow emissions. We analyzed N_2 and CO_2 number densities observed from October 2014 to May 2018. Observations cover in the dayside from 7 to 19 hr. The observations covered almost all solar longitudes within the two Martian Years. The retrieved CO_2 density has small uncertainty but the retrieved N_2 density has relatively larger uncertainty in particular above ~170 km due to the dimmer emission intensity. For precise analysis of the N_2/CO_2 ratio, we confine our analysis to the data at 140 km altitude where N_2/CO_2 has uncertainty less than 50%. We found that the N_2/CO_2 ratio at 140 km altitude significantly varies in the range of 0.02 to 0.20, which shows an annual sinusoidal trend. The higher ratio appears during aphelion and the lower ratio appears during perihelion. CO_2 and N_2 number densities also have similar annual variations. It is noted that the CO_2 density varies by a factor of 100, while N_2 density by a factor of 10. This large CO_2 variation affects the N_2/CO_2 ratio at 140 km. The potential sources of the seasonal variation we found are variations (1) of the surface mixing ratio, (2) of the homopause altitude, and (3) of the thermospheric temperature. In this paper, the effect of surface mixing ratio is discussed using Mars Climate Database version 5.3 [Forget et al., 1999; Lewis et al., 1999]. We also address the effects of other sources by considering the seasonal variation of homopause altitude [Slipski et al., 2018] and background temperature [Bougher et al., 2017; Stone et al., 2018].

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