Seasonal variation of the homopause altitudes on Mars derived from MAVEN/IUVS observations

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The altitude of the homopause can be controlled by the solar flux, global circulation and gravity wave breaking. The atmosphere below the homopause is well mixed by the eddy diffusion. Above the homopause, the mixing ratios of lighter species increase with height due to the molecular-diffusion separation. Therefore, the homopause altitude is a key to understanding the atmospheric constituents at exobase that has been lost to space. In addition, the turbopause, which is located at almost the same altitude as the homopause, is defined as the altitude where the molecular diffusion coefficient is equal to the eddy diffusion coefficient. The former coefficient can be derived from a number density. Although the eddy diffusion coefficient is hard to constrain by observations and had large uncertainties, it can be constrained by the homopause altitude.

On Mars, there have been a few limited observations of the homopause so far. The Viking probe was the first to suggest that it was located at ˜120-130 km altitude. Recently, Jakosky et al. [2017] showed substantial variation of the homopause altitude from February 2015 to June 2016 using data from in-situ measurements onboard MAVEN spacecraft. Due to the limitation of orbital motion of MAVEN, the main controlling factor of the variations has yet to be fully characterized. This measurement is usually made above ˜150 km altitude, which cannot reach the homopause, therefore they have to assume isothermal temperature atmosphere to infer the homopause altitude.

We aim to investigate the dayside homopause altitude on Mars using N_2/CO_2 density profiles derived from remote-sensing measurements by Imaging Ultraviolet Spectrograph (IUVS) onboard MAVEN. IUVS limb mode can retrieve N_2 and CO_2 density profiles from 130 to 220 km altitude, which covers the altitude range between the homopause and upper thermosphere. Both scale heights of N_2 and CO_2 density profiles below ˜150 km altitude have a similar trend. In contrast, they show different scale heights above ˜150 km altitude due to the diffusive separation. These profiles well represent the transition region between the well-mixed lower atmosphere, and the diffusive upper atmosphere. This feature implies that IUVS limb observations clearly captured the homopause.

Here, in order to estimate the homopause altitude from N_2/CO_2 profile, we applied a third polynomial fit between 130 and 193 km altitude range for averaged N_2/CO_2 for each orbit. The inferred homopause altitudes significantly change along time with a large-scale sinusoidal trend. The higher homopause (160-170 km) appears during the perihelion. The lower homopause (130-150 km) appears during the aphelion. We concluded that the dayside homopause altitudes are mainly driven by changing solar forcing due to heliocentric distance over longer time-scale. Furthermore, the inferred homopause altitudes gradually decrease throughout the mission with by ˜5 km from Martian Year (MY) 32 to MY33, which seems to be caused by the decrease in solar EUV. Our result represents a complicated combination of lower and upper atmospheric forcing upon the homopause altitude.

We have also characterized N_2/CO_2 profiles for each season. These data suggest that N_2/CO_2 profiles can be classified by depending on the season. Resulting N_2 to CO_2 mixing ratio at ˜190 km altitude in northern winter could have more than one-order larger than in northern summer. These differences are partly influenced by the homopause altitudes. Our result indicates the significant difference of atmospheric composition to be escaped in season.

We discussed the eddy diffusion coefficient at the homopause using our result. The eddy diffusion coefficient at the homopause is in the order of ˜10^4. This value is comparable order to that derived from the Viking probes. Our result shows no clear seasonal variation but gradually decreases throughout the mission.