Evolution of aerosol profile and convective instability in the middle atmosphere on Mars

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It is believed that Mars underwent drastic climate change, changing its environment from warm and wet to cold and dry. This gives rise to the idea that Mars may have hosted life in the past, and indeed, may do so even today. Atmospheric evolution is thus an important key to understanding the history of Martian habitability. However, precise estimates of past atmospheric inventories including water, and their loss mechanisms, are difficult to be obtained.

High-altitude (above 60 km) water vapor was first identified by SPICAM occultations onboard MEX (Maltagliati et al., 2011, 2013; Fedorova et al., 2018) especially in the southern summer, which happens to be a dusty season (at a solar longitude of 240 degree or later). Maltagliati et al. (2013) showed the links between such high-altitude water vapor and aerosols in their vertical profiles within a short time scale. This implies the importance of aerosols for key processes in the Martian water cycle and climate as a whole. Importantly, the new pathway of water loss proposed by recent studies implies higher loss to space, in addition to the diffuse-limited escape of H2 (Catling and Kasting, 2017).

One possible scenario for upward transport from the lower atmosphere is the enhanced diffusion caused by gravity waves (GWs) of lower atmospheric origin. GWs have significantly effects on large scale winds, thermal balance, and density in the upper atmosphere (e.g., Medvedev et al., 2011, Medvedev et al., 2016). Recent MAVEN data reveal that the atmospheric waves exist ubiquitously in the upper atmosphere (Bougher et al., 2015; England et al., 2017; Terada et al., 2017). The average amplitude of GWs in the Martian upper thermosphere is 10 % on the dayside and 20 % on the nightside, which is about 2 and 10 times larger than those on Venus and the low-latitude region of Earth. IUVS occultations onboard MAVEN suggest that observed wavelike perturbations likely represent propagating GWs of tropospheric origin (Nakagawa et al., under revision). Answering questions about the upper atmospheric sources of these waves and their possible links with those in the troposphere is a key to an understanding the efficient upward transport process from below.

The study presented here demonstrated for the first time the evolution of aerosol profile and convective instability resulting from superposition of various atmospheric waves during a martian year. More than hundreds-profiles obtained by IUVS stellar occultations with UV channel onboard MAVEN are retrieved, which covers the Mars Year (MY) 33-34 during March 2015 and October 2017. All profiles used in this study correspond to Level 2, version 06,07,12, revision 01 data provided by the Planetary Data System (PDS). The measured profiles exhibit drastic temporal variations and a greater variety of shapes, with the presence of detached layers. The aerosols were lofted higher into the middle atmosphere in the southern summer, whereas less aerosols in the southern winter. The higher detached layer above the persistent near-surface haze were identified in the southern summer. These results are consistent with previous studies (Montmessin et al., 2006; Maltagliati et al., 2013; Maattanen et al., 2013). Our results can also suggest correlated behavior between aerosols and convective instabilities layers. This highlights the role of the vertical mixing enhanced by the atmospheric waves in addition to the global circulation and the seasonal inflation/contraction. Related to changes in the homopause height, a fast vertical mixing at low pressure (high) altitude could be occurred in the southern summer. This potentially creates aerosol upsurges and influences the large scale vertical evolution. In this paper, the external penetration from above is also discussed as the potent source to generate the detached aerosol layers at 80-110 km altitudes.