Water cycle and its evolution: High-speed H_2O transport to upper 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 and water evolution is thus an important key to understanding the history of Martian habitability. Mars must somehow have lost most of its atmosphere and water. The evolution of the Mars environment is thought to have proceeded by some combination of atmospheric escape to space and surface-subsurface adsorption. Especially, a lack of global magnetic field on Mars must have a significant impact to the atmospheric escape. The upper atmosphere is the primary reservoir for atmospheric escape. Owing to the technical difficulties associated with observations, datasets of the upper atmosphere are limited. However, the last decade has seen a renewed interest in the upper atmosphere, thanks to the aggressive explorations by the Mars Reconnaissance Orbiter (MRO), Mars Express(MEX), and Mars Volatile Evolution (MAVEN) missions. Recent studies have highlighted various interesting facts related to the efficient of material/water transport from the lower to upper atmospheric reservoir which have an impact on the atmospheric escape or evolution.

High-altitude (above 60 km) H2O was first identified by SPICAM occultations [Maltagliati et al., 2011, 2013] in the southern summer, which happens to be a dusty season at a solar longitude of 240 degree or later. Chaffin et al. [2017] demonstrated that the high-altitude H2O can considerably increase H escape on the weekly timescale, which can potentially explain the observations. Purpose of this study is to clarify the mechanism for upward transport of H2O into the upper atmosphere and formation of the detached layer of H2O and aerosols, by using multi-spacecraft dataset in order to cover whole altitude range from lower to upper atmosphere.

Here we report the detection of an extensive layer of warm air at altitudes 70-100 km on the night side that we interpreted as the result of combinations of aerosol heating, thermal tides, and/or global circulation. Such a strong warm layer for which the current models have no explanation can maintain temperature to evaporate water ice adsorbed on the aerosols and can form the detached layer of water vapor. We also measured the mesospheric distribution sub-micron aerosols is abundant than our expectation at altitudes 70-100 km. Such a detached layer of aerosol can potentially explain the warm layer, and this implies the importance of aerosols for key processes in the Martian water cycle and climate as a whole. The remarkable heating at altitudes 70-80 km was also confirmed by our dedicated ground-based observations during global dust storm 2018. The new pathway of water loss proposed by this implies much higher loss to space, in addition to the diffuse-limited escape of H2.

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