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Transport of Water to the Martian Upper Atmosphere amid Regional and Global Dust Storms

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Abstract

Direct measurements of the Martian upper atmosphere from the MAVEN Neutral Gas and Ion Mass Spectrometer confirm the delivery of water into the lower thermosphere during two dust events. This water significantly impacts H production rates in this region, which can increase the H abundance in the exosphere and boost the H escape flux.

1. Introduction

Though Mars is currently cold and dry, it was warmer and wetter billions of years ago. Most of its water was lost to space over the last ~4 billion years.[1] Water in the lower atmosphere cannot normally diffuse upward beyond the hygropause, but H_2 produced in the lower atmosphere can diffuse into the upper atmosphere. There, H_2 is destroyed, producing H which escapes to space.[2,3] The H_2 that penetrates into the exosphere can also escape, though calculated escape fluxes vary widely due to relatively poor constraints.[4-7] Using *in situ* measurements of water-derived ions obtained by the NASA Mars Atmosphere and Volatile EvolutioN (MAVEN) Neutral Gas and Ion Mass Spectrometer (NGIMS) during a localized dust storm in Mars year (MY) 32 and the global dust storm of MY 34, we demonstrate the effects of rapid delivery of H_2O to the upper atmosphere. This H_2O is an additional source of H which could drive acute acceleration of H escape.

Diffusion of H_2 from the lower atmosphere is a slow and steady process which cannot explain observed rapid variations in exospheric H abundance.[8-11] The most likely cause for this rapid variation is direct transport of water into the middle and upper atmosphere.[12-14] This transport is possible due to a weakening of the hygropause. The water is then destroyed in the upper atmosphere, producing H.

We unambiguously detect the chemical intermediates that lie between water delivered from the lower atmosphere and H escape from the top of the atmosphere using direct measurements of ions produced from water. Assuming photochemical equilibrium, H_2O and H_2 abundances are calculated, providing insight into the transport and variation in the upper atmosphere of these hydrogen reservoirs, with a particular focus on localized dust activity during MY 32 and the global dust storm of MY 34. Calculated H production rates demonstrate that H_2O can become a significant source of escaping H during these events.

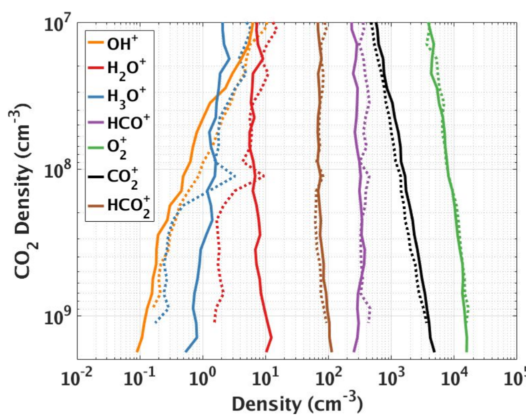

Figure 1. Mean ion abundance profiles measured by MAVEN NGIMS before (dotted) and during (solid) the MY 34 global dust storm.

2. Results

The abundances in the lower thermosphere of water-derived ions H_2O^+ and H_3O^+ increase markedly after the onset of dust activity during a local dust storm in MY 32 and the planet-encircling dust storm of MY 34 (**Figure 1**). In MY 32, the mean H_2O^+

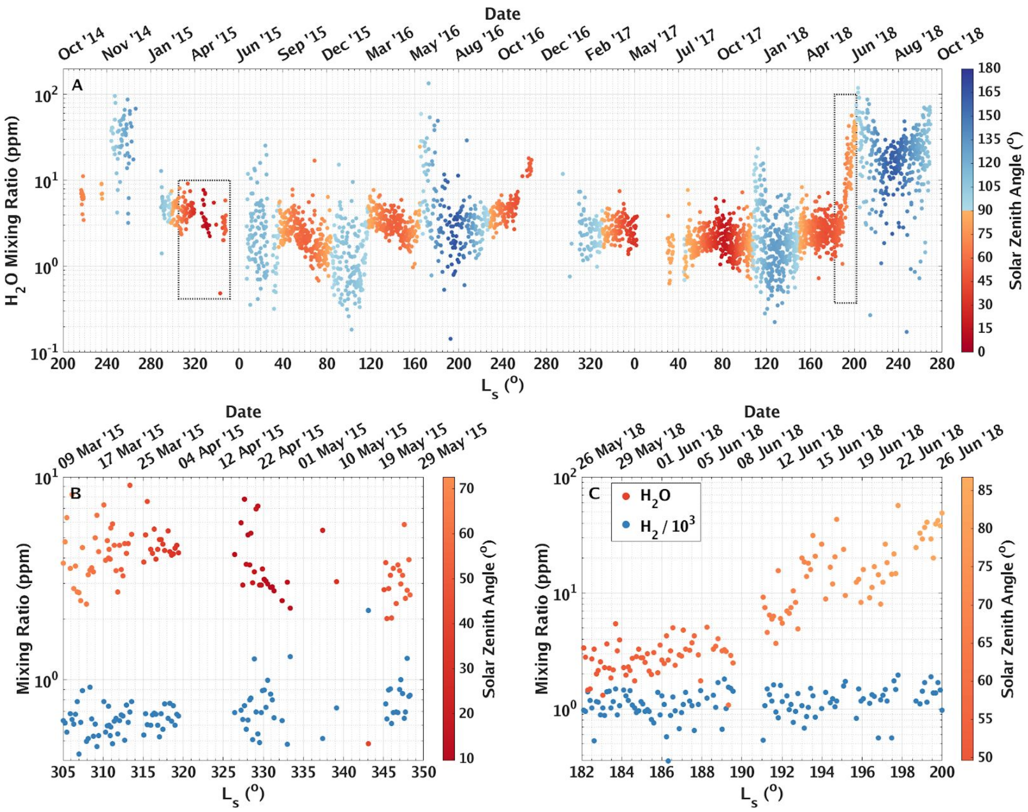

Figure 2. Mean H_2O and H_2 mixing ratios (A) over the course of the mission, (B) during a local dust storm in MY 32, and (C) during the MY 34 global dust storm. Each point is the mean H_2O (color according to colorbar) or H_2 (dark blue) mixing ratio between CO_2 densities of 5×10^8 and 10^9 cm^{-3} for a single orbit.

abundance at periapsis increases by a factor of 2 and the mean H_3O^+ abundance increases by a factor of 1.4. As can be seen in **Figure 1**, the mean periapsis H_2O^+ abundance increases by more than a factor of 6 during the MY 34 global dust storm and the mean H_3O^+ abundance increases by more than a factor of 3.

Calculated H_2O abundances demonstrate a significant injection of water into the lower thermosphere during the two events discussed above (**Figure 2**). At the onset of the event in MY 32, the H_2O mixing ratio at MAVEN periapsis increases by nearly 10%, from 4.55 to 4.88 ppm. In MY 34, the water abundance increased by a factor of 2.4 from a mean value of 2.97 ppm prior to the onset of the global dust storm to 7.07 ppm after the onset of the storm. Each of these values is the mean H_2O mixing ratio over 10 orbits prior to and during each dust storm. In **Figure 2**, the mean H_2 mixing ratio is shown in panels **B** and **C**. The H_2 mixing ratio does not change significantly at the onset of the two dust events discussed herein.

References

[1] Jakosky, B. M., et al. (2018) *Icarus, 315,* 146–157.
[2] Fox, J. L. (2015) *Icarus*, 252, 366–392.
[3] Krasnopolsky, V. A. (2018) *Icarus*, *321*, 62–70.
[4] Yung, Y. L., et al. (1988) *Icarus*, *76*, 146–159.
[5] Krasnopolsky, V. A. (2002) *JGR*, *107*, 11.
[6] Chaufray, J.-Y., et al. (2015) *Icarus*, *245*, 282–294.
[7] Chaufray, J.-Y., et al. (2018) *JGR*, *123*, 2441–2454.
[8] Chaffin, M. S., et al. (2014) *GRL, 41*, 314–320.
[9] Clarke, J. T., et al. (2014) *GRL, 41,* 8013–8020.
[10] Bhattacharyya, D., et al. (2015) *GRL, 42,* 8678–8685.
[11] Clarke, J. T., et al. (2017) *JGR*, *122*, 2336–2344.
[12] Maltagliati, L., et al. (2013) *Icarus, 223*, 942–962.
[13] Fedorova, A. A., et al. (2018) *Icarus, 300,* 440–457.
[14] Heavens, N. G., et al. (2018) *Nat. Astron., 2*, 126–132.