EPSC Abstracts
Vol. 16, EPSC2022-766, 2022
https://doi.org/10.5194/epsc2022-766
Europlanet Science Congress 2022

Measurements of water and its D/H as released from both Martian polar caps

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Introduction

The large enrichments of D/H currently measured in atmospheric water suggest that a large fraction, beyond 80%, of this water was lost over time[1,2], and Ar and O isotopic ratios measured with MAVEN[3] and TGO[4] indicate Mars has lost a large fraction of its atmosphere. As we attempt to trace back the history of water on Mars, it is unknown how much water remains locked in non-labile/sub-surface reservoirs, and an important question is whether all current labile reservoirs have evolved in the same way and undergone extensive exchange.

New measurements with TGO

We have analyzed data over the entirety a Martian year as measured with TGO/NOMAD, which probed the release of water from the two polar caps using the instrument's solar occultation mode. Specifically, the measurements presented here have been collected by the NOMAD[10] instrument suite onboard TGO. The data were collected employing the Solar Occultation (SO) channel/mode of the instrument.

Interpretation and extraction of molecular abundances from the calibrated data is done by employing the Planetary Spectrum Generator (PSG, https://psg.gsfc.nasa.gov)[11], and as reported in [12]. The model employs a layer-by-layer line-by-line method in a spherical and refractive geometry. We employ the latest linelists for H_2O, HDO, and CO_2 as compiled in the HITRAN-2020 database[13], which are complemented to include the latest H_2O and HDO broadening coefficients for a CO_2 atmosphere[14,15].

Probing the seasonal release from both caps

During Martian Year 34, the planet was engulfed in a global dust storm (GDS) that greatly perturbed the temperature and vertical structure of the Martian atmosphere. In addition, the lingering effects of the GDS were joined by a large regional dust storm that started during late southern summer (LS 320). These two major events greatly affected the climate of Mars, primarily leading to a strong increase in atmospheric temperature, a substantial rise in altitude of the hygropause, and subsequent transport of water to unexpectedly high altitudes[16–22].

Interestingly, during the GDS when the northern hemisphere was in the winter season, the climate was substantially warmer there than normal[23–25], leading to high-altitude water also in the northern hemisphere. Typically, the largest seasonal water columns are observed during summer in the northern hemisphere[26], and that may be true in MY35, but the vertical profile of water is highly compact (confined to altitudes below 20 km), even at the peak of northern summer (LS 90-130).

In all cases (all seasons and regions of the planet) the D/H declines quickly above the hygropause, from a nominal value above 5 VSMOW to a very low value near <2 VSMOW when HDO is not present (owing to its preferential freeze-out). For the values during the peak of the northern summer release (LS 80-130) and closer to the surface, the D/H varies in the range of 4-7 VSMOW near the hygropause. Importantly, this would mean that the D/H of the water liberated from the seasonal northern polar cap is the same as that of the water liberated from the seasonal southern polar cap, roughly 6-7 VSMOW. Yet, due to the confinement of water relatively close to the surface during northern summer, and the challenges associated with solar occultation probing of such narrow vertical region, our results cannot rule out an alternative scenario with a D/H different than that of the southern seasonal cap.

Discussions and conclusions

The new results presented here, which probe the vertical profiles of water and D/H for both seasonal caps, together with previous ground-based and orbital measurements, suggest a common and highly enriched value for this labile reservoir of water.

Atmospheric D/H behaves as an integrator of the differential individual atomic (H and D) escape rates, and therefore without any new supply of water into the system, the D/H of the labile sources will continue to increase. Among other phenomena, the chaotic changes in obliquity that Mars has experienced, and the corresponding impact on climate and regions of ice stability[28,29], could lead to large exchanges between the reservoirs and further homogenization of the D/H across the planet. Thus, the D/H value of the polar caps could be similar to the modern labile D/H value observed in the seasonal releases.

References

1. Jakosky, B. M. Annual Review of Earth and Planetary Sciences 49, 71–93 (2021).
2. Villanueva, G. L. et al.. Science 348, 218–221 (2015).
3. Jakosky, B. M. et al. Science (2017) doi:10.1126/science.aai7721.
4. Alday, J. et al. JGR: Planets 126, e2021JE006992 (2021).
5. Scheller, E. L., et al. Science 372, 56–62 (2021).
6. Plaut, J. J. et al. Science 316, 92 (2007).
7. Zuber, M. T. et al. Science 282, 2053 (1998).
8. Byrne, S. & Murray, B. C. JGR: Planets 107, 11-1-11–12 (2002).
9. Fishbaugh, K. E. & Head, J. W. Icarus 174, 444–474 (2005).
10. Vandaele, A. C. et al. Planetary and Space Science 119, 233–249 (2015).
11. Villanueva, G. L., et al. JQSRT 217, 86–104 (2018).
12. Villanueva, G. L. et al. Science Advances (2021) doi:10.1126/sciadv.abc8843.
13. Gordon, I. E. et al. JQSRT 107949 (2022) doi:10.1016/j.jqsrt.2021.107949.
14. Devi, V. M. et al. JQSRT 187, 472–488 (2017).
15. Régalia, L. et al.JQSRT 231, 126–135 (2019).
16. Aoki, S. et al. JGR: Planets 124, 3482–3497 (2019).
17. Belyaev, D. A. et al. GRL 48, e2021GL093411 (2021).
18. Chaffin, M. S. et al. Nat Astron 5, 1036–1042 (2021).
19. Heavens, N. G. et al. Nature Astronomy 2, 126–132 (2018).
20. Holmes, J. A. et al. Earth and Planetary Science Letters 571, 117109 (2021).

21. Neary, L. et al. GRL 47, e2019GL084354 (2020).
22. Stone, S. W. et al. Science (2020) doi:10.1126/science.aba5229.
23. Daerden, F. et al. JGR: Planets n/a, e2021JE007079 (2022).
24. Montabone, L. et al. JGR: Planets 125, e2019JE006111 (2020).
25. Rossi, L. et al. GRL 48, e2020GL090962 (2021).
26. Crismani, M. M. J. et al. JGR: Planets 126, e2021JE006878 (2021).
27. Laskar, J. et al. Icarus 170, 343 (2004).
28. Jakosky, B. M., Henderson, B. G. & Mellon, M. T. JGR: Planets 100, 1579–1584 (1995).
29. Levrard, B., Forget, F., Montmessin, F. & Laskar, J. JGR: Planets 112, (2007).