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► **To cite this version:**

Maxime Maurice, Forget François, Yangcheng Luo, Franck Lefèvre, Yassin Jaziri, et al.. Investigating the possibility of H₂O₂-induced warming on early Mars with a 3D GCM. Europlanet Science Congress 2024, Sep 2024, Berlin, Germany. EPSC Avstracts, 17, pp.EPSC2024-1051, 10.5194/epsc2024-1051 . insu-04677236

HAL Id: insu-04677236

<https://insu.hal.science/insu-04677236v1>

Submitted on 25 Aug 2024

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Investigating the possibility of H₂O₂-induced warming on early Mars with a 3D GCM

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Introduction

Liquid water is largely regarded as a *sine qua non* condition for life as we know it. Geomorphological, mineralogical and sedimentological evidences indicate the presence of perennial liquid water on the surface of Mars in the late Noachian, approximately 3.8 billion years ago (Ga) [1,2], suggesting that it was possibly habitable. Today, the low surface temperature on Mars precludes sustained liquid water. The solar flux was fainter 3.8 Ga than today, leading to a conundrum regarding the conditions that allowed for perennial liquid water on early Mars.

Although likely, a thicker (up to 2 bar) CO₂ atmosphere on early Mars falls short of heating up the surface temperature to the melting point of water (273 K) [3]. Thus, other infrared opacity contributors are necessary to further enhance the greenhouse effect. Recently, [4] suggested that such additional greenhouse effect could be due to hydrogen peroxide (H₂O₂), and calculated that an average of 1 ppm H₂O₂ in a 2 bar CO₂ atmosphere could raise the surface temperature to 273 K. Here we test this hypothesis using a global circulation model (the Generic PCM) and an H-C-O photochemical.

Model

In order to assess the possibility to produce H₂O₂, we adopted the most favorable conditions by optimizing the water content of the atmosphere, consider an already warm and wet early Mars. This was achieved by using the setup from [5], where warming is due to the collision-induced absorption of CO₂ and H₂. Notice that the high H₂ content assumed in the radiative transfer calculation is unrelated to the chemical model. Within these simulations, we include the H-C-O photochemical network considering 14 species and 52 reactions (including 12 photodissociation reactions). Although not self-consistent, this scenario allows us to study the chemistry on a warm and wet early Mars.

Results

We find that after 10 Martian years of evolution, the average amount of H₂O₂ starts to plateau. While the upper atmosphere has an H₂O₂ volume mixing ratio (VMR) above 1 ppm, the well-mixed lower atmosphere has an H₂O₂ VMR lower than 10⁻⁷ (Figure 1). This is likely too low to induce a

sufficient greenhouse warming. Because we used the most favorable conditions for H₂O₂, this result suggests that a more realistic, initially cold and dry early Mars couldn't have been warmed up by the greenhouse effect of H₂O₂.

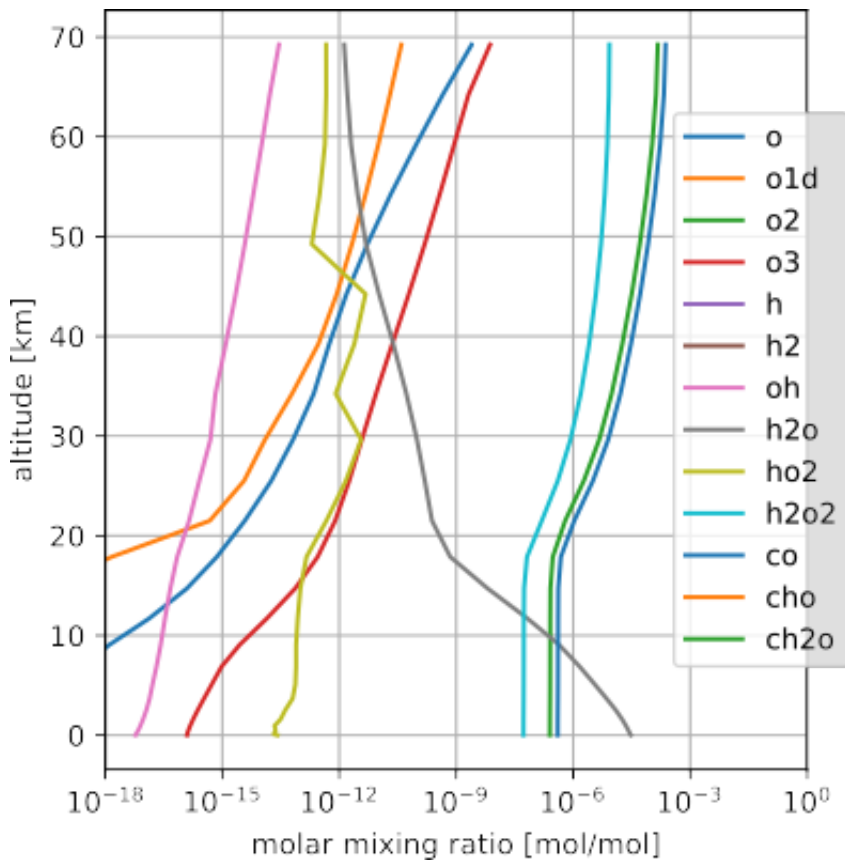


Figure 1: Molar mixing ratio of the various species after 10 Martian years.

References

- [1] Haberle et al. (2017) *The Early Mars Climate System, Cambridge University Press*
- [2] Rapin et al. (2023) *Nature*
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