

Thermal and Solar Wind-Driven Water Cycle Model on Airless Bodies: The Moon as a Test Case

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Introduction: Determining the origin of water (H_2O) and chemically bound hydroxyl radicals ($-\text{OH}$) on airless bodies is necessary and critical for understanding the origin, evolution, and overall accessibility of this potential resource for future human exploration in our Solar System. Previous studies [1, 2] of terrestrial minerals bombarded with keV protons have resulted in the appearance of absorption associated with chemically bound hydroxyls in the mid-infrared region and suggest that water on the moon has an origin attached to the solar wind. Also, previous measurements performed by our group have demonstrated that water can be produced from minerals with saturated OH terminal sites and defects at lunar relevant temperatures in a process known as recombinative desorption. This process involves the thermally activated reaction of two hydroxyl groups near one another. Upon reaction, the OH groups produce and release an H_2O molecule while healing the oxygen atom defect created during proton bombardment.

Given the previous work by us and others, we suggest that the solar wind is critical to the formation of water and other hydrogen-containing volatiles on all airless bodies. Utilizing available data sets on non-thermal and thermal rates of water formation and desorption from various hydroxyl-terminated metal oxides (SiO_2 , TiO_2 , and Al_2O_3), and experimental temperature program desorption data of Apollo sample (10084) lunar mare regolith, the $2.8\ \mu\text{m}$ optical signature on the Moon is modeled. Specifically, this band results from formation and loss pathways induced by the solar wind production of chemically bound hydroxyls and subsequent recombinative desorption. This mechanism forms gas-phase H_2O on the sun-lit side, which further undergoes photo-dissociation and dissociative adsorption. In conjunction with the continuous implantation via solar wind, re-hydroxylation of the surface is persistent. The cycle results in a latitude-dependent concentration of OH groups with a slight diurnal behavior.

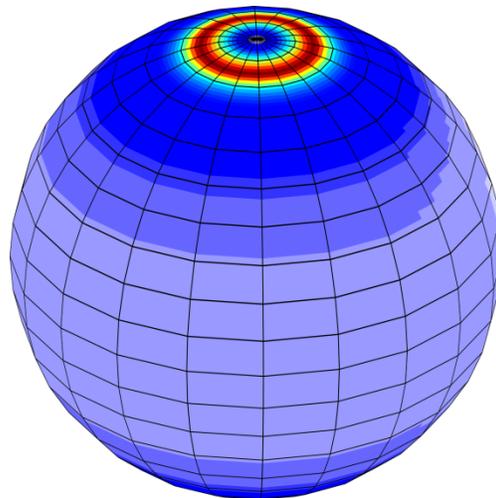


Figure 1: Simulated OH concentration after 1200 lunar days using our chemical kinetic model that centers on proton implantation followed by water formation and release via recombinative desorption. The lowest concentration is at the equator with subsequent build-up near the poles.

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References:

1. Schaible, M.J. and R.A. Baragiola, *Hydrogen implantation in silicates: the role of solar wind in SiOH bond formation on the surfaces of airless bodies in space*. Journal of Geophysical Research: Planets, 2014. **119**(9): p. 2017-2028.
2. Bradley, J.P., et al., *Detection of solar wind-produced water in irradiated rims on silicate minerals*. Proceedings of the National Academy of Sciences, 2014. **111**(5): p. 1732-1735.