

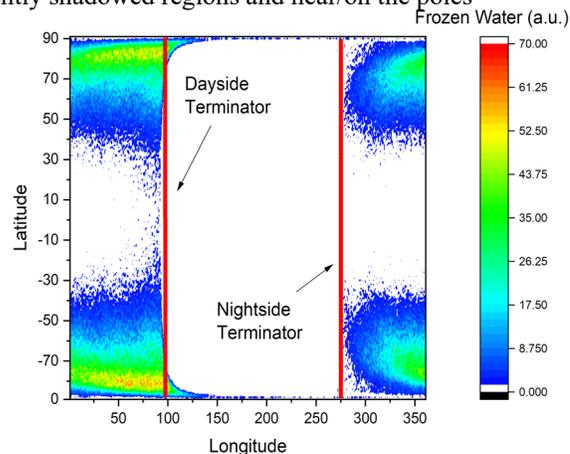
**In Situ Molecular Water Formation on Mercury.** B. M. Jones<sup>1</sup> and T. M. Orlandor<sup>1,2</sup>, <sup>1</sup>School of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, GA 30332, <sup>2</sup>Center for Space Technology and Research (CSTAR), Georgia Institute of Technology, Atlanta, GA 30332.

**Introduction:** Ground based radar observations of Mercury over two decades ago yielded maps of bright and depolarizing features near the poles [1, 2] and subsequent radar measurements isolated these abnormalities to the permanently shadowed regions [3]. These features were attributed to frozen water ice at the observed locations of the anomalies. Following these observations were the seminal papers based on the neutron spectrometer [4] and the Mercury Laser Altimeter (MLA) [5] on board the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft, both of which were in agreement that the PSRs contained water ice covered with a thin layer of possible organic material. Generally, it is believed that water ice and other volatile organic material was delivered via meteoritic impacts [4]. Here, we present an alternative source term for molecular water based on our recent efforts modelling solar wind interactions on the lunar surface [6].

It is well known that proton implantation into metal oxides results in the formation of chemically bound hydroxyls [7]. These hydroxyls have generally been accepted as the source of the 2.8  $\mu\text{m}$  infrared absorption band observed on the lunar surface [8]. Previous solar wind modelling efforts on airless bodies have mainly focused on the moon and primarily include diffusion of the implanted hydrogen up to the grain surface, whereupon it reacts, forms molecular hydrogen and subsequently dissipates from the surface [9-11]. Our model takes into consideration a well-known process known as recombinative desorption. Here, the implanted hydrogen will diffuse to the grain surface resulting in dangling M-OH bonds (M being a generic metal cation, e.g. Si, Al, Mg, Ti). From here, neighboring M-OH sites will react to form molecular water,  $\text{M-OH} + \text{M-OH} \rightarrow \text{MOM} + \text{H}_2\text{O}$ . Typically, the activation energies necessary for recombinative desorption (RD) to occur are prohibitively large ( $\sim 1$  eV). However, Mercury has two circumstances that help overcome this barrier. First, the surface temperatures are very high and second, the surface mineral compositions has large amounts (percent weight) of MgO [12] which has a relatively low RD activation energy ( $\sim 0.6$  eV) [13]. Utilizing the estimated precipitating proton flux [14] and these known OH formation and loss processes, an atomistic and molecular model describing the fate of solar wind-induced hydroxyl groups was applied to the surface of Mercury. Specifically, we incorporate experimentally derived diffusion constants, cross sections and rates for interfacial

OH formation and destruction involving water and hydrogen formation via recombinative desorption, photo-desorption, and interfacial surface reactions with OH/H<sub>2</sub>O and the soil (serpentinization).

**Results:** Preliminary results (Figure 1) show that molecular water is easily formed at Mercury relevant temperatures where protons are impinging onto the surface. As expected the water adsorbed on the night side will sublime upon reaching the dayside terminator where it will hop until it reacts with the surface via dissociative adsorption (i.e.  $\text{H}_2\text{O} + \text{M} \rightarrow \text{MOH} + \text{H}$ ) on the surface or physisorbs at a cold site i.e. night side or permanently shadowed regions. If the cold site is a permanently shadowed region, the frozen water is stable over thousands of years. Gas phase water will ultimately succumb to photo-dissociation, dissociative adsorption or molecular re-adsorption at a cold spot on the planet's surface. Consequently, a significant amount of water is not expected in the exosphere but is expected in permanently shadowed regions and near/on the poles



**Figure 1:** Location of frozen molecular water on the surface on mercury after simulating solar wind implantation and kinetics of recombinative desorption after six complete orbits. Red lines designate day and night side terminators.

**Summary:** Our solar-wind initiated reaction cycle has been adapted to examine the possible source term for molecular water on Mercury. The formation and loss mechanisms of solar wind produced chemically bound hydroxyl (-OH) groups on the surface of Mercury have been investigated by assuming that hydroxyls are constantly removed and replenished via a cycle that primarily involves formation and release H<sub>2</sub>O(g).

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**References:**

- [1]. Slade, M.A., B.J. Butler, and D.O. Muhleman, (1992), *Science*, 258, 635-640. [2]. Harmon, J.K. and M.A. Slade. (1992) *Science*, 258, 640-643. [3]. Harmon, J.K., M.A. Slade, and M.S. Rice. (2011) *Icarus*, 21, 37-50. [4]. Lawrence, D.J., et al. (2013) *Science*, 339, 292-296. [5]. Neumann, G.A., et al., (2013), *Science*, 339, 296-300. [6]. Jones, B.M., et al., (2018) *GRL* 45, 10,959-10,967. [7]. Schaible, M.J. and R.A. Baragiola. (2014) *JGR:Planets*, 119, 2017-2028. [8]. McCord, T., et al., (2011) *JGR:Planets*, 116, E6. [9]. Farrell, W., D. Hurley, and M. Zimmerman. (2015) *Icarus*, 255, 116-126. [10]. Starukhina, L.V. and Y.G. Shkuratov. (2000) *Icarus*, 147, 585-587. [11]. Tucker, O.J., et al. (2018) *JGR:Planets*, [doi.org/10.1029/2018JE00580](https://doi.org/10.1029/2018JE00580). [12]. Namur, O. and B. Charlier (2016) *Nature Geoscience*, 10, 9-17. [13]. Stirniman, M.J., et al., (1996) *J. Chem. Phys.* 105, 1295-1298. [14]. Benna, M., et al., (2010), *Icarus*, 209, 3-10.