LEVERAGING WATER SPILLAGE MEASURED BY WITNESS PLATES TO SUSTAINABLY PROBE PSR PROPERTIES. P. Saxena[1], J. L. McLain[1], O. J. Tucker[1], R. M. Killen[1], M. Sarantos[1], L. Morrissey[2], N. Abraham[1], and N. E. Petro[1], [1]NASA Goddard (prabal.saxena@nasa.gov), [2]Memorial University of Newfoundland

Introduction: Exploration of permanently shadowed regions (PSRs) in the lunar south pole to probe the water they may hold is a key step in enabling a sustainable human presence on the lunar surface. Estimates of how much water a particular PSR holds is important for determining the local in-situ resource potential and scientific information that may be held by the volatiles in the PSR. These estimates are complicated by a number of factors, some of which include the difficult environmental conditions that exist for an experiment that wishes to operate in a PSR as well as the desire to limit externalities in exploration that may damage the fragile environment of the PSR. However, a hypothesized model suggests that water is 'spilled' from inside a PSR to adjacent non-PSR areas though interactions of processes such as energetic particle flux and impacts within the PSR. We discuss and provide initial examples of how witness plates may be able to sustainably measure this spillage in order to ascertain key bounds on PSR properties. These witness plates may be used in a manner which captures time integrated estimates of water spillage from adjacent PSRs while avoiding potential damage to the PSR environment.

Spillage of Water from PSRs to Adjacent Terrain: A series of recent studies (Farrell et al. 2013, Farrell et al. 2015, Farrell et al. 2019, Nénon and Poppe 2021) have discussed the potential for water from PSRs to be liberated and transported from the crater floors that host these PSRs to topside adjacent regions by energetic processes such as energetic particle sputtering, impact vaporization and impact ejection. This model predicts that the transport of volatiles such as water is dependent the distance to the PSR and on both the flux of the input processes as well as the properties of the PSR – specifically the spatial volatile extent and abundance of water in the regolith. The ability to constrain some of these input fluxes and the deliberate selection of traverses in proximity to PSRs of interest may thus allow an estimate of the water properties of the PSR from outside the region. Increased sampling in both time and using multiple spatial locations can help narrow constraints on these properties. These properties are some of the most critical for assessing ISRU potential and scientific value of a PSR.

Using Witness Plates to Sample Spillage: Witness plates can be a powerful tool that can help to supplement familiar remote sensing and sample acquisition techniques in order to probe key processes on the lunar surface. They can be flexibly placed, for a nearly arbitrary time, and can be targeted for a specific process while having minimal environmental impact. In

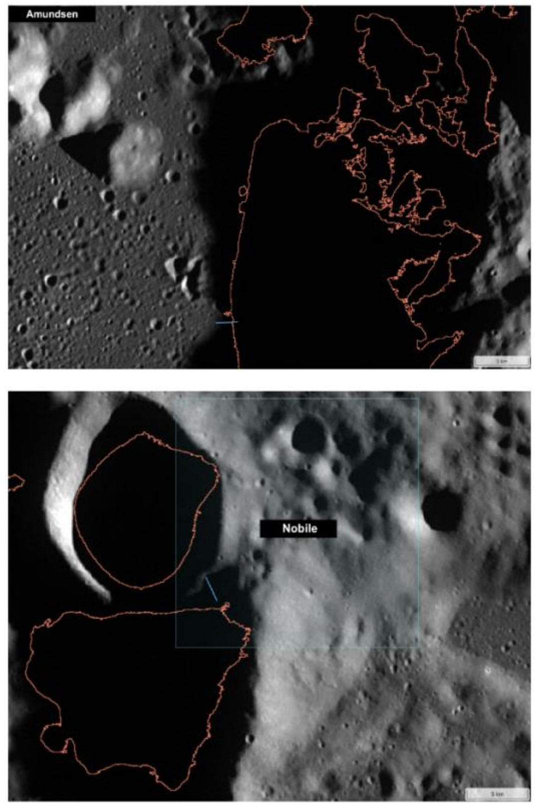

Figure 1: Two hypothetical traverses near Amundsen Crater and Nobile Crater. PSR regions are in orange, traverse paths in bright blue, and Artemis I candidate regions in light blue.

the case of witness plates that are used to measure spillage of water, such plates can be targeted by using a substrate reactive to water and/or can have a structure or morphology that preferentially retains incoming water while minimizing loss. For our study, we used witness plates that we called 'Biscuits' for their small, easily handle-able size that were agnostic regarding their structure beyond being hydrophilic but that came in two different geometries. The first geometry was a nearly flat one, with rim of the plate being only slightly higher than the target substrate in the interior, while the second geometry created what we called a 'PSR Biscuit'. This version contains a lid elevation relative to the interior that was larger than the maximum angle of incidence of the Sun at the corresponding traverse latitude. Given the high latitudes of the two regions examined, this did not result in a disproportionately elevated lid, but resulted in an interior target substrate robust against Sun driven loss processes. These Biscuits were the target site witness plates that captured incoming water.

Example Traverses and Assumptions: The two traverse sites – near the Amundsen PSR and the Nobile PSR (see figure 1) - were chosen due to interest in their adjacent PSRs from both literature and the Artemis I candidate regions as well as additional factors that included significant portions of the traverse that had access to sunlight, a relatively low or gradual topographical relief, and at least some small access to a shadowed region. Traverses were 2 km long, with values recorded approximately every 0.2 km. The closest point of the traverse was approximately 12.5 km from the PSR center in each case. The total PSR source region was approximated using the geometry of each PSR as about 35% of the source region used in Farrell et al., 2013, where the PSR source region was a 20 km circular crater PSR. Many of these assumptions are somewhat conservative and significantly higher values should be expected for traverses closer to a PSR center.

The net flux of water at a Biscuit was a competition between processes that led to infall from the PSR and that were loss processes at the Biscuit site – some of the input and loss processes were dependent on whether it was day or night, which our model also took into account (though as a simplification, this only included ~14-day day/night periods). Input processes were distance dependent spillage from sputtering, impact vaporization and impact ejecta, while loss processes were thermal desorption, sputtering loss and photon stimulated desorption. For PSR Biscuits, the latter two processes were not included. Values for the incident PSD photon flux, sputtering flux and yield, and thermal desorption relationship were taken from literature (DeSimone and Orlando, 2015, Johnson, 1990, Farrell et al. 2015, Andreas 2007). Model runs were produced for several PSR property and Biscuit property assumptions.

Results and Relevance to PSR Properties: Model results for the two traverses examined are given in figure 2. The top two panels of the figure contain information regarding the topography along each of the traverses and the maximum summer temperature at the points along the traverses, the latter of which was used to assess the impact of thermal desorption on retention of water by a Biscuit. The bottom two panels show the total water retained after a 10-year period at a point along a traverse for both types of Biscuit, with the conservative case and realistic case differing largely by both inclusion of attenuation of loss processes due to the high latitudes and also an increase in the water abundance in source regolith in the PSRs from 1 to 2%.

Increases in water abundance result in a corresponding increase in total water retained by Biscuits along the traverses. Though there are non-linearities in how the two scale, the increase in Biscuits is nearly linear to the PSR abundance increase. While also considering that these estimates are likely still conservative with respect to total water retained along these traverses for several reasons, design of detection and characterization methods of witness plates that can capture water from 'spillage' at some factor of these values may provide important diagnostic information of water content of a PSR from outside the PSR.

References:

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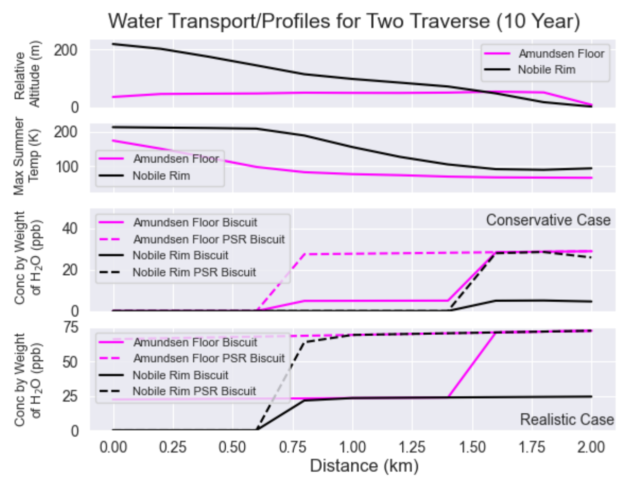

Figure 2: Results of Biscuit Model Simulations of capture of water from 'spillage' from adjacent PSRs. These results are for 10-year integrated cases with a 14 day diurnal cycle and given the assumptions stated in the text. The top two panels display the topography and maximum summer temperature of the points along the traverse. The bottom two panels show the total captured and retained water for Biscuits along the traverse by a concentration by weight of water (assuming a silica substrate). Differences between the types of Biscuits are due to minimization of loss processes while difference between cases are due to some of the assumptions listed in the text and water abundance on the PSR floor.