STABILITY LOCATIONS FOR LUNAR POLAR VOLATILES FROM DIVINER LUNAR RADIOMETER DATA: IMPLICATIONS FOR FUTURE SCIENTIFIC EXPLORATION. M.E. Landis1, P.O Hayne1, J.-P. Williams2, D.A. Paige1, 1Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO, USA. (margaret.landis@lasp.colorado.edu), 2Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, CA, USA.

Introduction: Lunar polar volatiles have been predicted previously through data-driven temperature models [e.g., 1] and detected via remote sensing and the LCROSS artificial impact experiment [2-7]. While the presence and stability of water and possibly other ices in the lunar polar regions have been well-documented, several key questions remain.

One key question is the source and replenishment rate of present-day lunar volatiles, with some mechanisms, like lunar volcanic activity [8], operating over possibly shorter time frames than others, like the solar wind. Fortunately, these sources would provide potentially diagnostic compositions within lunar volatiles deposits. For example, lunar volcanic activity would result in more sulfur within a volatile deposit than water [8], whereas a deposit dominated by a cometary source would have more water than sulfur, plus additional organic compounds [e.g., 9].

We use data from the Diviner instrument aboard the Lunar Reconnaissance Orbiter (LRO) to characterize the surface and near-surface temperatures of the north and south polar regions of the Moon. We identify the regions where a range of solar system volatiles of interest sublimate at rates ≤ 1 mm/Gyr.

The south pole is a proposed site for future exploration. We use this site for both robotic and human missions as described in NASA’s plans for the next decade of the south pole [10, 11]. A mobile platform for sampling local volatile presence and composition, especially a human-based one capable of making multiple measurements near the edge of predicted stability, would ground-truth predictions based on the thermal data and help determine the sources of lunar volatiles.

Data Analysis and Reduction: We analyzed Diviner data from July 2009-January 2018 and 60-90° latitude in each hemisphere. We manually removed <20 orbits (<<1% of LRO orbits used) that contained systematic errors, with warmer temperatures compared to all other orbits. We binned the temperature data to the size of the typical Diviner detector resolution (~250 m). To calculate bolometric temperatures from the radiances observed by the Diviner instrument, we followed the data reduction procedure described in [1]. Our resulting temperatures are consistent with [11].

We determine areas where volatiles are stable based on volatility temperatures given in [12], which correspond to surface volatile loss rate of 1 mm/Gyr. For surface stability, we identify regions where the maximum temperature is below the volatility temperature of the species of interest. For buried water ice, we identify regions where the annual average surface temperature results in vapor loss ≤ 1 mm/Gyr, modeled using Knudsen diffusion for airless bodies [e.g., 13, 14]. The annual average temperature approximates the constant temperature at depths greater than a few diurnal and seasonal skin depths (a few centimeters to a meter, based on typical lunar regolith properties [e.g., 15]). Therefore, these maps represent stability within the entire upper ~1 m.

Results: The locations of surface and buried volatiles of interest are shown in Fig. 1 & 2. Whether these stable sites in fact harbor these volatiles depends on the long-term lunar supply and destruction rates [e.g., 16]. This is the central question that in situ exploration would aid in answering.

While the south pole currently hosts more surface area where water ice would be stable than the north pole [17], the sub-surface buried ice stability areas do not show as significant a difference (Fig. 1). Additionally, large, flat floored craters like Amundsen (~81° S, 83° E; Fig. 1) could host near-surface water ice deposits that could be sampled without traverses into a persistently or permanently shadowed region.

Sampling several locations within a predicted continuous polar ice deposit, especially one that is within a flat floored lunar crater suggested to host significant buried water ice [e.g., as identified in 18], would shed light on the patchiness of such a water ice deposit. Patchiness is important to quantify as it would address how many of the currently stable locations ice actually have water ice present, and allow for the evaluation of the long-term water supply rate to the Moon.

Depending on how lunar water is delivered to the surface and subsurface, there could be significant contamination of surface water ice deposits by other volatiles. Sulfur, which would be a major co-occurring volatile if lunar water was derived primarily from lunar volcanism [e.g., 8], is stable in all of the same locations as water ice (Fig. 2). Volatiles that have known human health effects in sufficient doses, like mercury [19] and toluene (delivered by comets, [9]), could occur in surface water ice deposits. Sampling these locations and analyzing the volatiles would provide the relative volatile contributions of comets, lunar outgassing, and solar wind over time.
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**Figure 1.** Maps showing the surface (dark blue) and sub-surface (light blue) water ice stability locations for the north (left) and south (right) poleward of 60°. The green circle in the south polar map is the Vikram lander crash site. Grid lines are every 10°. Background: LRO Wide-Angle Camera mosaic.

**Figure 2.** Maps showing the locations where sulfur (yellow, least volatile), water (blue), and toluene (brown, most volatile) would be stable to sublimation on the lunar surface poleward of 60° for the north (left) and south (right) poles.