THERMAL STABILITY OF SURFACE AND SUBSURFACE VOLATILES AT THE LUNAR POLES FROM DIVINER LUNAR RADIOMETER DATA. M.E. Landis[1], P.O Hayne[1], J.-P. Williams[2], D.A. Paige[2], [1]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO, USA. (margaret.landis@lasp.colorado.edu), [2]Department 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]. Buried water ice has been linked to changes in lunar crater depth-to-diameter ratios with latitude [8] and is possibly indicative of previous lunar pole locations [9]. 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 of present-day lunar volatiles. Different sources of lunar volatiles would produce distinct compositional signatures in the volatile deposits. For example, lunar volcanic activity would result in more sulfur within a volatile deposit than water [10], whereas a deposit dominated by a cometary source would have more water than sulfur, plus additional organic compounds [e.g., 11].

The south pole is a proposed site for future exploration for both robotic and human missions as described in NASA's plans for the next decade of lunar exploration [12]. Knowing the composition and replenishment rate of volatiles at the poles requires knowing the mechanism by which they are predominantly delivered (e.g., lunar volcanism, comets, or solar wind-implantation).

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.

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 [13].

We determine areas where volatiles are stable based on volatility temperatures given in [14], which correspond to surface volatile loss rate of 1 mm/Gyr. For surface volatile stability, we identify regions where the maximum temperature is below the volatility temperature. 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., 15, 16]. In the Moon's polar cold traps, 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., 17]). 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 [18]. We will compare the buried water ice stability regions with neutron data from Lunar Prospector to determine the extent that ice fills these stable locations, and present the results at the conference.

While the south pole currently hosts more surface area where water ice would be stable than the north pole [19], 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. Based on our surface and subsurface water stability maps, it is unlikely that the Vikram lander crash (site identified in a NASA press release as ~71° S, 23° E) would have exposed H_2O.

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., 10], is stable on the in all of the same locations as water ice (Fig. 2). Volatiles that have known human health effects in sufficient doses, like mercury [20] and toluene (delivered by comets, [11]), could occur in surface water ice deposits. Our maps indicate that toluene would co-occur with water ice in several locations (Fig. 2), as both have similar stability temperatures (~88 K for toluene, ~107 K for water) higher than maximum annual polar temperatures (< 60 K) in widespread cold traps.

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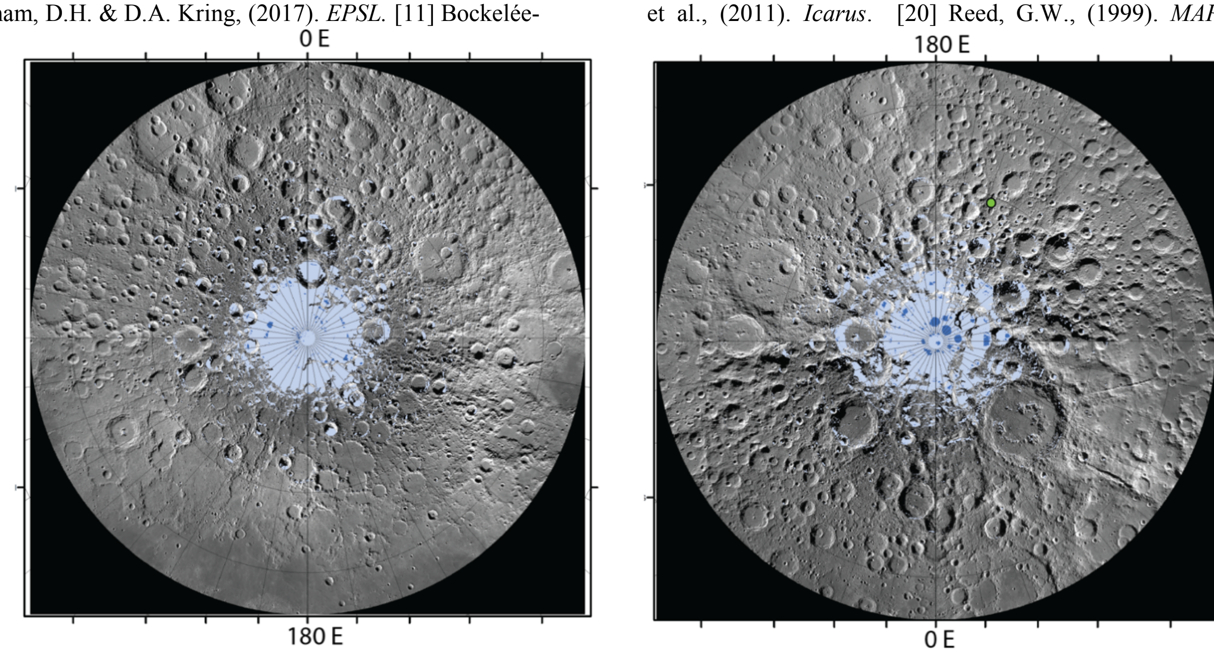

Figure 1. Maps showing the surface (dark blue) and sub-surface (light blue) water ice stability locations for the north (left) and south (right) poleward of 60°. The green circle in the south polar map is the Vikram lander crash site. Grid lines are every 10°. Background: LRO Wide-Angle Camera mosaic.

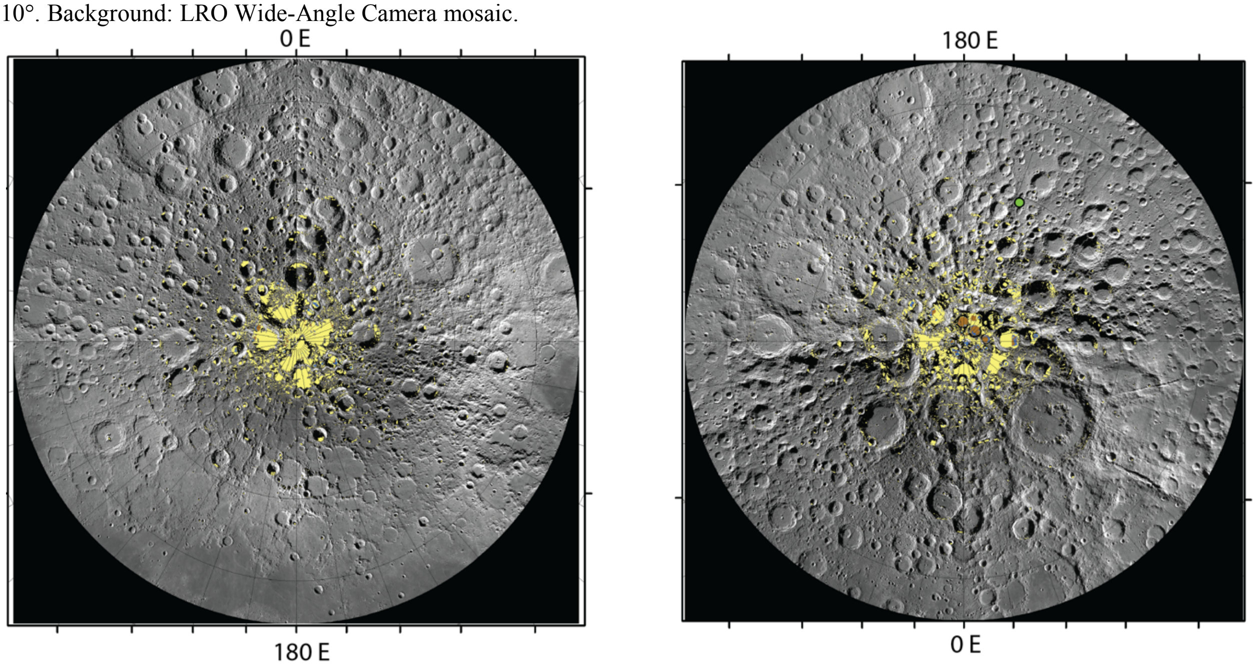

Figure 2. Maps showing the locations where sulfur (yellow, least volatile), water (blue), and toluene (brown, most volatile) would be stable to sublimation on the lunar surface poleward of 60° for the north (left) and south (right) poles.