TITLE: Limits on the Abundance and Burial Depth of Lunar Polar Ice

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The Diviner imaging radiometer experiment aboard the Lunar Reconnaissance Orbiter has revealed that surface temperatures in parts of the lunar polar regions are among the lowest in the solar system. Moreover, modeling of these Diviner data using realistic thermal conductivity profiles for lunar regolith and topography-based illumination has been done, with surprising results. Large expanses of circum-polar terrain appear to have near-subsurface temperatures well below 110K, despite receiving episodic low-angle solar illumination [Paige et al., 2010]. These subsurface cold traps could provide areally extensive reservoirs of volatiles.
Here we examine the limits to abundance and burial depth of putative volatiles, based on the signature they would create for orbital thermal and epithermal neutrons. Epithermals alone are not sufficient to break the abundance-depth ambiguity, while thermal neutrons provide an independent constraint on the problem. The subsurface cold traps are so large that even modest abundances, well below that inferred from LCROSS observations, would produce readily detectable signatures in the Lunar Prospector neutron spectrometer data [Colaprete et al., 2010]. Specifically, we forward-model the thermal and epithermal neutron leakage flux that would be observed for various ice concentrations, given the depth at which ice stability begins.
The LCROSS results point to a water-equivalent hydrogen abundance (WEH) in excess of 10 wt%, when all hydrogenous species are added together (except for H2, detected by LAMP on LRO [Gladstone et al., 2010]). When such an ice abundance is placed in a layer below the stability depth of Paige et al., the epithermal and thermal neutron leakage fluxes are vastly reduced and very much at odds with orbital observations. So clearly an environment that is conducive to cold trapping is necessary but not sufficient for the presence of volatiles such as water.
We present the limits on the abundances that are indeed consistent with orbital data. At the LCROSS impact site itself, the data are consistent with very high ice abundances at 50-100 cm depth. However, radar results rule out these high abundances.

LIMITS ON THE ABUNDANCE AND BURIAL DEPTH OF LUNAR POLAR ICE. Richard C Elphic[1], David A Paige[2], Matthew A Siegler[2], Ashwin R Vasavada[3], Luis A Teodoro[3], Vincent R Eke[4], [1]Planetary Systems Branch, NASA Ames Research Center, Moffett Field, CA, United States. [2]University of California, Los Angeles, CA, United States, [3]Jet Propulsion Laboratory, Pasadena, CA, United States, [4]Durham University, Durham, United Kingdom.

Introduction: The Diviner imaging radiometer experiment aboard the Lunar Reconnaissance Orbiter has revealed that surface temperatures in parts of the lunar polar regions are among the lowest in the solar system. Moreover, modeling of these Diviner data using realistic thermal conductivity profiles for lunar regolith and topography-based illumination has been done, with surprising results. Large expanses of circum-polar terrain appear to have near-subsurface temperatures well below 110K, despite receiving episodic low-angle solar illumination [Paige et al., 2010]. As can be seen by the depth-to-permafrost maps in Figure 1, these subsurface cold traps could provide areally extensive reservoirs of volatiles.

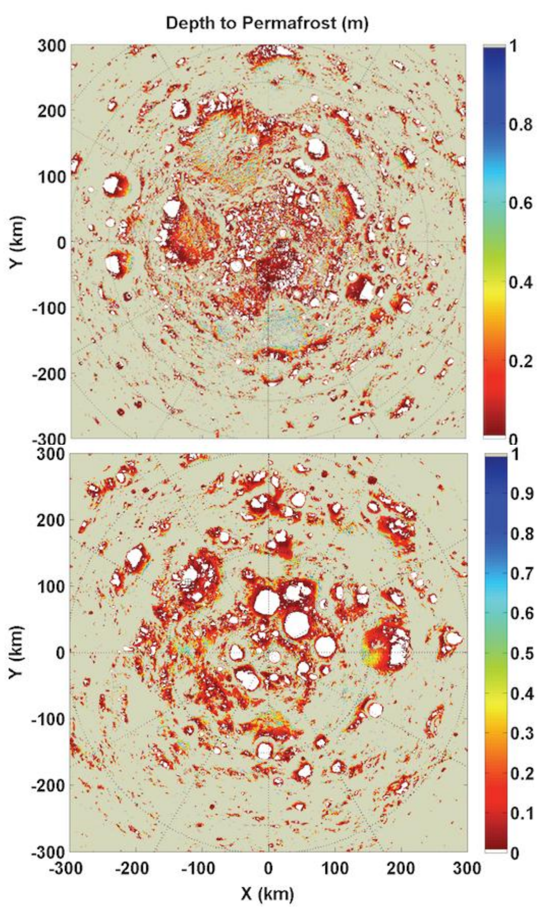

Fig. 1. Depth to the ice stability criterion of 1 mm/Ga sublimation loss. (top) North Pole, (bottom) South Pole.

Here we examine the limits to abundance and burial depth of putative volatiles, based on the signature they would create for orbital thermal and epithermal neutrons. Epithermals alone are not sufficient to break the abundance-depth ambiguity, while thermal neutrons provide an independent constraint on the problem. The subsurface cold traps are so large that even modest abundances, well below that inferred from LCROSS observations, would produce readily detectable signatures in the Lunar Prospector neutron spectrometer data [Colaprete et al., 2010]. Specifically, we forward-model the thermal and epithermal neutron leakage flux that would be observed for various ice concentrations, given the depth of ice stability.

Previous Results and Modeling: The LCROSS results point to a water-equivalent hydrogen abundance (WEH) of 5 -10 wt%, when all hydrogenous species are added together (except for H_2, detected by LAMP on LRO [Gladstone et al., 2010]). When such an ice abundance is placed in a layer below the stability depth of Paige et al., the epithermal and thermal neutron leakage fluxes are greatly reduced and very much at odds with orbital observations. However, burial of ice-bearing materials under dry regolith can mute these neutron signatures. Clearly an environment that is conducive to cold trapping is necessary but not sufficient for the near-surface presence of volatiles such as water, or else we would observe very large reductions in epithermal neutron flux from orbit.

We begin the forward modeling process with a modest abundance, 1 wt% WEH, assumed to be a semi-infinite layer under otherwise dry regolith. The depth is set by the thermal modeling of [1]. Even 1 wt% would produce much deeper epithermal neutron reductions than are observed. Thus, not all regions of shallow ice stability contain significant amounts of ice.

References: [1] Paige, D. A. et al, (2010), *Science,* DOI:10.1126/science.1187726, [2] Colaprete, A. et al., (2010) *Science,* DOI: 10.1126/science.1186986, [3] Gladstone, R. et al., (2010) *Science,* DOI: 10.1126/science.1186474