

**NEW AND EVOLVING VIEWS OF THE MOON'S VOLATILES FROM THE LUNAR RECONNAISSANCE ORBITER.** P. O. Hayne<sup>1</sup>, and the Lunar Reconnaissance Orbiter Science Team, <sup>1</sup>Jet Propulsion Laboratory, California Institute of Technology (Paul.O.Hayne@jpl.nasa.gov)

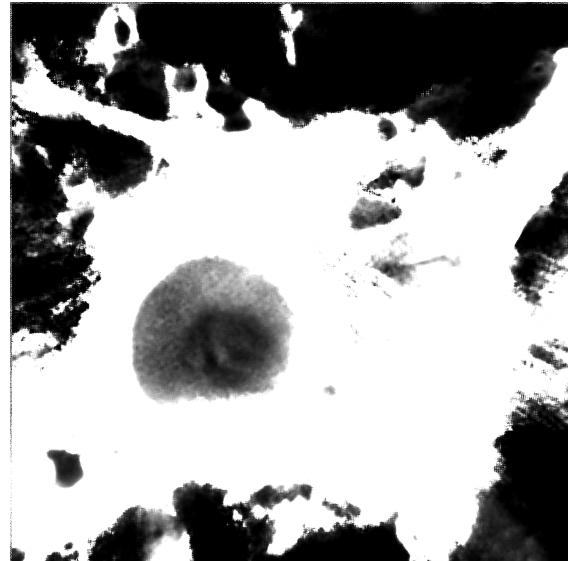
**Introduction:** Although the scientific basis for the possibility of water and other volatiles in the cold traps of the lunar polar regions was developed in the 1960's and '70's [1,2], only recently have the data become available to test the theories in detail. Furthermore, comparisons with other planetary bodies, particularly Mercury, has revealed surprising differences that may point to inconsistencies or holes in our understanding of the basic processes involving volatiles on airless bodies [3]. Addressing these gaps in understanding is critical to the future exploration of the Moon, for which water is a critical scientific and engineering resource [4].

**Lunar Reconnaissance Orbiter:** Launched in 2009, the Lunar Reconnaissance Orbiter (LRO) has been acquiring data from lunar orbit for more than six years. All seven of the remote sensing instruments on the payload have now contributed significantly to advancing understanding of volatiles on the Moon. Here we present results from these investigations, and discuss attempts to synthesize the disparate information to create a self-consistent model for lunar volatiles. In addition to the LRO data, we must take into account results from earlier missions [5,6], ground-based telescopes [7], and sample analyses [8].

**Results:** Here, we briefly summarize results from several recent and ongoing LRO investigations related to lunar volatiles.

**Diviner.** On surfaces with temperatures perennially below ~110 K, water ice is stable against sublimation for > 1 Gyr. The Diviner thermal infrared radiometer on LRO has fully mapped and characterized the temperature distributions of the Moon's polar cold traps [9]. Major results include: 1) the surface area available for cold-trapping volatiles is > 10<sup>5</sup> km<sup>2</sup>; 2) great diversity is observed among the temperature behavior of the cold traps; 3) comparisons with reflectance datasets (LOLA, LAMP) indicate a strong correlation between the lower temperatures < 110 K and spectral characteristics consistent with H<sub>2</sub>O frost at the surface [10,11].

**LAMP.** Surface reflectance within the coldest regions is consistently lower in the Lyman- $\alpha$  band, consistent with either frost or high porosity [12]. Reflectance ratios between the water ice "off-band" and "on-band" channels also shows behavior consistent with surface frost in the cold traps. However, the correlation with temperature is incomplete, and recent work has



*Figure: The well-calibrated solar channel of the LRO-Diviner instrument can be used for detailed accounting of incident and reflected photons within the perennial shadows, in this case Shackleton crater.*

focused on improving albedo maps in order to understand the detailed distribution of these putative frosts.

**LOLA.** Bidirectional reflectance measurements from LRO's laser altimeter show a systematic enhancement in the cold traps, consistent with the presence of water frost in many of these craters [11]. However, the single-wavelength data are not diagnostic of composition.

**LEND.** Epithermal neutron data show enhancements in hydrogen within the upper ~1 m at the high latitudes at both poles, with certain specific anomalous features at the ~10 – 100 km scale. Furthermore, LEND detects an overall trend in increased H as a function of latitude, with a break in slope near 70° [13]. This could be evidence for small-scale cold traps, below the resolution of the measurements.

**LROC.** Imaging within the perennial shadows has recently been performed using LRO's camera system, following clear detections of ice in Mercurian craters by the MESSENGER mission [14]. So far, no clear indication of surface frost has been found, although detailed modeling of scattered sunlight is still being studied in order to derive surface albedo.

**Mini-RF.** Recent bistatic radar measurements using the Arecibo telescope and LRO's Mini-RF instru-

ment provide some evidence for phase behavior consistent with macroscopic ( $> 1$  cm) pieces of water ice, or perhaps “ice lenses” buried just beneath the surface [15].

*CraTER*. Measurements of proton fluxes may be used to constrain the vertical distribution of hydrogen in the lunar soil. We will present examples of future observations that could enable new constraints on lunar volatile distributions.

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**Acknowledgement:** Part of this work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.