SYNTHESIZING SURFACE AND SUBSURFACE MEASUREMENTS OF WATER ICE IN THE POLAR REGIONS OF THE MOON. A. P. Jordan[1,2*], J. K. Wilson[1,2], N. A. Schwadron[1,2], and H. E. Spence[1,2], [1]EOS Space Science Center, University of New Hampshire, Durham, NH, USA (*email: a.p.jordan@unh.edu), [2]Solar System Exploration Research Virtual Institute, NASA Ames Research Center, Moffett Field, CA, USA.

Introduction: Knowing how water is distributed in the Moon's polar regions helps determine the origin of the water and how it can be accessed for in situ resource utilization. Yet it is unclear why some permanently shadowed regions (PSRs) lack ice and why surface and subsurface measurements seem to disagree regarding the locations of deposits of water ice. We show how to synthesize these disparate measurements—ultraviolet (UV), infrared, neutrons, and albedo protons—into a result that tightly constrains the origin of water ice on the Moon.

Surface Data: We first consider three instruments that can remotely measure even within PSRs. First, the Lyman Alpha Mapping Project (LAMP) on the Lunar Reconnaissance Orbiter (LRO) measures UV emitted by stars and the interplanetary medium and subsequently reflected off the lunar surface. LAMP's off-band to on-band signal ratio indicates the presence of surficial water ice. This ratio increases with increasing latitude, at least poleward of -75° and is independent of large PSRs [1]. Extrapolating beyond what the authors show suggests that water ice maybe detected as far equatorward as about -70°.

LRO also carries the Lunar Orbiter Laser Altimeter (LOLA), which can actively measure surface albedo with a 1064 nm laser. Regions of anomalously high albedo can be due to exposed water ice. The albedo as a function of latitude shows, in the authors' words, "upticks" above latitudes of ±70° [2], indicating an increasing fraction of water ice.

The third instrument is the Moon Mineralogy Mapper (M3) on Chandrayan-1. M3 has detected the specific absorption features of water ice in PSRs that are indirectly illuminated [3]. All detections occur poleward of ±70°.

Subsurface Data: Both the Neutron Spectrometer on Lunar Prospector (LPNS) and the Lunar Exploration Neutron Detector (LEND) have found similar trends with latitude due to hydrogen in the upper ~50 cm of regolith. Away from the poles, both datasets are fairly flat with latitude, but they show clear poleward decreases beginning near ±70° [4, 5]. Even when large regions of neutron suppression are removed from LEND data, the trend remains [6].

The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) on LRO measures protons ejected from regolith by cosmic rays. Cosmic ray collisions create protons and neutrons. The same hydrogen that suppresses neutrons leaving the regolith also enhances the "albedo" protons [7]. Although the current resolution in latitude is too low to determine whether a rollover occurs at ±70°, the data do show that albedo protons increase with increasing latitude. We are creating a new data product with improved statistics and background correction; perhaps it will show the same trend as the other datasets.

Modeling Cold Traps: The similarity between all the datasets, including one which unambiguously detects water ice spectra, strongly suggests that all are measuring water ice and not just various forms of hydrogen. This is further confirmed by simulations showing that surface and subsurface cold traps become important with increasing latitude [8]. Although the published results of these simulations do not extend equatorward of ±75°, the trends are consistent with what is observed by most of the instruments above. And because subsurface cold traps can extend to lower latitudes than surface cold traps, subsurface ice can be present to lower latitudes than subsurface ice. This difference could be revealed by comparing more carefully the above surface and subsurface measurements.

Conclusion: These measurements indicate that water ice is distributed throughout the polar regions of the Moon down to about ±70° latitude. This distribution may aid in situ resource utilization. Furthermore, the consistency across these datasets and simulations suggests an ancient cometary impact or impacts deposited the water. If the majority of the ice were created more constantly in time via the solar wind, we would expect most craters to be similar. An ancient impact or impacts, on the other hand, could create the above large scale correlation that would be disrupted on smaller scales, i.e., large PSR scales, by subsequent impacts. This could explain why the above datasets are correlated on large scales but may disagree on smaller scales. The above synthesis thus strongly constrains the possible origins of water ice on the Moon.

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