EPSC Abstracts
Vol. 13, EPSC-DPS2019-667-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Detecting water-ice in lunar highlands with 532 and 1560 nm lidar: The Volatile & Mineralogy Mapping Orbiter

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Abstract

Using a lunar highland breccia (meteorite NWA 11444) we have determined that 532 and 1560 nm reflectance is affected by variations in ice content, local slopes, and dust coatings and a number of spectral parameters should be able to characterize lunar highland regolith + water ice deposits.

1. Introduction

A lunar CubeSat mission proposal called VMMO (Volatile & Mineralogy Mapping Orbiter) is among the two 2018 winners of the European Space Agency (ESA)'s SysNova Challenge on LUnar Cubesats for Exploration (LUCE) [1, 2]. VMMO aims to address several aspects of future lunar exploration including:

- *Lunar Resource Prospecting*: *Mapping the location of relevant in-situ resources and volatiles in sufficient quantities to be operationally useful (fuel, life-support) for future sustained surface missions.*

The VMMO's primary science payload is the Lunar Volatile and Mineralogy Mapper (LVMM) - a miniaturised laser instrument that would probe for water ice in Shackleton Crater, near the South Pole. It will use a dual-wavelength chemical lidar at 532 nm and 1560 nm. Here we report laboratory results for mixtures of the lunar meteorite NWA 11444 + water-ice in the context of LVMM.

2. Experimental Procedure

NWA 11444 is a lunar highland melt breccia meteorite [3]. The sample was ground by hand and dry-sieved to <150 μm. Mixtures were made with 0-50 wt.% deionized water, frozen to -35°C, and lightly reground prior to spectral measurements. Reflectance spectra were acquired with an ASD HiSpec4 spectrometer and a bifurcated cable for coincident incidence and emission angles.

3. Results 1: Varying slope

Powdered NWA 11444 + water-ice mixtures (0, 10, 20, 30, 40, 50 wt.% water-ice) were measured for local slopes (tilts) of 0, 10, 20, 30, and 40° (Figure 1). The data show some scatter, but increasing tilt generally leads to decreasing 1560/532 nm reflectance ratio. It also appears that tilt changes cause little or no overlap with the other ice content series data. For 532 (Figure 2) or 1560 nm (Figure 3) reflectance vs. tilt, there is a generally positive correlation, with the exception of the 50 wt.% ice series.

4. Results 2: Varying ice content

Figures 1-3 can also be used to assess the effects of varying water-ice content: a vertical line joins spectra of varying ice content at a constant tilt. The samples with 0 and 10% water-ice content have similar 1560/532 nm ratios, while higher water-ice content results in a lower 1560/532 nm ratio. A decreasing 1560/532 nm ratio with increasing water-ice content is expected, as the 1560 nm band is located in the region of a strong water-ice absorption feature [3]. The effect of water-ice on 532 nm reflectance is less systematic (Figure 2). 532 nm reflectance varies by up to ~2x. In almost all cases, increasing water-ice content leads to lower reflectance. At 1560 nm (Figure 3), the range of reflectance is higher than for the 532 nm reflectance: up to a factor of ~3. With the exception of the 0 and 10 wt.% mixtures the other series do not overlap each other, and increasing water-ice leads to a decrease in 1560 nm reflectance.

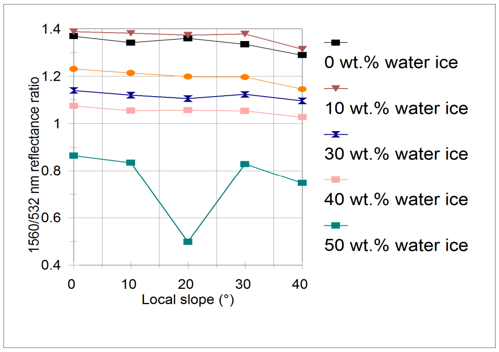

Figure 1. Local slope vs. 1560/532 nm ratio.

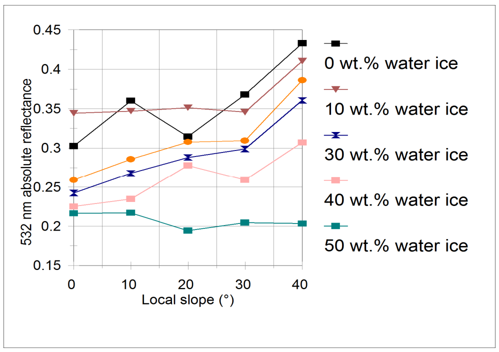

Figure 2. Local slope vs. 532 nm absolute reflectance.

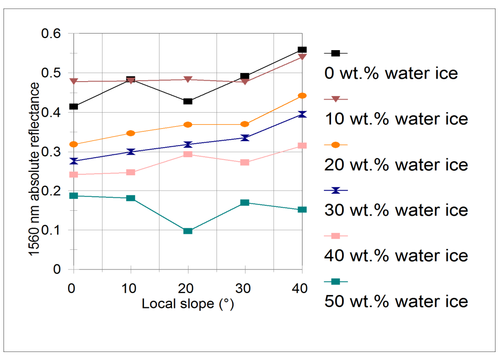

Figure 3. Local slope vs. 1560 nm reflectance.

5. Discussion

The results for mare versus highland + water ice differ [5, 6]. Highland material shows measurable and largely predictable spectral changes as a function of local slope and water-ice content. The non-systematics are likely a function of how well-mixed the samples are and sample surface texture. Further laboratory experiments will provide additional insights into the ability of VMMO to characterize surficial shadowed water-ice deposits. Dust coatings can also affect the detectability of surficial or near-surface water-ice, and the nature of the coating (thickness, porosity) will affect the ability of LVMM to detect such occurrences.

Acknowledgements

The authors thank ESA and CSA for supporting this study through various funding programs.

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