OBSERVING ICE SULIMATION FROM WATER-DOPED LUNAR SIMULANT AT CRYOGENIC TEMPERATURES.

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Introduction: NASA's Resource Prospector (RP) mission is intended to characterize the three-dimensional nature of volatiles in lunar polar and permanently shadowed regions [1]. The Near-Infrared Volatile Spectrometer System (NIRVSS, [2]) observes while a drill [3] penetrates to a maximum depth of 1 m. Any 10 cm increment of soil identified as containing water ice can be delivered to a heating crucible [4] with the evolved gas delivered to a gas chromatograph / mass spectrometer [5].

NIRVSS consists of two components; a spectrometer box (SB) and bracket assembly (BA), connected by two fiber optic cables. The SB contains separate short- and long-wavelength spectrometers, SW and LW respectively, that collectively span the 1600-3400 nm range. The BA contains an IR emitter (lamp), drill observation camera (DOC, 2048 x 2048 CMOS detector), 8 different wavelength LEDs, and a longwave calibration sensor (LCS) measuring the surface emissivity at four IR wavelengths.

Tests of various RP sub-systems have been undertaken in a large cryo-vacuum chamber at Glenn Research Center [6-8]. The chamber accommodates a tube (1.2 m high x 25.4 cm diameter) filled with lunar simulant, NU-LHT-3M, prepared with known abundances of water. Thermocouples are embedded at different depths, and also across the surface of the soil tube. In the chamber the tube is cooled with LN2 as the pressure is reduced to ~5-6x10^{-6} Torr. For the May 2016 tests two soil tubes were prepared with initially 2.5 Wt.% water. The shroud surrounding the soil tube was held at different temperatures for each tube to simulate a warm and cold lunar environment. Table 1 provides a summary of experimental conditions and Figure 1 shows the nominal view of the NIRVSS components, the drill foot, and the top of the soil tube.

Table 1. Experimental Conditions in 2016

Date	17 May 2016	26 May 2016
Name	Soil Tube 1 (ST1)	Soil Tube 2 (ST2)
Shroud Temperature	223 K	93 K

Once the average soil temperature reached ~178 K, drilling commenced. During drilling activities NIRVSS was alternating between obtaining spectra and obtaining images. Here we discuss NIRVSS spectral data obtained during controlled drill percussions.

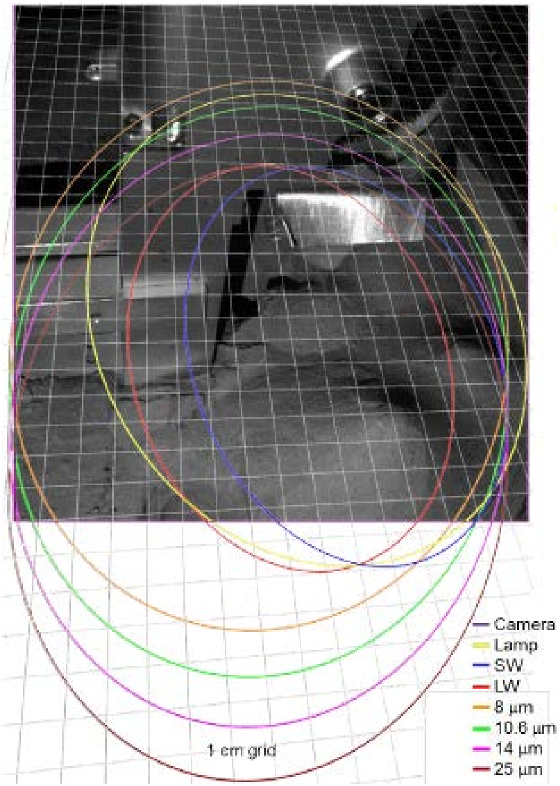

Figure 1. NIRVSS component fields-of-view using the DOC image as the reference frame.

Spectral parameters to track volatile behavior: Diagnostic signatures of ice occur near 2000 and 3000 nm. Two band depths (BD2000 and BD3000) were defined to track spectral signatures of ice during drilling. These parameters increase as new ice-bearing soils are emplaced onto the surface and decrease as the soils are exposed to the vacuum environment [9]. DOC imaging revealed complex behavior of the cuttings piles as the drilling proceeded. We observed down-slope movement of soil, local slope failures, and pile growth occasionally blocking the funnel and preventing new material from being emplaced on the surface. This dynamic activity presents challenges in using the active drilling observations to assess ice sublimation behavior. While the drill was static, percussions (a tapping equivalent) were performed in an attempt to document the sublimation behavior of exposed ice. Fig. 2 shows BD2000 (blue circles), and BD3000 (red circles) after the final of three one-second percussions for ST2, drill hole 3. Each percussion was fit as a 3-

term exponential decay function: BD= y0 + a*e$^{(-bx)}$, where x is the elapsed time after the percussion. Table 2 provides a summary of the exponential fits to each percussion and each BD. Examples fits are shown as the solid lines in Fig. 2 with residuals at the top.

Table 2. Fit parameters and standard errors for each percussion.

Band Depth	y_0	a	b	R^2	# pts
BD2000, P1	0.151± 0.000	0.012± 0.000	0.051± 0.003	0.986	48
BD2000, P2	0.148± 0.001	0.013± 0.001	0.032± 0.004	0.949	53
BD2000, P3	0.146± 0.000	0.009± 0.000	0.034± 0.002	0.988	72
BD3000, P1	0.489± 0.001	0.030± 0.001	0.054± 0.007	0.928	48
BD3000, P2	0.460± 0.006	0.056± 0.005	0.019± 0.004	0.942	53
BD3000, P3	0.448± 0.002	0.049± 0.001	0.024± 0.002	0.981	72

P1, P2, P3 are percussions 1, 2, and 3 respectively

Results: Fig. 2 shows BD2000 (blue circles), and BD3000 (red circles) after the final of three one second percussions, associated fits, and residuals. In spite of the relatively high R^2 values in Table 2, the residuals exhibit varability (gray arrows in Fig. 2) suggesting deviation from simple exponential behavior.

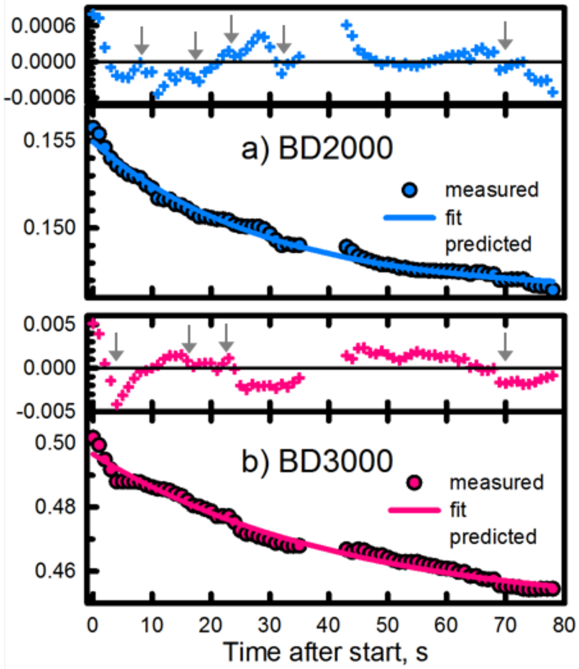

Figure 2. BD2000 and BD3000 after the last of three percussive events. Residuals are above each BD.

Discussion: BDs derived from the NIRVSS SW and LW spectrometers can both be used to document sublimation of water ice as drilling occurs and after percussive activity. Exponential fits to the BDs show initial BD values (y_0) decrease with each successive percussion, and the exponential decay value (b) decreases after the first percussion. The NIRVSS BDs also provide an estimate of the time required for exposed ice to sublime in simulated cold lunar environment and provide data for soil diffusion models. The residuals of the fits suggest: 1) fresh water ice may be exposed several times during the observational time period; and 2) sublimation behavior may not be described by a simple exponential, as suggested by [10].

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