POSSIBLE DETECTION OF WATER FROST BY THE CURIOSITY ROVER. R.V. Gough[1], W. Rapin[2], G.M. Martínez[3], P.-Y. Meslin[4], O. Gasnault[4], S. Schröder[5], R. Wiens[6]. [1]CIRES and Dept. of Chemistry, University of Colorado, Boulder, CO (raina.gough@colorado.edu). [2]Caltech - GPS, Pasadena, CA. [3]LPI, USRA, Houston, TX, [4]IRAP, CNRS-UPS, Toulouse, France. [5]DLR, Berlin, Germany. [6]LANL, Los Alamos, NM.

Introduction: Many orbital and ground-based retrievals of Martian water vapor, as well as models, suggest that water is exchanged seasonally and diurnally with the surface [*1-4*]. The multi-year record of temperature and humidity conditions measured at Gale Crater (4.6°S) by the Rover Environmental Monitoring Station (REMS) suggests that limited surface-atmosphere exchange of water vapor is occurring along the Curiosity traverse [*5*]. Based on comparisons of the ground temperature and the derived frost point temperature, frost is predicted to form at times in the southern winter at Gale crater, especially from L_s 90 to 100° [*6*]. Perhaps because the frost layer is predicted to be quite thin, on the order of 1 µm or less [*6*], frost has not been observed by any of the rover cameras. In fact, surface frost has only been observed at the Phoenix (68.2°N) and Viking Lander 2 (47.9°N) landing sites, while from mid to equatorial latitudes only indirect evidence exists [*7*]. The Laser Induced Breakdown Spectroscopy (LIBS) instrument, part of the ChemCam instrument package, is able to perform remote and sensitive elemental analysis that includes the identification of micron-thick water layers. Prior to this study, ChemCam LIBS had not positively identified enhanced diurnal hydration [*8,9*], although these prior analyses were primarily done during seasons that were not optimal for frost formation.

Here we report the preliminary results of the Mars Year (MY) 35 Frost Detection Campaign. In late 2019, three soil targets at different locations were analyzed with ChemCam LIBS. Spectra were collected in the daytime and at dawn to detect any enhanced hydrogen (H) on the soil in the early morning. REMS observations from these times were used to determine if frost was predicted. This campaign was conducted from L_s 89-104°, the beginning of southern winter and the time during which frost is most likely to form at Gale Crater [*6*].

Methods and observations:

ChemCam. The three soil targets analyzed by ChemCam for dawn frost during this campaign are shown in Figure 1. The targets (a) Kilpatrick (L_s = 89°, sol 2548), (b) Kinnordy (L_s = 97°, sol 2565) and (c) Kittybrewster (L_s = 104°, sol 2582) met the following selection criteria: (1) a fine grained soil patch, (2) larger than 5 cm in size and (3) more than 3 m from the rover. These last two criteria were to ensure thermal insulation from higher thermal inertia rocks and from the "warm" rover. For each soil target, a ChemCam raster was collected ~20 min before sunrise and another was collected midday, typically 13:00 local time. Each raster consists of 10 points spaced along a line (Fig. 1), with 10 shots on each point. The first shot at each point is used here for analysis as it samples the undisturbed soil surface. The hydrogen emission peak at 656.6 nm is extracted from the spectra [*9,10*] and several signal normalizations are tested to compare day/dawn pairs of observations.

REMS. During the dawn ChemCam frost detection observations, measurements of air temperature at 1.6 m, relative humidity at 1.6 m, and ground temperature, T_g, were collected. This provided an accurate snapshot of the rapidly changing environmental conditions near sunrise. From these observed parameters, the water vapor mixing ratio at 1.6 m was calculated. Assuming constant mixing ratio in the lower 1.6 m of atmosphere, the relative humidity and the frost point temperature, T_f, at the surface were determined.

Results:

REMS frost prediction. Figure 2 compares the diurnal cycle in T_g and T_f on the three sols of ChemCam frost detection attempts. It can be seen in Fig. 2a that T_g (red) does drop below T_f (blue) on sol 2548, even given the uncertainties in each. This occurred between 5 and 6 AM and is interpreted as a potential frost event. No frost event is seen on the other two sols of the campaign (Figs. 2b, c), as T_g fails to drop below T_f on either sol

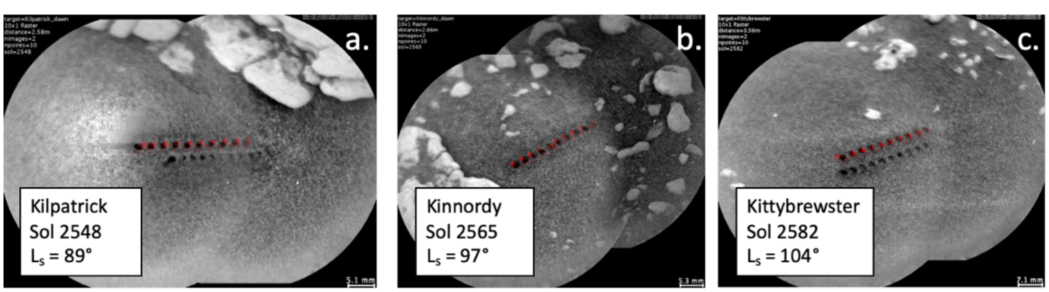

Figure 1. ChemCam Remote Micro-Imager (RMI) images of the three soil targets analyzed with LIBS during the daytime and at dawn as part of the MY 35 Frost Detection Campaign.

given the associated uncertainties. It should be noted that frost was also predicted by REMS on several other non-Frost Campaign sols during this time period.

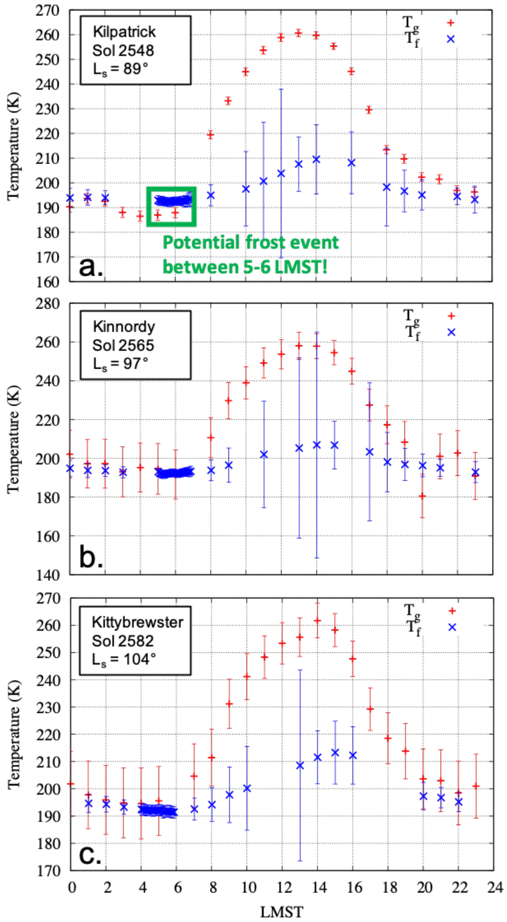

Figure 2. Diurnal evolution of ground temperature (red) and frost point temperature (blue) on sols 2548 (a), 2565 (b), and 2582 (c). Sunrise was ~05:50 AM on all sols.

ChemCam frost detection. The dawn vs. daytime normalized H signals are compared in Figure 3 for soil targets (a) Kilpatrick and (b) Kinnordy. For Kilpatrick, there was enhanced average H signal in shots at dawn relative to daytime, above point-to-point signal variability. It is necessary to normalize the data, but this result is independent of the normalization used for the H signal. It suggests that the H signal enhancement recorded increased water content on or in the top layer of soil just before sunrise. For Kinnordy, there is no difference in the H signal during dawn vs daytime suggesting there was no detectable change in water content overnight. Results for Kittybrewster, not shown, are similar to those of the Kinnordy target (i.e., no H enhancement was observed during dawn).

Conclusions: The REMS environmental conditions and the variations in LIBS H signal for the three MY 35 Frost Campaign targets tell a consistent story. Initial results and conclusions of this campaign are summarized in Fig 4. The target Kilpatrick likely contained more water before dawn than during the day on sol 2548 and we consider this a likely identification of frost. We are not able to determine the phase or distribution of this transient water; adsorbed water layers on soil grains are possible. Point-to-point variability and signal normalization are the main limitations of these LIBS measurements. Future campaigns and lab studies should improve our understanding of ChemCam sensitivity to frost.

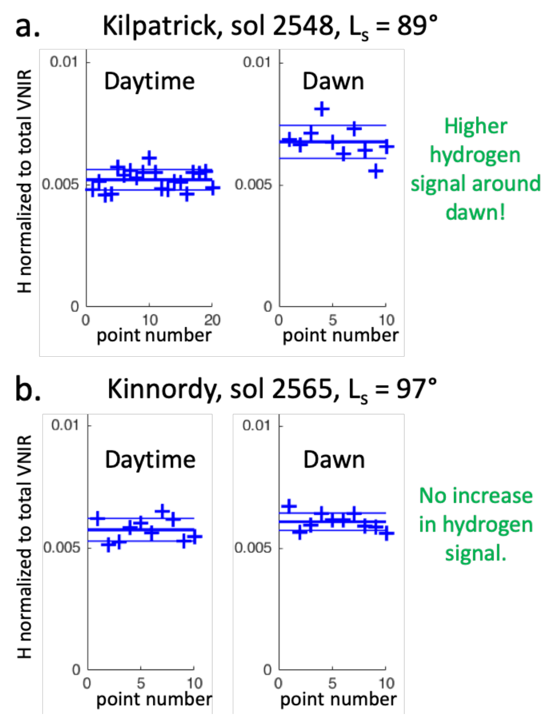

Figure 3. Comparison of ChemCam LIBS hydrogen signal collected at targets Kilpatrick (a) and Kinnordy (b) during the day (left) and dawn (right).

	Target, sol, L_s	REMS	ChemCam	Interpretation
1	Kilpatrick Sol 2548 L_s = 89°	Frost predicted ($T_g < T_f$)	Dawn H signal > daytime H signal	Frost present between 5 and 6 AM
2	Kinnordy Sol 2565 L_s = 97°	Frost not predicted ($T_g \geq T_f$)	No H signal difference, dawn vs. daytime	No frost present
3	Kittybrewster Sol 2582 L_s = 104°	Frost not predicted ($T_g \geq T_f$)	No H signal difference, dawn vs. daytime	No frost present

Figure 4. Summary of REMS and ChemCam results for the MY 35 Frost Detection Campaign soil targets.

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