Constraining the Spatial Extent and Timing of Local-scale Seasonal Frost in the Northern Mid Latitude Region of Mars. J. M. Widmer[1] and S. Diniega[2]. [1]University of Maryland (jwidmer@terpmail.umd.edu), [2]Jet Propulsion Laboratory, California Institute of Technology.

Introduction: CO_2 gas comprises ~95% of the martian atmosphere which can condense or precipitate if the surface temperature drops below the CO_2 frost point [1]. This drop in temperature forms solid CO_2 on the surface as diurnal or "daily" frost [2], seasonal frost [1], or snowfall [3]. Minute amounts of water frost can also condense onto the surface (possibly incorporated into the CO_2 frost), if sufficient water vapor is available [4]. The deposition and removal of seasonal frost have been proposed as geomorphic agents capable of altering the martian surface in a variety of ways [5]. Our work involves a methodology for detecting seasonal frost at high temporal and spatial resolution, in order to constrain the duration of the frosted season within specific study sites and at a scale relevant for geomorphic activity. This will provide important environmental constraints for investigations of active surface processes and additional environmental data to compare against current thermal models/ general circulation models (GCMs).

Fitting In with Previous CO_2 Studies: Most studies of regional scale frost formation on Mars have relied on GCM simulations or coarse-resolution observations. In 1966 Leighton and Murray modeled the behavior of CO_2 in its gaseous and solid states providing the foundation for future work. In another study, results from the NASA Ames GCM estimated the timing of seasonal CO_2 frost from 60°-90° latitude (polar regions) in both hemispheres [6]. GCM results from 60° N show CO_2 frost present during ~Ls 235-25, timing consistent with observations from the Mars Odyssey Gamma Ray Spectrometer (GRS) [6]. However, it should be noted that a GRS observation has a ground resolution of ~360-450km in diameter, ideal for a large regional view of frost [6].

At a local scale, an observation based CO_2 frost study in Russell crater identified dark flow features as activity driven by sublimating CO_2 on dunes, using HiRISE (visible) images and CRISM (near-IR) data from MRO [7]. MOC (visible) images from MGS have also been used to identify seasonal frost and its preferential formation on pole-facing crater rims [8].

Framework: Our study provides a new look at seasonal frost (both CO_2 and H_2O) appearance within dune fields and the craters that host them in the northern mid latitudes. The strength of this study is rooted in the combination of lower resolution data from MCS and THEMIS-IR with high resolution observations from HiRISE, CTX, THEMIS-VIS, and CRISM data. The high resolution data places a greater emphasis on the appearance of local scale seasonal frost as opposed to the regional or global scales discussed in current literature.

Data Types and Resolution: In our study, we determine timing of CO_2 frost primarily through surface brightness temperature measurements from MCS. This dataset has extensive spatial coverage but low resolution compared to our other datasets (Table 1). Additionally, we pull MCS data from a large (~150km radius) region around specific sites of interest so as to fill in the temporal coverage, but this dilutes connection between observed frost and our specific study sites.

To increase spatial resolution, we use higher-resolution data over smaller regions to "groundtruth" our MCS-derived timing and reconnect to our specific study sites. Pixels in THEMIS-IR thermal images provide surface temperatures similar to MCS data but with much higher resolution [9] (Table 1). THEMIS-VIS and short wavelength CRISM(-Vis) colored images allow frost to be detected as light blue and white colors, respectively. Targeted CRISM (FRT) observations show absorption spectrums for surface material at specific locations. Characteristic absorption bands in the spectrum at 1.435 μm and 1.5 μm allow us to definitively distinguish between CO_2 and H_2O frosts [10]. Lastly, CTX and HiRISE grayscale images display the martian surface with the highest resolutions (Table 1). Frost detections in these two datasets can be seen as the appearance/ disappearance of bright white patches on rocky surfaces, or dark patterns/ mass wasting flows on defrosting dunes [7].

Instrument	Data Type	Resolution (m/ pix)	Global Coverage (%)
HiRISE	Visible Image	0.25	3.1
CTX	Visible Image	4	100
CRISM (FRT)	Near-IR Data	18	1.1
CRISM-Vis	Visible Image	18	>1.1
THEMIS VIS	Visible Image	18	<100
THEMIS IR	Thermal Image	100	~100
MCS	Thermal Data	5000	100

Table 1: *Information on datasets used to identify and constrain timing of seasonal frost. Note the decrease in resolution acts a spatial scale from HiRISE (local scale) to MCS (regional scale).*

Putting It All Together: Combining these datasets can provide stronger evidence for frost appearance with detections across multiple instruments while offering longer temporal coverage than any single instrument can provide. Tightened constraints on the timing during which seasonal frost may interact with the surface – at a scale relevant for present-day activity, will improve our knowledge of the seasonal processes currently hypothesized to alter the martian landscape [5,11].

Study Sites: A study site, for the purpose of this work, is defined as a dune field in the northern mid latitude region (MLR), defined as 30º-65º N, with extensive high resolution data coverage (specifically HiRISE and CTX datasets) and may or may not contain the presence of seasonal frost. Figure 1 shows the distribution of six sites chosen for detailed study. Sites are represented as colored stars and vary in latitude and longitude values throughout the MLR.

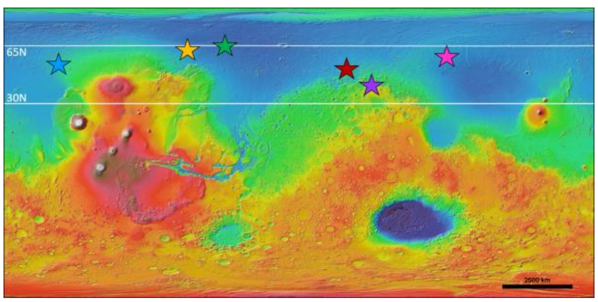

Figure 1: *Stars mark the positions of our study sites across the northern mid latitude region (30°-65° N) of Mars. Star color corresponds study results in Figure 2.*

Discussion: Six study sites were put through the above-mentioned suite of frost detection tests. We found that seasonal frost appeared at five study sites in the MLR between 64.5º-50.0º N. No seasonal frost was detected at the sixth study site located at 41.7° N. Timing of seasonal frost ranged from Ls 214-82 at latitude 64.5º N to Ls 256-283 at 50.0º N. As expected, the timing of seasonal frost within these regions of the MLR starts later and decreases in duration as the latitude decreases.

Variation in observation and measurement scales provides important context for our future work. Frost initially forms as isolated patches at the local scale and grows to cover regional sized areas over the course of the northern winter. As warmer temperatures arrive with the onset of spring, seasonal frost begins to sublimate, leaving small patches behind. As such, the highest resolution data, mainly HiRISE and CTX, are able to detect the small patches at the scale relevant for small-scale geomorphologic activity. However, high spatial resolution data often has sporadic temporal coverage so frequent, but coarser resolution datasets such as MCS and THEMIS-IR are better for constraining the timing of seasonal frost.

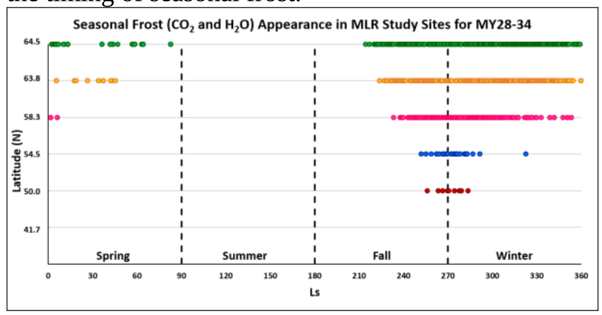

Figure 2: *Seasonal frost survey results from six northern mid latitude study sites show frost appearing between latitudes of 64.5º-50.0º N and no frost at 41.7º N. This suggests a regional boundary of the maximum seasonal frost extent near longitude 28.9º-44.4º E lies somewhere between 50.0º-41.7º N on Mars. Results are color coded to match their corresponding stars from Figure 1.*

Future Work: Immediate future work will include updates to the THEMIS data collection/ analysis, an expanded CRISM specific survey, and the addition of new study sites. These updates will assist in our long term goals of constraining the timing of CO_2 and H_2O seasonal frost at each study site as well as creating a map of seasonal frost observations that complements existing regional scale results.

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