ENDMEMBER CLASSIFICATION OF MARS SOUTH POLAR ICE EXPOSURES WITH CRISM MAPPING DATA. S. F. A. Cartwright[1], W. M. Calvin[1], F. P. Seelos[2], and K. D. Seelos[2], [1]Dept. of Geol. Sci. & Engineering, Univ. of Nevada—Reno, (scartwright@nevada.unr.edu), [2]Johns Hopkins Univ. Applied Physics Lab.

Introduction: Mars' south polar residual cap (SPRC) is a 1–10 m-thick deposit of high-albedo CO_2 ice overlying a ~4 km-high dome of dusty water ice layers known as the south polar layered deposits (SPLD) [1]. Additional water ice-rich deposits have been detected around the periphery of the SPRC and in an extensive outlying deposit [2]; these exposures are distinct from the underlying SPLD, but their exact nature remains unclear [3, 4]. Because variable mixtures of CO_2 ice, H_2O ice, and dust within these deposits influence their interaction with solar insolation and atmospheric cycling, constraining compositional variation across the south polar region is a critical step in understanding the formation, evolution, and preservation of Mars climate records.

In previous work [5, 6], we used short-wave infrared (SWIR) data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [7] to identify and map a suite of 21 spectral endmembers across the SPRC and surrounding ice exposures. Specifically, this work leveraged CRISM "targeted" data, which provide high spatial and spectral resolution views of localized sites (18–36 m/pix, 438 SWIR channels). To map the distribution of compositional endmembers more completely across the region, we now turn to CRISM "mapping" data, which cover broader swaths of the surface at coarser resolutions (90–180 m/pix, 55 SWIR channels). Here we present the results of endmember classification in a mosaic of CRISM Multispectral Window (MSW) observations and discuss their implications for south polar ice composition.

Methods: *Mosaic generation.* To balance spatial coverage with a consistent view of seasonal state (i.e., degree of CO_2 frost cover), the mosaic was restricted to observations acquired between solar longitude (L_S) 310–360º. Most of the resulting mosaic (**Fig. 1**) captures the surface after L_S 330º when the majority of seasonal CO_2 ice cover is expected to have been removed. Unlike other observing modes that were gathered across multiple Mars Years (MYs), all south polar MSW data were acquired during MY 28 following a significant dust event [8, 9]. To produce the clearest possible view of surface spectral variation, each of the 89 MSW observations were passed through a series of standard corrections that address atmospheric gas absorption, photometric effects, and spectral smile [10]. The map-projected observations were then stacked according to the L_S of acquisition to create the final mosaic at 90 m/pix resolution.

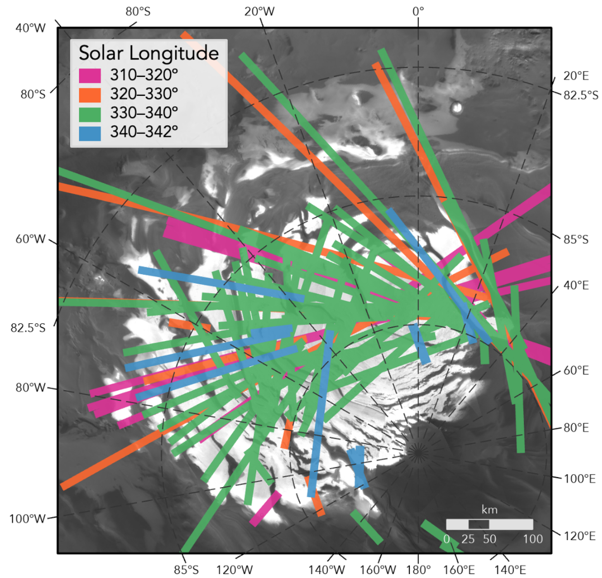

Figure 1. Spatial coverage and temporal sampling provided by a mosaic of 89 Multispectral Window (MSW) observations from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM).

Endmember classification. In the previous work with CRISM targeted data, we used iterative *k*-means clustering [11] to extract a set of spectral endmembers in common across a representative subset of high-quality observations. Those endmembers were then mapped across the entire dataset using a random forest classification model [12]. The latter process was also used to classify the MSW mosaic, but in this case, the random forest model was trained on spectra sourced from the targeted dataset and downsampled to the 55 mapping data wavelengths. This allowed each of the spectra in the MSW mosaic to be classified as one of the endmembers identified in targeted data analyses.

Preliminary Results & Discussion: *Influence of seasonal CO_2 ice.* A prominent characteristic of the classified MSW mosaic (**Fig. 2A**) is the presence of strip-to-strip variations in mapped endmembers within the SPRC. Broadly speaking, earlier observations (lower in the stacking order) are dominated by more CO_2 ice-rich endmembers associated with seasonal frost cover (reds of C1/C2) while later observations (top of the stacking order) show stronger H_2O ice signatures (yellows of C5/C6) consistent with the expected spectral expression of residual CO_2 ice. This endmember progression continues even after L_S 330º, suggesting that an unusually thick or long-lived seasonal cover was deposited following the large dust event of MY 28. Although this strong spectral influence from seasonal frost complicates the characterization of residual ice, the results suggest that CRISM mapping data could be used to track the retreat of the seasonal cap over the SPRC, which is difficult to do with thermal or visible data [8, 9].

Water ice-rich exposures. Strong H_2O ice absorptions (blues and pinks of W/Cd/Cw endmembers) are mapped consistently in two important contexts. The first is in association with peripheral water ice deposits mapped by [2](**Fig. 2C**), but importantly, these exposures display a variety of apparent compositions that can include stronger contributions from dust (paler blues of Dw) and/or CO_2 ice (pinks of Dc/Cd). This variation could have important implications for how dust and CO_2 ice are introduced into SPLD climate records. The second context is along low-albedo slope faces within the SPRC (**Fig. 2D**), which display strong CO_2 and H_2O ice features (pinks of Dc/Cd). These slopes face the higher elevations of the south polar dome and could be linked to interactions with solar insolation that drive the development of topography in the SPRC.

Conclusions & Next Steps: The classified MSW mosaic expands our understanding of compositional variation across south polar ice exposures by showing that 1) seasonal CO_2 frost in MY 28 played a significant role in surface spectral expression throughout the summer and 2) water ice exposures in and around the SPRC that may be linked to SPLD layer formation display unexpected variation in contributions from CO_2 ice and dust. Further analyses should focus on classifying individual observations to allow detailed tracking of seasonal ice retreat and on expanding classification to other CRISM mapping data to fill remaining gaps in coverage.

References: [1] Byrne (2009) *Annu. Rev. Earth Planet. Sci. 37,* 535–560. [2] Piqueux et al. (2008) *JGR, 113,* E08014. [3] Douté et al. (2007) *Plan. & Space Sci., 55,* 113–133. [4] Montmessin et al. (2007) *JGR, 112,* E08S17. [5] Cartwright et al. (2021) *LPSC 52,* #2169. [6] Cartwright et al. (2021) *AGU Fall Meeting,* #EP23C-03. [7] Murchie et al. (2007) *JGR, 112,* E05S03. [8] Piqueux et al. (2015) Icarus, 251, 164–180. [9] Calvin et al. (2017) *Icarus, 292,* 144–153. [10] Seelos & Murchie (2018) *LPSC 49,* #2325. [11] Elkan (2003) *12th Intl. Conf. on Machine Learning,* 147–153. [12] Breiman (2001) *Machine Learning,* 45(1), 5–32.

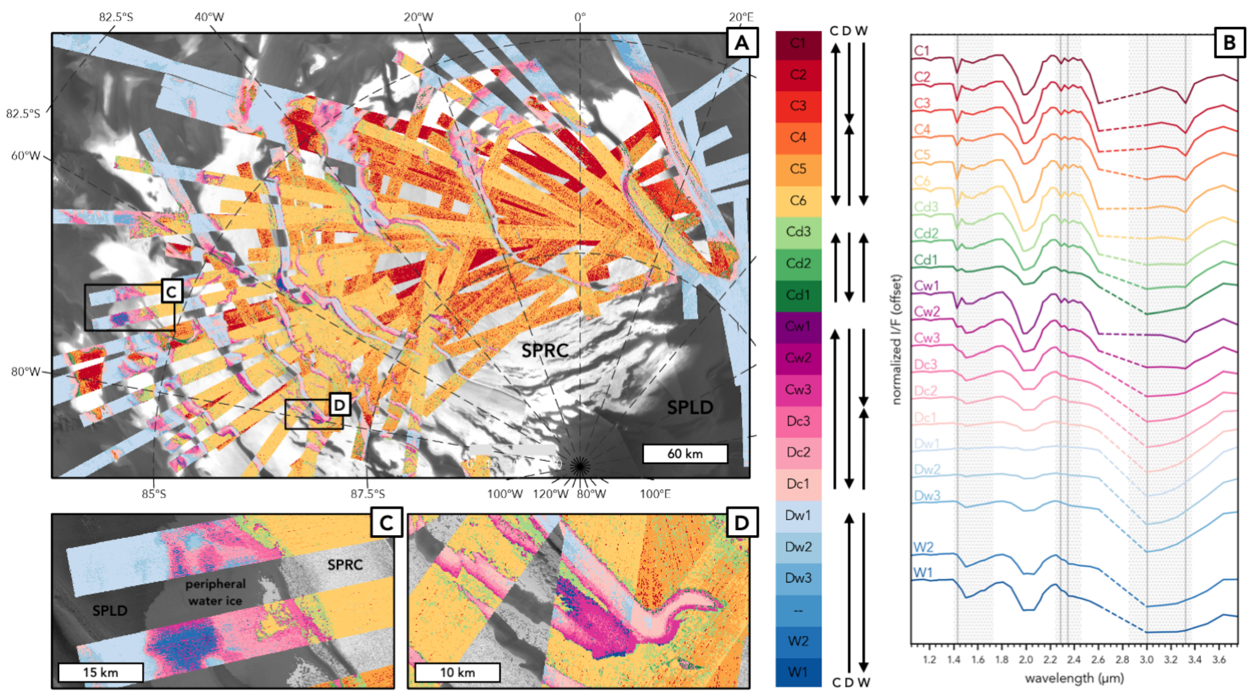

Figure 2. A) Endmember-classified MSW mosaic of the south polar region. **B)** Median spectra of mapped endmembers, which are sorted and named according to strengths and combinations of absorption features associated with CO_2 ice, dust, and H_2O ice (C, D, W, respectively). Arrows at the right of the legend also indicate these gradations. Endmember W3 was omitted from these analyses due to low sample size. **C)** Detail of peripheral H_2O ice deposit (intermediate albedo) showing variable contribution from CO_2 ice (pinks of Dc/Cw endmembers).
D) Detail showing a dark slope within the SPRC similarly mapped with strong CO_2 and H_2O ice features.