CRISM-DERIVED THERMOPHYSICAL PROPERTIES OF GALE CRATER, MARS. J. R. Christian[1,2], R. E. Arvidson[1,2], and J. A. O'Sullivan[3], [1]McDonnell Center for the Space Sciences, [2]Dept. of Earth and Planetary Sciences, Washington University in St. Louis, [3]Dept. of Electrical and Systems Engineering, Washington University in St. Louis

Introduction: Thermal inertia (TI), the square root of the product of heat capacity, density, and thermal conductivity, is a useful summary property for distinguishing surface materials from orbit. Thermal conductivity varies much more than either of the other two properties, allowing unconsolidated sediment (low TI) to be distinguished from bedrock (high TI) with high confidence, even with differences in mineralogy.

Current TI retrievals are from the Odyssey Orbiter THEMIS-based nighttime temperature measurements combined with TES bolometric albedo observations [1,2]. The KRC thermal model (a one-dimensional heat transport model) is used for the retrievals, and has been used for TI calculations since the Viking mission [3]. THEMIS-based TI retrievals are at a resolution of ~100 m/pixel.

In this abstract we leverage recent work to calculate surface temperatures from MRO CRISM data [4] at a resolution of 18-36 m/pixel [5, 6] to estimate TI at a resolution of ~18 m/pixel. Initial calibration work has been done using overlapping CRISM observations from Gale Crater, where data from the Curiosity Rover can be used for validation. High-resolution TI retrievals in Jezero Crater is in progress, and will be delivered to the Mars 2020 Rover Project for use in rover path planning [7] and scientific analysis as part of the CRISM Science Team's "Fandango".

Methods: TI values are estimated from CRISM-derived temperature data and bolometric Lambert albedo retrievals corrected for gases, aerosols, and local incidence angles. The KRC model combined with a regularized maximum-likelihood approach was used to simultaneously fit multiple overlapping CRISM observations taken at different solar longitudes, which gives better performance than simple inversion for a single scene. A Huber-class (edge-preserving) regularization term was added to enforce convex structure in the likelihood function and thus guarantee a global solution to the maximization algorithm (e.g. [8,9]).

Comparisons between simple KRC modeled diurnal temperature curves and observed temperatures from the REMS instrument on the Curiosity Rover [10] show a distinct phase lag; observed temperatures remain cool in the morning and warm in the afternoon about an hour or two longer than models predict. A more complicated KRC model, using two material layers with different TI, was thus used in our work to correct for this effect (as in [11]). As such, the maximum-likelihood approach used here treats every surface pixel as a linear combination of two materials, one of which has two layers with different TIs. This approach is unnecessary for THEMIS, since no phase lag is visible in the nighttime observations and a simple one-layer model is sufficient to match the data.

Initial Results: A preliminary TI map in a region in Gale Crater covering regions traversed and to be traversed by Curiosity, i.e., Glen Torridon and the Greenheugh pediment, is shown in Fig. 2. This estimate was derived from simultaneously fitting estimated surface temperatures from overlapping CRISM observations FRT0000B6F1, FRT00021C92, and HRL0000BABA. Results show good spatial correlation with morphology known from Curiosity. The ripple field in the center of the mapped region shows low TI, which is consistent with the known wind-blown sand ripples. The Vera Rubin Ridge and sulfate-bearing deposits to the southeast indicate a much higher TI values, consistent with bedrock or other consolidated material.

This TI retrieval is at a high enough spatial resolution that a thin cover layer can be detected on the Greenheugh pediment, interpreted as windblown sand using the HCPINDEX2 CRISM spectral parameter [12]. This is mapped in Fig. 2 as a region of lower TI values on the pediment (white arrow) sourced from the ripple field in the center of the map, with much lower TI to the east. This feature is visible but less distinct in HCPINDEX2 maps (Fig. 3) and is small enough that it cannot be seen at all in TI maps derived from THEMIS.

Validation: CRISM-derived TI maps have been compared to standard THEMIS-derived TI maps retrieved for the same region. Both maps show similar spatial patterns (e.g. ripple fields show low TI values, and the Vera Rubin Ridge shows high TI values), indicating that this approach is successfully capturing variations from CRISM data. Differences between the relative magnitude of TI values measured do remain, and are still under investigation.

One significant difference between the TI maps is the Greenheugh Pediment, which is mapped as high values by THEMIS. This is still under investigation, but may be because THEMIS-derived TI retrievals use TES albedos, which have a footprint of ~3 km. The Greenheugh Pediment surface has a much lower Lambert albedo (~0.10) than its surroundings in all directions (~0.20). THEMIS-based retrievals of TI over the Greenheugh Pediment use a higher albedo than CRISM-based retrievals, which may partially explain the differences observed in the two retrievals.

References: [1] Christensen PR et al., 2002, *Space Sci. Rev.*, 10.1023/B:SPAC.0000021008.16305.94. [2] Christensen, P. R. et al., 2001, *JGR Planets*, 10.1029/2000JE001370. [3] Kieffer, H. H. 2013, *JGR Planets*, 10.1029/2012JE004164. [4] Murchie, S. et a., 2007, *JGR Planets*, 10.1029/2006JE002682. [5] He, L. et al., 2019, LPSC abs. 2094. [6] Politte, D. V. et al., 2019, LPSC abs 2690. [7] Arvidson, R. E. et al., 2018, LPSC abs. 1514. [8]. Bouman, C. and K. Sauer, 1993, *IEEE Trans. Image Process.*, 10.1109/83.236536. [9] Kreisch, C. D. et al., 2017, *Icarus*, 10.1016/j.icarus.2016.09.033. [10] Gómez-Elvira, J. et al., 2012, *Space Sci. Rev.*, 10.1007/s11214-012-9921-1. [11] Vasavada, A. R. et al., 2017, *Icarus*, 10.1016/j.icarus.2016.11.035. [12] Viviano-Beck, C. E. et al., 2014, *JGR Planets*, 10.1002/2014JE004627.

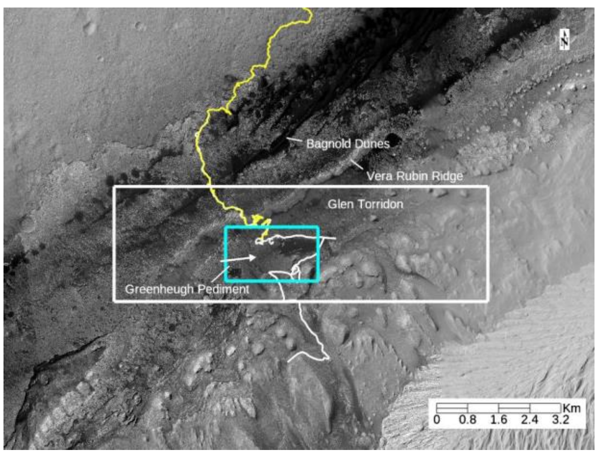

Figure 1 HiRISE mosaic within Gale Crater showing the recent path of the Curiosity Rover (yellow, through sol 2618) and strategic path (white, MSAR 9). The white box indicates the region where thermal inertia was retrieved from CRISM data (Fig. 2). The blue box is shown in higher detail in Fig. 4.

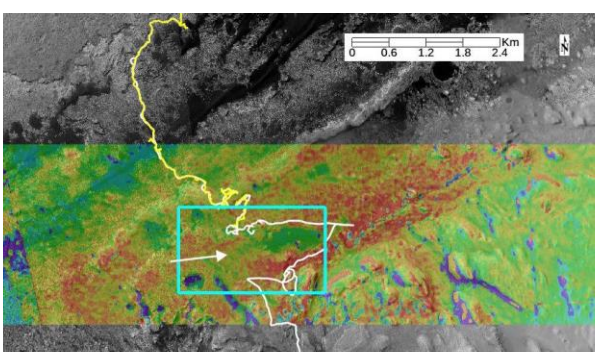

Figure 2 Estimated relative thermal inertia over Glen Torridon. Cool colors (low thermal inertia) correspond well to known sandy areas. The white arrow indicates thin windblown sand cover on the Greenheugh pediment, which can be seen here and in CRISM spectral parameters, but is too weak a signal to detect in THEMIS thermal inertia.

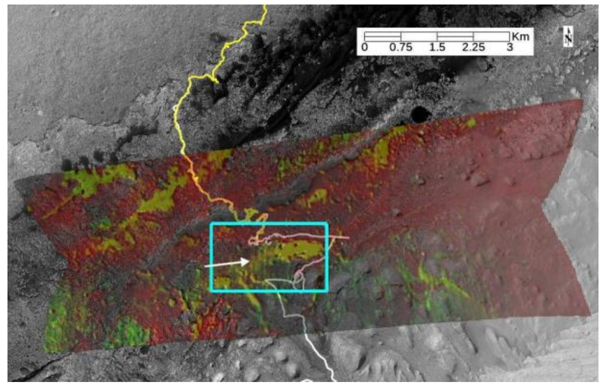

Figure 3 Spectral parameters OLINDEX3 (red), HCPINDEX2 (green), and LCPINDEX2 (blue) from CRISM scene FRT00021C92 [12]. The white box indicates the thermal inertia retrieval region shown in Fig. 2. The white arrow indicates the windblown sand cover detected in the thermal inertia map in Fig. 2.

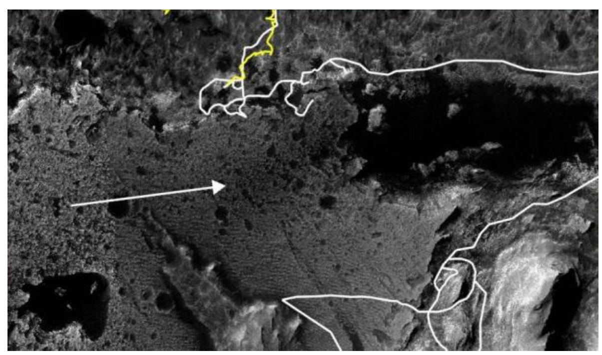

Figure 4 Close-up view of windblown sand on the Greenheugh pediment sourced from the dark ripple field to the east (blue box, Fig. 1). The windblown sand can be seen in thermal inertia as a low region (Fig 2.) and in the OLINDEX3 and HCPINDEX2 spectral parameters (Fig. 3).