

LOCALISED SEASONAL DUST DEPOSITION AT GALE CRATER: INFERENCES FROM THEMIS THERMAL INERTIA. V. G. Rangarajan^{1,2} and M. Ghosh², ¹Department of Earth Sciences, Indian Institute of Technology Kanpur, Kanpur 208016, Uttar Pradesh, India (vganesh@iitk.ac.in); ²Department of Remote Sensing, Birla Institute of Technology Mesra, Ranchi 835215, Jharkhand, India.

Introduction: Thermal inertia (TI) of a planetary surface exhibits its ability for heat storage and re-radiation during day and night time respectively. Consequently, their magnitudes are closely defined by the physical and thermal properties of the surface strata and the near surface thermal environment [1,2]. This has potentially paved the way for its utility as an effective tool in comprehending surface lithology from space based measurements, resulting in development of several thermal models [3,4] for surface thermophysical characterizations from thermal remote sensing data. TI values until now, have been usually thought of to be unchanging, at least for a short time period, unless the surface has been subjected to a massive degradation event in that interval. The present study however, reports of large variations in surface TI observed at locations along MSL Curiosity's traverse in Gale crater and also advocates the possibility of a potentially active surface deposition phenomena serving as a causal factor for these observed TI variations.

Datasets used: High resolution THEMIS thermal observations for four locations along MSL Curiosity's traverse at Gale crater namely Point Lake, Yellowknife Bay, Cooperstown and Mt. Remarkable (Fig 1) were acquired from PDS Geosciences Node. Only nighttime datasets were used in this study so as to eliminate the effects of sun-heated slopes. Additionally, only Band 9 measurements were used for analysis as they showed the largest signal to noise ratio and were considered to be relatively transparent to atmospheric dust [5].

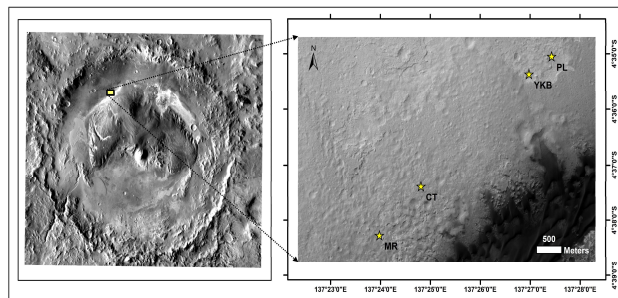


Fig 1 Map showing the four selected study locations – Point Lake (PL), John Klein - Yellowknife Bay (YKB), Cooperstown (CT) and Mt. Remarkable (MR) (Base Map: HiRISE imagery)

Methodology: THEMIS RDR data were initially pre-processed using the THMPROC tool and were later radiometrically calibrated to estimate brightness temperatures. Single point TI estimations were performed using a thermal model based on [3] that utilized a 7D lookup table approach comprising of parameters like albedo, TI, surface pressure, dust opacity, latitude, longitude and time of

the day [6]. MOLA-HRSC blended elevation and TES bolometric albedo layers were also served as additional inputs to take care of topographic effects. Dust optical depth values at corresponding times of observation for each THEMIS scene were retrieved from simulations using the Mars Climate Database v5.2.

Results: Upon analysis on a seasonal timescale, a perfectly sinusoidal variation of surface TI was observed at all four selected study locations at Gale, such that the surface possessed maximum TI during late southern autumn (Ls 70-90) and minimum TI during late southern spring (Ls 260-280) (Fig 2). It may be noted that the observed variations in surface TI are pretty large in magnitude, almost of the order of 300 to 400 t.i.u.

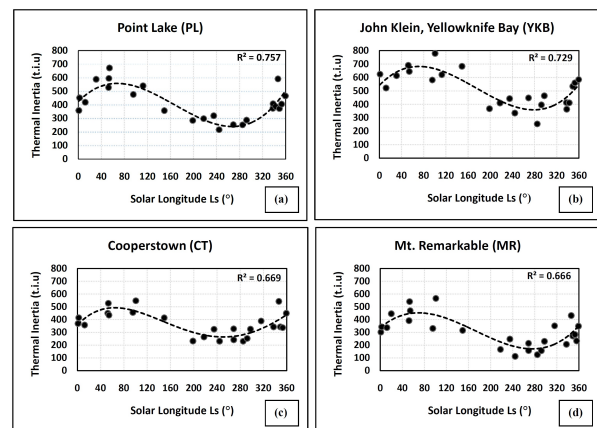


Fig 2 Seasonal TI variations observed at (a) Point Lake (b) John Klein, Yellowknife Bay (c) Cooperstown (d) Mt. Remarkable

We believe that this may be a result of an active seasonal surface dust deposition phenomena occurring at Gale. In other words, we believe that during the southern spring, during which most Martian global wide and localized dust storms generally occur, there is a layer of dust that may be deposited over the surface concealing the underlying bedrock, thereby resulting in reduced TI values. The strength of these dust storms recede towards late summer and into autumn. However, Martian atmospheric wind speeds remain fairly constant throughout the year. This therefore could result in possible removal of the deposited dust during the southern autumn, thereby exposing the bedrock underneath and resulting in higher surface TI values. Such variations in surface TI were also observed by [7] and [8], but their interpretations highlighted that it could be present due to inherent errors in the thermal model itself. However, if this were to be true, seasonal variability in inertia should be observed for all locations across the Martian surface.

In order to test their hypothesis, we undertook a case study on Nili Patera, one of the calderas of the Syrtis Major volcanic construct, that is predominantly known to be dust free [1]. Two locations A and B were selected in order to represent the high TI inner and the low TI outer flanks of the caldera respectively [5]. It may be seen that there is no significant variation observed in surface TI at Nili Patera as the ones seen at Gale (Fig 3). This somewhat asserts that our assumption that the seasonal variation observed at Gale may not be a result of incorporation of incorrect model physics and could possibly be a result of some active surface process occurring there.

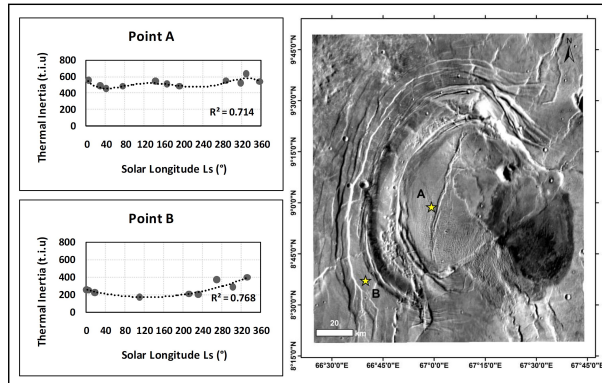


Fig 3 Seasonal TI variations at points A and B in Nili Patera, Syrtis Major Planum (Base Map: THEMIS Day IR Mosaic)

Initial attempts at confirming seasonal dust deposition as a possible causal factor for TI variations would suggest that we look into possible surface albedo variations. However, the large variations in dust optical depths between seasons would render their utility highly unreliable. Alternatively, particle size images were derived from the processed THEMIS thermal inertia based on laboratory empirical relations between thermal conductivity and particle size established by [9]. Mean atmospheric pressure of about 6 torr and average volumetric heat capacities of $1.3 \times 10^6 \text{ J m}^{-3} \text{ K}^{-1}$ were adopted in order to provide a fairly accurate representation of the conditions at Gale.

The generated particle size distribution maps also corroborate very well with our hypothesis of seasonal dust deposition, with the surface being dominated by finer soil grades in the dusty southern spring (Fig 4c) with the percentage of dust cover gradually reducing till it becomes almost negligible in the southern autumn/winter (Fig 4b). Moreover, the maps also indicate that the variations aren't localized to the four selected study locations but are also seen in adjoining regions.

Conclusions: Accurate derivation of TI holds key to its usefulness in aiding confident interpretation of surficial lithology of various planetary surfaces. The present study identified a large seasonal variability in surface TI at Gale of the order of 300 to 400 t.i.u. Such variations in surface TI were earlier attributed to incorrect model physics in the thermal model used for TI retrieval. However, this hypothesis was pretty much ruled out when such stark

variations were not visible in an alternative case study at Nili Patera.

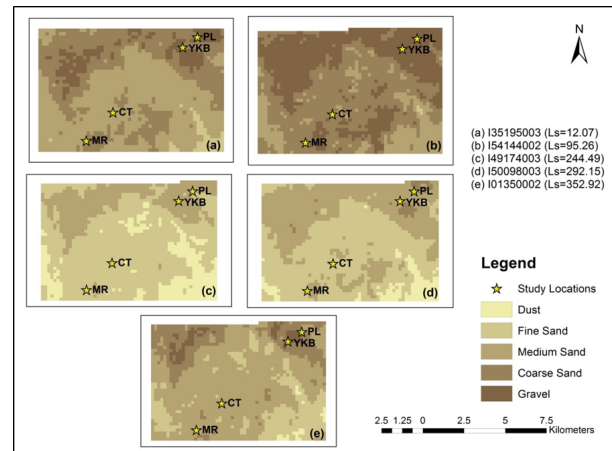


Fig 4 Particle size distribution maps for select THEMIS images

We attribute this variation in surface TI to the possible presence of an active surface dust deposition phenomena that allows for peaking and receding of TI during the southern autumn and the dusty southern spring respectively. Particle size maps generated from THEMIS TI also show similar seasonal trends and thereby support the occurrence of such deposition phenomena at Gale. Moreover, recent observations by [10] highlighting thin dust layer formations on the UV sensor onboard Curiosity further strengthen the plausibility of such a process occurring at Gale.

It can therefore be inferred that solely basing lithological discriminations on thermal inertia without due consideration given to image acquisition parameters would lead to very high ambiguity in geologic interpretations. Identification of such seasonal variations at different locations on the Martian surface, in the future could possibly help in understanding the global scenario of such active deposition phenomena and can potentially provide some key insights into the thickness and volume of dust deposit that may be necessary to cause such large surface TI variations as observed at Gale. Future work could also be directed at employing seasonal spectroscopic observations to identify dominant top layer mineralogy that may help in further understanding of the deposition phenomena.

References: [1] Rangarajan V. G. et al. (2018) *J Indian Soc. Remote Sens.*, 46(9), 1537–1551. [2] Rangarajan V. G. and Ghosh M. (2018) *EPSC 2018*, 12, EPSC2018-14. [3] Kieffer H. H. et al. (1977) *JGR*, 82 (28), 4249–4291. [4] Mellon M. et al. (2000) *Icarus*, 148 (2), 437–455. [5] Fergason R. L. et al. (2006) *JGR*, 111(E12), 1–22. [6] Piatek J. L. and Moersch J. E. (2006) *LPSC XXXVII*, Abstract #1158. [7] Putzig N. and Mellon M. (2007) *Icarus*, 191, 68–94. [8] Fergason R. L. (2013) *AGU Fall Meeting 2013 Abstracts*, P43C-2025. [9] Presley M. A. and Christensen P. R. (1997) *JGR*, 102(E3), 6551–6566. [10] Edgett K. S. and Newsom H. E. (2018) *Cambridge Scholars Publishing*, 81–104.