REGOLITH PROPERTIES NEAR THE INSIGHT LANDER DERIVED FROM 100 SOLS OF RADIOMETER MEASUREMENTS. S. Piqueux[1], N. Müller[2], M. Grott[2], J. Knollenberg[2], M. Siegler[3], E. Millour[4], F. Forget[4], M. Lemmon[5], M. Golombek[1], N. Williams[1], J. Maki[1], J. Grant[6], N. Warner[7], V. Ansan[8], I. Daubar[9], T. Spohn[2], S. Smrekar[1], B. Banerdt[1], Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, [2] DLR Institute for Planetary Research, Berlin, Germany, [3] Southern Methodist University, Dallas, Texas, USA, [4] Sorbonne Université, Paris, France, [5] Space Science Institute, College Station, Texas, USA, [6] National Air and Space Museum, Smithsonian Institution, Washington, DC, USA, [7] State University of New York at Geneseo, Geneseo, NY, USA, [8] Université de Nantes, Nantes, France, [9] Brown University, Providence, RI, USA.

Introduction: The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) landed on Mars in Elysium Planitia, on November 26 2018 with the goal of understanding the formation and evolution of terrestrial planets through the investigation of the Martian interior structure [1]. To meet these objectives, the lander carries multiple instruments including the Heat Flow and Physical Properties Package (HP^3, [2]) that consists of both a penetrator, colloquially referred to as "the mole", and a radiometer (RAD) positioned underneath the deck [3]. The RAD determined surface temperatures through radiance measurements at three distinct wavelength windows, and at two locations northwest of the lander. This dataset constitutes exceptional working material thanks to the acquisition frequency and repeatability: unlike previous temperature sensing assets deployed at the surface of Mars [4, 5, 6], the RAD is positioned on a fixed platform and repeatedly measures temperatures of a homogeneous and well-characterized surface with seemingly simple regolith configuration. Measurements will span over one full Martian year and are acquired in conjunction with other instruments probing the surrounding environment [1]. Here we present an analysis of the surficial diurnal temperature oscillations experienced near the lander, in Homestead Hollow, as measured by the far radiometer. We discuss these results in terms of the regolith physical properties. This work is complementary to the analysis of the regolith cooling recorded during Phobos transits [7], and the future analysis of seasonal cycles.

Approach: This work focusses on analyzing the far RAD data (Fig.1) acquired ~3.5 m away from the edge of the deck (in contrast with near RAD data < 1m away), as it is least impacted by the presence of the lander, and presents the least soil disruption from the landing retro-rockets [8]. All the temperature fits are performed using the KRC thermal model version 3.5.6 [9]. Brightness temperatures are corrected for non-unit emissivity, all derivations are performed on a per-sol basis, we exclude data acquired when dust opacity τ is >1, and to reduce processing cost, all selected data is binned with a time resolution of 1/24th of a sol. Fits are performed using data acquired at the most diagnostic times of the day, i.e. before dawn (Midnight-05:00) and around noon (11:00-14:00) with albedo and thermal inertia left as the

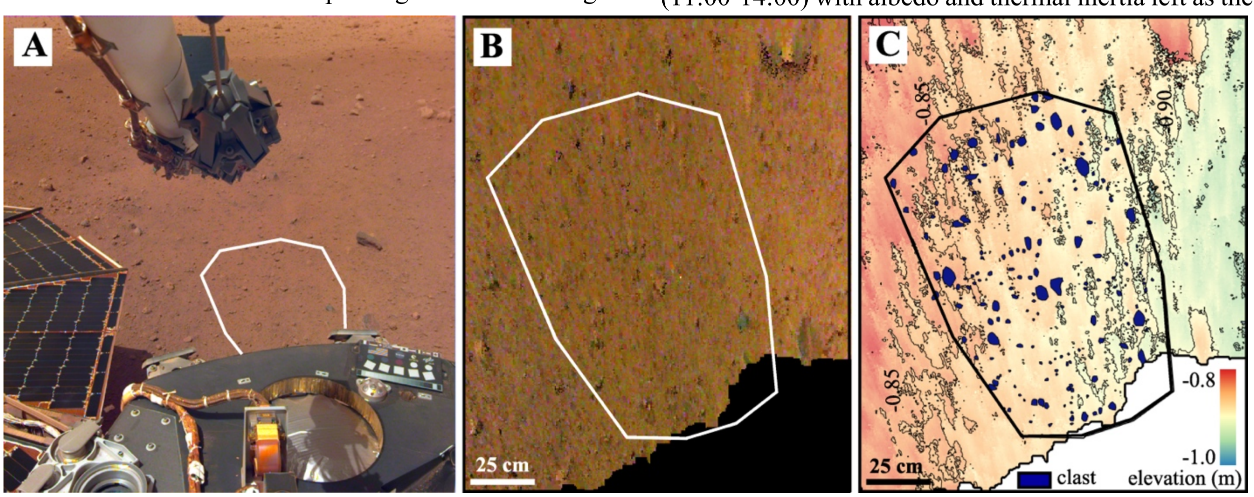

Fig. 1. A: Homestead Hollow looking towards north-northwest, showing parts of the lander deck and solar panels. The white line marks a fraction of the area monitored by the far RAD; B: equirectangular projection of the far RAD spot (5 mm pixel^{-1}); C: far RAD spot Digital Elevation Model, accuracy of 1 cm, 5 mm pixel^{-1} resolution. 5 cm contour lines, highlighting a tilted surface (~4°) toward the east-southeast. Clasts greater than 1cm are mapped in blue.

free parameters. We quantify the quality of each fit through RMS determination using the entire diurnal cycle for a given sol. Typically, Root Mean Square (RMS) ~0.5-0.7 K.

Results: The diurnal temperature cycles are adequately fit within error bars (generally ±1.5 K) using a albedo A=0.16 ± 0.01 and a homogenous regolith with a thermal inertia of I=189 ± 10 J m^{-2} K^{-1} s$^{-1/2}$ (skin depth ~2-4 cm) (see Fig. 2 for a fit example). Fig. 3 shows the individual A and I derived for selected sols meeting data distribution criteria listed here. Typical A values are noticeably lower than the pre-landing regional bolometric values derived from orbit, i.e., 0.24 [8], but similar to post-landing estimations from orbital and ground-based imagery showing a 35% decrease [10], i.e., to ~0.15-0.16. A darkening of the surface is consistent with the removal of surficial dust around the lander by retro-rockets. We have already observed a brightening of the surface in imagery, and anticipate future iterations of this work to quantify dust re-deposition.

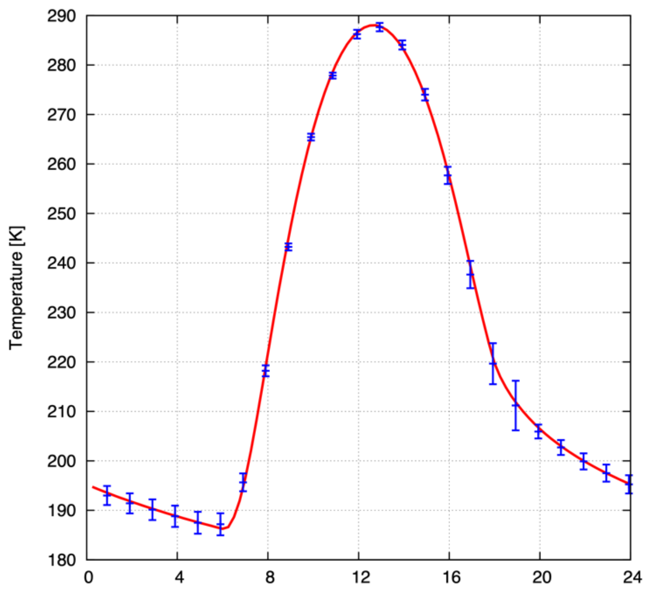

Fig. 2: Example of a diurnal temperature cycle (1/24th sol binning) on sol 32. See [3] for error bars discussion. Best, thermal inertia fits is reported in red yielding I=190 ± 10 J m^{-2} K^{-1} s$^{-1/2}$ (fits within error bars not shown for clarity). RMS = 0.6 K.

The derived I values (Fig 3.) correspond to fine ~150 µm sand [11], in good agreement with a pre-landing assessment leveraging orbital thermal infrared data [8,10], and with only few clasts large enough to influence I [8]. Such relatively low I values indicate very limited regolith cementation within the upper ~2 skin depths (i.e., ~4-8 cm), with cement volumes <<1%. Within measurements and fitting uncertainties, surficial (i.e., within the top 100's of µm) or deep (below several cm) layering with steep thermophysical interfaces is theoretically possible but indiscernible based on diurnal temperature cycle fittings. Muted thermophysical gradients would further complicate the identification of vertical heterogeneities from diurnal fits. Indeed, [7] finds that the cooling curves during Phobos transits is best fit with a 5 mm thick layer where the thermal conductivity k=0.02 J s^{-1} m^{-1} K^{-1} over coarser or more indurated material (k=0.05 J s^{-1} m^{-1} K^{-1}).

Future work will investigate the presence of deep (e.g., ~10+ cm) layering by leveraging seasonal temperature cycles, and the seasonal/interannual evolution of the albedo to help constrain the dust deposition rate.

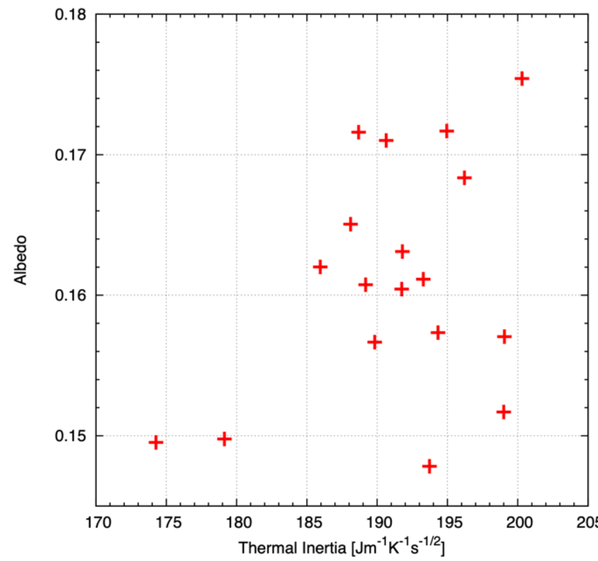

Fig. 3: A vs. I for 18 selected sols (criteria discussed in the text, including τ < 1., predawn and near-noon data available).

Acknowledgments: Work performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.

References: [1] Banerdt, W. B., et al., submitted; [2] Spohn, T., et al., 2018, doi.org/ 10.1007/s11214-018-0531-4, 2018; [3] Müller, N. T. et al., 9th Int. Conf. Mars, 2019, #6194; [4] Fergason, R. L., et al., 2006, doi:10.1029/ 2005JE002583; [5] Vasavada, A. R., 2017, doi: 10.1016/j.icarus.2016.11.035; [6] Edwards, C. S., 2018, doi:10.1029/2017je005501; [7] Müller et al., *in prep.*; [8] Golombek, M., et al., Nature Comm., submitted; [9] Kieffer, H. H., 2013, doi: 10.1029/2012JE004164; [10] Golombek, M., et al., 2017, doi: 10.1007/s11214-016-0321-9; [11] Presley, M. A., and P. R. Christensen, 1997, doi:10.1029/96JE03303.