ORBITAL INFRARED DATA SETS: AN APPROACH TO IMPROVING OUR KNOWLEDGE OF SURFACE AND SUBSURFACE PROPERTIES ON MARS.

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Introduction: Data sets of Mars obtained from orbiting instruments are critical for selecting safe and scientifically interesting landing sites and monitoring them during EDL and mission operations. Thermal infrared observations allow the derivation of surface temperature, bolometric albedo, and thermal inertia values of the surface and enables the *quantitative* determination of the physical properties of the surface and shallow subsurface at the decimeter to meter scales. Thermophysical data sets address Challenge Area 1: Instrumentation and Investigation Approaches, and specifically addresses orbital measurements of surface characteristics.

Existing Data Sets and Knowledge Gained: Fundamental knowledge regarding the martian surface has been gained through the interpretation of thermophysical data sets, such as the presence of meters- to decimeters-thick dust deposits in the Tharsis, Arabia Terra, and Elysium regions; the identification of in-situ exposures of bedrock; and information regarding the physical properties and intrinsic material strength of specific mineral classes, including phyllosilicates, sulfates, and iron sulfides [e.g, 1-9]. Knowledge of physical properties such as surface particle size, rock abundance, and sub-surface layering are critical for evaluating the safety of a landing site and have significantly influenced the selection of final lander locations [e.g., 9-13].

Thermal inertia has been instrumental in certifying potential landing sites, evaluating the safety of potential landing sites, and identifying and evaluating potential rover traverse routes. Thermal Emission Imaging Spectrometer (THEMIS)-derived thermal inertia maps are a staple of traverse planning for the Mars Exploration Rover mission, and have been used as an aide to long-term planning for the mission duration. In addition, THEMIS-derived thermal inertia values were critical to certifying the safety of Mars Exploration Rover and Mars Science Lander candidate landing sites [e.g., 10-12]. Predicted temperature data (a model-derived product derived from thermophysical data sets) was instrumental in identifying potential Mars Exploration Rover traverse routes and comparing the power impact from instrument heating between each route [13]. Thus, thermophysical data is critical for selecting scientifically interesting, safe, and traversable landing sites. This goal has been accomplished with 100-meter scale thermal data combined with 0.3 meter scale imaging and simply retainig current capabilities is valuable. However, with higher spatial resolution thermal information, the surface properties of landing sites could be interpreted at rover-scales with a higher degree of precision and confidence.

Current Challenges and Potential Solutions: The two order of magnitude mismatch between the scale of thermal data, visible data, and topography cause some significant challenges. Many applications that would improve our ability to understand properties of the surface and near subsurface cannot be utilized due to limiations in the spatial resolution and/or accuracy of the data itself. For example, applying a slope correction to derived thermal inertia is a complex modeling effort with significant uncertainties when there is one temperature measurement for 10^4 elevation points.

Seasonal variations in thermal inertia, and therefore the structure of the near subsurface, can be evaluated with current data sets at latitudes greater than 50˚ [14], but the lack of instrument precision prevents us from understanding subsurface characteristics near the equator, where the majority of potential landing sites are located. Similarly, diurnal variations in temperature also provide information about the physical structure of the shallow subsurface. However, sun-synchronous orbits provide temperature information at only two opposite times of day that cannot be ideal (~5 AM and ~1 PM local time are ideal). Information such as the depth to ice, thickness of dust, depth to bedrock and a host of other scenarios can be addressed at higher latitudes [e.g., 14-15] and could be addressed at equatorial localities with improved data obtained by new infrared instruments on a spacecraft in a more flexible orbit.

THEMIS has obtained the highest spatial resolution temperature and thermal inertia data set to date, yet at 100 meters per pixel, is often inadequate for quantitatively understanding the physical characteristics of surface features observed in Context Imager (CTX) or High Resolution Imaging Science Experiment (HiRISE) images, much less the Mars Exploration Rover (MER). The need to quantitatively understand the physical properties of features observed at the 1-10 meter scale has never been greater. Techniques to understand surface properties at sub-pixel scales are well established and can be applied to landing site evaluation with improved instrument accuracy and higher spatial resolution. For example, rock abundance was derived from IRTM and TES data sets [15-17], but the band selection of THEMIS does not allow rock abundance to be derived. Accurate knowledge of the percentage of rocks on the surface where high-resolution images are not available and at scales smaller than that of the TES instrument is needed to better characterize future landing sites. To accomplish this goal, an infrared instrument with high spatial resolution and filters selected at appropriate wavelength ranges is needed.

Similarly, the identification of materials, such as dust, sand, indurated materials, and bedrock, at the sub-pixel level is possible with improved instrument accuracy and well-chosen wavelength bands. The interpretation of features at the sub-pixel level in terrestrial remotely-sense infrared data sets has been performed for three decades [e.g., 18-22]. The application of these techniques could dramatically improve the interpretation of surface features and is possible with improved instrumentation.

Future Needs: With realistic improvements to existing technologies, many, if not all, of the challenges faced when trying to accurately understand surface properties at scales appropriate for landed missions can be addressed. There is a compelling need for a new orbiter to retain, if not expand, the capabilities provided by past orbiters. To address these challenges, a desired instrument set includes:

(1) A thermal infrared imager capable of viewing the surface and atmosphere with high temporal and spatial resolution. A non-sun-synchronous orbit complicates planning but is necessary to observe diurnal changes and characterize the sub-surface. The ability to roll the spacecraft to view the limb of the atmosphere is also highly desired [see also 23].

(2) More accurate and higher spatial resolution infrared data are necessary to quantitatively understand the physical nature of the surface at meter-scales. Adequate temperature observations can be achieved by an instrument designed to provide data of sufficient quality (an NEΔT of 0.5 K or better at a surface temperature of 180 K) to allow sub-pixel analysis of temperature and thermal inertia data. Improved confidence in the interpretation and certification of potential landing sites would result.

(3) Well selected bands are needed to address a wide range of science questions that have a direct impact on our understanding of both surface and atmospheric conditions that affect the selection of landing sites, EDL, and the health of rovers on the surface. Rock abundance, sub-pixel analyses, and continual monitoring of the atmosphere and polar caps all require an appropriate selection of bands to address these specific questions.

(4) Acquiring complementary data sets (i.e., albedo, opacity, and elevation) at the same resolution as temperature data would increase the accuracy of the interpretation of thermophysical data. The highest resolution bolometric albedo data set is 3-6 km per pixel scale, a much lower resolution than the temperature data available from THEMIS (100 m per pixel scale). Although albedo can be estimated from visible images, these cameras are typically not appropriately calibrated, and approximating a bolometric albedo without near- and mid-infrared data introduces unavoidable uncertainties. Bolometric albedo information obtained at the same resolution as surface temperature data would allow uncertainties in the derivation of thermal inertia to be reduced (up to 10% in many cases). Similarly, acquiring atmospheric opacity information at the same time as surface measurements insures that atmospheric properties are appropriately accounted for when modeling surface properties. Thus, the interpretation of surface features, such as the degree of induration of bedrock exposures and the grain size of aeolian material and bed forms, at the scale of tens of meters and of high interest to traversability would have much higher confidence.

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