INTERPRETING SUBPIXEL SURFACE ROUGHNESS AND BLOCK SIZE DISTRIBUTION TO IMPROVE THERMAL INERTIA INTERPRETATIONS OF MARS. C. M. Simurda[1], S. P. Scheidt[2], D. A. Crown[3], and M. S. Ramsey[1] [1]Department of Geology and Environmental Science, University of Pittsburgh, 4107 O'Hara Street SRCC, Room 200, Pittsburgh, PA, 15260 (cms256@pitt.edu), [2]Lunar and Planetary Laboratory, University of Arizona, 1629 E University Blvd, Tucson, AZ, 85721, [3]Planetary Science Institute, 1700 E. Fort Lowell Road, Suite 106, Tucson, AZ, 85719.

Introduction: Thermal inertia (TI) represents the resistance of a material to changes in temperature and can be used to estimate surface properties such as particle size and cementation [1]. Apparent thermal inertia (ATI) is commonly utilized for terrestrial data as an approximation for TI and calculated from the albedo and temperature data over the diurnal cycle [2]. However, estimation of surface properties such as particle size distribution is limited by the spatial resolution of those data. For example, within a pixel, the surface may be dominated by a continuous layer of cobbles or rocks or a simple "checkboard" mixing of larger blocks with fine-grained material (dust or sand), both of which would display a moderate ATI. Understanding the block size distribution within each pixel using ATI and high spatial resolution visible data can improve our understanding of natural surfaces; for example, distinguishing lava flow ages based on block size [3]. To improve the correlation between particle size mixtures and ATI values, a Mars analog site was selected and ground-based observations conducted.

Background: This study focuses on the rhyolite flows in the Mono Domes chain (California), which serve as a process analog for a martian mantled volcanic terrain [4,5]. The North Coulee flow is covered by deposits ranging in grain size from ash to boulders [6]. Even though minor differences in the trace elements exist, the deposits are considered compositionally homogenous [4,7]. This site was specifically selected due to the range of tephra deposit sizes and mantling thicknesses, which allow for a detailed investigation of the relationship between ATI values and particle size mixtures within a pixel.

Methods: To assess the subpixel distribution of blocks, multispectral data from orbital sensors with spatial resolutions ranging from 50 cm/pixel to 90 m/pixel were analyzed, along with field-based GPS and photogrammetry data, which provided ground truth for interpreting the properties derived from ATI. To quantify the particle size distribution below the satellite resolution, a DTM was created using over 4000 digital photographs taken of the site and a ground control point network established using differential GPS. Ground-based multi-view stereophotogrammetry was used to create a 3D point cloud and DTM [9]. Visible images, with progressively higher spatial resolution, were then analyzed to identify the surface roughness and particle size distribution. Utilizing the point cloud and WorldView2 data, areas were identified that represent three particle size categories; coarse, fine, and mixed (Table 1 and Fig. 1). The locations of trees were also categorized to determine the influence of vegetation on the ATI product.

Category	Particle Size	Visible Image
Coarse	Large blocks	Poorly sorted, shadows
Fine	Sand/fines	Highly sorted
Mixed	Mixture	Moderate sorting and shadows
Vegetation	Trees	Discrete green objects

Table.1. *Four categories defined by particle size and visible surface features. Colors correspond with those in figure 1.*

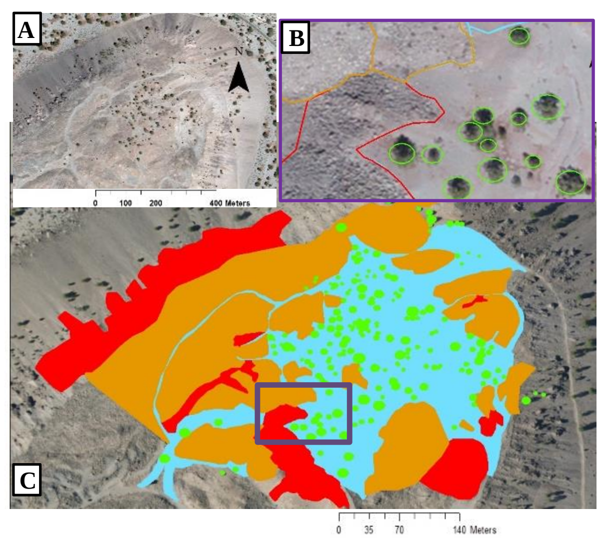

Figure 1. *(A) Northeast lobe of the North Coulee for context. (B) Examples of the four categories identified from WorldView2 50cm data. (C) Category shapefiles overlain on WorldView2 data [8].*

An ASTER-derived ATI image was created to assess the thermophysical characteristics of the coulee. The ATI pixels overlying the study are outlined for comparison with the particle size distribution categories. This information is required to further constrain the relationship between subpixel particle size distribution and ATI. The 5 cm DTM and point cloud density data were analyzed to evaluate the general category distribution mapping completed at the 50 cm spatial resolution of the WorldView2 data. The DTM provides the slope change, whereas the point cloud density is ideal for discriminating rough and smooth surfaces (Figs. 2B-C).

Results and Discussion: Analysis of the identified surface particle size distributions at the different spatial resolutions suggests that WorldView2 (orbital) data provide very similar results to the highest spatial resolution data. The 5 cm point cloud density data and the 50 cm WorldView2 category identifications (Fig. 2C) correlate well with the exception of areas along the edges of the identified zones that account for less than 10% difference.

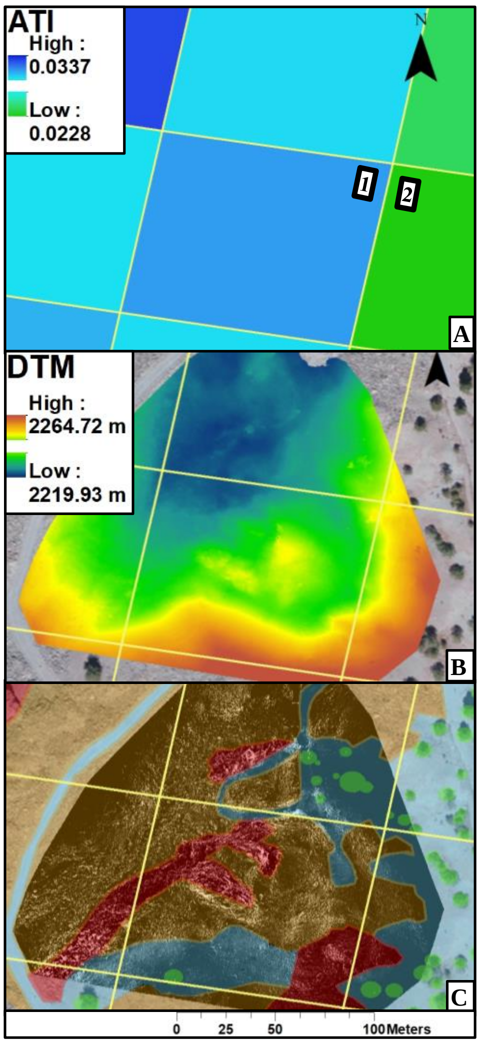

Figure 2. Study site with the ASTER pixel locations overlain. (A) ATI showing the variation over the study site. (B) DTM, created from the point cloud data [9]. (C) Comparison of point cloud density, category shapefiles defined from WorldView2 data (colors defined in Table 1), and ATI to determine the accuracy of particle size identification [8].

This suggests that high resolution orbital data (WorldView2) is adequate to accurately assess surface particle size distribution. A similar approach with HiRISE and THEMIS data could be used to better understand particle size distribution and surface properties of lava flows on Mars. The higher ATI pixel (Fig. 2A, pixel 1) is entirely covered by the point cloud data; this higher density of points suggests the region should contain larger particle sizes. The category distribution from WorldView2 data shows that over 75% is identified as either mixed or coarse. The neighboring pixel to the right (Fig. 2A, pixel 2) has a low ATI value and suggests this area should contain smaller particle sizes. Analysis of the category distribution from WorldView2 data shows over 80% of the area is identified as fine. These comparisons improve our understanding of how to quantitatively relate TI and block size in remote sensing data.

Summary: The next step is to directly compare the ATI to the particle size distribution determined from WorldView2 data. ATI values will be predicted based on the areal percentages of each particle size category in a pixel by using an ATI mixture model that uses idealized components. These predicted ATI values will then be compared to the ATI calculated from ASTER data. These results will further constrain the relationship between TI and particle size so that lower spatial resolution TIR data alone will sufficiently predict the thermophysical surface properties.

Using visible data to acquire TES and THEMIS subpixel information is ideal for understanding surface change with time on older lava flows on Mars. Currently, interpretation of the surface properties is limited by the spatial resolution of the thermal infrared data. The improved understanding of the subpixel particle size distribution, extracted using HiRISE or CTX data, will lead to better interpretation of surface properties when using remote sensing techniques. Future work will be on the Daedalia Planum region, which will lead to increasingly accurate surface composition identification and a better understanding of volcanic emplacement history on Mars.

References: [1] Hardgrove et al. (2009) EPSL, 285, 124-130. [2] Kahle (1987) Geophysics, 52.7, 858-874. [3] Anderson et al. (1998) GSA Bulletin, 110, 10, 1258-1267. [4] Bailey (1989) JGR, 81.5, 725-744. [5] Bursik and Sieh (1989) JGR, 94.B11, 15587-15609. [6] Sieh and Bursik (1986) JGR, 91.B12, 12539-12571. [7] Hildreth (2004) JVGR, 136.3-4, 169-198. [8] WorldView2 Imagery courtesy of the DigitalGlobe Foundation. (2015) www.digitalglobefoundation.org. [9] Scheidt et al. (2014) LPSC, 45, 1491.