THERMOPHYSICAL PROPERTIES OF TERRESTRIAL ROCK AND DEBRIS-COVERED GLACIERS AS ANALOGS FOR MARTIAN LOBATE DEBRIS APRONS. Jennifer L. Piatek, [1]Department of Physics and Earth Science, Central Connecticut State University, New Britain, CT (piatekjel@ccsu.edu)

Introduction: Martian geomorphologic features related to the presence of subsurface ice include rampart craters, thermokarst features, chaotic terrain, patterned ground, pingos, lineated valley fill, concentric crater fill, and lobate debris aprons [1-7]. Recent results suggest the presence of massive ice underneath a talus layer in lobate debris aprons in both the northern and southern hemispheres [8,9]. Lobate debris aprons are masses of debris extending from massif slopes, and are considered analogous to terrestrial rock glaciers, ice-lubricated debris flows, or debris-covered glaciers. Terrestrial rock glaciers are thought to form by downslope flow of massive ice lenses (as in a debris-covered glacier) or via permafrost creep when ice and rock debris are intimately mixed. This flow forms textures in the surface debris that can be observed via satellite. The thermophysical signature of terrestrial rock glacier and debris-covered glaciers can be compared to Martian lobate debris aprons to further understand the relationship of rock and ice in the interiors of these features.

Background: The term "rock glacier" (first used by [10]) in terrestrial geomorphology refers to a tongue-shaped mass of debris, sourced from nearby mountain slopes, that flows downslope due to the presence of ice within the debris. Borehole and geophysical studies suggest that the upper 1-10m of debris in an active rock glacier is free of ice [11-15]. Typical flow rates are 50-100 cm per year, comprised of both slow downslope creep and faster catastrophic mass movement events [16-20]. Active rock glaciers have steep front and side margins that degraded to lower angles once the feature becomes inactive. Surface debris is sorted by ice flow, forming features such as lineations parallel to flow direction and the development of ridge and furrow structures due to compressive stresses. This sorting of debris produces particle size variations that contribute to variations in thermal inertia, which produce variations in temperature than can be observed in thermal infrared datasets. Such variations have been noted in thermal inertia images derived from nighttime thermal infrared images taken by the Thermal Emission Imaging System (THEMIS) images of lobate debris aprons on Mars [21-23], where linear and curvilinear variations in thermal inertia are likely related to particle size variations on the surface of the aprons.

Image Analysis: Due to Earth's thick atmosphere, the modeling necessary to derive thermal inertia values from temperature images is complex and difficult. For this reason, thermal inertia is not directly calculated, but is instead examined via an apparent thermal inertia (ATI) calculation, which requires information about albedo and the difference between the daytime and nighttime temperatures [24,25]. For this study, images from the Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER), which is similar in both spectral and spatial resolution to THEMIS [26,27], allowing for good comparison of the two. ATI values are determined by dividing the temperature difference (day - night) of a surface by it's coalbedo (1 - albedo): in this case, temperatures are derived from ASTER thermal infrared (TIR) images, and bolometric albedos is derived from ASTER daytime visible/near-infrared (VNIR) images acquired at the same time as the daytime TIR images. Ideally, the two TIR images would be taken on the same day, but practically they are acquired within a few weeks of each other. Similar analyses of terrestrial alluvial fans have shown that variations in particle size related to emplacement mechanisms can be observed in such images [28,29].

Preliminary Results: Terrestrial rock glaciers, although typically smaller in scale, appear to exhibit thermophysical variations similar to Martian lobate debris aprons. Typically observed features include lineations parallel to downslope flow in the upper portions of the rock glacier and curvilinear variations associated with compressional ridge and furrow morphologies near the toe (see Figure 1). More pronounced variations, often curvilinear and truncated near the glacier's toe, are associated with debris-covered glaciers (see Figure 2). Although TIR measurements are not directly influenced by the internal ice (as the ice free debris layer is thicker than the thermal skin depth), flow processes are reflected in sorting of the surface debris. The observed differences between rock and debris-covered glaciers suggest that the state of ice within the interior of the feature (interstitial, as in a rock glacier; or massive, as in a debris-covered glacier) may be distinguished on the basis of different thermophysical variations.

Conclusions: The initial comparison of thermophysical expressions of terrestrial rock and debris-covered glaciers suggests that there may be a relationship between the observed variations and the type of downslope ice movement responsible for forming the feature.. Additional analyses will expand the terrestrial examples to explore the relationship between surface thermophysical variations and interior flow processes, as well as to extend the comparisons to include images of lobate debris aprons.

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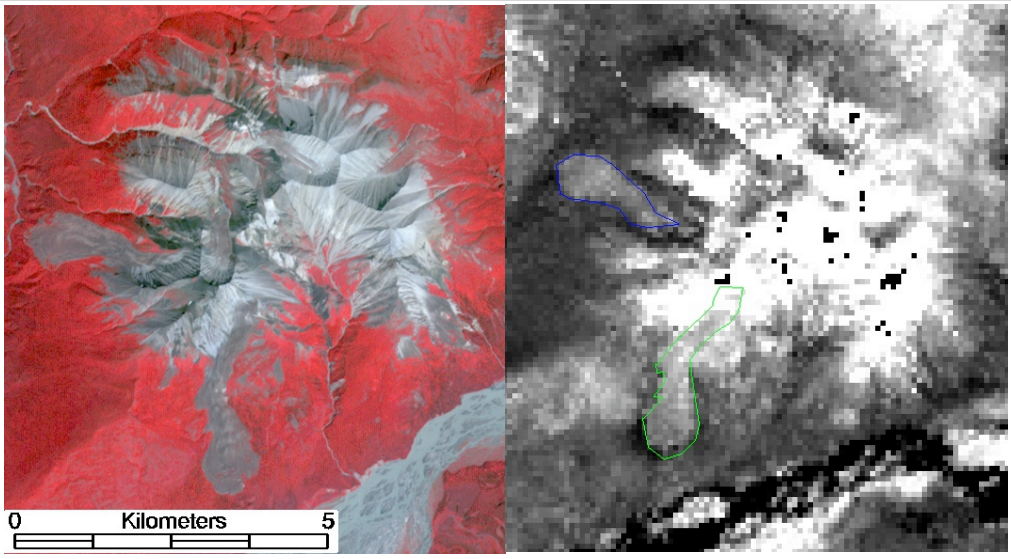

Figure 1: ASTER VNIR reflectance false color (left) and TIR-derived ATI (right) images of an area of the Wrangell- St. Elias National Park in SE Alaska. Two rock glaciers (outlined on the ATI image) are thermally distinct from the background and exhibit typical thermophysical variations.

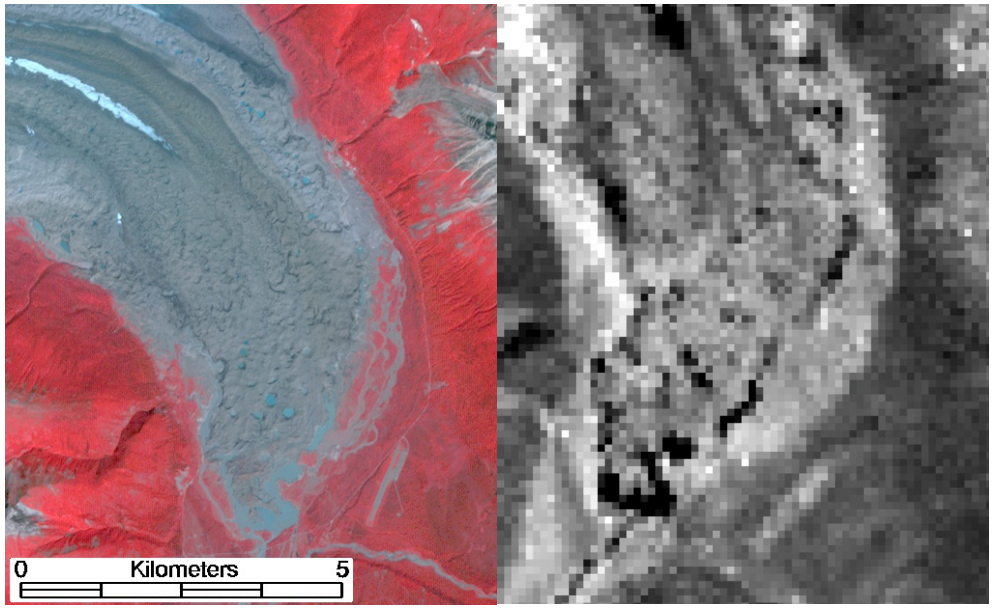

Figure 2: ASTER VNIR false color (left) and TIR-derived ATI (right) of the debris-covered toe of Kennicott Glacier (located west of Figure 1), which exhibits curvilinear thermophysical variations. Extreme ATI values (black/ white pixels) are associated with exposures of ice, snow, and water.