Super-resolution of Martian Chloride Sites and the Associated Mineral Assemblages. C. G. Hughes[1] and M. S. Ramsey, [1]Department of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260 USA, cgh1@pitt.edu, mramsey@pitt.edu

Introduction: Super-resolution is the process of improving spatial resolution from that of the original data source (or native) resolution. A first-order approach is the fusion of original data with an additional source, which has the desired resolution. There are a variety of techniques that can be used to fuse these data sets; however, a trade-off has been noted between techniques that are the most visually appealing and those that are most radiometrically accurate [1]. The technique for super-resolution presented here is a modification of an algorithm [2] that was originally tested successfully using multi-resolution data from the Earth orbiting Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument [4]. The spatial and spectral resolution of ASTER is broadly similar to the Mars orbiting Thermal Emission Imaging System (THEMIS) instrument [5]. The current study investigates the applicability of the technique to enhance the THEMIS thermal infrared (IR) data of a putative chloride deposit in Terra Syrenum using the instrument's visible (VIS) data. The result is a radiometrically-accurate TIR dataset at an improved spatial resolution of 36 m/pixel. It provides an independent approach to traditional sub-pixel deconvolution techniques, and it can be used in the search for small-scale thermal and compositional variations within the deposit and at its contact with the surrounding surficial deposits.

Chlorides: Data from the THEMIS instrument led to the discovery of unique spectral IR signatures that were postulated to be chloride deposits [6]. These are light-toned and located in topographic lows at a variety of altitudes. The spectral signatures are generally featureless, and exhibit a negative slope in the IR. One way negative slopes can arise is from a material that has a low non-unit emissivity across the entire spectral range coupled with an incorrect assumption of the maximum emissivity [6,7]. Due to the unique shape of the spectrum and the desire to better understand the stratigraphic relationship of the deposit, these data become a good candidate for super-resolution. As the spectra are dissimilar from their surroundings, those pixels containing the spectrum would be easily isolated and emphasized within data clustering approach used in the super-resolution algorithm [2].

Chlorides on Earth are frequently associated with other mineral assemblages that first precipitate from water, such as sulfates and carbonates. A collection of such minerals on Mars would strongly indicate the past presence of liquid water. Such a deposit could therefore indicate similar possible paleoenvironments [8,9]. Super-resolution of THEMIS IR data also allows detection of sub-pixel scale mineral assemblages located along the margins of the chloride deposits, which further clarifies the stratigraphic and compositional relationship of the deposit.

Preliminary Results: The modified super-resolution algorithm has been used on several THEMIS images [2,10]. Figure 1 shows a decorrelation stretch image of THEMIS IR data of a region near 221E, 39 S acquired in late November, 2009 at an Ls of 342.7°and a local time of 14.57. This region contains the chloride spectral signature, shown in dark blue and outlined in black. It is co-located with light-toned deposits in the VIS data that lies within a local topographic low. This region is grouped into two different clusters as seen in Figure 2. The western side of the unit forms a unique cluster, containing only surfaces with the chloride unit. The eastern side of the unit forms a separate VIS cluster, containing a number of TIR sub-clusters, one of which is the rest of the chloride unit. The other sub-clusters are surfaces that correspond to other, non-chloride bearing, light-toned units that were not discriminated in the original IR data. Despite this separation within the VIS clusters, the final super-resolved IR product is radiometrically accurate, producing very similar IR spectra between the two clusters (the eastern and western ends of the deposit). The IR spectra of the non-chloride deposits clustered with the eastern side chlorides is spectrally in the VIS different from them. The separation of the deposit into two different VIS clusters may indicate different weathering patterns between the eastern and western sides of the deposit, or changes in sub-pixel composition even at the super-resolved scale. Analysis of the non-chloride deposits clustered with the eastern chlorides may reveal the primary cause of this separation (i.e., if those regions show polygonal terrain or other weathering patterns in common with the eastern side of the chloride cluster).

Future Work: Data from a number of other instruments, such as HiRISE and CTX, have been acquired over the region of interest (Fig. 1). These data need to be integrated with the super-resolved THEMIS data. Furthermore, the spectra of the super-resolved data surrounding the chloride bearing units need to be examined for composition, using techniques such as spectral deconvolution [11]. Super-resolution will next

be applied to contemporaneous multi-band THEMIS IR and VIS data from multiple chloride sites, as well as to contemporaneous image pairs over this site to be acquired in the future. It is hoped that the entire light-toned unit in this region, as well as one or two of the other sites, will be acquired and super-resolved in this manner. In some locations, there are abundant multi-band TIR data sets, but fewer multi-band VIS data. In these areas, non-contemporaneous image pairs can be used, and the results compared to super-resolved data from the contemporaneous pairs. If practical, this may allow for the examination of temporal changes at the sub-pixel scale in these and other areas of interest. Once validated, this technique can be extended to the high-resolution source originating from other instruments, such as CRISM or HRSC. Because these instruments examine the surface at different look angles and local times, differing parts of the scene may be emphasized. The super-resolved data will also be compared to Earth analogue sites using data from ASTER and field-based validation.

References: [1] B. Zhukov et al. (1999), *IEEE Trans. Geol. and RS, 37,* 1212-1226. [2] C. Hughes et al. (2009), *LPS XL,* abs. #2359 [3] H. Tonooka (2005), *Proc. SPIE, 5657,* 9-19. [4] Y. Yamaguchi et al. (1998), *IEEE Trans. Geol. And RS, 36,* 1062-1071. [5] P. Christensen et al. (2004), *Space Science Reviews, 110,* 85-130 [6] M. Osterloo et al. (2008), *Science, 319*, 1651-1654 [7] J. Bandfield (2009), *Icarus, 202,* 414-428 [8] N. Tosca et al. (2008), *Science, 320,* 1204 – 1207 [9] D. Schulze-Makuch et al. (2008), *Int. J. Astrobiology, 7,* 117-141 [10] C. Hughes and M. Ramsey (2008), *LPS XXXIX,* abs. #2530 [11] M. Ramsey and P. Christensen (1998), *JGR, 103,* 577-596

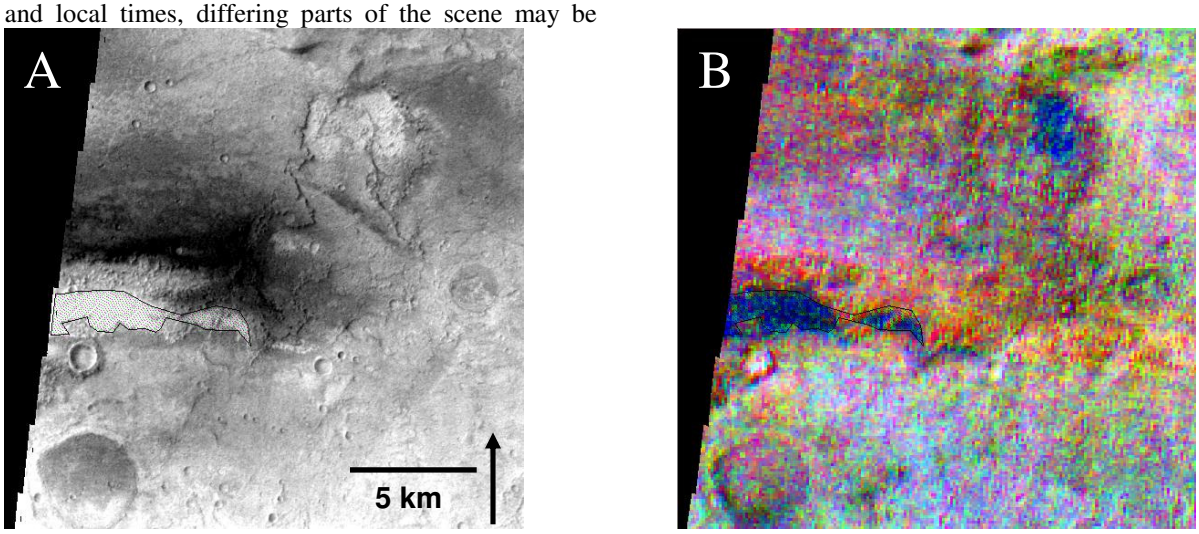

Figure 1. Chloride site. [A] THEMIS VIS Band 3 image of V34487008. The region of interest, a light-toned unit associated with the IR spectral signature of chloride, is outlined. [B] Decorrelation stretch (DCS) image of THEMIS bands 8-7-5 in R.G.B (I34487007). Dark blue areas are the chloride spectral signature.

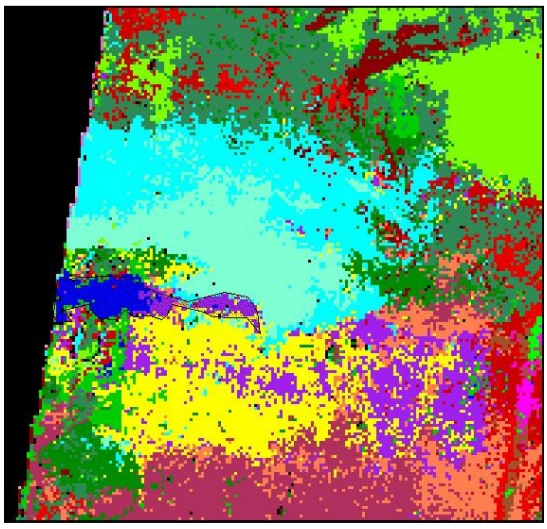

Figure 2. Classification map based on ISODATA clustering of the VIS bands covering the same area as Fig. 1. The region in dark blue within the marked area is the strongest chloride signature in the super-resolved area but is comprised of different spectral signatures (i.e., clusters) in the VIS data indicating mixing..