Improving THEMIS-based Compositional Analysis Accessibility: Generation of Emissivity Products and Processing Tools. C. Pan[1], C. S. Edwards[1], A.D. Rogers[2] [1]Dept. of Physics and Astronomy, Northern Arizona Univ., Flagstaff, AZ 86011 (cong.pan@nau.edu), [2]Stony Brook University, Stony Brook, NY 11794.

Introduction: The Thermal Emission Imaging System (THEMIS) on Mars Odyssey [1] includes a 10-band multispectral infrared imager with ~100 m/pixel spatial resolution covering ~6.8 to 14.9 μm, allowing the community to study the properties of the surface materials over nearly all of Mars. However, THEMIS data has been underutilized for surface spectral analysis due to the lack of a fully automated atmospheric correction tool or surface emissivity product. This work reports progress on our efforts to develop tools to perform atmospheric correction for THEMIS daytime radiance images, and produce a suite of atmospherically corrected data products for approximately ~100 high priority sites (e.g. past landing sites that were under consideration; sites from the humans-to-Mars workshops; sites have been widely studied within the planetary science community, etc.) for immediate accessibility over these sites of interest.

Methods: Atmospheric correction of THEMIS images involves correcting for atmospheric emission and atmospheric transmission/absorption from dust and water ice aerosols. Correction of atmospheric emission can be automated, whereas correction for atmospheric transmission and absorption requires some level of user intervention and therefore is only semi-automatic.

In order to retrieve surface information from satellite remote sensing data, radiance contributions from the atmosphere, such as scattering, absorbing and emission, must be removed. In terrestrial remote sensing, a variety of techniques have been used to separate atmospheric and surface contributions for thermal infrared data, including instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Landsat 1 through 8. Two kinds of techniques that have been widely used are radiative transfer modeling (e.g. MODTRAN (www.modtran.org)), and in-scene empirical methods that use the radiance data in the image cube to estimate the atmospheric component (e.g. dark object subtraction [2, 3]). On Mars, the atmospheric effects of THEMIS images [4] include (1) the radiation emitted by the atmosphere and suspended aerosols ("emission", an additive term of constant radiance) and (2) the wavelength-selective absorption of surface radiation by the atmosphere ("transmission", a multiplicative term of surface radiance attenuation).

$$I_{obs}(v,n) = A(v)B[T_{surf},v,n]+C(v) \quad (1)$$

where $B[T_{surf},v,n]$ is the Planck radiance for the highest measured brightness temperature in THEMIS bands 3-9 at each pixel, A(v) is the surface emissivity and atmospheric attenuation and C(v) is the atmospheric emission which is constant, for each THEMIS band v. Atmospheric emission is relatively constant over ~10 km spatial scales, and can be determined by solving for the equation (1) using the THEMIS calibrated radiance data of a region with the assumption that the surface emissivity is constant, and then removed from a relevant portion of or the entire image. Next, the transmission component can be calculated using the surface emissivity derived from TES (Thermal Emission Spectrometer) over a small uniform area and then subtracted from the image to produce a fully corrected surface emissivity cube. The method allows the surface emissivity of the uniform portion of a THEMIS image to match TES-derived surface emissivity, to determine the atmospheric contribution and then remove it from the image. However, it is usually not true that the atmospheric condition is constant over the entire THEMIS scene or across the elevation differences more than 1000 m. Therefore, we typically only apply the correction to a few thousand lines of THEMIS images at a time to avoid variable atmospheric contributions.

We correct atmospheric emission automatedly with a constant radiance removal algorithm that determines and removes the radiation emitted by the atmosphere and suspended aerosols [4]. The algorithm looks up the similar emissivity and different temperature within the small area and calculate the C(v) using Equation (1). When the algorithm goes through the entire image, it interpolates the C(v) within nearby areas to smooth it to derive the true atmospheric emission. The algorithm does not account for the radiance reflected from the surface and scattering but that component is assumed to be small for daytime data where the surface is warm relative to the atmosphere. Also, it is assumed that the dust is well mixed with the carbon dioxide [5, 6, 7]. Figure 1 illustrats the processes for the correction of atmospheric emission.

After the correction of atmospheric transmission, we correct the atmospheric transmission and absorption semi-automatedly. As it has been mentioned above, the assumption that there is no spatial variation of atmospheric condition over the THEMIS scene is not valid for a large area due to variations in atmospheric conditions, elevation, surface dust cover, significant latitudinal variations etc., so the correction is applied to a small area with 1000 lines of THEMIS image at a time with JMARS. Then we use a command line tool written in Davinci for a full atmospheric correction of images.

Results: Using the methods above, the atmospheric components have been corrected for a THEMIS image in our preliminary results (**Figure 2**). **Figure 2** shows the decorrelation stretch radiance images with

no atmospheric correction, only emission correction and fully atmospheric correction (**Figure 2.A-C**). There are transmission components within the radiance spectrum (**Figure 2.D**), which is different from the surface spectrum in **Figure 2.E** that there is an olivine absorption feature within ~11 μm. The surface emissivity within fully correction of atmospheric contribution will help to investigate the mineralogy correctly.

Future Work: We will generate a near-global data set of THEMIS images that have been corrected for atmospheric emission, using the best-available daytime THEMIS images. We will also develop a semi-automated tool for correcting for atmospheric absorption and transmission based on TES emissivity. The toolsets will allow a user to automatically atmospherically correct a THEMIS image given the line/sample range of the projected image. The tool will utilize pre-calculated TES surface emissivity spectra that overlap the THEMIS image.

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References: [1] Christensen, P. R., et al (2001), *Space Science Reviews*, 110, 85-130. [2] Spanner, M. A., et al (1990), *International Journal of Remote Sensing*, 11, 95-111. [3] Ekstrand, S., (1994), *Remote Sensing of Environment*, 47, 291-302. [4] Bandfield, J. L., et al (2004), *JGR*, 109, no. E10. [5] Bandfield, J. L., and Smith, M. D., (2003), Icarus,161, 47-65. [6] Smith, M. D., et al (2000), JGR, 105, 9589-9607. [7] Smith, M. D., et al (2003), JGR, 108, no. E11. [8] Edwards, C. S.,et al (2011), JGR, 116.

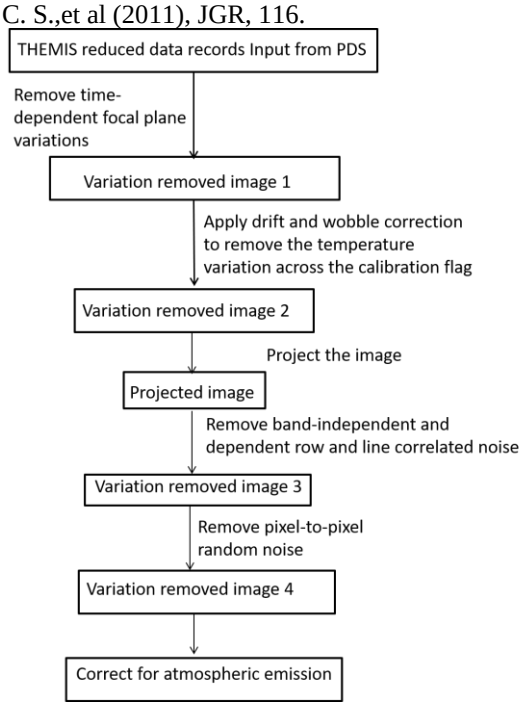

Figure 1. A flowchart illustrating the removal of variation and noise of THEMIS images after [8].

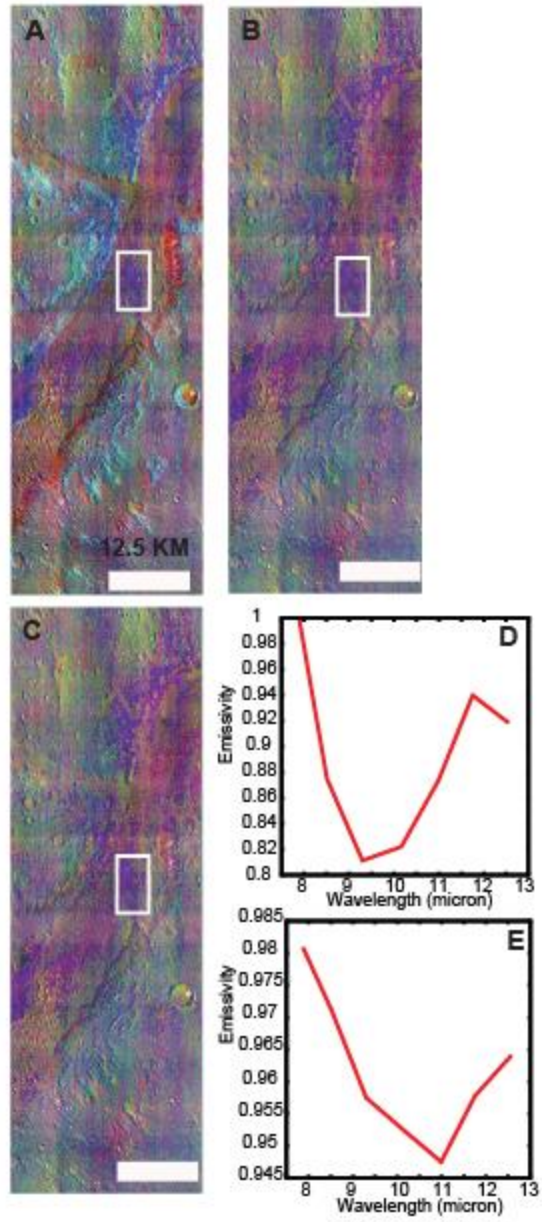

Figure 2. THEMIS emissivity of bands 8(~11.8 μm)-7(~11 μm)-5(~9.4 μm) as red-green-blue in the DCS mosaic of I41896003 and the corresponding spectra. A. The image with no atmospheric correction. B. The image with correction of emission only. Note that apparent emissivity variations with temperature/topography are dramatically reduced. C. The image with fully atmospheric correction. D. The spectrum derived from the white rectangle of B, indicating the atmospheric transmission components which have not been removed. E. The surface spectrum derived from the same area of the image with full correction in C, suggesting and olivine-rich surface mineralogy.