**EXTRACTING COMPOSITIONAL VARIATION FROM THEMIS DATA FOR FEATURES WITH LARGE TOPOGRAPHY ON MARS VIA ATMOSPHERIC EQUALIZATION.** F. S. Anderson[1], J.S. Drake[2], and V. E. Hamilton[1], [1]Hawai'i Institute of Geophysics and Planetology, University of Hawaii, 1680 East West Road, Honolulu, HI 96822, [2]Dickinson College, PO Box 1773, Carlisle, PA 17013; anderson@higp.hawaii.edu.

**Introduction:** We have developed a means of equalizing the atmospheric signature in Mars Odyssey Thermal Emission Imaging System (THEMIS) infrared data over regions with large topography such as the Valles Marineris (VM). This equalization allows for the analysis of compositional variations in regions that previously have been difficult to study because of the large differences in atmospheric path length that result from large changes in surface elevation. Specifically, our motivation for this study is to examine deposits that are small at the scales observable by the Thermal Emission Spectrometer (TES) onboard Mars Global Surveyor, but which are more readily resolved with THEMIS.

**The Problem:** THEMIS infrared images regularly are shown as color decorrelation stretches (DCS) of three spectral bands that enhance spectral differences between materials in the scene. Unfortunately, the floor materials of the Valles Marineris commonly are obscured in THEMIS DCS images as a result of the large topographic variation and attendant increase in atmospheric path length. Similarly, the effect of large slopes in the VM potentially masks the spectral signatures of cliff-forming outcrops.

**Constant Radiance Correction:** In the simplest terms, the observed thermal radiance at the sensor can be described as:

$$Rad_{obs} = Rad_{surf} \cdot Atten_{atm} + Emiss_{atm}$$

where $Rad_{surf}$ is the radiance of the surface, $Atten_{atm}$ is the attenuation of the surface radiance by the atmosphere, and $Emiss_{atm}$ is the emission from the atmosphere. The atmospheric emission term is constant, rather than proportional to the surface radiance, and independent of surface temperature. Unless this term is removed, apparent emissivity differences will be present as a function of surface temperature for surfaces that actually have uniform emissivity [1]. This term can be removed from the data by finding an area of constant emissivity but variable temperature within the scene, calculating the constant radiance term due to atmospheric emission for each band, and then subtracting that radiance from the image [1]. This constant radiance correction is effective at removing slope effects over areas of similar elevation, and thus atmospheric path length, but it cannot correct completely areas with large-scale topographic (i.e., path length) variations.

**Topographic Correction:** Because we know surface elevation with considerable accuracy from Mars Orbiter Laser Altimeter (MOLA) measurements [2], we also know relative atmospheric path length. After converting the constant radiance corrected images to apparent emissivity, we degrade the THEMIS spatial resolution to that of MOLA and then correlate apparent emissivity and elevation to determine a mathematical emissivity-elevation slope (EES) for each THEMIS band. Although the relationship is not perfectly linear, it can be modeled using a linear equation; the difference between the non-linear and linear equations is not enough to make a significant difference in the resulting correction factor. We use a minimum absolute deviation to find the best fit to the data, and record the slope, intercept, and standard deviation. Next, we equalize the spectral contribution from the atmosphere throughout the image by adjusting each pixel of each band to match the atmospheric contribution at a user-selected elevation (MOLA datum in this case). The net result for most pixels will be either an increase or decrease in the atmospheric contribution to the spectrum.

**Results:** We have analyzed ~120 images from the Valles Marineris and found that typical corrections are on the order of ~1-10% (emissivity), and introduced errors are on the order of ~0.5%. Portions of images with significant topographic slopes usually are not fully corrected in the area of the slope, although these usually are small fractions of the total image area. The magnitude of the correction is greatest in THEMIS bands 4 – 6 and varies with season in a manner that is consistent with observed seasonal variations in atmospheric pressure and dust abundance [3], as shown in Figure 1. Atmospheric opacity is strongest in bands 4 – 6, consistent with the larger corrections required in these bands.

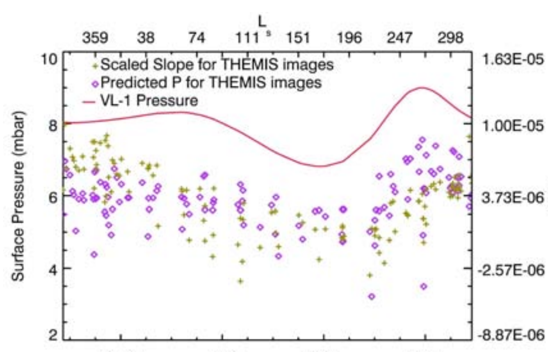


***Figure 1.*** *EES and Martian atmospheric parameters.*

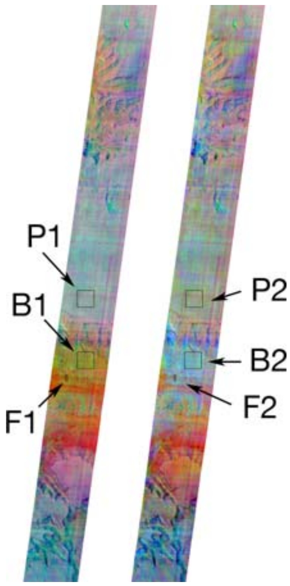


***Figure 2.*** *DCS image of the Valles Marineris before (left) and after (right) atmospheric equalization. F = Feature, B = Base, P = Plateau.*

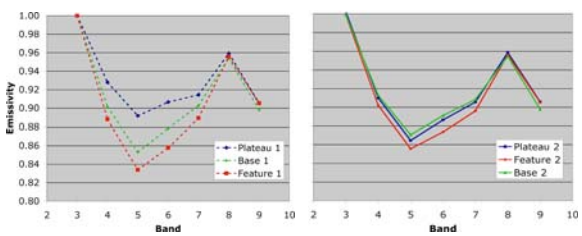


***Figure 3.*** *Apparent emissivity spectra retrieved before (a, left) and after (b, right) atmospheric equalization. Locations of spectra are shown in Figure 2.*

*Successful cases:* Although it may seem counterintuitive to increase the atmospheric contribution to some pixels' spectra, the result of the correction is to produce an emissivity image that represents a uniform elevation, and for which relative differences between spectra can be attributed to surface emissivity variations alone. Spectra throughout the image may be ratioed to remove atmospheric contributions [4], used for surface emissivity retrieval [1], or analyzed using a variety of classification schemes (e.g., pixel purity index, minimum noise fraction). Figure 2 shows an example of a successful atmospheric equalization. The uncorrected DCS image in Figure 2 exhibits substantial color variation, much of which appears correlated with topography. After the atmospheric equalization is applied it is apparent that some of the color variation in the original image was a result of path length differences, but that some of the color differences result from spectral variation of the surface materials. In this case, we examined a spatially small (~10 km), low albedo unit in Melas Chasma and were able to identify TES Type 1 [5] materials (Figures 3 & 4). Small deposits like this one especially benefit from our technique, because they may be too small to be examined using lower spatial resolution TES data.

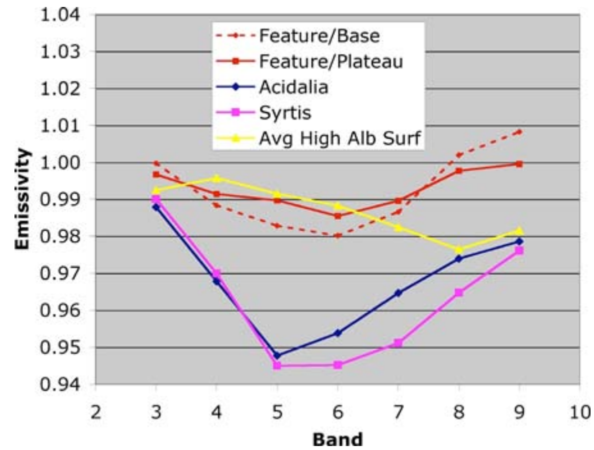


***Figure 4.*** *Ratios of atmospherically equalized spectra (Figure 3) and typical Martian surface spectra from [5 and 6].*

*Unsuccessful cases:* Although ~90% of the images were successfully corrected using this approach, there are cases where the result was not successful. Some of these were images acquired during periods of extremely high atmospheric dust opacity. The cause of the failure in other cases remains unknown, but in all failed cases, the EES was low. Possible explanations may include effects due to incidence angle, temperature, and/or other seasonal properties. Further testing may elucidate the specific reason(s) why some images are not successfully corrected.

**Future work:** We are expanding our study to include newly released THEMIS images over the VM as well as other regions of Mars with significant topographic variations. The correlation between EES and opacity is interesting and we will also begin to compare EES to opacities derived from THEMIS.

**References:** [1] Bandfield, J.L. et al. (2004) JGR, 109, doi:10.1029/2004JE002289. [2] Smith, D.E. et al. (1999) *Science, 284,* 1495-1503. [3] Smith et al. (2003) *JGR, 108,* doi:10.1029/2003JE002115. [4] Ruff, S.W. and Christensen, P.R. (2002) *JGR, 107,* doi:10.1029/2001JE001580. [5] Bandfield, J.L. et al. (2000) *Science, 287,* 1626-1630. [6] Bandfield, J.L. and Smith, M.D. (2003) *Icarus, 161,* 47-65.

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