MGS-TES PHASE EFFECTS AND THERMAL INFRARED DIRECTIONAL EMISSIVITY FIELD MEASUREMENTS OF MARTIAN ANALOG SITES K. M. Pitman[1, 2], J. L. Bandfield[3], and M. J. Wolff[2], [1]Dept. of Earth and Planetary Sciences, Washington University, Campus Box 1169, St. Louis, MO 63130-4862 <kpitman@levee.wustl.edu>, [2]Space Science Institute, 4750 Walnut St. Suite 205, Boulder, CO 80301, [3]Mars Space Flight Facility, Arizona State University, P. O. Box 876305, Tempe, AZ 85287-6305.

Introduction: The Mars Global Surveyor Thermal Emission Spectrometer (MGS-TES) instrument has returned thousands of multiple emission angle observations, collected over a variety of sites, in the thermal infrared (IR) wavelength region. These Emission Phase Function (EPF) sequences constitute a substantial remote sensing dataset at angles that are both on and off-nadir (i.e., observed from top down and at ~ 30, 50, and 70 degree angles from the vertical). Within a significant number of moderate to high albedo (bright) regions and a lesser number of low albedo regions, the EPF sequences display a clear and vital dependence on emission angle *e* (Tables 1, 2; Fig. 1). These emissivity data indicate that the angle at which a single Martian surface site is observed modifies the emissivity spectral profile; directional emissivity effects are also likely to be apparent in the datasets returned from the Mars Exploration Rovers. While a handful of previous studies have investigated directional emissivity effects for general classes of geologic materials or lunar terrain analogs (c.f., [1-6]), to date, little has been done in the field or in the laboratory to determine if these directional emissivity effects are also observed in Mars terrain analog sites here on Earth. We present a set of field emissivity data in the thermal IR wavelength region (λ ~ 7-13 μm) for three undisturbed Mars terrain analog sites (playa and evaporite surfaces in Death Valley National Park and Baker, CA) and analyze them for presence or absence of directional emissivity effects.

Site Measurements: We acquired a set of field emissivity (ε) data in the thermal IR (λ ~ 7-13 μm) with the Designs & Prototypes μFT-IR portable field spectrometer [7-8] for three undisturbed Mars terrain analog sites (Badwater Basin and Devil's Golf Course, Death Valley National Park; Silver Lake Playa, near Baker, CA) at varying angles of emergence. The carbonates, sulfates, and halite deposits found in the typical basinward sequence along the western margin of Badwater Basin are of interest for both the intrinsic directional emissivity spectral properties of these mineral types and the link to Mars mineralogy established by previous investigation [9]. Silver Lake Playa was vital to our study because it was selected as the test site for the field prototype of the 2003/2005 Mars FIDO rover; its surface is characterized as fine-grained, hard packed silt and clay with variable degrees of compaction, traversed by mudcracks [10]. Directional emissivity spectra (*e* = 0, 45, 55, 85 degrees) were obtained for approximately 15 targets (salt flats, smooth clay mud, sulfates) at Devil's Golf Course and Badwater Basin; additional targets (*e* = 0-80 degrees, in increments of 10 degrees) were measured at Silver Lake Playa and Dumont Dunes (near Baker, CA).

Laboratory Spectroscopy: Differences in emissivity spectra taken under field and laboratory conditions may be due to moisture content, porosity, and surface roughness variations [11]. Thus, in addition to acquiring field e spectra, we obtained 2.5" square, 1" deep hand samples from each site in order to measure laboratory ε spectra for exactly the same material. We acquired our laboratory ε spectra with the Nicolet Nexus 670 transmission spectrometer located at the Mars Space Flight Facility, ASU. This spectrometer is the same instrument used to calibrate the thermal emission spectrometers TES and THEMIS aboard Mars Global Surveyor and Mars Odyssey. The wavelength range acquired in the lab is ~ 5-50 μm, at 4 cm^{-1} resolution. To measure emissivity for the hand samples at angles corresponding to those observed in the field, we manufactured sample holders to achieve angles of tilt between 0 and 70 degrees in increments of 10 degrees.

Discussion: Of the Martian terrain analog sites studied here, the sand and playa samples showed the most promising evidence of directional emissivity effects in the 7-13 μm wavelength regime. The natural, undisturbed sites at Silver Lake Playa appeared to show evidence of directional emissivity effects at high angles of emergence. The field ε spectra acquired at Dumont Dunes displayed the clearest evidence of directional emissivity effects. Our findings in the sand and playa samples support the results of [6], who also found that sand and playa surfaces in the Lunar Crater Volcanic Field, NV, exhibit noticeable directional effects; we improved upon their experimental methods by using a tripod-mounted FT-IR rather than a handheld radiometer and also acquired our field emissivity spectra at smaller emergence angle intervals. The laboratory samples of quartz-feldspar sands taken from Dumont Dunes also exhibits the monotonically decreasing ε with increasing e trend at angles *e* = 20-40 degrees. Lab results for the playa surface did not unequivocally support or disprove the field emissivity spectra. The fact that sand, a low albedo material, exhibited strong directional emissivity effects in our field and lab study and in the previous investigations by others cited here is seemingly in contrast to the current inventory of MGS-TES EPF sequences which indicates that moderate to high albedo (dust covered) Martian surfaces exhibit directional emissivity effects. The facts that we see emissivity changing with angle of emergence for Mars analog sites and that the magnitude of the relative decrease in ε may change with the type of geologic material allow us to conclude that the spectral changes observed in the low albedo surface EPF sequences and the more subtle effects observed in the high albedo surface EPF sequences are in fact real.

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Table 1. Selected MGS-TES EPF Sequences Exhibiting Directional Emissivity Effects: Moderate to High Albedo Regions

OCK	ICK	Longitude (°)	Latitude(°)	T_{surf} (K)
2684	1897	67	15.3	276.9
2719	1803	347.7	5.7	275.2
2720	1897	17.6	15.2	276.6
2792	1897	279	15.3	276.3
2827	1803	199.8	5.6	276.2
2828	1897	229.6	15	276.8
2995	1742	327.9	-0.4	280.5
3020	1897	325.6	15.4	282.5
3128	1897	177	15.3	282.1

All calibrated, atmospherically corrected surface radiance spectra provided courtesy of J. Bandfield and the MGS-TES team. OCK ("Orbit Counter Keeper") and its subinterval ICK ("Incremental Counter Keeper") refer to the MGS-TES instrument team's orbit numbering system. Typical *e* values range include 0, 18, 29-30, 38-39, 43-46, 49, 51-52, 54-59, and 62-66 (both forward- and aft-viewing angles available for a subset of the *e* values reported here). There are preferentially more moderate to high albedo regions represented because the low albedo surfaces tend not to be uniform.

Table 2. Selected MGS-TES EPF Sequences Exhibiting Directional Emissivity Effects: Low Albedo Regions

OCK	ICK	Longitude (°)	Latitude(°)	T_{surf} (K)
5071	1746	354	0	292.1
6605	1452	339	-30	295.1
6881	1452	319	-30	287.1

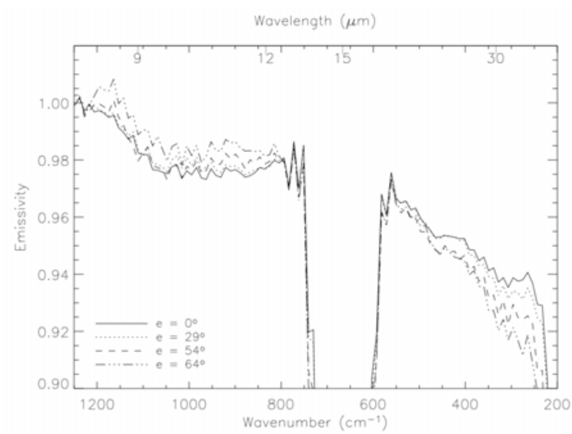

Fig. 1. Emissivity variations as a function of emergence angle *e* are observed in a representative MGS-TES EPF sequence set measured for a low albedo surface (OCK 6881 ICK 1452). As *e* increases, emissivity decreases.