LUNAR SURFACE ROUGHNESS AND ANISOTHERMALITY EFFECTS ON INFRARED MEASUREMENTS. J. L. Bandfield[1], P. O. Hayne[2], R. R. Ghent[3], B. T. Greenhagen[4], and D. A. Paige[5], [1]Earth and Space Sciences, University of Washington, Seattle, [2]Geological and Planetary Sciences, California Institute of Technology, [3]Department of Geology, University of Toronto, [4]Jet Propulsion Laboratory, California Institute of Technology, [4]Earth and Space Sciences, University of California, Los Angeles.

Introduction: The morphology of planetary surfaces is well documented by imaging systems on orbital spacecraft, but is limited in resolution to meter and (more often) greater scales. With the exception of a limited number of lander missions, it is not possible to use imaging systems to obtain a clear picture of sub-meter scale surface morphologies. Identification of these morphologies is important for understanding surface processes such as regolith/soil formation, rock generation, and near-surface ice related processes. In addition, understanding the surface character at meter and smaller scales is crucial for characterizing and evaluating the safety and trafficability of potential landing sites.

A number of techniques have been developed and used to gain insight into the sub-meter scale morphology of planetary surfaces. These include use of photometric (e.g. *1-4*), laser altimeter pulse width (e.g. *5*), and radar measurements (e.g. *6-7*) to define surface slopes and roughness. In addition, surface temperature measurements have been used to derive surface roughness, particle size, and rock abundance of surfaces (e.g. *8-13*). These methods provide quantitative information about the surface morphology that would otherwise be unobtainable via traditional imaging methods.

Methodology: Surface temperatures are dependent on the angle between the surface and the direction of solar illumination. A greater diversity of angles will result in a larger variation in temperatures. These temperature variations will result in a mixture of Planck radiance within the measurement field of view. Surface slopes are typically greater at smaller length scales [*14*] and slope distributions typically represent the smallest scale of the sensitivity of the measurement. For thermal infrared observations, this represents the smallest scale at which sunlit and shaded slopes remain thermally isolated. For typical lunar surfaces, this scale is less than a few millimeters.

The mixture of surface temperatures within the field of view results in two apparent effects in the data; 1) A dependence of brightness temperature on look angle. For example, when viewing a surface from a similar azimuth as the sun, sun-facing surfaces are dominant within the field of view and the brightness temperature is higher [*12*]. 2) Slopes in apparent emissivity spectra [*13,15*]. These slopes result from the derivation of emissivity assuming a single temperature, which cannot approximate the surface radiance of a mixture of temperatures. We have started investigating both of these effects in Lunar Reconnaissance Orbiter Diviner Radiometer Experiment data as well as exploring the potential effects on near-infrared spectral measurements.

There are three basic aspects to the modeling of surface roughness effects:

1) Thermal Model – For this work, we use a simple radiative equilibrium model for daytime measurements. Where the sun is below the local horizon, surface temperature is set to 100K. This is not appropriate for nighttime measurements, which use a 1-dimensional conductive model similar to [*16*]. We are planning on incorporating nighttime multiple emission angle measurements into this analysis.

2) Surface Model – We use a simple Gaussian distribution of slopes similar to that of [*14*]. This reduces the surface slopes/roughness to a single parameter (RMS slope distribution), while maintaining reasonable fidelity to natural surfaces.

3) Measurement/Observation Geometry – Using the modeled temperatures and slope distributions, the mixture of Planck radiances are calculated in proportion to their contribution to the measurement field of view. The data can then be convolved with the spectral response of the Diviner bandpasses.

Initial Results: Multiple emission angle observations were acquired over a highlands surface near 85W, 13N. Brightness temperature differences between symmetrical down-track/up-track observations are well-fit with 25-35 degree RMS slope distributions (Fig. 1). Brightness temperatures are lower at high emission angles from all azimuths, indicating that spectral emissivity is also likely dependent on emission angle.

Nadir observations acquired at separate local times show a clear change in spectral slope consistent with anisothermality due to surface roughness (Fig. 2). Anisothermality (and associated spectral slopes) increases with incresing solar incidence. This effect generally has greater magnitudes with increased roughness. These results are consistent with the multiple emission angle results as well as in situ observations of highlands surfaces [*14*].

These spectral slopes have a significant effect on the location of the Christiansen feature used to derive bulk surface mineralogy. An empirical correction for this has been developed by *17*. The work presented

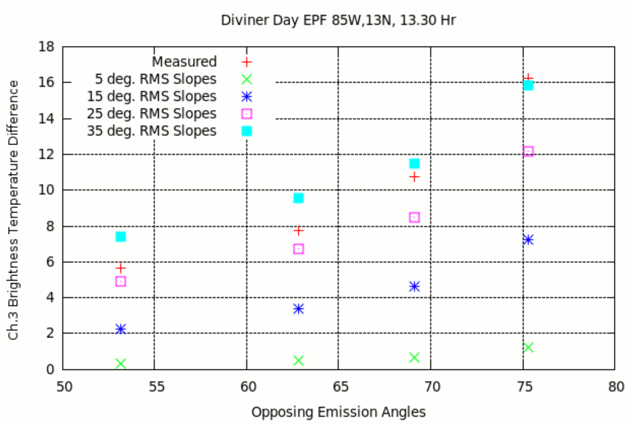

Figure 1. Measured change in Diviner Channel 3 brightness temperatures between up- and down-track observations. Measurements fall in-between modeled temperature differences for 25-35 degree RMS slope distributions.

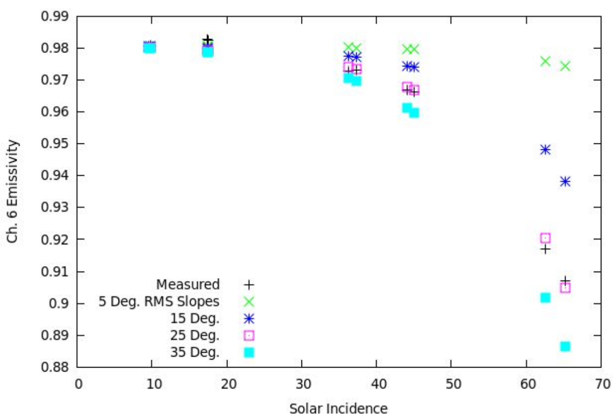

Figure 2. Apparent emissivity of Diviner Channel 6 measurements as a function of solar incidence. Lower emissivities result from greater anisothermality due to more shadowing. Measurements compare well with the modeled 25 degree RMS slope distribution.

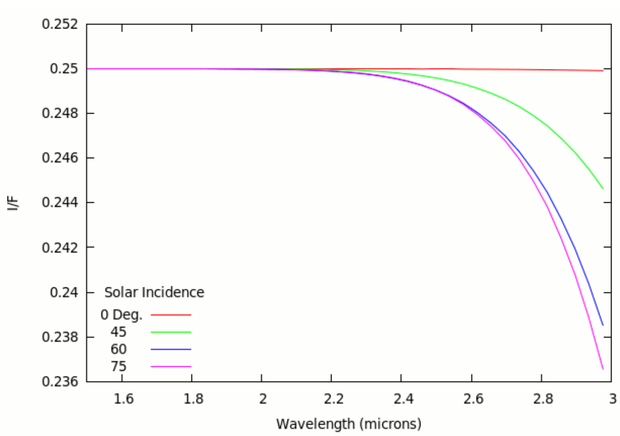

Figure 3. Simulated I/F spectra after thermal correction at 2.1 micron wavelengths assuming an isothermal surface. Simulated measurements assumed an RMS slope distribution of 25 degrees.

here shows that much of the shift in the Christiansen feature can be explained by anisothermality caused by surface roughness. This model can be used to remove roughness effects and clarify interpretations for mineralogical studies.

Similar modeling can be applied to near infrared observations. Effects of anisothermality are more prominent at shorter wavelengths for lunar surface temperatures. Although a higher surface temperature has a greater magnitude effect on near-infrared measurements, anisothermality effects increase at increasing angles of solar incidence. As a result, simple corrections assuming a single surface temperature generally result in larger apparent blue slopes in reflectance spectra at lower surface temperatures (Fig. 3). This will result in a dependence of the apparent depth of the 3 micron H_2O/OH^- absorption on latitude and local time as has been observed [*18*].

Conclusions: Surface roughness derived from both multiple emission angle and variable solar incidence measurements show RMS slope distributions of ~25-35 degrees, roughly consistent with previous in situ observations at millimeter scales. The high sensitivity of Diviner measurements to surface roughness allows for these properties to be mapped globally.

This high sensitivity also has a great deal of influence on both near- and thermal-infrared spectral measurements and may be partially responsible for the latitude and local time dependence of the depth of the 3 micron H2O/OH- absorption in lunar spectral data.

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