CAN WE USE REMOTE THERMAL EMISSION OBSERVATIONS TO DERIVE LUNAR SURFACE PROPERTIES? Mary L. Urquhart, Laboratory for Atmospheric and Space Physics and Astrophysical, Planetary, and Atmospheric Sciences Department, University of Colorado, Boulder, CO 80309-0392 (email urquhart@argyre.colorado.edu), and Bruce M. Jakosky Laboratory for Atmospheric and Space Physics and Department of Geological Sciences, University of Colorado, Boulder, CO 80309-0392 (email jakosky@argyre.colorado.edu)

Grain size, particle density, thermal conductivity, composition and rock abundance all play an important role in the thermal behavior of the lunar surface. Direct investigation of the grain size distribution, particle density, and thermal conductivity of the lunar surface layer is not presently possible, with the exception of the samples returned from the Apollo landing sites. An indirect measurement of lunar surface properties may be possible using remote thermal infrared observations. In order to better understand the interplay between grain size, density, rock abundance, and thermal conductivity a diurnal thermal model for the lunar surface and near subsurface with temperature-dependent specific heat and thermal conductivity was developed. Although particle size, bulk density, and thermal conductivity cannot be investigated completely independently, a clear relationship between these parameters, and their effects on lunar surface temperatures is determined. Thermal conductivity is dependent upon the other parameters of grain size, particle density, composition and rock abundance. To separate the effects each of these parameters have on the thermal conductivity, and hence the nighttime temperatures, laboratory data was used for granulated materials under vacuum conditions which varied only one parameter, while holding the others constant[1]. Since an increase in the bulk density of a material increases the thermal inertia of that substance, an increase in density results in an increase in nighttime temperatures. An increase in the average grain size of the regolith was found to correspond to a decrease in the minimum temperatures predicted by the model. Higher rock percentages of either vesicular basalt or breccia decrease the overall temperature variation of the models and increase the nighttime temperatures. (See figure 1). Since grain size, density, and rock abundance can each be varied within certain ranges to match an observed minimum temperature, some assumptions regarding the thermal properties of the surface must be made if regolith properties are to be determined remotely.

A temperature-dependent model which includes the transfer of radiative energy between grains is essential for the investigation of grain sizes using thermal infrared measurements on airless bodies. Due to the large surface temperature range which occurs over the course of a lunation, the variation with temperature of the specific heat and the thermal conductivity of the lunar surface must be considered if a proper interpretation of the thermal behavior of the moon's surface is to be made. The approach used is a finite difference model with the boundary condition of insolation at the surface to solve for the lunar surface temperature. A finite difference model with constant specific heat and thermal conductivity is used for comparison to the temperature-dependent model[2]. Minimum temperatures from the two models are used for the purpose of comparing the results of models run with different parameters to each other. Temperature–dependent runs show consistently lower nighttime surface temperatures (7 K on average) for all materials considered. The importance of using a temperature–dependent model is evident. The minimum temperatures for material which varies only in density is significantly lower for the temperature-dependent model than that predicted if the temperature dependence of the specific heat and thermal conductivity is neglected. A minimum temperature of, for example, 96 K would give a density estimate in the constant properties model which is 16 percent lower than that derived from the temperature dependent model. As with particle density, the need for the use of a temperature-dependent model in determining average grain size is clear. The constant properties model entirely ignores the radiation term of the thermal conductivity which is of critical importance in the thermal effects of increased grain size. As lower temperatures are representive of larger grain sizes, the constant properties model would predict smaller average grain sizes for a surface than would the temperature–dependent model. Higher rock percentages are predicted by the temperature–dependent model than are predicted if the temperature dependence of the specific heat and thermal conductivity are neglected.

The temperature-dependent model used fits well with the sparse data presently available. With further comparisons to Apollo 17 Infrared Scanning Radiometer data[3], and eventually Clementine data[4], the model may provide a powerful tool to aid in the determination of the properties of the average grain size, density, and grain size distribution of the lunar regolith. Care must be taken in interpretation of thermal observations; however, as some assumptions about the nature of the regolith must be made to derive properties such as density and grain size from measurements of the lunar surface temperature. General trends are evident from the model results to date. Increasing density corresponds to an increase in the overall thermal inertia, and therefore, an increase in the nighttime temperatures. On the other hand, an increase in average particle size causes a decrease in the observed surface temperature. Increased rock abundances of both vesicular basalt and breccia cause a general increase in overall nighttime surface temperature observed. Also evident is the necessity of using a temperature-dependent, rather than temperature independent model. If a thermal model with constant values of specific heat and thermal conductivity is used instead of a temperature dependent model, incorrect conclusions as to the density, grain size, and rock abundance can be made. This is particularly true in the lunar evening and nighttime.

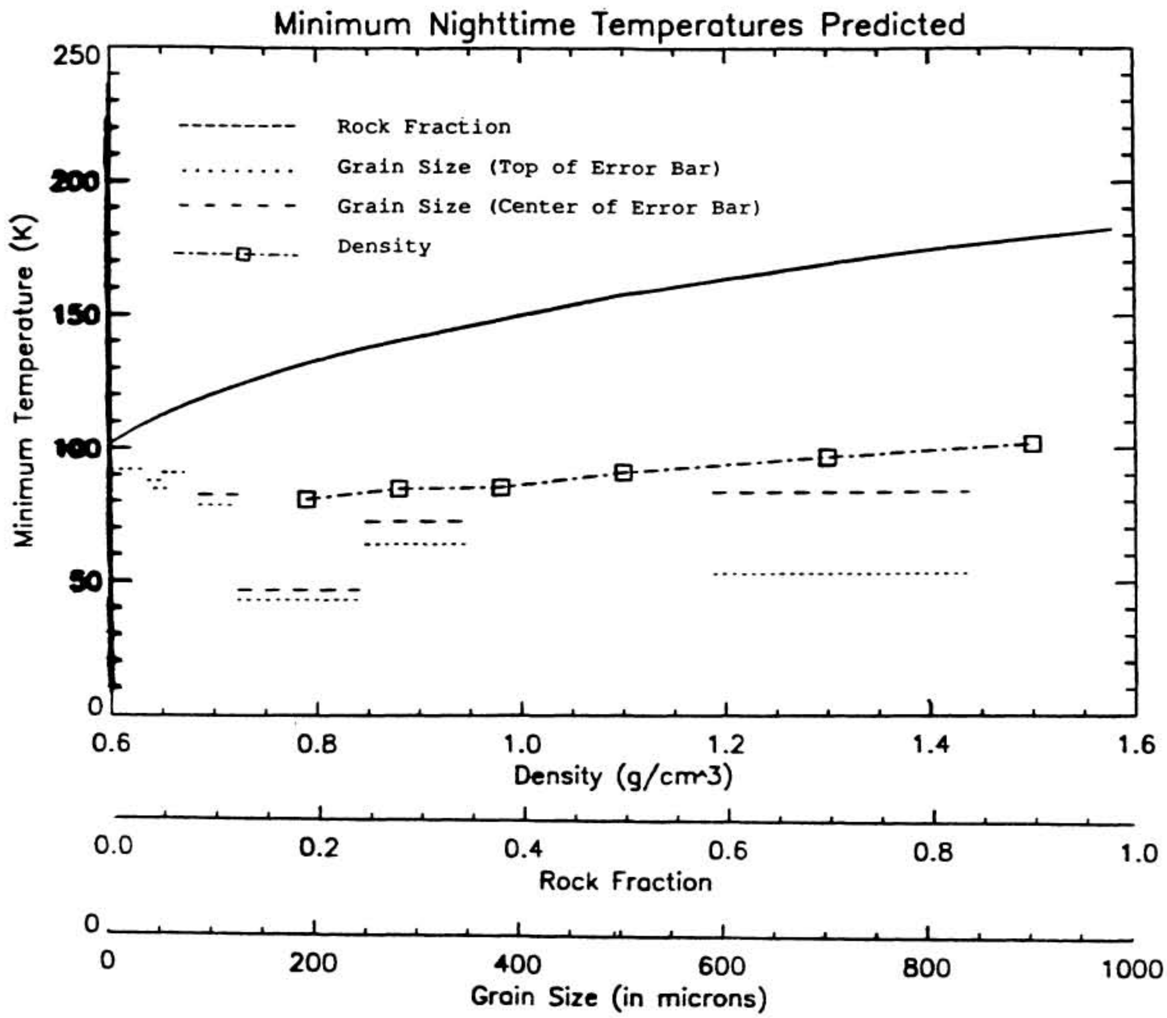

Figure 1: The effects of density, grainsize and rock abundance on the minimum surface temperature predicted by the temperature dependent model. Rock abundance and density both use thermal conductivities for granulated basalt. Grain sizes are for glass spheres.

[1]Wechsler, A.E., P.E. Glaser, A.D. Little, and J.A. Fountain (1972) *Thermal Characteristics of the Moon. Progress in Astronautics and Aeronautics, 28*, 51.
[1]Mellon M.T., and Jakosky B.M. (1993) *JGR, 98*, 3345.
[3]Mendell, W.W. (1976) PhD Thesis.
[4]Novette S., et al. (1994) *Science, 266*, 1777.