DERIVATION OF LUNAR REGOLITH PROPERTIES FROM LRO/DIVINER DATA AND THERMOPHYSICAL MODELING. J. Bürger[1], J. Blum[1], B. Gundlach[1], P. O. Hayne[2], M. Läuter[3] and T. Kramer[4] [1]Institute of Geophysics and Extraterrestrial Physics, TU Braunschweig, Germany (j.buerger@tu-bs.de), [2]Laboratory for Atmospheric and Space Physics, University of Colorado Boulder, CO, USA, [3]Zuse Institute Berlin, Germany, [4]Institute for Theoretical Physics, Johannes Kepler Universität Linz, Austria.

Introduction: In the Apollo era, the lunar regolith was characterized by several in-situ experiments and laboratory studies on returned samples. However, this only provided information on the regolith properties at the corresponding landing sites. To learn about properties on a global scale, remote sensing measurements are needed. In this study, we used brightness temperature measurements from the Diviner Lunar Radiometer Experiment on board the Lunar Reconnaissance Orbiter (LRO) and compared them with a thermophysical model. This method allows to constrain regolith properties of unsampled areas. We thereby expand upon previous studies [e.g., 1] by developing a microphysical thermal model that more directly simulates regolith properties, such as grain size or bulk density.

Lunar Regolith Thermophysical Model: The developed thermophysical model solves the one-dimensional heat transfer equation and takes as input the physical and thermophysical properties of the lunar regolith. The regolith bulk density profile is described by the stratification model of [2] and is a function of grain radius and depth. In the model, the steepness of the transition from the loose packing at the surface to the maximum bulk density in the deeper layers is described by the parameter Δ. The thermal conductivity is modeled as a function of temperature, regolith grain radius and volume filling factor [3], and the heat capacity is temperature-dependent [1].

The lunar highlands and maria are modeled separately, taking into account their different albedo [4] and mass density [5]. In addition, the thermal conductivity model is fitted by adding a scaling factor χ [6] to measurements on returned samples from the maria [7] and the highlands [8]. Figure 1 illustrates the thermal conductivity measurements and the model fits, which indicate a much lower thermal conductivity in the highlands than in the maria. For the model fits, a temperature-dependent thermal conductivity of the solid material was added, derived from [9], which approaches zero with decreasing temperature.

LRO/Diviner Measurements: LRO has been orbiting the Moon since 2009 and Diviner measures the brightness temperature of the lunar surface in four different thermal channels with wavelengths between 13 and 400 µm in high spatial-resolution [10]. For the comparison between measured and simulated temperatures, we focus on nighttime temperatures, as these are the most sensitive to thermophysical properties such as thermal conductivity and stratification. Because rocks are much warmer during the night and their presence hence increases the measured thermal emission, in this study we use the regolith temperatures derived by separating the effect of rocks from the Diviner measurements [11]. Figure 2 shows Diviner regolith temperatures near the lunar equator, separated into highlands and maria.

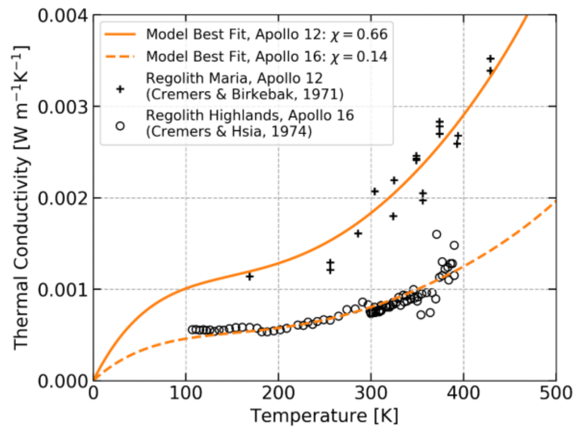

Figure 1: Measurements of the thermal conductivity of returned lunar samples from the Apollo 12 landing site [7] (classified as maria) and the Apollo 16 landing site [8] (classified as highlands) show a lower thermal conductivity for the highlands.

Derivation of Lunar Regolith Properties: Three model parameters are varied, namely the grain radius r, the deep layer density ρ_d, and the transition width Δ, and the best fitting parameter set is determined. Figure 2 shows the best model fits to regolith temperatures in the highlands and the maria. For the maria, we find r = 40 µm, Δ = 0.1 and ρ_d = 2000 kg m^{-3} with a RMSD = 0.35 K. However, for the highlands and a realistic parameter space, all simulation runs result in nighttime temperatures that are too cold to match the observations, due to the significantly lower thermal conductivity. Consequently, when the thermal conductivity model is fitted to the laboratory measurements of the returned regolith samples, the thermophysical model does not agree with the

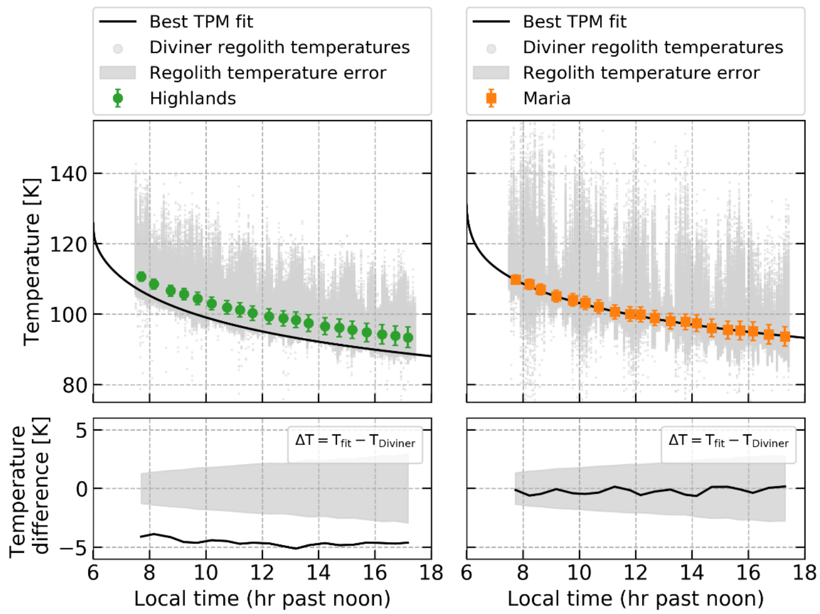

Figure 2: Comparison of modeled and measured lunar regolith temperatures. The observed mean regolith temperatures during nighttime are very similar for the highlands and the maria. In the thermophysical model the regolith grain radius, the deep layer density and the transition width Δ are varied. For the highlands, the simulated temperatures are always too cold, due to the significantly lower thermal conductivity suggested by [8] (see Figure 1).

observations in the highlands. Assuming the same thermal conductivity as for the maria, we find a best fit for the highlands with r = 40 µm, Δ = 0.2 and ρ_d = 1900 kg m^{-3} with a RMSD = 0.35 K.

Future Work: In-situ measurements of lunar regolith thermal conductivity [12] suggest values that are an order of magnitude higher than those determined in the laboratory. We will therefore revise the calibration of the thermal conductivity model and investigate thermal conductivity profiles that match the in-situ measured values in deeper layers.

The overall future goal is to create maps of derived regolith properties (grain radius and stratification properties) that could be used for future mission planning and understanding the geological history of the Moon.

References: [1] Hayne, P.O. et al. (2017) *JGR, 122*, 2371-2400. [2] Schräpler, R. et al. (2015) *Icarus, 257*, 33-46. [3] Gundlach, B. and Blum, J. (2012), *Icarus, 219,* 618-629. [4] Feng, J. et al. (2020) *JGR, 125,* E06130. [5] Kiefer, W. S. et al. (2012) *Geophys. Res. Lett., 39,* L07201. [6] Cremers, C. J. and Birkebak, R. C. (1971) *Lunar Planet. Sci. Conf. Proc. 2*, 2311-2315. [7] Cremers, C. J. & Hsia, H. S. (1974) *Lunar Planet. Sci. Conf. Proc. 3,* 2703-2708. [8] Gundlach, B. & Blum, J. (2013), *Icarus, 223,* 479-492. [9] Opeil, C. P. (2012) *Meteoritics & Plan. Sci. 47,* 319-329. [10] Paige, D. A. et al. (2010), *Space Sci. Rev., 150,* 125-160. [11] Bandfield, J. L. et al. (2011) *JGR, 116,* E00H02. [12] Langseth, M. G. et al. (1976) *Lunar Planet. Sci. Conf. Proc. 3*, 3143-3171.