



Verification of a thermal simulation tool for moving objects on the lunar surface

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The thermal environment of the Moon is a challenge for the design and successful operation of rovers and scientific instruments, especially for dynamic, mobile situations. Examples range from transport and stability of volatile samples in transport devices at the lunar poles to an analysis instrument, to astronauts exploring varied terrain. A dynamic thermal simulation tool for moving objects on the lunar surface was created and its verification for several test cases against Lunar Reconnaissance Orbiter DIVINER brightness temperature data is presented here.

The Thermal Moon Simulator (TherMoS) allows the prediction of incoming heat fluxes on a mobile object on the lunar surface and subsequent object temperatures. A model for regolith temperatures based on the models presented in [1,2] was set in a MATLAB simulation context. A time-marching numerical finite-difference approach was used to calculate the temperatures for log-distributed regolith depth nodes to a depth of 2m. The lunar interior heat flux was set to 0.033 [$W \cdot m^{-2}$], based on the early publications of [3]. The incoming heat fluxes are calculated with a ray tracing algorithm. Parallel solar rays and their diffuse reflected components lead to the solar heat flux for each surface element. Additionally each surface element emits hemispherical, diffuse infrared rays that are absorbed by the object as well as other lunar surface elements. The lunar topography is represented in a triangular mesh. The topography is either derived from Kaguya LALT data or generated artificially. In the latter case craters and boulders are placed manually or randomly in a level terrain. This approach is restricted to bowl shaped primary craters with a boulder size and spatial distribution that takes into account the region (mare or highland) and the parent crater diameter [4,5,6]. A thermal boulder model is integrated, based on work performed by [7]. This model also uses a finite-difference numerical approach to compute boulder temperatures for boulders with diameters $> 1m$. An orbit propagator is integrated to predict the sun angle at a given time and location on the Moon.

The verification was performed for several sites on the Moon for a timeframe of approx. 1 lunar hour. In case of single craters, for example Marius A and Callipus, the overall model produces temperatures accurate within 10 %. In case of more rugged terrain such as the Apollo 15 landing site, crater Ibn Bajja close to the lunar south pole, or in case of steep slope angles, deviations can be as high as 100 % in some places. This can be explained by the different spatial resolution of Kaguya LALT data compared to DIVINER brightness temperature data. The simulation tool is well suited to predict local heat fluxes from the lunar surface for engineering and mission operations related questions, within the mentioned restrictions.

[1] C.J. Cremers et al. (1971); [2] A.R. Vasavada et al. (1999); [3] M.G. Langseth et al. (1972); [4] F. Hörrz et al. (1991); [5] G. D. Bart et al. (2007); [6] M. J. Cintala et al. (1981); [7] E.C. Roelof et al. (1968)