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Model Surface Temperatures of Selected Study Regions on Mercury

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Abstract

The imaging spectrometer MERTIS (Mercury Radiometer and Thermal Infrared Spectrometer) is part of the payload of ESA's BepiColombo mission, which is scheduled for launch in 2014 [1]. The instrument consists of an IR-spectrometer and radiometer, which observe the surface in the wavelength range of 7-14 and 7-40µm, respectively. The four scientific objectives [1, 2] are to

a) study Mercury's surface composition,
b) identify rock-forming minerals,
c) globally map the surface mineralogy and
d) study surface temperature and thermal inertia.

1. Introduction

Previous studies of the lunar surface have shown that thermal emission contributes to the observed signal from a surface and can influence the spectral characteristics, e.g., the depths of absorption bands [e.g., 3-5]. Because this effect is even more pronounced at higher temperatures at Mercury, knowledge of the temperature at which a spectrum was taken is required for the accurate interpretation of thermal IR data. In addition, in order to determine study regions with optimal signal to noise ratios accurate knowledge of the solar insolation and resulting thermal variations are required.

In preparation of the MERTIS experiment, we performed detailed thermal models of the hermean surface. For our simulations, we developed a thermal model [6], which includes topography from MESSENGER MLA (Mercury Laser Altimeter [7]) or idealized crater geometries [8, 9], albedo of a specific surface, insolation cycles derived from the JPL Horizon System, scattering of solar insolation and infrared energy, and temperature and depth dependent thermophysical properties.

2. Method

In order to determine surface and subsurface temperatures, our model solves the one-dimensional heat transfer equation, including a depth and temperature dependent thermal inertia [6]. Thermal inertia represents the ability of a surface to adapt to temperature changes. The surface boundary condition is based on the energy balance relation; the energy entering the surface equals the energy leaving the surface. In addition to the direct solar insolation, reflectance and scattering from adjacent surface regions also influences the surface temperatures, especially in polar areas and in areas close to the terminator. Therefore it is necessary to include the local topography, as it influences the insolation and temperatures. Shadowing of a surface is either caused by topography features in the direct line to the Sun or self shadowing of sloping surfaces.

3. Comparison between Moon and Mercury – flat surfaces

For our simulations we assume a layered subsurface, similar to the model by [10], with a top layer of 2 cm over a more dense and conductive bottom layer. This stratigraphy is based on regolith properties derived from ground based and spacecraft observations, as well as lunar *in situ* measurements and returned samples. The model results agree well with the lunar measured data within the error bars for both, day- and nighttime temperatures [11-13]. Following [10] we assume that the top surface layers of the Moon and Mercury are similar.

Lunar and mercurian surface temperatures show the same general characteristics (fig. 1). Both have very steep temperature gradients at sunrise and sunset, due to the lack of an atmosphere and the fine grained regolith. Surface temperatures on the Moon vary about 280 K, on Mercury almost 600 K.

However, there are major differences due to the specific orbital characteristics of the two bodies. For example, at local noon, the near- and farside of the Moon receive sunlight under similar solar elevation angles. However, at this time of the lunar day the surface on the farside is slightly warmer than the nearside, because of the shorter distance to the Sun. During the orbit around the Sun the distance varies due to the eccentricity of the Earth-Moon-System, which results in different maximum temperatures during the course of a year. On Mercury, the 3:2 resonant rotation rate and the eccentric orbit cause distinct characteristics. At longitudes 0° and 180° local noon coincides with perihelion, which leads to a "warm pole". At longitudes 90° and 270° local noon coincides with aphelion, which results in a "cold pole". At these longitudes secondary sunrises and sunsets are visible when Mercury's orbital angular velocity exceeds the spin rate during perihelion.

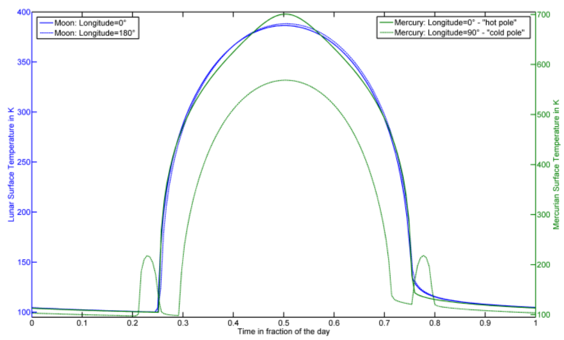

Figure 1: Comparison between flat-surface temperatures at different longitudes on the Moon (blue curves) and Mercury (green curves). The length of a lunar day is 29.5 Earth-days; a Mercurian day corresponds to 176 Earth-days.

3. Topography influence

Surface daytime temperatures are mainly controlled by their surface albedo and solar incidence angle. However, nighttime temperatures are affected by variations in the thermal inertia. For our model, some simplifications were necessary. Subsurface conditions are considered as homogeneous over the whole planet, the thermophysical properties are similar to lunar regolith from which soil properties have been determined.

Crater walls facing towards the Sun have higher insolation and therefore are significantly warmer than the walls facing away from the Sun. Near local noon all surface facets of craters at latitudes < 40° receive direct solar insolation and therefore the temperature difference within the crater is only on the order of 100 K. At higher latitudes the crater walls facing away from the Sun receive direct solar insolation under low elevation angles, which results in a relatively large temperature difference of > 300 K.

The slow rotation and close distance to the Sun of Mercury require a detailed analysis of shadowing effects at low elevation angles. During these times of the day, a fraction of the solar disk is below the horizon and the solar constant must be modified. The Sun can not be treated as a point source, as it would indicate darkness for areas where the sun is partially eclipsed. On the Moon this effect is less pronounced.

5. Summary and Conclusions

We developed a model that calculates surface temperatures on the Moon, which we extrapolated to Mercury. This model includes insolation cycles derived from JPL's Horizons software, albedo and topography of a study region, scattering of solar insolation and infrared energy, and temperature and depth dependend thermophysical properties derived from ground based and spacecraft observations, as well as lunar *in situ* measurements and returned samples. Results obtained for the lunar surface show good agreement to Apollo, Clementine-LWIR and LRO-Diviner measurements. These results have shown, that the temperature- and depth-dependent thermophysical properties of the regolith can not be neglected, due to the large temperature variations over a lunar and Mercurian day.

References

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