EPSC Abstracts
Vol. 6, EPSC-DPS2011-1639, 2011
EPSC-DPS Joint Meeting 2011

Stability of Ices in the North Polar Region of Mercury

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Abstract

We examine the thermal stability of water ice and other frozen volatiles inside selected impact craters in the north polar region of Mercury by means of a three-dimensional ray-tracing thermal model. The model utilizes topographic profiles and contour maps of specific craters measured by the MESSENGER Mercury Laser Altimeter instrument.

1. Introduction

Earth-based radar observations have revealed the presence of anomalously bright, depolarizing features that appear to be localized in the permanently shadowed regions of high-latitude impact craters [1]. As illustrated in the Arecibo Observatory radar image in Figure 1, these radar-bright features in the northern hemisphere extend from the north pole to latitudes equatorward of 70°N [2]. Observation of similar radar signatures over a range of radar wavelengths implies that they correspond to deposits that are highly transparent at radar wavelengths and extend to depths of several meters below the surface [1]. Thermal models using idealized crater topographic profiles have predicted the thermal stability of surface and subsurface water ice at these same latitudes [3].

One of the major goals of the MESSENGER mission is to characterize the nature of radar-bright craters and presumed associated frozen volatile deposits at the poles of Mercury through complementary orbital observations by a suite of instruments [4]. Here we report on the first efforts to examine the thermal stability of water ice and other frozen volatiles in the north polar region of Mercury using topographic profiles obtained by the Mercury Laser Altimeter (MLA) instrument [5] in conjunction with a three-dimensional ray-tracing thermal model previously used to study the thermal environment of polar craters on the Moon [6].

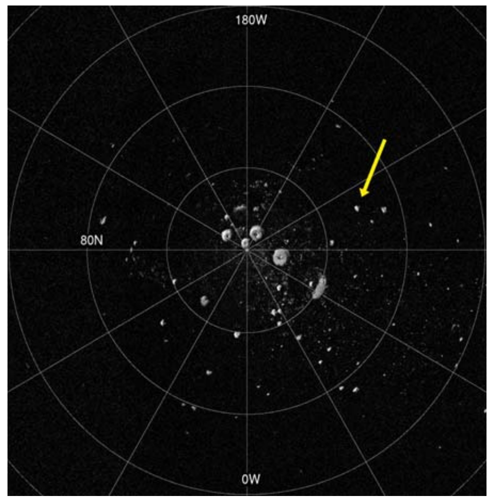

Figure 1. Radar image of the north polar region of Mercury obtained at the Arecibo Observatory [2]. The image is a polar stereographic projection with a latitude contour interval of 5°. The yellow arrow points to a radar-bright crater sampled by the MESSENGER MLA instrument, as shown in Figure 2.

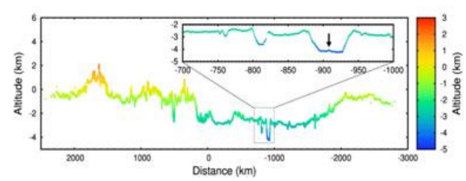

Figure 2. MESSENGER MLA profile segment from the northern hemisphere of Mercury. The inset highlights a traverse of the radar-bright crater shown in Figure 1.

2. Methodology

MESSENGER's MLA [5] has acquired, as of this writing, more than 100 topographic profiles in the north polar region. Some of the profiles collected to date, such as the one shown in Figure 2, transect impact craters with anomalous radar features. Digital elevation models (DEMs) produced from these data have been created for the interiors of these craters and surrounding terrains. These MLA DEMs are the principal input for a three-dimensional ray-tracing thermal model that has successfully reproduced surface temperature observations in the south polar region of the Moon made by the Lunar Reconnaissance Orbiter (LRO) Diviner Radiometer Experiment [6]. The model has been modified to account for the thermophysical properties and solar reflectance of the regolith of Mercury, several candidate ices, and Mercury's current orbital and axial elements. For each point on a DEM, the model computes time histories of direct solar and multiply scattered solar radiation, emitted multiply scattered infrared radiation, surface and subsurface temperature, and Earth visibility at the times of the highest resolution Earth-based radar observations

Specific issues that are being examined include the following:

1. What are the surface and subsurface temperatures inside selected north polar craters on Mercury, and are temperatures in regions with anomalous radar features distinct?

2. What volatile species are thermally stable as ices within these north polar craters and over what timescales?

3. Can the spatial patterns of anomalous radar reflectivity observed from Earth be matched by model predictions of the thermal stability of extensive deposits of one or more frozen volatile species?

The results of this work will contribute to our general understanding of the nature and history of ices on Mercury and other airless bodies in the inner solar system.

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