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Orbital Observations of Mercury with the Mercury Laser Altimeter

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Abstract

The Mercury Laser Altimeter, an instrument onboard the MESSENGER spacecraft, is currently providing precise, high-resolution measurements of the topography of the northern hemisphere of Mercury as the spacecraft executes its orbital mapping mission. The altimeter data are contributing to studies of planetary shape, crater and basin structure, tectonics, volcanism and internal structure. Collectively these observations will inform studies to reconstruct Mercury's geological and thermal evolution.

1. Introduction

Topography is a fundamental measurement that contributes to characterization of planetary surfaces at a range of spatial scales [1]. Consequently, the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft [2], the first orbital reconnaissance mission to map globally the planet Mercury, includes the Mercury laser altimeter (MLA) as part of the instrument payload.

2. The Mercury Laser Altimeter

The MLA [3] is a profiling laser altimeter that measures the round-trip time of flight of transmitted laser pulses reflected from the surface of Mercury. The instrument ranges at an 8-Hz rate. In combination with knowledge of the spacecraft orbit position and pointing in inertial space, MLA ranges provide high-precision measurements of surface topography referenced to Mercury's center of mass. As illustrated in Fig. 1, MLA's orbital coverage of the surface of Mercury is limited largely to the northern hemisphere. The distribution of altimeter tracks is controlled by the MESSENGER spacecraft orbit and the angle, with respect to nadir, at which the MLA ranges. The instrument samples the planet's surface with approximately a 1-m range error when the line-of-sight range to Mercury is less than 1,200 km under spacecraft nadir pointing or the slant range is less than 800 km. MESSENGER's orbital periapsis changes in altitude (200 to 500 km) and latitude (drifting northwards from the initial value of 60°N) over the course of the mission. Consequently, the pattern of topographic coverage is non-uniform. In addition, off-nadir ranging with MLA, as necessitated by spacecraft thermal requirements, to facilitate observations by other instruments, or to complete targeted profiles (e.g., north polar craters) causes spreading of the pulse that both increases range error and decreases returned signal strength.

3. Flyby Summary

MLA's performance was verified with respect to pre-launch tests by analysis of two equatorial profiles acquired during MESSENGER's first two flybys of Mercury during the mission's cruise phase [4, 5].

Near-equatorial profiles from the Mercury flybys refined inferences made from Earth-based radar ranging [cf. 6]. MLA profiles confirmed that equatorial topographic relief of Mercury is at least

5.5 km [4]. In addition, Mercury's long-wavelength equatorial topography is well fit by an ellipse aligned closely with the equatorial ellipticity of the gravity field [5].

4. Orbital Observations

A typical MLA profile is shown in Fig. 2. The profile underscores the variability of elevation in Mercury's northern hemisphere and the fact that most short-wavelength topography is associated with impact structures. In addition to craters, MLA has so far sampled ridges, graben, volcanic features and radar-bright polar craters. MLA is providing a precise geodetic grid that will enable the assimilation of uncontrolled topographic observations from stereo imaging [7], limb images [8] and occultations [9.]

A topographic model of the northern hemisphere, once assembled, will be combined with a gravity model in order to constrain further the internal structure of Mercury [e.g., 10-12].

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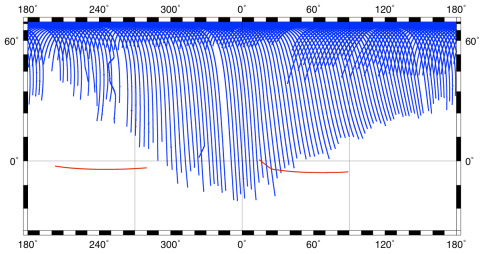

Figure 1. MLA coverage of Mercury as of 24 May, 2011. Red corresponds to flyby tracks and blue corresponds to orbital tracks.

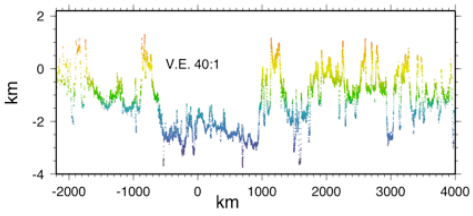

Figure 2. An MLA profile across the northern hemisphere on May 8, 2011. Elevation measurements are with respect to a sphere of radius 2440 km, and distance along track is measured with respect to the position of closest approach to the north pole at approximately 82.9°N, 227.6°E. The vertical exaggeration is 40:1.