IN-SITU MEASUREMENT OF MERCURY'S PHYSICAL LIBRATIONS USING IMAGE AND LASER ALTIMETER DATA FROM MESSENGER: GENERAL APPROACH AND SENSITIVITY ANALYSIS.

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Introduction: Observations of Mercury's physical librations present a special opportunity to derive constraints on the internal structure of the planet. The longitudinal librations are related to the orbital motion of the planet and have a main period of approximately 88 days [1]. Previous estimates using Earth-based radar observations suggest an amplitude of several hundred meters at the equator [2]. In this work we present the analysis of an idea for direct measurement of the librations by combining in-situ laser altimeter and image data obtained by the MESSENGER spacecraft.

Method: We use a recently developed method for co-registering laser altimeter profiles and digital terrain models (DTMs) obtained from stereo imaging [3]. Provided that the planetary surface is sufficiently rough, topographic data sets can be co-registered with very high accuracy, much below the size of individual laser spots or terrain model grid elements.

Co-registration is performed using least-squares fitting, i.e., by minimizing the standard deviation of the two datasets. As a result, we obtain three-dimensional shifts (in longitude, latitude, and height) that have to be applied to one of the datasets to be consistent with the other.

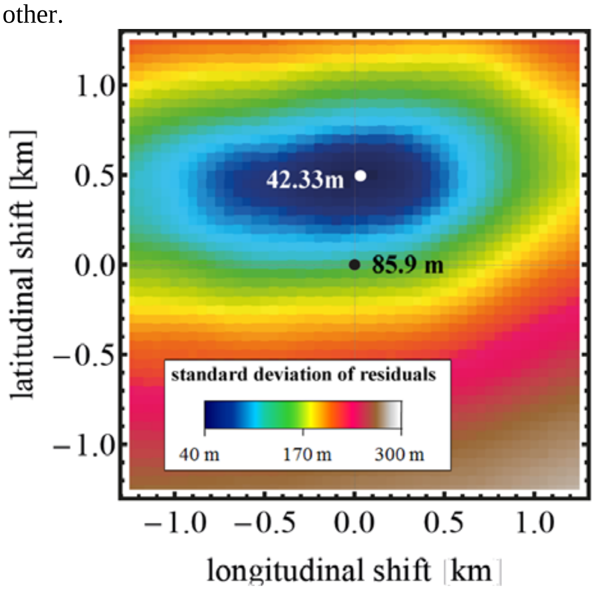

Figure 1. The residual field after co-registration of one MLA profile (MLASCIRDR1104050305) with a stereo DTM near Sander crater (see text for details).

An example residual field for one profile, i.e., the standard deviation of the datasets as a function of shifts in longitude and latitude, is shown in Figure 1. In the example, the co-registered position (standard deviation of 42.33 m) differs significantly from the nominal position (85.9 m).

Using complementary topographic datasets, i.e., a stereo DTM and a laser altimeter profile, covering the same area, it is possible to identify offsets of the two data sets, e.g, due to navigation data errors, instrument misalignments, or reference frame errors (e.g., involving an unknown libration function).

The method benefits from the complementarity of the two data sets. The laser altimeter profiles provide excellent height resolution and have been obtained one-by-one over a time period covering almost the entire libration phase function [4]. In contrast, the stereo models each have a wide area coverage and correspond nearly to a single time [5,6], as the DTMs are typically composed of large blocks (groups) of images taken within a few tens of minutes. During the DTM block adjustments (see [7] for details) the relative pointing or map error offsets of the different blocks are removed. We used topographic profiles acquired by the Mercury Laser Altimeter (MLA) early in the primary orbital phase of the MESSENGER mission between 29 March and 19 August 2011. We used three distinct DTMs (H03, Strindberg, Raditladi) computed from stereo images obtained by the Mercury Dual Imaging System (MDIS) [7].

We first derived the position of the MLA profiles on the surface, neglecting any libration. After co-registration with the stereo DTMs we obtained systematic longitudinal shift patterns of the laser profiles in relation to the stereo DTMs, probably representing the libration signature.

A total of 283 individual co-registrations were carried out. Data covering a few days to two weeks (depending on the DTM) were binned to one measurement point. The variance of the profile shifts in one bin was used to represent the error for the measurement.

We used the mathematical model described by Peale [1] and Margot [2] for the libration function. We introduced an additional amplitude scaling factor, *A*, which is the measurement parameter in our study.

Results: The results for the three DTMs from the orbital phase are displayed in Figure 2. Even though errors in co-registrations are large, we can clearly see a temporal variation of the longitudinal shifts showing the characteristic period and phase of the expected librations. On the basis of the libration function [1,2] we obtained a scaling factor $A = 0.91 \pm 0.38$. This result is in agreement with the current libration model of Mercury.

The large errors arise mainly because the DTMs are located at relatively high latitudes where their grid sizes are larger than the expected libration amplitude. With the arrival of more MLA profiles and DTMs at more favorable locations with a higher spatial resolution, we expect to reduce the error of the measurement and to obtain an accurate and independent in-situ measurement of the libration function.

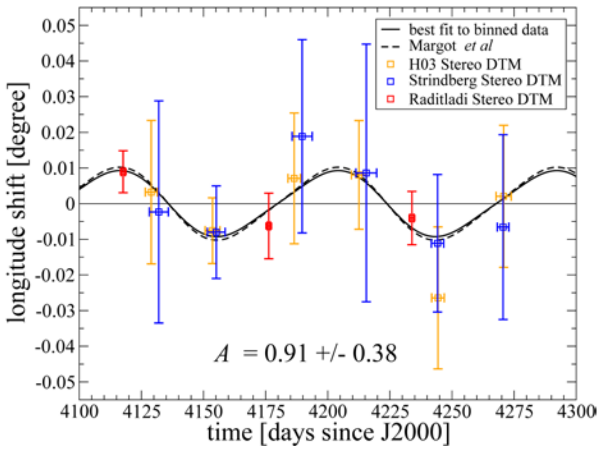

Figure 2. Temporal pattern of longitudinal shifts of MLA profiles for three different stereo DTMs. The dashed line represents the libration function from Margot [2] ($A = 1$); the solid curve represents the best fit to the data ($A = 0.91$; see text for further details).

References:

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