THE GRAVITY FIELD OF MERCURY FROM MESSENGER. Erwan Mazarico[1,2], Frank G. Lemoine[2], Sander J. Goossens[2,4], David E. Smith[1,2], Maria T. Zuber[1], Gregory A. Neumann[2], Mark H. Torrence[3,2], David D. Rowlands[2] and Sean C. Solomon[5]. [1] Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139 (mazarico@mit.edu); [2] Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771; [3] SGT Inc., Greenbelt, MD 20770; [4] CRESST, University of Maryland, Baltimore County, Baltimore, MD 21250; [5] Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015.

Introduction: On 18 March 2011, the MESSENGER spacecraft **[1]** was inserted into a ~12-hour, near-polar orbit around Mercury, with an initial periapsis altitude of 200 km, initial latitude of 60°N, and apoapsis at ~15,200 km altitude in the southern hemisphere. This highly eccentric orbit permits the mapping of regional gravitational structure in the northern hemisphere but limits the recoverability of the gravity field to long wavelengths at southern latitudes. At the ascending and descending nodes of the orbit (on the equator), the altitude of MESSENGER is about 4900 and 1200 km, respectively (Fig. 1). During the first few weeks after orbit insertion, MESSENGER was tracked at X-band (8 GHz) by stations of NASA's Deep Space Network (DSN). After an initial period of nearly continuous tracking, the typical coverage was typically limited to one periapsis per day.

The HgM002 field: The first orbital solution of the gravity field of Mercury, termed HgM002 **[2]** (Fig. 2), was derived from the processing of data between 18 March and 23 August 2011, a tracking period that spans more than two Mercury sidereal days. The data were processed in one-day batches ("arcs") to reduce the modeling errors from the non-conservative forces, especially radiation pressure. The normal equations were combined to invert spherical harmonic gravity field solutions to degree and order 20, a compromise between data sensitivity and global resolution. To limit the power at high degrees, a Kaula power-law constraint **[3]** was applied to Stokes coefficients above degree 2 (Fig. 3). That constraint ($4.10^{-5}/l^2$, where l is the harmonic degree) was derived from scaling of gravitational power for the Moon.

The gravity field in the northern hemisphere shows several regional anomalies that exceed 100 mGal in amplitude (Fig. 2). One such anomaly coincides with Mercury's northern rise, a locally elevated region (centered at 68°N, 33°E) **[4,5]** within the northern lowlands and north polar gravity low. Another is associated with the Caloris impact basin (35°N, 160°E), where some of the anomalous mass correlates with and can be attributed to regions of high topography on the basin floor **[4]**. Other positive gravity anomalies are not obviously associated with mapped impact basins at the current resolution of the gravity field. Attempts to resolve mascon anomalies similar to those seen at prominent basins on the Moon **[6]** and Mars **[7]** from tracking observations during MESSENGER's first two Mercury flybys **[8]** and the third Mariner 10 flyby **[9]** have not produced definitive results. From the harmonic solution HgM002, the only identifiable mascon basin is Caloris.

Continued work: The tracking data through 5 January 2012 have been processed to obtain updated solutions of the gravity field, and new radiometric-only solutions show only small differences from HgM002. Current efforts involve improved force modeling and the inclusion of additional data types.

Force modeling. Improved spacecraft modeling can enable increased arc length, which would benefit the

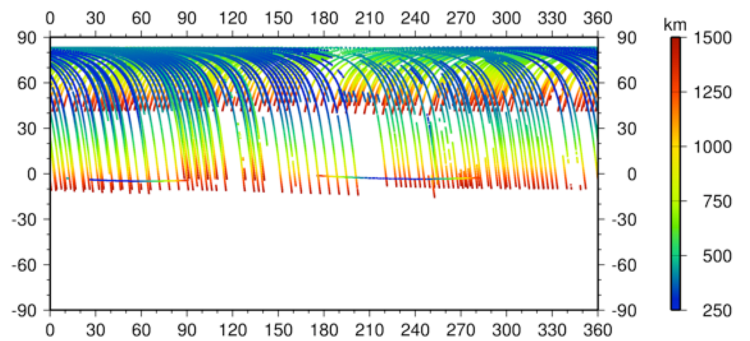

Figure 1. Coverage of radio tracking data acquired below 1500 km altitude, including the first and second Mercury flybys and orbital data acquired between 18 March and 23 August 2011. Cylindrical projection.

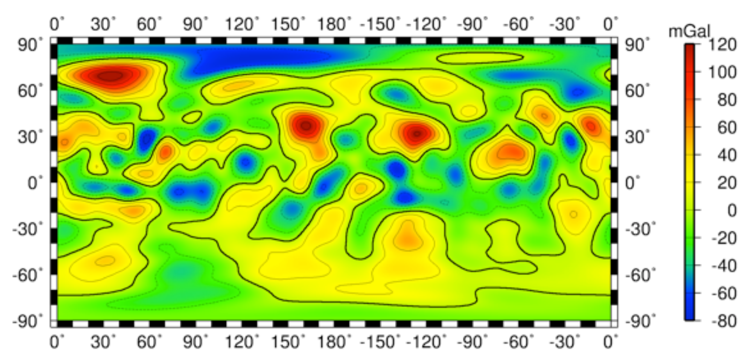

Figure 2. Map of free-air gravity anomalies on Mercury from the HgM002 gravity field. Cylindrical projection.

estimation of long-wavelength gravity signals such as the tidal Love number k_2 and of Mercury's orientation parameters. Because of the proximity to the Sun, the magnitudes of the various radiation pressure accelerations are high compared with those encountered at the Moon or Mars. The planetary albedo and thermal forces, usually treated together, must be considered and adjusted separately. We are also pursuing modeling efforts to include the thermal re-radiation acceleration from the spacecraft, driven principally by the high temperature of the sunshade.

Altimetric crossovers. The high-precision altimetric data collected by the MLA instrument can be used to improve the spacecraft trajectory, by providing constraints at the intersection of track pairs. We used such altimetric crossover data in the evaluation of the HgM002 field **[2]**. They contribute as well to the more recent gravity field solutions.

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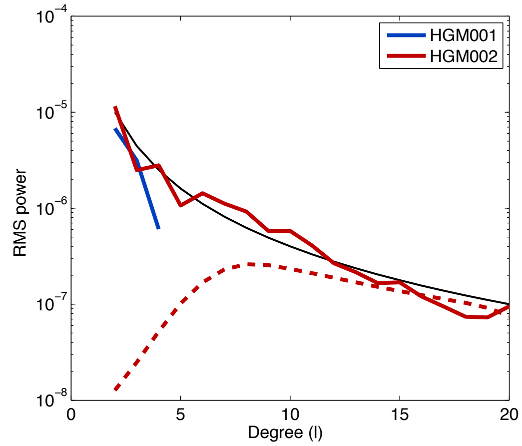

Figure 3. Power spectra of the HgM001 **[10]** and HgM002 gravity fields. The Kaula constraint (black) and the HgM002 error spectrum (dashed red) are also shown.