THE GRAVITY FIELD OF MERCURY AFTER THE MESSENGER LOW-ALTITUDE CAMPAIGN.
Erwan Mazarico[1], Antonio Genova[2], Sander Goossens[3], Frank G. Lemoine[1], David E. Smith[2], Maria T. Zuber[2], Gregory A. Neumann[1] and Sean C. Solomon[4,5]. [1] Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA (erwan.m.mazarico@nasa.gov); [2] Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA; [3] Center for Research and Exploration in Space Science and Technology, University of Maryland, Baltimore County, Baltimore, MD 21250, USA; [4] Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, USA; [5] Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA.

Introduction: The final year of the MESSENGER mission [1] was designed to take advantage of the remaining propellant onboard to provide a series of low-altitude observation campaigns and acquire novel scientific data about the innermost planet. The lower periapsis altitude greatly enhances the sensitivity to the short-wavelength gravity field, but only when the spacecraft is in view of Earth. After more than 3 years in orbit around Mercury, the MESSENGER spacecraft was tracked for the first time below 200-km altitude on 5 May 2014 by the NASA Deep Space Network (DSN). Between August and October, periapsis passages down to 25-km altitude were routinely tracked. These periods considerably improved the quality of the data coverage (Figure 1).

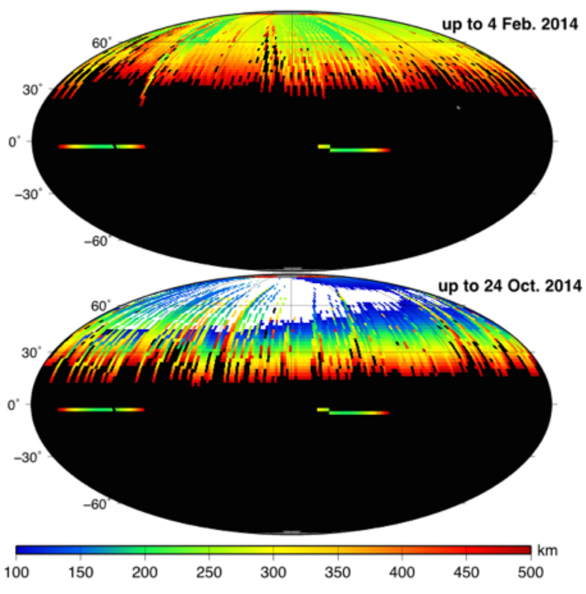

Figure 1. Coverage maps of the minimum altitude of the tracking data included in the gravity solutions. Black and white indicate >500 and <100 km altitude, respectively. Mollweide projection (centered on 0°E).

Data and Modeling: Our methodology largely follows that of our recent HgM005 solution [2]. Tracking data up to October 2014 are included into our new solution, compared with February 2014 for HgM005. In order to account for the large Doppler signals observed even relative to the HgM005 field expanded to degree and order 50 (spatial blocksize ~ 150 km) HgM005 field (Figure 2), we increased the number of estimated gravity coefficients to 5,773 (to degree and order 75; spatial blocksize ~ 100 km). We used the latest JPL Solar System ephemeris (DE432) [3]. We weighted each tracking pass according to its intrinsic noise level (computed after a spline detrending of the Doppler residuals) to prevent down-weighting of the signal attributable to gravity when using arc-by-arc weighting [2]. We slightly relaxed the regularization (Kaula), from $1.25\times10^{-5}/l^2$ to $3.0\times10^{-5}/l^2$, and applied it only at degree l=10 and above. With the addition of low-altitude data, the power spectrum increases globally at degrees 10 to 30; the looser Kaula constraint allows the field's power to follow the expected $4.0\times10^{-5}/l^2$ curve more closely, without substantially degrading southern hemisphere anomalies.

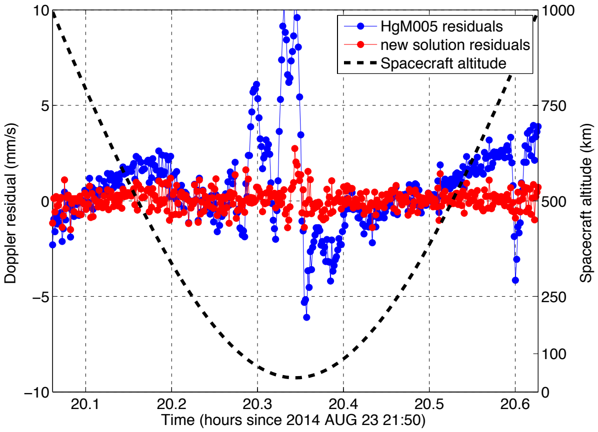

Figure 2. Line-of-sight Doppler residuals (in mm/s) relative to the *a priori* field (HgM005, l_{max}=50) and our new solution (l_{max}=75). Large gravity-related signals at low spacecraft altitude (black dashed curve) were not previously observed.

Results: Our new solution incorporates and accommodates all the low-altitude periapsis tracking data, as evidenced by the reduced Doppler residuals (e.g., Figure 2). Newly resolved short-wavelength features correlate with surface topography and indicate the quality of the field recovery. Figure 3 shows a comparison of the MLA topography [4], the new gravity anomalies, and the HgM005 gravity anomalies for the region (50-85°N, 180-240°E). Strindberg and unnamed craters to its northeast are evident in the gravity map, and Verdi and Purcell can also be discerned. None of those features were resolved in the HgM005 gravity field.

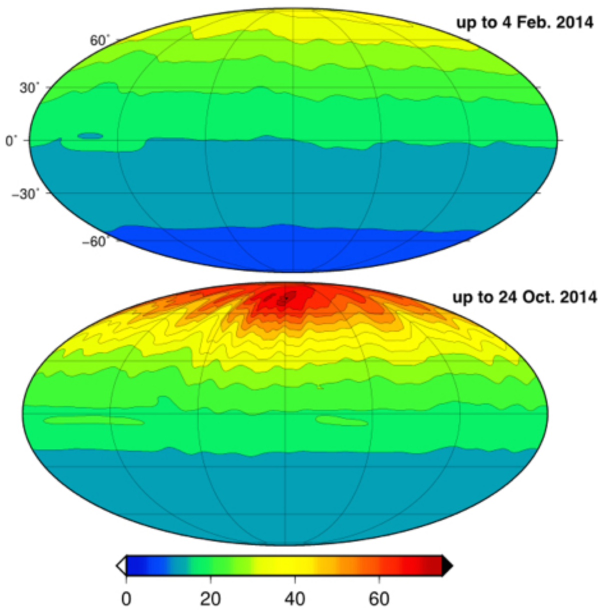

Figure 4. Maps of the degree strength of the HgM005 solution (top) and of our new solution (bottom). Mollweide projection (centered on 0°E).

The uneven low-altitude data coverage (Figure 1) leads to a spatially-variable resolution. As earlier [2], we computed a degree strength map from the full co-variance matrix obtained during the inversion. The degree strength at each location is computed as the degree at which the computed error spectrum intersects the Kaula constraint. Figure 4 shows that whereas the primarily zonal character of the HgM005 degree strength map is still present, specific locations at northern latitudes are now much better resolved than average, up to the maximum expansion degree of 75. Future gravity fields may be expanded to higher degrees to prevent aliasing, as suggested from the power spectrum. We also note that although the degree strength improved substantially at northern latitudes (from ~35 to >75), it increased only from ~15 to ~20 near the equator, because the minimum tracked altitude at non-northern latitudes did not decrease relatively as much because of MESSENGER's high orbital eccentricity (Figure 1).

In addition to the gravity field coefficients, we estimated the Mercury pole orientation and obtained an obliquity value of 2.016 ± 0.092 arcmin, consistent with results from Earth-based radar [5]. We also adjusted the tidal Love number k_2 and the Mercury ephemeris.

Conclusions: Before the end of its mission, MESSENGER will fly at very low altitudes for extended periods of time. Given the orbital geometry, however the periapses will not be visible from Earth and so no new tracking data will be available for altitudes lower than ~75 km. Nevertheless, the continuous tracking of MESSENGER in the northern hemisphere will help improve the uniformity of the spatial coverage at altitudes lower than ~150 km, which will further improve the overall quality of the Mercury gravity field.

References: [1] Solomon S.C. *et al.* (2007), *Space Sci. Rev. 131*, 3-39. [2] Mazarico E. *et al.* (2014), *JGR Planets*, in press. [3] Folkner W.M. (2014), JPL IOM 392R-14-003. [4] Zuber M.T. *et al.*, *Science 336,* 217-220. [5] Margot J.-L. *et al.* (2012), *JGR 117,* E00L09.

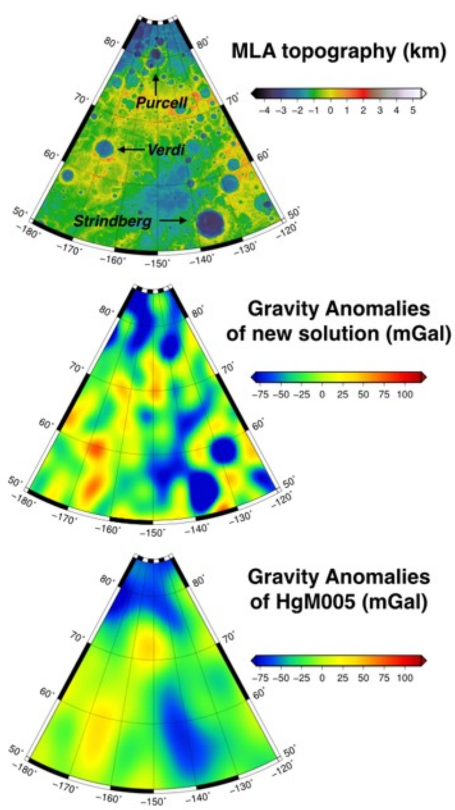

Figure 3. Maps of topography from the Mercury Laser Altimeter (top) and the free air gravity anomaly field of our new solution (middle) and of HgM005 (bottom). Lambert azimuthal projection.