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Mercury's gravity field and ephemeris after 3 years of MESSENGER orbital observations

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18 March 2014 will be the third anniversary of MESSENGER's insertion into orbit about Mercury. The initial orbit was highly eccentric and nearly polar, with a 12-h period and a periapsis at 200 km altitude and $\sim$60°N latitude. The third-body perturbation of the Sun combined with the high eccentricity of the orbit led to a substantial evolution of the periapsis, which drifted slowly northward and reached an altitude of 500 km several times before orbit-corrections maneuvers returned the periapsis altitude to $\sim$200 km. In March 2012, the mission orbital phase was extended for a second year, and the spacecraft transitioned to an 8-h orbit period one month later. A second extended mission started in March 2013, will last for another two years, and will eventually allow observations at very low altitudes (<100 km), starting in September 2014.

One of the main mission goals is the determination of the interior structure of Mercury, enabled by a suite of instruments that includes the radio system and a laser altimeter. The X-band tracking system and NASA's Deep Space Network (DSN) were used to determine the gravity field of Mercury. The effective spatial resolution of the gravity field is strongly dependent on latitude, however, because of MESSENGER's eccentric orbit and its high apoapsis over the southern hemisphere ($\sim$15,000 km in the first year, $\sim$10,000 km subsequently). The gravity field of the southern hemisphere remains largely unconstrained at short wavelengths, although the global long-wavelength field has been determined robustly.

Furthermore, MESSENGER radio tracking data represent an excellent opportunity to improve Mercury's ephemeris. The current knowledge of the orbit of Mercury around the Sun has been mainly defined by direct ranging. Range measurements from the three Mercury flybys and orbital phase of MESSENGER provide a strong data set to measure the motion of Mercury's center of mass. The 1-m range accuracy potentially allows the recovery of the gravitational oblateness of the Sun. This quantity is not only of interest for solar system dynamics but also a fundamental parameter for general relativity and a target for improved determination by the BepiColombo mission.

We summarize the latest analysis of radio tracking data of MESSENGER. Range and range-rate data have been processed to update Mercury's gravity field, expanded in spherical harmonics to degree and order 50, and ephemeris. The inclusion of range data stabilized our solution and mitigated non-gravitational perturbations (such as those from solar radiation pressure and surface thermal emission), which markedly affect the recovery of Mercury's rotational parameters and tides. We also present preliminary results on Mercury's obliquity, libration amplitude, and Love number k2.