GEOID-SHAPE CROSS-SPECTRAL METHOD CONSTRAINS PLANETARY STRUCTURE, COMPOSITION, AND EVOLUTION. J. M. Ménard, R. L. Patton, and A. J. Watkinson. Washington State University, Pullman WA (julie.menard@wsu.edu, rpatton@wsu.edu, watkinso@mail.wsu.edu).

**Introduction:** Gravity-topography cross-spectra for the Earth, Moon, and Mercury all exhibit distinctive, dual low (or negative) values at long wavelengths. Coincidentally, the dual lows in Earth’s spectra, at spherical harmonic degrees \(l=13\) and 6, occur at wavelengths that are one and two times the seismically-known thickness of the mantle, respectively [1]. Here we invert dual lows appearing in the lunar (Figure 1) and hermean (Figure 2) spectra for mantle thickness, and explore some of the geochemical and evolutionary implications of these findings.

**Figure 1: Degree correlation and admittance spectra for the Moon**

**Figure 2: Degree correlation and admittance spectra for Mercury**

**Geoid-Shape Cross-Spectral Method:** Spherical harmonics models of the gravity and topography of a planet can present low or negative correlations, which result from the deformation of competent layers within the planetary body [1]. They are interpreted as transitions between the shape and the structure of the planet [2], and are presented as shape anomaly (Figure 3) and gravity residual (Figure 4) maps, respectively [3]. We find that the material at the surface and depth of each planet is variable, and its response to loading is fundamentally wavelength-dependent [3].

**Spectral analysis of Earth:** At least two patterns can be identified on Earth's gravity-topography correlation spectra: one null, and one near-null correlations, or lows, are present at spherical harmonic degrees \(l=6\), and 13. They correspond to one and two times the seismically-known mantle thickness, respectively. As a result, we can give a good estimation of the mantle thickness for Earth, based solely on its gravity-topography correlation spectrum. The mantle thickness is then used to determine the thickness of the crust, and that of the core.
As crust, mantle, and core thicknesses are composition-dependent, the global composition and internal evolution of the planet can be inferred from mantle thickness.

**Applications to the Moon and Mercury:** The lunar (Figure 1) and hermean (Figure 2) gravity-topography correlation spectra each present dual lows comparable to those present on Earth's spectra.

Lunar dual lows are at spherical harmonic degrees $l=11$ and 21, and hermean dual lows are at $l=10$ and 21. The short wavelength lows relates to the mantle thickness, and the long wavelength lows to two times the mantle thickness.

Using conduction cooling times, we determine that the lunar fossil lithosphere is 3.6 to 3.8 Ga old, and that its mantle used to occupy 30% of the radius, which corresponds to a mantle thickness of approximately 500 km.

Comparatively, the hermean mantle is believed to still occupy 30% of the radius of the planet, which corresponds to a thickness of about 710 km, and is significantly higher than previous estimates [4]. Relating this to moment of inertia and geochemical models allows for a crustal production rate similar to those found on the other terrestrial planets. Similarly, the core composition of Mercury is then comparable to that of the other terrestrial planets.

The bulk composition and internal evolution of the Moon and Mercury can be determined using the dual lows in the gravity-topography spectra of the two planetary bodies. Similar studies can be done for various other planetary bodies.

**Conclusion:** The Moon’s gravity-topography cross-spectrum records a fossil mantle thickness of only 500 km. This shape is likely no younger than 3.6 Ga. Mercury’s gravity-topography cross-spectrum records a mantle thickness of about 710 km, significantly thicker than that estimated previously [4]. A thicker mantle can be reconciled with moment of inertia and geochemical models, suggesting that Mercury’s rate of crustal production is not unusually high.


**Additional Information:** We processed and analyzed gravity and topography models of the terrestrial planets with SHTOOLS v3.4, and visualized the results with GMT v5.1.0.