The Mystery of the Mars North Polar Gravity-Topography Correlation (or lack thereof). R. J. Phillips[1] , W. L. Sjogren[2], and C. L. Johnson[3], [1]Dept. of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130 (phillips@wustite.wustl.edu), [2]Jet Propulsion Laboratory, Pasadena, CA 91109, [3]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington D.C. 20015.

Introduction: Maps of moderately high resolution gravity data obtained from the Mars Global Surveyor (MGS) gravity calibration orbit campaign and high precision topography obtained from the Mars Orbiter Laser Altimeter (MOLA) experiment [1] reveal relationships between gravity and topography in high northern latitudes of Mars. Figure 1 shows the results of a JPL spherical harmonic gravity model bandpass filtered between degrees 6 and 50 contoured over a MOLA topographic image. A positive gravity anomaly exists over the main North Polar cap, but there are at least six additional positive gravity anomalies, as well as a number of smaller negative anomalies, with no obvious correlation to topography.

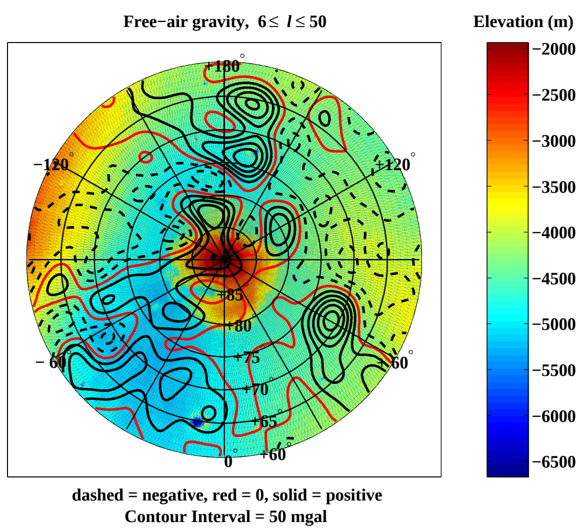

Figure 1. JPL free-air spherical harmonic gravity model contoured over MOLA topography from 60°N to the pole. Gravity model has been bandpassed between degrees 6 and 50.

Polar cap gravity: Focusing on the main cap itself, Figure 2 shows the gravity field bandpass filtered between degrees 12 and 50 contoured over a MOLA topographic image. It is evident that the main cap has an anomaly of about 125 mgal and that Chasma Boreale displays a negative anomaly in excess of –50 mgal. It is also equally clear that there are large uncorrelated positive and negative anomalies surrounding the cap.

Hypotheses for this lack of gravity-topography correlation can be divided into two classes: deep origin and shallow origin. Possibilities for a deep origin include (a) compositionally variable material in the lower crust or upper mantle, and (b) anisostasy of compensating interfaces due to rapid removal of surface material. For shallow origin, the candidates are (a) variation of the ice/rock ratio in the uppermost crust, (b) uncompensated aeolian deposits, (c) uncompensated removal of parts of the polar ice cap, and (d) uncompensated volcanic loads at the surface. It is possible that sedimentary (and volcanic) deposition is so intense and widespread in the north polar and high northern latitude regions of Mars that some of these positive anomalies are in fact mascons residing in ancient impact basins whose topography is buried.

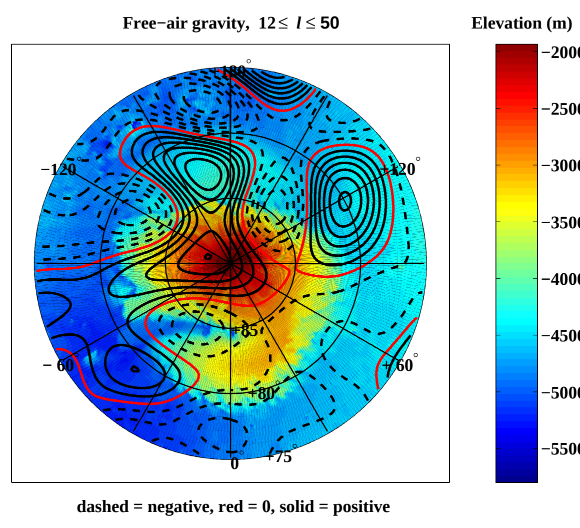

Figure 2. JPL free-air spherical harmonic gravity model contoured over MOLA topography from 75°N to the pole. Gravity model has been bandpassed between degrees 12 and 50.

Figure 3 shows polar passes 404 and 408 ascending from the (predominantly transverse) dune fields of Olympia Planitia onto the main cap. It is immediately obvious that the dune material acting as an uncompensated load cannot explain the gravity signal, which is negative over the highest portion of the dune field on Pass 404 and positive on Pass 408. However, the most negative portion of the gravity signal on Pass 404 is correlated with what may be an eroded “rampart” of the cap.

It is possible that if aeolian and sublimation processes can remove polar cap material faster than the crust and mantle can respond viscously, then the negative gravity anomaly in the vicinity of Pass 404 (see also Figure 2) may be analogous to negative gravity anomalies associated with post-glacial rebound on Earth. The whole of the uncorrelated anomalies surrounding the polar cap may reflect the surface and interior effects of removal of cap material followed by deposition and redistribution of sedimentary deposits derived from the layered terrain of the cap.

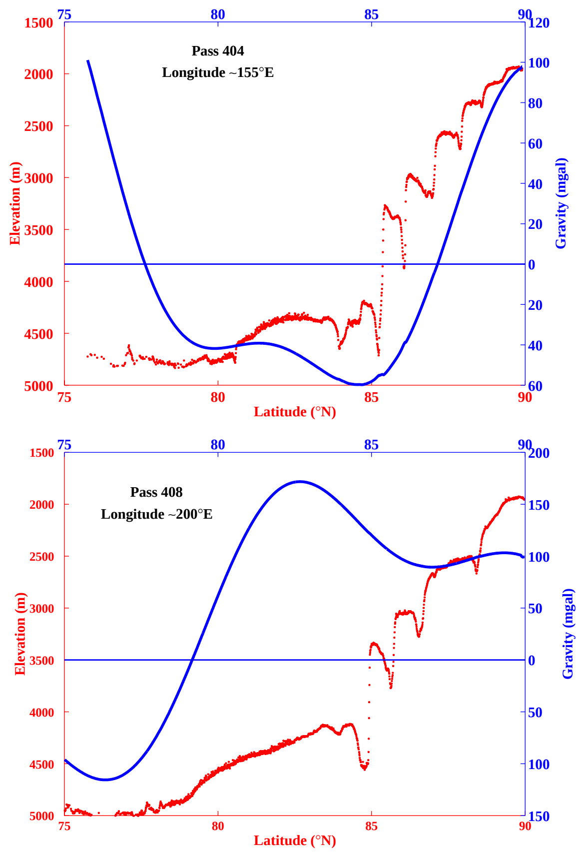

Figure 3. Elevations from MOLA passes 404 and 408, which traversed the North Pole. Also shown are the gravity signals from the spherical harmonic gravity model that has been bandpass filtered between degrees 12 and 50. The gravity signals shown were generated at the latitudes and longitudes of the MOLA surface sampling.

It is equally possible that the anomalies surrounding the cap have absolutely nothing to do with the cap *per se*. Given that the obliquity of Mars changes on time scales of 10^5 to 10^6 years [2], the present position of the cap is ephemeral on the geological time scale of the evolution of Mars. All of the gravity anomalies seen in Figure 1 (except for the cap itself) may have a more ancient origin, possibly related to a time when the planet was more volcanically active.

Modeling:

On the other hand, as noted above (Figure 2), the main portion of the polar cap has a correlated gravity anomaly of 125 mgal. A straightforward geophysical analysis treats the topography of the cap as a load on an elastic spherical shell and calculates the resulting gravity anomaly to compare to the “observed” field (the spherical harmonic gravity solution). The load is supported by a combination of static buoyancy plus flexural and membrane stresses. Preliminary modeling [3] shows that it is possible to get a reasonably good fit between model and data, with misfits typically only a few tens of mgals. A first-order exploration of the parameter space of crustal thickness, lithospheric thickness, and load density revealed the following: The fit of the model to data is insensitive to crustal thickness, produces a lower bound on elastic thickness of about 100 km, and produces a lower bound on load density of 1300 kg m^{-3}. This last result implies that ice and rock material could exist in nearly equal amounts in the North Pole cap.

References:

[1] M. T. Zuber *et al.* (1998) *Science*, *282*, 2053-2060.

[2] W. R. Ward, in *Mars*, 298-320, eds. H. H. Kieffer *et al.* (U. of Arizona, 1992).

[3] C. L. Johnson *et al.* (1999) *Icarus*, submitted.