THE CRUSTAL THICKNESS OF MARS: ACCURACY AND RESOLUTION. D.E. Smith$^1$ and M.T. Zuber$^2,1$. $^1$Laboratory for Terrestrial Physics, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, dsmith@thsiris.gsfc.nasa.gov; $^2$Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139-4073, zuber@mit.edu.

Mars Topography and Gravity Models. Since the arrival of the Mars Global Surveyor (MGS) spacecraft [1] at Mars and its entry into its mapping orbit in February 1999, the radio tracking [2,3] and altimetry data [4,5,6] from the mission have been part of the systematic mapping of the planet and used to develop very precise models of the gravity field and topography of Mars.

Until the altimetry function of MOLA failed on June 30, 2001, the instrument had acquired close to 700 million measurements of the planet’s radius, the majority of which have been used to develop a model of the topography with horizontal resolution of about 500 m and radial accuracy of better than 1 m [5,6]. Concurrently, Doppler and range tracking of MGS by the Deep Space Network at X-band frequencies, with accuracies of about 50 microns/s and about 5 m respectively, have provided orbital knowledge of MGS to the few meter level and enabled the gravity perturbations of the spacecraft to be used to develop improved gravity models of Mars. The recent models [7,8,9] have horizontal resolutions of about 200 km, or degree 65, when expressed in spherical harmonics, and have accuracies of the order of a few mGals at the poles and about 10 mGals at the equator at the highest resolution.

Crustal Thickness. The gravity and topography have been used [10,11] to estimate the crustal thickness of Mars. This estimation is based upon first deriving Bouguer gravity anomalies by removing the effect of topography from the gravity signal, and subsequently interpreting the resulting Bouguer gravity as due to a surface distribution of material of constant density but varying in thickness.

Fig. 1 shows a crustal thickness obtained as in [10] using the latest gravity [9] and topography [6] models, assuming a crustal density of 2900 kg m$^{-3}$ and a density contrast between the crust and mantle of 600 kg m$^{-3}$. Besides the obvious global scale variation in crustal thickness shown in Fig. 1 that has been interpreted previously [10,11,12], are clearly identifiable volcanoes, impact basins and the Valles Marineris, as well as small variations due to the limitations of the gravity data at the shortest wavelengths. In some cases processing has accentuated errors in the smaller and less well determined gravity coefficients; the topography is unlikely to be the cause of these effects because it is known to much higher resolution.

The determination of both gravity and crustal thickness at these shorter wavelengths is important in that they are similar in spatial scale to many impact basins. In principle, the crustal thickness model contains information about the cratering process [13], shallow target properties [14], and the response of the crust to impact events [e.g., 15].

Fig. 2 shows the degree variance of the crustal thickness model in Fig. 1 out to degree 36. The power at degree 36 is about 400 m, approximately 1 percent of the mean crustal thickness of nearly 50 km. The typical size of the noise-like structures seen in Fig. 1 is about 5 degrees, or 300 km, which is equivalent to degree 36 and suggests that the power in the Fig. 2 is too large at these degrees. This observation is supported by the best-fit curve in Fig. 2 that suggests the power is decreasing with degree at less than $1/L$, where $L$ is the degree, and therefore is divergent [cf. 16].

Fig. 3 is a zonal plot of the crustal thickness and reveals small undulations in thickness, particularly in the southern hemisphere. We believe that these features are probably caused by the correlations between the zonal harmonics of the gravity field, and imply a level of caution with regard to the interpretation of crustal thickness anomalies of this scale, 5 to 10 degrees, or 300 to 600 km.

So while it is clear that the most recent MGS gravity models are of excellent quality and resolve spatial structures at scales as fine as degree 65, it is also apparent that the amplitude of the power at such length scales is suspect. Our current best estimate is that crustal thickness models derived from MGS topography and gravity can be quantitatively interpreted to about degree and order 24, or about 450 km.

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Figure 1. Crustal thickness of Mars from MGS between latitudes 70°S and 70°N. The thinnest crust is a few kilometers thick under the Isidis impact basin. The thickest crust is about 90 km under south-central Tharsis.

Figure 2. Degree variance of crustal thickness model crust1025 to spherical harmonic degree 36.

Figure 3. Zonal variation of crustal thickness showing the short wavelength noise-like structure evident in the southern hemisphere and elsewhere. This structure is likely an artifact probably due to correlation and inseparability of high degree zonal coefficients in the gravity field.