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Modeling of surface and subsurface loads for the major Martian volcanoes: Implications for dynamic mantle processes on the planet.

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In the absence of in situ geophysical measurements, modeling the relationship between gravity and topography is one of the few methods that can be used to constrain the properties of a planet's interior. In this study, we model the localized spectral admittance of the large Martian volcanoes by assuming that surface and subsurface loads are elastically supported by the lithosphere. We systematically investigate the misfit function for the entire multi-dimensional space, which includes the elastic thickness, crustal thickness, load density, crustal density, and ratio of surface to subsurface loading. Our analysis represents an improvement over previous studies in several ways. First, our methodology computes the gravity anomaly, surface deflection, and load acting on the lithosphere in a self-consistent manner. Previous studies have not been able to correctly model the case when the load density differs from that of the crust. Secondly, we calculate localized admittance and coherence functions using localizing windows that concentrate almost all of their energy ($\sim$99\%) with the region of interest. Previous studies have employed sub-optimal windows that only concentrate about 92\% of their energy within the desired region. We find that the density of the Martian volcanoes is higher than what was previously published (i.e., $\sim$3200 $\pm$ 100 kg m^{-3}), and is more consistent with the density of Martian basaltic meteorites, which are believed to come either from the Tharsis or Elysium volcanic provinces. The elastic thickness is found to be moderately constrained for Elysium (56$\pm$20 km), Alba Patera (66$\pm$20 km), Olympus Mons (93$\pm$40 km) and Ascraeus (105$\pm$40 km). The crustal density is constrained only for Elysium (3270 $\pm$150 kg m^{-3}). Estimates for the density of the southern highlands crust are generally lower, and this seems to indicate that the northern hemisphere crust is more mafic in composition The crustal thickness was found not to be constrained for

any of the study regions. Finally, the investigation of possible subsurface loads shows evidence for dynamic processes acting under the volcanoes in this study. We found that all volcanoes are better modeled with the presence of less dense material in the upper mantle, which is either indicative of a mantle plume or a depleted mantle composition. The only exception is for Pavonis, where intrusive material in the crust gave the best results. An active plume beneath the major volcanoes is consistent with recent analyses of cratering statistics on Olympus Mons and the Elysium rise, which indicate that some lava flows erupted as late as10-30 Myr, as well as with the radiometric age of the Shergottites which have crystallization ages of about 180 Myr.