ANALYSIS OF MARTIAN GEOID AND TOPOGRAPHY BASED ON TEMPERATURE DEPENDENT LAYERED VISCOSITY MANTLE CONVECTION MODELS. Pavithra Sekhar[1] and Scott D. King[2], Virginia Polytechnic Institute and State University (4044 Derring hall (0420), Blacksburg, VA 24061; pav06@vt.edu[1]; sdk@vt.edu[2]).

Introduction: The Martian areoid (geoid) is dominated by two large highs, one over Tharsis and the other approximately 180 degrees away [1]. The most prominent long-wavelength topographic structures are due to the Tharsis Rise and the crustal dichotomy [2], where the Tharsis rise may be associated with a deeper mantle component [3]. The anti-Tharsis geoid high may be due to elastic deformation of the crust, which in turn may be due to the load created by Tharsis [4]. While Martian surface topography is dominated by the hemispherical dichotomy and Tharsis rise [5] by construction, gravity models have no degree-1 component. Gravity and topography have been used by Neumann et al. [6] to determine crustal thickness. However, due to the non-uniqueness of gravity, there is a tradeoff between Moho topography and internal structure of the mantle. According to Kiefer et al. [7], a significant fraction of the topography and geoid, up to spherical harmonic degree 10, is supported by mantle convection. Kiefer et al. [7] specifically note that degrees 2 through 4 of the geoid and topography are inconsistent with an isostatic model and require deep mantle structure.

Modeling: In this work, mantle convection simulations are performed using finite element code CitcomS [8][9] and [10]. The calculations are performed in a 3D spherical shell with a cold free-slip upper boundary and a free-slip core mantle boundary. We use time-dependent, rather than steady state, stagnant lid convection calculations with a temperature-dependent Newtonian rheology and a layered viscosity structure that includes a viscosity increase by a factor of 8 and 25 at a depth of 996 km [11]. This depth corresponds to the pressure of the phase transition between olivine and spinel and the pressure at which a viscosity increase on Earth is needed to explain the long wavelength geoid [12]. Due to Mars' lower gravity, this transition occurs in the mid-mantle in comparison to the upper mantle on Earth. Hence a viscosity jump might be expected at this depth [11].

We use the geoid and dynamic topographic data from models with different layered viscosity structure, Rayleigh numbers and internal heating values to test whether degree-1 structure is consistent with the observed gravity and topography from the MGS and Mars Odyssey missions.

Results: We have compiled numerous temperature-dependent viscosity calculations using different radial viscosity structures including both uniform viscosity with depth and layered viscosity cases. The layered viscosity models include a viscosity jump at 996 km, where the mantle viscosity is 8 to 25 times higher than the viscosity of the upper mantle; these calculations produce strong degree-1 structures in the thermal field consistent with previous results [11]. The calculations *without* a step increase in viscosity with depth have 10 or more plumes and there is a strong positive correlation between geoid and topography at wavelengths corresponding to the structure of the individual plumes. The models *with* a step increase in viscosity with depth have strong degree-1 geoid and topography components that are anti-correlated. The switch between positively and negatively correlated geoid and topography with the radial viscosity step is consistent with the results of Hager and Richards [12] for Earth.

Discussion: In the calculations with a uniform viscosity with depth there is a strong positive correlation between the geoid and topography and significant power in the short-wavelength harmonics (i.e., higher than degree 5). On the other hand, in the calculations with a layered viscosity structure there is a strong anti-correlation between the geoid and topographic structure and the power is in the low harmonics (particularly degree 1). The fact that the radial viscosity structure impacts the correlation between geoid and topography is not a surprising result [12], however this has yet to be exploited in understanding the dynamics of the Martian mantle. Kiefer et al. [7] showed that degrees 3 and 4 of the Martian geoid and topography are not well correlated and go on to show that these are consistent with the deep mantle structure. The poor correlation between degrees 3 and 4 remains the case in the most recent gravity and planetary shape models for Mars. In our convection calculations, with the exception of degree 1, which is anomalous, the geoid power spectra decreases linearly with degree. Thus we have yet to find calculations with anomalous power in the degree 2-4 geoid that would be consistent with the observations.

Conclusion: Comparing the gravity and topography from convection calculations to the observed gravity and topography fields from the MGS and Mars Odyssey missions provides us the opportunity to test Martian mantle models such as the degree-1 mantle structure.

Roberts and Zhong [11] also show phase transformation between ringwoodite and pervoskite just above the core can also produce degree 1 structure without requiring a step increase in viscosity with depth. We have yet to explore this case.

References:

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