
Introduction. Global maps of the spatial and spectral variation of the geoid/topography admittance of Venus are now available from recent Magellan data [1]. At length scales of 1000 to 5000 km, the admittance varies locally between about 0 and 35 m/km. High admittance values calculated spatially as geoid-topography-ratios (GTRs) by others [2] have been used to suggest the existence of an approximately 300-km-thick thermal boundary layer (TBL) [3, 4]. However, none of the admittance spectra, when considered for a given geographic area [1], or when averaged globally [1, 5], are well explained by primary compensation of topography at a single depth (300 km or otherwise). For the Earth, we have models of interior density constraints based on seismic tomography and plate tectonics. We do not have this luxury for Venus, and must rely on models of mantle convection to produce self-consistent families of interior density variations. We present the results of numerical models of convection which produce admittance spectra with spectral slopes similar to the observed spectra and which have thermal boundary layer thicknesses ranging from 100 to 300 km. The ambiguity in these results suggests that the magnitude of a single GTR estimate or spectral admittance should not be used to constrain the TBL thickness. This observation, combined with estimates of the mechanical plate thicknesses on Venus and their implications for planetary heat loss, suggest that there is no geophysical reason to reject the hypothesis of a 100- to 150-km-thick thermal boundary layer on Venus.

Convection Models. We employ a finite element convection model [6] to investigate the viability of using long-wavelength admittance spectra to constrain TBL thickness. Our computational domain is a full cylindrical annulus. The results presented here are for time-dependent, whole-mantle models from which we calculate topography, geoid, and the resulting admittance as functions of time, position, and wavelength. All models are between 50 and 80 percent internally heated and have a bottom-heated Rayleigh number of 10^6.

The admittance and correlation spectra averaged over the the whole annulus are presented for two different models in Figure 1. For reference, we include the globally averaged admittance and correlation spectra derived from Magellan data [5], and theoretical admittance spectra for Airy compensation at depths of 25, 100, 200, and 300 km. The correlations, while theoretically able to span values from -1 to 1, are effectively 1 for both models, and above 0.5 for the observed values. The TBL thicknesses are calculated by linearly extrapolating the surface geotherm to 90 percent of the interior temperature. The first model has a free-slip top boundary condition and an isoviscous interior, except for a 100-km-thick high viscosity lid, which results in a 250-km-thick TBL. The second model is isoviscous with a no-slip boundary condition at the top, which results in a 180-km-thick TBL. Both models have spectral slopes similar to that observed but with higher magnitudes than observed. None of the three spectra follow that predicted for a single compensation depth. We note that the modelled correlations are significantly higher than the observed values. Since admittances are calculated in a least-squares sense, decreasing the correlation has the effect of also decreasing the admittance.

An Airy compensation mechanism fails to estimate the TBL thickness because it is a static model that does not account for dynamic stresses induced by mantle flow. This is also true for a thermal or Pratt compensation model. The dynamic stresses are, by definition, sensitive to the spatial distribution and magnitudes of interior density anomalies as well as variations in the mantle viscosity structure [7]. Without an observation-based model for the interior density structure of Venus, we cannot constrain the TBL thickness by GTRs or admittances alone.

Discussion. We have previously interpreted the observed admittances in the context of a model in which compressive highland plateaus are remnants of an earlier regime of high crustal strain, the crust presently does not thicken or thin significantly in response to mantle-convective
tractions, and most long-wavelength topography not associated with the earlier regime arises from normal convective tractions at the base of the lithosphere [1]. Given the modelling results presented here, this scenario is able to match qualitatively the slope of the observed admittance spectra. However, these values cannot be used to constrain the average TBL thickness on Venus. Published estimates of mechanical plate thicknesses, $T_m$, based on elastic plate modelling span a range of 15 to 60 km for coronae, rifts, and volcanoes [8-12]. If we assume that this depth corresponds to a mantle temperature of 750°C, that the surface is at 500°C, and that the mantle has an interior temperature of 1250°C, we predict a TBL thickness of 50 to 150 km. We also note that volcanoes have an average surface age between one half and one fourth the average 300 to 500 Ma age of the plains [13,14], and have estimated $T_m$ values in the middle of the 15 to 60 km range [10]. Furthermore, a 50 to 150 km TBL thickness is within a factor of two of that estimated by scaling terrestrial heat flow to Venus, assuming that both planets have identical heat production per unit mass, a similar radial distribution of heat producing elements, and heat loss is solely by steady-state conduction [15]. Given these assumptions [15-17], the estimates of $T_m$ and that single GTRs or admittance values do not constrain TBL thickness, a 100- to 150-km-thick TBL can not be rejected on the basis of any current geophysical inferences. Furthermore, a 300-km-thick thermal boundary layer is neither required nor favored by any geophysical observation.


Figure 1. Bottom: Admittance spectra from two convection models and from the observed geoid and topography fields of Venus. Theoretical admittance curves for Airy compensation of topography at depths of 25, 100, 200, and 300 km are indicated by the labelled thick lines. Top: Correlation spectra for the two convection models and from the observed geoid and topography fields of Venus. The 98 percent confidence level is indicated by the solid line.