GLOBAL ADMITTANCE ESTIMATES OF ELASTIC AND CRUSTAL THICKNESS OF VENUS: RESULTS FROM TOP, HOT SPOT, AND BOTTOM LOADING MODELS.

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Introduction: We have calculated admittance spectra using the spatio-spectral method [14] for Venus by moving the central location of the spectrum over a 1° grid, create 360x180 admittance spectra. We invert the observed admittance using top-loading (TL), hot spot (HS), and bottom loading (BL) models, resulting in elastic, crustal, and lithospheric thickness estimates (T_e, Z_c, and Z_l) [0]. The result is a global map for interpreting subsurface structure. Estimated values of T_e and Z_c concur with previous TL local admittance results, but BL estimates indicate larger values than previously suspected.

Background: The relationship between gravity and topography as a function of wavelength, known as the admittance, can be used to constrain the subsurface structure of a planet [1-10]. Through global mapping our results add to the previous analyses by providing both global and regional context of surface and subsurface structure. In general previous local admittance models for Venus have found values of 20-50 km for Z_c, and 5-55 km for T_e.

Data: Admittance estimates were generated using a 360th degree and order topography model [11], and a 180th degree and order gravity model [12]. Error in the topography is expected to be low, while error in the gravity field limits its use to less than degree 120 [12]. However the degree strength of the gravity field was only calculated using a 120 degree and order model, the actual resolution is thought to be ~33% greater [13], with maximum degree strength locally exceeding 120. The degree strength limitations as well as the error in fitting the observed data with a predicted model are included explicitly in our models.

Method: *Admittance.* Observed and predicted admittance were calculated using a spatio-spectral method [14]. To maximize the resolution of local features a scaling parameter of 2 was chosen [14], corresponding to a maximum Nyquist frequency of ~450 km for a region with a degree strength of 120 [14]. To compensate for the underestimation of the degree strength in the gravity field, the Nyquist degree was set to the published degree strength [12,13].

Spectral Classification. Inverting 64,800 120 band admittance spectra was computationally prohibitive; instead, standard isodata methods for classifying remotely sensed spectra by iteratively identifying class means [15] were used. This approach identified 35 classes of common spectra, covering 89% of the planet.

Inversion of Spectral Classes. Spectral classes were fit with predicted admittance models generated assuming the gravity field was a function of the observed surface and the elastically supported crust-mantle interface topography; the spectra are fit using TL, HS, or BL models [3-10]. TL models assume loading of the elastic lithosphere from the surface, such as by a volcano, while BL models assume loading from the subsurface, such as by a low-density mantle plume. HS models assume both TL and BL loading in the same locale, but at different wavelengths. Isostatic compensation is equivalent to either TL or BL models with a small T_e value.

TL models are a function of T_e, which we constrained to 0-120 km, and Z_c, which we constrained to 0-100 km. A minimum of 5 sets of T_e and Z_c are used to generate a minimum curvature surface, which is searched for minima. Typically 15-25 admittance models are required to identify the best fit between the observed and predicted admittance curves.

The HS and BL models are similar, though there are three parameters defining a volume that must be searched for the best fit: Z_c (0-100 km), T_e (0-120 km), and Z_l (0-300 km), the depth to the density anomaly loading the subsurface. No fewer than 10 points are used to generate a minimum curvature volume; typically 30-70 models are required.

Results: We have successfully fit compensation models to 26 of the 35 spectral classes (**Fig. 1-4**). Our best-fit models identify 15 classes consistent with top loading (39% of the surface), 7 with bottom loading (35%), and 4 with a hot spot model (15%), a total coverage of 89%. The remaining 9 classes (11% of the surface) generally had large amplitude top loading signatures that could not be fit with our models. For the classes that were successfully modeled the estimated range of Z_c (0-90 km) and T_e (0-100 km) is larger than results for most previous studies, primarily because of the incorporation of bottom loading. 47% of the planet has $T_e < 20$ km, for which we cannot distinguish loading from isostasy, suggesting that these regions are tectonically inactive.

The combined parameter estimates for Z_c or T_e generally were consistent within the bottom loading models and the hot-spot and top-loading models (**Fig. 1-2**), though estimates of T_e varied significantly between bottom loading and top or hot spot models. Comparison of T_e and Z_c values for each class reveal that three ranges of T_e are common, including values < 20 km, values between 40-70 km, and a few locations with T_e greater than 90 km (**Fig. 1**). Z_c ranges from 0 to 80 km, for both top and bottom-loading (**Fig. 2**) models. The top-loading results largely are consistent with previous efforts for local regions [14; 16], however, significant differences in T_e and Z_c exist among top-loading features. The bottom-loading results for both T_e and Z_c generally were much larger in range. Z_c values for 50% of the resolved plains were high (~50 km). Bottom loading locations with an unusually high Z_c also were associated with large Z_L values.

Interpretation: A number of possibilities exist to explain the larger T_e values observed for bottom loading. Bottom-loading models may be biased towards deeper values than top loading; terrestrial use of bottom-loading models supports this view [17]. In addition, most previous results were obtained using different gravity fields, typically of degree and order less than 120 and used a wider parameter space than previously considered. Additionally there may be significant variations between short and long wavelength behavior (perhaps driven by global mantle processes), resulting in disparate interpretations for bottom and top-loading models. Possible interpretations include dynamic convective processes and variations in the thickness of a buoyant depleted mantle layer. Rebound following either detachment of the lower crust, due to a basalt eclogite transition, or delamination of the lower lithosphere, is also a possibility. Lastly, our results show large lithospheric variability across geologic provinces and small spatial regions that suggest evidence of paleo-flexure, and/or active lower lithospheric processes.

There are many interesting observations for the four classic Venusian terrains of plains, volcanic rises, crustal plateaus, and chasmata. For example, The observed bottom-loading signature in some plains regions may be derived from either relic downwelling that has experienced isostatic rebound or the influx of warmer less dense lithosphere. At Dione Regio there is a small central region with a large value T_e surrounded by terrain that generally has larger T_e values; Bell and Central Eistla Regiones also are ringed by a narrow band of higher elastic thickness values. At other large volcanic rises (Ulfrun, Themis, Laufey, and Imdr), there is not a clear distinction between the lithospheric properties on and off the rise. Ovda Regio also has much thicker crust than the surrounding plains, which forms a horseshoe shape near the center. Portions of the network of chasmata could not be modeled, though their admittance is consistent with large amplitude top-loading and high T_e.

A key finding is that the lithospheric properties typically vary over scales of 1000 km or less, except in some plains and crustal plateau regions. Both the scale and range of crustal and elastic thickness variations indicate that Venus remains an active planet and that geologic processes may be more complex than previously recognized. In many regions the correlation with surface geology is not obvious, and suggests that deformation of the lower lithosphere and crust may occur with little surface manifestation.

Overall, our mapping admittance results present a very different, more complex view of lithospheric properties on Venus and highlight the need to examine the relationship between small-scale (<1000 km) features and lithospheric properties to fully interpret the geologic history.

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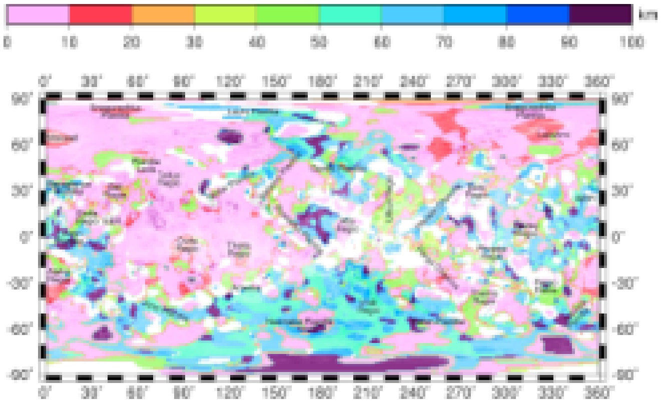

Figure 1. Elastic thickness for top-loaded regions over radar. White regions were not fit.

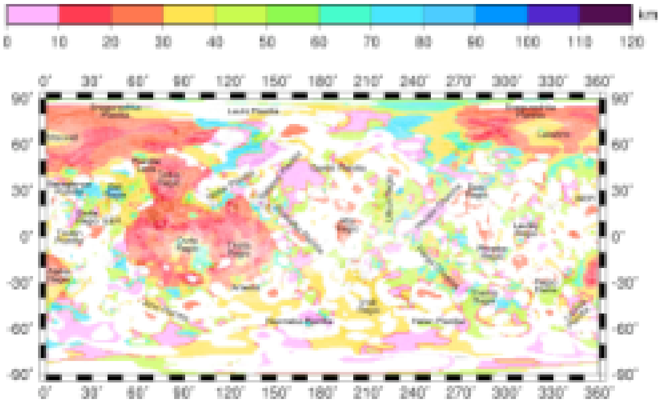

Figure 2: Crustal thickness for top-loaded regions over radar. White regions were not fit.

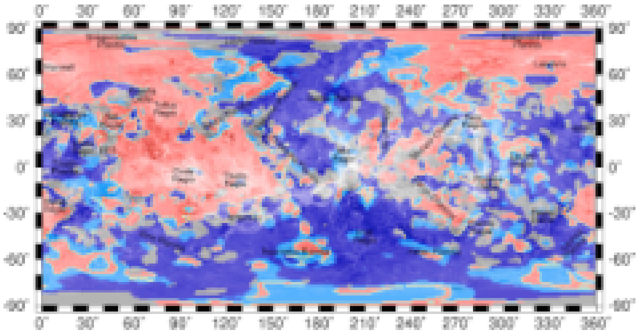

Figure 3: Top (red), hot spot (light blue), and bottom loading (dark blue) regions superposed on Magellan radar reflectivity. Gray regions were poorly fit by all of the models.

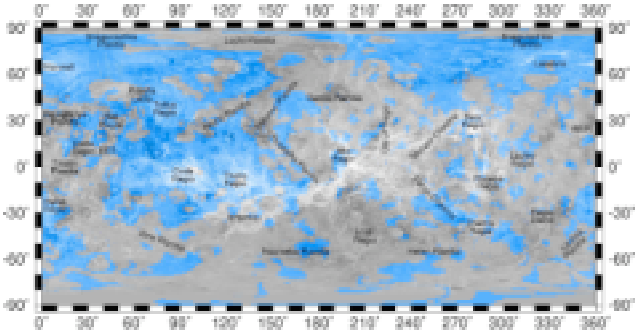

Figure 4: Within the area fit by TL, HS, or BL, the model range allows the blue regions to be fit (though poorly), by isostatic models. Data superposed on Magellan reflectivity data.