CRUSTAL THICKNESS OF VENUSIAN CRUSTAL PLATEAUS. J. S. Maia and M. A. Wieczorek, Observatoire de la Côte d'Azur, Laboratoire Lagrange, Université Côte d'Azur, Nice, France (julia.maia@oca.eu)

Introduction: Venus presents a young surface with a large variety of geologic structures. One of the main types of physiographic features found on this planet are the crustal plateaus, which are reminiscent of continents on Earth. These regions are generally associated with terrains known as tesserae that are strongly deformed and ridged terrains with limited volcanism. They are stratigraphically the oldest units preserved on Venus [1] and are crucial to decipher the tectonic and geodynamic processes that operate on the planet.

It is fairly well accepted that the high topography of these features are associated with some amount of crustal thickening. However, the thickening mechanism is still under debate. The main hypotheses consider the plateaus to be the surface expression of mantle downwelling [*e.g.* 2] or upwelling flows [*e.g.* 3]. More recently, it has been proposed that they were formed by massive melting following asteroidal impacts [4] or that they represent older parts of the crust that were not recycled during hypothesized cathastrophic subduction events, *i.e.* analogues to continental crust [5]. In order to test these formation models it is important to have accurate estimates of interior structure parameters for these regions, such as the crustal thickness (T_c), the elastic thickness (T_e), the relative importance of surface and subsurface loads, and the crustal density. Furthermore, these parameters are key constraints to understanding the thermal evolution of Venus.

The internal structure and lithosphere of a planet can be investigated by using the relation between gravity and topography data. For Venus the most complete set of these data were obtained during the Magellan mission. Most previous investigations of this type were done using initial Magellan gravity models with resolutions from spherical harmonic degrees 60 to 120. Many of these studies adopted spatial techniques (geoid to topography ratios, GTR) [6,7,8], whereas a few used early developed spatio-spectral localization techniques [9,10]. A few recent studies have focussed on constructing global crustal thickness maps [11,12,13].

In this study we compare observed and modeled localized spectral admittances of six crustal plateaus (Alpha, Tellus, Ovda, Thetis, W. Ovda and Phoebe Regiones), in order to revisit possible compensation mechanisms and present new estimations of their elastic and crustal thicknesses. We use the 180 degree gravity model MGNP180U [14] and topography dataset by [15].

Methods: We use the localized spectral analysis technique introduced by [16] to investigate locally the gravity and topography of Venus. With this method we can compute the observed localized admittance spectrum, which is the ratio of gravity and topography as a function of spherical harmonic degree, as well as the correlation between these datasets.

We compare the observed localized admittance with model predicitons from a geophysical loading model presented in [17]. This model treats the planet's lithosphere as a thin elastic shell subject to loads both on and beneath the surface. The subsurface loads are assumed to be in phase with the surface loads and two internal load arrangements are examined: either as a buoyant layer in the mantle, such as a mantle plume, or a dense layer within the crust, such as a magmatic intrusion. How much the lithosphere deflects is driven by its elastic thickness.

The model contains 4 primary free parameters, which are the elastic thickness, crustal thickness, crustal density and the subsurface loading parameter L, which indicates the ratio between surface and subsurface loads. The mantle density, Poisson's ratio and Young's modulus were set to constants based on representative values of Earth. We also fixed the crustal density to 2800 kg m^{-3} since our model was found to be largely insensitive to this parameter. Two more restrictive models were also tested: one only contained surface loads (with L set to 0), and the other used the assumption of Airy isostasy ($T_e = 0$).

Once the lithospheric deflection is computed we estimate the gravitational potential of the planet [15]. Then, we recompute the gravity field at the local radius of the analysis region and compute the localized admittance using a single localization window. Finally, we constrain the lithospheric properties of each region by calculating the root-mean-square misfit between the observed and estimated admittances. For each parameter we estimate the accepted range of values by defining a threshold based on the average of the admittance uncertainties.

Results: In Figure 1 we present the observed admittance and spectral correlation for Alpha Regio along with the best fitting predicted admittance curve. The spherical harmonic degree interval chosen to perform the fit is based on the degree strength in the region and the window size adopted in the localization procedure. For Alpha, our model fits the data well in this region for $T_e = 20^{+14}_{-10}$ and $T_c = 15^{+6}_{-14}$. The best fitting model does not have subsurface loads ($L = 0$), although the presence of a small dense layer in the crust is acceptable within uncertainties.

In general, the parameter values obtained for Alpha Regio are representative of the other crustal plateaus, with the exception of Phoebe Regio (discussed below) where the presence of a buoyant plume in the mantle suggested. For these regions, the absence of a buoyant mantle layer, combined with best-fitting loading parameters

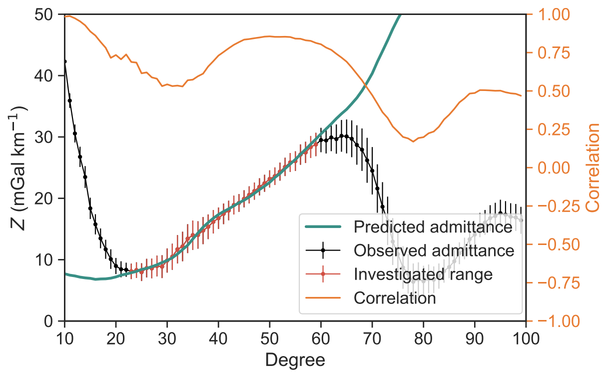

Figure 1: Observed and best-fit admittance curves for Alpha Regio. Points in red represent the degree range used to calculate the misfit between model and observations. We used a window size with a 16° radius and spectral bandwith of 16.

equal or very close to zero, shows that the plateaus are predominantly supported elastically by the lithosphere, as concluded in previous works [*e.g.* 10]. Furthermore, the best-fitting T_e for these regions vary from 5 to 25 km, but an elastic thickness of zero is acceptible for most cases, meaning that we cannot distinguish between flexural compensation and Airy isostasy.

The crustal thicknesses obtained for the six regions analyzed in this work are presented in Figure 2, all investigated using three different models. The stars represent the thickness when we allow the three studied parameters to vary, the crosses show estimations when only surface loads are considered, and the plus signs display results for the case of Airy isostasy. Finally, the dots show crustal thickness esimates of previous studies, where blue shades denote spatial analysis, browns are from spectral analysis and pink represent the use of global crustal thickness modeling.

The three analysis assumptions we tested give similar results for Ovda, Thetis, Alpha, Tellus, and W. Ovda. As expected, decreasing the number of free parameters reduces the uncertainties. When subsurface loads are included, only an upper bound on the crustal thickness is obtained. Assuming only surface loads and allowing T_e to vary, the crustal thickness is quite uniform among all units, ranging from 10 to 35 km. In most cases, when using the Airy isostasy model we obtain good fits with very narrow uncertainties. Our estimations are more consistent with results from spectral studies [9,10,11], while GTR analysis generally give thicker values [6,7,8].

Phoebe Regio is the only exception in our analysis. When internal loads are not included the crustal thickness values are above 60 km, which is about twice as large as for the other regions. Only for this region does the inclusion of subsurface loads have a large affect on the results. When subsurface loads are included, the best fitting crustal thickness is reduced to 20 km which is compatible with the other crustal plateaus. Of the regions studied, Phoebe is thus the only one that likely requires the support from an underlying mantle plume. Phoebe is also unique with respect to other plateaus in that its surface geomorphology is transitional between crustal plateaus and volcanic rises [*e.g.* 3].

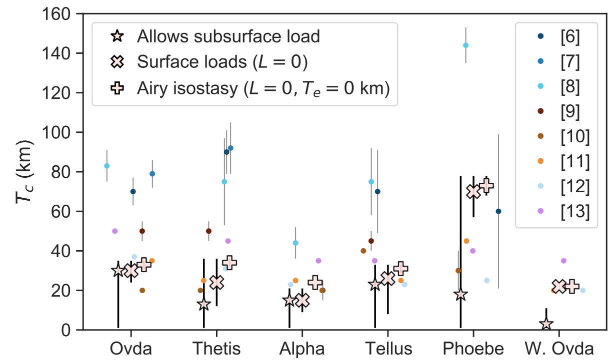

Figure 2: Crustal thickness estimations for the crustal plateaus. The three compensation models of this study are shown in light pink. The dots show previous studies results, blue shades are GTR studies, browns are spectral analysis and pink represents global crustal thickness modeling.

Conclusion: This study used a localized admittance analysis along with a lithospheric flexural model to investigate the internal structure of crustal plateaus on Venus. We found that T_e varies between 0 and 30 km, considering uncertainties. Furthermore, with the possible exception of Phoebe Regio, there is no need to add subsurface loads. Therefore, the studied regions are mostly consistent with the hypothesis of Airy isostasy.

The three models tested give similar results for the crustal thickness, with the exception of Phoebe. The thickness range found is similar to that found for Earth. These values show that the volume of crust on Venus over the total silicate volume is comparable to what is estimated for Earth, of $\sim 1\%$, while for Mars and the Moon they are around 5% and 8%, respectively [18]. Hence, Venus appears to produce crustal materials at a similar rate as Earth's.

References: [1] Ivanov M. A. & Head J. W. (2011) *Planet. Space Sci., 59*; [2] Bindschadler D. L. et al. (1992) *JGR, 97*; [3] Phillips R. J. & Hansen V. L. (1998) *Science, 279*; [4] Hansen V. L. (2006), *JGR, 111*; [5] Romeo, I. & Capote, R. (2011) *Planet. Space Sci., 59*; [6] Smrekar, S. E. & Phillips, R. J. (1991) *EPSL, 107*; [7] Kucinskas, A. B. & Turcotte, D. L. (1994) *Icarus, 112*; [8] Moore, W. B. & Schubert, G. (1997) *Icarus, 128*; [9] Grimm R. E. (1994) *Icarus, 112*; [10] Simons M. et al. (1997) *Geophys. J . Int, 131*; [11] Anderson, F. S. & Smrekar, S. E. (2006) *JGR, 111*; [12] James, P. B. et al. (2013) *JGR-Planets, 118*; [13] Jiménez-Díaz, A. et al. (2015) *Icarus, 260*; [14] Konopliv A. S. et al. (1999) *Icarus, 139*; [15] Wieczorek, M. A. (2015) *Treat. Geophys., 10.05*; [16] Wieczorek, M. A. & Simons F. J. (2007) *JFAA, 13*; [17] Broquet A. Wieczorek M. A. (2019) *JGR-Planets, 124*; [18] Wieczorek M. A. and Zuber M. T. (2004) *JGR, 109*.