CONSTRAINING VENUS' CONVECTION REGIME FROM BALTIS VALLIS TOPOGRAPHY. Nathan J. McGregor[1] (nmcgregor@ucsc.edu), F. Nimmo[1], C. Gillmann[2], G. J. Golabek[3], A. M. Plattner[4], and J. W. Conrad[5], [1]University of California Santa Cruz, Santa Cruz, CA, [2]Rice University, Houston, TX, [3]University of Bayreuth, Bayreuth, Germany, [4]University of Alabama, Tuscaloosa, AL, [5]NASA Marshall Space Flight Center, Huntsville, AL

Introduction: Baltis Vallis (BV) is a 6,800-km long lava channel on Venus with a present-day uphill flow direction (Fig.1). The apparently uphill flow must be a consequence of deformation changing the topography after flow emplacement. The topography of BV thus retains a record of Venus' convection history, as mantle convection causes time-dependent surface deformation [1]. [2] identified two wavelengths of deformation: ~300 km due to tectonic deformation and ~2000 km (Fig. 1). This 2000-km length scale is comparable to the thickness of the Venusian mantle, strongly suggesting that mantle convection is responsible for the observed deformation.

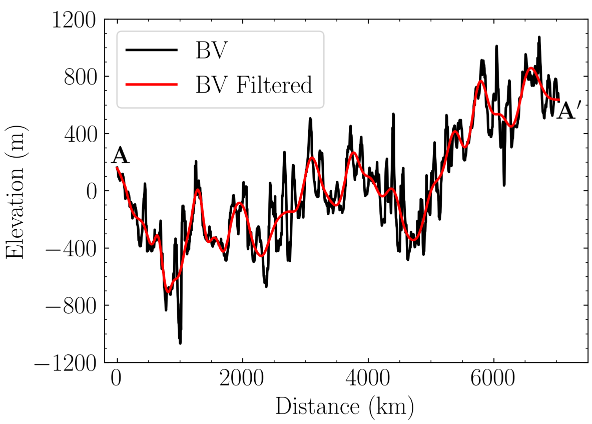

Figure 1: Original and filtered topographic profile of BV. A and A′ mark the inferred source and termination points, respectively. Short wavelengths are removed to highlight the long-wavelength deformation caused by mantle convection.

Venus' mean surface age is likely in the range 300-500 Ma [3-9]. The observed deformation of BV indicates that mantle convection was active over the past ~400 Myr and provides constraints on the length scales and vertical amplitudes involved [10]. We place constraints on Venus' present-day internal structure and dynamics (e.g., viscosity and heat flux) by comparing dynamical topography produced by numerical convection codes with the topography of BV.

Methods: We simulate time-dependent stagnant-lid mantle convection on Venus with a suite of coupled interior-surface evolution models [11-13] for a range of assumed mantle properties (Fig. 2).

We compare the simulated topographies of model BV profiles to the actual topography of BV using two metrics. The first metric is the root-mean-square (RMS) height [14]. A model is considered successful if its RMS height is similar to the RMS height of BV. The second metric is the "decorrelation time". Given a particular model time τ, the correlation between model BV topography at a later time τ_2 and an earlier time τ_1 is calculated. When this correlation first falls to zero, the decorrelation time is then $\tau_2 - \tau_1$. The decorrelation time is inspired by the observation of BV's present-day uphill flow and the inference that the present-day topography must be uncorrelated with the original topography when BV formed flowing downhill (Fig. 3). We compare this decorrelation time to the surface age of Venus (~400 Ma). A model is considered successful if the decorrelation time is less than the surface age of Venus.

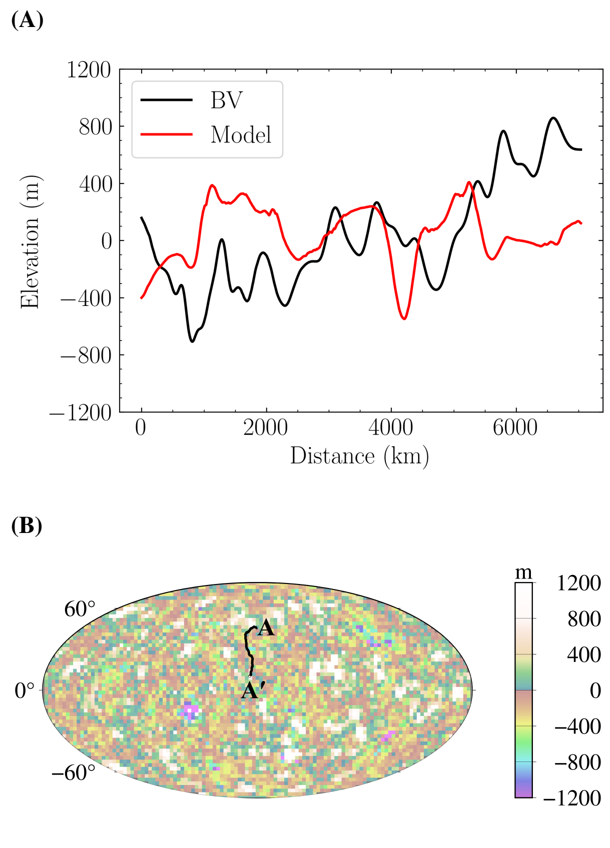

Figure 2: A snapshot from one of our convection models. (A) Filtered BV and model topographic profiles. (B) Model dynamic topography across Venus' surface with BV indicated.

For each model time-step, we obtain a range of topographic profiles by rotating BV's location on the sphere. We exclude the first 200 Myr of simulated mantle evolution from consideration to allow the simulations to stabilize.

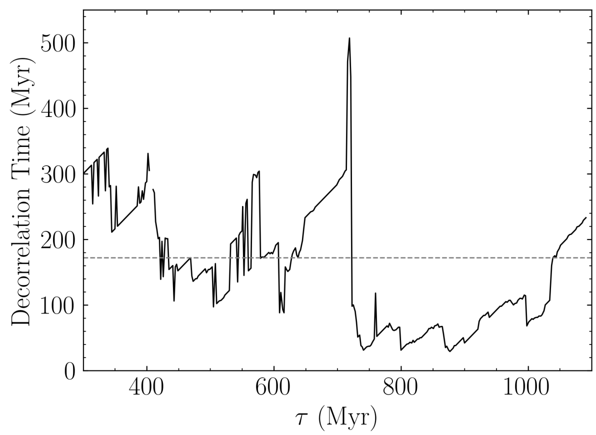

Figure 3: Decorrelation time (see text) as a function of the model time τ excluding the first 300 Myr of simulation for a single model (VL3). The dotted line shows the median decorrelation time for this model.

Results: From 14 mantle convection models, each initialized with different parameters, we identified two convection models, VL3 and L3, that best fit our metrics (Fig. 4). VL3 and L3 have a viscosity contrast $\Delta\eta$ of 10^8 and 10^7, respectively, and both have a Rayleigh number Ra of 10^8.

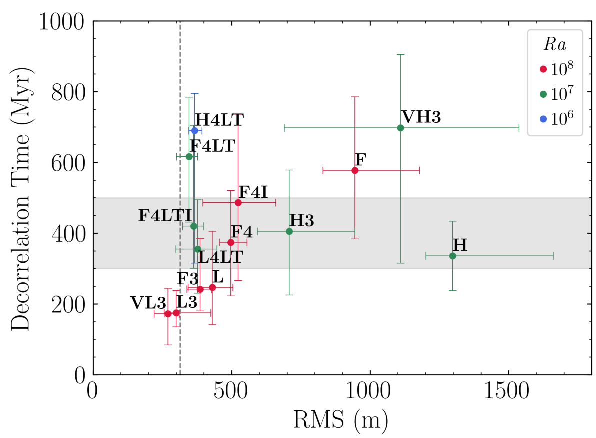

Figure 4: Decorrelation time and RMS height of our 14 mantle convection models. Color indicates the Rayleigh number Ra. Black dashed line shows BV's RMS height. The shaded region indicates the likely formation ages of Venus' canali [15]. Error bars are interquartile ranges.

Although Venus' heat flux is highly uncertain, our model fluxes (Fig. 5) are consistent with some inferred heat fluxes (10 to 60 $\mathrm{mW/m^2}$, [16] and 101 $\pm$ 88 $\mathrm{mW/m^2}$, [17]). Models with higher total surface heat fluxes tend to yield lower decorrelation times; our favored models have some of the highest heat fluxes. We also find that models with a higher Ra tend to have a lower RMS height, in agreement with [18].

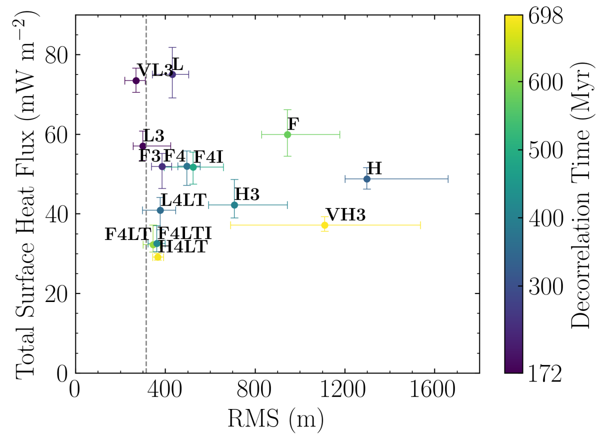

Figure 5: Total surface heat flux and RMS height of each model. Color indicates decorrelation time. BV's RMS height is plotted as a vertical line. Error bars are interquartile ranges.

Conclusions: Our favored models (VL3, L3) have vigorous convection beneath a stagnant lid, and high surface heat fluxes. The viscosity of the lower mantle in these models is $\sim 10^{20}$ Pa s, roughly two orders of magnitude lower than that of Earth's. The majority of the surface heat flux is due to melt advection, indicating high rates of volcanic resurfacing. While current data are insufficient to test these predictions, the selection of several new Venus missions will change this situation in the next decade. Once paired with these forthcoming observations, our work will be able to bring Venus' interior into sharper focus.

References: [1] Jindal et al. (2018) *COSPAR* B4.1. [2] Conrad et al. (2021) *LPSC* 2548. [3] Phillips et al. (1992) *JGR* 97. [4] Schaber et al. (1992) *JGR* 97. [5] Komatsu et al. (1993) *Icarus* 102. [6] Strom et al. (1994) *JGR* 99. [7] Herrick et al. (2011) *JGR:Planets* 116. [8] Le Feuvre et al. (2011) *Icarus* 214. [9] O'Rourke et al. (2014) *GRL* 41. [10] King (2018) *JGR:Planets* 123. [11] Armann et al. (2012) *JGR:Planets* 117. [12] Gillmann et al. (2014) *JGR:Planets* 119. [13] Gillmann et al. (2016) *Icarus* 268. [14] Shepard et al. (2001) *JGR:Planets* 106. [15] Williams-Jones et al. (1998) *JGR:Planets* 103. [16] Smrekar et al. (2012) *IPM* 1683. [17] Smrekar et al. (2022) *Nat. Geosci.* [18] Guimond et al. (2022) *PSJ* 3.