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Mantle dynamics models for Venus – comparison of spatial and spectral characteristics of inferred gravity anomalies and topography with observations

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Venus and Earth have similar size and probably also core radius, such that many results that have been obtained for Earth's mantle could apply to Venus as well. Yet a fundamental difference between the two planets is that Earth features plate tectonics, whereas Venus appears to be in the rigid lid regime. From a variety of constraints, a substantial increase of viscosity with depth in the Earth's mantle, reaching around 10**23 Pas in the lower mantle above D", can be inferred. Mantle convection models with a sufficiently high temperature as boundary condition at the core-mantle-boundary invariably yield thermal plumes. With a rigid lid as upper boundary and the high lower mantle viscosity, mantle dynamics models typically yield around 10 plumes, which are long-lived (hundreds of Myr lifespan) and slowly moving (typically < 1cm/yr). These modelling results appear to match well with the distribution of volcanism in space and time as inferred from observations.

Besides volcanism, topography and gravity anomalies can yield further insights towards the internal dynamics of Venus: If we assume the same spectrum (in terms of spherical harmonic expansion) of thermal density anomalies, as inferred from tomography models on Earth, and a similar radial viscosity structure, except without viscosity jump at the spinel-perovskite transition on Venus, we find that we can match most of both the gravity and topography spectrum on Venus up to about degree 40. This probably implies that – in contrast to Earth – topography on Venus is mostly dynamically supported from within. The main exception is degree two gravity on Venus, which is much less than predicted, implying that the mantle on Venus has much less degree-two structure, and therefore probably no features corresponding to the Earth's Large Low Shear wave Velocity Provinces (LLSVPs).

Here we focus on predictions from dynamic models: We compare model predictions of mantle density anomaly spectra for both Earth (where we prescribe subduction zone locations for the past 300 Myrs, and a chemically different basal layer, corresponding to the LLSVPs) and Venus (no subduction or chemical anomalies) with each other and with tomography. We compare predicted gravity and topography spectra for these models, and typical modeled gravity and topography profiles across plumes, with observations. This allows us to further constrain viscosity structure and elastic lithosphere thickness, and address the question whether all observations can be explained by thermal convection only, or compositional anomalies play a role on Venus as well.