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Geoid and topography on Venus: Isostatic or dynamic?

Rens Elbertsen[1], Paul Tackley[2], and Antoine Rozel[2]
[1]Department of Earth Sciences, Utrecht University, the Netherlands
[2]Institute of Geophysics, Department of Earth Sciences, ETH Zurich, Switzerland

Venus is commonly described as Earth's slightly smaller twin planet. However, the dynamics of plate tectonics present at Earth are not observed at Venus. Gravity and topography are key observations to help understand the interior dynamics of a planet. On Earth, the long-wavelength geoid and total surface topography are not well correlated, with the interpretation that total surface topography is mainly due to the ocean-continent dichotomy whereas geoid reflects density anomalies deep in the mantle, mainly caused by subducted slabs. Dynamic surface topography is small compared to the total surface topography. On Venus, in contrast, the geoid and topography are well correlated, indicating a more direct connection between convection and the lithosphere and crust.

For Venus, two end-member origins of geoid and topography variations have been proposed: 1) Deep-seated (i.e. below the lithosphere) density anomalies associated with mantle convection, which may require a recent global lithospheric overturn to be significant [1][2][3]. 2) Variations in lithosphere and crustal thickness that are isostatically compensated - the so-called "isostatic stagnant lid approximation" [4][5], which appears consistent with simple stagnant-lid convection experiments.

Here we analyse 2-D and 3-D dynamical thermo-chemical models of Venus' mantle and crust that include melting and crustal production, multiple composition-dependent phase transitions and strongly variable viscosities to test whether variations in crust and lithosphere thickness explain most of the geoid signal [4][5], or whether it is caused mostly by density variations below the lithosphere, and thus, what we can learn about the crust, lithosphere and deeper interior of Venus from observations, as well as which tectonic mode is most likely to explain the observed geoid signal. Multiple input parameter sets are used to recreate the end-member scenarios of stagnant-lid and episodic-lid tectonics and to investigate the influence of the different rheological parameters. Characteristic snapshots of simulations showing end-member tectonic behaviour are analysed to determine the depth ranges of heterogeneities that are the predominant influence on topography and geoid variations. Findings will also guide future efforts to combine gravity and topography observations to infer lithosphere and crustal thickness and their variations (e.g. [6][7]).

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