DYNAMIC MODELS FOR VENUS'S LONG-WAVELENGTH GEOID

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Unlike on Earth, long-wavelength geoid anomalies and topography correlate well on Venus(1). Previous investigators attempted to explain the strong positive correlation as due to deep isostatic compensation(2), but Venus's admittance curve(the spectral ratio of geoid to topography) for harmonic degrees 2 to 18 is inconsistent with either Airy or Pratt isostasy(3). Moreover, the required isostatic compensation depth of 150 to 300 km occurs at too large a depth for there to be any long term elastic strength(4). On the other hand, the admittance curve is consistent with dynamic support from mantle convection(3). In dynamic models, the admittance is sensitive to radial viscosity variations but relatively insensitive to the radial distribution of the density contrasts which drive the convective flow.

We have considered three different types of dynamic model: whole mantle convection, convection with a chemical boundary at 700 km depth separating the upper and lower mantles, and convection with a chemical boundary separating a crust of about 100 km thickness(5) from the underlying mantle. A whole mantle convection model with a high viscosity surface layer overlying a uniform viscosity mantle reproduces the observed admittance and can account for 70% of the variance in the degree 3 to 18 geoid. In Figure 1, we compare Venus's observed geoid with the geoid predicted by this model. A similar viscosity profile can also match the observed admittance in the chemically layered mantle model, provided that the upper and lower mantle convection cells are thermally coupled. On the other hand, models with a chemically stratified crust require a strong increase in viscosity with depth in order to reproduce the observed admittance. It may be possible to distinguish between these models by comparing their predicted lithospheric stresses with observed tectonic features(6). Based on the distribution of highlands, our preliminary opinion is that the whole mantle convection model is preferable, with the highlands occurring over mantle upwellings.

On Earth, the effective viscosity deduced from geoid modeling increases by a factor of about 300 from the asthenosphere to the lower mantle(7), whereas on Venus the mantle viscosity may be approximately constant with depth. Venus may lack an asthenosphere if it is on average cooler than Earth and hence substantially below the solidus in the upper mantle. Alternatively, the viscosity estimates for both planets may be biased by neglect of lateral viscosity variations. When compared with the laterally averaged radial viscosity profile determined from geoid modeling, the presence of hot, low viscosity plumes causes an underestimate of the increase in viscosity with depth, while high viscosity subducted slabs cause an overestimate of the increase in viscosity with depth (8). Thus, the different effective viscosity profiles for Venus and Earth may reflect their convective styles, with tectonism and mantle heat transport dominated by hot plumes on Venus and by subducted slabs on Earth. Convection at degree 2 appears much stronger on Earth than on Venus. A degree 2 convection structure may be unstable on Venus but may have been stabilized on Earth by the shielding effects of the Pangean supercontinental assemblage.

References

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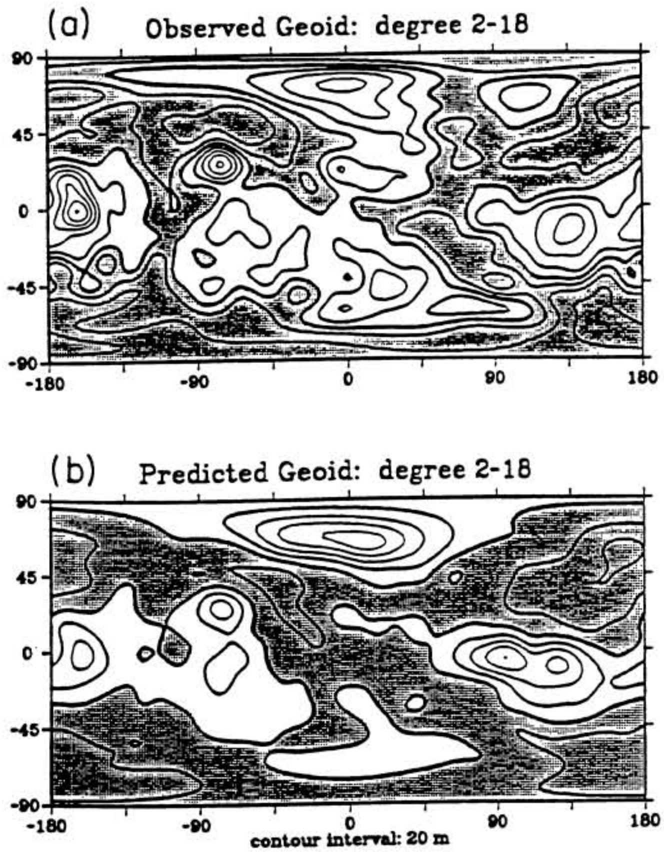

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Figure 1. Comparison of Venus's observed and dynamically predicted geoids. Fig. 1a is the observed geoid at degrees at degrees 2-18 and Fig. 1b is the dynamically predicted geoid for whole mantle convection in a uniform visosity mantle which is overlain by a high viscosity surface layer. Cylindrical equidistant projection. The contour interval is 20 m; lows are shaded. From Kiefer et al., Geophys. Res. Lett., in press 1986.