VENUS: GRAVITY, TOPOGRAPHY AND ISOSTATIC COMPENSATION

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Recently derived spherical harmonic models of Venusian topography (1) and gravity (2) reveal a number of interesting features of the planet. Both models are complete to eighteenth degree and order. The gravity model has been derived from 336 orbital arcs of low altitude (150-200 km at periapsis) tracking data and 78 arcs of higher altitude (950-1350 km at periapsis) data from Pioneer Venus Orbiter (PVO). Compared to a tenth degree model (3), which is based on the 78 high altitude arcs only, the current model provides a significant improvement in resolution and fidelity. For the low altitude arcs alone, the variance of the residuals for the present model is 18% of the data variance, compared to 48% for the tenth degree model. The topographic model was derived from $1^{o}x1^{o}$ averages of PVO radar altimeter data which cover 93% of the surface. Though an eighteenth degree harmonic series has limited resolution (10^{o} half wavelength) compared to the data spacing, it reproduces a significant fraction (81.7%) of the total variance in the $1^{o}x1^{o}$ data.

Venus differs significantly from the Earth in that it exhibits a significant correlation between long wavelength topography and gravity (figure 1). One way of understanding this situation is to consider that the observed gravity reflects both a "coherent" component, due to topography plus any compensating mass, and an "incoherent" contribution from those internal density variations which do not correlate with topography. It thus appears that the "incoherent" component (presumably dominated by processes at plate margins) is much more significant on Earth than on Venus.

The relative amplitudes of the gravity and topography harmonics provide information on the state of isostatic compensation. If we assume that the compensation mechanism is linear, the relationship between harmonic coefficients of gravity (G_{nm}) and topography (H_{nm}) can be expressed as

$$G_{nm} = F_n H_{nm} + I_{nm}$$

where F_n is a spectral admittance, whose value will depend on details of the compensation mechanism (4,5,6) and I_{nm} is the residual or isostatic anomaly. Figure 2 compares the empirically determined admittance with theoretical values for two different compensation models (7,8). For local Airy type compensation (dashed line), the topography is considered to be a load emplaced upon (and thereby deforming) the underlying surface. An alternative model (solid line) considers that both the surface topography and the gravity are responses to primary internal density variations. The internal loading model, in addition to its a priori plausibility, gives a much better fit to the observations. The actual admittance values suggest a globally averaged effective depth of compensation of 130 $\pm$ 40 km.

An isostatic anomaly map reveals fairly significant regional departures from the global average compensation mechanism. In particular, there are positive isostatic anomalies associated with the elevated terrains of Atla, Beta, Thetis and Tethus regiones, there is no appreciable anomaly at all over most of Ishtar terra, and negative anomalies are associated with both the low lying Helen and Aino planitia and with the highlands of Ovda regio. These positive and negative anomalies respectively imply compensation at depths greater than and less than the global average.

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VENUS GRAVITY

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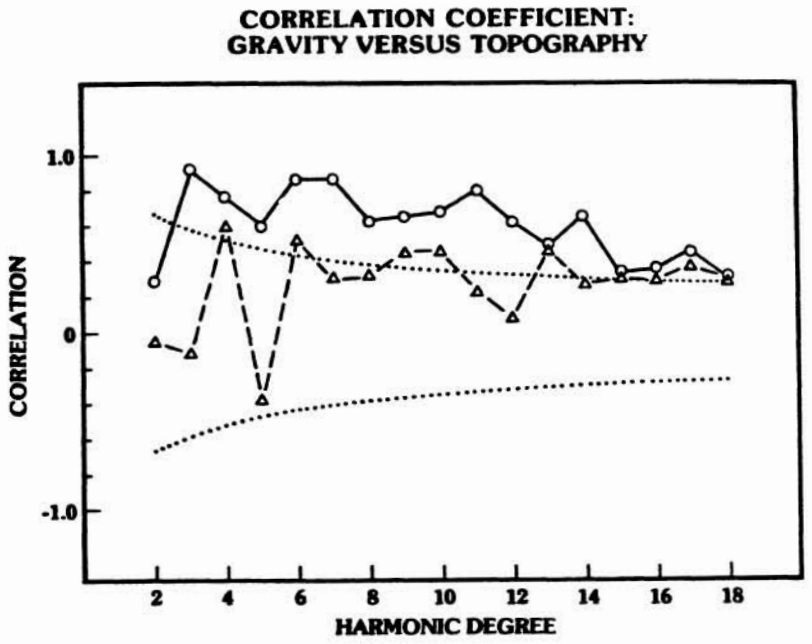

Figure 1. Correlation coefficients for gravity versus topography are compared for Venus (solid line) and Earth (dashed line). Also shown are 95% confidence limits for these coefficients (dotted lines).

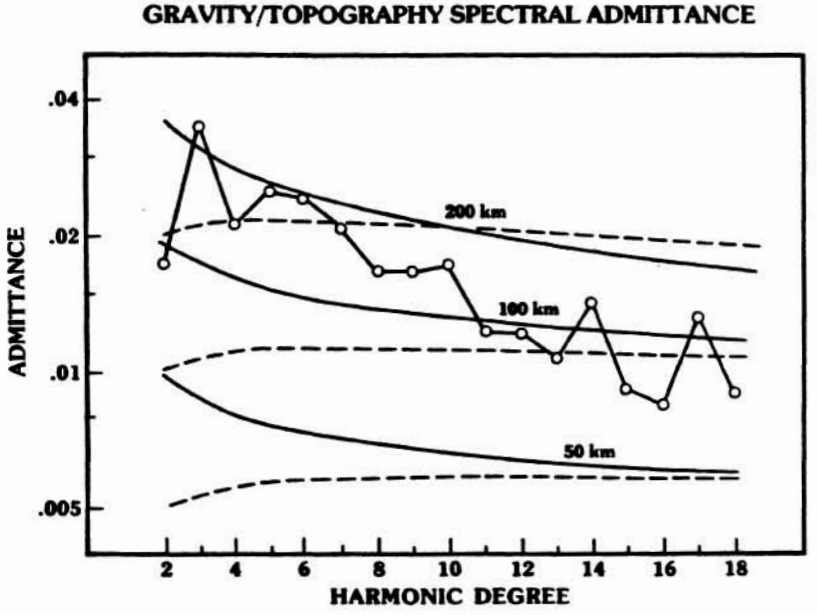

Figure 2. Empirical gravity/topography spectral admittance for Venus is compared to theoretical values for internal loading (solid lines) and surface loading (dashed lines) for various depths of compensation. The density of surface material is assumed to be 2.70 g cm^{-3}.