EFFECTIVE ELASTIC THICKNESS OF THE VENUSIAN LITHOSPHERE WITH LATERAL VISCOSITY VARIATIONS IN THE MANTLE. Louis Moresi, Seismological Laboratory 252–21, California Institute of Technology, Pasadena, CA 91101.

Both the Earth and Venus have a convecting mantle at the top of which is a relatively strong, mechanical boundary layer. The surface topography and gravity signals which result from the convection within the viscous mantle are modified by the elastic properties of this lithospheric boundary layer. In particular the ability of the of the lithosphere to support loads and transmit stresses from below is a function of the wavelength of the load — the lithosphere is strong to loading at shorter wavelengths [1]. As a consequence it is usual to expect that long wavelength topography cannot be supported by the mechanical strength of the lithosphere and must be compensated — isostatically or dynamically — within the uppermost mantle or the crust [2]. The flexural rigidity of the lithosphere can therefore be determined by estimating the greatest wavelength at which uncompensated surface topography can be supported, usually by measuring the admittance as a function of wavelength [3,4]. In fact this procedure for determining the elastic thickness relies upon being able to distinguish topography with underlying support from that supported by the brittle lithosphere on the basis of their each having a characteristic value of the admittance. However, in the presence of lateral viscosity variations in the mantle, it is possible for topography to be generated which is NOT compensated by density anomalies in the underlying mantle at the same wavelength. Although this effect is not likely to be important for the Earth, on Venus, where the high surface temperatures would be expected to give a weaker lithosphere, lateral viscosity variations in the mantle can give a misleadingly large apparent elastic thickness for the lithosphere.

In the Earth the strength of the oceanic lithosphere is sufficient to mask signals from the mantle with a wavelength greater than about 500 km — the elastic thickness corresponds to the depth to the 300-600°C isotherm [5,6]. On Venus, the higher surface temperature should lead to a smaller lithospheric elastic thickness allowing the surface expression of shorter wavelength topography with origin in mantle convection processes. Flexural models for Venus produce ambiguous results for the elastic thickness of the lithosphere. For mountainous areas a value between 10 and 20 km is obtained [7] whereas subduction models of coronae require a value of 30–40 km [8] which is very similar to that of oceanic lithosphere on the Earth.

Zuber and Nerem recently suggested that a regionally averaged effective elastic thickness could be obtained for Venus in areas where high quality gravity and altimetry data coexist [9]. If, however, the lithosphere of Venus is truly weak and short wavelengths in the topography are derived from underlying viscous flow processes then it is likely that lateral variations in the mantle viscosity will give rise to a falsely large value of the elastic thickness.

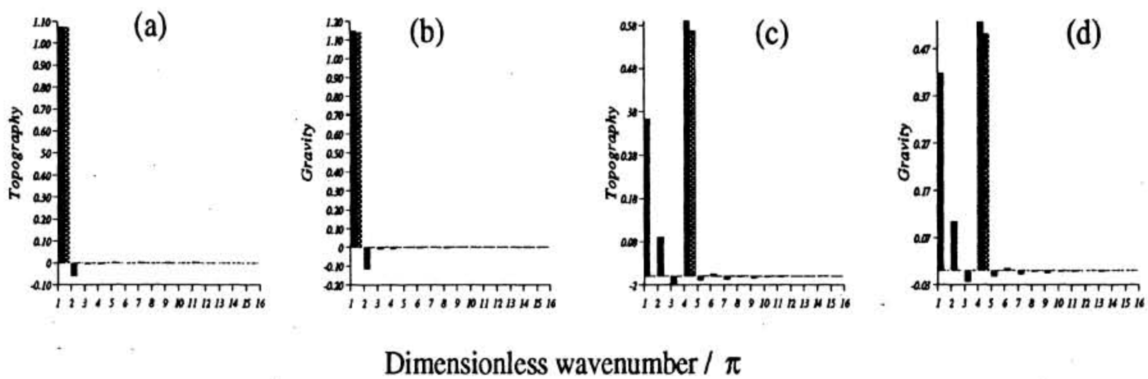

Figure 1: *Fraction of the topography (a,c) and gravity (b,d) signal produced at a wavenumber of* π *in a,b and at* 4π *in c,d by each of the wavenumbers in the temperature field along the horizontal axis.* $(k = 2\pi D_{\text{layer}}/\lambda)$ *At the shorter wavelength approximately half of the each signal at the surface is produced by coupling. The light bar indicates the signal recovered using a horizontally averaged viscosity with the full temperature field. Results are for a convecting layer, Ra* 10^5, *viscosity* $= \exp(-2.7T)$, *free boundaries, fixed temperature top and bottom.*

For constant viscosity convection models, the surface topography and gravity at a given wavelength are produced by density anomalies within the mantle of the same wavelength [10]. However, with temperature dependent viscosity, this relationship is not preserved. Perturbation calculations show that density anomalies with one wavelength can couple through the lateral viscosity variations to produce surface topography at both longer and shorter wavelengths [11].

The strongest coupling effects will be *observed* at the shortest wavelengths in the system where the temperature anomalies of the same wavelength are weakest and the surface observables are only sensitive to the structure of the uppermost mantle. This is borne out in numerical calculations of convection with temperature dependent viscosity, summarized in figure 1.

The most important property of short wavelength topography which is generated from long wavelength temperature anomalies within the mantle is that there is no compensating density anomaly of the same wavelength at shallow depth. This gives a value of the admittance at this wavelength which is the same as if the topography was supported on a strong, rigid lithosphere. This observation depends only upon the predominance of long wavelengths in the spectrum of the density anomalies in the mantle. The wavelength at which the topography appears to be uncompensated, though, must depend on the detailed structure of the convection and the strength of the lateral viscosity variation.

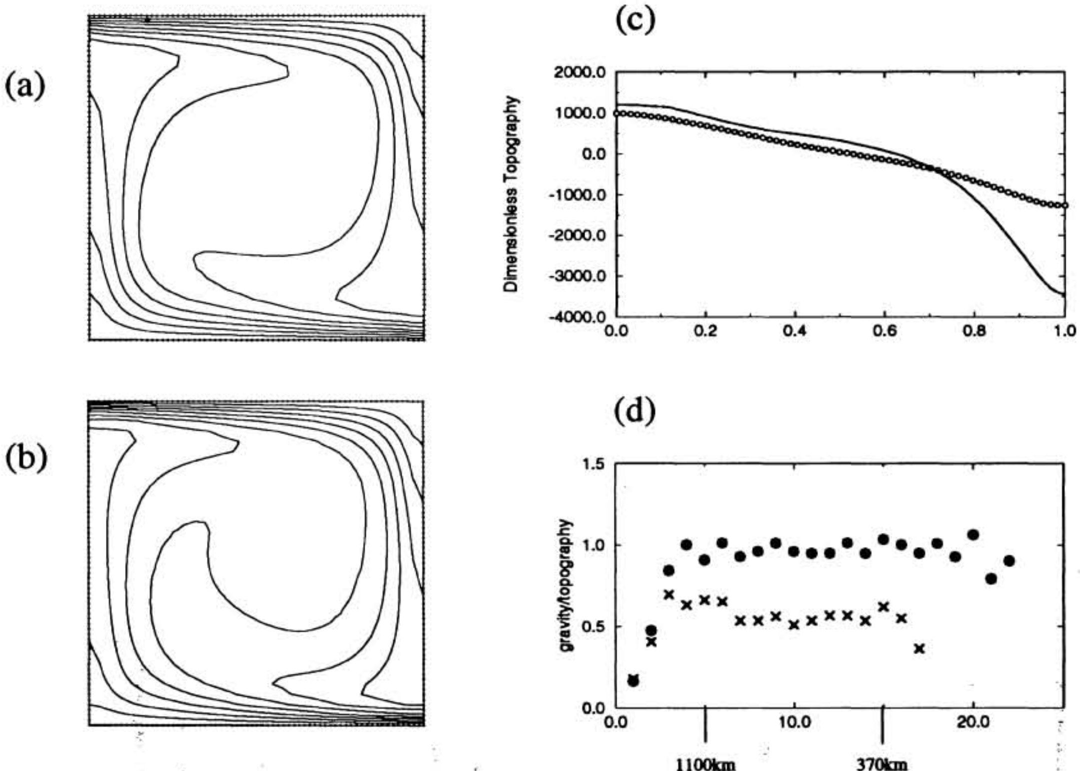

Figure 2: *(a) Constant viscosity convection model with free boundaries at Ra* 3.17×10^4, *64×64 grid. (b) Viscosity* $= \exp(-2.31T)$, *Ra* 10^4. *(c) Dimensionless topography for (a) shown with circles, (b) solid, thick line. (d) Admittance as a function of dimensionless wavenumber (and wavelength) for (a) shown by crosses and (b) shown by solid circles.*

The two solutions of figure 2 are chosen to have the same Nusselt number [12]. The variable viscosity solution has a richer topography spectrum at short wavelengths much of which is due to coupling from long wavelength temperature anomalies. High (uncompensated) values for the admittance occur for relatively long wavelengths of ~1000 km. At higher, more realistic Rayleigh numbers these effects are more pronounced but limited to shorter wavelengths. Coupling processes in broader boxes also give rise to phase shifts between the topography and gravity at intermediate wavelengths i.e. a genuinely complex admittance.

References [1] Walcott, R.,(1970) JGR 75, 3941–3954; [2] McKenzie, D.,(1967), JGR 72, 6261–6273; [3] McKenzie, D., C. Bowin, (1976), JGR 81, 1903–1915; [4] Watts A., (1978), JGR 83, 5989–6004; [5] Watts, A.,J. Bodine, N. Ribe, (1980), Nature 283, 532–537; [6] Watts, A.,J. Bodine, M. Steckler, (1980), JGR 85, 6369–6376; [7] Solomon, S., J. Head, (1990), GRL 17, 1393–1396; [8] Sandwell, D., G. Schubert, (1992), Science 257, 766-770; [9] Zuber, M., R. Nerem, (1992), EOS 73 suppl., 329; [10] Parsons B., S. Daly, (1983), JGR 88, 1131–1144; [11] Moresi, L., (1992) D.Phil. Thesis, Oxford University, UK; [12] Nataf, H.-C., F. Richer, (1982), Phys. Earth. Plan. Inter. 29, 320–329.