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Using gravity and topography data to analyse the viscous strength of tectonically active continental crust

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The response of an elastic lithosphere to external loading is relatively simple, and is well understood in principle. The layered lithosphere can deform only by flexure, and the resulting surface elevation and gravity anomalies are simple functions of horizontal wavenumber. The amplitude of deflection in the wavenumber domain may be expressed either as the convolution of the impulse response and the load function, or as a filter that acts on the load function in the wavenumber domain. For an elastic layer the important parameter is the flexural rigidity, proportional to elastic modulus and to layer thickness to the third power. Typically we assume that the unloaded layer is elastic, isotropic, homogeneous and of constant thickness, and that it overlies a homogeneous halfspace. These assumptions apply well enough to oceanic lithosphere but easily break down in the continental environment, where the lithosphere is generally anisotropic and inhomogeneous, and demonstrates long-term creep deformation as well as an elastic response. Buoyancy forces acting on internal density variations drive deformation that may produce laterally varying contraction or extension of the crustal layer. When deformation occurs, internal tectonic stresses imply that isostatic balance is not maintained. Topography is then determined by: (1) crustal thickness variation, (2) dynamic stress within or below the lithosphere, and (3) regional equilibration of these loads caused by any elastic component of the lithospheric response. The effect of (3) is probably small at wavelengths greater than about 100 km. The free-air gravity anomaly is then computed as the sum of four contributions: the direct gravitational effect of the internal density variation that causes topography components (1) and (2) and the opposing effect of the gravitational signal arising from each of those topography components. We examine some simple models of lithospheric

deformation in which both internal density variations and crustal thickness variations are produced by gravitational instability of a viscous lithosphere, computed using a 2D finite element method. We show that the Gravity to Topography Ratio (GTR) is diagnostic of the viscous strength of crust relative to mantle lithosphere in the viscous flow model. Interpreting such data in the context of an elastic plate model may lead to inconsistent or invalid inferences of elastic plate rigidity. It is preferable to use Free-air anomaly rather than Bouguer anomaly for these analyses because the Bouguer correction is often significantly larger than the uncorrected Free-air signal, and any error associated with the correction is likely to dominate the measured GTR.