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Geodetic expressions of upper mantle dynamics?

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Uplift and deformation along active continental plate margins is controlled by plate motions and stresses arising from local crust and mantle density heterogeneity. The crustal velocity field –which may be measured using modern geodetic techniques—primarily reflects the accommodation of relative plate motion by pure and simple shear deformation of the plate margins. However, flow within the lower crust and upper mantle may also contribute appreciably as deformation, magmatism, and other processes create lateral variations in gravitational potential energy and possibly lead to gravitational instabilities. Under some circumstances, negatively buoyant portions of lower crust developed near Moho depths may detach and sink through the lithospheric mantle, a process that has been invoked in the literature to explain uplift and crustal deformation patterns that are anomalous relative to what might be expected to result from plate motions alone. However, the question of whether or not such upper mantle processes might contribute observably to the active crustal deformation field has not been adequately explored. We have developed a 2D model for lithospheric dynamics that consists of a relatively high viscosity Maxwell viscoelastic crust overlying a lower viscosity mantle lithosphere that flows in response to a sinking negatively buoyant cylinder. We use the model to explore the possible implications of lower crustal foundering for geodetically observed crustal velocity fields along active continental margins. Preliminary results indicate that tractions on the base of the crust resulting from Stokes-like flow induced by negatively buoyant "sinkers" in the upper mantle (which may serve as a numerical analog for delaminated crustal roots) may result in horizontal motions of the crustal surface of order 1 mm/yr or more over distances of as small as 50 km (strain rates of order 20 nanostrain/yr) depending on the viscosity of the assumed Maxwell viscoelastic crust, the density contrast of the sinker relative to the ambient mantle, and other variables. These strain rates are comparable to strain rates typical of diffusely deforming continental plate boundary zones. The results may have important implications for geodynamic interpretations of high-resolution seismic images and geodetic velocity fields in the American Cordilleras, the Alpine-Himalayan system, and possibly elsewhere.