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How to approximate viscoelastic dynamic topographies of stagnant lid planetary bodies?

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Planetary mantles are viscoelastic media. However, since numerical models of thermal convection in a viscoelastic spherical shell are still very challenging, most of the studies concerning dynamic topography of planetary surfaces generated by mantle convection use one of the following simplified rheological set-up: i) IVF (instantaneous viscous flow), ii) viscous body with a free surface, or iii) hybrid methods combining viscous deformation and elastic filtering of the topography.
Justifications for the use of such approximations instead of a fully viscoelastic rheology have been made on the basis of simple tests with step-like viscosity structures, with small to moderate viscosity contrasts. However, because the rheology of planetary materials is thermally activated, the radial stratification of viscosity is more likely to be a continuous function of depth, and global viscosity contrasts might be very large. In our study, we systematically compare viscoelastic dynamic topography induced by an internal load to topographies generated by the three different simplified approaches listed above using a realistic viscosity profile for a stagnant lid associated to the lithosphere of a one plate planete. To this purpose, we compute response functions of surface topography and geoid using three different semi-spectral models that all include self-gravitation: a) a linear Maxwell body with a pseudo free upper surface, b) a viscous body with a pseudo free upper surface, and c) a viscous body with a free-slip condition at the surface.
Results obtained with this last model (IVF) can then be filtered using the elastic thin shell approximation: the effective elastic thickness then corresponds to the elastic thickness that is needed to fit the viscoelastic topography with an elastic filtering of the IVF topography. We show that the effective elastic thickness varies strongly with the degree of the load, with the depth of the load, and with the duration of the loading. These results naturally depend on the ratio between the mantle and the lithospheric thicknesses. We show that, in the case of Mars, it is not possible to approximate viscoelastic topographies generated by a stable plume using the elastic filtering of viscous dynamic topographies.