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Probing the influence of the mantle viscosity profile on the density spectrum and its effect on present-day surface observations

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Mantle convection drives large-scale vertical motion at the surface (dynamic topography), which is linked to present-day geoid undulations and residual topography. However, this link depends crucially on the mantle viscosity profile, which remains one of the largest uncertainties in global geodynamics. While instantaneous flow models based on seismic tomography have provided classic constraints on mantle viscosity structure, here the profile acts only to map a given density structure to surface observations. This means the viscosity profile is not necessarily consistent with the density structure. Here we tackle this problem using a suite of high-resolution time-dependent mantle circulation models which assimilate plate velocities over the past 400 Myrs. This allows us to study the role of the mantle viscosity profile in altering the density structure of the mantle through the planform of convection, in tandem to its role in mapping this to the surface through kernels. We find that the changes in the spherical harmonic density spectrum of the mantle, which result from a given change in the profile, can alter surface observations with the same magnitude as the changes to the kernel. The coupled influence of the profile on the mantle density spectrum and kernels, together with observed geoid undulations and residual topography, provides a new method of constraining the mantle viscosity profile using time-dependent convection modelling.