EXPLORING VISCOSITY VARIATIONS IN THE EARTH'S MANTLE

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This is an extensive study which has gathered a set of over 50 tomographic models in order to explore viscosity variations in the Earth's mantle. This study looks at a range of different viscosity variations and their effect on the mantle flow, dynamics and ultimately the surface manifestation of the dynamics. We seek to constrain the value of the viscosity parameter which is so important to our further studies of dynamics of the Earth's interior and plate motions.

Seismic tomography can be used to investigate radial viscosity variations on instantaneous flow models by predicting the global geoid and comparing with the observed geoid. This method is one of many that has been used to constrain viscosity structure in the Earth's mantle in the last few decades. Examining over 50 tomographic models we found notable differences by comparing a synthetically produced geoid with the observed geoid. We compared S- and P-wave tomographic models and found the S-wave models provided a better fit to the observed geoid. Using this large suite of 50 tomographic models, we have been able to constrain the radial viscosity structure of the Earth. We found that two types of viscosity profiles yielded equally good fits. A viscosity profile with a low transition zone viscosity and a lower mantle viscosity equal to the upper mantle, or a profile with a large lower mantle viscosity and a transition zone viscosity similar to the upper mantle.

Following the recent study by Rudolph et al. [2], we further investigated the effect of a mid-mantle viscosity increase. Based on viscosity structures found by Rudolph et al. [2], we constructed three cases of viscosity profiles which all included a jump in viscosity starting at 660 km depth and a further change in viscosity at 1000km depth (either an increase or a decrease in viscosity compared with the jump at 660 km). Over 8000 different viscosity profiles were tested using our 50 tomographic models. Our results show that increases at 660 km or 1000km depth were able to produce a global geoid that matches closely with the observed geoid. We conclude that there must be an increase in viscosity by 1000 km depth, but the location (depth) of the increase can vary slightly.

Using the set of radial viscosity profiles that gave the best fit to the observed geoid, we can explore a range of lateral viscosity variations and see how they affect the different types of tomographic models. Improving on previous studies of lateral viscosity variations (e.g. [1]), we systematically explore a large range of tomographic models and density-velocity conversion factors. We explore which type of tomographic model (S- or P- wave) is more strongly affected by lateral viscosity variations, as well as the effect on isotropic and anisotropic models. We constrain the strength of lateral viscosity variations necessary to produce a high correlation between observed and predicted geoid anomalies. We discuss the wavelength of flow that is most affected by the lateral viscosity variations.

This suite of tomographic models and our constrained viscosity profiles can further be used to investigate the effect on dynamic topography generated at the Earth's surface. Dynamic topography is the residual topography of the Earth after removing the isostatic topography. This dynamic topography is generated by the flow of the mantle. Being able to constrain the dynamic topography on the surface requires good constraints on the internal structure and dynamics of the Earth. Here, we present the tomographic models which produce more realistic amplitudes for dynamic topography based on the range of viscosity profiles we have previously constrained.

By constraining the range of viscosity values in the mantle, we can constrain the types of dynamics we expect to observe, from the geoid to dynamic topography. These results will be of future use to other studies of the internal and surface dynamics.

References

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