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Linking seismology, mineralogy and geodynamics with seismic anisotropy in the lowermost mantle

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The core-mantle boundary (CMB) is the site of the largest change in properties in the Earth, where the liquid outer core and solid mantle meet. Forming the lower boundary layer in the convecting mantle, D'' (the lowermost mantle) may hold the key to understanding dynamics both above and below. One property of the region which holds much potential to advance this understanding is its seismic anisotropy, which may be caused by factors such as the alignment of anisotropic mineral grains in response to mantle flow.

Anisotropy is widely observed in D'', yet not in the overlying mantle more than a few hundred kilometres above the CMB, as evidenced by numerous tomographic and waveform studies. Shear wave splitting is an unambiguous indicator of the presence of anisotropy and measurements thereof need not make any simplification regarding the kind of anisotropy. Such measurements therefore allow us to test the widest range of candidate processes which might cause D” anisotropy. Ultimately, if one cause such as mineral alignment is more likely than others, we can then use seismic anisotropy to directly infer flow in the lowermost mantle.

In order to test candidate processes for D'' anisotropy, we construct a series of elastic models of the lowermost mantle. Each is based on a different assumption regarding the cause of lowermost mantle anisotropy, concentrating thus far on the development of lattice-preferred orientation in dislocation creep in lower mantle mineral phases such as perovskite, post-perovskite and (Mg,Fe)O (and mixtures thereof). In order to do this, for these phases we require mineral physical data regarding the single-crystal elasticity and deformation mechanisms. Whilst there exists some uncertainty in these parameters, we can nevertheless test what effect these have on our final models. We then use a steady-state mantle flow field retrieved from seismic, geodetic and mineral physical observables, and calculate the texturing along pathlines in the lowermost mantle, eventually producing a three-dimensional model of completely general elasticity.

Observations of seismic anisotropy in ScS waves are then re-created for our candidate models and direct comparison can be made with the data. A complicating factor is that the ray-theoretical assumption may not accurately capture the sensitivity of the waves to varying D'' elastic structure, and thus we use a spectral-element approach to calculate synthetic seismograms at the same frequency as the observations ($\sim$0.2 Hz). The calculations involve thousands of processors and terabytes of memory, but are necessary for retrieving the wavefield in a fully anisotropic medium. We compare a new set of global observations of shear wave splitting in ScS, corrected for upper mantle anisotropy, and can potentially rule in or out different causative mechanisms for anisotropy in the lowermost mantle. More constraints can be incorporated in the future as our method allows the measurement of any seismic phase and any causative mechanism.