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Linking TERRA and DRex to relate mantle convection and seismic anisotropy

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Seismic anisotropy caused by flow induced alignment of the olivine crystals in Earth's upper mantle provides a powerful way to test our ideas of mantle convection. We have been working to directly combine computer simulations of mantle dynamics, using fluid mechanics at the continuum scale, with models of rock deformation to capture fabric evolution at the grain scale. By combining models of deformation at these two scales we hope to be able to rigorously test hypothesis linking mantle flow to seismic anisotropy in regions as diverse as subduction zones, the lithosphere-asthenosphere boundary, and the transition zone. We also intend to permit feedback, for example via geometrical softening, from the model of fabric development into the material properties used in the convection simulation. We are building a flexible framework for this approach which we call Theia. Our initial implementation uses the TERRA convection code (Baumgardner, J. Stat. Phys. 39:501-511, 1985; Davies et al. Geosci. Model Dev. 6:1095-1107, 2013) to drive DRex (Kaminski et al. Geophys. J. Int. 158:744-752, 2004), which is used to predict the evolution of crystallographic preferred orientation in the upper mantle.

Here we describe our current implementation which makes use of the ability of TERRA to track markers, or particles, through the evolving flow field. These tracers have previously been used to track attributes such as the bulk chemical composition or trace element ratios. Our modification is to use this technology to track a description of the current state of the texture and microstructure (encompassing an orientation distribution function, grain size parameters and dislocation density) such that we can advance models of polycrystalline deformation for many simultaneous DRex instances alongside and in sync with models of mantle convection. We will also describe initial results from our first use of the Theia framework where we are investigating the effect of asthenospheric viscosity on seismic anisotropy beneath the oceans. Key to this work is the ability of TERRA to incorporate plate motion history which acts to correctly locate the predicted anisotropy such that it can be directly compared with the anisotropy measured for the Earth.