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ANPAR: a new analytical parameterization of CPO generation in the mantle

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Seismic anisotropy in the upper mantle is primarily due to the crystallographic preferred orientation (CPO) of olivine crystals, and reflects the space- and time-dependence of the deformation experienced by mantle rocks. Incorporating the generation of CPO into models of mantle flow offers a powerful tool to link seismic observations with the process of mantle convection. However, existing models (VPSC, Second Order, D-Rex, etc.) for the evolution of CPO make predictions in good agreement with laboratory experiments, but are too computationally intensive to be incorporated into 3-D mantle flow codes, especially when the flow is time-dependent. Using the state-of-the-art Second Order (SO) self-consistent model as our benchmark, we show that its predictions of crystallographic spin as a function of crystal orientation can be parameterized analytically in a surprisingly simple way that reduces the computational cost by orders of magnitude. The parameterization allows for different strengths of the three dominant olivine slip systems, as well as a macroscopic strain rate tensor having an arbitrary orientation relative to the finite-strain ellipsoid that encodes the prior deformation history. The parameterization agrees almost perfectly with the SO model (it fits its predictions for CPO and crystallographic spin with a variance reduction > 99%), but with a computational cost that is smaller by a factor 2-8 $\times 10^4$. We will illustrate the predictions of the parameterization using three uniform deformations (uniaxial compression, pure shear, simple shear) and for a corner-flow model of a spreading ridge.