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New insights on mantle and lithosphere evolution from matching seismic anisotropy with quantitative geodynamic models

Lijun Liu (1), Jiashun Hu (1), Quan Zhou (1), and Manuele Faccenda (2)

(1) University of Illinois, Urbana, USA (ljliu@illinois.edu), (2) University of Padova, Padova, Italy

Seismic anisotropy provides a potentially powerful observational tool to quantify past and ongoing mantle processes. However, the interpretation of these data has been nonunique due to the uncertain nature of associated mantle dynamics. Recently, we have built a geodynamic framework DRexS through which we predict both depth-dependent seismic anisotropy and shear-wave splitting (SWS) records using 4-D data oriented subduction models. We first construct a spherical mantle convection model that assimilates available tectonic and geophysical constraints. Subsequently we feed the resulting mantle flow history into DRexS to calculate seismic anisotropy. This approach allows us to test different geodynamic scenarios.

Applications to the Americas generate new insights on the style of mantle flow and temporal evolution of continental lithosphere. In particular, we find that mantle deformation below an overriding plate (i.e. South America) follows pressure-driven Poiseuille flow, and that below a subducting plate (i.e. Nazca) follows plate-motion-driven Couette flow, both confirmed by seismic anisotropy. We infer that the tomographically imaged, widespread fast anomalies beneath the southern Atlantic represent foundered lithospheric roots that are compositional buoyant. Further examining the formation of anisotropy within the cratonic lithosphere supports late Mesozoic delamination, a process verified by other independent observations. With another model simulating the past-20 Ma mantle evolution below the western United States, we successfully reproduce the enigmatic circular pattern of SWS. We find that this observation reflects a complex picture of mantle deformation that involves active subduction along the west coast, ancient slabs sinking below the east coast, lateral lithosphere thickness variation, and hot-mantle intrusion through the segment Juan de Fuca slab.