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Linking compositional properties and epeirogenic movement in mantle flow models

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The adjoint method is a powerful emerging tool in geodynamics to compute retrodictions of past mantle flow from present-day seismic estimates of the mantle state. Specifically, the adjoint method provides us with an efficient means to investigate competing physical assumptions of mantle convection models by comparing the results of retrodictions against observables gleaned from the geologic record. Adjoint equations are now available for compressible and incompressible mantle flow.

A major complexity in mantle retrodiction studies is the interpretation of seismic state estimates. While there is growing consensus on the dominant role of thermal buoyancy as a driving mechanism for large-scale mantle convection, the role of chemical heterogeneity remains under debate. Two large low shear velocity provinces (LLSVPs) in the deep mantle are at the center of this debate, with various studies hinting at LLSVPs as being chemically distinct. Viable geodynamic interpretations of seismic state estimates of the mantle involve the use of thermodynamically self-consistent mantle mineralogy models, and are complicated by trade-offs between thermal and chemical contributions to seismic structure, as well as seismic filtering effects, leaving thermochemical or purely thermal interpretations of large scale mantle heterogeneity as options that must be considered in dynamic models of the Earth's mantle.

Here, we employ state-of-the-art mantle retrodiction models, using both synthetic and real-data studies, to explore the spatial and temporal evolution of thermal as well as thermo-chemical mantle flow. Specifically, we focus on observables with sensitivity to compositional properties of mantle convection, such as convectively maintained topography. Our results suggest a robust relation between the compositional mantle flow assumptions and the corresponding evolution of flow induced topography, potentially opening new avenues to learn about past mantle flow regimes.