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Reconstructing past upwellings to test mantle convection models

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Conflicting hypotheses regarding various aspects of solid Earth dynamics—for example, the rheology of the mantle, its chemical composition, the nature of seismic velocity anomalies—imply very different evolutions for the Earth's mantle. While testing future predictions associated to these hypotheses is unfeasible, it is possible to reconstruct the past history of mantle convection that they imply and test them against independent datasets gleaned e.g. from the geological record.

Reconstructions of past mantle flow are frequently achieved through the assimilation of kinematic models of past plate motions in the form of a velocity boundary condition and possibly an age-dependent lithospheric structure. This approach conditions the amount and location of subducted material, thus primarily affecting downwellings. Upwellings are affected only passively and their location, timing and strength are largely determined by arbitrary features of the initial condition.

By recasting mantle convection as an inverse problem and using the adjoint method to solve it one can find the initial condition that optimally fits past plate motions and a seismically-derived estimate for the present-day thermochemical state of the Earth's mantle. In this case, the reconstructed upwellings are strongly constrained by the present-day locations of buoyant anomalies in the mantle. Their time-dependent impact on dynamic topography and the tectonic force budget can thus be consistently assessed and evaluated.