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Reconstructing mantle flow and long-wavelength dynamic topography since the Jurassic Period (GD Division Outstanding ECS Award Lecture)

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Global tectonic reconstructions can be used as boundary conditions of forward mantle convection models to simulate past mantle flow and long-wavelength dynamic topography. The predictions of such models can be compared to seismic tomography, to estimates of residual topography and to geological indicators of past vertical motions.

Here we present models that reproduce the present-day structure of the lower mantle, including two large structures that resemble the Pacific and African Large Low Shear Velocity Provinces (LLSVPs, $\sim$15,000 km in diameter) and a smaller structure that resembles the recently discovered Perm Anomaly ($\sim$1,000 km in diameter). The match between predicted and seismically inferred lower mantle structure is quantified across a series of mantle flow and tomography models. In the models, the Perm-like anomaly forms in isolation within a closed and long-lived subduction network (East Asia, Northern Tethys and Mongol-Okhotsk) $\sim$22,000 km in circumference before migrating $\sim$1,500 km westward at an average rate of 1 cm yr^{-1} since 150 million years ago. These results indicate a greater mobility of deep mantle structures than previously recognized, and illustrate that the predictive power of mantle flow models has significantly increased over the last thirty years. We suggest that the mobile Perm Anomaly could be linked to the $\sim$258 Ma Emeishan volcanics, in contrast to the previously proposed $\sim$251 Ma Siberian Traps.

We also compare the present-day dynamic topography predicted by forward mantle flow models to residual topography models, and show that radial and lateral viscosity variations significantly influence the distribution of power of predicted dynamic topography as a function of spherical harmonic degree.

We finally show how past vertical motions preserved in the geological record and the present-day position of slabs in the mantle inferred from seismic tomography may be used to constrain tectonic reconstructions and mantle rheology, including examples focusing on the large-scale topographic asymmetry of the South Atlantic domain and on the uplift history of the eastern highlands of Australia.