Geophysical Research Abstracts
Vol. 16, EGU2014-6546-1, 2014
EGU General Assembly 2014

Retrodicting the Cenozoic evolution of the mantle: Implications for dynamic surface topography

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Seismic tomography is the essential starting ingredient for constructing realistic models of the mantle convective flow and for successfully predicting a wide range of convection-related surface observables. However, the lack of knowledge of the initial thermal state of the mantle in the geological past is still an outstanding problem in mantle convection. The resolution of this problem requires models of 3-D mantle evolution that yield maximum consistency with a wide suite of geophysical constraints. Quantifying the robustness of the reconstructed thermal evolution is another major concern. We have carried out mantle dynamic simulations (Glišović & Forte, EPSL 2014) using a pseudo-spectral solution for compressible-flow thermal convection in 3-D spectral geometry that directly incorporate: 1) joint seismic-geodynamic inversions of mantle density structure with constraints provided by mineral physics data (Simmons et al., GJI 2009); and 2) constraints on mantle viscosity inferred by inversion of a suite of convection-related and glacial isostatic adjustment data sets (Mitrovica & Forte, EPSL 2004) characterised by Earth-like Rayleigh numbers. These time-reversed convection simulations reveal how the buoyancy associated with hot, active upwellings is a major driver of the mantle-wide convective circulation and the changes in dynamic topography at the Earth's surface. These simulations reveal, for example, a stable and long-lived superplume under the East Pacific Rise (centred under the Easter and Pitcairn hotspots) that was previously identified by Rowley et al. (AGU 2011, Nature in review) on the basis of plate kinematic data. We also present 65 Myr reconstructions of the Reunion plume that gave rise to the Deccan Traps.