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Retrodictions of Mid Paleogene mantle flow and dynamic topography in the Atlantic region from compressible high resolution adjoint mantle convection models

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Although mantle convection at Earth-like vigour is a chaotic process, it has been shown by conceptual studies that one can constrain its flow history back in time for periods comparable to a mantle overturn, ≈100 million years, if knowledge of the tangential surface velocity field and estimates on the present-day heterogeneity state are available. Such retrodictions, enabled through computationally demanding adjoint methods, are a promising tool to improve our understanding of deep Earth processes, and to link uncertain geodynamic modelling parameters to geologic observables. Here we present the first mantle flow retrodictions for geodynamically plausible, compressible, high resolution Earth models with ≈670 million finite elements, going back in time to the Mid Paleogene. Our retrodictions involve the dynamic effects from a low viscosity zone (LVZ) in the upper mantle, assimilate a past plate motion model for the tangential surface velocity field, and probe the influence from uncertain modelling parameters by using two different estimates for the present-day heterogeneity state of the mantle as imaged by two recent seismic tomographic studies, and two different values for deep mantle viscosity. Focusing on the African hemisphere, we find that our retrodictions produce a spatially and temporally highly variable asthenosphere flow with faster-than-plate velocities, and a history of dynamic topography characterized by local doming events, in agreement with considerations on plate driving forces, and regional scale uplifts reported in the geologic literature. Our results suggest that improved constraints on non-isostatic vertical motion of Earth's surface — provided, for instance, by basin analysis, seismic stratigraphy, landform studies, or the sedimentation record — will play an important role in our understanding of the recent mantle flow history.