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Estimating the time evolution of the geoid: An application of the adjoint method in global mantle circulation models

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Forward simulations of mantle circulation processes in the Earth's interior suffer from the problem of an unknown initial condition, that is the temperature distribution of the past is not known a-priori. With the help of the adjoint method (Bunge (2003)), we are able to determine an optimal initial condition iteratively, given a temperature model of the present time. Here we use an s-wave tomography (Grand (1997)) as the estimator for present-day Earth structure. The seismic model is converted into temperature using a published self-consistent mineralogical model (Piazzoni (2007)), allowing us to constrain a time series of mantle flow consistent with the present-day estimator for the past 40 Myrs.

Temperature fluctuations initiate density anomalies, which in turn influence the Earth's external gravitational field. Gravity provides an important constraint for geodynamic modelling. We find a very high correlation of our model geoid for the present time to current satellite derived geoid solutions. Furthermore, our models of paleo circulation allow us to determine time-series of the geoid for the past 40 Ma. Some remarkable geodynamic features can be recognized from our proof-of-concept models, especially the sinking of the Farallon and the Tethys slab through the Earth's mantle, and their associated effects on past topography and geoid.