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On retrodictions of global mantle flow with assimilated surface velocities

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Modeling past states of Earth's mantle and relating them to geologic observations such as continental-scale uplift and subsidence is an effective method for testing mantle convection models. However, mantle convection is chaotic and two identical mantle models initialized with slightly different temperature fields diverge exponentially in time until they become uncorrelated, thus limiting retrodictions (i.e. reconstructions of past states of Earth's mantle obtained using present information) to the recent past. We show with 3-D spherical mantle convection models that retrodictions of mantle flow can be extended significantly if knowledge of the surface velocity field is available. Assimilating surface velocities produces in some cases negative Lyapunov times (i.e. e-folding times), implying that even a severely perturbed initial condition may evolve toward the reference state. A history of the surface velocity field for Earth can be obtained from past plate motion reconstructions for time periods of a mantle overturn, suggesting that mantle flow can be reconstructed over comparable times.