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Data assimilation for the time-dependent reconstruction of continents.

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Since the late sixties, plate tectonic theory has been the paradigm with which we characterise the large scale dynamics at the surface of the solid Earth. Applying this theory, geoscientists integrate a wide range of geological and geophysical observations to produce kinematic plate tectonic reconstructions; predictive time-dependent descriptions of both the configuration and motion of tectonic plates at the surface of the Earth over hundreds of millions of years. For recent times, tectonic reconstructions are constrained using primarily qualitative geological and paleontological observations supplemented with quantitative geophysical data, with an increasing reliance on quantitative disciplines such as paleomagnetism for modelling deeper time. Typically, these reconstructions are built via a largely manual process of integrating many individual time-dependent regional tectonic histories into a geometrically self-consistent global model. As a direct result of this approach, the quantitative estimation of both time-dependent plate configuration and motion uncertainties remain very complex. On the contrary, the application of ensemble-based data assimilation methods provide a statistically consistent framework within which one can assimilate data of variable nature and source within a dynamical model, providing quantitative uncertainties on the estimated trajectory of the system. To this, the application of data assimilation methods to the reconstruction of plate tectonics appears to be a promising line of research.

In this work, we demonstrate a first step in this direction by applying a particle filter to reconstruct time-dependent continental configurations and motions. As the trajectory of continents can be approximated by a series of rigid rotations on the surface of a sphere, we use this kinematic model to compute continent trajectories and assimilate paleomagnetic data (a quantitative dataset able to describe both the paleo-location and paleo-rotation of a given block), starting from present day and moving backward through time. The state of the system is considered as a list of unit quaternions describing the rotation of each continental block on the sphere. Here we present the results of an observing system simulation experiment using this technique, and a first application using a global paleomagnetic dataset.