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Inferring mantle viscosity through data assimilation of relative sea level observations in a glacial isostatic adjustment model

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We suggest to apply data assimilation in glacial isostatic adjustment (GIA) to constrain the mantle viscosity structure based on sea level observations. We apply the Parallel Data Assimilation Framework (PDAF) to assimilate sea level data into the time-domain spectral-finite element code VILMA in order to obtain better estimates of the mantle viscosity structure. In a first step, we reduce to a spherically symmetric earth structure and prescribe the glaciation history. A particle filter is used to propagate an ensemble of models in time. At epochs when observations are available, each particle's performance is estimated and the particles are resampled based on their performance to form a new ensemble that better resembles the true viscosity distribution.

Using this algorithm, we show the ability to recover mantle viscosities from a set of synthetic relative sea level observations. Those synthetic observations are obtained from a reference run with a given viscosity structure that defines the target viscosity values in our experiments. The viscosity estimation is applied to a three-layer model with an elastic lithosphere and two mantle layers, and to a multi-layer model with a smoother viscosity profile. We use various subsets of realistic observation locations (e.g. only observations from Fennoscandia) and show that it is possible to obtain the target viscosity values in those cases. We also vary the time from which observations are available to evolve the test cases towards a realistic scenario for the availability of relative sea level observations. The most relevant cases start at 26.5ka BP and at 10ka BP as they mark the beginning of the maximum glaciation and the end of deglaciation with a larger amount of observations following, respectively, and end at present day.