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Probabilistic spatial reconstruction constrained by physically motivated fields

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Climate reconstructions are usually performed using proxy data such as plant pollen that are only valid locally in space and time. However, the reconstructions exhibit errors that complicate spatial interpolation between locations. Using prior knowledge from a General Circulation Model (GCM) we define a dynamical stochastic process to estimate dominant spatial structures on global or regional scale. These physically motivated structures are used to constrain and interpolate the sparse proxy information using data assimilation. We estimate the expected state as well as the uncertainties in form of the error covariance matrix. This permits the combined estimation of e.g. summer and winter temperatures in space including an assessment of the uncertainties.

Further, the method requires the inverse covariance matrix, which can potentially be retrieved in a novel approach directly from the stochastic process without inversion of a large matrix. The approach allows to incorporate different types of information such as continental and marine proxies as well as to perform quality control of the input data. Within a Bayesian Hierarchical Model (BHM) it is further possible to identify the contributions of different sources of errors. The resulting probability density can finally be used to sample full climate fields for verification of GCM as well as generating initial conditions.