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Improved estimation of background-error covariance matrix in climate reconstruction

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Different methods exist to estimate the state of the atmosphere in the past. One of the techniques is data assimilation, which provides a framework to combine two sources of information: numerical models and observations. By merging the local information of observations with the spatially complete climate fields, we can obtain the best estimate of the atmospheric state.

In our 400-year monthly climate reconstruction, we use the Ensemble Kalman Fitting method that is derived from the Ensemble Square-Root Filter. The background-error covariance matrix is estimated for each assimilation step from the ensemble. Because only a limited number of members are computationally affordable, sampling errors of the estimated background-error covariance matrix are a problem. To eliminate spurious long-range covariances, the spatially distant covariances have to be removed by the so-called localization technique.

To accurately estimate the background-error covariance matrix is an essential part in data assimilation. Hence, we explore three ways to improve our covariance estimate: 1) doubling the number of ensemble members, 2) using a more sophisticated localization in zonal bands and in time, 3) blending the time-dependent covariance matrix estimated from the ensemble with a climatological covariance matrix. We validate the results with instrumental data sets to analyse which methodological modifications lead to the largest improvement.