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How well can we reconstruct global sea level rise and variability?

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Methods for reconstructing past global mean sea levels often rely on historical measurements from tide gauges combined with knowledge about the spatial covariance structure of the sea level field obtained from a shorter period with spatially well resolved satellite measurements.

In this paper we study the strengths and weaknesses of such reconstruction methods We apply a surrogate ensemble method based on sea levels from a 500 years climate model simulation. Tide gauges are simulated by selecting time-series from grid-points along continental coastlines and on ocean islands. Reconstructions of global mean sea levels can then be compared to the known target and the ensemble method allows an estimation of the statistical properties originating from the stochastic nature of the reconstructions.

We study different reconstruction methods previously used in the literature including projection and optimal interpolation methods based on EOF analysis of the calibration period. We also include methods where these EOFs are augmented with a homogeneous pattern with the purpose of better capturing a possible geographically homogeneous trend. These covariance based methods are compared to a simple weighted mean method.

We conclude that the projection and optimal interpolation methods are very sensitive to the length of the calibration period. For realistic lengths of 10 and 20 years very large biases and spread in the reconstructed 1900-1949 trends are found. Including a homogeneous pattern in the basis drastically improves the reconstructions of the trend. The projection and optimal interpolation methods are now comparable to the weighted mean with biases less than 10 % in the tend. However, the spread is still considerable. The amplitude of the year-to-year variability is in general strongly overestimated by all reconstruction methods. With regards to year-to-year variability several methods outperform the simple mean.

Finally, reconstruction errors are decomposed into contributions from the sparse coverage of tide gauges and the incomplete knowledge of the covariance structure of the sea level field. We find that the contributions of the different sources depend on the diagnostics of the reconstruction.

We note that sea level is constrained by the approximate conservation of the total mass of the ocean. This poses challenges for the sea level reconstructions that are not present for other fields such as temperature.