# A post-process smoother for improving the past reanalyses with sparse observations

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Reanalyses are fundamental for understanding weather and climate. They are products of combining numerical model forecasts with observations. In ocean reanalysis historical observations are often sparse and irregularly distributed, which makes the reconstruction of past ocean states particularly challenging. Many widely used ocean reanalysis systems are based on filtering approaches, such as 3DVar or ensemble Kalman filters, where observations are primarily used to update the model state at the analysis time. Smoother approaches like 4DVar can use observations from future times to improve estimates of earlier states, but implementing such systems usually requires substantial development effort and long production cycles. Here, we investigate a simple post-processing smoother that can be applied directly to existing filtering-based reanalyses. The method uses future analysis increments to retrospectively adjust earlier states, offering a practical way to improve reanalysis products without redesigning the underlying assimilation system. In an idealised experimental setup, we assess the smoother reanalyses using three metrics under various observation density and evolving configurations of observation networks. The latter configurations help us understand the impact of the post-process smoother in period of improved observation density. These metrics are used both to tune the smoother parameters and to diagnose how smoothing changes the accuracy and consistency with the model trajectory. The results show that tuning the post-processing smoother solely against root mean squared error can lead to dynamically inconsistent smoother reanalysis trajectories, whereas alternative parameter choices can improve consistency relative to the filtering reanalysis particularly for sparse observations.