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Exploring coral data for multi-decadal paleoclimate reanalysis with the Community Earth System Model

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The assimilation of paleo-proxy observations should help to constrain climate models in order to improve past climate field reconstructions (CFR). On the other hand, the study of how the assimilation of specific paleo-proxy observation types should be best done is still in relatively early stages. One important consideration is the mapping of prognostic or diagnostic state variables (e.g.; salinity, temperature or moisture) from the model space into the proxy space via a, generally nonlinear, forward operator (or Proxy System Model; PSM). This forward operator is key as it will serve to estimate the innovations, or observations minus model estimate of the proxy quantities, that in turn feed the assimilation process and resulting climate analysis. Here we focus on the assimilation of coral records of strontium to calcium (Sr/Ca) and d18O. For example, PSM based on calibrating linear regressions of the coral records as a function of prognostic variables of the ocean can be done with several strategies. Nonlinear regression could also be a possibility. In any case, it is interesting to note that if an existing covariance between the prognostic variables persists for the range of the studied climatic variability, a practical simplification of the statistical PSMs should be possible, irrespective of the kind of PSM. On the contrary, varying covariances between calibration and application times can hamper the application of statistical PSMs. Here, we explore several possibilities for building the PSM for the annual coral records from the PAGES2k database, and evaluate the CFR resulting from the corresponding assimilations. The tests are done with a 20-yr mean climate analysis for preindustrial conditions and the Community Earth System Model (CESM) as coupled atmosphere-ocean model, and a local ensemble transform Kalman filter (LETKF) as assimilation method.