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Millennial climate reconstructions through data assimilation: what can the proxies tell us about past climates?

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Reconstructions of climate variation over recent millennia make an important contribution towards our understanding of climate change, in particular by helping us to place the recent anthropogenically-forced changes in the context of natural variability. Therefore, it is important that we have a sound understanding of the reliability and precision of these reconstructions. Prior to the modern epoch (around 1850 onwards), direct measurements of climatic variables are not available, and the only sources of information are a number of proxy measurements of various types, with tree-rings being one of the best-known of these. These proxy data are extremely limited however, with there being typically tens of observations available globally during a single year. In this presentation, we investigate the identifiability of the climate state by these limited data. That is, we calculate the precision with which it is possible to estimate the climate state using tempo-spatially sparse data. In contrast to the regression-based and frequentist methods which have been widely adopted, we use an optimal data assimilation methodology to treat the problem as one of Bayesian estimation. We also consider issues of predictability, that is to what extent observations from adjacent years can inform on the climate of a given period, and therefore how useful filtering and smoothing strategies may be. Our investigations are based on a perfect model paradigm, in which pseudoproxy data are generated by a single model 'truth' run, with the aim being to reconstruct (as far as possible) the full state from these limited data. Using pseudoproxy data and a massive 10,000-member ensemble enables us to validate the methods and results precisely.