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Performance of Simulated El Niño-Southern Oscillation Climate Reconstructions over the Last Millennium: Comparison of Methods

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A key question in late-Holocene climate dynamics is the role of dominant modes in influencing climates in teleconnected regions of the world. For example, it has recently been proposed that ENSO had a key role in influencing the extended period of largely positive-phase NAO during ∼1100-1400 CE (Trouet et al., 2009, Science, 324, 78). Fundamental to understanding the global and regional climatological roles of dominant modes are primary data on the variations of the modes themselves, in particular paleoclimate data that greatly extend instrumental-period information. Establishing records of ENSO indices that span the past millennium has proven difficult, and well-verified reconstructions produced to date have non-trivial differences (cf., e.g., Braganza et al., 2009, Journal of Geophysical Research, 114, D05106).

This presentation examines important general questions regarding reconstructions of modal indices, including ENSO: is it best (1) to focus on proxy evidence from the most strongly influenced (or most strongly teleconnected) areas, (2) to combine proxy data from a large regional network encompassing the primary area of modal activity and teleconnections (e.g., around the Pacific Rim in the case of ENSO), or (3) to use climate field reconstruction (CFR) methods that assimilate up-to-global-scale proxy information? A systematic suite of reconstruction simulation experiments (RSEs), derived from NCAR CSM 1.4 millennium transient model output, is explored to test the various strengths and weaknesses of these three approaches for reconstructing the NINO3 index. By doing this, NINO3 reconstruction fidelity can be gauged over the entire simulated millennium via comparison to the known model target; such comparisons are restricted to brief "validation" periods in real-world reconstructions due to the length of the instrumental record.

For strategies (1) and (2), pseudoproxies are formed by adding white noise to the model output (seasonally-appropriate precipitation or temperature) at the simulated proxy locations, so that the correlation of the noise-added time series to the original CSM output emulates that of real-world proxy information to local instrumental climate data. White noise is considered a reasonable first-order approximation of random process in these two strategies, since all predictands and predictors used in the reconstruction algorithms are "pre-whitened" by removal of AR1 persistence, following dendrochronological methods. For strategy (3), pseudoproxies are similarly sampled at locations that approximate proxy availability in real-world CFR applications; white noise at a signal-to-noise ratio of 0.25 (by variance) is added (real-world noise characteristics are likely more complex than the model adopted in this case). Monte Carlo replication of the simulated reconstructions is then generated from multiple pseudoproxy noise realizations, and thus a probabilistic characterization of the uncertainty involved in the reconstruction process is derived.

The results of these experiments indicate that exploitation of low-noise proxy data (i.e., proxy information that closely tracks its associated teleconnected climatic variable) from the most-strongly teleconnected areas (strategy 1) is a preferable method for ENSO index reconstruction, in comparison to adding additional proxy information from less-strongly teleconnected areas (strategy 2). Average reconstruction fidelity was reduced by strategy (2) and the width of the estimated credible intervals (CIs) was widened relative to those generated using

strategy (1). The use of CFR methods, strategy (3), further enhances the width of the simulated CIs, even to the point of suggesting possible loss of reconstruction significance (at the 95% level) for a brief period. Given these widened CIs, however, the CFR method shows the highest reconstruction fidelity overall (restricted to the 19th and 20th centuries), suggesting it might be a preferable method along with strategy (1). The enhanced performance of the CFR method during this time is due at least in part to the fact that the CFR reconstructions better capture the 20th century trend than the reconstructions in strategies (1) and (2) (note that the pre-whitening process leaves the trend largely intact), and may also be due to the greater proxy richness exploited in the CFR method. This enhanced performance during the real-world time of calibration and verification should also lead to the caveat that it might suggest performance during such a limited period that gives an over-optimistic view of its true potential over the full millennium.