Reexamining disagreement between simulated and observed climate variability with water isotope physics and proxy system models

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Several studies have recently highlighted the 'reddened' spectrum observed in paleoclimate observations, suggesting the presence of scaling behavior in the climate system [1, 5, 6]. This scaling behavior may imply longer memory of extreme events with longer return periods in climate. GCMs generally fail to simulate this variability on long timescales, and thus the observed mismatch has been invoked as a means for casting doubt on the models' prediction power. However, these efforts to ground climate model simulations directly in paleoclimate observations are often impeded by assumptions surrounding errors in both the models and the proxy data. To address some of these assumptions, both tools may be evaluated in the frequency domain: comparing spectral characteristics of models and data removes model biases in the mean and variance, and also removes time-evolution issues related to internal variability in GCMs [1]. Another assumption, however, concerns the convoluted complexity of proxy systems; these archives may incorporate a multivariate or nonlinear response to climate. **A new data-model comparison strategy:** to address this we turn to proxy system modeling [4]. This forward approach uses water isotope-enabled GCMs and proxy system models (PSMs) as tools for simulating each process that alters the original climate signal (be it biological, physical, or geochemical). To illustrate the usefulness PSMs in data-model comparison, we disentangle the multivariate influences on proxy data spanning the last millennium using state-of-the-art PSMs for ice cores, tree-ring cellulose, speleothem calcite [2] and tree-ring width [7] forced with a last millennium water isotope-enabled simulation of SPEEDY-IER [3]. We address the following questions: (1) do the GCM+PSM-driven pseudoproxies exhibit variability comparable to proxy data? (2) if not, are there proxy system processes that alter the spectrum of simulated hydroclimatic variability, and are the impacts of these processes distinguishable from climate? We apply our method to four representative case studies and the PAGES2k database. We find that variables other than climate itself can significantly alter the spectrum of variability measured in proxy data. Caution is needed comparing models and data when such confounding proxy system effects, as well as measurement biases, are poorly constrained. We assert that much insight stands to be gained from translating GCM output to proxy units in the realm of model validation.