Uncertainties in climate data analysis: Perspectives on working with measurement errors and other unknowns

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ABSTRACT

Scientific inquiry requires that we formulate not only what we know, but also what we do not know and by how much. In climate data analysis, this involves an accurate specification of measured quantities and a consequent analysis that consciously propagates the measurement errors at each step. The dissertation presents a thorough analytical method to quantify errors of measurement inherent in paleoclimate data. An additional focus are the uncertainties in assessing the coupling between different factors that influence the global mean temperature (GMT).

Paleoclimate studies critically rely on 'proxy variables' that record climatic signals in natural archives. However, such proxy records inherently involve uncertainties in determining the age of the signal. We present a generic Bayesian approach to analytically determine the proxy record along with its associated uncertainty, resulting in a time-ordered sequence of correlated probability distributions rather than a precise time series. We further develop a recurrence based method to detect dynamical events from the proxy probability distributions. The methods are validated with synthetic examples and demonstrated with real-world proxy records. The proxy estimation step reveals the interrelations between proxy variability and uncertainty. The recurrence analysis of the East Asian Summer Monsoon during the last 9000 years confirms the well-known ‘dry' events at 8200 and 4400 BP, plus an additional significantly dry event at 6900 BP.

We also analyze the network of dependencies surrounding GMT. We find an intricate, directed network with multiple links between the different factors at multiple time delays. We further uncover a significant feedback from the GMT to the El Niño Southern Oscillation at quasi-biennial timescales. The analysis highlights the need of a more nuanced formulation of influences between different climatic factors, as well as the limitations in trying to estimate such dependencies.