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Identification of linear relationships from noisy data using errors-in-variables models – relevance for reconstruction of past climate from tree-ring (and other) proxy information

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Reliable reconstructions of past climate from proxy information are needed to assess if the recent climatic changes were abnormal compared to pre-industrial climate variability. Here, we focus on the problem that the parameters of the empirical transfer functions relating the proxies (predictors) and the target climatic quantities (predictands) can be seriously biased if the predictand and predictor noise is not adequately accounted for during statistical model identification, which would lead to corresponding biases of the low-frequency amplitudes of the reconstructed climatic time series. In fact, the non-consideration of the stochastic errors of the proxy data by the often used forward ordinary least squares (OLS) regression means the choice of the wrong statistical model for paleoclimate reconstruction from noisy proxy information. We demonstrate the necessity to apply errors-in-variables model (EVM) approaches for unbiased identification of linear structural relationships between noisy proxies and target climatic quantities by (1) introducing the underlying theoretical statistical concepts and (2) demonstrating the potential biases of using either the EVM approach, forward OLS regression, inverse OLS regression, or the reduced major axis method (equivalent to 'variance matching') for reconstructing climate time series by a simulation example using artificial noise-disturbed sinusoidal time series. All of these techniques can be considered special cases (with different assumptions regarding the noise characteristics) of the EVM approach, which is superior to the other techniques in conserving amplitude strength if the noise of both the predictors and predictands can be sufficiently approximated. Based on our statistical reasoning, we developed an alternative strategy including an approach for noise approximation for the reconstruction of past climatic conditions from tree-ring proxies which differs considerably from other often followed and widely accepted strategies, which we would like to put forward for discussion.