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Forward modeling of tree-ring data: a case study with a global network

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Information derived from tree-rings is one of the most powerful tools presently available for studying past climatic variability as well as identifying fundamental relationships between tree-growth and climate. Climate reconstructions are typically performed by extending linear relationships, established during the overlapping period of instrumental and climate proxy archives into the past. Such analyses, however, are limited by methodological assumptions, including stationarity and linearity of the climate-proxy relationship.

We investigate climate and tree-ring data using the Vaganov-Shashkin-Lite (VS-Lite) forward model of tree-ring width formation to examine the relations among actual tree growth and climate (as inferred from the simulated chronologies) to reconstruct past climate variability. The VS-lite model has been shown to produce skill comparable to that achieved using classical dendrochronological statistical modeling techniques when applied on simulations of a network of North American tree-ring chronologies. Although the detailed mechanistic processes such as photosynthesis, storage, or cell processes are not modeled directly, the net effect of the dominating nonlinear climatic controls on tree-growth are implemented into the model by the principle of limiting factors and threshold growth response functions. The VS-lite model requires as inputs only latitude, monthly mean temperature and monthly accumulated precipitation. Hence, this simple, process-based model enables ring-width simulation at any location where monthly climate records exist.

In this study, we analyse the growth response of simulated tree-rings to monthly climate conditions obtained from the 20th century reanalysis project back to 1871. These simulated tree-ring chronologies are compared to the climate-driven variability in worldwide observed tree-ring chronologies from the International Tree Ring Database. Results point toward the suitability of the relationship among actual tree growth and climate (as inferred from the simulated chronologies) for use in global palaeoclimate reconstructions.