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Tuning the voices of a choir: Introducing a new tool to enhance the signals that are stored in tree-ring archives

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Tree-ring based archives, such as ring-width or density, are frequently used proxies for the reconstruction of past environmental parameters at annual resolution (e.g. Fritts, 1976). In terms of tree-ring width based reconstructions, ring-width measurements are usually acquired from several (often at least 20) trees growing under similar conditions (the 'choir') which are then averaged to a so-called master chronology (the 'voice'). Theoretically, this averaging evens out the individual-specific noises that act upon single trees. A statistical measure which frequently has been assumed to reflect the quality of tree-ring based reconstructions is the so-called expressed population signal (EPS, Wigley et al., 1984). Investigators have often sought to maximize EPS independent of individual tree reactions, but rather aiming at large sample sizes, which increase the value of EPS. Although studies have shown that the environmental signal of master chronologies may be enhanced in comparison with single trees (e.g. Carrer, 2011), ecological theory suggests that depending on particular site conditions (e.g. dry vs. wet sites) different trees within populations may react on different environmental drivers. In this context, recent studies have aimed at an individual selection of trees to form groups of similar growth responses (e.g. Piovesan et al., 2008, Walker and Johnstone, 2014). Grouping may help to lower the noise in the resulting averaged chronologies and therefore potentially enhance the strength of the targeted signal further.
As a contribution to this particular topic, we present a new methodological approach - the Weighted Principal Component Analysis (WPCA), designed to identify variable growth responses in tree populations. To test its performance, we applied WPCA to various datasets which express different gradients of individual growth responses and compared WPCA to three other statistical approaches which have earlier been used in this context.
For all tested datasets WPCA resulted in a continuum of tree growth responses and was thus able to identify individual growth responses. To allow for a definition of groups based upon WPCA, we combined EPS with the Subsample Signal Strength (SSS), which allows for predicting the EPS of a population subsample (Wigley et al., 1984). If individual growth responses existed, EPS of WPCA defined subsamples was higher as expected from the SSS prediction, though it was lower than the overall EPS.
Average chronologies of groups defined by WPCA expressed much stronger responses to particular environmental parameters and thus a much higher potential for environmental reconstruction in comparison with the overall, site based, master chronology. With respect to the other studied approaches, WPCA appeared to be advantageous as it needs less a priori assumptions. Based on our analyses we conclude that WPCA allows for a more precise tuning of tree-ring based reconstructions and therefore is able to enhance the precision of estimates on past environmental conditions. In contrast, a rigorous maximization of EPS as frequently undertaken in many studies may even decrease the quality of environmental reconstructions if individual growth responses exist. As a consequence we suggest the application of WPCA prior to any tree-ring based reconstructions to maximize the precision of palaeo-environment reconstructions.

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