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Improving understanding of wood formation: a comparison of two models

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Wood formation is an important player in long-term sequestration of atmospheric CO_2.
Wood (secondary xylem) is produced as developing tracheids go through several developmental phases until they reach maturity: cell division, cell enlargement, secondary cell wall thickening and lignification, and programmed cell death. Understanding the drivers behind these processes is important in many disciplines, from forestry, dendrochronology, to predicting future dynamics of the global carbon cycle.
However, the controls on the timings and rates of these processes and their transitions are not yet fully understood. Models are a useful tool with which we can test wood growth hypotheses and compare the results with observations. Problematically, existing models contain different hypotheses on environmental controls and different assumptions on the importance of cellular phases. Nevertheless, they successfully support forestry applications, research on wood formation, and dendrochronology. We are in the process of developing a wood formation model for global vegetation and carbon cycle modelling. To our knowledge there is not a fully functional model that enables the predicting of wood growth and how it is driven by environmental factors for our purposes. We hence need to identify biologically realistic growth hypotheses on a parsimonious level suitable for computationally intensive global simulations.
Our first step in developing this model is to test existing models' suitability for this new application, by comparing them against new observations that are well-suited for this.
We compare two successfully applied process-based; the VS – model (Vaganov et al 2006) and the model by Deleuze et Houllier (1998). Both models (= growth hypotheses) have successfully reproduced observational data.
In the VS-model, a single relative growth rate drives both cambial activity and cellular growth. The relative growth rate is based on the principle of a limiting factor. This rate is influenced by daily values of radiation and the minimum value of a soil water content-dependent growth rate or a temperature- dependent growth rate. The VS model has successfully been applied as alternative to statistical models in dendrochronological research.
The model by Deleuze et Houllier (1998) assumes one most dominant limiting environmental effect per cell phase (temperature on cambial activity, water availability on enlarging cell activity and carbon availability on thickening cell activity). It has been used to predict wood density.
Here, we extract these hypotheses on wood formation from these models and insert them each into the same model framework. We compare these two models' growth hypotheses against observations of intra-annual dynamics and final tree ring anatomy from three conifer species (Abies alba Mill., Picea abies (L.) Karst. and Pinus sylvestris L.) from the Vosges mountains over a three year period. We evaluate these growth hypotheses' ability to reproduce tree ring properties at this particular site, not only on the tree ring anatomical level, as is commonly done for these models, but also with respect to intra-annual cellular dynamics. Strengths and weaknesses in the interrogated growth hypotheses are discussed and recommendations are made on minimal requirements for a wood formation model in the context of global vegetation modelling.