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How to make a tree ring: Coupling stem water flow and cambial activity in mature Alpine conifers

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Inter-annual tree-ring measurements are used to understand tree-growth responses to climatic variability and reconstruct past climate conditions. In parallel, mechanistic models use experimentally defined plant-atmosphere interactions to explain past growth responses and predict future environmental impact on forest productivity. Yet, substantial inconsistencies within mechanistic model ensembles and mismatches with empirical data indicate that significant progress is still needed to understand the processes occurring at an intra-annual resolution that drive annual growth. However, challenges arise due to i) few datasets describing climatic responses of high-resolution physiological processes over longer time-scales, ii) uncertainties on the main mechanistic process limiting radial stem growth and iii) complex interactions between multiple environmental factors which obscure detection of the main stem growth driver, generating a gap between our understanding of intra- and inter-annual growth mechanisms.

We attempt to bridge the gap between inter-annual tree-ring width and sub-daily radial stem-growth and provide a mechanistic perspective on how environmental conditions affect physiological processes that shape tree rings in conifers. We combine sub-hourly sap flow and point dendrometer measurements performed on mature Alpine conifers (Larix decidua) into an individual-based mechanistic tree-growth model to simulate sub-hourly cambial activity. The monitored trees are located along a high elevational transect in the Swiss Alps (Lötschental) to analyse the effect of increasing temperature. The model quantifies internal tree hydraulic pathways that regulate the turgidity within the cambial zone and induce cell enlargement for radial growth. The simulations are validated against intra-annual growth patterns derived from xylogenesis data and anatomical analyses. Our efforts advance the process-based understanding of how climate shapes the annual tree-ring structures and could potentially improve our ability to reconstruct the climate of the past and predict future growth under changing climate.