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Integrating dendrochronological data and functional processes in mechanistic models to study forest performance under global change

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Global warming and enhanced [CO_2] challenge forests performance, forcing species to adapt in response and acclimate to a new environment. The functional processes involved in carbon and water forest dynamics need to be modelled to understand how forests will respond to global change. Warming could be beneficial for certain species, particularly where species dynamics are limited by temperature. Yet there are multiple examples of forest decline and accelerated mortality in many locations worldwide, triggered by an enhancement in vulnerability to water stress particularly of the least drought-tolerant species. Although increasing [CO_2] could counterbalance the negative effect of water stress under certain conditions, the net response of trees to the interaction [CO_2] x climate most likely will be negative and dominated by water stress limitations in drought-limited environments. Models need to include the different forcing factors governing plant dynamics at different spatio-temporal scales. In addition they need to simultaneously address hypotheses related to species vulnerability such as ‘carbon starvation’ and ‘hydraulic failure’, which are very much linked both to carbon sink and carbon source limitations. Dendrochronological data combine a large temporal (from intra-annual to multicentennial) and spatial coverage. These data have proved very useful to improve our understanding on how both climate and [CO_2] interact to determine forest productivity and performance, and to produce more reliable, robust and realistic models. Dendrochronological data can help understand variability in carbon allocation in response to fast and abrupt changes in climate under an atmosphere with unprecedented high [CO_2] levels. It is important that models include biologically meaningful non-linear response thresholds to key environmental factors. I will show some applications of different types of dendrochronological data and different forest models, and discuss their use to understand key coupled processes determining forest productivity and water use efficiency on a changing world. This will include examples from classic annual individual growth indices and carbon stable isotopes to stand-based allometric estimates of aboveground woody biomass, combined with other data sources needed to study the C and water cycles in forests. To understand variability in carbon allocation to the stem it is necessary to link other traits and plant processes including leaf and cambial phenology, net photosynthesis and transpiration. We are still far from perfectly addressing the mechanisms determining plant functioning in models, particularly under expected scenarios of high temperatures and [CO_2] projected for the next century. For this reason there is much potential in using abundant dendrochronological data combined with other multiproxy data sources to improve models, but there are also different issues that need to be properly discussed given limitations in data and metadata. Discussion is encouraged to overcome shortcomings of current modelling approaches and propose future directions to improve model-data fusion using dendrochronological data to better understand the functional processes that will determine forest dynamics on a changing world.