Global ecological trends in wood cell production of coniferous trees

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As a consequence of recent climatic changes, many studies have reported an increase in tree growth, forest ecosystem net primary productivity, and terrestrial biosphere carbon up-take, making forests one of the largest carbon sink on Earth. Direct and remote observations, as well as eco-physiological models, have suggested that it is mainly the rise in temperature and the resulting extended period of growth that is responsible for forest enhanced productivity. However, up to now, there is no comprehensive observation-based study deciphering the respective roles of the length of the growing season versus its intensity, to confirm this interpretation. Based on a large wood-formation-monitoring dataset, encompassing numerous sites from Mediterranean to Boreal conifer forests, we tested the hypothesis that the length of the growing period is more important than the rate of growth to explain tree-ring width. Moreover, we explored the influence of the environmental conditions on the variation in both timings and rates of xylem cell production.

We collected data from more than 50 sites spread at various altitudes and latitudes, on three continents (America, Europe, Asia), in the extra tropical parts of the Northern Hemisphere (Boreal, Temperate and Mediterranean bioclimatic zones). Wood formation was monitored at a weekly time-step using histological sections of forming xylem collected from the stems of more than 15 conifer species. The critical dates of xylem phenology were assessed at tree level using logistic regressions, while the rates of cell production were computed using Gompertz models. A basic physical model was developed relating the total number of xylem cells with the rate and duration of its production. A sensitivity analyses was performed to reveal the global ecological patterns of tree-ring formation, while mixed effect models were used to quantify the influences of the environmental factors.

The basic physical model of xylem cell production was applied successfully to the whole dataset (including Mediterranean sites) explaining more than 80 % of the observed variability. The sensitivity analysis showed that the rate of xylem cell production contributed a bit more than the duration to the variation in the final number of cells. Trees presented contrasted strategies according to the bioclimatic zone they belong to: while Boreal trees grew at a high speed during a short time; Mediterranean trees proceeded slowly, but for an extended period of time. Nevertheless, even for Mediterranean trees, the rate of growth remained the first driver of the final number of cells. Moreover, we showed that xylem phenology was consistently explained by the change in thermal conditions occurring with altitude or latitude, while growth rate was more related to species effect and site conditions.
Our results confirm that recent global warming may have resulted in extended period of growth explaining the recent increase in forest productivity. However, we also showed that the rate of xylem cell production is indeed the first driver of tree radial growth, therefore species behavior and site conditions should be considered in vegetation models to assess the impact of climate changes on forest productivity.