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An integrated observation, experimental and modelling study to investigate source vs. sink limitation of wood growth processes in temperate trees

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Plant growth is a complex process, controlled by multiple internal and external factors. However, global vegetation models equate growth with carbon uptake net of respiration, rather than treating it explicitly. Therefore, the dynamical responses to environmental drivers are not realistically captured, and this omission maybe at least partly responsible for their biases with respect to observations. This situation exists because there is not yet a general model of balanced carbon source-sink processes. We have put together an integrated observational-experimental-modelling project to develop a new approach to address this problem.

We will address the current hypotheses:
1) The carbon sequestration over each growing season is limited by concurrent photosynthetic activity;
2) The extent to which growth is controlled by carbon sources or sinks is closely related to the relative proportions of earlywood and latewood;
3) Down-regulation of photosynthesis occurs as a result of the build up of phloem carbon;
4) Observed variance in carbon sequestration across year, species and treatments can be captured sufficiently well by our model of xylogenesis.

Our field-based research is focussed on the supply of carbon to the growing regions of three key North American species. Carbon supply to the lateral meristem of mature tree species of white pine (Pinus strobus), red maple (Acer rubrum L.) and red oak (Quercus rubrum L.) in Harvard Forest, Massachusetts, will be experimentally manipulated using compression techniques, traditional girdling and novel phloem chilling. This novel method decreases the outer stem temperature down to 2oC, inhibiting phloem transport and thereby manipulating the supply of carbon compounds from the canopy and roots. In 2017, the compression techniques and traditional girdling were shown to induce temporary and permanent changes to stem respiration, respectively. We will complement the experiment with phloem chilling in 2018. Measurements of non-structural carbon, photosynthesis, respiration and wood development at high temporal and spatial resolutions will be used to determine the relationships between carbon sources and sinks over time. Microcore observations will be taken to assess the impact of experimental treatments on xylogenesis and non-structural carbon reserves.

Processes controlling growth and wood development will be incorporated into a sink-limited vegetation model. Measurements of cellular development from weekly tree microcore observations will be used to test a xylogenesis model of tree growth. After careful evaluation, our resulting tree-level model will be expanded to additional tree types and other life forms and incorporated into the dynamic global vegetation model HYBRID. This new knowledge of the controls on plant growth will be used to assess historical and future terrestrial carbon processes, comparing source and sink controls on vegetation growth. An outline of the tree-growth model used in this research project is presented in session CL1.07 (Eckes et al). Our work has the potential to revolutionize our understanding of the role of vegetation in the global carbon cycle and the impacts of global environmental change on vegetation dynamics.