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Separating transpiration and stem water storage in a large boreal tree using Heat Ratio Method sap flow sensors

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Accurately estimating plant water uptake and use is essential to improving model prediction(s) and our understanding of current and future water fluxes within the forested landscapes. Water-use of mature trees is estimated from extrapolating physiological measurements taken at the leaf and branch scale in parallel with the increasing use of in-situ methods such as sap flow systems; estimating water volumes moving through the stem. However, temporal lags and discrepancies between canopy measurements and xylem sap-flow measurements have been reported, highlighting the importance of water storage along the stem in trees. Properly assessing the partitioning between flux and storage requires accurate sap flow measurements. Although largely tested on young and small trees, the accuracy of the Heat Ratio Method (HRM) on large diameter trees has yet to be directly tested and remains a significant knowledge gap to our understanding of sap flow measurements in mature trees.
Using a modified weighing lysimeter on a large mature boreal aspen (Populus tremuloides) equipped with 20 sap flow sensors, we tested the accuracy of the HRM sap flow measurements and assessed water storage dynamics along the stem.
Over 10 days, hourly sap-flow rates measured with the sensors showed a very good agreement with water uptake flow measured by the scale ($R2 > 0.9$) for the basal sensors, while cumulative water uptake was best estimated by sensors placed on the north and east sides of the trunk. Hourly upper-stem sap flow rates were significantly lower than basal-stem rates, suggesting substantial stem water storage. The partitioning between the transpiration stream and water storage in the sap flow rates varied with cardinal orientation across the stem. As a result, the strength of the correlation between hourly stem sap flow rates and climatic conditions changed with distance from the canopy.
Although the HRM sap flow sensors were shown to provide reliable estimates of total tree water use in this large boreal tree, the results show a substantial variation between cardinal orientation in sap flow measurements. We highlight the importance of measuring and separating the transpiration stream and stem water storage in the sap flow measurements, especially when correlating to climatic conditions and modelling water fluxes at both the individual tree and forested landscape scales.