SIMULATION OF THE THERMAL AND HYDRAULIC BEHAVIOR OF AN INDIVIDUAL TREE WITHIN A FOREST

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A computational tool was built to simulate coupled fluid flow and heat transport in a soil-root-stem system representing a tree in a seasonally-varying forest. The model approximates three-dimensional transient temperatures, water pressures, moisture contents, and velocities in the tree and soil using a continuous finite element method approximation on tetrahedra. The model also includes a parallel Monte-Carlo algorithm to simulate the diurnal external solar and environmental radiation regime consisting of sky and surrounding forest radiative effects. The forest and sky radiation were approximated on a discretized hemisphere composed of triangles with specified properties. Individual components of the model were compared against analytical solutions and the entire model was compared quantitatively with published observations.

The model was applied to a tree in a dense temperate hardwood forest. Surface heat exchange was driven with measured meteorological data. Because the study focus was on soil-root-stem interaction, the tree's entire leaf structure was not included. Rather, pressures measured in field experiments were imposed in the trunk at a height of two meters above the ground. Simulations included both large transpiration to reflect summer conditions and low or zero transpiration to represent winter. Results from the winter simulations indicate that the primary influence of temperature in the trunk was solar radiation and radiative energy from the soil and surrounding trees. The summer simulation showed sap flow in the trunk was the primary influence of temperature change with secondary effects from radiative energy from the soil and surrounding trees. Summer simulation results also showed drying of the soil by transpiration, leading to increased velocities in regions where the soil saturation was higher and decreased apparent thermal conductivity where saturation was lower.

For these simulations, transpiration occurred only through the large, discretized root structure. Uptake through the smaller, distributed root system is being added to the model.