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A Process Approach to Predicting Tree Mortality in Surface Fires

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Traditional methods for predicting post-fire tree mortality employ statistical models which neglect the processes linking fire behavior to tree-level mortality patterns. Here we present an alternative process approach which predicts tree-level mortality using heat transfer theory and tree allometry models. A linefire plume model drives independently validated conduction and lumped capacitance heat transfer analyses to predict time to meristem necrosis in tree stems, branches, and buds. Local stem, branch, and bud meristem necrosis is scaled to tree-level mortality using a sapwood area budget derived from tree allometry models. Thus, our approach provides a predictive, mechanistic model which explains how tree-level mortality patterns are governed by physical fire characteristics (fireline intensity and residence time), tree physiology (water content), and tree morphology (meristem height, bark thickness, branch/bud size, foliage architecture). To illustrate, we predict tree-level mortality for white spruce (*Picea glauca* (Moench) Voss) and lodgepole pine (*Pinus contorta* Loudon var. latifolia Engelm.) across a range of fire conditions typical of these communities. Models were parameterized using data collected from subalpine spruce and pine communities in the southern Canadian Rocky Mountains. Foliage effects were quantified using convection correlations obtained in a laminar flow wind tunnel for a Re range of 100 to 2000, typical for branches/buds in a linefire plume. Our results generally agree with empirical observations of tree mortality. However, results also suggest stem meristem necrosis (girdling) as the mechanism of whole tree mortality, challenging statistical model assumptions that crown meristem necrosis is the primary mechanism.