Wildland fires, including both wildfires and planned prescribed burns, are important ecological processes that shape ecosystems, regulate biogeochemical cycles, and maintain ecosystems' health. Understanding these fires is important for harnessing their ecological benefits while minimizing risks to human health, property, and air quality. The spread and behavior of wildland fires, from small-scale fuel ignition to large-scale plume development arises from the complex interactions among fuels, weather, and topography. Accurate prediction of fire behavior, therefore, requires properly representing these factors and their coupled interactions across multiple scales. Despite extensive research in fire modeling, the effect of key fuel properties on fire and plume behavior remains incompletely understood and is often inadequately represented in predictive models. In particular, the role of dynamically varying fuel moisture and foliage motion during fire has received limited attention, even though these factors critically influence fire spread and plume development. This gap limits our ability to reliably predict fire behavior.

This research aims to address these gaps through a systematic investigation of fuel moisture dynamics and canopy motion in wildland fires. To this end, a thermodynamic model to represent fuel moisture variation was developed. This model was then integrated into the physics-based fire prediction model to analyze how thermodynamically varying fuel moisture influences fire behavior. Building on this, the study examined the combined effects of atmospheric stability and fuel moisture on plume dynamics. Additionally, a separate study developed a method to investigate how the motion of foliage influences fire behavior, capturing how canopy movement alters turbulence, heat transfer, and fire propagation. In future, this method will be improved into a fully two-way coupled system, where dynamic canopy motion and fire behavior can influence each other.