Studying wildland fire spread using stationary fires

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Abstract

Experiments were performed using stationary gas burners and liquid fuel-soaked wicks to study fundamental wildland fire behaviour, including unsteady flame heating. These experiments were motivated by observations of instabilities in spreading fire experiments that suggest they play a critical role in fire spread. Stationary fire experiments in forced flow and on inclined surfaces exhibited instabilities similar to those observed in spreading fires but allowed for more detailed analysis of the mechanisms responsible. Large scale inclined experiments were performed using an ethylene gas-fed burner at angles from 10 to 60 degrees. Forced flow experiments were performed on liquid-soaked wicks and small scale gas burners at wind speeds from 0.2 to 3 m\textsuperscript{s}\textsuperscript{-1}. Results presented include observations of the general flame structure, including streamwise streak spacing and flame fluctuation frequencies which relate to instabilities observed in large spreading experiments. A description and correlations of flame geometry, useful for predictions of wildland fire spread are also presented.

Keywords: wildland fire, inclined flame spread, diffusion flame, flame pulsation

1. Introduction

Predicting the rate of spread (ROS) of large wildland fires is of critical importance for operational firefighting, prescribed burning, and calculating future wildfire potential. Currently, most of these models are based upon correlations derived from experiments performed in the 1970’s by Rothermel, Anderson and others (Finney \textit{et al.} 2013a). While these correlations provided a “leap forward” in the prediction of a steady ROS, they failed to capture essential physics and therefore break down under extreme wind, topographic, and other conditions (Finney \textit{et al.} 2013b). A considerable amount of effort is therefore being invested towards better understanding this fire behaviour, especially the mechanisms of heating to fuel particles. While it has proven difficult to study these phenomena in some large-scale spreading fires, a series of stationary, scaled experiments have been designed to determine the underlying physics that occur during fire spread.

Recent experiments of flame spread in discrete fuel beds have revealed the presence of buoyant instabilities which may lead to increased convective heating of fuel particles (Finney \textit{et al.} 2013a). Unfortunately, detailed fluid dynamics and convective heating measurements in spreading fires remain difficult to capture because of the moving burning region of the fire. This is compounded by changes in the flame front and fuel burnout with time, causing non-steady burning rates and dynamic fire behaviour that require dozens of expensive, large scale fire experiments to investigate. Stationary burners have long been used to study fires in the built environment (de Ris and Orloff 1975), therefore they offer an ideal configuration to study non-steady fire effects in a thorough, statistical manner, in essence capturing a snapshot of a moving fire front. Experiments here show these stationary burning regions contain two buoyant instabilities which are similar to spreading fires, appropriately scaling with macro-features of large spreading fires, however they provide enhanced measurement capabilities (Finney \textit{et al.} 2013a).