Fire in the Earth System Abstracts
Vol. 1 FES-Fire Behavior Modelling and Simulations-95
Valencia, Spain, 3-7 November, 2021

Temporal evolution of a wildland flame envelope: An experimental study on litter fires

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Abstract

This work is focused on the systematic investigation of the effects of several physical parameters on litter fires. In this context, an extensive parametric study is performed, using an inclinable fuel bed, aiming to evaluate the impact of surface slope, fuel load and fuel moisture content on the dynamic characteristics of the developing flame envelope. In total, 10 fire tests are performed; two sets of 3 identical tests are used to evaluate the "repeatability" of the testing methodology. The parametric study spans four different surface slope angles (0, 10, 20, 30 degrees), two different fuel load values (0.5, 1.0 kg/m^2) and two different fuel moisture content values (1%, 8%). The fuel used is dead "Pinus Halepensis" pine needles; particle density, surface-to-volume ratio and fuel moisture content are measured in order to establish adequate fuel homogeneity among the successive tests. A broad range of physical parameters is recorded using an extensive sensor network. The fuel bed (2 m x 2 m) is equipped with 86 thermocouples, 3 heat fluxes and 4 bi-directional Pitot tubes, aiming to record the temporal evolution of the gas and fuel temperature, the heat flux and the axial velocity. An exhaust hood is used to collect all combustion products; a gas sample is fed to an online gas analyser, thus allowing the estimation of the instantaneous Heat Release Rate, by means of oxygen calorimetry. Furthermore, the propagating flame is visually recorded using two optical cameras, located on perpendicular sides of the fuel bed. An image processing computer algorithm, developed in-house, is employed to determine the main geometrical characteristics of the flame envelope, namely flame height, length and angle. In addition, the instantaneous rate of spread of the fire is estimated using the video image sequence. The obtained results concerning the geometrical and spreading rate characteristics of the flame are, for the most part, in full agreement with relevant literature reports. Decreasing the fuel moisture content results in a significant increase of the flame height, length and rate of spread; however, the flame angle is not considerably affected. Also, doubling the fuel load leads to significantly enhanced rate of spread and substantially larger flame envelope. Finally, the gradual increase of the slope angle affects both the geometrical characteristics of the flame and its spreading rate.

Keywords: litter fire, fuel bed, flame envelope, measurements, rate of spread