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Experimental and numerical study of fire behaviour: effects of the width on the rate of spread

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Abstract
This study focuses on the influence of the fuel bed width on the rate of spread. An experimental set-up based on visible cameras combined with image processing was used and a direct linear transformation (DLT) algorithm was developed in order to quantify fire propagation features such as the rate of spread, the fire length, ... The present work gathers results aimed at demonstrating the dependence of the rate of spread on the fire front morphology. A new cellular automaton was developed to better understand the heat transfer mechanisms, investigating in particular the role of radiative transfer.

Keywords: Fire propagation, cellular automaton model, Fire front width effect, Radiative transfer

Glossary
HHV Higher heating value [kW/kg]  Hf Flame height [m]
LHV Lower heating value [kW/kg]  RVR Residual vegetation ratio [kg/kg]
RH Relative humidity [%]  CpDry Heat capacity [kJ/kg/K]
L Fuel bed width [m]  F View factor [-]
Lc Distance from a point to the cylinder centre [m]  Vf Flame volume [m³]
Rf Flame radius  Tf Flame temperature [K]
z Vertical coordinate [m]  φ Radiative heat flux [W]

1. Introduction

Every year, several million hectares of vegetation are burnt by forest fires or bush fires, ravaging both flora and fauna. The knowledge of the fire behaviour is an important issue in order to prevent from disaster or to try to control the fire propagation. In this frame, the accurate estimation of the propagation rate is of major interest for the fire prevention.

It is commonly accepted that the rate of spread depends on the vegetation properties, the topography and the meteorological conditions. Some fire propagation codes, such as Farsite [1] and Behave [2], take these parameters into account when simulating the fire behaviour. However, these models are unable to include the real fire front morphology (fire length, shape ...) in their predictions. The rates of spread are evaluated only for linear fire fronts and can overpredict the fire propagation in many other configurations. Only physical models involving space varying terms in balance equations, namely in radiation or convection models, are really able to reproduce the real fire behaviour.

Fingering (burnt areas with small fire front widths) is an example of a non linear configuration in real fires. In 2001, pictures of real fires taken from satellite were analysed by Caldarelli [3], focusing on the fractal dimension and lacunarities observed in fires. Indeed satellite images show the existence of fingerings. At this scale, the fire propagation is affected by the fire front morphology, as it was already observed experimentally by Anderson in 1968 [4]. It is very important to model efficiently the fire behaviour at small scale (meter scale) in order to predict accurately the fire front evolution against time.