Numerical Simulations of Brand Transport in Large Outdoor Fires

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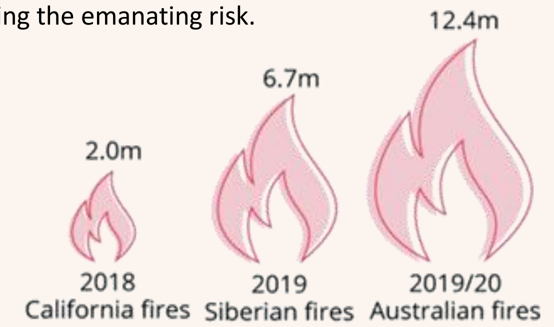
Large Outdoor Fires

Wildfires pose a serious threat to people and the environment. In 2005, more than 42 million homes in the US were located in the wildland-urban interface (WUI). The average annual number of homes destroyed by wildfires has risen from 850 to 1,100 (1984-past 2000) and each year the US government spends billions of dollars towards the suppression of wildfires and damages. [1] With the increasing number of people moving into WUI areas and due to climate change, the frequency of severe wildfires is anticipated to increase. [2,3]

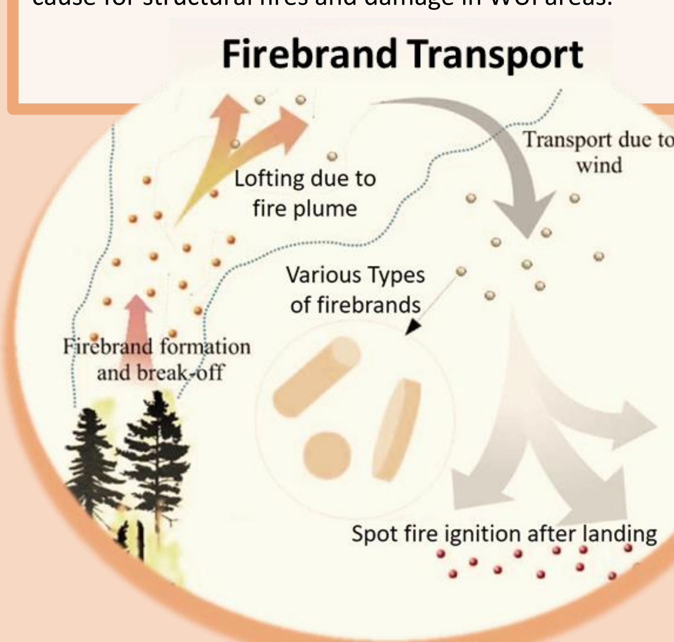
This reasons a research need to investigate the dynamics of outdoor fires to make them more predictable, thereby mitigating the emanating risk.



Acres burned in recent major wildfire events. [4]

Fire Spread in Wildfires

Fire spread occurs due to convection or radiation as in common applications and cases. However, wildfires also spread through "spotting", spot fires caused by downwind transportation of firebrands. Depending on the firebrand properties, the fire, and atmospheric conditions, secondary fires can be ignited thousands of meters ahead of the actual flame front of the fire. "Firebrand showers" are the major cause for structural fires and damage in WUI areas.

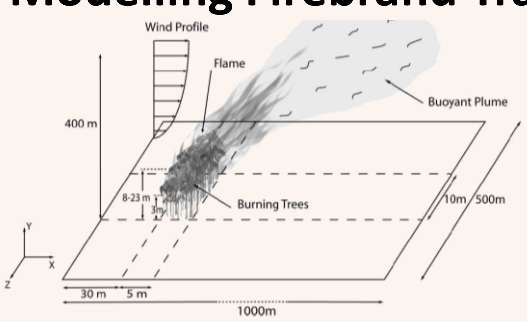


Schematic of the spotting process. [5]

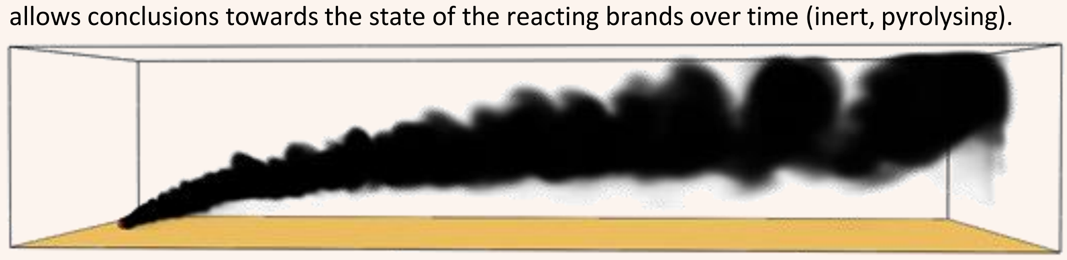
Research Intent

This work aims to develop a numerical model for the transportation of firebrands in outdoor fires using FDS to investigate the influence of characteristic properties and the dynamics involved in the process. Moreover, it is assessed how relevant phenomena and their interaction can be portrayed using FDS in order to advance the techniques for predictive modelling of wildfire behaviour and fire spread.

Modelling Firebrand Transport



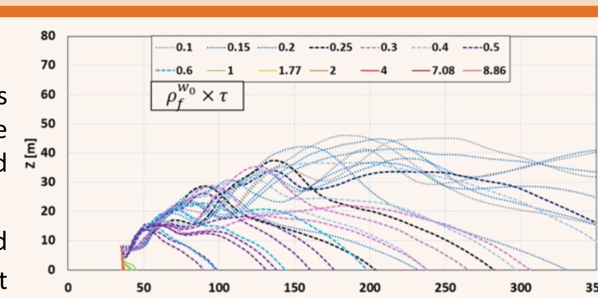
In the schematic on the left [6], the physical problem is shown within the computational domain. The present work closely followed the study by Sardoy et al. to allow comparison between the two approaches. A tree crown line fire with an intensity of 10 MW/m was mimicked through 2,000 particles each representing 2,017 small cylindrical particles with a constant mass loss rate. CO is taken as the prime combustible part of the pyrolysis products, which is invoked through reaction rates from first-order Arrhenius equations for the firebrands, which are released at the ridge between the top and the downstream side of the canopy at an initial temperature of 1044°C and velocity equal to the local gas velocity. Sub-models for pyrolysis and subsequent combustion of fuel gas are built-in, however a char oxidation model was still pending validation and detail examinations and was therefore not included at the time. Firebrands were represented through quadratic, plate-shaped particles in FDS. The side length was chosen through an equivalent area to disc-shaped particles with diameters of 4-10 cm. The thickness varied from 2 to 100 mm and densities of 50-200 kg/m³ were considered. The mass loss rate was chosen as the most reliable traceable property of particles in FDS that allows conclusions towards the state of the reacting brands over time (inert, pyrolysing).

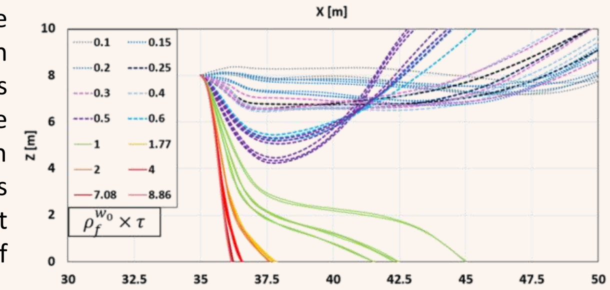


Results

The landing distance of firebrands was found to be heavily dependent on the product of the initial density and thickness, $\rho_f^{w_0} \times \tau$.

Particles with $\rho_f^{w_0} \times \tau \leq 0.6$ are lofted by the plume, whereas such ≥ 1 are not entrained in the plume and land on the ground in a flaming state. In comparison to [6], significantly longer trajectories are observed (>800 m) and the distribution of landing distances is much wider. However, only few trajectories are reported in [6]. Char oxidation must be invoked to identify the behaviour of firebrands downwind in the future.





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I want to express my gratitude to Prof. Arnaud Trouvé from UMD for his invaluable guidance and support throughout the thesis work and also thank Prof. Bart Merci from Ghent University for his supervision of the project.