An introduction to physics-based simulations of wildfires

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Wildfire science is an interdisciplinary field that has developed considerably over the past 30 years. The field encompasses work by ecologists and foresters, climate scientists, remote sensing scientists, meteorologists, social scientists, physicists, engineers, and mathematicians. The overarching goal is to better predict the ignition, spread, and impact of wildfires so that the risk of wildfire can be managed. The impact of wildfires in Australia is extreme, the 2019-2020 *Black Summer* fires are estimated to have cost over $100 billion. The 2009 *Black Saturday* fires in Victoria caused $4.5 billion worth of damage in a single afternoon.

Computational fluid dynamics (CFD) simulations offer an opportunity to better understand the processes that occur during wildfire. In wildfire science the term physics-based simulation refers to simulation methods that attempt to represent all physical processes, particularly combustion, as faithfully as possible. Current operational fire spread models simply advance a fire contour at a rate determined from empirical-derived statistical models and do not consider the action of the fire plume upon the atmosphere.

This presentation will introduce physics-based simulations for wildfire and we will discuss the validation of simulations of grass fires using experimental data, buoyancy- and wind-driven modes of propagation, the effect of ignition protocol on grass fire behaviour, and the simulation of merging junction fires.

Experimental grass fires data, such as the quasi-equilibrium rate of fire spread (R_{qe}), fire shape, and area over time may be used as quantities to validate the physics-based simulations. Physics-based simulations also support the notion of two primary regimes of fire spread: a buoyancy-driven mode where the fire plume dominates over the ambient wind, and a wind-driven mode where the ambient wind dominates over the fire plume. Wind-driven fires have elongated flames that may attach to the ground and enhanced convective heat transfer to unburnt fuels, whereas buoyancy-driven fires have more upright flames and appear to be dominated by radiation heat transfer to the unburnt fuels. Most operational models assume the fire propagates at a quasi-equilibrium rate R_{qe}, and use statistical models developed from experimental fires to estimate R_{qe} from known conditions, however, a simulation study has shown that the experimental fires must be ignited carefully to avoid spurious acceleration phases that can disturb the estimation of R_{qe}. Merging fires also violate the assumption of quasi-equilibrium spread such as when two lines of fire merge in a v-configuration, the apex accelerates more than can be expected from geometrical considerations. Physics-based simulation studies offer insight into the fire behaviour during merger and offer a promising method to develop reduced models of merger suitable for operational purposes.

This presentation will conclude by presenting an overview of simulations of gravity currents with applications to smoke transport and emerging work on the simulation of ember storms.