bushfire&natural HAZARDSCRC

Prediction of vorticity-driven wildfire propagation in operational time frames

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SPOTFIRE PROJECT

Dynamic modes of fire propagation present a significant challenge for operational fire spread simulation. Indeed, current operational fire simulation platforms are not generally able to account for such behaviours. Here we demonstrate a two-dimensional modelling approach that is able to accurately simulate vorticity-driven wildfire propagation well within operational time frames.

BACKGROUND

Fire-induced vorticity (like a fire whirl) can cause a bushfire to behave in an erratic or atypical manner. A key example is vorticity-driven lateral spread (VLS), which involves rapid lateral fire spread across the top of a steep, leeward slope in a direction approximately perpendicular to the synoptic wind direction.

This mode of fire propagation can pose a significant danger to firefighter and civilian safety, and has been implicated in the development of violent pyroconvection.

The distinctly dynamic nature of VLS means that it cannot be modelled using current operational fire simulation platforms, which rely on the assumption of quasi-steady fire spread. Figure 1 illustrates the vorticity dynamics that underpin the VLS phenomenon.

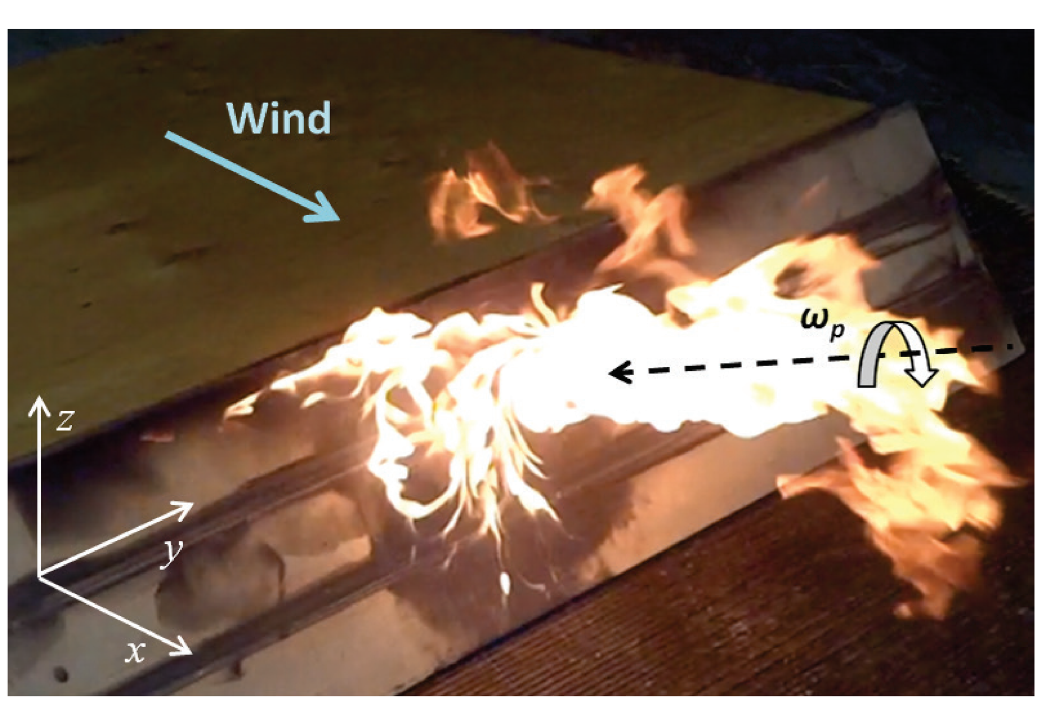

Figure 1: Experimental fire in a wind tunnel showing a fire-induced vortex (fire whirl) on the leeward slope of an idealised ridge. The pyrogenic vorticity $\boldsymbol{\omega}_p$ and its orientation are indicated in the figure

NEAR-FIELD MODELLING

Hilton et al. (2018) detailed a two-dimensional fire spread model that incorporates an induced 'pyrogenic' air flow close to the ground (mid-flame height). The model has the distinct advantage of being very computationally efficient.

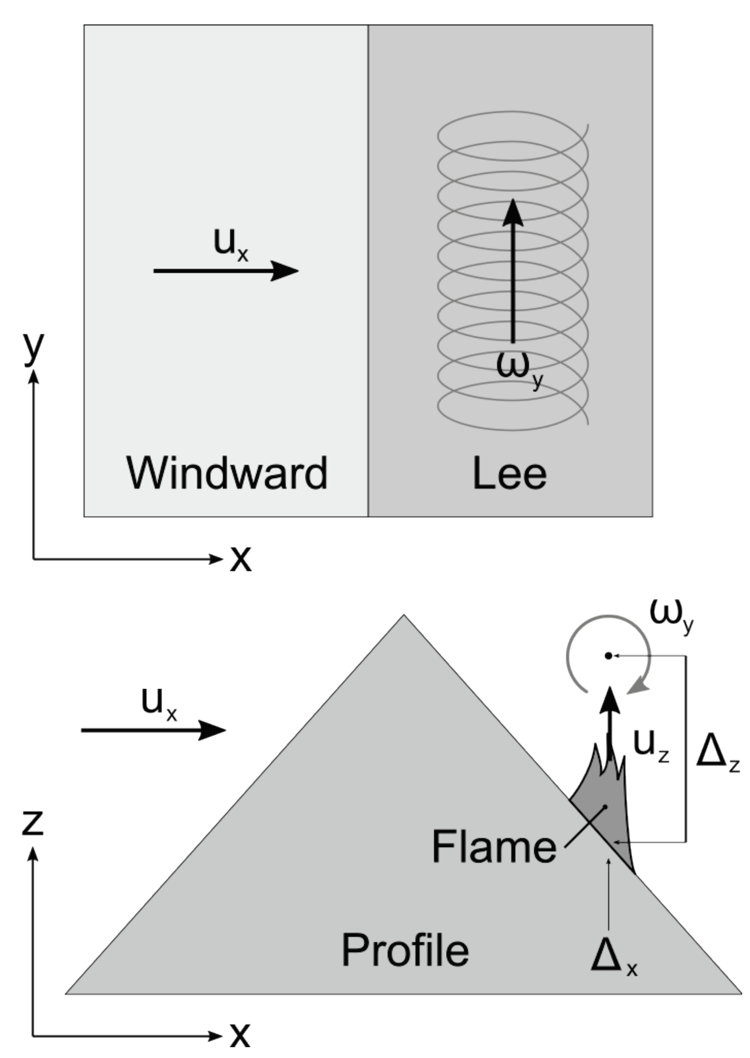

Figure2: Schematic set-up of the near-field model.

In the near-field (i.e. not too far away from the fire), the induced flow can be modelled as the combination of an irrotational flow and a rotational flow, the latter of which can be interpreted as pyrogenic vorticity. This provides a computationally efficient way to simulate vorticity-driven wildfire propagation. The VLS model set-up is shown in Fig 2. The model uses solutions of Poisson equations:

$$\nabla^2\psi = \nu, \nabla^2\boldsymbol{\eta} = \boldsymbol{\omega},$$

to model the pyrogenic flow:

$$\boldsymbol{u}_p = \nabla\psi + \nabla \times \boldsymbol{\eta}.$$

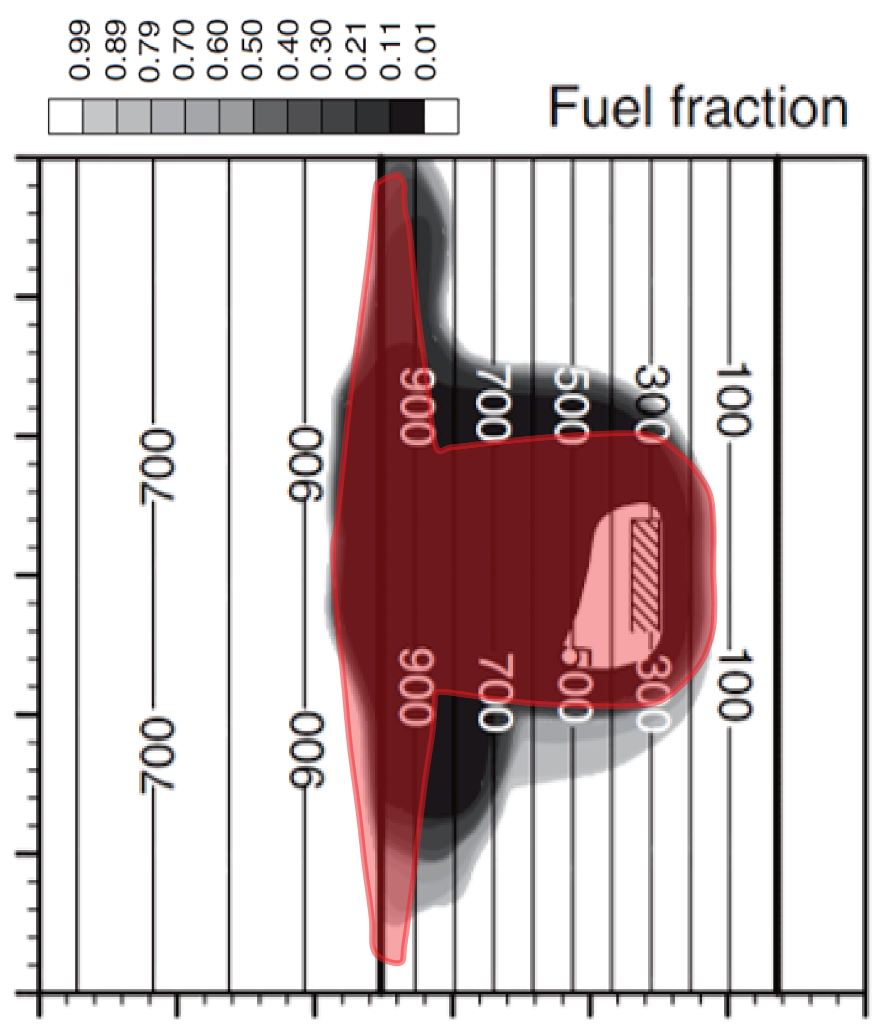

Figure 3: VLS simulated using a coupled fire-atmosphere model (grey scale), overlaid with corresponding output from the 2D pyrogenic potential model (red shading).

RESULTS

Figure 3 compares VLS simulation using a fully coupled fire-atmosphere model (approx. 10 hours simulation time) with that obtained using the 2D pyrogenic potential model (approx. 10 seconds simulation time). The simpler model is able to capture the key characteristics of VLS. Some differences remain on the leeward slopes, below the main region of lateral spread. These are likely due to flow turbulence in the coupled model, which is not accounted for in the pyrogenic potential model.

Nevertheless, the pyrogenic potential model offers a feasible operational approach to modelling dynamic modes of fire propagation.

Ongoing research will refine the model and increase its suitability for use in operational environments.

References and further reading:

Hilton, et al. (2018) Incorporating convective feedback in wildfire simulations using pyrogenic potential. *Environmental Modelling and Software*, 107, 12-24.

Sharples and Hilton (2019) Modelling vorticity-driven wildfire behaviour using near-field techniques. *Frontiers in Mechanical Engineering*, Under review.

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