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Numerical simulations of fire-spotting: flame characteristics formulation

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Wildland fire is a natural threat to environmental, economical and social systems. Uncontrolled ignitions occur worldwide regardless national fire-fighting strategy and cause a lot of damage, even the loss of human lives, thus the deeper understanding and modelling of wildfire nature and propagation has become more urgent.

Fire-spotting is a harmful phenomenon that accelerates the rate of the spread of fire by producing new independent ignitions by burning embers. Fire-spotting is strongly affected by wind and fire intensity, not only in transporting the firebrands, but in changing the form of the flame. Thus, the aim of this study is to establish the relation between the flame geometry and the fireline intensity in wildfires and apply it to the wildfire propagation model by the fire-spotting distribution.

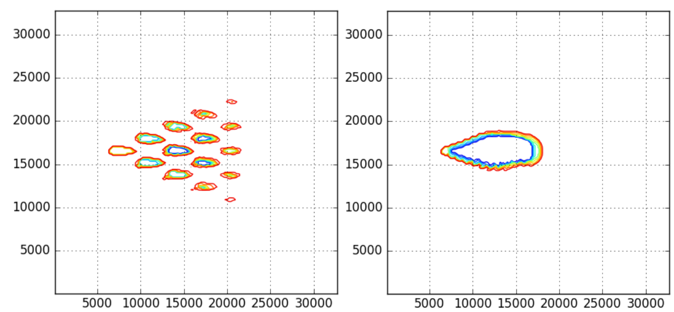
The flame characteristics are strongly affected by the wind and the fire intensity. Moreover, the flame length $L_{\rm f}$ and the flame height $H_{\rm f}$ are connected by the following trigonometric relation $H_{\rm f} = L_{\rm f} \cos\alpha_{\rm f}$, where $\alpha_{\rm f}$ is so-called flame angle, or flame tilt.

There is an important lack in the literature on the theoretical relation between the flame height and the fireline intensity, which is a fundamental descriptor of wildfires. In present study we establish theoretically the following relation between the flame height and the fireline intensity by using the energy conservation principle and the concept of the energy flow rate in the convection column above a fireline:

(1) $$H_{\rm f} = \left[\frac{1}{2g(\rho c_{\rm p} T_{\rm a})^2}\right]^{1/3} I^{2/3}\,.$$

Note that (1) agrees with the result of [1, 2].

The derived formula is also used to state the rate of spread of fire in terms of the flame height, and for estimating the Byrams energy criterion in terms of the temperature of the flame and of the ambient air. Inserting (1) into trigonometric relation above, the flame length can be derived in term of the fireline intensity. Derived formula is introduced into the fire-spotting model described in [3] via lognormal distribution parameters. The results of the inclusion of the flame length into the model are presented in figure (left), comparing with the parametrization given in [3] (right).



The flame length affects to the parameters of the distribution and the fire-spotting is observed.

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