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Fire-spotting generated fires: macro- and meso-scales effects

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Abstract

Fire-spotting is one of the key aspects of the wildfire propagation since it provokes new independent ignitions and may significantly accelerate the rate of spread. It cannot be studied isolated from the main fire-front propagation. Present study is based on idea to split the fire-front motion into two parts: a drifting and a fluctuating, which includes the randomness of turbulent hot-air transport and fire-spotting. The main advantage of such approach is its versatility since it can be applied to any existing fire spread model. Fire-spotting involves aspects among scales: from the combustion chemistry in microscale, to fire-atmosphere interaction in macroscale. Hence, we aim to estimate the physical parameters of the phenomena by employing a concurrent multiscale modelling. At the meso-scale level, fire-spotting is affected by the mean wind and fireline intensity, which is found to be in a strong interaction with the surrounding factors, such as fuel and local orography. This fact allows us to study the effect of the flame length, which can be specified by the fuel and temporal characteristics, and terrain slope to the fire-spotting. Empirical relations of the flame length – fireline intensity given in literature are generalized in present study by using the energy conservation principle. Contrasting to literature, the proposed physical formulation allows stating the rate of fire spread in terms of the flame geometry factors by including the effects of the horizontal mean wind and the terrain slope. At the macroscopic level, the impact of the atmospheric conditions is considered. The depth of the atmospheric boundary layer is considered in the estimation of the smoke-injection height including the uplift against the atmospheric stratification and the plume widening due to entrainment of the surrounding air. Implicit connection between the atmospheric stability and fire propagation allows the modelling of various scenarios. Numerical simulations showed that with stable conditions turbulence is not strong enough to merge the fires and, at large elapsed times, this results into a higher number of independent fires but lower burned area with respect to unstable conditions when the push of turbulence leads to faster merging resulting into a lower number of independent fires but higher burned area. Simulations showed also that terrain slope enhances the spread of the fire at a higher rate than it augments fire-spotting generated fires, such that a rapid merging occurs among independent fires.

Keywords: Wildland fire, Fire-spotting, Atmospheric stability, Flame length, Terrain slope

References

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