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The role of forest canopy-wind interactions on experimental fire behavior using coupled atmosphere-fire modeling

william antolin
CERFACS, GLOBC, France (antolin@cerfacs.fr)

Authors and affiliations: William Antolin[1], Mélanie C. Rochoux[1] and Patrick Le Moigne[2]

[1]CECI, Université de Toulouse, CNRS, CERFACS, Toulouse, France

[2]CNRM, Météo-France, CNRS, Université de Toulouse, Toulouse, France

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Abstract:

Experimental fires provide insights into the behavior of wildland fires and their interactions with the atmosphere. They help modelers build simulations capable of accurately describing fire dynamics, and which can help identify the key processes driving fire development. In particular, the FireFlux I case (a tall grass fire covering 30 hectares) was the first experimental fire to provide in situ measurements of atmospheric dynamics near the fire, highlighting the complexity of fire-induced flows and the importance of fire-induced upward vertical motion (Clements et al. 2007). Despite much theoretical work on forest canopy turbulence, its interactions with fire dynamics are still poorly understood, while they could play an important role (Heilman et al. 2021). [MR1]

One of the difficulties in wildland fire simulations stems from the disparity between scales. Highly detailed models based on computational fluid dynamics (CFD) tend to represent chemical, radiation, and turbulence processes at the cost of reduced domain size. Conversely, meteorological models tend to provide a better representation of ambient wind over a larger domain size, but this is at the expense of parameterization choices. An intermediate modeling scale is needed to represent the geographical and micrometeorological scales involved in a wildland fire, especially in the development of the fire plume and the induced air entrainment. In recent years, we have therefore worked on designing and validating a coupled atmosphere-fire model, Meso-NH/BLAZE (Costes et al. 2021), where BLAZE represents the fire as a propagating flaming front and Meso-NH is run in large-eddy simulation (LES) mode at high resolution (10-100 m). This preliminary work has highlighted the predominant influence of surface wind on fire behavior and thus the critical need to make it more representative.

In this study, we show that accounting for interactions between forest canopy, surface wind and fire can be done by adding a drag term in the Meso-NH momentum and TKE equations (Aumond et al. 2013), and by running coupled atmosphere-fire simulations at very high resolution (10m and finer). We also assess for the FireFlux I case, the impact of the forest canopy on fire spread through several original data analyses, including wavelet transforms, fire-canopy interaction statistics, and sensitivity to atmospheric turbulence.

References

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