

In this study, Muth et al. incorporate fire-induced meteorological changes into plume-rise modeling and examine the effects of fire–atmosphere coupling within the host model on plume development. The results demonstrate that fire-released heat plays a primary role in increasing plume height, mainly through enhanced buoyancy and cloud formation. In contrast, moisture released by fires has a negligible influence on plume dynamics. Beyond sensible and latent heat fluxes, aerosol–radiation interactions exert contrasting effects on plume injection height: initially, they reduce injection height by stabilizing the atmosphere, but subsequently increase it via a lofting effect. Overall, this work represents a significant advancement in the modeling of fire–atmosphere interactions. The findings align with previous studies in the literature. I think that the manuscript is suitable for publication in ACP once the following points are adequately addressed.

It is unclear how the calculated fire-induced sensible heat flux and moisture release are incorporated into the fire plume rise model and how they affect the grid-scale meteorological fields of the host model. For instance, is the fire-induced sensible heat flux added directly to the surface heat flux in the host model, or is it converted into temperature perturbations relative to the environmental temperature in the plume? Similarly, is the fire-induced moisture release included in the plume's water vapor content? If both terms are introduced into the governing equations of the plume model (it may be helpful to present these equations), how do they subsequently influence the air temperature and moisture fields in the host model?

Additionally, how is aerosol–radiation feedback incorporated into the fire plume rise model? Is this process represented in the governing equations for plume temperature and vertical velocity? Furthermore, how is this feedback subsequently transmitted to the host model—specifically through the direct radiative effects of fire aerosols? At present, many key details appear to be omitted. Thus, the authors should provide a clear and explicit description of these representations.

In the model configuration, the limited-area model simulations are conducted with a grid spacing of 6.6 km. Are the calculated fire-induced sensible flux and latent heat flux (i.e., the moisture release) upscale to be relative to the grid area or still relative to the burned area (i.e., sensible/latent heat per unit grid area or that per unit burned area)? As the authors noted, the grid spacing is still too coarse to explicitly resolve convection and the associated plume-rise processes, which, to some extent, will smooth out the fire heat effects. In this context, a recent study by Ma et al. (2025) innovatively addressed this issue by incorporating fire heat at the subgrid scale within the convection scheme of a global climate model. Regarding this point, I recommend that the authors include a thorough discussion of this in the final section of the manuscript.

Regarding Eq. (1) for estimating fire size within a grid cell: why did the authors not directly use observed burned area products? Equation (1) assumes a linear relationship between FRP and burned area, which may not hold in all cases. For instance, although

forest fires typically burn smaller areas than grass fires, they can exhibit higher FRP due to denser fuel loads (Zheng et al., 2021). Moreover, the triggering of convection is influenced by FRP density (i.e., FRP per unit burned area), rather than by total FRP (i.e., total fire heat or fire heat per unit grid area). The current approach may therefore underestimate the capacity of forest fires to initiate convection, given their high sensible heat intensity (i.e., sensible heat per unit burned area) (Ma et al., 2025).

It is unclear whether the parameters of the diurnal cycle function are applicable to Australian wildfires, or if they vary across different climate zones and fire regimes. Further clarification on this point would strengthen the manuscript.

The parameters in Eq. (7) should ideally be dependent on the fire regime. It would be more appropriate to integrate moisture release from different fire types using a lookup table, following the approach of Ma et al. (2025). Alternatively, the authors should provide a comprehensive discussion of the uncertainties associated with the current simplification.

I suggest reorganizing the manuscript to improve the logical flow. Presenting Section 3.2 first would be more effective, as it demonstrates that the ALL simulation agrees well with observations. Establishing the model's credibility upfront would provide a stronger foundation for presenting the sensitivity experiments in Section 3.1 for the mechanism analysis.

In the final section, I recommend that the authors include a discussion of the uncertainties in this study, including some of the issues raised earlier in this review.

Regarding the experimental design: the REF simulation was conducted as a global run at 13 km resolution, which differs from the 6.6 km grid spacing used in the limited-area simulations. This discrepancy in resolution may introduce additional uncertainty. To better isolate the impact of fires, it would be valuable to also include a limited-area simulation without fire influences for a more consistent comparison.

Figure 1: Consider adding a panel to schematically illustrate how the revised plume-rise model is coupled in ICON-ART to account for fire-induced meteorological feedbacks to the host model.

Figures 6 and 7: Why are there limited clouds over the biomass burning regions, despite the expected fire-induced convection? Also, suggest adding wind vectors to denote the downstream direction.

Figures 8 and 9: It seems that all the simulations show substantial discrepancies compared to observations.

References:

1. Ma, Q., Wei, L., Wang, Y., Zhang, G. J., Zhou, X., & Wang, B. (2025). Fire heat

affects the impacts of wildfires on air pollution in the United States. *Science*, 389(6765), 1137-1142.

2. B. Zheng et al., Increasing forest fire emissions despite the decline in global burned area. *Sci. Adv.* 7, eabh2646 (2021).