

Major comments

1. I am not convinced that the current modelling approach could qualify as a “spotting model”. A complete spotting model requires four components: generation of firebrands, transport, deposition/accumulation, and ignition. This work provides a transport method but relies on oversimplified generation, lacks details on deposition characteristics, and lacks ignition capabilities. I suggest clarifying this choice in the paper title, specifying that this work focuses on a firebrand transport model rather than a complete spotting model. The title has been changed to reflect this: “Transport dynamics of firebrands in a coupled Fire-Atmosphere model: an Eulerian approach”. The abstract and introduction have also been modified by deleting the mention of spotting model.
2. 21-22: “supporting its potential for operational wildfire modelling and decision making”. This statement oversells the paper's impact, as many components are currently missing for it to be considered a complete spotting model. The results are encouraging but not yet exploitable in an operational context. We have deleted this phrase. It now reads: “Results demonstrate that this simplified approach provides a credible and time-efficient firebrand deposition forecast.”
3. Model equations are not very clear. L.107 describes a “diffusion-advection conservation equation,” but Eq. 1 does not show any diffusion term; it is a pure advection equation. L.116 claims that “the source term includes the turbulent diffusion”, can you explicitly explain how? L.559-560 says “diffusivity assumed equal to that of the air flow”, where is the term in the equation? Also, you need to specify the units of each term of the equation in the text. If U is the wind flow and appears in the equation, where does the terminal velocity arise in the equation?

Indeed, this was not clear enough. The schema we are using is the Piecewise Parabolic Method that models the advection of a passive scalar. U is the vector : $(u,v,w-w_g)$ where u is the zonal velocity, v is the meridional velocity, w is the vertical velocity and w_g is the firebrand terminal velocity defined by equation 2.

As a result, section 2.2.2 now reads:

“In the Eulerian model, firebrands are considered as a continuous concentration field. Its spatiotemporal evolution is described by an advection conservation equation (1). Where ρ_{ref} is the reference air density, C_i is the concentration of the i -th firebrand class, U is the advecting wind vector ($m.s^{-1}$) given by $(u,v,w-w_g)$ where u is the zonal velocity, v the meridional velocity, w the vertical velocity and w_g the firebrand terminal velocity. S_i is the source and sink terms (corresponding to the injection and deposition of firebrands). The equation is written for a general number of firebrands (index i), as the modelling options could include multiple types of firebrand densities, or different firebrand states (burning and non-burning firebrands, for instance).

$$\frac{\partial(\rho_{ref}C_i)}{\partial t} + \nabla(\rho_{ref}C_iU) = \rho_{ref}S_i \quad (1)$$

The advection of the firebrand concentration field is calculated using the piecewise parabolic method (PPM). Specifically, the PPM scheme used here incorporates the flux limiter (Skamarock, 2006). When using this scheme in Meso-NH, numerical diffusion of the scalar field is not activated to prevent damping of well resolved extrema (Lac et al., 2018). Firebrand concentration and air parcel relative velocity is represented by the addition of a vertical terminal velocity to the wind flow (Tarifa et al., 1967, 1965; Thomas et al., 2020). In this study, the Eulerian model accounts for a single firebrand species with a mean vertical terminal velocity given by equation 2. Using $g=9.81 \text{ m.s}^{-2}$, $\rho_0= 350 \text{ kg.m}^{-3}$, $\rho_{atm}= 1.2 \text{ kg.m}^{-3}$, and an adjustment factor $\lambda=0.0023$ (Alonso-Pinar et al., 2025b), the resulting terminal velocity was 3.2 m.s^{-1} . Rotational impacts and aerodynamic lift are neglected.”

And Line 830 (previously 559-560):

“Firebrand transport was modelled using a scalar advection equation. This assumption may be overly conservative. Due to their inertia, large firebrands (denser than air) do not follow the smallest turbulent eddies but rather respond to the larger turbulent structures.”

4. A mass conservation study is missing. This study is mandatory for the verification of every transport scheme. The authors need to verify that the mass of firebrands you inject equals the sum of the mass of firebrands in the atmosphere and the mass deposited (and account for mass flux at lateral boundaries) at all times. If the model is not perfectly conservative, one will need to quantify the degree of non-conservativity and assess whether this could be a limitation.

We did a mass conservation study on the idealized case but did not include it in the results of the paper. It has now been added in section 2.3:

“A preliminary set of simulations were performed using the idealized configuration to study the mass conservation of the Eulerian model. By accumulating the injection and deposition of firebrands during the simulation, it was possible to calculate their difference and evaluate the firebrand mass loss. It was found that the numerical scheme influenced the mass loss. Among the three available numerical schemes (Lac et al.; 2018), the unrestricted PPM00, the monotonic version PPM01 and a monotonic scheme with a flux limiter PPM02, the latter conserved 96% of the injected firebrand mass. At the scale of the full simulation, this residual was considered sufficiently small that it does not affect the main conclusions of the study.”

5. If I understand correctly, the Eulerian model does not include aerodynamic interactions, and the terminal velocity is only a function of firebrands' density. On the other hand, the Lagrangian model uses a drag model and should account for the particle's aspect ratio. How did you account for this extra degree of freedom in the validation dataset? How did you select firebrands' properties for the Lagrangian model? If the Eulerian model is supposed to represent an

average firebrand, shouldn't your validation dataset contain multiple runs of the Lagrangian model with various aerodynamic properties to account for the diversity of particles and compare the average of this ensemble to the Eulerian results?

Yes, in the Lagrangian simulation, firebrand initial properties are randomly assigned: thickness, radius and density are randomly obtained from a uniform distribution using the values in Table 1 (from <https://doi.org/10.1016/j.firesaf.2025.104348>).

As a result, the Lagrangian description does take into account various aerodynamic properties (length, diameter) allowing for a comparison with the Eulerian model. These informations were not included in the previous paper and have now been added to section 2.5:

“The firebrand characteristics (length, height, density) are randomly assigned based on existing literature and a previous numerical study on Lagrangian simulated firebrands (Alonso-Pinar et al., 2025a).”

6. The injection parameters seem a bit too arbitrary and unrealistic. A flux of $1 \text{ kg/m}^2/\text{s}$ for 60s is 60 kg/m^2 of firebrands injected. This way over any wildland fuel load. For comparison, considering your heat flux of 60 kW/m^2 for 250s and a combustion constant of 17.433 MJ/kg (usual for vegetation, value used in WRF-SFIRE), the fuel load you use for the real case is 0.86 kg/m^2 , which is 70 times lower than the firebrand load you inject in the atmosphere. Using an unrealistic value can inform the deposition pattern, but the authors cannot reasonably examine the absolute deposited mass (L.456 is hardly defensible to me); one can only study normalized deposition. Moreover, to apply this model to an arbitrary injection value, the authors would need to demonstrate whether the transport is sensitive to the injection rate (how do the deposition pattern/values change at $0.5 \text{ kg/m}^2/\text{s}$ versus $2 \text{ kg/m}^2/\text{s}$?).

Indeed, we acknowledge that this value is not related with fuel properties and might seem unrealistic, and we have added a sentence to note this in section 2.1.1: “Although this value is very large compared to a standard fuel load, it provides a unit reference, easy to scale and further compare. This choice makes the results directly scalable. Since the present Eulerian transport formulation does not include firebrand–firebrand interactions, source-induced flow modifications, or concentration-dependent settling/deposition, the governing equation is linear in firebrand concentration. As a result, multiplying the injection rate by a linear factor multiplies both airborne mass and deposited mass by it, while leaving the normalized spatial deposition pattern unchanged. For this reason, the idealized study is best interpreted as a unit-source response, from which results for any other injection intensity can be obtained by linear rescaling.”

During the development of the model, tests were conducted and the injection rate did not affect the deposition patterns due to the lack of interaction: the

firebrand field is advected by the wind with an imposed vertical velocity. Regarding L456 (now L688 due to modifications in the manuscript), we do examine the absolute deposited mass. Normalizing it by the total injected mass during the event is going to linearly scale all values by the same amount. The deposition patterns are going to be identical.

7. 130: What element in Fig.7 of Filkov et al. 2017 justifies the delay of 30s? An increase in wind speed is not necessarily perfectly located at the fire front. Why is this delay important for the transport model? Does it change the firebrand landing location?

In Fig. 7 of Filkov et al. (2017), a change in wind velocity occurs at minute 10, while firebrands are only recorded 30–60 seconds later. The inclusion of a time delay is motivated by physical considerations, as a finite period is required after flame arrival for firebrands to be generated. Preliminary tests indicated that this delay does not significantly influence deposition patterns, provided it remains within the same order of magnitude (0–10 minutes).

8. There is no section about deposition. How do you compute the deposition flux? 227 is not very explicit.

Section 2.2.3 has been added to provide more details about the firebrand deposition and its calculation. It now reads:

“2.2.3 Firebrand deposition

Deposition is obtained through a temporal integration of this firebrand mass flux at the ground cell. Specifically, the sum of all values is computed, which corresponds to the total instantaneous flux of particles reaching the ground over the domain. This quantity is multiplied by the atmospheric time step, providing the amount deposited during that time increment. The result is accumulated over time to produce a cumulative deposition: a simulation output variable is obtained every 20 seconds to limit disk writing. Two separate accumulations are performed: one for injected particles from the ground and one for deposited particles. In both cases, the method is equivalent: deposition is calculated as the time integral of the spatially integrated ground flux, assuming that the flux is uniformly distributed over each grid cell and constant within an atmospheric time step.”

9. 235: Normalized to what quantity? The total mass injected, the mass injected into one cell? This is critical information that needs to be explicitly described. Thanks for noticing this. It has been incorporated in L363: “The mass ground landing distribution was normalized by the total mass injected.”

10. 1. Ticks must be revised as the top right panel is not exploitable due to only one tick being present. Orography of the hill must be shown as contours in 1b. I am not sure to understand how the authors compute “occurrence” with the Eulerian model. L. 238, the distribution may look similar, but one seems to have an order of magnitude difference for the mid-range (5 to 8 km). Can the authors explain it? The Eulerian result exhibits significant dissymmetry. Is it something to be expected from this ignition/spread pattern? We have now included more vertical ticks in the top and right panels of Figure 1.

We have decided not to show the hill contours as it would add too much information to the plot : overimposing hill contours and firebrand deposition contours might be confusing. We have nevertheless included a reference to our previous work where the reader can visualize the hill shape and dimensions. The difference for the mid-range distribution was attributed to differences in terms of terminal velocity. The Eulerian approach uses a fixed-value terminal velocity while the Lagrangian approach computes individual terminal velocities for each simulated firebrand.

Horizontal dissimetry was attributed to the interaction between the spread pattern (following an arc-shaped profile representative of wildfires) and its interaction with the boundary layer wind profile creating dynamic effects of the plume producing a slightly dissymmetrical plume.

11. I am not sure about the scientific merit of Section 3.2.4, which compares the computational cost of fire vs. no-fire simulations. The expected computation cost study compares 3 simulations: coupled without firebrand transport (reference), coupled with Lagrangian transport, and coupled with new Eulerian transport. This can be done for idealized and/or real configurations. The objective of section 3.2.4 is to show that including a Eulerian description of firebrand transport is not prohibitive and can be done without adding too much calculation time: 172 minutes with the Eulerian model and 143 without it. We tried to compare our results to the ones from Frediani et al. (2025) but they do not seem to report any computational time.

12. To extend the analysis in Fig. 9, I would like to see statistics on the deposition value at each observed spot.

As it can be seen in Figure 9, the deposited firebrand field has a large extent when compared to the point locations of the reported spot fires. As a result, a quantitative assessment of the deposited firebrand mass in the pixels containing a reported spot fire would make more sense with more data points coming from different case studies. This paper did not aim to provide a quantitatively verified model, which is impractical due to the current Eulerian model assumptions, but rather to introduce a new firebrand transport approach that had not been

considered yet. We have provided two main elements providing physical consistency: the comparison of the simulated firebrand field with radar data of firebrands while being transported, for the first time, and the comparison of deposited firebrand mass with reported spot fires.