

Main Comments

1. Fuel description. L66: “Four main fuel classes were identified: grassland, forest, artificial surfaces and constructions, and water bodies”, these are not fuel classes, these are land cover classes. I don’t understand why this was used, instead of Corine Land Cover. Shrubs are missing. Moreover, I don’t understand why the authors need fuel data from EU land cover considering that they are running idealized cases (you can simply assign a fuel class) and a fire in Australia that one would expect to have detailed fuel data. Which fuel models were used?

Indeed, there’s a mistake: the term “fuel classes” has been changed to land cover classes. We did not use the CLC dataset as the case study is in Australia. Instead, the ESA World Cover dataset was used for Mt Bolton case study. There was an error in the original text. For the idealized cases (flat and hill terrain), a homogeneous fuel layer was used. This has been corrected in the new version.

While more detailed fuel data relevant to the Victorian landscape might have been available, the fuel combustion parameters used in the Rothermel model are usually not available. This is why we used standard fuel classes such as grassland and forest cover. In the case of the Mt Bolton bushfire, no shrubs were present among the identified fuels.

2. L98 “We acknowledge that the Rothermel model was developed for, and is typically applied to, Northern Hemisphere coniferous forests, but our analysis focuses on ForeFire’s performance in spotting transport rather than firebrand generation or forward rate of spread”. This should be in the discussion section under the limitations of the fire spread simulation.

Indeed, this has been moved to the discussion part (first paragraph, section 4.2). Thanks for noticing it.

3. Simulation setup (section 2.3) would benefit from having a clearer separation between the idealized simulations vs. the real case simulation.

We have split section 2.3 into two new sections: “Section 2.3 Idealized simulation setup” and “Section 2.4 Mt Bolton simulation setup”.

1. L194-195: Rate of spread is expressed in m/min, not ha/min. Please correct.

We were referring to the “burnt area rate of spread”. We have now modified the text to include this distinction (L205).

2. “Verification of the model” (section 2.5). This section encapsulates two main concerns:

1. It looks like the authors did a “model comparison” where they compare the results of this new model with another model. It is not clear (from the beginning) why this was done and what kind of added-value this brings to paper. The model comparison should ideally be stated in the objectives of the paper. Reading the paper further, it looks like one of the objectives is to compare computational costs...
2. It is stated in the objectives that the model will be validated against the extensive observations of Mt Bolton fire. Reading the Methods section there is no reference to “validation” and Figure 3 does not show spotfire landing location. Moreover, “verification”, “model intercomparison” and “validation” are separate things that should be distinguished.

Please revise both aspects so that it is clear to the reader what is intended in each step of the analysis. Verify is not the best term. Use evaluate\assess in the first case, validate in the second.

1. Using the idealized case as a canonical case study, we compared the two approaches to simulate the firebrand trajectories. We acknowledge that the reason was not present in the original manuscript, and we have updated the objectives of the study:

L77 “The main goal is to introduce and evaluate the model using both idealized and realistic case studies. To achieve this goal, several objectives are identified: perform a comparison between the Lagrangian and Eulerian approaches in terms of deposited firebrands and computational costs, perform a comparison between the Radar observations and the simulation results, and finally to perform a comparison of spot fires between the Eulerian approach and field observations.”

2. We chose to show the spot fires only in Figure 9 to focus on the comparison between the reported spot fires and the results from the model. Figure 3 is rather focused on the comparison between observed and simulated fire contours: we think that adding the spot fires would make the figure confusing. We have also simplified Figure 3 to ease the comparison between the simulated fire contours and the observed fire contours.

We have changed the title of section 2.5 to “Section 2-5 Evaluation and validation of the models”. In this section, the first paragraph has been modified to describe the methods used to evaluate the Eulerian model by comparing its results to the Lagrangian model results. The second paragraph has also been modified to present the methods used to validate the Eulerian model using the Mt Bolton case:

L242 “The model is then verified based on the simulations of Mt Bolton wildfire. Firebrands were injected using the parametrization explained in sections 2.2.2, and 2.4. A first evaluation of the model is done by comparing radar echoes to

the simulation results. The firebrand fields are compared in terms of maximum reached height and horizontal displacement. A qualitative comparison is then performed between the reported spot fires produced during the wildfire event and the ground landing densities of firebrand mass flux obtained as a cumulative function of time. A choice was made to accumulate values every 30 minutes. This choice results from balancing the atmospheric and firebrand time dynamics and a time interval that can be useful in an operational context. All times reported are in Australian Eastern Daylight Time (LT; UTC+11), which accounts for daylight saving.”

3. There are some Methods missing, regarding how the assessment and validation were done. One example: first paragraph of section 3.2.3 refers to Methods and not Results.

We have moved this paragraph and another one from section 3.2.2 describing the Radar methods to the new section 2.5.

New section 2.5 now contains a complete description of the methods used. Please see our answer to comment #5.

4. Figure 1: where are the “orange contours”? Where is the ignition? What do these range values mean? (this is never mentioned in the paper)

“Orange contours” were referring to the filled contours colours using a colormap based on orange / red colours. This was not clear and the figure caption has been updated to:

“Figure 1 - Landing normalized mass densities of the Lagrangian (filled contours with an orange colormap) and Eulerian (blackgrey lines) model for values 260 0.01, 0.1, 1, 10, 100 and histogram of longitudinal (top) and axial (right) landing densities...”.

We tried to include the fire location in Figure 1 but it already has too much information. Regarding the ranges, this information was missing in the original figure. The ranges indicate an accumulated mass over a ground cell. This has now been corrected in Figure 1. Finally, in L160 we refer to our previous papers that contains detailed information about the fire description in the idealized simulation.

5. I do not understand why the authors compare surface progressions nor surface rate of spread (section 3.2.1) if the objective of the work is to implement and evaluate a spotting model. This is stated in the objectives (Section 1) but also on the sentence “but our analysis focuses on ForeFire’s performance in spotting transport rather than firebrand generation or forward rate of spread” (section

2.1). Additionally, it doesn't seem to make much sense to evaluate the progressions considering that "the available combustible fuel was limited to the burn area of the observed fire".

Indeed, this was confusing. The paper does not focus in detail on the firebrand generation process or the fire spread model. However, as we have elements of comparison for the fire spread, we think it does bring useful information to evaluate the simulated fire spread with the observed fire contours. We have included this in section 2.5.

For example, the comparison shows that the results from the simulation match the fire progression dynamics and shows that the simulation lags around 30 minutes compared to the actual fire progression. This explains the differences in terms of the dynamics of the deposited firebrands in Figure 9.

The available combustible was limited to the observed burnt area to account for fire extinction operations that limited the fire spread. We do not claim that the final burnt area is accurate but rather focus on the dynamics of the simulated fire. In that sense, we think that comparing the fire contours is an important method to check whether the model reproduces well the fire dynamics.

To improve this, we have extended section 2.5. Section 2.5 reads:

"2.5 Evaluation and validation of the model

The Eulerian transport model was evaluated on a set of idealized experiments with a fire forcing the atmosphere in two different idealized topographies: a flat terrain and a hill terrain. The Eulerian model is compared against a Lagrangian model that contains a description of the firebrand aerodynamic and combustion behaviour (Alonso-Pinar et al., 2025a). To describe the aerodynamics effect, the drag model from (Haider and Levenspiel, 1989) is chosen. The combustion model from (Oliveira et al., 2014) was chosen to calculate the size reduction of the firebrand. To perform the comparison, longitudinal and horizontal travelled distances are compared between the two models and the Fraction Skill Score, a measure of the spatial and intensity accuracy of a model, is used to conclude (Roberts and Lean, 2008). FSS provides a measure of the forecast skill (in this case the Eulerian approach) against spatial scales for a given threshold intensity. The score has a range between 0 (zero skill forecast) and 1 (perfect skill forecast). In both cases, firebrands were injected from the same area (Lagrangian firebrands' initial position was randomized following (Alonso-Pinar et al., 2025a)) and during the same time interval (firebrands were injected from 18,000 seconds until 18,600 seconds since the beginning of the simulation).

The model is then verified based on the simulations of Mt Bolton wildfire. Firebrands were injected using the parametrization explained in sections 2-2-2

and 2-3. A first evaluation of the model is done by comparing radar echoes to the simulation results. The firebrand fields are compared in terms of maximum reached height and horizontal displacement. A qualitative comparison is then performed between the reported spot fires produced during the wildfire event and the ground landing densities of firebrand mass flux obtained as a cumulative function of time. A choice was made to accumulate values every 30 minutes. This choice results from balancing the atmospheric and firebrand time dynamics and a time interval that can be useful in an operational context. All times reported are in Australian Eastern Daylight Time (LT; UTC+11), which accounts for daylight saving.

Finally, to assess the realism of the simulation, model results are evaluated against visual observations and radar measurements. Specifically, the atmospheric model computes the liquid mixing ratio within a given atmospheric grid cell defined as the sum of the rain drops ratio and cloud droplets ratio as parametrized by the ICE3 microphysics scheme (Caniaux et al., 1994; Pinty et al., 2001). This provides an indication of liquid water content and can be directly compared to radar measurements. In addition, simulated TKE contours are used to identify and locate the regions of high turbulence within the plume. We compared the simulated plume to observations by using the plume top height, defined in the simulation as the maximum cell height containing at least 0.01 g.kg^{-1} of smoke (a passive tracer injected at the fire location). To assess pyroconvective episodes of the plume, we analyse the temporal evolution of the fraction of the grid cell surface area containing at least 0.005 kg of deposited firebrand mass relative to the total injection surface area. Finally, fire progression contours are compared to conclude on the realism of the simulation.”

6. Figure 10: if plume measurements were done on the field, shouldn't they be displayed here?

The initial idea of Figure 10 was to show that the simulation describes the link between intense convective episodes and spotting activity.

7. Why didn't you compare the spotting simulations vs. observations considering the two models (Eulerian and LAgrangian)? This would allow a more complete analysis of the quality of the model you propose, besides the gains in computation time.

We compared both models in an idealized configuration and showed that the Eulerian model was faster and produced similar results when compared to the Lagrangian model.

The objective of the realistic simulation was not to intercompare the model again but rather to validate the Eulerian approach using observational data.

8. "it is likely that the ERA5 re-analysis has a time shift with respect to the actual wind behaviour, leading to a time difference in terms of fire progression." No weather station data available for comparison?

We appreciate the suggestion. We have compared data from a weather station located in the Ballarat aerodrome (15km to the south with respect to the fire location) to the ERA5 reanalysis. Figure 11 shows wind direction during the fire as recorded by the automatic weather station, at the same location as the AWS using ERA5 data and at the fire ignition location using ERA5 data. Although ERA5 reproduces well the general trend of the wind shift, the wind direction values are larger (coming from the North) than the measured values by the AWS explaining the time difference in terms of fire progression between the simulation and the observation.

See the figure added:

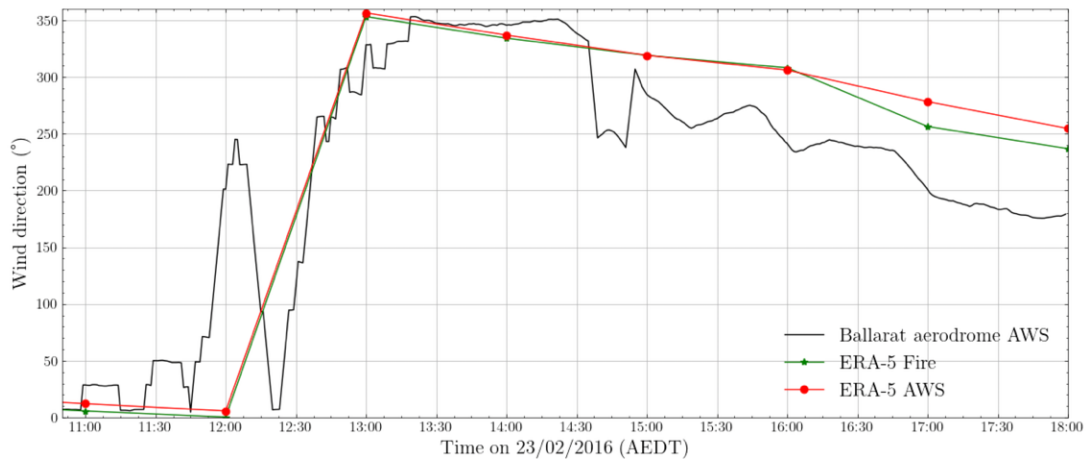


Figure 11 – Horizontal wind direction as a function of the local time for the AWS located in the Ballarat aerodrome, using ERA5 data at the same location and using ERA5 data at the bushfire ignition location. The plotted AWS data is the 10-minute moving average calculated from a 1-minute sampling signal.

9. A 30min difference between alert and ignition is quite large. What background information did you use to support this?

This information is directly coming from the Country Fire Authority (CFA).

10. Regarding the quality and usefulness of the Method implement to represent spotting: I believe the paper would benefit from a quantitative assessment of the distribution of the estimated accumulated mass over the observed spot fires. Is the distribution over the observed spot fires significantly different than the distribution over "non-spot" locations?

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. Although it is impractical to make this quantitative comparison, 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.