Reviewer Report:

An emergency response model for evaluating the formation and dispersion of plumes originating from major fires (BUOYANT v4.20)

The paper presents recent developments implemented within an existing plume dispersion model for forest and pool fires, which aim to improve how the emissions source is parameterized within the modelling system. Given the sensitivity of plume rise and subsequent dispersion to source input parameters, estimation of buoyancy, mass and momentum fluxes is key to improving model prediction accuracy. Unlorturnaly, while this paper provides the means to estimate these parameters, it is missing key model evaluation to support the presented approach.

General Comments

Moving away from static inputs towards a more physical model for fire source parameters is incredibly valuable. The authors present an approach for estimating various source properties derived from the classic MTT model, which in my view constitutes the main contribution of the paper. However, no attempt is made to actually evaluate this "source term model".

The inter-comparison study with RxCADRE data presented in the paper specifically excludes the source term model, focusing instead on the two previously-studied components of BUOYANT (plume rise and dispersion). While such results are still valuable, they do not substitute for proper evaluation of the derivations presented in Section 2 and, in the current state, provide no supporting evidence for the main contribution of the paper.

Fortunately, RxCADRE dataset is incredibly detailed and can be used to extend the evaluation to include the source term model. My recommendation for the publication of this paper would, hence, be contingent on the authors demonstrating the results for the following:

Comparison of RxCADRE observations to:

- BUOYANT model with ***observations*** as source inputs (this is essentially what's currently included in the paper), with more details included on methodology (as per comments below)
- BUOYANT model with ***old*** source term parameterization (fixed parameters)
- BUOYANT model with ***new*** source term model included
- Operational version of BUOYANT (if different from above)

Lastly, Section 4 of the paper is dedicated entirely to an overview of an operational modelling system. It is my understanding that the system is supposed to be accessible online, however no links are provided in the paper (aside from those pointing to an offline archive of the Fortran source code for the BUOYANT model). My current review of Section 4 is, hence, fairly superficial. If the authors are unable to provide access to the model for peer-evaluation, my recommendation would be to exclude this section from the manuscript.

Specific Comments

Section 1

The current overview is rather scattered, jumping from plume rise, to combustion, to air quality modeling , to emissions, to CFD models and, finally, to BUOYANT, with little effort to connect the topics. The broad context should be covered in a more concise and logical way (e.g. are satellite emissions studies and CFD models even relevant?), while the work pertaining directly to BUOYANT model needs to be covered in greater detail.

Line 34: Please include more recent review works on plume rise from wildfires
Line 35: How does this section connect to the previous one? How are combustion studies relevant?
Line 61: "satellite-based estimates of wildland fires": what does that mean? Emissions from wildland fires?
Line 63, 65: why should measuring FRP "require inputs"? How are FRP-based emissions estimates relevant to this work?
Line 71: how does this section connect to the previous one and what is the relevance?
Line 80: Given the overview of literature provided, what are the current knowledge gaps this manuscript is going to address? What is missing?
Line 81-87: please include more detail about literature on the BUOYANT model and the relevant findings
Line 93: what do authors mean by "all other models"?

Section 2

Figure 1(b). Does the model actually include full vertical profiles, or is it a two-layer atmosphere? I.e. please move all information from Appendix D into the body of the paper. It's critical for understanding how the model works.
Line 139 - 150: This belongs in Introduction
Line 148: Which "model"? What were the specific findings? If the agreement was great, why would BUOYANT need improvement? What were the limitations?
Line 151: What do authors mean by "treatments"? Have the above-mentioned model evaluation studies all relied on these three fixed parameters? What are the parameters?
Line 174: Which "separate models" are the authors referring to?
Line 175: I struggle with this assumption for wildland fires. Winds modify convective fluxes, also wildfires generate their own winds. Please provide more support for this. Thorough model evaluation with observational data would, of course, constitute the best supporting evidence.
Line 200: How does the model handle fuel moisture then? It's a critical parameter for wildland fires.
Line 224: So which terms are going to be used in the subsequent modelling steps? A summary table would be helpful.
Line 257: Please clarify further what atmospheric stability structure is considered. Does "calm" refer to neutral stably stratified vertical profile?
Line 258: MTT applies specifically to point sources
Line 280: The original entrainment assumption of the MTT model doesn't hold for wildland fires. Has the RS entrainment model been used for such scenarios? If so, please provide a reference. If not, please provide support for the assumption.

Line 316: How does this connect to the previous paragraph? As mentioned above, a summary table of modeled parameters can likely help with clarity and structure.
Eqn 10: At which height? I.e. this is not considering entrainment/detrainment. Please clarify the assumptions used for your definitions
Line 348: Which "model" and which "computer model". Please see my suggestion in the Writing Style section.

Section 3
As noted above, my main concern with this model evaluation is that it ignores entirely what has been presented in the previous parts of the paper. Moreover, evaluation of the plume rise and dispersion components of BUOYANT has been previously performed, based on authors' own Introduction. What is then the main goal and novelty of this section then? It is critical that this portion of the manuscript is expanded to include a full evaluation of the source term module (see General Comments above).

Please make a table of all required model input parameters, showing the estimates based on (a) RxCADRE data (b) the source term model presented. Please include a description of how each value was obtained, pointing to specific equations, data sources etc.

Lastly, please include a detailed discussion (either under model evaluation, or as a separate section) addressing model performance and placing it in context of earlier published work.

Line: 406: Please include the following information: dimensions of the burn, how it was inited (and how long was the ignition process), duration of the active burning.
Line 420: Which heat fluxes, specifically? How was FRP estimated?
Line 450: There are vertical atmospheric soundings that were collected during the experimental campaign (see Clements 2016). Are these used for the study? Or does it solely rely on a 30m tower observations? If so, please explain why.
Line 456: Please create a Figure showing the observed vs. modeled atmospheric profile.
Line 458: Were the winds considered to be uniform? Is BUOYANT able to account for vertical wind shear? Please move all the answers to these questions out of Appendix D and into the paper.
Line 466: The paper presents a new source term model. Model evaluation, therefore, CANNOT exclude the source term parameterization.
Line 471: "the BUOYANT model" as per Line 121, *includes* source term module. As noted above, please provide the estimates of all model input parameters using the source term module.
Line 484: Please plot the used FRP and area values on Figure 2 as a horizontal lines. They seem a bit low to represent the average (though my eye-balling could be wrong). It would be great, if the authors presented some sort of sensitivity analysis of the model to these input parameters.
Line 486: Abstract states that the BUOYANT model estimates cross-plume integrated values. My understanding is that in the current section the authors are presenting instantaneous concentrations. Please explain the discrepancy.
Line 507: "temporally well-captured" is a bit generous. Figure 3(a) estimates plume rise to be at half the measured value.
Line 513: Are these middle points in 3(b) calculated using center of mass? (they probably should be).

Line 519: There's quite a bit of a disagreement, actually (for good reasons). 4(a) shows no smoke above 590m, while observed values extend to 1230m. There's likely directional wind shear present, as higher observed values are shifted in the cross-wind directions. As noted above, a plot of vertical vs modeled atmospheric profile is much needed. Figure 3(b) drastically underestimates plume width. Once again, there's likely a logical explanation for this. Namely, as far as I recall, the lot was ignited with multiple straight lines (strip head fire ignition) of roughly 1km length, and the model attempts to represent the same fire strips with a circle of 158m radius (based on the configuration file provided in supplementary material). One shouldn't expect this assumption to work well in the given scenario. Figure 3(c) again, suggests lack of wind shear and strong concentration overestimation. Please include an objective description of model performance here, as well as in Discussion. Also, please explain why the observed values at 280m (green line) in 3(c) simply cut off. Lastly, there appears be no plume growth and widening at all: it remains 2km wide from 1.7km to 11km downwind. Please explain. This, in part, explains the overestimation of concentration values further downwind.
Line 528: Please be more specific: what are the differences? What are the challenges? Wasn't the source term model designed to address these challenges?
Line 541: What meteorological inputs are referred to, specifically? Full vertical atmospheric profile was measured during the RxCADRE campaign, so the vertical structure did not need to be estimated. Again, please include a figure for the vertical profile used in BUOYANT vs observations.
Line 545: Given observed values were available, this argument cannot be used to explain the discrepancies between modelled and measured concentrations.

Section 4.
Please provide a link to the online operational version of the model (if it's indeed available in the paper somewhere and I missed it, my apologies! Please move the link the beginning of Section 4.1 for easy access).
Without access to the system, the following comments do not constitute proper peer-review. Please also include the operational version of the model in the evaluation.

Line 632: Ambient pressure, wind and temperature profiles are standard model output. What's being "evaluated"?
Line 635: Is roughness length the only parameter that actually needs estimation?
Line 660: What do authors mean by "efficient functioning"?

Conclusions:
Here the authors seem to mix summary with discussion. Please see my earlier comment, regarding clearly separating out results from discussion.

Line 665: As above, please clarify whether this is a cross-plume integrated model or not. Figure 4 would only be possible if the fields are NOT cross-plume integrated.
Line 671: which characteristics, specifically?
Line 684-687: Description of the campaign belongs in the intro/methods, not in conclusion.
Line 687-691: Please see comments to Section 3.

Lines 693-712: This very much resembles a Discussion section, and should be relocated away from Conclusions, accordingly, together with responses to comments for Line 519 (please see above)
Line 696: What are the challenges, specifically? What are the major sources of uncertainty, specifically?

Appendix C
Line 935: that seems to be a fairly extreme assumption, I am very curious to see how the source term model performs for the L2F burn.

Appendix D
Please move this into the main body of the paper.

Writing Style
The authors use the term "evaluate" extensively, to refer to both "estimation" and "measurement" of a particular parameter. My recommendation would be to specifically indicate whether a particular term is *estimated* (i.e. modelled) vs. *measured* (i.e. obtained from observations) vs. *calculated.*

The variable use of term "model" to refer to BUOYANT with multiple components, as well as to BUOYANT without the source term model, to the source model and to the computer model is rather confusing. My suggestion would be to call BUOYANT (with all three components) a model, and individual sub-models (dispersion, plume rise, source term) - modules. Operational version can be referred to as BUOYANTops, or something on those lines.

Please note that the draft requires extensive English language editing.

References

Clements Craig B., Lareau Neil P., Seto Daisuke, Contezac Jonathan, Davis Braniff, Teske Casey, Zajkowski Thomas J., Hudak Andrew T., Bright Benjamin C., Dickinson Matthew B., Butler Bret W., Jimenez Daniel, Hiers J. Kevin (2015) Fire weather conditions and fire–atmosphere interactions observed during low-intensity prescribed fires – RxCADRE 2012. *International Journal of Wildland Fire* **25**, 90-101.