We sincerely thank the Reviewer for their comments and insights. Please find our responses structured as follows:

- Original Reviewer comments in ***bold italics***
- Author responses as regular text
- Manuscript edits and changes in blue

Reviewer #2 Comments:

General remarks:

This paper introduces updraft velocity scales that are used during daytime CBLs. The scaling was developed using a set of model-derived synthetic plumes from WRF-SFIRE. The paper is novel and well-written. This reviewer feels that the observational dataset used is not ideal compared to other wildfire plume observations available. A limitation to the study and proposed methodology is the use of fireline intensity (heat flux) as this parameter is very difficult to observe in the field and even more so for wildfires. The data used are limited to the flame zone, but not the plume base. As the authors do recognize, the data from multiple sensors, have a range of values. It may be worthwhile to use sensible heat flux values calculated from the in situ tower observations. Overall, this is an excellent paper, well written and justified. I recommend publication after Minor Revisions.

We have explored using fire area and average heat flux instead of fireline intensity as input parameters for our model, however, we were not successful. We thank the Reviewer for pointing out this limitation. We added the following clarification in Section 5.5 (Limitations) of the manuscript:

Unlike many existing methods, our parameterization relies on fireline intensity parameter *I*, rather than average fire heat flux value, as input. While this approach offers an advantage for modelling plumes from complex ignition sources (such as shown in Fig. 8), fireline intensity is difficult to observe in the field.

We address observational datasets in the next comment.

While we are aware of the anemometer data from L2G in-situ tower, we find it's challenging to use as a means of quantifying fire behavior. Estimated sensible heat flux values naturally depend on the height from which the vertical velocity and temperature data are obtained, as well as the averaging period used. Also, given the variability amongst the in-fire sensors, we are hesitant to rely on observations from a single (tower) location.

While the proposed method for estimating plume rise is somewhat novel, it is unclear why the authors don't use more observational data. The authors state that observations are limited and that is somewhat true, but given the recent publication of key wildfire plume datasets (RaDFIRE; Clements et al. 2018), the authors should really use wildfire observations verses low-intensity prescribed fires from RxCADRE. Another issue with the methodology presented in this study is that the authors use a vertical velocity scale for plume rise, but have no vertical velocity observations. Vertical velocity data are also available from the RxCADRE dataset. Additionally, a very recent paper by Rodriguez et al. (2020) show deep updraft velocities in a megafire that could be used as an extreme boundary for the parameterization. Additionally, a dataset from Lareau and Clements (2017) of a wildfire that includes plume evolution in a cross-wind is available as was also used by (Mallia et al. 2019).

Key issue with both RaDFIRE dataset and the one described by Rodriguez et al. (2020), is that to our knowledge neither provides spatiotemporally linked fire behavior data. Lareau and Clements (2017) use inverted Brigg's equations to produce a rough estimate of fire heat flux. In the absence of fire behavior observations, it is not possible to properly constrain our model using these data.

While in-situ tower data from RxCADRE indeed include vertical velocities over the passing fire front, the observations are limited to near-surface heights. Our parameterized vertical velocity scale is calculated over the plume penetration region starting from upper ABL. We feel that comparing it with near-surface data may not be meaningful.

We were unable to locate a reference matching Mallia et al. (2019). We did find a paper by Mallia et al. (2018), but they've considered RxCADRE L2F dataset in their study.

Some specific comments:

Line 148: It is not clear what the authors are defining as Fireline Intensity: ". . . fireline intensity parameter I, which is the kinematic heat flux into the atmosphere integrated across the fireline depth (in units of Km2s−1),. . ." I would call this the fire heat flux vs Byram's Fireline Intensity which has units of kW /m.

We've added the following clarification in the manuscript:
…This velocity scale is related to the fireline intensity parameter *I*, which is the kinematic heat flux into the atmosphere integrated across the fireline depth (in units of $\mathrm{Km^2\ s^{-1}}$), and to the mixed-layer depth z_i. Note, that *I* effectively corresponds to the kinematic form of Byram's Fireline Intensity (in units of $\mathrm{kW\ m^{-1}}$).

We maintained the kinematic form throughout the manuscript to ensure unit consistency in the model equations.

Line 205: Replace "lot" with "plot."

Corrected.

In Figure 2a, the mean plume centerline has a loop just downwind of the initial injection. Is this realistic? I would imagine that this feature represents the CBL, but would be averaged out as observed in the remainder of the downwind plume. Can the authors comment on this structure and whether this is realistic?

Figure 2a shows cross-wind integrated, rather than spatially/temporally averaged view of the plume. Hence, we would expect some random oscillatory centerline behavior near the heat source, driven not only by CBL thermals, but also fluctuations in fire intensity and propagation speed (at prior time steps). These fluctuations are naturally suppressed further downwind, as the plume settles in the stable layers above the CBL. Plume widening further masks these oscillations in cross-wind view. We added the following clarification to the manuscript (2nd paragraph of Section 2.3):

…As a result, our approach is based on defining a region, where the concentration distribution is quasi-stationary. We consider the last frame of each simulation for this analysis. Using CWI integrated tracer values, we locate the plume centerline (Fig. 2a). Due to random effects of ABL thermals as well as fluctuations in fire intensity and propagation speed, both centerline height and concentration can vary near the heat source. These oscillations are naturally suppressed in the stable layers above the ABL, as the plume travels downwind and undergoes additional widening and mixing.

References:

Lareau, Neil P., and Craig B. Clements. "The mean and turbulent properties of a wildfire convective plume." *Journal of Applied Meteorology and Climatology* 56.8 (2017): 2289-2299.

Mallia, Derek V., et al. "Optimizing smoke and plume rise modeling approaches at local scales." *Atmosphere* 9.5 (2018): 166.

Rodriguez, B., et al. "Extreme Pyroconvective Updrafts During a Megafire." *Geophysical Research Letters* 47.18 (2020): e2020GL089001.