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Interactive comment on "Wildfire smoke-plume rise: a simple energy balance parameterization" *by* Nadya Moisseeva and Roland Stull

Anonymous Referee #1

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General remarks:

The authors present a new plume rise parameterization based on LES simulations using a synthetic plume-rise data set from WRF-SFIRE LES runs. The parameterization presented here is inexpensive and is able replicate fire plume rises that penetrate through the daytime PBL. Considering the current ongoing fires during the 2020 fire season, significant work is needed to better predict wildfire plume rises and smoke dispersion. As a result, the work carried out here is very timely and important.

With that said, the reviewer has some concerns in regard to the study presented here.

There are a number of plume rise modeling frameworks out there (Briggs, 1975; Sofeiv et al. 2012, Freitas et al. 2007; 2010), why develop yet another plume rise model? This

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Discussion paper

should be made clear in the introduction section. For example, what is meant by an idealized heat source? Does this statement refer to the plume geometry?

The biggest limitation of this study is that it does not consider moisture sources, especially in the ambient atmosphere. Studies have shown that PyroCb development is strongly dependent on mid-level moisture. While PyroCbs are somewhat rare, these plumes are often responsible for some of the largest mass injections (2018) of smoke in the atmosphere, with some of these rivaling that of significant volcanic eruptions. PyroCus, which are far more common than PyroCb, are also strongly impacted by the vertical moisture profile (albeit less so then PyroCbs).

It was noted by the authors that weakly buoyant plumes that do not penetrate into the free troposphere were not considered as part of the data set. Why did the authors use the RxCADRE L2G as a case study? Overall, most of the RxCADRE prescribe burns were lower intensity fires. The largest burn (L2F), had a plume rise height that only reached an altitude of 1.5 km, which was still below the PBL. The reviewer does understand that there are a limited number of data sets where the plume rise is measured with constrained lower boundary conditions (i.e heat fluxes)

The reviewer has concerns that this study may be too limited in scope. The authors do not include plumes that fall below the PBL in their data set while this parameterization is only applicable for plumes that do not reach the lifting condensation level, which is height where plumes would be driven latent heat releases. As a result, it must be concluded that this parameterization will only valid for plumes greater than the PBL but less than the LCL, which seems like a narrow range of plumes that this parameterization is appropriate for. Furthermore, PyroCu and PyroCb events are usually associated with large fires that emit a lot of pollutants at high altitudes. Usually, its these smoke emissions that last the longest in the atmosphere (Peterson et al. 2018; Christian et al. 2019) and are the pollutants that fire researchers and forecasters are probably most interested in.

As a result, the reviewer implores that the authors consider the effects of vertical moisture profiles within their parameterization. This work could be significantly more impactful if this limitation can be remedied as the parameterization presented here would have a clear advantage over the semi-empirical plume rise formulas discussed in Sofiev et al. (2012) and Briggs (1975).

Specific comments:

Line 49: Mallia et al. 2018 did not use WRF-SFIRE, so this may not be an appropriate citation for this particular statement. Mallia et al. 2020 did use WRF-SFIRE though in their analysis though (see citation below).

Lines 52-58: While WRF-SFIRE is a well-documented coupled fire-atmosphere model, the authors should consider expanding the description for this modeling framework. Not all reviewers may be familiar with WRF-SFIRE.

Line 56: Why were these key parameters selected? For example, why not include ambient moisture? A number of well-known studies have shown that ambient moisture profile can significantly impact fire plume rise development, especially for PyroCb development (Freitas et al. 2007; Peterson et al. 2017; Tory et al. 2018)

Lines 53-78: A figure showing the numerical setup could be helpful to add here.

Line 93-94: Can the authors provide recommendations on how atmospheric transport models should deal with weakly buoyant non-penetrative plumes that do not penetrate into the free troposphere?

Lines 200-206: Why use RxCADRE when the authors were excluding plume rises that fell below the PBL height? Most of the RxCADRE burns were relatively small with plume rises that only reached an altitude of 1300 m.

Lines 218-219: What time was the sounding relative to the start of the burn?

Lines 263: Is there a way that the author could test this hypothesis?

Line 281: This conclusion section is really limited. Perhaps the authors could better synthesize the results in their study?

In addition, this parameterization seems to be limited to plumes that fall above the PBL but less than the LCL (i.e cases where the is no PyroCu or PyroCb development). As a result, who is this parameterization geared towards? Why not just use the parameterization discussed in Freitas et al. 2007, which includes entrainment, wind shear (without restriction), and moisture effects. While the reviewer appreciates that this model can be run at a low computation cost, it seems like this parameterization comes with a number of cavaets that could limit its usefulness.

Figure 1: This is not referenced in the text, except in the conclusion section.

Figure 2a: Might be worthwhile to add distance to the x-axis here even though it is done in

Figure 2b. Took a second to figure out what the x-axis was showing. The reviewer also recommends switching panels b and d since panel b corresponds to the plume in cross section (panel a)

References:

Christian, K., Wang, J., Ge, C., Peterson, D., Hyer, E., Yorks, J., & McGill, M. (2019). Radiative forcing and stratospheric warming of pyrocumulonimbus smoke aerosols: First modeling results with multisensor (EPIC, CALIPSO, and CATS) views from space. Geophysical Research Letters, 46, 10,061–10,071. https://doi.org/10.1029/2019GL082360

Mallia, D.V.; Kochanski, A.K.; Urbanski, S.P.; Lin, J.C. Optimizing Smoke and Plume Rise Modeling Approaches at Local Scales. Atmosphere 2018, 9, 166.

Peterson et al. (2017): A Conceptual Model for Development of Intense Pyrocumulonimbus in Western North America. DOI: 10.1175/MWR-D-16-0232.1

Peterson et al. (2018): Wildfire-driven thunderstorms cause a volcano-like stratospheric injection of smoke

Tory et al. (2018) Thermodynamics of Pyrocumulus: A Conceptual Study. MWR.

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