Summary/recommendation:
This is an excellent paper that provides a simplified overview of the anticipated effects on mass enhancement and hygroscopicity of plume size, initial mass loading, and assumed functionalization and fragmentation reactions. The authors provide details on both near-field (5 hours of aging) and highly aged (120 hours of aging) results. Both timescales are of interest to the biomass burning aerosol community. The authors have done a good job carefully walking through their many results. They also provide an excellent 'discussion' section in which they place their work within the broader framework of observations and chemical transport models; this section should serve as a nice reference for many in the community and will hopefully assist in guiding others with further lines of research based on the authors' work. I recommend that this paper be published after a few minor revisions, as stated below.

General Comments:
Part of the basis of this study is to build upon the Bian et al. (2017) model. Hodshire et al. (2019) also built upon the Bian et al. (2017) model to test in a similarly theoretical model the effects of fire (plume) size and background aerosol concentration on the near-field aging of aerosol size distributions. This paper may be worth mentioning within the intro and may provide as an appropriate citation for portions of the near-field discussions of EnR.

Hodshire, A. L., Bian, Q., Ramnarine, E., Lonsdale, C. R., Alvarado, M. J., Kreidenweis, S. M., Jathar, S. H. and Pierce, J. R.: More than emissions and chemistry: Fire size, dilution, and background aerosol also greatly influence near‐field biomass burning aerosol aging, J. Geophys. Res. Atmos., 2018JD029674, doi:10.1029/2018JD029674, 2019.

Page 9: In Table 1 for the S15 scheme, the authors reference '"fresh" SOG (βfrag = 0) and reactions involving "aged" SOG (βfrag = 0.85)': it's clear where βfrag = 0.85 come in from the text on pg 9 and equation 11. However, it's not clear where βfrag = 0 would be in equations 9 or 10, if one where to assume that βfrag != 0 for the fresh SOG. Can the authors include this information within the relevant equations?

Page 10: Can the authors comment in the text on why they chose to only use the FragSVSOA configuration?

Page 13: "This period is representative of the typical lifetime of BB aerosol in Siberia under conditions without precipitation (Paris et al., 2009)": can the authors comment on the relative lifetime of BB aerosol in other important fire environments, such as the Amazon, Africa, etc, in order to place the 120 hour designation into a broader context? Also, as the authors are choosing variables representative of Siberia (e.g. diurnal cycle) chose to use 5 ug m-3 as their background aerosol concentration, can they comment on how well this is anticipated to represent the Siberian

natural background during the fire season? The authors may also consider pointing out that only considering a relatively clean background is a limitation of the study, as entrainment of more polluted backgrounds will change the partitioning and evaporation rates of the plume particles (see e.g. Hodshire et al., 2019).

Hodshire, A. L., Bian, Q., Ramnarine, E., Lonsdale, C. R., Alvarado, M. J., Kreidenweis, S. M., Jathar, S. H. and Pierce, J. R.: More than emissions and chemistry: Fire size, dilution, and background aerosol also greatly influence near‐field biomass burning aerosol aging, J. Geophys. Res. Atmos., 2018JD029674, doi:10.1029/2018JD029674, 2019.

Page 15: The authors could consider using only the 'EnR' or the 'γ_a' notation throughout, as having 2 different variable names for the same thing is a little confusing.

Section 3.1: Can the authors briefly justify in the text why they chose their given fixed value of initial mass loading for the analysis in Fig 2 and fixed value of plume size for the analysis in Fig 3?

Also, why does Figure 4 (and Figure 8) only show results for the T18 and T18f schemes? Perhaps along with a brief justification for this choice the authors could also consider including the results of the other VBS schemes in a supplemental figure. I see that the authors note on lines 9-10 of page 20 "Note that only simulations for the "extreme" values of C0 and Sp (among those considered in this study) are shown in Fig 4. Simulations with other (intermediate) parameter values would fall between the brown and blue curves." But does this include all other schemes, that is, that all of the VBS schemes used fall between the brown and blue curves? This should be made clear in the text.

The authors could help the reader by being more explicit as to why smaller fires have higher hygroscopicity parameter values than larger fires. A brief sentence or 2 would go well on pg 20 (first paragraph) that clearly points out again that smaller fires can undergo more oxidation reactions (more gas phase material available both from initial partitioning and initial evaporation by dilution). Plume-size dependencancy on e.g. oxidation and partitioning is a complex subject that could aid from simple explanations and reminders such as this throughout.

Page 26: Can the authors comment in the text on whether there is information to say how realistic each βfrag value is?

It is worth pointing out somewhere within the text (possibly in the methods?) that a limitation of this study is that the largest fires may be have limited oxidation reactions and thus limited SOA

formation and/or fragmentation occurring within the dense initial plumes if the plume is dense enough to limit photochemistry, and that this study doesn't try to account for that effect.

Figures/Tables:

For each figure that has a horizontal dashed line at EnR=1, the caption should state that that line is there to indicate where 'no mass enhancement' occurs.

Figure 2: What are the shaded bands on panel d? Presumably this is not a designation of 'nighttime'. They may be present to guide the eye but are confusing and should be explained. I recommend either removing them or making them distinct from the nighttime bands in panels a-c.

Figure 6 and 7: It's difficult to see the dashed line for C^{Tot}/C_o within some of the panels (e.g. Fig 6 panel a); can this line be made more distinctive?

Technical comments:

Page 5 line 11: Bian et al., 2017 simulated 4 hours of aging (not 5).

Page 8 line 17: are the SVOCs evenly distributed across the 5 bins? Please clarify