Review of **The impact of biomass burning on upper tropospheric carbon monoxide : A study using MOCAGE global model and IAGOS airborne data** by **M. Cussac et al., ACPD 2020**

This manuscript provides a nice study on the impact of biomass burning injection height parameterization on upper tropospheric CO, and the general contribution of biomass burning emissions on the upper tropospheric CO burdens, by using information on the injection height of biomass burning emissions as available from the GFAS product, the SOFT-IO tools for attributing emission sources, and the MOCAGE CTM.

The study is overall clear, and well-designed. Nevertheless, I have several concerns which the authors should address before this can be accepted for publication.

1. The structure of the manuscript is not ideal. I was expecting a general model validation of (upper-)tropospheric CO near the start, but this is only covered Sec. 4.1. I suggest to shift this to Sec. 3, e.g. just before Sec. 3.1
2. Although the evaluation metrics can well be defended (pdfs, MNMB, FGE, r), the data-aggregation is not fully suitable. There are three instances for this.
   a. when evaluating the impact of injection height in Table 3, I believe the authors should equally evaluate the improvement (if any) against IAGOS measurement that do not contain biomass burning contribution. I acknowledge that this are many more instances, (as already seen from Fig. 3) which implies that the changes are expected to be small. But in any case it'd be a good to check if there is no degradation, and hopefully an improvement, in this respect.
   b. Likewise, in Table 4 the authors present a general overview of the statistical scores in the UTLS, in terms of MNMB, FGE and r. But as the authors discuss, there are large gradients in CO in this region, which makes it hard to judge from these statistics to what extend these are captured. Unfortunately this is also not really visible from Fig. 13, which overall focusses on the free troposphere. Therefore I suggest that the authors also present metrics specific for below and above the tropopause, using the 2 PVU metric + / - a pressure range, e.g. as the authors already specify on Page 21, line 5.
   Additionally a figure presenting the vertical profile of CO in the UTLS region, ideally on the vertical axis the pressure level with respect to the tropopause altitude, would be very instructive.
   c. Finally, for Figure 13, it'd be good to discuss (or even present) similar evaluations, but specific for the four seasons, (or at least for summer and winter seasons), considering that there is a rather large seasonal cycle in tropospheric CO, and likewise variations in general CTM abilities to capture this, which would be good to quantify.
3. Although the manuscript is overall clearly written, there are still many issues. The introduction lacks many references, many acronyms are not defined, sentences are often not in proper English, and there are many typo's.
4. Finally, the authors emphasize the impact of pyroconvection throughout the manuscript, but an important impact of the revised injection height parameterization appears that overall much more is injected at lower altitudes compared to the reference configuration, whereas not even a single event where a likely pyroconvection has been sampled by IAGOS, is assessed in a little more detail. This makes the reference to this process a little out of balance.

Other general comments

P2

L25: To put the emission numbers in perspective, can the authors provide an estimate of the secondary CO production from VOC and CH4 oxidation?

L29: GFAS, GFED, IS4FIRES: Missing references.

P3: L9: The authors quickly argue that the use of airborne campaigns is limited. This is a very short conclusion. I think this deserves a little more elaboration, e.g. including a few studies based on campaign data, and/or reporting on some interesting findings.

P8.

L2'both anthropogenic and biogenic emissions are injected into the 5 lowest levels' . Why are biogenic emissions not injected at the surface layer?

L3: 'with an exponential decay': what do you mean?

L10-L23: in this section I am missing a reference where the overall performance of MOCAGE tropospheric chemistry is given; now bits and pieces are given from other references. This links a bit to my request to start Sec 3.1 with a general evaluation of tropospheric CO, if there is no suitable general evaluation reference existing.

P12, L1-L4: The authors show that in simulation INJH MOCAGE captures better the observed events with high CO (particularly those > 200 ppb), which they attribute to the higher injection height for the largest fires. However, from Figure 7 it is actually clear that injection of majority of fire emissions is now actually at much lower altitudes than before, which could possibly imply that for background conditions the MOCAGE now shows a larger negative bias in the UTLS than before? Could the authors comment?

In this line of thinking, to evaluate purely the effect of the injection height, it could be interesting to correct for the effect of a potential background model bias in CO, which also interferes with the evaluations shown in Figures 6, 8 and 9, which intend to focus on the effect of injection height, not the effect of potential model biases.

L7: "under-represents the CO enhancement": I think in this configuration this should read 'CO amount', as the authors did not actually compute the enhancement (see previous comment)

L8: "diffusive": I think this is only part of the explanation. Please consider general model biases. E.g. here it would be useful to directly refer to a corresponding evaluation for against IAGOS observations where likely fire emission contributions are excluded.

P15

L1-4 "to summarize…" I think these two sentences contradict each other. Either the original injection profile is good, or the GFAS product is good. Also the authors currently only focus on the impact in the UTLS. Although interesting, the largest impact of a different injection height might actually be for plumes at lower altitudes, where profiles on average look very different.

P18, Table 4: The overall small MNMB may not be very meaningful considering the large vertical gradients in this altitude range. Therefore I would appreciate if the authors could also compute the metrics for below and above the tropopause separately.

L15. 'MOCAGE seems to correctly represent the transition..' I find this difficult to judge. Here A figure showing the vertical profiles in CO with respect to the tropopause level would be very useful.

P19,

L18: 'realistic UTLS' -> 'realistic free tropospheric' ?

Figure 13: It'd be good to show this kind of evaluations for the different seasons separately. (or alternatively in the supplementary material)

P25

L15: "as well as its gradient in the UT". First of all, the vertical profiles as presented so far were not very clear in presenting the gradient in the UT. Secondly, it is not clear what is concluded from this evaluation.

Specific comments

Abstract: Please use present or past tense consistently.

L6: The use of these GFAS products lead**s** to improved MOCAGE skill to simulate fire plumes originating from boreal **forest** wildfires.
L10: 'as the previous one': which 'one'?
L11: database -> observations
L13: were -> where; … biomass emissions were toggled …

Throughout the manuscript: Please check where you use 'quantity': I think it is better to use 'amount'

P2:
L5: great -> large
L8: focus is made here -> here we focus

L11: Methane (CH4) **and VOC** …
L13 'carbon dioxide'
L14: 'due to their shorter lifetime': this is not generally true. E.g. C2H6 has a lifetime of approx. two months

L23: 'in the **free** troposphere' ?
L23: since the occurrence of this phenomenon …

L34: class-> classification. Also good to add reference here?
L35: Their intensity: Unclear which intensity is meant here.

P3:

L1: 'pyroconvection can occur': please add references here.

L3: sensibility-> sensitivity?

L5: The authors refer to IASI, but the reference Deeter et al. is for MOPITT. Please resolve this inconsistency

L6: 'lack vertical resolution in UTLS': I think this is not only in UTLS, but generally?

L7 and L12: O3 -> O_3

L8: On **the** one hand…

L13: 'most likely source' -> 'most probable sources'?

L14: 'pathways' : you mean transport pathways, or chemical pathways.

L15/16: Suggest to change to: "This is why the analysis of large datasets require other kinds of additional information.."

L16: "Lagrangian backward transport calculation": add reference?

L20: …ability of global simulations performed by the MOCAGE … . Also please add reference to MOCAGE, and consider explaining ACRONYM.

L25: .. observed plumes: add reference

L32: (and elsewhere) : please consider to use 'trace gases' instead of 'species'

L34: Rewrite sentence

P4

L8: 'latest': A bit unclear where this refers to.

L11: 'by comparing difference MOCAGE simulations' -> 'through MOCAGE sensitivity experiments'

P2:L35, P3 L31: the year 2013 is chosen for this study, but throughout the manuscript none/or slightly varying arguments are given why 2013 is chosen. Please be consistent, and provide arguments preferably in introduction (and summary) only.

P5,

L3: summarized

L4 trajectory…'

L7: 'but does not simulate CO background': What do you mean with this phrase?

L8: '12 zones', but Figure 1 shows 14 zones?

L16: 'as the regional median': how are the regions defined here?

P6, Fig. 3: 'contribution is here mostly from NHAF'. How is 'mostly' be defined here?

L1: '2 PVU': What do you do for the tropics?

P7:

L8: 'in the CAMS project (..)'. This is not really a project. Please change to 'in the Copernicus Atmosphere Monitoring Service (CAMS)'

L10: 'six': Please check this number

L14: Could you give a few more updates on MOCAGE here? Particularly, which solver are you using, are you running in conjunction with aerosol; do you treat heterogeneous chemistry in the troposphere?

L16: '700-800 meter': Isn't this too coarse to resolve the UTLS region? Can you comment, ideally referring to potential past studies on UTLS, and sensitivity to model resolution?

L16: 'upper troposphere and **lower** stratosphere '

P8,

L10: Consider rewriting this sentence, e.g. : "MOCAGE has already been used to study various aspects of the chemical composition of the atmosphere, including the structure of the UTLS, and biomass burning plume
transport."

L16 "enhancement was due to a biomass burning plume"
L16-17 "in order to correctly represent intercontinental transport of the plume"
L17: 'in this study': Which study do the authors refer to here?

L19: '…and their direct impact to the aerosol budget over the Mediterranean basin'

L27: 'MACCity'

P9
L2: 'GFAS'. It doesn't hurt to add an extra reference here.
L4: 'emitted quantities' -> 'emission of trace gases and aerosol' ?
L7 'overall'-> multiyear
L11: repartition -> repartitioning
L13: 'The choice…' -> In this approach the injection height was set depending on …
L14: 'above the maximum of injection fraction'?

L18 'front of the fire'

P11, L21: Please explain acronym 'TTL'

P15
L5 'using the GFAS', 'carbon monoxide'. This sentence is very unclear, by the way.
L6: "The results are.. " also rewrite this sentence

L9: 'at this pressure' -> 'at this pressure level'/ at this altitude range'
L11: 'parallel' -> latitude
L12-13: confusing sentence. Please rewrite into something like 'It results in less CO being found for simulation INJ at this altitude (..) and more North ..'

P17,
L3: 'consistently enough' strange use of wording 'consistently'. Maybe change to 'with sufficient amounts' ?
L6 'performed'->'created'
L10: 2000m : what is the corresponding pressure level?
L15 'repartition'-> 'repartitioning'

P19
L8 'vertical gradient of CO in the UTLS and concentrations are captured' This is not very clear.

L12: 'IndiaS'

P21

L2 "the impact" of what?

L5 : '2 PVU'

L9 "simulation to the" : "simulation from the"

L10 "yearly"-> "annual mean"

L16 biomass burning, **namely** …

L18: "42 and 20% of CO emissions": which CO emissions are referred here? Total? Total fire ? regional?

L19 "driven" -> transported

L19 while **a fraction of** boreal fire emissions

L20 "(**approximately** 2 months)"

P23

L12 the authors write "Australian forest are also not known for their pyroconvective events".

I'm not sure about this statement. I think there have been fire events reported, even in literature, which also contain pyroconvection. Please check.

P24

L8: "This study aimed at improving the understanding **the contribution** of biomass burning emissions to upper tropospheric carbon monoxide"
L10: "We have chosen that this study would span over a single year" suggest to reformulate to something like "We have chosen a single year simulation, …"
L11: "efficiency" -> "costs"

P25

L1: 'dur'->due

L1: "… pyroconvection **for a selection of large fire events"**

L5: "however"-> "nevertheless"

L6: "It was also shown.." Please check and rewrite sentence

L7 "To go a step…" please check and rewrite sentence

L18-L19: Please check/rewrite sentence

L25-L31: Please check/rewrite sentence to be more accurate and improve readability.