General Comments:

This study evaluates the coupled effects of biomass-burning aerosols from southern Africa on the regional climate, simulated by the CNRM-CM model over the period from 1990-2014. The large mass of emissions, combined with their steady presence for several months, exert strong effects on clouds, radiation, and the sea surface temperature. By comparing with a model run without these smoke emissions, the study shows that there are large and distinct effects in JJA (which is the majority of the annual burning period) and SON. These effects drive large local uncertainty in radiative balance, and this work provides an important analysis on when, where, and how BBA effects manifest. The paper is well-written and makes a convincing argument especially for the value of a dynamical ocean model in capturing regional trends outside of the main burning season. There are some points of clarification and background that do not detract from the overall work, and I recommend publication after minor corrections.

First of all, we would like to thank the reviewer for his relevant comments. In the new version, we have taken them into account thereby improving and clarifying the text and figures of the article.

Specific Comments

Introduction:

As this study is a model application, studying the effects of toggling BBA emissions on and off, it necessarily can't avoid inherent model biases. The authors show that the model represents smoke SSA well, but I would like to see some comment on model performance for other properties central to the study, where available, such as other smoke attributes or placement, cloud properties, or winds.

This is indeed an important point. We now provide information on the main features of the CNRM-CM model in terms of BBA, cloud properties and wind fields. Regarding BBA, the simulations show maxima (AOD ~ 0.7 at 550 nm) over Congo and Angola with a plume covering the whole SEA during the JJA season with a strong decrease in AOD at ~15°W (Figure 1a). This regional pattern is in relatively good agreement with spatial AOD satellite inversions or reanalysis products, as shown in Mallet et al. 2020. This specific point is now clearly indicated in the part 3.1. With regard to clouds, we now point out that the CNRM-CM model suffers to represent low-level clouds over this region. Such a bias occurs in many state-of-the-art model (e.g., CMIP6, e.g. Figure S3 of Crnivec et al., 2023 from https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022JD038437). This point has been added and the possible implications are discussed in the part 3.1. In particular, we indicate that this limits the reflection of solar radiation and therefore decrease the absorption of radiation by BBA and radiative heating. We now highlight this important point based on the study by Feng et al. (2015), showing that for AOD of ~1 and SSA of ~0.90 at 550 nm (typical of the values observed in this region), an increase in cloud optical depth induces a decrease in the SW direct radiative effect for smoke aerosols above clouds at TOA. This indicates the enhancement of solar absorption by BBA as cloud reflectivity increases, which could contribute to an increase in radiative heating by smoke aerosols. This point is now indicated and could explain the fact that the simulated heating rates in CNRM-CM are somewhat lower than the values estimated over this region. Finally, we integrated the mean wind fields at 950 and 850 hPa over the JJA season in Figure 7. These new figures clearly show the southwesterly flow over the tropical Africa, which is characteristic of the region and responsible for the development of the West African monsoon in JJA. This point is now indicated in the part 3.3.

Crnivec. N., Cesana, G. and Pincus R., Evaluating the representation of tropical stratocumulus and shallow cumulus clouds as well as their radiative effects in CMIP6 models using satellite observations, Journal of Geophysical Research: Atmospheres 128 (23), e2022JD038437, 2023.

Feng, N., and S. A. Christopher (2015), Measurement-based estimates of direct radiative effects of absorbing aerosols above clouds, J. Geophys. Res. Atmos., 120, 6908–6921, doi:10.1002/2015JD023252.

Lines 63-64: I understand that "few" is relative, but there are multiple recent studies overall analyzing the impact of African BBA on clouds, dynamics, and precipitation in the region. There have been several modeling studies addressing aspects of this question in the last several years with various methods, such as following the field campaigns AEROCLO-SA, ORACLES, CLARIFY, or LASIC. These may have important differences with this work, but they remain studies of this region on these topics. For example: Lu et al 2018, Gordon et al 2018, Diamond et al 2022, Perez et al 2023.

We agree with this comment and we have now modified the sentence in the introduction as follows : « In <u>parallel</u> to the interactions between desert dust aerosols and the hydrological cycle over Tropical Africa (Solmon, 2008, 2012; Balkanski et al., 2021), <u>different</u> studies have addressed the impact of BBA plumes emitted over central Africa on cloud properties, atmospheric dynamics and precipitation in the tropics (Lu et al., 2018; Gordon et al., 2018; Diamond et al., 2022; Chaboureau et al., 2022 and Baró Pérez et al., 2024). Recently, Solmon et al. (2021) and Ajoku et al. (2019)...»

Methods:

Please add some physical description of the different size modes, such as the central diameter of each size bin. Aerosol optical and microphysical processes depend heavily on size ranges and this will give better context to other studies comparing to this work with different size schemes or parameters.

We now detail this specific point in the part 3.1. The central effective radius for natural desert dust (0.1, 0.83 and 5.8 µm) and sea salt (central effective radius of 0.15, 1.9 and 19.1 µm) are provided. We also mentioned the Rémy et al. (2022) reference which indicates the parameters of the size distribution for other aerosol species (organic matter, black carbon, sulfates, nitrate fine/coarse and ammonium) used in TACTIC.»

Rémy, S., Kipling, Z., Huijnen, V., Flemming, J., Nabat, P., Michou, M., Ades, M., Engelen, R., and Peuch, V.-H.: Description and evaluation of the tropospheric aerosol scheme in the Integrated Forecasting System (IFS-AER, cycle 47R1) of ECMWF, Geosci. Model Dev., 15, 4881–4912, https://doi.org/10.5194/gmd-15-4881-2022, 2022.

Line 132 and 142: Are nitrates and ammonium considered hydrophobic or hydrophilic, or something else?

Ammonium-nitrates particles are considered as hydrophylic. This is now indicated in the text and the reference of Druge et al. (2019) describing this aerosol species has been added.

Since precipitation changes are one of the focus topics of this work, I would like to see some mention of the impact of the missing second indirect effect as a standing uncertainty that could possibly modulate these results.

You are fully right that the second indirect effect is not represented in the CNRM-CM model. Note that, to our knowledge, this is the case in the majority of global climate models. The very complex processes involved in the second indirect effect are generally accessible in very high spatial (~km) resolution models that explicitly represent convection and the interactions between hydrophilic aerosols and clouds. We agree that the implication of missing this process deserve further discussion, now added in Part 2.2. Several recent studies emphasize that the effects of BBA solar absorption outweigh the interactions with microphysics. As an exemple, Che et al. (2021) showed that the absorption effect of BBA is the most significant on clouds and radiation over the SEA using the UK Earth System Model, which includes the first and second indirect aerosol effects (Mulcahy et al. 2020). They showed that the liquid water path over the SEA is significantly enhanced, mainly due to the solar absorption of the BBA, especially when located above the stratocumulus clouds. Using the WRF-Chem-CAM regional model with large-eddy simulations,

Diamond et al. (2022) also indicated a significant increase in cloud cover for a given event when all smoke effects are included, mainly driven by the large-scale thermodynamic and dynamic semi-direct effects. Finally, at the climate scale, Solmon et al. (2021) showed that the "microphysical" radiative effect is relatively weak compared to the direct/semi-direct effects on the cloud and precipitation response (although the authors note that the contribution of the indirect effects should be taken with caution due to a rather simplified representation in climate models).

Che et al.,: Cloud adjustments dominate the overall negative aerosol radiative effects of biomass burning aerosols in UKESM1 climate model simulations over the south-eastern Atlantic, Atmos. Chem. Phys., 21, 17–33, 2021

Mulcahy et al.,: Description and evaluation of aerosol in UKESM1 and HadGEM3-GC3.1 CMIP6 historical simulations, 13, 6383-6423, https://doi.org/10.5194/gmd-13-6383-2020, 2020.

Diamond, M. S., et al.,: Cloud adjustments from large-scale smoke–circulation interactions strongly modulate the southeastern Atlantic stratocumulus-to-cumulus transition, Atmos. Chem. Phys., 22, 12113–12151, https://doi.org/10.5194/acp-22-12113-2022, 2022.

Solmon, F., et al., Modulation of West African Monsson Precipitation by Central and Southern African Biomass Aerosol Emissions, npj Climate and Atmospheric Science, 4:54, 2021.

Line 149: Add a comment that defines the term "anomaly" used throughout the paper as in reference to the difference between these models, and exactly how it is being calculated.

We have now clarified this point by modifying the following sentence : « In the results presented thereafter, all the anomalies <u>analysed for different variables</u> correspond to the differences between the CNRM-CM simulations with and without <u>the biomass-burning emissions</u>. <u>In addition,</u> the statistical test applied is the Wilks test (Wilks, 2006, 2016) <u>to ensure the robustness of the results.</u> »

Results:

193-194: Is the modeled SSA being 0.03-0.08 higher than observations playing a part in this heating differential ?

This is an excellent point that could contribute to the underestimate of solar heating rate due to BBA. This is now included in the text «This may be due to a slight over-estimation of the BBA SSA during the plume transport over the SEA».

Technical corrections

Figure formatting:

- Figure titles have "Anm" in the title but not defined.
- Several figure axes are labeled with the word 'Presion', which I believe should be 'Pressure'
- The dashed grid lines for lat/lon should be labeled in most or all figures
- Since every model being used here is CPL_ndg, it isn't necessary in figure titles since it doesn't differentiate anything.

All the figures have been modified following the different remarks.

"Positive feedback" and "negative feedback" are used in multiple places when the context suggests the authors intend to mean 'Positive/negative **effect**' instead. The usage of feedback implies to me that the effect is self-reinforcing or self-destroying via some mechanism, rather than simply reporting an increase or decrease of some quantity. (examples at least at lines 5, 18, 415, 441, 451,)

We agree with this remark and the term « feedback » has been changed by « effect » in the text.

Line 48: "indicate" should be "indicates"

This is now changed.

Line 66: Should read "From the methodological…"

This is now modified.

Line 95: Confusing sentence structure about what is causative and what is impacted- consider rewriting as "The overall effect on the solar surface radiative budget by both the BBA direct effect and changes in tropical clouds is also discussed."

This is now changed in the text.

Line 106: Is the second mention of "carbon cycle" redundant ?

This is right and now removed in the new version.

Line 108: missing right parenthesis)

Now changed in the text.

Line 128: ambiguous usage of "supposed" - do you mean "assumed"? Or "intended"?

This term is effectively not adapted. We have now used « assumed » in the new version.

Line 128: "Externally mixed" does not refer to aerosol particles being separated by sources, but by species. I.e., a single particle is composed of a single species.

This is right and now changed.

Line 152: Should read 26N, not 26S

This is now modified.

Line 159: If this applies to every simulation used here, I don't see the need to specify a new acronym and put it in figure titles, as that would lead me to expect an un-coupled or un-nudged configuration to come up.

This is right. We have now removed the acronym in the text and for all figures.

Line 162: Replace "thereafter" with "hereafter" or "below"

This is now changed in the text.

Line 165: Should read "...anomaly for JJA shows…" without the 'the'

This is now modified.

224: Change to "...anomaly is low west of 5°W…" rather than 'above'

This is now changed in the text.

225: Specify what LW radiation means here - it seems to mean downwelling LW emissions from clouds, but is not clear the source.

This is effectively right and mean the downwelling emissions from clouds. This point has been detailled in the text.

272: 'Atlantic coast' should read 'African coast'

This is now changed in the text.

288: ‘low cloud response’ is ambiguous. Does it refer to the response of low clouds? Or the relatively *weak* cloud response ?

This was effectively not clear and refers to the response of low-level clouds. This is now changed in the text.

329: Should read ‘...the ocean modulates the BBA…” not ‘modulate’

This is now changed.

337: The wording is confusing with “on the other hand”, since both results come from CNRM-CM. Perhaps change to “On the other hand, there is a moderate positive impact over northern Angola in CNRM-CM simulations.”

This sentence is now modified in the text.

350: What do you mean ‘more important’?

This is effectively not enough clear and we have now modified this sentence : «...in particular the drying over the coastal regions of Liberia, Sierra Leone and Guinea which is more important in this study (<u>-1.5 mm by day</u>) compared to the RegCM simulations (<u>-0.6 mm by day</u>).»

428: What does precipitation ‘by day’ mean? Use either ‘per day’/’daily’, or ‘during the daytime’ depending on what you are saying.

This was effectively wrong and the unit is $mm.day^{-1}$. This is now changed.

429: change ‘on’ to ‘in’

This is changed.