We are very grateful for the insightful comments from the reviewers, which have allowed us to clarify and improve the manuscript. We addressed the reviewers' comments with the comments marked in black and our response in blue.

Reviewer comments 1:

The authors study the fire-precipitation interactions and their feedback on the fire's variability in Mexico and central America. The work is interesting suitable for the publication in EGU sphere. I recommended a major revision after addressing following comments.

The present study period is 2003-2019. According to my knowledge, the GFED4s data is available during 1997-2022. QFED is also available during 2000-2022. I wonder if the authors could extend the analysis using the full dataset available in both GFED4s and QFED. If the authors do not plan to use the full dataset, the authors need to explain the reason why you choose to focus on the period during 2003-2019.

We thank the reviewer for the comment. Based on your comment, we have looked at the extended period of 1997-2023 with the available data and found the quasi-biennial variability still exists after 2019. In the revised version, however, we still focus on the period of 2003-2019 because some of the data used in our analysis are not available.

We started this work quite a few years ago when the data was only available till 2019. This is the period when most of the years are with either non-ENSO or weak/moderate ENSO events. Without the major influence of ENSO, the East Pacific-North Pacific (EP-NP) pattern becomes the dominant factor contributing to the quasi-biennial variability of precipitation and fire activities. In contrast, in extremely strong ENSO years, the influence of ENSO may outweigh the influence of the EP-NP pattern or even modulate the EP-NP pattern itself.

In fact, we can see from the extended time series of the regional sum of fire consumption from the GFEDv4.1s dataset and regional mean fire AOD from the MERRA-2 reanalysis that the quasi-biennial variability of fire activities remains prominent during 2002-2023 (Fig. R1a-b). Exceptions of the biennial variability mostly occur in the several years prior to 2001, which are more related to the extremely strong 1997-1998 El Nino event that was regarded as one of the most powerful El Nino events in recorded history. Moreover, during the decaying phase of this El Nino event, a strong multi-year La Nina event was developed and spanned across the years of 1998-2000. Consequently, two peak fire seasons occurred respectively in the years 2008 and 2000, which dominated the interannual variability of fire activities before 2001. It should be cautioned that the less remarkable magnitude of fire AOD in the year 1998 compared to the corresponding fire emission is partly caused by a change in the MERRA2 retrieval algorithm which results in an artificial increasing trend in the retrieved AOD.

As fire emissions in the year 2003 is currently not available for the QFED data, we have looked at the additional dataset that was not used in the original manuscript to examine the fire variability after 2019. The CAMS Global Fire Assimilation System (GFAS) is another widely used fire emission dataset that provides the data for the year 2023 (data starts in 2003). Similar to the QFED data, the GFAS data is also a top-down fire inventory that uses fire radiative power to estimate fire emissions. The temporal variation of fire-emitted BC from GFAS data confirms our conclusion that the quasi-biennial variability remains significant till 2023 (Fig. R1c). We did not extend the analysis of CALIPSO AOD because the CALIPSO team updated the retrieval algorithm after 2020. As a result, the CALIPSO v4-20 AOD is no longer available after August 2020, while the v4-21 AOD only provides data after July 2020.

We have now elaborated in the revised manuscript why we specifically focus on the period of 2003-2019, though the **quasi-**biennial variability of fire is still significant till 2023 based on the available data. The extended time series of fire-consumed dry matter and fire AOD over the whole period of 1997-2023 have been added in the supplementary material for reference.

Lines 94-96 "We focused on the fire activities after 2003 to exclude the influence of the extremely strong ENSO events, specifically the 1997/1998 El Niño event and the subsequent 1998-2000 La Niña event, which are among the most powerful ENSO events in recorded history.

Line 186-188 "Note that among the four datasets, the GFEDv4.1s inventory and MERRA-2 reanalysis data provide data till the year of 2023, and the quasi-biennial variability in the extended time series remains robust till 2023 (Fig. S1)."

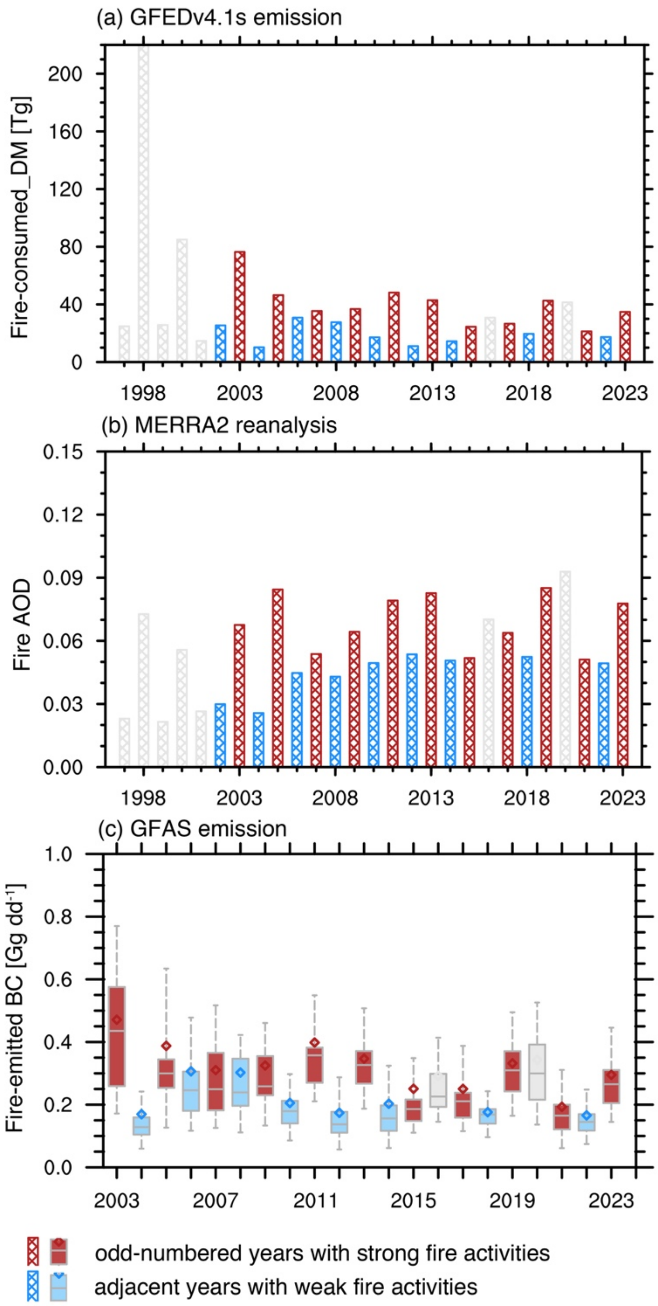

Figure R1. Quasi-biennial variability of fire activities over the SMCA region: (a) The regional sum of the total dry matter consumed by fire activities during peak burning seasons over 1997-2023 based on the GFEDv4.1s inventory. (b) Regional mean fire aerosol optical depth (AOD) during peak burning seasons over 1997-2023 based on MERRA-2 reanalysis. (c) Distributions of the daily sum of fire-emitted black carbon (BC) based on the GFAS emission data over 2003-2023. Boxes denote the 25th and 75th percentiles. Bars outside the boxes denote the 10th and 90th percentiles. Bars within the boxes denote the medium values, and dots denote regional mean values. To better indicate the quasi-biennial variability of fire activities, the odd-numbered years with strong fire activities are denoted by red, and their adjacent years with weak fire activities are denoted by blue, years with exceptions are indicated by gray.

The authors used the LAI as the surrogate of the fuel load and concluded that there is insignificant relationship between fuel load (inferred from the LAI) and fire consumption. I am concerned about this proxy choice since the LAI is a dimensionless quantity that characterizes the canopy coverage and not biomass available to burn. I wonder if the authors could try some other metrics such as primary productivity dataset (e.g., MODIS GPP or NPP) to see if the similar results could be reached.

We thank the reviewer for the suggestion. We have re-examined the role of fuel load by using MODIS gross primary production (GPP) data as a potential proxy for fuel load. Figure R2 shows the interannual variation of regional mean GPP over the SMCA region in the month (March) before the fire season. The quasi-biennial variability is not obvious as seen in GPP data (figure R2). Values of GPP in some odd-numbered years (years with strong fire activities) are weaker compared to adjacent even-numbered years, e.g., in years 2003, 2005, and 2013. The correlation between regional mean GPP and fire consumption is even slightly negative. Similar results are found when using maximum GPP in March or 8-day composites of GPP prior to the fire season as a proxy for fuel load. Hence, with the use of the additional proxy for fuel load, we could exclude the possibility that fuel load primarily contributes to the quasi-biennial variability of fire activities.

We have now revised the previous manuscript as below:

Line 102-109: "We used the MODIS version 6.1 gross primary productivity (GPP) product (MOD17A2H), which measures the growth of the terrestrial vegetation as a proxy for fuel load. A cumulative 8-day composite of NPP values is provided with a 500m pixel size. The average GPP in the month (March) before the burning season is examined."

Line 210-214: "After having examined the GPP (surrogate for fuel load) prior to the burning season, we found little evidence regarding the role of fuel availability in contributing to the interannual variation of fires (Fig. S3). Lower values of GPP are found in some strong fire years compared to their adjacent years, e.g., the years 2003 and 2005. Correlations between regional GPP and fire-consumed dry matter are even slightly negative."

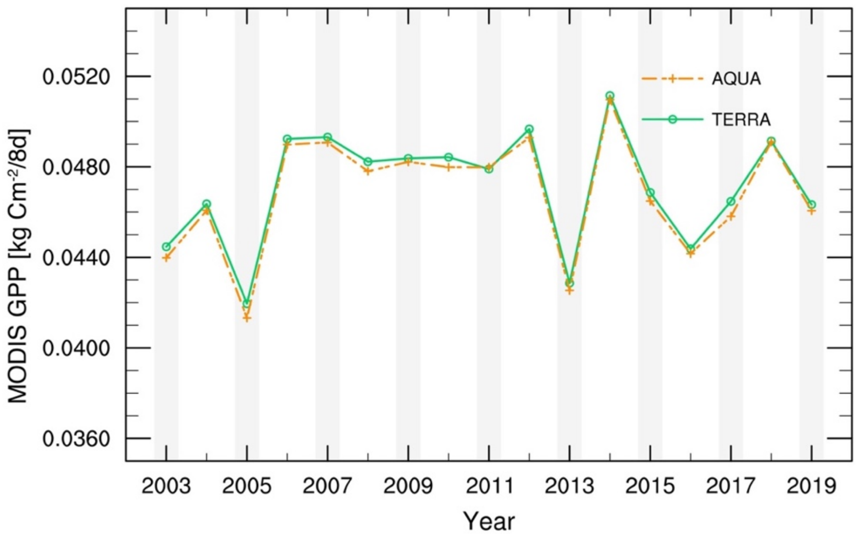

Figure R2. Temporal variations of the regional mean GPP averaged over the SMCA region in the month (March) prior to the peak burning season.

Precipitation might be one reason to explain this biennial variability. I wonder if the authors get a chance to look at the vapor pressure deficit or relative humidity interannual variation. How are they related to the fire emission variations in Mexico and Central America?

We thank the reviewer for the comment. Based on your comment we now have analyzed the interannual variation of relative humidity (RH) and vapor pressure deficit (VPD) using hourly ERA5 reanalysis data (figures R3 and R4). VPD is calculated following Chiodi et al. (2021). As shown in the composite analysis (figure R3), years with strong fire activities correspond to anomalously high VPD and low RH. Moreover, the interannual variations of both VPD and RH are highly correlated with that of precipitation and temperature during fire seasons. Correlations of regional mean VPD with precipitation and temperature reach -0.8 and 0.7 respectively, while correlations of regional mean RH with precipitation and temperature reach 0.7 and -0.5 respectively. In the previous manuscript, we thoroughly examined the evolution features of precipitation and temperature as well as their influence on fire activities. Now we have briefly discussed the influence of VPD and RH as below in the revised manuscript:

Line 228-232 "Other meteorological metrics such as vapor pressure deficit (VPD) and relative humidity (RH) are also frequently used to help understand fire-meteorology interactions. Here we found the interannual variations of regional mean VPD and RH are highly correlated with precipitation (R =-0.8 for VPD and R=0.7 for RH, respectively) and temperature (R = 0.7 for VPD and R = -0.5 for RH, respectively) over the SMCA region."

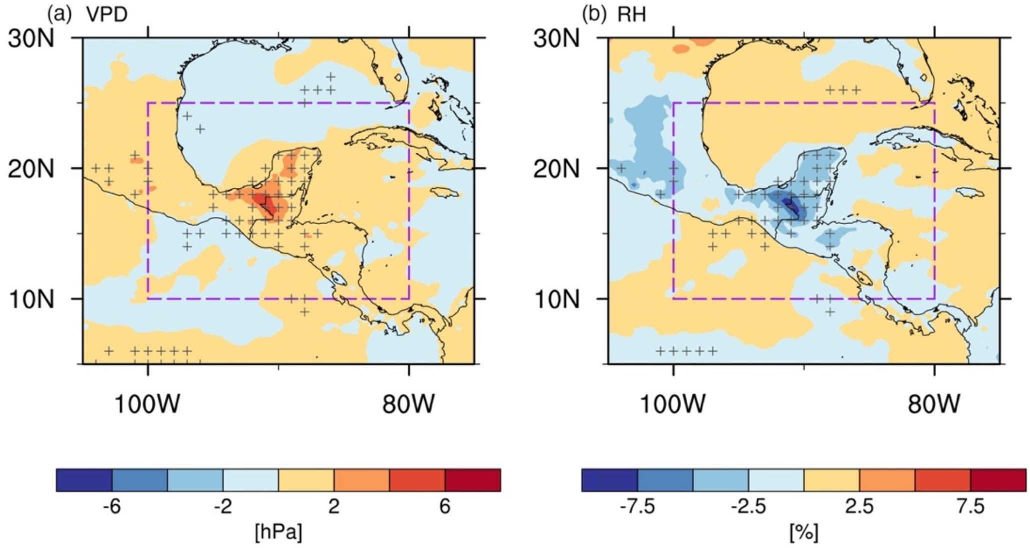

Figure R3 Differences of composites of (a) vapor pressure deficit and (b) relative humidity between strong and weak fire years. Stippling indicates the differences are statistically significant at the 90% confidence level based on T-test.

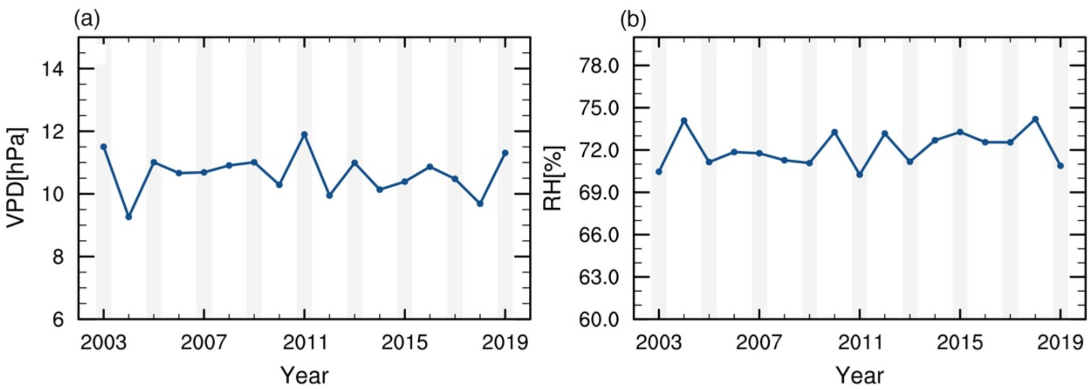

Figure R4 Temporal variations of the regional mean (a) vapor pressure deficit and relative humidity averaged over SMCA in the peak burning season (Apr-May). Shaded areas indicate the odd-numbered years with strong fire activities.

Please carefully check the figure caption. For example, Fig. 8 figure caption is confusing. The panel labels are labeled from a) to f). But only label a) and b) are mentioned in the figure caption.

We have revised it accordingly and have also carefully checked all other figure captions.

Some panel labels are missing in the figures (e.g., Figure 5 missing labels a) and b)).

This has been revised accordingly.

Reference

Chiodi, A. M., Potter, B. E., and Larkin, N. K.: Multi-Decadal Change in Western US Nighttime Vapor Pressure Deficit, Geophysical Research Letters, 48, e2021GL09283010.1029/2021GL092830, 2021.

Reviewer comments 2:

Overall, this work presents a compelling study of the quasi-biennial variability of fire characteristics over southern Mexico and Central America (SMCA) and demonstrates the role of fire-precipitation interactions at both interannual and sub seasonal timescales in shaping the observed patterns. The manuscript is well-written and the main results are clearly highlighted throughout the text. All the figures are appropriately labeled and captioned; it's evident that the authors have devoted significant effort to effectively communicating their results.

I'm flagging this manuscript as a major revision because there are a couple of important areas (see major comments below) that deserve a more careful examination. However, once these are addressed, I'll be happy to review the revised manuscript's suitability for publication.

Major comments:

Although in L200-201 the authors acknowledge that "fuel availability might play a role in the interannual variation of fires," they do not explore this further since LAI, their surrogate for fuel load, does not show any correlation with fire characteristics. In the model world, this would be fine. However, in general, it has been conclusively demonstrated (see https://journals.ametsoc.org/view/journals/bams/84/5/bams-84-5-595.xml and https://www.publish.csiro.au/wf/WF19087) that, for arid and semi-arid regions, antecedent precipitation in 1-2 years prior to a major fire season shows significant correlations with burned area by promoting the growth of highly flammable fine fuels. Ignoring the effect of precipitation variability on fuel availability might artificially enhance the estimated amplification of the quasi-biennial cycle by the short timescale feedback. I recommend at least discussing this potential source of bias.

Moreover, besides good physiological reasons for not using LAI, specifically that it does not account for variability of vegetation density on the surface, the AVHRR record used in the analysis also suffers from measurement issues due to orbital change and sensor degradation (see Section 3.4.2 in https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018RG000608).

I recommend that the authors explore other remote-sensed predictors such as: --maximum GPP instead as illustrated in this paper

https://iopscience.iop.org/article/10.1088/1748-9326/ac8be4

or, -- fractional land cover as used in

https://gmd.copernicus.org/articles/16/3407/2023/gmd-16-3407-2023.html; fractional land cover for the SMCA study region may be found here:

https://2018mexicolandcover10m.esa.int

We thank the reviewer for this comment. We have checked all three additional datasets recommended by the reviewer and eventually chose gross primary productivity (GPP) as a proxy for fuel load in the revised version. The fractional land cover data used in Buch et al. (2022) is obtained from the National Land Cover Dataset (NLCD), which only provides annual observations for the years 2004, 2006, 2008, 2011, 2013, 2016 and is not sufficient to reveal the interannual characteristics of fuel load. The second land cover data provided by the link, however, directs us to a new website https://worldcover2021.esa.int/, and the global land cover product is only available for the year 2021. Hence, we used the MODIS version 6.1 GPP products obtained from Terra and Aqua platforms (MOD17A2H and MYD17A2H) as a proxy for fuel load.

Figure R1 shows the interannual variation of the regional mean GPP over the SMCA region in the month (March) prior to the fire season. The quasi-biennial variability is not obvious as seen in GPP data (figure R1). Values of GPP in some odd-numbered years (years with strong fire activities) are weaker compared to adjacent even-numbered years, e.g., in years 2003, 2005, and 2013. The correlation between regional mean GPP and fire-consumed dry matter is even slightly negative. Similar results are found when using maximum GPP in March or 8-day composites of GPP prior to the fire season as a proxy for fuel load. Hence, with the use of the additional proxy for fuel load, we could exclude the possibility that fuel load primarily contributes to the quasi-biennial variability of fire activities, further inferring the weak influence of antecedent precipitation on the quasi-biennial variability of fire by indirectly modifying the fuel availability.

We have now revised the previous manuscript as below:

Line 102-107: "We used the MODIS version 6.1 gross primary productivity (GPP) product (MOD17A2H), which measures the growth of the terrestrial vegetation as a proxy for fuel load. A cumulative 8-day composite of NPP values is provided with a 500m pixel size. The average GPP in the month (March) prior to the burning season is *examined."*

Line 210-214: "After having examined the GPP (surrogate for fuel load) prior to the burning season, we found little evidence regarding the role of fuel availability in contributing to the interannual variation of fires (Fig. S3). Lower values of GPP are found in some strong fire years compared to their adjacent years, e.g., the years 2003 and 2005. Correlations between regional GPP and fire-consumed dry matter are even slightly negative."

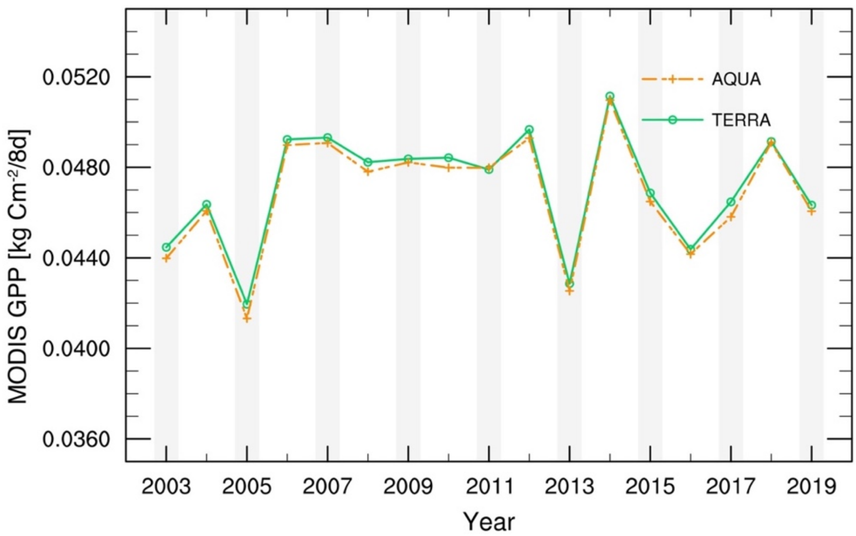

Figure R1. Temporal variations of the regional mean GPP averaged over the SMCA region in the month (March) prior to the peak burning season.

The authors should also emphasize the fact that meteorological conditions, such as mean temperature and precipitation during a fire season, are a clear confounder to any estimated amplification from the short timescale feedback. That is, although they clearly illustrate using model experiments that there is a fire-enhancing precipitation pattern contrast between strong and weak fire years (Fig. 9c), it's not quite clear what the magnitude of this effect is relative to the average difference in expected burned area due to meteorological variability between these years. One potential way to explore the magnitude of the short-term feedback could be through artificially suppressing aerosol-radiation interactions (as in Huang et. al. 2023) and comparing burned areas among similar strong fire years. A careful analysis of this point in the Results or Discussion section would suffice if running new model experiments is cumbersome.

We thank the reviewer for the comment. We agree that a direct estimate of changes in burned areas (or fire-consumed dry matter) would be useful to quantify the contributions of short-time feedback to the quasi-biennial variability of fire activities, which can be achieved by using climate/weather models with an interactive fire module. Nevertheless, in Huang et al.'s (2023) work, this is estimated based on an empirical relationship between the fire weather index (FWI, as a function of meteorological variables) and burned areas instead of online simulations of fire-climate interactions. Basically, they first constructed a linear regression relationship between the observed burned areas and FWI from ERA5 reanalysis using long-term historical data ($y = ax + b$, where y refers to burned areas and x refers to FWI). They then conducted sensitivity simulations with and without aerosol-radiation interactions using the Weather Research and Forecasting Model (WRF) and calculated the difference in FWI between the sensitivity simulations. Eventually, based on the regression equation and the simulated fire-induced difference in FWI, they roughly inferred the change in burned areas that are induced by fire-weather feedback.

Here in the revised version, we followed Huang et al.'s (2023) work and examined the relationship between the observed fire-consumed dry matter from GFEDv4.1s data and FWI from ERA5 reanalysis during 2003-2019. In our work, as precipitation is found to be a dominant contributor to the interannual variability of fire activities, we also examined the relationship between the observed fire-consumed dry matter and precipitation over 2003-2019. As shown in Fig. R2, fire-consumed dry matter is highly correlated with both FWI and precipitation with correlation coefficients of 0.8 and -0.7 respectively.

The estimated change in fire-consumed dry matter induced by the precipitation-fire feedback is around 15.3% (3.36Tg relative to the total difference in fire-consumed dry matter of 22Tg between years with strong and weak fire activities). It should be cautioned with the large uncertainty for this estimate because of multiple feedbacks involved at the global scale and large biases for simulated meteorological variables at regional scales in global climate models. We admitted the limitation and added more discussion regarding this issue including emphasizing the importance of using interactive fire-climate models to quantify the contributions of short-term feedback. See Line 467-473 in the revised manuscript:

Line 467-473: "Moreover, though we demonstrated positive feedback between fire-emitted aerosols and precipitation exists on short timescales, to what extent this feedback contributes to the quasi-biennial variability of fire activities remains unquantified due to the absence of coupled fire-climate interactions in current model simulations. Future efforts to quantify how different factors and feedback work together to shape the quasi-biennial variability of precipitation and fire activities using interactive fire-climate models would further benefit the prediction and management of fire activities over the SMCA region."

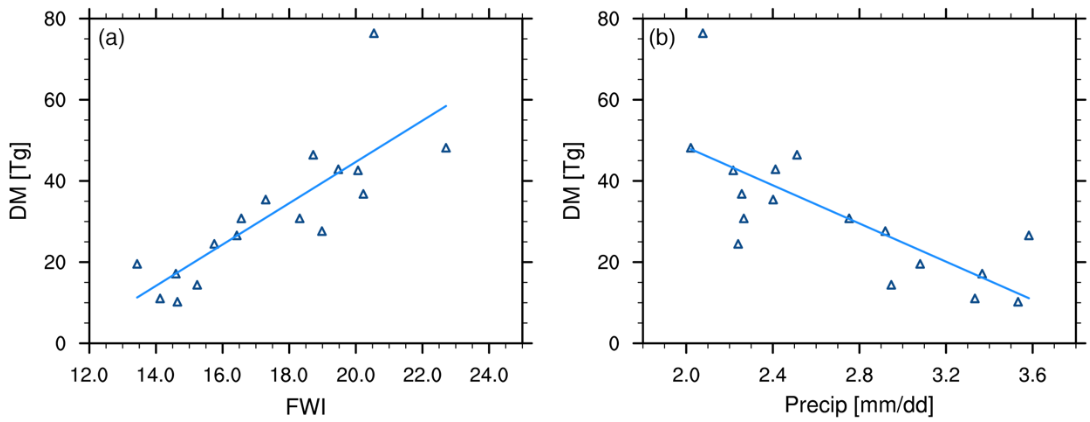

Figure R2. Scatterplots indicating the relationship between the regional sum of fire-consumed dry matter and regional mean (a) fire weather index and (b) precipitation in peak burning seasons over the SMCA region during 2003-2019. Triangles represent values in individual fire seasons and the lines are the linear regression lines.

Minor comments:

L78: Change "characteristic" to characteristics

This has been corrected.

L79-80: Use present tense to maintain consistency throughout the paragraph; specifically change "explored" and "provided" to explore and provide respectively

This has been corrected.

L90: Is "fire consumption" correct here? It might be fuel consumption or fire-consumed fuel instead. Please verify.

We thank the reviewer for the suggestion. We have changed “fire consumption” to either “fire-consumed dry matter” or “fire consumption of dry matter” in the revised manuscript.

L103: Change "previous" to prior

This has been corrected.

L135-136: What is the specific way in which the fire inventory is modified but anthropogenic emissions are kept unchanged? Consider adding a 1-2 sentence clarification

We thank the reviewer for the comment. In the CESM2 model, fire emissions and anthropogenic emissions are specified separately in different files. This has been clarified in the revised manuscript.

L162: Clarify if the difference in fire-consumed dry matter mentioned here is for one particular year or the whole study period.

We thank the reviewer for the comment. We have clarified in the revised manuscript that the difference refers to the difference in the average of fire-consumed dry matter between odd-numbered and even-numbered years.

L165 and L173: Omit "basically" -- the sentences read fine without it

The has been revised.

L202 and L210: Rephrase "fire consumption" as suggested above

This has been revised accordingly.

Fig. 2: I'm not sure if it's easily feasible with the current analysis set up, but including an additional plot of fire counts in the study region between 2003 and 2019 will help in visually emphasizing fire prone areas

We thank the reviewer for the suggestion. We provided the spatial distributions of fire-consumed dry matter in the supplementary information (Fig. S2) to help illustrate the spatial features of fire activities.

Fig. 2: make the stippling bolder/bigger as it's hard to see the pattern in presence of colors

This has been revised accordingly.

In Fig. 3 are the temperature and precipitation anomalies calculated with respect to the 2003-2019 mean? Please clarify in the caption

This has been revised.

L383: Typo in "quai-"

This has been revised.