We are grateful to the referees for their time and energy in providing helpful comments and guidance that have improved the manuscript. In this document, we describe how we have addressed the reviewer's comments. Referee comments are shown in black italics and author responses are shown in blue regular text. A manuscript with tracking changes are attached at the end.

Reviewer #1

The authors present an interesting and very valuable study of the radiative forcing from wildfire emissions, using a version of the GISS-E2 model coupled with a vegetation model and the Pechony and Shindell (2009) fire parameterisation. The authors rightly point out that there have been relatively few studies to investigate the radiative impact of fire emissions in climate models, and there is considerable model diversity among the few studies that have looked at this. This study is therefore significant by adding another very useful data point to help constrain an otherwise poorly-known quantity. The authors' Table 2 (comparing their values with the handful of previous studies, which used different models), is particularly useful in this regard as a reference to anyone wanting to know the state-of-the-art of our current estimates of fire radiative forcing. Another selling point is that uniquely (to my current knowledge) the authors used a fire parameterisation to interactively diagnose fire emissions in their climate model, rather than prescribing them. The paper is well-written and presented, with good quality figures. I have some specific concerns around how the study is described – which I feel is currently a little misleading – which I have outlined below. However, subject to addressing this by slightly re-framing some of the description of the study, I think this is a useful contribution which will be very appropriate for publication in Atmospheric Chemistry and Physics.

- Thank you for your positive evaluations.

Main comments:

The main issue with the current description of the study, is that it is framed throughout as diagnosing two-way interactions between climate and fire emissions (for example, but not limited to: the title ("Fire-climate interactions…"), the abstract (e.g. L17-L19), the introduction (e.g. L82, and especially L91-L93 "The main objectives are… to quantify *the feedback of fire-induced climate effects to fire emissions and air pollutants", and the conclusion (e.g. L327-328)). However, this is *not* what the study actually does, because the authors use atmosphere-only simulations where sea-surface temperatures are prescribed, and therefore the modelled climate is not free to respond to the radiative forcing from fire emissions. The authors acknowledge this in L195-L197 ("Given that the model is driven by prescribed SST and SIC, only the rapid adjustments of atmospheric variables are taken into account"), but this contrasts sharply with the impression given repeatedly throughout the rest of the manuscript that the emissions -> climate response -> emissions feedback is being investigated. Rapid adjustments are not at all comparable to the full climate response (indeed, this is why fixed-SST simulations are used to diagnose effective radiative forcing!). This is especially apparent in the very small climate responses that the authors diagnose – for instance, a global mean surface temperature response of -0.06 K, which is an order of magnitude smaller than the full surface temperature response you would expect from a -0.6 Wm-2 radiative forcing. In a fully-coupled atmosphere-ocean simulation, the climate responses would therefore be vastly different, both in magnitude and probably spatial pattern. What the authors have primarily done, is presented a (very useful!!) analysis of aerosol effective radiative forcing due to interactive wildfires in the GISS-E2 model. Whilst the analysis of the fire responses to rapid adjustments is interesting, it should not be claimed as diagnosing the fire-climate feedback on fire emissions. I recommend the authors therefore reframe the sections of the paper mentioned above, to emphasise that the study primarily investigates radiative forcing from fires, and make it much clearer from the outset that the only feedbacks included are those due to rapid adjustments.*

➢ In the revised paper, we modified the descriptions to emphasize that we focus on the rapid adjustments of climate.

In the Abstract:

(1) "Meanwhile, these instantaneous environmental perturbations can feed back to affect fire emissions." (Line 18)

(2) "Globally, fire emissions reduce by 2%-3% because of the fire-induced fast responses in humidity, lightning, and LAI." (Lines 29-30)

In the Introduction:

(3) "Aerosol radiative effect is the instantaneous radiative impact on energy balance of climate system, representing the fast adjustment or response before changing global mean surface air temperature (TAS)." (Lines 65-67)

(4) "Impact of fire-induced instantaneous climatic perturbations to fire activities on the global scale have not been fully assessed." (Lines 85-86)

(5) "Models provide unique tools to explore fire-climate interactions resulting from aerosol radiative effect especially at the regional to global scales."(Lines 88-89)

(6) "The main objectives are (1) to isolate the radiative effects of fire aerosols through ADE, AIE, and AAE processes and (2) to quantify the feedback of fire-induced instantaneous climate effects to fire emissions." (Lines 94-96)

In the Methods:

(7) "The radiative effect simulated with such model configuration is termed the effective radiative forcing (ERF)." (Line 258-259)

In the Results:

(8) Change the subtitle from "3.3 Fire-induced climatic change" to "3.3 Fire-induced fast climatic responses" (Line 312)

(9) Change the subtitle from "3.4 Fire-climate interactions" to "3.4 Climate feedback to fire aerosol radiative effect" (Line 331)

(10) "The fire-aerosol-induced fast response in precipitation, VPD, lightning, and LAI can feed back to affect fire emissions." (Lines 332-333)

(11) "To illustrate the joint the impacts of fire-aerosol-induced instantaneous climatic change, we count the number out of the four factors contributing positive effects to fire emissions over land grids (Fig. 5d)." (Lines 340-342)

In the Conclusions:

(12) "These fire-induced fast climatic responses further affect VPD, LAI, and lightning ignitions, leading to reductions in global fire emissions of BC by 2% and OC by 3%." (Lines 361-363)

(13) "Despite these limitations, we made the first attempt to assess the two-way interaction between fire emissions and climate via aerosol radiative effects." (Lines 404-405).

Section 2.4: "Within each group, two runs are performed with (YF) or without (NF) fire emissions. For YF simulations, fire-induced aerosols are dynamically calculated based on fire emissions and atmospheric transport". It's a little unclear whether only the aerosol emissions were changed between the YF and NF runs. The results only ever refer to aerosol effects, however the description of the fire parameterization in section 2.3 describes trace gas emissions from fire (NOx, CO, CH4) being simulated as well. Were these trace gas fire emissions also disabled in the NF simulations? In which case, the comparison of YF-NF does not solely include radiative perturbations from aerosols. However, if fire trace gas emissions were kept on and it was only the aerosol emissions that change, then it should be made clearer that these other fire emissions were held constant throughout.

- The differences between YF and NF include the emissions of both primary aerosols and aerosol precursor gases (such as NO_x, SO_2, NH_3). In the revised paper, we clarified as follows: "The fire emissions include both primary aerosols and trace gases, the latter of which react with other species to form the secondary aerosols. These particles could be transported across the globe by the three-dimensional atmospheric circulation and eventually removed through either dry or wet deposition." (Lines 227-230) and "For YF simulations, fire-induced aerosols including primarily emitted and secondarily formed are dynamically calculated based on fire parameterization (see section 2.3) and atmospheric transport." (Lines 238-240).

L319-L326: The consideration of whether the different aerosol radiative effects and rapid adjustments are additive or not is potentially very interesting. However, it is really hard to know how significant this effect really is, since no indication of uncertainty ranges are given for the global mean values. E.g. the authors note that the temperature rapid adjustments from the individual processes sum to -0.037K, whereas the total temperature rapid adjustment was -0.061. These are both very small numbers and the difference between them could easily be due to internal variability rather than because of a non-linear response. Similarly (probably even more so) for the precipitation changes. Could the authors estimate a measure of uncertainty (e.g. from the internal variability across the 20 individual years of their simulations?) to help establish whether these values are *robustly different from each other, or indeed from zero?*

- In the revised paper, standard deviations of radiative effects and climatic feedback have been added by using "±" after the global mean or sum values. Please check the updated numbers with uncertainties throughout the paper.

Minor comments:

L92-L93 "to quantify the feedback… to air pollutants" – as far as I can see, there isn't really any discussion or analysis regarding the effects on air quality, i.e. no figure showing changes in PM, aerosol concentrations, or any similar metric. So I would also remove the mention of feedbacks on air pollutants, as it seems to be something else which isn't truly in the scope of the paper

- We removed "air pollutants" in the revised paper.

L221: "78% of the total effects" – maybe change this to "78% of the total TOA radiative effect" or something similar, since this number only refers to the TOA quantity and not to the other radiative or other effects of AIE (for instance, in the surface RF, AIE appears to account for less than the ADE)

- Corrected as suggested.

L312-L315: the authors mention that a limitation of their study is that SSTs are prescribed, whereas in a fully coupled model "air-ocean interactions may cause complex feedbacks to aerosol radiative effects". This may be true, but there is no mention/discussion of the far more significant distinction: that in a model with a fully coupled ocean, the magnitude (and probably spatial pattern) of the climate response will be vastly different. (C.f. my first main comment above – this is another example where the authors seem to gloss over whether or not these atmopshere-only simulations truly diagnose the climate response to fire emissions, and subsequent feedbacks).

- As we responded to your main concern, we revised the paper throughout to emphasize that we focus on the fast climatic responses of fire aerosols. In the discussion section, we added following statement: "Although most of fire-induced AOD changes are located on land (Fig. S2), the air-sea interaction may cause complex climatic responses to aerosol radiative effects. In a recent study, Jiang et al. (2020) emphasized the role of slow feedback contributed by fire aerosols on global precipitation reduction by using a coupled model. Such air-sea interaction will modify the magnitude and/or spatial pattern of fast climatic responses revealed in this study, and should be explored in the future studies with coupled ocean models." (Lines 378-384).

Section 4 – another potential limitation that could be very briefly mentioned here, is that climate conditions (SSTs, sea ice) were used from a single year (2000) which was repeated. Fire emissions can be somewhat variable from year-to-year, for instance in El Niño years some regions can experience significant changes in annual fire emissions (e.g. Burton et al. 2020, https://doi.org/10.3389/feart.2020.00199), so I guess it's possible that the fire emissions and resulting ERF could differ over certain regions if the model were driven by SSTs from a different year?

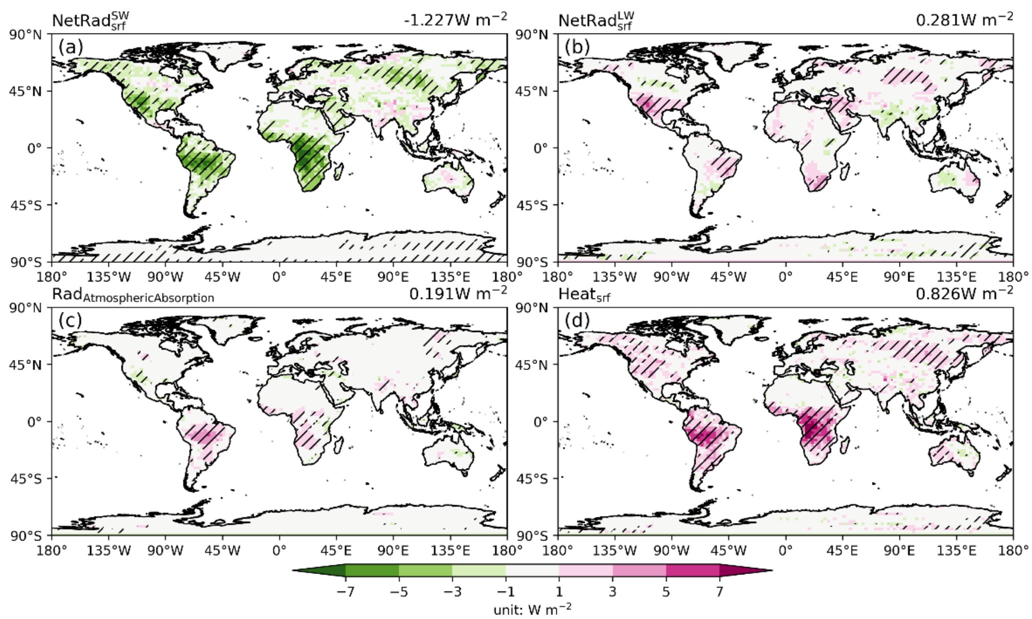
- For this study, we mainly focus on the comparison of different radiative processes of fire aerosols, and their feedback to fire emissions. The impact of climate variability on fire emissions is an interesting topic that can be explored in future studies. We acknowledge such limitation as follows: "For each simulation, climatological mean CO_2 concentrations, SST/SIC, and population density during 1995-2005 are used as boundary conditions to drive the model. Such configuration ignores the year-to-year variability in climate systems, which may cause significant changes in annual fire emissions (Burton et al. 2020)." (Lines 250-253).

Supplementary figures S3, S4, S5: "Positive values represent the increase of downward radiation" – these figures show sensible and latent heat fluxes which are not radiative fluxes, so strictly this phrase doesn't make sense. Suggest changing it to "positive values represent a downward heat flux" or something similar.

- Corrected as suggested.

Given that the primary (and very useful!) result of the paper is the analysis of the different aerosol radiative contributions to the total fire radiative forcing, it would be *worthwhile also including a plot of the atmospheric absorption component. I realized this can be deduced by differencing Fig 1 and Fig 2, but would be great to see it included as a figure as well, rather than having to eyeball it.*

- We have modified Fig. 2 to include the atmospheric absorption. Please notice that Fig. 1 is the global average (including ocean regions) while Fig. 2 is the average over land grids. We also added descriptions as follows: "As a result, fire aerosols induce a net atmospheric absorption of 0.191 $\pm$0.289 W m^{-2} over land grids (Fig. 2c)." (Lines 302-303).



- Fig. 2 Changes in (a) surface net shortwave radiation, (b) surface net longwave radiation, (c) atmospheric absorbed radiation, and (d) surface heat flux (sensible + latent) over land grids caused by fire aerosols. Positive values represent the increase of downward radiation/heat for (a, b and d) and absorption for (c). Global average value is shown at the top of each panel. Slashes denote areas with significant ($p < 0.1$) changes.