We thank the reviewer for his/her thoughtful, valuable and detailed comments and suggestions that have helped us improve the paper quality. Our detailed responses (Blue) to the reviewer's questions and comments (*Italic*) are listed below.

Reviewer #1:

The paper "Spatio-temporal variation characteristics of global wildfires and their emissions" presents a very detailed analysis of fire burned area, fire fraction, fire radiative power, and fire count in different regions and different seasons using satellite remote sensing data, emission data, and meteorological data. The study found that while the burned area of wildfires has decreased slightly over the past 20 years, there are pronounced regional and seasonal variations in the burned fraction, fire count, and fire radiative power of wildfires. The study also found that emissions from wildfires decreased in some regions (such as Northern Canada, Alaska, and Northeast China) while increasing in others (such as Siberia) and that the intensity of wildfire development is primarily affected by the abundance of vegetation, while weather conditions can also indirectly influence wildfire incidence. The study concludes by suggesting that this research can provide support for the control of wildfire activity across regions and seasons.
The paper is well-structured, the research question is well-defined, and the methods used are appropriate for the research question. The study findings are well presented and the conclusion is well drawn.

We highly appreciate the positive comments from the reviewer which encourage us a lot. We also thank the reviewer for the detailed suggestions and comments. We have gone through all the comments and revised the original manuscript accordingly.

General comments:
1. Introduction: it would be better to include more papers from previous studies in your paper, particularly those focused on burned area trends, fire intensity trends, global patterns of wildfires, variations in fire season, and the impact of weather on wildfires. These studies would provide a more comprehensive understanding of the topic.

We agree with the reviewer and appreciate the suggestion. We have added the introduction at Lines 77-91: "**In terms of BA, forest fires made up the majority of the area burned in Equatorial Asia, followed by the North America. Savanna fires were extremely prevalent in Africa and considerably less in South America. Farmland fires were the most prevalent in Europe and the Middle East, while grassland fires were dominant in Central Asia and South America (Giglio et al., 2013; van Wees et al., 2022). The majority of the world's regions, particularly those with forests in mid- and high-latitudes, will see a future with a higher danger of wildfires as global warming progresses (Yu and Ginoux, 2022; Zhu et al., 2021).**

In the past decade or so, although the reduction of man-made fires in tropical areas has led to the reduction of the global area of over-fire, the trend in other regions is on the rise, the frequency of extreme wildfire events is increasing, and the difference in seasonal variation is more obvious (Bowman et al., 2020; Senande-Rivera et al., 2022; Zheng et al., 2021). Several recent studies (Huang et

al., 2023; Xu et al., 2022) have found that the BA of wildfires in the West Bank of the United States and the Indo-China Peninsula in Southeast Asia has increased and has significant synoptic scale changes, and the strongest frequency spectrum is in the time scale of 1 week and 2 weeks, respectively. The former is controlled by wind speed and humidity, while the latter is mainly modulated by rainfall (Huang et al., 2023).".

2. This paper found a decrease in burned areas in the western US, however, other studies have found an increase in burned areas in the same region. For example:
M. Burke, A. Driscoll, S. Heft-Neal, J. Xue, J. Burney, M. Wara, The changing risk and burden of wildfire in the United States. Proc. Natl. Acad. Sci. U.S.A. 118, e2011048118 (2021).
Y. Zhuang, R. Fu, B. D. Santer, R. E. Dickinson, A. Hall, Quantifying contributions of natural variability and anthropogenic forcings on increased fire weather risk over the western United States. Proc. Natl. Acad. Sci. U.S.A. 118, e2111875118 (2021).
This discrepancy in findings is noteworthy and deserves further investigation. I would recommend considering comparing the findings in your paper with previous studies and discussing the differences.

Sorry for the confusion. In this study, we found that the burning area of fires in the western United States has been rising slowly in the past 20 years, and this overall conclusion is basically consistent with the above two studies. However, there are some differences between our study and these two studies, as shown in Table R1. In addition, our newly added Fig. 4 also directly shows the increasing trend of BA in the western US.

Following the reviewer's suggestion, we added relevant discussion about the comparison at Lines 196-200: "**The BA, which is frequently employed in existing studies as a single metric to quantify fire changes (Senande-Rivera et al., 2022; Zheng et al., 2021), shows a steady decreasing trend based on both global observation data and model simulations (Fig. 1). However, there is also an increasing trend of BA in many specific regions, such as the Arctic and the western United States (Burke et al., 2021; Engelmann et al., 2021; Zhuang et al., 2021)**.".

Table R1. Comparison of differences among the three studies.

	Study area	The period
Burke et al., PNAS	Public and private US lands	1983-2020
Zhuang et al., PNAS	The Western US	1979-2020 (May to September)
This study	The Western US	2001-2020

3. This study utilized GFAS emission data, however, it has been shown in the paper by Li et al. (2020) that GFAS data is much lower than other widely used emission data products. This difference in the data sets could have a significant impact on the results of your study. I recommend comparing GFAS with other emission data products (e.g., QFED, FEER, GFED, etc.) to make your results more robust and reliable.
Li, Y., Tong, D. Q., Ngan, F., Cohen, M. D., Stein, A. F., Kondragunta, S., et al. (2020). Ensemble PM2.5 forecasting during the 2018 Camp Fire event using the HYSPLIT transport and dispersion

model. Journal of Geophysical Research: Atmospheres, 125, e2020JD032768. https://doi.org/10.1029/2020JD032768

We appreciate the useful information and comment from the reviewer.

As the reviewer said, GFAS, QFED, FEER, GFED and FINN are widely used emission data, but there are also some differences among them. The main factors causing the difference of the above emission data include fire detection, emission factor, biome types and burning stages. The reason why we chose the GFAS data was formally carefully screened, and we referred to the paper on the comparison of these emission data (Pan et al., 2020). Relevant studies (Kaiser et al., 2012; Pan et al., 2020) found that the biomass burning OC emissions derived from GFED3.1, GFED4s, FINN1.5, GFAS1.2, FEER1.0, and QFED2.4 can differ by up to a factor of 3.8 on an annual average, with values of 15.65, 13.76, 19.48, 18.22, 28.48, and 51.93 Tg C, respectively. The biomass burning BC emissions can differ by up to a factor of 3.4 on an annual average.

In general, higher biomass burning emissions are estimated from QFED2.4 globally and regionally, followed by FEER1.0. GFAS data ranked in the middle of the global and regional emissions assessment, showing relatively stable performance and effectively avoiding overestimation and underestimation in regional studies (Kaiser et al., 2012; Pan et al., 2020). More importantly, the object of this study is to analyze the changes of global and typical regional wildfire emission trends and the attribution of differences in emission change trends, rather than absolute differences. Therefore, we finally used GFAS data after comprehensive consideration. We modified the description of GFAS data at Lines 141-149: "**The fire emission data used in this study is the Global Fire Assimilation System (GFAS), which has been widely used in previous studies (Fan et al., 2021; Kaiser et al., 2012; Li et a., 2020; Pan et al., 2020). Note that different products could provide biomass burning OC emissions with large differences (Kaiser et al., 2012; Pan et al., 2020), introducing uncertainties to our analysis. For example, Li et al. (2020) suggested the low biases of GFAS in biomass emissions. However, there are also studies (Kaiser et al., 2012; Pan et al., 2020) showing that GFAS is more stable than other data in the description of fire emissions, which is suitable for the analysis and comparison of fire emission trends in this study. Thus, the NASA's Terra and Aqua MODIS active fire products are used by the GFAS to estimate daily fire emissions with a horizontal resolution of 0.1° (Kaiser et al., 2012).**".

Kaiser, J. W., Heil, A., Andreae, M. O., Benedetti, A., Chubarova, N., Jones, L., Morcrette, J.-J., Razinger, M., Schultz, M. G., Suttie, M., and van der Werf, G. R.: Biomass burning emissions estimated with a global fire assimilation system based on observed fire radiative power, Biogeosciences, 9, 527–554, https://doi.org/10.5194/bg-9-527-2012, 2012.

Pan, X., Ichoku, C., Chin, M., Bian, H., Darmenov, A., Colarco, P., Ellison, L., Kucsera, T., da Silva, A., Wang, J., Oda, T., and Cui, G.: Six global biomass burning emission datasets: intercomparison and application in one global aerosol model, Atmos. Chem. Phys., 20, 969–994, https://doi.org/10.5194/acp-20-969-2020, 2020.

Li, Y., Tong, D. Q., Ngan, F., Cohen, M. D., Stein, A. F., Kondragunta, S., Zhang, X., Ichoku, C., Hyer, E. J., and Kahn, R. A.: Ensemble $PM_{2.5}$ forecasting during the 2018 camp fire event using the HYSPLIT transport and dispersion model, J. Geophys. Res.-Atmos., 125, e2020JD032768, https://doi.org/10.1029/2020JD032768, 2020.

Specific comments:

1. *Line 59: Please add more references for wildfire impact on human health. Below are some examples:*

   Reid, C.E., Brauer, M., Johnston, F.H., Jerrett, M., Balmes, J.R., Elliott, C.T.: Critical review of health impacts of wildfire smoke exposure. Environ. Health Perspect. 124, 1334–1343, 2016.

   Cascio WE.: Wildland fire smoke and human health. Sci Total Environ. doi: 10.1016/j.scitotenv.2017.12.086, 2018.

   O'Neill, S. M., Diao, M., Raffuse, S., Al-Hamdan, M., Barik, M., Jia, Y., Reid, S., et al.: A multi-analysis approach for estimating regional health impacts from the 2017 Northern California wildfires, Journal of the Air & Waste Management Association, 71:7, 791- 814, DOI: 10.1080/10962247.2021.1891994, 2021.

   Liu, Y., Austin, E., Xiang, J., Gould, T., Larson, T., & Seto, E.: Health impact assessment of the 2020 Washington State wildfire smoke episode: Excess health burden attributable to increased PM2.5 exposures and potential exposure reductions. GeoHealth, 5, e2020GH000359. https://doi. org/10.1029/2020GH000359, 2021.

   Li, Y., Tong, D., Ma, S., Zhang, X., Kondragunta, S., Li, F., & Saylor, R.: Dominance of wildfires impact on air quality exceedances during the 2020 record-breaking wildfire season in the United States. Geophysical Research Letters, 48, e2021GL094908. https://doi.org/10.1029/2021GL094908, 2021.

We appreciate the useful information and comment. We have added them at Lines 57-59: "**Fires have a harmful effect on the climate and human society (Cascio., 2018; Li et al., 2021). On one hand, fires can substantially worsen air quality and endanger human health by spewing out harmful gases (Liu et al., 2021; O'Neill et al., 2021; Reid et al., 2016)**.".

2. *Introduction: Please include more papers on burned area trends, fire intensity trends, global patterns of wildfires, variations in fire season, and the impact of weather on wildfires.*

Following the reviewer's suggestion, we added the introduction at Lines 77-91: "**In terms of BA, forest fires made up the majority of the area burned in Equatorial Asia, followed by the North America. Savanna fires were extremely prevalent in Africa and considerably less in South America. Farmland fires were the most prevalent in Europe and the Middle East, while grassland fires were dominant in Central Asia and South America (Giglio et al., 2013; van Wees et al., 2022). The majority of the world's regions, particularly those with forests in mid- and high-latitudes, will see a future with a higher danger of wildfires as global warming progresses (Yu and Ginoux, 2022; Zhu et al., 2021).**

In the past decade or so, although the reduction of man-made fires in tropical areas has led to the reduction of the global area of over-fire, the trend in other regions is on the rise, the frequency of extreme wildfire events is increasing,

and the difference in seasonal variation is more obvious (Bowman et al., 2020; Senande-Rivera et al., 2022; Zheng et al., 2021). Several recent studies (Huang et al., 2023; Xu et al., 2022) have found that the BA of wildfires in the West Bank of the United States and the Indo-China Peninsula in Southeast Asia has increased and has significant synoptic scale changes, and the strongest frequency spectrum is in the time scale of 1 week and 2 weeks, respectively. The former is controlled by wind speed and humidity, while the latter is mainly modulated by rainfall (Huang et al., 2023).".

3. *Line 109: Please provide the full name for MODIS. Make sure you have provided the full name of any abbreviation before using it for the first time in your paper. Please check throughout the paper.*

Sorry for the mistake. We have added the full spell for MODIS and checked the paper throughout.

4. *Line 110: full names for MCD, MCD64CMQ, and MCD14DL are missing.*

We thank the reviewer's comments and have added their full names.

According to the product guide, full name of MCD14DL is MODIS/Aqua+Terra Thermal Anomalies/Fire locations 1km V0061 NRT (Near real-time) distributed by LANCE FIRMS (https://www.earthdata.nasa.gov/learn/find-data/near-real-time/firms/mcd14dl-nrt). The combined (Terra and Aqua) MODIS NRT active fire products (MCD14DL) are processed using the standard MOD14/MYD14, where MOD14 (Terra) and MYD14 (Aqua) are Level 2 Fire Products. Therefore, MCD means a product that combines Aqua and Terra.

MCD64 is the Collection 6 Moderate Resolution Imaging Spectroradiometer (MODIS) Burned Area product suite. The products with suffix CMQ refer to CMG fire products, where CMG refers to Climate Modeling Grid. Therefore, MCD64CMQ is the Climate Modeling Grid Burned Area Monthly Product (https://modis-fire.umd.edu/files/MODIS_C6_BA_User_Guide_1.3.pdf).

Accordingly, we have added the descriptions in section 2.2.1 of the manuscript.

5. *Line 117: full names for MOD, and MYD are missing.*

We have added the full names now.

6. *Line 117: Please add the reference for the FIRMS product here.*

Added.

7. *Line 123: full name for FireCCI is missing.*

Added.

8. *Section 2.2.2: Compare GFAS with other widely used fire emission products. (See general comments)*

We have added the corresponding information as replied in the general comment.

Thanks.

9. *Line 134: full names for ERA, ERA-Interim, and ERA5 are missing.*

Thanks for helping figure them out and we have added the full names now.

10. *Line 153: any reference for the definition of the fire month? Why do you use 80% rather than 70% or another percentage?*

This is a good question. Here we refer to the study of Archibald et al. (2013). In their research, a monthly climatology of burned area was first produced from the entire time series. The monthly burned areas were then ranked, and the average fire season length was defined as the number of months required to reach 80% of the total average annual burned area (analysis of values from 70% to 85% showed that the results were not sensitive to the threshold chosen). Therefore, we have adopted 80% as the threshold in this study, and we have also added the reference at lines174-176: "**The month with 80% of the annual average burned area is the fire month, and the fire month number is the duration of the fire season (Archibald et al., 2013)**.".

Archibald, S., Lehmann, C.E.R., Gómez-Dans, J.L., Bradstock, R.A.: Defining pyromes and global syndromes of fire regimes, Proceedings of the National Academy of Sciences, 110, 6442-6447, https://doi.org/10.1073/pnas.1211466110, 2013.

11. *Figure 1: It would be better to show the trend of burned areas in the 12 different regions defined in table 1.*

The reviewer provides us useful comments. According to the current structure of this study, we have added the trend of burned areas in the 12 different regions as Figure R1 (Figure 4 in manuscript), and added the corresponding descriptions at lines 283-287: "**Although the global fire BA shows a downward trend, the changes in 12 regions are not consistent (Fig. 4). Specifically, the BA increased in WUS, SI, and SI regions, and decreased in NAF, SAF, and CE regions, while the trend change in other regions was not obvious. At the same time, we need point out that the regions with large BA are mainly located in low latitude, such as NAF, SAF and NAU, and their changes have a greater contribution to the reduction of global BA**.".

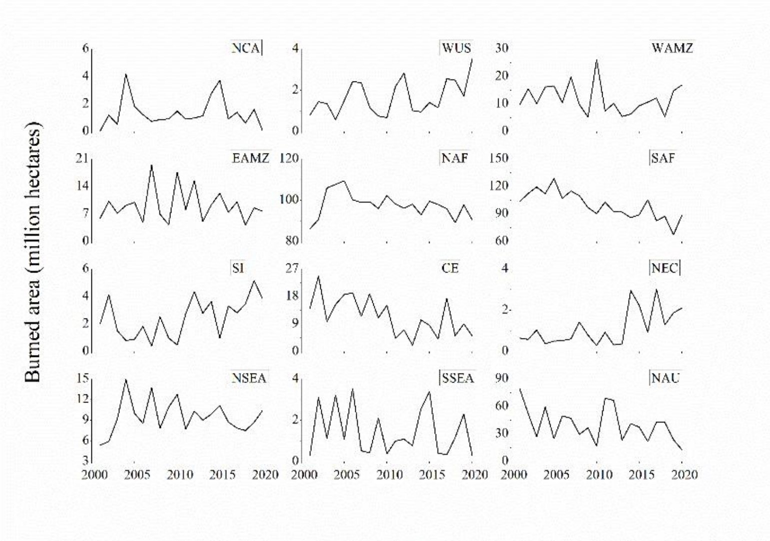

Figure R1. The trend of burned areas in the 12 different regions.

12. Figure 1: Please explain the difference in the results of MODIS and FireCCI.

We thank the reviewer's comments. After a careful inspection, we found that there were small errors in our previous programming, which led to differences between the two sets of data in Figure R2 (Figure 1 in manuscript). With the help of this comment, we have corrected all of them, and the results can still prove that the burning area shows a decreasing trend.

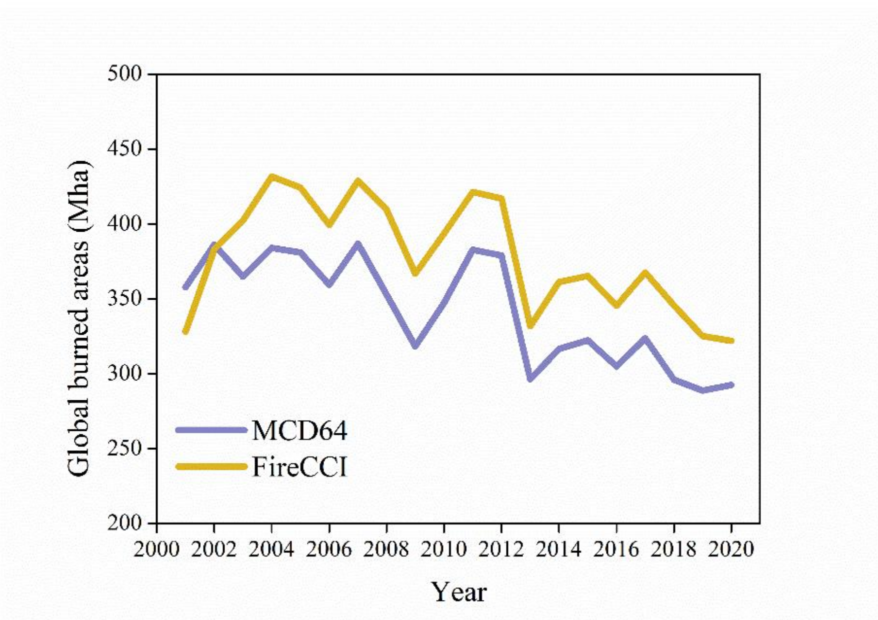

Figure R2. Global burned areas derived from MCD64 and FireCCI.

13. Figure 2: Please add the time period in the figure 2 caption.

Thanks, we have added it in Fig. 2 of the manuscript: "**Figure 2. The spatial distribution of global fire burned fraction (BF), fire count (FC) and fire radiation power (FRP) from 2001 to 2019.**".

14. *Line 199: It's interesting to see how land use affects the fire trend. It'd be better to add one figure and some discussion about the BA, BF, BC, and FRP trends in different land use type regions.*

We appreciate the reviewer's comments. We have another study dedicated to studying the spatiotemporal change characteristics of wildfire in different land use types, which is also under review. In order to avoid repetition of the topic content, we add a part of discussion at lines 223-227: "**From the perspective of land use type, the BA and FC show linear correlation in most cases. Specifically, in forests, fires mainly increase in temperate and boreal forest areas, and in farmland, fires mainly increase in South Asia and East Asia, while the area of global grassland fires generally shows a downward trend except for parts of the United States and Australia.**".

15. *Line 254: According to Sofiev et al. (2012), plume injection height is related to FRP. It'd be better to show the scatter plot of FRP and APT.*

Sofiev, M., Ermakova, T., & Vankevich, R.: Evaluation of the smoke-injection height from wild-land fires using remote-sensing data. Atmospheric Chemistry and Physics, 12(4), 1995–2006. https://doi.org/10.5194/acp-12-1995-2012, 2012.

This is a good suggestion. We carefully studied the above research and showed the relationship between plume injection height and FRP (Fig. R1). We find that Fig. R3 is consistent with the result (Figure R4) of Sofiev et al. (2012). It can be seen from the scatter plot that ATP is mainly distributed at 500-3500m and FRP is mainly distributed at 0-2000 MW, but there is obviously no significant linear relationship between the two indicators. In this study, we mainly want to analyze the relative changes of wildfire burning area, plume injection height and FRP in 12 regions to reflect the regional differences. Therefore, the relationship analysis between plume injection height and FRP is not included in this study. We need to further study the specific impact and response relationship between them in future.

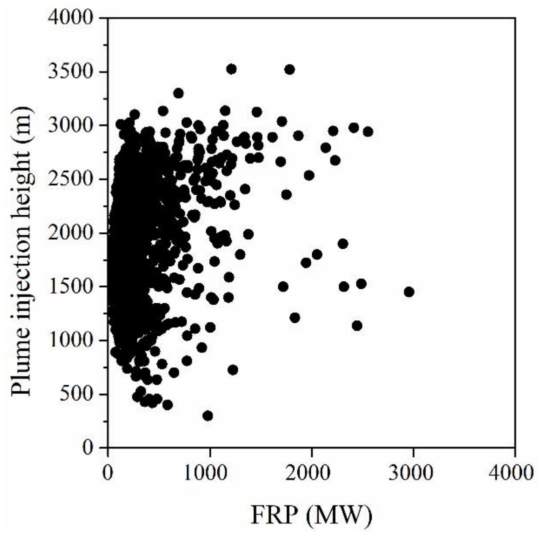

Figure. R3. The scatter plot of plume injection height and FRP.

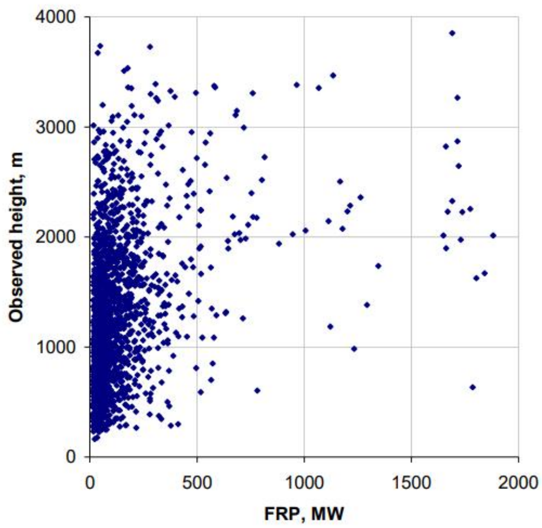

Figure R4. The scatter plot in the study of Sofiev et al. (2012).

16. *Line 264: The relative changes of FRP of NAU is not the highest. NCA, SI, and WUS is higher than NAU.*

We apologize for our wrong description. We have modified it at lines 299-300: "**The relative changes of BA, and APT of NAU are all the highest, and its FRP is also relatively high, as observed in Fig. 5, suggesting that the fire occurred frequently with high intensity**.".

17. *Line 274-303: This paragraph is very long. Consider separating it into two paragraphs.*

We appreciate this comment and have modified it as suggested.

18. *Figure 5: Can you explain why there is no data for SI in the Jan and Feb (2003-2011)?*

This is a good question. In principle, we are not sure about the reasons, while we are sure that the dataset did not provide the information in January and February from 2003 to 2011. One likely (we are not sure if it is) reason is the climate warming. We know that Siberia (SI) is in the high latitude of the northern hemisphere, where the winter is cold and long, making wildfires and their emissions rare or even nore in January and February at early stage such as before 2011. With the global warming, the wildfire becomes possible recently such as in February after 2011.

19. *Line 295: The increase in SI is only after May. There is a decrease from Jan-April.*

We have modified the sentence at lines 328-330: "**NCA and NEC showed a significant decrease in the mean value of emission fluxes from 2012 to 2020, while SI showed a significant increase in the mean value of emission fluxes from May to November during 2012-2020.**".

20. *Figure 6: Please provide the time period in the caption.*

Added.

21. Line 388: why use 2001-2009 instead of 20 years (2001-2019)?

Sorry for our typo and it is actually 2001-2019. We have corrected it at Lines 422-424: "**In 2001-2019, the precipitation in western Amazon decreased in summer, and the relative humidity and soil moisture showed a declining trend in summer and autumn, which were favorable for the occurrence and spread of fire**.".