

MS Title: Future prediction of Siberian wildfire and aerosol emissions via the improved fire module of the spatially explicit individual-based dynamic global vegetation model

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General comment

The manuscript titled "Future prediction of Siberian wildfire and aerosol emissions via the improved fire module of the spatially explicit individual-based dynamic global vegetation model" by Reza Kusuma Nurrohman and colleagues evaluates the implementation of the SPITFIRE fire module into the SEIB dynamic global vegetation model for Siberia. The model is forced with reanalysis data provided by CRU and with global climate model data produced by MirocAR5 for the historical period as well as four emission scenarios until 2100. The manuscript compares simulated and observed fire-related variables and evaluates the impact of wildfires on emissions and tree mortality. The text would benefit from restructuring and enhanced focus on the aspects that really matter. Large parts of the results section are very descriptive, and it is not always self-evident why these results matter and what they imply. It is worthwhile for the authors to revisit the entire text and carefully assess what information is really worth communicating. Additionally, restructuring the results section such that it first evaluates the model during the historical period and then describes future projections afterwards is recommended. Furthermore, adding an overview figure or table that systematically compares and summarizes model performance for the old and new versions of the model is suggested. This is important to convince the reader that the new version is indeed superior. Finally, many of the literature references are outdated and should be replaced with more recent ones. I recommend that the manuscript may be considered for publication in Biogeosciences after major revision. Please find my detailed comments below.

Detailed Comments

- L1 Note that when you are assessing the impact of emission scenarios, you should refer to *projections* rather than to *predictions*. Also, but this is completely up to the authors, my personal recommendation is to choose a more catchy title. For instance, you could simply shorten the title to: "Future projections of Siberian wildfire and aerosol emissions"
- L17 In statistics, we distinguish between accuracy and precision. You don't want precise values, rather you want accurate values.
- L21 Before writing about the future changes, please add a sentence that describes how well the model reproduces historic values.
- L23 The absolute numbers are not very intuitive. Please provide the relative changes in emissions and trends, instead.
- L38 Please find more recent references here. A good place to start would be the 6th Assessment Report, Working Group I, Chapter 5.

- L43 Currently this sentence reads as if the fact that small fires matter is consistent with a positive trend in fires. This does not make sense to me. Please replace "This finding" with something more explicit.
- L61 Please use more recent references if you want to provide numbers that represent "current estimates", e.g. Friedlingstein, Pierre, et al. "Global carbon budget 2023." *Earth System Science Data* 15.12 (2023): 5301-5369.
- L122 Please find more recent reference. The study is 20 years old and much has happened in the last two decades.
- L124 Please don't cite the entire report. Specify the working group and chapter. Also, replace this reference with the most recent assessment report.
- L146 The notation suggests that E is a function of n_{ig} . What is n_{ig} ?
- L148 Please consider using a bar rather than an underscore to indicate the mean area.
- L149 A grid is composed of gridcells. Please replace "grid" with "gridcell".
- L264 Please include an analysis that shows how the inclusion of SPITFIRE affects the model's ability to reproduce the observed patterns during the historical period. So far you only write that the pattern of the new model version is different.
- L275 Do lowest and highest values refer to spatially averaged annual mean values? Please explain.
- L284 Does "uniform spatial distribution" mean that the amount of burned biomass is equal across gridcells? Please clarify.
- L290 Do you have any thoughts on what causes the box-like pattern? Also, why does the default model version produce values across the entire domain, while the SPITFIRE model version has many gridcells with no values?
- L292 You write that "from 2006 to 2100, the value decreased from 5.09 to 5.05 kg DM m⁻²". Do the values refer to 2006 and 2100? Since there may be considerable variability, it may be better to compare 20 year averages instead, or calculate the trend.
- L301 What are "estimation parameters"?
- L305 What do you mean by common roots? Please rewrite this sentence.
- L307 I am not sure what you are trying to communicate here. You find that a high fire frequency coincides with a low AGB. Do you think this makes sense because fires burn trees and therefore biomass is low? Or is it counter-intuitive because the more biomass, the more fuel load, the higher the probability of fires? How do you interpret your results?
- L314 See comment as for L292.

L321 What does "full" refer to in this context?

L322 Why is NPP "the most measurable element of the carbon cycle"? NPP is actually difficult to measure at a canopy scale. The eddy covariance method for instance, measures NEE, from which GPP and ecosystem respiration are then derived. You could also make the case that carbon pools are easier to measure than carbon fluxes.

L325 Please add relative measures here as well, as absolute values alone are not very intuitive.

L337 Why does this matter and what do you conclude from this?

L349 Why does this matter and what do you conclude from this?

L360 Does the "annual average spatial distribution" expressed in percentage refer to the correlation coefficient R of annual mean values of individual gridcells? If that is the case, please express your results in terms of fraction ($R^2 = 0.79$). Please do that consistently throughout the text.

L369 Please quantify how similar the modeled and the observed values are using a statistical metric, such as a correlation coefficient, bias, or RMSE.

L371 Since both values are identical the word "while" does not fit here. Same applies to the next sentence. Please rephrase.

L402 Is this total *annual* rainfall? Is this really rainfall or precipitation, which is the sum of rainfall and snowfall?

L403 This sentence seems to contradict the previous sentence, with two different rainfall values for the same region and time period. Please rewrite.

L417 The sentence does not make any sense to me. Why would CO₂ emissions be representative for other GHG emissions, simply because most of the mass emitted is CO₂? The next sentence on the emission factor gives a better rationale. I suggest you delete the first sentence and rewrite this part. Also, I suggest that you remind the reader what the other emissions are.

L425 What is the difference between the CO₂ emission values given here and the ones quoted in the previous sentence? Both are described as annual average values.

L434 Equation 29 is located in the supplementary material. If you want to use this equation in your argument, I suggest you describe it in the text. Otherwise it is difficult to follow your argument, unless one reads the corresponding text in the supplementary material.

L454 The low-emission area only contains a few gridcells, so I don't think these values are very meaningful. To my understanding, Figure 11 shows CO₂ emissions associated with fires. Why then do some grid cells have negative values? Also, the chosen color legend makes it difficult to determine whether the emissions are low but positive or negative. Finally, the legend says that the figure shows annual average differences 1996-2100. Differences with respect to what?

- L501 You arite that the "lighting flash rate affected fire ignition in Siberia by 46%". This sounds as if 46% of the fire ignition was caused by lightning. However, the next sentence suggests that the 46% value refers to a correlation coefficient, which does not translate into the proportion of fires caused by lightning. Please rewrite.
- L505 Replace "Rothermell (1972)" with "(Rothermell, 1972)"
- L525 What is the "burned area parameter"? Do you know how this parameter uncertainty affects the estimated emissions?
- L536 Replace "and eventually causing" with "and thereby contributing".
- L537 The variable that determines the strength of the carbon sink is NBP, which includes disturbances such as wildfires, rather than NPP. Assessing the impact of wildfires on NPP is valid, but, given the focus of this paper on wildfires, I suggest you also write about NBP.
- L544 Replace "circumpolar" with "Circumpolar"
- L541 You may want to mention that wildfires and insect outbreaks are not necessarily independent, e.g. the likelihood of wildfire often increases after insect outbreaks.
- L545 Cite more recent literature, e.g. the IPCC Sixth Assessment Report, Working Group I, Chapter 4.
- L567 For RCP8.5 it should be far more than 2 degrees C. Please provide more accurate numbers here.
- L571 Many DGVMs prescribe tree allometry. Is this also the case for SEIB? If yes, then that is why fires have no impact on tree allometry.
- L580 A decrease in fire emissions in subsequent years could also be caused by the fact that there is simply less biomass available for burning, since some of the biomass has been burnt during previous years.
- L586 It is not clear to me what point you are trying to make. Do you simply want to say that the model is able to account for the effect of fire history on future fires? This is to be expected, and I don't think it deserves a discussion. But I may be missing the point, in which case I suggest you rewrite this paragraph.
- L596 You cannot draw the conclusion that a model is accurate, simply because its response is consistent with the change in the perturbation. I would just write that the trend in fire emissions is consistent with the different scenario-dependent trends in radiative forcings.
- L599 The projected increase depends on your emission sceanrio, and currently ranges between 1.5 and 6.0 degrees C by 2100 compared to 1850-1900 mean value (IPCC, AR6, WGI, Chapter 4).

Tables

Table 2: Replace RCP80 with RCP8.5 and use a consistent notation in table in text (e.g. RCP8.5 rather than RCP85)

Table 4: Replace "Baseline" with "Historical". Note the meaning of +/- (1 or 2 standard deviations?)

Figures

Figure 3 Move the text in the Figure caption into the main text as you are describing the figure.

Figure 4 and 5 All panels look very similar. If you want to work out the differences, then I suggest you provide a different type of plot.

Figure 6 Replace "Principle component" with "Principal component". Why do you need to do a PCA here? This would deserve description in the main text, if it is really worthwhile. As I mention above, please verify whether SEIB prescribes allometric relationships, which would explain why the impact of fires is small on allometry. I am not sure whether this analysis is worth including.

Figure S16 Does this figure show that the model tends to overestimate AGB between 25 and 75 Mg ha⁻¹? I would also add a diagonal 1:1 line so the reader sees where the dots should ideally be located. What do the colors of the dots represent? Please replace the horizontal axis label *Ha* with *ha*.

Figure 8 Why does SEIB-DGVM has uncertainty bars but GFED4s does not? Also, explain the meaning of the uncertainty bar in the Figure caption. Is this +/- SD across multiple years?

Figure 12 Increase axis value fontsize