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Geoscientific Model Development Discussions
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Interactive comment on "Coupling interactive fire with atmospheric composition and climate in the UK Earth System Model" *by* João C. Teixeira et al.

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Comment 1. As I started reading through the manuscript, it was unclear to me if the manuscript was going to compare results from run with specified/prescribed and interactively simulated fire emissions. It was unclear if the prescribed/specified fire emissions had inter-annual variability or not. Please try to make this clear upfront.

Response: The Introduction text was changed to reflect this - Lines 100-101

Comment 2. When discussing results, PLEASE mention the figure and its panels in parenthesis so that it's explicitly clear that the results and/or discussion follows from which figure and from which of its panel.

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Discussion paper

Response: As the reviewer noted, the reference to figure and its panels can improve the understanding of the discussion and readability. Reference to figures and respective panels have been added to the manuscript - Lines 397, 401, 408, 409, 412, 416, 439, 443, 447, 449, 454, 455, 460, 463, 479, 480, 483,496, 501, 510, 519 and 521.

Comment 3. There are no sub-headings and panel identifications in several figures which made it really difficult. For example, in Figure 11 and 12 there are no sub headings on panels. The acronyms NHAF, NHSA, SHAF, SHSA threw me off several times. I missed the distinction between NHAF and NHSA even after reading the Figure 11 caption multiple times.

Response: The authors thank the reviewer for raising this. The Figures 3 to 15, which contain several panels were changed to include sub-headings better identifying them.

Comment 4. The INFERNO fire model appears fairly simple. I am surprised that the average burnt area per PFT (in equation 1) is specified a priori as a model parameter. First, what are the units of this quantity? Table 1 says its units are km2 but it has to be km2 per unit SOMETHING? Is it per unit grid cell area (unlikely), per unit 1000 km2, per unit ignition? Second, and assuming this quantity represents average area burned per unit ignition, this seems to imply that area burned per unit ignition can never exceed this, assuming Fpft (the flammability) varies from 0 to 1 (please mention this). If true, it's not correct to call this quantity average area burned for a given PFT

Response: The units for average burnt area are km2 per ignition. This has been corrected in both Table 1 and the model description in line 127. INFERNO does assume this as the maximum burned area which is burnt in any given time, rescaling it according to fire activity, represented by flammability, and we think referring to it as "scaled average burned area" would be more appropriate. The manuscript has been changed to reflect this in Table 1, line 127 and 297.

Comment 5. In equation (1) and elsewhere the lack of units makes it difficult to understand things. Please mention units for all terms of all equations.

Response: Units have been added throughout the manuscript to help with the understanding of equations. Changes have been made in lines 123, 125, 128, 132, 143, 144, 145 and 153.

Comment 6. My logic tells me that INFERNO should be a module of JULES. If this is the case then meteorological variables from the atmospheric component are passed to JULES which then provides quantities like soil moisture to INFERNO. As it reads, the manuscript seems to imply that INFERNO is a separate component.

Response: As the reviewer noted, INFERNO is a module of JULES, however when JULES is coupled to the UM atmospheric model there is a set of conditional compiling statements that exclude INFERNO for being compiled, making INFERNO only available when JULES was used in standalone mode. Further work had to be developed to ensure an interface between INFERNO, JULES and the UM was available, passing on the atmospheric variables to INFERNO. In Section 2 of the manuscript the authors try to highlight this by describing the atmospheric coupling which also includes the coupling to the atmospheric composition model UKCA.

Comment 7. The part related to INFERNO's description needs an equation for I_{N}, natural ignitions. As a reader, I was curious to know how natural ignitions are modelled as a function of lightning frequency.

Response: INFERNO does not parameterize natural ignitions (from cloud to ground lightning). These need to be provided to INFERNO either as a constant value, based on ancillary data or modelled/parameterized externally through the atmosphere model as described in section 2.1 in lines 118 to 122. Considering this and the advantages of the coupling of INFERNO to the atmosphere model (UM) we have opted to provide the natural ignitions parameterized by the UM which follows the approached described in Price and Rind (1994), as described in the section 2.3 of the manuscript (lines 216 to 222).

Comment 8. In equation (2), it seems theta cannot be the soil moisture (which varies

between 0 and porosity, typically around 0.4), it seems theta is more likely the soil wetness which varies between 0 and 1, as the soil moisture itself varies between 0 and porosity.

Response: The authors thank the reviewer for their comment. The equation has been changed to reflect this.Theta is the unfrozen soil moisture as a fraction of saturation. This has now been corrected in lines 141 and 142.

Comment 9. On page 6, line 186-187, I am troubled by the fact that emission factors for aerosols are doubled. Does it mean that the standard emission factors based on Andreae (2019) are too low?

Response: The factor of 2 scaling applied to biomass burning aerosols is a common practice applied in Earth System Models and it is applied in the standard configuration of UKESM1 where biomass burning emissions are prescribed. This is used to improve the agreement between observed and simulated aerosol optical depth (AOD) across the three evaluated wave lengths (440, 550, 700 nm) when compared to observations. As stated in the manuscript, this has previously been described by Johnson et al. (2016) and Kaiser et al. (2012). In these studies, the authors acknowledge that the discrepancy between modelled and observed AOD (prior to emission scaling) could be due to other biases or missing processes in the models.

For this study, and to make a comparison between the simulations with prescribed and interactive fire emissions more comparable, we decided to follow suit and applied the same scaling factor when coupling INFERNO emissions to the atmospheric composition component of UKESM1.

Comment 10. In section 3.2.1 changes to land cover result in several differences in regions where the land cover is not changed due to teleconnections. Clearly, these are primarily due to land-atmosphere interactions and not due to fire-atmosphere interactions. Please make this clear

Response: The authors thank the reviewer for their comment. Detailing the mechanism that leads to impacts at a global scale cause either the land cover change or the fire-composition-atmosphere feedbacks, as well as the primary forcings, can lead to extensive work that is out of the scope for this manuscript. The authors have decided to remove this statement (lines 366 to 369) and added a sentence to clarify that effects could have a contribution from both the land cover change as well as the fire-atmosphere-composition feedbacks and would prefer to revisit this in the future on a manuscript focused on this topic..

Comment 11. Figure 10. Please make it clear on y-axis that the quantity being shown is CO. Also, please check there are units and quantity name on y-axis of all similar plots.

Response: The y-axis of Figure 10 was updated to clearly identify the data being shown

Comment 12. Page 8, line 224, "Aerosol emissions are distributed vertically following an exponential increasing function . . .". Does this mean there are more emissions at the surface and less up in the atmosphere or the other way round?

Response: This means that there are higher values for biomass burning aerosols emissions at the higher levels than at the surface. The authors have now changed the text to make this clear in the document - line 230.

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