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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Received and published: 14 June 2021

Comment 1: Line 34: black carbon is missing a letter

Response: Changed to fix the missing letter

Comment 2: Line 90 introduce the significance of peat fires. The authors should note that both GFED4s and GFAS rely on MODIS products, which are less capable of detecting low temperature smouldering peat fires than VIIRS and other moderate resolution sensors. By line 320, it is noted that peatland fires are not included. It would be good to clarify this at the beginning of the manuscript

Response: The main INFERNO model limitations have now been added to the last

paragraph of section 2.1 - lines 161 and 162.

"Furthermore, it should be highlighted that in this configuration of INFERNO, there are no interactions between fire and vegetation and it does not include a peat burning capability."

Furthermore, the lack of efficiency in detecting low temperature smouldering peat fires in the observation datasets is also mentioned in lines 330-332 to highlight possible observational bias.

Comment 3: Lines 235-237: Some extra spaces in the text. Further GFED4s is a multi-sensor satellite dataset that uses a statistical model to predict small fires. The small fires are not observed directly from active fire data.

Response: The authors thank the reviewer for raising this. In line 245 we now highlight that small fires are statistically modelled in GFED4s. The extra spaces were removed from the text.

Comment 4: Section 3.1: The model's poor performance in the boreal means a significant underestimation of burned area in forest and peat areas that are often the dominant source regions of emissions for the Northern Hemisphere - as well as large impacts on the Arctic. If the point of INFERNO is to develop a coupled fire-climate-composition Earth system model, leaving out much of the boreal does not mean the model estimates burned area fraction well. Why is this happening? The authors have a good explanation for why north Africa is underestimated. Can the authors explain why the overestimation of tree fraction in the SHSA produces smaller fires? Recent Amazonia fires have shown smaller fires in grasslands turning into large understory fire complexes that dry out the system for large canopy fires. Is this fire behaviour of rainforests well represented in the model?

Response: Achieving a good performance modelling fires at the Earth System Model spatial and time scales is a state of the art challenge. The work developed by Li et

al. (2019), in the context of FireMIP, provides a global multi-model estimate of fire emissions for the historical (1700–2012) period - it shows that there is a tendency for fire models to underestimate biomass burning emission in the boreal regions and that there is also a large spatial variability between models. This happens mainly due to the different treatment of the land surface between models (e.g. not including peatland fires in INFERNO) and the way anthropogenic fire behaviour is modelled, for example, the treatment of crop fires seasonality.

Despite INFERNO's limitations for this region, interactively modeling fire in Earth System Models provides benefits and several advantages at a global scale.

An explanation for the reason why an overestimation of tree fraction results in smaller fires in SHSA is provided in lines 291-294 and follows below:

"In addition, there is an overestimation of tree fraction in savanna biomes, such as the southern Africa region (SHAF) and the southern edge of the Amazon forest region (SHSA). The differences in the specified average burnt areas for these biomes – smaller for trees than grasses – causes an underestimation of fire size in these regions."

With regards to the fire behaviours of rainforests, unfortunately INFERNO does not represent these regional scale effects which are specific to certain biomes. INFERNO is a simple fire model that was designed for Earth System Model applications, and thus it focuses on the large-scale occurrence of fires and the large-scale aspects of fire behaviour.

Li, Fang, et al. "Historical (1700–2012) global multi-model estimates of the fire emissions from the Fire Modeling Intercomparison Project (FireMIP)." Atmospheric Chemistry and Physics 19.19 (2019): 12545-12567.

Commnet 5: Figure 1 and the dominant PFT: since the model was found to be sensitive to underlying vegetation, do that authors have an uncertainty analysis of the PFT

used in UKESM1UKESM1-AMIP configuration with other global land use products, like the MCD12C1 0.05 degree MODIS land cover product for climate modeling? The PFT ignores the Cerrado and established croplands in eastern Amazonia, as well as over-estimating C4 grasses in northern Australia.

Response: A description and evaluation of the vegetation modelling in UKESM1 is provided in Sellar et al. (2019). In their work the authors compared modelled vegetation results to the IGBP-LUCC and CCI-LC land cover data sets and highlight notable bias which include an excess of C3 grass in tundra regions which the observations indicate should contain more bare ground. The southern extension of the Saharan bare soil causing a deficit of grassland in the Sahel, caused by biases result from precipitation deficits in these regions, associated with errors in the position and intensity of monsoon rains. And a small overestimation of tree fraction in savanna biomes, most notably on the southern edge of the Amazon forest attributed due to the lack of fire disturbance, the inclusion of which would be expected to improve vegetation structure in these regions.

Comment 6: Figure 3. Burnt area fraction is underestimated in the boreal and all of Australia, as noted by the authors, but also in the Indo-Gangetic Plain, the southeastern U.S., much of central American and extending into Ecuador, Venezuela, and Colombia, eastern China, and Indonesia. In terms of climate, nor representing emissions from peat fires in southeast Asia and near the Himalayas and Andes calls into question the performance of the fire-composition-climate coupling. Further, many of these locations of human dominated fire regimes - whereby lightning strikes are not the main drivers of fire. So how well is the HDI performing?

Response: Although the model presents an underestimation of biomass burning emissions for a myriad of regions which are important at the local to regional scales, these represent a relatively small contribution to the overall biomass emission budget, with regions such as South America and Africa dominating at a global scale. Therefore, the impact in the atmospheric composition and consequent feedback in the Earth System context is relatively small. This can be seen by the comparison of modelled atmo-

spheric composition fields (aerosols and carbon monoxide) with observed datasets. However, this doesn't mean that those regions where we find negative biases are of least importance. They provide a contribution at regional scales and these biases need to be taken into account and their inherent limitations when the model results are analysed.

As noted, in the regions pointed by the reviewer, the main driver of fire ignition are human activities. It is known that humans can change background levels of natural ïňĄre activity and that different cultural and political inïňĆuences in the management of ïňĄre can shape fire regimes at a regional level. Moreover, due to their nature, cultural and political influences on fire management have a high spatial and temporal variability. For these reasons, it is difficult to include these detailed processes in the model. Introducing the HDI dependence in ignitions represents an attempt to include these cultural and political inïňĆuences in the model. The authors acknowledge that this is not an ideal representation of these effects but it provides a significant improvement in regional model results. However, discussion of the impact of these is out of scope in this document, as it would significantly increase the length and complexity of this paper. A separate paper is under preparation where the details and performance of the introduction of this parameterization will be presented.

Interactive comment on Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-298, 2020.