Response to Review: A global fuel characteristic model and dataset for wildfire prediction

The authors would like to thank both reviews for their detailed feedback highlighting several key points for improvement on the manuscript. The suggested changes have been made and we believe they improve the quality of the manuscript. Below is a point-by-point response to each comment, including the changes made within the manuscript.

McNorton and Di Giuseppe present a new global model of biomass / fuel load and fuel moisture to aid efforts to better understand variability in fire activity and better predict wildfires. The approach is rooted in ESA-CCI biomass data but combined with other datasets to get temporal variability. To move from standing tree biomass to fuel loads (including litter) the authors used ratios of dead to live biomass based on the literature. Also satellite data of leaf area index are used as well as quite a bit of parameterization. Then the fuel moisture content of these different fuel classes is modeled.

The paper is well written and the methods are clear. I see the need for this work but have two major concerns that need to be addressed before publication

1) There is a very strong focus on standing tree biomass (both from a methodological point of view and for evaluation). Clearly this is important but standing live biomass is often not the main fuel source for fires. For example, in L147 the authors state that fuel loads in the Boreal region in the summer are 10% dead fuels. In general, however, emissions there stem for the vast majority from dead fuels (organic soil) according to for example the ABoVE campaign (Walker et al., 2020). Also in many other biomes the surface fuels area key, and models that aim to say something about fire danger should therefore (also) focus on surface fuels. In the current paper these are modeled, but seem of secondary importance and most of the evaluations are on standing biomass. One potential way forward is to evaluate the new dataset with the data from Walker et al. (2020) and the literature review by Van Wees et al. (2022) which specifically focuses on those papers that studied biomass from a fire perspective. Somewhat related, I was also wondering how realistic the large (sometimes doubling) seasonal changes in live and dead wood are (Figure 2 and 3)?

We agree this is a good point, the ESA-CCI product considers the living component of the biomass, and we use this to infer an estimate for both live and dead or surface dry mass. We have included this caveat in the text. As noted, our efforts are not limited to just considering the ESA-CCI product and the seasonal and interannual modulation of biomass is a key component of the work, which is done separately from the ESA-CCI product using a vegetation model and atmospheric flux inversions. Therefore, we feel that whilst the magnitude of biomass may be prone to some errors the spatial and temporal patterns provide a useful product for training fire models. One glaring omission from the original submission was the exclusion of table 1 which summarises the fractional weighting between fuel types, this has now been included for clarity.

We agree we failed to perform an evaluation on the dead or surface biomass, datasets for such estimates are limited. However, we thank the reviewer for pointing out the observation dataset compiled within van Wees *et al*. (2022). We have now performed a comparison between the field measurements from Walker et al. (2020) and Van Wees et al. (2022), which provide an excellent opportunity to evaluate our fuel ratios that we had not previously considered. The evaluation is added to the main text and shows reasonable agreement between our model and the observation, with obvious limitations on performance due to the representation error. The figure of the comparison has been included in the supplementary material.

The omission of below ground fuel, or organic soil, is also an issue for our study, one that we seek to address in future iterations of the fuel model, we have included this caveat in the discussion text.

2) It is good to see that the soil moisture values are calibrated / compared to in situ data. The correlation is rather poor though with on average about 25% of the variability being explained (even lower for agriculture but the authors provide a good reason for that). I fully realize a perfect fit will be impossible but I respectfully doubt how useful the model is in this case. Simple example (L464): "Seasonal fire activity is reasonably well captured by both FSI (R = 0.58) and DFMC (R = 0.38)." In most fields of research these are low to moderate correlations; a model that in a range of evaluations shows little correlation may not be fit for the purpose. Clearly the evaluations of total AGB are more promising but as mentioned in 1) they may be less relevant. One way forward would be to iteratively adjust the parameterisations (not just for the soil moisture but in all steps) until the best comparison with evaluation data is found in some optimisation exercise. If this exercise shows that much variability is still not captured the authors need to re-think their approach

We thank the reviewer again for their comments. To clarify the derivation of LFMC is calibrated using *in-situ* data, the soil moisture itself is fully modelled but is informed through observations through the assimilation methodology of ERA-5 Land.

It is slightly unclear which correlation is being referred to here so for clarity we will try and explain but have also updated the text to better capture this. The LFMC, which is calibrated using *in-situ* data, provides correlation, R, values between 0.36-0.72, which we consider to be reasonable considering the large representation error, as described in the text. As mentioned, agriculture is lower for the reasons explained in the text. Unfortunately, accurate observation datasets for LFMC are not readily available at our model resolution for evaluation, we did however attempt to validate using MODIS LFMC, which itself has limitations as described in the text. Importantly LFMC is unlikely to directly correlate with fire activity, as LFMC is largely dependent on plant phenology as described in the text. Therefore, LFMC is often controlled more by the phenological state than by the fire susceptibility. We have now further emphasized this point in the text.

The example given (L464) is for model DFMC correlated with fire activity within a specific domain, Alberta, Canada and time, 2014. Out of all examples, this is the lowest correlation value and is unsurprising given DFMC is just one component of fire activity, others including fuel load and ignition mechanisms. We have added this to the text for clarity. Despite this, the correlation between DFMC and fire activity for the other 3 regions is notably higher (0.90, 0.86, 0.94), suggesting the Canada case is somewhat unique and possibly more dependent on the other factors (load / ignition).

We feel an important consideration is that we are attempting to provide the most realistic input variables to a potential fire model and not provide an optimum fire prediction, hence why we have attempted to validate fuel load and moisture prior to focusing on fire activity. This is fundamental to providing an accurate input dataset to potential fire models.

References:

Walker, X. J., Rogers, B. M., Veraverbeke, S., Johnstone, J. F., Baltzer, J. L., Barrett, K., Bourgeau-Chavez, L., Day, N. J., de Groot, W. J., Dieleman, C. M., Goetz, S., Hoy, E., Jenkins, L. K., Kane, E. S., Parisien, M.-A., Potter, S., Schuur, E. A. G., Turetsky, M., Whitman, E., and Mack, M. C.: Fuel availability not fire weather controls boreal wildfire sever- ity and carbon emissions, Nat. Clim. Chang., 10, 1130–1136, https://doi.org/10.1038/s41558-020-00920-8, 2020

van Wees, D., van der Werf, G. R., Randerson, J. T., Rogers, B. M., Chen, Y., Veraverbeke, S., Giglio, L., and Morton, D. C.: Global biomass burning fuel consumption and emissions at 500 m spatial resolution based on the Global Fire Emissions Database (GFED), Geosci. Model Dev., 15, 8411–8437, https://doi.org/10.5194/gmd-15-8411-2022, 2022.

(the database is mentioned under ‘Code and Availability’, direct link: https://doi.org/10.5281/zenodo.7229039)