Response to Anonymous Referee 3 for the manuscript

Fire weather index data under historical and SSP projections in CMIP6 from 1850 to 2100

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We would like to thank the reviewers for their valuable comments. We have addressed all comments of the Anonymous Referee #1, Anonymous Referee #2 and Anonymous Referee #3 through appropriate changes and hope that the revised manuscript satisfies the Referees' concerns.

The Response to the Referees file provides complete documentation of the changes made in response to each comment. While this comprehensive explanation requires some repetition of material throughout the answer, our intention is that it helps to evaluate how each comment has been addressed.

Referees' comments are shown in black. The authors' response is shown in green text. The text quoted from the manuscript is shown between quotation marks in italics. Numbers of lines correspond to the version including tracked changes.

Summary of modifications:

- Modification of abstract and introductions
- Extensive changes to the Usages Notes
- Highlighted the novelty of the dataset in abstract and introduction
- To answer concerns on RHmean vs RHmin, the paper has been rewritten to feature the data produced using RHmin as main dataset and the data produced using RHmean as secondary dataset.
    - Description of data: updated section 2.1 and Figures 1 & A1 exchanged
    - Sensitivity analysis: updated section 3.1, 3.2 & 3.3; updated Figures 3-5 and A2-A4
    - Results: updated section 3.5; updated Figures 7, 8 and A6.
    - Data: nothing changed, both datasets were already provided.
- Minor revisions in the text

The authors calculated the Canadian Fire Weather Index (FWI) with all available simulations of the CMIP6. A sensitivity analysis of the default versus the improved version shows significant

differences in final FWI. The authors recommended the one with average relative humidity for studies requiring large ensembles and the one with minimum relative humidity for studies focused on actual FWI values. They further found that at a global warming level of 3 degC, the mean fire weather would on average double in duration and intensity, while associated 1-in-10-year events would triple in duration and increase by half in intensity. The dataset and results are interesting and would be very helpful for the community. However, I do have a few concerns and questions for the authors to address.

We thank you for your overall positive evaluation and recommendations. We have made necessary changes in the manuscript in the light of these comments and hope that these revisions have addressed all the concerns.

Major comments

(1) My major concern is that all the datasets and results are purely model simulations without any evaluations of the model quantities used for FWI calculation or the FWI directly for historical periods. Without this important piece, it is difficult to convince readers how reliable and accurate this FWI dataset would be. I suggest at least doing some evaluations for those major model meteorological quantities used for FWI calculations and/or FWI directly (e.g., USGS FWI: https://www.usgs.gov/fire-danger-forecast/wildland-fire-potential-index-wfpi).

We are grateful for your comment. Our work is indeed purely based on model simulations. The objective of this paper is to provide a database to the community. Analyzing the whole CMIP6 database is a much bigger task, the work of several publications. We kindly ask the reviewer to understand that this is not feasible in such a data paper. Following your recommendations, we now include references for the reader for further information on this topic.

Lines 111-117:
"We highlight that using CMIP6 data comes with limitations. Although this is the result of a large community effort (Tebaldi et al., 2021), there may be some biases and discrepancies in these inputs (Wilcox and Donner, 2007; Rossow et al., 2013; Pfahl et al., 2017; McKitrick and Christy, 2020). Analysis of these biases have been performed for temperatures in (Fan et al., 2020), regional precipitations (Rivera and Arnould, 2020; Agel and Barlow, 2020; Ajibola et al., 2020), relative humidity (Douville et al., 2022) and wind (Shen et al., 2022). A bias-corrected version of CMIP6 data may be used as inputs, but existing datasets do not provide the necessary variables for the computation of the FWI (Carvalho et al., 2021; Xu et al., 2021), nor the full ensemble that we use here."

Comparing the FWI directly represents indeed less work, because it is only one dataset, by implicitly simplifying by not counting DC, DMC, FFMC, ISI and BUI). The Anonymous Referee #2 shared your opinion about a need for comparison to existing FWI products and suggested FWI products. It would be indeed very useful to compare the historical period of our results to observations-based FWI. The dataset that you kindly suggest (USGS FWI) is actually for another index, the Wildfire Fire Potential Index (WFPI), not the FWI. The data differs, the algorithm differs, the region is only for the US region and the final quantities have different

“units” and scales. Comparisons of the different fire indices exist and are cited in this manuscript.

However, a FWI data product based on the ERA5-Interim reanalysis dataset has been produced by Vitolo et al., 2019, which was brought to our attention by the Anonymous Referee #2. Yet, comparing a model-based FWI dataset to an observation-based FWI dataset would still remain an endeavor in our case due to the sheer size of the database.

A study on this comparison was actually submitted very shortly before this manuscript, which came to our attention only now. It examines how well 16 GCMs from the CMIP6 simulate fire weather indicators from the Canadian Forest Fire Weather Index System between 1979-2014 period (Gallo et al., submitted, https://doi.org/10.5194/gmd-2022-223). This work finds that, globally, the ensemble mean represents the variability, magnitude, and spatial extent of fire weather indicators reasonably well, compared to the latest global fire reanalysis. However, the performance of each GCM varies by region and season. The authors have done this evaluation only over the historical period, one single ensemble member, 16 GCMs and without providing the database. In our case, we obtained a total of 1486 runs.

Reproducing this comparison with the full ensemble would duplicate their work, although with a much higher size. We kindly ask the reviewer to understand that this amount of work is not feasible in this manuscript. Therefore, we acknowledge that this different research question is indeed interesting and recommend this ambitious work for future users in the Usage Notes while highlighting Vitolo et al, 2019 as a product to do this comparison and Gallo et al., (submitted) as an example. The text stating the is as follows;

Lines 61-62:
“Historical fire weather can be investigated with observations, remote sensing products or more spatially and temporally homogeneous reanalysis datasets (Vitolo et al., 2019).”

Lines 443-449:
“Comparison of FWI results with observations to evaluate the biases in the models. Compared to observations, some models show biases in their outputs. How does that affect the calculation of a compound product like the FWI? The FWI can be calculated using data based either on models or on observations (e.g. (Vitolo et al., 2019)). One may use the dataset provided here to evaluate the discrepancies and eventually how it affects future projections in fire weather. A first work in this direction has been produced with 16 ESMs and 1 ensemble member over the historical period (Gallo et al., 2022).”

A comparison to FWI from CMIP5 may have been produced thanks to Abtzoglou et al., 2019, although the data was not provided in Abatzoglou et al., 2019. However, we acknowledge that one may envisage to do this work, equally ambitious, in the Usage Notes:

Lines 480-483:
“FWI under CMIP5 and CMIP6. The FWI has been calculated for CMIP5 runs in (Abatzoglou et al., 2019), while the provided dataset calculates the FWI for the latest CMIP6 exercise. A comparison of both

datasets would allow us to identify changes in fire weather between the ESMs. Coupled to their respective burned areas, one may disentangle the causes for differences in fires under ESMs between fire modules and fire weather of the models."

(2) It is also not very clear to me what the key novelty of this dataset is. Is the algorithm relatively new compared to the previous methods? Is this the first global FWI dataset? Also, there needs to be some discussions in the introduction about the existing global/regional FWI or fire index datasets (if any).

We thank the reviewer for this comment. Indeed, we did not sufficiently highlight the novelty of our study in the Introduction section. There are two main points:

1. This study makes available for the first time the FWI index produced using the CMIP6 dataset, enabling many usages. Using a database based on the CMIP6 ensembles has several interests. First, this is the latest modeling exercise, thus accounting for the efforts in developing CMIP5 ESMs to CMIP6 ESMs. Then, not only the models have changed, but also the projections. The SSP-RCP framework is meant to map the mitigation and adaptation space, thus of interest for research questions related to fire weather. Finally, the CMIP6 exercise had more Tier 1 and Tier 2 variables, leading to a greater number of runs and variables to better understand processes related to fires.
2. Besides, the algorithm used is new in that it merges the improvements from different algorithms.

We acknowledge that we should have emphasized the novelty of this dataset. Following your recommendations, we are now writing:
Lines 12-16:
"Therefore, in this study we calculate and provide for the first time the Canadian Fire Weather Index (FWI) with all available simulations of the 6th phase of the Coupled Model Intercomparison Project (CMIP6). Furthermore, we expand its regional applicability by combining improvements on the original algorithm for the FWI from several packages."

Lines 78-84:
"Here, we present a new dataset of FWI, based on climate data from the 6th phase of the Coupled Model Intercomparison Project (CMIP6) and using an improved algorithm. We build upon the work of (Abatzoglou et al., 2019) for the previous generation of CMIP models. The novelty of this work comes from (1) the expanded regional applicability thanks to improvements on the original algorithm, (2) using the latest CMIP data covering historical and shared socioeconomic pathways (SSPs), from 1850 to 2100, and (3) providing the whole database to the users, thus enabling a large range of usages."

Regarding your recommendation on the existing datasets, we have added references to Vitolo et al., (2019), which provides an excellent and available dataset for comparison. We also mention the incoming comparison paper from Gallo et al., (submitted).

Lines 444-449:

"Comparison of FWI results with observations to evaluate the biases in the models. Compared to observations, some models show biases in their outputs. How does that affect the calculation of a compound product like the FWI? The FWI can be calculated using data based either on models or on observations (e.g. (Vitolo et al., 2019)). One may use the dataset provided here to evaluate the discrepancies and eventually how it affects future projections in fire weather. A first work in this direction has been produced with 16 ESMs and 1 ensemble member over the historical period (Gallo et al., 2022)."

Minor comments:

(1) Please clarify the spatial and temporal resolutions of the dataset in the abstract.

Thank you. We have added this information to the abstract.
Lines 25-27:
"Ultimately, this new fire weather dataset provides a large ensemble of simulations to understand the potential impacts of climate change spanning a range of shared socioeconomic narratives with their radiative forcing trajectories over 1850-2100 at annual and 2.5° x 2.5° resolutions."

(2) Section 2.1: please provide the spatial resolution for the CMIP6 model simulations.

Thank you for your comment. We understand that you may feel it is necessary to include a comprehensive list of information; however, as we are already sharing the data regridded to a common grid for the reader (2.5ºX2.5º resolution), we refer to a study where they can find detailed information about the original grid resolution of each model (Tebaldi et al., 2021 https://doi.org/10.5194/esd-12-253-2021).

Line 109:
"We highlight that using CMIP6 data comes with limitations. Although this is the result of a large community effort (Tebaldi et al., 2021)"