Response to Anonymous Referee 1 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
- Highlighted the novelty of the dataset in abstract and introduction
- Extensive changes to the Usages Notes
- 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

Fire weather index (FWI) is an important indicator for depicting potential fire risks. When ignitions and fuel couple with higher FWI, serious wildfires could be triggered. In this study, Quilcaille et al., generated the FWI data from history and under various SSP scenarios based on the Earth System Models (ESMs) of CMIP6. They used all available ESMs with all ensemble runs under all scenarios, therefore the generated dataset is potentially useful for understanding future changes of fire weather risks and their uncertainty. The paper is generally well written, and I only have some minor concerns listed below. I would recommend this work for publication after the concerns being addressed.

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

Minor Comments:

(1) Validation of the adjustments: Three types of adjustments including effective day length, drying factor, and overwintering were involved in the products, and it seems that such adjustments were empirical. For example, the settings of carry-over fraction and effectiveness of winter precipitation for overwintering seem subjective. Since the results (e.g., Fig., 3-5) showed considerable differences for the adjustments relative to the original ones, how to guarantee that the adjustments were more effective for deducing fire risks? If the adjusted ones were not more effective on reflecting fire risks, why people should use them instead of the original ones?

Thank you for this comment. The original algorithm was designed for Canada, providing an empirical assessment of the fire risk in this region. Though, several components of the original algorithm were not appropriate for other world regions. That is why these adjustments are meant to extend this original algorithm to other world regions. For instance, you mention Figure 3, showing differences brought by the adjustments on the effective day length. In the original algorithm, all grid points receive the same day length, whether they are in Canada or not. These adjustments aim at correcting, providing the effective day length adequate for each grid point. Also, the Canadian Forestry Service that designed the original algorithm recommends using overwintering. As such, the adjusted algorithm is more effective at calculating fire risks in other world regions, and people should use the adjusted ones instead of the original ones.

We understand the reviewer's concern on "why people should use them instead of the original ones". We have now clarified the text in Abstract on this aspect as follows:

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."

(2) Average versus minimum relative humidity: I understand that there are larger ensembles for FWI using average relative humidity, but it seems not clear whether such FWI based on average relative humidity achieve reasonable performance on reflecting fire risks relative to that based on minimum relative humidity. Since Fig.6 showed noticeable differences between these two FWIs and the annual indicators such as "fwixd" were based on the exact

FWI values, it is reasonable for the potential users to know whether they used FWIs were reliable or not.

We thank the reviewer for pointing this out. The Anonymous Referee #2 shared concerns on this aspect as well. For these reasons, the focus in this manuscript has shifted from the average relative humidity to the minimum relative humidity. The sensitivity analysis and the description of results are now based on the FWI calculated with minimum relative humidity, and the FWI using average relative humidity is now only featured as another possibility for users seeking more members, and described in the sensitivity analysis to this variable. Both datasets remain unchanged in the archive.

(3) Usage notes: the possible paths for data users deserve more explanation or discussion. It is important for the users to clearly know the usage of the data and what kinds of highly urgent scientific questions can be answered with the produced data. For example, why the listed opportunities in line 410-420 are important? what kinds of scientific questions remained in the fire weather studies but could be answered with the produced data?

We are grateful for this comment. We have developed this paragraph to explain further how these opportunities are indeed important research questions, and how this new dataset may be of use.

Lines 437-483:

"The provided data is produced by the Institute of Atmospheric and Climate Science Institute of ETH Zurich. It is an open source and entirely free dataset. To illustrate possible paths for data users, we indicate in the following list some of the many opportunities where this dataset could be used. Some may rather be considered as research questions while some other points may be of interest for societal issues regarding fires.

As detailed in Section 2, we highlight that CMIP6 data may come with biases, while observations provide more realistic inputs and information for fire related studies. Though, observations have lower temporal and spatial availability and cover only the historical period. Thus model-based data facilitates large scale analysis.

- *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).*
- *Discrepancies in FWI across ESMs projections. The ESMs show different regional evolutions in some variables, though the effect of these discrepancies on the FWI remains unclear. One may investigate how much do projections in fire weather depend on the ESM by using the provided dataset and investigate reasons for the (dis)agreements.*
- *Dependencies of the FWI to ensemble members. The former path could be extended to the ensemble members. An uncertainty in the projections of the FWI arises from the initial conditions as well. The provided dataset may be used to assess this uncertainty and eventually the natural variability in FWI.*

- *Dependencies of the FWI to scenarios. Another dimension of projections in the FWI is the choice of the scenario. Under low warming scenarios, the Earth system gets more time to stabilize, allowing for different regimes, e.g. in the water cycle. It may help to investigate the response of the fire regimes across different scenarios. For example, the differences between low warming or high warming scenarios or even overshoot scenarios can be investigated using the provided dataset.*
- *It can be used to understand the effects of humidity regimes on fire regimes: minimum relative humidity and average relative humidity have different dynamics, and it is still unclear how they may affect the dynamics of fire weather in current and future climate. The provided dataset may help in assessing these regimes and their differences.*
- *Comparison of climatology of FWI in preindustrial, current, and future climate. Figure 8 of this manuscript gives a brief overview of this path. What should we expect from fire weather at different levels of climate change? Such a question would be of interest to inform society for the implications of climate change, and the provided dataset may help to answer it.*
- *Relationship of fire weather to modeled burned area. There is literature showing the correlation between FWI and burned area(Jones et al., 2022), in spite of other relevant factors such as fire ignition. One may use the provided dataset to check in the CMIP6 ensemble whether these relationships could be improved, and how they could be used, e.g. in impact models.*
- *Attribution studies of FWI to anthropogenic climate change under historical and future projections. Heatwaves, droughts and other extreme events have been attributed to climate change, but only limited studies have been able to attribute fires or mega-fires to climate change. The lack of relevant data explains this reduced number of attribution studies. Thanks to this provided dataset, attribution studies may use this data to assess changes in probabilities due to climate change. Though, the provided dataset does not provide runs under the scenario "hist-nat", the historical run with only natural forcings but not anthropogenic forcings. It remains possible to use this dataset by considering pre-industrial period and current period with their corresponding natural variability.*
- *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."*

(4) The title: this study focused on the Canadian fire weather index data, therefore many other fire weather indexes in Table A (line 420) were not involved. So I suggest to revise the title to highlight "Canadian fire weather index".

We thank the Anonymous Referee #1 for this insightful comment. This index is indeed the "Canadian Fire Weather Index" and should therefore be called the CFWI. Though, its widespread use has led it to be simply named Fire Weather Index and FWI, despite the other indexes. This is the case for Bedia et al., 2018 or Abatzoglou et al., 2019 for work on the FWI at a large geographical scale, or for applications of the FWI in specific regions (papers cited lines 200-202).

Thus, we decide to comply to the uses of this term in the literature and apologize to Anonymous Referee #1