Review of the paper (NHESS-2023-51) entitled “Climate change impacts on regional fire weather in heterogeneous landscapes of Central Europe”.

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Recommendation for publication:

Acceptation after (pending on) minor revisions before publication, with few clarification and addition to be made in the current version of the article.

General comments: This paper investigates a regional SMILE (Single Model Initial-Condition Large Ensembles) of the Canadian regional climate model version 5 (CRCM5-LE) over Central Europe (Hydrological Bavaria) under the RCP8.5 scenario from 1980 to 2099, to analyze fire danger trends in a currently not fire-prone area. This evaluation of fire danger (vs current climatic conditions) uses Canadian Fire Weather Index (FWI), and the 3-hourly meteorological data from the large ensemble of available CRCM5-LE simulations. The authors demonstrate that this ensemble (at 0.11°) is a suitable dataset to disentangle climate trends from natural variability in a multivariate fire danger metric. Various results show the increase in the median and extreme percentile of the FWI in the northern parts of the study area (in July and August). The southern parts of the study region are less strongly affected, but time of emergence (TOE) is reached there in the early 2040’s. In the northern parts, the climate change trend exceeds natural variability in the late 2040’s. In the future, a 100 year (return period) FWI event will occur every 30 years by 2050 and every 10 years by 2099. This study is of a strong interest in order to help the refinement of fire management strategy to reduce the consequences of such forest fires, and to improve the preparation or adaptive capacity knowing the potential changes of this natural hazard under on-going climate change.

The article is well written, and well-articulated in term of scientific findings and presentation of main outcomes. I will suggest to add insights or discuss limitations from the use of one single RCM driven by one specific GCM (i.e. CanESM2) whatever the number of ensemble runs used, as systematic biases from the driving GCM can influence the downscaling simulations and derived products (ex. FWI). For example, as noted in various studies, biased atmospheric circulation features due to coarse-scale resolution (ex. around 2.8° for the CanESM2 model) and/or missing orographic drag, sea surface temperature simulated features, etc. which affect the simulated blocking features (see Pithan et al., 2016; Schiemann et al., 2017; Davini and d'Andrea, 2020) or atmospheric circulation variability responsible for the occurrence of climate extremes over Europe (see Faranda et al., 2023). As revealed in the recent work of Faranda et al. (2023), atmospheric circulation changes modulate extreme events already in the present climate in Europe, and summer heatwaves as well as large regional and seasonal changes in precipitation and surface wind, i.e. hazards or meteorological variables responsible for the occurrence and severity of fire danger (variables used to compute the FWI indices). Also, as shown in Zappa et al. (2014), CanESM2 tends to have one of the largest track density biases for extratropical cyclones among CMIP5-GCMs, as well as in blocking frequency biases over both Norwegian Sea, and central Europe (see their Figure 3). These two features of atmospheric circulation variability play a key role in the occurrence of both anomalies of temperature and precipitation across the study area. Faranda et al., (2023) and Strommen et al. (2019) strongly argue to use at least three or more ensemble members to deal with the importance of the regional response to anthropogenic forcing (Corti et al., 1999; Palmer, 1999), representing these atmospheric regimes correctly whatever the GCM. Also as noted in Deser et al. (2020), the use (in future works) of large ensembles from different GCMs will give new insights into uncertainties due to internal variability versus model differences. In fact, concerning the so-call internal variability (or natural variability mentioned in the paper that it is partly evaluated from the CRCM5-LE), the current study cannot consider using one single ensemble from one RCM-GCM matrix, structural variability from the differences in (GCM) model formulation, including physics and parameterization, resolution, etc. This structural variability strongly affects the climate change responses at the regional or local scale (uncertainties in the dynamical downscaling simulations depend on the driving GCM; see different studies from the EURO-CORDEX project).

In summary, after having recall the shortcoming and include nuance about the robustness of the climate change signals for the FWI indices across the area, using one single ensemble sample from one combination of RCM-GCM, the paper is sufficiently relevant and scientific documented (sound) to be published after minor revisions. Please see also my specific comments below.

Specific comments:

Please be consistent when you use RCP8.5 (without “space” between P and 8.5) in the text.

Abstract:

Please add few words or one sentence considering the need to use larger downscaling ensemble from different GCMs in order to develop more robust climate change signals for all meteorological variables used to compute the FWI indices (further work).

Introduction:

Line 22: Please add (Canada) after British Columbia.

Line 63: Please nuance this statement, as natural variability of the climate system is not fully represented by one single model initial-condition large ensemble, as a GCM generates a simplification of a complex reality (i.e. the climate system) and includes structural variability and biases that we need to consider in any downscaling exercise (see Strommen et al., 2019; Deser et al., 2020; and recommendations or Plausibility criteria in the new CORDEX-CMIP6 in Sobolowski et al., 2023).

Data and Methods

Line 96: As mentioned in Fargeon et al. (2020) and many other studies, bias correction alters the physical consistency of modeled climate and meteorological variables in particular at high frequency (ex. sub-daily values). Quantile mapping makes strong assumptions regarding bias stationarity and can break the co-variation between climatic variables, in particular at high frequency or meteorological scale (i.e. that is the case here when computing the daily FWI indices). Can the authors provide some insight about these drawbacks or physical consistency among meteorological variables after bias correction and the implication of this in computing FWI indices ?

Line 100: "*FWI extremes are significantly better*…": Yes, but these FWI extremes are physically coherent and consistent with meteorological fields ?

Study area

Line 112: Please can the authors provide some reference from which dataset these (climatological) values come from ? E-Obs, …?

The Canadian Fire Weather Index

Line 125: Please correct "… asses**s**…".

Estimating Fire Danger using the CRCM5-LE

Line 170: "…, *this does affect the climate change impacts assessment*…". Yes, but the CRCM5 ensemble seems to underestimate the internannual anomalies of FWI that we see from the reference (ERA5) database. Please can you comment this, as the year 2002 seems to be not in the range of below 75th percentiles of the observed FWI across Europe but rather on more extreme side? This underestimation of interannual FWI anomaly can be due to the debiased method which has an effect on the decreasing year to year variability of each of the ensemble simulations?

Discussion

Line 278: "… *next few decades*…". This mean 2080s? Please be precise.

Data basis

Line 302: "…*uncertainties related to emission scenarios and the chosen climate model*". You do not discuss this point (i.e. choice RCM or single RCM-GCM), please provide some insights as suggested in the general comments.

Spatio-Temporal Trends and Variability

Line 359: "… *on the whole year instead of the summer season only*": Potential avenue will be to use take into account the snow cover season or overwintering conditions, based on cumulative precipitation during the cold season, as used in Canada (see McElhinny et al., 2020).

Line 373: "…*or the slight overestimation of the CRCM5-LE*…": Again, this can be due to the lack or limited internannual variability in the debiased CRCM5-LE variables? Please comment slightly on this issue.

Line 374: " … *a substantial larger database*…". Yes, but this is a single model (CRCM5) driven by an ensemble of one GCM (CanESM2), as in Fargeon et al. (2020) they use 2 RCMs driven by 3 different GCMs. Please nuance this statement.

Line 375: "… *which helps to better represent natural variability*": See my previous remarks, natural variability is more complex that internal variability extracted from one single RCM-GCM matrix, as at least you need to consider more range of boundary conditions, from as many as possible GCMs as those are the main source of uncertainties in particular from the atmospheric circulation over Europe pointed out by Faranda et al. (2023).

Line 377: " … *fire danger are robust*…": From the ensemble runs used (i.e. link to the sample size or RCM-GCM matrix). Please nuance this statement.

<u>Conclusion</u>

Line 404: "*We accept all of the three hypotheses*…": Please be more explicit and comment about these, in particular H2 and H3.

<u>References</u>

Line 531: The reference Separovic et al. (2013) is not at the right place in the list.

References:

Corti S., F. Molteni, T. N. Palmer (1999). Signature of recent climate change in frequencies of natural atmospheric circulation regimes. Nature 398, 799–802

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