Reviewer 3

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 ongoing 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.

We appreciate the careful revision of RC-3 on our manuscript. We clarified the remarked sections specifically and improved the overall description of our modelling set-up, which is a regionally downscaled single-model initial condition large ensemble (SMILE).

We agree with RC-3 that our modelling setup cannot represent model spread because our analysis focuses on a regional SMILE of one GCM-RCM combination only. The reason for this model choice is that we want to overcome biases in atmospheric circulation features due to coarse-scale resolution, e.g. orographic drag, by using a regionally and dynamically downscaled SMILE. Rather than on in-between model spread, this study focuses on the quantification of internal variability, which requires the use of a SMILE (s. Deser et al. 2020). This is also proposed by Faranda et al. (2023). The SMILE used in our study (CRCM5-LE) was compared to the CORDEX-Family by Von Trentini et al. (2019). However, to date only 2 other regional SMILES for the area of interest exist, but they differ in the study domain and spatial resolution (s. Von Trentini 2020). The implications of the regional downscaling of the CanESM2-LE using the CRCM5 was investigated by Böhnisch et al. (2020). The study of Böhnisch et al. (2020) shows that “important large-scale teleconnections present in the driving data propagate properly to the fine-scale dynamics in the RCM”. Further, the studies of Mittermeier et al. (2019 and 2021) demonstrate that the CRCM5-LE is capable to quantify large scale pressure patterns which lead to heat-waves and extreme precipitation (i. e. Vb-Cyclones).

Since we find this was not clearly enough emphasized in our initial manuscript, we edited the introduction and discussion section and reflected the strengths and weaknesses of the CRCM5-LE better by adding new paragraphs:

New Paragraph (Introduction): *In this study, we use the CRCM5-LE, a regionally dynamically downscaled high-resolution SMILE (0.11° grid cell size) nested into the CanESM2-LE (Fyfe et al., 2017), to disentangle climate change induced fire danger trends from natural variability over heterogeneous landscapes in Central Europe. Benefits of using a regional SMILE are the better spatial representation of climatic patterns for regional- and local-scale analyses, i.e. NAO (Böhnisch et al., 2020) and pressure patterns leading to extreme precipitation (Mittermeier et al., 2019) or drought and heat events (Mittermeier et al., 2021) in the study area. In comparison to the global CanESM2-LE, the regional CRCM5-LE replicates response structures more precisely and incorporates durable high-resolution geographical characteristics that are prominently apparent in the ensemble mean.*

New Paragraph (Discussion): *While the SMILE-setup used in our study allows us to estimate the internal variability and the forced response of the selected climate change scenario (Suarez-Gutierrez et al., 2021; Deser et al., 2012), it can not account for the structural uncertainty of the climate model (Deser et al., 2020), which can be assessed only in multi-model studies (i. e. Fargeon et al. (2020)). In order to quantify both, internal variability and structural uncertainty, multiple SMILEs as provided by the "Multi-Model Large Ensemble Archive" (MMLEA) (Deser et al., 2020) should be used. However, all SMILES in the MMLEA are based on Global Climate Models (GCMs) with a spatial resolution ranging between 2.8° and 0.9° (Deser et al., 2020). On a regional and local scale, a higher spatial resolution is needed to quantify climate change impacts. For Europe, only two other dynamically downscaled SMILEs from Regional Climate Models (RCMs) exist: The 16-member EC-EARTH-RACMO ensemble at 0.11° (Aalbers et al., 2018) and the 21-member CESM-CCLM ensemble at 0.44° grid cell size (Fischer et* *al., 2013; Brönnimann et al., 2018). The three models differ in their study domain (EC-EARTH-RACMO) and spatial resolution (CESM-CCLM) from the CRCM5-LE (Wood, 2023; von Trentini et al., 2020).*

Specific comments:

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

We unified to RCP8.5 and RCP2.6 without a blank space.

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).

Thank you for your comment. We agree that this should be nuanced in the abstract and therefore added a new sentence to the abstract.

New: *To date, only a few dynamically downscaled regional SMILEs exist, although they enhance the spatial representation of climatic patterns on a regional or local scale.*

Introduction:

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

We added *(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).

We added a statement highlighting that a SMILE – while capturing internal variability - does not allow for the quantification of the structural uncertainty. For this latter purpose, a multi-model large ensemble has to be used.

New: *This limitation, i.e. the confusion of natural variability and model uncertainty for changes in fire danger estimates in regions with currently temperate climate, can be overcome by evaluating climate model simulations derived from a single model initial-condition large ensemble (SMILE). SMILEs represent an ensemble of simulations derived using one single climate model started at different initial conditions. The ensemble spread between the different SMILE members provides a robust estimate of the internal variability, from which the forced response of the climate change scenario (i. e. RCP 8.5) can be estimated by averaging over the SMILE members (Deser et al., 2020). Therefore, SMILEs are capable to robustly sample extreme events and their probability distribution (Maher et al., 2021). While SMILEs allow for the quantification of internal variability, they do not enable a quantification of model uncertaint (Deser et al., 2020).*

Data and Methods

Line 96: As mentioned in Fargeon et al. (2020) and many other studies, bias correction alters the physical consistency of modelled 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?

Thank you for this remark. We agree that univariate bias correction methods may not perfectly represent the covariation between variables. This is especially relevant for multivariate indices like the FWI used in this study. Zscheischler et al. (2019) analyze the effect of univariate bias adjustment for multi-variate hazards and discuss different studies arguing for and against the need of multi-variate bias correction methods. For example, Yang et al. (2015) argue that a univariate bias correction is sufficient, while Cannon et al. (2018) propose the opposite. They find that "we cannot draw the general conclusion that multivariate bias adjustment is not necessary in any case from individual, typically regional, studies" and "it is difficult to pin down under which exact circumstances univariate bias adjustment might fail".

We added a section to the discussion, where we discuss the advantages and disadvantages of univariate / multi-variate bias correction:

New Paragraph:

Correcting the bias between climate model data and observation data is often an inevitable step in climate impact studies (Piani et al., 2010). The CRCM5-LE was bias adjusted using the quantile mapping approach after Mpelasoka and Chiew (2009), for each of the FWI variables separately (Poschlod et al., 2020). Univariate bias correction methods, as used in our study, can change the co-variation between multiple variables (Zscheischler et al., 2019). Changing the co-variation through bias-adjustment can affect the analyses of fire weather indices, like the FWI, which is why there have been calls for the usage of multi-variate bias correction methods (Cannon, 2018). Despite these concerns, (Yang et al., 2015) showed that bias-adjusting multiple variables separately was sufficient to study fire weather changes in Sweden and Zscheischler et al., (2019) state that the reasons for univariate bias adjustment to fail are hard to specify. Furthermore, multivariate bias correction is non-trivial and while fixing co-variation issues lead to other problems e.g. with temporal or spatial dependencies (i. e. Vrac, 2018). In this regard, we assume that the bias correction applied on the CRCM5-LE is appropriate.

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

Together with your previous comment, we discuss this in the new discussion paragraph. The studies of Yang et al (2015) and Cannon et al. (2018) have shown that bias-corrected climate model output better reflects observed fire danger. We therefore adjusted this section:

Old: *Bias corrected data are commonly used for projections of fire weather indicators like the FWI (e. g. Yang et al. (2015), Kirchmeier-Young et al. (2017), Ruffault et al. (2020), Fargeon et al. (2020)), because frequencies of FWI extremes are significantly better represented than in non-bias-corrected climate data (Yang et al., 2015).*

New: *Bias corrected data are commonly used for projections of fire weather indicators like the FWI (e. g. Yang et al., 2015; Cannon, 2018; Kirchmeier-Young et al., 2017; Ruffault et al., 2017; Fargeon et al., 2020), because frequencies of FWI extremes are significantly better represented than in non-bias-corrected climate model data (Yang et al., 2015).*

<u>Study area</u>

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

We added a notation that the data is derived from the meteorological SDCLIREF dataset. This Sub-Daily Climatological REFerence dataset (SDCLIREF) was created within the scope of the project that this study is based on (ClimEx). It combines hourly and disaggregated daily station data and is described in detail by Brunner et al. (2021).

New:

The ClimEx project's own meteorological Sub-Daily Climatological REFerence dataset (SDCLIREF) served as an observation reference served. It combines hourly and disaggregated daily station data and is described in detail by Brunner et al. 2021.

[…]

The mean precipitation over the study areas increases from north to south, with annual precipitation sums between 500 and 1100 mm for the South German Escarpment, 1000 mm for the Eastern Mountain Ranges, 1500 and 2500 mm in the Alpine Foreland and 1000 and 2000 mm in the Alps, according to the SDCLIREF observation dataset for the present climate period between 1980 and 2009 (present).

The Canadian Fire Weather Index

Line 125: Please correct "… assess…".

We corrected "assesses" to "assess".

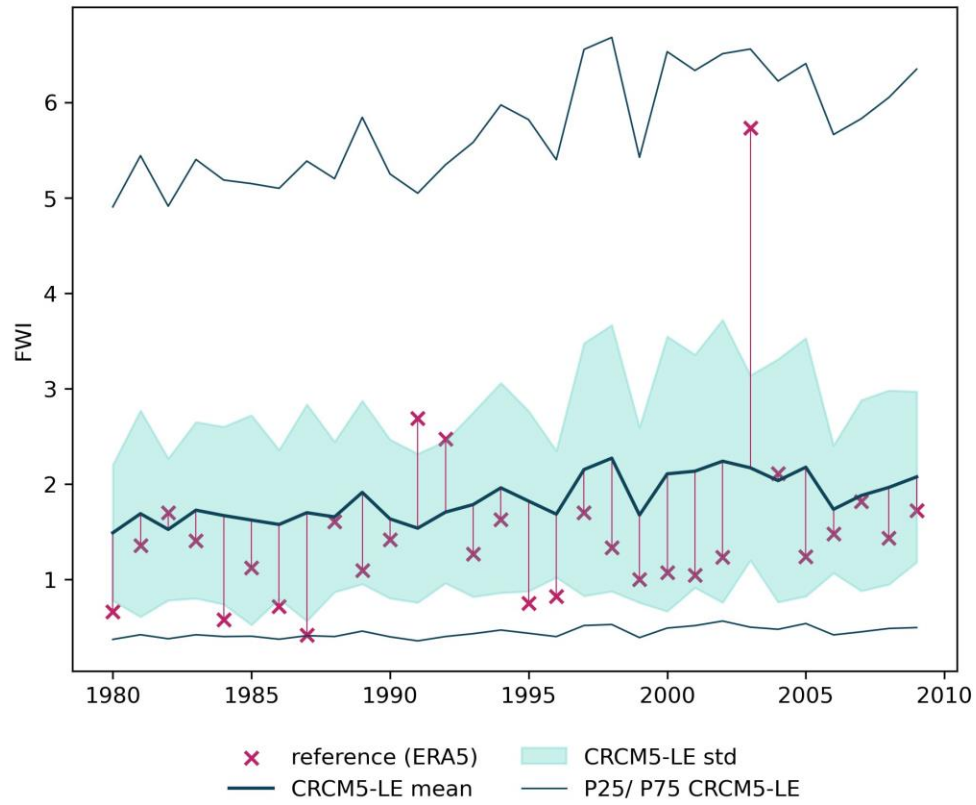
Estimating Fire Danger using the CRCM5-LE

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?

Thank you for pointing this out. We realized that the outlier in the ERA-5 Dataset is referring to the year 2003 and the time periods between our comparison differed (ERA-5: 1981-2010, CRCM5-LE: 1980-2009). We remade the figures by using a unified time period (1980 – 2009). The year 2003, especially the summer months, were affected by an extreme heat wave in Europe, which is reflected by the high FWI value in the ERA-5 dataset. However, the CRCM5-LE data is modeled data and does not contain observed values. Figure 3 shows, that the 2003 heatwave lies below the 75th percentile of our single-model initial-condition large ensemble and is well situated in the ensemble spread. Following the framework of Suarez-Guiterrez et al. (2021) (https://doi.org/10.1007/s00382-021-05821-w), we interpret that the CRCM5-LE overestimates internal variability, because most observation points lie between one standard deviation in the ensemble and all observation points lie between the 25th and 75th percentile of the ensemble. For this reason, we cannot precisely answer how the bias correction should affect an underestimation of interannual FWI anomalies.

We added to this paragraph a remark, that the ensemble overestimates interannual variability:

New: *The CRCM5-LE overestimates the internal variability in comparison to the reference dataset (s. Figure 3 following the framework of Suarez-Guiterrez et al. (2021) to evaluate internal variability in SMILEs.)*



Median FWI for the CRCM5-LE mean (thick blue line) and standard deviation (light blue shading) in comparison to the reference dataset of Vitolo et al. (2020) marked pink (X for values, lines for deviation from the CRCM5-LE mean). Top and bottom blue lines mark the 25th and 75th percentile of the CRCM5-LE.

Further we discussed this more closely in the answer to your comment (RC-3) on Line 302.

Discussion

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

We changed "*next few decades*" to "*until the end of the 21st century*" to be precise that we mean our whole observation until the end of the century.

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.

We changed this section in correspondence to comment 69 of RC1 and added a section that explains the difference between the CRCM5-LE and other CORDEX models in terms of precipitation and temperature.

Old: *Lastly, the SMILE used in this study assesses climate change signals against internal climate variability but does not consider uncertainties related to emission scenarios and the chosen climate model. However, the choice of emissions scenarios also introduces uncertainty. Fire danger increase is projected and analyzed only for the RCP8.5 scenario, which represents the strongest temperature increase scenario. It remains open and subject to policy making if this scenario becomes reality. Arnell et al. (2021) find that reducing emissions to a level consistent with an increase of a global mean* *temperature of 2°C, i.e. RCP 2.6, reduces fire danger substantially compared to RCP8.5. This finding implies that our change estimates represent an upper boundary of changes in fire danger expected in the future.*

New: *The SMILE used in this study allowed us to identify climate change signals in the FWI and compare them against internal climate variability. However, SMILES do not consider scenario and structural, model specific uncertainty, because only one scenario and one climate model are usually available. In comparison to the CORDEX ensemble, the CRCM5-LE shows drier and warmer climate change signals for temperature and precipitation (Von Trentini et al., 2019). These characteristics of the CRCM5-LE are in line with the results from the validation (see Figure 3) and indicate an overestimation of our results. Fire danger increase is projected and analysed only for the RCP8.5 scenario, which represents the strongest temperature increase scenario. Arnell et al. (2021) find that reducing emissions to a level consistent with an increase of a global mean temperature of 2°C, i.e. RCP2.6, reduces fire danger substantially compared to RCP8.5. Due to the strong warm and dry climate change signal in the CRCM5-LE (Von Trentini et al., 2019), we assume that our change estimates represent an upper bound of changes in fire danger expected in the future.*

Further, we added a paragraph discussing the benefits and downsides of using a regionally downscaled SMILE.

New: *All SMILES in the MMLEA are based on Global Climate Models (GCMs) with a spatial resolution rang- ing between 2.8 and 0.9° (Deser et al., 2020). On a regional and local scale, a higher spatial resolution is needed to quantify climate change impacts. For Europe, only two other dynamically downscaled SMILEs from Regional Climate Models (RCMs) exist: The 16-member EC-EARTH-RACMO ensemble at 0.11° (Aalbers et al., 2018) and the 21-member CESM-CCLM ensemble at 0.44° grid cell size (Fischer et al., 2013; Brönnimann et al., 2018). The three models differ in their study domain (EC-EARTH-RACMO) and spatial resolution (CESM-CCLM) from the CRCM5-LE (Wood, 2023; von Trentini et al., 2020).*

<u>Spatio-Temporal Trends and Variability</u>

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).

Thank you for this comment, we indeed did not discuss the overwintering option of the Drought Code. We added this to this section, which was already edited in RC-1 comment 80:

Old: *For the Southern Alps, Wastl et al. (2012) identified the main fire season between December and April because of low precipitation and missing vegetation cover in the winter half year. Therefore, future studies assessing changes in fire danger in the Alps should focus on the whole year instead of the summer season only.*

New: *For the Southern Alps, Wastl et al. (2012) identified the main fire season between December and April because of low precipitation and decreased fuel moisture outside the vegetation period in the months December to April (Conedera et al. 2020). With respect to the increasing altitude of vegetation, increasing length of the vegetation period and decreasing snow cover (Rumpf et al, 2022), future studies assessing changes in fire danger and fire events in the Alps and other temperate climate regions should consider analyzing the whole year instead of the summer months only. If the FWI can not be calculated continuously, the long term moisture deficit represented by the Drought Code (DC) should be "overwintered" in further studies. Overwintering in case of the DC means, that the value of the DC* *in the new fire season is set to the last value of the DC in the previous season (Wang et al., 2017). However, the FWI can not capture these land cover and vegetation specific changes and therefore other methods should be considered to quantify fire danger outside of the summer period (see e.g. Pezzatti 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.

We value your comment regarding the overestimation of natural variability of the CRCM5-LE. This section was already revised in RC-1 (comment 82.). However, we reedited the section to emphasize more strongly that the CRCM5-LE is a regionally downscaled single-model initial-condition large ensemble (SMILE) of a GCM (CanESM2-LE), resulting in 50 climate realizations of a spatial resolution of 0.11°.

Old: *The CRCM5-LE used in our study embodies a substantially larger database than the database used by Fargeon et al. (2020) thanks to its SMILE-setup, which helps to better represent natural variability.*

New: *Due to its SMILE setup, the CRCM5-LE used in our study embodies a substantially larger database (50 members) and is able to quantify natural variability in contrast to the climate multi-model database (5 members) used by Fargeon et al. (2020).*

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).

Thank you for your comment, which we highly appreciate, because it demonstrates that our study set-up is not clearly described. The CRCM5-LE used in this study (s. Leduc et al. 2019) is a single-model initial condition large ensemble, which is widely used on a global scale (e. g. Deser et al. 2020, Suarez-Guiterrez et al. 2021) to distinguish internal / natural variability from the forced response of a climate model simulation. Faranda et al. (2023) state that they would use "initial condition large ensembles to separate forced signals from internal variability in the context of our analog analysis" in future work. However, our study does not aim to quantify model uncertainty but to study climate variability. We added a section on this to the discussion (s. your comment on the abstract and line 62, RC-3 Abstract, RC-3 Introduction Line 63). We hope the changes in the previous comments clarify the modelling setup in our study.

New Paragraph (Discussion): *While the SMILE-setup used in our study allows us to estimate the internal variability and the forced response of the selected climate change scenario (Suarez-Gutierrez et al., 2021; Deser et al., 2012), it can not account for the structural uncertainty of the climate model (Deser et al., 2020), which can be assessed only in multi-model studies (i. e. Fargeon et al. (2020)). In order to quantify both, internal variability and structural uncertainty, multiple SMILEs as provided by the "Multi-Model Large Ensemble Archive" (MMLEA) (Deser et al., 2020) should be used. However, all SMILES in the MMLEA are based on Global Climate Models (GCMs) with a spatial resolution ranging between 2.8° and 0.9° (Deser et al., 2020). On a regional and local scale, a higher spatial resolution is needed to quantify climate change impacts. For Europe, only two other dynamically downscaled SMILEs from Regional Climate Models (RCMs) exist: The 16-member EC-EARTH-RACMO ensemble at*

0.11° (Aalbers et al., 2018) and the 21-member CESM-CCLM ensemble at 0.44° grid cell size (Fischer et al., 2013; Brönnimann et al., 2018). The three models differ in their study domain (EC-EARTH-RACMO) and spatial resolution (CESM-CCLM) from the CRCM5-LE (Wood, 2023; von Trentini et al., 2020).

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.

Thank you for your comment. We changed the sentence to emphazise that we used a regionally downscaled SMILE:

Old: *While Fargeon et al. (2020) point out that fire danger increases are hard to distinguish from natural variability in northern France in multi-model ensembles, we demonstrate using a SMILE that increases in fire danger are robust for Central Europe*.

New: *While Fargeon et al. (2020) point out that fire danger increases are hard to distinguish from natural variability in northern France in multi-model ensembles, we demonstrate that increases in fire danger can robustly be quantified for Central Europe by using a regional SMILE.*

<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.

We appreciate your comment, which was also remarked in a similar way by RC-1 (comment 92). We restructured the conclusions to follow the different research questions/hypotheses.

Old: *The strongest increases and most hazardous developments are observed North of the river Danube in the summer months July and August for the subregions South German Escarpment and Eastern Mountain Ranges. Regions south of the Danube (Alps and Alpine Foreland), are less strongly affected by changes in the FWI but increases are still significant. Further, we find that the FWI has a stronger variability for regions with heterogeneous terrain (i.e. the Alps and the Eastern Mountain Ranges) than for regions with less complex terrain (i. e. Alpine Foreland and Southgerman Escarpment). The time of emergence (TOE) is reached in all subregions of the study area before 2050 and the return period of a present 100- year event shifts towards a 10-year event by 2090. We accept all of our three hypotheses, stated in the introduction (chapter 1). Our results reveal more serious developments than assumed in the original hypotheses.*

New: *Our results provide clear answers to our initially proposed research questions. They demonstrate that fire danger increases significantly throughout the study area. We find the strongest changes and highest fire danger levels north of the river Danube in the summer months July and August for the subregions South German Escarpment and Eastern Mountain Ranges. Our results also show that the time of emergence (TOE) is reached in all subregions before 2050. Further, we showed that not only the mean but also the lower boundary of the running mean, represented by the CRCM5-LEs standard deviation, exceeds the upper boundaries of the present climate (1980 - 2009) standard deviation before 2099 in all subregions for the 90th FWI percentile. Last, our findings highlight that the return period of present 100-year events shifts towards 10-year events by 2090 and the return periods for 100-, 50- and 20-year events shift to 50-, 20- and 10-year events, respectively, before 2050 throughout the analyzed subregions.*

References

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

We corrected the misplacement of the reference Separovic.