Responses to Reviewer 3's comments

Summary:

Liu et al. investigated the role of Atlantic Multi-decadal Oscillation (AMO) in influencing the relationship between El Niño-Southern Oscillation (ENSO) and Australian fire weather, using both reanalysis data and ocean basin experiments (OBE). Their findings suggest that the positive AMO enhances the ENSO-Australian fire weather relationship, potentially through atmospheric teleconnection mechanisms. These results are important for advancing our understanding of fire-climate relationships. However, the approach and data used in the study may be difficult to follow, as it involves analyses from both reanalysis and OBE. It'll also be helpful to provide additional analysis regarding the contributions of individual meteorological factors, such as increased temperature versus wind speed, to the AMO-strengthened ENSO-Australian fire weather relationship.

Reply: We thank this reviewer for the helpful suggestions, which have greatly helped us improve the manuscript. We have studied the comments carefully and made revisions, which we hope will meet the journal standards. Our responses to each of the comments and suggestions are as follows. The referee's original comments are shown in blue. Our replies are shown in black. The corresponding changes in the manuscript are shown in *Italic black*

General comments

1. The authors analyzed both the reanalysis and OBE model results, but when each dataset is used and why they are used are not very clear. It would be helpful to have an overview at the end of the Introduction and/or in Methodology to remind the readers of these.

Reply: We appreciate the insightful recommendations provided by the reviewers. In response, we have incorporated a comprehensive summary at the conclusion of sections 2.1 and 2.2 within the Data and Methods segment. This addition serves to elucidate the rationale behind the utilization of each dataset and delineate the specific circumstances in which they are employed, thereby enhancing the clarity and coherence of our manuscript for the readers (refer to Lines 72-75 and Lines 111-113).

We also cited them here:

Utilizing these reanalysis datasets, we generate composite maps of meteorological variables corresponding to distinct phases of the ENSO and AMO. The objective of these composite maps is to elucidate the modulating effect of the AMO on the influence of ENSO in Australia.

The OBE results were primarily employed to discern the impact of the AMO and to ascertain the underlying teleconnection pattern between the AMO and the ENSO-Australian FWI relationship.

2. Fig. 1a shows the stronger correlation between ENSO and FWI during positive AMO, and Fig. 2 presents increased temperature, reduced precipitation, stronger high pressure, and larger winds. It'll be interesting to show which meteorological factor contributes most to the strengthened ENSO-FWI relationship under positive AMO.

Reply: Thanks for pointing it out. By comparing Figure 2d-f and g-i, it becomes evident that T2M predominantly contributes to strengthening the ENSO-FWI relationship in Western Australia, while TP and SLP primarily influence this relationship in Eastern Australia. This disparity can be partially attributed to the atmospheric circulation patterns depicted in Figure 2f and i. In Western Australia, during the positive phase of the AMO, warm advection from lower latitudes heats the land, resulting in warmer conditions compared to the negative phase. Conversely, in Eastern Australia, the wind mainly blows from land to sea with limited water vapor content during the positive phase of the AMO. In the negative phase, however, a greater amount of vapor is transported from the southern sea of Australia, leading to increased precipitation in Eastern Australia.

We also expanded our explanation for Figure 2 in Lines 190-197 and cited it here:

It is indeed crucial to identify the meteorological factors that most significantly contribute to the strengthened ENSO-FWI relationship under the positive AMO phase. As evidenced, T2M plays a dominant role in reinforcing the ENSO-FWI relationship in Western Australia, whereas TP and SLP mainly influence this relationship in Eastern Australia. This distinction can be partly ascribed to the atmospheric circulation patterns illustrated in Figure 2f and i. During the positive phase of the AMO, warm advection from lower latitudes heats the land in Western Australia, resulting in warmer conditions than those observed in the negative phase. On the other hand, in Eastern Australia, the wind predominantly blows from land to sea with limited water vapor content during the positive phase of the AMO. During the negative phase, however, an increased volume of vapor is transported from the southern sea of Australia, leading to enhanced precipitation in Eastern Australia.

Specific comments

1. line 40: I think the approach is not clear at this point (and after Data and Methods section). Maybe it's better to have an overview of the approaches to help readers understand the plan for investigating the Atlantic impact on Australian fire weather.

Reply: Apologies for any confusion, and thank you for your feedback. In light of your suggestion, we have incorporated an overview of the methodological approaches at the end of the Introduction section, which will assist readers in comprehending the overall plan for investigating the Atlantic Ocean's impact on Australian fire weather conditions. This overview delineates our examination of the ENSO-fire weather connection under distinct AMO phases, the construction of composite maps, the utilization of numerical simulation experiments, and the comprehensive analysis of underlying mechanisms (refer to Lines 40-47). We believe that this addition will enhance the clarity and coherence of the manuscript, providing readers with a more accessible roadmap for navigating the complexities of the study.

We also cited it here:

In this study, we systematically examine the influence of the Atlantic Ocean on Australian fire weather conditions and explore its potential role in modulating the ENSO-Australian fire weather relationship. To achieve this, we first scrutinize the ENSO-fire weather connection under distinct AMO phases, identifying an amplification of this relationship during the positive AMO phase. Subsequently, we construct composite maps of various meteorological variables during contrasting ENSO and AMO phases, utilizing an array of multi-source reanalysis datasets. To further substantiate these findings, we employ numerical simulation experiments, providing robust validation of the observed impacts. Lastly, we endeavor to elucidate the underlying mechanisms responsible for these effects through a comprehensive analysis of the simulation results.

2. line 50: Please specify the meteorological factors considered in the FWI (e.g., wind, temperature, etc.)

Reply: Thanks for pointing this out. We have specified the meteorological factors considered in the calculation of FWI in Lines 61-62 and cited it here:

For obtaining this index, it be explicitly calculated using daily meteorological variables including T2M, relative humidity, TP, and WND10.

3. line 52: "...fuel availability (drought conditions)" is confusing. Do you mean drought conditions affect fuel availability? Please explain it in detail.

Reply: Thanks for your helpful suggestion. This sentence indicates that the Fire Weather Index (FWI) incorporates a component related to fuel availability, which is influenced by drought conditions. In other words, the FWI considers the presence and amount of combustible material (fuel) that is available for fires, and this availability is affected by the level of dryness or drought in a given area. We have added the explanation as suggested in Lines 54-60 and cited it here:

The Fire Weather Index (FWI) is a numerical rating system that estimates fire intensity based on prevailing weather conditions. It has been demonstrated to be a reliable indicator of fire risk due to its consideration of two key factors: fuel availability and the ease of fire spread. Fuel availability is represented by a component related to drought conditions, which affect the presence and amount of combustible materials in an area, affected by the level of dryness in a given area. The ease of spread is a measure of how quickly and extensively a fire can propagate under specific weather conditions normally measured by surface wind speed (Simpson et al., 2014). By incorporating both of these factors, this provides a comprehensive assessment of the potential danger and intensity of fires.

4. line 63: How do you match and compare products with different spatial resolutions?

Reply: Thanks for pointing it out. No additional processing was applied to the raw reanalysis data. We solely visualized the synthesized meteorological variable fields under different ENSO and AMO phases on a map and conducted a comparison of the resulting outcomes. The composite maps therefore remain their original resolution. The observed consistency among the results from various datasets serves to reinforce the credibility and robustness of our conclusions.

5. line 97: Why do you separate into the two regions? As mentioned by reviewer #1, AMO is usually defined by SST over the North Atlantic. It'll be helpful to elaborate on why you separated the two regions.

Reply: Thanks for your constructive suggestions. The rationale for distinguishing between the Tropical Atlantic and North Atlantic regions stems from the dissimilar sea surface temperature (SST) variability observed in these two areas, as illustrated in Figure R1. Notably, the Tropical Atlantic SST began to exhibit a decreasing trend around 2010, whereas the North Atlantic SST continued to fluctuate without a discernible decline. This distinction enables us to isolate the contributions of the tropical and northern segments of the Atlantic, thereby facilitating a more comprehensive understanding of their respective roles in influencing climate dynamics.

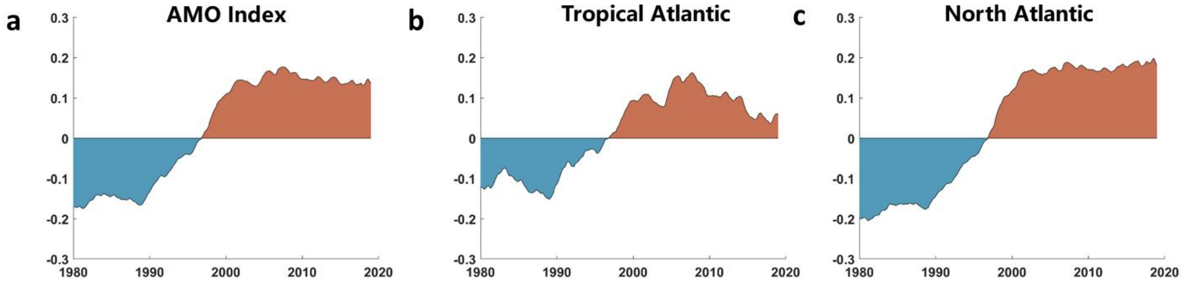

Figure R1 SST anomaly in Atlantic regions from 1980 to 2019. (a) AMO Index

(0-80°N), (b) Tropical Atlantic SST Index (0°-20°N), and (c) North Atlantic SST Index (20°N-80°N)

We also added the explanation for the separating into two regions in the manuscript in Lines 109-111 and cited it here:

The rationale for distinguishing between the Tropical Atlantic and North Atlantic regions stems from the dissimilar sea surface temperature (SST) variability observed in these two areas (not shown).

6. lines 104-105: Have you analyzed the effects of the ENSO or AMO leading the peak fire season on fire weather? For example, the effect of ENSO 3 or more months prior to peak fire season on fire weather in peak fire season. Chen et al. (2016) showed that NINO4 with a lead time of 10 months has a high correlation with burned areas in Australia.

Reply: We acknowledge the importance of considering the potential influence of ENSO and AMO leading the peak fire season on fire weather conditions in Australia. Nevertheless, it ought to be noted that there may be a reduction in the correlation coefficients when analyzing longer leading times pertaining to the fire weather index (FWI), as shown in Figure R2. This contrast with previous findings by Chen et al. (2016), who assessed the burnt area instead of fire weather, which may require a few months to respond to the weather. Consequently, based on the aforementioned reasons, our study focuses on evaluating the impact of ENSO on the concurrent FWI conditions in Australia.

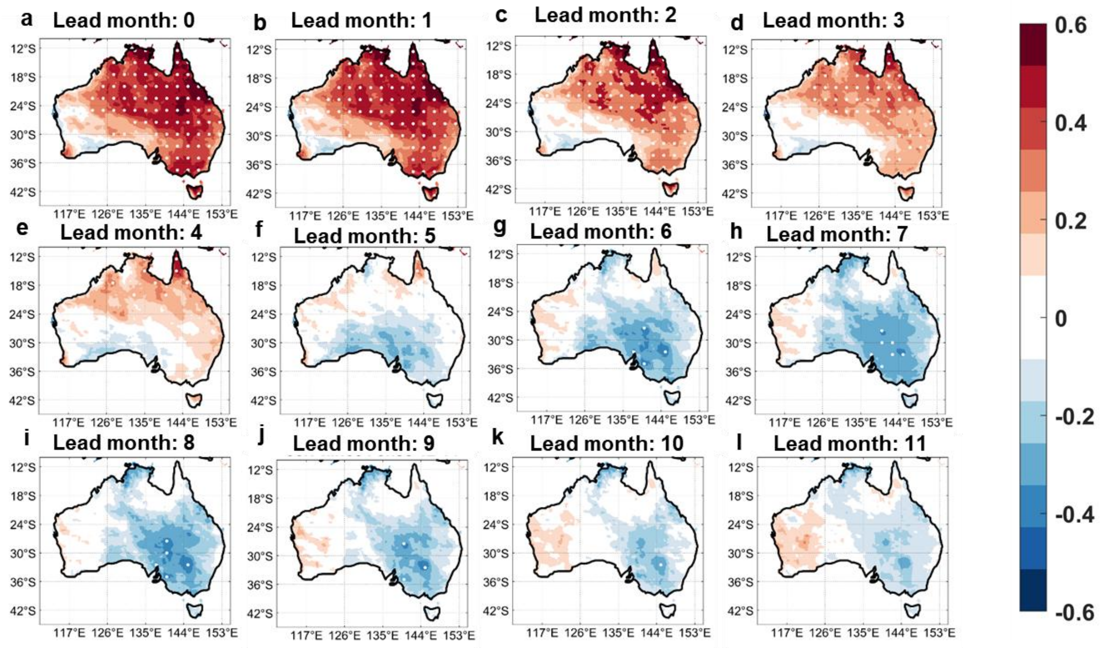

Figure R2 The distribution of correlation coefficients between Australian FWI and Nino 3.4 index with different leading time.

7. lines 114-115: How does global warming affect the ENSO-FWI relationship? I know the analyses focus on the effect of natural variability, but it'll be interesting to understand how global warming plays a role in modulating the ENSO-fire weather relationship, along with the contribution from AMO. Several reviewers also mentioned this.

Reply: Thanks for your constructive suggestions. Global warming might contribute to this correlation transition, and it is hypothesized to be responsible for this correlation transition by the previous work (Mariani et al., 2018). However, given that the global warming trend slowed down or even paused between ~2000 and 2015, this hypothesis seems unjustified, motivating us to find other potential causes (decadal climate variability, such as AMO).

In order to assess the influence of global warming on the ENSO-FWI relationship, we constructed a composite map incorporating FWI (fire weather) and TP (total precipitation) variables, as depicted in Figure R2. The responses of FWI and TP are observed to be more pronounced during the positive phase of AMO in comparison to its negative phase. This observation is in strong agreement with the findings presented in Figure 2 of the manuscript, further substantiating that the composite map remains consistent irrespective of whether FWI and meteorological variables are detrended or not. Consequently, it can be inferred that global warming may not play a predominant role in modulating the ENSO-Australian FWI relationship.

Nonetheless, in the original manuscript, all physical quantities have been detrended to exclude the potential influence of global warming and ensure that its impact on our analysis is minimized.

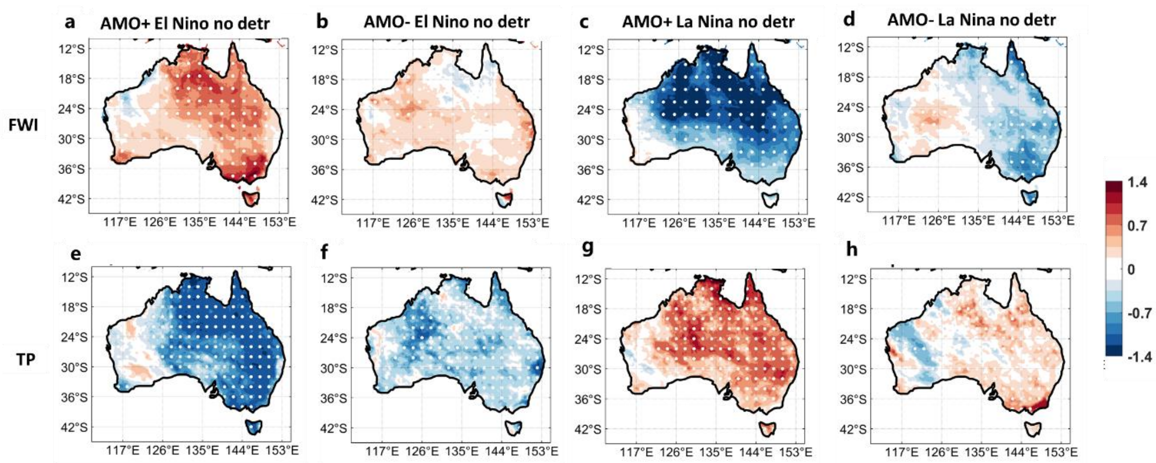

Figure R3. The composite map for the normalized reanalysis SON (a-d) FWI (fire weather index) and (e-h) TP (total precipitation) in (a, e) El Niño events when the AMO indexes are positive, (b, f) El Niño events when AMO indexes are negative, (c) La Niña events when AMO indexes are positive, and (d) La Niña events when AMO indexes are negative from 1980 to 2019. The area with white dots passed the significance test of p-value < 0.05 by Student's t-test.

8. lines 146-151: Figures 2j-l show the composite of AMO, while the following sentences mainly describe positive AMO. It would be helpful to include the

composite analysis for positive AMO only and negative AMO only so that there would be evidence supporting the description of positive AMO.

Reply: We appreciate your valuable input. In our analysis, we have indeed examined both El Niño and La Niña conditions during distinct AMO phases, as illustrated in Figure R3. Our findings reveal that the responses of Australian fire weather are not only intensified during El Niño events but also exhibit a similar amplification in La Niña conditions during the positive phase of AMO.

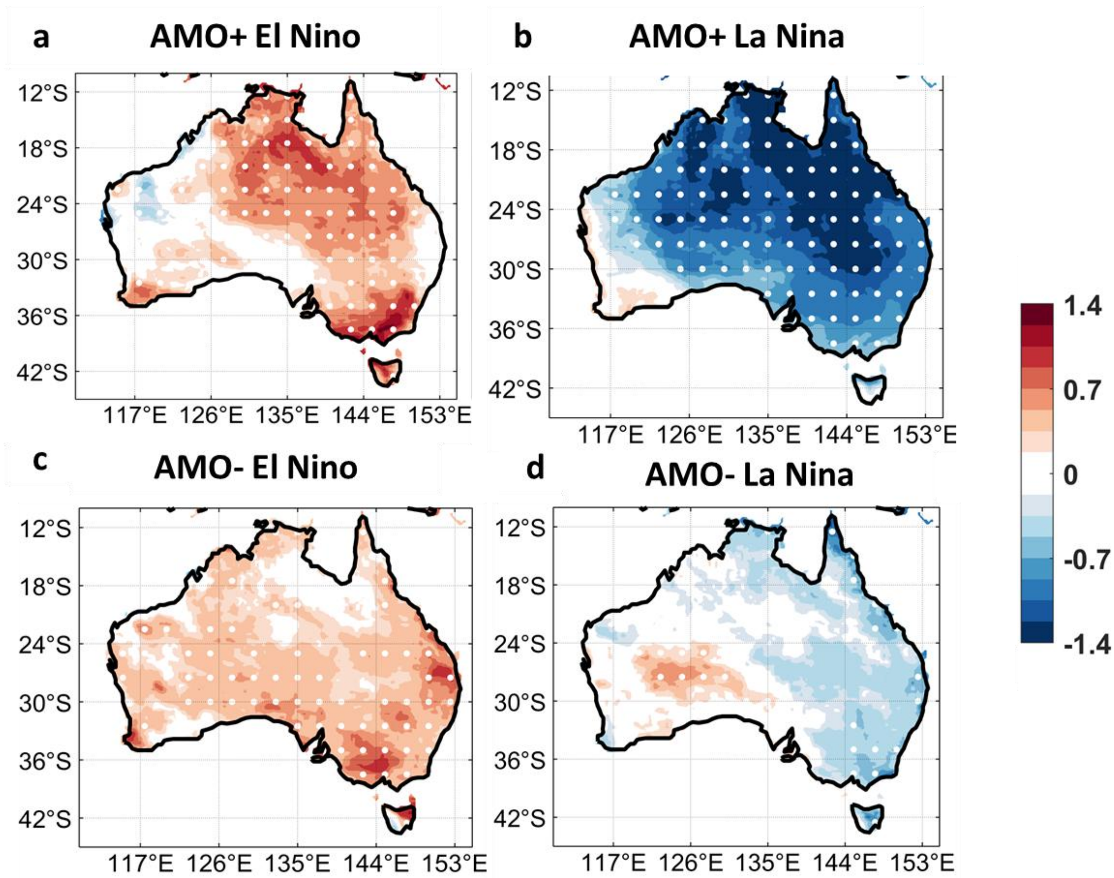

Figure R4. The composite map for the detrended and normalized reanalysis SON FWI in (a) El Niño events when the AMO indexes are positive, (b) La Niña events when AMO indexes are negative, (c) El Niño events when AMO indexes are negative, and (d) La Niña events when AMO indexes are negative. The area with white dots passed the significance test of p-value < 0.05 by Student’s t-test.

While the AMO indeed modulates the ENSO-FWI relationship in both El Niño and La Niña events, our analysis indicates that El Niño events may result in more severe fire weather in Australia compared to La Niña events. Consequently, this study primarily emphasizes the modulation of Australian fire weather during El Niño conditions.

We added the following discussion concerning the examination on the modulation effect of AMO on La Niña events in Lines 214-217 and cited them here:

Although AMO modulates the ENSO-FWI relationship in both El Niño and La Niña events (Figure S5), El Niño events may induce more severe fire weather in Australia compared to La Niña events (Figure 2a-c). Consequently, our subsequent discussion primarily focuses on the modulation of Australian fire weather during El Niño conditions.

9. lines 227-229: I wonder whether any large fire event is associated with ENSO and positive AMO in history. Or how would the results or conclusions change by replacing fire weather with burned areas or fire emissions? The authors demonstrate the effects of ENSO and AMO on fire weather while lacking actual fire events.

Reply: In recent decades, two significant fire events, the 2009 Black Saturday bushfires, the 2015 Sampson Flat bushfire and the 2019-2020 "Black Summer" bushfires, have been associated with ENSO and positive AMO phases. The 2009 Black Saturday bushfires resulted in 173 fatalities and the destruction of over 2,000 houses (https://www.britannica.com/explore/savingearth/the-australian-black-saturday-bushfires-of-2009). The 2015 Samson Flat bushfire occurred in South Australia, burned around 12,500 hectares, and destroyed 27 homes (https://www.wikiwand.com/en/2015_Sampson_Flat_bushfires). The 2019-2020 Australian bushfires, which affected multiple states, including New South Wales, Victoria, and South Australia, burnt approximately 19 million hectares and claimed 33 lives (https://wwf.org.au/what-we-do/australian-bushfires/). Both events appear to be closely associated with El Niño occurrences during the positive phase of AMO as illustrated in Figure R4.

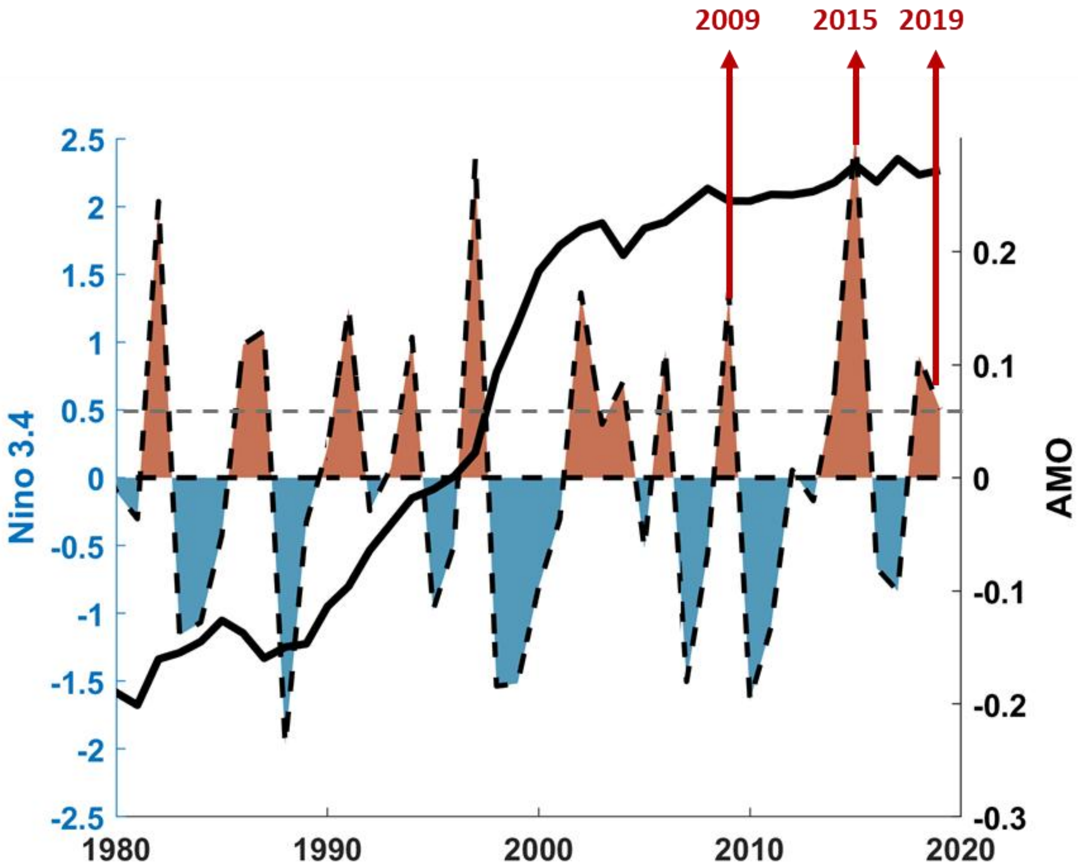

Figure R5 Time series of Niño 3.4 and AMO indexes from 1980 to 2019. The shade corresponds to Niño 3.4 index. The black solid line indicates the AMO index. The gray doted line indicates the threshhold for identifying El Niño events. The arrow indicate large fire events in recent decades corresponding to El Niño occurrences during the positive phase of AMO.

However, due to the limited temporal range of satellite-derived datasets (e.g., fire point and burned area, primarily from 2000 to present), assessing AMO's modulation effect on the ENSO-Australian fire relationship may prove challenging.

In light of these limitations, we have revised our manuscript to primarily focus on "fire weather" rather than "fire" events. This approach allows for a more robust examination of the complex interplay between ENSO, AMO, and fire weather in the context of these devastating events, while acknowledging the constraints imposed by available data.

Technical comments

1. lines 81-82: “In addition, simple stochastic variability…..behaviors.” This sentence is not clear. Please revise it.

Reply: Thanks for your suggestions and sorry for the confusion. We have revised this sentence and cited it here:

Moreover, basic random fluctuations may contribute to observed decadal shifts and should be considered as a potential factor influencing variable ENSO behaviours.

2. line 96: Please specify SON in the main text.

Reply: Thanks for your helpful suggestions. We have specified SON in Lines 116-119 and cited it here:

Given that the peak season for fire weather in Australia primarily occurs during the local spring (September, October, and November; SON) (Earl & Simmonds, 2017), *we selected the model responses to SON North Atlantic SST (25°N-65°N, 10°W-60°W) and Tropical Atlantic SST (0-20°N, 10°W-60°W) in the OBE for further analysis.*

3. lines 130-131: Broken sentence. Please revise it.

Reply: Thanks for your suggestions. We have revised this sentence in Lines 168-170 and cited it here:

In an effort to elucidate the potential reinforcement of the ENSO and Australian FWI relationship by the AMO, we conducted a comprehensive examination of the effects on Australian meteorological conditions, placing particular emphasis on the coherent interplay between ENSO and AMO.

4. lines 183-185: The sentence is confusing ("…., we examine the responses of the 500 hPa geopotential height (GPH) responses …). There are two responses in the sentence.

   Reply: Thanks for pointing it out. We have deleted one "response" in the sentence and cited the sentence here (refer to Lines 237-239):

   To elucidate the physical processes underlying the Atlantic's impact on Australia, we investigate the responses of the 200 hPa geopotential height (GPH) and stream function (SF) in the North and Tropical Atlantic OBE and the mechanisms by which the North Atlantic and Tropical Atlantic individually influence the Australian FWI.

References

Yang Chen et al,: Environ. Res. Lett. 11, 045001, https://doi.org/04500110.1088/1748-9326/11/4/045001, 2016

Mariani, M., Holz, A., Veblen, T. T., Williamson, G., Fletcher, M. S., and Bowman, D. M. J. S.: Climate Change Amplifications of Climate-Fire Teleconnections in the Southern Hemisphere, Geophys. Res. Lett., 45(10), 5071-5081, https://doi.org/10.1029/2018GL078294, 2018.