Responses to Reviewer 2's comments

Summary:

This study states that the ENSO-Australian fire relationship can be modulated by the phase changes of AMO. Specially, Atlantic warming may induce warmer temperature and less precipitation, which serves to enhance wildfires when combined with positive ENSO phase. This result is useful in understanding the recent shift in the ENSO-Australian fire relationship and in future wildfire projection in Australia. However, to further improve this manuscript, there are a few issues and questions that need to be addressed。

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 detailed 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*

1. The authors mainly looked at the AMO effect on positive ENSO-Australian fire relationship, i.e., the modulation of Australian fire weather during El Nino conditions. Could they also examine La Nina conditions? Will responses of Australian fire weather also be strengthened during La Nina?

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 R1. 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.

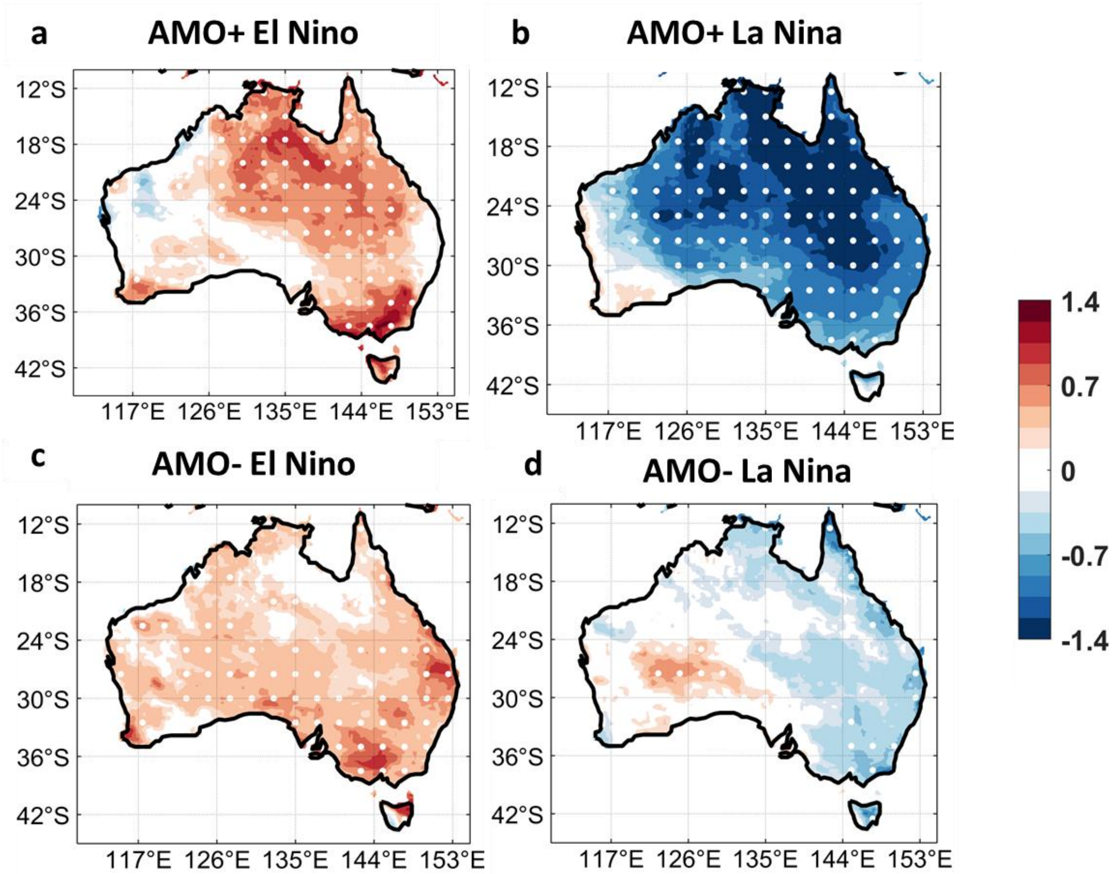

Figure R1. The composite map for the detrended and normalized reanalysis SON FWI in (a) El Niño events when the AMO indexes are positive, (b) La Niña events when AMO indexes are negative, (c) El Niño events when AMO indexes are negative, and (d) La Niña events when AMO indexes are negative. The area 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.

2. While it is plausible that AMO modulates the ENSO-Australian fire relationship, another major decadal climate variability, PDO, also shifted its phase around 2000. PDO may exert an even stronger impact on Australian weather. How could the authors exclude the effect of PDO?

Reply: Thank you for highlighting the importance of considering the Interdecadal Pacific Oscillation (PDO) in our analysis. We have indeed investigated the relationship between ENSO and Australia's FWI under various PDO phases using reanalysis data, as well as the Pacific impact on Australia through model simulations. Given the coincident phase transitions of the AMO and PDO in the 1990s, we extended our examination to a longer time series, commencing from 1959, which encompasses a complete PDO and AMO cycle (Figure R2).

Figure R3 presents the ENSO composite maps of Australian meteorological fields under distinct PDO phases, analogous to Figure 2 in the main text. It reveals that the composite maps under varying PDO phases do not exhibit a substantial contrast compared to those under different AMO phases. Although the negative PDO is correlated with marginally stronger temperature (Figure R3 d&g) and precipitation (Figure R3 e&h) alterations, these changes are predominantly statistically insignificant. The SLP and wind fields display minimal contrast (Figure R3 f&i). In comparison, even for the extended time series, the ENSO composites under contrasting AMO phases remain distinct, with a markedly stronger response under the positive AMO (Figure R3). This outcome suggests that changes in the ENSO-Australia weather relationship under different PDO phases are relatively minor compared to those under the AMO. Nevertheless, as FWI data is only accessible from 1981, our main text will continue to emphasize the period between 1981 and 2019.

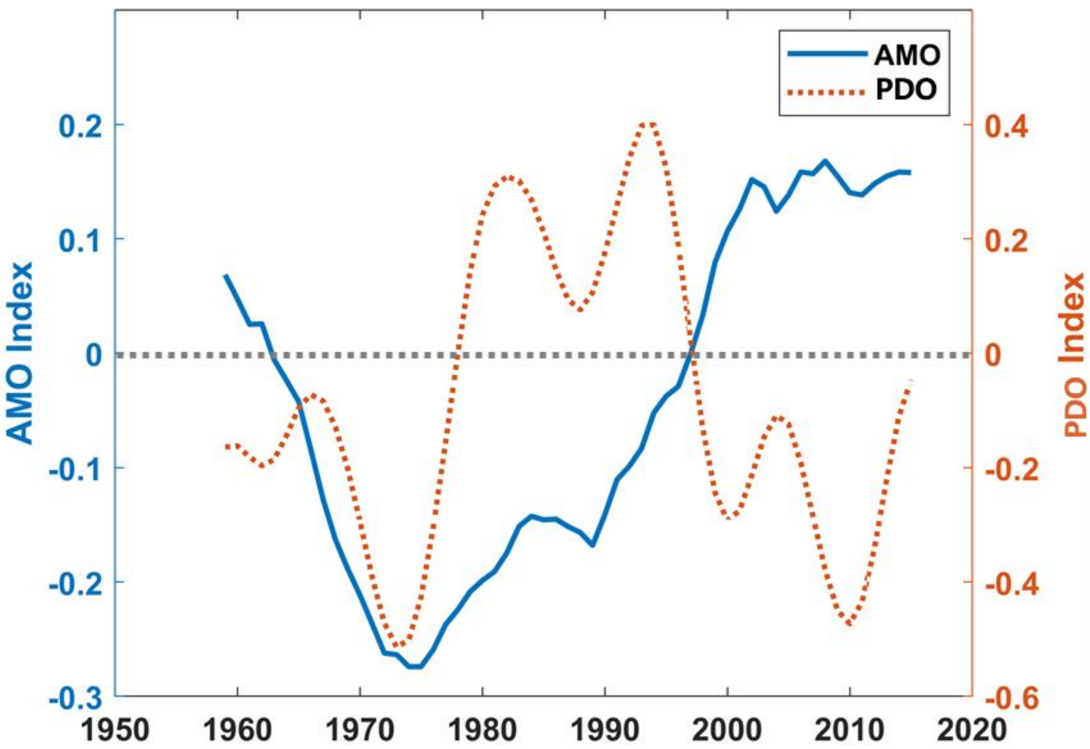

Figure R2. Time series of monthly AMO and PDO index from 1959 to 2015. The gray dashed line represents zero.

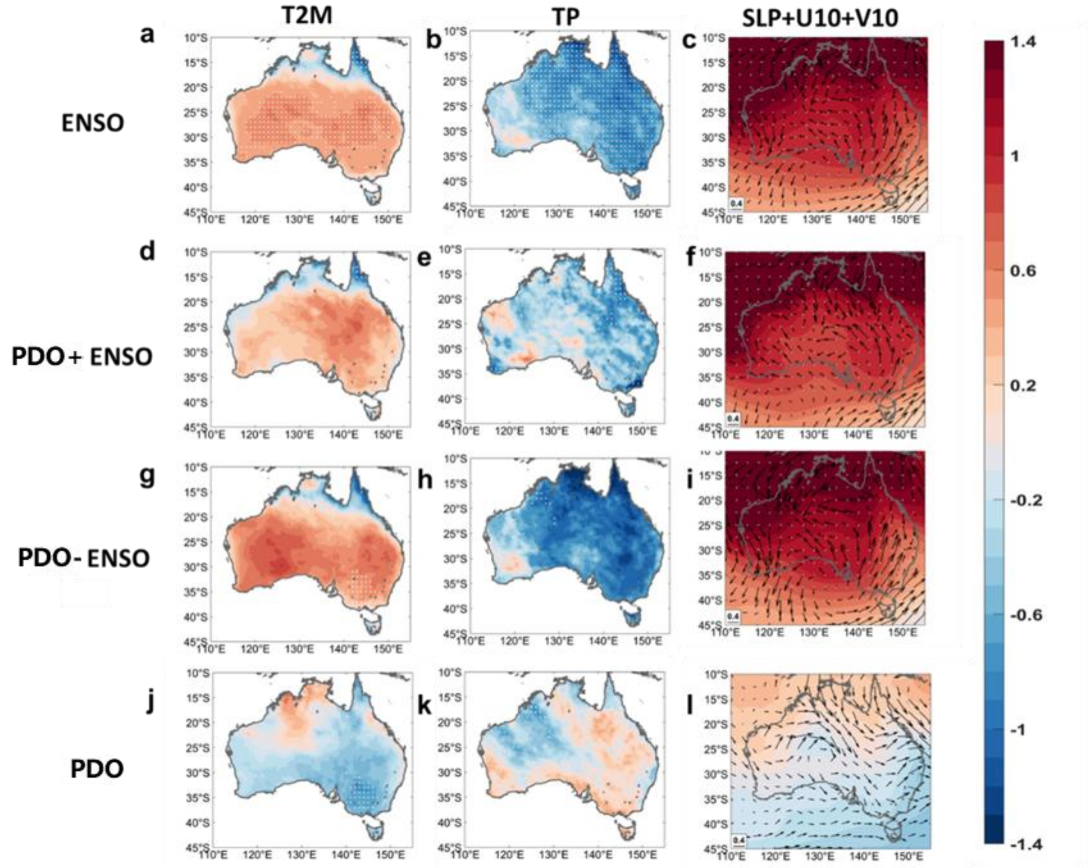

Figure R3. The difference maps for the ERA5 detrended and normalized reanalysis SON (a, d, g, j) 2m temperature (T2M), (b, e, h, k) Total Precipitation (TP), and (c, f, I, l) Sea Level Pressure (SLP)+10m zonal and meridional winds (U10+V10) in conditions with (a-c) ENSO composite (El Nino composite minus La Nina composite), (d-f) ENSO composite with PDO+, (g-i) ENSO composite with PDO-, and (j-l) PDO composite from 1959 to 2019. The composite results are calculated using meteorological variables with positive indices minus those with negative ones. The area with white dots passed the significance test of p-value < 0.05 by Student's t-test.

Additionally, we assess the response of Australian meteorological variables to Pacific forcing using ocean basin experiments (OBE). The detrended and normalized SON meteorological variables are regressed on the detrended and normalized SON Tropical and North Pacific SST in OBE. The regression coefficients, representing the responses of local meteorological variables to remote SST forcings in the corresponding ocean basin, are displayed in Figure R4. For the Tropical Pacific SST anomaly, the responses of T2M, TP, and SLP in Australia do not pass the Student's t-test with a p-value < 0.05. Concerning the North Pacific, the T2M and TP responses are statistically significant in northern Australia (passing the significance test with a p-value < 0.05 by Student's t-test). However, the response magnitudes are relatively small, and the response area is confined to northern Australia. In conclusion, the responses of meteorological fields in Australia to Pacific forcing appear considerably weaker compared to those for Atlantic forcing.

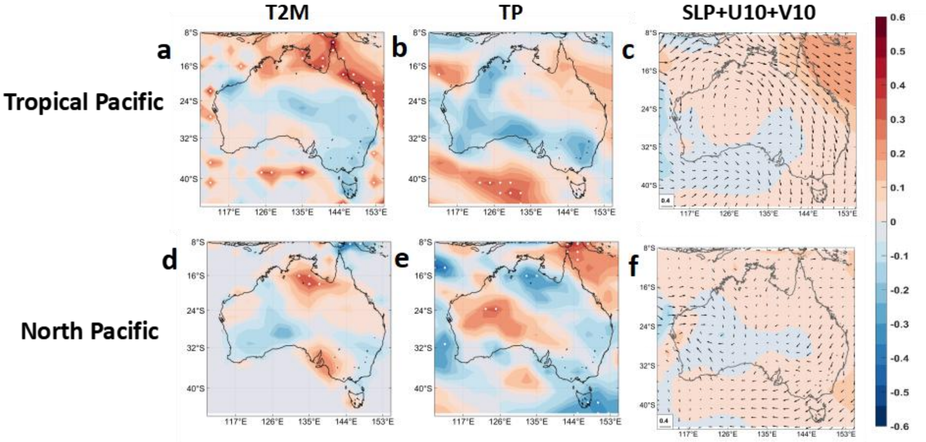

Figure R4 Regression coefficients of detrended and normalized SON (a, d) T2M, (b, e) TP and (c, f) SLP+U10+V10 onto detrended and normalized SON (a, b) Tropical Pacific (80°-130°W, 0-20°S) SST and North Pacific (170°E-140°W, 25-45°N) SST in the OBE. The area with white dots passed the significance test of p ⩽ 0.05 by Student's *t*-test.

We refrain from concentrating on the PDO in this study, as it is frequently regarded as the interdecadal modulation of high-frequency ENSO variability (Henley et al., 2015). Furthermore, the spatial patterns of surface temperature and precipitation anomalies linked to PDO and ENSO have been reported to exhibit considerable similarities (Deser et al., 2004), rendering the PDO and ENSO potentially indistinguishable in both tropical and extratropical regions (Chen and Wallace, 2015; Zhang et al., 1997). Notably, Atlantic variability may also influence Pacific variability on decadal time scales (Li et al., 2016), and the PDO phase transition could be partially associated with the AMO.

In summary, given that the PDO's impact on the ENSO-Australia FWI relationship is less pronounced than that of the AMO, and the difficulty in fully distinguishing between the PDO and ENSO, we prioritize examining the AMO in this context. Consequently, we attribute the AMO's phase transition as the primary factor contributing to the heightened ENSO-Australia FWI relationship observed in the 21st century.

We also added the following discussion of the role of PDO in the Lines 313-318 and cited it here:

It is worth noting that Pacific decadal variability, such as the Pacific Decadal Oscillation (PDO), plays a crucial role in Australia's climate (Power et al., 1999). However, prior research suggests that Pacific variability may be partially induced by Atlantic variability (Li et al., 2016; Ren et al., 2021), underscoring the latter's significance in Earth's climate system. We also examined the modulation effect of the Interdecadal Pacific Oscillation (IPO) or PDO on ENSO and Australian FWI but found it less pronounced than that of the AMO in both observations and simulations (Figures not shown).

3. The authors only used fire weather to represent fire activities. This may not be exactly equal to the actual fire counts or emissions. It is suggested to validate the correlation between ENSO and Australian fires using other proxies such as burned area, fire counts, etc.

Reply: We appreciate your observation and agree that fire weather may not directly correspond to actual fire counts and burned area. Nevertheless, it is essential to acknowledge that the majority of data on fire points and burned areas are derived from satellite observations, which have a relatively short temporal range (primarily from 2000 to present). Consequently, employing these datasets to examine the AMO's modulation effect on the ENSO-Australian fire relationship may not be feasible.

In light of this, we have revised our manuscript carefully to primarily concentrate on "fire weather" rather than "fire". This approach allows us to circumvent the limitations posed by the restricted availability of satellite-derived data while maintaining a focus on the broader climatic factors influencing fire-related phenomena in the Australian context.

4. Figure S8 did not give any statistical significance test of SST anomaly, which should be presented for clarity.

Reply: We are grateful for the valuable feedback and have accordingly conducted a statistical significance test for the SST anomaly in Figure S8. For the convenience of the readers, we have also included the corresponding figure here (Figure R5).

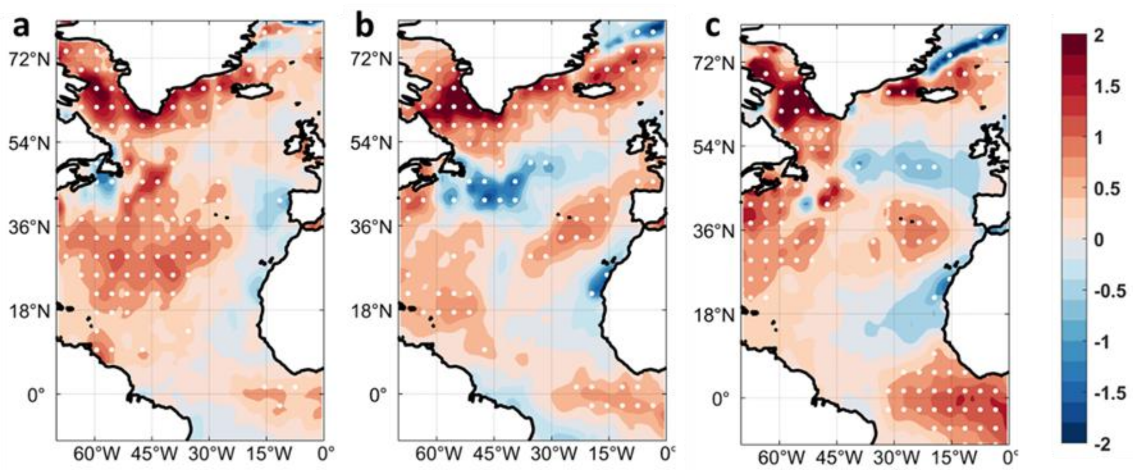

Figure R5. North Atlantic SST anomaly in **(a)** September, **(b)** October, and **(c)** November 2019. The climatology mean SST is calculated using 1980-2009 SST. The area with white dots passed the significance test of p-value < 0.05 by Student’s *t*-test.

References

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Deser, C., Phillips, A. S., & Hurrell, J. W. (2004). Pacific interdecadal climate variability: Linkages between the tropics and the North Pacific during boreal winter since 1900. *JOURNAL OF CLIMATE*, *17*(16), 3109-3124.

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