Responses to Reviewer 5’s comments

Summary:

The authors attempted to explore the underlying mechanism of AMO shift affecting the relationship of ENSO with wildfires in Australia using several reanalysis data and numerical sensitivity simulations. They showed the correlation between ENSO and Australia fire weather index increased from 0.17 to 0.70 when AMO shifted from its negative phase to positive phase. The specifical impacting process was that the positive AMO can generate Rossby wave trains and result in the high pressure in Australia and then increased the local temperature and wind speed but decreased precipitation. This paper is well writing and the finding is valuable. I think it can be published after several corrections.

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*

1. This work mainly explored the effect of AMO shift on the wildfires in Australia. It is ok. What about the role of global warming? How to distinguish its role?

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 R1. 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 elements 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 account for the potential influence of global warming and ensure that its impact on our analysis is minimized.

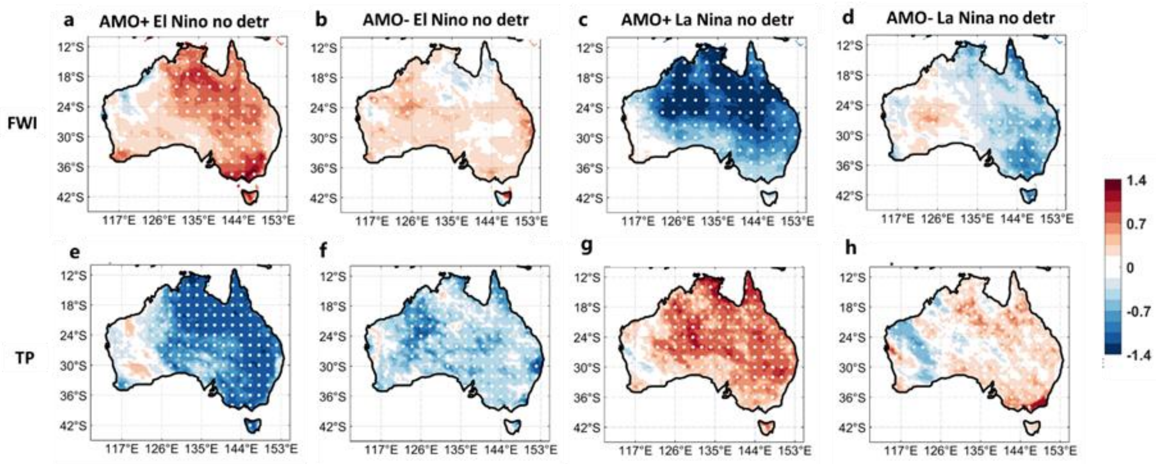

Figure R1. The composite map for the normalized reanalysis SON (a-d) FWI (fire weather index) and (e-h) TP (total precipitation) in (a, e) El Niño events when the AMO indexes are positive, (b, f) El Niño events when AMO indexes are negative, (c)

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.

2. The authors highlighted the roles of SST anomalies over the tropical Atlantic and northern Atlantic. The SST effect over tropical Atlantic is ok and the signals are significant. But it is not for north Atlantic, and the correlations between North Atlantic SST and local factors are much weak, in which most of grids have not passed the significant test. So, the main discussions of this paper are suggested to focus on the tropical Atlantic SST anomaly.

Reply: We appreciate your valuable suggestions. The influence of the tropical Atlantic appears more pronounced and statistically significant, which may be attributable to its closer proximity to Australia. Although weaker than the Tropical Atlantic SST, the impact of North Atlantic SST on Australia's precipitation is indeed noteworthy, particularly across southern and western regions (Figure 3e). Moreover, their change directions concur with those under Tropical Atlantic forcing, i.e., positive North Atlantic SST anomalies correspond to increased T2M and decreased TP in southern Australia. Considering the AMO encompasses SST fluctuations in both the tropical and North Atlantic regions, it is imperative to account for the influence of the North Atlantic in our analysis.

We added the following explanation in Lines 223-228 and cited it here:

Although the responses of these meteorological variables are relatively weaker to North Atlantic forcing (Figure 3d-f), their change directions concur with those under Tropical Atlantic forcing, i.e., positive North Atlantic SST anomalies correspond to increased T2M and decreased TP in southern Australia. Furthermore, the influence of the tropical Atlantic appears more pronounced and statistically significant, which *may be attributable to its closer proximity to Australia. Nevertheless, the impact of the North Atlantic on precipitation remains statistically significant across southern and western Australia, warranting further consideration.*

3. To explain the effects of SST anomalies over tropical and north Atlantic on wildfires in Australia, the authors mentioned that the SST anomalies can generate Rossby wave and then affecting the local atmospheric circulations. However, it should be noted that this process involves both hemispheres, and whether the Rossby wave can spread to the southern hemisphere due to trade winds is a matter of debate. The authors can do further analyses to validate this process, such as EP flux, stream function, etc.

Reply: Thanks for your insightful comments and suggestions. We have done further analysis of stream function to further validate this process and modified Figure 4 in the manuscript.

Cross-hemisphere Rossby wave propagation has been substantiated in previous studies, demonstrating the capability of Rossby waves to traverse from the northern to the southern hemisphere (Nagaraju et al., 2018; Zhao et al., 2019). Li et al. (2015) assert that stationary Rossby waves can cross the equator under the influence of meridional background wind, with their direction and tilt structure contingent upon the meridional background wind. To corroborate this process, we have analyzed the regression coefficients of 200 Pa geopotential height and stream function in relation to SST (Figure 4a & b) and Rossby wave source anomaly (Figure 4e & f) in ocean basin experiments for both tropical and North Atlantic regions.

The patterns observed in Figure 4 (a-d) correspond well with the equatorial windows and wave guides for Rossby wave propagation in the upper troposphere, as delineated by Li et al. (2019) in Figure R2. This comprehensive analysis not only supports the cross-hemisphere propagation of stationary Rossby waves under the influence of meridional background wind, but also contributes to a more in-depth understanding of the underlying processes governing atmospheric dynamics.

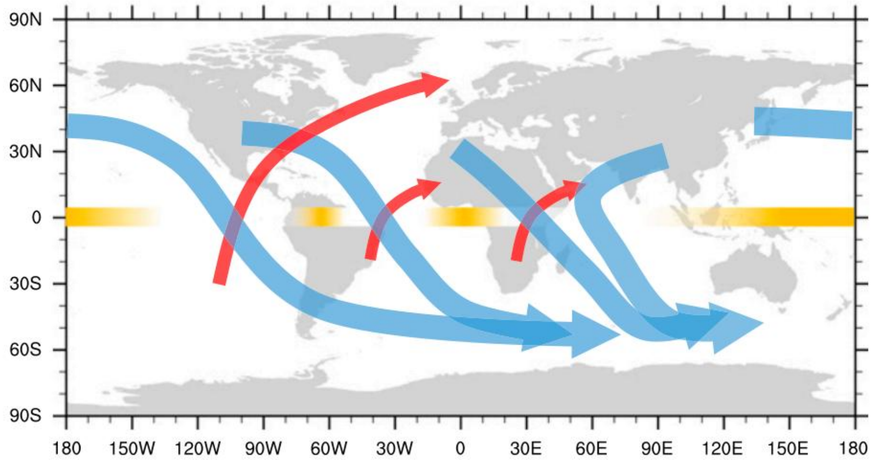

Figure R2. Schematic diagram for the main CEW ducts. The blue (red) arrows denote the NH-to-SH (SH-to-NH) propagation ducts. The thick arrows indicate high NCEW and thin arrows indicate low NCEW. The equatorial windows and barriers are indicated by a transparent yellow belt around the equator. Darker yellow denotes stronger barrier sections, while transparency denotes windows (The Figure is adapted from Li et al., 2019).

We also extended our discussion in Lines 245-281 and cited it here:

In the case of the Tropical Atlantic, thermal forcing in this region drives changes to the zonal Walker circulation. These alterations may result in upward vertical motion and localized convection over the Atlantic, with corresponding low-level convergence and upper-level divergence subsequently producing an intensification of the local Hadley circulation (Li et al., 2014; Li et al., 2015). This process enhances upper-level convergence at the descending branch of the Hadley cell (Simpkins et al., 2014), leading to an intensification of the local Hadley circulation and the generation of a significant source of Rossby waves that propagate eastward with the climatological mean flow in the Southern Hemisphere (Figure 4e). This Rossby wave *source is evident over the South Atlantic (30°S, 20°W in Figure 4e), and the corresponding Rossby wave will propagate toward Australia, intensifying high pressure in the region (Figure 4a). The regression coefficients of the 200 hPa stream function further corroborate this Rossby wave propagation from the South Atlantic to Australia (Figure 4c). With sea surface temperature (SST) warming in the tropical Atlantic, the response of the stream function in the upper level above Australia corresponds to a high-pressure center with descending airflow in this region (Figure 4c). In summary, anomalous deep convection in response to increased SST in the Tropical Atlantic drives anomalous divergence of the large-scale flow that extends away from local heating by modulating the Hadley and Walker circulations. This process has been discussed in detail by Simpkins et al. (2014).*

Regarding the North Atlantic, warmer Atlantic temperatures heat the air above, forming a local high-pressure center in the upper troposphere. This signal generates the Rossby wave source over the North Atlantic (Figure 4e), with the corresponding Rossby wave train propagating from west to east, featuring alternating high and low-pressure centers that culminate in a high-pressure anomaly in Australia (Figure 4b). This high pressure corresponds to descending motions over Australia, characterized by drier and hotter air that is unfavorable for cloud and rain formation. It is worth noting that stationary Rossby waves can cross the equator under the influence of meridional background wind, and their direction and tilt structure depend on the meridional background wind (Li et al., 2015). Furthermore, the responses of the stream function are in strong accordance with those of GPH, with a high-pressure center above Australia. These responses lend further support to the cross-equator propagation under the influence of North Atlantic SST forcing (35°W, 30°N in Figure 4d). The patterns of regression coefficients (Figure 4 a-d) also correspond well to the equatorial windows and wave guides for Rossby wave propagation in the upper troposphere as identified in previous studies (Li et al., 2019). The southward propagation of Rossby waves originating from the Atlantic is also supported by *previous works (Miller et al., 2007; Zhao et al., 2019), which form the basis of the teleconnection between the North Atlantic and Australia. Previous studies also indicate that the Atlantic Multidecadal Oscillation (AMO) can modulate El Niño–Southern Oscillation (ENSO) effects through similar Rossby wave dynamics (Lin and Li, 2012; Nagaraju et al., 2018). The impact of AMO on ENSO itself has been widely discussed in previous studies, including its influence on ENSO's amplitude, flavor, and predictability. The AMO is known to force changes in the Walker circulation in the tropical Pacific Ocean, affecting ENSO's amplitude (Levine et al., 2017) by impacting the depth of the equatorial thermocline and the positive feedback effect of the thermocline (Geng et al., 2020). For ENSO's flavor, the positive AMO enhances the zonal sea surface temperature gradient in the central Pacific, strengthening zonal advective feedback and favoring extreme and Central Pacific (CP) El Niño development (Gan et al., 2022; Yu et al., 2015). Regarding ENSO predictability, it is modulated by the Atlantic mean state bias and systematic errors in inter-basin interactions (Chikamoto et al., 2020).*

4. Line 55-: Is the FWI calculated from these local factors? or it obtained from the other source?

Reply: Thanks for pointing this out. The Fire Weather Index (FWI) employed in this study was obtained from the Copernicus Emergency Service's fire danger indices historical data (https://doi.org/10.24381/cds.0e89c522). This globally recognized index is derived from local meteorological factors, including 2m temperature, relative humidity, and other pertinent variables, to estimate fire danger. The FWI comprises distinct components that encompass the influence of fuel moisture and wind on fire behavior and propagation. An elevated FWI value signifies meteorological conditions that are more conducive to wildfire initiation. A comprehensive description of the FWI calculation methodology is illustrated in Figure R3.

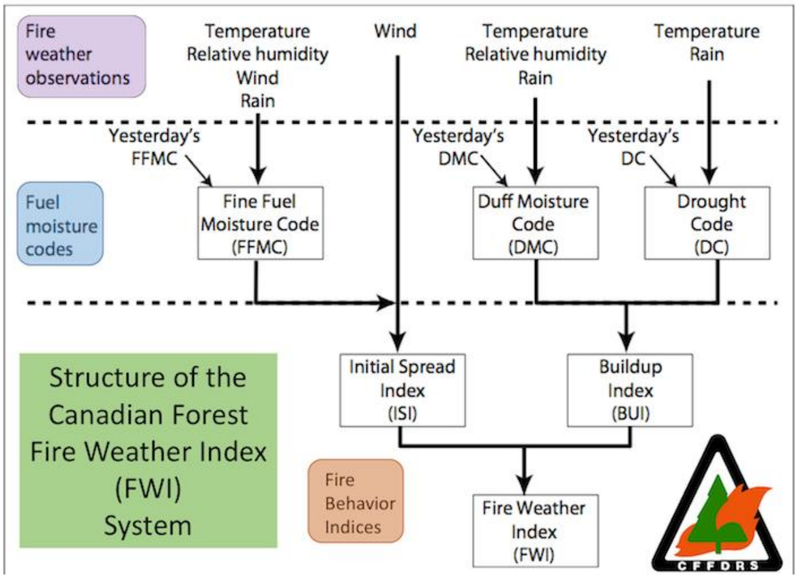

Figure R3. Detailed calculation processes of Fire Weather Index (FWI) (The figure is from National Wildfire Coordinating Group, https://www.nwcg.gov/publications/pms437/cffdrs/fire-weather-index-system)

5. Line 75: How to choose the positive and negative phase years of Nino 3.4?

Reply: The positive phase year of the Niño 3.4 index is determined when the absolute value of the three-month moving average surpasses 0.5°C for a minimum of five months, and the opposite holds true for the negative phase year. This definition is extensively adopted in the National Oceanic and Atmospheric Administration's (NOAA) operational El Niño Southern Oscillation (ENSO) forecasts and numerous prior investigations (Trenberth, 1997). The Niño 3.4 index dataset was acquired from the National Center for Atmospheric Research (NCAR) Climate Data Guide (https://climatedataguide.ucar.edu/climate-data/nino-sst-indices-nino-12-3-34-4-oni-and-tni).

We also added explanation of our choosing processes in Lines 97-98 and cited it here:

> *The positive phase year of Niño 3.4 is determined when the absolute value of the*

moving average of the Niño 3.4 index in three months exceeds 0.5℃ for at least five months, and vice versa (Trenberth, 1997).

6. Section 2.2: In the OBE, the monthly SST variability is added to the climate mean. However, the early sentence mentioned that the trends were added to the model. Which is right?

Reply: Sorry for the confusion and thanks for pointing this out. The monthly SST variability is added to the climate mean, instead of SST trends. We have revised the sentences in Section 2.2 in Lines 105-108 and cited them here:

The North and Tropical Atlantic Sea Surface Temperature (SST) variabilities were incorporated into the model to assess the response of meteorological variables in Australia to these remote forcings. Specifically, the monthly SST variability from 1979 to 2015 was added to the North Atlantic region (25°N-75°N) and the tropical Pacific region (20°N-20°S), with a 10° buffer zone to the north and south of each region.

7. For the OBE, the authors have run eight members. Is there any difference for the initial condition?

Reply: Thanks for pointing this out. These ensemble members have different initial conditions. We first performed CAM simulation forced by climatological forcing for eight model years. The restart files for each year are used as the initial condition of the eight ensemble members.

We also added the explanation of more details of the OBE in Lines 111-113 and cited it here:

We initially performed the CAM simulation driven by climatological forcing for *eight model years. The restart files for each year served as the initial condition for the eight ensemble members.*

8. Line 100: Both the words of “rainfall” and “precipitation” are used in this paper. Strictly, there are some differences between them. Please keep the same expression across this paper.

Reply: You are right and thanks for your helpful suggestions. Precipitation includes liquid and frozen water falling to the Earth’s surface. Rainfall only refers to liquid water. We have kept the uniform expression “precipitation” across the paper.

9. For the orders of Figures in this paper, it seemed disorder. For example, Figure 2 are mainly explained first in the main document, rather than Figure 1.

Reply: Thanks for your constructive suggestions. We have modified the main text to ensure that Figure 1 mentioned first.

10. Line 137: This sentence confused me and it not agreed well with the display in Figure 2f and i.

Reply: Sorry for the confusion and thanks for pointing this out. Surface pressure and wind speed increases are both stronger during El Niño when AMO is at its positive phase. We have revised our expression in Lines 182-184 and cited it here:

Furthermore, SLP and WND10 responses are markedly more robust during positive AMO phases compared to negative phases (Figure 2f & i). Specifically, El Niño events in the positive phase of AMO are characterized by elevated SLP and intensified surface winds.

11. Line 168: I have not found the results of OBE. To increase readability, please showing the parallel panels of OBE with reanalysis.

Reply: Thanks for your suggestions and sorry for the confusion. We apologize for not showing the parallel panels of OBE with reanalysis. This is mainly because if it is displayed in that way, the number of subplots will be 18, which may reduce the readability of this figure. In turn, we modified the expression citing the corresponding figures to increase its readability in Lines 230-232 and cited it here:

> *The consistent results in reanalysis (Figure 2) and OBE (Figure 3) suggest that the positive AMO phase, associated with warm North and Tropical Atlantic SST anomalies, induces warmer and drier weather in Australia, particularly in the southern region.*

References

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