Summary:

This manuscript connects (synoptic-scale) weather regimes and modes of climate variability including the El Niño Southern Oscillation (ENSO), the Arctic Oscillation (AO), the North Atlantic Oscillation (NAO), and the Pacific North American pattern (PNA) to April-May U.S. tornado activity using a hybrid model and composite analysis. The role of sea surface temperatures (SSTs) as a source of predictability is also assessed. The predictions from the hybrid model, which incorporates the relationship between five weather regimes and tornado activity identified over the recent (1981-2023) historical period, have a significant correlation with observed April-May tornado outbreaks, but not with tornado days. The hybrid model is found to perform better during the positive phases of the AO, NAO, PNA, and ENSO as well as the negative phases of the NAO, AO, and ENSO. Probability anomalies of tornado activity were also found to be associated with different phases of ENSO, AO, NAO, and the PNA. For instance, tornado outbreak probability was found to be enhanced during the negative phase of the AO and La Niña, whereas tornado outbreak probability was found to be diminished during the positive phases of the NAO and the PNA. The relationship between climate modes and April-May U.S. tornado activity was further assessed by compositing the large-scale atmospheric conditions during each mode's various phases. The occurrence of weather regimes was also found to be modulated by the various considered climate modes. Finally, the SST anomalies were composited relative to weather regime and active and inactive tornado activity years, indicating that North Atlantic and North Pacific SSTs could also provide a source of predictability for April-May U.S. tornado activity.

The analysis shown in this manuscript is an interesting perspective on the seasonal prediction of late spring U.S. tornado activity, incorporating sources of predictability across synoptic and climate scales. However, there are several major comments that need to be addressed before publication. The climate modes, whose influence on April-May U.S. tornado activity are considered, need to have more in depth discussion including what the modes are and why they may be a source of predictability for U.S. tornado activity. Further, these climate modes are discussed as "low-frequency" which is not correct. This language should be updated throughout the manuscript. The section which connects the various phases of the considered climate modes to the large-scale environmental conditions and tornado activity has several inconsistencies between the referenced figures and the text and should be re-worked for clarity. Finally, the authors should carefully consider the analysis of the possible role of SSTs shown in section 3.3, and whether to incorporate some of the suggested changes indicated below or remove this section from the manuscript.

Major comments:

In the introduction, there is a substantial discussion of how modes of climate variability including the ENSO, AO, and the PNA have been found to impact U.S. tornado activity in the winter and spring. Then, in the results, the role of ENSO, AO, the PNA, and the NAO in modulating U.S. April-May tornado activity is considered. However, what these climate modes are and why they impact U.S. weather and climate (e.g., why would these climate modes possibly impact U.S. tornado activity) is never discussed in the manuscript. The authors should add a discussion which defines each relevant mode and why it might offer an additional source of predictability for U.S. tornado activity (whether it has been shown in previous literature, or whether it has a known influence on other aspects of U.S. weather and climate).

In section 2.1: Weather regimes used in this paper are mentioned to be derived from Graber et al. (2025). If this is the case, the line in the abstract stating, "Using ERA5 reanalysis, we identify five April-May weather regimes from 1981-2023, some of which strongly modulate tornado activity," should be removed since they are taken from another study. Then the statement from Lines 13-15 can be rephrased to something like, "Five previously identified weather regimes are incorporated into a hybrid model to predict April-May CONUS tornado activity…" If the weather regimes are identified organically in this study, but just using the same methods as in Graber et al. (2025), then section 2.1 should be rephrased to state such and the abstract can be left as is.

There are several statements in the section running from Line 221 to Line 256 where the discussion is inconsistent with what is shown in the figures. Please re-work this discussion.

- Lines 228-229: "TD" should be replaced with "TO"
- Lines 230-232: Why would enhanced VWS in the presence of negative MUCAPE anomalies be supportive of suppressed TD activity and enhanced TO activity when AO -? Figure 5a also indicates that AO - is associated with largely positive anomalies of TD probability (except over the MW). Also, here we are looking at April-May composite anomalies of 500 hPa height, MUCAPE and VWS anomalies, so couldn't you also argue that enhanced VWS is only occurring on days where MUCAPE is already high? This sentence needs to be re-worked.
- Lines 233-234: This sentence should be rephrased to, "The TD and TO probability anomalies during the NAO phases are sometimes in agreement with those during AO phases," or something similar. There are many places where there is not consistency (e.g., for TDs - CONUS (NAO/AO +), NGP (NAO/AO -), SE (AO/NAO +); TOs - MW (AO/NAO +), NGP (NAO/AO -), SGP (NAO/AO +)). Also: why would the probability anomalies during NAO phases be consistent with that of AO phases? Why might they not?
- Lines 236-243: This section needs to be re-worked. At the beginning it is stated that during NAO + there are negative anomalies of MUCAPE, leading to reduced TD probabilities. However, Figure S2e indicates positive anomalies of MUCAPE, if anything. Additionally, the sentence from lines 240-243 states that 500 hPa height anomalies during the NAO + lead to enhanced MUCAPE and positive TO probability anomalies. This last sentence may be referring to the NAO -? Either way, these two statements are in contradiction with one another and are also not correct.

Section 3.3: Possible role of SST anomalies could use some additional consideration.

- ENSO (via the Nino3.4 index), one of the modes of climate variability that is considered in section 3.2, is defined using central and east Pacific sea surface temperature anomalies, and as such, is inherently considering the role of SST anomalies in influencing the atmosphere. Thus, this section is not necessarily independent of section 3.2.
- How would the results be different if the months of April and May were considered?
- Composite analysis considers 60 years of data, which is then composited into 10 groups (~6 samples per composite). Please add the number of samples that goes into each composite in Figure 7 (e.g., n=XX). Additionally, the reason why some of the SST fields are noisy could be due to sample size issues.
- I wonder if it might be fruitful to composite SST anomalies relative to only active and inactive tornado years, and then 500 hPa heights could also be composited in this way. Resemblance or not to weather regime anomaly patterns could connect SST fields to weather regimes and

potentially modes of climate variability. This would also increase sample size and should show a less noisy SST field.

Minor comments:

Throughout the manuscript, the authors refer to ENSO, AO, the NAO, and the PNA as “low-frequency climate modes.” In climate science, low-frequency climate modes are known to be those that operate on decadal to multidecadal timescales (e.g., the Pacific Decadal Oscillation, Atlantic Multidecadal Variability). ENSO is known to be an interannual mode of climate variability (Bjerknes, 1969), while AO, NAO, and the PNA are intraseasonal climate modes (Hurrell, 1995; Thompson & Wallace, 1998; Wallace & Gutzler, 1981). Please change the wording in the general description of these climate modes from “low-frequency climate modes” to something like “modes of climate variability.”

In section 2.1, the authors mention removing the seasonal cycle from April-May 500 hPa heights, but they do not mention detrending. Given the recent warming trend, the authors should detrend the 500 hPa heights before any other analysis (as they mentioned doing in Graber et al. (2025). Additionally, the authors should elaborate more on the method used to identify the considered weather regimes. Are just the same weather regimes that are identified in Graber et al. (2025) used for this analysis, or is the same method used to identify the weather regimes considered here?

In the introduction paragraph from Lines 66-80 which discusses that weather regimes fill the gap between tornado activity and modes of climate variability, can you please discuss a bit more how weather regimes fill this gap. For example, if tornado activity is largely a mesoscale phenomena, and climate modes have global impacts (and longer time scales), where do weather regimes fit into the continuum (e.g., synoptic scale)?

In lines 216-220, several regions of the U.S. are described. Please show the delineation of these regions in a supplementary figure. This is particularly important given the later discussion which looks at anomalies of TD and TO probabilities over the CONUS and regionally.

Line-by-line comments:

- Line 29: Tornado outbreaks (TOs) should be defined here.
- Line 41: Madden Julian Oscillation should be written out in words.
- Line 43: El Niño Southern Oscillation should be written out in words.
- Line 87: ERA5 should be written out as the “European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis, version 5 (ERA5).” Then, in line 96, ECMWF can just be written out.
- Lines 96-104: Please elaborate on how far out ECMWF seasonal forecasts go out (i.e., up to seven months in the future)
- Lines 108-110: Are tornado outbreaks and tornado days defined in this way by any other literature other than Graber et al. (2024) and Graber et al. (2025)? Are there other definitions of tornado outbreaks and tornado days that have been previously used? If so, why was this particular definition selected?
- Line 120: No need to cite Graber et al. (2025) again as it was cited at the beginning of the paragraph.

- Lines 141-142: “ENSO3.4” → “Nino3.4”
- Lines 147-148: “... where the climatological mean TD probability (P_c) is defined as the total number of TDs divided by the total number of days; P_r is TD probability for the given phase of the climate mode…” → “... where the climatological mean TD **(TO)** probability (P_c) is defined as the total number of TDs **(TOs)** divided by the total number of days; P_r is TD **(TO)** probability for the given phase of the climate mode…”
- Lines 153-154: “WR-A features anomalous highs over both the western and eastern U.S. coasts.” → “WR-A features anomalous highs centered over the Pacific Northwest and off of the U.S. east coast.”
- Line 155: “Southeast” → “southeast”
- Line 156: Remove “CONUS”
- Lines 161-162: “The impacts of the WRs on tornado activity in the CONUS…” → “The impacts of the WRs on CONUS tornado activity…”
- Lines 163-165: Please briefly describe why certain weather regimes are more or less favorable for tornado activity.
- Line 183: “(Fig. 3a-b)” → “(Fig. 3)”
- Lines 305: Why do you restrict analysis in the earlier part of the study to 1981-2023, if 1960-2023 are going to be considered for section 3.3.?
- Lines 305-307: Do you mean to say that, “For each WR, active and inactive years are identified as the years when the spring time **tornado** count of the WR exceeds +/-1 standard deviation,”?
- Figure 1: The legends for Figure 1f and Figure 1h are incorrect. What do the light green bars in 1f represent? What do the pink bars in 1h represent? Are these bars the thin lines in the legend?
- Figure 5g and 5h: “positive” and “negative” might be changed to “El Niño” and “La Niña” for clarity.
- Figure 7: “500H anomalies are shown in black contours.” → “500H anomalies are shown in gray contours.”

Citations

Bjerknes, J. (1969). ATMOSPHERIC TELECONNECTIONS FROM THE EQUATORIAL PACIFIC. Retrieved from https://journals.ametsoc.org/view/journals/mwre/97/3/1520-0493_1969_097_0163_atftep_2_3_co_2.xml

Graber, M., Wang, Z., & Trapp, R. J. (2025). Linking weather regimes to the variability of warm-season tornado activity over the United States. Weather and Climate Dynamics, 6(3), 807–816. https://doi.org/10.5194/wcd-6-807-2025

Hurrell, J. W. (1995). Decadal Trends in the North Atlantic Oscillation: Regional Temperatures and Precipitation. Science, 269(5224), 676–679. https://doi.org/10.1126/science.269.5224.676

Thompson, D. W. J., & Wallace, J. M. (1998). The Arctic oscillation signature in the wintertime geopotential height and temperature fields. Geophysical Research Letters, 25(9), 1297–1300. https://doi.org/10.1029/98GL00950

Wallace, J. M., & Gutzler, D. S. (1981). Teleconnections in the geopotential height field during the Northern Hemisphere winter, 109, 784–812.