Toward Understanding Climatic Influences on Cold-Season Tornado Events

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INTRODUCTION & BACKGROUND

While U.S. tornadoes are most common during spring months, destructive "cold-season" tornado events, defined in this study as occurring during the months of November–February (NDJF), can be particularly dangerous for the unsuspecting public. Recent cold-season tornado outbreaks (e.g. 5-6 February 2008, 17 November 2013) motivate research into their climatic influences, predictability, and comparison with springtime tornado environments. Previous investigation of cold-season tornadoes has focused on their relationship to ENSO, but other factors certainly exist. This study aims to explore climatic influences from thermodynamics, kinematics, oceanic signals, and teleconnections on the frequency of cold-season tornadoes through a case study analysis of the most and least tornadic cold seasons, as well as address their climatic trends through time.

Four regions are defined for analysis, and (E)F1-(E)F5 tornado counts are taken from the SPC *Storm Data* archive. Daily and monthly values of dynamic and thermodynamic variables are taken from the Climate Forecast System Reanalysis (CFSR) for the period 1979-2014. Teleconnection indices are provided by Climate Prediction Center archives, and SST anomalies are taken from the Extended Reconstructed Sea Surface Temperature (ERSST) database.

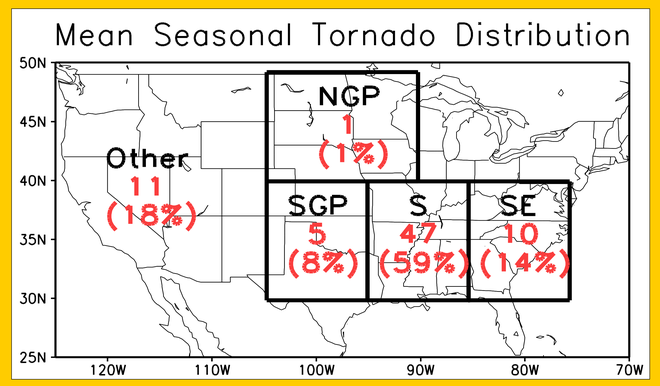

Fig. 1: Mean NDJF tornado counts across distinct regions for the period 1979-2014.

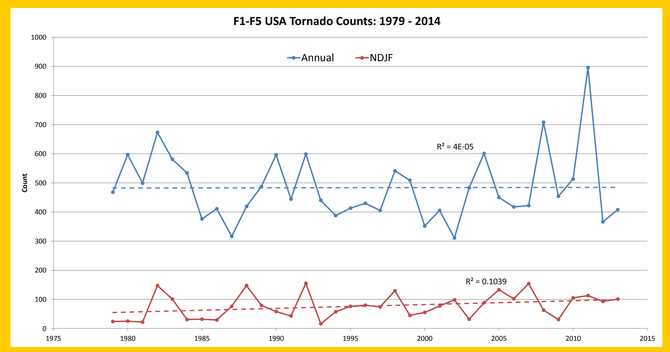

Fig. 2: Time series of (E)F1 - (E)F5 annual and NDJF tornado counts for 1979-2014.

- The majority of NDJF tornadoes occur in the South region (Fig. 1).
- Annual counts show no trend through time, but NDJF counts show an 81% increase from 1979-80 to 2013-14, although great variability exists (Fig. 2).

CASE STUDY: Most Active vs. Least Active Seasons

CAPE & 0-6km Shear

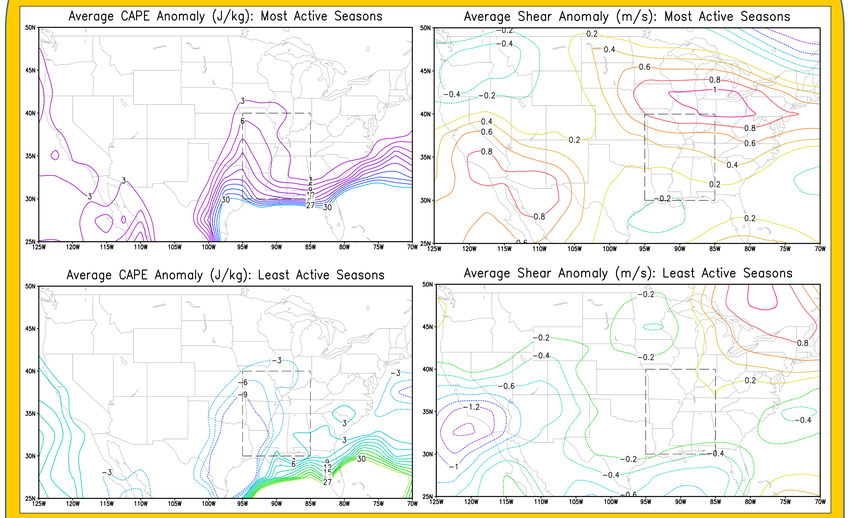

Fig. 3: CAPE (left) and shear (right) anomalies for most tornadic (top) and least tornadic (bottom) cold seasons. The most-active South region is boxed.

- CAPE is strongly correlated in the South region, with positive anomalies in the most active seasons and negative anomalies in the least active seasons.
- Vertical shear shows little to no correlation to tornado counts in the South region.

Pacific Ocean Sea Surface Temperatures

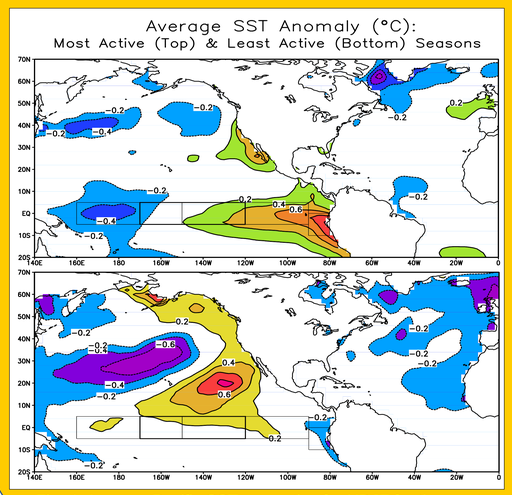

Fig. 4: Average Pacific SST anomalies for NDJF for the most tornadic (top) and least tornadic (bottom) cold seasons

- Mean SST anomalies for Niño Region 3.4 are near 0 for both cases.
- More cold-season tornadoes are seen during La Nina, but each of the 3 most tornadic seasons represent a different ENSO phase.
- ENSO drives spatial shifts in tornado distribution by altering the position of the mean jet stream.
- Strong correlation exists between the TransNiño Index (TNI) and cold-season tornado frequencies.

Large-Scale Circulation / Teleconnections

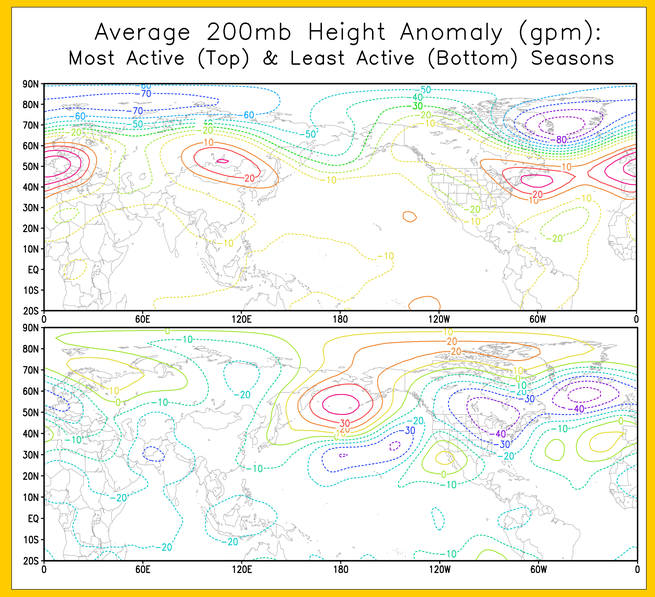

Fig. 5: Mean 200mb height anomalies for the most tornadic and least tornadic cold seasons.

- An anomalous trough in the western U.S. and an anomalous ridge in the eastern U.S. are seen during the most active seasons.
- Mostly negative anomalies are present across the U.S. for the least active seasons.
- The upper-level pattern for the most and least active seasons resembles the positive and negative phase Arctic Oscillation, respectively. A strong correlation exists between the mean NDJF AO Index and the NDJF tornado count anomaly.

CONCLUSIONS

- **NDJF tornado counts are increasing across the United States, especially in the South, although large interannual variability exists.**
- **CAPE is correlated to NDJF tornado counts in the South, but vertical shear is not.**
- **Pacific SST anomalies for the most active cold seasons are indicative of a positive phase TNI pattern, but no appreciable relationship can be found between ENSO phase and tornado frequency.**
- **The anomalous upper-level trough and ridge pattern during the most active cold seasons is favorable for severe weather and tornadoes in the south and southeastern U.S.**
- **The most active cold seasons are linked with a positive phase AO, which indicates lower heights in the Arctic region, and thus a lack of cold air intrusion southward toward the U.S.**

References

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