Identifying Teleconnections Between Southeastern US Tornado Outbreaks and Daily Climate Indices

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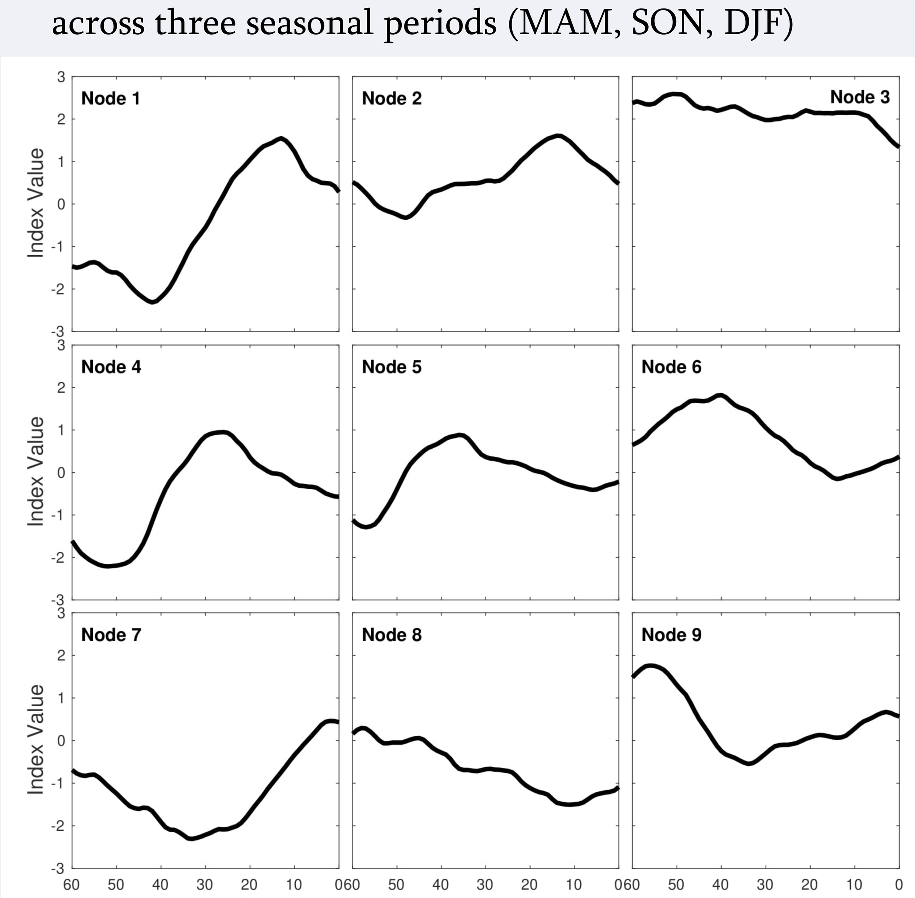
Background

Recent literature has sought to improve our understanding of southeastern US tornadoes due to their deviation from traditional storm characteristics in terms of diurnal and seasonal timing, as well as storm environment (e.g. high-shear low-CAPE, or HSLC environments). Numerous studies have also attempted to relate global circulation patterns, such as El Niño Southern Oscillation (ENSO), to CONUS hail and tornado prevalence towards improving subseasonal and seasonal forecasting. Few studies, however, have considered the intersection of these two topics.

This study utilizes a self-organizing map (SOM) technique to characterize the predominant modes of variability in numerous daily climate indices – Arctic Oscillation (AO), North Atlantic Oscillation (NAO), Pacific-North American (PNA) pattern, East/West Pacific Oscillation (EPO/WPO), and both raw and detrended Gulf of Mexico SST anomalies (SSTA/SSTAD) – in advance of Southeast severe convective (SC) days. The spatiotemporal characteristics of the storm reports coincident with these patterns are considered. Furthermore, the regional environments corresponding with these patterns are examined in order to provide a physical link between climate-scale variability and Southeast storm environments, with particular consideration being given to HSLC environments.

Self-Organizing Map Design

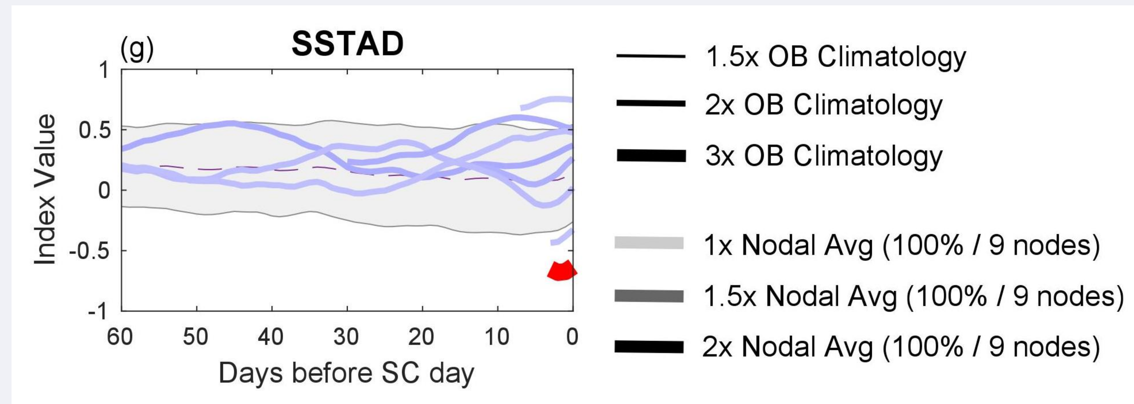
- **SC day:** 12Z -12Z period with > 5 hail or severe wind reports, or >= 1 tornado report in domain
- Reports associated with tropical cyclones filtered out following methodology of Edwards (2010)
- Climate indices preceding SC days were gathered at 5 lead times (3 days, 1 week, 2 weeks, 1 month, and 2 months) to span possible temporal scales of influence
- 3 x 3 SOM created for each pattern and lead time across three seasonal periods (MAM, SON, DJF)



Node Significance Testing

- **Test 1:** Student's t-test to determine if the fraction of outbreak (OB) days grouped in a node exceeds seasonal climatology
- **Test 2:** Determine if a node accounts for an above average (> 100% / 9 nodes per SOM ≈ 11.11%) fraction of OB days, indicative of its predictive value
- Same process carried out for null OB patterns as well
- Resultant patterns (both favorable and null) are composited across tested lead times for each teleconnection pattern
- For example, SON SSTAD (shown below) contains an OB pattern consisting over strong, negative anomalies over a period of 3 days

⇩ OB patterns associated with SON SSTAD (favorable patterns in red, null patterns in blue, average SC pattern in dotted purple with ±1 standard deviation shaded in gray)



- Overlap with these null patterns and consistency across other SOM dimensions (i.e. different size SOM configurations) was also taken into consideration when selecting nodes for additional physical analysis

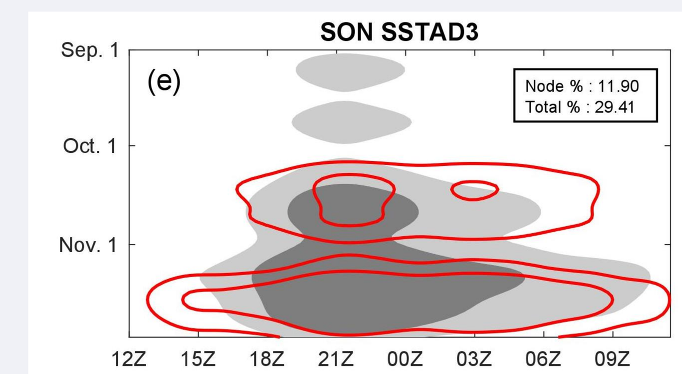
Comparison with Literature

- Select patterns shown below for comparison with literature
- For each pattern, studies consistent with said pattern are shown in green, contrasting shown in red, and inconclusive in black

Season	Pattern/Lead	Type of Pattern	Related Literature
MAM	NAO30	Positive to negative	Elsner et al. (2016)
	PNA60	Sustained negative	Munoz and Enfield (2011) Allen et al. (2015) Cook et al. (2017)
SON	NAO30/60	Negative to positive	Elsner et al. (2016)
	SSTA/SSTAD3	Sustained negative	Thompson et al. (1994) Edwards and Weiss (1996)
DJF	AO30	Positive to neutral	Childs et. al (2018)
	NAO30	Sustained positive	Elsner et al. (2016)
	SSTAD14	Negative to positive	Edwards and Weiss (1996)

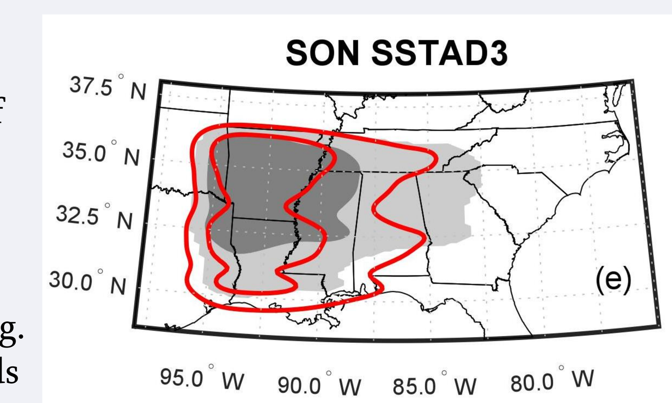
Spatiotemporal Distribution

- Kernel density estimates (KDEs) of temporal and spatial characteristics of storm reports associated with OB node patterns and seasonal climatology were computed



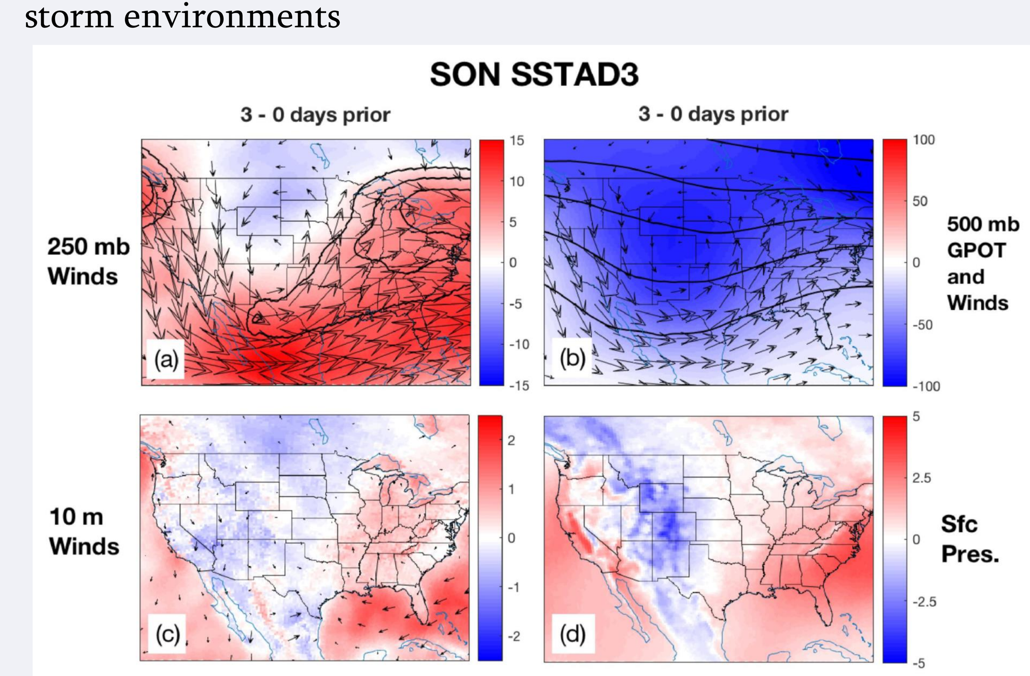
⇦ Temporal (left) and spatial (below) KDEs for SSTAD3, with 70th and 90th percentile contours (climatology in gray, nodal distribution in red)

- Numerous cool season patterns exhibit diurnal broadening, indicative of nocturnal storms
- Spatial maps vary by teleconnection and their physical mechanisms (e.g. SSTA nodes skew towards Gulf Coast)

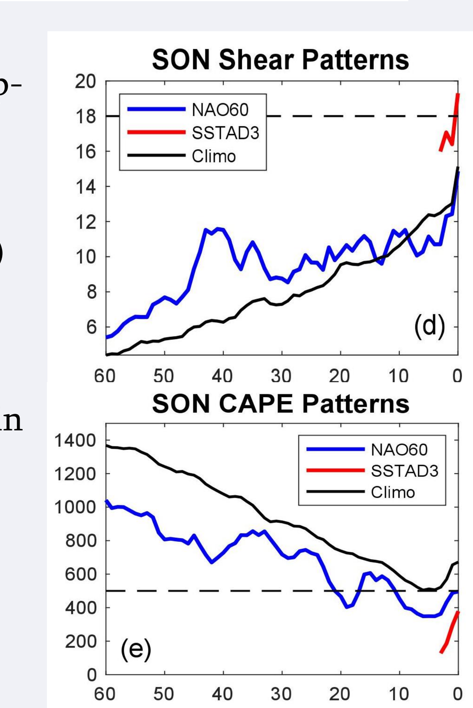


Environmental Characteristics

- Synoptic composite anomalies (relative to SC climatology) computed to highlight the influence of OB patterns on regional storm environments



- Time series of thermodynamic and kinematic variables (e.g. CAPE and deep-layer shear) coincident with select OB patterns also considered
- HSLC conditions (in dotted black, right) gauged using criteria put forth in Sherburn and Parker (2014)
- For some OB patterns (especially those in MAM), regional conditions support increased CAPE and shear
- Several cool season patterns (such as SSTAD3) exhibit reduced CAPE and enhanced shear partially in response to the synoptic regime in place



Conclusions

1. Self-organizing maps are capable of identifying patterns of climate-scale variability which bear physical relationship with Southeast US storm environments, particularly tornado outbreaks.
2. AO and NAO are strongly related to Southeast outbreaks at longer leads times of 1-2 months, while the influence SSTA/SSTAD patterns are largest on a shorter time scale of 3 days.
3. The ramifications of these OB patterns are both dynamic, via modulation of jet stream position (and thus, cyclone track) and regional shear values, and thermodynamic, via alteration of lower tropospheric flow patterns and influx of Gulf moist instability.
4. Net effect of these regional effects vary by season:
   a. **Spring months** → high-shear, high-CAPE conditions supported by both season and synoptic regime in place
   b. **Fall months** → high-shear, low-CAPE conditions, uniquely invigorated by teleconnection patterns
   c. **Winter months** → high-shear, low-CAPE conditions, but as a result of the season

Future Research Directions

- Explore environmental characteristics of unexamined patterns and null patterns
- Expand SOM methodology to different regions, time periods, and climate indices
- Rework SOM methodology to identify patterns of multidimensional data (as in Anderson-Fry et al. 2017) conducive to tornado outbreaks, and determine teleconnection patterns corresponding to these patterns after the fact

⇦ **Scan QR code to link directly to Brown and Nowotarski (2020) for full results and analysis.**

References

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