Winter Significant Tornado Variability in Relation to ENSO and the Gulf of Mexico

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OBJECTIVES

1. How do Gulf of Mexico (GoM) sea surface temperature anomalies (SSTAs) and phases of the El Niño-Southern Oscillation (ENSO) influence winter (December, January, and February; DJF) significant (EF2+) tornado frequency and favorable environments?
2. Do more intense El Niño and La Niña events lead to greater modulation of significant tornado activity and environments across the contiguous United States (CONUS)?
3. Does a particular ENSO index, such as the Oceanic Niño Index (CPC 2016) or Modoki index (Ashok et al. 2007), exhibit a stronger interrelationship with significant tornado variability?

MOTIVATION

- Allen et al. (2015) and Cook et al. (2017) demonstrated that winter tornado frequency increases across the Midwest during La Niña and across the Gulf Coast during El Niño, but substantial tornado variability *remains unexplained* by ENSO. Unexplained tornado variability could be related to influences from GoM SSTAs (Molina et al. 2016), the degree of El Niño or La Niña intensity, and internal variability of ENSO atmospheric and oceanic components.
- Significant tornadoes account for >95% of tornado-related fatalities and DJF tornadoes are rated significant *more frequently* than those of other seasons.
- DJF tornadoes have a decreased diurnal cycle and are climatologically favored in the densely populated southeast CONUS, with long-term trends showing that risk exposure and tornado occurrence are increasing in the Southeast (Ashley and Strader 2016; Krocak and Brooks 2018; Childs et al. 2018).

DATA

- DJF significant tornadoes were sourced from NOAA's Storm Prediction Center storm report database (Schaefer and Edwards 1999).
- Oceanic Niño Index (ONI; CPC 2016) was used to classify ENSO-neutral (-0.5<ONI<0.5), El Niño (ONI≥0.5), and La Niña (ONI≤-0.5).
- NOAA's NCEI Optimum Interpolation (OISST) and Advanced Very High Resolution Radiometer (AVHRR) daily temporal and 0.25° spatial resolution SSTs were employed for analysis (Reynolds et al. 2007) and linearly detrended using least squares regression.
- 32-km and 3-hourly temporal resolution North American Regional Reanalysis (NARR; Mesinger et al. 2006) was used to derive the frequency of significant tornado parameter (STP; Thompson et al. 2003) ≥1 events, associated with significant tornado frequency.

The most active significant tornado DJFs occurred during strong El Niño and La Niña events with positive GoM SSTAs (α=0.05), which is physically reasonable:

- La Niña shifts the polar jet stream northward over the northern Pacific Ocean, increasing meridional flow and cyclogenesis downstream.
- El Niño intensifies the subtropical jet over the Gulf Coast resulting in stronger winds aloft (Allen et al. 2015; Cook et al. 2017).
- Positive GoM SSTAs enhance evaporative fluxes and moisture available for advection northward towards the CONUS preceding severe thunderstorm events.

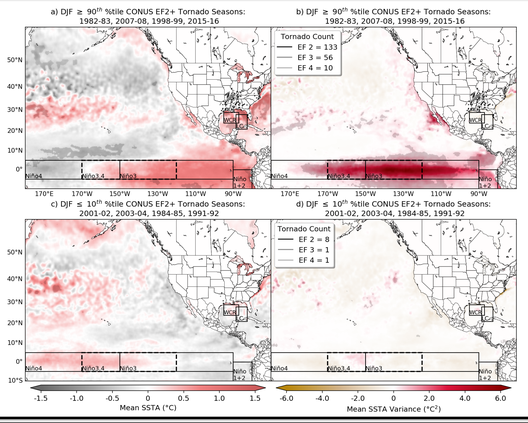
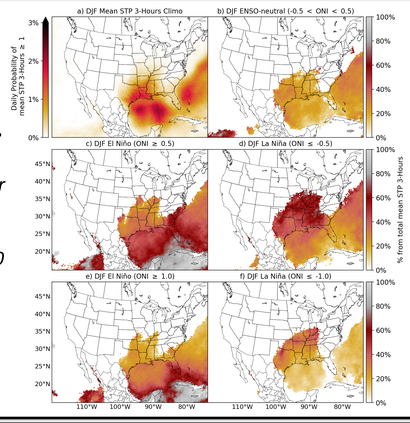


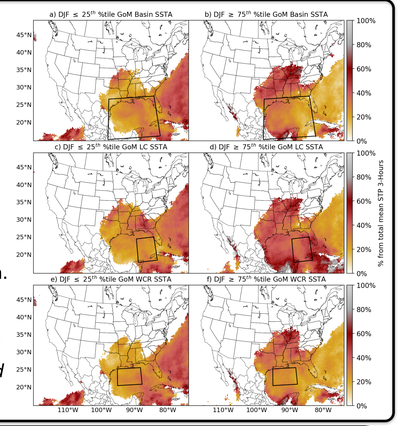
Figure 1 (left): SSTA mean (a, c) and variance (b, d) from DJF climatology (1981-2016) during the ≥90th %tile and ≤10th %tile of ranked significant tornado seasonal totals for the CONUS. Two-tailed statistical significance determined using a 20,000 member Monte Carlo distribution of bootstrap anomalies from climatology, as indicated with stippling.

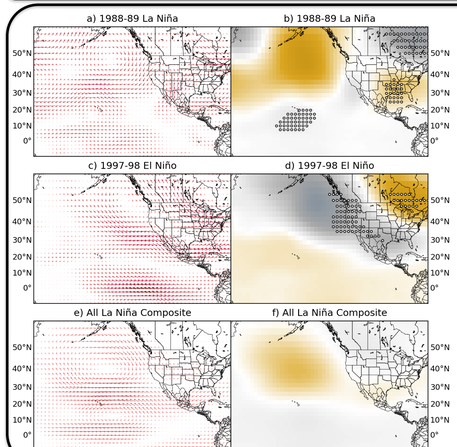


Most STP ≥1 events in DJF occur from eastern Texas to southern Missouri, but ENSO and the GoM modulate climatology.

- El Niño and La Niña phases coincide with more STP ≥1 events than ENSO-neutral phases; La Niña STP ≥1 events peak across the Midwest and El Niño STP ≥1 events peak across Florida.
- Moderate-to-strong La Niña phases do not favor STP ≥1 events from Florida to the Mid-Atlantic.
- Positive GoM SSTA DJFs coincide with more STP ≥1 events.

Figures 2 (left) and 3 (right): DJF climatology of mean STP 3-Hours, with mean STP 3-Hours defined as the occurrences of STP ≥1 per 3-h. *DJF daily probability of STP ≥1 (2a), and percent total of STP ≥1 during ENSO-neutral (2b), El Niño (2c), La Niña (2d), moderate-to-strong El Niño (2e) and La Niña (2f), and during the ≥75th %tile and ≤25th %tile of GoM basin (3a,b), Loop Current (LC) region (3c,d), and warm core ring (WCR) region SSTAs (3e,f; Vukovich 2007).*

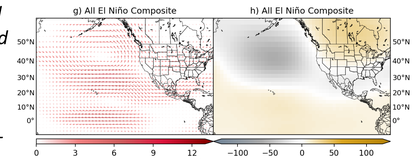


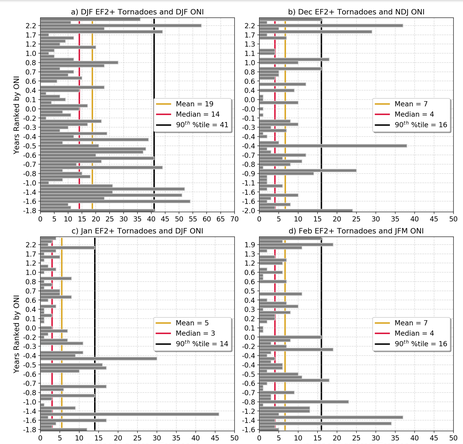


Why do some strong ENSO events result in low significant tornado frequencies?

- 1988-89 Strong La Niña (DJF ONI: -1.7): Unfavorable upstream jet dynamics resulted in fewer significant tornadoes and anomalous ridging in the Southeast.
- 1997-98 Strong El Niño (DJF ONI: 2.2): Anomalous upstream troughing contributed to an intensified and southerly displaced subtropical jet, which reduced favorable kinematics across the Southeast and resulted in fewer significant tornadoes. GoM SSTs were also anomalously cool; potentially a result of increased cloud cover from jet influences (Park and Leovy 2004).

Figure 4 a-h: 88-89 La Niña and 97-98 El Niño 300-hPa winds and 500-hPa geopotential height anomalies from corresponding ENSO phase climatology using NOAA NCEP Reanalysis II (1979-2016) ; α=0.05 as in Figure 1.

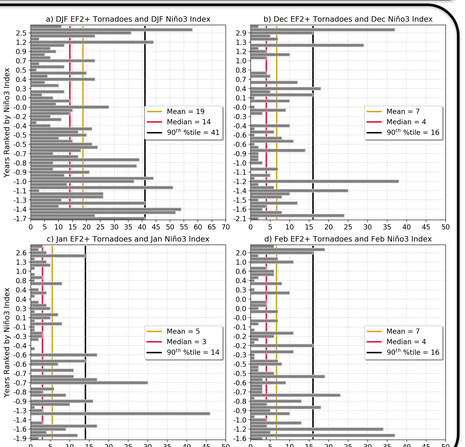




Both ONI and Niño-3 SSTs capture ENSO influences on significant tornado activity analogously.

- The 3-month running mean used in ONI does not obscure the relationship between the oceanic component of ENSO and significant tornadoes.
- On a monthly basis, La Niña exerts a greater influence on significant tornado frequency in January and February.
- Relationships between significant tornado frequency and Niño-1+2, Niño-4, and the Modoki (Ashok et al. 2007) indices were unclear.

Figures 5 (left) and 6 (right): significant tornadoes (1953-2016) ranked by ONI and Niño-3 index. Niño-3 index derived from Niño-3 region SSTAs using 1981-2010 as a base period.



CONCLUSIONS

1. DJF significant tornado frequency and favorable environments increase across the Midwest (Gulf Coast) during strong La Niña (El Niño) events, especially when concurrent with positive GoM SSTAs.
2. Strong ENSO events are related to increased significant tornado occurrences, but also exhibit high variability, with some coinciding with low significant tornado totals. Thus, strong El Niño and La Niña events yield higher uncertainty in seasonal predictability.
3. ONI and Niño-3 index relationships with DJF significant tornado activity are comparable, which contrast the inconclusive results of Niño-1+2, Niño-4, and Modoki (Ashok et al. 2007) indices.

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Data links: NOAA SPC (http://www.spc.noaa.gov/wcm/), NOAA CPC (http://www.cpc.ncep.noaa.gov/data/indices/oni.ascii.txt), IRI (http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCDC/.OISST/.version2/.AVHRR/.sst/), NOAA ESRL (https://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis2.html), and NARR STP from Prof. Gensini.

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This poster displays work published in the following article, which can be provided upon request:
Molina, M. J., J. T. Allen, and V. A. Gensini (2018). "The Gulf of Mexico and ENSO Influence on Subseasonal and Seasonal CONUS Winter Tornado Variability." *Journal of Applied Meteorology and Climatology*.