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Gulf of Mexico Influence on Sub-seasonal and Seasonal Severe Thunderstorm Frequency

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1. Introduction

Considerable year-to-year variability is evident in the Storm Prediction Center (SPC) tornado data set, despite inherent non-meteorological limitations (Fig. 1 left panel; Verbout *et al.*, 2006; Doswell *et al.*, 2009; Edwards *et al.*, 2013). Year-to-year variability is also present when considering billion-dollar severe thunderstorm disaster events (Fig. 1 right panel; Smith and Matthews, 2015). A better understanding as to why tornado activity can vary considerably from one year to the next can help the public and insurers better prepare for future severe thunderstorm activity. Previous studies have identified relationships between the climate system and severe thunderstorms during the winter (DJF) and spring (MAM) seasons, including the El Niño-Southern Oscillation (ENSO; Allen *et al.*, 2015; Cook *et al.*, 2017) and Gulf of Mexico (GoM) sea surface temperatures (SSTs; Molina *et al.*, 2016). La Niña has been related to increases in the frequency of tornadic activity across areas east of the Rocky Mountains, due increased leeside cyclogenesis and meridional flow (Allen *et al.*, 2015; Cook *et al.*, 2017). In contrast, El Niño has been associated with decreases in tornado frequency inland of the Gulf Coast (Allen *et al.*, 2015; Cook *et al.*, 2017). Warm (cold) GoM SSTs serve as a source of increased (decreased) moisture and buoyancy for advection towards the contiguous United States (CONUS), potentially contributing to severe thunderstorm development (Molina *et al.*, 2016).

2. Methodology

In order to explore the year-to-year variability associated with tornadic activity, the GoM, and ENSO, this study uses the significant tornado parameter (STP; Thompson *et al.*, 2003), serving as an environmental proxy of significant tornadoes (F/EF2+). STP values greater than one have been associated with most F/EF2 or greater intensity tornadoes, while STP values less than one have been associated with mostly non-tornadic

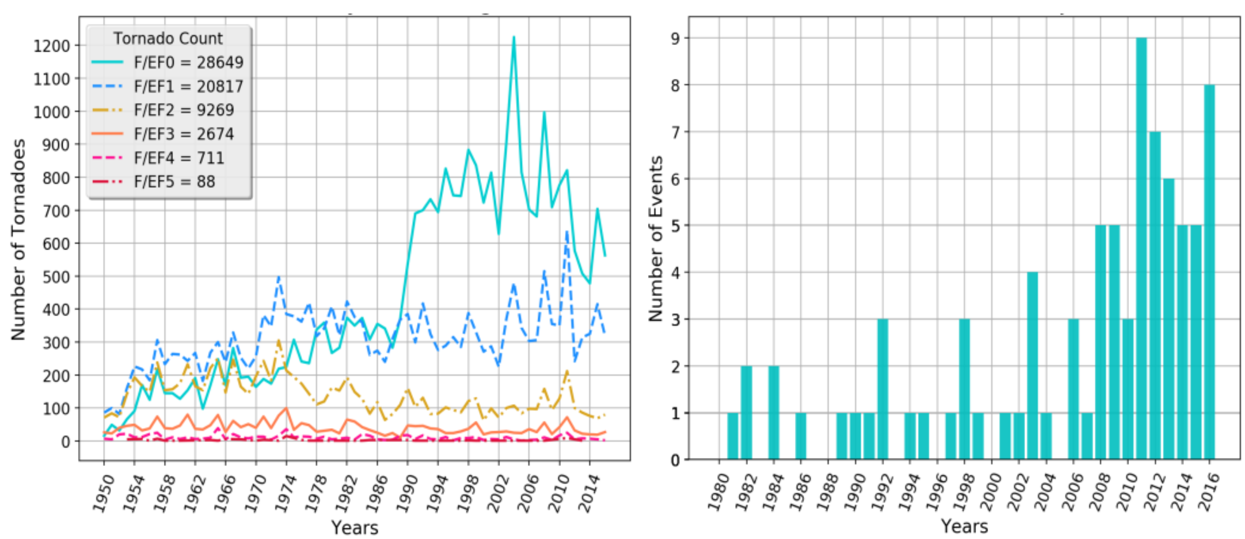

Fig. 1 Tornadoes (1950-2016) in the U.S. stratified by E/EF intensity (left) and billion-dollar severe thunderstorm disaster events (Consumer Price Index (CPI) adjusted; right).

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supercells (Thompson *et al.*, 2003). Mirroring the formulation from Thompson *et al.*, (2003) and Gensini and Marinaro, (2015), STP as used in this study is:

$$STP = \frac{sbCAPE}{1500\ J\ kg^{-1}} \times \frac{(2000 - sbLCL)}{1000\ m} \times \frac{SRH01}{150\ m^2\ s^{-2}} \times \frac{BWD06}{20\ m\ s^{-1}}$$

where sbCAPE is surface-based convective available potential energy, sbLCL is surface-based lifting condensation level, SRH01 is storm relative helicity from 0-1 km, and BWD06 is bulk wind difference from 0-6 km (Thompson *et al.*, 2003). Using the North American Regional Reanalysis (NARR; 1982-2016) data set of 32 km horizontal grid spacing and 3-hourly temporal resolution (Mesinger *et al.*, 2006), a binary data set was constructed from STP. Grid cells with STP ≥ 1 were assigned a value of 1, and grid cells with STP < 1 were assigned a value of zero (named "STP Hours" in this study), where STP Hours encompass a 3-hour time period. A climatology of STP was constructed for DJF and MAM (Fig. 2).

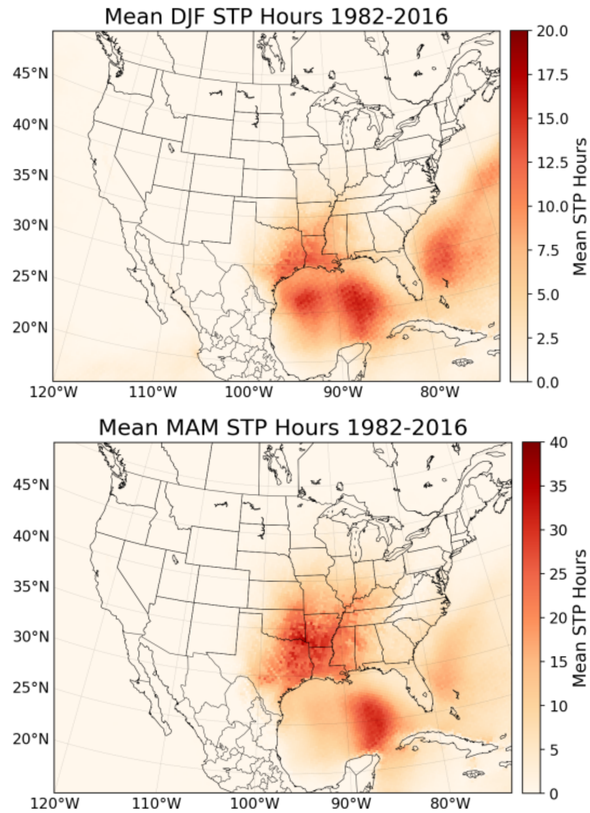

Fig. 2 1982-2016 DJF (top) and MAM (bottom) STP Hours climatology.

The climatology of DJF 3-hourly mean STP Hours shows values of approximately 10-15 hours across southeast Texas, Louisiana, and southern Arkansas, which is equivalent to about 45 hours of STP ⩾ 1. MAM 3-hourly mean STP Hours shows values of greater magnitude than DJF, of approximately 20-40 from eastern Texas to the mid-south region. This is equivalent to approximately 5 full days of STP ⩾ 1. A series of composite analyses were run using daily, 0.25-degree resolution SST anomalies (SSTAs; Reynolds *et al.*, 2007) and STP Hours, to explore the relationship between GoM SSTA variability and a favorable tornadic environment. Statistical significance was determined using a 95-percentile, two-tailed test from a bootstrapped set of composite differences.

3. Results

Results show that during DJF, the warmest quartile (25%) of GoM SSTAs results in a significant 50-66% increase in STP Hours frequency from northeastern Texas to the Great Lakes region, while the coldest quartile results in a 20-33% decrease in STP Hours frequency across the south (Fig. 3 upper two panels). MAM results show that the warmest GoM quartile results in a significant increase in STP Hours frequency across central Texas, while the coldest GoM quartile results in a significant decrease in STP Hours frequency across the Great Plains (Fig. 3 lower two panels). These results are physically plausible; warmer GoM SSTs make low level moisture more readily available for advection to the CONUS (east of the Rockies), resulting in greater buoyancy available for storm development. These results are consistent when considering ENSO-neutral years (not shown), suggesting that GoM SSTs can serve as an independent predictand for MAM and potentially DJF severe thunderstorms, during ENSO and ENSO-neutral years. It is important to note that a favorable tornado environment does not necessarily lead to convective initiation, and that a number of other severe thunderstorm formation ingredients are necessary in the development of severe convection. Additionally, the STP parameter applied for this analysis is not without limitations. STP is calibrated for identifying conditions favorable to strong tornadoes produced by discrete supercells, and was formulated primarily for the Great Plains, and thus does not account for all strong tornado events (Thompson *et al.*, 2003). Thus, STP will not capture the full range of possible tornado environments. Overall, the results here suggest that GoM weights the likelihood of severe thunderstorm activity and should be considered a predictor for subseasonal and seasonal forecasts of convective weather.

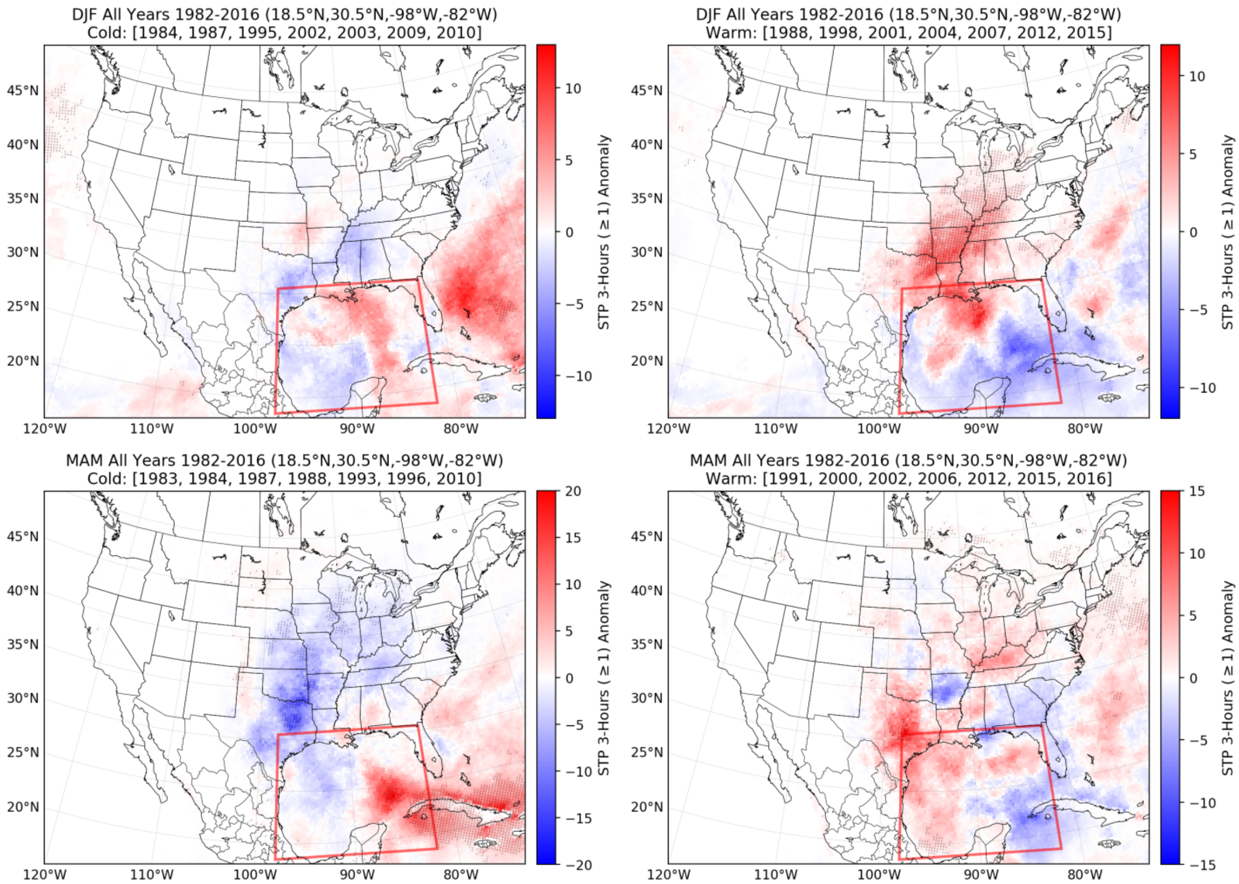

Fig. 3 GoM coldest (left column) and warmest (right column) SST quartile composites of STP Hours anomalies for DJF (upper panels) and MAM (lower panels).

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