Diurnal Variability in Tropical Cyclone Tornado Occurrence

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1. Introduction

Motivation

- Tornadoes account for 3% of fatalities in landfalling tropical cyclones (TCs; Rappaport 2014);
- Prior work has shown a pronounced peak in tropical cyclone tornado reports during the late morning into the evening (McCaul Jr. 1991; Schultz and Cecil 2009);
- Moreover, there is weaker diurnal variability associated with tornadoes in the inner TC core (i.e., ≤200 km from TC center) compared to those in the outer region (i.e., ≥200 km from TC center; Schultz and Cecil 2009);
- However, the spatial variability of the diurnal cycle of TC tornadoes has not been well-documented;

Objective and Hypothesis

Objective: This study aimed to examine the diurnal variability in the location of TC tornadoes. We hypothesize that the tornadoes that occur either further from the TC center or the coast have stronger diurnal variability.

2. Methodology

Datasets

- **TC track data:** 6-h TC data during 1995–2020 from IBTrACS Best-Track are examined (Knapp et al. 2010);
- **TC tornado data:** tornado track and damage data during 1995–2020 from SPC TCTOR are studied (Edwards 2010);
- **Coastal data:** Data from the 1-km × 1-km Global Self-consistent, Hierarchical, High-resolution Geography (GSHHG) are used to calculate the distance of tornadoes from the U.S. coastline (Wessel and Smith 1996);

Methods

- **Part of our analysis categorizes tornado reports by their distance from coastlines according to the terciles of the distribution:**
  1. Coastal (0–33rd percentile of TC tornado distance from coast)
     a. <21 km
  2. Transition (–66th percentile)
     a. 21–122 km
  3. Inland (66–100th percentile)
     a. >122 km
- Our analysis analyzes how the diurnal variability of TC tornadoes changes as a function of: 1) geographical and 2) TC-relative location.

3. Results: Diurnal Variability of TC-Relative Location of Tornadoes

Overview

Determine the sensitivity of diurnal variability in tornado occurrence with distance from TC center.

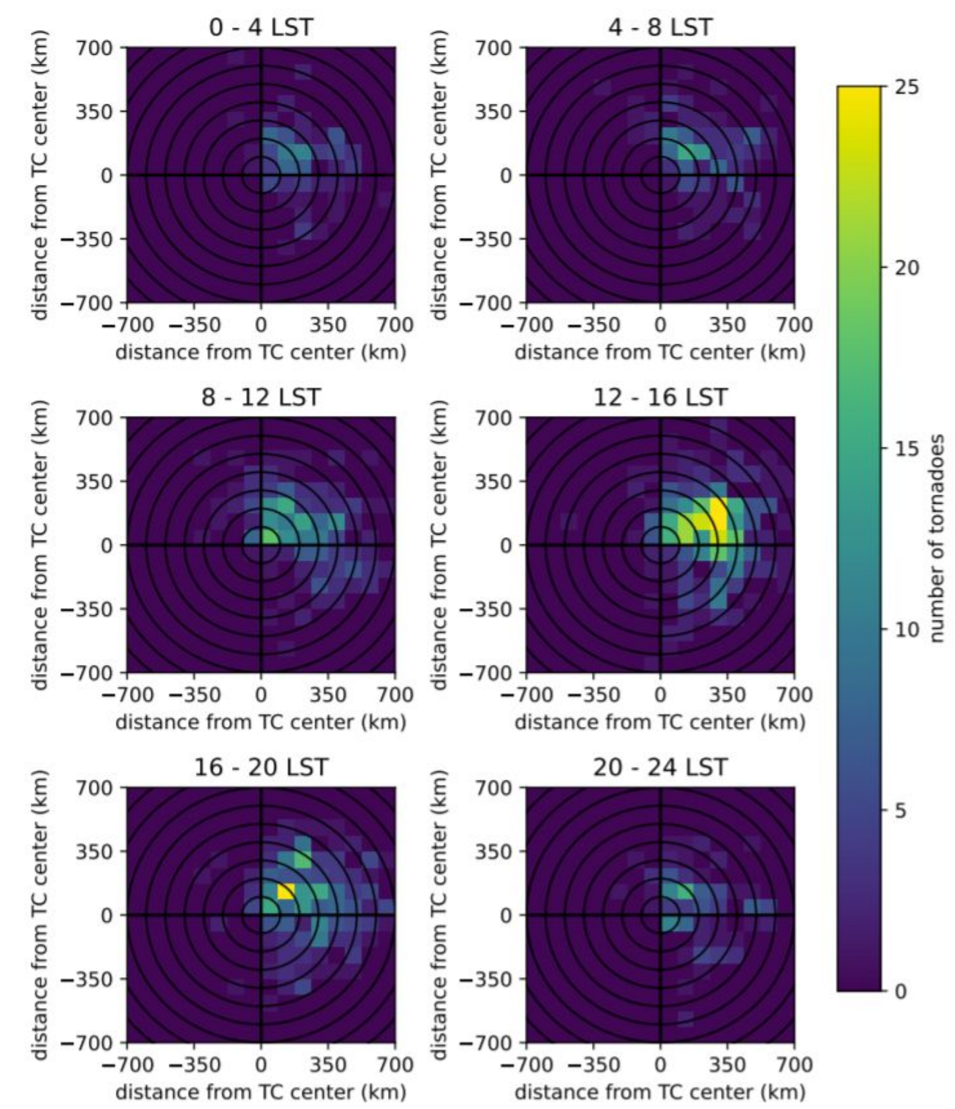

Figure 1: TC-relative plot of number of tornadoes in a true-North coordinate separated into 4-h LST bins. Range rings are every 100 km.

Synopsis

1. Outer region of northeast quadrant shows great variability in tornado occurrence with a sharp peak in activity concentrated between 12–16 LST (Fig. 1);
2. Inner-core diurnal variability is comparatively muted in easter (Fig. 1);
3. Variability is strongest between 100–500 km from TC center with the sharpest peak at the 300–400 km radial bin (Fig. 2);
4. Peak occurrence of tornadoes also differs slightly among radii with a 12–14 LST peak for the 100–300 km bin, and 14–16 LST for the 300–500 km bin (Fig. 2);

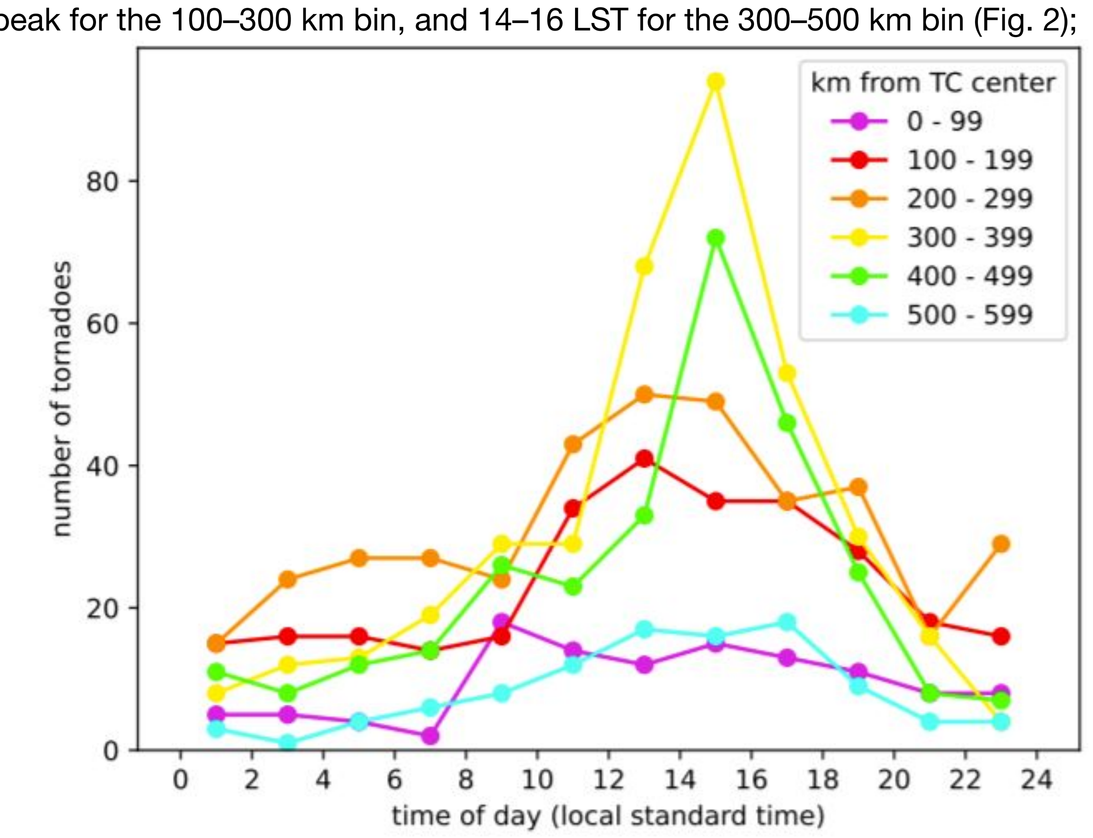

Figure 2: Distribution of the number of tornadoes stratified by their distance from TC center

4. Results: Diurnal Variability in Geographic Location of Tornadoes

Overview

Analyze the relation between geographical location, specifically distance from the coast and TC tornado occurrence.

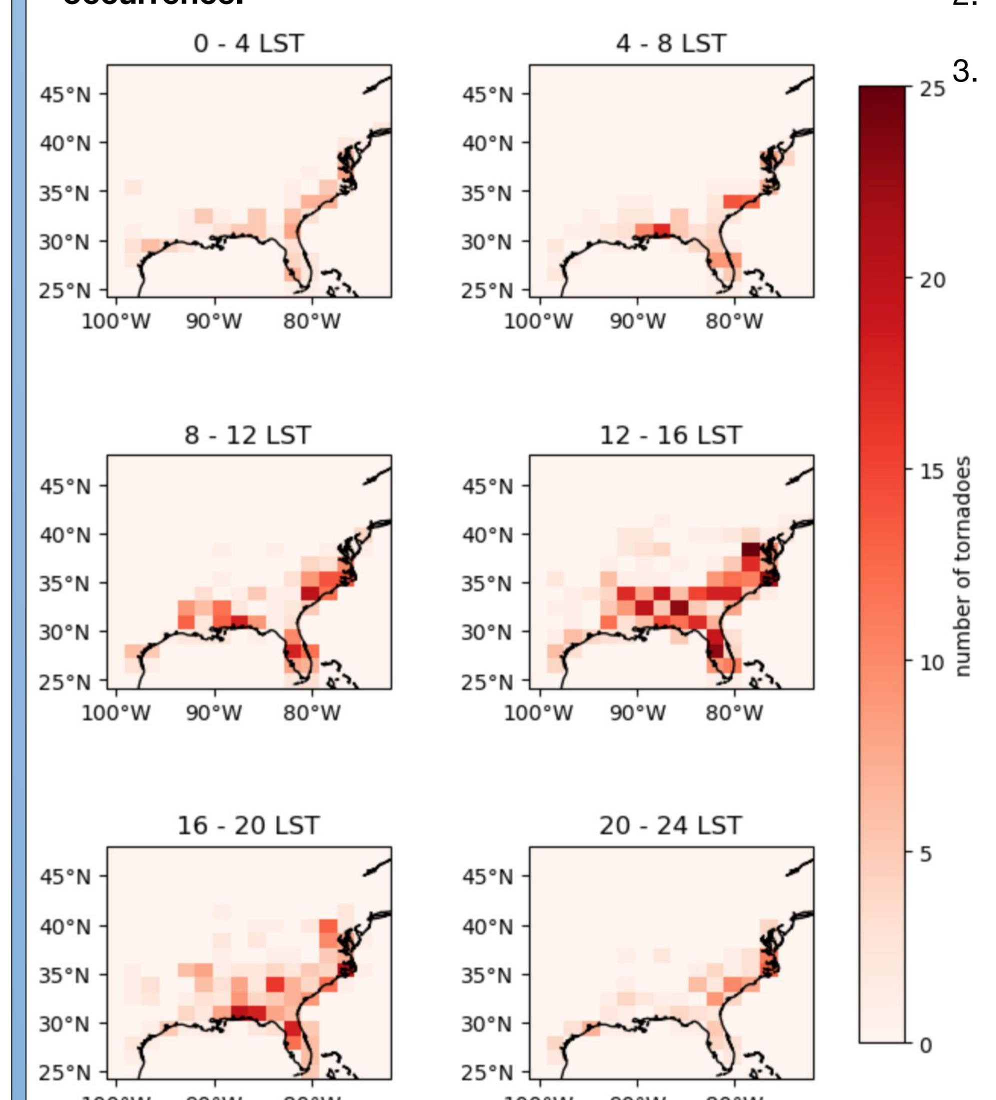

Figure 3: Map view of the number of TC tornadoes stratified into 4-h LST bins.

Synopsis

1. Strongest diurnal variability associated with inland tornadoes (Fig. 3);
2. Inland tornadoes show sharp peak in occurrence between 14–16 LST (Fig. 4);
3. Coastal tornadoes show a broader peak between 10–18 LST that is 3 times higher than nocturnal numbers (Fig. 4);

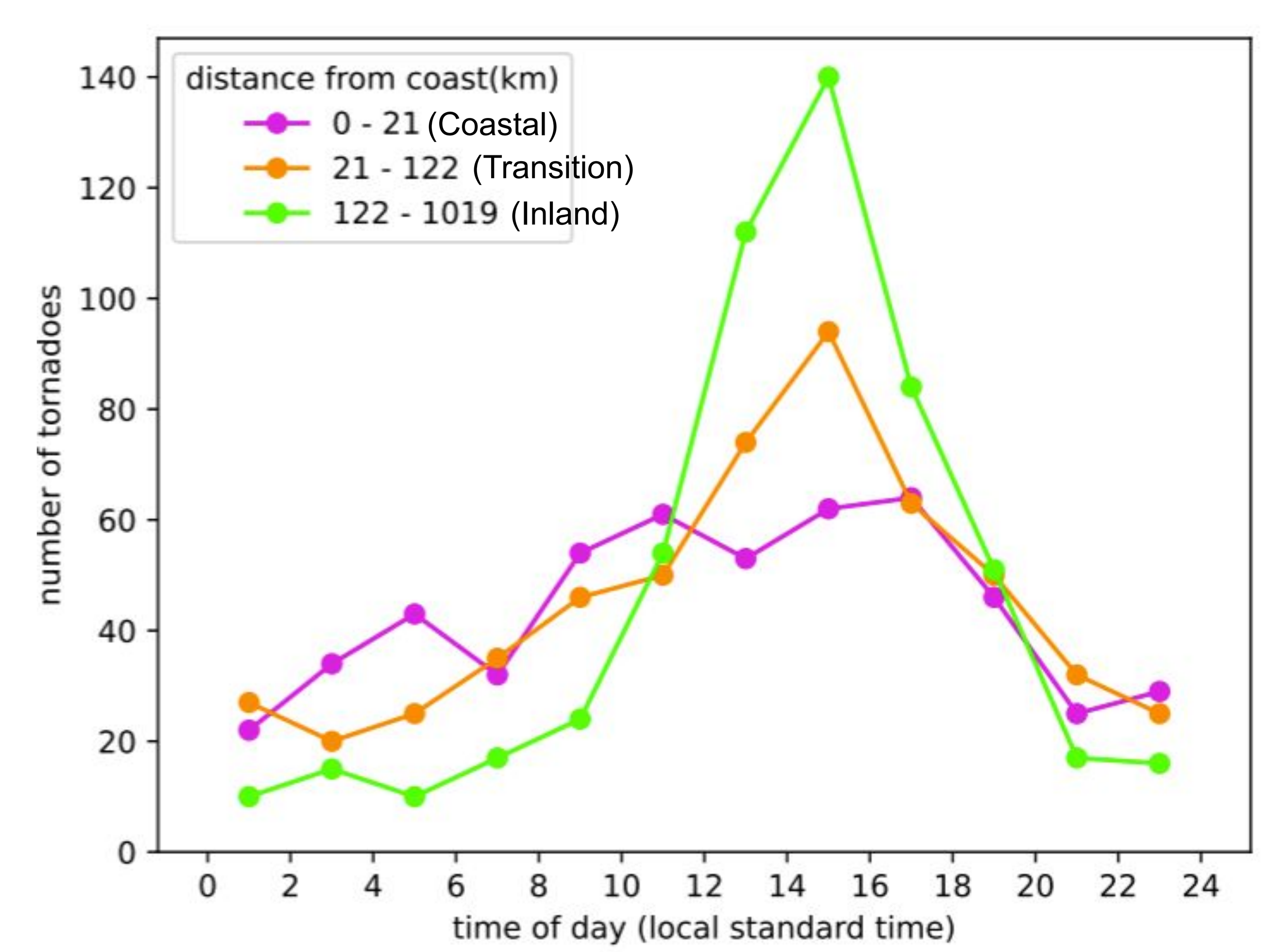

Figure 4: As in Fig. 2, but stratified by TC tornado distance from the coast.

5. Results: Joint Sensitivity of Diurnal Variability to TC-Relative and Geographic Location

Overview

Analyze the joint diurnal variability in tornadoes associated with TC-relative location versus their distance from the coast.

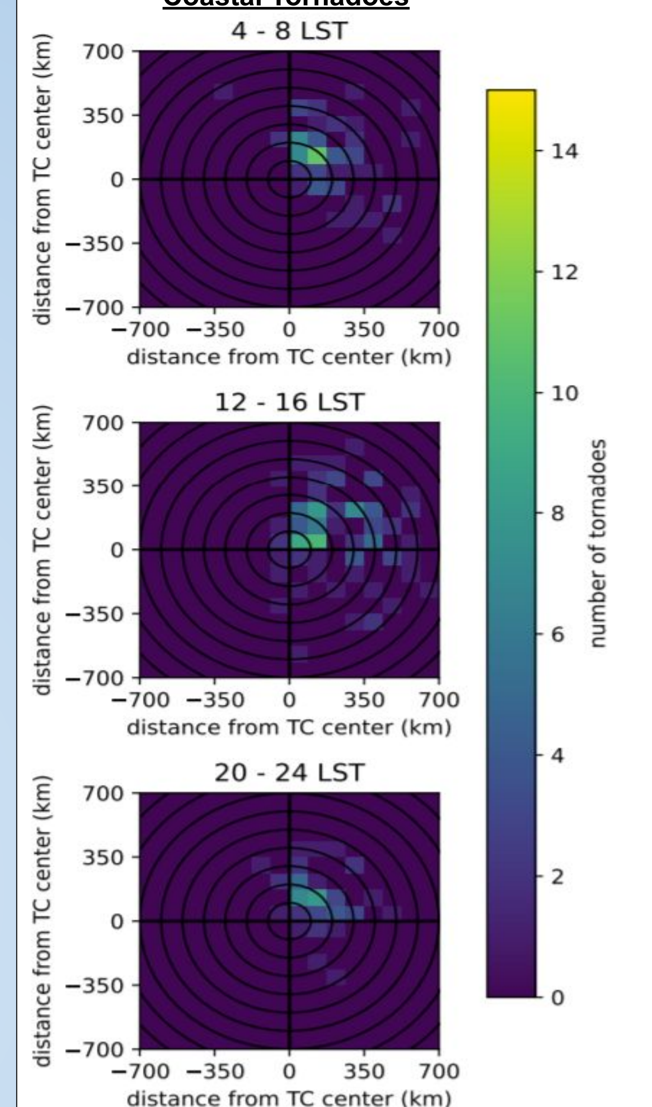

Fig. 5: As in Fig. 1, but for coastal tornadoes

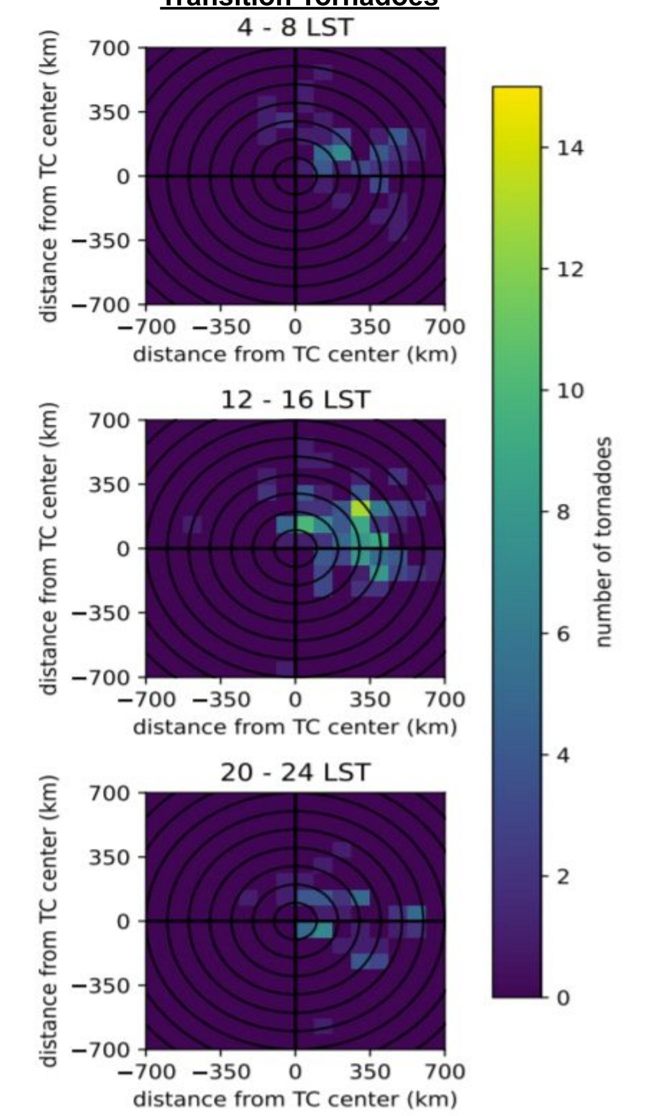

Fig. 6: As in Fig. 1, but for transition tornadoes

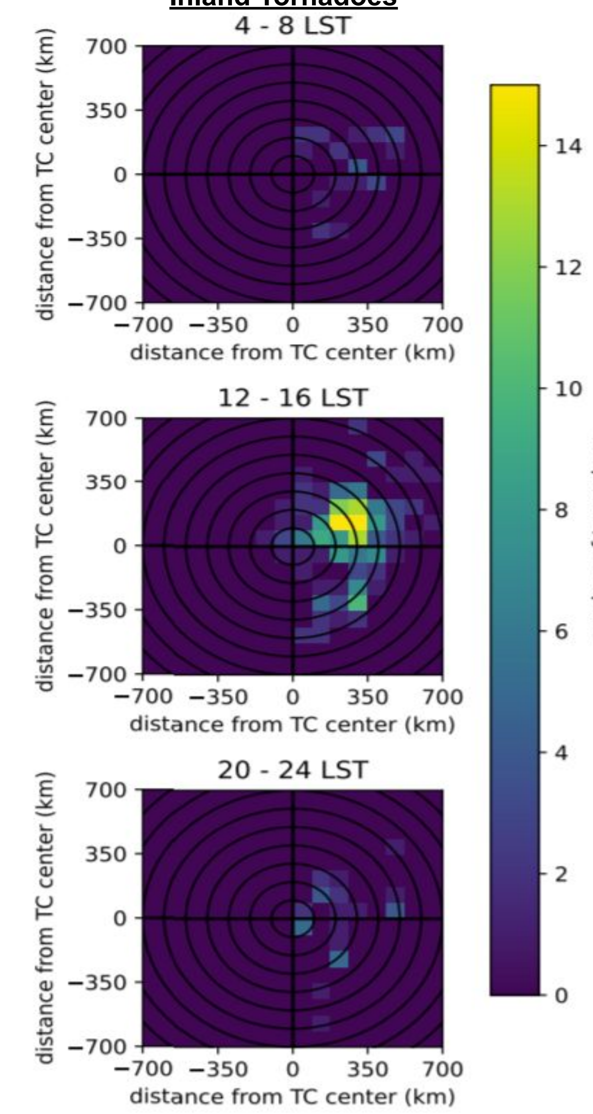

Fig. 7: As in Fig. 1, but for inland tornadoes

Synopsis

1. Coastal tornadoes occur the least often and are primarily located in the northeast quadrant of the TC (Fig. 5);
2. Transition tornadoes occur more often with a maximum in the northeast quadrant of the TC (Fig. 6);
3. Inland tornadoes occur the most, with a peak in occurrence during 12–16 LST within the northeast quadrant of the TC (Fig. 7).

6. Summary and Discussion

- This study examined sensitivity of diurnal variability in TC tornadoes to their TC-relative and geographic location using multi-decadal observational datasets;
- Our most important findings include:
  1. **TC-relative location:** outer region tornadoes occur more often, especially those occurring 300–500 km from the TC, compared to inner region tornadoes;
  2. **Geographical location**: inland TC tornadoes exhibited greater variability compared to those at coasts with sharp peak during the mid-to-late afternoon;
  3. **Joint sensitivity to TC-relative and geographical location:** coastal tornadoes show weak diurnal variability while almost exclusively occupying the northeast quadrant, while inland tornadoes show strong diurnal variability on the eastern half of the TC with a peak in the outer northeast quadrant;
- Future work will focus on examining whether convective-scale environment derived from radiosondes show similar diurnal variability and the mechanisms driving these differences in the diurnal cycle.

7. Acknowledgments

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