



# Impacts of Extratropical Transition on Tropical Cyclone Tornado Occurrence

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## 1. Introduction

### Motivation

- Tornadoes account for 3% of fatalities caused by landfalling TCs (Rappaport 2014).
- 42% of landfalling tropical cyclones (TCs) in the Atlantic Basin undergo extratropical transition (Hart 2001).
- Only one study has investigated and compared the difference in tornado location between TCs in different stages (phases) of extratropical transition (Hill et al. 1966).
- There is an incomplete understanding regarding how the process of extratropical transition impacts tornado occurrence.

### Objective

This study investigates how extratropical transition impacts the number, timing, and location of tornadoes.

## 2. Data/Methods

### Data

- TC Tornado Data – Tornado timing, track, and damage rating from 1995-2020 were obtained from SPC TCTOR (Edwards 2010)
- TC Data – 6-h TC data from 1995-2020 were obtained from IBTrACS Best-Track (Landsea and Franklin 2013)
- Reanalysis Data – 6-hourly ERA5 (Hersbach et al. (2020); extratropical transition stage/phase designation.

### Methods

- Cyclone Phase Space – Utilized to objectively define start and end of transition with 2 parameters (Hart 2003)
  - Thermal Symmetry: Measures TC motion-relative lower-tropospheric layer thickness symmetry. Quantifies frontal structure of TC.
  - Thermal Wind: Measures TC lower-level thickness. Quantifies whether TC is warm or cold core.
- 3 Phases throughout Extratropical Transition:
  - Tropical Phase: Warm core and non-frontal (N=562 tornadoes)
  - Transition Phase: Warm core and frontal (N=434)
  - Extratropical Phase: Cold (sometimes warm) core and frontal (N=161)
- 9 TCs discarded due to disagreement between Best-Track and Phase Space transition times, resulting in 49 total TCs in dataset.

## 3. Results: TC-Relative Tornado Location

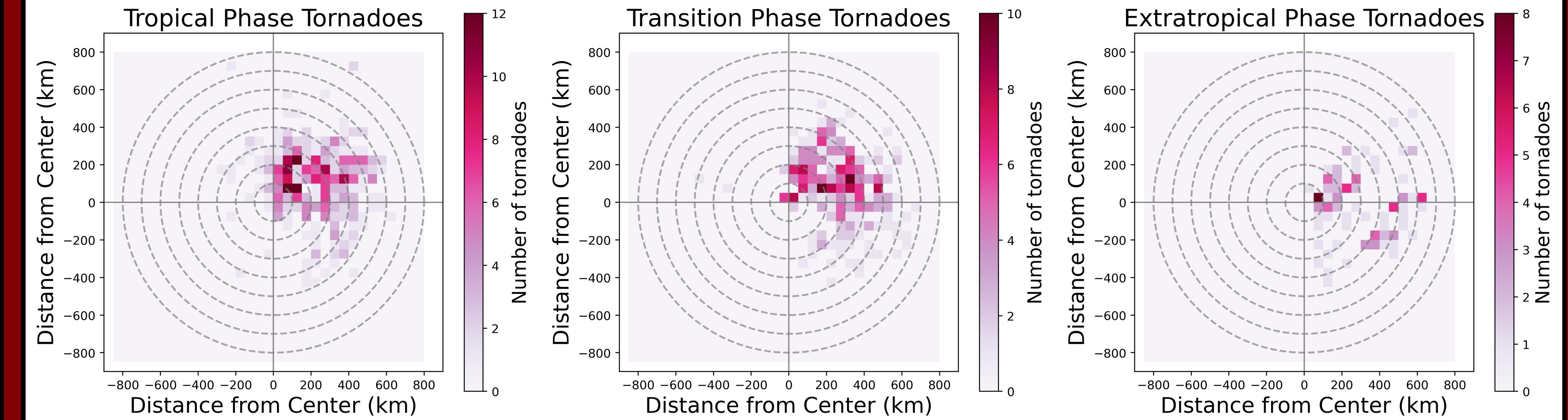


Figure 1. TC-relative and true north-relative location of tornadoes for the tropical, transition, and extratropical phases. Shading indicates number of tornadoes. Dashed gray lines indicate distance from the center for every 100 km.

- Tropical and Transition Phases: Most tornadoes in **northeast quadrant of TC** within a **500 km** radius.
- Extratropical Phase: Most tornadoes within **300 km**. Higher percentage of tornadoes occur in the west half of a TC when compared to tropical and transition phases.

## 4. Results: Tornado Location

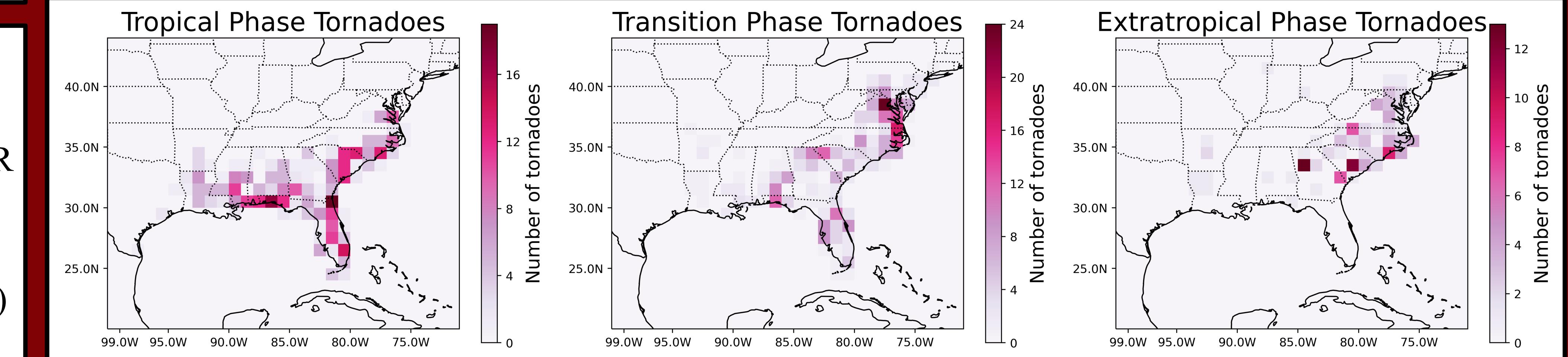


Figure 2. TC location on the United States at the time of tornado occurrence for the tropical, transition, and extratropical phases.

- As transition progresses, tornadoes become **less concentrated along the coast** and are more likely to occur **farther north**
- Transition phase tornadoes have **greatest spread**, reaching from the southeast US to Mid-Atlantic.

## 5. Results: Tornado Frequency

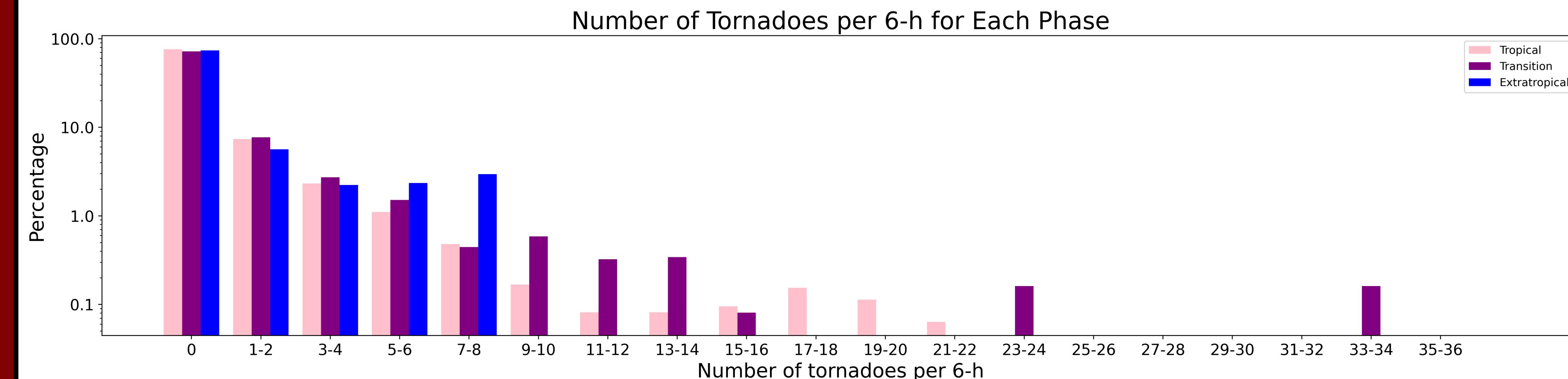


Figure 3. Frequency of tornado occurrence shown by number of tornadoes per 6-h for tropical, transition, and extratropical phases.

- Most 6-h periods have **no tornadoes**.
- Transition phase contains the extreme frequencies, with the maximum of 33 tornadoes in 6 hours.
- In general, as transition progresses, the **maximum frequency of tornadoes decreases**.

## 6. Results: Local Standard Time of Tornadoes

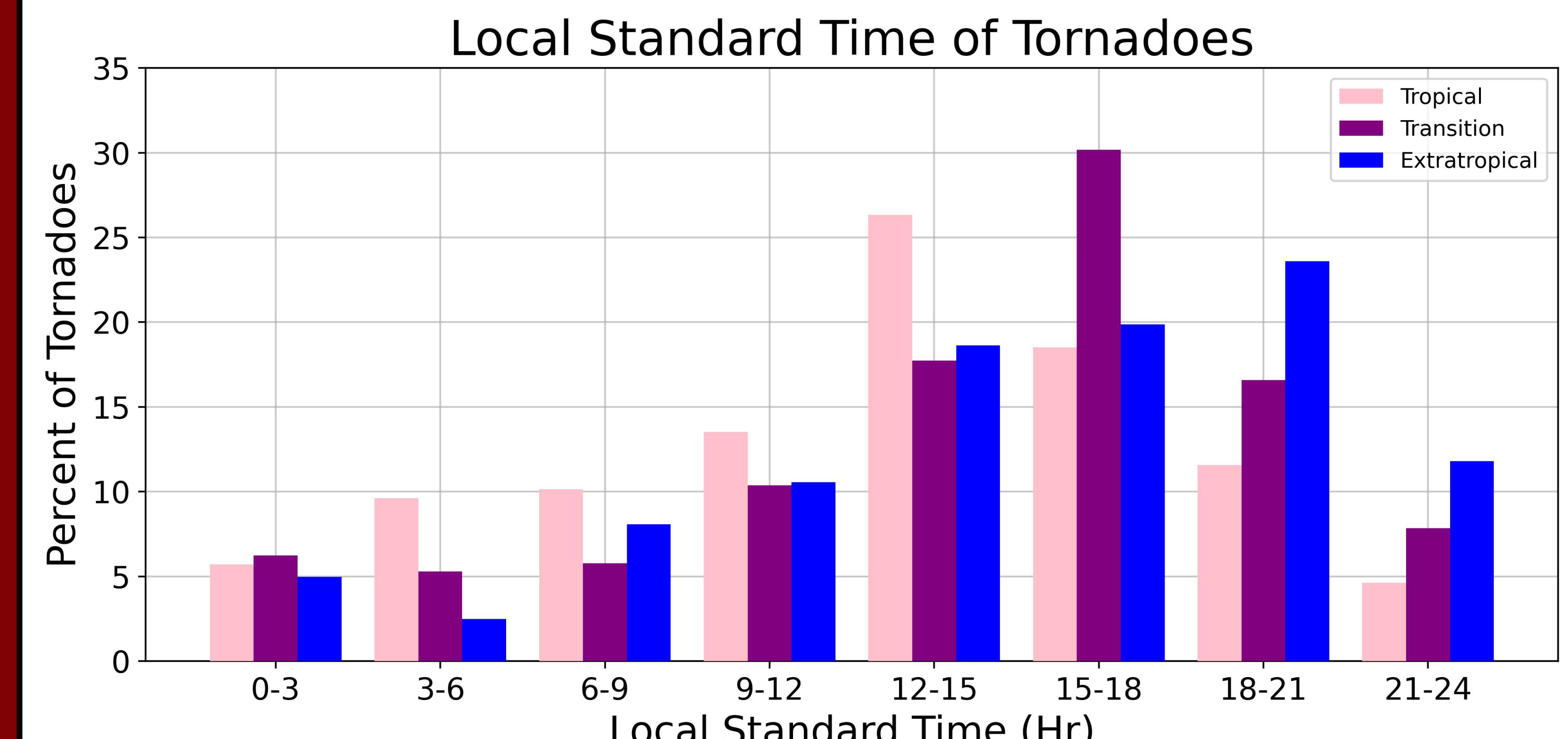


Figure 4. Local standard time of tornado occurrence for the tropical, transition, and extratropical phases.

- There is clear diurnal variability for all 3 phases.
- As transition progresses, the **peak LST occurs later**.
- Extratropical phase has the least pronounced peak.

## 7. Discussion and Summary

This study examined the difference in characteristics of tornadoes between the tropical, transitioning, and extratropical phase of cyclones.

As transition progresses...

- Most tornadoes remain within the **northeast quadrant**, but a higher portion occur outside of this quadrant in the extratropical phase.
- The location of tornadoes becomes **less confined to the U.S. coast** and trends to the **north**.
- The maximum **frequency of tornadoes decreases**, the extreme frequencies occurring during the transition phase.
- The time of day at which the most tornadoes occur becomes **later**, with most occurring in the **afternoon/evening**.

Future work will focus on analyzing radiosonde and dropsonde data to understand the difference in environments between the phases and to explain the results discovered thus far.

## 8. Acknowledgements

This research has been supported by the National Science Foundation under Grant AGS-2028151. We would like to thank Drs. Jason Furtado, James Ruppert, and Patrick Skinner for their support with this project.

## 9. References

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