A Comparison of the Radar and Lightning Characteristics Between Tropical Cyclone Tornadoes and Waterspouts and Their Associated Warnings

Kate Stapleton[1], Benjamin Schenkel[1,2,3], Thea Sandmæl[1,3], A. Addison Alford[1,2,3], and Roger Edwards[4]

1: NOAA/OAR/NSSL, 2: School of Meteorology, University of Oklahoma,
3: Cooperative Institute for Severe and High-Impact Weather Research and Operations, 4: NOAA/NWS Storm Prediction Center

Introduction

Motivation:

- There are no recent studies of tropical cyclone (TC) waterspouts. TC waterspouts present a greater hazard if they move onshore and become tornadoes.
- TC tornadoes are often weak EF 0/1 (Edwards 2012).
- TC tornadoes favor the northeast quadrant of the TC and usually occur in the TC's outer rainbands (Edwards 2012).
- TC tornadic cells tend to be shallow and have few lightning flashes (Edwards 2012, Alford et al. 2023, Schenkel et al. 2023).

Objective:

- Determine how TC waterspouts and tornadoes differ in their location, lightning, and radar characteristics.

Hypotheses:

1. We expect TC waterspouts to have low magnitudes of lightning and radar-derived variables when compared to TC tornadoes.
2. We expect similar TC-relative locations for waterspouts and tornadoes.
3. We expect fewer lighting flashes with TC waterspouts.

Data & Methods

Data:

Timeframe: 2013-2023

- **TCs**: National Hurricane Center Hurricane Track Data (HURDAT2)
- **TC Tornadoes**: Storm Prediction Center TC Tornado Dataset (499 TC tornadoes, 40 TCs)
- **TC Waterspouts**: NCEI Waterspout Reports, QC'ed Data (91 TC waterspouts, 34 TCs)
- **Azimuthal Shear**: AzShear, Lowest Tilt - 0.5°, WSR-88D Network, closest scan to tornado/waterspout start time
- **Lightning**: Earth Networks Total Lightning Network (ENTLN), cloud-to-ground and intracloud lightning

Methods:

TC Waterspouts and Tornadoes were compared based on their:

- Climatological Characteristics
- Radar Derived Variables
- Lightning Data

Results: TC Relative Distributions of Tornadoes and Waterspouts

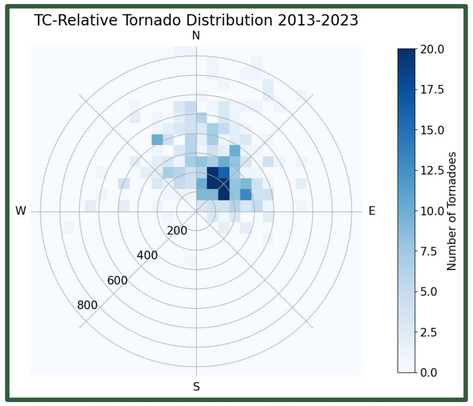


Figure 1: TC-relative distribution of TC tornadoes. Shading indicates the number of tornadoes.

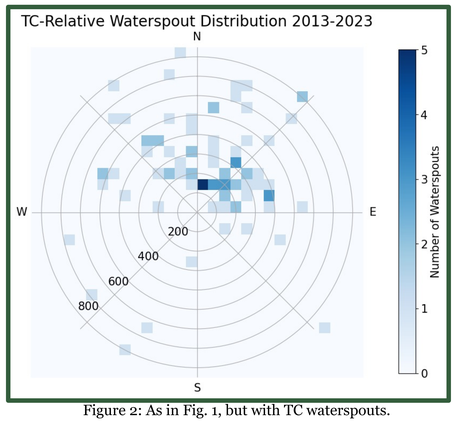


Figure 2: As in Fig. 1, but with TC waterspouts.

- Both TC tornadoes (Fig. 1) and waterspouts (Fig. 2) favor the Northeast quadrant in the TC-relative framework
- TC waterspouts have much more variability than TC tornadoes.
- The sample size of TC waterspouts is significantly smaller, therefore specific cases have a larger impact.

Results: Lightning & Radar Data Associated with TC Tornado and Waterspout Supercells

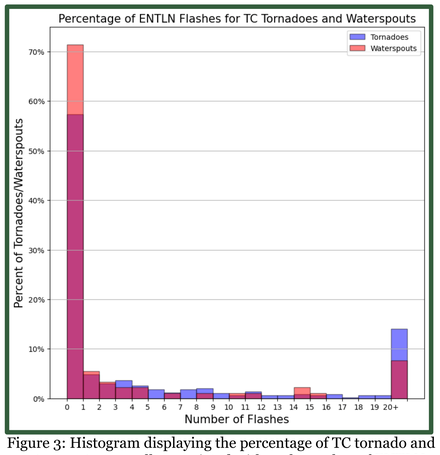


Figure 3: Histogram displaying the percentage of TC tornado and waterspout supercells associated with each number of ENTLN lightning flashes.

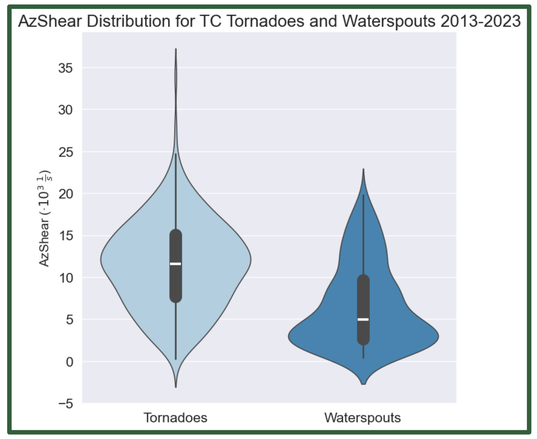


Figure 4: Violin plots displaying the distribution of AzShear values for TC tornado and waterspout supercells. The box and whisker plots include the median, upper and lower quartiles, the maximum, and the minimum, excluding outliers.

- Supercells producing TC tornadoes and waterspouts usually have few lightning flashes (Fig. 3).
- A higher percentage of TC waterspout supercells have no lightning (Fig. 3).
- TC tornado supercells have higher AzShear values than storms producing TC waterspouts (Fig. 4).
- The difference in means is 4.867 s^{-1} and is statistically significant at the 95% confidence level (Fig. 4).

- In the TC-relative framework, TC tornadoes have high AzShear values extending into the northwest and northeast quadrants.
- For TC waterspouts, high AzShear values are strongly favored in the northeast quadrant, while low AzShear values are favored in all other quadrants.

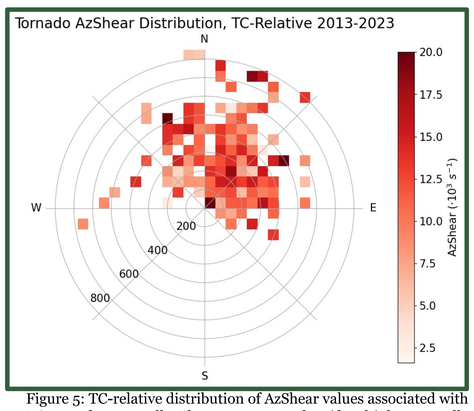


Figure 5: TC-relative distribution of AzShear values associated with TC tornado supercells. The average was taken if multiple supercells had the same TC-relative location.

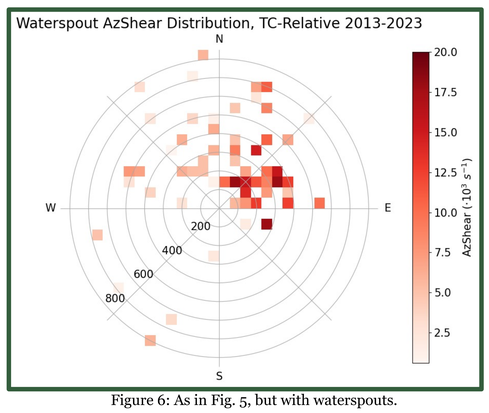


Figure 6: As in Fig. 5, but with waterspouts.

Summary & Discussion

We compared the radar, lightning, and TC-relative characteristics of TC tornadoes and waterspouts.

From this analysis have concluded:

1. The TC relative location of TC tornadoes is more consistent than TC waterspouts (Fig. 1 & 2).
2. Both TC tornadoes and TC waterspouts tend to have few lightning flashes. There is a larger percentage of TC waterspouts with no lightning (Fig. 3).
3. Magnitudes of rotation are larger in TC tornado storms. TC waterspout rotation magnitudes are skewed towards low values (Fig. 4).
4. Larger rotation magnitudes favor the northeast quadrant for TC waterspouts, while TC tornadoes have no obvious preference (Fig. 5 & 6).

Implications:

- The variable distribution of TC waterspouts may indicate the northeast quadrant is not a standard for TC waterspouts (Fig. 1 & 2).
- Traditional Azimuthal Shear warning thresholds for TC tornadoes may be too high for TC waterspouts (Fig. 4).
- TC waterspouts with higher rotation values may indicate different dynamical processes from waterspouts with weak rotation values (Fig. 6).

Future Work

- Our next steps will include analyzing the warning data for TC tornadoes and waterspouts.
- **This analysis can be used to establish differences between TC tornadoes and waterspouts so they can be better understood and predicted.**

References/Acknowledgements

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