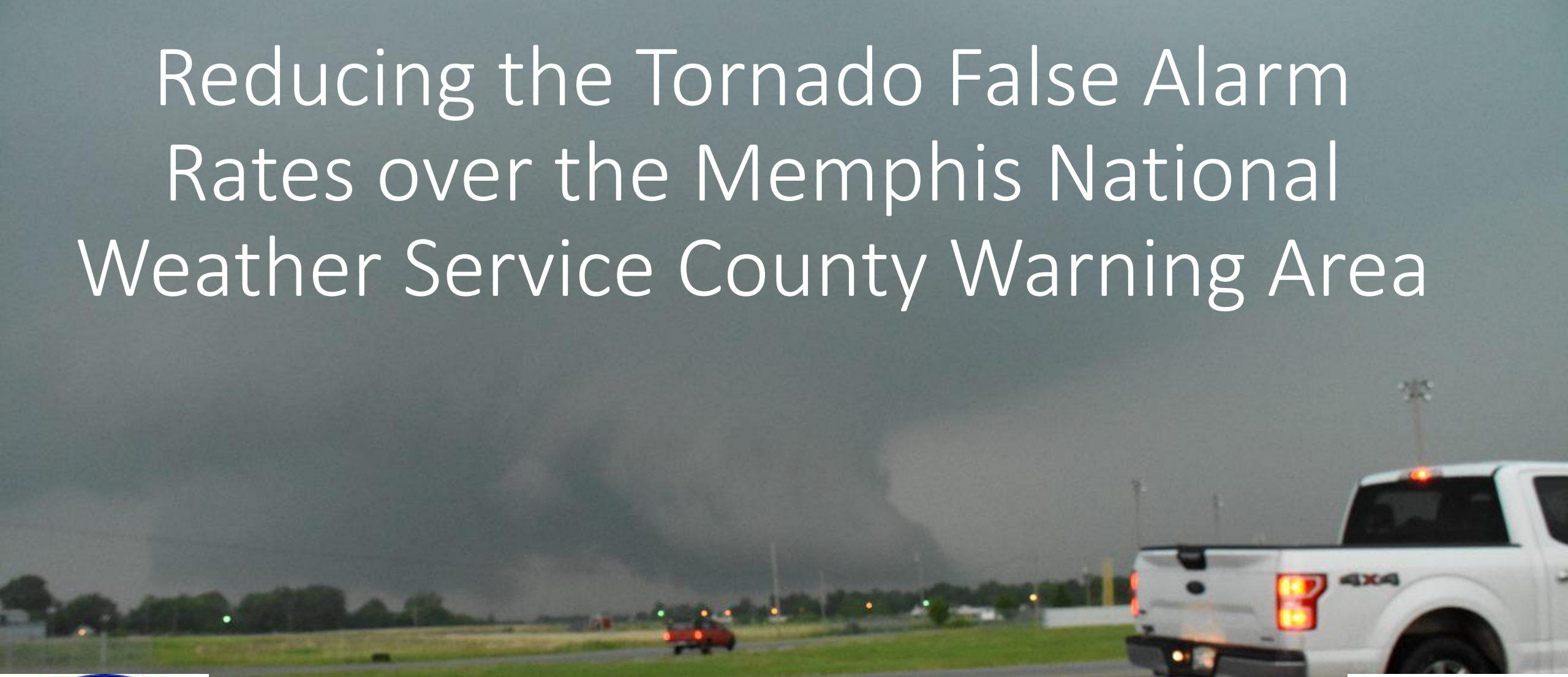
Reducing the Tornado False Alarm Rates over the Memphis National Weather Service County Warning Area

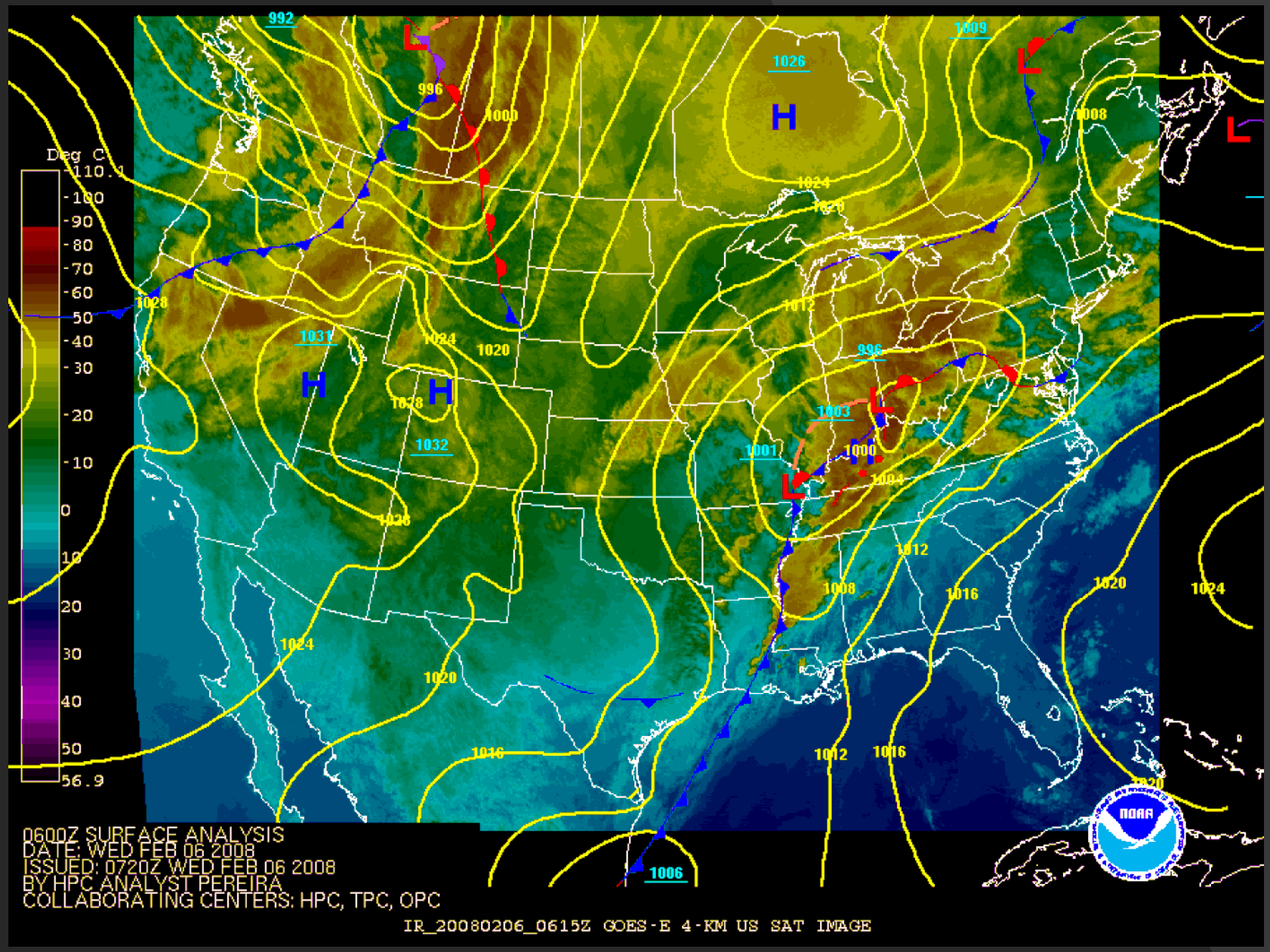


Masters in Earth Sciences with concentration in Interdisciplinary Studies

Preston Bradley

Overview

- Introduction
- Literature Review
- Study Area and Hypotheses
- Methods
- Results
- Conclusions
- Future Work



Introduction

- Importance = decrease the false alarm rate and improve tornado detection
- False alarm rate (FAR) = ratio of tornado warnings with no confirmed tornadoes to the total number of tornado warnings (Brotzge et al. 2011)
- FAR is used to assess a forecaster's skill or performance on warnings
- FAR for the Memphis National Weather Service Forecast Office (NWSFO) from 2012-2018 was 83%
- Over the same time period, NWSFO Birmingham, Little Rock, and Nashville were 58%, 85%, and 80%, respectively
- Average FAR for the region was about 76.5%
- Trainor et al. (2015) found that people are less likely to take protective actions and seek shelter in areas with high FAR.
- Brotzge et al. (2013), Donavon (2014) and Simmons and Sutter (2009) suggest that high FAR could lead to higher fatalities.

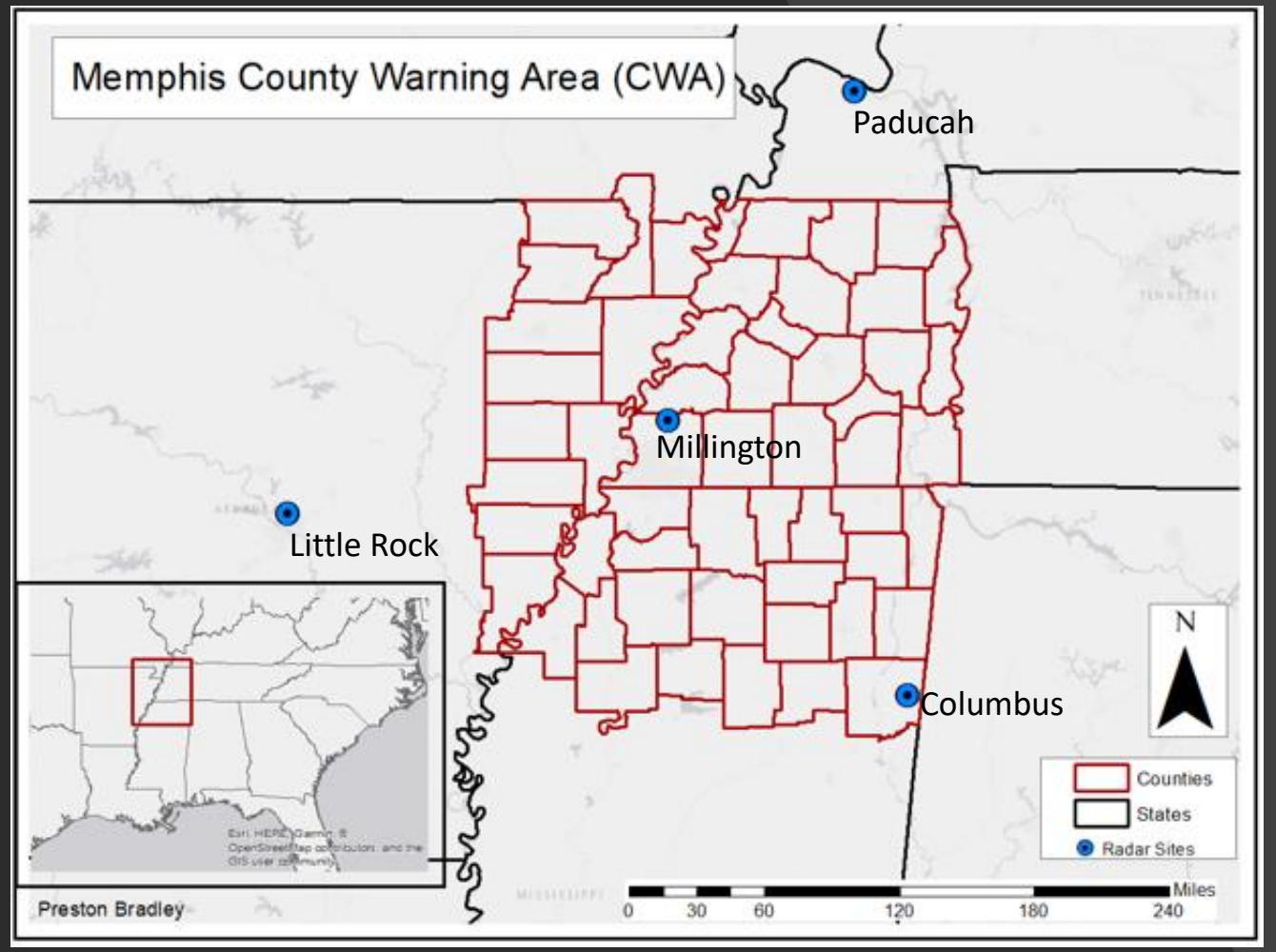
Literature Review

- Davis and Parker (2014)
  - Study years from 2008-2011 over Mid-Atlantic Region
  - High shear and low convectively available potential energy (CAPE) environments
  - Radar signatures were used to determine storm's progression
  - Statistical significance was found to help determine tornadic vs non tornadic vortices within 60 km of the radar for non supercells
- Smith et al. (2015)
  - Study from 2009 to 2013 over the contiguous U.S.
  - Used rotational velocity (V_{rot}) and significant tornado parameter to diagnose probability of tornado damage/rating
  - Peak V_{rot} used during the life cycle of the tornadoes
  - Relationship exists between 0.5-degree tilt, peak V_{rot}, and EF scale for all convective modes
- Rogers et al. (2016)
  - Analyzed 138 Quasi-Linear Convective Systems (QLCS) from 2009-2013 over lower Mississippi River Valley
  - Found mean rotational velocity for QLCS tornadoes between 31 and 35 knots consistent with Smith et al. (2015)

Study Area and Hypotheses

- Localizing the Smith et al. (2015) study to the Memphis County Warning Area (CWA) will improve tornado detection and the decrease FAR across the region.

- Assessing the combined radar signatures and storm environment data by region may yield important differences that impact tornado detection and the FAR.



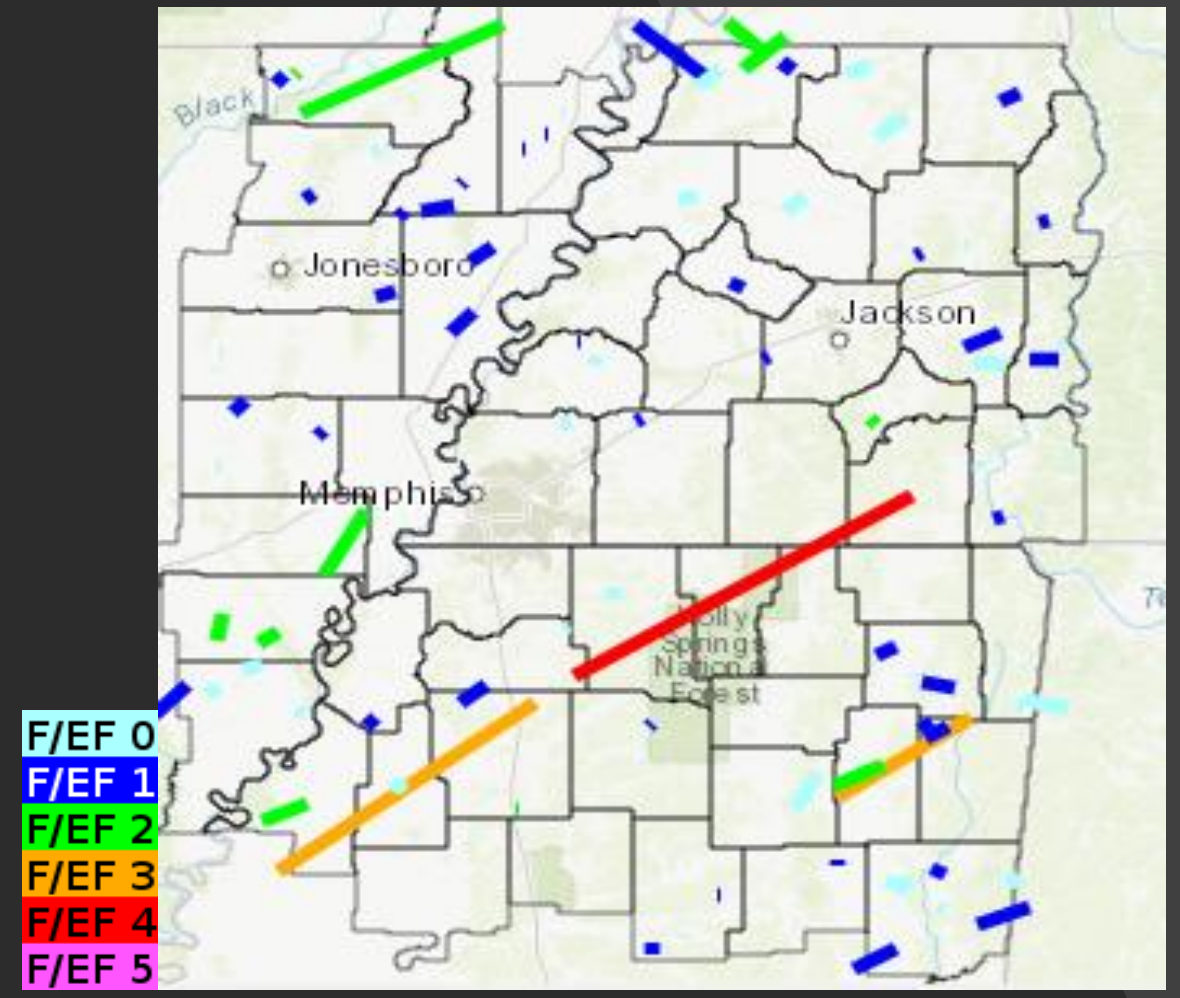
Methodology

Confirmed Cases

- NWS Tornado Database 2012-2018 (www.midsouthtornadoes.msstate.edu)
- Tornadoes must have been within 65 nautical miles from closest radar site and tracked one mile or more.
- 41 storms met the criteria

Test Cases

- Tornadic and non-tornadic storms from 2019
- Iowa State's NWS Storm Based Warning Verification (mesonet.agron.iastate.edu/cow/)
- Tornado warnings must have been within 65 nautical miles from closest radar site.
- Each warning was analyzed separately
- 35 storms met the criteria

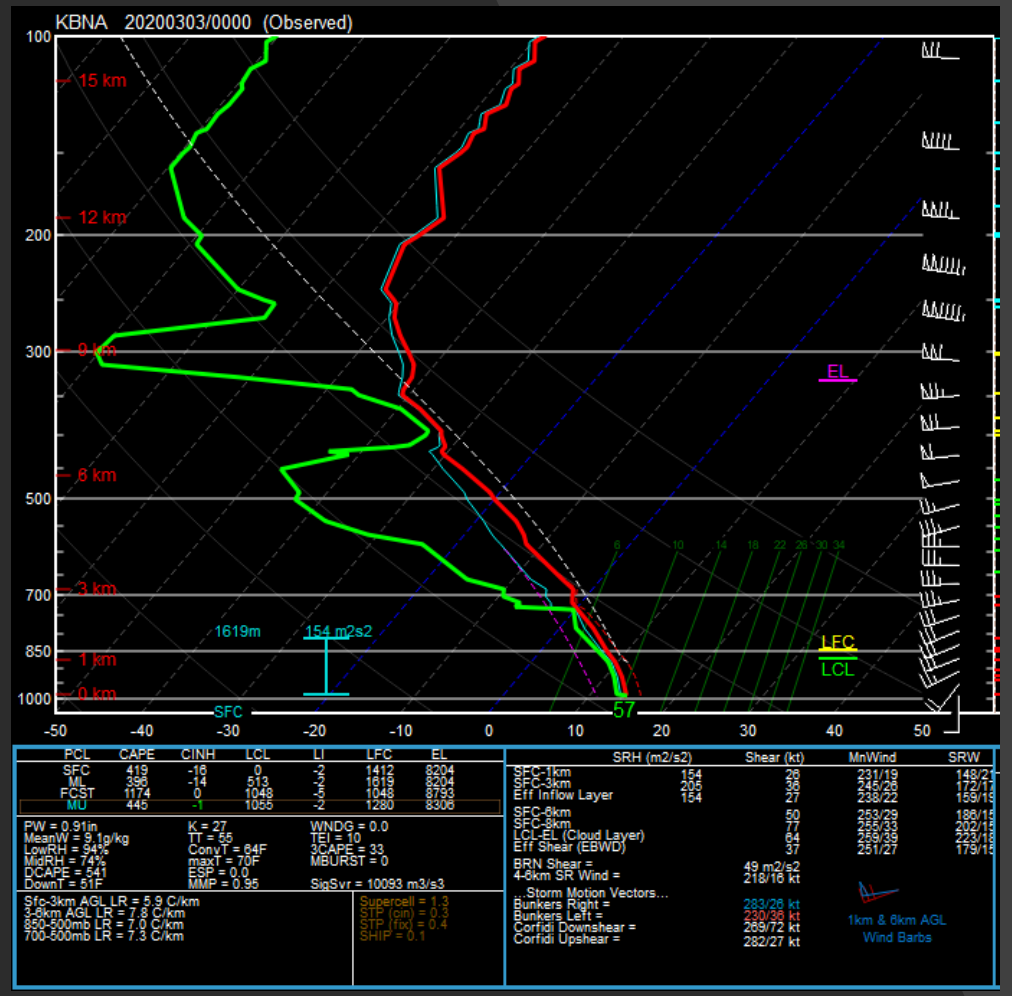


Tornado Rating and Tracks 2012-2018

Methodology

Storm Environment Data

- Analyzed during the specific hour of the tornado's formation
- Parameters Analyzed:
  - Lifted Condensation Level
  - Level of Free Convection
  - Mixed-Layer CAPE
  - Surface-Based CAPE
  - Effective Bulk Shear
  - Effective-Layer Significant Tornado Parameter
  - Fixed-Layer Significant Tornado Parameter
  - 0-3 km Energy Helicity Index
  - 0-1 km Energy Helicity Index

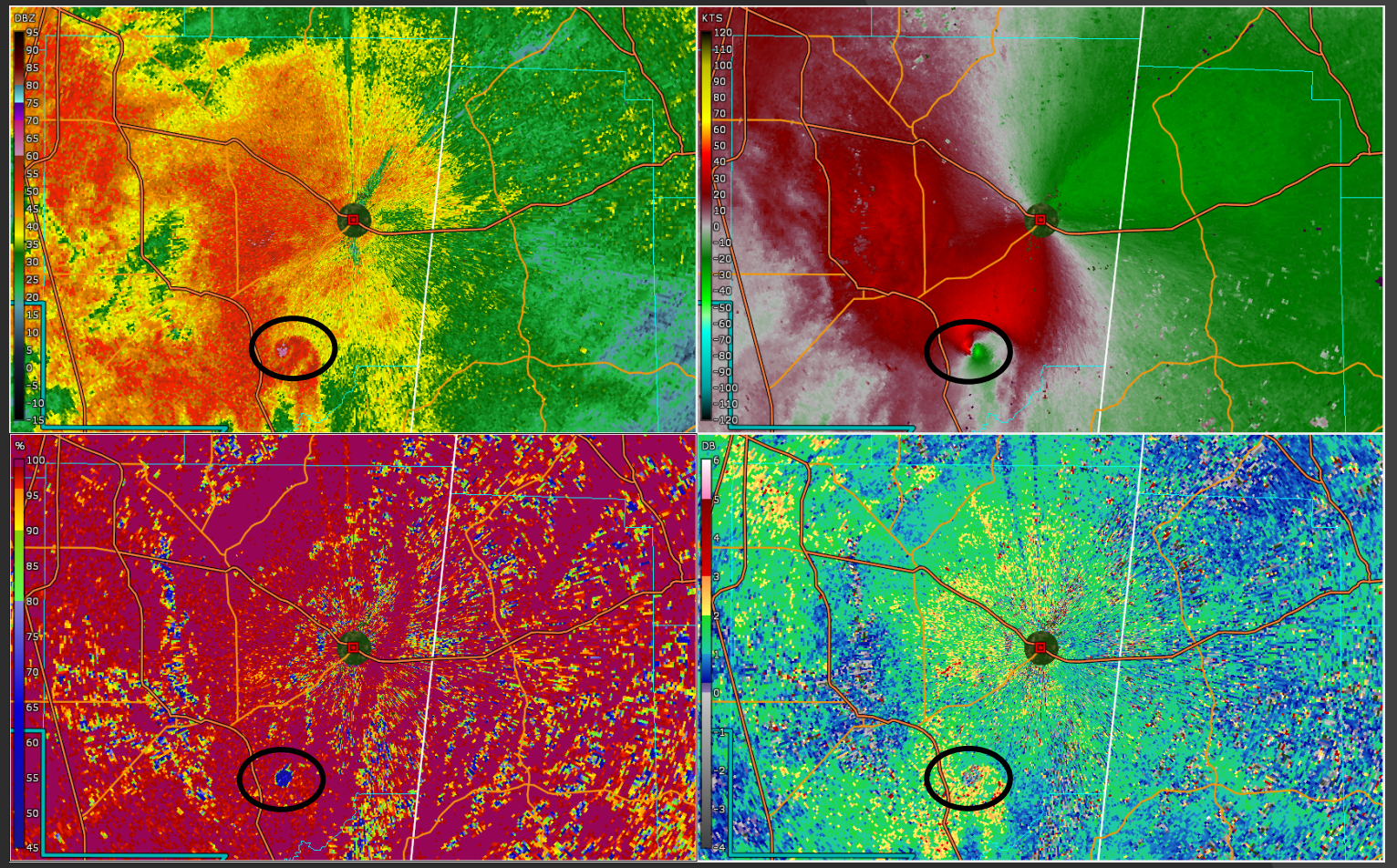


Nashville, TN Sounding
00Z, 3 March 2020

Methodology

Radar Data

- Reflectivity (top left)
- Storm Relative Velocity (top right)
  - Rotational Velocity computed from Storm Relative Velocity (Falk and Parker 1998)
  - $V_{rot} = (| V_{inbound} + V_{outbound} |) / 2$
- Normalized Rotation (not shown)
- Correlation Coefficient (bottom left)
- Differential Reflectivity (bottom right)



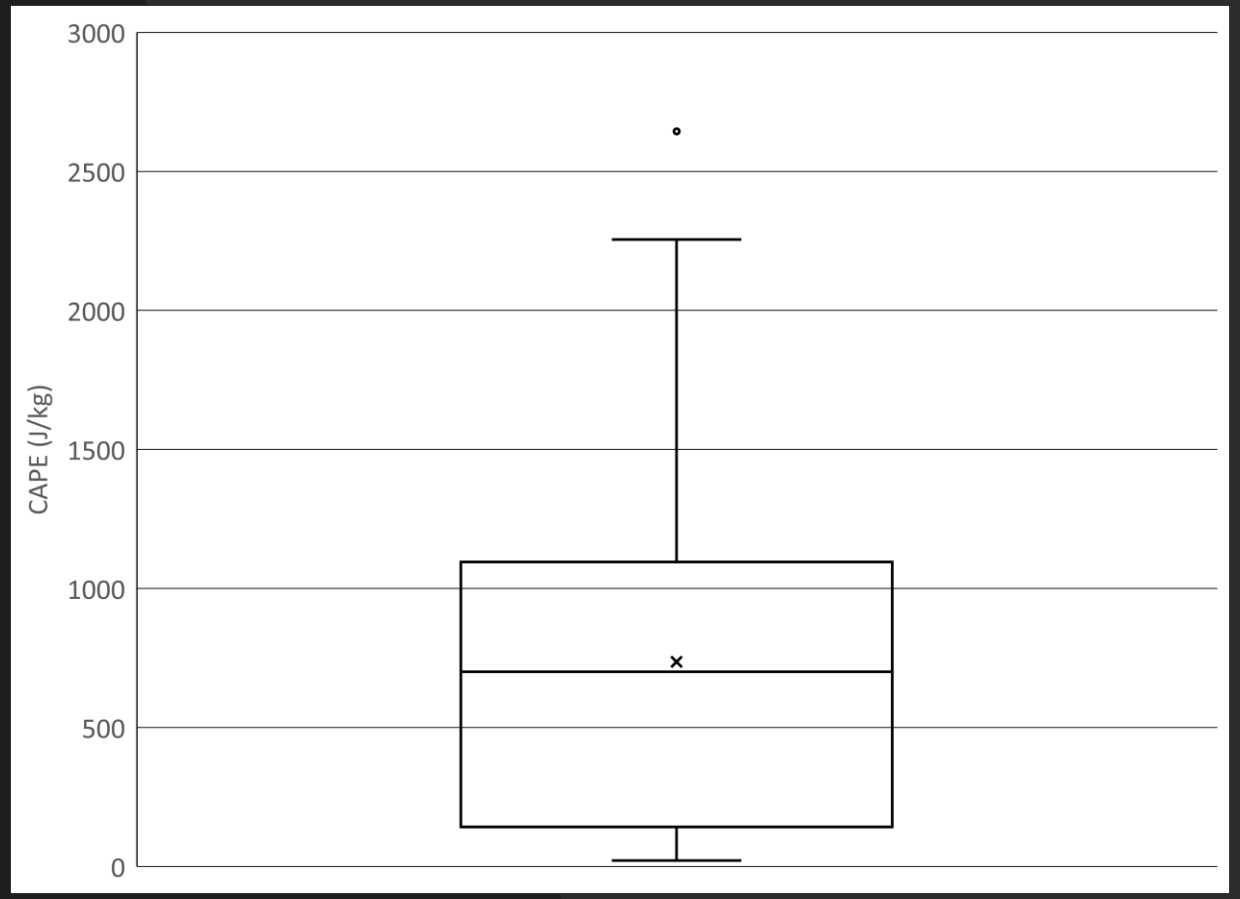
KGWX Radar
4/13/2019

Methodology

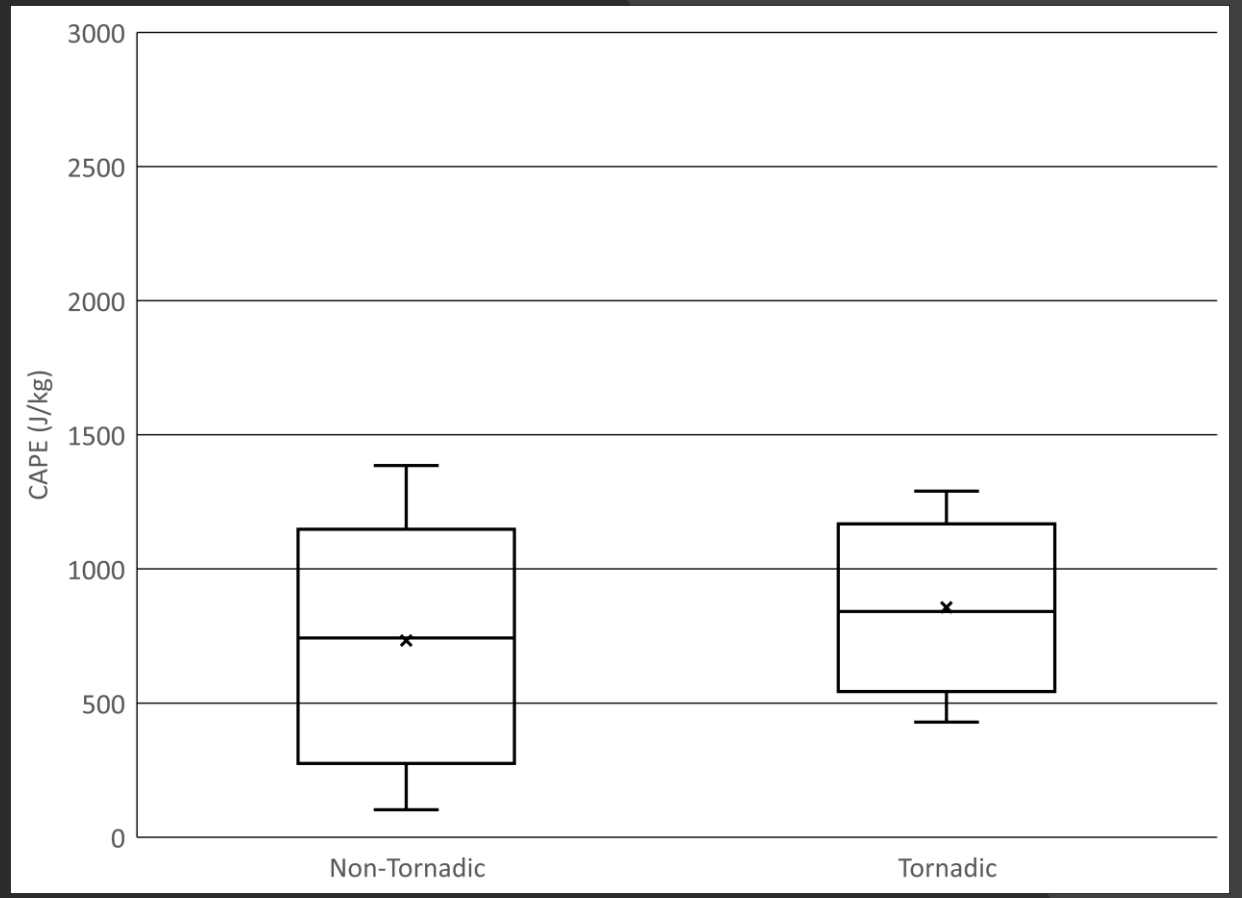
Analysis

- GR2Analyst
- Box and Whisker Plot
- Stepwise Regression Model

Results

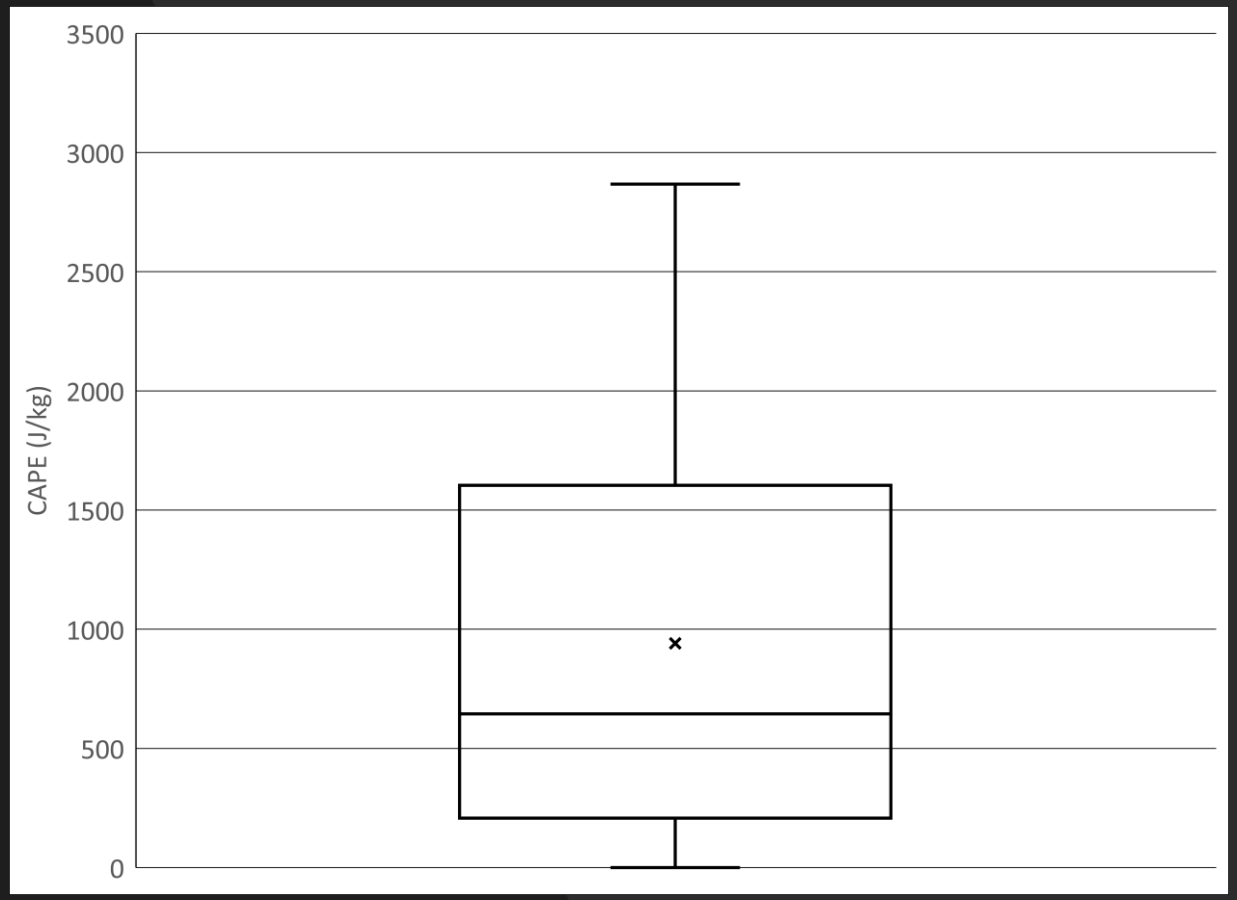


Mixed-Layer CAPE
Confirmed Cases

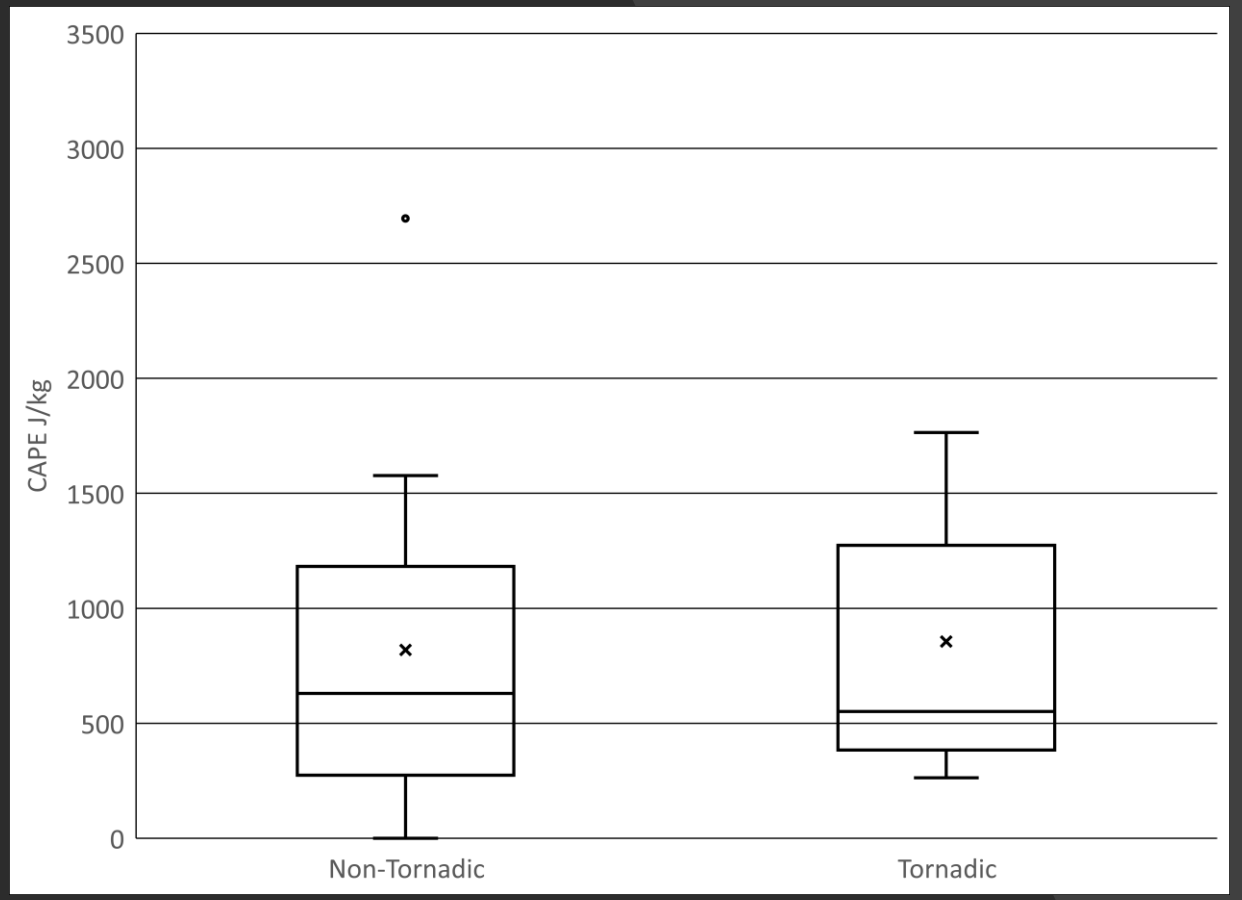


Mixed-Layer CAPE
Test Cases

Results

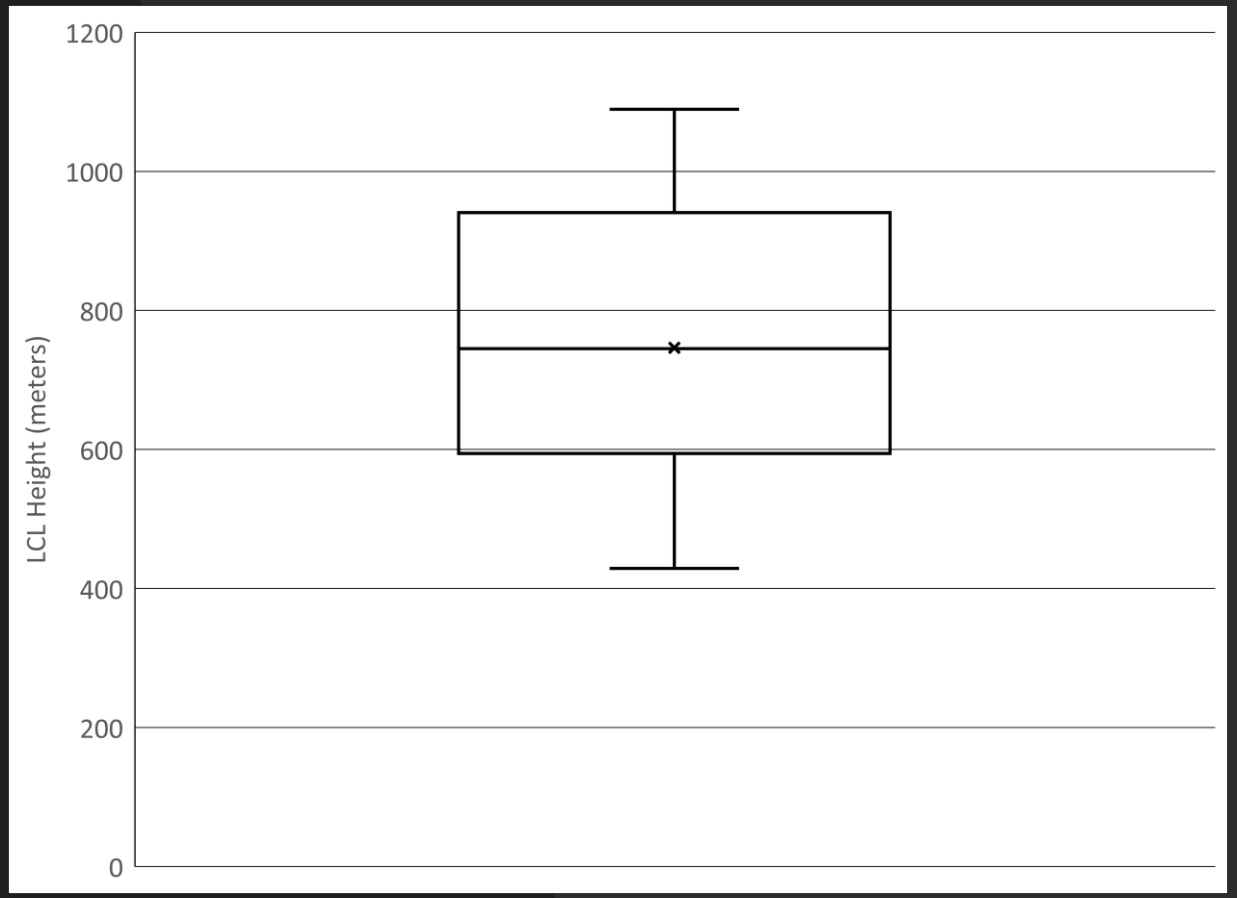


Surface-Based CAPE
Confirmed Cases



Surface-Based CAPE
Test Cases

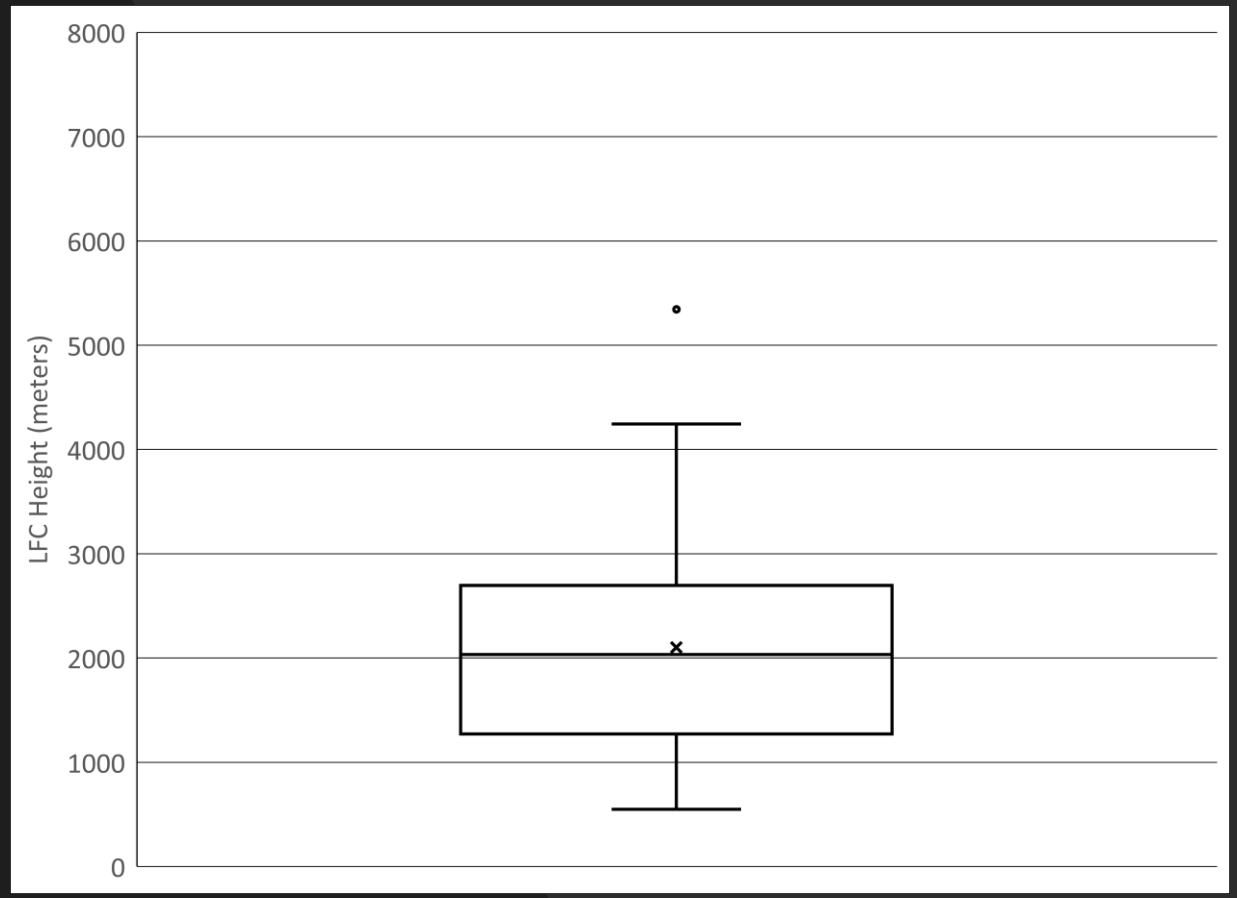
Results



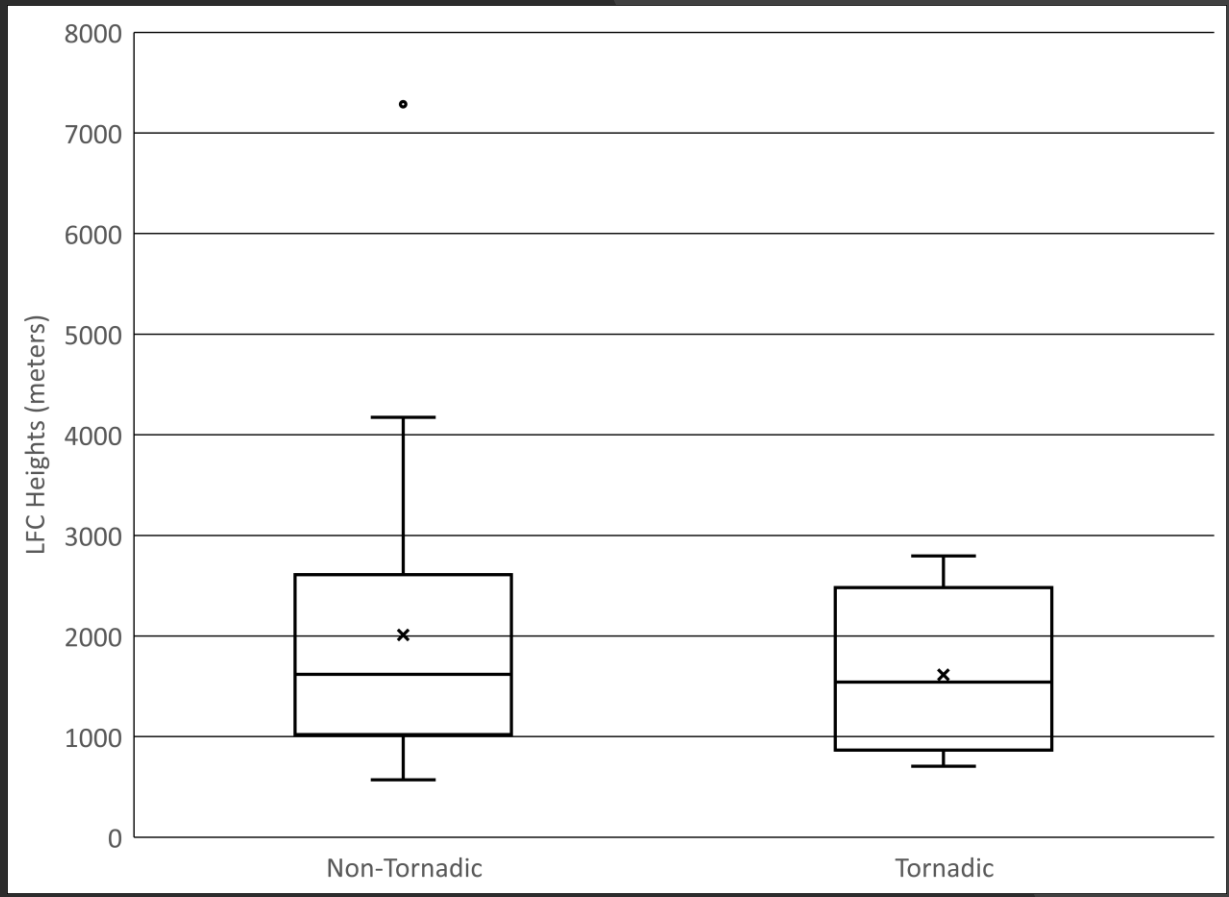
Lifted Condensation Level
Confirmed Cases

Lifted Condensation Level
Test Cases

Results

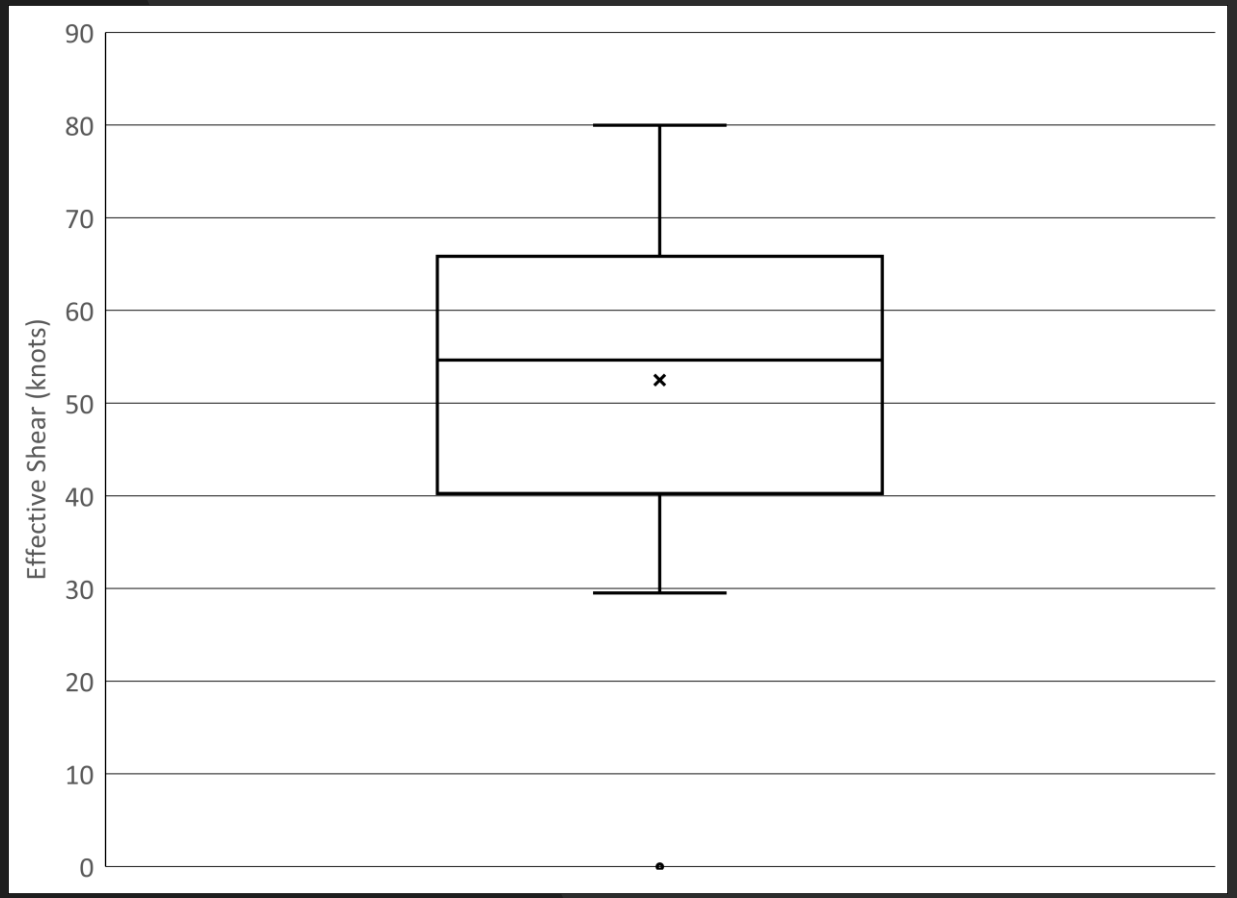


Level of Free Convection
Confirmed Cases

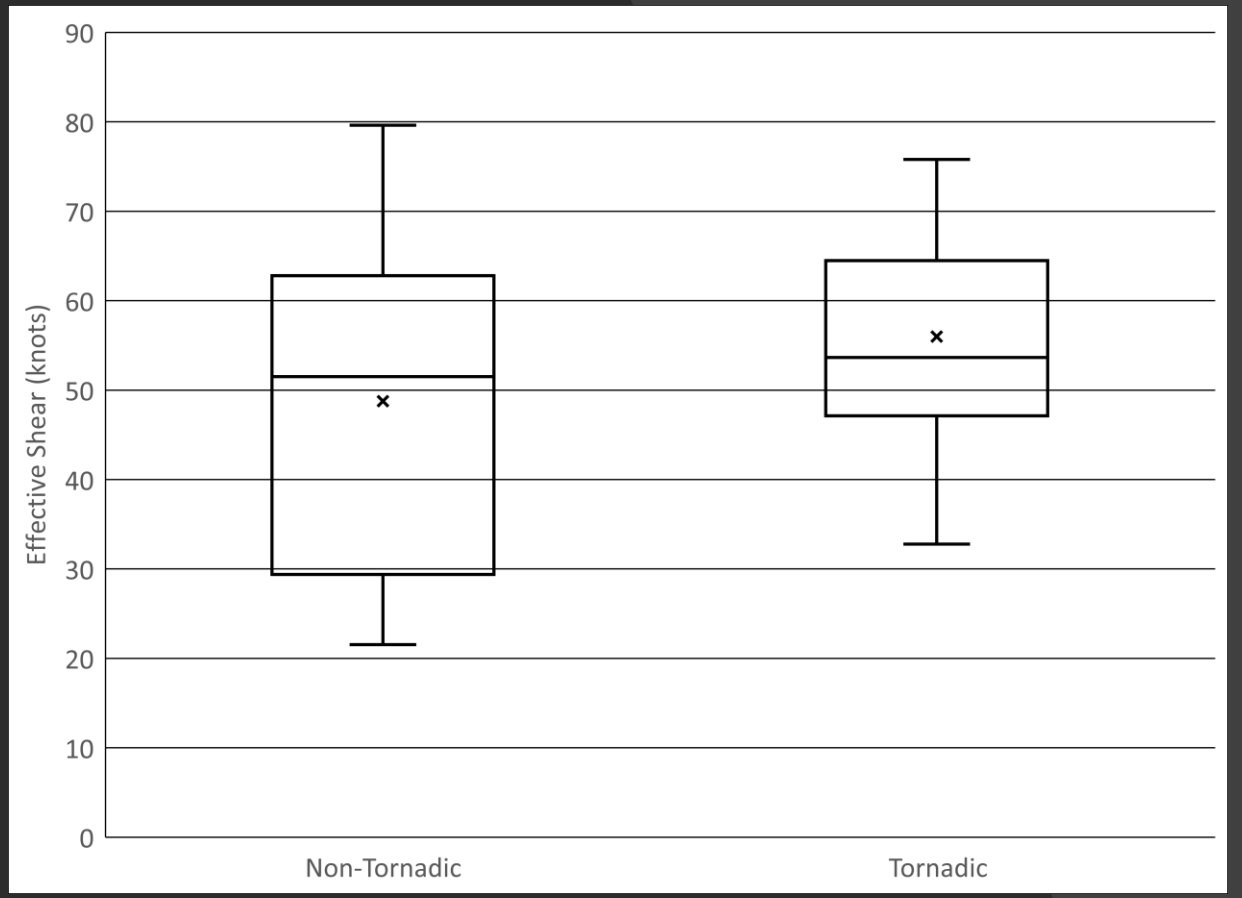


Level of Free Convection
Test Cases

Results

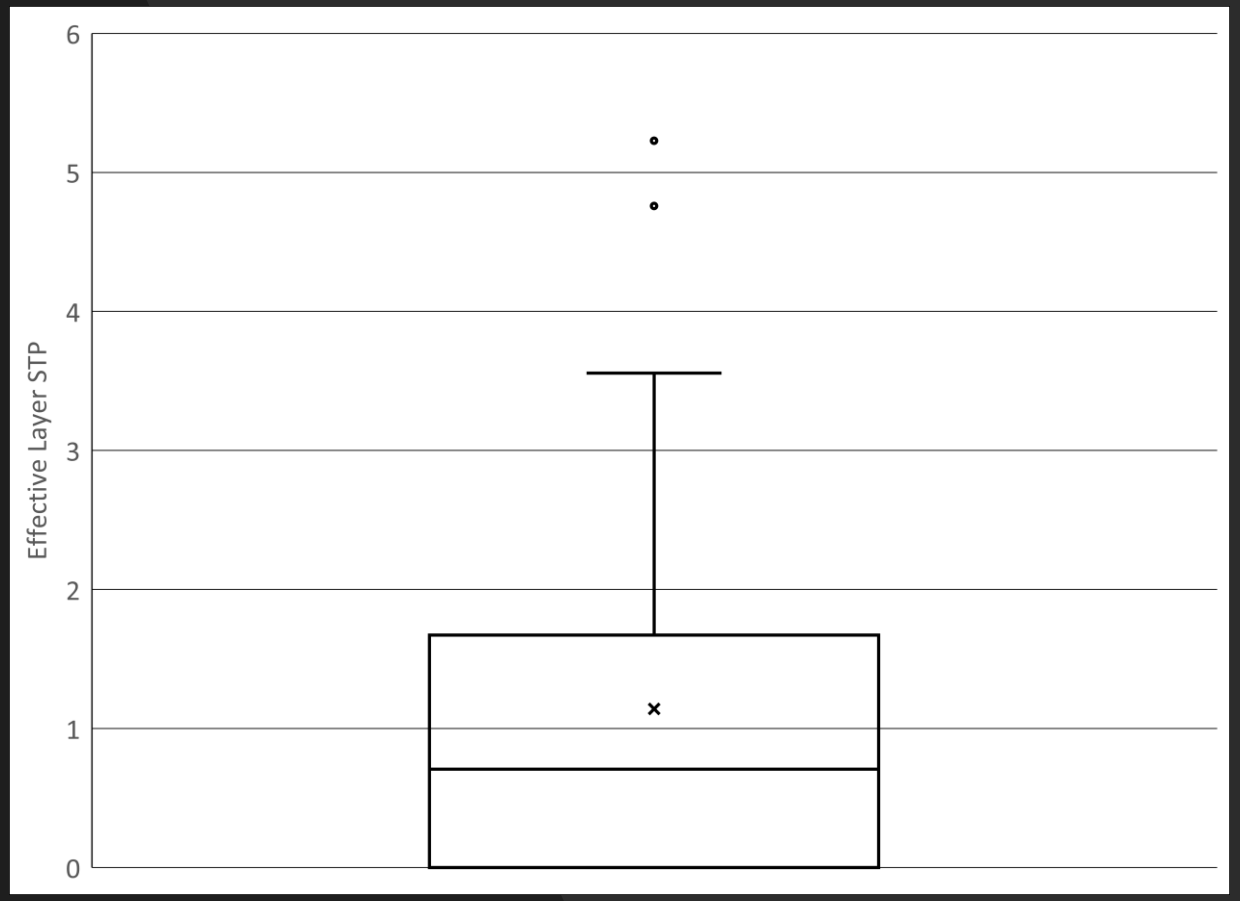


Effective Bulk Shear
Confirmed Cases

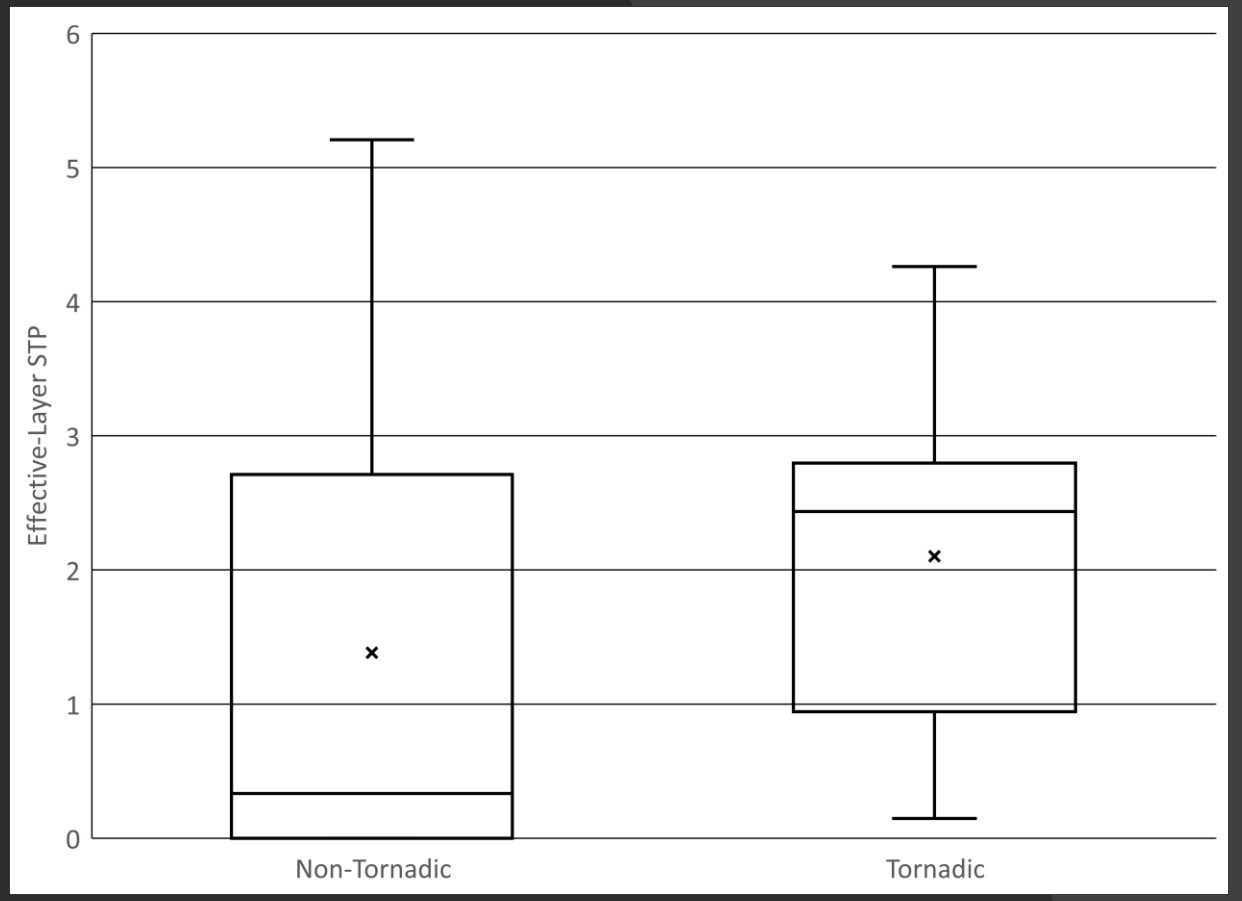


Effective Bulk Shear
Test Cases

Results

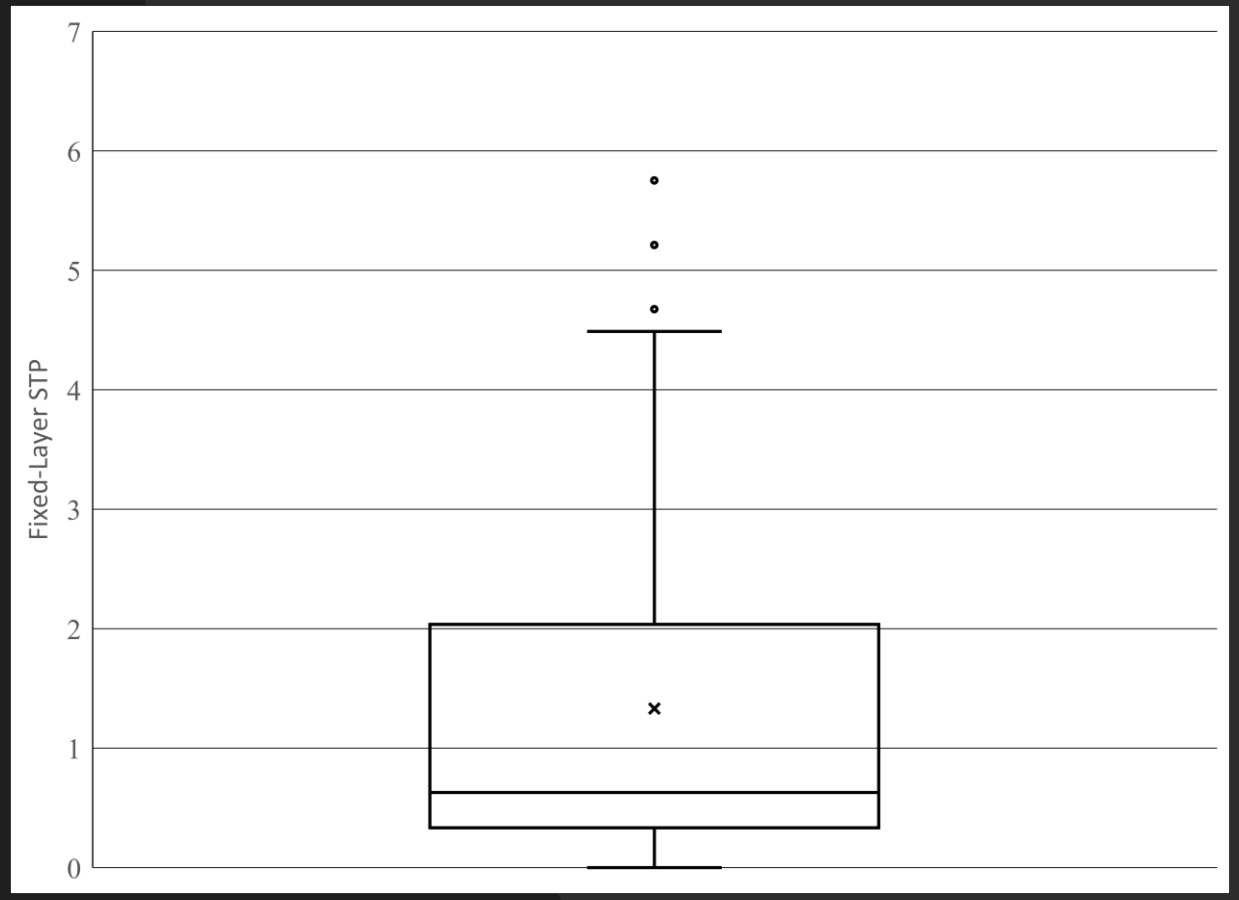


Effective-Layer Significant Tornado Parameter
Confirmed Cases

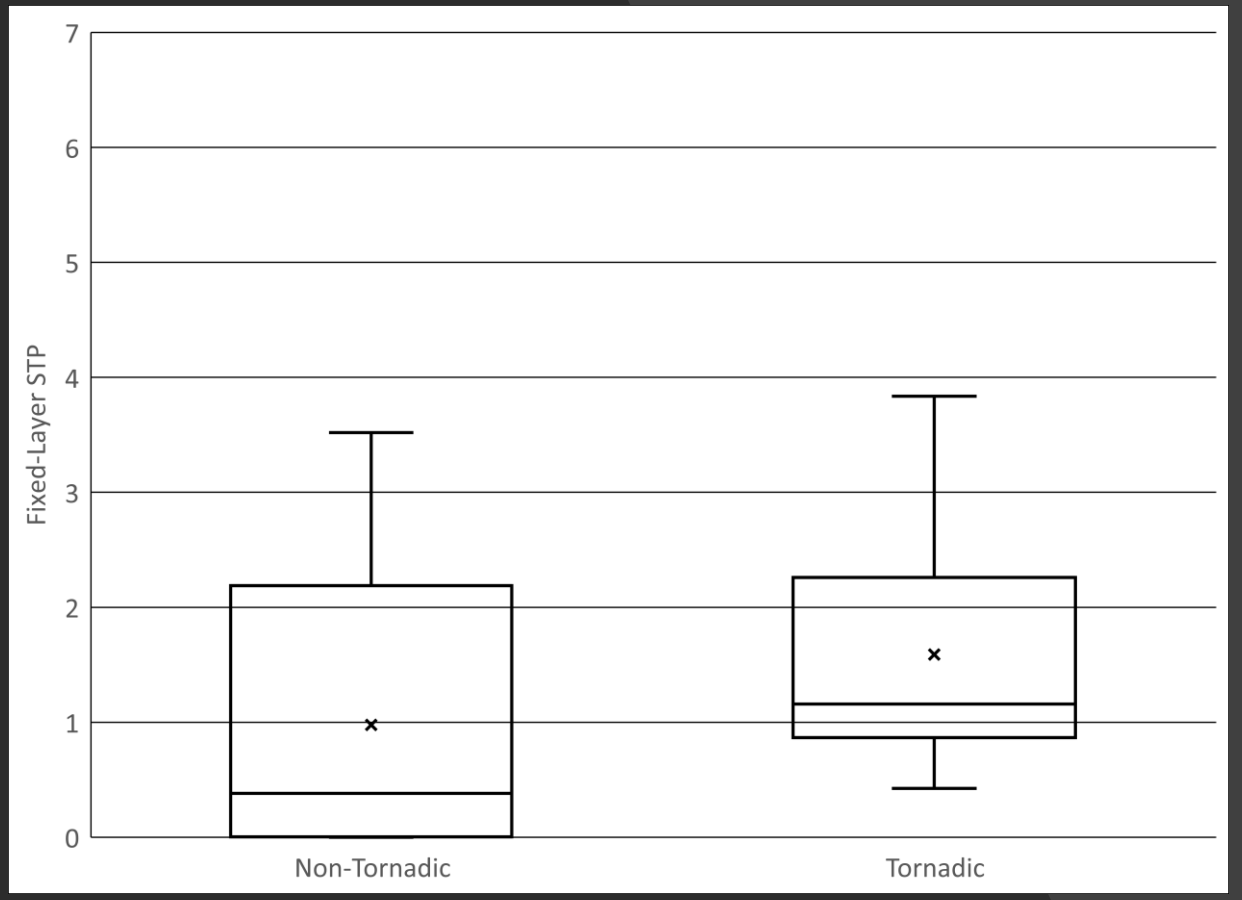


Effective-Layer Significant Tornado Parameter
Test Cases

Results

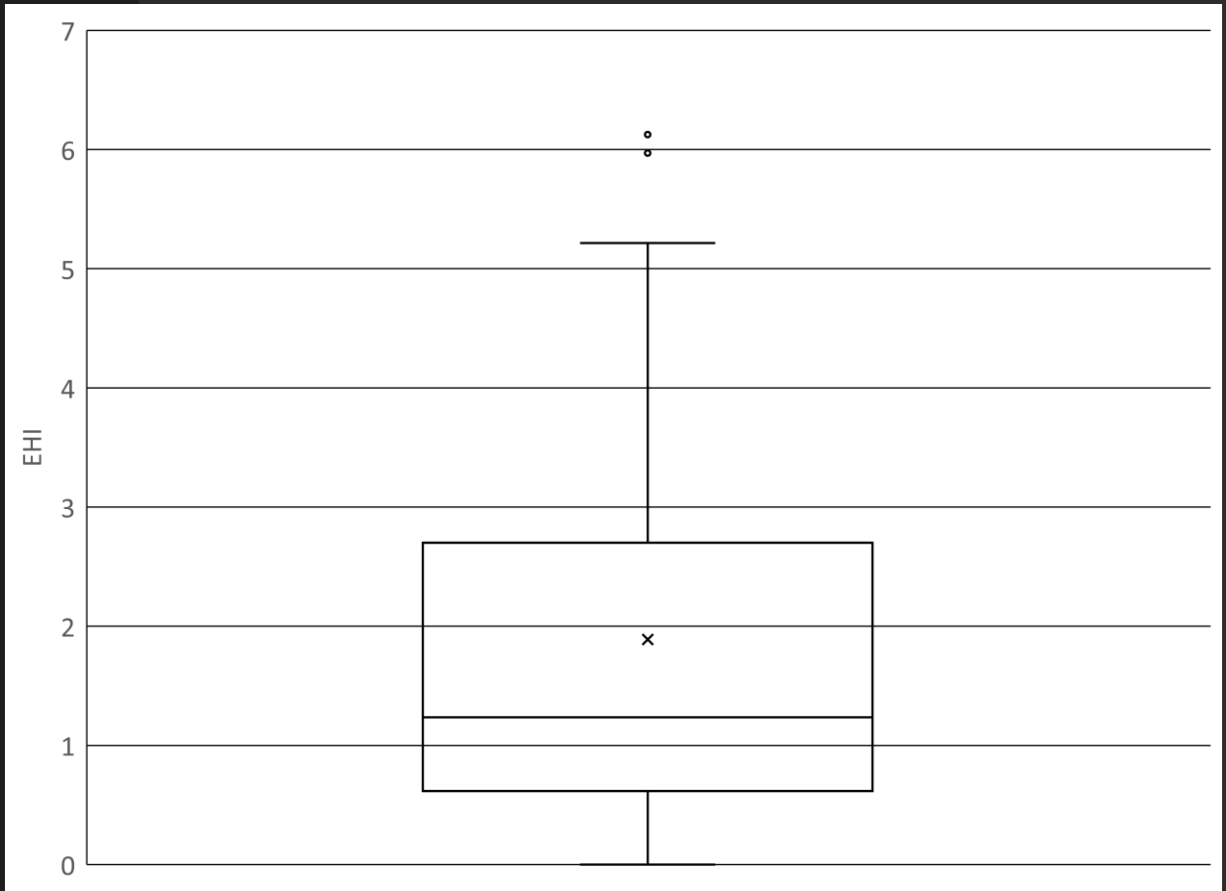


Fixed-Layer Significant Tornado Parameter
Confirmed Cases

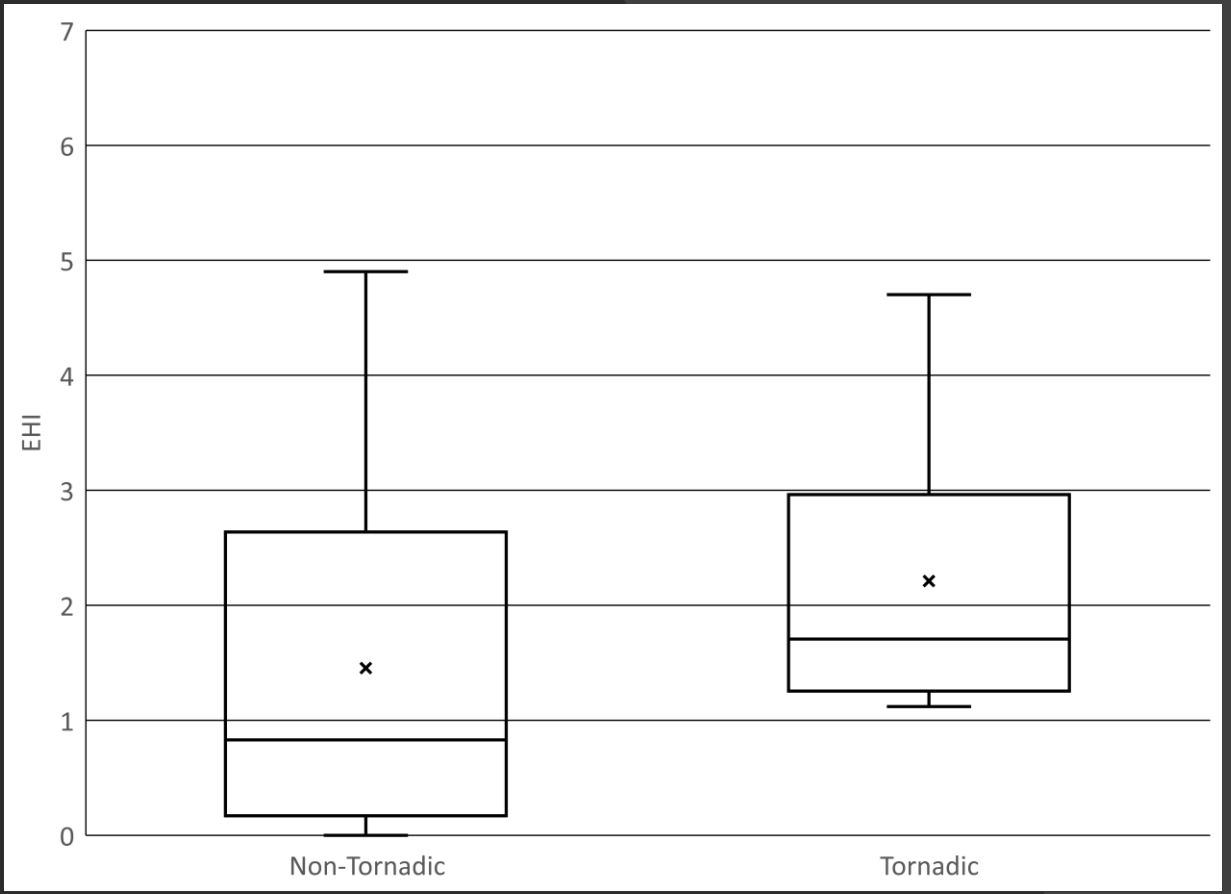


Fixed-Layer Significant Tornado Parameter
Test Cases

Results

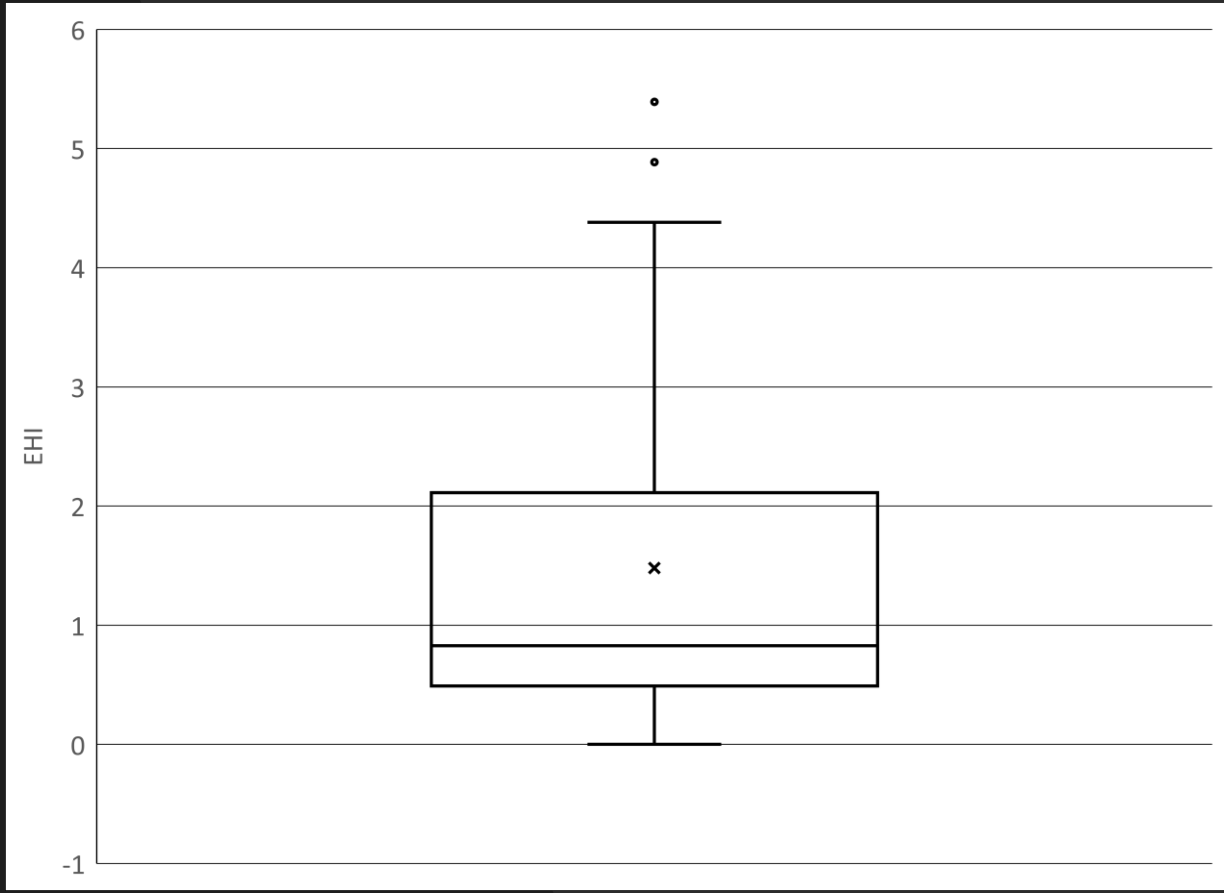


0-3 km Energy Helicity Index
Confirmed Cases

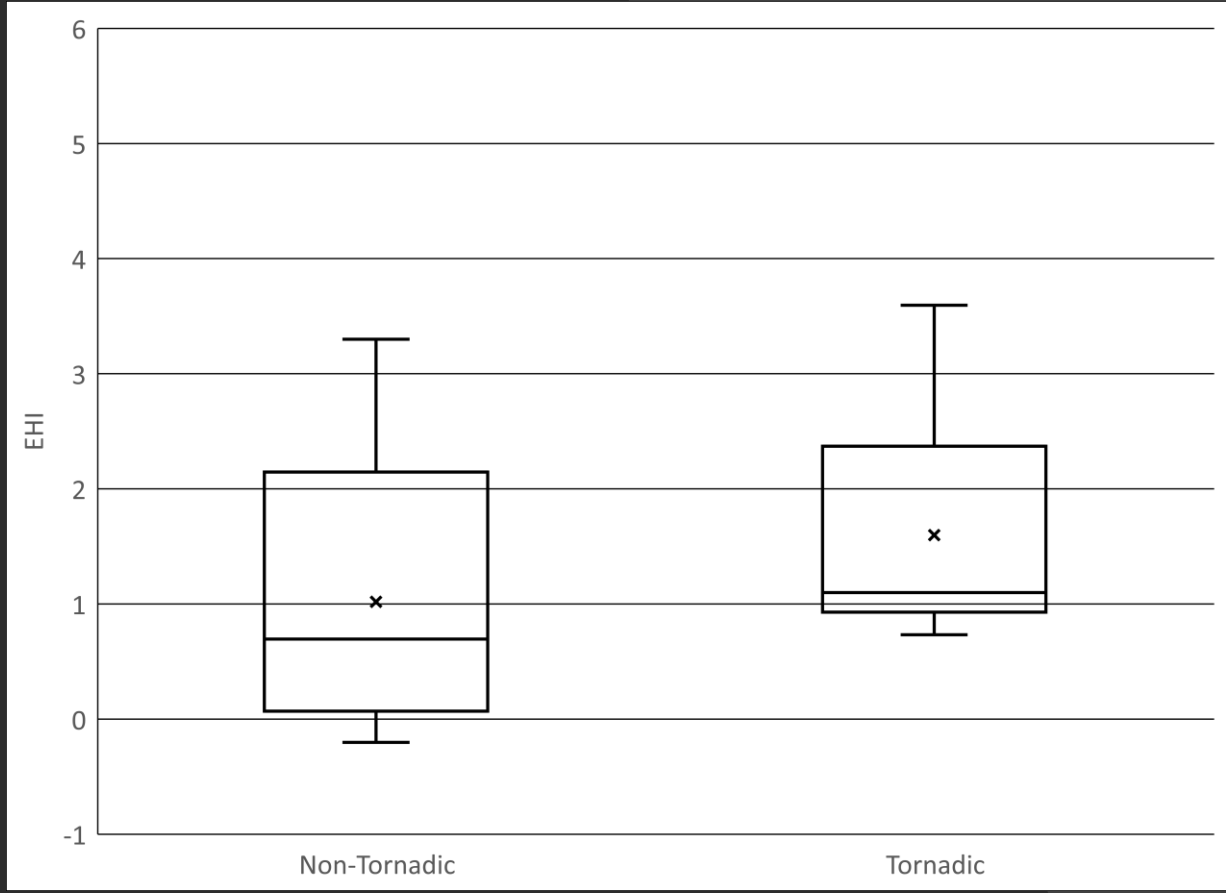


0-3 km Energy Helicity Index
Test Cases

Results

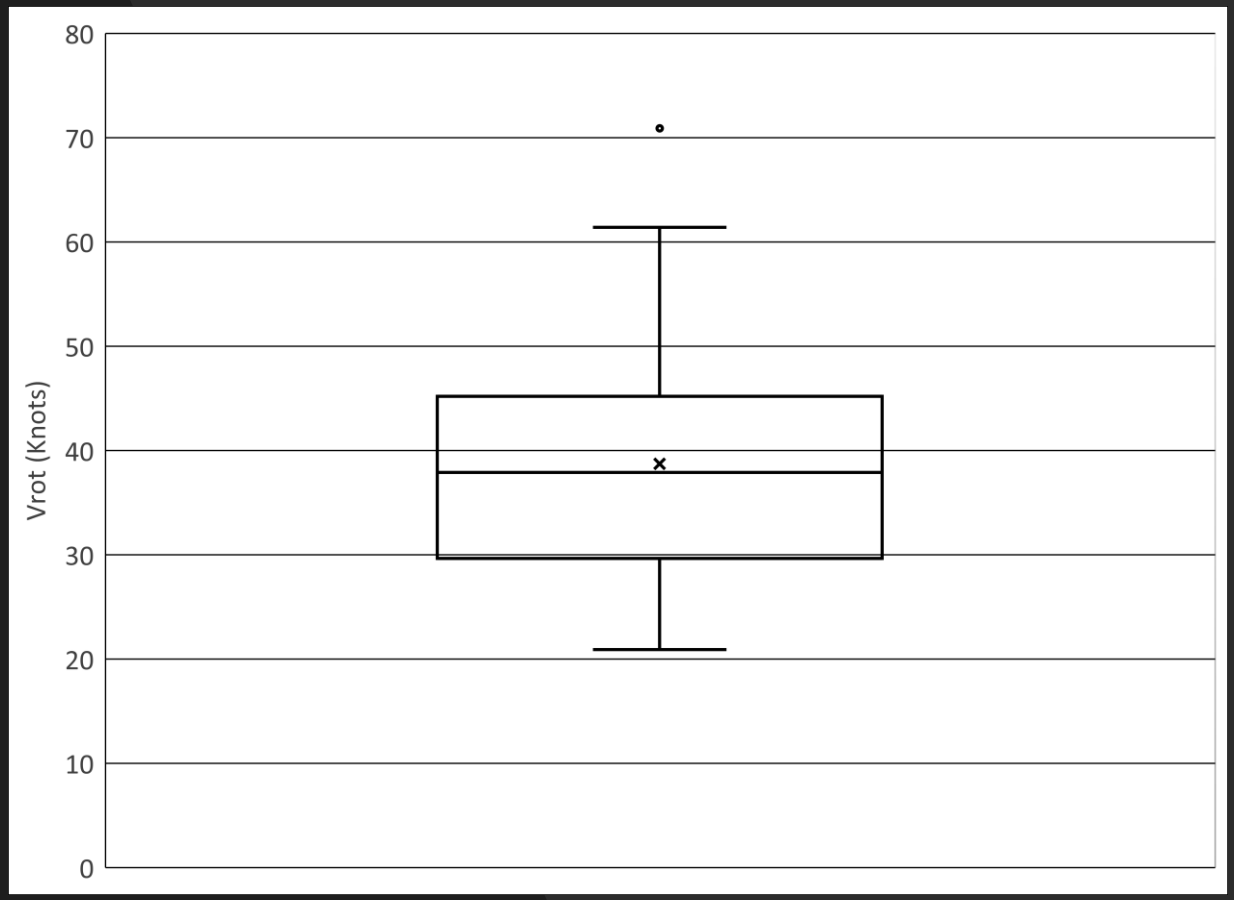


0-1 km Energy Helicity Index
Confirmed Cases

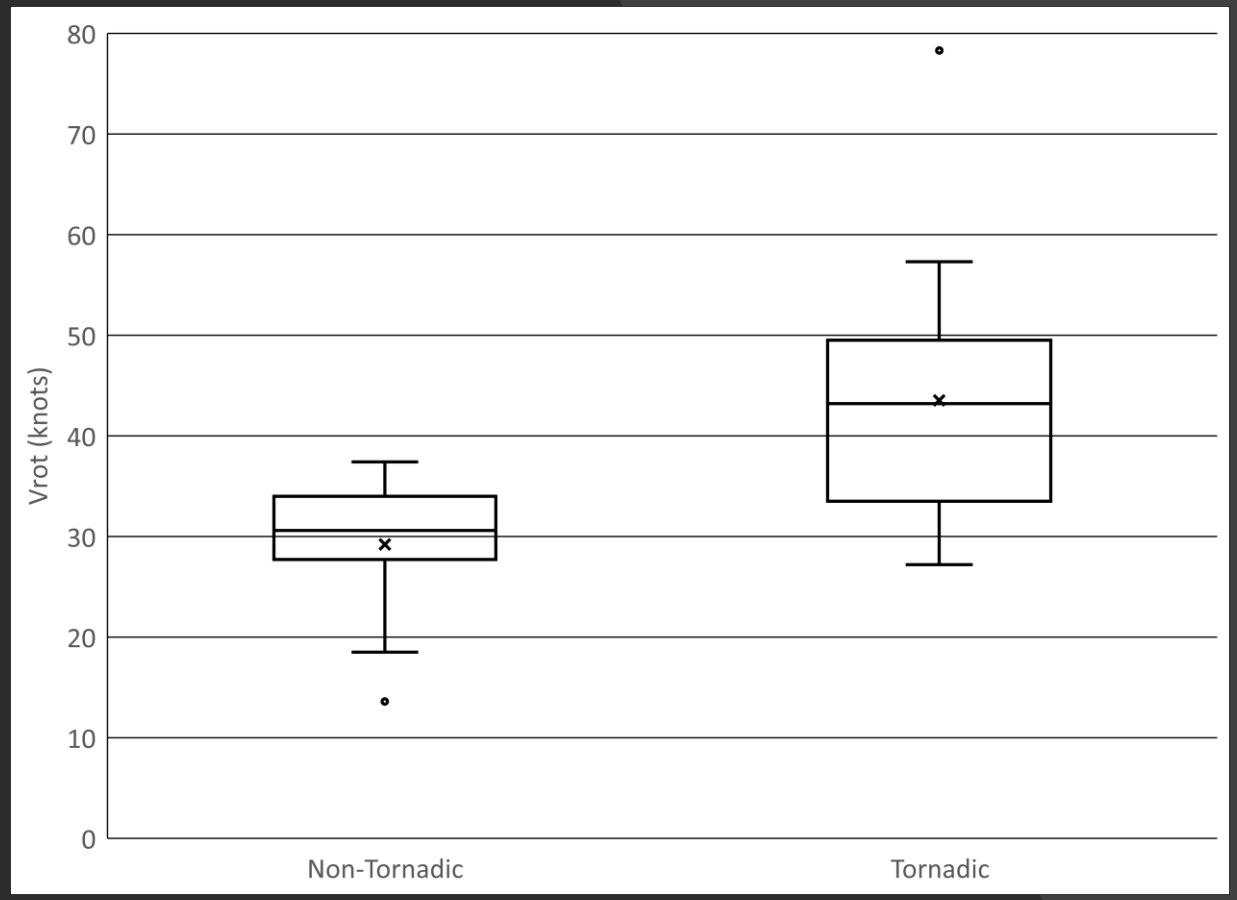


0-1 km Energy Helicity Index
Test Cases

Results

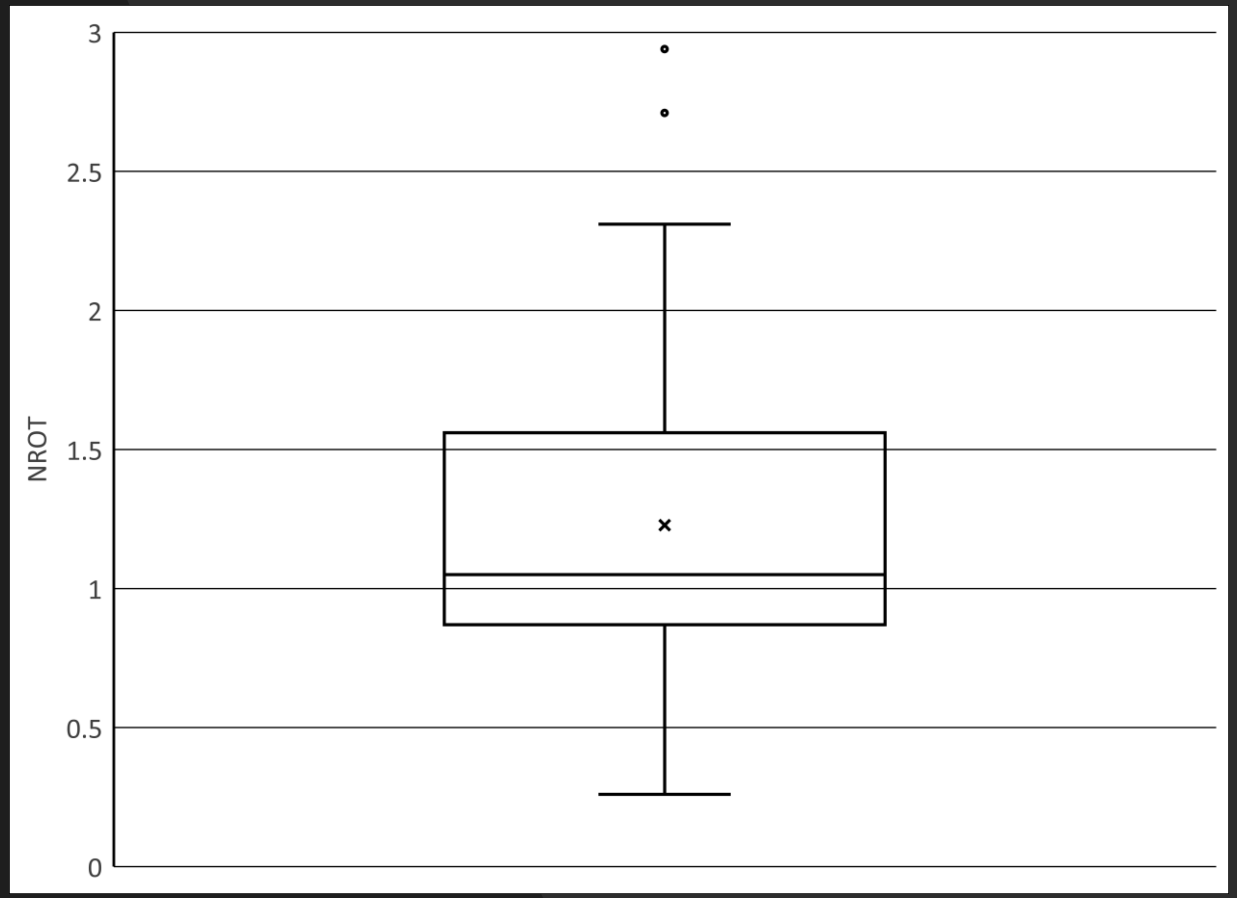


Starting Point Rotational Velocity
Confirmed Cases

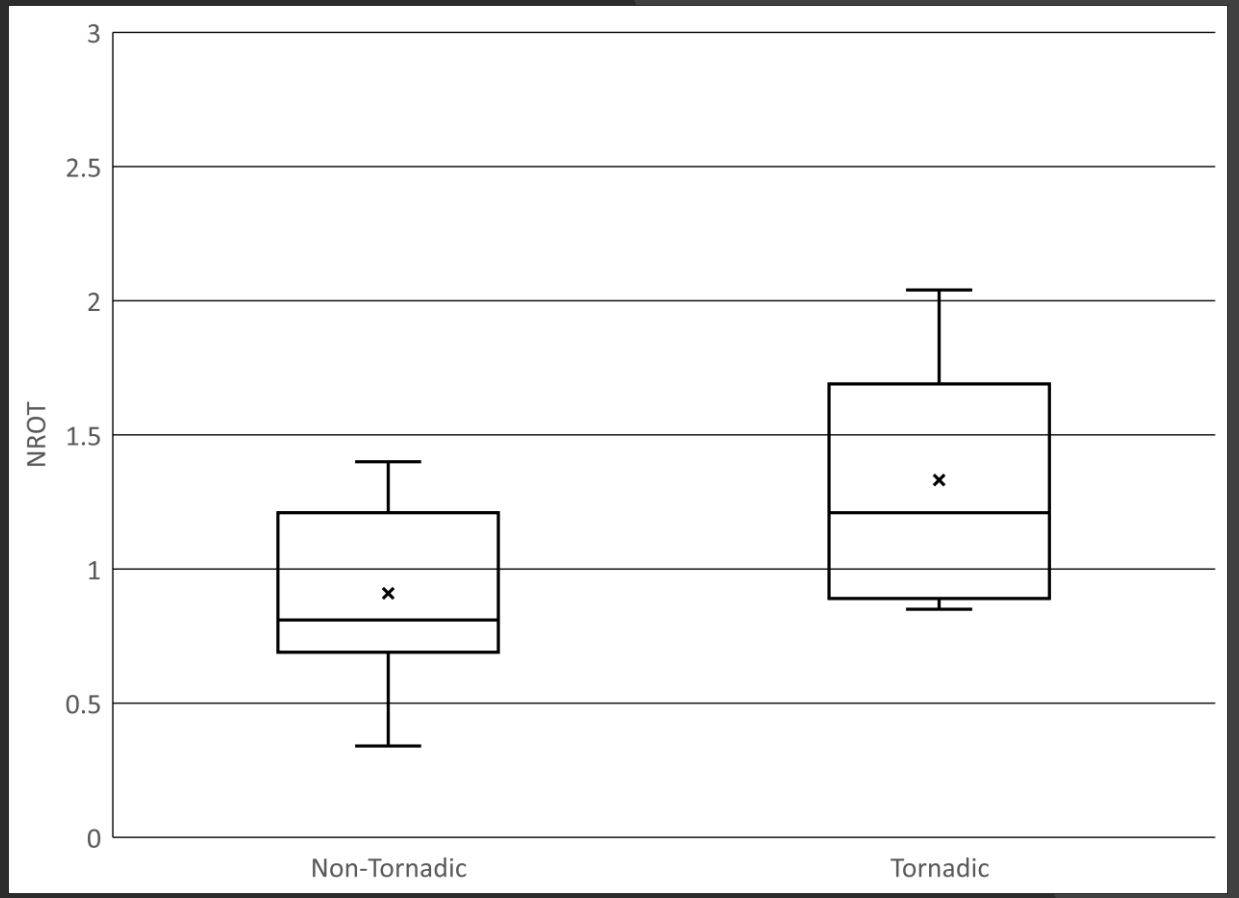


Starting Point Rotational Velocity
Test Cases

Results

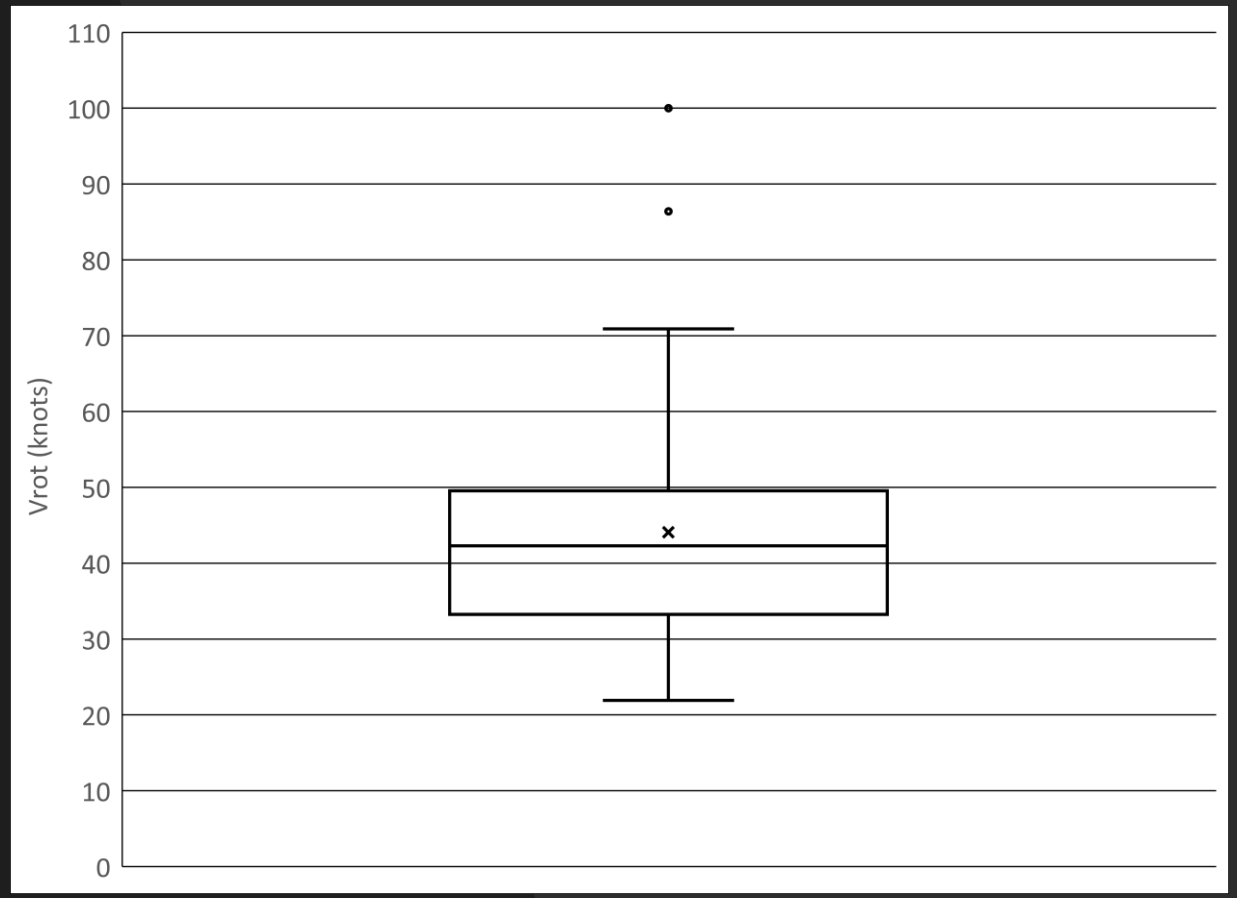


Starting Point Normalized Rotation
Confirmed Cases

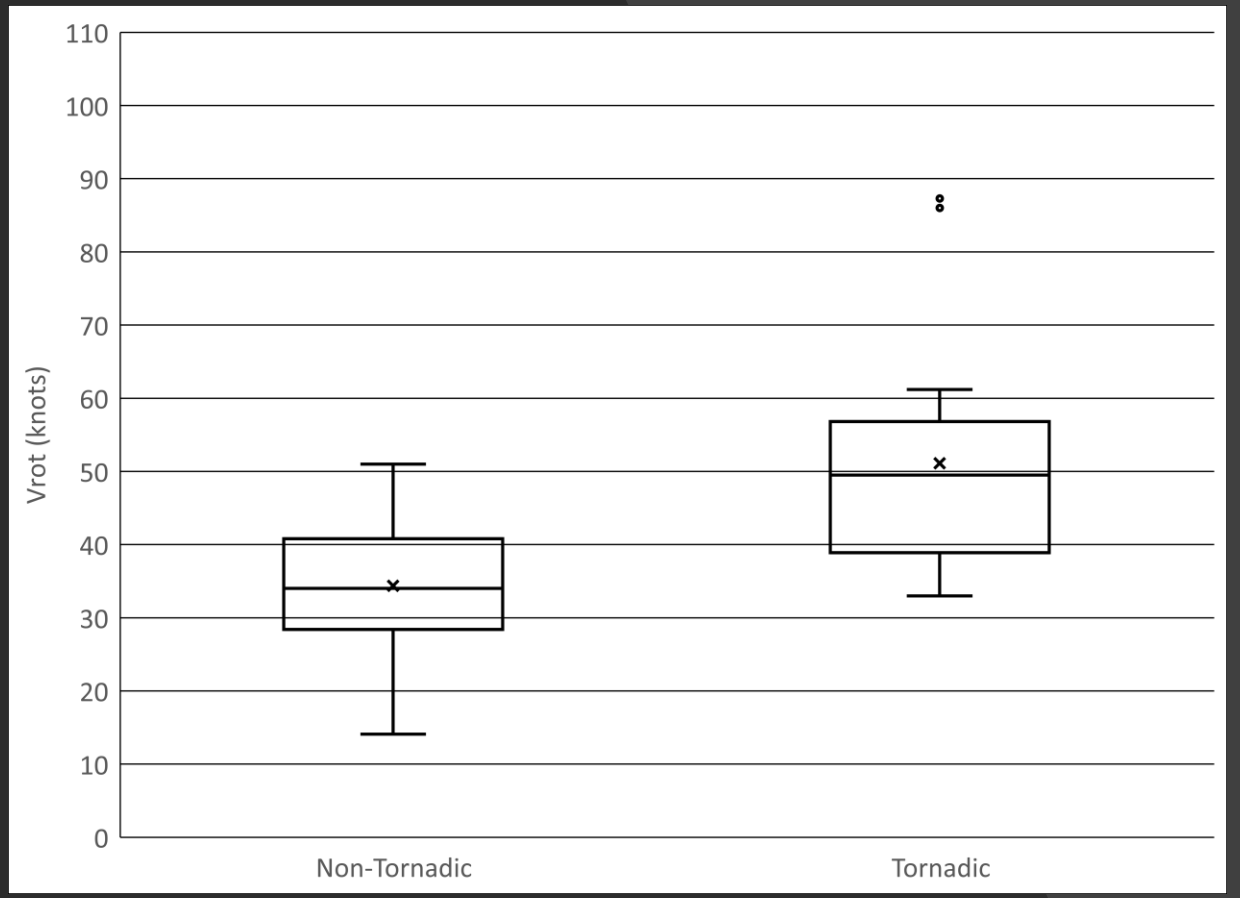


Starting Point Normalized Rotation
Test Cases

Results

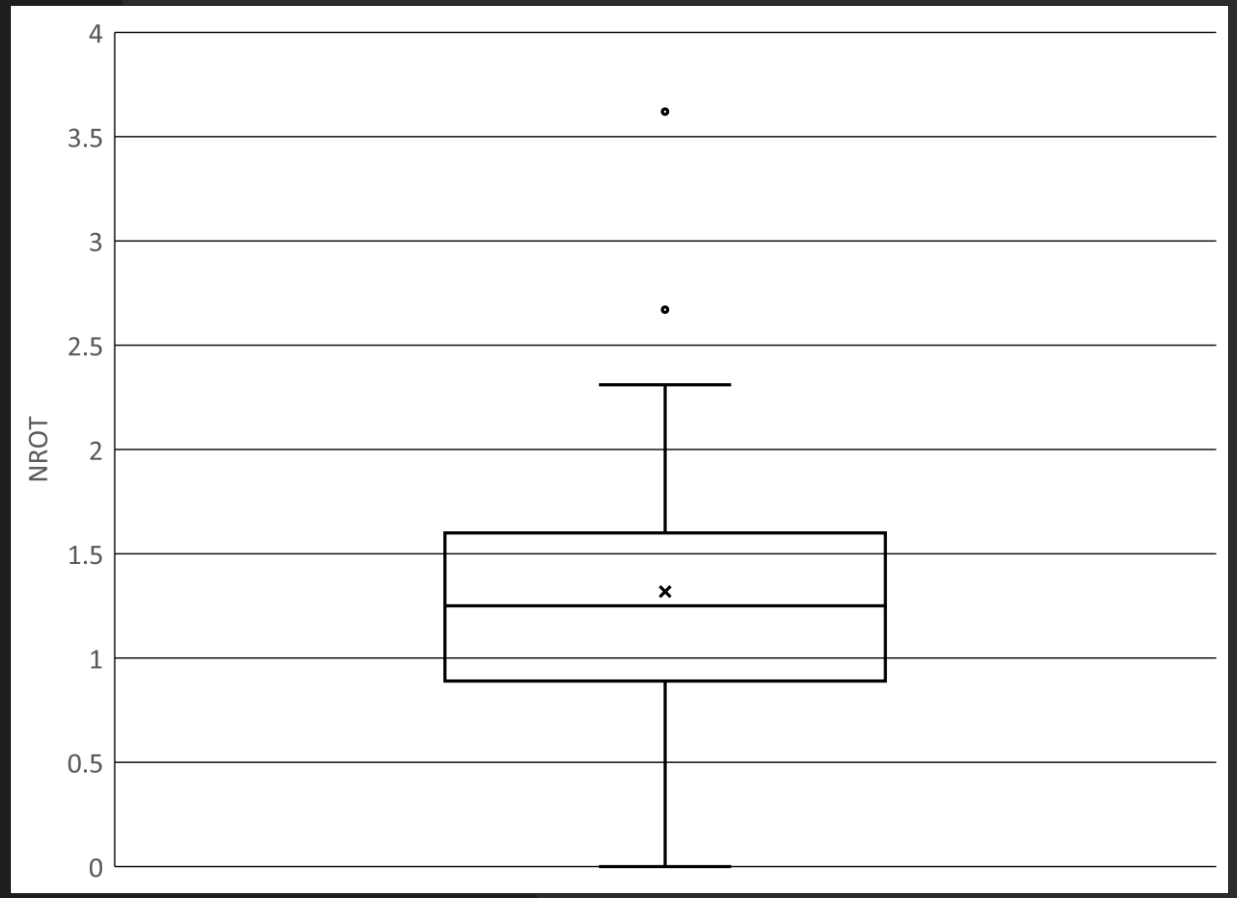


Peak Intensity Rotational Velocity
Confirmed Cases

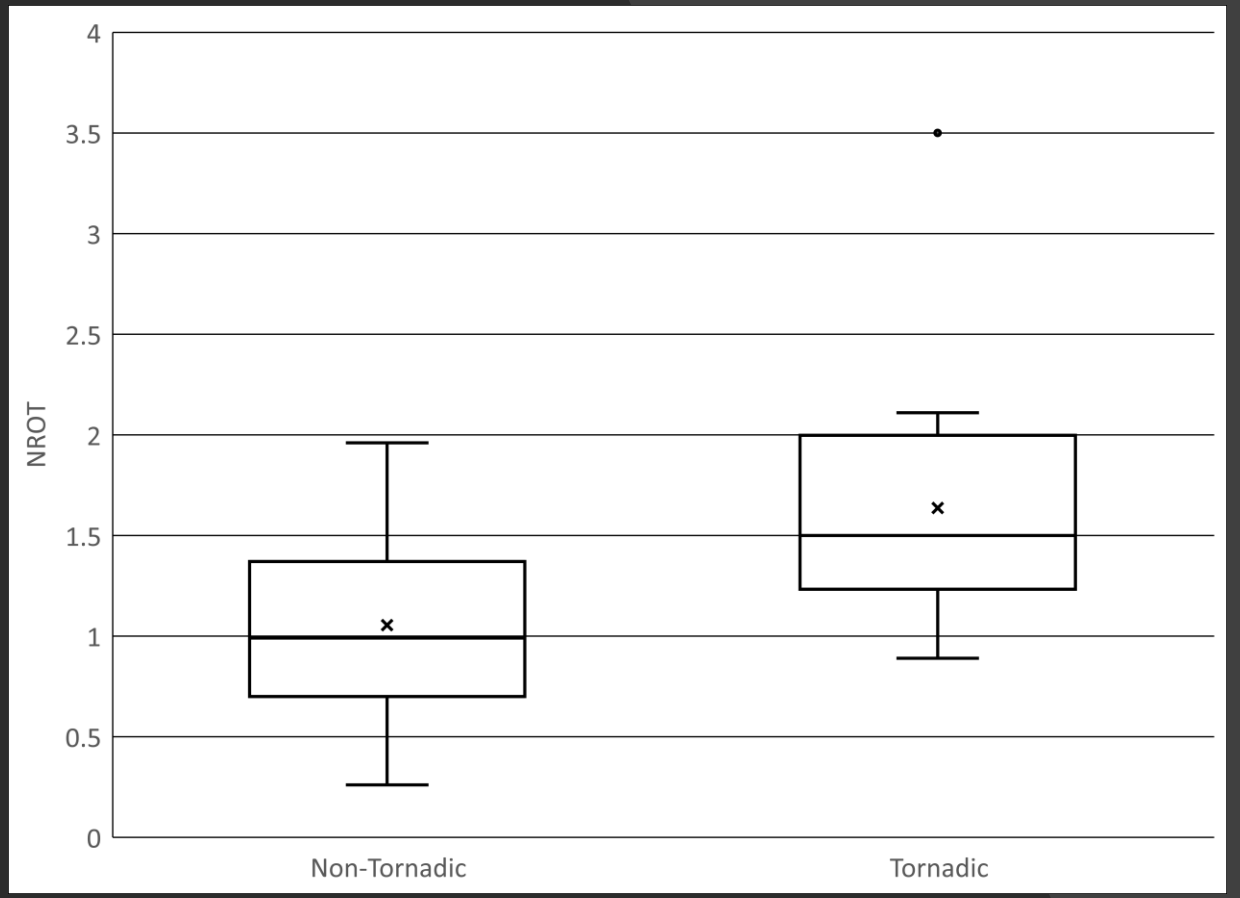


Peak Intensity Rotational Velocity
Test Cases

Results



Peak Intensity Normalized Rotation
Confirmed Cases



Peak Intensity Normalized Rotation
Test Cases

Results

Variable	Estimate	Std. Error	T-value	P-Value
Vrot	**0.5650**	**0.0096**	**2.376**	**0.0233**
CC	0.0228	0.0087	-1.547	0.1312
ZDR	**-0.0134**	**0.1400**	**3.679**	**0.0008**
M1CP	0.0004	0.0002	1.902	0.0656
MLFC	**0.0003**	**0.0001**	**2.316**	**0.0267**
dBZ	-0.0158	0.0118	-1.347	0.1869

Starting Point
Confirmed Cases

Adjusted R-squared
0.3852

Variable	Estimate	Std. Error	T-value	P-Value
Vrot	**0.0385**	**0.0071**	**5.45**	**<0.0001**
ZDR	**-0.0240**	**0.0882**	**-2.722**	**0.0119**
CC	0.0084	0.0062	1.345	0.1913
SBCP	**-0.0004**	**0.0002**	**-2.143**	**0.0424**
M1CP	0.0007	0.0004	1.971	0.0604
MMLH	-0.0006	0.0004	-1.452	0.1594
EHI1	**-1.9676**	**0.4648**	**-4.234**	**0.0003**
EHI3	**1.5675**	**0.3544**	**4.423**	**0.0002**

Starting Point
Test Cases

Adjusted R-squared
0.6015

- Variables selected from stepwise regression modeling (significant=bold)
- Vrot=rotational velocity, CC=correlation coefficient, ZDR=differential reflectivity, M1CP=mixed-layer CAPE, MLFC=level of free convection, dBZ=reflectivity, SBCP=surface-based CAPE, MMLH=lifted condensation level, EHI1=0-1 km energy helicity index, EHI3=0-3 km energy helicity index

Results

Variable	Estimate	Std. Error	T-value	P-Value
Diameter	-0.1903	0.1220	-1.561	0.1289
Vrot	**0.0204**	**0.0076**	**2.679**	**0.0119**
dBZ	**0.0549**	**0.1780**	**3.086**	**0.0043**
SBCP	0.0005	0.0004	1.314	0.1989
M1CP	-0.0006	0.0004	-1.321	0.1964
MMLH	**-0.0014**	**0.0006**	**-2.468**	**0.0195**
ESHR	**0.0199**	**0.0079**	**2.509**	**0.0178**
SIGT	**-0.8230**	**0.2555**	**-3.248**	**0.0029**
STPC	**0.3448**	**0.1634**	**2.110**	**0.0433**
EHI3	**0.4643**	**0.2139**	**2.170**	**0.0381**

Adjusted R-squared
0.4984

Peak Intensity
Confirmed Cases

Variable	Estimate	Std. Error	T-value	P-Value
Diameter	-0.1193	0.0844	-1.414	0.1696
Vrot	**0.0254**	**0.0084**	**3.019**	**0.0058**
SBCP	-0.0005	0.0025	-2.012	0.0551
M1CP	0.0005	0.0032	1.436	0.1634
SIGT	**-0.8936**	**0.3343**	**-2.673**	**0.0130**
EHI3	**0.6746**	**0.2871**	**2.350**	**0.0270**

Adjusted R-squared
0.3239

Peak Intensity
Test Cases

- Vrot=rotational velocity, dBZ=reflectivity, SBCP=surface-based CAPE, M1CP=mixed-layer CAPE, MMLH=lifted condensation level, ESHR=effective bulk shear, SIGT=fixed-layer significant tornado parameter, STPC=effective-layer significant tornado parameter, EHI3=0-3 km energy helicity index

Results

Variable	Estimate	Std. Error	T-value	P-Value
M1CP	-0.0071	0.0030	-2.377	0.0212
EHI1	3.2195	1.3160	2.446	0.0178

Starting Point

Adjusted R-squared
0.0921

Variable	Estimate	Std. Error	T-value	P-Value
SBCP	-0.0107	0.0035	-3.062	0.0035
EHI3	7.7322	1.7656	4.379	<0.0001

Peak Intensity

Adjusted R-squared
0.2417

- All tornadoes in both confirmed and test cases were combined into single datasets for starting point and peak intensity to test the influence of the storm environment paraments on rotational velocity
- M1CP=mixed-layer CAPE, SBCP=surface-based CAPE, EHI1=0-1 km energy helicity index, EHI3=0-3 km energy helicity index

Conclusions

- Vrot found statistically significant in all regression models
- Vrot values were higher in this study than Smith et al. 2015
  - Storms exceeding 20 knots will required extra attention
  - Possible to regionalized values from Smith et al. 2015 for use in impact based warnings (IBWs)
- Combination of Vrot and a tweaked EHI with an emphasis on shear and low CAPE environments might aid in reducing the FAR
- Little evidence for storm environment having influence on Vrot

Future Work

- Expand the study area to a larger portion of the Southeast with similar climatology
- Include high shear/low-CAPE environmental parameters similar to SHERB or a modified version of SHERB
- Explore interactions terms in depth in the modeling phase and a binary term for tornadic debris signature following guidelines of WDTD (2016)

Questions/Acknowledgements

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Dr. Arleen Hill
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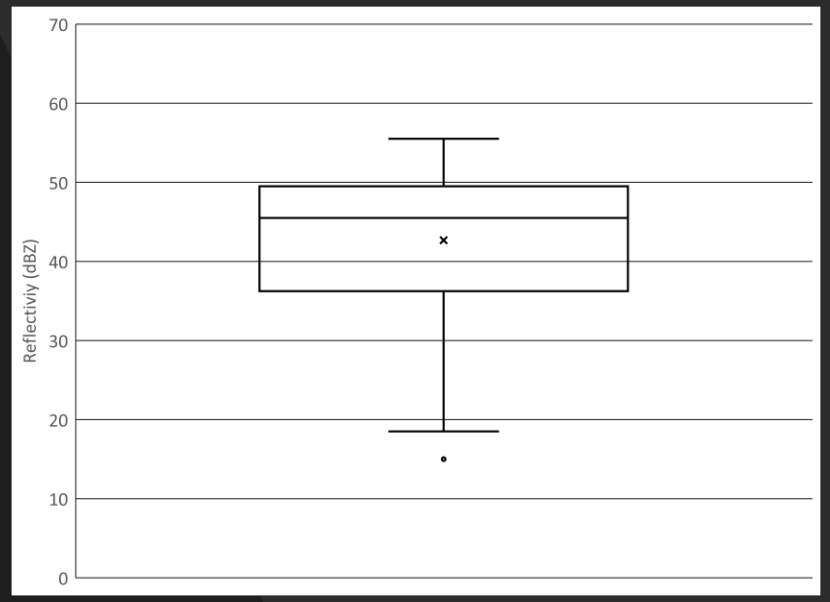
Dr. Mike Brown

Storm Prediction Center (SPC)
Dr. Marsh

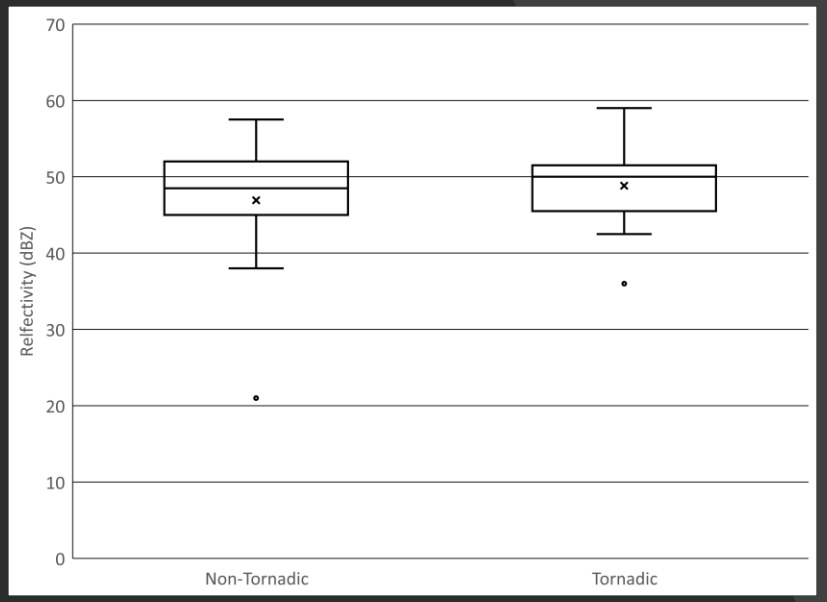
Friends and Family
Alex Kent
My parents


The End

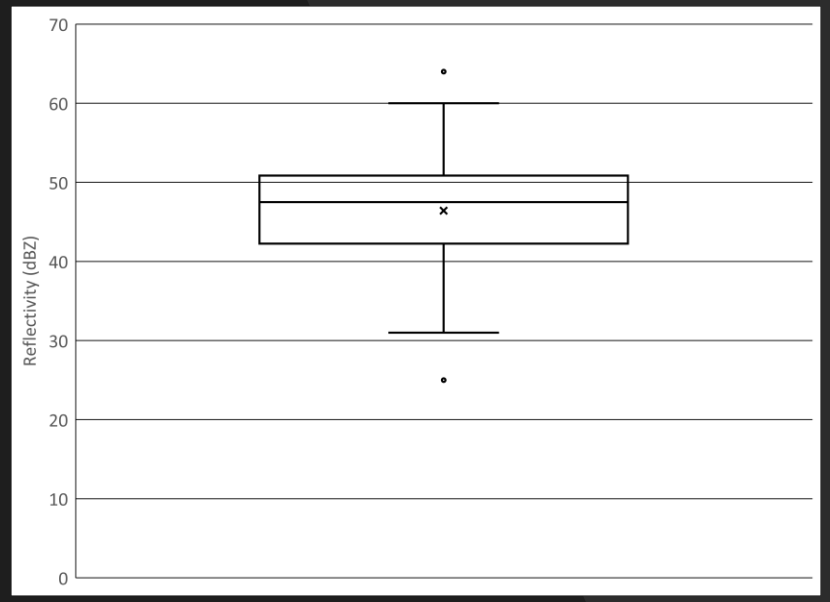
Starting Point dBZ Confirmed Cases



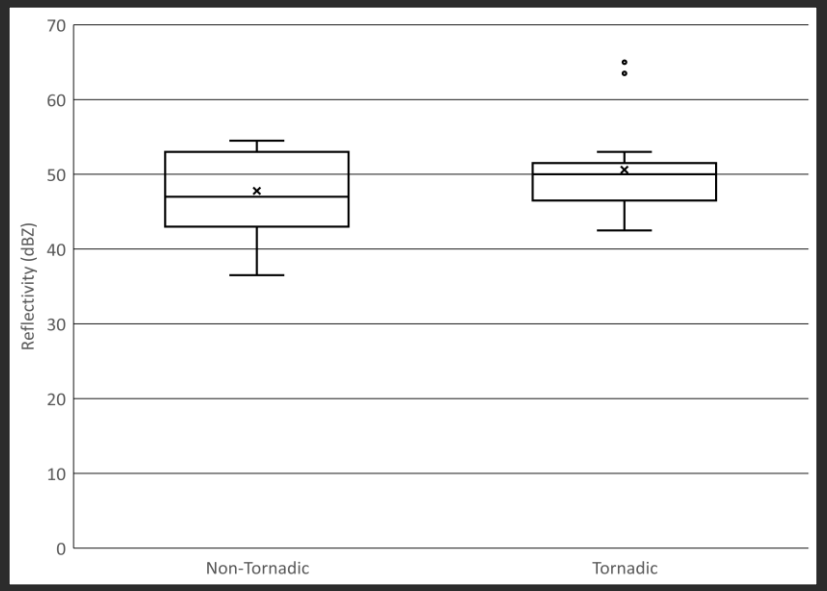
Starting Point dBZ Test Cases



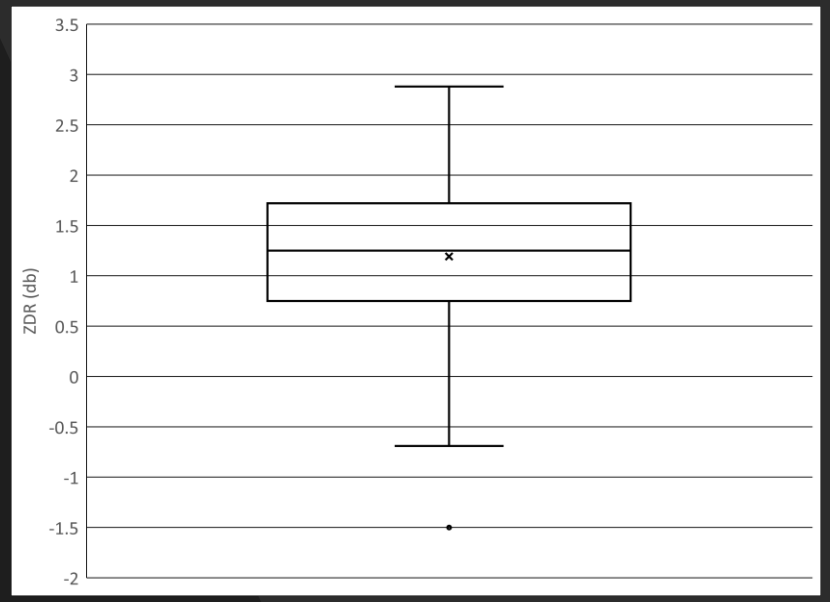
Peak Intensity dBZ Confirmed Cases



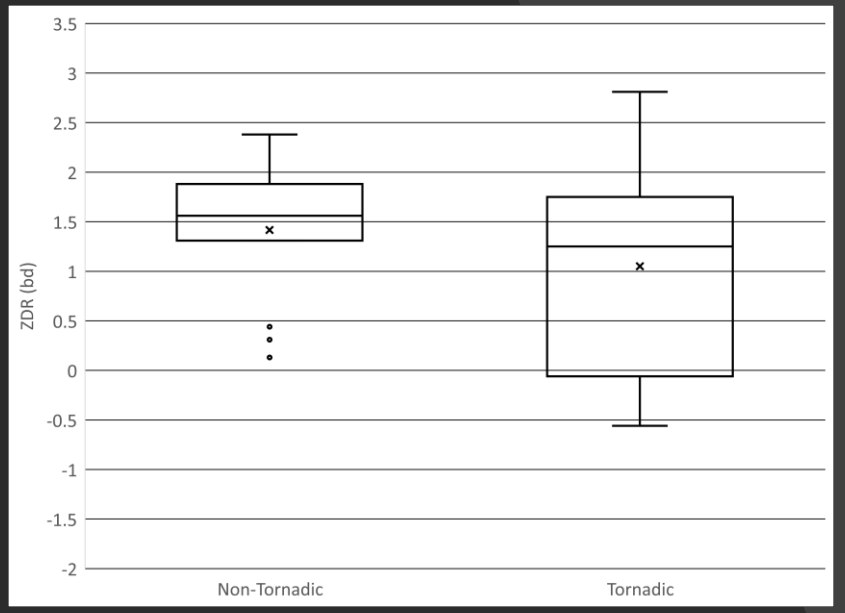
Peak Intensity dBZ Test Cases



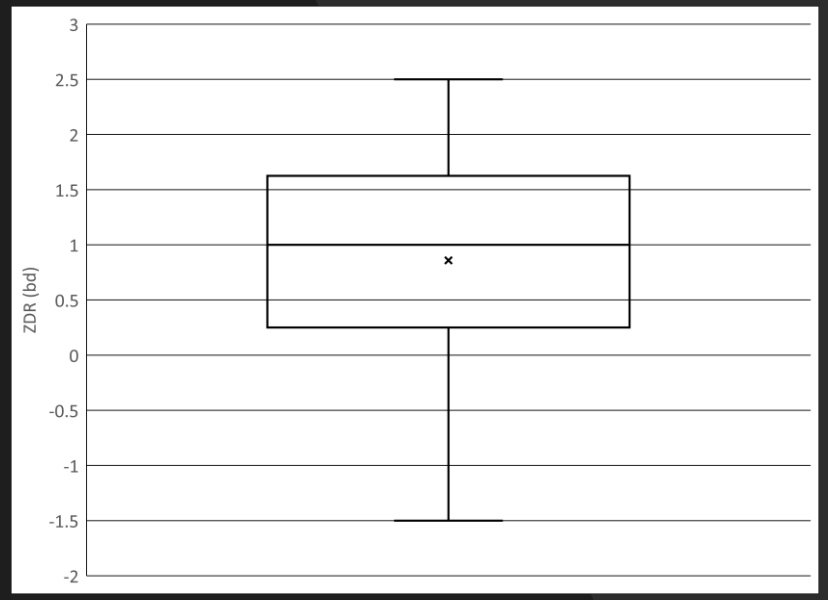
Beginning ZDR for the Confirmed Cases



Beginning ZDR for the Test Cases



Peak ZDR for the Confirmed Cases



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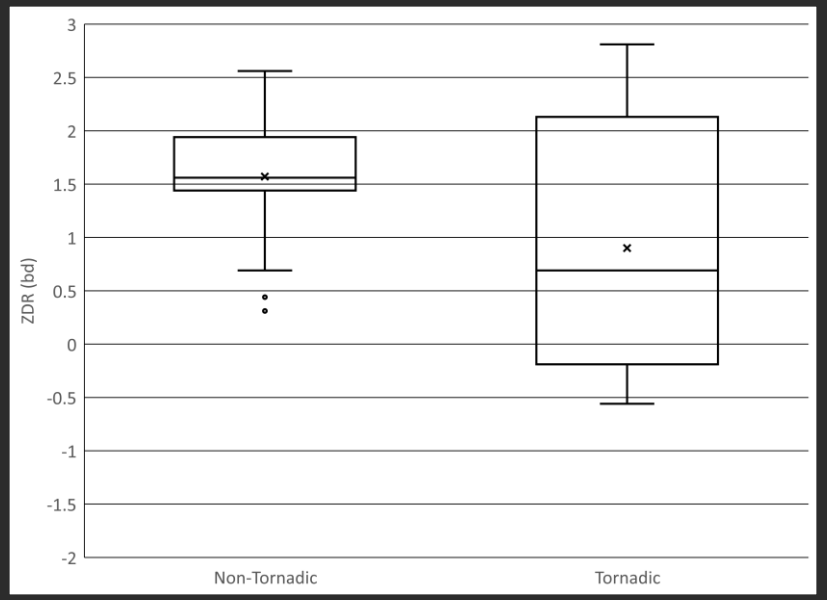

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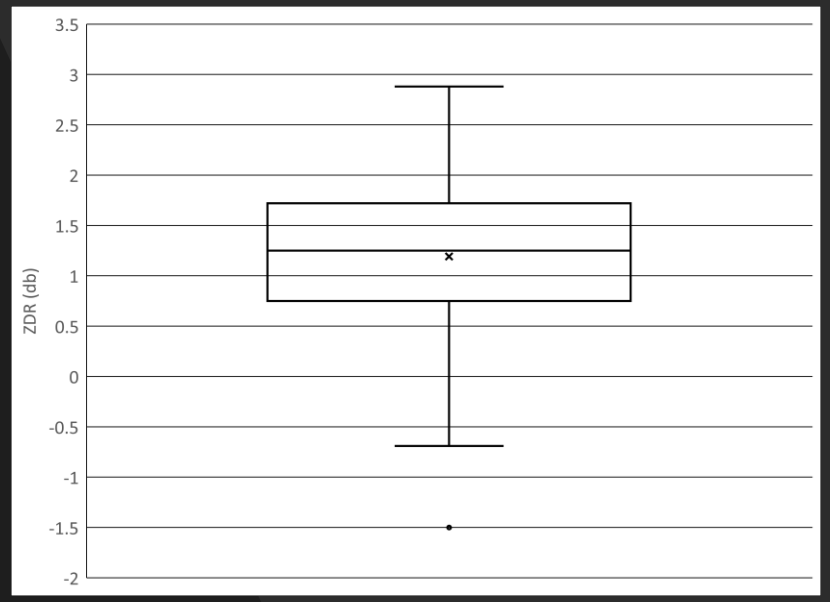

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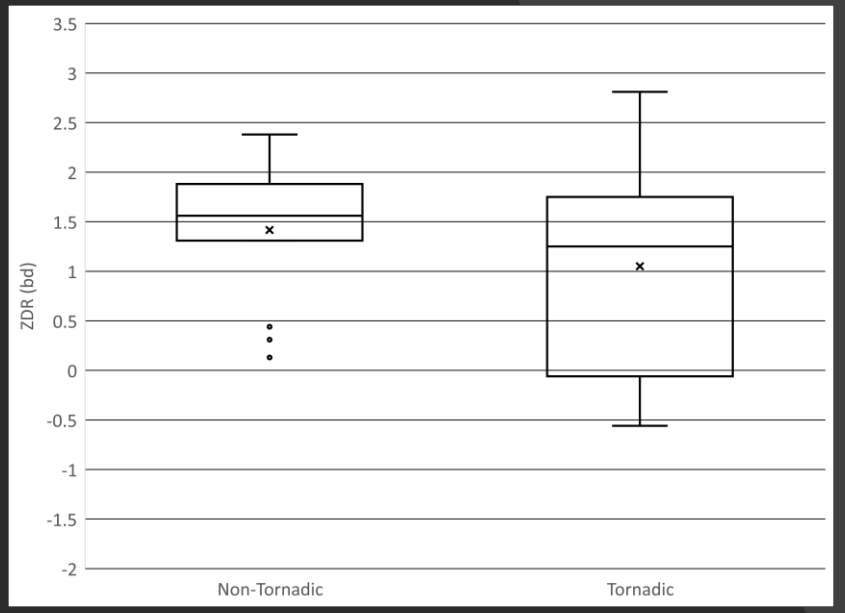

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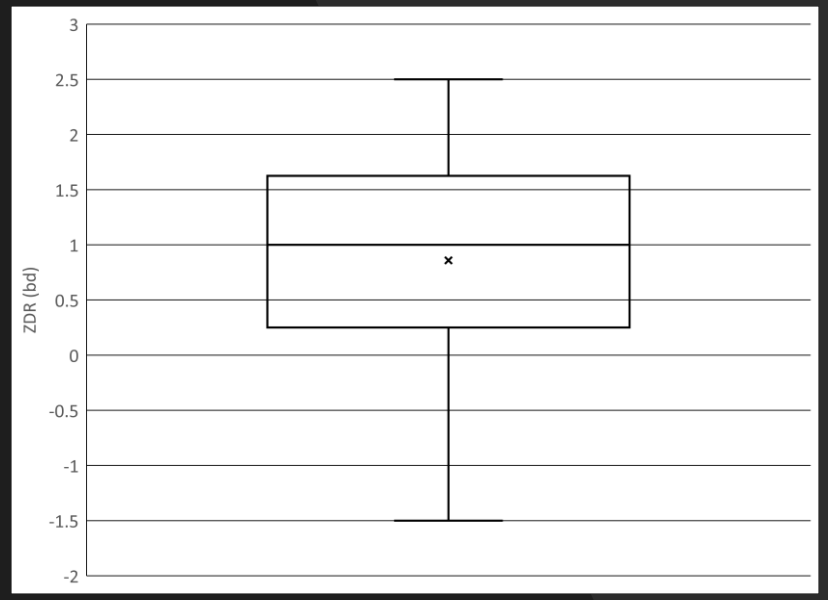

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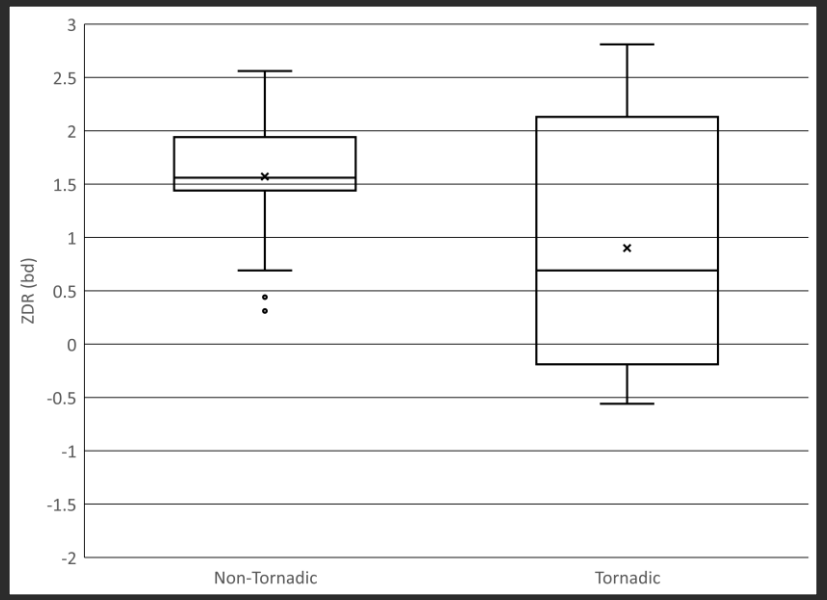

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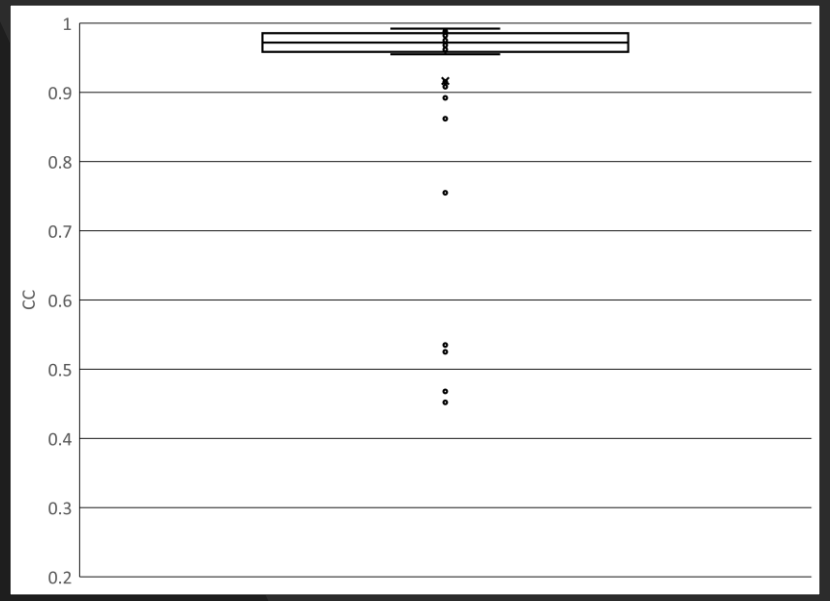

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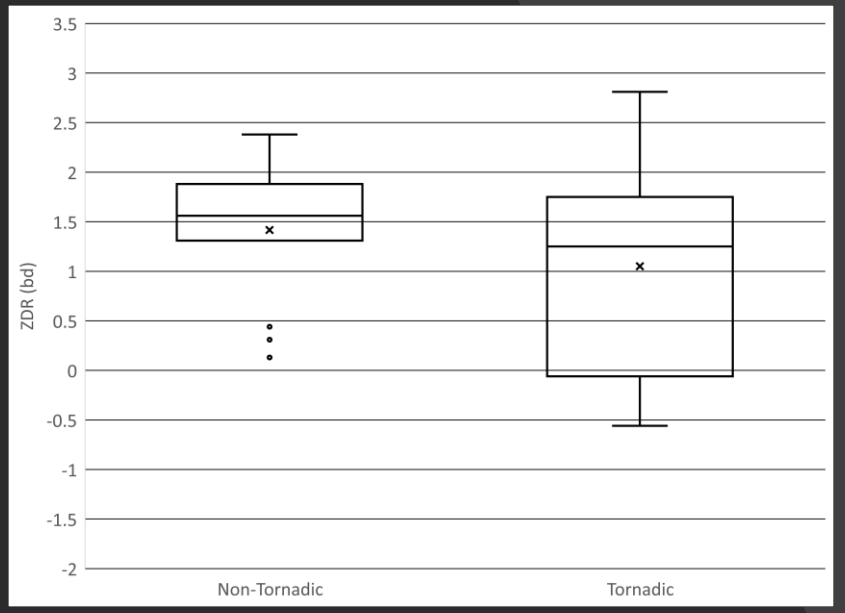

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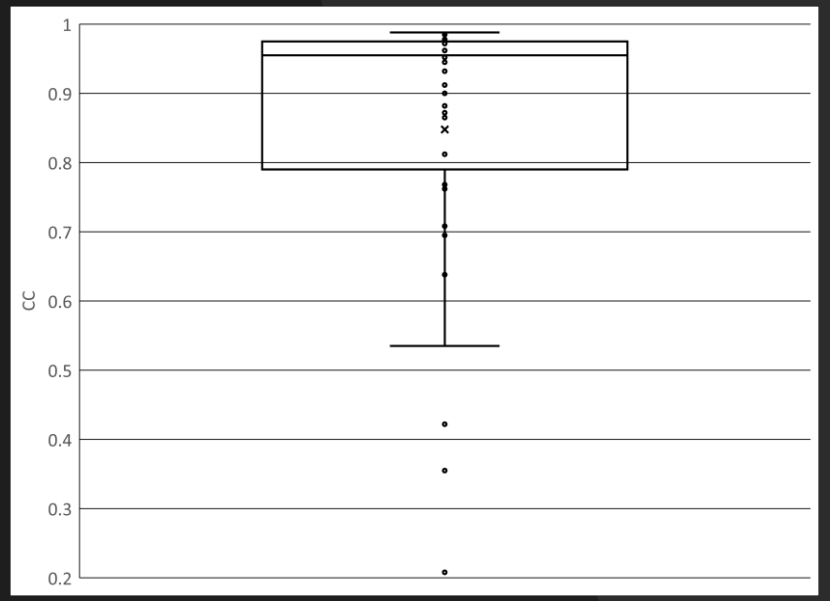

Peak CC for the Test Cases