Katz
Katz School
of Science and Health

Tumbling with Tornadoes:

A Tornado Simulation Project DAV 5300

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Content

- Tornado Introduction
- EDA
- Correlation Analysis
- Logistic Regression & Random Forest
- Simulation
- Probabilistic Simulation
- Economic Loss Model
- Conclusion

Tornado Introduction

Probability in Weather Simulations:

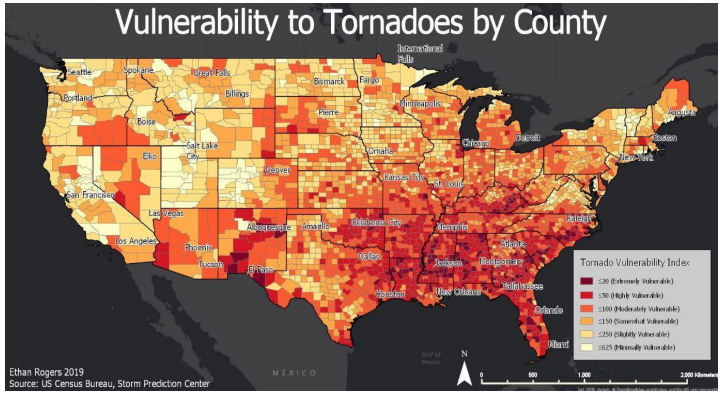
- Weather is very complex
  - Severe weather is harder to model, especially in the short term
- Data and Observations are the keys to making simulations
  - The calculations and constantly evolving

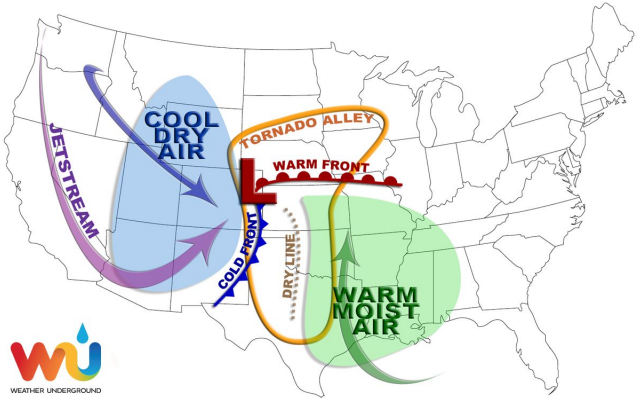
About Tornadoes:

- Narrow, violently rotating column of air that extends from a thunderstorm to the ground
- Australia, Europe, Africa, Asia, and South America
- Form from two collisions of air masses
  - Warm moist air and dry cool air
- About 1,200 tornadoes hit the US annually

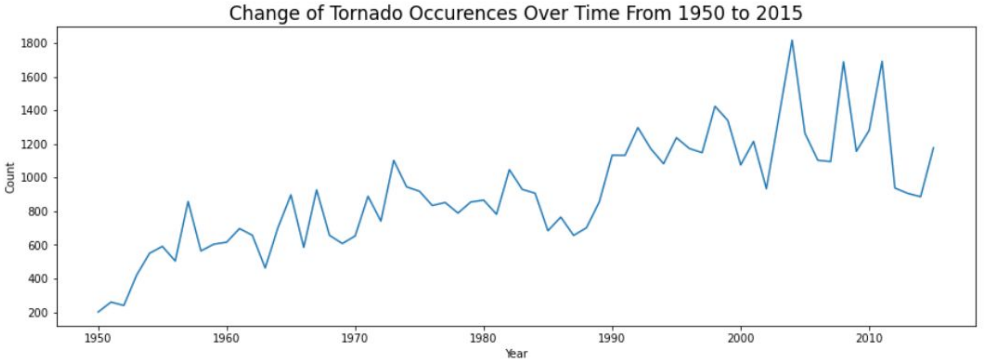
Dataset Introduction:

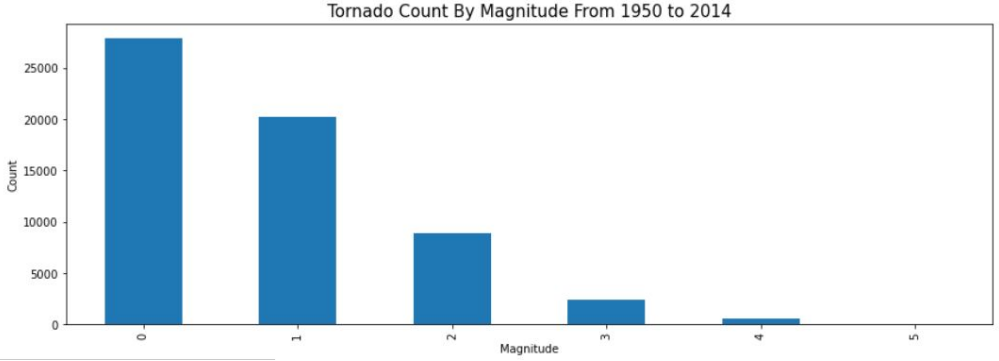
- From the NOAA and the NCDC
- 60k+ rows, 13 columns from 1950 to 2015

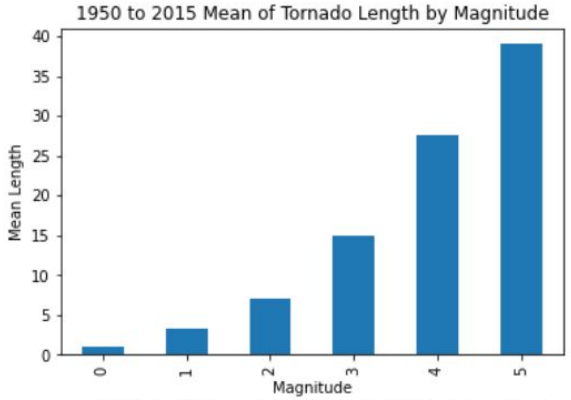


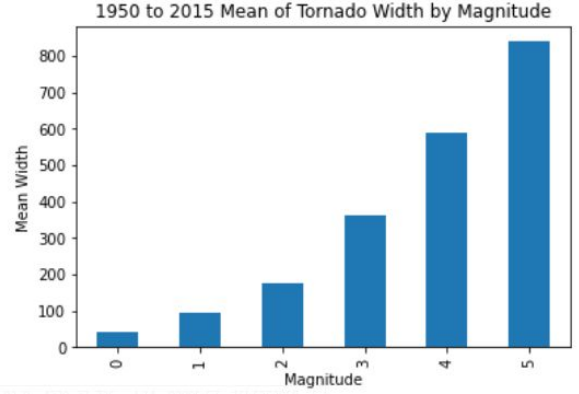


EDA


Change of Tornado Occurences Over Time From 1950 to 2015
Count
Year
1800
1600
1400
1200
1000
800
600
400
200
1950
1960
1970
1980
1990
2000
2010


Tornado Count By Magnitude From 1950 to 2014
Count
Magnitude
25000
20000
15000
10000
5000
0
0
1
2
3
4
5


1950 to 2015 Mean of Tornado Length by Magnitude
Mean Length
Magnitude
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5


1950 to 2015 Mean of Tornado Width by Magnitude
Mean Width
Magnitude
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5

Correlation Analysis

Strong Correlation

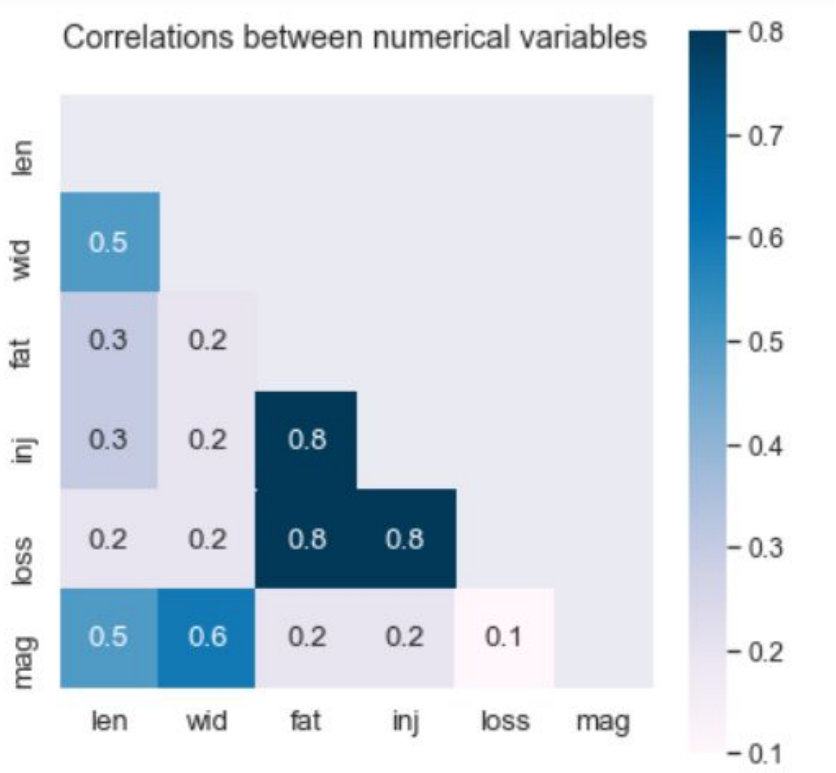
- Injuries and Fatalities
- Injuries and Losses
- Fatalities and Losses

Moderate Correlation

- Length and Magnitude
- Width and Magnitude
- Length and Width

Weak Correlation

- Length and Fatalities
- Length and Injuries
- Length and Losses
- Width and Fatalities
- Width and Injuries
- Width and Losses
- Fatalities and Magnitude
- Injuries and Magnitude
- Losses and Magnitude



Logistic Regression & Random Forest

Logistic Regression

	precision	recall	f1-score	support
0	0.72	0.96	0.83	4541
1	0.47	0.28	0.35	2060
2	0.26	0.04	0.06	590
3	0.53	0.05	0.09	172
4	0.00	0.00	0.00	38
5	0.00	0.00	0.00	4
accuracy			0.67	7405
macro avg	0.33	0.22	0.22	7405
weighted avg	0.61	0.67	0.61	7405

Random Forest

	precision	recall	f1-score	support
0	0.80	0.89	0.84	4541
1	0.52	0.53	0.52	2060
2	0.34	0.09	0.14	590
3	0.52	0.19	0.28	172
4	0.33	0.05	0.09	38
5	0.00	0.00	0.00	4
accuracy			0.71	7405
macro avg	0.42	0.29	0.31	7405
weighted avg	0.67	0.71	0.68	7405

Precision: Percentage of correct predictions
Total Positive / (Total Positive + False Positive)

Recall: Percentage of positive instances
Total Positive / (Total Positive + False Negatives)

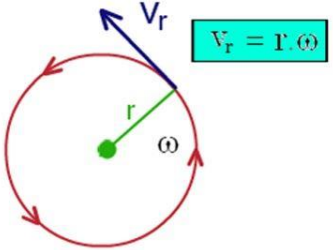
F1: Percentage of correct positive prediction
2*(Recall * Precision) / (Recall + Precision)

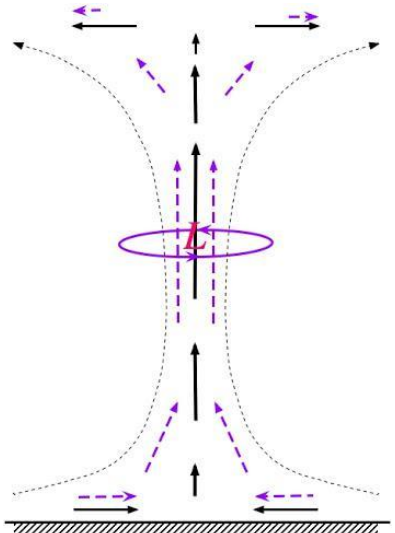
Support: Number of occurrences per category in a dataset

Mathematical Model

Some physics background:

- Tornadoes are rotating columns of air
  - Use the laws of circular motion to think about this
- Equation for angular velocity is $\omega = v_r / r$
  - Radial velocity ranges for F-scale ranges:
    - F0: 0 - 73 mph
    - F1: 74 - 112 mph
    - F2: 113 - 157 mph
    - F3: 158 - 206 mph
    - F4: 207 - 260 mph
    - F5: > 261 mph





$A =$

ω_{11}	ω_{12}	ω_{13}	…	ω_{1n}
ω_{21}	ω_{22}	ω_{23}	…	ω_{2n}
…	…	…	…	…
ω_{n1}	ω_{n2}	ω_{n3}	…	ω_{nn}

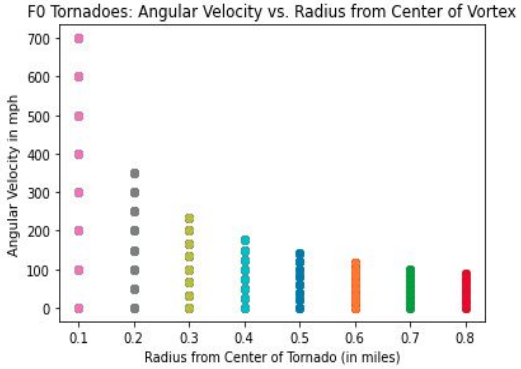
v_r ←

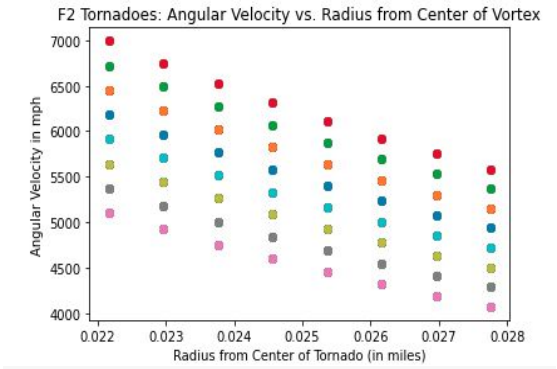
↑ r

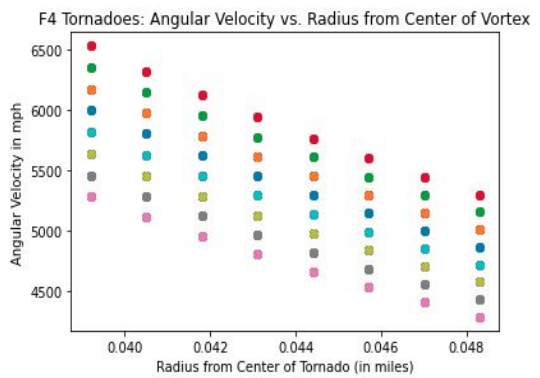
$B =$

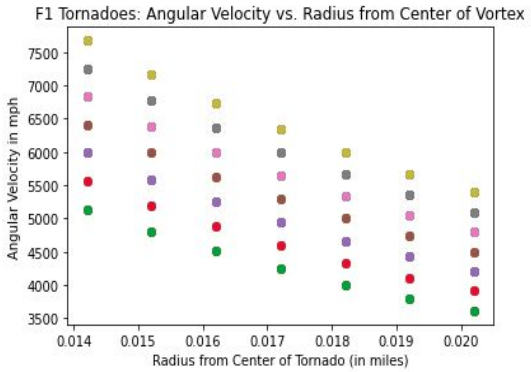
r_{11}	…	r_{1n}
r_{21}	…	r_{2n}
r_{n1}	…	r_{nn}

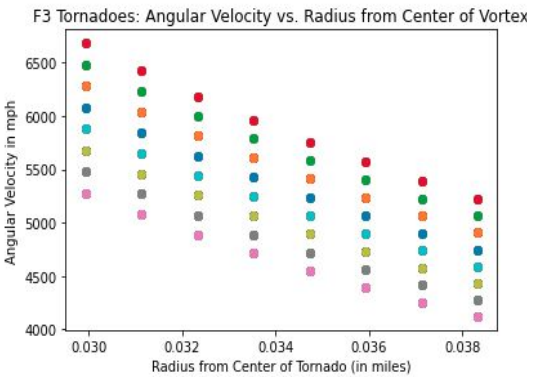
Mathematical Model

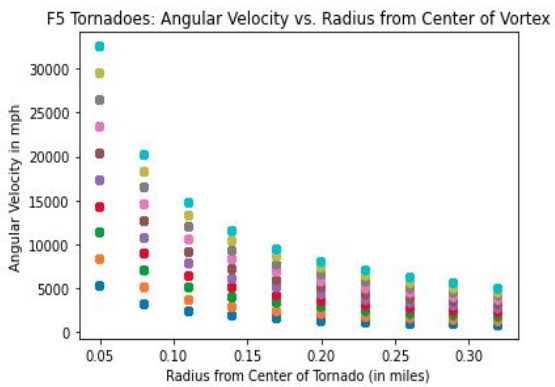




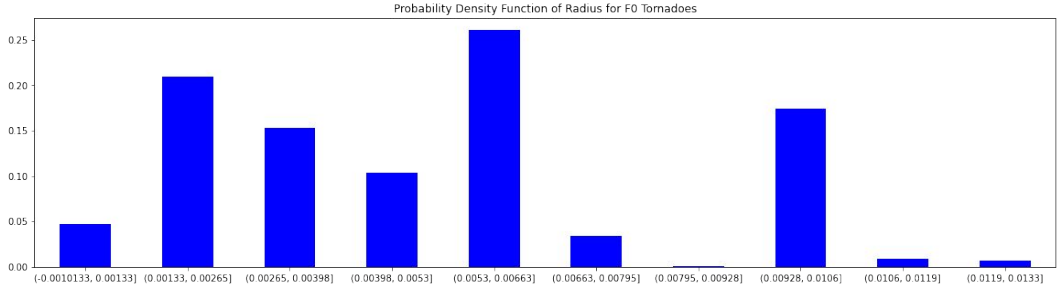


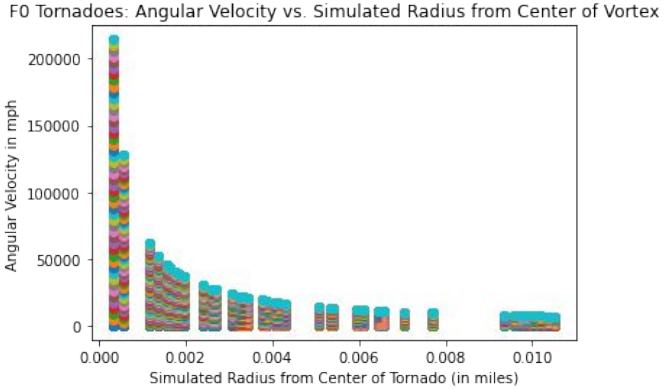


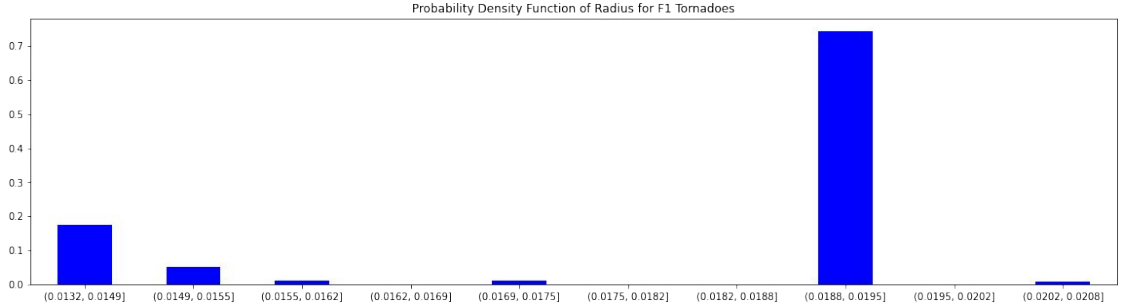


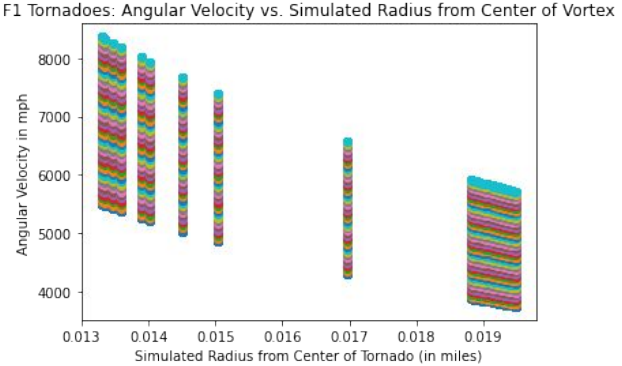


Probabilistic Simulation

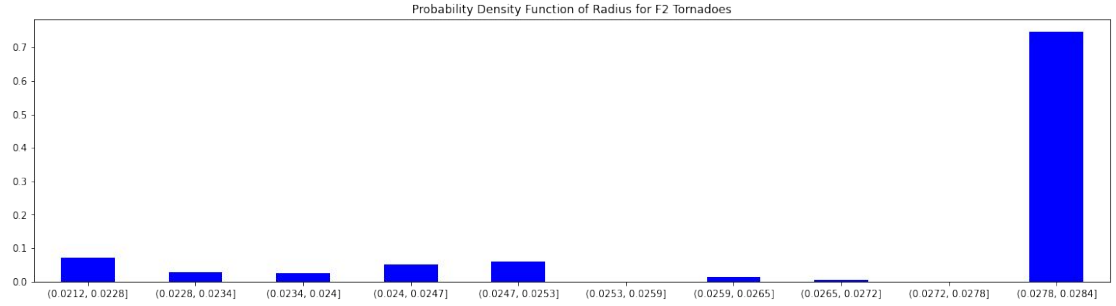


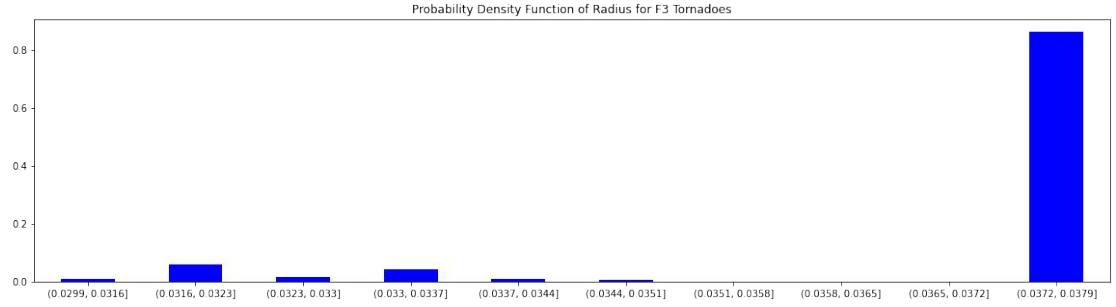


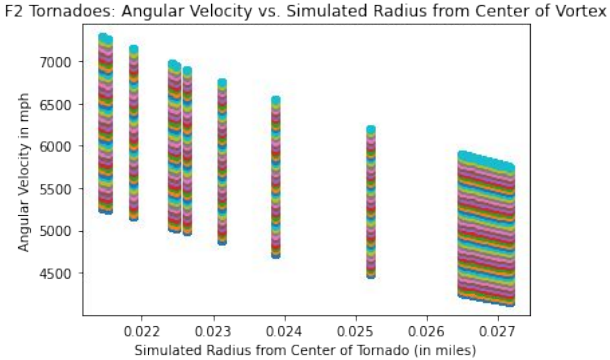


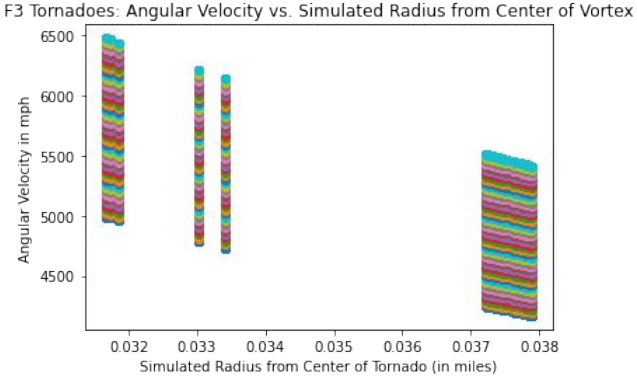


Probabilistic Simulation

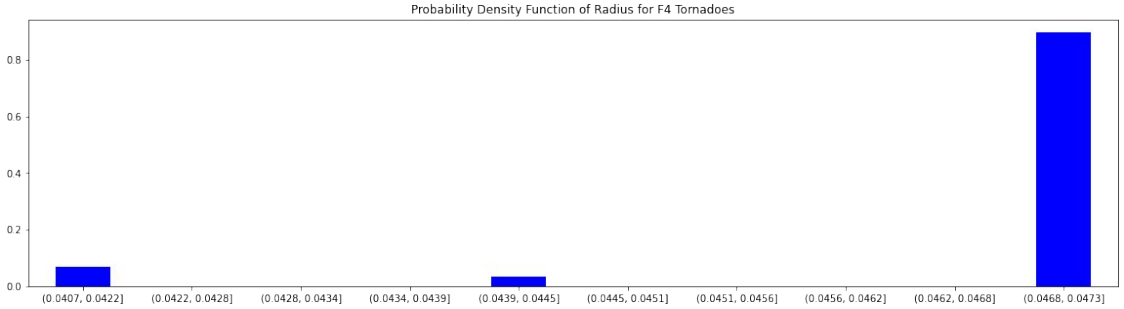


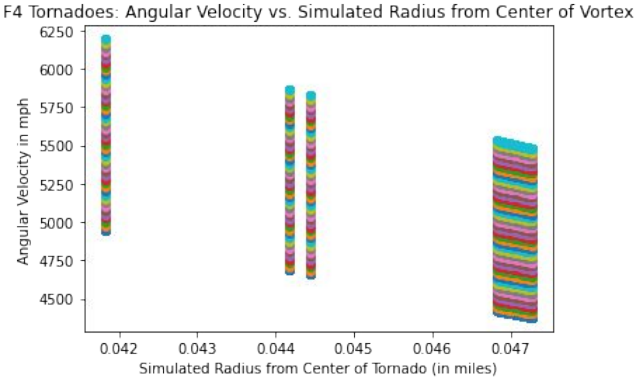


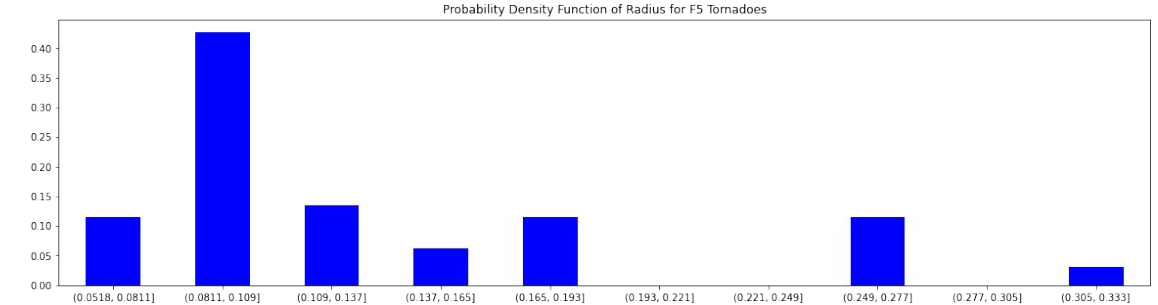


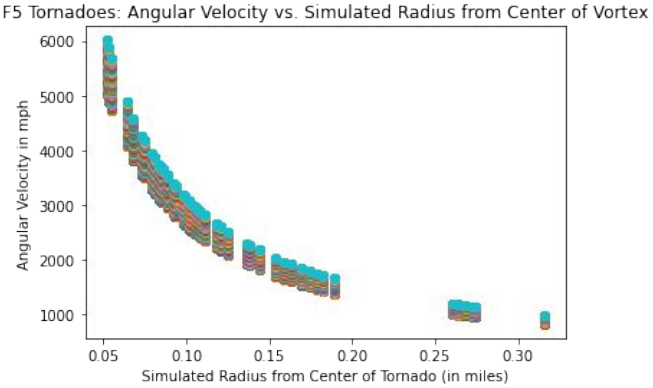


Probabilistic Simulation

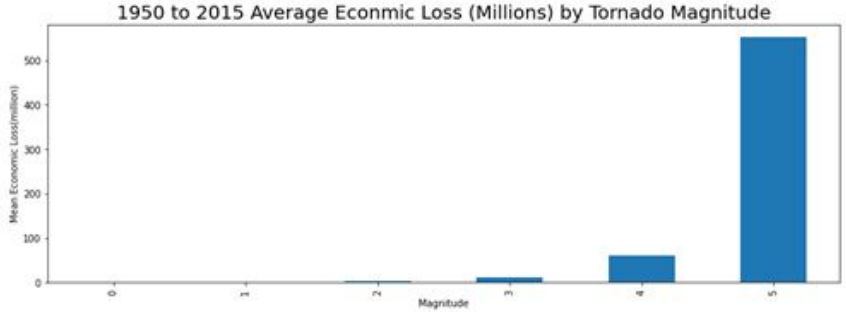


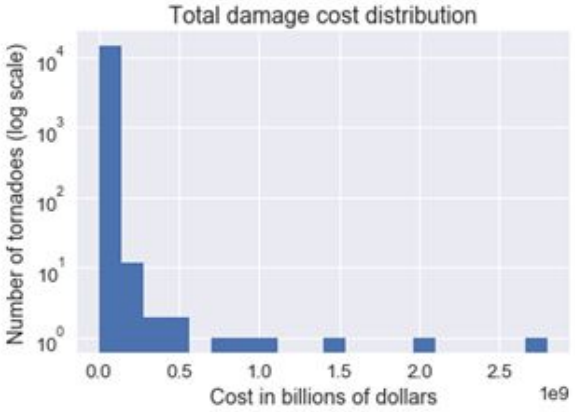






Economic Loss Model





Model Baseline

```
Baseline RMSE:    22.3109329267541
Baseline R2:      -0.003842043891185032
```

Linear Regression

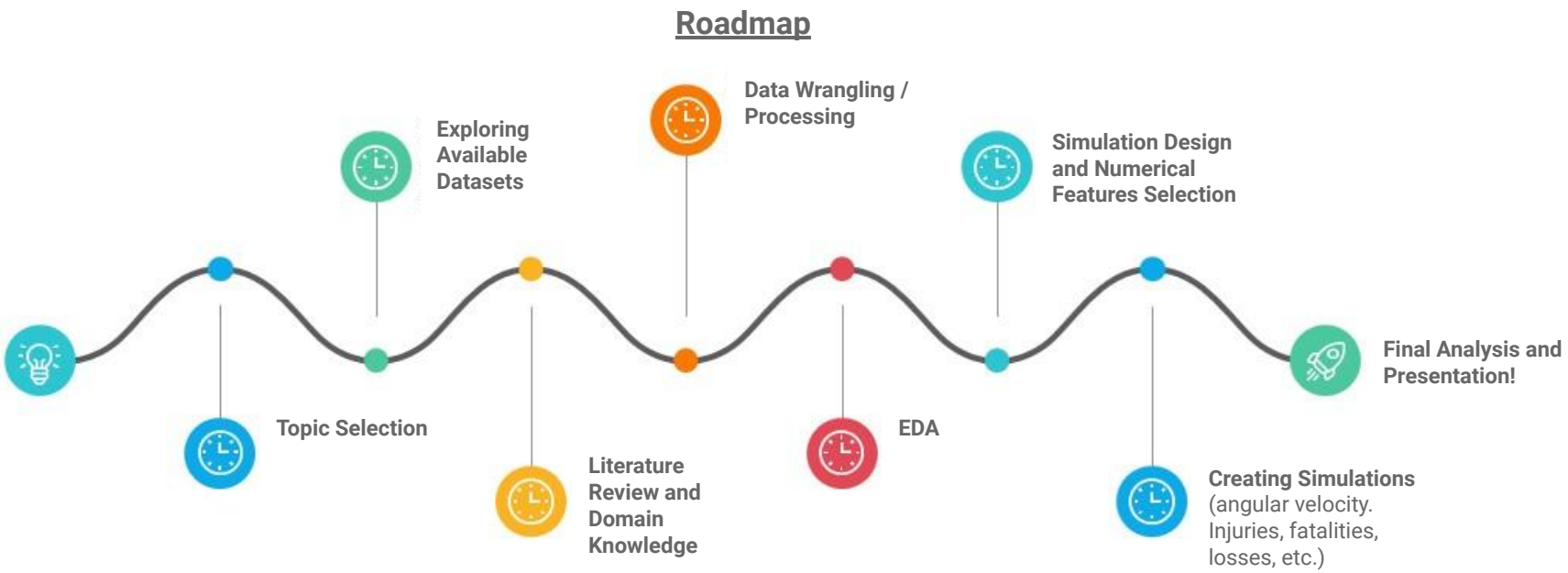
```
Linear Reg 1 - RMSE:                18.495819925158944
Linear Reg 1 - R2:                  0.31011437291787824
```

Linear Regression/ Lasso Regularization

```
Linear Reg 2 - RMSE:                 18.37598455888654
Linear Reg 2 - R2:                   0.31902502157457124
```

Next Steps / Roadmap

- Exploring the relationship between angular velocity, magnitude, and radius more deeply
- Investigating creating simulations using injuries, fatalities, and losses attributes



Sources

- https://www1.ncdc.noaa.gov/pub/data/swdi/stormevents/csvfiles/
- nssl.noaa.gov/education/svrwx101/tornadoes/
- nssl.noaa.gov/education/svrwx101/tornadoes/
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- https://www.nssl.noaa.gov/research/tornadoes/#:~:text=The%20U.S.%20typically%20has%20more,warnings%20to%20help%20save%20lives.
- https://journals.ametsoc.org/view/journals/wefo/33/4/waf-d-17-0170_1.xml