Examining Tornado Vulnerability Using the U.S. National Weather Service Damage Assessment Toolkit

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Motivation

Understanding tornado vulnerability is critical in making efforts to decrease the threat to life and property in communities across the country. Advancements in technology have not only improved tornado forecasts and warnings, but also the collection of tornado damage survey data. The National Weather Service (NWS) Damage Assessment Toolkit (DAT) contains the most extensive GIS-based damage survey data available to the public but has yet to be utilized as a means to assess tornado vulnerability on a regional scale. This research demonstrates how the DAT can be used to examine physical and social factors that may contribute to tornado casualties in the U.S. This study is important for future research as the DAT will continue to expand and later be used for climatological studies and comprehensive vulnerability assessments. Thus, it is relevant to forecasters and climatologists as well as insurance and disaster management agencies.

Data

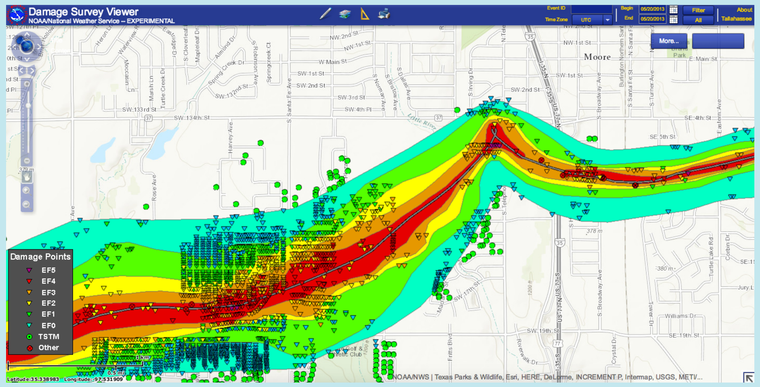
NWS Damage Assessment Toolkit Data

- Tornado damage polygons from 2008–2015
  - 1612 total tornado swaths making up 714 individual tornadoes, 89 with casualties
  - Maximum EF Scale rating, swath & path area, casualties

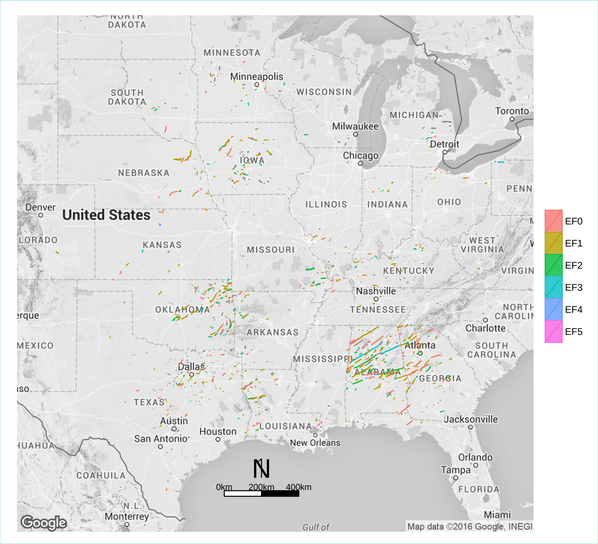
U.S. Census Tract Data (MPC 2011)

- Boundary shapefiles from 2010 Decennial Census
- Summary tables from the 2008-2012 5-Year American Community Survey
  - Population, housing units, education, unemployment, poverty, elderly, and non-English speakers
    - e.g., Brooks and Doswell (2002), Merrell et al. (2005), Ashley (2007), Simmons and Sutter (2011), among others

NWS Damage Assessment Toolkit (DAT)



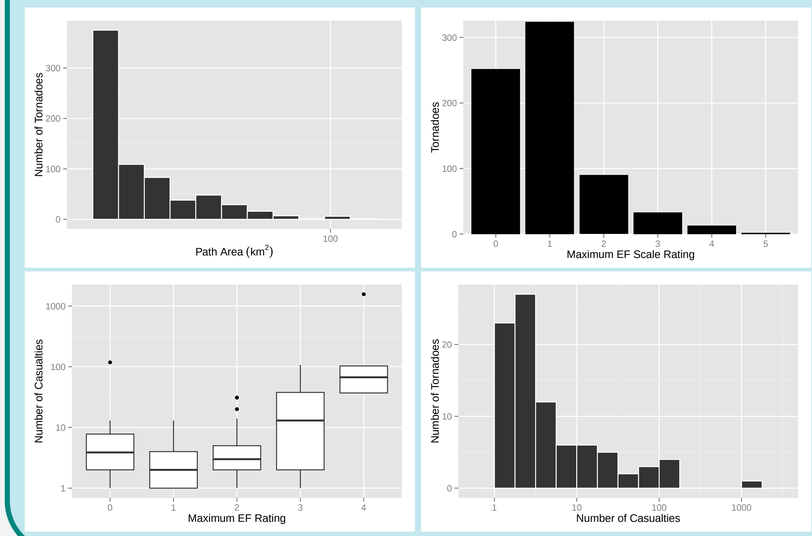
Study Area



Methods

- Compute damage swath and path areas
- Intersect tornado paths with Census tracts
- Perform area weighting of socioeconomic data
- Examine relationships among tornado casualties and physical/social factors
- Develop predictive models of tornado casualties

Tornado Characteristics & Casualties



Regression Models

Logistic regression models examine how the occurrence of at least one casualty is related to socioeconomic factors while accounting for max EF rating, total path area, and population density.

$$\text{logit}(p) = \log(p/(1-p)) = \beta_I + \beta_{EF} \cdot \text{EF} + \beta_{PA} \cdot \text{PA} + \beta_{PD} \cdot \text{PD} + \beta_X \cdot \text{X}$$

Similarly, log-linear regression models examine how the number of casualties is related to socioeconomic factors.

$$\log(C) = \beta_I + \beta_{EF} \cdot \text{EF} + \beta_{PA} \cdot \text{PA} + \beta_{PD} \cdot \text{PD} + \beta_X \cdot \text{X} + \epsilon$$

Results

Incidence of casualties:

Baseline logistic regression model.

	Estimate	Std. Error	Z value	P value
β_I	−3.193	0.225	−14.213	< .001
β_{EF}	0.900	0.132	6.837	< .001
β_{PA}	0.032	0.010	3.072	0.002
β_{PD}	0.000	0.000	−0.051	0.959

Additional models.

Factor (X)	Estimate on β_X (P value)	AIC
% Unemployment	0.200 (0.001)	441.65
% Education Under HS	0.053 (0.029)	447.15
% Elderly	−0.051 (0.106)	449.16
% Mobile Homes	0.014 (0.234)	450.47
% Non-English Speakers	0.044 (0.398)	451.21
% Poverty	0.000 (0.977)	451.87

Magnitude of casualties:

Baseline log-linear regression model.

	Estimate	Std. Error	t value	P value
β_I	0.263	0.225	1.167	0.247
β_{EF}	0.388	0.113	3.422	< 0.001
β_{PA}	0.026	0.004	6.888	< 0.001
β_{PD}	0.002	0.001	3.011	0.003

Additional models.

Factor (X)	Estimate on β_X (P value)	Adj. R^2
% Elderly	−0.051 (0.074)	0.507
% Poverty	−0.041 (0.151)	0.500
% Mobile Homes	−0.009 (0.461)	0.491
% Unemployment	−0.041 0.549	0.490
% Non-English Speakers	−0.004 0.929	0.487
% Education Under HS	−0.020 0.422	0.471

Conclusions

- The DAT can be used to examine tornado impacts *statistically*.
- All chosen factors have sig. positive correlations with casualties.
- Percent unemployment produces best model for predicting incidence of casualties, while percent elderly is best for magnitude.