Comparing WRF-Derived Methods for Estimating Tornado Outbreak Casualties in the US Deep South

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Introduction

This project was conducted at the National Weather Service's Shreveport WFO. Previous work on historical event reanalysis with the WRF (Weather Research and Forecasting) model was done at this office in 2021, but the project was discontinued after analyzing one case. This project picks up where the previous researchers left off by having three focus cases and uses the output data to estimate the number of casualties that would occur if that same event were to happen today, which promotes a Weather Ready Nation. This method of modern casualty estimation was compared to a new method developed based on work from Mishra Et al. and Antonescu Et al. that uses demographic information to determine population vulnerability.

Question: How do the modern casualty estimation methods compare to each other and to the observed casualty counts that occurred with the corresponding historical case?

On one hand, the estimated number of casualties could be less than the respective observed historical count due to improvements in forecasting and increased lead time. On the other hand, population in the focus domains have increased since the case actually occurred, which could make the estimated number of modern casualties higher.

Data Sources and Tools

ECMWF, ATSDR, Storm Prediction Center, NASA

Tools: UECM WRF on WCOSS, VS Code, Python and R coding languages, ArcGIS Pro

Methods

Data and Running WRF

- Select tornado outbreaks in the Deep South with 10+ tornadoes to run simulations on
- Run the case simulations with a time buffer on either side of the main event

Modelling Method 1: Environmental Variables

- Calculate the highest value of mean layer CAPE, 1000-500 hPa Bulk Shear (DLBS), and 1000-850 hPa Bulk Shear (SLBS) using Python Notebook
- Input these values into the Casualty Count Negative Binomial Regression model developed by Schroder and Elsner 2021, along with domain population, the domain center point's coordinates, and the current year

Modelling Method 2: Social Vulnerability

- Use the Social Vulnerability Index to get the vulnerability percentile for each census tract across the entire US
- Divide each percentile by 100 to get the associated fatality rate for each census tract. This will result in fatality rates ranging from 0.1% to 1%, as described in Antonescu Et al.
- Create a buffer around each tornado using max path width, calculate the area in each census tract that is contained in the path, and use the population density to estimate the population in each tract within the path (rounding up to the nearest integer in cases of values of 0.25 or greater)
- Use the fatality rate and population within the path of each tract to calculate the number of fatalities, multiply each tract's fatality count by 15 to estimate the injury count for each tract, and add these estimates together to get total casualties estimated

Contact Information

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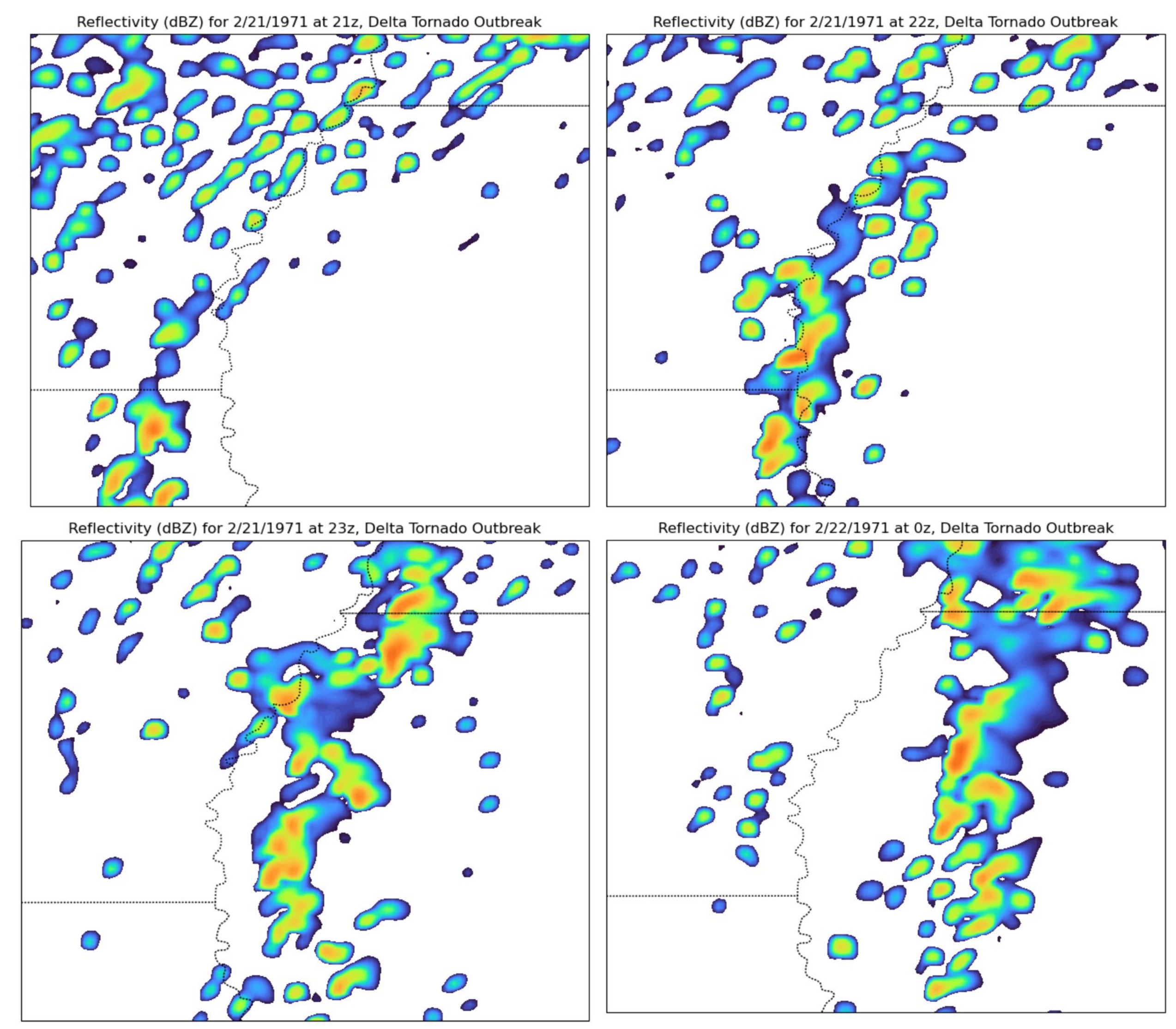
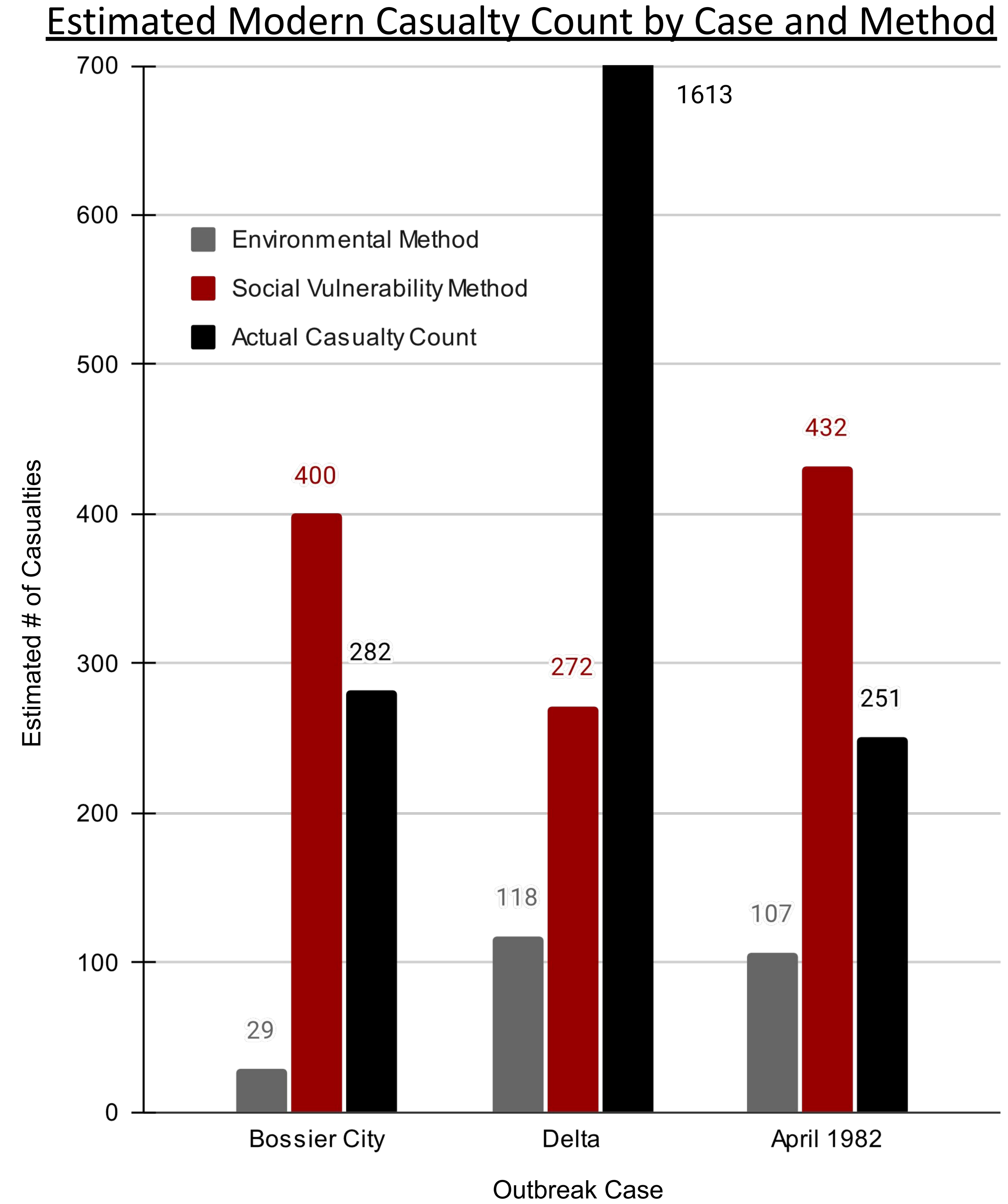
Contact me if you have any questions or want to talk about the project!

Results

Example WRF Output Map: Reflectivity

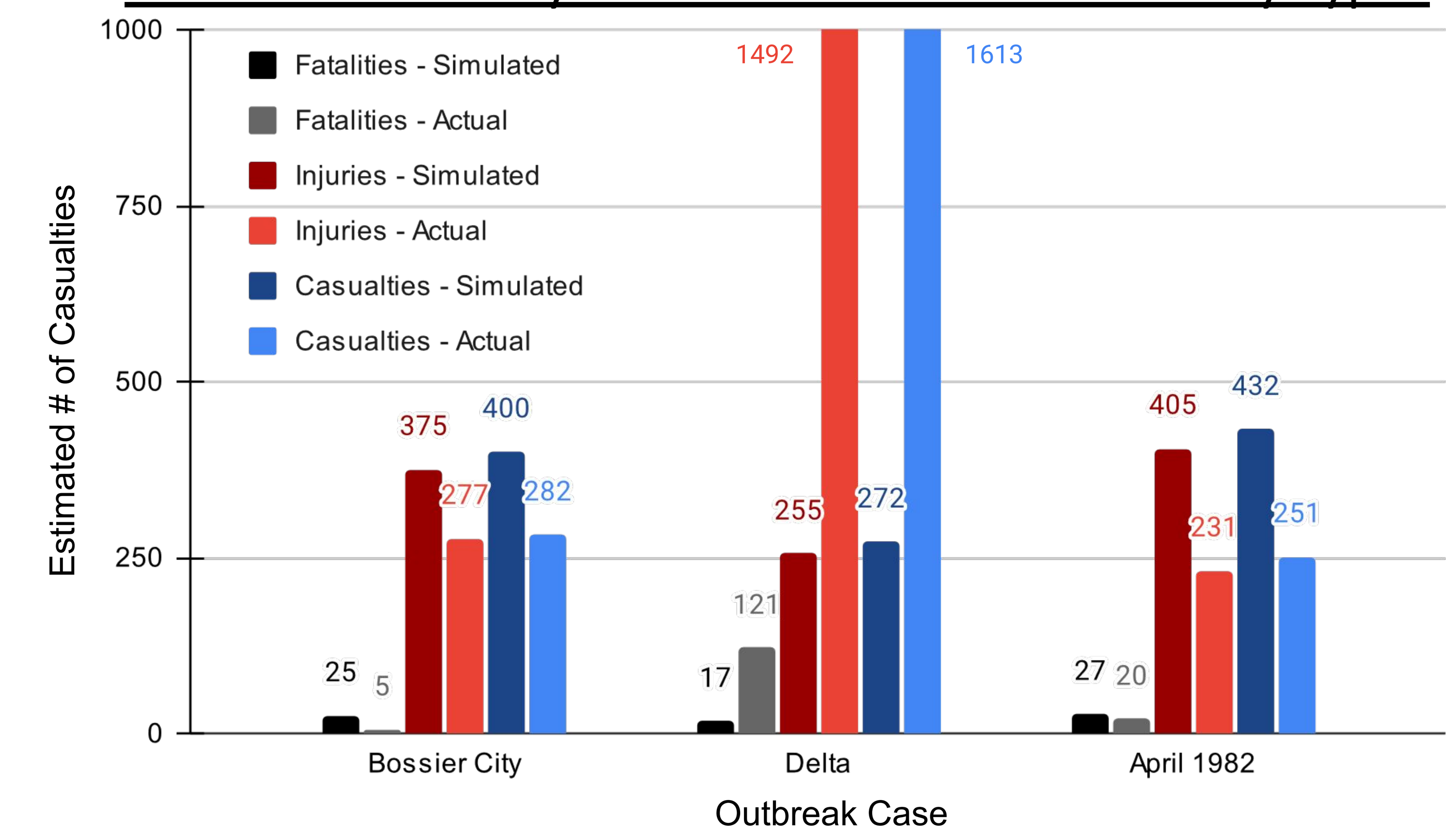


Estimated Modern Casualty Count by Case and Method



Results cont.

Social Vulnerability Method vs Observed Casualty Types



Conclusions and Future Research

Conclusions:

- The WRF produced environments that were plausible
- The casualty estimation methods produced varying results depending on the case
  - Environmental Method: this method predicted lower casualty counts than each of the observed casualties for each case
    - Could be accurate, or due to the year variable falsely decreasing the value
  - Social Vulnerability Method: this method predicted a higher casualty count for the Bossier City and April 1982 cases and a lower casualty count for the Delta case compared to the observed casualties
    - These values are reasonable with the population trends in each region

Future Research:

- Reconducting this study with changes in place to reduce overall error such as:
  - Having a larger dataset of cases
  - Assuming tornado tracks have nonlinear paths and widths
  - Assuming there is a non-uniform distribution of population density
- Reconducting this study in different areas of the United States
- Finding a model of modern casualty estimation that would combine demographic vulnerability characteristics and environmental variables for greater accuracy

References and Acknowledgements

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