Simulating Self-Assembly of Tornado Storm Chasers Using Agent-Based Modeling

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Project Motivation

- ❖ The paper by Seimon et al (2016) provides information on the El Reno tornado of May 31, 2013 that led to fatalities of several storm chasers.
- ❖ This paper also provides detail in a data collection process from storm chasers during this event.
- ❖ While valuable data was collected, some of which is shown in Figure 1, challenges that were faced throughout the process include the positioning of the storm chasers during the storm.
- ❖ Tornadoes continue to be one of the more difficult weather phenomena to predict, due to a lack of data that meteorologists have from tornadoes.

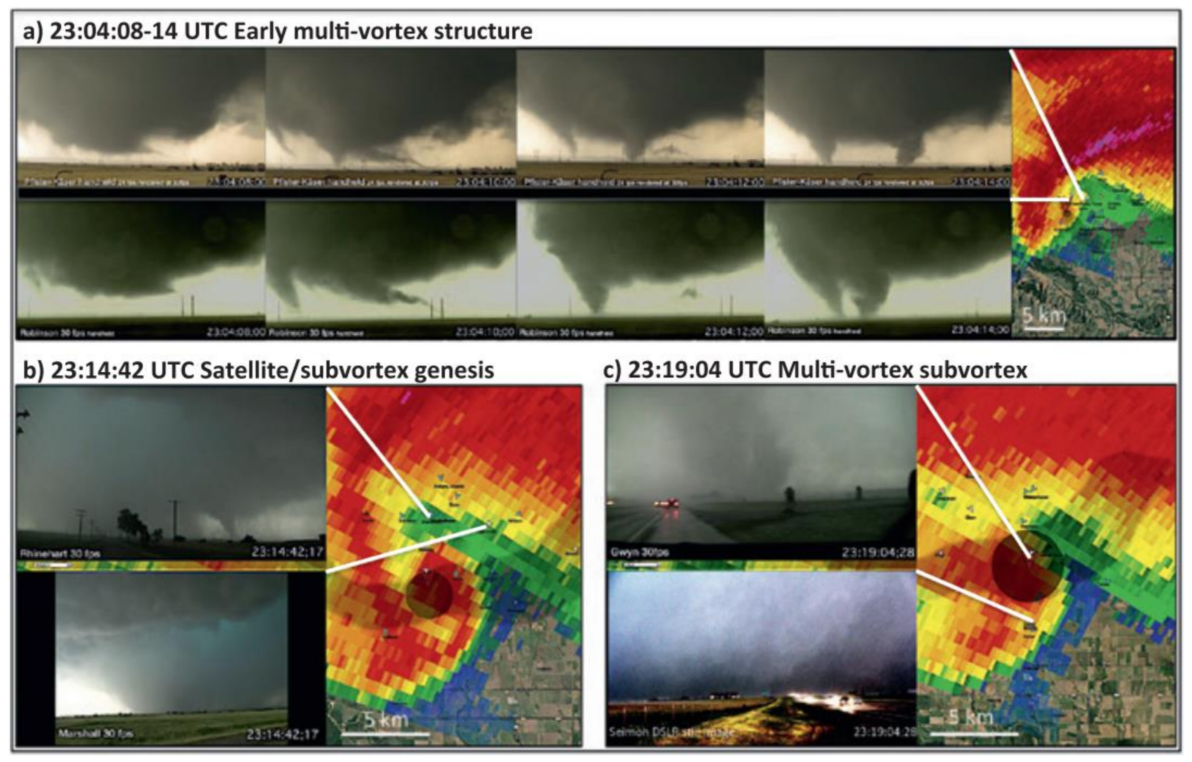


Figure 1: Structure of the storm that produced the El Reno tornado at various times, including images collected as part of the data visualization tool. Seimon et al (2016).

Introduction

The aim of the project is to create an agent-based model to simulate paths of storm chasers in a tornadic thunderstorm environment. The model will simulate various paths of thunderstorms and determine paths for the storm chasers to take. The storms that will be simulated will take place on a standard grid-spaced road system, similar to the road system that is found in Oklahoma. The model uses roads that are in a 10 km × 10 km grid system, which shows the average spacing of the road system in Oklahoma as well as other states in tornado alley. This, however, is not the limiting extent to the paths in which chasers are able to take, as many more local roads are also available for travel.

Methodology

Developing the agent-based model requires the utilization of several variables to model the storm movement as well as the path of the storm chasers. These variables that are given to each chaser include:

- The velocity of the storm
- Each chaser's individual risk tolerance
- Each chaser's position prior to the re-evaluation of where to go next

Independent variables in the simulation were those in relation to the storm itself. These variables include the storm velocity, storm radius, and if the storm maintains a constant velocity throughout the simulation or changes velocity.

Since tornadic thunderstorms have the potential to quickly change direction, storm chasers need to constantly be aware of the location of the storm and direction it is moving. With new radar imagery becoming available approximately every 2 minutes during a severe thunderstorm situation, the reevaluation of position is done every 2 minutes.

Numerous trials were conducted using different environments to observe how chasers would interact with the different storm types. Figure 2 shows how simulated chasers reacted to the storm movement at four different times during the simulation.

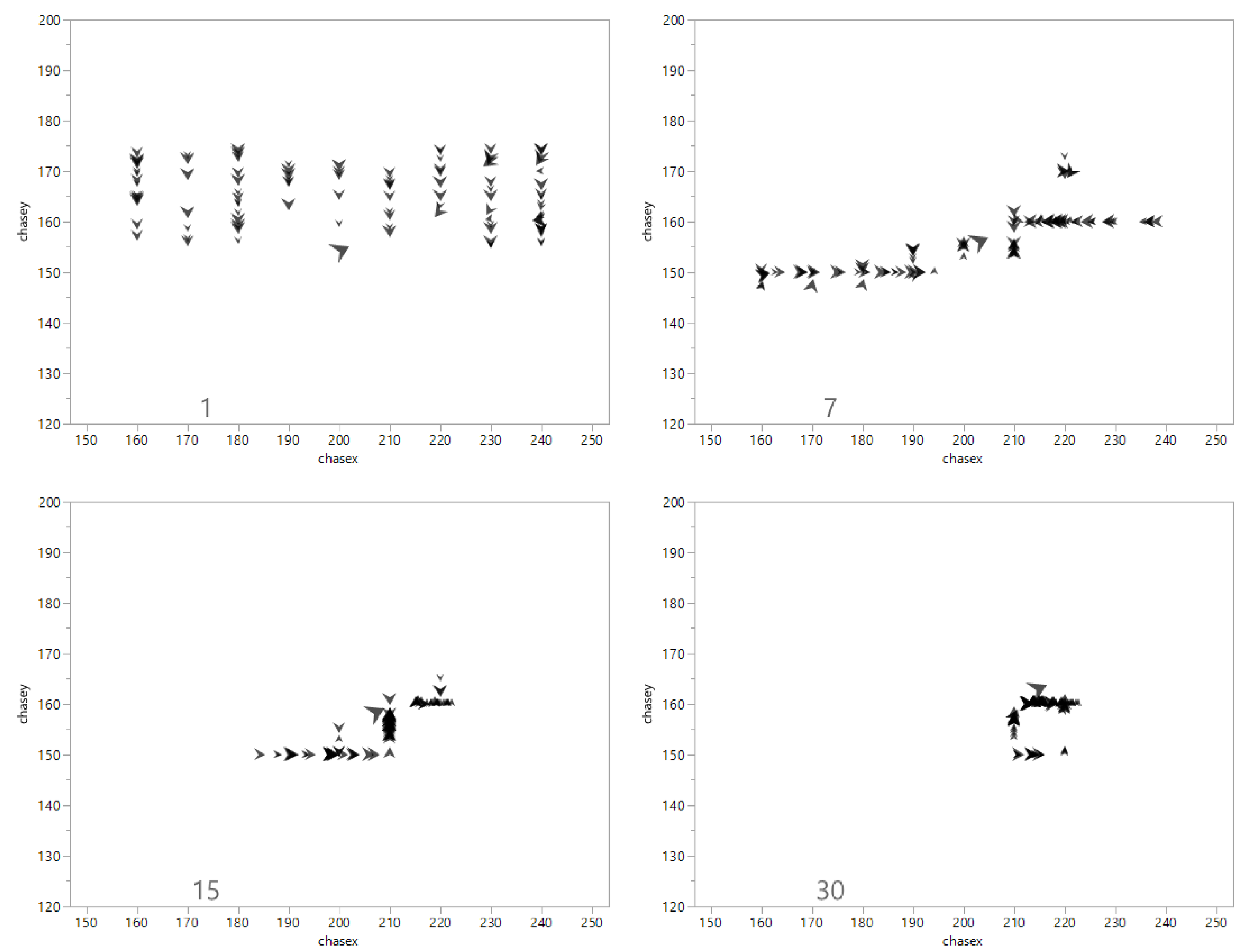
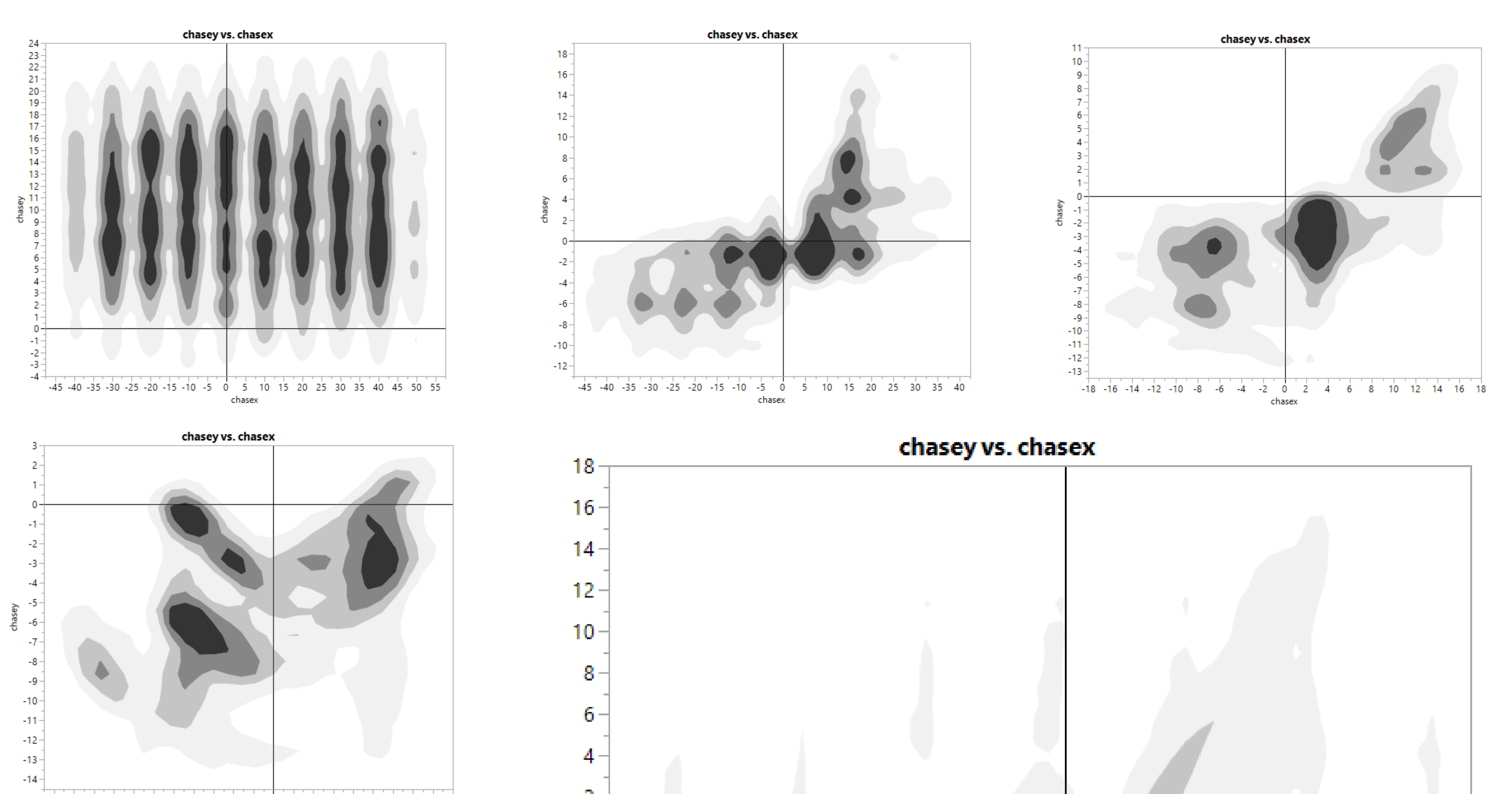


Figure 2: Simulated chaser and tornado positions output in a simulated event where the tornado is moving at (15 km hr^{-1}, 9 km hr^{-1}). The tornado can be identified as the larger arrow pointing to the east-northeast throughout all frames, while the chasers can be identified as smaller triangles pointing at varying directions throughout the frames. The simulated positions are shown at times from initialization of 0 minutes (upper-left), 12 minutes (upper-right), 28 minutes (lower-left), and 58 minutes (lower-right).

Results

In analyzing the results, it was visually easier to qualitatively determine the chasers' assembly by analyzing contour maps as opposed to the maps showing the chaser locations. It is known that the ideal position for storm chasers is to be to the southeast of the storm, so a plot of the chasers' storm-relative position was developed. The contoured image of their average position from 100 runs of the same trial is shown in Figure 3.



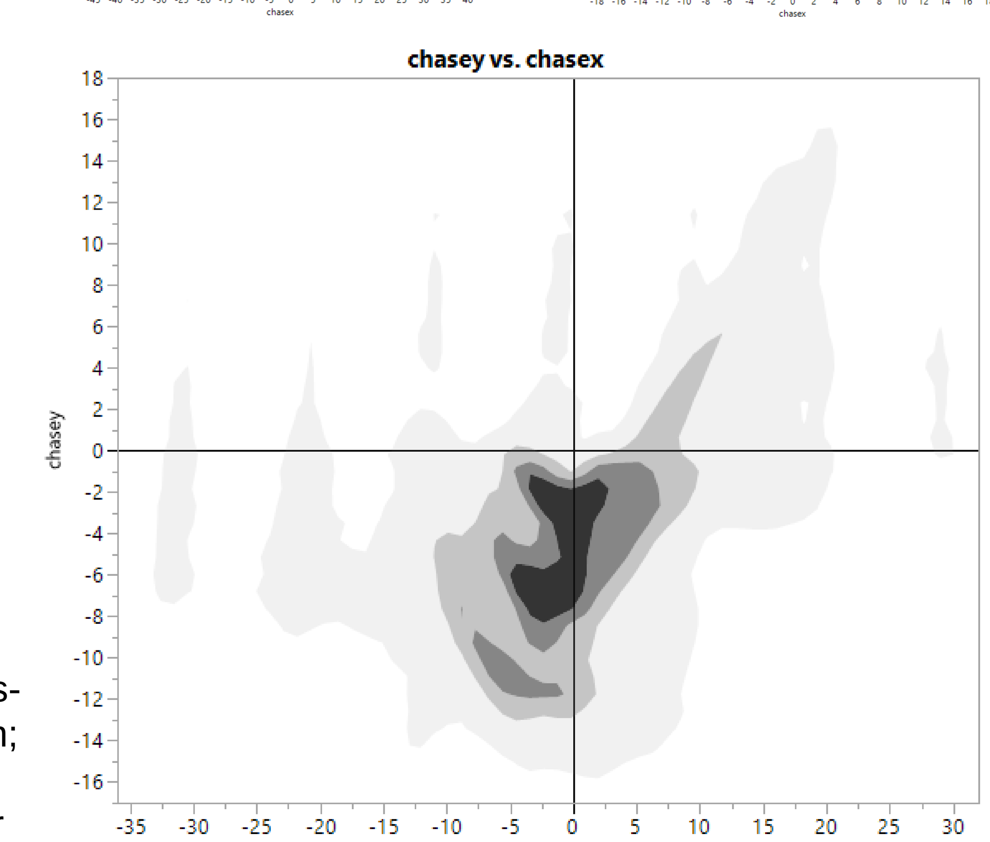
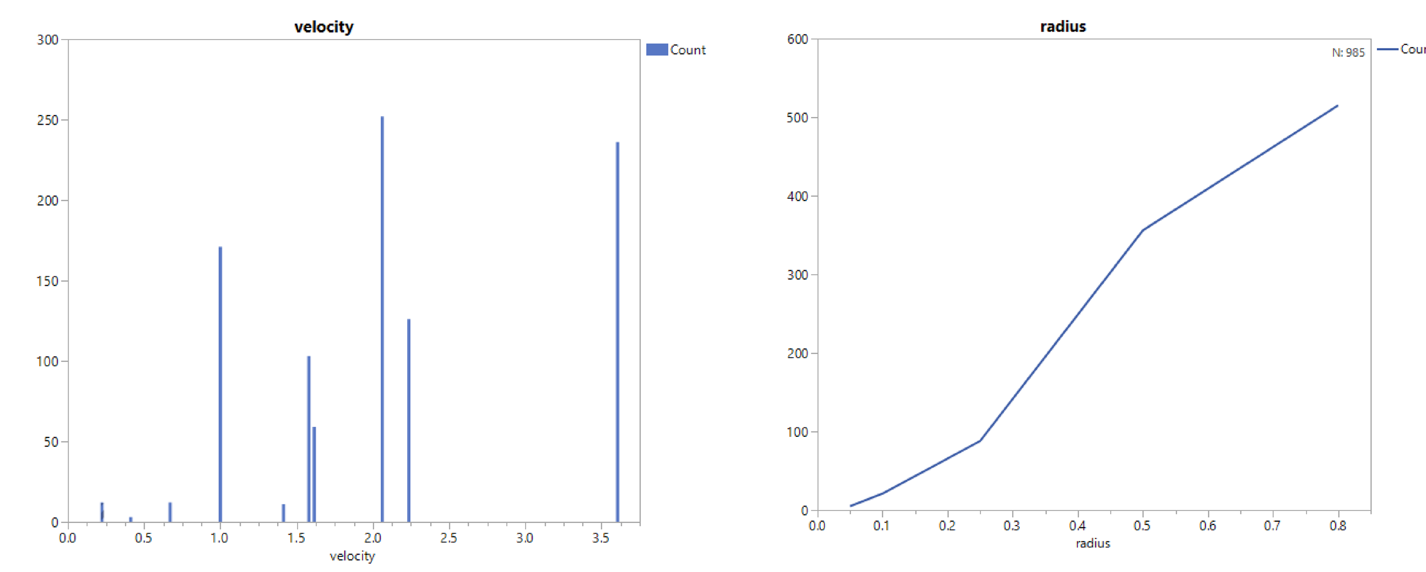


Figure 3: Contour maps of storm-relative positions of chasers at initialization (upper-left); 12 minutes- (upper-center), 28 minutes- (upper-right), and 58 minutes- (middle-left) past initialization; and at all times (lower-right). Lighter colors indicate higher densities of storm chasers.

The model also simulates the event in which storm chasers are overrun by the tornado. Once a chaser moves too close to the storm, the model deems them to be overrun and removes them from the remainder of the simulation. The number of casualties were compared to a variety of variables, including storm speed, tornado radius, and time of the casualties. Note that chaser casualties that occurred within the first two minutes were omitted as these occurred due to the random distribution of chasers when the storm initialized.



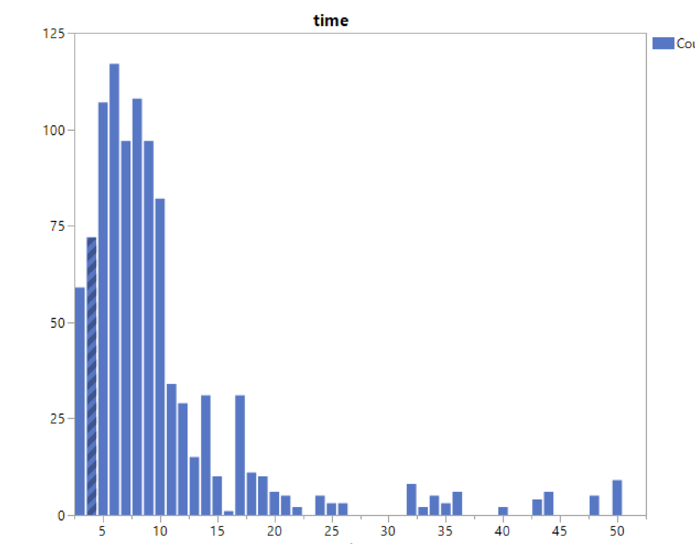


Figure 4: Number of chasers overrun compared to storm speed (upper-left), tornado radius (upper-right), and time since storm initialization (left).

Future Work and Impact

As we continue to analyze the data from the simulations run thus far, we will continue to observe different trends with the storm chaser behavior. We have observed many simulations where the chasers are positioned in the ideal southeastern location of the storm, but it is necessary to better understand why certain events show the chasers positioned elsewhere, such as directly to the south, to the southwest, or in some cases, to the northwest. Additional simulations will also be run with this model. Some of the simulations will be of idealized tornado paths, some of which will have changes in direction during the storm progression. Other simulations may include the paths of archived storms to analyze how the model positions chasers around the storm. Simulations will be run with more evenly spread variables to be able to quantitively analyze the results in a more effective manner.

Given the potential impact that tornadoes have on the public, this project has the potential to have significant benefits to the community, with better positioning of storm chasers leading to a greater chance of more valuable data being collected.

References

Seimon et al.2016: Crowdsourcing the 2016 El Reno Tornado: A New Approach for Collation and Display of Storm Chaser Imagery for Scientific Applications. *Bull. Amer. Meteor. Soc.*, https://doi.org/10.1175/BAMS-D-15-00174.1, in press.