Data Driven Simulation of Small-Scale Rainfall Kinetics

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MATH 438

Background

Understanding the physics of rain fall has applications to a large number of fields, from agriculture to planetary science. This understanding requires modeling small-scale rainfall which can be used as a tool to either study the rain itself, or as the basis of more complex models of larger scale phenomena. We set out to model a small-scale rain fall event based on rain disdrometer data.

Theory

The model output will be an animation of rain falling on a water surface. To achieve this we will simulate new drops falling and rippling across the surface. The model will run for 30 seconds with 10 time steps per second. For each time step, we must therefore calculate the number of drops that fall, the drop size, and the dissipation speed. The first two parameters will be fit from data and values randomly sampled. The third parameter, calculated from drop kinetic energy, is derived analytically .

Algorithm and Plotting

1. Determine the rainfall intensity
2. Calculate the median drop size
3. Calculate the number of drops
4. Calculate the stochastic size of each drop
5. Calculate the KE of each drop

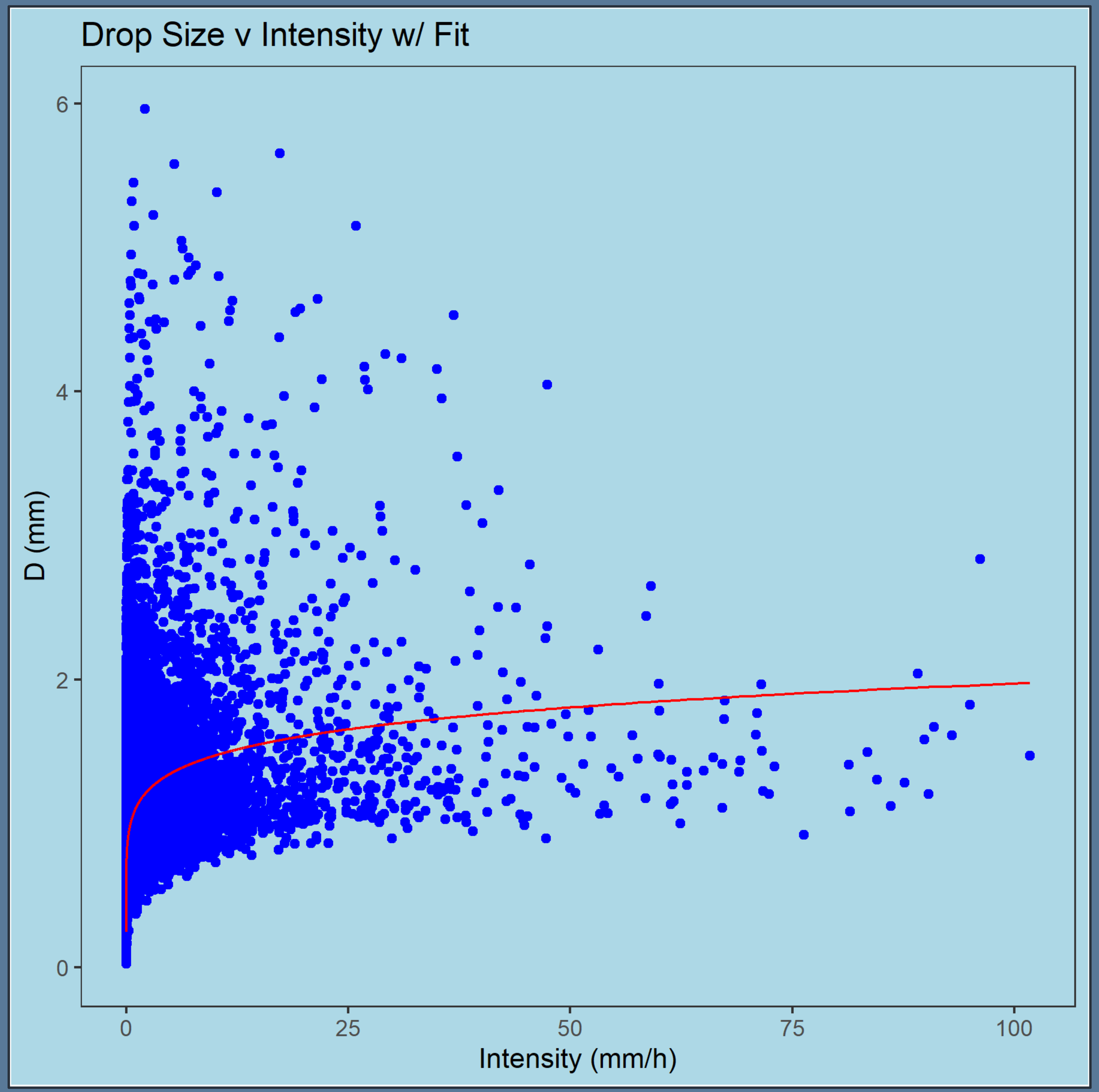
1. Assign each new drop a random position
2. Calculate its ripple size and speed
3. Plot all drops
4. Update drop sizes

References

1. Cao Q. & Zhang G. (2008). Analysis of Video Disdrometer and Polarimetric Radar Data to Characterize Rain Microphysics in Oklahoma. JAMC.
2. Marshall J.S. & Palmer W.K. (1948). The Distribution of Raindrops with Size. JMET.

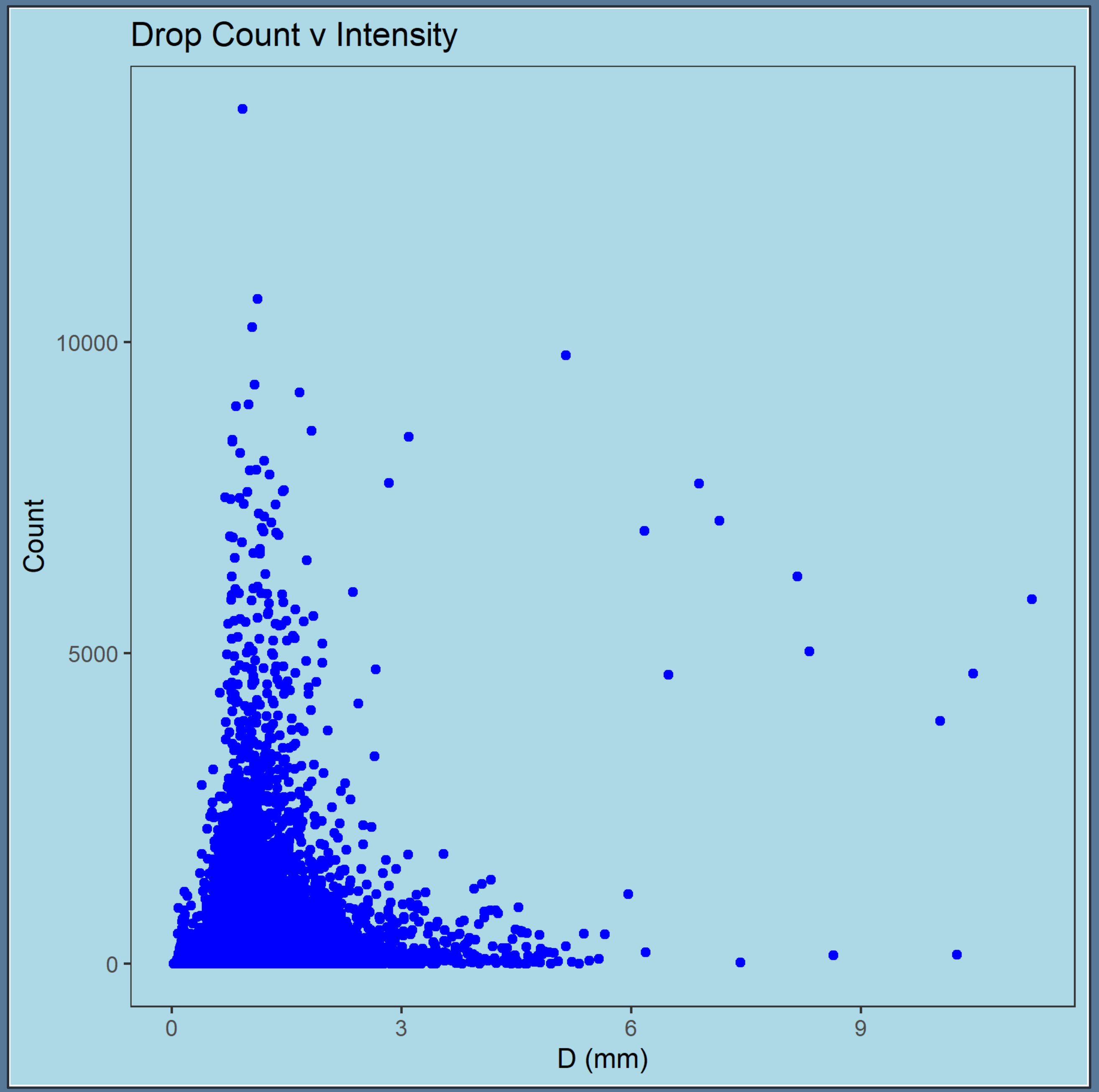
INPUTS

Figure 1



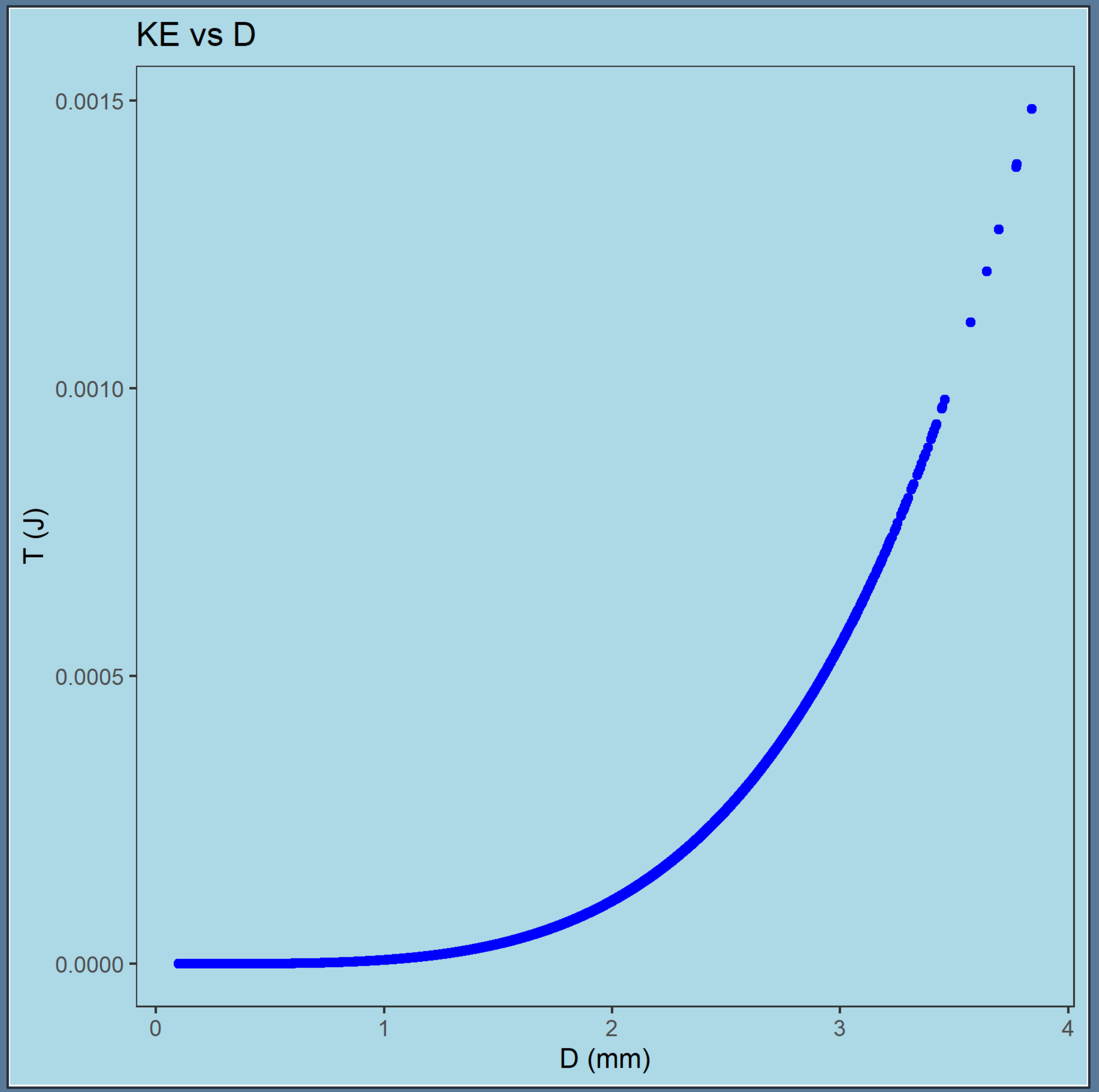
Left: Rain drop size as a function of the rainfall intensity. A linear regression was fit to the data[1] (shown in red). The fitted equation was used to find the median drop size, with actual drop sizes found from a normal distribution with SD calculated from the data.

Figure 2



Left: Drop count as a function of the median drop size. Drop count is gamma distributed[2]. A gamma distribution was fit to data binned around the given intensity value and a random value was pulled from the fitted distribution. This value was then adjusted for the modeled area.

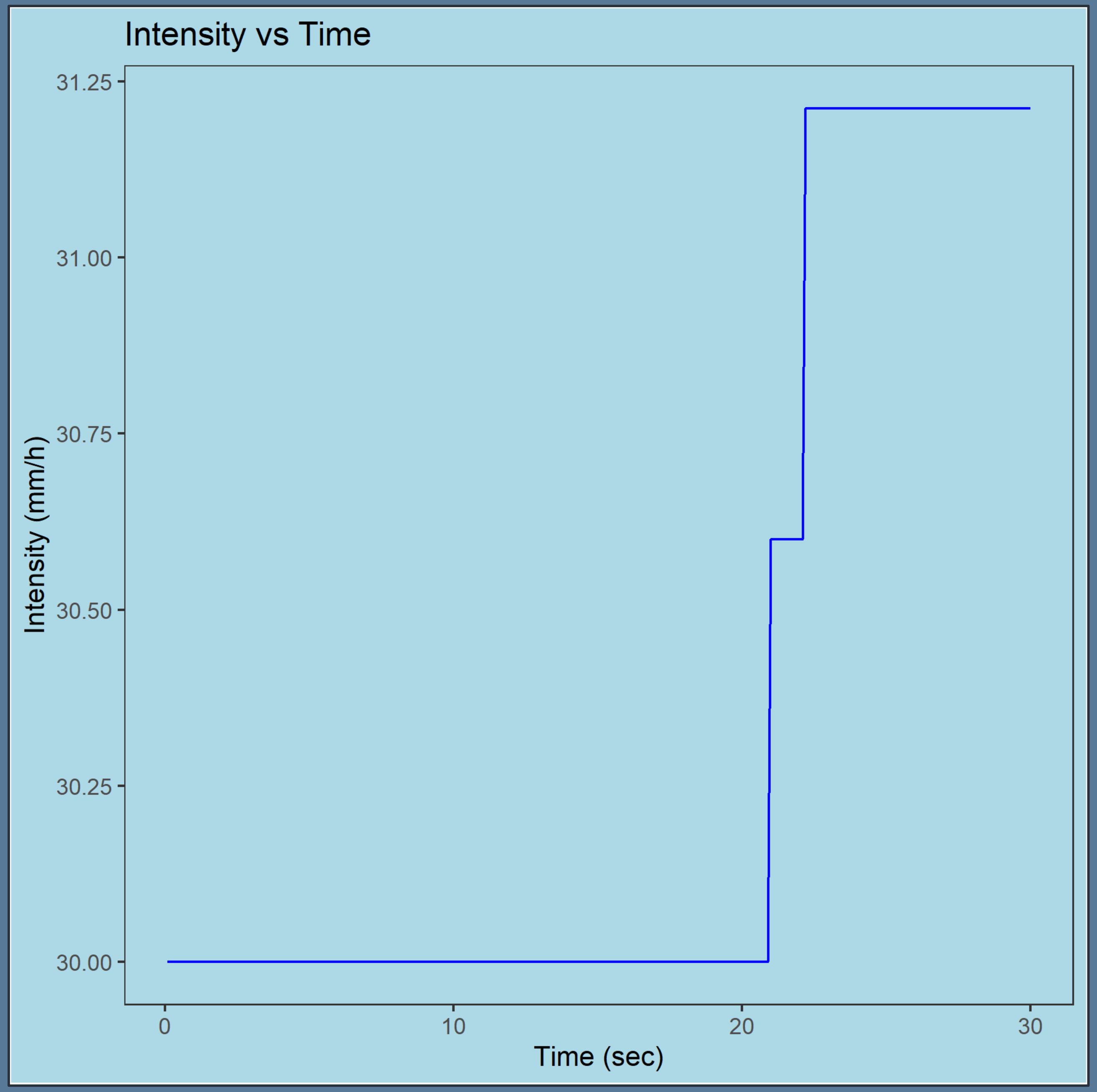
Figure 3



Left: The KE of the rain drop as a function of the drop size, derived assuming spherical shape, constant density, and that the drop is a perfect sphere that impacts the surface at terminal velocity.

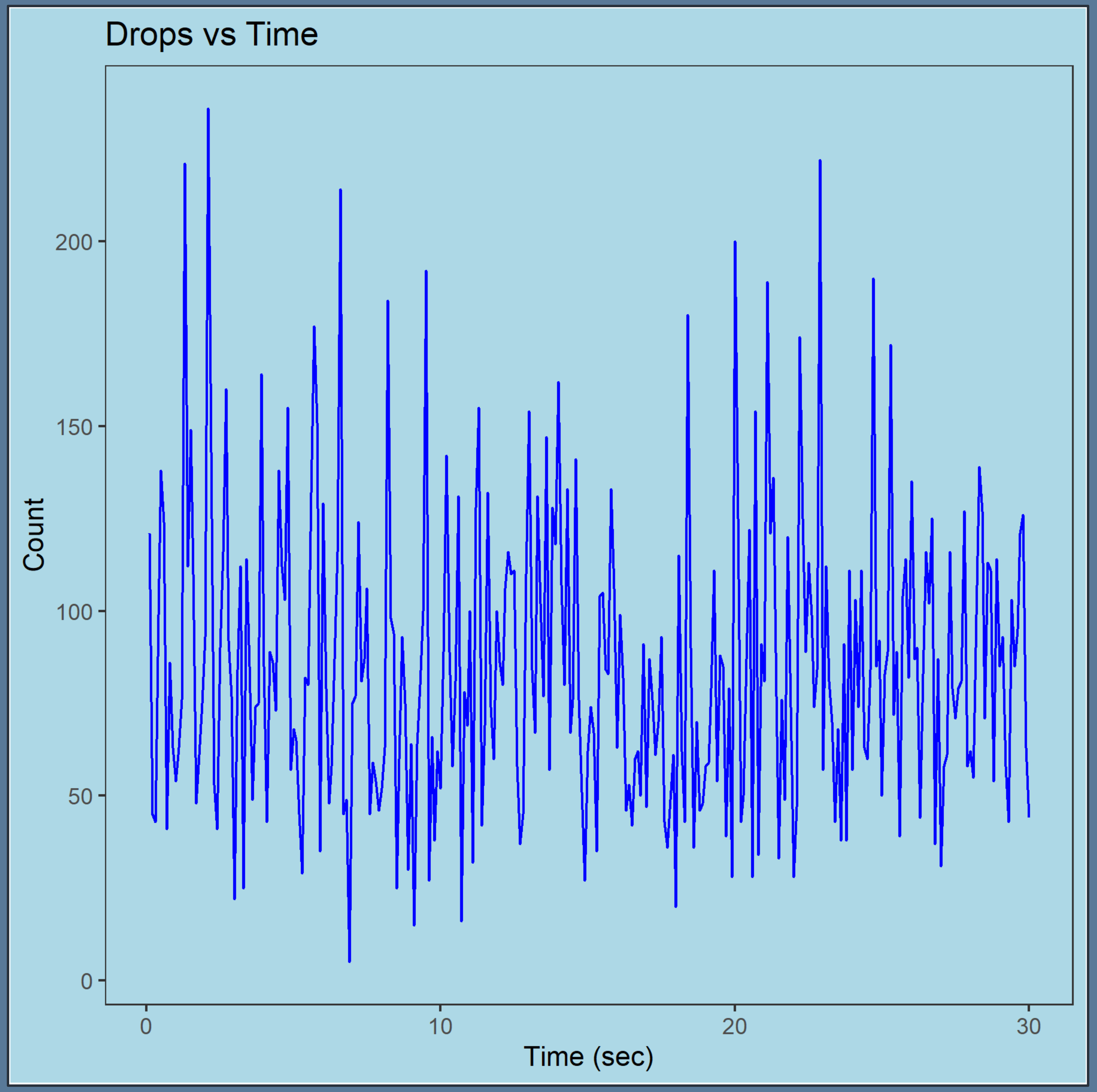
OUTPUTS

Figure 4



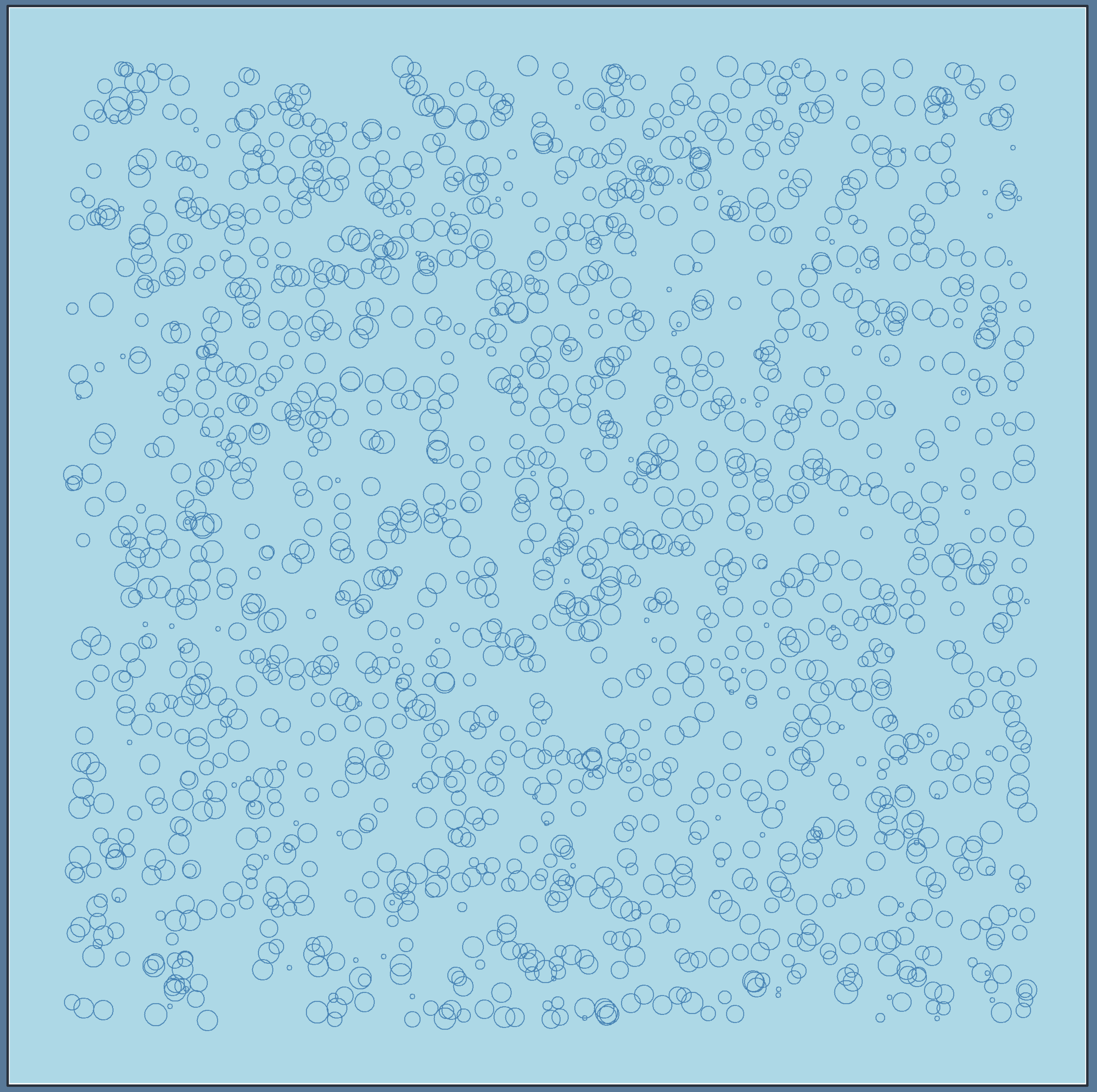
Left: The variation in the rainfall intensity over the model runtime. Intensity varied as a simple Markov process with a 1% chance to increase by 2% and a 1% chance to decrease by 2% at any given time step.

Figure 5



Left: The variation in the drop count over the model runtime. The high tail spikes created by the gamma distribution are easily seen.

Figure 6



Left: The final rainfall animation.