When do Hurricanes Hit New York?

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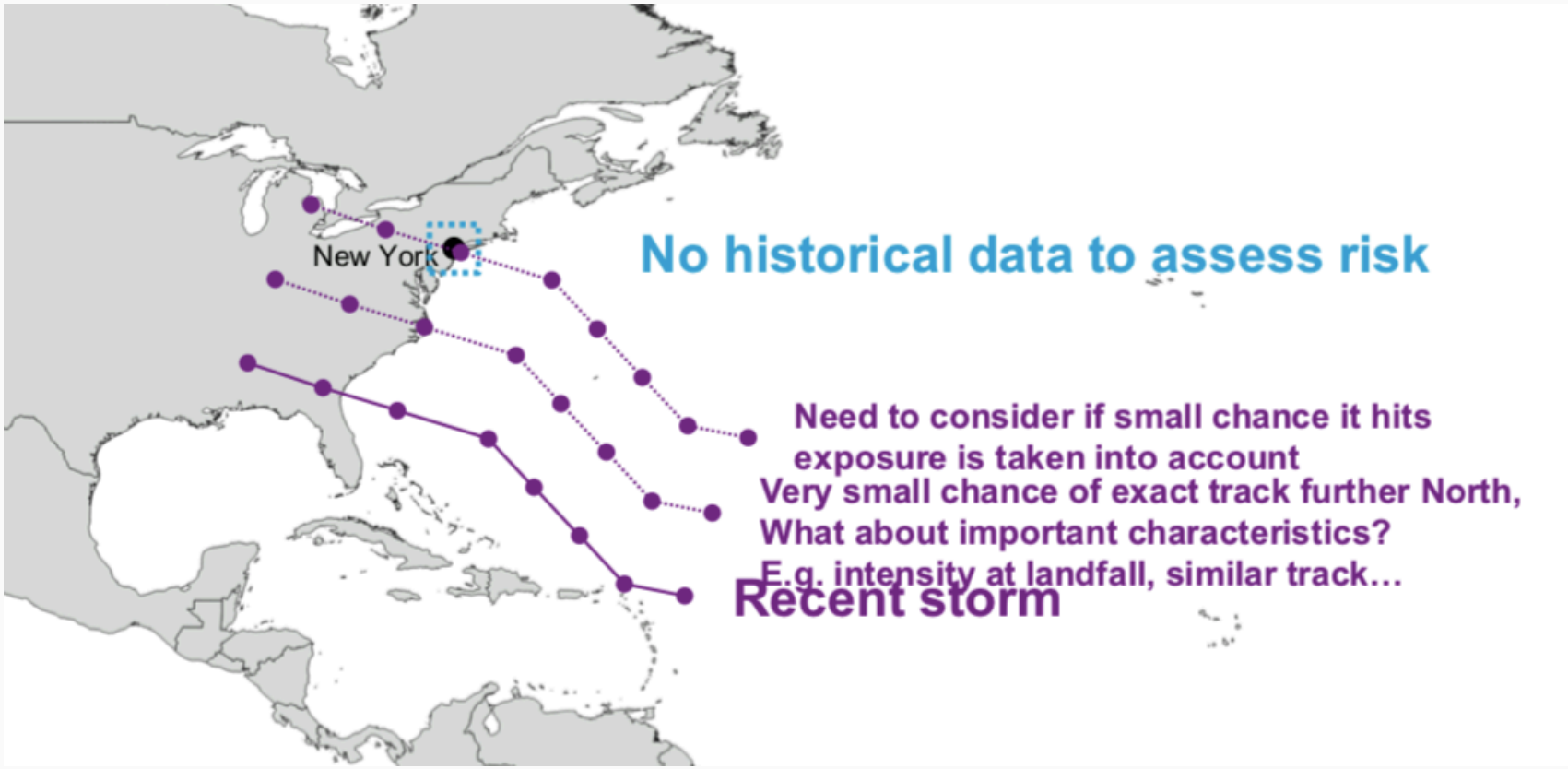
ITT9 with Willis Towers Watson

The Problem

Rare Hurricanes



The Models

Hurricanes as a Random Walk

One methodology is to use historical data of hurricanes and wind flow to create a Markov chain to simulate paths of hurricane[1].

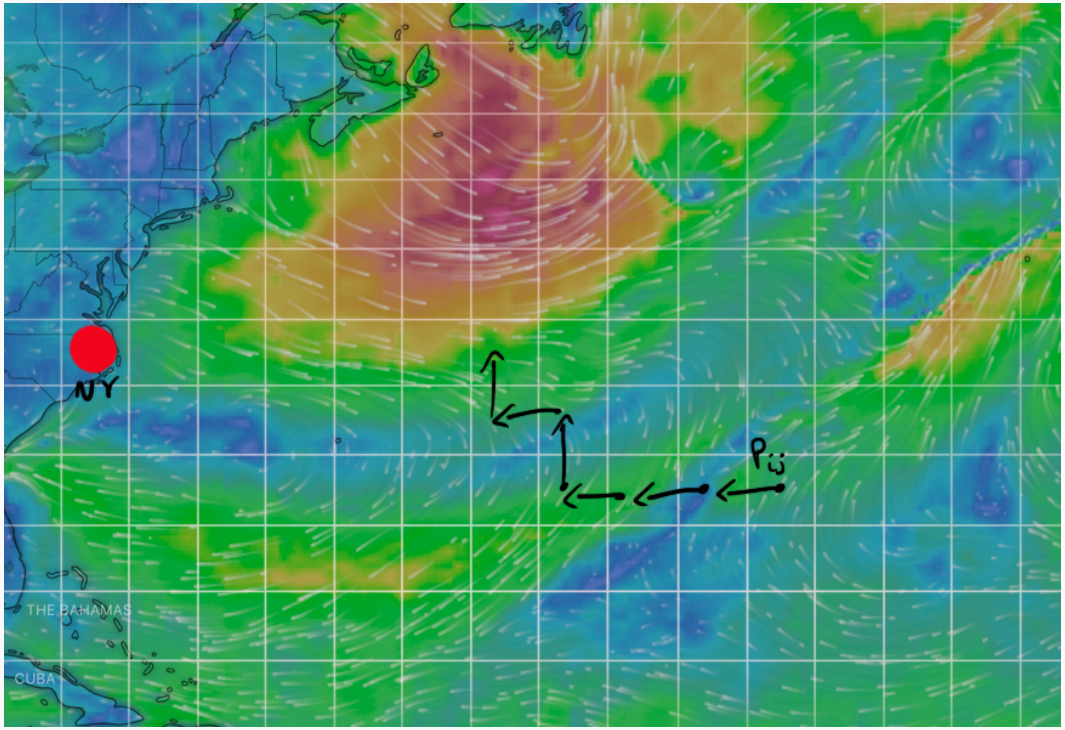


Figure 1: Background image taken from Windy.com

[1] Open source code for such models: http://geoscienceaustralia.github.io/tcrm/docs/intro.html.

Random Deviations from Flow Lines

Another model is one where hurricanes travel along flow lines with random pertubations perpendicular to the flow.

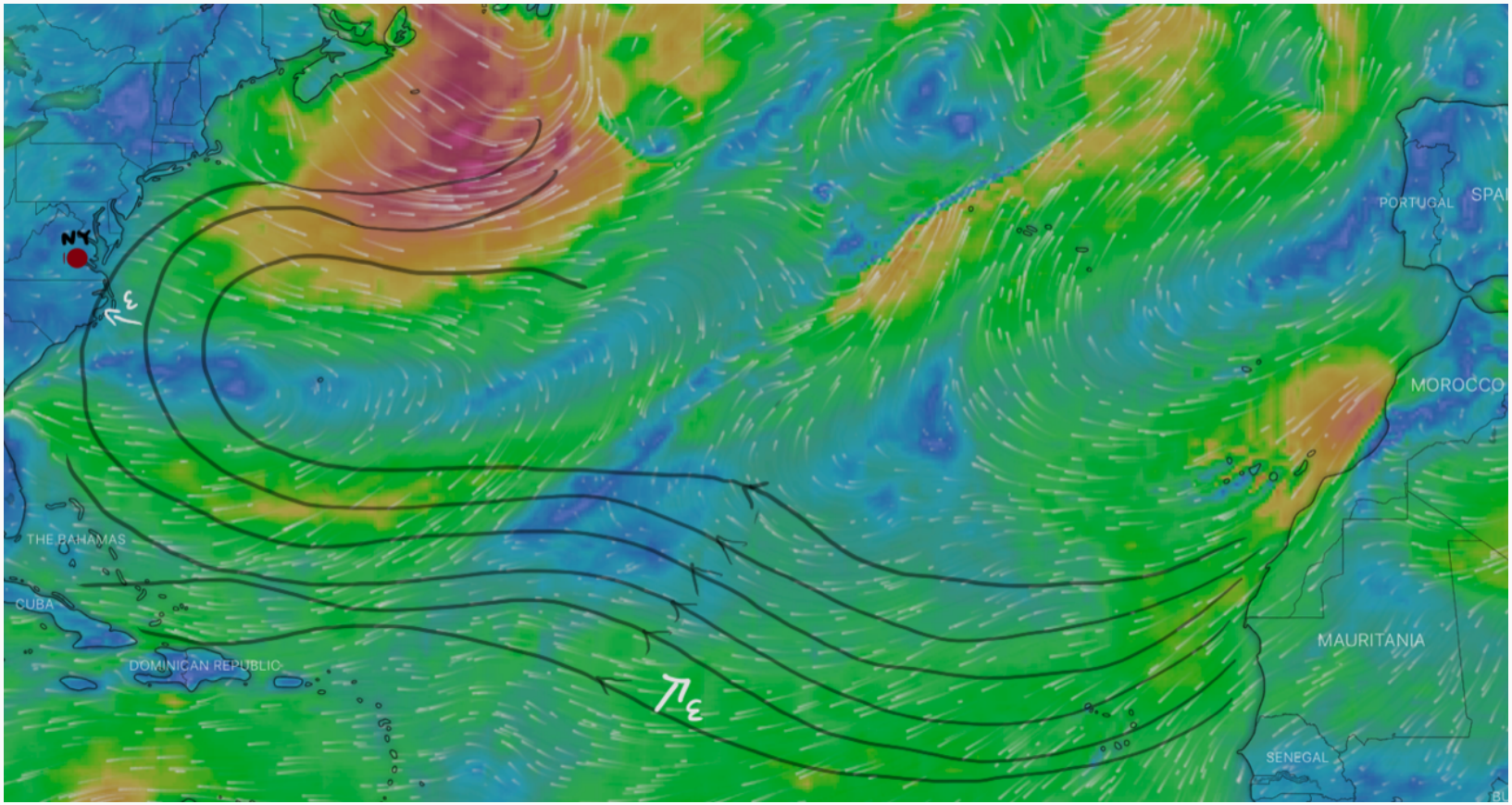


Figure 2: Background image taken from Windy.com

Rare to Typical

Rare Event Sampling

Events of interest to us will be computationally expensive to realise with ordinary methods. There are existing techniques to ease this computational burden.

Cloning - We clone copies of the process in simulations that have atypical paths. (This week).

Biasing - Augment our probability distribution appropriately so we see atypical events with greater frequency. (Future work).

Cloning

1. We assign a weight of 1 to the initial particle.
2. When the initial particle hits a certain **level** for the first time it dies and produces a number of **offspring** that evolve according to the same law of the initial process.
3. The offspring have weight uniformly distributed among them.
4. This process continues as the particles encounter higher levels.

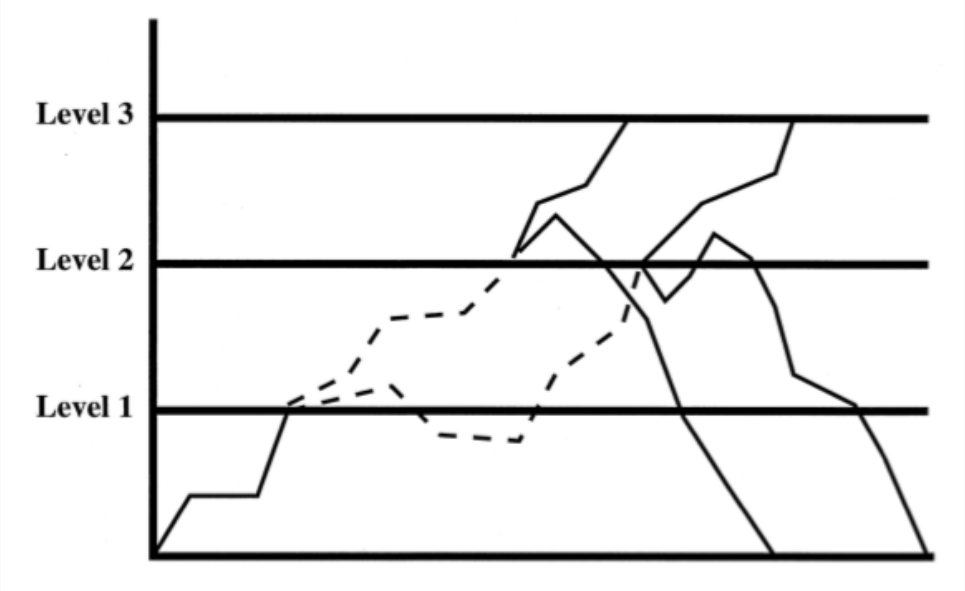
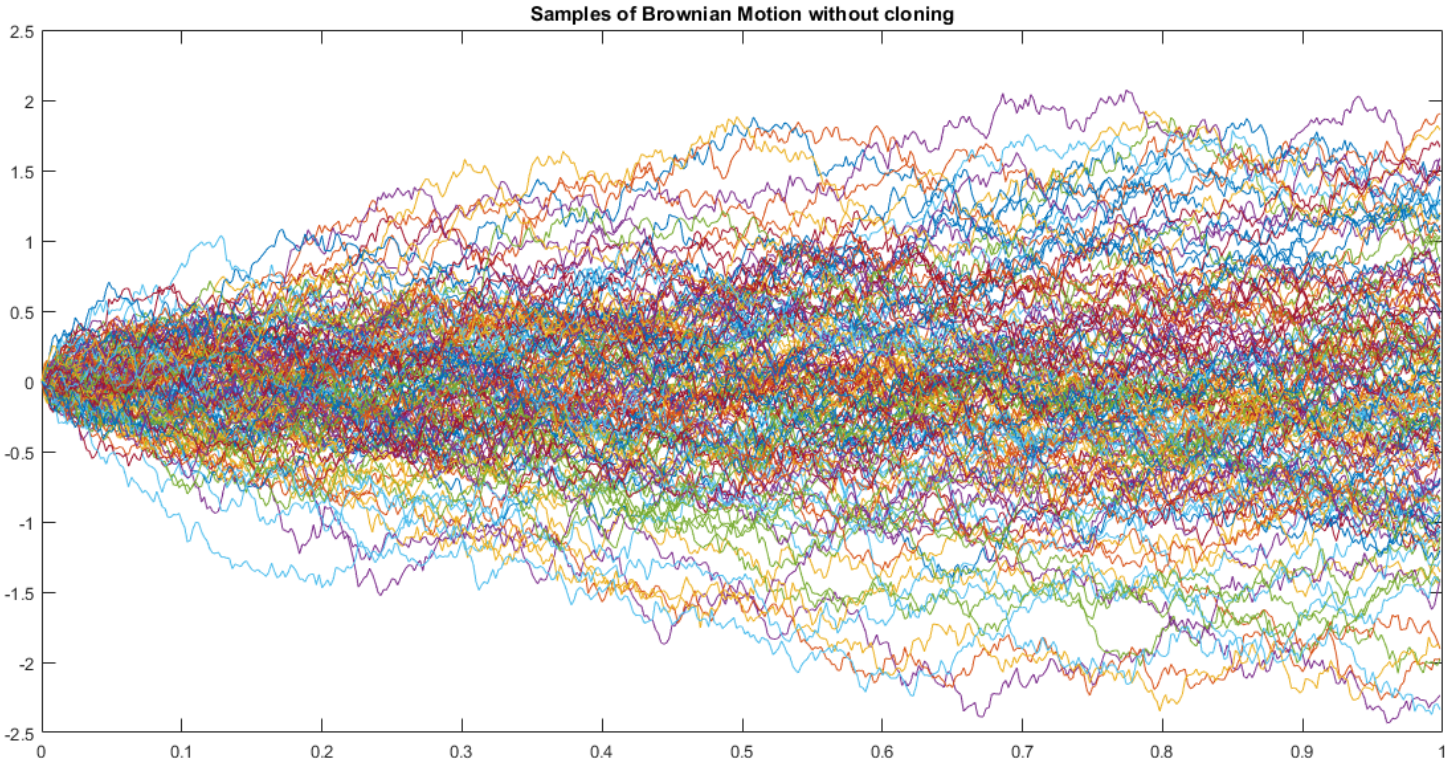


Figure 3: Example of cloning from Glasserman et al [2]

Proof of Principle

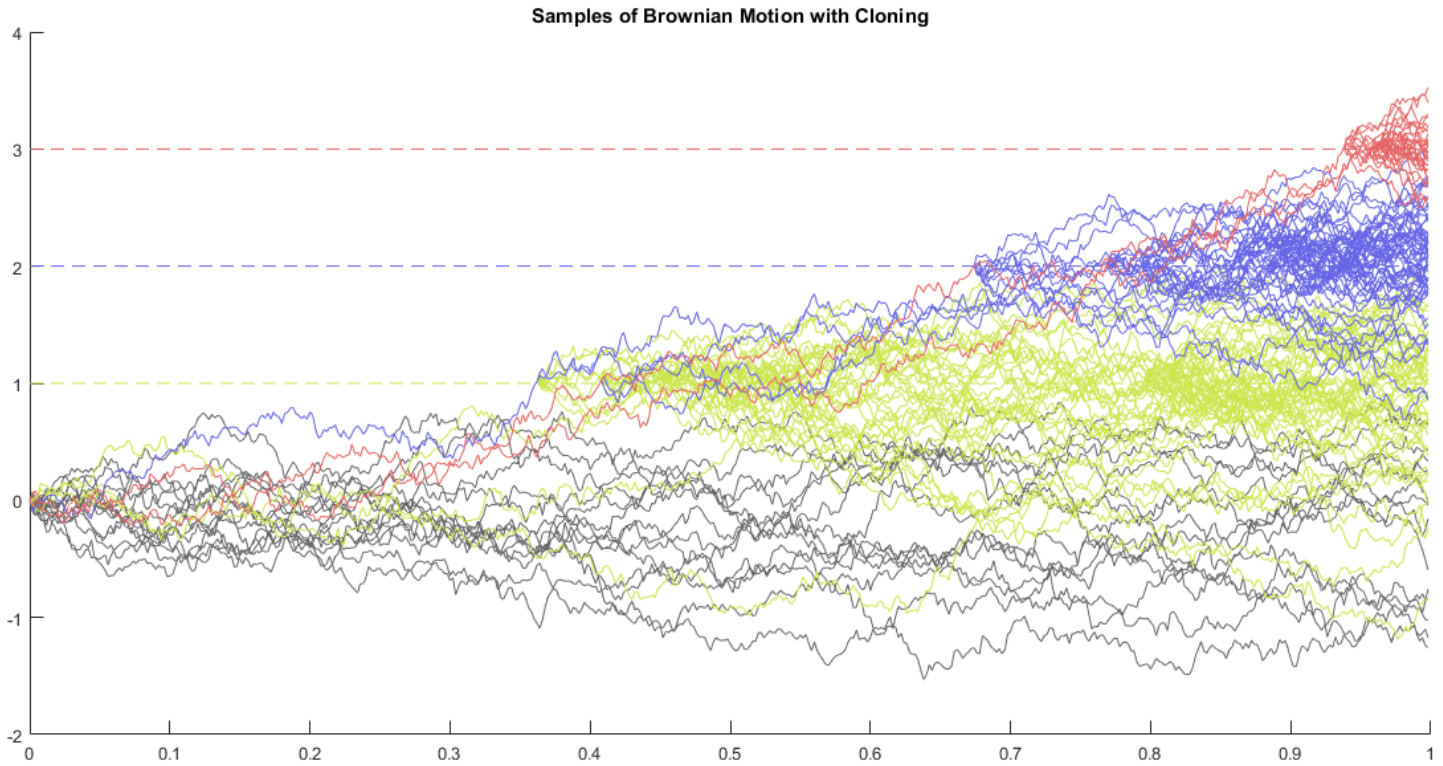
Brownian Motion Sampling Without Cloning

What can we assert about atypical paths? Atypical paths in this context reach large values.



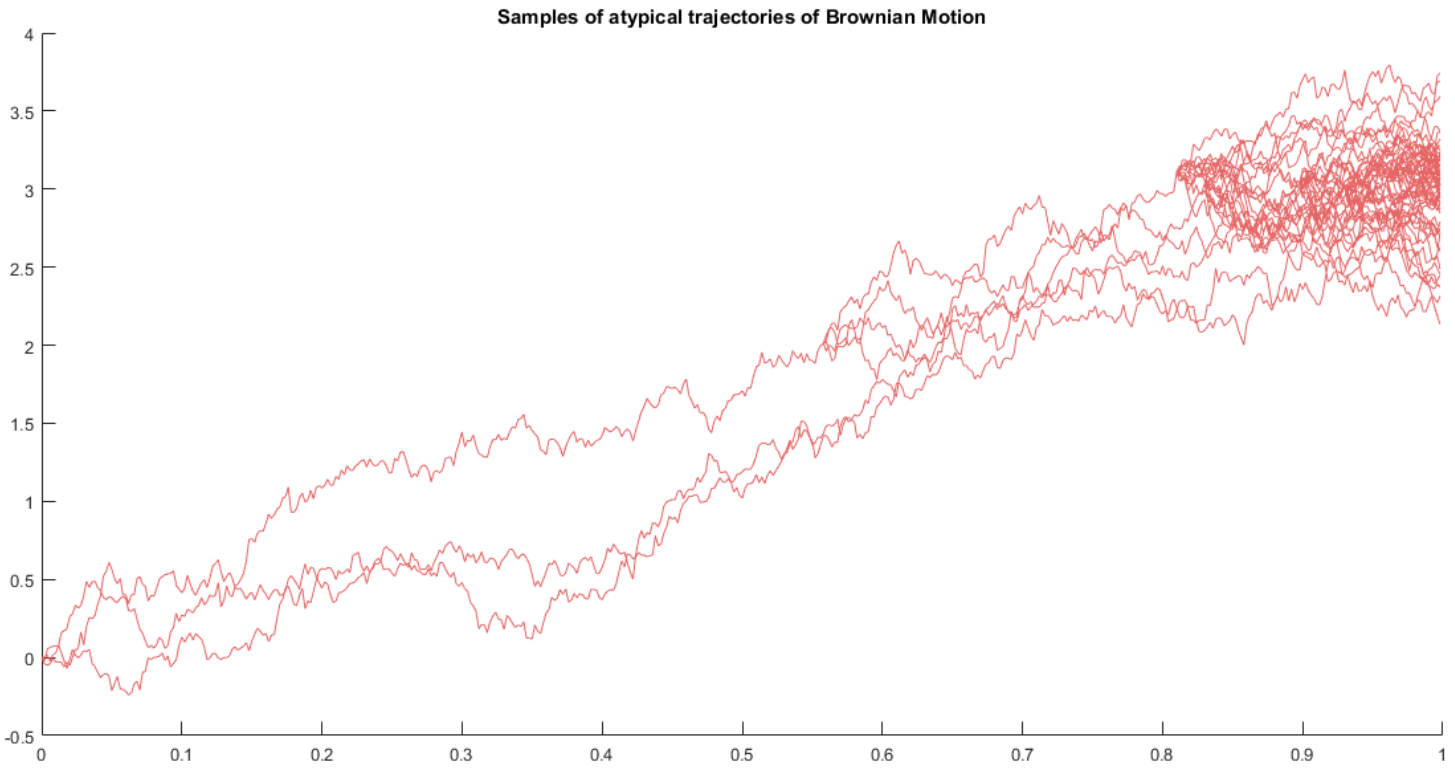
Brownian Motion Sampling with Cloning

Now we start to see more atypical paths.



Atypical Trajectories

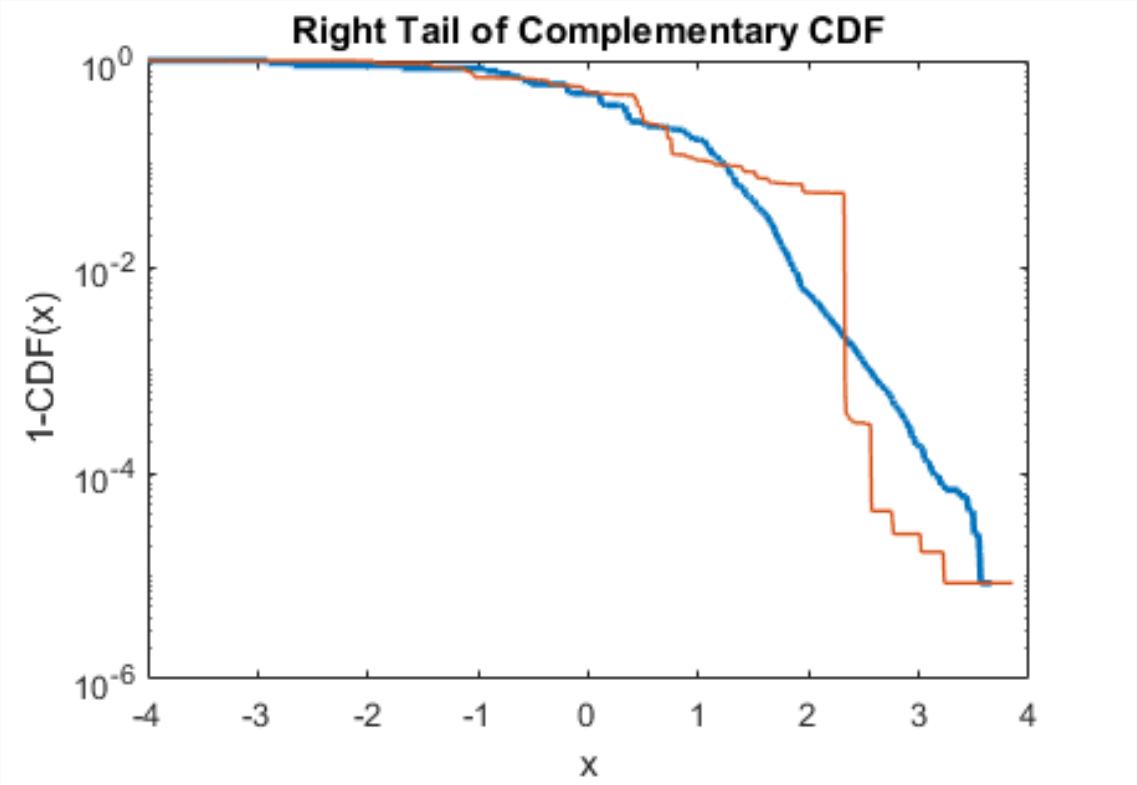
Using the cloning technique we can see how atypical trajectories behave for Brownian motion.



Estimating Probabilities of Rare Events

Without cloning and access to atypical paths we only have a coarse understanding of rare events.

With cloning we have more information about the tails of the distribution where the rare events lie.



Future Directions

- Apply techniques to real models for hurricane track simulation.
- Optimise level setting and offspring distribution.
- Implement biasing to reach rarer events with more precision.

References

1. Brewer, T., Clark, S.R., Bradford, R. and Jack, R.L., 2018. Efficient characterisation of large deviations using population dynamics. Journal of Statistical Mechanics: Theory and Experiment, 2018(5), p.053204.
2. Glasserman, P., Heidelberger, P., Shahabuddin, P. and Zajic, T., 1999. Multilevel splitting for estimating rare event probabilities. Operations Research, 47(4), pp.585-600.
3. Rumpf, J., Weindl, H., Höppe, P., Rauch, E. and Schmidt, V., 2007. Stochastic modelling of tropical cyclone tracks. Mathematical Methods of Operations Research, 66(3), pp.475-490.