Investigating Disease Epidemics through Simulation with a focus on Chikungunya in the Americas

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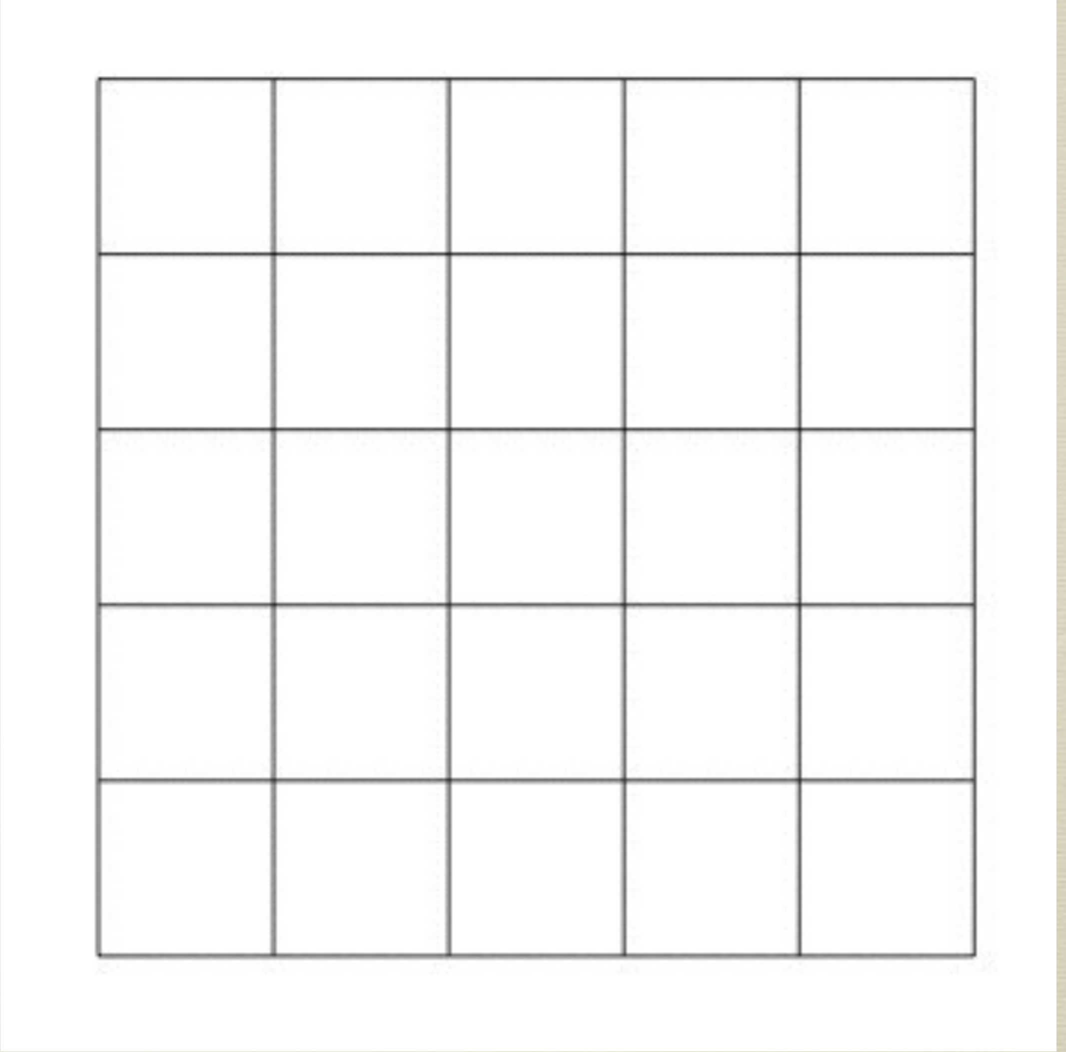
Agent Based Models

* An agent-based model (ABM) is a computational model that simulates the actions and interactions of autonomous agents to observe the effects on a system.
* Agents can take a number of forms, depending on the granularity of the available data (how the data is given), and computational feasibility.
* Examples could be an agent that represent individual members of a population, administrative regions, farms, or other domain specific units of interest.
* The goal of this ABM is to see how an infectious disease spreads through agents in a population over time.

Conway's Game of Life

* To understand how an agent-based model works, we run a Conway's Game of Life Simulation.
* Is a 2-D grid (population) composed of square cells (agents). Each cell has two possible states: alive or dead.
* Each cell interacts with its 8 neighbors.
* There are 4 Rules that determine whether the cell is alive or dead:
    1. Any live cell with fewer than two live neighbors dies, as if caused by under-population.
    2. Any live cell with two or three live neighbors lives on to the next generation.
    3. Any live cell with more than three live neighbors dies, as if by overcrowding.
    4. Any dead cell with exactly three live neighbors becomes a live cell, as if by reproduction.



Disease Simulation

* Is a 2-D grid of square cells. Each cell represents an amount of people with two possible states: infected or non-infected, and each cell interacts with its 8 neighbors.

* For this simulation, we infect some people in the center of the grid.

* By a specific probability function we will see how the disease will spread through the grid. This probability function depends of two infectious coefficients, the first determine often the people will be infected by the people that is infected on the same cell; the second will tell how much the people will be infected by the infected surroundings.

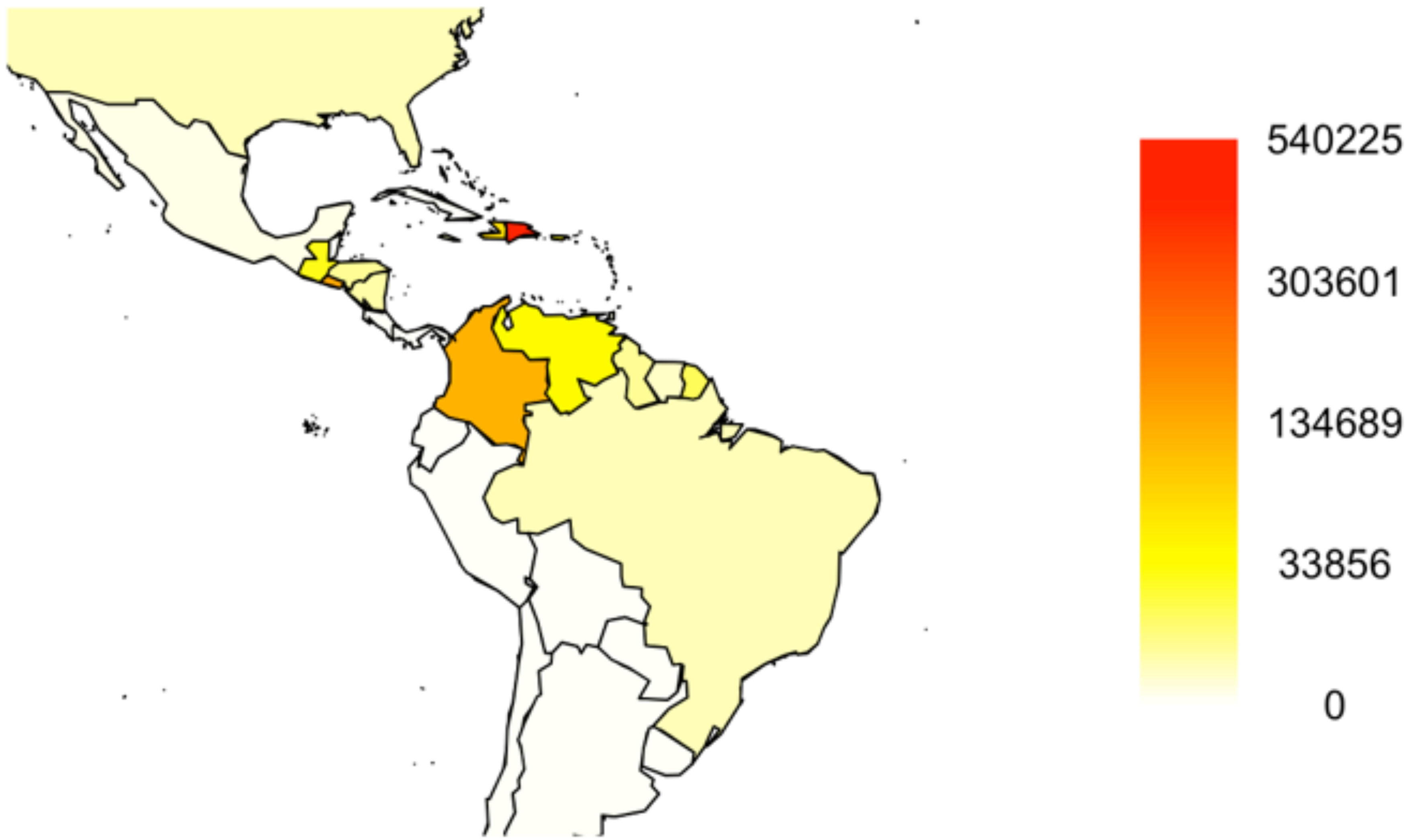
* Then we will see how the disease gets removed from the people by a removing probability function.

* We can change the infectious coefficients and the probability of removing the disease and will see different effects on the simulation.

About Chikungunya

- The data is from PAHO.
- Case Definition:
  - Clinical Criteria: acute onset of fever >101.3°F and severe arthralgia/arthritis not explained by other medical conditions.
  - Epidemiological criteria: residing or having visited epidemic areas, having reported transmission within 15 days prior to the onset of symptoms.
- Virus that is transmitted to people by two different mosquitoes: *Aedes aegypti* and *Aedes albopictus.*
- Most common symptoms are fever and joint pain.
- It first appearances on Africa, Asia, Europe and Oceania. It was found for the first time in the Americas on Caribbean Islands.
- For this project we will focus on how the Chikungunya has spread on the Americas.

How Many Individuals Have Been Infected per Country

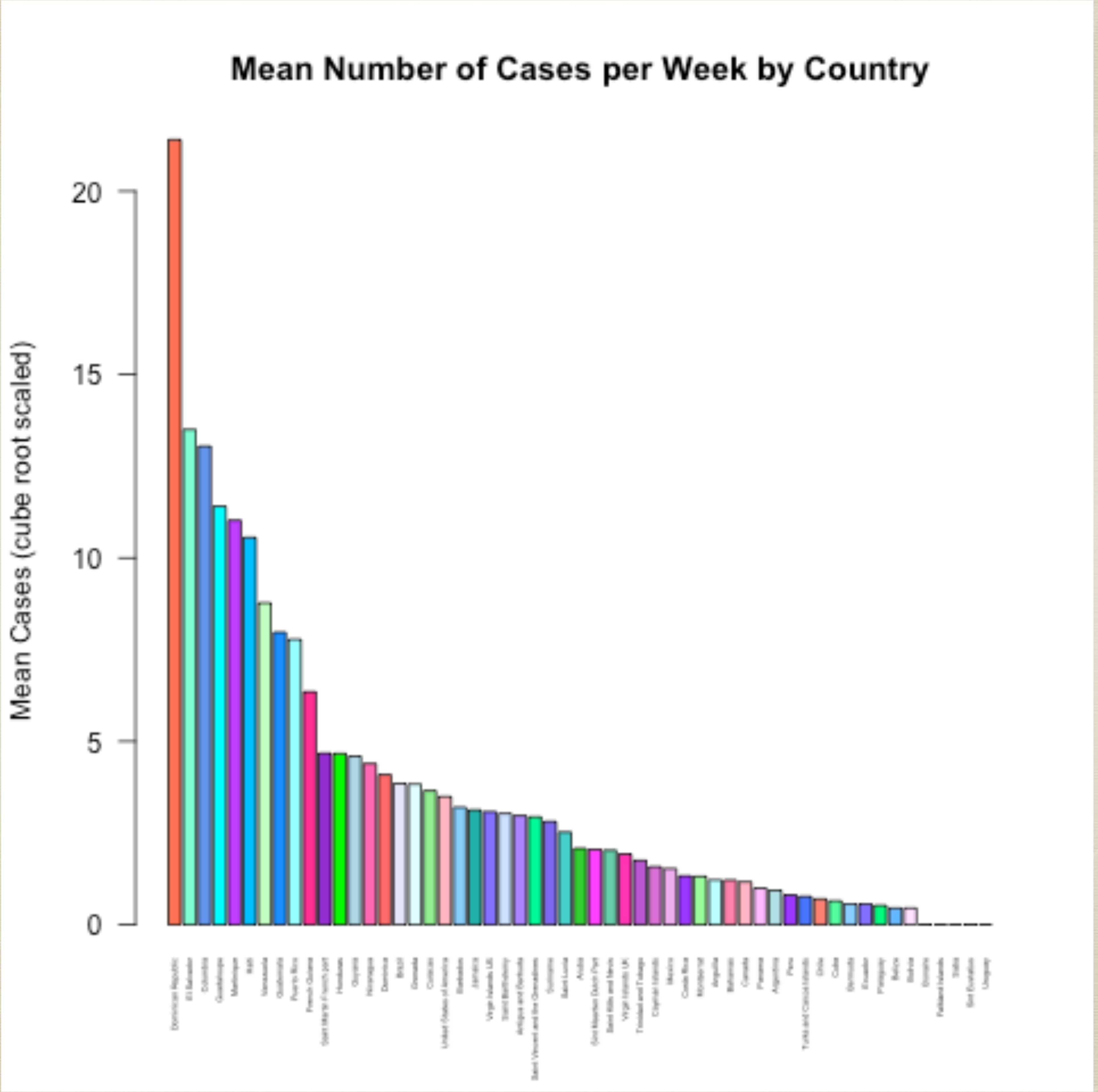


Summary Statistics of Chikungunya

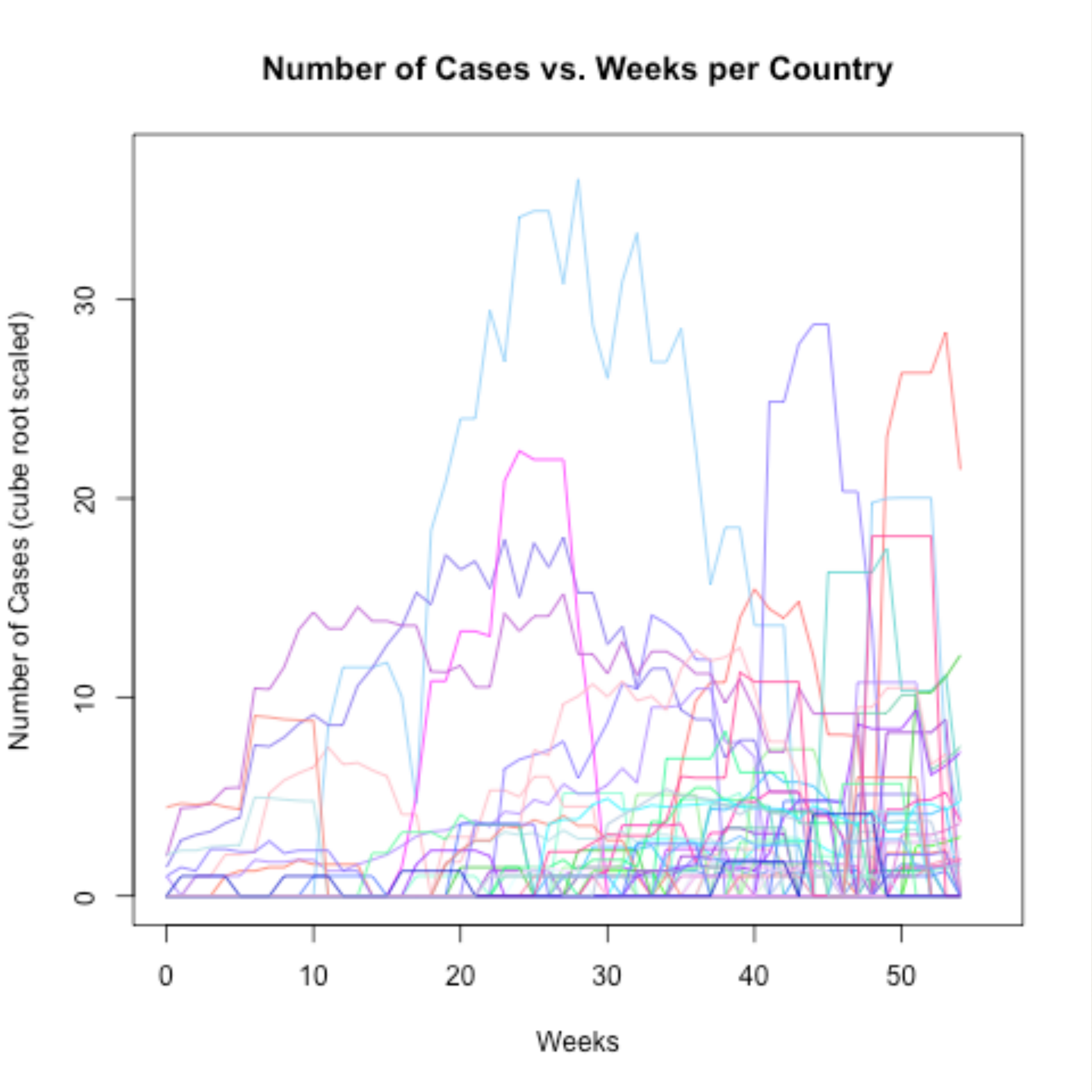
Region	Mean per Week	Standard Deviation per Week
Anguilla	1.818	3.068
Antigua and Barbuda	26.291	49.580
Argentina	0.818	1.124
Aruba	9.018	15.504
Bahamas	1.800	3.817
Barbados	32.764	59.528
Belize	0.091	0.290
Bermuda	0.182	0.580
Bolivi	0.091	0.290
Bonaire	0.000	0.000
Brazil	56.927	169.61
Canada	1.600	5.213
Cayman Islands	3.945	10.213
Chile	0.345	1.518
Colombia	2219.982	5357.882
Costa Rica	2.345	5.739
Cuba	0.273	0.622
Curacao	48.764	113.314
Dominica	68.400	103.788
Dominican Republic	9805.145	13059.122
Ecuador	0.182	0.580
El Savador	2461.527	5938.001
Falkland Islands	0.000	0.000
French Guiana	255.855	423.589
Grenada	56.345	123.765
Guadaloupe	1484.273	1796.431
Guatemala	506.000	1323.422
Guyana	96.836	352.685
Haiti	1176.564	3026.685

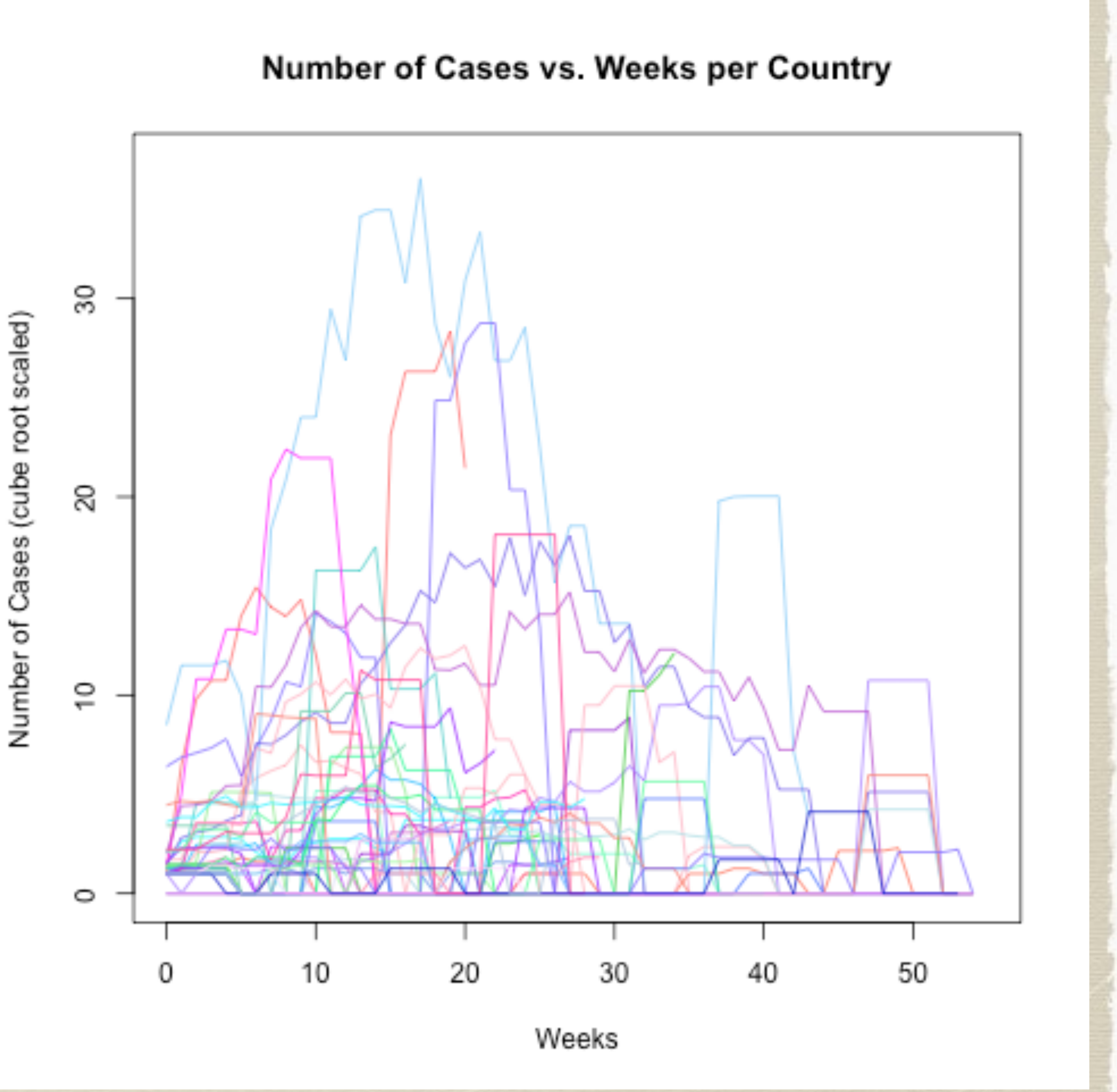
Summary Statistics of Chikungunya

Region	Mean per Week	Standard Deviation per Week
Honduras	101.527	262.472
Jamaica	30.582	46.410
Martinique	1340.655	1007.475
Mexico	3.582	10.177
Montserrat	2.273	6.072
Nicaragua	84.782	196.198
Panama	0.982	1.545
Paraguay	0.145	0.356
Peru	0.527	1.26
Puerto Rico	470.909	597.697
Saba	0.000	0.000
Saint Barthelemy	27.909	35.001
Saint Kitts and Nevis	8.364	23.098
Saint Lucia	16.109	32.854
Saint Martin French Part	102.127	203.636
Saint Vincent and Grenadines	25.364	51.968
Sint Eustatius	0.000	0.000
Sint Maarten Dutch Part	8.582	13.168
Suriname	22.236	44.088
Trinidad and Tobago	5.364	8.685
Turks and Caicos Islands	0.455	0.878
United States Of America	42.582	43.915
Uruguay	0.000	0.000
Venezuela	675.255	1716.756
Virgin Islands UK	7.145	20.113
Virgin Islands US	29.236	43.248


Mean Number of Cases per Week by Country
Mean Cases (cube root scaled)
20
15
10
5
0

Number of Cases vs. Weeks per Country





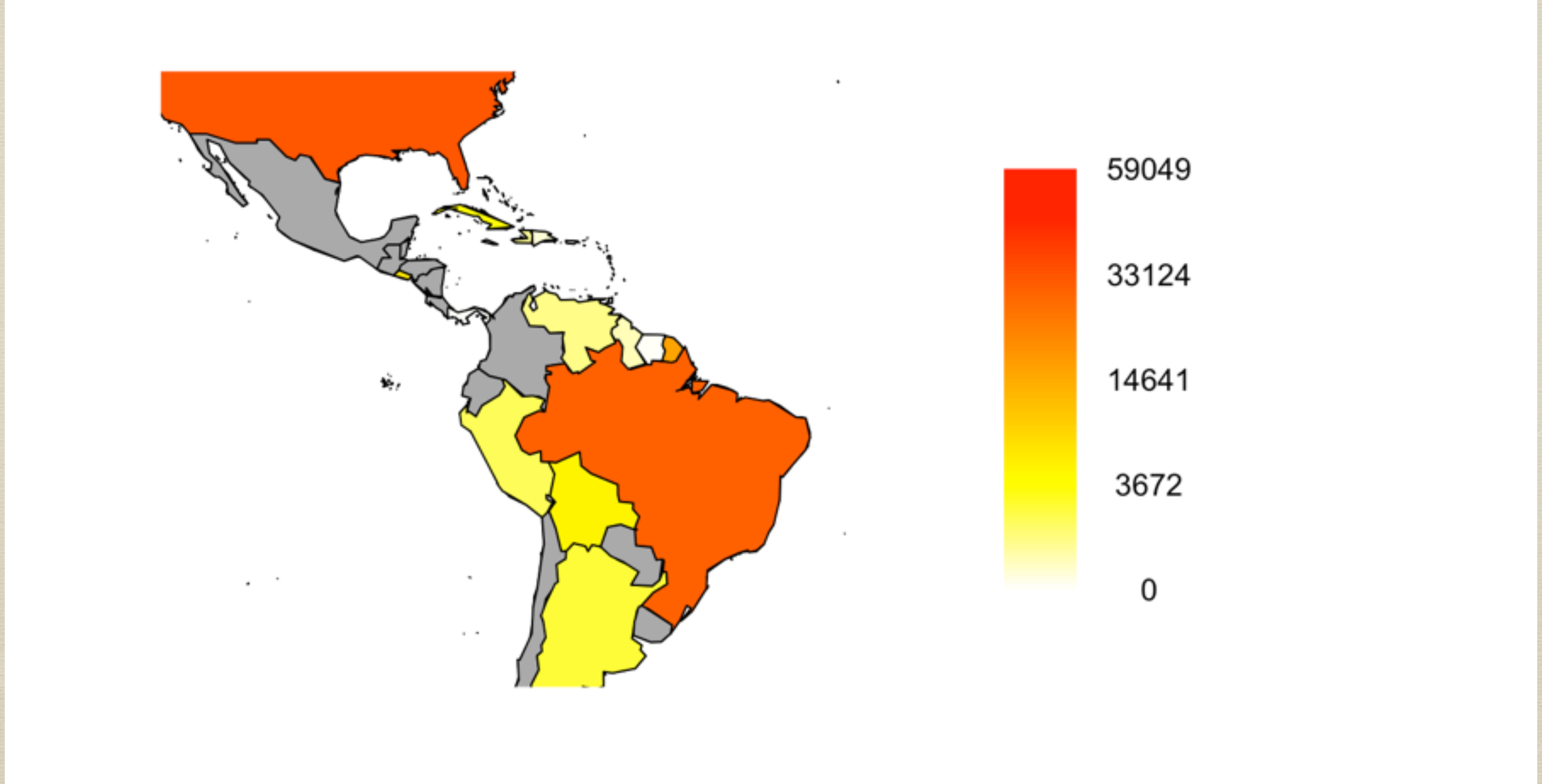
* We considered the first 30 weeks for the simulation because after the 30 weeks there was a clear shift in the disease dynamics.

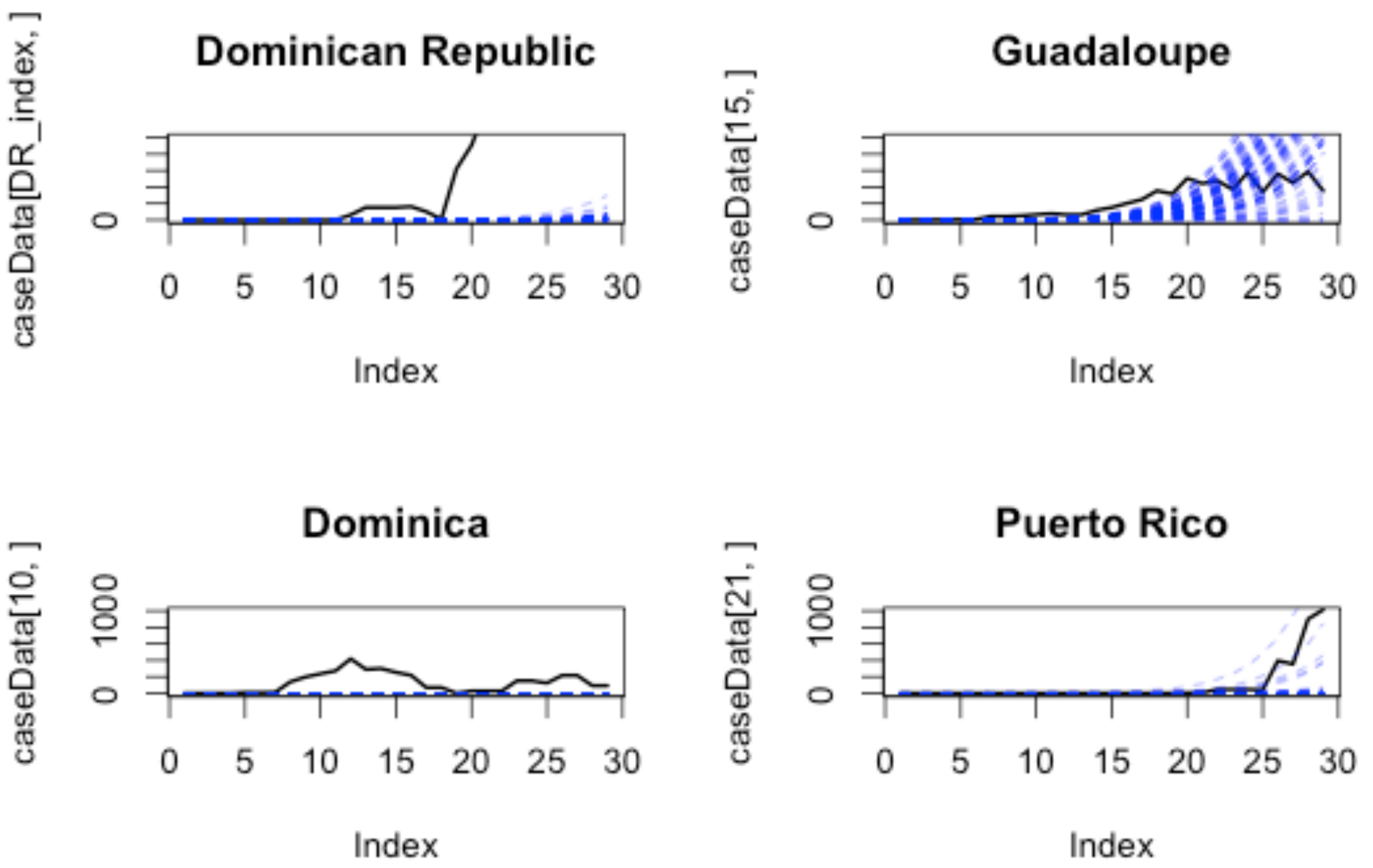
* This could be due to multiple reasons:
  * Public Health awareness
  * Seasonal

* Like the first Disease Simulations we saw earlier, we will take the baseline data and run the simulation. For this one we will consider the distance between the countries since the surroundings of the countries are different from the surroundings of the 2-D grid.

* For this simulation we are just considering space (countries), time (weeks), and distance (between countries), we do not consider the mosquitoes and other factors.

Interactive Map of Chikungunya from Simulation





Dominican Republic
caseData[DR_index,]
Index
Guadaloupe
caseData[15,]
Index
Dominica
caseData[10,]
Index
Puerto Rico
caseData[21,]
Index

Future Works

* Find, if possible, a better simulation which describes the data for each country for the first weeks.
* Do the same we have done but with the other part of the data (last 25 weeks).
* Describe the data for other continents.
* Look at other factors that could influence the spread of Chikungunya.

References

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R version 3.1.1 (2014-07-10) -- "Sock it to Me" Copyright (C) 2014 The R Foundation for Statistical Computing Platform: x86_64-apple-darwin13.1.0 (64-bit)

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Questions