Some coronavirus epidemic scenarios as of 3/16/2020

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Here are four scenarios: optimistic vs. pessimistic individual outbreak models; and optimistic vs. pessimistic pandemic models.

An outbreak is the entire disease evolution within a single, isolated population center. A center has 10m people. You will see additional parameters in the scenarios below. I'm assuming that the death rate is actually about 1.5% of cases. It would be higher if hospitals get overwhelmed.

A pandemic consists of multiple outbreaks that communicate by people traveling between infected population centers.

I'm assuming that we are today roughly at cycle 8 of the outbreak, and that social distancing is being imposed, either stringently or in a sloppy way, reducing the naïve disease spread rate (also called R0) from 2.5 to either 1.2 or 1.6. It's possible to argue that we are effectively a little earlier than cycle 8, which would make everything less severe; but it's hard to be confident in identifying exactly where we are in the epidemic's evolution.

These models include the emergence of "herd immunity".

"Active infections" represents the fraction of the population that is actively infected and can spread to uninfected people at each week (cycle).

The range of cumulative infections in each outbreak center is from 40% to about 75% of the population, but could be considerably better in a pandemic where some centers impose distancing before their outbreaks really take off.

Optimistic single outbreak model.

In this projection we are at about cycle 8 now, and we suppress the spread rate down to about 1.20 by social distancing, from the naïve R0 of about 2.5. The outbreak peaks somewhere between weeks 12 and 16, which would put it between mid-April and mid-May. We would not be confident of subsidence for several weeks after.

```
Playing with parameters
  10 million population
  Infection cycle time 1 weeks
  Naive mean spread rate R0 is 2.50 new infections per infected individual
  Standard deviation of the generated log-normal R0 distribution ~ 2.37
  Standard deviation of the underlying Gaussian distribution is 0.80
  Death rate 1.50%
  Extinguishing event will begin on cycle 8
  Spread rate 1.20 after extinguishing event
  Herd immunity effect included
Will run 20 trials
Best trial, per 10 million population:
     258,947 was the largest number of concurrent active infections, or 2.59% of population
   3,659,357 cases occurred by end of simulation, or 36.6% of population
      54,890 died, or 0.549% of population
Worst trial, per 10 million population:
     306,151 was the largest number of concurrent active infections, or 3.06% of population
   3,822,819 cases occurred by end of simulation, or 38.2% of population
      57,342 died, or 0.573% of population
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Ratio of worst/best cases = 1.04
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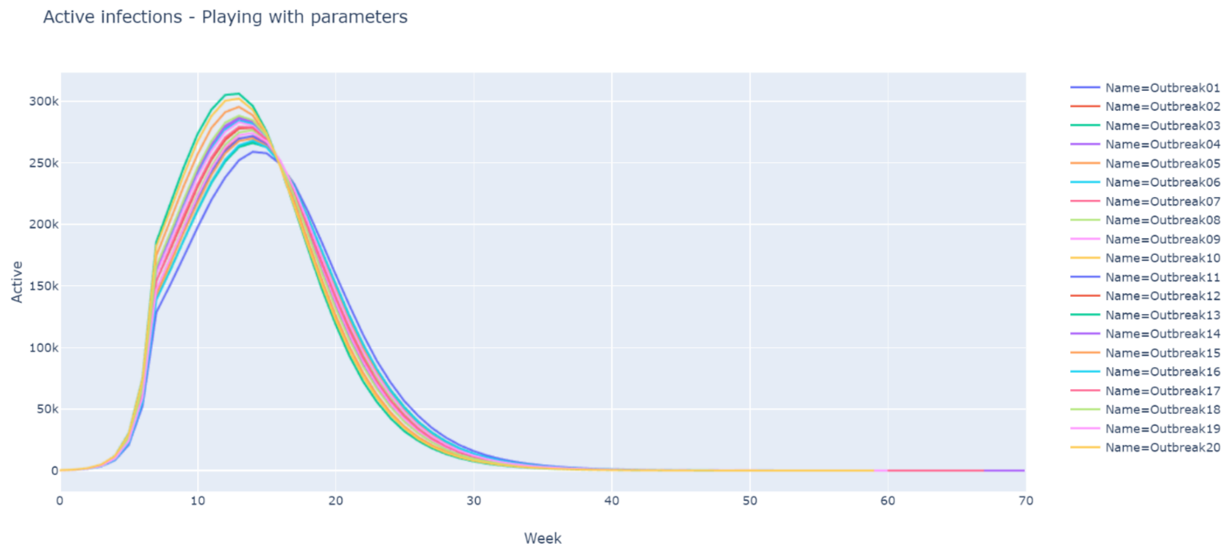

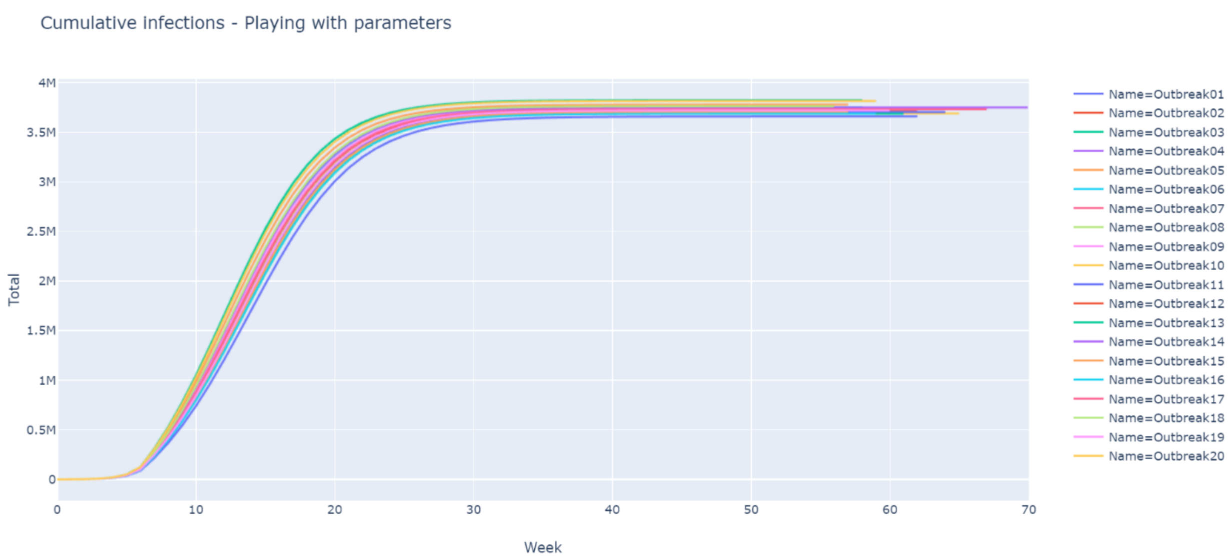

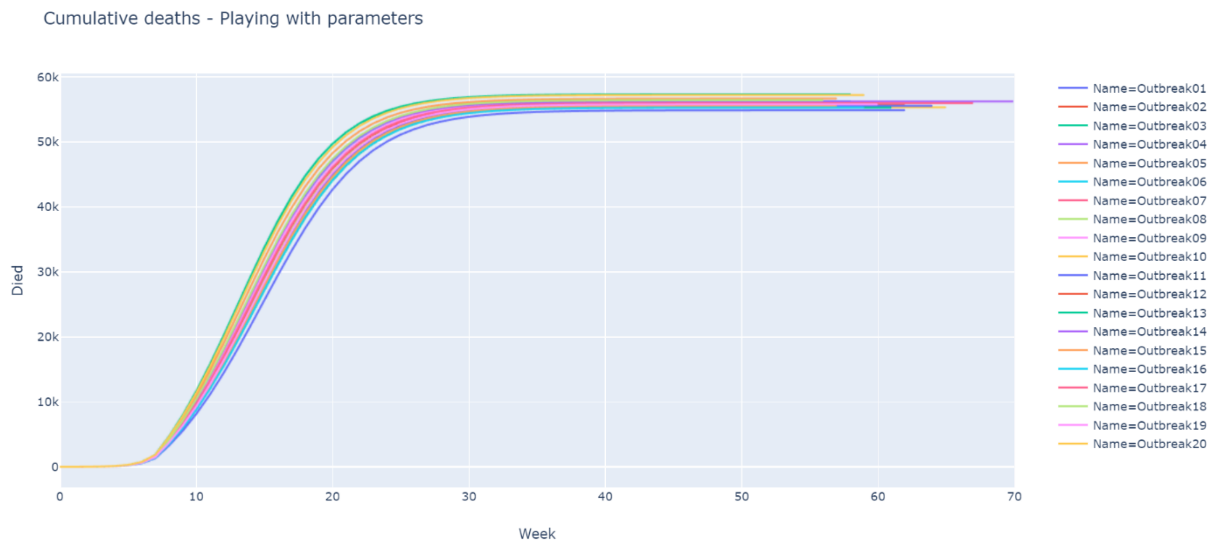

Pessimistic single outbreak model.

Here is a pessimistic outlook. In this case social distancing doesn't kick in until week 10, and is sloppy, so the spread rate only drops to 1.60 per infected case. Then the peak is around week 11 or 12, call it mid-April or 3rd week of April, because things are worse. Also the epidemic tails off faster. We might be pretty confident it's ending around week 12 or 13. It's over by week 18. Unfortunately a lot more people die compared to the optimistic scenario.

```
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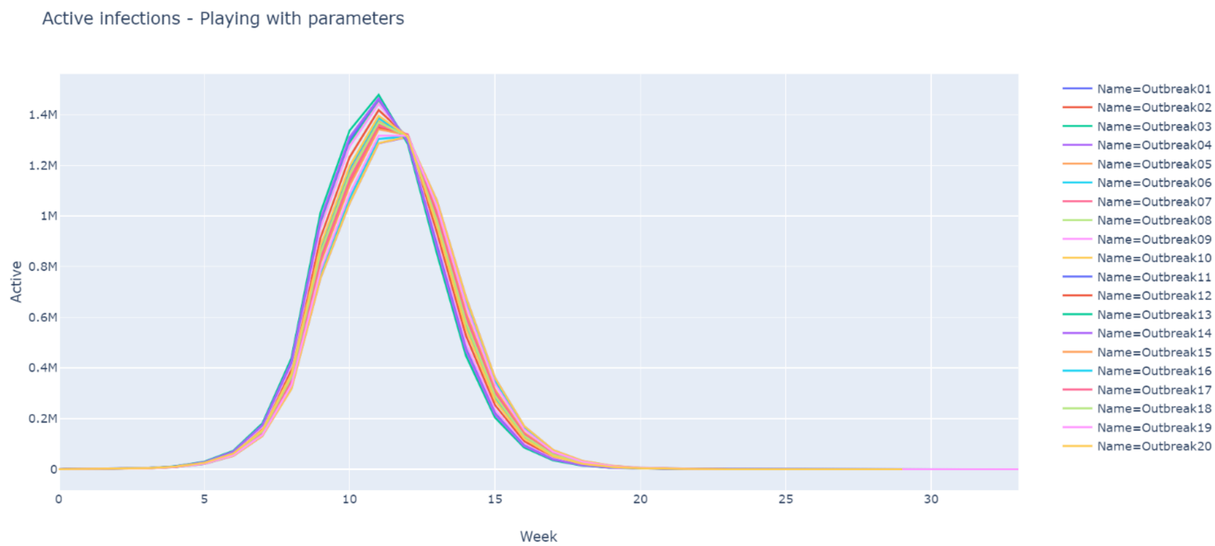
  10 million population
  Infection cycle time 1 weeks
  Naive mean spread rate R0 is 2.50 new infections per infected individual
  Standard deviation of the generated log-normal R0 distribution ~ 2.39
  Standard deviation of the underlying Gaussian distribution is 0.80
  Death rate 1.50%
  Extinguishing event will begin on cycle 10
  Spread rate 1.60 after extinguishing event
  Herd immunity effect included
Will run 20 trials
Best trial, per 10 million population:
   1,310,847 was the largest number of concurrent active infections, or 13.11% of population
   7,343,913 cases occurred by end of simulation, or 73.4% of population
     110,159 died, or 1.102% of population
Worst trial, per 10 million population:
   1,478,654 was the largest number of concurrent active infections, or 14.79% of population
   7,506,252 cases occurred by end of simulation, or 75.1% of population
     112,594 died, or 1.126% of population
Ratio of worst/best cases = 1.02
```


Active infections - Playing with parameters
Active
Week
0
0.2M
0.4M
0.6M
0.8M
1M
1.2M
1.4M
0
5
10
15
20
25
30
Name=Outbreak01
Name=Outbreak02
Name=Outbreak03
Name=Outbreak04
Name=Outbreak05
Name=Outbreak06
Name=Outbreak07
Name=Outbreak08
Name=Outbreak09
Name=Outbreak10
Name=Outbreak11
Name=Outbreak12
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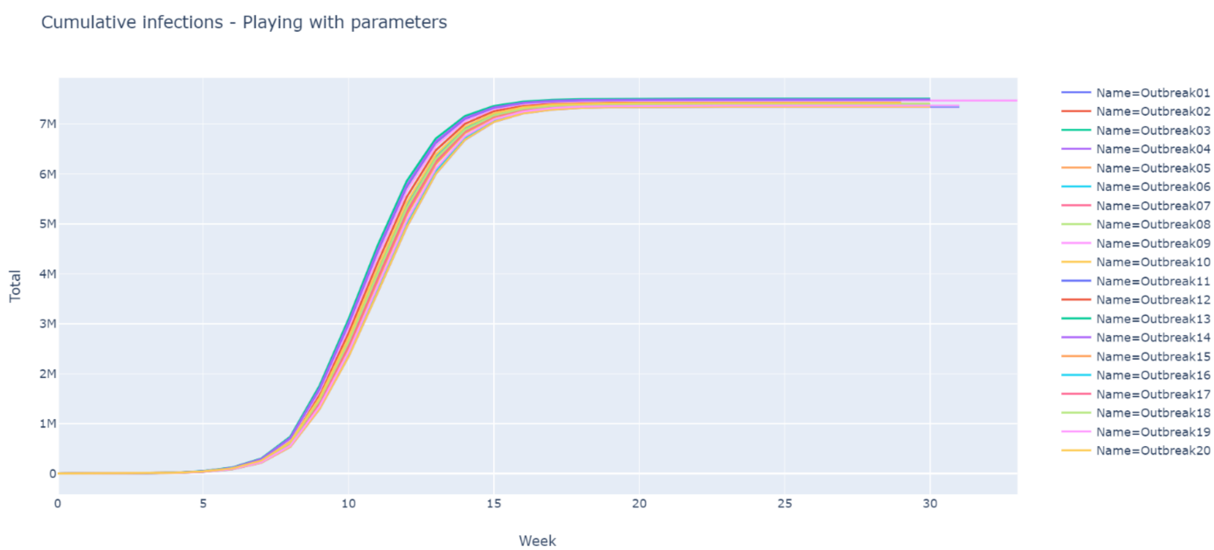
Name=Outbreak19
Name=Outbreak20


Cumulative infections - Playing with parameters
Total
Week
0
1M
2M
3M
4M
5M
6M
7M
0
5
10
15
20
25
30
Name=Outbreak01
Name=Outbreak02
Name=Outbreak03
Name=Outbreak04
Name=Outbreak05
Name=Outbreak06
Name=Outbreak07
Name=Outbreak08
Name=Outbreak09
Name=Outbreak10
Name=Outbreak11
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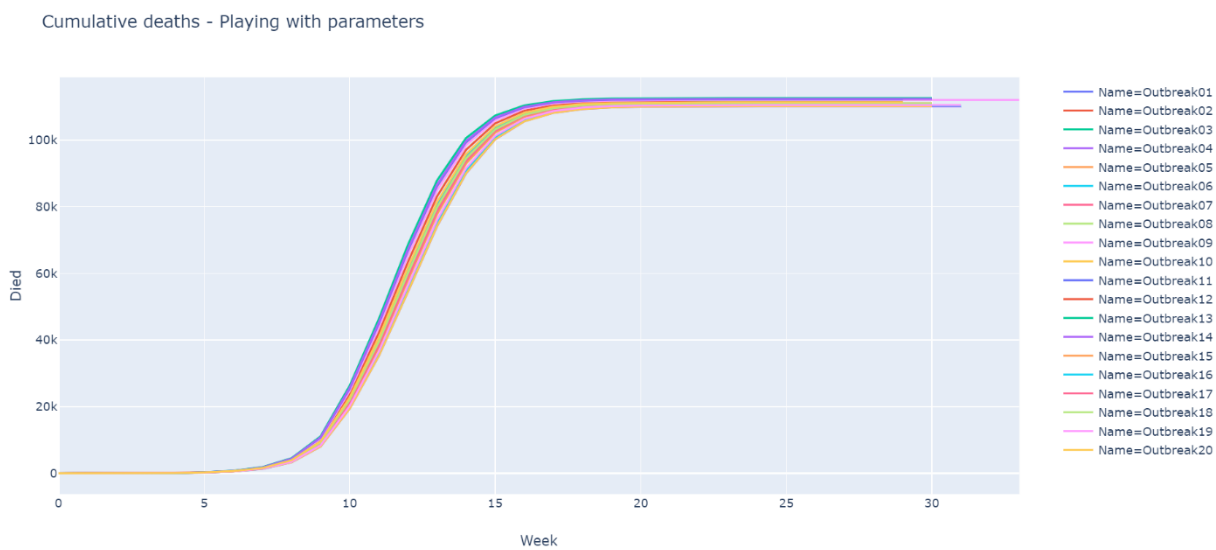
Name=Outbreak19
Name=Outbreak20

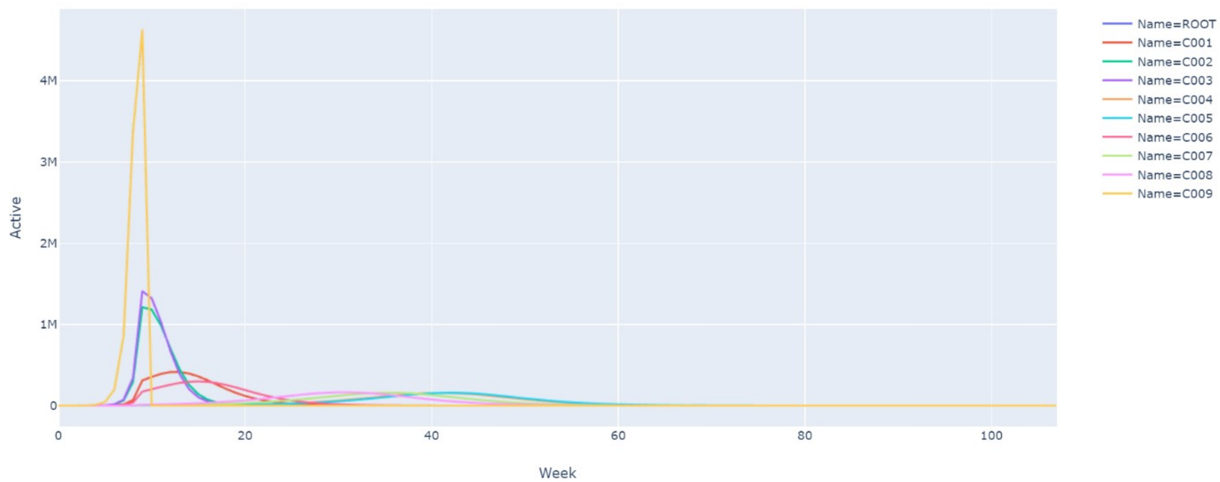


Optimistic pandemic model

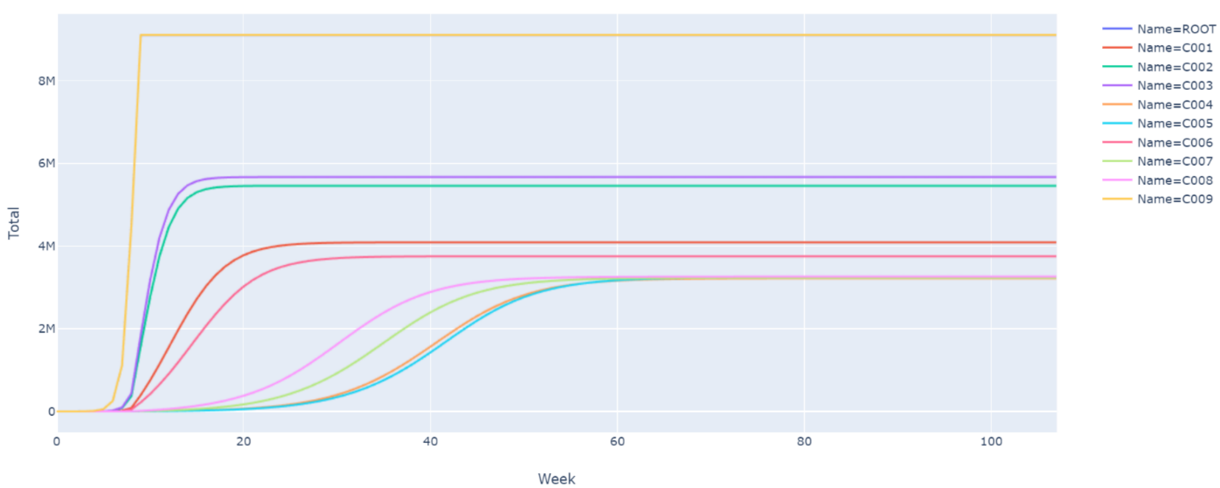
Here we use the same optimistic assumptions as for a single outbreak, and assume a global travel quarantine is imposed. What you see is that the original infection center has a pretty bad experience, but others are progressively better. The effect looks like waves, but the later waves are rather mild compared to the first one. You can also see that it goes on a long time, maybe a year or more at a low level. This is, however, quite optimistic; we may already have infected all the big population centers by air travel.

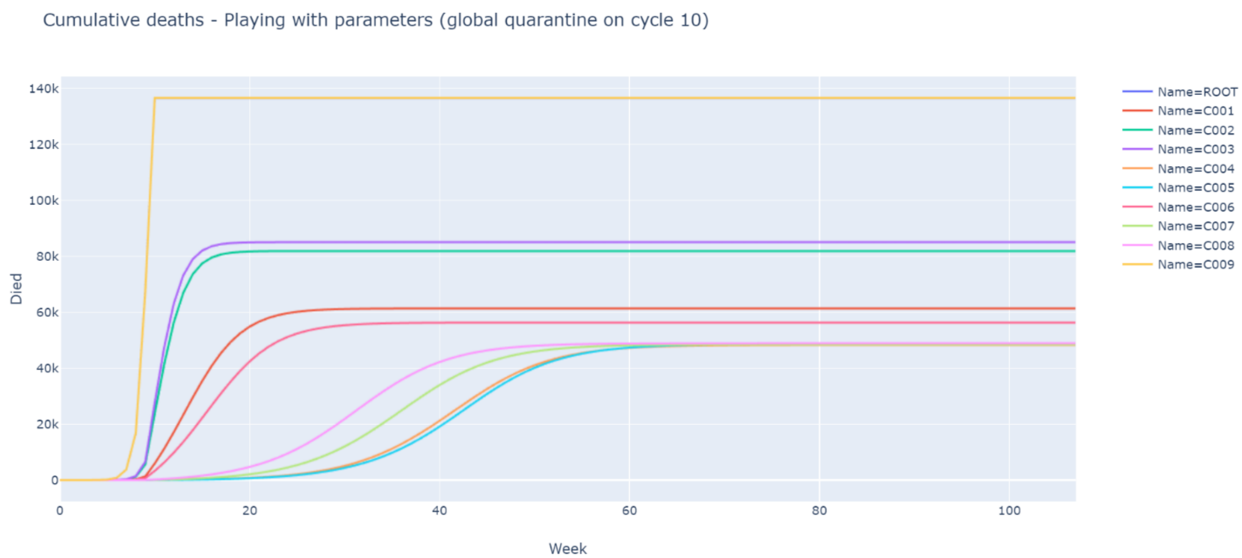
```
Playing with parameters
  10 million population
  Infection cycle time 1 weeks
  Naive mean spread rate R0 is 2.50 new infections per infected individual
  Standard deviation of the generated log-normal R0 distribution ~ 2.36
  Standard deviation of the underlying Gaussian distribution is 0.80
  Death rate 1.50%
  Extinguishing event will begin on cycle 10
  Spread rate 1.20 after extinguishing event
  Herd immunity effect included
Global travel quarantine will be imposed at cycle 10
```

Active infections - Playing with parameters (global quarantine on cycle 10)



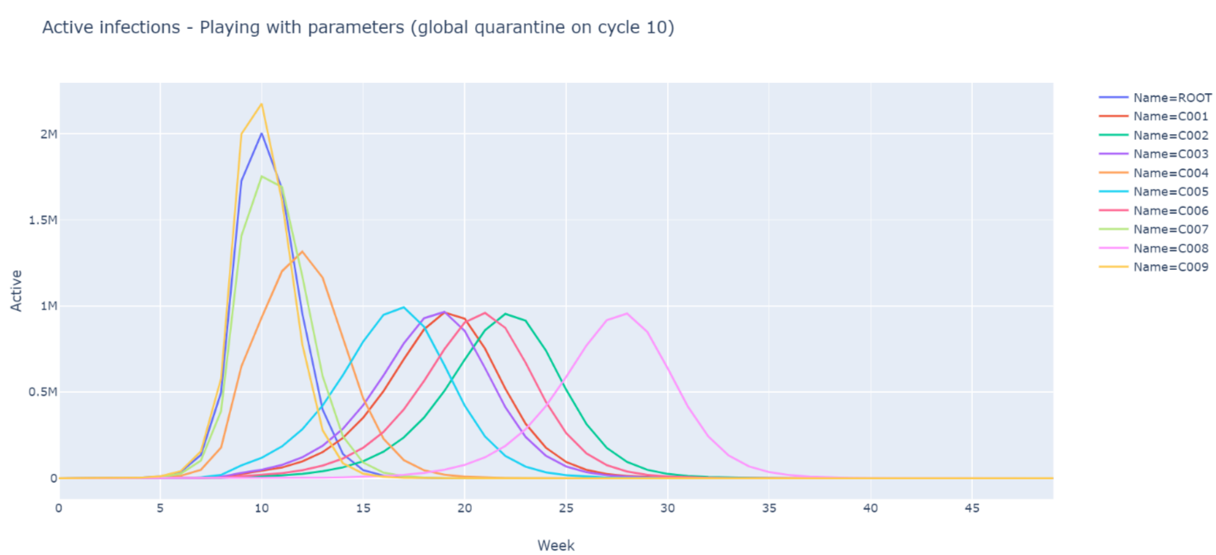
Cumulative infections - Playing with parameters (global quarantine on cycle 10)

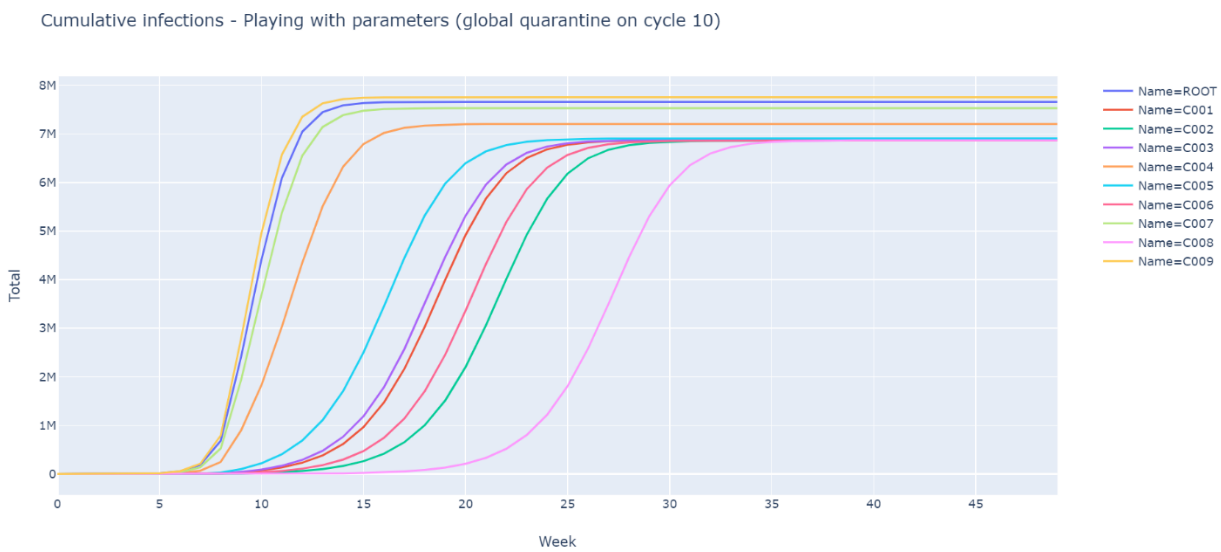


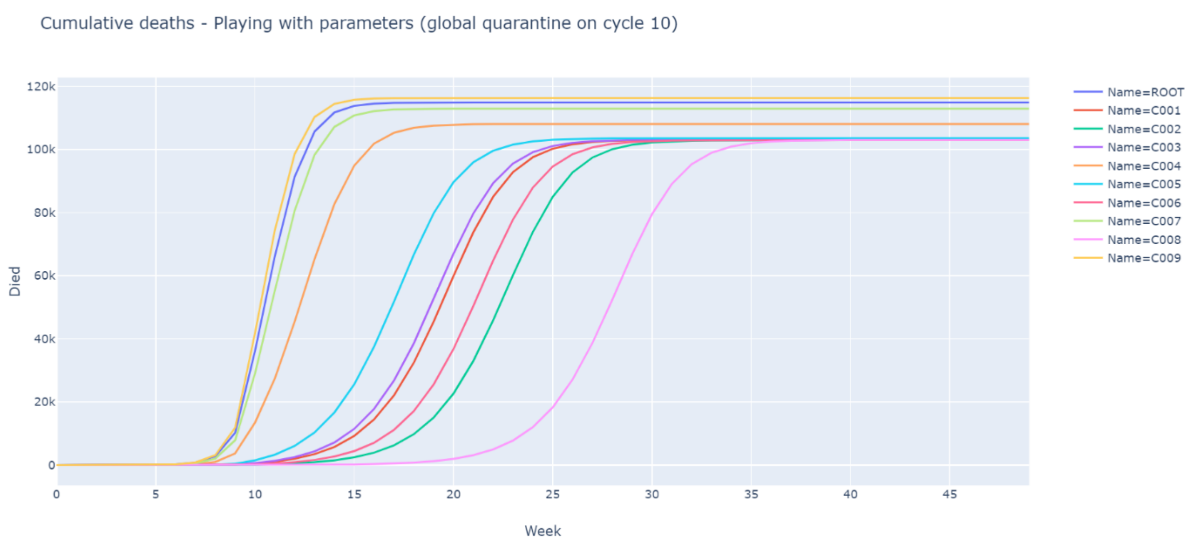


Pessimistic pandemic model

If we treat the country as a pandemic and impose a widespread travel quarantine at cycle 10, and assume that some population centers are protected and get infected later, the outcome *might* look something like this. But it's very stochastic, you might want to think of this more as an illustrated possibility, because travel has probably already infected most of our big population centers. What you see here is multiple population centers, some of which managed to clamp down before the infection had really spread very much. Those centers which become infected *after* social distancing and travel quarantine is imposed have better outcomes.







Observations

These models reinforce two messages that the CDC has been emphasizing: act early, and be stringent. It's not possible to try too hard, and seemingly small differences can produce huge changes in outcome; for example, between 40% vs. 75% of the population becoming infected.

Maybe in the end almost everyone will become infected, but stringent efforts can save a lot of lives, avoid hospital overload, and give time for treatments to be developed and applied. We all have to try hard; every opportunity to reduce transmission is precious. We can't afford blunders like the airport fiascos of this past weekend, which were recipes for sending the disease to every population center in the United States.