



# Modeling 2019-nCoV

Mapping 2019-nCoV

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Lancet Article

PUBLIC HEALTH

## Modeling the Spread of 2019-nCoV

By Lauren Gardner, January 26, 2020

### Collaborators

This work is being led by Lauren Gardner at Johns Hopkins University [CSSE](#), in collaboration with Aleksa Zlojutro and David Rey at [rCITI](#) at UNSW Sydney, and Ensheng Dong at JHU [CSSE](#). At JHU, we have previously developed an [interactive dashboard](#) mapping the outbreak in real-time, and a written [blog](#).

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## Model Implementation

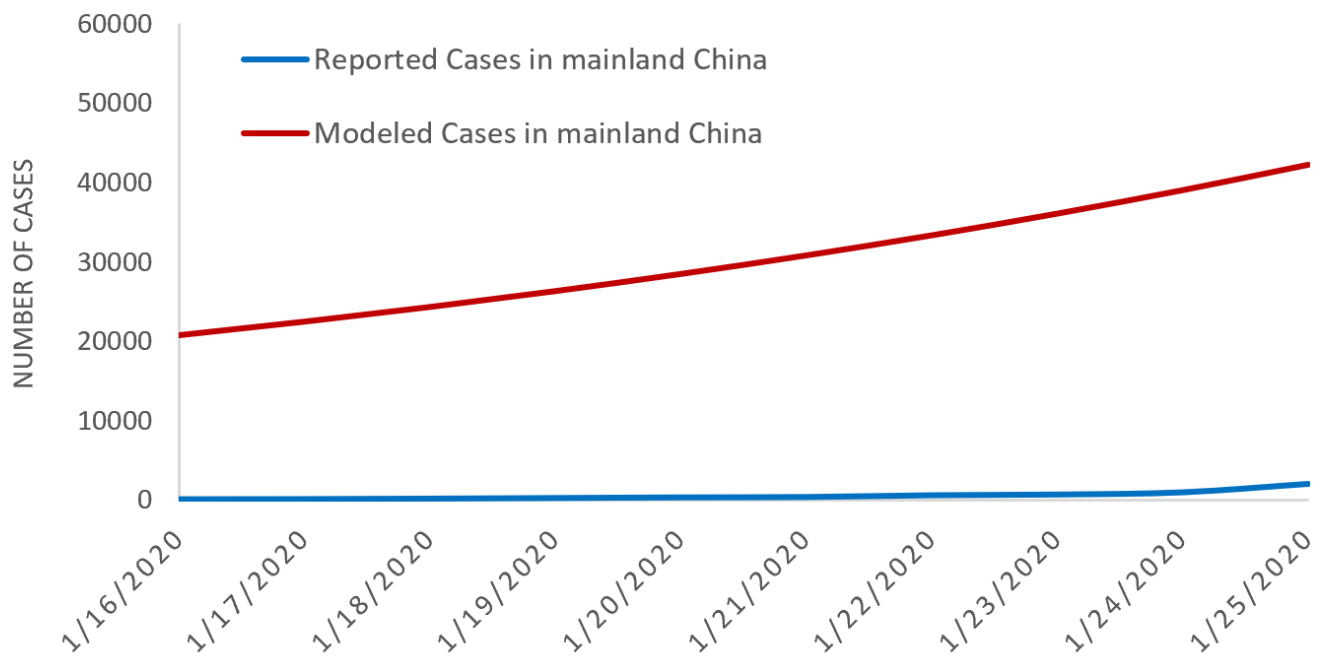
We implemented a [previously published](#) model that integrates both outbreak dynamics and outbreak control into a decision-support tool for mitigating infectious disease pandemics at the onset of an outbreak through border control to evaluate the 2019-nCoV epidemic. A stochastic metapopulation epidemic simulation tool is used to simulate global outbreak dynamics, and the border control mechanism considered is passenger screening upon arrival at airports (entry screening), which is used to identify infected or at-risk individuals. More detail on the model is available in the [supplementary file](#).

Our metapopulation model is based on a global network of local, city-level, populations connected by edges representing passenger air travel between cities. At each node of the network, we locally model outbreak dynamics using a discrete-time Susceptible-Exposed-Infected-Recovered (SEIR) compartmental model. IATA monthly passenger travel volumes for all travel routes connecting airport pairs (including stopovers) is used to construct the weighted edges. The SEIR parameters are defined based on a 10 day period from exposure to recovery, aligning with a previously published [report](#), divided into a 5 day latent period and 5 day recovery period. The effective contact rate corresponds to a reproductive number of 2, which aligns with an estimate from [Imperial College](#) London, reporting a range between 1.5 and 3.5. We assume initial cases of 2019-nCoV are only present in Wuhan, and no border control is accounted for. The model results presented are based on an average of 250 runs.

## Results

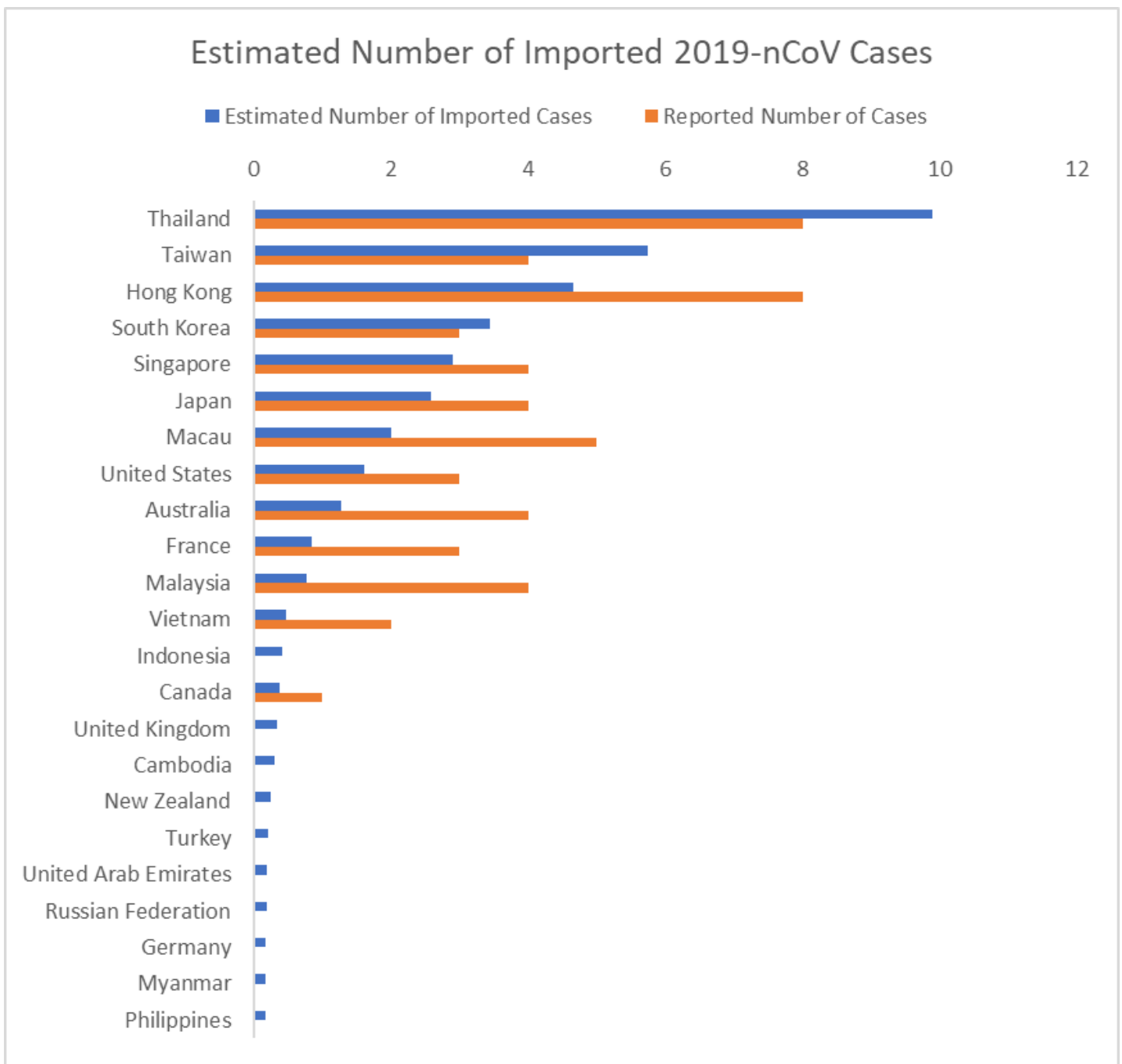
The simulation model is run for a time period between the start of the outbreak, up until January 25. We then estimate the expected number of cases in mainland China, as well as the global distribution of the infected travelers.

We estimate 40 cases of 2019-nCoV to have been exported outside of mainland China by January 25, as was reported, at which point we believe the number of 2019-nCoV cases in mainland China are likely much higher than that reported throughout January. Specifically, we estimate there to be around 20,000 cases of 2019-nCoV in mainland China on January 25 (at which time closer to 2000 were reported). We also estimate there were already hundreds of human cases of 2019-nCoV in Wuhan in early December. The estimated versus confirmed cases during January are presented in Figure 1. Our estimates are slightly higher than those from two other modeling exercises, namely, a report out of [Imperial College](#) estimated 4000 cases in mainland China on January 18, and a report out of [Northeastern University](#) estimated 12,700 on January 24. However, there was a substantial and rapid increase in reported cases outside of China during these dates, which is still occurring, and likely to lead to higher estimates than those in this study.



**Figure 1. Estimated vs. Reported Cases of 2019 n-CoV cases globally.**

The simulation provides the expected number of imported cases arriving at each airport globally (based on final travel destinations of travelers) as of Jan 25. By aggregating this over all airports in a country we can estimate the total number of imported cases in each country. Figure 2 below illustrates our estimated number of imported cases arriving in each country compared with the number of 2019-nCoV reported cases as of January 26. The results align with the number of air travel reported cases outside of mainland China early in the outbreak. Specifically, the 12 countries/regions we identify at highest risk have all reported at least one case.



**Figure 2. List of Countries/Regions with highest risk of imported 2019-nCoV cases.**

We further present the results at the airport level (based on their final travel destination), to identify the set of cities inside and outside China at highest risk of case importation. The top 50 airports in China and outside of China are illustrated in Figure 3 and 4 below, respectively, and listed in Table 1 and 2 in the [supplementary file](#). The cities at highest risk are generally those in China that receive high direct or indirect travel from WUH. While many of the cities outside China that we identify at high risk have already reported cases, these cities should be prepared for additional cases to be reported over the coming days, likely in travelers whom departed Wuhan before the travel ban was implemented on January 23. In the U.S., our high risk airports have already been designated for screening by the CDC, namely LAX, JFK, SFO, ATL and ORD. By considering complete travel paths (with stopover airports), we identify additional airports that are at risk of exposure to infected travelers, and

suggest the international airports in Seattle, Washington-Dulles, Newark, Detroit, Boston, Houston, Las Vegas, Dallas Fort Worth and Honolulu in the U.S., also be considered for enhanced screening and security.



Figure 3. Map of the 50 Highest risk airports for 2019-nCoV arriving travelers within mainland China.





**Figure 4. Map of the 50 Highest risk airports for 2019-nCoV arriving travelers outside mainland China.**

## Limitations

There are multiple modeling assumptions and limitations that should be noted regarding the results presented.

- In the day after this analysis was completed, travel reported cases increased by 40%, from 40 to 56. Therefore, it is likely the estimated number of cases reported in this study are a lower bound.
- There is still uncertainty about the transmission of 2019-nCoV, specifically surrounding the reproductive number and incubation period. The parameters chosen in this analysis fall in the uncertainty intervals provided to date. However, the substantial increase in cases being reported in late January indicate the parameters we used are too conservative, and the incubation period may be longer than we specified here, thus we are underestimating risk. More data will help us finer tune our estimates.
- Asymptomatic infections are not considered. If asymptomatic infections prove capable of spreading the virus, then these results would be further underestimating risk.
- The model only accounts for passenger air travel, and excludes mobility within and between cities via other modes of transport. Therefore, the spreading risk between regions connected via alternatives modes of travel is underestimated. This is most applicable to spread within China, which we are underestimating.
- The SEIR parameters used to model the outbreak within each city are deterministic. However, the spread of infected travelers moving between cities is modeled stochastically.
- Arrival passenger screening at airports and the complete air travel ban implemented in Wuhan on January 23 are not accounted for in this analysis. However, it is unlikely these policies impact the results presented, which are based on the start of the outbreak until January 25.
- No local control mechanisms (prophylactics, vaccines, school closures, quarantine efforts) within cities are accounted for. Thus, the reproductive number is assumed to be constant over time, and across all locations.
- We are using 2015 Travel data, because that is the most recent complete (airport-to-airport) data we had available in the lab.

## Next Stages

The next stage of our modeling exercise will be forward looking, with two main points of focus. First, will be the identification of those travel routes likely to continue spreading 2019-nCoV cases around the world, assuming travelers are no longer departing Wuhan directly, and outbreaks are ongoing in multiple other cities in China.

Second, we will identify the set of airports globally that should be prioritized for passenger screening.

## Reference:

1. Zlojutro, A, Rey, D and L Gardner\*. (2019) "Optimizing border control policies for global outbreak mitigation". *Scientific Reports* 9:2216. DOI <https://doi.org/10.1038/s41598-019-38665-w> (Open Source link) <https://rdcu.be/bniOs>



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