County-level SARS-Cov-2/COVID-19 modelling to support local outbreak response and hospital surge planning

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Results as of April 24, 2020

When a novel infectious disease appears, policy-makers, public health officials, health care providers and businesses require information to guide decisions for reducing the impact of the disease. During a pandemic, these decisions will need to be made real-time under rapidly changing, uncertain conditions, with limited data and (if any) prior experience. Modeling is a well-established approach to use what we know about a disease now to predict what would happen over the future course of a pandemic and how our actions may affect that course. However, most currently used models address epidemic dynamics at the higher aggregate levels of the state or nation. Health officials, by contrast, also require information on how the epidemic is progressing at local administrative levels, such as the county, to help with outbreak and hospital surge planning.

How we created our COVID-19 model

We extended the standard SEIR model based on current understanding of the population processes involved in SARS-CoV-2 transmission and the social interventions proposed for curbing the epidemic in communities (https://covid.crc.nd.edu/methodology.html) as the basis for our COVID-19 model. The model uniquely uses daily updated data on confirmed cases of COVID-19 reported at the county level and information on lockdowns and either implemented or proposed restrictions in human movements and mixing in order to forecast how the epidemic will play out in a given local region. We use iterative data assimilation and continuous integration methods to carry out the model updating automatically so that the most up-to-date informed model that accounts for daily changing transmission conditions at the local county level is obtained for making forecasts. The model is also designed to use hospital capacity data to provide predictions for helping with surge planning by regional hospital systems.

What the model predicts

The model estimates, along with uncertainty measures, the number of daily COVID-19 cases, how many people require hospitalization and ICU care, and how many people will die during the course of the pandemic. It predicts:

- When most people will get COVID-19 (date of the peak of the outbreak)
- How many people that will be
- When will new cases decline

- When more beds, ICU care, and ventilators will be needed.
- How will easing of present lockdowns play out
- What types of social interventions and their intensity are needed to manage easing of lockdowns such that resurgence of infections are minimized

Figures 1 a and b illustrate the fits of our model to cumulative confirmed cases and deaths due to COVID-19 in Tampa. These fits show that the model is able to predict both reported cases and deaths well.

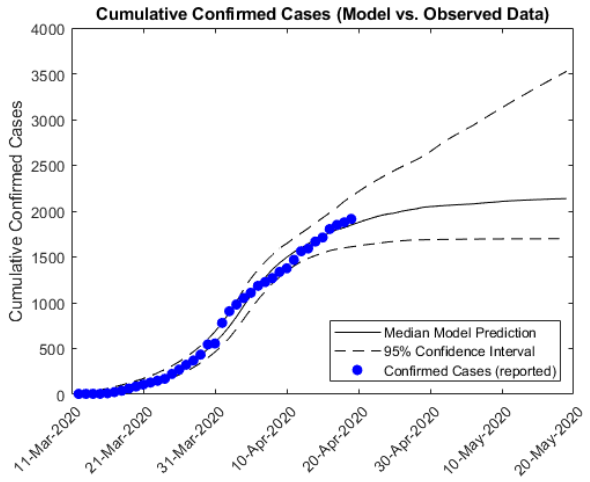


Fig 1a

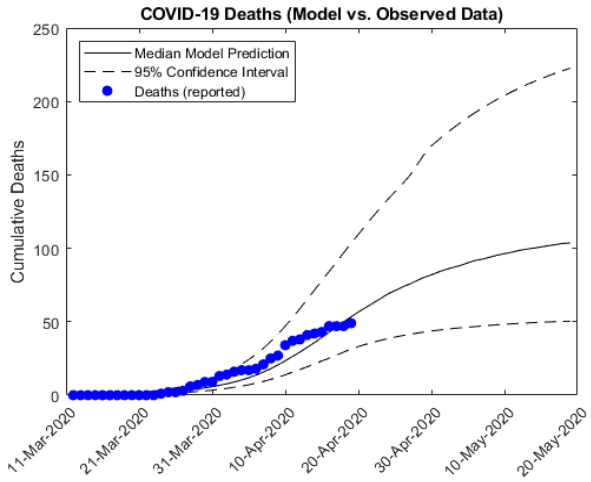


Fig 1b

Figure 2 shows forecasts made by the model fitted to data in Fig 1 for changes in daily confirmed COVID-19 cases. These forecasts take account of the estimated effects of the lockdown implemented in Tampa, and show that at its peak which occurred before April 10th the peak daily cases predicted for the epidemic that has occurred thus far in Tampa ranged between 635 to 690 cases.

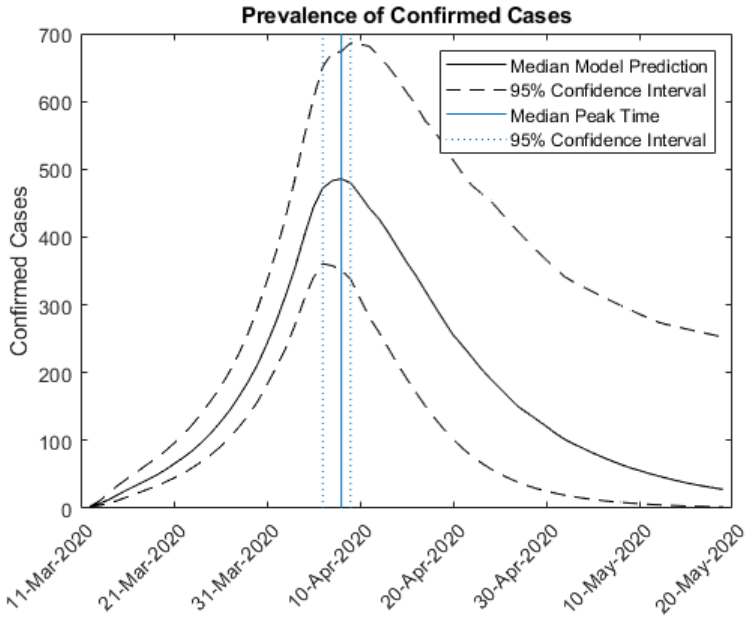


Fig 2

Figure 3 shows predictions of changes in new cases over the first outbreak, and illustrates that the number of new cases increased to about 118 per day at the peak of the epidemic around 3-4 of April after which time a steady decline in new cases is predicted until the epidemic fades out.

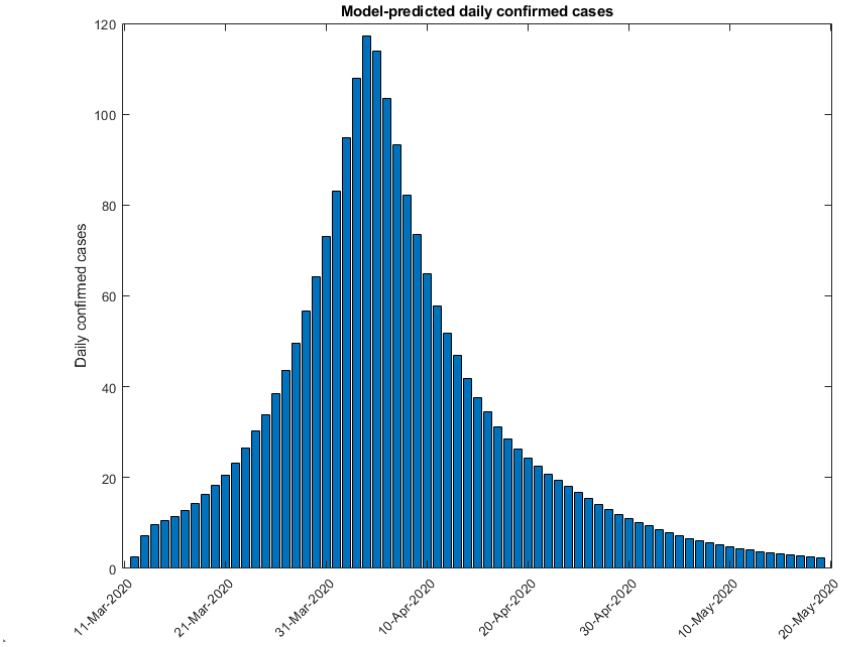
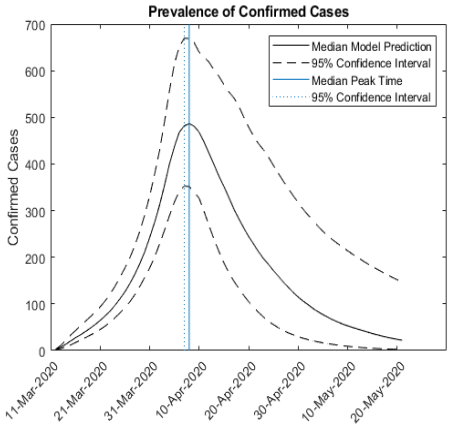
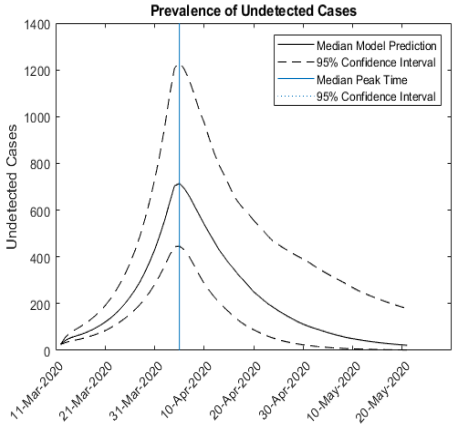


Fig 3

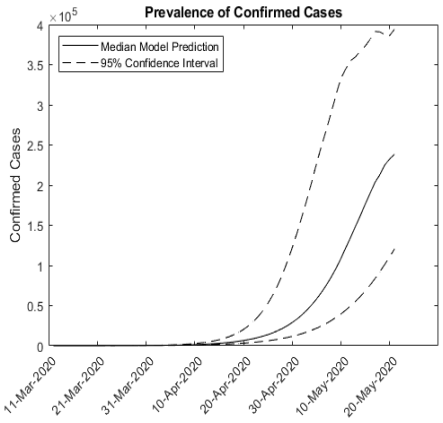
Figure 4 compares the 1st wave epidemic size in Tampa with and without the imposed lockdown. The results demonstrate that Florida's lockdown drastically managed to suppress the size of the 1st wave compared to what it would have been without the lockdown.

Epidemic size with lockdown (100s)





Epidemic size without lockdown (100,000s)



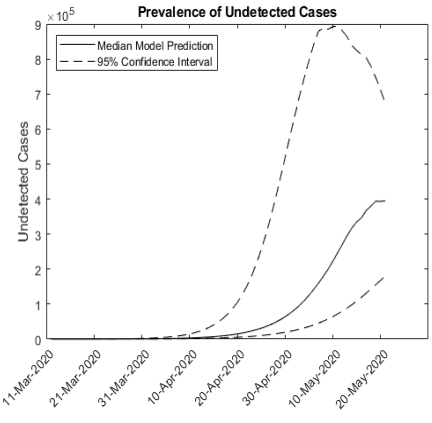
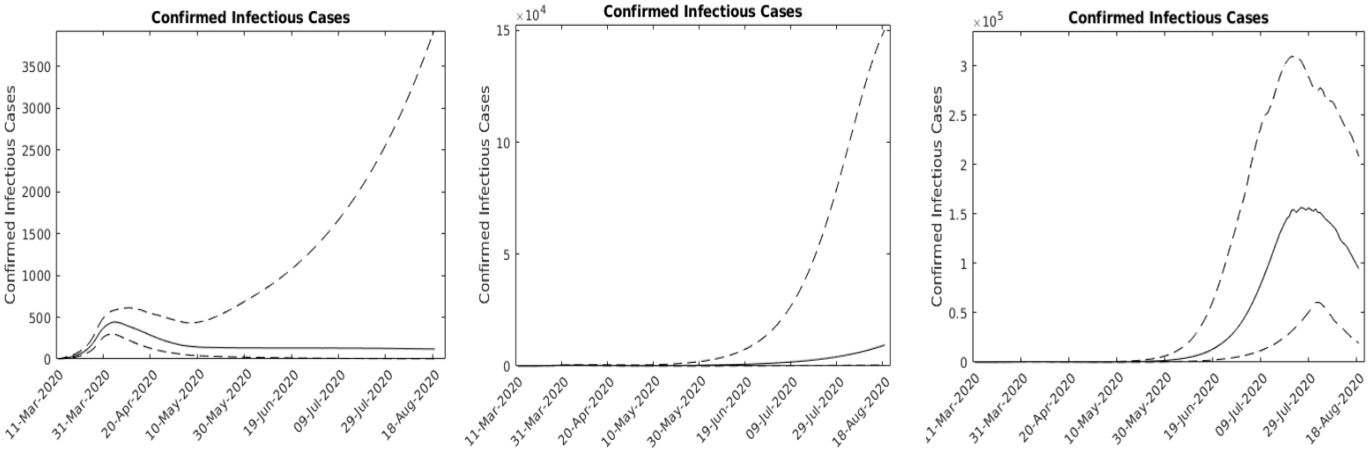


Fig 4

Figure 5 predicts the impact of releasing the lockdown imposed on March 27 from May 4. The simulations in each figure depict the number of confirmed cases that may be expected if the earlier lockdown is released by just 10%, 25% to 50% without any continued social measures. Note that higher releases will lead to an explosive and earlier resurgence of infectious cases that would overwhelm the current hospital capacity in Tampa.



10% Release on May 4th

25% Release on May 4th

50% Release on May 4th

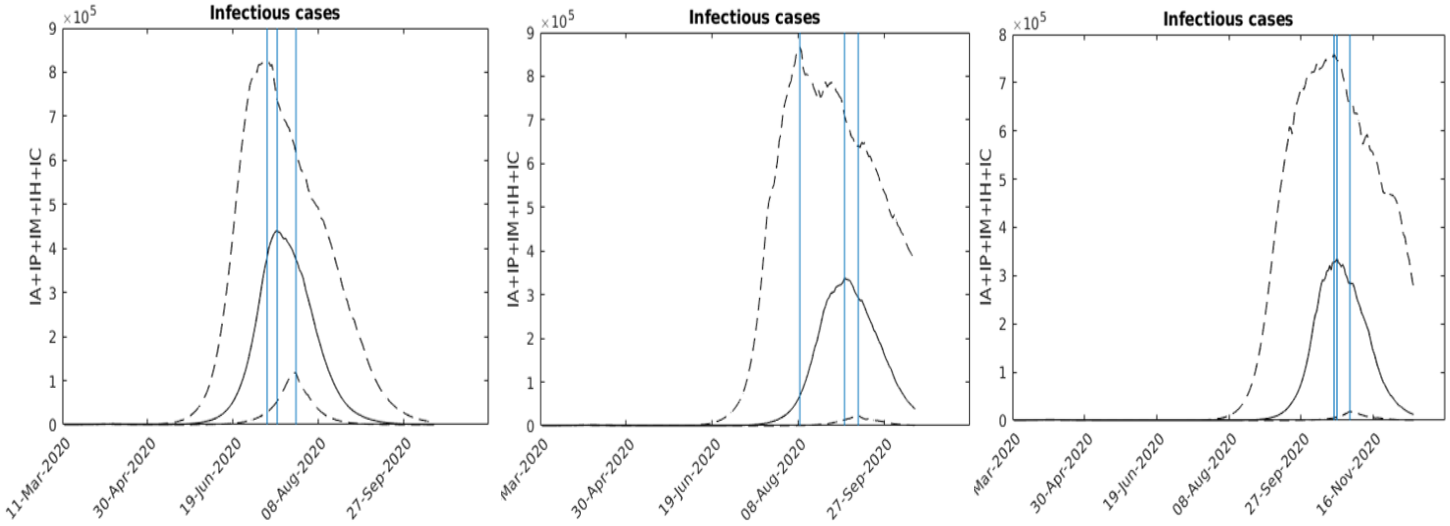
Fig 5

Figure 6. Releasing the lockdown later (to June and July 1st for example) will still lead to 2nd waves without further social mitigation measures in place because sizeable infected cases are still available to seed a new epidemic (Figs. 2 and 4). However, a lag period of 2-3 weeks exists between full release of lockdowns and a second surge, which provides a window for strong tracing, testing, and isolation of the few infected cases remaining to arrest the 2nd wave. Releasing later will shift the peak of the 2nd wave to occur later in the year; it will have only a moderate impact on the number of infectious cases predicted to occur at 2nd wave peak, which will overwhelm current hospital resources (Fig. 7).

May 1st release

June 1st release

July 1st release



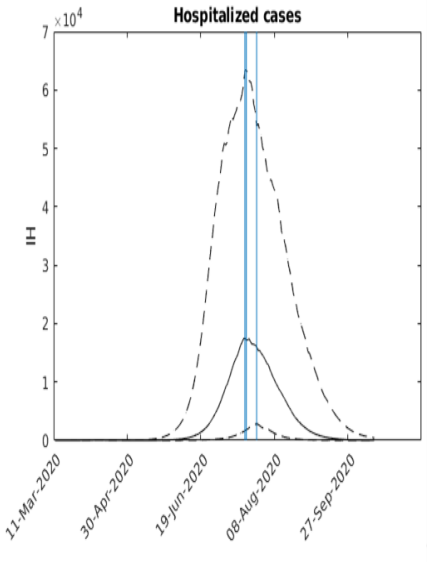
439,600 cases On July 16th

338,000 cases On Sept 5th

335,000 cases On Oct 22th

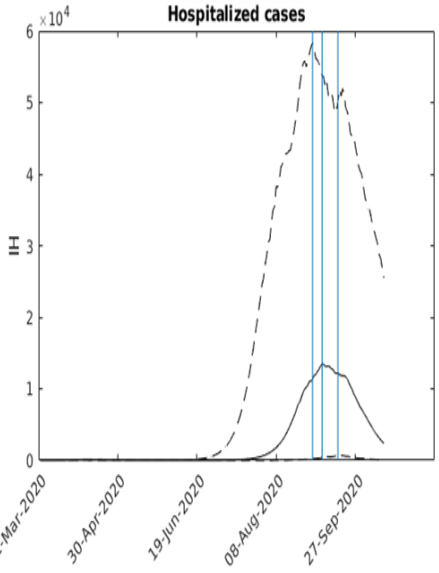
Fig 6

May 1st release



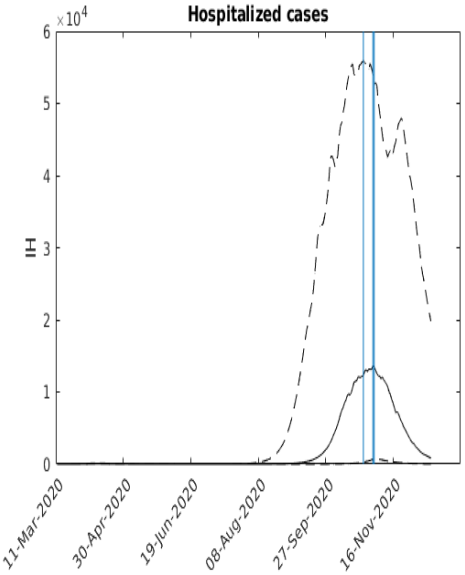
17,490 cases
On July 19th

June 1st release



13,450 cases
On Sept. 6th

July 1st release



13,640 cases
On Nov. 1th

Fig 7

Findings thus far

- The lockdown in Tampa which was instituted on March 27th has dramatically suppressed the pandemic
- Peak epidemic date is predicted to have occurred but endpoint of the 1st outbreak will occur only by end of June if current lockdown is continued
- New cases will begin to decline from April 4.
- Releasing lockdowns before the 1st outbreak ends will lead to significantly bigger 2nd waves if mitigation measures, such as social distancing/face coverings and screening and isolating currently undetected cases, are not practiced especially when the release is high.
- Later releases without mitigation measures will still lead to large 2nd waves although this will occur later in the year. There may be a window of 2-3 weeks after release to resurgence of 2nd wave cases to ramp up testing, tracing and quarantine capacity for arresting 2nd waves.
- Such 2nd waves can overwhelm hospital resources if not suppressed by social measures.

Importance of the model

Our automated data-driven model allows the capture of local transmission conditions and their change on the course of the SARS-CoV-2 epidemic at the county level. The model helps local public health and government officials “try out” different intervention measures (lockdowns, social distancing, quarantines) to understand how they might affect the timing and number of COVID-19 cases and deaths and the demand for hospital beds, ICU care, ventilators and other services at the county level. These predictions will help officials make decisions to best prepare the local health system so that it is not overloaded and will be able to manage these demands.