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HPC for epidemic modeling with limited data: COVID-19 Case Studies

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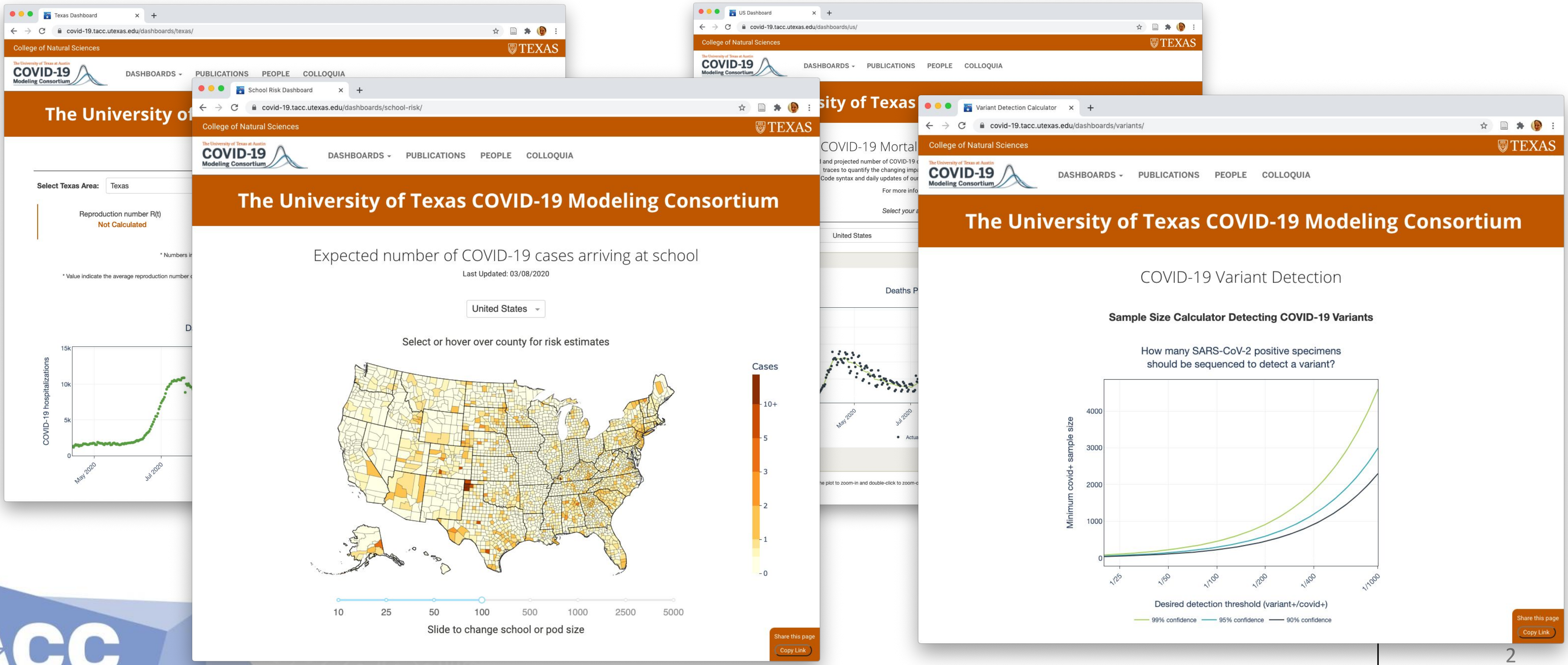
ECSS Symposium | March 16, 2021

The University of Texas at Austin
COVID-19 Modeling Consortium

Situational awareness models

public facing dashboards at https://covid-19.tacc.utexas.edu/



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Conclusions after 1 year of COVID-19

- Small amounts of data can provide crucial insights when used carefully
- Public health data collection, aggregation and dissemination have changed dramatically in the last 12 months (but need more investment)
- HPC and HPC Centers support fast iteration and short turn-around on research and production models

The University of Texas at Austin
COVID-19 Modeling Consortium

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https://covid-19.tacc.utexas.edu/

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Modeling the first wave


Daily COVID-19 Hospitalizations in the Austin-Round Rock MSA
COVID-19 hospitalizations
600
400
200
0
Mar 2020
May 2020
Sep 2020
Nov 2020
Jan 2021
“lockdowns” begin in Austin, TX

Modeling the first wave: model life cycle

define question

collect data

select model

implement model

analyze results

critique, validate

communicate

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Dr. Anne Marie Darling @amdar1ing · Mar 11, 2020 ···

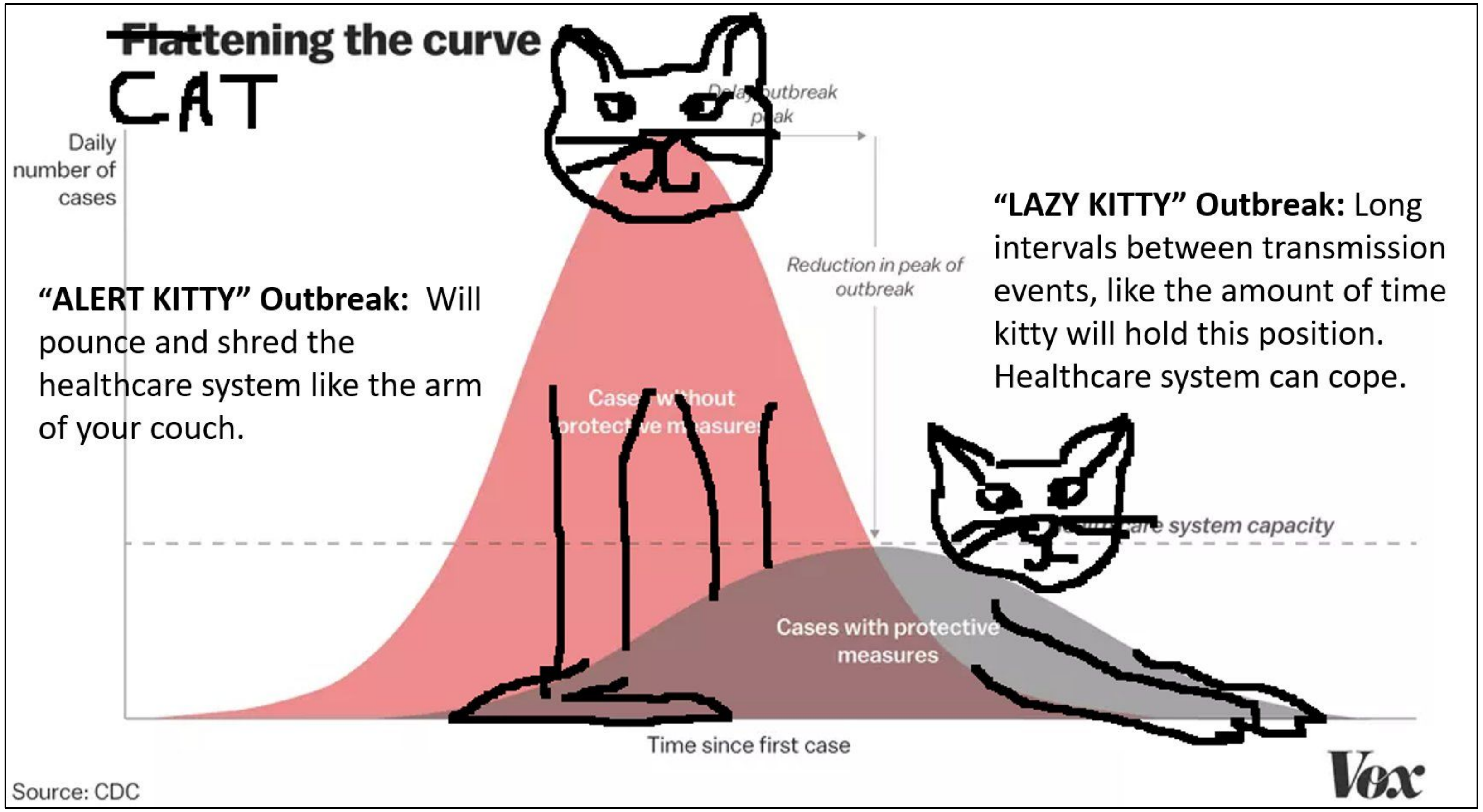
Lots of science-y folks are posting this graph. But if there is one thing I have learned from being on the internet, it is this:

Data/graphs: Not compelling to many.

Kitties: Compelling to many.

So I present: #Catteningthecurve.

#scicomm #epitwitter

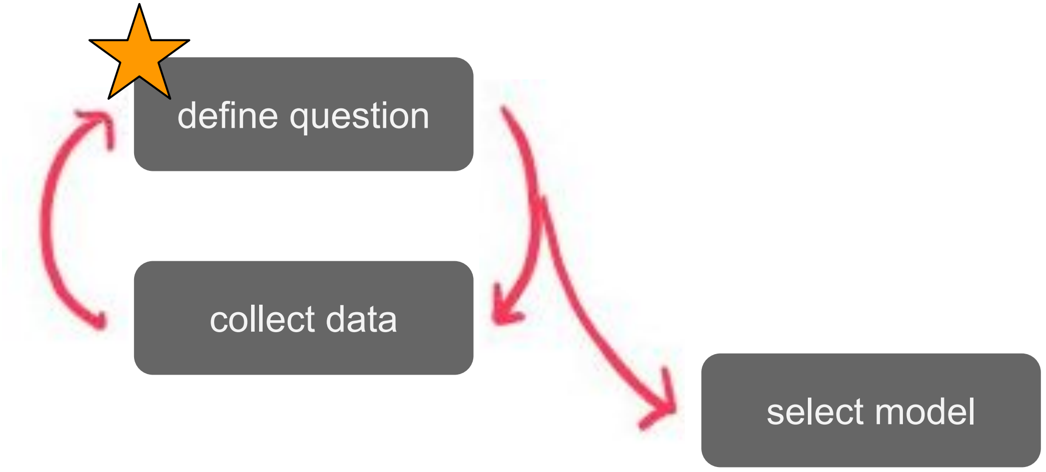


"ALERT KITTY" Outbreak: Will pounce and shred the healthcare system like the arm of your couch.

"LAZY KITTY" Outbreak: Long intervals between transmission events, like the amount of time kitty will hold this position. Healthcare system can cope.

Are we flat yet? (How bad will this get?)

Healthcare demand projections



Many groups with shared goal:

IHME
Measuring what matters

Imperial College COVID-19 Response Team

JOHNS HOPKINS UNIVERSITY & MEDICINE | CORONAVIRUS RESOURCE CENTER

Los Alamos NATIONAL LABORATORY

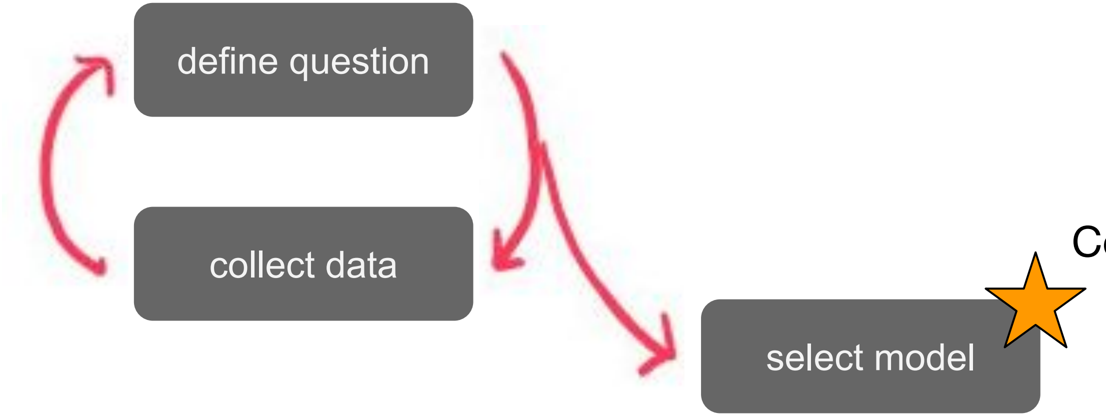
Are we flat yet? (How bad will this get?)
Healthcare demand projections

Rate parameters are informed by observations from clinical literature and define time course of infection.

Age-structured contact patterns are drawn from journal studies and informed by local demographics.

Risk of severe outcome and mortality informed by comorbidities data.

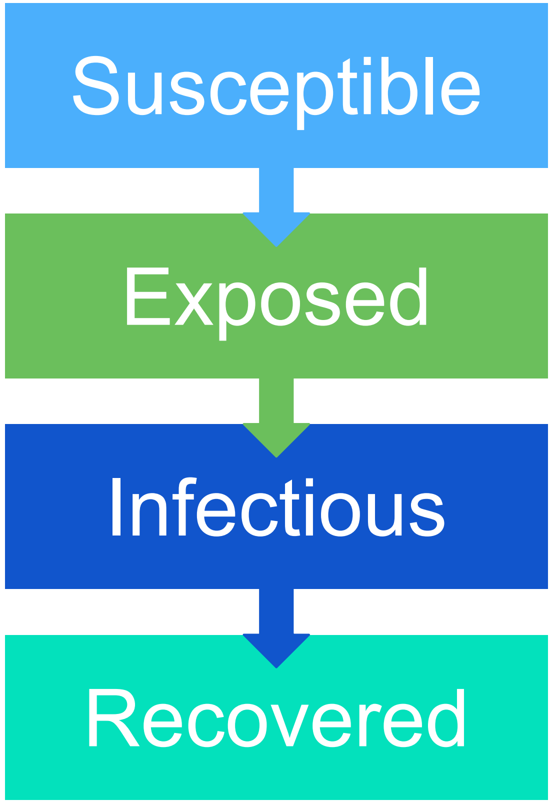
Are we flat yet? (How bad will this get?)
Healthcare demand projections



Compartmental disease transmission model

Compartmental disease transmission models

System of equations to track the population in each compartment through time

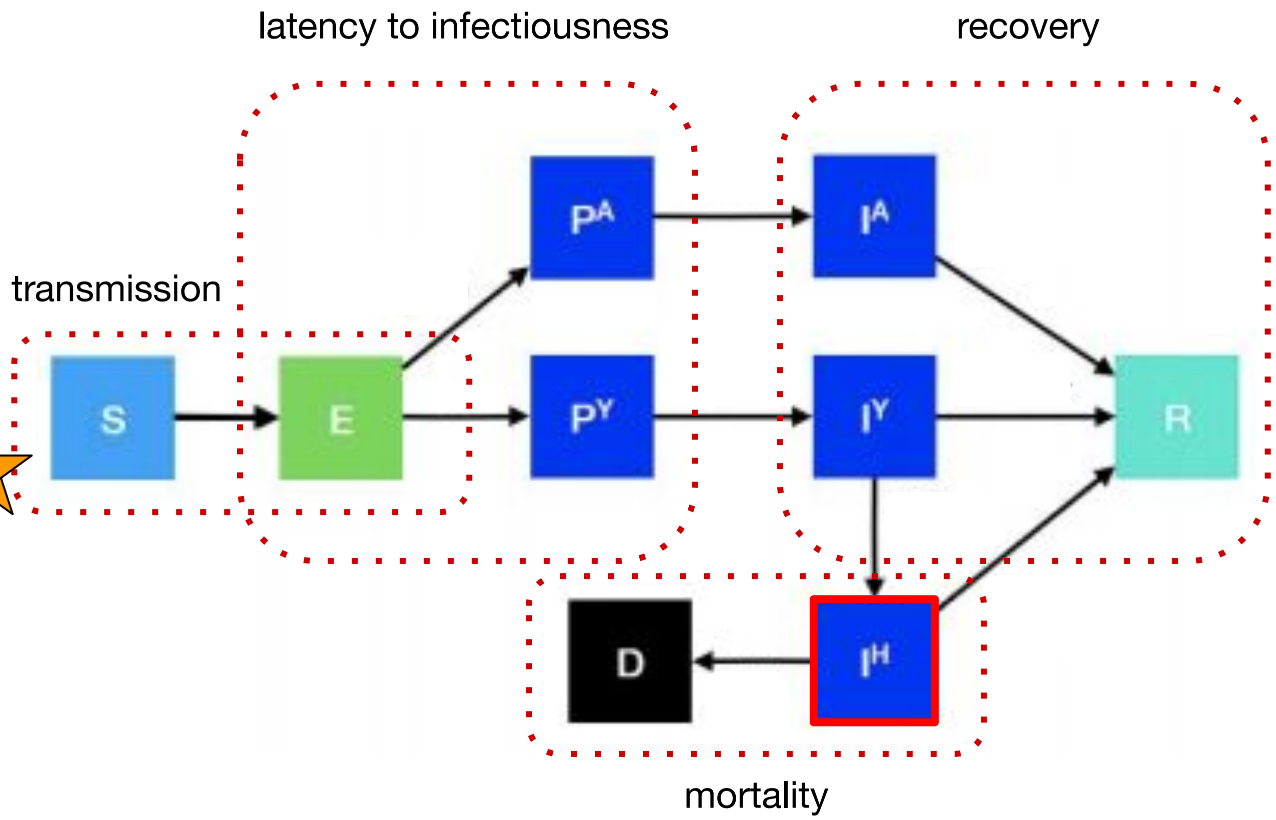


$$\frac{dS}{dt} = \frac{SI}{N}\beta$$

where β is the per capita per contact probability of transmission from an infected person to a susceptible person

Healthcare demand projections

What is the demand for hospital capacity?



Rate parameters (fixed)
- latency
- transmission
- mortality/recovery

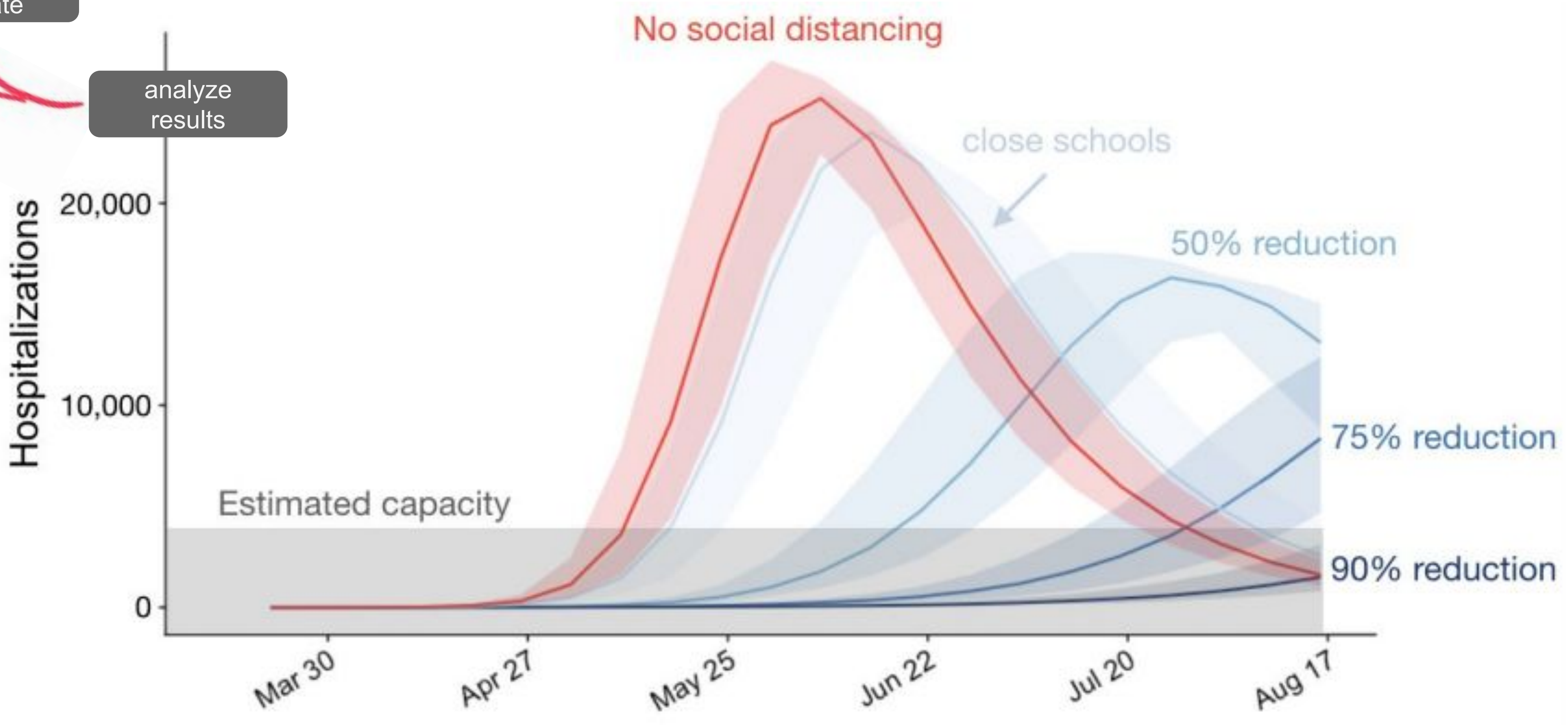
Contact patterns (school, work and home)
Local demography and risk

March 26, 2020 Healthcare demand projections

critique, validate

analyze results

communicate



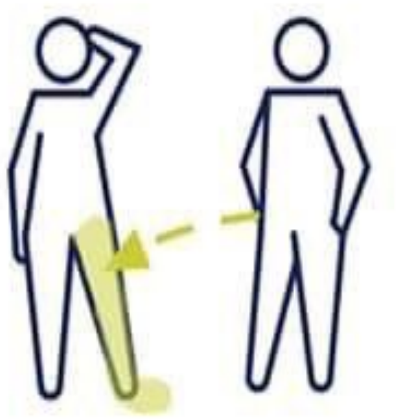
$$\frac{dS}{dt} = \frac{SI}{N}\beta$$

Remy Pasco et al. https://doi.org/10.15781/tmvs-g131

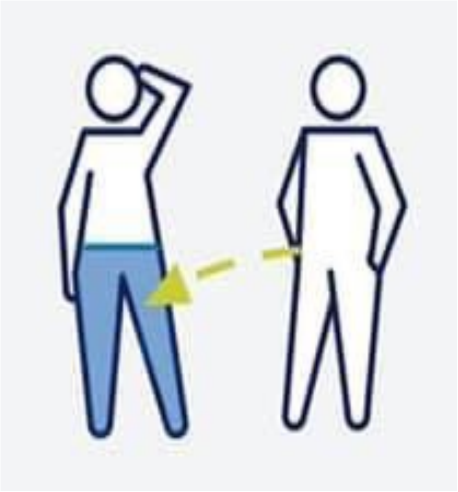
Behavior impacts transmission probability

critique, validate

analyze results



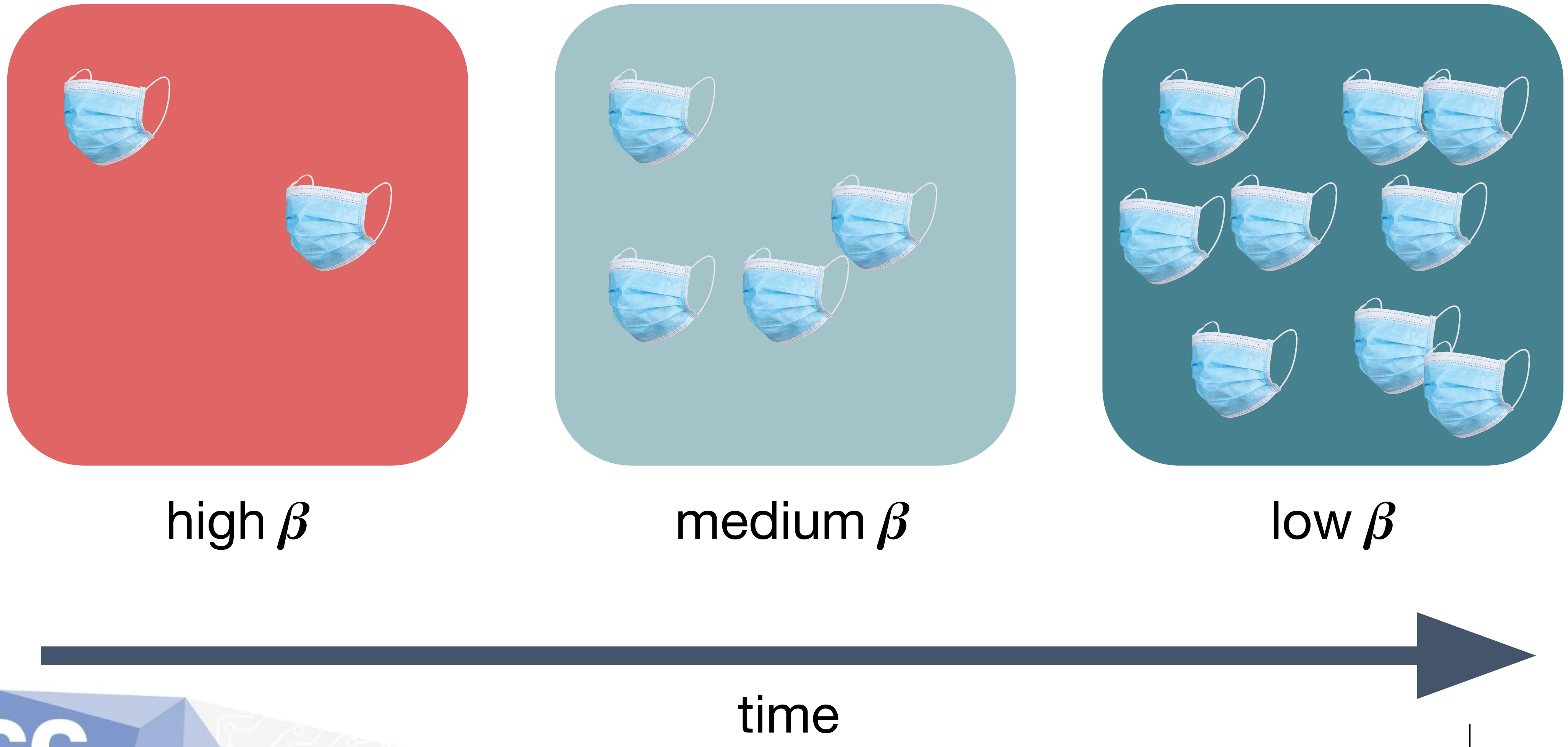
high transmission



medium transmission

low transmission

Behavioral norms (and intervention policies) have evolved over time



Update model and data

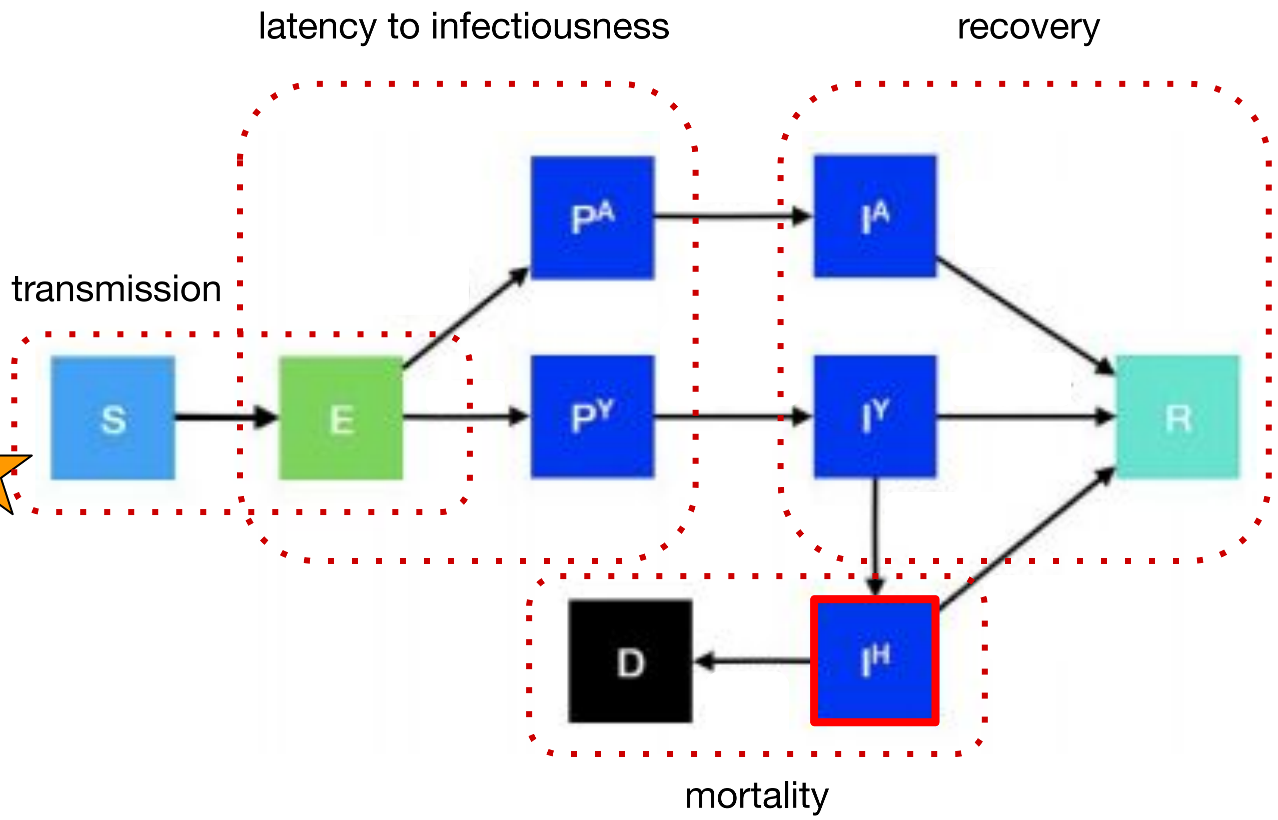
What is the demand for hospital capacity?

Rate parameters (fixed)
- latency
- mortality/recovery

Variable transmission

Contact patterns (school, work and home)

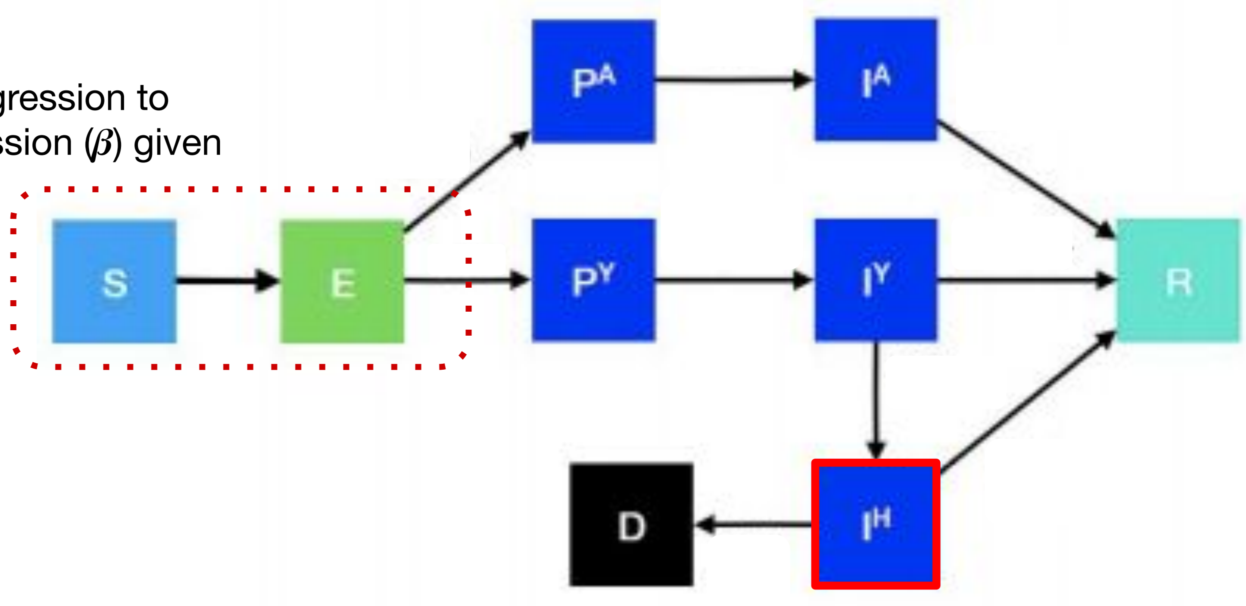
Local demography and risk



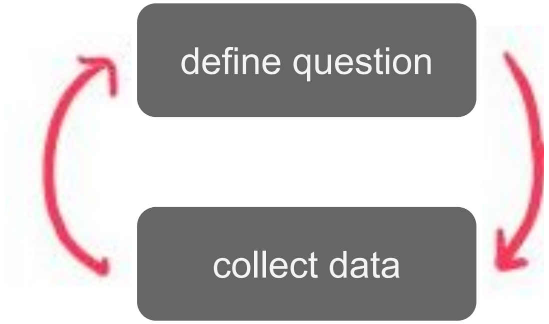
Estimating transmission probability, β

What transmission probability would produce the observed hospitalizations?

Least squares regression to estimate transmission (β) given hospitalizations



Estimating β as a function of available data



Possible Questions (what will happen?)	**Informative Data (what has happened?)**
How many infections do we expect?	How many cases have been reported? ● Are suspected cases being tested? ● Do testing policies bias case reports?
How many hospitalizations do we expect?	How many have been hospitalized with COVID-19?
How many deaths do we expect?	How many deaths have been attributed to COVID-19?

Stepwise transmission probability estimation

1. Estimate baseline transmission probability for a time period with
   - known hospital census (“heads in beds”)
   - no intervention policies
2. Estimate transmission reduction for subsequent time period with
   - known hospital census
   - constant(ish) intervention policy

Hospitalizations as a new, key metric in pandemic surveillance

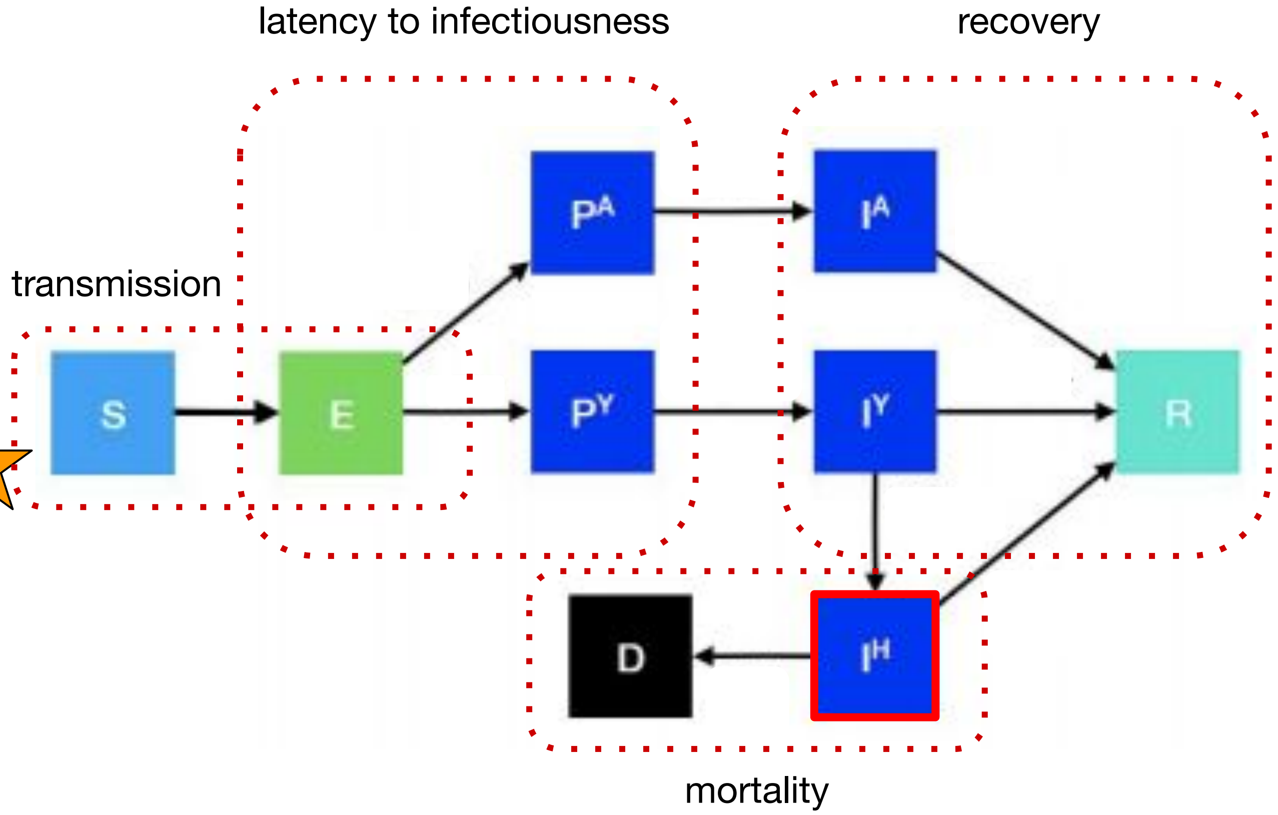
- Reliable but lagged
  - only true COVID-19 cases are reported
  - it takes on approx. 7 days between infection and hospitalization
- Incomplete but actionable
  - many COVID-19 cases do not produce severe infection
  - no standardized reporting infrastructure for hospitalizations
  - hospital demand projections inform resource allocation and planning
- Proxy for **<u>severe</u>** SARS-CoV-2 infection

Update model and data

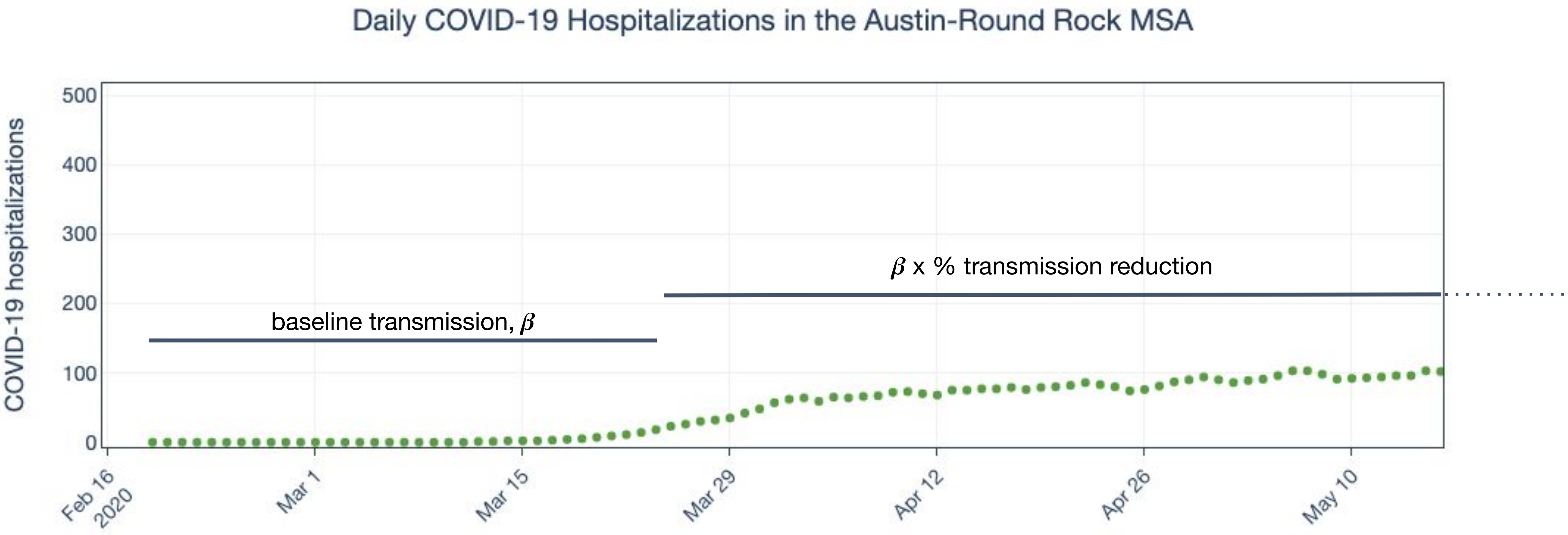
What is the demand for hospital capacity?

Rate parameters (fixed)
- latency
- mortality/recovery

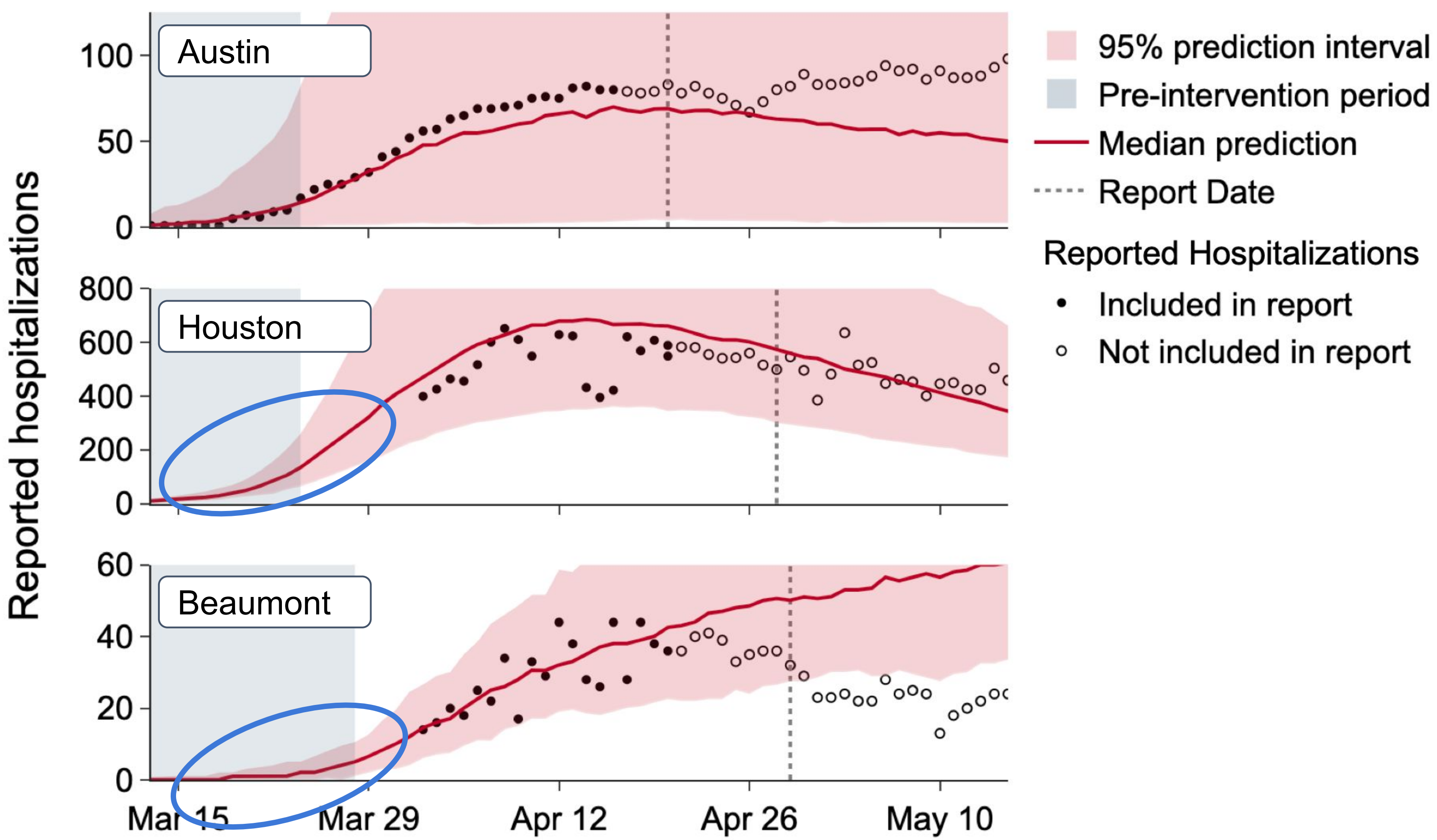
Variable transmission
Contact patterns (school, work and home)
Local demography and risk
Hospital census



Stepwise transmission probability estimation



April 20, 2020 Healthcare demand projections



Kelly Pierce et al.

Impact of HPC on projection turn-around

TABLE 1. Model run types and wall clock times.

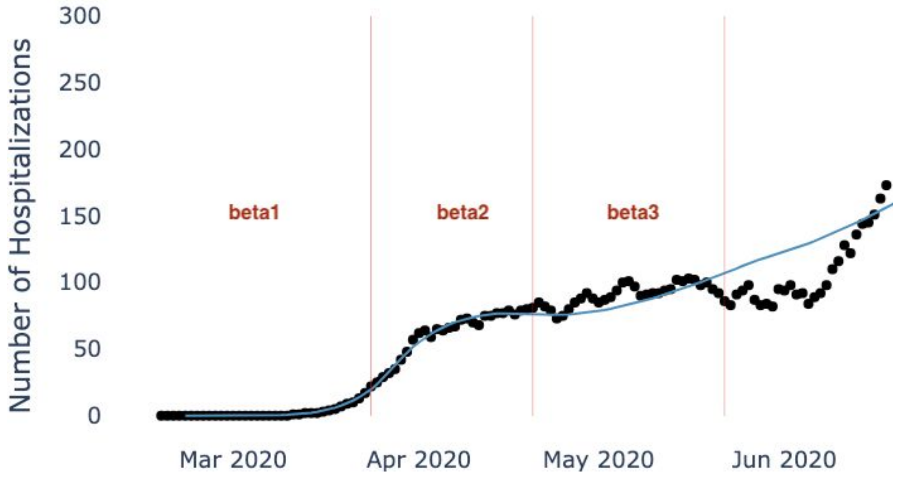
Run type	N runs	Single core wall clock time (s)[a]	Single node wall clock time (s)[b]
Deterministic fitting	30	189	189
Stochastic	2100	6.31	240
Hybrid	4300	12.6	968
Total	6330	208	1397

[a]*Average single core wall clock time on Frontera Intel Xeon Platinum 8280 from 10 benchmark runs.*
[b]*Average wall clock time multiplied by the number of 56 core Intel Xeon Platinum 8280 nodes required for the run volume specified.*

The problem with stepwise transmission

critique, validate

analyze results



https://www.texastribune.org/2020/07/31/coronavirus-timeline-texas/

March 6, 2020 6 confirmed cases
Austin officials cancel SXSW

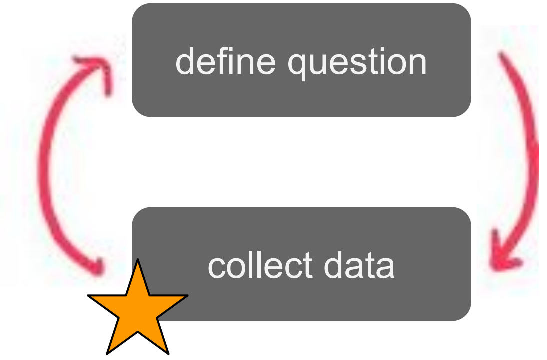
March 13, 2020 50 confirmed cases
Governor declares statewide emergency

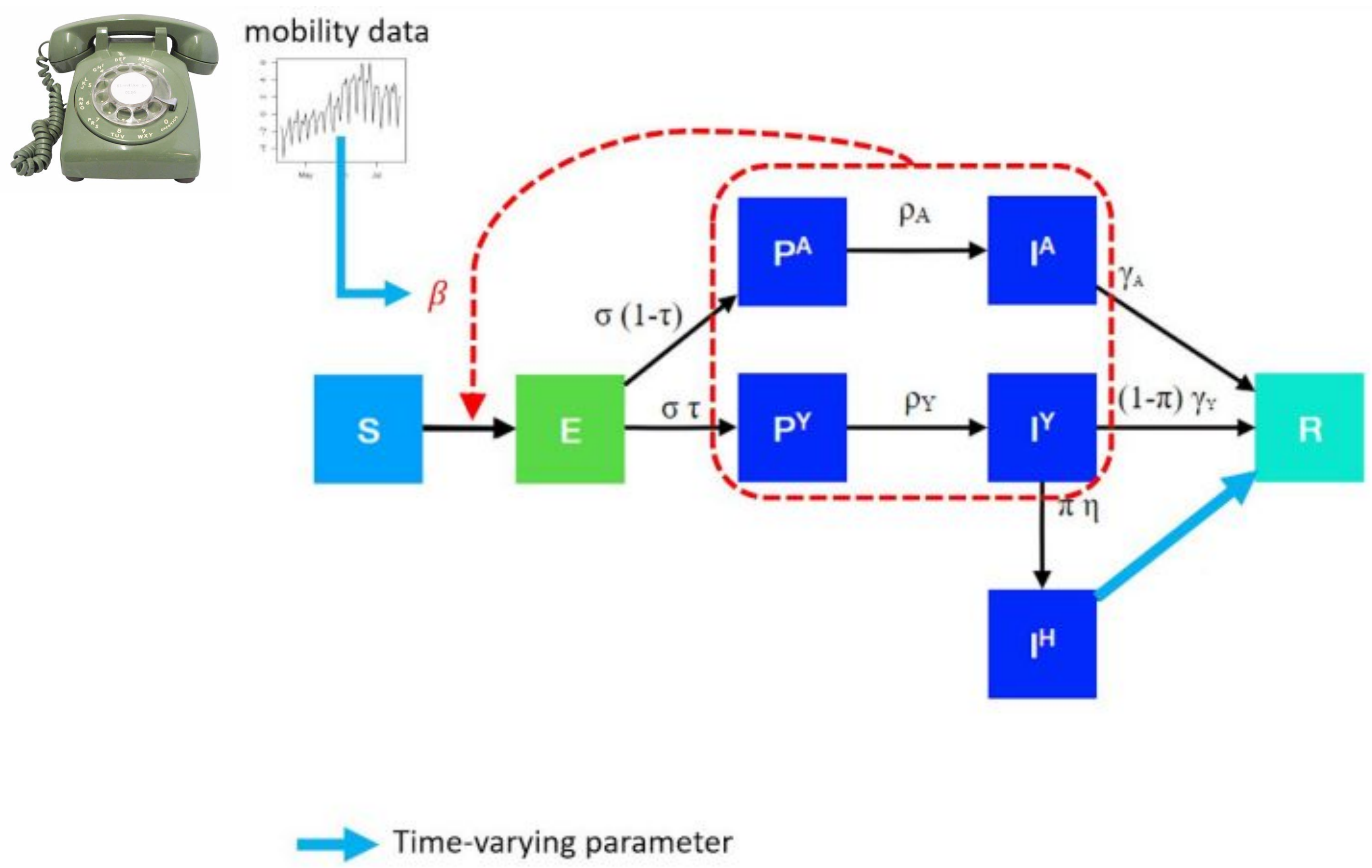
March 31, 2020 3,266 confirmed cases
Governor tells Texans to stay home, closes schools until May 4

April 3, 2020 5,330 confirmed cases
CDC recommends cloth face coverings

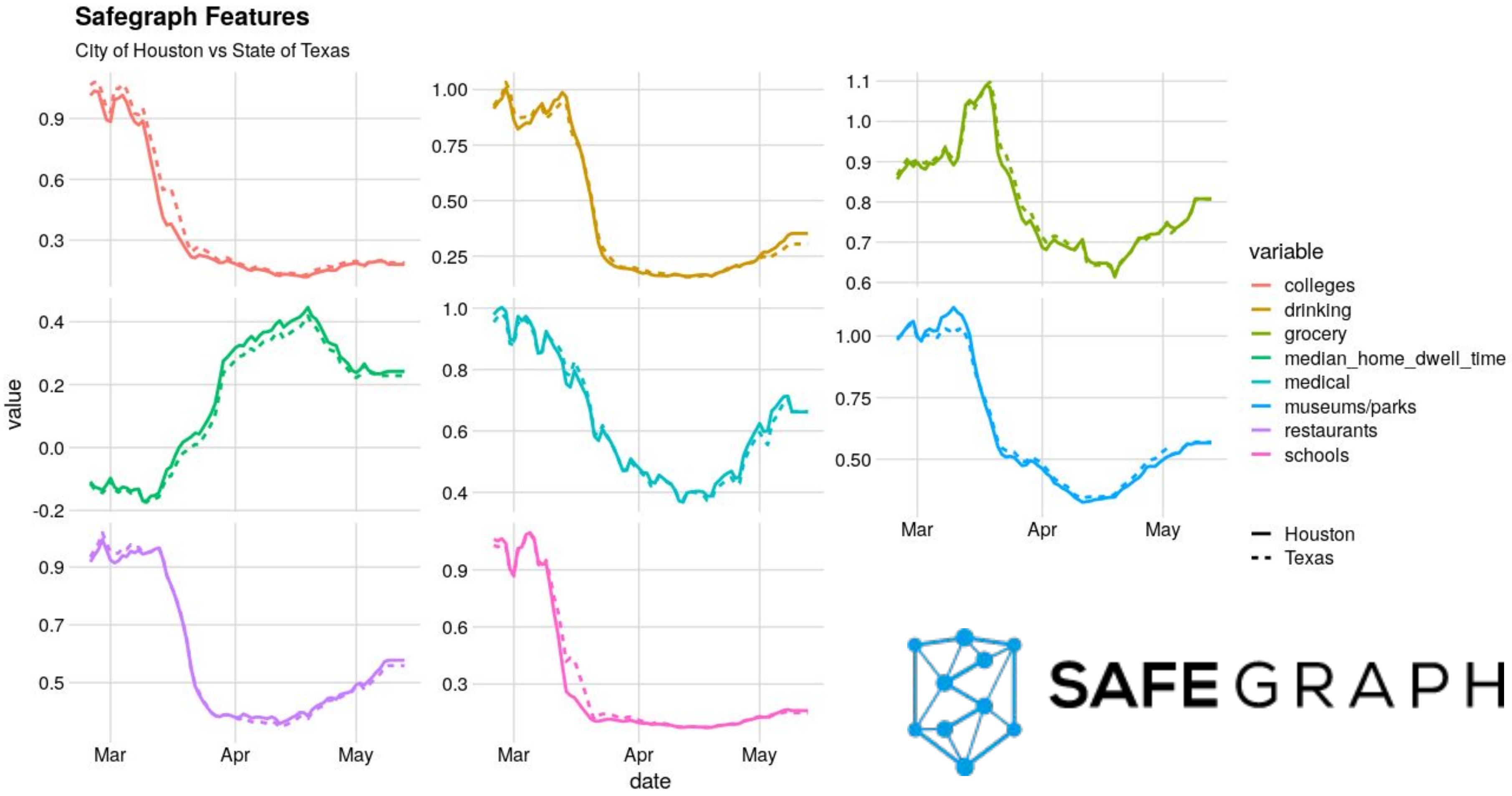
May 1, 2020 29,229 confirmed cases
Several businesses reopen

Cell phone mobility data as a proxy for behavior





Cell phone mobility data as a proxy for behavior

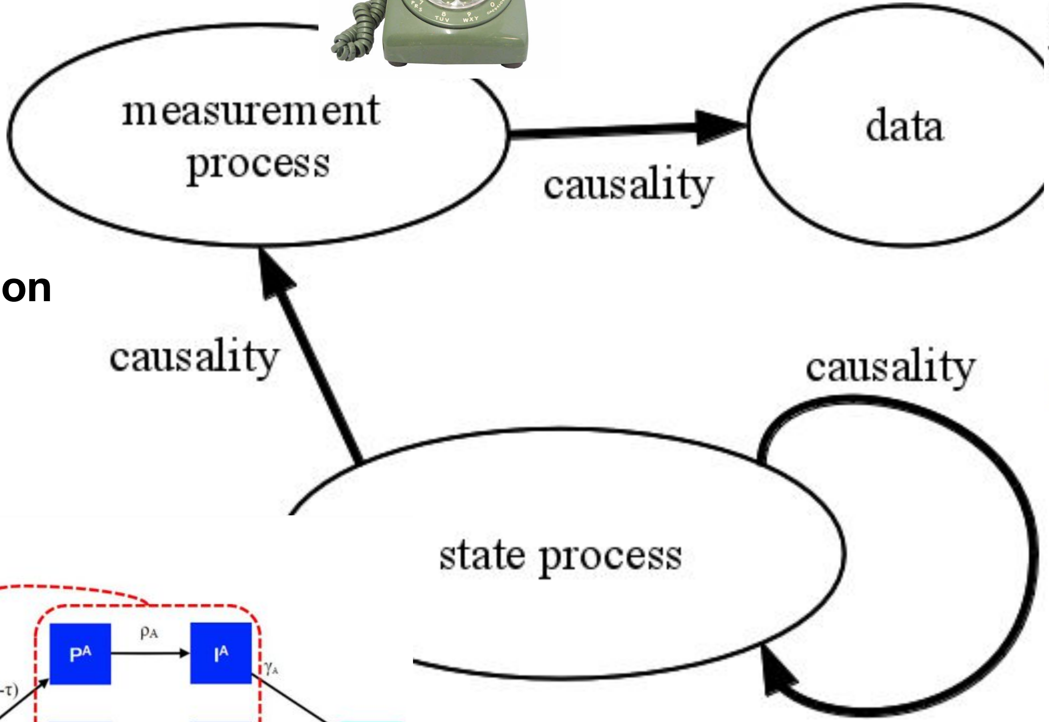


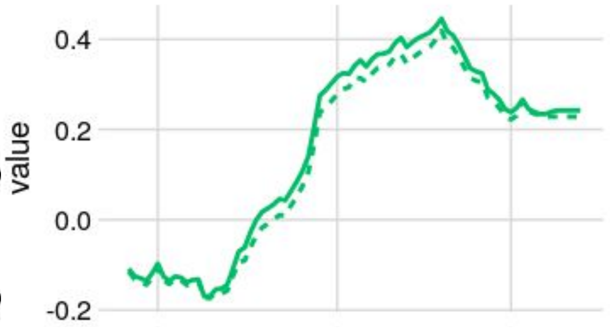
SAFEGRAPH

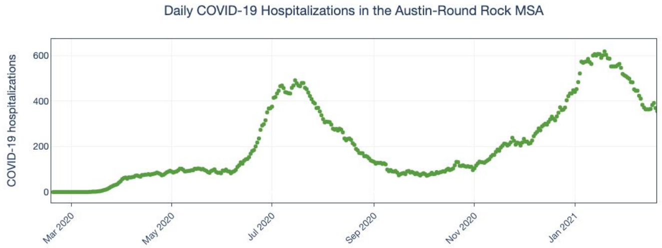
Mauricio Tec, James Scott, Spencer Woody

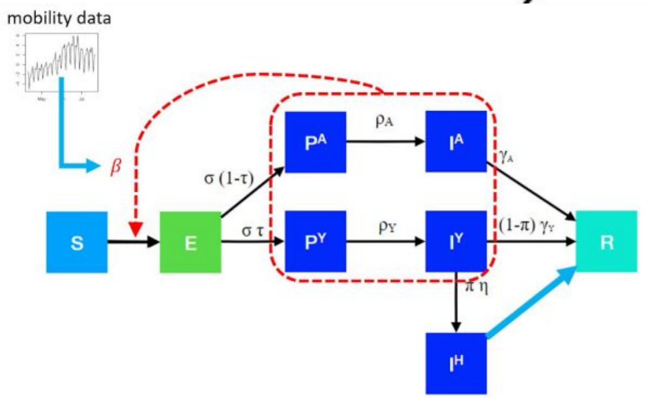
Regression using partially observed Markov processes

+ hospitalization

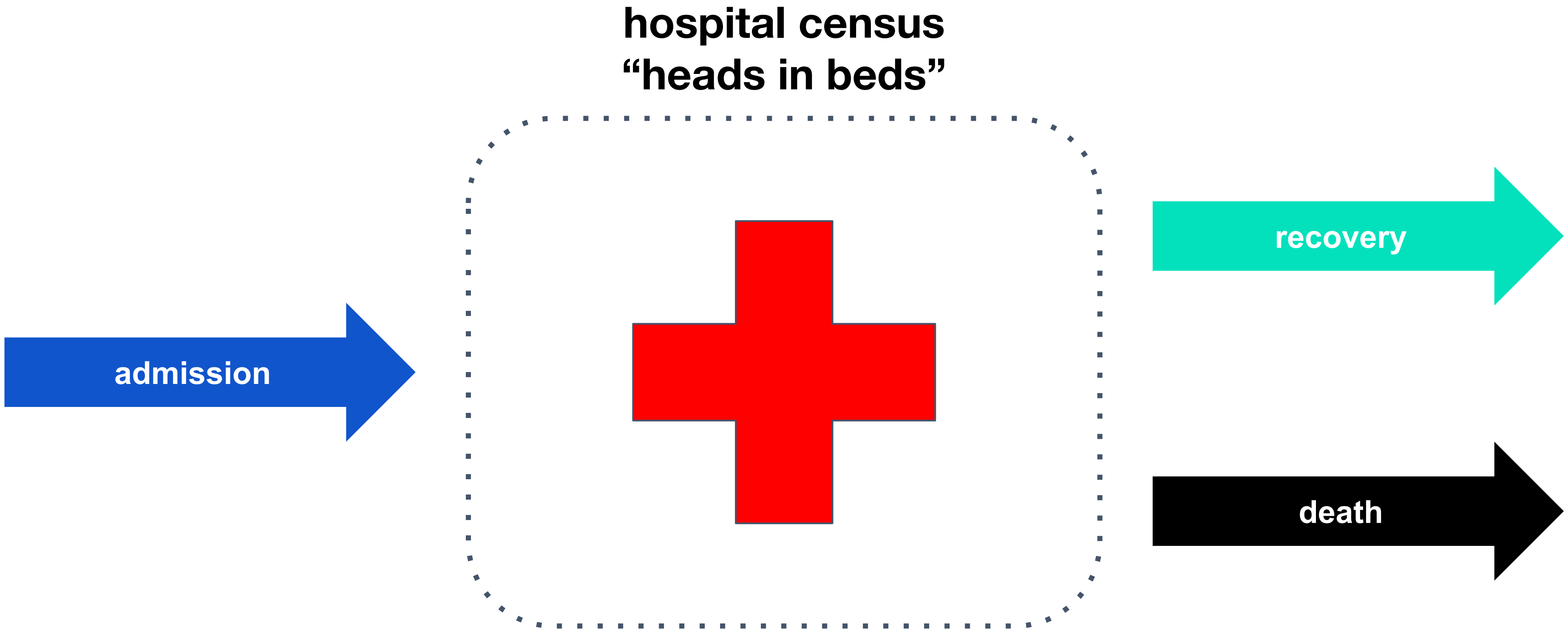








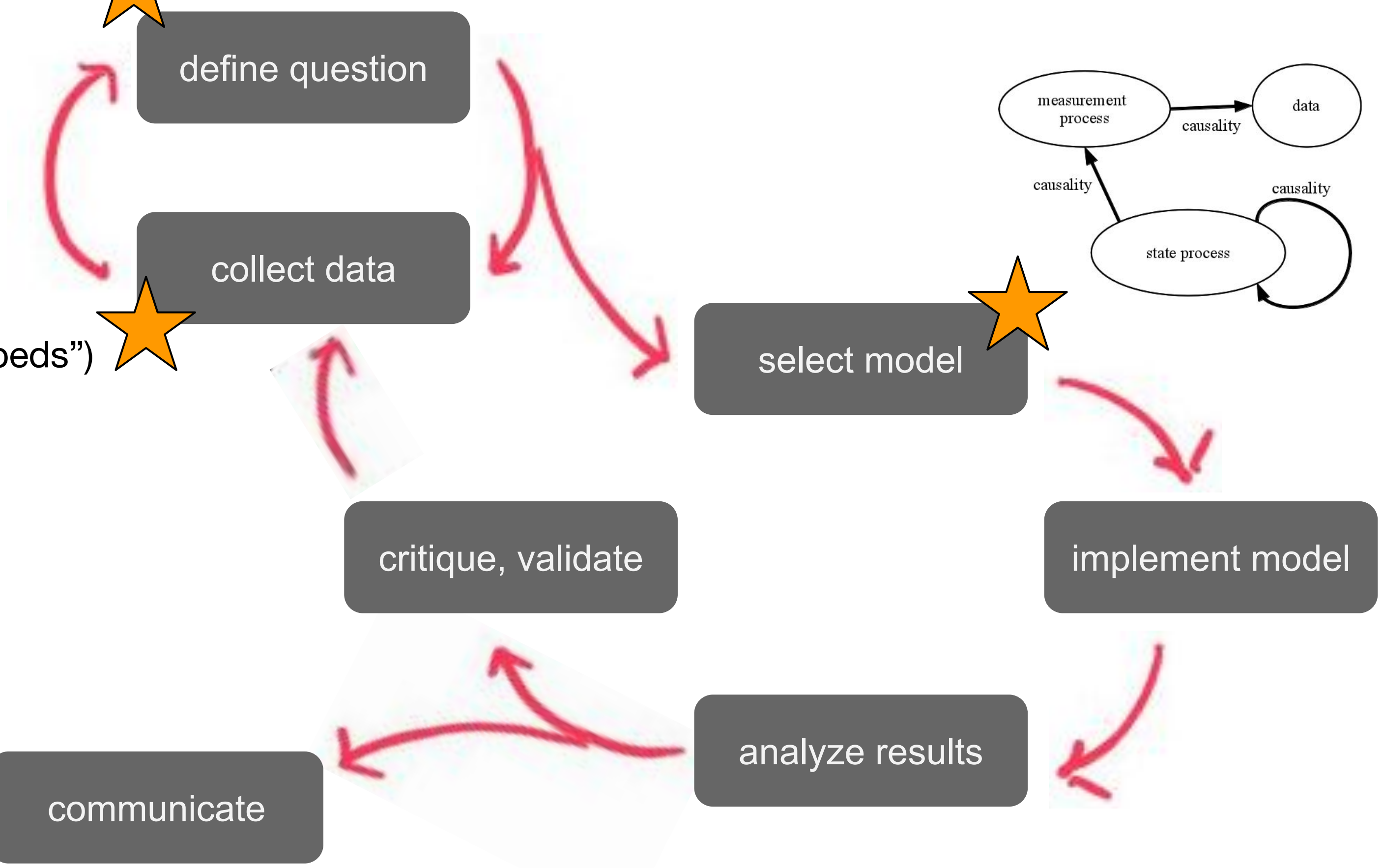
Hospital census vs admits and discharges

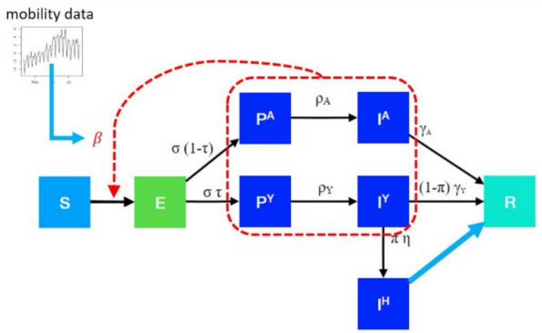


First choice: hospital admission data (“line list” data)
Second choice: hospital census data

Revisiting the model life cycle

What is the demand for hospital capacity?





Hospital census (“heads in beds”)
or admissions + discharges

Rate parameters
- latency
- transmission and behavior
- mortality/recovery

Contact patterns

Mobility

Implementation

- Combination of R and Python
  - partially observed Markov processes in `pomp` R package
  - python utilities for processing mobility data, dashboard visualizations
- Trivially parallel simulations
- Modeling a single locality takes approximately 4 hours (minimal optimization - room for automation and improvement)

FRONTERA STAMPEDE2

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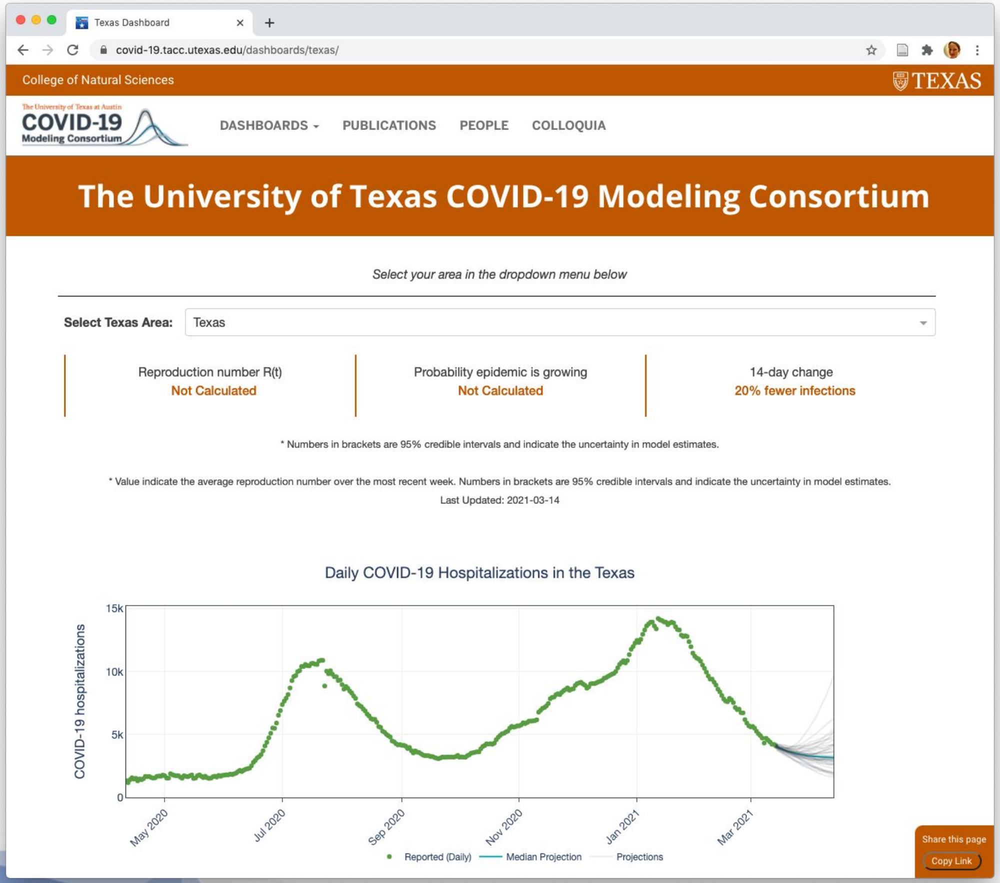
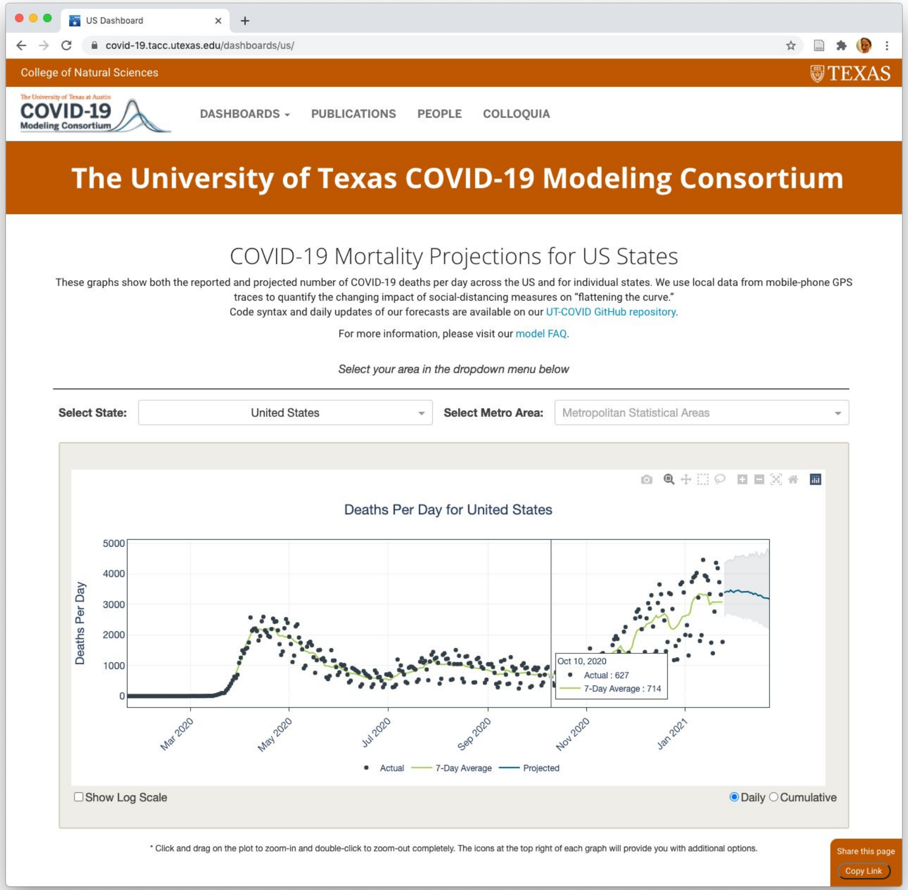
Projection dashboards

Healthcare demands in Texas



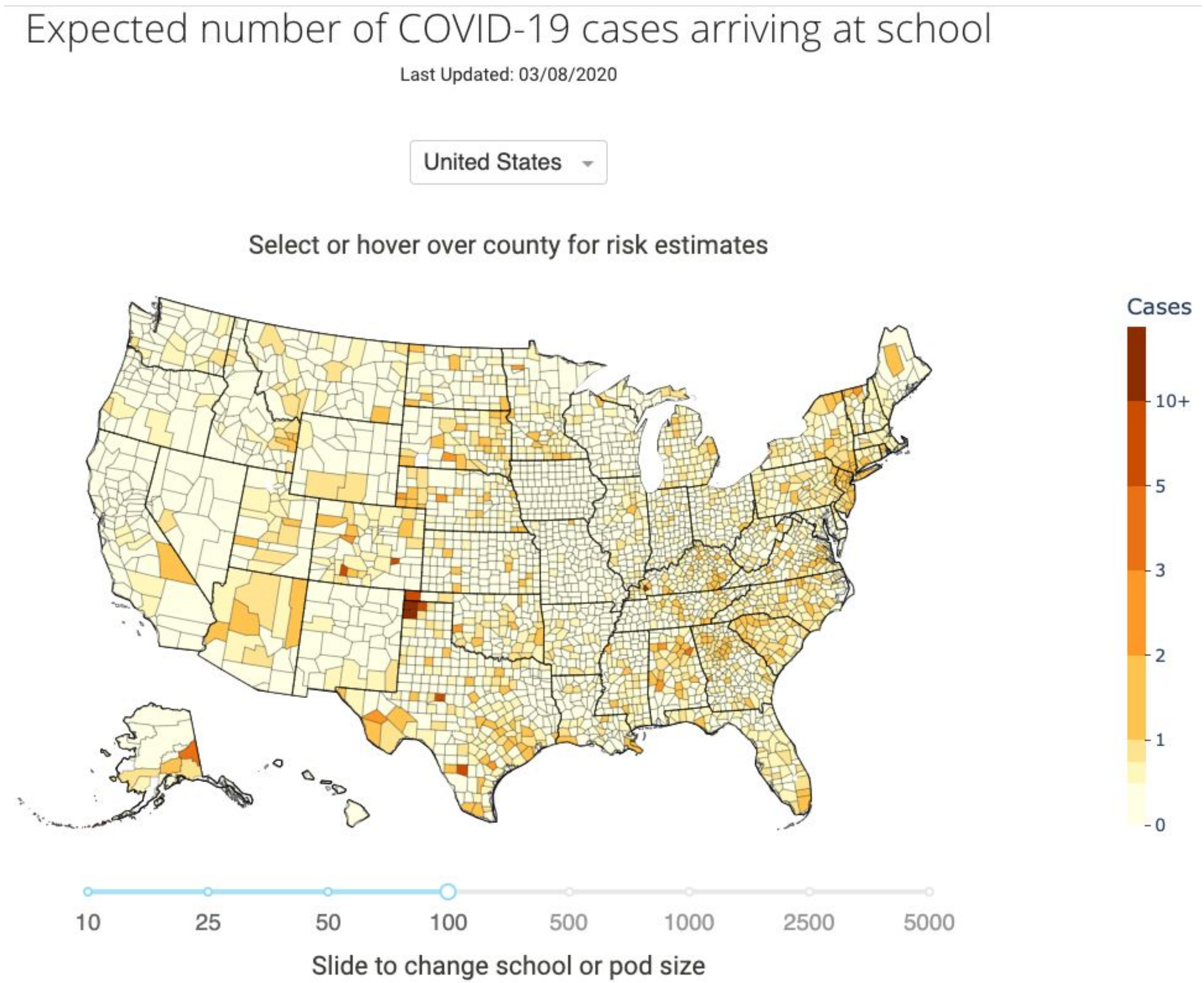
Mortality across the United States



Mauricio Tec, James Scott, Spencer Woody, Kelly Gaither, Maytal Dahan

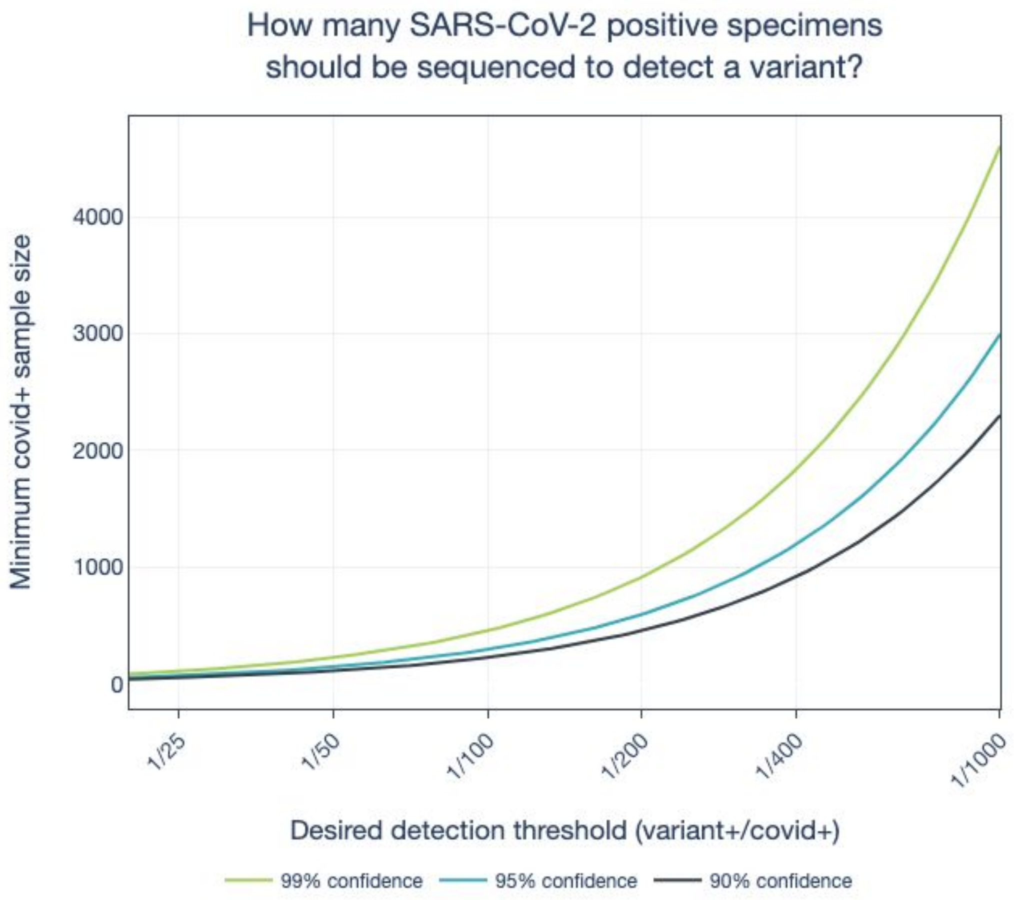
Beyond “flattening the curve”

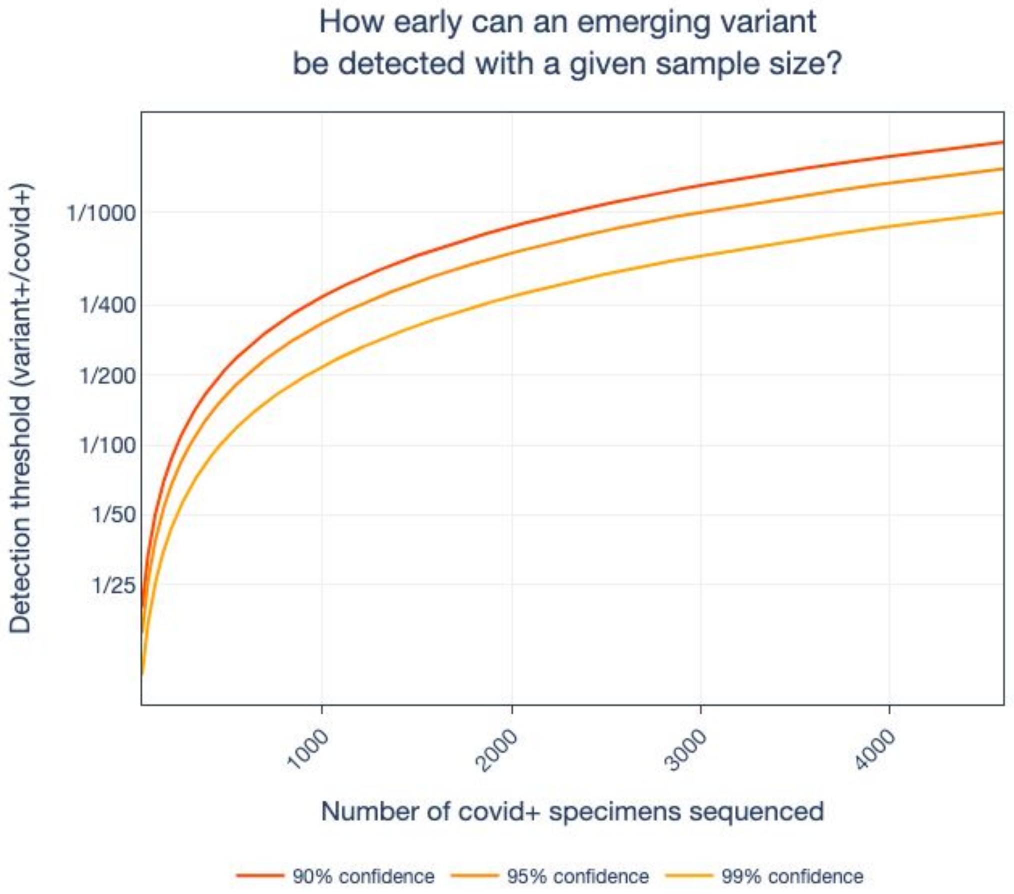
School reopening - introduction risk



Spencer Fox, Michael Lachmman, Kelly Gaither

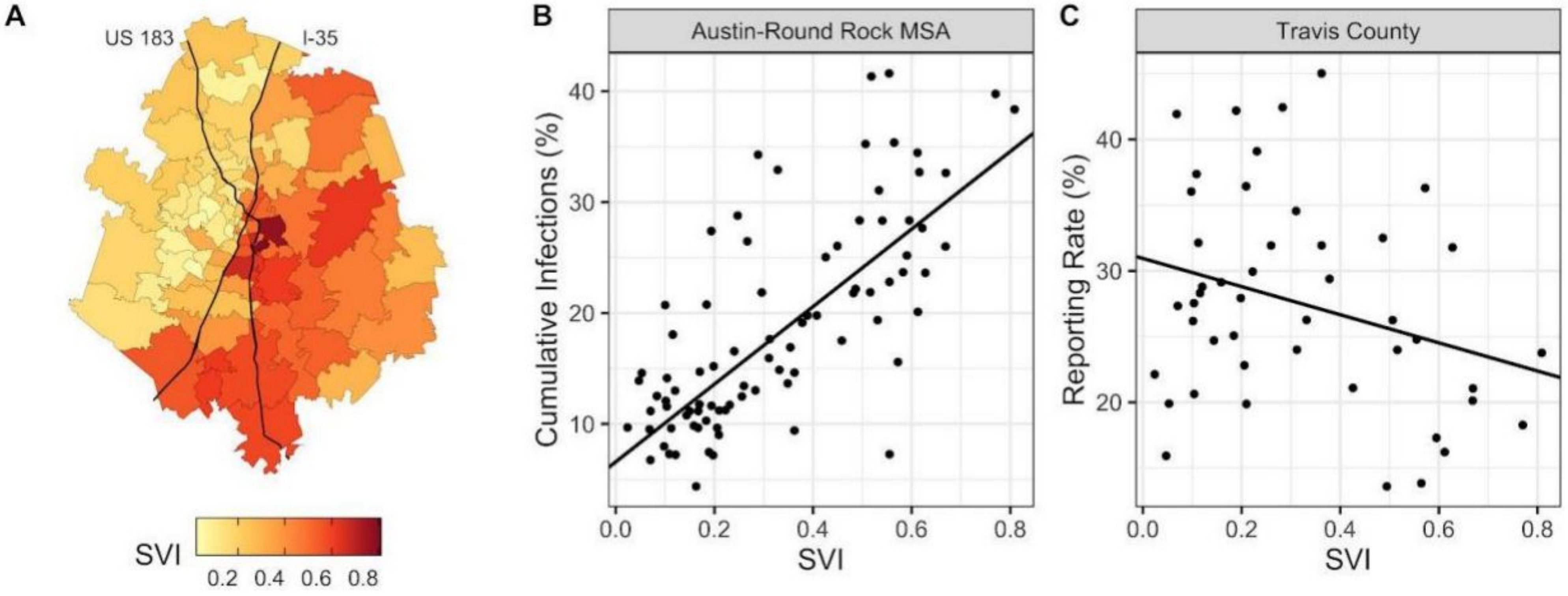
Variant detection





Heterogeneous vulnerability and burden

Social Vulnerability Index (SVI) predicts vulnerability and infection burden



Emily Javan, et al. https://sites.cns.utexas.edu/sites/default/files/cid/files/austin_covid-19_spatial_burden_report.pdf?m=1611796135

Conclusions after 1 year of COVID-19

- **Hospital census or admissions data are critical.**
  - Small amounts of data can provide crucial insights when used carefully
  - Public health data collection, aggregation and dissemination have changed dramatically in the last 12 months (but need more investment)
- **Fast model development allowed the consortium to expand research capacity.**
  - HPC and HPC Centers support fast iteration and short turn-around on research and production models

Contact

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