

Network Systems
Science & Advanced
Computing

Biocomplexity Institute
& Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

September 9th, 2020

(data current to September 8th)

Biocomplexity Institute Technical report: TR 2020-111



BIOCOMPLEXITY INSTITUTE

biocomplexity.virginia.edu

About Us

- Biocomplexity Institute at the University of Virginia
 - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
 - Pandemic response for Influenza, Ebola, Zika, and others



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Overview

- **Goal:** Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
 - Calibrate explanatory mechanistic model to observed cases
 - Project infections through November
 - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
 - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
 - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Mixed trends remain, with strong surges in several districts.**
- Incidence hovers at national average, which is higher this week ~13/100K.
- Projections are also mixed across a range of slow-growth, plateaus, and declines.
- Recent updates:
 - Adaptive Fitting projection remains, slight adjustments to projection filtering.
 - Trajectory descriptions more fully developed.
- The situation is changing rapidly. Models will be updated regularly.

Situation Assessment

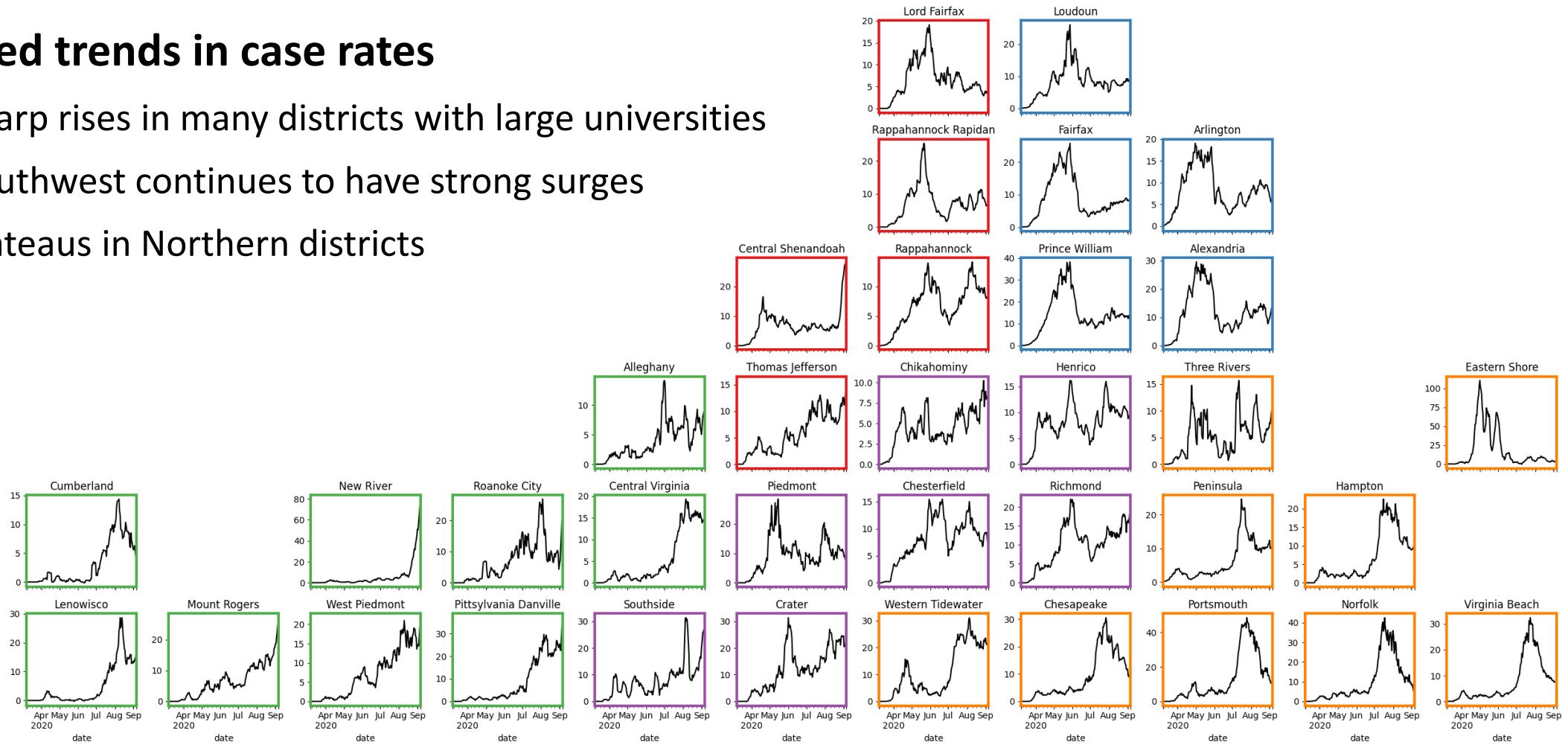


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Case Rate (per 100k) by VDH District

Mixed trends in case rates

- Sharp rises in many districts with large universities
- Southwest continues to have strong surges
- Plateaus in Northern districts

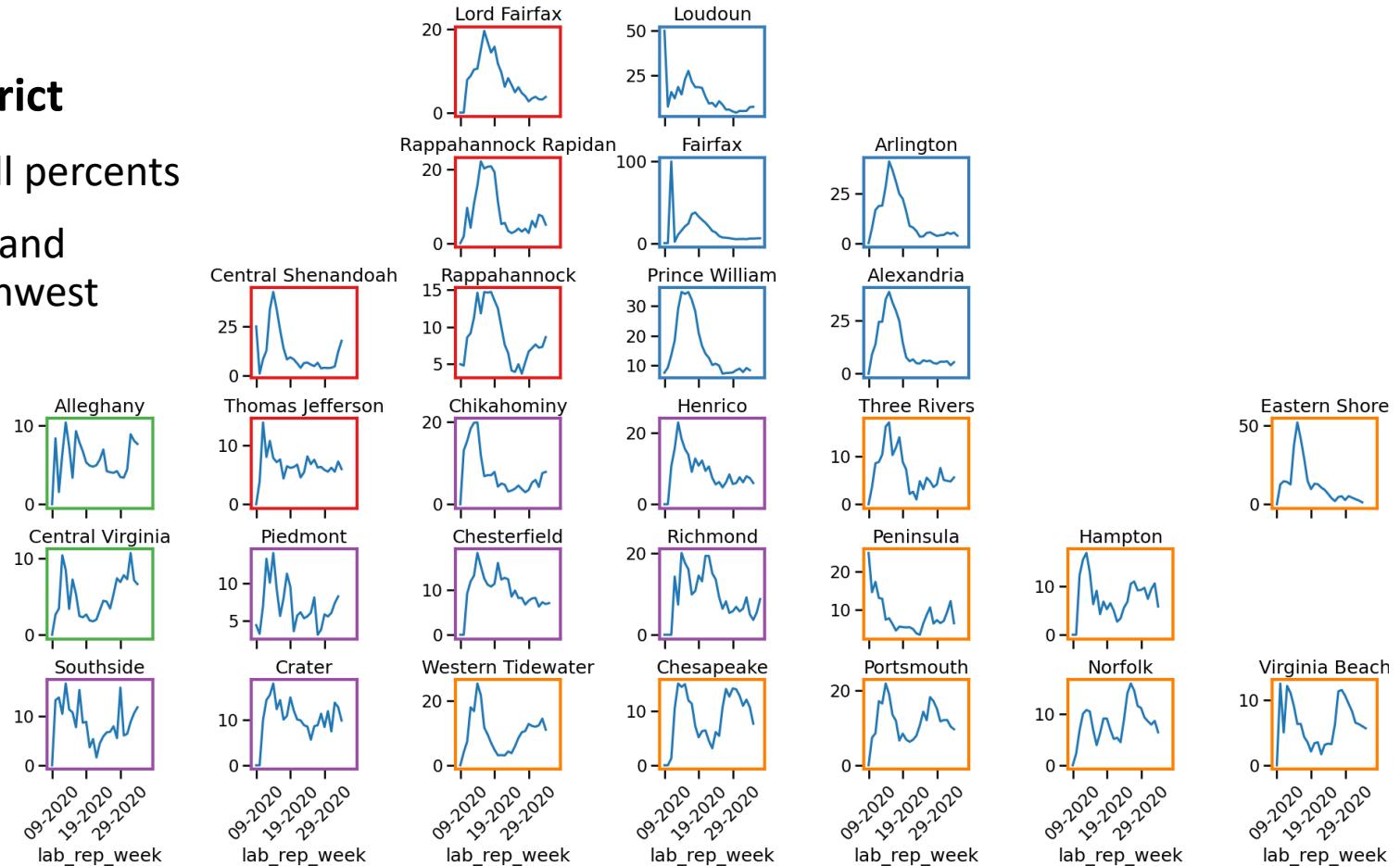
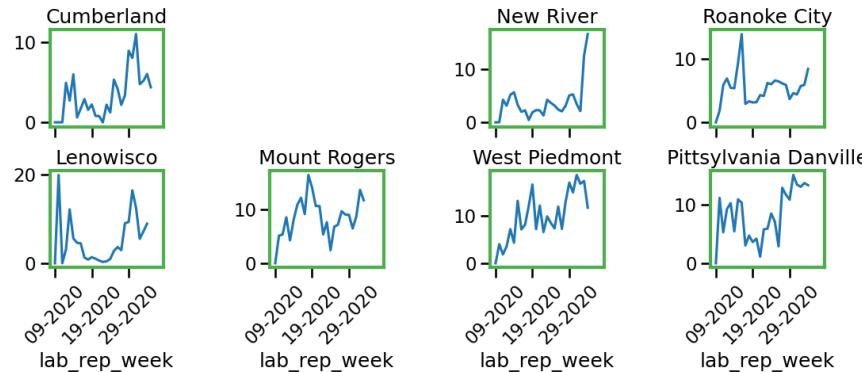


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Test Positivity by VDH District

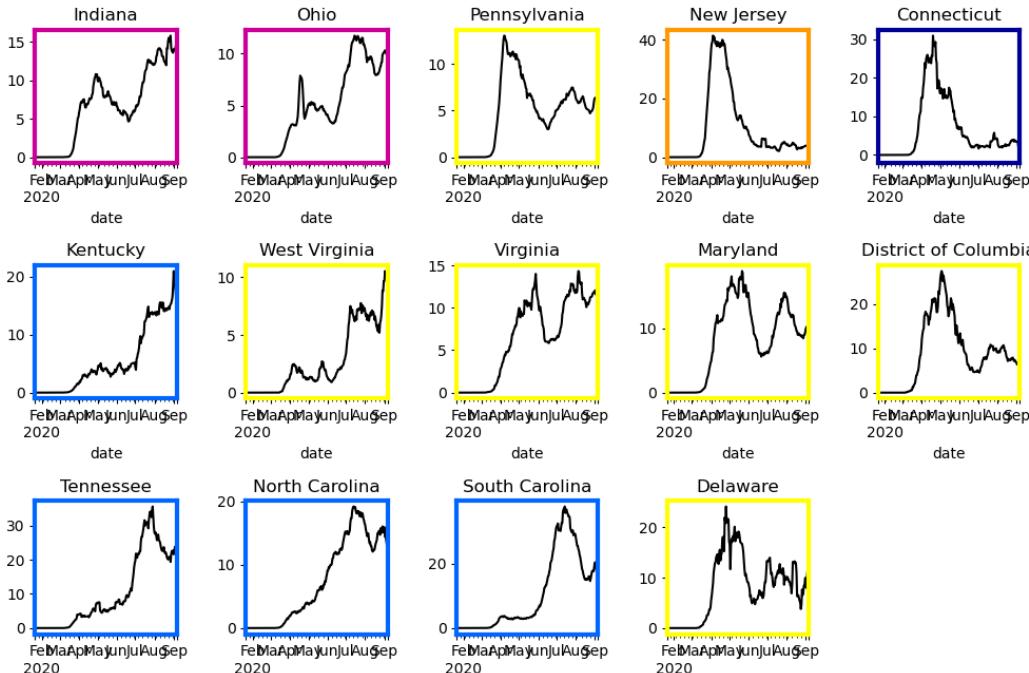
Weekly changes in test positivity by district

- Most districts moving towards lower overall percents
- Areas with most growth also showing high and increasing test positivity, especially in Southwest



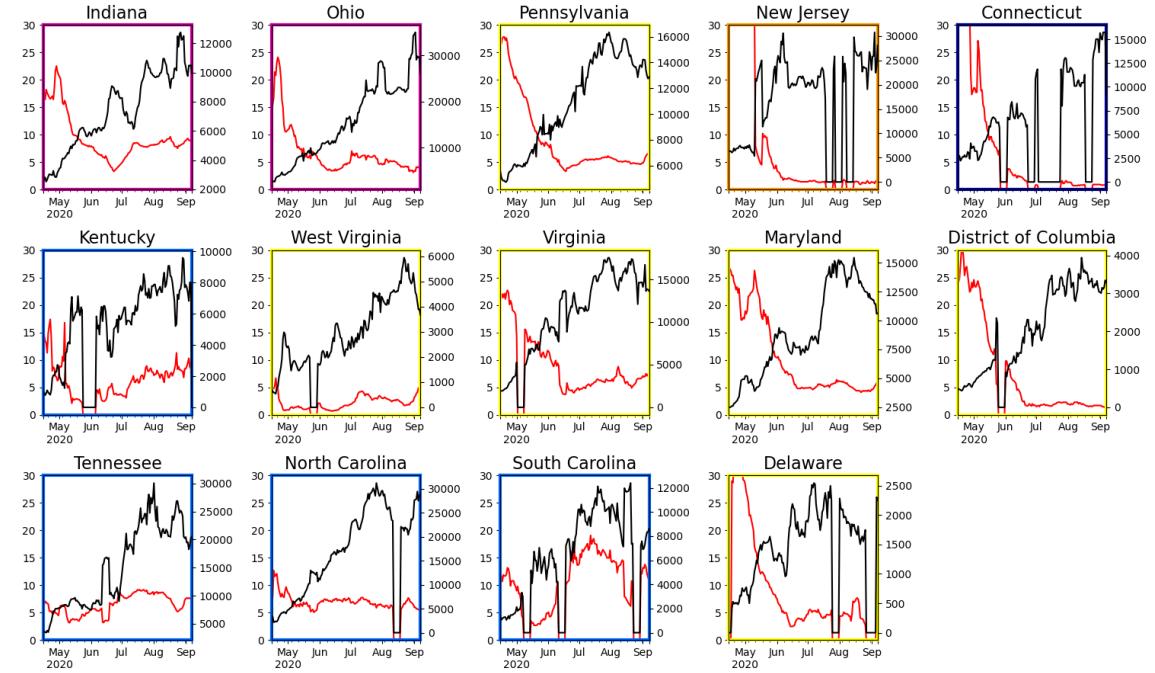
Other State Comparisons

Case Rate per 100K population



- Most states experiencing declines or plateaus in last weeks
- SC and NC showing some rebounds
- KY and WV plateauing, and TN declining but still quite high

Tests per Day and Test Positivity

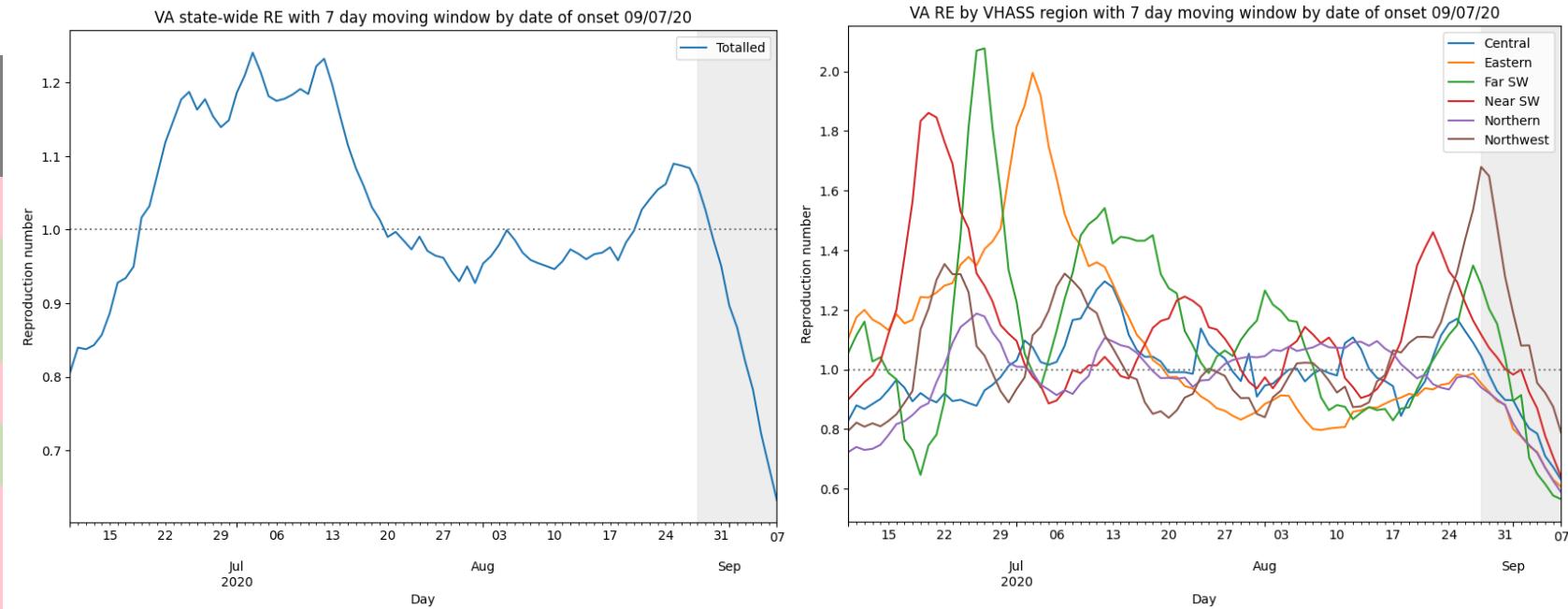


- Good signs as test positivity shows recent decline in most states
- Testing volumes steady or growing in most states

Estimating Daily Reproductive Number

August 29th Estimates

Region	Current R_e	Diff Last Week
State-wide	1.027	0.023
Central	0.982	-0.005
Eastern	0.925	-0.004
Far SW	1.203	0.239
Near SW	1.073	-0.348
Northern	0.921	0.028
Northwest	1.649	0.538



Methodology

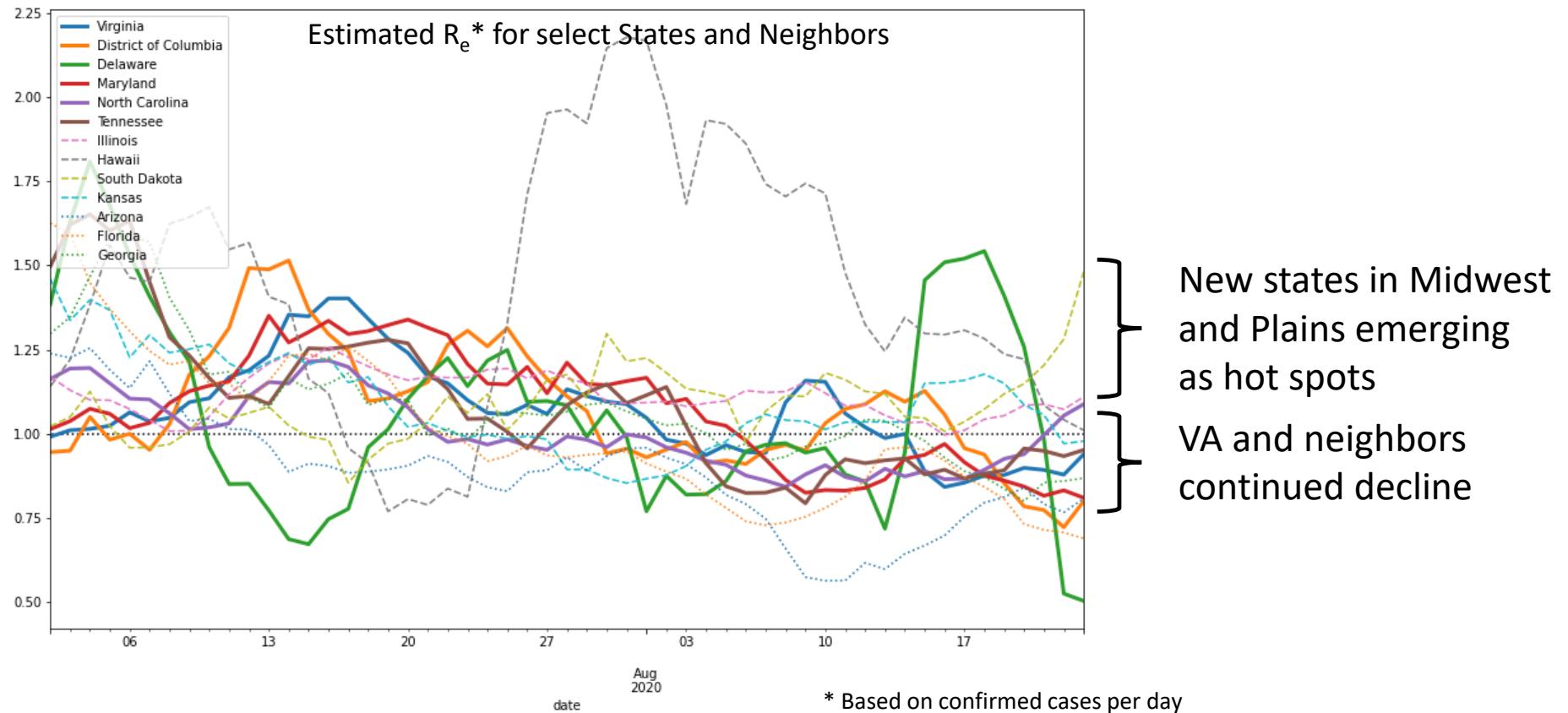
- Wallinga-Teunis method (EpiEstim¹) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, <https://doi.org/10.1093/aje/kwt133>

Other State Comparisons

Reproductive Number (R_e) has downward trend across hotspots and Virginia's neighbors

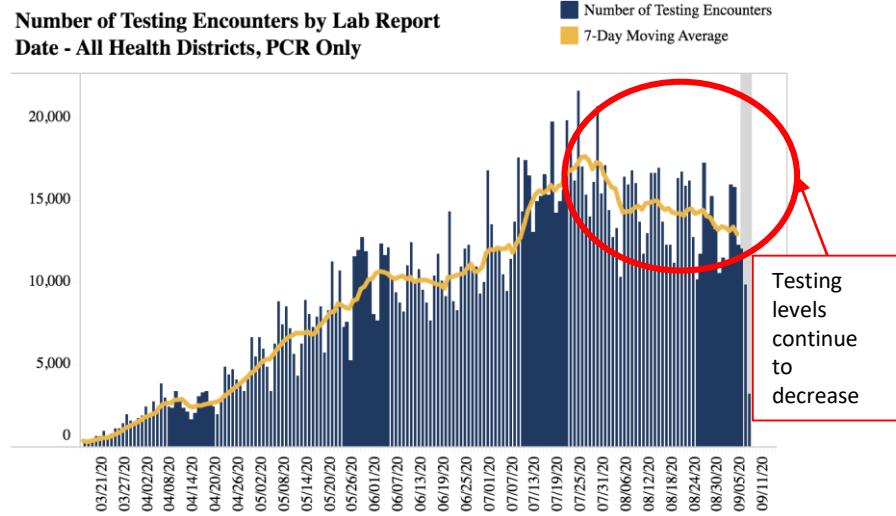
- New states in Midwest and Plains emerging as hot spots, IL, KS, SD as well as HI
- Virginia and neighboring states are mostly at and below 1



Changes in Case Detection

Timeframe (weeks)	Mean days	% difference from overall mean
April (13-16)	8.58	37.29%
May (17-21)	5.75	-7.97%
June (22-25)	5.84	-6.50%
July (26-30)	6.22	-0.39%
Aug (31-33)	4.55	-27.11%
Overall (13-33)	6.25	0%

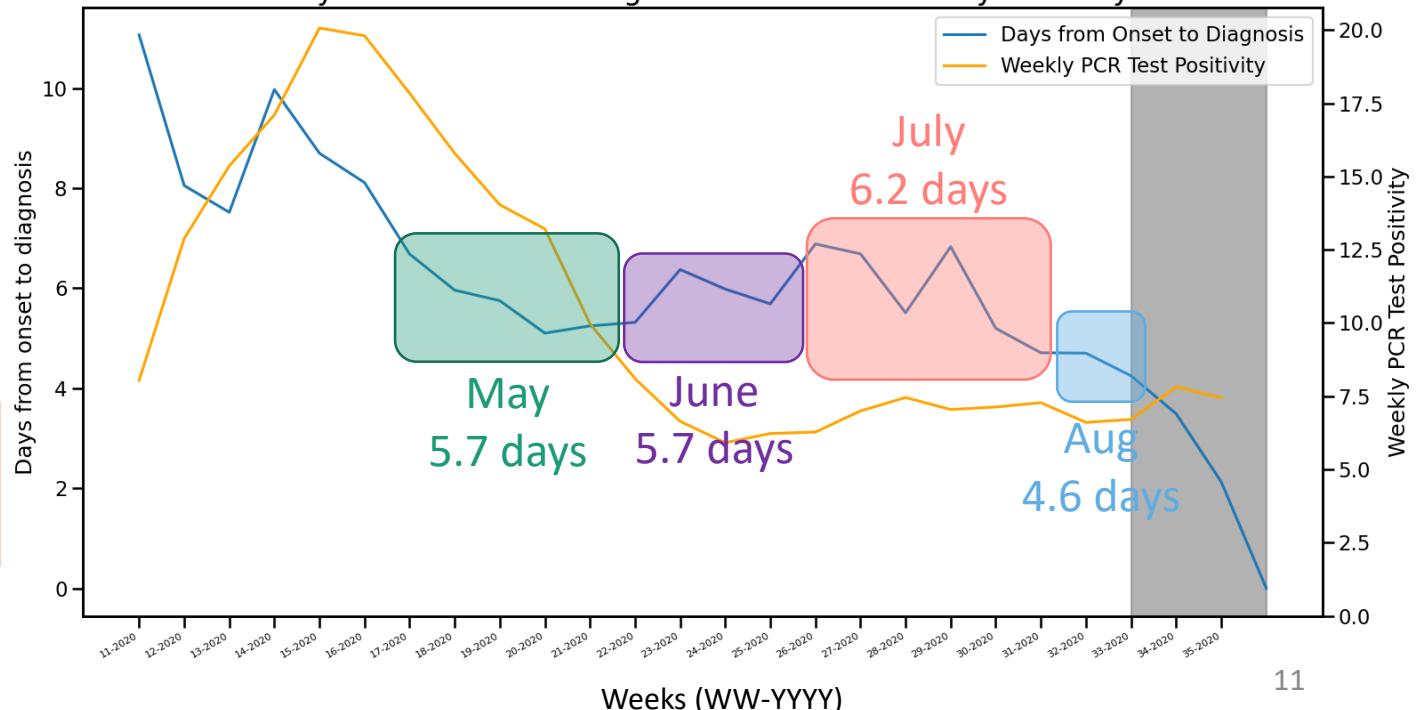
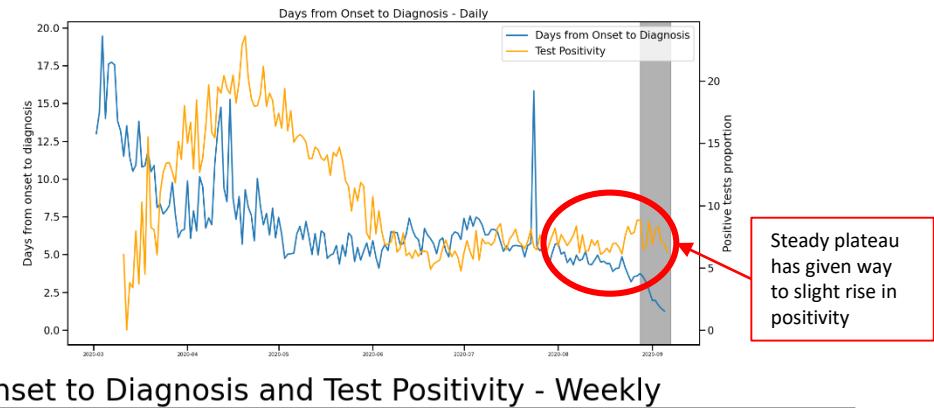
Testing Encounters and test positivity have steadied and increased



9-Sep-20

Accessed 10pm September 8, 2020
<https://www.vdh.virginia.gov/coronavirus/>

Test positivity vs. Onset to Diagnosis

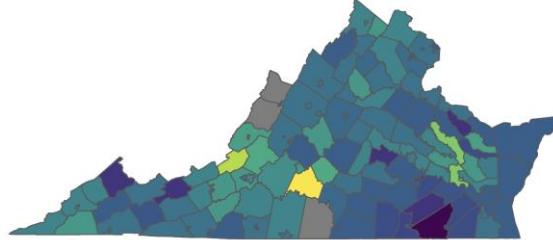


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Changes in Case Detection – By District/Age

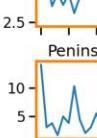
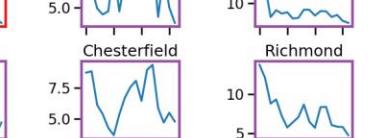
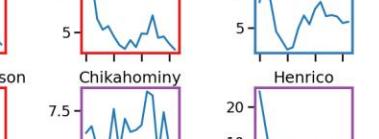
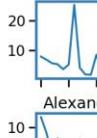
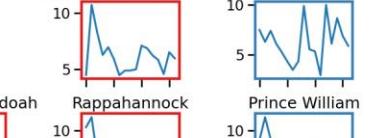
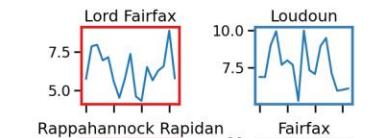
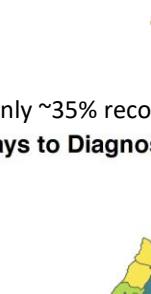
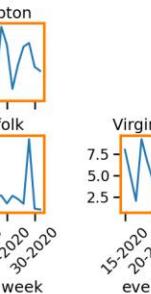
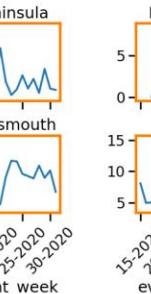
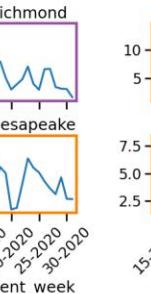
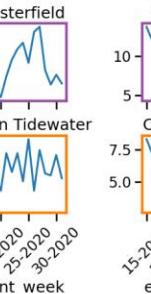
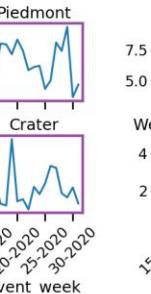
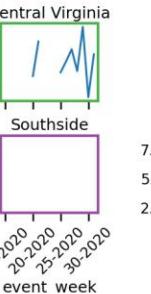
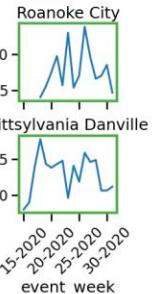
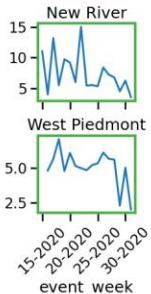
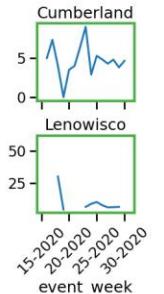
Median Days to Diagnosis

since March 1st



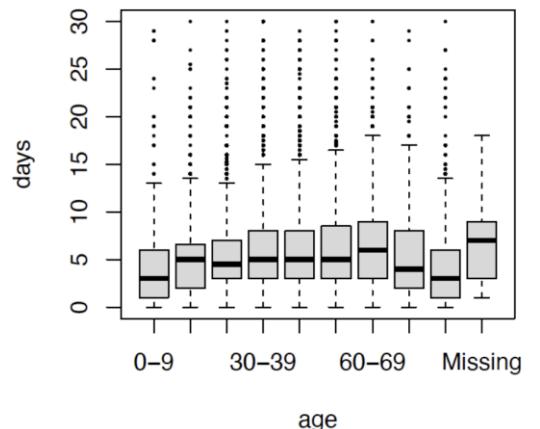
Days to Diagnosis

0.0 2.5 5.0 7.5 10.0 12.5

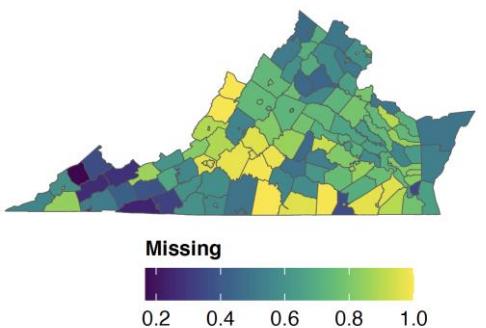


Slight variations by age group
(0-9, 70-79 and 80-89 have lower medians)
No significant variation by severity (hosp./ICU)

Delay by Age Group



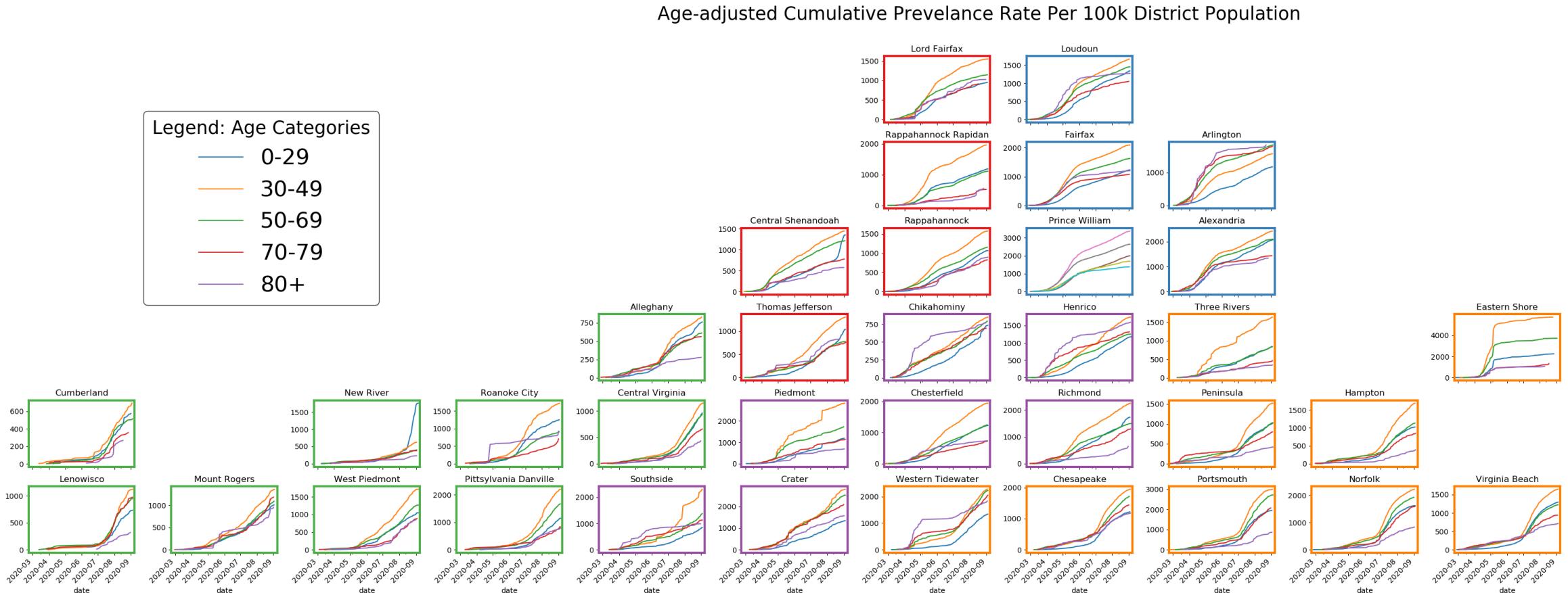
Only ~35% records have entries
Days to Diagnosis Missing Rate



Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

- Younger age groups outpace older in many districts

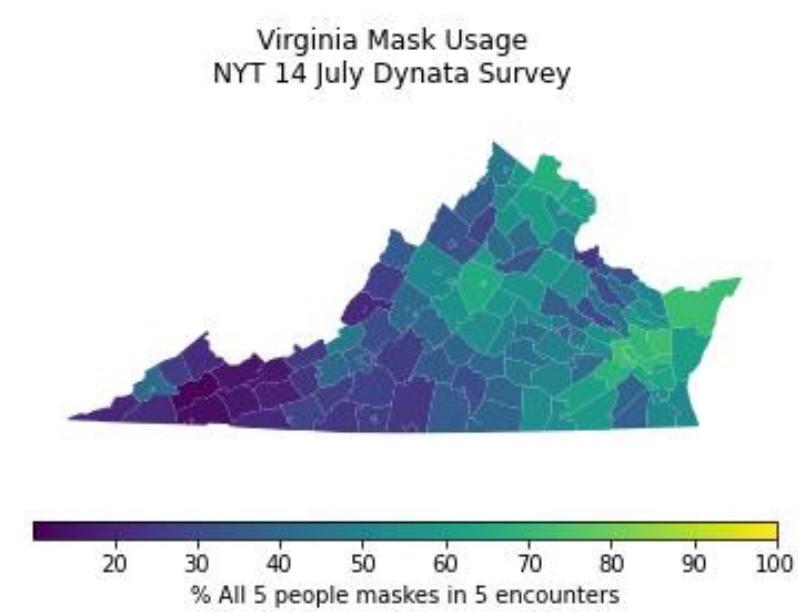
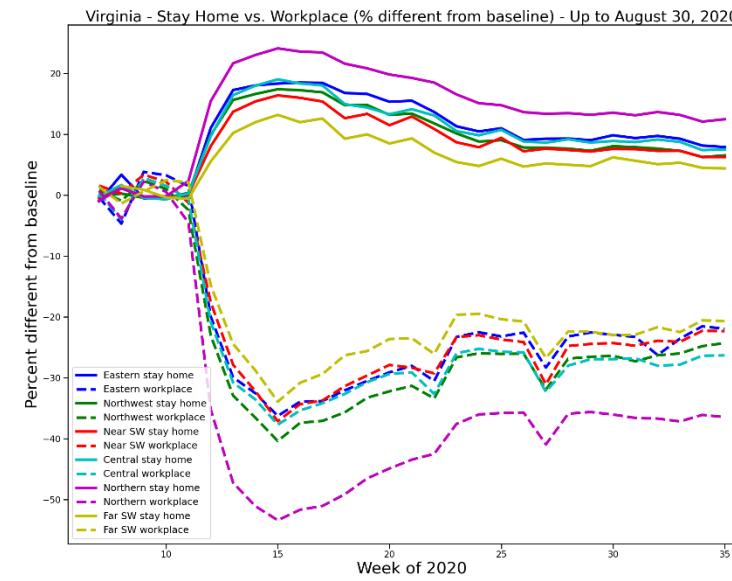
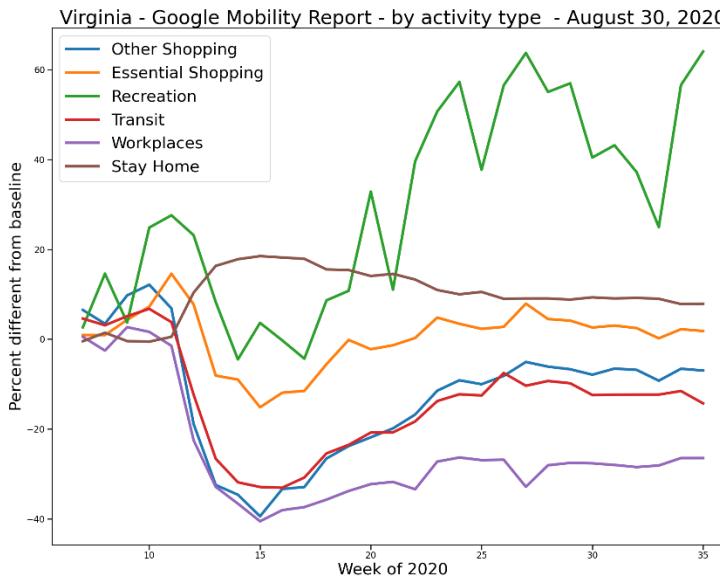


Estimating Effects of Social Distancing

Google Mobility data shows continued slow rebound (as of July 26th)

<https://www.google.com/covid19/mobility/>

- Continued slow reduction of those staying at home. Workplace levels remain low.
 - Urban/Rural variations in levels (e.g., Northern vs Far SW)
- Essential shopping back to baseline. Other shopping/transit trending towards baseline.
- Parks and recreation significantly higher than baseline (seasonal effects).
- Mask usage not evenly distributed, higher in Northern central, lower Southwest and Richmond area.



District Trajectories – New Surges starting

Hockey stick fit used to describe recent growth patterns

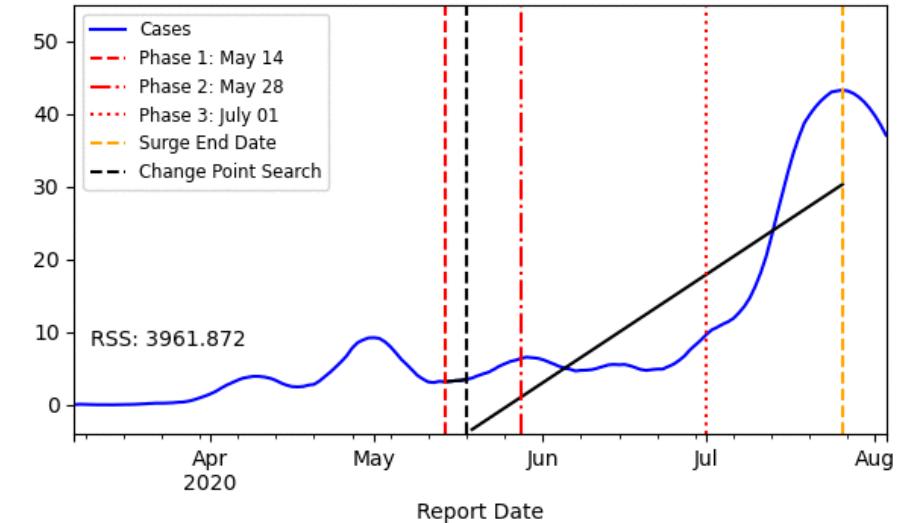
Declining: Sustained decreases following a recent peak

Plateau: Steady level with minimal trend up or down

Slow Growth: Sustained growth not rapid enough to be considered a Surge

In Surge: Currently experiencing sustained rapid growth and exceeds recent inflection points

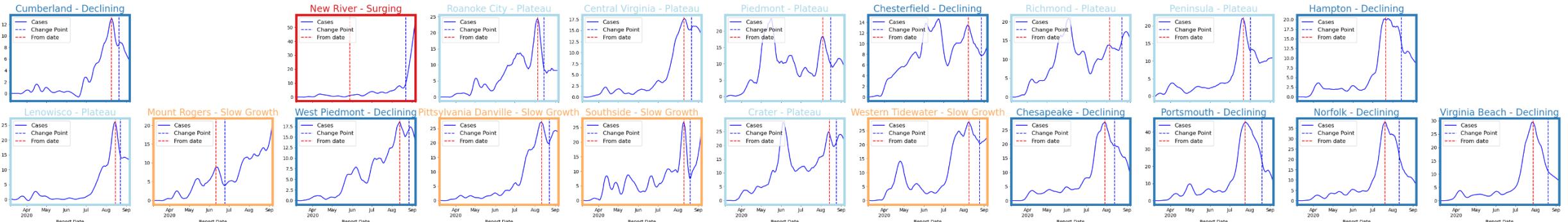
Hockey stick fit
Portsmouth



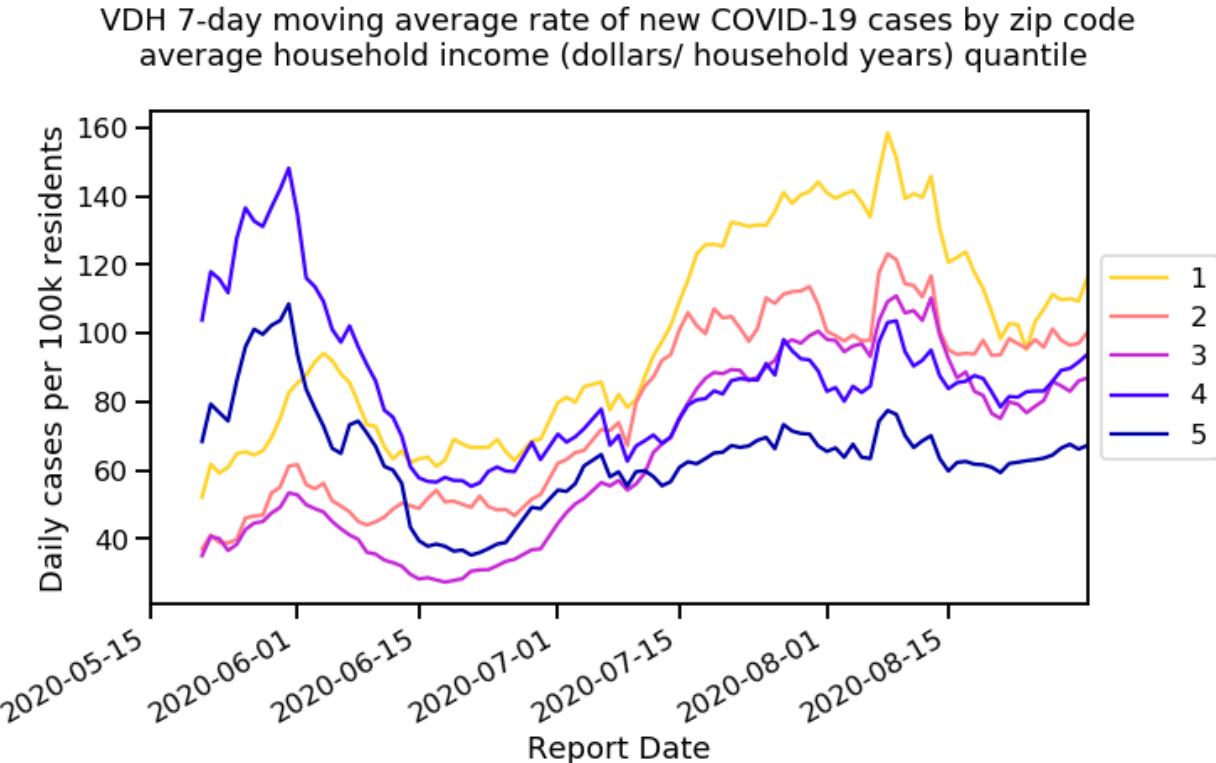
Status	# Districts (last week)
Declining	13 (13)
Plateau	10 (12)
Slow Growth	10 (8)
In Surge	2 (2)

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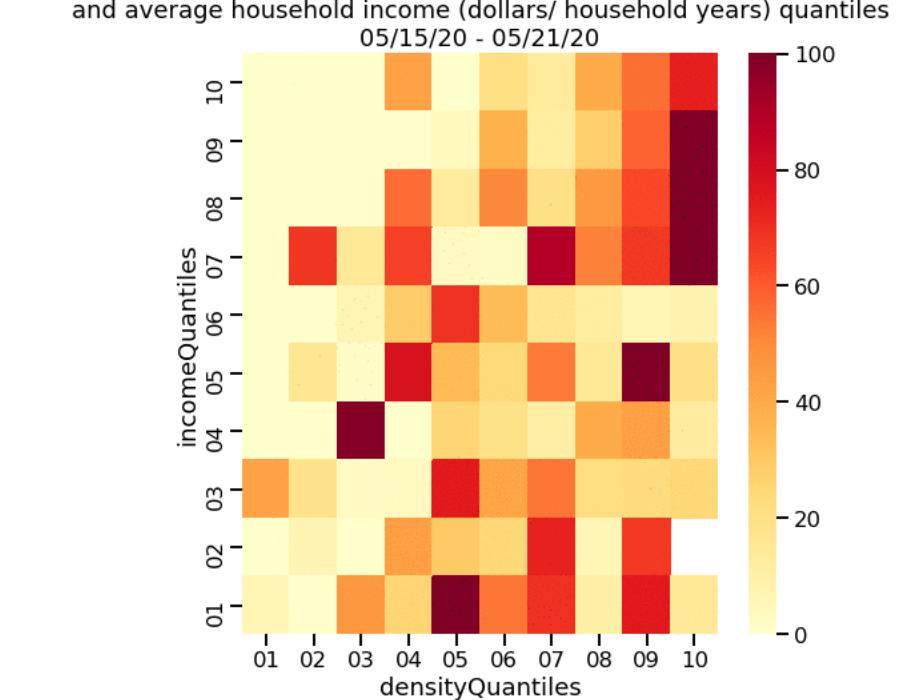


Impact across Density and Income



Lower 20% income zip codes still reporting highest case rates

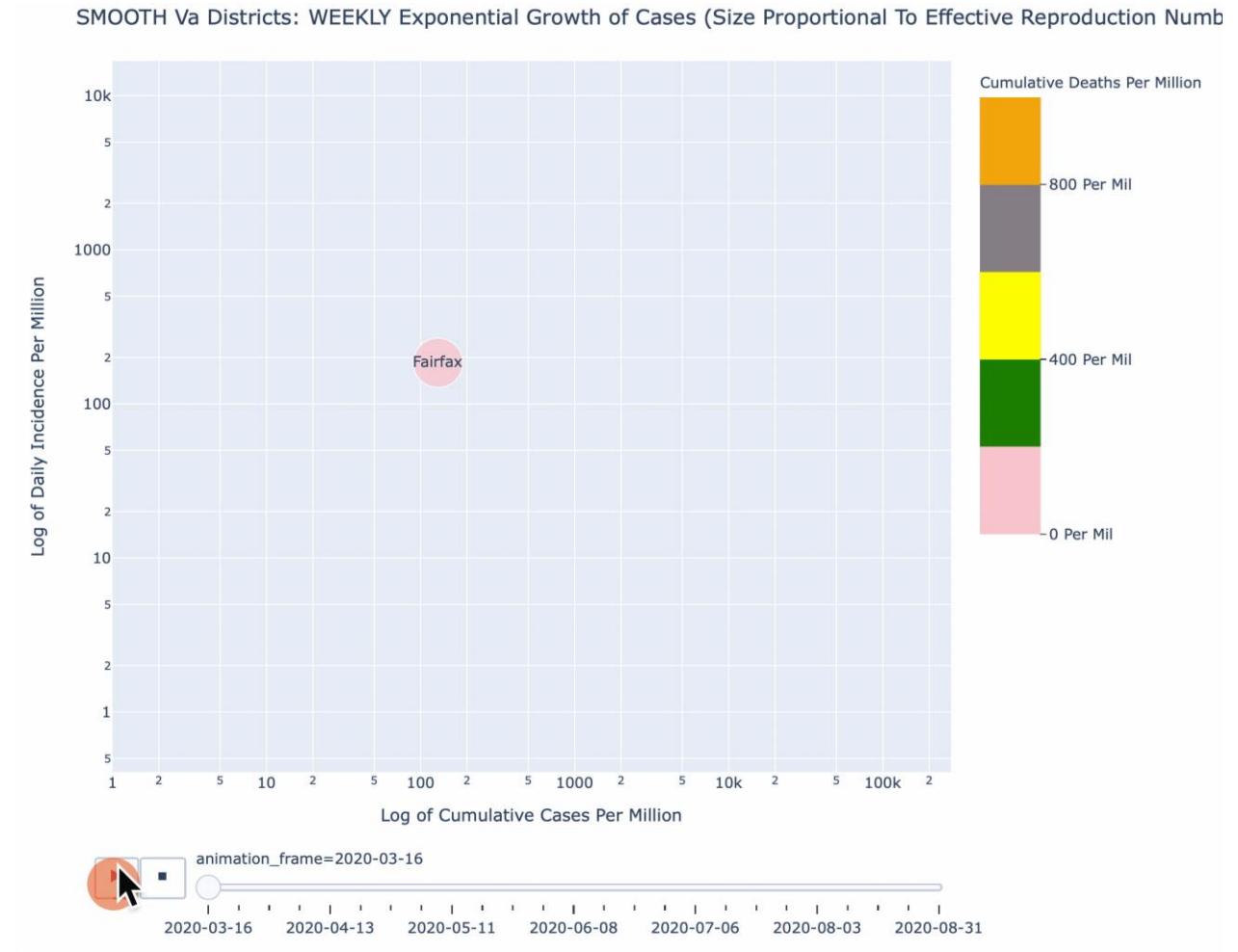
VDH mean cases per 100k by zip code population density (person/ sq mile)
and average household income (dollars/ household years) quantiles



Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes

Evolution of Infections by District

- From January to Present
- Cumulative cases vs. Daily Incidence
- Placed on log scale to minimize the differences between districts
- Colors represent cumulative deaths per million population
- Size changes based on daily estimated reproductive number

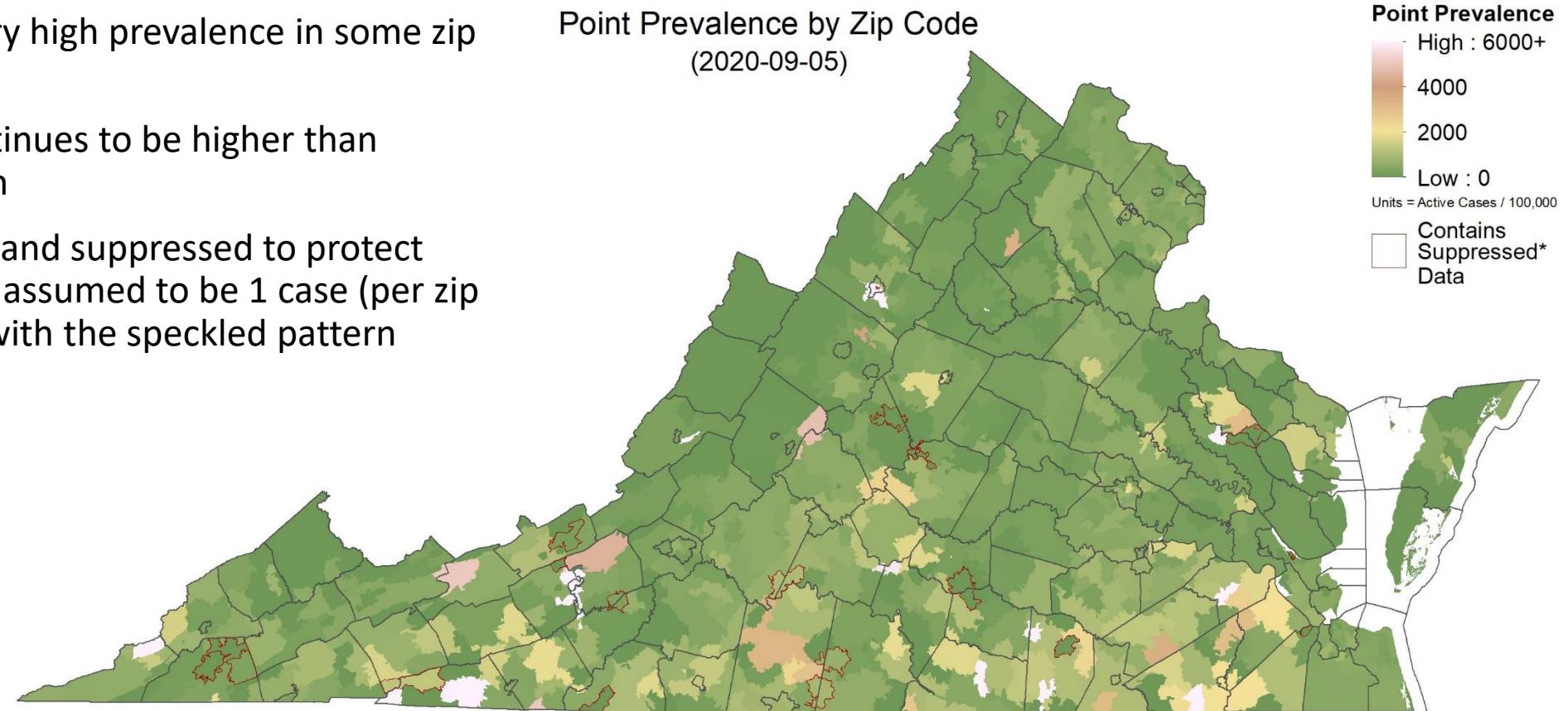


Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Concentrations of very high prevalence in some zip codes
- Southern border continues to be higher than northern and western
- Many counts are low and suppressed to protect anonymity, those are assumed to be 1 case (per zip per day) and shown with the speckled pattern

Point Prevalence by Zip Code
(2020-09-05)



Model Update – Adaptive Fitting



Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

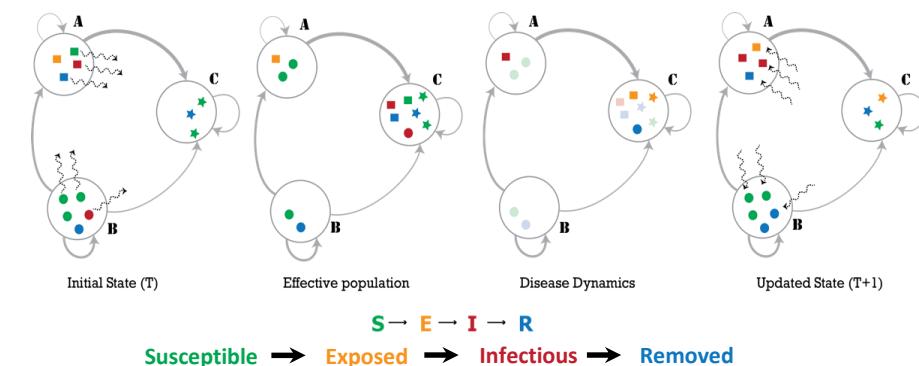
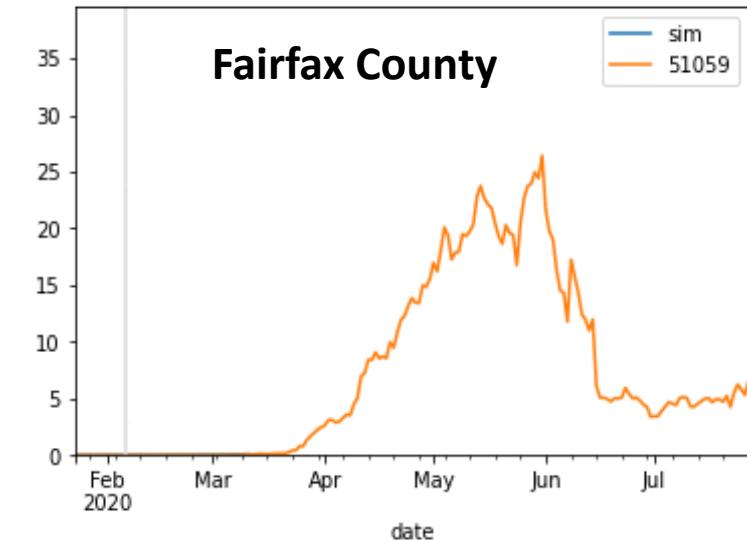
- Allows history to be precisely captured, and used to guide bounds on projections

Model: An alternative use of the same meta-population model, PatchSim

- Allows for future “what-if” Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

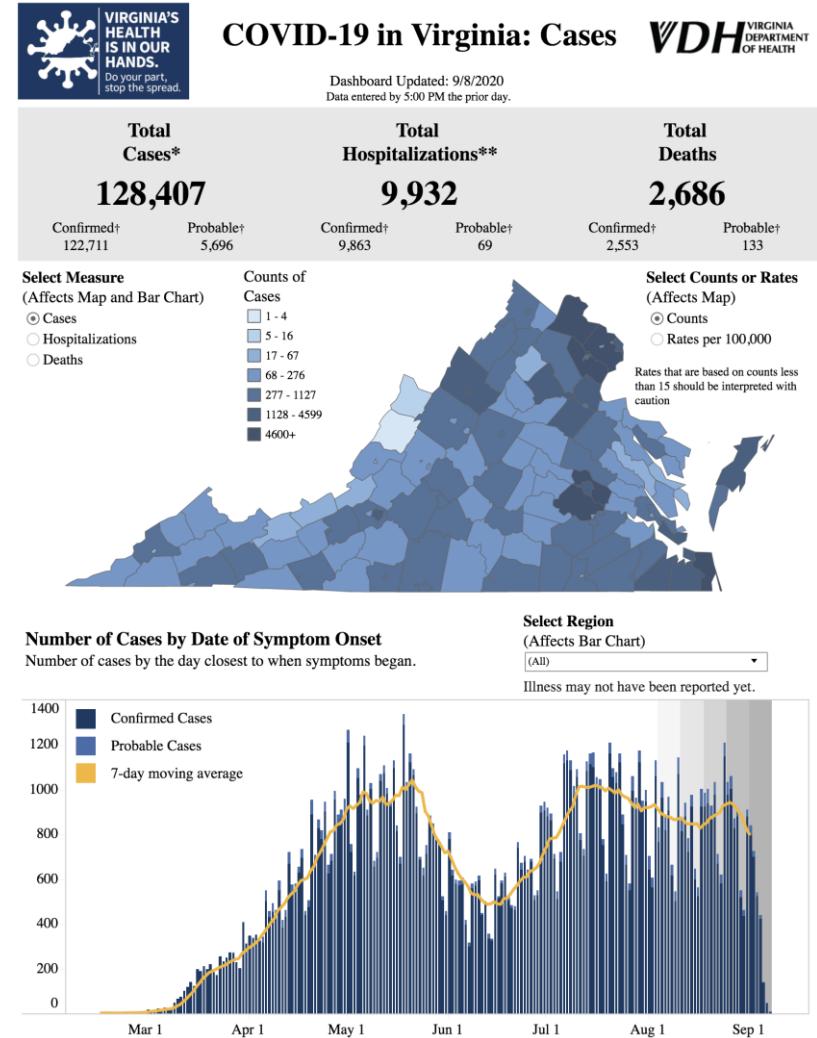
External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding



Calibration Approach

- **Data:**
 - County level case counts by date of onset (from VDH)
 - Confirmed cases for model fitting
- **Calibration:** fit model to observed data
 - Tune transmissibility across ranges of:
 - Duration of incubation (5-9 days), infectiousness (3-7 days)
 - Undocumented case rate (2x to 15x)
 - Detection delay: exposure to confirmation (4-12 days)
 - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes using the most recent parameters with constraints learned from the history of the fit parameters
 - Mean trend from last 7 days used, adjusted by variances in the previous 3 weeks
 - 1 week interpolation to smooth transitions in rapidly changing trajectories
 - Particles with high error or variance filtered out



Scenarios – Seasonal Effects

- Societal changes in the coming weeks may lead to an increase in transmission rates
 - Start of in-person school
 - Changes to workplace attendance
 - Seasonal impact of weather patterns
- Three scenarios provided to capture possible trajectories related to these changes starting following Labor Day, Sept 7th, 2020
 - Adaptive: No change from base projection
 - Adaptive-Low: 10% increase in transmission starting Sept 8th, 2020
 - Adaptive-High: 20% increase in transmission starting Sept 8th, 2020

Model Results

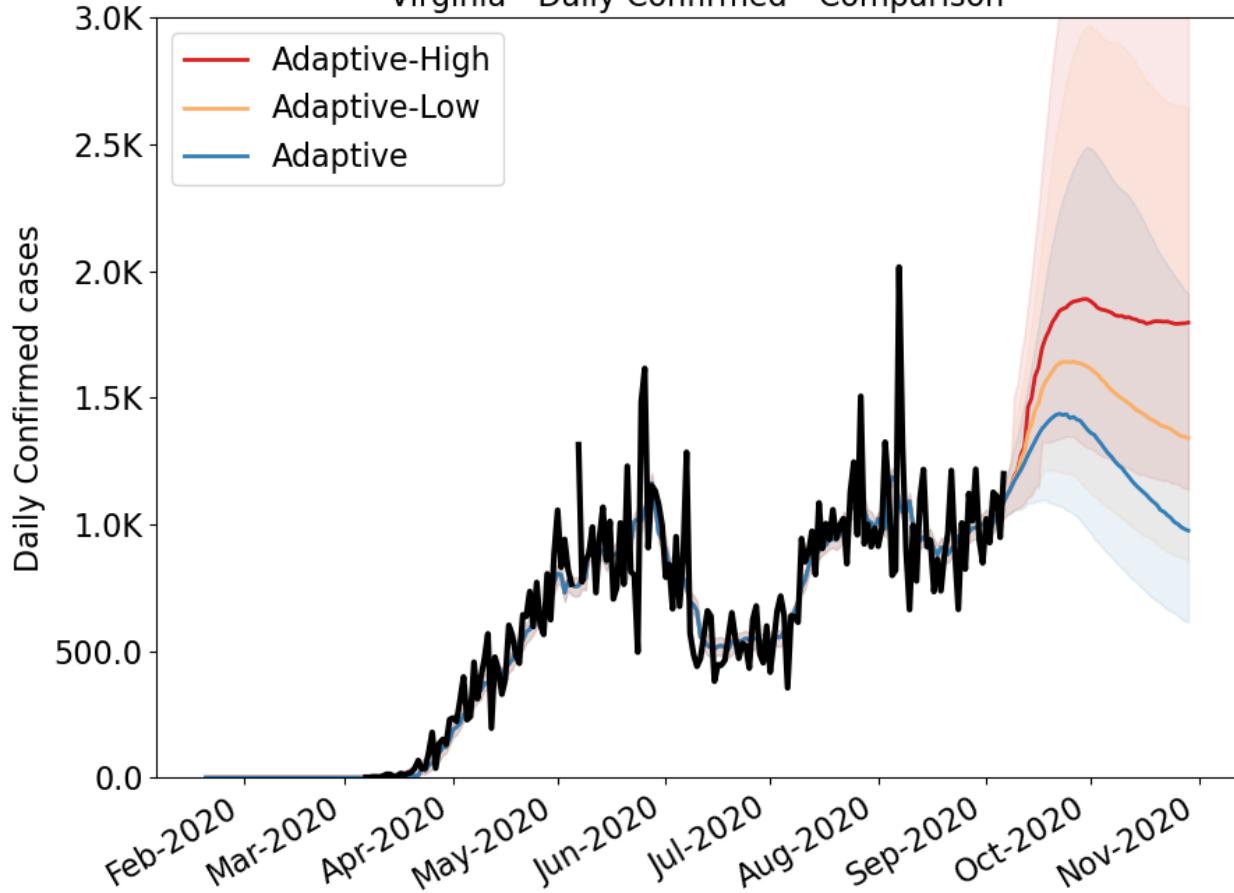


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Outcome Projections

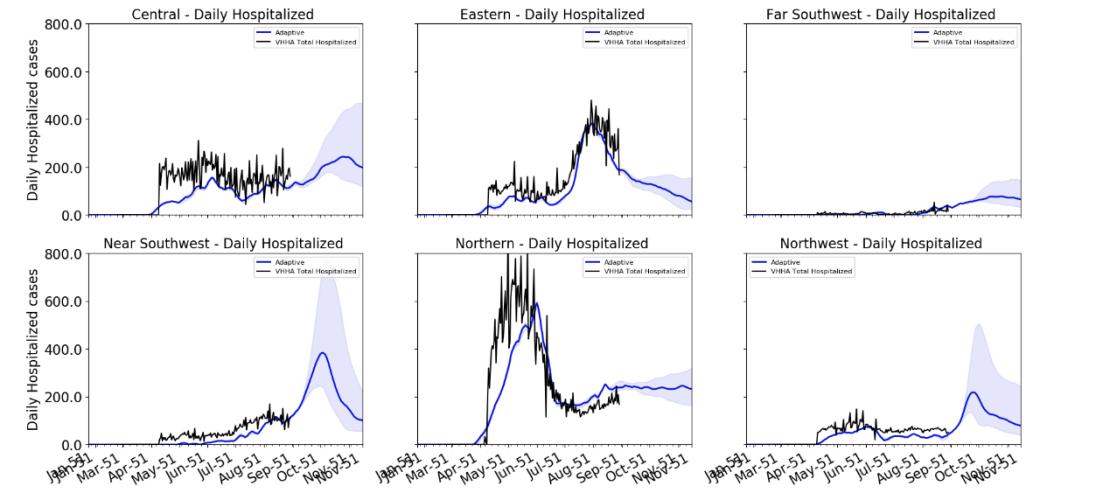
Confirmed cases

Virginia - Daily Confirmed - Comparison



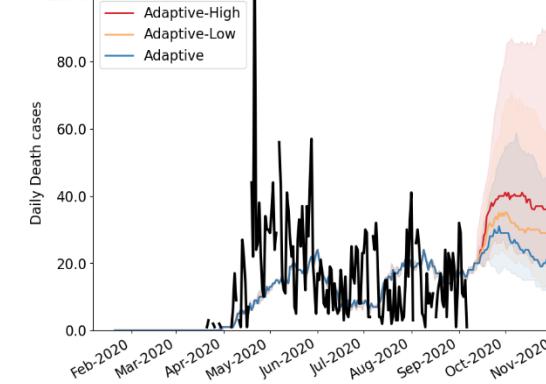
Estimated Hospital Occupancy

Virginia: Daily Total Confirmed Hospitalized Versus Sim - 8 Day Rolling



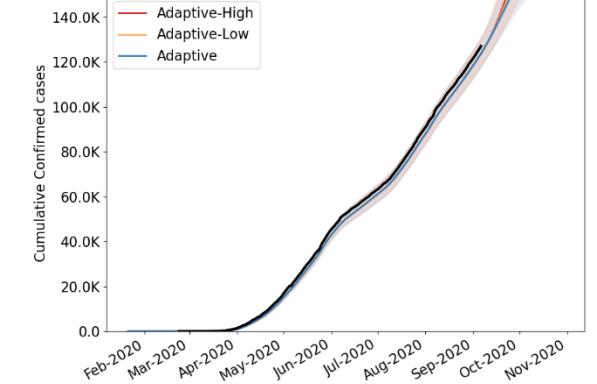
Daily Deaths

Virginia - Daily Death - Comparison



Cumulative Confirmed cases

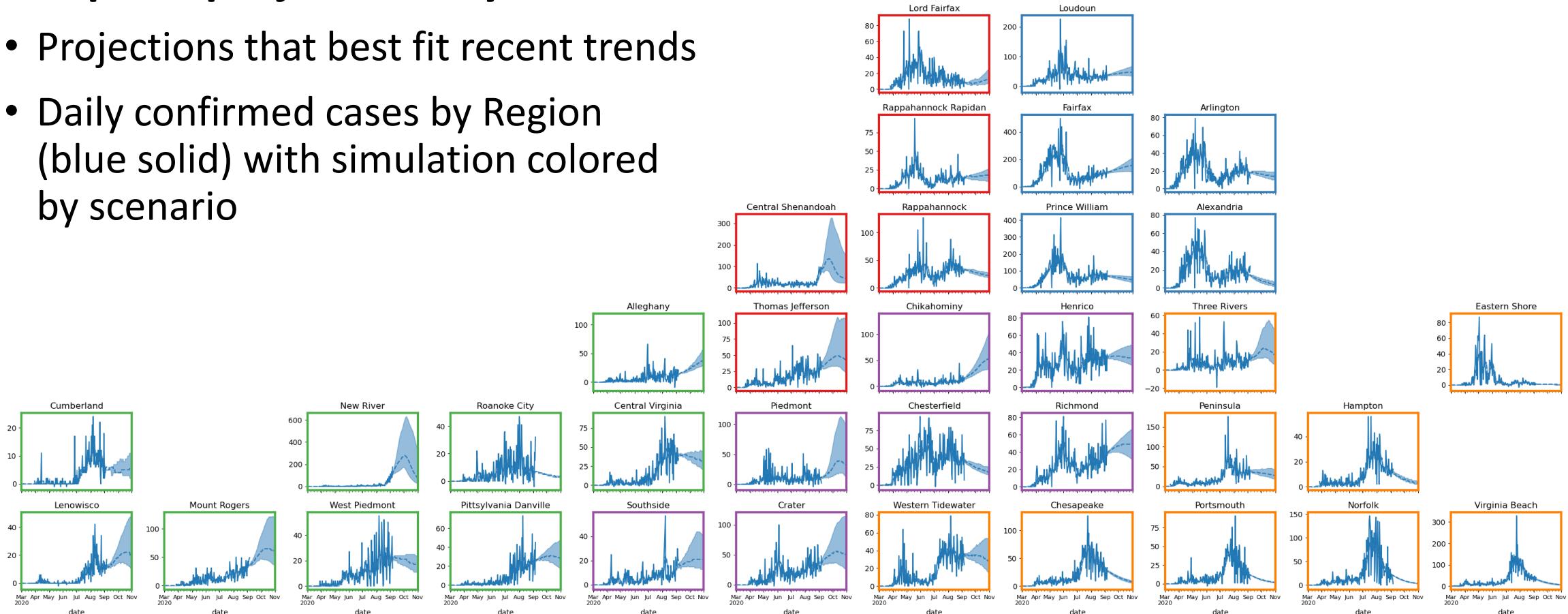
Virginia - Cumulative Confirmed - Comparison



District Level Projections: Adaptive

Adaptive projections by District

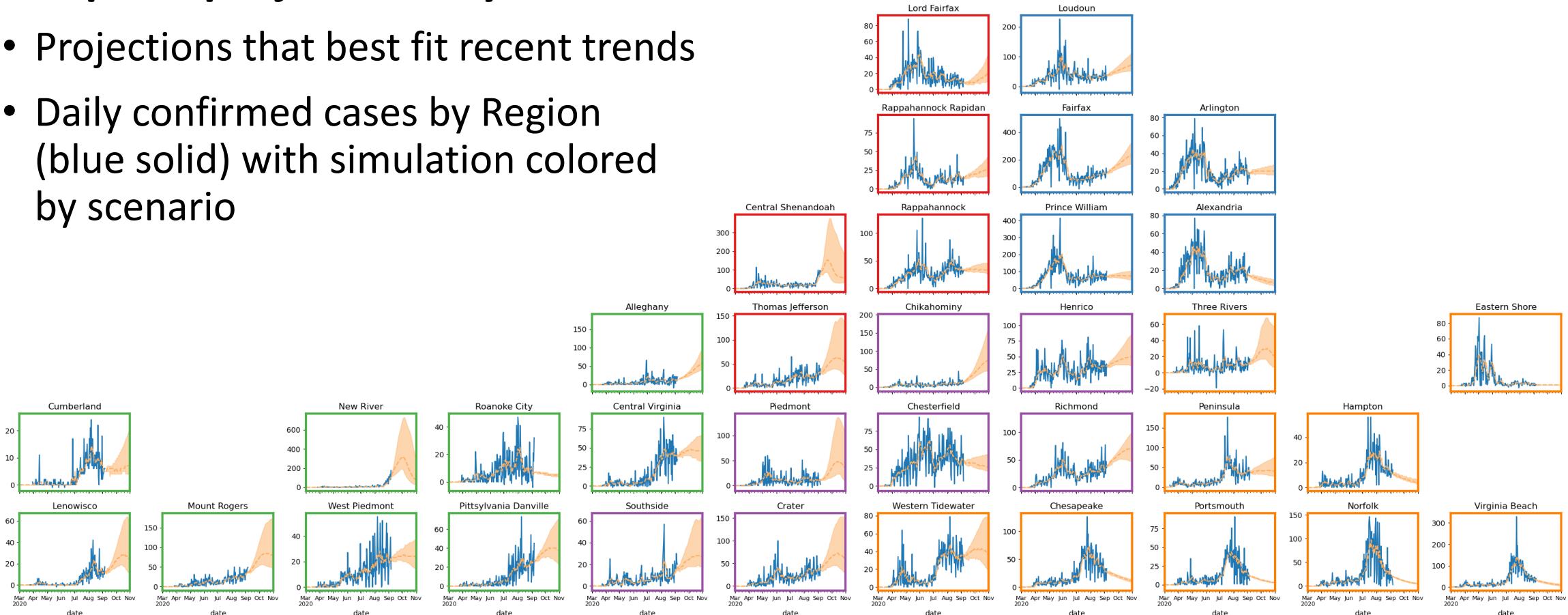
- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-Low

Adaptive projections by District

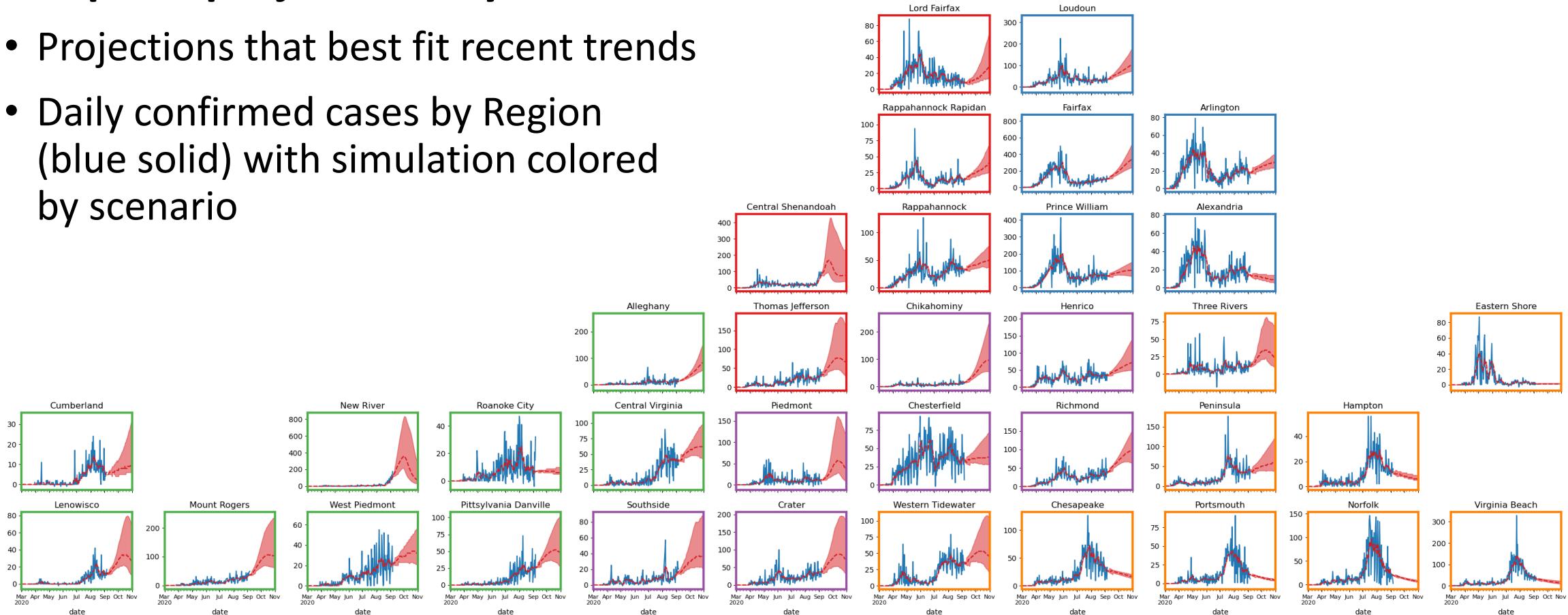
- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-High

Adaptive projections by District

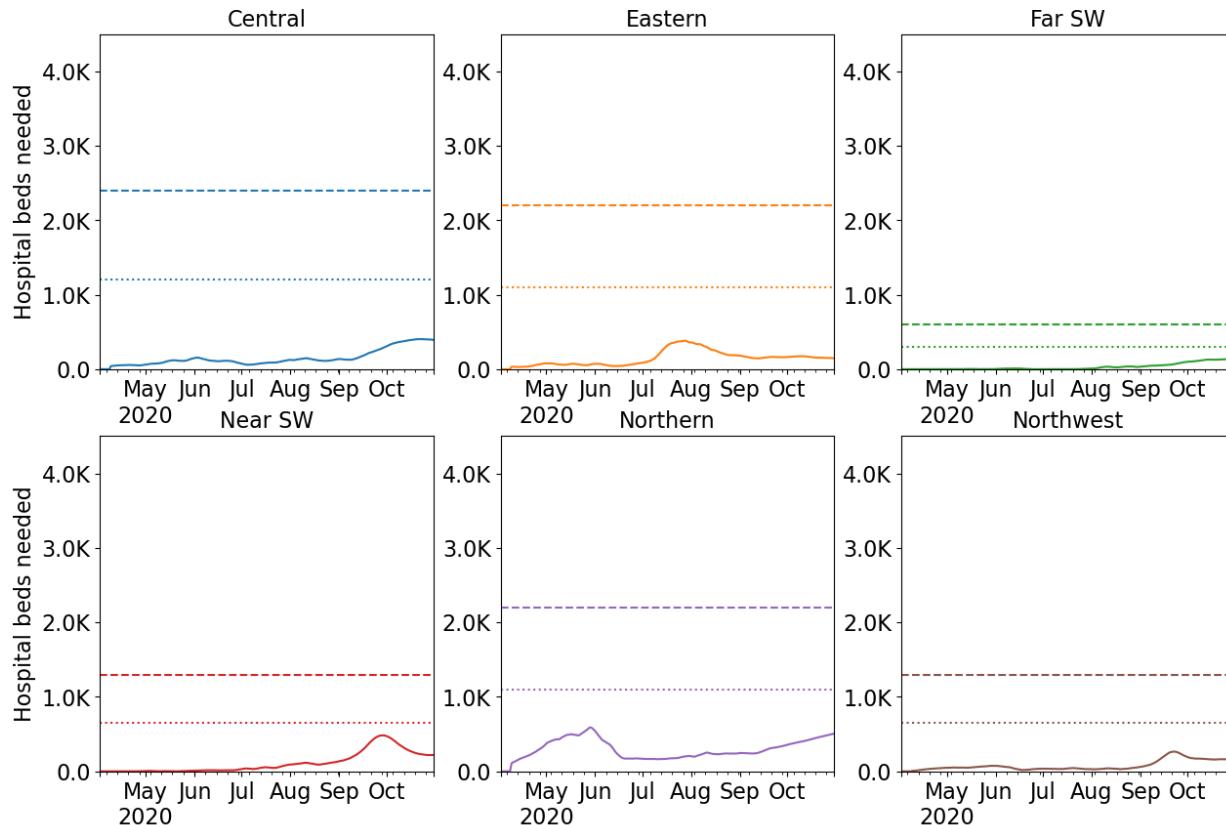
- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



Hospital Demand and Capacity by Region

Capacities by Region – Adaptive-High

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds



* Assumes average length of stay of 8 days

Week Ending	Adaptive	Adaptive-High
9/6/20	7,010	7,010
9/13/20	7,982	8,080
9/20/20	9,270	10,896
9/27/20	9,980	12,797
10/4/20	9,724	13,170
10/11/20	8,973	12,868
10/18/20	8,199	12,674
10/25/20	7,520	12,588
11/1/20	6,938	12,547
11/8/20	6,478	12,450
11/15/20	6,073	12,241
11/22/20	5,670	11,850

Based on Adaptive-High scenario

- No regions forecast to exceed capacity

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Mixed trends remain, with strong surges in several districts.**
- Incidence hovers at national average, which is higher this week ~13/100K.
- Projections are also mixed across a range of slow-growth, plateaus, and declines.
- Recent updates:
 - Adaptive Fitting projection remains, slight adjustments to projection filtering.
 - Trajectory descriptions more fully developed.
- The situation is changing rapidly. Models will be updated regularly.

References

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- Arindam Fadikar, Dave Higdon, Jiangzhuo Chen, Bryan Lewis, Srinivasan Venkatramanan, and Madhav Marathe. Calibrating a stochastic, agent-based model using quantile-based emulation. *SIAM/ASA Journal on Uncertainty Quantification*, 6(4):1685–1706, 2018.
- Adiga, Aniruddha, Srinivasan Venkatramanan, Akhil Peddireddy, et al. "Evaluating the impact of international airline suspensions on COVID-19 direct importation risk." *medRxiv* (2020)
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- Biocomplexity Institute. COVID-19 Surveillance Dashboard. <https://nssac.bii.virginia.edu/covid-19/dashboard/>
- Google. COVID-19 community mobility reports. <https://www.google.com/covid19/mobility/>
- Cuebiq: COVID-19 Mobility insights. <https://www.cuebiq.com/visitation-insights-covid19/>
- Biocomplexity page for data and other resources related to COVID-19: <https://covid19.biocomplexity.virginia.edu/>

Questions?

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Biocomplexity COVID-19 Response Team

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Supplemental Slides

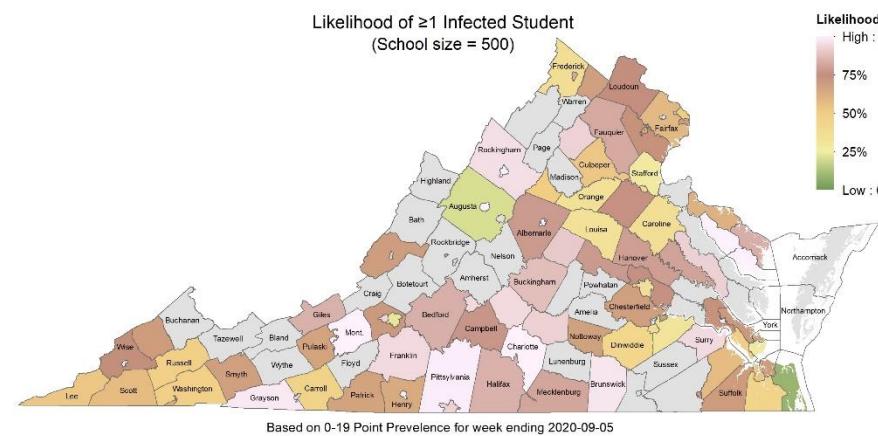
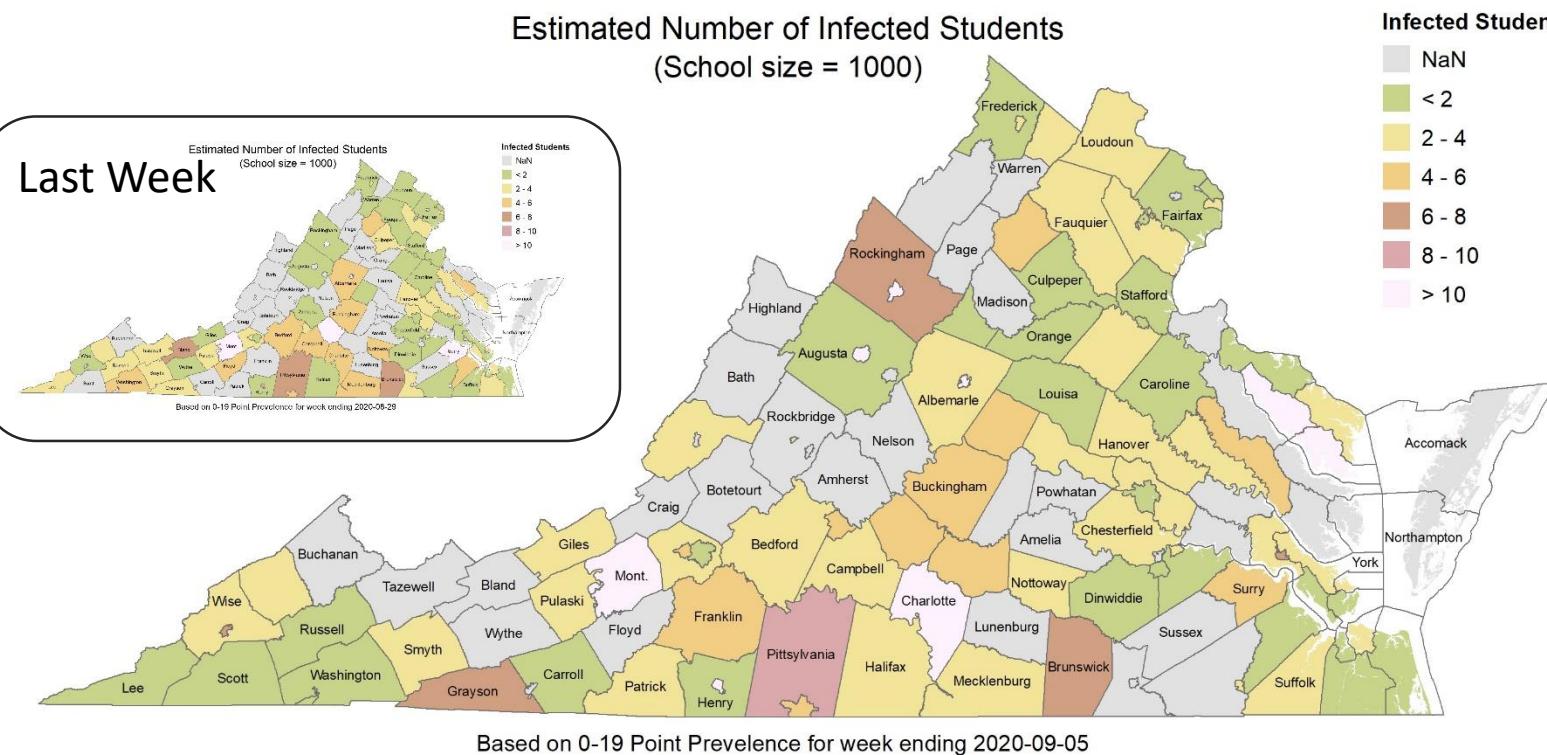


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School Age Prevalence

If all schools were open this past week, how many infected students might we expect to be in attendance?

- Based on prevalence during week of August 30 – Sept 5th
- Using school-age incidence in the last week, we estimate the likelihood any collection of school age kids in a school size of 500 will have at least one infection
- Assume that for each confirmed case there are 6 other undetected infections



Recent Parameter Validation

New York State announced sero-prevalence survey results on May 2nd

- 15,000 antibody tests conducted randomly through the state at grocery stores
- **Total Attack Rate:** 12.3%

Estimation of undetected infections

- Total infections in NY = 2.46M, total of 300K confirmed cases
- Confirmed case detection = 12% of infections (close to 15% used in model)

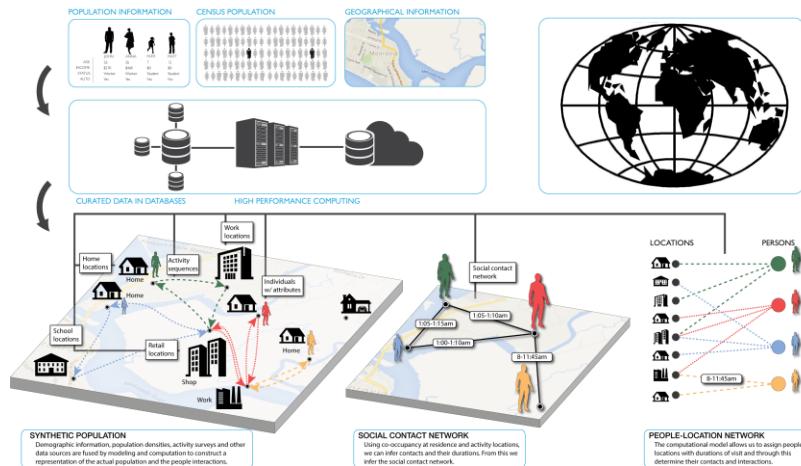
Estimation of hospitalizations from infections

- Total infections in NY = 2.46M, total of 66K hospitalizations
- Hospitalizations = 2.7% of infections (close to 2.25% used in model)

Agent-based Model (ABM)

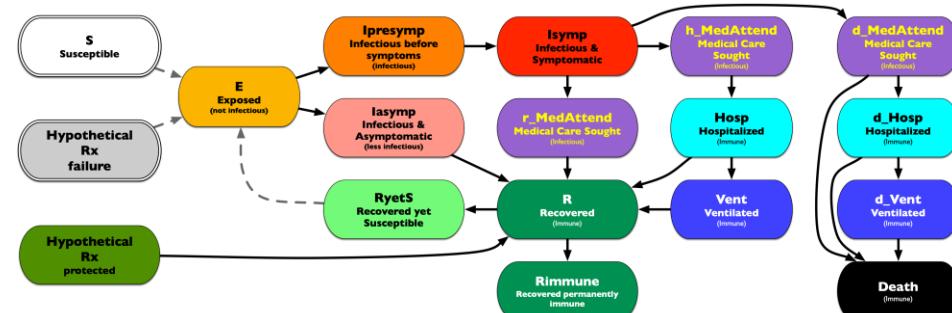
EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments

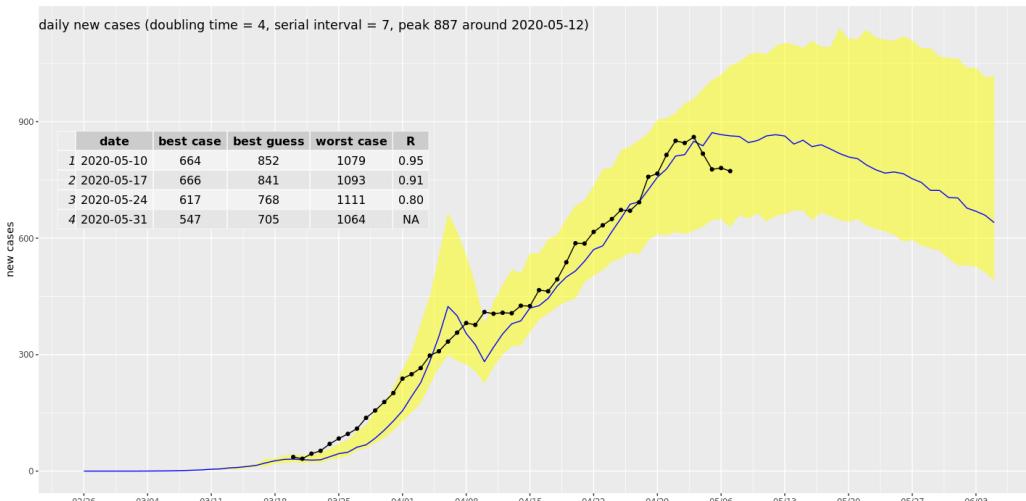


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ABM Social Distancing Rebound Study Design

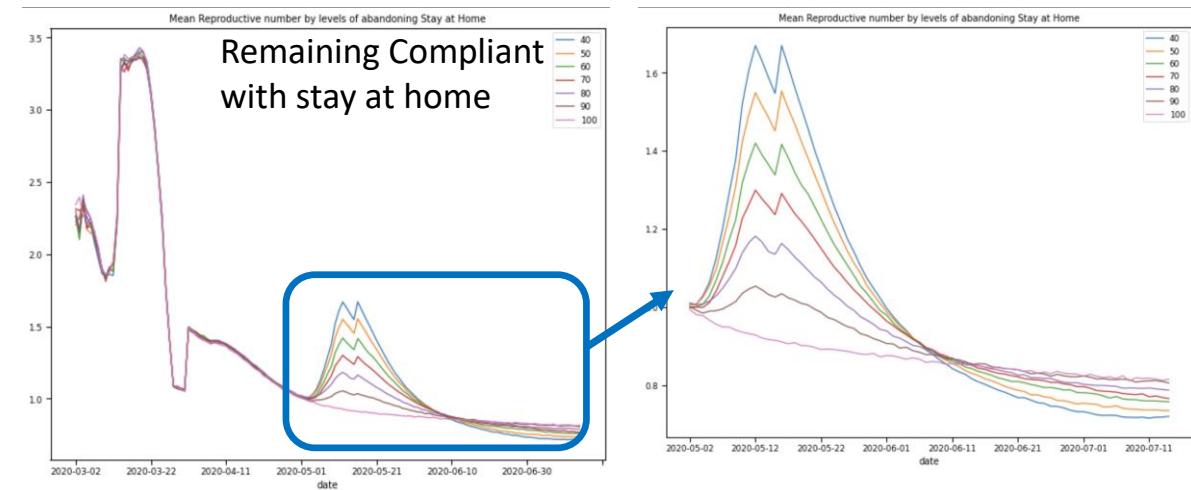
Study of "Stay Home" policy adherence

- Calibration to current state in epidemic
- Implement “release” of different proportions of people from “staying at home”



Calibration to Current State

- Adjust transmission and adherence to current policies to current observations
- For Virginia, with same seeding approach as PatchSim

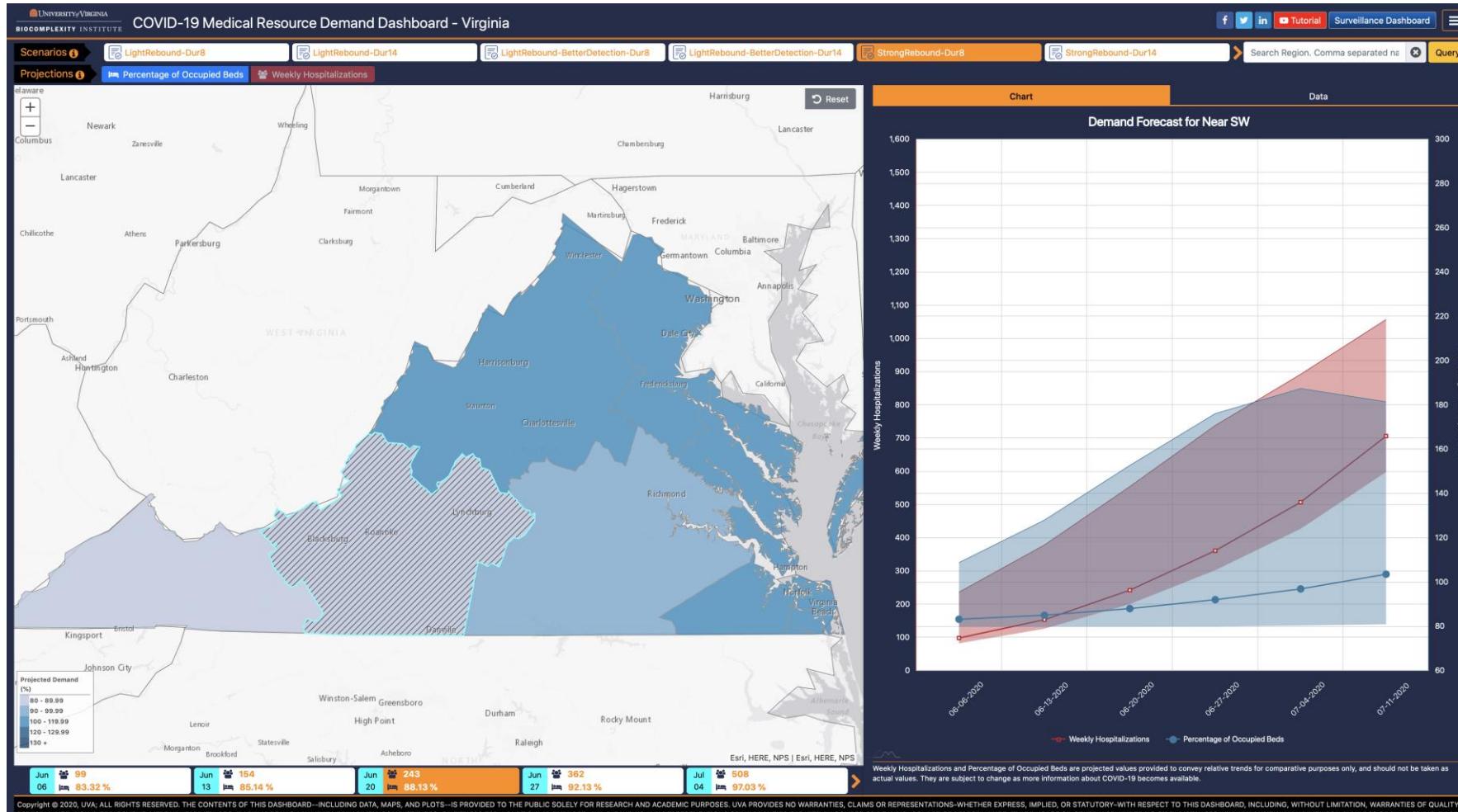


Impacts on Reproductive number with release

- After release, spike in transmission driven by additional interactions at work, retail, and other
- At 25% release (70-80% remain compliant)
- Translates to 15% increase in transmission, which represents a 1/6th return to pre-pandemic levels

Medical Resource Demand Dashboard

<https://nssac.bii.virginia.edu/covid-19/vmrddash/>



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