

Network Systems
Science & Advanced
Computing

Biocomplexity Institute
& Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

September 23rd, 2020

(data current to September 22nd)

Biocomplexity Institute Technical report: TR 2020-115



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, surges continue in several districts.**
- VA weekly incidence (11.6/100K) below national average (14/100K) which is slightly down compared to last week.
- Projections are also mixed across a range of slow-growth, plateaus, and declines.
- Recent updates:
 - Adaptive Fitting projection remains, slight adjustments to projection filtering.
 - Planning Scenarios moved to Oct 1st.
- The situation is changing rapidly. Models will be updated regularly.



Situation Assessment

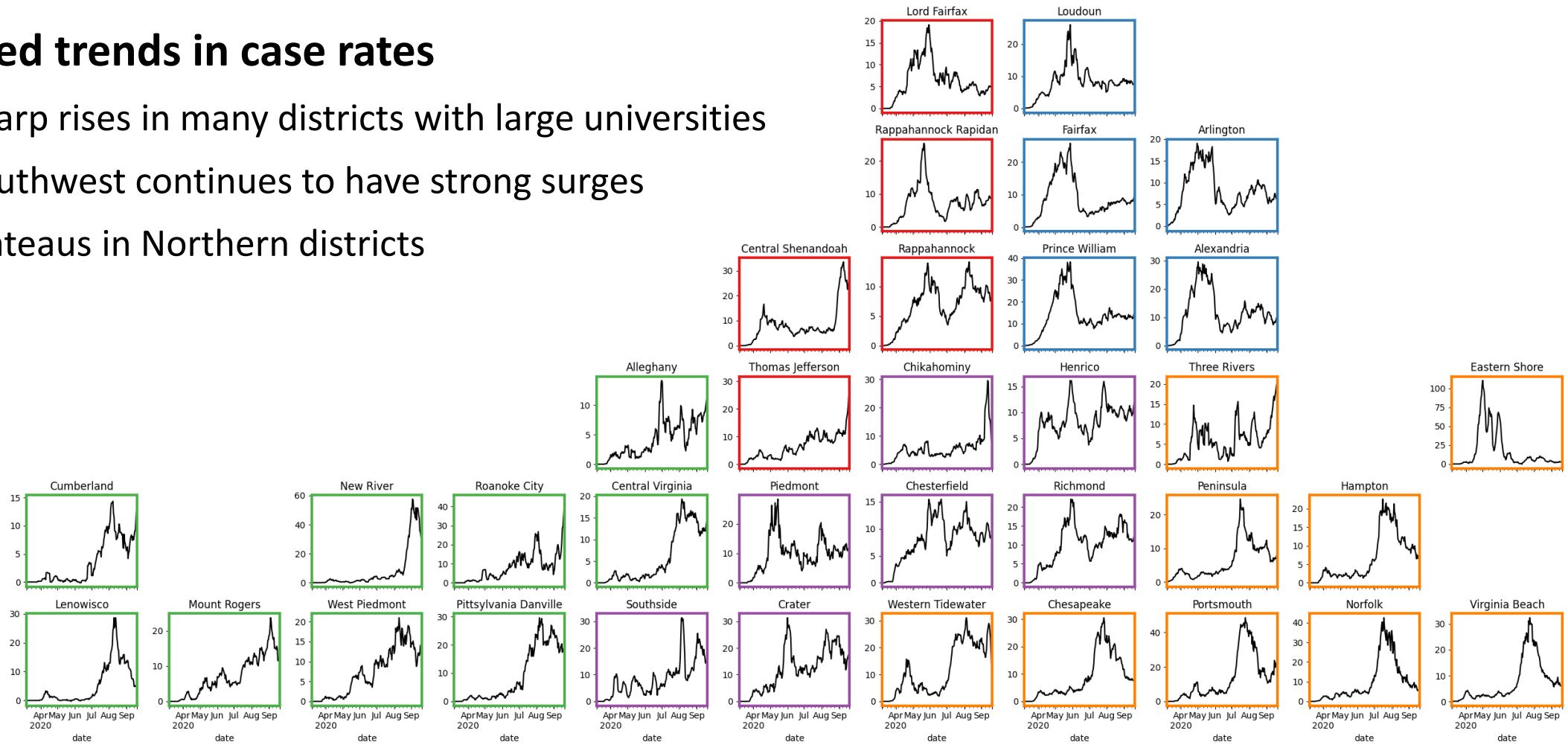


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Case Rate (per 100k) by VDH District

Mixed trends in case rates

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

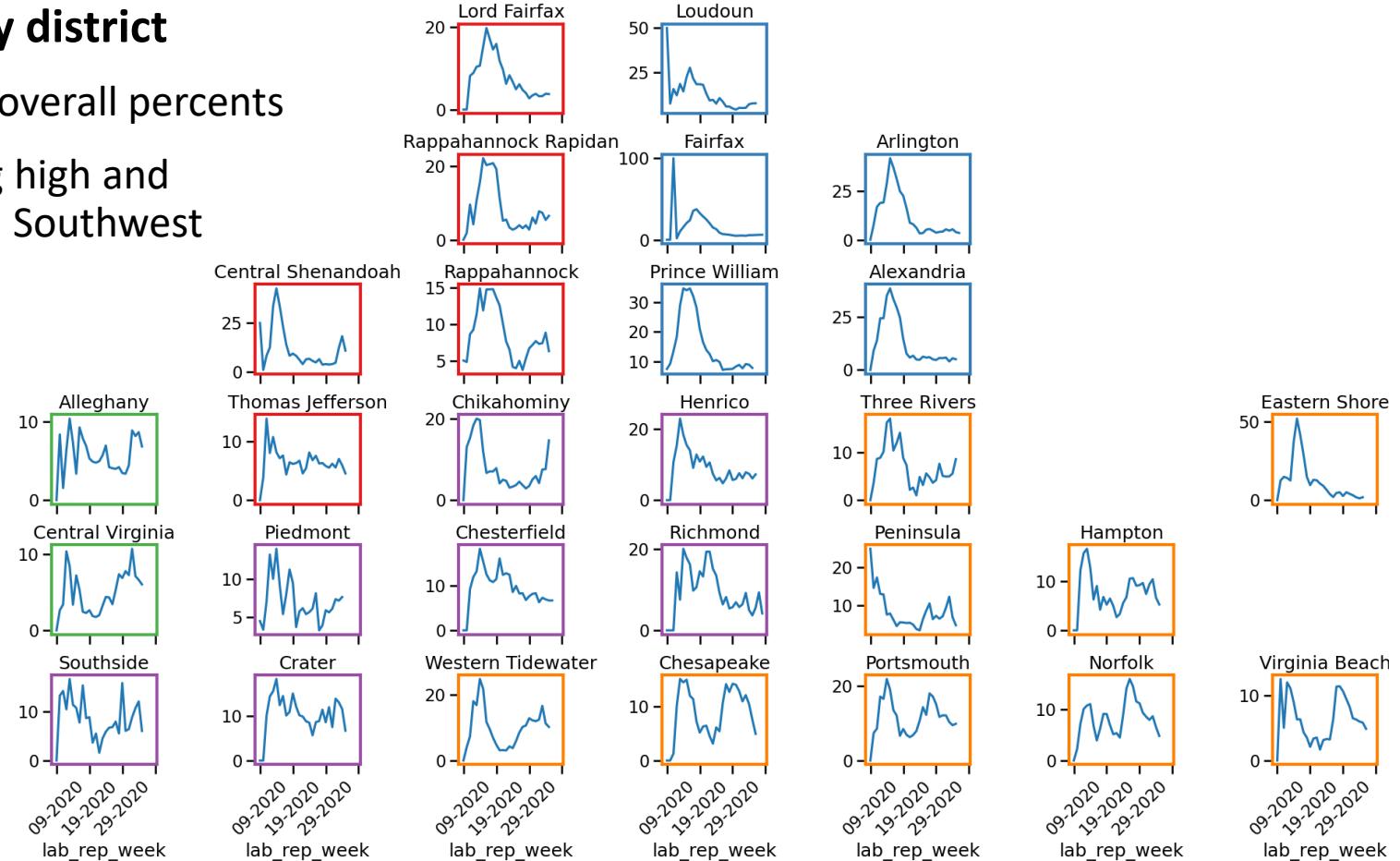
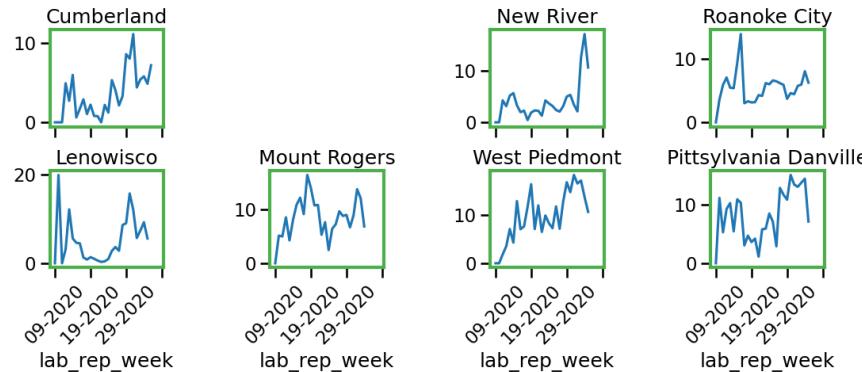


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Test Positivity by VDH District

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



District Trajectories – New Surges starting

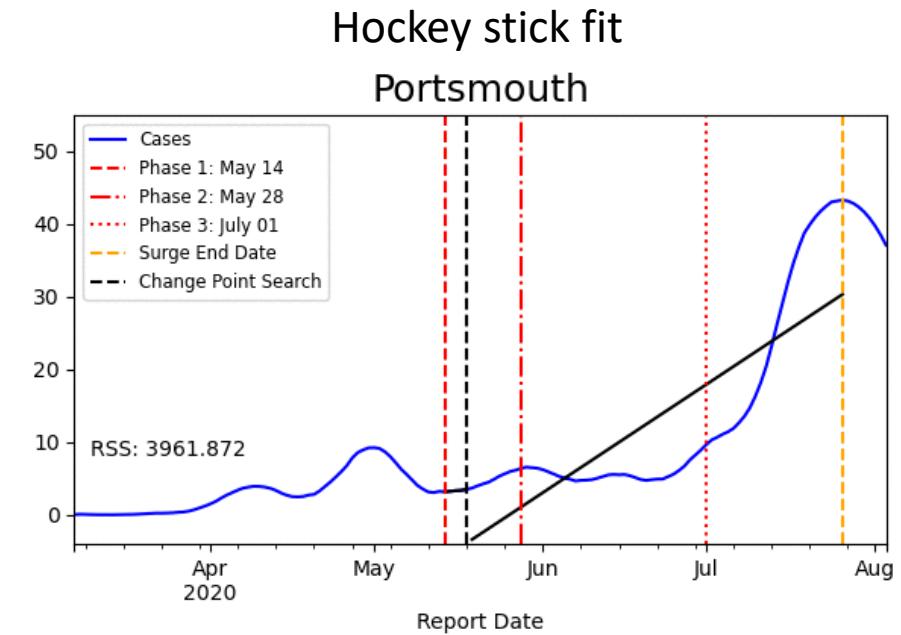
Hockey stick fit used to describe recent growth patterns

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

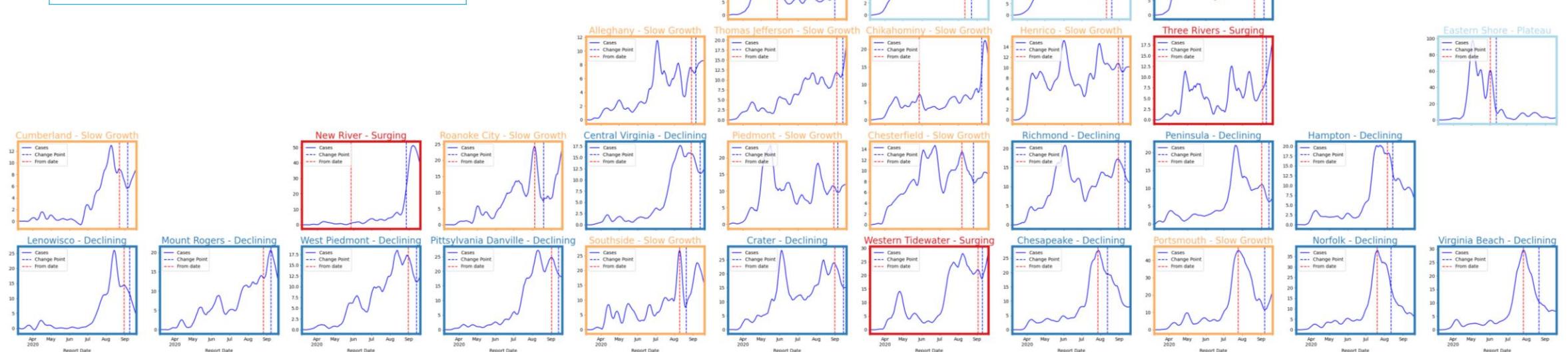
In Surge: Currently experiencing sustained rapid growth and exceeds recent inflection points



Status	# Districts (last week)
Declining	13 (13)
Plateau	6 (10)
Slow Growth	13 (10)
In Surge	3 (2)

District Trajectories – Declines outpace Growth

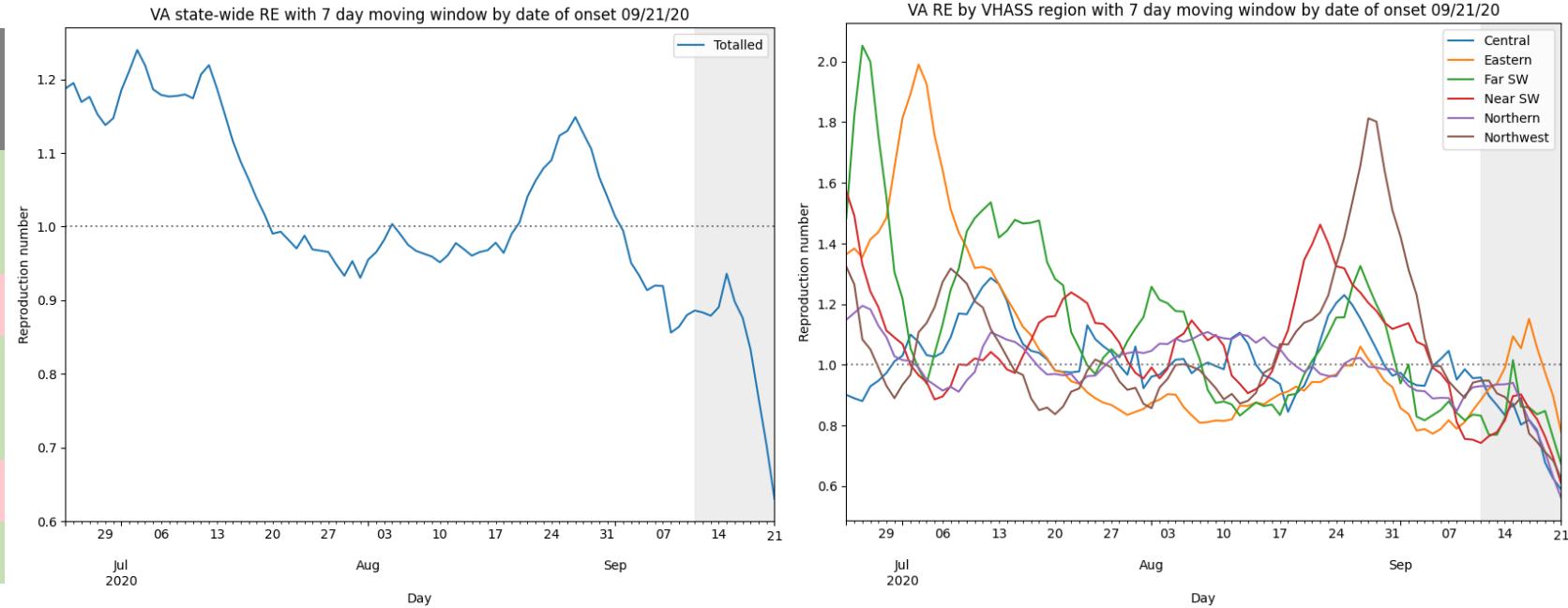
Status	# Districts (last week)
Declining	13 (13)
Plateau	6 (10)
Slow Growth	13 (10)
In Surge	3 (2)



Estimating Daily Reproductive Number

September 12th Estimates

Region	Current R_e	Diff Last Week
State-wide	0.883	-0.011
Central	0.898	-0.067
Eastern	0.921	0.130
Far SW	0.769	-0.045
Near SW	0.764	-0.224
Northern	0.929	0.096
Northwest	0.948	-0.035



Methodology

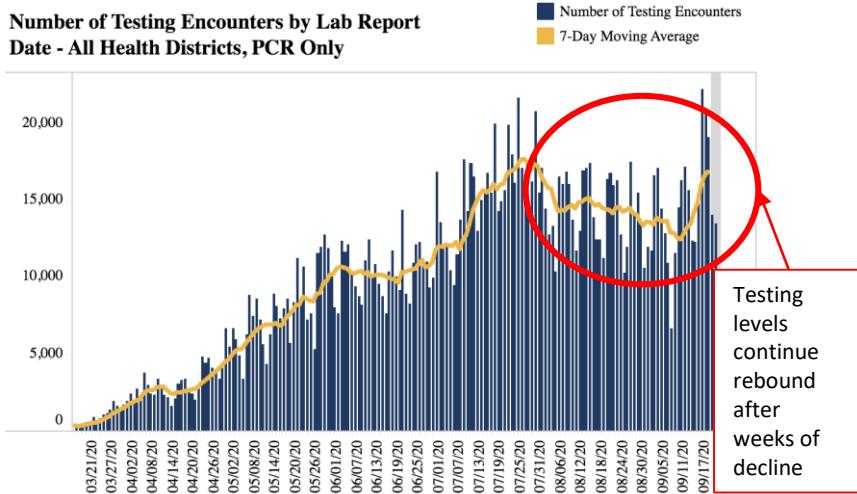
- Wallinga-Teunis method (EpiEstim¹) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

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>

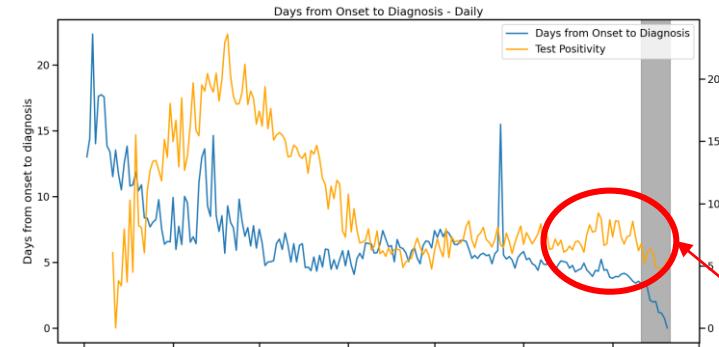
Changes in Case Detection

Timeframe (weeks)	Mean days	% difference from overall mean
April (13-16)	8.42	39%
May (17-21)	5.66	-7%
June (22-25)	5.85	-3%
July (26-30)	6.26	3%
Aug (31-34)	4.67	-23%
Sept [first week] (35)	3.94	-35%
Overall (13-33)	6.06	0%

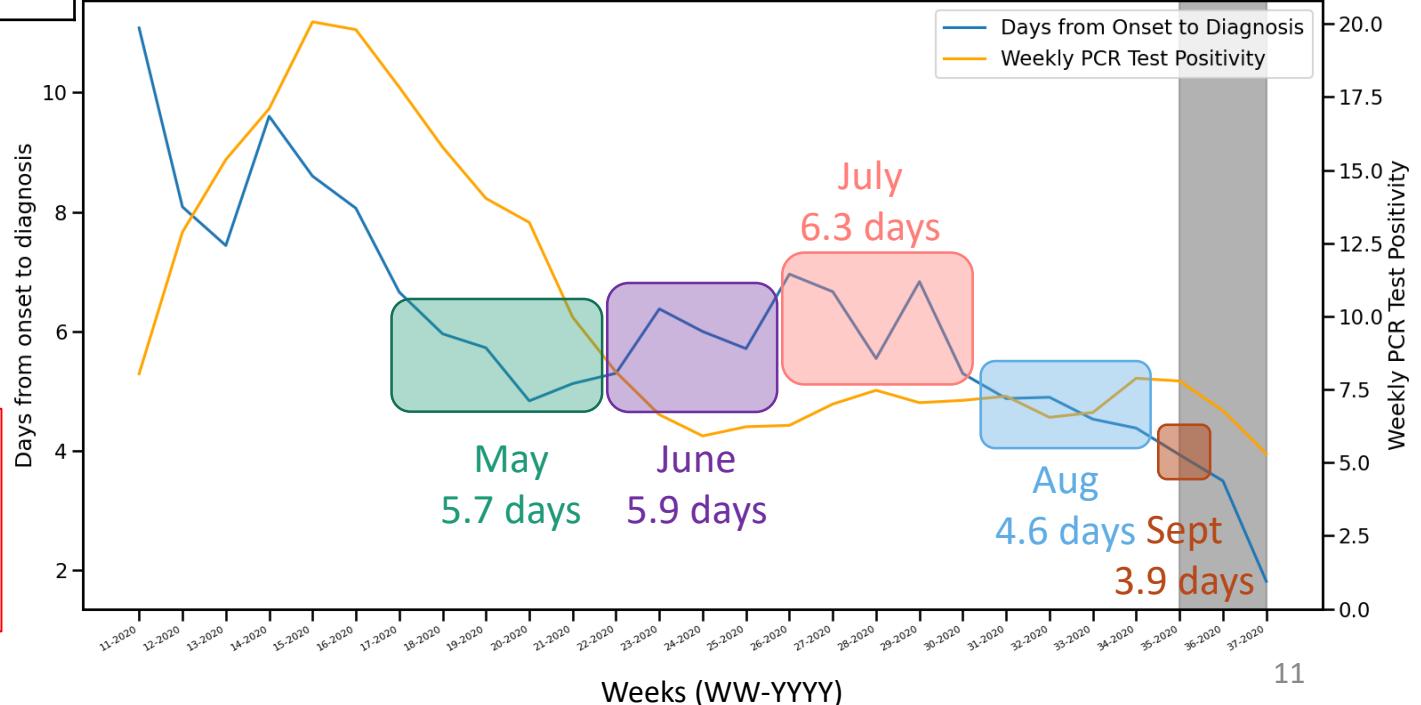
Testing Encounters and test positivity have steadied and increased



Test positivity vs. Onset to Diagnosis



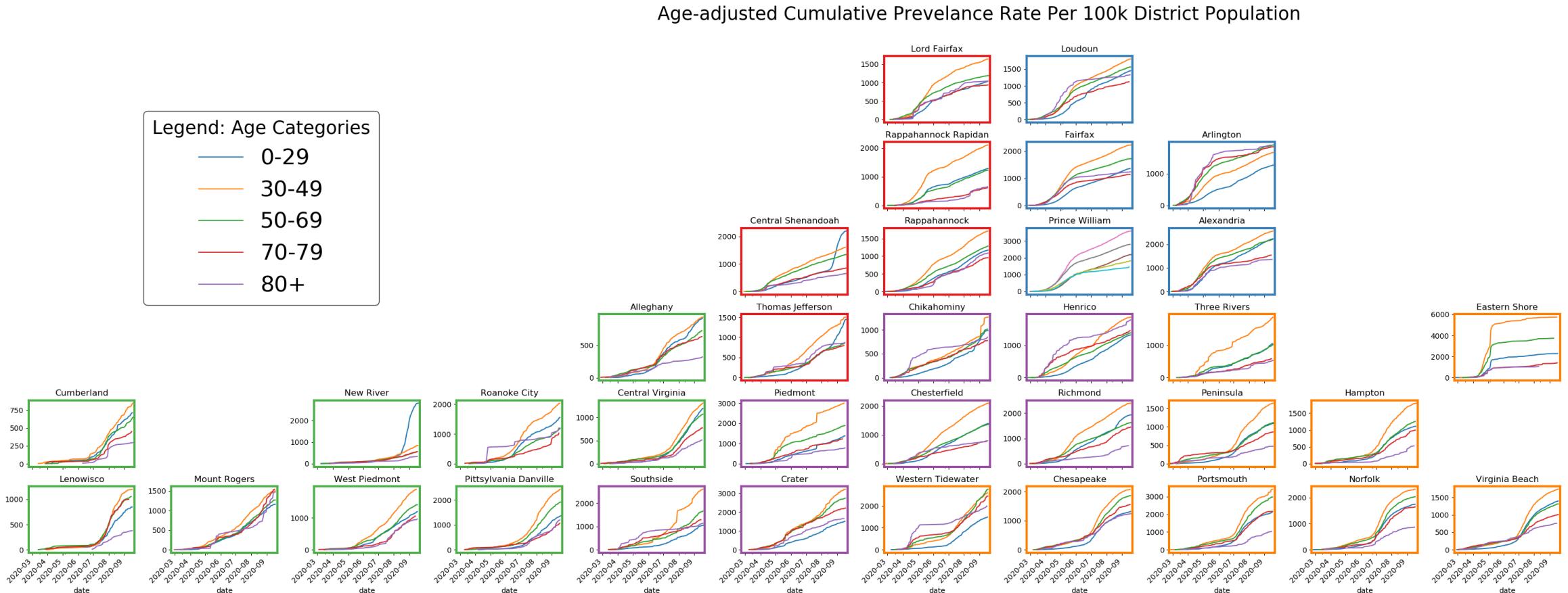
Days from Onset to Diagnosis and Test Positivity - Weekly



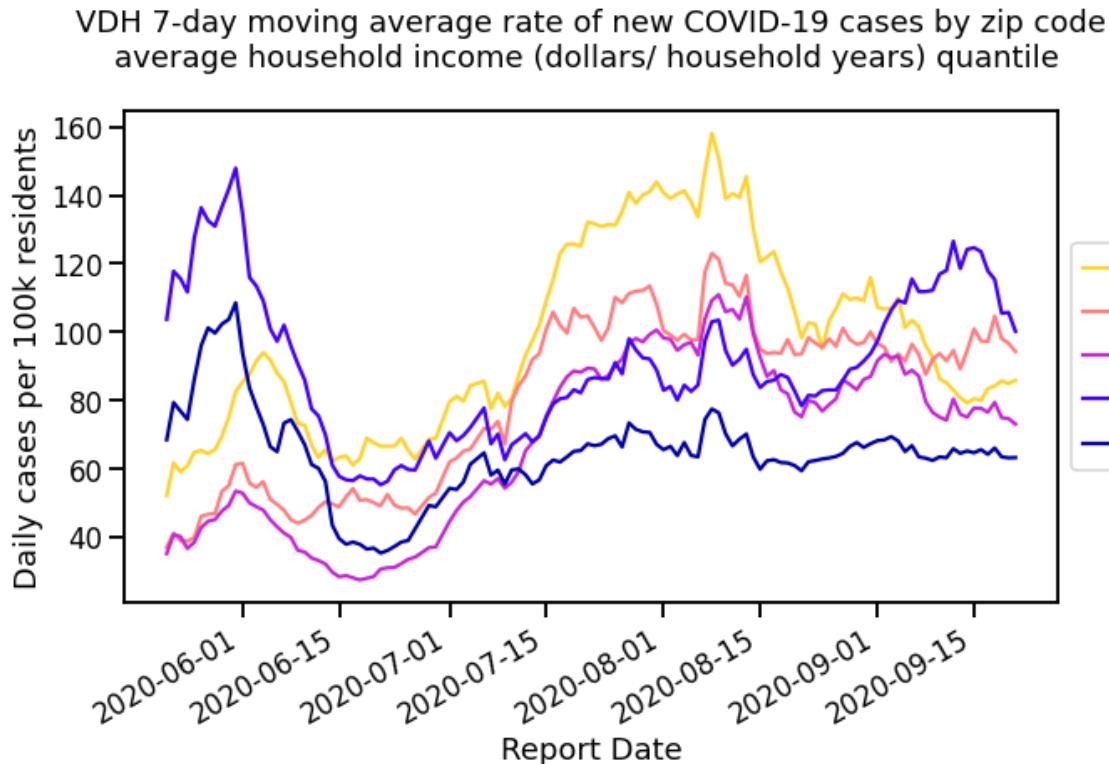
Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

- Younger age groups outpace older in many districts

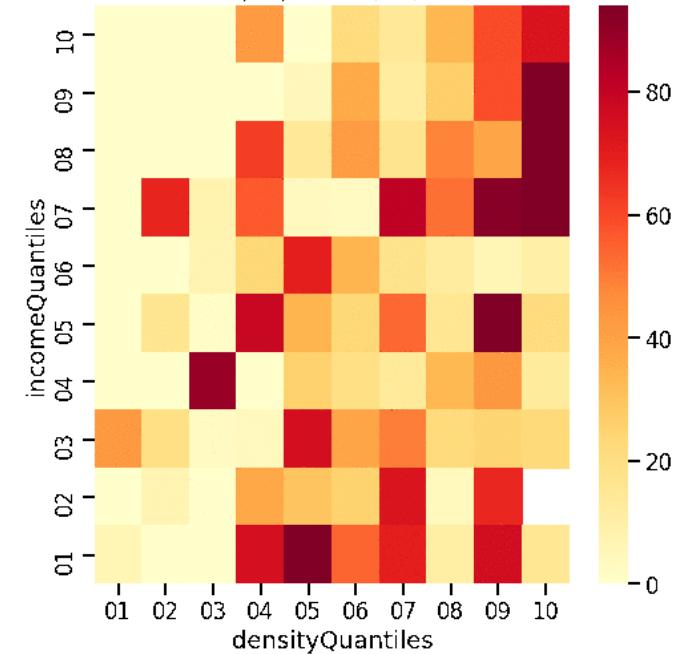


Impact across Density and Income



Shift back to higher income zip codes partially driven by surges in areas surrounding universities

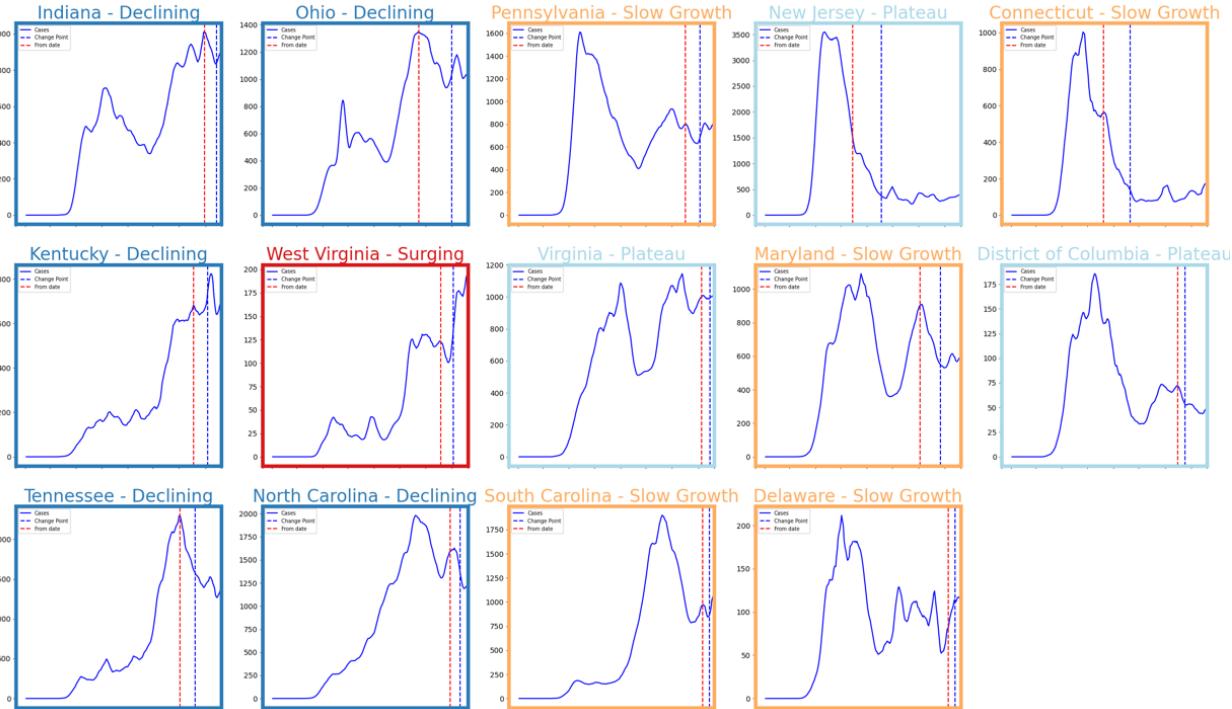
VDH mean cases per 100k by zip code population density (person/ sq mile)
and average household income (dollars/ household years) quantiles
05/15/20 - 05/21/20



Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes, then recently back to denser wealthier zip codes

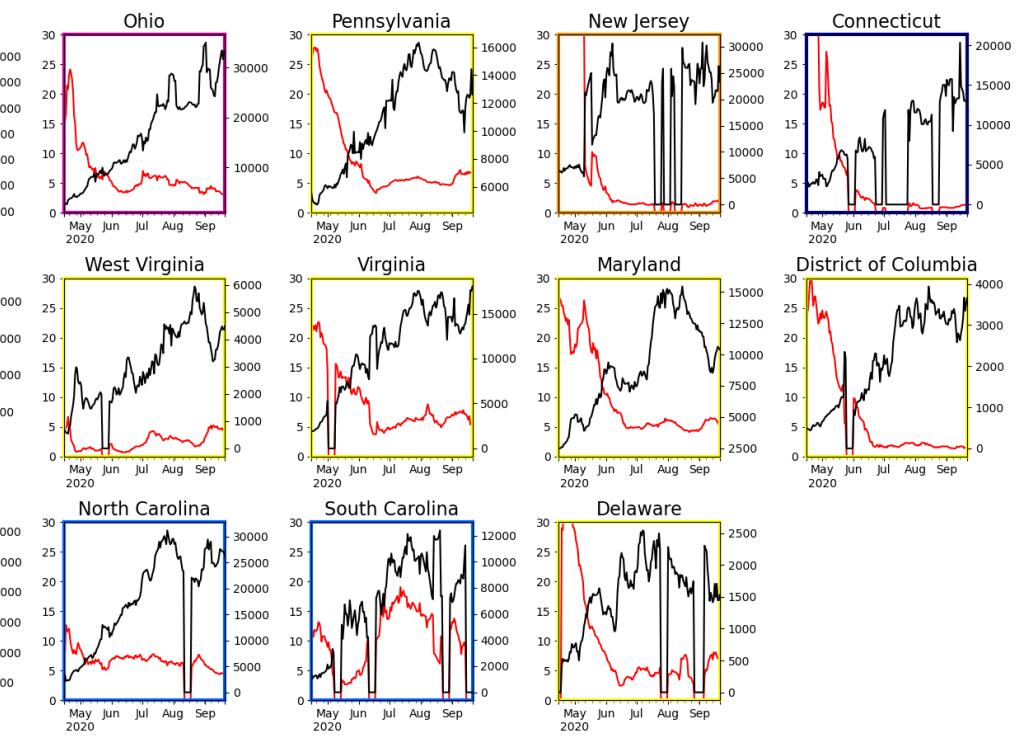
Other State Comparisons

Trajectories of States



- Mixture of trajectories
- VA plateauing
- WV surging, but many others declining
- MD, DE, PA, SC showing slow growth

Tests per Day and Test Positivity



- Test positivity mixed, VA shows steady pattern with recent dip.
- Testing volumes steady and plateaued in most states.

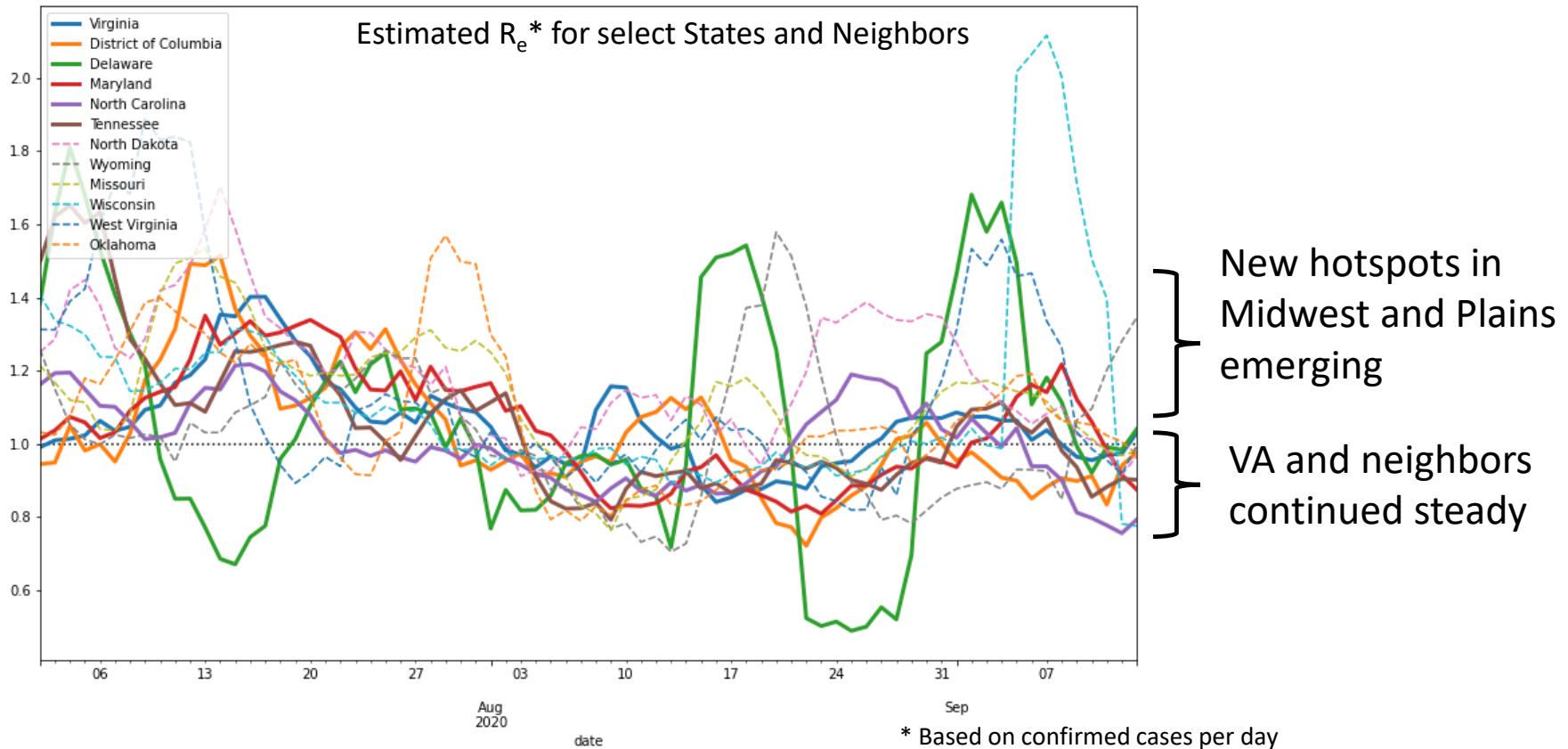


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Other State Comparisons

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

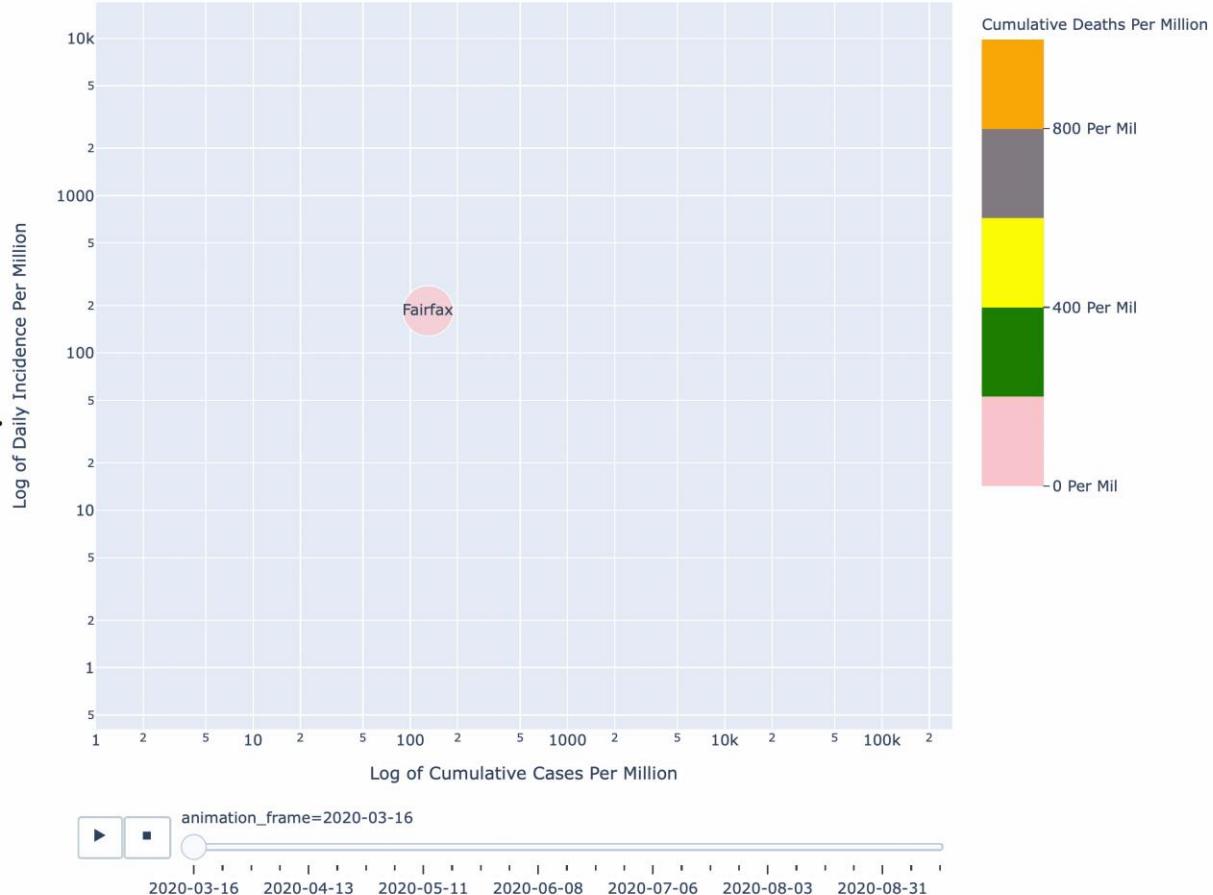
- New states in Midwest and Plains emerging as hot spots: MO, ND, OK, WI, WY, as well as WV
- Virginia and neighboring states are mostly at and below 1



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

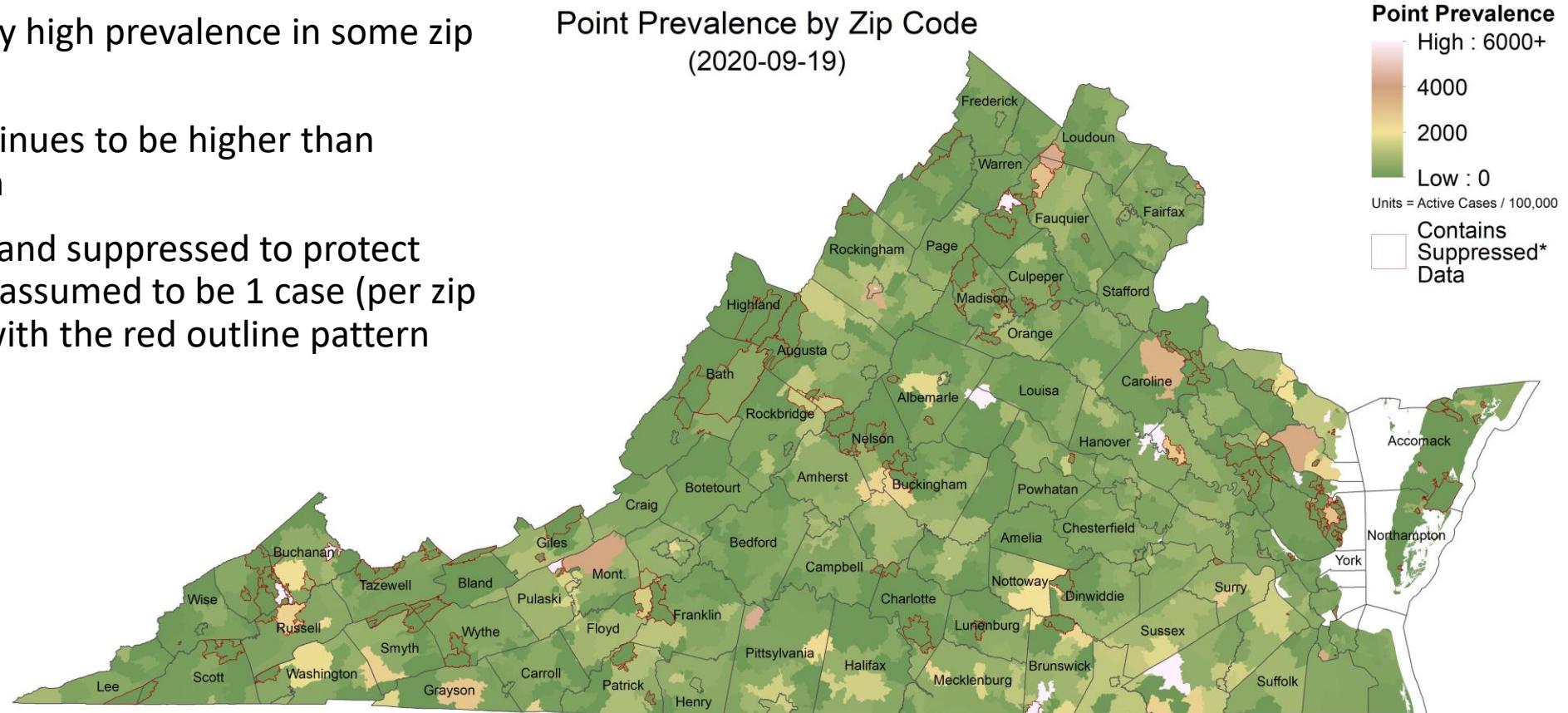
SMOOTH Va Districts: WEEKLY Exponential Growth of Cases (Size Proportional To Effective Reproduction Number)



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 red outline pattern

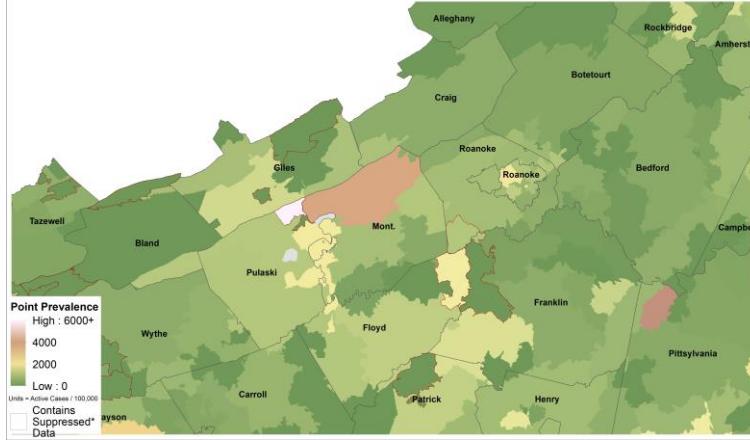


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Zip code level weekly Case Rate (per 100K)

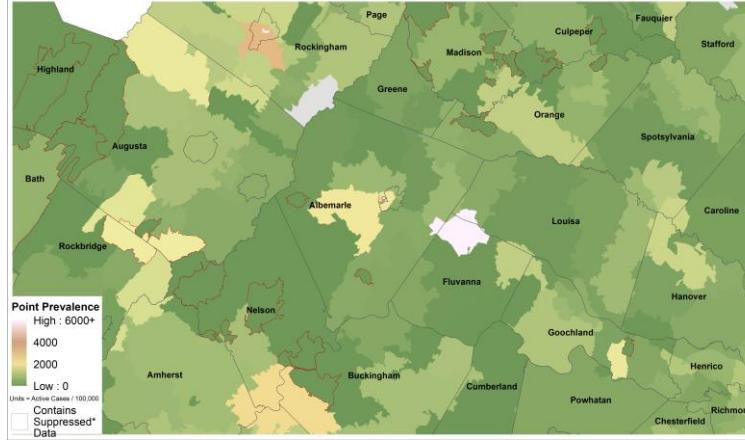
Roanoke / B'burg

Point Prevalence by Zip Code
2020-09-13 to 2020-09-19



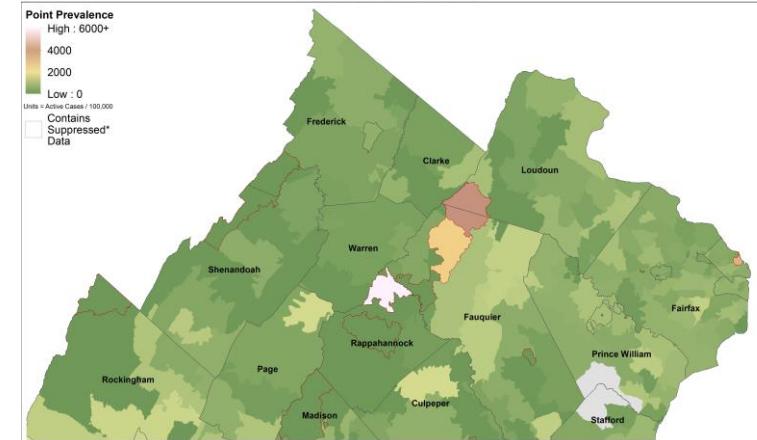
Albemarle

Point Prevalence by Zip Code
2020-09-13 to 2020-09-19



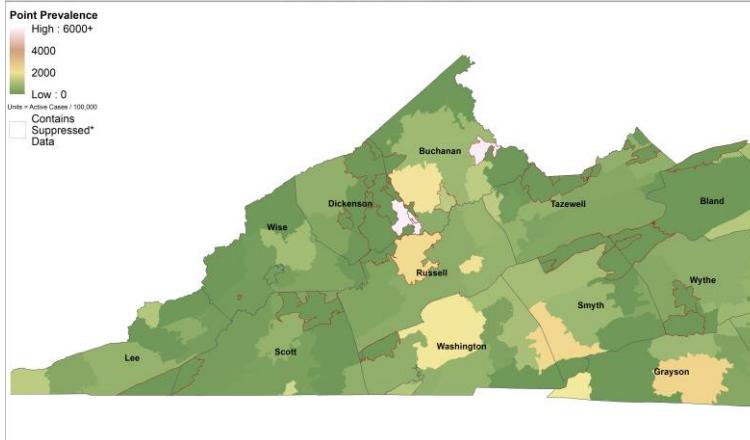
Northern Virginia

Point Prevalence by Zip Code
2020-09-13 to 2020-09-19



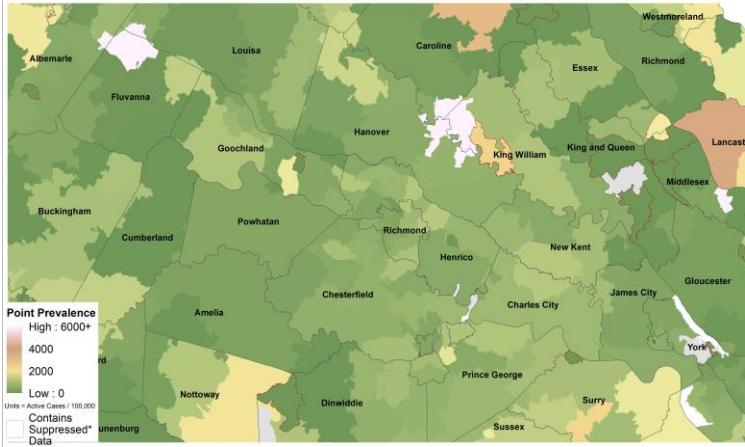
Far Southwest

Point Prevalence by Zip Code
2020-09-06 to 2020-09-12



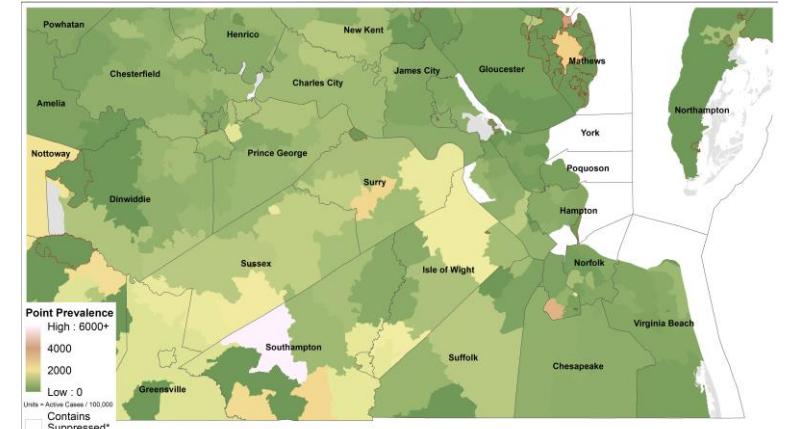
Richmond

Point Prevalence by Zip Code
2020-09-13 to 2020-09-19



Tidewater

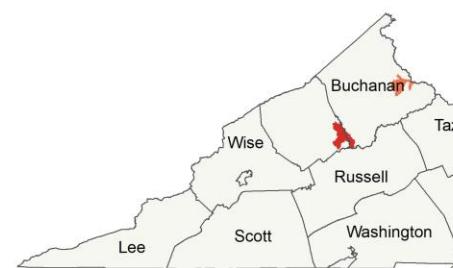
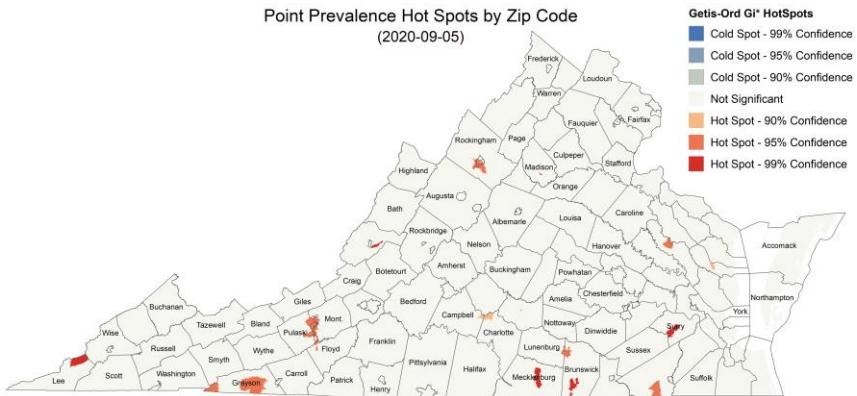
Point Prevalence by Zip Code
2020-09-13 to 2020-09-19



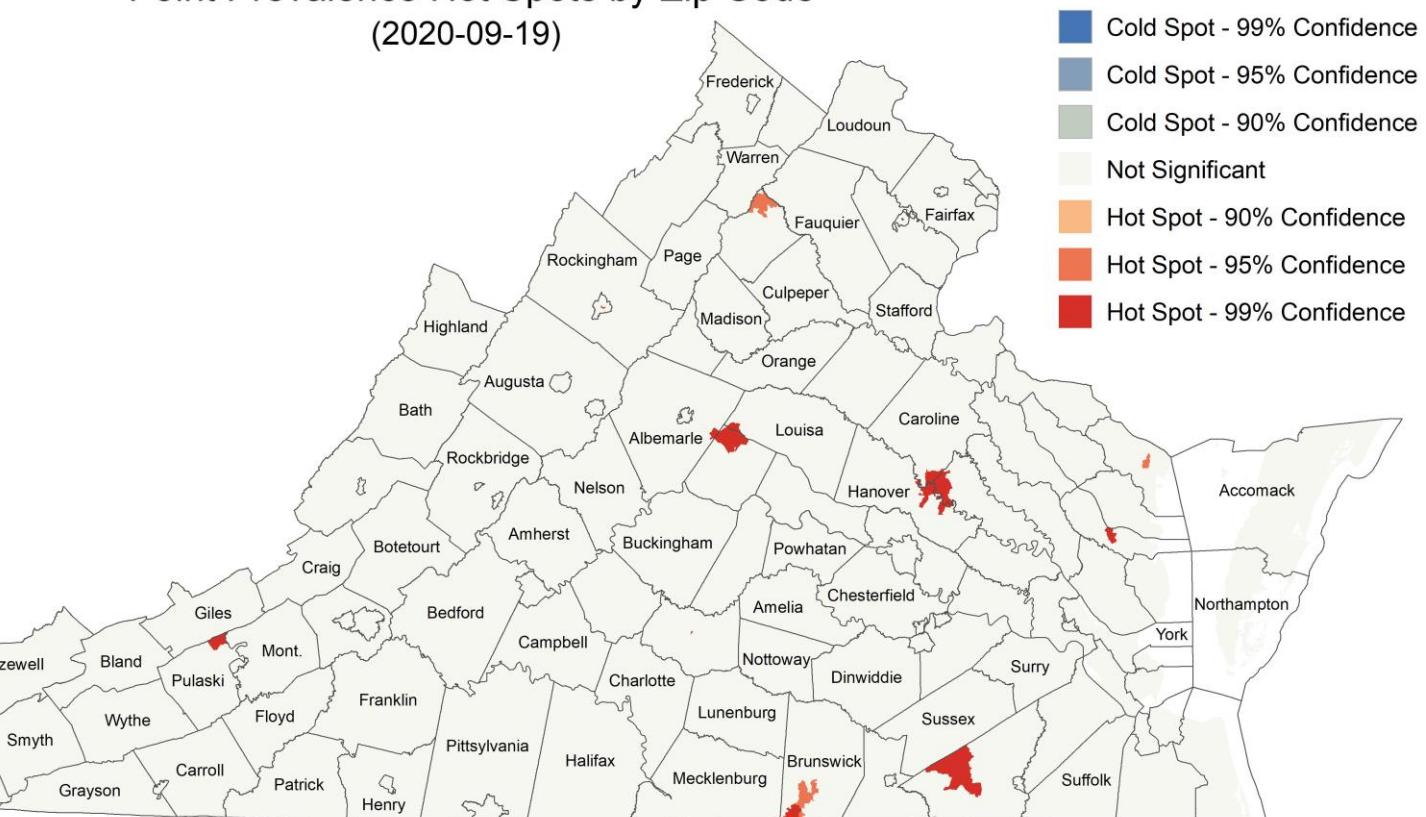
24-Sep-20

Zip Code Hot Spots

Previous weeks



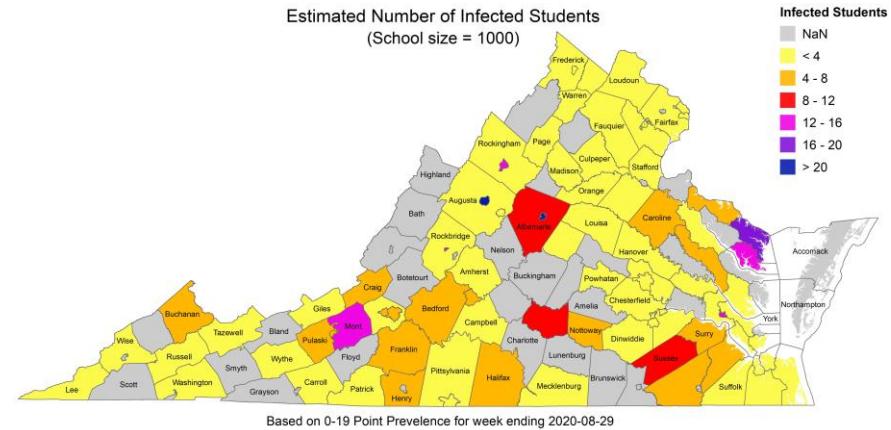
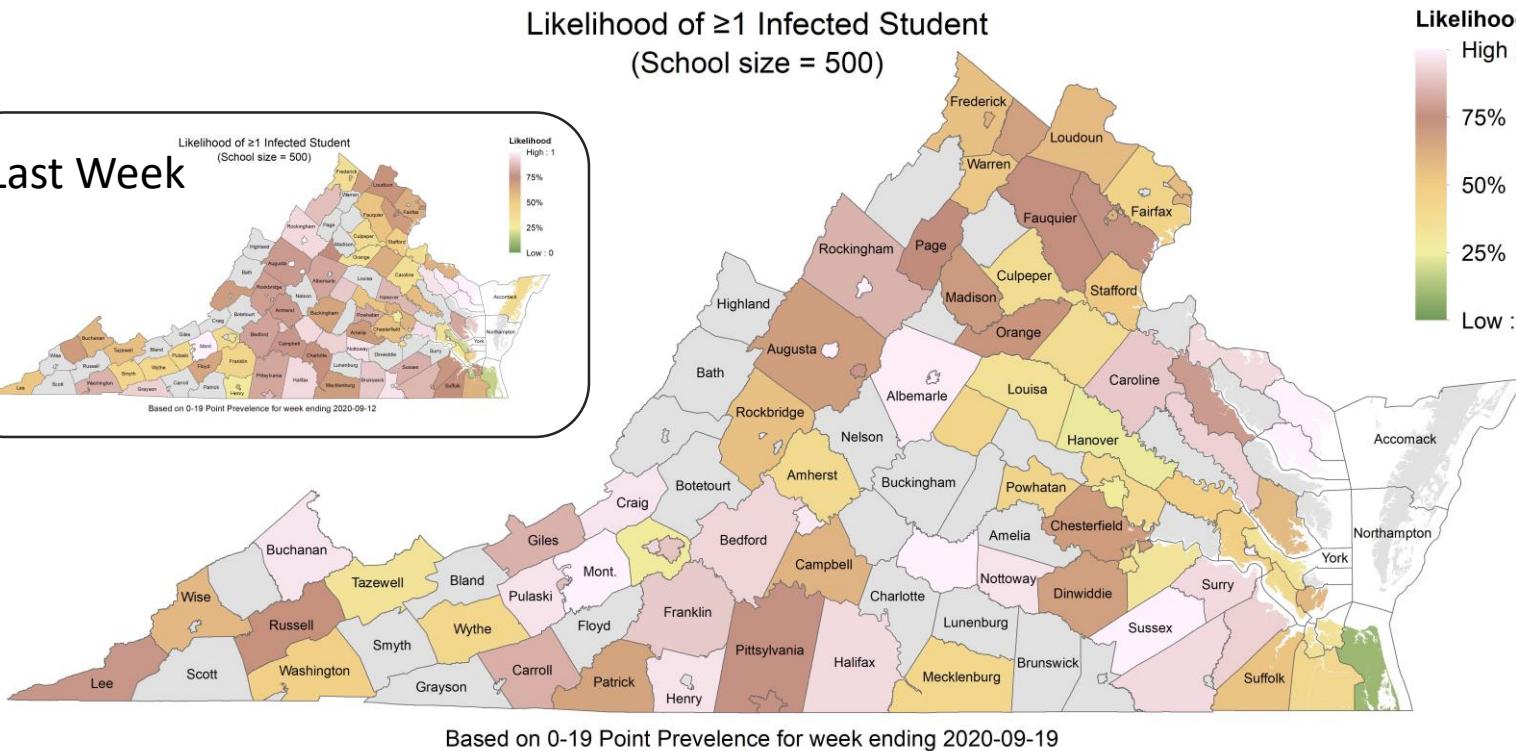
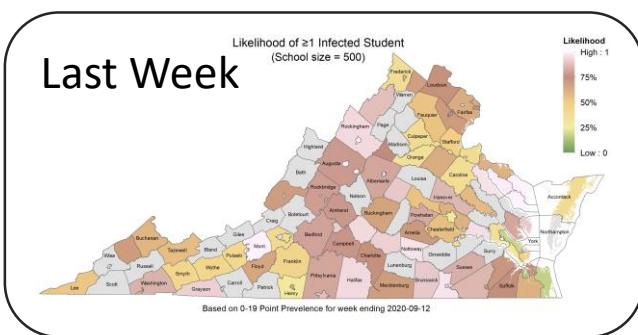
Point Prevalence Hot Spots by Zip Code
(2020-09-19)



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 Sept 13th – Sept 20th
- 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



Model Update – Adaptive Fitting

Adaptive Fitting Approach

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

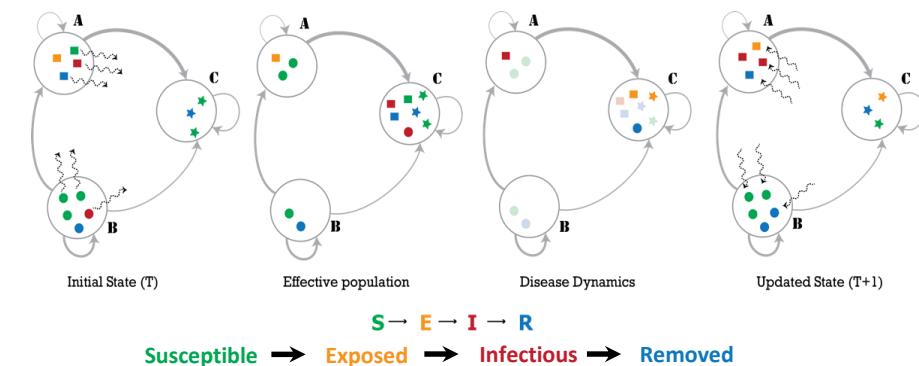
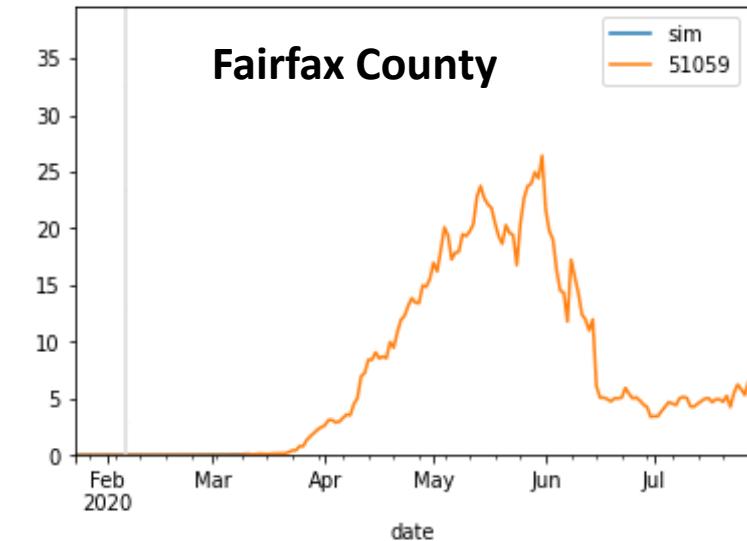
- Allows history to be precisely captured, and used to guide bounds on projections

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

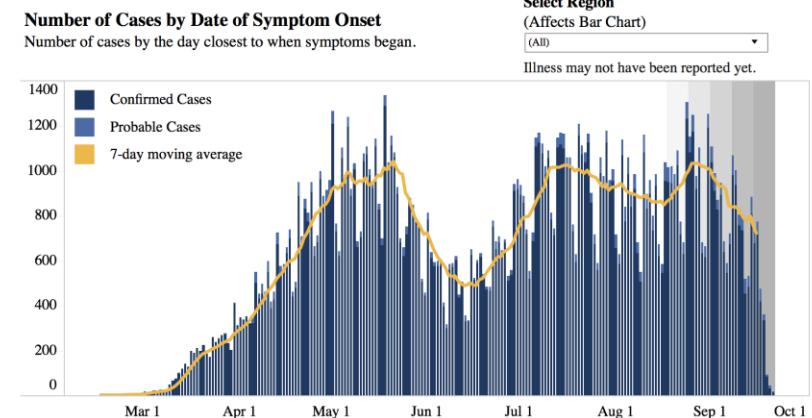
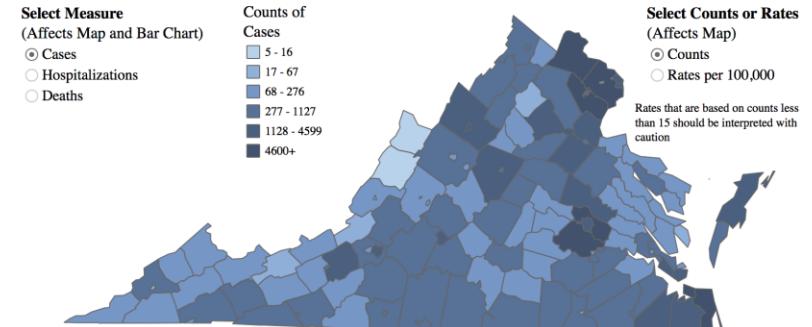
- **Data:**
 - County level case counts by date of onset (from VDH)
 - Confirmed cases for model fitting
- **Calibration:** fit model to observed data
 - Tune transmissibility across ranges of:
 - Duration of incubation (5-9 days), infectiousness (3-7 days)
 - Undocumented case rate (2x to 15x)
 - Detection 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



COVID-19 in Virginia: Cases **VDH** VIRGINIA DEPARTMENT OF HEALTH

Dashboard Updated: 9/22/2020
Data entered by 5:00 PM the prior day.

Total Cases*	Total Hospitalizations**	Total Deaths
142,010	10,675	3,060
Confirmed† 135,101	Probable† 6,909	Confirmed† 2,853



Accessed 9am September 23, 2020
<https://www.vdh.virginia.gov/coronavirus/>

Scenarios – Seasonal Effects

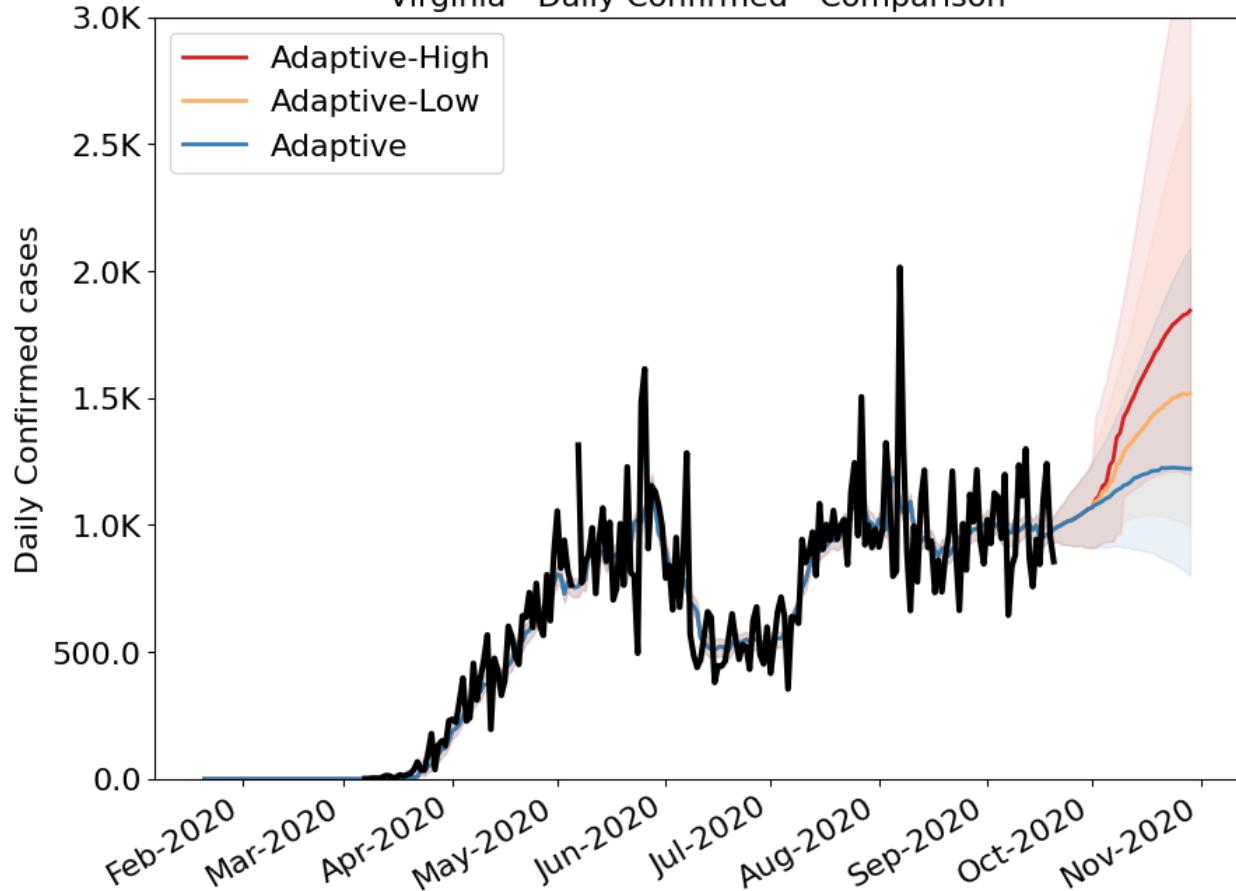
- Societal changes in the coming weeks may lead to an increase in transmission rates
 - Start of in-person school
 - Changes to workplace attendance
 - Seasonal impact of weather patterns
- Three scenarios provided to capture possible trajectories related to these changes starting at beginning of flu season, Oct 1st, 2020
 - Adaptive: No change from base projection
 - Adaptive-Low: 10% increase in transmission starting Oct 1st, 2020
 - Adaptive-High: 20% increase in transmission starting Oct 1st, 2020

Model Results

Outcome Projections

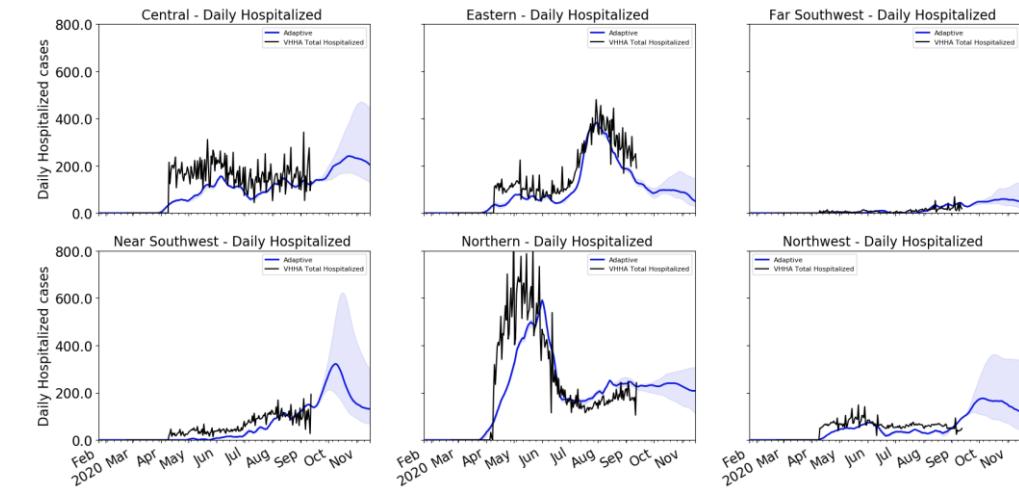
Confirmed cases

Virginia - Daily Confirmed - Comparison

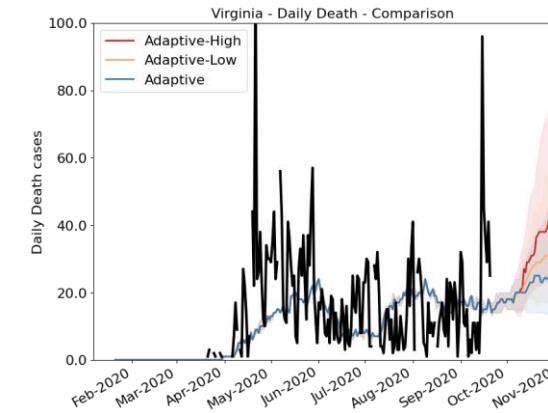


Estimated Hospital Occupancy

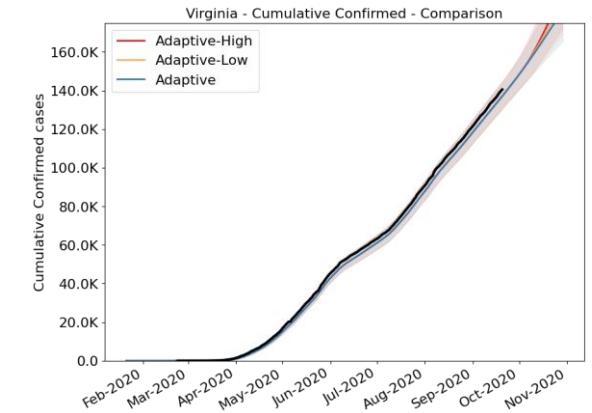
Virginia: Daily Total Confirmed Hospitalized Versus Sim - 8 Day Rolling



Daily Deaths



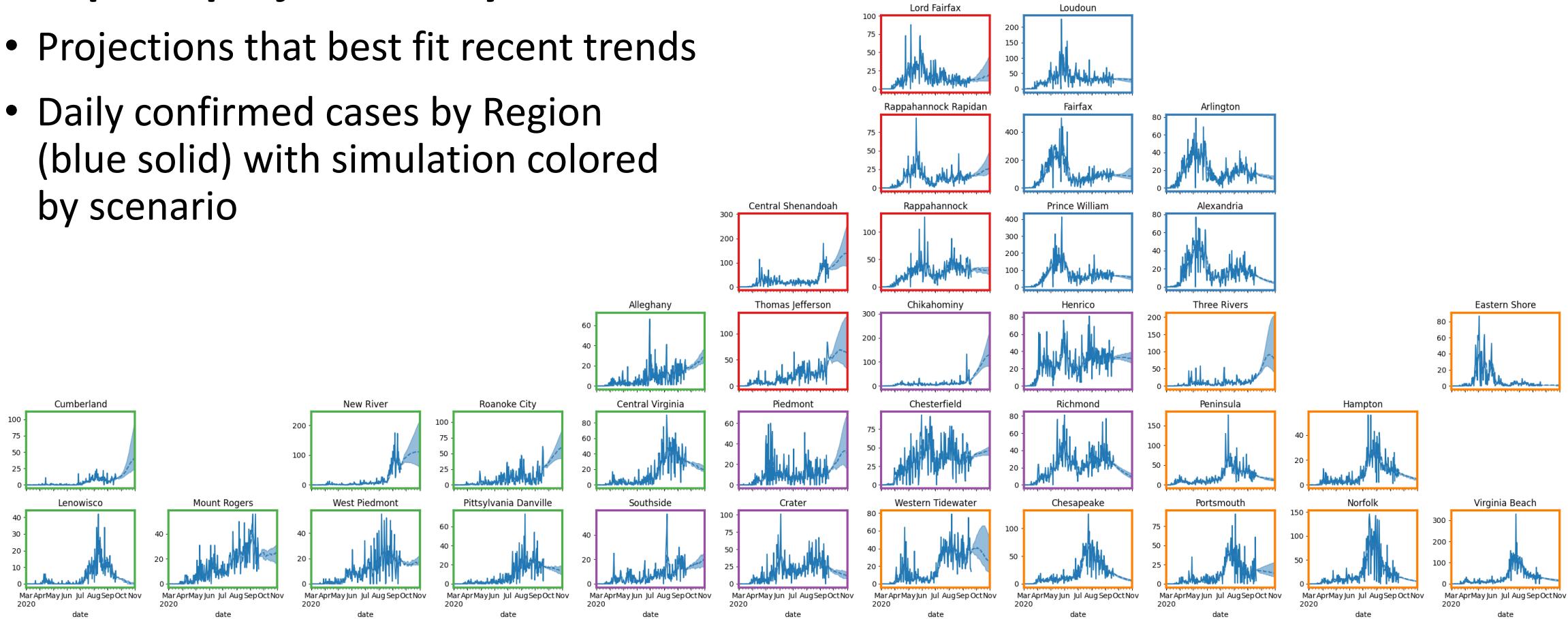
Cumulative Confirmed cases



District Level Projections: Adaptive

Adaptive projections by District

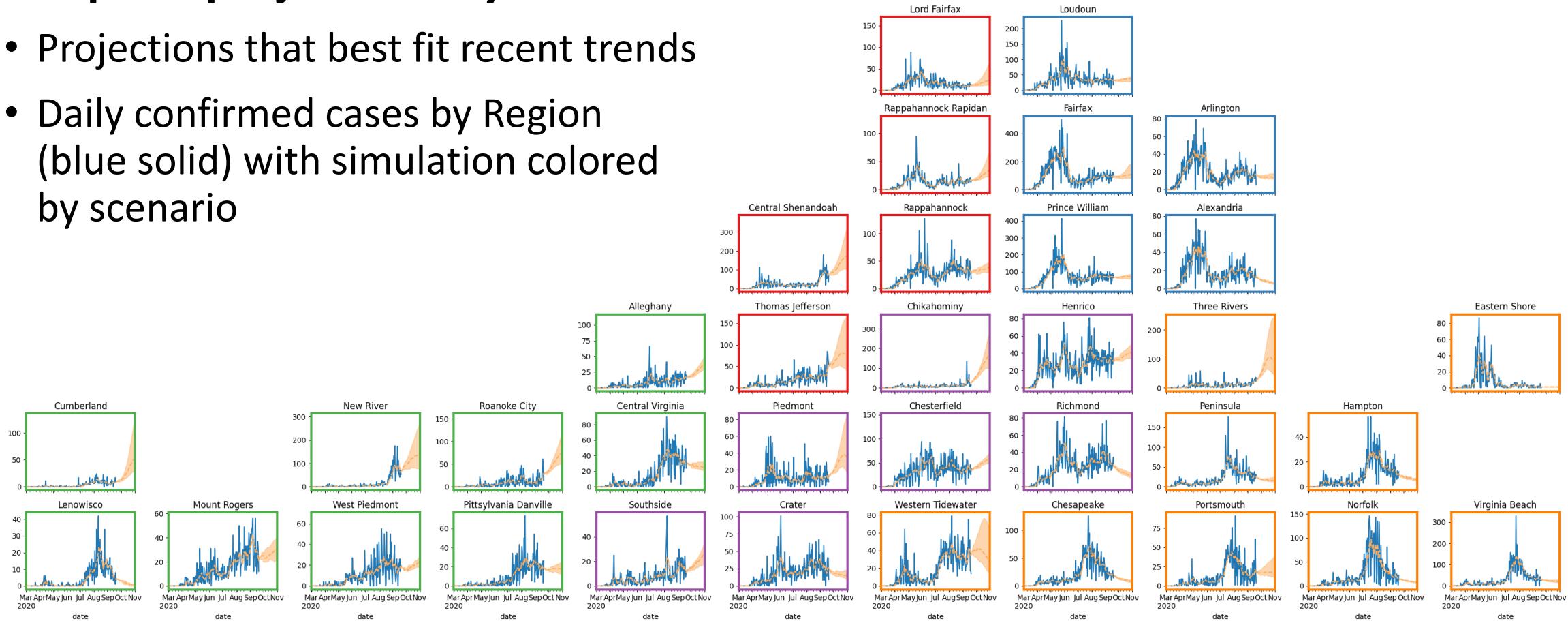
- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-Low

Adaptive projections by District

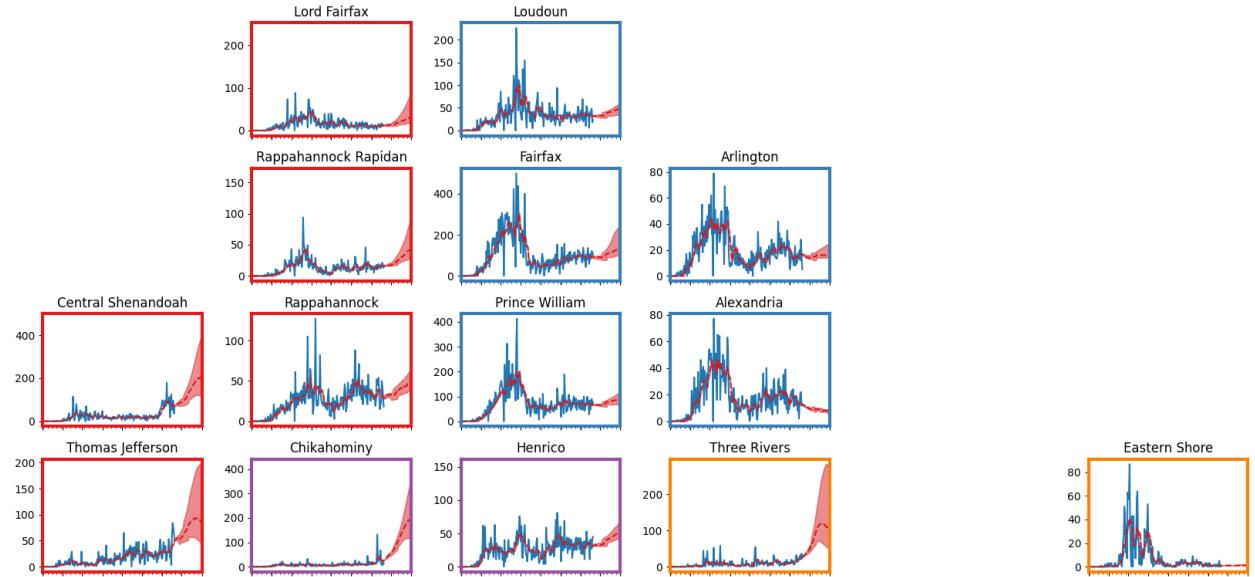
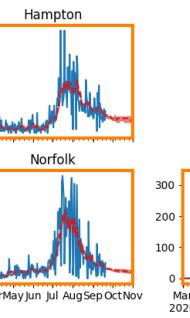
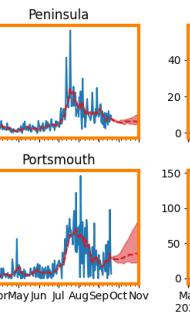
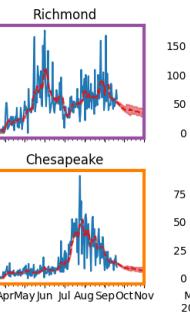
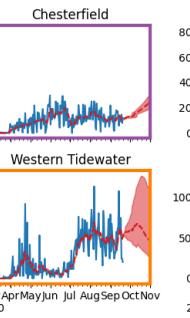
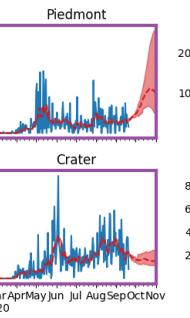
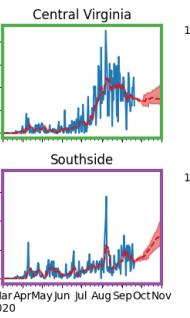
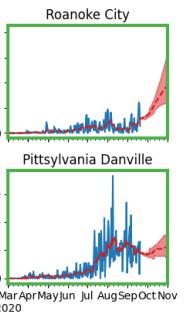
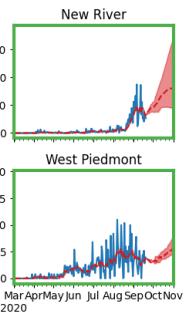
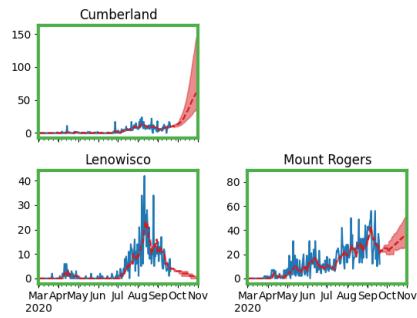
- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-High

Adaptive projections by District

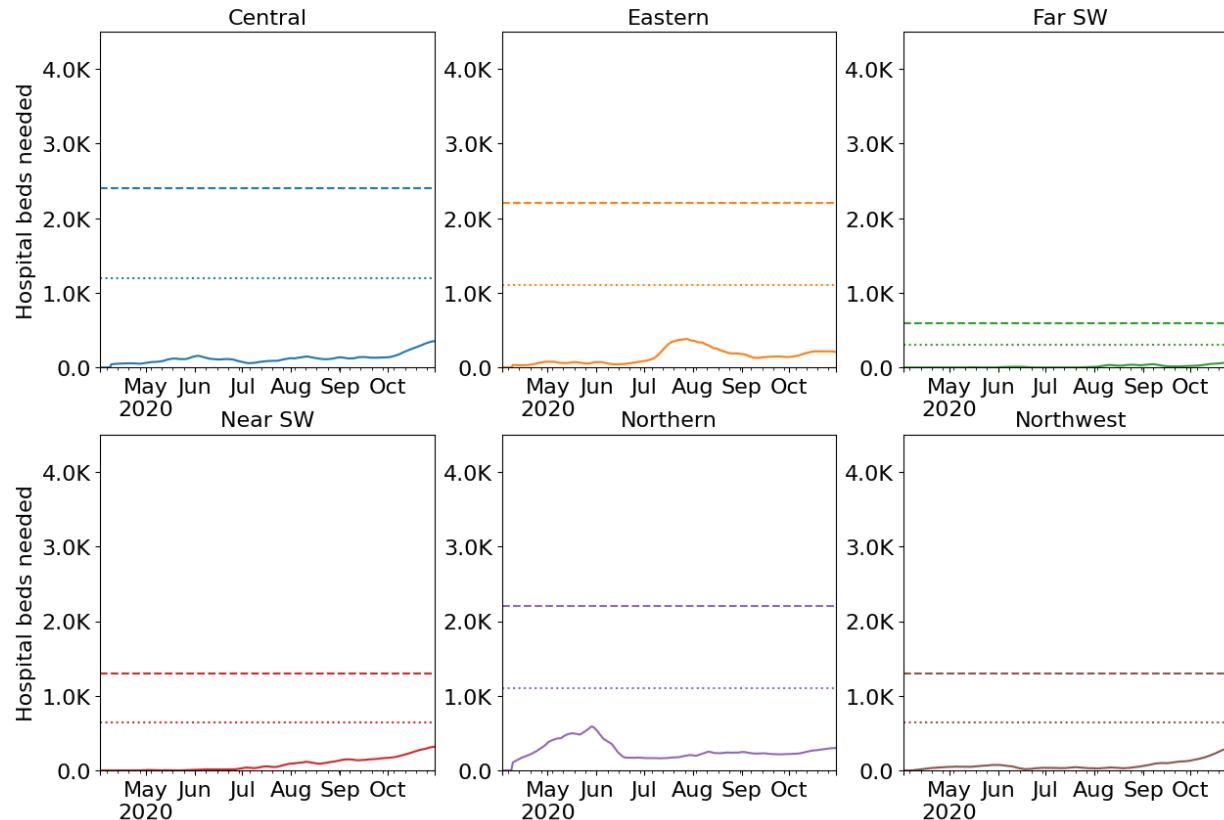
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Hospital Demand and Capacity by Region

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
9/20/20	6,852	6,852
9/27/20	6,983	6,983
10/4/20	7,372	7,392
10/11/20	7,803	8,630
10/18/20	8,256	10,578
10/25/20	8,518	11,898
11/1/20	8,558	12,756
11/8/20	8,306	12,984
11/15/20	7,812	12,710
11/22/20	7,248	12,190
11/29/20	6,608	11,512
12/06/20	5,948	10,804

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, surges continue in several districts.**
- VA weekly incidence (11.6/100K) below national average (14/100K) which is slightly down compared to last week.
- Projections are also mixed across a range of slow-growth, plateaus, and declines.
- Recent updates:
 - Adaptive Fitting projection remains, slight adjustments to projection filtering.
 - Planning Scenarios moved to Oct 1st.
- The situation is changing rapidly. Models will be updated regularly.



References

- Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS computational biology* 15.9 (2019): e1007111.
- 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)
- NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. <https://github.com/NSSAC/PatchSim> (Accessed on 04/10/2020).
- Virginia Department of Health. COVID-19 in Virginia. <http://www.vdh.virginia.gov/coronavirus/> (Accessed on 04/10/2020)
- 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/>
- 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

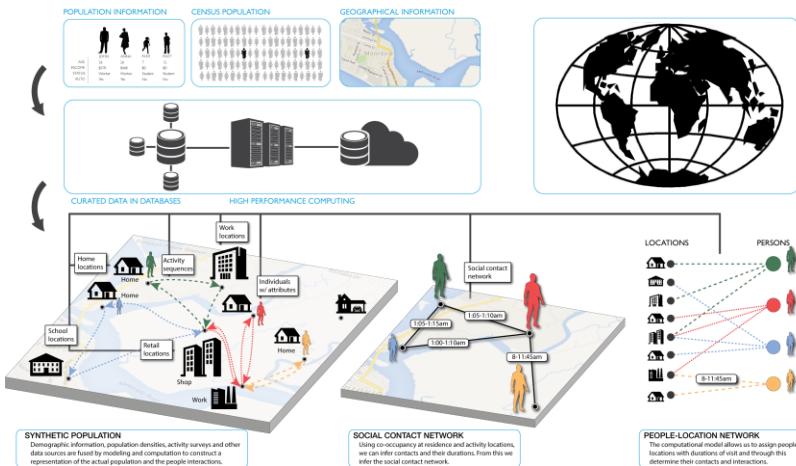


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Agent-based Model (ABM)

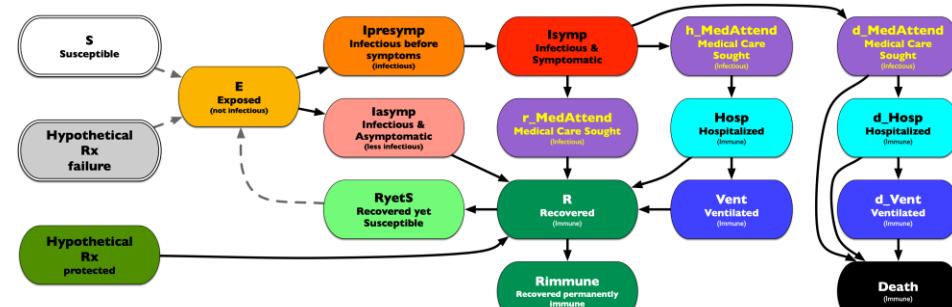
EpiHiper: Distributed network-based stochastic disease transmission simulations

- 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

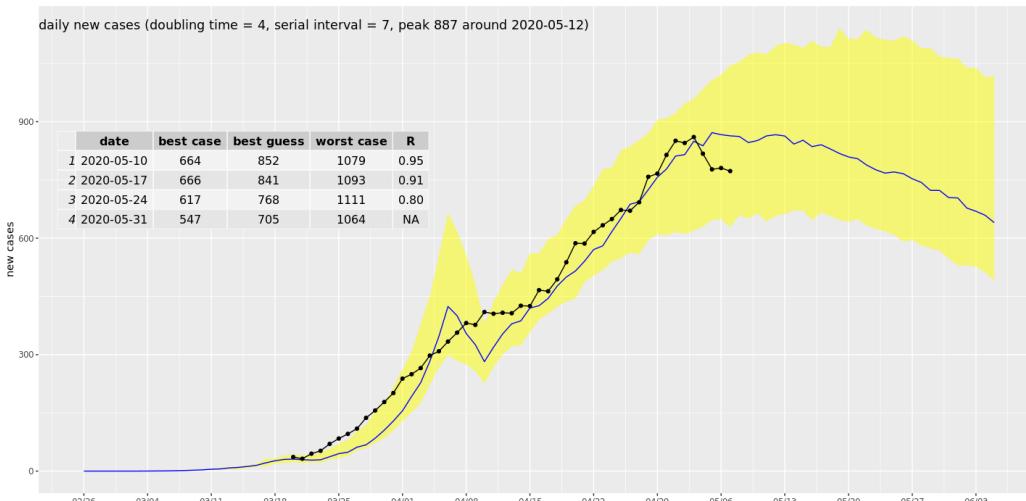


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ABM Social Distancing Rebound Study Design

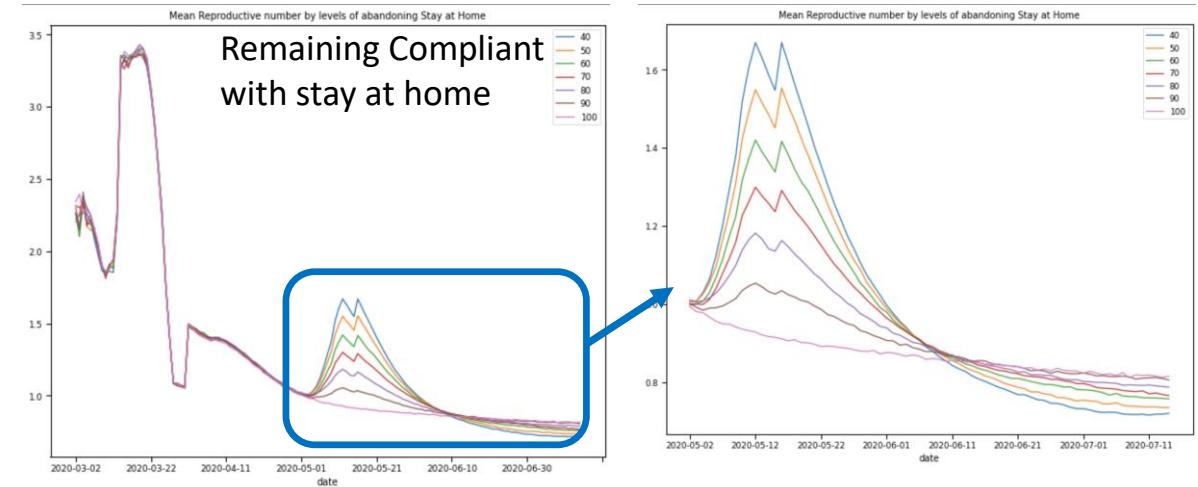
Study of "Stay Home" policy adherence

- 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/>

