Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

September 30th, 2020

(data current to September 28th)

Biocomplexity Institute Technical report: TR 2020-117

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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

Points of Contact

Bryan Lewis
brylew@virginia.edu

Srini Venkatramanan
srini@virginia.edu

Madhav Marathe
marathe@virginia.edu

Chris Barrett
ChrisBarrett@virginia.edu

Biocomplexity COVID-19 Response Team

Aniruddha Adiga, Abhijin Adiga, Hannah Baek, Chris Barrett, Golda Barrow, Richard Beckman, Parantapa Bhattacharya, Andrei Bura, Jiangzhuo Chen, Clark Cucinell, Patrick Corbett, Allan Dickerman, Stephen Eubank, Arindam Fadikar, Joshua Goldstein, Stefan Hoops, Ben Hurt, Sallie Keller, Ron Kenyon, Brian Klahn, Gizem Korkmaz, Vicki Lancaster, Bryan Lewis, Dustin Machi, Chunhong Mao, Achla Marathe, Madhav Marathe, Fanchao Meng, Henning Mortveit, Mark Orr, Joseph Outten, Akhil Peddireddy, Przemyslaw Porebski, SS Ravi, Erin Raymond, Jose Bayoan Santiago Calderon, James Schlitt, Aaron Schroeder, Stephanie Shipp, Samarth Swarup, Alex Telionis, Srinivasan Venkatramanan, Anil Vullikanti, James Walke, Amanda Wilson, Dawen Xie

Overview

- **Goal**: Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project infections through December
  - 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:

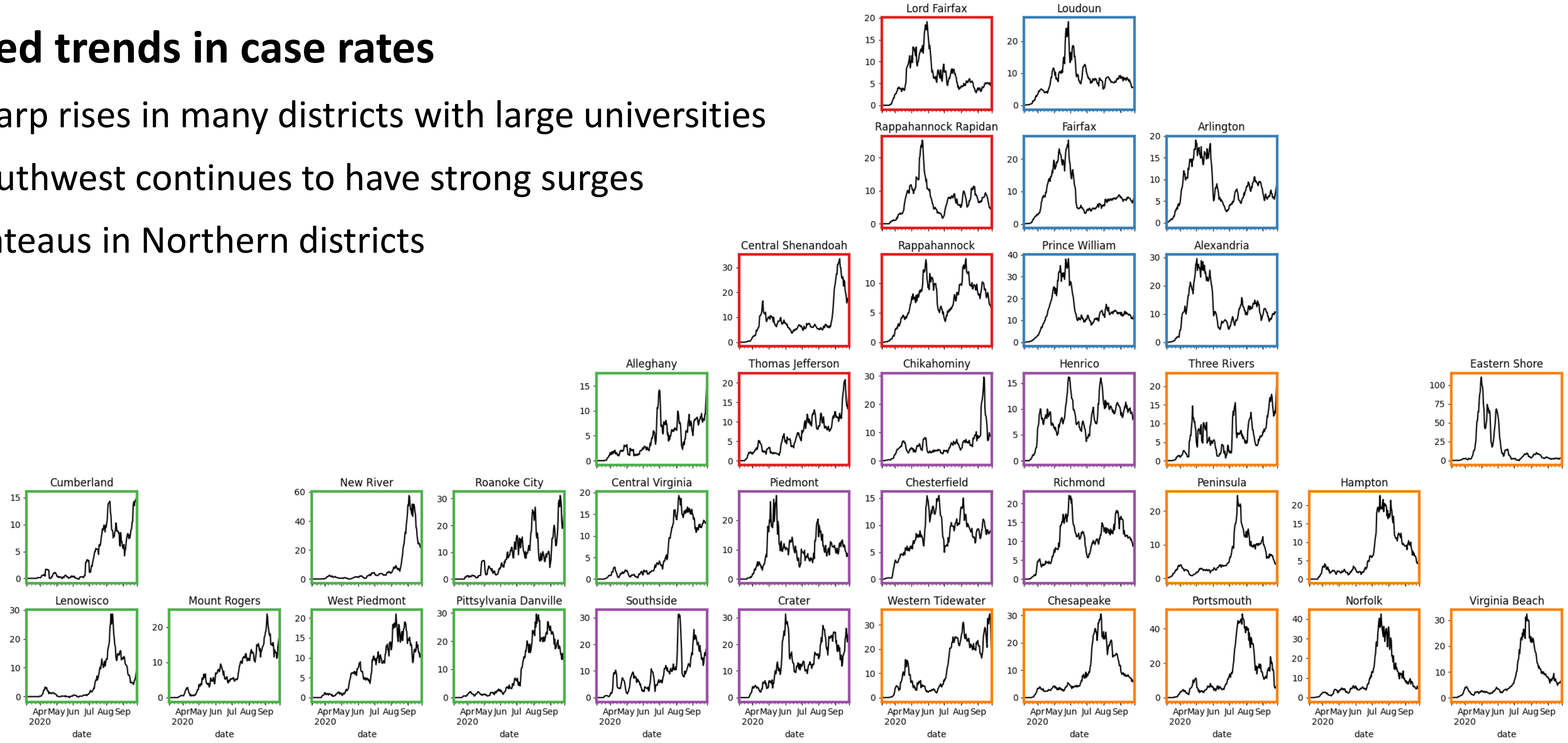
- **Holding steady with declines outpacing growth.**
- VA weekly incidence (9.2/100K) continues to decline and now well below the national average (15/100K) which has been climbing, fueled by growth in the Plains and Mountain West.
- Projections are also mixed across commonwealth with declines outpacing growth.
- Recent updates:
  - Adaptive Fitting projection process has been streamlined.
  - Planning Scenarios moved to Nov 1st.
- The situation is changing rapidly. Models will be updated regularly.

Situation Assessment

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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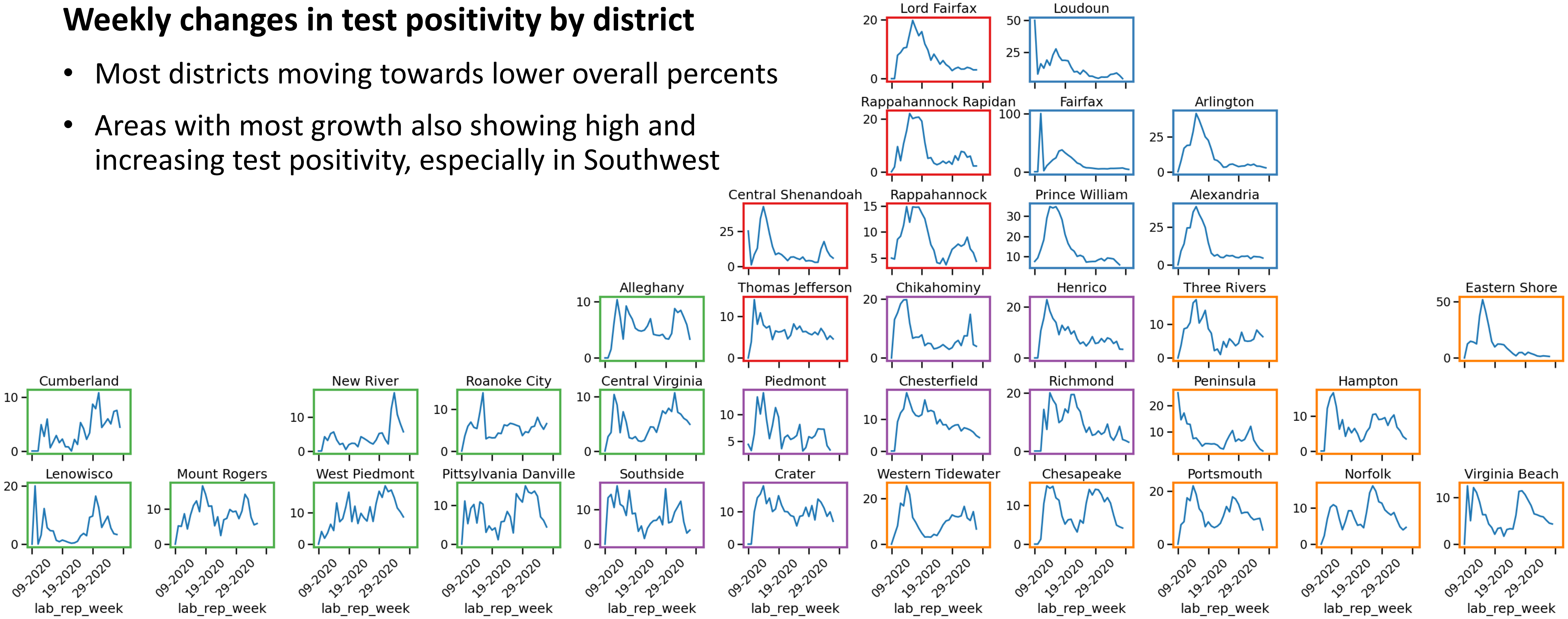
Test Positivity by VDH District

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



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District Trajectories – New Surges starting

Hockey stick fit used to describe recent growth patterns based on recent trends from last peak or inflection points (based on smoothed case rates per 100k)

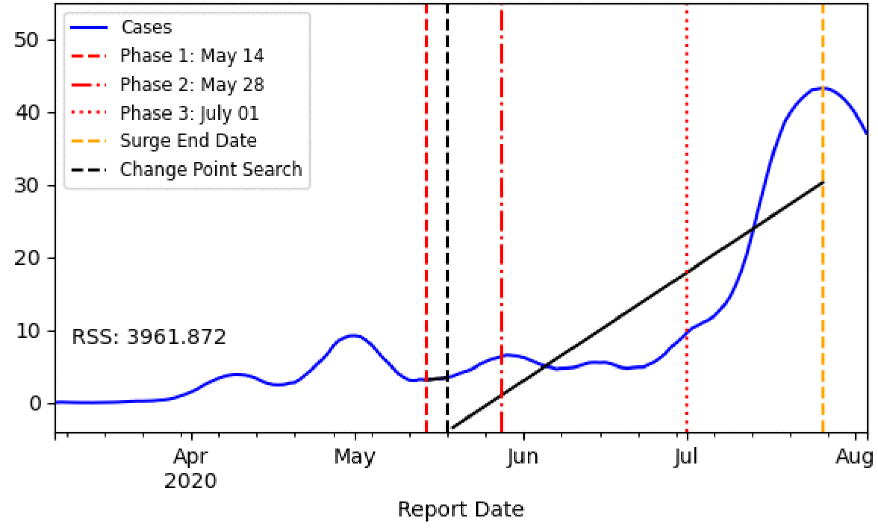
Declining: Sustained decreases following a recent peak

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

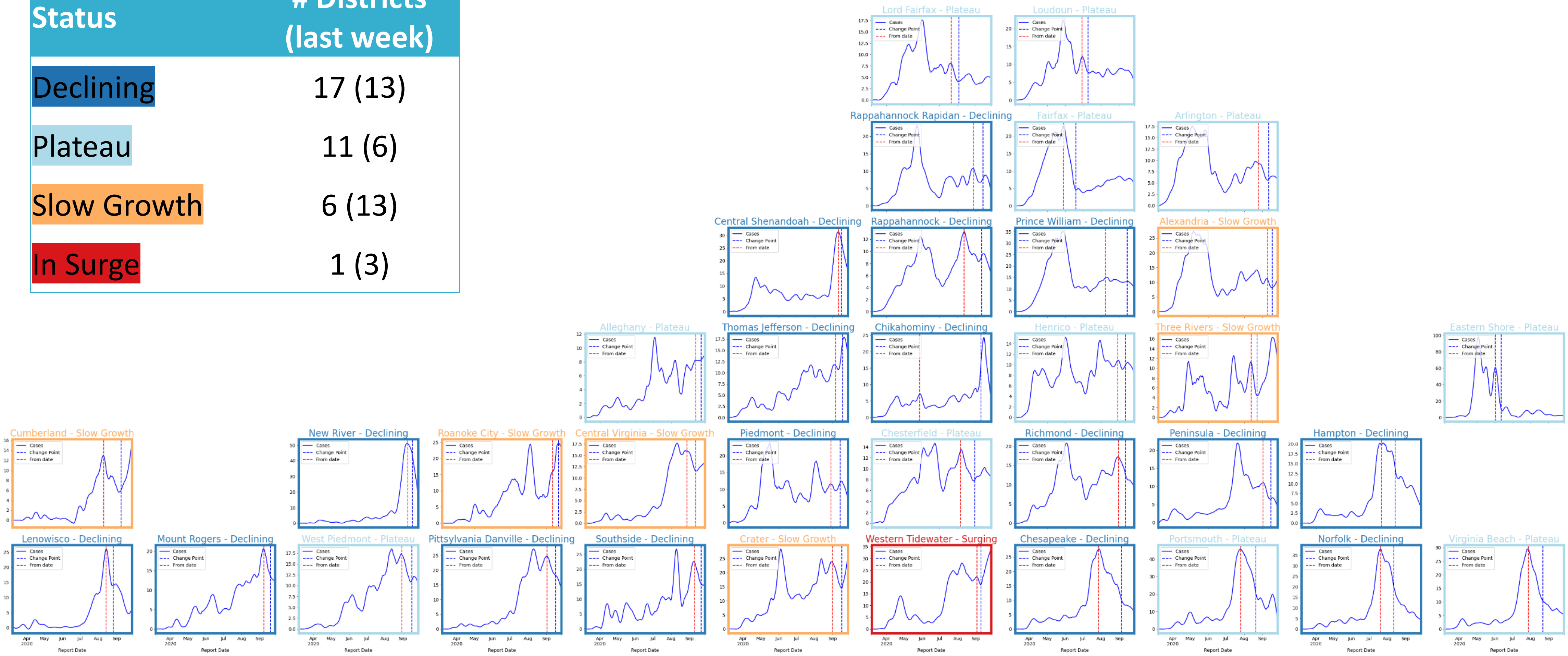
Hockey stick fit
Portsmouth



Status	# Districts (last week)
Declining	17 (13)
Plateau	11 (6)
Slow Growth	6 (13)
In Surge	1 (3)

District Trajectories – Declines outpace Growth

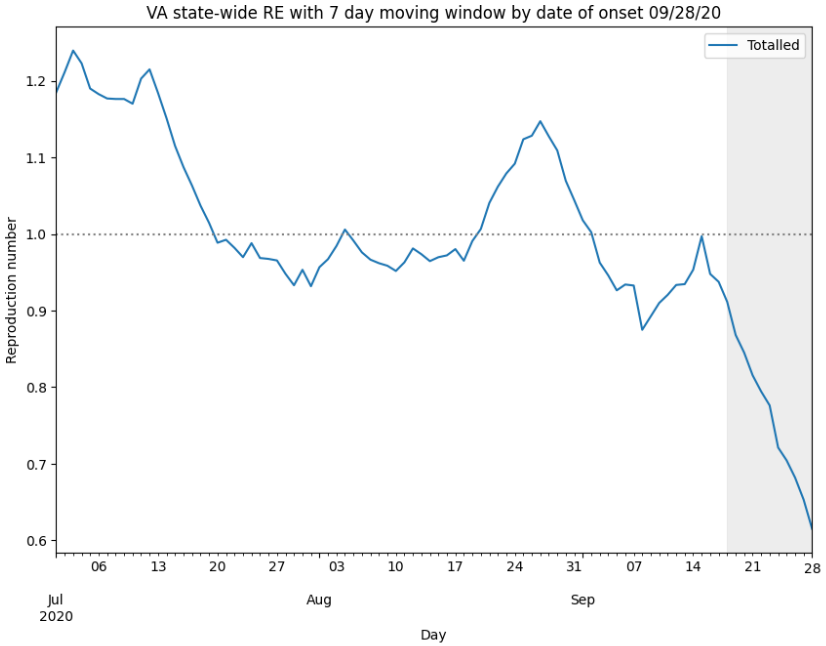
Status	# Districts (last week)
Declining	17 (13)
Plateau	11 (6)
Slow Growth	6 (13)
In Surge	1 (3)

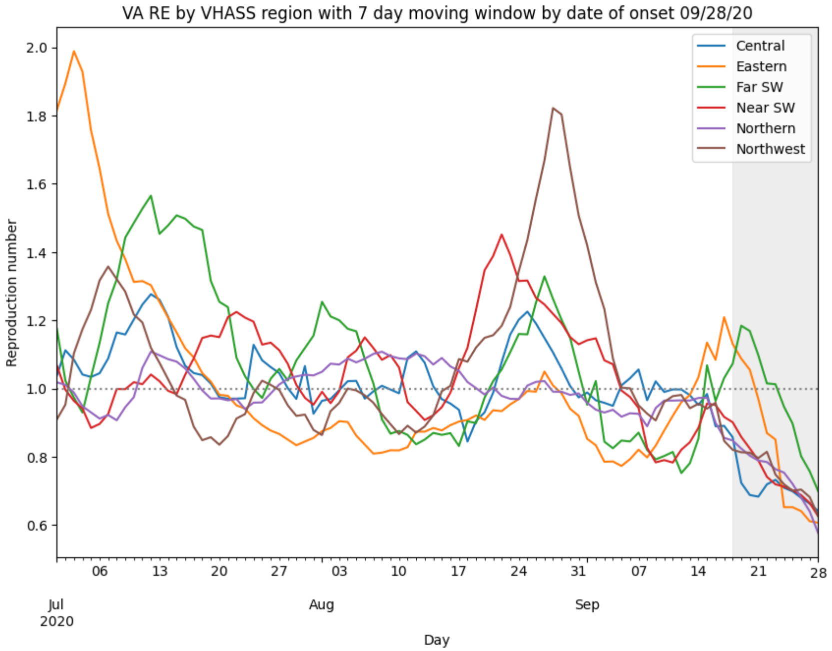


Estimating Daily Reproductive Number

September 19th Estimates

Region	Current R_e	Diff Last Week
State-wide	0.868	-0.015
Central	0.724	-0.175
Eastern	1.088	0.167
Far SW	1.184	0.415
Near SW	0.858	0.094
Northern	0.824	-0.105
Northwest	0.813	-0.135





Methodology

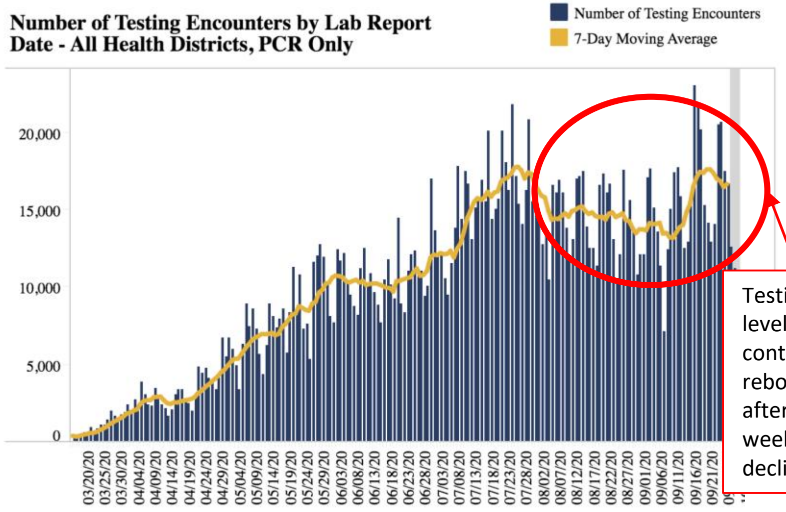
- Wallinga-Teunis method (EpiEstim[1]) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

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)	8.54	42%
May (17-21)	5.63	-7%
June (22-25)	5.88	-2%
July (26-30)	6.26	4%
Aug (31-34)	4.75	-21%
Sept (2w,35-36)	4.21	-30%
Overall (13-33)	6.02	0%

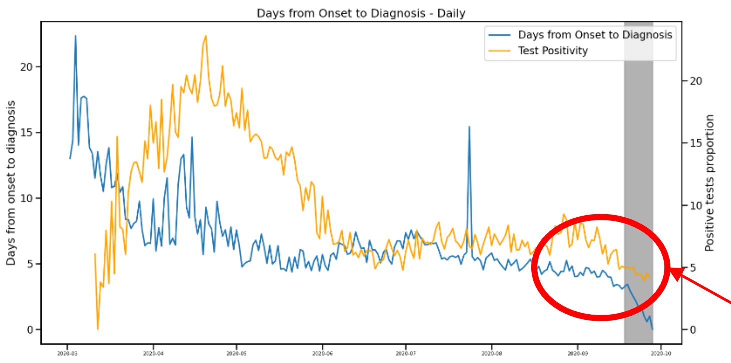
Testing Encounters and test positivity have steadied and increased



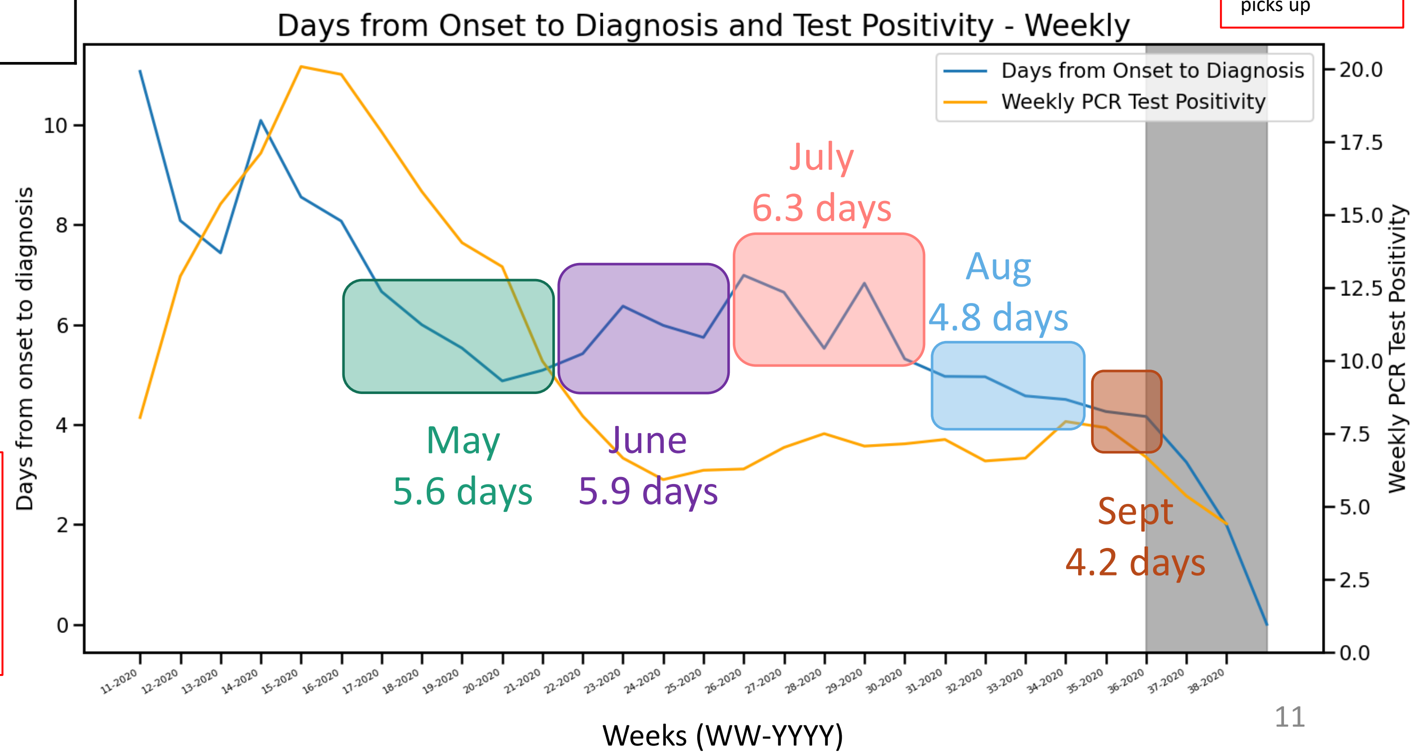
Testing levels continue rebound after weeks of decline

Accessed 9:30am September 30, 2020
https://www.vdh.virginia.gov/coronavirus/

Test positivity vs. Onset to Diagnosis



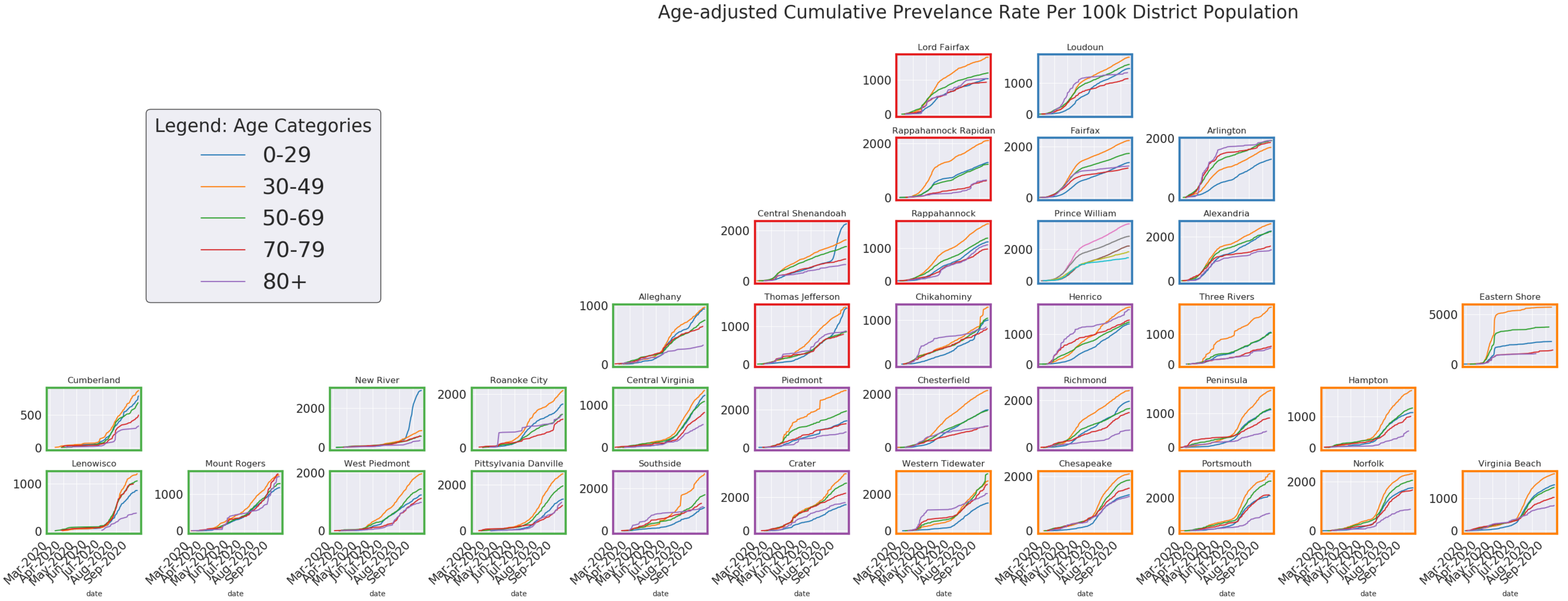
Steady plateau has given way to stead decline in positivity as testing volume picks up



Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

- Younger age groups outpace older in many districts



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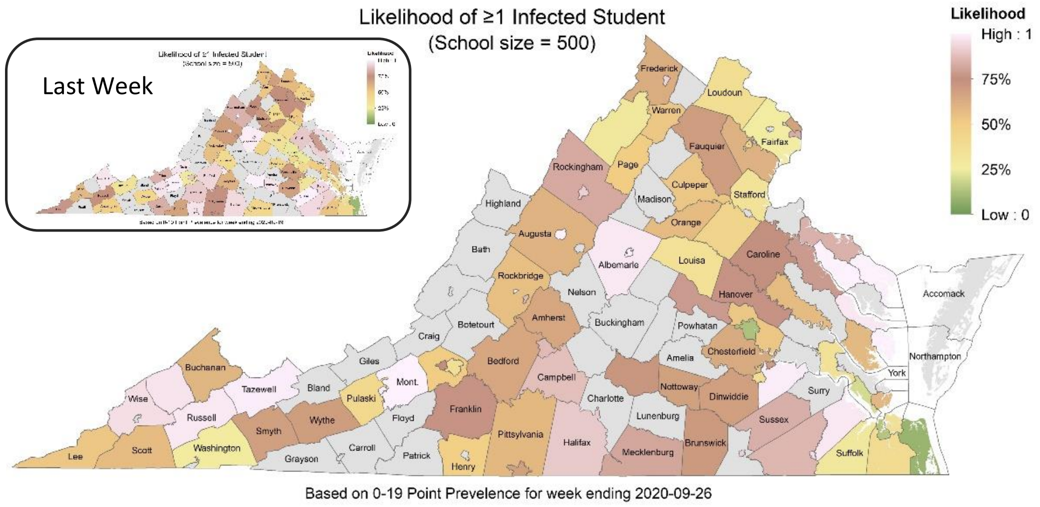
Age-Specific Case Prevalence

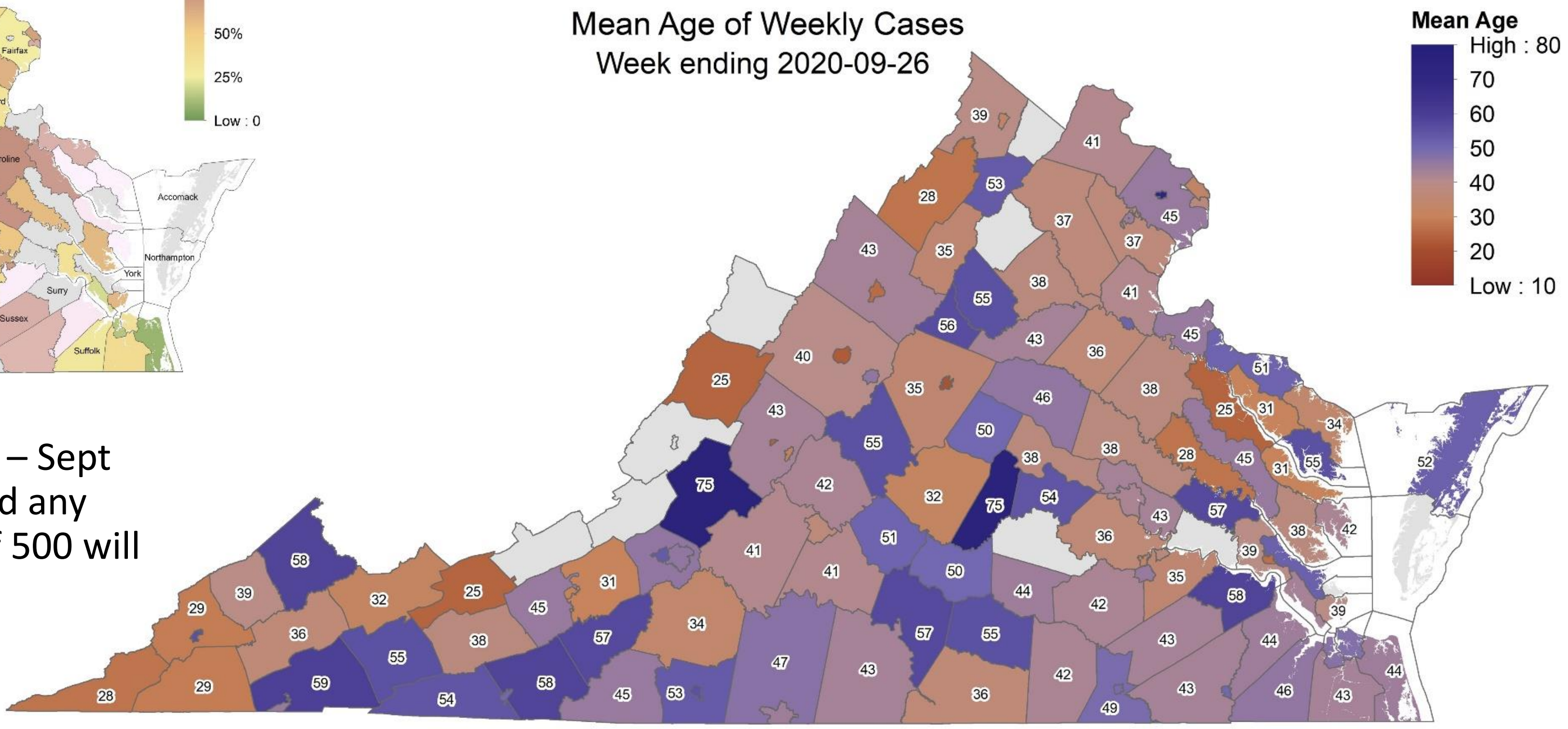
During this past week, what might we find in a fully open school?



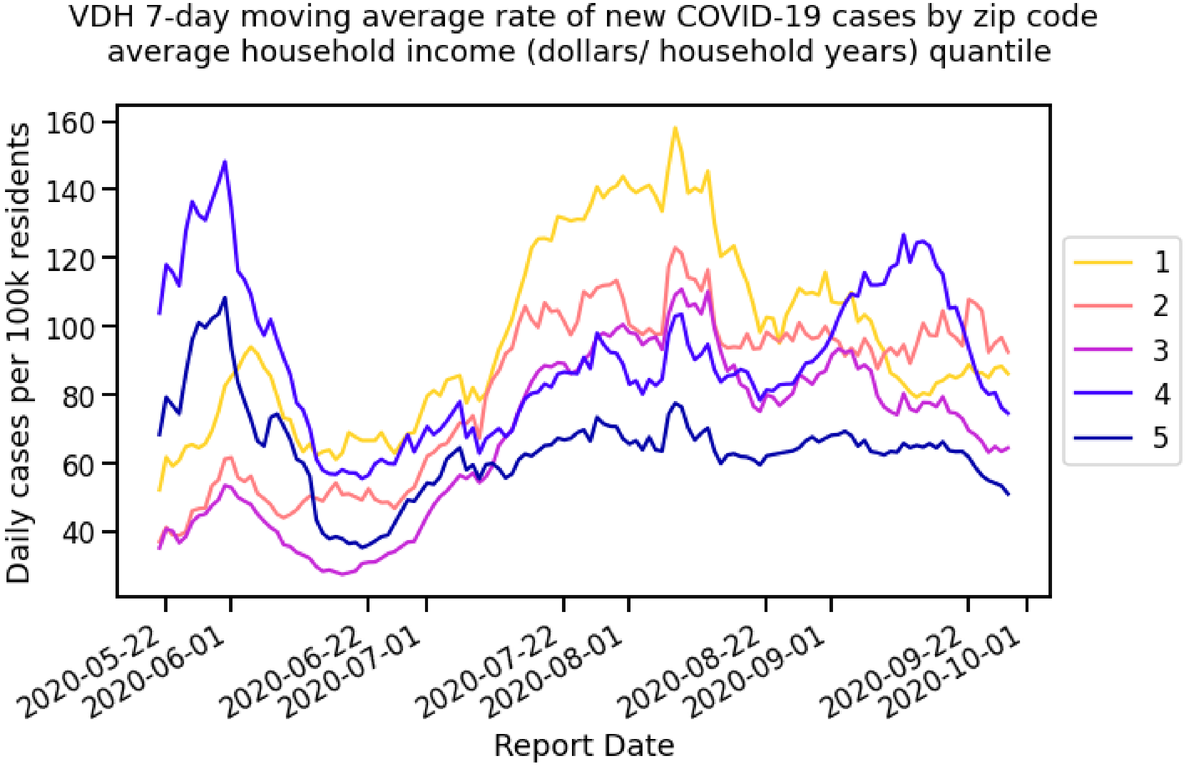
Based on prevalence during week of Sept 19th – Sept 26th of school-aged cases, what is the likelihood any collection of school age kids in a school size of 500 will have at least one infection

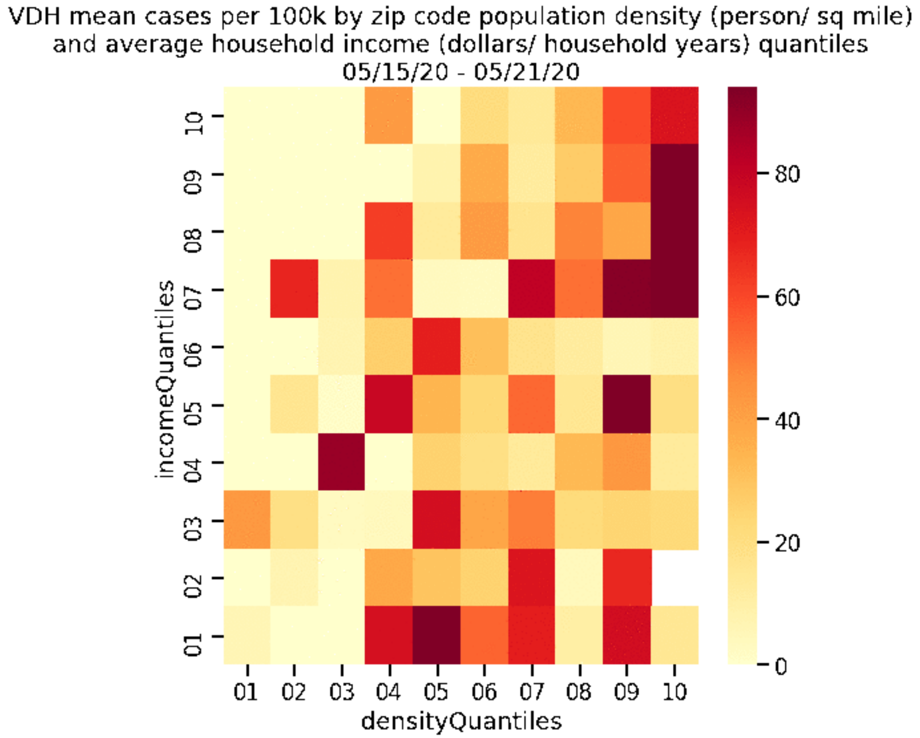
What is the average age of the cases by county?

Younger cases in Northern VA, Tidewater, and around universities



Impact across Density and Income





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

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

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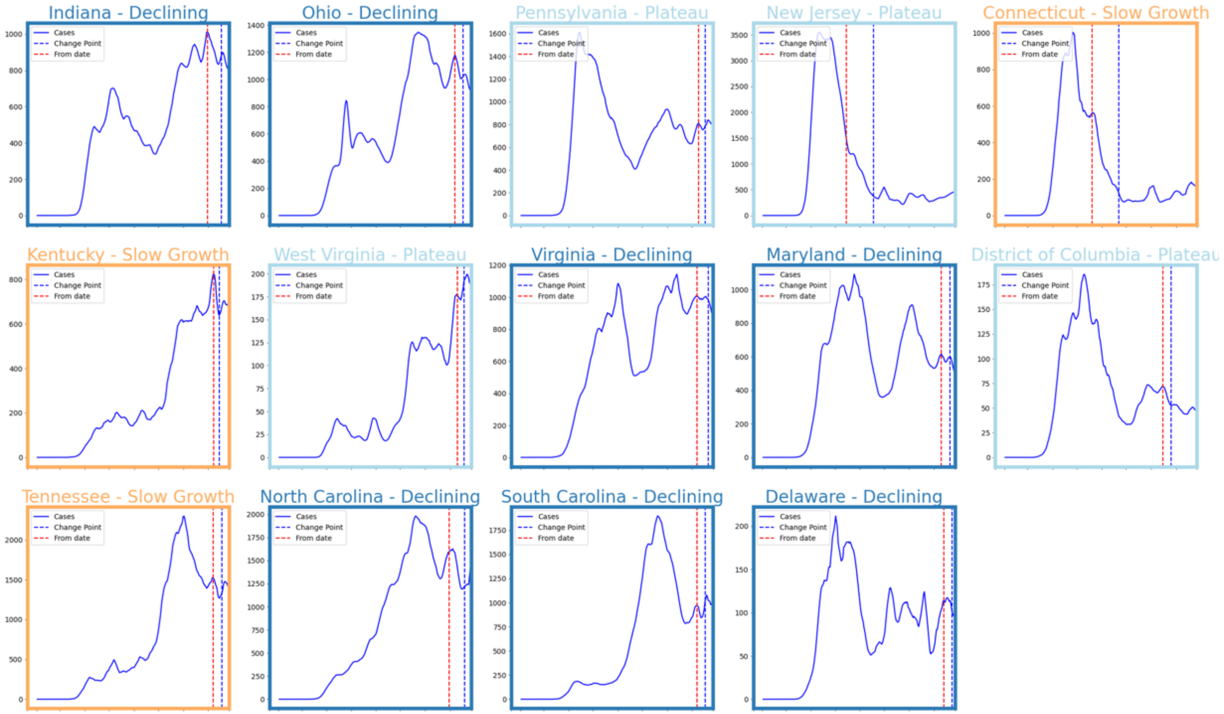
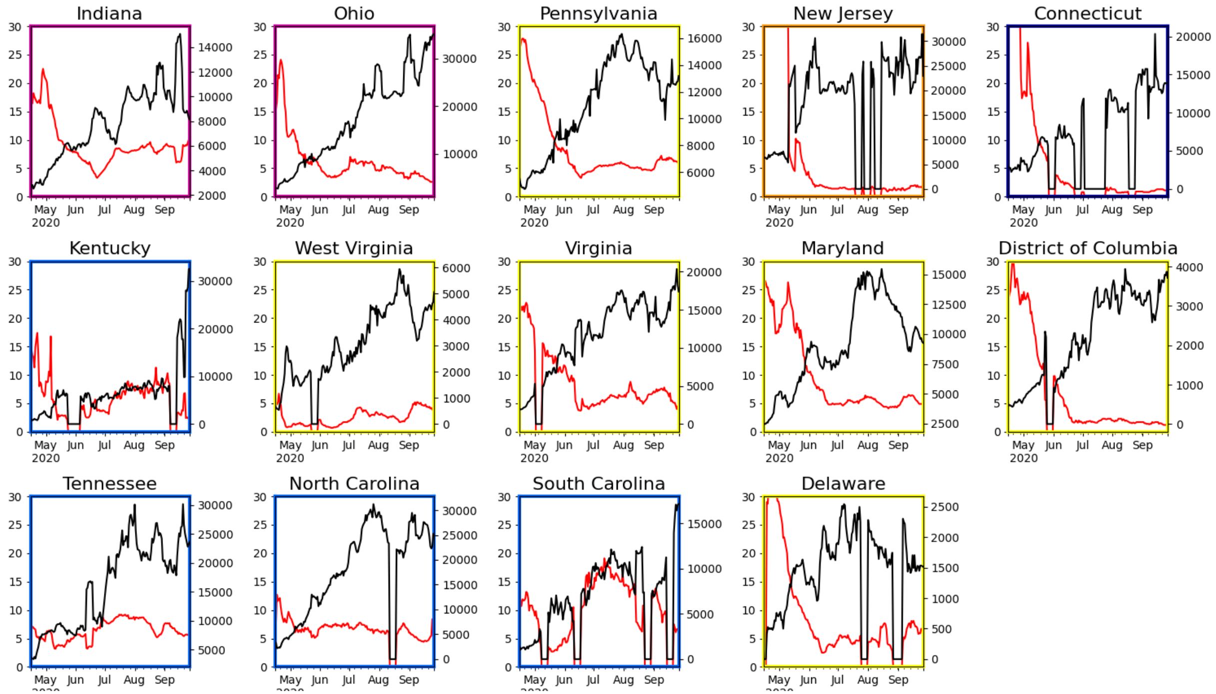
Other State Comparisons

Trajectories of States



- VA declining
- WV previously surging now plateauing along with DC
- MD, DE, and NC now declining
- KY and TN have limited slow growth

Tests per Day and Test Positivity

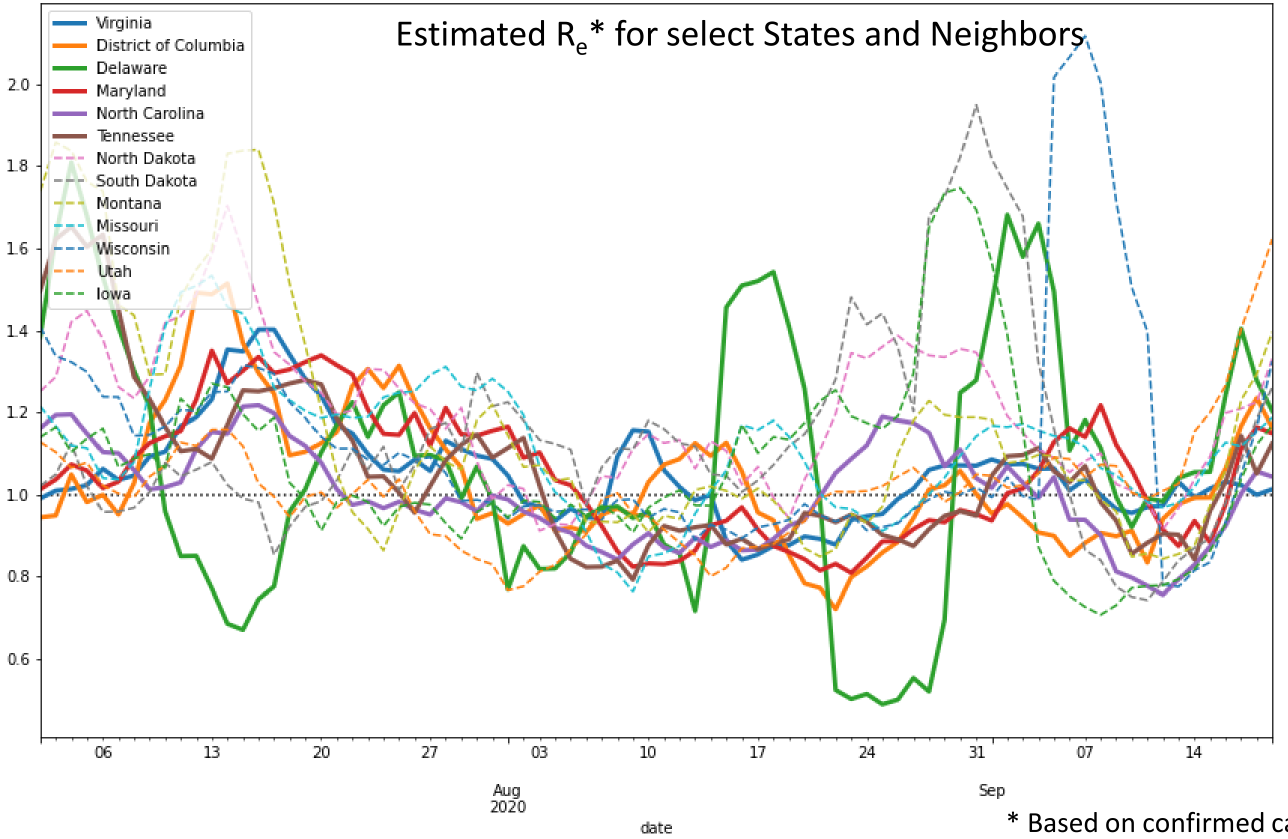


- Test positivity mixed, VA continues to decline.
- Testing volumes steadily growing in VA.

Other State Comparisons

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

- New states in Plains and Mountain West emerging as hot spots: ND, SD, MT, MO, WI, UT, and IA
- Virginia and neighboring states are mostly at and below 1, though slightly up



* Based on confirmed cases per day

New hotspots in Plains and Mountain West emerging

VA and neighbors continued steady

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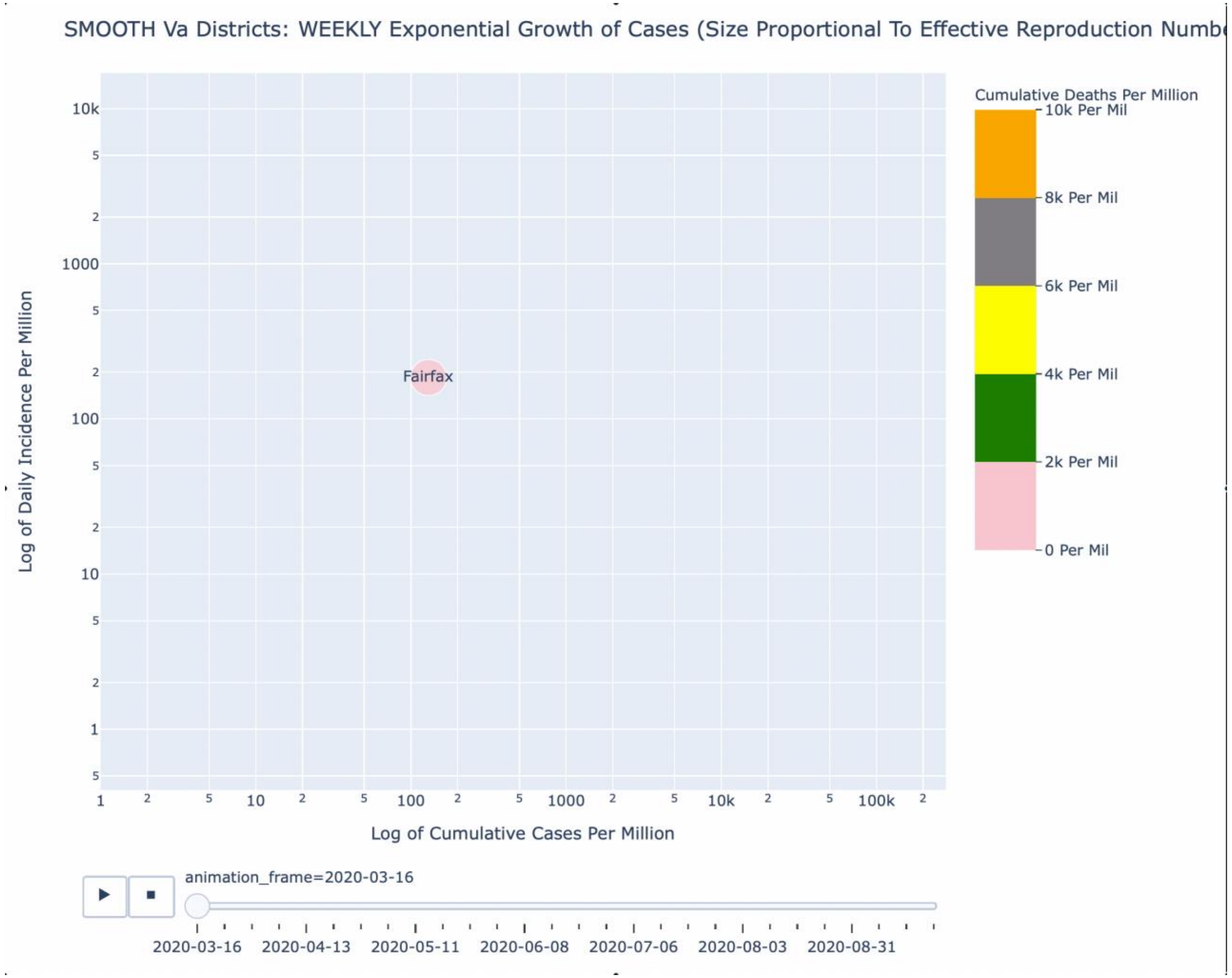
Evolution of Infections by District

- 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



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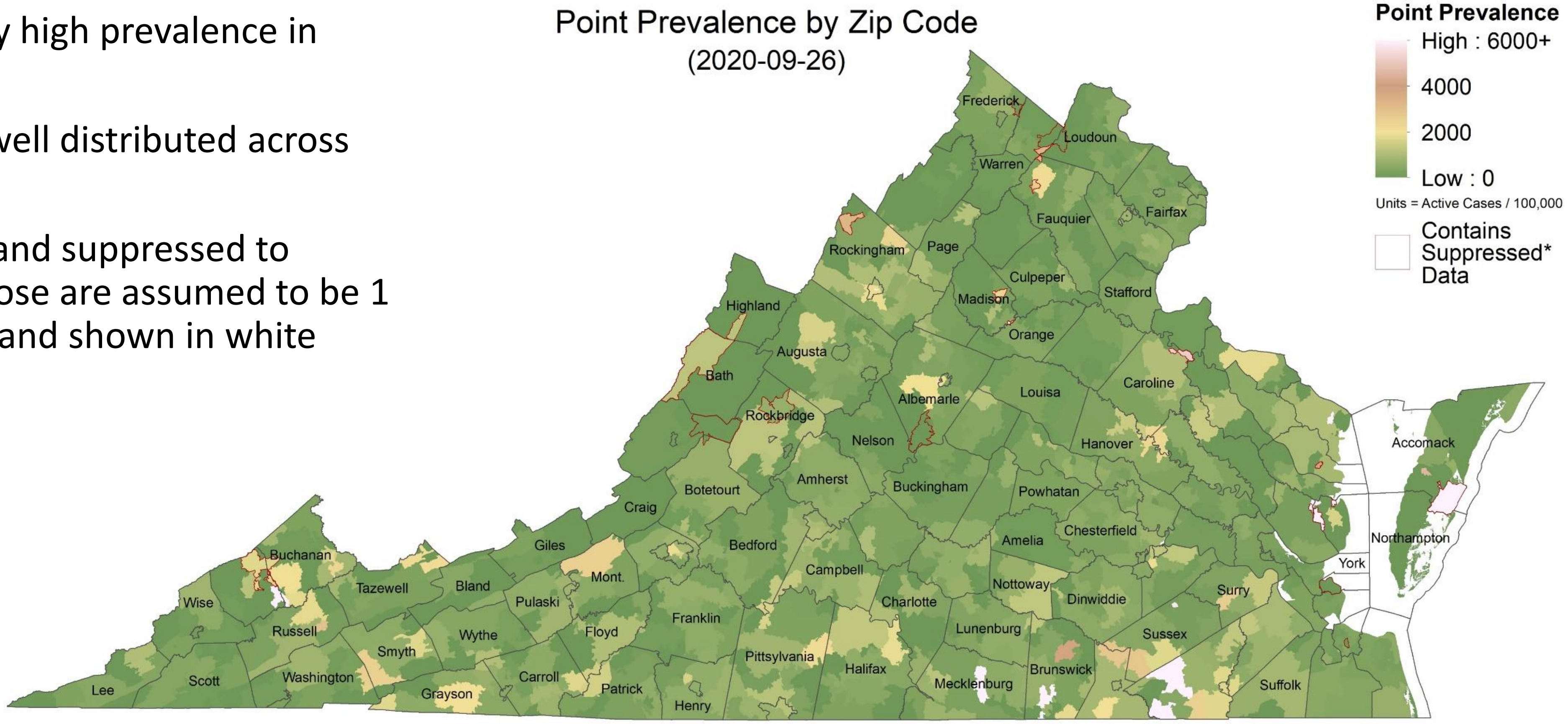
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Concentrations of very high prevalence in some zip codes
- High prevalence zips well distributed across the commonwealth
- Many counts are low and suppressed to protect anonymity, those are assumed to be 1 case (per zip per day) and shown in white



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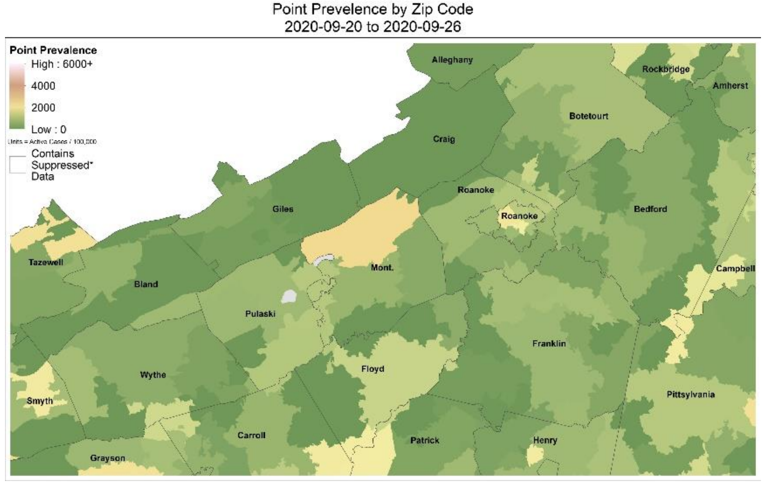
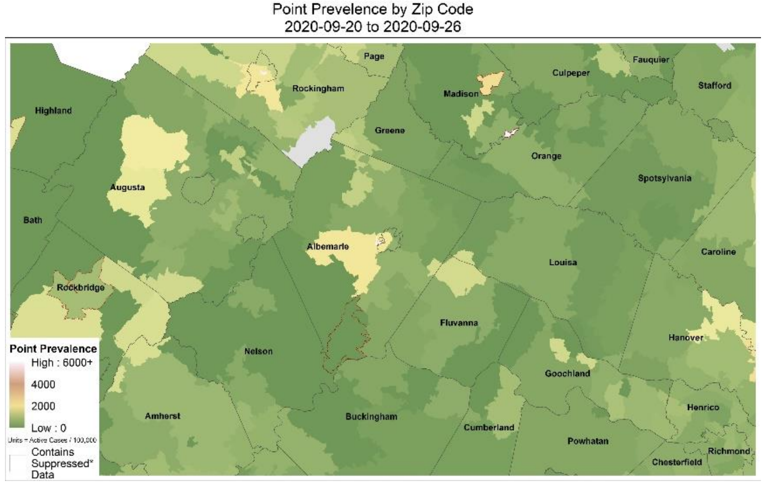
Zip code level weekly Case Rate (per 100K)

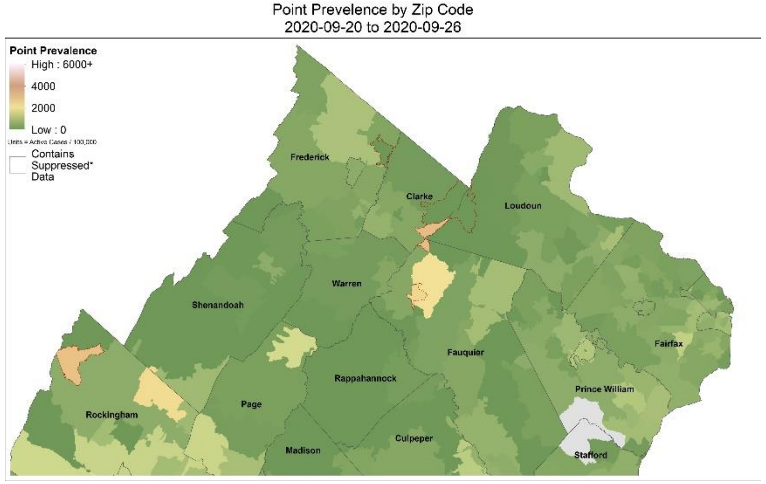
Roanoke / B'burg



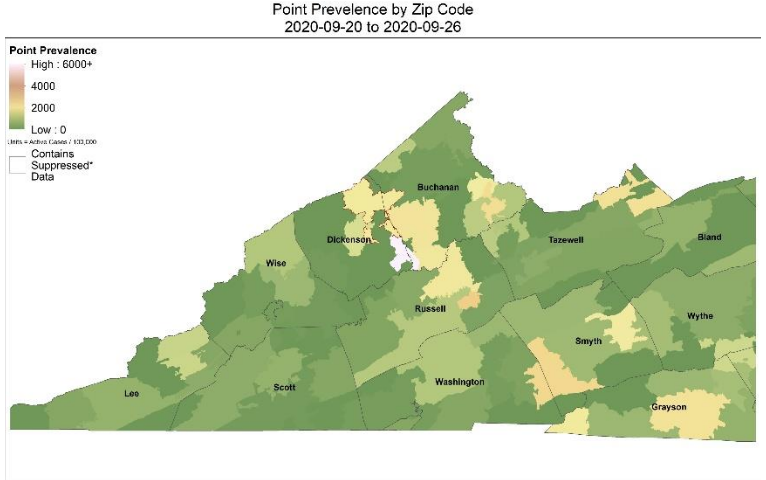
Albemarle



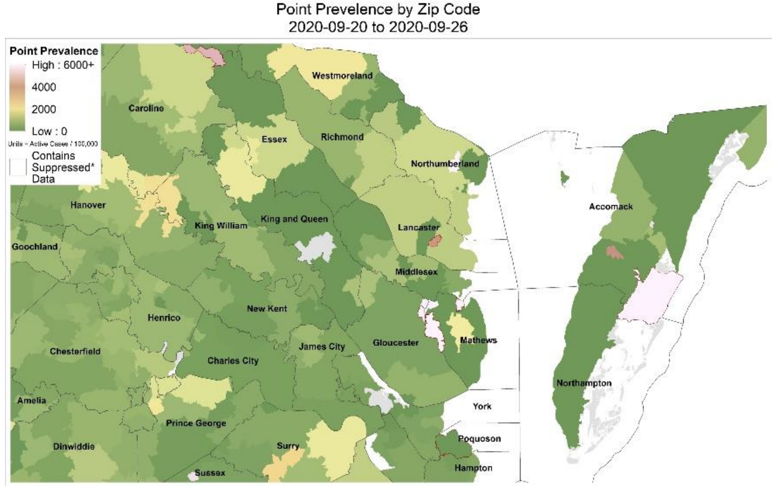
Northern Virginia



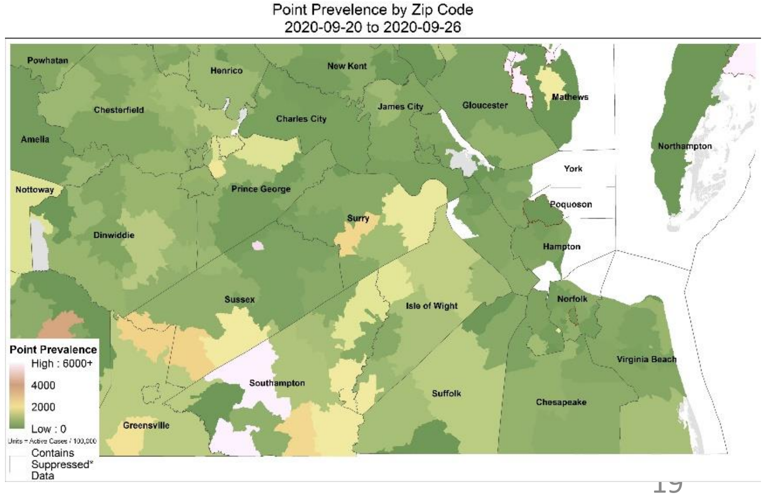
Far Southwest



Three Rivers

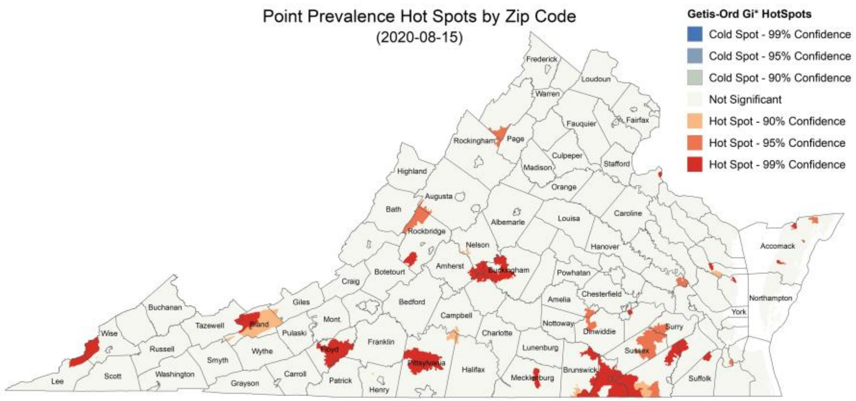


Tidewater



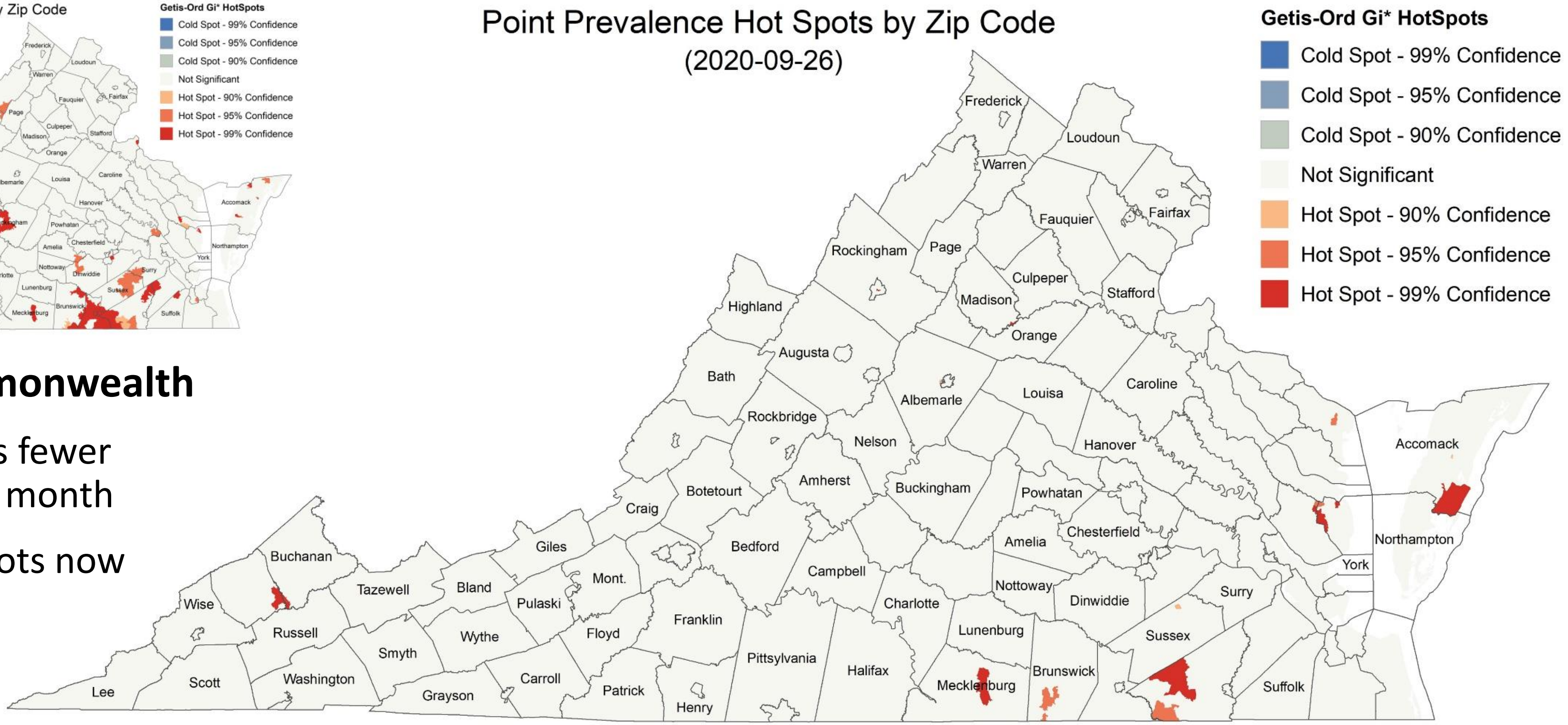
Zip Code Hot Spots

Previous weeks



Hotspots across commonwealth

- General trend towards fewer hotspots over the last month
- Most university hotspots now less significant



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Model Update – Adaptive Fitting

Adaptive Fitting Approach

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

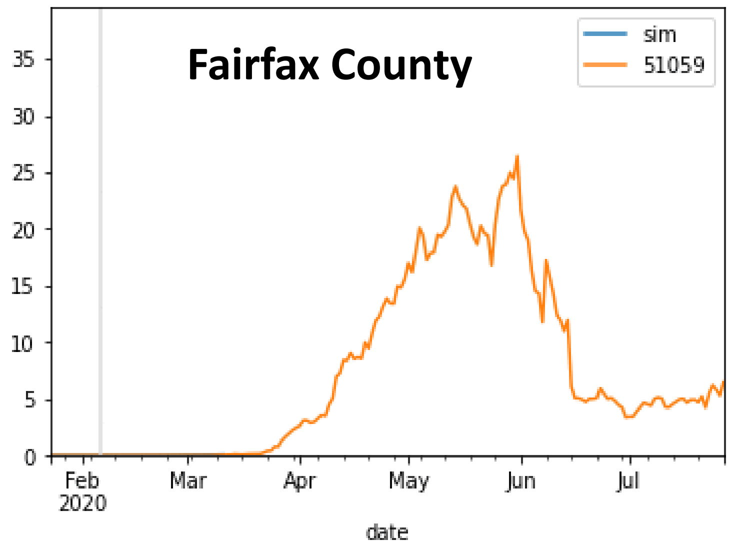
- Allows history to be precisely captured, and used to guide bounds on projections

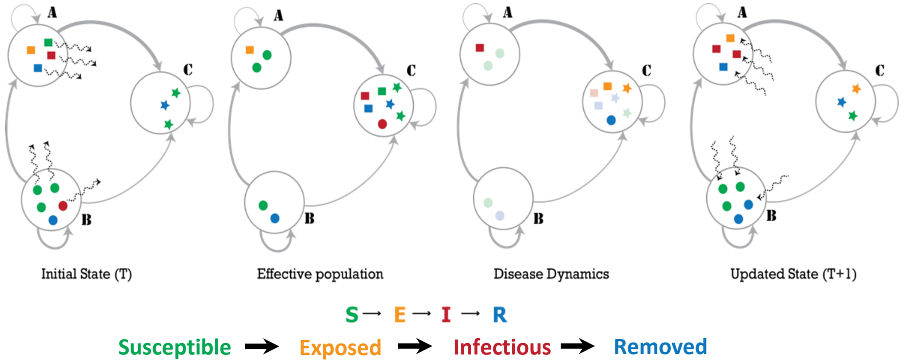
Model: An alternative use of the same meta-population model, PatchSim

  - 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

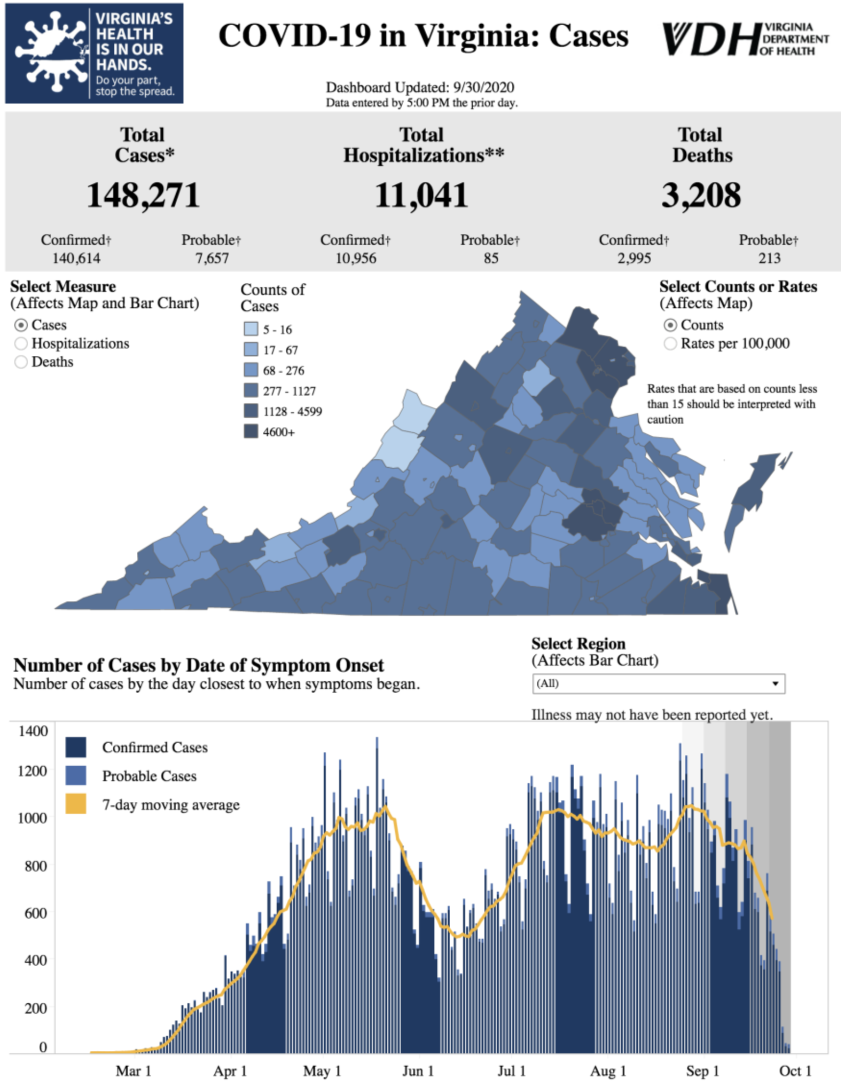
  - Widespread pandemic eliminates sensitivity to initial conditions
  - Uses steady 1 case per 10M population per day external seeding





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



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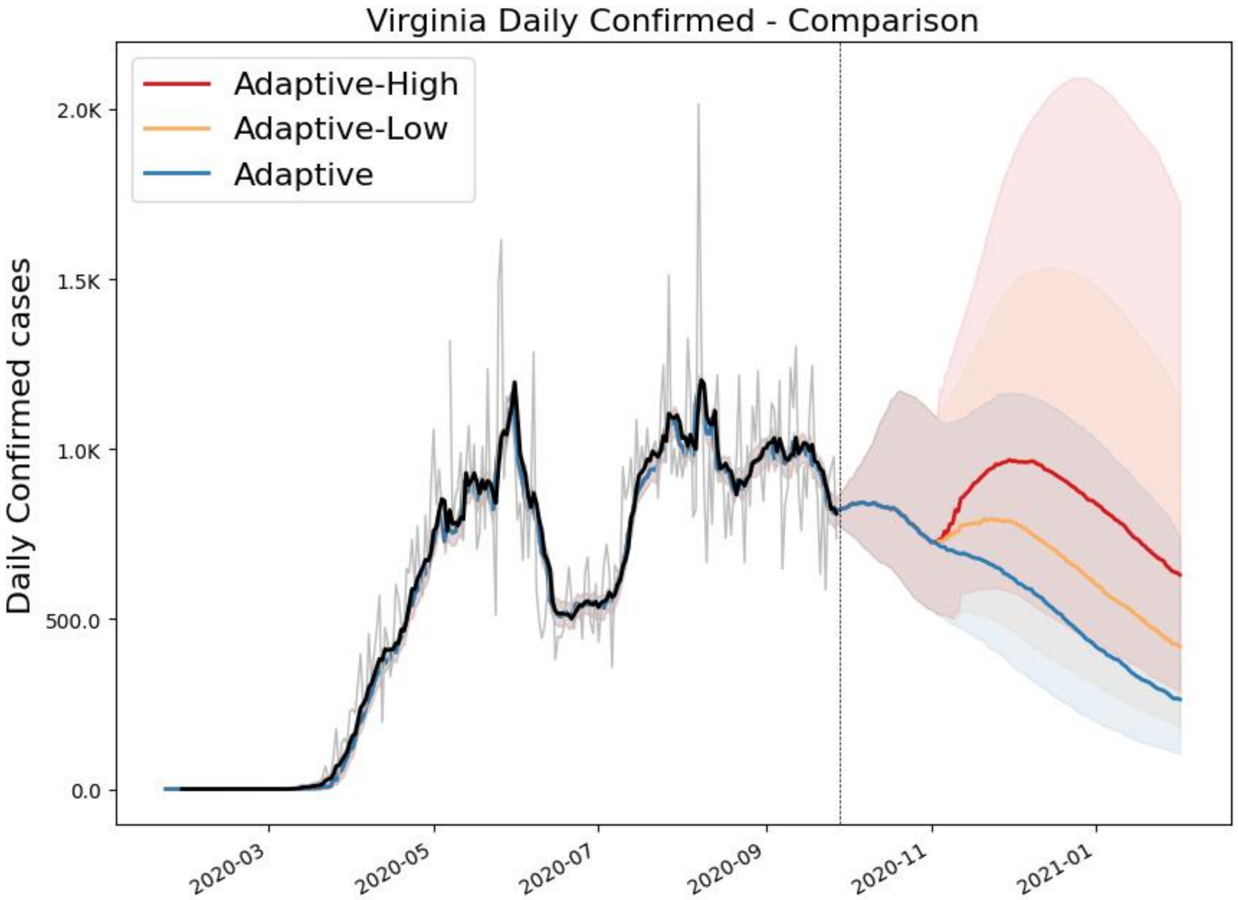
Scenarios – Seasonal Effects

- 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 Nov 1st, 2020
  - Adaptive-High: 20% increase in transmission starting Nov 1st, 2020

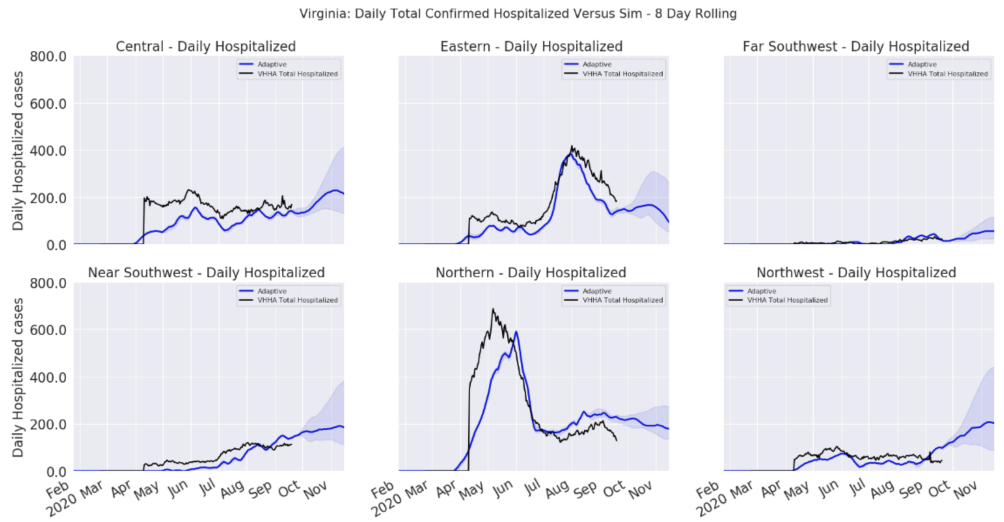
Model Results

Outcome Projections

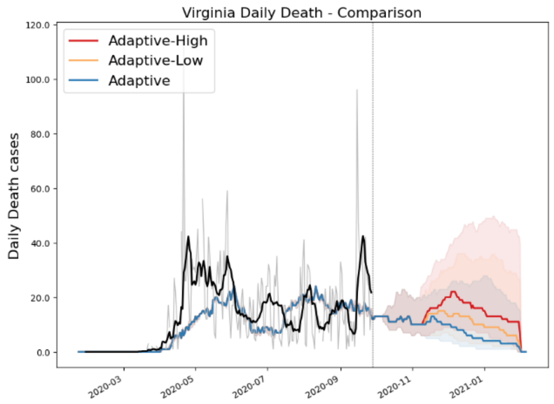
Confirmed cases



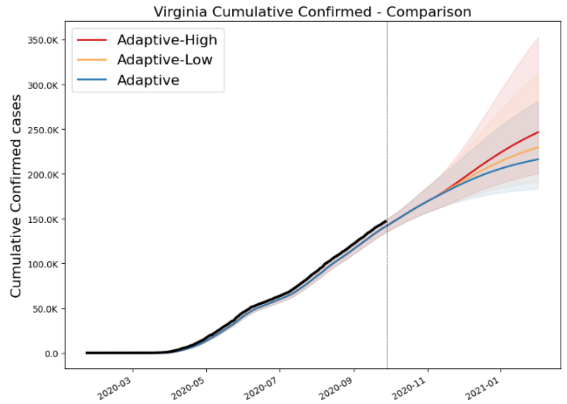
Estimated Hospital Occupancy



Daily Deaths



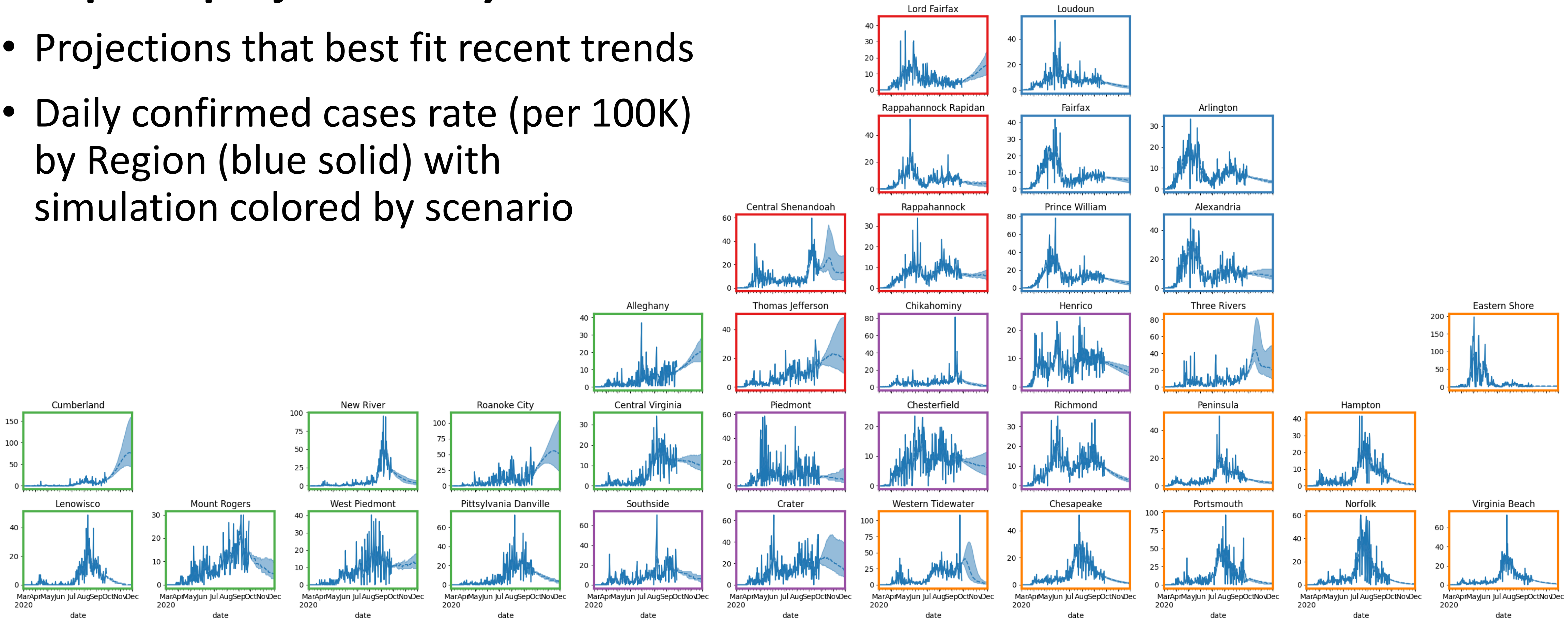
Cumulative Confirmed cases



District Level Projections: Adaptive

Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario



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District Level Projections: Adaptive-Low

Adaptive projections by District

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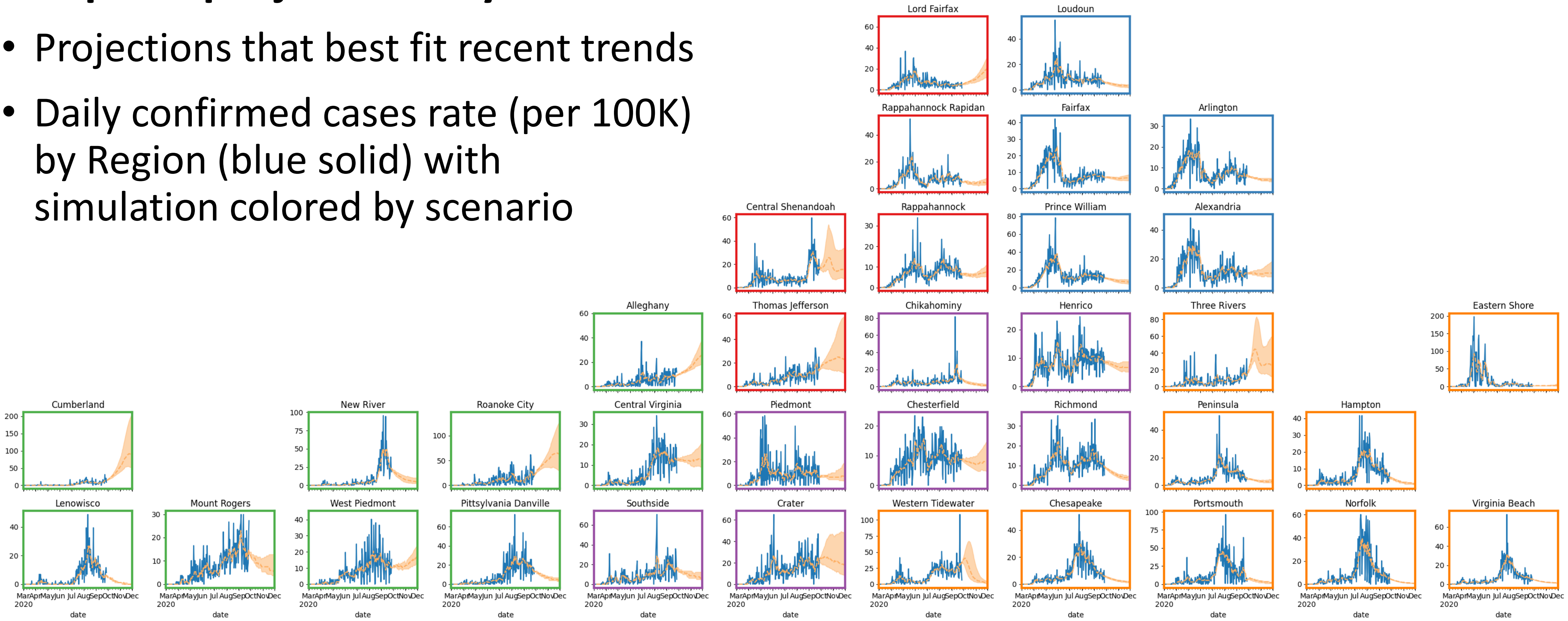

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District Level Projections: Adaptive-High

Adaptive projections by District

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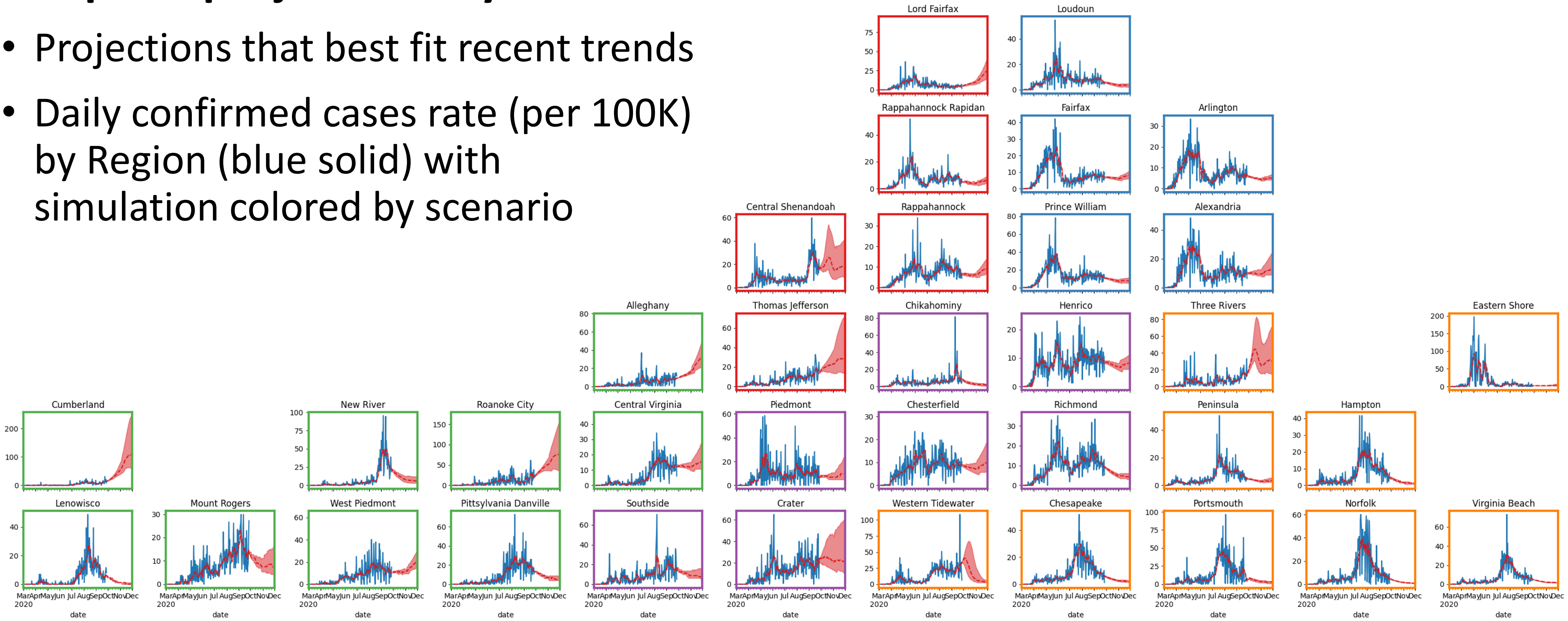

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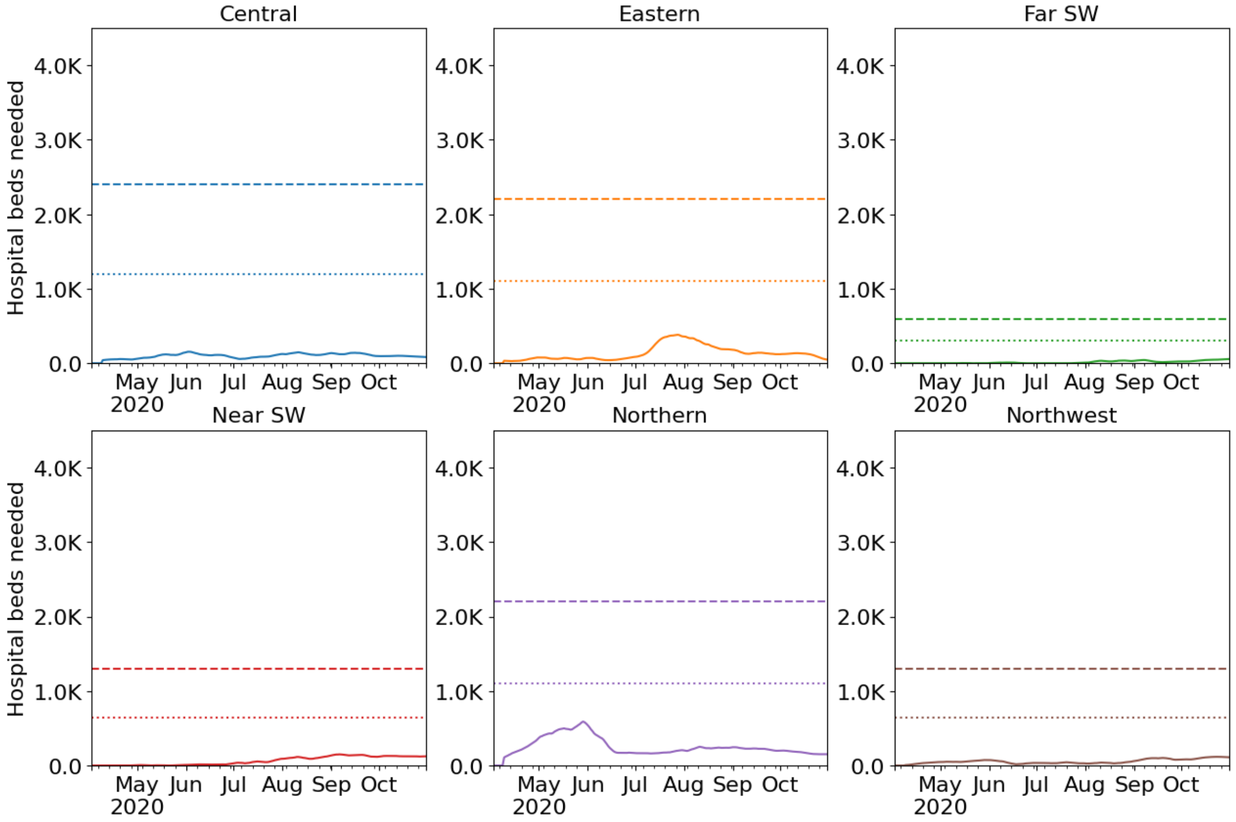
Hospital Demand and Capacity by Region

Capacities by Region – Adaptive-High

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



Week Ending	Adaptive	Adaptive-High
9/27/20	5,987	5,987
10/4/20	5,813	5,813
10/11/20	5,881	5,881
10/18/20	5,806	5,806
10/25/20	5,599	5,599
11/1/20	5,236	5,236
11/8/20	4,996	5,208
11/15/20	4,854	5,881
11/22/20	4,726	6,390
11/29/20	4,532	6,678
12/06/20	4,263	6,744
12/13/20	4,005	6,691

Based on Adaptive-High scenario

- No regions forecast to exceed capacity

* Assumes average length of stay of 8 days

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

- **Holding steady with declines outpacing growth.**
- VA weekly incidence (9.2/100K) continues to decline and now well below the national average (15/100K) which has been climbing, fueled by growth in the Plains and Mountain West.
- Projections are also mixed across commonwealth with declines outpacing growth.
- Recent updates:
  - Adaptive Fitting projection process has been streamlined.
  - Planning Scenarios moved to Nov 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.

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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

Aniruddha Adiga, Abhijin Adiga, Hannah Baek, Chris Barrett, Golda Barrow, Richard Beckman, Parantapa Bhattacharya, Andrei Bura, Jiangzhuo Chen, Patrick Corbett, Clark Cucinell, Allan Dickerman, Stephen Eubank, Arindam Fadikar, Joshua Goldstein, Stefan Hoops, Ben Hurt, Sallie Keller, Ron Kenyon, Brian Klahn, Gizem Korkmaz, Vicki Lancaster, Bryan Lewis, Dustin Machi, Chunhong Mao, Achla Marathe, Madhav Marathe, Fanchao Meng, Henning Mortveit, Mark Orr, Joseph Outten, Akhil Peddireddy, Przemyslaw Porebski, SS Ravi, Erin Raymond, Jose Bayoan Santiago Calderon, James Schlitt, Aaron Schroeder, Stephanie Shipp, Samarth Swarup, Alex Telionis, Srinivasan Venkatramanan, Anil Vullikanti, James Walke, Amanda Wilson, Dawen Xie

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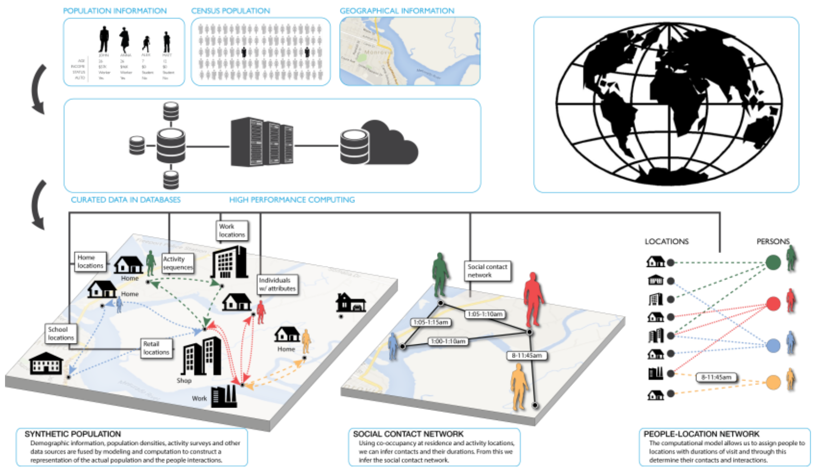
Supplemental Slides

Agent-based Model (ABM)

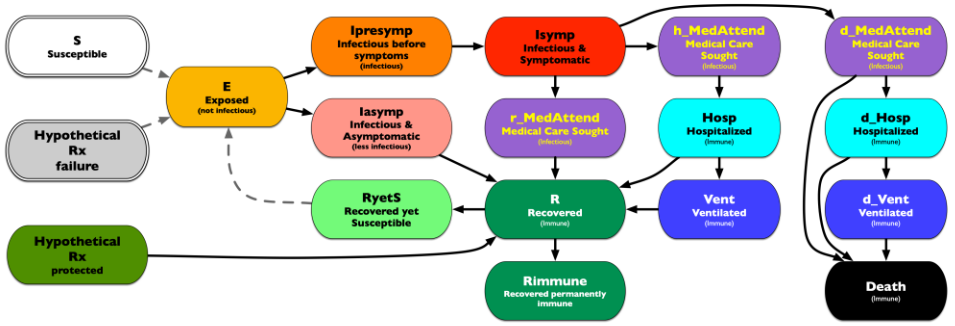
EpiHiper: Distributed network-based stochastic disease transmission simulations

- 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



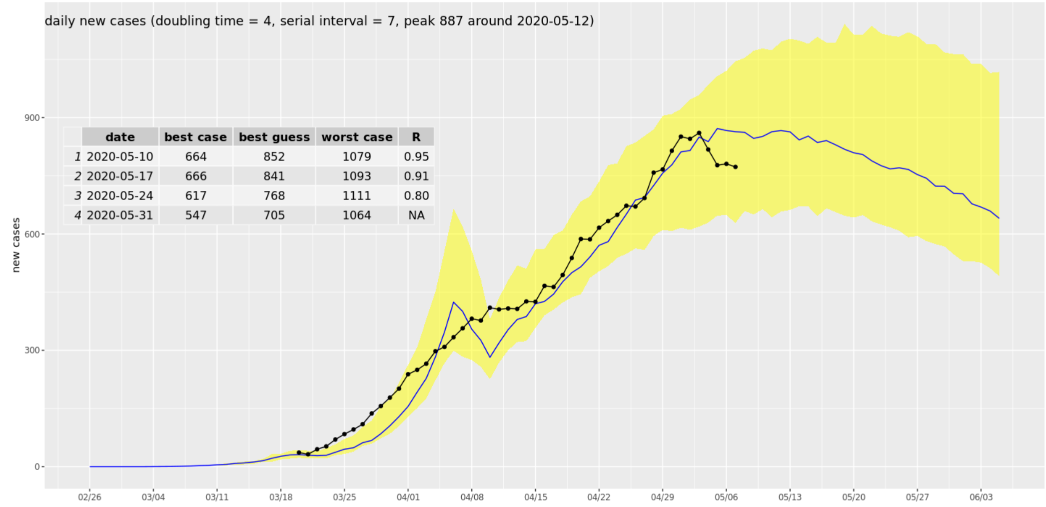
Detailed Disease Course of COVID-19

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

ABM Social Distancing Rebound Study Design

Study of ”Stay Home” policy adherence

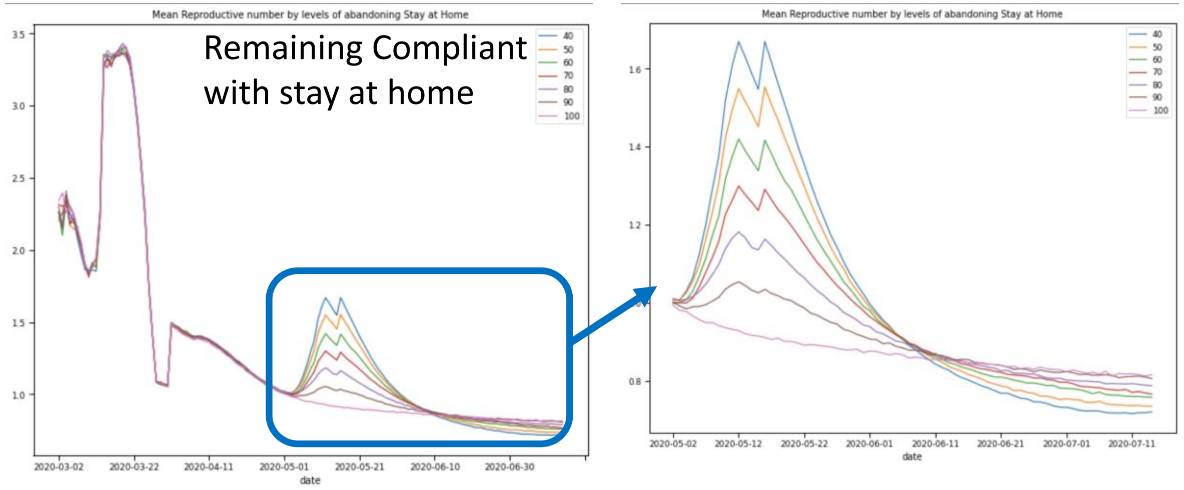
- Calibration to current state in epidemic
- Implement “release” of different proportions of people from ”staying at home”



	date	best case	best guess	worst case	R
1	2020-05-10	664	852	1079	0.95
2	2020-05-17	666	841	1093	0.91
3	2020-05-24	617	768	1111	0.80
4	2020-05-31	547	705	1064	NA

Calibration to Current State

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

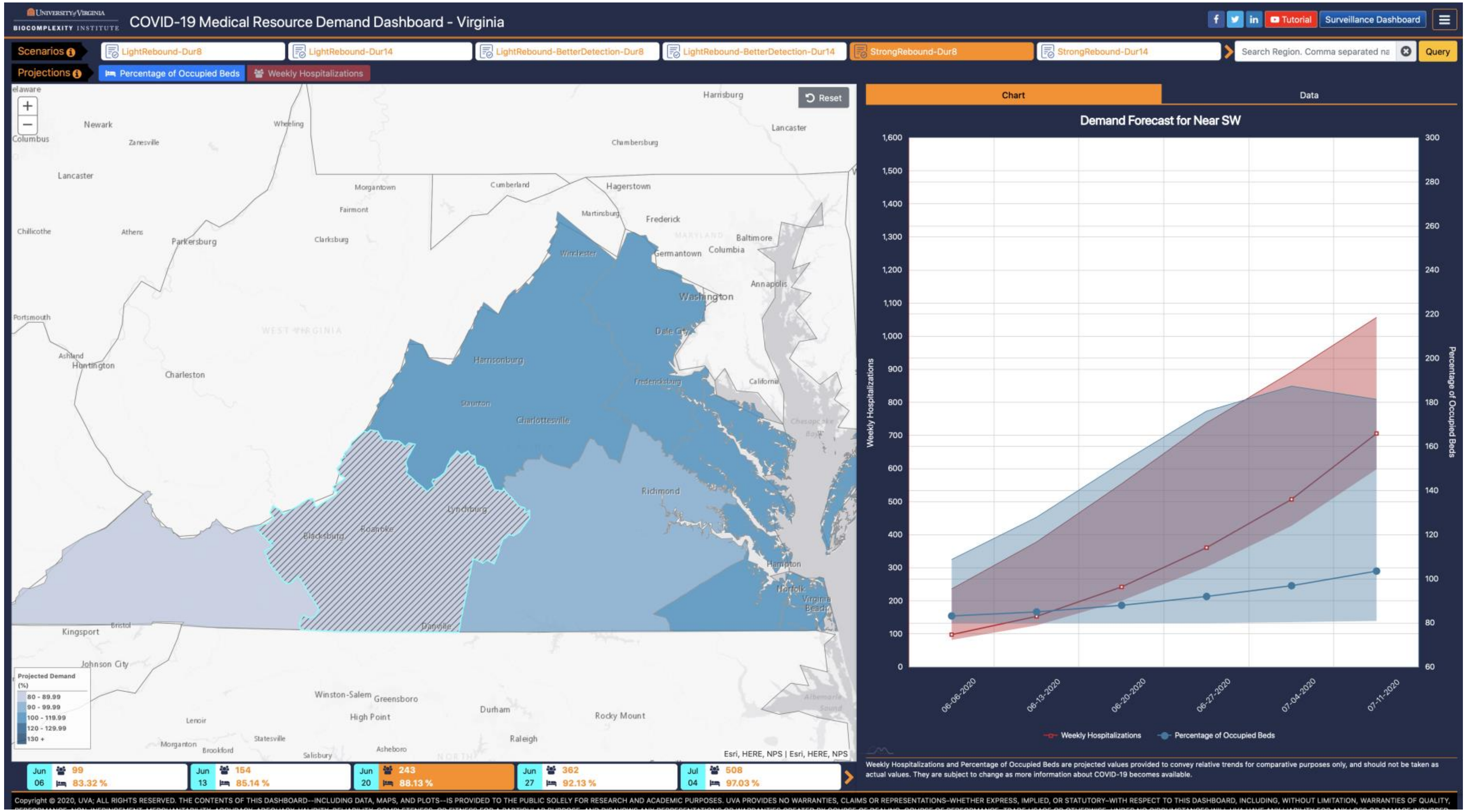


Impacts on Reproductive number with release

- 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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