Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

September 16th, 2020

(data current to September 15th)

Biocomplexity Institute Technical report: TR 2020-113

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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

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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:

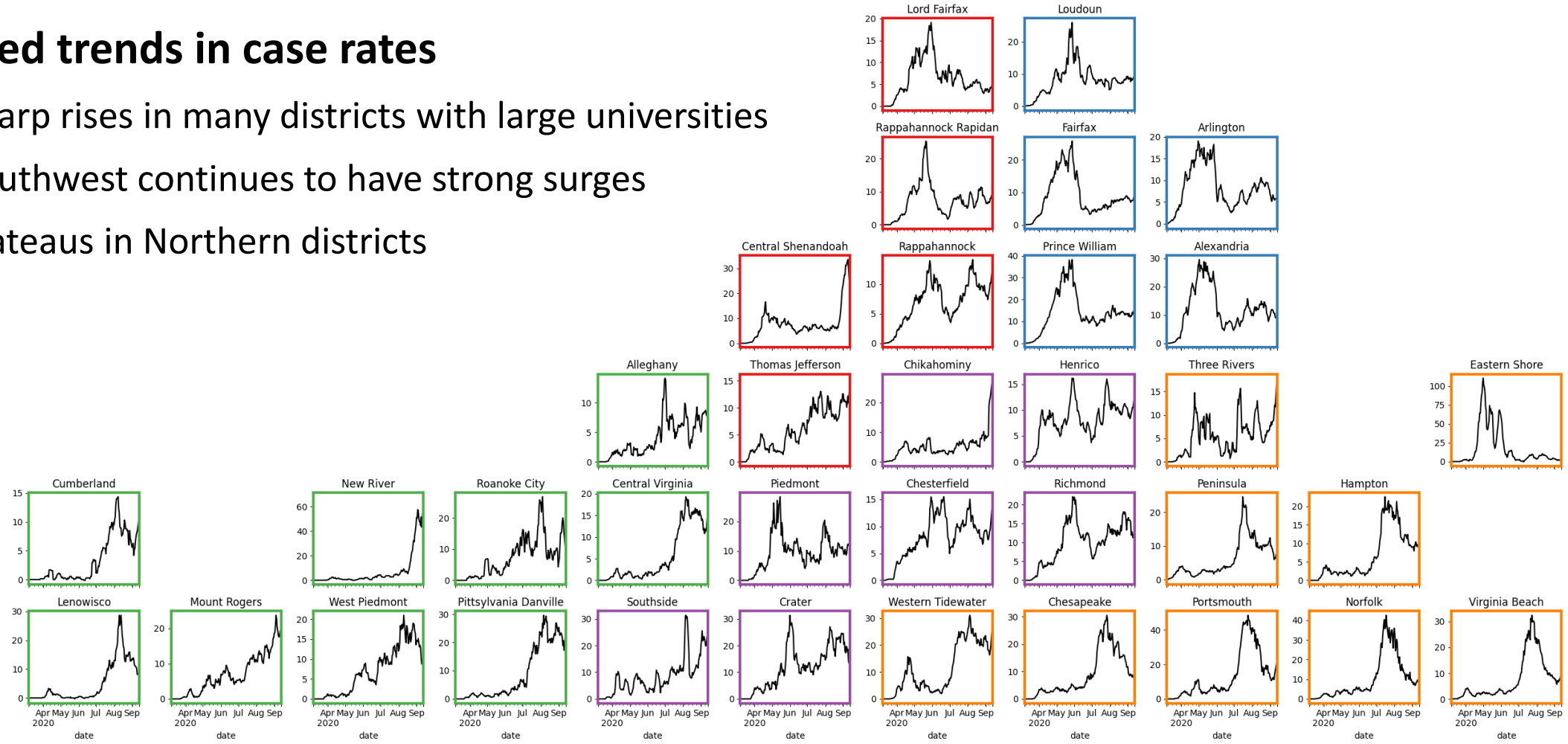
- **Mixed trends remain, surges continue in several districts.**
- Incidence (weekly) hovers at national average which is slightly higher this week ~12/100K.
- Projections are also mixed across a range of slow-growth, plateaus, and declines.
- Recent updates:
  - Adaptive Fitting projection remains, slight adjustments to projection filtering.
  - Trajectory descriptions more fully developed.
- The situation is changing rapidly. Models will be updated regularly.

Situation Assessment

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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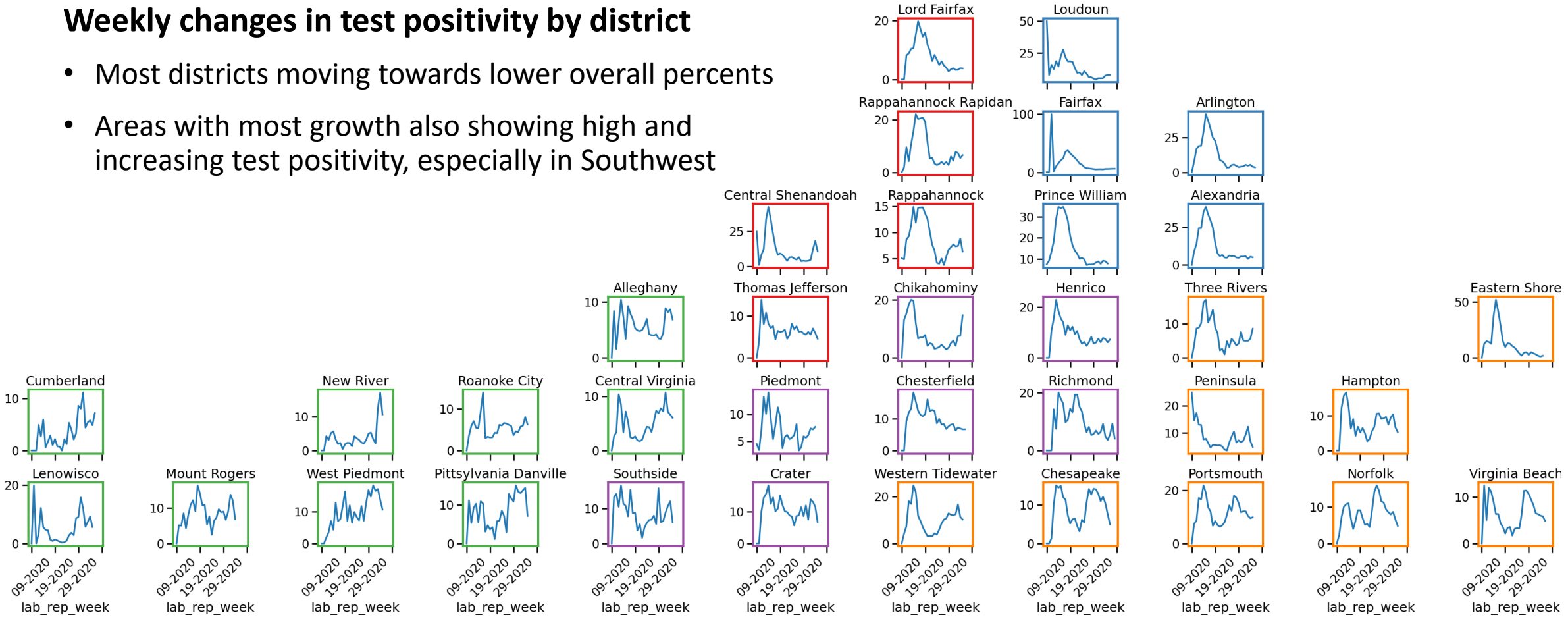
Test Positivity by VDH District

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

Declining: Sustained decreases following a recent peak

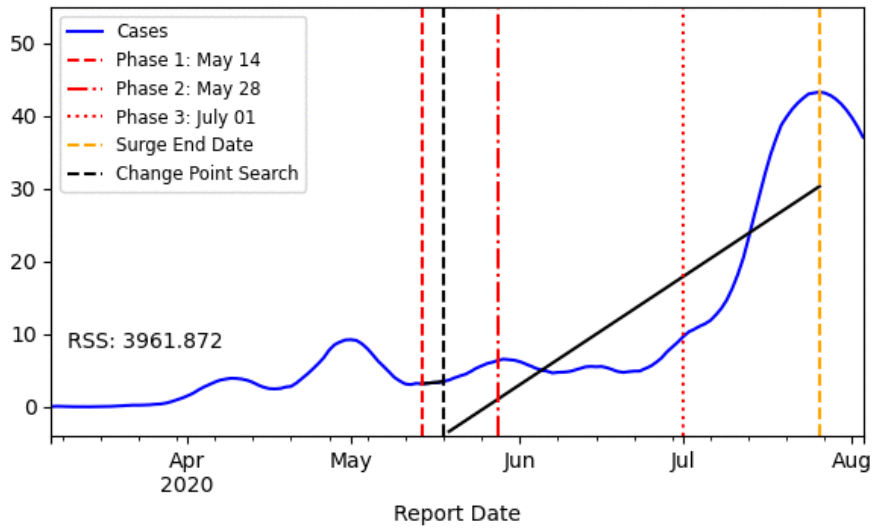
Plateau: Steady level with minimal trend up or down

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

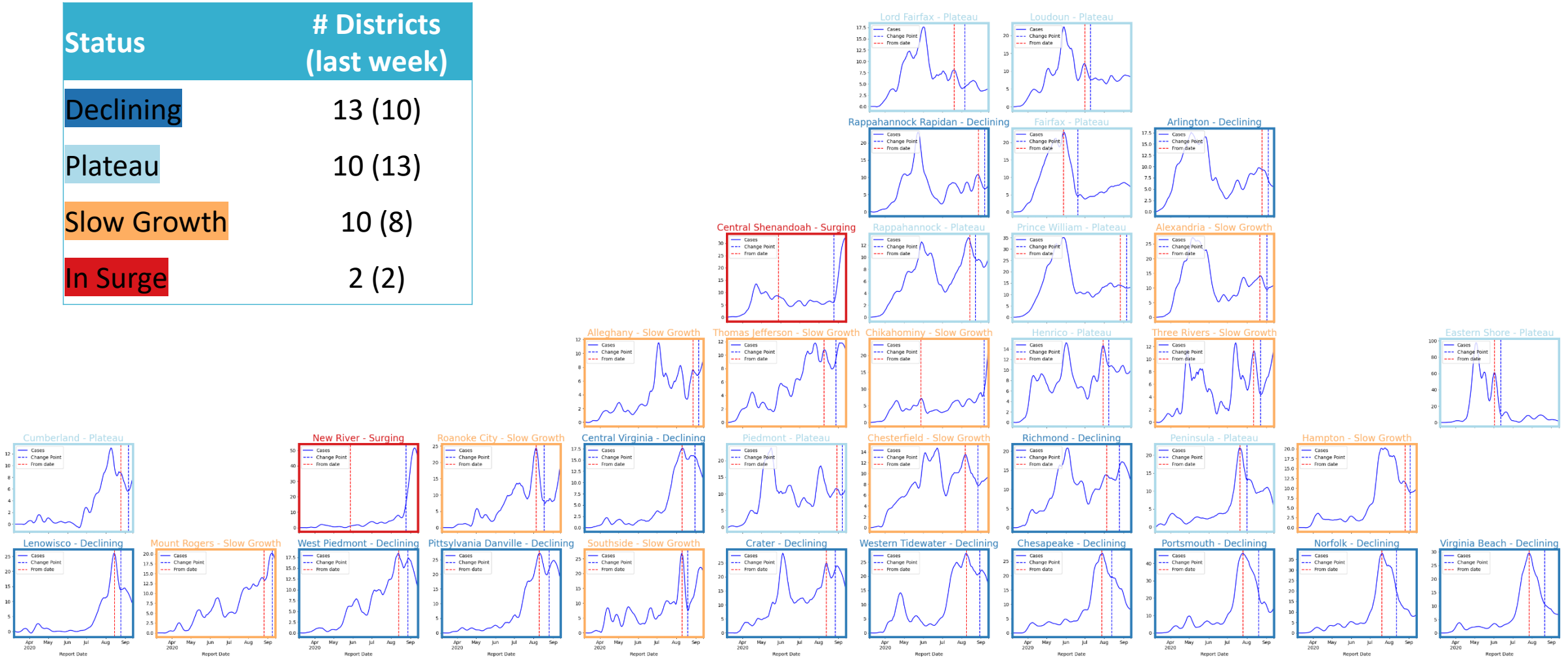
Portsmouth



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

District Trajectories – Declines outpace Growth

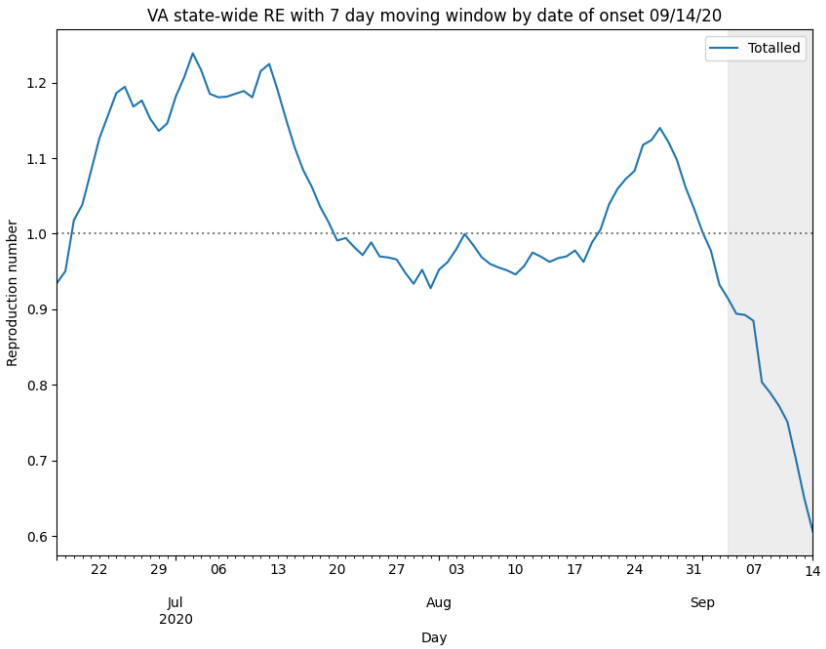
Status	# Districts (last week)
Declining	13 (10)
Plateau	10 (13)
Slow Growth	10 (8)
In Surge	2 (2)

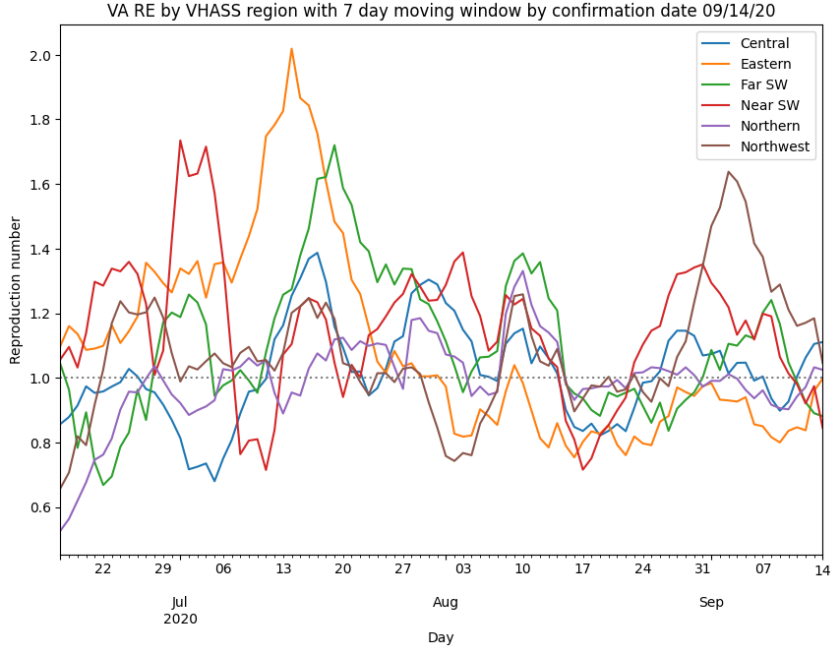


Estimating Daily Reproductive Number

September 5th Estimates

Region	Current R_e	Diff Last Week
State-wide	0.894	-0.133
Central	0.965	-0.017
Eastern	0.791	-0.134
Far SW	0.814	-0.389
Near SW	0.988	-0.084
Northern	0.833	-0.088
Northwest	0.983	-0.666





Methodology

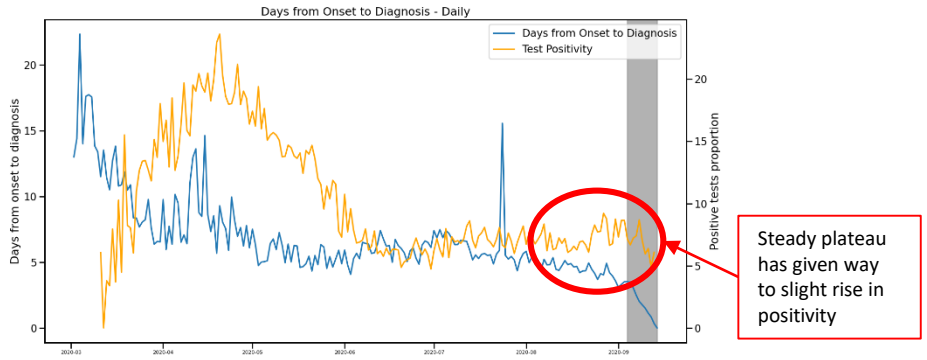
- Wallinga-Teunis method (EpiEstim[1]) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

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

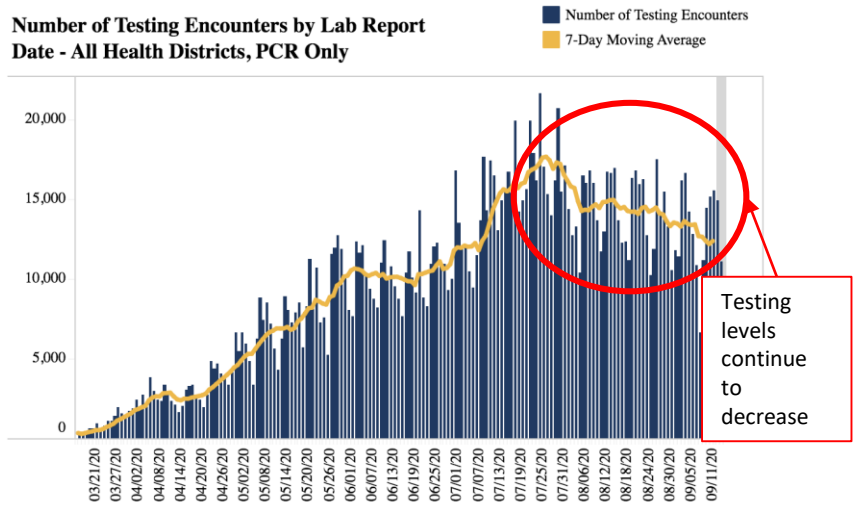
Changes in Case Detection

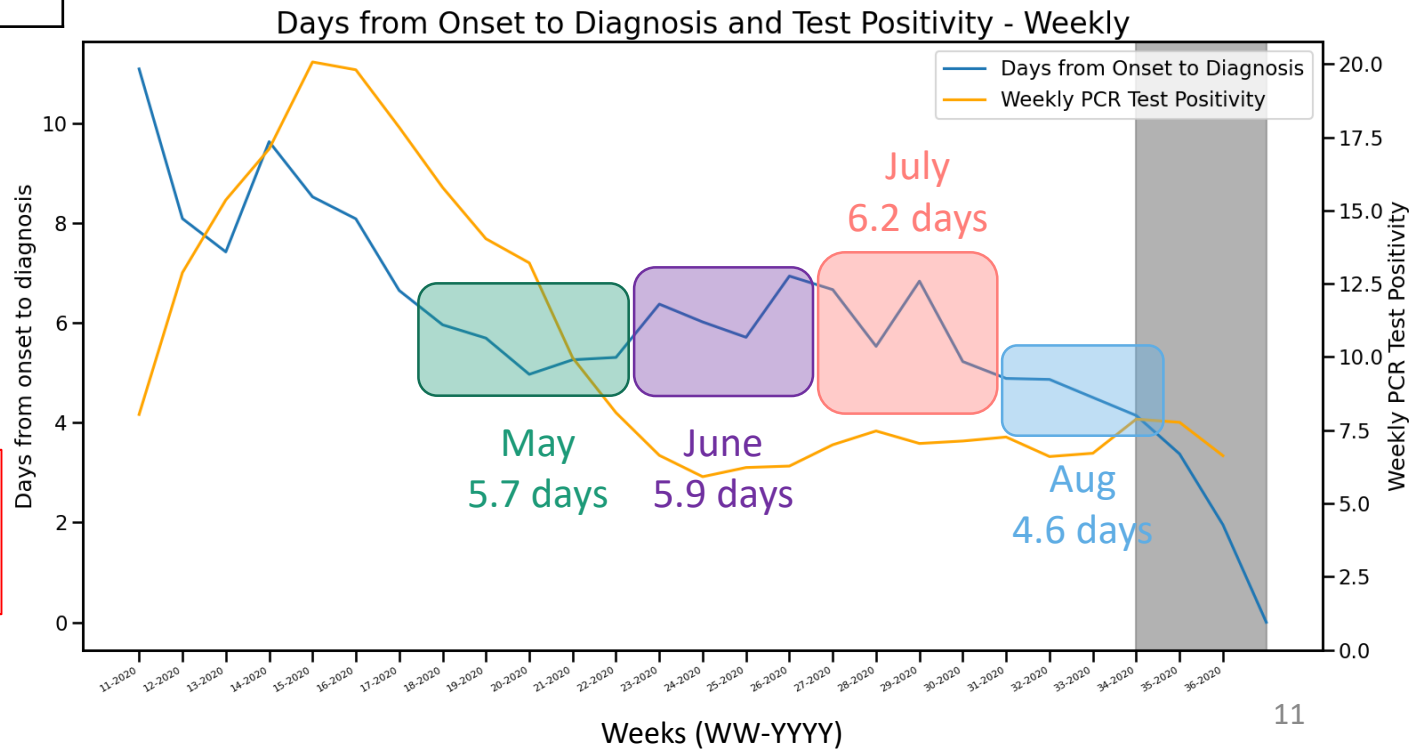
Timeframe (weeks)	Mean days	% difference from overall mean
April (13-16)	8.42	36.94%
May (17-21)	5.71	-7.14%
June (22-25)	5.85	-4.76%
July (26-30)	6.24	1.51%
Aug (31-34)	4.60	-25.15%
Overall (13-33)	6.15	0%

Test positivity vs. Onset to Diagnosis



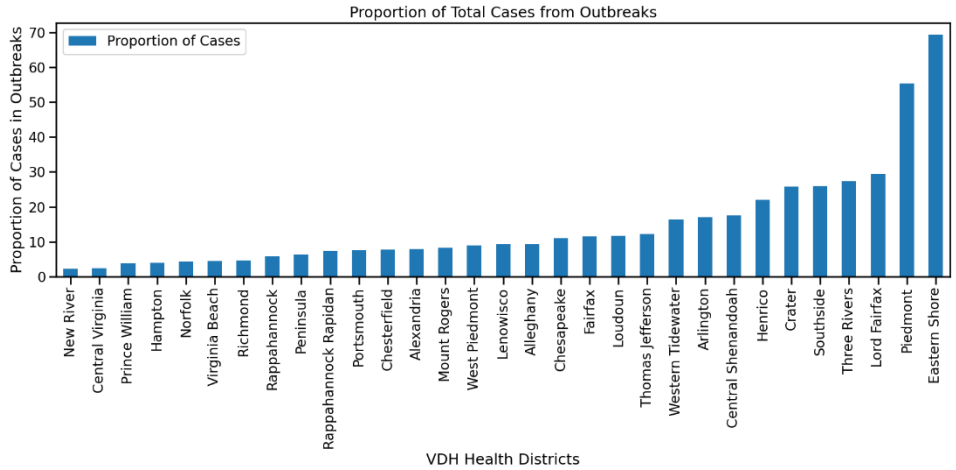
Testing Encounters and test positivity have steadied and increased





Accessed 8:30am September 16, 2020
https://www.vdh.virginia.gov/coronavirus/

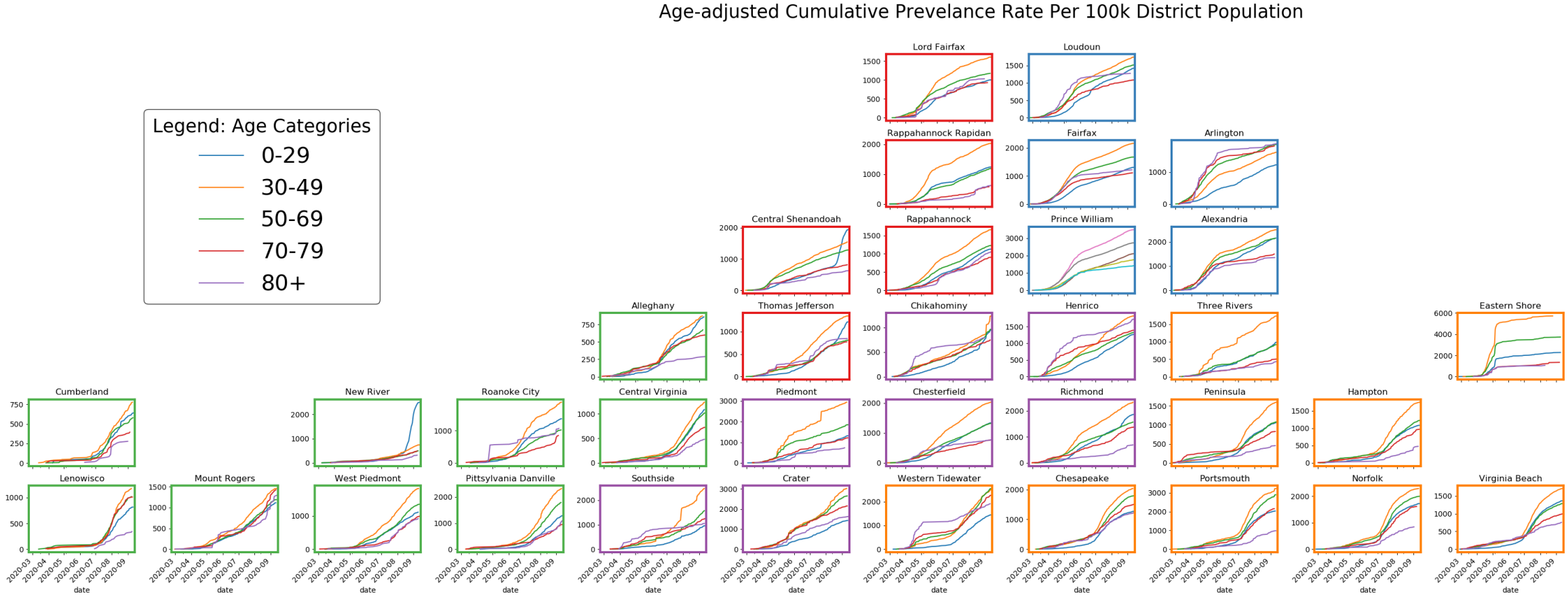
Proportion of Cases Associated with Outbreaks



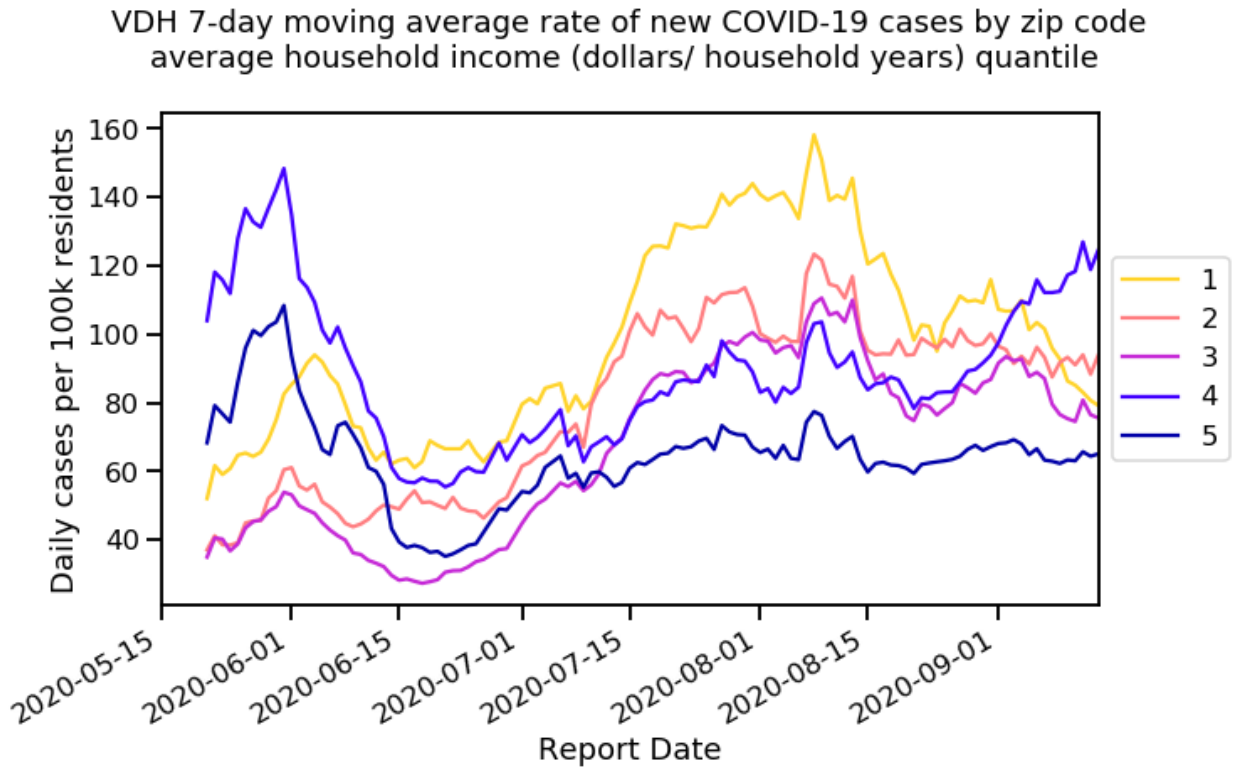
Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

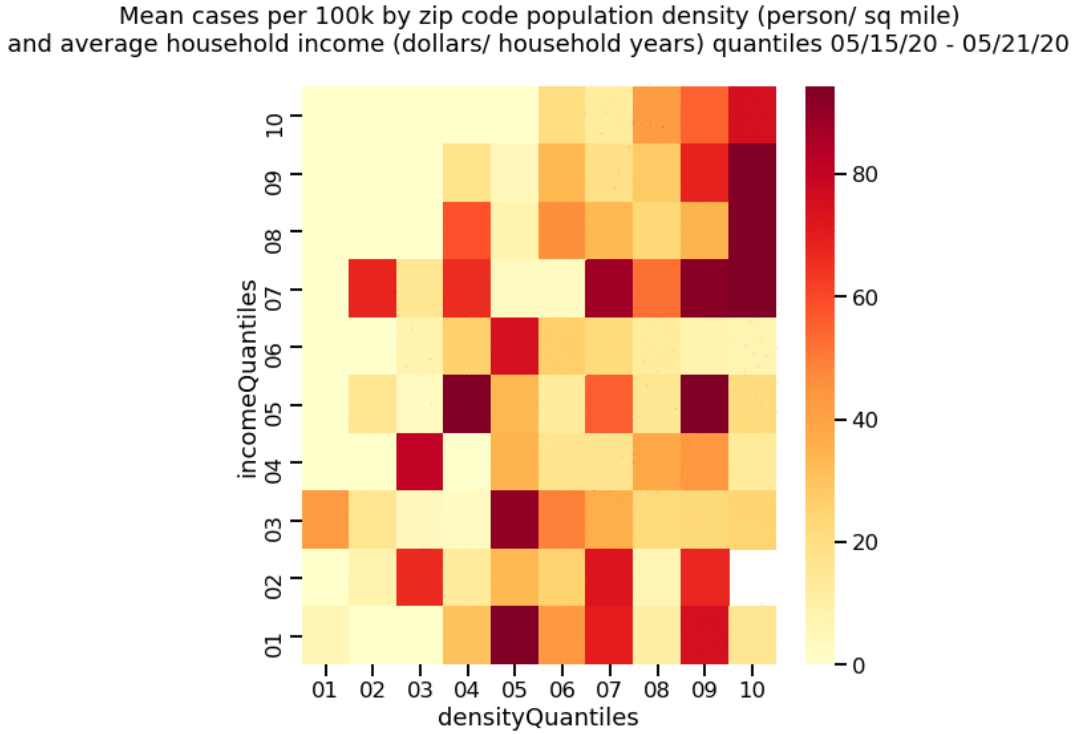
- Younger age groups outpace older in many districts



Impact across Density and Income



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

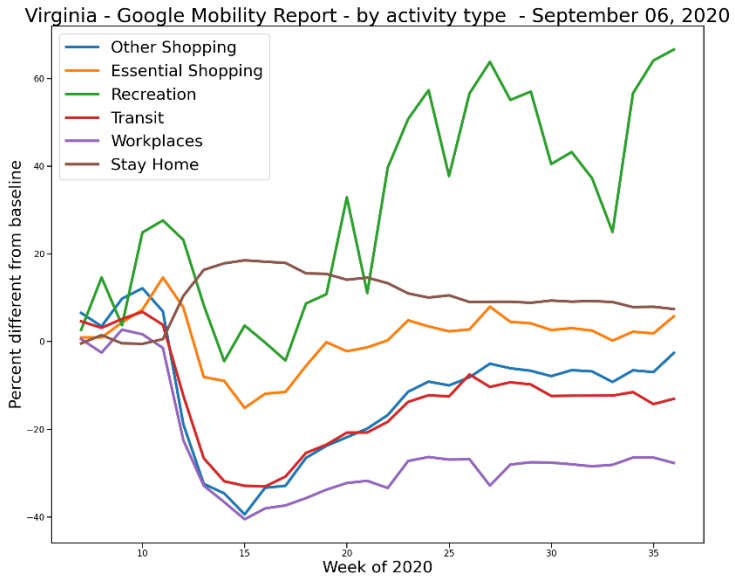


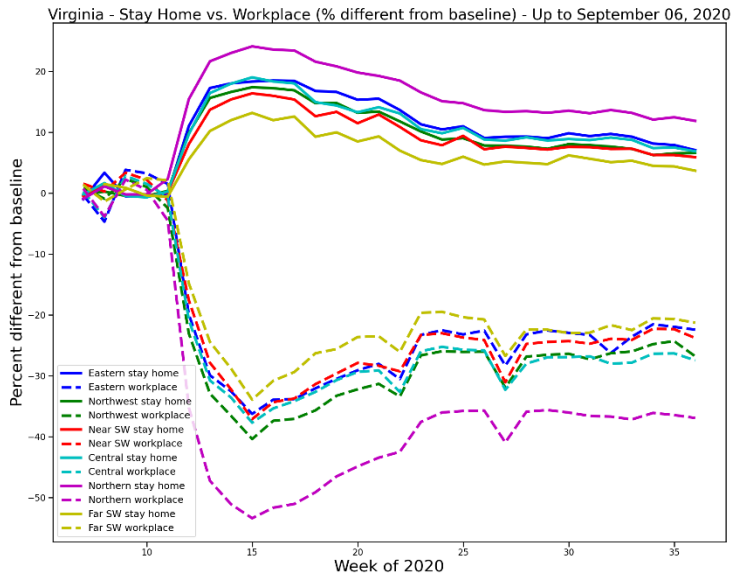
Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes, then recently back to denser wealthier zip codes

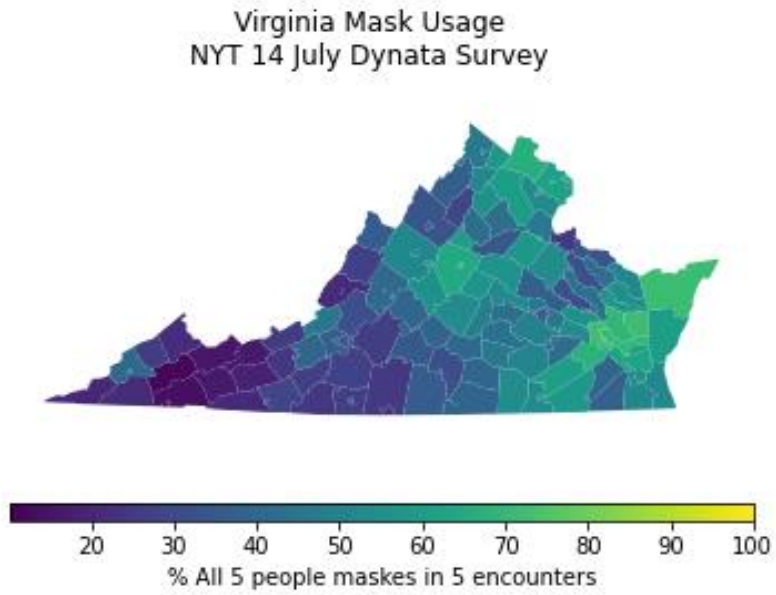
Estimating Effects of Social Distancing

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.

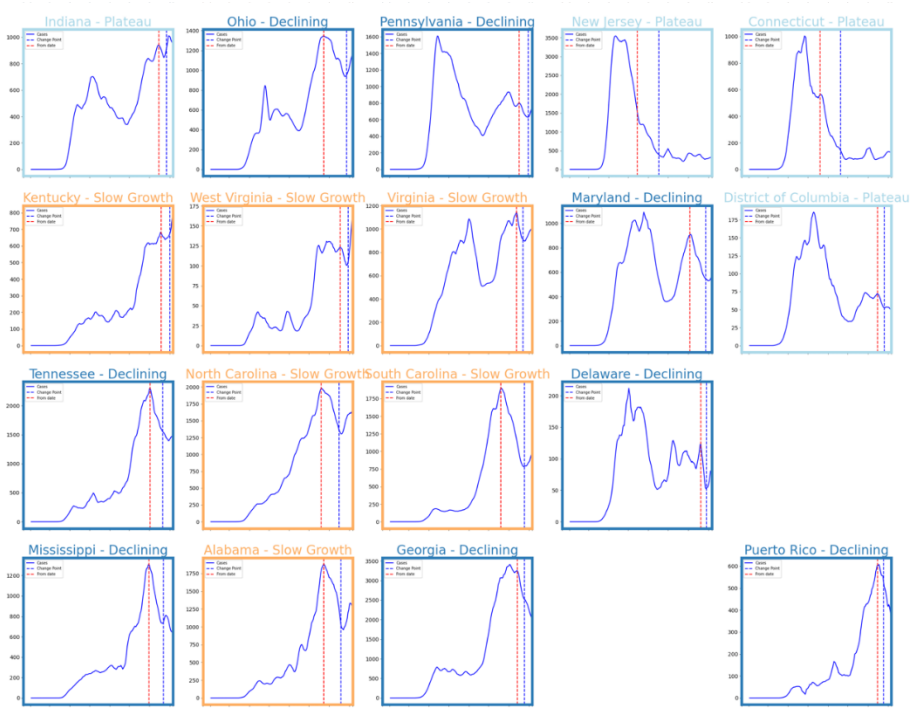






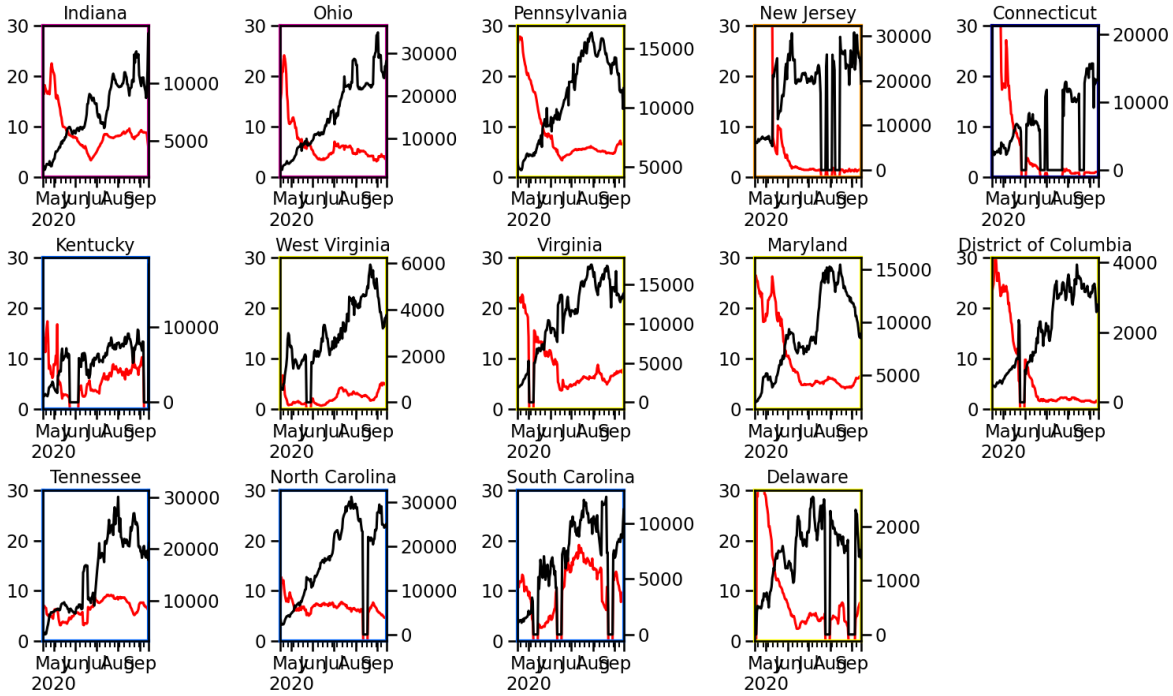
Other State Comparisons

Trajectories of States



- Mixture of trajectories
- VA, KY, WV, NC, SC showing slow growth
- Others declining and steady plateaus
- TN and SC still at a high level

Tests per Day and Test Positivity

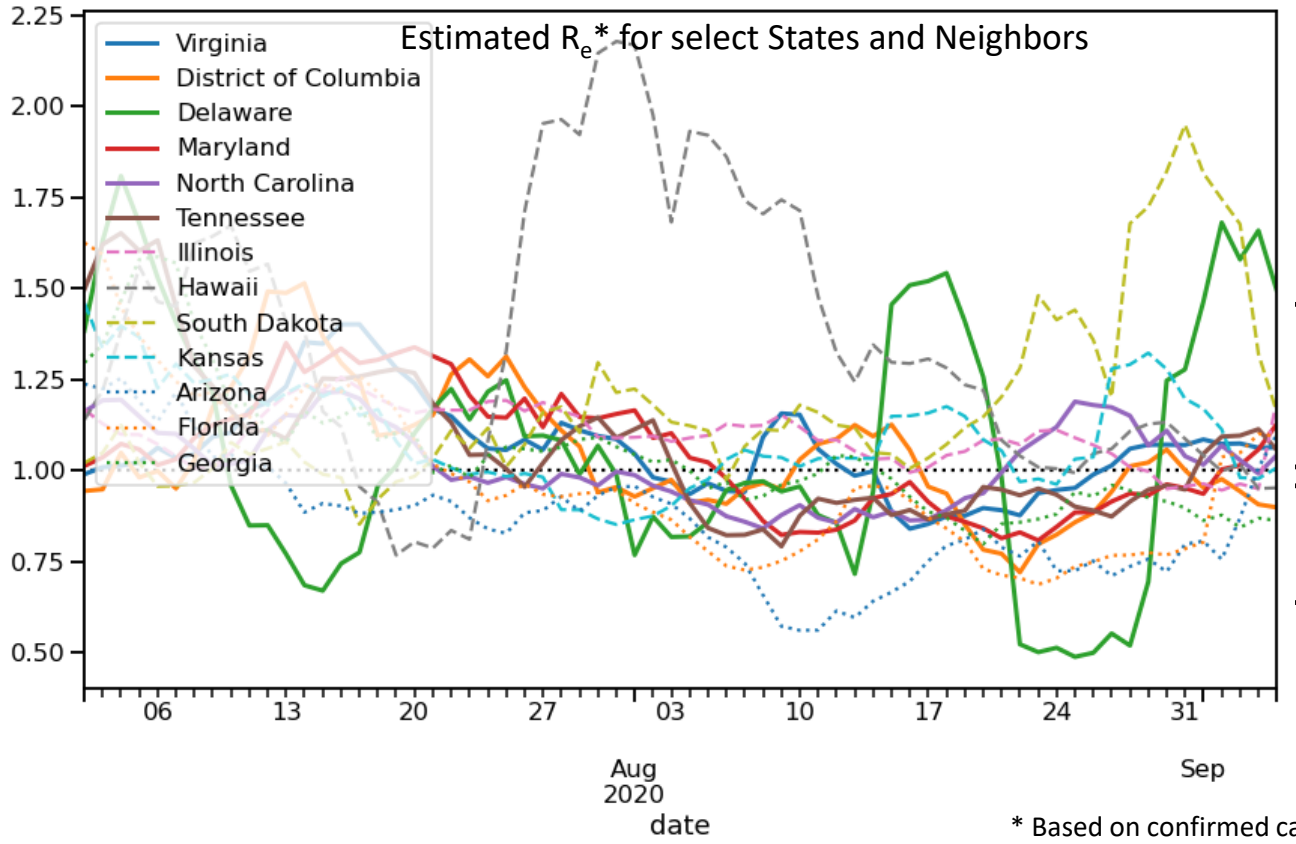


- Test positivity mixed, VA shows steady slow growth.
- Testing volumes steady and plateaued in most states.

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



New hotspots in Midwest and Plains slowing down

VA and neighbors continued decline

* Based on confirmed cases per day

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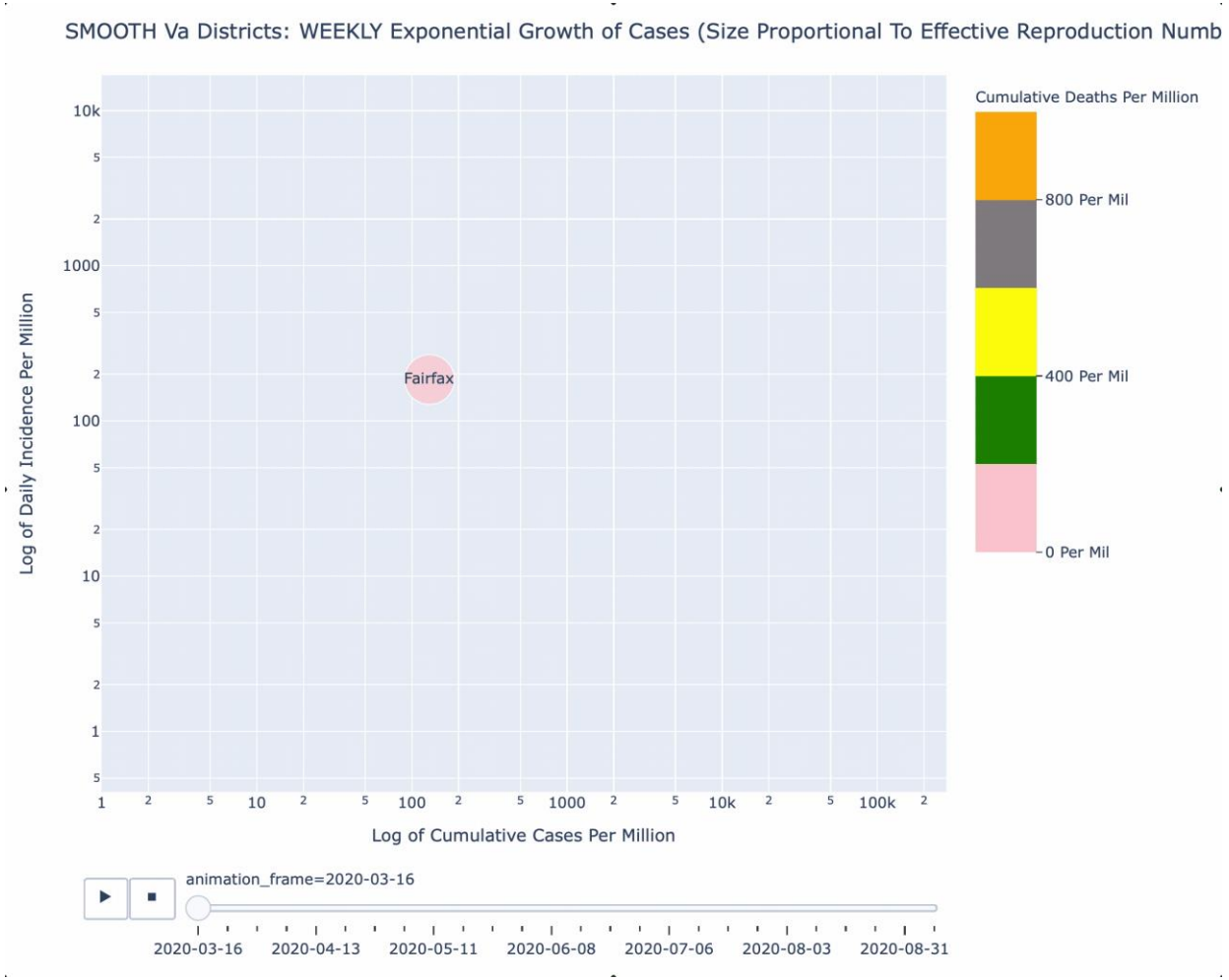
Evolution of Infections by District

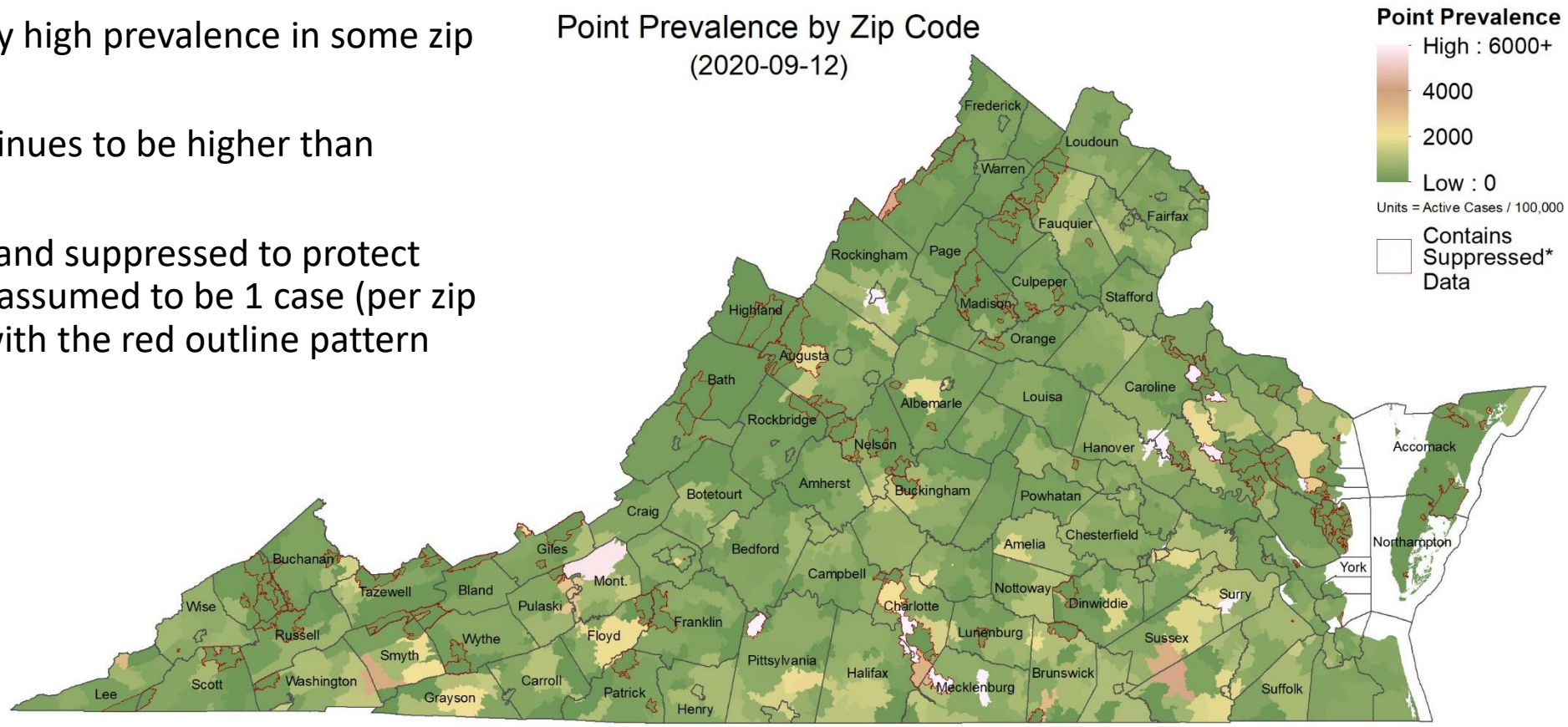
- From January to Present
- Cumulative cases vs. Daily Incidence
- Placed on log scale to minimize the differences between districts
- Colors represent cumulative deaths per million population
- Size changes based on daily estimated reproductive number



Zip code level weekly Case Rate (per 100K)

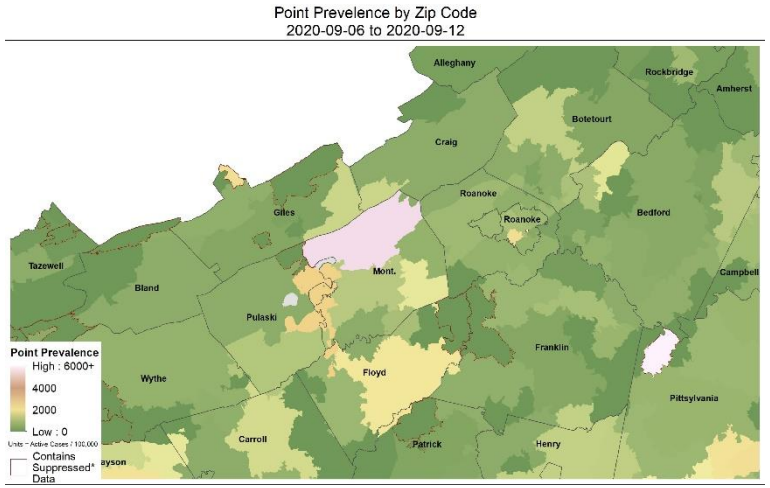
Case Rates in the last week by zip code

- 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

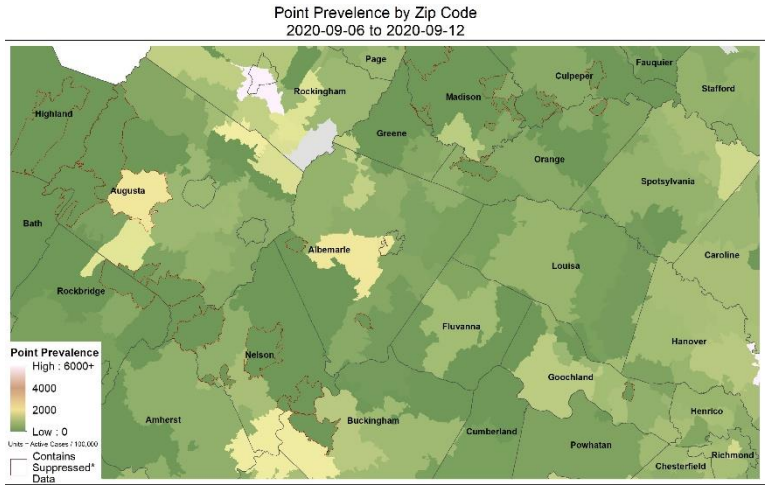


Zip code level weekly Case Rate (per 100K)

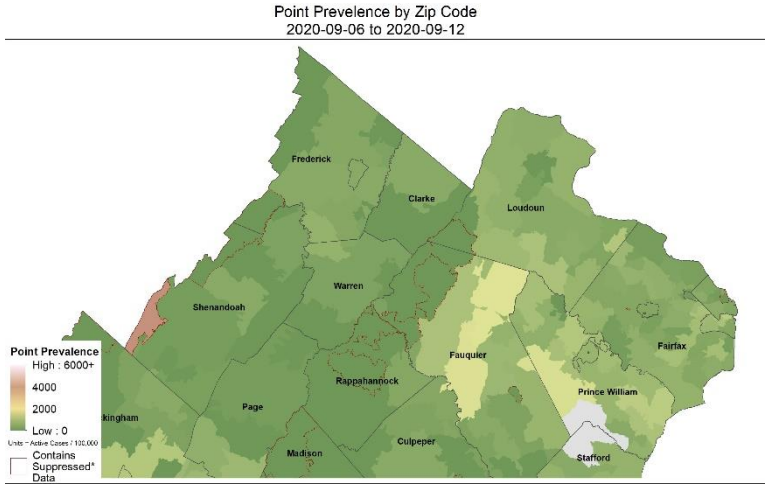
Roanoke / B'burg



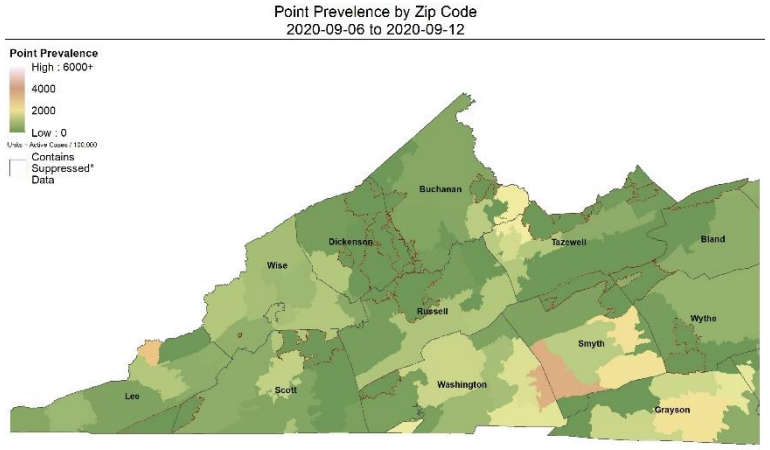
Albemarle



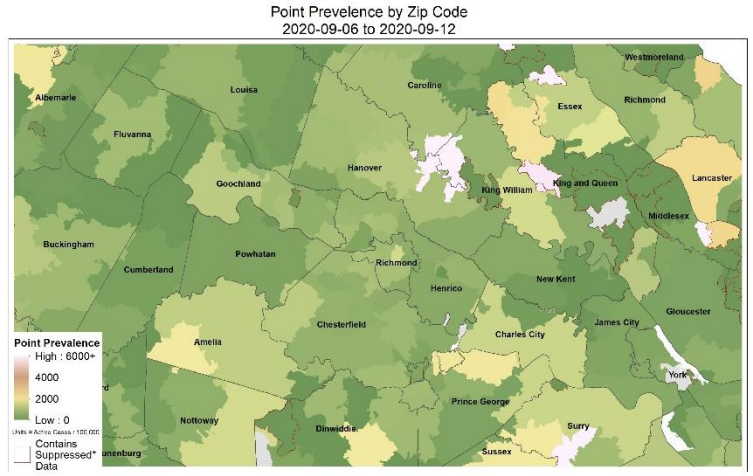
Northern Virginia



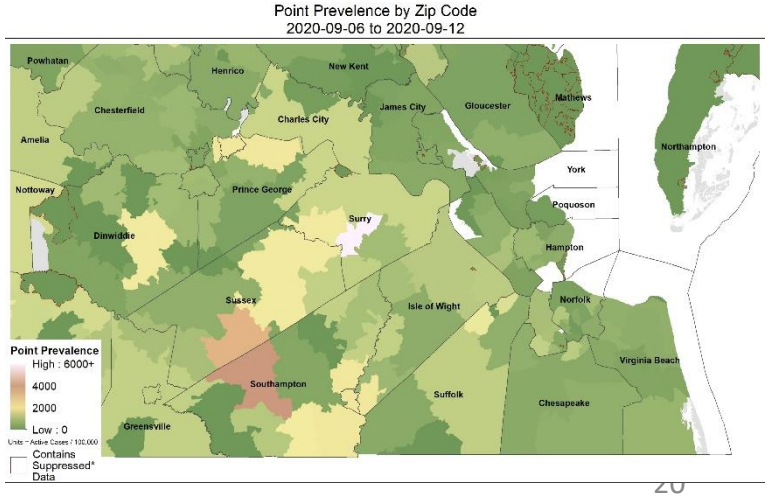
Far Southwest



Richmond

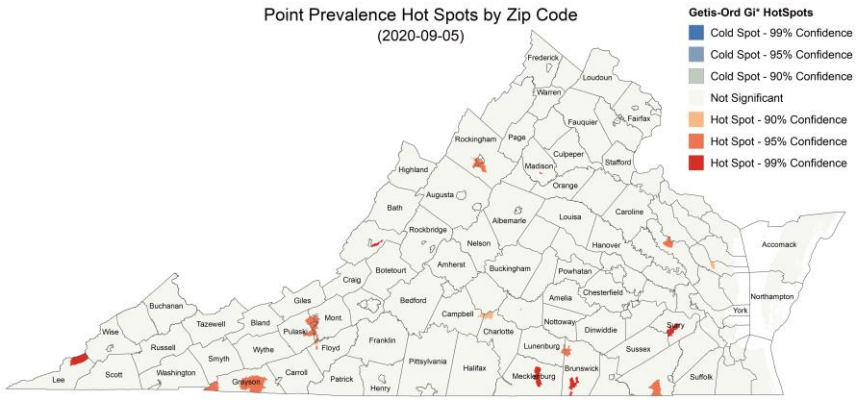


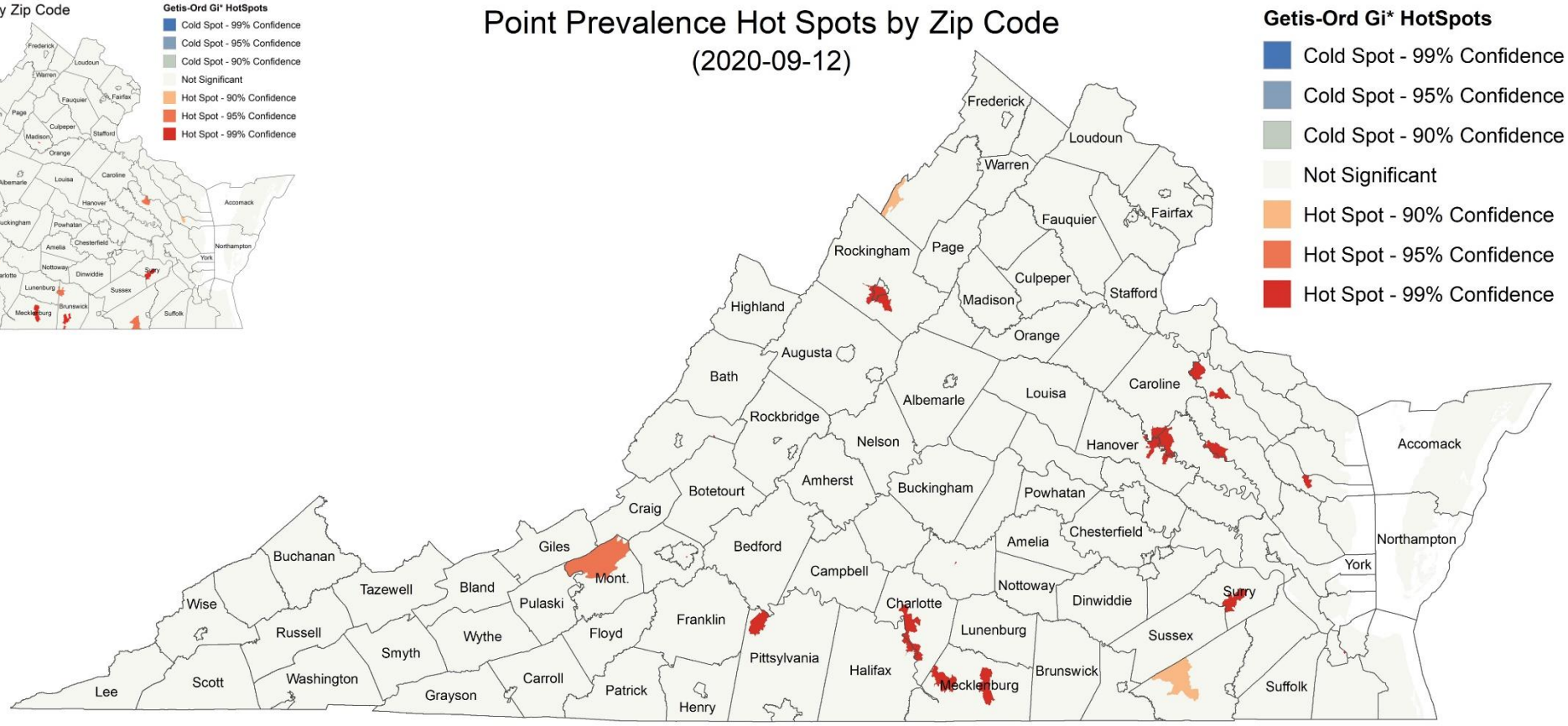
Tidewater



Zip Code Hot Spots

Previous weeks





Model Update – Adaptive Fitting

Adaptive Fitting Approach

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

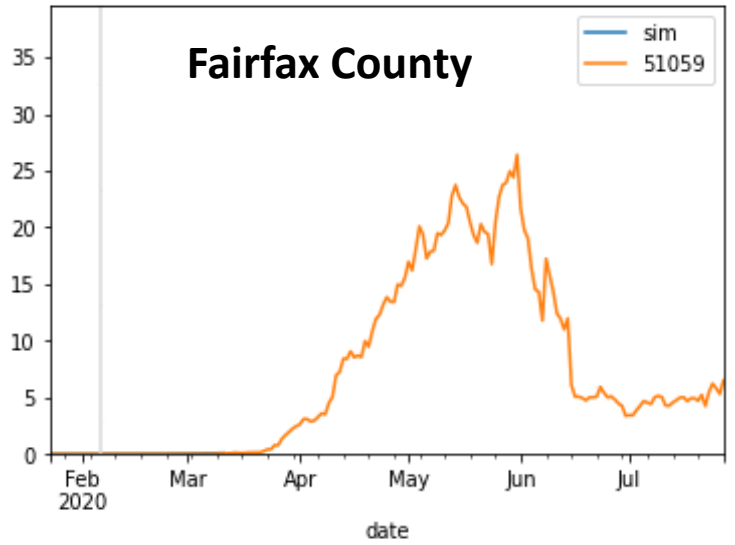
- Allows history to be precisely captured, and used to guide bounds on projections

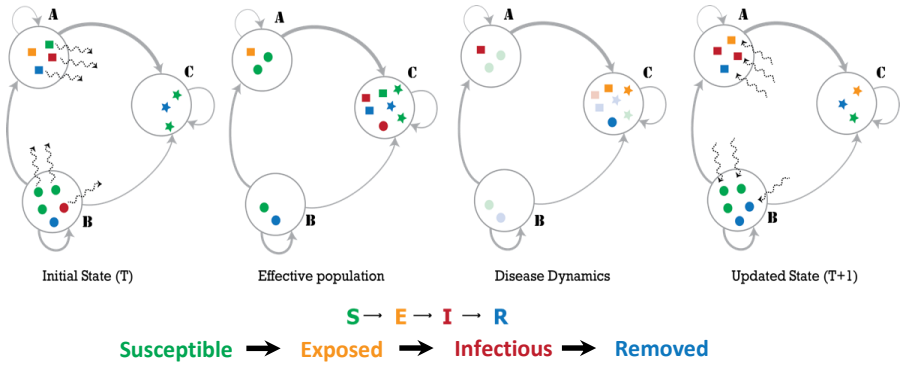
Model: An alternative use of the same meta-population model, PatchSim

- 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





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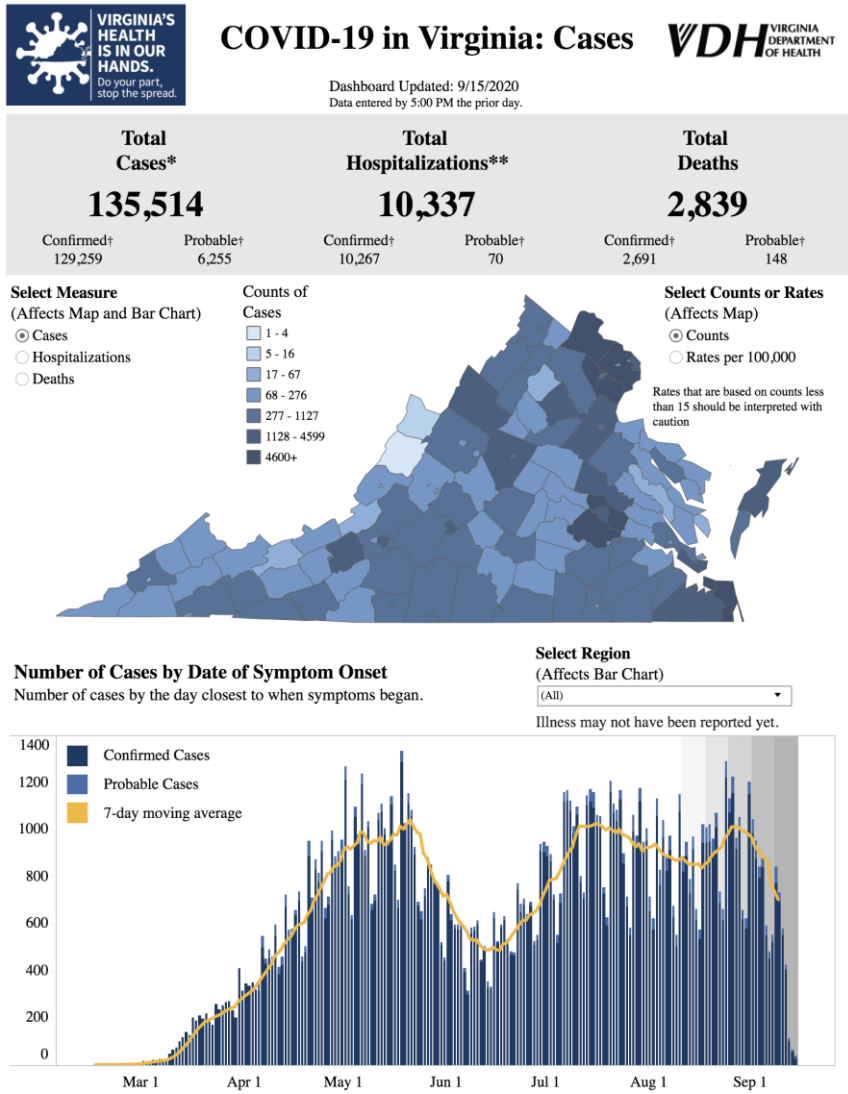
Calibration Approach

- **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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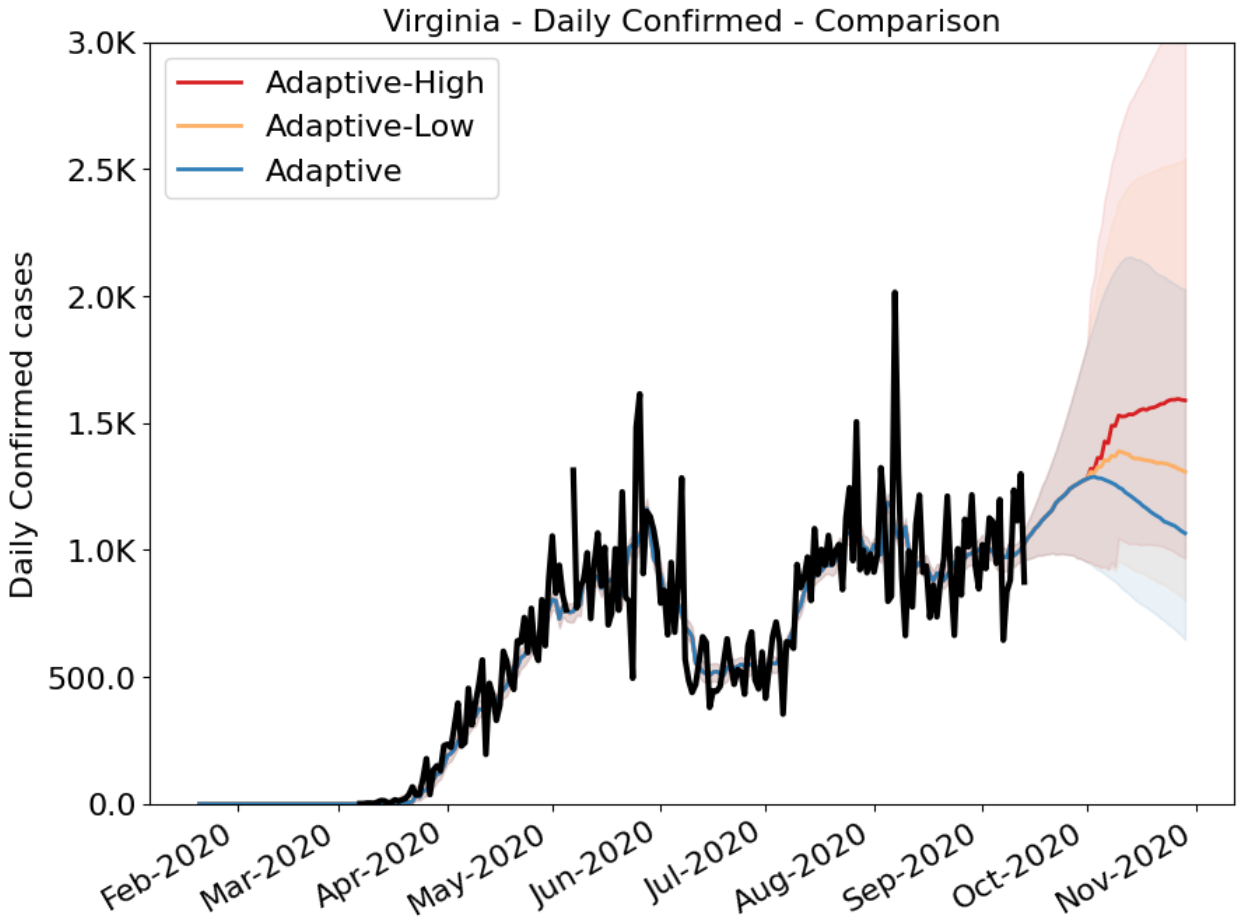
Scenarios – Seasonal Effects

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

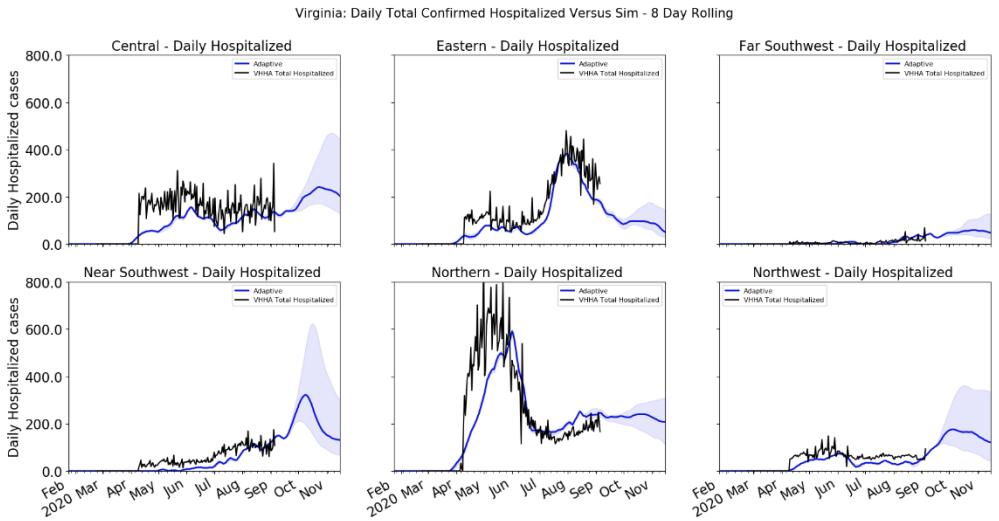
Model Results

Outcome Projections

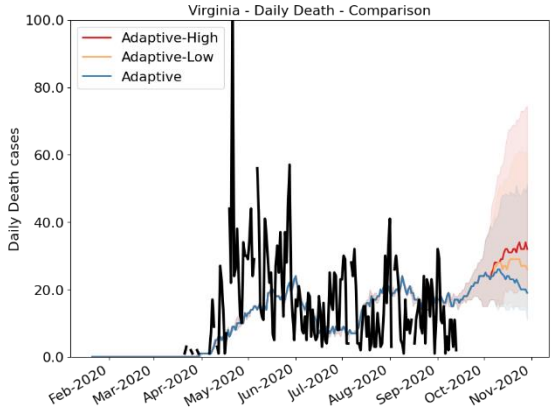
Confirmed cases



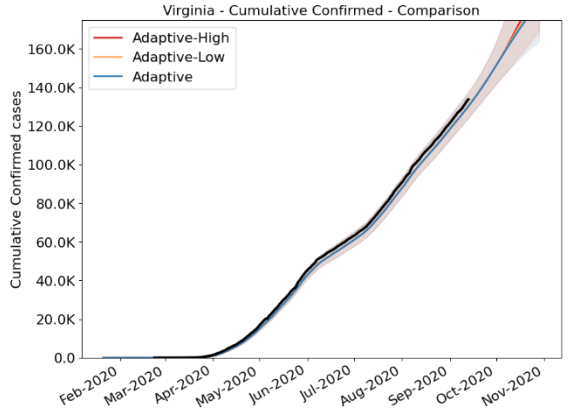
Estimated Hospital Occupancy



Daily Deaths



Cumulative Confirmed cases



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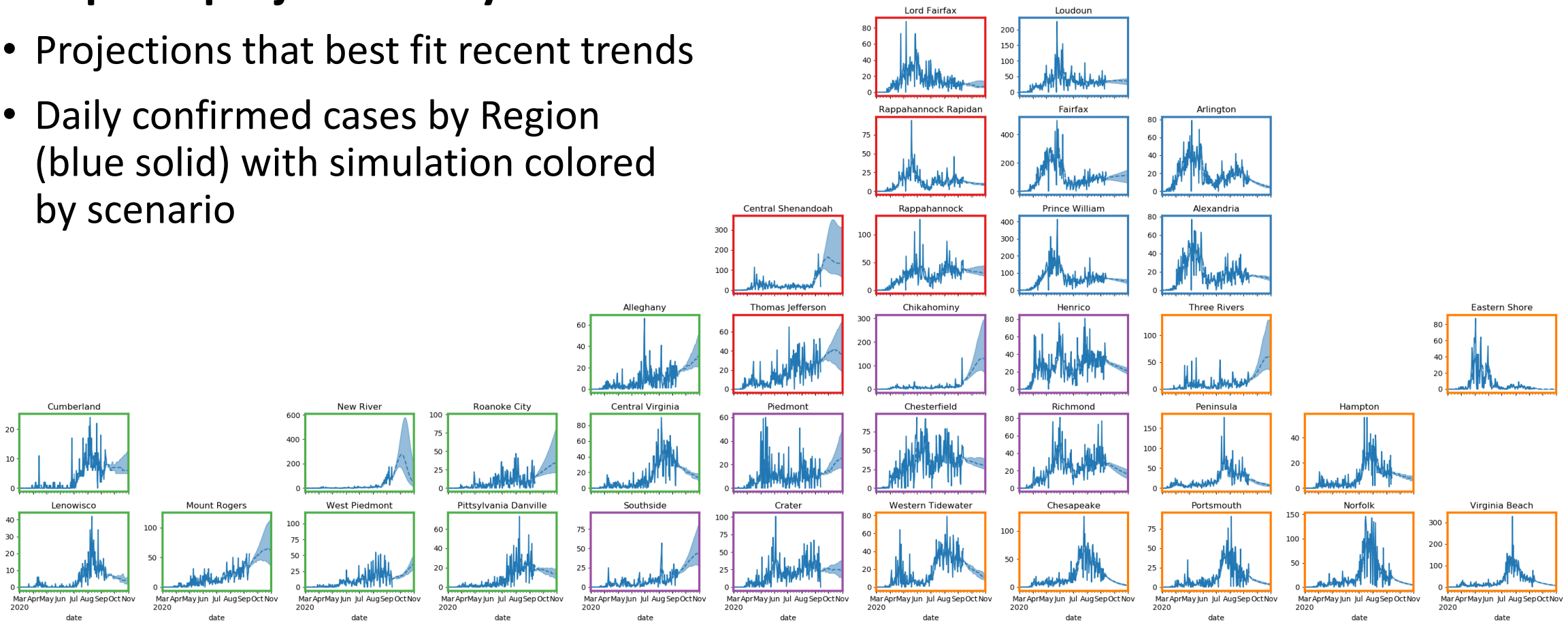
District Level Projections: Adaptive

Adaptive projections by District

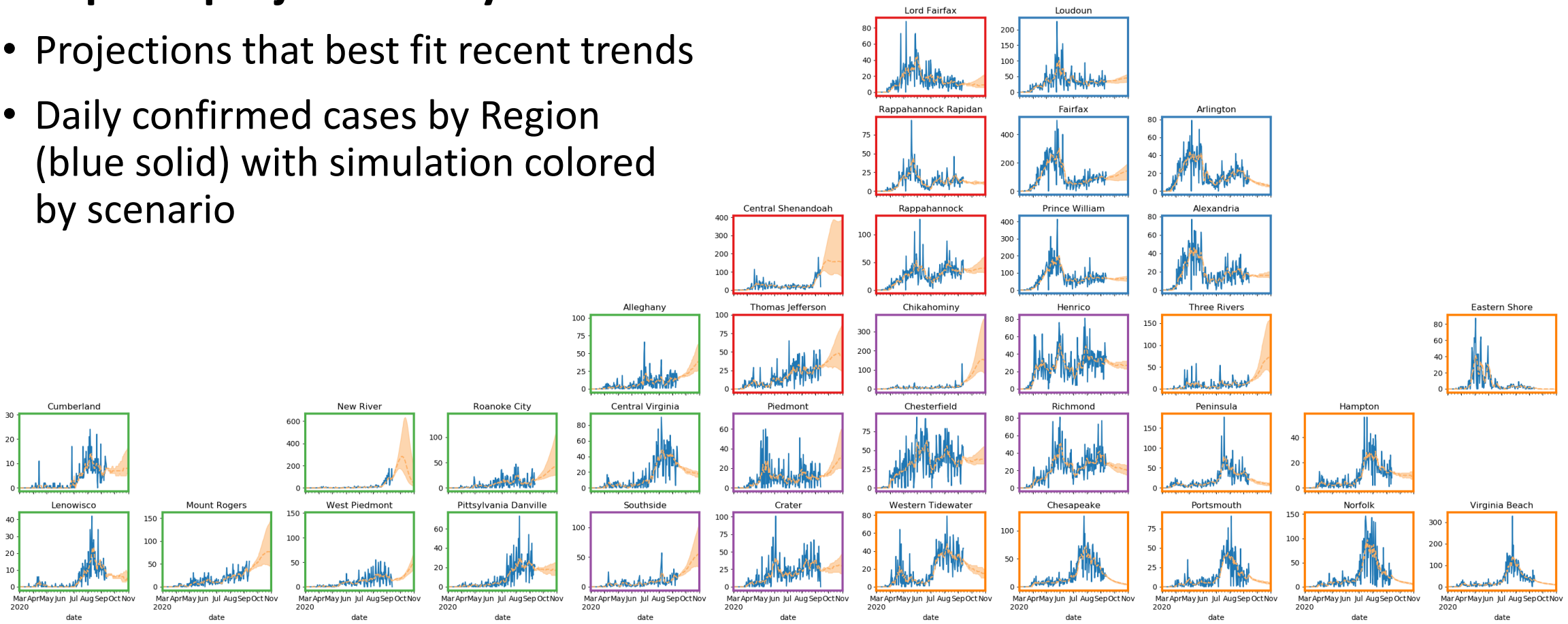
- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-Low

Adaptive projections by District

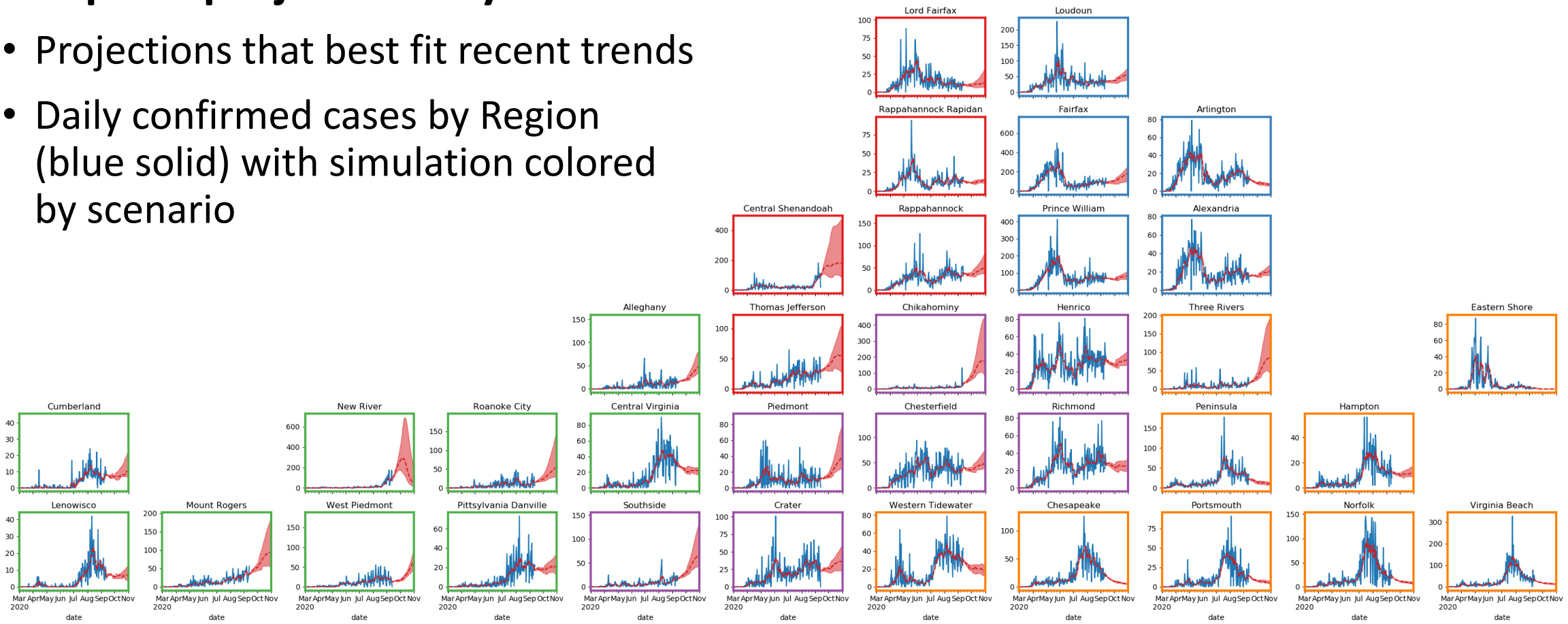
- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-High

Adaptive projections by District

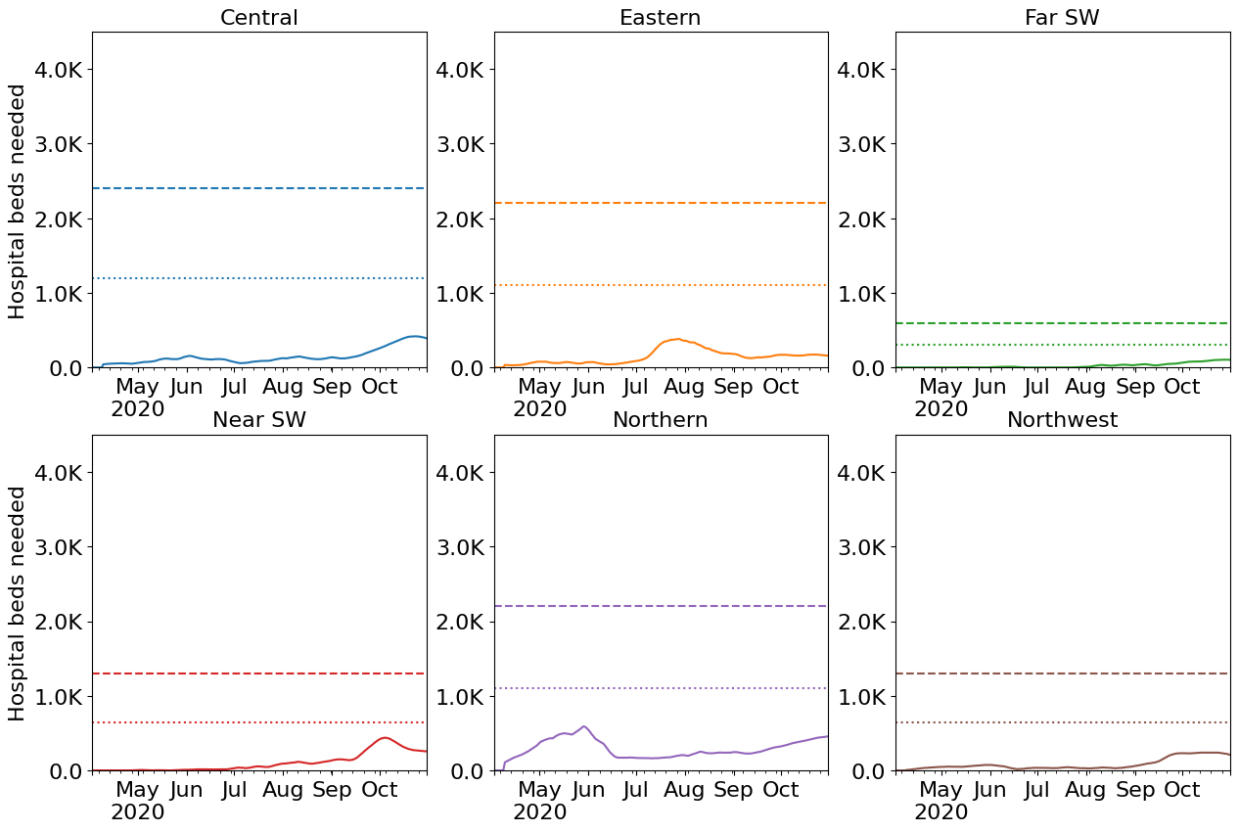
- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



Hospital Demand and Capacity by Region

Capacities by Region – Adaptive-High

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



Week Ending	Adaptive	Adaptive-High
9/13/20	6,853	6,854
9/20/20	7,434	7,434
9/27/20	8,251	8,248
10/4/20	8,861	8,892
10/11/20	8,928	9,868
10/18/20	8,526	10,742
10/25/20	8,011	10,947
11/1/20	7,595	11,137
11/8/20	7,108	10,966
11/15/20	6,531	10,475
11/22/20	5,900	9,912
11/29/20	5,265	9,356

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:

- **Mixed trends remain, surges continue in several districts.**
- Incidence (weekly) hovers at national average which is slightly higher this week ~12/100K.
- 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.

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Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/

Questions?

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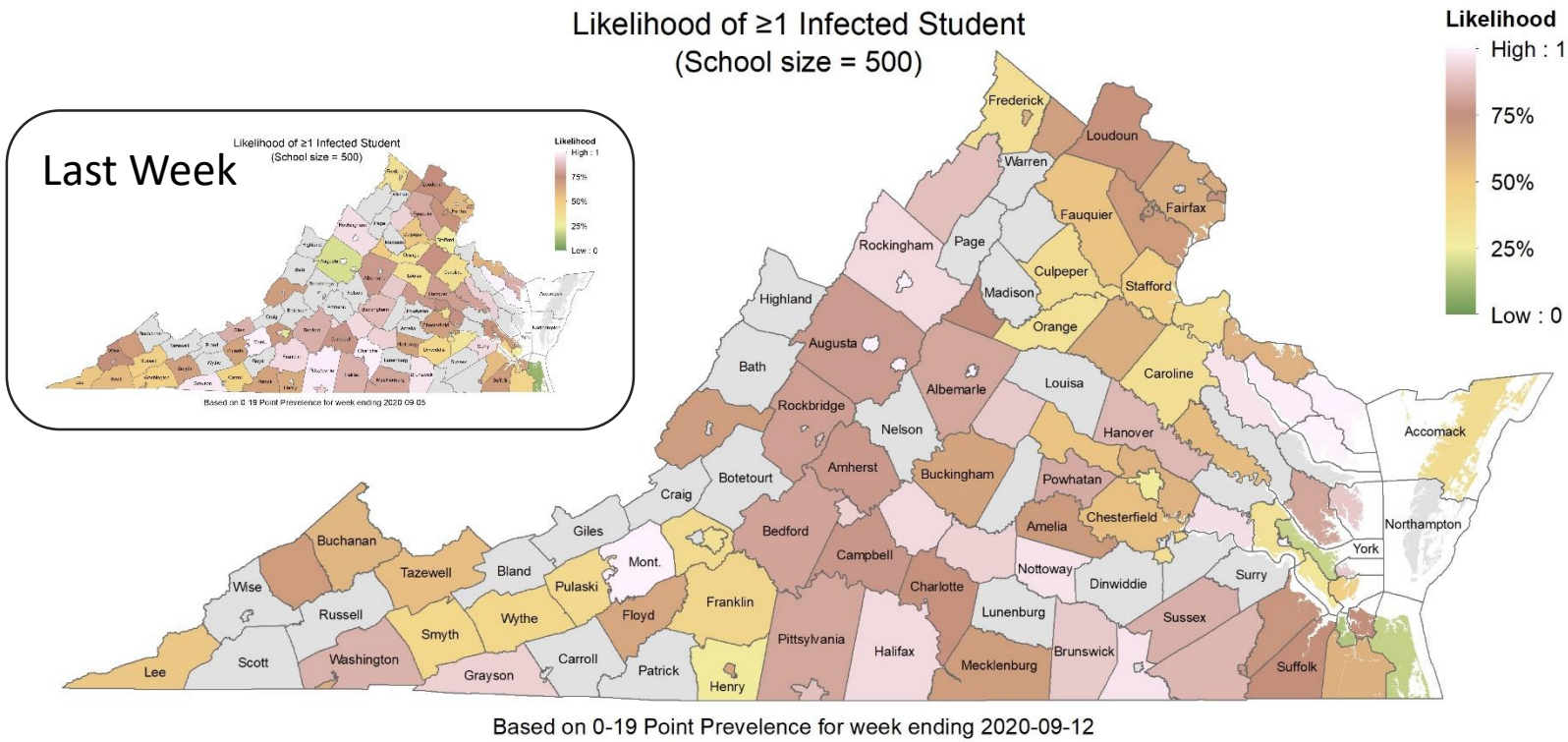
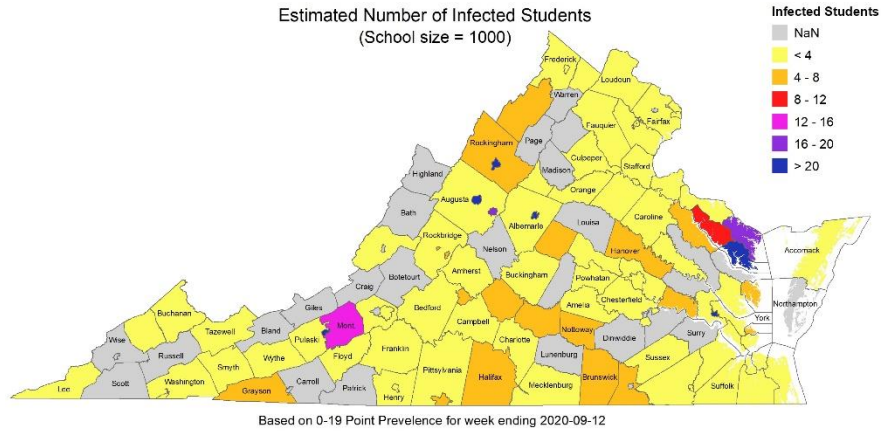
Supplemental Slides

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 6th – Sept 12th
- 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



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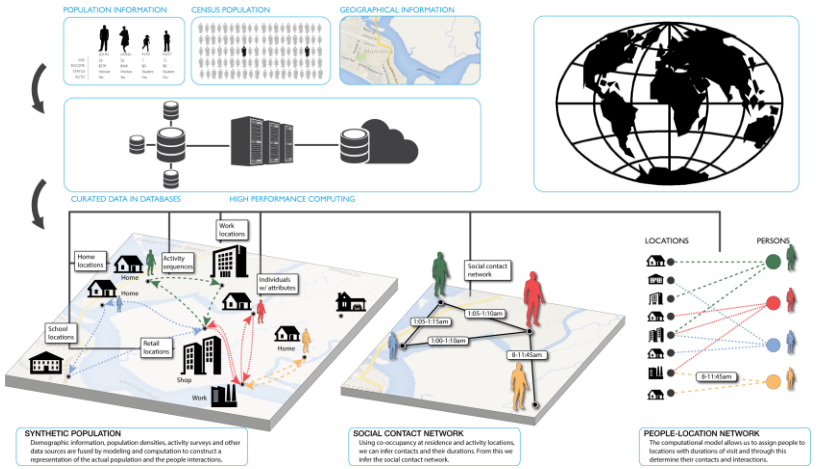
Agent-based Model (ABM)

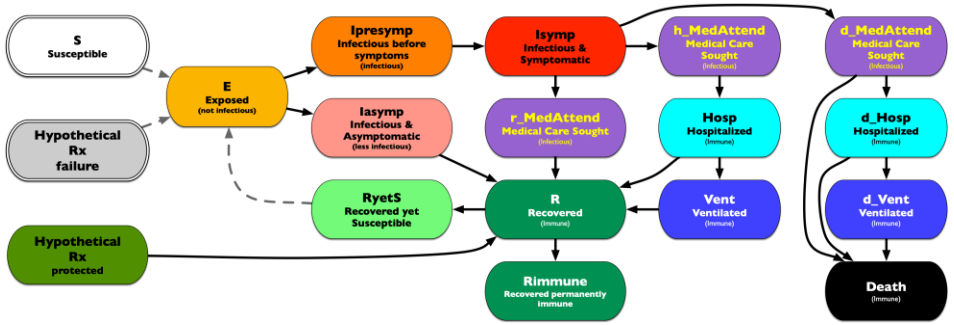
EpiHiper: Distributed network-based stochastic disease transmission simulations

- 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



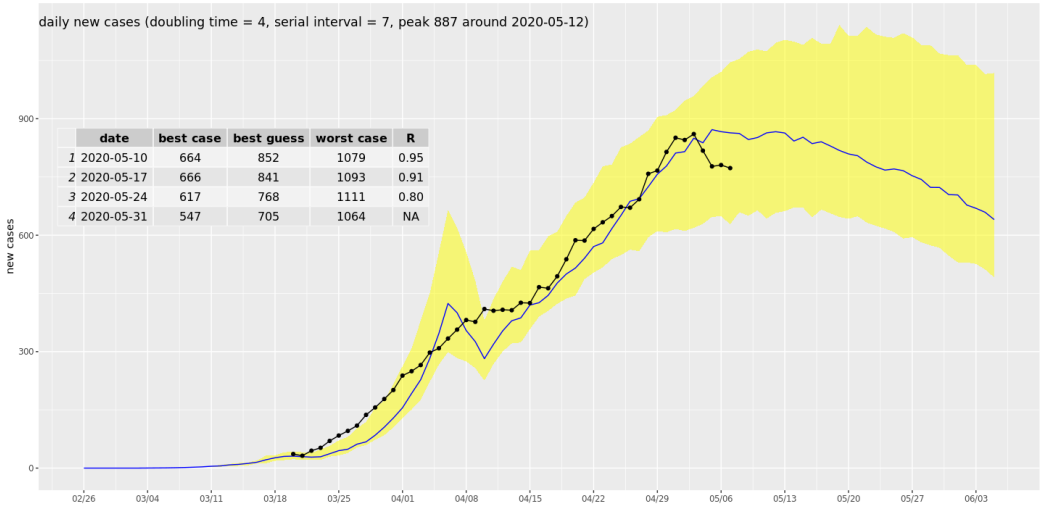
Detailed Disease Course of COVID-19

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

ABM Social Distancing Rebound Study Design

Study of ”Stay Home” policy adherence

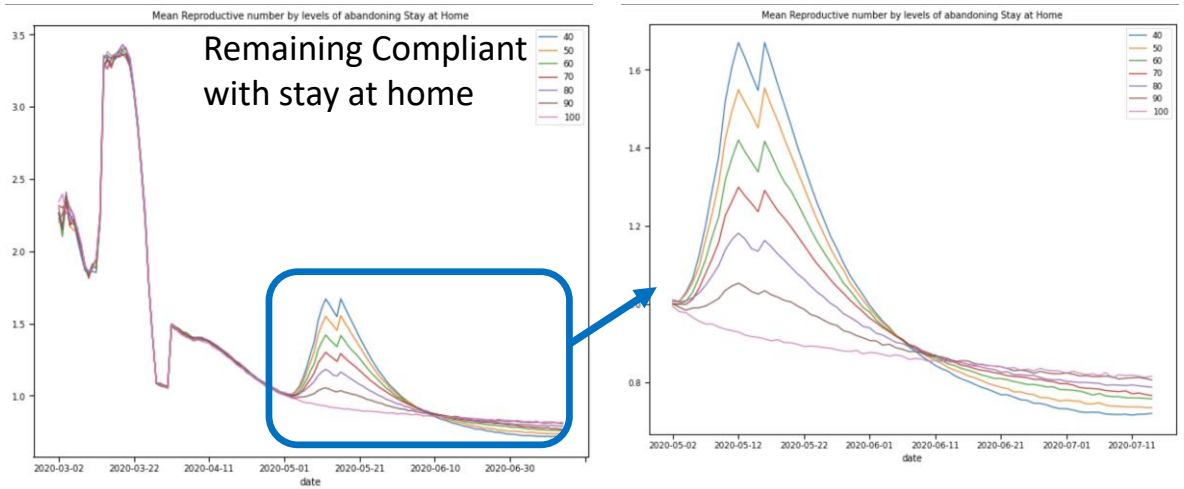
- Calibration to current state in epidemic
- Implement “release” of different proportions of people from ”staying at home”



	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

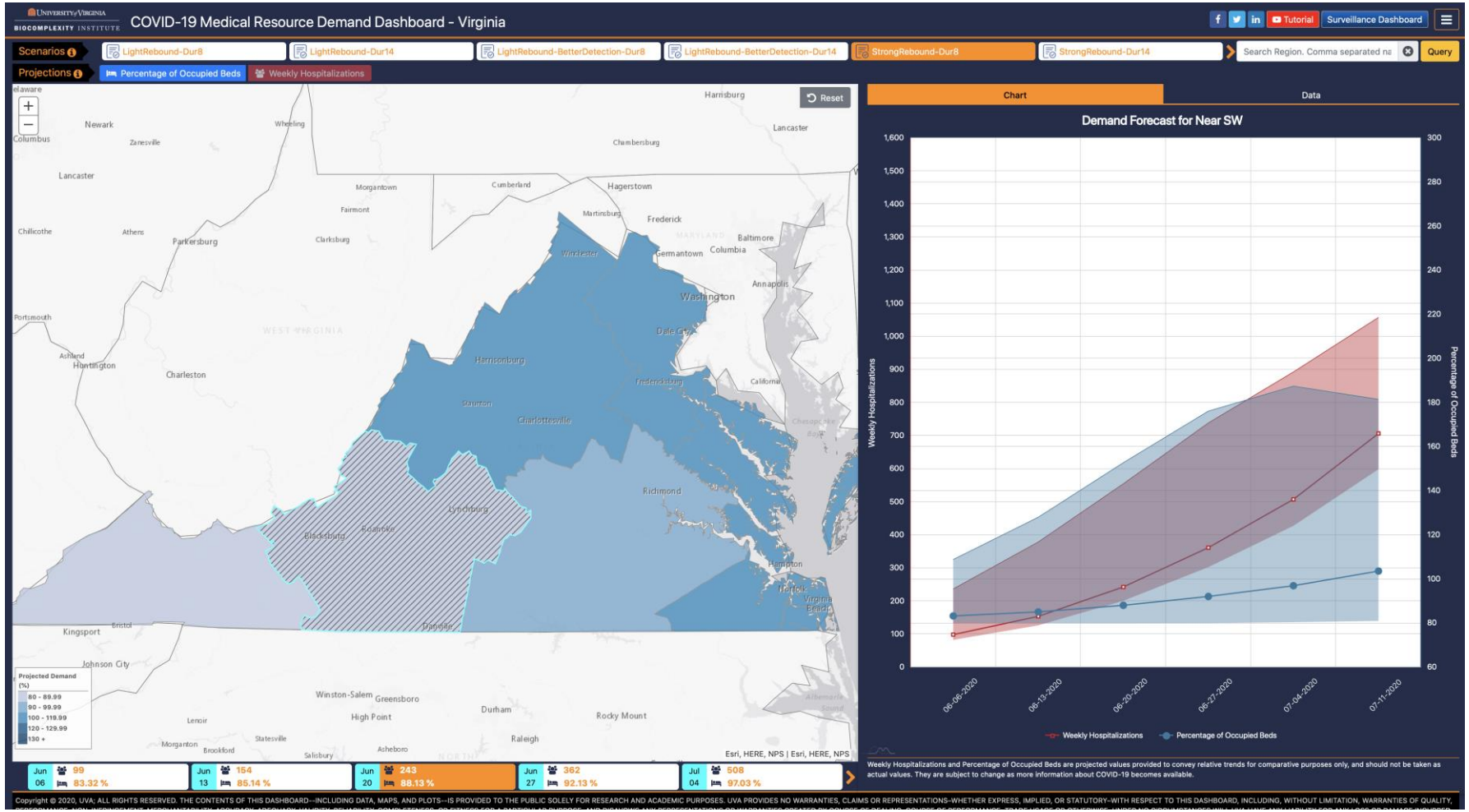


Impacts on Reproductive number with release

- 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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