Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

December 2nd, 2020 (sneak peek Nov. 30th)

(data current to November 30th)

Biocomplexity Institute Technical report: TR 2020-154

UNIVERSITY of VIRGINIA

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

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

UNIVERSITY of VIRGINIA

BIOCOMPLEXITY INSTITUTE

Overview

- **Goal**: Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project infections for next 4 months
  - 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:

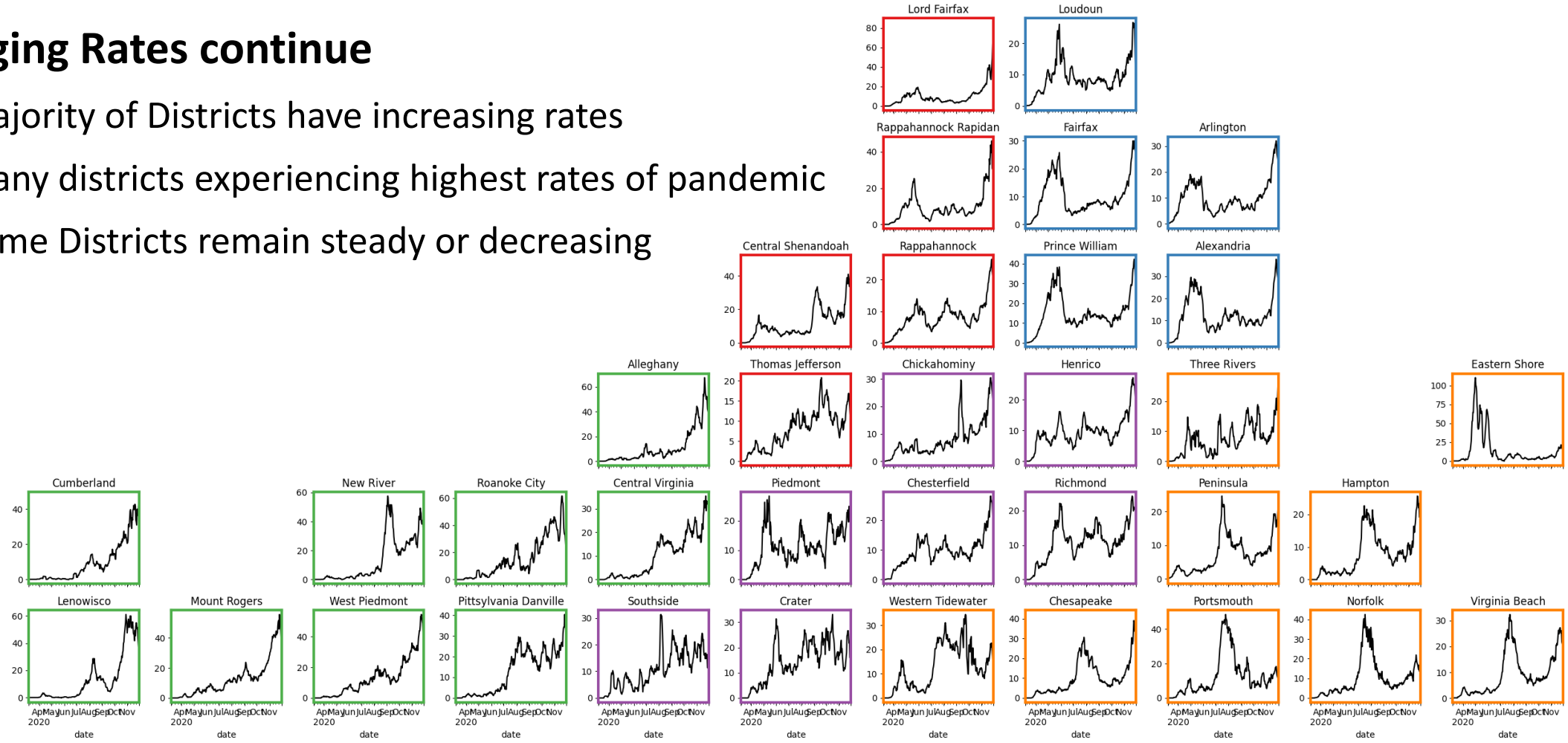
- **Case growth in Virginia speeds up, recording highest case rates of epidemic**
- VA mean weekly incidence (28/100K) slightly up (from 27) as national surge finally slows a little (to 53/100K from 63/100K).
- Reporting delays and overall testing decreases may impact projections, which are mostly up, showing potential for strain on health care system in some regions as early as December.
- Recent updates:
  - Ensemble of statistical and Machine Learning models integrated with Adaptive to guide projections
  - Extending projection trend window to 3 weeks to counter holiday effects
  - Planning scenarios pushed to Dec 10th and case ascertainment rates remain as updated in previous weeks
- The situation is changing rapidly. Models will be updated regularly.

Situation Assessment

Case Rate (per 100k) by VDH District

Surging Rates continue

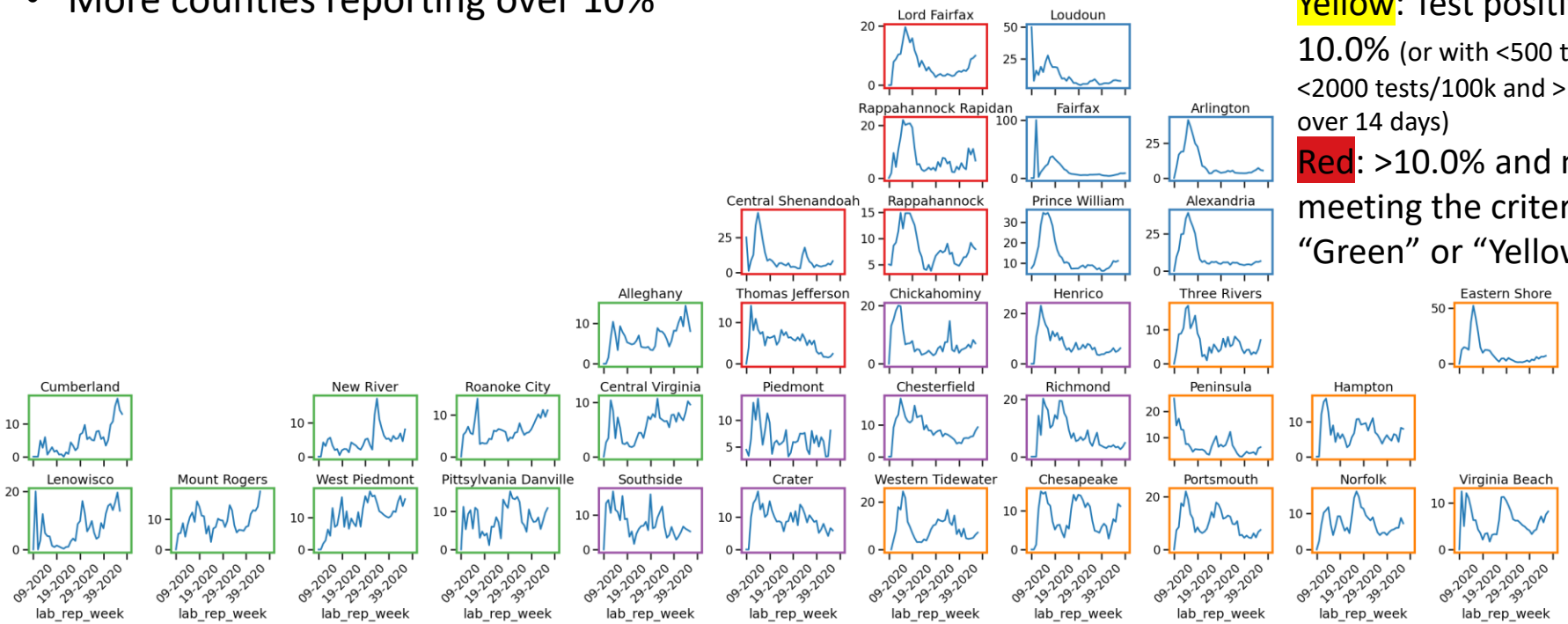
- Majority of Districts have increasing rates
- Many districts experiencing highest rates of pandemic
- Some Districts remain steady or decreasing



Test Positivity by VDH District

Weekly changes in test positivity by district

- Increasing levels in many districts throughout the commonwealth
- More counties reporting over 10%



County level test positivity rates for RT-PCR tests.

Green: Test positivity <5.0% (or with <20 tests in past 14 days)

Yellow: Test positivity 5.0%-10.0% (or with <500 tests and <2000 tests/100k and >10% positivity over 14 days)

Red: >10.0% and not meeting the criteria for "Green" or "Yellow"

County	Oct-28	Nov-04	Nov-11	Nov-18
Amherst County	Red	Yellow	Yellow	Red
Augusta County	Yellow	Yellow	Yellow	Red
Bath County	Yellow	Yellow	Green	Red
Bedford County	Red	Red	Yellow	Red
Bland County	Yellow	Yellow	Yellow	Red
Botetourt County	Red	Red	Red	Red
Bristol City	Red	Red	Red	Red
Buena Vista City	Yellow	Green	Yellow	Red
Campbell County	Red	Red	Red	Red
Carroll County	Red	Red	Red	Red
Chesapeake City	Green	Yellow	Yellow	Red
Chesterfield County	Yellow	Yellow	Yellow	Red
Clarke County	Green	Yellow	Red	Red
Covington City	Red	Red	Red	Red
Craig County	Red	Red	Red	Red
Culpeper County	Yellow	Yellow	Red	Red
Dickenson County	Yellow	Yellow	Red	Red
Dinwiddie County	Yellow	Yellow	Yellow	Red
Fairfax County	Yellow	Yellow	Red	Red
Franklin County	Red	Red	Red	Red
Frederick County	Yellow	Yellow	Red	Red
Galax City	Red	Red	Red	Red
Giles County	Yellow	Red	Red	Red
Halifax County	Yellow	Yellow	Red	Red
Henry County	Red	Red	Red	Red
Lee County	Red	Red	Red	Red
Loudoun County	Yellow	Yellow	Yellow	Red
Manassas City	Yellow	Yellow	Red	Red
Martinsville City	Red	Red	Red	Red
Norton City	Yellow	Yellow	Red	Red
Patrick County	Yellow	Yellow	Red	Red
Pittsylvania County	Red	Yellow	Yellow	Red
Prince George County	Red	Red	Red	Red
Prince William County	Red	Red	Red	Red
Pulaski County	Red	Red	Red	Red
Roanoke City	Red	Red	Red	Red
Roanoke County	Red	Red	Red	Red
Rockingham County	Yellow	Red	Red	Red
Russell County	Yellow	Yellow	Red	Red
Salem City	Red	Red	Red	Red
Smyth County	Green	Yellow	Red	Red
Stafford County	Yellow	Yellow	Red	Red
Tazewell County	Red	Red	Red	Red
Washington County	Red	Red	Red	Red
Winchester City	Yellow	Yellow	Red	Red
Wise County	Red	Red	Red	Red
Wythe County	Red	Yellow	Red	Red

https://data.cms.gov/stories/s/q5r5-gjyu

UNIVERSITY of VIRGINIA

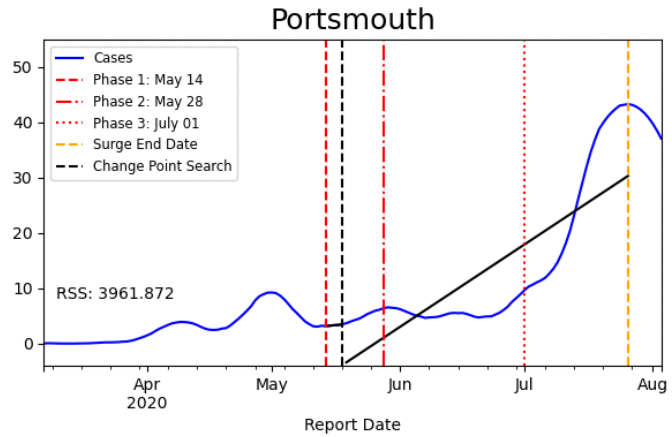
BIOCOMPLEXITY INSTITUTE

District Trajectories

Goal: Define epochs of a Health District's COVID-19 incidence to characterize the current trajectory

Method: Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period's slope to define the trajectory

Hockey stick fit

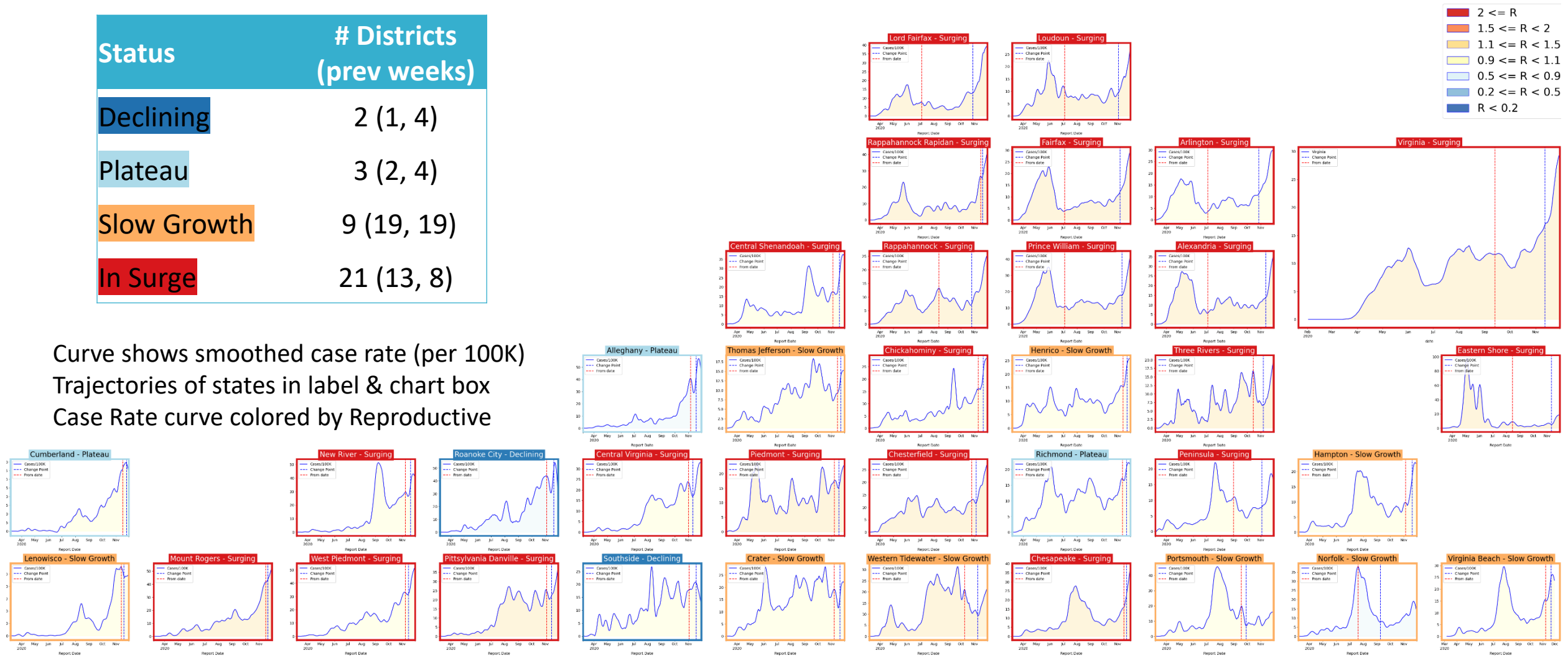


Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (prev weeks)
Declining	Sustained decreases following a recent peak	below -0.9	2 (1, 4)
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5	3 (2, 4)
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	9 (19, 19)
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater	21 (13, 8)

District Trajectories

Status	# Districts (prev weeks)
Declining	2 (1, 4)
Plateau	3 (2, 4)
Slow Growth	9 (19, 19)
In Surge	21 (13, 8)

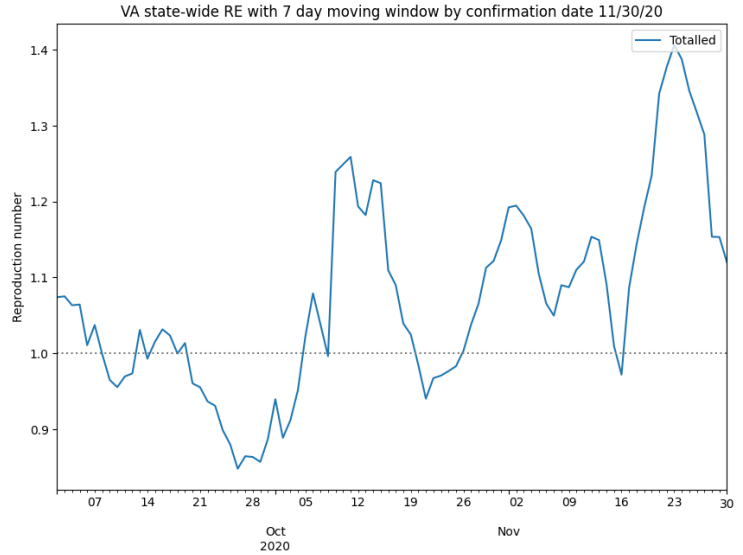
Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive

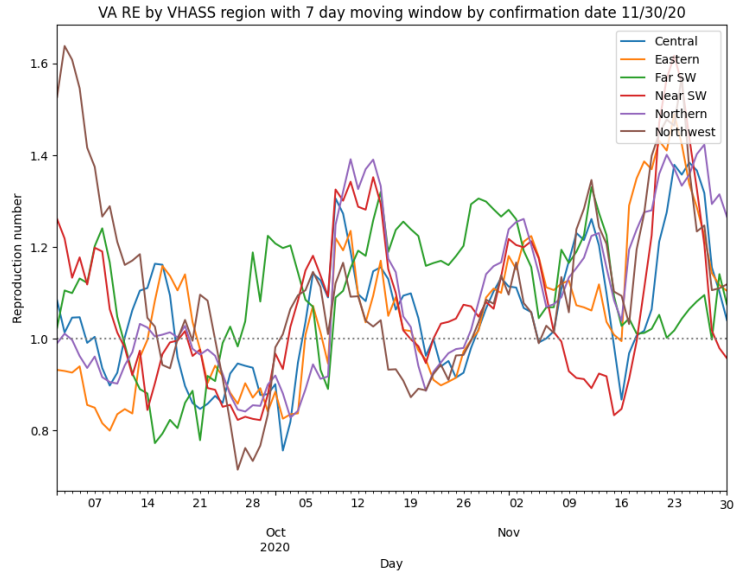


Estimating Daily Reproductive Number

Nov 30th Estimates

Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	1.120	-0.286
Central	1.041	-0.339
Eastern	1.104	-0.385
Far SW	1.075	0.057
Near SW	0.957	-0.659
Northern	1.266	-0.105
Northwest	1.119	-0.346





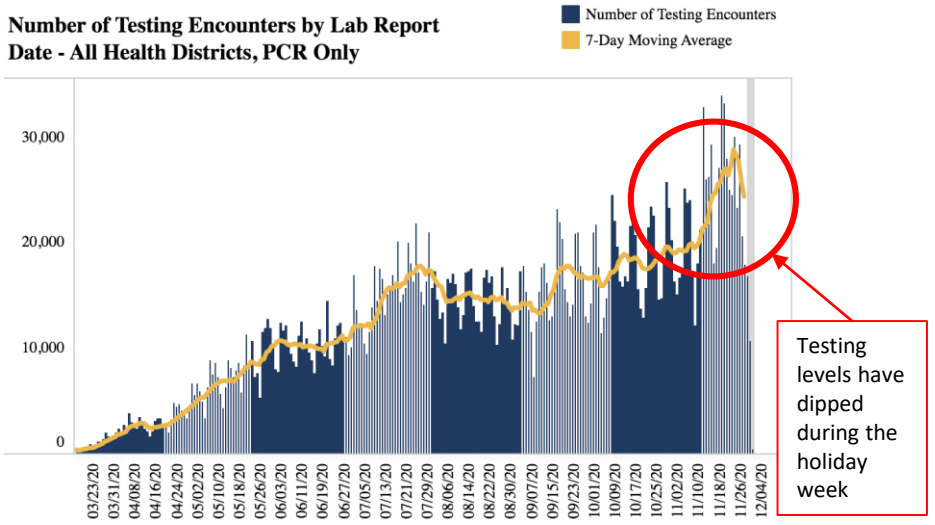
Methodology

- Wallinga-Teunis method (EpiEstim[1]) for cases by **confirmation date**
- Serial interval: 6 days (2 day std dev)
- Using Confirmation date since due to increasingly unstable estimates from onset date 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

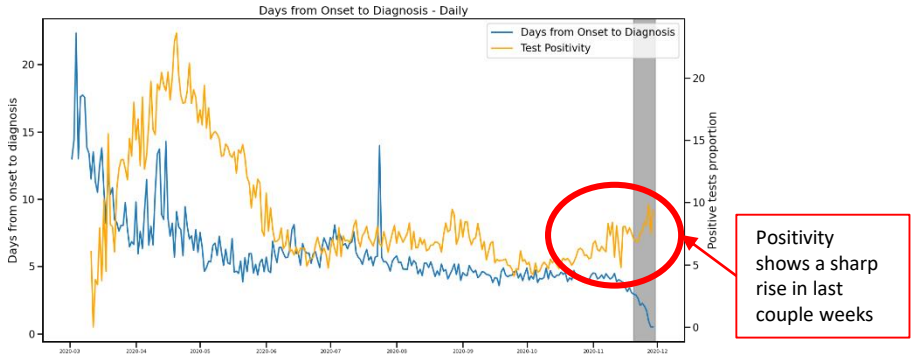
Changes in Case Detection

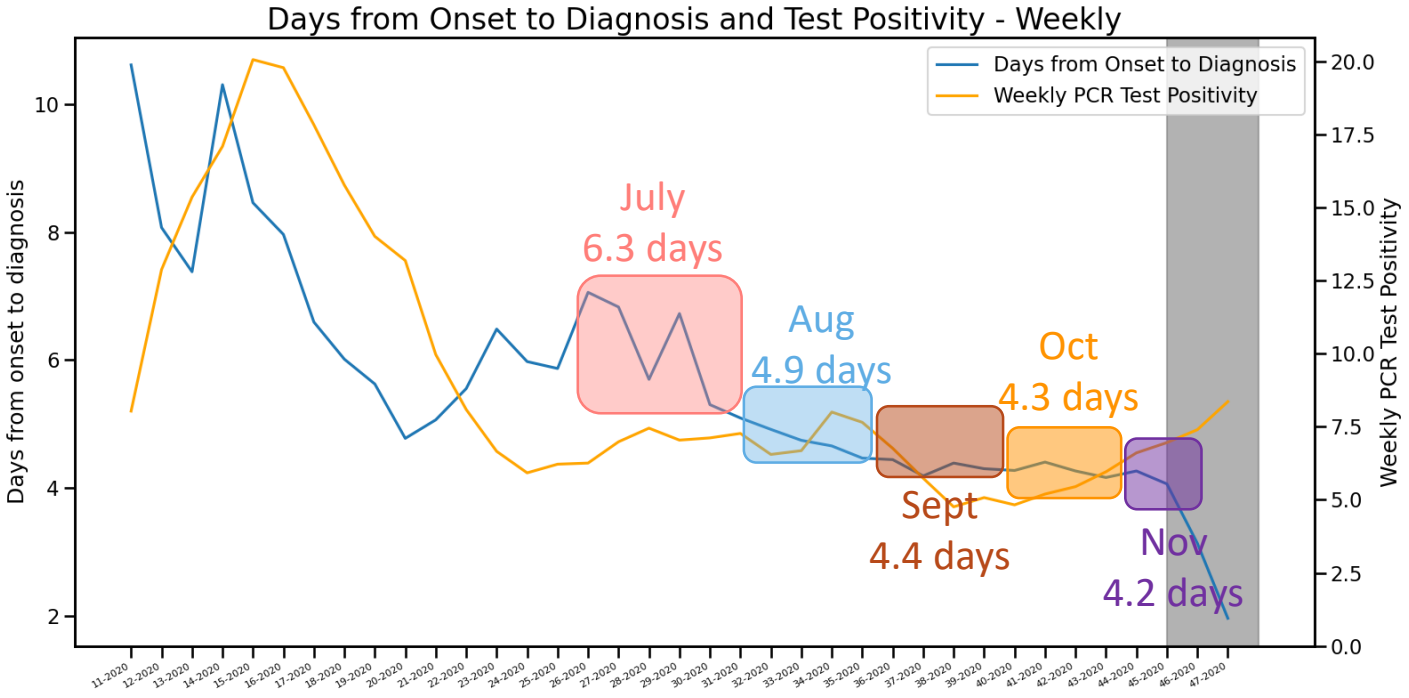
Timeframe (weeks)	Mean days	% difference from overall mean
April (13-16)	8.5	51%
May (17-21)	5.6	0%
June (22-25)	6.0	6%
July (26-30)	6.3	12%
Aug (31-34)	4.9	-14%
Sept (35-38)	4.4	-22%
Oct (39-43)	4.3	-25%
Nov (44-46)	4.2	-25%
Overall (13-46)	5.6	0%



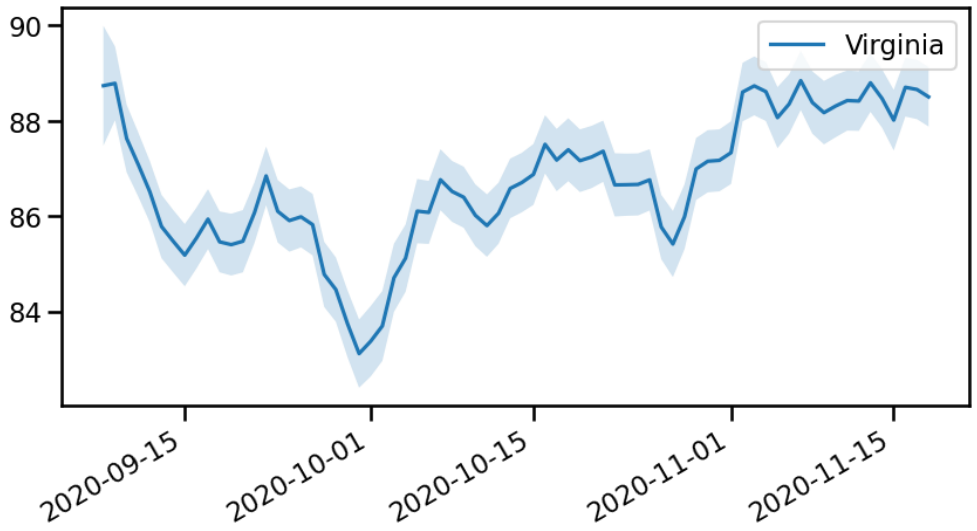
Accessed 8:30am December 2, 2020
https://www.vdh.virginia.gov/coronavirus/

Test positivity vs. Onset to Diagnosis





Mask usage in Virginia



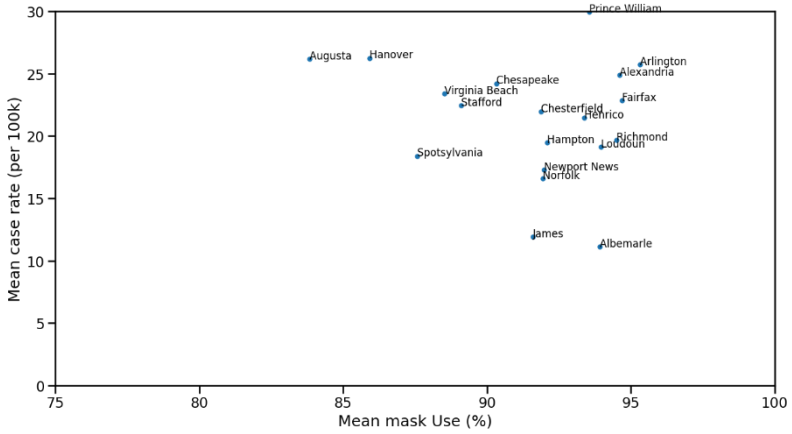
Some county level fluctuations since beginning of Sept., though data quality may be affected by sample sizes.

State level mask usage as reported via Facebook surveys over the past month shows ranges from 83% to 89%

- Relatively stable over time
- Limited variance across the commonwealth
- ~3000 daily responses from VA

Data Source: https://covidcast.cmu.edu

Correlations seen at national level with mask use and case rate start to emerge across VA counties, due to surging growth and more limited survey results due to election



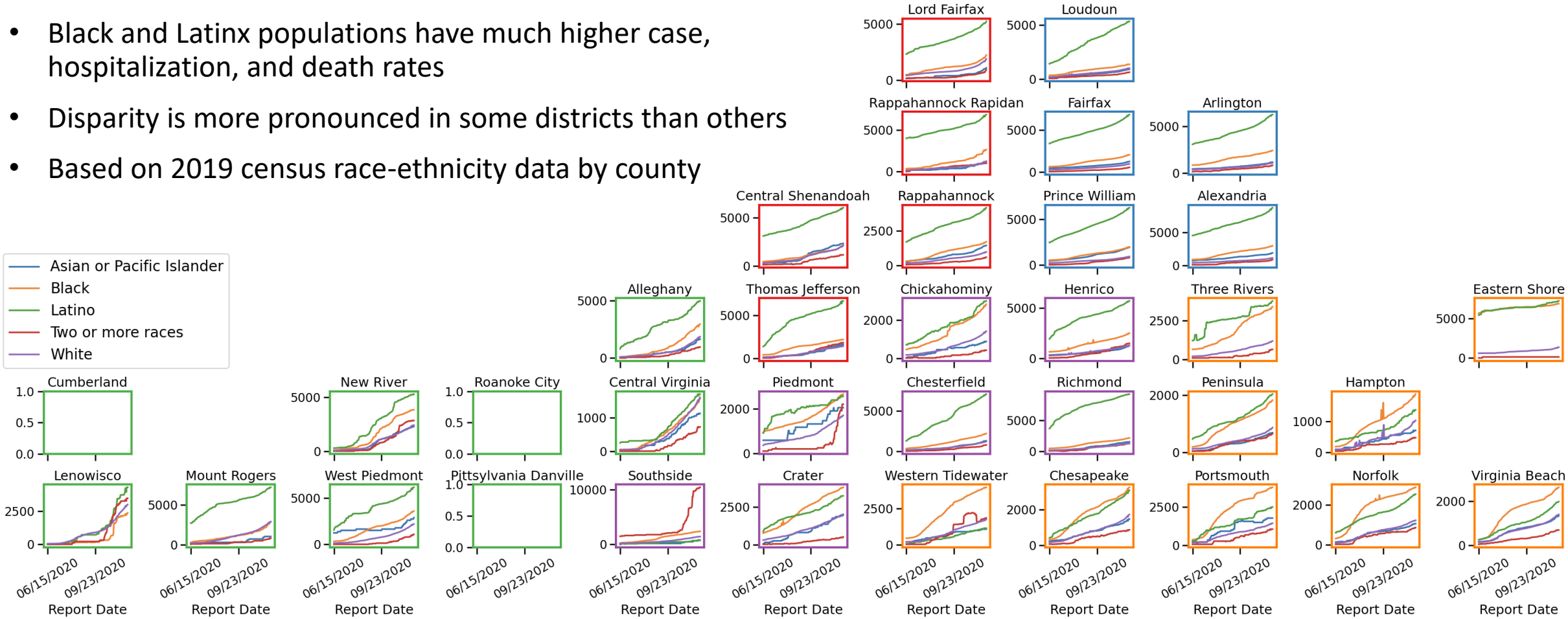
UNIVERSITY of VIRGINIA

BIOCOMPLEXITY INSTITUTE

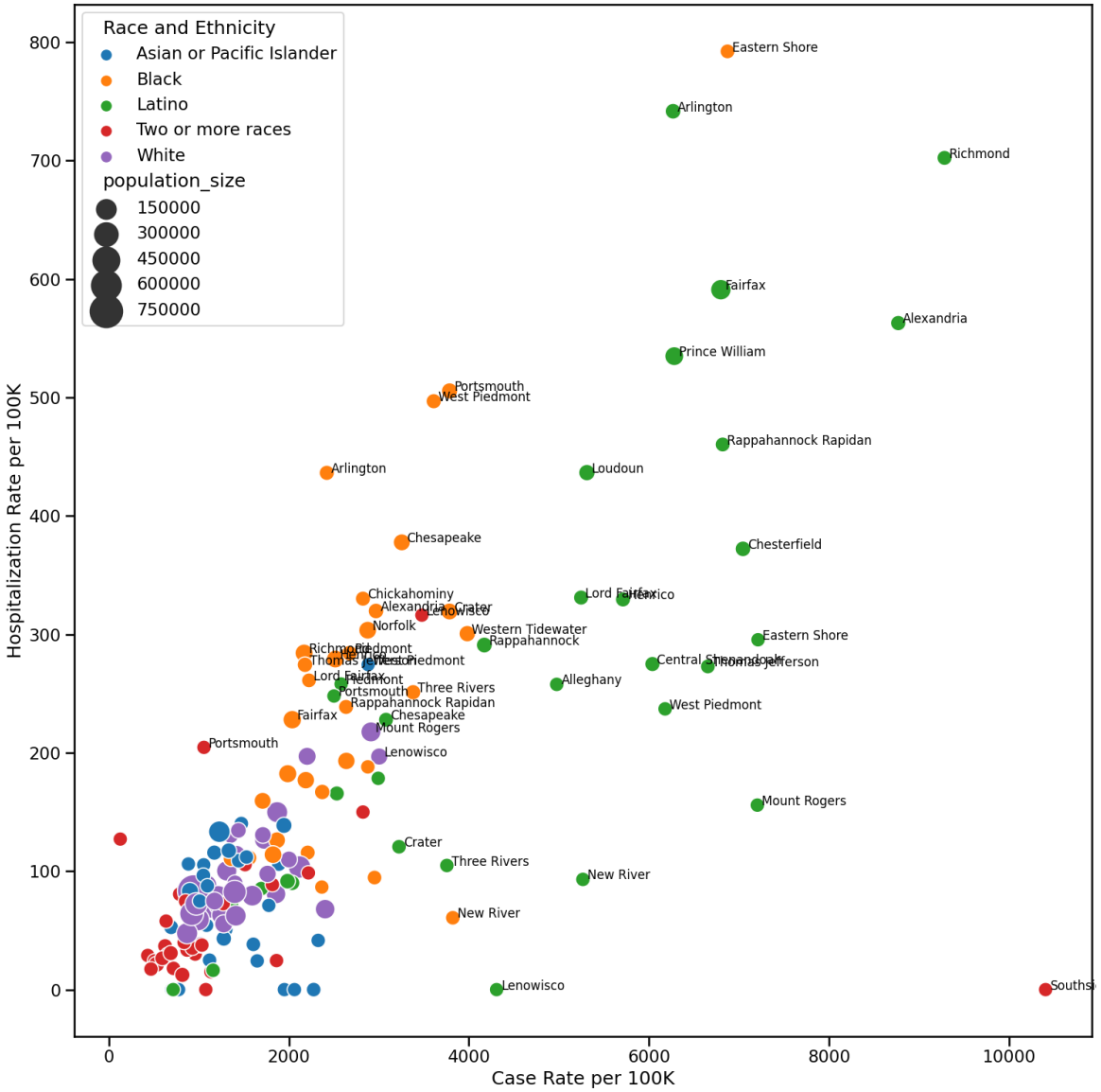
Race and Ethnicity Attack Rates (per 100K)

Cumulative Race and Ethnicity Attack Rates (per 100k)

- Black and Latinx populations have much higher case, hospitalization, and death rates
- Disparity is more pronounced in some districts than others
- Based on 2019 census race-ethnicity data by county



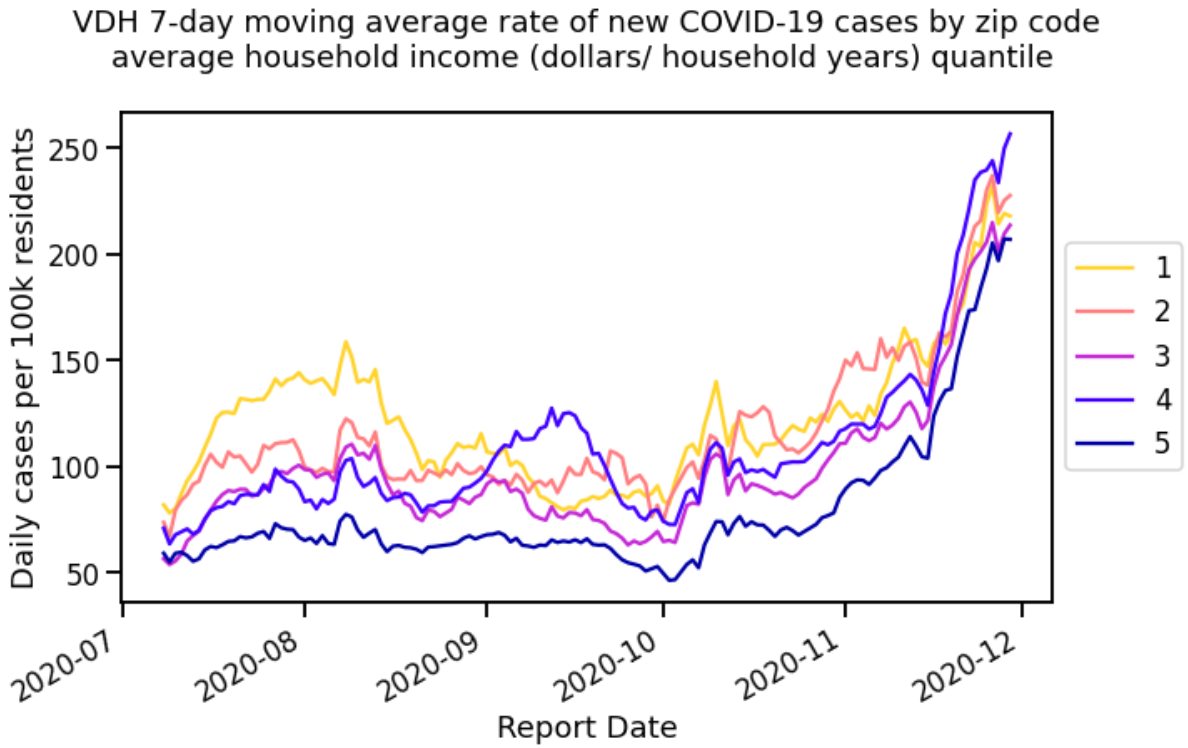
Race and Ethnicity cases per 100K



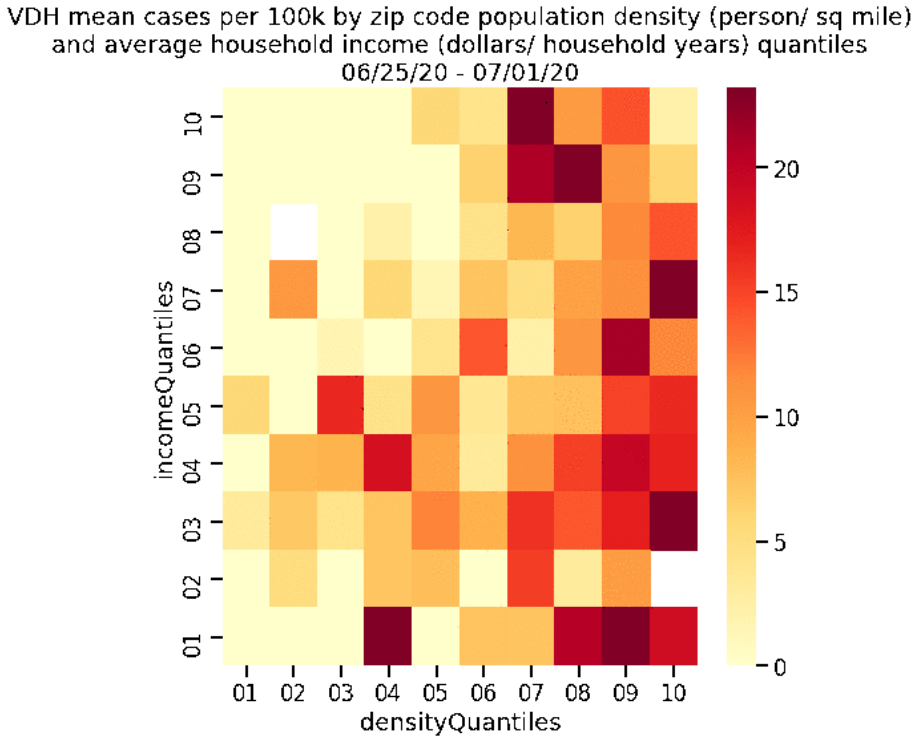
Rates per 100K of each Racial-Ethnic population by Health District

- Each Health District's Racial-Ethnic population is plotted by their Hospitalization and Case Rate
- Points are sized based on their overall population size
- Overlapping labels removed for clarity

Impact across Density and Income



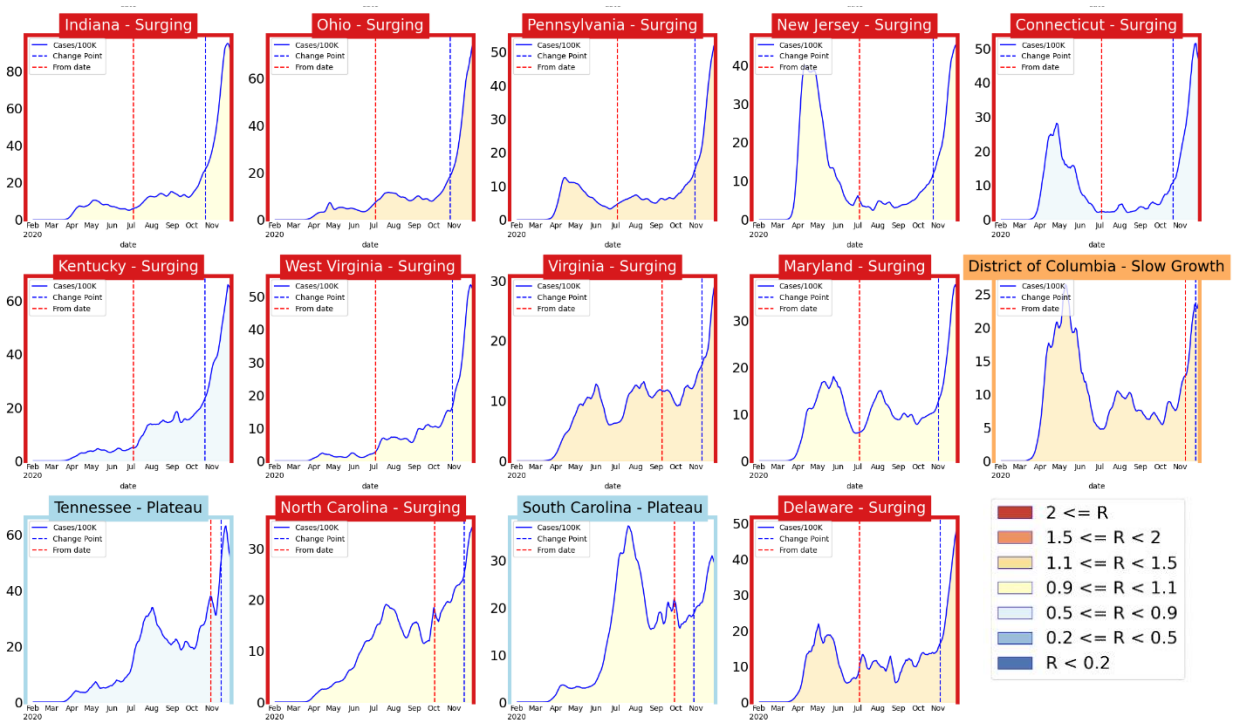
All zip codes show rapid growth, with 4th quintile (60-80th percentile) now bearing the highest rate



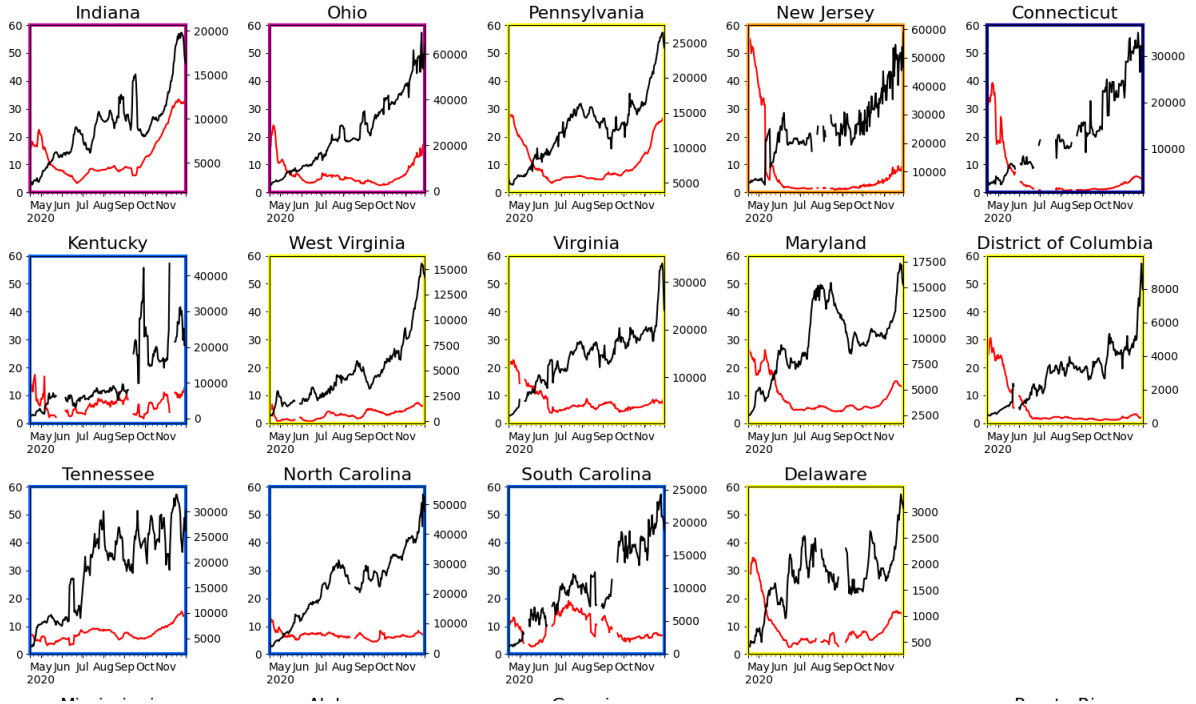
Full evolution of pandemic, shows shifts from denser and wealthier zip codes to poorer and less dense zip codes, followed by a repeat of the pattern. Recently see an uptick across the spectrum of density and income

Other State Comparisons

Trajectories of States



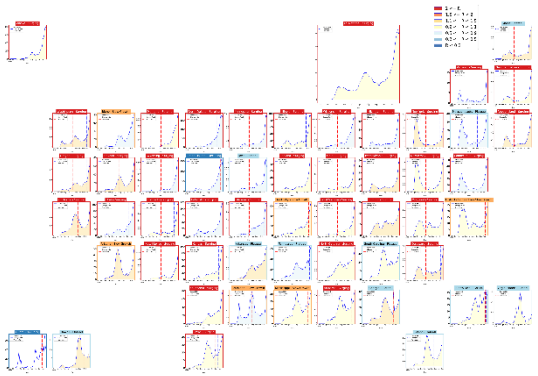
Tests per Day and Test Positivity

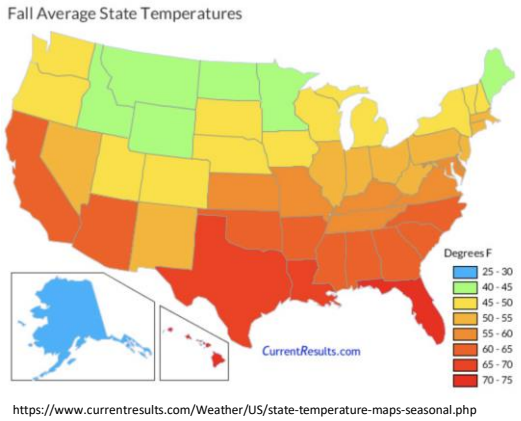


- VA and most of mid-Atlantic states are in surge (37 total in US)
- TN and SC showing some slowing, other have minor deviations which may be related reporting artifacts from the holiday

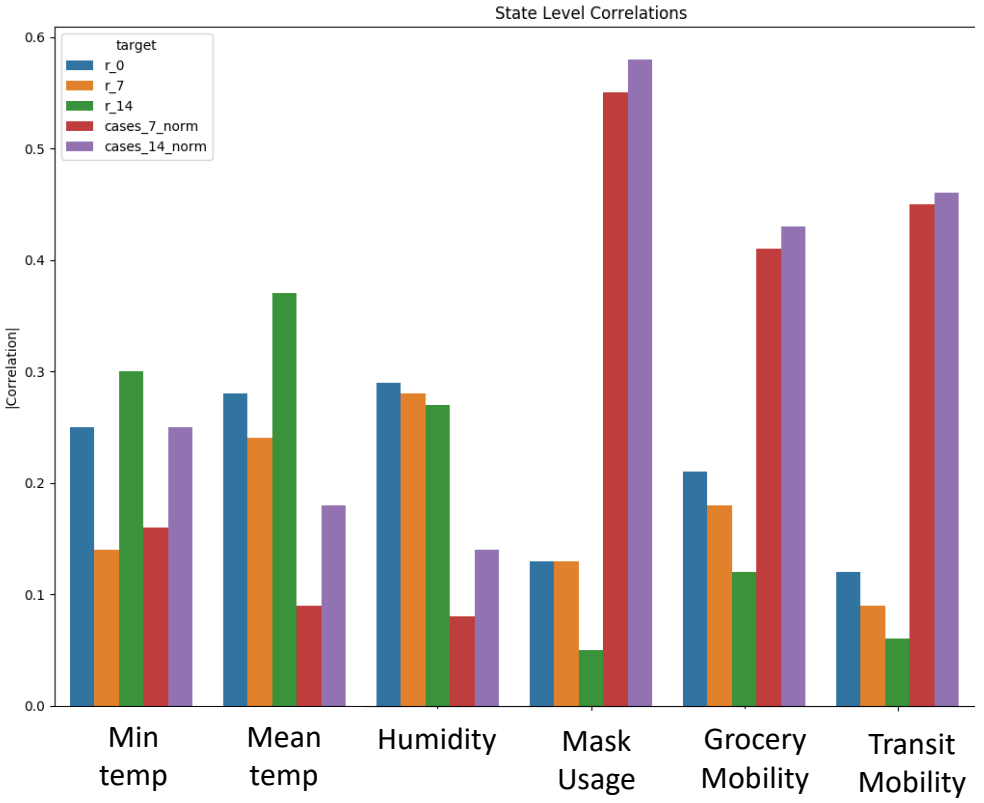
- VA's test positivity rate continues to rise with many of its neighbors
- Testing volumes have increased for many with recent disruption from the holiday

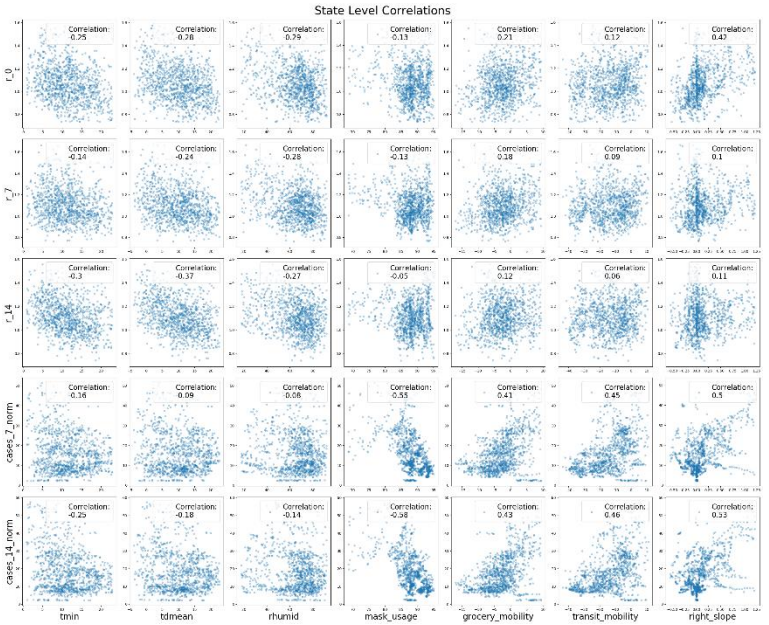
Growth Associated with Temperature and Humidity





https://www.currentresults.com/Weather/US/state-temperature-maps-seasonal.php





- As weather cools and humidity drops, SARS-CoV2 survival and chance of transmission may rise
- Correlations with other factors are also strong for R (0, 7, 14 day delay) and confirmed cases (7 and 14 day delay)
- Weather variables better correlation with R estimates, while mobility and mask usage correlate well with case rates

Zip code level weekly Case Rate (per 100K)

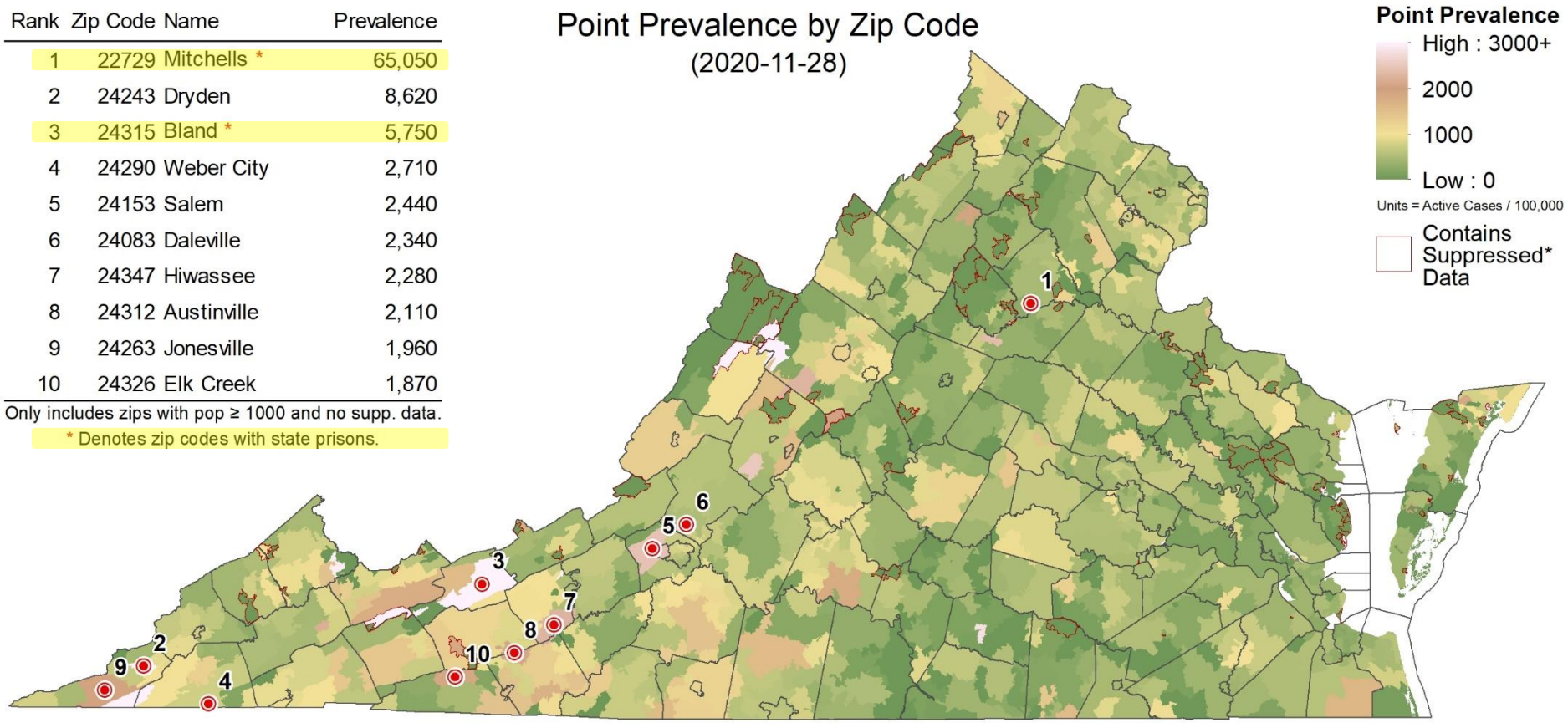
Case Rates in the last week by zip code

- Concentrations of very high prevalence in many zip codes
- Several of the top ten zip codes are home to prisons
- Southwest has considerable concentration of high prevalence zips
- Some counts are low and suppressed to protect anonymity, those are shown in white

Rank	Zip Code	Name	Prevalence
1	22729	Mitchells *	65,050
2	24243	Dryden	8,620
3	24315	Bland *	5,750
4	24290	Weber City	2,710
5	24153	Salem	2,440
6	24083	Daleville	2,340
7	24347	Hiwassee	2,280
8	24312	Austinville	2,110
9	24263	Jonesville	1,960
10	24326	Elk Creek	1,870

Only includes zips with pop ≥ 1000 and no supp. data.

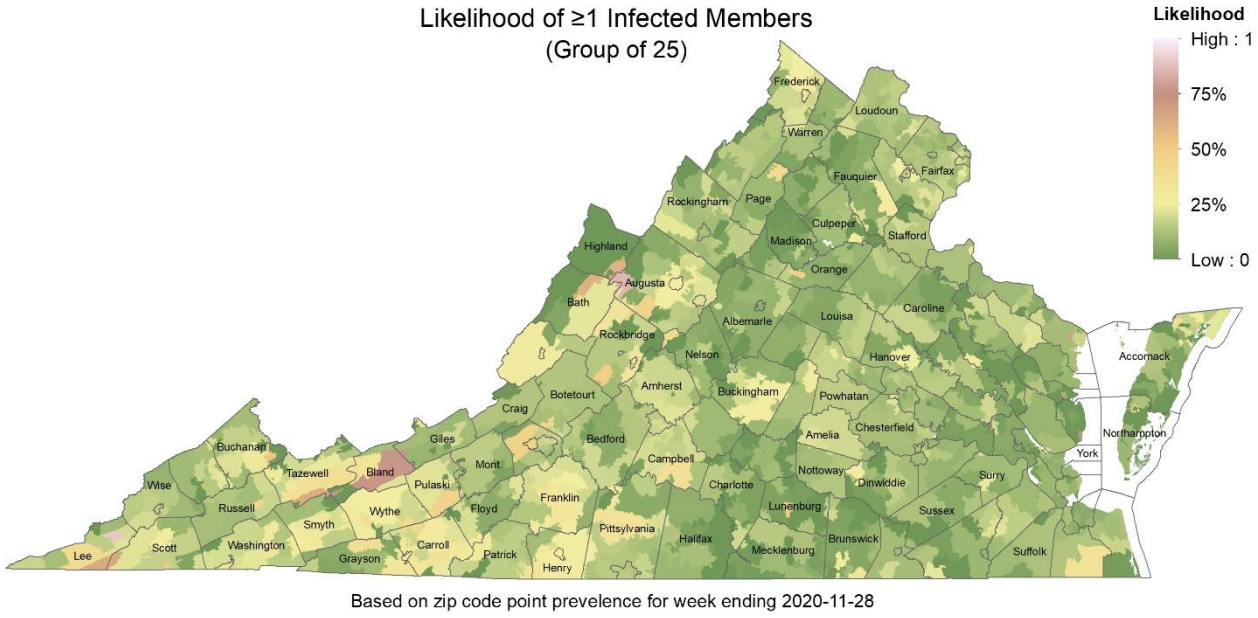
* Denotes zip codes with state prisons.

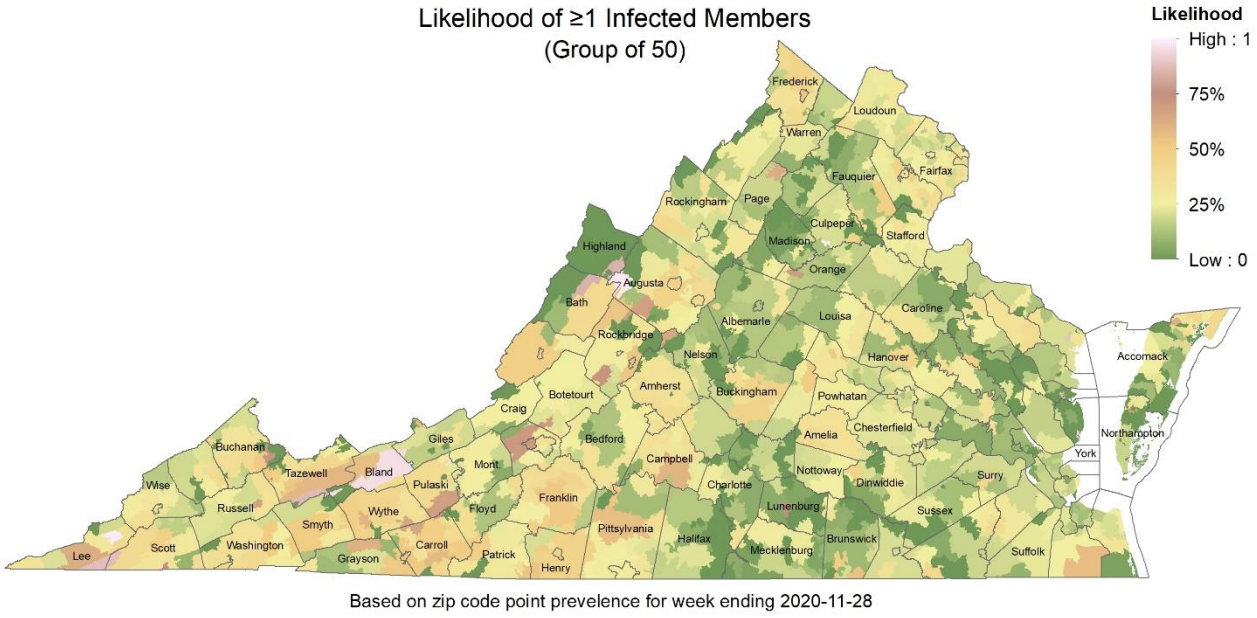


Risk of Exposure by Group Size

Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25 or 50)

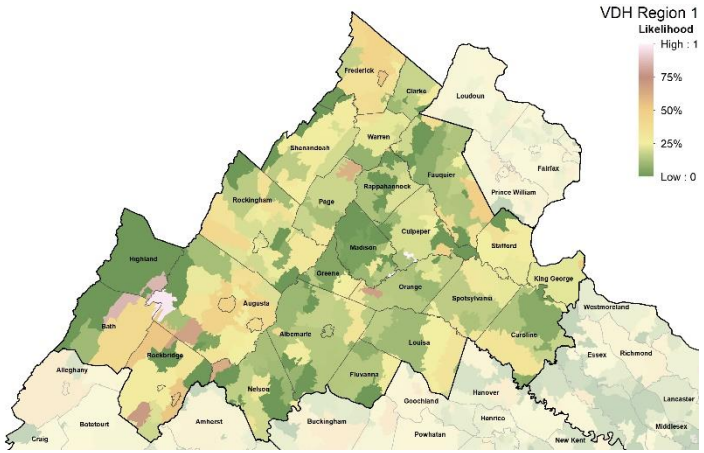
- Assumes 3 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey)
- Moderate risk for groups of 50 across the commonwealth, especially in the southern half of the state
- Some zip codes have high likelihood of exposure even in groups of 25



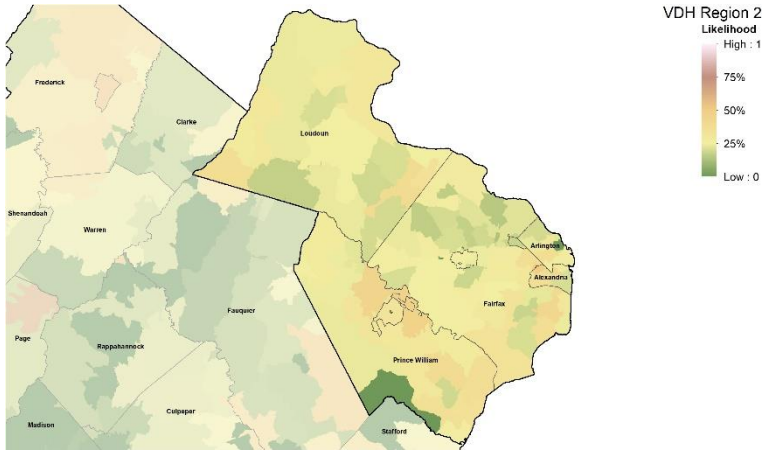


Risk of Exposure in Groups of 50

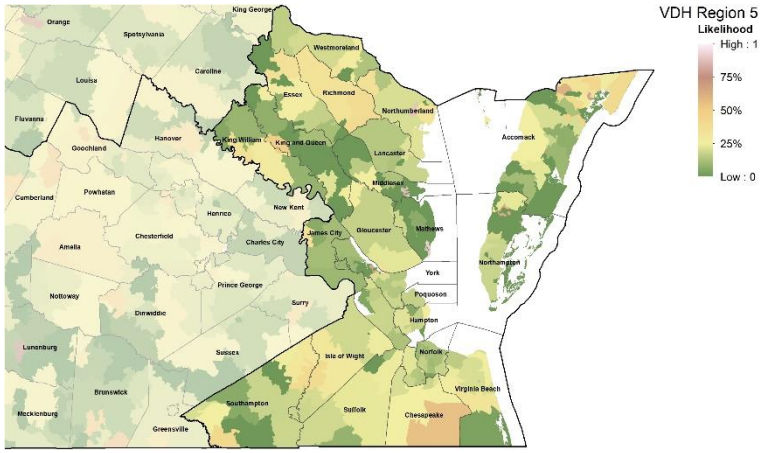
Northwest



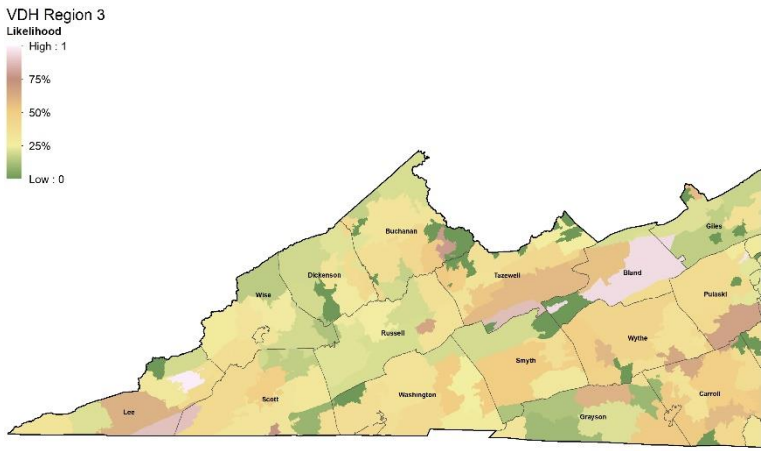
North



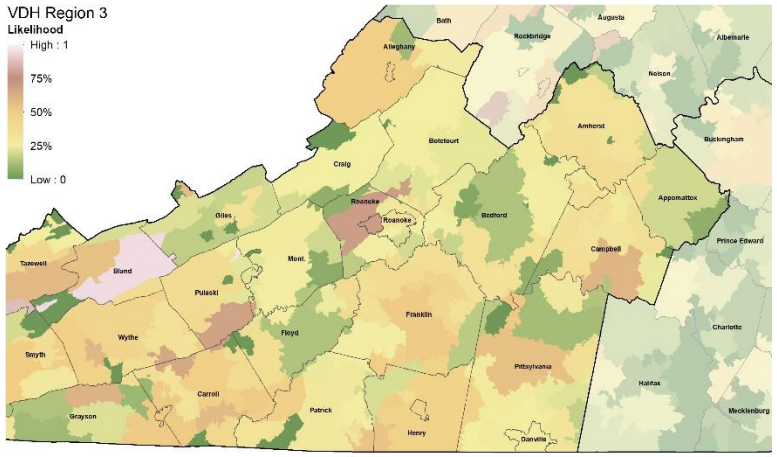
Eastern



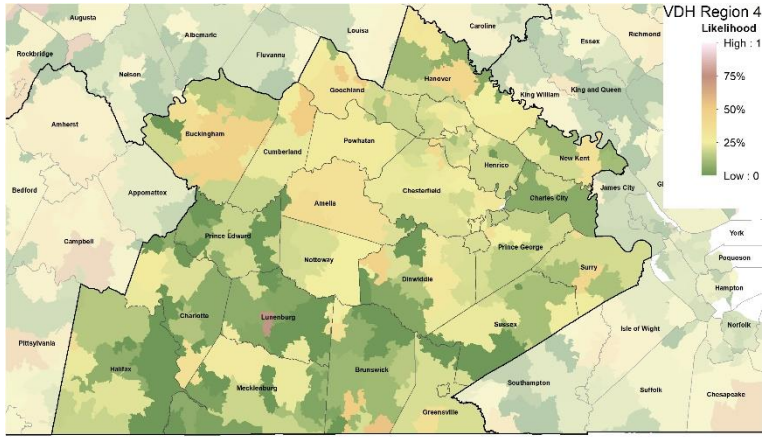
Far Southwest



Near Southwest



Central



UNIVERSITY of VIRGINIA

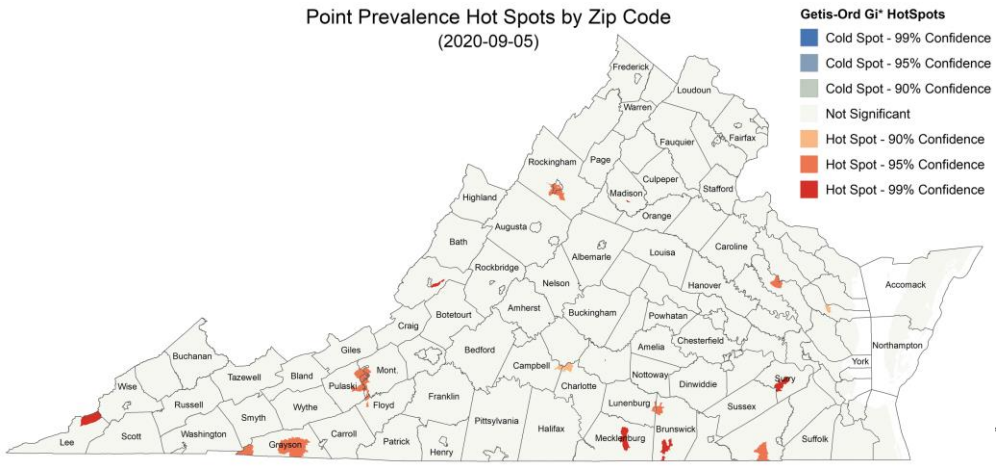
BIOCOMPLEXITY INSTITUTE

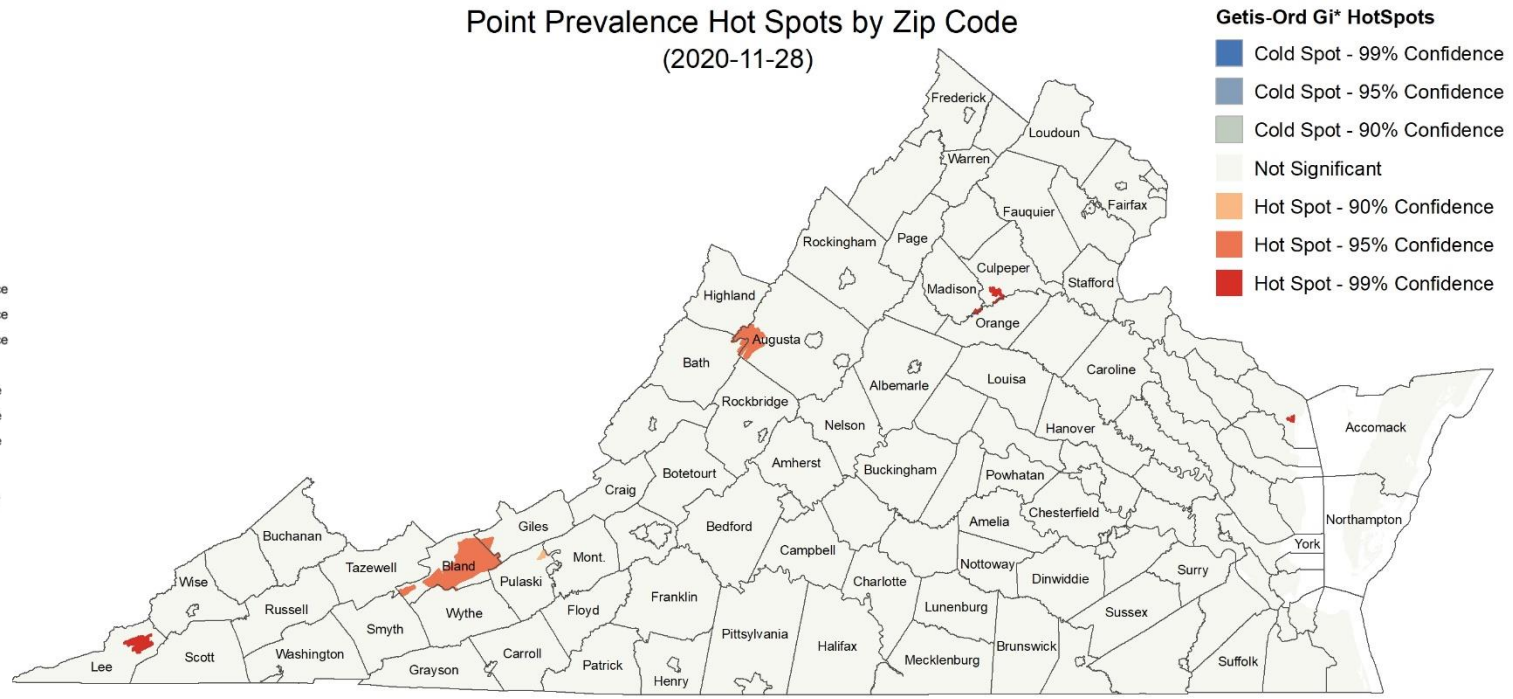
Zip Code Hot Spots

Hotspots across commonwealth

- More spread out but remain concentrated in the Southwest
- Captures some very high prevalence rates in some zips

Previous weeks





Model Update – Adaptive Fitting

Adaptive Fitting Approach

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

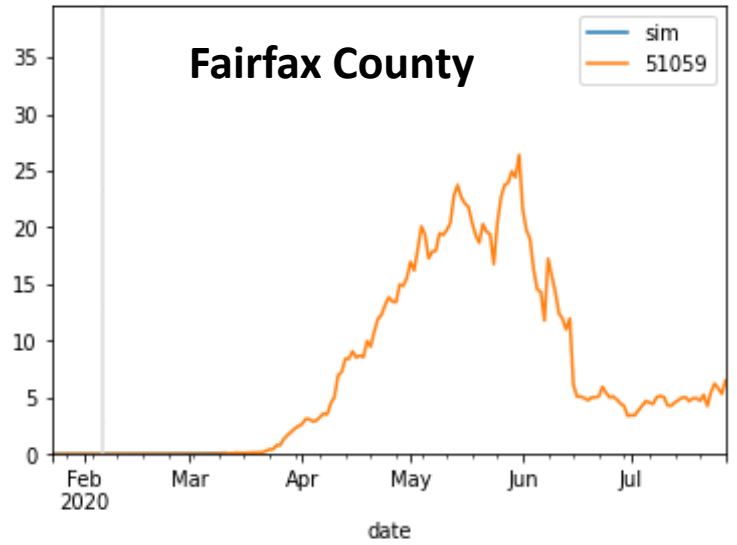
- Allows history to be precisely captured, and used to guide bounds on projections

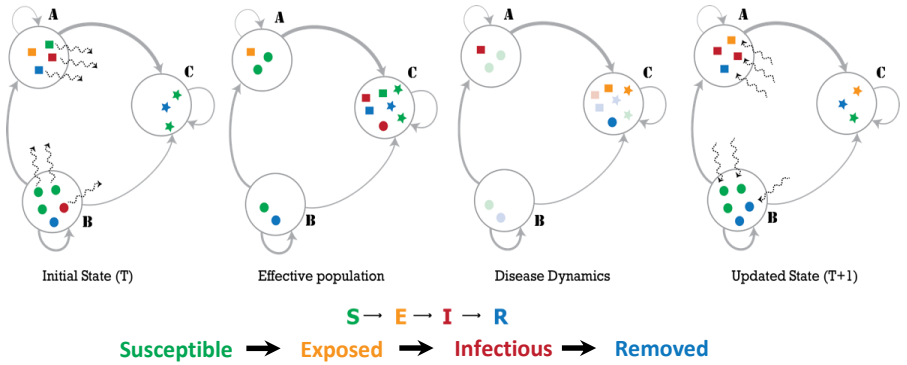
Model: An alternative use of the same meta-population model, PatchSim

- 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



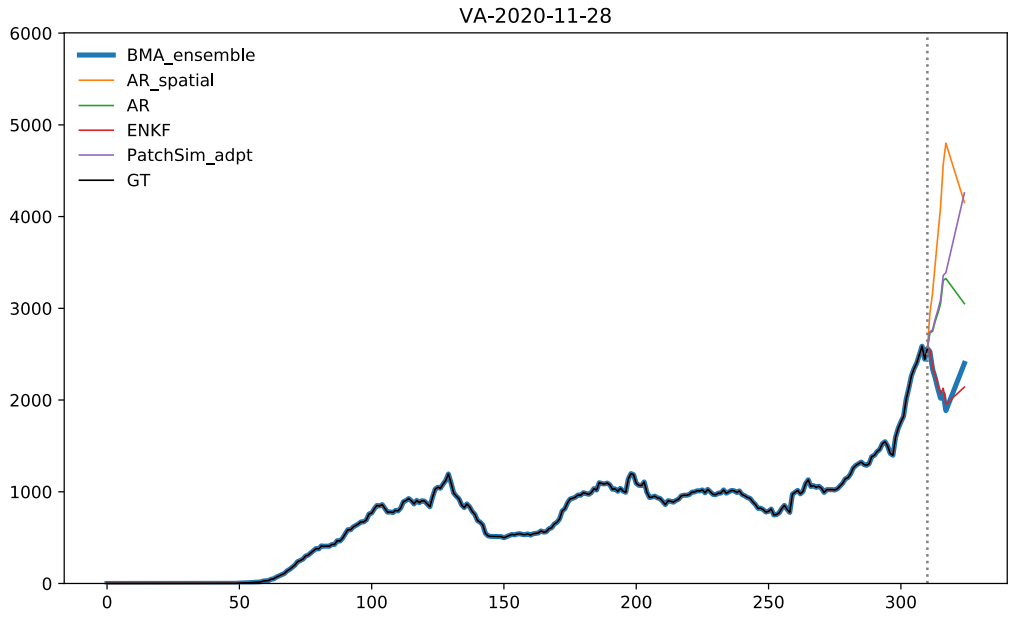


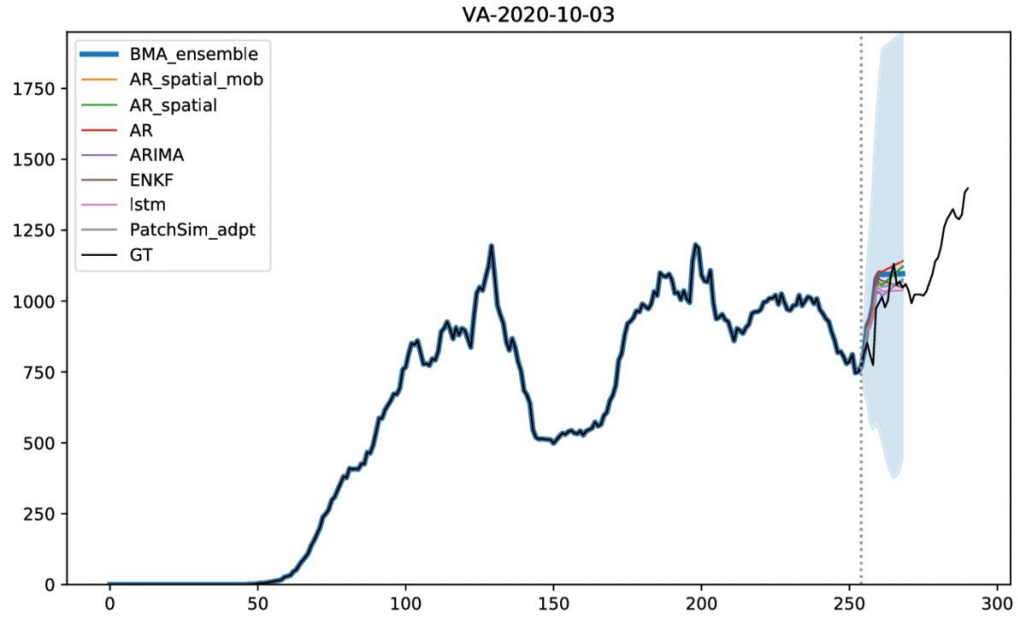
UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

Using Ensemble Model to Guide Projections

An ensemble methodology that combines the Adaptive Fitting and machine learning and statistical models has been developed and refined

- **Models**: Adaptive Fitting, ARIMA, LSTM, AR, spatially driven AR, Kalman Filters (ENKF)
- This approach facilitates the use of other data streams (weather, mobility, etc.)
- Ensemble provides scaffolding for the Adaptive Fitting's short-term projections

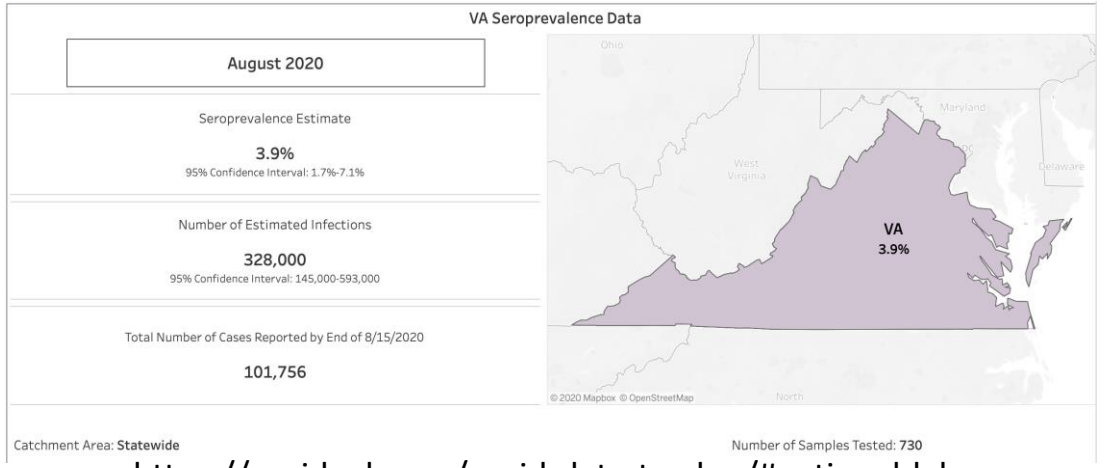




Seroprevalence updates to model design

Several seroprevalence studies provide better picture of how many actual infections have occurred

- Virginia Serology Study estimated 2.4% of Virginians estimated infected (as of Aug 15th)
- CDC Nationwide Commercial Laboratory Seroprevalence Survey estimated 3.9% [1.7% – 7.1%] seroprevalence as of Aug 15th **(Updates recently released, similar and will be included next week)**



https://covid.cdc.gov/covid-data-tracker/#national-lab

These findings are equivalent to an ascertainment ratio of ~3x, with bounds of (1x to 7x)

- Thus for 3x there are 3 total infections in the population for every confirmed case
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being used)

Virginia Coronavirus Serology Project

Interim findings by region and statewide - July 22, 2020

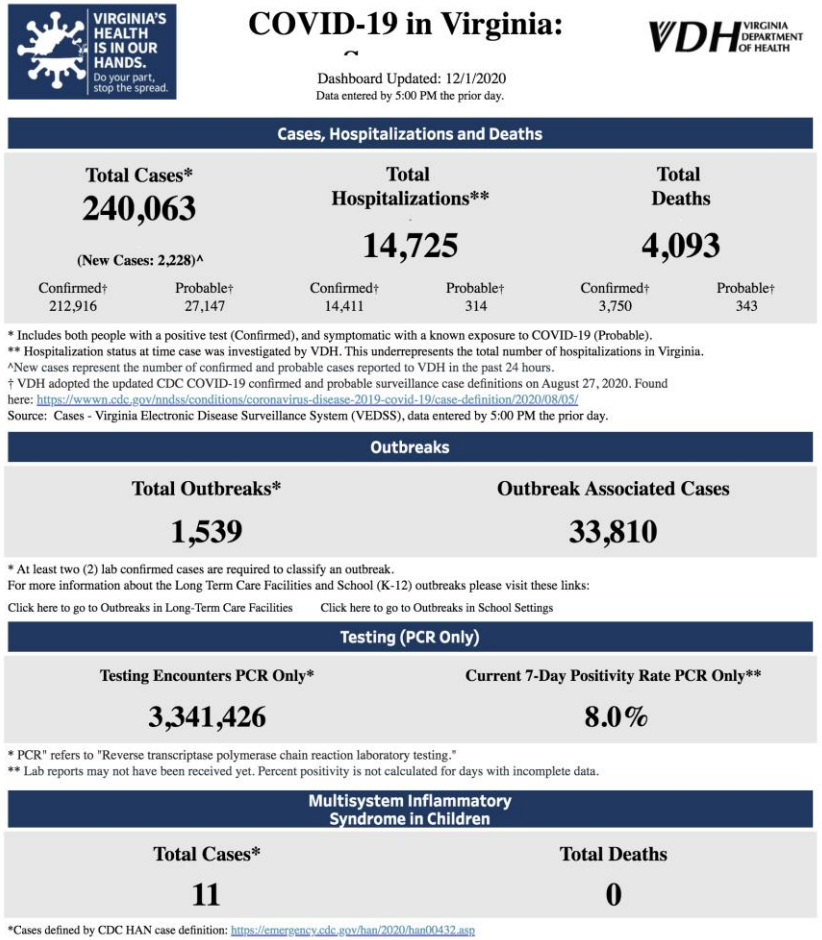
Region	Number of participants	Number antibody positive	Crude prevalence per 100 participants	Weighted prevalence*	
				per 100 population	(95% CI)
Central	400	8	2.0	3.0	(0.5, 5.5)
East	707	9	1.3	1.5	(-0.2, 3.2)
Northern	819	36	4.4	4.2	(2.5, 5.9)
Northwest	756	11	1.5	0.9	(0.2, 1.6)
Southwest	431	3	0.7	1.0	(-0.2, 2.1)
Virginia	3,113	67	2.2	2.4	(1.6, 3.1)

* Weighted prevalence is reweighted by region, age, sex, race, ethnicity, and insurance status to match census population.

https://www.vdh.virginia.gov/content/uploads/sites/8/2020/08/VDH-Serology-Projects-Update-8-13-2020.pdf

Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** fit model to observed data and ensemble's forecast
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (1x to 7x) guided by seroprevalence studies
    - 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 generated using the collection of fit models run into the future
  - **Mean trend from last 14 days of observed cases and first week of ensemble's forecast used**
  - Outliers removed based on variances in the previous 3 weeks
  - 2 week interpolation to smooth transitions in rapidly changing trajectories



VIRGINIA'S HEALTH IS IN OUR HANDS. Do your part, stop the spread.

COVID-19 in Virginia:

VDH VIRGINIA DEPARTMENT OF HEALTH

Dashboard Updated: 12/1/2020
Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths

Total Cases*	Total Hospitalizations**	Total Deaths
240,063	14,725	4,093
(New Cases: 2,228)^		

Confirmed†	Probable†	Confirmed†	Probable†	Confirmed†	Probable†
212,916	27,147	14,411	314	3,750	343

* Includes both people with a positive test (Confirmed), and symptomatic with a known exposure to COVID-19 (Probable).
** Hospitalization status at time case was investigated by VDH. This underrepresents the total number of hospitalizations in Virginia.
^New cases represent the number of confirmed and probable cases reported to VDH in the past 24 hours.
† VDH adopted the updated CDC COVID-19 confirmed and probable surveillance case definitions on August 27, 2020. Found here: https://wwwn.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/08/05/
Source: Cases - Virginia Electronic Disease Surveillance System (VEDSS), data entered by 5:00 PM the prior day.

Outbreaks

Total Outbreaks*	Outbreak Associated Cases
1,539	33,810

* At least two (2) lab confirmed cases are required to classify an outbreak.
For more information about the Long Term Care Facilities and School (K-12) outbreaks please visit these links:
Click here to go to Outbreaks in Long-Term Care Facilities Click here to go to Outbreaks in School Settings

Testing (PCR Only)

Testing Encounters PCR Only*	Current 7-Day Positivity Rate PCR Only**
3,341,426	8.0%

* PCR" refers to "Reverse transcriptase polymerase chain reaction laboratory testing."
** Lab reports may not have been received yet. Percent positivity is not calculated for days with incomplete data.

Multisystem Inflammatory Syndrome in Children

Total Cases*	Total Deaths
11	0

*Cases defined by CDC HAN case definition: https://emergency.cdc.gov/han/2020/han00432.asp

Accessed 8:30am December 2, 2020
https://www.vdh.virginia.gov/coronavirus/

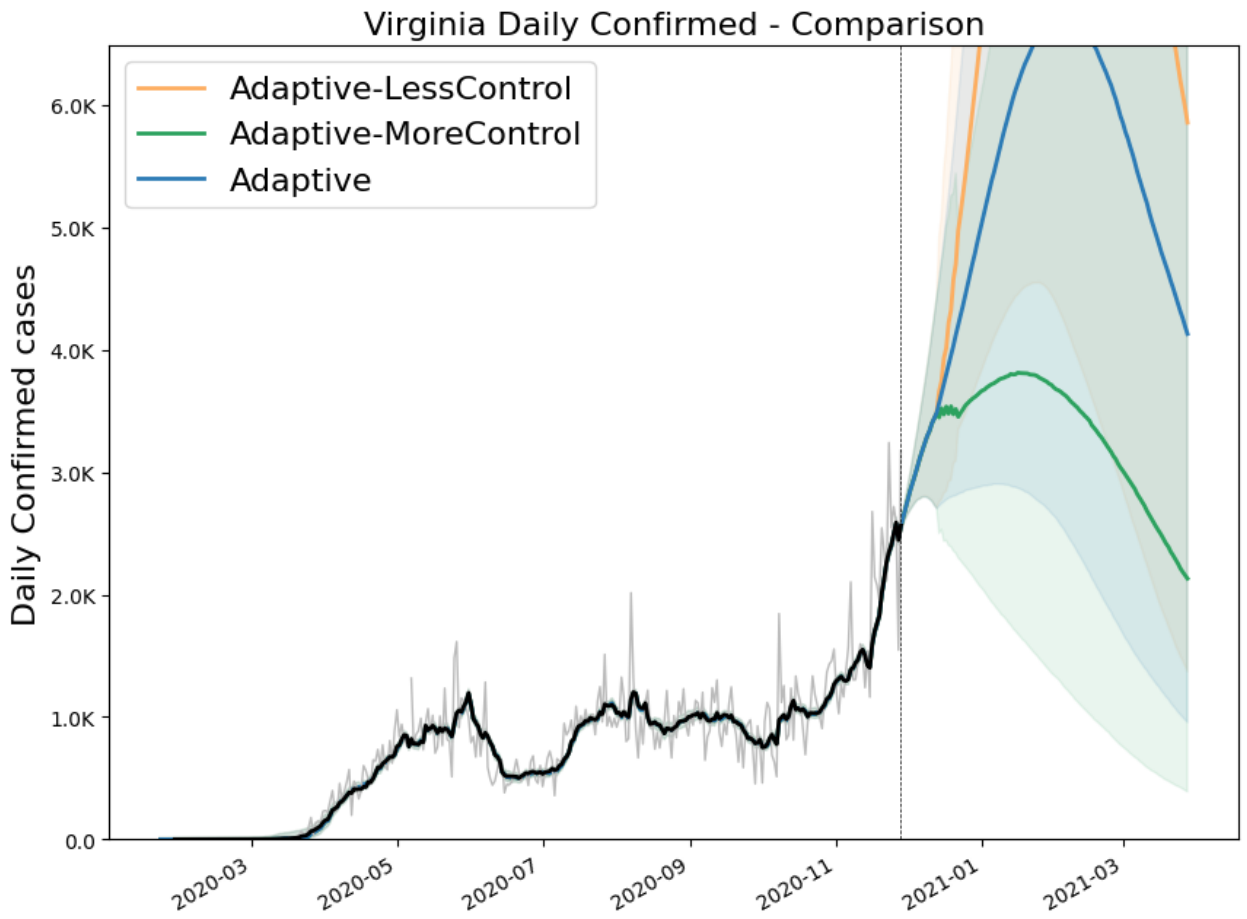
Scenarios – Seasonal Effects

- Societal changes in the past month have led to an increase in transmission rates, these could continue to drive transmission
  - Seasonal impact of weather patterns
  - More interactions at places of learning
  - Travel related to holidays and traditional large family gatherings
  - Fatigue with infection control practices
- Population's behaviors determine the level of control of transmission we can achieve
- Three scenarios capture possible trajectories starting Dec 10th, 2020
  - Adaptive: No change from base projection
  - Adaptive-MoreControl: 15% decrease in transmission starting Dec 10th, 2020
  - Adaptive-LessControl: 15% increase in transmission starting Dec 10th, 2020

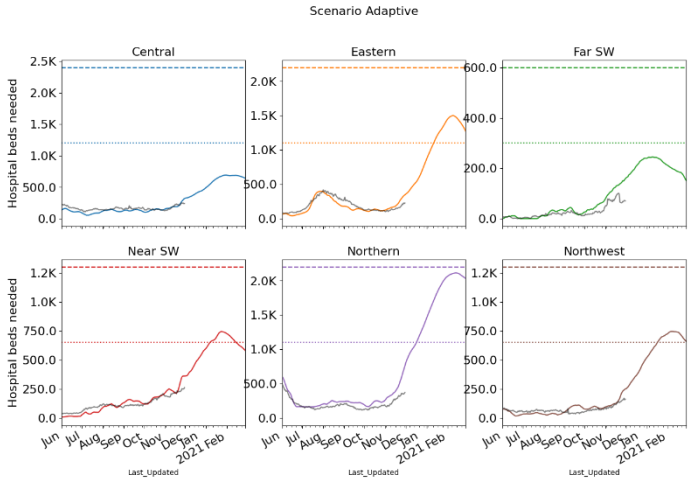
Model Results

Outcome Projections

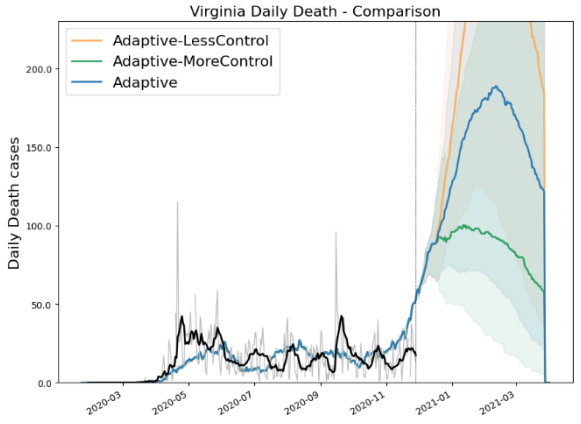
Confirmed cases



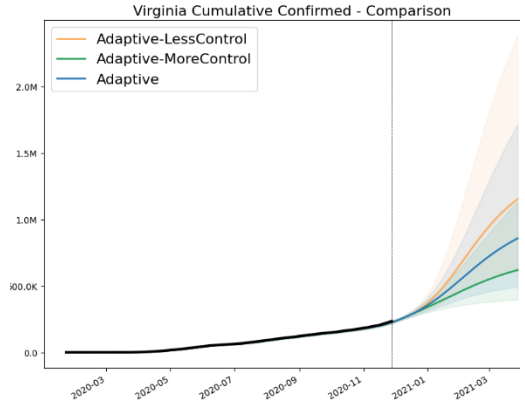
Estimated Hospital Occupancy



Daily Deaths



Cumulative Confirmed cases

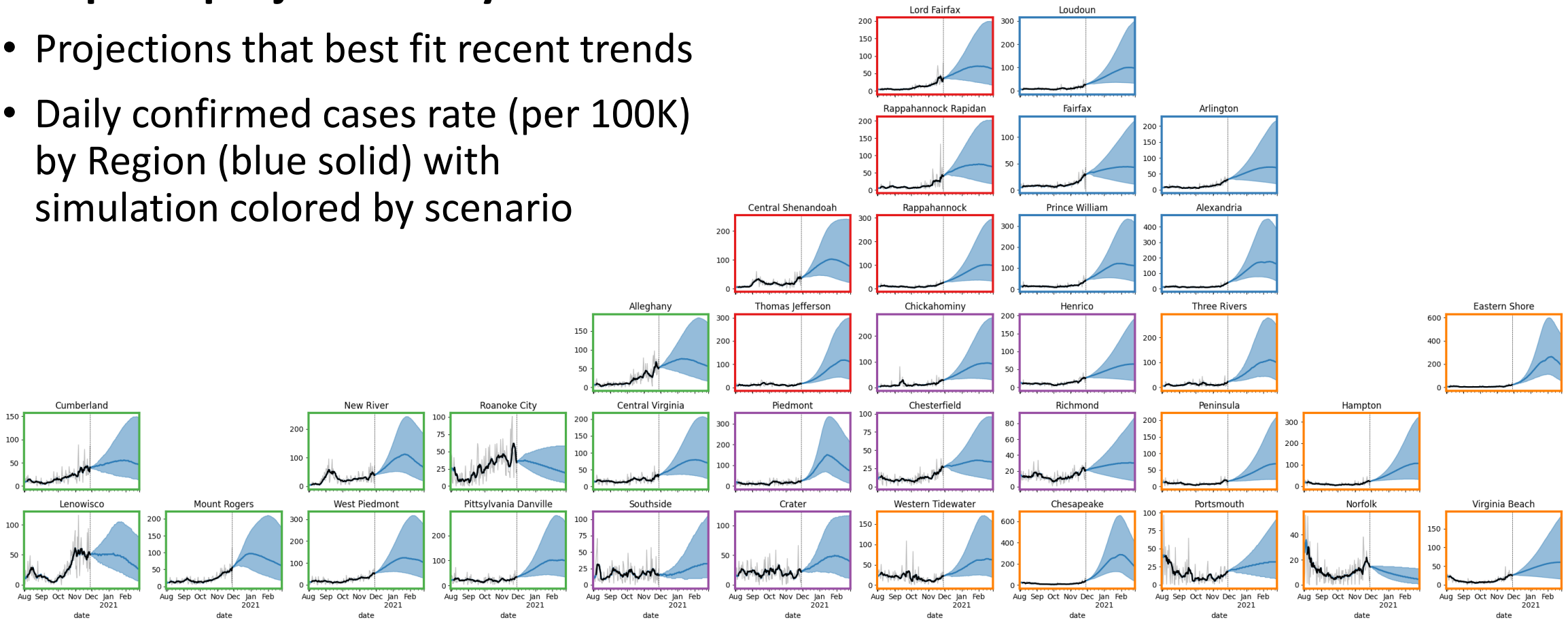


UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

District Level Projections: Adaptive

Adaptive projections by District

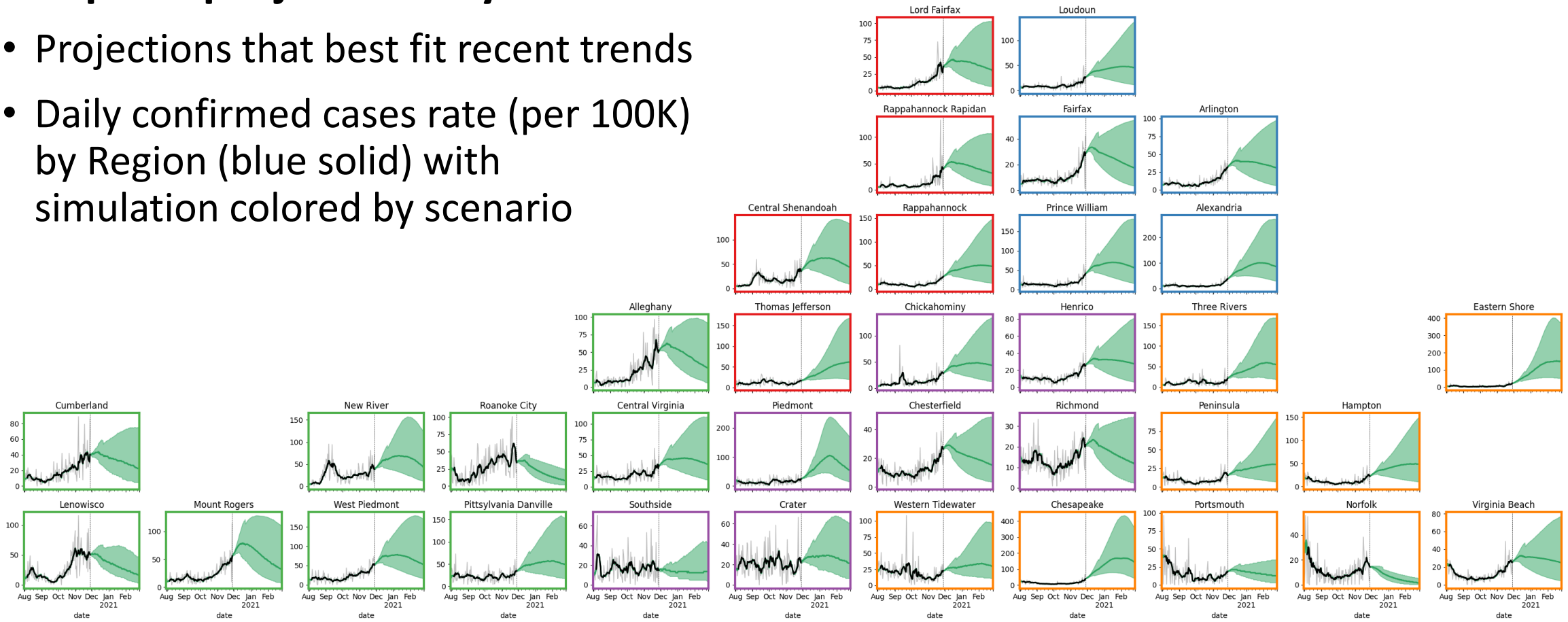
- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-MoreControl

Adaptive projections by District

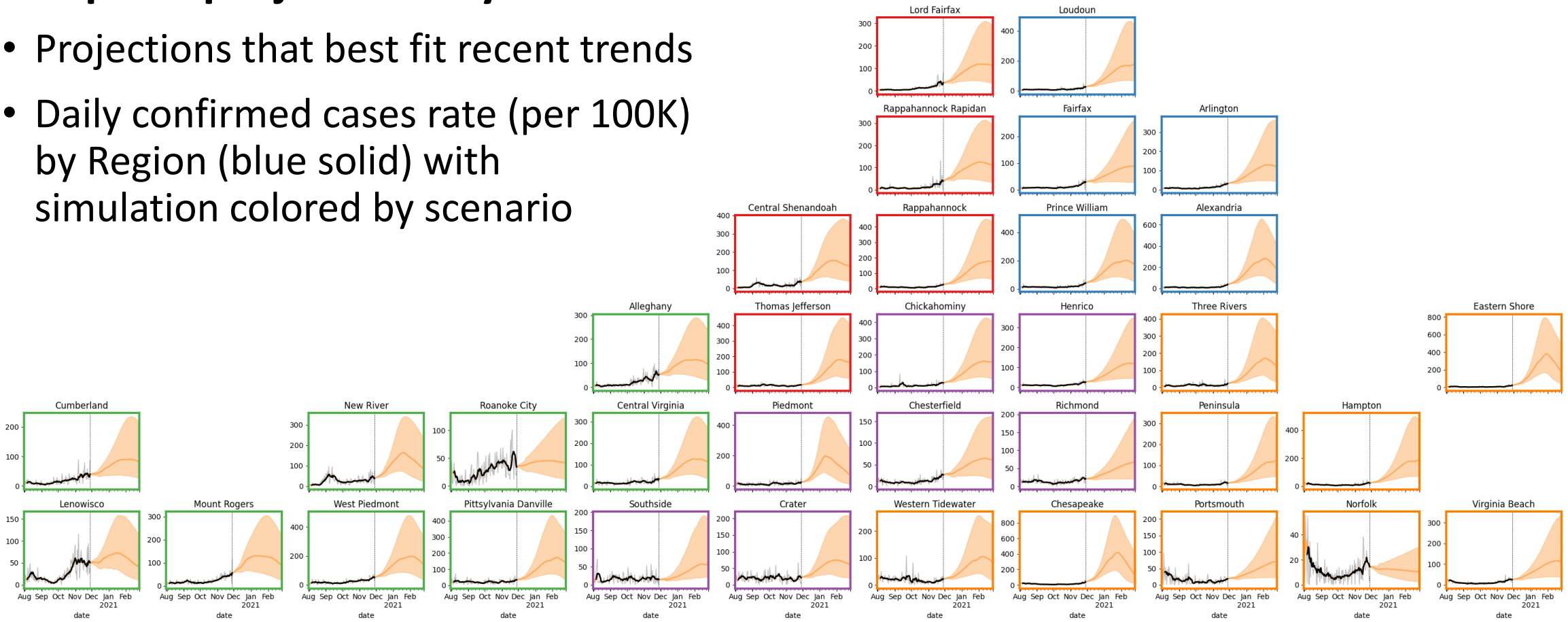
- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-LessControl

Adaptive projections by District

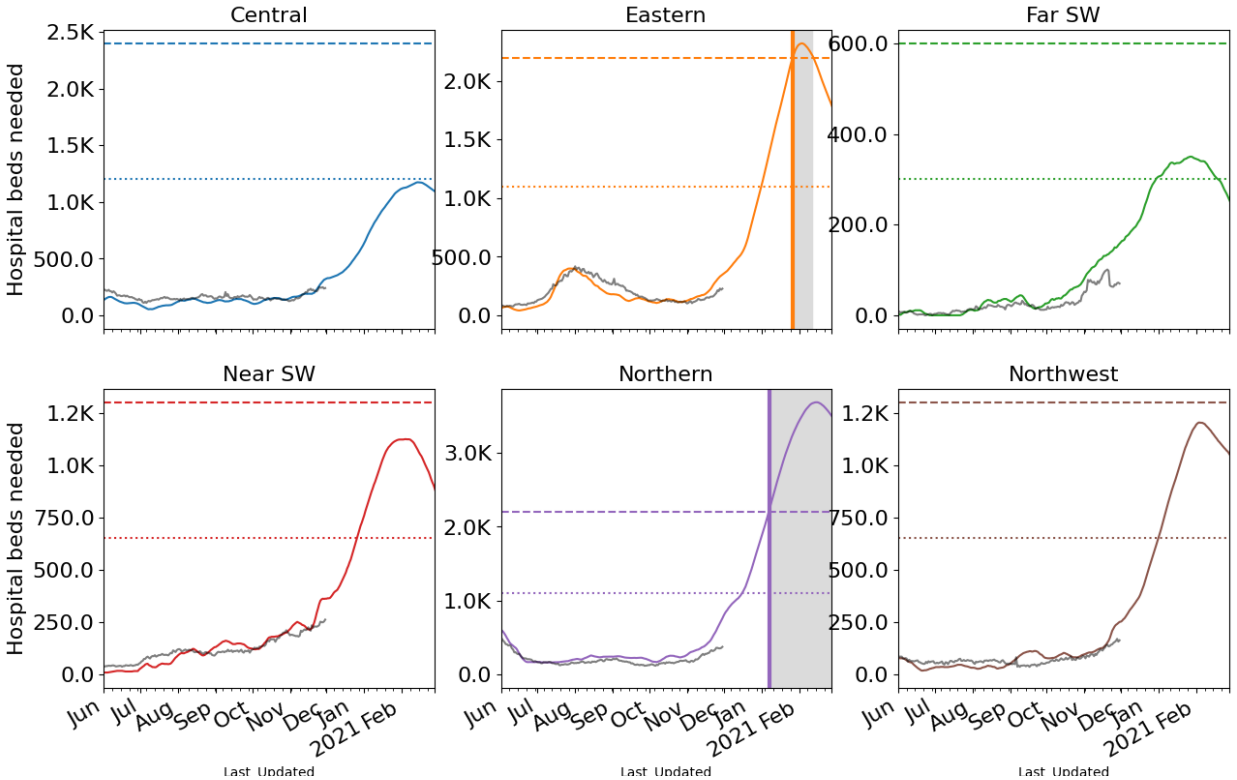
- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario



Hospital Demand and Bed Capacity by Region

Capacities* by Region – Adaptive-LessControl

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



Week Ending	Adaptive	Adaptive-LessControl
11/22/20	13,257	13,257
11/29/20	17,448	17,447
12/06/20	20,416	20,412
12/13/20	23,381	23,376
12/20/20	26,600	28,471
12/27/20	30,580	36,851
1/3/20	34,724	45,471
1/10/20	38,742	54,750
1/17/20	42,348	63,417
1/24/20	44,973	70,537
1/31/20	46,666	75,282
2/7/20	47,238	77,159

If Adaptive-LessControl scenario persists:

- All regions approach initial bed capacity this winter
- Over capacity may occur in Northern (early January); Eastern (late January) .

* 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:

- **Case growth in Virginia speeds up, recording highest case rates of epidemic**
- VA mean weekly incidence (28/100K) slightly up (from 27) as national surge finally slows a little (to 53/100K from 63/100K).
- Reporting delays and overall testing decreases may impact projections, which are mostly up, showing potential for strain on health care system in some regions as early as December.
- Recent updates:
  - Ensemble of statistical and Machine Learning models integrated with Adaptive to guide projections
  - Extending projection trend window to 3 weeks to counter holiday effects
  - Planning scenarios pushed to Dec 10th and case ascertainment rates remain as updated in previous weeks
- 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?

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, 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

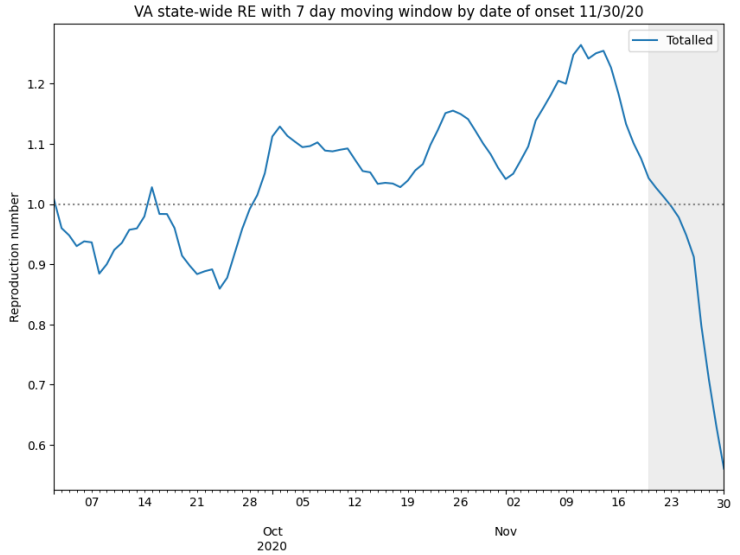
UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

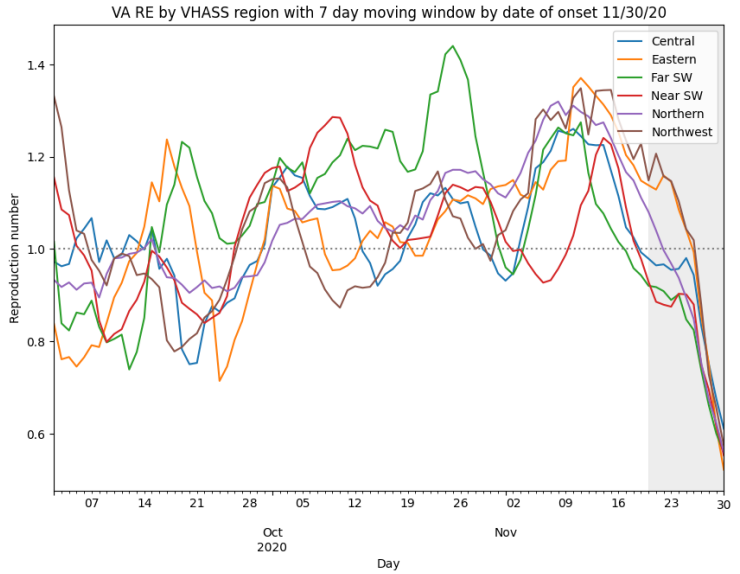
Supplemental Slides

Estimating Daily Reproductive Number

Nov 30th Estimates

Region	Date of Onset R_e	Date Onset Diff Last Week
State-wide	1.030	-0.222
Central	0.963	-0.264
Eastern	1.121	-0.188
Far SW	0.908	-0.166
Near SW	0.922	-0.311
Northern	1.069	-0.207
Northwest	1.135	-0.205





Methodology

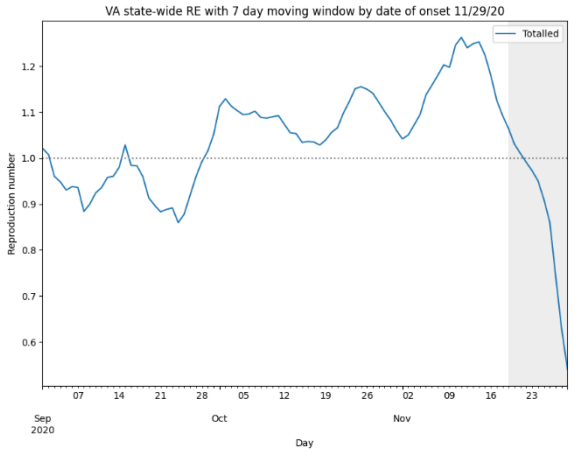
- Wallinga-Teunis method (EpiEstim[1]) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

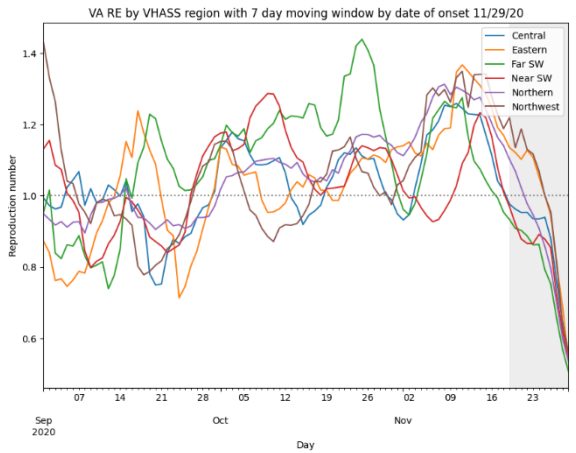
1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Estimating Daily Reproductive Number

Region	Date of Onset R_e	Confirmed Date R_e	Range of R_e	Onset Diff Last Week	Confirmed Diff Last Week	Range of Diff from Last Week
State-wide	1.030	1.234	[1.03-1.234]	-0.222	0.143	[-0.22 to 0.14]
Central	0.963	1.064	[0.963-1.064]	-0.264	-0.035	[-0.26 to -0.03]
Eastern	1.121	1.369	[1.121-1.369]	-0.188	0.332	[-0.19 to 0.33]
Far SW	0.908	1.022	[0.908-1.022]	-0.166	-0.204	[-0.17 to -0.2]
Near SW	0.922	1.225	[0.922-1.225]	-0.311	0.307	[-0.31 to 0.31]
Northern	1.069	1.280	[1.069-1.28]	-0.207	0.125	[-0.21 to 0.12]
Northwest	1.135	1.399	[1.135-1.399]	-0.205	0.192	[-0.21 to 0.19]

Nov 20th Estimates



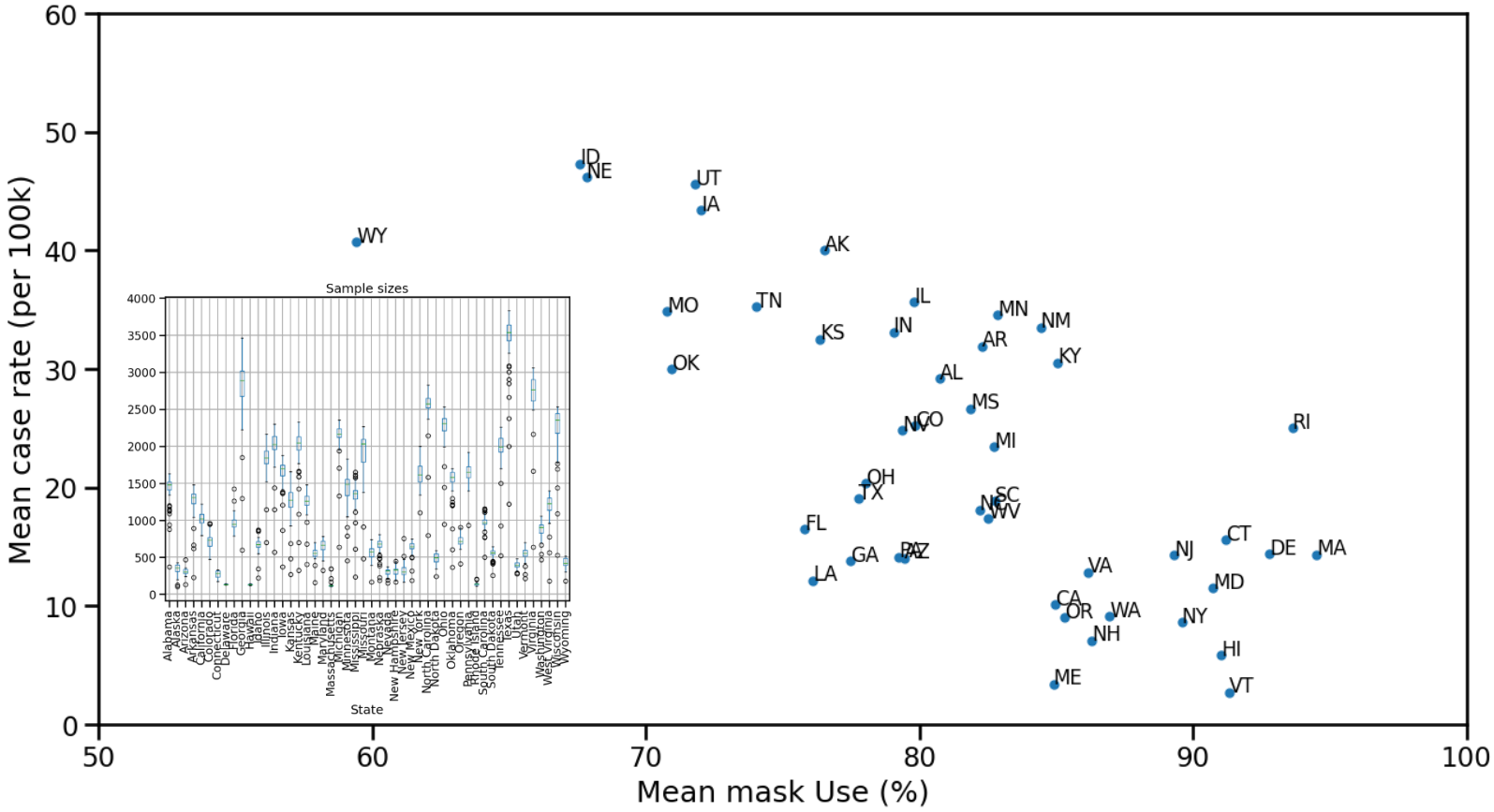


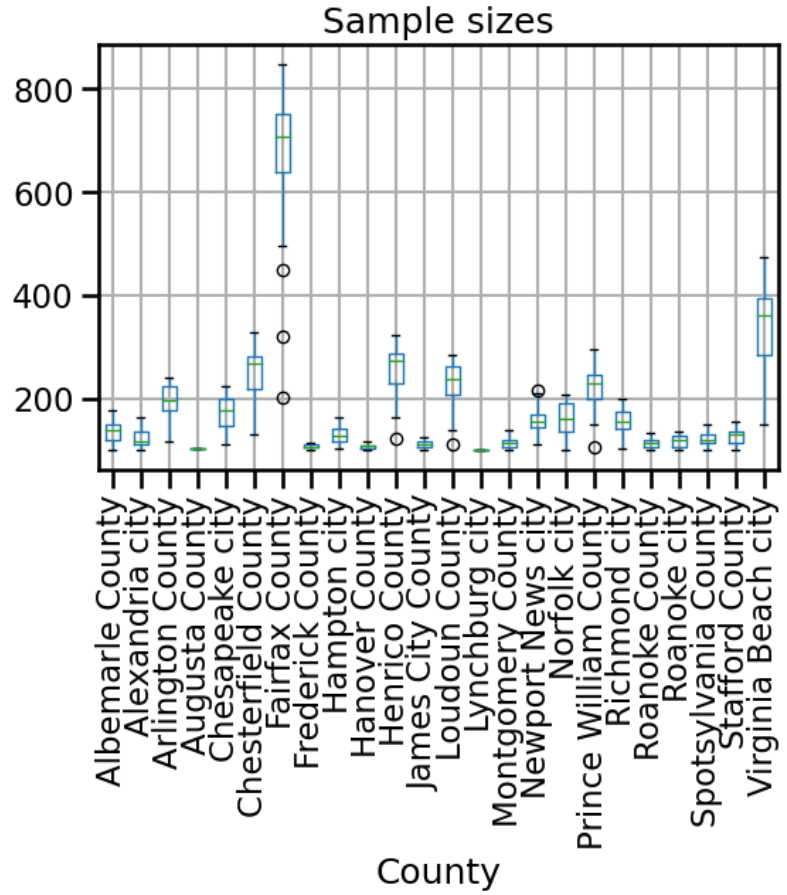
Methodology

- 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

Mask usage sample sizes





Test positivity across VA counties

- CMS weekly summary (used for guiding nursing homes testing protocol)
- Data: COVID-19 Electronic Lab Reporting (CELR); HHS Unified Testing Dataset;
- County level testing counts and test positivity rates for RT-PCR tests.
  - Green: Test positivity <5.0% or with <20 tests in past 14 days
  - Yellow: Test positivity 5.0%-10.0% or with <500 tests and <2000 tests/100k and >10% positivity over 14 days
  - Red: >10.0% and not meeting the criteria for "Green" or "Yellow"

https://data.cms.gov/stories/s/q5r5-gjyu

County	Oct-21	Oct-28	Nov-04	Nov-11
Alleghany County	Yellow	Red	Red	Red
Botetourt County	Yellow	Red	Red	Red
Bristol City	Red	Red	Red	Red
Buckingham County	Green	Yellow	Red	Red
Campbell County	Red	Red	Red	Red
Carroll County	Yellow	Red	Red	Red
Charles City County	Yellow	Yellow	Green	Red
Clarke County	Green	Green	Yellow	Red
Covington City	Green	Red	Red	Red
Craig County	Red	Red	Red	Red
Culpeper County	Yellow	Yellow	Yellow	Red
Cumberland County	Green	Yellow	Yellow	Red
Dickenson County	Yellow	Yellow	Yellow	Red
Fairfax County	Yellow	Yellow	Yellow	Red
Franklin County	Red	Red	Red	Red
Frederick County	Yellow	Yellow	Yellow	Red
Galax City	Red	Red	Red	Red
Giles County	Yellow	Yellow	Red	Red
Grayson County	Yellow	Red	Red	Red
Halifax County	Green	Yellow	Yellow	Red
Henry County	Red	Red	Red	Red
Lee County	Red	Red	Red	Red
Manassas City	Red	Yellow	Yellow	Red
Martinsville City	Red	Red	Red	Red
Norton City	Green	Yellow	Yellow	Red
Patrick County	Yellow	Yellow	Yellow	Red
Prince George County	Red	Red	Red	Red
Prince William County	Yellow	Red	Red	Red
Pulaski County	Yellow	Red	Red	Red
Roanoke City	Yellow	Red	Red	Red
Roanoke County	Red	Red	Red	Red
Rockingham County	Yellow	Yellow	Red	Red
Russell County	Yellow	Yellow	Yellow	Red
Salem City	Yellow	Red	Red	Red
Scott County	Red	Red	Red	Red
Smyth County	Green	Green	Yellow	Red
Stafford County	Yellow	Yellow	Yellow	Red
Tazewell County	Red	Red	Red	Red
Washington County	Red	Red	Red	Red
Winchester City	Green	Yellow	Yellow	Red
Wise County	Red	Red	Red	Red
Wythe County	Red	Red	Yellow	Red

Red on Nov 11 (latest)

County	Oct-21	Oct-28	Nov-04	Nov-11
Amherst County	Red	Red	Yellow	Yellow
Bedford County	Red	Red	Red	Yellow
Bristol City	Red	Red	Red	Red
Campbell County	Red	Red	Red	Red
Charlotte County	Red	Red	Red	Yellow
Craig County	Red	Red	Red	Red
Franklin City	Red	Red	Red	Yellow
Franklin County	Red	Red	Red	Red
Galax City	Red	Red	Red	Red
Greensville County	Red	Green	Green	Green
Henry County	Red	Red	Red	Red
Lee County	Red	Red	Red	Red
Manassas City	Red	Yellow	Yellow	Red
Martinsville City	Red	Red	Red	Red
Prince Edward County	Red	Red	Yellow	Yellow
Prince George County	Red	Red	Red	Red
Radford City	Red	Red	Red	Yellow
Roanoke County	Red	Red	Red	Red
Scott County	Red	Red	Red	Red
Southampton County	Red	Red	Yellow	Green
Tazewell County	Red	Red	Red	Red
Washington County	Red	Red	Red	Red
Wise County	Red	Red	Red	Red
Wythe County	Red	Red	Yellow	Red

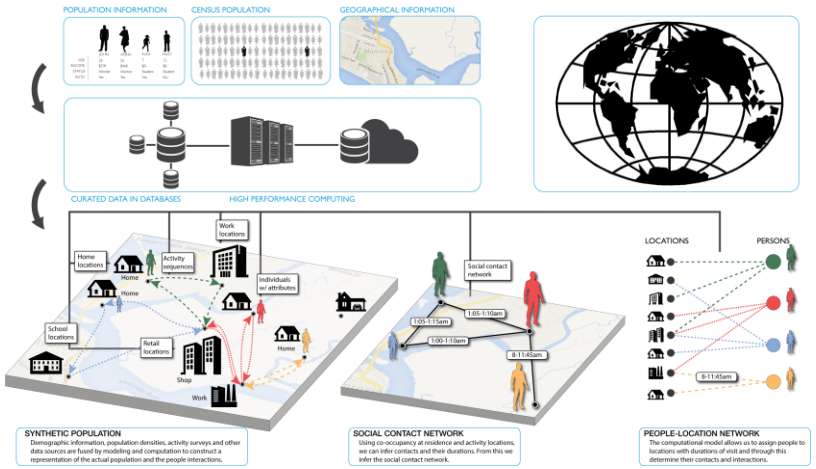
Red on Oct 21 (4-week back)

UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

Agent-based Model (ABM)

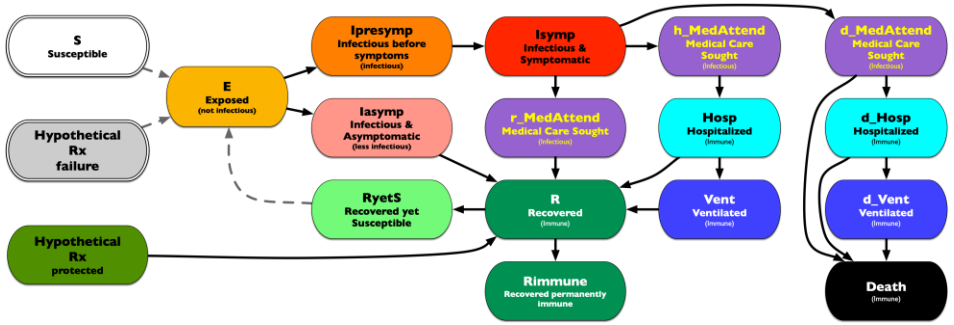
EpiHiper: Distributed network-based stochastic disease transmission simulations

- 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



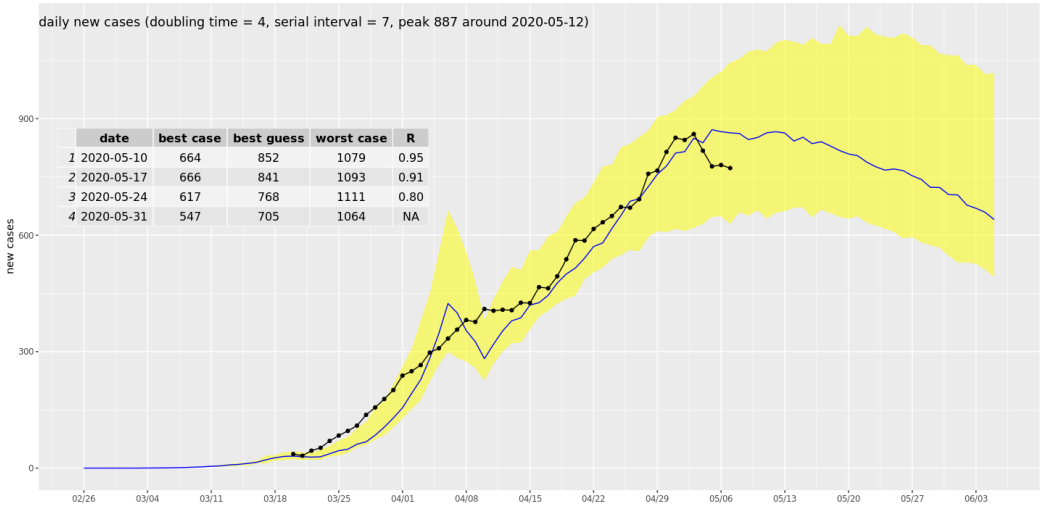
Detailed Disease Course of COVID-19

- 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

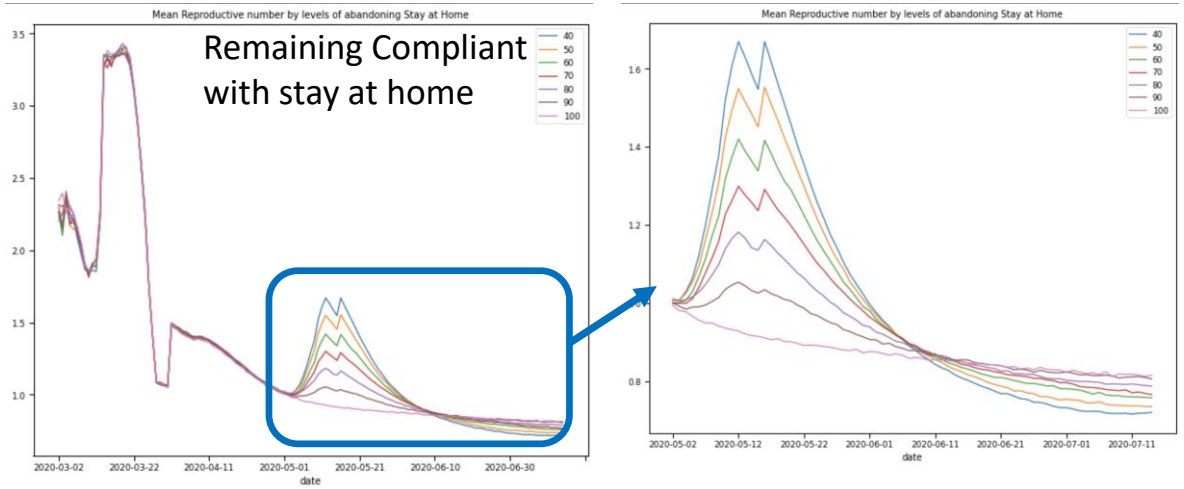
- Calibration to current state in epidemic
- Implement “release” of different proportions of people from ”staying at home”



	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

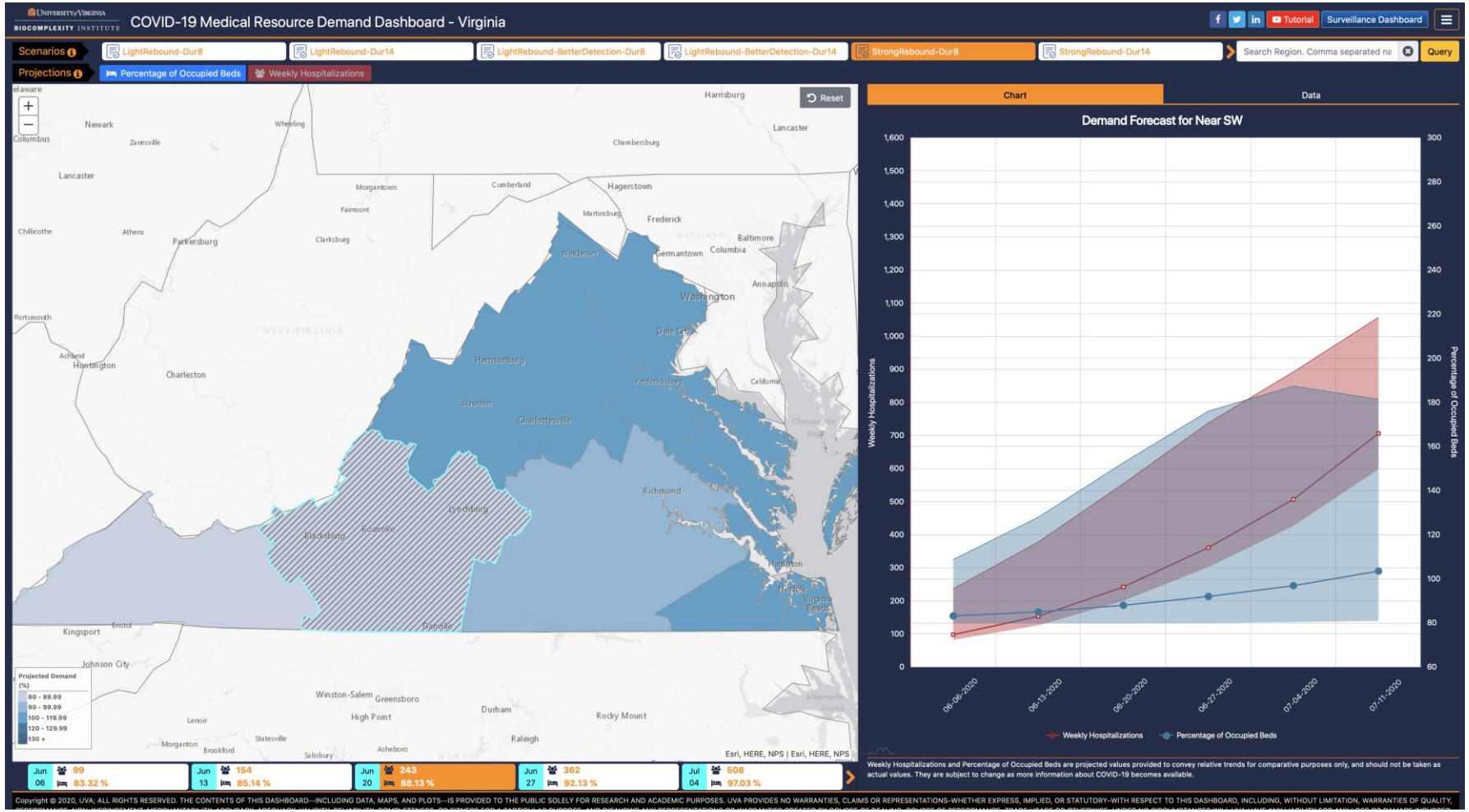


Impacts on Reproductive number with release

- 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/



UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE