Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

August 31ˢᵗ, 2022

(data current to August 27ᵗʰ – August 30ᵗʰ)
Biocomplexity Institute Technical report: TR BI-2022-1747

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

Model Development, Outbreak Analytics, and Delivery Team
Przemyslaw Porebski, Joseph Outten, Brian Klahn, Alex Telionis,
Srinivasan Venkatramanan, Bryan Lewis,
Aniruddha Adiga, Hannah Baek, Chris Barrett, Jiangzhuo Chen, Patrick Corbett,
Stephen Eubank, Galen Harrison, Ben Hurt, Dustin Machi, Achla Marathe,
Madhav Marathe, Mark Orr, Akhil Peddireddy, Erin Raymond, James Schlitt, Anil Vullikanti,
Lijing Wang, James Walke, Andrew Warren, 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 based on scenarios 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

UNIVERSITY *of* VIRGINIA

BIOCOMPLEXITY INSTITUTE

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Case rates have remained flat as have hospitalizations**

- VA weekly case rate flat at 206 per 100K from 203 per 100K

  - US weekly case rate is down to 174 per 100K from 189 per 100K

  - VA hospital occupancy (rolling 7 day mean of 791 slightly down from 798 a week ago) currently on month plateau

- Sub-variant prevalence evolution as expected

- Projections from last week remain largely on target

The situation continues to change. Models continue to be updated regularly.

Situation Assessment

UNIVERSITY *of* VIRGINIA

BIOCOMPLEXITY INSTITUTE

Case Rates (per 100k) and Test Positivity
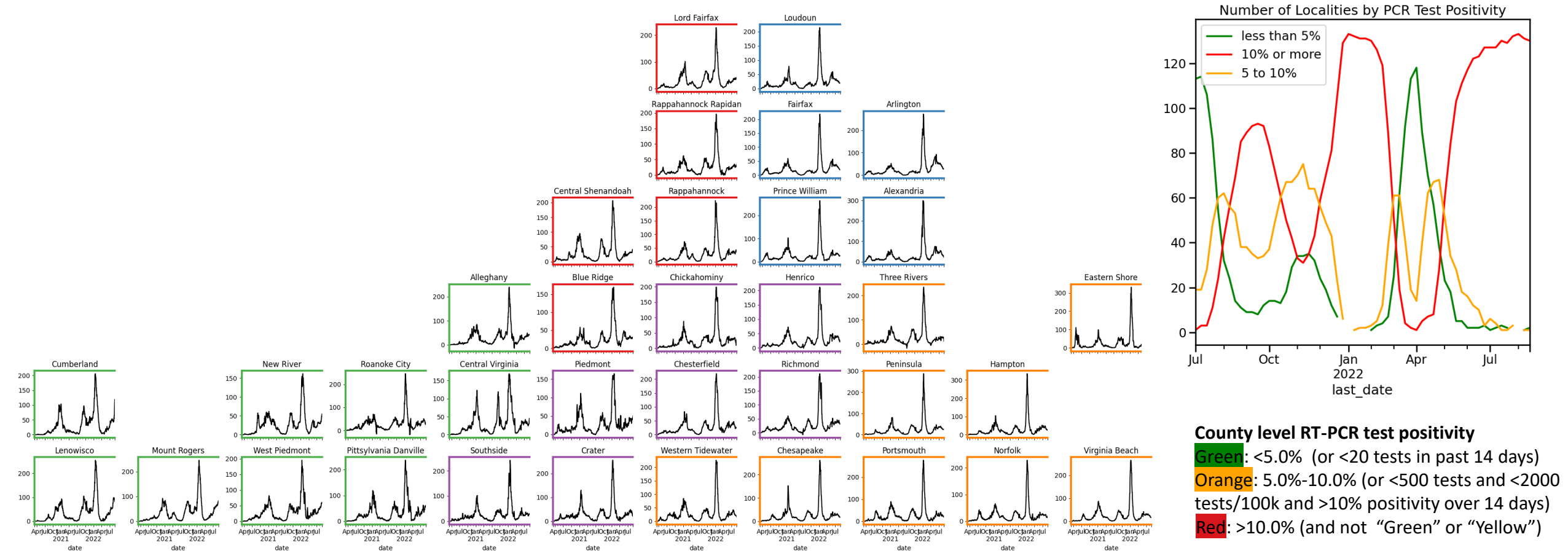
County level RT-PCR test positivity
Green: <5.0% (or <20 tests in past 14 days)
Orange: 5.0%-10.0% (or <500 tests and <2000 tests/100k and >10% positivity over 14 days)
Red: >10.0% (and not "Green" or "Yellow")

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
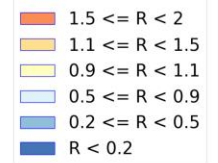
Hockey stick fit
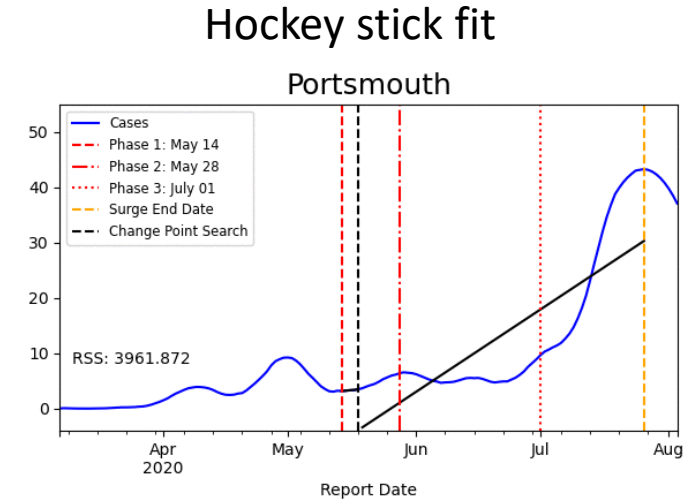
Trajectory	Description	Weekly Case Rate Slope (per 100k)	Weekly Hosp Rate Slope (per 100k)
Declining	Sustained decreases following a recent peak	slope < -0.88/day	slope < -0.07/day
Plateau	Steady level with minimal trend up or down	-0.88/day < slope < 0.42/day	-0.07/day < slope < 0.07/day
Slow Growth	Sustained growth not rapid enough to be considered a Surge	0.42/day < slope < 2.45/day	0.07/day < slope < 0.21/day
In Surge	Currently experiencing sustained rapid and significant growth	2.45/day < slope	0.21/day < slope

UNIVERSITY *of* VIRGINIA

BIOCOMPLEXITY INSTITUTE

District Case Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	17 (28)
Plateau	5 (3)
Slow Growth	9 (2)
In Surge	4 (2)

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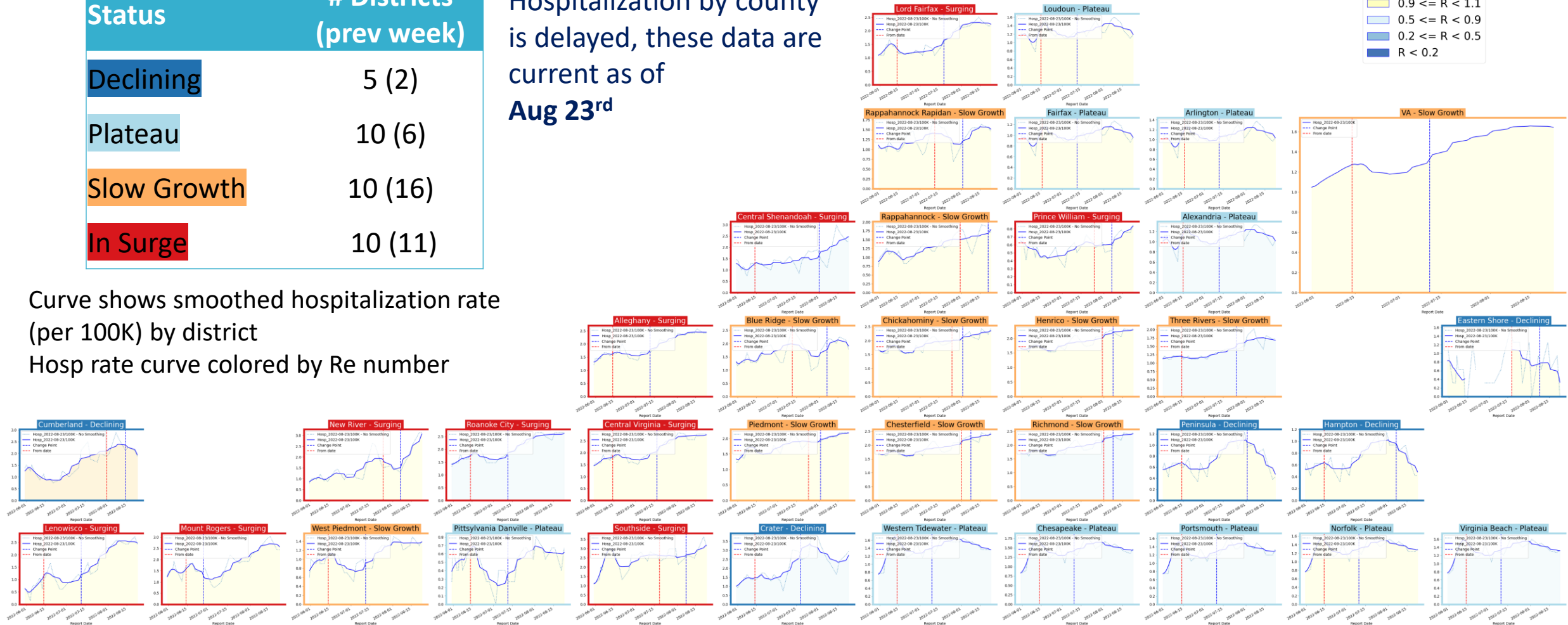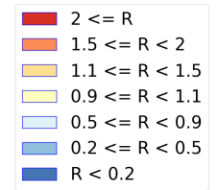Case Rate curve colored by Reproductive number

Legend:
- 1.5 <= R < 2
- 1.1 <= R < 1.5
- 0.9 <= R < 1.1
- 0.5 <= R < 0.9
- 0.2 <= R < 0.5
- R < 0.2

UNIVERSITY of VIRGINIA

BIOCOMPLEXITY INSTITUTE
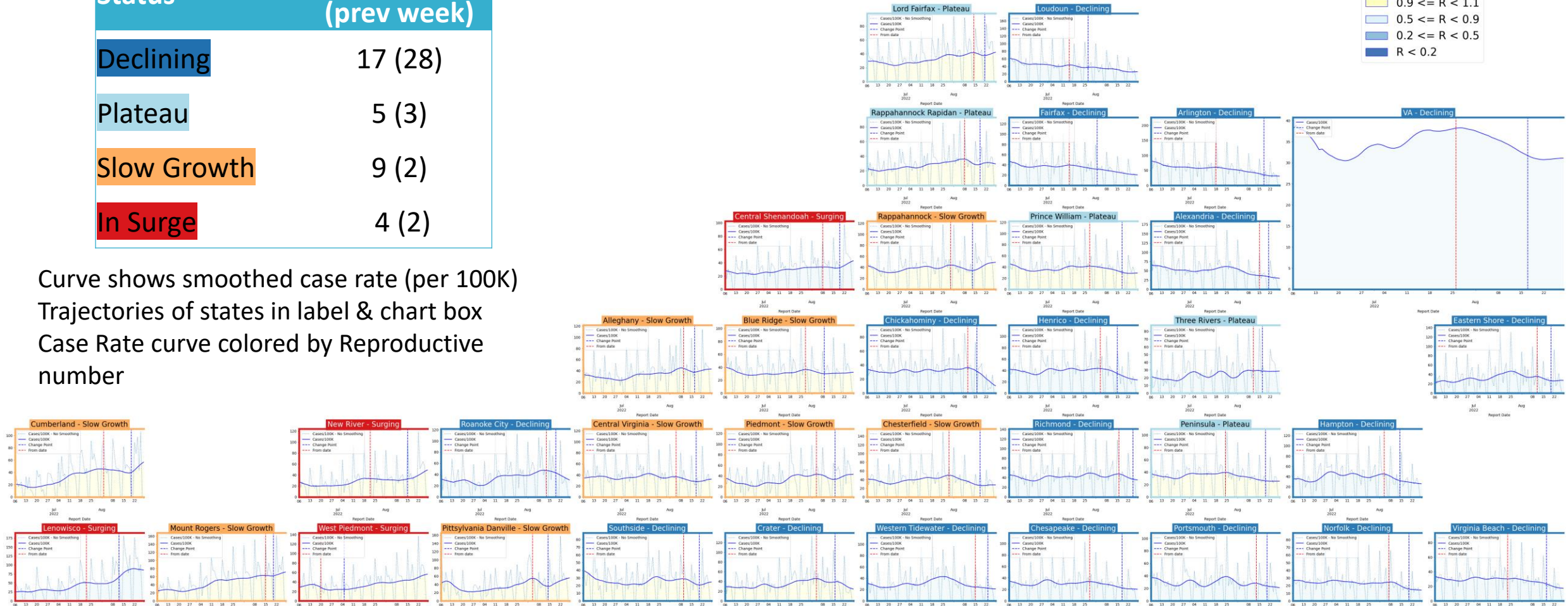
District Hospital Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	5 (2)
Plateau	10 (6)
Slow Growth	10 (16)
In Surge	10 (11)

Hospitalization by county is delayed, these data are current as of **Aug 23rd**

Curve shows smoothed hospitalization rate (per 100K) by district
Hosp rate curve colored by Re number

UNIVERSITY of VIRGINIA

BIOCOMPLEXITY INSTITUTE

CDC's COVID-19 Community Levels

Last week (Virginia map)

Legend:
- Low_both
- Medium_single
- High_single
- Medium_both

Last week (USA map)

VA — COVID-19 Community Level Trends - Virginia

USA — COVID-19 Community Level Trends - USA
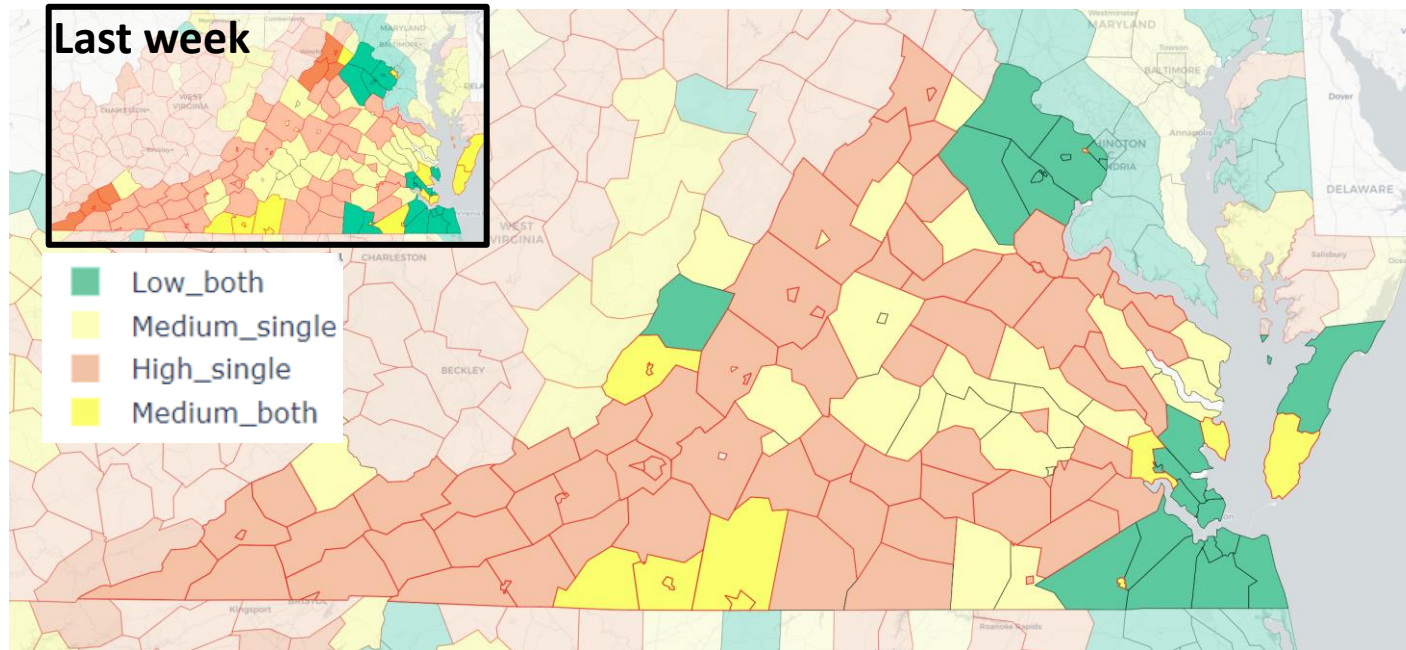
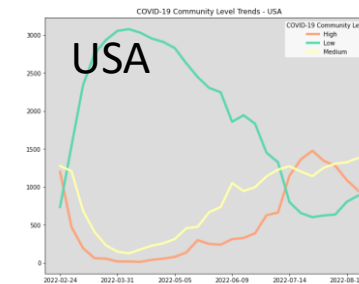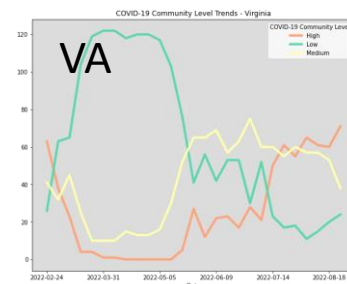**Red outline indicates county had 200 or more cases per 100k in last week**

Pale color indicates either beds or occupancy set the level for this county

Dark color indicates both beds and occupancy set the level for this county
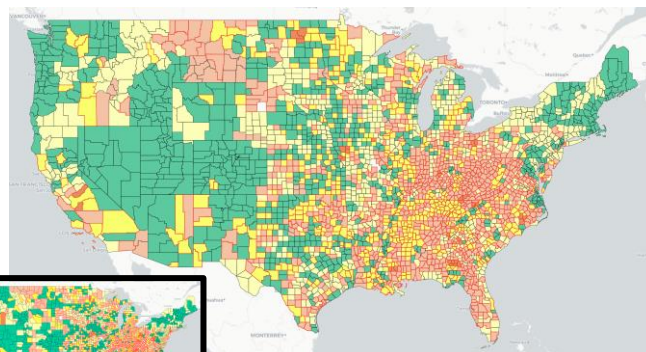
COVID-19 Community Levels – Use the Highest Level that Applies to Your Community				
New COVID-19 Cases Per 100,000 people in the past 7 days	Indicators	Low	Medium	High
Fewer than 200	New COVID-19 admissions per 100,000 population (7-day total)	<10.0	10.0-19.9	≥20.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	<10.0%	10.0-14.9%	≥15.0%
200 or more	New COVID-19 admissions per 100,000 population (7-day total)	NA	<10.0	≥10.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	NA	<10.0%	≥10.0%

The COVID-19 community level is determined by the higher of the new admissions and inpatient beds metrics, based on the current level of new cases per 100,000 population in the past 7 days

UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

2-Sep-22

Data from: CDC Data Tracker Portal
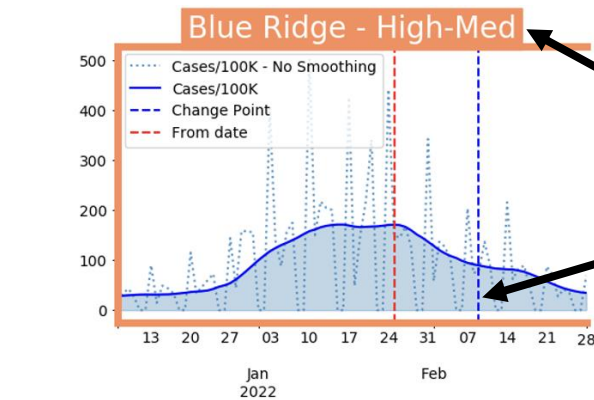
10

District Trajectories with Community Levels

Curve shows smoothed case rate (per 100K)
CDC's new Community Level aggregated to district level in label & chart box color
Case Rate curve colored by Trajectory

District's Aggregate Community Level
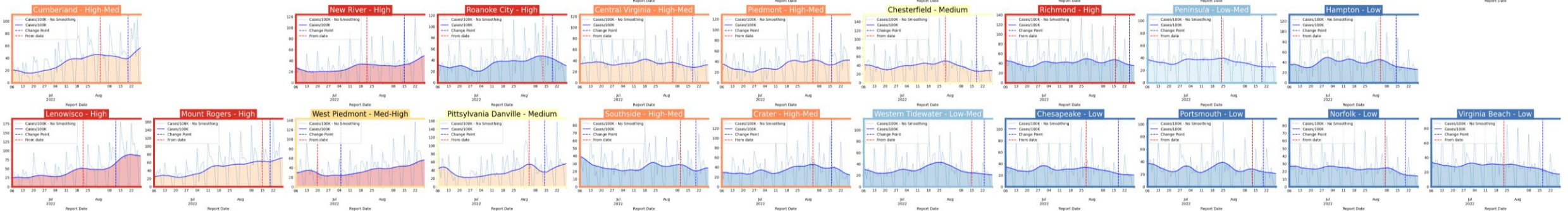Aggregate level a simple mean of all levels for counties in district

Case rate Trajectory

UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

Estimating Daily Reproductive Number –
Redistributed gap

August 29th Estimates

| Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	0.936	-0.017
Central	0.922	0.007
Eastern	0.916	0.036
Far SW	1.042	0.086
Near SW	1.005	-0.031
Northern	0.935	0.021
Northwest	0.838	-0.200

Methodology

- Wallinga-Teunis method (EpiEstim[1]) for cases by **confirmation date**
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- 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


VA state-wide RE with 7 day moving window by confirmation date redistributed GT 2022-08-29

VA RE by VHASS region with 7 day moving window by confirmation date redistributed GT 2022-08-29
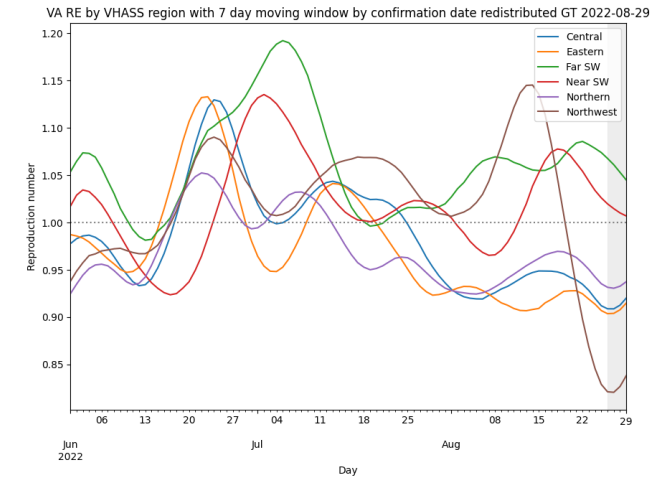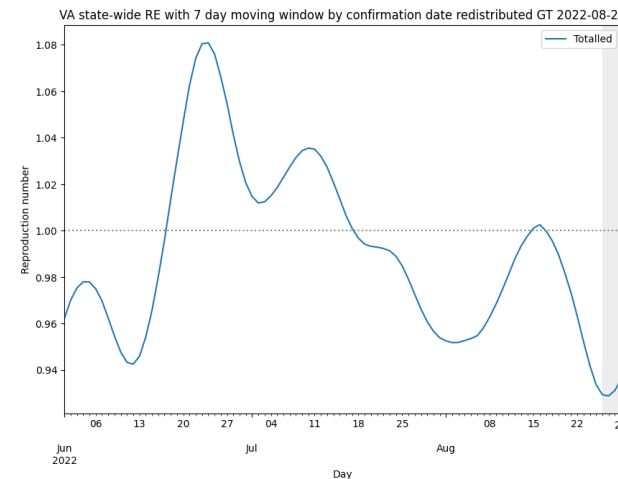
Skipping Weekend Reports & holidays biases estimates

Redistributed "big" report day to fill in gaps, and then estimate R from "smoothed" time series

Virginia
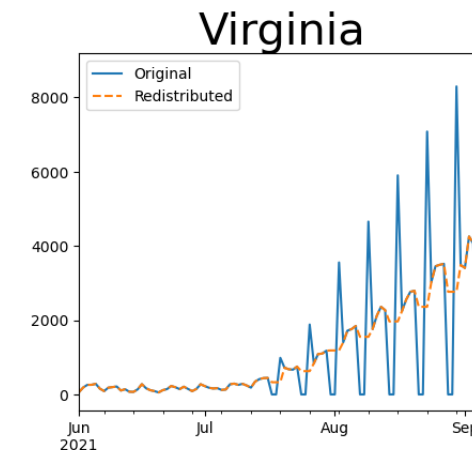
Wastewater Monitoring

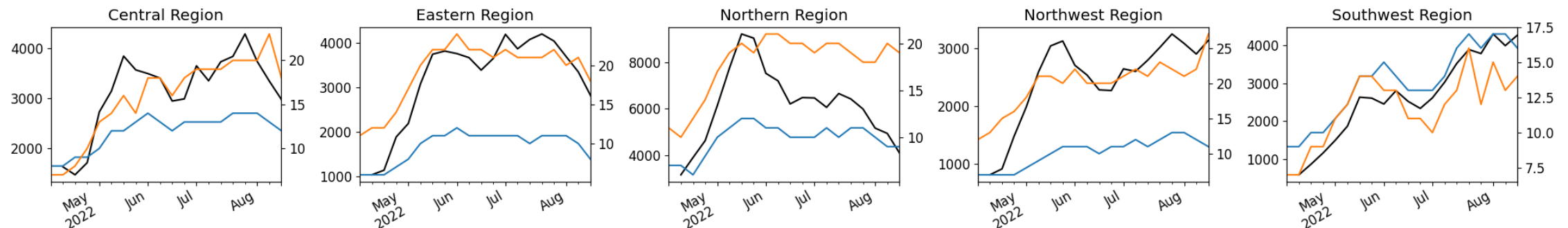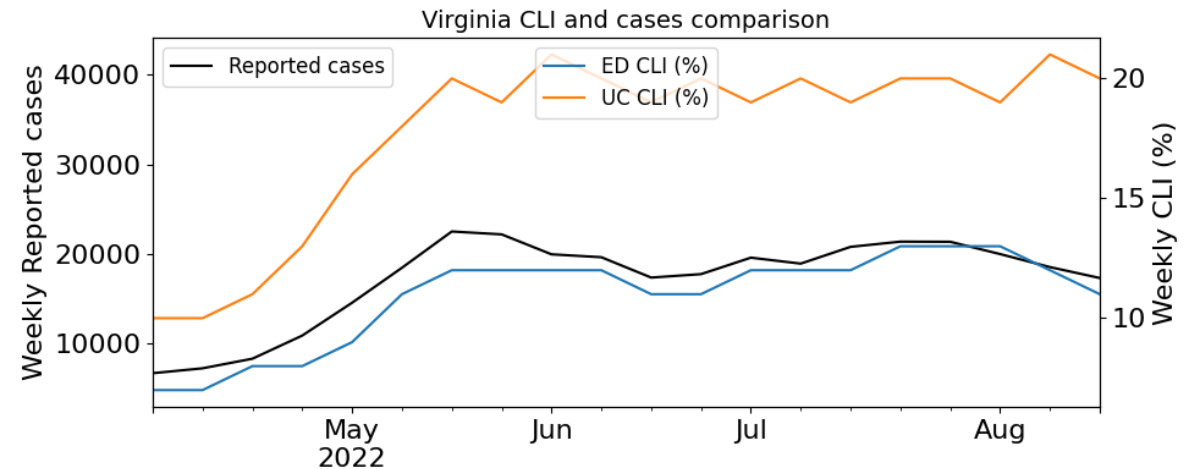**Wastewater provides a coarse early warning of COVID-19 levels in communities**

- Overall in the US, there is an increase in sites with increased levels of virus compared to 15 days ago
- Current virus levels are at or exceeding max of previous historical levels, has slowed, though more sites are entering upper quintiles

UNIVERSITY *of* VIRGINIA

BIOCOMPLEXITY INSTITUTE

Data Source: CDC Data Tracker
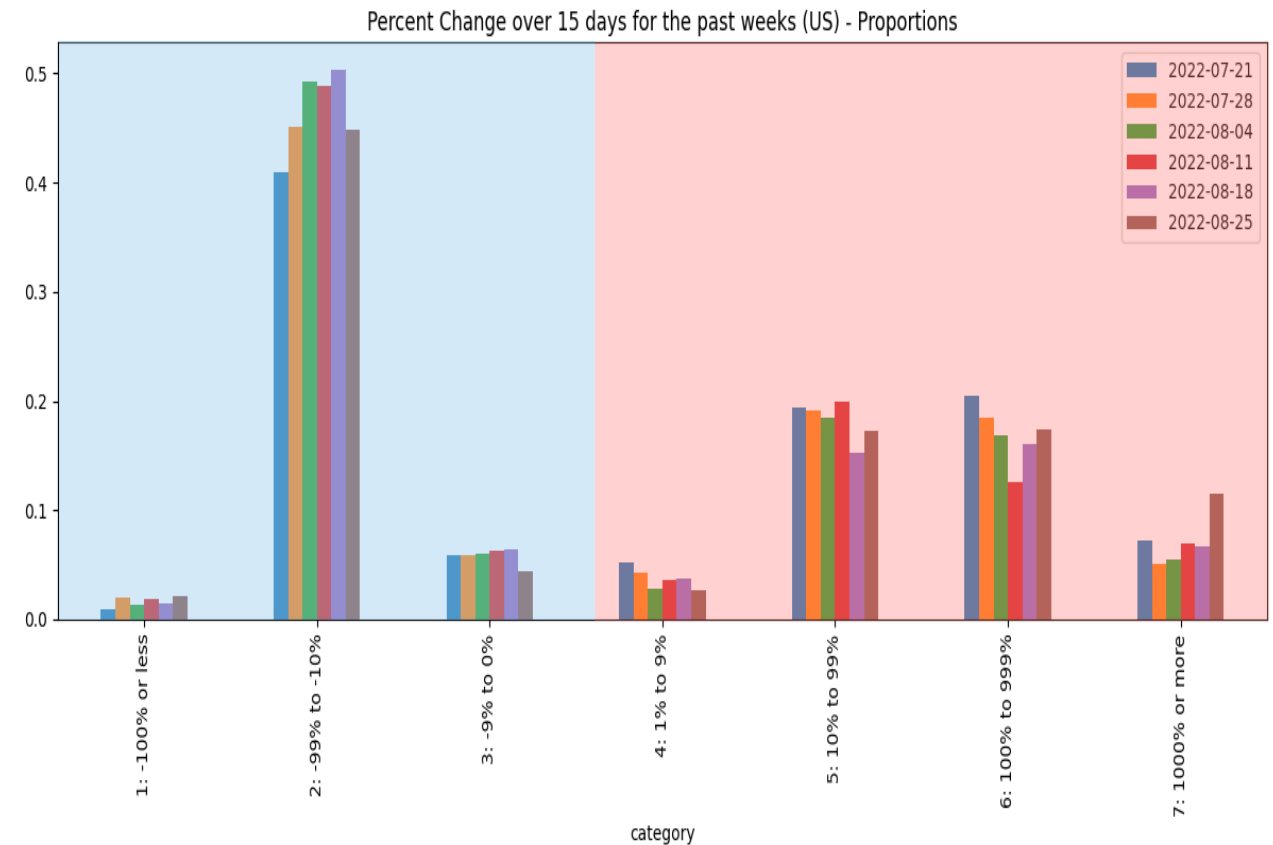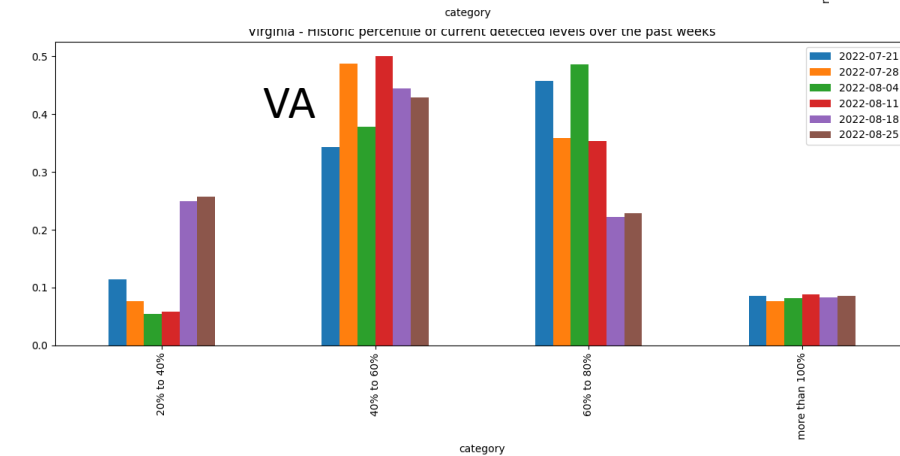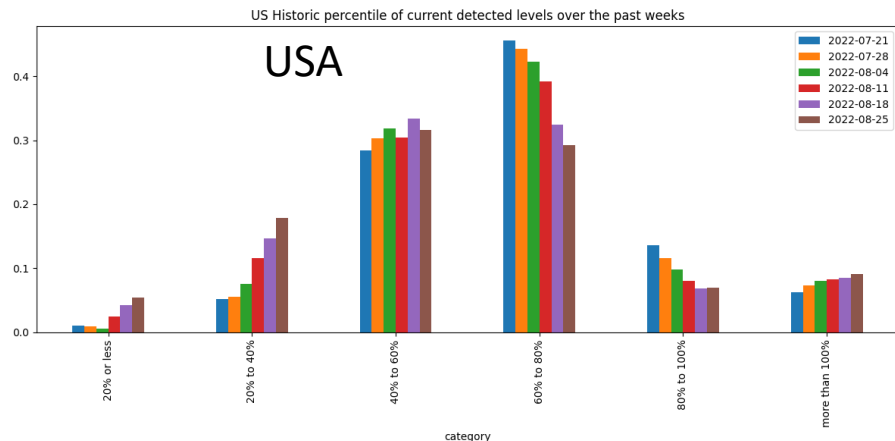
COVID-like Illness Activity

COVID-like Illness (CLI) gives a measure of COVID transmission in the community

- Emergency Dept (ED)-based CLI is more correlated with case reporting
- Urgent Care (UC) is a leading indicator but prone to some false positives
- **Current trends in UC CLI have plateaued since May 2022, mixed by region**

Virginia CLI and cases comparison

Central Region · Eastern Region · Northern Region · Northwest Region · Southwest Region

UNIVERSITY *of* VIRGINIA

BIOCOMPLEXITY INSTITUTE

# Hospitalizations and Severe Outcomes

Proportion of most severe outcomes decreasing among those who are hospitalized

- ICU has declined from ~20% of hospitalizations to nearly 10% since the first wave of Omicron
- Similar levels of decline experienced for mechanical ventilation and death
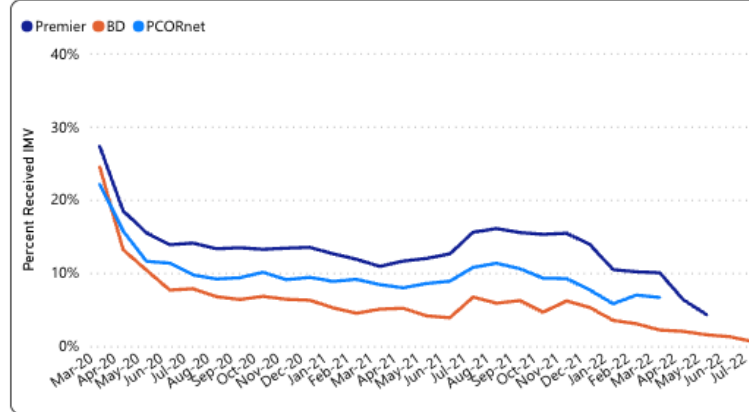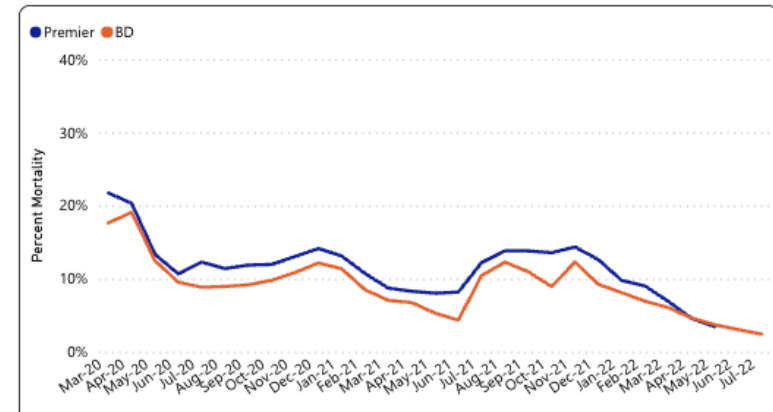

Number of hospitalized COVID-19 patients
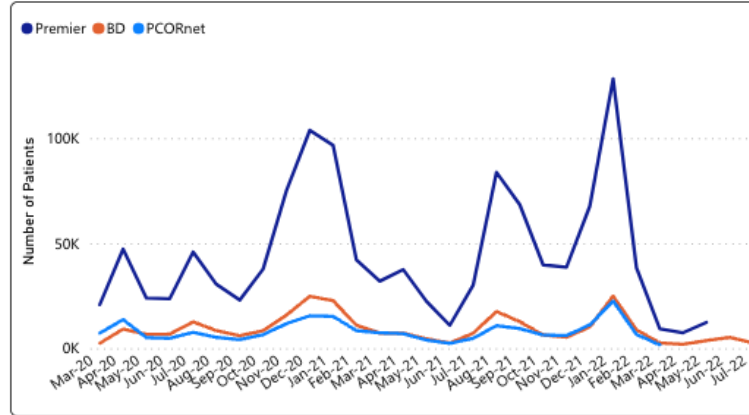
Intensive care unit (ICU) admission among hospitalized COVID-19 patients (%)
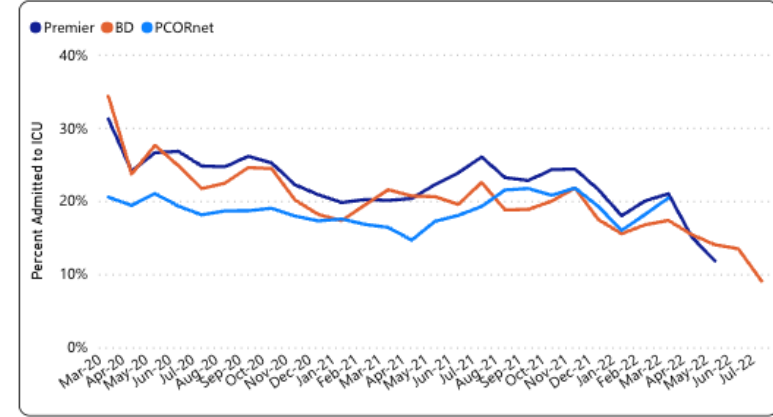
Invasive mechanical ventilation (IMV) among hospitalized COVID-19 patients (%)

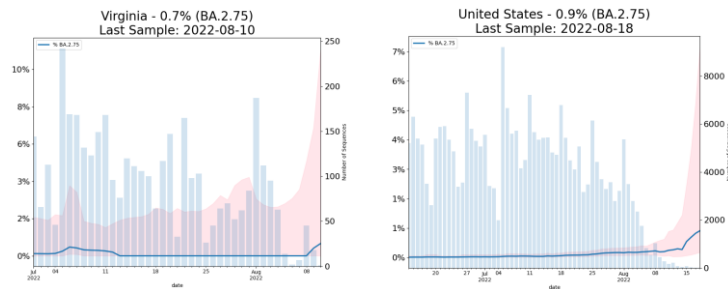Mortality among hospitalized COVID-19 patients (%)

Data Source: CDC Data Tracker

SARS-CoV2 Variants of Concern

Emerging new variants will alter the future trajectories of pandemic and have implications for future control
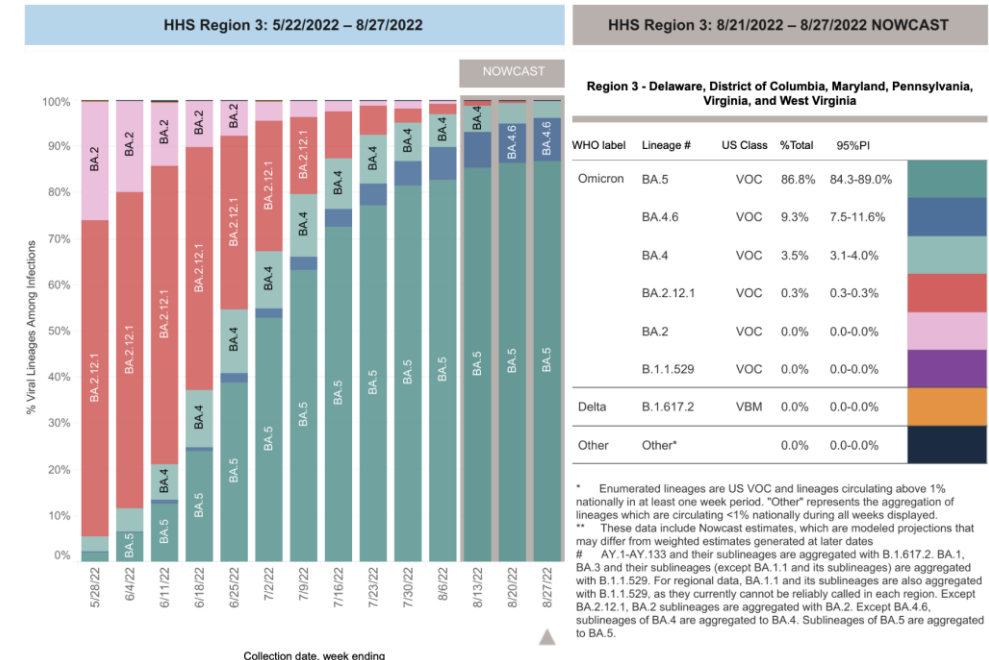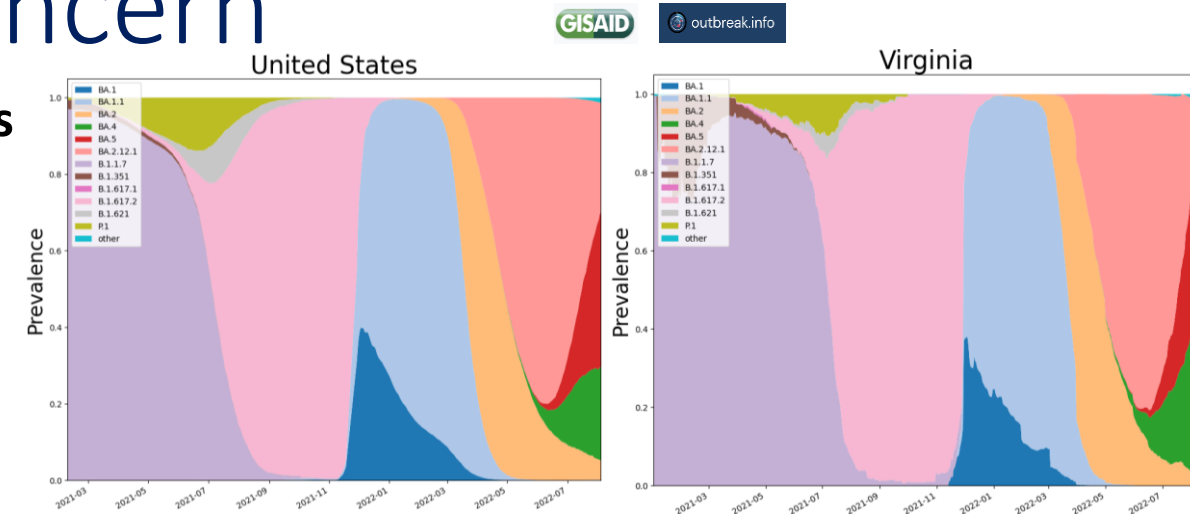
- Emerging variants can:
  - Increase transmissibility
  - Increase severity (more hospitalizations and/or deaths)
  - Limit immunity provided by prior infection and vaccinations

Omicron Updates (Region 3)

- BA.2.12.1 growth has continued to decline, shrinking to about 1%

- BA.4 has declined as well, now contributing about 4%, but BA.4.6 is now at 9% (up slightly from 8.5% last week)

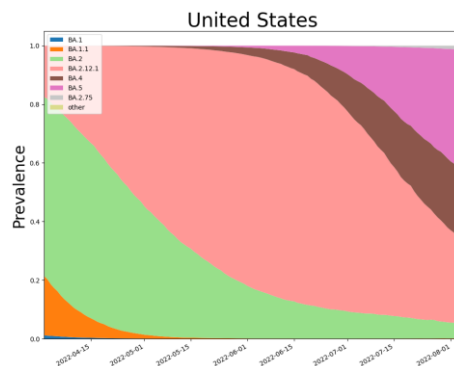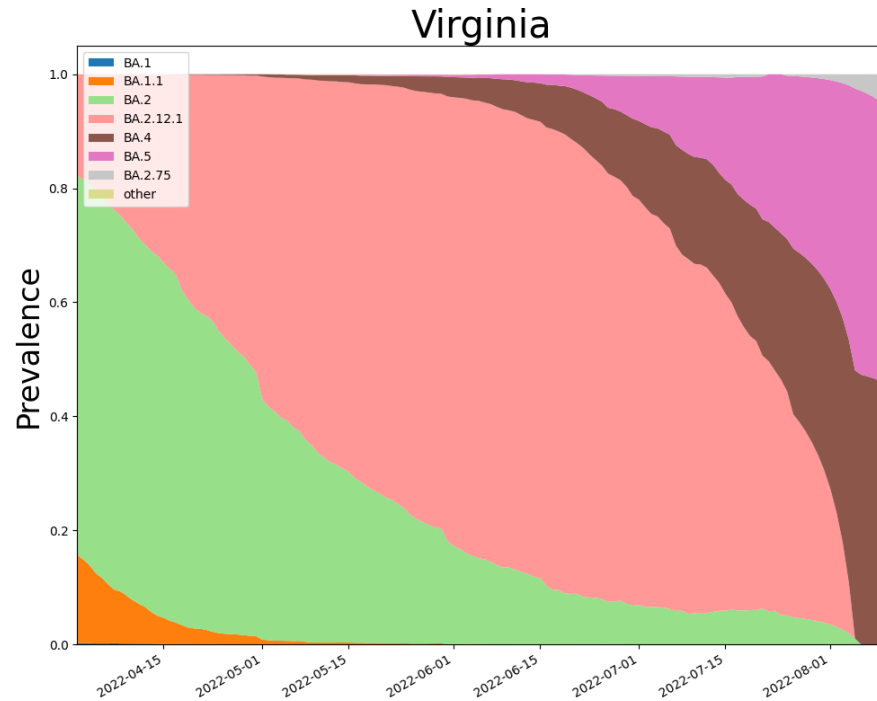- BA.5 has stagnated, nowcasted at 87% again for a 2nd week

**BA.2.75 detected in US
(very limited samples)**

Region 3 - Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia

WHO label	Lineage #	US Class	%Total	95%PI	
Omicron	BA.5	VOC	86.8%	84.3-89.0%	
	BA.4.6	VOC	9.3%	7.5-11.6%	
	BA.4	VOC	3.5%	3.1-4.0%	
	BA.2.12.1	VOC	0.3%	0.3-0.3%	
	BA.2	VOC	0.0%	0.0-0.0%	
	B.1.1.529	VOC	0.0%	0.0-0.0%	
Delta	B.1.617.2	VBM	0.0%	0.0-0.0%	
Other	Other*		0.0%	0.0-0.0%	

*   Enumerated lineages are US VOC and lineages circulating above 1% nationally in at least one week period. "Other" represents the aggregation of lineages which are circulating <1% nationally during all weeks displayed.
**   These data include Nowcast estimates, which are modeled projections that may differ from weighted estimates generated at later dates
#   AY.1-AY.133 and their sublineages are aggregated with B.1.617.2. BA.1, BA.3 and their sublineages (except BA.1.1 and its sublineages) are aggregated with B.1.1.529. For regional data, BA.1.1 and its sublineages are also aggregated with B.1.1.529, as they currently cannot be reliably called in each region. Except BA.2.12.1, BA.2 sublineages are aggregated with BA.2. Except BA.4.6, sublineages of BA.4 are aggregated to BA.4. Sublineages of BA.5 are aggregated to BA.5.

CDC Variant Tracking

SARS-CoV2 Omicron and Sub-Variants

As detected in whole Genomes in public repositories

VoC Polynomial Fit Projections
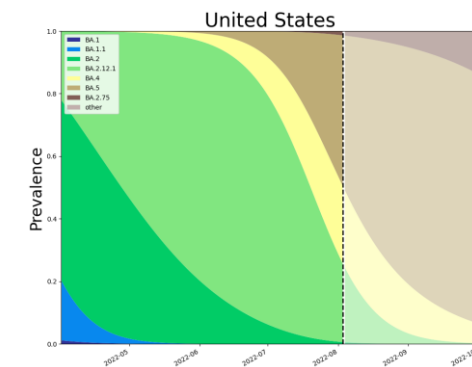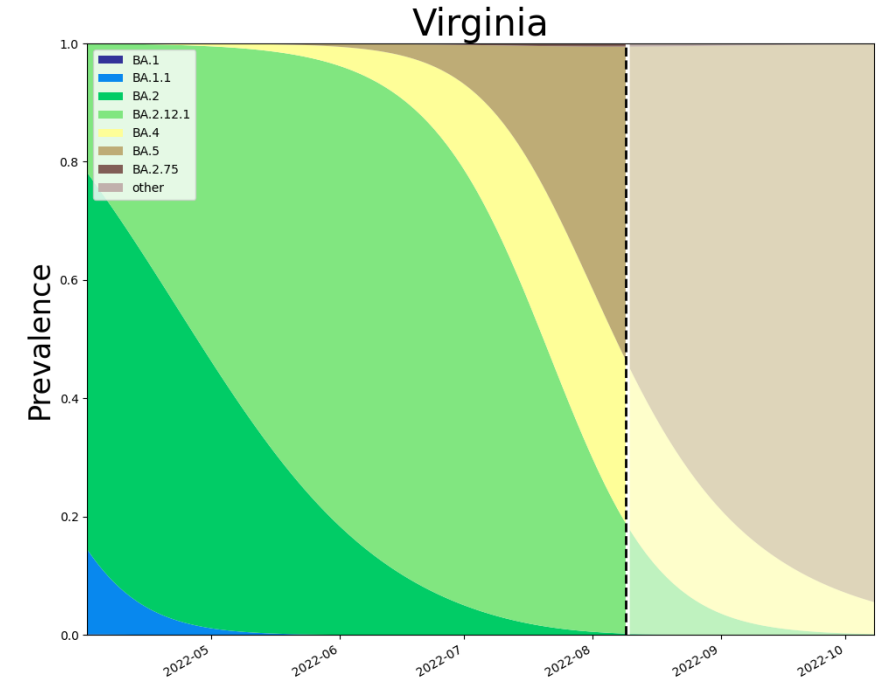
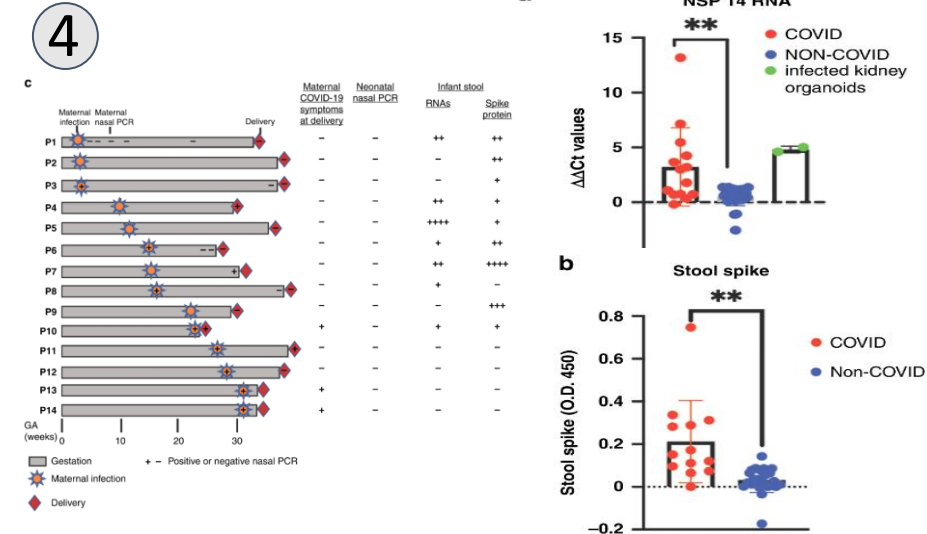Note: Data lags force projections to start in past. Everything from dotted line forward is a projection.

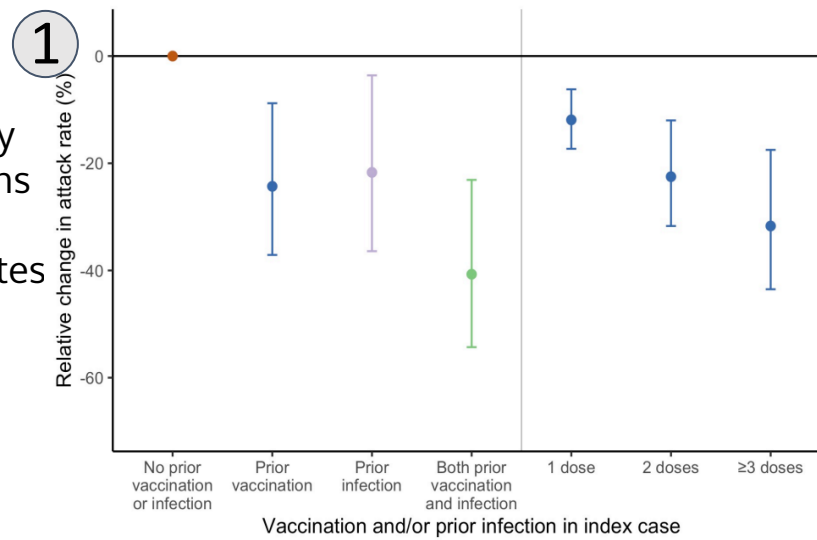**BIOCOMPLEXITY** INSTITUTE

Pandemic Pubs

1. Vaccine-derived and naturally acquired immunity independently reduce the infectiousness of persons with Omicron SARS-CoV-2 infections.

2. Among patients 65 years of age or older, the rates of hospitalization and death due to Covid-19 were significantly lower among those who received Paxlovid than among those who did not.

3. USA: estimated annual cost in lost wages is around $170 billion a year (potentially as high as $230 billion)

4. In utero transmission of SARS-CoV-2 and possible persistent intestinal viral reservoirs in newborns.

Surveillance across 35 California prisons to understand the impact of vaccination and prior infection on infectiousness; 22,334 confirmed SARS-CoV-2 infections and 31 hospitalizations due to COVID-19 in the study population (N=111,687) in a 5-month period (December 15, 2021 - May 23, 2022) from widespread circulation of the Omicron variant. Vaccination, prior infection, and both vaccination and prior infection reduced an index case's risk of transmitting to close contacts by 24% (9-37%), 21% (4-36%) and 41% (23-54%), respectively.
https://www.medrxiv.org/content/10.1101/2022.08.08.22278547v1

Israel: 109,254 patients met the eligibility criteria, of whom 3902 (4%) received Paxlovid during the study period. For patients 65 years of age or older, the rate of hospitalization due to Covid-19 was 14.7 cases per 100,000 person-days among treated patients as compared with 58.9 cases per 100,000 person-days among untreated patients (adjusted hazard ratio, 0.27; 95% confidence interval [CI], 0.15 to 0.49) Among patients 40 to 64 years of age, the rate of hospitalization due to Covid-19 was 15.2 cases per 100,000 person-days among treated patients and 15.8 cases per 100,000 person-days among untreated patients (adjusted hazard ratio, 0.74; 95% CI, 0.35 to 1.58)
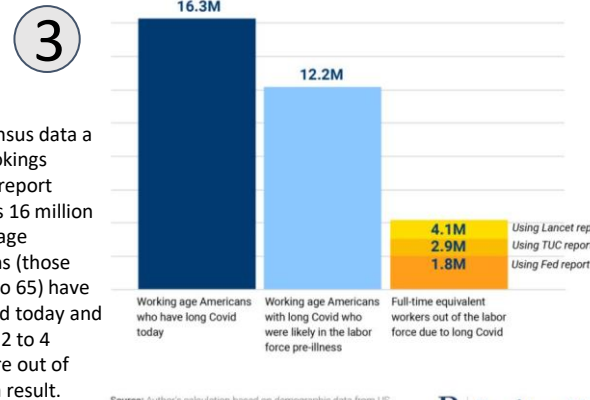https://www.nejm.org/doi/full/10.1056/NEJMoa2204919?query=featured_home

Cornell: A cohort study investigated stool from 14 newborns born at 25–41 weeks admitted at delivery whose mothers had COVID-19 during pregnancy. Eleven mothers had COVID-19 resolved more than 10 weeks before delivery. Newborn stool was evaluated for SARS-CoV-2 RNA, Spike protein, and induction of inflammatory cytokines interleukin-6 (IL-6) and interferon-γ (IFN-γ) in macrophages. Despite negative SARS CoV-2 nasal PCRs from all newborns, viral RNAs and Spike protein were detected in the stool of 11 out of 14 newborns as early as the first day of life and increased over time in 6.
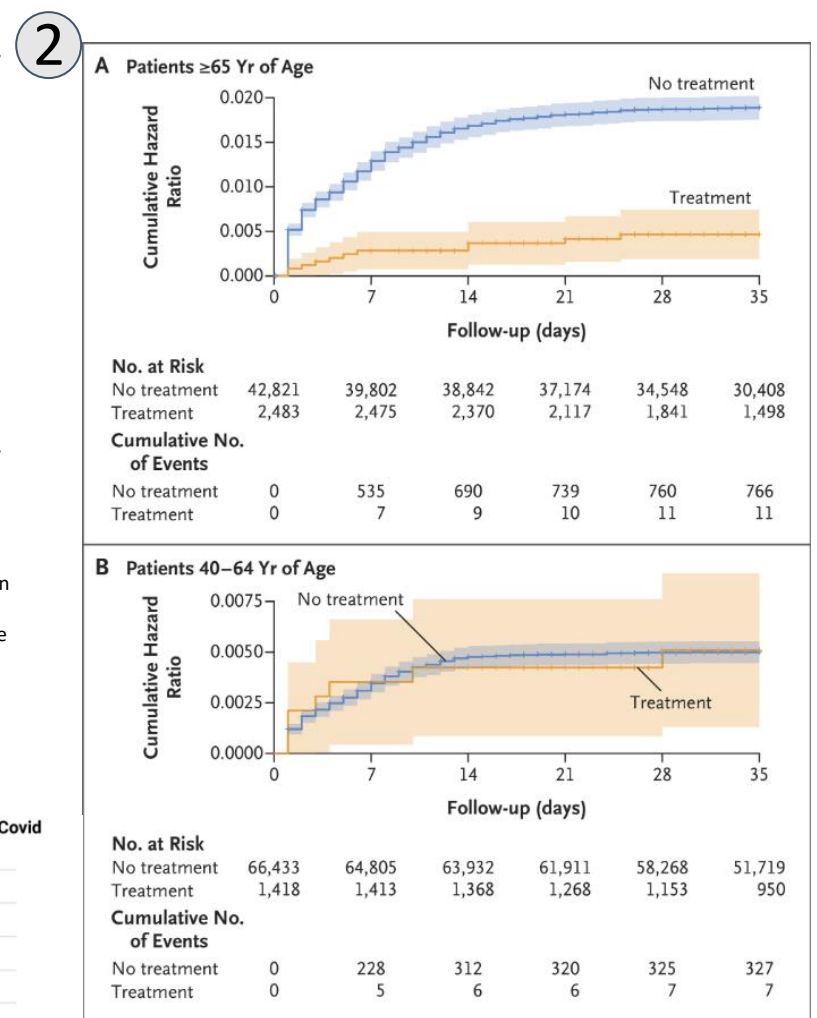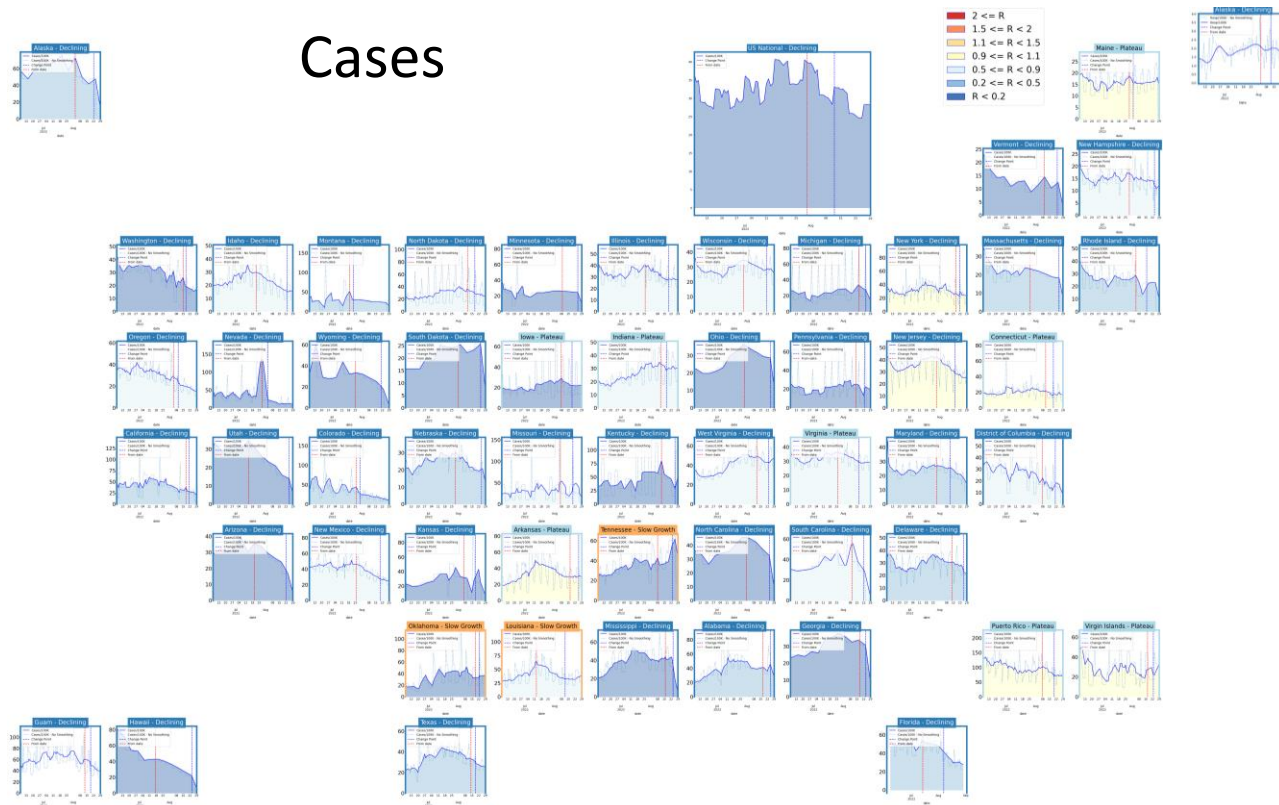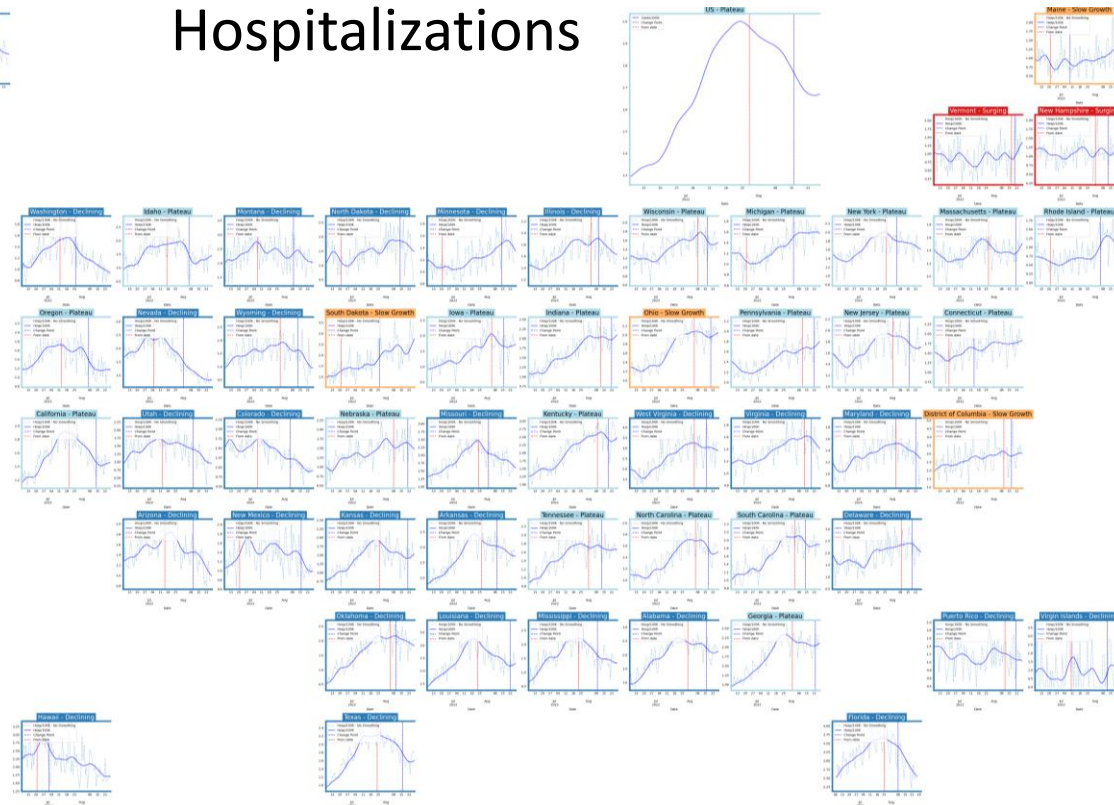https://www.medrxiv.org/content/10.1101/2022.06.14.22276401v1

Using Census data a new Brookings Institute report estimates 16 million working-age Americans (those aged 18 to 65) have long Covid today and of those, 2 to 4 million are out of work as a result.

https://www.brookings.edu/research/new-data-shows-long-covid-is-keeping-as-many-as-4-million-people-out-of-work/

United States Case & Hospitalizations

Cases

Hospitalizations

Status	# States
Declining	43 (53)
Plateau	8 (0)
Slow Growth	3 (1)
In Surge	0 (0)

Status	# States
Declining	28 (22)
Plateau	19 (24)
Slow Growth	4 (6)
In Surge	2 (1)

2-Sep-22

Virginia and Her Neighbors

Cases

Hospitalizations

UNIVERSITY of VIRGINIA

BIOCOMPLEXITY INSTITUTE
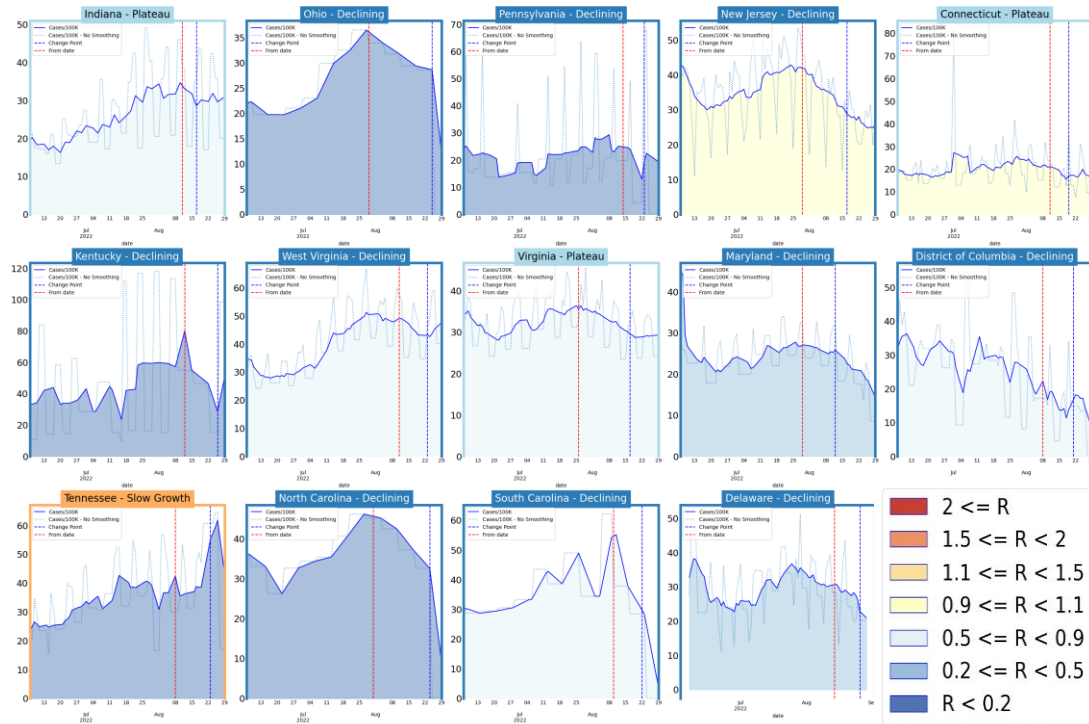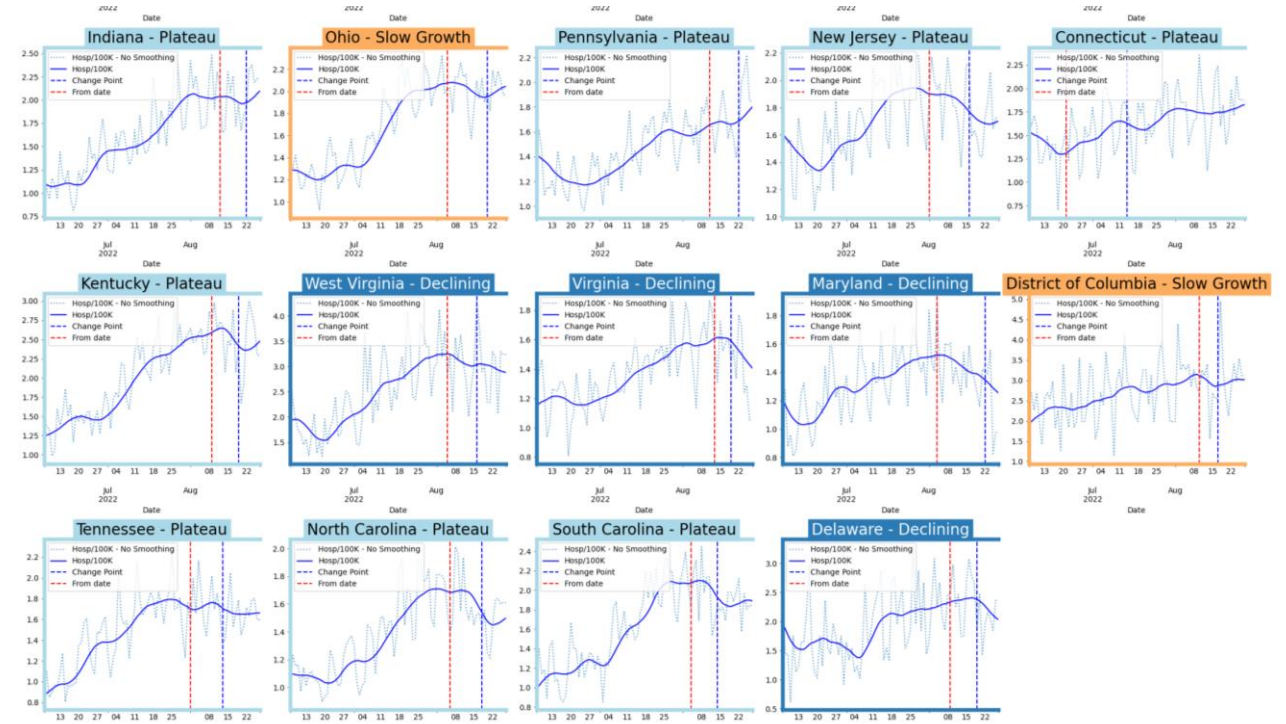
Using Ensemble Model to Guide Projections

Ensemble methodology that combines the Adaptive with machine learning and statistical models such as:

- Autoregressive (AR, ARIMA)

- Neural networks (LSTM)

- Kalman filtering (EnKF)

Weekly forecasts done at county level.

Models chosen because of their track record in disease forecasting and to increase diversity and robustness.

Ensemble forecast provides additional 'surveillance' for making scenario-based projections.

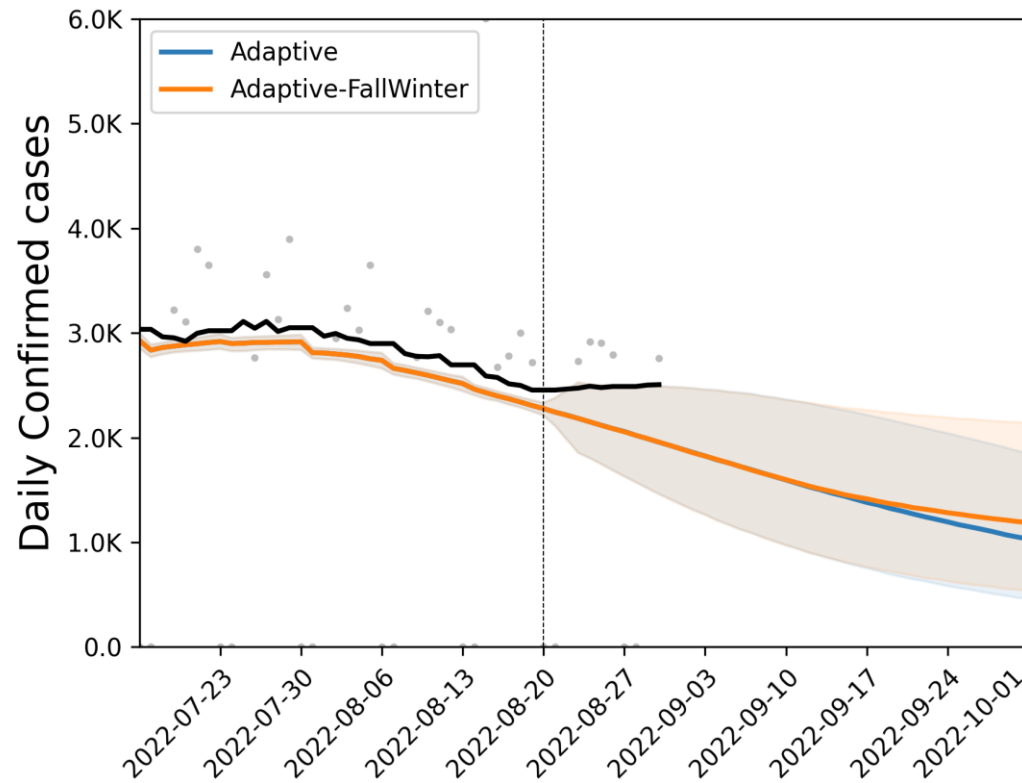Also submitted to CDC Forecast Hub.

UNIVERSITY *of* VIRGINIA

BIOCOMPLEXITY INSTITUTE
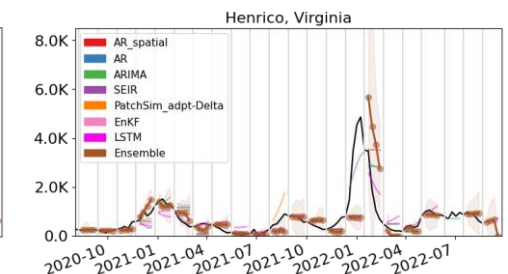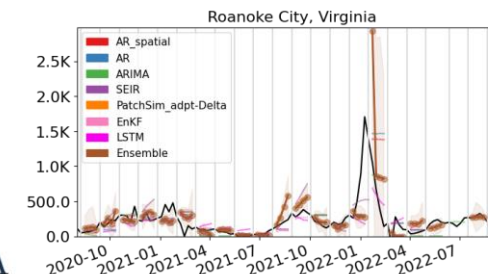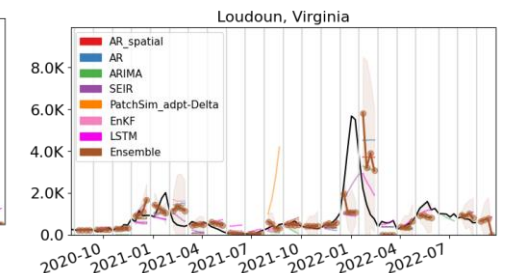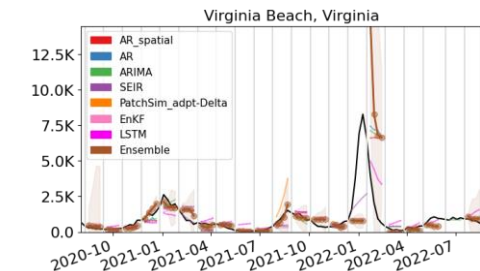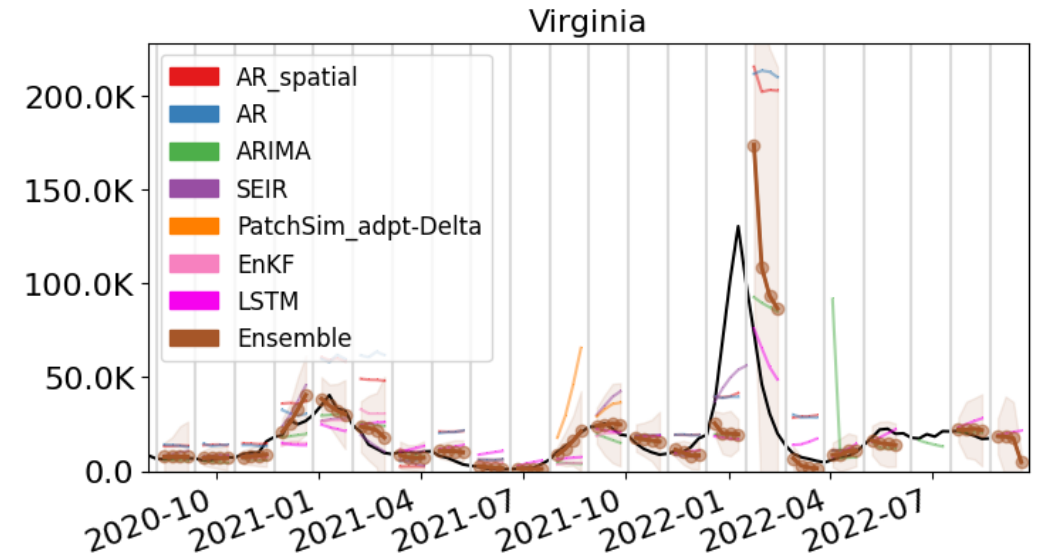
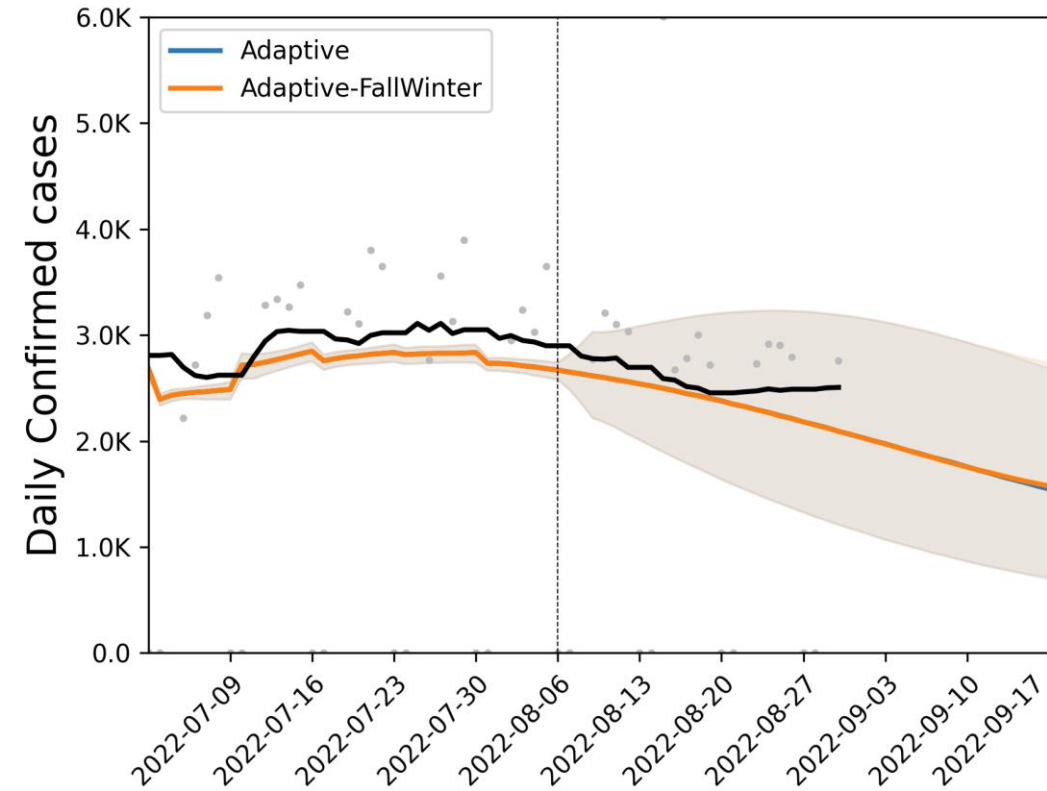# Case projection comparison

Projection from 1 weeks ago

Virginia Daily Confirmed - Comparison 2022-08-20
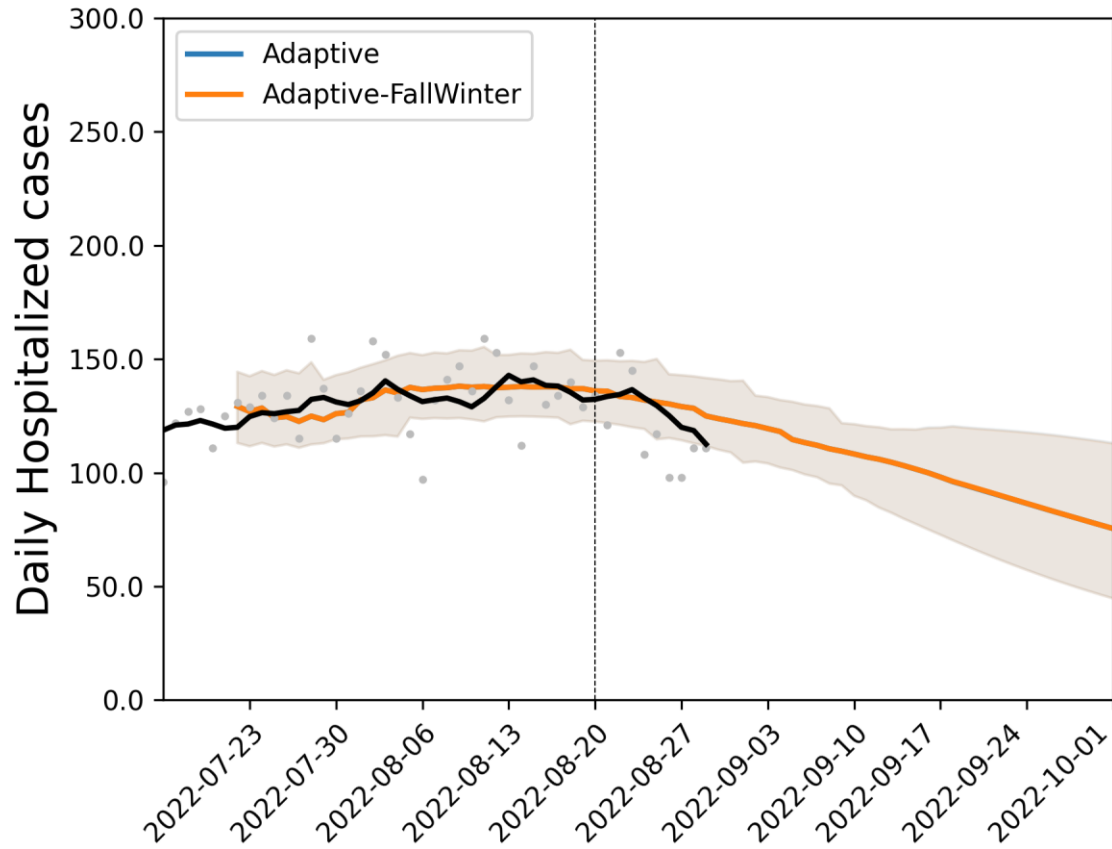

Projection from 3 weeks ago

Virginia Daily Confirmed - Comparison 2022-08-06
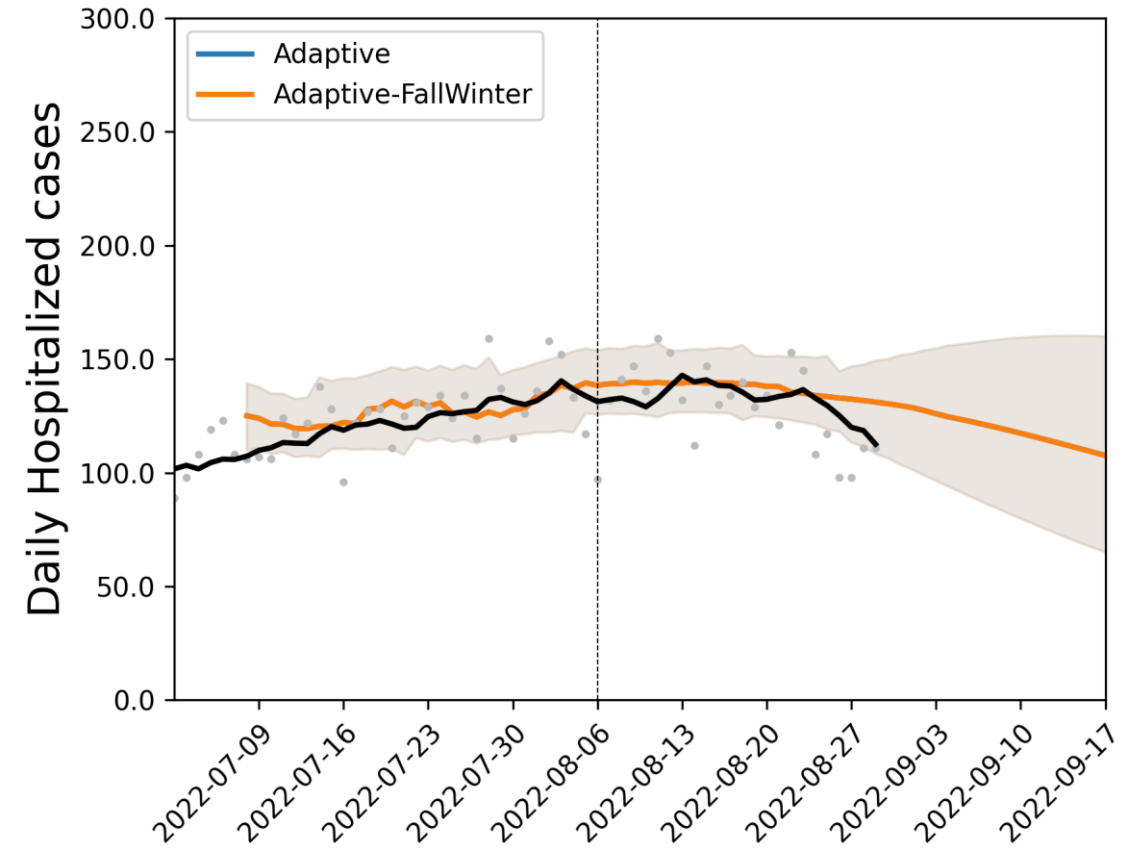
Hospitalization projection comparison

Projection from 1 weeks ago

Virginia Daily Hospitalized - Comparison 2022-08-20

Projection from 3 weeks ago

Virginia Daily Hospitalized - Comparison 2022-08-06

Scenario Modeling Hub – COVID-19 (Rd15), Flu (Rd1)

Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios

- Round 15 results published
  - Scenarios: Test benefits of reformulated fall boosters w/ and w/out a new variant
  - Timing of reformulated boosters is one of the axes

- Flu scenarios currently being generated
  - Impact of missed flu seasons on pre-season immunity
  - Testing different seasonal vaccine coverage and efficacy

https://covid19scenariomodelinghub.org/viz.html

Projected Incident Cases by Epidemiological Week and by Scenario for Round 15 - US
(- Projection Epiweek; -- Current Week)
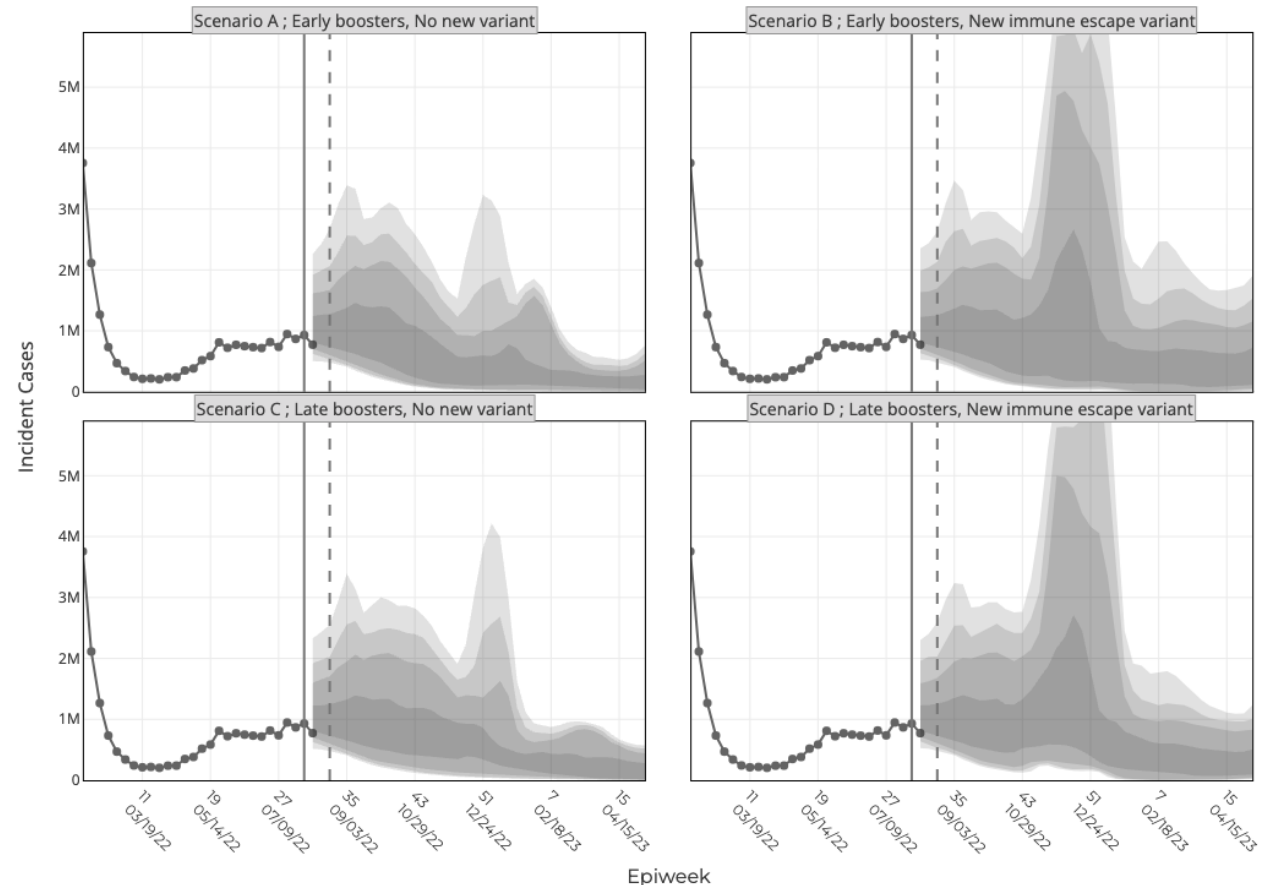
Key Takeaways

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

- **Case rates have remained flat as have hospitalizations**

- VA weekly case rate flat at 206 per 100K from 203 per 100K

    - US weekly case rate is down to 174 per 100K from 189 per 100K

    - VA hospital occupancy (rolling 7 day mean of 791 slightly down from 798 a week ago) currently on month plateau

- Sub-variant prevalence evolution as expected

- Projections from last week remain largely on target

The situation continues to change. Models continue to be updated regularly.

Additional Analyses

UNIVERSITY *of* VIRGINIA

BIOCOMPLEXITY INSTITUTE

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

Virginia Department of Health. COVID-19 in Virginia. http://www.vdh.virginia.gov/coronavirus/

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/

UNIVERSITY *of* VIRGINIA

BIOCOMPLEXITY INSTITUTE

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, Jiangzhuo Chen, Clark Cucinell, Patrick Corbett, Allan Dickerman, Stephen Eubank, Stefan Hoops, Ben Hurt, Ron Kenyon, Brian Klahn, Bryan Lewis, Dustin Machi, Chunhong Mao, Achla Marathe, Madhav Marathe, Henning Mortveit, Mark Orr, Joseph Outten, Akhil Peddireddy, Przemyslaw Porebski, Erin Raymond, Jose Bayoan Santiago Calderon, James Schlitt, Samarth Swarup, Alex Telionis, Srinivasan Venkatramanan, Anil Vullikanti, James Walke, Andrew Warren, Amanda Wilson, Dawen Xie

UNIVERSITY *of* **VIRGINIA**

BIOCOMPLEXITY INSTITUTE