Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

July 6th, 2022

(data current to July 3rd – 5th)

Biocomplexity Institute Technical report: TR BI-2022-1605

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About Us

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response for Influenza, Ebola, Zika, and others

Points of Contact

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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

Key Takeaways

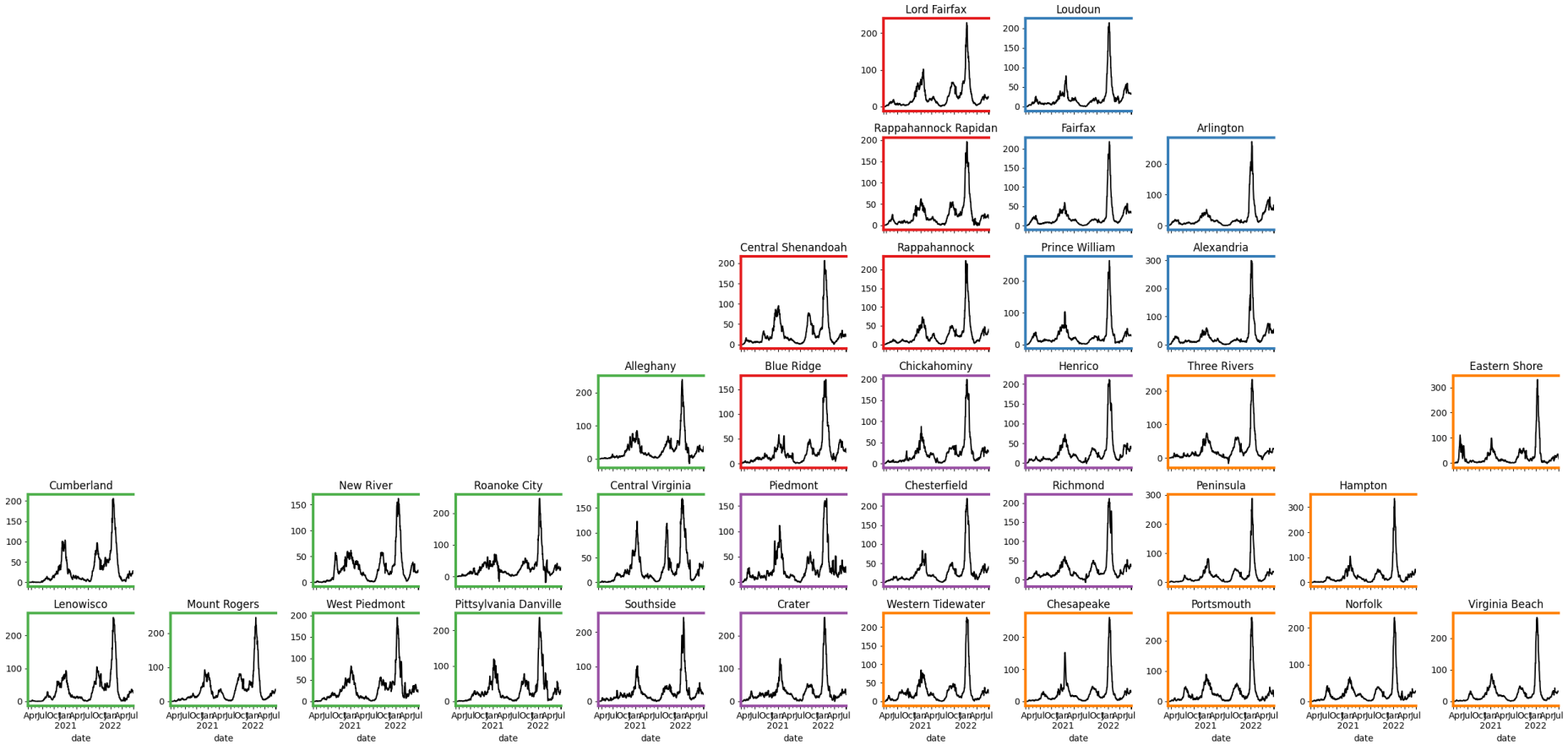
Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

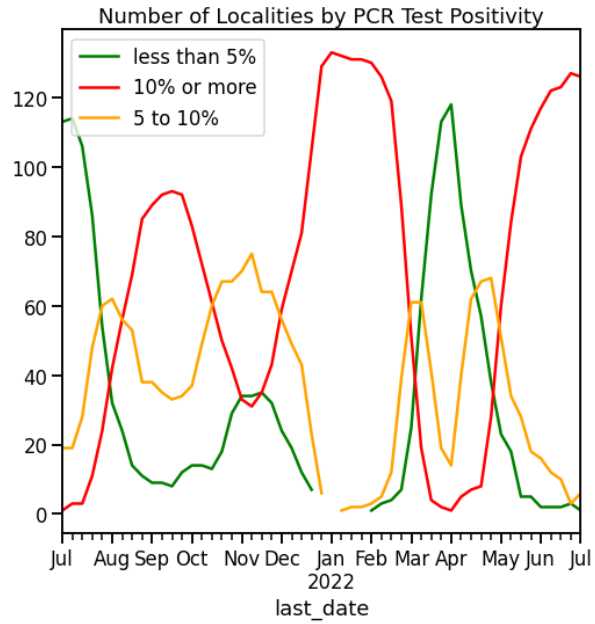
- **Case rates remain high and are slightly up, hospitalizations are climbing more quickly than cases**
- VA weekly case rate slightly up to 221/100K from 215/100K
  - US also slightly down to 218/100K from 233/100K
  - VA hospital occupancy (rolling 7 day mean of 599) continues to rise for past 10 days
- Omicron sub-variants BA.4 and BA.5 continue to grow, crossing 50% combined with BA.5 outpacing BA.4

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

Situation Assessment

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)

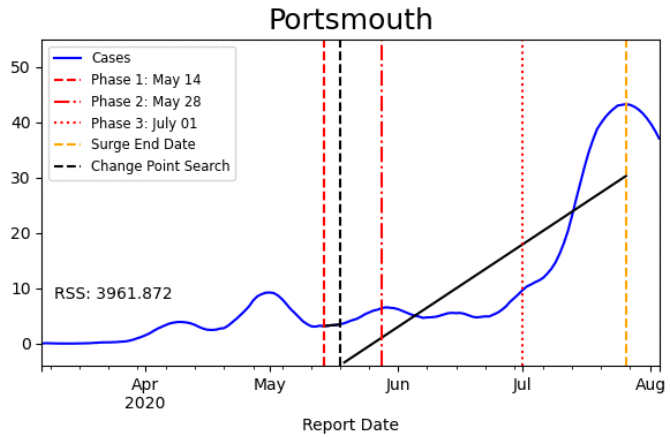
Red: >10.0% (and not "Green" or "Yellow")

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

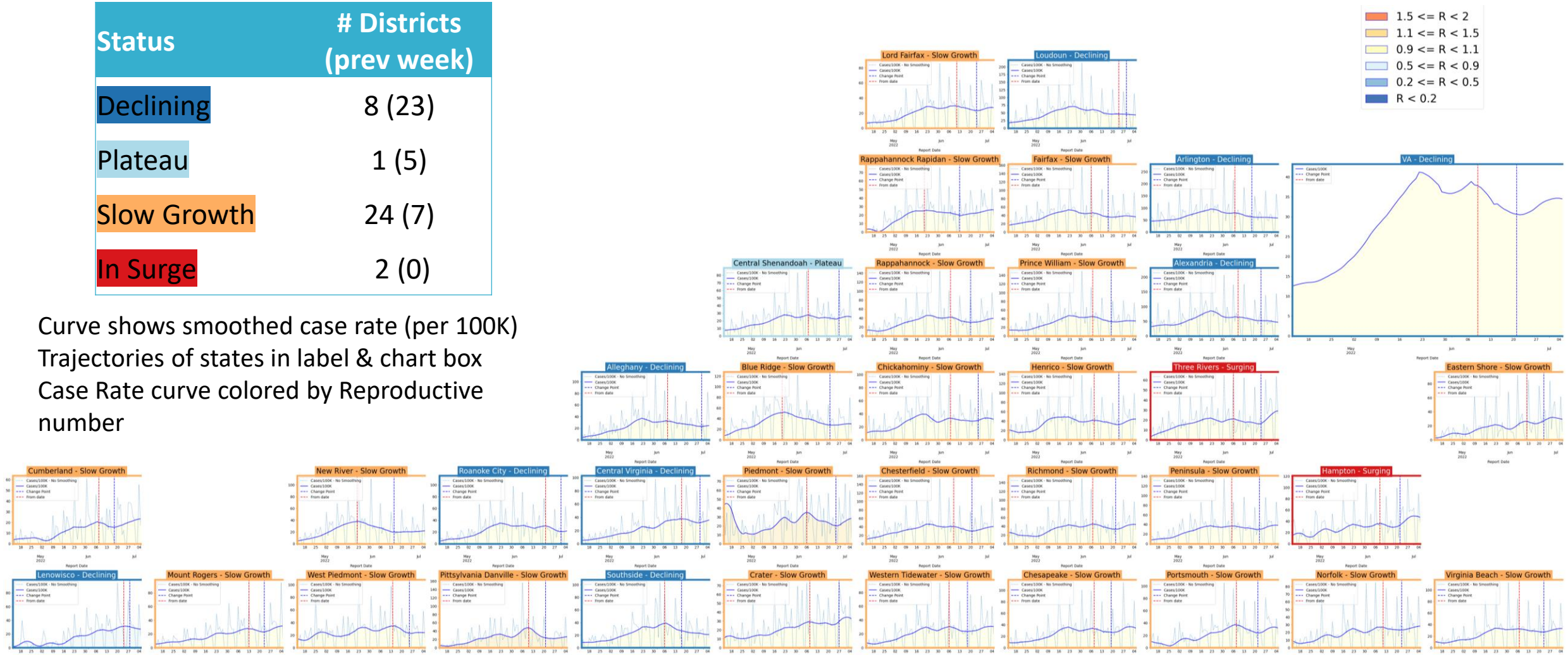


Trajectory	Description	Weekly Case Rate (per 100K) bounds
Declining	Sustained decreases following a recent peak	below -0.9
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater

District Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	8 (23)
Plateau	1 (5)
Slow Growth	24 (7)
In Surge	2 (0)

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



CDC's new COVID-19 Community Levels

What Prevention Steps Should You Take Based on Your COVID-19 Community Level?

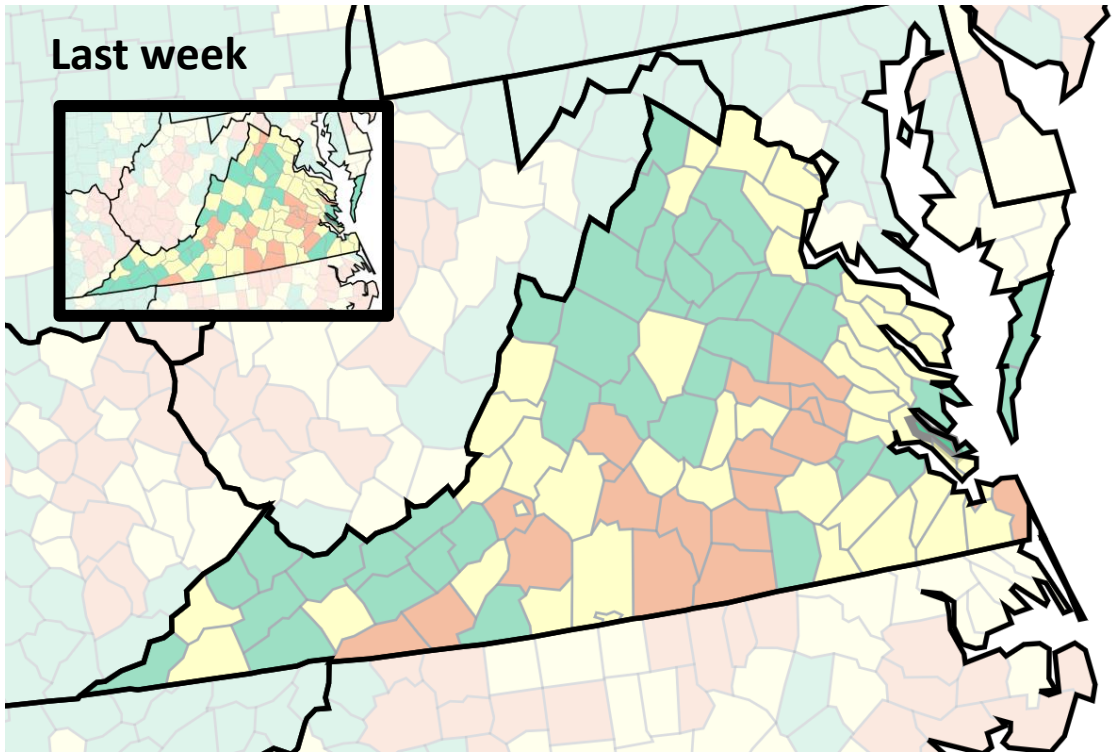
Low	Medium	High
• Stay up to date with COVID-19 vaccines • Get tested if you have symptoms	• If you are at high risk for severe illness, talk to your healthcare provider about whether you need to wear a mask and take other precautions • Stay up to date with COVID-19 vaccines • Get tested if you have symptoms	• Wear a mask indoors in public • Stay up to date with COVID-19 vaccines • Get tested if you have symptoms • Additional precautions may be needed for people at high risk for severe illness

People may choose to mask at any time. People with symptoms, a positive test, or exposure to someone with COVID-19 should wear a mask.

COVID-19 Community Levels – Use the Highest Level that Applies to Your Community

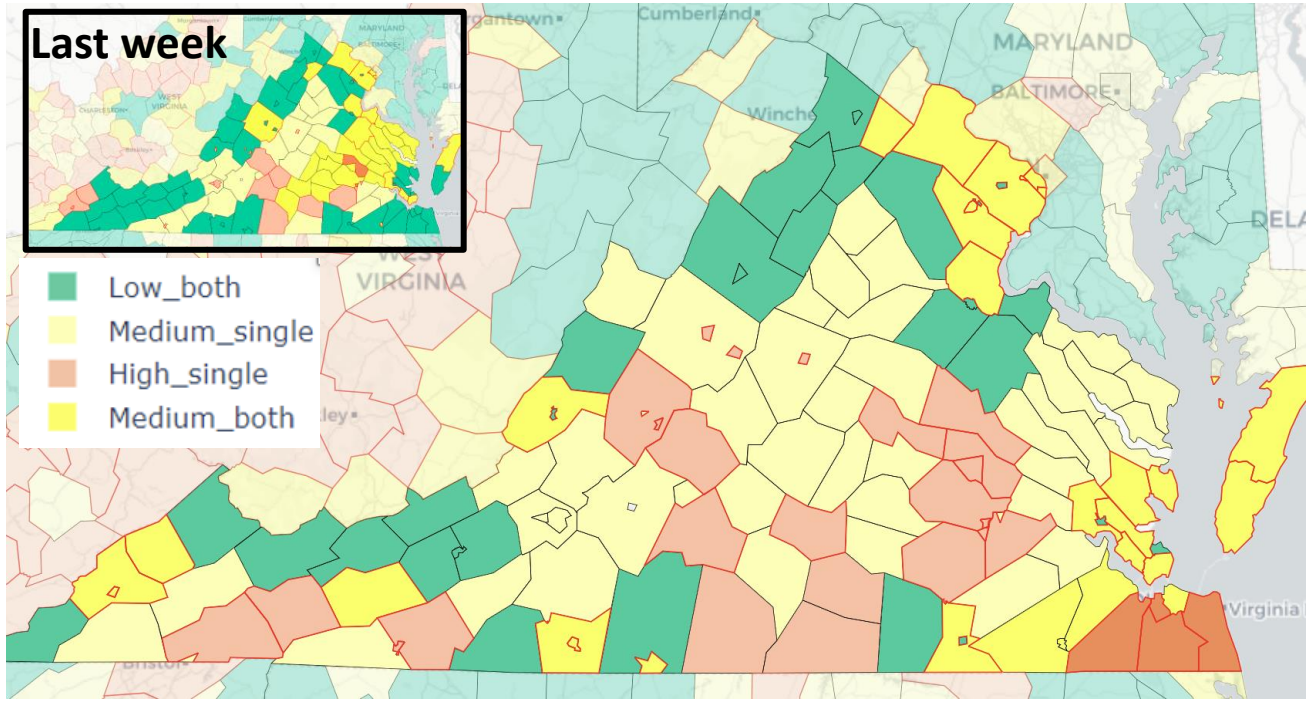
New COVID-19 Cases Per 100,000 people in the past 7 days	Indicators	Low	Medium	High
Fewer than 200	New COVID-19 admissions per 100,000 population (7-day total)	<10.0	10.0-19.9	≥20.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	<10.0%	10.0-14.9%	≥15.0%
200 or more	New 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%

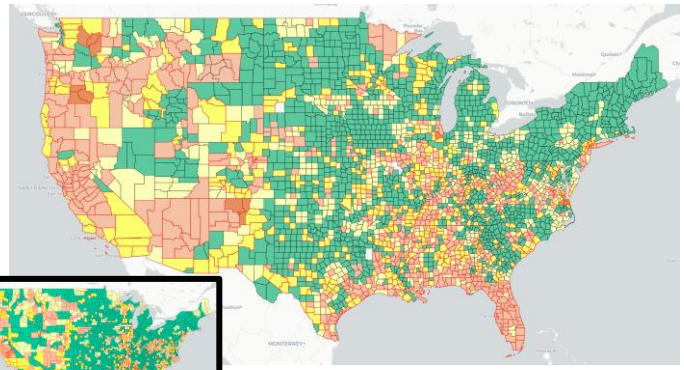
The COVID-19 community level is determined by the higher of the new admissions and inpatient beds metrics, based on the current level of new cases per 100,000 population in the past 7 days

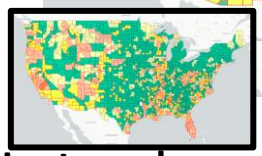


[CDC Data Tracker Portal]

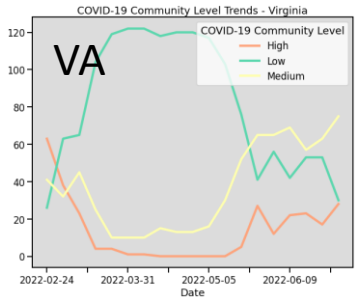
CDC's new COVID-19 Community Levels

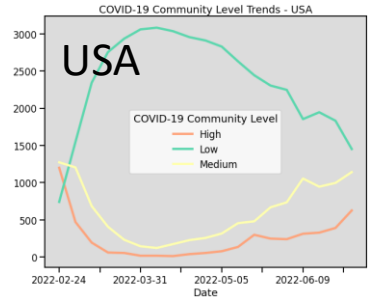






Last week





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
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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

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Data from: CDC Data Tracker Portal

District Trajectories with Community Levels

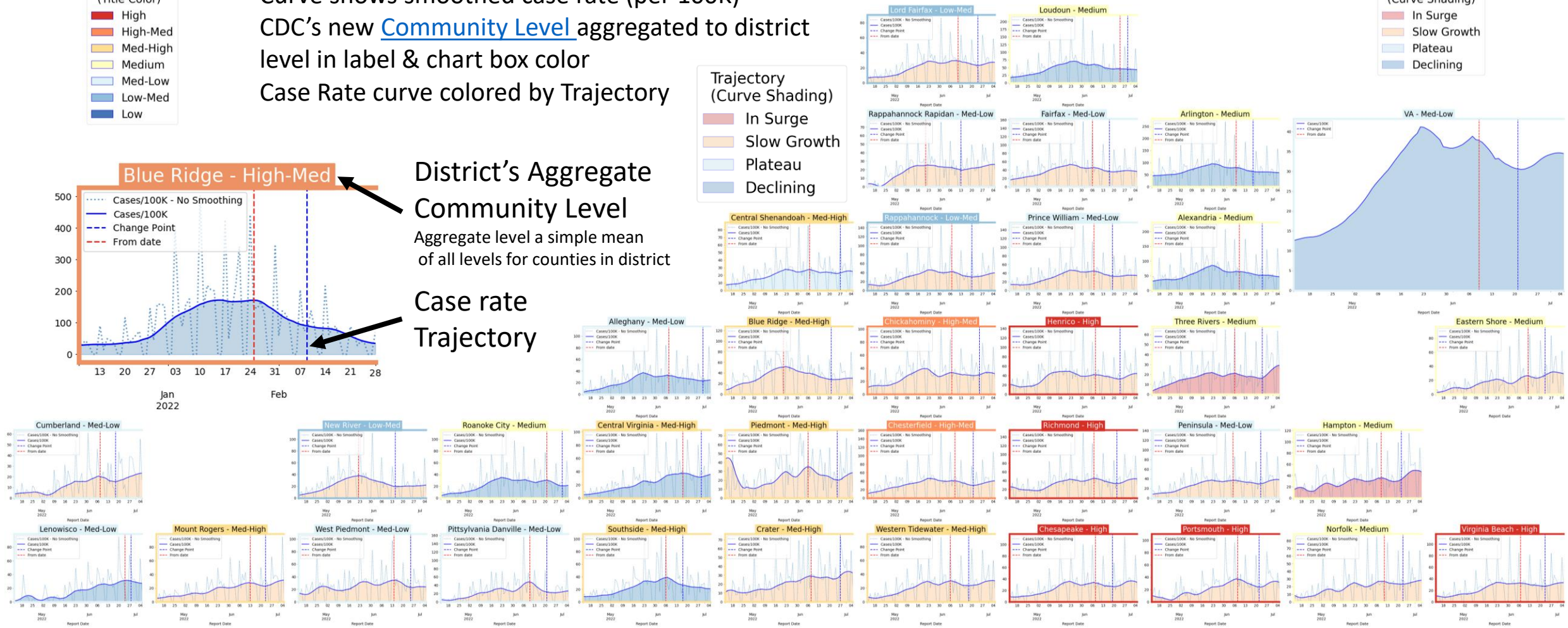
Community Level (Title Color)
- High
- High-Med
- Med-High
- Medium
- Med-Low
- Low-Med
- Low

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

Trajectory (Curve Shading)
- In Surge
- Slow Growth
- Plateau
- Declining

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

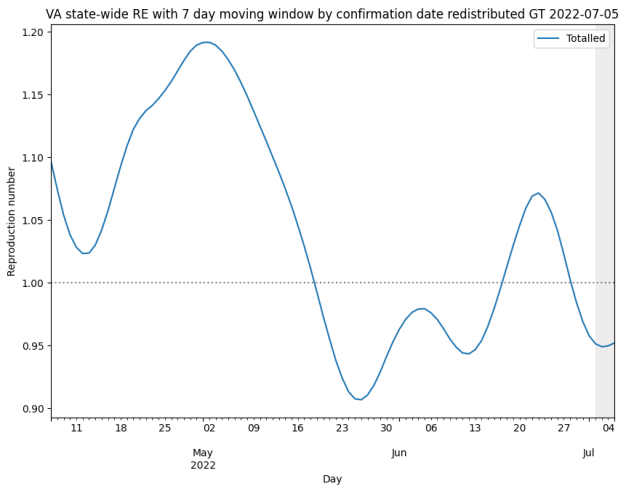
Case rate Trajectory

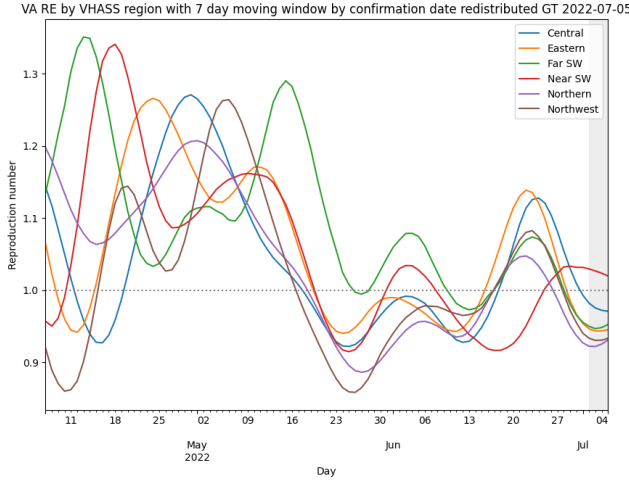


Estimating Daily Reproductive Number – Redistributed gap

July 5th Estimates

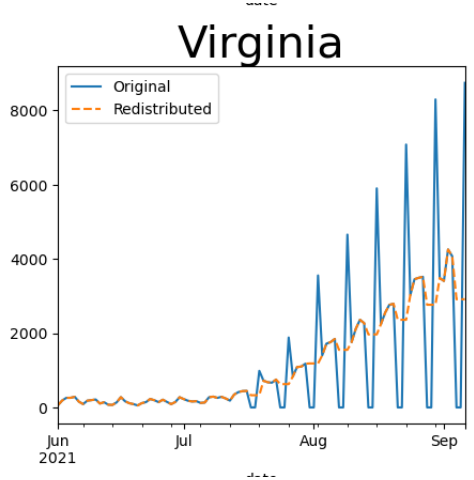
Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	0.952	-0.044
Central	0.971	-0.037
Eastern	0.945	-0.121
Far SW	0.953	-0.002
Near SW	1.020	0.182
Northern	0.931	-0.069
Northwest	0.933	-0.016





Skipping Weekend Reports & holidays biases estimates

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



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

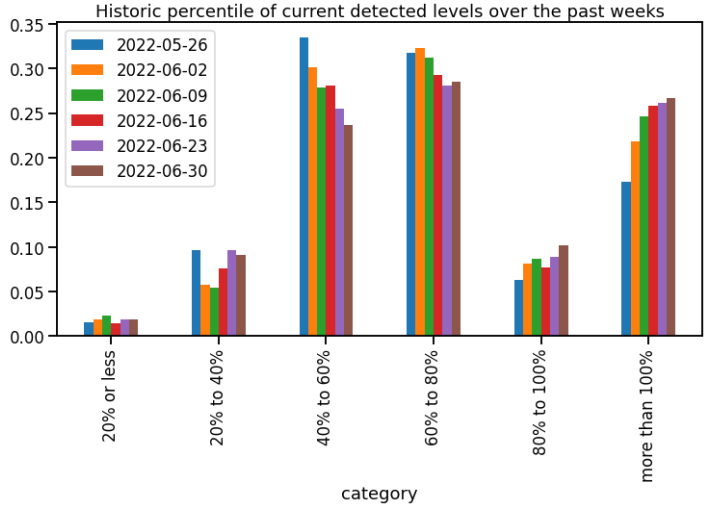
1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Wastewater Monitoring

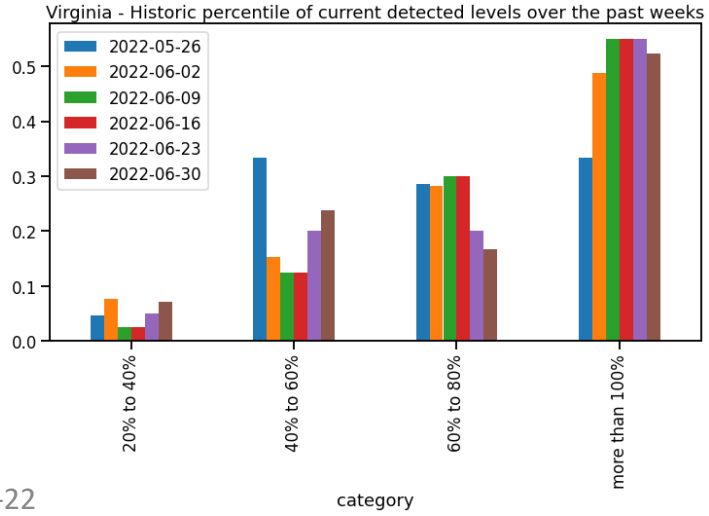
Wastewater provides a coarse early warning of COVID-19 levels in communities

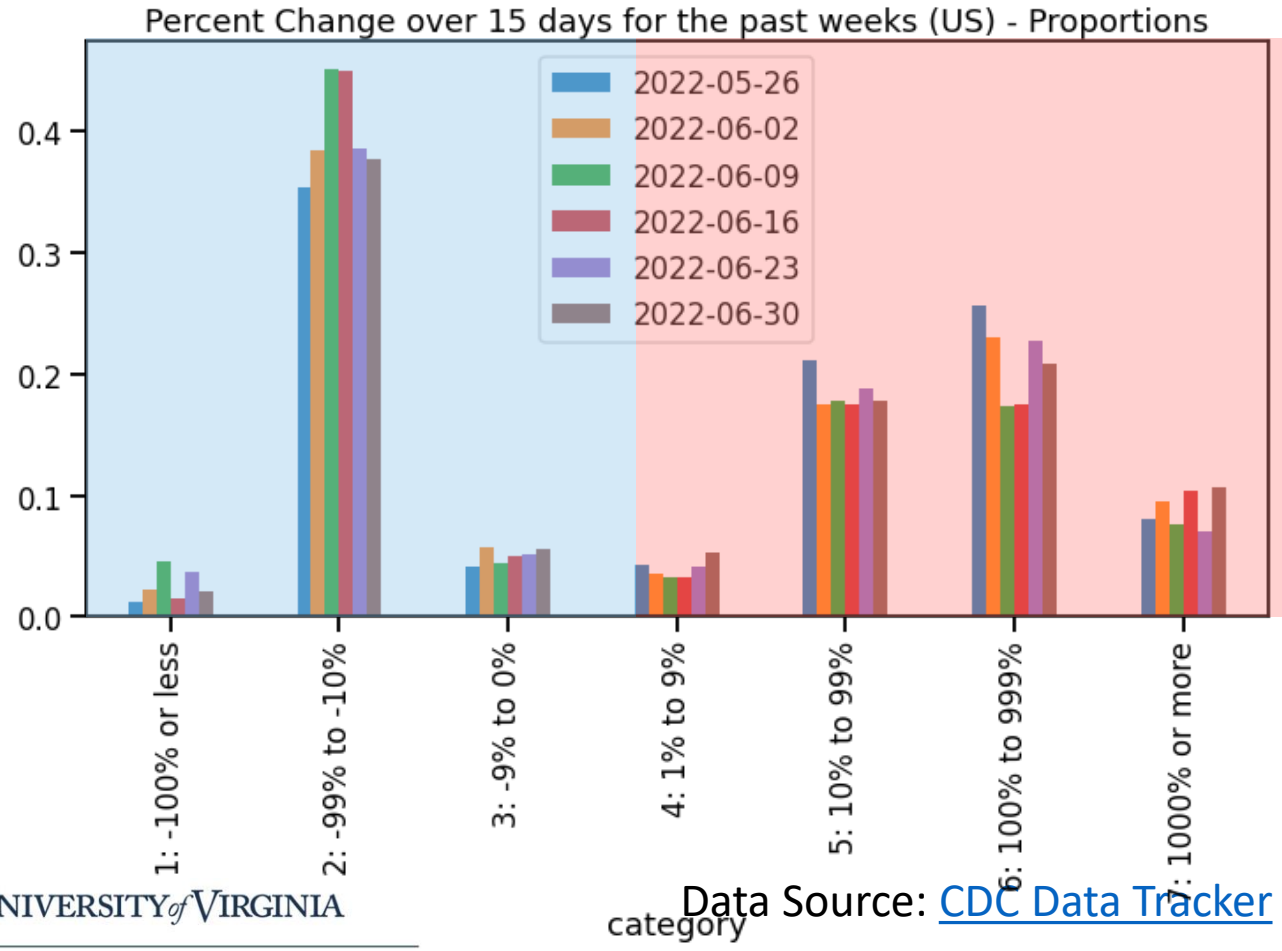
- Overall in the US, there is an increase in sites with increased levels of virus compared to 15 days ago
- Current virus levels are at or exceeding max of previous historical levels, has slowed, though more sites are entering upper quintiles

USA



VA



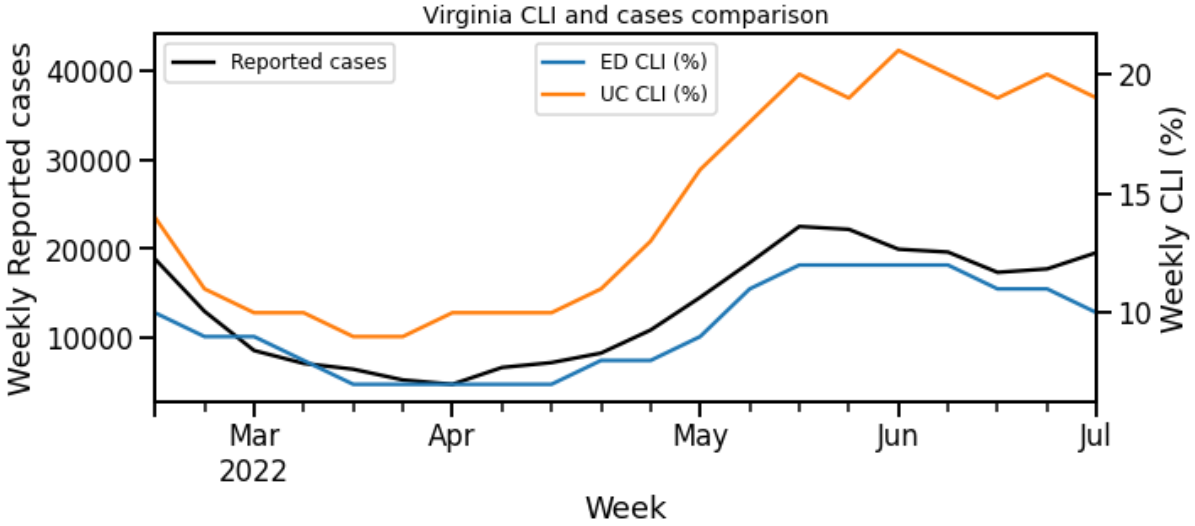


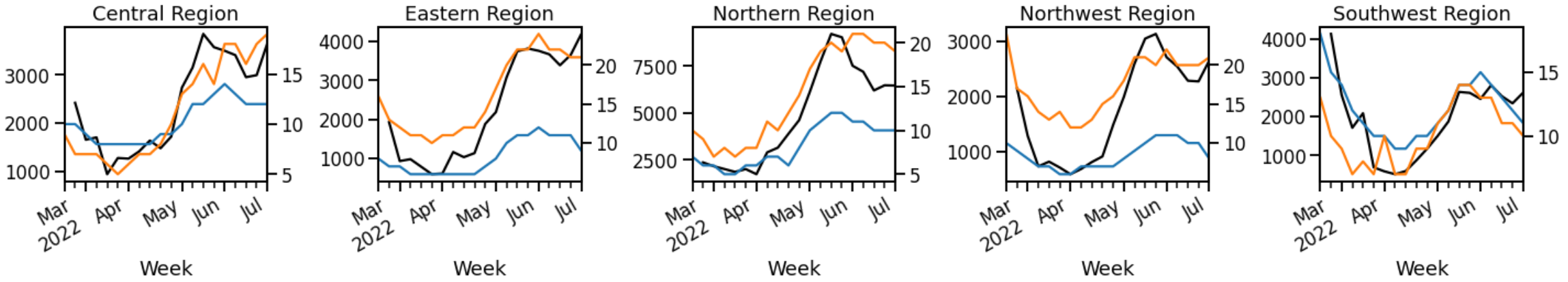
Data Source: [CDC Data Tracker]

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 for last four weeks state-wide, mixed by region**





SARS-CoV2 Variants of Concern

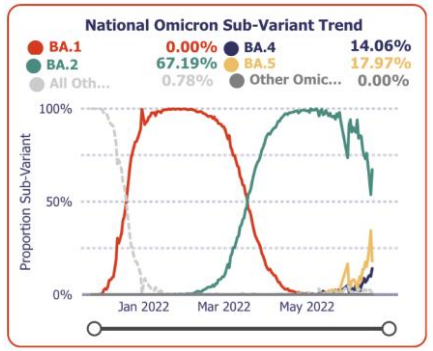
GISAID outbreak.info

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

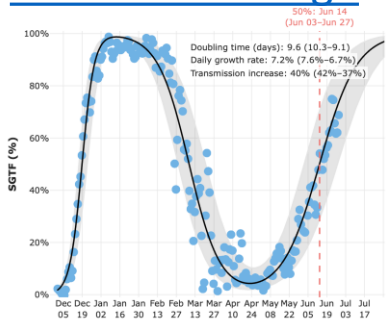
Omicron Updates

- BA.2.12.1 growth has started to decline, shrinking to 40% after 5 weeks in the the 65%-75% prevalence range (Region 3)
- BA.4 growing, nowcasted at 18% (up from 17% last week)
- BA.5 also growing rapidly, nowcasted at 41% (up from 25% last week)
- BA.4 and BA.5 have same mutation as BA.1 that produces S-gene target failure, so can be tracked in more real time with SGTF from some PCR tests

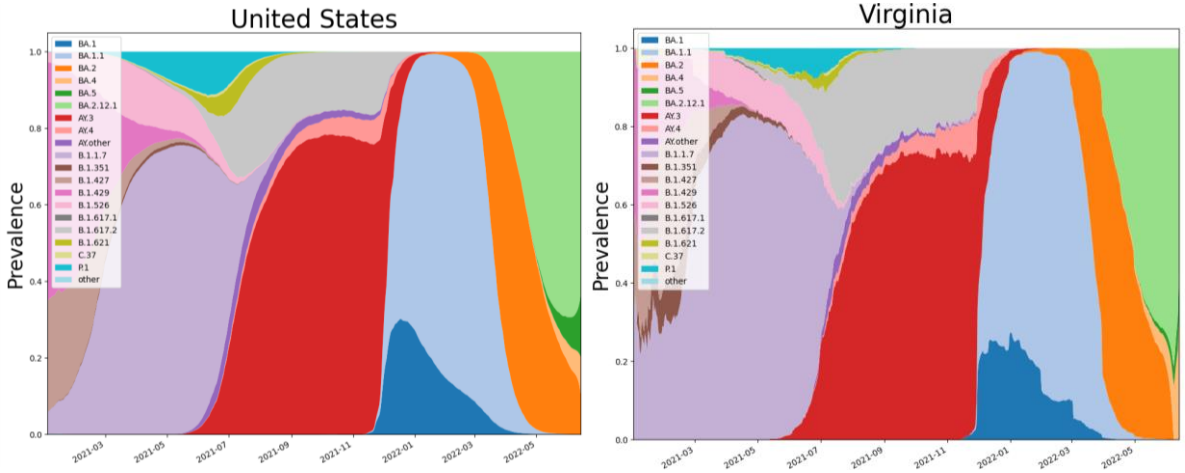


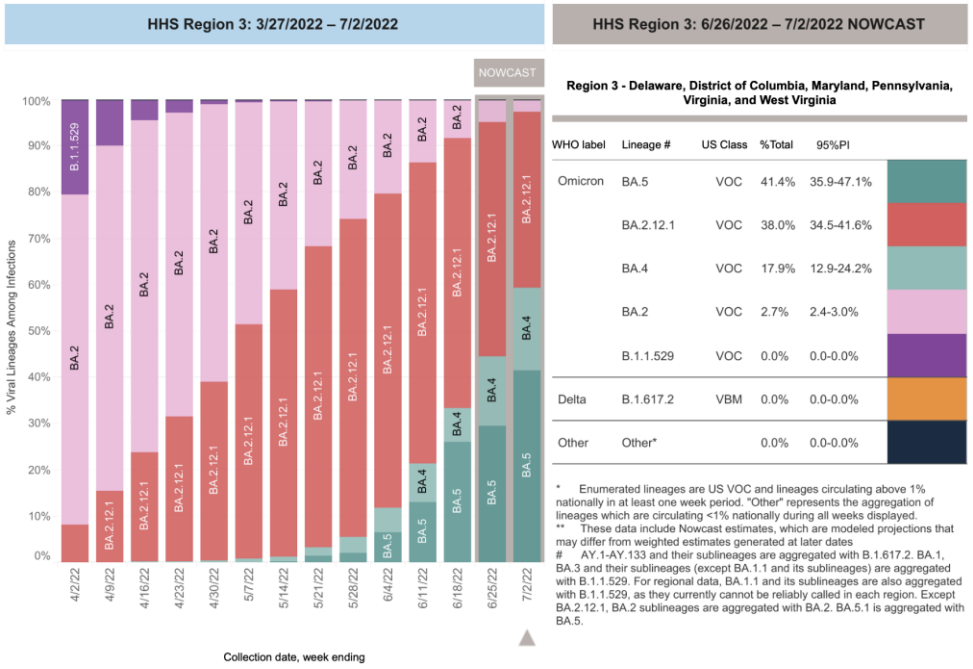
[Walgreens](#) based on sequencing and thus lags by 2 weeks now National 31% BA.4/5

[SGTF in San Diego](#)



Currently estimated to be over 80% in San Diego

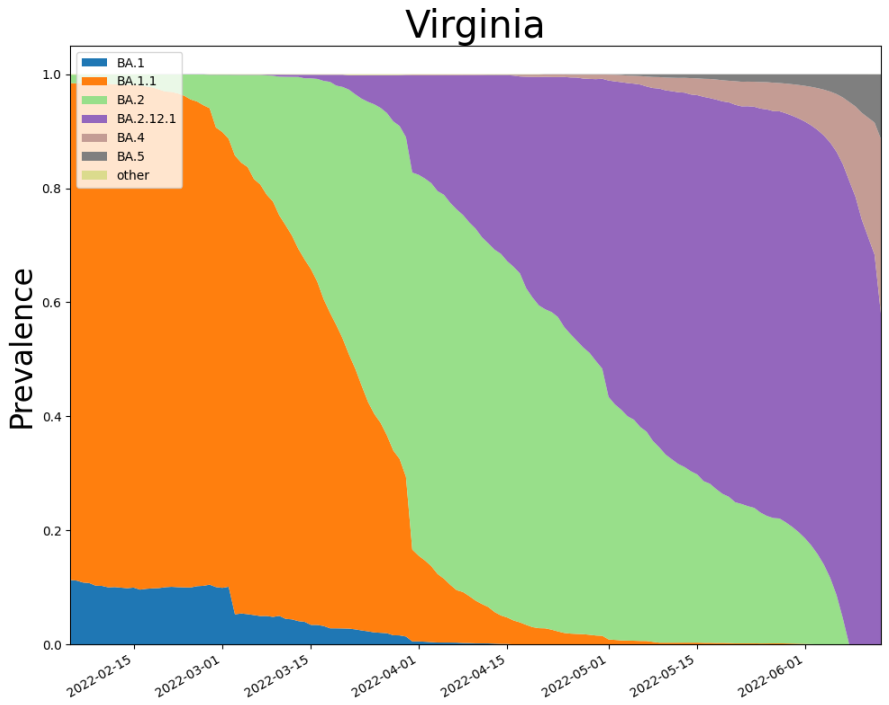


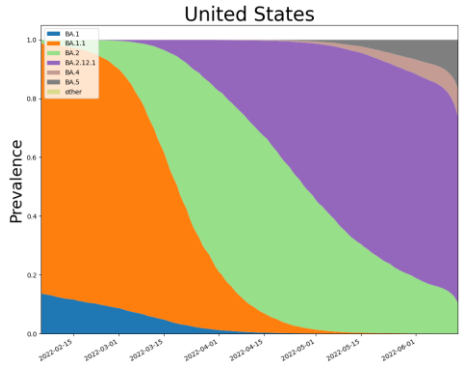


CDC [CDC Variant Tracking](#)

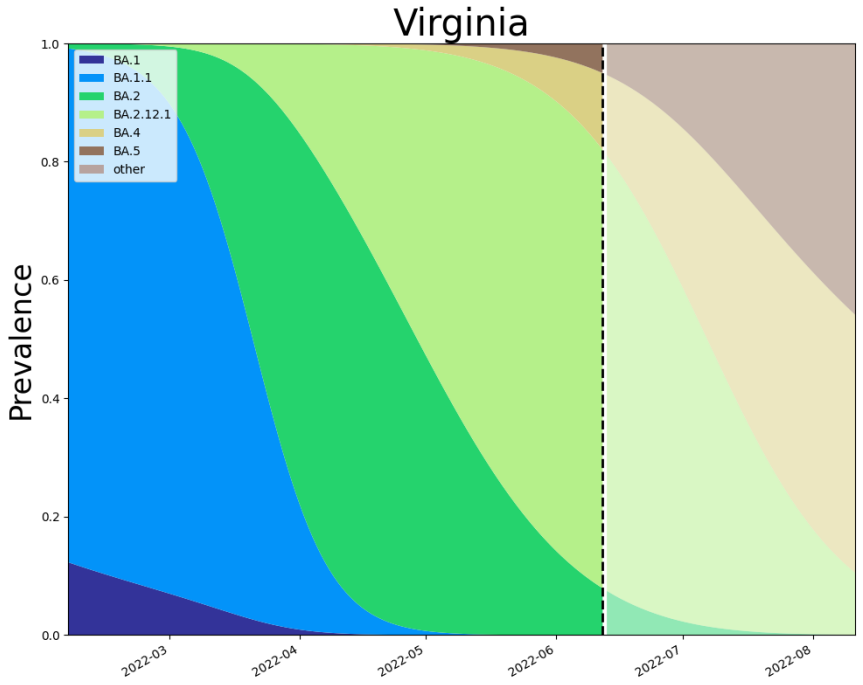
SARS-CoV2 Omicron and Sub-Variants

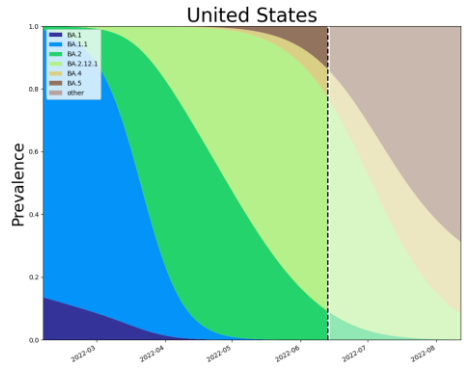
As detected in whole Genomes in public repositories





VoC Polynomial Fit Projections





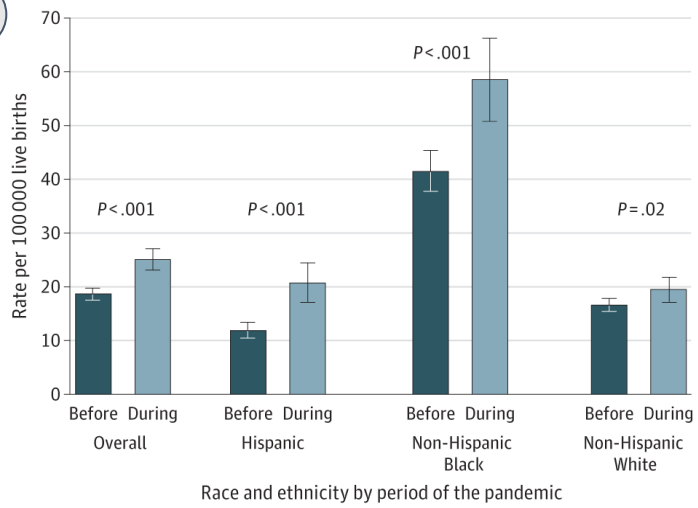
Note: Data lags force projections to start in past. Everything from dotted line forward is a projection.

GISAID outbreak.info

Pandemic Pubs (last week)

1. The National Center for Health Statistics (NCHS) reported an 18.4% increase in US maternal mortality.
2. UK analysis suggests wastewater analysis can be a cost effective early indicator of increasing case count.
3. New study from Denmark indicates people who tested positive had a 3.5 times increased risk of being diagnosed with Alzheimer's disease, 2.6 times with Parkinson's disease, 2.7 times with ischaemic stroke and a 4.8 times increased with intracerebral haemorrhage
4. UKHSA technical update highlights growth advantage of BA.5 due to immune escape. Increase in hospitalizations being monitored.
5. Constellation of symptoms 6 months after infection in young adults is suggestive of a higher risk of developing metabolic disorders and possible cardiovascular complications

1



Maternal mortality rates and percentages with a secondary COVID-19 code were compared by timing, race and ethnicity, and underlying cause. Between 2019 and 2020 death during pregnancy or within 42 days of pregnancy relative increase was 44.4% among Hispanic, 25.7% among non-Hispanic Black, and 6.1% among non-Hispanic White women.
https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2793640

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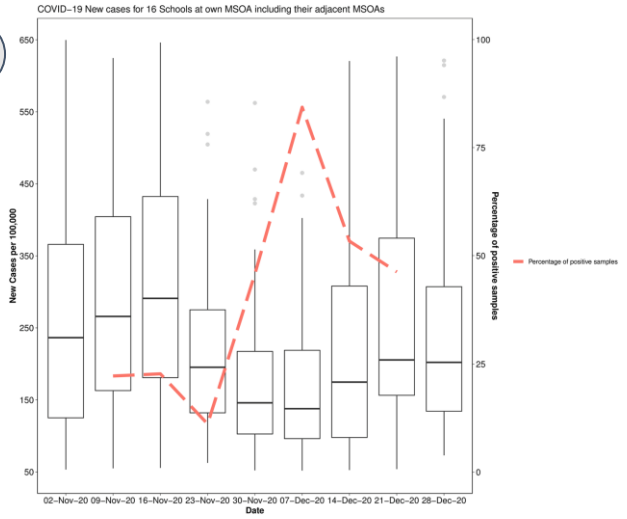

As part of a government-funded epidemiological surveillance pilot program, a wastewater-based epidemiology approach was used to monitor the occurrence of SARS-CoV-2 in Sixteen schools (10 primary, 5 secondary and 1 post-16 and further education for a total of 17 sites) in England. A lead/lag analysis was performed between the weekly positivity rates in schools and community cases to identify the maximum correlation between school and community timeseries using the Pearson's correlation coefficient. This analysis shows a maximum correlation between the two-time series when school data are shifted two weeks into the future (Pearson's correlation coefficient 0.33, p<0.01) Suggesting that the signal in school wastewater precedes the increase in the number of cases in the community.
https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0270168

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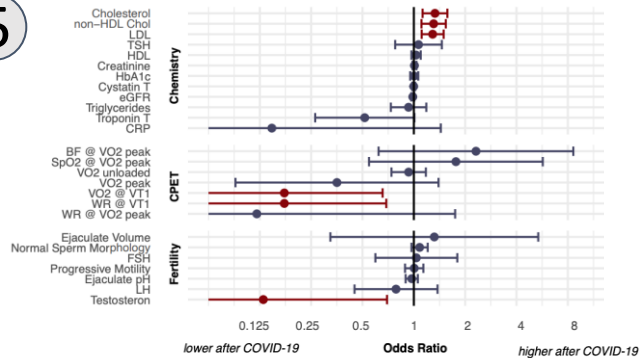

Swiss study 501 participants (5.6% females) with a median age of 21 years (range 19-29). Cases of previous COVID - 19 (>6 months (mean 10 months) since diagnosis, n=177) were compared with never infected controls (n=248). Even mild infections in young adults can lead to sequelae that persist several months post infection with significantly more fatigue, hyposomia, poorer psychological scores and a short-term, negative impact on male fertility. Other symptoms include higher body mass index, dyslipidemia and lower physical endurance 6 months post COVID-19
https://www.medrxiv.org/content/10.1101/2022.02.11.22270836v1

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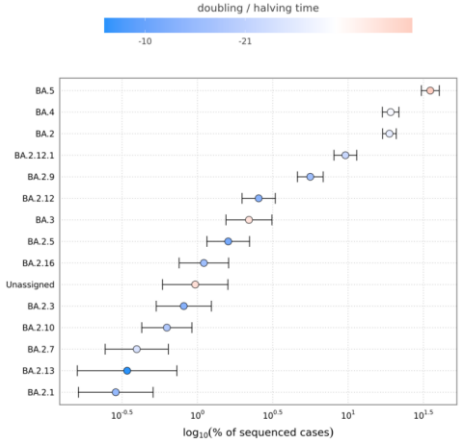

"Laboratory data from Genotype2Phenotype (G2P) Consortium (unpublished) and others suggest that there is a minimal change in fusogenicity of the spike of BA.4 and BA.5 (compared to other Omicron variants), and that the entry route is similar to that of BA.1 and BA.2. **Other data from G2P (cited when available) shows some changes in the interaction with the human host cell by BA.4 and BA.5 virus compared with earlier Omicron variants that could be associated with increased fitness. Neutralisation data has been described previously. Taken together the laboratory data suggest small changes in antigenicity and potentially small increases in fitness may both contribute to the observed growth advantage.**"
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1086494/Technical-Briefing-43-28.06.22.pdf

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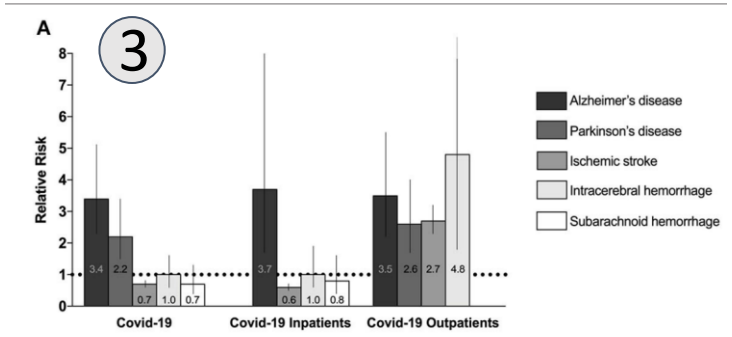


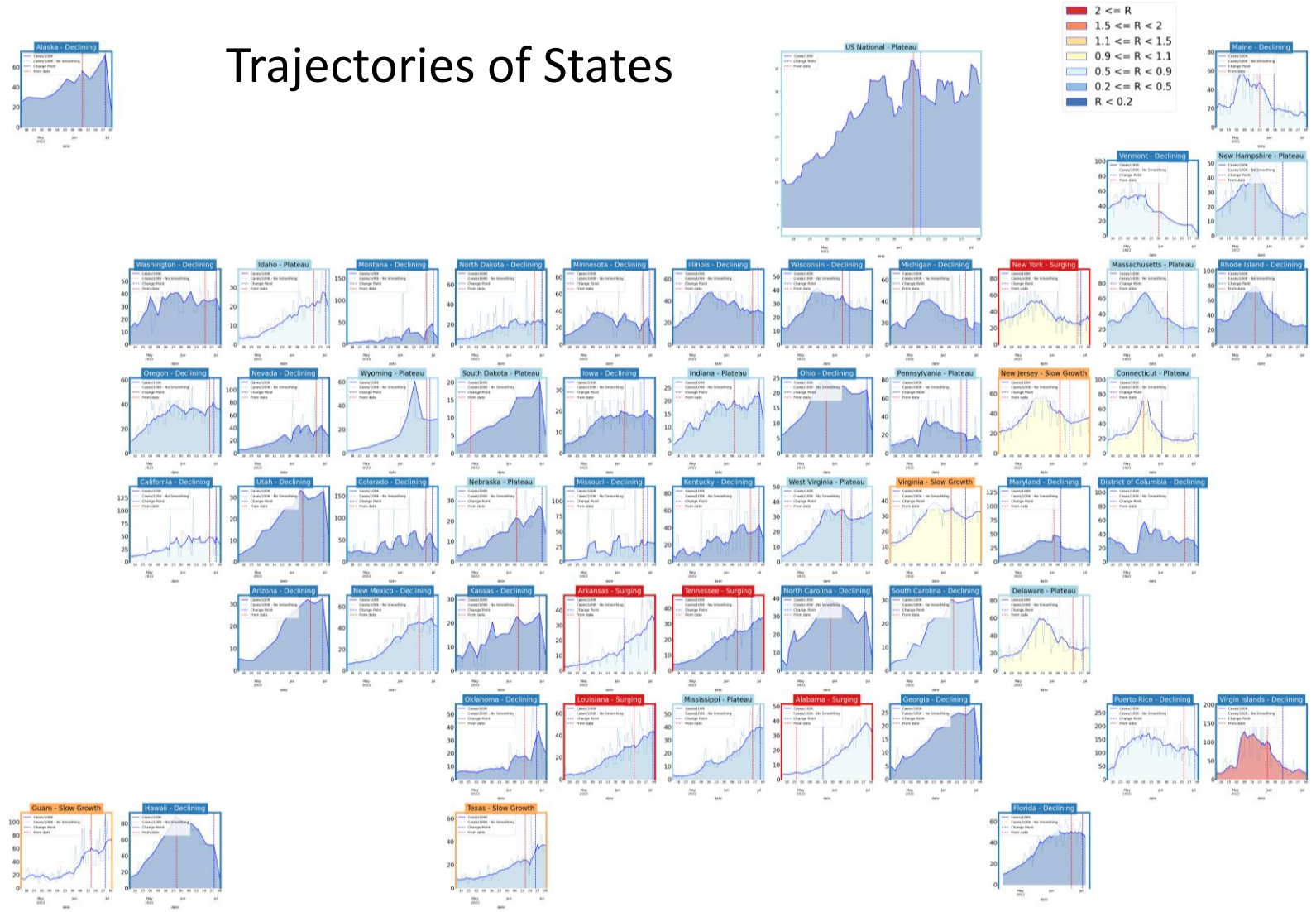
A new study which analysed the health records of more than half of the Danish population, found that those who had tested positive for COVID-19 were at an increased risk of Alzheimer's disease, Parkinson's disease, and ischaemic stroke. **Out of the 919,731 individuals that tested for COVID-19 within the study, researchers found that the 43,375 people who tested positive had a 3.5 times increased risk of being diagnosed with Alzheimer's disease, 2.6 times with Parkinson's disease, 2.7 times with ischaemic stroke and a 4.8 times increased with intracerebral haemorrhage.**
https://www.frontiersin.org/articles/10.3389/fneur.2022.904796/full

United States Case Rates

- Rebounding activity, mainly in the Northeast

Status	# States
Declining	33 (38)
Plateau	12 (12)
Slow Growth	4 (5)
In Surge	5 (6)

Trajectories of States



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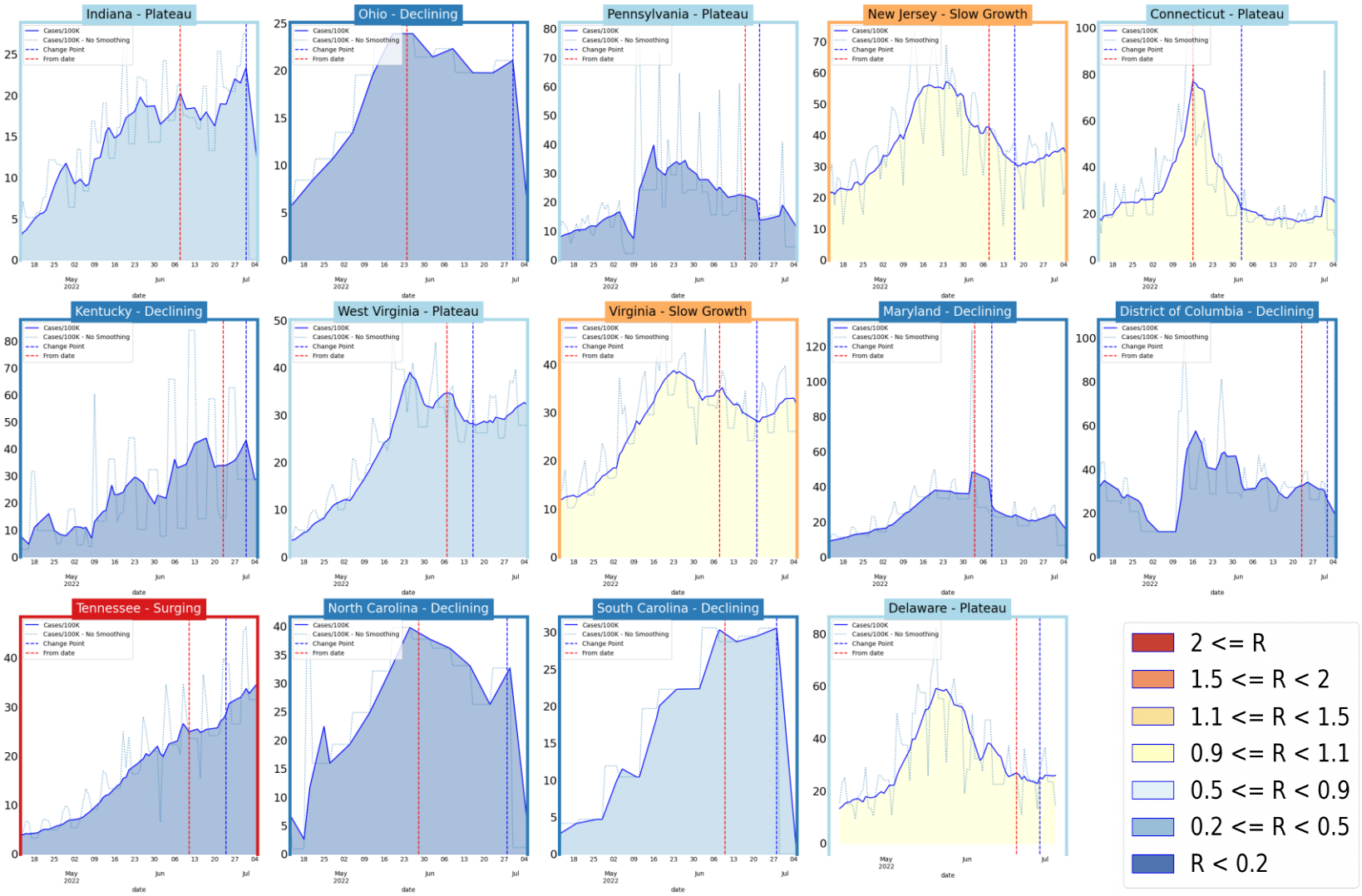
Virginia and Her Neighbors



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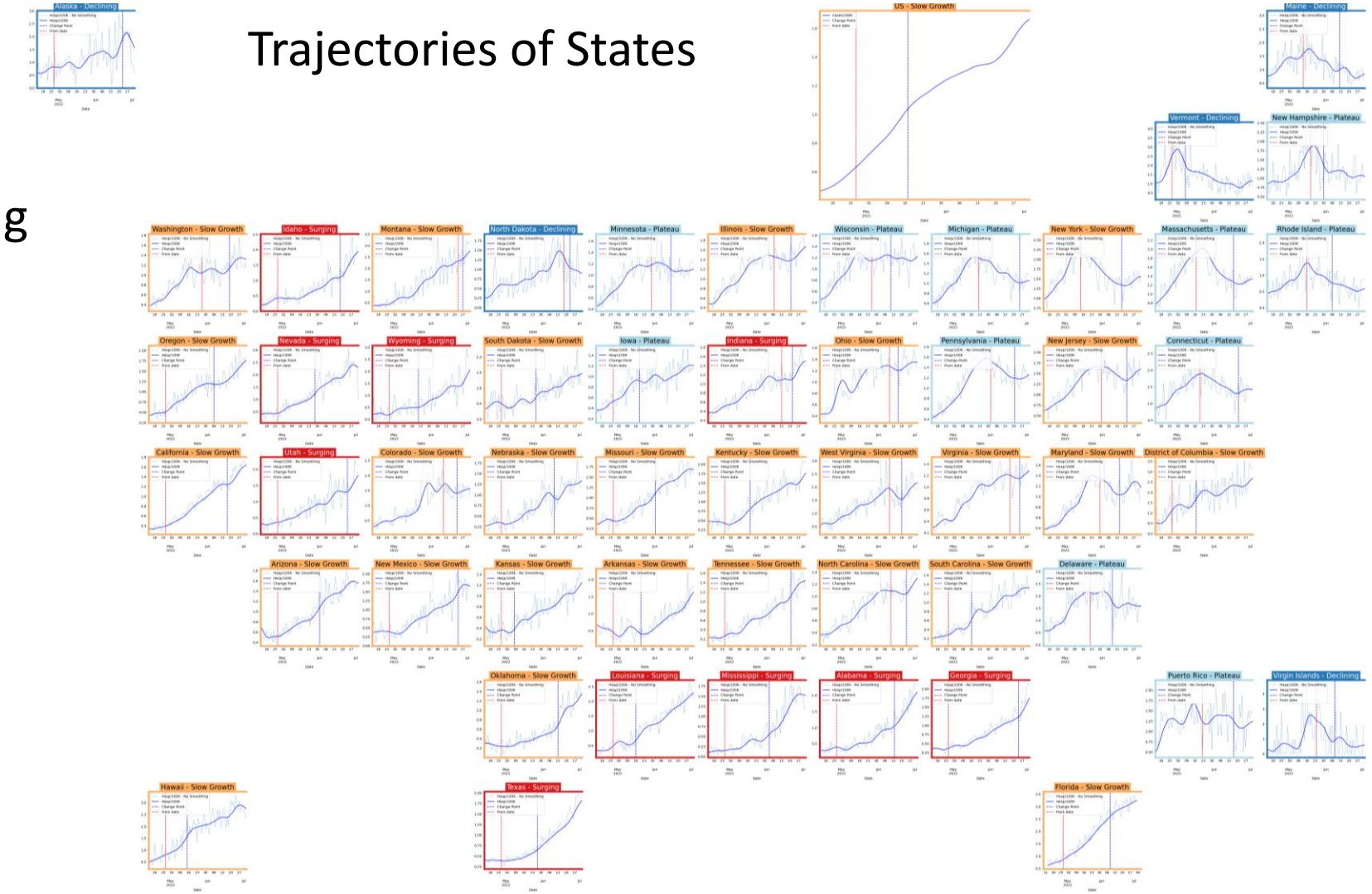
United States Hospitalizations

- Hospital admissions are lagging case rates
- Declines seem to be leveling off in Northeast, surges in southern in Central US follow cases

Status	# States
Declining	5 (10)
Plateau	11 (13)
Slow Growth	27 (19)
In Surge	10 (11)

Trajectories of States



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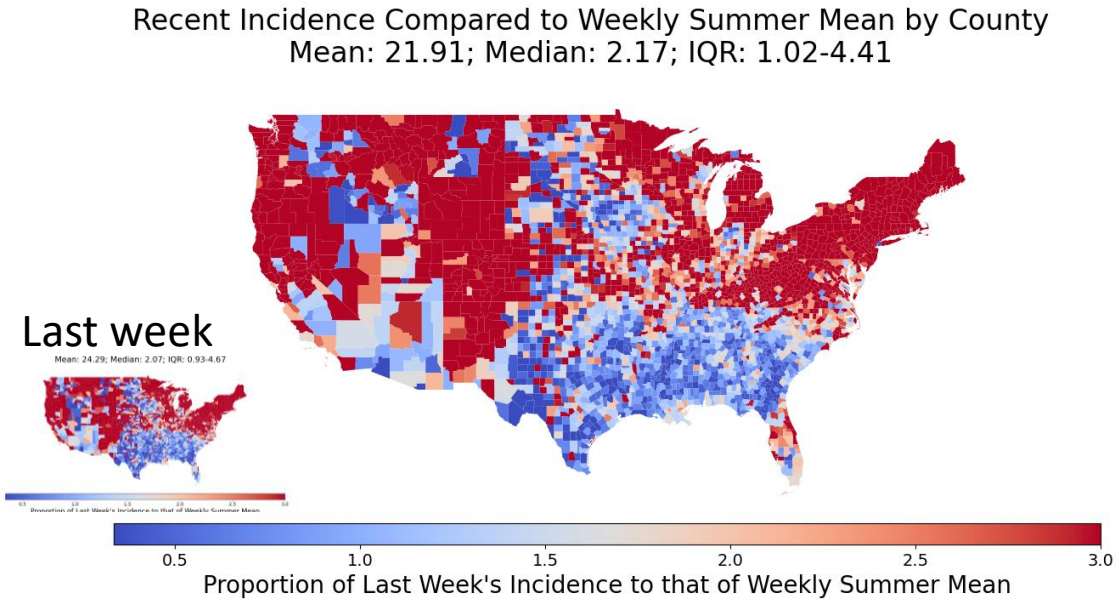
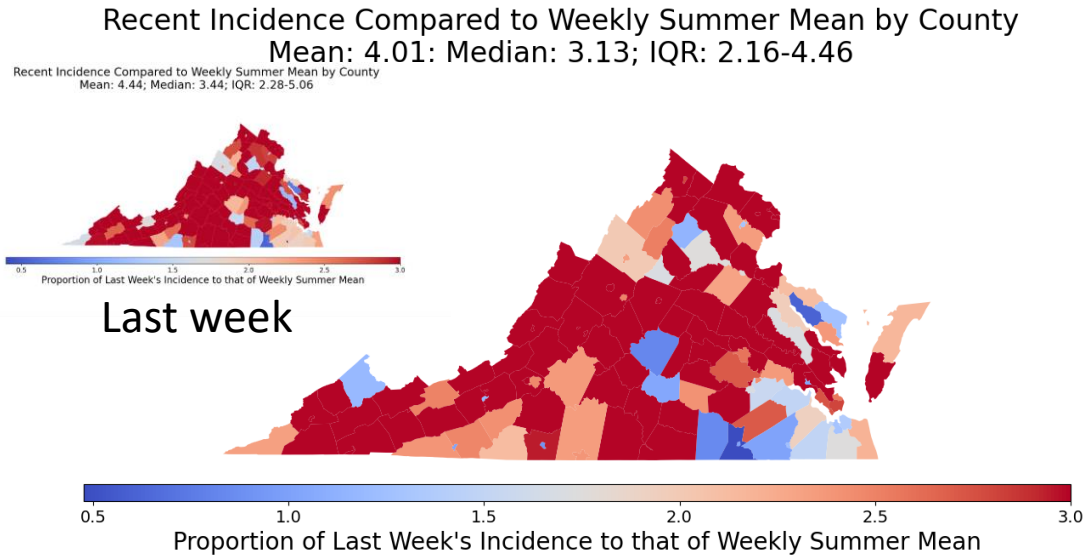
County-level comparison to last Summer





Using Ensemble Model to Guide Projections

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

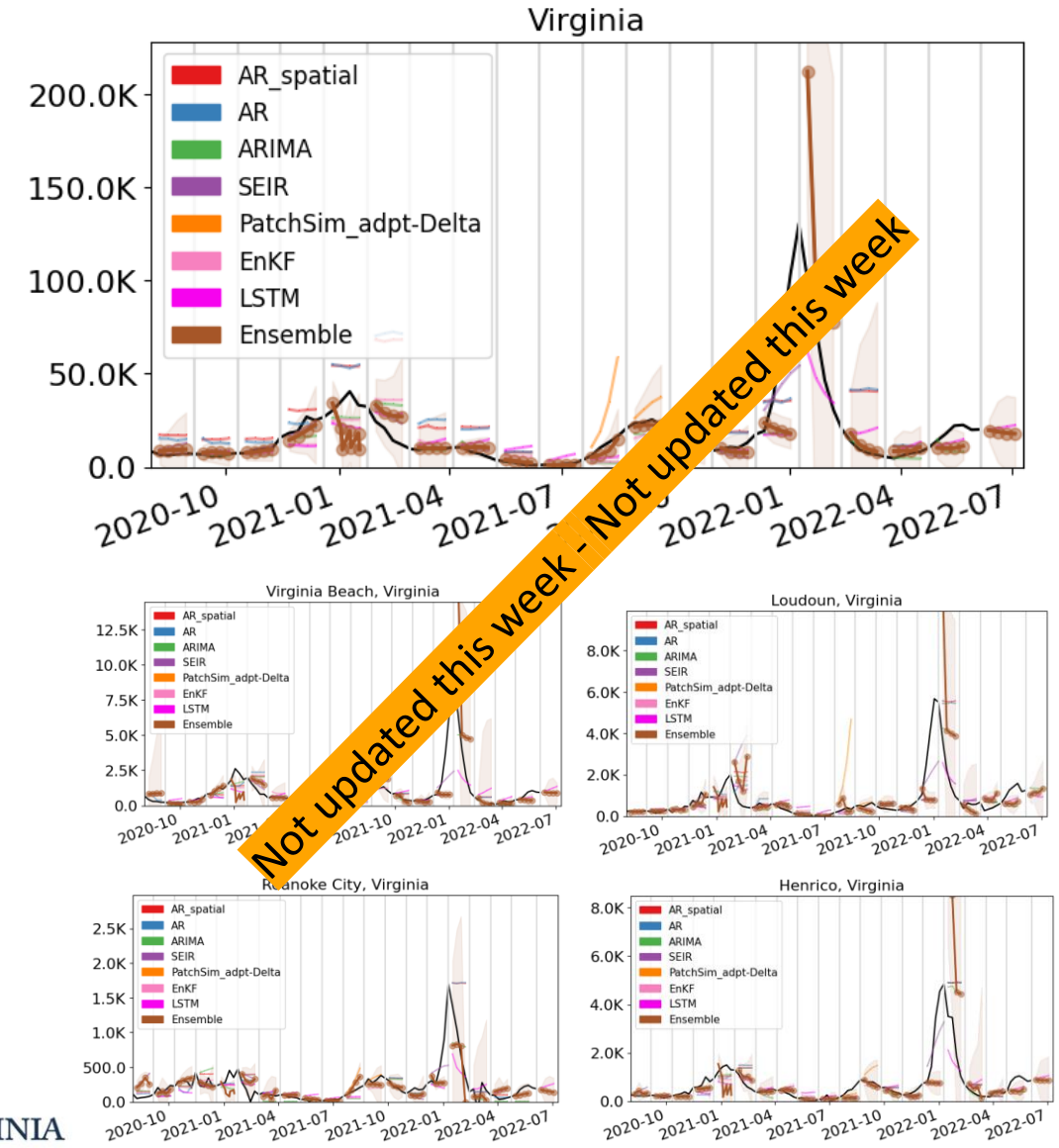
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

Weekly forecasts done at county level.

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

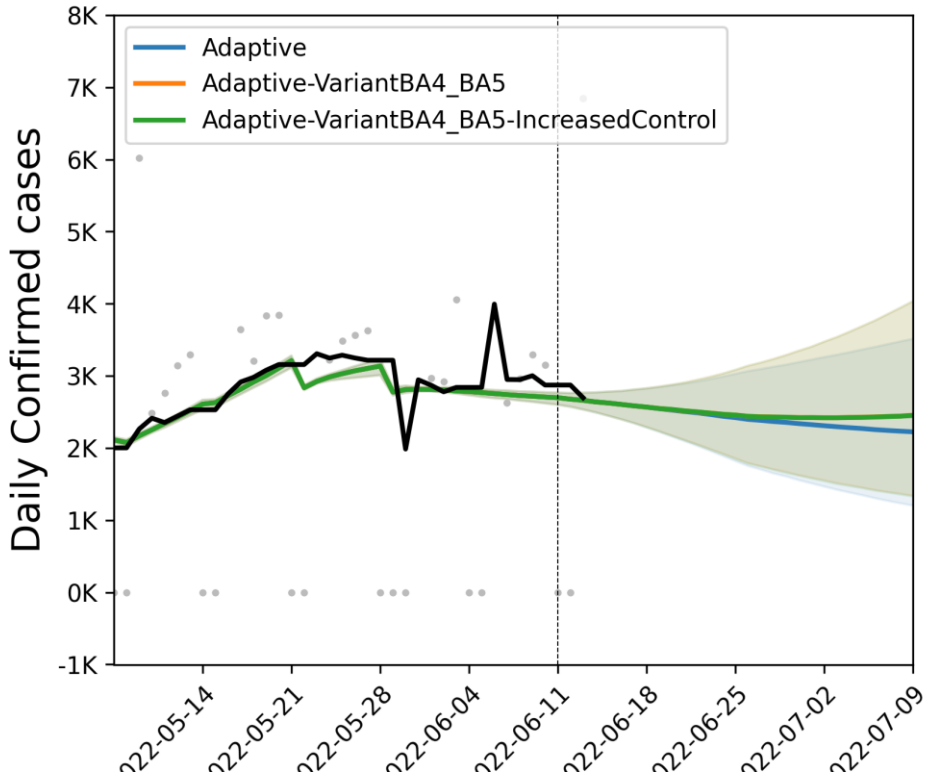
Ensemble forecast provides additional 'surveillance' for making scenario-based projections.

Also submitted to CDC Forecast Hub.

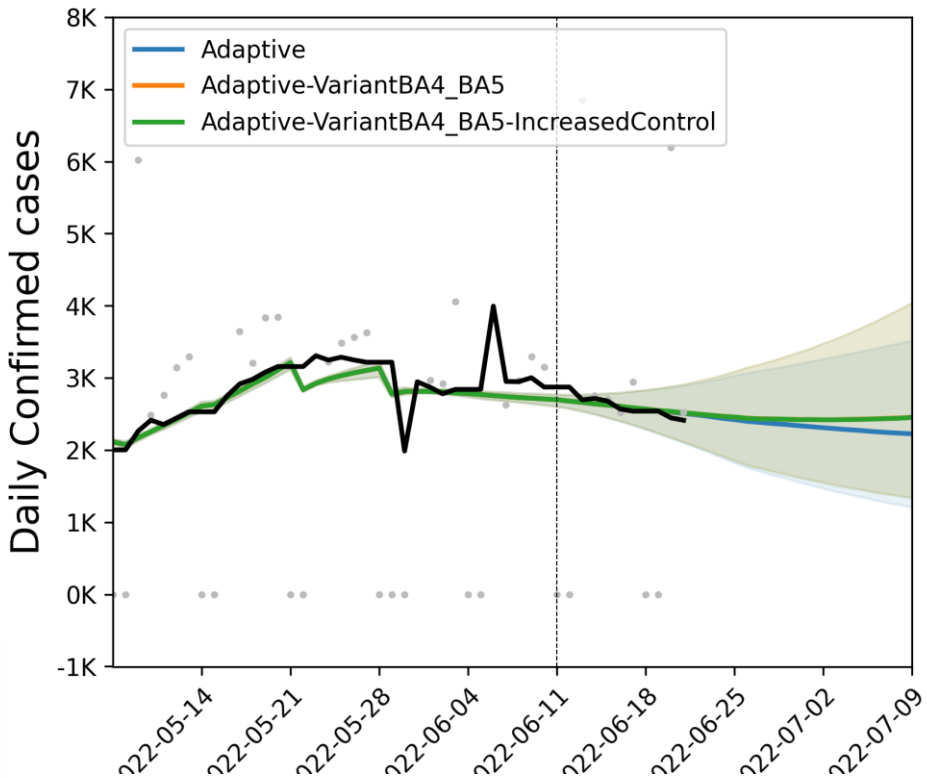


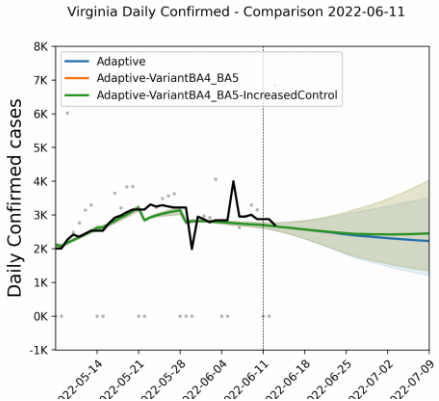
Last projection comparison – 1 week ago

With Last Week's Case Data



With This Week's Case Data





Key Takeaways

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

- **Case rates remain high but are slowly declining, hospitalizations have started to decline**
- VA 7-day mean daily case rate down to 29/100K from 34/100K
  - US has flattened, only slightly up to 30/100K from 29/100K
  - VA hospital occupancy (rolling 7 day mean of 544) has declined slightly after a couple weeks in a plateau
- Omicron sub-variants BA.4 and BA.5 continue to grow with BA.5 starting to outpace BA.4
- Model projections from last week remain on target

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

Additional Analyses

Overview of relevant on-going studies

Other projects coordinated with CDC and VDH:

- **Scenario Modeling Hub:** Consortium of academic teams coordinated via MIDAS / CDC to that provides regular national projections based on timely scenarios
- **Genomic Surveillance:** Analyses of genomic sequencing data, VA surveillance data, and collaboration with VA DCLS to identify sample sizes needed to detect and track outbreaks driven by introduction of new variants etc.
- **Mobility Data driven Outreach locations:** Collaboration with VDH state and local, Stanford, and SafeGraph to leverage anonymized cell data to help identify sites most frequently visited by different demographic groups

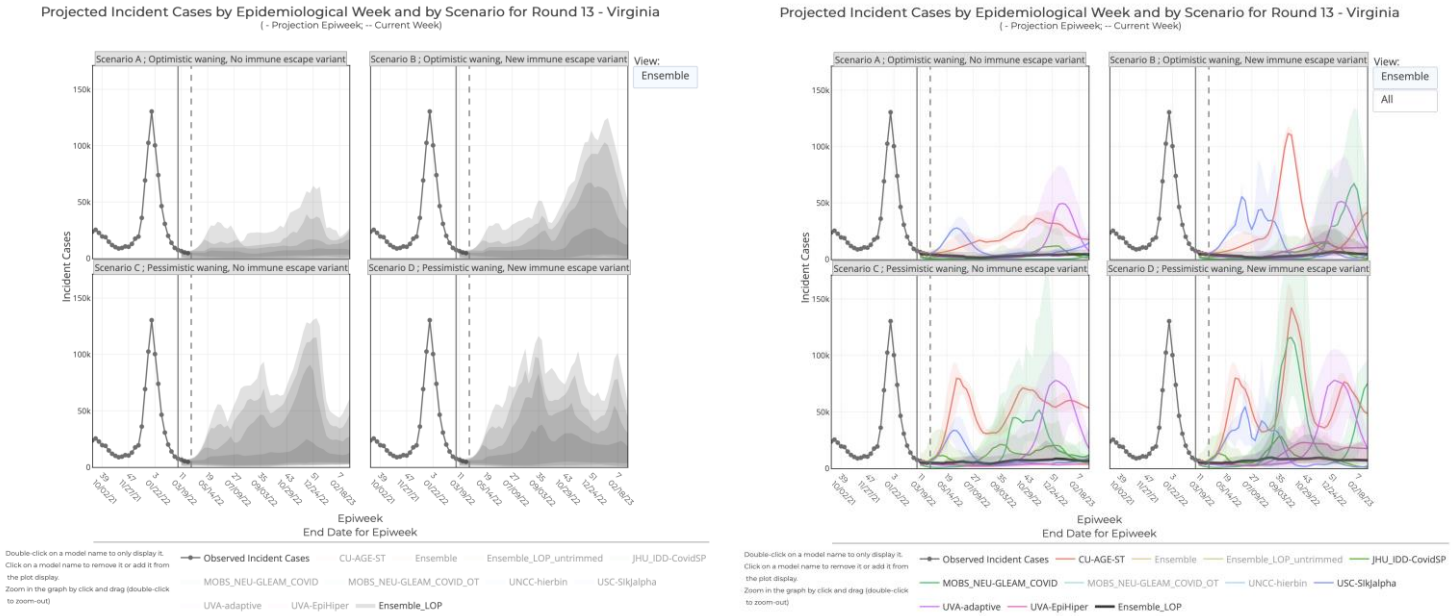
COVID-19 Scenario Modeling Hub – Round 13

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

- Round 13 results getting finalized
  - Scenarios: New Variant in Summer and waning compared (yes/no new variant vs. 4 month or 10 month waning)
- Prelim results shared internally
- Only national consortium tracking Omicron wave well
- Rounds 4-12 now available

Round 4 Results were published May 5th, 2021 in MMWR

https://covid19scenariomodelinghub.org/viz.html



Busiest Places: Mobility Data Can Assist

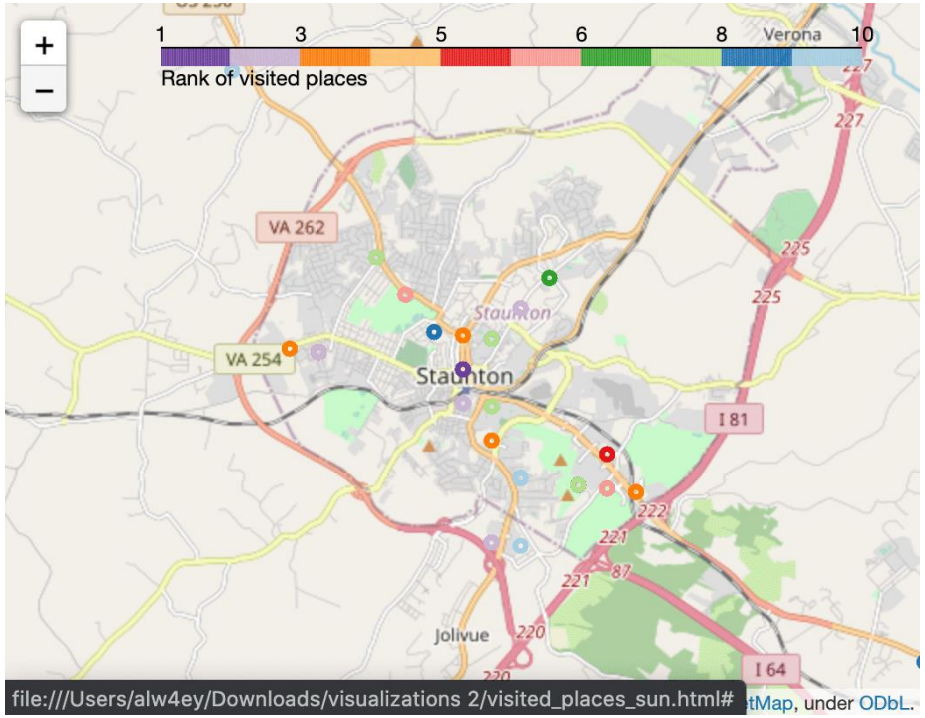
SafeGraph provides fine-grained mobility measures

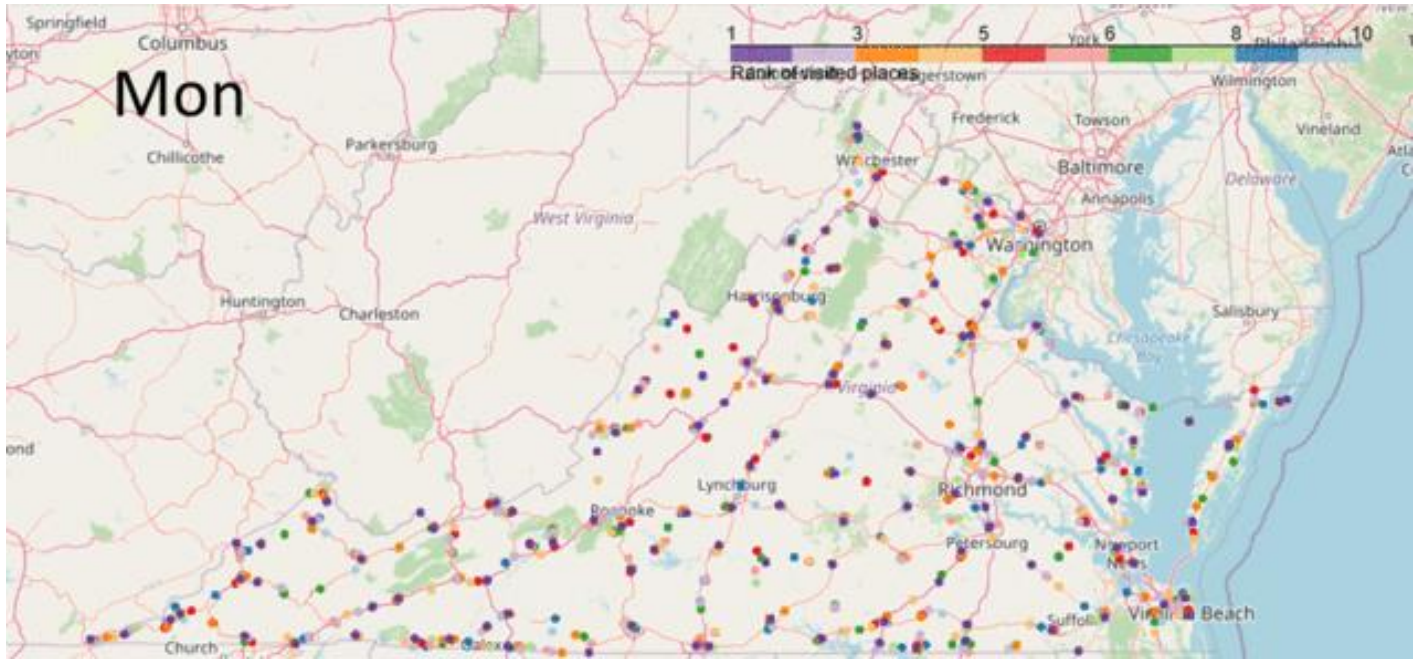
- SafeGraph: anonymized geolocation data aggregated from numerous cell phone apps
- One of the most fine-grained and high-coverage mobility data sources available: 6.4 million POIs in the US; 158,869 POIs in VA
- Has been utilized by hundreds of researchers, governments, and the CDC to aid COVID-19 efforts (Chang, Pierson, Koh, et al., *Nature* 2020; Chang et al, KDD 2021)
- Daily and hourly number of visits to points-of-interest (POIs), i.e., non-residential locations such as restaurants, bars, gas stations, malls, grocery stores, churches, etc.
- Weekly reports per POI of ***where visitors are coming from*** (at the census block group level)
- Still has limitations to be aware of (e.g., less representation among children and seniors)

SAFEGRAPH

Find the Busiest Locations

POIs are individual addresses, need some aggregation to busy areas

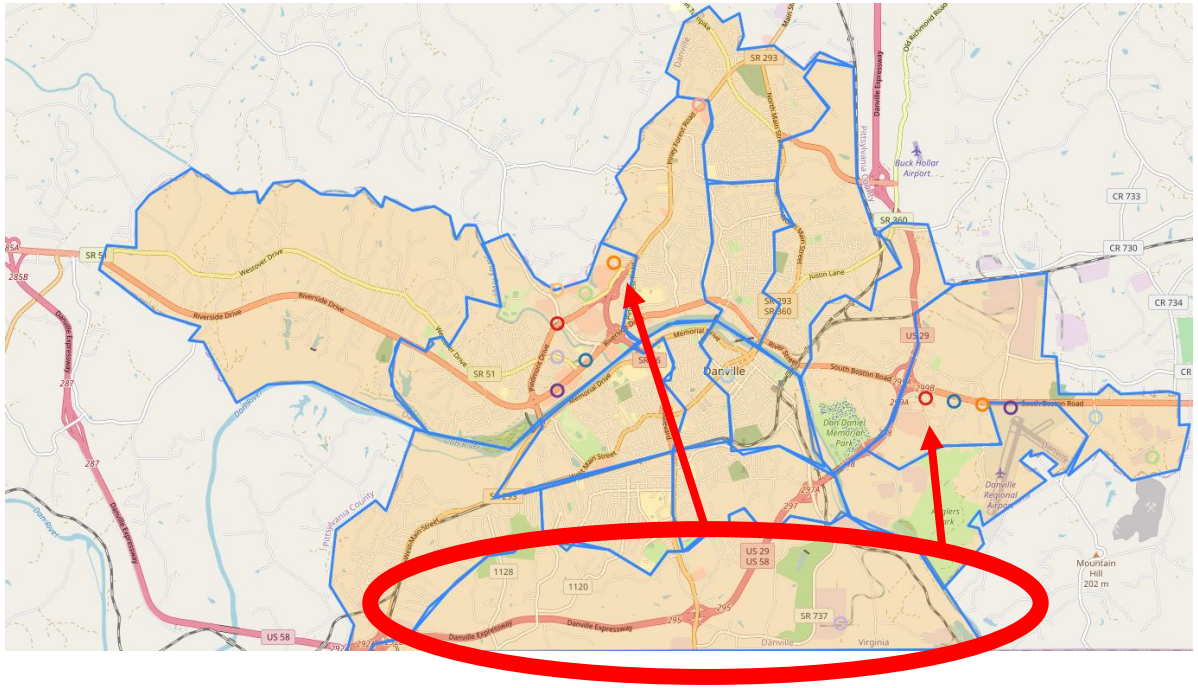




Busiest locations vary by day of week (and time of day)

Find locations visited by Target Population

Census Block Groups in Danville



1. Use census data to characterize the populations of the different census block groups
2. Identify most frequently visited POIs for each CBG
3. Cluster most visited POIs
4. Provide potential sites grouped by the demographic groups they likely serve

Goal: Provide frequently visited locations based on populations and vaccination levels one desires to reach

Example: List of locations in the Southside frequented by Black Virginians

Overview of the current roster of targeted populations

These are the current roster of targeted population groups that we are providing as part of the weekly delivery to VDH. (This roster is subject to change.)

- Whole population (eg, no target population filters are applied)
- Race Black
- Ethnicity Latinx
- Ages 20-40
- Ages 20-30
- Ages 30-40
- Unvaccinated populations
- Latinx or Black NEW

Data Elements in the CSV

HighlyVisitedAddress
This is the address of the POI in the L14 that sees the most visits. It is provided to make it easier to find the L14 on the map.

Rank & LocationWeight
The LocationWeight is estimated # of visits to POIs in the L14 from the target group. Rank indicates the order from most- to 25th most-visited

AreaMostVisitedPeriod
This is the 4-hour period in the week when the L14 sees its highest traffic. This is not target group-specifi

NEW

Population Group
For a targeted file like this one, these will all be the same value.

AreaMostVisitedDay
This is the day of the week when most visitors go to this S2 location. This is not target group-specific.

Lat and Lon
This is the latitude and longitude for the center of the L14.

VDH District

S2 Key (L14)

County

Locality	District	PopulationGroup	LocationID	Rank	LocationWeight	AreaMostVisitedDay	HighlyVisitedAddress	AreaMostVisitedPeriod	Lat	Lon
Accomack Cc	Eastern Shor	Latinx or Black	89ba2b55	1	4966.030095	Friday	25297 Lankford Hwy Rt 13 N, C	Friday 17:00-21:00	37.6978738	-75.716796
Accomack Cc	Eastern Shor	Latinx or Black	89ba2caf	2	3728.476605	Friday	26036 Lankford Hwy, Onley, VA	Friday 15:00-19:00	37.6881681	-75.722612
Accomack Cc	Eastern Shor	Latinx or Black	89ba2b57	3	3508.193676	Saturday	25274 Lankford Hwy, Onley, VA	Saturday 13:00-17:00	37.69859	-75.722612
Accomack Cc	Eastern Shor	Latinx or Black	89bbd4ad	4	2582.802769	Wednesday	25102 Lankford Hwy, Onley, VA	Sunday 11:00-15:00	37.7023677	-75.710981
Accomack Cc	Eastern Shor	Latinx or Black	89ba2b53	5	1844.868961	Sunday	25102 Lankford Hwy, Onley, VA	Friday 16:00-20:00	37.7030842	-75.716796
Albemarle Cc	Blue Ridge	Latinx or Black	89b38647	1	14088.0684	Thursday	1215 Lee St, University of Virg	Thursday 07:00-11:00	38.0327733	-78.500766
Albemarle Cc	Blue Ridge	Latinx or Black	89b477ff	2	6999.363545	Saturday	1980 Rio Hill Ctr, Charlottesvill	Saturday 12:00-16:00	38.087391	-78.472353
Albemarle Cc	Blue Ridge	Latinx or Black	89b38645	3	5824.383454	Wednesday	Cabell Hall 525 Mccormick Roa	Wednesday 11:00-15:00	38.033334	-78.506447
Albemarle Cc	Blue Ridge	Latinx or Black	89b3888d	4	5078.488029	Friday	540 Pantops Ctr, Pantops, VA,	Thursday 11:00-15:00	38.0334982	-78.455301
Albemarle Cc	Blue Ridge	Latinx or Black	89b387fd	5	4655.844131	Saturday	100 Twentyninth Place Ct, Cha	Saturday 11:00-15:00	38.077516	-78.478036

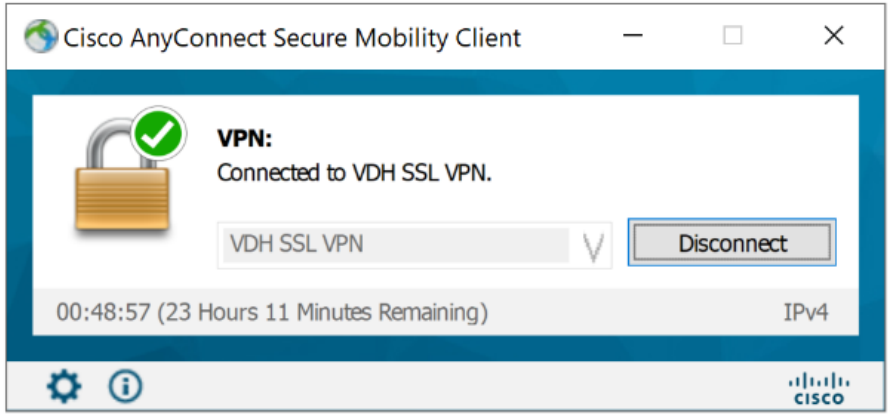
Mobility Data Updated Weekly

Box: https://virginia.box.com/s/03kq8el0kzd9w43wz2g3myozov76uizo

- Excel sheets and simple HTML maps packaged for use

VDH has a dashboard available upon request to allow interactive viewing

- https://arcgis.vdh.virginia.gov/portal/apps/opsdashboard/index.html#/8631cfc4f181460fafc7e1923f41d581
- Dashboard is restricted to VDH offices and those who VPN into the CoV Network



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/

Questions?

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