Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

August 18th, 2021

(data current to August 15th – 18th)

Biocomplexity Institute Technical report: TR 2021-092

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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

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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:

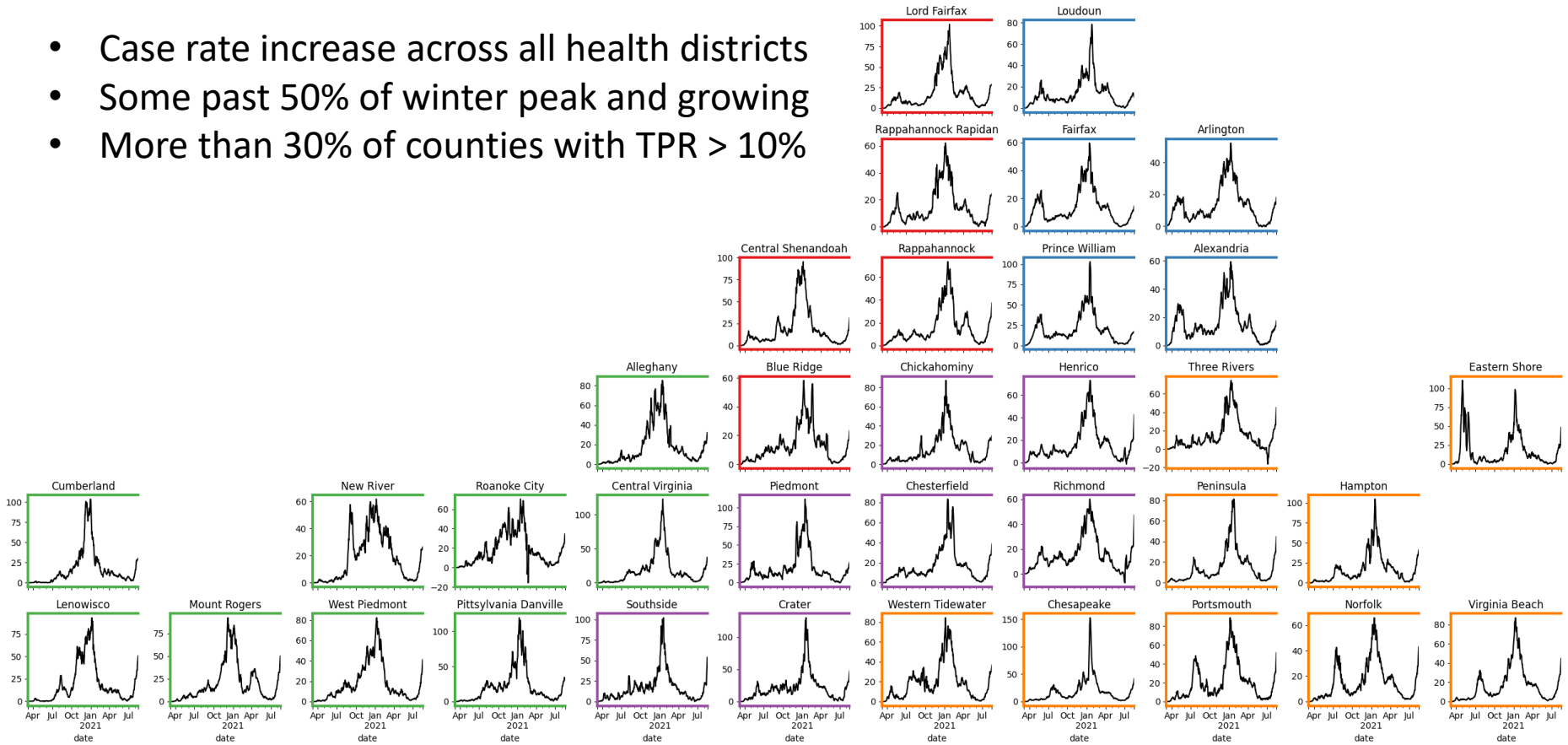
- **Case rates in Virginia continue to rise quickly amidst a background of surges across the nation**
- VA mean weekly incidence up to 24/100K from 14/100K, US up to 38/100K (from 25/100K)
- Vaccination rates continue to pick speed and acceptance among the unvaccinated persists
- Projections continue to show significant uptick in activity, with larger growth possibly fueled by Delta's increasing prevalence, even in areas with high vaccination coverage
- Recent updates:
  - Updated Surge Control scenario to commence sooner as mask use has increased recently
  - Adjusted hospitalization and death modeling to adapt to the observed impacts of Delta

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

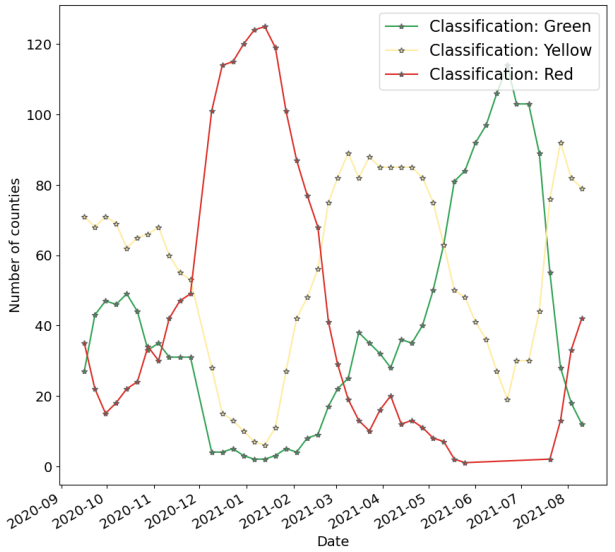
Situation Assessment

Case Rates (per 100k) and Test Positivity

- Case rate increase across all health districts
- Some past 50% of winter peak and growing
- More than 30% of counties with TPR > 10%



Data source: https://data.cms.gov/covid-19/covid-19-nursing-home-data



County level RT-PCR test positivity

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

Yellow: 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")

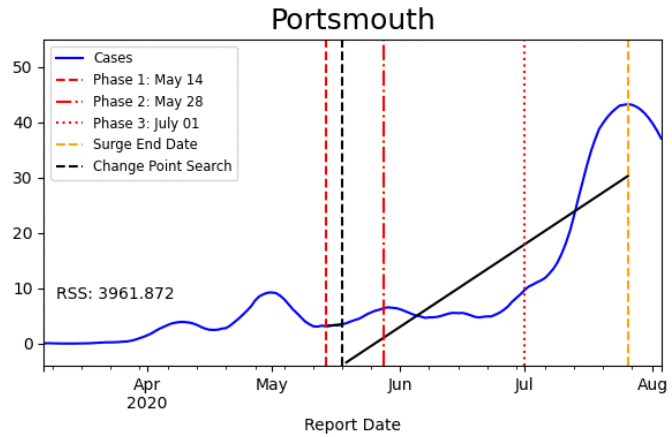
Classification	Green	Red	Yellow
date			
2021-07-20	55.0	2.0	76.0
2021-07-27	28.0	13.0	92.0
2021-08-03	18.0	33.0	82.0
2021-08-10	12.0	42.0	79.0

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

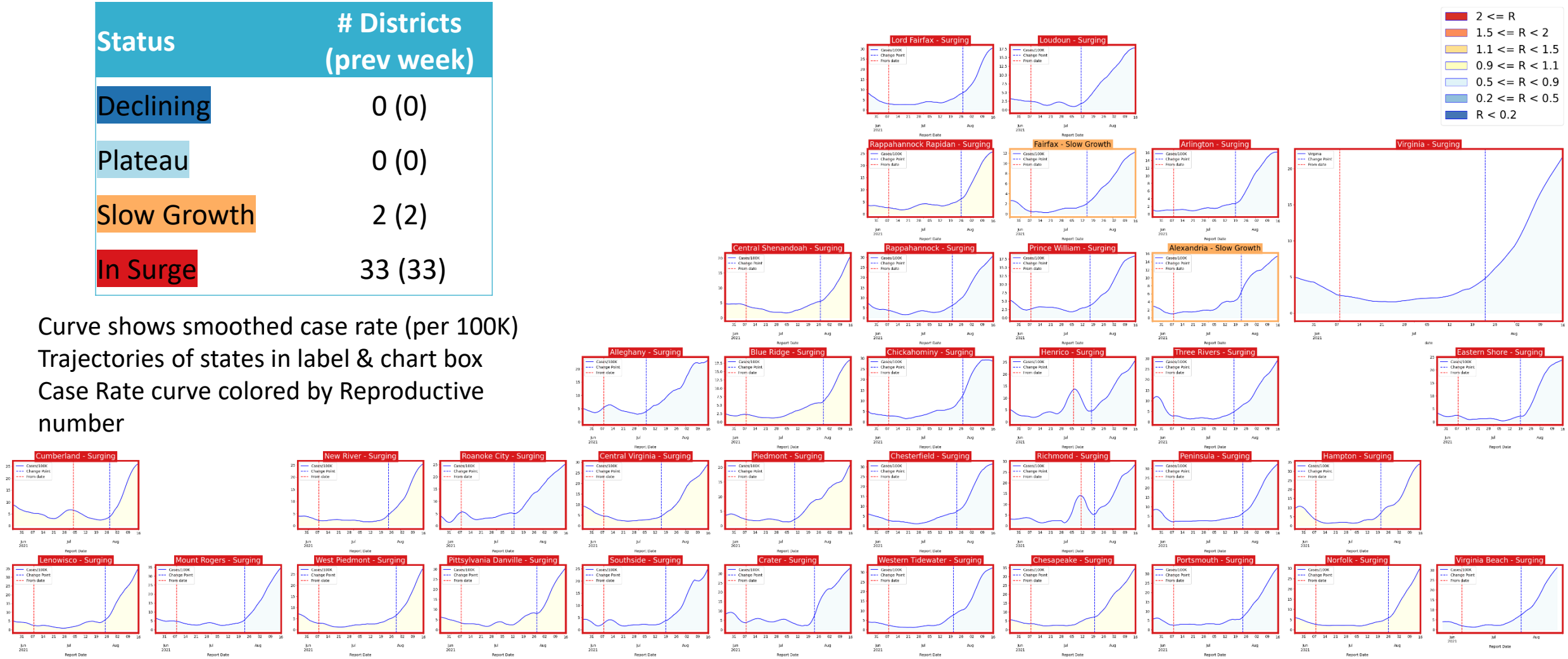


Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (prev week)
Declining	Sustained decreases following a recent peak	below -0.9	0 (1)
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5	0 (1)
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	2 (23)
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater	33 (10)

District Trajectories – last 10 weeks

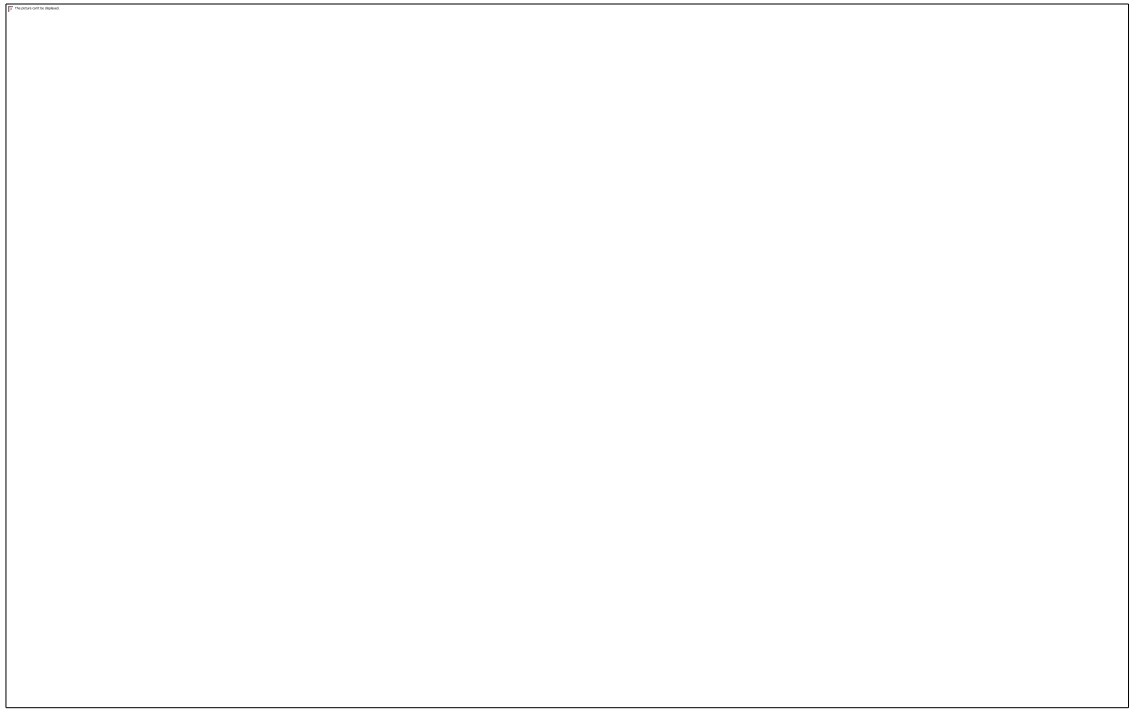
Status	# Districts (prev week)
Declining	0 (0)
Plateau	0 (0)
Slow Growth	2 (2)
In Surge	33 (33)

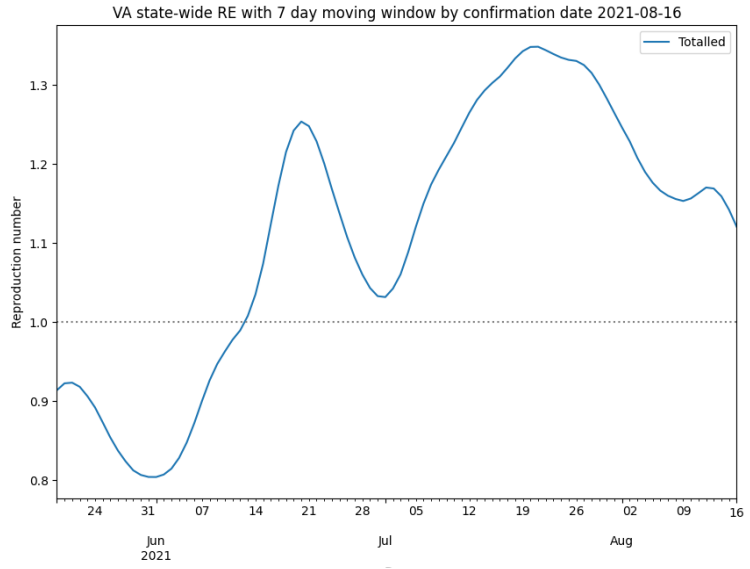
Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive number

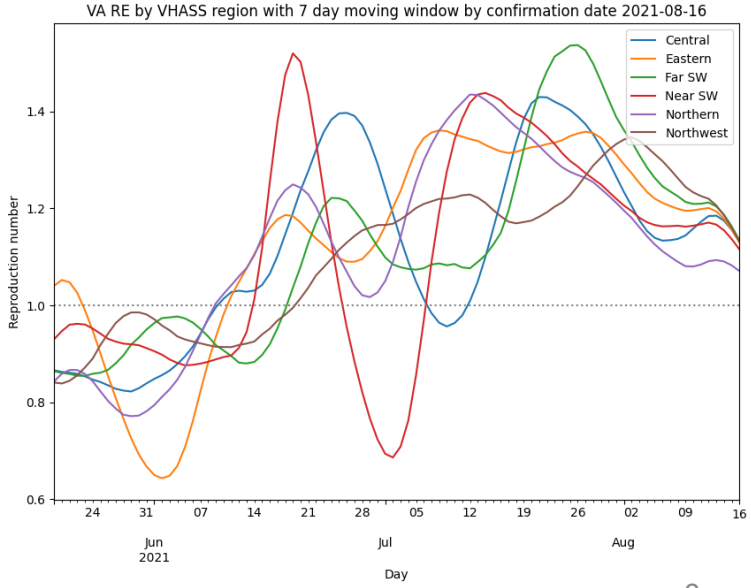


Estimating Daily Reproductive Number

August 16th Estimates





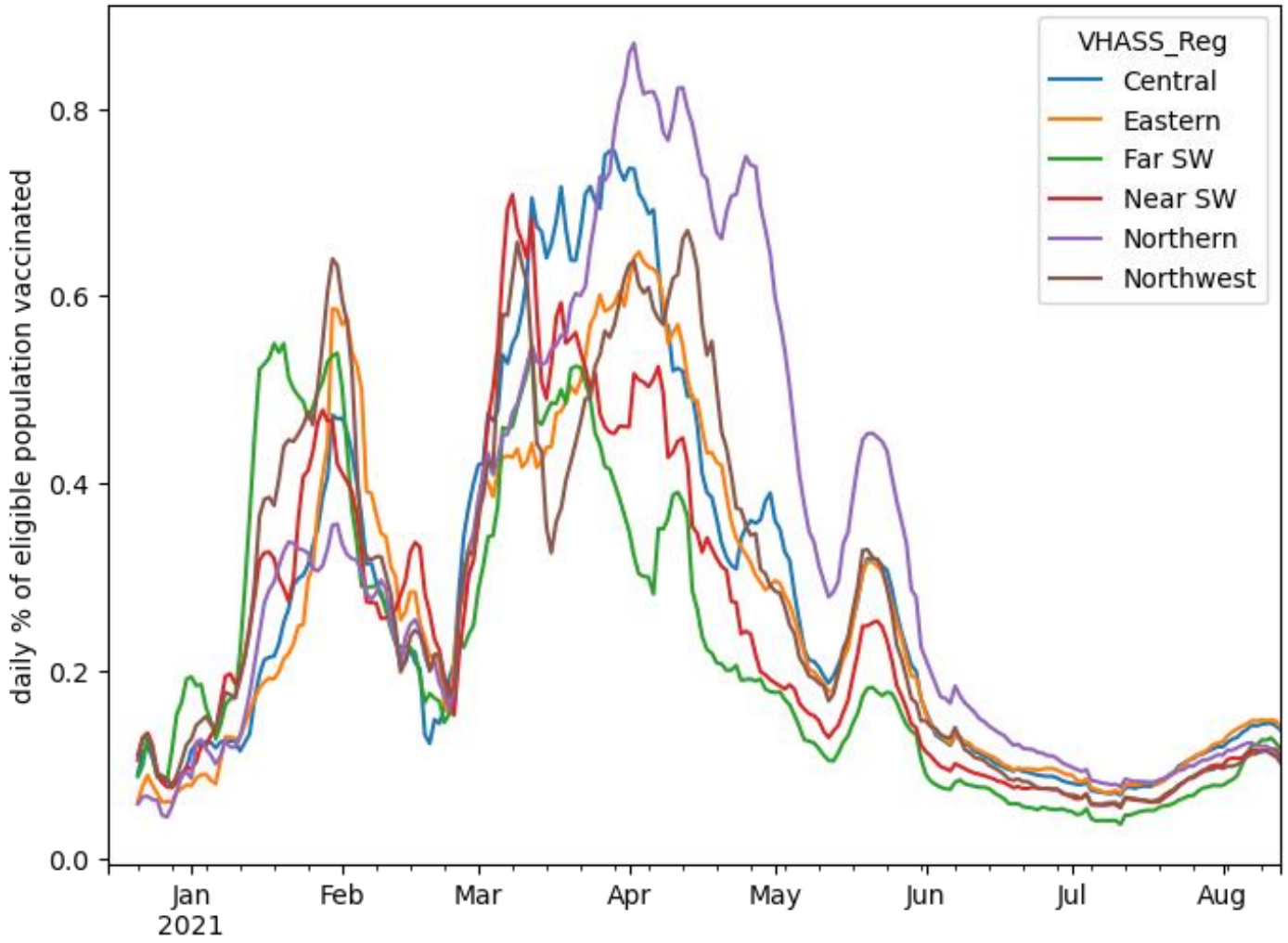


Methodology

- 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

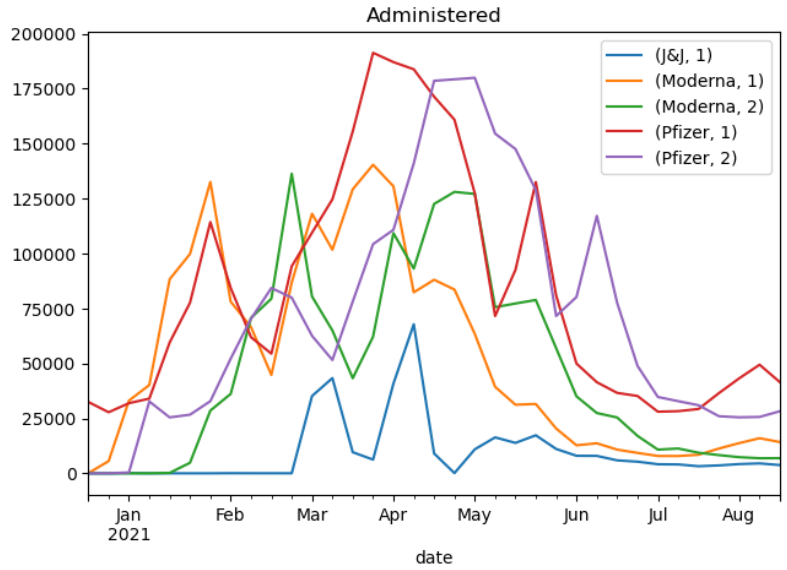
1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Vaccination Administration Slows



Regional Vaccine courses initiated per day:

- Total counts of first dose of vaccines across regions
- Continued rise across all regions
- Reflected in 1st dose of Pfizer and Moderna uptick



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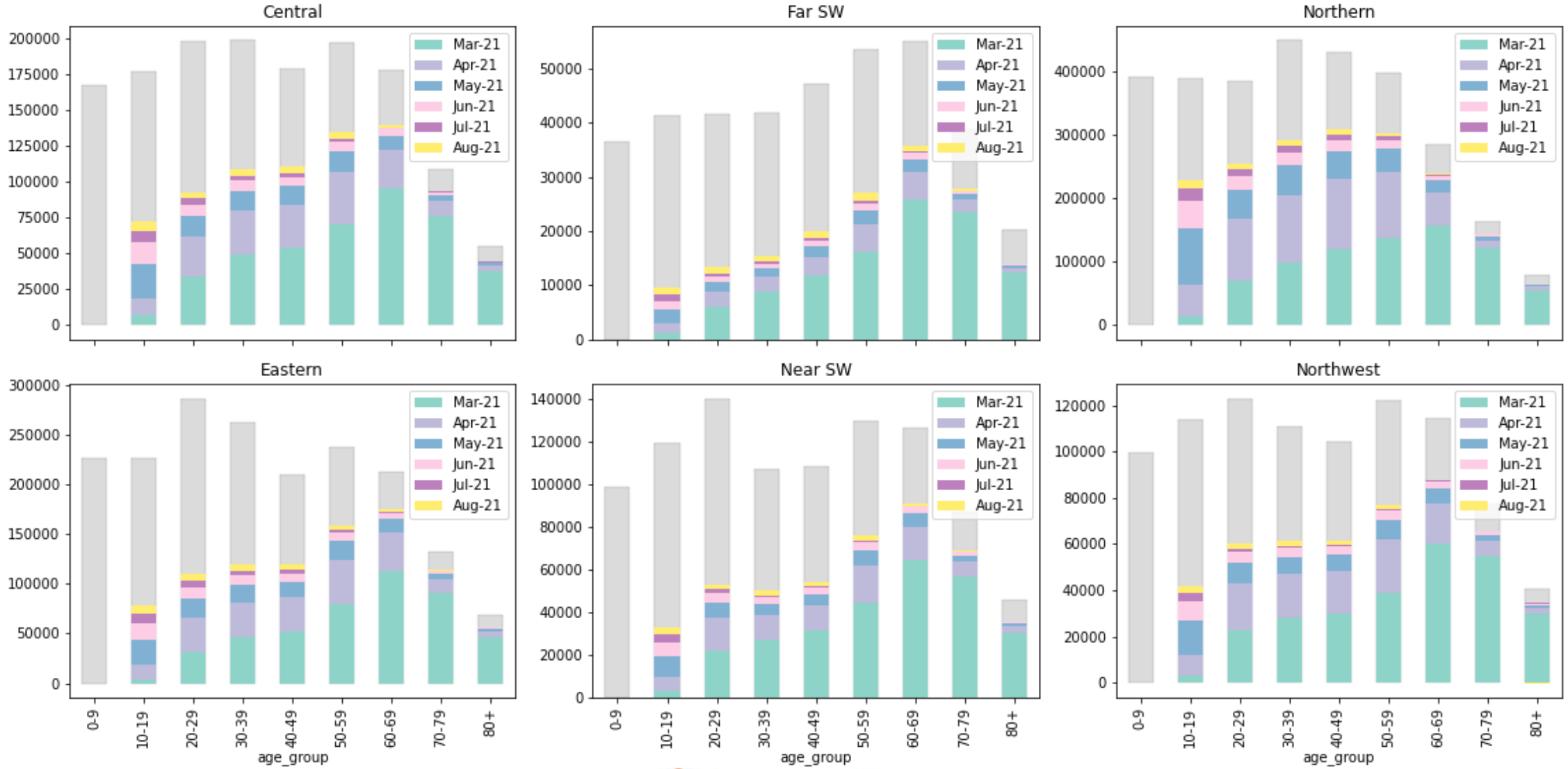
Vaccinations Shift to Younger Populations

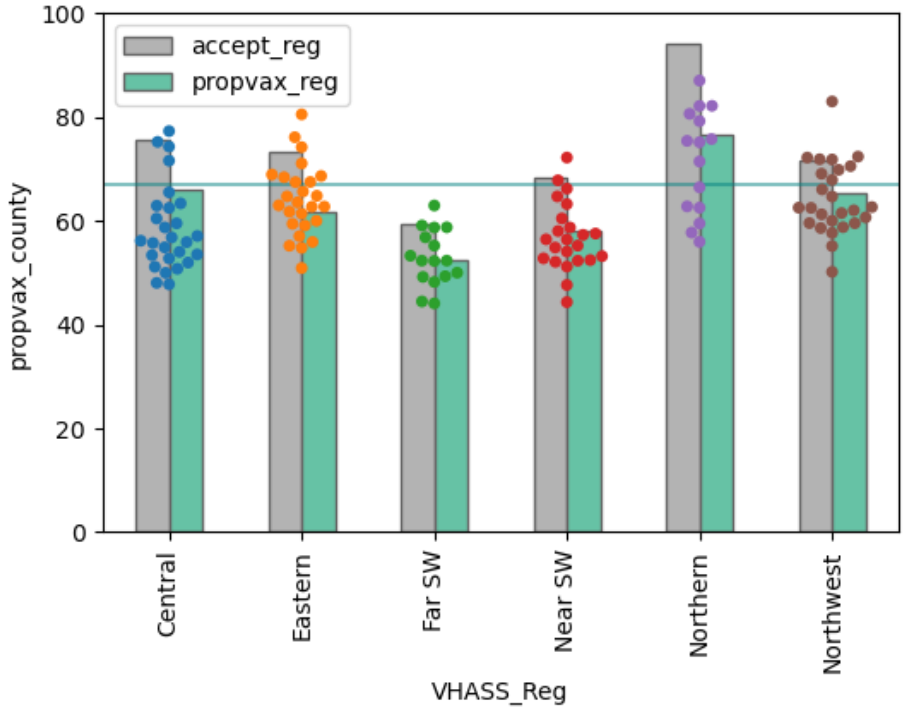


Vaccination Acceptance by Region

Corrections to surveys:

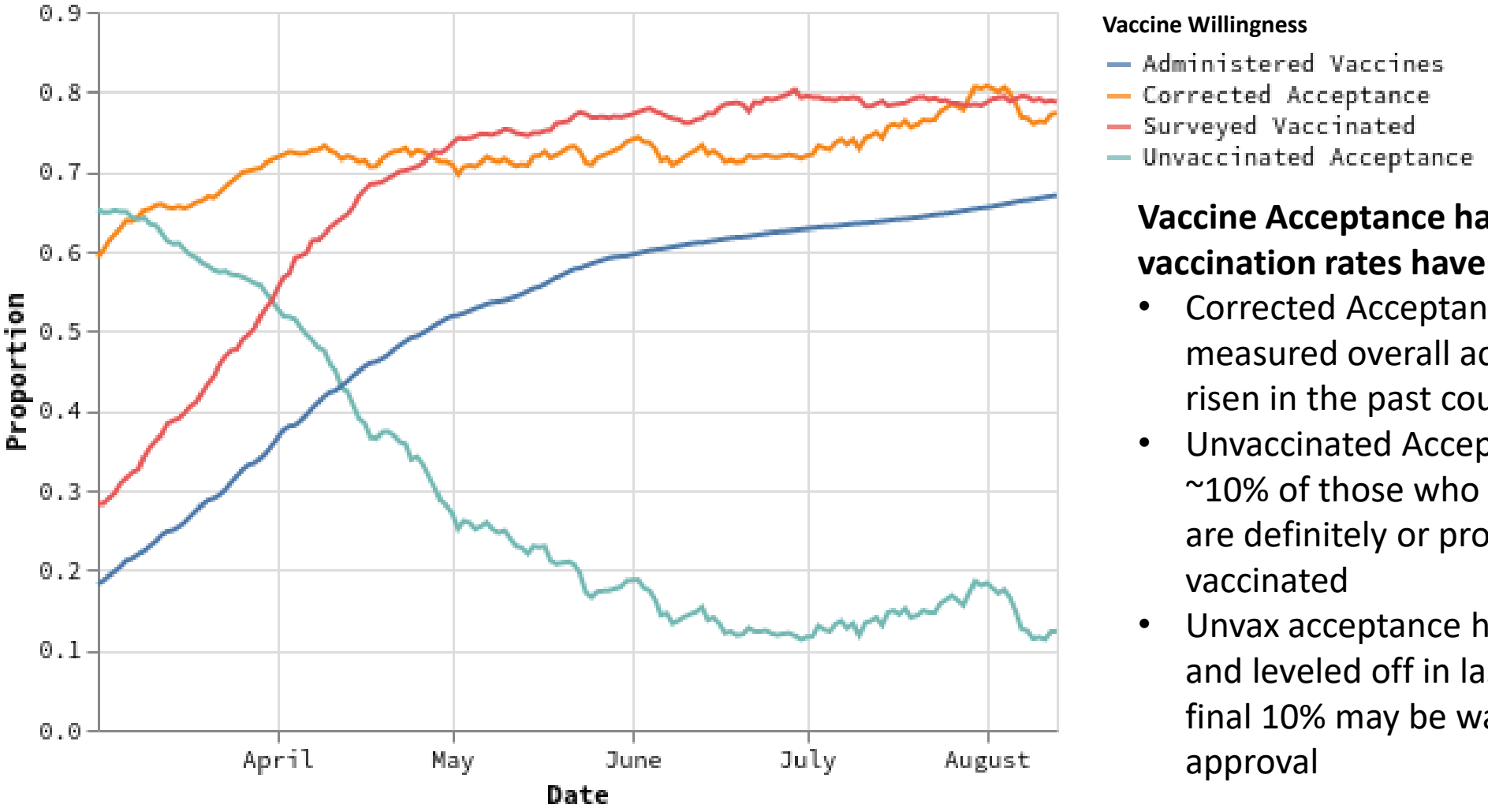
- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at the state level and corrected in same manner

Region	COVIDcast accepting corrected	VDH proportion eligible vaccinated
Central	76%	66%
Eastern	73%	62%
Far SW	59%	52%
Near SW	68%	58%
Northern	94%	77%
Northwest	71%	65%
Virginia	**78%**	**67%**



Grey Bar: Survey measured and corrected acceptance
Green Bar: Proportion of eligible population administered a vaccine
Dots: Proportion administered at least one dose for each county

Vaccine Acceptance Components over Time



Vaccine Acceptance has risen as vaccination rates have climbed

- Corrected Acceptance reflects the daily measured overall acceptance and has risen in the past couple days
- Unvaccinated Acceptance shows still ~10% of those who are unvaccinated are definitely or probably willing to be vaccinated
- Unvax acceptance has declined a bit and leveled off in last couple of weeks, final 10% may be waiting for FDA approval

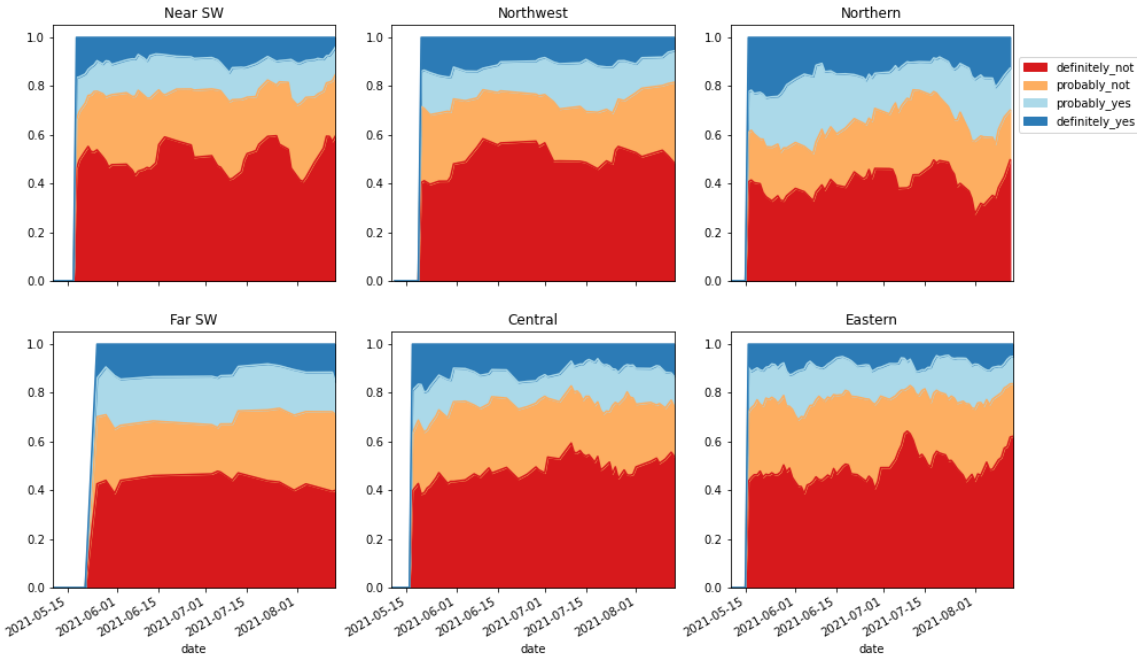
Data Source: https://covidcast.cmu.edu

Vaccine Acceptance by Region- COVIDcast

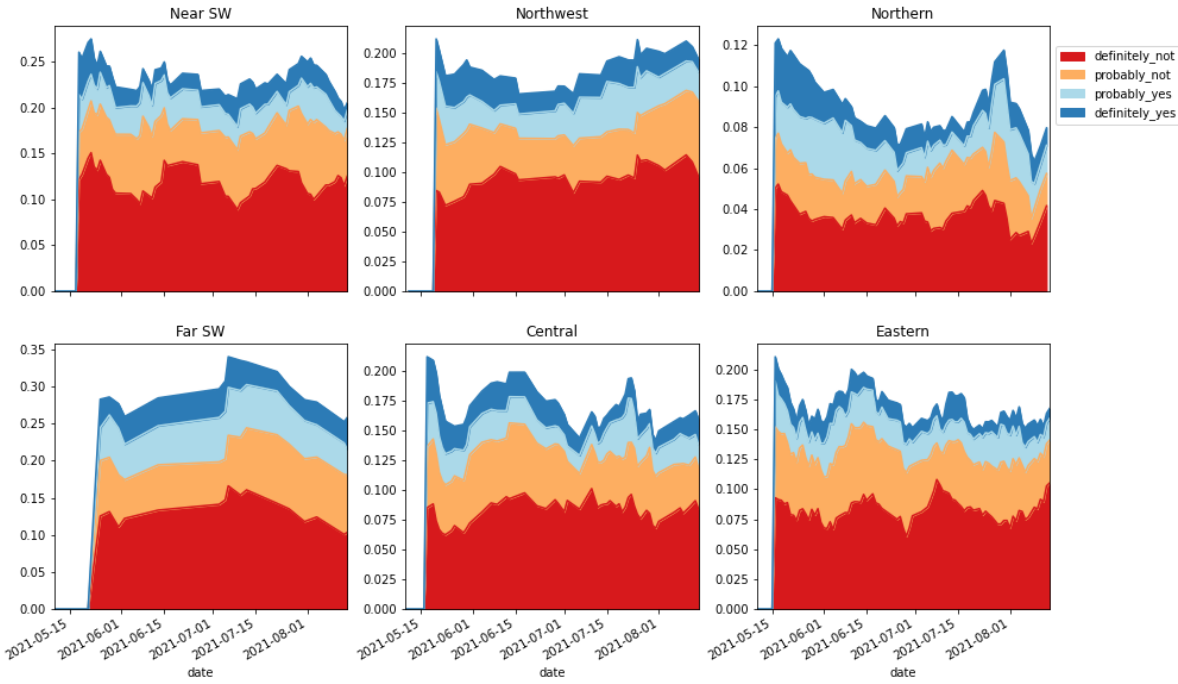
Levels of Acceptance and potential acceptance in flux:

- Most regions (except Central and Far SW) see vaccine uptake in the “Definitely Yes”.
- Among the unvaccinated, about 20-30% remain in the Definitely/Probably “Yes” categories.
- About 50% of the Unvaccinated seem to be in the “Definitely Not” category.

Unvaccinated Only



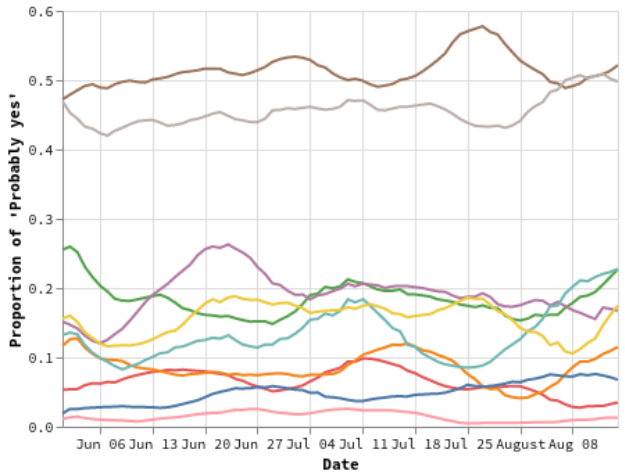
All Respondents



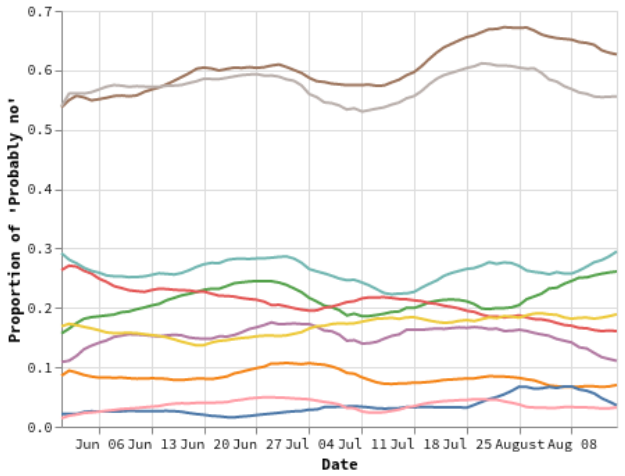
Data Source: https://covidcast.cmu.edu

Reasons for Hesitancy by Likeliness to Accept

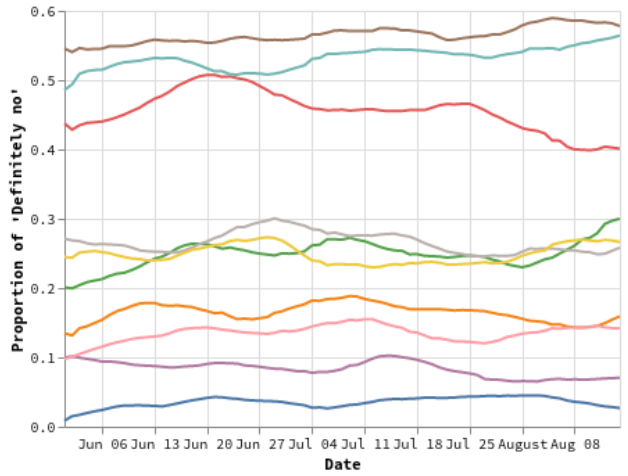
Probably Yes

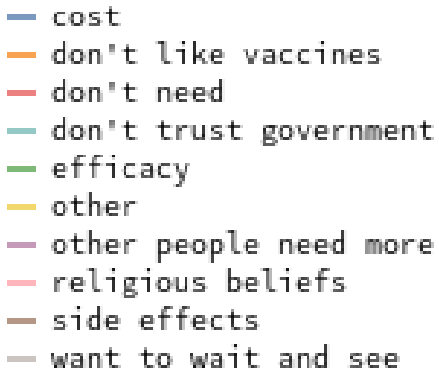


Probably No



Definitely No





Reasons for Hesitancy vary across tiers of likeliness to accept the vaccine

- Probably Yes and Probably No most concerned about side effects & are waiting to see
- Definitely No are concerned about side effects but also don't think they need the vaccine and don't trust the government, though don't need is declining
- Most other reasons are below 30% within these tiers of likeliness

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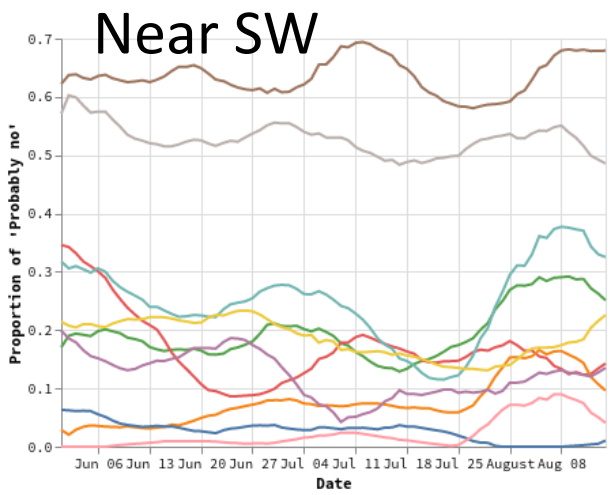
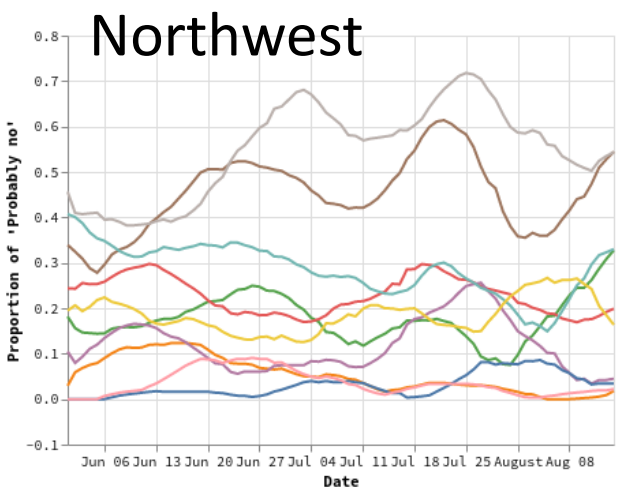
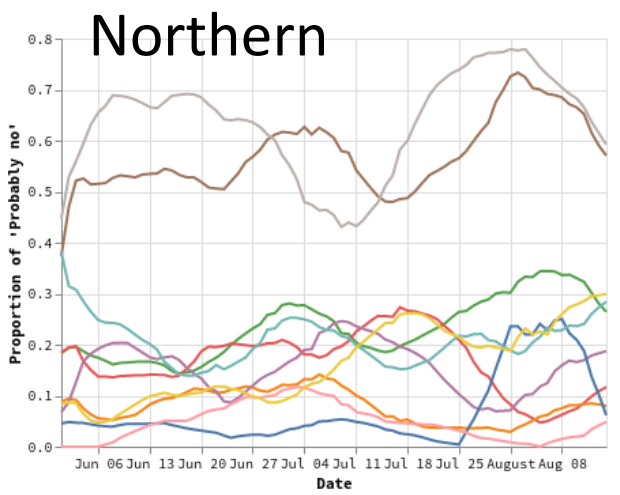
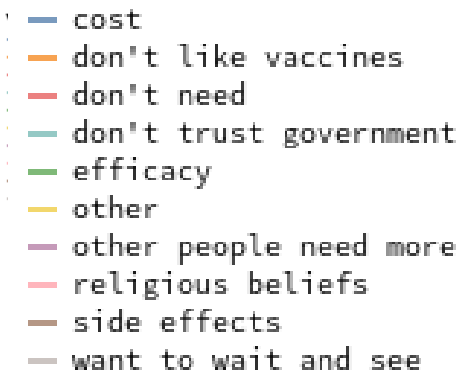
Data Source: https://covidcast.cmu.edu

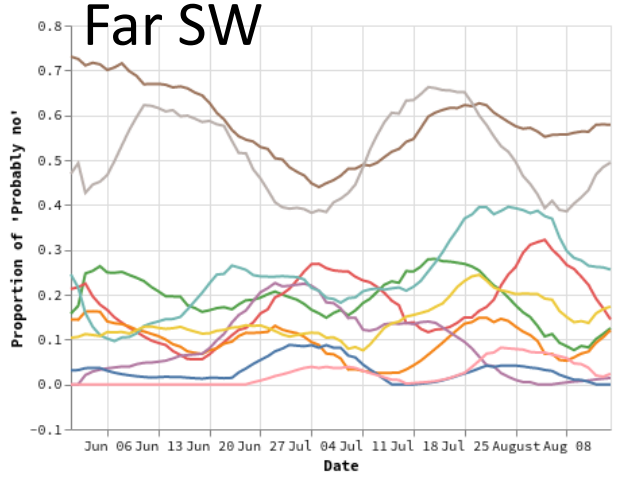
Reasons for Hesitancy of Probably No by Region

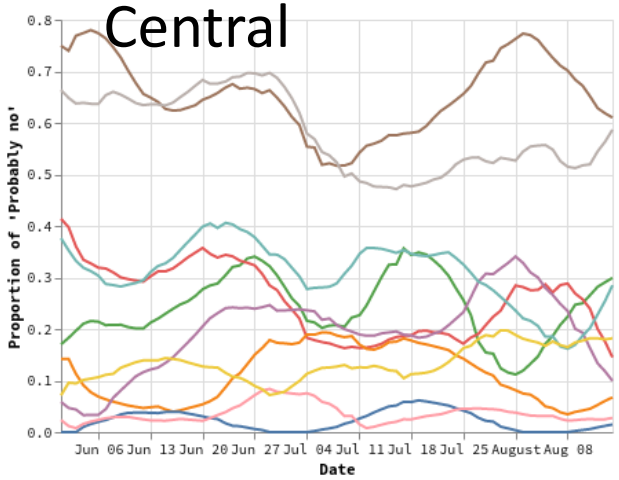


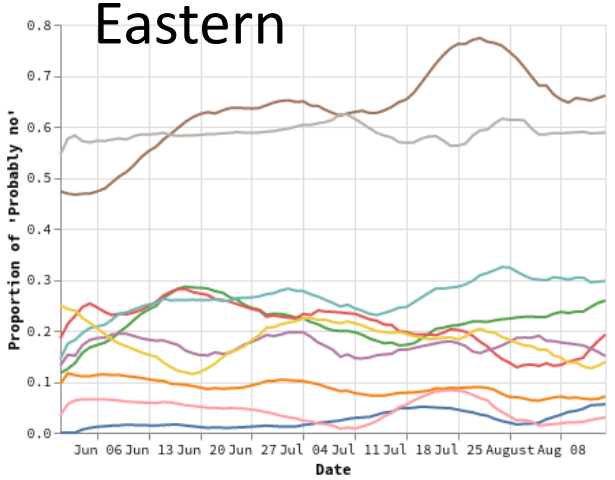












Reasons for Hesitancy vary across Regions

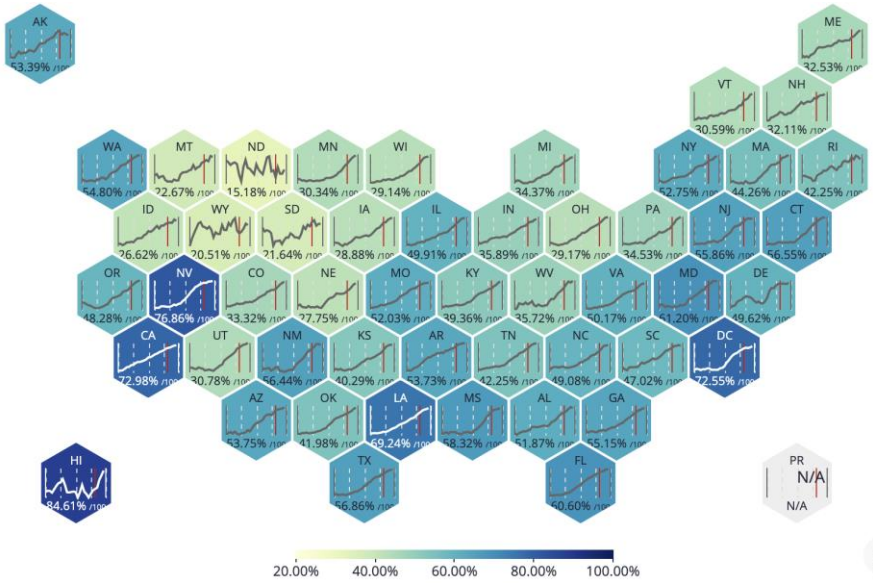
- Side Effects and waiting to see safety are primary
- Most movement in last couple weeks seen in trust of govt and efficacy

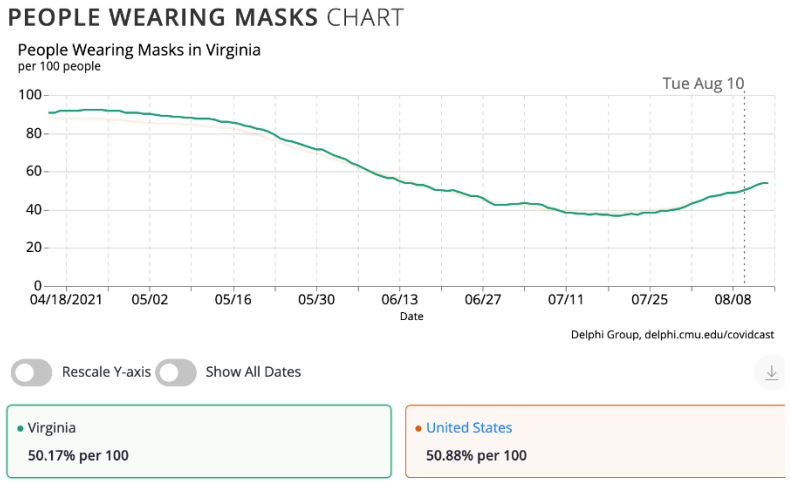
Data Source: https://covidcast.cmu.edu

Mask Usage Increases

Self-reported mask usage has declined for months, but rebounded

- State-wide up to 50% from 43% a couple weeks ago
- Similar to US overall, with mixed movement across VA counties





VIRGINIA COUNTIES

COUNTY	CHANGE LAST 7 DAYS	PER 100	HISTORICAL TREND 7/18–8/15
United States	↑ +13.30%	50.88% /100	8/10
Virginia	↑ +11.15%	50.17% /100	8/10
Virginia Beach, VA	↓ −4.81%	41.13% /100	8/10
Chesterfield County, VA	→ +2.12%	48.16% /100	8/10
Chesapeake, VA	↑ +28.49%	50.23% /100	8/10
Albemarle County, VA	+100.00%	52.66% /100	8/10
Norfolk, VA	↑ +11.61%	53.12% /100	8/10
Loudoun County, VA	↑ +15.61%	56.87% /100	8/10
Hampton, VA	+100.00%	57.75% /100	8/10
Henrico County, VA	↑ +23.15%	58.71% /100	8/10
Arlington County, VA	→ +3.82%	60.85% /100	8/10
Prince William County, VA	↑ +5.87%	62.96% /100	8/10
Newport News, VA	↑ +20.47%	65.08% /100	8/10
Fairfax, VA	↑ +13.01%	67.12% /100	8/10
Richmond, VA	↑ +39.38%	70.24% /100	8/10

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

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Mask Wearing by Vaccine Willingness

Among the different tiers of vaccine acceptance, mask wearing increasing

- Only those who would "definitely not" take the vaccine if offered have a low level of mask usage
- "Probably Not" beginning to stagnate in mask usage
- All other Vaccine willingness levels have similar mask wearing levels

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

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
- Genomic surveillance remains very limited
  - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future

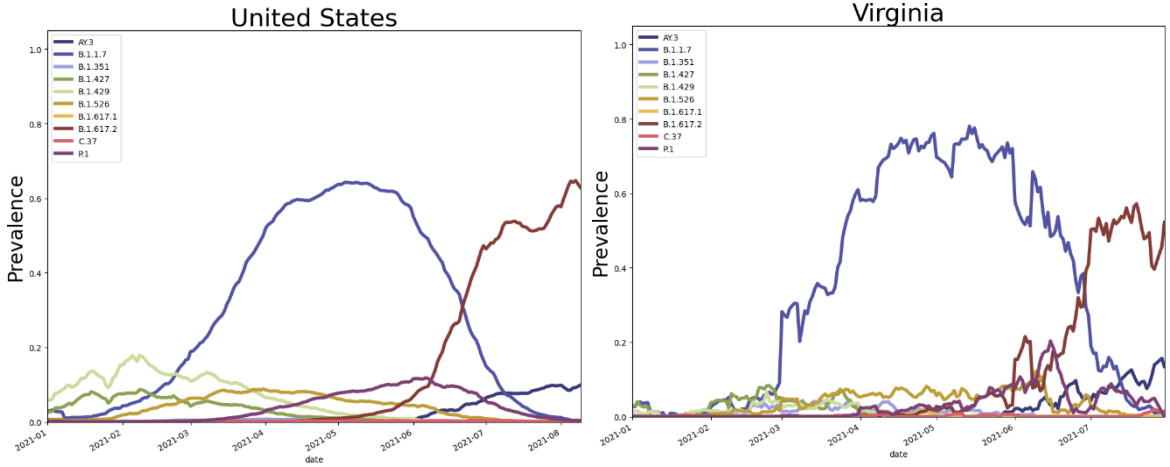
	New WHO Name	Transmissibility	Immune Evasiveness	Vaccine Effectiveness^
Ancestral		—	—	✓
D614G		+	—	✓
B.1.1.7	Alpha	+++	—	✓
B.1.351	Beta	+	++++	✓
P.1	Gamma	++	++	✓
B.1.429	Epsilon	+	+	✓
B.1.526	Iota	+	+	✓
B.1.617.2	Delta	++++*	++#	✓

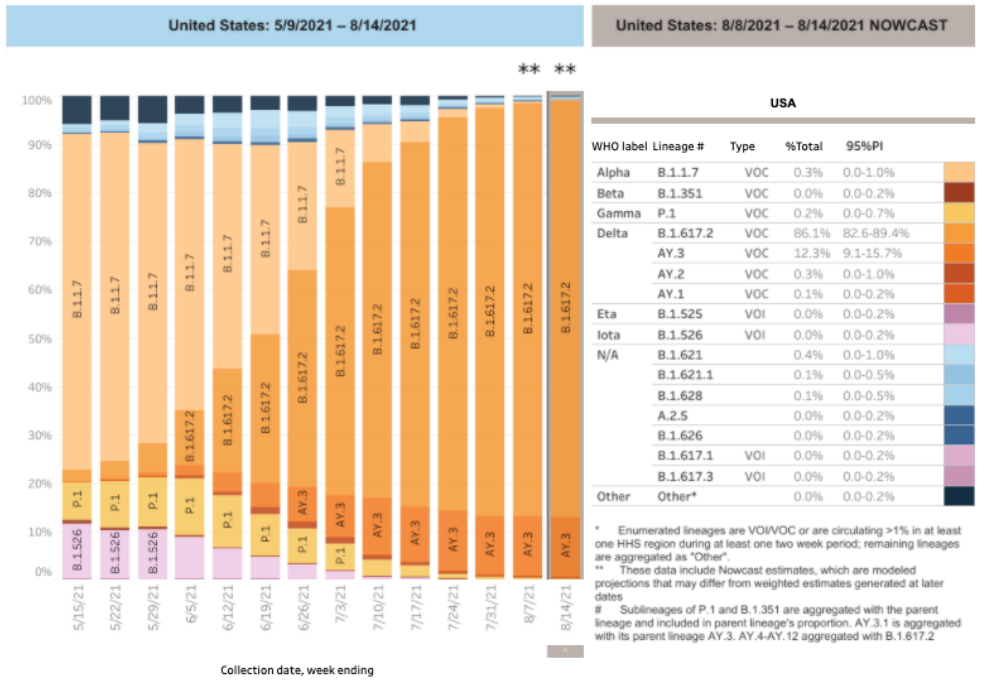
*Relative transmissibility to B.1.1.7 yet to be fully defined
^Effectiveness from real world evidence vs. severe illness, not all vaccines are effective vs all variants, and importance of 2-doses, especially for B.1.617.2 for which 1 dose of mRNA or AZ is only ~30% effective # May carry more immune escape than P.1, to be determined

World Health Organization

WHO and Eric Topol

GISAID outbreak.info





USA

WHO label	Lineage #	Type	%Total	95%PI
Alpha	B.1.1.7	VOC	0.3%	0.0-1.0%
Beta	B.1.351	VOC	0.0%	0.0-0.2%
Gamma	P.1	VOC	0.2%	0.0-0.7%
Delta	B.1.617.2	VOC	86.1%	82.6-89.4%
	AY.3	VOC	12.3%	9.1-15.7%
	AY.2	VOC	0.3%	0.0-1.0%
	AY.1	VOC	0.1%	0.0-0.2%
Eta	B.1.525	VOI	0.0%	0.0-0.2%
Iota	B.1.526	VOI	0.0%	0.0-0.2%
N/A	B.1.621		0.4%	0.0-1.0%
	B.1.621.1		0.1%	0.0-0.5%
	B.1.628		0.1%	0.0-0.5%
	A.2.5		0.0%	0.0-0.2%
	B.1.626		0.0%	0.0-0.2%
	B.1.617.1	VOI	0.0%	0.0-0.2%
	B.1.617.3	VOI	0.0%	0.0-0.2%
Other	Other*		0.0%	0.0-0.2%

* Enumerated lineages are VOI/VOC or are circulating >1% in at least one HHS region during at least one two week period; remaining lineages are aggregated as "Other".
** These data include Nowcast estimates, which are modeled projections that may differ from weighted estimates generated at later dates
# Sublineages of P.1 and B.1.351 are aggregated with the parent lineage and included in parent lineage's proportion. AY.3.1 is aggregated with its parent lineage AY.3. AY.4-AY.12 aggregated with B.1.617.2

CDC

CDC Variant Tracking

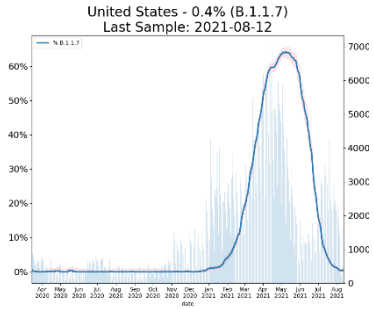
SARS-CoV2 Variants of Concern

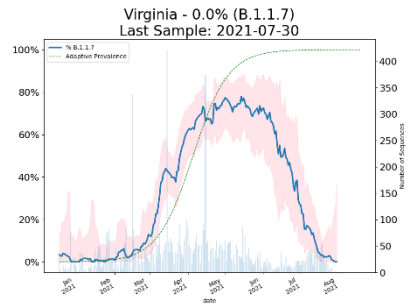
Alpha α - Lineage B.1.1.7

Prevalence: Nationally low, decline from a high of 60% (VA reached about 80%)

Transmissibility: Estimated increase of 50% compared to previous variants. B.1.1.7's mutations boost its overall levels of viremia; study from Public Health England shows contacts of B.1.1.7 cases are more likely (50%) to test positive

Severity: Increased risk of hospitalization (60%) and mortality (60%). Danish study shows B.1.1.7 to have a 64% higher risk of hospitalization, while Public Health Scotland studies showed a range of 40% to 60%; Study in Nature estimates 60% higher mortality

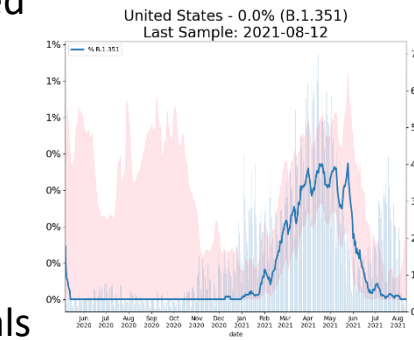


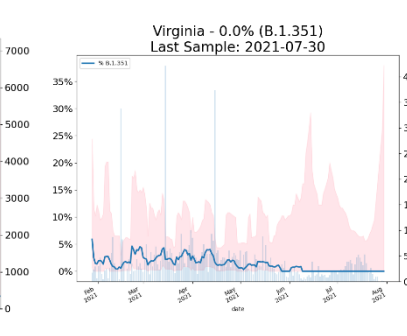


Beta β - Lineage B.1.351

Prevalence: Levels have remained low, as this variant's transmissibility can't compete with B.1.1.7, however, as more of the population becomes immune it may gain an advantage

Immune Escape: Many studies show that convalescent sera from previously infected individuals does not neutralize B.1.351 virus well which is predictive of protection, however, vaccine induced immunity shows signs of effectiveness

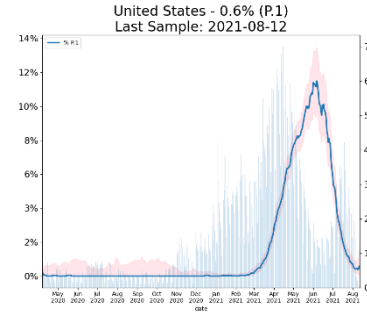


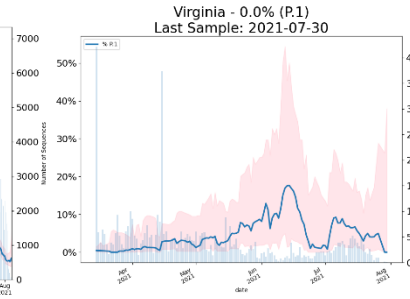


Gamma γ - Lineage P.1

Prevalence: Nationally low, declining from a high of 12%

Study estimates 17-32% of all infections in Manaus in 2021 were reinfections, which helps explain data from Brazil demonstrating P.1's continued dominance in Rio despite presence of B.1.1.7

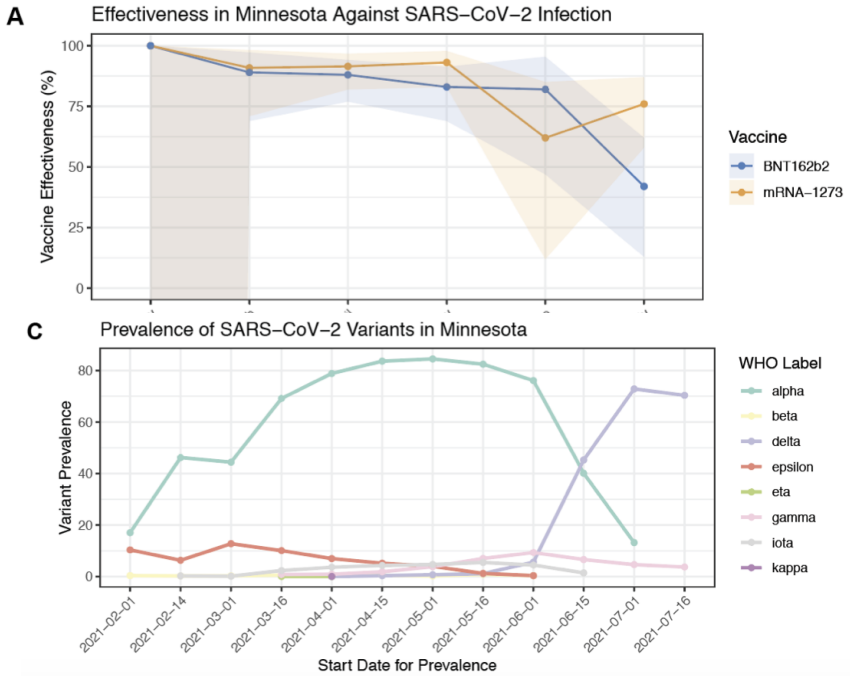




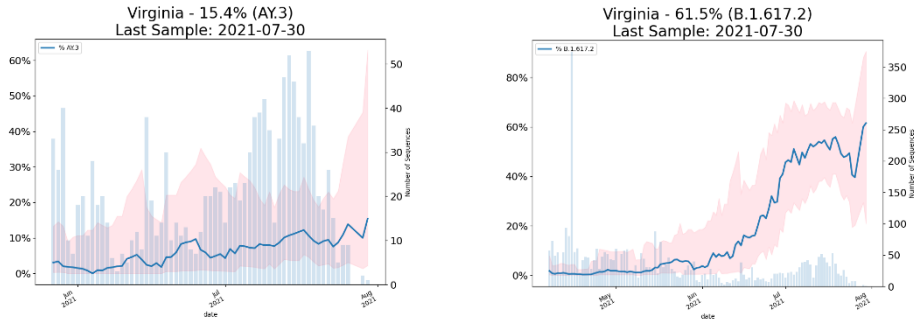
SARS-CoV2 Variants of Concern

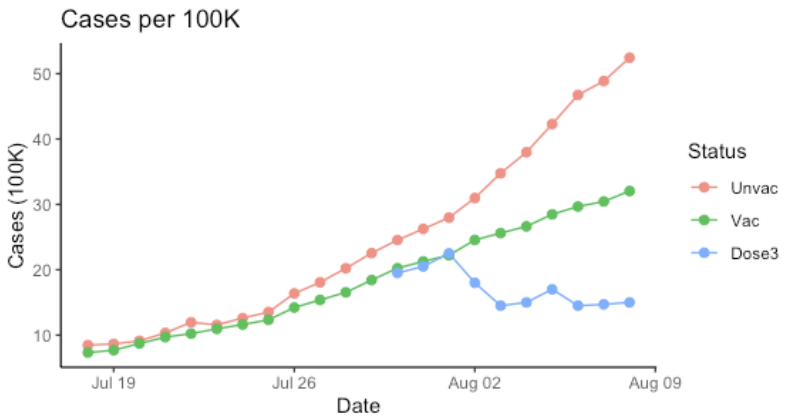
Delta δ - Lineage B.1.617.2 and related subvariants

- Delta plus δ+ lineage which contains the K417N mutation is emerging as a sub-variant that is even more transmissible; declared a VoC in India
- Delta variant now dominates most of Europe and US
- CDC recommends resumption of mask wearing indoors due to reports of breakthrough infections of the vaccinated possibly being transmissible
- Recent study from Mayo clinic shows Delta reducing the efficacy of mRNA vaccines (Pfizer more so than Moderna) along with other reports. Israeli study showed 64% efficacy against infection, however, a 3rd dose may counteract this reduction
- Public Health Scotland study in Lancet suggests Delta is 2x more likely to cause hospitalization than Alpha
- Subvariant AY.3 of Delta is increasingly prevalent (15.4%), may be more transmissible than Delta itself



Vax effectiveness drops as Delta rises.
Measured effectiveness of Pfizer (BNT162b2) and Moderna (mRNA-1273) over time in the Mayo Clinic health system. BioRxiv

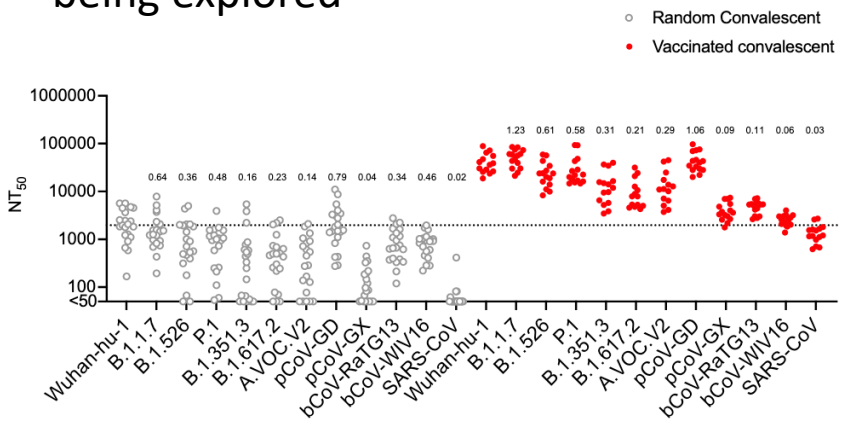




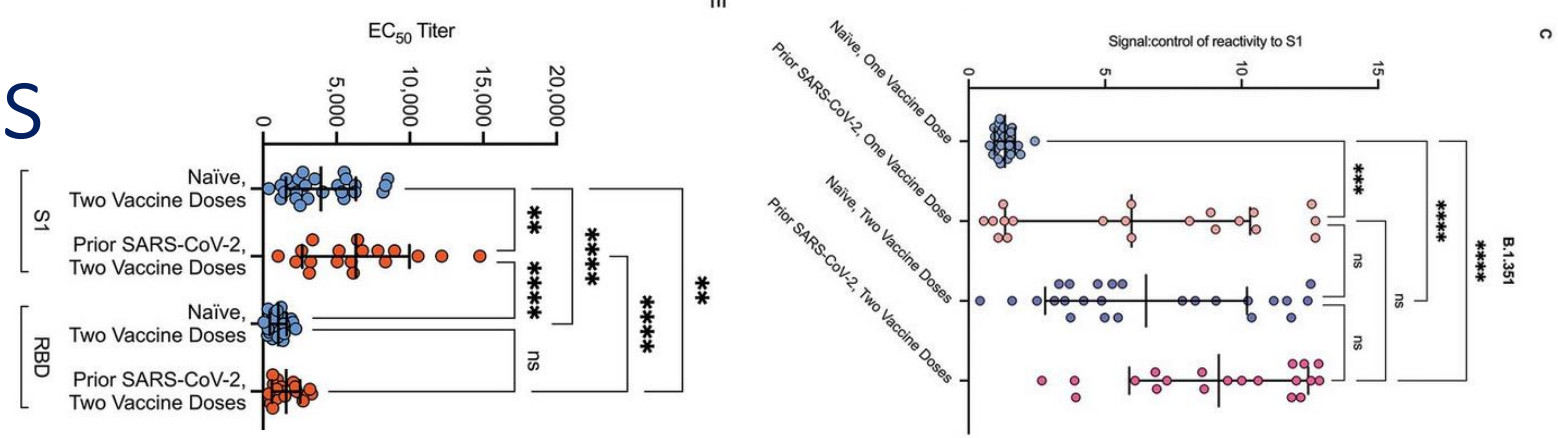
3rd dose of Vax seems to be more effective even against Delta
Preliminary data on third dose against Delta in Israel
Eric Topol
Israeli gov data

Variants & Vaccines

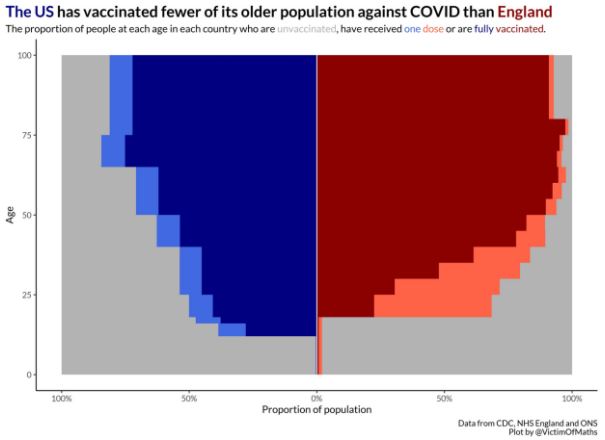
- Exposure to natural infection in between doses may broaden an individual's immune response
- Meta-analysis shows most cases develop some long-term symptom
- GISAID strain acceptance may bias analysis of existing variants
- US lags UK in protection of elderly
- Future targets for vax improvements being explored



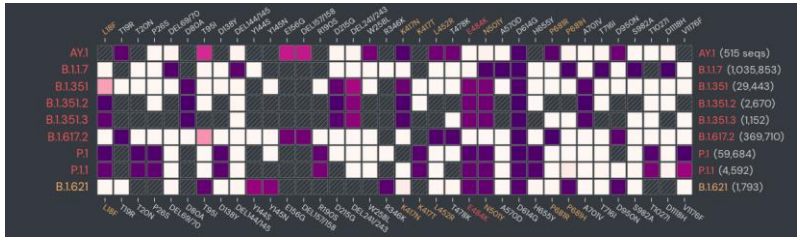
Recent preprint from Rockefeller University showed that neutralizing activity against SARS-CoV-2 is polyclonal and heterogeneous among individuals with respect to epitope targets, indicating potential enhancements to future vaccines. Additionally showed significant potency and breadth of neutralization to various mutant profiles **following mRNA vaccination** of previously SARS-CoV-2 infected individuals.
https://www.biorxiv.org/content/10.1101/2021.08.06.455491v1.full.pdf



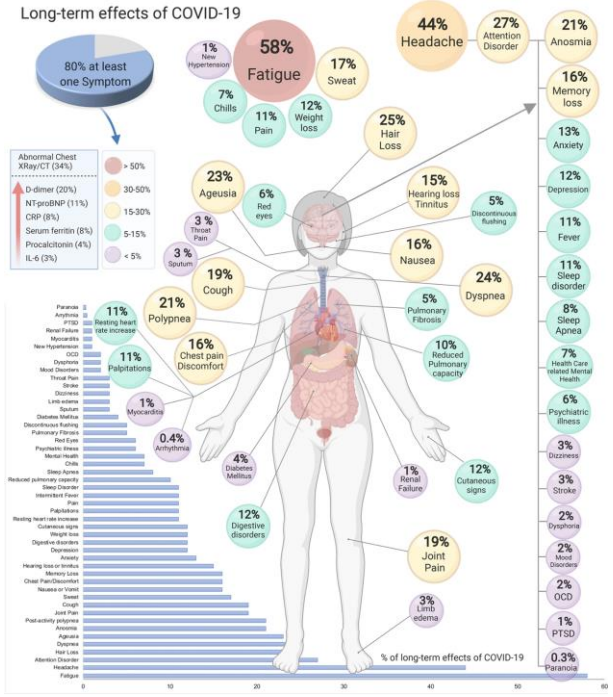
Researchers at University of Nottingham show that multiple exposures to SARS-CoV-2 spike protein in the context of a delayed second dose expand the neutralizing breadth of the antibody response to neutralization-resistant SARS-CoV-2 variants.
https://stm.sciencemag.org/content/early/2021/08/10/scitranslmed.abj0847



https://twitter.com/VictimOfMaths/status/1425109797750333449



Potential biases of using only data pulls from GISAID for surveillance. B.1.621 sequences being rejected
https://twitter.com/NathanGrubaugh/status/1420797454782402560

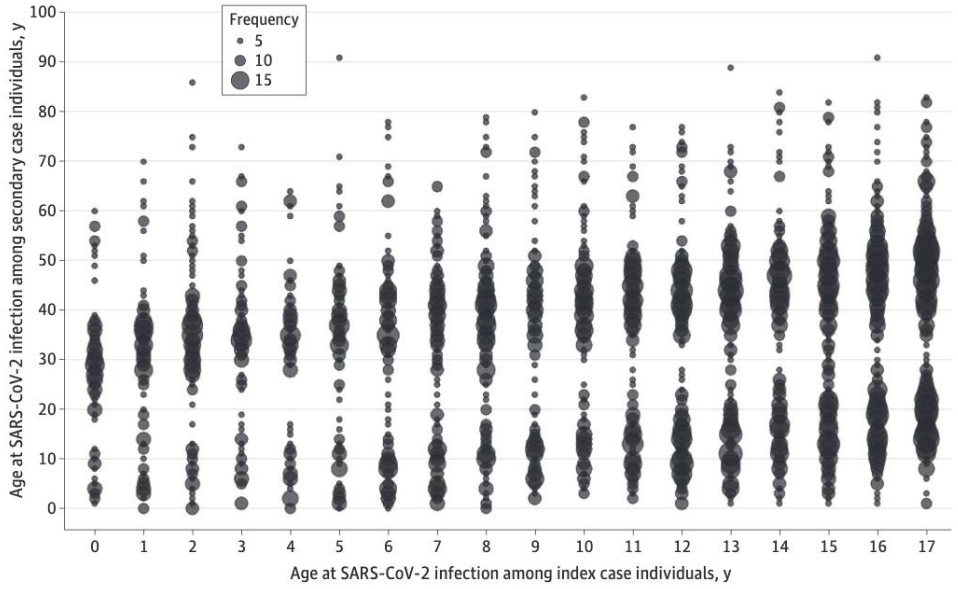


Meta-analysis estimated that 80% of the infected patients with SARS-CoV-2 developed one or more long-term symptoms.
https://www.nature.com/articles/s41598-021-95565-8

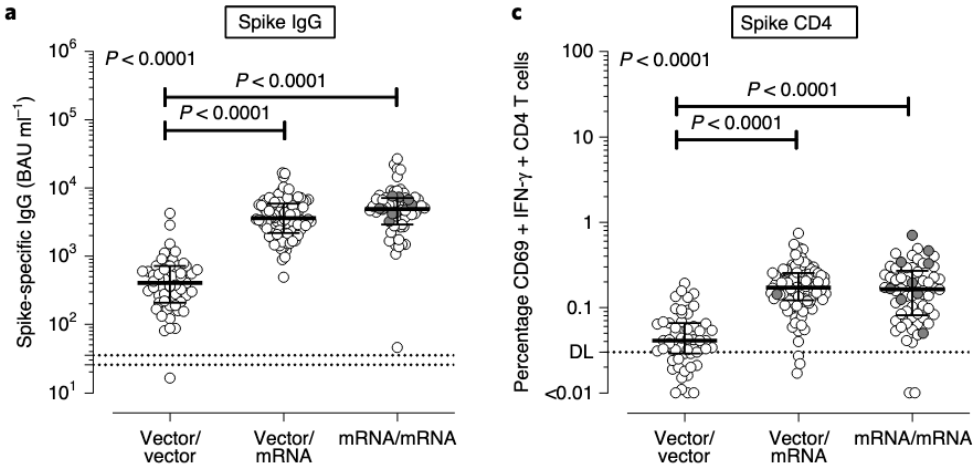
Intervention Studies

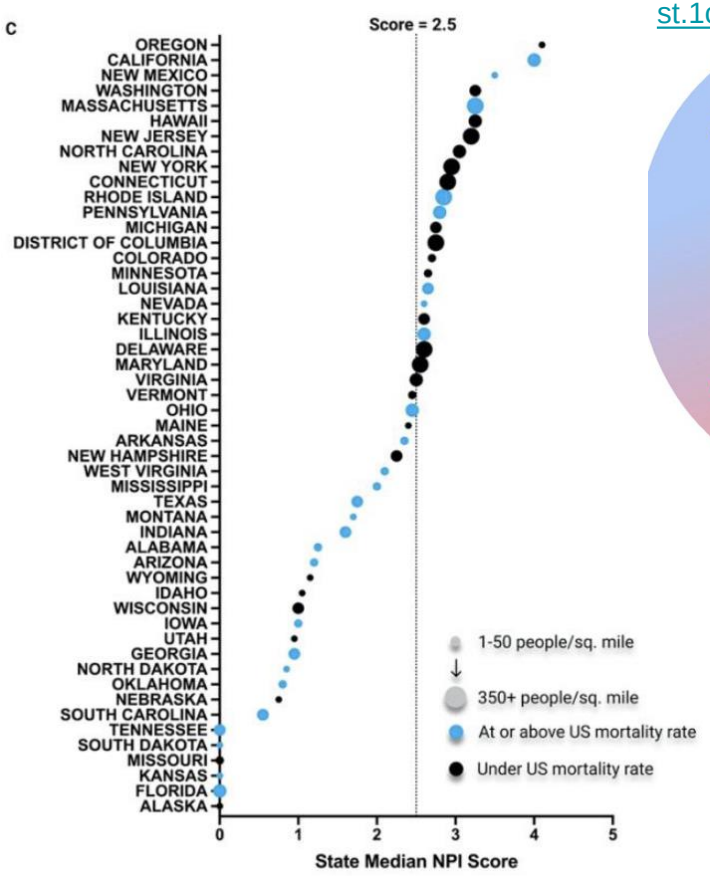
Outcomes	2 doses versus no dose		1 dose versus no dose		2 doses vs no dose >=14 days		1 dose vs. no dose >=21 days		Previous infection versus no infection	
	Effectiveness	95%CI	Effectiveness	95%CI	Effectiveness	95%CI	Effectiveness	95%CI	Effectiveness	95%CI
Symptomatic infections	24%	6 to 38	4%	-26 to 27	28%	10 to 41	18%	-10 to 38	93%	87 to 96
Moderate to Severe Disease	65%	42 to 79	7%	-68 to 48	67%	44 to 81	37%	-24 to 68	89%	57 to 97
Need for oxygen therapy	75%	42 to 89	12%	-111 to 63	76%	37 to 89	53%	-44 to 85	85%	-9 to 98
Deaths	97%	43 to 99.8	70%	-157 to 97	97%	43 to 99.8	69%	-160 to 97	NA	NA

A recent study from New Delhi characterizes the effectiveness of the **AstraZeneca** vaccine against the Delta variant. Researchers found that **efficacy was only 18% effective at preventing symptomatic infections among HCW after 21 days.** https://www.ejinme.com/action/showPdf?pii=S0953-6205%2821%2900271-5



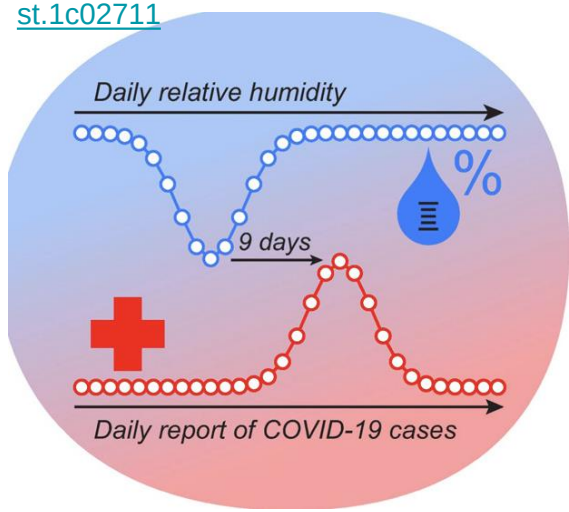
Ontario study of 6280 households maps the frequency and distribution of age among 1717 secondary attacks. Showed that **younger children (0-3 years) may transmit covid more frequently to their household than other age segments** https://jamanetwork.com/journals/jamapediatrics/fullarticle/2783022





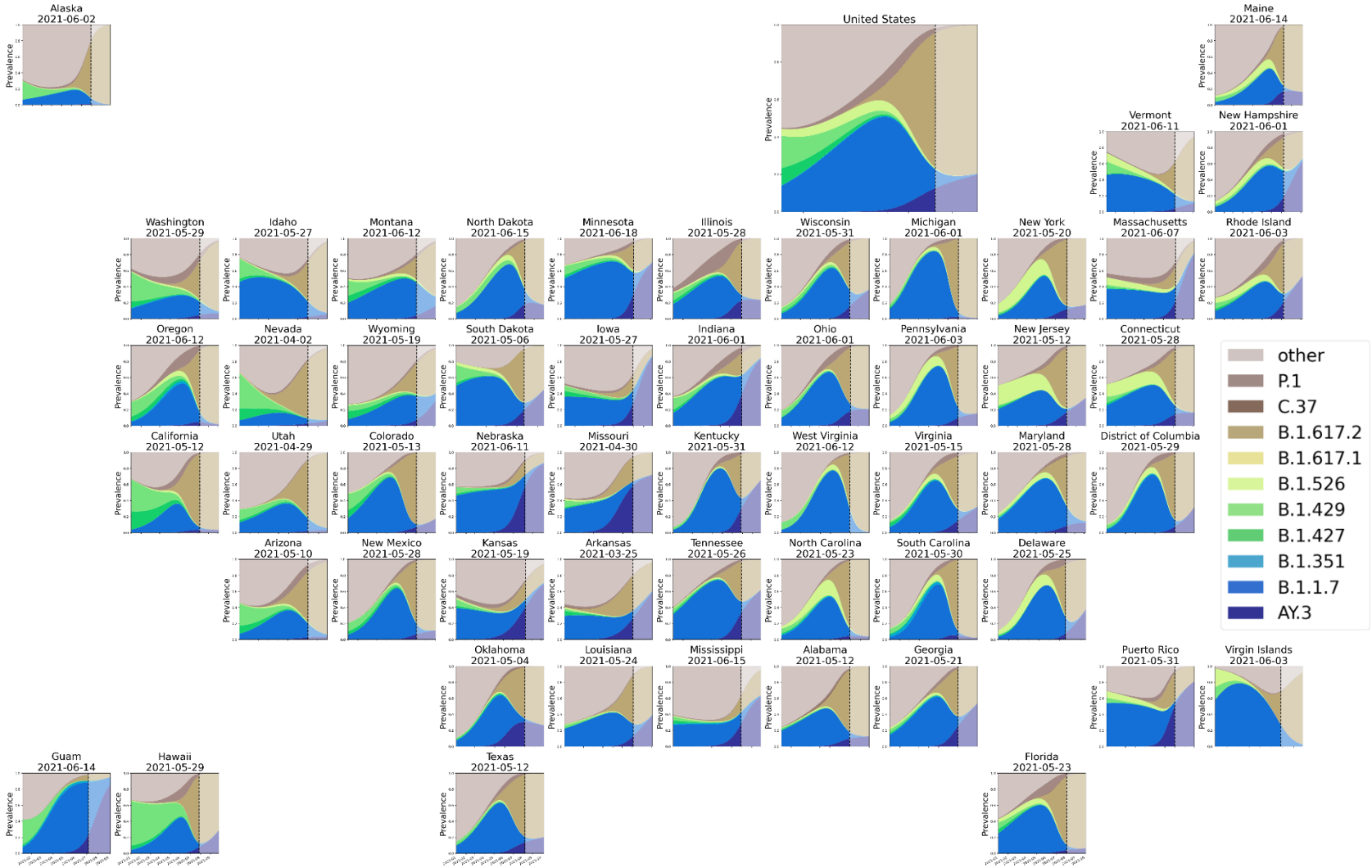
Heterologous vector/mRNA **boosting** induces **strong humoral and cellular immune responses** with accept-
able reactogenicity profiles. https://www.nature.com/articles/s41591-021-01464-w.pdf

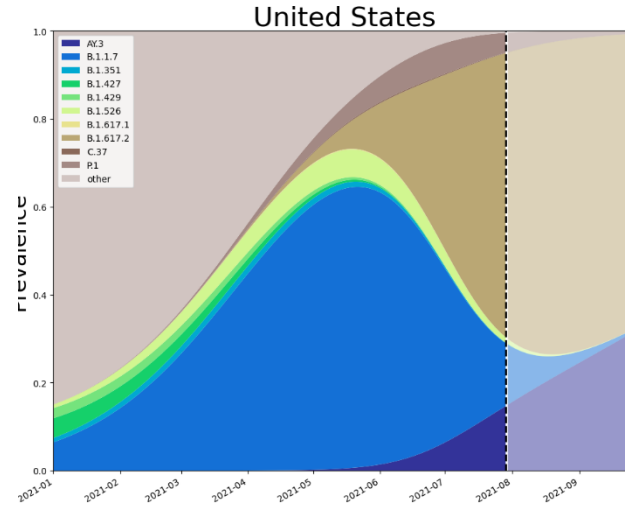
Time series analyses show that **low atmospheric humidity facilitates the transmission of COVID-19** during winter in the city of Buenos Aires. https://pubs.acs.org/doi/full/10.1021/acs.est.1c02711

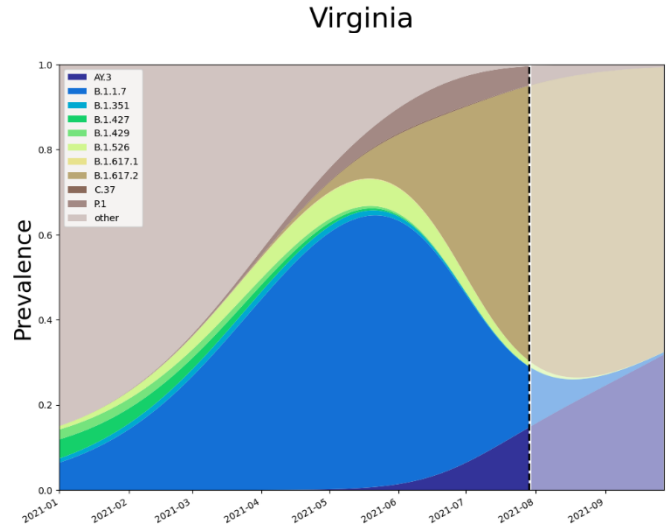


Recent CMU study found that even a **moderate amount of well-timed restrictions can have a substantial impact on lowering COVID-19** transmission. Also observed a clear geographical impact on SARS-CoV-2 trajectories. https://www.medrxiv.org/content/10.1101/2021.07.28.21261286v1.full#F3

Variant of Concern Trajectories

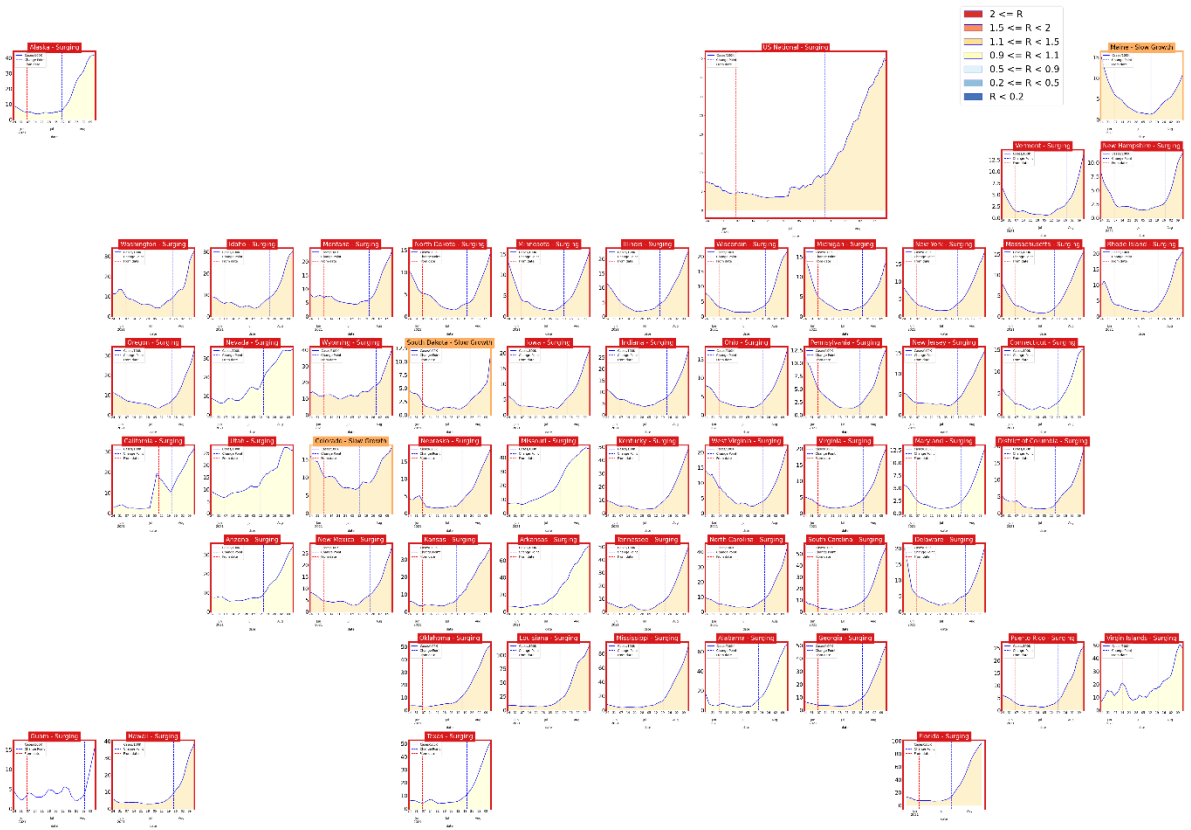






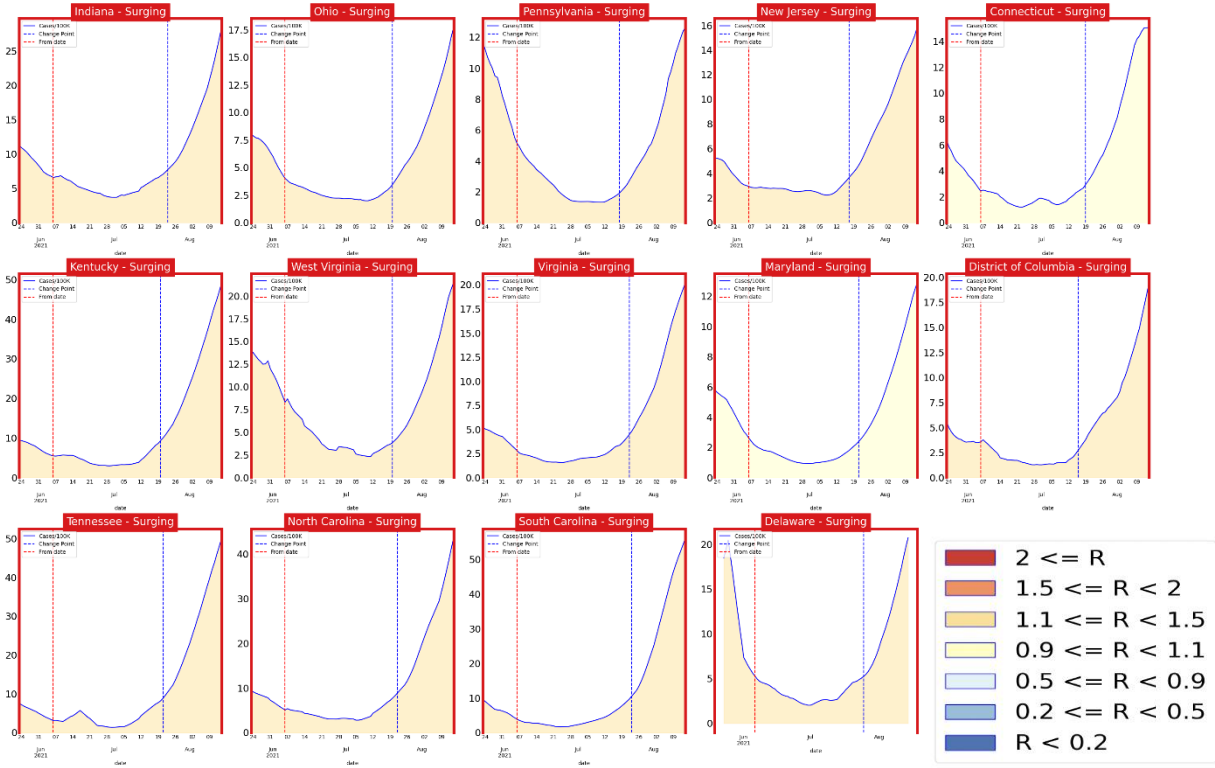
Other State Comparisons

Trajectories of States



- Most of the country is in Surge, some with very high case rates
- Early surges show some signs of slowing, but continue rapid growth

Virginia and her neighbors

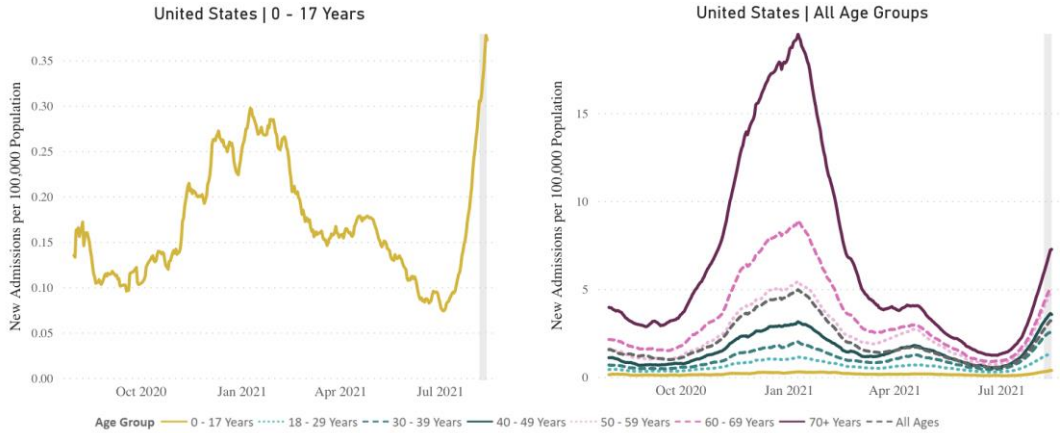


- VA and many neighbors show slight upward trends
- Many neighbors are in surge and/or have returned to rates above 10/100K

Hospitalizations across the US

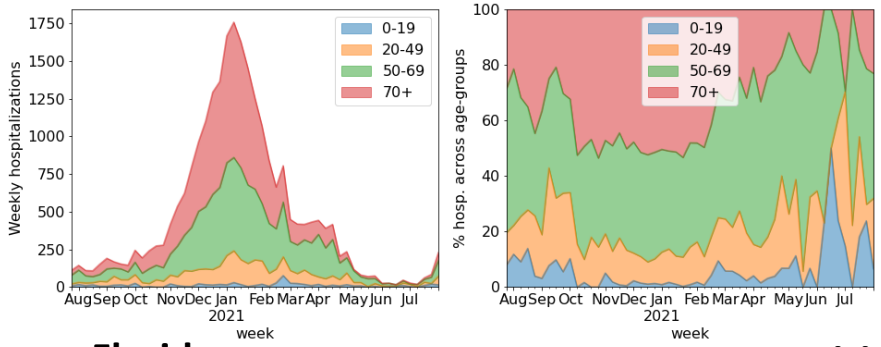
Hospitalization rates remain low in VA, but rapid change is possible as seen in other states

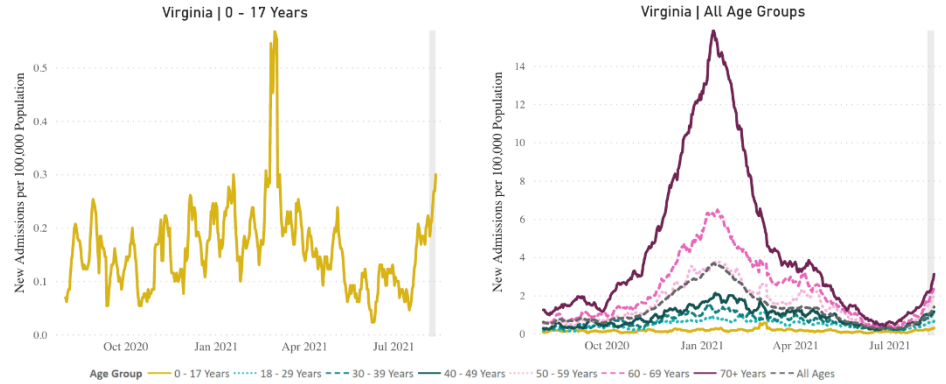
- Hotspot states see rapid rise in hospitalizations especially among the younger age groups
- Nationally pediatric hospitalizations are at an all time high since the pandemic began



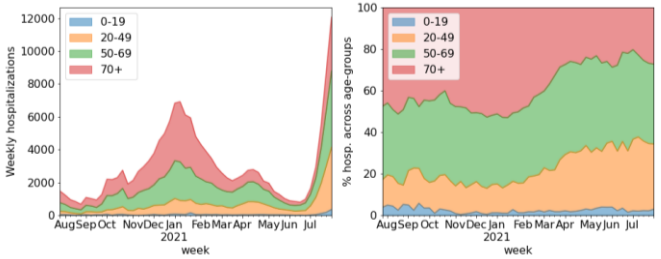
Source: https://covid.cdc.gov/covid-data-tracker/#new-hospital-admissions

Virginia

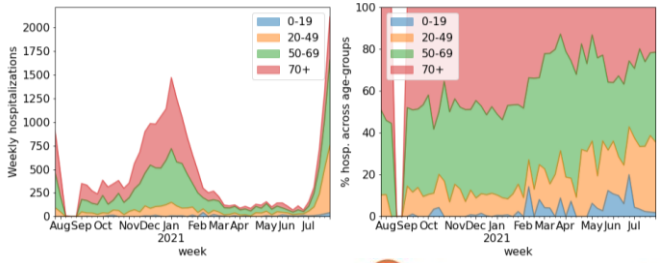


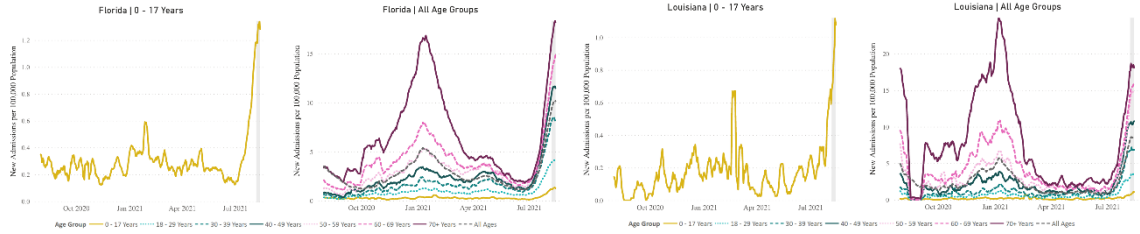


Florida



Louisiana





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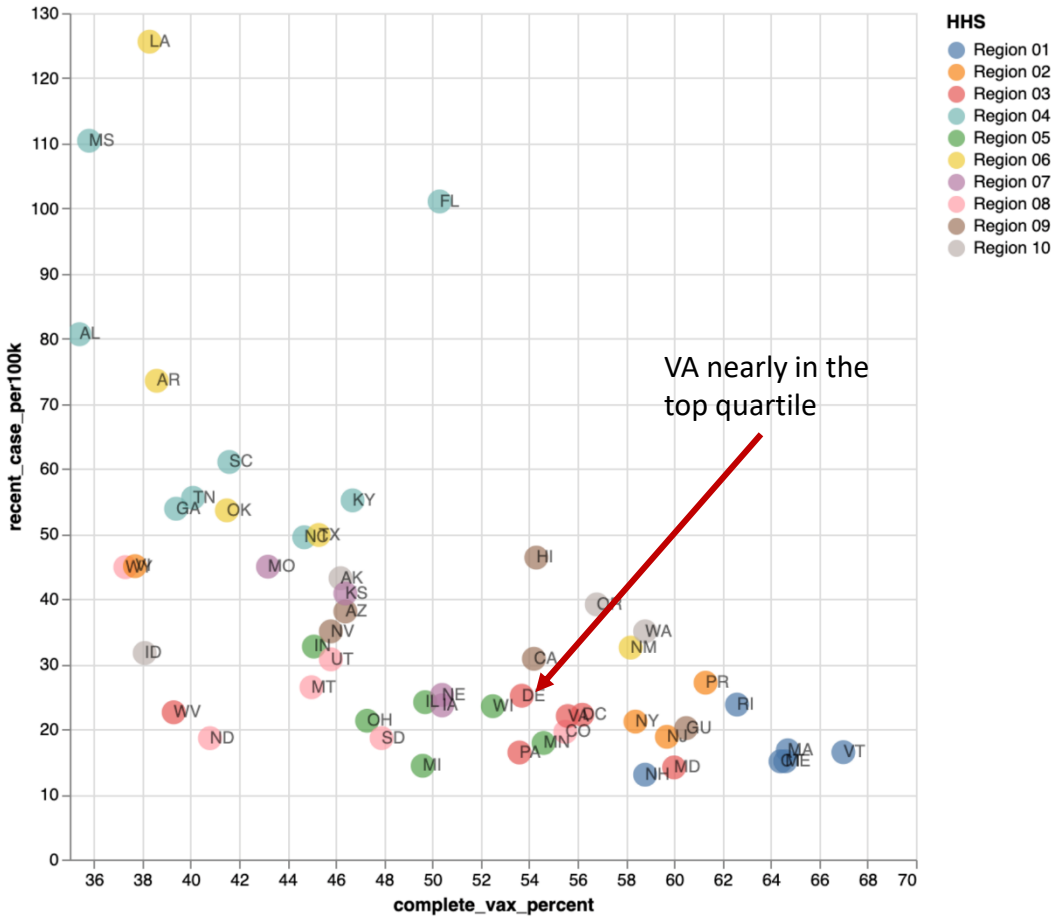
Recent Cases Correlate with Vax Coverage

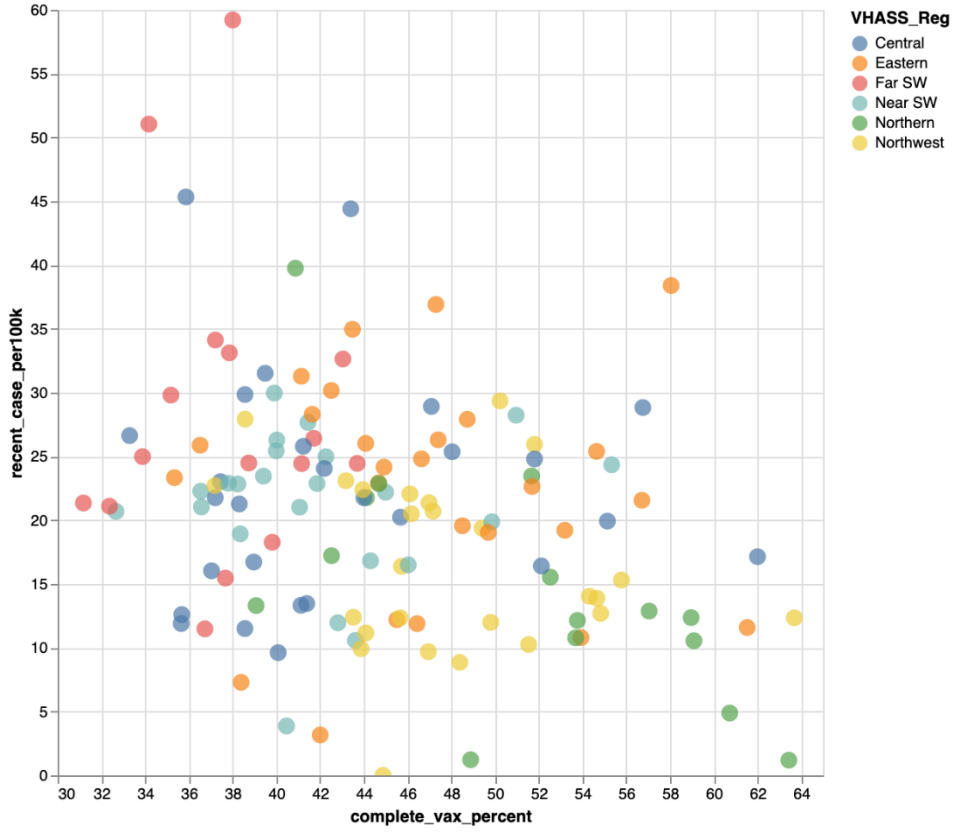
Mean cases per 100K vs. vaccine coverage

- States with lower vax coverage have had the worst case spikes
- Virginia 14th out of 51 states in fully vaccinated coverage

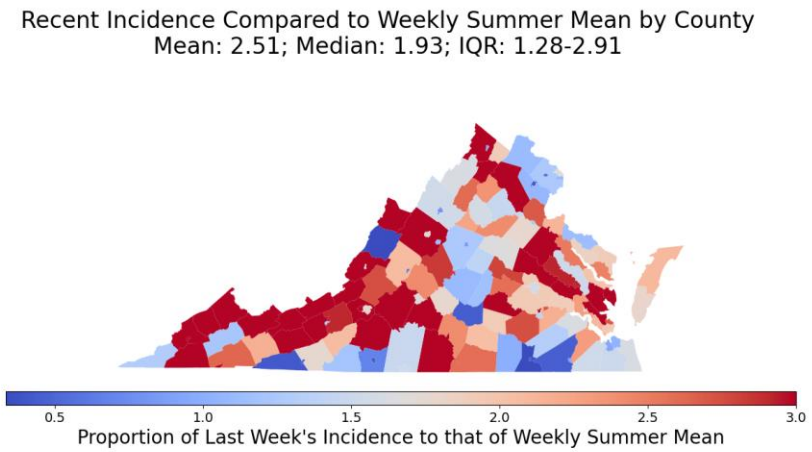


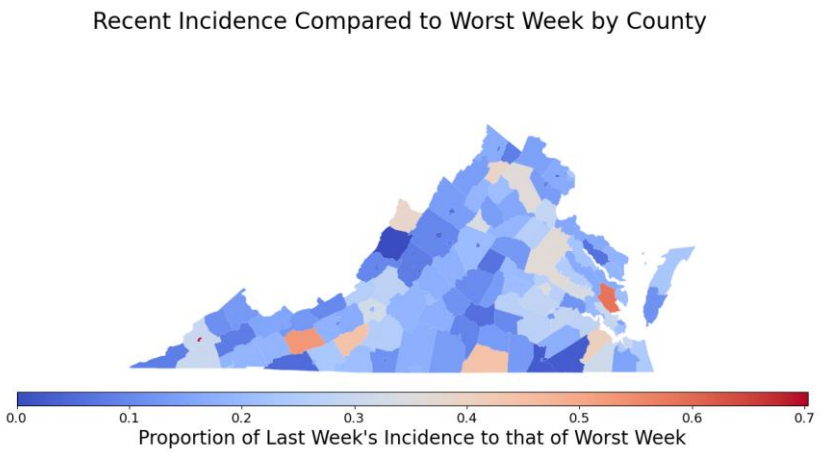
Virginia Counties

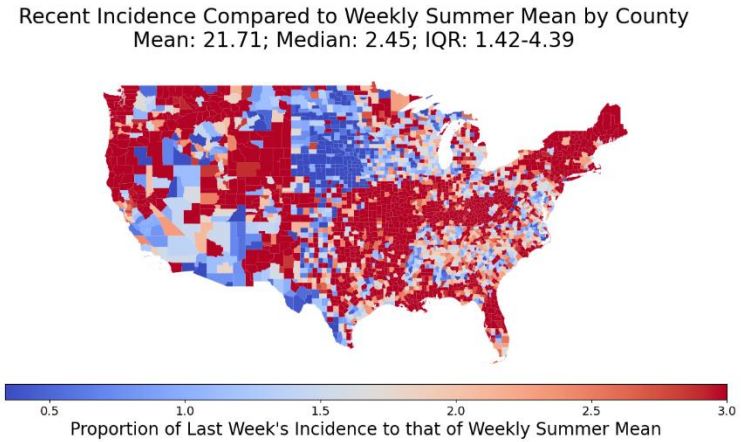
- Counties with higher vax coverage are maintaining lower case rates (e.g., Albemarle, Fairfax city)
- Many counties with low vax coverage starting to rise as delta surge reaches more remote areas of state

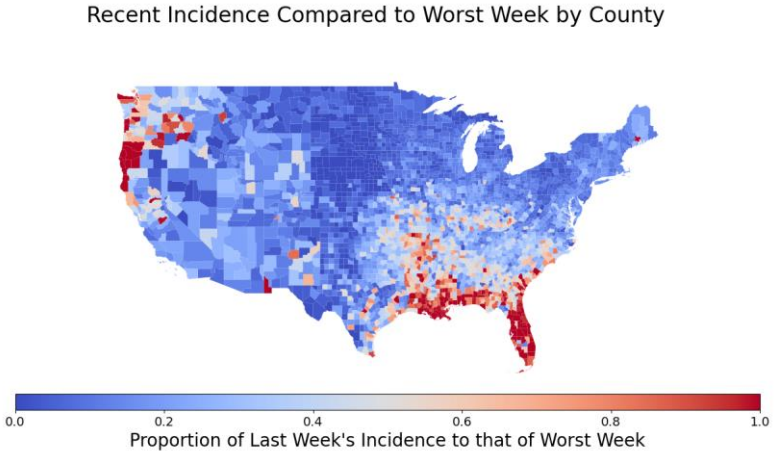


Recent Incidence Compared to Worst Week









Percentage of counties with Higher case rates

Region	Above Summer'20 Mean	Above 50% of Worst Week
Virginia	90.9%	5.3%
United States	90.7%	24.7%

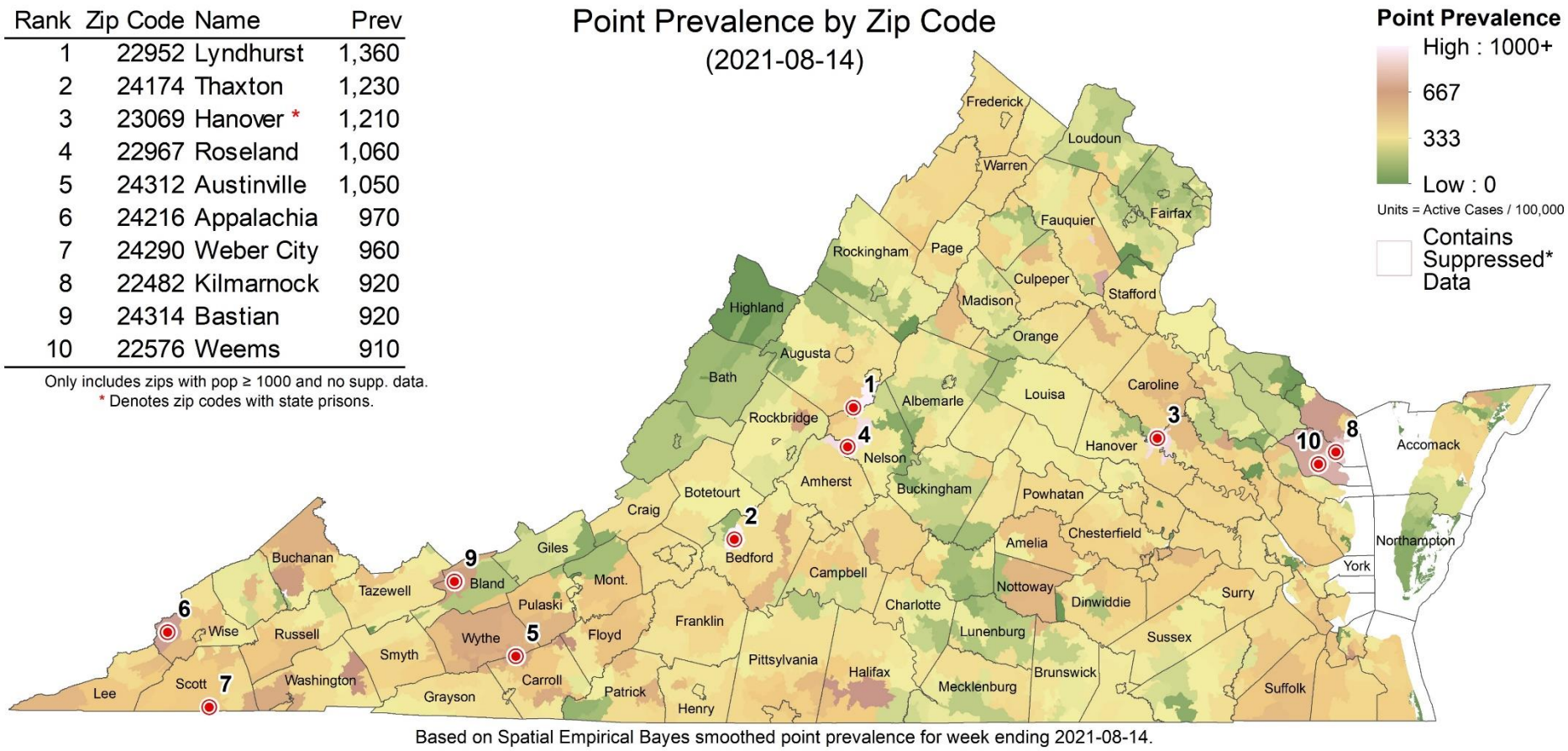
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Clusters of high prevalence in Southwest and Eastern
- Some counts are low and suppressed to protect anonymity, those are shown in white

Rank	Zip Code	Name	Prev
1	22952	Lyndhurst	1,360
2	24174	Thaxton	1,230
3	23069	Hanover *	1,210
4	22967	Roseland	1,060
5	24312	Austinville	1,050
6	24216	Appalachia	970
7	24290	Weber City	960
8	22482	Kilmarnock	920
9	24314	Bastian	920
10	22576	Weems	910

Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.

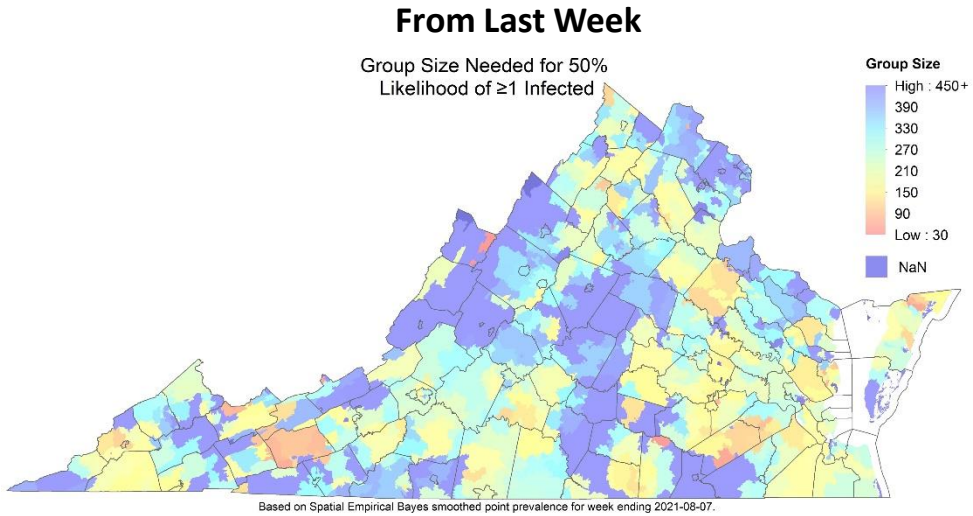


Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-08-14.

Risk of Exposure by Group Size

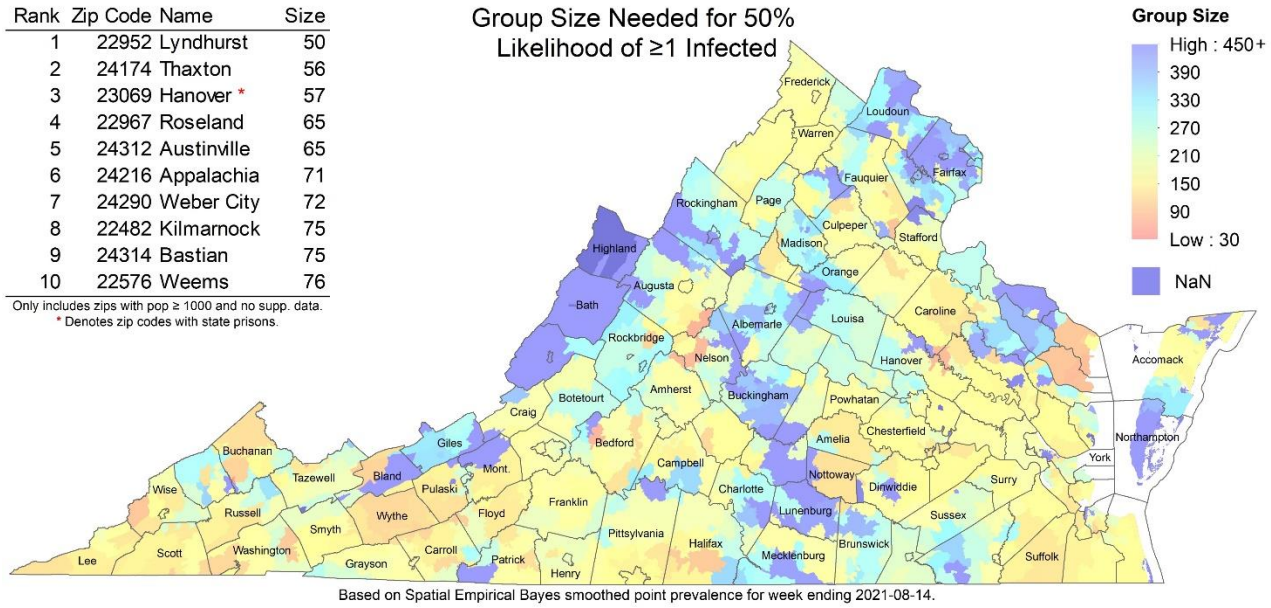
Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)

- **Group Size**: Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 50 in Lyndhurst, there is a 50% chance someone will be infected)



Rank	Zip Code	Name	Size
1	22952	Lyndhurst	50
2	24174	Thaxton	56
3	23069	Hanover *	57
4	22967	Roseland	65
5	24312	Austinville	65
6	24216	Appalachia	71
7	24290	Weber City	72
8	22482	Kilmarnock	75
9	24314	Bastian	75
10	22576	Weems	76

Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.



Current Hot-Spots

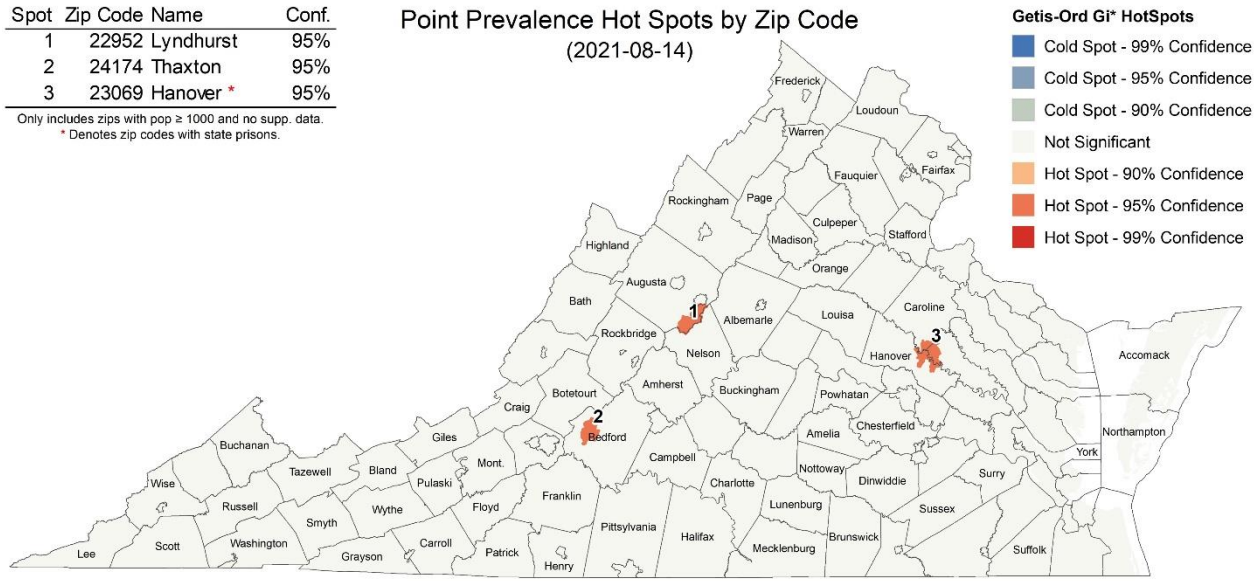
Case rates that are significantly different from neighboring areas or model projections

- **Spatial**: Getis-Ord Gi* based hot spots compare clusters of zip codes with weekly case prevalence higher than nearby zip codes to identify larger areas with statistically significant deviations
- **Temporal**: The weekly case rate (per 100K) projected last week compared to observed by county, which highlights temporal fluctuations that differ from the model's projections

Spatial Hotspots

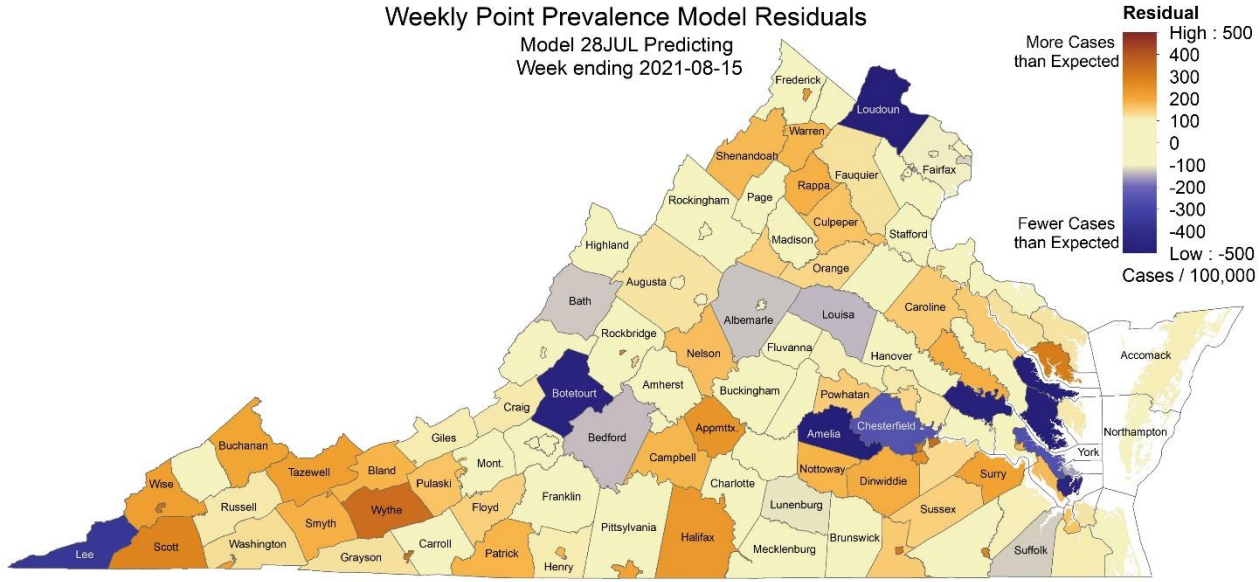
Spot	Zip Code	Name	Conf.
1	22952	Lyndhurst	95%
2	24174	Thaxton	95%
3	23069	Hanover *	95%

Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.



Based on Global Empirical Bayes smoothed point prevalence for week ending 2021-08-14.

Clustered Temporal Hotspots



Moran's I = 0.008516, Z-Score = 0.847361, P-Value = 0.396794
No Residual Autocorrelation Detected

Model Update – Adaptive Fitting

Adaptive Fitting Approach

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

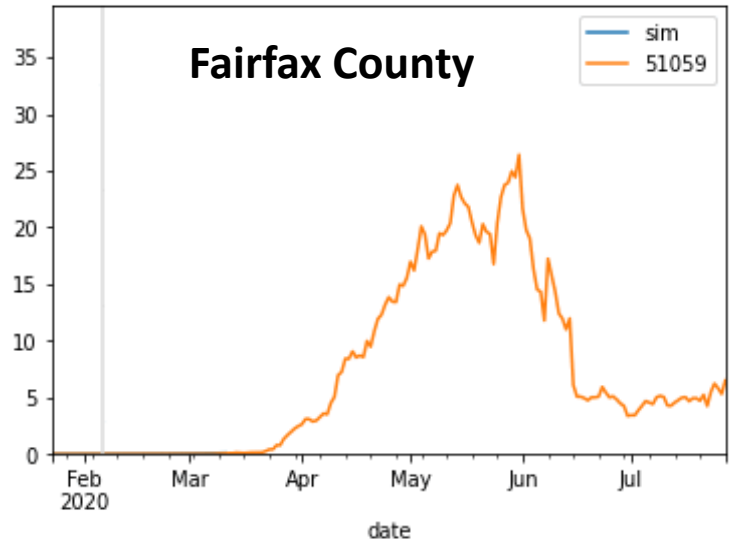
- Allows history to be precisely captured, and used to guide bounds on projections

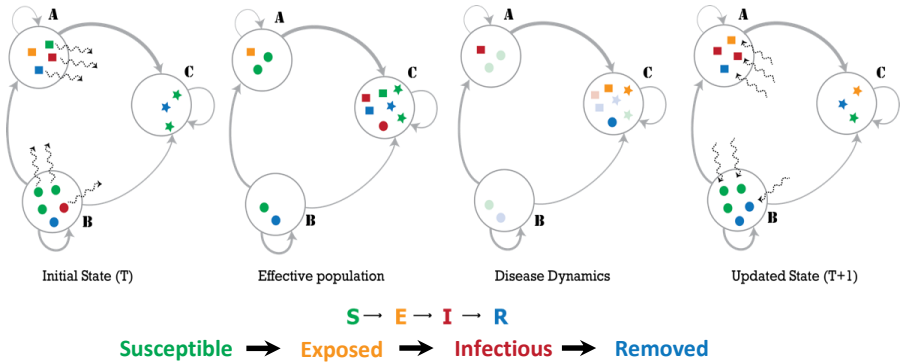
Model: An alternative use of the same meta-population model, PatchSim

- Allows for future "what-if" Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

External Seeding: Steady low-level importation

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





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Using Ensemble Model to Guide Projections

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

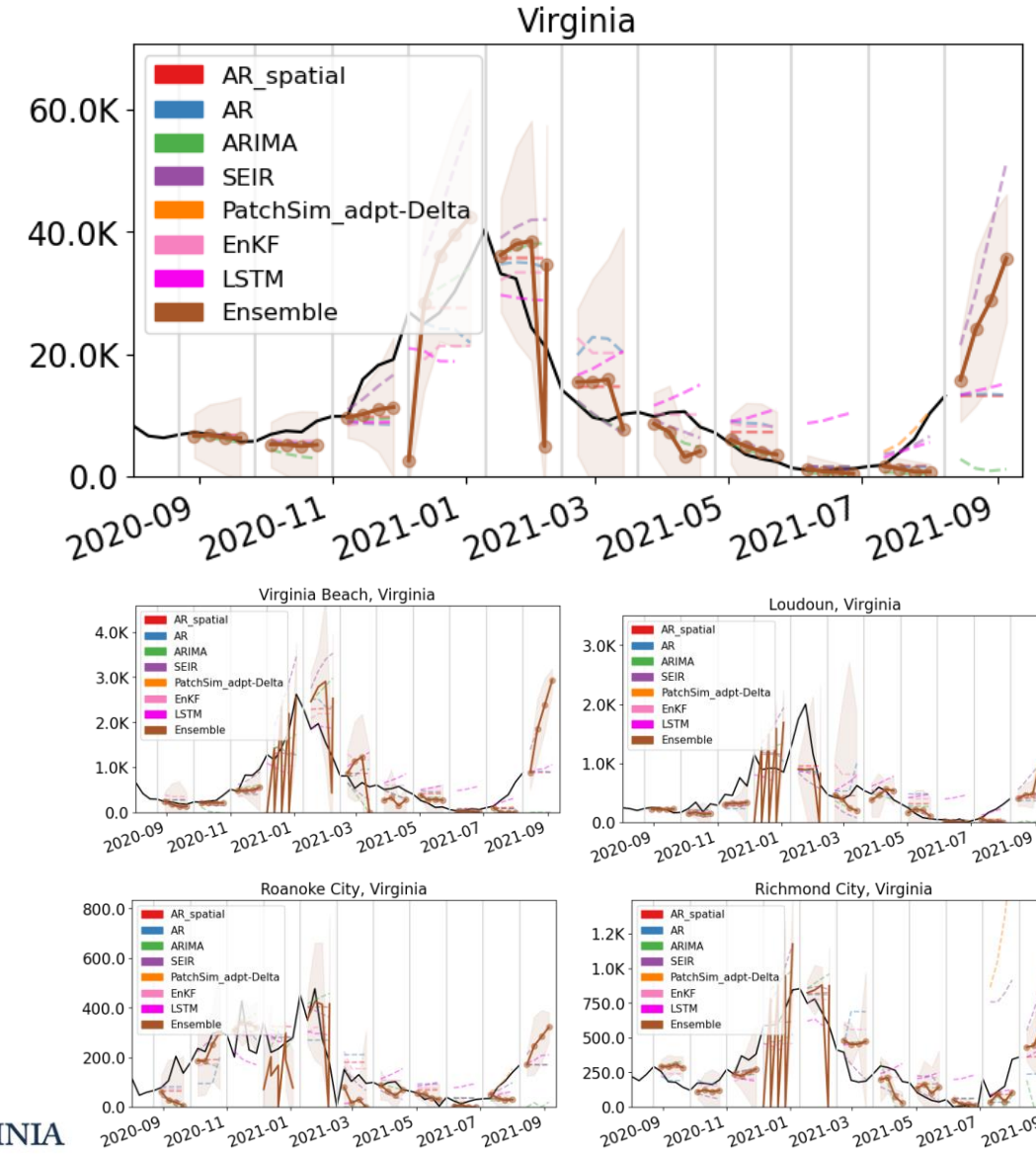
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

<u>Weekly forecasts</u> 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.



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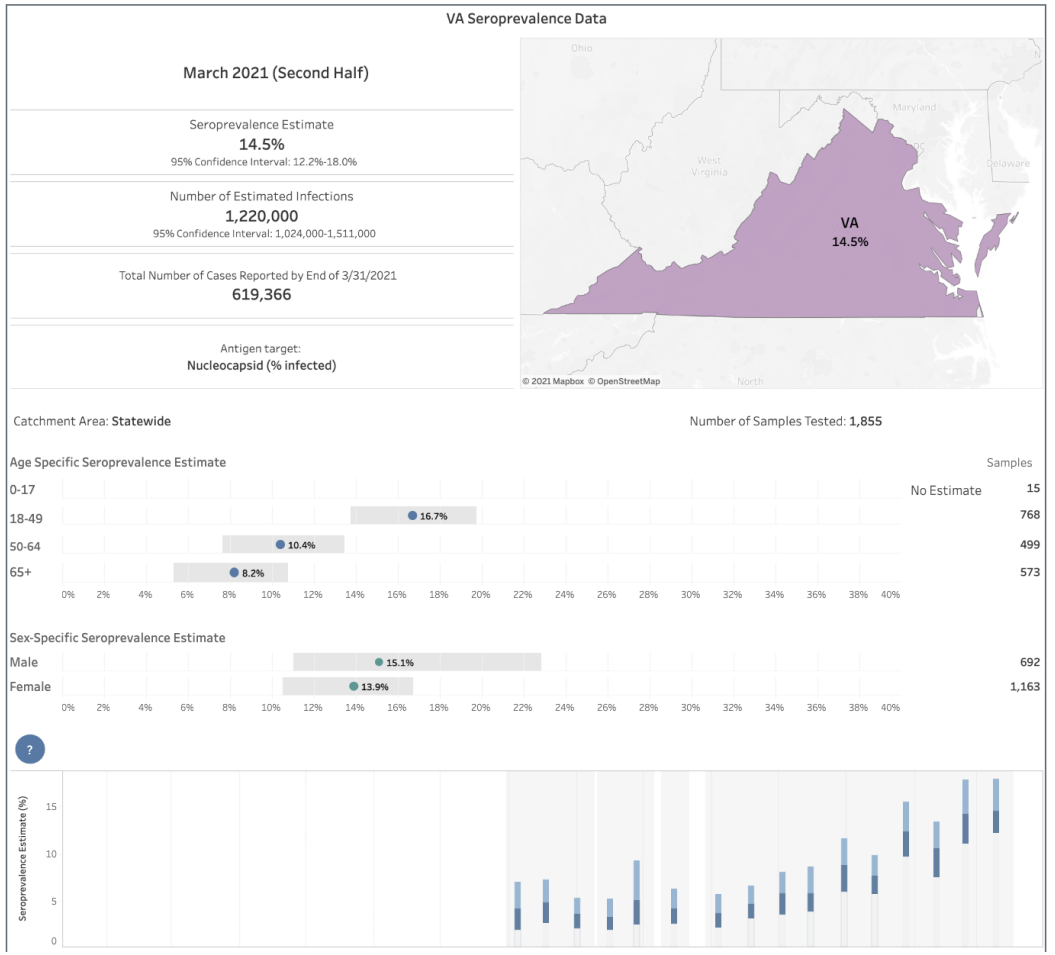
Seroprevalence updates to model design

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

- CDC Nationwide Commercial Laboratory Seroprevalence Survey estimated 14.5% [12% – 18%] seroprevalence as of March 4th – 17th up from 10.5% a month earlier

These findings are equivalent to an ascertainment ratio of ~2x in the future, with bounds of (1.3x to 3x)

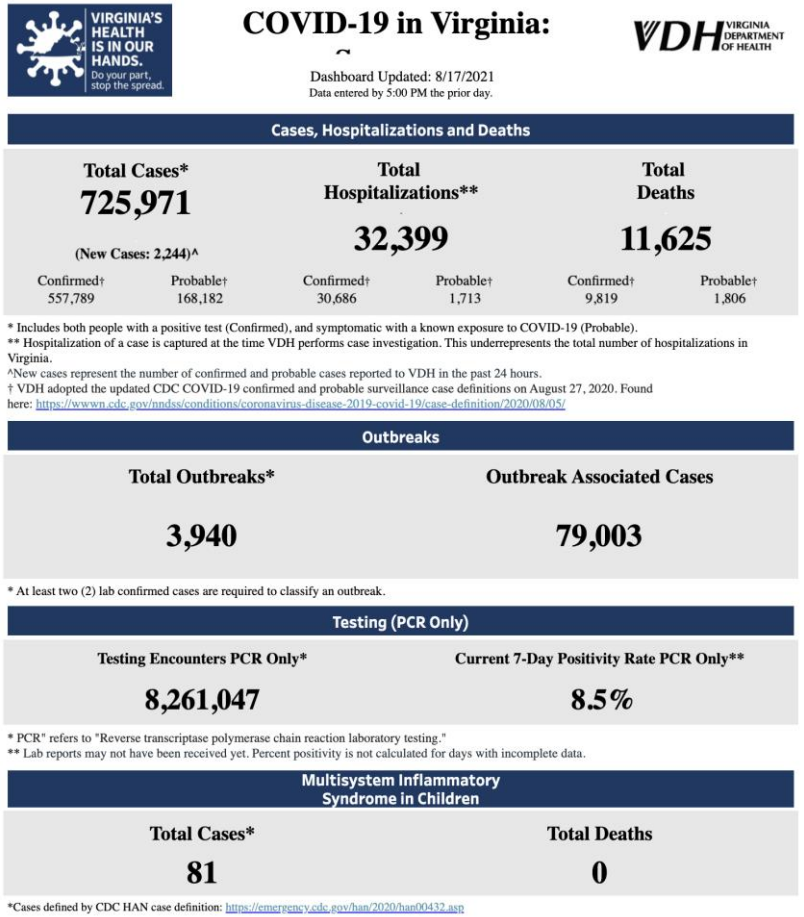
- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- This measure now fully tracks the estimated ascertainment over time
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being used)



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

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 7 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: 8/17/2021
Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths

Total Cases*	Total Hospitalizations**	Total Deaths
725,971	32,399	11,625
(New Cases: 2,244)^		
Confirmed† 557,789 / Probable† 168,182	Confirmed† 30,686 / Probable† 1,713	Confirmed† 9,819 / Probable† 1,806

* Includes both people with a positive test (Confirmed), and symptomatic with a known exposure to COVID-19 (Probable).
** Hospitalization of a case is captured at the time VDH performs case investigation. 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/

Outbreaks

Total Outbreaks*	Outbreak Associated Cases
3,940	79,003

* At least two (2) lab confirmed cases are required to classify an outbreak.

Testing (PCR Only)

Testing Encounters PCR Only*	Current 7-Day Positivity Rate PCR Only**
8,261,047	8.5%

* 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
81	0

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

Accessed 8:15pm August 17, 2021
https://www.vdh.virginia.gov/coronavirus/

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Scenarios – Transmission Conditions

- Variety of factors continue to drive transmission rates
  - Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices
- Plausible levels of transmission can be bounded by past experience
  - Assess transmission levels at the county level from May 1, 2020 – Sept 1, 2020 or current, whichever is highest
- Projection Scenario:
  - **Adaptive-Delta:** Control remains as is currently experienced into the future with assumption that Delta continues to become more dominant
  - **Adaptive-Surge Control:** Starting now behaviors and mitigation efforts ramp up over a 2-week period culminating in a 25% reduction in transmission
  - **Adaptive-SpringControl:** Immediate return to the mean levels of transmission experienced in May 2021

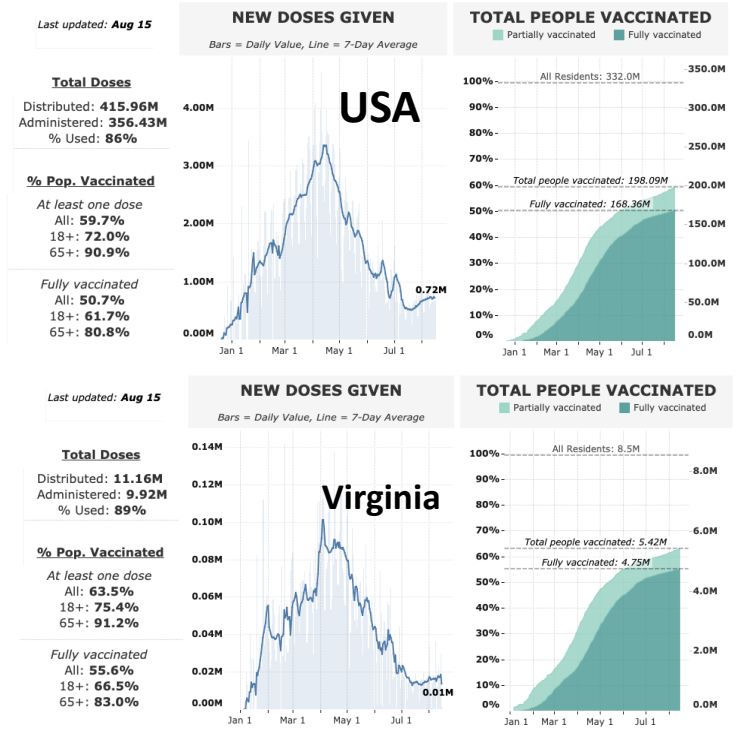
Scenarios – Vaccination Conditions

Vaccine Characteristics

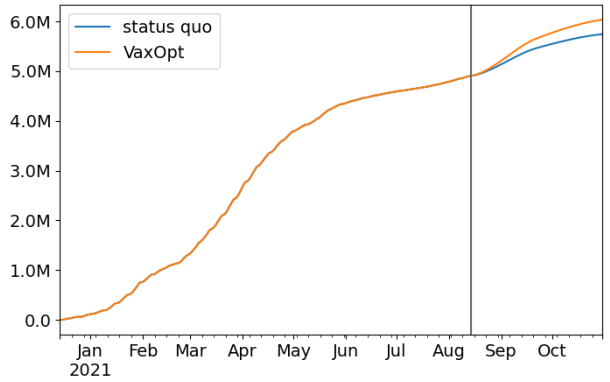
- **Pfizer/Moderna**: 50% after first dose, 95% after second dose (3.5 week gap)
- **J & J** : 67% efficacy after first (and only) dose
- Delay to efficacy from doses is 14 days, immunity lasts at least 7m (NEJM study)

Vaccine Administration Scenarios

- **Status quo (no label):** COVIDcast corrected acceptance estimates (statewide mean is ~78%) reached by end of October.
- **Optimistic (VaxOpt):** Expand VA mean acceptance to ~85% (with all counties reaching a minimum of 65%, max of 95%) by end of October
- Acceptance at county level = regional acceptance +/- relative current vax
- Front-loaded rollout (two-thirds of the remaining in half the time)



Source: https://ckelly17.github.io/vaccine_dashboard.html



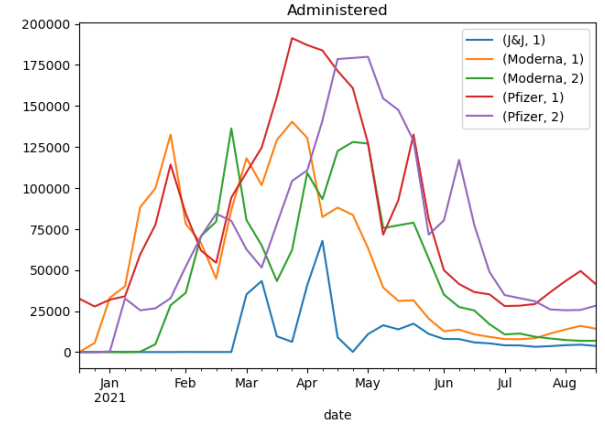
Monthly first doses

Date	status quo	VaxOpt
2020-12-31	108.8K	108.8K
2021-01-31	643.6K	643.6K
2021-02-28	556.4K	556.4K
2021-03-31	1.3M	1.3M
2021-04-30	1.2M	1.2M
2021-05-31	572.6K	572.6K
2021-06-30	241.6K	241.6K
2021-07-31	195.4K	195.4K
2021-08-31	339.5K	406.3K
2021-09-30	418.4K	571.6K
2021-10-31	206.3K	277.7K

Cumulative

Date	status quo	VaxOpt
2020-12-31	108.8K	108.8K
2021-01-31	752.4K	752.4K
2021-02-28	1.3M	1.3M
2021-03-31	2.6M	2.6M
2021-04-30	3.8M	3.8M
2021-05-31	4.3M	4.3M
2021-06-30	4.6M	4.6M
2021-07-31	4.8M	4.8M
2021-08-31	5.1M	5.2M
2021-09-30	5.5M	5.8M
2021-10-31	5.7M	6.0M

Weekly VA doses administered by manufacturer



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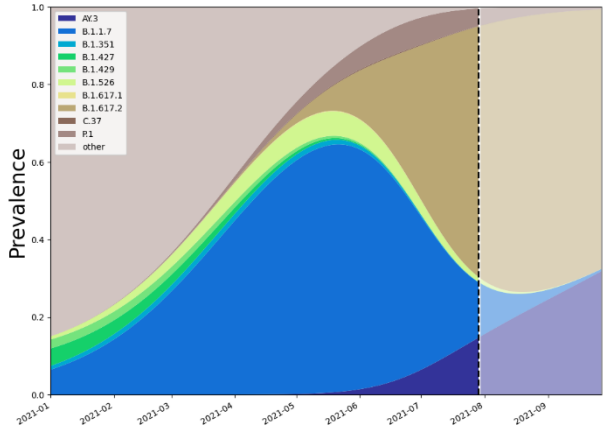
Scenarios – Delta δ Variant Condition

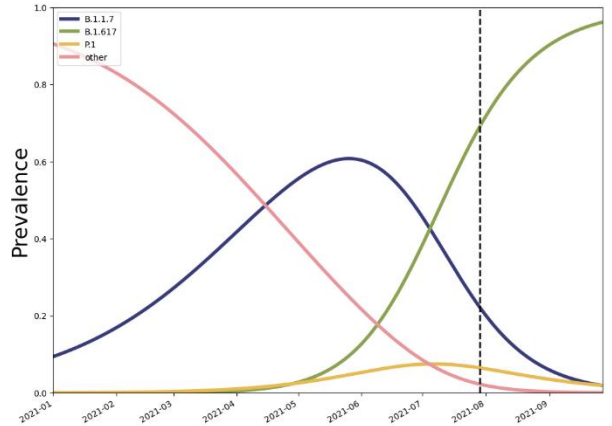
Variant Delta δ has exhibited ability to outcompete other variants and now is dominant in the US and most states

Transmissibility: Delta's relative transmissibility compared to Alpha is better understood (60% more transmissible) and its weighted growth fits a 60% growth advantage well

Immune Escape: Delta has been observed to evade immunity, both natural and vaccine-induced, however, uncertainty remains high thus this is **NOT** factored into the model

Severity: Delta, similar to Alpha, appears to cause more severe illness with estimates ranging from 50% to 200%, at the moment assume 60%





Delta Variant Scenario:

- Continues to grow on 60% more transmissible trajectory, reached 50% prevalence on June 29th and is also 60% more severe than Alpha

Projection Scenarios – Combined Conditions

Name	Txm Controls	Variant Boosting	Vax	Description
Adaptive-Delta	C	60%	SQ	Likely trajectory based on conditions remaining similar to now, but with increasing prevalence of Delta variant
Adaptive-Delta-VaxOpt	C	60%	VO	Vaccination through October reaches an optimistically high level of expanded coverage (85%), with increasing prevalence of Delta variant
Adaptive-SurgeControl	25%	60%	SQ	Transmission rates in the next month reduced through increased control from non-pharmaceutical interventions, with status quo vax and Delta
Adaptive-SpringControl	Spring	60%	SQ	Transmission rates return the rates experienced in May 2021 with status quo vaccination and increasing prevalence of Delta

Transmission Controls: C = Current levels persist into the future
25% = Transmission rates are reduced by 25% with a gradual introduction, concluding in 4 weeks
Spring = Transmission rates return to May 2021 levels

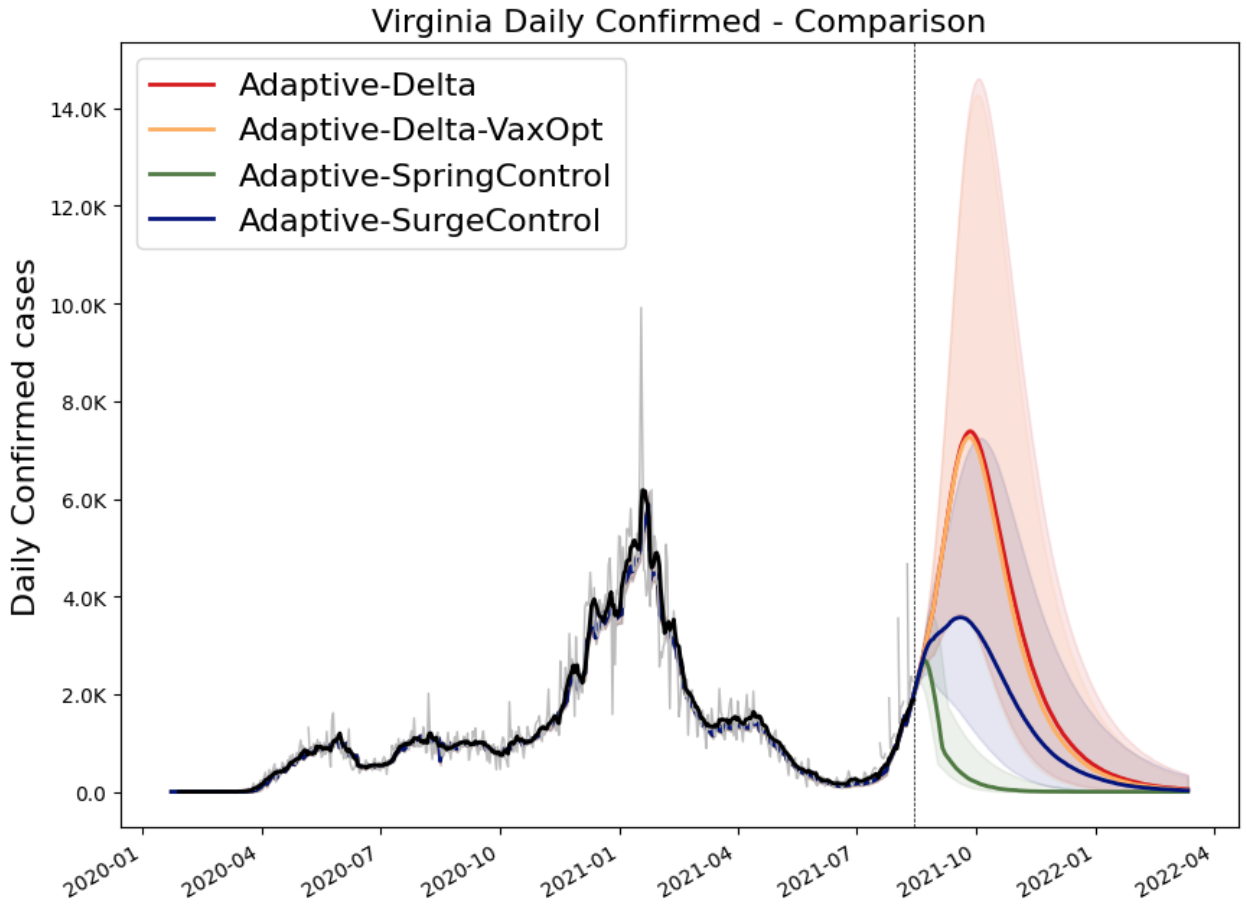
Variant Boosting: None = Variety of variants, no future txm boosting, but with severity impacts from current levels
60% = Prevalence of Delta ramps up according to logistic growth and is 60% more transmissible

Vaccinations: SQ = Status quo acceptance leads to low rates of vaccination through the summer
VO = Vaccination acceptance optimistically expands with increased rates through the summer

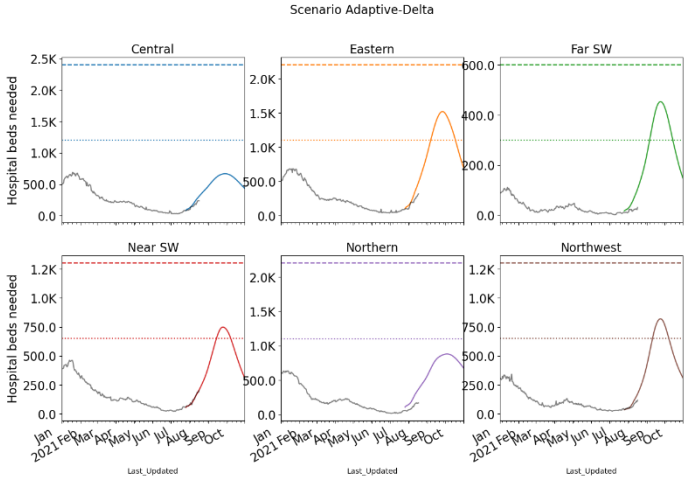
Model Results

Outcome Projections

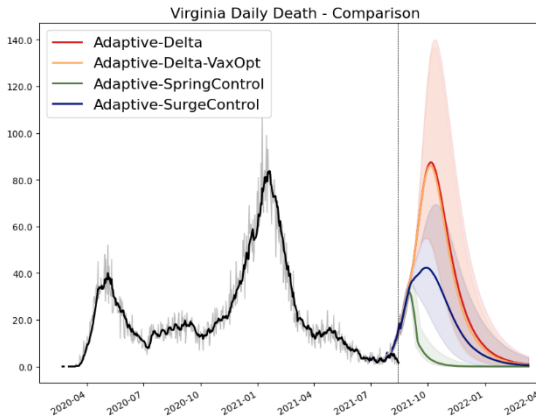
Confirmed cases



Estimated Hospital Occupancy

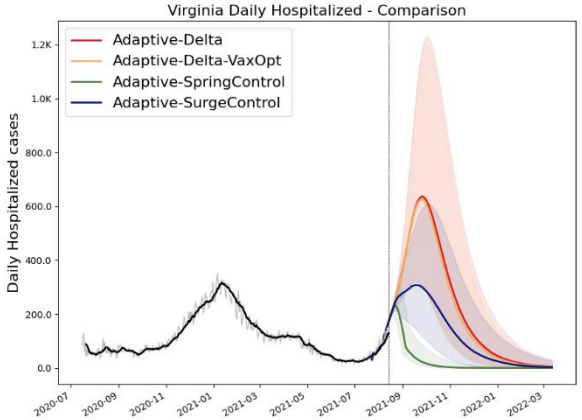


Daily Deaths



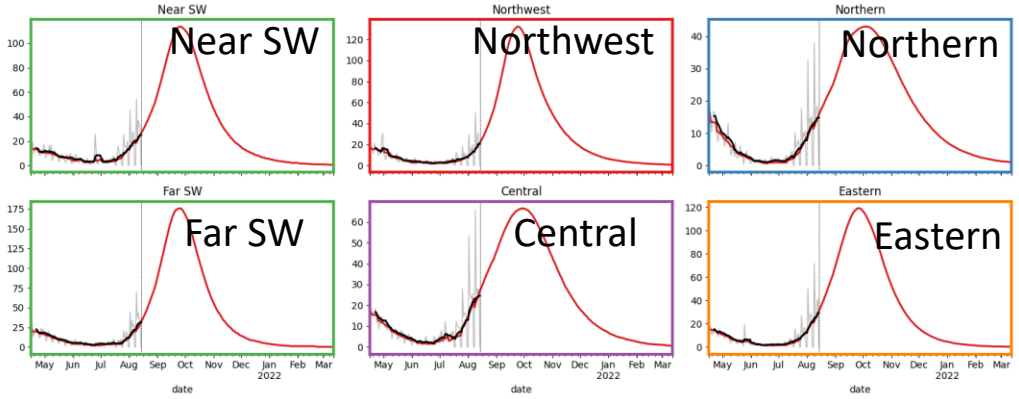
Death ground truth from VDH "Event Date" data, most recent dates are not complete

Daily Hospitalized



District Level Projections: Adaptive-Delta

Projections by Region

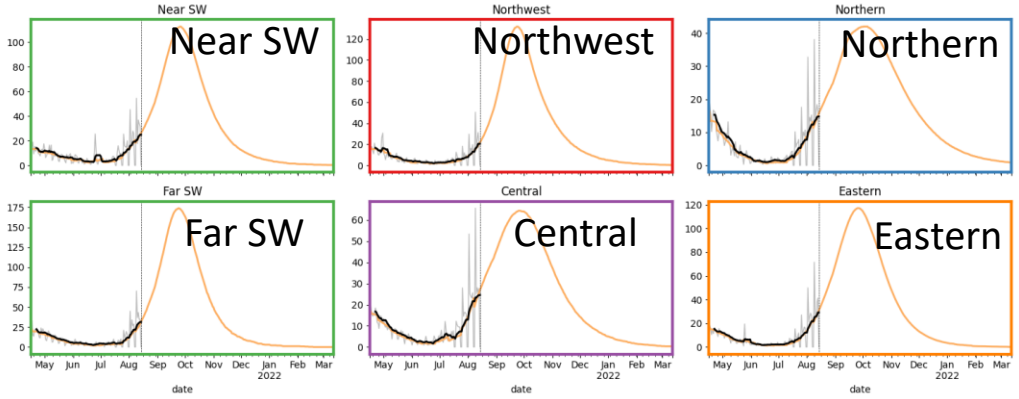


Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

District Level Projections: Adaptive-Delta-VaxOpt

Projections by Region

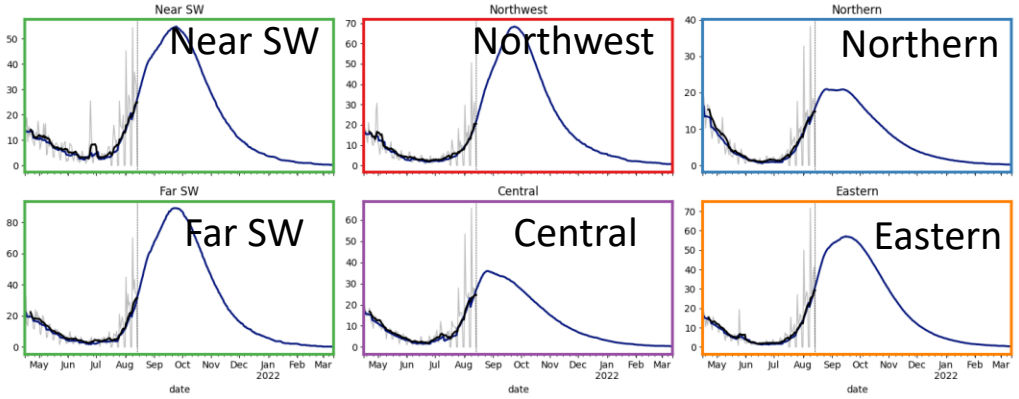


Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

District Level Projections: SurgeControl

Projections by Region

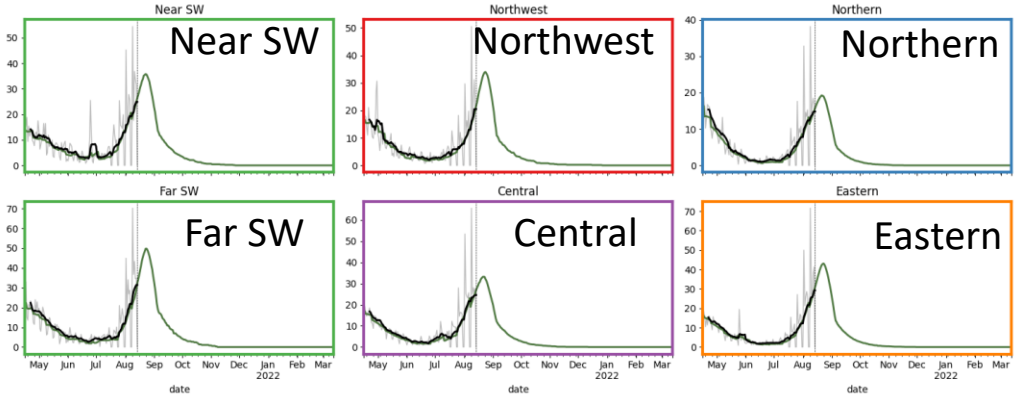


Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

District Level Projections: SpringControl

Projections by Region



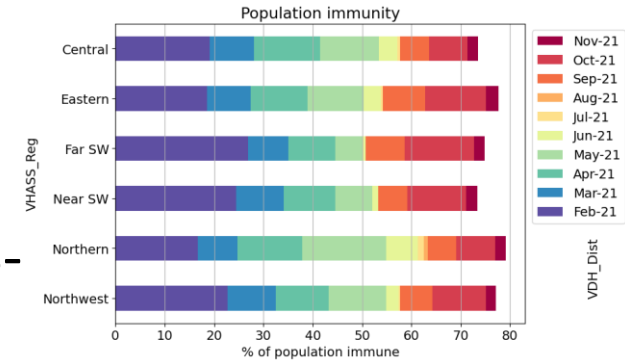
Projections by District

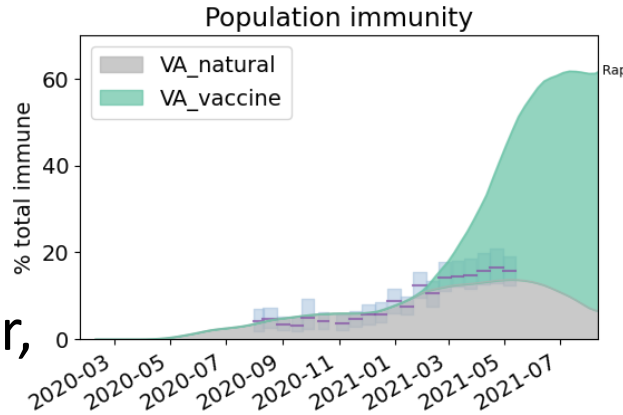
Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

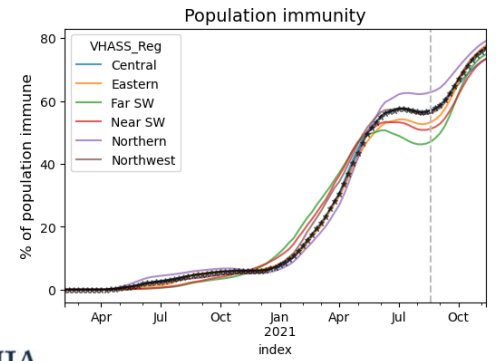
Virginia's Progress on Population Immunity

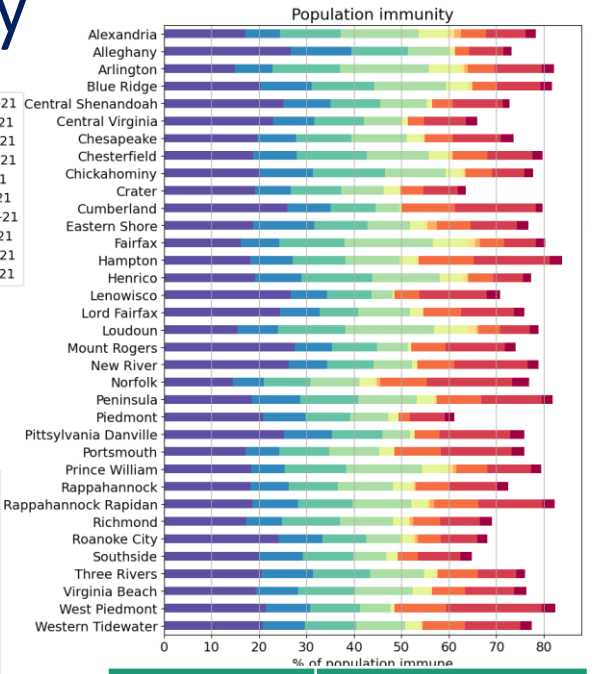
Natural Immunity and Vaccines combine to produce a population level of immunity

- Duration of immunity from infection with SARS-CoV2 still not well understood
  - We assume a conservative 6 month period of protection for these calculations
  - Do **not** factor in variant immune escape
  - Natural immunity is well calibrated to recent seroprevalence surveys
- Vaccine induced immunity is likely to last longer, we assume indefinite protection
  - This also assumes that all administered vaccines remain protective against current and future variants
- Population immunity depends on a very high proportion of the population getting vaccinated
  - Current models track measured seroprevalence









Region	% pop immune (est.)*
Central	57%
Eastern	53%
Far SW	46%
Near SW	51%
Northern	62%
Northwest	56%
Virginia	57%

* As of August 15, 2021 (updated to account for entire population)

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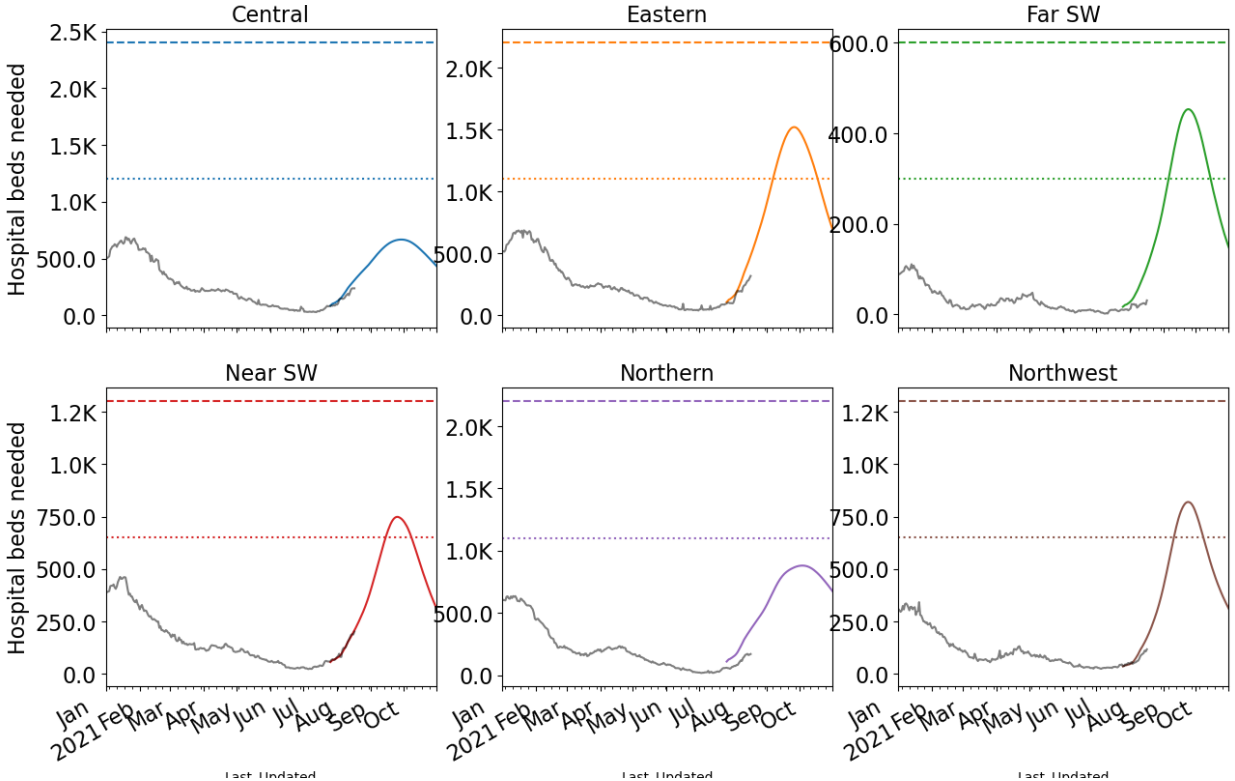
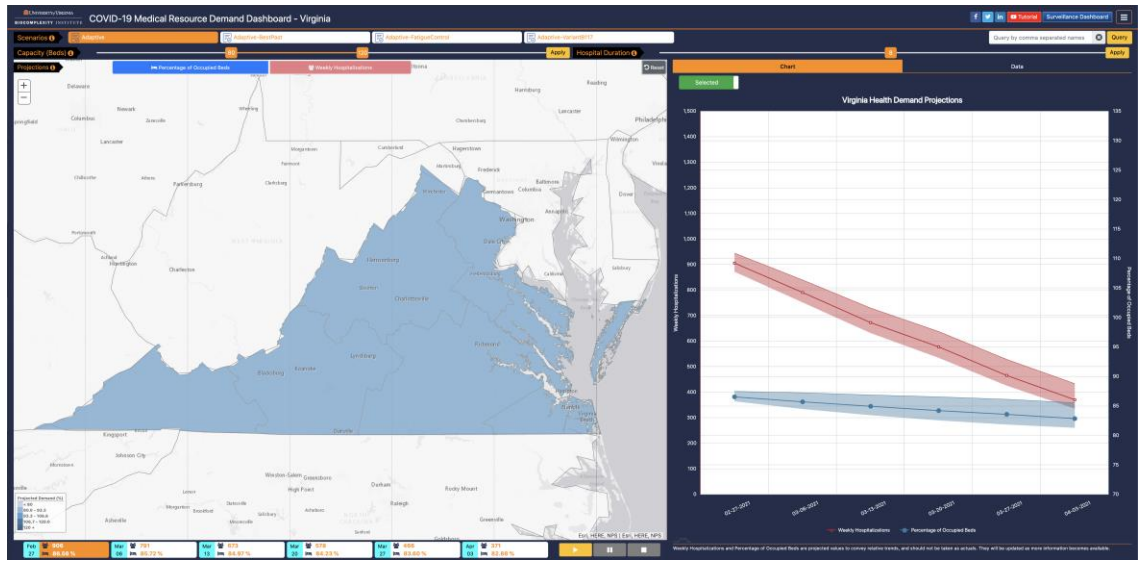
Hospital Demand and Bed Capacity by Region

Capacities* by Region – Adaptive-Delta

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





https://nssac.bii.virginia.edu/covid-19/vmrddash/

Adaptive-Delta scenario shows that if the Delta fueled surge continues unabated:

- Eastern, Southwest and Northwest could approach initial capacities

* 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 rates in Virginia continue to rise quickly amidst a background of surges across the nation**
- VA mean weekly incidence up to 24/100K from 14/100K, US up to 38/100K (from 25/100K)
- Vaccination rates continue to pick speed and acceptance among the unvaccinated persists
- Projections continue to show significant uptick in activity, with larger growth possibly fueled by Delta's increasing prevalence, even in areas with high vaccination coverage
- Recent updates:
  - Updated Surge Control scenario to commence sooner as mask use has increased recently
  - Adjusted hospitalization and death modeling to adapt to the observed impacts of Delta
- 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 Mobile Vaccine Clinic Site Selection:** Collaboration with VDH state and local, Stanford, and SafeGraph to leverage anonymized cell data to help identify

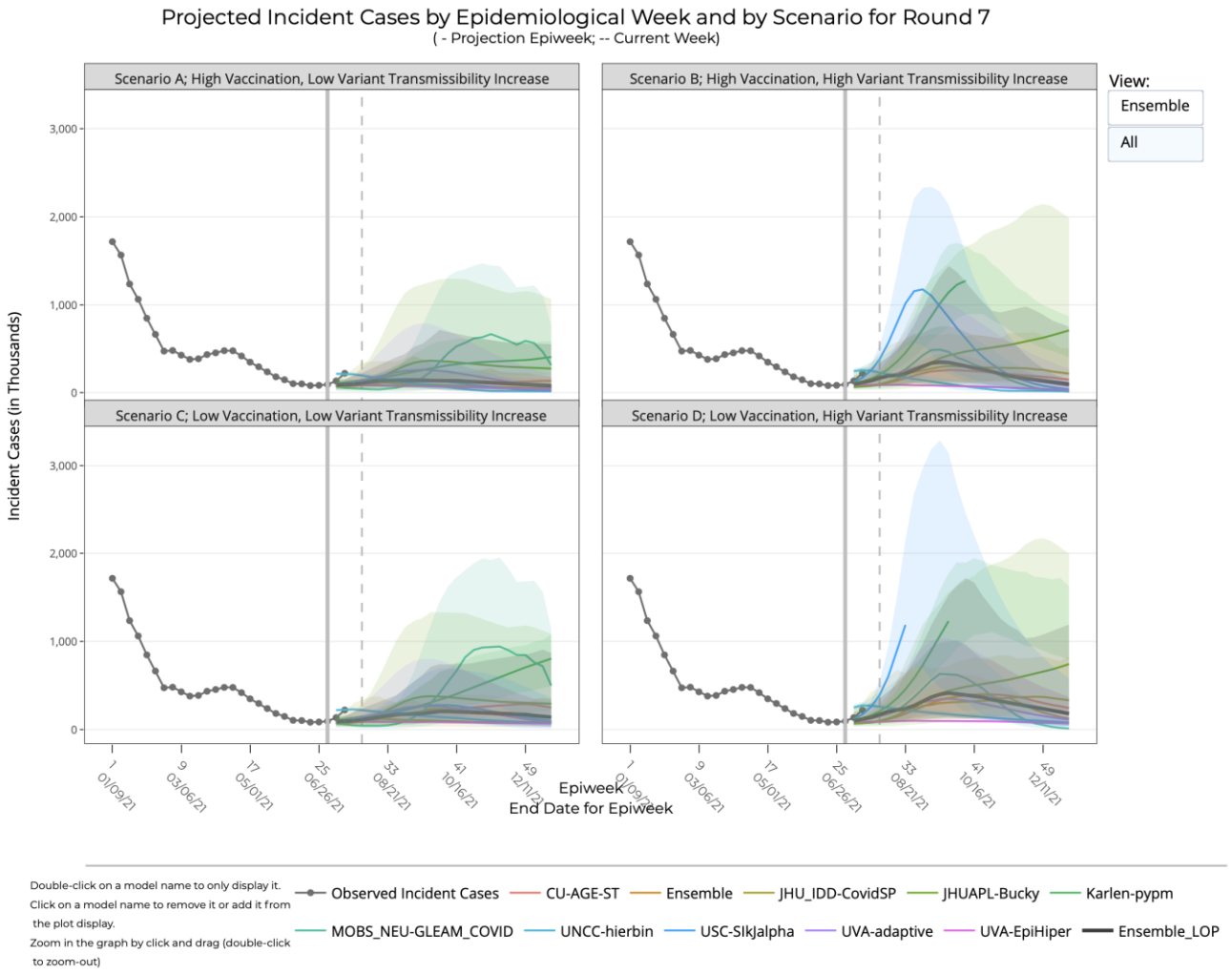
COVID-19 Scenario Modeling Hub

Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios that vary vaccine rates (high – low) and impact of the Delta variant (high and low)

- Round 8 in planning
- Round 7 now available

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

https://covid19scenariomodelinghub.org/viz.html



COVID-19 Scenario Modeling Hub – Round 7

Round 7 scenarios explore the effects of a variant similar to Delta (B.1.617.2) against different backgrounds of vaccination. Includes some vax escape

Vaccinations by Nov 30

- LowVacc – 70% overall coverage
- HighVacc – 80% overall coverage

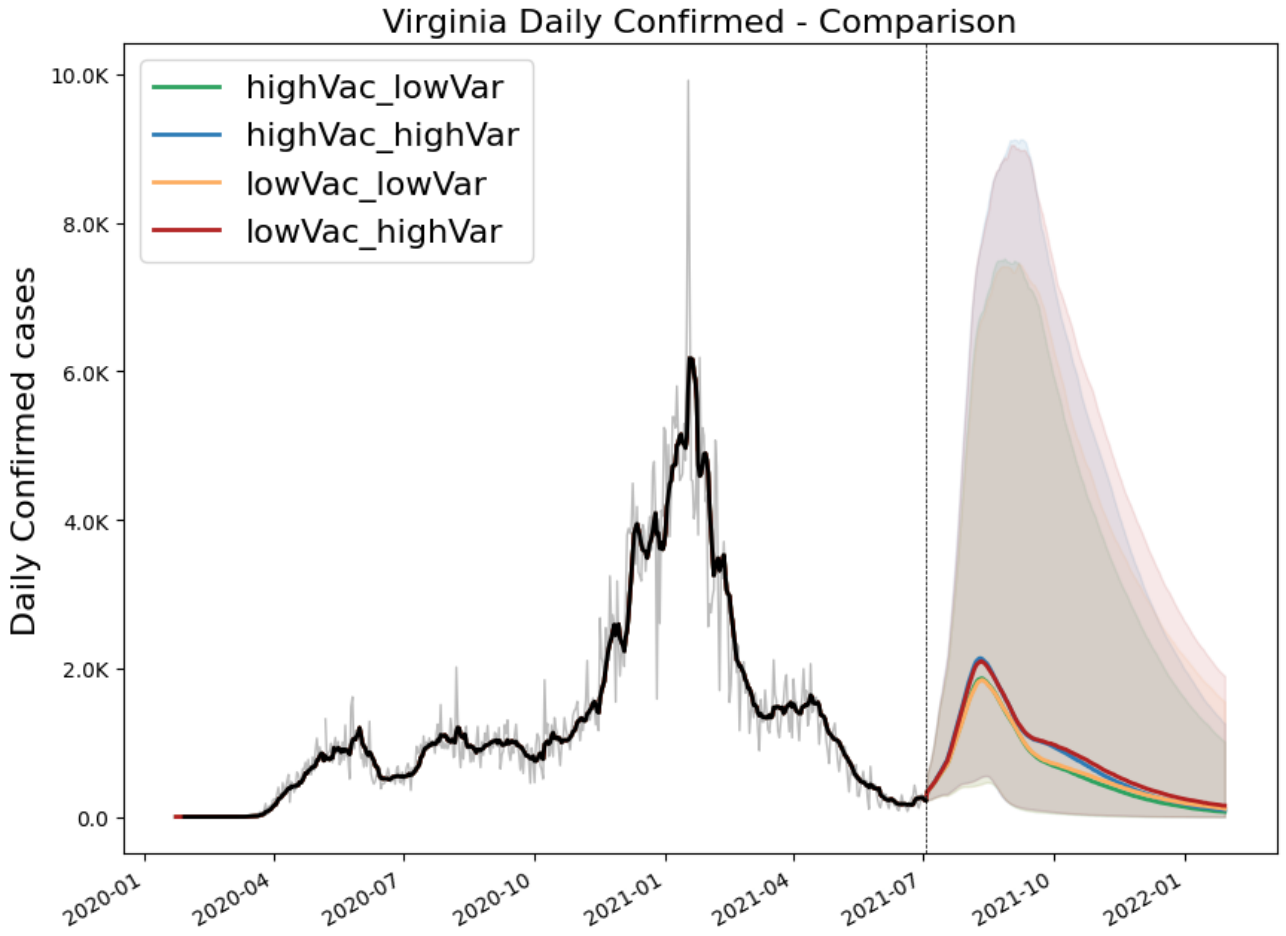
Emerging Variant Impact (5% prevalence on May 29th)

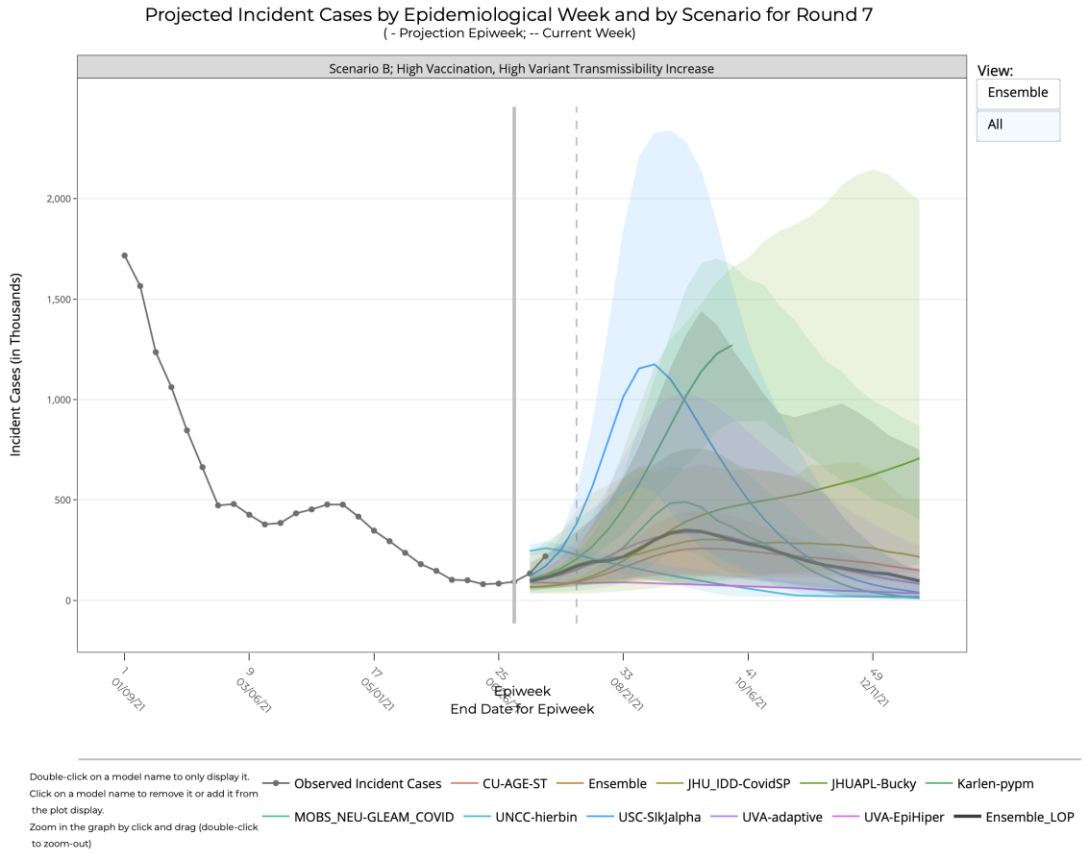
- LowVar – 40% more transmissible
- HighVar – 60% more transmissible

https://covid19scenariomodelinghub.org/viz.html

See more detailed notes for each scenario below	**LowVar** **Low Impact Variant** *(low transmissibility increase, no immune escape)*	**HighVar** **High Impact Variant** *(high transmissibility increase, no immune escape)*
High Vaccination *(Low hesitancy)* **HighVacc**	***Scenario A*** Vaccination: - Coverage saturates at **80% nationally** among the vaccine-eligible population* by December 31, 2021** - VE is **50%/90%** for Pfizer/Moderna against the Delta variant, against symptoms (1st /2nd dose) - J&J no longer used Variant: - **40% increased transmissibility** as compared with Alpha for Delta variant. Initial prevalence estimated at state-level by teams.	***Scenario B*** Vaccination: - Coverage saturates at **80% nationally** among the vaccine-eligible population* by December 31, 2021** - VE is **35%/85%** for Pfizer/Moderna against the Delta variant, against symptoms (1st /2nd dose) - J&J no longer used Variant: **60% increased transmissibility** as compared with Alpha for Delta variant. Initial prevalence estimated at state-level by teams.
Low Vaccination *(High hesitancy)* **LowVacc**	***Scenario C*** Vaccination: - Coverage saturates at **70% nationally** among the vaccine-eligible population* by December 31, 2021** - VE is **50%/90%** for Pfizer/Moderna against the Delta variant, against symptoms (1st /2nd dose) - J&J no longer used Variant: - **40% increased transmissibility** as compared with Alpha for Delta variant. Initial prevalence estimated at state-level by teams.	***Scenario D*** Vaccination: - Coverage saturates at **70% nationally** among the vaccine-eligible population* by December 31, 2021** - VE is **35%/85%** for Pfizer/Moderna against the Delta variant, against symptoms (1st /2nd dose) - J&J no longer used Variant: **60% increased transmissibility** as compared with Alpha for Delta variant. Initial prevalence estimated at state-level by teams.

Modeling Hub – Round 7 Prelim Results





https://covid19scenariomodelinghub.org/viz.html

COVID-19 Scenario Modeling Hub – Round 8 (ongoing)

Round 8 scenarios targeted at exploring the effect of waning immunity (natural and vaccine-induced) and varying levels of protection after waning

Waning Rates

- Slow – exp. waning with mean=3yrs
- Fast – exp. waning with mean=1yr
- No waning (Sc A) as baseline

Protection after Waning

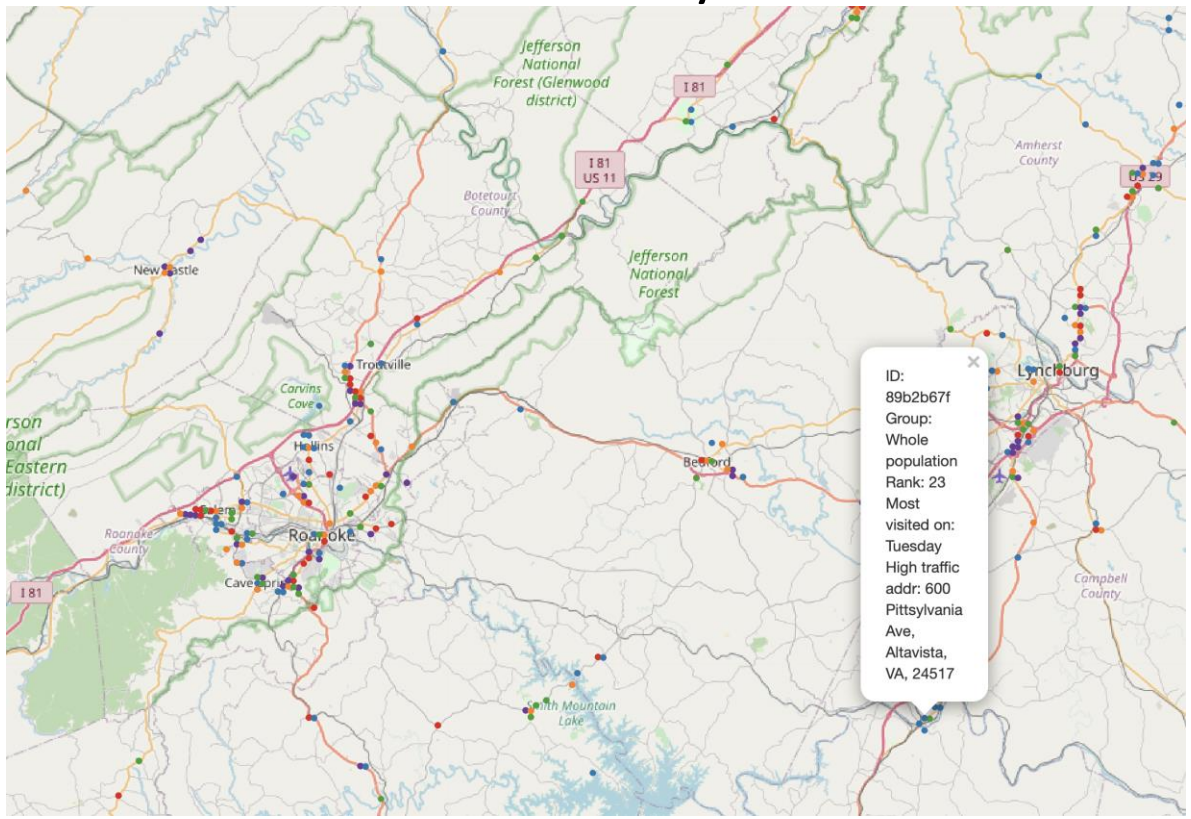
- Age stratified protection from infection
- 80% or 90% protection from hosp/death

		Slow Waning	**Fast Waning**
See detailed notes on each scenario below		**Slow waning of natural and vaccine-induced immunity** *(from no waning to exponential waning with mean of 3 yrs)*	**Fast waning of natural and vaccine-induced immunity** *(exponential waning with mean of 1 year)*
High protection against infection and severe disease after waning	**High Protection**	***Scenario A*** No Waning: - Vaccine-induced and natural immunity retain their initial protection throughout the simulation period	***Scenario B*** Waning: - **Exponentially distributed immune waning with mean of 1 year** (time to transition to partially immune state) In partially immune state: - Protection from infection is: **- 70% ≤ 65yrs** **- 35% > 65yrs** - Protection from hospitalization and death is **90%**
Low protection against infection and severe disease after waning	**Low Protection**	***Scenario C*** Waning: - **Exponentially distributed immune waning with mean of 3 years** (time to transition to partially immune state) In partially immune state: - Protection from infection is: **- 50% ≤ 65yrs** **- 25% > 65yrs** - Protection from hospitalization and death is **80%**	***Scenario D*** Waning: - **Exponentially distributed immune waning with mean of 1 year** (time to transition to partially immune state) In partially immune state: - Protection from infection is: **- 50% ≤ 65yrs** **- 25% > 65yrs** - Protection from hospitalization and death is **80%**

https://covid19scenariomodelinghub.org/

Data Recommended Mobile Vax Clinic Sites

Detailed and Timely Locations



Data Delivered and Disseminated to Locals

Provides a list of areas most visited by a given demographic group based on SafeGraph mobility data that links visits to specific sites and the home Census Block Group of the anonymized visitors

Demographic Groups: Black, Lantinx, Young Adults (20-40), Unvaccinated, and Whole Population

Data Included: Rank, Weight, most visited Day of Week, Highly Visited Address, and Lat-Long of area

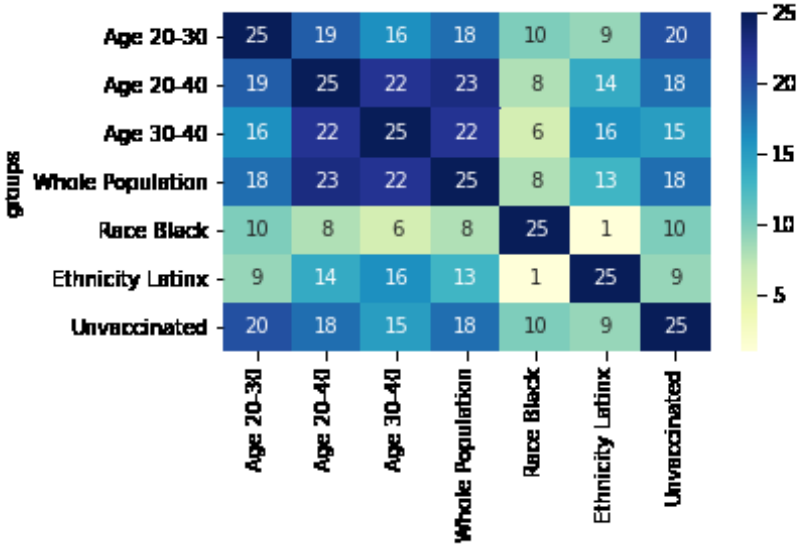
Goal: Provide frequently visited locations based on populations and vaccination levels one desires to reach

Example: List of location in the Southside frequented by 20-40 year olds

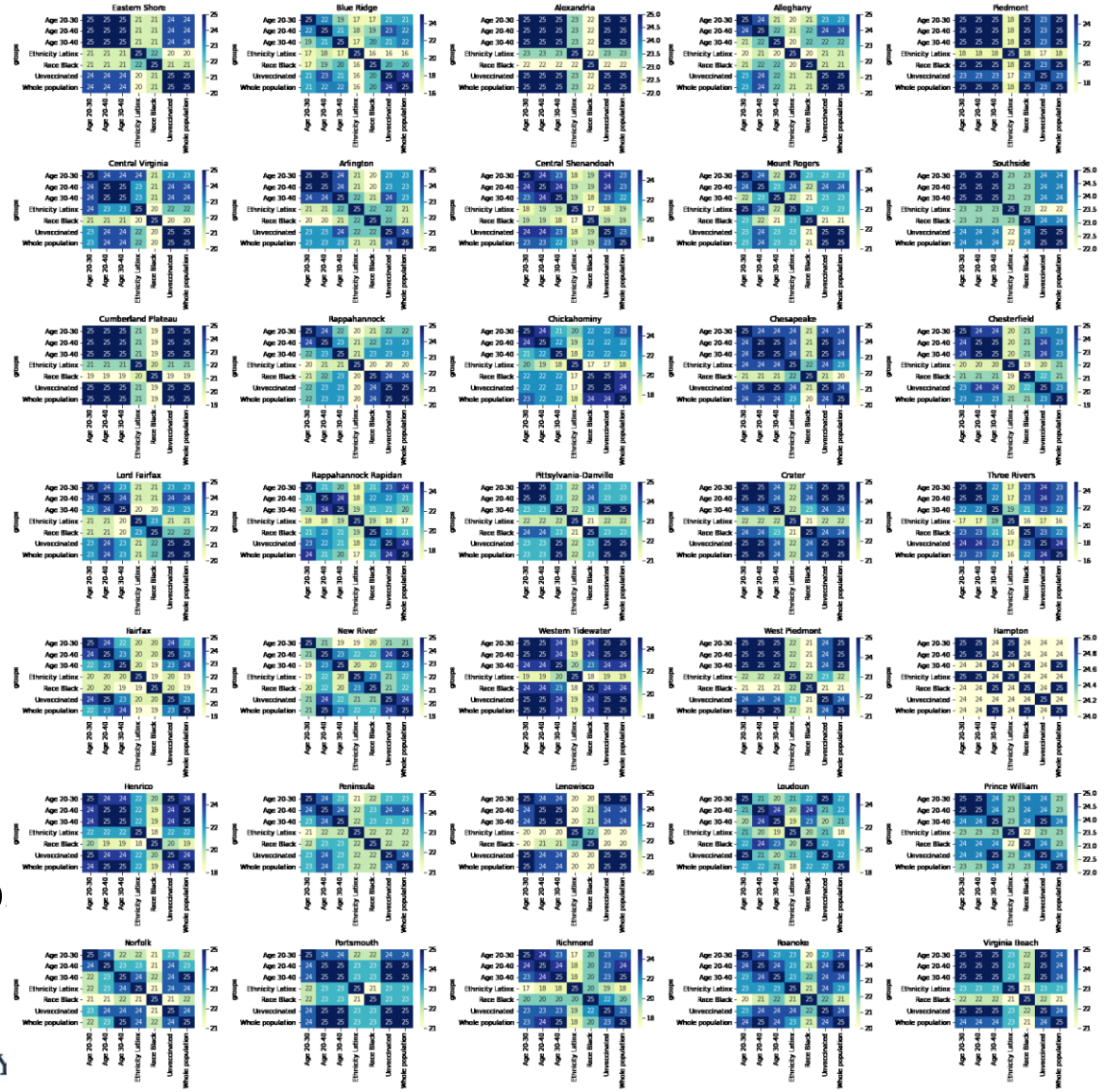
Data Recommended Mobile Vax Clinic Sites

Overlap of locations between groups

State Level



Within VDH Health Districts



Different groups visit different areas

- Least overlap between Black and Latinx
- Overlap in ages highest, but drops with large gap
- Districts have different overlap patterns

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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

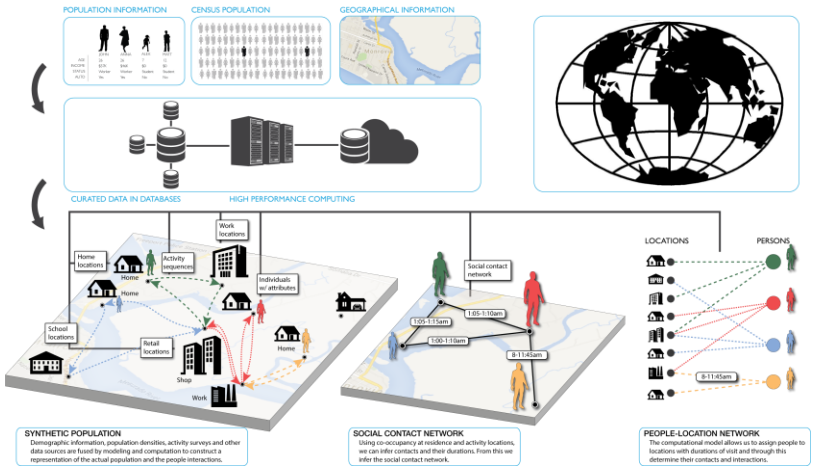
Aniruddha Adiga, Abhijin Adiga, Hannah Baek, Chris Barrett, Golda Barrow, Richard Beckman, Parantapa Bhattacharya, Jiangzhuo Chen, Clark Cucinell, Patrick Corbett, Allan Dickerman, Stephen Eubank, Stefan Hoops, Ben Hurt, Ron Kenyon, Brian Klahn, Bryan Lewis, Dustin Machi, Chunhong Mao, Achla Marathe, 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

Supplemental Slides

Agent-based Model (ABM)

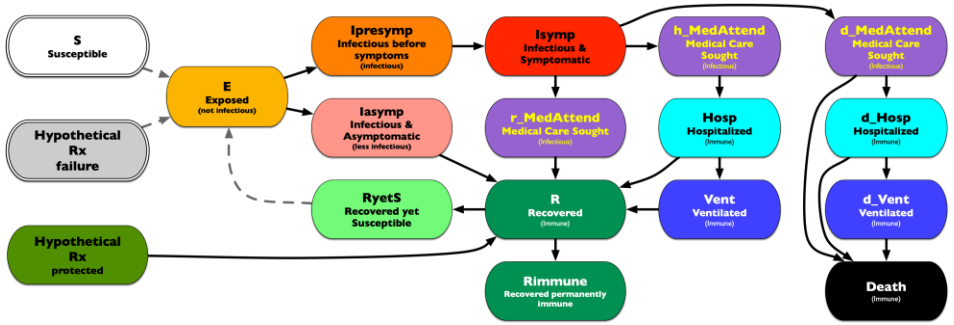
EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



Detailed Disease Course of COVID-19

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